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Hydrogeology and Environmental Flow Needs Assessment of a Groundwater Licence Application near Lumby, B.C.

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Cover Photograph:
Bessette Creek near Riggins Road. Photo by David Thomson, November 28, 2017.

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The original expert report on the topics of water use accounting and environmental flow needs was peer reviewed by Ron Ptolemy, Provincial Instream Flow Specialist for the Ministry of Environment and Climate Change Strategy. Richard Bailey, Chinook and Coho Stock Assessment, Fisheries and Oceans Canada contributed recent information on salmon stock status. That expert report also built on two previous projects. The first project, Associated (2016), was led by Brian Guy of Associated Environmental Consultants Inc., and was peer reviewed by Andrew Petersen, Water Management Specialist, Ministry of Agriculture, Richard McCleary and Elinor McGrath, Fisheries Biologist, Okanagan Nation Alliance. This project was funded by the Ministry of Forests, Lands, Natural Resource Operations and Rural Development to guide the emergency response to widespread drought in the region in 2015. The second project, Epp (2014), was completed by Phil Epp of Trout Creek Hydrology and Soils and was peer reviewed by Ron Ptolemy, Richard McCleary, and Christian St. Pierre of the Ministry of Forests, Lands, Natural Resource Operations and Rural Development. That project was funded through the British Columbia Habitat Conservation Trust Foundation.

The original expert report on Hydrogeology submitted to the Environmental Appeal Board was peer reviewed by Skye Thomson, P.Geo. and Section Head of the South Area Groundwater Science Team. Klaus Rathfelder of the Ministry of Environment provided review and comment on use of the analytical model from streamflow depletion.

EXECUTIVE SUMMARY

The purpose of this report is to summarize the technical information related to the refusal of a new groundwater use license application in British Columbia under the *Water Sustainability Act* (*WSA*).

As part of the adjudication of a groundwater license application for a well near Lumby, B.C., it was determined that a reasonable likelihood of hydraulic connectivity existed between the well and nearby Bessette Creek, a stream with high fisheries values and seasonal water shortages. The technical information provided by the applicant was insufficient to address statutory decision-maker concerns. Based on the assessment, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNR) refused the license application. The decision to refuse the license was subsequently appealed by the applicant.

Three reports were submitted by FLNR as part of the Environmental Assessment Board (EAB) appeal process and in defence of the Water Manager's decision: (1) a Hydrogeology report; (2) a Water Use Accounting and Environmental Flow Needs report; and (3) a supplemental Hydrogeology report. An analytical model based on methodologies outlined in Rathfelder (2016) was used to estimate the water demand and hydraulic connectivity in the study area and to estimate the effects of the subject pumping well on Bessette Creek.

The development of the analytical model was critical in demonstrating hydraulic connectivity and the environmental impacts of groundwater withdrawal on Bessette Creek. The EAB upheld the Ministry's decision to refuse a new groundwater licence application on this oversubscribed system based, in part, on the establishment of hydraulic connection between the well and Bessette Creek, the quantification of the impact of the withdrawal, and the water use accounting / environmental flow needs report.

This report provides a summary of the technical information provided by the applicant, the subsequent information review and discussions, and the supplemental technical information provided to defend the refusal. In doing so, it is hoped the public and professional community gain an appreciation for the context around the refusal.

The outcome of the EAB decision reinforces the importance of science-based decision making, particularly as it relates to the implementation of the *Water Sustainability Act* and quantifying the effects of groundwater withdrawals on surface water. It also underscores the statutory decision-makers' authority to request additional information from an applicant necessary to adjudicate the water licence application. The Board accepted both the approach that was used and the determination that environmental flow needs can be affected by pumping from hydraulically connected aquifers. The Board further recommended the aquifer in question receive a fully recorded designation.

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ACRONYMS

AGRI	British Columbia Ministry of Agriculture
ALUI	Agriculture land use inventory
BP	Before Present (years)
CEFT	Critical Environmental Flow Threshold
DFO	Department of Fisheries and Oceans Canada
DTSID	Distributed Temperature Sensing to Identify groundwater Discharge
EAB	Environmental Appeal Board
EcoCat	Ecological Reports Catalogue (B.C. Environment)
EFN	Environmental Flow Needs (British Columbia Environmental Flow Needs website)
ENV	British Columbia Ministry of Environment and Climate Change Strategy
FLNR	British Columbia Ministry of Forests, Lands, Natural Resource Operations and Rural Development
GPM	Gallons per minute
GW	Groundwater
LT MAD	Long-term Mean Annual Discharge (this estimate of the long-term “naturalized” water supply = LT MAF + long-term mean annual water demand)
LT MAF	Long-term Mean Annual Flow (for a gauging station of interest, the daily mean flows are averaged for each year, and subsequently the mean annual flows are averaged for the period of interest)
POD	Point of Diversion
QP	Qualified Professional
SDM	Statutory Decision Maker
SME	Subject Matter Expert
WSA	*Water Sustainability Act*
WSC	Water Survey of Canada
WSR	Water Sustainability Regulation
WTN	Well Tag Number

Authorship

This document includes two subject-matter-expert reports by that have been re-organized and supplemented by introductory, background and concluding material. For clarity, some chapters are entirely attributed to one or the other authors as follows:

Rich McCleary authored Chapter 6

David Thomson authored Chapters 3 and 5

The remainder of the chapters were co-written and/or combine material from both reports.

1. INTRODUCTION

1.1 Background

In 1965 Bessette Creek, a stream with high fisheries values, was designated as a fully recorded surface water source. Although this designation did not immediately prevent the water managers from issuing additional surface water licenses, it represented the recognition of a problem arising from a finite water source and a pattern of growing demand to meet agricultural needs. In 1984, due to ongoing experiences with water shortages, and its fully recorded status, the Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNR) began to refuse surface water license applications on Bessette Creek unless they were supported by storage.

To meet the increasing water demand in the Bessette Creek watershed after 1983, groundwater wells became an increasingly important source. However, on February 29, 2016 the *Water Sustainability Act* (*WSA*) came into effect, which included a requirement to assess and regulate non-domestic groundwater use.

In 2016, a new groundwater use application was received by FLNR for a well that was drilled on July 7, 2016. The application was to supply irrigation to a 100-acre property north of Lumby B.C. that was previously farmed for hay production using natural precipitation and flood irrigation from a small spring. The new proposed source well was drilled 320 m away from Bessette Creek.

FLNR staff reviewed the application and subsequent technical information. The water license application (File 20003234) was ultimately refused by the Water Manager on the following basis:

"Bessette Creek is reasonably likely to be hydraulically connected to the aquifer from which you have proposed to draw water. There is insufficient flow in Bessette Creek to maintain environmental flows." – Robert Warner, Water Manager.

This decision was appealed to the Environmental Appeal Board (EAB) under Section 105 of the *WSA*. The EAB Panel was satisfied that both a hydraulic connection existed, and since it existed, that environmental flow needs of Bessette Creek would be impacted (Mattison, 2018). The EAB upheld the Ministry's decision to refuse a new groundwater licence application on this oversubscribed system.

1.2 Purpose

The purpose of this report is to share scientific and technical knowledge surrounding the review and decision to refuse a new groundwater use application in the Bessette Creek drainage. This report represents a case study emphasizing specific Water Sustainability Act provisions regarding Environmental Flow Needs (EFN) and hydraulic connection between surface water and groundwater. The analytical model of streamflow depletion and the details of the long-standing over-allocation problem were instrumental in providing evidence to support the decision.

1.3 Content and Outline

This report consists largely of a summary of three main reports, and associated supplemental responses:

- Technical Assessment to Support New Groundwater Licence Application: Irrigation well located at 1219 Mabel Lake Rd (WWAL, 2016)
- Expert Report on Hydraulic Connection from Subject Well 112051 to Bessette Creek (Thomson, 2017a).
- Expert Report: Water Use Accounting and Environmental Flow Needs for Bessette Creek (McCleary, 2017).

Some sections, such as 1.4 below, were not in the materials cited above but are provided here in the interest of completeness. There has been no extension of the original analyses provided in support of the EAB decision.

1.4 Site Setting

The site is located in the southern interior of British Columbia, near Lumby, B.C. (Figure 1). The area is associated with the middle Shuswap River Watershed within the Northern Okanagan Basin ecosection, which is described by Demarchi (2011: p. 123) as follows:

This ecosection is in a rainshadow of the Thompson Plateau and the Coast Mountains to the west, as well, surface heating in the summer creates convective currents that aid in keeping this area cloud-free and dry. In the summer, hot subtropical air can overwhelm this area and bring hot dry conditions.

The nearest Environment Canada Climate Station (Lumby – Sigalet Road Station ID 1164730) indicates annual average values (1971-2000) as follows:

- Temperature: 6.7 °C
- Total precipitation (mm): 628
- Precipitation as snowfall (mm): 165

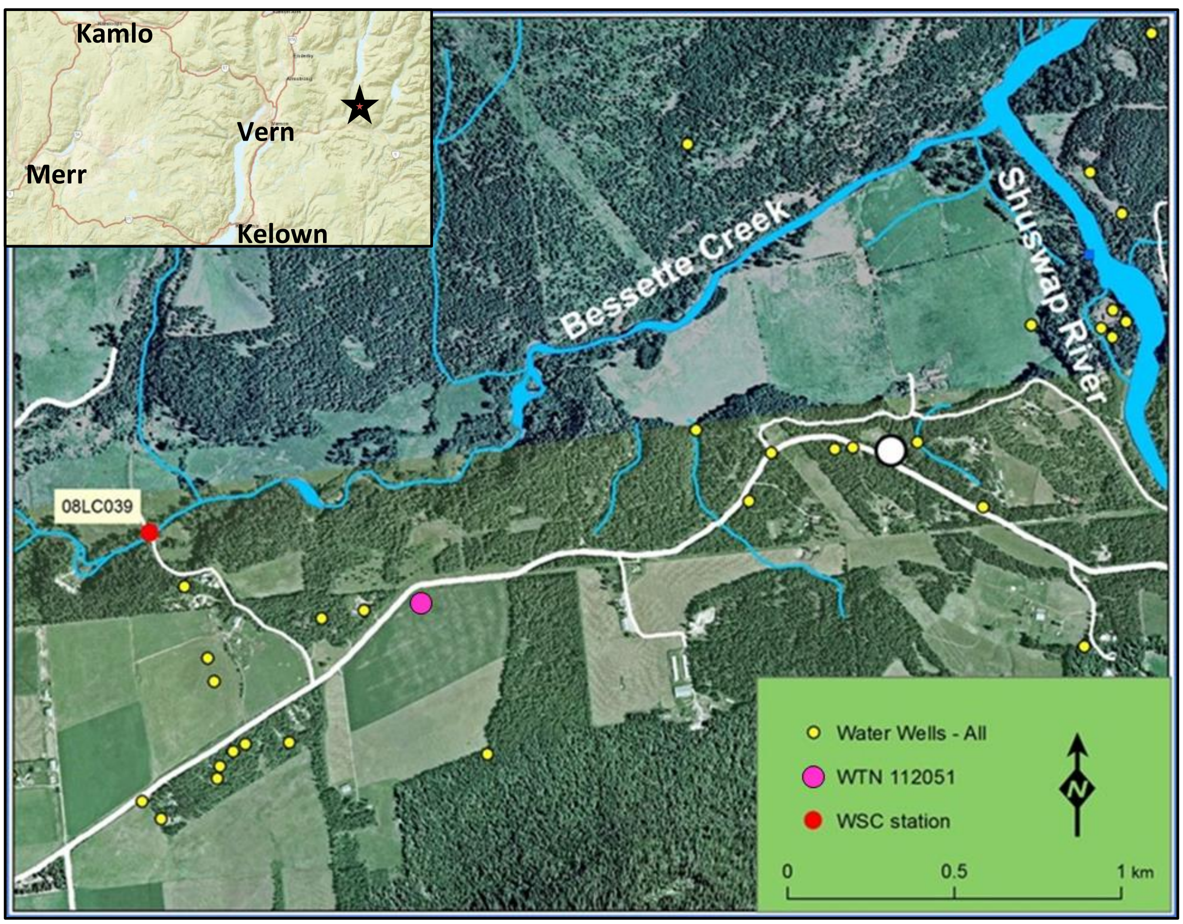


Figure 1: Area surrounding the subject well (WTN 112051) showing other wells and WSC hydrometric station 08LC039 – Bessette Creek above Beaverjack Creek (Data source: B.C. Data Catalogue).

Bessette Creek is located approximately 320 m north of the subject well (WTN 112051), where it flows adjacent to the south bank of an incised trench (Figure 1). From that location, Bessette Creek flows approximately 2.5 km to the east-northeast to its confluence with the Shuswap River. Water Survey of Canada (WSC) Station 08LC039 (Bessette Creek above Beaverjack Creek) is located where Riggins Road crosses Bessette Creek, less than 1 km northwest of the subject well (Figure 1).

2. BESSETTE CREEK WATERSHED

At the confluence with the Shuswap River, the Bessette Creek watershed has a total drainage area of 797 km^2. The subject well is identified as Well Tag Number (WTN) 112051. This well is located approximately 2.5 km from the confluence of Bessette Creek and the Shuswap River (Figure 2), and is about 320 m to the south of Bessette Creek (Thomson, 2017a). In 2017, the WSC operated a total of three active gauging stations in the Bessette Creek watershed including:

1. 08LC042 – Bessette Creek above the Lumby Lagoon Outfall;
2. 08LC040 – Vance Creek below Deafies Creek; and
3. 08LC039 – Bessette Creek above Beaverjack Creek.

The WSC Station 08LC039 – Bessette Creek above Beaverjack Creek is in close proximity to the subject well and provides the best available reference flows for EFN assessment. The drainage area at 08LC039 is 769 km^2 or 96.5 percent of the total drainage area of Bessette Creek. Therefore, this gauging station provided a reasonable representation of the flow state for the larger watershed area of 797 km^2.

Several mapped sand and gravel aquifers occupy the lowlands of Bessette Creek with bedrock aquifers extending into higher elevations. The subject well is completed in Aquifer 318, a mapped sand and gravel aquifer in a series of similar aquifers along the valley corridors from the Shuswap River to Lumby and then further to Lavington and Coldstream (Figure 3). Note that some remapping of aquifers occurred in this area in 2018 (Stewart and Allard, 2018).

2.1 History and Inter-Watershed Diversion

When considering the history of flow shortages, it is helpful to consider the two main categories of water users in Bessette Creek: (1) private users; and (2) public waterworks utilities. The three main differences between these users are:

1. much larger quantities of water use are authorized under single licences for public waterworks in comparison to relatively smaller quantities for private users;
2. public waterworks mainly rely on water storage to meet the large demands while private users rely on summer baseflow water to meet the demands which are predominately for irrigation; and
3. public waterworks export water for use outside of the Bessette Creek watershed while private users irrigate lands within the watershed boundary.

Bessette Creek is unique among watersheds in the Thompson-Okanagan Region because of the large quantity of water that is diverted out of the Thompson River watershed to support irrigation and drinking water demands on lands located within the Okanagan River watershed. This inter-basin transfer is the result of water resources engineering efforts that date back to 1906 to develop storage in the Bessette Creek watershed for use in water scarce areas near Coldstream and Vernon (see Appendix A, Water Licence C017841).

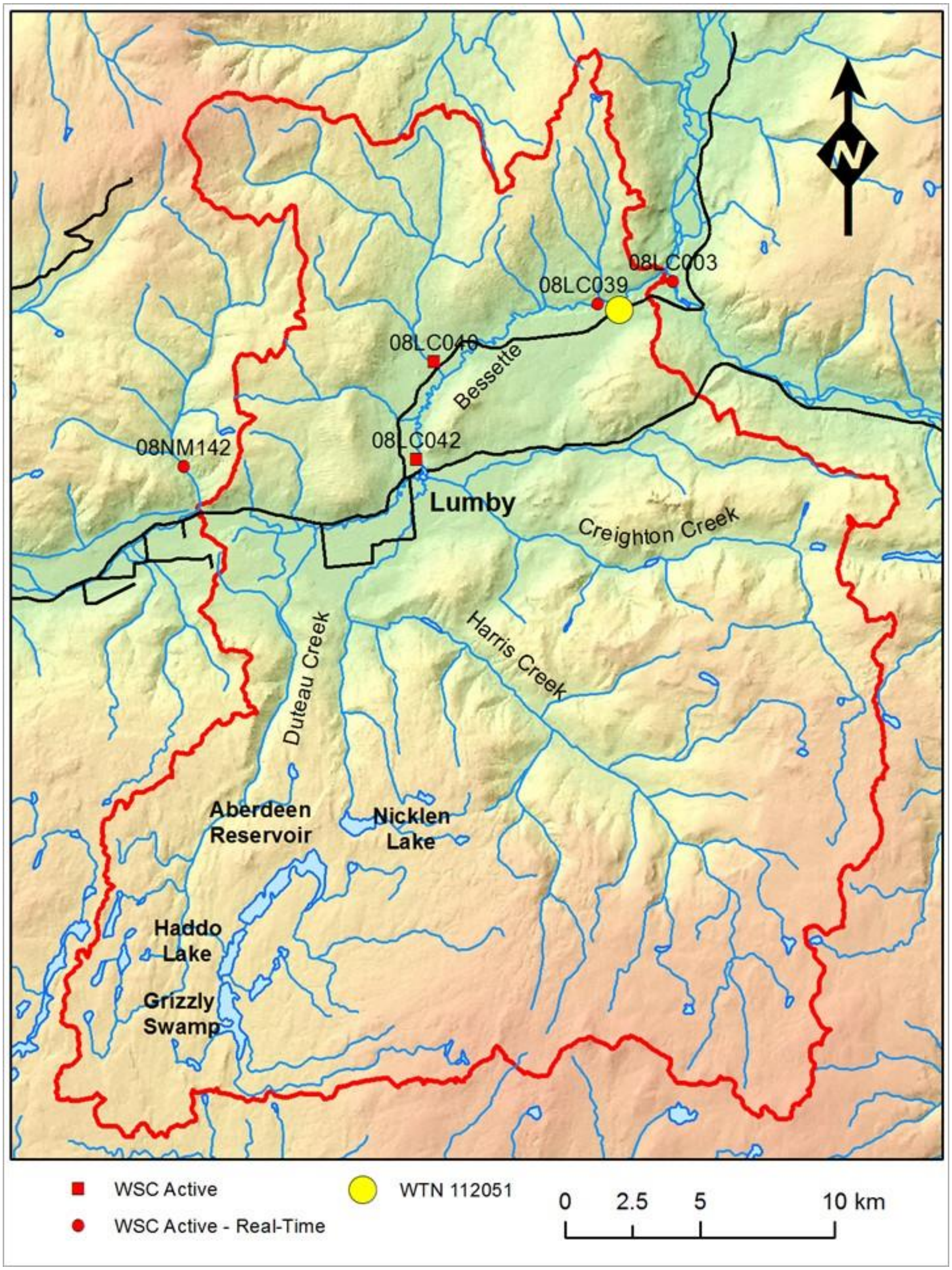


Figure 2. Overview map of Bessette Creek watershed including approximate location of well WTN 112051 and nearby Water Survey of Canada gauging station Bessette Creek above Beaverjack Creek (08LC039) (Data source: B.C. Data Catalogue).

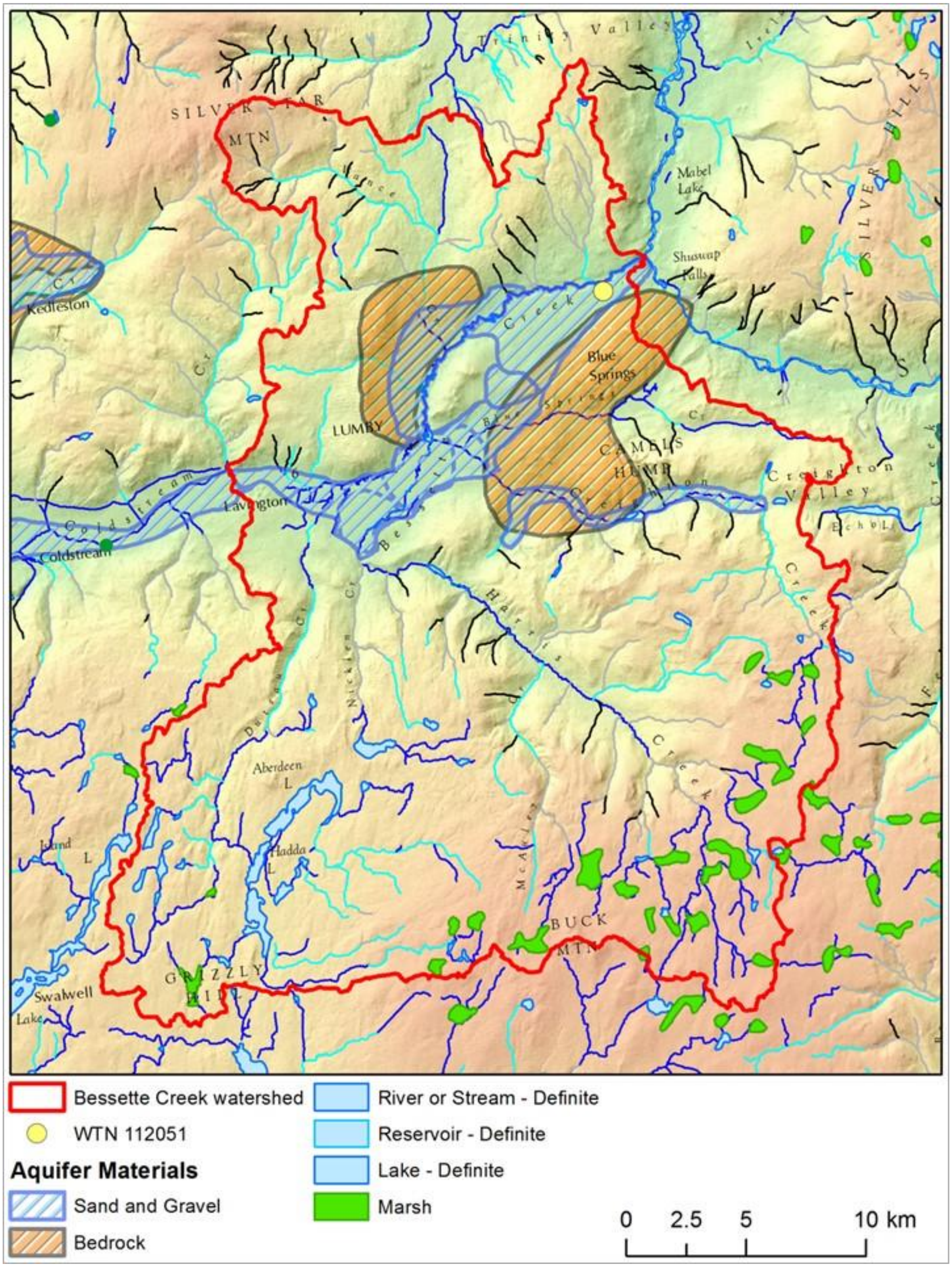


Figure 3. Overview map of Bessette Creek watershed with mapped aquifers displayed by material and location of well WTN 112051 (Data source: B.C. Data Catalogue).

2.1.1 *Droughts since 2015 in the South Thompson Basin and Bessette Creek*

The Bessette Creek watershed provides an accurate early warning of drought within the South Thompson watershed. During the summer low flow season, the Thompson-Okanagan Regional Drought Response Team tracks the flows in a number of streams within Bessette Creek watershed to inform the drought status (FLNR, 2019). There are four stations within Bessette Creek watershed with a history of low flow problems during the late summer that are contained on the Watch List in the drought plan (see stream names and some station locations on Figure 2):

1. Bessette Creek above Beaverjack Creek (08LC039);
2. Bessette Creek above Lumby Lagoon Outfall (8LC042);
3. Duteau Creek near Lavington (08LC006); and
4. Creighton Creek near Lumby (08LC033) located 15 km upstream from Lumby in upper reaches.

In the South Thompson Basin, during the five-year period of record between 2015 and 2019, there were four years with Level 3 drought, two of which elevated to Level 4 drought (maximum reductions in water use) (Table 1). These levels were informed by flow conditions in the Bessette Creek watershed and other flow sensitive streams in the basin.

Table 1. Dates for elevation of drought level in the South Thompson River watershed (data extracted from British Columbia Drought Information Portal website, Historical BC Drought Information tab: 2015, 2016, 2017, 2018 and 2019 Drought Levels at a Glance tables[1]).

Year	Date for Level 2 – Dry Conditions (voluntary conservation)	Date for Level 3 – Very Dry Conditions (voluntary conservation and restrictions)	Date for Level 4 – Extremely Dry Conditions (voluntary conservation, restrictions and regulatory action if necessary)
2015	25-Jun	09-Jul	23-Jul
2016	No drought		
2017	03-Aug	28-Aug	08-Sep
2018	14-Jun	23-Aug	
2019	30-May	13-Jun	

[1] British Columbia Drought Information Portal

2.1.2 *Water Allocation Restrictions*

Water allocation restrictions in Bessette Creek that date back to 1965 (Table 2) are listed on the provincial website: British Columbia Water Allocation Restrictions.

As indicated on this website, the designation of fully recorded does not legally prevent further licensing. Rather it is an administrative designation to alert Statutory Decision Makers (SDM) to possible issues. Under the WSA, these designations apply to both aquifers and surface water bodies, and are also viewable on iMapBC and the Water Resources Atlas of B.C.

Although the records indicate that the fully recorded status was initiated on Sept. 3, 1965, additional licences were issued until 1983 (Figure 4). The records did not indicate any additional licences issued after 1983. The overall pattern shows an early phase of development near the turn of the century and a second phase from 1950 to 1983 (Figure 4).

Table 2. Water allocation restrictions for Bessette Creek from page 229 of Registered Water Allocation Restrictions pdf file based on a query dated October 2017.

Region Name	District Precinct Name	Restriction Description /Effective Date	Point Comments	Point Code	Water Rights Map	NTS Code (1:50k)	Source	Gazetted /Alias
Okanagan	Ver - lumby	Bessette creek - fr 1965/ 09/ 30	Fully recorded above Lumby unless storage provided - short term to June 30th; 02 61467. 1988/01/26 freshet only April 1 - June 30th; 8000982. Fully recorded for irrigation and large consumptive purposes unless fully supported by storage to p	RS60635	82.L.036. 2.2	082L/7	Bessette Creek	Gazetted

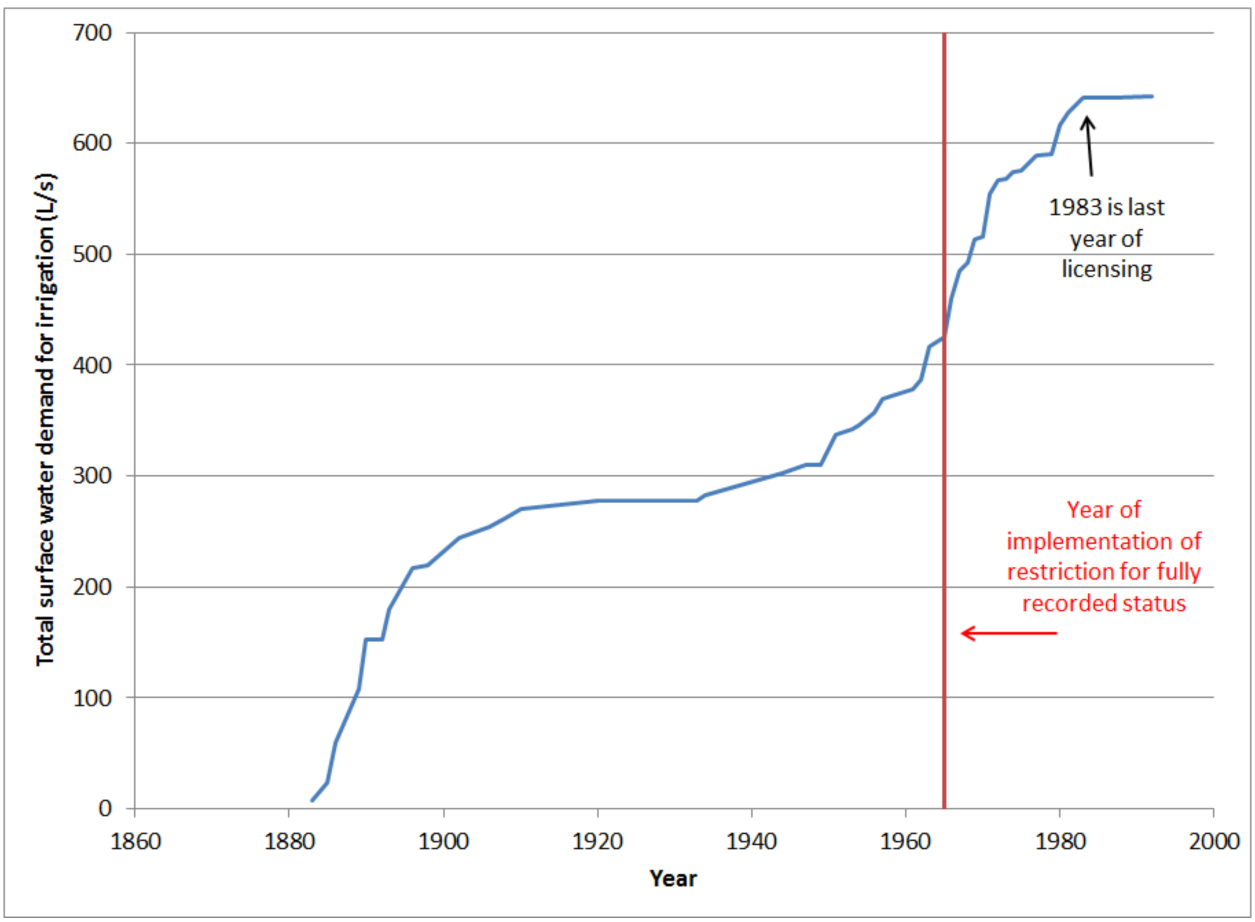


Figure 4. Chart showing total surface water demand for irrigation licences for lands within Bessette Creek watershed by year. Instantaneous demand was calculated from annual licenced quantity based on 120 irrigable days per year.

2.2 Aquatic and Environmental Flow Concerns

There are three main considerations relating to the Environmental Flow Needs (EFNs) of Bessette Creek:

1. In 1965, in response to documented flow shortages, the Province designated Bessette Creek as fully recorded for irrigation and large consumptive purposes unless fully supported by storage.
2. The Provincial and Federal Governments have made considerable investments in the development of conservation storage and EFN assessments to mitigate some of the ongoing impacts to the aquatic ecosystem resulting from flow shortages. Despite these investments, flows have dropped to levels with potentially serious ecosystem impacts (Level 3 drought) during four of the five years between 2015 and 2019 (Table 1).
3. The flow shortage problem is particularly evident during August and September. Highly valued fish populations impacted by these shortages include kokanee, plus juvenile and adult populations of Chinook Salmon, Coho Salmon and rainbow trout.

The problem of flow shortages has been flagged in several review documents. In a study of the hydrology and water use for 73 salmon streams in Thompson River watershed, Rood and Hamilton (1995, pg. 17) developed a series of indices to characterize water use in relation to water supply including:

Index 1: licenced water demand for August / mean 7 day summer low flow; and

Index 3: licenced water demand for August / mean August flow.

For Index 1, from the set of 73 salmon streams, Bessette Creek had the fifth highest value of 110%, with two other Bessette Creek tributaries including Duteau Creek and Harris Creek having the first and fourth highest with 719% and 132% respectively (Rood and Hamilton, 1995, Tables 8, 9 and 10, pages 50-55). For Index 3, Bessette Creek had the fourth highest value (65%), with two other Bessette Creek tributaries including Duteau Creek and Harris Creek having the first and third highest with 312% and 67% respectively (Rood and Hamilton, 1995, Tables 8, 9 and 10, pages 50-55). The authors flagged Bessette Creek as a sensitive stream and recommended a review of the water licence management plan and additional work on instream flow needs.

More recently, habitat restoration and instream flow conservation are recommended actions to counter temperature and flow related fish kills known to occur in Bessette Creek watershed during drought conditions (Fraser Basin Council, 2016). According to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2016), drought and elevated water temperatures are also identified threats to the long-term survival of all Interior Fraser River Coho Salmon, which include the South Thompson population and those Coho Salmon that inhabit Bessette Creek. This population is currently listed as Threatened by COSEWIC. This designation means: "A wildlife species that is likely to become an endangered if nothing is done to reverse the factors leading to its extirpation or extinction" (COSEWIC, 2019). In comparison an Endangered designation means: "A wildlife species facing imminent extirpation or extinction." The increasing demand for surface water and groundwater in the Thompson River watershed is rising threat (COSEWIC, 2016: p. 25). Regulation of groundwater use could influence this pressure (COSEWIC, 2016: p. 36) and therefore contribute to the recovery. This recommendation is consistent with a growing body of knowledge that highlights the importance of conserving groundwater upwelling areas for various life cycle activities including spawning, egg incubation, cool water refuge locations during drought and open-water areas overwintering.

The two distinct populations of Chinook Salmon that inhabit Bessette Creek include: (1) Shuswap River – summer timing (CK-15); and (2) South Thompson River – Bessette Creek (CK-16) (DFO, 2013). Of these two populations, the latter – recognized by its smaller body size and earlier migration – has been assigned a Red status under the Wild Salmon Policy triggering a shift in management emphasis from a social / economic to biological (DFO, 2016). Management priorities include identifying measures to protect fish and reduce known causes of mortality. For example, the timing of the Chinook Salmon recreational fishery in the Shuswap River and the minimum size limits are set to minimize harvest from the CK-16 unit (http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/fresh-douce/region8-eng.html).

Conserving EFNs in Bessette Creek is of particular importance given the declining trends in Coho Salmon and Chinook Salmon populations that utilize this watershed. These trends are evident for Coho Salmon across the South Thompson Watershed (COSEWIC, 2016) (Figure 5a), and also for Coho and Chinook Salmon within Bessette Creek watershed (personal communication with DFO biologists Lynda Ritchie and Sue Lemke, 2017) (Figure 5b). The main action to recover the Coho Salmon population was the unprecedented closure of all direct commercial fisheries in 1998, which resulted in a modest recovery (COSEWIC, 2016) (Figure 5a and 5b).

In 2002, Interior Fraser River Coho Salmon were listed as Endangered; following a reassessment, the status was downgraded to Threatened (COSEWIC, 2016). Reassessments occur periodically. Consequences of a listing increase when a COSEWIC listing is also accepted as a listing under the Federal Species at Risk Act (SARA). Such a change in designation may trigger additional conservation measures including development of a Stewardship Action Plan (see Species at Risk Act, 2002, Section 10.1) to address documented habitat impacts including exacerbated low flows due to water use.

2.3 Geology and Hydrogeology

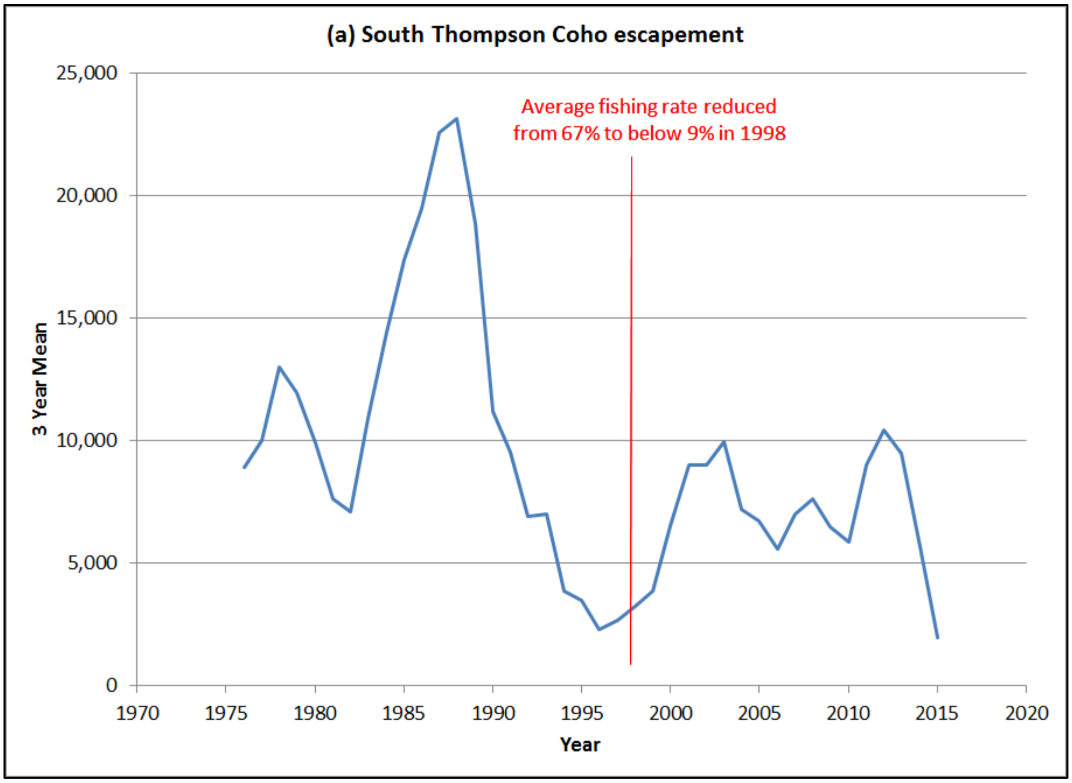
Fulton and Smith (1978) describe the glacial and nonglacial depositional history of sediments in British Columbia's southern interior through two glacial and two nonglacial periods. The time stratigraphic sequence for the area from oldest to youngest sediments includes the Westwold Sediments (nonglacial period), Okanagan Center Drift (Penultimate Glaciation), Bessette Sediments (Olympia nonglacial period), Kamloops Lake Drift (Fraser Glaciation), and recent postglacial sediments. The three youngest divisions are visible in the cover photo.

The Bessette Sediments are inferred to be deposits from the last major interglacial period (43,800 – 19,000 years before present (BP)). They are fluvial deposits, comprised of coarser grained materials sorted by streams and finer grained sediments which settled out on floodplains.

Kamloops Lake Drift, which is comprised of deposits from the last major ice advance, overlie the Bessette Sediments (Fulton and Smith, 1978). Deglaciation subsequently eroded the landscape until it resembled more closely what we observe in present day.

The type section for Bessette Sediments (Figure 6) – a reference point for stratigraphic interpretations - was mapped by Fulton and Smith (1978) near the WSC Gauging Station 08LC039 Bessette Creek above Beaverjack Creek (see Figure 1) at the Riggins Road bridge crossing approximately 1 km northwest of the subject well.

Within this type section, approximately 22 m of "interbedded silt, sand and gravel containing plant remains" comprise the mapped Bessette Sediments at the Riggins Road exposure (Fulton and Smith, 1978, p. 976). Fulton notes that the total thickness may be greater, owing to the bottom of the exposure being at stream level. Regionally, unconsolidated material resting on bedrock may be comprised of Okanagan Centre Drift.



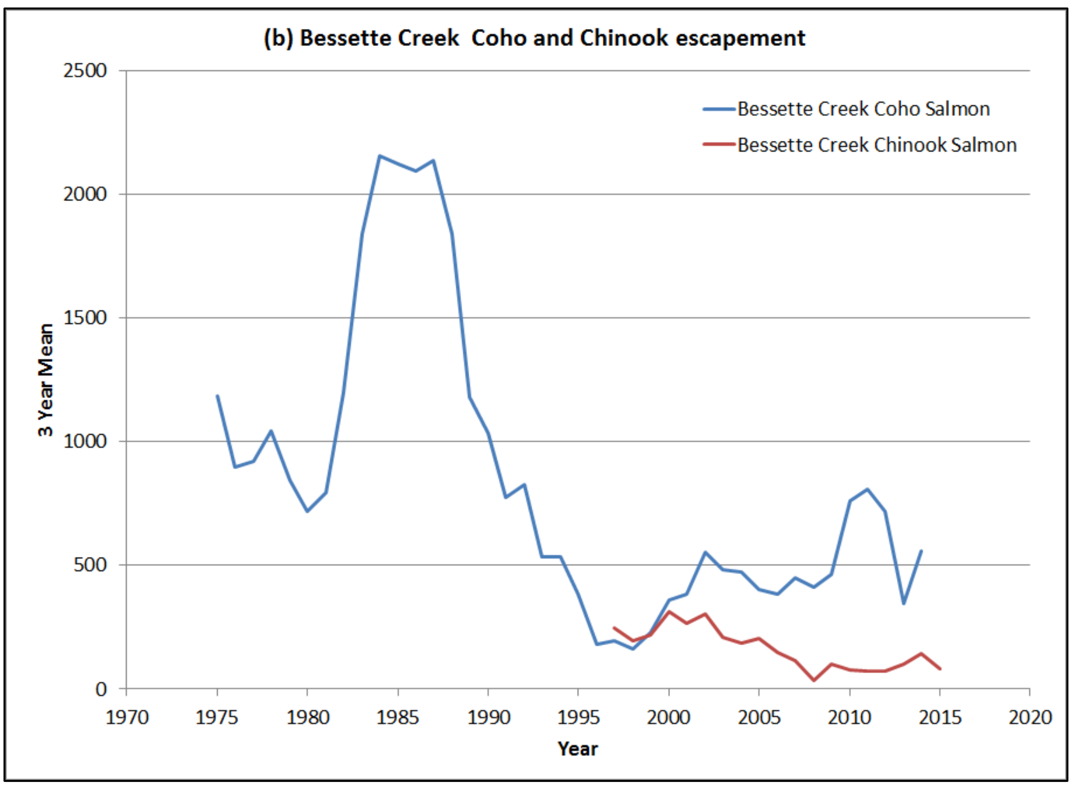


Figure 5. Three year running mean estimates of escapement for (a) the South Thompson sub-population of Interior Fraser Coho Salmon with data from Table 2 by COSEWIC (2016), and (b) Bessette Creek escapement of Coho (based on data from Lynda Ritchie DFO biologist 2017) and Chinook Salmon (based on data from Sue Lemke DFO Biologist in 2017).

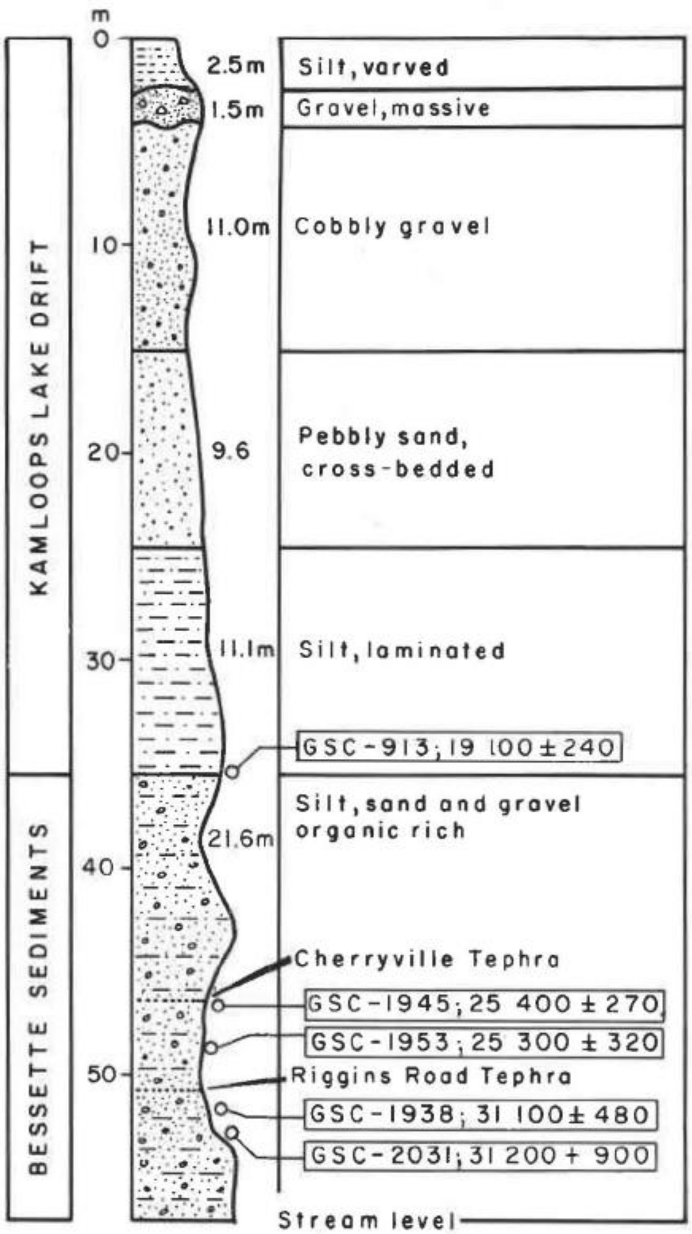


Figure 6. Bessette Type Section (from Fulton and Smith, 1978, p. 977). © Canadian Science Publishing or its licensors.

The Bessette Sediments are overlain at this location by another approximately 34 m of Kamloops Lake Drift. Kamloops Lake Drift was deposited during the last major glaciation, which ended approximately 10,000 years BP (Fulton and Smith, 1978). An excerpt from this publication is reproduced as Figure 6.

Bedrock in the area is mapped as Triassic age fine-grained sedimentary rocks of the Nicola Group. At the time of Fulton's writing, the bottom of the unconsolidated package had not been encountered. In 1989, during the drilling of Well Tag Number (WTN) 62555, close to the site, "granite bedrock" was encountered by the driller at approximately 100 m depth. It is shown in the cross-section presented in Figure 7.

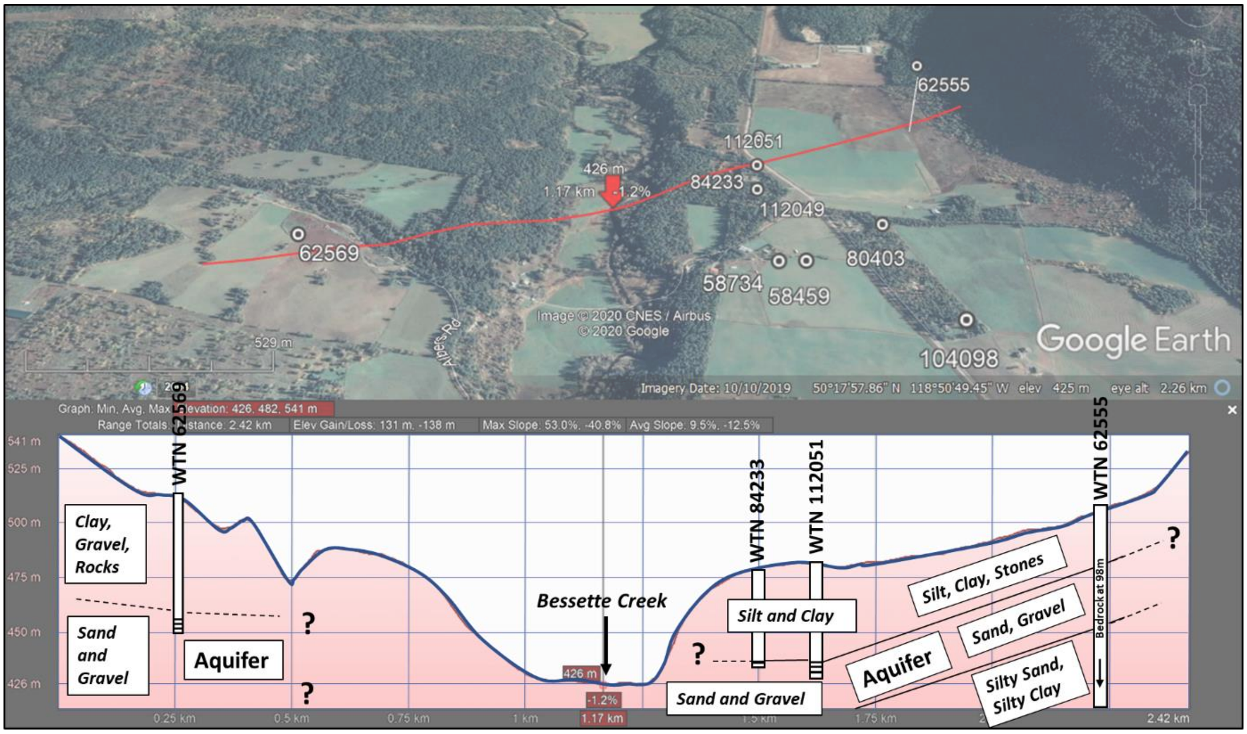


Figure 7. Cross-section through subject well and Bessette Creek (after WWAL, 2017a).

The subject well (WTN 112051) is constructed in an aquifer whose northwest boundary was mapped, at the time, along Bessette Creek, owing to the potential for interactions (i.e. recharge/discharge) between the aquifer and Bessette creek (ENV, 2012). It was remapped in 2017-18 as part of a larger project remapping aquifers throughout the North Okanagan (Stewart and Allard, 2018). The remapping showed this aquifer (Aquifer No. 318) to extend northward from Lumby through to Shuswap River near Shuswap falls, with Bessette Creek now within the aquifer footprint. The hydrogeologic cross-section (Figure 7) implies that the aquifer was likely continuous across the present-day Bessette creek valley bottom and was subsequently eroded through these valley bottom sediments since the last glaciation.

The aquifer information sheet (Stewart and Allard, 2018) indicates recharge likely occurs via bedrock discharge to overlying fans and colluvium, leakage from the surficial aquifer (Aquifer 319) and kame deposits (Aquifer 1002) in the southeast part of the aquifer. The sheet also speaks to the potential for hydraulic connection: “West of Shuswap Falls, the aquifer may provide significant baseflow to Bessette Creek.” It also indicates “The aquifer may be locally vulnerable where Bessette Creek has eroded through overlying units close to the top of the aquifer.” This is similar to the previous information sheet (ENV, 2012) which indicated “The eastern aquifer boundary follows Bessette Creek since this appears to be a potential groundwater discharge/recharge area.”

3. <u>GROUNDWATER USE APPLICATION</u>

A technical assessment report completed by a Qualified Professional (QP) in support of a new groundwater use licence application, dated October 28, 2016 (WWAL, 2016), was submitted to FLNR. The application was referred to David Thomson, Regional Hydrogeologist, for review and comment. The following describes information obtained from the report.

The groundwater application was found to be missing several components listed in the Technical Assessment Guidance (Todd et al., 2016). Key pieces of the report are summarized below.

3.1 Hydrogeology

The hydrogeological aspects of the report can be summarized as below:

- A 203-mm diameter well was installed to 52.4 m below grade
- The 60- and 80-slot screen assembly was 5.5 m long
- The static water level was reported as 36 m below top of casing
- The QP described the aquifer as locally unconfined
- A 24-hour pumping test was conducted by a pump installer at 15.8 L/s (250 US gallons per minute (GPM))
- A domestic well 350 m away, interpreted to be in the same aquifer, was monitored during the pumping test
- Bessette Creek was described as being 500 m north of the well, however online mapping tools place the distance at 320 m
- WSC gauge 080LC039 (Beaverjack) is located approximately 1 km away from the well on Bessette Creek, and somewhat upstream, where Riggins Road crosses the Creek (Figure 1).

The application proposed to use the well at a rate of 15.8 L/s (250 US GPM) for a total volume of 160,000 m^3 over the irrigation season.

3.2 Pumping Test Results

A pumping test was completed on the subject well. Drawdown measurements from the 24-hour pumping test are plotted below (Figure 8) on semi-log paper. Two main straight-line components are visible from approximately 10 to 100 minutes, and also from 100 – 1000 minutes. The interpretation is not reproduced here for proprietary reasons. Manually measured groundwater elevations increased 5 centimeters from 1080 – 1320 minutes, and then an additional 8 centimeters drawdown occurred between 1380 minutes through to the remainder of the test. Only manual readings were taken.

Deviations from theoretical time-drawdown relationships in a pumping test often indicate a boundary condition (Kruseman and de Ridder, 2000), so the QP was asked to explain the late-term rise and then decrease in groundwater levels after 1000 minutes. It was clarified that no differences in pumping rate were recorded, and that this "blip" was not viewed as a boundary condition. The interpretation line drawn by the consultant was flatter than the 100-1000 minute slope and drawn through the "blip" and extended to 100 days for interpretation using the Ministry of Environment method (ENV, 1999).

The QP's interpretation resulted in a safe yield calculation of 222 US GPM, whereas a conventional interpretation through only the late-time straight-line portion from 100 to 1000 minutes - ignoring the reason for the anomalous late time water level recovery - resulted in a safe yield of 206.8 US GPM using available software (Duffield, 2007).

The supplemental professional report (WWAL, 2017a) did not further discuss the potential sources of the "blip" in the pumping test response but did provide an estimate of transmissivity of 329.5 m^2/day from recovery data.

The nearest wells were domestic sources reported to be 350 and 950 m away. The closest well was monitored during the pumping test and the depth to water "changed less than 0.2 ft (5 cm) during the test" (WWAL, 2016).

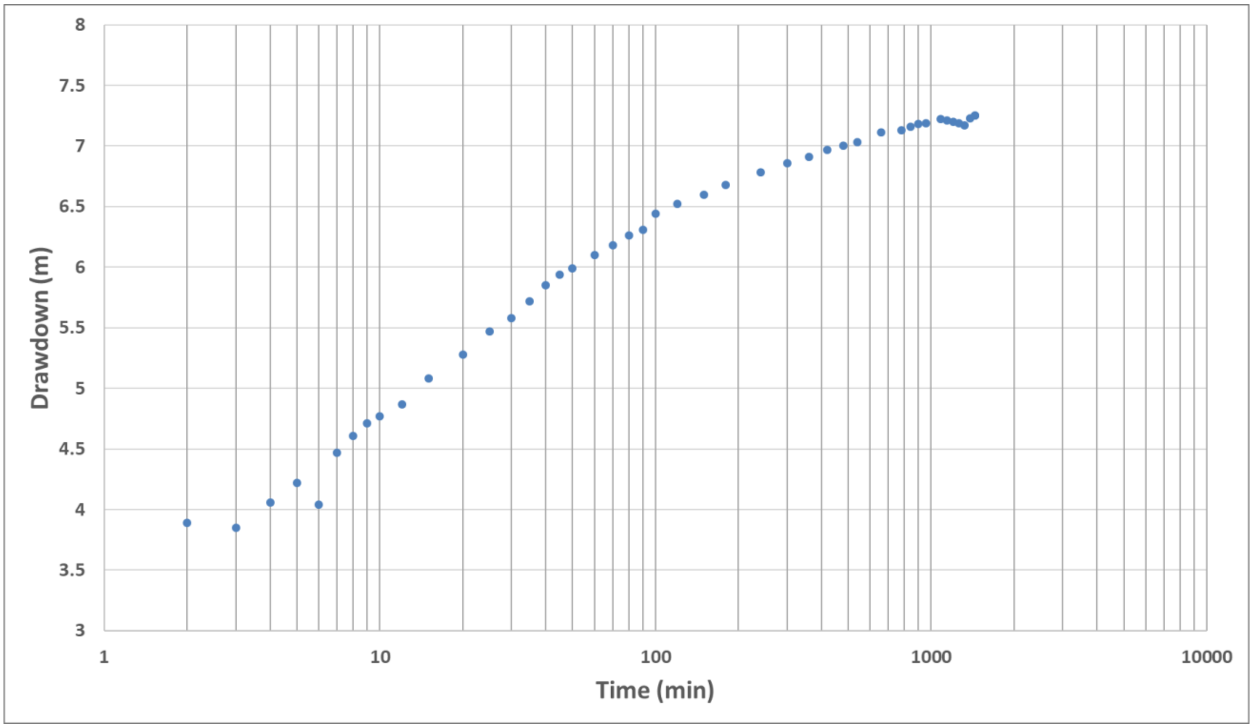


Figure 8. 24-hour drawdown data from the technical assessment WWAL (2016), plotted without interpretation.

3.3 Hydraulic Connection

Hydraulic connection between a well and surface water body can take two forms: pumping a well intercepts groundwater that would naturally discharge to the surface water body, or directly diverts water from the surface water body. Evidence supporting or refuting hydraulic connection between surface and groundwater, in the general case, can be comprised of multiple lines of evidence and based on professional judgement. Hydraulic connection is discussed in detail in Water Science Series publication WSS 2016-01 (Province of B.C., 2016).

The QP addressed the question of hydraulic connection by three main lines of thought:

1. any connection was probably difficult to measure or estimate;
2. groundwater flow is likely toward the Shuswap River (no water allocation restrictions) rather than Bessette Creek (allocation restrictions);
3. "…the likelihood that the proposed well use would have a significant effect on Bessette Creek stream flow and aquatic resources is low…" (WWAL, 2016; p 6).

3.3.1 Measuring Connection

No attempt was made by the QP to estimate the degree of hydraulic connection between the well and Bessette Creek using streamflow depletion models or similar tools. The relationship between the magnitude of the proposed pumping volume and that of the streamflow was reported. It was stated in the QP report that "The proposed irrigation well average flow rate of 0.0075 m^3/sec (120 US GPM) comprises approximately 4% of the recorded low flow at the upstream gauge and 4.7% of monthly low flow at the downstream gauge, and less than 1% of typical August low flows." (WWAL, 2016; p 6). The proposed peak usage rate of 250 US GPM represents a much higher percentage (9.8%) of the low flow in Bessette Creek.

3.3.2 Groundwater Flow Direction

The QP asserted that groundwater flowed primarily from the direction of the subject well toward Shuswap River, some 2300 m away, rather than toward Bessette Creek, 320 m away. During the appeal proceedings, supporting evidence consisted of a watershed-scale map (Golder, 2012) indicating groundwater flow direction toward the Shuswap River. The scale of the map was sufficiently large that Bessette Creek was not even illustrated, and therefore was considered to have minimal relevance to the local-scale issues.

3.3.3 EFN and Likelihood of Significant Effect

The report did not provide an EFN assessment, stating the effects of groundwater withdrawal on flows in Bessette Creek couldn't be determined with available data. Further, the report states "…it appears the magnitude of any effects is likely to be small" (WWAL, 2016; p 6) and the time lag for effects of pumping is likely to be "…several months or more…" (WWAL, 2016: p 6).

3.4 Technical Assessment Review

During the technical review of the application, the Regional Hydrogeologist noted deficiencies in the report from what was required in the Provincial Guidance for Technical Assessments (Todd et al., 2016), and accordingly requested further technical clarification from the applicant. The clarification request, pertaining to hydrogeology was verbatim as follows:

- Hydrogeological maps and cross sections;
- Discussion of potential connection to adjacent aquifers, as noted in Aquifer Description Report for Aquifer 318;
- Available values for the hydraulic properties of the source aquifer;
- Detailed diagram of the well; and
- With respect to the report provided, the following information needs are requested:
    - Identification of likely boundary conditions inferred from observed pumping response;
    - Discussion on the apparent recharge boundary toward the end of the test, particularly whether +/- 5 GPM fluctuations described correlate with this time period. Is it believed these fluctuations could be responsible for the apparent recharge? No pumping fluctuations are noted in the data table;
    - Discussion of other possible interpretations for the apparent recharge boundary;
    - Discussion of the nearly 1 m difference in static water levels between completion of development and start of the constant rate test;
    - Clarification of total drawdown of 7.25 m per data table or 6.7 m per table 2 within text;
    - Discussion of best fit line going through a period of recharge;
    - Available drawdown in a confined aquifer is commonly the difference between static water level and the top of the confined aquifer. Please identify the top of the confined aquifer and evaluate safe long-term yield on that basis;
    - Consider analyzing recovery portion of the test to aid in understanding the aquifer response to pumping, as it removes artifacts of pumping variations; and
    - Commonly, calculations of aquifer transmissivity are provided when doing a pump test. Consider doing so for completeness, particularly if other values exist to compare to.

The Water Officer and Regional Hydrogeologist met with the QP to discuss these and other concerns prior to the QP submitting a supplemental report.

3.5 Responses to Concerns

A supplemental report was provided in 2017 (WWAL, 2017a). In this report the QP stated the aquifer was locally unconfined based on the well log, and that there was no evidence of a recharge boundary, despite increasing water levels occurring for the last 5 hours of the pumping test. The cross-section submitted also supported the potential that Bessette Creek could have a recharge/discharge relationship with the aquifer. The Aquifer Information Sheet (ENV, 2012) at the time stated that Bessette Creek was thought to be a potential recharge/discharge boundary. This further indicated to the Regional Hydrogeologist a hydraulic connection may exist between the subject well and Bessette Creek.

Upon review of the available information, the QP and applicant were informed by FLNR that the aquifer and well were considered hydraulically connected to Bessette Creek and EFN-related restrictions remain in place for the creek. FLNR outlined other options for the applicant and QP to consider, such as a more rigorous determination of the degree of hydraulic connection, a conditional license with reduced quantity or seasonal restrictions, drilling a new well in another aquifer, or using storage. The applicant did not provide additional information or a modified application, and instead requested that a decision be made on the information already submitted. Based on the information provided, the statutory decision maker refused the application.

4. <u>APPEAL OF DECISION</u>

The decision to refuse the license was made on June 27, 2017. The basis for the decision was as follows:

"*Bessette Creek is reasonably likely to be hydraulically connected to the aquifer from which you have proposed to draw water. There is insufficient flow in Bessette Creek to maintain environmental flow needs*." (Warner, 2017)

The appeal was received by the Environmental Appeal Board on July 14, 2017. The basis for the appeal was described by the appellant as both administrative and technical, and addressed both subjects of the decision, groundwater and EFNs. Those concerns are summarized by topic in Table 3 below.

Table 3. Summary of concerns identified by the Appellant in the Notice of Appeal.

Number	Concern	Topic
1.	The hydraulic connectivity between the subject well and Bessette Creek, and the extent of that hydraulic connectivity to the creek versus the Shuswap River.	Groundwater
2.	The extent of loss of groundwater contribution to Bessette Creek from pumping the well.	Groundwater
3.	The timing of loss of groundwater contribution to Bessette Creek from pumping the well for irrigation purpose during the irrigation season.	Groundwater
4.	The timing of low flow periods in Bessette Creek.	EFNs
5.	The EFNs of Bessette Creek during those low flow periods.	EFNs
6.	The environmental values of Bessette Creek benefitting from protecting the EFNs of the creek.	EFNs
7.	The significance of loss of groundwater contribution (Item #2) to the EFNs of Bessette Creek during low flow periods.	EFNs
8.	The role of releases from storage on the EFNs of Bessette Creek, including during low flow periods	EFNs

The concerns raised during the notice of appeal were not substantiated with any new scientific analyses. The focus was on the uncertainties surrounding the issue of hydraulic connection, direction of groundwater flow, timing of effect, and whether that effect could be measured.

The administrative issues raised are summarized as follows:

- ENV didn't make enough effort to tell people that there was no more water available for non-domestic wells; and,
- FLNR should have designated Bessette Creek a sensitive stream as recommended by a report in 2014.

The appeal also requested the EAB reverse the water license refusal and order FLNR to grant the applicants an irrigation license for 80,000 m^3/year (half the original application request), put a temporary moratorium on new groundwater and surface water licenses in the watershed and associated aquifers, put a temporary moratorium on drilling new non-domestic wells, and initiate a Water Sustainability Plan for Bessette Creek.

5. <u>DEFENCE OF DECISION – HYDROGEOLOGY</u>

The *WSA* requires those wishing to divert and use groundwater for non-domestic purposes to apply for an authorization. During the application process, the applicant may be required to provide specific information to the SDM to help inform the decision. The Technical Assessment Guidance document (Todd et al., 2016) broadly outlines those information requirements. As described above, additional information was requested by the SDM, however the applicant did not provide the requested information and instead requested a decision be made in the absence of the information FLNR felt was necessary to make the decision. Subsequent to the appeal being filed, the Province of British Columbia provided a defence of the decision.

The defence of the decision comprised of subject matter expert (SME) reports from Regional Hydrogeologist, David Thomson, and Aquatic Biologist, Richard McCleary. Mr. Thomson established the reasonable likelihood of hydraulic connection and quantified it with an analytical model using methodology outlined by ENV (Rathfelder, 2016). Mr. McCleary used the same analytical model to provide an accounting of water use for the entire watershed, demonstrating that there is insufficient flow in Bessette Creek to maintain environmental flows.

5.1 Defence of Decision – First Response

The response to the appeal consisted of addressing the questions of hydraulic connection, streamflow depletion, and groundwater flow direction.

5.1.1 Hydraulic Connection

One basis for the appeal was that while a hydraulic connection may be present it was not clearly established. Further, the QP stated that it was not possible to estimate the timing of effect of the hydraulic connection.

Hydraulic connection between a groundwater well and a surface water body can occur in two ways as noted earlier. In the present case it was considered that groundwater travelling toward Bessette Creek would be intercepted by the applicant's well. The cross-section supplied by the QP gave rise to 'reasonable likelihood' of hydraulic connection. The hydraulic gradient toward Bessette Creek, from the well, was twice that of toward Shuswap River, further supporting the reasonable likelihood that groundwater pumped from the well would intercept water that otherwise would flow to Bessette Creek. The aquifer information sheet at the time (ENV, 2012) indicated the aquifer boundary was drawn along the creek owing to the creek's potential discharge/recharge relationship.

5.1.2 Streamflow Depletion Model

To estimate the effect (rate of depletion), and timing of effect (time lag of depletion), a series of analytical models were used following methodologies described in ENV publication Rathfelder (2016). The primary input parameters are pumping rate, length of pumping time, distance to the stream, and transmissivity.

For the purpose of the modelling exercise, the well was run at the proposed maximum usage rate (250 US GPM) for 117.4 days of continuous pumping, when the requested license amount of 160,000 m^3 would be reached. The distance between the well and the creek was indicated by WWAL (2016) as 500 m. It was measured by the Regional Hydrogeologist using several online tools as being approximately 320 m away. Both distances were used in the output below. A transmissivity of 329 m^2/d was the lowest of two values calculated by the QP and was used in the model. Some other parameters such as stream width were also input, but the model is most sensitive to transmissivity and distance. The model was allowed to recover from pumping for the duration of the year, and a second year of irrigation was simulated.

The model was run using distances to Bessette Creek of 500 m (QP estimate) and 320 m (online measurements). Figure 9 shows that at a distance of 500 m, the maximum rate of streamflow depletion reaches approximately half of the pumping rate at the end of the pumping season, or 125 US GPM. At a distance of 320 m (Figure 10), the depletion is estimated at between 65 to 70%. This model suggests that at the height of the irrigation season, approximately 8 litres per second would be diverted to the well which otherwise would travel to the stream, if the well were active.

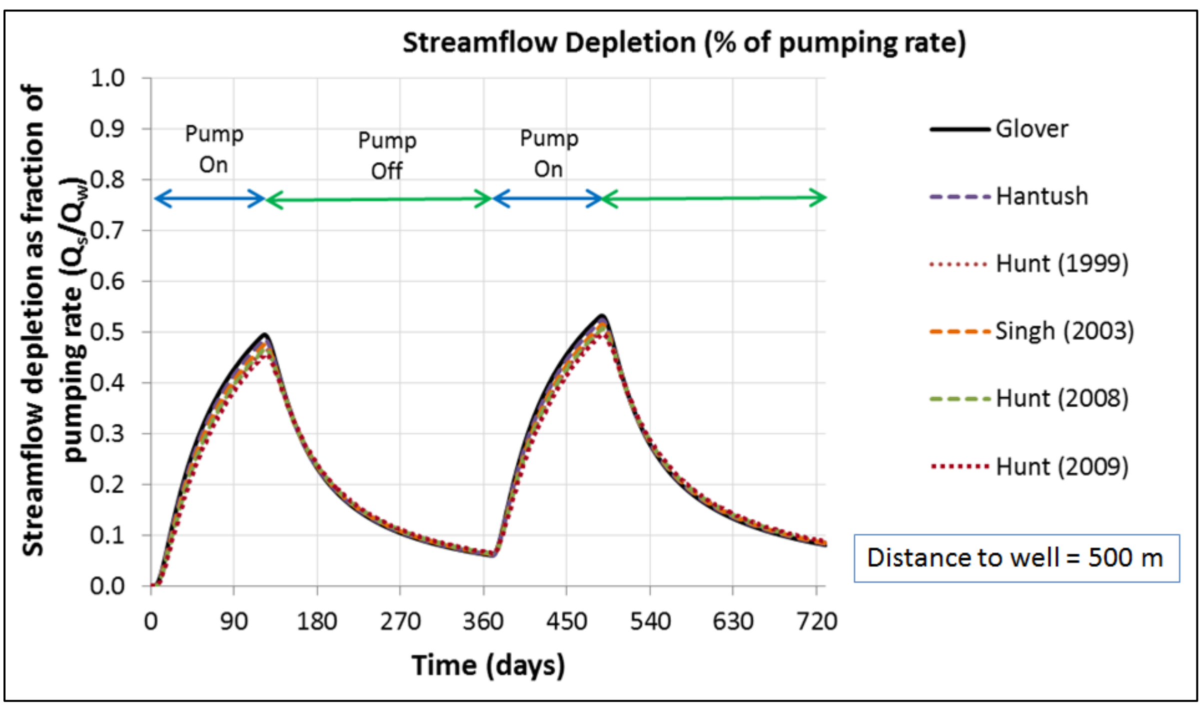


Figure 9. Modelled streamflow depletion as a fraction of pumping a well 500 m away. Results for several analytical models are shown to be in close agreement.

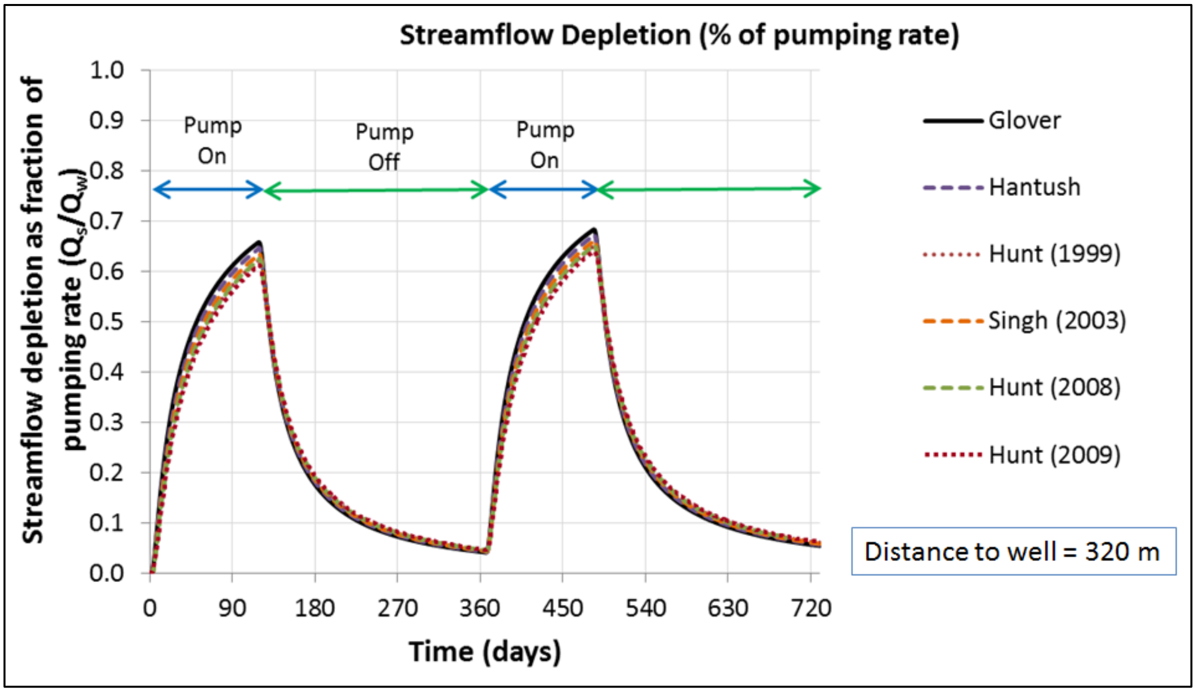


Figure 10. Modelled streamflow depletion as a fraction of pumping a well 320 m away. Results for several analytical models are shown to be in close agreement.

Rathfelder (2016) showed sensitivity analyses indicating that at progressively greater distances, the maximum depletion effect may be reached at some significant time (days to months) after pumping ceases. A graph illustrating the estimated effect for the subject well is provided below (Figure 11). When distance is held constant and transmissivity is varied by an order of magnitude, a similar magnitude of response as below, is seen in the model.

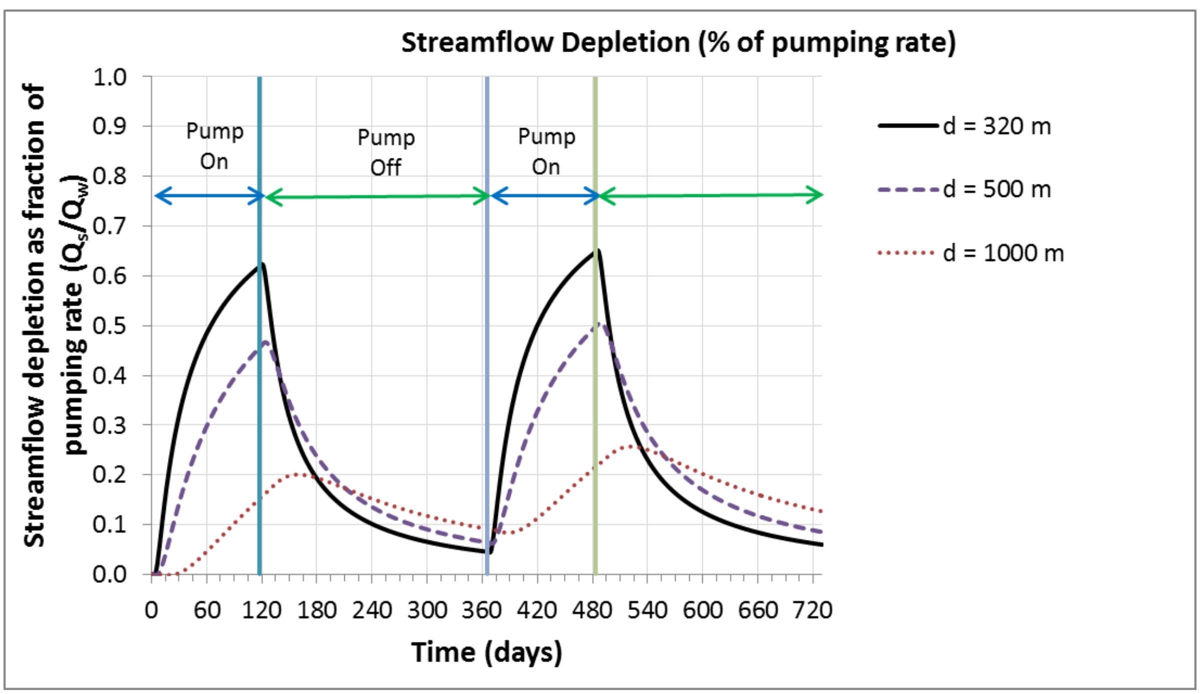


Figure 11. Variation of streamflow depletion with distance from well.

5.1.3 Groundwater Flow Direction

The groundwater elevation in the well was compared to that at the Shuswap River, and Bessette Creek. The water bodies are 2300 m and 320 m away from the well, respectively. The respective hydraulic gradients were calculated as 0.049 m/m toward Bessette Creek, and 0.0099 m/m toward Shuswap River using elevation data supplied by the QP. Since there is a steeper hydraulic gradient toward Bessette Creek, this indicates groundwater flow will be predominantly toward Bessette Creek.

5.2 Appellant Response

The Appellant's QP responded to the Province's defence on November 17, 2017 with a 4-page letter (WWAL, 2017b). It continued to highlight uncertainties around groundwater flow direction, and the hydraulic connection between the aquifer systems and Bessette Creek. The letter stated:

- half the original license request of 80,000 m^3/year would be sufficient, and requested a license be granted in that amount;
- groundwater flow is likely to be east-northeast toward the (unrestricted) Shuswap River rather than toward Bessette Creek;
- the nature and extent of the hydraulic connection "remains unproven";
- as much as 80% of flow from Aquifer 318 discharges to Shuswap River;
- while groundwater extraction from the subject well "would probably induce a small reduction in groundwater flow that would otherwise discharge to the lower-most reaches of Bessette Creek", the effect would not be measurable; and,
- the time lag between groundwater pumping and stream flow effects would not likely coincide with the August-September low-flow period.

The appellant's response provided no new evidence to support the above statements.

5.3 Defence of Decision – Second Response

To better respond to ongoing questions regarding hydraulic connection, the Regional Hydrogeologist made a field visit to Bessette Creek at its closest access point, at a bridge (Riggins Road) where the WSC gauge 08LC039 is located (Figure 12), to take photographs and record observations. This is less than 1 km from the subject well location (Figure 1). From the bridge, a large exposure of unconsolidated sediments is present upstream, to the west (Figure 13 and Figure 14). These sediments were mapped as representative of the type section referred to in Geologic Survey of Canada reports as Bessette Sediments (Fulton and Smith, 1978). These were previously described in Section 2.3.

Photographs of the exposure and the surrounding valley were taken in order to improve the conceptual model for groundwater flow in the area. Views of the mapped outcrop are presented from the valley floor and opposite side of the valley.

The second response by the Regional Hydrogeologist (Thomson, 2017b) consisted primarily of annotated photographs taken during the field visit, accompanied by a short letter with additional descriptions and statements reaffirming the assessment of hydraulic connection and groundwater flow direction. The sharp relief of the valley shown in the photographs supports the assertion that the dominant local groundwater flow direction is from the well toward the valley bottom (Bessette Creek), rather than toward Shuswap River. Figure 15 provides a view of the features shown in Figures 12 through 14, from across the valley.

Figure 12. Bessette Creek at Riggins Road, valley floor and opposite valley wall (view to the northwest). The Beaverjack WSC Gauge is visible to the right of the bridge. Image: David Thomson, November 28, 2017

Figure 13. Exposure of mapped Bessette Sediments visible upstream of bridge (west). Image: David Thomson, November 28, 2017

Figure 14. Closer view of outcrop, with Bessette Creek in the foreground. Coarser grained sediments at the top of exposure are interpreted by Fulton and Smith (1978) to be Kamloops Lake Drift. Image: David Thomson, November 28, 2017.

Figure 15. View of incised valley floor with Bessette Creek at opposite valley wall. Mapped outcrop is to the right side of the picture. The Applicant Well is approximately 1 km to the left of the outcrop. Image: David Thomson, November 28, 2017.

6. DEFENCE OF DECISION – WATER USE ACCOUNTING AND ENVIRONMENTAL FLOW NEEDS

An EFN assessment in support of a water allocation decision can be summarized as a water balance exercise where a positive balance supports the additional allocation whereas a negative balance indicates that the allocation will interfere the environmental flow needs of the stream. For this exercise, the water balance equation, which is applied at both the annual and monthly time scales, has two main terms including: (1) the natural water supply, and (2) the water demand:

$$water\ balance = water\ supply - water\ demand \qquad \textit{Equation 1}$$

For managed systems, because there is no readily available measure of natural water supply, the supply term in the equation is the sum of the residual flow and the actual water withdrawals:

$$naturalized\ water\ supply = residual\ water\ supply + actual\ demand \qquad \textit{Equation 2}$$

Because the water demand is the sum of the total licensed allotment and the EFN, the water balance equation can be solved using:

$$water\ balance = (residual\ flow + actual\ demand) - (licensed\ demand + EFN) \qquad \textit{Equation 3}$$

To understand the long-term reliability of a water supply, a decision-maker can consider a range of water supplies that will be encountered over time due to the natural long-term variability (i.e., period of several decades) in runoff. To accomplish this goal, the water balance was assessed for both average flow and drought conditions.

The following sections describe the steps taken to solve each term and then finally to solve the water balance. Given the lack of direct measures for some of the terms in these equations, indirect approaches, or work arounds, represented the only practical way forward. To manage the inherent uncertainty with this approach, multiple sources of information were used and the problem was examined from different angles, each with a unique set of considerations. Although this multiple lines of evidence approach can generate different numerical values, the reader is reminded to focus on the outcome of the water balance exercise and whether there is a surplus or deficit, and whether this surplus or deficit is low, medium or high. Alignment in outcomes across each line of evidence provides support for the conclusion. This approach was intended to generate the best available information for the decision maker to consider during their adjudication of this water license application.

6.1 Naturalized Water Supply

The formula used to estimate the naturalized water supply is:

$$LT\ MAD = LT\ MAF + \textit{Annual demand} \qquad \textit{Equation 4}$$

Where:

LT MAD = long-term mean annual discharge; and
LT MAF = long-term mean annual flow (i.e., residual flow).

For this study on Bessette Creek, the formula used to estimate the demand at either annual or monthly time scales is:

$$\text{Total Demand} = \text{water utilities demand} + \text{surface water irrigation demand} \\ + \text{streamflow depletion from groundwater irrigation}$$

Equation 5

Residual Flow at the Nearest WSC Station

Residual flow is defined as the flow that remains in a stream after all upstream diversions have been removed. In managed watersheds, this is the value that the gauging stations report. In the Okanagan Region, a common approach for determining the residual flow at a Water Survey of Canada gauging station of interest is to use the records from the standard period between 1996 and 2010 (e.g., Associated, 2017). This period corresponds to a series of years when there were numerous Water Survey of Canada gauging stations in operation during which there were also a wide range of flood and drought conditions (Figure 16). The LT MAF for the standard period of 1996-2010 at WSC Station 08LC039 - Bessette Creek above Beaverjack Creek (see Figure 2 for location) is 3.62 m^3/s or 114,160 ML/year (Table 4). Because precipitation patterns are known to vary at cycles of a decade or more, there is always a chance that the 15-year standard period from 1996 to 2010 may not represent the conditions that fish are adapted to. For Bessette Creek above Beaverjack Creek, the LT MAF for the 45-year period from 1970-2014 is 3.63 m^3/s (calculated with Rstats fasstr package (Goetz and Schwarz, 2020), so the value for LT MAF using the standard period from 1996-2010 of 3.62 m^3/s is reasonable.

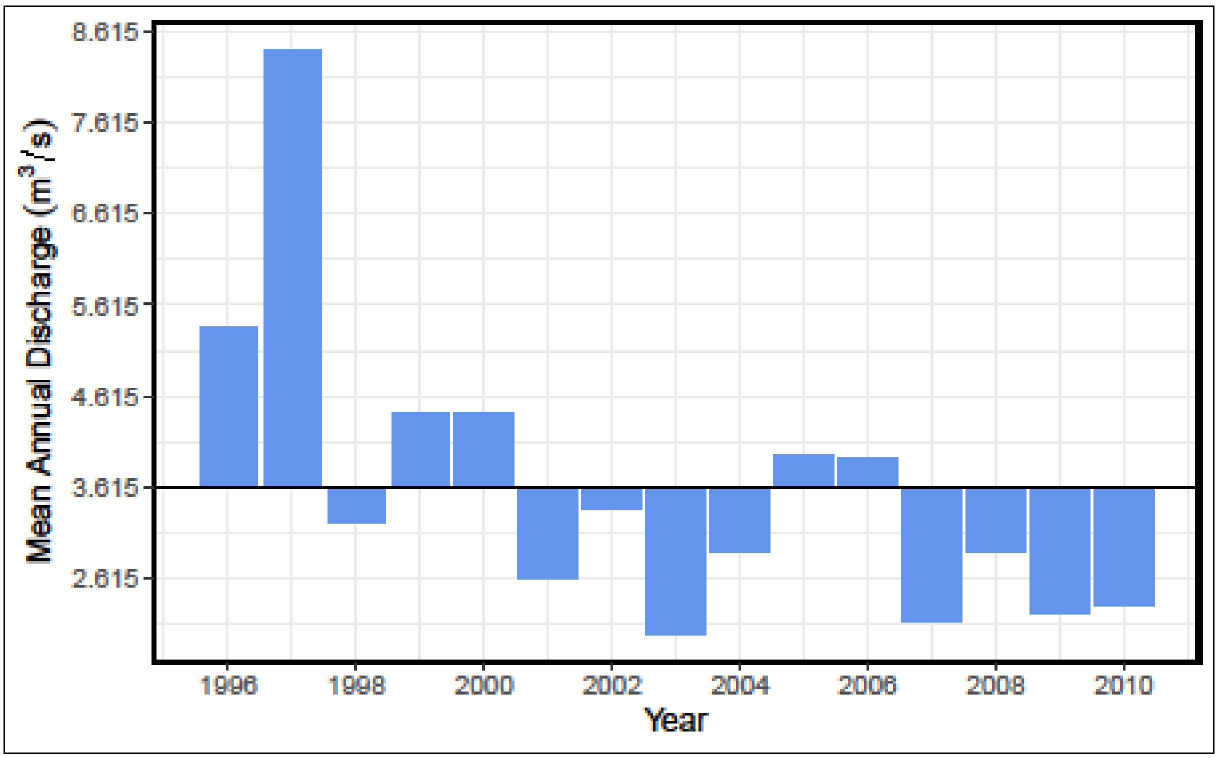


Figure 16. Differences between yearly mean annual flow and long-term mean annual flow (LT MAF = 3.62 m^3/s) for WSC 08LC039, Bessette Creek above Beaverjack Creek for 1996 – 2010. Figure produced using "plot_annual_means" function in Rstats fasstr package (Goetz and Schwarz, 2020).

The residual daily flows for Bessette Creek are highly variable between individual years, with long-term averages highest during May and June, and notable periods of low flow in January, February, August and September (Figure 17). According to Epp (2014), the year 2003 is an important reference year for water management for two reasons: (1) it was one of three years in the early 2000's when the Duteau Creek reservoirs managed by the Regional District of North Okanagan failed to refill during the freshet; and (2) extremely low summer flows occurred in Bessette Creek (Epp, 2014). Flows in 2003 from mid-July to early September were the lowest flows on record (Figure 17).

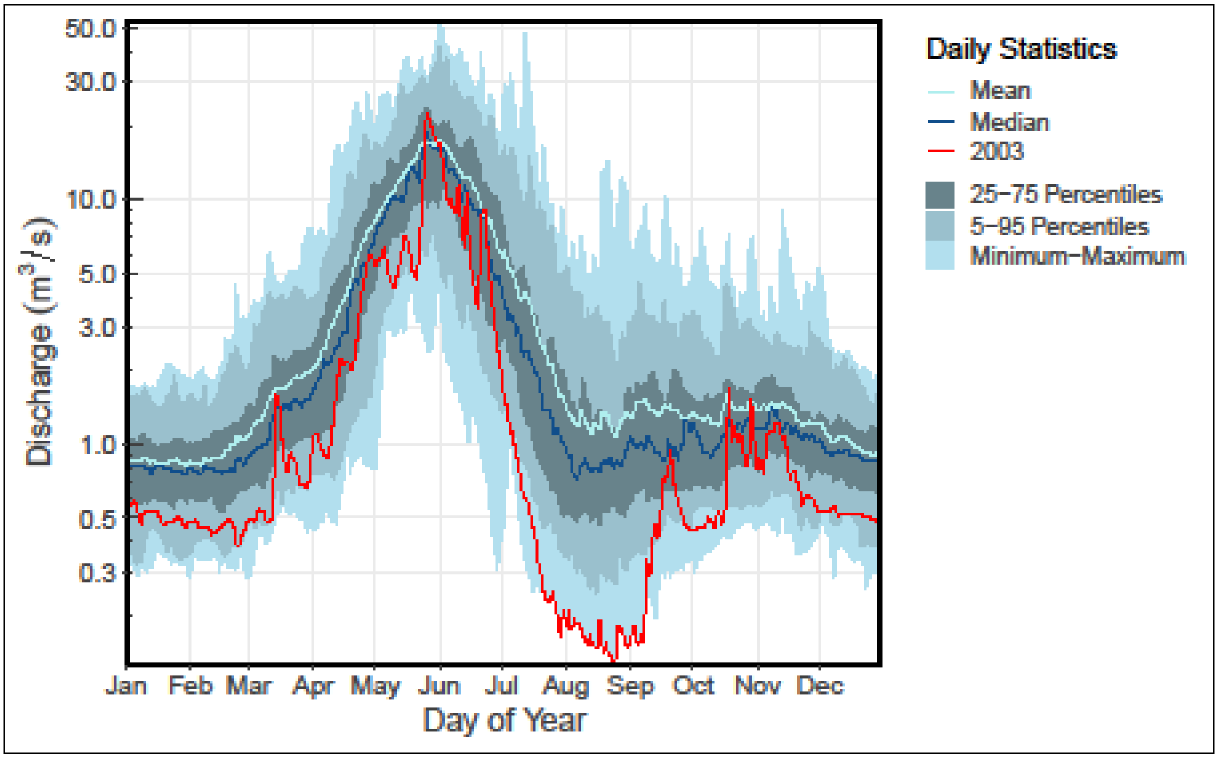


Figure 17. Hydrograph with daily flow summary statistics for WSC Station Bessette Creek above Beaverjack Creek (08LC039) for the entire period of historic record from 1970-2014 plus daily flows from 2003. Figure produced using "plot_daily_stats" function in Rstats fasstr package (Goetz and Schwarz, 2020).

The approach for determining the naturalized flow was to add the residual flow and estimated water use (Equation 4). A specific type of annual hydrograph using monthly timesteps can help to visualize the concept of this naturalization exercise (Figure 18). In this figure, the total area under the line that includes the green and blue shading represents the estimate of the total naturalized flow per month. The green shading represents that portion of the total water supply that typically used for consumptive purposes, which for Bessette Creek is predominantly irrigation to support agriculture. Therefore, the green could be viewed largely as the Bessette Creek water that is lost through evapotranspiration to support crop production. The blue shading represents that water that is retained within Bessette Creek that is available to meet the environmental flow needs. The specific methods for estimating the monthly values of residual flow and water use that were used in this figure are detailed later in this chapter.

The naturalized long-term annual mean annual discharge (LT MAD) is an important reference value with a long history of use in environmental flow needs science (Tennant 1976). The flow naturalization exercise was also completed at the annual scale, when the total annual residual flow (measured at in ML per year), and the total annual water use (water utilities, surface water irrigation, and groundwater irrigation) are added to provide an estimate of the total annual naturalized flow.

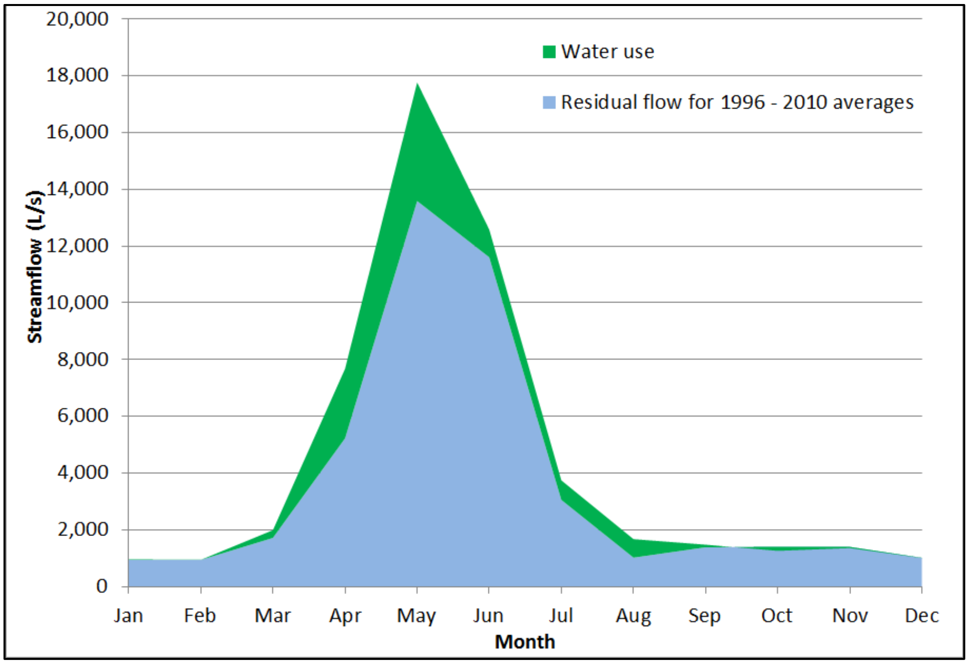


Figure 18. Naturalized flow represented with stacked area chart showing residual flow (blue shading) and water use (green shading) (e.g., Naturalized flow = residual flow + estimated water use) for average flow conditions for the 1996 – 2010 period.

The approach for estimating irrigation water demand at both the annual and monthly time steps was consistent with standard water conservation practices that are also used for irrigation water licensing in British Columbia whereby the quantity of water required to irrigate a crop is determined in consideration of soil water holding capacity, crop type, climate, and irrigation system efficiency (e.g., Tam and Petersen, 2014). This approach identifies the quantity of water required to meet the full demand of the growing crop while preventing the application of surplus water beyond soil field capacity that could either return to a stream through overland flow or return to an aquifer through saturated interflow. Any occurrence of surplus irrigation water returning to a surface water or groundwater source could indicate over-irrigation and lack of compliance with the conservation principles that underpin determination of irrigation requirements. Based on this premise, return flow is excluded from the water budget approach applied in this exercise.

The flow naturalization exercise was first completed to provide an estimate of the naturalized long-term mean annual discharge or LT MAD (Table 4 and Figure 19). Demand estimates were summarized using the different values of water demand from Epp (2014), Associated (2016), and McCleary (this chapter). The two different residual flow values were used including those from Epp (2014) and those from McCleary (this chapter). The LT MAD ranged from a low of 4.19 m^3/s to a high of 4.96 m^3/s (Table 4).

From these three estimates, it is important to note that streamflow depletion from groundwater irrigation of 12,620 ML/year that was based on the data in Associated (2016) is much higher than estimate of 2,979 ML/year from McCleary (this chapter) (Table 4 and Figure 19). Associated (2016) did not report the streamflow depletion from groundwater irrigation, but they did provide data that could be extrapolated to provide a reasonable estimate. The methods used to generate the estimated value of 12,620 ML/year for streamflow depletion from groundwater irrigation are detailed in the footnotes of Table 5. The differences in streamflow depletion from groundwater irrigation are largely due to differences in the extent of the irrigated land-base. This discrepancy will remain a difficult issue to resolve until at least March 1, 2022 when a water licence will be required for all irrigation, at which time any discrepancies between an agricultural land use inventory and the water licence records would indicate unlicensed and unlawful water use. After all groundwater licenses are entered into the Provincial database, an updated summary of licensed withdrawals could be completed (Table 13), and the streamflow depletion from groundwater irrigation quantity provided by McCleary (this chapter) could be updated. At such time, a closer alignment is expected between the streamflow depletion from groundwater irrigation provided by Associated (2016) and a new estimate based on the methods of McCleary (this chapter).

Table 4. Three estimates of naturalized flow based on work from Epp (2014), Associated (2016), and McCleary (this chapter).

Purpose	Method 1 Data predominantly from Epp (2014)		Method 2 Data predominantly from Associated (2016)		Method 3 Data predominantly from McCleary (this chapter)	
	Annual quantity (ML/year)	Annual quantity (m^3/s)	Annual quantity (ML/year)	Annual quantity (m^3/s)	Annual quantity (ML/year)	Annual quantity (m^3/s)
Demand: Water utilities	14,292[1]	0.45[5]	14,292[1]	0.45[5]	14,292[1]	0.45[5]
Demand: Surface water irrigation	5,622[1]	0.18[5]	15,237[6]	0.49[5]	6,660[9]	0.21[5]
Streamflow depletion from groundwater irrigation	2,979[2]	0.09[5]	12,620[7]	0.40[5]	2,979[2]	0.09[5]
Subtotal: Demand	**22,893**	**0.72**	**42,149**	**1.34**	**23,931**	**0.75**
Residual flow (LT MAF)	109,430[4]	3.47[3]	114,160[4]	3.62[8]	114,160[4]	3.62[8]
Grand Total: Naturalized flow (LT MAD)	**132,323**	**4.19**	**156,309**	**4.96**	**138,091**	**4.37**

Data from Epp (2014)	Data from Associated (2016)	Data from McCleary (this chapter)	Calculated field

[1] 14,291,642 m^3/year and 5,622,474 m^3/year from Epp (2014), Table 5, pg. 21. Units converted and rounded to 14,292 ML/year and 5,622 ML/year. The water utilities demand from Epp (2014) was used in all three methods.
[2] 2,979 ML/year from McCleary (this chapter) Table B3.
[3] 3.473 m^3/s from Epp (2014), Table 6, pg. 24 rounded to 3.47 m^3/s
[4] Unit conversion from m^3/s
[5] Unit conversion from ML/year
[6] 15,237 ML/year from Table 5.
[7] 12,620 ML/year from Table 12.
[8] Calculated with Rstats fasstr package (Goetz and Schwarz, 2020) using “calc_longterm_mean” function with start year = 1996, and end year = 2010 for WSC 08LC039.
[9] See Table 5

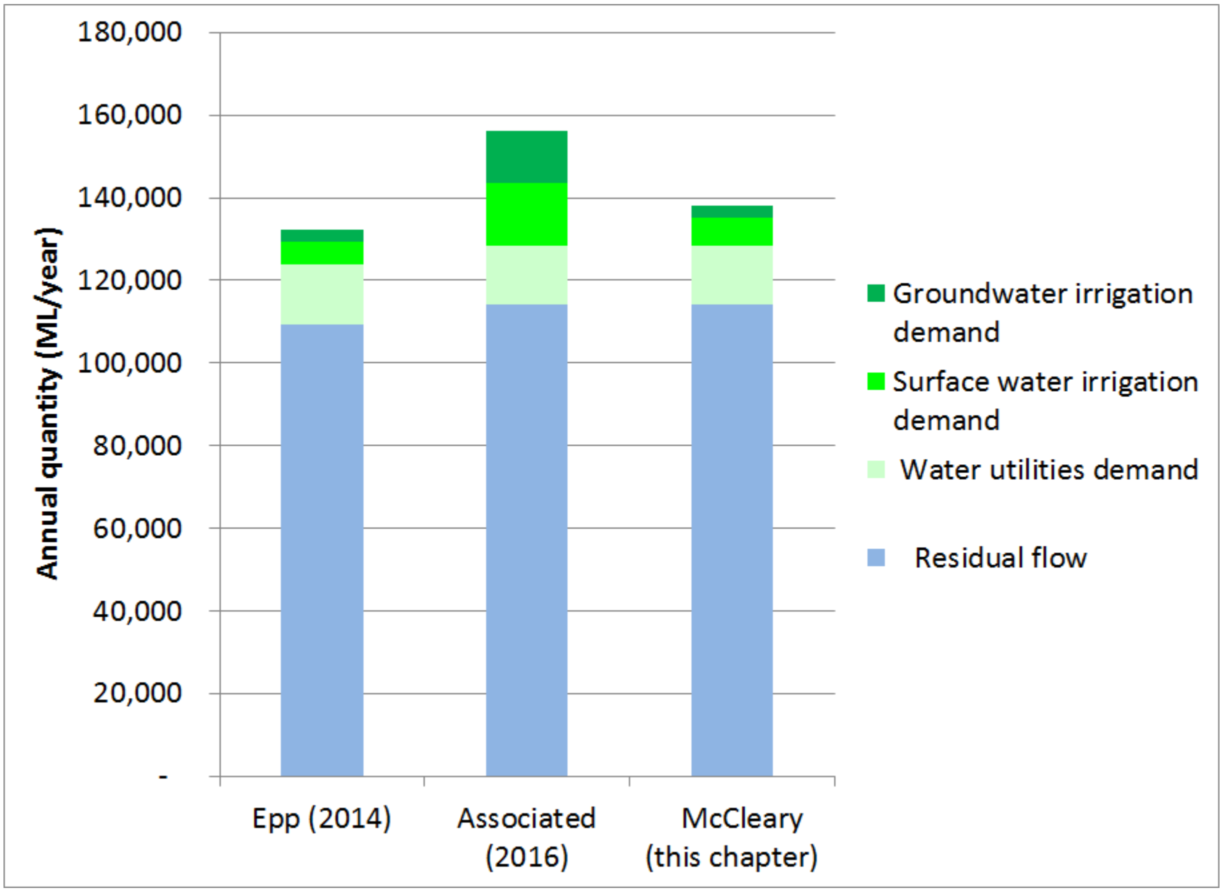


Figure 19. Stacked bar chart with three estimates of naturalized annual flow for Bessette Creek above Beaverjack Creek (08LC039) based on total of groundwater irrigation, surface water irrigation, water utilities and long-term mean annual residual flow.

Flow naturalization charts were prepared for all three estimates (Appendix B - Figure B1), however, given similarities, the following discussion is limited to the McCleary estimate (Figure 19). When the demands from irrigation and water utilities are pooled for each month and viewed for both average and drought conditions, several important considerations relating to this discussion are evident (Figure 19). In an average year, the total demand represents 17% of the total naturalized supply, whereas in the 2003 drought year, the demand represents 28% of the total naturalized supply. In an average year during the month of August, the demand represents 39% of the naturalized supply, whereas in the 2003 drought, the demand represents 80% of the naturalized supply (Figure 19a and b). Note that these water use ratios are much higher when the demand estimates adapted from Associated (2016) are considered (Appendix B – Figure B1c and f). To place these diversion rates into context, when applied to Bessette Creek, the risk management framework within the Environmental Flow Needs Policy shifts to the highest risk management level for diversion rates greater than 10% for a small size stream (FLNR and ENV, 2014). Although the August water use ratio of 39% from McCleary (this chapter) is different than the 65% ratio provided by Rood and Hamilton (1995), the conclusions are the same – Bessette Creek has an over-allocation problem, whereby the current levels of licensed use are expected to limit important aquatic ecosystem functions and create a setting for fish-flow conflicts.

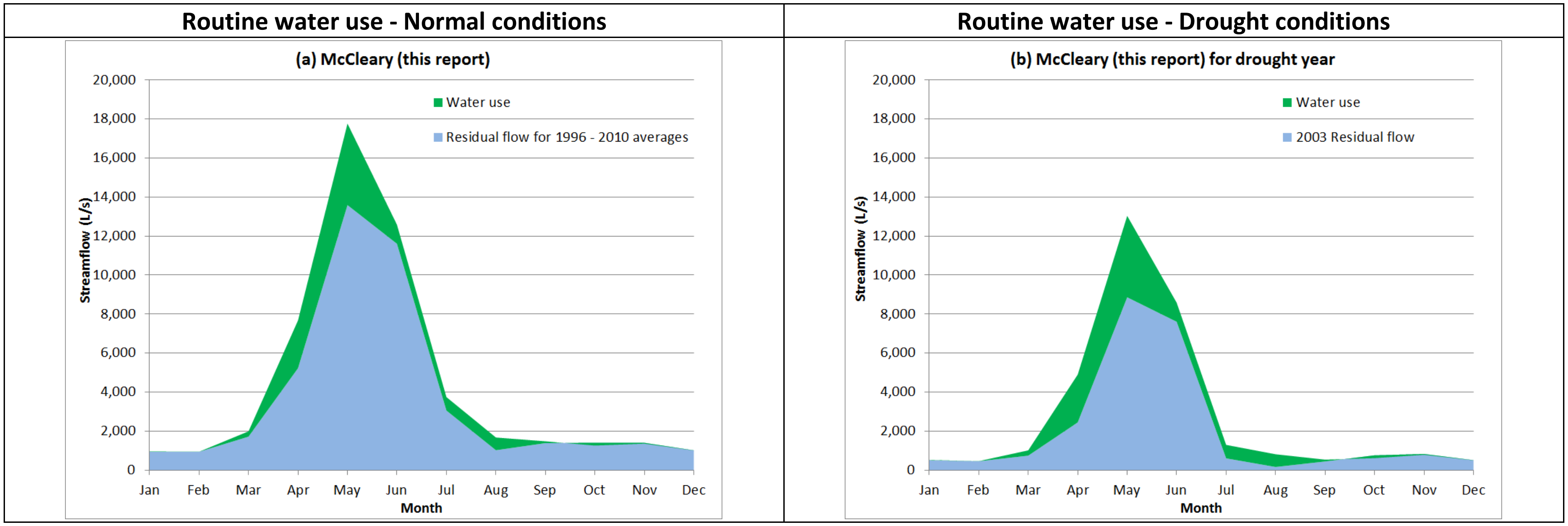


Figure 20. Naturalized flow represented with stacked area charts showing residual flow (blue shading) and water use (green shading) (e.g., Naturalized flow = residual flow + water use) for two different scenarios including: (a) average flow conditions for the 1996 – 2010 period; and (b) drought conditions from 2003.

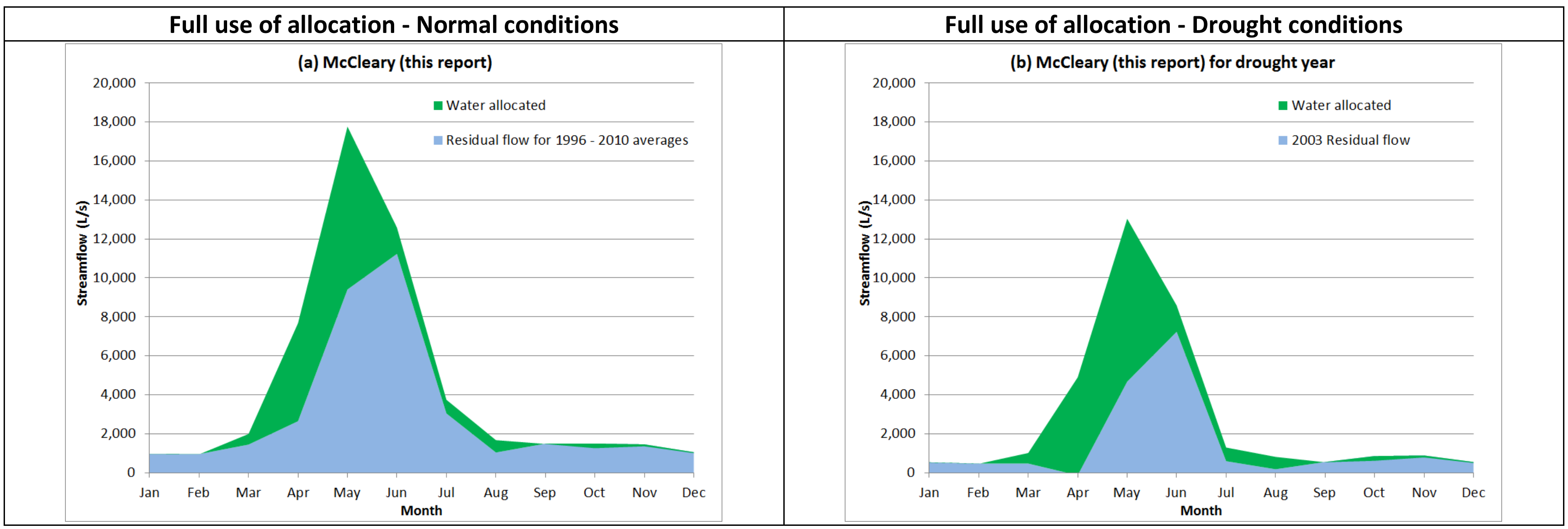


Figure 21. Naturalized flow represented with stacked area charts showing residual flow (blue shading) and licenced water allocation (green shading) (e.g., Naturalized flow = residual flow + water allocation) for two different scenarios including: (a) average flow conditions for the 1996 – 2010 period; and (b) drought conditions from 2003.

6.1.1 *Actual Demand*

There are two factors that limit the accuracy of an actual demand estimate. First, actual use varies according to seasonal weather patterns with higher use expected during extended hot and dry periods typical of drought (e.g., Associated, 2016). Second, a direct measurement of water use is only possible in a basin with universal water metering for all diversions. In Bessette Creek, local water utilities have provided metering information on their withdrawals (Epp, 2014); however, indirect approaches are required for estimating actual water use by private irrigators (e.g., Associated, 2016). In recognition of the potential inaccuracies associated with the indirect approaches, the results include three different estimates of actual water use which are examined for congruence.

The three main categories of annual demand include: annual demand for irrigation from surface water; annual demand for water utilities from surface water; and annual demand for irrigation from groundwater. Estimating the actual demand is challenging for several reasons:

1. For irrigation licences, the quantity of water used in relation to the quantity of water licensed is highly variable depending upon the practices of the licence holder and other factors (heat, rainfall). For example, in a study of irrigation water use in Creighton Creek watershed, a tributary to Bessette Creek, Minor (2005) found that the percentage of licensed water used annually ranged from 52 – 158% of the allocated amount and averaged 91%.
2. Some surface water users have changed their point of diversion from a creek to a groundwater well. For example, the Town of Lumby switched the source for their waterworks from a surface water Point of Diversion from Duteau Creek, to groundwater wells in the same vicinity (Epp, 2014). As of October 2017, there had been no application for changes to the licence submitted. For this case, Epp (2014) utilized the reported quantity of water withdrawn from these groundwater wells to indicate surface water use.
3. The *WSA* requires a licence or authorization to divert water from an aquifer for non-domestic purposes; however, those who were using groundwater on or before Feb. 29, 2016 will be brought into the licensing and date-based priority allocation system, provided that they apply prior to the end of the transition period which closes on March 1, 2022. (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/laws-rules/gw_licensing_brochure.pdf). Therefore, it is also important to consider groundwater use that was occurring on or before Feb. 29, 2016 when accounting for total annual water use in the Bessette Creek watershed.
4. There is no single accepted standard procedure for estimating actual demand.

6.1.2 *Estimates of Total Annual Use for Water Utilities*

Based on reported volumes provided by the various water purveyors, Epp (2014) estimated the total annual use by water utilities at 14,292 ML/year. This quantity represents the best available estimate.

6.1.3 *Estimates of Total Annual Use for Irrigation*

Estimates of annual irrigation use indicate a range between 5,622 to 15,326 ML/year (Table 5). The differences appear to be largely due to two factors. First, the various authors selected different values for duty (i.e., depth of water applied over an area over the course of the irrigation season) and irrigation efficiency. Based on the study by Minor (2005), Epp (2014) assumed that 90% of the allocated water was applied. Associated (2016) estimated the cumulative crop evapotranspiration at the end of the growing season to be approximately 820 mm (see their Figure 3-2), in comparison to the standard 762 mm (2.5 feet) for irrigation licences in the Bessette Creek watershed. This analysis applied the standard duty and an irrigation efficiency of 1.0. Secondly, the various authors had different extents of irrigated land. The small differences (8.2 km^2 versus 8.7 km^2) between McCleary versus Epp (2014) may be the result of the different query procedures and small errors in licence interpretation that were corrected by McCleary. The larger differences between these values and the 12.6 km^2 reported by Associated (2016) arise because the later determined the irrigated area from 2014 Ministry of Agriculture Land Use Inventory (AGRI, 2016). These discrepancies may reflect that the goals of the 2014 inventory were not to provide information with the level of detail required for regulatory water management purposes, rather two goals of the 2014 inventory were to provide a general characterization of the existing and potential level of agricultural development, and also to enable the estimation of agricultural water demand with the use of an agricultural demand model (AGRI, 2016). Discrepancies in land area may be the result of the methods used in the 2014 inventory whereby a combination of remote sensing and field visits were used to create the dataset; however, an actual confirmation from individual land owners on their irrigated land extent and water source would have been beyond the scope, budget and authority of the inventory team. The discrepancies in land area may also reflect that unauthorized surface water diversion for irrigation has been known to occur in the Bessette Creek watershed (FLNR internal information), and such parcels may have been included in the 2014 inventory but would not have been identified in the water license query approach used by Epp (2014) and McCleary (this chapter).

While there is a lack of alignment in the extent of irrigated area, the overall findings from the use of the Agricultural Land Use Inventory data (AGRI, 2016) that were summarized by Associated (2016) are that the irrigated land base in the Bessette Creek watershed is extensive and that both surface water and groundwater sources are widely used. Furthermore, it should be emphasized that although the methods used by McCleary (this chapter) are repeatable, they are based on an incomplete inventory of lands that are irrigated by groundwater and as a result, they should be considered as an underestimate.

6.1.4 Estimates of Total Monthly Demand from Surface Water

Consistent with the previously described strategy, this report applies two different approaches for estimating total monthly demand from surface water.

The first approach, which is limited to irrigation demands only, is based on the Associated (2016) application of an agricultural water demand model and agricultural land use inventory for lands within Bessette Creek watershed to provide estimates of total monthly demand supplied by surface water. One modification was made to the estimates provided by Associated (2016, see Table 3-5, p. 23/55); specifically, the results for the sub-watershed titled “Bessette Creek above Duteau Creek confluence” were modified to exclude the demand from those lands that are backed by storage from Nicklen Lake because the true timing for the use of the water occurs when Nicklen Lake is filled rather than when the water is applied (Table 6).

For the second approach, which is based on two slightly different licence queries (i.e., Epp, 2014 and McCleary, this chapter) to estimate total monthly demand using the licence query based estimates, monthly apportionments were determined for each purpose based on known local water use practices and existing references (Table 7), and then applied to divide the total annual use for each purpose across the year (Appendix B - Table B1.).

Table 5. Summary of annual surface water extractions to support irrigation in the Bessette Creek watershed.

Water use descriptor	Method 1: Data predominantly from Epp (2014)	Method 2 Data predominantly from Associated (2016)	Method 3 Data predominantly from McCleary (this chapter)
Duty measured at point of application (mm/year)	762[1]	820[7]	762[1]
Irrigation efficiency (% of water released from irrigation equipment that enters soil)	1.0[2]	0.7[8]	1.0[2]
Average licenced use (% of licenced quantity that is used on an annual basis)	0.9[3]	NA	1.0[12]
Estimated duty at point of withdrawal (mm/year)	686[4]	1,219[9]	762
Area irrigated by surface water (km^2)	8.2[5]	12.5[10]	8.7[14]
Irrigation water use (ML/year)	5,622[6]	15,237[11]	6,660[13]

Data from Epp (2014)	Data from Associated (2016)	Data from McCleary (this chapter)	Calculated field

[1] The standard duty applied to irrigation licenses in the Lumby area was 2.5 feet (see Appendix A, Water Licence C66387). The unit conversion of 2.5 feet is 762 mm.

[2] Epp (2014) does not apply a correction for irrigation efficiency when estimating irrigation water use. The same approach was applied by McCleary (this chapter).

[3] Epp (2014) pg. 20.

[4] 686 mm/year = 762 mm/year* 0.9

[5] 8.2 km = (5,622 ML/year * 1000 m^3/ML)/ ((686 mm/year * 1 m / 1,000 mm)*1,000,000 m/km^2)

[6] Epp (2014) pg. 21 – 5,622,474 m^3/year converted to ML/year and rounded to nearest whole number.

[7] Associated (2016) use Crop Evapotranspiration (ET_c) rather than duty for estimating water demand. Cumulative crop evapotranspiration was extracted from Associated (2016) pg. 23/55, Figure 3.2.

[8] Associated (2016) pg. 16/55.

[9] For estimating water demand, the general approach used by Associated (2016) is to apply the formula of IR = ET_c / I_e where IR = irrigation requirement, . ET_c = crop evapotranspiration, and I_e = irrigation efficiency. The same principle was applied: 1,219 mm/year = 820 mm/year / 0.7.

[10] From Associated (2016) pg. 24/55, Table 3-6: 12.5 km^2 = 4.4 km^2 + 1.9 km^2 + 1.5 km^2 + 4.7 km^2

[11] 15,326 ML/year = ((1,219 mm/year * 1 m / 1,000 mm)*1,000,000 m/km^2)*12.5 km^2 * 1 ML/1000 m^3

[12] The decision to 1.0 rather than 0.9 was based on internal FLNRORD information indicating that within the Bessette Creek watershed to a limited extent, some license holders have irrigated lands that are in addition to the appurtenant lands that are specified on their individual water licenses.

[13] From McCleary (this chapter) Table 13: 6,660 ML/year = 6,659,552 m^3/year * (1 ML/1000 m^3)

[14] 8.7 km = (6,600 ML/year * 1000 m^3/ML)/ ((762 mm/year * 1 m / 1,000 mm)*1,000,000 m/km^2)

Table 6. Mean monthly normal irrigation water demand supplied by surface water from baseflow (i.e., not backed by storage) for the selected sub-basins within the Bessette Creek watershed (modified from Associated, 2016).

Sub watershed	Total area	Average instantaneous demand by month (m^3/s)					
		Apr	May	June	July	Aug	Sept
Duteau	4.4 km^2	0.23	0.36	0.44	0.50	0.41	0.21
Bessette above Duteau	0.7 km^2	0.03	0.05	0.06	0.07	0.06	0.03
Creighton	1.5 km^2	0.07	0.11	0.14	0.16	0.13	0.07
Bessette below Duteau	4.7 km^2	0.22	0.36	0.43	0.49	0.40	0.21
Total surface water from baseflow	**11.3** km^2	**0.56**	**0.88**	**1.07**	**1.22**	**0.98**	**0.52**
Total demand (ML)	13,848	1,447	2,366	2,785	3,265	2,636	1,349

Table 7. Monthly apportionment of licensed water withdrawals or release by purpose.

Month	All diversions for storage (%)	Conservation storage release: Grizzly (%)	Conservation storage release: Nicklen (%)	Domestic, livestock and fire protection	Irrigation and release from private irrigation storage (%)	Water utilities release from storage (%)
Jan	0	0.06	0	1/12	0	0.01
Feb	0	0.06	0	1/12	0	0.01
Mar	0.04	0.06	0	1/12	0	0.01
Apr	0.35	0	0	1/12	0	0.01
May	0.57	0	0	1/12	0.15	0.14
Jun	0.04	0	0	1/12	0.25	0.23
Jul	0	0.11	0	1/12	0.25	0.23
Aug	0	0.11	0.12	1/12	0.25	0.23
Sep	0	0.18	0.44	1/12	0.10	0.10
Oct	0	0.14	0.35	1/12	0	0.01
Nov	0	0.14	0.09	1/12	0	0.01
Dec	0	0.14	0	1/12	0	0.01
Rationale	Consistent with monthly changes in Duteau Reservoir volumes (pg. 72 Epp, 2014)	Consistent with DFO release schedule through low flow months (pg. 74 Epp, 2014)	Consistent with median values from release schedule for Nicklen Lake conservation storage (pg. 64 Epp, 2014)	As per daily volume on licence	Rood and Hamilton (1995)	Irrigation demand from Rood and Hamilton (1995) plus utilities from daily licence demand

6.1.5 Estimates of Total Annual Demand for Groundwater Withdrawals

An EFN assessment must include an estimate of the cumulative licenced withdrawal amount (FLNR and ENV, 2014), which after February 29, 2016 (the date the *WSA* came into force) includes the licensed surface water plus new groundwater allocations. Although very few licences have been issued for existing groundwater wells in the area with a history of beneficial use prior to March 1, 2016, there are provisions in the Water Sustainability Regulations to issue such licences providing that the user submits an application before March 1, 2022.

Irrigation groundwater use appears to represent a substantial proportion of the total water use in the Bessette Creek watershed. For example, based on the Ministry of Agriculture land use inventory (ALUI) for the Regional District of North Okanagan that covered Bessette Creek watershed (AGRI, 2016), Associated (2016) estimated that of the total 26.8 km^2 of irrigated land in the watershed, 14.3 km^2 or 53% of total are supplied by groundwater (Table 8). The methods used in the ALUI included an initial GIS-based remotely sensed land delineation based on aerial photographs followed up with a field survey where additional land use descriptors including presence/absence of irrigation were noted (AGRI, 2016). While this survey represents a reasonable approximation, the true extent of irrigation groundwater use may be better understood after March 1, 2022 when a licence will be required for any irrigation regardless of whether the source is from surface or groundwater (see Appendix D - WSR Sec. 55). This is assuming that everyone who meets the criteria to transition to a licence will do so to avoid the loss of seniority and potential loss of irrigation rights; however, there is no guarantee of this.

Table 8. Summary of irrigated lands by surface water and groundwater for the selected sub-basins within the Bessette Creek watershed (Data reformatted from Associated, 2016, page 13).

Sub watershed	Total irrigated area (km^2)	Irrigated area supplied by groundwater (km^2)	Irrigated area supplied by surface water (km^2)
Duteau	6.10	1.70	4.40
Upper Bessette	4.50	2.60	1.90
Creighton	2.50	1.00	1.50
Lower Bessette	13.70	9.00	4.70
Total	26.80	14.30 (53%)	12.50 (47%)

In October 2017, a GIS search of registered groundwater wells in the Bessette Creek watershed identified a total of 284 wells that likely were used for non-domestic purposes, including 212 with an unknown water use purpose and 36 for irrigation use (Figure 22 and Appendix B - Table B2). Although a portion of the wells for unknown purpose could be for irrigation, they were not included in the following analysis. This approach, based on incomplete public information, was expected to underestimate irrigation demand from groundwaters but was used because it represents a repeatable approach in an area with minimal available data. Also note the difference between registered wells and licenced wells. Those wells listed within GWELLS database prior to 2016 include those that were voluntarily registered by the driller, whereas as of March 1, 2016, drillers were required to register all new wells (https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells/information-for-property-owners/well-records-registration).

Although wells are registered, they are not necessarily licensed. In fact, as of October 2017 only two of the 36 registered water wells in the area had been licenced (Appendix B - Table B2).

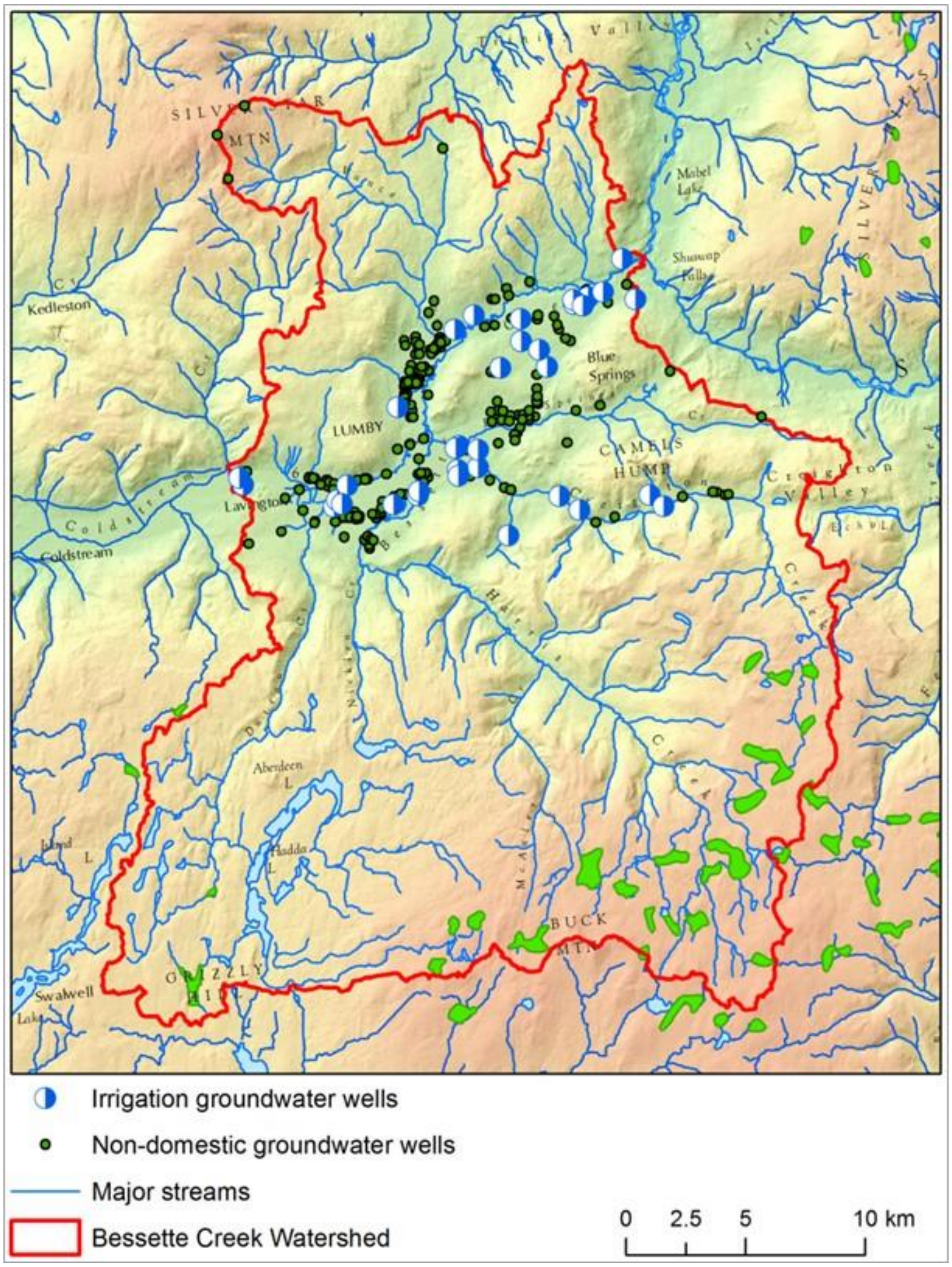


Figure 22. Map of two categories of groundwater wells in the Bessette Creek watershed including irrigation wells and non-domestic wells. Groundwater wells data layer available in iMapBC.

To illustrate the trend in development of the groundwater resource to support agriculture in Bessette Creek, a graph was prepared to show the estimated cumulative groundwater pumping rate by year, based on the values from the GWELLS database for the 36 irrigation registered irrigation wells. The graph shows a sharp increase in the total groundwater yield starting near 1990 and continuing through to 2016 (Figure 23). The yield from the three wells drilled after the *WSA* came into force on February 29, 2016 represents an additional 9% increase in demand.

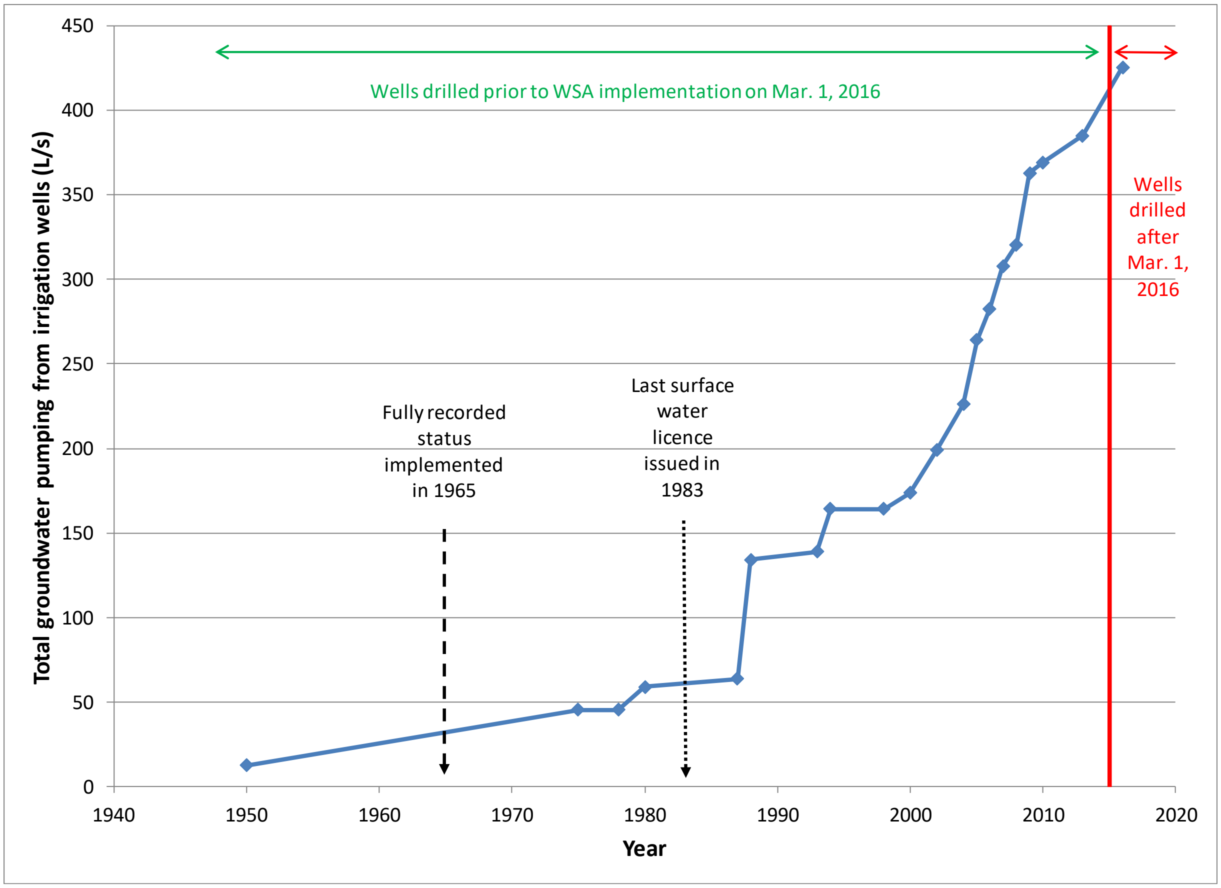


Figure 23. Graph of the total groundwater pumping rate from registered irrigation wells by year for the Bessette Creek watershed. Pumping rate equals the total yield value (gallons per minute) for all wells for each year.

For the case of a groundwater well located in an aquifer that is hydraulically connected to a stream, water pumped from that well will be sourced from a combination of aquifer storage or depletion of streamflow, with the proportion of streamflow depletion a function of the pumping rate, length of pumping time, distance to the stream and transmissivity of the aquifer (Rathfelder, 2016). For all water balance work completed in this study, that proportion of the groundwater irrigation demand that translates into streamflow depletion is the important quantity used to estimate total demand (Equation 5).

Due to the expected importance of the irrigation demand sourced from groundwater in Bessette Creek, two separate estimates of the potential cumulative streamflow depletion from groundwater irrigation were prepared. The first used the Glover model (Rathfelder, 2016) applied to all registered wells in the watershed. The second approach utilized preliminary information on groundwater demand presented by Associated (2016). Associated (2016) did not present an estimate of irrigation demand supplied by groundwater in their drought response study because in 2015 there were no provisions under the *Water Sustainability Act* to restrict groundwater use during times of water scarcity. Nor did they indicate what proportion of the groundwater demand translated into streamflow depletion.

6.1.6 Irrigation Groundwater Demand and Streamflow Depletion

The methodology applied in this section represents an objective approach for generating a basin-scale estimate of irrigation groundwater demand utilizing existing information contained within the Provincial groundwater wells spatial data layer and the GWELLS database. These information sources have been developed from the combination of historical information, which has largely been provided on a voluntary basis, plus new information that must be provided by irrigation well owners to meet *WSA* requirements for registration and licensing. The results are based on queries that were completed in October 2017 when the data sources were known to be incomplete. Therefore, the groundwater demand estimates presented were expected to under-represent actual groundwater use. These data sources should become more comprehensive after March 1, 2022 once licenses are required for all existing non-domestic (e.g., irrigation) wells. Therefore, the results from similar methodologies should become more accurate over time.

For the purposes of this assessment, three different scenarios for basin-scale groundwater pumping were identified:

- **Scenario 1**: This scenario considers all licensed wells plus wells that may transition into a licence based on a construction date prior to March 1, 2016. This scenario represents the total that could be licensed provided that all registered irrigation wells are licensed. It does not account for registered wells for other purposes (e.g., other, private domestic), nor is there a way to account for unregistered wells that were beneficially used prior to the March 1, 2016 deadline.
- **Scenario 2**: This is Scenario 1 plus the yield from WTN W112051. This scenario represents the total demand should the licence application under appeal be granted.
- **Scenario 3**: This is Scenario 1 plus both registered high-volume irrigation wells that were drilled after the March 1, 2016 deadline. Note that the GWELLS database shows a second irrigation well drilled within Bessette Creek watershed with an earlier construction date and higher yield than W112051 (Table 9). As of Oct. 31, 2017, this second well was not licensed nor was there any evidence that an application had been submitted. The connectivity status of this second well was also unconfirmed. This scenario represents the total demand for the case that both wells are licensed and hydraulically connected to Bessette Creek.

Table 9. Summary of unlicensed irrigation wells that were registered as of Oct. 2017 with construction dates after the February 29, 2016 deadline for transition to licence.

Well Tag Number	Construction Date	Yield (US gpm)
W112051 (this appeal)	2016-07-07	200
W112958	2016-05-20	350

In this next section, it will be important to understand the two related, but different terms:

1. **Groundwater pumping rate**: the rate at which water is extracted from an aquifer and applied to the land to meet the irrigation demand. This is a constant rate typically equal to the capacity of the pump.
2. **Streamflow depletion rate**: the rate at which water is depleted from the creek in question due to pumping from a hydraulically connected aquifer. This rate changes over the duration of the pumping season with recovery starting at the end of the pumping season. The rate may increase from one year to the next if complete aquifer recharge does not occur. Note that Figure 10 shows streamflow depletion expressed as a fraction of the pumping rate. In the following sections relating to annual and monthly streamflow depletion from groundwater irrigation, the streamflow depletion is expressed as an absolute rate in L/s for the entire Bessette Creek watershed. The yield information from the GWELLS database in 2017 (Appendix B - Table B2), was used to estimate the cumulative groundwater pumping rate for all wells in each of the three scenarios (Table 10).

Table 10. Estimate of total annual demand and total irrigated area supported by groundwater wells under two different scenarios based on wells registered as of Oct. 17, 2017.

Scenario	Total pumping rate (l/s)	Irrigation days	Duty (m)	Annual Demand (ML)	Irrigated area (km^2)
1) Licensed wells plus all transitional wells	391	120	0.762	4,053	5.3
2) Scenario 1 + W112051	404	120	0.762	4,184	5.5
3) All registered wells	426	120	0.762	4,413	5.8

Next, to approximate the basin-scale streamflow depletion based on the Glover model, the following approach was applied. First, two of the model inputs were adjusted as follows:

1. Distance from well to stream: this was set to 356 m, the median value calculated for all 36 wells (Appendix 2 - Table B2).
2. Pumping rate: this was set to the appropriate value for each scenario (Table 10)

Second, the y axis of the output chart was modified to display "Streamflow depletion rate (L/s)" rather than "Streamflow depletion as fraction of pumping rate (Qs/Qw)." Important limitations with this approach relate to pooling of the data from all 36 wells and completing a single model run rather than having a hydrogeologist model each well individually and total the results. For example, this approach assumes that the aquifers that the other wells are pumping from share similar physical and hydraulic properties as the sand and gravel aquifer modelled by Thomson (this report, chapter 5), including the assumption that the source aquifers are hydraulically connected. Although this has not been confirmed, this was a reasonable assumption given the nature of the question. In consideration of these limitations, the outputs represent a best available approximation of the basin-scale effects of groundwater pumping for irrigation on streamflow depletion for Bessette Creek using existing information.

Important findings as shown in Figure 24 include:

1. Based on a May 11 irrigation start date, streamflow depletion rates have the steepest climb during the first 60 days and peak abruptly at the end of the pumping period. For example, in Scenario 1, depletion rates of 191 and 243 L/s were achieved respectively on days 60 and 120. These values indicate that 79% of maximum depletion rate was achieved halfway through the 120-day pumping period.
2. Immediately after shut-off, the depletion rates drop very rapidly before tailing out to a minimum carry-over value near 20 L/s at the start of the next pumping cycle.
3. In Year 1, the maximum streamflow depletion rates for the three scenarios were predicted as 243 L/s, 251 L/s and 265 L/s. Scenarios 2 and 3 represent a 3% and 9% increase in streamflow depletion, respectively, over the base case in Scenario 1.

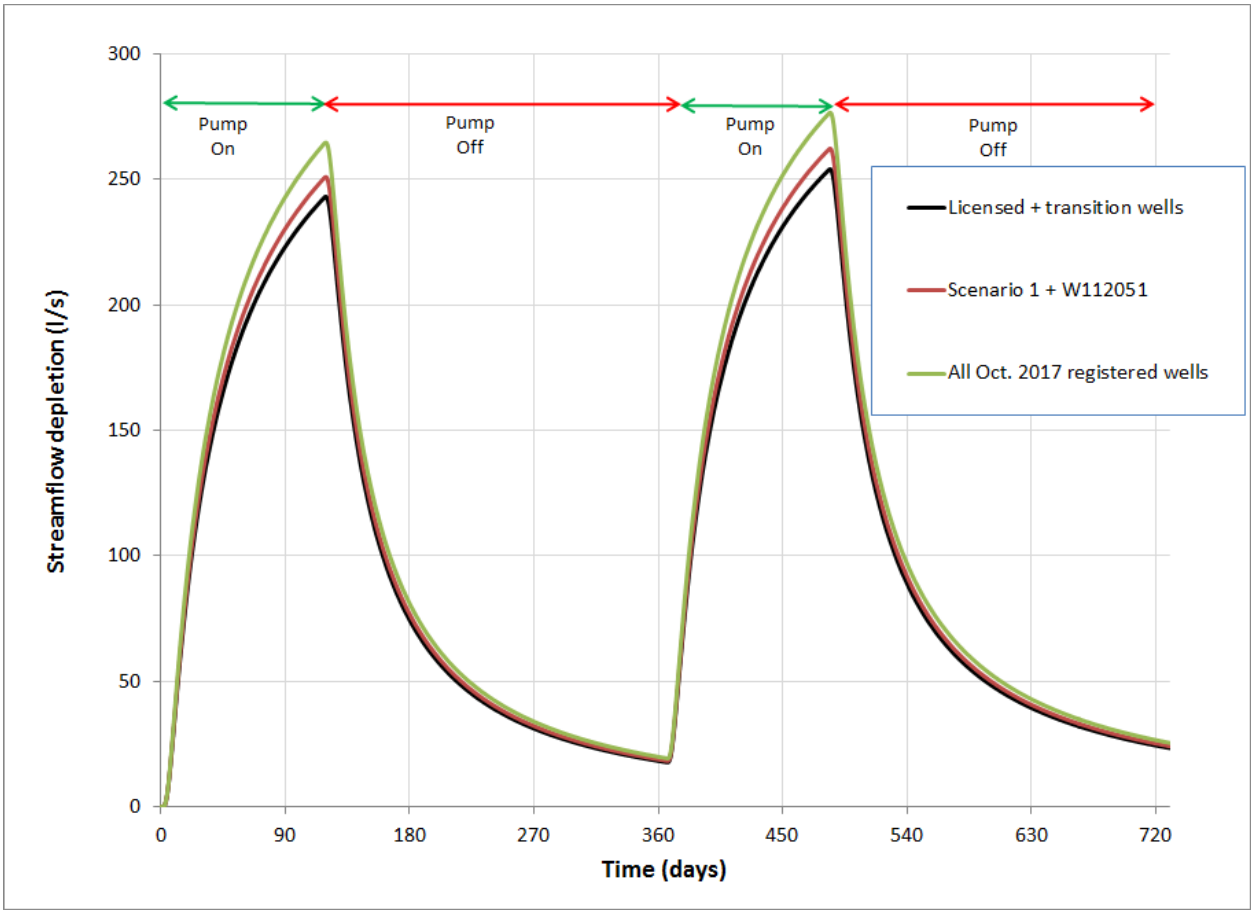


Figure 24. Predicted cumulative streamflow depletion for three different groundwater use scenarios including: (1) all licensed wells plus wells that may transition into a licence based a construction date prior to March 1, 2016; (2) Scenario 1 plus Well Tag Number W112051; and (3) all wells that were registered and shown within the Provincial wells database in Oct. 2017. Estimates were based on: (1) continuous pumping for 117 days from May 11 to Sept. 5; (2) median distance from well to stream of 356 m; and (3) total pumping rates of 391 L/s, 404 L/s and 426 L/s respectively for the three scenarios.

The daily predictions from the Glover model were used to estimate average monthly streamflow depletion rates for each of the three scenarios (Figure 25). All scenarios peak in August before some recovery in September due to the end of the pumping season on September 5. This chart also highlights an important distinction between surface water irrigation sources and groundwater sources. Specifically, while the effect of surface water withdrawals ends on the last day of use, the streamflow depletion from groundwater pumping extends in a declining pattern through the fall and winter low flow periods.

Similar to the patterns in maximum annual streamflow depletion for the month of August, Scenarios 2 and 3 represent a 3% and 10% increase in streamflow depletion over the base case in Scenario 1 (Appendix B - Table B3). The total annual streamflow depletion rates were 2979 ML, 3075 ML and 3244 ML for the respective scenarios.

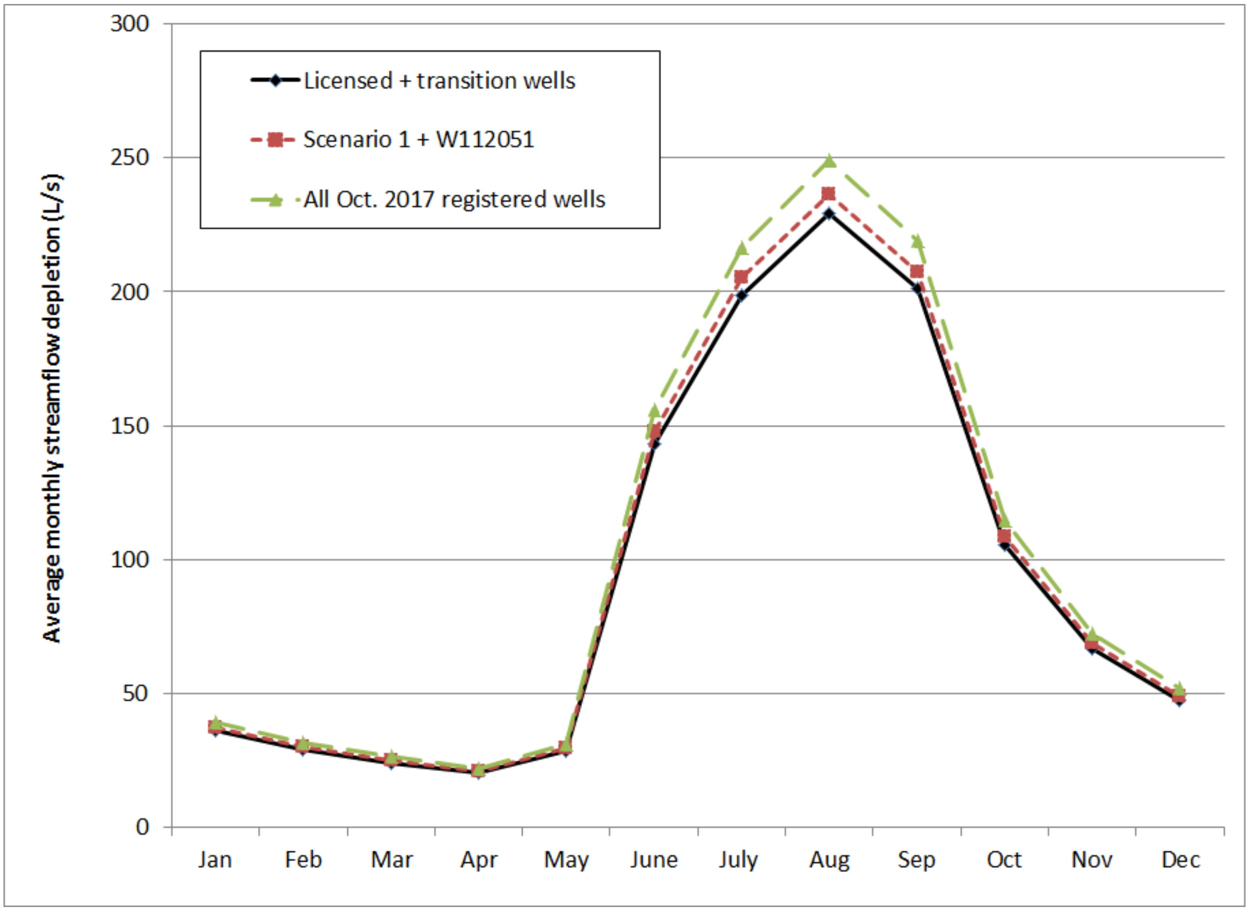


Figure 25. Estimates of average monthly streamflow depletion from three different groundwater use scenarios including: (1) all licensed wells plus wells that may transition into a licence based a construction date prior to March 1, 2016; (2) Scenario 1 plus Well Tag Number W112051; and (3) all wells that were registered and shown within the Provincial wells database in Oct. 2017.

6.1.7 Streamflow Depletion from Groundwater Irrigation Based on Associated (2016)

Although Associated (2016) did not directly report on irrigation groundwater demand, they provided the background information to generate this value. This includes: (1) an area based estimate of irrigation water demand supplied by surface water (Table 6); and (2) a summary of irrigated land area including separate estimates for irrigated area supplied by groundwater and irrigated area supplied by surface water (Table 8). To estimate the total pumping rate required for the 14.3 km^2 area irrigated by groundwater, the demand rates for those lands irrigated with surface water indicated by Associated (2016) were extrapolated to those areas irrigated by groundwater (Table 11).

Table 11. Mean monthly normal irrigation water demand supplied by groundwater for the selected sub-basins within the Bessette Creek watershed (adapted from Associated, 2016).

Sub watershed	Total area irrigated by groundwater [1]	Average instantaneous demand by month (L/s)[2]					
		Apr	May	June	July	August	Sept
Duteau	1.7 km^2	90	140	170	190	160	80
Bessette above Duteau	2.6 km^2	130	200	240	280	220	120
Creighton	1.0 km^2	50	80	90	100	80	40
Bessette below Duteau	9.0 km^2	430	680	830	940	760	400
Total area	14.3 km^2						
Total pumping rate (L/s)		690	1,100	1,330	1,510	1,220	650
Streamflow depletion rate (L/s)[3]		511	814	984	1,117	903	481
Total demand (based on total pumping rate * seconds per month)	17,170 ML	1,793 ML	2,934 ML	3,453 ML	4,048 ML	3,269 ML	1,672 ML

[1] From Associated (2016) pg. 24/55, Table 3-6: 14.3 km^2 = 1.7 km^2 + 2.6 km^2 + 1.0 km^2 + 9.0 km^2

[2] Data was adapted from Associated (2016) pg. 23/55, Table 3-5 as follows: for each month and for each subbasin, the mean monthly surface water demand per km^2 was determined. Because the crop evapotranspiration rate does not vary by water source, the groundwater demand was estimated by multiplying the mean monthly water demand per km^2 determined for surface water sources, by the area irrigated with groundwater for that subbasin. For example, for the Duteau Creek subbasin for the month of April, the water demand for 4.4 km^2 was 0.23 m^3/s or 0.05 $m^3/s/km^2$. The groundwater demand for the month of April for the Duteau Creek subbasin would be 0.05 $m^3/s/km^2$ * 1.7 km^2 = 0.09 m^3/s or 90 L/s. These adaptations were applied to each subbasin for each month.

[3] Streamflow depletion rate = Total pumping rate * 0.74 (see Table 12).

One additional step was required to convert the irrigation demand supplied by groundwater into an estimate of streamflow depletion. To make this conversion, first we calculated the ratio of "streamflow depletion" to "groundwater irrigation demand" from the watershed application of the Glover model and then we applied this ratio to the total annual groundwater irrigation demand estimate adapted from Associated (2016). The value of the ratio was 0.74 (Table 12). To check the plausibility of this estimate, we compared the ratios between the two different sources for land area (i.e., 2.7 times more land irrigated in Associated, 2016 scenario) and streamflow depletion (i.e., 4.2 times higher streamflow depletion rate). These differences are expected given the higher duty in the work by Associated (2016) (Table 5). We also used this ratio to estimate monthly streamflow depletion (see second last row in previous table (Table 11). Note that one of the limitations of this approach for estimating streamflow depletion based on the work by Associated (2016) is that there was no straight-forward means to estimate the month by month streamflow depletion from October through March. As a result the estimates of streamflow depletion based on Associated (2016) are limited to monthly values through the irrigation season (Table 11), and a single value for the entire year (Table 12). Although the monthly values from October through March are not provided, this exercise does provide the essential information for the decision maker to consider during the months of August and September when fish-flow conflicts are greatest. Resolving the water balance during the remainder of the year could be an appropriate task for a future study.

Table 12. Ratio of streamflow depletion to water irrigation demand for Scenario 1 with extrapolation to groundwater irrigation demand (adapted from Associated, 2016).

Source	Land area irrigated by groundwater	May – Sept. groundwater irrigation demand	Annual streamflow depletion	$\frac{streamflow\ depletion}{irrigation\ demand}$
Basin scale estimate of irrigation groundwater demand based on groundwater wells spatial data layer and the GWELLS database (McCleary, this chapter)	5.3 km^2	4,053 ML (see Table 10)	2,979 ML (see Table B3)	0.74
Adapted from Associated (2016)	14.3 km^2 (see [1])	17,170 ML (see Table 11)	12,620 ML (from application of 0.74 ratio to irrigation demand)	0.74[1]
Ratio	2.7	4.2	4.2	

[1] This ratio was determined by McCleary (this chapter) and then applied to the estimate based on the data from Associated (2016).

6.2 Licensed Demand

The assessment of existing water allocation was completed in 2017 using a two-step process. First, using ArcGIS, all mapped Points of Diversion (PODs) within the Bessette Creek watershed were identified. Second, the output table from the ArcGIS query was exported and analyzed using Microsoft Excel.

6.2.1 Total Annual Licensed Demand

Determining the total quantity of licensed withdrawals in watersheds with storage, such as Bessette Creek, is more complex than in watersheds without storage because storage water is licenced twice – first, when it is diverted from its original source and placed in storage and second, when it is diverted for its intended use after release from storage. To provide information relevant for this EFN assessment, we describe annual use with four categories including: (1) total diversions (storage + intended use); (2) diversions backed by storage; (3) diversions not backed by storage; and (4) total consumptive use. Annual withdrawals are also described separately for private and public waterworks before overall use is presented.

A total of 301 PODs lie within the Bessette Creek watershed (Figure 26). These PODs are associated with 255 active licenses, including 234 licences held by private users and 31 held by waterworks utilities (Table 13). These active licences were held by 146 different licence holders.

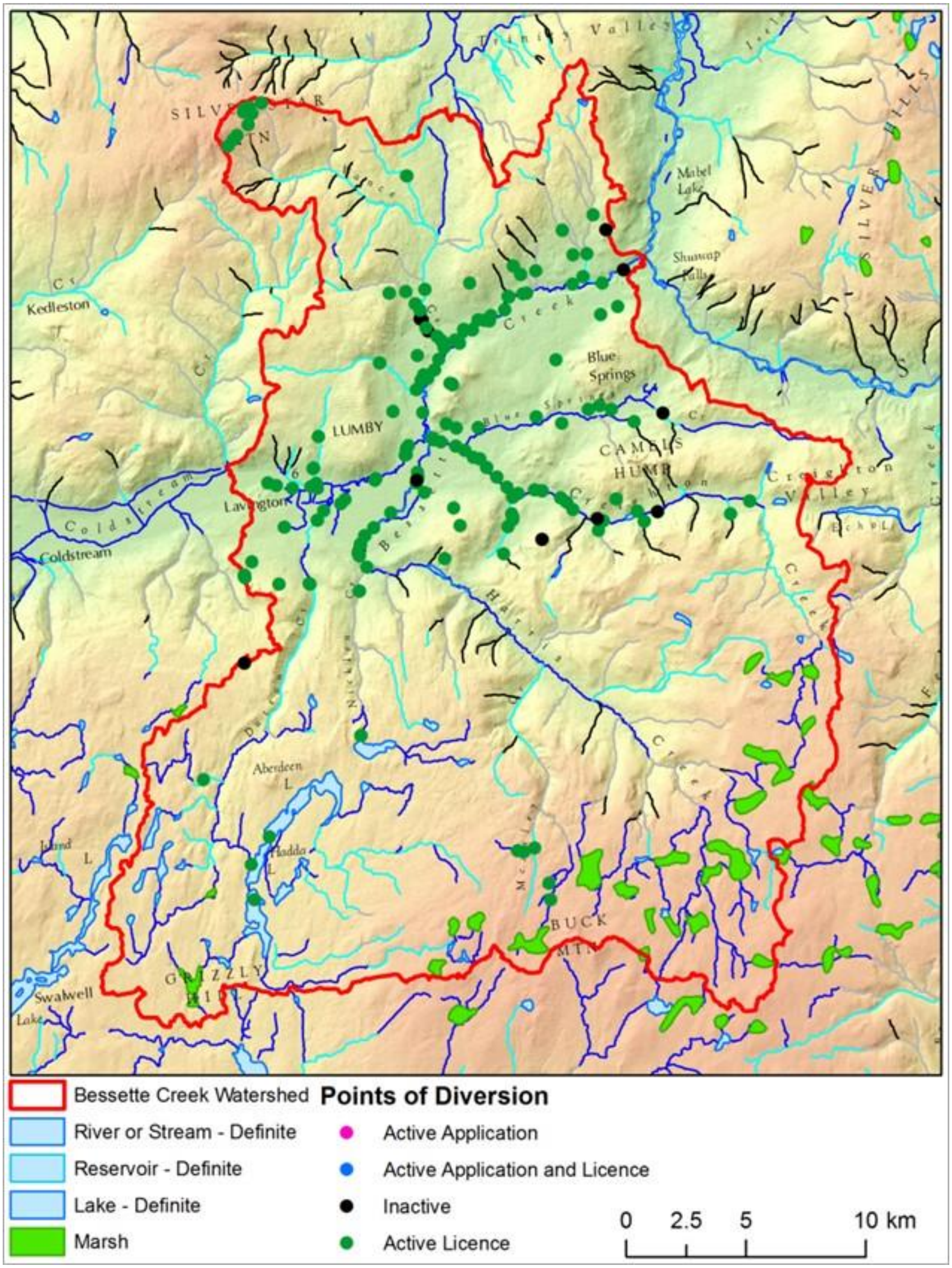


Figure 26. Map of points of diversion within the Bessette Creek watershed.

Table 13. Summary of licenced withdrawals in the Bessette Creek watershed.

Purpose	Number of Licences	Total Diversion (m^3/year)	Backed by Storage (m^3/year)	Not Backed by Storage (m^3/year)	Consumptive Use (m^3/year)
Part 1. Non-Utilities					
Conservation storage	2	2,713,656		2,713,656	
Conservation use	3	2,713,656	2,713,656		
Domestic	70	90,894		90,894	90,894
Stream storage: private irrigation	10	938,680		938,680	0
Irrigation: private	115	6,659,552	938,680	5,720,872	6,659,552
Livestock & animal	31	59,637		59,637	59,637
Misc. industrial: fire protection	3	65,561		65,561	65,561
Subtotal Non-Utilities	**234**	**13,241,636**	**3,652,336**	**9,589,299**	**6,875,643**
Part 2. Utilities					
Stream storage: non-power	10	**33,470,480**	-	**33,470,480**	
Waterworks: local provide	8	4,047,643	3,217,982	829,661	4,047,643
Irrigation: local provide	3	31,862,639	30,252,498	1,610,140	31,862,639
Subtotal Waterworks Withdrawals	**11**	**35,910,282**	**33,470,480**	**2,439,802**	**35,910,282**
Subtotal Utilities	**31**	**69,380,761**	**33,470,480**	**35,910,282**	**35,910,282**
Total	**255**	**82,622,397**	**37,122,816**	**45,499,581**	**42,785,925**

Conservation storage licences are held by two government agencies, including Fisheries and Oceans Canada from Duteau Creek into Grizzly Swamp (diversion from Oct. 1 to June 15, release from April 1 to September 30) and FLNR Fish and Wildlife Section from Nicklen Creek into Nicklen Lake with similar timing. Both licences were acquired to help mitigate chronic water shortages for instream flows that occur during the irrigation season.

Among the non-utility licences, private irrigation had the largest consumptive use (Table 13). A small number of the private irrigation licences are backed by storage on Nicklen Lake. So, although total allocations for private irrigation amount to 6,659,552 m^3/year, about 14% of this total comes from storage within Nicklen Lake, which fills through the winter and spring freshet and typically releases after July 1 through the end of the irrigation season. This leaves 5,720,872 m^3/year of direct diversions for private agriculture. The total consumptive use by all non-utilities that were not backed by storage was 6,875,643 m^3/year.

Public water utilities are licensed to divert a total of 33,470,480 m^3/year into their various storage reservoirs (Table 13), which include Haddo Lake, Aberdeen Lakes, Grizzly Lake, Headgates Reservoir (Figure 27) and Goose Lake located west of Vernon. While the majority of waterworks licences held by the Regional District of North Okanagan are backed by storage, those held by the Village of Lumby are for direct withdrawal from Duteau Creek for 829,661 m^3/year (Table 13). Because the Village of Lumby has switched to a groundwater well without changing the POD in their license and the properties of the aquifer are unknown, the accounting followed the terms of the license on record. Once these factors were considered, the total annual licenced withdrawal within Bessette Creek watershed by utilities for consumptive use was 35,910,282 m^3/year (Table 13). This estimate is comparable to the estimate of 36,325,113 m^3/year provided by Epp (2014), with a slight difference due to an error in the provincial water licence database that was corrected in 2014 . As of October 2017, when this query was completed, the total quantity of water licenced for consumptive use by private licence holders and public utilities within the Bessette Creek watershed was 42,785,925 m^3/year (Table 13).

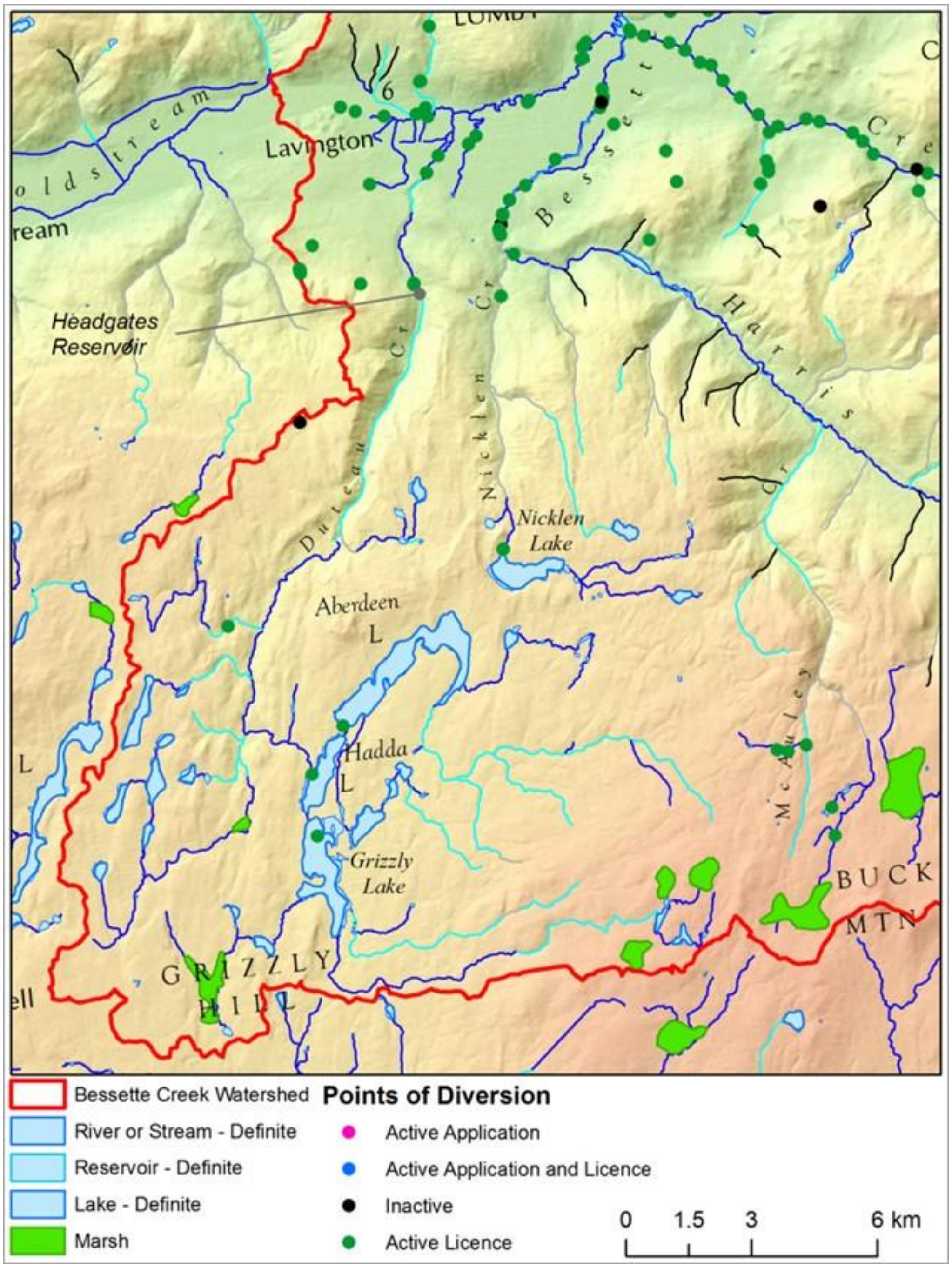


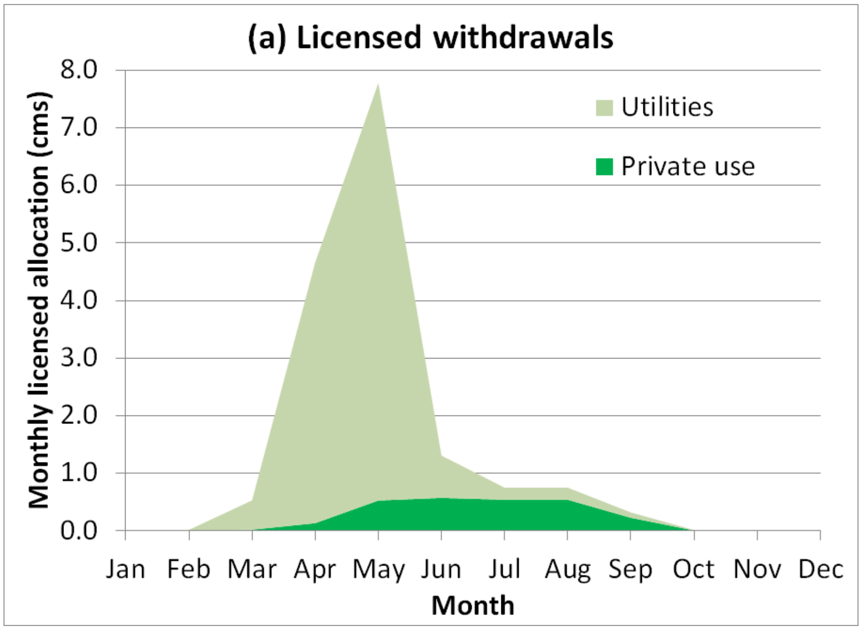
Figure 27. Map of storage reservoirs and points of diversion within the Bessette Creek watershed.

6.2.2 Instantaneous Licensed Demand by Month

For an EFN assessment, it is important to understand how the quantity of allocated water changes throughout the year because both the natural water supply and environmental flow needs also vary through the seasons. Using each month as a benchmark, the total annual use for each purpose, as described in Table 13, was apportioned by month. To allow comparison of licenced withdrawals, natural water supply and EFNs, the total water use for each month was expressed as an instantaneous quantity (i.e., m^3/s) rather than the total amount (i.e., m^3/month).

While water licences often state the season of use, they do not typically describe how that use is apportioned throughout the year. The monthly apportionment values that were applied for the actual demand estimates (Table 7) were also used for estimating licensed demand. The total licenced demand peaks at 7.8 m^3/s in the month of May then steps down to 0.8 m^3/s in August (Figure 28a and Appendix B -Table B4).

The results from this approach highlight that when licensed use and actual use are compared, actual use for water utilities represents a fraction of the total licensed allocation for that purpose (Figure 28a versus Figure 28b and Appendix B - Table B1. versus Table B4). Because there were no reports containing measured values for actual private use, licensed use and actual use are identical.



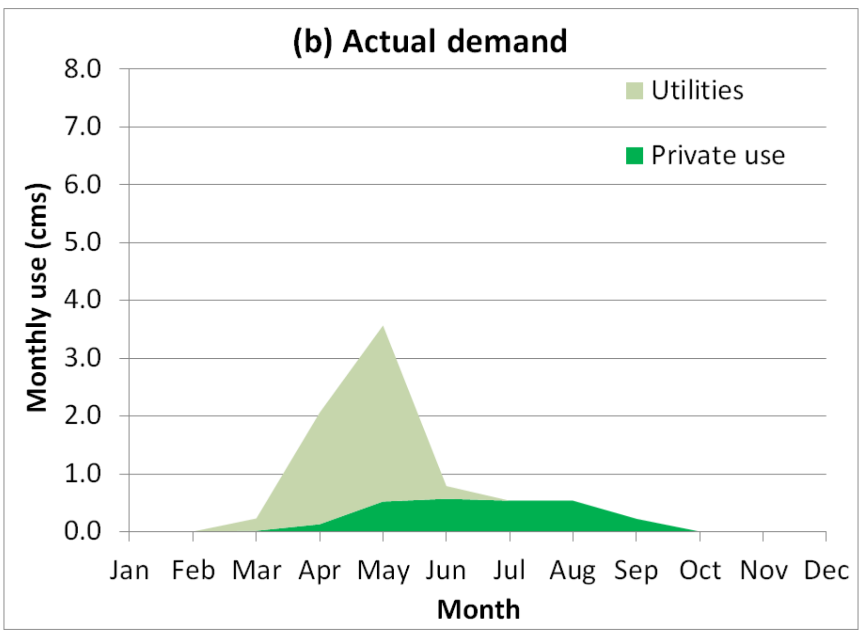


Figure 28. Stacked area charts with (a) licensed consumptive use for utilities and private irrigation by month; and (b) actual demand for utilities and private irrigation by month.

6.2.3 Review of Licence Refusals and Cancellations

Management responses in watersheds with documented over-allocation issues can include refusing new licence applications, cancelling existing licences, encouraging applicants to abandon their applications and encouraging licensees to abandon licences that are not meeting beneficial use requirements. A search of PODs from Bessette Creek (query completed in Oct. 2017) identified five licence applications that have been refused (Appendix B - Table B5). Of these five, the only application for an irrigation licence that was refused had a priority date of 1991-07-30.

Through the POD search, we identified a total of 16 licences that were listed as cancelled, licence abandoned, or application abandoned (Appendix B - Table B6). The total quantity of water potentially allocated through the seven irrigation licences in this list was 235,027 m^3/year. These numbers indicate the type of work that FLNR Water Management have undertaken to reconcile an over-subscribed water problem.

6.3 Environmental Flow Needs

6.3.1 Definitions and Specific Questions

In this section, it will be important to understand the difference between target EFNs and critical environmental flow thresholds. The definitions for these terms under the *WSA* are:

> "**environmental flow needs**", in relation to a stream, means the volume and timing of water flow required for the proper functioning of the aquatic ecosystem of the stream; and,
>
> "**critical environmental flow threshold**", in relation to the flow of water in a stream, means the volume of water flow below which significant or irreversible harm to the aquatic ecosystem of the stream is likely to occur.

It is also important to differentiate between the licensed (allocation) demand and the actual demand. The licensed (allocation) demand represents the total quantity of water that has been licensed, whereas the actual demand is the quantity of water that is typically used. As shown in Sections 6.1.1 and 6.2, the allocation demand is much greater, largely due to the unused portions of the water utilities licenses.

Given the history of flow shortages, a statutory decision maker can consider four separate questions relating to environmental flow needs in Bessette Creek, including:

1. Will the target environmental flow needs be met under total allocation use during average flow conditions?
2. Will flows remain above critical environmental flow thresholds under total allocation use during average flow conditions?
3. Will the target environmental flow needs be met under total allocation use during drought?
4. Will flows remain above critical environmental flow thresholds under total allocation use during drought?

The answers to the questions help to understand the degree to which the proper functioning of the aquatic system will be conserved under average and drought conditions given the scenario where full use is made of the water allocated within the basin. Additionally, because Temporary Protection Orders (e.g., WSA Sections 66, 67 or 68) can come into force when streamflow drops below the critical environmental flow threshold (CEFT), it can be helpful to understand if the CEFT will be met under average and drought conditions given the full use scenario.

6.3.2 Values

This assessment focuses on several Bessette Creek fish species of high economic and cultural value that are known to be sensitive to flow conditions (Table 14). Associated (2016) provide a more comprehensive list of fish that inhabit Bessette Creek. Flow requirements for each target species vary according to life stage. The suite of life stages varies depending on the species but can include: (1) Adult spawning migration; (2) Spawning; (3) Incubation; (4) Rearing; (5) Smolt emigration + fry movement; and (6) Overwintering.

Table 14. Target species for Bessette Creek EFN.

Fish Species	Stock
Rainbow trout (*Oncorhynchus mykiss*)	1. Resident 2. Migratory (Mabel Lake to Duteau Creek)
Coho Salmon (*Oncorhynchus kisutch*)	1. Interior Fraser Coho
Chinook Salmon (*Oncorhynchus tshawytscha*)	1. Shuswap River – summer timing (CK-15) 2. South Thompson River – Bessette Creek (CK-16)
Kokanee (*Oncorhynchus nerka*)	1. Migratory (Mabel Lake to Bessette Creek)

In addition to target species, the target flow required to complete important ecological functions must also be identified. These ecological functions are:

1. Fish food production: invertebrate drift
2. Flushing flows
3. Icing (extreme low flows during winter can promote frazil ice and anchor ice formation, which can be harmful to fish)
4. Freshet ramp down
5. Wetland/tributary/side channel linkage
6. Channel maintenance

6.3.3 Setting EFN Target Flows and Critical Flow Thresholds

The flow requirements for each of these functions were set largely based on Epp (2014) and Ptolemy and Lewis (2002), with some modifications to address known issues specific to Bessette Creek (Appendix C - Table C1). Using a table with each month divided into 4 smaller time slots (roughly one week each), all relevant time slots for each life stage or function were identified (Appendix C - Table C2). Next, for each time slot a dominant period was flagged. Then based on the flow requirements for the dominant period (Appendix C - Table C1), the EFN target flows and critical environmental flow thresholds were set (Appendix C - Table C2).

6.4 Water Balance

The findings from this exercise are summarized in Figure 29 and Figure 30. In these figures the naturalized flow is represented by the sum of the allocated water (green shading) and residual water (blue shading). The black line represents the EFN target and the red line represents the critical environmental flow threshold. When the residual water (blue shading) is greater than the EFN target (black line) or the critical environmental flow threshold (red line), there is a positive water balance. When the residual water is less than the EFN target or the critical environmental flow threshold, there is a negative water balance and water extractions will interfere with EFN. These figures illustrate the answers to the four questions posed in Section 6.3.1.

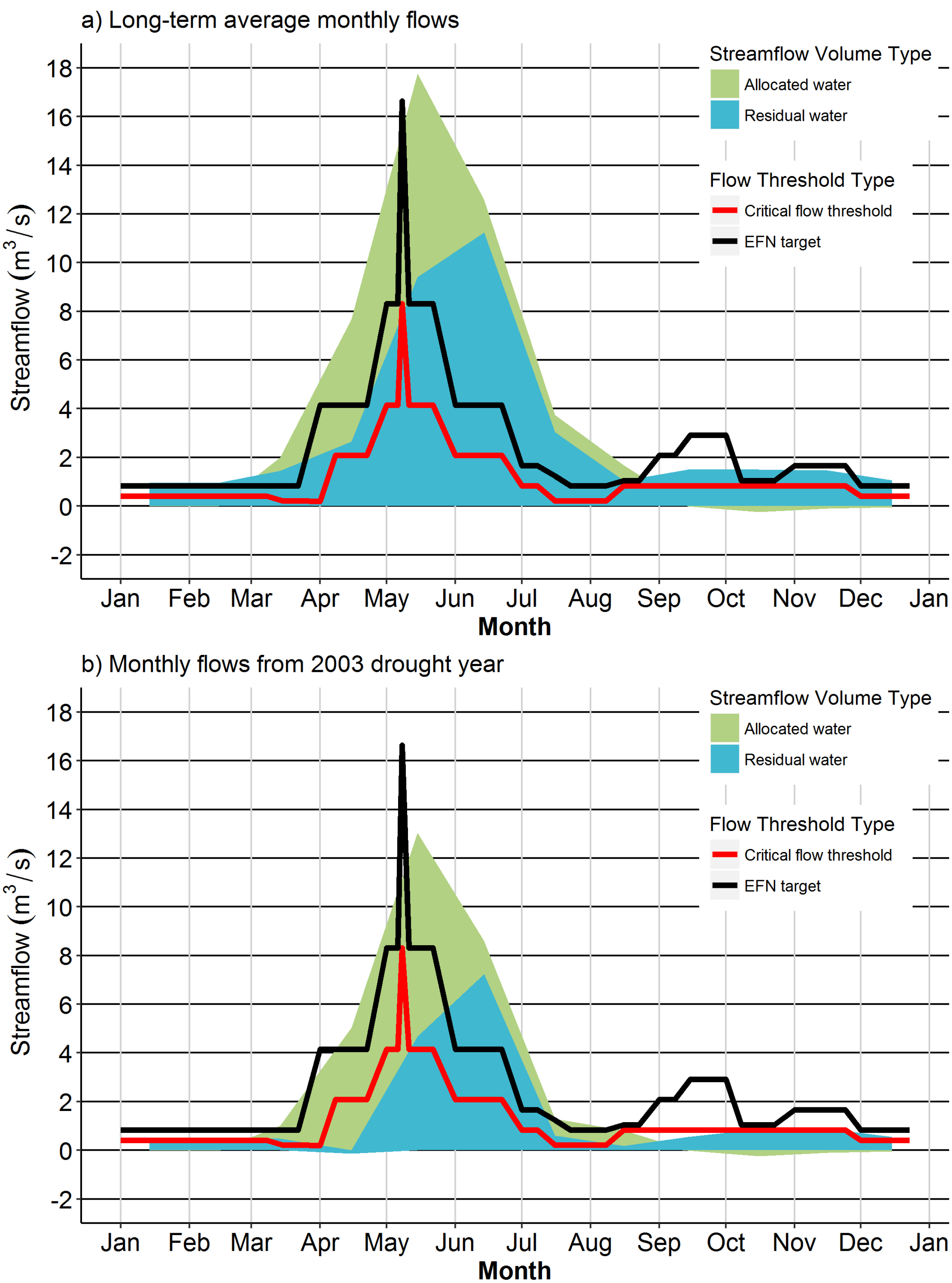


Figure 29. Hydrograph for Bessette Creek above Beaverjack Creek (08LC039) with allocated water and monthly residual flows (blue shading + green shading = naturalized flow), with environmental flow needs, and critical environmental flow thresholds for (a) average flow conditions and (b) the 2003 drought year.

6.4.1 *Will the target environmental flow needs be met under total allocation use during average flow conditions?*

Under average conditions and full allocation scenario, there are two seasons of shortfall when the residual flow fails to meet the target EFNs (i.e., black EFN target line is above the blue shading for residual water - Figure 29a). The first occurs during the spring freshet and includes a period in April when the flows are below the 4.2 m^3/s target for behavioural cues for migratory rainbow trout spawning and also below the short-term 16.6 m^3/s target for channel maintenance. The shortfalls during the spring are the result of the large diversion of water for storage in the Duteau Creek reservoirs. The consequences include delaying the rainbow trout migration and year-to-year persistence of channel-spanning beaver dams that can impact upstream fish migration. The later problem was encountered in 2010 during stream channel surveys (Warman et al., 2011).

The second season of shortfall is during the month of September during the spawning season for the smaller bodied Chinook Salmon (CK-16) in early September and for the larger Shuswap River Chinook Salmon (CK-15) later in the month (see Figure 30a for late summer season). It is important to note that EFN shortfalls are predicted even under naturalized flow conditions (blue + green shading - Figure 30a). Fish have adapted to this particular flow shortage to some degree by using short-term spikes in flow associated with fall rainstorms to migrate to suitable habitats. However, the quantity of flow during September remains an important limiting factor to Chinook Salmon production in Bessette Creek (Epp, 2014).

6.4.2 *Will flows remain above critical environmental flow thresholds under total allocation use during average flow conditions?*

For the scenario of full allocation demand during average flow conditions, streamflow is predicted to remain above the critical flow threshold through all seasons (Figure 29a).

6.4.3 *Will the target environmental flow needs be met under total allocation use during drought?*

For the scenario of full allocation demand during a drought year, there are two extended seasons of shortfall when residual flows are less than target EFNs. The first instance starts in January and continues through the end of May (Figure 29b). The values and periods affected include: (1) egg incubation for all species; (2) overwintering for rainbow trout, Chinook Salmon and Coho Salmon; (3) juvenile rearing for the same species; (4) migratory rainbow trout behavioral cues and spawning; and (6) channel flushing and flushing flows.

The second instance starts in mid-July and extends through September (Figure 30b). The values and periods effected include: (1) juvenile rearing for rainbow trout, Chinook Salmon and Coho Salmon; (2) migration for Chinook Salmon; and (3) spawning for Chinook Salmon.

It is important to note that under the naturalized condition, periods of shortfall would occur but are limited to January, February and September (Figure 29b)

6.4.4 *Will flows remain above critical environmental flow thresholds under total allocation use during drought?*

For the scenario of full allocation demand during drought, streamflow is predicted to drop below the critical environmental flow thresholds for two periods including March through May, and mid-July through September (Figure 30b). The species and periods affected are described above.

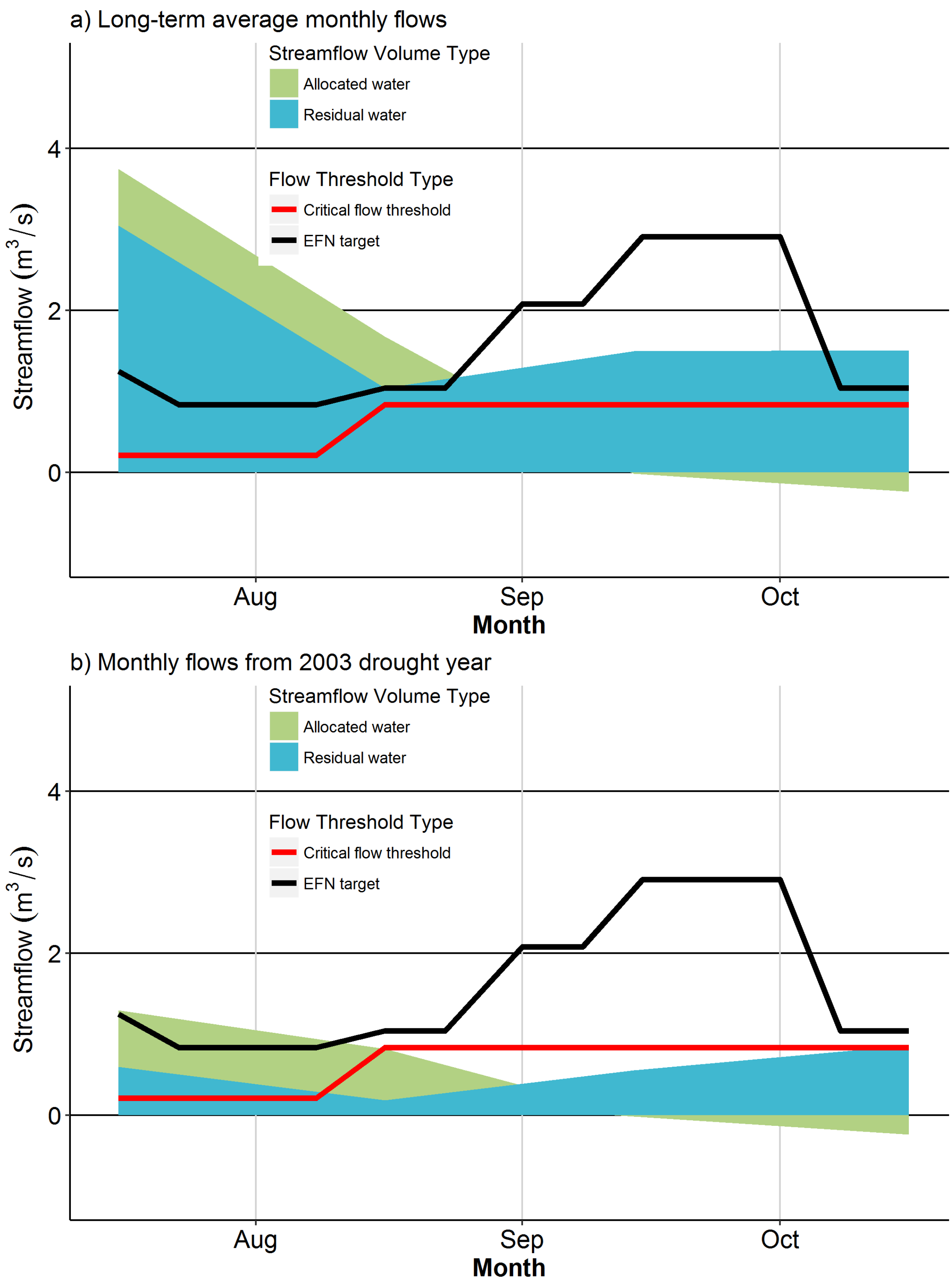


Figure 30. Hydrograph for the late summer season for Bessette Creek above Beaverjack Creek (08LC039) with allocated water and monthly residual flows (blue shading + green shading = naturalized flow), with environmental flow needs, and critical flows for (a) average flow conditions and (b) the 2003 drought year.

7. PANEL FINDINGS AND EAB DECISION – IMPLICATIONS

The scientific information presented above is a nearly complete record of material submitted to the Environmental Appeal Board in support of the Province's refusal to grant the water license application, as the appeal was based only on written evidence. As noted earlier there has been no extension of the original analyses, in order to preserve the context of the decision, for the reader. The section below summarizes key elements of the Panel's findings and decision.

The Panel (Mattison, 2018) characterized the appeal as raising administrative and technical issues as follows:

1. "Whether the Ministry failed to provide adequate information and communication before accepting the Appellants' water license application, which caused the Appellants to incur unnecessary expenses when the Water Manager's Decision to refuse the license had already been made."
2. "Whether there is enough water to issue a groundwater license to the Appellants for 80,000 m^3/year from Aquifer 318."

With respect to the first issue, the panel noted the Water Manager has certain obligations as a decision maker, including to "consider the environmental flow needs of a stream in deciding an application in relation to the stream or an aquifer the decision maker considers is reasonably likely to be hydraulically connected to that stream". It also noted the Ministry (FLNR) can request information required to make a decision. Specifically,

> "The Panel finds that the Ministry's requests for hydrogeological information were clearly an attempt to determine if and, if so, when withdrawals from Aquifer 318 would affect the flow in Bessette Creek. This information would be needed for the Water Manager to decide whether to grant the Appellants application. The Panel finds that there was clear authority for the information requests that were made during the application process. Specifically, the Panel finds that the requests for further information were consistent with the powers provided in Sections 12, 14, and 15 of the *Act* regarding license applications." (Mattison, 2018: paragraph 53)

The Panel also found there was "…no failure of procedural fairness…" (Mattison, 2018: paragraph 58).

With respect to the second issue, the panel relied largely on the hydrologic expert report (McCleary, 2017). The Panel found:

> "…clear evidence that Aquifer 318 is reasonably likely to be hydraulically connected to Bessette Creek…" (Mattison, 2018: paragraph 88), and also that:

> "…the amount of streamflow depletion associated with the requested groundwater withdrawal from the Appellants' well is difficult to measure, but further development of aquifers that are hydraulically connected to Bessette Creek, such as Aquifer 318, presents a risk of additional harm to the proper functioning of the aquatic ecosystem of Bessette Creek." (Mattison, 2018: paragraph 89)

The Province of British Columbia's case presented the history of the watershed being fully allocated for more than fifty years, and a long-term record of water flows near the subject well. The long-term nature of Bessette Creek being water short has led to numerous other studies, some of which were referenced and employed in Chapter 6 – Water use accounting and environmental flow needs. The ability to use different scientific approaches that concurred with other methods and evidence helped backstop the decision to refuse the license.

The Panel did note the applicant was provided with other options that they did not wish to pursue. Instead, the decision maker was asked to render a decision based on information available. The Panel also noted that FLNR clearly had authority to make all information requests. This reinforces for future groundwater license applicants the ability of the decision maker to request information they deem necessary to adjudicate a license decision.

The EAB Panel made a singular recommendation as follows:

- "…the Ministry consider designating Aquifer 318 fully recorded for licensing purposes, or alternately, designating the Bessette Creek watershed under section 65 of the Act for the purpose of developing a water sustainability plan, as the Appellants suggested"

This recommendation was implemented. Aquifer 318 and other aquifers now can be assigned the same designations as streams. Based on the outcome of this case, as of December 2019, Aquifer 318 is designated as FR (Fully Recorded). As of December 2019, nearby aquifers 316 and 319 were designated PWS (Possibly Water Short). Such designations are publicly viewable in the aquifers layer in iMapBC. In 2018, these aquifers (as well as others between Vernon and Cherryville) were reviewed and mapping updated to better reflect current hydrogeologic information (Stewart and Allard, 2018).

8. SUMMARY

As part of the adjudication of a groundwater license application for a well near Lumby, B.C., it was determined that a reasonable likelihood of hydraulic connectivity existed between the well and nearby Bessette Creek. A new use groundwater application license was submitted to the Province of B.C. The technical assessment provided by the applicant (hydrogeology report) was incomplete when compared to the provincial Technical Assessment Guidelines (see Todd et al., 2016). Responses to additional information requests from the statutory decision maker were incomplete, did not fully address statutory decision-maker concerns and created additional questions, which the applicant's Qualified Professional argued were not able to be complied with, such as estimating the magnitude and timing of impacts to Bessette Creek.

Ultimately the applicant requested a decision be made on the available information, and the application was refused on the basis of a likely hydraulic connection to Bessette Creek and potential to negatively impact the environmental flow needs of the creek. The decision to refuse the license was subsequently appealed by the applicant.

FLNR defended the decision through two expert reports. A hydrogeology expert report demonstrated the likelihood of a hydraulic connection between the subject well and Bessette Creek and used an analytical model to estimate the timing and magnitude of that connection if the license were to be issued. This information was then incorporated into a watershed-scale, water-use accounting exercise to highlight the following key points: (1) during the early spring reservoir refill period and late summer irrigation season, the existing licensed surface water and groundwater withdrawals frequently interfere with environmental flow needs in Bessette Creek – during these periods, Bessette Creek watershed is over-allocated; and (2) although the depletion associated with the single well in question may be difficult to detect, additional water allocation adds to the existing over-allocation problem and contributes to the risk of further losses to the productive capacity of the Bessette Creek aquatic ecosystem. There are several key points that also can be extracted from the respective hydrogeological and EFN assessment reports.

8.1 Key Points

1. The decision maker decides whether an aquifer is reasonably likely to be connected to a stream. The test of 'reasonable likelihood' is based on the consideration and evaluation of all technical information, data, and interpretations to the decision maker. The decision maker weighs the direct and indirect lines of evidence to inform the decision on hydraulic connectivity.
2. The decision maker authority to request information required to make a decision is reinforced.
3. Bessette Creek supports sensitive fish stocks including Interior Fraser Coho Salmon and South Thompson River – Bessette Creek Chinook Salmon that have been impacted by high levels of water withdrawal in the region.
4. During an average runoff year with the existing allocation, residual streamflow in Bessette Creek is below target EFNs during the spring reservoir refill period and also during the late summer irrigation period. These shortfalls translate to chronic reductions in productive capacity of the aquatic ecosystem.
5. During a drought year, residual streamflow in Bessette Creek can drop below critical environmental flow thresholds during the spring reservoir refill period and the summer irrigation period. Regulatory intervention and more comprehensive water use planning through the WSA may be required to prevent irreversible harm to the ecosystem as a result of drought.
6. Given the overlap in timing of groundwater abstraction at the basin scale and the onset of Chinook Salmon migration, additional groundwater withdrawals will exasperate existing water use impacts.
7. Within the Duteau Creek tributary, water diversion during the spring freshet to fill storage results in downstream flows that are below EFN targets and therefore the over-allocation problem cannot be rectified through the development of additional storage in that subbasin.
8. Estimates of irrigated acreage in Bessette Creek range from a low of 13.5 km^2 to a high of 26.8 km^2. This discrepancy makes it difficult to predict the existing water demand but should be resolved over time as transitional groundwater wells are licensed.
9. Until more robust water tools are developed that can account for diversion and release from storage, EFN assessment should use the multiple lines of evidence approach for water use accounting, as was used within this study.
10. Although the predicted maximum streamflow depletion of 8 L/s associated with the groundwater withdrawals from WTN 112051 would have been difficult to detect, continued development of aquifers that are connected to Bessette Creek present the risk of additional losses to the productive capacity of the Bessette Creek aquatic ecosystem and would add to the over-allocation problem.

8.2 Conclusion

The outcome of the EAB decision reinforces the importance of science-based decision making, particularly as it relates to the implementation of the *Water Sustainability Act* and quantifying the effects of groundwater withdrawals on surface water. It also underscores the statutory decision-makers' authority to request additional information from an applicant necessary to adjudicate the water licence application.

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APPENDIX A. RELEVANT WATER LICENSES

Greater Vernon Water, Regional District of North Okanagan, Water Licence C017841 (page 1)

W.R.B. 13—4M-347-2281 (2)

PROVINCE OF BRITISH COLUMBIA. | WATER RIGHTS BRANCH. | DEPARTMENT OF LANDS AND FORESTS.

CONDITIONAL WATER LICENCE.

VERNON IRRIGATION DISTRICT of Vernon, B.C., is

hereby authorized to store water as follows:—

(*a.*) The sources of the water-supply ~~is~~ are Aberdeen and Haddo Lakes.

(*b.*) The points of storage are ~~is~~ located as shown on the attached plan.

(*c.*) The date from which this licence shall have precedence is 1st September, 1906.

(*d.*) The purpose for which the water is to be used is as set out in Conditional Water Licence No. 17841

(*e.*) The maximum quantity of water which may be stored is 20,000 acre feet per annum.

and such additional quantity as the Engineer may from time to time determine should be allowed for losses.

(*f.*) The period of the year during which the water may be stored is 1st October to 15th June.

(*g.*) The land upon which the water is to be used and to which this licence is appurtenant is as set out in Conditional Water Licence No. 17841

(*h.*) The works authorized to be constructed are earth dams.

and they shall be located approximately as shown on the attached plan.

(*i.*) The construction of the said works has already been ~~shall be~~ commenced ~~on or before the~~ ~~day of~~ ~~19~~ and shall be completed and the water beneficially used on or before the 31st day of December 19 60.

(j) This licence is issued in substitution of Conditional Water Licences Nos. 5546, 10652 and 11580 hereby surrendered and cancelled.

84-30247
J.H.

Deputy Comptroller of Water Rights.

File No. 091905 Date issued June 2, 1947 Licence No. 17841

DEPARTMENT OF LANDS AND FORESTS
WATER RIGHTS BRANCH
PARLIAMENT BUILDINGS
VICTORIA, B.C.

ORDER

WATER ACT

Section 15

FILE NO. 091905

In the matter of Conditional Water Licence No. 17842, Aberdeen and Haddo Lakes, which authorizes the storage of 20,000 acre feet per annum of water.

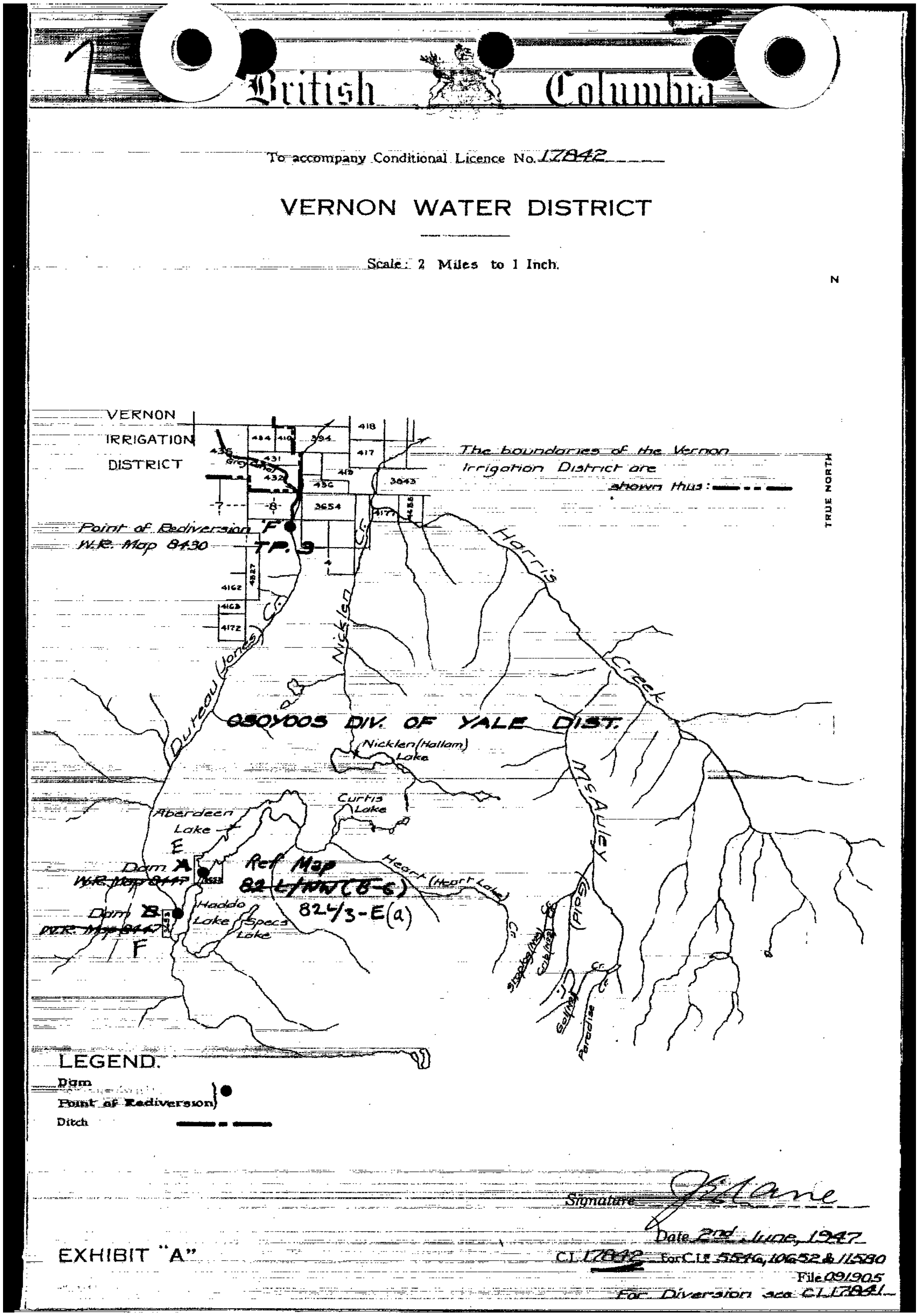
Being satisfied that no person's rights will be injuriously affected, I hereby authorize the construction of an earth-fill dam (30 feet in height), spillway and inclined gate, in lieu of the works previously authorized on Aberdeen Lake.

I also extend the date by which the works shall be completed and the water beneficially used to the 31st day of December, 1966.

Dated at Victoria, B.C., this 22nd day of October, 1964.

H.D. DeBeck,
Deputy Comptroller of Water Rights.

Greater Vernon Water, Regional District of North Okanagan, Water Licence C017841 (page 3)



Water licence C66387 held by a private landowner for the purpose of irrigation with point of diversion in Bessette Creek showing typical application of a duty of 2.5 feet for irrigation purposes (i.e., 15.80 acre feet per annum / 6.3 acres = 2.5 feet) (downloaded from British Columbia Water Licence Search website on Oct. 26, 2020).

WATER MANAGEMENT BRANCH

MINISTRY OF ENVIRONMENT

THE PROVINCE OF BRITISH COLUMBIA—WATER ACT

CONDITIONAL WATER LICENCE

Rhonda Couchman of Albers Road, Lumby, B.C. V0E 2G0

is hereby authorized to divert and use water as follows:

(a) The stream on which the rights are granted is Bessette Creek.

(b) The point of diversion is located as shown on the attached plan.

(c) The date from which this licence shall have precedence is 24th June, 1963.

(d) The purpose for which this licence is issued is irrigation.

(e) The maximum quantity of water which may be diverted is 15.80 acre feet per annum.

(f) The period of the year during which the water may be used is 1st April to 30th September.

(g) The land upon which the water is to be used and to which this licence is appurtenant is Lot 1 of Section 16, Township 40, Osoyoos Division of Yale District, Plan 20087, except Plan 31484, of which 6.3 acres may be irrigated.

(h) The works authorized to be constructed are diversion structure, pump, pipe and sprinkler system, which shall be located approximately as shown on the attached plan.

(i) The construction of the said works shall be completed and the water beneficially used prior to the 31st day of December, 1994. Thereafter, the licensee shall continue to make a regular beneficial use of water in the manner authorized herein.

(j) This licence is issued in substitution of Conditional Water Licence 28473, in part.

J. E. Farrell
Deputy Comptroller of Water Rights

File No. 0250707 Date issued: 28th March, 1991 CONDITIONAL LICENCE 66387

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APPENDIX B. WATER USE ACCOUNTING TABLES AND FIGURES

Table B1. Monthly mean instantaneous actual demand (m^3/s) by purpose.

Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Part 1. Conservation													
Storage: Grizzly	0.000	0.000	0.018	0.167	0.263	0.019	0.000	0.000	0.000	0.000	0.000	0.000	**0.04**
Storage release: Grizzly	-0.028	-0.031	-0.028	0.000	0.000	0.000	-0.051	-0.051	-0.086	-0.064	-0.067	-0.064	**-0.04**
Storage: Nicklen	0.000	0.000	0.022	0.200	0.315	0.023	0.000	0.000	0.000	0.000	0.000	0.000	**0.05**
Storage release: Nicklen	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.066	-0.251	-0.193	-0.051	0.000	**-0.05**
Subtotal	**-0.028**	**-0.031**	**0.013**	**0.366**	**0.578**	**0.042**	**-0.051**	**-0.117**	**-0.337**	**-0.258**	**-0.118**	**-0.064**	**0.00**
Part 2. Private													
Domestic	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	**0.00**
Storage: irrigation	0.000	0.000	0.014	0.127	0.200	0.014	0.000	0.000	0.000	0.000	0.000	0.000	**0.03**
Storage release	0.000	0.000	0.000	0.000	-0.053	-0.091	-0.088	-0.088	-0.036	0.000	0.000	0.000	**-0.03**
Irrigation	0.000	0.000	0.000	0.000	0.373	0.642	0.622	0.622	0.257	0.000	0.000	0.000	**0.21**
Livestock	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	**0.00**
Fire protection	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	**0.00**
Subtotal Non-Utilities	**0.007**	**0.007**	**0.021**	**0.134**	**0.527**	**0.573**	**0.541**	**0.541**	**0.228**	**0.007**	**0.007**	**0.007**	**0.22**
Part 3. Utilities													
Storage	0.000	0.000	0.213	1.930	3.041	0.221	0.000	0.000	0.000	0.000	0.000	0.000	0.45
Storage release	-0.050	-0.055	-0.050	-0.052	-0.760	-1.275	-1.234	-1.234	-0.541	-0.050	-0.052	-0.050	-0.45
Waterworks	0.050	0.055	0.050	0.052	0.050	0.052	0.050	0.050	0.052	0.050	0.052	0.050	0.05
Irrigation	0.000	0.000	0.000	0.000	0.710	1.223	1.184	1.184	0.489	0.000	0.000	0.000	0.40
Subtotal: Utilities	**0.000**	**0.000**	**0.213**	**1.930**	**3.041**	**0.221**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.45**
Subtotal: Consumptive	**0.007**	**0.007**	**0.234**	**2.064**	**3.568**	**0.794**	**0.541**	**0.541**	**0.228**	**0.007**	**0.007**	**0.007**	**0.67**
Total	**-0.021**	**-0.023**	**0.247**	**2.430**	**4.146**	**0.836**	**0.490**	**0.424**	**-0.109**	**-0.251**	**-0.111**	**-0.058**	**0.67**

Table B2. Summary of registered wells for the purpose of irrigation within Bessette Creek watershed (source is BC Provincial groundwater wells data layer). Well tag number 112051 shown in yellow. Wells sorted by construction date. Thick line indicating wells constructed after Water Sustainability Act implementation on Mar. 1, 2016. Based on a query completed in October 2017.

Well tag number	Aquifer type	Construction year	Well depth (m)	Yield (US gpm)[1]	Licensed	Distance (m)
8654	Unconfined	1950	64	200	Unlicensed	379
32060	Unconfined	1975	115	120	Licensed	1984
32152	Unconfined	1975	176	250	Unlicensed	986
32188	Unconfined	1975	145	150	Unlicensed	798
39070	Unconfined	1978	95	0	Unlicensed	36
44383	Unconfined	1980	194	200	Unlicensed	1348
45613	Unconfined	1980	150	15	Unlicensed	765
57256	Unconfined	1987	176	75	Unlicensed	259
58057	Unconfined	1988	178	75	Unlicensed	216
58134	Unconfined	1988	257	190	Unlicensed	517
58156	Unconfined	1988	75	150	Unlicensed	119
58171	Unconfined	1988	188	500	Unlicensed	25
58459	Unconfined	1988	170	100	Unlicensed	493
58599	Unconfined	1988	260	100	Unlicensed	680
70089		1993	70	60	Unlicensed	356
108721	Unconfined	1993	85	18	Unlicensed	734
82878		1994	217	400	Unlicensed	1656
79627		1998	194	0	Unlicensed	355
84408	Unconfined	2000	176	150	Unlicensed	65
84287	Unconfined	2002	57	400	Unlicensed	41
90659	Unconfined	2004	73	400	Unlicensed	189
90827	Unconfined	2004	80	30	Unlicensed	267
87590		2005	236	600	Unlicensed	2117
93957	Unconfined	2006	222	100	Unlicensed	752
104095	Unconfined	2006	76	200	Unlicensed	73
104047		2007	88	300	Unlicensed	341
104077		2007	185	100	Unlicensed	6
104079		2008	411	200	Unlicensed	1955
104011	Unconfined	2009	98	600	Unlicensed	89
104035		2009	600	4	Unlicensed	1320
104044		2009	98	66	Unlicensed	102
104006		2010	255	100	Unlicensed	1671
108662	Unconfined	2013	55	250	Unlicensed	194
112051	Unconfined	2016	172	200	Unlicensed	373
112101		2016	76	93	Licensed	29
112958	Unconfined	2016	277	350	Unlicensed	203
Median			171	150		356
Total				6746		

[1] The conversion rate from US gallons per minute to litres per second is 1 US gpm = 0.06309 l/s, therefore 6,746 US gpm equals 426 l/s.

Table B3. Summary of monthly and annual streamflow depletion for registered irrigation wells under three different scenarios.

Month	Average monthly streamflow depletion (L/s)		
	Scenario 1: Licensed plus all transition wells	**Scenario 2**: Scenario 1 + W112051	**Scenario 3**: All registered wells
Jan	36	37	39
Feb	29	30	32
Mar	24	25	26
Apr	20	21	22
May	28	29	31
June	143	148	156
July	199	205	217
Aug	229	236	249
Sep	201	207	219
Oct	105	109	115
Nov	66	69	72
Dec	47	49	52
Total Annual (ML/year)	**2,979 ML**	**3,075 ML**	**3,244 ML**

Table B4. Monthly mean instantaneous licensed demand (m^3/s) by purpose.

Purpose	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Part 1. Conservation													
Storage: Grizzly	0.000	0.000	0.018	0.167	0.263	0.019	0.000	0.000	0.000	0.000	0.000	0.000	**0.04**
Storage release: Grizzly	-0.028	-0.031	-0.028	0.000	0.000	0.000	-0.051	-0.051	-0.086	-0.064	-0.067	-0.064	**-0.04**
Storage: Nicklen	0.000	0.000	0.022	0.200	0.315	0.023	0.000	0.000	0.000	0.000	0.000	0.000	**0.05**
Storage release: Nicklen	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.066	-0.251	-0.193	-0.051	0.000	**-0.05**
Subtotal	**-0.028**	**-0.031**	**0.013**	**0.366**	**0.578**	**0.042**	**-0.051**	**-0.117**	**-0.337**	**-0.258**	**-0.118**	**-0.064**	**0.00**
Part 2. Private													
Domestic	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	**0.00**
Storage: irrigation	0.000	0.000	0.014	0.127	0.200	0.014	0.000	0.000	0.000	0.000	0.000	0.000	**0.03**
Storage release	0.000	0.000	0.000	0.000	-0.053	-0.091	-0.088	-0.088	-0.036	0.000	0.000	0.000	**-0.03**
Irrigation	0.000	0.000	0.000	0.000	0.373	0.642	0.622	0.622	0.257	0.000	0.000	0.000	**0.21**
Livestock	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	**0.00**
Fire protection	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	**0.00**
Subtotal Non-Utilities	**0.007**	**0.007**	**0.021**	**0.134**	**0.527**	**0.573**	**0.541**	**0.541**	**0.228**	**0.007**	**0.007**	**0.007**	**0.22**
Part 3. Utilities													
Storage	0.000	0.000	0.500	4.520	7.123	0.517	0.000	0.000	0.000	0.000	0.000	0.000	**1.05**
Storage release	-0.117	-0.130	-0.117	-0.121	-1.781	-2.986	-2.889	-2.889	-1.267	-0.117	-0.121	-0.117	**-1.05**
Waterworks	0.126	0.139	0.126	0.130	0.126	0.130	0.126	0.126	0.130	0.126	0.130	0.126	**0.13**
Irrigation	0.000	0.000	0.000	0.000	1.784	3.073	2.974	2.974	1.229	0.000	0.000	0.000	**1.00**
Subtotal: Utilities	**0.009**	**0.009**	**0.508**	**4.528**	**7.253**	**0.734**	**0.211**	**0.211**	**0.092**	**0.009**	**0.009**	**0.009**	**1.13**
Subtotal: Consumptive	**0.015**	**0.017**	**0.529**	**4.662**	**7.780**	**1.307**	**0.751**	**0.751**	**0.320**	**0.015**	**0.016**	**0.015**	**1.35**
Total	-0.012	-0.014	0.542	5.029	8.357	1.349	0.701	0.634	-0.017	-0.243	-0.102	-0.049	**1.35**

Table B5. Refused water licence applications from the points of diversion search within Bessette Creek sorted by priority date.

Licence No.	Priority date	Licence status	Stream name	Purpose	Quantity	Units
Z103389	19910730	Refused application	Vance Creek	Domestic	4.546	MD
Z104013	19911220	Refused application	Bessette Creek	Irrigation: private	3083.700	MY
Z107035	19930901	Refused application	Alberts Creek	Domestic	2.273	MD
Z107035	19930901	Refused application	Alberts Creek	Power: residential	0.000	MS
Z123251	20071031	Refused application	Creighton Creek	Domestic	2.273	MD

Table B6. Cancelled water licences, abandoned licences and abandoned applications from the points of diversion search within Bessette Creek sorted by priority date.

Licence No.	Priority date	Licence status	Stream name	Purpose	Quantity (MY)
C110794	19540205	Cancelled	Bessette Creek	Irrigation: private	6,167
C128842	19670608	Abandoned	Creighton Creek	Irrigation: private	49,709
C070261	19680527	Abandoned	Vance Creek	Irrigation: private	61,674
F065196	19690120	Abandoned	Vance Creek	Domestic	996
C070406	19690612	Abandoned	Bessette Creek	Irrigation: private	296
Z103392	19880721	Abandon Appl.	Blue Springs Creek	Vehicle & eqpt: mine	165,932
Z103313	19900516	Abandon Appl.	Duteau Creek	Conservation: storage	418,150
Z103900	19910530	Abandon Appl.	Bessette Creek	Irrigation: private	61,674
Z103847	19911112	Abandon Appl.	Ross Spring	Domestic	830
Z104830	19920528	Abandon Appl.	ZZ Spring (65892)	Irrigation: private	49,339
Z104830	19920528	Abandon Appl.	ZZ Spring (65892)	Stream storage: non-power	49,339
Z106126	19930218	Abandon Appl.	Churchill Creek	Domestic	830
Z119430	20040402	Abandon Appl.	Reets Creek	Domestic	830
Z119430	20040402	Abandon Appl.	Reets Creek	Irrigation: private	6,167
Z122090	20060721	Abandon Appl.	ZZ Spring (80012)	Domestic	830
Z122090	20060721	Abandon Appl.	ZZ Spring (80012)	Livestock & animal: stock	2,157
Total Count	**16**			**Total Quantity**	**874,920**

Normal conditions	Drought conditions

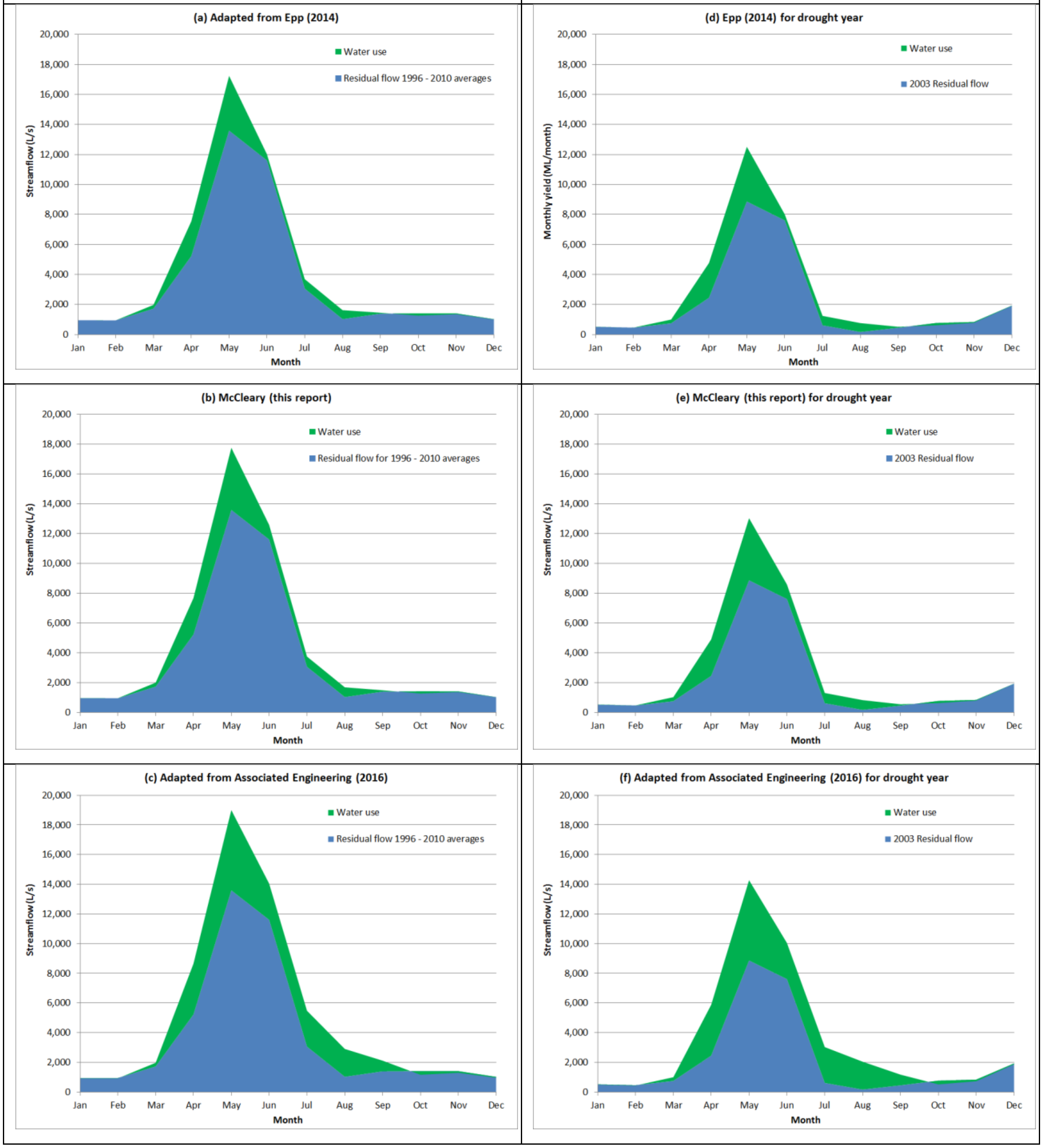

Figure B1. Naturalized flow conditions represented with stacked area charts showing the sum of residual flow (blue shading) and water use (green shading) (e.g., Naturalized flow = residual flow + water use). Three different estimates are provided based on Epp (2014), McCleary (this report) and Associated (2016) for two different scenarios including average flow conditions for the 1996–2010 period (a-c) and drought conditions from 2003 (d-f).

APPENDIX C. ENVIRONMENTAL FLOW NEEDS TABLES AND FIGURES

Table C1. EFN target flows and critical environmental flow thresholds by species / function and period for Bessette Creek based on Epp (2014), Ptolemy and Lewis (2002) and other considerations.

Species or Function	Period	EFN target flow (% of LT MAD)	Critical environmental flow threshold (% of LT MAD)
Ecological	Channel Maintenance	200	100
Ecological	Flushing Flows	400	200
Ecological	Freshet ramp down	40	20
Ecological	Invertebrate Drift	20	5
All fish	Overwintering	20	10
Chinook Salmon	Rearing - chinook	20	5
Chinook Salmon (CK-15)	Migration - large chinook	50	20
Chinook Salmon (CK-15)	Spawning - small chinook	50	20
Chinook Salmon (CK-16)	Migration - small chinook	25	20
Chinook Salmon (CK-16)	Spawning - large chinook	70	20
Coho and Chinook Salmon	Smolt emigration	100	50
Coho Salmon	Migration - coho	25	20
Coho Salmon	Spawning - coho	40	20
Kokanee	Migration - kokanee	10	10
Kokanee	Spawning - kokanee	20	10
Rainbow trout	Spawning cues - large rainbow	100	50
Rainbow trout	Rearing - rainbow	30	5
Rainbow trout - migratory	Migration - large rainbow	40	25
Rainbow trout - migratory	Spawning - large rainbow	55	25

Table C2. Fish periodicity chart with fish species, environmental flow needs and critical environmental flow thresholds by week for Bessette Creek above Beaverjack Creek.

Fish Species/Indicator	Lifestage/Period	January				February				March				April				May				June				July				August				September				October				November				December			
Rainbow trout	Adult spawning migration													2	2	2	2	1	1	1	1	1	1																										
	Spawning															1	1	1	1	1	1	1	1																										
	Incubation																1	1	1	1	1	1	1	1	1	1	1	1	1																		
	Rearing											1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1								
	Overwintering	2	2	2	2	2	2	2	2	2	2																																	1	1	1	1	2	2	2	2
Chinook salmon	Adult spawning migration																									1	1	1	1	1	1	1	1	1	1														
Lower Bessette Creek	Spawning																																			2	2	2											
Mid Shuswap Under Yearly CU	Incubation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																				1	1	1	1	1	1	1	1	1	1	1	1	1
	Rearing															1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1								
	Smolt emmigration + fry movement											1	1	1	1	1	1	1	1	1	1	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
	Overwintering	1	1	1	1	1	1	1	1	1	1																																	1	1	1	1	1	1	1	1
Chinook salmon	Adult spawning migration																									1	1	1	1	1	1	2	2	1	1														
Duteau Creek	Spawning																																1	2	2	1	1	1	1										
Small bodied yearling	Incubation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Rearing											2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
	Smolt emmigration + fry movement											1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
	Overwintering	1	1	1	1	1	1	1	1	1	1																																	1	1	1	1	1	1	1	1
Coho salmon	Adult spawning migration																																		1	1	1	1	2	2	2	1	1	1	1	1	1	1	1
Duteau Creek population	Spawning																																							1	1	2	2	2	2	1	1	1	1
Bessette Creek population	Incubation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																								1	1	1	1	1	1	1	1	1
	Rearing											1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
	Smolt emmigration + fry movement															1	1	1	1	1	1	1	1	1	1	1	1	1	1																				
	Overwintering	1	1	1	1	1	1	1	1	1	1																																	1	1	1	1	1	1	1	1
Kokanee	Adult spawning migration																																		1	1	1	1	1										
	Spawning																																			1	1	1	1										
	Incubation	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1																				1	1	1	1	1	1	1	1	1	1	1	1	1
Food Production	Invertebrate Drift											1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
Ecological Flows	Flushing flows													1	1	1	1	1	2	1	1	1																											
	Icing	1	1	1	1	1	1	1	1																																					1	1	1	1
	Freshet rampdown	1	1	1	1	1	1	1	1																	2	2																			1	1	1	1
	Wetland/trib/side channel linkage													1	1	1	1	1	1	1	1	1																											
	Channel maintenance																1	2	1	2	2																												
Dominant period		Overwintering	Overwintering	Overwintering	Overwintering	Overwintering	Overwintering	Overwintering	Overwintering	Overwintering	Overwintering	Rearing - chinook	Rearing - chinook	Behavioural cues - rainbow spawning	Behavioural cues - rainbow spawning	Behavioural cues - rainbow spawning	Behavioural cues - rainbow spawning	Channel Maintenace	Flushing flows	Channel Maintenace	Channel Maintenace	Smolt emmigration	Smolt emmigration	Smolt emmigration	Smolt emmigration	Freshet rampdown	Freshet rampdown	Rearing - rainbow	Rearing - chinook	Rearing - chinook	Rearing - chinook	Migration - small chinook	Migration - small chinook	Spawning - small chinook	Spawning - small chinook	Spawning - large chinook	Spawning - large chinook	Spawning - large chinook	Migration - coho	Migration - coho	Migration - coho	Spawning - coho	Spawning - coho	Spawning - coho	Spawning - coho	Overwintering	Overwintering	Overwintering	Overwintering
EFN Target (fraction of LT MAD)		0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.0	1.0	1.0	1.0	2.0	4.0	2.0	2.0	1.0	1.0	1.0	1.0	0.4	0.4	0.3	0.2	0.2	0.2	0.3	0.3	0.5	0.5	0.7	0.7	0.7	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.2	0.2	0.2	0.2
EFN Target (cms)		0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	4.2	4.2	4.2	4.2	8.3	16.6	8.3	8.3	4.2	4.2	4.2	4.2	1.7	1.7	1.2	0.8	0.8	0.8	1.0	1.0	2.1	2.1	2.9	2.9	2.9	1.0	1.0	1.0	1.7	1.7	1.7	1.7	0.8	0.8	0.8	0.8
Critical Flow Threshold (% LT MAD)		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	1.0	2.0	1.0	1.0	0.5	0.5	0.5	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Critical Flow Threshold (cms)		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.2	0.2	2.1	2.1	2.1	4.2	8.3	4.2	4.2	2.1	2.1	2.1	2.1	0.8	0.8	0.2	0.2	0.2	0.2	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.4	0.4	0.4	0.4
Month		January				February				March				April				May				June				July				August				September				October				November				December			

Table C3. Summer low flow frequency analysis (Log Pearson III) from Bessette Creek above Beaverjack Creek (08LC039) for the months June through September. Table produced using "compute_annual_frequencies" function from June through September daily flows in Rstats fasstr package (Goetz and Schwarz, 2020).

Return Period (Years)	Probability	Index	Discharge (cms)
2	0.5	**30Q2**	0.7094
5	0.2	**30Q5**	0.4582
10	0.1	**30Q10**	0.3587
25	0.04	**30Q25**	0.2728
50	0.02	**30Q50**	0.2270
100	0.01	**30Q100**	0.1914
200	0.005	**30Q200**	0.1632

APPENDIX D. RELEVANT SECTIONS OF THE WATER SUSTAINABILITY REGULATION

Part 7 — Transitional Provision

Transition — groundwater licensing

55 (1) A person to whom section 140 (1) of the Act applies must apply on or before March 1, 2022 for an authorization authorizing the person's diversion and use of water from an aquifer.

(2) Subject to this section, the Act and the regulations apply in relation to an application under subsection (1).

(3) Despite section 12 (1) (b) (ii) *[application and decision maker initiative procedures]* of the Act, if an application under subsection (1) of this section is received on or before March 1, 2022, the applicant is exempt from the requirement to pay an application fee.

(4) Applications under subsection (1) are exempt from section 15 (1) *[environmental flow needs]* of the Act.

(5) For the purposes of section 22 (1) *[precedence of rights]* of the Act, the date set out in an authorization issued in relation to an application under subsection (1) of this section is to be the person's date of first use in relation to the diversion and use of water from the aquifer.

[am. B.C. Regs. 94/2016, s. 5; 301/2016, s. (a); 238/2017, Sch. A, s. 1 (b); 27/2019, s. (b).]

Repealed

56 Repealed. [B.C. Reg. 278/2019, s. 2.]

http://www.bclaws.ca/civix/document/id/complete/statreg/36_2016