ENVIRONMENTAL FLOWS AND HYDROLOGIC ASSESSMENT

FOR THE

BESSETTE CREEK WATERSHED

2011 - 2013

Final report

Prepared
by

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EXECUTIVE SUMMARY

This final report was prepared following the third year of flow monitoring and weighted useable habitat width calculations for environmental flows in the Bessette Creek watershed. Results from all three years are presented in this report and the discussion and recommendations have been updated and expanded to reflect the larger data set and additional information regarding Duteau Creek water supply operations received in year three.

The Bessette Creek watershed supports a number of important fish stocks, including Chinook and Coho salmon, Kokanee and both adfluvial and resident rainbow trout. It has a history of severe low flows that can occur during the late summer and early fall in all of the major tributaries due to water use, and in spring in Duteau Creek when the water storage reservoirs are being filled.

Bessette Creek was included on a list of the "most sensitive salmon streams" in the South Thompson - Shuswap (Rood and Hamilton, 1995), and proposed as a "Candidate Sensitive Stream" under the Fish Protection Act in 2001 (Ministry of Environment, 2001). Bessette Creek was again considered for action under the Fish Protection Act in 2009 due to extremely low flows, and is still considered to be the highest priority stream for fish flow restoration in the Shuswap river watershed (White, 2011). The Bessette Creek Coho are part of the Thompson Coho Conservation Unit which are listed as endangered under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the Chinook are also considered a stock of concern (Watts, 2012).

The 2011 to 2013 flow / habitat monitoring program builds on and expands the existing information sources for fish protection planning as follows: historic Water Survey of Canada (WSC) hydrometric data was reviewed to document annual and seasonal flow patterns and frequency of low flows; consumptive water use licences were summarized by stream segment for comparison of reported and estimated water use to the flow records; riffle and glide transects were established at eight locations in the Bessette Creek watershed to evaluate how usable fish habitat width for the focal species and life stages varies with the changing flows in summer and fall; usable width / flow results were used to project reference flow levels as a percentage of long term mean annual discharge (%LTmad) for optimal, intermediate and minimal usable habitat widths for spawning and rearing conditions at each site; the reference flows were compared to the historic hydrometric records; and observations were made in regard to water use relative to flows and how the conservation storage in Nicklen Lake could be used to supplement low flows.

The results, observations and recommendations from the 2011 to 2013 Bessette Creek flow / habitat evaluation can be summarized as follows:

Flows

- The mean annual flows in lower Bessette Creek have been quite variable since annual recording began in 1976, ranging from 1.51 m^3/sec in 1987, to 8.43 m^3/sec in 1997, and averaging 3.47 m^3/sec over the entire period.
- The highest monthly flows occur in May (spring freshet) and the lowest monthly flows often occur in August (summer low flows and water use), but winter flows can also be very low in some years. Long term mean monthly August flows are 1.26 m^3/sec (36% of long term mean annual discharge (LTmad)), but mean monthly August flows of only 0.16 m^3/sec (4%LTmad) were recorded in 2003.
- Excel trend lines indicate both declining annual and summer / fall flows since WSC flow monitoring began in Bessette Creek in the 1970's.
- The 2011 to 2013 flow monitoring in Duteau Creek shows that Duteau Creek flows are highly regulated and highly variable as a result of the flow regulation. Extreme low flows can occur during the reservoir filling period in May, and in July when reservoir spill ends, and daily minimum flows during July to September are well below the average monthly flows due to the operational difficulties in matching reservoir releases to variable irrigation demands.
- Despite the operational challenges, Duteau Creek often supplies more than 50% of the August and September Bessette Creek flows at Lumby.
- The 2011 to 2013 flow monitoring for Creighton Creek demonstrates while the natural flow above the irrigation diversions remained relatively high (>25%) as a percentage of the long term mean annual discharge in August and September, the low overall volumes are highly susceptible to extreme reduction from irrigation diversions during low flows.
- The 2011 to 2013 flow monitoring for Bessette Creek above Lumby demonstrates low (approaching 10%LTmad) natural flows by late August with further reductions in flow due to irrigation diversions and flow losses to groundwater, with flows as low as 5%LTmad measured in 2012.

Consumptive Water Use & Naturalized Flows

- Review of water licence information showed 109 private irrigation licences and 11 Local Authority waterworks / irrigation licences in the Bessette Creek watershed. Most of the Local Authority licences (but only a few of the private irrigation licences) have associated water storage reservoirs which are filled during freshet to supply water for the diversions during summer, fall and winter low flows.
- The total annual licenced volume is equivalent to 39% of the mean annual flow at the lower Bessette Creek hydrometric site, but actual use as reported (water utilities) and estimated (private use) adds to only about 50% of the licenced volume (i.e. twice as much water is licenced for removal relative to what is actually being used). Virtually all of the under-utilized licencing is associated with the water utilities.
- Naturalized long term mean annual discharge (LTmad) was calculated for all the historic WSC station sites by adding water use (reported and estimated based on

licences, but excluding unknown groundwater use) to mean annual residual flow data. Monthly naturalized flows were calculated for July, August and September.

- The August flow reduction is calculated to be 0.493 m^3/sec in an average year. Together with the mean August flow, this indicates an average of 28% reduction from natural August flow conditions due to water use. In 2003 however, the lowest reported flow only 0.124 m^3/sec suggesting that as much as 80% of the naturalized flow may have been diverted for water use. Lowest August flow in 2009 was reported at 0.484 m^3/sec indicating water use was approximately equal to the residual flow (i.e. 50% reduction from natural flow of naturalized flow that would have been very close to 1.0 m^3/sec).
- Volume of groundwater use is unreported and unknown other than the Village of Lumby wells. Observation well 292 near Lumby has groundwater level fluctuations that closely match the annual pattern of stream flows, and even replicates some short term high flows, suggesting a close connection between groundwater and surface flows. There are a number of wells with yields between 100 and 1,200 gal/min (equivalent to 0.006 to 0.073 m^3/sec) that could be using water in addition to the licenced use and further reducing surface flows.

Usable Habit Width / Flow & Riffle Passage

- Usable habitat width vs. flow analyses show that usable width is typically very low at the lowest flows measured, increases proportionally to increases in flow to an inflection point on the curve, and then increases more gradually to a maximum value at the optimal flow after which it declines somewhat due to the very high velocities associated with the high flows.
- Rearing usable widths for rainbow trout parr and Chinook juveniles are typically maximized at flows of 40% to 60%LTmad in Bessette Creek and maximum usable widths at flow of up to 95% LTmad in Creighton and Duteau Creeks, with intermediate (inflection point) values at 50% to 60 % of the flow at which the maximum usable width occurs.
- Spawning usable widths vary more by species, with large bodied fish such as Chinook salmon requiring greater depths and favouring higher velocities than smaller bodied fish like Kokanee. Flows corresponding to maximum usable width for spawning vary from 40% to 60%LTmad for Kokanee to more than 100%LTmad in most locations for Chinook salmon, with intermediate values ranging from 20% (Kokanee) to >70%LTmad (Chinook)and minimal values ranging from 10% (Kokanee) to >50%LTmad (Chinook).
- The flows (as %LTmad) that correspond to minimal, intermediate and maximum usable widths for each species and life stage vary somewhat among the transects, reflecting the specific stream geometry at that site, and in general, usable widths optimize at higher flows in smaller tributaries (e.g. Creighton Creek) than in the mainstem of Bessette Creek.
- Low flows through riffles can also act as an obstacle to fish passage due to the shallow depths associated with low flows in riffles. Riffle passage for Kokanee is usually adequate at flows of 10%LTmad, but larger bodied fish such as Coho

benefit from more than 25%LTmad for passage and Chinook passage "requirements" exceed 50% at many locations.

Fish and Fish Habitat vs. Historic Stream Flows and Spawner Counts vs. Flows

- Comparison to historic freshet flows shows that rainbow trout spawning flows and ecological requirements as per the periodicity chart are generally satisfied in Bessette and Creighton Creeks, but the Duteau Creek data (which ends in 1996) shows peak freshet flows below 200%LTmad in 50% of the years and below 100%LTmad in 25% of the years, indicating Duteau Creek flows often fall short of spring ecological flow requirements and optimal rainbow spawning flows.
- Historic median August flows are approximately 20%LTmad in lower Bessette and Duteau Creeks, but flows of less than 10%LTmad occur in 10% of the years, indicating relatively common minimal flows for rainbow trout and Chinook salmon rearing during August. Historic (to 1983) median August flows in Bessette Creek above Lumby were less than 10%LTmad, indicating very poor rearing conditions in the agricultural water usage area above Lumby. Lower Creighton Creek also has high water usage relative to flow and would be expected to have similar flow limitations.
- Historic flows typically increased in September and October due to both fall rains and lower water use. Median fall spawning flows are 30%LTmad in lower Bessette Creek, but 25% of the years had September flows of less than 20%LTmad, indicating minimal usable width for spawning and limited depths for riffle passage, especially for the larger bodied Chinook and Coho salmon. Flows also increase upstream in Duteau, Creighton and Bessette above Lumby, but the increases are more variable and noticeably lower in Bessette above Lumby.
- Limited spawning data from 2005 to 2011 was compared to Bessette Creek mean monthly flows for September through November. The correlations are weak due to limited data and other variables, but show that very limited spawning occurred when mean monthly flows were less than 20%LTmad and that highest numbers of spawners occurred when mean monthly flows exceeded 30% LTmad.

Environmental Flow Targets for the Bessette Creek Watershed

- Weighted usable width and riffle passage results are used in conjunction with naturalized flows and other environmental flow considerations to create a Table of mean monthly flow targets for streams in the Bessette Creek watershed.
- The weighted usable width and riffle passage results demonstrate that very low flows provide minimal to no habitat for fish rearing and spawning, and that fish passage is also limited at very low flows. Usable width and fish passage increase with increasing flows, with maximum width values for many species and life stages at flows that exceed natural flows. As such the target values do not represent the flows that maximize fish habitat, but rather represent flow targets that should be able to be achieved most years within the regulated water use regime of this watershed.

- The monthly targets are presented in a BC-Modified Tennant Method style format, with winter and freshet flow targets based on the BC-Modified Tennant %LTmad targets, and rearing, spawning and passage flows reflecting the Bessette Creek watershed results from this project.
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Conservation Storage / Nicklen Lake Storage Release Strategy

- The Nicklen Lake storage release strategy presents a new water release plan to both meet downstream irrigation needs and optimize downstream environmental values.
- Refill calculations show that Nicklen Lake should refill completely from full drawdown under average to dry conditions (5 year return period), but that complete refill shouldn't be expected in all years which will reduce available conservation storage releases when that occurs.
- Recommended agricultural storage releases are 0.120 m^3/sec from July 15 to September 30, which will use most of the agricultural storage volume of 822 ML.
- Recommended conservation storage releases are for 0.160 m^3/sec from August 15 to October 31 (or later if operationally feasible) if there is no realtime reference site for variable flow releases. This will use 72% of the conservation storage of 1,460 ML by October 31.
- If realtime reference flows are available, then the conservation storage is recommended to be released in 0.040 m^3/sec increments up to a maximum value of 0.200 m^3/sec to meet target flows of 15%LTmad in August, and 25%LTmad in September and October. The entire volume of conservation storage would be used after 84 days at the maximum rate.
- Monthly monitoring of the Nicklen Lake level and the release volume should be recorded by MFLNRO staff from July through October in conjunction with dam inspections, and adjustments to the releases need to be communicated to the dam operator if Nicklen Lake has not refilled, or volume is reducing faster than planned for.

Duteau Creek Water Balance

- A water balance for the 1997 to 2013 period was constructed for Duteau Creek at the Headgates using available reservoir levels, Headgates diversion data, Headgates spill calculations and available seasonal flow monitoring data. April 1 and May 1 snowcourse data is also included for the Aberdeen Lake, Oyama Lake and Postill Lake snowcourses. Various aspects of the water balance are summarized, and naturalized flows are simulated from the available data.
- The snowcourse data indicates that consideration of the Oyama and Postill snowcourses which are located outside of the Duteau Creek watershed is also useful, as the results are usually similar and can flag anomalous results such as 2009 when runoff was low relative to a high Aberdeen (but not Oyama and Postill) snowcourse reading. The Oyama and Postill snowcourses also generally still have snow on May 1, providing a later reading for runoff forecasts.

- The Duteau Creek reservoirs did not fill completely in 2003, 2007 and 2009, and reservoir volumes continue to decline through fall and winter in many of the years.
- Annual diversions at the Headgates are variable, ranging from 11,348 ML in 1997, to 19,751 ML in 2002, with an average value of 15,212 ML for the period.
- Flow below the Headgates is calculated from the Headgates spill level plus the fisheries and downstream licence releases through the Headgates. The calculated annual flows below the Headgates using Headgates spill vary from 0.189 m^3/sec in 2009 to 2.533 m^3/sec in 1997, with an average value of 0.872 m^3/sec. Comparison of calculated spill to recent seasonal flow monitoring in Duteau Creek and WSC flow records at Lumby indicates that Headgates spill calculations overestimate flow, particularly as spill volume increases.
- The naturalized flow simulation documents how natural flow would have varied over the 1997 to 2013 period, but the flow magnitudes are overestimated in proportion to the overestimation of headgates spill. Also, negative values are calculated for some months. Negative values in August and September indicate that evaporation from the reservoir lakes can exceed natural flows during dry hot periods, but negative values in winter indicate losses which are not being accounted for due to imprecise data and/or unexpected and unaccounted for losses such as seepage to groundwater.

Duteau Creek Operational Issues & Environmental Flows

- Duteau Creek supplies approximately 60% of the water used each year by Greater Vernon Services - Water. The existing Greater Vernon Services - Water Duteau Creek consumptive water use licencing (34,582 ML) and storage licences (33,051 ML) are close to the calculated mean annual discharge (including the McAuley Creek diversion) of 1.153 m^3/sec or 36,272 ML based on historical WSC Duteau Creek flow and reported diversion. The actual reservoir capacity and reported diversion are about 55% (19,969 ML) and 42% (15,212 ML) respectively of the naturalized mean annual discharge. The actual use is already a very high percentage of the average flow, and relatively close to the total flow in very dry years. Duteau Creek flows are highly regulated, particularly in dry years, and construction of additional reservoir capacity and/or increased diversion as is being considered in the Master Water Plan (AECOM, 2013b) within the existing licences could eliminate all natural flow in Duteau Creek.
- The mean annual runoff from the Duteau Creek sub-basin area that has been calculated for the Greater Vernon Water Master Plan exceeds the naturalized flow calculated from historical WSC flow and reported diversion by about 40%. As such, the Master Water Plan runoff estimates create an unrealistic expectation of water supply capability from Duteau Creek and lead to unattainable water supply recommendations.
- The historical WSC flow data indicates limited freshet flows below the water diversion Headgates, with median flows only reaching 200%LTmad, and lower quartile flows that only reach 100%LTmad. Uncontrolled runoff from the lower Duteau Creek area, which is about 40% of the total area above the Headgates, is

diverted for consumption and Goose Lake refill, but the typical monthly diversions attributed to April and May are relatively low when compared to the runoff that is estimated from that area. This suggests substantial overestimation of runoff from the lower Duteau area in the Master Water Plan.

- Seasonal MFLRNO flow monitoring shows two periods where Duteau Creek is particularly prone to detrimental extreme low flows due to reservoir / Headgates operations. The first often occurs in mid May as the lower watershed freshet diminishes, while diversions are increasing due to higher demand and flow from the upper watershed is still filling the reservoirs. Additional releases from the still filling reservoirs are required to bridge this low flow period prior to the reservoirs spilling to maintain Duteau Creek flows below the Headgates for adfluvial rainbow trout spawning. The second period occurs as the reservoir spill is ending in early July and higher reservoir releases are needed a few days earlier to prevent the extreme low flows during the transition from runoff to storage releases.
- Seasonal MFLRNO flow monitoring also shows that Duteau Creek flows below the Headgates are highly variable in summer, due in part to lack of balancing capability between the reservoirs and the Headgates. This results in a relatively high average summer flow (Duteau Creek can account for more than 50% of the flow in Bessette Creek at Lumby during late summer and early fall low flows), but the highly variable nature of the flows likely negates some of the fisheries benefits that would be expected from that volume of average flow.
- Reservoir refill is variable from year to year, but median reservoir inflows are high relative to reservoir volume. Low refill years like 2003, 2007 and 2009 are predictable based on snow course data and reservoir levels, which should allow for additional releases while reservoirs are filling in most years without undue risk to the water supply.
- The current minimum flow policy for fish flows and downstream priority licences has very low minimum flow requirements that are at or below natural long term low flows in most months. Consideration should be given to increasing the minimum fish flows for all but drought years, and DFO conservation storage in Grizzly Swamp should be routinely released to increase fish flows during critical periods.
- The McAuley Creek (Gold-Paradise) Diversion licence is an irrigation licence authorizing April 1 to September 30 withdrawals. Since the diverted water passes through the Aberdeen reservoir, changing the timing to October 1 to June 15, consistent with storage licences is recommended for both operational and Bessette Creek summer low flow considerations.

Recommendations

- This report presents instream flow recommendations for the Bessette Creek watershed based on stream specific weighted usable width calculations in relation to focal species and life stages and in consideration of naturalized flows and authorized water uses. Historic WSC records and recent seasonal flow monitoring demonstrate that flows are routinely below the instream flow recommendations for a variety of reasons. A number of recommendations are presented to highlight actions to improve instream flows relative to the recommendations. The recommendations include: formalizing the instream flow recommendations as flow targets; adopting the Nicklen Lake storage releases and monitoring strategy; maintaining / expanding the Duteau Creek flow and diversion monitoring; reducing water demand from Duteau Creek by filling Goose Lake from another source; re-evaluating the Duteau Creek water supply plans with revised runoff calculations and undertaking a formal water use plan for Duteau Creek if reservoir capacity and/or Duteau Creek water supply is to be increased; modify Duteau Creek reservoir operations to better meet instream flows; a formal DFO conservation release strategy; changing the timing of the McAuley Ck diversion licence: and pursuing designation of Bessette Creek as a Sensitive Stream under the Fish Protection Act to facilitate additional water use regulation as required to meet minimum instream flows.

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DEFINITIONS

Environmental Flow Needs. Environmental flow needs describes the quantity and timing of water flows required to sustain freshwater ecosystems.

Inflection Point. Inflection point is used to characterize the point on the polynomial trend line where the slope of the curve appears to change from almost linear increase in usable width with increasing flow, to a much more gradual increase in usable width with flow to the maximum value.

Long Term Mean Annual Discharge (LTmad). The arithmetic mean of all of the individual naturalized mean annual discharge values at a specific point on a stream or river over a multi-year period of record.

Long Term Mean Annual Flow (LTmaf). The arithmetic mean of all of the individual mean annual flow values at a specific point on a stream or river over a multi-year period of record.

Long Term Mean Monthly Flow (LTmmf). The arithmetic mean of all of the individual mean monthly flow values for a specific month at a specific point on a stream or river over a multi-year period of record.

Lower Quartile (P25). The value represented by the 25th percentile in a range of data. 25% of the values will be lower, and 75% will be higher.

Low (50%) Weighted Usable Width Flow. The flow, expressed as %LTmad, that corresponds to the point on the weighted usable habitat width curve that indicates 50% of the maximum weighted usable width. The selection of 50% is arbitrary, but in most cases weighted usable width is very rapidly diminishing towards zero with even small decreases in flow. This applies well to rearing flows in riffles, and spawning flows in larger streams and smaller bodied fish, but less so when applied to Coho and Chinook spawning in smaller streams like Creighton and Duteau.

Max. The highest value in a range of data.

Maximum Weighted Usable Width Flow. The flow, expressed as %LTmad, that corresponds to the highest point (i.e. the maximum amount of weighted usable habitat width for that transect) on the weighted usable habitat width curve.

Mean. The arithmetic mean of all values in a range of data. Establishes the average volume when used with flow data.

Median (P50). The value represented by the 50th percentile in a range of data. Establishes the average flow condition when used with flow data, as 50% of the values will be lower, and 50% will be higher.

Mean Annual Discharge (MAD). The naturalized mean annual flow. Calculated by adjusting the mean annual flow to compensate for flow regulation and water withdrawals. The mean annual discharge is the equivalent to the mean annual flow rate that would occur naturally in the absence of storage reservoirs and water extractions.

Mean Annual Flow (MAF). The arithmetic mean of all of the individual daily mean actual or residual flows for a given water year at a specific site on a stream or river. The mean annual flow is equivalent to the constant flow rate that would yield the same volume of water in that year as the sum of all continuously measured flows.

Mean Monthly Flow (MMF). The arithmetic mean of all of the individual daily mean actual or residual flows for a given water month at a specific site on a stream or river. The mean monthly flow is equivalent to the constant flow rate that would yield the same volume of water in that month in that year as the sum of all continuously measured flows.

Medium (80%) Weighted Usable Width Flow. The flow, expressed as %LTmad, at which the weighted usable width value is 80% of maximum weighted usable width for that transect. This intermediate flow often corresponds to the inflection point on the weighted usable habitat width curve, where the weighted usable width curve changes from quickly diminishing usable widths at lower flows to smaller increases in weighted usable width with increasing flows.

Min. The lowest value in a range of data.

Naturalized Flow. This is the flow that would occur naturally in the absence of all forms of flow regulation such as storage reservoirs and water withdrawals.

Reference Flows. Used to express flow values on a standardized basis (%LTmad) for comparison of flows for different species and life stages of fish at various locations in the watershed. In this project, reference flows correspond to Maximum, Eightieth Percentage and Low levels of weighted usable width based on interpretation of the results curves for calculated usable fish habitat width plotted against flow at varying flow levels. Maximum corresponds to the flow with the most usable width. Eightieth percentage is the flow where the weighted usable width is 80% of the maximum, and generally corresponds to the inflection point between rapidly diminishing usable widths below and gradually increasing usable widths above. Low is a more arbitrary point on the curve where weighted usable width is 50% of the maximum usable width and is usually rapidly diminishing with further decreases in flow.

Residual Flows. The actual volume of water flowing at a specific point on a stream or river at a point in time that can be recorded by stream flow measurements. The term residual flow is used to describe the flow that remains in the stream after flow reductions due to water extractions.

Upper Quartile (P75). The value represented by the 75th percentile in a range of data. 75% of the values will be lower, and 25% will be higher.

ENVIRONMENTAL FLOWS and HYDROLOGIC ASSESSMENT for the BESSETTE CREEK WATERSHED 2011 - 2013

P. Epp

March, 2014

1. INTRODUCTION AND BACKGOUND

This report presents the results of the 2011, 2012 and 2013 weighted usable width for fish habitat evaluations relative to historic and recent flows in the Bessette Creek watershed, including work on Bessette, Duteau and Creighton Creeks. The report also includes an Operating Strategy for the conservation storage in Nicklen Lake reservoir and recommendations for conservation storage releases from the Grizzly Lake and other operational considerations relating to regulated flows in Duteau Creek. The project is led by the Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), with funding provided through the Habitat Conservation Trust Foundation, and with additional in-kind support through the Department of Fisheries and Oceans (DFO). Administration for the project was provided through the BC Conservation Foundation.

Bessette Creek is one of the largest tributaries of the Shuswap River, emptying into the Shuswap River about 13 km northeast of the village of Lumby and 15 km above the south end of Mabel Lake. Its watershed covers 795 km^2, or about 15% of the entire Shuswap Watershed above Mara Lake (Figure 1). Three main tributaries: from west to east, Duteau, Harris, and Creighton Creeks, combine near Lumby to form Bessette Creek. Creighton Creek is the smallest at about 110 km^2, while Harris (together with Nicklen) is the largest at about 250 km^2. Altitudes in the watershed range from 412 m at the mouth of Bessette Creek to 2004 m at the summit of the Buck Hills in the Harris Creek headwaters.

Broad descriptions of the biophysical characteristics are based on the Ecoregion Classification System (Demarchi, 2011). The Bessette Creek watershed lies in a transitional area from the North Okanagan Highland Ecoregion which is part of the Southern Interior Ecoprovince to the Columbia Highlands Ecoregion which is part of the Southern Interior Mountains Ecoprovince.

The valley bottoms and lower elevations along Bessette Creek and it's tributaries are in the **Northern Okanagan Basin Ecosection**. This ecosection is characterized by a wide trench and foothills located between the Thompson Plateau to the west and the Northern Okanagan Highlands to the east. This ecosection is in a rainshadow of the Thompson Plateau and the Coast Mountains to the west. 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. Winters are typically cool, and cold dense Arctic air seldom invades here from the north.

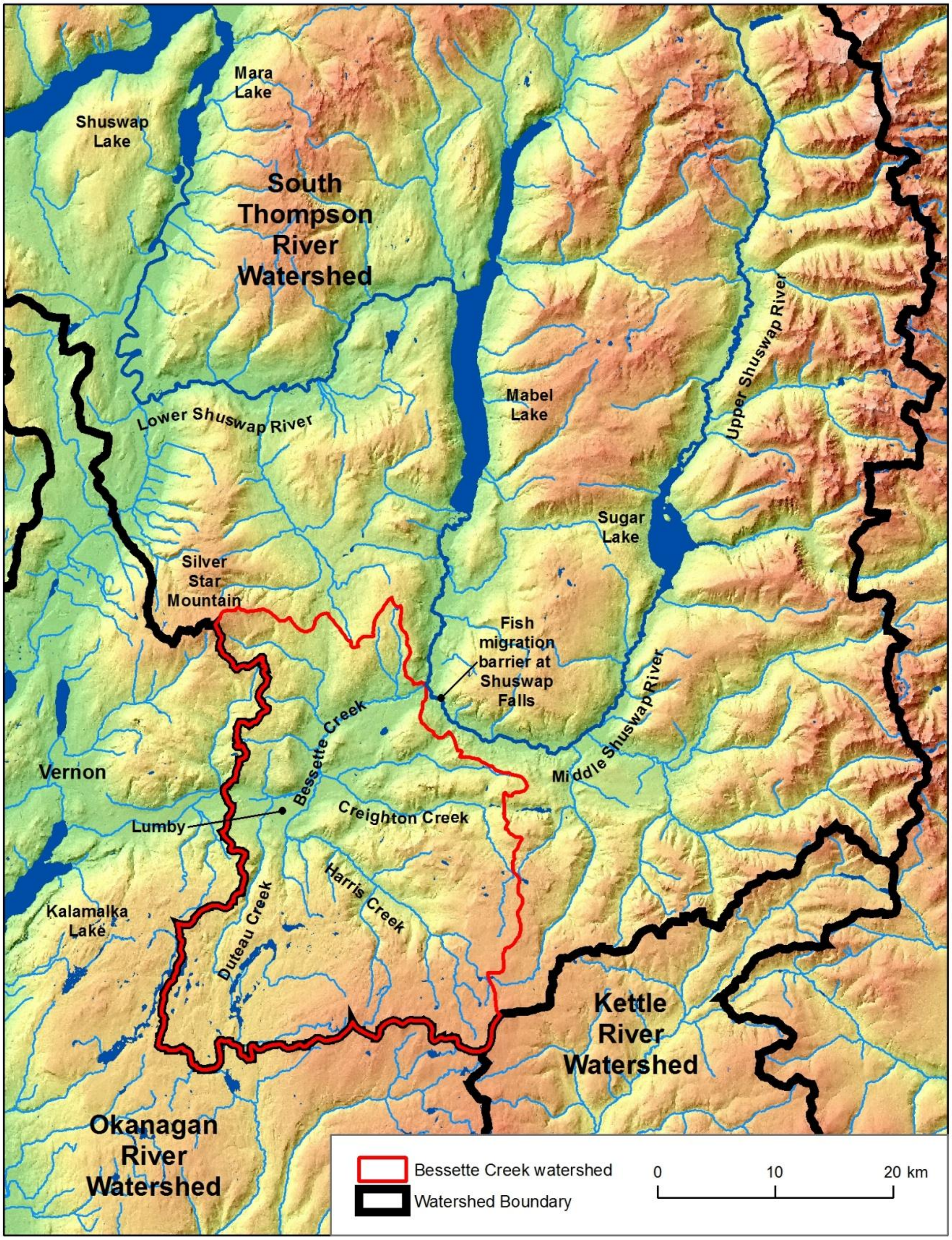


Figure 1. Overview map of the Bessette Creek watershed within the Shuswap and South Thompson River watersheds.

The higher elevations to the south of Bessette Creek are in the **Northern Okanagan Highland Ecosection**. This is a cool, moist, rolling upland ecosection that is transitional in height from the lower plateaus to the west and the higher mountains to the east. Differential weathering has produced gentle step-like slopes. Glacial ice covered the greatly rounded summits and upland and deposited a mantle of drift. Vegetation zones reflect the higher relief than areas to the west and the moister climate caused by Pacific air rising over the Columbia Mountains to the east. The Douglas-fir zone occurs in the lower slopes of the main valleys. The Montane Spruce zone, with Lodgepole pine dominated forests, occurs in the western and southern uplands; Engelmann Spruce - Subalpine Fir Zone occurs on the highest upland areas; and the moist Interior Cedar - Hemlock Zone occurs on valley slopes in the eastern portion of the ecosection.

The higher elevations to the north of Bessette Creek are in the **Shuswap Basin Ecosection**. This ecosection is characterized by rolling plateau uplands, steep sided plateau walls, and large inter-plateau lowlands. It has a dry montane climate, except in areas where topographic shading provides an environment for the Interior Cedar Hemlock forests. Lodgepole pine forests occur over most of the uplands and higher areas have the colder, moister Engelmann Spruce - Subalpine Fir forests.

The Bessette Creek watershed supports a number of important fish stocks, including Chinook and Coho salmon, Kokanee and both adfluvial and resident rainbow trout.

In 1995, Bessette Creek, along with the Duteau and Harris Creek tributaries, was included on a list of the "most sensitive salmon streams" in the South Thompson - Shuswap Habitat Management Area, due to high water demand, in a Department of Fisheries & Oceans - Fraser River Action Plan report (Rood and Hamilton, 1995).

Bessette Creek was proposed as "Candidate Sensitive Stream" under the Fish Protection Act in 2001 (Ministry of Environment, 2001). Reasons for considering Bessette Creek for Sensitive Stream designation included: important populations of Coho and Chinook salmon and rainbow trout which were far below potential production, and in the case of Coho, had declined sharply since the 1980s; the available water supply was inadequate in most years to support both sustainable fish populations and existing off-stream uses during low-flow periods, especially in Duteau Creek which has very heavy irrigation demand; and, a recovery plan could focus on negotiating with Vernon Irrigation District (now Greater Vernon Services - Water) for larger water releases, restoring riparian vegetation, promoting more efficient water use, and (if feasible) developing additional water storage in the Creighton Creek and Harris Creek watersheds.

In 2003, Bessette Creek was rated as having Very High Species Sensitivity, Very High Innate Capacity to Produce Fish and Very High Significance as a Habitat Protection Focus Area in the report titled "Selection of Focal Watersheds for the Protection and Restoration of Fish Stocks and Fish Habitat in the Okanagan Region" by Matthews and Bull, 2003.

Bessette Creek was again considered for action under the Fish Protection Act in 2009 due to extremely low flows, was highest on the Regional Stream Watch List for low flows in Shuswap tributaries in 2010, and is still considered to be the highest priority stream for fish flow restoration in the Shuswap River watershed (White, 2011).

Bessette Creek Coho are part of the Thompson Coho Conservation Unit which are listed as endangered under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The Chinook stocks (particularly the 4 sub 2's) are also considered a stock of concern. Declines for both salmon species have a negative effect on multiple stakeholder fishing opportunities (commercial and recreation) including First Nations for food and ceremonial purposes (Watts, 2012). Bessette Creek and it's tributaries are also very important for Shuswap Lake rainbow trout spawning (Askey, 2013).

2011 to 2013 Project Objectives

The project was initiated in 2011 and expanded / modified in 2012 and 2013 with the following objectives:

1. Measure depths and velocities over a range of flows at riffle and glide transects at various points in Bessette, Creighton and Duteau Creeks to calculate and demonstrate weighted usable width vs. flow relationships in the Bessette Creek watershed.

2. Use the weighted usable width vs. flow relationships to specify a range of reference flows that span the range from low to maximum weighted usable width flow conditions for the focal fish species (Coho, Chinook, Kokanee and rainbow trout) and life stages (spawning and rearing) in the Bessette Creek watershed.

3. Compare existing (residual after water extraction) flows to the reference flows for the focal species and life stages to quantify the frequency and timing of low flows in relation to the reference flows.

4. Compare water use flow reductions to the residual flows and reference flows to naturalize the stream flows and to document the water use implications in relation to the stream's abilities to meet reference flows for the focal species and life stages.

5. Develop an operating strategy for the conservation storage volume available in Nicklen Lake to specify volume and timing of storage releases to supplement downstream flows for the focal species and life stages in Bessette Creek.

6. Evaluate the conservation storage in Grizzly Swamp, and the instream flow release strategies through Aberdeen Lake for the focal species and life stages in Duteau and Bessette Creeks.

7. Evaluate the available reservoir storage refill / drawdown and water diversion data for the Duteau Creek sub-basin to calculate detailed naturalized flows for Duteau Creek for comparison to regulated flows in order to make recommendations for alternative water management options to reduce flow related impacts on the focal species and life stages in Duteau and Bessette Creeks.

8. Provide a set of recommended actions, that if implemented, will improve aquatic habitat conditions for fish and other aquatic biota and balance water use for instream and offstream values.

2. METHODS / MEASUREMENTS

This study uses existing, mostly Water Survey of Canada (WSC, 2012), hydrometric data, supplemented with recent seasonal flow monitoring (done to BC RIC standards) within the Bessette Creek watershed and water licence information available from the Water Licences Query website (Province of BC, 2012) in conjunction with stream transect measurements and weighted usable width calculations specific to this study. Additionally, Duteau Ck. water supply operations information (reservoir levels, Headgates spill levels and Headgates diversion volumes) was obtained from the Regional District of North Okanagan (RDNO) for evaluations specific to that portion of the watershed. These three sources of data (WSC, MFLNRO and RDNO) provide information from the upper, middle and lower watershed (Figure 2).

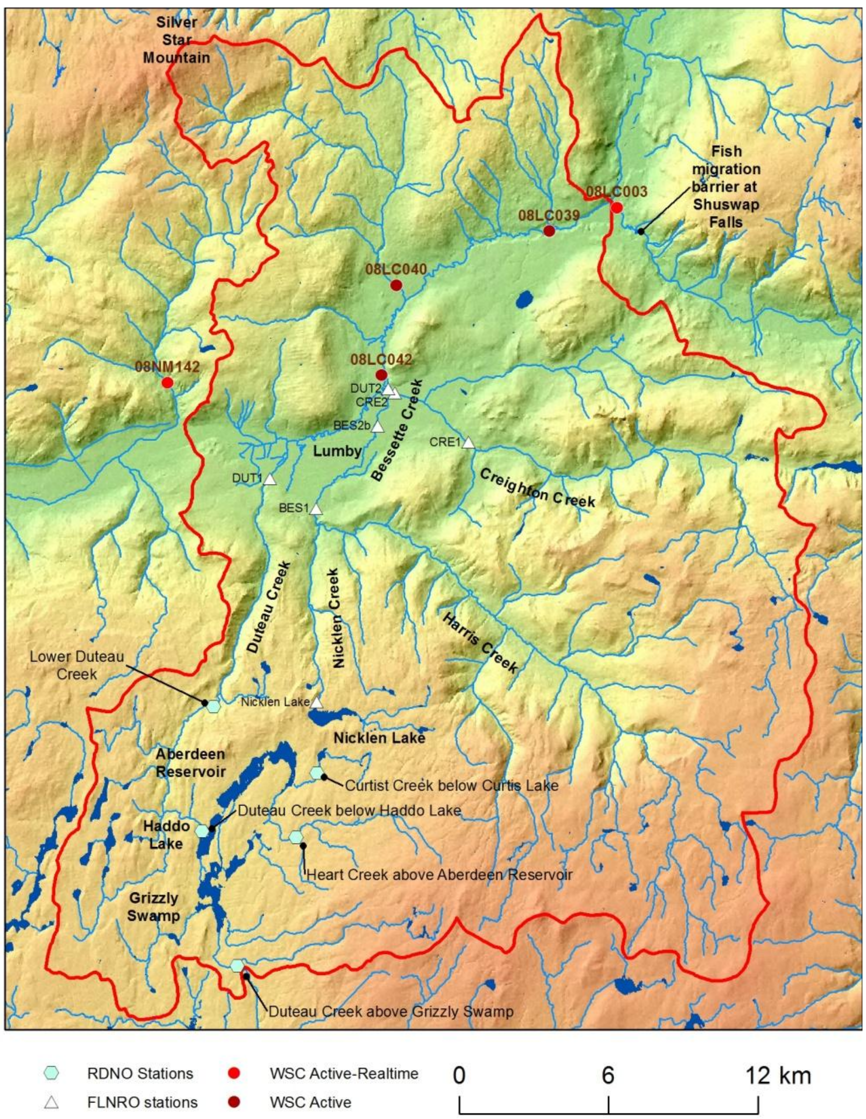


Figure 2. Bessette Creek watershed with WSC, MFLNRO and RDNO stations.

Hydrometric Data & Flows

Hydrometric data documents the volume of water that has been measured at various points in the watershed. The data is summarized on a daily, monthly and annual basis and periods of measurement for existing data sets range in length from recent seasonal (July to October) measurements for only 2 years, to year round records for a number of decades. All of the active stations are listed below in **Error! Reference source not found.** and shown on Figure 2, and the inactive stations are listed in Table 3. Note that in order to understand the effects of the multiple water withdrawals for irrigation purposes, the MFLNRO stations were paired for each of Duteau, Bessette and Creighton Creeks to include one station immediately upstream of the lands intensively developed for agriculture and one station at a downstream location.

Table 1. Bessette Creek Watershed Active Hydrometric Stations

Station	**Station ID**	**Length/Duration of Record**
Bessette Creek above Beaverjack Creek	08LC039	1970-1972, 1975-2013
Bessette Creek above Lumby Lagoon Outfall	08LC042	1973-2013
Vance Creek below Deafies Creek	08LC040	1970-2013
Duteau Creek above Grizzly Swamp	RDNO	2008-2013
Curtis Creek below Curtis Lake	RDNO	2008-2013
Heart Creek above Aberdeen Reservoir	RDNO	2008-2013
Lower Duteau Creek (above Headgates)	RDNO	2011 - 2013
Bessette Creek above Horner Road	MFLNRO	2011-2013
Bessette Creek at Lumby	MFLNRO	2011
Bessette Creek above Lumby	MFLNRO	2012-2013
Duteau Creek at Whitevale Road	MFLNRO	2010-2013
Duteau Creek at Lumby	MFLNRO	2011-2013
Creighton Creek at Salvas	MFLNRO	2011-2013
Creighton Creek near Bessette	MFLNRO	2012-2013

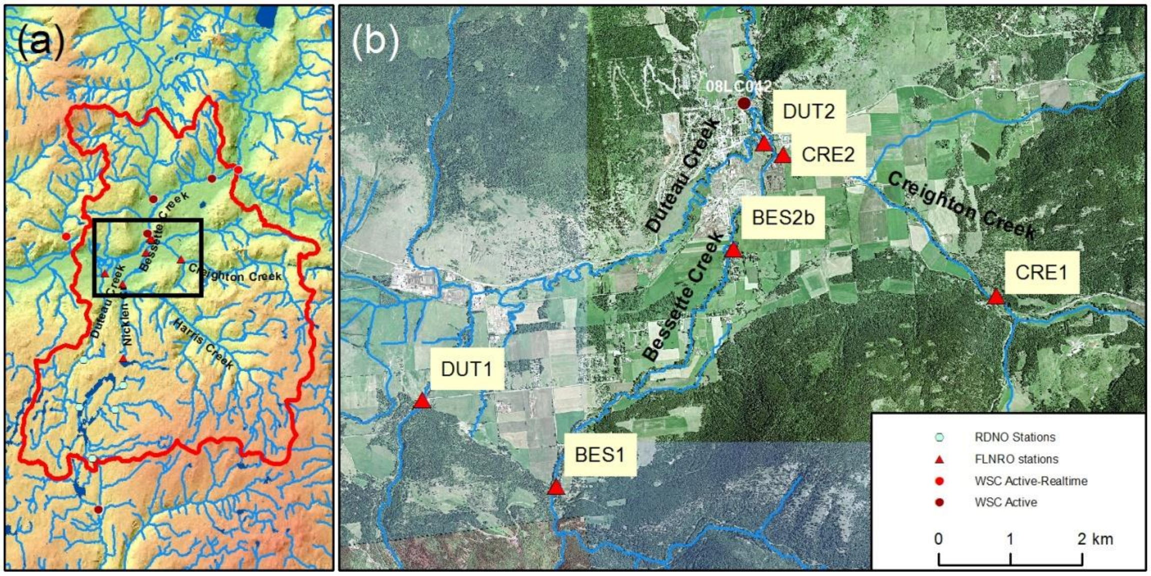


Figure 3. (a) Overview map of Bessette Creek watershed with hydro stations and extent rectangle for FLNRO stations, and (b) orthophoto of Lumby and agricultural lands with paired FLNRO stations and transects.

Table 2. Bessette Creek Watershed Inactive Hydrometric Stations

Station	**Station ID**	**Length/Duration of Record**
Duteau Creek near Lavington	08LC006	1919-1921, 1935-1996
Bessette Creek near Lumby	08LC005	1919, 1943-1948, 1965-1983
VID Diversion near Lavington	08LC007	1919-1921, 1935-1951, 1964-1966
Duteau Creek at Outlet of Haddo Lake	08LC014	1921, 1973-1979
Creighton Creek near Lumby	08LC033	1959-1966
Nicklen Creek near Lumby (Upper Station)	08LC010	1921
Nicklen Creek near Lumby (Lower Station)	08LC008	1920
McAuley Creek near Lumby	08LC009	1920
Creighton Creek near Creighton Valley	08LC046	1977

The WSC hydrometric data (including partial preliminary data for 2011, 2012 and 2013) has been downloaded and summarized in Excel workbooks which are used to generate statistical flows (e.g. minimum, decile, quartile, median, mean, and maximum) when the flow records are long enough, and in conjunction with estimated water use, long term mean annual discharge (LTmad) for various points in the watershed. The statistical flow data and data for specific years of interest are also used to produce charts for comparing flow data to reference flows for fish and fish habitat and serve as a basis for evaluating low flows and water use management / conservation flow release options vs. fish flow management objectives.

Water Licences / Type of Use

The Province of BC (2012) provides a web-based BC Water Licenses Query tool that can be used to search for water licenses using a variety of search criteria such as stream name, license number, purpose, quantity, water district/precinct, and watershed. License details such as restrictions on use (e.g., timing of use for irrigation licenses) and special clauses are also viewable on the scanned licenses directory that is accessible through the water licenses query tool. A water license search for the Vernon-Lumby precinct (which includes all of the Shuswap watershed upstream of Mabel Lake) identified a total of 439 licenses. These licenses were downloaded into an Excel workbook where the licenses were sorted by purpose within the precinct. More than 60% of the licences, such as those for domestic use and stock watering, are for very small volumes which make up less than 2% of the total water allocation in the precinct. The small volume licences were ignored, and correlation of water licences to stream segments in the Bessette watershed was restricted to the large consumptive licences (irrigation, irrigation local authority and waterworks local authority) and the associated storage licences and the conservation storage licences.

Water usage is licensed in three different types of units depending on the purpose: m^3/sec, m^3/day, and m^3/year. For comparison purposes, the volumes for each use have been converted to standard units of m^3/sec in this study. Irrigation type licenses (Irrigation and Irrigation Local Authority) are for seasonal (April to September) use, while all others are for year round use, so the conversion to m^3/sec is shown on both a seasonal and an annual basis. The annual m^3/sec equivalent reflects the average annual consumption, which can be compared to the mean annual flow or mean annual discharge to compare allocation to surface flows on an annual basis. The seasonal m^3/sec equivalent reflects the volume of consumption that can be expected on a high irrigation demand day in summer, which can be compared directly to the associated July and August mean monthly flows. The lowest flows of the summer typically occur in August when natural flows are very low and water use is high. Flows are also often still low in September, but water use diminishes in September and would be less than the seasonal m^3/sec equivalent, so that value can't be compared directly to September flows.

Groundwater Well Use

Groundwater use (wells) are not licenced in B.C., so there is no readily available summation of overall groundwater use, other than the volume reported by the Village of Lumby (Golder, 2012). Lumby now uses wells in place of their surface water licence on Duteau Creek. Review of the wells location layer on iMapBC (BC Min of Forests, Lands and Natural Resource Operations 2012) shows several hundred well locations within the Bessette Creek drainage. Many of the wells are low yield and are likely used for domestic purposes, but a number of the wells are shown with yields ranging from of more than 100 gal / min to 1200 gal / min (equivalent to flows ranging from 0.006 to 0.073

m^3/sec if pumped at full yield). Water use volumes from wells is mostly unknown, but this is a potentially high and non quantified consumptive water use.

There is one groundwater observation well, monitored as part of the BC Ministry of Environment's Observation Well Network in the Bessette Creek watershed. Observation Well #294 is located approximately 4 km southwest of Lumby along Whitevale Road approximately 600 m from Bessette Creek. About 10 depth to water table measurements per year were recorded manually between December 1986 and December 2003. The well depth recording was automated in December 2003, with hourly depth to water table information currently available to December 31, 2012 online at: http://www.env.gov.bc.ca/wsd/data_searches/obswell/map/obsWells.html.

Duteau Ck. Water Supply Operations Information

Flow in Duteau Creek at the Headgates (the water supply control structure) is diverted into the Greater Vernon Water Supply system for domestic and irrigation needs, "fisheries flow releases" (minimum flows agreed to with DFO) are delivered to the downstream channel via a low level outlet from the Headgates intake works, and any excess water (whenever flow exceeds diversion and low level outlet settings) spills over a the Headgates weir. The WSC hydrometric station located down stream of the water diversion Headgates on Duteau Creek (Duteau Creek near Lavington - 08LC006) was discontinued in 1996, with no comparable flow monitoring in Duteau Ck. below the Headgates diversion until the seasonal flow measurements were started by MFLNRO in 2011. The fisheries flows in conjunction with the Headgates spill data can however be used to estimate flow as a surrogate for hydrometric data.

Records for the depth of the Headgates spill were obtained from RDNO covering the period from 1997 to 2013. The data set contains manually recorded level records for the entire period, plus SCADA data starting in 2006. The manual data consists of one or two records per day, but with a number of missing dates. For the manual readings, values were averaged for days with two readings, and values for missing dates were interpolated. The SCADA data sets have four levels recorded at set times each day, and these were also average to daily values. The original SCADA system was replaced with a new SCADA system late in 2011. The SCADA generally represents a much better data set as the four measurements per day provide better representation of the daily fluctuation and there are no missing days requiring interpolation. However, the original SCADA was replaced due to concerns with reliability, and review of the data indicates that in fact the original SCADA ceased to operate correctly on July 18, 2010, requiring a default to the manual data from then until the new SCADA began on December 24, 2011. The daily Headgates spill were converted to daily flow values using the weir rating curve supplied with the data. Daily flows below the Headgates are then calculated by adding the daily headgates spill data to the daily fisheries flows which are assumed to always be met. Precision of the data and the sources of error are discussed in more detail when the data results are presented in Section 7.

Available daily Headgates water supply diversion data and reservoir levels for the three Duteau reservoirs (Aberdeen Lake, Haddo Lake and Grizzly Swamp) plus Goose Lake (which is filled from Duteau Creek) were also obtained from RDNO for the period of 1997 to 2013. The reservoir level data is based on periodic manual readings of the reservoir levels, with daily values between calculated with linear interpolation. The daily diversion data and the changes in daily reservoir volumes are used in conjunction with the calculated daily flow data to calculate naturalized flows (flows that would occur naturally if there were no storage reservoirs or water supply diversions) in Duteau Creek.

Fish Periodicity

An initial step when evaluating stream flows relative to fish requirements, is to compile biological information including species and life stages present, timing of key biological activities such as spawning, incubation, migration, active rearing, overwintering, and specific ecological needs, such as geomorphological considerations, into a species periodicity chart. The periodicity chart is used to determine the focal species and when flows for specific species and life stages are required. Table 3 is a periodicity chart provided by Dean Watts (Senior Habitat Biologist, Fisheries and Oceans Canada, Kamloops, B.C., pers. comm.) with input from Provincial Biologists relative to Kokanee and rainbow trout.

The focal species for this project are: Chinook and Coho salmon, rainbow trout and Kokanee, and the life stages of interest are adult migration and spawning and juvenile rearing. Reference to the periodicity information in Table 3 indicates the seasonal periods during which migration, spawning and rearing are expected to occur on an annual basis.

Adfluvial (large trout from Mabel Lake) rainbow trout start their spawning migration in April, with spawning into mid June, and rearing throughout the summer and fall. Resident rainbow trout are also present, with spawning and rearing during the same period. Both juvenile and resident rainbow overwinter in the streams.

Chinook salmon can start adult migration into streams as early as July, with spawning from late August through October, depending on flows and stream temperatures and Chinook rearing occurs from spring through fall, with juveniles overwintering as well.

Coho salmon begin their adult migration in October, with spawning extending into the winter, and juvenile rearing from spring through fall, with juveniles overwintering as well.

Kokanee adult migration begins in early September, with spawning until mid October. Kokanee fry migrate downstream to Mabel Lake after hatching in spring and so do not have summer rearing requirements in the Bessette watershed.

Table 3. Fish Periodicity Chart for Bessette/Duteau Creek near Lumby, British Columbia.

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Ecological Function												
Flushing				xx**xx**	**xxx**x	x						
Icing	**xxxx**	**xx**xx	x									xx**xx**
Wetland/trib/sidechannel linkage				xxxx	xxxx	x						
Channel Maintenance (approx. 400% MAD)				**x**	**xx**							
Species												
Chinook Salmon - Bessette												
Smolt Emmigration (**xxxx**) and Fry movement			xxx	xxxx	xxxx	xxxx	**xxxx**	**xxxx**	xxxx	xxxx		
Adult Migration							xxxx	xxxx	xx			
Spawning									**xx**	**xxxx**		
Incubation	xxxx	xxxx	xxxx	xxxx							xxxx	xxxx
Rearing												
Over-wintering	xxxx	xxxx	xxx								xxxx	xxxx
Chinook Salmon - Duteau												
Smolt Emmigration (**xxxx**) and Fry movement	xxxx	xxxx	xxx	**xxxx**	**xxxx**	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
Adult Migration							xxxx	xxxx	xx			
Spawning								x	**xxxx**	xx		
Incubation	xxxx	xxxx	xxxx	xxxx					xxxx	xxxx	xxxx	xxxx
Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
Over-wintering	xxxx	xxxx	xx								xxxx	xxxx

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Coho Salmon - Bessette												
Adult Migration									xxx	xx**xx**	**xxx**x	xxxx
Spawning	xx									xx	**xxxx**	**x**xxx
Incubation	xxxx	xxxx	xxxx	xxxx							xxxx	xxxx
Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
Smolt migration				xx	**xxxx**	**x**xxx	xxxx					
Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Coho Salmon - Duteau												
Adult Migration									xxx	xx**xx**	**xxx**x	xxxx
Spawning	xx									xx	**xxxx**	**x**xxx
Incubation	xxxx	xxxx	xxxx	xxxx						xx	xxxx	xxxx
Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
Smolt migration				xx	**xxxx**	**x**xxx	xxxx					
Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Rainbow Trout - Duteau/Creighton												
Adult passage into mainstem and tributaries				xxx**x**	**xxxx**	x						
Spawning				xx	**xxxx**	xx						
Incubation				x	xxxx	**xxxx**	**xxxx**					
Rearing			xx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
Over-wintering	xxxx	xxxx	xx								xxxx	xxxx
Kokanee - Bessette												
Adult passage into mainstem and tributaries									xxx	xx		
Spawning									xx	**x**x		
Incubation	xxxx	xxxx	xxxx	xxxx							xxxx	xxxx

Weighted Usable Width for Fish & Fish Habitat

Weighted Usable Width evaluation, which is a Physical Habitat Simulation (PHABSIM) technique, was applied at eight sets of transect locations in the Bessette Creek watershed (Figure 3). PHABSIM simulates changes of wetted width, depth, and velocity as a function of discharge with habitat suitability by life-stage and species to calculate the weighted quantity of habitat (usable width). This analysis can be used to provide habitat vs. flow relationships in streams of different sizes and geographical locations for several salmonid species (or all salmonids as a group) at each of four life stages.

Pairs of transects were established at six locations in 2011 for use in weighted usable width evaluations. Numerous years of snorkel observations in BC and other watersheds indicate that rainbow parr and adults tend to orientate in or near fast-water habitats that positions them in close proximity to drifting insects originating from riffles, rapids or cascades, while spawning occurs in deeper moving water such as found in glides and pool tailouts. Each transect set had a riffle transect for evaluating rearing usable widths for juvenile life stages and a glide transect for spawning usable widths. Each transect has 20 or more verticals evenly spaced across the wetted width, with depth and velocity recorded at each vertical. The initial measurements were done in July, with subsequent sets of measurements timed to conduct measurements at the full range of flows that occurred between July and October in 2011. The number of sets of measurements ranged from 8 at the Duteau Creek sites to 13 at one of the Bessette Creek sites.

For 2012, measurements were repeated at five of the 2011 sites, the Bessette Lumby site was moved upstream of the Creighton Creek confluence, and a second site was added on Creighton Creek near it's confluence with Bessette Creek. Also four sites included two riffle transects in 2012. The initial transect measurements were done in June for glides and July for riffles, and continued on into October to conduct measurements over as wide a range of flows as possible. The number of sets of measurements in 2012 ranged from 7 at the Duteau Creek riffle sites to 13 at the Creighton Creek glide sites.

The depth and velocity data from the flow transects was transferred to a series of Excel workbooks that calculate weighted usable width for rearing and spawning for all of the species of interest on each of the measurement dates. The usable width is weighted from the probability of use in each cell based on habitat suitability indices (HSI) look up tables, mostly provided by R. Ptolemy (MOE Fisheries Biologist Victoria BC pers. comm.), multiplied by the cell widths and then summed for a total weighted usable width for that transect at that flow. The original HSI curves sere developed for use in Water Use Plans by a team of BC specialists that included R. Ptolemy. Informal validation of these HSI curves is based on direct snorkel observations and electrofishing of fish in context to meso-habitat conditions over several years of reach-level surveys in other BC watersheds, but there has been no effort to further validate the HSI values in this study. An additional set of HSI values for Chinook salmon from Washington State (as reported in Triton, 2009) was also used to develop alternative weighted usable widths for Chinook spawning based on Chinook known to be spawning in smaller tributary streams rather than rivers in Washington State. It should be noted that the Bessette Creek Chinook are large bodied in spite of the relatively small stream size, so results based on both sets of

Chinook HSI curves are considered in this project. HSI tables for the values used in this project are recorded in Appendix A. The usable widths for each date were plotted against the associated flow values to generate a set of charts of how usable width varies with flow in each transect. The relationships are often complex, with a 3rd order polynomial trend line generally providing the best fit to the data.

Weighted usable width analyses were not conducted in 2013.

MFLNRO Seasonal Hydrometric Stations

A water level recorder with an accompanying staff gauge was also established at each glide transect location except for Bessette 3 which is near a WSC hydrometric station. The water level recorders automatically record water levels at fixed intervals (usually 1 hour). The width, depth and velocity data were measured for the glide transects, and this data was used to calculate the flow volume for each measurement set. The staff gauge level was also recorded each time, and the flow volumes in conjunction with the staff gauge levels are used to calculate a rating curve for each glide site. The rating curve is applied to each set of level recordings to generate the flows associated with recorded level, and then the levels were averaged to provide daily flows for each glide site.

The water level recorders were installed at the glide sites in all three years.

3. RESULTS & DISCUSSION: STREAM FLOWS, WATER USE & NATURALIZED FLOWS

3.1. Stream Flows

Annual Flows

Figure 4 illustrates the range in mean annual flows recorded from 1976 to 2010 by WSC at the Bessette Creek above Beaverjack Creek hydrometric station. The long term mean annual flow (LTmaf) is 3.47 m^3/sec and the range in mean annual flows is from a low of 1.51 m^3/sec in 1987, to a high of 8.43 m^3/sec in 1997. Similar mean annual flow patterns are seen at the other Bessette watershed hydrometric stations as flows vary from year to year in response to variations in annual runoff which is primarily determined by variations in annual precipitation. The mean annual flows appear to have diminished by about 13% over the past 35 years as demonstrated by the trend line on the mean annual flow data. Land and water use, as well as forest harvesting and forest health issues may be partially responsible for some of the trend, but increasing mean annual temperatures due to climate change are considered to be more likely responsible for the apparent trend based on a recent assessment in the Shuswap River watershed (Golder, 2012).

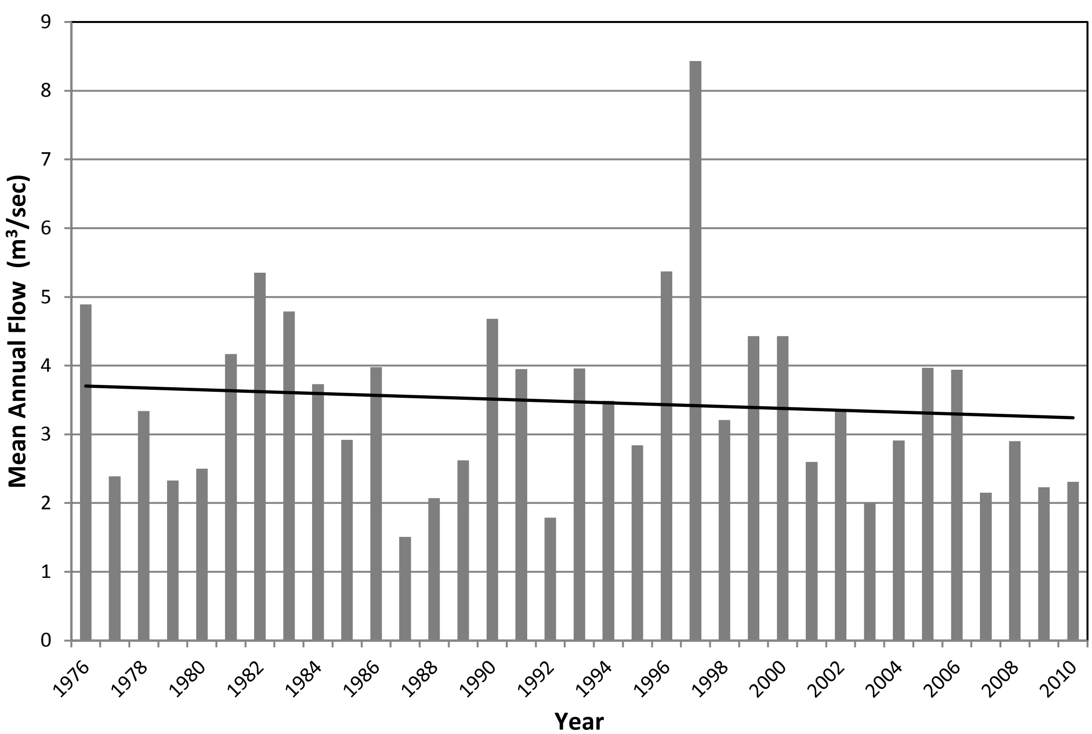


Figure 4. Mean Annual Flows (with trend line) at Bessette Ck above Beaverjack Ck (WSC 08LC039)

Monthly Flows

Figure 5 illustrates the range in mean monthly flows from 1970 to 2010 in Bessette Creek at the WSC hydrometric station above Beaverjack Creek. Snowmelt runoff begins to increase flows in late March to early April, with flows rising to the freshet peak in late May. Flows then decline steadily towards summer low flows in August (low natural flows coupled with high water use), and remain low through the winter, with fluctuations in flow due to fall storms and periods of warmer temperatures in winter that result in low elevation snow melt. Mean monthly flows in individual years can vary significantly from the long term mean and median monthly flows (represented by Mean and Median in **Figure 5**) as shown in the range between minimum and maximum mean monthly flows.

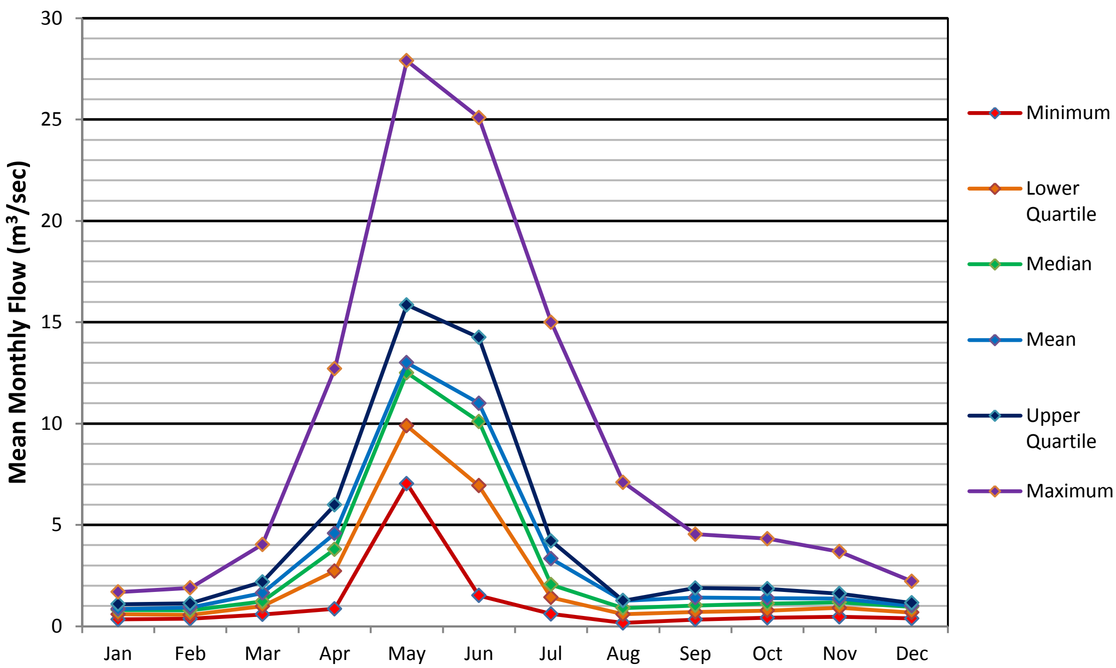


Figure 5. Range in Mean Monthly Flows at Bessette Ck above Beaverjack Ck (WSC 08LC039)

It is important to differentiate between Mean and Median flows when using average flow values. Mean is the arithmetic mean of all of the values in a range, while median represents the middle value in the range. Mean flows are useful for things like reservoir storages where there is carryover capability from one year to the next and average volumes are applicable. Median is more useful when portraying an average flow condition where half of the values will be lower and half will be higher. The Mean flow value is higher than the Median flow because high flows bias the mean more than low flows, and the significance of the difference is most pronounced at low flows. In the August flows in Figure 5 for example, the values for Mean and the 75th percentile flows are identical, indicating that the mean flow for August is equivalent of a 1 in 4 year high flow, while the lower Median value represents the average year flow.

Figure 6 illustrates the range and trend in mean monthly August flows from 1970 to 2010 in Bessette Creek at the WSC above Beaverjack Creek hydrometric station. The long term mean August flow is 1.26 m^3/sec (31%LTmad) while the median August flow is 0.90 m^3/sec (22%LTmad), but mean monthly August flows range from a low of 0.16 m^3/sec (4%LTmad) in 2003, to a high of 7.10 m^3/sec (172%LTmad) in 1976. The trend line suggests that mean monthly August flows have diminished by about 50% over the past 40 years. The trend line slope is influenced by the high August flow in 1976, but it is noteworthy that the last year with mean monthly August flows of over 0.90 m^3/sec (22%LTmad) was 2004, and 2001 and 2004 are the only two years from 2001 to 2010 to exceed the long term median monthly for August over the entire period. August flows are highly regulated as a result of water use within the Bessette Creek watershed as well as the volumes of water released from storage, and diversion of water out of the watershed, by Greater Vernon Services - Water. As such it is difficult to separate the water use and regulation from climate change and other factors as the reasons for the declining flows. Regardless of reasons why, it is apparent that August flows, which are important for juvenile Chinook and Coho salmon and rainbow trout rearing, as well as Chinook salmon migration and spawning have declined substantially in recent years.

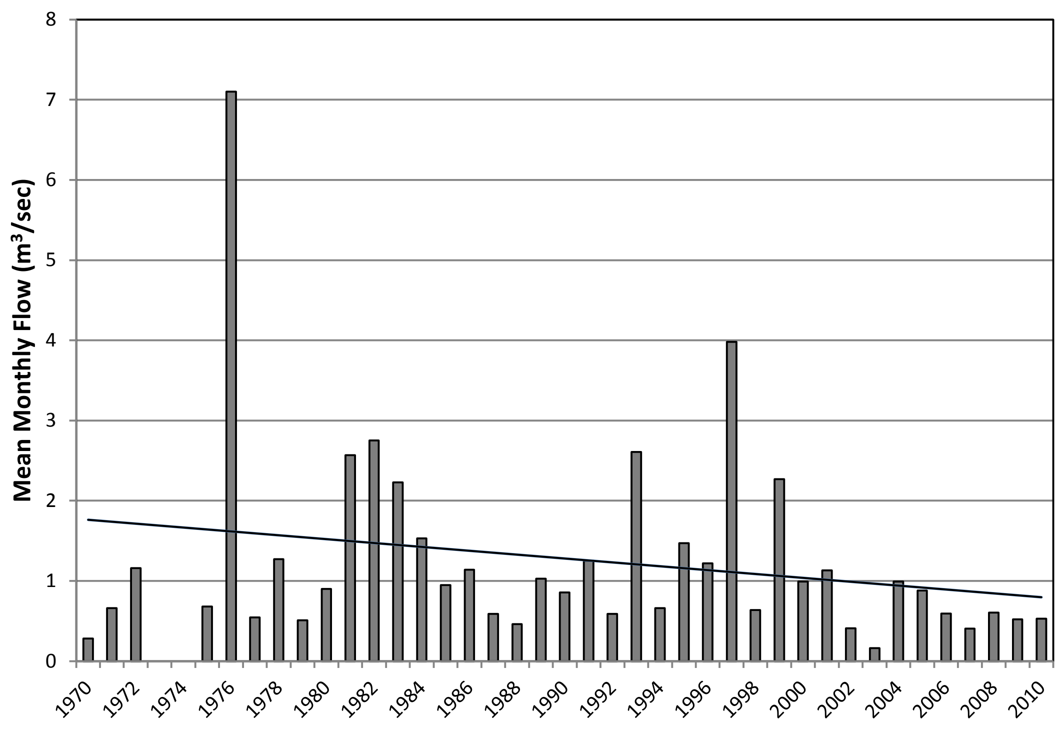


Figure 6. Range and Trend in Mean Monthly August Flows at Bessette Ck above Beaverjack Ck (WSC 08LC039)

September and October flows, which are critical for Coho and Chinook salmon and Kokanee spawning, also show declining trends in mean monthly flows over the same time period, although the declines are much less pronounced in October.

Daily Flows

Figure 7 illustrates the range of July to October daily flows from 1970 to 2010 in Bessette Creek at the WSC Bessette Creek above Beaverjack Creek hydrometric station. Flows from 2003, 2009 and 2012 (preliminary data) are also shown to illustrate the seasonal flows from several recent years. 2003 has extremely low summer flows, reaching a low of 0.12 m^3/sec (3%LTmad) in late August, and 2003 established the minimum flow levels on record from late July through early September. Concerns were raised again regarding low flow levels in 2009, particularly when flows were below the lower quartile during September. Preliminary flow data for 2012 shows very high flow in early July, followed by a return toward median flows in late July, a storm peak in early August, and then flows that diminish to lower quartile flows in September and October.

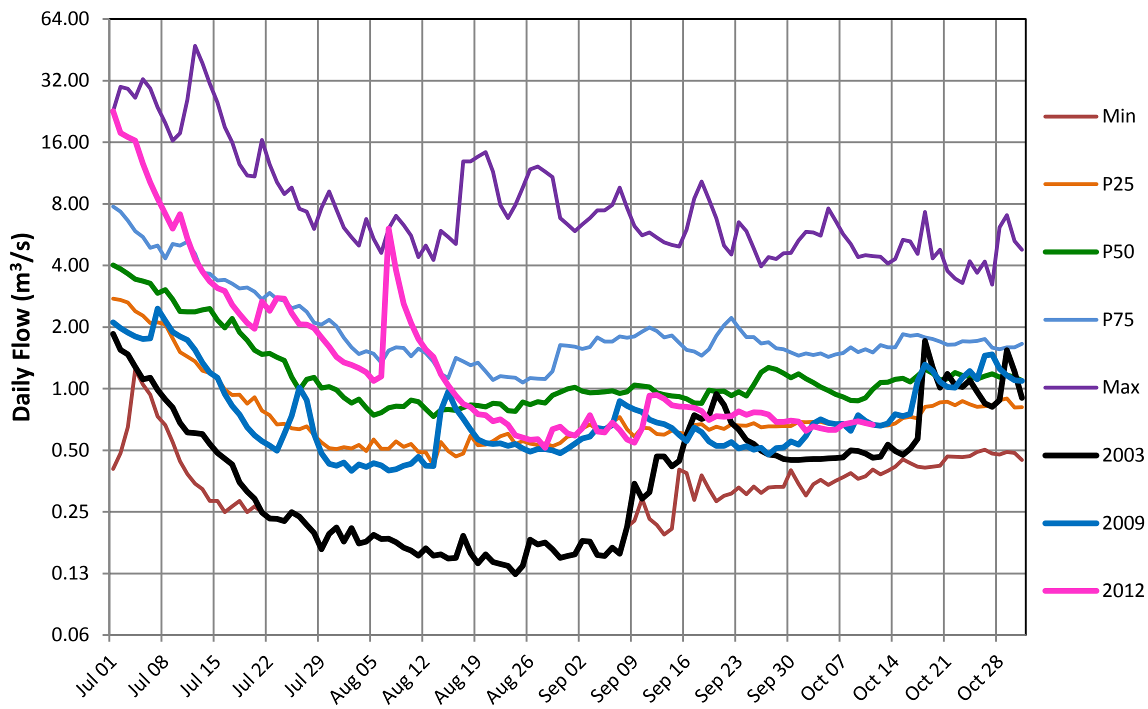


Figure 7. Range in Daily flow from July through October at Bessette Ck above Beaverjack Ck (WSC 08LC039)

The statistical flows in Figure 7 also demonstrate that median August flows are only about 0.90 m^3/sec (22%LTmad), and increase to about 1.00 to 1.20m^3/sec (24% to 29%LTmad) in September and October, while the lower quartile are only about 0.50 m^3/sec (12%LTmad) in August, increasing to 0.70 to 0.80 m^3/sec (17% to 19%LTmad) in September and October.

3.2. Water Licences / Water Use

Consumptive Water Use

Review of the water licence information available through the web-based BC Water Licenses Query tool (Province of BC, 2012) shows that there are 109 irrigation licences with 9 associated storage licences, and 11 Local Authority Waterworks and Irrigation licences with 6 associated storage licences within the Bessette Creek watershed. These licences account for virtually all of the licenced consumptive water use as described in Section 2. METHODS / MEASUREMENTS, *Water Licences / Type of Use*, so no effort has been made to detail the small scale licences such as for domestic and stock watering uses.

The irrigation and local authority licences, along with their associated storage were sorted according to location in the watershed so that the water licences could be matched to the hydrometric sites. Table 4 shows how much water is licenced for irrigation and water utility use in the Bessette Creek watershed in relation to the sub-basins and WSC station locations. The total licenced volume is equivalent to 39% of the mean annual flow at the lower Bessette Creek above Beaverjack Creek hydrometric site.

Licenced water use does not however equate to actual volume of use, particularly for the water utilities which typically use much less water than they have been licenced for. Average annual water use data, including well use by the Village of Lumby is available from the water utilities and was summarized in Golder, 2012. Average irrigation licence use is assumed at 90% of licenced volumes.

Table 4. Bessette Creek Watershed Water Licence Summary

Sub-Basin	**Irrigation**	**Water Utilities**	**Equivalent Annual Flow**
	MY	**MY**	**MS**
Bessette ds WSC	1,646,696	-	0.052
Bessette between WSC	129,515	-	0.004
Bessette above WSC	978,890	9,867,840	0.344
Vance ds WSC	231,401	-	0.007
Vance us WSC	585,410	252,938	0.027
Creighton ds WSC	2,145,367	-	0.068
Creighton us WSC	-	-	0.000
Duteau ds WSC	659,431	829,661	0.047
Duteau us WSC	-	25,374,673	0.805
Total	6,376,709	36,325,113	1.354

Table 5 summarizes the licence (and Lumby well use) information by location within the watershed. Water use is shown as both an equivalent annual flow reduction (used to calculate flows for the Long Term Mean Annual Discharge (LTmad) values at the WSC stations), and as an equivalent August flow reduction to compare to summer low flows.

Table 5. Bessette Creek Watershed Reported /Estimated Water Use Summary

Sub-Basin	**Irrigation (90% of Licences)**	**Water Utilities (Reported Volumes)**	**Equivalent Annual Flow Reduction**	**Equivalent[1] August Flow Reduction**
	MY	**MY**	**MS**	**MS**
Bessette ds WSC	116,564	-	0.004	0.011
Bessette between WSC	1,482,026	-	0.047	0.138
Bessette above WSC	881,001	4,107,240[2]	0.158	0.039[3]
Vance ds WSC	208,261		0.007	0.019
Vance us WSC	526,869	17,642	0.017	0.049
Creighton ds WSC	1,930,830	-	0.061	0.180
Creighton us WSC	-	-	-	-
Duteau ds WSC	593,488	345,321[4]	0.030	0.066
Duteau us WSC	-	11,104,760[2]	0.352	-
Total	5,622,474	14,291,642	0.676	0.493

The August flow reduction calculation assumes that all of the water utility August water use is supplied by releases from storage reservoirs which were filled during spring freshet, that the Nicklen Creek licences in the Upper Bessette watershed are also fully supported by their associated storage in August, and that irrigation use in August is 25% (Rood and Hamilton, 1995) of the total annual use. This estimates average August daily flow reduction as opposed to peak August daily flow reduction which would be higher than the average.

[1] Equivalent August flow reduction assumes that water utilities (other than Lumby wells) and Nicklen Ck irrigation licences are fully supported by storage releases in August and thereby do not have any associated August flow reductions.

[2] Greater Vernon Services Water reported average annual water use volume of 15,212 ML/year was proportioned between Upper Bessette (27%) and Duteau Creek (73%) based on the proportion of the McAuley Ck (Bessette tributary) licence to the Duteau Ck licences.

[3] Equivalent August Flow reduction in Upper Bessette Creek was adjusted by removing the licenced volume for the licences that are supported by storage in Nicklen Lake.

[4] Represents the reported well use by the Village of Lumby which uses wells rather than their Duteau Creek surface water licence.

The assumptions used in estimating the equivalent August flow reduction represent average conditions for surface water use. Flow reductions should be lower in wet years when less water should be used for irrigation. Flow reductions are also likely to be higher in dry years due to higher irrigation, assuming that there is water available for withdrawals. August flow reduction could also be higher if sufficient water to meet associated withdrawals is not being released from storage. The flow reductions also exclude all wells except for those operated by the Village of Lumby. Based on well yield values, there could be considerably more flow reduction if wells are being used for irrigation and there is not an equivalent licenced volume which is not being used (wells are sometimes used in place of licenced surface withdrawals for operational reasons and in that case, the use is offsetting).

Conservation Storage

There are two conservation storage licences in the Bessette Creek watershed. Fisheries and Oceans Canada (DFO) holds a licence issued in 1978 for 1,233,480 cubic meters / year (MY) for conservation storage in Grizzly Swamp in the Duteau Creek sub-basin, and the Fish & Wildlife Science & Allocation Section (Province of BC) holds a licence issued in 2002 for 1,480,176 cubic meters / year (MY) for conservation storage in Nicklen Lake in the Upper Bessette Creek sub-basin.

Groundwater Use

Review of the wells location layer on iMapBC (BC Min of Forests, Lands and Natural Resource Operations 2012) shows several hundred well locations within the Bessette Creek drainage. Many of the wells are low yield and are likely used for domestic purposes, but a number of the wells are shown with yields ranging from of more than 100 gal / min to 1200 gal / min (equivalent to flows ranging from 0.006 to 0.073 m^3/sec if pumped at full yield). Water use volumes from wells is mostly unknown, but this is a potentially high and non quantified consumptive water use.

Figure 8 demonstrates the relationship between Bessette Creek stream flow at Lumby and the depth to groundwater at Observation Network Well #294 located about 600 m from Bessette Creek along Whitevale Road. Stream flow is plotted in log scale to mute the peaks relative to low flows. There is a very distinct annual fluctuation in groundwater level that mirrors the annual stream flow pattern, with a delay of several weeks from the start of freshet flows in spring to the start of decrease in depth to groundwater and a corresponding lag in time to the highest annual groundwater level following the peak of freshet in Bessette Creek. Other stream flow peaks are also sometimes (but not always) mirrored in the groundwater level changes. The depth to the lowest water table of the year also appears to have increased in conjunction with lower late summer, fall and winter flows in the more recent years.

The close correlation between stream flow and groundwater levels indicates that the shallow surface aquifer is hydraulically connected to Bessette and strongly suggests that groundwater use will result in a corresponding reduction of instream flow.

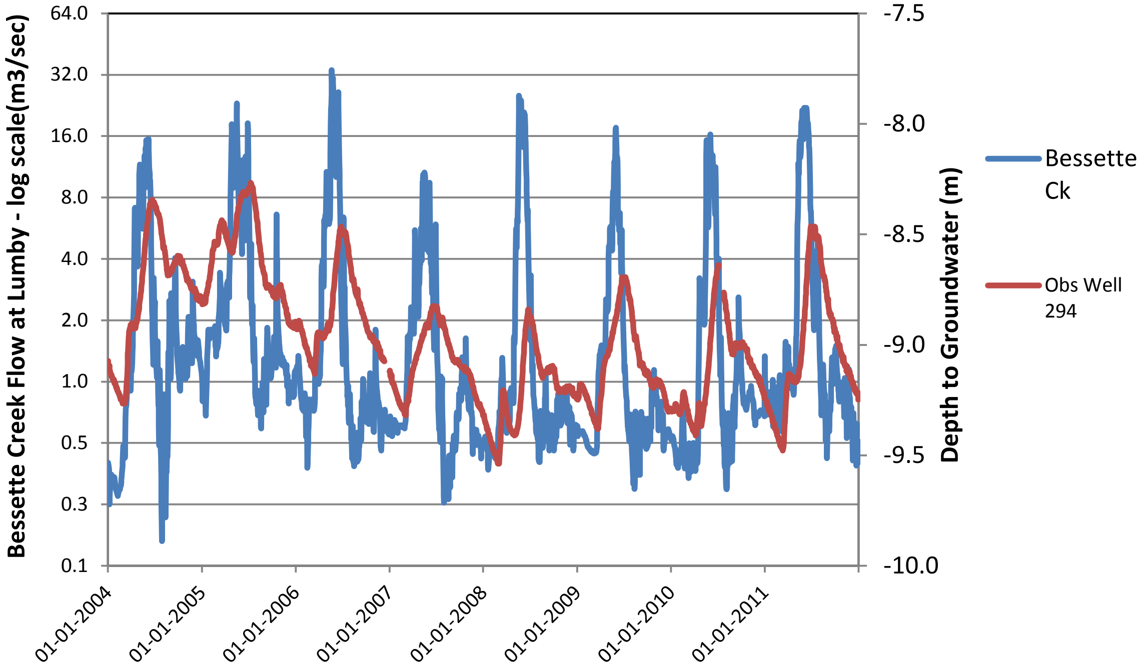


Figure 8. Comparison of Daily Flow in Bessette Ck at Lumby (WSC 08LC042) to Daily Depth to Groundwater at Observation Well 292 near Lumby.

3.3. Naturalized Annual Flows / Long Term Mean Annual Discharge

Naturalized Annual Flows

The reported (water utilities) and estimated (irrigation licences) water uses were added to the mean annual flows from the hydrometric site data to derive long term mean annual discharge (LTmad) volumes for representative WSC hydrometric sites. Calculated LTmad values as well as average annual unit runoff values are shown in Table 6.

Note that for calculating naturalized LTmad, the McAuley diversion portion of the Greater Vernon Services Water use is assigned to Bessette above Lumby rather than Duteau Creek, but the McAuley diversion area is subtracted from Bessette and added to Duteau to reflect current runoff and flow.

Long term mean annual discharge (LTmad) values are also required for each of the weighted usable width transect locations in order to calculate %LTmad. Calculated LTmad values as well as average annual unit runoff values are shown in Table 7, and the extrapolations and calculations to determine these LTmad values for 2012 are described below. The difference in watershed area between Bessette Creek above Lumby Lagoon and the sum of the areas at the Duteau near Lavington, Bessette near Lumby and Creighton near Lumby WSC stations is 148 km^2, and the difference in mean annual discharge flow is 0.319 m^3/sec, which equates to an average unit runoff of 68 mm/year for this area. This unit runoff is used to help extrapolate mean annual discharge values from the WSC station locations to the 2011and 2012 transect locations.

Table 6. Bessette Creek Watershed Calculated Long Term Mean Annual Discharge (LTmad) Volumes at Active and Discontinued Hydrometric Stations

WSC Station	Station ID	Mean Annual Flow	Annual Water Use	LTmad	Area	Annual Runoff
		m^3/sec	m^3/sec	m^3/sec	km^2	mm
Bessette above Beaverjack	08LC039	3.473	0.688	4.158	769	171
Bessette below Lumby	08LC042	3.001	0.601	3.600	632	180
Bessette above Lumby	08LC005	1.804	0.155	1.959	253	244
Bessette above - McAuley	-	1.804	0.028	1.832	246	231
Vance	08LC040	0.462	0.017	0.479	71	213
Duteau	08LC006	0.671	0.355	1.026	178	182
Duteau + McAuley	-	0.671p g26 &	0.482	1.153	185	197
Creighton	08LC046	0.297	-	0.297	37.6	249

Table 7. Bessette Creek Watershed Calculated Long Term Mean Annual Discharge (LTmad) Volumes at Transect Locations

Habitat Transect	Station ID	LTmad	Area	Annual Runoff
		m^3/sec	km^2	mm
Bessette above Horner Road	Bes 1	1.959	248	249
Bessette at Lumby	Bes 2 2011	2.479	399	186
Bessette above Lumby	Bes 2 2012	1.959	253	244
Bessette Beaverjack	Bes 3	4.129	769	169
Duteau at Whitevale Rd	Dut 1	1.008	183	175
Duteau at Lumby	Dut 2	1.083	233	144
Creighton at Salvas	Cre 1	0.416	93	125
Creighton Lower	Cre 2	0.426	98	122

Bessette above Horner Road (Bes 1) is assumed to have the same LTmad value of 1.959 m^3/sec as the inactive WSC station (08LC005) above Lumby. The contributing watershed area is about 5 km^2 less at this location, but the 2012 and 2013 transect measurements show less flow at the former WSC site during July through October, so extrapolating the WSC value to this location may in fact underestimate LTmad slightly at this location.

Bessette above Lumby on Shuswap Ave (Bes 2 2012) is located in approximately the same location as inactive WSC station 08LC005 so is assigned the same LTmad of 1.959 m^3/sec as calculated for this location based on the historic WSC data and water use in Table 6.

Bessette at Lumby (Bes 2 2011) is located upstream of the confluence with Duteau Creek. LTmad for this site is calculated by subtracting the estimated LTmad value of 1.121 m^3/sec for Duteau at Lumby (Dut 2) from the LTmad value of 3.600 m^3/sec calculated for the WSC station 08LC042 which is located below the Duteau confluence, for a net LTmad value of 2.479 m^3/sec.

Bessette above Beaverjack (Bes 3) is located at WSC station 08LC039 and is assigned the same LTmad value of 4.129 m^3/sec as calculated for this location in Table 6.

Duteau Creek at Whitevale Road (Dut 1) is located downstream of the inactive WSC Duteau Creek near Lavington station 08LC007, and with an additional contributing area of about 5 km^2 between, is assigned an additional 0.011 m^3/sec for an estimated LTmad of 1.037 m^3/sec.

Duteau Creek at Lumby (Dut 2) is located near the confluence with Bessette Creek. There is an additional 40 km^2 of contributing watershed area between the inactive WSC Duteau Creek near Lavington station 08LC007 so 0.086 m^3/sec is added to the WSC value of 1.026 m^3/sec to estimate the LTmad at Dut 2 as 1.1.1123 m^3/sec.

Cre 1 is located well downstream of the inactive WSC Creighton Ck near Lumby (08LC033) which has a calculated LTmad of 0.297 m^3/sec, with an additional contributing watershed area of about 55 km^2, so an additional 0.119 m^3/sec (see proportioning rationale below) for an estimated LTmad of 0.416 m^3/sec.

Cre 2 is located further downstream than Cre1, with an additional contributing area of about 5 km^2, so the Cre 1 LTmad value is increased by 0.010 m^3/sec for an estimated LTmad value of 0.426 m^3/sec.

Naturalized Monthly Flows

Residual daily flows as shown in Figure 7 could be naturalized by adding estimated water use. The daily naturalized results would be approximate at best though, and potentially misleading because daily water use can't be estimated with any precision. Daily water use is too variable from day to day to extrapolate annual averages down to a daily basis.

Residual monthly flows are better suited to naturalization as monthly water use patterns will be less variable from year to year and can be estimated with greater confidence. Even so, naturalized monthly flows will be most realistic for the median (average year) flows, with greater margin for error on the very low flow years. Water demand is higher in dry years due to high temperatures and low precipitation, but water use may actually be lower (e.g. Creighton Ck in August) due to low flows limiting water availability for extraction from the creeks.

Estimated average daily water diversions on an annual basis, as well as for July, August and September are shown in Table 8 for each WSC hydrometric station location and the Creighton and Duteau confluences with Bessette Creek. Water usage is shown as both m^3/sec and a percentage of the long term mean annual discharge. Annual water use estimates include all reported and estimated water usage, and assumes that there is no year to year variation in volume diverted to storage for seasonal use. Annual storage diversion does in fact vary, but does not affect the July to September use estimates which are the focus of this Table. July and August use is calculated as 25% of the annual irrigation use estimate and September use is calculated as 10% of the annual irrigation use estimate as per Rood and Hamilton, 1995. Water utility use from Duteau and Bessette diversion, as well as the irrigation use from Nicklen Lake is assumed to be satisfied from storage. This likely underestimates the July usage, as Nicklen storage is not opened until August and Duteau flow may also be diverted or retained in storage if the reservoirs are not full.

Table 8. Estimated Daily Water Diversions on Annual and Monthly Basis for July, August and September for Naturalizing Residual Flows at WSC Hydrometric Station Locations

	LTmad m^3/sec	Annual m^3/sec	Jul m^3/sec	Aug m^3/sec	Sep m^3/sec	Annual %mad	Jul %mad	Aug %mad	Sep %mad
Lower Bessette 08LC039	4.129	0.646	0.482	0.482	0.199	16%	12%	12%	5%
Bessette at Lumby 08LC042	3.572	0.572	0.285	0.285	0.114	16%	8%	8%	3%
Bessette above Lumby 08LC005	1.959	0.155	0.039	0.039	0.016	8%	2%	2%	1%
Creighton 08LC033	0.297	-	-	-	-	0%	-	-	-
Creighton at Bessette	0.426	0.061	0.180	0.180	0.074	14%	42%	42%	17%
Duteau near Lavington 08LC005	0.997	0.326	-	-	-	33%	-	-	-
Duteau at Lumby	1.083	0.345	0.066	0.066	0.026	32%	6%	6%	2%
Vance 08LC040	0.479	0.017	0.049	0.049	0.020	4%	10%	10%	4%

Estimated daily water diversions for July, August and September are compared and added to the median mean monthly flows for naturalized median monthly flows at the WSC hydrometric sites Table 9 in units of m3/sec and in Table 10 as %LTmad.

Tables 8, 9 and 10 demonstrate that July residual median mean monthly flows are near or above 50 %LTmad for all stations except for Duteau near Lavington where flows are highly regulated by Greater Vernon Services - Water. August median residual median mean monthly flows are generally close to or higher than 20%LTmad for all except the historic Bessette site above Lumby, and the September median residual flows for all sites are above 20% LTmad. Naturalizing these residual flows by adding estimated water use increases the monthly flows by as much as 12%LTmad in July and August.

Table 9. Median Mean Monthly Flows, Estimated Daily Water Diversions and Naturalized Median Monthly Flows for July, August and September at WSC Hydrometric Station Locations as m^3/sec.

	Residual Median Mean Monthly Flow			Estimated Monthly Water Use			Naturalized Median Mean Monthly Flow		
	Jul m^3/sec	**Aug m^3/sec**	**Sep m^3/sec**	**Jul m^3/sec**	**Aug m^3/sec**	**Sep m^3/sec**	**Jul m^3/sec**	**Aug m^3/sec**	**Sep m^3/sec**
Lower Bessette 08LC039	2.050	0.901	1.020	0.482	0.482	0.199	2.532	1.383	1.219
Bessette at Lumby 08LC042	1.680	0.692	0.738	0.285	0.285	0.114	1.965	0.977	0.852
Bessette above Lumby 08LC005	1.145	0.276	0.405	0.039	0.039	0.016	1.184	0.315	0.420
Creighton 08LC033	0.309	0.086	0.065	-	-	-	0.309	0.086	0.065
Duteau near Lavington 08LC005	0.256	0.228	0.273	-	-	-	0.256	0.228	0.273
Vance 08LC040	0.305	0.132	0.096	0.049	0.049	0.020	0.354	0.181	0.116

Table 10. Median Mean Monthly Flows, Estimated Daily Water Diversions and Naturalized Median Monthly Flows for July, August and September at WSC Hydrometric Station Locations as %LTmad

	Residual Median Mean Monthly Flow			Estimated Monthly Water Use			Naturalized Median Mean Monthly Flow		
	Jul %LTmad	**Aug %LTmad**	**Sep %LTmad**	**Jul %LTmad**	**Aug %LTmad**	**Sep %LTmad**	**Jul %LTmad**	**Aug %LTmad**	**Sep %LTmad**
Lower Bessette 08LC039	50%	22%	25%	12%	12%	5%	61%	33%	30%
Bessette at Lumby 08LC042	47%	19%	21%	8%	8%	3%	55%	27%	24%
Bessette above Lumby 08LC005	58%	14%	21%	2%	2%	1%	60%	16%	21%
Creighton 08LC033	104%	29%	22%	0%	0%	0%	104%	29%	22%
Duteau near Lavington 08LC005	26%	23%	27%	0%	0%	0%	26%	23%	27%
Vance 08LC040	64%	28%	20%	10%	10%	4%	74%	38%	24%

3.4. MFLNRO Seasonal Flow Measurements - 2011 to 2013

MFLNRO staff set up and operated 5 seasonal flow monitoring stations in the Bessette Creek watershed in 2011, and 6 stations in 2012 and 2013 (Figure 2). The stations were set up gather additional seasonal (relative to the ongoing WSC annual and the recent RDNO seasonal hydrometric stations) flow information. The flow information helps to understand flow relationships in and among the three major tributaries (Duteau, Creighton and Bessette Creeks), documents how flows change seasonally in relation to natural factors including groundwater losses as well as irrigation, and shows which portions of the watershed are most susceptible to low flows. The results are summarized below, with reference to WSC results in Bessette and RDNO results in Duteau for wider comparisons.

Duteau Creek

The 2011 to 2013 Duteau Creek daily flows for the MFLNRO Duteau1 site are shown in Figure 9 for year to year comparison. The Duteau 1 site is located at Whitevale Road, below the Greater Vernon Services - Water Headgates diversion, but above the agricultural irrigation licences in Duteau Creek. Results show variable start dates which miss the early freshet in two years, and have missing high flow values when the higher flows exceeded measurement capabilities in June and early July.

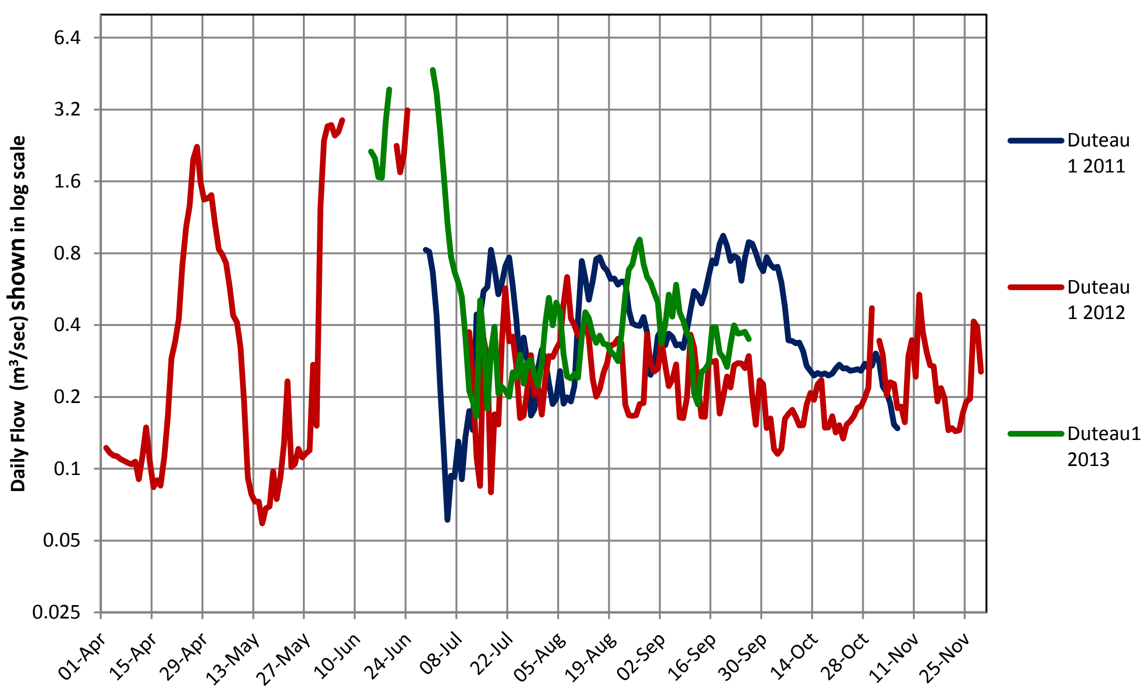


Figure 9. Duteau Creek 2011 to 2013 Daily Flows for Duteau 1.

Early freshet conditions are only recorded in 2012, which had a low elevation freshet that lasted for approximately 4 weeks and peaked on April 27 at 2.23 m^3/sec (225%LTmad) at the MFLNRO Duteau 1 site before dropping down to 0.06 m^3/sec on May 15. Flows then peak in June, well above the highest recorded values. Flows in both 2011 and 2012 show very low flows in early to mid July (0.06 m^3/sec in 2011 and 0.08 m^3/sec in 2012) as freshet ends and Duteau Ck flows are regulated by reservoir releases and Headgates diversion volumes. From mid July on, flows exhibit considerable day to day variability, with generally lower flows in 2012 than in 2011 and 2013. The variability in daily flows likely reflects relatively constant releases from storage matched to anticipated diversion demand, resulting in increased spill over the Headgates whenever wetter and cooler weather increases stream flow and reduces irrigation demands.

The 2013 Duteau Creek daily flows for the MFLNRO Duteau1 and Duteau 2 sites and the RDNO Lower Duteau site are compared in Figure 10. Flow monitoring results for the downstream MFLNRO Duteau 2 site show very similar flow patterns, but there is consistently more flow at Duteau 2, suggesting that Duteau Creek is likely being recharged by groundwater in it's lower reaches. There is also a very noticeable increase in the relative flows at Duteau 2 at the end of September, consistent with the end of irrigation. Flow monitoring results for the RDNO Lower Duteau site also show similar overall patterns as Duteau 1, but are offset by the Headgates diversion volumes between Lower Duteau and Duteau 1.

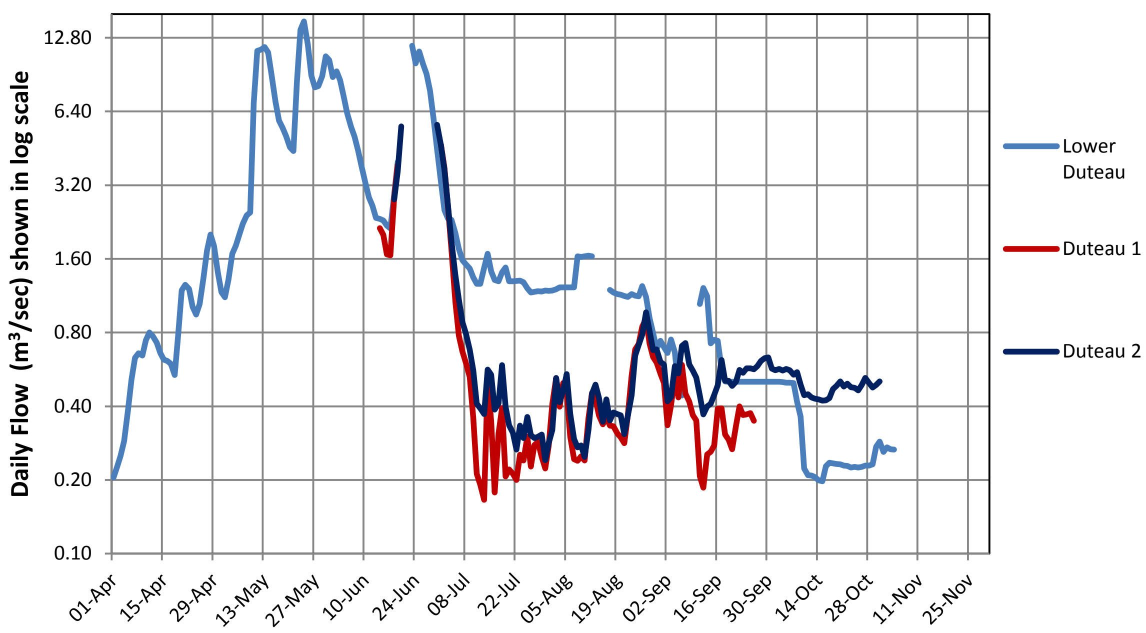


Figure 10. Duteau Creek 2013 Daily Flow Comparison for Duteau 1, Duteau 2 and Lower Duteau..

Table 11 summarizes the mean monthly flows and the differences in flow between Duteau 1 and Duteau 2 over the three years. Values for most months are based on complete or almost complete data sets, except for most November and some of the May and June data.

Table 11. Mean[5] Monthly flows (m^3/sec) at Duteau Creek Duteau 1 and Duteau 2 Seasonal Sites with Comparisons between Duteau 2 and Duteau 1.

	Duteau 1			Duteau 2			Duteau 2 - Duteau 1		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Apr		0.502							
May		0.331							
Jun	0.819	2.546							
Jul	0.367	0.246	0.718	0.573	0.410	0.838	0.194	0.164	0.119
Aug	0.445	0.304	0.451	0.563	0.363	0.698	0.117	0.059	0.117
Sep	0.605	0.242	0.362	0.710	0.340	0.595	0.104	0.098	0.119
Oct	0.351	0.177		0.522	0.326	0.523	0.171	0.150	
Nov		0.251		0.418	0.401			0.166	

Mean monthly flows from July into October at Duteau 1 are relatively high in all three years, with average monthly flows generally exceeding 25%LTmad, with a low monthly average of 18%LTmad in October 2012 to a high of 71%Ltmad in July 2013. Daily flows are quite variable though, with lowest daily flows in July ranging from 6%LTmad in 2011 to 16%LTmad in 2013. Flows at Duteau 2 are consistently higher than at Duteau 1, averaging 0.150 to 0.200 m^3/sec higher in October and November, and around 0.100 m^3/sec higher in August and September. The increase in relative of flow of about 0.075 m^3/sec in October and November is attributed to the end of irrigation withdrawals, and compares well to the estimated irrigation use of 0.066 m^3/sec for this stream section in Table 5.

[5] Some mean monthly flow values are based on months with partial flow data and so do not represent a true mean monthly flow.

Table 12 summarizes the differences between Duteau 1 and the RDNO Lower Duteau station over the three years. Values for most months are based on complete or almost complete data sets, except for most November and some of the May and June data.

The difference in flow between the RDNO Lower Duteau station and Duteau 1 should approximately match the GVS diversion as that is the main difference in flow between the two sites. Note that the high difference calculated for June 2012 is based on limited data recorded at very high flows and is not an accurate reflection of the flow difference during that period of time. The negative value calculated for October 2011 also is indicative of some level of error in the measurements as lower flows upstream of the diversion are not likely.

Table 12. Mean[6] Monthly flows (m^3/sec) at MFLNRO Duteau Creek Duteau 1 and RDNO Lower Duteau Seasonal Sites with Monthly Flow Comparisons between Lower Duteau and Duteau 1.

	RDNO Lower Duteau			MFLNRO Duteau 1			Lower Duteau - Duteau 1		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
Apr			0.854		0.502				
May		1.016	6.921		0.331			0.830	
Jun		7.168	5.806	0.819	2.546			3.275	0.280
Jul	1.022	2.195	1.533	0.367	0.246	0.718	0.660	1.112	1.005
Aug	2.282	1.447	1.204	0.445	0.304	0.451	1.837	1.143	0.741
Sep	1.469	0.882	0.631	0.605	0.242	0.362	0.864	0.639	0.320
Oct	0.313	0.327	0.300	0.351	0.177		-0.038	0.156	
Nov	0.313			0.200	0.251		0.053		

Creighton Creek

The 2011 to 2103 Creighton Creek daily flows at Creighton 1, upstream of most of the agricultural irrigation diversions are shown in Figure 11 for year to year flow comparison. The 2012 flow data shows freshet flows which start in late April and appear to be diminishing in early June, before high flows in mid June disrupt the flow monitoring. Flows then diminish through July and into early August, with a storm peak on August 7. Flows in August 2011 and 2012 reached minimum flows of about 0.13 m^3/sec in August and remained at that level until flows increased due to fall rains in September / October. Flows in 2013 remained considerably at levels above 0.20 m^3/sec until mid October after which flows declined to lower levels than the fall 2011 and 2012 flows.

The 2013 Creighton Creek daily flows for both the Creighton 1 site representing relatively natural flows conditions and the Creighton 2 site near the confluence with Bessette Creek below the agricultural irrigation diversions are shown in Figure 12.

Figure 12 demonstrates a significant reduction in flow at the downstream site starting in early July as freshet flows are ending, presumably due to agricultural diversions for irrigation. The differences are most pronounced in July and August, lower in September and then gone by the end of October, consistent with agricultural use diversions.

[6] Some mean monthly flow values are based on months with partial flow data and so do not represent a true mean monthly flow.

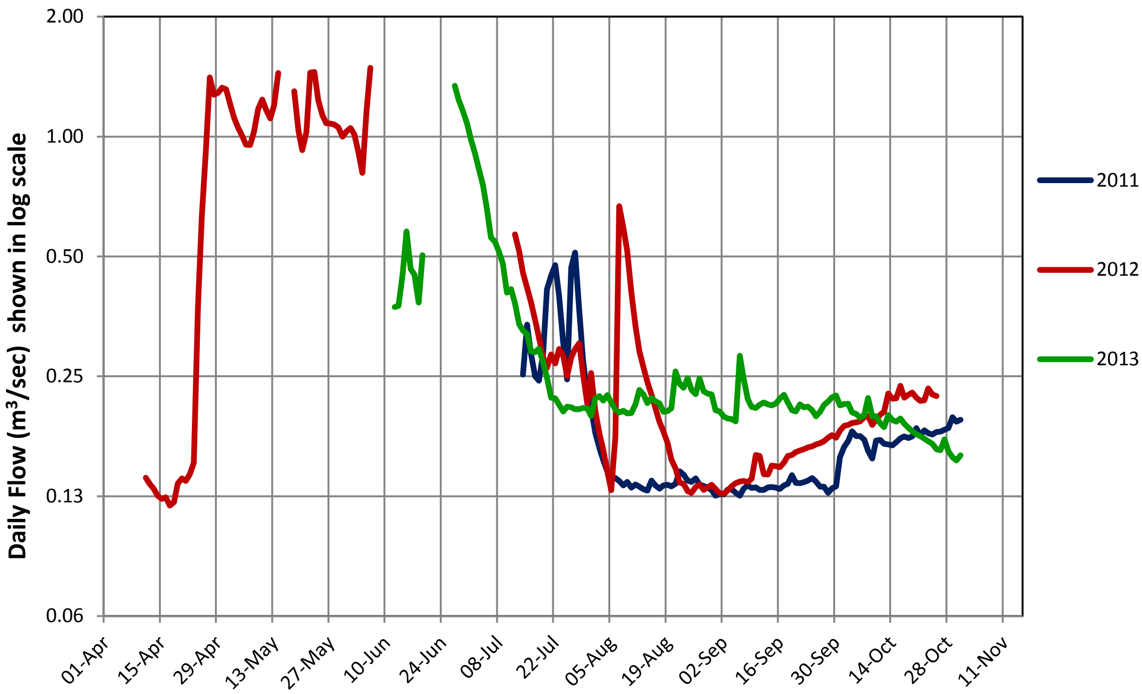


Figure 11. Creighton Creek Daily Flows for 2011 to 2013 Above Most of the Agricultural Use (Creighton 1).

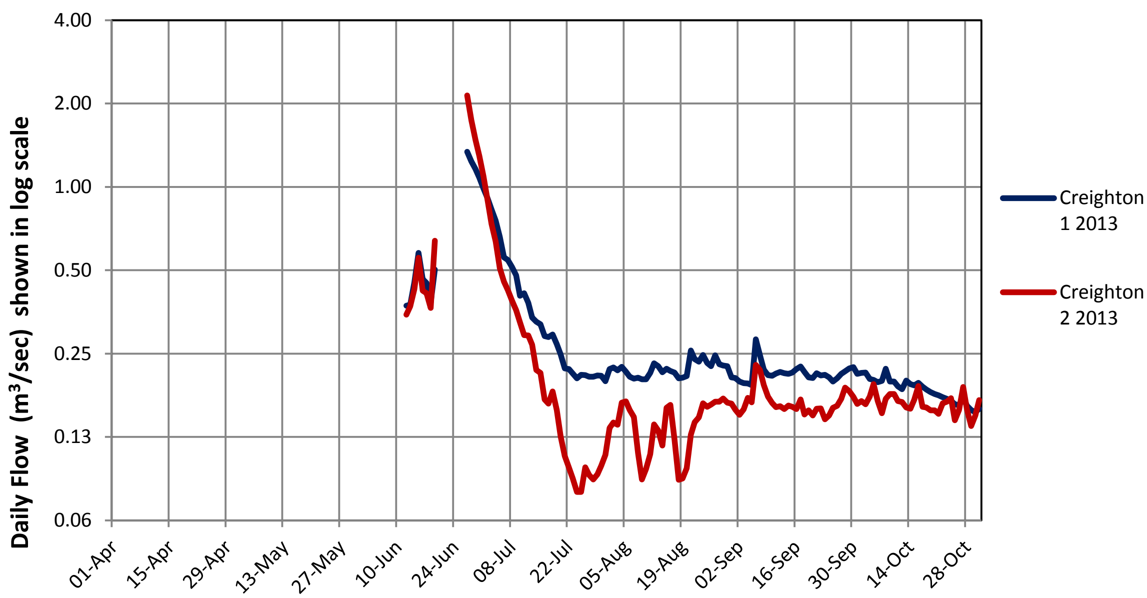


Figure 12. Creighton Creek Daily Flows for 2013 Above Most of the Agricultural Use (Creighton 1) and Near the Bessette Creek Confluence (Creighton 2).

The mean monthly flows for both sites for 2011 to 2013 are shown in **Error! Not a valid bookmark self-reference.**. Note that the Creighton 2 - Creighton 1 column comparison does not equal the Creighton 2 column minus the Creighton 1 column for May to August in 2012 because the flow records are discontinuous. The average flows per station use all of the values for that station, but the comparison only uses days with data available for both locations.

Table 13. Mean[7] Monthly flows (m^3/sec) at Creighton Creek Seasonal Sites, with Monthly Comparisons between Creighton 1 and Creighton 2 for 2012 and 2013.

	Creighton 1			Creighton 2		Creighton 2 - Creighton 1	
	2011	2012	2013	2012	2013	2012	2013
Apr		0.447					
May		1.137		1.065		-0.068[8]	
Jun		1.072	0.700	1.169	0.849	-0.109[8]	0.149
Jul	0.333	0.326	0.391	0.489	0.288	-0.043[8]	-0.103
Aug	0.138	0.223	0.220	0.347	0.139	-0.061[8]	-0.082
Sep	0.132	0.152	0.213	0.086	0.167	-0.066	-0.046
Oct	0.176	0.209	0.186	0.162	0.165	-0.048	-0.021

The Creighton 2 - Creighton 1 comparison shows consistently lower summer and fall flows at Creighton 2, including September when water diversions would be expected to be lower, and October when there should be no agricultural water diversions. The average July and August flow reduction between the 2 sites are considerably lower than the than the 0.180 m^3/sec estimated water use in July and August based on irrigation licences as per Table 5. The average monthly flow in both years was high enough to sustain more withdrawals, but they may not have been required due to the wet conditions which led to the high flows in early to mid August. In 2011, the August mean monthly flows above the agricultural area were less than estimated monthly water use for August, indicating that it was impossible to use 0.180 m^3/sec in August 2011, unless some of the water was being pumped from groundwater wells. These results suggest that Table 5 is likely overestimating the late summer water withdrawals in Creighton Creek due to lack of availability, unless groundwater is also being used.

Bessette Creek

The 2011 to 2013 Bessette Creek daily flows for the MFLNRO Bessette 1 site are shown in Figure 13Figure 9 as a comparison of year to year flows and seasonal flow pattern. Bessette 1 is located above Horner Road, and above most of the agricultural irrigation licences in Duteau Creek. Flows at this site are reduced by the volume and timing

[7] Some mean monthly flow values are based on months with partial flow data and so do not represent a true mean monthly flow.

[8] These values are different than the difference between the monthly averages for Creighton 2 minus Creighton 1 because the flow records are discontinuous, and this calculation is done with only the days with measured flows for both sites.

(primarily spring to early summer) of the McAuley diversion into the Duteau Creek watershed, and by storage in Nicklen Lake, and then are increased again from some time in August to the end of October by storage releases from Nicklen Lake.

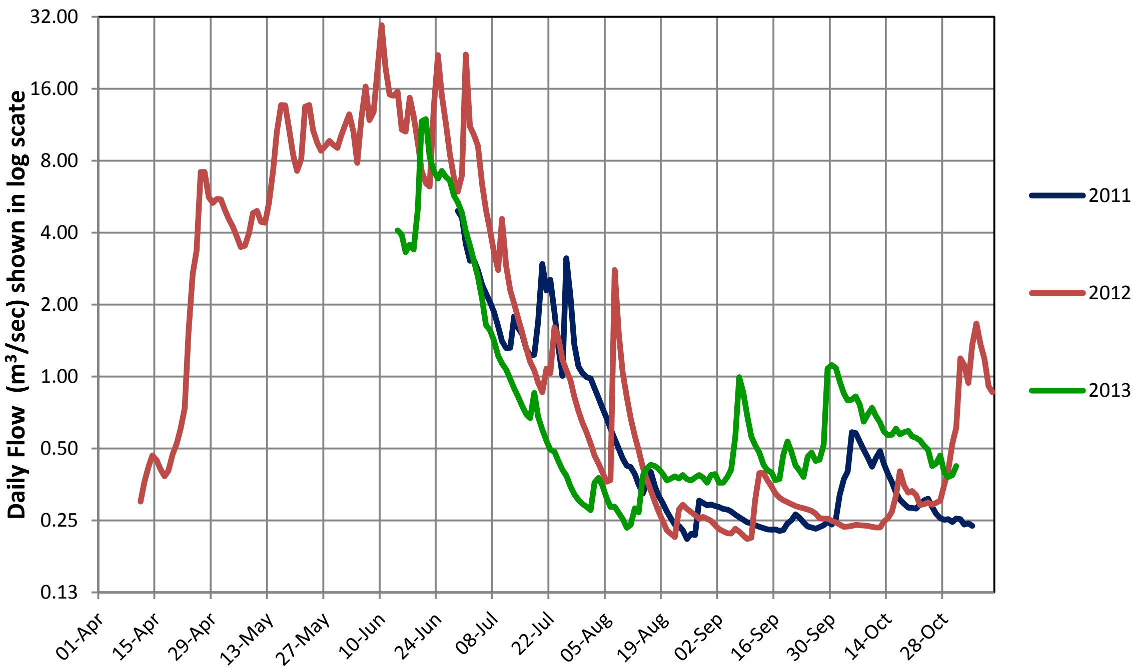


Figure 13. Bessette Creek Daily Flows for 2011 to 2013 Above Most of the Agricultural Use (Bessette 1).

The flow pattern shows freshet flows starting in early April, peaking in late May to early June, and then diminishing to low flows in August. Storm peaks temporarily increase flows in summer, but flows usually diminish back to previous levels relatively quickly. The start of Nicklen Lake releases is reflected by the increase in flows on Aug 27, 2011, Aug 20, 2012 and Aug 13, 2013. Storage releases were initiated when Bessette 1 flows were in the 0.220 to 0.250 m^3/sec range. Flows in 2011 and 2012 diminished back to that range over the following weeks, but remained at the increased levels (likely due to wetter climatic conditions) in 2013.

Flows for the 2013 are compared for the two MFLNRO seasonal stations and the two WSC stations (preliminary data) in Figure 14.

Flow patterns for all four Bessette sites are similar with increasing downstream flows, except for Bessette 2 where flows drop to much lower levels than the upstream Bessette 1 site in July. The decreased flow at Bessette 2B reflects both diversions for agricultural irrigation as well as natural streamflow losses to groundwater.

The mean monthly flows for 2011 to 2013 are shown in Table 14, including the difference in flow between Bessette 1 and Bessette 2B in the last two years (Bes 2B was started in 2012). The decrease in flow between the two sites is highest in August when irrigation use is highest, and then diminishes in September but continues into October and November reflecting the additional loss to groundwater in this section of Bessette Creek.

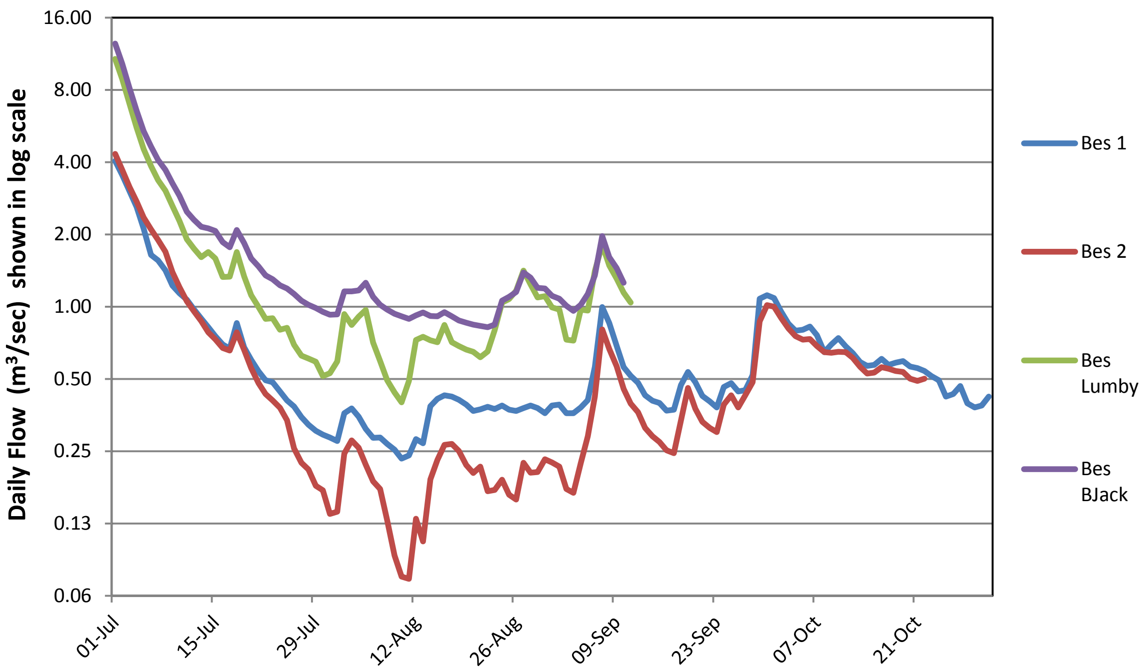


Figure 14. Bessette Creek Daily Flows for 2013 Above Agricultural Irrigation (Bessette 1), Above Creighton Confluence (Bessette 2B), below Creighton and Duteau confluences (Bes Lumby) and below Vance Creek (Bes Bjack).

Table 14. Mean[9] Monthly flows (m^3/sec) at Bessette Creek Seasonal Sites, with Monthly Comparisons between Bessette 1 and Bessette 2B for 2012 and 2013.

	Bessette 1			Bessette 2B		Bessette 2B - Bessette 1	
	2011	2012	2013	2012	2013	2012	2013
Jun	4.785		6.225		6.426		0.201
Jul	1.898	3.416	1.117	1.174	1.146		0.029
Aug	0.416	0.498	0.347	0.339	0.190	-0.159	-0.157
Sep	0.248	0.275	0.526	0.179	0.408	-0.096	-0.119
Oct	0.356	0.301	0.617	0.256	0.573	-0.045	-0.045
Nov	0.243	1.177		1.204		-0.014	

Irrigation use was estimated from sprinkler counts on the flow measurement days, with estimated irrigation compared to the flow differences on those days in Figure 15

[9] Some mean monthly flow values are based on months with partial flow data and so do not represent a true mean monthly flow.

(supplied by Minor, 2013). This comparison suggests that loss to groundwater is in fact larger than the irrigation component of the loss in August.

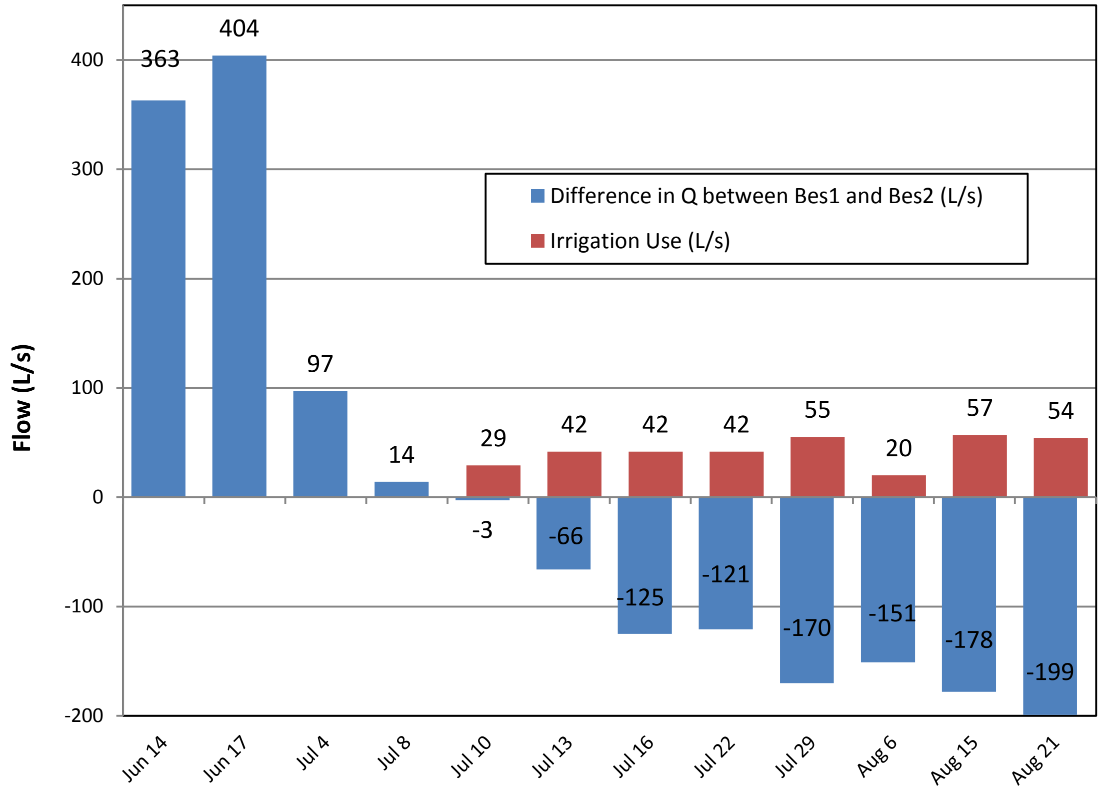


Figure 15. Difference in Bessette Creek Flow Measurements in 2013 between Bes 1 Above Agricultural Irrigation and Bes 2B near Lumby with Total flow Difference and Estimated Irrigation Volume from Sprinkler Counts.

Bessette, Duteau, and Creighton Creek Comparison

The flows from the three streams above the confluences near Lumby are compared with the WSC Bessette Creek station below the confluences in Figure 16. All three upstream MFLNRO sites show steep flow reduction in early July, but with the magnitude of flow loss much higher in Bessette than in Creighton and Duteau. By late July, the Bessette flows are well below Duteau Creek and drop below Creighton Creek flows in early August reflecting the loss to groundwater in addition to irrigation losses. Duteau Creek flows are variable but remain higher than Bessette flows through August and much of September reflecting flow regulation resulting in significant Headgates spill. The flow pattern in Bessette Creek below the tributaries is dictated by the Bessette flows in July, but then more so by Duteau flows during August and September before Bessette Creek flows return to higher levels during a wetter period in October. The sum of the three upstream flows is also compared to the WSC Bessette flows near Lumby, with the nearly identical flow comparison validating the flow measurements.

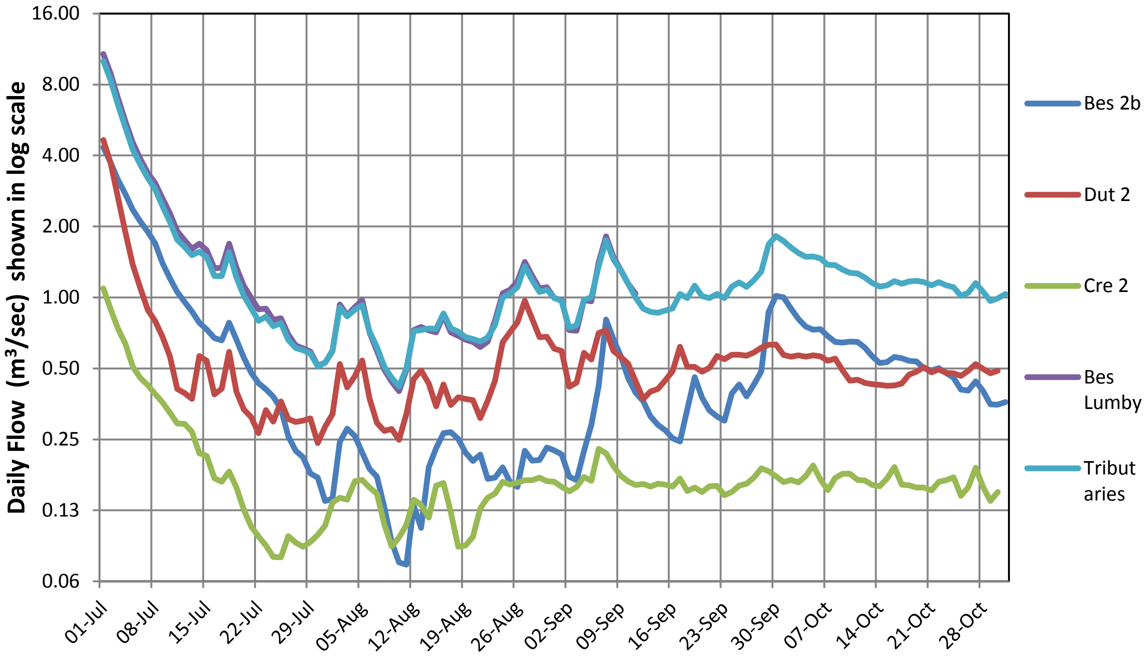


Figure 16. Bessette, Duteau and Creighton Creeks 2012 Seasonal Flow Monitoring Comparison from July 1 to October 31.

4. RESULTS & DISCUSSION: FISH HABITAT USABLE WIDTH & RIFFLE PASSAGE

4.1 Fish Habitat Usable Width in Riffles

Riffle Wetted Widths, Depths and Velocities

Weighted usable widths are determined by combinations of wetted width, depth and velocity. Figure 17, Figure 18 and Figure 19 demonstrate how wetted width, depth and velocity vary with flow expressed as %LTmad in the 12 riffle transects measured in 2011 and 2012.

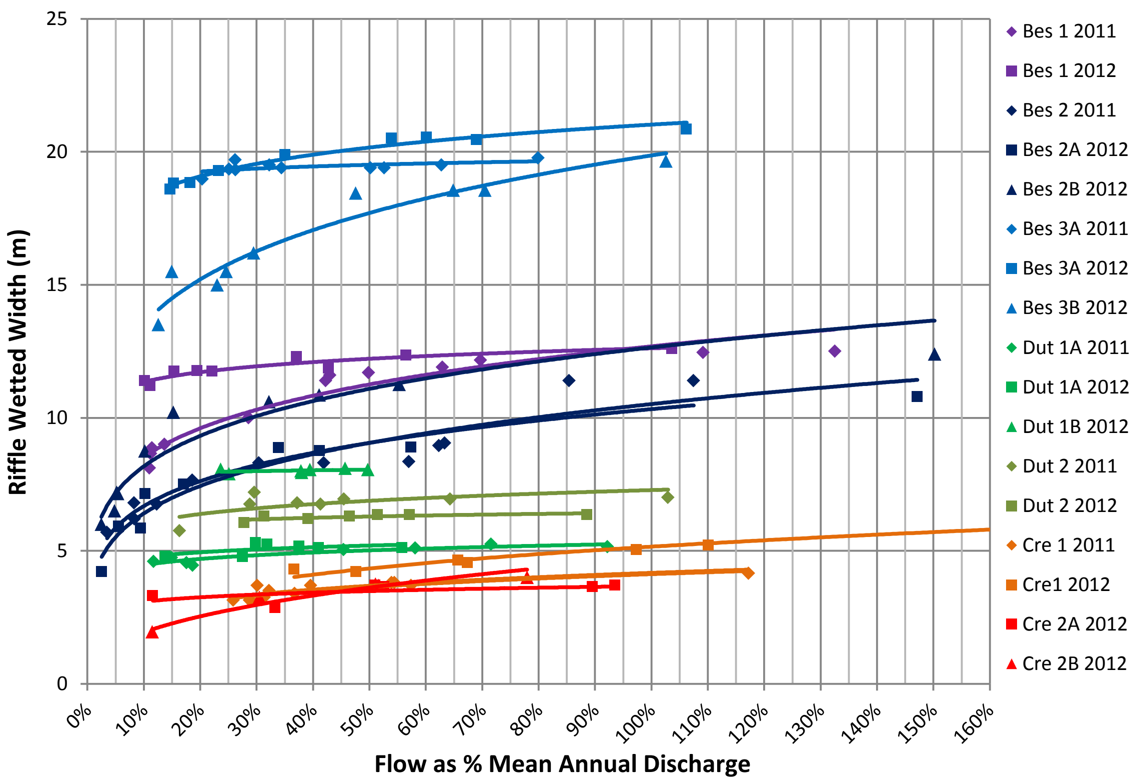


Figure 17. Riffle Wetted Width vs. Flow as %LTmad in 2011 & 2012

As expected the wetted width is decreasing gradually with decreased flow expressed as %LTmad over most of the flow range. It is also apparent that wetted width is diminishing more rapidly as flow decreases below an inflection point at approximately 10%LTmad, as demonstrated by Bessette 2A and 2B where transects with the lowest flows as % of LTmad were measured, as there will be virtually no wetted width at zero flow.

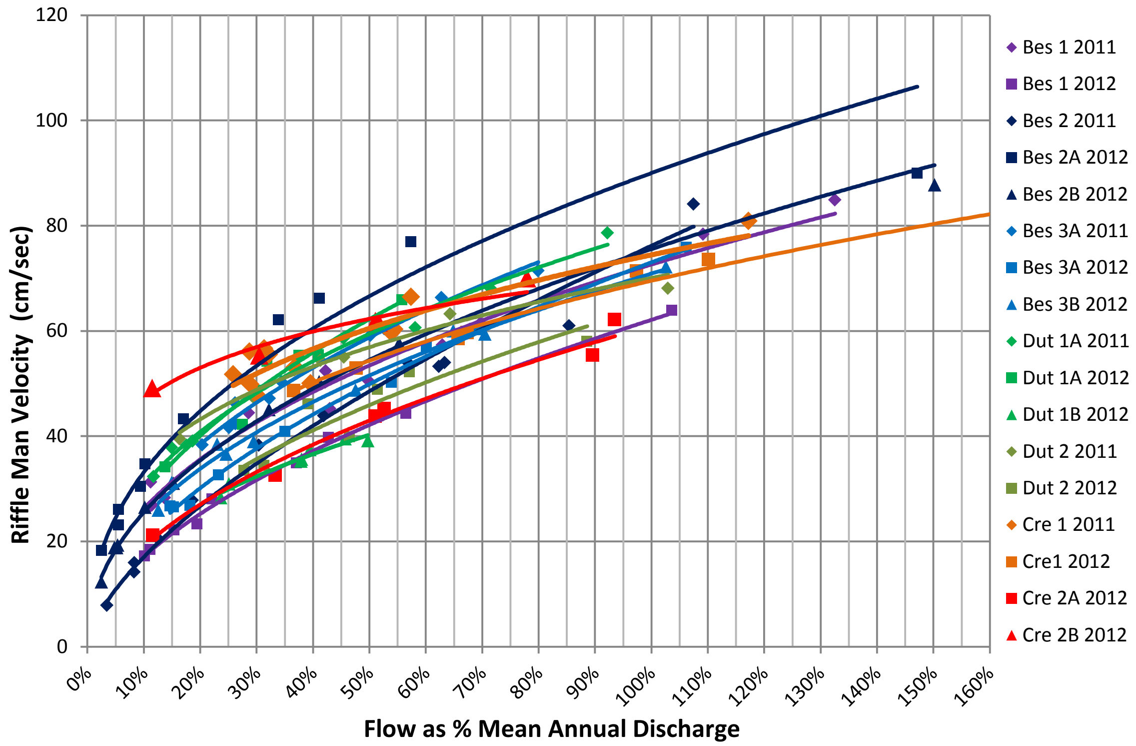


Figure 18. Riffle Mean Velocity vs. Flow as %LTmad in 2011 & 2012

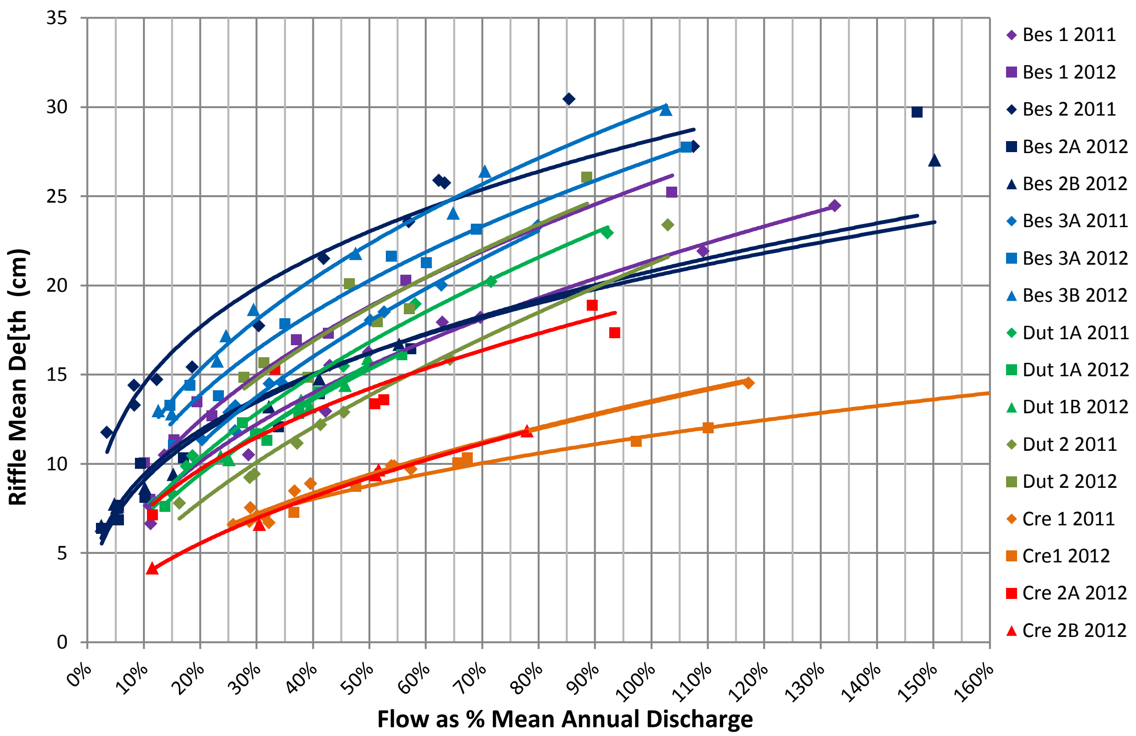


Figure 19. Mean Riffle Depth vs. Flow as %LTmad in 2011 & 2012

The mean riffle velocity also diminishes with decreasing flow, but with a more gradual rate of change than in the depth / flow relationship, and an inflection point for the rate of change at about 30% LTmad. The Habitat Suitability Index (HSI) information that is used to derive the weighted usable width indicates that the ideal (100% probability of use) riffle velocity for rainbow parr is between 25 and 55 cm/sec, with 80% probability of use at 17 cm/sec and 50% probability of use at 9 cm/sec. Similarly the ideal (100% probability of use) riffle velocity for Chinook salmon juveniles is between 25 and 33 cm/sec, with 80% probability of use at 15 cm/sec and 50% probability of use at 8 cm/sec, while rainbow trout fry and Coho juveniles prefer slower velocities. Figure 18 demonstrates that while riffle velocities are adequate for both rainbow trout and Chinook rearing at flows of 10%LTmad in most transects, riffle velocities are better for fish life stages of interest at 20% to 30%LTmad.

The mean riffle depths also diminish with decreasing flow, with inflection point for the rate of change ranging at about 10% to 30% LTmad depending on the transect location. The ideal (100 % probability of use) riffle depth for rainbow trout parr is greater than 33 cm, with 80% probability of use at 22 cm. and 50% probability of use at 14 cm. Similarly, the ideal (100 % probability of use) riffle depth for Chinook salmon juveniles is greater than 22 cm, with 80% probability of use at 17 cm. and 50% probability of use at 13 cm. Figure 19 demonstrates that riffle depth is limiting weighted usable width for rainbow trout parr and Chinook juveniles as the typical mean riffle width is only about 15 cm at 20%LTmad in the Bessette Creek transects, and below 10 cm at 20% LTmad in many of the Duteau and Creighton Creek transects.

Weighted Usable Widths for Rearing in Riffle Transects

Weighted Usable width results are presented in Figure 20 (Bessette 1) and in Appendix B (all transects) for riffle transects measured in 2011 and 2012, focussing on rainbow trout and Coho and Chinook salmon rearing, and photographs of each transect at representative flows are included in Appendix D. The weighted usable riffle results for rainbow trout parr and Chinook salmon juveniles show a general trend of increasing weighted usable width with flow from very low values at flows of 10% or less (see Figures B3 and B4 in Appendix B for results at flows of <3% LTmad), to maximum or near maximum usable widths at flows of 40% to 60%LTmad in Bessette Creek and maximum usable widths at flow of up to 95% LTmad in Creighton and Duteau Creeks. There is also an inflection point at approximately 50% to 60% of the flow at which the maximum usable width occurs that represents the change from quickly diminishing usable widths at lower flows to smaller increases in weighted usable width with increasing flows and has about 80% of the maximum usable widths.

The specific results are highly influenced by channel geometry, transect location and transect characteristics, so while the trend in changes in usable width is generally similar among the transects, the absolute usable widths, as well as the shapes of the curves vary significantly among the locations. There are also year to year variations in each transect when freshet flows are high enough to rearrange the substrate in the channel, but the general results remain similar.

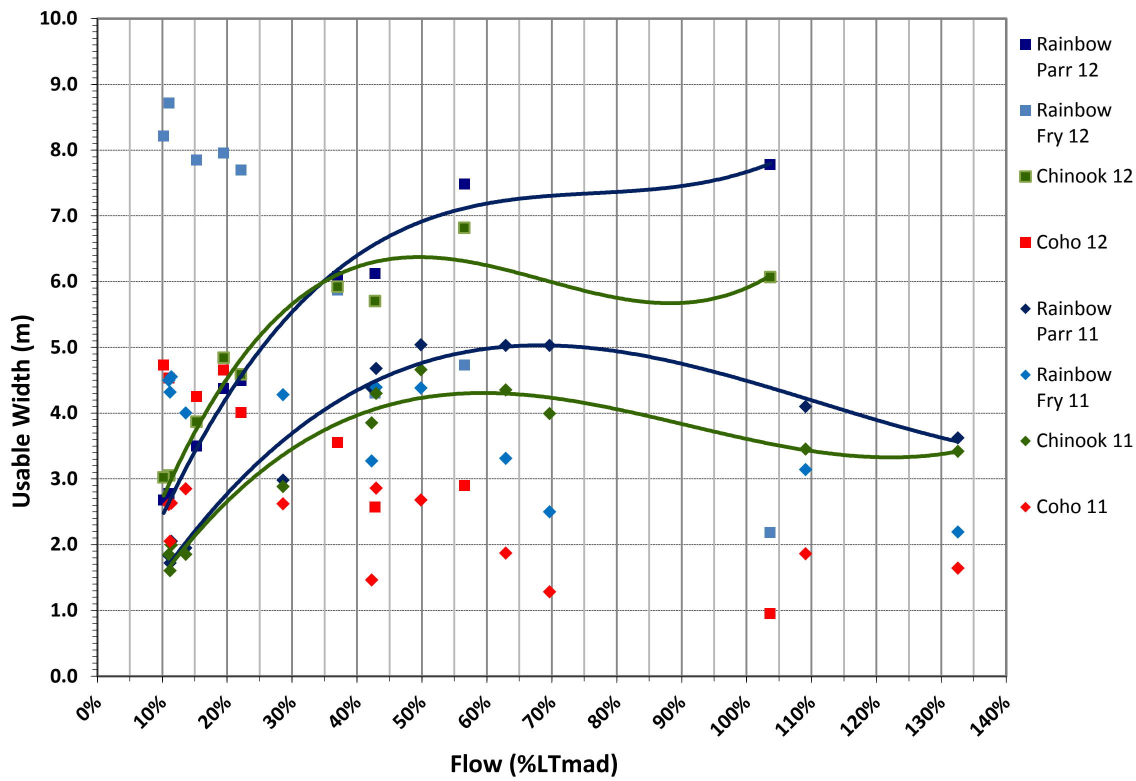


Figure 20. Weighted Usable Width vs. Flow as %LTmad in Riffle at Bessette 1

More specific values that correspond to maximum, medium (80%) and low (50%)[10] flows for rainbow trout parr and Chinook salmon juvenile rearing based on the weighted width curves for riffle transects are shown in Table 15. Note that these results are based on 1 to 2 seasons of measurements, with locations designated as A and B located in adjacent riffles at the same general location in the stream. These results demonstrate how usable habitat width varies with flow, but the values need to be considered as approximate due to the limited nature of the measurements. The results also need to be considered in the context of residual and naturalized flows, as optimal and even intermediate reference flows for some species and life stages are higher than natural flows during the applicable time periods.

[10] See definitions section on pages xiv to xvi for definitions of maximum, medium (50%) and low (50%) weighted usable width flows.

Table 15. Bessette Creek Watershed Maximum, Medium and Low Reference Flows as %LTmad for Rainbow Parr and Chinook Juvenile Rearing.

		Bes 1	Bes 2	Bes 2A	Bes 2B	Bes 3A	Bes 3B
Rainbow Parr	Maximum	65%	-	40%	55%	55%	55%
	Medium 80%	35%	-	20%	30%	30%	30%
	Low (50%)	15%	-	10%	15%	15%	15%
Chinook Juveniles	Maximum	55%	-	30%	40%	40%	45%
	Medium 80%	30%	-	15%	20%	20%	25%
	Low (50%)	15%	-	7%	10%	10%	15%

		Dut 1A	Dut 1B	Dut 2	Cre 1	Cre 2A	Cre 2B
Rainbow Parr	Maximum	60%	>50%	90%	95%	95%	>80%
	Medium 80%	30%	35%	60%	60%	60%	50%
	Low (50%)	15%	20%	30%	30%	30%	30%
Chinook Juveniles	Maximum	40%	>50%	75%	90%	80%	70%
	Medium 80%	20%	35%	45%	60%	50%	50%
	Low (50%)	10%	20%	20%	30%	25%	25%

4.2. Fish Habitat Usable Width in Glides

Glide Wetted Widths, Depths and Velocities

Weighted usable widths are determined by combinations of wetted width, depth and velocity. Figure 21, Figure 22, and Figure 23 demonstrate how wetted width, depth and velocity vary with flow expressed as %LTmad in the 12 riffle transects measured in 2011 and 2012.

As expected, the wetted width shown in Figure 21 is decreasing gradually with decreased flow expressed as %LTmad over most of the flow range. It is also apparent that wetted width is diminishing more rapidly as flow decreases below an inflection point at approximately 10%LTmad, particularly as demonstrated by the Bessette 2 transects where the lowest flows as %LTmad were measured. These width / flow relationship results demonstrate that depths and velocities are the determining factors for the weighted usable width at flows higher than 20%LTmad, but that declining wetted width also starts to significantly reduce the weighted usable widths for spawning at flows of less than 20%LTmad.

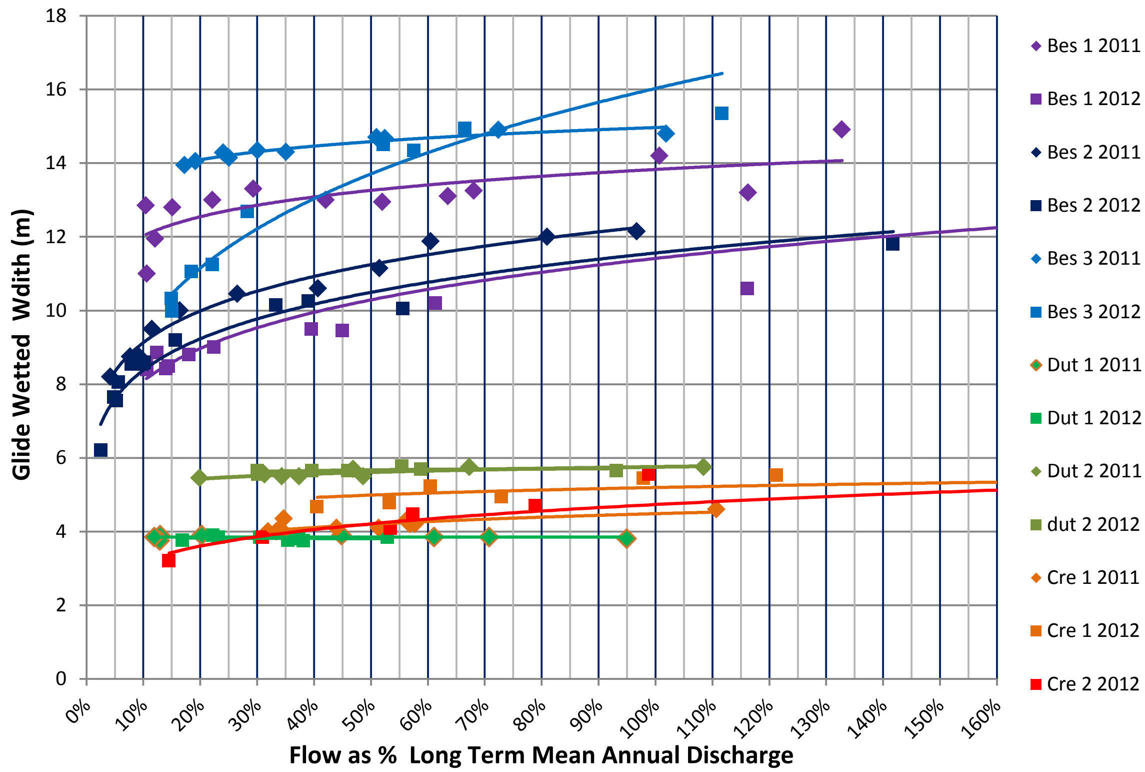


Figure 21. Glide Wetted Width vs. Flow as %LTmad in 2011 & 2012

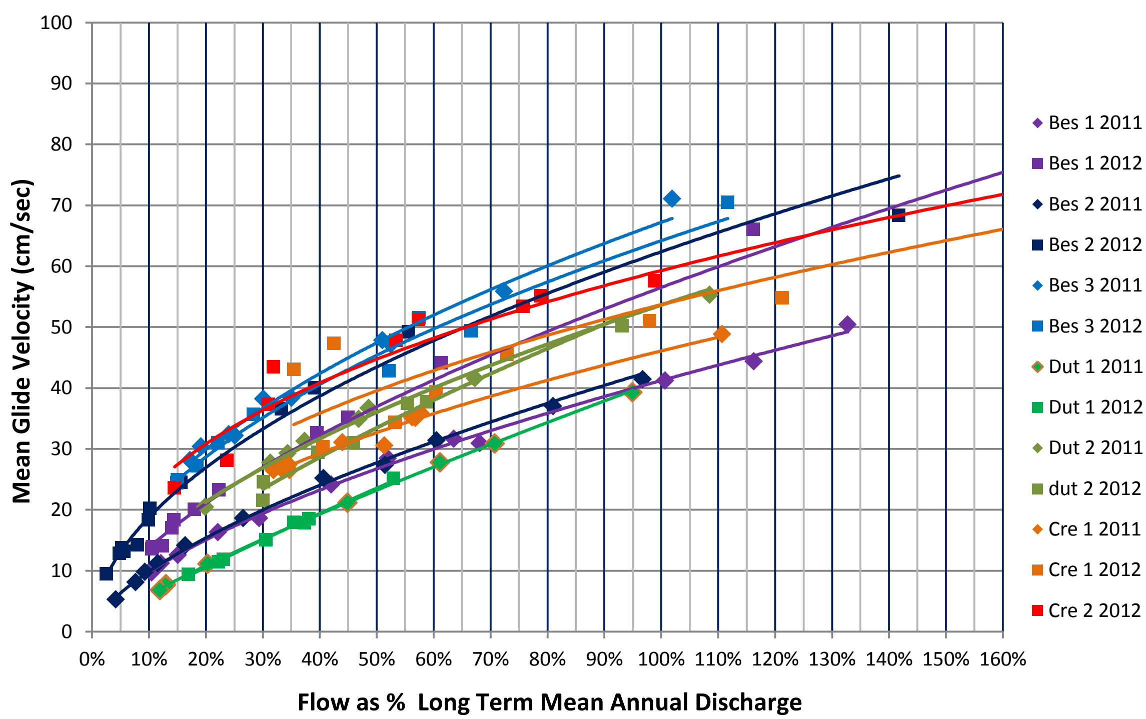


Figure 22. Glide Mean Velocity vs. Flow as %LTmad in 2011 & 2012

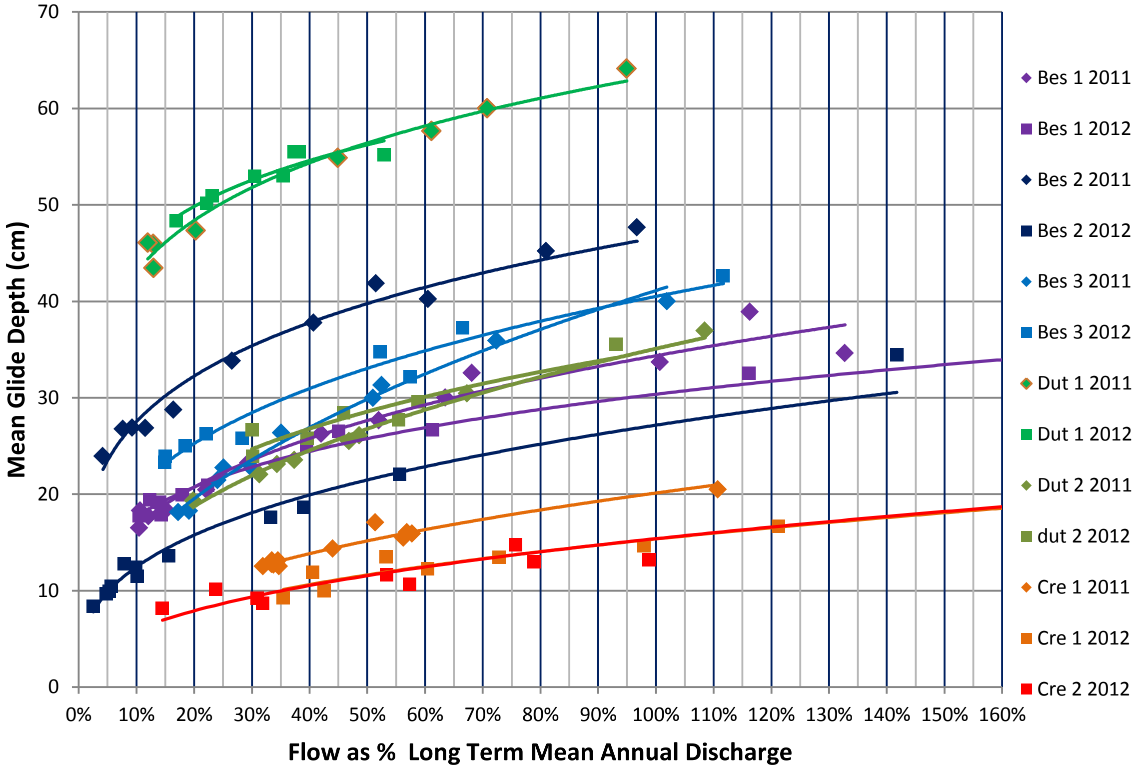


Figure 23. Mean Glide Depth vs. Flow as %LTmad in 2011 & 2012

Glide velocity also diminishes with decreasing flow with an inflection point in the rate of change for velocity that occurs at around 20%LTmad. The Habitat Suitability Index (HSI) information used to derive weighted usable width indicates the 100% probability of use velocity for Chinook salmon spawning is above 50 cm/sec, with 80% probability of use at 39 cm/sec, 50% probability of use at 24 cm/sec and no probability of use below 15 cm/sec. Coho Salmon have lower velocity preferences, with the 100% probability of use velocity for Coho salmon spawning between 46 and 71 cm/sec, with 80% probability of use at 30 cm/sec, 50% probability of use at 18 cm/sec, and no probability of spawning use below 7 cm/sec. Rainbow trout spawning velocity preferences are very close to Coho salmon, while the 100% probability of use velocity for Kokanee spawning is lower at between 30 and 61 cm/sec, with 80% probability of use at 24 cm/sec, 50% probability of use at 15 cm/sec, and no probability of use below 1 cm/sec. Figure 22 demonstrates that glide velocities are limiting spawning probability for all species at low flows, with the greatest impact on the high velocity preference Chinook Salmon which would require 10 to 30%LTmad (depending on the transect) to get above 0% probability of use. Coho salmon and rainbow trout minimum depths will be met at lower flows, but Coho would require up to 15%LTmad to get above 0% probability of use. Ideal velocities for Chinook and Coho spawning would generally require above 100%LTmad and are not likely to be achieved in most glide transects in the Bessette watershed.

Glide depths also diminish with decreasing flow, with inflection points for rates of change between 10% and 20%LTmad depending on the transect location. The 100 %

probability of use glide depth for Chinook salmon spawning is above 80 cm, with 80% probability of use at 69 cm, 50% probability of use at 52 cm and no probability of use below 24 cm. Coho Salmon have lower depth preferences, with 100% probability of use depth for Coho salmon spawning at 30 cm, with 80% probability of use at 29 cm, 50% probability of use at 24 cm, and no probability of spawning use below 6 cm. Rainbow trout spawning depth preferences are very close to Coho salmon, while 100% probability of use depth for Kokanee spawning is lower at between 15 and 30 cm, with 80% probability of use at 12 cm, 50% probability of use at 9 cm, and no probability of use below 2 cm. Figure 23 demonstrates that glide depths also limit spawning probability for all species at low flows, but not as much as the velocities. Greatest impact is on the high depth preference Chinook Salmon which would require 5 to 100%LTmad (depending on the transect) to get above 0% probability of use. Coho salmon and rainbow trout will have adequate depth for some spawning at all but the most extreme low flows but will require 30 to 100%LTmad to meet 100% probability for spawning based on depth.

Weighted Usable Widths for Spawning in Glide Transects

Weighted Usable width results are presented in Figure 24 (Bessette 1) and in Appendix C (all locations) for the glide transects measured in 2011 and 2012, focussing on rainbow trout and Coho and Chinook salmon and Kokanee spawning, and photographs of each transect at representative flows are included in Appendix D. Two sets of Chinook results are shown - one set based on the standard BC Chinook HSI curves, and a 2nd set based on the HSI curves for Washington State stream spawning Chinook. The weighted usable riffle results for rainbow trout, Chinook and Coho salmon and Kokanee spawning show a general trend of increasing weighted usable width with flow from negligible to very low values at 10% to 20%LTmad to maximum widths at flows of 40%LTmad to >100%LTmad depending on the species in Bessette and Duteau Creeks. Preferred depths and velocities for spawning increase with body size, so weighted usable widths for Kokanee spawning maximize at lower flows than the larger bodied rainbow trout and Coho, and Chinook require the highest flows to maximize weighted usable width for spawning. Creighton Creek deviates from the general trend for Bessette and Duteau Creeks due to the smaller stream size, with flows of greater than 100%LTmad to >300%LTmad required to maximize weighted usable width and negligible weighted usable width for the larger bodied fish at flows of less than 50%LTmad.

More specific values flows that correspond to maximum, medium (80%) and low (50%)[11] flows for rainbow trout and Coho and Chinook salmon spawning based on the weighted width curves for glide transects are shown in Table 16. Note that these results are based on 1 to 2 seasons of measurements at 1 transect at each location. These results demonstrate how usable habitat width varies with flow, but the values need to be considered as approximate due to the limited nature of the measurements. The results also need to be considered in the context of residual and naturalized flows, as maximum and even intermediate and low reference flows for some species and life stages are higher than natural flows during the applicable time periods.

[11] See definitions section on pages xiv and xvi for definitions of maximum, medium (50%) and low (50%) weighted usable width flows.

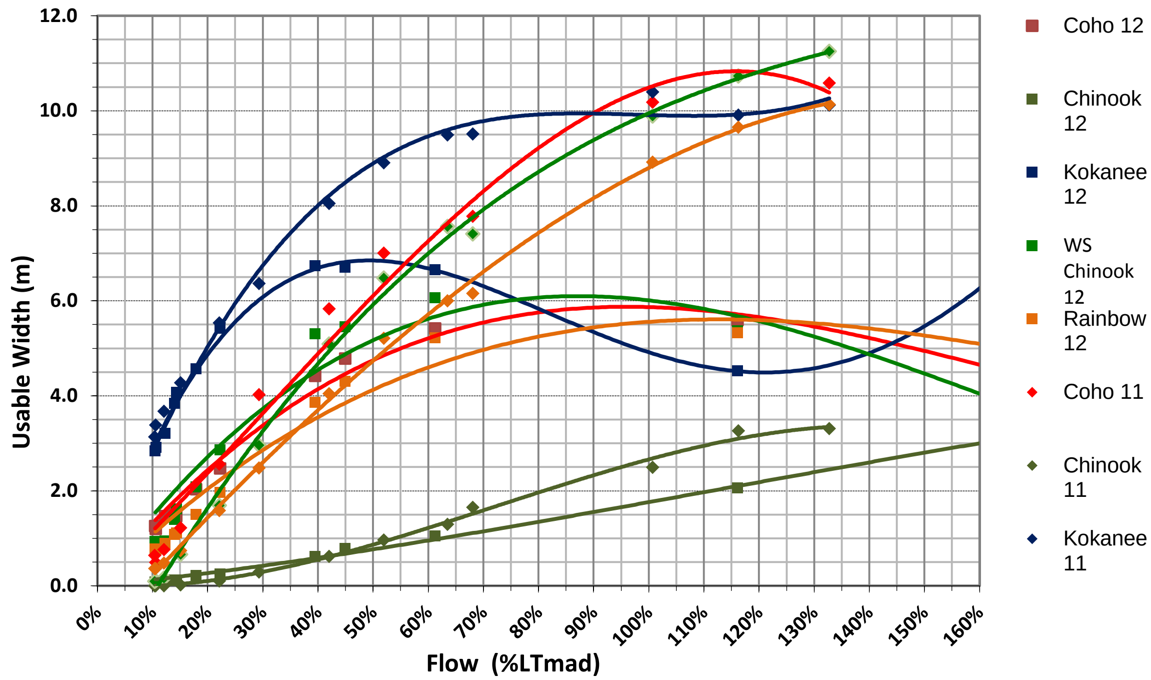


Figure 24. Weighted Usable Width vs. Flow as %LTmad in Glide at Bessette 1.

Table 16. Bessette Creek Watershed Maximum, Medium and Low Reference Flows as %LTmad for Rainbow Trout and Coho and Chinook Salmon Spawning.

		Bes1G	Bes2G	Bes3G	Dut1G	Dut2G	Cre1G	Cre2G
Rainbow Spawning	Maximum	120%	115%	95%	100%	110%	180%	280%
	Medium 80%	60%	80%	55%	70%	70%	110%	200%
	Low (50%)	30%	50%	25%	40%	45%	60%	80%
Kokanee Spawning	Maximum	60%	50%	45%	40%	55%	110%	110%
	Medium 80%	30%	30%	20%	20%	30%	55%	55%
	Low (50%)	20%	15%	10%	10%	15%	25%	30%
Coho Spawning	Maximum	100%	115%	80%	85%	100%	220%	>300%
	Medium 80%	60%	80%	40%	55%	65%	135%	250%
	Low (50%)	30%	55%	25%	30%	40%	85%	175%
WS Stream Chinook Spawning	Maximum	90%	110%	85%	85%	80%	160%	200%
	Medium 80%	50%	75%	50%	60%	60%	90%	100%
	Low (50%)	25%	45%	20%	40%	30%	50%	50%
Chinook Spawning	Maximum	130%	>140%	110%	100%	110%	>300	>300%
	Medium 80%	100%	120%	70%	70%	80%	250%	300%
	Low (50%)	65%	100%	45%	50%	60%	175%	250%

4.3. Minimum Riffle Passage Flows for Spawning

Riffles represent the shallowest sections in the streams, and as such, can limit fish access to spawning areas if riffles become too shallow to allow fish passage. Reiser and Bjornn (1979) indicate the following as minimum passage depths for fish migrating to spawning areas, and recommend that at least 25% of the wetted channel width meet these minimum depths.

Chinook Salmon	0.24 m
Coho Salmon	0.18 m
Large Trout	0.18 m
Trout	0.12 m

Figure 25 shows the 75th percentile (25% of the values are greater than this) depths for each riffle at the flows measured in this study, with reference depths of 12, 28 and 24 cm. As noted for the usable width results, the Bessette 2 riffle site in 2011 also had unusually deep riffle depths which are not typical of the riffles which constrain fish passage at low flows in Bessette Creek.

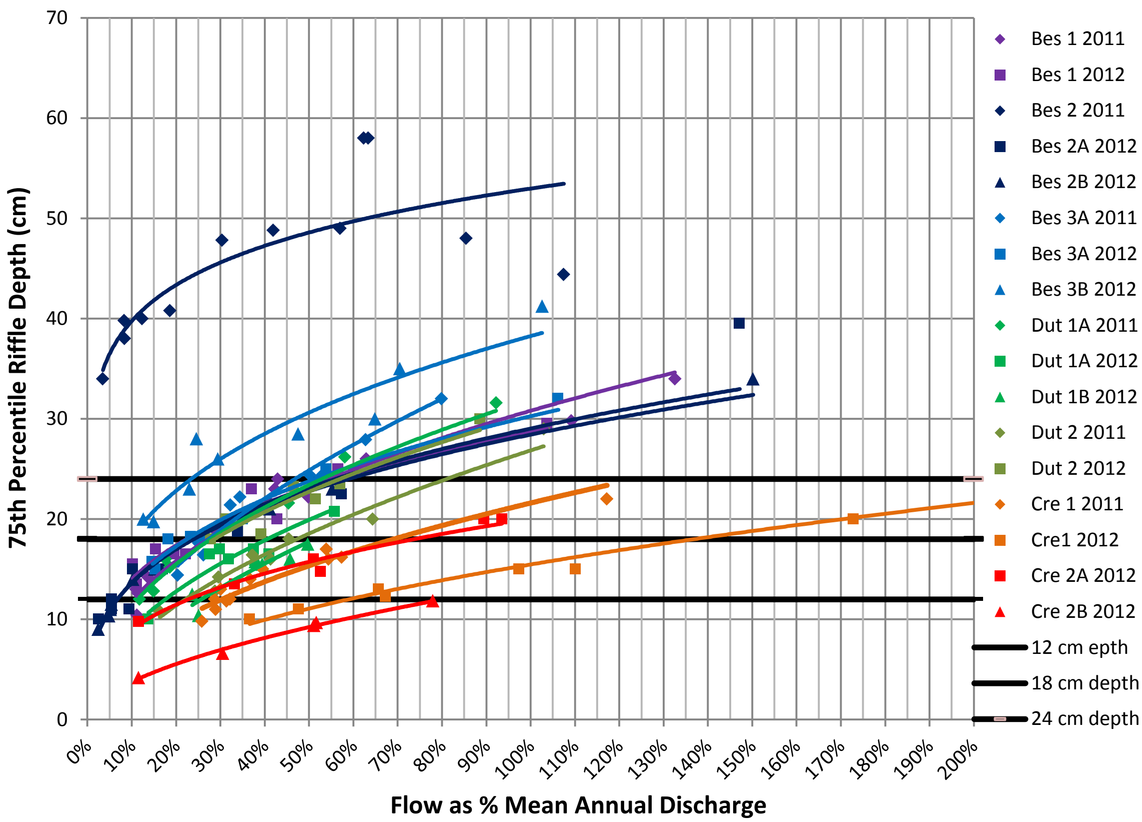


Figure 25. 75th Percentile Riffle Depth vs. Flow as %LTmad in 2011 & 2012

Table 17 shows the stream flows, expressed as %LTmad, on Figure 25 that correspond to the minimum fish passage depths. For the purposes of this assessment, Kokanee are assumed to have the same depth requirements for migration as trout, and adfluvial rainbow trout and stream spawning Chinook are assumed to have similar depth requirements as Coho.

Table 17. Bessette Creek Minimum Riffle Passage Flows as %LTmad for Rainbow Trout and Coho and Chinook Salmon Spawning.

	Bes 1	Bes 2	Bes 2A	Bes 2B	Bes 3A	Bes 3B
Adfluvial Rainbow Trout	25%	-	25%	25%	25%	10%
Kokanee	10%	-	7%	7%	10%	5%
Coho Salmon	25%	-	25%	25%	25%	10%
WS Stream Chinook	25%	-	25%	25%	25%	10%
Chinook Salmon	55%	-	55%	55%	50%	25%

	Dut 1A	Dut 1B	Dut 2	Cre 1	Cre 2A	Cre 2B
Adfluvial Rainbow Trout	35%	50%	40%	90%	35%	90%
Kokanee	15%	25%	20%	35%	12%	35%
Coho Salmon	35%	50%	40%	90%	35%	90%
WS Stream Chinook	35%	50%	40%	90%	35%	90%
Chinook Salmon	60%	85%	70%	150%	75%	150%

The values in Table 17 indicate that while riffle depths will be adequate for Kokanee passage at 10%LTmad in the Bessette Creek riffles, flows of 25%LTmad are specified for larger bodied fish such as Coho salmon and full sized Chinook salmon passage typically would benefit from > 50%LTmad. Even greater %LTmad flows are specified for passage in the Duteau and Creighton Ck riffles due to the shallower depths at comparable %LTmad in these narrower stream channels.

4.4. Fish and Fish Habitat vs. Stream Flows

Table 15, Table 16 and Table 17 indicate a wide range of weighted usable width vs. flow results and riffle passage flow results, beginning with 10%LTmad as the minimum flow for some species and life stages (e.g. Kokanee spawning and passage in Bessette Creek) to over 300%LTmad for optimal flows for Chinook salmon spawning in Creighton Creek. As indicated in the discussion of those results, weighted usable width results can be used to provide general guidance for flow requirements by species and life stage in these streams, but need to be considered in terms of residual and naturalized flows in order to establish realistic expectations.

Residual Flows vs. Reference Flows

Flow values of 10%, 20%, 30%, 60% and 100%LTmad are shown against historic residual flows on Figure 26, Figure 27, Figure 28 and Figure 29 for Lower Bessette, Bessette above Lumby, Duteau and Creighton Creeks respectively.

Figure 26 shows that for lower Bessette Creek, spring freshet flows satisfy the ecological requirements as per the periodicity chart in Table 3, and rainbow trout spawning flows. August has the lowest flows, with median (P50) flows close to 20%LTmad, but historic flow values in 10% of years (P10) fall below 10%LTmad, and flows as low as 10%LTmad occurred in both 2009 and 2010. Flows generally increase in September due to a combination of less irrigation, conservation storage releases and wetter fall weather, but in 25% of the years (P25), September flows are still below 20%LTmad and median (P50) September flows remain below 30%LTmad.

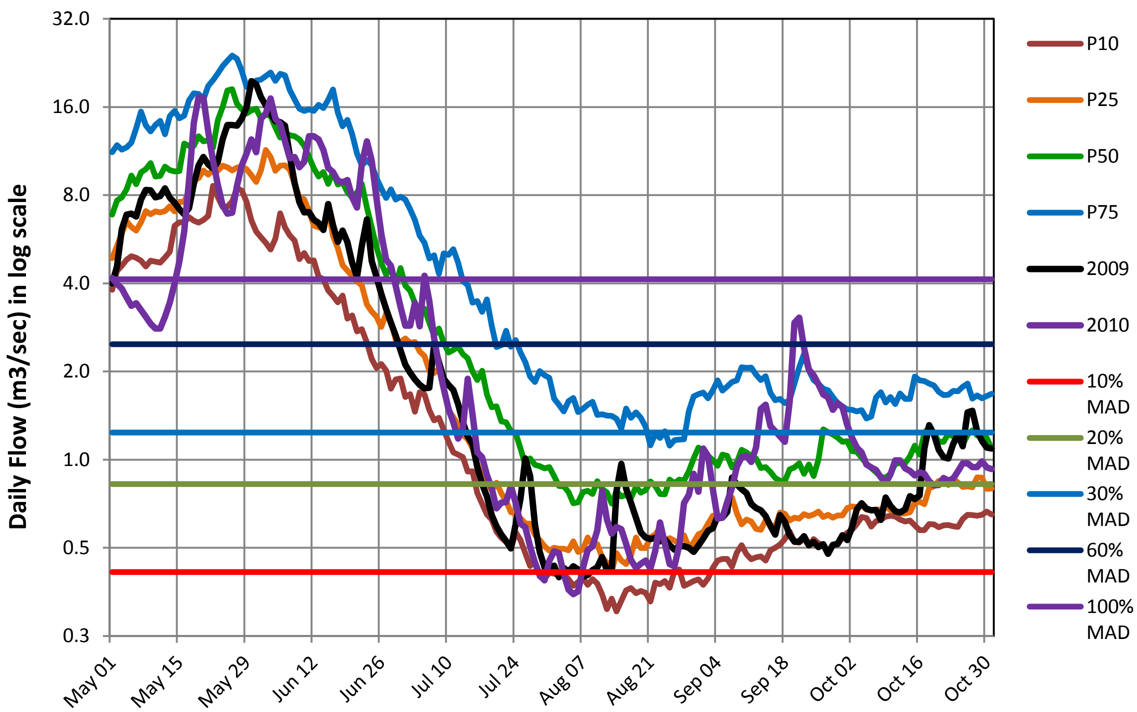


Figure 26. Statistical Daily Flows at Bessette Ck above Beaverjack Ck for the period from 1970 to 2010 with %LTmad Flows and 2009 and 2010 Flows.

The Bessette Creek above Lumby flows in Figure 27 show historic data to 1983, so may not be an accurate reflection of current flows based on current land use and water releases from the Nicklen Lake storage. Figure 27 shows that spring freshet flows in Bessette Creek above Lumby also satisfied ecological requirements as per the periodicity chart in Table 3, and rainbow trout spawning flows. Median (P50) flows were less than 10%LTmad for August and much of September, but 30%LTmad was achieved in September in 25% of the years (P75).

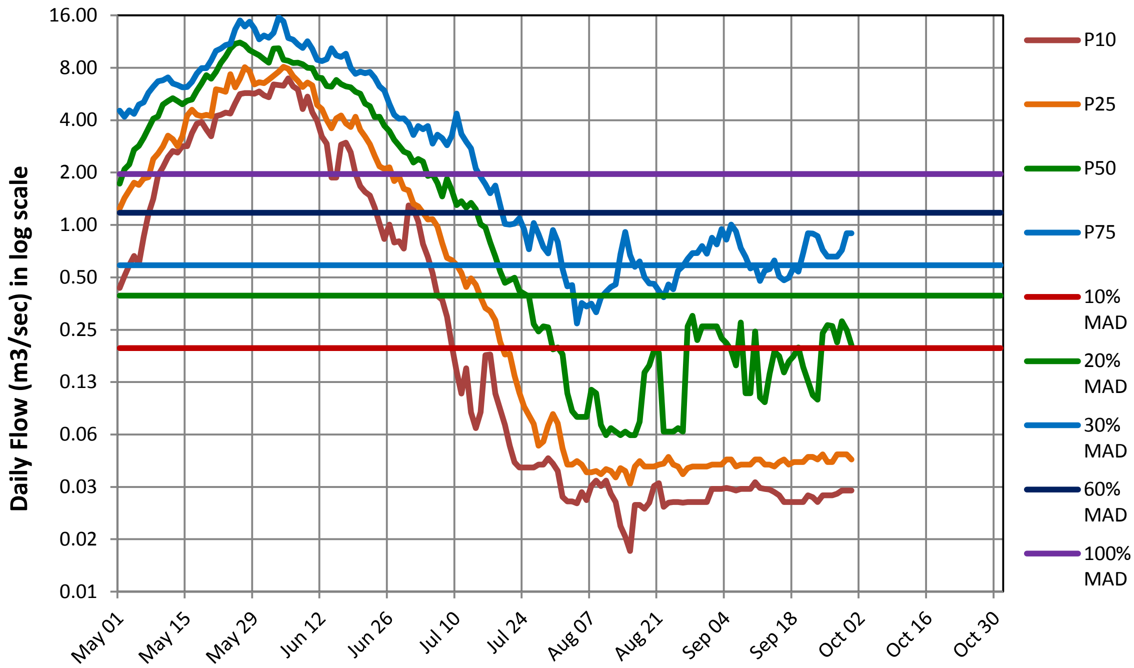


Figure 27. Statistical Daily Flows at Bessette Ck above Lumby for the period from 1919, 1943 to 1948 and 1965 to 1983 with %LTmad Flows.

The Duteau Creek flows in Figure 28 show historic data ending in 1996, so this may not be an accurate reflection of current flows as the data predates current fish flow release policies. The data shows highly regulated flows with a significantly diminished freshet relative to Bessette Creek and Creighton Creeks, and low summer and fall flows. Spring freshet flows in Duteau Creek had median (P50) flows at 200%LTmad, but 25% of the years (P25) have flows between 60% and 100%LTmad. Ecological requirements like flushing flows as per the periodicity chart in Table 3 were only met by median and greater flows, and rainbow trout spawning flows were only met at the flows that occurred in 25% of the years (P25). Median (P50) flows were at about 20%LTmad for August, but dropped below 20%LTmad in mid September and October, and flows in 25% of the years (P25) were below 10%LTmad from the end of June through to the end of October.

The Creighton Creek flows in Figure 29 show a short term historic data set starting in 1959 and ending in 1966. The WSC site was above most of the water licences with no flow regulation, so flows could still reasonably represent conditions at this site. Creighton Creek spring freshet flows satisfy the ecological requirements as per the periodicity chart in Table 3, and rainbow trout spawning flows. August has the lowest flows, with median (P50) flows close to 20%LTmad, but the calculated 10th percentile value (P10) is around 10%LTmad. Flows generally increase in September and October due to wetter fall weather. The calculated 25% of the years flow (P25) was above 20%LTmad and median flows approached 60%LTmad in late October. Since these flows were measured above most of the Creighton Ck water use, significantly lower flows should be expected from July through September in lower Creighton Creek near the confluence with Bessette Creek.

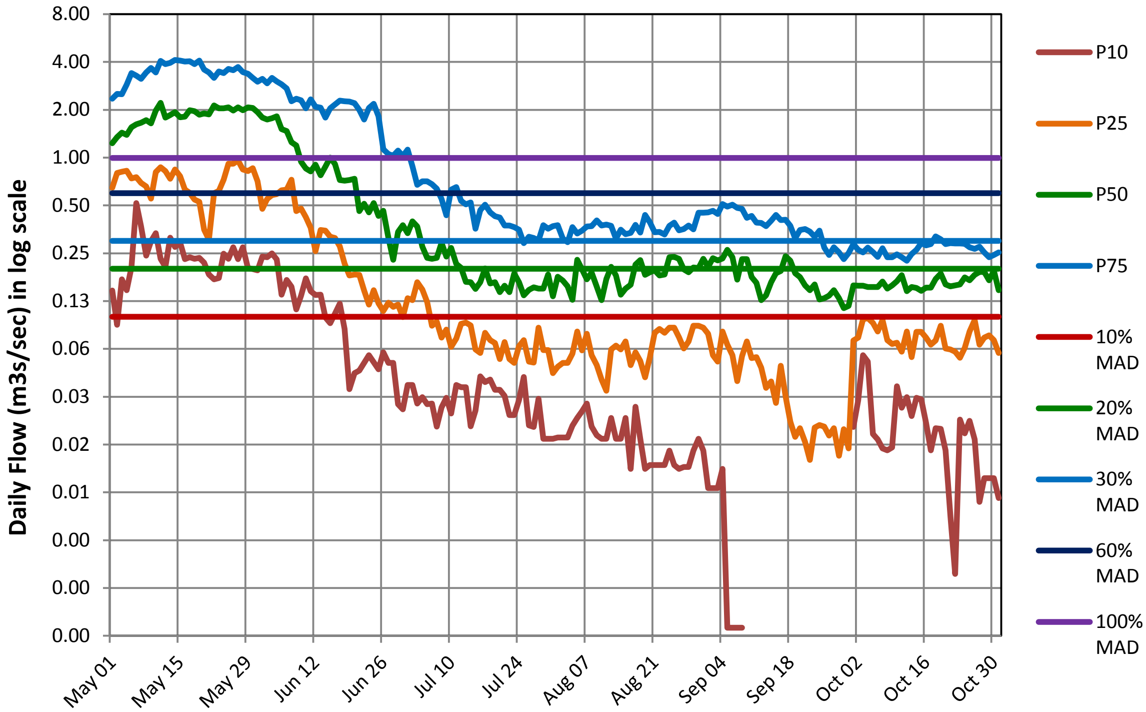


Figure 28. Statistical Daily Flows at Duteau Ck near Lavington for the period from 1919 to 1921 and 1935 to 1996 with %LTmad Flows.

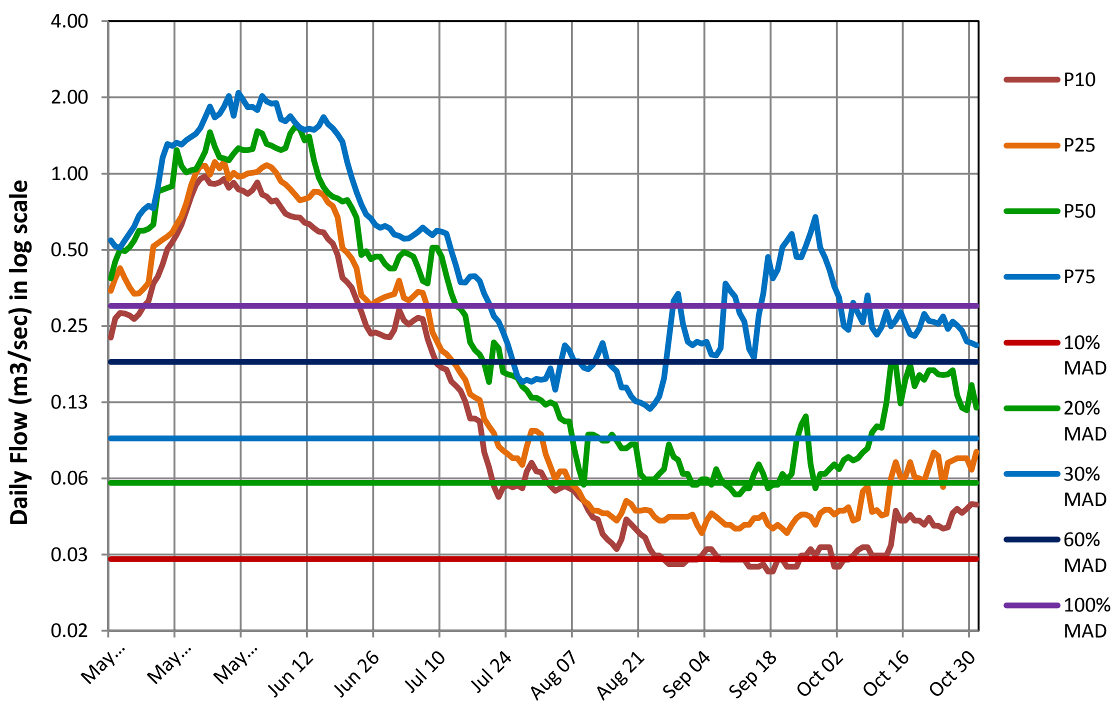


Figure 29. Statistical Daily Flows at Creighton Ck near Lumby for the period from 1959 to 1966 with %LTmad Flows.

Chinook and Coho Salmon Spawner Counts vs Bessette Creek Flows

A limited amount of salmon spawner enumeration data is available to compare spawning fish numbers to flows as shown in Table 18. Chinook counts are available starting in 2008, and Coho counts from 2005. Peak spawning dates are available for Bessette Creek and for Chinook in Duteau Creek.

Table 18. Bessette and Duteau Creek Chinook and Coho Spawner Counts and Peak Spawning Dates.

	Bessette				Duteau			
Year	Chinook		Coho		Chinook		Coho	
2005	-	-	15	14 Nov	-	-	191	-
2006	-	-	21	20 Nov	-	-	26	-
2007	-	-	68	-	-	-	363	-
2008	71	24 Sep	51	19 Nov	6	23 Sep	103	-
2009	25	28 Sep	46	24 Oct	3	16 Sep	110	-
2010	135	26 Sep	53	27 Oct	49	30 Sep	369	-
2011	8	26 Sep	46	28 Nov	0	-	193	-

Table 19 compares the total numbers of Chinook and Coho spawners for Bessette and Duteau Creeks combined with the mean September, October and November flows in lower Bessette Creek. Spawner numbers are combined for Duteau and Bessette as there is no flow data for Duteau Creek for the comparison.

Table 19. Combined Bessette and Duteau Creek Chinook and Coho Spawner Counts and Mean Monthly Flows for September to November in Bessette Creek.

	Spawner Numbers		Mean Monthly Flows (%LTmad)		
Year	Coho	Chinook	Sept	Oct	Nov
2005	206		33%	59%	39%
2006	47		18%	19%	24%
2007	431		15%	30%	21%
2008	154	77	17%	18%	24%
2009	156	28	15%	22%	22%
2010	422	184	34%	23%	24%
2011	239	8	26%	29%	24%

These spawner numbers are plotted against mean annual September flows for Chinook, and against both mean annual October and November flow for Coho in Figure 30.

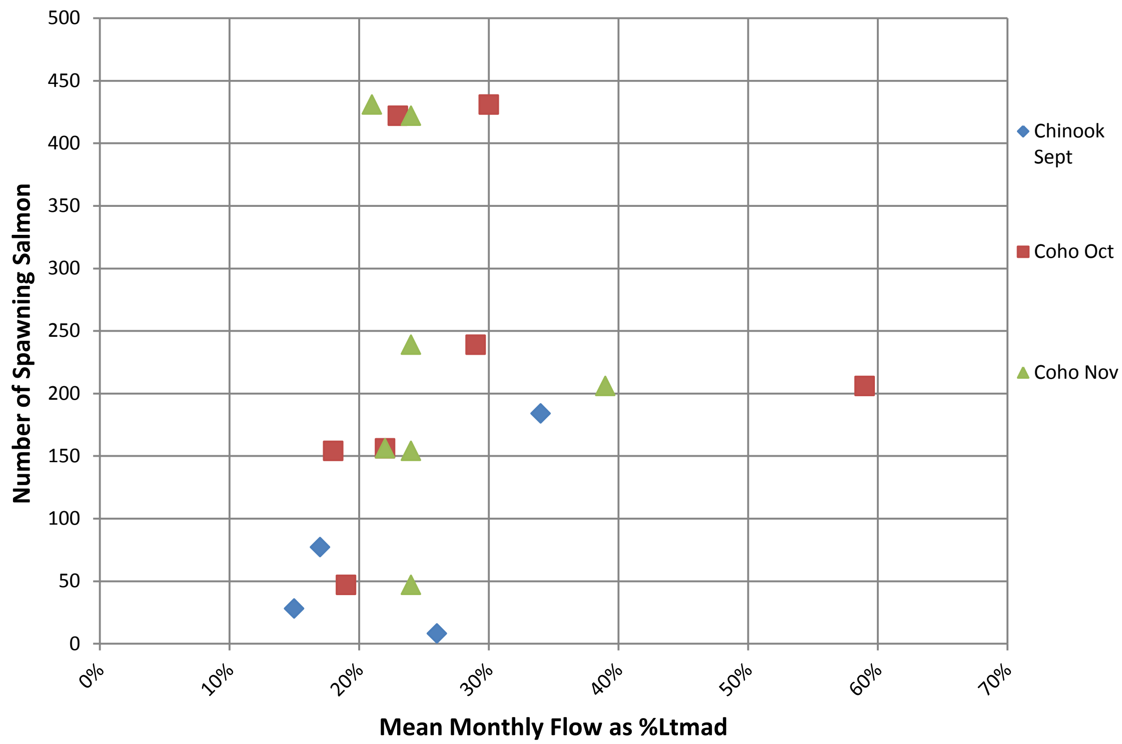


Figure 30. Chinook and Coho Salmon Spawning Numbers vs September (Chinook) and October and November (Coho) Mean Monthly Flows in Lower Bessette Creek.

The data presented in Figure 30 for Coho and Chinook spawner numbers between 2005 and 2011 does not show much correlation with the lower Bessette Creek mean monthly flows during the spawning periods. This is not surprising because the number of years with data is low and the correlation is with Bessette Creek flows while much of the Coho spawning occurs in Duteau Creek. Also, the number of fish returning to the Shuswap River each year is variable, so fish numbers can be low due to factors which are unrelated to Bessette and Duteau Creek flows.

Several observations and inferences can be made though based on Figure 30. First, both Chinook and Coho salmon spawners were present when mean monthly flows in Bessette Creek were under 20%LTmad. This may indicate that some fish passage occurs at less than the minimum passage flows shown in Table 17, or that there were enough days with higher flows within the month to allow for fish passage. Second, while there is little correlation between spawner numbers and flows due to low spawner numbers at some higher flows, the highest number of Chinook spawners is at >30%LTmad, and the numbers are low for both years with less than 20%LTmad September flows. Similarly, the highest numbers of Coho occur when October and November flows exceed 20%LTmad, and the lowest numbers occur when October flows are less than 20%LTmad.

5. RECOMMENDED ENVIRONMENTAL FLOW TARGETS FOR THE BESSETTE CREEK WATERSHED

Formal instream flow targets for the Bessette Creek watershed, including Bessette, Duteau and Creighton Creeks would be set by Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) and/or Department of Fisheries and Oceans (DFO) staff through a process such as a Water Use Plan or the Fish Protection Act. The following discussion suggests how the Fish Periodicity information from Table 3 could be used in conjunction with the BC-Modified Tennant (Hatfield, et al, 2003) and the PHABSIM Weighted Usable Width results and the Riffle Passage results described in Section 3.3 to set instream flow targets for the Bessette Creek watershed. The Chinook and Coho Salmon Spawner Counts vs Bessette Creek Flows from Section 3.4 are also taken into account in these recommendations.

Relative to the annual hydrologic cycle, the first consideration is for channel maintenance as well as migration and spawning flows associated with spring freshet. Short term flows of up to 400%LTmad are recommended for sediment flushing and channel maintenance, with longer term freshet flows of up to 200% LTmad on the shoulders of the peak providing the cues for smolt out migration and spawning by rainbow trout, as well as migration in and out by the adfluvial rainbow trout. The PHABSIM results in Table 16 indicate that flows of 50% to 100% LTmad will provide for medium to high levels spawning width in Bessette and Duteau Creeks, and the riffle passage results in Table 17 indicate that flows of 25% to 50% LTmad are required for the adfluvial rainbow trout migration after spawning.

Following freshet, there are requirements for summer rearing flows for resident rainbow trout adults, rainbow trout parr and fry, and Coho and Chinook salmon juveniles, with rainbow trout and Chinook salmon have the highest flow requirements.

Table 15 indicates that 20 to 30% LTmad will provide for a medium level of usable width in Bessette and Duteau Creek for rainbow trout and Chinook salmon rearing. These flows are high for rainbow trout and Coho fry which will adjust by moving to slower water along the stream margins and outside of the riffles.

Spawning migration for Chinook salmon begins in summer if flows and temperatures are adequate, and continues into September with spawning in September and October. Coho salmon begin spawning migration in September with spawning from October through December. Kokanee migration and spawning takes place in September and October. Kokanee have lower migration and spawning flow requirements than Coho and Chinook salmon, and will have adequate migration and spawning at the minimum flows that sustain salmon migration and spawning. Table 17 indicates that minimum flows of 25%LTmad are required for Coho salmon passage up Bessette Creek, with flows of 50% plus required for the larger bodied Chinook salmon. Relatively short duration flows at these levels will be adequate for upstream movement, but adequate flows to maintain the fish at the destination are also required to prevent pre spawning mortality. Table 16 indicates that Coho and Chinook salmon spawning will be low at the migration flows, with weighted usable width for salmon spawning increasing to flows greater than 100%LTmad.

The final stage in the annual hydrologic cycle are overwintering flows for Coho and Chinook salmon and Kokanee egg incubation, and rainbow trout juvenile and resident adult as well as Coho and Chinook salmon juvenile overwintering. Minimum flows of 20%LTmad are generally recommended to prevent egg damage and ice free refuge areas for the overwintering fish.

Table 20 presents the instream flows as discussed above in a BC-Tennant style table with monthly flow recommendations as %LTmad, and median monthly and lower quartile monthly flows for lower Bessette Creek.

Table 20. Instream Flow Recommendations as %LTmad for Bessette Creek watershed, with monthly target flows compared to median monthly flows and lower quartile flows at the Bessette Creek WSC station No. 08LC039 (above Beaverjack Creek).

Month	Target % Mean Annual Discharge*	Instream Flow Target (m^3/s)	Median Monthly Flow (m^3/s)	Lower Quartile Monthly Flow** (m^3/s)
January	20	0.84	0.80	0.59
February	20	0.84	0.79	0.56
March	20	0.84	1.22	0.98
April	100	4.2	3.8	2.72
May	200	8.4	12.5	9.89
June	100	4.2	10.1	6.94
July	40 - 20***	1.68 - 0.84***	2.05	1.42
August	20	0.84	0.90	0.59
September	25 - 100****	1.05 - 4.20****	1.02	0.70
October	25 - 100****	1.05 - 4.20****	1.12	0.77
November	25	1.05	1.18	0.90
December	20	0.84	0.95	0.68

* Mean annual discharge (MAD) calculated as 4.2 m^3/s.

** Lower Quartile Flow approximates the 1 in 4 year mean monthly low flow.

*** High end of flow range is for early July for adfluvial trout spawning / migration, reducing to summer rearing by mid July

**** Spawning target flows as % MAD are shown as the minimum riffle passage flows which also represent relatively minimal weighted usable width for spawning up to spawning flows that represent medium to high levels of weighted usable width for spawning. Passage and spawning flows can satisfied by shorter duration flows than monthly during the fall spawning period.

6. NICKLEN LAKE STORAGE RELEASE STRATEGY

6.1. Purpose of Storage Release Strategy

The purpose of the storage release strategy is to present a new water release plan to both meet downstream irrigation needs and optimize downstream environmental values.

6.2. Nicklen Lake Water Storage Licences

Nicklen Lake, a naturally occurring waterbody, was developed as a water storage reservoir in about 1939 (BC Ministry of Environment, 1978). The reservoir now has a surface area of 88.9 ha, a total volume of 10,978 ML (Figure 31) with available live storage of 2,304 ML (21 % of total volume) when full. At the full drawdown of 2.9 meters, the lake area is reduced to 70.9 ha with a remaining depth of 38 m. Water is released into Nicklen Creek through two means : (1) over the crest of a spillway once the reservoir exceeds full pool (Figure 32), and (2) through a manually operated lower level release valve located 2.9 m below the full pool elevation (Figure 33 and Figure 34). The MFLRNO, Fish and Wildlife Division, Penticton office shares responsibility for operation of the dam and water releases, but historically, MFLNRO has made arrangements for a local resident (one of the agricultural licencees) to operate the valve.

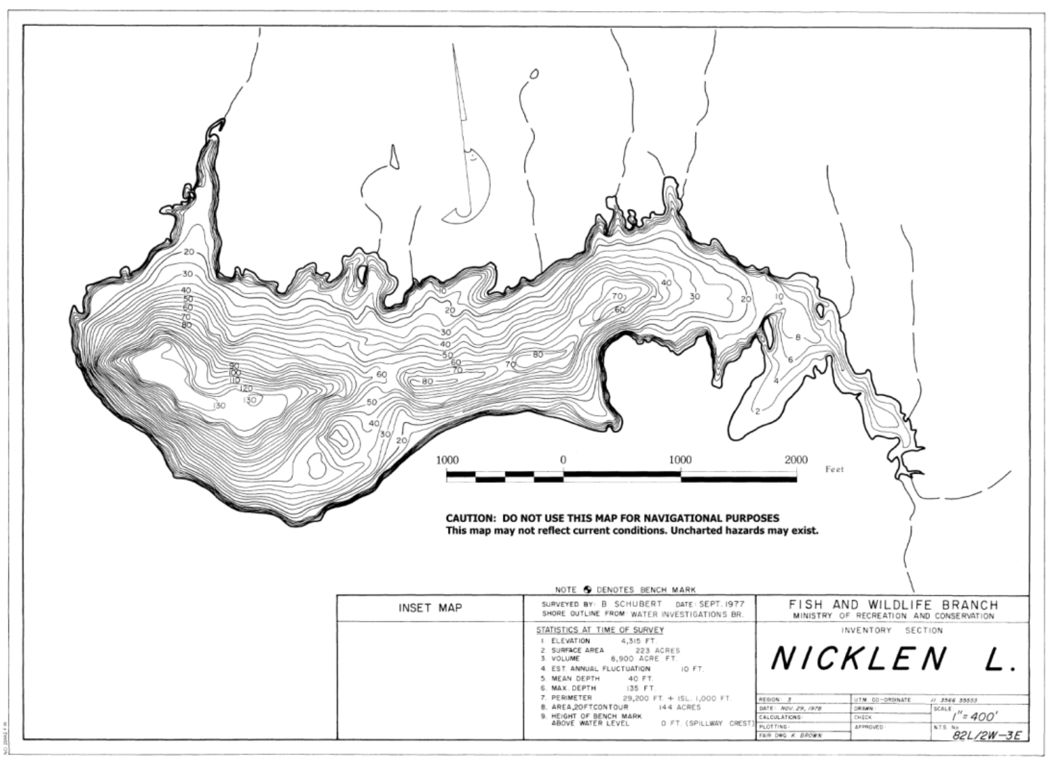


Figure 31. Nicklen Lake bathymetry**.**

Figure 32. Upstream view of spillway crest at Nicklen Lake outlet on June 20, 2012.

Figure 33. Upstream view of Nicklen Creek with old flume and water release pipe in background taken on May 29, 2013.

Figure 34. View from dam on Nicklen Lake to screw gate which controls the water release valve.

There are six water licences issued for water storage in Nicklen Lake to support agricultural irrigation in the Bessette Creek watershed. The licences have priority dates ranging from 1947 to 1969 and authorize a combined storage volume of 822 ML. There are 9 irrigation licences associated with the storage for a combined authorized annual use of 509 ML. These irrigation licences have priority dates ranging from 1893 to 1969.

There is also one conservation storage licence held by the BC Ministry of Forests, Lands and Natural Resource Operations for 1,480 ML, issued in 2002 with a priority date of 1989. The conservation storage is intended to be released as needed to supplement flows in Bessette Creek for improved rearing flows for juvenile rainbow trout and Chinook salmon in August and September, as well as spawning flows for Chinook and Coho salmon from August through to November.

6.3. Water Use and Conservation Storage Relative to Residual Flows

Releases from Nicklen Lake to support agricultural irrigation are made by the storage licence holders, and there was no formal agreement or operating policy in place to guide releases of the conservation storage when this project was initiated. As such, it is understood that the conservation storage was not routinely released unless requested by Ministry staff (as occurred in late September of 2009) or there was a need to lower storage in the fall for dam maintenance.

The volume of the storage licences is more than adequate to cover the entire seasonal water use authorized by the associated irrigation licences, but it is also understood that storage was historically not released until August, unless flows at the diversion points in Bessette Creek became low relative to withdrawal volumes, with no defined flow level at which to begin storage releases. There are no records for when the storage release was ended each year, but it is understood that the storage release gate needs to be closed in late October or early November each year to ensure that winter weather doesn't hamper closing the gate.

Table 21 shows historic median mean monthly flows in Bessette Creek at the lower WSC station above Beaverjack Creek for August through November in relation to estimated irrigation water use and potential flow increases that could be achieved if the conservation flows were released over periods of 60, 90 or 120 days duration. Flow values are shown both as m^3/sec and as %LTmad for comparison to reference flow levels and the recommended instream flows in Table 20.

Table 21. Bessette Creek Median of Mean Monthly Flows, Estimated Water Use for Irrigation and Potential Flow Increases from Release of Nicklen Lake Conservation Storage.

	Median of Mean Monthly Residual Flows				Estimated Water Use		Nicklen Lake Conservation Storage		
	Aug	Sep	Oct	Nov	Aug	Sep	60 days	90 days	120 days
Lower Bessette (m^3/sec)	0.90	1.02	1.12	1.18	0.482	0.193	0.286	0.190	0.143
Lower Bessette (%LTmad)	22%	25%	27%	29%	12%	5%	7%	5%	3%

Table 21 demonstrates that while estimated water use is high relative to flows for the lower Bessette Creek site, median residual flows are above 20%LT in August and in the 25% to 29%LTmad range in September through November. Full use of the Nicklen Lake conservation storage over a 60 to 120 day period could add another 3% to 7%LTmad to the monthly flows in lower Bessette Creek. With median or greater flows, use of conservation storage in the fall would meet August reference flows of 20%LTmad and September to November reference flows of 30%LTmad without any reductions in the estimated water use.

Median flows should be met 50% of the time, but flows have tended to be lower over the past 10 years. From 2001 to 2010, mean monthly August flows were below median (P50) in 8 years and September, October and November flows were below median (P50) in 7 years. The lowest flows in the past decade occurred in 2003, with record low flows in August and very low flows in September to November. Table 22 shows the same analysis as in Table 21, but for 2003 rather than the historic median flows at the WSC station above Beaverjack Creek.

Table 22. Bessette Creek 2003 Mean Monthly Flows, Estimated Water Use for Irrigation and Potential Flow Increases from Release of Nicklen Lake Conservation Storage.

	2003 Monthly Residual Flows				Estimated Water Use		Nicklen Lake Storage		
	Aug	Sep	Oct	Nov	Aug	Sep	60 days	90 days	120 days
Lower Bessette (m^3/sec)	0.16	0.45	0.76	0.83	0.482	0.193	0.286	0.190	0.143
Lower Bessette (%LTmad)	4%	11%	18%	20%	12%	5%	7%	5%	3%

Table 22 demonstrates the high impact that water use withdrawals can have on August and September flows in very dry years like 2003, where the estimated water use is much higher than the residual flows. It is extremely important to fully utilize the agricultural storage in Nicklen Lake in these dry years, in conjunction with the conservation storage. While use of Nicklen Lake conservation storage could have increased Bessette Creek flows significantly, they still would only have been sufficient to raise rearing flows to 10%LTmad for juvenile rainbow trout and Chinook salmon in August and to increase spawning flows for Chinook to 19%LTmad in September, with nothing left for release in October or November. Adding the estimated water use to the residual flows suggests that naturalized flows would have been around 16%LTmad in August and September in the absence of water use. This indicates that water use reductions in August and September in conjunction with agricultural and conservation storage releases would also have been highly beneficial to achieve higher spawning flows for Chinook in September and higher Coho spawning flows in October and November.

6.4. Nicklen Lake Refill

Uncertainty has been expressed regarding the annual refill of Nicklen Lake if most or all of both the agricultural and the conservation storage is used. It is understood that Nicklen Lake has refilled every year based on the irrigation releases, but the irrigation storage is only about one third of the full storage capacity of Nicklen Lake. As such there is no history of how well Nicklen Lake would refill from significantly more drawdown each year. An evaluation of the annual runoff volume into Nicklen Lake is provided in Appendix F.

These refill calculations show that Nicklen Lake should refill completely from full drawdown under average to dry conditions (5 year return period), but that complete refill from full drawdown should not be expected in significantly drier than average conditions (10 year return period), and that under extremely dry conditions (20 year return period) only about 70% of the storage capacity would be refilled. This demonstrates that there will always be enough refill to satisfy irrigation storage, but the full volume of conservation storage may not be available following years with low refill.

Since the agricultural storage will always be satisfied, no year to year adjustments to the recommended storage releases for agricultural users should be needed. The full volume of conservation storage may not however be available in all years, so reductions of the recommended conservation storage releases will be needed if Nicklen Lake has not completely refilled by about July 1.

6.5. Recommended Nicklen Lake Storage Releases for Agricultural Users

The agricultural irrigation licences associated with the agricultural portion of the storage total 509 ML / year, and all of the irrigation licences associated with the Bessette Ck portion of the watershed upstream of Lumby total 979 ML / year relative to the agricultural storage volume of 822 ML. As such it had been assumed that all of the mid to late summer water use by the agricultural water users that have access to Nicklen Lake storage was being offset by Nicklen Lake storage releases. It became apparent in 2011 and 2012 however, that Nicklen Lake storage release was actually only being initiated in late August when Bessette Creek flows were already quite low. The releases continued well past the end of the irrigation season in September, blending agricultural release and conservation release. Given that the Nicklen Lake agricultural storage exceeds the volume of associated licences, storage releases to support agricultural diversions should be starting earlier in the summer, with additional conservation storage releases as needed starting in August or September as needed.

Meeting peak demands for the licences associated with the storage requires a flow equivalent to about 1% of the licenced volume of 509 ML which equates to 0.060 m^3/sec, and which could be sustained for a period of 160 days (entire irrigation season) from a storage volume of 822 ML, well beyond the needs of those licences. Meeting peak demands for all of the licences along Bessette Ck upstream of Lumby would require 0.113 m^3/sec which could be sustained for 84 days (most of July, August and September) based on the storage, and spreading the agricultural storage over a 61 day period (August and September) would allow for a release of 0.156 m^3/sec for 2 months.

Given the volume of storage available in relation to licenced irrigation volumes, it is recommended that storage releases for agricultural users should be initiated at a rate of 0.120 m^3/sec on July 15 each year, and maintained at that rate until September 30. July 15 approximates when the 25th percentile flows reach 20% LTmad in the historic WSC above Lumby flow record. A release of 0.120 m^3/sec exceeds the requirements of the licences associated with the agricultural storage, but flow monitoring results from 2011 to 2013 (see Section 3.4) indicate that a portion of the flow released from Nicklen Lake is not reflected in the increased flows measured in Bessette Creek after the Nicklen Lake release starts. Also, while this start date and release rate will nearly deplete the agricultural storage by the end of September each year, that storage will be replaced each year during spring refill, so it should be released to ensure ongoing beneficial use of the storage. The start of agricultural storage release could be fine tuned to match flows in Bessette Creek, but without an accessible realtime flow trigger, a simple automatic start date of July 15 is recommended.

6.6. Recommended Nicklen Lake Conservation Storage Releases for Environmental Flows

Variable Releases Based on Bessette Ck Flow Targets

Based on the instream flow recommendations in Table 20, it appears reasonable to suggest conservation flow releases and water use management should be directed towards achieving minimum flows of 20%LTmad in August for rainbow trout and Chinook salmon rearing, and flows of >25%LTmad in September through November for Chinook and Coho salmon spawning. Based on these flows, a simple operating strategy would be to start releasing enough conservation storage in August to maintain flows of 20%LTmad if/when the residual flows drop below 20%LTmad in August, and then adjust flows as needed to maintain flows of greater than 25%LTmad in September, October and November. Total conservation storage equates to 14%LTmad on a monthly basis.

The simple operating strategy as above would work well if median flows were the norm. Unfortunately, flows are quite variable from month to month and year to year, and monthly flows have tended to be below median for much of the past decade. Table 23 shows the mean monthly flows from 2001 to 2010, and the application of the simple strategy.

Table 23. Conservation Flow Release Based on Satisfying 20%LTmad in August and 30% in September to November.

	Residual Flows				Storage Releases				Residual /Enhanced Flows			
Year	Aug	Sep	Oct	Nov	Aug	Sep	Oct	Nov	Aug	Sep	Oct	Nov
2001	27%	19%	20%	29%		6%	5%		27%	25%	25%	29%
2002	10%	14%	15%	14%	10%	4%			20%	18%	15%	14%
2003	4%	11%	18%	20%	14%				18%	11%	18%	20%
2004	24%	61%	34%	53%					24%	61%	34%	53%
2005	21%	33%	59%	39%					21%	33%	59%	39%
2006	14%	18%	19%	24%	6%	7%			20%	25%	20%	24%
2007	10%	15%	30%	21%	10%	4%			20%	19%	30%	21%
2008	15%	17%	18%	24%	5%	8%			20%	25%	19%	24%
2009	13%	15%	22%	22%	7%	7%			20%	22%	22%	22%
2010	13%	34%	23%	24%	7%		2%	1%	20%	34%	25%	25%

Table 23 demonstrates that trying to satisfy 20%LTmad in August, works well for August, but the 25% targets for September and October are only met in 5 and 4 years respectively, with most or all of the conservation storage used in all the years except 2004 and 2005. Smaller releases are required in August and September in order to ensure that some storage is still left to supplement flows in October.

A 2nd operating strategy is to reduce the August trigger for conservation flow release to 15%LTmad, and limit the conservation storage volume release to the equivalent of 5%LTmad in Bessette Ck above Beaverjack in all of the months. Total conservation storage equates to 14%LTmad on a monthly basis and each %LTmad equates to an actual flow of 41 L/sec. As such, flow changes should be made in 1%LTmad or 0.040 m^3/sec increments and the maximum release rate would be 0.200 m^3/sec.

Table 24 indicates that while the alternative strategy is still not ideal, it does distribute the conservation flow better. Rearing flows of 15%LTmad in August are achieved in all years except 2003, September Chinook spawning are above 20% in all years except 2003, and October Coho spawning flows are above 20% in all years except 2002. Note too that the historic flows might have been higher if storage releases for agricultural diversions had been released earlier as proposed above, in which case the values shown in Table 24 could have been higher than indicated.

Table 24. Conservation Flow Release Based on Satisfying 15%LTmad in August and 25%LTmad in September to November.

	Residual Flows				Storage Releases				Enhanced Flows			
Year	Aug	Sep	Oct	Nov	Aug	Sep	Oct	Nov	Aug	Sep	Oct	Nov
2001	27%	19%	20%	29%		5%	5%		27%	24%	25%	29%
2002	10%	14%	15%	14%	5%	5%	4%	2%	15%	23%	19%	16%
2003	4%	11%	18%	20%	5%	5%	4%		9%	16%	22%	20%
2004	24%	61%	34%	53%					24%	61%	34%	53%
2005	21%	33%	59%	39%					21%	33%	59%	39%
2006	14%	18%	19%	24%	1%	5%	5%	1%	15%	23%	24%	25%
2007	10%	15%	30%	21%	5%	5%		4%	15%	20%	30%	25%
2008	15%	17%	18%	24%		5%	5%	1%	15%	22%	23%	25%
2009	13%	15%	22%	22%	2%	5%	3%	3%	15%	20%	24%	25%
2010	13%	34%	23%	24%	2%		2%	1%	15%	34%	25%	25%

This discussion assumes that August rearing flows are of relatively similar importance as September Chinook spawning and October / November Coho spawning. Modifications to the monthly targets for determining releases should be made by MFLNRO & DFO staff as appropriate if the relative importance of the rearing vs spawning flows is viewed differently in the future.

Dam Operation Concerns

The drawback of both of these variable conservation release strategies is that the conservation storage release from Nicklen Lake needs to be varied according to the flows in Bessette Creek. There are two issues with this. First, changing the flow requires a trip up to Nicklen Lake to make the adjustment. Second, and more importantly, the variable release requires a realtime means of determining flows in Bessette Creek to guide the adjustments.

Stream Gauging Recommendations

The only nearby hydrometric station with realtime flow reporting is in Coldstream Ck. Comparison of Coldstream Ck flows with Bessette Ck flows indicates distinct differences in the flow volumes, but it is possible to predict the start of low flows in Bessette Creek using the realtime flows. As indicated in Appendix E, a Coldstream Ck realtime flow of 0.115 m^3/sec has often corresponded to 20% LTmad in Bessette Ck, but that is based on historic comparisons. Earlier release of agricultural storage will alter the relationship, and of course Coldstream Ck can't be used to predict the flows in Bessette Ck once the Bessette flows become more regulated over the summer due to the combination of storage releases and agricultural withdrawals.

A hydrometric station on Bessette Creek with realtime data availability or at least an easily accessible and readable staff gauge with an up-to-date rating curve is needed for this variable flow strategy to work. Adding realtime data output to one of the two active WSC stations on Bessette Creek would work, but since both stations are below the confluence with Duteau and Creighton Creeks, the Duteau Creek flow regulation and the Creighton Ck withdrawals would both also have considerable influence on the reported flows. The alternative would be a staff gauge with a rating curve on Bessette Ck at an easily accessible location such as at the Horner Road crossing. This would be more relevant to Bessette Ck upstream of Lumby, but would require more the storage operator to read and interpret the staff gauge levels, would require ongoing effort to create and maintain the rating curve, and unless the gauge were accompanied by a level recorder (more effort) there would be no continuous water level / flow record to compare to the management actions taken. As such, conversion of a WSC station to realtime status is recommended as the preferred action for this strategy to work, with either that or the staff gauge with rating curve essential for implementation of this strategy.

Constant Rate Flow Releases

In the absence of realtime flow information to trigger conservation flow release variations, a constant release on a month by month basis is recommended. This is not the most efficient means of meeting flow targets with a limited storage volume, but seems like the best alternative in the absence of a means of matching releases to variable flows.

The 25th percentile flows (about 1 in 4 year low flows) in the WSC hydrometric station above Beaverjack Ck are 14% of LTmad in August, 17%LTmad in September and 19%LTmad in October. These August values are close to the minimum target of 15%, but August flows have been particularly low in some years in the last decade, so starting the conservation flow release on August 15 is recommended. Releasing the conservation storage at a rate of 0.160 m^3/sec from August 15 to October 31 will add about 4%LTmad to the Bessette Creek flows above Beaverjack for that period, and will use about 1,100 ML (about 75%) of the conservation storage volume of 1,480 ML. Resulting 25th percentile flows would be 18%LTmad in the 2nd half of August, 21%LTmad in September and 23%LTmad in October.

The constant rate flow releases will be less efficient at meeting instream flow targets in some years, but are seen as the best way to release the conservation storage each year in the absence of realtime flow reporting in the Bessette Creek watershed. The recommended rate is a starting point to gain experience with flow increases and Nicklen Lake drawdown. Any adjustments to the releases should be made by the Senior Fisheries Biologist at the Ministry of Forests, Lands and Natural Resource Operations office in Penticton, and communicated to whoever is in charge of operating the control on Nicklen Lake.

6.7. Nicklen Release Settings and Lake Level and Flow Release Monitoring

Sections 6.4 and 6.5 recommend storage release at a rate of 0.120 m^3/sec from July 15 to September 30, plus conservation storage release at either a variable rate of up to 0.200 m^3/sec whenever required after August 1 or a constant rate of 0.160 m^3/sec starting on August 15, and continuing until the end of October. This means that the recommended storage releases from Nicklen Lake would range from 0.120 m^3/sec to 0.280 m^3/sec if constant releases were utilized (Figure 35) or anywhere from 0.040 m^3/sec to 0.320 m^3/sec in 0.040 m^3/sec increments if the variable conservation release strategy is used. It is understood that MFLNRO staff have measured Nicklen outflows and installed a staff gauge to indicate outflow level. Levels corresponding to outflows of 0.040 m^3/sec to 0.320 m^3/sec in 0.040 m^3/sec increments need to be defined (if not already done) and communicated to the Nicklen Lake operator to ensure that that there is a clear understanding of how to adjust the control structure to achieve the desired flows.

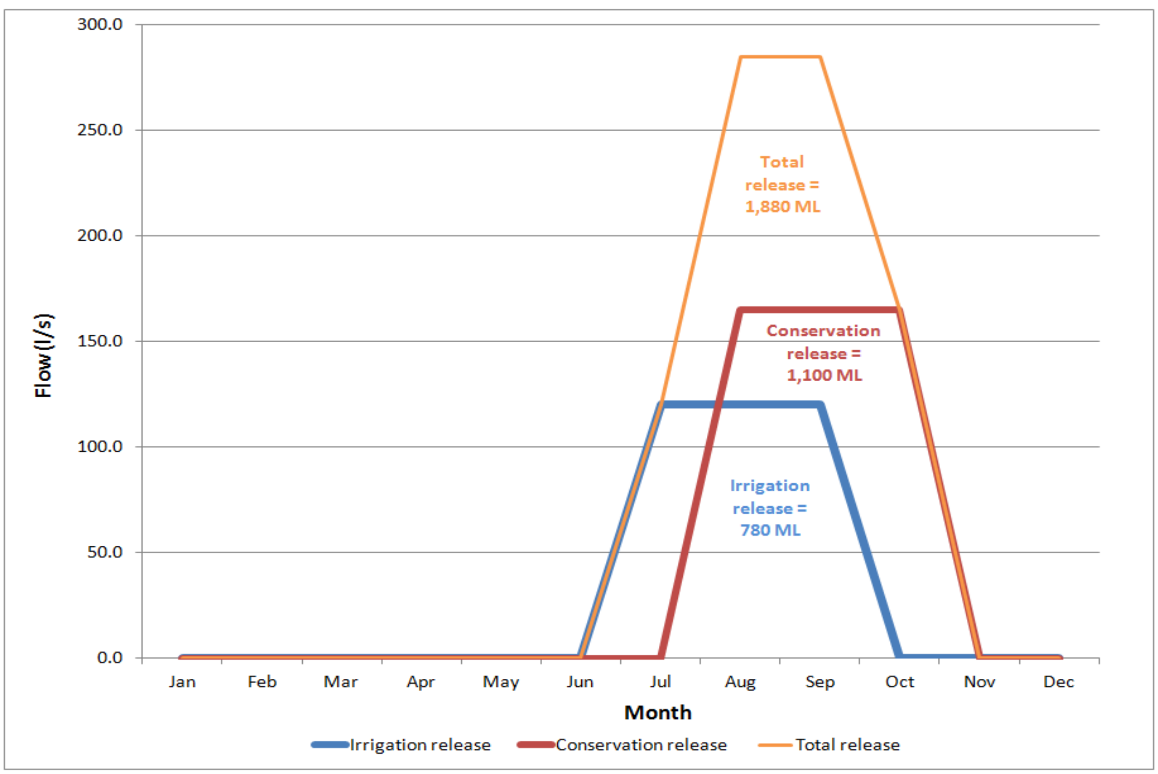


Figure 35. Nicklen Release Hydrograph showing constant flow release scenario.

The recommended agricultural and conservation storage release strategy will result in substantial drawdown on Nicklen Lake each year, and will likely result in occasional incomplete refill of Nicklen Lake. As such, Nicklen Lake level should be checked around July 1 each year to determine if there is complete refill. If not full, the available volume of conservation storage should be calculated from the Nicklen Lake storage capacity table and the conservation releases for that year should be reduced proportionally. It is understood that MFLNRO Fisheries staff in Penticton are required to make monthly dam inspections, so this determination of refill level and conservation storage release adjustment would be associated with that inspection.

Nicklen Lake levels and releases should also be monitored periodically during the storage release season to ensure that storage releases are occurring at the appropriate rates and that storage volume is reducing at the expected rate. The release volume monitoring is simply to confirm that the storage release strategy is being implemented correctly and the Nicklen Lake storage monitoring is needed particularly to confirm that storage volume is not being depleted quicker than expected. Storage could be depleted quicker if releases were higher than expected, there were unexpected high storage losses due to evaporation or seepage, or there are errors in the storage/capacity table. Alternately, storage could be depleted slower if reservoir inflow is higher than expected during the summer and fall storage release period. Maintaining records of release rates and Nicklen Lake levels is essential to building up an operating history record to guide any future modifications of the Nicklen Lake storage release strategies. As with the July Nicklen Lake level monitoring, the ongoing release and lake level monitoring would fit well with the monthly dam inspections by the MFLNRO staff.

A rule curve for Nicklen Lake storage releases is provided in Appendix G. Comparing the Nicklen Lake level to the rule curves for any given date between July 1 and November 15 demonstrates if the storage is being drawn down as expected, or if adjustments are needed to reduce the drawdown rate. The rule curves can also be used to determine appropriate lower than normal release rates at the start of July if Nicklen Lake is not completely full at that time.

7. DUTEAU CREEK WATER BALANCE

The Duteau Creek portion of the Bessette Creek watershed has an area of approximately 235 km^2, about 30% of the total Bessette Creek watershed (Figure 2). Duteau Creek flows are highly regulated with large water storage reservoirs, controlled reservoir releases (except for spill during freshet), and substantial diversion to the Greater Vernon Water utility. Several issues and questions relating to reservoir management, diversions and headgates spill in relation to environmental flows were identified in the 2012 report. A water balance for Duteau Creek was constructed following the 2013 flow seasonal flow monitoring to provide additional information relating to these questions and concerns.

The Duteau Creek water balance was constructed with a daily time step using information available from 1997 to 2013. The water balance is available as an Excel workbook, and monthly averages are included in Appendix G. Included are April 1 and May 1 snow course information, seasonal reservoir inflows for 3 streams (2008 - 2013), total reservoir volumes for the 3 Duteau Creek reservoirs, Goose Lake reservoir volumes, flows measured in Duteau Creek above the headgates (2011 - 2013 only), headgates diversions, calculated headgates spill and flows measured below the headgates (2011 - 2013), as well as calculated naturalized flows, the proportion of reservoir change attributable to the measured tributaries and the proportion of naturalized flows attributable to the measured tributaries. Each component of the water balance is described below.

7.1. Snow Course Data

Snow course data for Aberdeen Lake (1F01A in the Duteau Creek watershed), Oyama Lake (2F19 at similar elevation but in the Okanagan to the west of Duteau Creek) and Postill Lake (2F07 at similar elevation but in the Okanagan to the south of Duteau Creek) was downloaded from http://a100.gov.bc.ca/pub/mss/stationlist.do. Additional data for several missing values at the Aberdeen snow course was obtained from RDNO. Snow water equivalent data for April 1 and May 1 is expressed as % Normalized (Normal is the average value for the 3 decades ending in 2010) for easy comparison to average conditions. The two nearby snow courses are included for additional comparison of snow pack to reservoir refill considerations. The snow course data is summarized in Table 25.

7.2. Reservoir Stream Inflows

A seasonal flow monitoring program was initiated by RDNO for 3 tributaries of the Duteau Creek reservoirs in 2008, and expanded to include Duteau Creek above the Headgates in 2011 (G2O Services, 2012, 2013 and 2014). The Upper Duteau results are summarized below in Table 26. April flows are not included in the calculations because the flow monitoring usually started too late in April to provide a monthly average for April. May to October runoff is calculated by converting the flow to volume for the 6 months and then dividing by area. Annual runoff would be somewhat higher than calculated for May to October as there is additional flow from November through April. Curtis and Heart Creeks are in the Aberdeen Lake catchment, with Heart Creek including the Gold-Paradise Diversion, and Duteau Creek is in the Grizzly Lake catchment area.

Table 25. Summary of April 1 and May 1 Snow Water Equivalent Data for Aberdeen Lake, Oyama Lake and Postill Lake Snow Courses.

	April 1 Snow Water Equivalent			May 1 Snow Water Equivalent		
	Aberdeen	Oyama	Postill	Aberdeen	Oyama	Postill
	124 mm	155 mm	202 mm	19 mm	55 mm	121 mm
Year	% Normalized	% Normalized	% Normalized	% Normalized	% Normalized	% Normalized
1997	170%	164%	145%	415%	197%	132%
1998	88%	110%	101%	0%	96%	66%
1999	106%	128%	133%	0%	134%	144%
2000	113%	121%	106%	0%	53%	86%
2001	72%	79%	81%	167%	170%	121%
2002	97%	118%	115%	103%	123%	113%
2003	76%	57%	83%	0%	11%	82%
2004	110%	104%	117%	0%	27%	49%
2005	47%	70%	86%	0%	11%	54%
2006	114%	113%	109%	0%	89%	104%
2007	84%	83%	92%	0%	27%	53%
2008	117%	93%	93%	604%	235%	136%
2009	145%	95%	96%	81%	172%	130%
2010	54%	77%	79%	0%	13%	32%
2011	119%	105%	103%	890%	319%	164%
2012	123%	112%	122%	0%	116%	0%
2013	115%	88%	96%	426%	80%	109%

Table 26. Mean May to October Flows and May to October Runoff at Upper Duteau Seasonal Flow Monitoring Stations

	Mean May to October Flow (m^3/s)			May to October Runoff (m)		
	Curtis Ck	Heart Ck	Duteau Ck	Curtis Ck	Heart Ck	Duteau Ck
2008	0.161	0.376	0.239	0.277	0.172	0.249
2009	0.075	0.448	0.252	0.106	0.205	0.262
2010	0.112	0.516	0.326	0.158	0.236	0.340
2011	0.179	0.702	0.415	0.252	0.321	0.433
2012	0.163	0.782	0.397	0.230	0.358	0.414
2013	0.197	0.569	0.362	0.334	0.313	0.499
Avg.	0.148	0.565	0.332	0.251	0.311	0.417

7.3. Duteau **Reservoir Volumes**

An Excel workbook with the daily reservoir levels and volumes from 1997 to 2013 for Aberdeen Lake, Grizzly Swamp, and Haddo Lake, as well as Goose Lake levels and other information, was obtained from RDNO. It is understood that reservoir levels are recorded manually on an ad hoc basis, and that linear interpolation was used to fill values between dates. A few dates in the earlier years were still blank and further linear interpolation was done to create levels for all dates.

The RDNO Excel workbook also contained level / volume relationship charts for each reservoir and the lookup tables that were used to generate the volumes for each reservoir. Total full volume for the 3 reservoirs was indicated as 18,291 ML. It was noted that the calculated volumes were capped at the full capacity of each reservoir, and that there was a discrepancy between the full volume of 18,291 in the RDNO workbook vs. the 19,600 ML indicated by McNeil in his 1991 report. As such, the reservoir plans and accompanying storage capacity tables for each reservoir were obtained from MFLNRO, and new lookup tables were created for this project. The storage capacity tables confirm a full pool volume of 19,691 ML, with most of the difference (1,230 ML) in Aberdeen Lake. The new lookup tables were used to calculate the volumes used in this project, which including the overfull amounts when the reservoirs are spilling.

Monthly (and mid monthly for April, May and June) reservoir volumes are shown in Table 27. Total reservoir volumes above 19,000 ML indicating full or close to full capacity are shown with a green background. Full capacity was not reached in 2003, 2007 and 2009.

The monthly change in reservoir volumes is shown in Table 28. It is noteworthy that not only do the monthly reservoir volumes decline during July, August and September when water diversions are high and inflows are low, but the reservoir volumes usually continue to decline through the fall and winter, with only sporadic occurrences of months with positive monthly water volume changes.

7.4. Duteau Headgates Diversion Volumes

A series of Excel files with daily diversion data was also obtained from RDNO, with the earliest data going back to when the North Okanagan Water Association (NOWA) operated the water utility. The diversion records are not complete, with all of 2003 and the first 3 months of 2004 missing, as well as 4 months in 2006 and the last 2 months in 2009, and only monthly data available for the first 9 months of 2010.

The monthly and annual diversion volumes are shown on

Table 29. Note that annual diversion volumes are only calculated for years with complete monthly records, but the mean annual diversion is the sum of the mean monthly diversions.

Table 27. Monthly Aberdeen Lake, Grizzly Swamp and Haddo Lake Total Reservoir Volumes

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Median
1 Jan	12,986	12,941	4,363	11,969	8,990	9,756	4,612	3,359	14,030	8,309	6,194	7,082	7,295	3,844	6,771	6,131	10,568	7,295
1 Feb	9,876	12,293	4,457	11,793	8,960	9,847	4,309	3,117	15,593	8,330	5,858	6,740	6,645	3,341	6,331	5,675	10,547	6,740
1 Mar	9,417	11,917	4,568	11,220	8,415	9,771	4,060	2,993	16,613	7,928	5,094	6,495	6,242	3,170	5,895	5,434	10,295	6,495
1 Apr	9,126	12,328	6,728	11,230	7,953	10,175	4,565	3,617	17,239	10,679	6,440	6,270	5,699	3,022	5,596	5,026	11,030	6,728
1 May	13,048	17,376	12,564	18,320	10,598	13,986	8,023	10,296	19,761	14,414	10,919	6,801	7,051	5,590	6,001	11,168	16,948	11,168
1 Jun	19,026	19,553	18,891	19,503	19,347	20,248	14,437	18,917	20,259	19,933	15,116	19,543	14,287	13,525	20,060	19,783	20,032	19,503
1 Jul	19,506	18,442	19,575	19,133	19,216	18,631	16,773	19,187	19,751	19,427	15,642	19,100	16,061	19,175	19,679	20,282	20,541	19,187
1 Aug	18,967	14,000	16,711	16,231	16,248	13,997	11,950	15,468	17,189	15,024	13,160	14,510	11,803	15,855	17,629	17,806	16,747	15,855
1 Sep	13,634	8,120	11,952	11,443	11,997	9,212	6,839	11,618	11,672	10,015	9,224	10,589	7,505	10,633	12,344	13,562	12,691	11,443
1 Oct	13,245	5,229	9,533	10,342	9,046	6,264	4,616	12,061	9,137	7,369	7,139	8,949	5,499	8,952	8,603	11,177	11,712	8,952
1 Nov	12,832	4,482	9,278	9,882	8,715	5,546	4,137	11,977	9,200	6,790	7,419	7,856	5,152	7,849	7,465	10,718	-	7,849
1 Dec	13,340	4,633	11,514	9,480	9,692	5,105	3,733	12,901	8,716	6,554	7,269	7,587	4,571	7,435	6,843	10,631	-	7,435
31 Dec	12,939	4,361	11,984	9,009	9,756	4,629	3,374	13,991	8,314	6,209	7,123	7,321	3,861	6,794	6,157	10,569	-	7,123

Table 28. Monthly Changes in Aberdeen Lake, Grizzly Swamp and Haddo Lake Total Reservoir Volumes

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Jan	-3,110	-648	94	-176	-30	91	-303	-242	1,563	21	-336	-342	-650	-503	-440	-456	-21	-323
Feb	-459	-376	111	-573	-545	-76	-249	-124	1,020	-402	-764	-245	-403	-171	-436	-241	-252	-246
Mar	-291	411	2,160	10	-462	404	505	624	626	2,751	1,346	-225	-543	-148	-299	-408	735	423
Apr	3,922	5,048	5,836	7,090	2,645	3,811	3,458	6,679	2,522	3,735	4,479	531	1,352	2,568	405	6,142	5,918	3,891
May	5,978	2,177	6,327	1,183	8,749	6,262	6,414	8,621	498	5,519	4,197	12,742	7,236	7,935	14,059	8,615	3,084	6,447
Jun	480	-1,111	684	-370	-131	-1,617	2,336	270	-508	-506	526	-443	1,774	5,650	-381	499	509	451
Jul	-539	-4,442	-2,864	-2,902	-2,968	-4,634	-4,823	-3,719	-2,562	-4,403	-2,482	-4,590	-4,258	-3,320	-2,050	-2,476	-3,794	-3,343
Aug	-5,333	-5,880	-4,759	-4,788	-4,251	-4,785	-5,111	-3,850	-5,517	-5,009	-3,936	-3,921	-4,298	-5,222	-5,285	-4,244	-4,056	-4,720
Sep	-389	-2,891	-2,419	-1,101	-2,951	-2,948	-2,223	443	-2,535	-2,646	-2,085	-1,640	-2,006	-1,681	-3,741	-2,385	-979	-2,010
Oct	-413	-747	-255	-460	-331	-718	-479	-84	63	-579	280	-1,093	-347	-1,103	-1,138	-459		- 491
Nov	508	151	2,236	-402	977	-441	-404	924	-484	-236	-150	-269	-581	-414	-622	-87		44
Dec	-401	-272	470	-471	64	-476	-359	1,090	-402	-345	-146	-266	-710	-641	-686	-62		-226

Table 29. Monthly and Annual Duteau Headgates Diversion Volumes

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Jan	412	303	368	423	231	360			248	527	307	237	221	184	148	188	136	286
Feb	413	292	235	565	215	345			355	717	263	272	239	212	143	153	268	312
Mar	439	428	336	629	240	548			570	552	291	292	363	216	334	189	652	404
Apr	532	1,019	504	860	621	981		536	936		559	363	644	405	297	344	376	598
May	1,367	2,428	1,382	1,567	2,094	1,923		2,064	2,830		2,358	1,506	2,276	1,282	1,305	1,735	1,475	1,839
Jun	1,732	2,963	2,300	2,500	1,833	3,462		2,770	1,904	1,485	2,261	2,456	3,388	1,552	1,404	1,334	1,014	2,147
Jul	2,165	3,769	3,070	3,498	3,724	4,632		4,228	3,370		3,257	4,381	4,004	3,876	3,313	2,900	3,105	3,553
Aug	2,792	2,110	3,393	3,770	3,811	4,430		3,658	4,216	4,030	3,839	3,390	3,531	4,337	4,072	3,637	3,169	3,637
Sep	1,082	2,110	1,645	1,351	2,014	2,010		766	1,380	1,867	1,692	1,472	1,298	1,367	2,667	1,942	774	1,590
Oct	233	446	503	481	441	441		356	341	421	312	287	220	510	212	419	171	362
Nov	52	301	366	240	325	326		263	330	285	219	188		201	216	128	125	238
Dec	131	306	380	258	325	295		250	340		213	201		133	204	152		245
Annual	11,348	16,474	14,481	16,141	15,876	19,751			16,820		15,571	15,046		14,274	14,315	13,120		15,212

7.5. Duteau Headgates Spill Volumes

Flow in Duteau Creek above the Headgates consists of runoff from the unregulated portion of the Duteau Creek watershed above the Headgates plus the volume released and/or spilling from the Haddo Lake reservoir. Flow at the Headgates is diverted into the Greater Vernon waterworks to satisfy demand as per the volumes summarized in

Table 29, passed through the Headgates to satisfy minimum fisheries flows and priority water licence requirements as per the following schedule, and any excess water spills over the Headgates.

	Fisheries m^3/sec	Priority Water Licences m^3/sec	Total m^3/sec
Jan 1 - Mar 31	0.057		0.057
Apr 1 - Aug 31	0.113	0.057	0.170
Sept 1 - Sep 30	0.170	0.057	0.227
Oct 1 - Dec 31	0.142		0.142

Flow volumes in Duteau Creek below the Headgates can range from the low flows released through the Headgates in winter to satisfy the minimum fisheries flows to very large magnitude flows when the reservoirs are spilling during spring freshet. A Water Survey of Canada hydrometric station was operated below the Headgates with 58 years of seasonal and full annual records between 1919 and 1996. The highest daily flow value of 16.2 m^3/sec was recorded on June 4, 1990. Minimum flows of 0.000 m^3/sec were recorded for one or more days in 29 of those 58 years.

Flows in Duteau Creek below the Headgates are approximated for the period after 1996 by calculating flows from Headgates spill records plus the fisheries / priority licence flow through the Headgates. Depth of Headgates spill was initially only recorded manually, with morning and/or afternoon records, but also with a number of days no records available. All manual records to Aug. 2, 2013 were obtained from RDNO. The early records are relatively complete, mostly just missing some weekends, but manual records became more sporadic after the introduction of a SCADA system late in 2006 with the most sporadic records in the last few years. For manual records, the depths are averaged to a daily value when there are 2 values per day, and missing records are filled by linear interpolation between measured values. Daily levels are then converted to flows using the lookup table supplied with the data, and fisheries flows as per the schedule above are added to simulate Duteau Creek flows below the Headgates. Days where the water level is below the Headgates spillway default to just the fisheries / priority licence flows.

SCADA records for the depth of spill are available from Jan 1, 2006 until 2013, with 4 records per day recorded at 6 hour intervals. The SCADA data is converted to flows by averaging the 4 values each day to a daily value and then applying the same lookup table as used for the manual data and adding the fisheries / priority licence flows. It is apparent that the original SCADA unit stopped responding to changing Headpond levels on July 28, 2010, as all values change by the same marginal amount from that date on. Data from a new SCADA unit is available from Dec 22, 2011.

Flows based on SCADA spill depth records should be more precise as the values are 4 records per day with no missing days. As such, Headgates spill based flows in the water balance use the manual spill levels until the end of 2005, the old SCADA data from 2006 until it stopped working in 2010, manual spill data again until the new SCADA became operational in late 2011, and then the new SCADA data to the end of the records.

The simulated mean monthly Duteau Creek flows below the Headgates are summarized in Table 30. **Note that flow comparisons to measured flows (WSC at Lumby and MFLNRO seasonal flow monitoring) demonstrate that while the Duteau Creek Headgates spill simulated flow patterns are consistent with measured values, the spill simulation consistently overestimates flow.** For example, the Mean Annual Flow in Bessette Creek at Lumby from 1974 to 1995 is 2.986 m^3/sec, slightly higher than the 1997 to 2010 value of 2.920 m^3/sec. As such Duteau Ck flows which are a significant part of the Bessette Creek flow at Lumby would also be expected to remain similar too, but the comparable values are 0.671 m^3/sec from the 1974 to 1995 WSC data and 0.852 for the Headgates spill simulation for 1997 to 2010, suggesting a 27% overestimation.

Table 30. Simulated Mean Monthly Duteau Creek Below Headgates Flows from Headgates Spill plus Fisheries / Priority Licences

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Jan	0.603	0.955	0.071	0.564	0.281	0.350	0.182	0.060	0.359	0.239	0.151	0.115	0.057	0.057	0.067	0.711	0.790	0.330
Feb	0.504	0.335	0.057	0.341	0.225	0.224	0.178	0.057	0.378	0.365	0.115	0.070	0.064	0.057	0.121	0.435	0.326	0.227
Mar	1.067	0.319	0.109	0.302	0.245	0.221	0.108	0.079	0.547	0.187	0.233	0.059	0.057	0.057	0.061	0.469	0.208	0.255
Apr	4.511	1.702	1.311	2.009	0.612	1.268	0.658	1.176	3.151	1.625	0.804	0.186	0.249	0.220	0.170	1.331	2.403	1.376
May	7.905	4.974	2.573	5.642	0.860	5.033	0.343	0.624	3.691	4.569	0.274	1.128	0.474	0.193	0.638	0.730	7.991	2.802
Jun	5.686	0.554	5.670	3.941	3.668	4.546	0.345	2.539	2.578	4.892	0.239	3.295	0.173	1.122	3.733	8.870	8.486	3.549
Jul	4.886	0.402	1.787	0.517	0.480	0.378	0.219	0.266	0.751	0.286	0.185	0.177	0.181	0.179	0.404	2.237	0.991	0.843
Aug	1.278	0.353	0.949	0.342	0.369	0.231	0.172	0.464	0.700	0.239	0.170	0.200	0.173	0.228	0.888	0.538	0.955	0.485
Sep	1.921	0.387	0.845	0.373	0.369	0.263	0.232	0.308	0.560	0.309	0.201	0.215	0.202	0.295	0.857	0.581	0.977	0.523
Oct	1.434	0.247	0.400	0.312	0.259	0.224	0.190	0.365	0.441	0.209	0.143	0.165	0.162	0.144	0.368	0.575	0.639	0.369
Nov	0.142	0.182	0.488	0.297	0.247	0.238	0.171	0.396	0.244	0.199	0.149	0.179	0.164	0.153	0.259	0.762		0.267
Dec	0.331	0.299	0.395	0.290	0.581	0.194	0.164	0.394	0.575	0.209	0.143	0.382	0.299	0.146	0.178	0.868		0.340
Annual	2.533	0.899	1.221	1.245	0.681	1.099	0.246	0.558	1.166	1.110	0.234	0.512	0.189	0.237	0.641	1.500		0.872

The flow patterns and the magnitude discrepancies are demonstrated in Figure 36 and Figure 37 which compare the simulated flows in Duteau Creek below the Headgates to measured flows in Bessette Creek at the WSC station at Lumby (preliminary data) and measured flows at the MFLNRO seasonal site in Duteau Creek at Whitevale Road. The Headgates spill to Bessette comparison demonstrates the similar flow patterns, other than when the Duteau Creek reservoirs are being filled in May, but also shows simulated flow below Headgates that exceeds the entire Bessette Creek Flow at Lumby at times in late summer and fall. The Headgates spill to Duteau Creek flow at Whitevale Road (Duteau 1) comparison details the overestimation of the headgates flow simulation in 2012.

Overestimation of Headgates spill is likely due to either an inaccurate rating curve for the depth of spill, and /or an incorrect offset for the Headpond level relative to the spill. Verification of the Headgates spill rating curve with a series for flow measurements, verification of the offset value, and verification of SCADA accuracy are all recommended to improve confidence in using Headgates spill as an indicator of Duteau Creek flows. Headgates spill can easily be re-calculated if rating curve or offsets issues are identified.

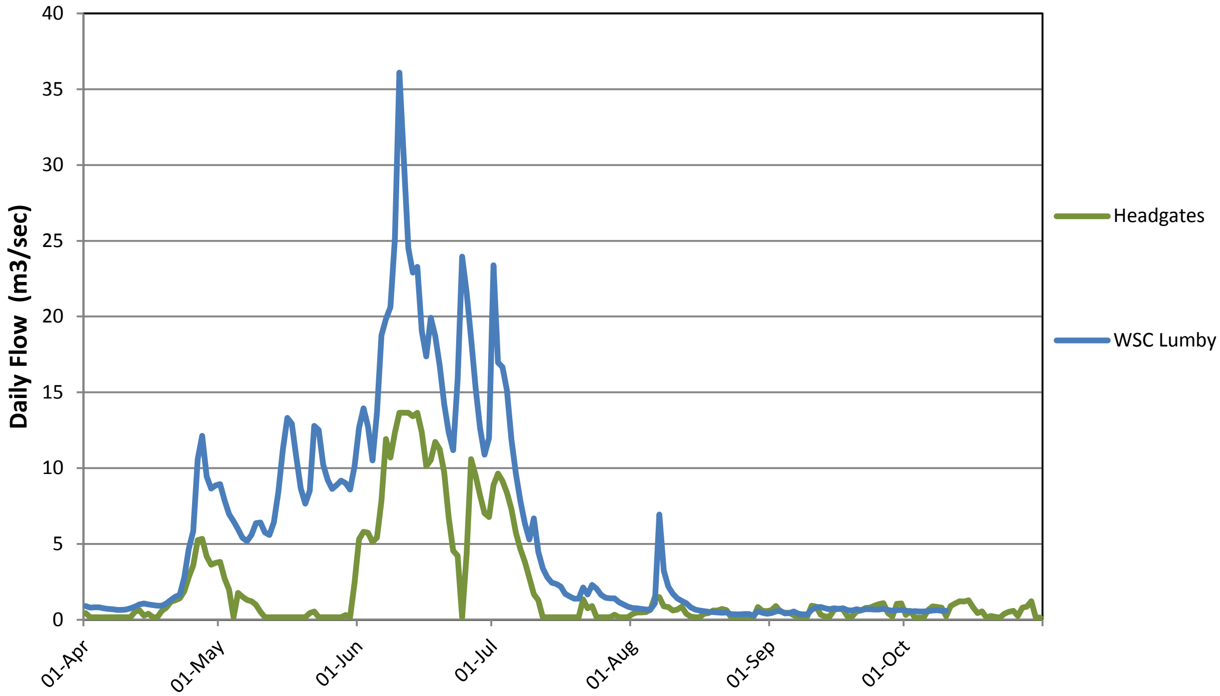


Figure 36. Simulated Duteau below Headgates flow compared to Bessette Creek at Lumby, April to October, 2012.

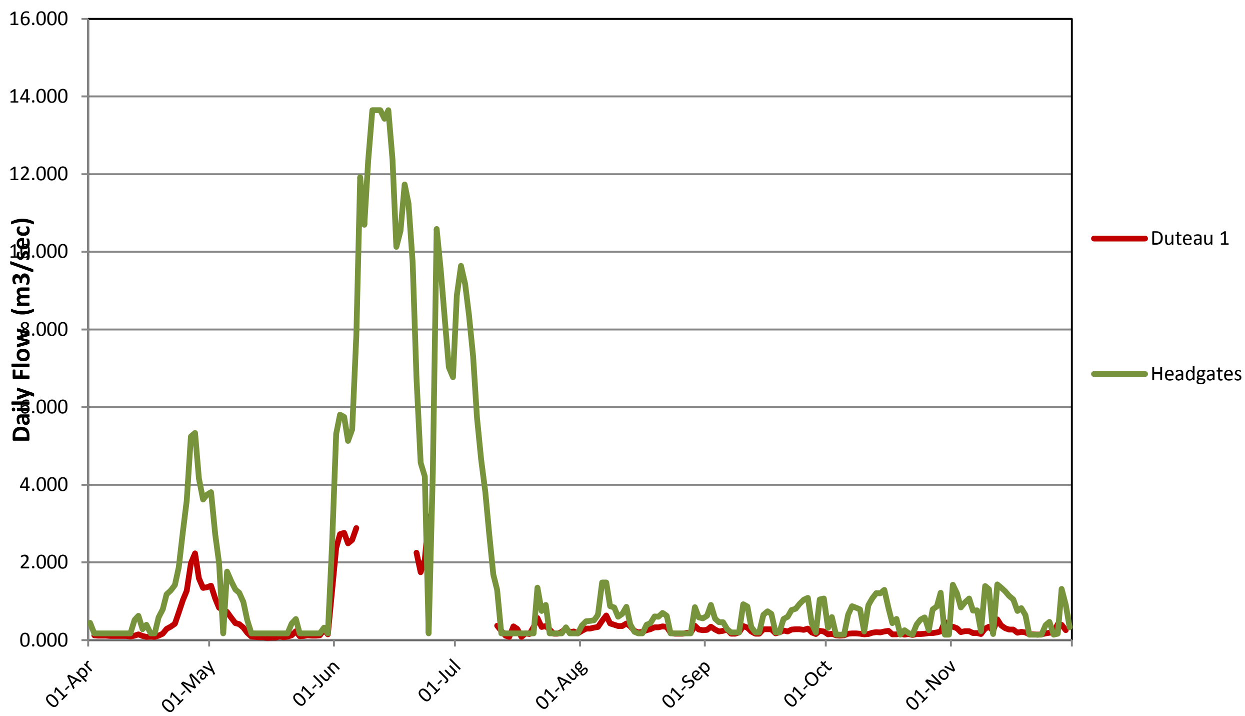


Figure 37. Simulated Duteau below Headgates flow compared to Measured Duteau at Whitevale Road, April to October, 2012.

7.6. Lower Duteau Flow Monitoring

The RDNO seasonal flow monitoring program for the 3 Duteau reservoir tributaries was expanded in 2011 to add a site in Lower Duteau Creek above the Headgates (G2O Services, 2012, 2013 and 2014). Since there should be very little change in flow between this site and the Headgates, data from this site can also be used to compare to the simulated flow below the Headgates plus the reported diversions. As with the comparisons in Section 7.5, flows measured at this site above the Headgates are consistently lower than the sum of the simulated flows below the Headgates and the Greater Vernon Water diversions at the Headgates, confirming that the Headgates spill simulation volumes are too high.

The MFLNRO seasonal flows for the Duteau 1 site below the Headgates (discussed in Section 3.4 and compared to Headgates flows in Figure 37) are also included in the water balance, and when available, are used in place of the simulated Headgates flows to simulate naturalized flows in the Duteau Creek watershed as described below.

7.7. Duteau Creek Naturalized Flow Simulation

The combination of reservoir volume changes, diversion into the Greater Vernon Water system at the Headgates and simulated flows below Headgates (or Duteau 1 flows when available) are used to simulate naturalized flows for Duteau Creek at the Headgates for the period from 1997 to 2013, similar to the naturalization done by McNeil in 1991. The naturalization is done on a daily time step, and then summarized as monthly data in Table 31. Naturalized flows are not calculated for all of 2003, and several months in each of 2004, 2006, and 2009 as no diversion data was not available for those time periods, and only on a monthly basis for the first 9 months of 2010. The missing data in 2004 and 2009 was in the winter, so average monthly diversion data was used for to estimate the annual values for those years, but annual values are not calculated for 2003 and 2006. The annual average simulated naturalized flow of 1.441 shown in Table 31 is biased by inclusion of 1997 (very wet year) and omission of 2003 (very dry year). A better approximation of the mean annual simulated naturalized flow for all of the years using this method is 1.354 m^3/sec calculated by adding the average annual diversion of 15,212 ML (equivalent to 0.482 m^3/sec) to average simulated flow below the Headgates (0.872 m^3/sec). Even this is still a high estimate given that the Headgates spill overestimation as described above.

The simulated naturalized flows are useful for comparing flow patterns and relative flow magnitudes, but they should not be construed as accurate in an absolute sense due to limitations in the source data. In particular, the overestimation of the headgates spill as discussed and demonstrated in Section 7.5 results in an overestimation of flows. The actual average annual flow values is in the range is better represented by the value of 1.153 m^3/sec calculated from the historic WSC hydrometric data flow value of 0.671 m^3/sec to the 1997 to 2013 average annual diversion rate of 0.482 m^3/sec or the naturalized flow value of 1.187 m^3/sec represented by the average annual volume of 37,448 ML calculated by McNeil, 1991.

Table 31. Simulated Naturalized Flows for Duteau Creek at the Greater Vernon Water Headgates..

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Jan	-0.416	0.834	0.243	0.671	0.362	0.524			1.022	0.421	0.137	0.045	-0.103	-0.063	-0.055	0.598	0.831	0.330
Feb	0.487	0.293	0.197	0.339	0.099	0.345			0.970	0.525	-0.078	0.079	-0.014	0.058	-0.015	0.394	0.355	0.261
Mar	1.123	0.596	0.983	0.367	0.048	0.441		0.327	1.009	1.286	0.756	0.081	-0.010	0.085	0.073	0.392	0.518	0.505
Apr	6.079	3.890	3.736	4.938	1.846	2.986		3.785	4.473		2.509	0.289	0.933	1.168	0.369	2.697	4.608	2.954
May	10.753	6.881	5.517	6.957	4.919	8.353		4.770	5.011		2.962	6.530	3.569	3.376	5.773	4.355	9.800	5.967
Jun	6.581	1.275	6.849	4.842	4.458	5.444		3.973	3.086	5.279	1.390	4.333	2.798	4.358	5.036	8.399	8.699	4.800
Jul	5.500	0.220	1.918	0.820	0.817	0.354		0.652	1.255		0.593	0.167	0.183	0.594	0.936	2.479	0.611	1.140
Aug	0.295	-0.248	0.412	-0.042	0.270	0.039		0.263	0.143	-0.167	0.112	-0.089	-0.173	-0.140	0.178	0.092	0.011	0.060
Sep	2.243	0.038	0.523	0.324	-0.097	-0.195		0.658	0.025	-0.115	-0.058	-0.018	-0.170	-0.013	-0.029	-0.026	0.336	0.214
Oct	1.395	0.126	0.480	0.323	0.234	0.126		0.486	0.545	0.110	0.283	-0.034	-0.005	-0.088	-0.056	0.109	0.742	0.298
Nov	0.378	0.346	1.468	0.231	0.767	0.182		0.847	0.187	0.227	0.256	0.129		0.072	0.098	0.269		0.379
Dec	0.257	0.319	0.732	0.205	0.725	0.127		0.903	0.546	0.141	0.190	0.368		-0.033	0.058	0.899		0.382
Annual	2.890	1.214	1.922	1.665	1.204	1.561		1.420	1.523		0.754	0.990	0.627	0.781	1.026	1.712		1.441

Note: These simulated naturalized flows are an indicator of the relative magnitude of monthly and annual flows, but they should not be construed as being accurate in an absolute sense. The accuracy of the values is compromised by the overestimation of the Headgates spill as discussed and demonstrated in Section 7.5 and by negative values which are discussed below in Section 7.8. Actual average naturalized flows are better represented by the value 01.153 m^3/sec calculated from historic WSC hydrometric data and average annual diversion data.

Additional issues with the simulated naturalized flow calculations are demonstrated by the fact that the calculations result in negative flows for some months. This is logical in August and September when evaporation from reservoirs and other lakes and wetlands could exceed the low natural flows, and could be explained by interpolation of reservoir levels and time lags on a daily basis, but is unexpected as a monthly average value. Negative values for the simulated naturalized flows are discussed in more detail in Section 7.8.

7.8. Negative Simulated Naturalized Flow Values

Negative values in the simulated naturalized flow calculations indicate that either there the water balance is not accounting for all factors, or that there are issues in the source data or the associated calculations.

Negative values in August and September are explained by evaporation losses from the reservoir surfaces which was not included as a separate item in the water balance (i.e. reservoir volume changes reflect inflow / outflow as well as evaporation losses). The median reservoir volume on August 1 is 15,855 ML or about 80% of full capacity which equates to an area of approximately of 1,000 ha if all of the reservoirs were drawn down uniformly. The Kalamalka Wood Lake Basin Water Resource Management Study (Water Investigations Branch, 1974) indicated that average lake evaporation from the upland lakes averages 15.7 inches (400 mm), distributed as 26% in June, 32% in July, 30% in August, 11% in September and 1% in October. Using these values the daily August evaporation from a surface of 1,000 ha would be 38.6 ML or 0.447 m^3/day. The actual daily evaporation will fluctuate significantly from this due to climatic and reservoir levels, but this average August approximation demonstrates that reservoir evaporation easily explains the negative August values, and likely also explains the negative September values.

Negative simulated naturalized flows are also shown in some or all of December, January and February in 1997, 2007, 2009, 2010 and 2011, with up to 3 months of consecutive negative values in several of these years. Negative values indicate that the reported reservoir drawdown volumes exceed the sum of the volume diverted at the Headgates and the flow volume in Duteau Creek below the Headgates. Since that can't actually occur unless water is being lost through something like evaporation, the negative values point to issues with one or more of the three sets of values. Reservoir level reading are seen as least likely to be the issue (other than perhaps with January 1997) because 3 consecutive months with negative values would require a number of incorrect levels readings across all 3 reservoirs. Simulated flows below the Headgates are the logical culprit given the issues demonstrated in Section 7.5, but negative values require the headgates spill to be underestimated rather than overestimated. During the negative periods in both 2009 and 2010, the Headpond levels were below the spill level, so the only way these values could have been too low is if the fisheries flow through the Headgates was higher than the 0.057 m^3/sec winter minimum. Other than that, the only other explanation is that the diversion volumes at the Headgates are higher than reported. Coincidentally, the winter negatives are most prevalent in 2009 to 2011 when the reported winter diversions are lower than average.

The monthly naturalized flows calculated by McNeil in 1991 also show occasional negative monthly values for his 1975 to 1990 period. That data set shows negative values in January (1), August (2), September (4), October (2), November (1) and December (1). There are several instances of back to back August - September and September - October negative values, but only one negative 2 month winter period (Nov - Dec in 1979).

7.9. Goose Lake Reservoir

Goose Lake reservoir levels were also obtained from RDNO and added to the water balance. Goose Lake is filled from the Duteau Creek watershed so questions have been raised previously in regard to the impact this has on Duteau Creek flows in April and May during adfluvial rainbow trout spawning.

Monthly volume changes in the Goose Lake reservoir are shown in Table 32. Note that since Goose Lake is used as a balancing reservoir as well as for water supply, actual diversion volumes to Goose Lake could be higher than indicated by the volume changes. Monthly diversions are typically highest in April at an average of 285 ML / month, equivalent to an average flow of 0.109 m^3/sec.

Table 32. Monthly volume changes (ML) in the Goose Lake Reservoir.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Mean
Jan		-183.1	237.4	-1.5	12.9	9.7	43.4	203.1	54.7	189.0	117.8	89.3	86.7	67.6	-42.1			59.0
Feb	42.8	-70.2	8.1	223.2	0.0	78.1	34.6	36.2	37.8	239.5	50.8	96.5	102.9	85.0	-36.6			61.9
Mar	237.2	-72.2	-6.8	397.3	-1.6	279.3	260.0	18.8	37.0	357.5	151.2	190.1	157.2	91.8	-41.8			137.0
Apr	417.0	687.6	67.7	323.9	234.7	555.2	289.1	87.8	600.2	250.2	75.1	227.6	222.0	271.2	-34.9			285.0
May	442.3	538.2	79.2	361.7	470.2	394.4	-54.9	234.8	118.2	433.8	37.1	266.7	306.3	145.4	173.2			263.1
Jun	127.8	36.6	125.5	38.6	-61.0	-5.5	-73.7	-129.7	-466.2	-198.3	77.3	-410.4	30.9	0.0				-60.5
Jul	-114.1	-434.0	-156.9	-127.5	-130.5	-408.3	-667.4	-402.7	-485.5	-257.2	-398.1	-344.0	-326.0	-29.2			-195.7	-298.5
Aug	-164.1	-134.3	-475.6	-323.2	-435.3	-167.3	-148.3	86.9	-281.4	-256.6	-349.2	-182.6	-54.7	-43.0			-183.9	-207.5
Sep	-53.6	-58.7	-4.0	128.9	-238.1	-143.2	-42.8	-197.1	-249.5	-203.3	-90.9	-103.0	-79.6	-40.1				-98.2
Oct	-264.8	78.0	-202.7	-71.9	-332.6	67.6	268.3	-219.6	-127.3	148.6	53.1	-479.9	5.6	-42.7				-80.0
Nov	-185.8	137.6	-309.9	-186.6	-236.7	62.7	117.4	36.2	6.6	98.9	61.9	32.0	65.2	-41.1				-24.4
Dec	-334.0	111.8	-248.0	-51.5	-65.9	45.0	107.8	54.7	0.0	194.7	64.4	83.4	78.0	-41.0				0.0
total	151	637	-886	712	-784	768	134	-191	-755	997	-150	-534	595	424	1.026			

8. DUTEAU RESERVOIRS MANAGEMENT / DUTEAU CREEK HEADGATES SPILL AND ENVIRONMENTAL FLOWS DISCUSSION

8.1. Reservoir Storage, Licencing and Water Use

Greater Vernon Services - Water (GVS) supplies water to the Greater Vernon area from a number of sources, including Duteau Creek and Kalamalka Lake as the two major water sources. Approximately 60% of the annual water use is currently supplied from Duteau Creek (GVW, 2014).

The total GVS consumptive use licencing from Duteau Creek is 34,582 ML (AECOM et al, 2013b) and total related reservoir storage licencing (including Goose Lake west of Vernon) is 33,051 ML (AECOM et al, 2013b). The actual reservoir capacity is 19,691 ML in the Upper Duteau reservoirs (BC Min of Environment, 1965, 1980 & 1981) and 2,360 ML in Goose Lake (AECOM et al, 2013b), and average annual diversion from Duteau Creek from 1997 to 2013 has been approximately 15,212 ML (RDNO, 2013). On an annual average basis, licencing represents a daily equivalent volume of 1.097 m^3/sec, licenced storage volume is equivalent to 1.048 m^3/sec, constructed storage volume (including Goose Lake) represents is equivalent to a daily equivalent volume of 0.699 m^3/sec, and annual diversion represents a daily equivalent volume of 0.482 m^3/sec. Year to year diversion is highly variable, ranging from 11,348 ML in 1997 to 19,751 in 2002.

Including the McAuley Creek (Gold-Paradise) diversion, the long term mean annual discharge (LTmad) at the Duteau Creek Headgates diversion is 1.153 m^3/sec (36,272 ML) based on historic WSC data at the Headgates plus annual diversion of 15,212 ML. It is very clear that reservoir management, Headgates operation and diversions to Vernon will control flows in Duteau Creek below the Headgates as the licenced water use is 97% of the calculated LTmad, licenced storage is 91%, actual constructed storage is 61% and the average diversion is 42%, but was 54% in 2002. The relative impact on Duteau Creek flows will be even larger in dry years when flows could be just 50 to 60% of the LTmad value and water use exceeds the average. Potential future flow impacts are much greater yet, as alternatives are being considered to substantially increase the storage within, and diversion from the Duteau Creek watershed (AECOM et al, 2013b).

8.2. Duteau Creek Above Headgates Runoff Estimates

AECOM et al, in their 2013 Evaluation of Water Supply Sources report (Technical Memorandum No. 2 of the Master Water Plan), divided Duteau Creek above the Headgates into 5 sub-catchments: Grizzly Lake, Aberdeen Lake, Haddo Lake and Gold-Paradise Diversion drain into the reservoirs, while flow from Lower Duteau (including the Flyfish Lakes area) is downstream of the reservoirs. This report updates previously calculated average annual runoff values calculated using runoff curve "c" from Obedkoff, 1998 and the median elevation from each sub-catchment using techniques consistent with updates for the Okanagan Water Supply and Demand Project. The median elevation, calculated mean annual runoff, area, mean annual runoff volume and mean annual runoff as discharge for the five sub-catchments are shown in Table 33.

Table 33. Duteau Sub-Catchment Runoff Volumes (after AECOM et al, 2013a)

Sub-Catchment	Median Elevation (m)	Average Annual Runoff (m)	Area (km^2)	Annual Runoff Volume (ML)	Mean Annual Discharge (m^3/sec)
Grizzly Lake	1,384	0.29	51.3	14,735	0.467
Aberdeen Lake	1,394	0.29	45.6	13,389	0.425
Gold-Paradise (McAuley Ck) Diversion	1,788	0.70	6.6	4,611	0.146
Haddo Lake	1,300	0.24	3.7	503	0.016
Upper Duteau Subtotal			107.2	33,618	1.066
Lower Duteau	1,309	0.24	71.2	17,340	0.550
Total			178.4	50,958	1.616

The calculated mean annual discharge from this area / runoff values in Table 33 is 1.616 m^3/sec. This compares to 1.153 m^3/sec for the same watershed area (including Gold-Paradise diversion) calculated by adding the 0.482 m^3/sec (the flow equivalent of the average annual water use of 15,212 ML) to the mean annual flow of 0.671 m^3/sec at the historic WSC station below the Headgates. The calculated flow based on estimated runoff is 40% higher than the calculated flow based on historic measured flow and reported water use since 1997.

This suggests that the average annual runoff values calculated for this area for the Master Water Plan are much too high and/or the historic average annual diversion volume that matches the WSC data was substantially higher than the current usage value. A similar calculation of average annual runoff using net change in reservoir storage, WSC measured flow below the headgates and annual diversion at the headgates for the period from 1975 to 1990 was undertaken by the Ministry of Environment in 1991 (McNeil, 1991). This study documented the average annual water use at 16,495 ML/year, with maximum water use of 20,302 ML in 1987, and the average net annual volume of water available in the Duteau Creek watershed was calculated at 37,448 ML (1.187 m^3/sec). In comparison to this historic analysis, the Master Water Plan runoff estimate is still 36% too high. Note too that while current average water use has declined from the 1975 to 1990 period, annual flows too are now generally lower as demonstrated in Section 3.

Based on the above, it is apparent that the Master Water Plan has overestimated the mean Duteau Creek runoff by at least 35%. Sections 8.3 and 8.4 discuss the Master Water Plan runoff estimates in relation to available flow monitoring to try to provide a greater understanding of why the runoff is overestimated. Note though that any estimation of runoff in a specific watershed using regional runoff estimation techniques is only an approximation of actual average runoff. The scatter of points around the trendlines in Figure 2 of Obedkoff's 1998 report indicates that the precision of regional runoff estimation is plus or minus 40 to 50%.

8.3. Upper Duteau Creek Flow Monitoring: 2008 - 2013

A seasonal flow monitoring program was initiated by RDNO for 3 sites upstream of the Duteau Creek reservoirs in 2008, and was expanded to include 1 site between the reservoirs and the Headgates in 2011 (G2O Services, 2012, 2013 and 2014). The Upper Duteau results are summarized below in Table 34. Note that annual runoff values would be higher, particularly for the lower elevation Curtis Creek sub-basin where the freshet peak is in May and which would have significant runoff in April. April flows are not included in the calculations because the flow monitoring usually started too late in April to provide a monthly average for April. Curtis Creek and Heart Creek, which includes the Gold-Paradise (McAuley Ck) Diversion, are in the Aberdeen Lake catchment, and Duteau Creek is in the Grizzly Lake catchment area.

Table 34. Mean May to October Flows and May to October Runoff at Upper Duteau Seasonal Flow Monitoring Stations

	Mean May to October Flow (m^3/s)			May to October Runoff (m)		
	Curtis Ck	Heart Ck	Duteau Ck	Curtis Ck	Heart Ck	Duteau Ck
2008	0.161	0.376	0.239	0.277	0.172	0.249
2009	0.075	0.448	0.252	0.106	0.205	0.262
2010	0.112	0.516	0.326	0.158	0.236	0.340
2011	0.179	0.702	0.415	0.252	0.321	0.433
2012	0.163	0.782	0.397	0.230	0.358	0.414
2013	0.197	0.569	0.362	0.334	0.313	0.499
Avg.	0.148	0.565	0.332	0.251	0.311	0.417

Averaging the measured runoff from the three tributaries and weighting for contributing area provides an average May to October runoff value for 2008 to 2013 of 0.327 m. This compares to the equivalent annual calculation of 0.314 m for the combined reservoir contributing areas in Table 33. The two values are quite comparable, and since the measured values don't include April or the late fall and winter flows, they suggest that runoff values for the area above the reservoirs should be relatively accurate unless the tributaries measured do not accurately represent the overall contributing area.

In order to test how well the 3 measured tributaries represent the larger watershed, the combined average monthly flows from the 3 tributaries were compared to the simulated naturalized flows for May and June from 2008 to 2013. Based on this comparison, the May and June flows from the 3 tributaries represent 63% of the total simulated naturalized flows for those two months. Since the total contributing area of the 3 tributaries is 50.6 km^2, compared to the area contributing to the reservoirs of 107.2 km^2, the runoff associated with these tributaries is clearly not representative of the larger area contributing runoff to the reservoirs and even less so for the total watershed area of 178.4 km^2. The misrepresentation is not really surprising, given that these 3 are the largest tributaries and they drain from the highest and most eastern area of the catchment.

8.4. Flyfish Lakes & Lower Duteau Estimated Runoff / Monthly Flows

The Lower Duteau Creek (including Flyfish Lakes) sub-catchments has an area of 71.2 km^2, which is 40% of the total contributing watershed area (including the Gold-Paradise diversion) above the Headgates. The average annual runoff for the Lower Duteau Creek sub-catchment was estimated at 17,340 ML (Table 33) which is 52% of the total estimated runoff above the Headgates. When converted to flows, the Lower Duteau sub-catchment would contribute an estimated mean annual flow of 0.55 m^3/sec at the Headgates.

The RDNO seasonal flow monitoring has included a station on Lower Duteau Creek above the Headgates from 2011 to 2013, but the data to date does not provide enough data to evaluate April, May and June flows when the bulk of the Lower Duteau Creek runoff would be expected because there is no way to differentiate the flow that is being released and / or spilling from the reservoirs from the Lower Duteau flow.

An attempt was made in the 2012 interim report (Epp, 2012) to validate the Lower Duteau runoff estimate by comparing monthly flows from Coldstream, Vance, Clarke (lower elevation Vernon Ck tributary) and Daves Creeks (lower elevation Mission Ck tributary) to the historical WSC Duteau Creek flows as a proportion of mean annual flow for each month. A key assumption in this exercise was that the reservoirs were essentially closed at the end of the irrigation season resulting in very little flow from the upper watershed until the reservoirs were full and spilling in June. The reservoir level records obtained for the water balance however demonstrate that the reservoirs are usually drawn down significantly during the winter months and can be full and spilling by early to mid May in early runoff years, which invalidates any conclusions drawn from the 2012 comparison.

8.5. Headgates Operation, Diversion to Goose Lake and Environmental Flows

Headgates operations are understood to be as follows:

- There is a pipe through the Headgates to pass flows for fish (DFO agreement) and downstream priority licences as per the following schedule from Kerr Wood Leidal & Dobson, 2008:

	Fisheries m^3/sec	Priority Water Licences m^3/sec	Total m^3/sec
Jan 1 - Mar 31	0.057		0.057
Apr 1 - Aug 31	0.113	0.057	0.170
Sept 1 - Sep 30	0.170	0.057	0.227
Oct 1 - Dec 31	0.142		0.142

- Water is diverted to Greater Vernon at the Headgates to primarily satisfy irrigation demands in summer, but also for domestic use and to refill Goose reservoir as needed. Diversions are variable from year to year, with the average monthly volumes calculated from the 1997 to 2013 diversion data obtained from RDNO. Average Goose Lake volume changes (as flow equivalent) are also shown below. The average Goose Lake levels increase from January to May and decrease from June to November, but since Goose Lake also functions as a balancing reservoir, the level changes may not fully represent the total diversion volumes to Goose Lake. The average monthly diversions to Goose Lake as represented by the Goose Lake level changes are not very high, but do represent 50% of the average April diversion, and level changes in Goose Lake in some years have exceeded the equivalent of a 0.200 m^3/sec diversion. Note too that winter refilling of Goose Lake comes at the expense of Duteau Creek reservoirs drawdown and/or Duteau Creek winter base flows.

	Monthly Volume ML	Equivalent Flow m^3/sec	Goose Lake m^3/sec
January	286	0.107	0.017
February	312	0.128	0.025
March	404	0.151	0.051
April	598	0.231	0.109
May	1,839	0.687	0.098
June	2,147	0.828	-0.028
July	3,553	1.326	-0.111
August	3,637	1.358	-0.078
September	1,590	0.613	-0.038
October	362	0.135	-0.030
November	238	0.092	-0.009
December	245	0.091	0.000
Total / Average	15,212	0.482	

- Diversions for consumption and Goose Lake refill as well as downstream releases during winter and spring months are supplied by unregulated runoff from the Flyfish Lakes / Lower Duteau sub-catchment as well as reservoir releases, with spill at the Headgates when flows exceed the diversion and downstream release through the Headgates. The typical reservoir draw downs through fall and winter as per Table 28 required to satisfy both diversion and downstream flows confirms that there is very limited runoff from Lower Duteau watershed during fall and winter months.

- Runoff from the Upper Duteau sub-catchments is stored in the Aberdeen, Grizzly and Haddo reservoirs, with releases and spill from Aberdeen and Grizzly routed through Haddo into Duteau Creek. In most years the reservoirs would be expected to fill completely in May to June, with spill contributing to the unregulated downstream runoff, followed by increased reliance on reservoir releases to meet diversion and downstream needs. In low runoff years the reservoirs do not fill completely, and more water needs to be released earlier to supplement the unregulated Lower Duteau runoff to meet the diversion and downstream releases.

- All of the flow in Lower Duteau Creek that exceeds the diversions and releases for fish and downstream licences spills over the Headgates. During winter and spring the spill volume is dependant on the balance between diversion volumes and the Lower Duteau runoff plus reservoir releases. Higher releases from storage are then required to balance diversions and Headgates releases as freshet flows in Lower Duteau Creek diminish into summer. Variable spill volumes can be expected as the release volume is set at Haddo Lake to match maximum expected diversion rates and declining runoff from Lower Duteau Creek, but weather fluctuations can reduce demand and increase runoff resulting in excess flow at the Headgates which then spills.

8.6. Headgates Release vs. Recommended Environmental Flows for Bessette Creek Watershed

The Headgates flow releases described in Section 8.5 include flows for fish and priority downstream licences based on an agreement with DFO. These fish flows range from a low value of 0.057 m^3/sec (5.7%LTmad) in January to March to a high value of 0.170 m^3/sec (17%LTmad) in September for salmon spawning, with intermediate values of 0.113 m^3/sec (11.3%LTmad) from April to August and 0.142 m^3/sec (14.2%LTmad) during the remainder of the fall spawning season from October to December. These values are well below current environmental flow recommendations for high value fish streams in BC (e.g. Table 20), and make no provision for higher flows during freshet that are required for stream channel maintenance, fry out-migration and adfluvial trout spawning.

The Headgates release flows could be considered as absolute minimum short term survival flows during water short periods, but target flows for normal flow regulation and future water storage and use planning should be based on the more conservative Environmental Flow Recommendations in Table 20 for sustainable fish populations in Duteau Creek.

8.7. Historic Regulated Duteau Creek Flows Compared to Environmental Flows for Spring Fry Out-migration, Summer Rearing and Fall Spawning

The Headgates release volumes from Section 8.5 and the Instream Flow Recommendations for the Bessette Creek watershed from Table 20 are plotted against historic WSC Duteau flows to 1996 in Figure 38.

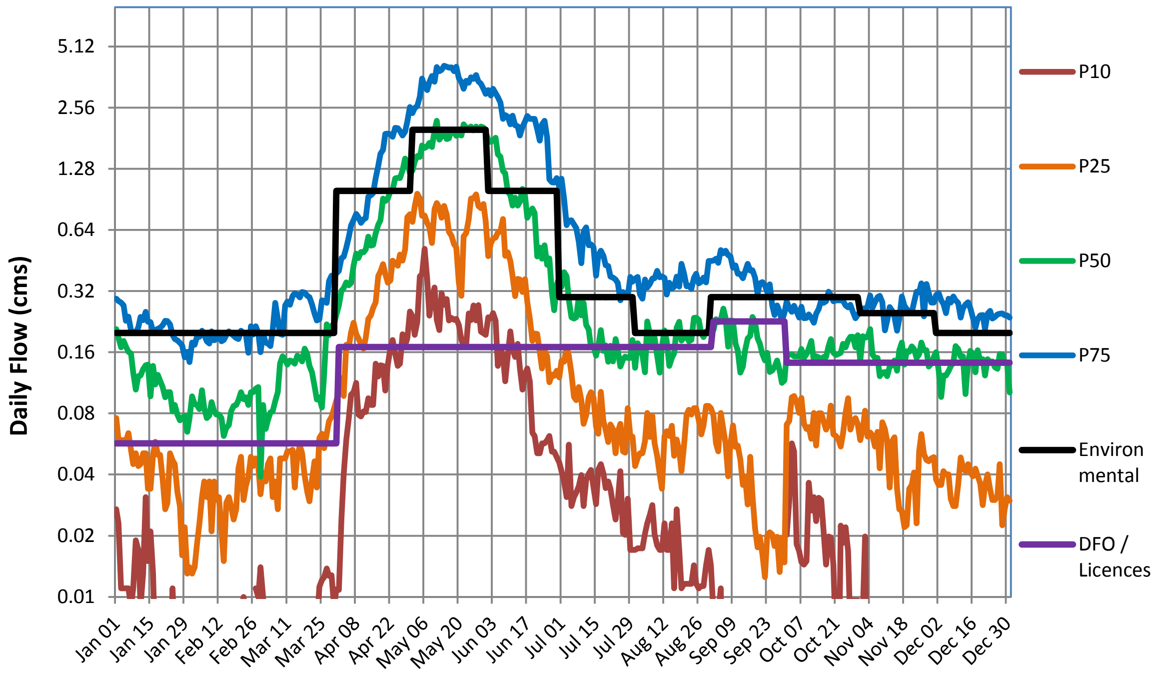


Figure 38. Historic (1919 - 1996) WSC Duteau Ck flows near Lavington Compared to Headgates Operating Policy Releases for DFO Fish Flows and Priority Downstream Licences, and to Recommended Environmental Flows for Bessette Creek Watershed.

Figure 38 shows that historically, the average year (P50) generally met the current Headgates release flows that are set to match the DFO agreement plus priority downstream licences from mid July to December 31, and exceeded them from January until mid July. One in four year low flows (P25) however only met the targeted release flows from mid April to mid June, indicating that historically, Duteau Creek flows were routinely well below the current Headgates release policy flows.

The recommended environmental flows were met by the 1 in 4 year (P75) high flows, but the average year (P50) flows only satisfied these recommendations from April to June, and the one in four year (P25) flows fell far short of the recommended environmental flows throughout the year.

The historic flows are based on 58 years of data between 1919 and 1996, with just seasonal flow measurements prior to 1973. As such, the flow data represents historical water regulation and may not accurately reflect the current water management.

Comparable flows to those shown in Figure 38 using the flows calculated below the Headgates using Headgates spill data plus the DFO / priority licence flows for the period from 1997 to 2013 are shown in Figure 39.

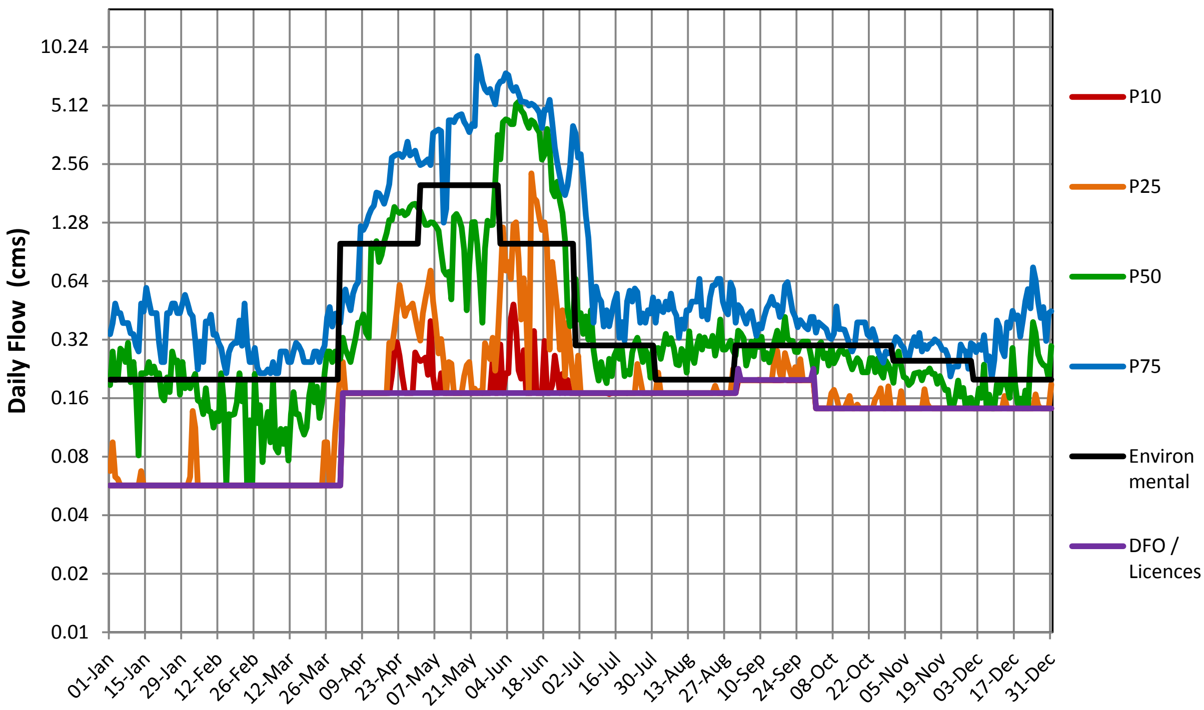


Figure 39. Simulated 1997 - 2013 Duteau Creek Flows below the Headgates Compared to Headgates Operating Policy Releases for DFO Fish Flows and Priority Downstream Licences, and to Recommended Environmental Flows for Bessette Creek Watershed.

There are several notable differences in the recent simulated flows versus the historic measured flows. First, the simulated flows assume that the DFO / Priority Licence volumes are always met, so the 10th and 25th percentile flows meet and are shown as meeting and exceeding the minimum flows for DFO and the priority licences. Second, the simulated flows are generally higher than the historic flows such that the median flows approximate, or come close to meeting the recommended environmental flows for much of the year, although as noted previously, the flow simulation appears to exaggerate the flows below Headgates. Third, the simulated flows show a distinct reduction in flows in mid May in the 10th and 25th percentile flows as well as the median flows, with the P10 and P25 flows dropping down to very low levels during the adfluvial rainbow spawning period.

8.8. Recent Regulated Duteau Creek Flows Compared to Simulated Naturalized Flows and Environmental Flows for Spring Fry Out-migration, Summer Rearing and Fall Spawning

Figure 40 shows the MFLNRO seasonal flow monitoring at Whitevale Road (Duteau 1) for 2011 , 2012 and 2013, with the simulated flow below Headgates for the early periods of 2011 and 2013. plotted against Headgates release volumes for fisheries and priority downstream licences from Section 8.5 and the Instream Flow Recommendations for Duteau Creek as per the %LTmad values from Table 20.

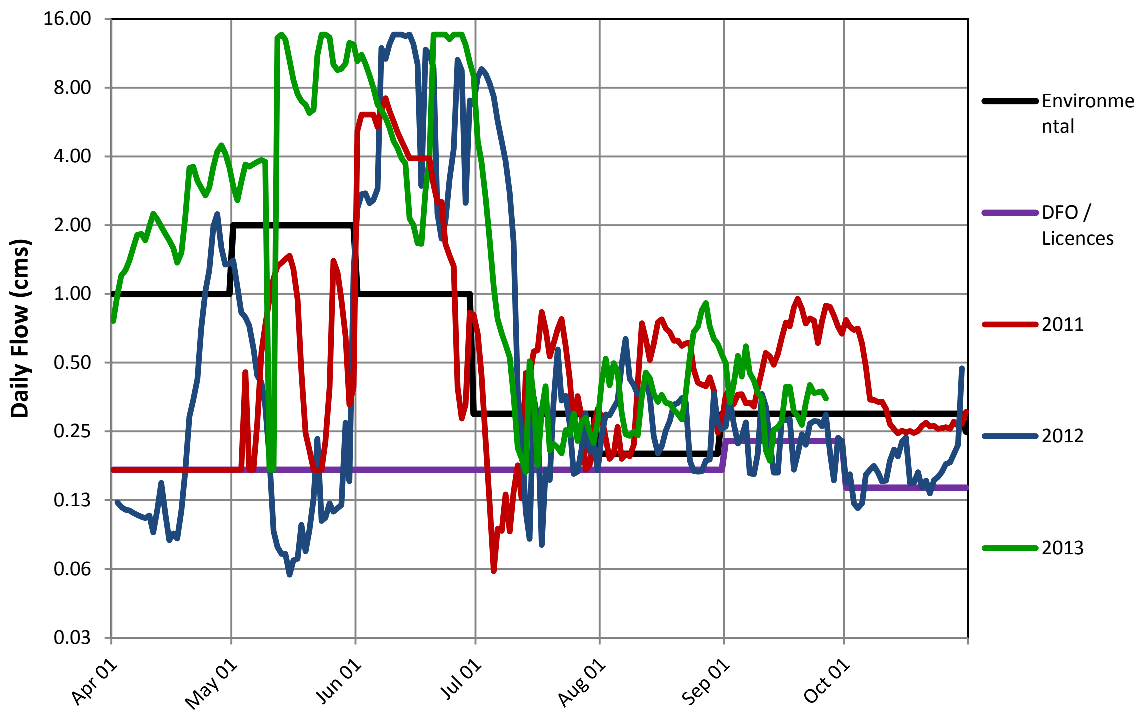


Figure 40. MFLNRO Seasonal Flow Monitoring in Duteau Ck at Whitevale Road (Duteau 1) for 2011, 2012 and 2013 (with Headgates Simulated Flows for early 2011 and 2013) Compared to Headgates Operating Policy Releases for DFO Fish Flows and Priority Downstream Licences, and to Recommended Environmental Flows for Duteau Creek.

The 2011 and 2013 flow monitoring started on June 30, and 14 June respectively, while the 2012 flow monitoring started on April 2, so the simulated flows below the Headgates have been added to the measured flows to provide comparisons for the earlier periods. Flow measurements were also disrupted for portions of June and July in 2012 and 2013 by freshet flows that exceeded the measurement capabilities of the seasonal station. These high flow periods are missing from the chart, but are well above the instream flow recommendations.
The flow comparison demonstrates that while in general, the DFO / priority licences flows were met most of the time and the recommended environmental flows were met much of the time, there are notable environmental flow issues associated with the flow regulation.

- There were periods in both 2011 and 2012 during which the measured flow values were well below minimum DFO policy flows. The most notable low flows occurred in May 2012 when lower elevation runoff was diminishing while water demand was increasing and reservoir releases were inadequate to make up the shortfall. A second notable period of low flows occurred in July in both 2011 and 2012 when freshet ended and reservoir releases were again inadequate to meet the demand and downstream flow. Lower flows also occurred in early April 2011, along with sporadic minor occurrences in September and October of 2011.
- The periods of measured flows that are below the DFO threshold indicate that releases through the Headgates are not as uniform, nor as dependable as would be expected with a pipe through the Headgates. It has been suggested that the lower flows relate to the lower head level when Headpond levels are low. Regardless of why, the lower than expected flows are an issue that should be resolved.
- Data from all three years indicates that Duteau Creek flows below the Headgates fluctuate significantly on a day to day basis from mid July through to the end of October. This results in relatively high average flows that exceed the DFO thresholds, and often meet the Environmental flow recommendations, but the flows frequently drop down to, or even below, the minimum DFO level such that there is little if any environmental benefit to the higher average flows. Better flow balancing could benefit the environmental values while reducing reservoir drawdown with more uniform flows.
- A missing element in the DFO flow thresholds are the higher flows required in late April / May for salmon fry out migration and adfluvial (from Mabel Lake) rainbow trout spawning. The flow pattern shows increasing flows in Duteau Creek below the Headgates in April in 2012 and 2013 and in early May in 2011, but in each year there are days to weeks in mid May where the flow is severely reduced due to the combination of diminishing runoff from lower Duteau Creek, increasing diversions at the Headgates, and Upper Duteau runoff being retained in the reservoirs. High flows then resume in late May or June when the reservoirs are full and spilling. The severely reduced flow pattern in mid May is highly detrimental to the spawning trout, and should, if at all possible, be eliminated by releasing more water from the upper watershed in May to eliminate the low flows. The 40% LTmad recommended as the lowest flow for rainbow trout spawning in Duteau Creek as per Table 16 indicates that flows of least 0.40 m^3/sec should be maintained in Duteau Ck below the Headgates during May.

8.9. Duteau Reservoirs Drawdown and Refill

Runoff, Drawdown and April to June Diversion as Reservoir Refill Factors

The data in Table 27 indicates that the Duteau Creek reservoirs did not fill completely in 3 of the last 17 years - 2003, 2007 and 2009. The low simulated naturalized flows shown in Table 31 for 2007 and 2009, as well as the well know low flows in 2003 were undoubtedly a significant factor in the reservoir filling. Runoff and reservoir inflows are not the only factors affecting reservoir refill.

Reservoir drawdowns also factor into reservoir refill. Reservoir drawdown levels vary significantly from year to year, from an April 1 volume of 3,022 ML in 2010 to an April 1 volume of 17,239 ML in 2005, and a median April 1 volume of 6,728 ML. The starting level of 4,565 ML in 2003 was well below median levels and undoubtedly a factor that year, while 2007 and 2009 April 1 levels were closer to median values for April 1 at 6,440 ML and 5,699 ML respectively. While risk of refilling is higher at lower April 1 volumes, drawdown to levels below 6,000 ML is not necessarily a problem as evidenced by 2004, 2010, 2011 and 2012 which all had complete reservoir refill despite April 1 levels below 6,000 ML.

Water diversions at the Headgates are also highly variable from year to year, ranging from 10,880 ML in 1997 to 19,751 ML in 2002, with a median value of 15,212 ML. Monthly water diversions are also highly variable from year to year, and high diversion rates in April, May and June necessitate reservoir releases while the reservoirs are filling, which in turn can impact reservoir refill. This was a particular factor in 2009 when the April to May diversion was 6,308 ML, which was 1,731 ML higher than the average diversion rate for those 3 months of 4,577 ML. The difference would not have been enough to completely refill the reservoirs in 2009, but the unfilled volume would have been substantially reduced.

Snowpack as an Indicator of Runoff Volume

Snowpack readings are widely used as an indicator to predict runoff volumes relative to average or normal conditions. High snowpack readings on April 1 and May 1 should translate into higher than normal runoff and above average reservoir refill, while lower than normal snowpack readings would suggest lower than normal conditions. Validity of snow course readings as an indicator of normal conditions may be questioned following the 2009 experience where the April 1 reading at the Aberdeen snow course was 145% of normal, but the Duteau reservoirs didn't fill. The relationship between the April change in reservoir volume is plotted against the April 1 snow course water equivalent in Figure 41.

Figure 41 demonstrates that there is a relatively good correlation between reservoir refill and the Aberdeen snow course readings with 4 notable exceptions -1997, 2009, 2011, and 2012. For all except 2009, the low April runoff was offset by high runoff in May and June, leaving 2009 as the year where a high April 1 snowpack reading did not translate into enough runoff to fill the reservoirs. While the Aberdeen snow course in 2009 has an April 1 % normal value of 145%, the nearby Oyama and Postill snow courses were at 95% and 96% normal, suggesting that the 2009 value for Aberdeen was anomalous. Also, as discussed above, part of the reservoir refill issue in 2009 was the much higher than average diversion rate in April to June of 2009 which reduced the reservoir refill. Taken together, complete refill from a lower than average reservoir volume on April 1 should not be expected with the higher than normal diversion rate and a snowpack that was likely below normal. Reference to the Oyama and Postill Lake snow courses data is recommended for better runoff predictions than relying just on the Aberdeen snow course.

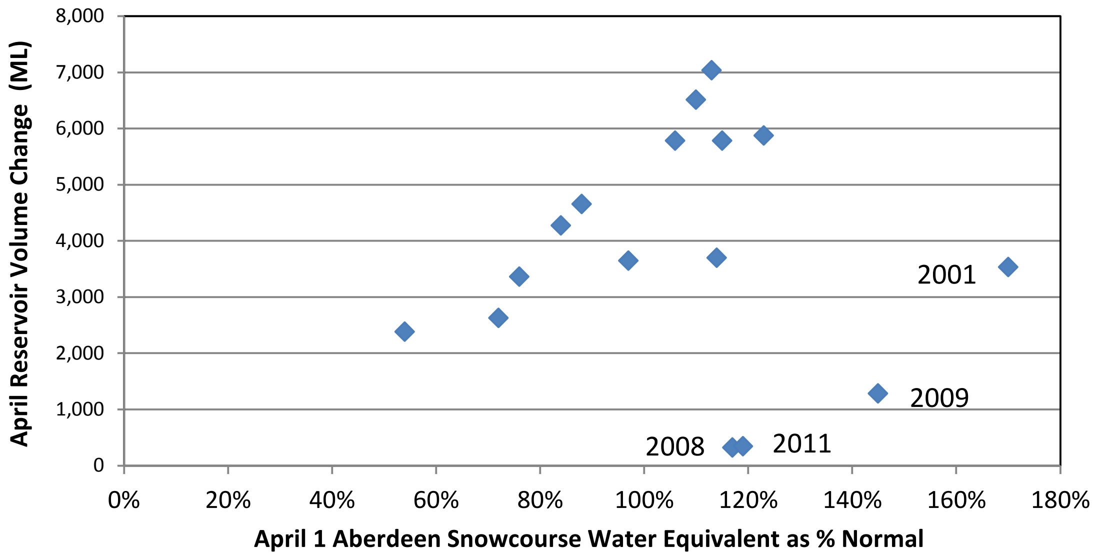


Figure 41. April reservoir volume changes vs. April 1 Aberdeen snowcourse readings.

Assessing Risk of Reservoirs Not Completely Refilling

Current reservoir refill practice, based on the hydrometric records and Headgates spill data, appears to be very conservative, focussing on filling the reservoirs as early as possible to ensure complete refill for minimal risk to the water supply. This practice likely does not significantly alter downstream flood hazards in years like 2013, because the reservoirs would have been full and spilling in June prior to the late June high flows even with much less conservative refill practices. The focus on reservoir early refill in all years does however significantly and mostly unnecessarily reduce downstream flows in May during the critical adfluvial rainbow trout spawning period.

The probability of reservoir refill between from April 1, when refill typically starts, to June 30 when spring runoff is ending, is primarily determined by the reservoir level on April 1, the snowpack at that time and weather during the April to June period, with reservoir releases to help meet Headgates diversions and downstream flows as an additional factor in drier years. Of these factors, only reservoir level and snowpack are known on April 1, so any early predictions will be subject to considerable uncertainty.

A simple risk rating system could be based on assigning points to April 1 reservoir level and April 1 snow course readings to rate the risk of reservoir not filling completely. The example in

Risk, 4 to 6 to Medium Risk and 7 to 9 to High Risk. The values used are somewhat arbitrary, intended just to demonstrate a concept.

Table 35 assigns points for April 1 reservoir levels as follows: 6 points for < 4,000 ML, 4 points for 4,000 to 7,000 ML, 2 points for 7,000 to 10,000 ML, and 0 points for > 10,000 ML. Since runoff is based on both snowpack and April to June precipitation, snow course reading points are assigned as: 3 points for < 84% normal, 2 points for 84% to 110 % normal, 1 point for 110 to 117% normal and 0 points for > 117% normal. The percentages chosen represent the lower quartile, median and upper quartile values. Totals of 0 to 3 are assigned to Low

Risk, 4 to 6 to Medium Risk and 7 to 9 to High Risk. The values used are somewhat arbitrary, intended just to demonstrate a concept.

Table 35. Example Risk of Reservoirs Not Refilling Analysis.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Reservoir Level	9,126	12,328	6,728	11,230	7,953	10,175	4,565	3,617	17,239	10,679	6,440	6,270	5,699	3,022	5,596	5,026	11,030
Snowpack	170%	88%	106%	113%	72%	97%	76%	110%	47%	114%	84%	117%	145%	54%	119%	123%	115%
Reservoir Level	2	0	4	0	2	0	4	6	0	0	4	4	4	6	4	4	0
Snowpack	0	2	1	0	3	2	3	1	3	1	3	0	0	3	0	0	1
Total	2	2	5	0	5	2	7	7	3	1	7	4	4	9	4	4	1
Risk	Low	Low	Med	Low	Med	Low	High	High	Low	Low	High	Med	Med	High	Med	Med	Low

This example correctly identifies 2003 and 2007 as High risk, but also includes 2004 and 2010 as High risk due to the low April 1 reservoir levels. 2009 is rated as only a Medium risk with a score of 4, although it should be noted that if the nearby Oyama snow course percentage of 95% had been used, the total score would have increased to 6, close to the High rating. Also, as shown in

Table 29, Headgates diversions in May and June of 2009 were approximately 1,700 ML higher than average which would have had approximately the same impact as average diversion starting from an April 1 reservoir level of 4,000 ML which could have increased the risk rating by another 2 points. The example suggests that risk of refilling can be approximated on April 1 based on reservoir levels and snow course readings, but given the importance of April to June precipitation and temperatures to runoff timing and runoff, April 1 risk ratings are likely to overestimate risk.

Estimating Minimum and Median Annual Reservoir Inflows

Minimum spring inflow reservoir volume increases can be determined from the reservoir volume changes in the three years during which the reservoirs did not fill completely. The April to June reservoir volume changes for those three years are 12,208 ML in 2003, 9,202 ML in 2007 and 10,362 ML in 2009. Since the diversion rates in 2007 during April to June were approximately 500 ML above average, the 9,200 ML refill from 2007 could be considered as a reasonable, and perhaps conservative approximation of the minimum refill level for the three Duteau reservoirs. Note that the volume changes are not likely the full inflow as water was likely being released from Haddo to meet the diversions and Duteau Creek flows below the Headgates.

Changes in reservoir volumes can not however be used to evaluate higher reservoir refills like median or maximum values because water starts spilling as soon as the reservoir are full, with only minimal additional volume increases possible during the spill period. An alternative way to calculate reservoir refill is to convert the simulated naturalized flows for April to June (Table 31) to volume and estimate the percentage of that which would have flowed through the reservoirs. Using 60% as the reservoir percentage (lower than the Master Water Plan proportion of 65% to account for naturalized runoff overestimation) indicates maximum refill in excess of 36,000 ML in both 1997 and 2013, and a median value of 19,733 ML, approximately the same as the reservoir capacity. This calculation is subject to all of the uncertainties discussed previously in regard to the naturalization process, as well as questions as to what the correct proportion of flow is for the reservoir portion. Comparison of the reservoir refill calculated this way to the volume changes shows this calculation overestimated the refill by 19% and 11 % for 2007 and 2009 respectively and underestimated it by 13% for 2010. The overestimation for 2007 and 2009 is at least in part explained by the probability that some inflow was not accounted for in the volume change because reservoir releases were likely during the refill period. As such this suggests that this method could be used as an approximation of the historic reservoir inflows with an assumed error value of +/- 10 to 15%.

This analysis confirms that the only years with low runoff were 2003 (assumed from Headgates spill data since diversion data for naturalization is not available), 2007 and 2009 with adequate runoff in all other years to completely refill the reservoirs from very low levels, with 2010 (actual volume increase calculated at 16,153 ML) as the next lowest reservoir refill volume.

Consequences of Reservoirs Not Completely Refilling

Reservoirs not completely filling during spring runoff is generally viewed negatively and perceived as a significant risk to the adequacy of the water supply. Complete refill every year may not however be necessary for water supply reliability. The more important consideration is whether or not the available volume is adequate to meet the demand, rather than whether or not the reservoirs reached full volume.

Consequences of not refilling can be evaluated by comparing July 1 to April 1 drawdown volumes to the minimum April 1 to July 1 refill volume, and April 1 start of refill volumes. The median July to following year March reservoir drawdown is 10,718 ML, approximately 1,500 ML more than the minimum refill volume of 9,202 in 2007. So in 2007, when the April 1 to July 1 reservoir inflow change only totalled 9,202 ML for a July 1 volume of 15,642 ML (lowest value for 1997 to 2013 period), the July 1 to following April 1 drawdown was 9,372 ML and the 2008 April 1 volume was 6,270, not much lower than the previous year April 1 start of 6,440 ML. Even with the median drawdown of 10,718 ML, the April 1 volume in 2008 would still have been 4,924 ML which would easily have refilled in 2008. In fact, even starting from an April 1 reservoir volume of 4,000 ML, after 2 years of minimum reservoir inflows (highly unlikely) and 2 years of average drawdown, the starting volume in the 3rd year would still be 1,000 ML. Not only are 2 consecutive years of inflows that low highly unlikely, but water use reductions would also be implemented and it is highly likely that the diversions and drawdown would be reduced to more closely match the low refill (as per 2007 drawdown).

So, complete refill from the lowest reservoir volumes should be expected more than 80% of years based on the reservoir inflows calculated above, and while complete reservoir refill each year is desirable, drawdowns to well below the median volume value of 6,728 ML and refill to volumes as low as 13,500 ML appear to have minimal consequences for adequate water supply.

8.10. Duteau Creek Base Flow Calculations

It is understood that fisheries flows described above in Section 8.5 are intended to approximate Duteau Creek base flows, but there does not appear to be any associated documentation explaining how these values were derived or what base flows in Duteau Creek might actually be. The following provides a representation of Duteau Creek low flows by converting the monthly naturalized Duteau Creek volumes in McNeil (1991) to flows, and comparing these to Coldstream Creek and Vance Creek expressed as % of mean flows to compensate for the variance in stream size.

The McNeil values are used rather than the simulated naturalized flows shown in Table 31, because the McNeil values will be more accurate as they utilize WSC hydrometric data rather than the simulated Headgates flows. The McNeil (1991) monthly volumes at the Headgates (actual flows adjusted for reservoir volume changes and diversions) are shown below in Table 36. It is noteworthy that the flows calculated by McNeil also exhibit negative values not just in August and September when they could be anticipated due to reservoir evaporation, but also in October, November, December and January. Since these calculated values include measured flows below the Headgates, they also suggest under reported water diversions unless there is yet unidentified factor in the water balance that accounts for significant winter water losses.

Table 36. Naturalized Flows for Duteau Creek at the Greater Vernon Water Headgates from McNeil, 1991.

	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Mean
Jan	0.075	0.207	0.133	0.056	0.098	0.352	0.491	0.111	0.476	0.252	0.164	0.380	0.096	0.085	- 0.104	0.351	0.201
Feb	0.088	0.153	0.095	0.076	0.193	0.319	0.456	0.653	0.773	0.264	0.119	0.217	0.517	0.099	0.286	0.083	0.274
Mar	0.224	0.155	0.145	0.237	0.599	0.498	0.485	0.309	0.499	0.335	0.151	0.283	0.945	0.600	0.307	0.313	0.380
Apr	0.390	0.732	2.727	2.605	0.765	2.312	1.515	0.785	3.614	2.164	2.269	4.350	1.563	2.225	2.001	1.100	1.945
May	5.884	6.863	3.625	5.431	5.824	3.870	5.120	8.075	7.802	4.173	4.741	5.236	2.530	3.201	4.410	3.931	5.045
Jun	4.157	4.461	1.699	2.566	1.796	2.891	5.416	4.198	3.107	4.166	2.197	2.798	0.275	1.789	2.845	10.238	3.412
Jul	0.210	1.450	0.405	0.327	0.589	1.002	2.428	4.555	1.065	1.294	0.807	2.506	0.081	1.025	1.385	1.853	1.311
Aug	0.126	2.097	0.067	0.395	-0.041	0.302	0.203	0.701	0.744	0.108	0.059	0.509	- 0.043	0.301	0.662	0.673	0.429
Sep	0.122	1.196	0.058	1.296	- 0.240	0.345	0.522	0.333	0.294	- 0.152	0.061	0.610	0.065	0.369	- 0.144	- 0.079	0.291
Oct	0.385	0.516	0.084	0.767	0.072	0.214	0.453	0.427	0.426	0.119	0.318	0.187	- 0.009	0.600	- 0.063	0.467	0.310
Nov	0.131	0.220	0.060	0.542	- 0.241	0.276	0.655	0.311	0.419	0.267	0.632	0.167	0.074	0.396	0.475	0.740	0.320
Dec	0.179	0.091	0.068	0.226	- 0.133	0.306	0.323	0.587	0.729	0.100	0.362	0.228	0.111	0.328	0.403	0.575	0.280
Annual	1.003	1.521	0.765	1.214	0.781	1.059	1.509	1.767	1.667	1.092	0.994	1.460	0.517	0.922	1.042	1.686	1.187

The flows shown in Table 36 were converted to percentages of the average annual flow value of 1.187 m^3/sec, and are summarized in Table 37, along with the similar calculations for Coldstream Creek and Vance Creek. Both streams have long hydrometric records which should represent relatively close comparisons to natural flow distribution patterns in Duteau Creek. The headwaters for both streams are located approximately 20 km north of the Duteau Creek Headgates on the slopes of Silver Star Mountain, with Coldstream Creek draining to the south and then west to Kalamalka Lake and Vance Creek draining to the southeast to Bessette Creek below Lumby. Coldstream Creek has no water regulation above the hydrometric station, while Vance Creek has a small storage reservoir at Silver Star and some irrigation licences above the hydrometric station. Both streams have lower annual discharge values than Duteau Creek which should result in lower summer, fall and winter low flows as a percentage of mean annual discharge due to scale variations in the hydrologic processes.

Table 37. Flow Comparisons for Duteau Creek at the GVW (McNeil, 1991) with Coldstream and Vance Creeks as % MAD

	Duteau Creek at Headgates				Coldstream Creek				Vance Creek				Fisheries Flow
	Min	P10	P25	Median	Min	P10	P25	Median	Min	P10	P25	Median	Mean
Jan	-9%	6%	8%	13%	6%	9%	14%	19%	7%	9%	12%	16%	5%
Feb	6%	7%	8%	17%	6%	11%	13%	18%	7%	10%	12%	17%	5%
Mar	12%	13%	20%	26%	6%	16%	21%	33%	9%	15%	21%	30%	5%
Apr	33%	63%	86%	175%	47%	85%	115%	208%	41%	68%	125%	191%	10%
May	213%	288%	330%	415%	79%	169%	237%	389%	130%	212%	272%	370%	10%
Jun	23%	147%	177%	242%	43%	81%	104%	191%	47%	116%	133%	204%	10%
Jul	7%	23%	46%	88%	20%	36%	52%	72%	22%	41%	45%	66%	10%
Aug	-4%	1%	8%	25%	7%	13%	24%	32%	11%	12%	19%	29%	10%
Sep	-20%	-12%	2%	18%	6%	12%	17%	22%	6%	11%	14%	18%	14%
Oct	-5%	3%	9%	30%	6%	15%	16%	25%	7%	11%	15%	19%	12%
Nov	-20%	6%	13%	25%	8%	15%	17%	26%	6%	11%	16%	22%	12%
Dec	-11%	7%	9%	23%	7%	11%	15%	19%	7%	9%	13%	19%	12%
Annual	43.6%	65.1%	82.2%	90.6%	35%	46%	71%	103%	40%	53%	69%	99%	9%

The comparison of the Duteau Creek naturalized flows from McNeil (1991) to Coldstream and Vance Creeks as % of mean annual discharge demonstrates reasonably good correlation, but some obvious differences in the Duteau Creek values resulting from aspects of the flow regulation. First, the minimum flows for August through January for Duteau Creek show negative values of up to -20% of the mean annual discharge, indicating that minimum and lower percentile flows are significantly under calculated in the naturalization process, with under reporting of fall and winter diversions as the most likely reason for this under representation of natural flow. Second, the naturalization calculation does not account for reservoir surface evaporation, resulting in exaggerated low flows in summer and early fall as demonstrated by the very low August and September flow calculations for minimum, as well as the 10th and 25th percentile flows.

Comparison of the fisheries flow values to Coldstream Creek and Vance Creek flows as % MAD demonstrates that fisheries flows (other than for September) are at best representative of 10th percentile flows, and for the January to March period are lower than the lowest flows recorded since 1968 in Coldstream Creek and 1979 in Vance Creek. It is apparent that the fisheries flows are extremely conservative (i.e. overly low) relative to natural low flows, and for a number of the months are nowhere close to the environmental flows recommended for the larger streams in the Bessette Creek watershed as per Table 20. As such, the current fisheries flows could be considered to be adequate for drought years, but consideration should be given to increasing these flows to better address environmental flow recommendations in dry, average and wet years.

8.11. DFO Conservation Storage Releases

Fisheries and Oceans Canada (DFO) holds a licence issued in 1978 for 1,233,480 cubic meters / year (MY) for conservation storage in Grizzly Swamp in the Duteau Creek drainage. As discussed in previous sections, the current fisheries flows fall far short of the environmental flow recommendations for overwintering flows, spring spawning flows for adfluvial trout spawning and channel maintenance. and summer rearing flows. The fisheries flows are closer to minimal fall spawning flows, but even those are still well below recommendations. The current fisheries flows should be routinely increased for all but drought years, and in no way should they be considered as use of the conservation storage.

Specific recommendations as to how to utilize the DFO conservation storage are beyond the scope of this study, and also would be dependent on what other changes are made to bring the Duteau Creek flows routinely closer to meeting the environmental flow recommendations. At current fisheries flow levels, any of overwintering flows, adfluvial rainbow spawning flows, fry outmigration flows, summer rearing flows and fall spawning flows could benefit from conservation storage releases. However, picking one portion of the year to enhance may not be overly effective as the various life stages are inter-related. For example, enhancing spawning flows to increase spawning may not achieve much gain if redds dry out in winter, there is inadequate flow for fry migration flows or summer rearing flows are inadequate for rearing. The limited volume of conservation storage is perhaps best utilized on an as needed basis as flows for portions of the year are often well above the minimum fisheries flows due a variety of reasons. Deciding on when to utilize the storage though requires real-time flow information to determine the need for conservation storage releases. In the absence of real-time data to trigger ad hoc releases, the best strategy my simply be to add the conservation storage volume to the fisheries flows. The conservation storage volume equates to a daily flow of 0.039 m^3/sec spread over 365 days which could be uniformly added to the fisheries flows for the entire year, or could be concentrated at higher rate(s) for a portion or portions of the year as determined by DFO

8.12. McAuley (Gold-Paradise) Diversion Licence

The Regional District of North Okanagan is authorized (Licence No. 017839) to divert 9,868 ML of water annually from McAuley Creek (Gold-Paradise diversion) in the Upper Bessette drainage into Heart Creek which drains into Aberdeen Lake. The licence has a priority date of 1921, and authorizes diversion for irrigation from April 1 to September 30 each year.

The McAuley Creek water is not however diverted directly into irrigation waterworks, but rather is diverted over to Heart Creek in the Duteau Creek drainage, from where it flows into Aberdeen Lake and then Haddo Lake which are storage reservoirs with storage authorized from October 1 to June 15. As such it would appear to have been more logical for the diversion to be authorized for storage from October 1 to June 15, with subsequent use for irrigation from April 1 to September 30.

It is understood that the diversion was historically operated consistent with the April to September timing, but after a major landslide lower in McAuley Creek in 2002, the diversion was left open year round to reduce stream flow through the slide debris. Without further direction to go back to the licence conditions, the diversion was then left permanently open until direction in the fall of 2013 to revert back to the licence timing.

Consideration should be given to changing the diversion timing to be consistent with October 1 to June 15 storage so that summer base flows from upper McAuley Creek continue to flow into Bessette Creek where summer flows above Lumby are routinely very low due to stream losses to groundwater. Alternately, if the licence timing is left as is, minimum residual instream flows should be specified for McAuley Creek as it would be unreasonable to divert 100% of the flow from a stream with downstream fisheries values.

Irrespective of authorized diversion timing, consideration should also be given to stopping the diversion from McAuley Creek when Aberdeen Lake is full and spilling to reduce downstream flooding in Duteau Creek. Storage reservoirs are not meant to attenuate flood flows, and high flows from upper Duteau Creek in wet years are a natural occurrence with or without reservoirs. Routing of McAuley Creek flows into Duteau Creek on the other hand are not natural, and could significantly increase flood risk if McAuley Creek flows continue to be diverted into Duteau Creek after the reservoirs are full and spilling.

9. RECOMMENDATIONS

Instream flow recommendations for the Bessette Creek watershed are defined in Table 20 based on consideration of weighted usable widths for the rearing and spawning habitat for the focal species, riffle passage, and fish spawning numbers in relation to residual and naturalized flows as discussed in Section 4. Comparison of the instream flow targets to residual flows indicates that the target flows are not consistently met under current practices and conditions. Instream flow recommendations are not likely to be met at all times in all years due in part to natural flow limitations in drier years, but implementing the flow recommendations will improve aquatic habitat conditions for fish and other aquatic biota and balance water use for instream and offstream values.

9.1. Formalize the Instream Flow Recommendations as Target Flows

The recommended instream flows in Table 20 are used to evaluate the adequacy of current residual flows and recommendations for improving the residual flows are focussed on the time periods where the residual flows fall short of the desired values. Implementing the recommendations that follow will be facilitated if instream flow recommendations are formalized as the instream flow targets for the Bessette Creek watershed. As such, it is recommended that:

- The MFLNRO Regional Aquatic Biologist to lead a process to have the instream flow recommendations adopted by the BC Ministry of Forests, Lands and Natural Resource Operations and DFO as the flow targets for the Bessette Creek watershed until such time as they are confirmed or supplanted by new Provincial policy based instream flow targets.

9.2. Nicklen Lake Storage Releases and Monitoring

Release of Nicklen Lake Storage for agricultural use and conservation flows is critical to maintaining flows in Bessette Creek. The following actions are recommended to maximize use of the available storage.

- The Nicklen lake reservoir operator to start agricultural storage release on or about July 15 at a release rate of 0.120 m^3/sec and continue at this rate until September 30.
- The Nicklen lake reservoir operator to release conservation storage to a maximum rate of 0.200 m^3/sec (equivalent to 5%LTmad in Bessette Ck above Beaverjack) or as needed in 0.040 m^3/sec increments to increase flows in Creek to 15%LTmad in August and 25%LTmad in September and October (and November if operationally feasible) **<u>if</u>** a realtime flow monitoring site is established in Bessette Creek.
- **<u>In the absence of a realtime flow monitoring reference site</u>**, the Nicklen Lake operator to release conservation storage at a constant rate of 0.160 m^3/sec (equivalent to 4%LTmad in Bessette Ck above Beaverjack) starting on August 15 and continuing until as late into November as operationally possible.

- MFLNRO staff to communicate the release strategy and release settings in 0.040 m^3/sec increments to the storage release operator.
- In the event that Nicklen Lake has not completely refilled prior to storage release, the conservation storage releases should be reduced proportionally to the volume of conservation storage available, with no changes to the agricultural storage release.
- Monthly monitoring of the Nicklen Lake level and the release volume to be recorded by MFLNRO staff from July through October in conjunction with dam inspections.
- Communication of release targets and any modifications thereof due to incomplete refill or modified targets will be the responsibility of the MFLNRO Fisheries staff in Penticton.

9.3. Duteau Creek Flow and Diversion Monitoring

Duteau Creek flow monitoring is critical to maintaining an accurate water balance for Duteau Creek to quantify runoff, reservoir refill and success in meeting environmental flow targets. The following actions are recommended for RDNO to improve the accuracy of the water balance information in this report, as well as future data recording.

- Continue flow monitoring at existing seasonal sites (Upper Duteau Creek, Heart Creek, Curtis Creek and Lower Duteau Creek to expand the information base for reservoir inflows. Expand the flow monitoring program to include Duteau Creek flows leaving Haddo Lake (assess quality of the historical data from this location) and flows below the Headgates.
- Pending the recovery of suitable historic hydrometric data for Duteau Creek leaving Haddo Lake, complete a water balance analysis for Duteau Creek at the outflow of Haddo Lake to confirm runoff volumes and also potentially evaporation rates using the three sources of RDNO hydrometric data including: (1) the existing seasonal sites; (2) reservoir water levels; and (3) the outflow data from the RDNO station immediately downstream from Haddo Lake (need to confirm the length of record and quality of the data).
- Verify the Headgates spill rating curves, the flow settings / volumes for the Headgates fisheries flow pipe, and the accuracy and zero level for the current Headgates spill SCADA system.
- Verify the Headgates diversion volume reporting (negative naturalized flow calculations in winter months suggest under reporting of Headgates diversions)

9.4. Goose Lake Reservoir Refill

Goose Lake is currently refilled from a portion of the diversions at the Duteau Creek Headgates, with most of the refill in winter and spring. Refill from Duteau Creek has several issues: water diverted to Goose Lake is subject to costly water treatment, Duteau reservoirs are drawn down in winter to fill Goose Lake, and the spring runoff flows that would help to meet environmental flow targets are reduced by the Goose Lake diversion. To resolve these issues, the following is recommended:

- RDNO to evaluate water source alternatives (e.g. BX Creek or Okanagan Lake) for Goose Lake refill to reduce water demand from Duteau Creek.

9.5. Duteau Creek Reservoir Expansion Plans

The mean annual reported water diversion at the Headgates from Duteau Creek (including the McAuley diversion) since 1997 is 15,212 ML, with the maximum annual diversion in 2002 at 19,751 ML. The recent (2013) Master Water Plan consider several options for increasing water supply from Duteau Creek by an additional 24,000 ML/year (3,000 ML of which would be via increased diversion from McAuley Creek). Inherent in the analysis is modelled average annual runoff of 50,958 ML from Duteau Creek above the Headgates. The modelled runoff value is not consistent with the mean annual runoff volume of 37,448 ML calculated by McNeil (1991) using WSC flow records from below the Headgates and reported diversions at the Headgates, nor with similar annual runoff estimates in this study. The high average annual diversion rate of 42% of the measurement based average annual runoff, coupled with reservoir refill operations results in Duteau Creek flows that are often below recommended environmental flows. Increasing storage and diversion from Duteau Creek is a severe risk for fish and aquatic values in Duteau Creek downstream of the Headgates. The following actions are recommended to protect the aquatic values in Duteau Creek if reservoir capacity and/or water supply from Duteau Creek is to be increased.

- RDNO to revise the Master Water Plan runoff estimates to match runoff calculated from the historic WSC flow record and the reported diversion volumes, and amend recommendations accordingly.
- RDNO to undertake a formal (i.e. signed by DFO and WSD) Water Use Plan for Duteau Creek with defined instream flow requirements for aquatic values in relation to water supply as a condition for any increase in Duteau Creek supplied reservoir storage capacity and/or Duteau Creek water diversions.

9.6. Duteau Creek Reservoir Operations and Instream Flows

Flows below the Headgates are quite variable relative to the DFO / Downstream Licence flow requirements as well as the Environmental Flow Recommendations in this report. There are specific periods where instream flows are routinely low, and periods where average flows are adequate, but environmental values don't benefit from the average because flows range much lower than average. The following actions are recommended for RDNO to increase and stabilize instream flows:

- Increase winter storage releases from Haddo reservoir and/or stop diverting Duteau Creek flows to Goose Lake to increase winter flows in Duteau Creek. The current flow release policy of 0.057 m^3/sec for January to March could be retained as the minimum when reservoirs are severely depleted, but routine winter releases should be closer to the recommended 20%LTmad value of 0.200 m^3/sec.
- Release additional flow from Haddo reservoir in May to eliminate the extreme low flows that can occur in Duteau Creek when water diversion is increasing, the lower

watershed runoff is diminishing, and the reservoirs in the upper watershed are not yet spilling. This is a critical period for adfluvial rainbow trout spawning and salmon smolt out migration. After flows exceed 0.400 m^3/sec in April (or May), flows should be maintained at or above that level by Haddo releases until the reservoirs are spilling enough to maintain that level, or it is clear that the reservoirs won't spill due to low runoff.

- Improve reservoir release operations and diversion balancing capabilities to reduce the flow variability below the Headgates. Remote gate operation on Haddo reservoir would allow for quicker and easier reservoir release adjustments. Larger balancing capabilities at or below the Headgates would allow for more uniform diversion rates which reduce the uncontrolled / unpredictable spill at the Headgates.
- Improve the fish flow / downstream licence release mechanism / structure to release to reduce / eliminate the flow variability that is attributed to lower flows at lower levels in the Headpond.

9.7. DFO Conservation Storage

DFO has a licence to store 1,233 ML in the Grizzly Lake reservoir each year for conservation flow releases, but there does not appear to be a formal policy for timing and volume of conservation flow releases. It has been suggested that the conservation flows are accounted in the Headgates flow release policy for fish and downstream licences. To evaluate this, the minimum flows in the current fish flow / downstream licence Headgates release policy were compared with minimum, low and average flows as %LTmad in Coldstream and Vance Creeks (nearby but smaller creeks) and naturalized flow calculations for Duteau Creek. The comparison demonstrates that the current fish flows represent at best 25th percentile flows in September, 10th percentile flows in summer and other fall months, and lowest flows on record in the January to March period. The current fish flow release policy is very low relative to base flows and should in no way be construed as utilizing the DFO conservation flows. The following action is recommended to ensure that the DFO conservation flows are consistently utilized:

- DFO staff, in consultation with the MFLRNO aquatic biologist, to design and formalize with RDNO, a conservation flow release strategy to routinely use the conservation storage to enhance fish flows in Duteau Creek.

9.8. McAuley (Gold-Paradise) Diversion Licence

The McAuley Creek diversion licence authorizes a substantial diversion from the Harris Creek drainage into Duteau Creek for the purpose of irrigation from April 1 to September 30. However, the water is first diverted into Aberdeen Lake, and as such the timing of the diversion would be more appropriate in accordance with storage licences (October 1 to June 15). Changing the timing should be beneficial to both operational considerations for RDNO and summer low flows downstream of the McAuley Creek diversion. The following actions are recommended:

RDNO to initiate discussions with the MFLNRO Water Stewardship Division in regard to converting the timing of the McAuley diversion licence to reflect reservoir storage prior to use for irrigation.

9.9. Designate Bessette Creek as a Sensitive Stream Under the Fish Protection Act

Even with implementation of all of the above recommendations, Bessette Creek will still have very low instream flows in some years due to the high water allocations in relation to summer and fall flows in drier years. Maintaining minimum instream flows in Bessette Creek in those years is likely to require additional water use regulation, over and above the preceding recommendations. A proactive approach, with pre-determined flow references and actions (e.g. 20% LTmad for notification that actions may be required and 10% LTmad as the action level) is needed for a timely and effective response when low flows are developing. As such it is recommended that:

- The MFLNRO Regional Aquatic Biologist to lead a process to have Bessette Creek named as a Sensitive Stream under the Fish Protection Act to define a process whereby specific water use regulation actions occur in the Bessette Creek watershed when flows reach pre-determined low flow levels.

9.10. Develop a Fish Population Monitoring Program to Evaluate the Health of Fish Populations in the Bessette Creek Watershed

- Given the high aquatic values and multiple impacts relating to water and land-use, a comprehensive program is required to confirm the specific linkages between water use and fish population impacts and also to evaluate the effectiveness of the proposed water management changes. The complex nature of the watershed and management actions warrant expert involvement in development of a monitoring program. Partnerships with water users, universities, governments (DFO, MFLNRO, First Nations) and other stakeholders are required.

10. REFERENCES

Askey, Paul, 2013. Personal Communication. Senior Fisheries Biologist, Ministry of Forests, Lands and Natural Resource Operations, Penticton, B.C.

AECOM, Associated Engineering (B.C.) Ltd., and Kerr Wood Leidal Associates, Ltd., 2013a. Greater Vernon Water (GVW) Technical Memorandum No. 2, Evaluation of Water Supply Sources. Regional District of North Okanagan, Coldstream, B.C.

AECOM, Associated Engineering (B.C.) Ltd., and Kerr Wood Leidal Associates, Ltd., 2013b. Greater Vernon Water (GVW) Technical Memorandum No. 3, Source Storage and Supply. Regional District of North Okanagan, Coldstream, B.C.

B.C. Ministry of Environment, 1965. Aberdeen Lake Reservoir Storage and Basin Data Accompanying Plan of Reservoir. Water Management Branch, B.C. Ministry of Environment, Victoria, B.C.

B.C. Ministry of Environment, 1978. Nicklen Lake Reservoir Plan of Reservoir. Environmental and Engineering Services, Water Investigations Branch, B.C. Ministry of Environment, Victoria, B.C.

B.C. Ministry of Environment, 1980. Grizzly Swamp Reservoir Storage and Basin Data Accompanying Plan of Reservoir. Environmental and Engineering Services, Water Investigations Branch, B.C. Ministry of Environment, Victoria, B.C.

B.C. Ministry of Environment, 1981. Haddo Lake Reservoir Plan of Reservoir. Inventory and Engineering Branch, B.C. Ministry of Environment, Victoria, B.C.

B.C. Ministry of Environment, 2001. Profile of a Candidate Stream under the Fish Protection Act: Bessette Creek. British Columbia Ministry of Environment, Victoria, B.C.

British Columbia Ministry of Forests, Lands, and Natural Resource Operations, 2012. iMapBC [web application]. Province of British Columbia, Victoria, BC. Accessed online <http://webmaps.gov.bc.ca/imfx/imf.jsp? site=imapbc>.

Caverly, Alan, 2012. Personal Communication. E-mail dated May 30, 2012. Aquatic Ecologist, Ministry of Forests, Lands and Natural Resource Operations, Kamloops, B.C.

Demarchi, D.A., 2011. The British Columbia Ecoregion Classification, Third Edition. Ecosystem Information Section, British Columbia Ministry of Environment, Victoria, B.C.

Epp, P., 2012. Environmental Flows and Hydrologic Assessment for the Bessette Creek Watershed, 2011 and 2012 Interim Report. Prepared for the BC Ministry of Forests, Lands and Natural Resource Operations, Kamloops, B.C.

Estes, C., 1998. Annual Summary of Instream Flow Reservations and Protection in Alaska. Fisheries Data Series No. 98-40. Alaska Department of Fish and Game.

G2O Service, 2012. Duteau Creek Water Supply and Hydrology Study (Year 4 - 2011 Report). Prepared for the Regional District of North Okanagan, Coldstream B.C.

G2O Service, 2013. Daily Discharge Summaries for Upper Duteau, Heart, Curtis and Lower Duteau Hydrometric Stations for 2012. E-mail from Gary van Emmerick, G2O Services, Kelowna, B.C.

Golder, 2012. Phase 1 - Shuswap River Sustainability Plan Technical Assessment of the Shuswap River Watershed. Golder Associates. Prepared for Regional District of North Okanagan, Coldstream, B.C. Web accessed at: http://www.rdno.ca/docs/120203_shuswap_tech_assess_text.pdf

GVW, 2014. Greater Vernon Water website, water sources. Web accessed at: http://www.rdno.ca/index.php/services/engineering/water/greater-vernon-water/water-sources.

Hatfield, T., A. Lewis, D. Olson, and M. Bradford. 2003. Development of Instream Flow Thresholds as Guidelines for Reviewing Proposed Water Uses. British Columbia Ministry of Sustainable Resource Management and Ministry of Water, Land, and Air Protection, Victoria, B.C.

Kerr Wood Leidal Associates Limited, 2008. Duteau Creek Water Source Project Alternatives. Prepared for Greater Vernon Services - Water, Coldstream, B.C.

Kerr Wood Leidal Associates Limited, and Dobson Engineering Ltd., 2008. Duteau Creek Water Watershed Assessment & Recommendations for Source Protection. Draft report prepared for Regional District of North Okanagan, Greater Vernon Services - Water, Coldstream, B.C.

Matthews, S., and C.J. Bull, 2003. Selection of Focal Watersheds For the Protection and Restoration of Fish Stocks and Fish Habitat in the Okanagan Region. Environmental Stewardship Division, Ministry of Water, Land and Air Protection, Penticton, B.C.

McNeil, R.Y., 1991. Report on the Derivation of an Operating Rule Curve for Duteau Creek Reservoirs. Hydrology Section, Water Management Division, B.C. Environment.

Minor, Tom, 2013. Personal Communication. Included on flow measurement data sent to P. Epp on August 23, 2013.

Obedkoff, W., 1998, Streamflow in the Southern Interior Region. Water Inventory Section, Inventory Branch, B.C. Ministry of Environment, Lands and Parks, Victoria, B.C.

Province of British Columbia, 2012. Water Licenses Web Query. Accessed online at: <http://a100.gov.bc.ca/pub/wtrwhse/water_licenses.input>.

Ptolemy, R. Personal Communication. HSI and workbooks.

RDNO, 2013. Water diversion data received from Z. Marcolin and R. Clark in e-mails dated: Nov. 12, 2013, Dec. 12, 2013, and Jan. 8, 2014.

Reiser, D.W. and T.C. Bjornn. 1979. Habitat Requirements of Anadromous Salmonids. General Technical Report PNW-96. Pacific Northwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Portland Oregon.

Rood, K.M., and R.E. Hamilton, 1995. Hydrology and Water Use for Salmon Streams in the Thompson River Watershed, British Columbia. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2297. Fraser River Action Plan, Department of Fisheries & Oceans, Vancouver, B.C.

Triton, 2009. Habitat Suitability for Small Bodied Chinook in the Thompson Nicola Watershed. Prepared by Triton Environmental Consultants, Richmond, B.C. for Fraser Basin Council, BC Ministry of Environment and Fisheries and Oceans Canada.

Water Investigations Branch, 1974. Kalamalka-Wood Lake Basin Water Management Study, 1974. Water Investigations Branch, British Columbia Water Resources Service, Departments of Forests, Lands and Water Resources, Victoria, B.C.

Water Survey of Canada (WSC). 2012. Water Survey of Canada Archived Hydrometric Data. Website: http://www.wsc.ec.gc.ca/applications/H2O/index-eng.cfm.

Watts, Dean, 2012. Personal Communication. E-mails dated Feb 24, 2012 and June 1, 2012. Senior Habitat Biologist, Fisheries and Oceans Canada, Kamloops, B.C.

White, Tara, 2011. Personal Communication. Phone call and e-mail in regard to fisheries priorities of Bessette Creek. Senior Fisheries Biologist, Ministry of Forests, Lands and Natural Resource Operations, Penticton, B.C.

Appendix A

Habitat Suitability Index Values
for Weighted Usable Width Charts
for Riffle and Glide Transects in
Bessette, Duteau and Creighton Creeks

Rainbow fry (summer)

depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0.00	0.20
0.01	0.20	0.01	0.50
0.02	0.40	0.02	0.70
0.03	0.60	0.03	0.80
0.04	0.80	0.04	0.85
0.05	1.00	0.05	0.90
0.06	1.00	0.06	0.95
0.07	1.00	0.07	1.00
0.08	1.00	0.08	1.00
0.09	1.00	0.09	1.00
0.10	1.00	0.10	1.00
0.11	1.00	0.11	1.00
0.12	1.00	0.12	1.00
0.13	1.00	0.13	1.00
0.14	1.00	0.14	1.00
0.15	1.00	0.15	1.00
0.16	1.00	0.16	1.00
0.17	1.00	0.17	1.00
0.18	1.00	0.18	1.00
0.19	1.00	0.19	1.00
0.20	1.00	0.20	1.00
0.21	1.00	0.21	0.97
0.22	1.00	0.22	0.94
0.23	1.00	0.23	0.92
0.24	1.00	0.24	0.89
0.25	1.00	0.25	0.86
0.26	0.97	0.26	0.82
0.27	0.94	0.27	0.79
0.28	0.91	0.28	0.75
0.29	0.88	0.29	0.72
0.30	0.85	0.30	0.68
0.31	0.82	0.31	0.65
0.32	0.78	0.32	0.62
0.33	0.75	0.33	0.58
0.34	0.71	0.34	0.55
0.35	0.68	0.35	0.52
0.36	0.65	0.36	0.49
0.37	0.62	0.37	0.45
0.38	0.58	0.38	0.42
0.39	0.55	0.39	0.38
0.40	0.52	0.40	0.35
0.41	0.48	0.41	0.32
0.42	0.46	0.42	0.3
0.43	0.43	0.43	0.27
0.44	0.40	0.44	0.25
0.45	0.38	0.45	0.22
0.46	0.36	0.46	0.21
0.47	0.34	0.47	0.20
0.48	0.31	0.48	0.18
0.49	0.29	0.49	0.17
0.50	0.27	0.50	0.16
0.51	0.25	0.51	0.15
0.52	0.23	0.52	0.14
0.53	0.22	0.53	0.13
0.54	0.20	0.54	0.12
0.55	0.18	0.55	0.11
0.56	0.17	0.56	0.10
0.57	0.16	0.57	0.09
0.58	0.15	0.58	0.08
0.59	0.14	0.59	0.07
0.60	0.13	0.60	0.06
0.61	0.12	0.61	0.05
0.62	0.12	0.62	0.05
0.63	0.11	0.63	0.04
0.64	0.11	0.64	0.04
0.65	0.10	0.65	0.02
0.66	0.10	0.66	0.02
0.67	0.10	0.67	0.02
0.68	0.10	0.68	0.01
0.69	0.10	0.69	0.006
0.70	0.10	0.70	0
0.71	0.10	0.71	0
0.72	0.10	0.72	0
0.73	0.10	0.73	0
0.74	0.10	0.74	0
0.75	0.10	0.75	0
0.76	0.10	0.76	0
0.77	0.10	0.77	0
0.78	0.10	0.78	0
0.79	0.10	0.79	0
0.80	0.10	0.80	0
0.81	0.10	0.81	0
0.82	0.10	0.82	0
0.83	0.10	0.83	0
0.84	0.10	0.84	0
0.85	0.10	0.85	0
0.86	0.10	0.86	0
0.87	0.10	0.87	0
0.88	0.10	0.88	0
0.89	0.10	0.89	0
0.90	0.10	0.90	0
0.91	0.10	0.91	0
0.92	0.10	0.92	0
0.93	0.10	0.93	0
0.94	0.10	0.94	0
0.95	0.10	0.95	0
0.96	0.10	0.96	0
0.97	0.10	0.97	0
0.98	0.10	0.98	0
0.99	0.10	0.99	0
1.00	0.10	1.00	0

Rainbow parr (summer)			
depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0.00	0
0.01	0	0.01	0.05
0.02	0	0.02	0.11
0.03	0.04	0.03	0.18
0.04	0.09	0.04	0.25
0.05	0.13	0.05	0.30
0.06	0.17	0.06	0.35
0.07	0.21	0.07	0.40
0.08	0.25	0.08	0.45
0.09	0.29	0.09	0.50
0.10	0.33	0.10	0.55
0.11	0.37	0.11	0.59
0.12	0.42	0.12	0.63
0.13	0.46	0.13	0.67
0.14	0.51	0.14	0.71
0.15	0.55	0.15	0.75
0.16	0.59	0.16	0.78
0.17	0.63	0.17	0.81
0.18	0.67	0.18	0.84
0.19	0.71	0.19	0.87
0.20	0.75	0.20	0.90
0.21	0.78	0.21	0.92
0.22	0.81	0.22	0.94
0.23	0.85	0.23	0.96
0.24	0.88	0.24	0.98
0.25	0.91	0.25	1.00
0.26	0.92	0.26	1.00
0.27	0.94	0.27	1.00
0.28	0.95	0.28	1.00
0.29	0.97	0.29	1.00
0.30	0.98	0.30	1.00
0.31	0.98	0.31	1.00
0.32	0.99	0.32	1.00
0.33	0.99	0.33	1.00
0.34	1.00	0.34	1.00
0.35	1.00	0.35	1.00
0.36	1.00	0.36	1.00
0.37	1.00	0.37	1.00
0.38	1.00	0.38	1.00
0.39	1.00	0.39	1.00
0.40	1.00	0.40	1.00
0.41	1.00	0.41	1.00
0.42	1.00	0.42	1.00
0.43	1.00	0.43	1.00
0.44	1.00	0.44	1.00
0.45	1.00	0.45	1.00
0.46	1.00	0.46	1.00
0.47	1.00	0.47	1.00
0.48	1.00	0.48	1.00
0.49	1.00	0.49	1.00

depth (m)	probability of use	velocity (m/s)	probability of use
0.50	1.00	0.50	1.00
0.51	1.00	0.51	1.00
0.52	1.00	0.52	1.00
0.53	1.00	0.53	1.00
0.54	1.00	0.54	1.00
0.55	1.00	0.55	1.00
0.56	1.00	0.56	0.99
0.57	1.00	0.57	0.97
0.58	1.00	0.58	0.96
0.59	1.00	0.59	0.94
0.60	1.00	0.60	0.93
0.61	1.00	0.61	0.91
0.62	1.00	0.62	0.9
0.63	1.00	0.63	0.88
0.64	1.00	0.64	0.87
0.65	1.00	0.65	0.85
0.66	1.00	0.66	0.83
0.67	1.00	0.67	0.81
0.68	1.00	0.68	0.8
0.69	1.00	0.69	0.78
0.70	1.00	0.70	0.76
0.71	1.00	0.71	0.74
0.72	1.00	0.72	0.73
0.73	1.00	0.73	0.71
0.74	1.00	0.74	0.7
0.75	1.00	0.75	0.68
0.76	1.00	0.76	0.66
0.77	1.00	0.77	0.64
0.78	1.00	0.78	0.63
0.79	1.00	0.79	0.61
0.80	1.00	0.80	0.59
0.81	1.00	0.81	0.57
0.82	1.00	0.82	0.55
0.83	1.00	0.83	0.54
0.84	1.00	0.84	0.52
0.85	1.00	0.85	0.5
0.86	1.00	0.86	0.48
0.87	1.00	0.87	0.47
0.88	1.00	0.88	0.45
0.89	1.00	0.89	0.44
0.90	1.00	0.90	0.42
0.91	1.00	0.91	0.41
0.92	1.00	0.92	0.39
0.93	1.00	0.93	0.38
0.94	1.00	0.94	0.36
0.95	1.00	0.95	0.35
0.96	1.00	0.96	0.34
0.97	1.00	0.97	0.32
0.98	1.00	0.98	0.31
0.99	1.00	0.99	0.29
1.00	1.00	1.00	0.28

Coho (summer)

depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0.00	1.00
0.01	0.05	0.01	1.00
0.02	0.12	0.02	1.00
0.03	0.20	0.03	1.00
0.04	0.27	0.04	1.00
0.05	0.34	0.05	1.00
0.06	0.40	0.06	1.00
0.07	0.45	0.07	1.00
0.08	0.51	0.08	1.00
0.09	0.56	0.09	1.00
0.10	0.61	0.10	1.00
0.11	0.66	0.11	1.00
0.12	0.70	0.12	1.00
0.13	0.74	0.13	0.96
0.14	0.78	0.14	0.94
0.15	0.81	0.15	0.91
0.16	0.84	0.16	0.88
0.17	0.87	0.17	0.84
0.18	0.89	0.18	0.80
0.19	0.92	0.19	0.76
0.20	0.94	0.20	0.72
0.21	0.95	0.21	0.68
0.22	0.97	0.22	0.64
0.23	0.98	0.23	0.60
0.24	0.99	0.24	0.56
0.25	1.00	0.25	0.52
0.26	1.00	0.26	0.48
0.27	1.00	0.27	0.44
0.28	1.00	0.28	0.40
0.29	1.00	0.29	0.36
0.30	1.00	0.30	0.33
0.31	1.00	0.31	0.30
0.32	1.00	0.32	0.26
0.33	1.00	0.33	0.23
0.34	1.00	0.34	0.20
0.35	1.00	0.35	0.18
0.36	1.00	0.36	0.14
0.37	1.00	0.37	0.12
0.38	1.00	0.38	0.10
0.39	1.00	0.39	0.08
0.40	1.00	0.40	0.06
0.41	1.00	0.41	0.04
0.42	1.00	0.42	0.03
0.43	1.00	0.43	0.02
0.44	1.00	0.44	0.01
0.45	1.00	0.45	0
0.46	1.00	0.46	0
0.47	1.00	0.47	0
0.48	1.00	0.48	0
0.49	1.00	0.49	0

depth (m)	probability of use	velocity (m/s)	probability of use
0.5	1.00	0.50	0
0.51	1.00	0.51	0
0.52	1.00	0.52	0
0.53	1.00	0.53	0
0.54	1.00	0.54	0
0.55	1.00	0.55	0
0.56	1.00	0.56	0
0.57	1.00	0.57	0
0.58	1.00	0.58	0
0.59	1.00	0.59	0
0.60	1.00	0.60	0
0.61	1.00	0.61	0
0.62	1.00	0.62	0
0.63	1.00	0.63	0
0.64	1.00	0.64	0
0.65	1.00	0.65	0
0.66	1.00	0.66	0
0.67	1.00	0.67	0
0.68	1.00	0.68	0
0.69	1.00	0.69	0
0.70	1.00	0.70	0
0.71	1.00	0.71	0
0.72	1.00	0.72	0
0.73	1.00	0.73	0
0.74	1.00	0.74	0
0.75	1.00	0.75	0
0.76	1.00	0.76	0
0.77	1.00	0.77	0
0.78	1.00	0.78	0
0.79	1.00	0.79	0
0.80	1.00	0.80	0
0.81	1.00	0.81	0
0.82	1.00	0.82	0
0.83	1.00	0.83	0
0.84	1.00	0.84	0
0.85	1.00	0.85	0
0.86	1.00	0.86	0
0.87	1.00	0.87	0
0.88	1.00	0.88	0
0.89	1.00	0.89	0
0.90	1.00	0.90	0
0.91	1.00	0.91	0
0.92	1.00	0.92	0
0.93	1.00	0.93	0
0.94	1.00	0.94	0
0.95	1.00	0.95	0
0.96	1.00	0.96	0
0.97	1.00	0.97	0
0.98	1.00	0.98	0
0.99	1.00	0.99	0
1.00	1.00	1.00	0

Chinook (summer)			
depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0.00	0
0.01	0.03	0.01	0.08
0.02	0.05	0.02	0.15
0.03	0.08	0.03	0.22
0.04	0.1	0.04	0.28
0.05	0.12	0.05	0.35
0.06	0.15	0.06	0.41
0.07	0.18	0.07	0.46
0.08	0.22	0.08	0.52
0.09	0.26	0.09	0.57
0.10	0.3	0.10	0.63
0.11	0.37	0.11	0.67
0.12	0.42	0.12	0.71
0.13	0.5	0.13	0.74
0.14	0.58	0.14	0.78
0.15	0.63	0.15	0.82
0.16	0.72	0.16	0.84
0.17	0.78	0.17	0.87
0.18	0.85	0.18	0.89
0.19	0.91	0.19	0.92
0.20	0.96	0.20	0.94
0.21	0.99	0.21	0.95
0.22	1.00	0.22	0.96
0.23	1.00	0.23	0.97
0.24	1.00	0.24	0.98
0.25	1.00	0.25	0.99
0.26	1.00	0.26	1.00
0.27	1.00	0.27	1.00
0.28	1.00	0.28	1.00
0.29	1.00	0.29	1.00
0.30	1.00	0.30	1.00
0.31	1.00	0.31	1.00
0.32	1.00	0.32	1.00
0.33	1.00	0.33	1.00
0.34	1.00	0.34	0.99
0.35	1.00	0.35	0.98
0.36	1.00	0.36	0.97
0.37	1.00	0.37	0.96
0.38	1.00	0.38	0.95
0.39	1.00	0.39	0.94
0.40	1.00	0.40	0.93
0.41	1.00	0.41	0.91
0.42	1.00	0.42	0.9
0.43	1.00	0.43	0.88
0.44	1.00	0.44	0.87
0.45	1.00	0.45	0.85
0.46	1.00	0.46	0.83
0.47	1.00	0.47	0.82
0.48	1.00	0.48	0.8
0.49	1.00	0.49	0.79

depth (m)	probability of use	velocity (m/s)	probability of use
0.5	1.00	0.50	0.77
0.51	1.00	0.51	0.75
0.52	1.00	0.52	0.73
0.53	1.00	0.53	0.71
0.54	1.00	0.54	0.69
0.55	1.00	0.55	0.68
0.56	1.00	0.56	0.66
0.57	1.00	0.57	0.64
0.58	1.00	0.58	0.62
0.59	1.00	0.59	0.6
0.6	1.00	0.60	0.58
0.61	1.00	0.61	0.56
0.62	1.00	0.62	0.54
0.63	1.00	0.63	0.52
0.64	1.00	0.64	0.50
0.65	1.00	0.65	0.48
0.66	1.00	0.66	0.47
0.67	1.00	0.67	0.45
0.68	1.00	0.68	0.43
0.69	1.00	0.69	0.41
0.7	1.00	0.70	0.39
0.71	1.00	0.71	0.38
0.72	1.00	0.72	0.36
0.73	1.00	0.73	0.35
0.74	1.00	0.74	0.33
0.75	1.00	0.75	0.32
0.76	1.00	0.76	0.31
0.77	1.00	0.77	0.29
0.78	1.00	0.78	0.28
0.79	1.00	0.79	0.26
0.8	1.00	0.80	0.25
0.81	1.00	0.81	0.24
0.82	1.00	0.82	0.23
0.83	1.00	0.83	0.22
0.84	1.00	0.84	0.21
0.85	1.00	0.85	0.20
0.86	1.00	0.86	0.19
0.87	1.00	0.87	0.18
0.88	1.00	0.88	0.17
0.89	1.00	0.89	0.16
0.9	1.00	0.90	0.15
0.91	1.00	0.91	0.14
0.92	1.00	0.92	0.14
0.93	1.00	0.93	0.14
0.94	1.00	0.94	0.13
0.95	1.00	0.95	0.12
0.96	1.00	0.96	0.12
0.97	1.00	0.97	0.12
0.98	1.00	0.98	0.11
0.99	1.00	0.99	0.10
1.00	1.00	1.00	0.10

Rainbow spawn (spring)

Depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0	0
0.01	0	0.01	0
0.02	0	0.02	0
0.03	0	0.03	0
0.04	0	0.04	0
0.05	0	0.05	0
0.06	0.02	0.06	0.01
0.07	0.04	0.07	0.02
0.08	0.06	0.08	0.03
0.09	0.08	0.09	0.04
0.10	0.10	0.10	0.05
0.11	0.12	0.11	0.08
0.12	0.14	0.12	0.10
0.13	0.16	0.13	0.12
0.14	0.18	0.14	0.15
0.15	0.20	0.15	0.18
0.16	0.23	0.16	0.20
0.17	0.26	0.17	0.22
0.18	0.30	0.18	0.25
0.19	0.35	0.19	0.28
0.20	0.40	0.20	0.30
0.21	0.45	0.21	0.33
0.22	0.50	0.22	0.36
0.23	0.55	0.23	0.39
0.24	0.60	0.24	0.42
0.25	0.65	0.25	0.45
0.26	0.70	0.26	0.48
0.27	0.75	0.27	0.51
0.28	0.80	0.28	0.54
0.29	0.85	0.29	0.57
0.30	0.90	0.30	0.60
0.31	0.95	0.31	0.62
0.32	0.98	0.32	0.64
0.33	1.00	0.33	0.66
0.34	1.00	0.34	0.68
0.35	1.00	0.35	0.70
0.36	1.00	0.36	0.72
0.37	1.00	0.37	0.74
0.38	1.00	0.38	0.76
0.39	1.00	0.39	0.78
0.40	1.00	0.40	0.80
0.41	1.00	0.41	0.82
0.42	1.00	0.42	0.83
0.43	1.00	0.43	0.85
0.44	1.00	0.44	0.87
0.45	1.00	0.45	0.88
0.46	1.00	0.46	0.90
0.47	1.00	0.47	0.92
0.48	1.00	0.48	0.94
0.49	1.00	0.49	0.96

depth (m)	probability of use	velocity (m/s)	probability of use
0.50	1.00	0.50	0.98
0.51	1.00	0.51	1.00
0.52	1.00	0.52	1.00
0.53	1.00	0.53	1.00
0.54	1.00	0.54	1.00
0.55	1.00	0.55	1.00
0.56	1.00	0.56	1.00
0.57	1.00	0.57	1.00
0.58	1.00	0.58	1.00
0.59	1.00	0.59	1.00
0.60	1.00	0.60	1.00
0.61	1.00	0.61	1.00
0.62	1.00	0.62	1.00
0.63	1.00	0.63	1.00
0.64	1.00	0.64	1.00
0.65	1.00	0.65	1.00
0.66	1.00	0.66	1.00
0.67	1.00	0.67	1.00
0.68	1.00	0.68	1.00
0.69	1.00	0.69	1.00
0.70	1.00	0.70	1.00
0.71	1.00	0.71	1.00
0.72	1.00	0.72	1.00
0.73	1.00	0.73	1.00
0.74	1.00	0.74	1.00
0.75	1.00	0.75	1.00
0.76	0.98	0.76	1.00
0.77	0.95	0.77	1.00
0.78	0.93	0.78	1.00
0.79	0.90	0.79	1.00
0.80	0.85	0.80	1.00
0.81	0.80	0.81	1.00
0.82	0.75	0.82	1.00
0.83	0.70	0.83	1.00
0.84	0.65	0.84	1.00
0.85	0.60	0.85	1.00
0.86	0.55	0.86	1.00
0.87	0.50	0.87	1.00
0.88	0.45	0.88	1.00
0.89	0.40	0.89	1.00
0.90	0.35	0.90	1.00
0.91	0.30	0.91	0.96
0.92	0.28	0.92	0.92
0.93	0.26	0.93	0.88
0.94	0.24	0.94	0.84
0.95	0.22	0.95	0.80
0.96	0.20	0.96	0.76
0.97	0.18	0.97	0.72
0.98	0.17	0.98	0.68
0.99	0.16	0.99	0.64
1.00	0.15	1.00	0.60

Coho (fall)			
depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0.00	0
0.01	0	0.01	0
0.02	0	0.02	0
0.03	0	0.03	0
0.04	0	0.04	0
0.05	0	0.05	0
0.06	0	0.06	0
0.07	0.0067	0.07	0.05
0.08	0.0133	0.08	0.10
0.09	0.02	0.09	0.15
0.10	0.0267	0.10	0.20
0.11	0.0333	0.11	0.25
0.12	0.04	0.12	0.30
0.13	0.048	0.13	0.33
0.14	0.056	0.14	0.36
0.15	0.064	0.15	0.40
0.16	0.072	0.16	0.43
0.17	0.08	0.17	0.46
0.18	0.11	0.18	0.50
0.19	0.13	0.19	0.525
0.20	0.16	0.20	0.55
0.21	0.24	0.21	0.575
0.22	0.32	0.22	0.60
0.23	0.40	0.23	0.63
0.24	0.47	0.24	0.66
0.25	0.53	0.25	0.70
0.26	0.6	0.26	0.72
0.27	0.67	0.27	0.74
0.28	0.73	0.28	0.76
0.29	0.80	0.29	0.78
0.30	1.00	0.30	0.80
0.31	1.00	0.31	0.82
0.32	1.00	0.32	0.84
0.33	1.00	0.33	0.86
0.34	1.00	0.34	0.88
0.35	1.00	0.35	0.90
0.36	1.00	0.36	0.91
0.37	1.00	0.37	0.92
0.38	1.00	0.38	0.93
0.39	1.00	0.39	0.94
0.40	1.00	0.40	0.95
0.41	1.00	0.41	0.96
0.42	1.00	0.42	0.97
0.43	1.00	0.43	0.98
0.44	1.00	0.44	0.99
0.45	1.00	0.45	0.995
0.46	1.00	0.46	1.00
0.47	1.00	0.47	1.00
0.48	1.00	0.48	1.00
0.49	1.00	0.49	1.00

depth (m)	probability of use	velocity (m/s)	probability of use
0.50	1.00	0.50	1.00
0.51	1.00	0.51	1.00
0.52	1.00	0.52	1.00
0.53	1.00	0.53	1.00
0.54	1.00	0.54	1.00
0.55	1.00	0.55	1.00
0.56	1.00	0.56	1.00
0.57	1.00	0.57	1.00
0.58	1.00	0.58	1.00
0.59	1.00	0.59	1.00
0.60	1.00	0.60	1.00
0.61	1.00	0.61	1.00
0.62	1.00	0.62	1.00
0.63	1.00	0.63	1.00
0.64	1.00	0.64	1.00
0.65	1.00	0.65	1.00
0.66	1.00	0.66	1.00
0.67	1.00	0.67	1.00
0.68	1.00	0.68	1.00
0.69	1.00	0.69	1.00
0.70	1.00	0.70	1.00
0.71	1.00	0.71	0.99
0.72	1.00	0.72	0.96
0.73	1.00	0.73	0.95
0.74	1.00	0.74	0.93
0.75	1.00	0.75	0.91
0.76	1.00	0.76	0.90
0.77	1.00	0.77	0.88
0.78	1.00	0.78	0.86
0.79	1.00	0.79	0.84
0.80	1.00	0.80	0.83
0.81	1.00	0.81	0.81
0.82	1.00	0.82	0.79
0.83	1.00	0.83	0.77
0.84	1.00	0.84	0.75
0.85	1.00	0.85	0.74
0.86	1.00	0.86	0.72
0.87	1.00	0.87	0.70
0.88	1.00	0.88	0.69
0.89	1.00	0.89	0.67
0.90	1.00	0.90	0.65
0.91	1.00	0.91	0.63
0.92	1.00	0.92	0.62
0.93	1.00	0.93	0.60
0.94	1.00	0.94	0.59
0.95	1.00	0.95	0.57
0.96	1.00	0.96	0.56
0.97	1.00	0.97	0.55
0.98	1.00	0.98	0.53
0.99	1.00	0.99	0.52
1.00	1.00	1.00	0.51

Chinook (fall)			
depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0.00	0
0.01	0	0.01	0
0.02	0	0.02	0
0.03	0	0.03	0
0.04	0	0.04	0
0.05	0	0.05	0
0.06	0	0.06	0
0.07	0	0.07	0
0.08	0	0.08	0
0.09	0	0.09	0
0.10	0	0.10	0
0.11	0	0.11	0
0.12	0	0.12	0
0.13	0	0.13	0
0.14	0	0.14	0
0.15	0	0.15	0
0.16	0	0.16	0.055
0.17	0	0.17	0.11
0.18	0	0.18	0.165
0.19	0	0.19	0.22
0.20	0	0.20	0.28
0.21	0	0.21	0.33
0.22	0	0.22	0.385
0.23	0	0.23	0.44
0.24	0	0.24	0.50
0.25	0.02	0.25	0.55
0.26	0.04	0.26	0.57
0.27	0.05	0.27	0.59
0.28	0.07	0.28	0.60
0.29	0.09	0.29	0.62
0.30	0.11	0.30	0.64
0.31	0.125	0.31	0.66
0.32	0.14	0.32	0.68
0.33	0.16	0.33	0.69
0.34	0.18	0.34	0.71
0.35	0.20	0.35	0.73
0.36	0.21	0.36	0.75
0.37	0.23	0.37	0.77
0.38	0.25	0.38	0.78
0.39	0.27	0.39	0.80
0.40	0.29	0.40	0.82
0.41	0.30	0.41	0.84
0.42	0.32	0.42	0.86
0.43	0.34	0.43	0.87
0.44	0.36	0.44	0.89
0.45	0.38	0.45	0.91
0.46	0.39	0.46	0.93
0.47	0.41	0.47	0.95
0.48	0.43	0.48	0.96
0.49	0.45	0.49	0.98
depth (m)	probability of use	velocity (m/s)	probability of use
0.50	0.46	0.50	1.00
0.51	0.48	0.51	1.00
0.52	0.50	0.52	1.00
0.53	0.52	0.53	1.00
0.54	0.54	0.54	1.00
0.55	0.55	0.55	1.00
0.56	0.57	0.56	1.00
0.57	0.59	0.57	1.00
0.58	0.61	0.58	1.00
0.59	0.625	0.59	1.00
0.60	0.64	0.60	1.00
0.61	0.66	0.61	1.00
0.62	0.68	0.62	1.00
0.63	0.70	0.63	1.00
0.64	0.71	0.64	1.00
0.65	0.73	0.65	1.00
0.66	0.75	0.66	1.00
0.67	0.77	0.67	1.00
0.68	0.79	0.68	1.00
0.69	0.80	0.69	1.00
0.70	0.82	0.70	1.00
0.71	0.84	0.71	1.00
0.72	0.86	0.72	1.00
0.73	0.88	0.73	1.00
0.74	0.89	0.74	1.00
0.75	0.91	0.75	1.00
0.76	0.93	0.76	1.00
0.77	0.95	0.77	1.00
0.78	0.96	0.78	1.00
0.79	0.98	0.79	1.00
0.80	1.00	0.80	1.00
0.81	1.00	0.81	1.00
0.82	1.00	0.82	1.00
0.83	1.00	0.83	1.00
0.84	1.00	0.84	1.00
0.85	1.00	0.85	1.00
0.86	1.00	0.86	1.00
0.87	1.00	0.87	1.00
0.88	1.00	0.88	1.00
0.89	1.00	0.89	1.00
0.90	1.00	0.90	1.00
0.91	1.00	0.91	1.00
0.92	1.00	0.92	1.00
0.93	1.00	0.93	1.00
0.94	1.00	0.94	1.00
0.95	1.00	0.95	1.00
0.96	1.00	0.96	1.00
0.97	1.00	0.97	1.00
0.98	1.00	0.98	1.00
0.99	1.00	0.99	1.00
1.00	1.00	1.00	1.00

Washington State Stream Chinook (fall)

depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0.00	0
0.01	0	0.01	0
0.02	0	0.02	0
0.03	0	0.03	0
0.04	0	0.04	0
0.05	0	0.05	0
0.06	0	0.06	0
0.07	0	0.07	0
0.08	0.05	0.08	0
0.09	0.09	0.09	0
0.10	0.14	0.10	0
0.11	0.18	0.11	0
0.12	0.23	0.12	0
0.13	0.27	0.13	0
0.14	0.32	0.14	0
0.15	0.36	0.15	0
0.16	0.41	0.16	0.06
0.17	0.45	0.17	0.12
0.18	0.50	0.18	0.18
0.19	0.55	0.19	0.24
0.20	0.59	0.20	0.30
0.21	0.64	0.21	0.36
0.22	0.68	0.22	0.42
0.23	0.73	0.23	0.48
0.24	0.77	0.24	0.54
0.25	0.82	0.25	0.60
0.26	0.86	0.26	0.66
0.27	0.91	0.27	0.72
0.28	0.95	0.28	0.78
0.29	1.00	0.29	0.84
0.30	1.00	0.30	0.90
0.31	1.00	0.31	0.90
0.32	1.00	0.32	0.91
0.33	1.00	0.33	0.91
0.34	1.00	0.34	0.92
0.35	1.00	0.35	0.92
0.36	1.00	0.36	0.93
0.37	1.00	0.37	0.93
0.38	1.00	0.38	0.93
0.39	1.00	0.39	0.94
0.40	1.00	0.40	0.94
0.41	1.00	0.41	0.95
0.42	1.00	0.42	0.95
0.43	1.00	0.43	0.96
0.44	1.00	0.44	0.96
0.45	1.00	0.45	0.97
0.46	1.00	0.46	0.97
0.47	1.00	0.47	0.97
0.48	1.00	0.48	0.98
Depth (m)	1.00 1.00	velocity (m/s)	probability of use
0.49	1.00	0.49	0.98
0.50	1.00	0.50	0.99
0.51	1.00	0.51	0.99
0.52	1.00	0.52	1.00
0.53	1.00	0.53	1.00
0.54	1.00	0.54	1.00
0.55	1.00	0.55	1.00
0.56	1.00	0.56	1.00
0.57	1.00	0.57	1.00
0.58	1.00	0.58	1.00
0.59	1.00	0.59	1.00
0.60	1.00	0.60	1.00
0.61	1.00	0.61	1.00
0.62	1.00	0.62	1.00
0.63	1.00	0.63	1.00
0.64	1.00	0.64	1.00
0.65	1.00	0.65	1.00
0.66	1.00	0.66	1.00
0.67	1.00	0.67	1.00
0.68	1.00	0.68	1.00
0.69	1.00	0.69	1.00
0.70	1.00	0.70	0.98
0.71	1.00	0.71	0.96
0.72	1.00	0.72	0.94
0.73	1.00	0.73	0.93
0.74	1.00	0.74	0.91
0.75	1.00	0.75	0.89
0.76	1.00	0.76	0.87
0.77	1.00	0.77	0.85
0.78	1.00	0.78	0.83
0.79	1.00	0.79	0.81
0.80	1.00	0.80	0.80
0.81	1.00	0.81	0.78
0.82	1.00	0.82	0.76
0.83	1.00	0.83	0.74
0.84	1.00	0.84	0.72
0.85	1.00	0.85	0.70
0.86	1.00	0.86	0.69
0.87	1.00	0.87	0.67
0.88	1.00	0.88	0.65
0.89	1.00	0.89	0.63
0.90	1.00	0.90	0.61
0.91	1.00	0.91	0.59
0.92	0.97	0.92	0.57
0.93	0.94	0.93	0.56
0.94	0.91	0.94	0.54
0.95	0.88	0.95	0.52
0.96	0.84	0.96	0.50
0.97	0.81	0.97	0.48
0.98	0.78	0.98	0.46
0.99	0.75	0.99	0.44
1.00	0.72	1.00	0.43

Kokanee (fall)

depth (m)	probability of use	velocity (m/s)	probability of use
0	0	0.00	0
0.01	0	0.01	0.03
0.02	0	0.02	0.06
0.03	0.01	0.03	0.10
0.04	0.09	0.04	0.13
0.05	0.18	0.05	0.16
0.06	0.26	0.06	0.20
0.07	0.34	0.07	0.25
0.08	0.42	0.08	0.27
0.09	0.51	0.09	0.30
0.10	0.59	0.10	0.33
0.11	0.67	0.11	0.36
0.12	0.75	0.12	0.40
0.13	0.84	0.13	0.43
0.14	0.92	0.14	0.47
0.15	1.00	0.15	0.50
0.16	1.00	0.16	0.53
0.17	1.00	0.17	0.57
0.18	1.00	0.18	0.60
0.19	1.00	0.19	0.63
0.20	1.00	0.20	0.67
0.21	1.00	0.21	0.70
0.22	1.00	0.22	0.73
0.23	1.00	0.23	0.77
0.24	1.00	0.24	0.80
0.25	1.00	0.25	0.83
0.26	1.00	0.26	0.87
0.27	1.00	0.27	0.90
0.28	1.00	0.28	0.93
0.29	1.00	0.29	0.97
0.30	1.00	0.30	1.00
0.31	0.99	0.31	1.00
0.32	0.98	0.32	1.00
0.33	0.97	0.33	1.00
0.34	0.96	0.34	1.00
0.35	0.95	0.35	1.00
0.36	0.94	0.36	1.00
0.37	0.93	0.37	1.00
0.38	0.92	0.38	1.00
0.39	0.91	0.39	1.00
0.40	0.90	0.40	1.00
0.41	0.88	0.41	1.00
0.42	0.86	0.42	1.00
0.43	0.84	0.43	1.00
0.44	0.82	0.44	1.00
0.45	0.80	0.45	1.00
0.46	0.77	0.46	1.00
0.47	0.74	0.47	1.00
0.48	0.71	0.48	1.00
0.49	0.68	0.49	1.00
0.50	0.65	0.50	1.00
0.51	0.62	0.51	1.00
0.52	0.59	0.52	1.00
0.53	0.56	0.53	1.00
0.54	0.52	0.54	1.00
0.55	0.48	0.55	1.00
0.56	0.44	0.56	1.00
0.57	0.40	0.57	1.00
0.58	0.36	0.58	1.00
0.59	0.32	0.59	1.00
0.60	0.28	0.60	1.00
0.61	0.24	0.61	1.00
0.62	0.20	0.62	0.97
0.63	0.18	0.63	0.93
0.64	0.16	0.64	0.90
0.65	0.14	0.65	0.87
0.66	0.12	0.66	0.83
0.67	0.10	0.67	0.80
0.68	0.08	0.68	0.77
0.69	0.06	0.69	0.73
0.70	0.05	0.70	0.70
0.71	0.05	0.71	0.67
0.72	0.04	0.72	0.63
0.73	0.04	0.73	0.60
0.74	0.03	0.74	0.57
0.75	0.03	0.75	0.53
0.76	0.02	0.76	0.50
0.77	0.02	0.77	0.49
0.78	0.01	0.78	0.47
0.79	0.01	0.79	0.46
0.80	0	0.80	0.45
0.81	0	0.81	0.44
0.82	0	0.82	0.42
0.83	0	0.83	0.41
0.84	0	0.84	0.40
0.85	0	0.85	0.39
0.86	0	0.86	0.37
0.87	0	0.87	0.36
0.88	0	0.88	0.35
0.89	0	0.89	0.34
0.90	0	0.90	0.32
0.91	0	0.91	0.31
0.92	0.00	0.92	0.29
0.93	0.00	0.93	0.28
0.94	0.00	0.94	0.27
0.95	0.00	0.95	0.26
0.96	0.00	0.96	0.24
0.97	0.00	0.97	0.23
0.98	0.00	0.98	0.22
0.99	0.00	0.99	0.20
1.00	0.00	1.00	0.19

Appendix B

Weighted Usable Width Charts for Riffle Transects in Bessette, Duteau and Creighton Creeks

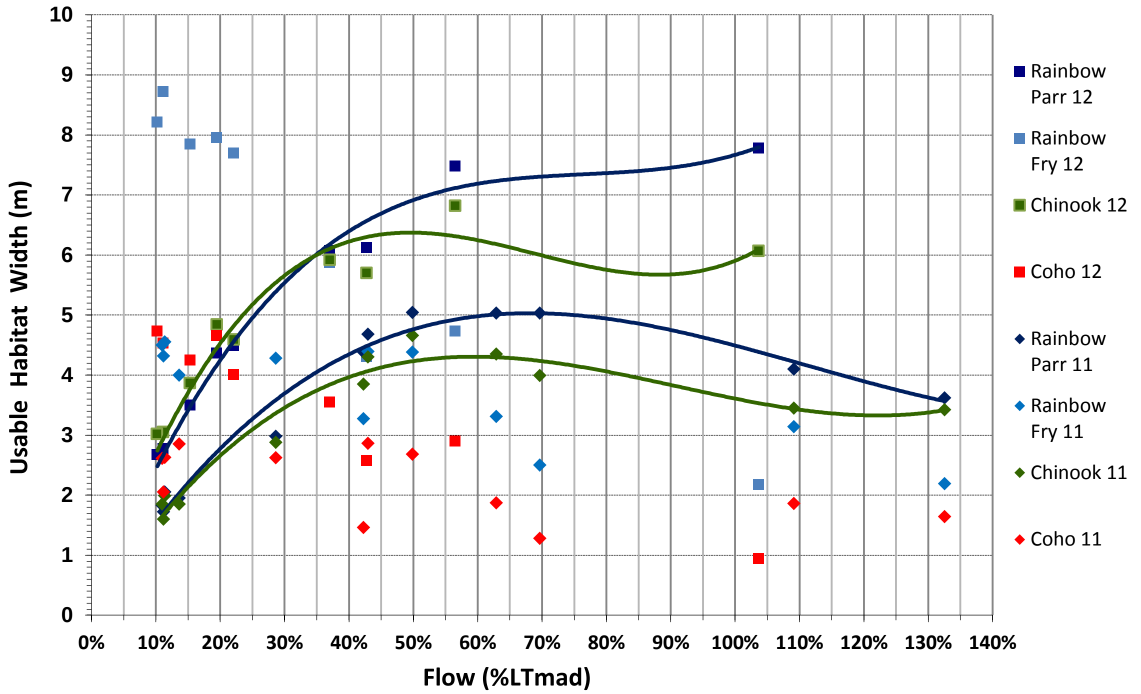


Figure B1. Weighted Usable Width vs. Flow as %LTmad in Riffle at Bessette 1.

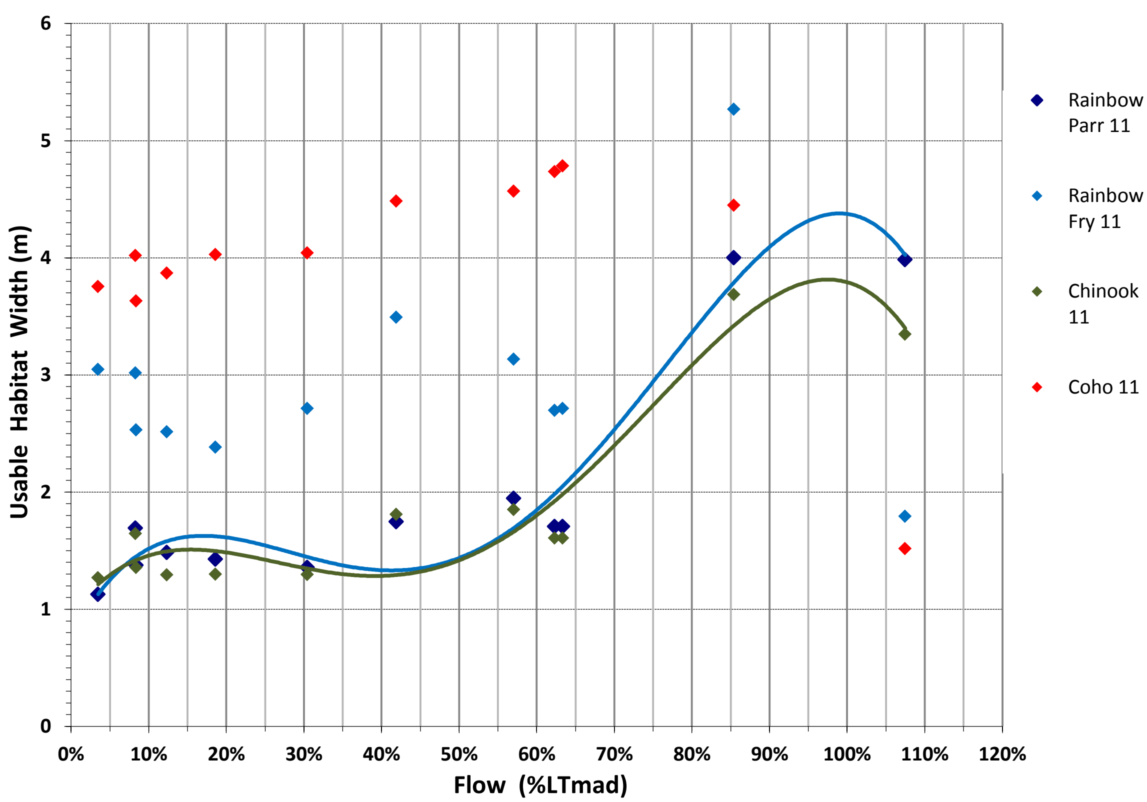


Figure B2. Weighted Usable Width vs. Flow as %LTmad in Riffle at Bessette 2.

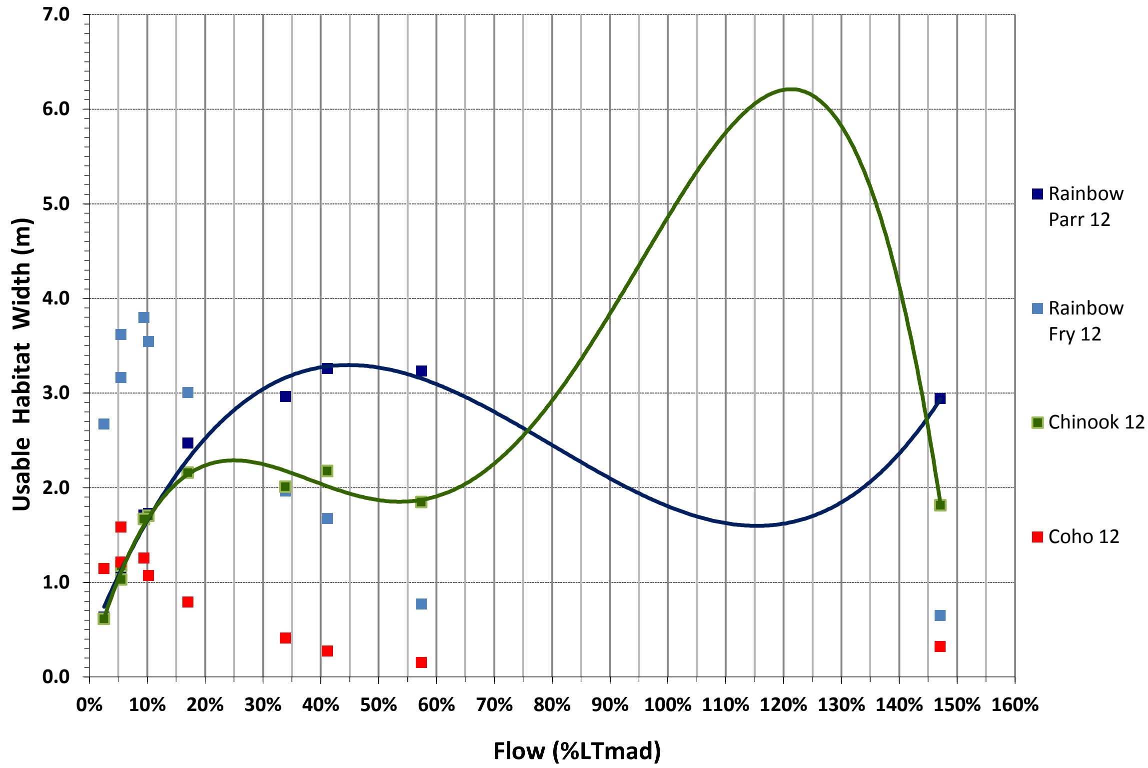


Figure B3. Weighted Usable Width vs. Flow as %LTmad in Riffle at Bessette 2A.

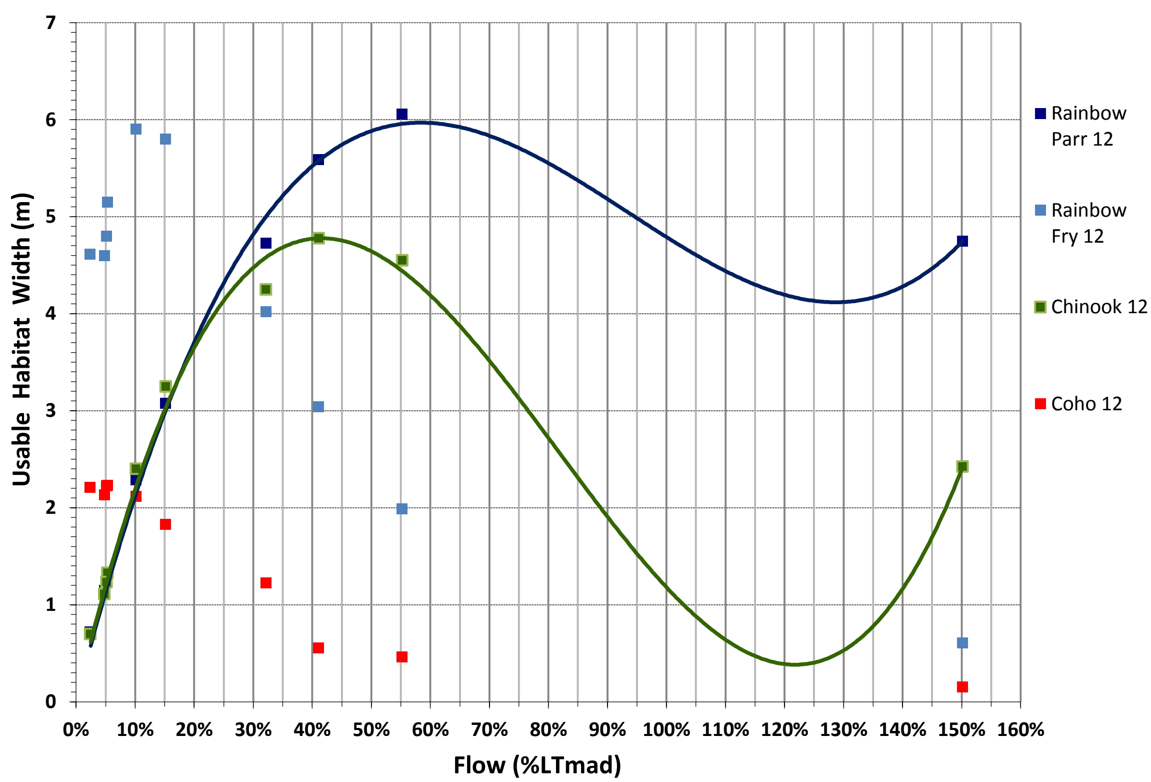


Figure B4. Weighted Usable Width vs. Flow as %LTmad in Riffle at Bessette 2B.

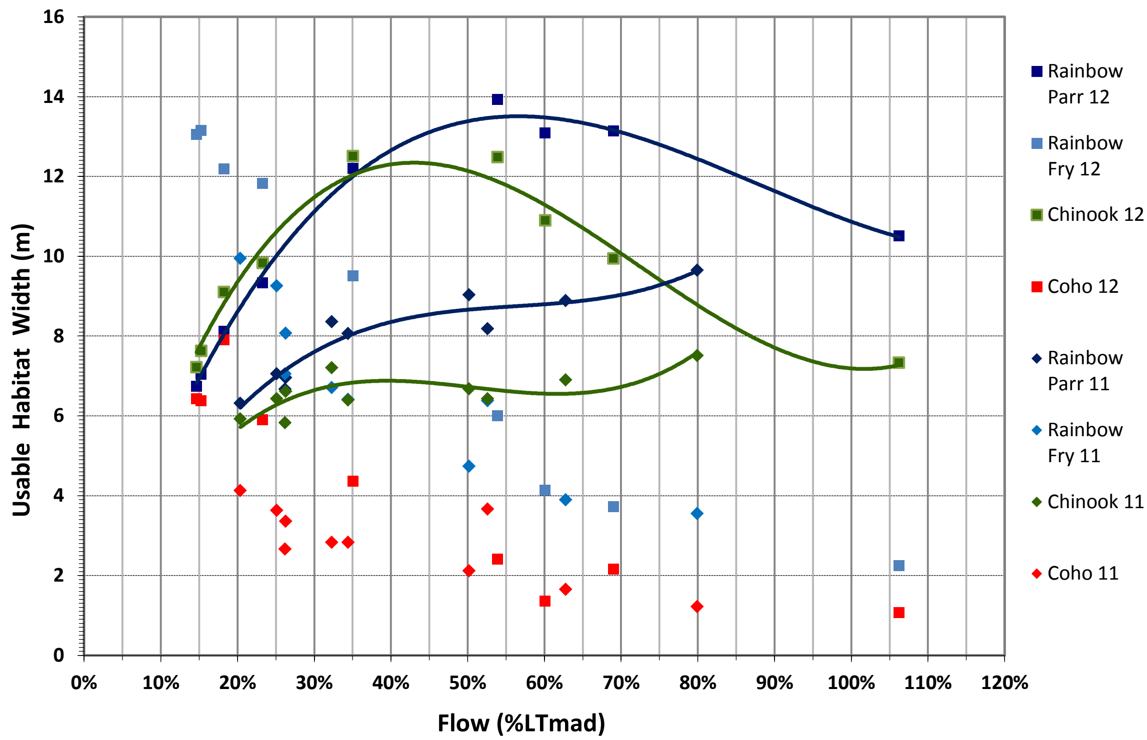


Figure B5. Weighted Usable Width vs. Flow as %LTmad in Riffle at Bessette 3A.

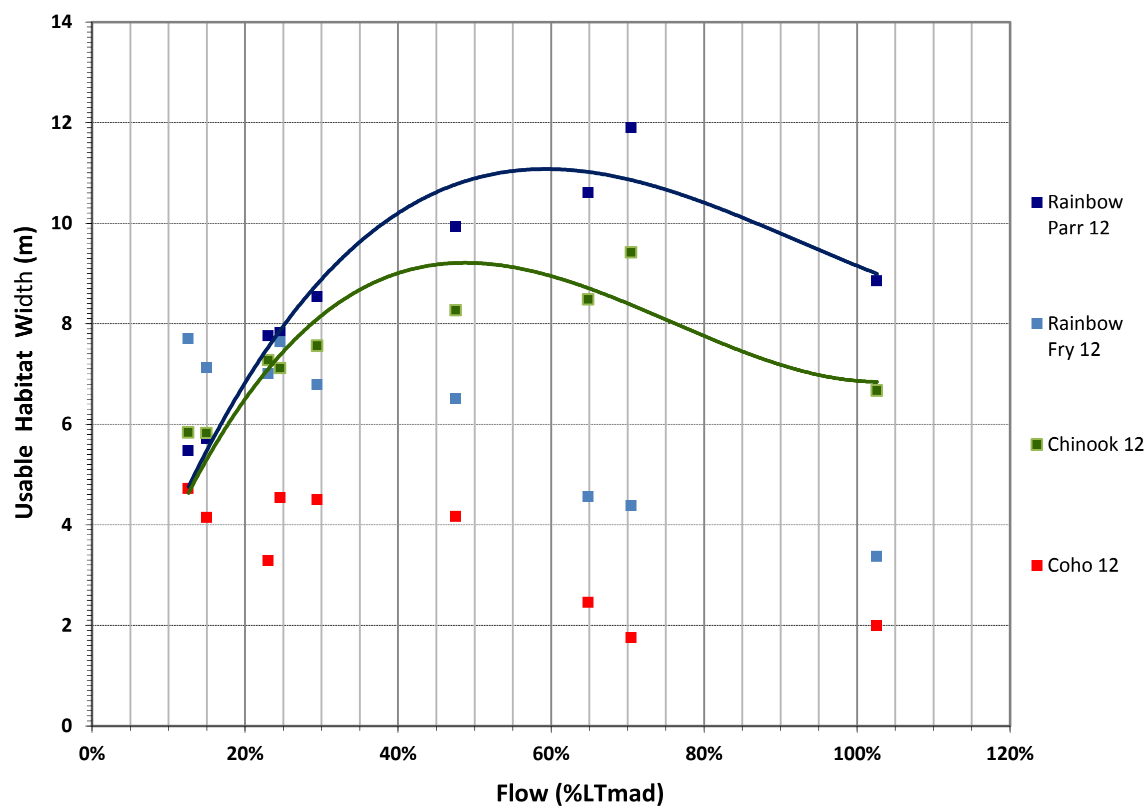


Figure B6. Weighted Usable Width vs. Flow as %LTmad in Riffle at Bessette 3B.

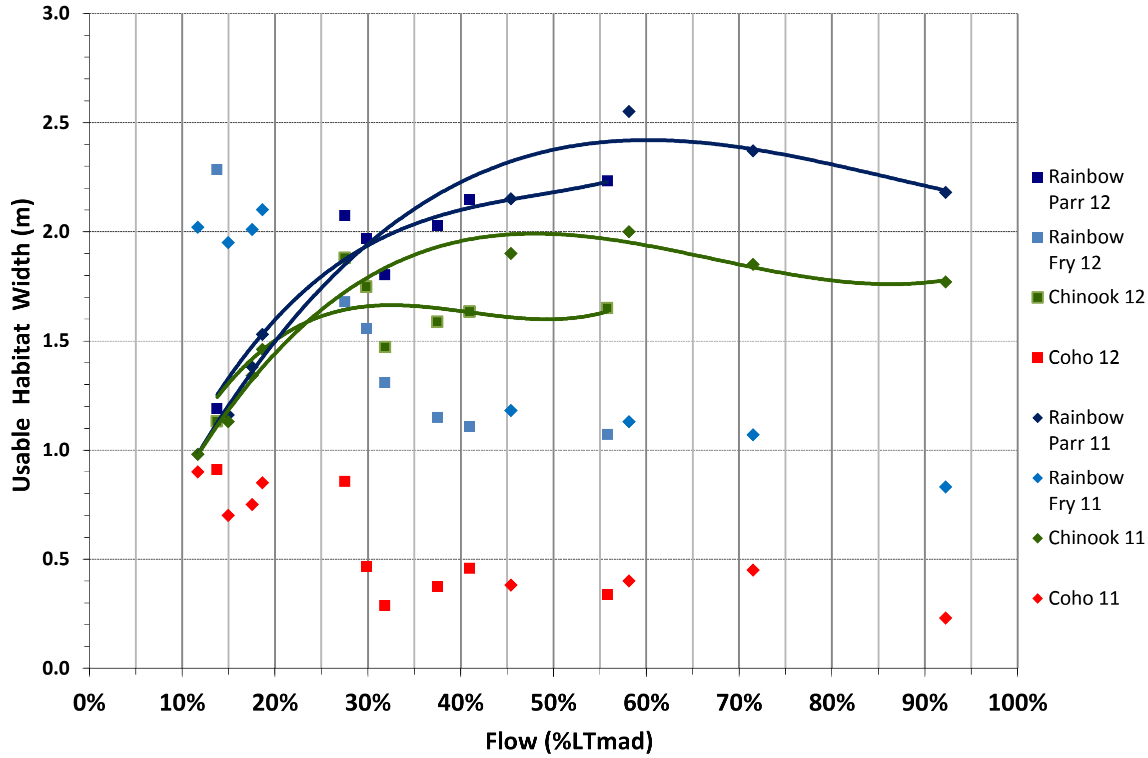


Figure B7. Weighted Usable Width vs. Flow as %LTmad in Riffle at Duteau 1A.

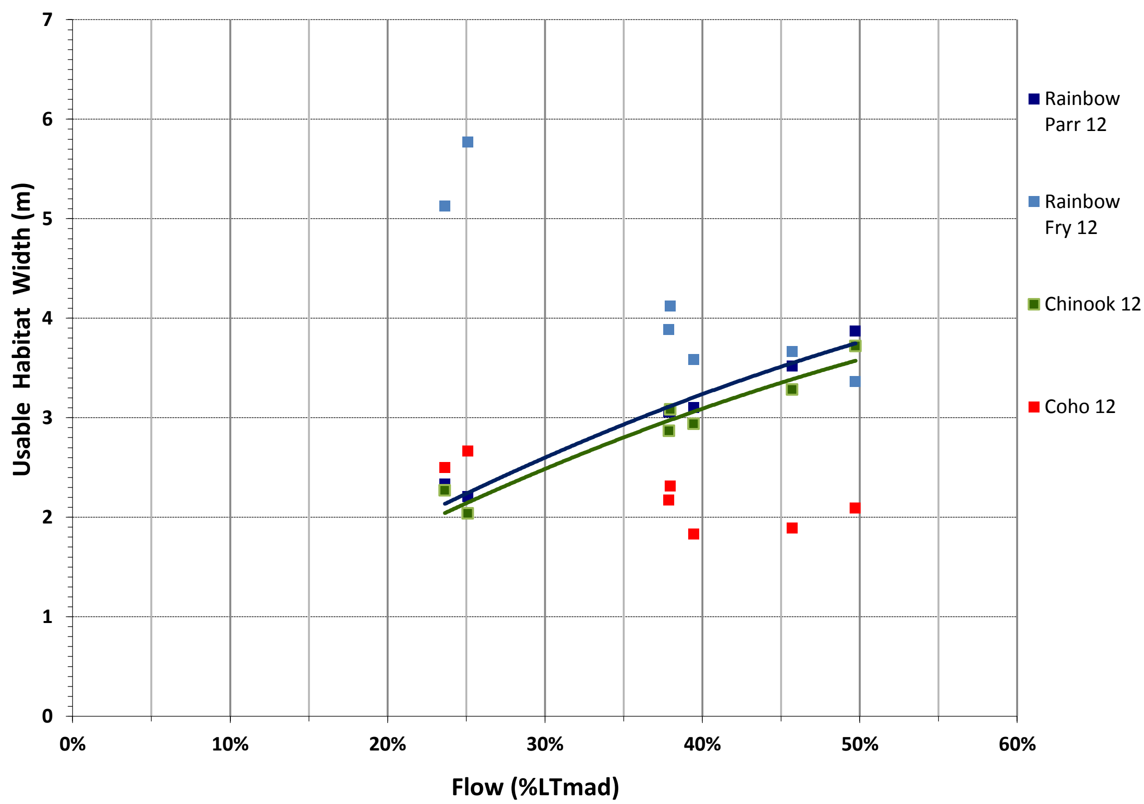


Figure B8. Weighted Usable Width vs. Flow as %LTmad in Riffle at Duteau 1B.

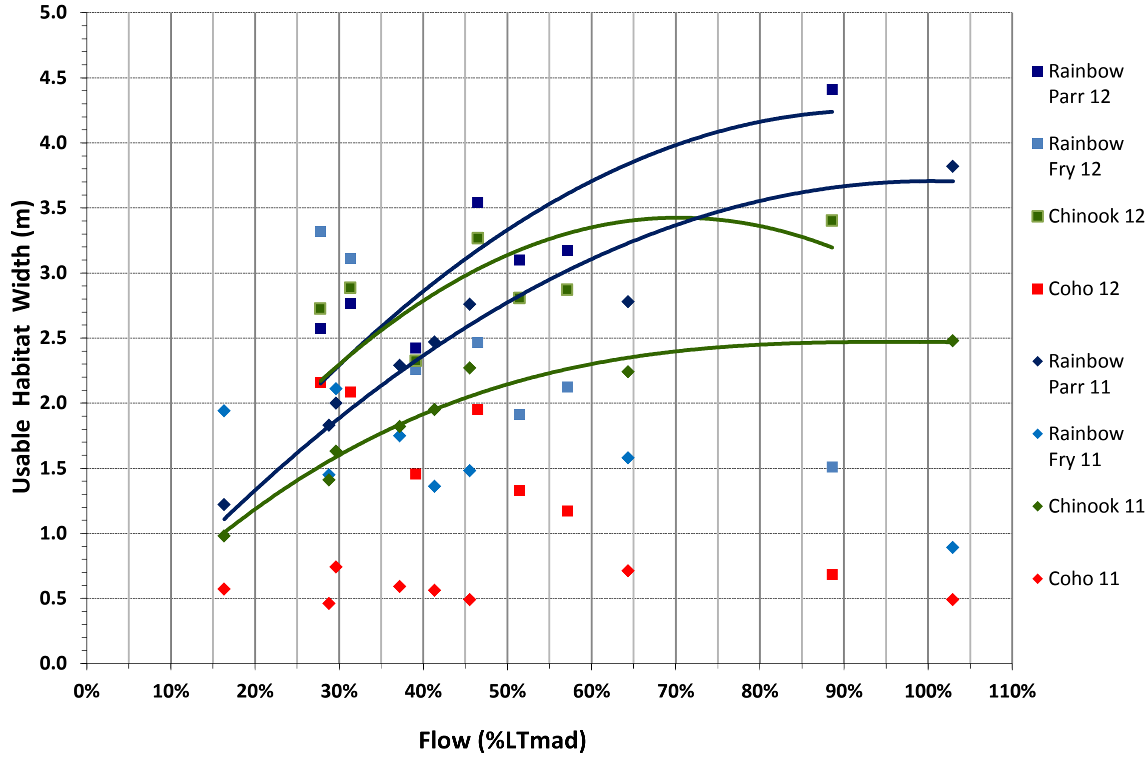


Figure B9. Weighted Usable Width vs. Flow as %LTmad in Riffle at Duteau 2.

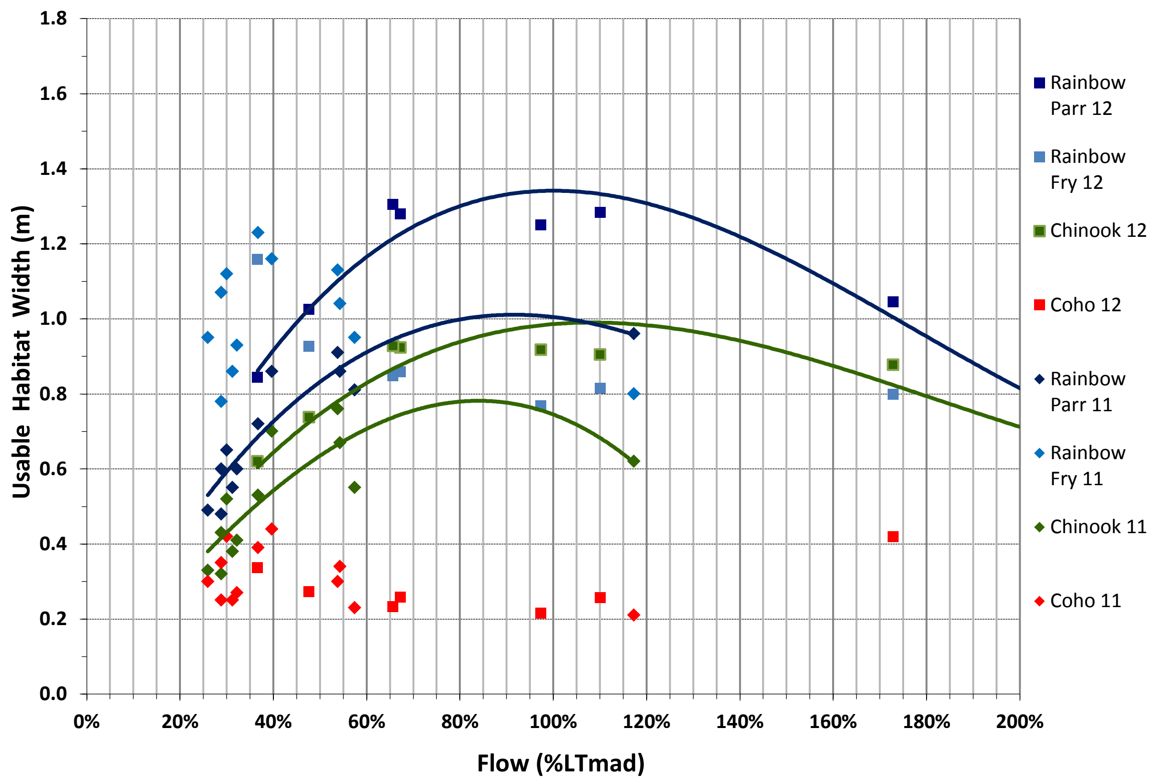


Figure B10. Weighted Usable Width vs. Flow as %LTmad in Riffle at Creighton 1.

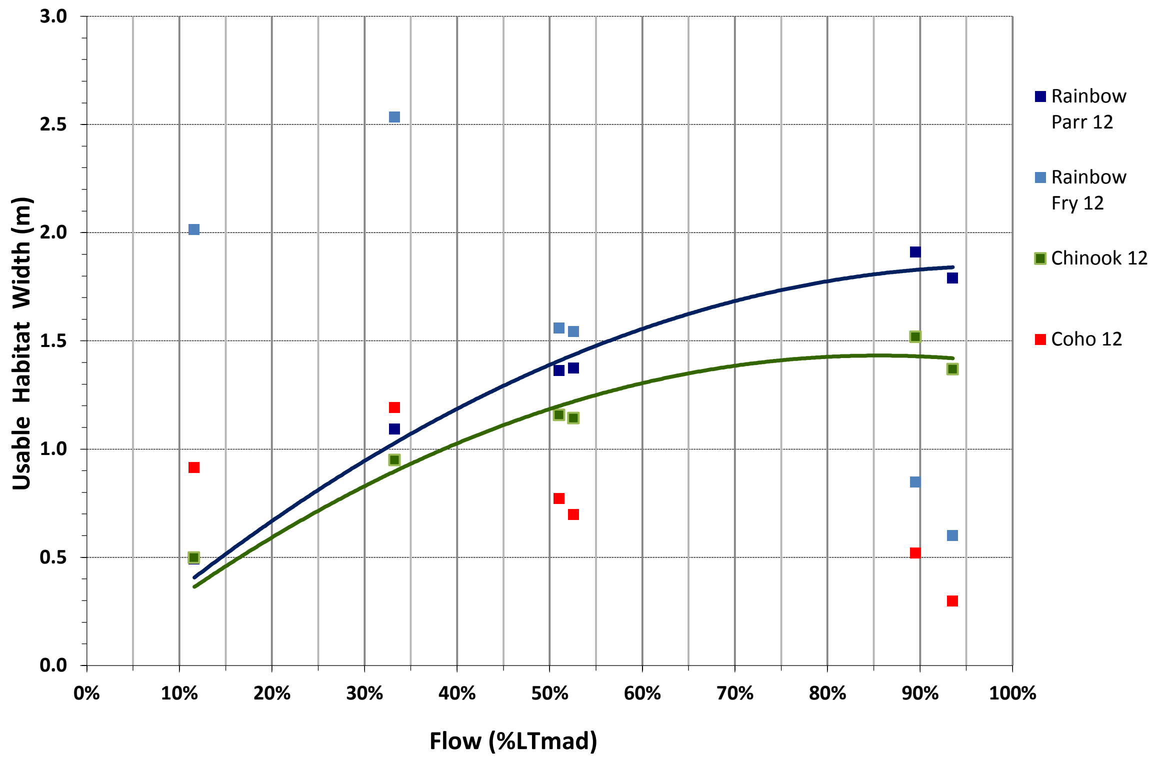


Figure B11 Weighted Usable Width vs. Flow as %LTmad in Riffle at Creighton 2A.

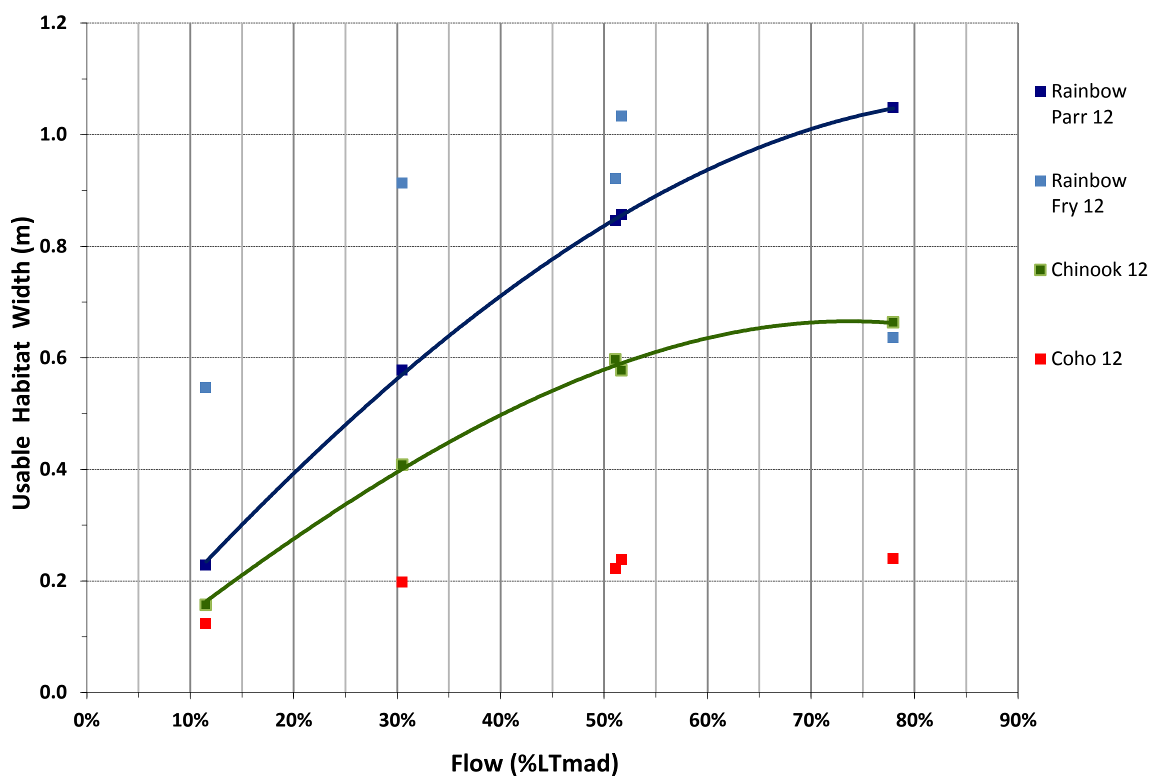


Figure B12. Weighted Usable Width vs. Flow as %LTmad in Riffle at Creighton 2B.

Appendix C

Weighted Usable Width Charts
for Glide Transects in
Bessette, Duteau and Creighton Creeks

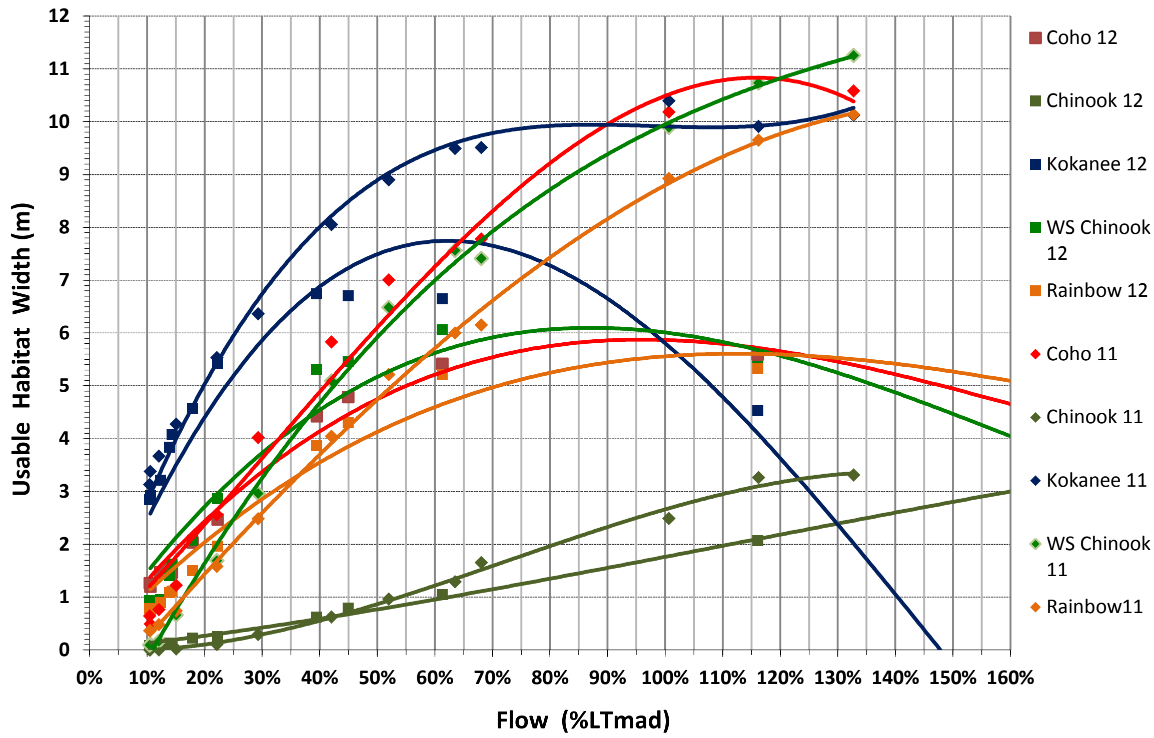


Figure C1. Weighted Usable Width vs. Flow as %LTmad in Glide at Bessette 1.

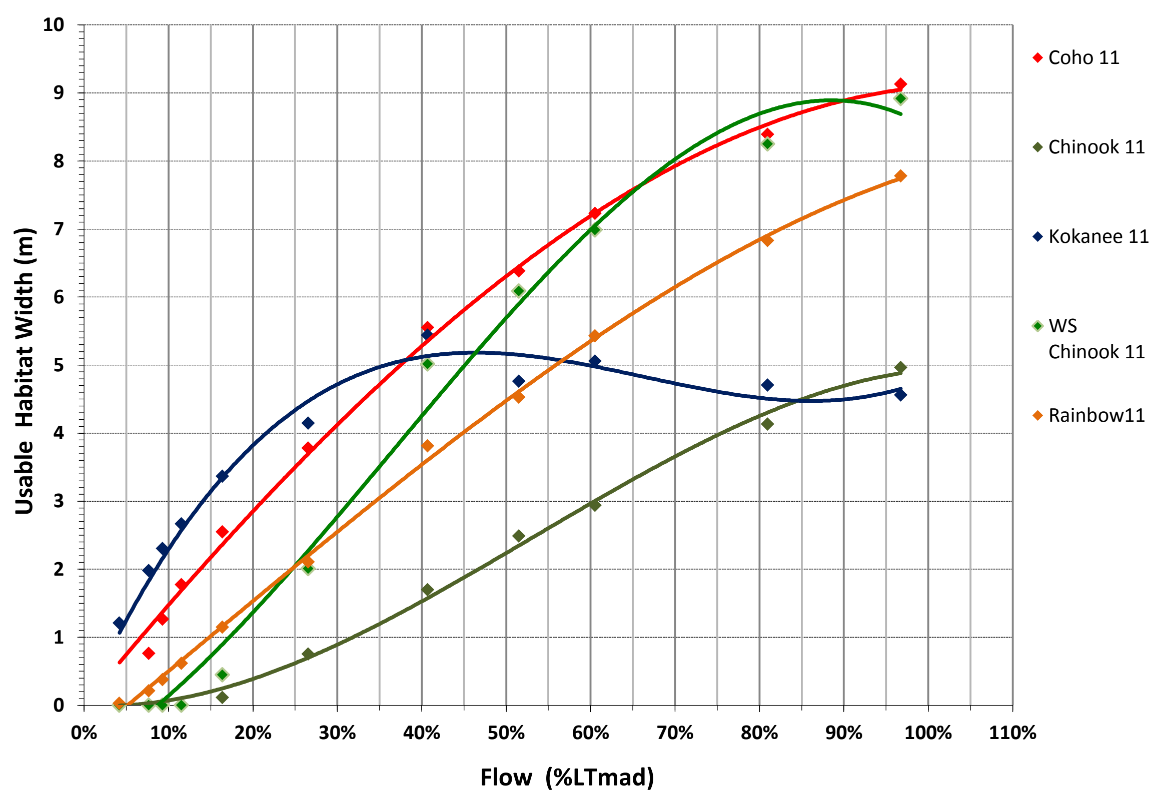


Figure C2. Weighted Usable Width vs. Flow as %LTmad in Glide at Bessette 2(11).

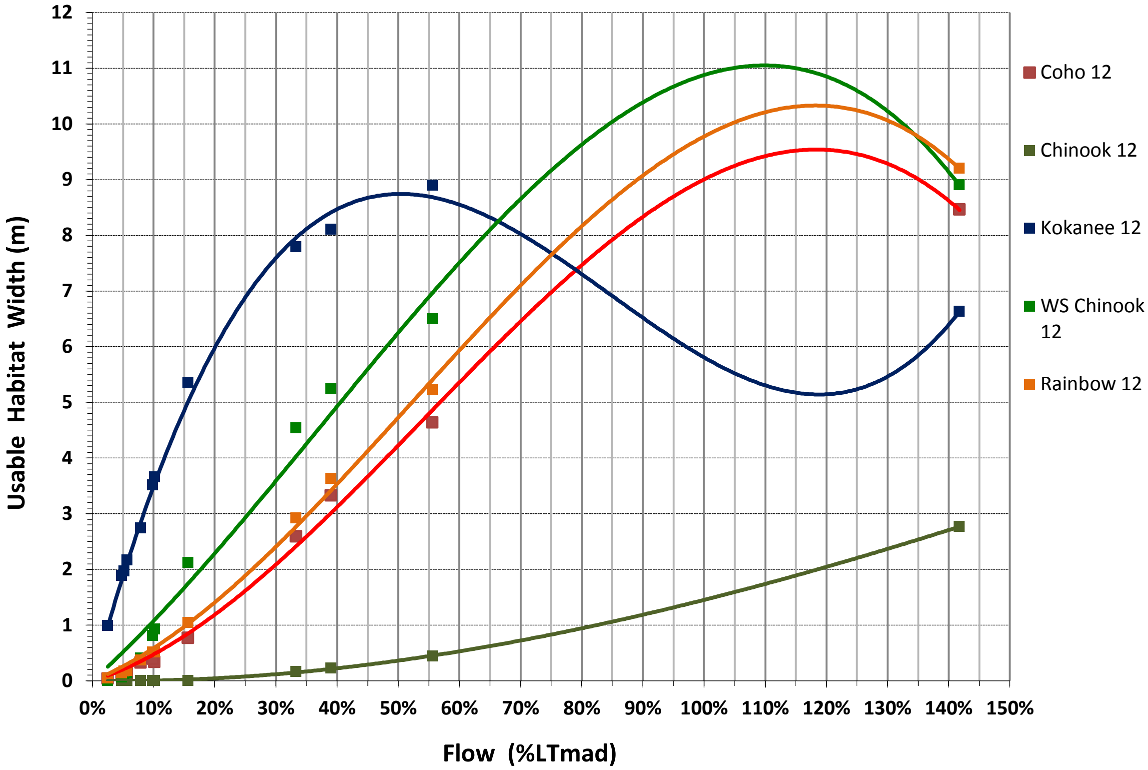


Figure C3. Weighted Usable Width vs. Flow as %LTmad in Glide at Bessette 2(12).

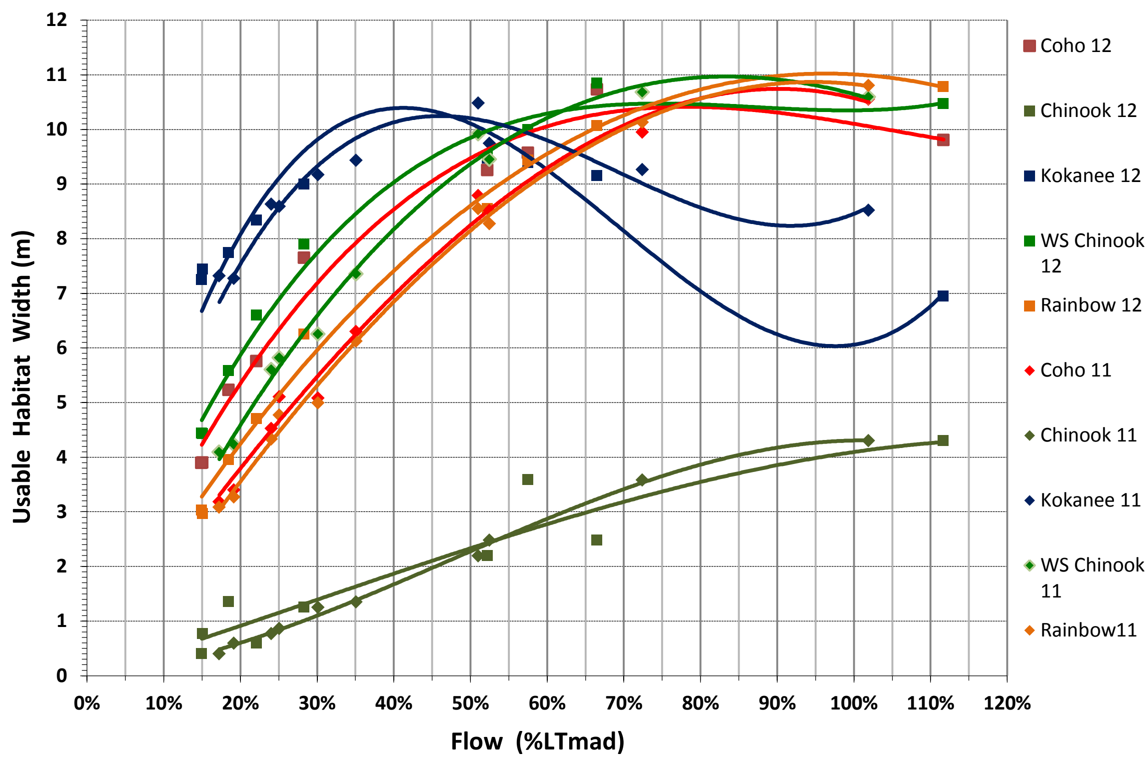


Figure C4. Weighted Usable Width vs. Flow as %LTmad in Riffle at Bessette 3.

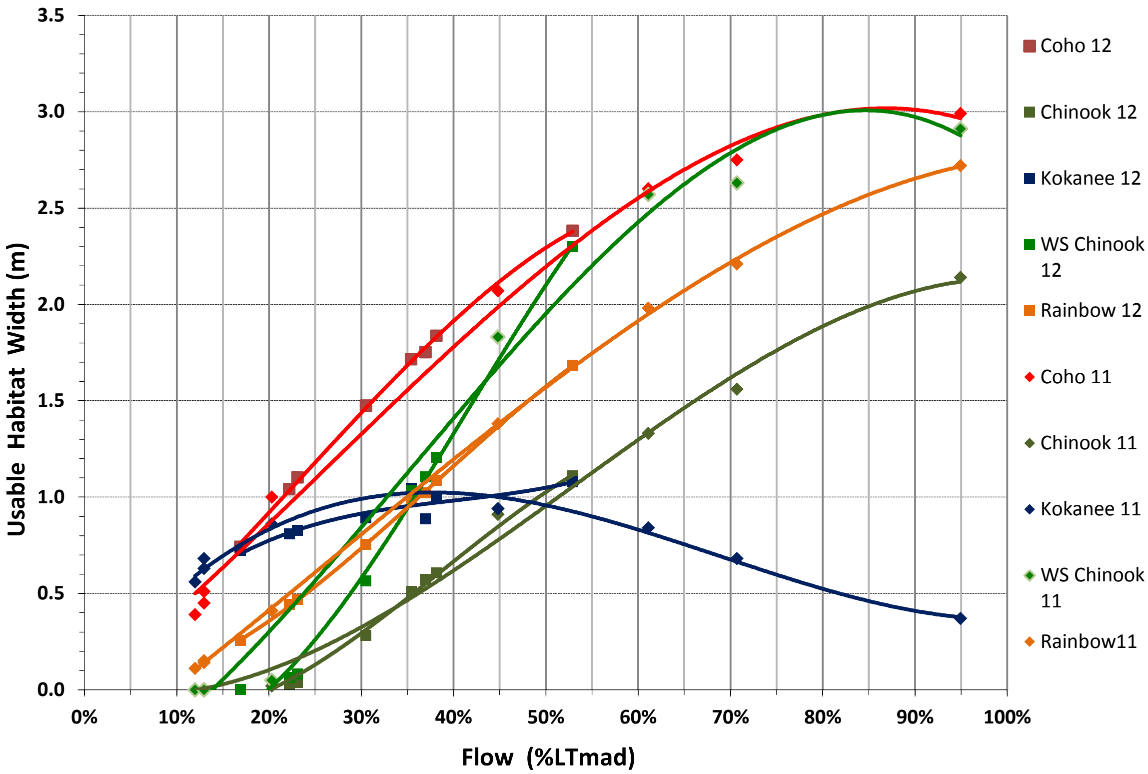


Figure C5. Weighted Usable Width vs. Flow as %LTmad in Glide at Duteau 1.

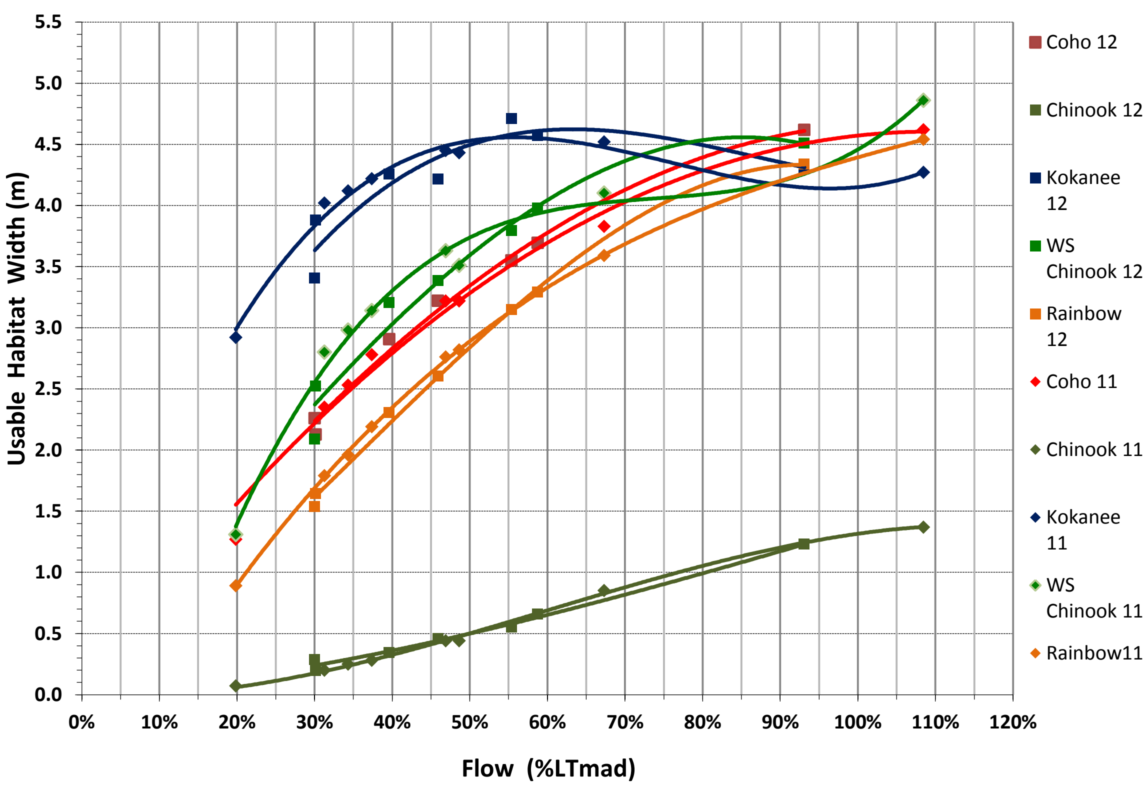


Figure C6. Weighted Usable Width vs. Flow as %LTmad in Glide at Duteau 2.

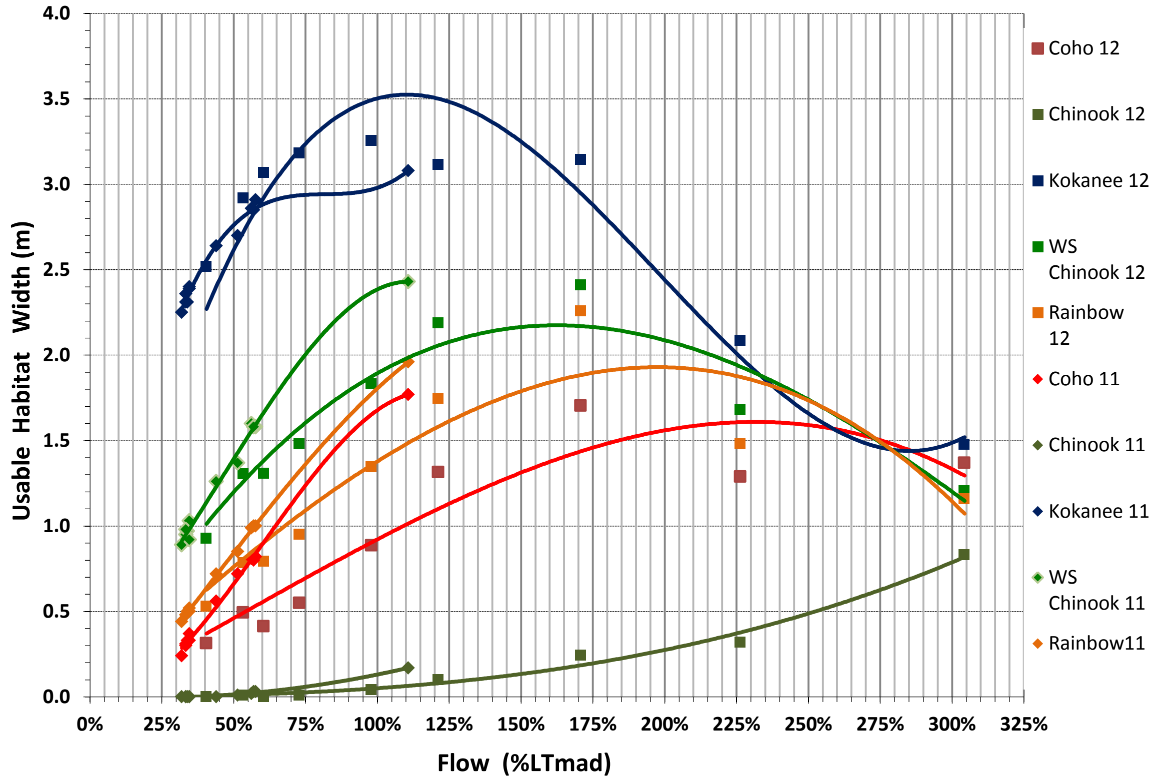


Figure C7. Weighted Usable Width vs. Flow as %LTmad in Glide at Creighton 1.

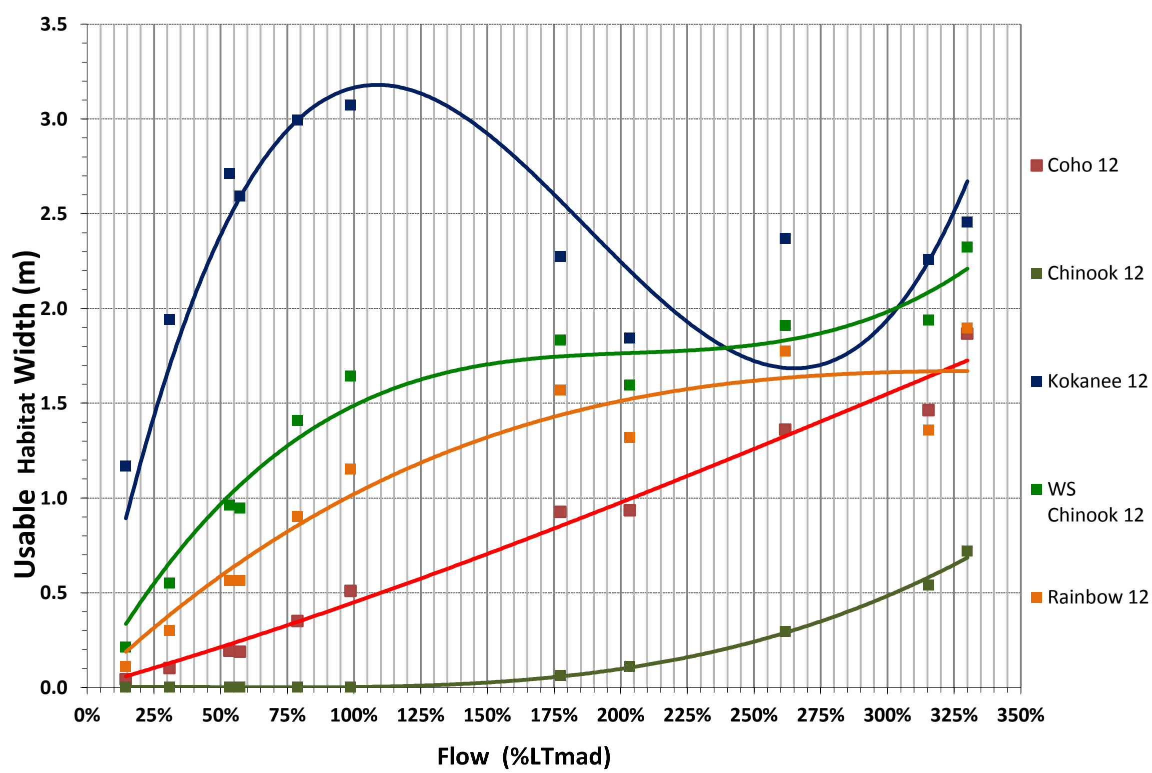


Figure C8. Weighted Usable Width vs. Flow as %LTmad in Glide at Creighton 2.

Appendix D

Photographs
of
Riffle and Glide Transects in
Bessette, Duteau and Creighton Creeks

Bes 1 Riffle (above Horner Road)

2,138 L/sec 109%LTmad

1,223 L/sec 63%LTmad

828 L/sec 42%LTmad

383 L/sec 20%LTmad

267 L/sec 14%LTmad

220 L/sec 11%LTmad

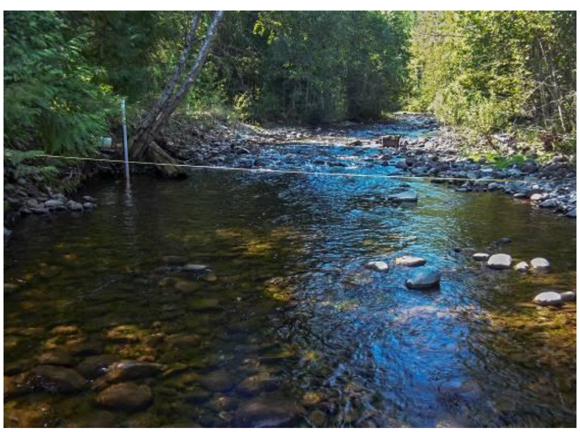
Bes 1 Glide (above Horner Road)

2,276 L/sec 116%LTmad

1,202 L/sec 61%LTmad

775 L/sec 40%LTmad

438 L/sec 22%LTmad



274 L/sec 14%LTmad

207 L/sec 11%LTmad

Bes 2 Riffle (at Lumby)

1,545 L/sec 62%LTmad

1,039 L/sec 42%LTmad

306 L/sec 12%LTmad

206 L/sec 8%LTmad

87 L/sec 3%LTmad

Bes 2 Glide (at Lumby)

1,500 L/sec 61%LTmad

1,009 L/sec 41%LTmad

286 L/sec 12%LTmad

230 L/sec 9%LTmad

Bes 2A Riffle (at Shuswap Ave)

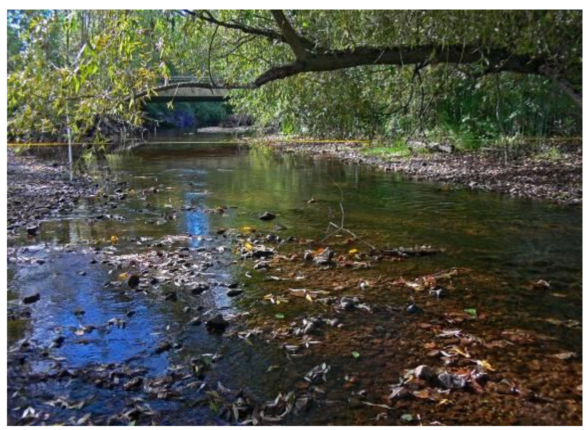
2,883 L/sec 147%LTmad

1,125 L/sec 57%LTmad

664 L/sec 34%LTmad

334 L/sec 17%LTmad

201 L/sec 10%LTmad



109 L/sec 6%LTmad

Bes 2B Riffle (at Shuswap Ave)

2,943 L/sec 150%LTmad

1,083 L/sec 55%LTmad

631 L/sec 32%LTmad

299 L/sec 15%LTmad

200 L/sec 10%LTmad

95 L/sec 5%LTmad

Bes 2A Glide (at Shuswap Ave)

1090 L/sec 56%LTmad

765 L/sec 39%LTmad

653 L/sec 33%LTmad

307 L/sec 16%LTmad

194 L/sec 10%LTmad

95 L/sec 5%LTmad

Bes 3A Riffle (above Beaverjack Creek)

4,387 L/sec 106%LTmad

2,483 L/sec 60% LTmad

1,448 L/sec 35%LTmad

1,085 L/sec 26%LTmad

841 L/sec 20%LTmad

606 L/sec 15%LTmad

Bes 3B Riffle (above Beaverjack Creek)

4,237 L/sec 103%LTmad

2,680 L/sec 65% LTmad

1,965 L/sec 48%LTmad

1,217 L/sec 29%LTmad

952 L/sec 23%LTmad

520 L/sec 13%LTmad

Bes 3 Glide (above Beaverjack Creek)

4,612 L/sec 112%LTmad

2.748 L/sec 67%LTmad

2,156 L/sec 52%LTmad

1,170 L/sec 28%LTmad

914 L/sec 22%LTmad

617 L/sec 15%LTmad

Dut 1A Riffle (at Whitevale Road)

930 L/sec 92%LTmad

721 L/sec 72%LTmad

413 L/sec 41%LTmad

278 L/sec 28%LTmad

177 L/sec 18%LTmad

118 L/sec 12%LTmad

Dut 1B Riffle (at Whitevale Road)

501 L/sec 50%LTmad

382 L/sec 38%LTmad

238 L/sec 24%LTmad

Dut 1 Glide (at Whitevale Road)

957 L/sec 95%LTmad

616 L/sec 61%LTmad

452 L/sec 45%LTmad

308 L/sec 31%LTmad

205 L/sec 20%LTmad

131 L/sec 13%LTmad

Dut 2 Riffle (at Lumby

697 L/sec 64%LTmad

557 L/sec 51%LTmad

404 L/sec 39%LTmad

321 L/sec 30%LTmad

177 L/sec 16%LTmad

Dut 2 Glide (at Lumby)

1,175 L/sec 108%LTmad

637 L/sec 59%LTmad

430 L/sec 40%LTmad

327 L/sec 30%LTmad

Cre 1 Riffle (at Salvas)

488 L/sec 117%LTmad

239 L/sec 57%LTmad

165 L/sec 40%LTmad

130 L/sec 31%LTmad

108 L/sec 26%LTmad

Cre 1 Glide (at Salvas)

461 L/sec 111%LTmad

252 L/sec 60%LTmad

214 L/sec 51%LTmad

169 L/sec 41%LTmad

139 L/sec 33%LTmad

Cre 2A Riffle (Lower Creighton Ck)

399 L/sec 94%LTmad

217 L/sec 51%LTmad

142 L/sec 33%LTmad

91 L/sec 21%LTmad

50 L/sec 12%LTmad

25 L/sec 6%LTmad

Cre 2B Riffle (Lower Creighton Ck)

332 L/sec 78%LTmad

218 L/sec 51%LTmad

130 L/sec 31%LTmad

49 L/sec 12%LTmad

Cre 2 Glide (Lower Creighton Creek)

867 L/sec 204%LTmad

336 L/sec 79%LTmad

227 L/sec 53%LTmad

132 L/sec 31%LTmad

62 L/sec 15%LTmad

Appendix E

Coldstream Creek Realtime Flows
as Bessette Creek Flow Surrogate

Coldstream Creek Realtime Flows as Bessette Creek Flow Surrogate

Coldstream Creek is a small watershed with an unregulated drainage area of 60 km^2, a median elevation of 1120 m, an elevation range of about 610 m to 1660 m, and a realtime WSC hydrometric station located approximately 15 km northwest of Nicklen Lake and less than 10 km west of Lumby. This compares to a drainage area of 253 km^2 at the historic WSC hydrometric station on Bessette Creek upstream of Lumby and an elevation range of 510 m to 2000 m. As such, while Coldstream Creek is a smaller drainage than Bessette with lower peak elevations, it could be expected to act as a reasonable surrogate for indicating naturalized flows in the highly regulated Bessette Creek watershed.

Historic WSC daily flows for the active hydrometric stations on Coldstream Creek, Vance Creek and Bessette at Lumby (includes Bessette above Lumby, as well as Duteau and Creighton Creeks) were converted to %LTmad to standardize flows for comparison purposes. The first comparison is shown in **Error! Reference source not found.** which compares the median daily flow from April 1 to October 31 for the 3 hydrometric stations for the periods of record for each station (1967 to 2010 for Coldstream, 1970 to 2010 for Vance, and 1973 to 2010 for Bessette).

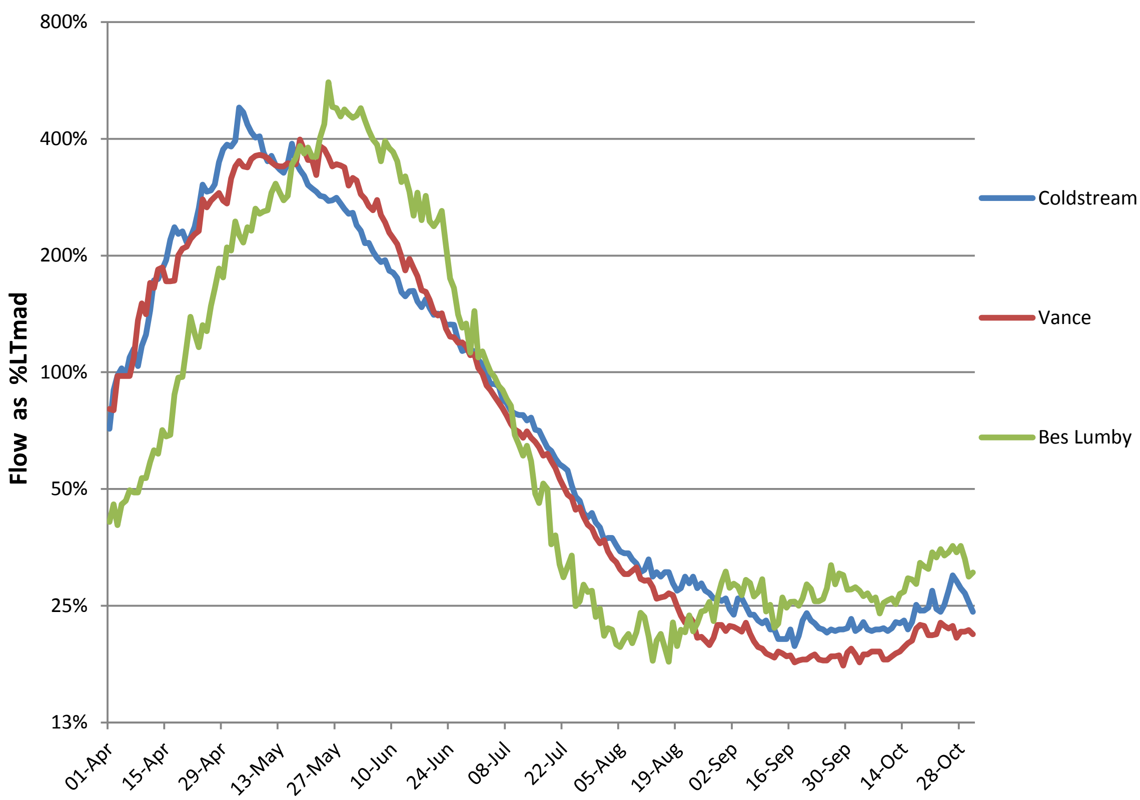


Figure E1. Median Daily Flow (as %LTmad) for Coldstream, Vance and Bessette Creeks.

The comparison of daily median flows demonstrates some similarity in the flow patterns, with closer correlation between Coldstream and Vance Creek than between Coldstream and Bessette Creeks. Coldstream Creek freshet occurs in early May, followed by Vance Creek in mid May and Bessette Creek in late May. The Vance Creek flow pattern is the closest to that of Coldstream Creek, with a somewhat later freshet peak translating to higher early June flows and steeper flow recession, but quite comparable flows as %LTmad from mid June to mid August, followed by consistently lower flows in Vance Creek from mid August through October. The later Bessette Creek freshet peak translates into much higher flows in June, followed by steeper recession and markedly lower flow in July and August. Bessette Creek flow then recovers to higher levels in September and October. The differences in median flow patterns between Coldstream and Vance Creeks seem consistent with differences in runoff patterns due to area and elevations, as well as water use in Vance Creek, while the substantially lower summer flows followed by higher fall flows in the Bessette flow pattern suggest considerable flow regulation in addition to runoff patterns differences. The magnitude of the flow differences between Bessette Creek and Coldstream Creek appear to go beyond what is likely due to flow regulation though.

For 2011, relatively natural (natural flow plus Nicklen Lake release starting in late August) flow data is available for Bessette Creek above Horner Road starting in late June. This data was used to compare "natural" Bessette Creek flows with preliminary flow data for Bessette at Lumby and Vance, as well as realtime Coldstream Creek flow data. The results are shown in Figure E2.

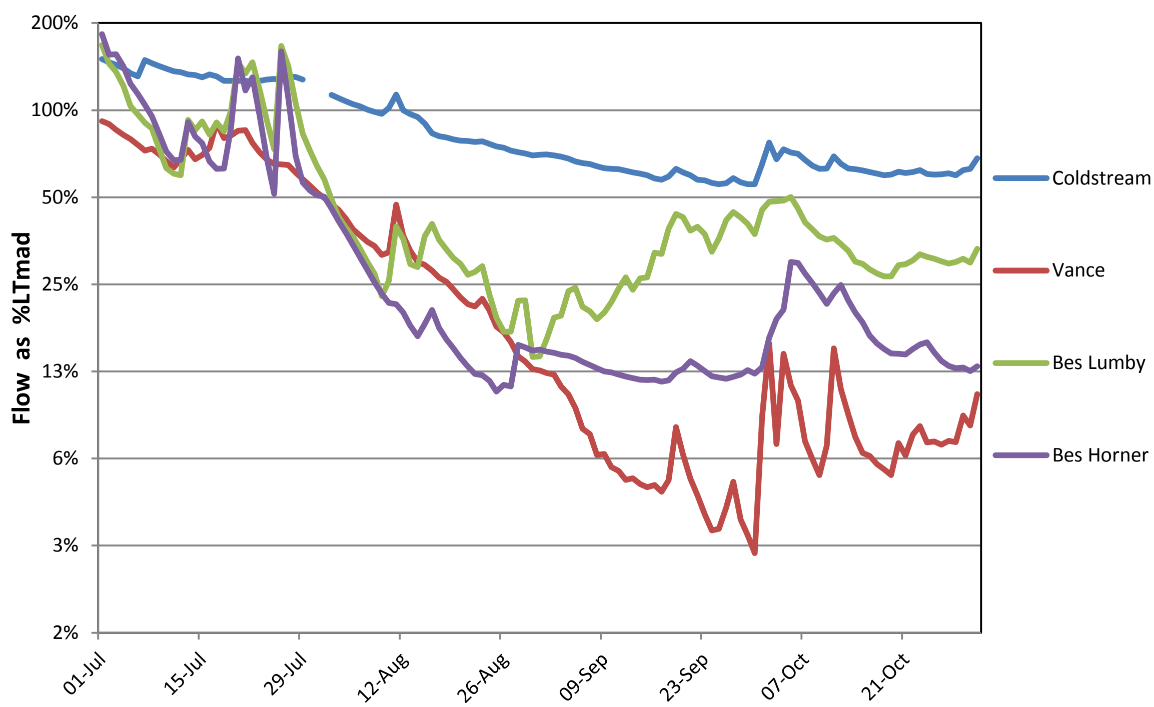


Figure E2. 2011 Daily Flow (as %LTmad) for Coldstream, Vance and Bessette Creeks.

The 2011 comparison also indicates that the summer and fall flow patterns in Bessette Creek are quite different from Coldstream Creek. As such, while Coldstream Creek could be used as a broad indicator of flow trends (e.g. dry, normal or wet summer), the differences in flow pattern expressed as %LTmad are too large to use Coldstream Creek realtime flows as a surrogate for natural flows in Bessette Creek.

A third comparison between lower Bessette and Coldstream Creek flows was made by determining the dates for each year in the last decade on which the Bessette Creek above Beaverjack Creek flows first diminished below 20% LTmad, and then comparing then comparing Coldstream flows for those dates to see if there is any correlation there. The Coldstream Creek flow values that match the dates on which lower Bessette reached 20%LTmad range from 0.081 m^3/sec to 0.179 m^3/sec, with an average of 0.115 m^3/sec. The range seems too large for good correlation, but when the date on which the average flow of 0.115 m^3/sec was reached in Coldstream Creek was compared to the date on which Bessette Creek reached 20%LTmad, most years were within 3 days. The two exceptions were 2007 when Coldstream Creek reached 0.115 m^3/sec 14 days early, and 2010 when Coldstream Creek was13 days later reaching 0.115 m^3/sec. The 2007 exception is explained by Bessette Creek having been almost down to 20%LTmad 16 days earlier which would have been a 2 day difference from the Coldstream value, but there is no similar explanation for the 2010 difference. Results of this correlation are summarized in Table E1.

Table E1. Bessette and Duteau Creek Chinook and Coho Spawner Counts and Peak Spawning Dates.

Year	Date Bessette Flow <20%LTmad	Coldstream Flow on Bessette 20% Date (m^3/sec)	Date Coldstream Flow < 0.115 m^3/sec	Date Difference (days)
2000	12-Aug	0.107	10-Aug	-2
2001	15-Aug	0.084	11-Aug	-4
2002	17-Jul	0.114	17-Jul	0
2003	09-Jul	0.094	07-Jul	-2
2004	18-Jul	0.104	15-Jul	-3
2005	07-Aug	0.116	08-Aug	1
2006	29-Jul	0.116	30-Jul	1
2007	27-Jul	0.081	13-Jul	-14
2008	16-Jul	0.140	19-Jul	3
2009	17-Jul	0.130	19-Jul	2
2010	19-Jul	0.179	01-Aug	13
Avg.	25 Jul	0.115	24 Jul	

This third comparison using a specific flow in Coldstream Creek to predict when a flow level in Bessette Creek will be reached shows remarkably good correlation given the degree to which Bessette Creek flows can be altered by flow regulation in Duteau Creek and water use in all of the major tributaries. The correlation will not always work as a low Bessette low flow predictor as evidenced by the 2010 results, but in the absence of realtime flow data in Bessette Creek, specific Coldstream Creek flows as a surrogate for Bessette Creek flow levels appears to be useable.

Appendix F

Nicklen Lake Refill Calculations

Nicklen Lake Refill Calculations

There has been uncertainty regarding the annual refill of Nicklen Lake if a significant volume of the conservation storage is used. It is understood that Nicklen Lake has refilled every year following releases for irrigation, but the licenced storage for irrigation (666 AF) is only about one third of the full storage capacity (1868 AF) of Nicklen Lake, so there is as yet limited refill experience based on conservation storage releases in addition to the irrigation releases, and no refill records based on a substantial drawdown.

Runoff in ungauged sub-basins like Nicklen Creek can be estimated using regional elevation-runoff curves developed by the Province for the Southern Interior region (Obedkoff, 1998). Obedkoff's runoff curves were generated by plotting average annual runoff from WSC hydrometric station data against the median elevations of the contributing area for that station. .

Direct comparison of the Nicklen Lake median catchment area to Obedkoff's runoff curve for sub-zone c (Okanagan Highland) results in an average annual runoff estimate of 300 mm / year. The catchment area for Nicklen Lake is 5.4 square miles (B.C. Ministry of Environment, 1978), so using an annual runoff of 300 mm, the average annual inflow to Nicklen Lake is calculated as 4,195,800 m^3 (3,402 AF) which equates to 182% of the entire storage volume of Nicklen Lake. This suggests that Nicklen Lake should refill relatively reliably, but adjustments to the average annual runoff volume need to account for runoff during the refill period rather than the entire year, evaporation from the surface of the lake, and annual variability in runoff volume.

First, based on monthly Vance Creek hydrometric data (1970 to 2010), runoff from November 1 to June 30 averages 86% of the annual runoff, so only 3,608,400 m^3 (2,925 AF) would be expected to flow into storage before July 1 in an average year. Second, there will be evaporation losses from the Nicklen Lake surface. The 1974 Kalamalka-Wood Lake Basin Water Management Study (Water Investigations Branch, 1974) measured evaporation from a number of lakes over several years, and determined that average upland lake evaporation was 13.6 inches, with 26% of the volume occurring in June, 32% in July, 30% in August and 11% in September. Using a full pool elevation of 215 Acres, the average lake evaporation in June would be 73 AF (90,000 m^3), which would be conservative since there would also be some precipitation on the lake surface during this period. This results in a net refill volume of 3,518,400 m^3 (2852 AF). A further loss of 208 AF should be expected during July to September, but that is past the refill period and should be more than offset by the ongoing inflow (the other 14% of the annual runoff) and precipitation during the July to October period and so that is not factored into the refill calculations.

Based on the above, the net refill into Nicklen Lake for an average runoff year would be:

Average Year	3,518,400 m3	2,852 AF	153% of Storage Capacity

Flows for drier than average years are calculated based on the % of average flow in the Vance Creek hydrometric records from 1970 to 2010. P20 represents the value at which 20% of historic values have been lower and 80% higher, at P10 10% have been lower and 90% higher, and at P5, 5% have been lower and 95% higher. These values approximate historical return flows of 1 in 5 years, 1 in 10 years and 1 in 20 years respectively.

P20 (66% of Mean)	2,322,100 m^3	1,883 AF	101% of Storage Capacity
P10 (53% of Mean)	1,864,700 m^3	1,512 AF	81% of Storage Capacity
P5 (45% of Mean)	1,583,300 m^3	1,284 AF	69% of Storage Capacity

These refill calculations show that Nicklen Lake should refill completely from full drawdown under average to dry conditions (5 year return period), but that complete refill from full drawdown should not be expected in significantly drier than average conditions (10 year return period), and that under extremely dry conditions (20 year return period) only about 70% of the storage capacity would be refilled. This would still more than meet the irrigation storage, but would limit the available conservation storage in the drier years.

Nicklen Lake Refill Calculation Validation

The above calculations and discussion are based on regional runoff values, and as such represent the best available estimate of Nicklen Lake refill probabilities, but are subject to all of the inherent lack of precision from using regional runoff rather than sub-basin specific flows (which are unavailable). There is also no formal operating history (water levels and releases) to validate these estimates directly. Fortunately though the Regional District of North Okanagan initiated a flow monitoring program on 3 neighbouring Duteau reservoir tributaries in 2008, and these results can be used to at least partially validate the Nicklen Lake calculations.

The most conservative comparison is with the Curtis Creek results. Curtis Creek is immediately to the south of Nicklen Creek and has a smaller area of 9.3 km^2 above the monitoring station as compared to the Nicklen Lake contributing area of 14 km^2 and a lower maximum elevation in the contributing area of about 1520 m compared to 1680 m in the Nicklen Lake drainage. Over the 6 years, the average May and June flow in Curtis Creek was 0.412 m^3/sec, which equates to an average May/June runoff of 234 mm, compared to the November to June mean runoff of 258 mm (86% of 300 mm) calculated for the Nicklen Lake drainage using the regional runoff curves. Flow measurement records for April in Curtis Creek are not available for 2008 and 2010, and are subject to icing conditions for the early part of April in the 4 years where flows are available. As such, April data was not used for the calculations, but April inflows should be adequate to make up the 24 mm difference between the measured May/June runoff average for Curtis Creek and the adjusted regional runoff estimate. The comparable May/June mean runoff values for 2008 to 2013 for the higher maximum elevation Heart Creek and Duteau Creek sub-drainages are 311 mm and 417 mm respectively.

The Curtis, Heart and Duteau Ck monitoring results from the adjacent Duteau Creek watershed provide strong confirmation that using 258 mm as the November to June mean runoff for refill calculations is reasonable, and perhaps conservative because the elevation range is between the Curtis and the Heart and Duteau sub-drainages.

The Curtis, Heart and Upper Duteau Ck monitoring results also provide valuable insight into the annual variability of the runoff. Runoff for the individual years ranges from 51% of 6 year mean in 2009 to 133% in 20131 in Curtis Creek, 66% of the 6 year mean in 2009 to 138% in 2012 in Heart Creek, and 73% of the 6 year mean in 2009 to 127% in 2011 in Upper Duteau Creek, with 2008 to 2010 all below average, and 2011 to 2013 all above average. These percentage are most pronounced in Curtis Creek in 2009, but it's also interesting to note that the lowest flows occurred in 2008 rather than 2009 in Heart and Upper Duteau Creeks, and the highest flows were in Curtis in 2013, Heart in 2012, and Upper Duteau in 2011.

The Curtis, Heart and Duteau Ck monitoring results also provide valuable insight into the timing of the runoff. Observations by Ministry of Forests, Lands and Natural Resource Operations staff on May 29, 2012 (Caverly, 2012) indicated that Nicklen Lake had not yet refilled completely, even though May 1 Okanagan - Kettle and South Thompson snowpacks were slightly above normal. This raised questions regarding the Nicklen inflow estimates which had at that time been done solely based on the regional elevation-runoff calculations. It was thought that Nicklen Lake would have been expected to be spilling by the end of May in a normal runoff year after only partial drawdown if the Duteau based runoff estimates were correct. The Curtis, Heart and Duteau flow monitoring results demonstrate however that while the lower elevation Curtis Creek has peak flows in May, the higher elevation Heart and Duteau Creek drainages usually have higher mean June flows than in May. As such, complete refill shouldn't be expected until June unless it is a very wet spring and / or there was no conservation storage drawdown in the preceding year.

Regional Runoff Trends and Implications for Nicklen Lake Refill

The validation based on monitoring results from the RDNO Duteau Creek tributaries monitoring indicates that the runoff values calculated from the regional elevation-runoff curves are valid for the Nicklen Lake catchment area. However, as described in Section 3 of the report, the Bessette Creek flows from 1976 to 2010 show a distinct trend to lower annual runoff over time. Volume of runoff is determined by climatic factors which are cyclical over time, so annual runoff may increase again over the next decade to maintain the longer term average used in the elevation-runoff calculations, with the 2011 to 2013 flow results supporting this. It is also possible that runoff volume is decreasing over time in response to a changing climate, and that 80% to 90 % of the longer term mean runoff is the new mean. In that case, the relative elevation-runoff relationships should remain relatively valid, but the projected refill quantities would need to be reduced by approximately 10% to 20% to reflect the new mean conditions.

A formal program of recording reservoir levels (at least monthly during April to October) and releases is recommended to document annual inflows / outflows which can be compared to Vance Creek, the RDNO Duteau Creek results and other stream flows for historical context to establish a level of comfort with the above refill estimates.

Appendix G

Nicklen Lake Storage Release Rule Curves

Construction and Use of Nicklen Lake Reservoir Release Rule Curves

Figure G1 presents a set of rule curves that demonstrate how Nicklen Lake is expected to drawdown from July 1 to November 15 each year with the recommended agricultural and conservation flow releases, as well as a series of lower conservation flow releases in the event that storage is being drawn down faster than expected, and / or Nicklen Lake was not completely full at the start of July.

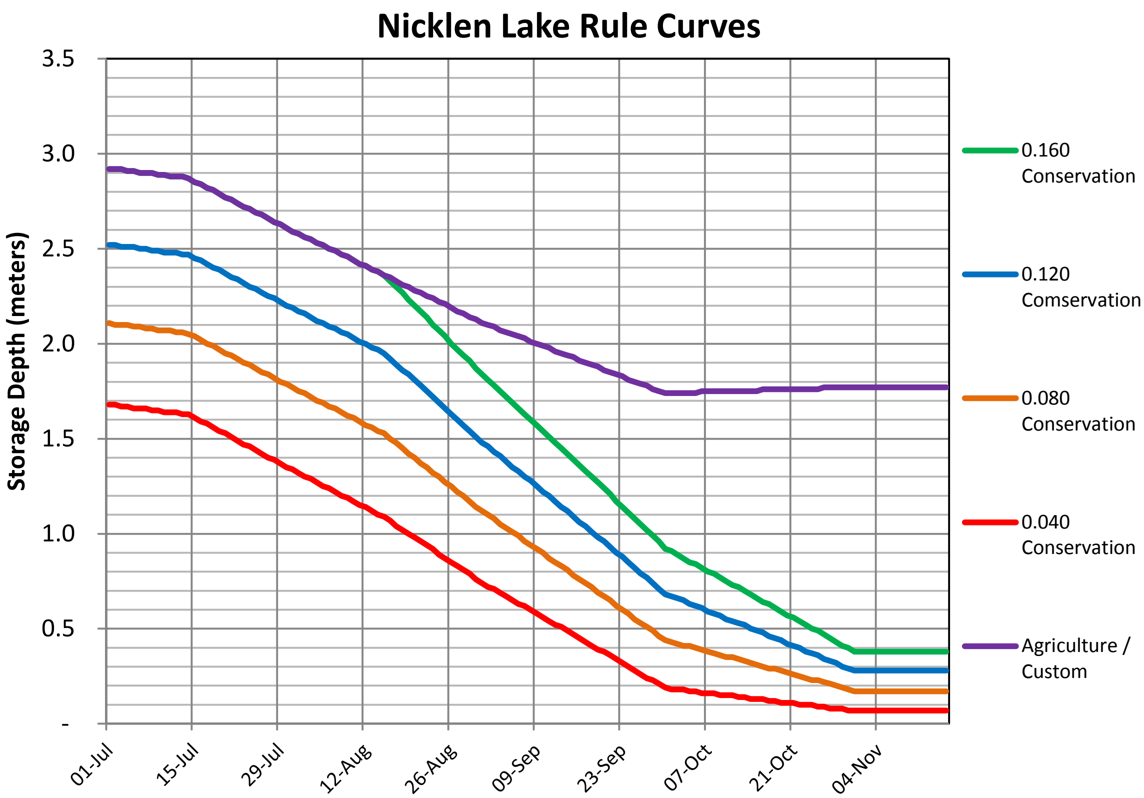


Figure G1. Nicklen Lake Storage Release Rule Curves

The Nicklen Lake rule curves were constructed as follows. Starting levels for the Agriculture / Custom and the 0.160 Conservation curves were assigned as 2.92 which represents the depth between the spillway and the invert of the outlet pipe with an available storage volume of 2302 ML. The 0.120 Conservation curve starts at 2.52 which represents the depth of storage when Nicklen Lake is at 85% of the storage capacity (1958 ML). The 0.080 Conservation curve starts at 2.11 which represents the depth of storage when Nicklen Lake is at 70% of the storage capacity (1613 ML) and the 0.040 Conservation curve starts at 1.68 which represents the depth of storage when Nicklen Lake is at 55% of the storage capacity (1267 ML). The lake level change is then calculated daily for each curve, taking into account average daily evaporation minus precipitation (positive in July and August, negative in September and October) and the daily agricultural release of 0.120 m^3/sec from July 15 to September 30 for the Agriculture / Custom curve, plus the conservation storage releases of 0.160, 0.120, 0.080 or 0.040 m^3/sec respectively for the other four curves. The evaporation - precipitation is calculated directly as a depth loss, while the releases are calculated as volume and then converted to depth using a lookup table based on the Nicklen Lake storage capacity chart. Average monthly lake evaporation and precipitation values are as per the values reported in the Kalamalka-Wood Lake Basin report for upland reservoir lakes.

The Nicklen Lake rule curves can be used in three ways. First, they can be used to plan the storage releases for the year based on the Nicklen Lake starting level in July. If Nicklen Lake is at or above 2.87 on July 15, the expected releases would be 0.120 m^3/sec from the agricultural storage starting on July 15 and 0.160 m^3/sec from the conservation storage starting on August 15, with the agricultural release ending on September 30 and the conservation release ending on October 31. If the Nicklen Lake level on July 15 is lower than 2.87, the agricultural storage release should still be initiated at 0.120 m^3/sec, but a lower conservation storage release would be planned for in accordance with which curve the level is above. For example, if the July 15 level is only 2.70, then conservation storage releases would be planned at 0.120 m^3/sec and the 0.120 Conservation curve would be followed, and if only 2.40 then the planned conservation release would be 0.080 m^3/sec and the 0.080 Conservation curve would apply, etc.

Second, the Nicklen Lake level should be checked periodically and recorded and compared to the rule curves. This should take place as a matter of course on July 15, August 15, and September 30 when changes to the release rates are scheduled, but additional level readings would be beneficial. At each level to rule curve comparison, if the level remains above the curve based on the starting elevation, then releases should continue as planned. However, if the recorded level is below the starting rule curve for that date, then the conservation storage release should be adjusted downwards accordingly to ensure that the storage is not completely drained prematurely.

Third, the Agriculture Excel spreadsheet which was used to create the rule curves can be modified by MFLNRO staff to model alternate storage release scenarios. The Agriculture / Custom curve currently shows just drawdown with the recommended agricultural storage release, but there is a blank data column for conservation storage releases which could be used to model drawdown from full pool for any volume of conservation storage as desired. Similarly, any of the other curves can be modified by simply changing the starting depth and / or the agricultural and conservation storage release rates to model whatever scenario is desired.

The Nicklen Lake rule curves are provided as a guide to helping to make storage release decisions and in season adjustments. Confirmation of the planned releases, and any in season adjustments should be made by, or in consultation with, the Senior Fisheries Biologist at the Ministry of Forests, Lands and Natural Resource Operations office in Penticton.