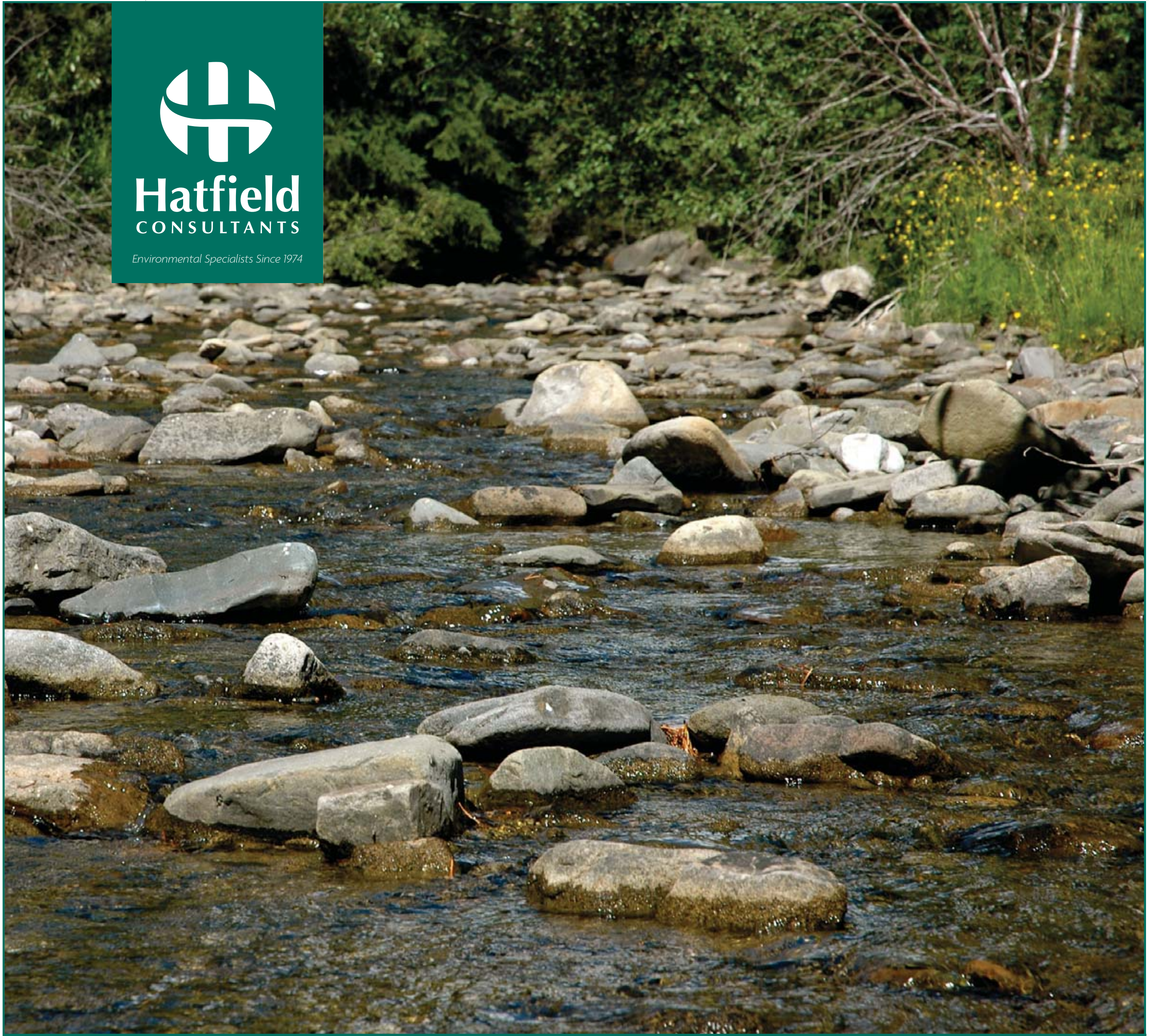
Appendix A3

Instream Flow Assessment



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Grassy Mountain Coal Project
Instream Flow Assessment

January 2017

Prepared for:

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Blairmore, Alberta

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INSTREAM FLOW ASSESSMENT:
GRASSY MOUNTAIN COAL PROJECT

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LIST OF ACRONYMS

ADV	acoustic doppler velocimeter
AER	Alberta Energy Regulator
AWS	area weighted suitability
BC	British Columbia
BCIFM	BC instream flow methodology
CEAA	Canadian Environmental Assessment Agency
COSEWIC	Committee on the Status of Endangered Wildlife
CRDA	central rock disposal area
CSI	combined suitability index
DFO	Fisheries and Oceans Canada
EIA	environmental impact assessment
ESCC	Endangered Species Conservation Committee
FHAP	fish habitat assessment procedures
HSC	habitat suitability curves
IFA	instream flow assessment
IFIM	instream flow incremental methodology
IFN	instream flow needs
LWD	large woody debris
LSA	local study area
MAD	mean annual discharge
MAP	mean annual precipitation
MMD	mean monthly discharge
MOE	Ministry of Environment
NRDA	North rock disposal area
PAG	potential acid generating rocks
PHABSIM	physical habitat simulation model
Q	Discharge
SARA	Species at Risk Act
SEFA	system for environmental flow analysis

SRDA	South rock disposal area
SZ	saturated zone
SZF	stage of zero flow
TSS	total suspended solids
VC	valued component
VDF	velocity distribution factor
WL	water level
WMP	water quality management plan
WSC	Water Survey of Canada
WSCT	Westslope cutthroat trout
WY	water year
XS	cross-section
YOY	young-of-year

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EXECUTIVE SUMMARY

Activities associated with the proposed Grassy Mountain Coal Project (the Project) may affect stream flow in Gold Creek and Blairmore Creek, tributaries of the Crowsnest River that support Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*; WSCT) and other aquatic life that this species relies upon to fulfill its life history. Alberta populations of WSCT are listed as *Threatened* under the federal Species at Risk Act (SARA), which prohibits activities that may harm or destroy their critical habitat. Potential flow reductions may occur in Gold Creek because of water diversions, water withdrawals, and/or reductions in run-off due to capture, treatment, and storage of water by various Project components as per the Project's proposed Water Quality Management Plan (WMP). Potential increases in flow may occur in Blaimore Creek due to the release of water through the proposed WMP. Scheduled Project phases following a baseline period (2017) include construction (2018), operations (2019-2042), decommissioning (2043-2044) and closure (2045-2099).

An instream flow assessment (IFA) was conducted to evaluate the potential for flow-related effects on WSCT and their habitat in these watercourses. For each of five study reaches on Gold Creek, and three study reaches on Blairmore Creek, predictions were made for baseline and all Project phases of hydraulic conditions important for WSCT (i.e., stream depth, width, water velocity, substrate) and the Area Weighted Suitability (AWS) of habitat, calculated by applying WSCT life-stage specific Habitat Suitability Curves (HSCs) to these hydraulic conditions. The percentage change in average monthly AWS, expressed in metres squared per reach, during biologically relevant time-periods (stanzas) was used to assess the potential effects of predicted flow changes on WSCT habitat during each Project phase relative to baseline. The threshold for "no significant" effect to fish due to predicted flow changes was a <10% reduction in total WSCT AWS in each Project phase (i.e., at least 90% of total WSCT habitat remained available during relevant biological stanzas).

This approach used was based on instream flow assessment methods applied within both BC and Alberta. These methods are consistent with the habitat component of the Instream Flow Incremental Methodology. Both methods assume that habitat for fish and other aquatic species changes as a function of flow and that predictive models can be developed to describe this relationship for a given stream.

Most stream-transect data used to develop the IFA models were collected during the June-October 2016 period; additional data collection occurred in 2013-2014 and March-May 2016. In total, 42 transects (27 on Gold Creek and 15 on Blairmore Creek) were established and measured over a range of stream flows, and used to develop calibrated hydraulic habitat models for the eight reaches. Each reach represented a unique hydro-geomorphic section with relatively homogenous morphology, gradient, substrates, and discharge. Reaches were selected because of their proximity to flow-altering mine infrastructure and their use by WSCT for spawning, rearing, overwintering, and invertebrate drift (i.e., food supply).

Once calibrated, each hydraulic habitat model was run using a hydrological time-series that included baseline and all Project phases. Baseline flows integrated the long-term (1975-2016) flow variability gauged at Water Survey of Canada (WSC) hydrometric stations on Gold Creek and Crowsnest River; these records were then transposed to local hydrometric gauges on Gold and Blairmore Creeks using regression analyses of concurrent flow data available for periods of 2013, 2014 and 2016. The resulting (synthetic) long-term flow records at local gauges were then transposed to each reach empirically, using flow data collected to support the IFA analyses. Estimated reach-average flows were then combined with the most appropriate monthly runoff changes predicted through all Project phases (2018-2099) using a water and load balance model developed separately for the Project by SRK Consultants, which predicted typical runoff losses along Gold Creek of between 3-7% (up to a maximum of 10.4%) and typical runoff gains along Blairmore Creek of between 5-15% (up to a maximum of 35.4%), relative to baseline conditions.

During open-water months (the most biologically relevant for WSCT), there was reasonable confidence in the applicability of the synthetic flow records given that the regression analyses incorporated both extreme wet conditions (primarily May to June 2014) and extreme dry conditions (primarily May to September 2016), relative to typical conditions in these months. These 2016 conditions limited the range of flows over which most transects were sampled during the IFA field surveys (lowest to highest water levels and flows were largely limited to 0.1 m and 50% difference, respectively). A small number of IFA transects were tied into existing locations with available higher-flow data (e.g., local hydrometric gauges or transects established in May 2016), which together with strict adherence to best rating-curve extrapolation procedures, helped to build confidence within the hydraulic habitat predictions during normal to wet months. Because lower flows are commonly associated with sub-optimal habitat, the dry conditions at the time of surveys provided increased confidence to predict potential WSCT habitat losses during reduced-flow conditions that may result either naturally (e.g., during droughts), from Project effects, or both.

IFA model predictions indicated that, without mitigation, Project-related flow changes would cause changes of less than 10% in habitat area (AWS) relative to long-term baseline conditions in all study reaches and all stanzas for WSCT rearing, spawning, fry or overwintering, when averaged across each Project phase. Results exceeding the 10% significance threshold indicating the potential for limitations to WSCT habitat only were predicted on Gold Creek when using a more stringent (single-month) timeframe, a more conservative flow scenario (continuous 1-in-10 and 1-in-20 year low flow conditions), or both. For the most conservative scenario (1-in-20 year low flow condition, when monthly and annual flows were less than half of average conditions), Project-related WSCT habitat losses of up to 20% in a single month were predicted for selected stanzas (adult and juvenile rearing, and spawning), in the three lowest-flow reaches including two upstream of the confluence with Caudron Creek and in a flow-losing reach further downstream near historic coal development where surface flows partly travel subsurface. Spawning habitat in these three reaches was predicted to decrease an average of 9-11% during the two-year decommissioning period (2043-2044), a period of highest Project-related flow reductions. No losses of habitat for fry emergence/rearing or overwintering of greater than 10% were predicted for any single month in any scenario.

Given the threatened status of WSCT, a conservate approach was adopted in this study at every stage of the model development and subsequent interpretation of results. Although predicted habitat losses of greater than 10% on Gold Creek indicate the potential for significant, adverse effects in some modelled scenarios, the probability of these specific scenarios occurring is low: for instance, a 1-in-20 year low flow year (i.e., with 5% probability of occurrence in any one year) is unlikely to coincide with the period of highest predicted Project-related losses in flow (2038-2042). Worst-case predictions of habitat losses in individual months assumes these effects on habitat, their use by specific fish life-stages, and fish production occur instantaneously, when in reality the response is more protracted and reflects a longer past history (e.g., poor spawning conditions the previous year). Short-term mitigation measures have been proposed for supplementing flows during dry years, which is aimed to alleviate any elevated risk for causing incremental residual effects to critical habitat. Similarly, the predicted Project-related alterations to fish habitat under average conditions will be counterbalanced through the implementation of a Habitat Offsetting Plan that aims to create a net gain of WSCT habitat in Gold Creek.

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1	First version, draft	20170110			
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1.0 INTRODUCTION

As the proposed Grassy Mountain Coal Project (the Project) may result in potential flow changes to neighbouring watercourses that support aquatic life this report provides the detailed methods for, and results of, and Instream Flow Assessment (IFA) to quantify potential effects from any predicted changes in flow. These watercourses include Gold Creek and Blairmore Creek, both tributaries to the Crowsnest River (Figure 1-1). The results of the IFA were used to support the Aquatic Ecology component of the Project's Envirionmental Impact Assessment (EIA).

Based on water balance modeling developed for the Project (SRK 2016b; Appendix 10B), potential flow reductions may occur in Gold Creek as a result of the capture, treatment, and storage of water by various Project components as per the Project's proposed Water Quality Management Plan (WMP); (SRK 2016a; Appendix 10C). Conversely, potential increases in flow may occur in Blaimore Creek due to the release of water through the proposed WMP. Based on these predicted changes in flow, to assesstheir potential effects on fish and fish habitat, an instream flow assessment (IFA) was conducted to:

- Assess the potential for flow-related effects on fish and their associated habitat in these watercourses; and
- Determine the need for mitigation measures to minimize or eliminate potential flow-related effects in these watercourses.

The following describes the assessment of potential flow changes on fish habitat associated specifically with Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*; WSCT), during construction, operations, reclamation, and closure phases of the Project. It does so by comparing model-predicted indices of species-specific habitat availability and suitability in these watercourses during the different Project phases to these same indices under baseline conditions (i.e., natural, pre-construction flows).

For the operations phase, predictions were calculated for scenarios post-implementation of the WMP in both Gold Creek and Blairmore Creek watersheds. This operation scenario is provided to reflect the state of flows in Gold and Blairmore Creeks as surface water and groundwater are intercepted and then augmented by pumping water to select nodes into Blairmore Creek (SRK 2016a; Appendix 10C). This flow-augmentation scheme would continue through the closure phase as various Project components are decommissioned after mining.

The closure phase includes predicted increases in flow to upper Gold Creek as the proposed self sustaining end-pit lake fills and discharges (SRK 2016b; Appendix 10B).

1.1 STATUS OF ALBERTA WESTSLOPE CUTTROAT TROUT

1.1.1 Regulatory Framework

In 2007, the Alberta Government approved the listing of WSCT as threatened under Alberta's *Wildlife Act* based on recommendations from the Endangered Species Conservation Committee (ESCC) and formally listed under Schedule 6 of the Alberta's Wildlife Regulation in 2009 (Alberta Westslope Cutthroat Trout Recovery Team 2013). The national status of WSCT was reviewed by the Committee of the Status of Endangered Wildlife in Canada (COSEWIC) in 2006 (COSEWIC 2006; Alberta Westslope Cutthroat Trout

Recovery Team 2013). COSEWIC determined that Alberta pure populations of WSCT have become severely depressed in response to a multitude of factors including habitat loss/degradation, competition and hybridization with non-native (introduced) species, and angler exploitation. Thus, in 2013, the Alberta population was listed as *Threatened* under the federal *Species at Risk Act* (SARA). This statute prohibits activities that harm aquatic species listed under the *Act* as threatened, endangered, or extirpated. *SARA* also prohibits activities that destroy any listed species' "critical habitat," as identified in federally adopted "recovery strategies" for listed threatened or endangered species. While the *Act* does not expressly require the maintenance of Instream Flow Needs (IFNs) in rivers with listed species, the *Act*'s core prohibitions, and provisions for the adoption and implementation of "recovery strategies," impliedly require IFN-related federal decisions with respect to water withdrawals and other activities that may impair any such IFNs (Wenig et al. 2006).

1.1.2 Life History

As defined in Section 2.0 of the Alberta Recovery Plan, critical habitat for Alberta populations of WSCT is identified as all areas of bankfull waterbodies currently occupied by naturally occurring, pure-strain populations within the original WSCT distribution. The bankfull level is the usual or average level to which a body of water rises at its highest point and remains for sufficient time so as to change the characteristics of the land. In flowing waters (rivers, streams) this refers to the "active channel bank-full level" which is often the 1:2 year flood flow return level. The biophysical attributes of WSCT critical habitat are summarized in Table 1-1.

In Alberta, WSCT spawning typically takes place between May and July depending on location, and usually occurs when water temperatures reach 10°C (Nelson and Paetz 1992) (6°C in high elevation populations; S. Humphries pers. comm. *in* DFO [2014]). Incubation is also temperature dependent and its duration generally persisits for six to seven weeks. Once the eggs hatch, alevins typically remain in the redd for an addiitonal one to two weeks (Nelson and Paetz 1992; Scott and Crossman 1973). Following emergence, fry migrate to low energy lateral habitats, which are areas with low water velocity and appropriate cover. In 2016, the onset of spawning was observed to commence in early May and concluded by early June (Hatfield 2016a), which is considered early given the atypical freshet flows (mid-April) experienced compared to average freshet timing and flows (June).

Larger juveniles move into pools where they establish social dominance based on size (ASRD and ACA 2006). Juveniles require large territories and the availability of suitable pool habitat is often a limiting factor in the species productivity even in dynamic streams (Schmetterling 2001). Juveniles preferred window of rearing stream temperature is between 4°C and 15°C (DFO 2014).

Adult habitat for WSCT can be varied depending on the particular life history type. The resident life history type typically remain in their natal stream for their entire life. For fluvial (riverine) forms, slow pools formed by boulders or large wood complexex (LWD) with fast adjacent water and plenty of cover (e.g., undercut banks, instream structures) are needed. Given the existing natural and man-made obstructions limiting migration and potential niche shifts in Gold and Blaimore Creeks, the fluvial and resident form are most likely present. As with juveniles, adult WSCT prefer rearing water temperatures between 4°C and 15°C (DFO 2014).

Suitable overwintering habitat appears to be largely determined by local groundwater influx and the absence of anchor ice (Brown and Mackay 1995a). During winter months, fluvial adults will congregate in slow deep pools sheltered from high flows while juveniles often overwinter in cover provided by boulders and other large instream structures.

Westslope Cutthroat Trout are sensitive to changes in water temperature and are not typically found in waters where maximum stream temperature repeatedly exceeds 22°C (Behnke and Zarn 1976). Their preferred temperature range is 9 to 12°C (Alberta Westslope Cutthroat Trout Recovery Team 2013). More recent work by Bear et al. (2007) found the upper incipient lethal temperature of WSCT is 19.6°C, and a maximum daily temperature between 13°C and 15°C ensures suitable thermal temperature for WSCT, with optimum growth occurring at 13.6°C. Bear et al. (2007) found that 15°C is the upper range at which optimum growth for WSCT occurs.

Riparian vegetation is considered an essential element of WSCT habitat. Not only does it serve to stabilize stream banks, reduce predaton and aid in maintaining low stream temperatures through reduced insolation (Reeves et al. 1997), but the riparian input of terrestrial insects (macroinvertebrates) is often an important food source during the summer months (Behnke 1992).

1.1.3 Local Populations

Blairmore Creek and Gold Creek watersheds contain watercourses that SARA and Alberta's Wildlife Regulation have designated as "critical habitat" for WSCT. In November 2015, Fisheries and Oceans Canada (DFO) issued a formal habitat protection order under SARA for designated areas identified to occur in the Gold Creek watershed and, to a lesser extent, Blairmore Creek watershed.

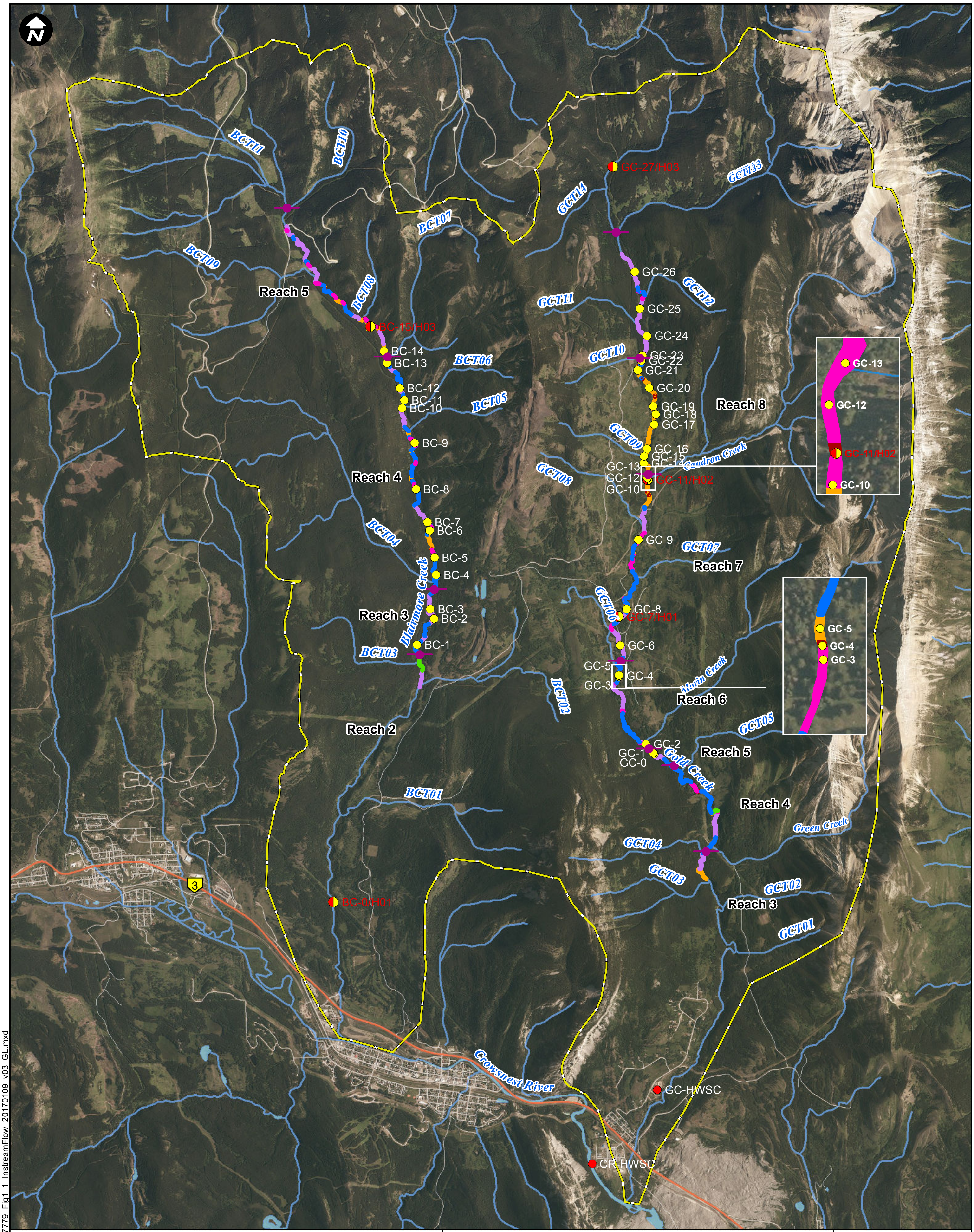
Gold Creek's downstream extent of critical habitat is a water supply dam and the upstream extent of critical habitat is sampling reaches on the mainstem and tributaries where WSCT were caught prior to baseline sampling for this Project (Hatfield 2016a). The following tributaries to Gold Creek are also included as critical habitat: Morin Creek and Caudron Creek. These two tributaries will not be influenced by the Project.

For Blairmore Creek, critical habitat for WSCT is found within an unnamed tributary to Blairmore Creek (BCT04 in Figure 1-1) and will not be influenced by the Project. No critical habitat under *SARA* is currently designated on Blairmore Creek mainstem as the genetic integrity of the current population does not meet the criteria for listing (i.e., ≥ 99% pure WSCT origin). The WSCT populaton that inhabitat Blairmore Creek mainstem is assigned as a provincial 'conservation population' given the limited hybridization (i.e., low introgression) levels with introduced Rainbow Trout (*Oncorhynchus mykiss*) as well as the population's potential for recovery and sustainability (Alberta Westslope Recovery Team 2013).

Table 1-1 **General description of functions, features and attributes of critical habitat for each life stage of the Westslope Cutthroat Trout.**

Life Stage (Bioperiod)	Habitat Function	Feature(s)	Attributes
Spawn through alveins	Spawning Incubation	Riffles (pool or shallow runs, tail-outs)	▪ Clean cold water ▪ Depth 0.10-0.75 m ▪ Velocity 0.25-0.8 m/s ▪ Sediment/silt free gravel substrate ▪ Temperature 6-10°C.
Fry to Parr (to age 1)	Nursery (rearing)	Riffles backwaters	▪ Clean cold water ▪ Velocities 0.01-0.4 m/s ▪ Sediment/silt free gravel/cobble substrates ▪ Depths 0.05 m - >1.5 m ▪ Temperature 4-15°C. ▪ LWD, bedrock, boulders, riparian vegetation
Juvenile (age 1 to maturity)	Overwintering Cover (rearing) Feeding (rearing)	Riffles Pools Backwaters Food availability	▪ Clean cold water ▪ Velocities 0.01-0.8 m/s ▪ Sediment/silt free gravel/cobble substrates ▪ Depths 0.05 m - >1.5 m ▪ Temperature 4-15°C. ▪ Large woody debris, bedrock, boulders, riparian vegetation ▪ Invertebrate production ▪ Undercut bank
Adult	Overwintering Cover (rearing) Feeding (rearing) Movement	Pools Runs Riffles Food availability	▪ Clean cold water ▪ Velocities 0.01- >1.0 m/s ▪ Sediment/silt free gravel/cobble substrates ▪ Depths 0.05 m - >1.5 m ▪ Temperature 4-15°C. ▪ Large woody debris, bedrock, boulders, riparian vegetation ▪ Invertebrate production ▪ Undercut banks ▪ Barrier free movement to complete life cycle

*adopted from DFO (2014)



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LEGEND

- Macrohabitat Reach Break
- 🔴 Hydrometric Station
- 🟡 Instream Flow Transect
- ● Instream Flow Transect & Hydrometric Station
- Primary Highway
- Road
- Watercourse
- Waterbody
- ☐ Local Study Area

Mesohabitat Unit Type

- 🟧 Riffle Run Pool (tertiary)
- 🟥 Pool
- 🟪 Pool Riffle (tertiary)
- 🟦 Riffle
- 🟪 Run
- 🟩 Step Pool (tertiary)

PROJECT

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

Hatfield CONSULTANTS

TITLE

OVERVIEW OF INSTREAM FLOW, HABITAT AND HYDROMETRIC SAMPLING, 2013-2016

NOTES

Data Sources: Government of Canada, Government of Alberta, ESRI Basemap
Datum/Projection: UTM NAD 83 Zone 11

0 1 2 4
Kilometres

PROJECT: 7779
DRAWN BY: SS / EDITED BY: GL
CHECKED BY: CB
DATE: January 09, 2017

FIGURE

1.1

2.0 POTENTIAL PROJECT EFFECTS ON RUNOFF

The Project mine life is currently proposed to be 24 years, and includes the following processes and/or infrastructure (Figure 2-1):

- Mining coal by conventional open pit methods;
- Ex-pit disposal of waste rock until in-pit locations for backfilling become available. Three areas have been delineated: the North Rock Disposal Area (NRDA), the Central Rock Disposal Area (CRDA), and the South Rock Disposal Area (SRDA);
- Blending of potentially acid rock drainage generating (PAG) and non-PAG waste rock to mitigate acid rock drainage (ARD) potential;
- Optimized pit and waste rock dump design and scheduling to allow the routing of contact water to saturated zones (SZs) in backfilled pits, and attenuation of nitrate, nitrite, and selenium in sub-oxic conditions. The hydraulic residence time of impacted water will be maximized within the SZs;
- Disposal of coarse and fine coal processing wastes as a combined filtered product in dedicated disposal areas at locations where contact water will report to the SZs;
- Water management to limit contact of clean water with waste piles;
- High efficiency capture of contact water; and,
- Active pumping of contact water from collection/surge ponds into SZs to enhance attenuation of selenium, nitrate and nitrite as needed.

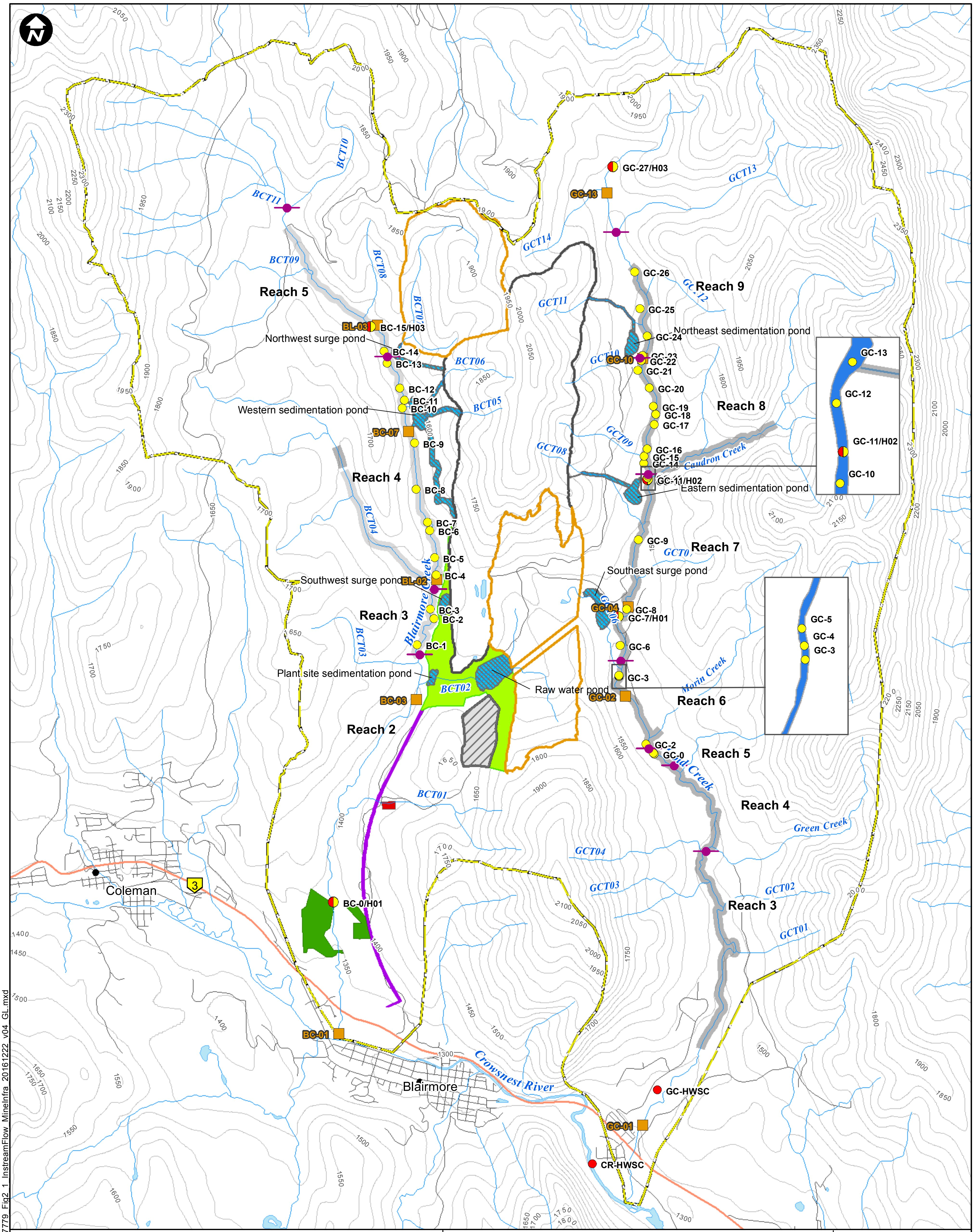
Throughout the mine life, four sedimentation/release ponds, four surge ponds and numerous contact water ditches are to be constructed in carefully selected locations to collect the contact water from the site. The sedimentation ponds will be used to settle total suspended solids (TSS) from surface runoff and pit water and then released to either Blairmore Creek or Gold Creek. If the quality does not meet the release criteria it can be directed towards the SZs as needed. The surge ponds will collect and store water as further management and treatment is required as part of the selenium mitigation plan. This water is to be pumped to the raw water pond for use in the coal wash plant or directed to the SZs.

Acid-generating waste rock will be managed to minimize the generation of acid and associated oxidation products at the source (SRK 2016a; Appendix 10C). As a result, the resultant treated effluent from a water treatment plant (WTP) will be directed to multiple discharge nodes in Blairmore Creek (BC-07, BL-02, and BC-03; Figure 2-1).

Potential changes to runoff was evaluated at various stations along Gold and Blairmore Creeks. SRK (2016c; Figure 42; Consultant Report #4) outlines the location of the stations/model nodes in Gold and Blairmore Creeks along with catchment delineations for each node (Figure 2-1).

Estimates of potential changes to runoff for average hydrological conditions are illustrated in SRK (2016c; Figure 43; Consultant Report #4) for Gold Creek and for Blairmore Creek SRK (2016c, Figure 46; Consultant Report #4). The estimated runoff changes are based on the results of the water and load balance model (SRK 2016b; Appendix 10B) that was developed for the Project. The water and load balance model operates on a monthly time-step;therefore, flows and flow changes are evaluated on the basis of monthly flows. A complete description of methodology and assumptions used in the development of the water balance model is provided in SRK (2016b; Appendix 10B). Estimated runoff changes includes both surface flow, interflow and base flow (i.e., groundwater flow).

A separate assessment was completed for specific changes to the groundwater flow regime (SRK 2016d; Consultant Report #3). Table 17 within SRK (2016d; Consultant Report #3) summarizes predicted changes to base flow in Blairmore Creek and Gold Creek. The water-balance model incorporated the combined effects of the estimated changes to the groundwater flow regime and to surface flow. The estimated groundwater reduction is caused by interception of open pit mine water and seepage from waste rock areas. The intercepted mine water will be conveyed through the saturated backfills where nitrate and selenium will be attenuated, through a discharge treatment system (if required) at which point the water will be discharged to locations in Blairmore Creek where the water was originally collected; therefore, the estimated reduction in groundwater flow is matched by an increase in surface water flow at those nodes.



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LEGEND

- Macrohabitat Reach Break
- ● Hydrometric Station
- ● Instream Flow Transect
- ◐ Instream Flow Transect & Hydrometric Station
- ■ Flow Prediction Node (SRK 2016)
- Identified Westslope Cutthroat Trout Critical Habitat (greater than 99% pure)
- Near Pure WSCT Population (95% to 99% pure)
- Primary Highway
- Road
- 50 m Contour
- Watercourse
- Waterbody
- Local Study
- Ultimate Pit Extent
- Ultimate Rock Disposal Area Extent
- ▨ Topsoil Storage
- ▨ Ponds and Ditches
- 🟥 Construction Camp
- Covered Conveyor, Access Road and Powerline ROW
- 🟩 Coal Handling Processing Plant and Infrastructure
- 🟩 Proposed Golf Course

PROJECT

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

Hatfield CONSULTANTS

TITLE

PROPOSED MINE INFRASTRUCTURE IN RELATION TO INSTREAM FLOW AND HYDROMETRIC SAMPLING, 2013-2016

NOTES

Data Sources: Government of Canada, Government of Alberta
Datum/Projection: UTM NAD 83 Zone 11

0 1 2 4
Kilometres

PROJECT: 7779
DRAWN BY: SS / EDITED BY: GL
CHECKED BY: CB
DATE: December 22, 2016

FIGURE

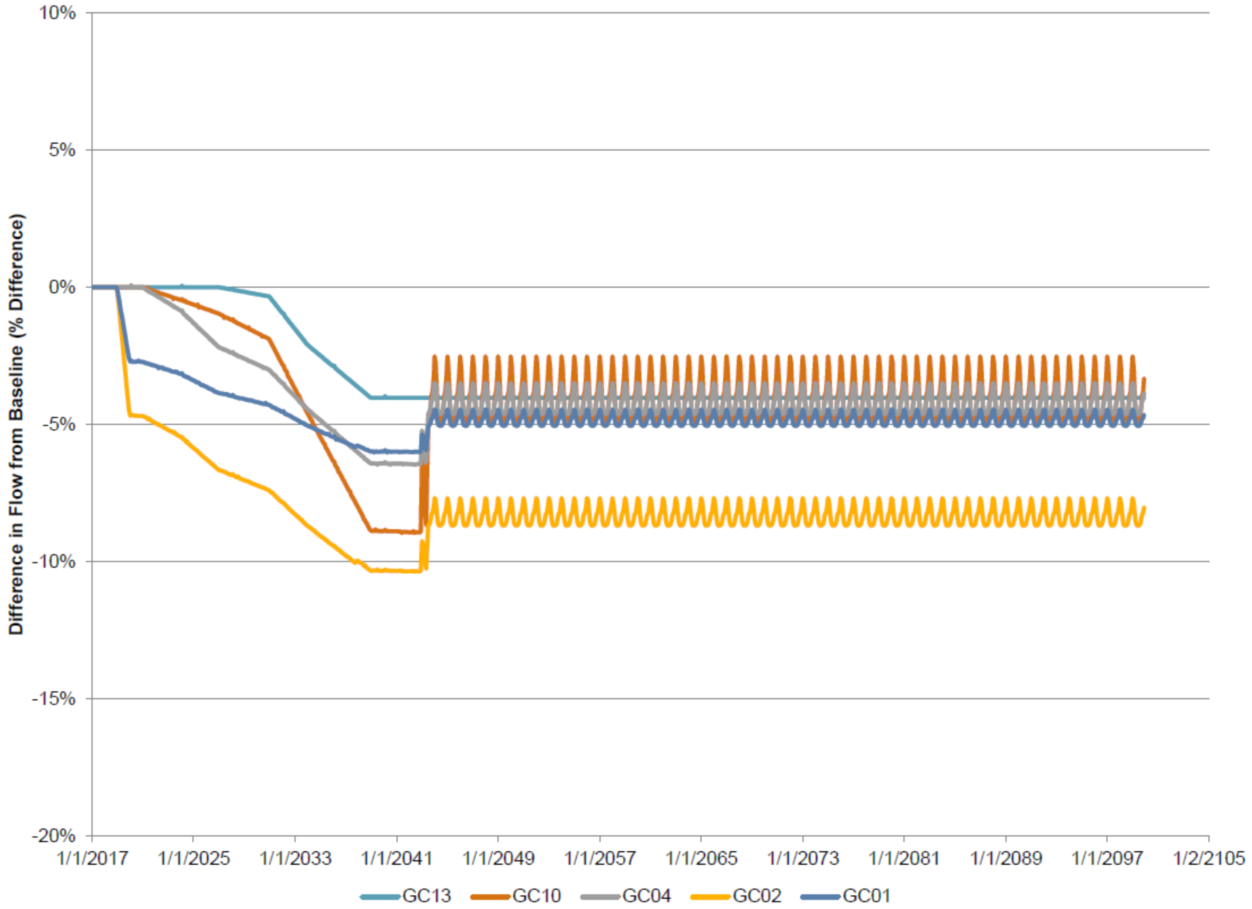
2.1

2.1 GOLD CREEK

The proposed open pit intersects portions of the upper reaches of the western catchments for Gold Creek. Water intercepted by those areas is proposed to be routed to the saturated zones, which would then be discharged to Blairmore Creek. A water quality monitoring plan for the saturated zones will be implemented to ensure water released from the saturated zones to Blairmore Creek meet the Project identified guidelines. As part of the water quality monitoring plan, if deemed necessary, an intermediate step may require the discharge from the saturated zones to be treated for removal of metals.

Based on the model outputs (SRK 2016b, 2016c, 2016d, shown in Figure 2-2 below), net losses of total flow are anticipated in all reaches of Gold Creek, reaching a maximum of 4% at node GC-13, 6-9% at nodes GC-10, GC-04 and GC-01, and just over 10% at node GC-02 (located in Reach 6 of Figure 2-1).

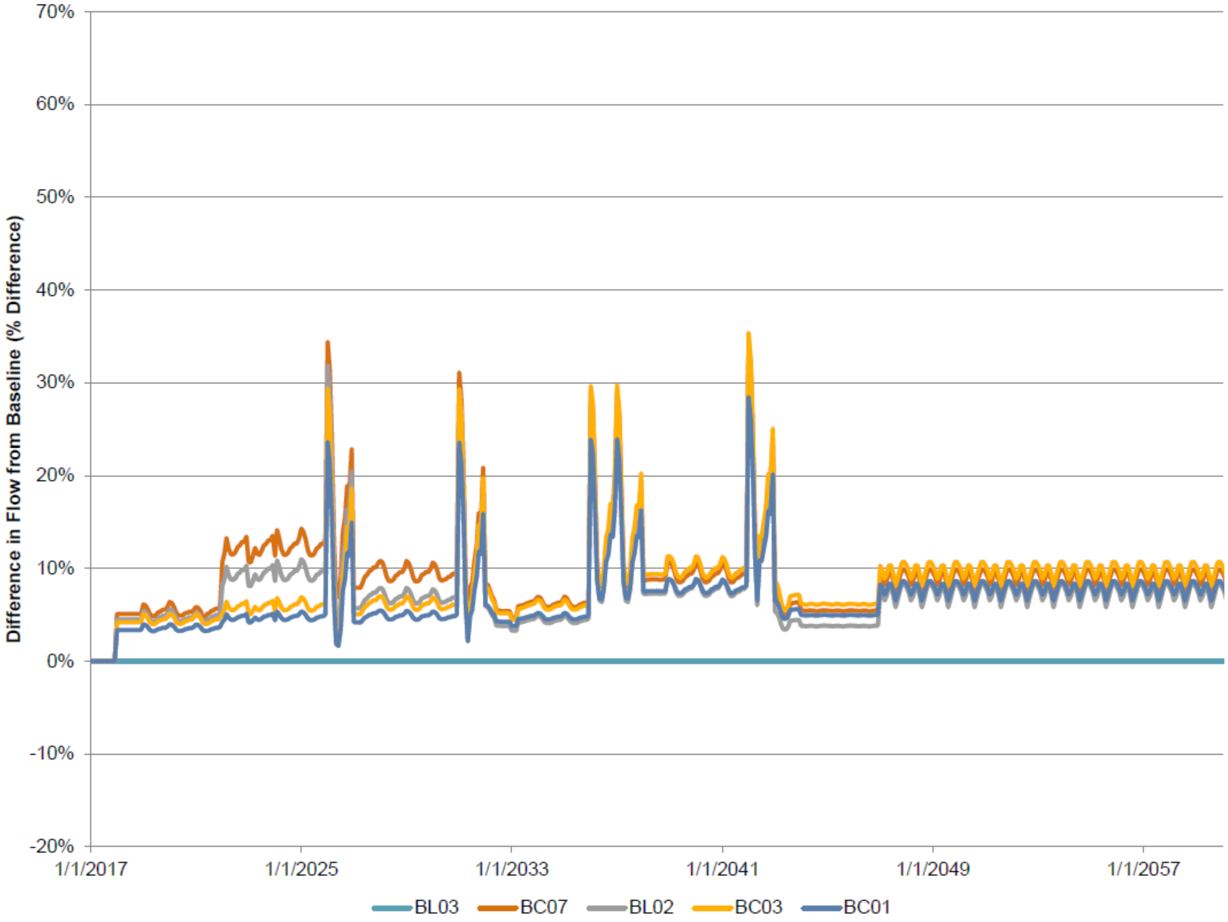
Figure 2-2 Total flow changes at Prediction Nodes on Gold Creek (SRK 2016b, 2016c, 2016d) in average hydrological conditions.



2.2 BLAIRMORE CREEK

Flows in Blairmore Creek are expected to increase relative to baseline conditions as a result of the additional contribution of flow from some Gold Creek sub-catchments, but more importantly because of the estimated increase in runoff caused by changes to the hydrological characteristics of developed mine areas (i.e., increase in runoff coefficients for pit walls and waste rock areas) (SRK 2016b, 2016c, 2016d). For most of a calendar year, the maximum increase to flow is expected to be less than +15% for all stations (Figure 2-3). Large flow changes are possible during the low flow season (December to March); however, the water balance model (Appendix 10B,Appendix B- Catchment Delineation Maps) assumes that the discharge from the saturated zones or from any water treatment will be controlled based on the rate of accumulation of water in the saturated zone and the stream flow conditions in Blairmore Creek.

Figure 2-3 Total flow changes at Prediction Nodes on Blairmore Creek (SRK 2016b, 2016c, 2016d) in average hydrological conditions.



3.0 INSTREAM FLOW ASSESSMENT METHODOLOGY

3.1 STUDY AREA

The Project is situated in the watersheds of Blairmore Creek (50 km²) and Gold Creek (63 km²), drainages which collectively represent 11% of the Crowsnest River watershed. The Crowsnest River is part of the Oldman River watershed, which flows into the Saskatchewan River, ultimately discharging into Lake Winnipeg.

The study boundary of the IFA adopted the aquatic LSA for the Aquatic Ecology Effects Assessment, which was selected based on the Project footprint, boundaries of the local watersheds and the spatial extent of potential immediate direct and indirect effects of the Project on hydrogeology, surface water hydrology, water quality, and fisheries and aquatic resources. The LSA was also defined as the conservative downstream limit of potential fish and fish habitat that may be influenced by the Project with a focus on the critical habitat defined in the WSCT provincial and federal Recovery Plans (Alberta Westslope Cutthroat Trout Recovery Team 2013, DFO 2014) assigned to Gold Creek and Blairmore Creek.

3.2 APPROACH

The hydraulic habitat component of the Instream Flow Incremental Methodology (IFIM) (Bovee 1982, Bovee et al., 1998) was used in this IFA to predict the effect of flow changes on fish habitat in the two study streams.

This approach is consistent with the BC Instream Flow Methodology (BCIFM) (Lewis et al. 2004) and is supported by Fisheries and Oceans Canada (DFO) for projects of similar magnitude and complexity to this Project (DFO 2013). This is because the IFIM approach uses models to simulate habitat quantity and quality over a range of stream flows and allows various scenarios to be compared and evaluated simultaneously and iteratively.

The hydraulic habitat component of an IFIM links a traditional hydraulic engineering model to fish habitat suitability criteria (HSC) curves based on water depth, velocity, and bed particle size. In IFIM, this model component is called the Physical Habitat Simulation Model (PHABSIM). Instead of PHABSIM, we have used the *System for Environmental Flow Analysis* (SEFA) software (Payne and Jowett 2013), which is the latest state-of-the-science in hydraulic-habitat analysis. Both are software programs that build hydraulic habitat models to determine how fish habitat quantity and quality vary as functions of stream discharge. This is consistent with the objectives of the IFIM and BCIFM.

Modeling analyses focused on WSCT, the primary valued component (VC) fish species identified for the Environmental Assessment (Hatfield 2016a). This species represented 98% of fish captures during baseline surveys conducted in the LSA and are provincially and federally protected in in both watersheds (Section 1.1). HSCs for WSCT were compiled from various literature and provincial sources (Ron Ptolemy, BC Ministry of Environment, pers. comm.). The selection of preferred HSCs is described in Section 3.5.1.

The hydrology data used to support the IFA analyses were developed using various sources, including regional hydrometric stations with long-term records, local hydrometric stations with short-term records, and other local data collected specifically to support the IFA analyses. While the spatial and temporal runoff dynamics were previously established for Gold and Blairmore Creek (SRK 2016c; Consultant Report #4), this particular analysis did not differentiate between the separate pathways contributing to runoff (i.e., surface flows, interflow, and groundwater), since only total flows were needed to support the Water and Load Balance Model (Appendix 10B,Appendix B- Catchment Delineation Maps)). Only surface flows, which support fish habitat, are of relevance to this IFA. The results from streamflow gauging programs identified complex relationships between surface and subsurface (ultimately total) flows, especially on Gold Creek, that must be fully characterized in this document in order to confidently support the IFA analyses. The hydrology data and the methods applied to produce the data are introduced throughout this IFA study, including Appendix A1.

3.3 STUDY DESIGN

Study design followed guidelines provided by Lewis et al. (2004) and Hatfield et al. (2007). Separate hydraulic habitat models were developed in SEFA for each identified bioperiod (see Section 3.6) for WSCT in each section of each stream potentially affected by flow changes created by the Project. Each modeled stream section was defined by relatively homogenous hydro-geomorphic (macrohabitat) conditions (i.e., stream morphology, gradient, substrate, and discharge). This delineation of stream sections was used to minimize the inherent errors associated with attempting to predict complex instream flow conditions with simplified models.

Discreet macrohabitat-reaches (i.e., hydro-geomorphic sections) were identified in each watercourse based on detailed habitat mapping using stream surveys following the *Fish Habitat Assessment Procedures (*FHAP; Johnson and Slaney, 1996) (Figure 1-1). Delineated macro-reaches were further characterized and subdivided into mesohabitat units (i.e., runs, pools, riffles) using the FHAP datasets. Characteristics defined by Johnson and Slaney (1996) were used to identify and map the distribution of run, riffle and pool meso-habitats in each potentially affected watercourse (Hatfield 2016a).

Transects were established in select mesohabitat units within each macro-reach to collect the data required for the development and calibration of hydraulic habitat models. Detailed channel cross-section, water surface elevation, substrate composition, and vertical depth and water velocity profiles were collected during initial survey visits to each transect. Only water surface elevations were collected at each transect during repeat visits over the range of flows necessary to calibrate the models. A representative stream discharge was collected for each modelled stream section during each repeat visit.

3.3.1 Gold Creek

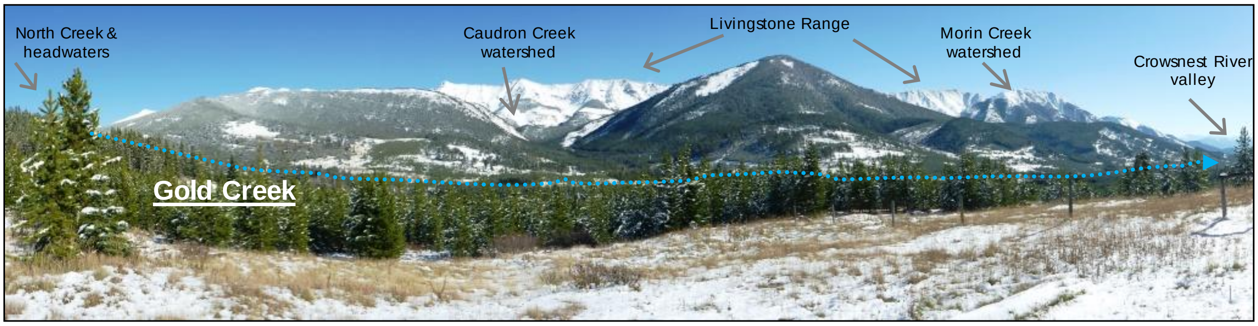
3.3.1.1 Project Hydrology

Watershed description

The 63.3 km^2 Gold Creek watershed is situated in the eastern foothills of the Rocky Mountains just north of Blairmore (Figure 1-1, Figure 3-1). Gold Creek, approximately 19 km in length, is a tributary of the Crowsnest River watershed. The average watershed slope is 19% with elevations ranging from 1,300 masl near the mouth to 2,500 masl on the Livingstone Range (eastern watershed boundary); individual reach morphology descriptions are detailed in the subsequent section. The Mean Annual

Precipitation (MAP) across the watershed is estimated to be 777 mm (SRK 2016c; Consultant Report #4). Former mining and logging developments characterize sections of the watershed.

Figure 3-1 Gold Creek Watershed.



Note: photo taken on October 12 2016 from eastern slope of Grassy Mountain, looking east across Gold Creek watershed. Gold Creek watercourse (blue dotted line) is approximate and shown for guidance only.

Hydrometric Data

Three local study area hydrometric gauges were installed along Gold Creek in support of this IFA and the hydrology baseline study (SRK 2016c; Consultant Report #4). A mid-watershed gauge at GC-7/H01 (Figure 1-1) operated from September 2013 to August 2014 and again from March to October 2016. Gauges further upstream at GC-11/H02 and GC-27/H03 (Figure 1-1) both operated from May to October 2016. WSC have gauged flows at Gold Creek near Frank (GC-HWSC, Figure 1-1) since 1975, typically from April to November (8 months) each year.

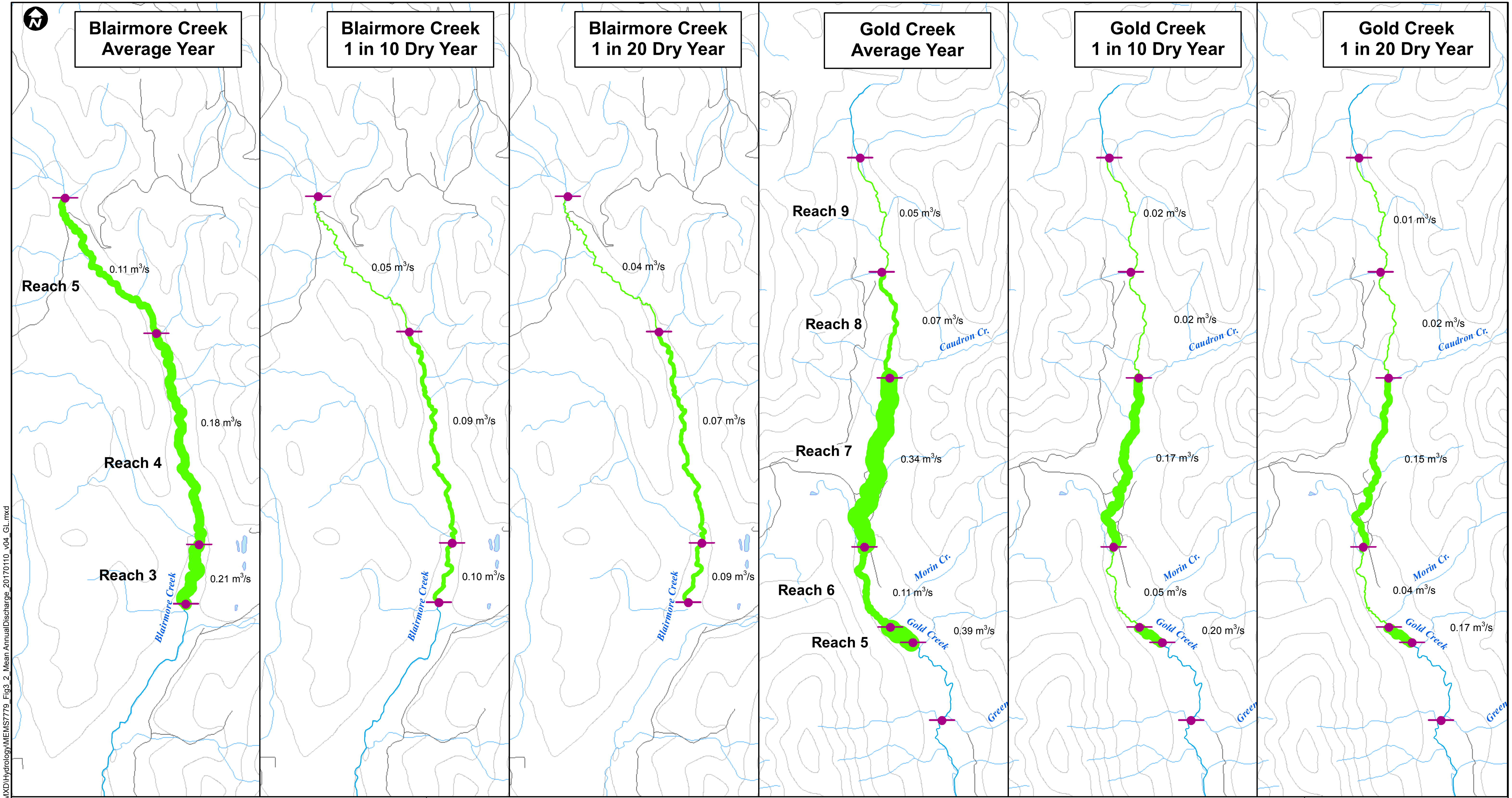
Long-term synthetic daily flow data series extending from November 1975 to October 2016 (41-year period) were then developed for the three local gauges, based on the regression analysis between daily flows gauged concurrently between each local gauge and the WSC gauge. For characterizing hydrological conditions across each reach, required for the IFA analyses, the synthetic time series most appropriate to each reach was selected then adjusted empirically using the ratio of measured flows between gauge locations and appropriate reach-specific locations. The alternative approach of pro-rating the synthetic data based on reach drainage area characteristics was not used given the weak association between flows and drainage area outlined below (particularly around the Caudron Creek and Lille Townsite areas).

Spatial flow variability

The hydrometric data indicate significant flow variability along the length of Gold Creek. Figure 3-2 displays the estimated long-term Mean Annual Discharge (MAD) values characterizing each study reach delineated for this IFA and other components of the Fish and Aquatics Baseline Technical Report (Hatfield 2016a). Under normal baseline conditions, MAD in the upper catchment increases from 0.047 m^3/s in Reach 9 near the headwaters, to 0.068 m^3/s in Reach 8 above the confluence with Caudron Creek. In Reach 7 downstream of the Caudron Creek confluence, MAD increases approximately five-fold to 0.342 m^3/s, due to significant inflows from the Caudron Creek watershed which is higher and wetter than Gold Creek and dominated by steep unforested slopes which enhance precipitation runoff. Significant groundwater contributions dominate Caudron Creek streamflows during drier conditions. The confluence and differences in flow contribution are shown visually in Figure 3-3.

Streamflow data indicate that Reach 7 is a losing reach, in which a small proportion (typically ~10%) of stream water is increasingly lost subsurface to the channel bed and bank sediments which comprise the hyporheic zone. These losses become more considerable along Reach 6 (MAD 0.105 m^3/s), located close to a legacy mined area including the historic townsite of Lille. Gold Creek temporarily became dry near Lille (Figure 3-4), during exceptionally dry conditions in fall 2016 when the water table dropped below the level of the stream. Flow impacts through similar 'rock drain' type systems (natural or artificial) have been documented either as targeted studies (e.g., Symons 1987), and in other hydrological assessments (ARD 2011), which support IFA analyses (Ecofish 2016). ARD (2011) documented the case of SS Creek in the BC coastal range, where flow was also observed to disappear entirely into the colluvium deposit during extremely dry conditions, and was assumed to follow preferential pathways at rates dependent on the local hydraulic gradient (generally, faster than through matrix flow but slower than within the surface channel).

Downstream of Lille, Gold Creek begins to regain stream water from the hyporheic zone, then increases considerably at the confluence with Morin Creek watershed, with many physical similarities to those of Caudron Creek watershed. The estimated MAD in Reach 5 (downstream of Morin Creek) is 0.392 m^3/s. Flows then continue to accumulate during the remaining 6.5 km distance down to the confluence with the Crowsnest River in Frank. The MAD of Gold Creek near Frank estimated at the WSC gauge is 0.669 m^3/s.



LEGEND

- Macrohabitat Reach Break
- Primary Highway
- Road
- 100m Contour
- Watercourse
- Waterbody

Mean Annual Discharge (m^3/s)

- 0.00 - 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20
- 0.21 - 0.25
- 0.26 - 0.30
- 0.31 - 0.40

PROJECT

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

Hatfield CONSULTANTS

PROJECT: 7779
DRAWN BY: GL
CHECKED BY: CB
DATE: January 10, 2017

TITLE

REACH-SCALE MEAN ANNUAL DISCHARGE (m^3/s) APPLIED WITHIN IFN ANALYSES DURING AVERAGE AND DROUGHT CONDITIONS

NOTES

Data Sources: Government of Canada, Government of Alberta
Datum/Projection: UTM NAD 83 Zone 11

0 1 2 4
Kilometres

FIGURE
3.2

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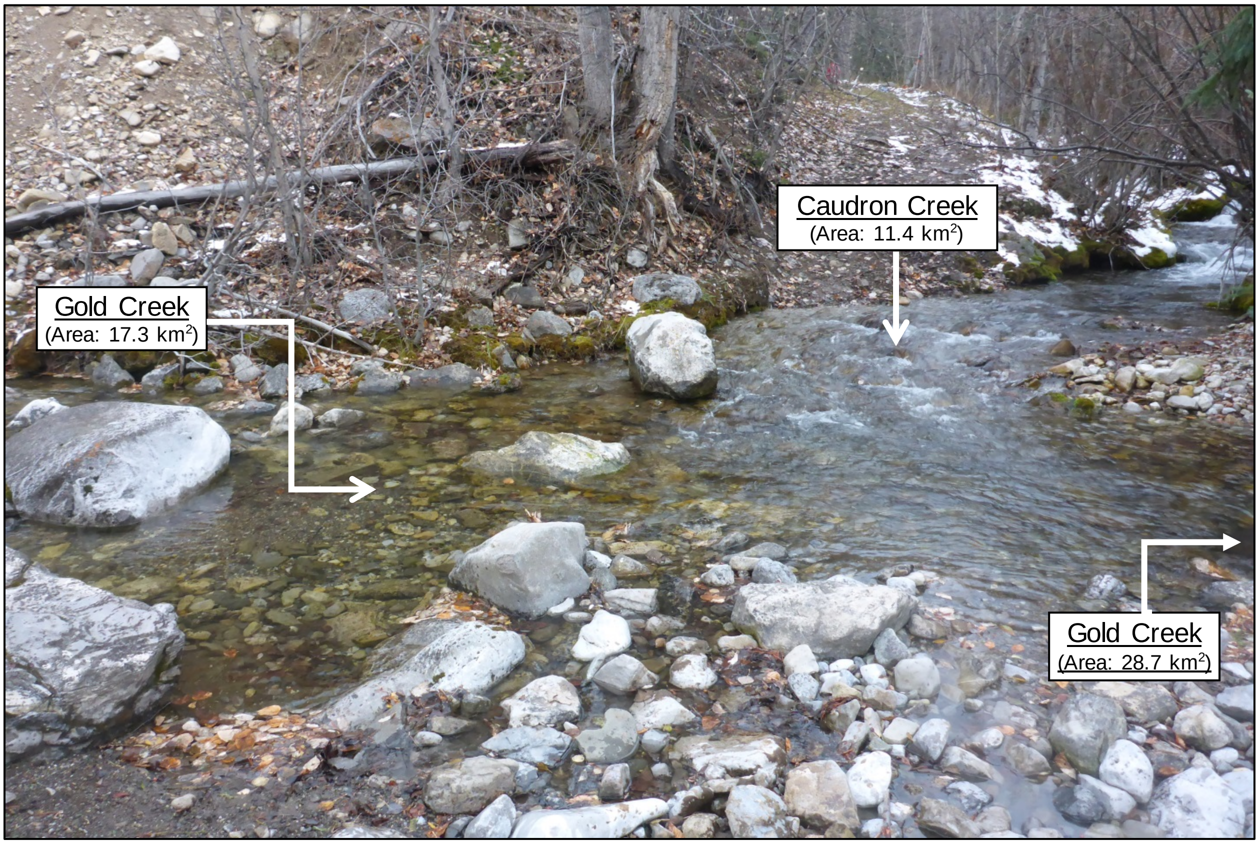
Figure 3-3 Confluence of Gold Creek and Caudron Creek.



Note: photo taken on October 13 2016. Areas refer to individual drainage areas.

Figure 3-4 Gold Creek surface flow dynamics around Lille historic townsite.

Panel A

Historical coal slack pile at Lille, May 18 2016, with adjacent surface flow. Looking downstream.

Panel B

Adjacent to historical coal slack pile (just downstream of Panel A), May 18 2016, with surface flow present in both channels shown. Looking upstream.

Panel C

Same view/location as Panel B, September 14 2016, with intermittent flow in one channel only (tree in channel fell since May 18). Looking upstream.

Seasonal and monthly flow variability

Estimated long-term monthly and annual flows for each study reach (Reaches 5 to 9), in addition to the WSC gauge, are tabulated in Table 3-1. The data for all locations on Gold Creek indicate that monthly flows increase during spring freshet, to a peak in June, before receding through summer to base flows during fall and winter. At the WSC gauge (where there is most confidence in the long-term data), flows during June and the May-July period contribute 21% and 49% of annual runoff, respectively, equivalent to 250% and 198% of MAD. For all other months, contributions range from 4-9% of annual runoff, equivalent to 47-80% of MAD. The annual range of MMD is slightly smaller than for Crowsnest River watershed (2-27% monthly contributions; SRK 2016c; Consultant Report #4) and other regional watersheds draining wetter, more mountainous terrain. Gold Creek watershed is more arid, with relatively higher groundwater contributions during drier months.

Towards the headwaters in Reaches 8 and 9 (upstream of Caudron Creek confluence), the estimated annual range of MMD (1-33% monthly contributions, equivalent to 12-393% of MAD) is more dominated by freshet, less dominated by base flows, since winter low flows and colder air temperatures can restrict subsurface flows due to the freezing of surface ice on the stream bottom (e.g., Bradford and Heinonen 2008). Mid-watershed (Reaches 5 to 7), the estimated annual range of MMD (3-25% monthly contributions, equivalent to 39-304% of MAD) is inbetween those further upstream (Reaches 8 and 9) and downstream (WSC gauge, Table 3-1).

Data collected at the GC-7/H01 local hydrometric gauge (Reach 7) during the 2013-2014 winter support the importance of groundwater contributions to Gold Creek during base flows. From December 2013 to March 2014, continuous measured water temperatures averaged 1.1 ºC and reached a maximum of 4.7 ºC, well above freezing. Large spikes in water level, associated with backwatering effects when the stream surface completely freezes, only occurred four separate times covering a total of ~3 weeks. Flows of 0.162 and 0.117 m^3/s were measured, respectively, on January 20 and April 2 2014, and the stream was essentially ice-free in both instances. Additional winter sampling will help to characterize Gold Creek under a wider range of winter conditions.

Table 3-1 Flow statistics for Reaches 9 (upstream) to 5 (downstream) and the WSC gauge (near the mouth) on Gold Creek.

	Reach 9			Reach 8			Reach 7			Reach 6			Reach 5			WSC Gauge		
Mean Annual Discharge (m^3/s)	0.047			0.068			0.342			0.105			0.392			0.669		
Annual Runoff (million m^3)	1.479			2.157			10.809			3.323			12.391			21.136		
Month	MMD (m^3/s)	MAD[1] (%)	AR (%)	MMD (m^3/s)	MAD[1] (%)	AR[2] (%)	MMD (m^3/s)	MAD[1] (%)	AR[2] (%)	MMD (m^3/s)	MAD[1] (%)	AR[2] (%)	MMD (m^3/s)	MAD[1] (%)	AR[2] (%)	MMD[3] (m^3/s)	MAD[1] (%)	AR[2] (%)
Jan	0.005	12%	1%	0.008	12%	1%	0.138	40%	3%	0.042	40%	3%	0.158	40%	3%	0.338	51%	4%
Feb	0.005	11%	1%	0.008	11%	1%	0.133	39%	3%	0.041	39%	3%	0.152	39%	3%	0.313	47%	4%
Mar	0.006	12%	1%	0.008	12%	1%	0.140	41%	3%	0.043	41%	3%	0.161	41%	3%	0.351	53%	4%
Apr	0.016	34%	3%	0.023	34%	3%	0.289	85%	7%	0.089	85%	7%	0.332	85%	7%	0.537	80%	7%
May	0.147	311%	27%	0.212	310%	26%	0.828	242%	21%	0.254	242%	21%	0.949	242%	21%	1.395	208%	17%
Jun	0.185	393%	33%	0.268	393%	32%	1.038	304%	25%	0.319	304%	25%	1.190	304%	25%	1.673	250%	21%
Jul	0.079	167%	14%	0.114	167%	14%	0.467	136%	12%	0.143	136%	12%	0.535	136%	12%	0.905	135%	11%
Aug	0.044	92%	8%	0.063	92%	8%	0.290	85%	7%	0.089	85%	7%	0.332	85%	7%	0.643	96%	8%
Sep	0.030	64%	5%	0.044	65%	5%	0.240	70%	6%	0.074	70%	6%	0.275	70%	6%	0.544	81%	7%
Oct	0.025	54%	5%	0.037	54%	5%	0.219	64%	5%	0.067	64%	5%	0.251	64%	5%	0.505	75%	6%
Nov	0.017	37%	3%	0.025	37%	3%	0.176	52%	4%	0.054	52%	4%	0.202	52%	4%	0.435	65%	5%
Dec	0.006	12%	1%	0.008	12%	1%	0.147	43%	4%	0.045	43%	4%	0.168	43%	4%	0.383	57%	5%

Notes:

1 MAD (%) represents the ratio of MMD to MAD.

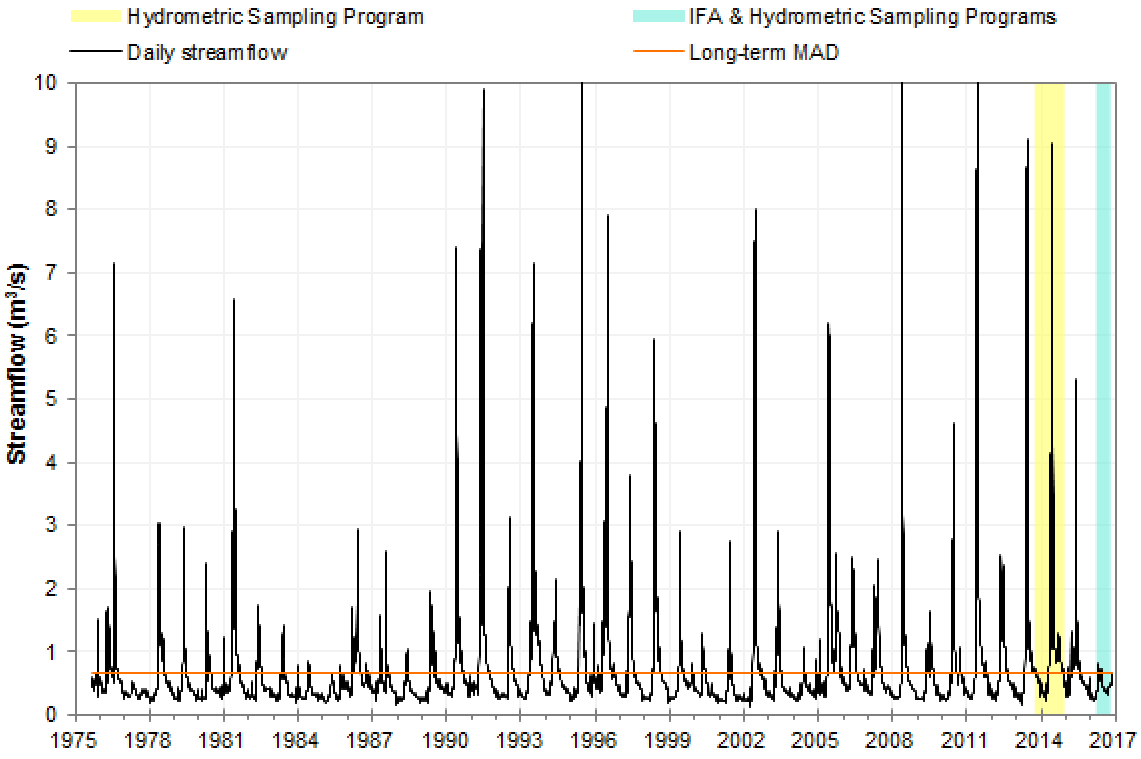
2 AR (%) represents the monthly runoff sum (not shown) to annual runoff sum.

3 WSC MMD values from April to November calculated from published daily data from 1975-2014 and provisional daily data from 2015-2016 are within a few % of corresponding WSC values published online and in HYDAT (calculated from 1975-2014 data) and published online in SRK 2016c (calculated from 1975-2012 data). December to March values were estimated using daily Crowsnest River at Frank WSC data from 1975-2014 and provisional daily data from 2015-2016, pro-rated for drainage area, similar to SRK 2016c.

Flow conditions during the hydrometric and IFA sampling programs

Figure 3-5 displays the 1975-2016 (41-year) record of daily flows at WSC Gold Creek near Frank station, the corresponding MAD, and dates of the main sampling programs associated with this study (September 2013-August 2014 for hydrometric sampling; March-October 2016 for IFA and hydrometric sampling).

Figure 3-5 Daily streamflows gauged at WSC Gold Creek near Frank and relation to the hydrometric and IFA sampling programs.



Notes:

1- For visual clarity at lower flows, the seven days with gauged flows exceeding 10 m^3/s are not shown, including three in June 1995, two in May 2008 and two in June 2011. The maximum daily flow was 24.8 m^3/s on June 6 1995.

2- April-November flows obtained from published WSC Gold Creek near Frank daily data from 1975-2014 and provisional WSC daily data from 2015-2016; December-March flows estimated using published WSC Crowsnest River at Frank daily data from 1975-2014 and provisional daily data from 2015-2016, pro-rated for drainage area, similar to SRK 2016c.

In terms of Water Year (WY) runoff sums[1], 209 mm of stream runoff was estimated at the WSC gauge during the 2016 WY (i.e., November 1 2015 to October 31 2016, covering all 2016 IFA and hydrometric related sampling). This was the 8th lowest on record indicating that conditions were generally very dry during the 2016 sampling programs. Only the 1977, 1983-1985, 1988, 2001 and 2004 WY were lower, extending down to a minimum of 175 mm in 1985. A frequency analysis performed on the annual runoff time-series using a two parameter lognormal probability distribution indicated the 2016 WY to be approximately a 1 in 9 dry-year event (i.e., with an 11% probability of occurrence in any one year).

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[1] Annual runoff sums calculated on a WY timeframe from November 1 to October 31 each year characterize the annual hydrological cycle of snow accumulation beginning in November, spring freshet, and recession to baseflows by late October, more realistically than a calendar year timeframe.

The annual data mask significant seasonal differences that occurred within the 2016 WY. At the WSC gauge, the mean flow from November 2015 to March 2016 was 0.324 m^3/s, only ~10% lower than normal during these months (0.364 m^3/s, Table 3-1). The mean April 2016 flow (0.598 m^3/s) was ~10% higher than normal (0.537 m^3/s), but this included the peak freshet period that was much earlier and lower magnitude than normal (due to warm temperatures and exceptionally low snowpack). The absence of a defined freshet, plus extremely low rainfall amounts in subsequent months, promoted exceptionally low flows to persist throughout the May-September period. The mean May, June and July flows (0.622, 0.545 and 0.396 m^3/s, respectively) were below half (45%, 33% and 44%) of normal, and corresponding August and September flows (both 0.37 m^3/s, 57% and 69% of normal) were also very dry relative to normal. Flows in October (mean 0.505 m^3/s) were exactly normal following rainfall events. All mean monthly flows in the 2016 WY remained below MAD (0.669 m^3/s), and daily flows only exceeded MAD from April 20-29 and May 26-June 3 (total 19 days).

The 2013-2014 hydrometric sampling program occurred primarily within the 2014 WY, when 486 mm of stream runoff was estimated at the WSC gauge. This was the 6th highest on record indicating that conditions were generally very wet during this program. Only the 1991, 1993, 1996, 2005 and 2011 WY were higher, with a maximum of 550 mm in 1996. Measured flows at GC-7/H01 during January, May, July and August 2014 all exceeded corresponding Reach 7 long-term MMD values (Table 3-1), though the measured flows in April and June 2014 were slightly lower. The flow measurement on May 28, 2014 (2.03 m^3/s) was over double the Reach 7 May MMD value (0.828 m^3/s) and 594% of the Reach 7 MAD value (0.342 m^3/s). These higher-flow 2014 data complement the very low-flow 2016 data, which reduces uncertainty in the production of long-term hydrometric data used for initialzing the IFA analyses.

3.3.1.2 Macrohabitat

Gold Creek was delineated into nine reaches ranging from 437 m (Reach 3) to 3,183 m (Reach 7, Table 3-2) in length (Hatfield 2016a). The five most upstream reaches (Reaches 5 to 9) form the focus of this IFA and are shown in Figure 1-1. Reaches 1 and 2 extend beyond the designated critical habitat for WSCT and the vicinity of the Project footprint, and Reaches 3 and 4 are downstream of the greatest predicted habitat losses associated with the Project (based on smaller baseline flows, proximity to project infrastructure, and identified fish migration barriers).

Along all reaches, average wetted width observed during the May 2016 surveys gradually increased from the headwaters (4.2 m, Reach 9) to the most downstream reach (10.8 m, Reach 3, Table 3-2). Average bankfull width observed during the August 2015 surveys was 6.3 m, ranging from 1.3 m at a site in Reach 3 to 15.8 m at a site in Reach 7. The two shortest reaches in Gold Creek are the steepest (Reach 3, 3.3% gradient; Reach 5, 2.9% gradient), with the remaining reaches ranging from 0.5 to 0.9% gradient (Table 3-2).

Table 3-2 Macrohabitat reach characterization in Gold Creek and Blairmore Creek.

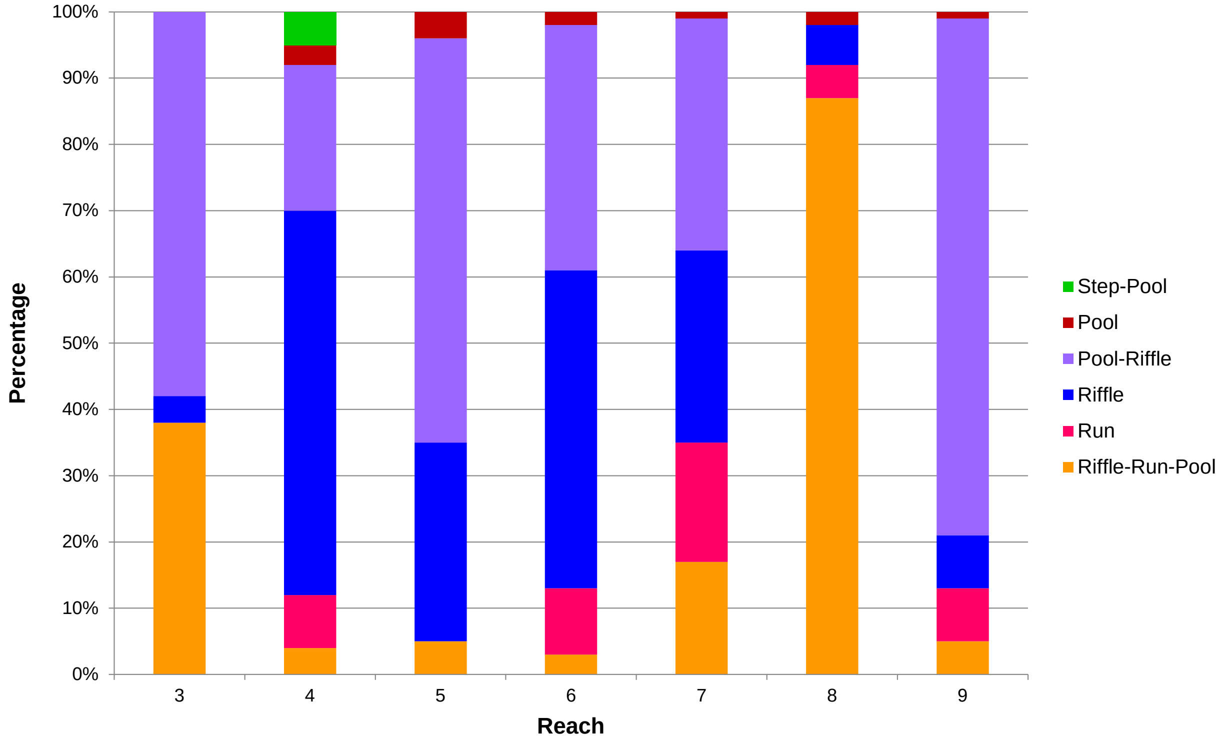
Watercourse	Reach	Length (m)	Average wetted width[1] (m)	% Gradient	Habitat changes simulated
Gold Creek	3	437	10.8	3.3	×
	4	1,820	7.5	0.8	×
	5	502	7.8	2.9	✓
	6	1,683	5.7	0.9	✓
	7	3,183	6.4	0.5	✓
	8	1,906	5.6	0.8	✓
	9	2,130	4.2	0.8	✓
Blairmore Creek	2	399	1.1	3.6	×
	3	1,167	4.9	1.3	✓
	4	3,942	4.6	0.4	✓
	5	3,230	3.0	0.5	✓

3.3.1.3 Mesohabitat

A total 11.7 km of potential fish habitat was characterized and mapped for Gold Creek (Reaches 3 to 9) between March and May of 2016. The mesohabitat units indentified by the FHAP were digitized and are presented for Gold Creek in Figure 1-1. The total wetted area surveyed was 71,840 m^2, with average wetted width of 6.86 m.

The percentage of each habitat type within the seven reaches on Gold Creek is illustrated in Figure 3-6. Pool-riffle is the most common morphology occurring in all reaches except for Reach 8, but the majority of pools that were included in the pool-riffle characterization were of tertiary class (i.e., less than 50% of the wetted width). Reach 3 is comprised mostly of pool-riffle (58%) and riffle-run-pool (38%), with a small portion (4%) of riffle. Reach 4 is the most hydraulically diverse reach, comprised mostly of riffles (58%), and pool-riffles (22%) with a small proportion riffle-run-pool, run, pool and step-pool (<10% each). Reaches 5 to 7 are fairly similar to each other, containing mostly riffles (29% to 48%) and pool-riffles (35% to 61%). Reach 8 is fairly different from the other six reaches, as most of the area is comprised of riffle-run-pool morphology (87%). Reach 9 is dominated by pool-riffle (78%) with smaller components of riffle-run, run, riffle and pools (< 10% each). The location of the habitat units through Gold Creek are shown in Figure 1-1.

Figure 3-6 **Percentage of mesohabitat types in Gold Creek for Reaches 3 (downstream) through 9 (upstream).**



For this assessment, cross-sections (XS) were established in representative runs, riffles, and pools, in Reaches 5 to 9 on Gold Creek. All six morphology types classified in Figure 3-6 either represent these three main mesohabitats individually, or some aggregation of these mesohabitats (i.e., runs and/or riffles and/or pools). A photographic comparison of representative run, riffle and pool mesohabitats is shown in Figure 3-7 for each of the five study reaches on Gold Creek.

For each XS, hydraulic relationships (stream width, depth and velocity) and ultimately a flow-habitat relationship was developed, for the purpose of predicting XS-specific project effects on flow and habitat (Section 3.6.2). For predicting reach-scale project impacts on flow and habitat, the XS-specific results were weighted according to the distribution of runs, riffles and pools within each reach. The process by which the six (6) mapped morphologies (Figure 3-6) were classified into reach-scale distributions of run, riffle and pool is outlined in Section 3.6.2.4

Habitat Use in Gold Creek

Spawning in Gold Creek was not found to be geographically concentrated, but rather was found in 2016 to be spread throughout classified reaches and based on habitat availability (Hatfield 2016a). Larger fish were observed spawning earlier; the early survey window (May) had more mature fish (30+ cm fork length class) than in the later survey window where more mature fish in the 20+ cm fork length class were observed. Stream discharge was slightly higher in the earlier survey window and may explain the size differential observed across the survey windows, given larger fish can generally handle higher flows. Low numbers of fish were observed in the lower reaches of Gold Creek with the exception of Reach 2 (Hatfield 2016a; Table 4.7; Figure 4.1). Reaches 7 and 8 displayed the highest density of spawning adults over the survey window. Young-of-year (YOY) fry were not observed in Gold Creek during 2016 juvenile recruitment surveys (Hatfield 2016a) suggesting spawning habitat may be a limiting feature under low flow conditions. The low flows experienced in Gold Creek in 2016 (Figure 3-5) may also indirectly influence egg incubation given the contribution of flow and associated cold stream temperatures provided by Caudron Creek.

Suitable quality overwintering habitat in Gold Creek is also a potential limiting feature for WSCT as the majority was isolated to Reach 7 (Hatfield 2016a). Fish appear to utilize deep pool habitat associated with slower water velocities for overwintering, where multiple size classes congregated in large numbers. While many of the habitat units in the upper reaches of Gold Creek (reaches 8, 9) contain small tertiary pools (i.e., < 50% of wetted width) that support fish, deep primary pools (primary, > 50% of wetted width) were preferred as displayed by baseline snorkel survey fish counts (Hatfield 2016a).

Summer rearing fish densities were much less in the lower reaches (Reaches 3 to 6) relative to the upper reaches (reaches 7 to 9) based on snorkel and electrofishing surveys. In the upper-most reach of Gold Creek (Reach 9) fish density was highest and dominated by fish of smaller fork lengths. The lower reaches supported fewer fish; however, these fish were on average larger (Hatfield 2016a).

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Figure 3-7 Photographic summary of representative run, riffle and pool mesohabitats on Gold Creek, sampled during the IFA.

Primary Habitat	**Reach 9**	**Reach 8**	**Reach 7**	**Reach 6**	**Reach 5**
Run (glide)	XS ID: GC-26 	GC-22 	GC-9 	GC-3 	GC-1 
Riffle	GC-25 	GC-21 	GC-12 	GC-5 	GC-0 
Pool	GC-24 	GC-15 	GC-11/H02 	GC4 	*No pool sampled in this reach*

Note: See Figure 1-1 for location of reaches and individual XS. All photos were taken between September 13-17 2016.

3.3.1.4 Gold Creek Cross-Section Network and Sampling Schedule

A final total of 28 XS were established on Gold Creek for the purposes of sampling flow-hydraulic relationships in the field, and developing flow-habitat relationships required as part of this IFA (Figure 1-1, Table 3-3). Of these 28 XS, 27 XS were established in Reaches 5 through 9, including two (2), four (4), seven (7), ten (10), and four (4) in Reach 5, 6, 7, 8 and 9, respectively. The remaining transect, GC-27/H03 (a dual IFA XS and hydrometric station location upstream of Reach 9) was later excluded from habitat analysis, though the derived flow data were still used within the IFA.

The schedule of field sampling along Gold Creek is presented in Table 3-3. All sampling was conducted in 2016, with the individual exception of XS GC-07/H01 (an additional dual IFA XS and hydrometric station monitoring location) where the stage-discharge data collected as part of hydrometric monitoring between September 2013 to August 2014 could be integrated within the IFA analysis. Six XS were initially established during field visits to Gold Creek in March or May 2016, as part of wider aquatic-related sampling programs in these months including the FHAP habitat mapping. This included the setup of dual IFA XS and hydrometric station monitoring locations at GC-11/H02 (Gold Creek at Caudron Creek confluence) and GC-27/H03 (Gold Creek headwaters). An additional 10 XS were established in late-June 2016, and six of the seven XS established prior to June were also sampled during this field program. In early-July 2016, a further six XS were established, three each in Reach 5 and Reach 9, to expand the spatial coverage of IFA XS further upstream and downstream in response to updated modeling predictions of Project flows (SRK 2016c; Consultant Report #4). The final five XS were established during the subsequent field program in mid-September 2016, three around the Morin Creek confluence to expand the XS network even further downstream, and two in Reach 7 (downstream of the Caudron Creek confluence) to improve the data coverage between existing widely-seperated XS. All 28 XS were sampled during a final field program in mid-October 2016.

The total number of completed IFA field surveys (including the minimum XS sampling requirement of stage measurements, Section 3.4.2) was 12 at GC-7/H01, three to four at the 22 XS established between March to July 2016, and two at the five XS established in September 2016 (Table 3-3).

Table 3-3 Schedule of XS and hydrometric station sampling associated with the IFA, Gold Creek, 2013-2016.

Reach	XS ID	2013				2014								2016								Data inventory		
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Q	WL	#Months data
5	GC-0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	WL	QWL	1	2	-
	GC-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	QWL	2	2	-
6	GC-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	QWL	2	2	-
	GC-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	QWL	QWL	3	2	-
	GC-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	GC-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
7	GC-6	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	QWL	-	-	WL	WL	2	4	-
	GC-7/H01	QWL	-	-	-	QWL	-	-	QWL	QWL	QWL	QWL	QWL	QWL	-	QWL	QWL	-	-	QWL	QWL	12	12	20
	GC-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	QWL	2	2	-
	GC-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	WL	QWL	1	2	-
	GC-11/H02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	QWL	-	-	QWL	WL	3	4	6
	GC-12	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	QWL	-	-	WL	WL	2	3	-
8	GC-13	-	-	-	-	-	-	-	-	-	-	-	-		-	-	QWL	-	-	QWL	QWL	3	3	-
	GC-14	-	-	-	-	-	-	-	-	-	-	-	-	Q	-	-	QWL	-	-	WL	WL	2	3	-
	GC-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	QWL	-	-	QWL	QWL	4	4	-
9	GC-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	WL	WL	1	3	-
	GC-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	GC-25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	GC-26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	QWL	QWL	3	3	-
Above 9	GC-27/H03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	-	-	QWL	QWL	3	3	6

Notes: Shaded months contain available, continuous hydrometric (stage-discharge) data
Bold, underlined XS-IDs represent the primary node in each reach where monthly flows are estimated and used to initialize reach-scale habitat simulations
Q indicates a cross-section area and velocity was sampled, from which a discharge (Q) estimate is available
WL indicates a stage (water-level) measurement was sampled, that could be applied within IFS rating-curve development (i.e., referenced to the XS-specific datum)

3.3.2 Blairmore Creek

3.3.2.1 Project Hydrology

Watershed description

The 49.8 km^2 Blairmore Creek watershed is situated to the west of Gold Creek watershed (Figure 1-1, Figure 3-8), and represents another tributary of the Crowsnest River watershed. The average slope is 22% with elevations ranging from 1,300 masl near the mouth to 2,300 masl on the western watershed boundary; individual reach morphology descriptions are detailed in the subsequent section. The MAP across the watershed is estimated to be 719 mm (SRK 2016c; Consultant Report #4). This watershed has remained largely forested, relative to Gold Creek.

Figure 3-8 Blairmore Creek Watershed.

Note: photo looking northwest across Blairmore Creek watershed. Western watershed boundary is the terrain in foreground; Crowsnest Mountain in background is outside of Blairmore Creek Watershed. Source: Mayhood 2015.

Hydrometric Data

Three local study area hydrometric gauges were installed along Blairmore Creek in support of this IFA and the hydrology baseline study (SRK 2016c; Consultant Report #4). A lower-watershed gauge at BC-0/H01 (Figure 1-1), and upper- watershed gauge at BC-15/H01 operated from September 2013 to August 2014 and again from March to October 2016. A mid-watershed gauge at BC-H02 operated from October 2013-August 2014 but was not recommissioned in 2016.

Similar to the process for Gold Creek, long-term synthetic daily flow data series extending from November 1975 to October 2016 (41-year period) were then developed for these local gauges, based on the regression analysis between daily flows gauged concurrently between each local gauge and the WSC gauge on Crowsnest River at Frank. Correlations were slightly higher with this gauge than using the WSC gauge on Gold Creek near Frank. The synthetic time series most appropriate to each reach was selected then adjusted empirically using the ratio of measured flows between gauge locations and appropriate reach-specific locations.

Spatial flow variability

Flows along the length of Blairmore Creek are spatially less complex than along Gold Creek. Figure 3-2 displays the estimated long-term Mean Annual Discharge (MAD) values characterizing each study reach delineated for this IFA and other components of the Fish and Aquatics Baseline Technical Report (Hatfield 2016a). Under normal baseline conditions, MAD in the upper catchment increases from 0.110 m^3/s in Reach 5, to 0.175 m^3/s in Reach 4, to 0.208 m^3/s in Reach 3. The long-term MAD estimated at a local gauging station 2 km from the mouth (BC-0/H01 in Figure 1-1) is 0.235 m^3/s.

Seasonal and monthly flow variability

Estimated long-term monthly and annual flows for each study reach (Reaches 3 to 5), in addition to the downstream gauge at BC-0/H01, are summarized in Table 3-4. Like Gold Creek, monthly flows increase during spring freshet, to a peak in June, before receding through summer to base flows during fall and winter. Flows across all reaches during June and the May-July period contribute 34% and 74% of annual runoff, respectively, equivalent to 335% and 312% of MAD. For all other months, contributions range from 1-13% of annual runoff, equivalent to 17-147% of MAD. The annual range of MMD is higher than on Gold Creek (Table 3-1), since groundwater contributions and base flows are lower, whereas the freshet contribution to annual runoff is more dominant. This is similar to the Crowsnest River and other regional watersheds draining areas of the central Rockies (e.g., SRK 2016c; Consultant Report #4). Measured streamflows and water temperatures across all Blairmore Creek hydrometric gauges during the 2013-2014 winter were lower than at GC-7/H01, even at the downstream gauge (BC-0/H01) where the drainage area is approximately 50% higher than at GC-7/H01.

Table 3-4 Flow statistics for Reaches 5 (upstream) to 3 (downstream) and the BC-0/H01 gauge (lower watershed) on Blairmore Creek.

	Reach 5			Reach 4			Reach 3			BC-0/H01		
Mean Annual Discharge (m^3/s)	0.110			0.175			0.208			0.235		
Annual Runoff (million m^3)	3.422			5.454			6.475			7.282		
Month	MMD (m^3/s)	MAD[1] (%)	AR[2] (%)	MMD (m^3/s)	MAD[1] (%)	AR[2] (%)	MMD (m^3/s)	MAD[1] (%)	AR[2] (%)	MMD (m^3/s)	MAD[1] (%)	AR[2] (%)
Jan	0.019	17%	1%	0.030	17%	1%	0.035	17%	1%	0.061	26%	2%
Feb	0.017	16%	1%	0.027	16%	1%	0.032	16%	1%	0.058	24%	2%
Mar	0.020	18%	2%	0.032	18%	2%	0.038	18%	2%	0.064	27%	2%
Apr	0.162	147%	13%	0.258	147%	13%	0.306	147%	13%	0.286	122%	11%
May	0.367	335%	29%	0.585	335%	29%	0.694	335%	29%	0.772	328%	28%
Jun	0.432	394%	34%	0.689	394%	34%	0.818	394%	34%	0.917	390%	34%
Jul	0.138	126%	11%	0.220	126%	11%	0.261	126%	11%	0.254	108%	9%
Aug	0.053	48%	4%	0.084	48%	4%	0.099	48%	4%	0.114	49%	4%
Sep	0.033	30%	3%	0.052	30%	3%	0.062	30%	3%	0.085	36%	3%
Oct	0.029	27%	2%	0.047	27%	2%	0.056	27%	2%	0.080	34%	3%
Nov	0.028	25%	2%	0.044	25%	2%	0.053	25%	2%	0.072	30%	3%
Dec	0.021	20%	2%	0.034	20%	2%	0.041	20%	2%	0.067	28%	2%

Notes:

[1] MAD (%) represents the ratio of MMD to MAD.

[2] AR (%) represents the monthly runoff sum (not shown) to annual runoff sum.

3.3.2.2 Macrohabitat

Blairmore Creek was delineated into five reaches (Figure 2-1) ranging from 399 m (Reach 2) to 3,942 m (Reach 4, Table 3-2) in length (Hatfield 2016a). Reach 1 extends beyond the provincial conservation designation for WSCT and the Project footprint; Reach 2 is also downstream of the greatest predicted habitat loss area (based on smaller baseline flows, proximity to project infrastructure, and fish barriers).

The most-downstream reach is the narrowest and the steepest (Reach 2) and the reach immediately upstream is the widest (Reach 3, Table 3-2). The gradient in the upper reaches (Reach 4 and 5) is less steep, compared to the lower reaches (Table 3-2).

3.3.2.3 Mesohabitat

A total 8.7 km of potential fish habitat was assessed and mapped in Blairmore Creek (Reaches 2 to 5) between March and May of 2016. The mesohabitat units indentified by the FHAP were digitized and are presented for Blairmore Creek (Figure 1-1). The total wetted area surveyed was 35,395 m^2, and average wetted width was 3.4 m.

The percentage of each habitat type within the four reaches on Blairmore Creek is illustrated in Figure 3-9. Reach 2 differed from the other three reaches, with half of the area comprised of step-pool morphology (49%), and the remainder pool-riffle morphology (47%) with only small segments of pools and runs (< 3% each, Figure 3-9). Reaches 3, 4 and 5 are dominated by riffles (24% to 55%) and pool-riffle units (18% to 46%, Figure 3-9). The upper reaches have a higher proportion of riffle-run-pool (15% to 22%) compared to the lower reaches. Pools represent less than 2% of all area in each reach (Figure 3-9). A photographic comparison of representative run, riffle and pool mesohabitats is shown in Figure 3-7 for each of the three study reaches on Blairmore Creek. The derived reach-scale distributions of runs, riffles and pools (used for upscaling Project predicted impacts on flow and habitat at individual XS) are introduced in Section 3.6.2.4.

Habitat Use in Blairmore Creek

Like Gold Creek, spawning in Blairmore Creek was not geographically concentrated in 2016, but rather dispersed among classified reaches based on habitat availability (Hatfield 2016a). Stream discharge was slightly higher in the earlier survey window and may explain the size differential observed across the survey windows, given larger fish can generally handle higher flows. All surveyed reaches in Blairmore Creek exhibited mature spawning WSCT over the survey window (Hatfield 2016a Table 4.7; Figure 4.1). YOY fry were observed throughout Blairmore Creek during 2016 juvenile recruitment surveys (Hatfield 2016a) suggesting spawning habitat and egg incubation do not appear to be limiting features under low flow (drought) conditions.

Similar to Gold Creek, suitable quality overwintering habitat in Blairmore Creek is also a potential limiting feature for WSCT as the majority was isolated to Reaches 3 and 4 (Hatfield 2016a). WSCT appear to utilize deep pool habitat associated with slower water velocities, where multiple size classes congregated in large numbers. The upper reaches of Blairmore Creek contain small tertiary pools, which do support fish, however are not as preferred.

Fish density based on snorkel surveys was higher in the upper reach of Blairmore Creek compared to the lower reach, and was dominated by smaller fish (Hatfield 2016a). Fish density based on mark-and-recapture surveys was much higher in Reach 5 of Blairmore Creek relative to the lower reaches, and was dominated by smaller fish.

Figure 3-9 Percentage of mesohabitat types by area in Reaches 2 (downstream) to 5 (upstream) of Blairmore Creek.

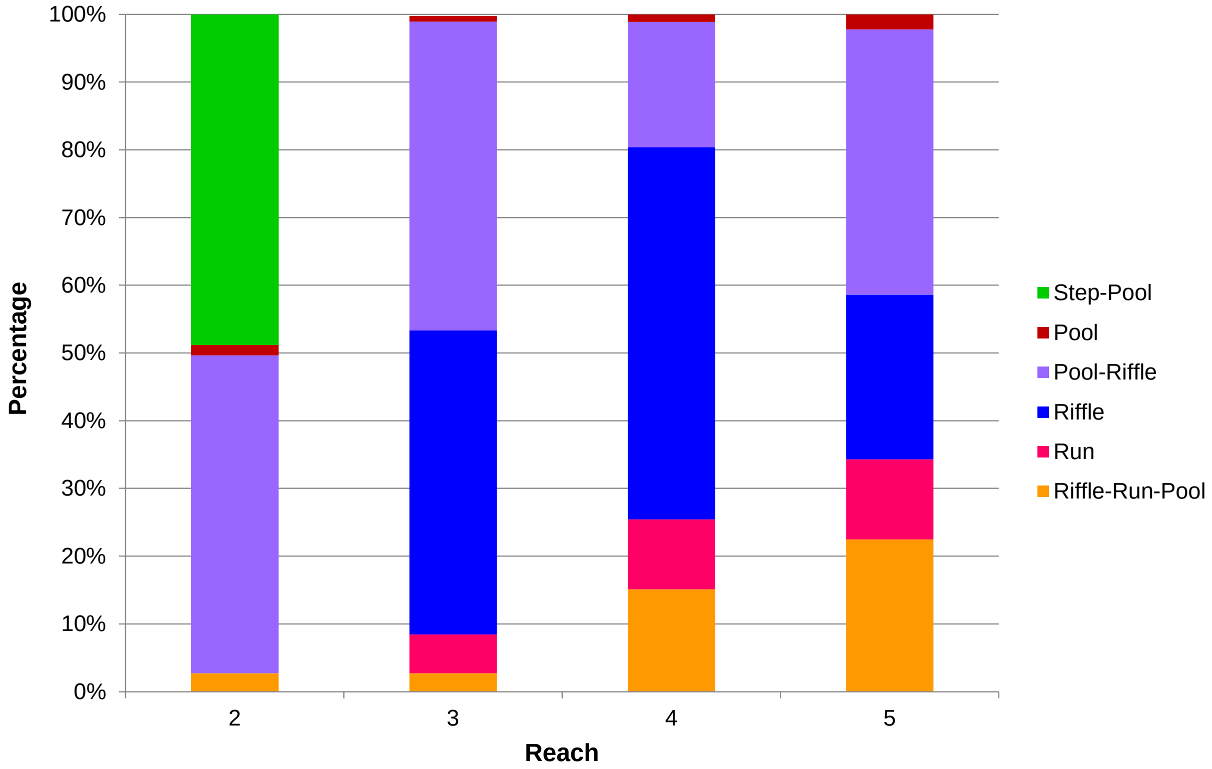

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Figure 3-10 Photographic summary of representative mesohabitats on Blairmore Creek, sampled during the IFA.

Primary Habitat	Reach 5	Reach 4	Reach 3
Run/ glide	XS ID: BC-15/H03 	BC-8 	BC-2 
Riffle	BC-14 	BC-11 	BC-1 
Pool	*No pool sampled in this reach*	BC-7 	*No pool sampled in this reach*

Note: See Figure 1-1 for location of reaches and individual XS. All photos were taken between September 13-17 2016.

3.3.2.4 Cross-section network and sampling schedule

A total of 16 XS were established on Blairmore Creek, including three (3) XS in Reach 3, ten (10) XS in Reach 4, and two (2) in Reach 5 (Figure 1-1, Table 3-5). The remaining transect, BC-0/H01 (a dual IFA XS and hydrometric station location towards the mouth of Blairmore Creek and far downstream of Reach 3) was later excluded from habitat analysis, though the derived flow data were still used within the IFA analysis. The XS at BC-5 represented a braided riffle, consisting of a a main and secondary channel.

The schedule of field sampling along Blairmore Creek is displayed in Table 3-5. All sampling was conducted in 2016, with the exceptions of BC-0/H01 and another dual IFA XS and hydrometric station monitoring location (BC-15/H03) where the stage-discharge data collected as part of hydrometric monitoring between September 2013 to August 2014 could be integrated within the IFA analysis. The intermediate hydrometric station (BC-H02, close to XS BC-04) also operated from 2013-2014, but was not recommissioned in 2016 for either IFA or hydrometric data purposes. BC-0/H01 and BC-15/H03 were also sampled in March 2016 as part of wider aquatic-related sampling programs in this month, and later in early-July, mid-September and mid-October 2016 during the main IFA field programs. Nine field surveys were completed at these two XS between 2013 to 2016. The remaining 14 XS were all established during the early-July 2016 field program, and resampled during the mid-September and mid-October 2016 field programs, for a total of three field surveys (Table 3-5).

Table 3-5 Schedule of XS and hydrometric station sampling associated with the IFN Assessment, Blairmore Creek, 2013-2016.

Reach	XS ID	2013				2014								2016								Data inventory summary		
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Q	WL	#Months data
Below 3	BC-0/H01	QWL	-	-	-	QWL	-	-	QWL	QWL	QWL	QWL	QWL	QWL	-	-	-	-	-	-	QWL	9	9	20
3	BC-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	BC-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	QWL	QWL	3	3	-
	BC-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
4	BC-H02[1]	-	QWL	-	-	QWL	-	-	-	QWL	QWL	QWL	QWL	-	-	-	-	-	-	-	-	6	6	11
	BC-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	QWL	QWL	3	3	-
	BC-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	BC-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	BC-7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	BC-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	QWL	QWL	3	3	-
	BC-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	BC-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	BC-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	BC-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	QWL	QWL	3	3	-
	BC-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
5	BC-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	QWL	-	WL	WL	1	3	-
	BC-15/H03	-	QWL	-	-	QWL	-	-	-	-	QWL	QWL	QWL	QWL	-	-	-	QWL	-	QWL	QWL	9	9	29[2]

Notes: Shaded months contain available, continuous hydrometric (stage-discharge) data.

Bold, underlined XS-IDs represent the primary node in each reach where monthly flows are estimated and used to initialize reach-scale habitat simulations.

Q indicates a cross-section area and velocity was sampled, from which a discharge (Q) estimate is available.

WL indicates a stage (water-level) measurement was sampled, that could be applied within IFS rating-curve development (i.e., referenced to the XS-specific datum).

[1] BC-H02 was not recommissioned during the 2016 IFA study.

[2] BC-15/H03 also collected time-series data from May 2015 to March 2016 but this data is lower quality (there were no field visits during this period).

3.4 STREAM HYDRAULICS SAMPLING

Field practices for the sampling of stream hydraulic variables (including width, depth, velocity and substrate) followed the BCIFM guidelines (Lewis et al. 2004), BC Hydrometric Standards (BC MOE 2009), and SEFA guidelines (Jowett et al. 2016).

3.4.1 Initial Site Visit

The following methods were used to establish and sample an IFA XS during the initial visit (termed the 'survey flow' in SEFA).

Three benchmarks were installed at most XS, or more at select XS (primarily joint hydrology station and XS locations). Where longitudinal spacing and riparian visibility allowed, a common set of three benchmarks was established for a cluster of adjacent transects. One benchmark was assigned an arbitrary datum of 100 m height, and all surveyed elevations (bed or water surface) were then calculated relative to this height. Two of the three benchmarks were located well above the bankfall stream height and also served as the left and right bank XS end points.

Using standard survey leveling equipment (optical level, tripod and stadia rod), all benchmarks were surveyed to the nearest millimetre. The water surface elevation was also surveyed to the nearest millimetre, at the water edge on both left and right sides of the channel, and additionally in the middle of the channel if there was a notable left-to-right gradient (of at least five millimeters) due to stream bends or other hydraulic controls on the flow distribution. Except during time constraints, a second survey of the water surface elevation and benchmarks (using a different level position) was undertaken in order to 'close' the survey as outlined in the BC Hydrometric Standards (BC MOE 2009). The water surface elevation of both main and secondary channels was independently surveyed at BC-5.

Water surface elevations were also surveyed at points upstream and downstream of the XS in order to determine the stream gradient through the XS; the longitudinal range was contingent on available line of sight from the survey equipment. An additional key measurement of bed elevation was obtained downstream of the XS, at the best-estimate of the lowest point within a hydraulic control feature, termed the Stage of Zero Flow (SZF). The SZF height is critical within XS rating curve development (Section 3.6.2.2), and is relatively easy to locate and measure as the base of a tailout within pool or run/glide mesohabitats. In lower-gradient riffles and some runs the SZF may not be clear and instead has to be estimated mathematically during rating curve development, but for natural, irregular channels the SZF is expected to be higher than the thalweg for all but the very lowest of stream stages (Rantz et al. 1982).

Streamflow measurements were conducted using the velocity-area method, following the BC Hydrometric Standards (BC MOE 2009). Vertical depth and velocity profiles were collected at no less than 20 points within the wetted width, and often closer to 30, meeting the requirements that flow calculations be based on more than 20 sampled panels across each stream and that no individual panel contributes more than 10% of the total flow. (Only in the very small secondary channel at BC-5 were fewer points measured). Water depths were read to the nearest centimetre using a graduated top-set wading rod. Water velocities were sampled for 40 seconds at each vertical, using a Sontek Flowtracker handheld ADV (Acoustic Doppler Velocimeter) positioned at 0.6 of the stream depth, with a manufacturer's stated accuracy in velocity of ±1%. There were no water depths exceeding 0.75 m, at which point the average velocity from

0.2 and 0.8 of the stream depth would have been sampled, although the 0.2 and 0.8 configuration was used in the instance of two plunge-type pool XS where the majority of flow occurred towards the surface and would have been underestimated from velocity sampling at 0.6 of the stream depth alone.

The resulting streamflow values were only used for analytical purposes in the instance of sampled XS at run/glide mesohabitats (or pools which were not plunge-type), where conditions promote the highest accuracy of depth and/or velocity data collection. Errors in flow can easily approach 20%, particularly in riffle mesohabitats where there is turbulence and potential shallow depths, or in plunge-type pools where is a complicated three-dimensional velocity structure (e.g., with fast surface layers and eddies towards the bed or stream sides) (e.g., Waddle 2012). The velocity data from riffles and pools were still required by SEFA, at each XS during the initial survey flow, given this distribution is then extrapolated higher or lower as part of the hydraulic prediction process for other flow values.

The dry bed profile was surveyed from the edge of the wetted width to the XS end-point (benchmark) on both banks. This data was then combined with the bed profile measured along the wetted width, calculated as mean water surface elevation minus water depth, in order to characterize the full XS bed profile running between end-points. The majority of XS were between 10-20 m wide, with wetted widths between 2.5-5 m, including a total of 40-45 sampling points consisting of 20-25 points along the wetted width and 10 dry points on each bank. The common spacing between points was approximately 0.1-0.2 m along the wetted width and 0.5-1 m along the banks.

Substrate data were collected along both wetted width and dry locations of each XS, using size classes recommended by SEFA guidelines (Jowett et al. 2016) that are very similar to corresponding size classes in the BCIFM (Lewis et al. 2004) guidelines. Additional, related variables were sampled in accordance with the BCIFM guidelines that are not required by SEFA, including select cover types (such as woody debris, vegetation, or undercut banks), D_{95} particle diameter, and substrate roughness (the height of the average substrate particle protruding from the streambed). The cover types listed above were also characterized during baseline surveys (Hatfield 2016a) and only those types forms affected by changes in flow (depth, substrate) were included in the IFA.

Each transect was documented with a series of photographs as per the BCIFM guidelines (Lewis et al. 2004), including photos of the benchmarks, views across the XS from the left and right banks, and views of the XS taken from 20 m upstream and downstream (or closer depending on available line of sight). The upstream and downstream views of each XS, photographed during each sampling program, are shown in Appendix A2, complete with the corresponding surveyed XS bed geometry and derived rating curve.

3.4.2 Calibration Revisits

During subsequent visits to all IFA XS, the benchmarks and water surface elevations were surveyed using the same leveling procedures as for the initial visit. Photographs were taken across each XS and from upstream/downstream of each XS. Consistent with SEFA guidelines (Jowett et al. 2016), flow measurements were only conducted at XS located in run, glide and (non plunge-type) pool mesohabitats, to ensure accurate flow data collection outlined above. These measured flow values were later applied unchanged to nearby XS without flow measurements, including those in riffle and plunge-type pool mesohabitats, for the purpose of developing rating curves at all XS in the network.

3.5 HYDROLOGY INPUT DATA

3.5.1 Average Hydrological Conditions

Procedures for developing baseline flows along and Gold Creek and Blairmore Creek, for input into the SEFA hydraulic habitat models, were introduced in Section 3.3.1.1 and are described fully in Appendix A1. A summary of the estimated MAD values specific to each study reach, during average hydrological conditions, were presented in Figure 3-2. The Mean Monthly Discharge (MMD) time-series specific ro each reach (Table 3-1, Table 3-4) were assumed representative of baseline conditions during 2017.

Predicted project flows for input into each hydraulic habitat model were generated as follows. Monthly total flow changes were predicted by SRK (2016c; Consultant Report #4) from the start of construction (2018) until the end of mine (2099), at five (5) model nodes each on Gold Creek and Blairmore Creek (Figure 2-1). These were calculated using a watershed model (GoldSim^{TM}) developed using regional precipitation data, assumptions on runoff yield between undisturbed and disturbed watershed areas, and a Water Quality Management Plan for controlling and treating surface waters and groundwater affected by mine operations (SRK 2016a). Mine operations were grouped into the following main phases, including baseline (2017), construction (2018), operations (2019-2042), decommissioning (2043-2044) and closure (2045-2099). The predicted total flow changes did not differentiate between the constituents of runoff (i.e., surface channel flow, interflow, and groundwater), and for the purposes of this IFA there was assumed to be no difference between predicted changes in total and surface channel flow. For each hydraulic habitat model (reach), monthly project flows from 2018-2099 were simulated by combining the combination of MMD baseline (2017) time series and Project flow changes at selected SRK nodes shown in Table 3-6.

Table 3-6 Summary of data sources applied for reach scale hydrology characterization.

Stream	Reach	Synthetic Hydrograph applied[1]	Model Prediction Node applied[2] (SRK 2016c)
Gold Creek	9	GC-26	GC-10
	8	GC-22	GC-10
	7	GC-7/H01	GC-04
	6	GC-3	GC-02
	5	GC-1	GC-02
Blairmore Creek	5	BC-15/H03	BL-03
	4	BC-12	BL-02
	3	BC-2	BL-02

Notes:

[1] Synthetic hydrograph production methods were described in Appendix A1 and long-term monthly statistics were summarized in Table 3-1 and Table 3-4.

[2] Project changes on runoff originate from SRK (2016c) and data are shown in Figure 2-2 and Figure 2-3; node locations are shown in Figure 2-1.

3.5.2 Drought Hydrology Conditions

Extreme low-flow (i.e., dry) conditions are of particular concern to habitat availability and fish abundance. A method was introduced to generate baseline (2017) MMD time-series for both 1-in-10 year and 1-in-20 year return period low flows (i.e., with 10% and 5% probability of occurrence, respectively, in any one year). Annual runoff sums were calculated from the long-term (1976-2016) synthetic hydrographs generated for each hydraulic habitat model (study reach). A frequency analysis was performed on each annual time series, using the hydrologic modeling toolbox facility within Aquarius Software. A two parameter lognormal probability distribution was used for the frequency analysis, though a Log Pearson Type III probability distribution was found to produce similar results and either distribution is common for the analysis of annual streamflow volumes across North America (e.g., Vogel and Wilson, 1996). The resulting 1-in-10 and 1-in-20 low flow (dry) year annual sums were then disaggregated into MMD values, using the monthly average runoff distribution calculated specific to each long-term synthetic hydrograph. The same analysis procedures were applied to generate monthly precipitation values during a 1-in-10 dry year and 1-in-10 wet year as input to the watershed model (SRK 2016b), and other fisheries-based assessments also use 1-in-10 dry year and related flow metrics (e.g., Golder 2014).

For predicting project flows and hydraulic habitat changes during extreme dry conditions, the 1-in-10 dry year and 1-in-20 dry year MMD time-series from above, assumed to represent baseline (2017) flow conditions, were then adjusted by applying the appropriate node time-series of total flow changes predicted by the watershed model (Appendix 10B,Appendix B- Catchment Delineation Maps) for all Project phases (2018-2099). The hydraulic habitat predictions applied the 1-in-10 dry year scenario generated by the watershed model (this conservatively assumes that each year from 2018-2099 was a 1-in-10 dry year), though differences between dry, average and wet year scenarios were typically small (few percent or less).

3.6 ANALYTICAL METHODS

3.6.1 Selection of Habitat Suitability Criteria

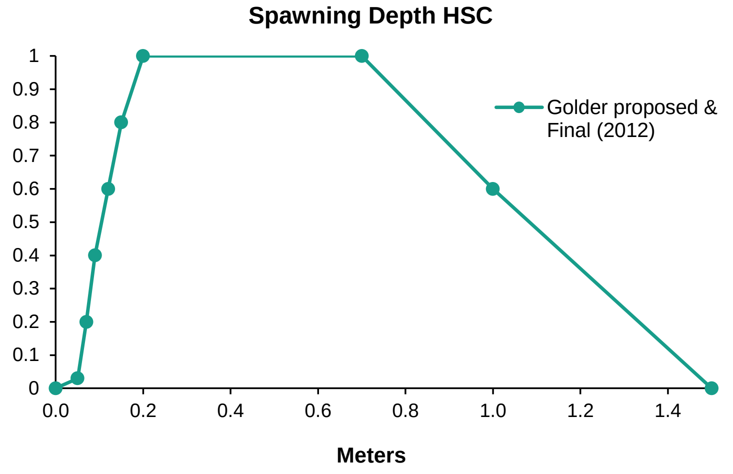
Species-specific WSCT HSCs for depth, velocity, and substrate were compiled from a number of readily available literature and expert sources. A memo describing the steps applied for compiling, evalutating, and selecting the preferred HSC curves for this IFA was provided to the Alberta Energy Regulator (AER), Canadian Environmental Assessment Agency (CEAA) and DFO on December 6, 2016 (Hatfield 2016b; Appendix A2). In summary, the steps exercised in the evaluation and selection of the preferred HSC curves included the following:

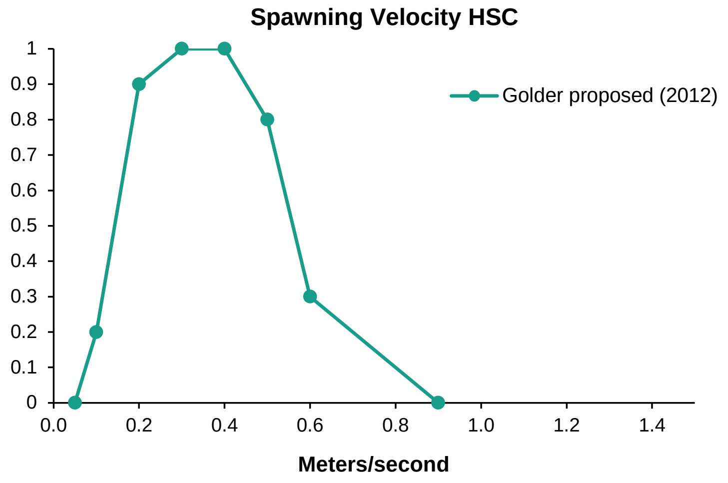
- WSCT were confirmed as the target fish species for the IFA given their presence and distribution throughout both Gold Creek and Blairmore Creek in the aquatic local study area (LSA) as well as their *SARA* threatened and provincial conservation population designations.
- HSC literature sources specific to WSCT were identified and HSC curves for key life stages/bioperiods (e.g., spawning/incubation, fry rearing, juvenile rearing, adult rearing/holding, overwintering) were compiled for comparison.

- Literature HSC curves were evaluated based on how they were generated by the authors (e.g., use of data from multiple cutthroat trout sub-species or only WSCT, the geographic location of watercourses used in the development/refinement of HSC curves, the amount of data used to build the HSC curves, size and physical habitat characteristics of watercourse(s) used in developing/refining HSCs, professional peer review).
- Coarse validation of HSCs using field data collected from the target watercourses (e.g., snorkel data during spawning/overwintering/rearing surveys, evaluation of local hydrograph during the WSCT spawning window etc.).

The preferred WSCT-specific HSC Curves for depth, velocity, and substrate are presented below in Figure 3-11 to Figure 3-16. The substrate HSCs selected were to account for spawning and cover habitat components that can be altered by changes in flow for the species.

Figure 3-11 WSCT Spawning Habitat Suitability Criteria Curves.


Spawning Depth HSC


Spawning Velocity HSC

Depth HSC (meters)

Index	0	0.03	0.2	0.4	0.6	0.8	1	1	0.6	0
Value	0	0.05	0.07	0.09	0.12	0.15	0.2	0.7	1	1.5

Velocity HSC (m/s)

Index	0	0.2	0.9	1	1	0.8	0.3	0
Value	0.05	0.1	0.2	0.3	0.4	0.5	0.6	0.9

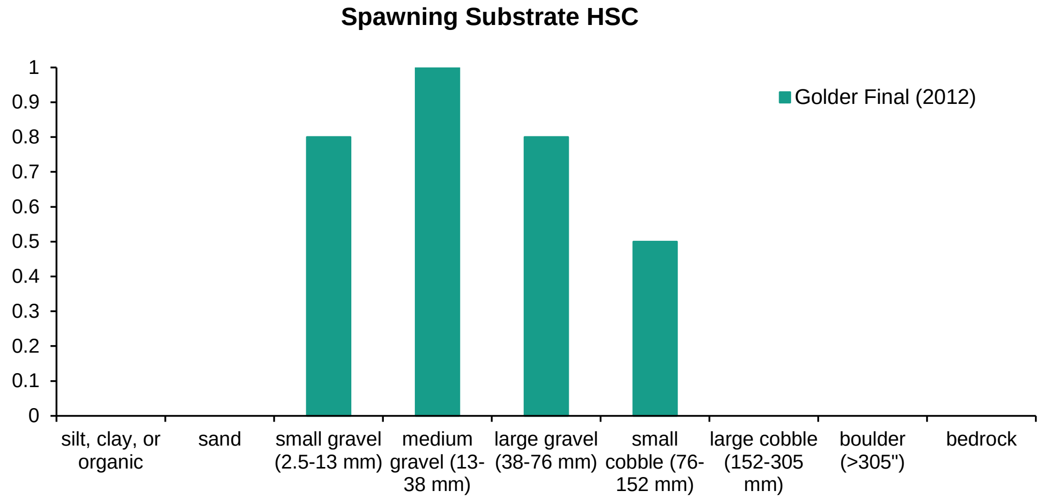
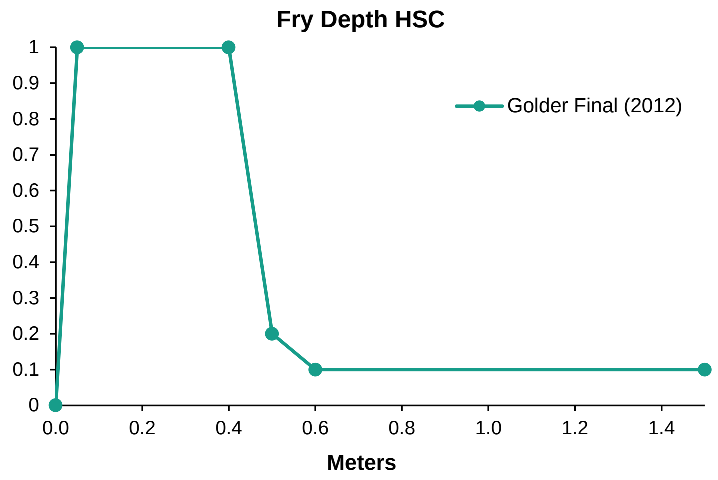
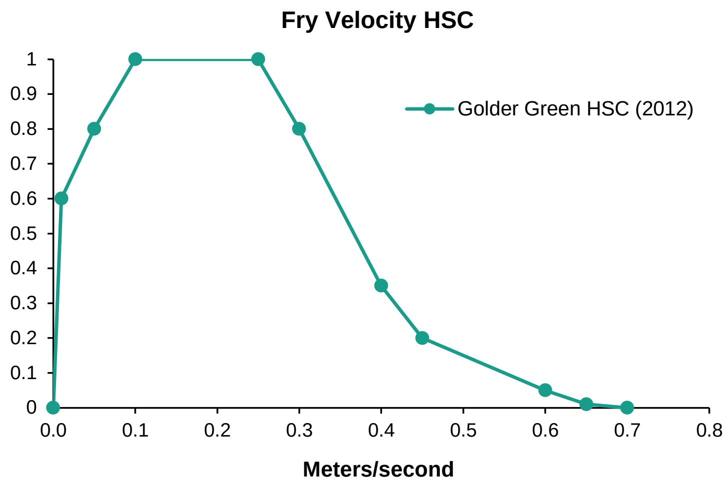

Spawning Substrate HSC

Figure 3-12 WSCT Fry (Rearing) Habitat Suitability Criteria Curves.





Depth HSC (meters)						
Index	0	1	1	0.2	0.1	0.1
Value	0	0.05	0.4	0.5	0.6	1.5

Velocity HSC (m/s)											
Index	0	0.6	0.8	1	1	0.8	0.35	0.2	0.05	0.01	0
Value	0	0.01	0.05	0.1	0.25	0.3	0.4	0.45	0.6	0.65	0.7

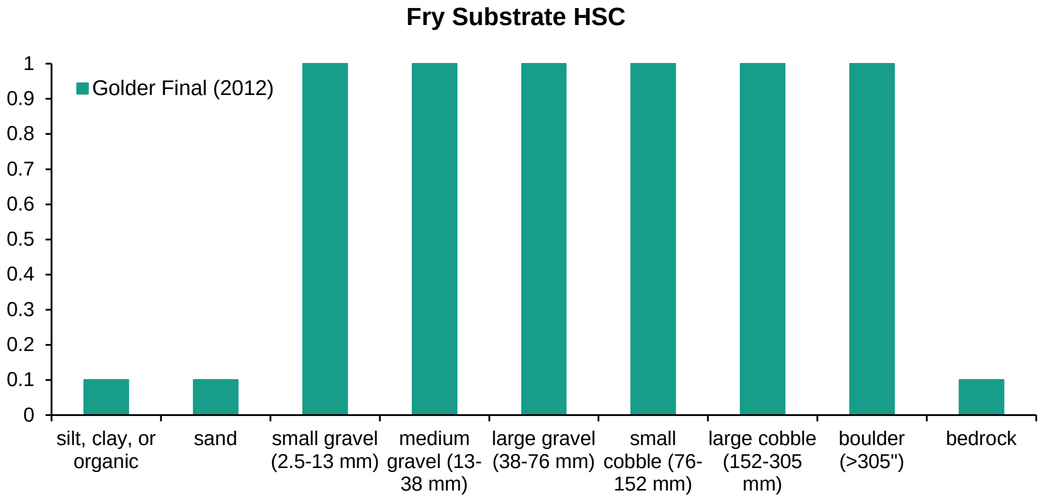
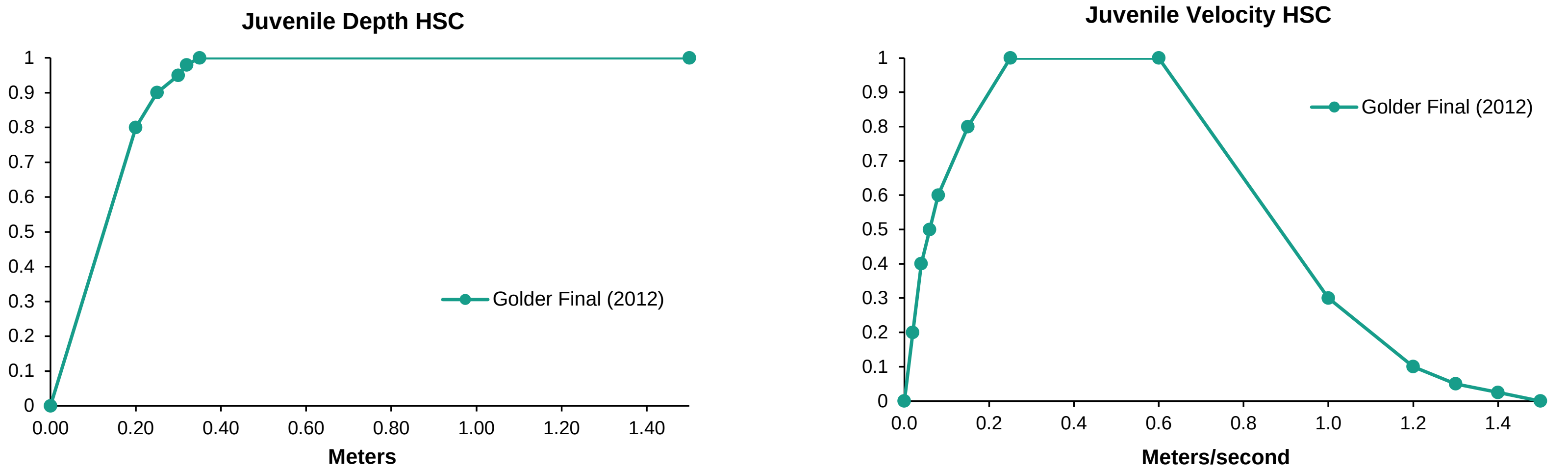


Figure 3-13 WSCT Juvenile (Rearing) Habitat Suitability Criteria Curves.



Depth HSC (meters)							
Index	0	0.8	0.9	0.95	0.98	1	1
Value	0	0.2	0.25	0.3	0.32	0.35	1.5

Velocity HSC (m/s)													
Index	0	0.2	0.4	0.5	0.6	0.8	1	1	0.3	0.1	0.05	0.025	0
Value	0	0.02	0.04	0.06	0.08	0.15	0.25	0.6	1	1.2	1.3	1.4	1.5

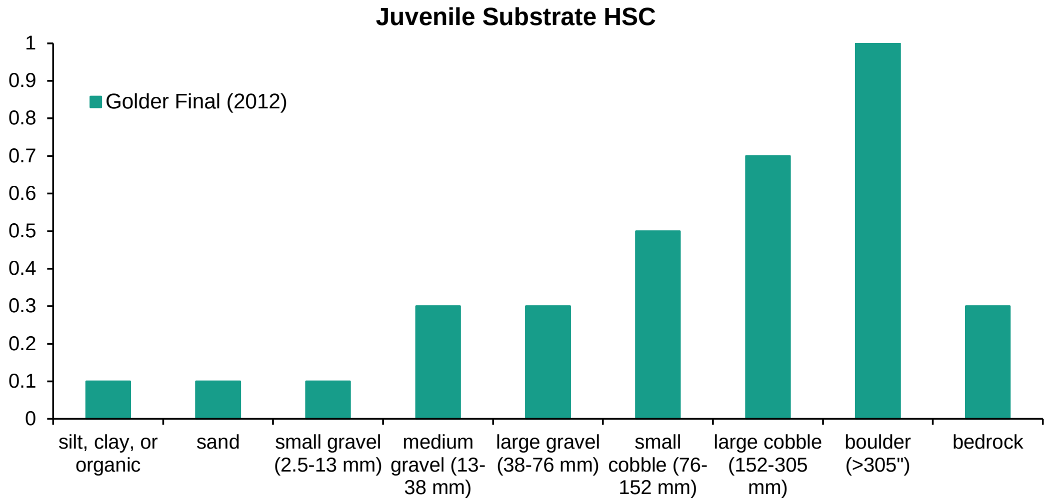
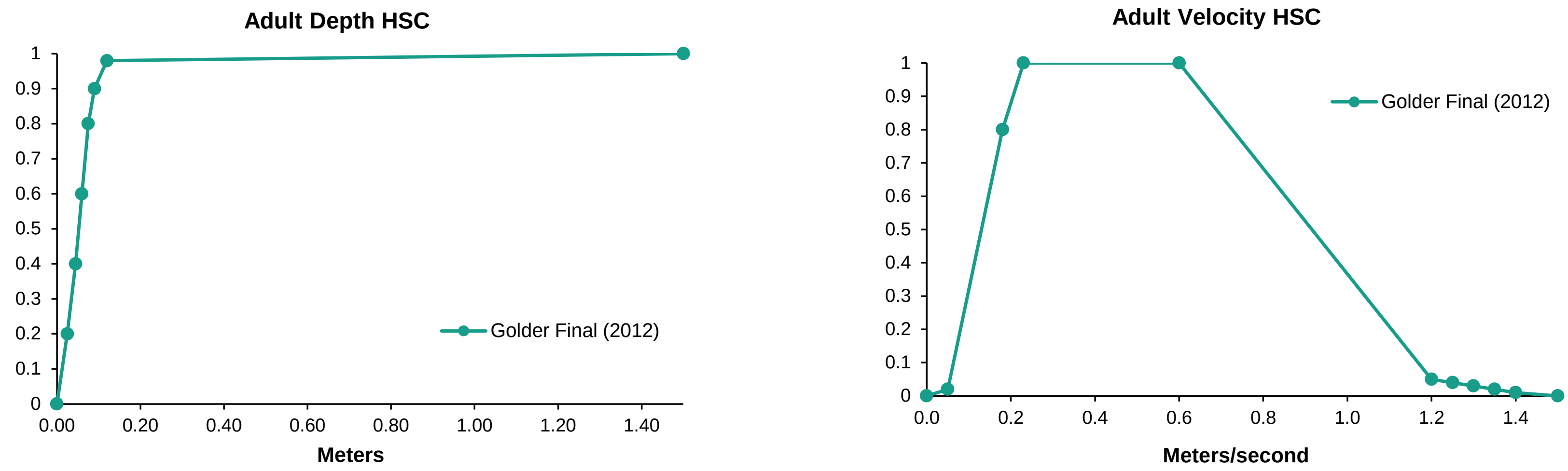


Figure 3-14 WSCT Adult (Rearing/Holding) Habitat Suitability Criteria Curves.



Depth HSC (meters)								
Index	0	0.2	0.4	0.6	0.8	0.9	0.98	1
Value	0	0.025	0.045	0.06	0.075	0.09	0.12	1.5

Velocity HSC (m/s)											
Index	0	0.02	0.8	1	1	0.05	0.04	0.03	0.02	0.01	0
Value	0	0.05	0.18	0.23	0.6	1.2	1.25	1.3	1.35	1.4	1.5

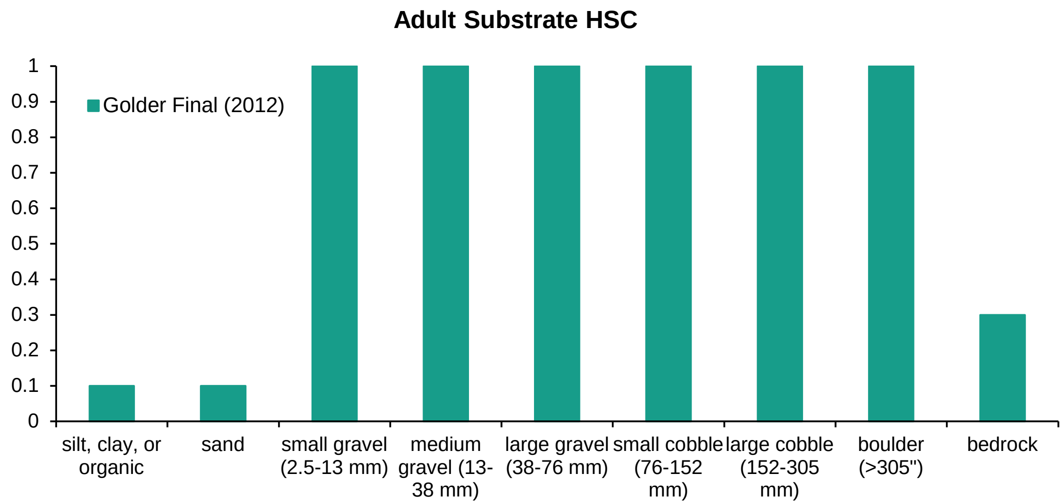
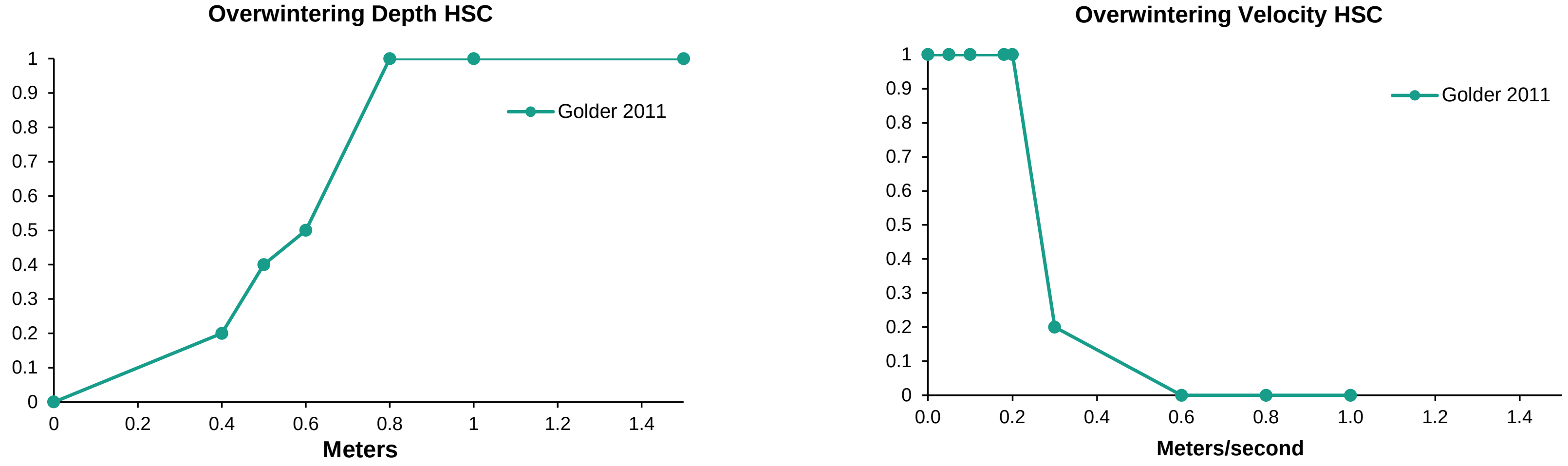


Figure 3-15 WSCT Overwintering Habitat Suitability Criteria Curves.


Overwintering Depth HSC

Overwintering Velocity HSC

Depth HSC (meters)								
Index	0	0.2	0.4	0.5	1	1	1	1
Value	0	0.4	0.5	0.6	0.8	1	1.5	2

Velocity HSC (m/s)									
Index	1	1	1	1	1	0.2	0	0	0
Value	0	0.05	0.1	0.18	0.2	0.3	0.6	0.8	1

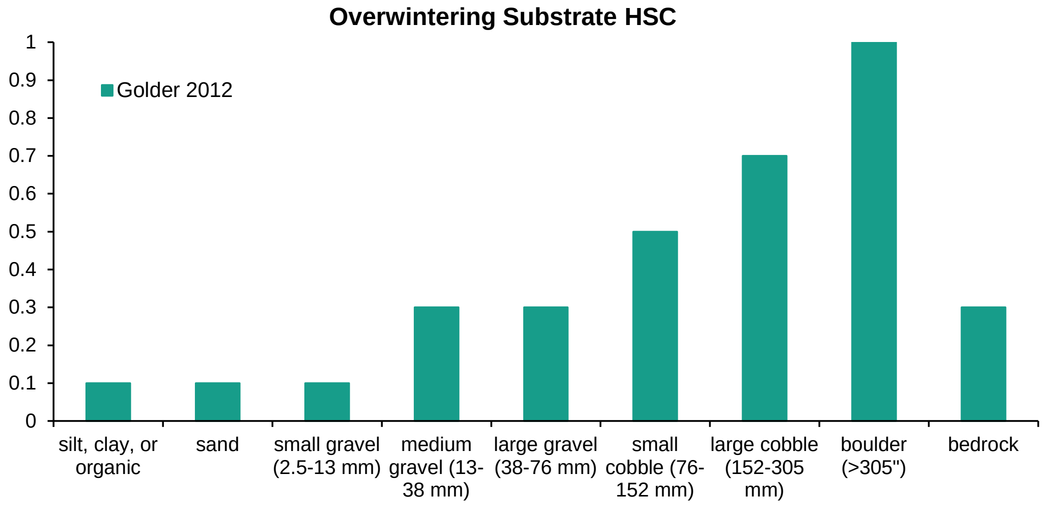
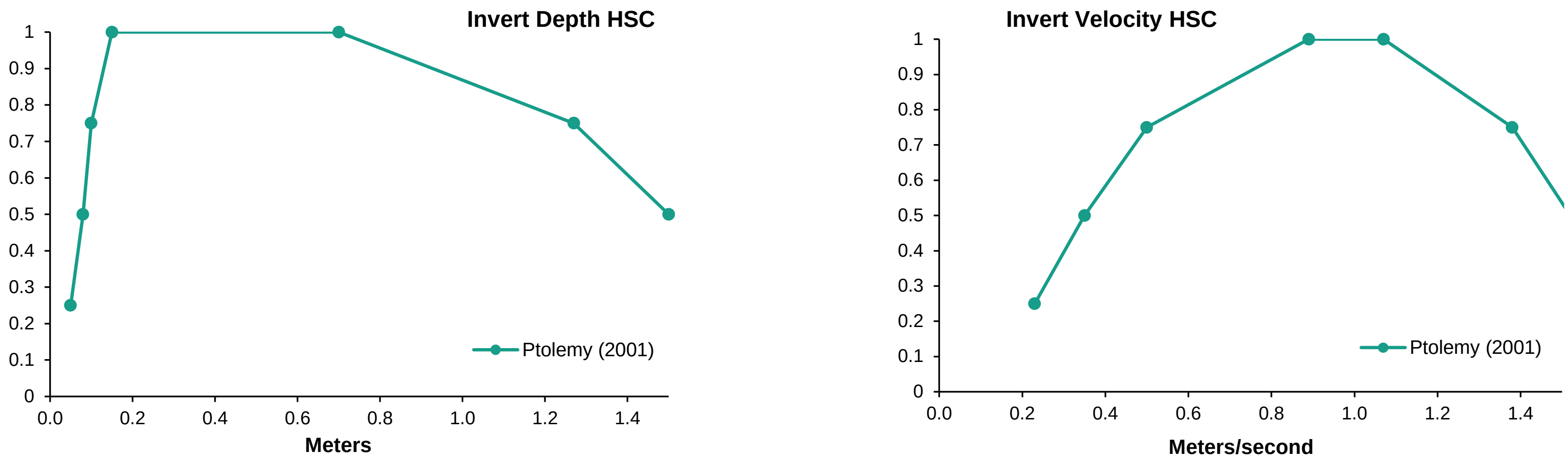

Overwintering Substrate HSC

Figure 3-16 Invertebrate Drift Habitat Suitability Criteria.



Depth HSC								
Index	0.25	0.5	0.75	1	1	0.75	0.5	0.25
Value	0.05	0.08	0.1	0.15	0.7	1.27	1.5	2.94

Velocity HSC								
Index	0.25	0.5	0.75	1	1	0.75	0.5	0.25
Value	0.23	0.35	0.5	0.89	1.07	1.38	1.52	1.66

3.6.2 Development of Hydraulic Habitat Models

3.6.2.1 Data Pre-processing

The required data inputs for each cross-section (XS) were assembled and entered into SEFA, including:

- Cross-section channel bed profile;
- Substrate composition;
- Stream velocity distribution on the survey (initial) flow;
- Measured Stage of Zero Flow (SZF) bed elevation, if available; and
- One surface water elevation (stage) and discharge measurement per field visit.

Within SEFA, the following changes were implemented prior to the calibration of individual XS rating curves:

- Any differences in surveyed surface water elevation across the wetted width (typically a few mm or less) were averaged;
- Any stage-discharge measurements affected by ice during the winter of 2013-2014 and/or 2015-2016 were removed in the case of three (3) joint hydrometric station/XS transects;
- Bank overhangs occurred in a small number of XS (7), but inclusion of these lead to large modeling errors most notably in velocity and were removed[2] in accordance with recommended practice both in SEFA (Jowett et al. 2016) and PHABSIM applications (Waddle 2012);
- Dry channels (i.e., visibly dry sections where bed elevation was surveyed lower than the main channel water surface elevation) occurred at four (4) Blairmore Creek XS, but these were removed[3] to avoid the model incorrectly simulating (over-estimating) the presence of water and habitat availability in these sections (this process likely underestimated habitat at much higher flows when the dry channels became wet); and
- The measured velocity distribution was adjusted[4] at one XS (GC-24, a small pond XS in the most upstream reach on Gold Creek), since measurement conditions were largely stagnant and unsuitable for flow sampling (estimated flow zero), and hydraulic predictions of velocity require a positive survey flow value to run.

The BC-5 braided riffle XS was separated into the component main and secondary channels, each setup with independent bed geometry and stage-discharge measurements, as per SEFA guidelines.

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[2] Bank overhangs were removed by adjusting the horizontal offset of the overhang position, to 0.01 m beyond the water's edge offset, thereby creating a near-vertical wall without affecting the measured stream hydraulic properties such as wetted width

[3] Dry channel sections were removed by adjusting bed elevations to 0.01 m above the highest-surveyed surface water elevation

[4] 0 positive velocity readings spaced 0.1 m apart occurred within a 0.9 m wide section of GC-24, range 0.01-0.04 m/s; these were all increased by a factor of 1.98 (adjusted range 0.02-0.08 m/s) to equalize the total flow measured here and at the adjacent GC-26 XS (run) of 15.2 L/s.

3.6.2.2 XS rating curve calibration

The stage-discharge rating curve for each XS was generated automatically in SEFA, using a best-fit regression technique which minized the deviations between a log-log regression line fitted through the survey flow and other available stage-discharge points including the Stage of Zero Flow (SZF). The fitted equation takes the form of:

$$Q = a * (WL\text{-}SZF)^{b} \qquad [1]$$

where

Q is the discharge, WL is the water level (i.e., stage), SZF is the Stage of Zero Flow, and ‘a’ and ‘b’ are calibration coefficients calculated automatically based on least squares regression. The coefficient ‘a’ represents the discharge when the effective depth of flow (WL-SZF) equals one.

The exponent ‘b’ value is of considerable importance, and depends on a range of factors including the XS channel geometry, and type of hydraulic control (section or channel). An increasing (decreasing) exponent value implies flow changes are increasingly accommodated by changes in velocity (channel area). For natural channels hydraulically controlled by a rock outcrop, riffle, or gravel bar (as is common in North America), the stage-discharge relation conforms to the general principles for flow over a broad-crested weir, and the exponent value ‘b’ should theoretically vary between 1.5 (the exponent for a rectangular weir) and 2.5 (the exponent for a triangular, i.e., notched weir) (Rantz et al., 1982). The Hydrology Project (1999) also stated b to vary between 1.6-2.5 for most geometrical shapes of channel, with the exception of deep narrow rivers (‘b’ occasionally above 3), or compound rivers with flat braided channels and/or flows across the floodplain (‘b’ occasionally above 5). Unusual stage-discharge relations and the value of ‘b’ may also occur due to temporary channel cross-section changes associated with scour and fill, growth and decay of aquatic vegetation, debris jams and ice, or during periods of highly unsteady (rapidly changing) flow (e.g., Braca 2008).

Rating curves for the five (5) joint hydrometric station/XS transects were initially developed within Aquarius Software (version 3.1) (Aquatic Informatics 2016) for purposes of producing daily flow time-series at the local gauges, using a best-fit regression method similar to SEFA. Three of these locations contained a large number of available stage-discharge measurements (approximately 10 in the instance of BC-0/H01, BC-15/H03 and GC-7/H01 dating back to 2013), and the final range of ‘b’ exponents across all five (5) locations was calculated to be 2.0-2.5 (i.e., within the expected range of ‘b’ values outlined above). Rating curves for the same locations were then setup in SEFA for predicting hydraulic and habitat conditions, and final curve equations were virtually identical except for minor differences associated with the SEFA procedure of passing the fitted curve through the survey flow (Aquarius does not).

For all other XS locations, the number of available stage-discharge measurements was limited between two and five, though measurements at most XS locations of the SZF (i.e., theoretical stage where flow would cease) served as an additional, quasi stage-discharge measurement. The choice was made to restrict predicted ‘b’ values at these locations, to the theoretical range of 1.5-2.5 later assessed as appropriate to this study based on the calculated ‘b’ values obtained for joint hydrometric station/XS locations. In many instances, the automated curve fitting procedure produced ‘b’ values between 1.5-2.5, even with relatively limited data, and no further action was required. Where ‘b’ was initially predicted outside of this range, the SZF value (whether estimated from field surveys or as the XS thalweg in the absence of any information) was adjusted on a trial-and-error basis until the corresponding ‘b’ value fell within range.

This calibration method, restricting the value of ‘b’, is theoretically much stronger with respect to XS hydraulic predictions when extrapolated far outside of the measured range of flow conditions. It follows that different combinations of calculated ‘a’, ‘b’, and SZF values applied within equation [1] can produce near-identical rating curves over the measured range (both in terms of model error statistics and when plotted visibly). However, these same rating curve parameter combinations will produce, increasingly divergent hydraulic predictions as the simulated flow range extends further away from the measured flow range. For instance, the predicted ‘b’ value will be much higher (potentially 5 or more) for a pool XS if the SZF was not field-surveyed and the software defaults to using the pool thalweg depth (e.g., 0.6 m), than if the true (field-surveyed) SZF value was applied instead (e.g., 0.2 m depth at the pool tailout, resulting in a ‘b’ value of 2.5). For any given increase in flow, the rating curve with ‘b’ value 5 would then predict a small or even negligible rate of stage change, offset by a very large (and likely unrealistic) gain within mean velocity, relative to the rating curve with ‘b’ value 2.5, which would more realistically predict moderate changes both within stage (i.e., depth and area) and mean velocity. It is because of this type of uncertainty that hydraulic predictions are not recommended outside of the measured flow range (e.g., Rantz et al. 1982), but this criteria is too restrictive for most predictive studies. SEFA guidelines for extrapolating rating curves (no greater than 2.5 times the highest measured flow or no less than half the lowest measured flow, Jowett et al. 2016) were largely followed in the current study by using monthly flow simulations.

Two metrics were calculated in SEFA to evaluate the goodness of fit of each calibrated rating curve to available stage-discharge measurements. These included the mean error in discharge (i.e., the average percentage error between predicted discharges using the rating curve, and measured discharges) and the coefficient of determination (R^2) between measured and predicted stages (Jowett et al. 2016).

3.6.2.3 Velocity Calibration

The SEFA prediction of velocity distribution is as follows. Each calibrated rating curve is used to predict the stage (water surface elevation) for a given discharge value, from which the water depth distribution and cross-sectional area can also be predicted (based on water surface location above the measured bed profile). Since discharge represents the product of cross-sectional area and mean velocity, mean velocity can be estimated as discharge divided by cross-sectional area. For predicting the distribution of velocities across each XS, the measured velocity distribution obtained at the survey flow is adjusted at each point using a Velocity Distribution Factor (VDF), until the required mean velocity is achieved.

Similar to Manning’s N roughness coefficient for a point measurement, VDFs represent the ratio of measured velocity at a given point, to the velocity calculated assuming uniform flow conditions across a transect and that point velocities are proportional to water conveyances at that point. By default, dry points on the bank during the survey flow are assigned VDF values equal to the nearest measured point in water, for the purpose of estimating velocity conditions at those same bank locations when submerged as part of higher flow simulations (Jowett et al. 2016).

The predicted VDF and resulting velocity values are likely to be overestimated at bank locations where there are obstacles such as trees, boulders or large woody debris, which are unlikely to move even in significant flooding events. The calibration procedure in these instances was to locate these on the XS using field notes and photographs, then to adjust the corresponding predicted VDF values to zero. This forced predicted velocities at these obstacle locations to be zero across the range of simulated flows, which is a more realistic outcome than when no obstacle is introduced. There were no VDF adjustments completed inside the wetted width section (during the survey flow).

The 'best estimate VDF' sensitivity tool available within SEFA (Jowett et al. 2016) modifies predicted velocity distributions from the measured (calibrated) distribution at low-flows to uniform distribution at high flows was applied in the case of one low-flow and one high-flow reach (Gold Creek reaches 8 and 7, respectively) to quantify uncertainties in higher-flow velocity distribution. A more uniform velocity distribution at high flows (than was measured at low-flows) represents a fair assumption for certain XS and mesohabitat types (e.g., riffles and runs where larger sediments become 'drowned out' or mobile during higher flows), but is incorrect at others (e.g., plunge pools with flow-diverting boulders where the velocity distribution remains highly irregular across the range of expected flows).

3.6.2.4 Calculation of Available Habitat

Individual XS

The amount of physical habitat area can be predicted at each XS for a range of flows or a time-series of flows (e.g., monthly flow values or across bioperiods) following the calibration of hydraulic variables specific to each XS. Firstly, the Combined Suitability Index (CSI) is calculated by multiplying the habitat suitability criteria (between 0 and 1) for depth, velocity and substrate (Section 3.6.1) to the physical characteristics (water depth, velocity, substrate) simulated across each XS. AWS is then calculated as the CSI weighted by area, in units of square metres of habitat per metre of stream channel length or width (m^2/m) (Jowett et al. 2016). As a hypothetical example, the AWS of a 1 m long section of stream channel, containing a 5 m wide XS, will be 5 m^2/m, 2.5 m^2/m and 0 m^2/m for XS-averaged CSI values of 1, 0.5, and 0 respectively.

Reach-scale

The combined AWS for each study reach is calculated by weighting individual XS results of AWS, by the relative abundance of each mesohabitat sampled by individual XS. The proportions of runs, riffles and pools comprising each reach were estimated as follows, since these were the basic mesohabitat types sampled within the network of IFA XS. Of the six morphology types used to characterize mesohabitat distribution within these Creeks (Hatfield 2016a: Section 3.3), three were individual run, riffle and pool units, and their corresponding reach proportions required no adjustment for the purposes of this analysis. The remaining three, including riffle-run-pool, pool-riffle and step-pool were assumed to represent the following composition of runs, riffles and pools:

Riffle-run-pool:	30% run, 60% riffle, 10% pool;
Pool-riffle:	10% run, 70% riffle, 20% pool; and
Step-pool:	10% run, 60% riffle, 30% pool.

Table 3-7 summarizes the various reach-scale distributions mapped and applied within SEFA calculations of hydraulics and AWS (habitat). This includes both the mapped mesohabitat distributions (as shown in

Figure 3-6 for Gold Creek and Figure 3-9 for Blairmore Creek) and recalculated distributions applying the weighting factors outlined above (for aggregated morphology types). The recalculated (run, riffle, pool) distributions indicate that riffles formed the dominant mesohabitat across all reaches (average 69%, range 58-78%), whereas the remaining proportion generally favoured runs (average 19%, range 8-31%) over pools (average 12%, range 6-17%). This was broadly reflected in the number of sampled riffle XS (22 total in the 8 study reaches, Table 3-7), more than in runs (14 total) and pools (6 total), though in relative terms runs and pools were disproportionately sampled (i.e., as a % of the total XS number, relative to corresponding areal coverages). This is because large deep pools generally provide optimum habitat conditions for most WSCT bioperiods (predominant overwintering habitat), whereas runs generally provide not only higher quality habitat (relative to riffles) but important flow measurement locations required to characterize flow conditions specific to each reach (Section 3.4.1).

Table 3-7 **Reach-scale mesohabitat distributions: original mapping, sampled by the IFA XS, and applied within AWS calculations.**

Reach #	Variable	Run	Riffle	Pool	Run-riffle-pool	Pool-Riffle	Step-Pool	Total
Gold Creek								
9	Mapped distribution[1]	8%	8%	1%	5%	78%	0%	100%
	Distribution for IFA analysis[2]	17%	66%	17%	-	-	-	100%
	#IFA XS	1	2	1	-	-	-	4
	% weighting per IFA XS[3]	17%	33%	17%	-	-	-	100%
8	Mapped distribution[1]	5%	6%	2%	87%	0%	0%	100%
	Distribution for IFA analysis[2]	31%	58%	11%	-	-	-	100%
	#IFA XS	2	6	2	-	-	-	10
	% weighting per IFA XS[3]	16%	10%	5%	-	-	-	100%
7	Mapped distribution[1]	18%	29%	1%	17%	35%	0%	100%
	Distribution for IFA analysis[2]	27%	64%	10%	-	-	-	100%
	#IFA XS	3	3	1	-	-	-	7
	% weighting per IFA XS[3]	9%	21%	10%	-	-	-	100%
6	Mapped distribution[1]	10%	48%	2%	3%	37%	0%	100%
	Distribution for IFA analysis[2]	15%	76%	10%	-	-	-	100%
	#IFA XS	2	1	1	-	-	-	4
	% weighting per IFA XS[3]	7%	76%	10%	-	-	-	100%
5	Mapped distribution[1]	0%	30%	4%	5%	61%	0%	100%
	Distribution for IFA analysis[2]	8%	76%	17%	-	-	-	100%
	#IFA XS	1	1	0	-	-	-	2
	% weighting per IFA XS[3]	8%	76%	0%	-	-	-	83%
Blairmore Creek								
5	Mapped distribution[1]	12%	24%	2%	22%	39%	0%	100%
	Distribution for IFA analysis[2]	22%	65%	12%	-	-	-	100%
	#IFA XS	1	1	0	-	-	-	2
	% weighting per IFA XS[3]	22%	65%	0%	-	-	-	88%
4	Mapped distribution[1]	10%	55%	1%	15%	18%	0%	100%
	Distribution for IFA analysis[2]	17%	77%	6%	-	-	-	100%
	#IFA XS	3	6	1	-	-	-	10
	% weighting per IFA XS[3]	6%	13%	6%	-	-	-	100%
3	Mapped distribution[1]	6%	45%	1%	3%	46%	0%	100%
	Distribution for IFA analysis[2]	11%	78%	10%	-	-	-	100%
	#IFA XS	1	2	0	-	-	-	3
	% weighting per IFA XS[3]	11%	39%	0%	-	-	-	90%

Note: for presentation, all % values are rounded to the nearest %.

[1] Mapped distribution using original Fish and Aquatics Technical Baseline Report classification (Hatfield 2016), as replicated in Figure 3-6 (Gold Creek) and Figure 3-9 (Blairmore Creek) of this study.

[2] Mapped distribution reclassified into the three main primary mesohabitat types as sampled in the IFN XS network, using the component % values for aggreagated mesohabitat classes outlined in the text.

[3] % weighting applied to each IFA XS for calculating reach-scale hydraulic and habitat properties in IFN analysis. Total % represents: (# run XS x % weighting per run XS) + (# riffle XS x % weighting per riffle XS) + (# pool XS x % weighting per pool XS). Total % sums to less than 100% in the three reaches with no sampled pool IFA XS.

In SEFA, each IFA XS within a reach was assigned a weighting factor equal to the abundance of the mesohabitat type it represented, divided by the number of XS sampled within each mesohabitat type (e.g., five riffle XS within a reach containing 60% riffles would each be assigned equal weighting of 12%). The calculated weighting (% abundance) factors applied to each IFA XS are summarized in Table 3-7, and are also shown in subsequent graphs displaying hydraulic or habitat predictions specific to individual XS. SEFA then calculates available reach-scale habitat (AWS) as the product of reach length, and AWS calculated at each XS weighted for percent (%) abundance. For instance, a hypothetical 1 km reach consisting of 60% riffles, 30% runs, and 10% pools, as sampled by 1 riffle XS with predicted AWS 3 m^2/m, 1 run XS with predicted AWS 4 m^2/m, and 1 pool XS with predicted AWS 6 m^2/m, would result in [1000 x {(3 * 0.6) + (4 * 0.3) + (6 * 0.1)}] = 3,600 m^2 of available habitat area. The mean AWS value, 3.6 m^2/m, is lower than in run or pool areas due to the areal dominance of riffle areas containing lower quality habitat.

In Reach 5 of Gold Creek, and Reaches 3 and 5 of Blairmore Creek, pools were mapped originally but were not sampled by any IFA XS (Table 3-7); therefore, the weighting factors applied to remaining (run and riffle) XS did not sum to 100% in these reaches.

3.6.3 Biological Stanzas

Fish and other aquatic organisms have evolved along with the biological processes of seasonal variation in river flow (Bunn and Arthington 2002; Poff et al. 1997). Timing, frequency, duration, and magnitude of river flow conditions are temporally variable components of the natural flow regime (Poff et al. 1997).

Faunal habitat needs vary seasonally due to different life stages (e.g., spawning or overwintering) as well as environmental conditions. This approach is captured in the concept of bioperiods (Parasiewicz 2008). Bioperiods are seasons characterized by the habitat requirements of the fauna and of the flow regime itself as each vary through the course of a calendar year. When attempting to assess changes and prescribe protective instream flows, it is necessary to take into consideration these flow and habitat fluctuations.

Predictions of AWS were made for “biologically relevant stanzas” of time defined for key bioperiods of WSCT (spawning/egg incubation, fry rearing, juvenile rearing, adult rearing/holding, overwintering, food supply) present in both Gold and Blaimore Creeks at different times of the year (Table 3-8). These stanzas were selected based on WSCT life-history information (Table 1-1) verified during baseline surveys conducted in both Creeks in 2016 (Hatfield 2016a), and by the shape of the natural hydrograph. The timing and duration of each stanza was selected to best reflect the time periods that determine fish production in any given year. For the sake of simplicity, the end and the beginning of each bioperiod was set to coincide with the beginning or ending dates of a calendar month (Table 3-8, Table 3-9).

Table 3-8 Biologically Relevant Stanzas in Gold and Blairmore Creeks.

Stream	Stanza	Bioperiod
Gold Creek	1 Oct - 30 Apr	Overwintering
	1 May - 30 June	Freshet Flows: substrate scour and cleaning of fine sediments from spawning gravels
	1 May - 31 Jul	Spawning
	1 Jun - 31 Aug	Egg incubation
	1 Jul - 30 Sep	Hatching
	1 Aug - 30 Sep	Fry Nursery (Emergence/Rearing)
	1 Mar - 31 Oct	Rearing (Adult & Juvenile)
Blairmore Creek	1 Oct - 30 Apr	Overwintering
	1 May - 30 June	Freshet Flows: substrate scour and cleaning of fine sediments from spawning gravels
	1 May - 31 Jul	Spawning
	1 Jun - 31 Aug	Egg incubation
	1 Jul - 30 Sep	Hatching
	1 Aug - 30 Sep	Fry Emergence/Rearing
	1 Mar - 31 Oct	Rearing (Adult & Juvenile)

Table 3-9 Westslope Cutthroat Trout Life History and Periodicity for Gold and Blairmore Creeks.

Species	Bioperiod	Life-History Stage											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Westslope Cutthroat Trout	Egg Incubation[1,2]						🟥	🟥	🟥				
	Hatching[1,2,3]							🟥	🟥	🟥			
	Fry Emergence[1,2,3]								🟥 *****	🟥			
	Rearing (feeding)[1,2,3]			🟩 *****	🟩 *****	🟩 *****	🟩 *****	🟩 *****	🟩 *****	🟩 *****	🟩 *****		
	Overwintering[1,2]	🟧	🟧	🟧 *****	🟧						🟧 *****	🟧	🟧
	Spawning Migration[1,2]			🟦	🟦								
	Spawning[1,2,3]					🟦 *****	🟦 *****	🟦					

* indicates where periodicity confirmed by field data collection

🟥 Egg-Fry 🟩 Fry-Adult 🟧 Fry-Adult 🟦 Adult spawn

[1] Fisheries and Oceans Canada. Recovery Strategy for the Alberta populations of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) in Canada [Final]. Species at Risk Act Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. iv + 28 pp + Appendices

[2] The Alberta Westslope Cutthroat Trout Recovery Team. 2013. Alberta Westslope Trout Recovery Plan: 2012-2017. Alberta Environment & Sustainable Resource Development, Alberta Species at Risk Recovery Plan No. 28. Edmonton, AB. 77pp.

[3] Gill, C. 2006. Westslope Cutthroat Trout. Report prepared by Fortsite Consultants for the BC Ministry of Environment.

3.6.4 Assessment of Potential Effects of Flow Changes in Gold and Blairmore Creek

The assessment of potential effects on fish habitat due to changes in flows was conducted using a time series approach. A 1-year time series of simulated mean monthly flows were generated from the 41-year time series of daily flows estimated for each study reach along Gold and Blairmore Creeks; this 1-year time series was assumed to represent baseline flow conditions during 2017 (prior to mine construction in 2018). This 1-year monthly time series was converted to corresponding simulated monthly habitat time series for WSCT spawning and incubation, fry/juvenile/adult rearing, overwintering, and food supply in each watercourse. This was done using the HSC curves and the hydraulic models in SEFA.

The simulated monthly habitat time series for each species life stage during each Project phase were compared to the baseline (1-year) monthly habitat time series to assess potential flow related effects. The project phases included construction (2018; 1-year length), operations (2019-2042; 24-year length), decommissioning (2043-2044; 2-year length) and closure (2045-2099; 54-year length). Doing so provided a comparison of total habitat availability over time (i.e., area under the curve) during different Project phases in each watercourse.

The percentage change in average monthly AWS, as expressed in metres squared (m^2/m), during “biologically relevant stanzas” was the metric used to assess potential effects of predicted flow changes to fish habitat and food supply in Gold and Blairmore Creeks during each Project phase. Average monthly AWS was calculated as the total stanza habitat during each calendar month, divided by the total number of months included in the total stanza estimate.

The threshold for “no significant” effect to fish due to predicted flow changes in each Project watercourse was that at least 90% of total habitat availability remained over the relevant biological stanzas for WSCT (i.e., no more than a 10% reduction in total AWS over each project phase).

The 10% flow threshold was used as the significance screening based on recommendations from recent publications. A recent proposal for a broadly applied “presumptive standard” for evaluating flow departure from natural conditions using a sustainable boundary approach argued that a departure from natural flow conditions of less than or equal to 10% would result in a high level of ecological protection whereby the natural structure and function of the ecosystem would be maintained (Richter et al. 2012). In reviewing available environmental flow assessment methods, a framework for ecological flows to support fisheries in Canada was recently published that incorporates several of the concepts discussed above (DFO 2013). The framework applies a percent-of-flow approach and recommends that cumulative flow alterations remain within 10% of natural instantaneous flow. Maintaining flows within 10% of natural flow was expected to have a low likelihood of having detectable negative effects on the ecosystem (DFO 2013). Due to the complex hydrological dynamics and predicted flow reductions in Gold Creek as well as the notable predicted flow increases in Blairmore Creek, multiple macro-reaches within both watercourses were assessed below the 10% threshold.

3.7 ASSUMPTIONS AND LIMITATIONS

All models are simplistic depictions of reality and, by their nature, include various assumptions and limitations. Both limitations in models and the inherent variability of physical and biological systems mean that there are uncertainties in model predictions. Models may not predict future conditions accurately or may make predictions with high degrees of uncertainty. Conservatism in making assumptions can lower the probability of Type I errors (i.e., predicting an effect when no effect actually occurs or “false positives”) and Type II errors (i.e., predicting no effect when an effect actually does occur or “false negatives”). Doing so lowers the risk of making incorrect management decisions due to uncertainty.This IFA uses calibrated hydraulic habitat models to represent and predict how the availability and suitability of habitat for various bioperiods associated with westslope cutthroat trout varies with stream flow. These models were used to assess potential effects to the species during mine-phase scenarios. These models rely on four sources of input data:

- Species-specific habitat suitability curves that depict the preference for different water depths, velocities, and substrate (where applicable) by different life stages of WSCT;
- Mapped distribution of mesohabitats across model reaches for weighting cross-section results;
- Hydraulic relationships depicting how water depths and water velocities vary with flow; and
- A hydrological data time series that depicts baseline flows and predicts flows under different future conditions.

There are limitations within each of these inputs that translates into uncertainty within the predictions and results of this IFA. The species-specific habitat suitability curves were developed based on extensive development and evaluation from multiple sources (e.g., provincial data sets, nearby studies), and fish-specific data generated during field surveys for this Project (spring, summer, overwinter snorkeling data) were used to ensure representation of site conditions. The main uncertainties related to flows, hydraulic variables, and mesohabitat distribution are summarized in Table 3-10.

3.7.1 Time-series Approach

Potential effects due to flow changes caused by construction, operation, decommissioning, and closure of the Project were assessed using a time-series approach. This approach reflects the availability and suitability of habitat for fish over the long-term by summing the total available habitat predicted by the hydraulic habitat models and HSCs over the predicted flow time series. The resulting aggregate statistic of AWS was used to assess whether significant adverse effects will occur by comparing predicted AWS under each project phase to AWS under baseline conditions. This is appropriate because the same underlying flow time-series is used for baseline and Project phase scenarios.

This time-series approach is considered state-of-the-science and is the method recommended by the BC Instream Flow Guidelines. However, like any approach, it has its limitations and assumptions. First, it assumes that the flow time-series used is broadly representative of conditions that fish would experience over the duration of the project phases. Therefore, the longer the flow time-series used, the more likely extreme events are included. This study took advantage of a 41-year time series of daily flows compiled directly from the Gold Creek WSC hydrometric gauge and generated a 1-year time series of simulated mean monthly flows estimated for each study reach along Gold Creek. While no corresponding long-term gauge was available on Blairmore Creek, a scaled version of the Crowsnest River daily flow record could be used given there was good correlation between concurrent daily flows on Blairmore Creek and Crownsest River spanning both low-flow and high-flow conditions (Appendix A1). We consider the 41-year data set to be copious for assessing potential effects across Gold and Blairmore creeks because this length of time includes representative wet and dry conditions that have occurred over the 41 year data record.

Second, the models used a monthly time-step instead of a daily time-step. This was necessary because the watershed model cannot accurately represent the changes caused by the Project on a daily time step. While this limitation prevents the analysis of extreme high and low flow events that fish would experience in any given day in any given year, the monthly time-step was considered sufficiently accurate to predict potential effects to different life stages of fish. This is because production of different life stages of rainbow trout and kokanee typically reflect stream habitat conditions over the course of months (e.g., summer rearing) as opposed to days. Generalizing over a monthly time-step was therefore consistent with the duration of use and with the biological stanzas selected for analysis.

Third, by aggregating AWS over time, the time series approach does not analyse individual extreme events. These events, such as they exist in the flow time series, are instead amalgamated into the final total AWS statistic. Because of this, the effects of potentially flow-limiting events, such as extreme dry conditions, are not explicitly modeled or assessed. This limitation is addressed by using conservative assumptions on how the output data is interpreted (see below for details) and is therefore not considered to result in inaccurate or unrealistic predictions.

Finally, the time-series approach assumes that any change in flow has an instantaneous effect on habitat, its use by fish, and fish production. In reality, the response of fish populations to changes in flow is more plastic and reflects a longer past history (e.g., poor spawning conditions the previous year). Therefore, because the time-series approach allows instantaneous improvement or degradation of habitat conditions, it ignores the population level effects of these good and bad events. In general, this tends to result in conservative estimates of potential effects, so our modelling results are considered to reasonably assess and address the potential for Project-related effects.

Monitoring to evaluate the accuracy of WSCT hydraulic habitat model predictions and the potential effects of flow changes in Gold and Blairmore creeks will be required during the operations and closure periods. Monitoring will need to continue until long-term trends in habitat availability have been confirmed.

Table 3-10 Key uncertainties within IFA data inputs, and methods to quantify and/or reduce these uncertainties within the current study or in future surveys.

Variable	Uncertainty/Limitation	Actions taken to quantify and or reduce uncertainties (including any conservative approaches used)	Recommended future monitoring to reduce uncertainty/limitation
Hydrology (flow time-series)	Long-term WSC Gold Creek gauge provides invaluable long-term record of flow variability for Gold Creek watershed, April-November annually, and short-term gauges on Gold (GC-7/H01) and Blairmore (BC-0/H01 and BC-15/H03) Creeks provide some confidence of flow variability closer towards the mine area, across a wide range of flows (e.g., winter and high freshet flows in 2014; drought conditions in 2016). Key uncertainties in streamflows, with emphasis on most critical fish habitat, remain: ▪ Along the length of both Creeks during winter low flows; ▪ Blairmore Creek in Reaches 3 to 4 (area of predicted large winter flow increases at end of operations); and ▪ Gold Creek in Reaches 6, 8 and 9 (low-flow reaches subject to Project-related flow losses). Temporal and spatial flow changes in Gold Creek (Reach 6) are the least understood, and may be non-linearly related to temporal flow changes in adjacent reaches based on the flow pathways taken through the rock-drain (e.g., primarily subsurface during extreme drought conditions and primarily surface during higher flows; Figure 3-4). Assumptions have been made in this study that (a) no climate change impacts affect weather and flow patterns throughout the mine life, and (b) predicted Project flow changes to total runoff (SRK 2016b) are identical to changes in surface flows. Addressing these uncertainties is beyond the scope of this project, but surface flows may either increase or decrease if either assumption is invalid.	Synthethic streamflows produced for hydrometric station locations were adjusted per reach using the ratio of flow measurements at hydrometric stations to reach-specific locations (Appendix A1); adjustments based on drainage area would grossly overestimate Gold Creek flows upstream of Caudron (Reaches 8 and 9) and around Lille (Reach 6). Many reach-specific locations used in this process were selected in the upper reach extent (i.e., above any small tributary inflows), to maintain some conservatism within the derived reach flows (e.g., GC-26, GC -23, GC-1 in Gold Creek Reaches 9, 8, and 5 respectively; BC-12 in Blairmore Creek Reach 4); in Gold Creek Reach 7 the downstream location (GC-7/H01) with lower measured flows was used. Each IFA field program was conducted as efficiently as possible, to reduce the potential for changes in weather and flows that would degrade the hydrologic calibration process (e.g., translating hydrometric-station to individual reaches based on measured flow differences) and the understanding of spatial flow patterns across the entire study area. Conservative habitat simulations used low flow metrics (1-in-10 and 1-in-20 year low flows) corresponding with dry conditions to identify worst-case habitat losses relative to long-term average baseline conditions. Conservative project flows were applied within simulations across Blairmore Creek Reach 4 using SRK 2016c prediction data from node BL-02 (near downstream end) instead of node BC-07 (upper end); other reaches did not have multiple nodes available to select from.	Install additional year-round hydrometric gauges towards the upstream extent of Gold Creek Reach 9 (e.g., around XS GC-26), Reach 8 (e.g., around GC-22) and Reach 6 (e.g., around GC-3), also Blairmore Creek Reach 4 (e.g., around BC-12) and Blairmore Creek Reach 3 (e.g., around BC-3).
Range of stage-discharge measurements	The majority of XS rating curves were developed from June-October 2016 stage-discharge measurements covering a limited flow range (almost entirely below long-term MAD, measured flow range ≤ 50% difference between lowest and highest flows, and measured stage range ≤ 0.1 m difference), though these low flow data are invaluable for characterizing habitat-limiting conditions for most WSCT life cycles. Errors within discharge measurements become increasingly larger at lower flows (e.g., stream depths measured to 1 cm accuracy represent larger measurement errors within a stream 0.1 m deep relative to a stream 0.5 m deep).	Adherence to rating-curve theory (e.g., range of exponent 'b' values) when extrapolating hydraulic predictions to higher flows. Uncertainties in flow-habitat predictions were implicitly reduced through use of a monthly model timestep which averages the much higher range of daily flow variability. For reaches with 3 or more XS, a bootstrap procedure was used to determine 80% confidence intervals in these predictions across the range of flows simulated. Potential measurement errors in discharge measurements were reduced as much as possible; e.g., velocity measurements used recommended 40-second) sampling intervals and the ADV flowmeter (this technology can more reliably operate in shallower streams down- to ~0.05 m depth- compared to propeller-type (e.g. Swoffer) flowmeters).	Complete XS surveys in average and wet conditions to validate the existing rating curves and predictions of stage (and derived geometry variables, e.g., width, depth, area) resulting from these curves
Stream velocity	XS distributions in riffles and pools were measured during the initial (survey) flow then model-extrapolated across the range of monthly flows as per SEFA guidelines. Other studies (e.g., Ecofish 2011) interpolated between measured velocity distributions spanning a wide flow-range, but this was not possible given the limited range in flows and velocities in the current IFA. Theoretically, the velocity distribution becomes more uniform at higher flows as the effects of larger sediments or roughness elements are 'drowned out' (e.g., Jowett et al 2016).	The bootstrap procedure outlined above integrates stream velocity on flow-habitat productions. The 'best estimate VDF' sensitivity tool available within SEFA (Jowett et al. 2016) modifies predicted velocity distributions from the measured (calibrated) distribution at low-flows to uniform distribution at high flows was applied in the case of one low-flow and one high-flow reach (Gold Creek reaches 8 and 7, respectively) to quantify uncertainties in higher-flow velocity distribution.	As above; complete high-flow XS surveys for characterizing velocity distributions to validate model predictions and refine (e.g., interpolate between low- and high-flow distributions)
Winter hydraulics	Rating curves developed from open-water measurements lead to hydraulic prediction errors under ice (due to ice effects on geometry and friction), but overwintering WSCT are likely restricted to deeper mesohabitats (e.g., pools) which represent a small proportion of reach lengths (Table 3-7) and are less sensitive to winter low flows or ice effects (e.g., Bradford and Heinonen 2008).	Continuous streamflow data at hydrometric stations (ultimately across reaches) were corrected for ice-effects such as backwater (Appendix A1)	Identify pertinent results from an ongoing over-wintering habitat study by University of Lethbridge; conduct additional hydraulic sampling as necessary.
Mesohabitat distribution	The IFA XS network did not sample any extremely high-gradient mesohabitats (e.g., chutes, waterfalls), although the wider distribution of these is very limited in both Creeks and they provide poor quality (or no) habitat for most WSCT life cycles (Hatfield 2016a). The final number of riffle to deeper mesohabitat (e.g., run/glide/pool) XS slightly under (over) represented corresponding reach-scale distributions (Figure 1-1, Table 3-7), but runs/glides provide optimum flow measurement locations and glides/pools generally provide better quality habitat.	Individual XS were classified within riffles, runs and pools; the results from these were then weighted according to the mapped mesohabitat distributions for each reach. Similarly, reach-scale habitat predictions for the three reaches with no pool XS were assumed representative for the majority (run and riffle) of reach length and did not attempt to make up (potentially overestimate) the remainder of reach habitat within pools.	Establish an XS in extremely high-gradient (chute/waterfall) mesohabitat to validate the assumption of poor quality/no habitat.

4.0 HYDRAULIC MODELLING RESULTS

4.1 GOLD CREEK

4.1.1 Flow-Hydraulic Relationships

The results of simulated hydraulic properties at each XS are grouped into the five study reaches on Gold Creek, and presented from Figure 4-1 (Reach 9, most upstream) to Figure 4-5 (Reach 5, most downstream). In each instance, the results include the calibrated rating curves (modelled stage-discharge relationships), and simulated flow-dependent relationships with XS wetted width, XS mean depth, and XS mean velocity. For clarity at lower flows, the graphs do not extend much above the stated range of predicted monthly flow values in each reach during the simulation period (baseline through closure phases).

Overall, the 23 calibrated XS rating curves across all reaches (Figure 4-1 to Figure 4-5) were of good model accuracy against measured stage-discharge data (the 5 XS with only 2 measured stage-discharge points were excluded from this analysis). The average R^2 was 0.97 and the average mean error was 7.0%. All 23 R^2 values were 0.87 or higher, and the mean error was less than 10% at 18 of 23 XS (10-25% at the remaining five XS).

The relationships between flow and each simulated hydraulic variable were in line with expectations and and corresponding results from similar studies (e.g., AMEC 2015). Wetted widths were largely insensitive to changes in flow above a certain threshold (approximately 0.05 m^3/s, though this varied between reaches), and decreased more rapidly below this threshold down towards zero flow. Both wetted widths and average depths were commonly smallest in riffles, intermediate value in runs, and largest in pools. Conversely, mean steam velocities were commonly slowest in pools, intermediate speed in runs, and fastest in riffles.

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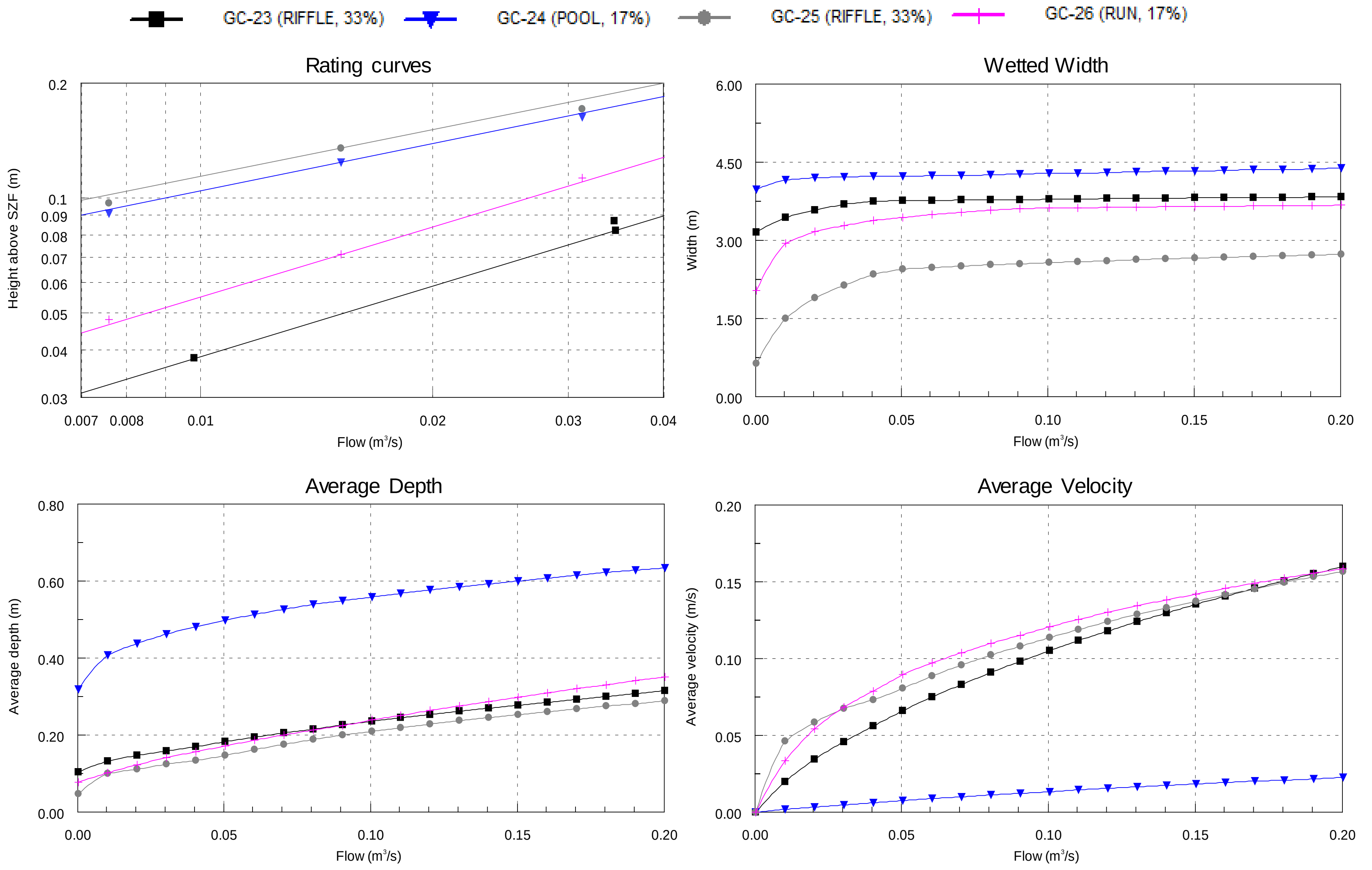
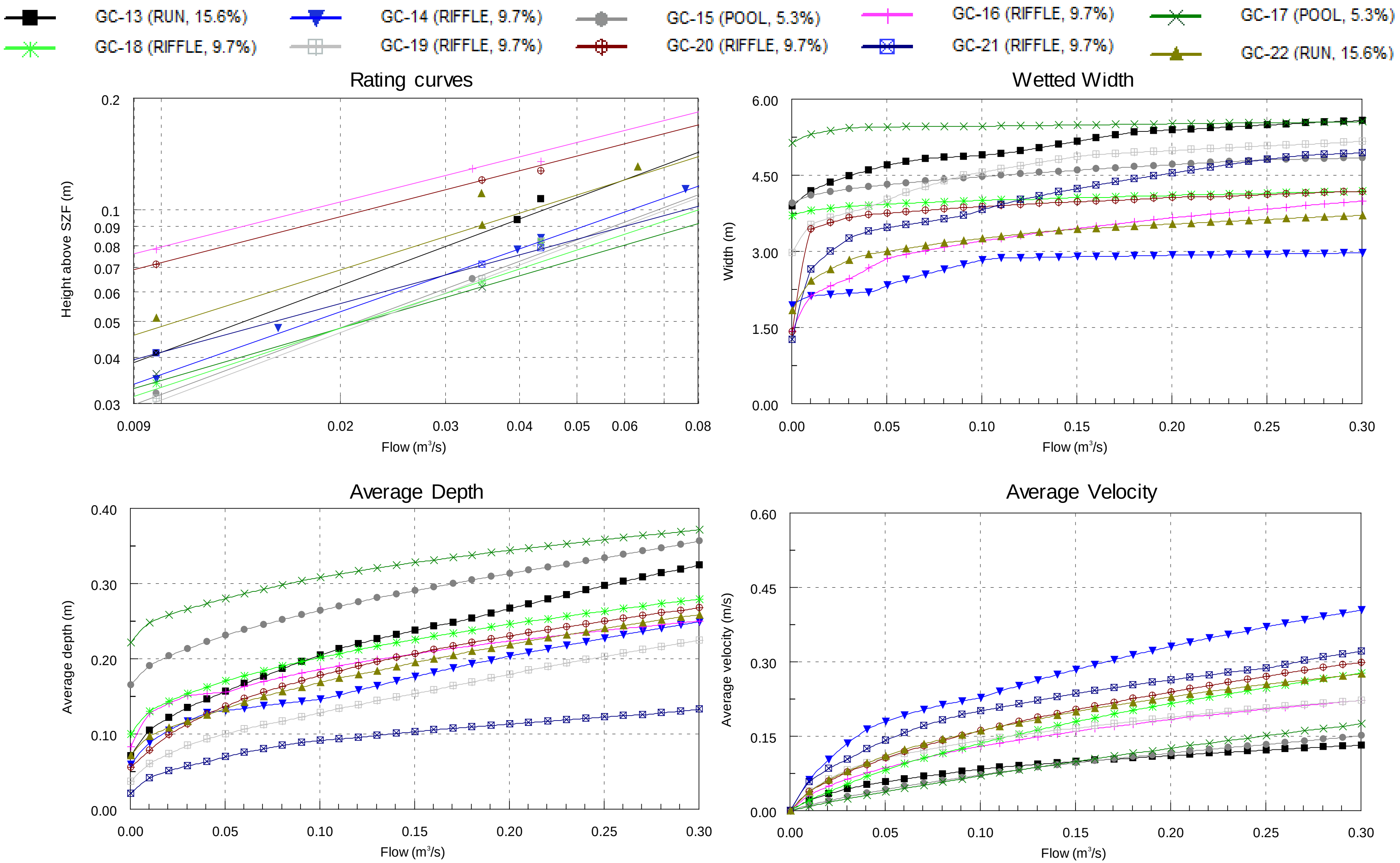
Figure 4-1 Predicted hydraulics at Reach 9, Gold Creek.



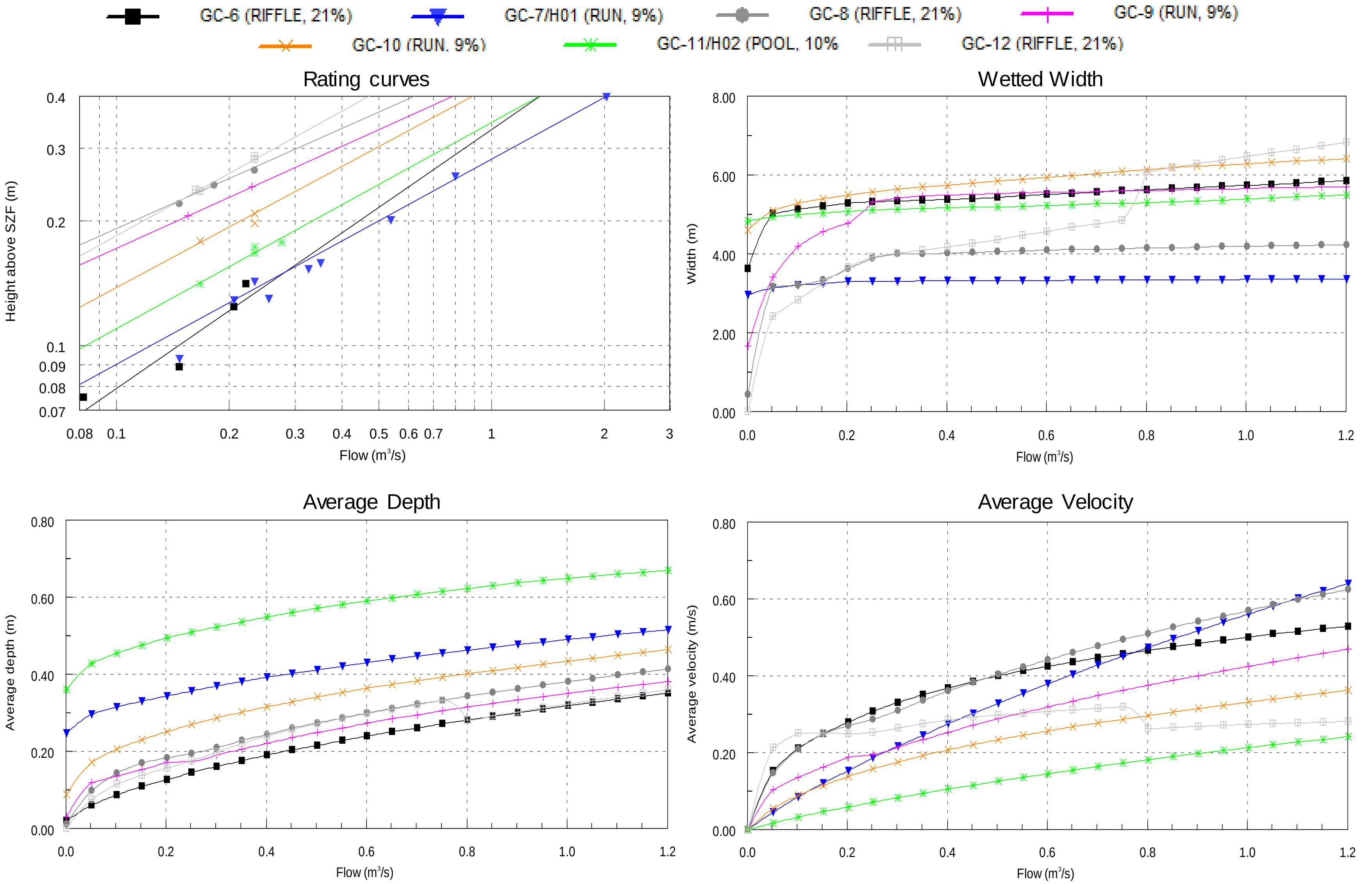
Note: For average hydrological conditions during baseline, the MAD is 0.047 m^3/s and MMD range from 0.005 m^3/s (February) to 0.185 m^3/s (June)

Figure 4-2 Predicted hydraulics at Reach 8, Gold Creek.



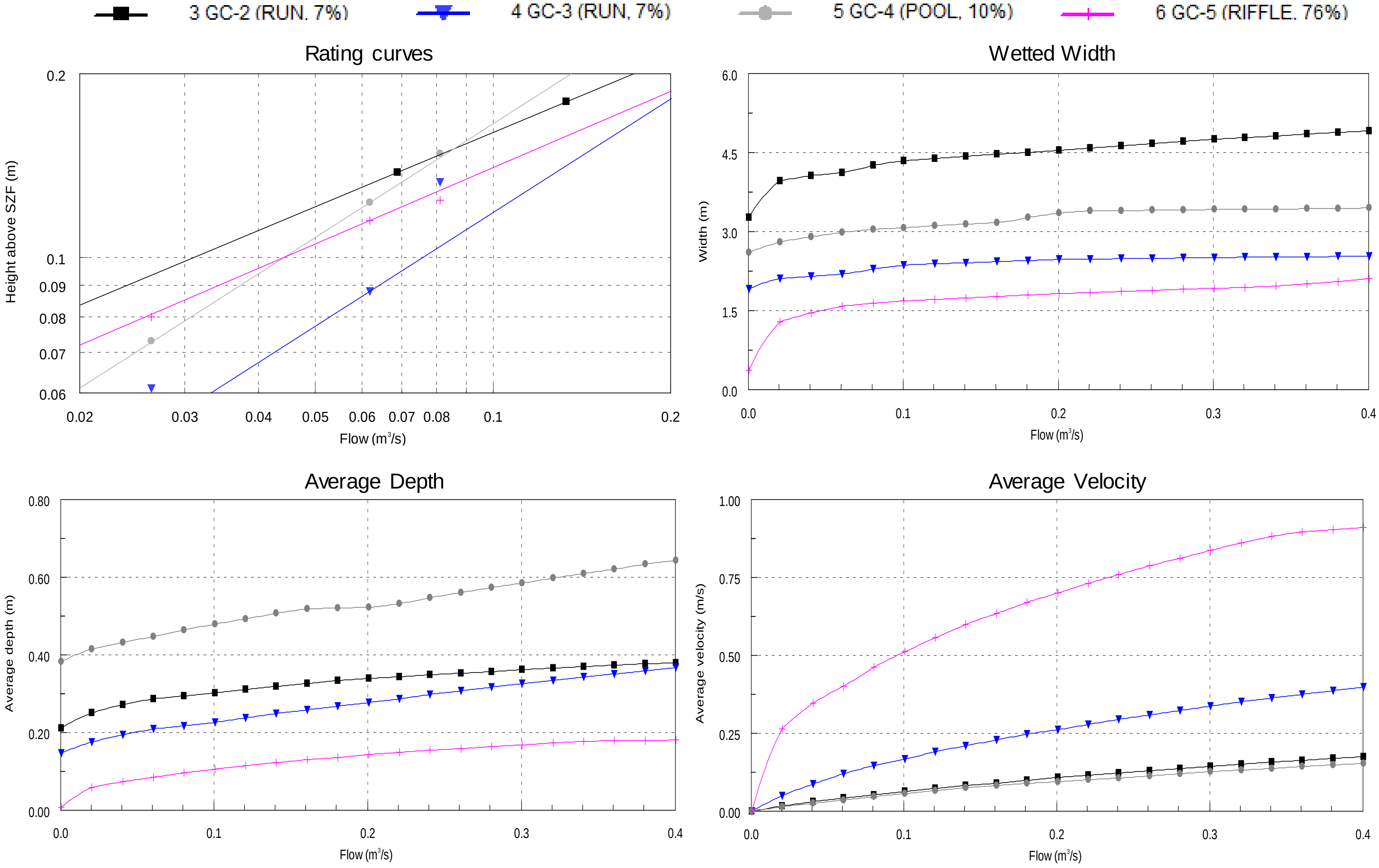
Note: For average hydrological conditions during baseline, the MAD is 0.068 m^3/s and MMD range from 0.008 m^3/s (February) to 0.268 m^3/s (June)

Figure 4-3 Predicted hydraulics at Reach 7, Gold Creek.



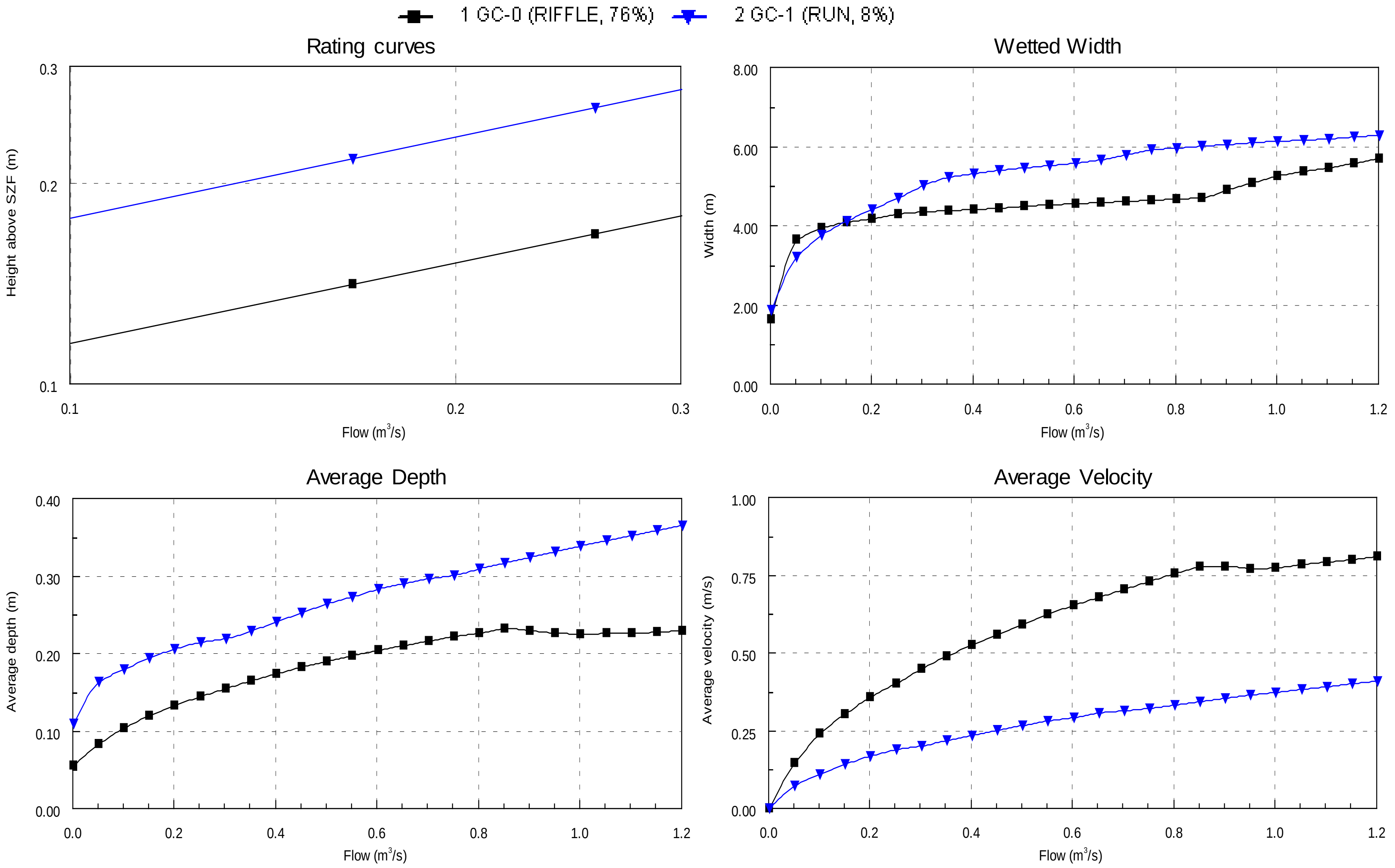
Note: For average hydrological conditions during baseline, the MAD is 0.342 m^3/s and MMD range from 0.133 m^3/s (February) to 1.038 m^3/s (June)

Figure 4-4 Predicted hydraulics at Reach 6, Gold Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.105 m^3/s and MMD range from 0.041 m^3/s (February) to 0.319 m^3/s (June)

Figure 4-5 Predicted hydraulics at Reach 5, Gold Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.392 m^3/s and MMD range from 0.152 m^3/s (February) to 1.190 m^3/s (June)

4.1.2 Flow-Habitat Relationships

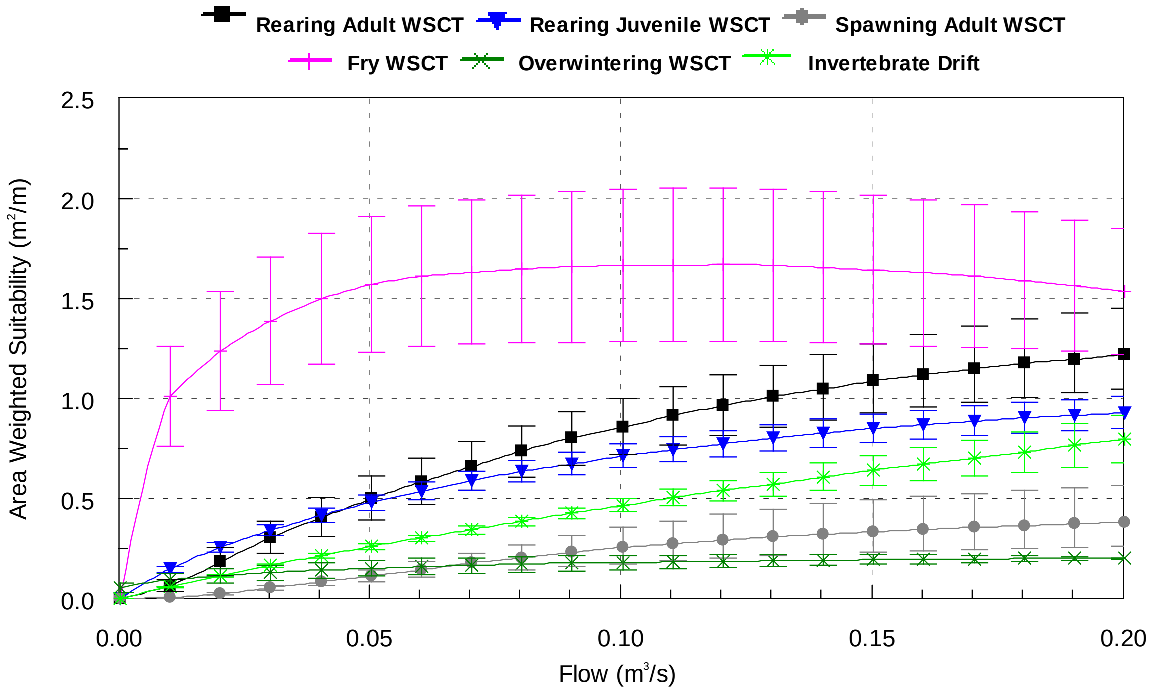
The results of simulated flow-habitat relationships across each reach are presented from from Figure 4-6 (Reach 9, most upstream) to Figure 4-10 (Reach 5, most downstream).

Reaches 9 and 8

Upstream of Caudron Creek confluence in Reaches 9 and 8 (Figure 4-6 and Figure 4-7, respectively), habitat quality (as indicated by AWS) increased across the range of monthly simulated flows, for the adult and juvenile rearing, spawning and overwintering bioperiods. For adult rearing, AWS during June (the highest MMD) was approximately 1.2 m^2/m and 2.2 m^2/m in Reaches 9 and 8, respectively, whereas corresponding spawning values were lower (0.9 m^2/m and 1.2 m2/m, respectively) given the reduced suitabilities of spawning WSCT to depth, velocity and substrate (Section 3.6.1). Overwintering habitat remained extremely limited (<0.1 m^2/m) for flows of ≤0.01 m^3/s which characterize the December-March MMD in both reaches.

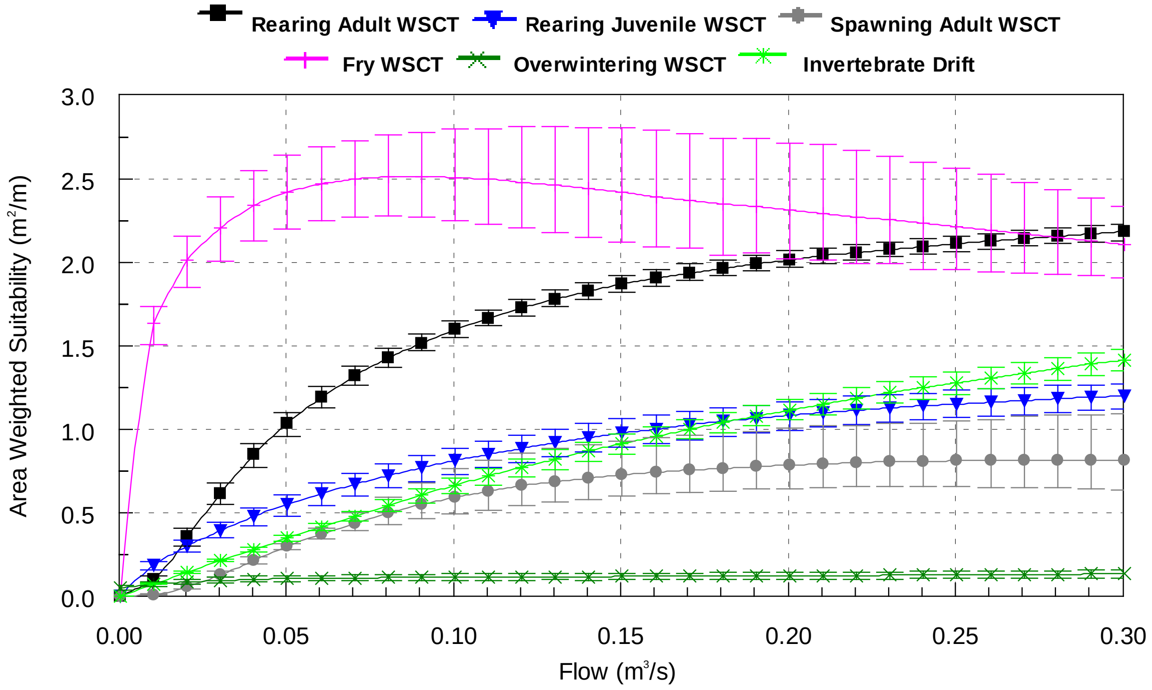
Fry habitat increased exponentially at very low flows, given the suitability of fry to shallower and slower water (Section 3.6.1), and remained higher for all other bioperiods across the range of MMD simulated in these reaches. MMD values during August (when fry typically emerge; Table 3-8) of 0.04 m^3/s (Reach 9) and 0.06 m^3/s (Reach 8) were near-optimum for maximizing fry AWS, though AWS values during much wetter conditions decreased in response to lower suitabilities associated with deeper and faster water.

Figure 4-6 Habitat (AWS) as a function of flow, Reach 9 Gold Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.047 m^3/s and MMD range from 0.005 m^3/s (February) to 0.185 m^3/s (June). Confidence bars shown at the 80% level using 2,000 bootstrap runs.

Figure 4-7 Habitat (AWS) as a function of flow, Reach 8 Gold Creek.



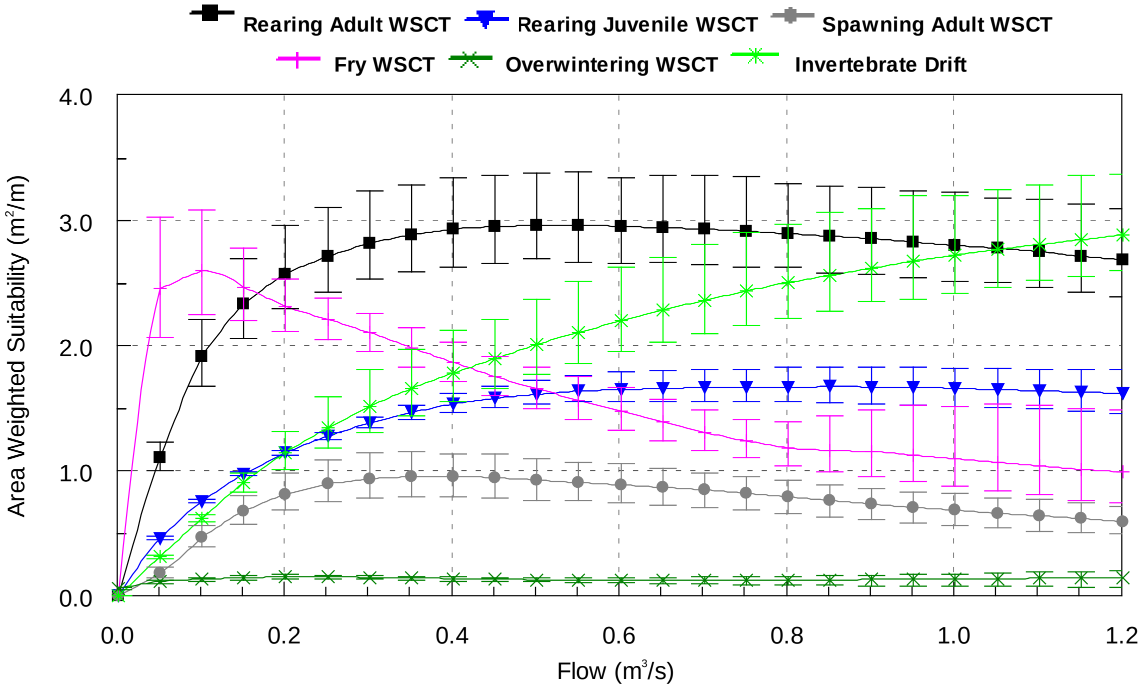
Note: For average hydrological conditions during baseline, the MAD is 0.068 m^3/s and MMD range from 0.008 m^3/s (February) to 0.268 m^3/s (June). Confidence bars shown at the 80% level using 2,000 bootstrap runs.

Reach 7

In the higher flow conditions associated downstream of the Caudron Creek-Gold Creek confluence, habitat quality in Reach 7 was most notably higher for adult and juvenile rearing (Figure 4-8). Maximum AWS values of 3 m^2/m (adult rearing) and 1.7 m^2/m (juvenile rearing) were reached at the optimum flows of ~0.6 m^2/m and ~0.8 m^2/m respectively, which generally characterize MMD in May and July. During peak freshet in June (MMD ~1.0 m^2/m) or in wetter conditions, AWS slowly began to decrease as mean stream velocity increasingly exceeded the threshold for optimizing habitat quality (0.6 m/s for both adult and juvenile rearing, Section 3.6.1); predicted XS velocities shown in Figure 4-3).

Optimum fry habitat was 2.5 m^2/m AWS at 0.1 m^3/s, though for normal conditions during fry emergence (August-September, MMD 0.24-0.29 m^3/s) the predicted AWS was slightly lower. While optimum spawning habitat was ~1.0 m^2/m AWS at 0.4 m^3/s, habitat was insensitive to higher flows and remained above 0.7 m^2/m throughout spawning (MMD ~0.5-1.0 m^3/s during May-July). Predicted overwintering habitat (~0.1-0.2 m^3/s for mid-winter MMD) was only marginally higher than further upstream in Reaches 8 and 9.

Figure 4-8 Habitat (AWS) as a function of flow, Reach 7 Gold Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.342 m^3/s and MMD range from 0.133 m^3/s (February) to 1.038 m^3/s (June). Confidence bars shown at the 80% level using 2,000 bootstrap runs.

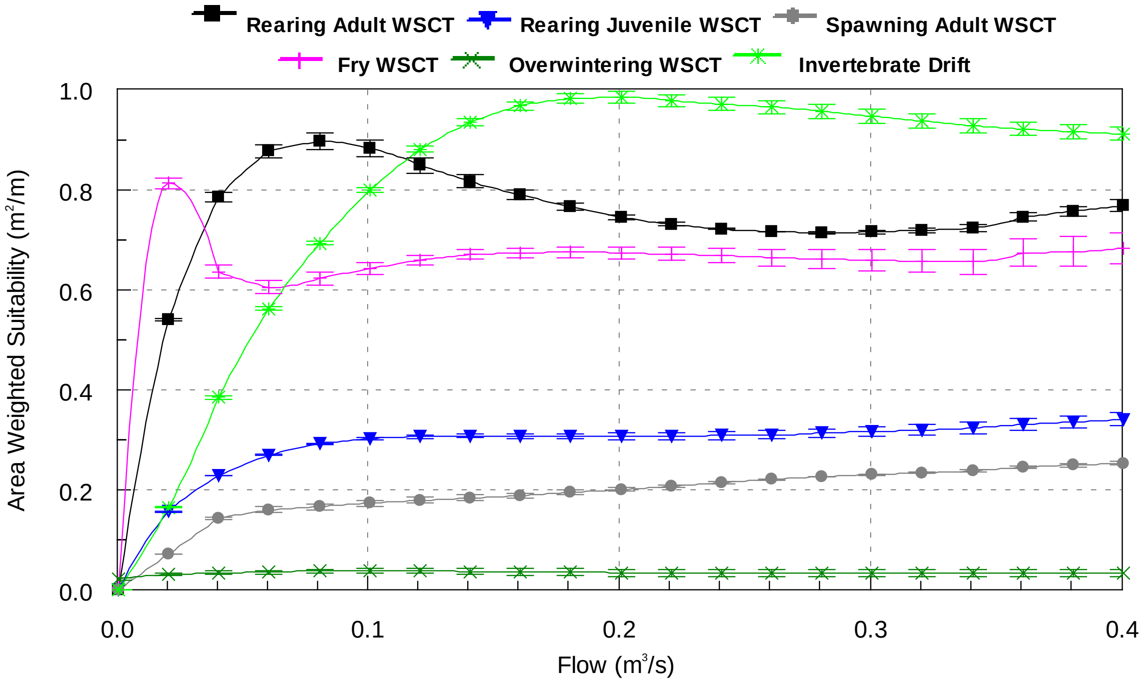
Reach 6

In Reach 6, where surface flows are partially lost subsurface (MAD and MMD only slightly higher than in Reach 8, upstream of Caudron Creek), habitat quality was predicted as very poor (AWS <1 m^2/m) across all bioperiods and range of simulated flows (Figure 4-9). For a given bioperiod, the optimum AWS value was less than half of the corresponding Reach 8 value. These differences can be attributed to the difference in substrate characteristics sampled in these reaches. In Reach 6, three of the four XS (runs at GC-2 and GC-3, and pool at GC-4, see Appendix A2 for photos) were largely dominated by fine-grained sediment (e.g., silt or sand), which provide low quality habitat for all bioperiods (typical HSI values of 0.1). Only the cobble-dominated riffle (GC-5) provided suitable substrate conditions, but AWS here was reduced due to sub-optimal (shallow) water depths and (excessive) water velocities (Figure 4-4). All XS in Reach 8 were dominated by sediments ranging from fine gravels to boulders, each of which provide higher quality habitat.

Reach 5

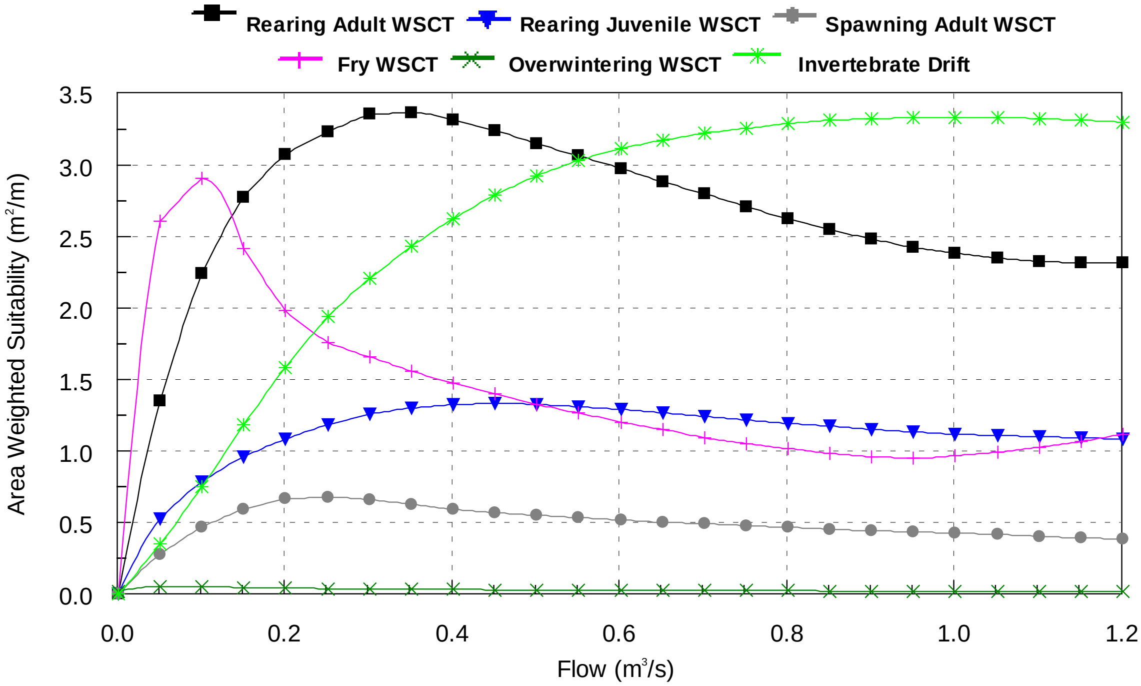
In Reach 5 downstream of the Morin Creek-Gold Creek confluence, where flows were marginally higher than in Reach 7 and nearly triple those in Reach 6, AWS values predicted for adult rearing, juvenile rearing, and fry were broadly similar to those predicted in Reach 7. Corresponding optimum AWS values for these three bioperiods were 3.4 m^2/m, 1.3 m^2/m and 3 m^2/m, respectively. The predicted AWS for spawning and overwintering WSCT was lower in Reach 5 than in Reach 7 given these bioperiods generally favour deeper and/or slower stream conditions, which were less abundant across Reach 5.

Figure 4-9 Habitat (AWS) as a function of flow, Reach 6 Gold Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.105 m^3/s and MMD range from 0.041 m^3/s (February) to 0.319 m^3/s (June). Confidence bars shown at the 80% level using 2,000 bootstrap runs.

Figure 4-10 Habitat (AWS) as a function of flow, Reach 5 Gold Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.392 m^3/s and MMD range from 0.152 m^3/s (February) to 1.190 m^3/s (June). No confidence bars are shown since there were only 2 XS in this reach.

4.1.2.1 Velocity sensitivity

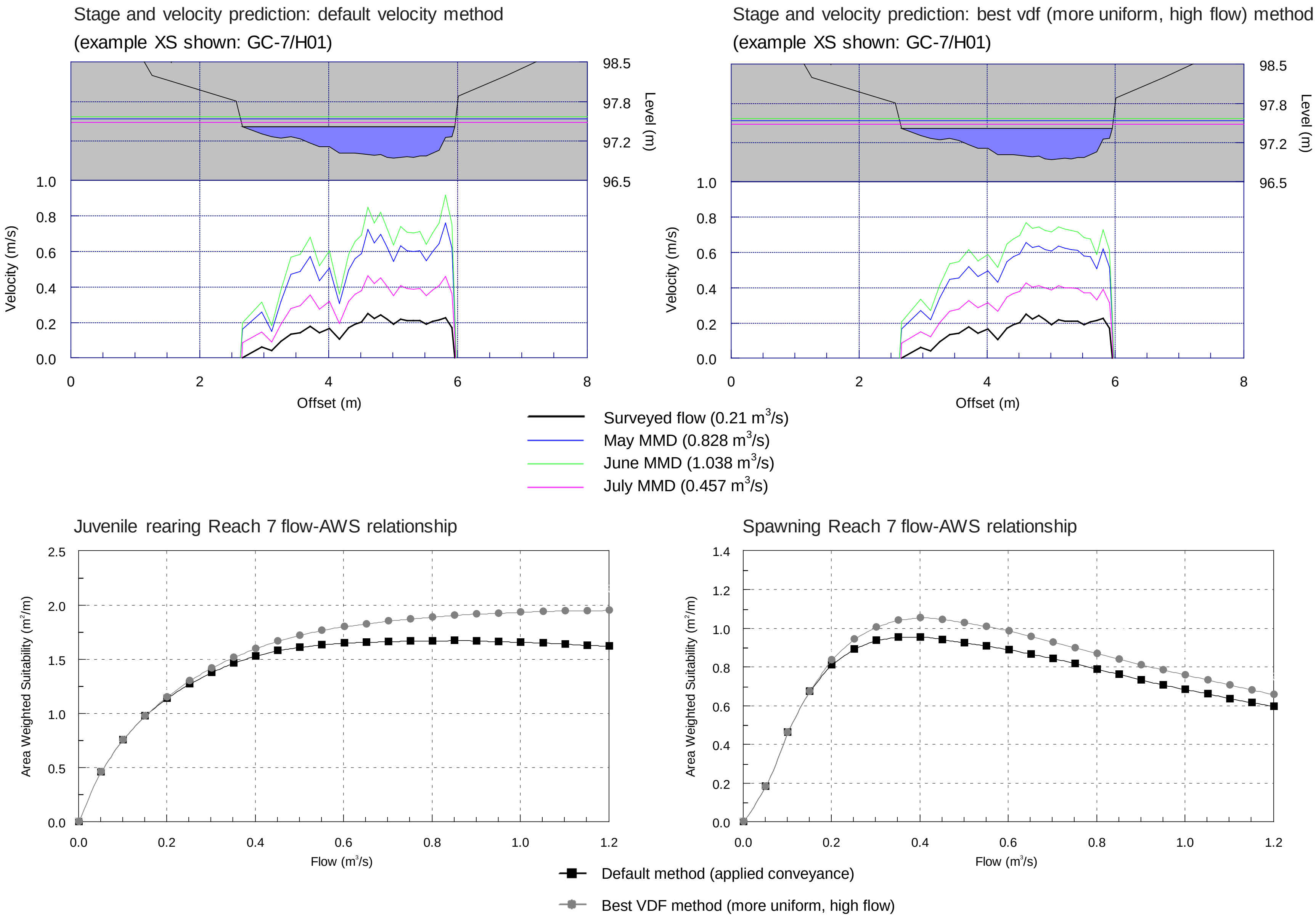
Results of the sensitivity analysis to determine potential effects on AWS due to different, modelled assumptions of XS velocity distribution during higher flows are summarized in Figure 4-11 and Figure 4-12 (Reaches 7 and 8 on Gold Creek, respectively, corresponding to higher and lower-flow environments).

For both reaches, the first set of results include the difference in simulated velocity distribution when applying the May MMD, June MMD, and July MMD baseline (2017) flows during these reaches, using the example of XS GC-7/H01 (in Reach 7, Figure 4-11) and XS GC-13 (in Reach 8, Figure 4-12). The default velocity prediction option (extrapolation of measured velocity distribution with no smoothing) maintains more irregulararity from the measured distribution, relative to the 'best estimate VDF' tool, which produces an increasingly smoother distribution at higher flows (due to the increased hypothetical reliance on XS conveyance, or hydraulic depth, as opposed to measured instances of flow acceleration or deceleration around larger sediments).

The second set of results display the sensitivity of the reach-average flow-habitat relationships, specifically for the juvenile rearing and spawing bioperiods, which occur throughout the typical high flow months (May-July). In Reach 7, during June (the highest estimated baseline MMD at 1.038 m^3/s), the predicted AWS for juvenile rearing and spawning was 17% and 11% higher, respectively, when applying the more uniform velocity distribution (best estimate VDF tool), which predicted more suitable velocity conditions across the watercourse. At much lower flows (e.g., up to the July MMD, 0.457 m^3/s), there was essentially no difference between velocity distributions since the predicted distribution increasingly resembled the (low-flow) measured distribution. In Reach 8, there was even less AWS increase during June (7% and 9% for juvenile rearing and spawning, respectively), since velocity conditions in this reach remained less optimal even at the highest flows.

These results indicate that the transition to uniform velocity conditions expected during the highest flows only serve to increase habitat quality, but these habitat gains are relatively short-lived (e.g., May-June) and are greater in higher-flow reaches. An exception to this trend may be during extreme or peak (hourly to daily) flows, much higher than the estimated June MMD, when habitat may be enhanced by the presence of low-velocity eddies that serve as fish refuge areas. In low-flow conditions (spatially or temporally), the results indicate no overall advantage of one or the other distribution types, and the default calculation option used throughout this study is adequate.

Figure 4-11 Sensitivity of velocity distribution prediction; Gold Creek Reach 7.



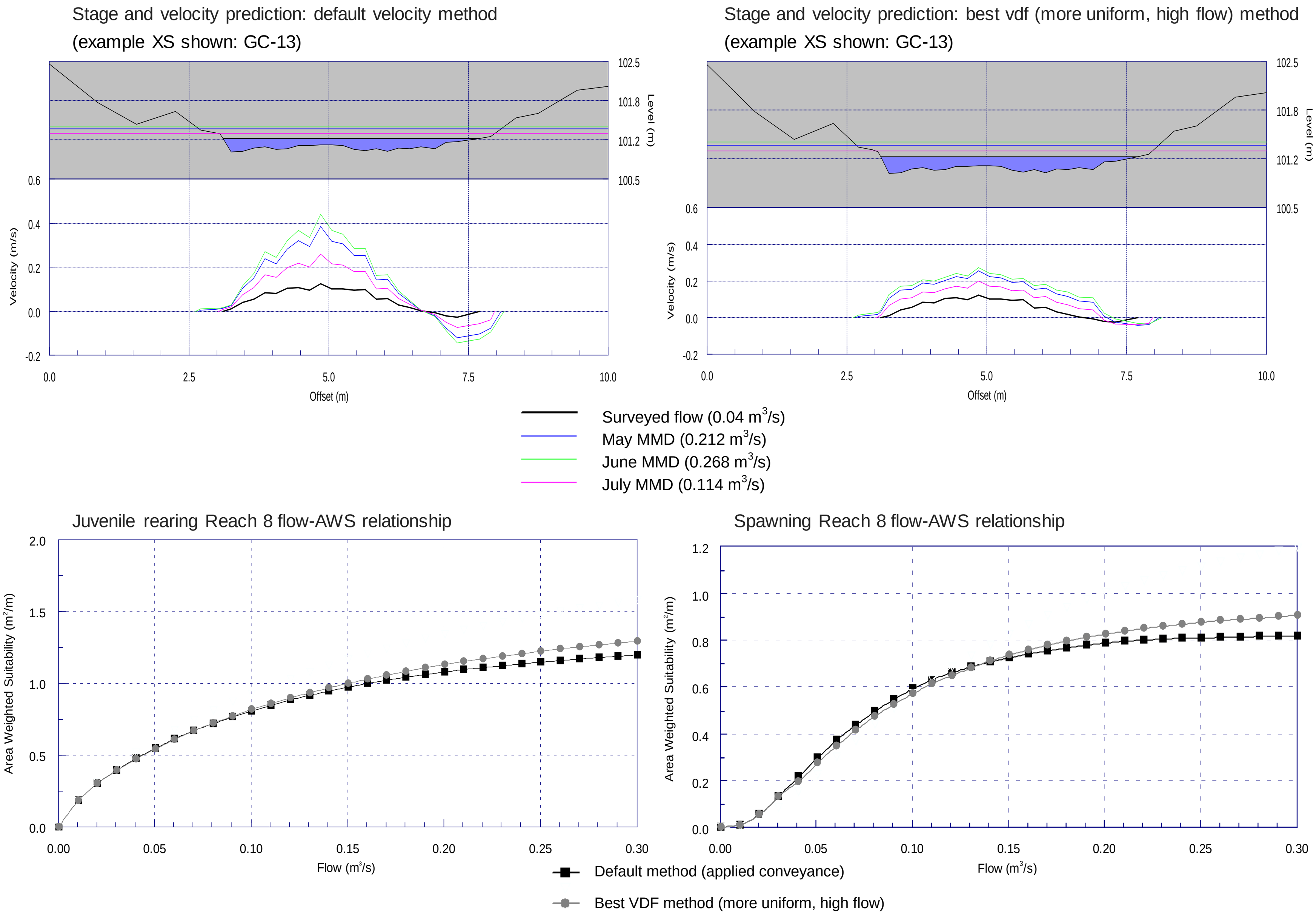
Stage and velocity prediction: default velocity method (example XS shown: GC-7/H01)

Stage and velocity prediction: best vdf (more uniform, high flow) method (example XS shown: GC-7/H01)

Juvenile rearing Reach 7 flow-AWS relationship

Spawning Reach 7 flow-AWS relationship

Figure 4-12 Sensitivity of velocity distribution prediction; Gold Creek Reach 8.



Stage and velocity prediction: default velocity method (example XS shown: GC-13)

Stage and velocity prediction: best vdf (more uniform, high flow) method (example XS shown: GC-13)

Juvenile rearing Reach 8 flow-AWS relationship

Spawning Reach 8 flow-AWS relationship

4.1.3 Project Changes to Habitat

4.1.3.1 Average Hydrological Conditions

The predicted changes in AWS on Gold Creek, for each reach, bioperiod, and project phase are summarized for average hydrological conditions in Table 4-1. The approach used for this assessment was summarized in Section 3.6.4. During mine construction in 2018, there were no changes predicted to surface flows along the length of Gold Creek (SRK Hydro 2016c); therefore, no changes in habitat were predicted.

Reach 9

For Reach 9 during the operations phase (2019-2042), there were marginal habitat losses predicted, which averaged 1-2 % (2-32 m^2) of the baseline habitat area depending on the bioperiod. The largest habitat loss calculated for any individual month within a given bioperiod and project phase was 9%, which approached, but does not exceed, the 10% threshold for classifying significant effects. During the decommissioning phase (2043-2044), average habitat losses (1-4%, equivalent to 2-52 m^2) were slightly higher than during operations, but the maximum monthly habitat loss was again 9% suggesting that no significant adverse effects are anticipated. Similarly during the closure phase, when the land is increasingly reclaimed and flows recovered slightly, the average habitat losses (1-3%, equivalent to 2-47 m^2) and worst-case individual month (9%) all remained below the 10% significance threshold.

Reach 8

For Reach 8, mean habitat losses averaged across each bioperiod were broadly similar to corresponding values for Reach 9, including 1-2% (1-46 m^2) during operations, 0-3% (2-69 m^2) during decommissiong, and 0-2% (1-61 m^2) during closure. Of particular note, monthly habitat losses were predicted to be as high as 12% in the case of adult rearing, which occurred each April from 2038-2042 (operations) and again in April 2043 (decommissioning). This represents approximately 99 m^2 of habitat change (loss), relative to the predicted baseline April value (723 m^2). The April MMD value (0.023 m^3/s during baseline) was the lowest of all six months with adult rearing and falls within the most sensitive area of habitat changes with flow as shown in Figure 4-7. This factor coupled with the maximum flow losses predicted to occur between 2038-2043 combined to produce this particular result.

Reach 7 and 5

In the much higher flow environment of Reach 7, habitat changes were much less sensitive to the predicted flow changes occurring post-construction. For adult/juvenile rearing and overwintering bioperiods, both average and worst-case habitat losses during an individual month were up to 3%. Small habitat gains of 1-2% (on average) were predicted for the spawning and fry bioperiods, since the slight flow reductions improved habitat quality based on the corresponding flow-AWS relationships shown in Figure 4-8. Similarly for Reach 5, worst-case habitat losses during an individual month were up to 4%, whereas very small average gains in habitat (0-4%) were predicted for all bioperiods and post-construction mine phases.

Reach 6

In Reach 6, with the exception of fry habitat, which remained largely unchanged between mine phases, post-construction habitat losses for the four other bioperiods all averaged 2-5% and did not exceed 9% in any individual month. Flows here were approximately 50% higher than in Reach 8, and these were sufficient to keep individual month habitat losses below 10%, even though the predicted total flow reductions in this reach (node GC-02, SRK 2016c, Figure 2-1) were higher than at all other nodes on Gold Creek (reaching 10.4% during 2041-2042, ~1.5% higher than at node GC-10 applied within Reach 8 predictions).

All reaches

Cumulative predicted habitat changes across all five study reaches were as follows. Approximately 214-272 m^2 of adult rearing habitat was predicted to be lost during the three post-construction mine phases, but in relative terms this represented around 1-2% of the baseline habitat area. Similarly, 151-192 m^2 of juvenile rearing habitat and 8-10 m^2 of overwintering habitat is predicted to be lost, representing 2% and 1% of the corresponding baseline habitat areas, respectively. Approximately, 24-28 m^2 of spawning habitat is predicted to be lost, while 75-96 m^2 of fry habitat is precited to be gained, but in both instances these changes rounded to 0% change relative to corresponding baseline habitat areas. All bioperiod-habitat changes under average flow conditions remained well below the 10% threshold, suggesting that significant adverse effects are not anticipated. On an individual monthly basis the losses of adult rearing habitat did briefly exceed the 10% (12% during consecutive April months between 2038-2043, the peak flow reduction period), which may result in some limitations to this particular life stage.

4.1.3.2 Drought Hydrological Conditions

The predicted changes in AWS on Gold Creek, for each reach, bioperiod, and project phase are summarized for 1-in-10 and 1-in-20 dry year conditions in Table 4-2 and Table 4-3, respectively. The differences in MAD between reaches and hydrological conditions were presented in Figure 3-2.

During 1-in-10 dry year conditions (Table 4-2), predicted habitat losses averaged across bioperiods and project phases generally increased relative to the losses during average hydrological conditions, but there were no results exceeding the 10% significance threshold. At the individual monthly timescale, there were more worst-case habitat losses exceeding 10% (range 11-19%) relative to average hydrological conditions, and these occurred for the adult and juvenile rearing, and spawning bioperiods across Reaches 8 and 9 (upstream of Caudron Creek confluence) and Reach 6 (near Lille). In the higher flow reaches (Reaches 5 and 7), habitat quality for the spawning and fry bioperiods improved relative to average hydrological conditions, since the drought flows are closer to the optimum flows for maximizing habitat in these bioperiods (Figure 4-8 for Reach 7, Figure 4-10 for Reach 5). Cumulative predicted habitat losses across all five study reaches were highest during the decommissioning period, including a total of 378 m^2 of adult reading habitat (equivalent to 3% of the baseline habitat area), 218 m^2 of juvenile rearing habitat (3% of baseline), 145 m^2 of spawning habitat (3% of baseline), 58 m^2 of fry habitat (0% of baseline) and 7 m^2 of overwintering habitat (1% of baseline).

During 1-in-20 dry year conditions (Table 4-3), predicted habitat losses averaged across bioperiods and project phases increased further, relative to the other conditions, especially across Reaches 8 and 9 (upstream of the Caudron Creek confluence) and Reach 6 (near Lille). The mean habitat losses remained less than 10% of baseline areas across all bioperiods during the operations and closure phases; however, spawning habitat averaged across the 2-year decommissioning period decreased by 11% in Reach 9 and 10% in Reach 6 implying potential effects to spawning habitat if extreme drought conditions occur within the early-2040 period when the greatest project-related flow losses are predicted to occur (SRK 2016c; Consultant Report #4). The worst-case habitat losses for individual months exceeded 10% for the adult and juvenile rearing, and spawning bioperiods across Reaches 8 and 9 and Reach 6, up to a maximum of 20% in the case of Reach 9 spawning habitat in July 2042 (operations) and July 2043 (decommissioning). Cumulative predicted habitat losses across all five study reaches were highest during the decommissioning period, including a total of 393 m^2 of adult rearing habitat (equivalent to 3% of the baseline habitat area), 209 m^2 of juvenile rearing habitat (3% of baseline), 159 m^2 of spawning habitat (3% of baseline), 117 m^2 of fry habitat (1% of baseline) and 10 m^2 of overwintering habitat (1% of baseline).

Table 4-1 Gold Creek Habitat Area predictions, 2017-2099, during average hydrological conditions.

					Baseline 2017	Construction 2018				Operations 2019-2042				Decommissioning 2043-2044				Closure 2045-2099			
Reach details			*Westslope Cutthroat Trout*		Mean Suitable Area	Mean Suitable Area	Difference from baseline period Mean		Difference from baseline period 1-month max	Mean Suitable Area	Difference from baseline period Mean		Difference from baseline period 1-month max	Mean Suitable Area	Difference from baseline period Mean		Difference from baseline period 1-month max	Mean Suitable Area	Difference from baseline period Mean		Difference from baseline period 1-month max
#	Description	Length (m)	Bioperiod	Stanza	m^2 AWS[1]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]
9	GCT10 trib to North Creek	2,130	Rearing (Adult)	Apr 1-Sep 30	1,371	1,371	0	0%	0%	1,338	-32	-2%	-9%	1,319	-52	-4%	-9%	1,323	-47	-3%	-9%
			Rearing (Juvenile)	Apr 1-Sep 30	1,199	1,199	0	0%	0%	1,177	-22	-2%	-6%	1,164	-34	-3%	-5%	1,168	-31	-3%	-5%
			Spawning	May 1-Jul 31	638	638	0	0%	0%	624	-14	-2%	-9%	615	-23	-4%	-5%	618	-20	-3%	-5%
			Fry	Jul 1-Sep 30	3,235	3,235	0	0%	0%	3,214	-21	-1%	-2%	3,205	-31	-1%	-2%	3,205	-31	-1%	-2%
			Overwintering	Oct 1-Mar 31	191	191	0	0%	0%	189	-2	-1%	-5%	190	-2	-1%	-5%	190	-2	-1%	-5%
8	Above Caudron Creek to GCT10 trib	1,906	Rearing (Adult)	Apr 1-Sep 30	2,684	2,684	0	0%	0%	2,638	-46	-2%	-12%	2,615	-69	-3%	-12%	2,623	-61	-2%	-6%
			Rearing (Juvenile)	Apr 1-Sep 30	1,461	1,461	0	0%	0%	1,438	-23	-2%	-6%	1,426	-35	-2%	-6%	1,430	-30	-2%	-3%
			Spawning	May 1-Jul 31	1,428	1,428	0	0%	0%	1,415	-14	-1%	-5%	1,407	-21	-1%	-3%	1,410	-18	-1%	-3%
			Fry	Jul 1-Sep 30	4,658	4,658	0	0%	0%	4,646	-11	0%	-1%	4,646	-11	0%	-1%	4,646	-11	0%	-1%
			Overwintering	Oct 1-Mar 31	149	149	0	0%	0%	148	-1	-1%	-3%	147	-2	-1%	-3%	148	-1	-1%	-3%
7	Gold Creek Bridge to Caudron Creek	3,183	Rearing (Adult)	Apr 1-Sep 30	8,950	8,950	0	0%	0%	8,930	-20	0%	-2%	8,924	-25	0%	-1%	8,924	-26	0%	-1%
			Rearing (Juvenile)	Apr 1-Sep 30	4,702	4,702	0	0%	0%	4,666	-37	-1%	-3%	4,652	-51	-1%	-3%	4,654	-48	-1%	-2%
			Spawning	May 1-Jul 31	2,514	2,514	0	0%	0%	2,553	39	2%	0%	2,575	61	2%	1%	2,568	54	2%	1%
			Fry	Jul 1-Sep 30	6,430	6,430	0	0%	0%	6,505	75	1%	0%	6,530	101	2%	1%	6,530	101	2%	1%
			Overwintering	Oct 1-Mar 31	456	456	0	0%	0%	453	-2	-1%	-1%	453	-3	-1%	-1%	453	-3	-1%	-1%
6	Above Morin Creek to Gold Creek Bridge	1,683	Rearing (Adult)	Apr 1-Sep 30	3,626	3,626	0	0%	0%	3,501	-124	-3%	-9%	3,474	-152	-4%	-8%	3,478	-148	-4%	-8%
			Rearing (Juvenile)	Apr 1-Sep 30	1,583	1,583	0	0%	0%	1,515	-67	-4%	-8%	1,500	-82	-5%	-7%	1,503	-79	-5%	-7%
			Spawning	May 1-Jul 31	1,395	1,395	0	0%	0%	1,351	-43	-3%	-8%	1,341	-53	-4%	-7%	1,344	-51	-4%	-7%
			Fry	Jul 1-Sep 30	4,301	4,301	0	0%	0%	4,309	8	0%	-1%	4,310	9	0%	-1%	4,310	9	0%	-1%
			Overwintering	Oct 1-Mar 31	185	185	0	0%	0%	181	-3	-2%	-3%	181	-4	-2%	-3%	181	-3	-2%	-2%
5	Below Morin Creek	502	Rearing (Adult)	Apr 1-Sep 30	1,491	1,491	0	0%	0%	1,499	8	1%	-2%	1,502	11	1%	-2%	1,501	10	1%	-2%
			Rearing (Juvenile)	Apr 1-Sep 30	612	612	0	0%	0%	609	-3	0%	-4%	609	-3	0%	-3%	609	-3	0%	-3%
			Spawning	May 1-Jul 31	227	227	0	0%	0%	235	8	3%	1%	236	9	4%	3%	236	9	4%	3%
			Fry	Jul 1-Sep 30	764	764	0	0%	0%	789	25	3%	1%	791	28	4%	3%	791	28	4%	3%
			Overwintering	Oct 1-Mar 31	20	20	0	0%	0%	20	1	3%	0%	20	1	3%	2%	20	1	3%	2%
GOLD CREEK SUMMARY		**Total Length (m)**	**Bioperiod**	**Stanza**	TOTAL AWS (m^2)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
ALL REACHES (5 to 9)		**9,404**	**Rearing (Adult)**	**Apr 1-Sep 30**	18,121	18,121	**0**	**0%**	0%	17,907	**-214**	**-1%**	-12%	17,833	**-288**	**-2%**	-12%	17,849	**-272**	**-2%**	-9%
			Rearing (Juvenile)	**Apr 1-Sep 30**	9,556	9,556	**0**	**0%**	0%	9,405	**-151**	**-2%**	-8%	9,351	**-205**	**-2%**	-7%	9,364	**-192**	**-2%**	-7%
			Spawning	**May 1-Jul 31**	6,202	6,202	**0**	**0%**	0%	6,177	**-24**	**0%**	-9%	6,174	**-27**	**0%**	-7%	6,175	**-26**	**0%**	-7%
			Fry	**Jul 1-Sep 30**	19,387	19,387	**0**	**0%**	0%	19,462	**75**	**0%**	-2%	19,483	**96**	**0%**	-2%	19,483	**96**	**0%**	-2%
			Overwintering	**Oct 1-Mar 31**	1,001	1,001	**0**	**0%**	0%	992	**-8**	**-1%**	-5%	991	**-10**	**-1%**	-5%	992	**-8**	**-1%**	-5%

Notes:

Boxed values represent predicted habitat changes of 10% or more.

[1] AWS = Area Weighted Suitability; the total surface area of predicted suitable habitat, calculated as the product of reach length and m^2 suitable wetted width (weighted by individual cross-section suitability results).

[2] This represents the single month within a given reach, stanza and mine life stage which produces the largest % habitat loss below the corresponding monthly baseline value.

Table 4-2 Gold Creek Habitat Area predictions, 2017-2099, during dry hydrological conditions (1-in-10 year recurrence).

					Baseline	Construction				Operations				Decommissioning				Closure			
					2017	2018				2019-2042				2043-2044				2045-2099			
Reach details			*Westslope Cutthrout Trout*		Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
							Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	Bioperiod	Stanza	m^2 AWS	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]
9	GCT10 trib to North Creek	2,130	Rearing (Adult)	Apr 1-Sep 30	545	545	0	0%	0%	527	-19	-3%	-19%	513	-32	-6%	-11%	520	-26	-5%	-11%
			Rearing (Juvenile)	Apr 1-Sep 30	619	619	0	0%	0%	604	-15	-2%	-11%	593	-26	-4%	-9%	597	-22	-3%	-9%
			Spawning	May 1-Jul 31	209	209	0	0%	0%	199	-9	-5%	-15%	191	-18	-9%	-12%	195	-13	-6%	-8%
			Fry	Jul 1-Sep 30	2,462	2,462	0	0%	0%	2,419	-43	-2%	-7%	2,388	-74	-3%	-7%	2,388	-74	-3%	-7%
			Overwintering	Oct 1-Mar 31	150	150	0	0%	0%	149	-1	-1%	-6%	149	-1	-1%	-5%	149	-1	-1%	-5%
8	Above Caudron Creek to GCT10 trib	1,906	Rearing (Adult)	Apr 1-Sep 30	1,353	1,353	0	0%	0%	1,315	-38	-3%	-15%	1,292	-60	-4%	-14%	1,304	-48	-4%	-14%
			Rearing (Juvenile)	Apr 1-Sep 30	822	822	0	0%	0%	803	-19	-2%	-11%	792	-30	-4%	-11%	797	-24	-3%	-11%
			Spawning	May 1-Jul 31	745	745	0	0%	0%	718	-26	-4%	-13%	696	-49	-7%	-9%	709	-36	-5%	-9%
			Fry	Jul 1-Sep 30	3,900	3,900	0	0%	0%	3,871	-29	-1%	-3%	3,869	-31	-1%	-1%	3,869	-31	-1%	-1%
			Overwintering	Oct 1-Mar 31	118	118	0	0%	0%	117	-1	-1%	-5%	118	0	0%	0%	118	0	0%	0%
7	Gold Creek Bridge to Caudron Creek	3,183	Rearing (Adult)	Apr 1-Sep 30	8,080	8,080	0	0%	0%	8,004	-76	-1%	-3%	7,969	-110	-1%	-3%	7,977	-102	-1%	-2%
			Rearing (Juvenile)	Apr 1-Sep 30	3,795	3,795	0	0%	0%	3,739	-56	-1%	-4%	3,712	-83	-2%	-4%	3,719	-76	-2%	-3%
			Spawning	May 1-Jul 31	2,906	2,906	0	0%	0%	2,901	-5	0%	-3%	2,901	-5	0%	-2%	2,901	-5	0%	-2%
			Fry	Jul 1-Sep 30	7,712	7,712	0	0%	0%	7,762	50	1%	0%	7,780	68	1%	0%	7,778	66	1%	0%
			Overwintering	Oct 1-Mar 31	392	392	0	0%	0%	389	-3	-1%	-2%	389	-3	-1%	-1%	388	-3	-1%	-1%
6	Above Morin Creek to Gold Creek Bridge	1,683	Rearing (Adult)	Apr 1-Sep 30	2,474	2,474	0	0%	0%	2,350	-124	-5%	-12%	2,316	-158	-6%	-12%	2,327	-147	-6%	-9%
			Rearing (Juvenile)	Apr 1-Sep 30	1,037	1,037	0	0%	0%	984	-53	-5%	-9%	970	-67	-6%	-9%	975	-62	-6%	-7%
			Spawning	May 1-Jul 31	899	899	0	0%	0%	835	-64	-7%	-15%	819	-80	-9%	-13%	826	-73	-8%	-11%
			Fry	Jul 1-Sep 30	4,048	4,048	0	0%	0%	3,989	-59	-1%	-3%	3,973	-75	-2%	-3%	3,974	-75	-2%	-3%
			Overwintering	Oct 1-Mar 31	158	158	0	0%	0%	155	-3	-2%	-3%	155	-3	-2%	-3%	154	-4	-2%	-3%
5	Below Morin Creek	502	Rearing (Adult)	Apr 1-Sep 30	1,492	1,492	0	0%	0%	1,476	-16	-1%	-6%	1,475	-17	-1%	-5%	1,475	-17	-1%	-5%
			Rearing (Juvenile)	Apr 1-Sep 30	563	563	0	0%	0%	553	-10	-2%	-6%	551	-12	-2%	-5%	552	-11	-2%	-4%
			Spawning	May 1-Jul 31	292	292	0	0%	0%	298	6	2%	0%	299	7	2%	0%	299	7	2%	1%
			Fry	Jul 1-Sep 30	1,103	1,103	0	0%	0%	1,151	49	4%	1%	1,157	54	5%	3%	1,156	53	5%	3%
			Overwintering	Oct 1-Mar 31	24	24	0	0%	0%	25	0	2%	0%	25	1	2%	2%	25	1	2%	2%
GOLD CREEK SUMMARY		**Total Length (m)**	**Bioperiod**	**Stanza**	**TOTAL AWS (m^2)**	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
ALL REACHES (5 to 9)		**9,404**	**Rearing (Adult)**	**Apr 1-Sep 30**	**13,944**	**13,944**	**0**	**0%**	0%	**13,671**	**-273**	**-2%**	-19%	**13,566**	**-378**	**-3%**	-14%	**13,603**	**-341**	**-2%**	-14%
			Rearing (Juvenile)	**Apr 1-Sep 30**	**6,836**	**6,836**	**0**	**0%**	0%	**6,682**	**-154**	**-2%**	-11%	**6,618**	**-218**	**-3%**	-11%	**6,640**	**-195**	**-3%**	-11%
			Spawning	**May 1-Jul 31**	**5,051**	**5,051**	**0**	**0%**	0%	**4,951**	**-99**	**-2%**	-15%	**4,906**	**-145**	**-3%**	-13%	**4,930**	**-121**	**-2%**	-11%
			Fry	**Jul 1-Sep 30**	**19,225**	**19,225**	**0**	**0%**	0%	**19,192**	**-33**	**0%**	-7%	**19,167**	**-58**	**0%**	-7%	**19,165**	**-60**	**0%**	-7%
			Overwintering	**Oct 1-Mar 31**	**842**	**842**	**0**	**0%**	0%	**835**	**-7**	**-1%**	-6%	**835**	**-7**	**-1%**	-5%	**835**	**-7**	**-1%**	-5%

Notes:

Boxed values represent predicted habitat changes of 10% or more.

[1] AWS = Area Weighted Suitability; the total surface area of predicted suitable habitat, calculated as the product of reach length and m^2 suitable wetted width (weighted by individual cross-section suitability results).

[2] This represents the single month within a given reach, stanza and mine life stage which produces the largest % habitat loss below the corresponding monthly baseline value.

Table 4-3 Gold Creek Habitat Area predictions, 2017-2099, during very dry hydrological conditions (1-in-20 year recurrence).

					Baseline 2017	Construction 2018				Operations 2019-2042				Decommissioning 2043-2044				Closure 2045-2099			
Reach details			*Westslope Cutthroat Trout*		Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
							Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	Bioperiod	Stanza	m^2 AWS	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]
9	GCT10 trib to North Creek	2,130	Rearing (Adult)	Apr 1-Sep 30	425	425	0	0%	0%	407	-17	-4%	$\boxed{-14\%}$	395	-30	-7%	$\boxed{-14\%}$	401	-24	-6%	$\boxed{-14\%}$
			Rearing (Juvenile)	Apr 1-Sep 30	520	520	0	0%	0%	506	-15	-3%	$\boxed{-12\%}$	496	-24	-5%	$\boxed{-12\%}$	500	-20	-4%	$\boxed{-12\%}$
			Spawning	May 1-Jul 31	146	146	0	0%	0%	137	-9	-6%	$\boxed{-20\%}$	130	-16	$\boxed{-11\%}$	$\boxed{-20\%}$	133	-13	-9%	$\boxed{-10\%}$
			Fry	Jul 1-Sep 30	2,239	2,239	0	0%	0%	2,191	-48	-2%	-9%	2,163	-77	-3%	-9%	2,170	-70	-3%	-9%
			Overwintering	Oct 1-Mar 31	142	142	0	0%	0%	140	-2	-1%	-6%	139	-3	-2%	-6%	139	-3	-2%	-6%
8	Above Caudron Creek to GCT10 trib	1,906	Rearing (Adult)	Apr 1-Sep 30	1,092	1,092	0	0%	0%	1,055	-37	-3%	$\boxed{-18\%}$	1,036	-56	-5%	$\boxed{-18\%}$	1,049	-42	-4%	-9%
			Rearing (Juvenile)	Apr 1-Sep 30	701	701	0	0%	0%	685	-17	-2%	$\boxed{-15\%}$	677	-24	-3%	$\boxed{-15\%}$	685	-17	-2%	-4%
			Spawning	May 1-Jul 31	565	565	0	0%	0%	538	-27	-5%	$\boxed{-19\%}$	517	-48	-9%	$\boxed{-13\%}$	528	-37	-7%	$\boxed{-13\%}$
			Fry	Jul 1-Sep 30	3,651	3,651	0	0%	0%	3,619	-32	-1%	-3%	3,630	-22	-1%	-2%	3,630	-22	-1%	-2%
			Overwintering	Oct 1-Mar 31	113	113	0	0%	0%	112	-1	0%	-3%	112	-1	-1%	-3%	112	-1	-1%	-3%
7	Gold Creek Bridge to Caudron Creek	3,183	Rearing (Adult)	Apr 1-Sep 30	7,711	7,711	0	0%	0%	7,626	-85	-1%	-5%	7,590	-121	-2%	-3%	7,599	-112	-1%	-3%
			Rearing (Juvenile)	Apr 1-Sep 30	3,528	3,528	0	0%	0%	3,472	-56	-2%	-4%	3,446	-82	-2%	-4%	3,454	-74	-2%	-3%
			Spawning	May 1-Jul 31	2,873	2,873	0	0%	0%	2,858	-16	-1%	-4%	2,849	-24	-1%	-3%	2,851	-22	-1%	-3%
			Fry	Jul 1-Sep 30	7,902	7,902	0	0%	0%	7,926	24	0%	-1%	7,938	36	0%	0%	7,936	34	0%	0%
			Overwintering	Oct 1-Mar 31	377	377	0	0%	0%	374	-3	-1%	-2%	373	-4	-1%	-2%	374	-3	-1%	-1%
6	Above Morin Creek to Gold Creek Bridge	1,683	Rearing (Adult)	Apr 1-Sep 30	2,213	2,213	0	0%	0%	2,083	-131	-6%	$\boxed{-14\%}$	2,052	-161	-7%	$\boxed{-12\%}$	2,063	-151	-7%	$\boxed{-11\%}$
			Rearing (Juvenile)	Apr 1-Sep 30	928	928	0	0%	0%	877	-51	-6%	$\boxed{-10\%}$	865	-64	-7%	-9%	869	-60	-6%	-8%
			Spawning	May 1-Jul 31	769	769	0	0%	0%	707	-62	-8%	$\boxed{-16\%}$	692	-76	$\boxed{-10\%}$	$\boxed{-14\%}$	698	-71	-9%	$\boxed{-12\%}$
			Fry	Jul 1-Sep 30	3,920	3,920	0	0%	0%	3,829	-91	-2%	-5%	3,812	-109	-3%	-4%	3,814	-106	-3%	-4%
			Overwintering	Oct 1-Mar 31	152	152	0	0%	0%	149	-3	-2%	-4%	149	-3	-2%	-3%	149	-3	-2%	-3%
5	Below Morin Creek	502	Rearing (Adult)	Apr 1-Sep 30	1,456	1,456	0	0%	0%	1,434	-22	-1%	-6%	1,431	-25	-2%	-5%	1,431	-25	-2%	-5%
			Rearing (Juvenile)	Apr 1-Sep 30	541	541	0	0%	0%	530	-12	-2%	-5%	527	-14	-3%	-5%	528	-14	-3%	-4%
			Spawning	May 1-Jul 31	303	303	0	0%	0%	307	5	2%	0%	309	6	2%	0%	308	5	2%	0%
			Fry	Jul 1-Sep 30	1,206	1,206	0	0%	0%	1,253	47	4%	1%	1,261	55	5%	1%	1,260	54	4%	1%
			Overwintering	Oct 1-Mar 31	25	25	0	0%	0%	25	0	1%	0%	25	0	1%	0%	25	0	1%	0%
GOLD CREEK SUMMARY		**Total Length (m)**	**Bioperiod**	**Stanza**	**TOTAL AWS (m^2)**	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
ALL REACHES (5 to 9)		**9,404**	**Rearing (Adult)**	**Apr 1-Sep 30**	**12,897**	**12,897**	**0**	**0%**	0%	**12,605**	**-292**	**-2%**	$\boxed{-18\%}$	**12,504**	**-393**	**-3%**	$\boxed{-18\%}$	**12,543**	**-354**	**-3%**	$\boxed{-14\%}$
			Rearing (Juvenile)	**Apr 1-Sep 30**	**6,219**	**6,219**	**0**	**0%**	0%	**6,069**	**-150**	**-2%**	$\boxed{-15\%}$	**6,010**	**-209**	**-3%**	$\boxed{-15\%}$	**6,036**	**-183**	**-3%**	$\boxed{-12\%}$
			Spawning	**May 1-Jul 31**	**4,655**	**4,655**	**0**	**0%**	0%	**4,546**	**-108**	**-2%**	$\boxed{-20\%}$	**4,496**	**-159**	**-3%**	$\boxed{-20\%}$	**4,518**	**-137**	**-3%**	$\boxed{-13\%}$
			Fry	**Jul 1-Sep 30**	**18,919**	**18,919**	**0**	**0%**	0%	**18,819**	**-100**	**-1%**	-9%	**18,802**	**-117**	**-1%**	-9%	**18,810**	**-109**	**-1%**	-9%
			Overwintering	**Oct 1-Mar 31**	**809**	**809**	**0**	**0%**	0%	**801**	**-8**	**-1%**	-6%	**799**	**-10**	**-1%**	-6%	**800**	**-9**	**-1%**	-6%

Notes:

Boxed values represent predicted habitat changes of 10% or more.

[1] AWS = Area Weighted Suitability; the total surface area of predicted suitable habitat, calculated as the product of reach length and m^2 suitable wetted width (weighted by individual cross-section suitability results).

[2] This represents the single month within a given reach, stanza and mine life stage which produces the largest % habitat loss below the corresponding monthly baseline value.

4.2 BLAIRMORE CREEK

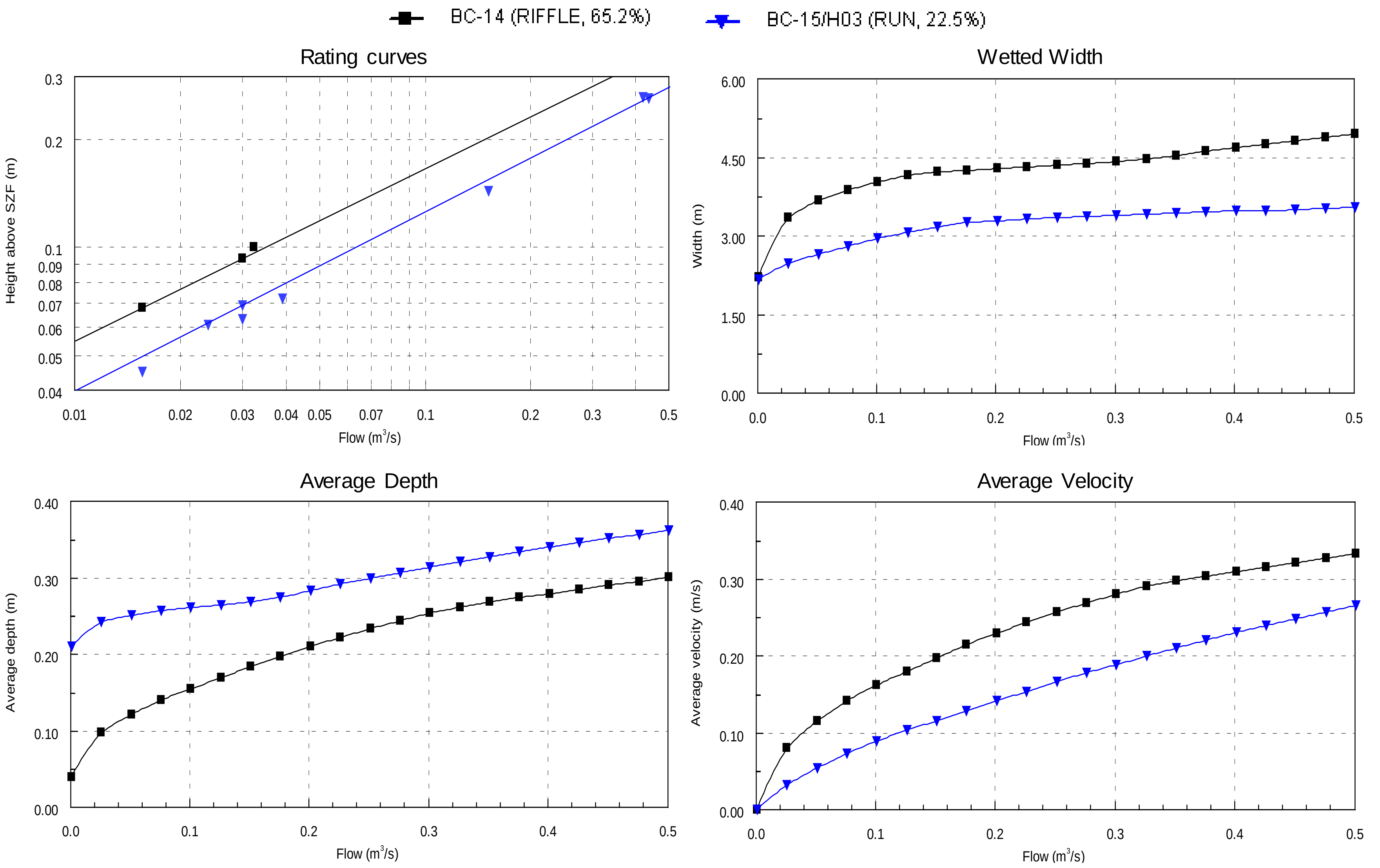
4.2.1 Flow-Hydraulic Relationships

Simulated hydraulic properties at each XS, grouped into the three study reaches on Blairmore Creek, are presented from Figure 4-13 (Reach 5, most upstream) to Figure 4-15 (Reach 3, most downstream). In each instance, results include the calibrated rating curves (modelled stage-discharge relationships), and simulated flow-dependent relationships with XS wetted width, XS mean depth, and XS mean velocity.

Overall, there were 17 calibrated XS rating curves across all three reaches of Blairmore Creek, including BC-0/H01 (ultimately not used in final habitat analysis) and separate rating curves for the braided riffle XS at BC-5 (one each for the main and secondary channels, river right and left, respectively). The accuracy of these curves against measured stage-discharge data was generally good; average R^2 was 0.96 and the average mean error was 4.5%. Individual R^2 values were 0.73 or higher, and the mean error was less than 10% at 17 of 18 XS (11.4 % at the remaining XS, BC-1).

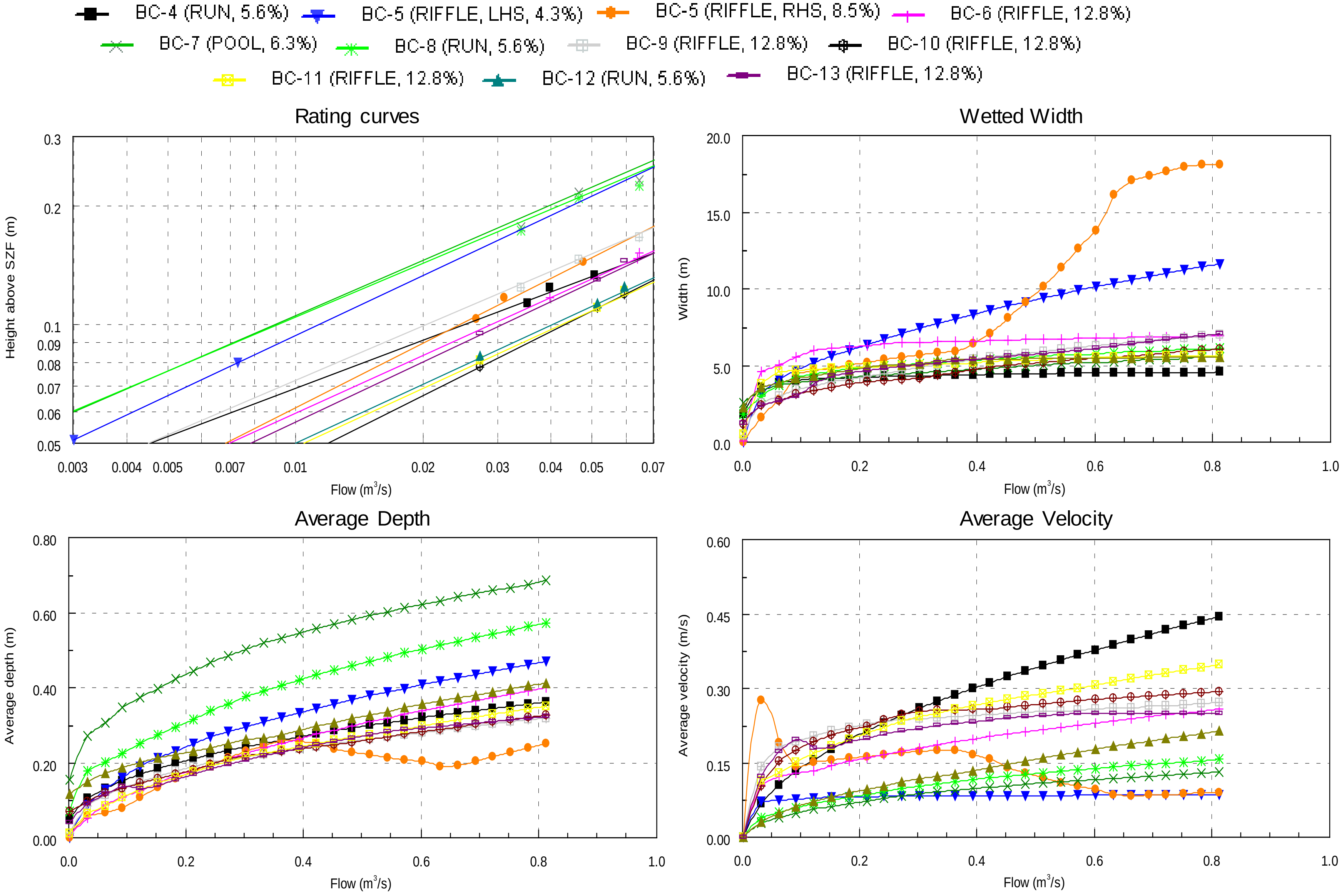
With the exception of BC-5, the hydraulic predictions were broadly similar to those for Gold Creek and other studies (e.g., AMEC 2015). Wetted widths were largely insensitive to changes in flow above a certain threshold (approximately 0.05 m^3/s, though this varied between reaches), and decreased more rapidly below this threshold down towards zero flow. Both wetted widths and average depths were commonly smallest in riffles, intermediate value in runs, and largest in pools. Conversely, mean steam velocities were commonly slowest in pools, intermediate speed in runs, and fastest in riffles. For the main channel at BC-5, from flows of 0.4 to ~0.65 m^3/s, wetted widths were predicted to increase exponentially, while average depths decreased, as much of the low-lying dry area inbetween channels became increasingly wetted.

Figure 4-13 Predicted hydraulics at Reach 5, Blairmore Creek.



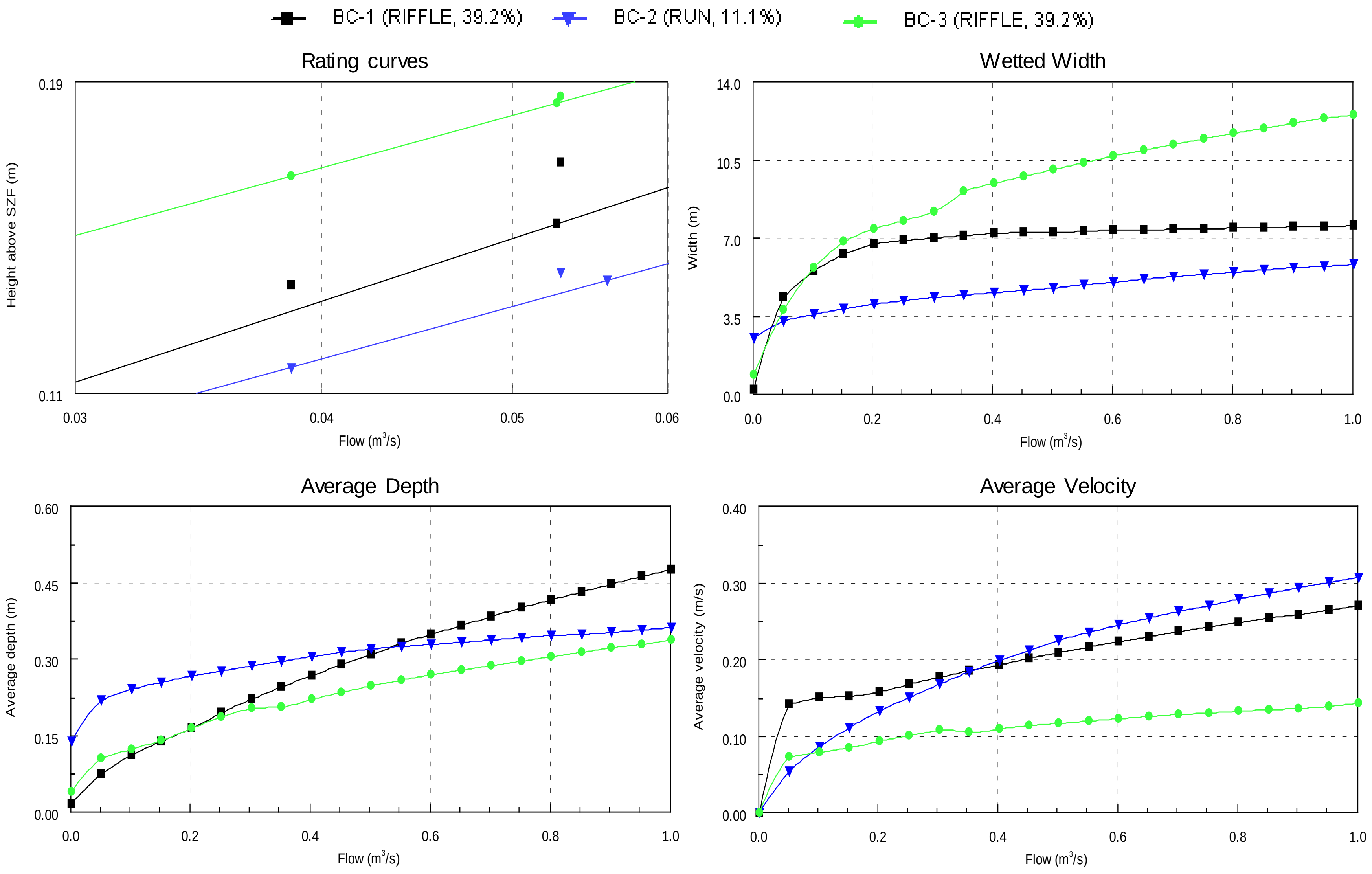
Note: For average hydrological conditions during baseline, the MAD is 0.110 m^3/s and MMD range from 0.017 m^3/s (February) to 0.432 m^3/s (June).

Figure 4-14 Predicted hydraulics at Reach 4, Blairmore Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.175 m^3/s and MMD range from 0.027 m^3/s (February) to 0.689 m^3/s (June).

Figure 4-15 Predicted hydraulics at Reach 3, Blairmore Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.208 m^3/s and MMD range from 0.032 m^3/s (February) to 0.818 m^3/s (June).

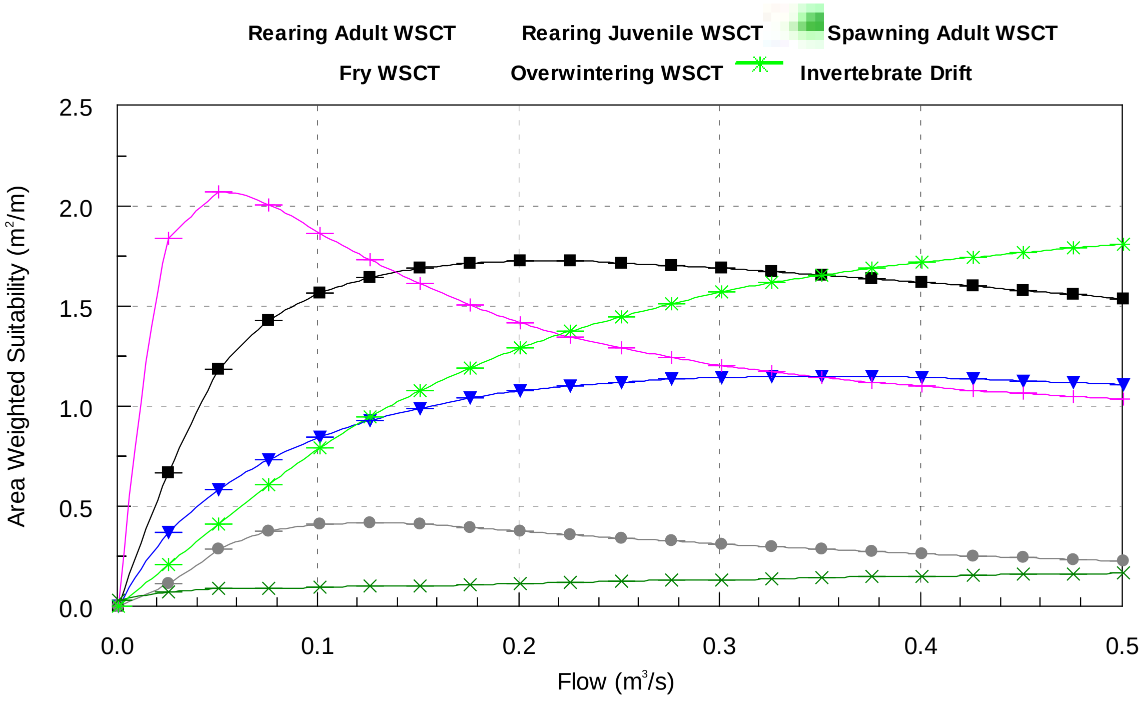
4.2.2 Flow-habitat Relationships

The results of simulated flow-habitat relationships across each reach are presented from Figure 4-16 (Reach 5, most upstream) to Figure 4-18 (Reach 3, most downstream). Generally, the shape of the curves for each bioperiod approximated those presented and discussed for Gold Creek (Figure 4-6 to Figure 4-10). There was less spatial variability both in the baseline flow regime (which doubled from Reach 5 to Reach 3, Figure 3-2) and substrate material relative to Gold Creek, which reflect the greater homogeneity in habitat quality along Blairmore Creek.

Reach 5

In Reach 5 (Figure 4-16), the MAD (0.110 m³/s) was very similar to Reach 6 on Gold Creek (near Lille; 0.105 m³/s); however, the predicted habitat area in Blairmore Creek Reach 5 was over twice as great as Gold Creek Reach 6, due to the predominantely cobble (highly suitable) substrate in Reach 6 relative to the fines (unsuitable) substrate near Lille. Optimum flows for maximizing AWS were 0.05 m³/s (fry), 0.1 m³/s (spawning), 0.2 m³/s (adult rearing) and 0.35 m² (juvenile rearing). Overwintering habitat was very limited (~0.1 m²/m) during the mid-winter MMD of ~0.02 m³/s.

Figure 4-16 Habitat (AWS) as a function of flow, Reach 5 Blairmore Creek.

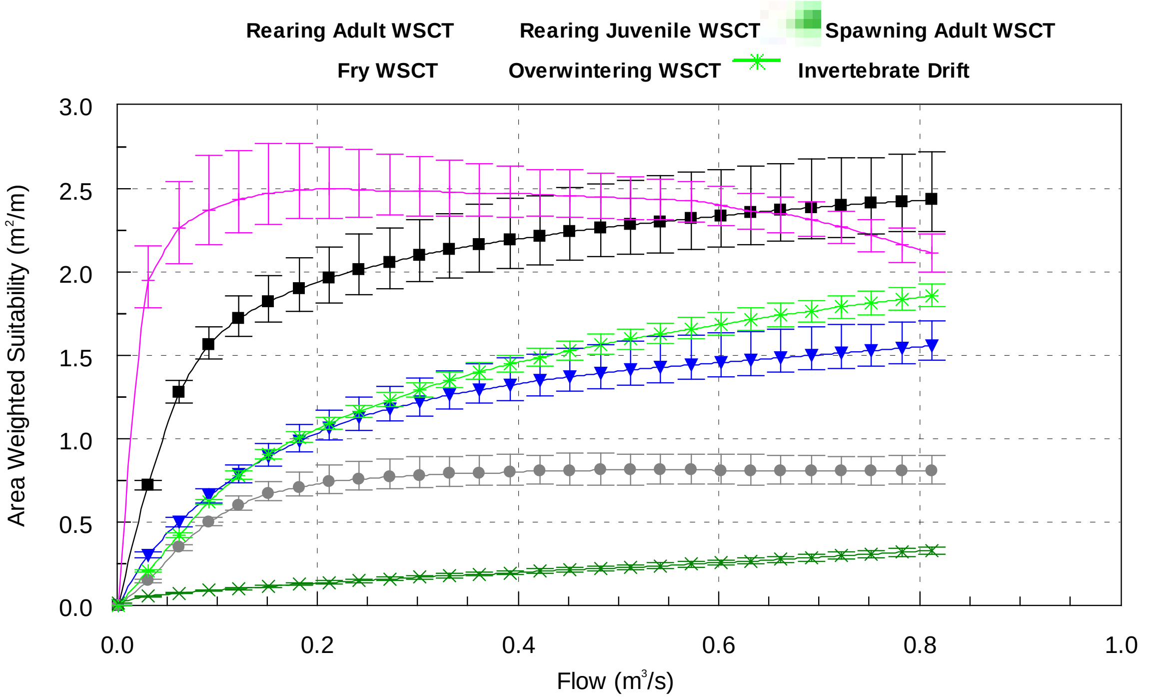


Note: For average hydrological conditions during baseline, the MAD is 0.110 m³/s and MMD range from 0.017 m³/s (February) to 0.432 m³/s (June). No confidence bars are shown since there were only 2 XS in this reach.

Reach 4

In Reach 4 (Figure 4-17), flows were higher (MAD 0.175 m³/s) than in Reach 5, and the 10 XS covered a wider range of meshoabitats (including a deep pool at BC-7). With the exception of the run at BC-8, substrate at all XS was dominated by the highly suitable larger sediments (cobble, gravel and/or boulders). AWS values exceeded 2 m²/m during the MMD associated with fry and adult rearing bioperiods, and 1 m²/m for the juvenile rearing bioperiod. Spawning habitat remained at ~0.75 m²/m across all spawning months, and overwintering habitat was again very limited (~0.1 m²/m).

Figure 4-17 Habitat (AWS) as a function of flow, Reach 4 Blairmore Creek.

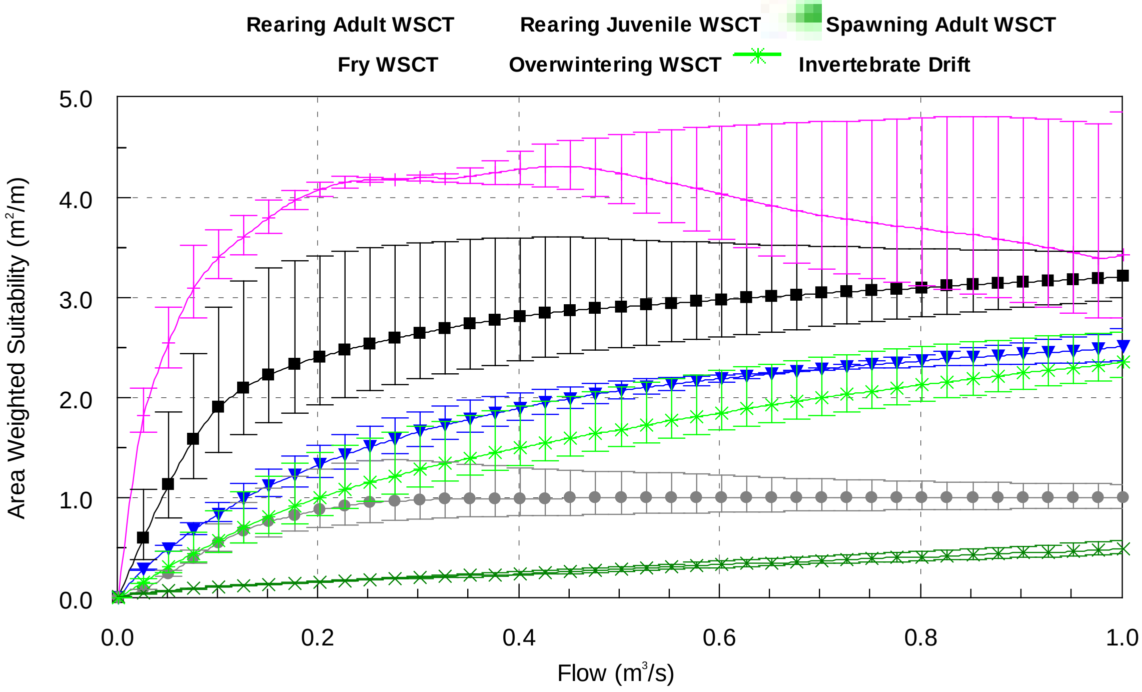


Note: For average hydrological conditions during baseline, the MAD is 0.175 m³/s and MMD range from 0.027 m³/s (February) to 0.689 m³/s (June). Confidence bars shown at the 80% level using 2,000 bootstrap runs.

Reach 3

In Reach 3 (Figure 4-18), flows were again higher (MAD 0.208 m³/s), which supported wetted widths of up to several metres (Figure 4-15). No pool was sampled in this reach, though relatively deep and slow-moving water occurred at BC-2. Peak AWS values for relevant MMD values during each bioperiod reached or exceeded 4 m²/m for fry, 3 m²/m for adult rearing, 2 m²/m for juvenile rearing, and 1 m²/m for spawning. Overwintering habitat remained very limited (~0.1 m²/m).

Figure 4-18 Habitat (AWS) as a function of flow, Reach 3 Blairmore Creek.



Note: For average hydrological conditions during baseline, the MAD is 0.208 m^3/s and MMD range from 0.032 m^3/s (February) to 0.818 m^3/s (June). Confidence bars shown at the 80% level using 2,000 bootstrap runs.

4.2.3 Project Changes to Habitat

4.2.3.1 Average Hydrological Conditions

The predicted changes in AWS on Blairmore Creek, for each reach, bioperiod, and project phase are summarized for average hydrological conditions in Table 4-4. The approach used for this assessment is summarized in Section 3.6.4.

Reach 5

Reach 5 as approximated by the model prediction node BL-03 (Figure 2-1) was assumed to remain upstream of all mine-related impacts on total flow (SRK 2016a); therefore, no changes from baseline (2017) habitat area were predicted during any project phase (Table 4-4) or during drought conditions.

Reaches 3 and 4

Project effects were predicted to increase flows downstream of Reach 5, relative to the baseline period, beginning during the construction (2018) phase (Appendix 10a). The flow changes simulated at model prediction node BL-02, located at the transition between Reaches 3 and 4 (Figure 2-1), were applied within habitat change predictions for both reaches and provided a more conservative estimate of the positive flow changes than at node BC-07 (upper Reach 4; Figure 2-1). The predicted flow gains at BL-02 remained below 10% during 92% of all months from 2018-2099. Flow gains of 10% or higher were predicted primarily during winter and some fall months during certain operations-phase years, and most months of 2042 including January when the largest individual monthly flow gain (33%) was predicted.

Mean habitat changes in AWS for Reach 4 were extremely small for each project phase and bioperiod. Since the predicted flow gains primarily occurred during winter, predicted habitat changes during spawning (May-July) were essentially absent, whereas the highest gains (4% average, equivalent to 10 m^2) were during the overwintering bioperiod with very limited baseline habitat (233 m^2). No habitat losses were predicted for any bioperiod and project phase, even at the (worst-case) individual monthly timescale. Results were similar across Reach 3, but gains in the overwintering habitat reached 7% on average during construction, and 3-5% on average during other phases, though the baseline habitat area in this reach (70 m^2) was even more limited.

Cumulative predicted habitat gains across all three study reaches ranged between 111-196 m^2 of adult rearing habitat (1% of baseline), 84-155 m^2 of juvenile rearing habitat (1-2% of baseline), 9-18 m^2 of spawning habitat (0% of baseline), 85-147 m^2 of fry habitat (0-1% of baseline) and 7-15 m^2 of overwintering habitat (1-3% of baseline).

4.2.3.2 Drought Hydrological Conditions

The predicted changes in AWS on Blairmore Creek, for each reach, bioperiod, and project phase are summarized for 1-in-10 and 1-in-20 dry year conditions in Table 4-5 and Table 4-6, respectively. The differences in MAD between reaches and hydrological conditions were presented in Figure 3-2.

With the exception of spawning habitat in Reach 5, predicted baseline habitat areas were highest during average hydrological conditions and lowest during 1-in-20 dry year conditions, the same pattern as across Gold Creek. The predicted habitat gains due to Project impacts on flow ranged from 0-8% (average gains per bioperiod and project phase) and 0-3% (worst-case monthly gains) relative to baseline conditions, under all hydrological conditions.

4.3 INVERTEBRATE DRIFT

Table 4-7 and Table 4-8 tabulate the available habitat for invertebrate drift on Gold Creek during average and 1-in-10 dry year conditions, respectively. Corresponding results are presented for Blairmore Creek in Table 4-9 and Table 4-10.

On Gold Creek, habitat losses were predicted to be under 10% across all reaches, including both long-term average losses (across Project phases) and during any one individual month. During dry conditions, losses of between 10-13% occurred in individual months (dependent on Project phase and study reach), but were very low (maximum 4%) averaged across Project phases. On Blairmore Creek, average gains of invertebrate drift habitat were all between 1-3%, for both hydrologic conditions.

Flow changes in both Gold and Blairmore creeks are not expected to alter invertebrate drift, whether it be short or moderate distances.

Table 4-4 Blairmore Creek Habitat Area Predictions, 2017-2099, during average hydrological conditions.

					Baseline 2017	Construction 2018				Operations 2019-2042				Decommissioning 2043-2044				Closure 2045-2099			
Reach details			*Westslope Cutthroat Trout*		Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
							Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	Bioperiod	Stanza	m^2 AWS[1]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]
5	Above Mine Influence	3,230	Rearing (Adult)	Apr 1-Sep 30	4,657	4,657	0	0%	0%	4,657	0	0%	0%	4,657	0	0%	0%	4,657	0	0%	0%
			Rearing (Juvenile)	Apr 1-Sep 30	2,850	2,850	0	0%	0%	2,850	0	0%	0%	2,850	0	0%	0%	2,850	0	0%	0%
			Spawning	May 1-Jul 31	1,006	1,006	0	0%	0%	1,006	0	0%	0%	1,006	0	0%	0%	1,006	0	0%	0%
			Fry	Jul 1-Sep 30	6,075	6,075	0	0%	0%	6,075	0	0%	0%	6,075	0	0%	0%	6,075	0	0%	0%
			Overwintering	Oct 1-Mar 31	222	222	0	0%	0%	222	0	0%	0%	222	0	0%	0%	222	0	0%	0%
4	Northwest Surge Pond to BLT4 trib	3,942	Rearing (Adult)	Apr 1-Sep 30	7,463	7,561	98	1%	1%	7,605	142	2%	0%	7,542	79	1%	0%	7,604	141	2%	1%
			Rearing (Juvenile)	Apr 1-Sep 30	4,113	4,180	67	2%	1%	4,211	98	2%	0%	4,167	55	1%	1%	4,215	102	2%	1%
			Spawning	May 1-Jul 31	3,104	3,112	8	0%	0%	3,115	11	0%	0%	3,110	7	0%	0%	3,117	13	0%	0%
			Fry	Jul 1-Sep 30	9,219	9,273	54	1%	0%	9,297	78	1%	0%	9,263	44	0%	0%	9,286	67	1%	0%
			Overwintering	Oct 1-Mar 31	233	237	5	2%	0%	243	10	4%	0%	237	4	2%	0%	241	8	3%	0%
3	1km reach below BLT4 trib	1,167	Rearing (Adult)	Apr 1-Sep 30	2,832	2,868	35	1%	1%	2,886	54	2%	0%	2,864	32	1%	0%	2,883	51	2%	1%
			Rearing (Juvenile)	Apr 1-Sep 30	1,805	1,839	35	2%	1%	1,857	52	3%	1%	1,835	30	2%	1%	1,858	53	3%	1%
			Spawning	May 1-Jul 31	1,148	1,151	3	0%	0%	1,152	4	0%	0%	1,150	2	0%	0%	1,152	5	0%	0%
			Fry	Jul 1-Sep 30	4,019	4,063	44	1%	0%	4,088	69	2%	0%	4,061	41	1%	0%	4,073	54	1%	0%
			Overwintering	Oct 1-Mar 31	70	72	2	3%	2%	75	5	7%	2%	72	2	3%	2%	74	4	5%	2%

BLAIRMORE CREEK SUMMARY	**Total Length (m)**	**Bioperiod**	**Stanza**	TOTAL AWS (m^2)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
ALL REACHES (3 to 5)	**8,339**	**Rearing (Adult)**	**Apr 1-Sep 30**	14,952	**15,085**	**133**	**1%**	0%	15,148	**196**	**1%**	0%	15,062	**111**	**1%**	0%	15,144	**192**	**1%**	0%
		Rearing (Juvenile)	**Apr 1-Sep 30**	8,768	**8,869**	**102**	**1%**	0%	8,918	**150**	**2%**	0%	8,852	**84**	**1%**	0%	8,923	**155**	**2%**	0%
		Spawning	**May 1-Jul 31**	5,257	**5,268**	**11**	**0%**	0%	5,272	**15**	**0%**	0%	5,266	**9**	**0%**	0%	5,275	**18**	**0%**	0%
		Fry	**Jul 1-Sep 30**	19,313	**19,410**	**97**	**1%**	0%	19,460	**147**	**1%**	0%	19,398	**85**	**0%**	0%	19,434	**121**	**1%**	0%
		Overwintering	**Oct 1-Mar 31**	525	**532**	**7**	**1%**	0%	540	**15**	**3%**	0%	531	**7**	**1%**	0%	536	**12**	**2%**	0%

Notes:

Boxed values represent predicted habitat changes of 10% or more.

[1] AWS = Area Weighted Suitability; the total surface area of predicted suitable habitat, calculated as the product of reach length and m^2 suitable wetted width (weighted by individual cross-section suitability results).

[2] This represents the single month within a given reach, stanza and mine life stage which produces the largest % habitat loss below the corresponding monthly baseline value.

Table 4-5 Blairmore Creek Habitat Area predictions, 2017-2099, during dry hydrological conditions (1-in-10 year recurrence).

					Baseline	Construction				Operations				Decommissioning				Closure			
					2017	2018				2019-2042				2043-2044				2045-2099			
Reach details			*Westslope Cutthroat Trout*		Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
							Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	Bioperiod	Stanza	m^2 AWS	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2
5	Above Mine Influence	3,230	Rearing (Adult)	Apr 1-Sep 30	3,969	3,969	0	0%	0%	3,969	0	0%	0%	3,969	0	0%	0%	3,969	0	0%	0%
			Rearing (Juvenile)	Apr 1-Sep 30	2,259	2,259	0	0%	0%	2,259	0	0%	0%	2,259	0	0%	0%	2,259	0	0%	0%
			Spawning	May 1-Jul 31	1,190	1,190	0	0%	0%	1,190	0	0%	0%	1,190	0	0%	0%	1,190	0	0%	0%
			Fry	Jul 1-Sep 30	5,637	5,637	0	0%	0%	5,637	0	0%	0%	5,637	0	0%	0%	5,637	0	0%	0%
			Overwintering	Oct 1-Mar 31	169	169	0	0%	0%	169	0	0%	0%	169	0	0%	0%	169	0	0%	0%
4	Northwest Surge Pond to BLT4 trib	3,942	Rearing (Adult)	Apr 1-Sep 30	6,007	6,140	133	2%	1%	6,169	162	3%	0%	6,073	66	1%	0%	6,134	127	2%	0%
			Rearing (Juvenile)	Apr 1-Sep 30	3,040	3,132	92	3%	2%	3,149	109	4%	1%	3,080	40	1%	1%	3,134	94	3%	1%
			Spawning	May 1-Jul 31	2,801	2,838	37	1%	1%	2,845	44	2%	0%	2,816	14	1%	0%	2,844	42	2%	0%
			Fry	Jul 1-Sep 30	8,164	8,340	176	2%	0%	8,381	218	3%	0%	8,258	95	1%	0%	8,325	161	2%	0%
			Overwintering	Oct 1-Mar 31	159	165	6	4%	2%	170	11	7%	0%	163	4	2%	0%	165	6	4%	0%
3	1km reach below BLT4 trib	1,167	Rearing (Adult)	Apr 1-Sep 30	2,262	2,312	50	2%	1%	2,323	61	3%	0%	2,285	23	1%	0%	2,311	49	2%	1%
			Rearing (Juvenile)	Apr 1-Sep 30	1,270	1,315	45	4%	3%	1,323	52	4%	0%	1,290	20	2%	1%	1,317	47	4%	1%
			Spawning	May 1-Jul 31	1,030	1,044	14	1%	0%	1,046	16	2%	0%	1,036	6	1%	0%	1,044	14	1%	0%
			Fry	Jul 1-Sep 30	4,019	4,063	44	1%	0%	4,088	69	2%	0%	4,061	41	1%	0%	4,073	54	1%	0%
			Overwintering	Oct 1-Mar 31	70	72	2	3%	2%	75	5	7%	2%	72	2	3%	2%	74	4	5%	2%
BLAIRMORE CREEK SUMMARY		**Total Length (m)**	**Bioperiod**	**Stanza**	TOTAL AWS (m^2)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
ALL REACHES (3 to 5)		**8,339**	**Rearing (Adult)**	**Apr 1-Sep 30**	12,238	12,420	**183**	**1%**	0%	12,461	**223**	**2%**	0%	12,327	**89**	**1%**	0%	12,414	**176**	**1%**	0%
			Rearing (Juvenile)	**Apr 1-Sep 30**	6,569	6,706	**137**	**2%**	0%	6,731	**162**	**2%**	0%	6,629	**60**	**1%**	0%	6,711	**142**	**2%**	0%
			Spawning	**May 1-Jul 31**	5,021	5,072	**51**	**1%**	0%	5,081	**60**	**1%**	0%	5,042	**21**	**0%**	0%	5,077	**56**	**1%**	0%
			Fry	**Jul 1-Sep 30**	16,862	17,126	**264**	**2%**	0%	17,190	**329**	**2%**	0%	17,002	**140**	**1%**	0%	17,102	**240**	**1%**	0%
			Overwintering	**Oct 1-Mar 31**	369	377	**8**	**2%**	0%	383	**14**	**4%**	0%	373	**4**	**1%**	0%	377	**8**	**2%**	0%

Notes:

Boxed values represent predicted habitat changes of 10% or more.

[1] AWS = Area Weighted Suitability; the total surface area of predicted suitable habitat, calculated as the product of reach length and m^2 suitable wetted width (weighted by individual cross-section suitability results).

[2] This represents the single month within a given reach, stanza and mine life stage which produces the largest % habitat loss below the corresponding monthly baseline value.

Table 4-6 Blairmore Creek Habitat Area predictions, 2017-2099, during very dry hydrological conditions (1-in-20 year recurrence).

					Baseline	Construction				Operations				Decommissioning				Closure			
					2017	2018				2019-2042				2043-2044				2045-2099			
Reach details			*Westslope Cutthroat Trout*		Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
							Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	Bioperiod	Stanza	m^2 AWS	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]
5	Above Mine Influence	3,230	Rearing (Adult)	Apr 1-Sep 30	3,743	3,743	0	0%	0%	3,743	0	0%	0%	3,743	0	0%	0%	3,743	0	0%	0%
			Rearing (Juvenile)	Apr 1-Sep 30	2,087	2,087	0	0%	0%	2,087	0	0%	0%	2,087	0	0%	0%	2,087	0	0%	0%
			Spawning	May 1-Jul 31	1,194	1,194	0	0%	0%	1,194	0	0%	0%	1,194	0	0%	0%	1,194	0	0%	0%
			Fry	Jul 1-Sep 30	5,292	5,292	0	0%	0%	5,292	0	0%	0%	5,292	0	0%	0%	5,292	0	0%	0%
			Overwintering	Oct 1-Mar 31	158	158	0	0%	0%	158	0	0%	0%	158	0	0%	0%	158	0	0%	0%
4	Northwest Surge Pond to BLT4 trib	3,942	Rearing (Adult)	Apr 1-Sep 30	5,669	5,779	110	2%	1%	5,824	155	3%	0%	5,725	56	1%	0%	5,787	118	2%	0%
			Rearing (Juvenile)	Apr 1-Sep 30	2,793	2,874	81	3%	2%	2,898	105	4%	1%	2,830	37	1%	1%	2,883	90	3%	1%
			Spawning	May 1-Jul 31	2,679	2,719	39	1%	1%	2,727	47	2%	0%	2,695	16	1%	0%	2,727	47	2%	0%
			Fry	Jul 1-Sep 30	7,767	7,881	114	1%	1%	7,983	216	3%	0%	7,858	91	1%	0%	7,883	116	1%	0%
			Overwintering	Oct 1-Mar 31	145	150	6	4%	2%	155	10	7%	0%	148	4	3%	0%	150	6	4%	0%
3	1km reach below BLT4 trib	1,167	Rearing (Adult)	Apr 1-Sep 30	2,119	2,172	53	3%	1%	2,182	64	3%	0%	2,144	26	1%	0%	2,171	52	2%	1%
			Rearing (Juvenile)	Apr 1-Sep 30	1,146	1,192	45	4%	3%	1,198	52	5%	1%	1,166	20	2%	1%	1,194	47	4%	1%
			Spawning	May 1-Jul 31	987	1,004	17	2%	0%	1,005	18	2%	0%	994	7	1%	0%	1,004	17	2%	0%
			Fry	Jul 1-Sep 30	2,787	2,894	107	4%	2%	2,921	134	5%	0%	2,845	59	2%	0%	2,878	91	3%	1%
			Overwintering	Oct 1-Mar 31	36	38	2	5%	3%	39	3	8%	0%	37	1	2%	0%	38	2	5%	0%
BLAIRMORE CREEK SUMMARY		**Total Length (m)**	**Bioperiod**	**Stanza**	TOTAL AWS (m^2)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	TOTAL AWS (m^2)	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
ALL REACHES (3 to 5)		**8,339**	**Rearing (Adult)**	**Apr 1-Sep 30**	11,531	11,694	**163**	**1%**	0%	11,750	**218**	**2%**	0%	11,612	**81**	**1%**	0%	11,701	**170**	**1%**	0%
			Rearing (Juvenile)	**Apr 1-Sep 30**	6,026	6,153	**127**	**2%**	0%	6,183	**157**	**3%**	0%	6,084	**57**	**1%**	0%	6,164	**137**	**2%**	0%
			Spawning	**May 1-Jul 31**	4,860	4,917	**57**	**1%**	0%	4,925	**65**	**1%**	0%	4,883	**22**	**0%**	0%	4,925	**65**	**1%**	0%
			Fry	**Jul 1-Sep 30**	15,846	16,067	**222**	**1%**	0%	16,196	**350**	**2%**	0%	15,995	**149**	**1%**	0%	16,053	**207**	**1%**	0%
			Overwintering	**Oct 1-Mar 31**	339	347	**8**	**2%**	0%	352	**13**	**4%**	0%	344	**5**	**1%**	0%	347	**8**	**2%**	0%

Notes:

Boxed values represent predicted habitat changes of 10% or more.

[1] AWS = Area Weighted Suitability; the total surface area of predicted suitable habitat, calculated as the product of reach length and m^2 suitable wetted width (weighted by individual cross-section suitability results).

[2] This represents the single month within a given reach, stanza and mine life stage which produces the largest % habitat loss below the corresponding monthly baseline value.

Table 4-7 Gold Creek Habitat Area Predictions for Benthic Invertebrates, 2017-2099, during during average hydrological conditions.

			Baseline 2017	Construction 2018				Operations 2019-2042				Decommissioning 2043-2044				Closure 2045-2099			
Reach details			Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
					Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	m^2 AWS	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2
9	GCT10 trib to North Creek	2,130	817	817	0	0%	0%	793	-24	-3%	-8%	781	-36	-4%	-6%	784	-34	-4%	-6%
8	Above Caudron Creek to GCT10 trib	1,906	1,339	1,339	0	0%	0%	1,301	-38	-3%	-9%	1,285	-54	-4%	-5%	1,289	-50	-4%	-5%
7	Gold Creek Bridge to Caudron Creek	3,183	5,939	5,939	0	0%	0%	5,834	-106	-2%	-5%	5,793	-146	-2%	-3%	5,796	-143	-2%	-3%
6	Above Morin Creek to Gold Creek Bridge	1,683	1,378	1,378	0	0%	0%	1,340	-37	-3%	-8%	1,334	-44	-3%	-7%	1,333	-44	-3%	-7%
5	Below Morin Creek	502	1,345	1,345	0	0%	0%	1,307	-38	-3%	-8%	1,303	-43	-3%	-6%	1,303	-43	-3%	-6%
GOLD CREEK SUMMARY		**Total Length (m)**	**TOTAL AWS (m^2)**	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
		9,404	**10,819**	**10,819**	**0**	**0%**	**0%**	**10,575**	**-243**	**-2%**	**-9%**	**10,496**	**-323**	**-3%**	**-7%**	**10,505**	**-314**	**-3%**	**-7%**

Table 4-8 Gold Creek Habitat Area Predictions for Benthic Invertebrates, 2017-2099, during dry hydrological conditions (1-in-10 year recurrence).

			Baseline 2017	Construction 2018				Operations 2019-2042				Decommissioning 2043-2044				Closure 2045-2099			
Reach details			Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
					Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	m^2 AWS	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2	m^2 AWS^1	m^2 AWS^1	% AWS^1	% AWS^2
9	GCT10 trib to North Creek	2,130	318	318	0	0%	0%	308	-10	-3%	-13%	300	-18	-6%	-10%	302	-16	-5%	-10%
8	Above Caudron Creek to GCT10 trib	1,906	527	527	0	0%	0%	510	-16	-3%	-9%	500	-27	-5%	-8%	506	-21	-4%	-5%
7	Gold Creek Bridge to Caudron Creek	3,183	3,929	3,929	0	0%	0%	3,835	-94	-2%	-6%	3,792	-137	-3%	-4%	3,802	-127	-3%	-4%
6	Above Morin Creek to Gold Creek Bridge	1,683	1,001	1,001	0	0%	0%	955	-46	-5%	-10%	942	-58	-6%	-10%	945	-56	-6%	-10%
5	Below Morin Creek	502	947	947	0	0%	0%	897	-50	-5%	-12%	888	-59	-6%	-10%	891	-56	-6%	-10%
GOLD CREEK SUMMARY		**Total Length (m)**	**TOTAL AWS (m^2)**	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
		9,404	**6,722**	**6,722**	**0**	**0%**	**0%**	**6,505**	**-217**	**-3%**	**-13%**	**6,423**	**-299**	**-4%**	**-10%**	**6,446**	**-276**	**-4%**	**-10%**

Notes (both tables):

Boxed values represent predicted habitat changes of 10% or more.

The bioperiod for Benthic Invertebrates is June 1-September 30.

[1] AWS = Area Weighted Suitability; the total surface area of predicted suitable habitat, calculated as the product of reach length and m^2 suitable wetted width (weighted by individual cross-section suitability results).

[2] This represents the single month within a given reach, stanza and mine life stage which produces the largest % habitat loss below the corresponding monthly baseline value.

Table 4-9 Blairmore Creek Habitat Area Predictions for Benthic Invertebrates, 2017-2099, during during average hydrological conditions.

			Baseline 2017	Construction 2018				Operations 2019-2042				Decommissioning 2043-2044				Closure 2045-2099			
Reach details			Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
					Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	m^2 AWS	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]
5	Above Mine Influence	3,230	2,801	2,801	0	0%	0%	2,801	0	0%	0%	2,801	0	0%	0%	2,801	0	0%	0%
4	Northwest Surge Pond to BLT4 trib	3,942	3,761	3,856	96	3%	1%	3,901	140	4%	1%	3,836	75	2%	1%	3,905	144	4%	1%
3	1km reach below BLT4 trib	1,167	1,246	1,280	34	3%	2%	1,297	51	4%	2%	1,275	29	2%	2%	1,298	52	4%	2%
	BLAIRMORE CREEK SUMMARY	**Total Length (m)**	**TOTAL AWS (m^2)**	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
		8,339	**7,808**	**7,938**	**130**	**2%**	**0%**	**7,999**	**191**	**2%**	**0%**	**7,912**	**105**	**1%**	**0%**	**8,004**	**196**	**3%**	**0%**

Table 4-10 Blairmore Creek Habitat Area Predictions for Benthic Invertebrates, 2017-2099, during dry hydrological conditions (1-in-10 year recurrence).

			Baseline 2017	Construction 2018				Operations 2019-2042				Decommissioning 2043-2044				Closure 2045-2099			
Reach details			Mean Suitable Area	Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period			Mean Suitable Area	Difference from baseline period		
					Mean		1-month max		Mean		1-month max		Mean		1-month max		Mean		1-month max
#	Description	Length (m)	m^2 AWS	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]	m^2 AWS[1]	m^2 AWS[1]	% AWS[1]	% AWS[2]
5	Above Mine Influence	3,230	3,406	3,406	0	0%	0%	3,406	0	0%	0%	3,406	0	0%	0%	3,406	0	0%	0%
4	Northwest Surge Pond to BLT4 trib	3,942	2,482	2,583	101	4%	3%	2,604	121	5%	1%	2,531	49	2%	1%	2,588	105	4%	1%
3	1km reach below BLT4 trib	1,167	784	817	33	4%	3%	823	39	5%	0%	799	15	2%	1%	818	34	4%	1%
	BLAIRMORE CREEK SUMMARY	**Total Length (m)**	**TOTAL AWS (m^2)**	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)	**TOTAL AWS (m^2)**	**TOTAL CHANGE AWS (m^2)**	**AVERAGE CHANGE AWS (%)**	1-month max loss AWS (%)
		8,339	**6,673**	**6,807**	**134**	**2%**	**0%**	**6,833**	**160**	**2%**	**0%**	**6,736**	**64**	**1%**	**0%**	**6,812**	**139**	**2%**	**0%**

Notes (both tables):

Boxed values represent predicted habitat changes of 10% or more.

The bioperiod for Benthic Invertebrates is June 1-September 30.

[1] AWS = Area Weighted Suitability; the total surface area of predicted suitable habitat, calculated as the product of reach length and m^2 suitable wetted width (weighted by individual cross-section suitability results).

[2] This represents the single month within a given reach, stanza and mine life stage which produces the largest % habitat loss below the corresponding monthly baseline value.

5.0 SUMMARY

An instream flow assessment (IFA) was conducted to evaluate the potential for flow-related effects on WSCT and their habitat in five study reaches on Gold Creek and three study reaches on Blairmore Creek. Predictions were made for baseline and all Project phases of hydraulic conditions important for WSCT (i.e., stream depth, width, water velocity, substrate) and the Area Weighted Suitability (AWS) of habitat, calculated by applying WSCT life-stage specific Habitat Suitability Curves (HSCs) to these hydraulic conditions. Most stream-transect data used to develop the IFA models were collected during the June-October 2016 period, which was very dry (i.e., low flows were experienced) relative to typical conditions during these months; this provided elevated confidence in the predictions of potential habitat quantity and suitability alterations during reduced-flow conditions that may result either naturally (e.g., during droughts), from Project-related effects, or both.

During average hydrological conditions, the IFA model predictions suggested that, without mitigation, Project-related flow changes would cause changes of less than 10% in habitat area (AWS) relative to long-term baseline conditions in all study reaches and all stanzas for WSCT rearing, spawning, fry or overwintering, when averaged across each Project phase. Results exceeding the 10% significance threshold indicating the potential for limitations to WSCT habitat only were predicted on Gold Creek when using a more stringent (single-month) timeframe, a more conservative flow scenario (continuous 1-in-10 and 1-in-20 year low flow conditions), or both, but the probability of these specific scenarios occurring is low.

Short-term mitigation measures have been proposed for supplementing flows during dry years, which is aimed to alleviate any elevated risk for causing incremental residual effects to critical habitat. Similarly, the predicted Project-related alterations to fish habitat under average conditions will be counterbalanced through the implementation of a Habitat Offsetting Plan that aims to create a net gain of WSCT habitat in Gold Creek. After implementing these measures, the residual effects predicted from changes in hydrology from the Project on the WCST populations are expected to be mitigated.

During the Project operation, monitoring activities will be completed across all disciplines related to the health of WSCT populations and habitat quality, to ultimately confirm there are no serious, irreversible changes occurring at the population level nor any decreases in the resilience of WSCT population along the length of Gold and Blairmore creeks. Recommended monitoring and follow-up activities have been covered in this and other documents submitted as part of the Aquatic Ecology Effects Assessment.

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APPENDICES

Appendix A1

Local Hydrology Baseline Data

HYDROLOGY BASELINE ASSESSMENT: GRASSY MOUNTAIN COAL PROJECT

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1.0 INTRODUCTION

1.1 PURPOSE

The purpose of the Hydrology Baseline Assessment is to characterize the baseline hydrological environment in Gold Creek and Blairmore Creek watersheds; specifically, stream flows along the length of Gold Creek and Blairmore Creek. The data presented in this report describe existing conditions prior to the proposed mine development. The specific objectives of the baseline study are to:

- Characterize hydrological regimes that could potentially be affected by the Project;
- Provide baseline information necessary to support the completion of an Instream Flow Assessment (IFA) and a wider Aquatic Effects Assessment (AEA) for the Project Environmental Impact Assessment (EIA); and
- Provide supporting information that may be used in any required mitigation, offsetting (i.e., compensation), and/or adaptive monitoring programs.

The focus of this assessment are the methods, and results, of the hydrometric monitoring and derived products that characterize baseline conditions, including:

- Hydrographs at each local gauge for the duration of continuously collected field data;
- Long-term (1975-2016) synthetic hydrographs at each local gauge, estimated from correlation of local gauge and regional (Water Survey of Canada) gauge data; and
- Application of the synthetic hydrographs to estimate long-term, reach-average flow characteristics (1975-2016) in support of the Grassy Mountain Instream Flow Assessment (IFA).

This approach is entirely empirically-based and differs from an associated assessment (SRK 2016) which applies a regional watershed modelling approach to predict total runoff volumes across Gold and Blairmore Creek watersheds as the proposed mine infrastructure develops through time. Total runoff includes the individual contributions from overland flow, interflow and groundwater, and these volumes are likely higher than in the stream channel alone. There is some overlap between assessments, given that the SRK (2016) assessment utilizes the local and WSC hydrometric data to assist in the model calibration process.

1.2 MONITORING NETWORK

The Grassy Mountain baseline hydrology network includes six local monitoring stations encompassing the area considered most likely to manifest potential effects related to Project operations (Table 1-1). The baseline program also incorporates the hydrology data from long-term hydrology stations operated by Water Survey of Canada (WSC) on the Crowsnest River (WSC Station 05AA008) and Gold Creek (WSC Station 05AA030); the location of all (six) local and (two) WSC stations are displayed in Figure 1-1 of the IFA Main report. Climate data from the nearby Pelletier Creek monitoring station, operated by Alberta Environment and Parks (AEP, station 305NJ61) are used to characterize the temperature and precipitation conditions during the period of hydrometric monitoring for this assessment.

Table 1-1 Summary of the Grassy Mountain Hydrology Baseline Assessment local monitoring stations.

Station	Station Location	Status	Drainage Area (km^2)	UTM Coordinates (NAD 83, Zone 11U)		Period of Record[a]
				Easting	Northing	
BC-15/H03	Blairmore Creek Upper	Active	15.0	684163	5508587	Oct 2013-Aug 2014 May 2015-present
BC-H02	Blairmore Creek Middle	Inactive	23.7	684976	5505089	Oct 2013-Aug 2014
BL-0/H01	Blairmore Creek Lower	Active	47.7	683555	5500660	Sep 2013-Dec 2014 Mar 2016-present
GC-27/H03	Gold Creek Headwaters	Active	2.2	687414	5510790	May 2016-present
GC-11/H02	Gold Creek below Caudron Creek	Active	28.7	687873	5506468	May 2016-present
GC-7/H01	Gold Creek above Morin Creek	Active	31.5	687472	5504582	Sep 2013-Dec 2014 Mar 2016-present

[a] Period of record refers to the period for which any data are available; it does not necessarily indicate continuous monitoring.

2.0 METHODS

2.1 HYDROMETRIC MONITORING

Activities conducted at the six local hydrometric stations during field visits between September 2013 and October 2016 are summarized in Table 2-1, including measurements of discharge (Q), water level (WL, i.e., stage), and station installation or decommissioning.

Table 2-1 Activities conducted during Grassy Mountain hydrometric baseline field visits, September 2013 to October 2016.

		BC-15/H03	BC-H02	BL-0/H01	GC-27/H03	GC-11/H02	GC-7/H01
Sep 2013	Station installation	-	-	✓	-	-	✓
	WL and Q	-	-	✓	-	-	✓
Oct 2013	Station installation	✓	✓	-	-	-	-
Jan 2014	WL and Q	✓	✓	✓	-	-	✓
Apr 2014	WL and Q	-	-	✓	-	-	✓
May 2014	WL and Q	-	✓	✓	-	-	✓
Jun 2014	WL and Q	✓	✓	✓	-	-	✓
Jul 2014 (early)	WL and Q	✓	✓	✓	-	-	✓
Jul 2014 (late)	WL and Q	-	-	✓	-	-	-
Aug 2014	WL and Q	✓	✓	✓	-	-	✓
Dec 2014	Station decommission	a	✓	✓	-	-	✓

Table 2-1 (Cont'd.)

		BC-15/H03	BC-H02	BL-0/H01	GC-27/H03	GC-11/H02	GC-7/H01
Mar 2016	Station reactivation	a	-	✓	-	-	✓
	WL and Q	✓	-	✓	-	-	✓
May 2016	Station installation	-	-	-	✓	✓	-
	WL and Q	-	-	-	✓	✓	✓
June 2016	WL and Q	-	-	-	-	✓	✓
July 2016	WL and Q	✓	-	-	-	-	-
Sept 2016	WL and Q	✓	-	-	✓	✓	✓
Oct 2016	WL and Q	✓	-	✓	✓	✓	✓

-: Activity not planned for visit.

a: BC-15/H03 was not decommissioned in December 2014 and a partial continuous record is available in 2015.

Water Level Measurement

Continuous water level measurements at all stations were made using Campbell Scientific CR200X dataloggers and OTT PLS pressure transducers. Manually surveyed water levels from each station were used to provide a reference for the continuous water levels. Procedures were derived from government standards (BC MOE 2009) and are summarized below:

- Water levels were surveyed against two to three independent benchmarks at each station. One benchmark was assigned an arbitrary datum of 100 m height, and all surveyed elevations were calculated relative to this height;
- Water level readings were collected using an automatic level with a precision of 0.001 m (1 mm);
- Water level and benchmark elevation readings were repeated with a second automatic level set-up (i.e., a different automatic level elevation); and
- Elevation differences for each surveyed location (water level and each benchmark) were calculated between the independent automatic level positions, with a precision tolerance of 0.005 m (5 mm). If water level readings differed by more than the accepted tolerance, water level and benchmark readings were repeated until precision was within 5 mm.

Discharge Measurement

Stream discharge measurements followed procedures consistent with Water Survey of Canada (WSC 2001), United States Geological Survey (USGS 1982), and BC Ministry of Environment (BC MOE 2009) recommendations and protocols.

Standards for velocity-area discharge measurements are summarized below:

- A Sontek FlowTracker Acoustic Doppler velocimeter (ADV) was used to measure water velocity. Water velocities were derived from a 40-second average;

- Each stream cross-section was sampled using a minimum of 20 vertical measurements (panels). Vertical measurements were sufficiently distributed to limit individual panel flow to less than 10% of total stream flow;
- For open-water flow, in each panel one velocity measurement was made at 60% of the depth below the surface (all streams were <0.75 m deep); and
- For under-ice flow, the same procedures were used, with the exceptions that velocity was observed at 50% of the under-ice depth and under-ice measurements were subject to a velocity correction factor of 0.9 to account for friction at the ice-water interface.

Rating Curve Development

Paired manual measurements of water level (stage) and streamflow (discharge) were used to develop stage-discharge relationships, or rating curves, which in turn were used to derive a continuous record of discharge from the continuous water level values measured by the pressure transducers. The Aquarius 3.10.71 Hydrologic Workstation Edition® software program (Aquatic Informatics, Vancouver, BC) was used for all rating curve and time series data analyses.

The stage-discharge relationship is described by the general equation:

$$Q = a\,(WL - SZF)^{b}$$

where Q is discharge (m^3/s), WL is the stage (m), SZF is the Stage of Zero Flow (m), and ‘a’ and ‘b’ are unitless calibration coefficients. The coefficient ‘a’ represents the discharge when the effective depth of flow (WL-SZF) equals one.

The exponent ‘b’ value is of considerable importance, and depends on a range of factors including the cross-sectional channel geometry and type of hydraulic control (e.g., the governing downstream channel conditions and features). For natural channels hydraulically controlled by a rock outcrop, riffle, or gravel bar, the ‘b’ value typically ranges from 1.5 (for rectangular channel geometry) to 2.5 (for triangular or ‘notched’ channel geometry) (Rantz et al. 1982). Unusual stage-discharge relations and the value of ‘b’ may occur due to temporary channel cross-section changes associated with scour and fill, growth and decay of aquatic vegetation, debris jams, ice, or during periods of rapidly changing flow (e.g., Braca 2008).

The base rating curves were developed using measurements considered to represent the most stable hydraulic conditions of each system. The base curves were shifted based on manual measurements, to account for transient changes in hydraulic controls (e.g., ice, cycles of sediment scour and deposition).

At least ten water level and discharge measurements, distributed across a range of flows, are typically required to create a reliable rating curve (BC MOE 2009). Rating curves that are developed with fewer points, or with measurements across a narrow range of flows, should be interpreted with caution due to the limited information available to validate the curve. A qualitative assessment of each rating curve is provided in the rating curve discussion (Section 3.0), based on the number of measurements used in development of the curve, the fit of measurements to the curve, and the range of discharges covered by the measurements. If the curve was based on ten or more measurements, the measurements generally fit the curve well (i.e., few outliers), and the measurements spanned a relatively wide range of discharges, the curve was assessed as good quality. If the curve was based on fewer than ten measurements, the measurements showed more scatter around the curve, or there were few reliable measurements available to define the upper end of the curve, the curve was assessed as fair quality. Rating curves for the two newest stations (GC-27/H03 and GC-11/H02), both established in May 2016, were designated preliminary.

Continuous discharge data were assigned grades derived from WSC criteria, as follows:

- Flows greater than two times the highest manual flow measurement or less than half of the lowest manual flow measurement used to develop the rating curve, and flows that were estimated rather than directly derived, were graded ‘E’ (estimate);
- Periods when flows were potentially affected by ice were graded ‘B’ (backwater due to ice);
- Days with two or more hours of missing data were graded ‘A’ (partial); and
- Data that were not recorded during the operational period of a station were graded ‘M’ (missing).

Quality assurance and quality control for hydrometric data was conducted using a number of methods, as determined by site characteristics. Continuous water level records were compared against manual water level surveys completed during each station visit, to identify any sensor drift and/or bio-fouling effects. Manual and derived discharges in each stream were compared to ensure there was agreement between the upstream and downstream stations.

2.2 SYNTHETIC HYDROGRAPH GENERATION

Hydrometric stations installed for more than 20 years at specific points of interest represent the best long-term streamflow estimates; however, these data records rarely exist. For the purposes of the Grassy Mountain IFA, estimates of long-term (synthetic) streamflows were required to characterize baseline conditions in each study reach (Reaches 5 to 9 on Gold Creek, Reaches 3 to 5 on Blairmore Creek). This required a two-stage process, including (1) estimation of synthetic hydrographs at the six local hydrometric (‘primary’) gauges on Gold and Blairmore creeks (Table 1-1), and (2) adjusting these hydrographs empirically, using available streamflow measurements collected at (‘secondary’) gauge locations specific to each reach. The resulting synthetic hydrographs cover the 41-year period from 1975- 2016 (the record of gauged flows available from the WSC Gold Creek near Frank station).

2.2.1 Primary Gauge Synthetic Hydrographs

In the absence of long-term flow records at specific points of interest, daily streamflows from the short-term local hydrometric gauges on Gold and Blairmore Creeks (Table 1-1) can be related to the concurrent daily streamflow records from the long-term WSC gauges in order to establish a relationship between the short-term and long-term sites. These relationships can then be used to transform the longer-term WSC records to each short-term gauge. Stronger relationships translate to higher confidence in the derived long-term records at local gauges, and vice versa. R^2 values are commonly used to quantify the strength of relationship, representing the proportion of the total variation in the observed data points that can be explained by the regression equation, ranging between values of zero (no relationship) and one (perfectly correlated relationship). It is analogous to the Nash-Sutcliffe (NS) efficiency measure for comparison of modeled results, although NS takes into account any bias of the relationship.

Ideally, a regression model would be trained with three or more years of consecutive flow data and validated against three or more years of independent flow data (ARD 2011), although other guidelines are shorter (e.g., two years of local gauge data, Hatfield et al 2007). In this study, the duration of local gauge hydrographs ranged from 6 months (stations GC-11/H02 and GC-27/H03) to 29 months (station BC-15/H03). Ongoing hydrometric monitoring will help to meet these target record lengths.

Seasonal-based regression relationships were developed to capture differences in unit flow values (i.e., measured streamflows per km^2 unit of contributing area) that an annual regression of values would not capture, although there were insufficient data to use the shorter monthly timestep as used by ARD (2011). The seasonal relationships were defined in this study, as follows:

- Winter months;
- Early freshet (April);
- Lower-flow open-water conditions (below a threshold Mean Annual Discharge (MAD) value at the WSC gauge); and
- Higher-flow open-water conditions (above a threshold MAD value at the WSC gauge).

Within the open-water period, a distinction between lower-flow and higher-flow conditions was made since the primary objective of this regression analysis was to best-estimate the lower-flow conditions during the May to October period, which covers the most critical bioperiods (e.g., rearing/feeding, spawning, and fry emergence) associated with the Westslope Cutthroat Trout fish species relevant to the Grassy Mountain IFA study.

The main uncertainties within each seasonal relationship were as follows. Winter data were only collected at the three Blairmore Creek gauges, and lower Gold Creek (GC-7/H01) gauge, during a single winter period (2013-2014). Since the WSC Gold Creek near Frank gauge does not monitor through winter (typically December to March), the regression with GC-7/H01 during this one available winter was developed using the data collected year-round from WSC Crowsnest River at Frank, pro-rated for area. There were more data available for developing the April relationships (April 2014 and April 2016 at BC-0/H01, BC-15/H03, GC-7/H01, WSC Gold Creek and WSC Crowsnest River gauges); however, April 2014 was pre-freshet and the flows remained low (representative of winter), whereas April 2016 contained the peak freshet and the flows were significantly higher than in winter. Relationships developed for this transitory month will change annually, and remain limited when spanning across a multi-year period. During high flows (e.g., >200% MAD) from May to October, rating curves for all gauges are poorly defined (relative to low or moderate flows), and the regression relationships are also disproportionately skewed by the largest flows. The concurrent data available at GC-7/H01, Blairmore Creek and WSC gauges from May to August 2014 helped to reduce some uncertainty within the high-flow relationships, since this period was extremely wet (streamflow measurements on May 28, 2014 at GC-7/H01 and BC-0/H01 were approximately six and ten times higher, respectively, than the corresponding long-term MAD values estimated at these locations). Low flows (e.g., <200% MAD) from May to October were well characterized within the 2016 hydrometric data; however, streamflow measurements in support of the IFA indicate complex surface water-groundwater connections along Gold Creek, which may vary under different flow conditions and ultimately reduce the strength of derived relationships.

Given the brevity of available data, all data within the winter and april periods were used to train the regression model, and future gauged data will be used to update and/or validate the derived regressions during these periods. During open-water conditions, the low-flow and high-flow regressions were trained with all datapoints except during the September to October 2013 period, which was used as a brief validation period given both flow conditions occurred. Short validation periods of a few months have also been used in other studies with limited data availability (e.g., ARD 2011).

2.2.2 Secondary Gauge Synthetic Hydrographs

For each study reach on Gold and Blairmore creeks, an appropriate primary gauge synthetic hydrograph was selected from the three available options on each creek, based on proximity, available concurrent data and derived strength of relationships, and perceived ability to represent the hydrologic regime characterizing each reach (e.g., flashier response to precipitation events in upstream reaches, and vice versa).

A secondary gauge location was selected in each reach without a suitable primary gauge available. The secondary gauge represented a location where multiple streamflow measurements were conducted and where long-term synthetic hydrographs would be generated, but no continuous data were available. Secondary gauge streamflow measurements were conducted from June to October 2016 in support of IFA field programs, to the same standards as those outlined above for hydrometric stations. The ratio of flows measured at a secondary gauge location to the flows measured at a corresponding primary gauge location was calculated and represented an Empirical Adjustment Factor (EAF). The corresponding long-term primary gauge hydrograph was then multiplied by the EAF to derive a long-term secondary gauge hydrograph. All EAF values were representative of low-flow conditions that characterized all 2016 field programs, and may vary during different flow conditions, but these were considered ideal for estimating critical low flow effects on fish habitat of primary importance to the IFA.

The alternative adjustment method, pro-rating the primary gauge data based on drainage area differences to the secondary gauge location, was not used given the large spatial differences in measured unit runoff that were identified during the IFA field programs (Section 3.2.1.1 of the IFA). For instance, pro-rating the Gold Creek flows gauged just downstream of the Caudron Creek confluence (at GC-11/H02, drainage area 28.7 km^2) to just above the Caudron Creek confluence (at GC-13, drainage area 17.3 km^2) would severly overestimate the GC-13 flows (i.e., 60% of those at GC-11 based on the ratio of areas), compared to measured GC-13 streamflows that were 10-20% of those at GC-11 given the dominance of Caudron Creek inflows to GC-11. Similarly, pro-rating the Gold Creek flows gauged at GC-7/H01, drainage area 31.5 km^2) to Reach 6 near Lille (at GC-3, drainage area 31.8 km^2) would severly overestimate the GC-3 flows (i.e., 101% of those at GC-7/H01 based on the ratio of areas), compared to measured GC-3 streamflows that were approximately one-third of those at GC-7/H01 due to the large flow losses subsurface that occur in Reach 6.

3.0 RESULTS AND DISCUSSION

3.1 HYDROMETRIC MONITORING

3.1.1 Stage-Discharge Rating Curves

Summary information including equations for each of the base rating curves are provided in Table 3-1. Open ended rating equations may potentially be updated in the future to incorporate information from additional water level and discharge observations.

Rating curves are provided in graphical format in Figure 3-1 to Figure 3-6. Only the manual measurements that were assessed as 'good' or 'excellent' quality were used to develop the rating curves.

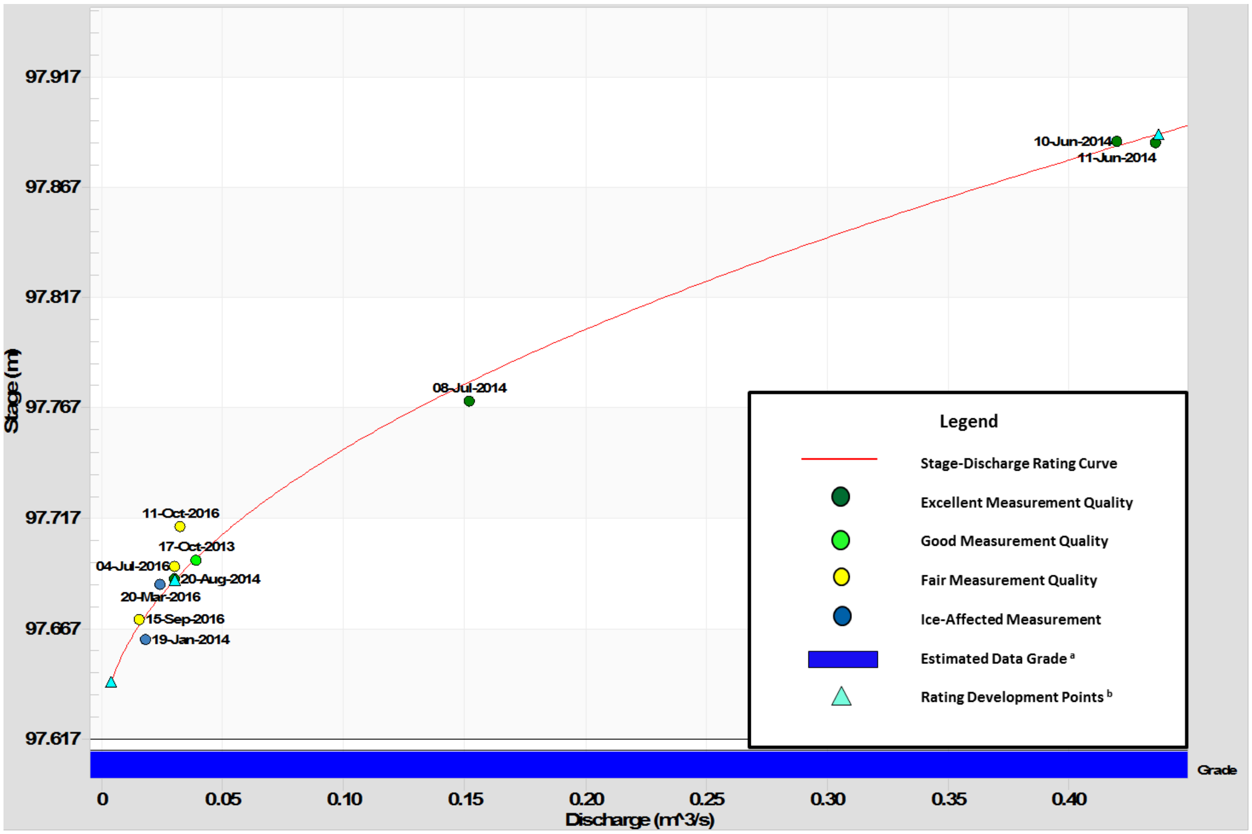
Table 3-1 Rating curve summary for local hydrometric gauges, 2013- 2016.

Station	Rating Period Start Date	Rating Period End Date	Rating Equation[1]	Estimated Discharge[2]
Blairmore Creek				
BC-15/H03	Oct 2013	Open ended	$Q = 5.85 \cdot (WL-97.617)^{2.00}$	Full range
BL-H02	Oct 2013	Aug 2014	$Q = 13.03 \cdot (WL-97.662)^{2.01}$	Full range
BL-0/H01	Sep 2013	Open ended	$Q = 14.24 \cdot (WL-97.995)^{2.49}$	$<0.06\ m^3/s$ $>4.96\ m^3/s$
Gold Creek				
GC-27/H03	May 2016	Open ended	$Q = 2.07 \cdot (WL-99.133)^{2.03}$	Full range
GC-11/H02	May 2016	Open ended	$Q = 10.18 \cdot (WL-99.020)^{2.00}$	Full range
GC-7/H01	Sep 2013	Open ended	$Q = 11.26 \cdot (WL-97.262)^{2.03}$	$<0.07\ m^3/s$ $>4.06\ m^3/s$

[1] WL refers to water level corrected to the local datum.

[2] Continuous discharge data are considered 'estimated' when they have been derived from: (1) rating curve extrapolations less than 0.5x the lowest or greater than 2x the highest manually measured discharges used to build the curve, or (2) rating curve equations that are based on a limited number and range of manual measurements.

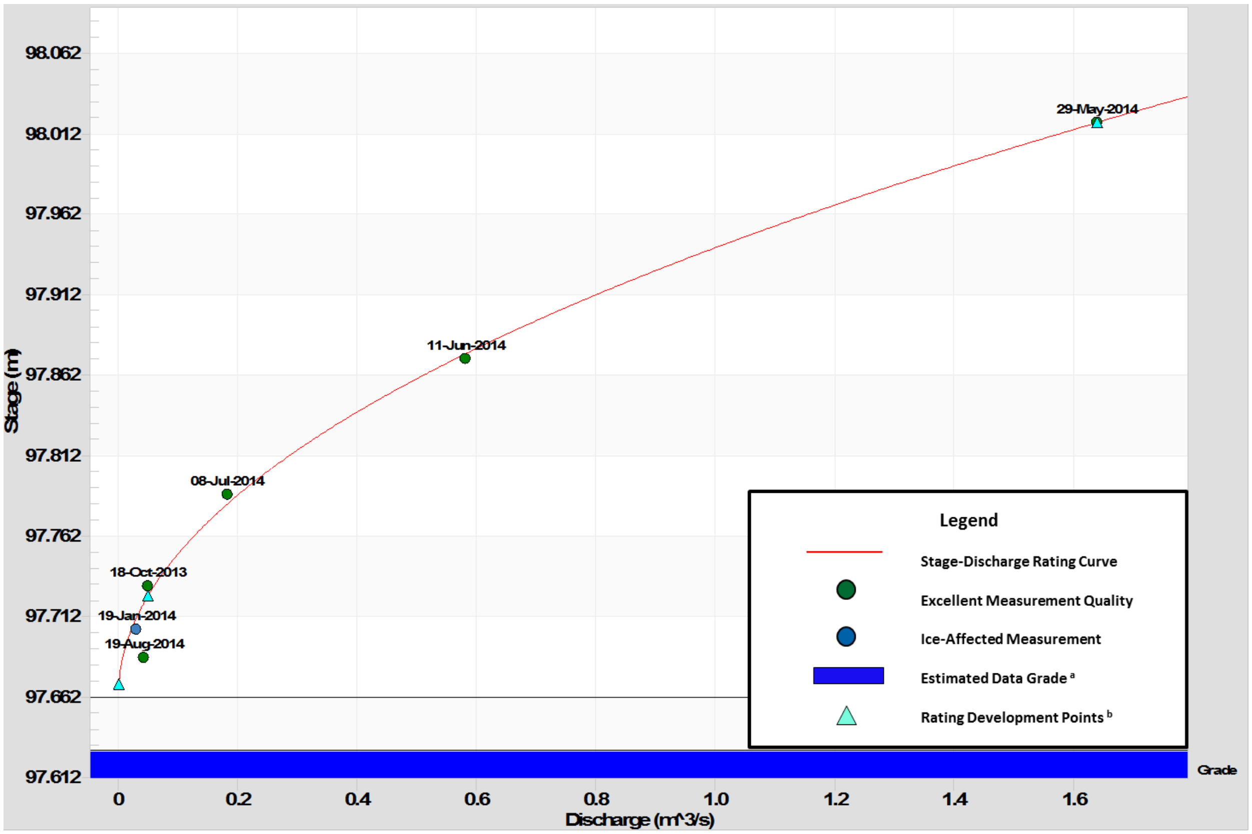
Figure 3-1 BC-15/H03 stage-discharge rating curve and manual measurements, October 2013 to October 2016.



[a] Estimated data grade indicated in blue at base of graph indicates that the entire rating curve is considered ‘estimated’ due to the low number of manual measurements used to develop the curve.

[b] Rating development points refer to fixed stage-discharge points that are used to develop a rating curve. These development points are analogous with the lowest and highest manually measured stage-discharge points (i.e., Rating Measurements) that were used to build the curve.

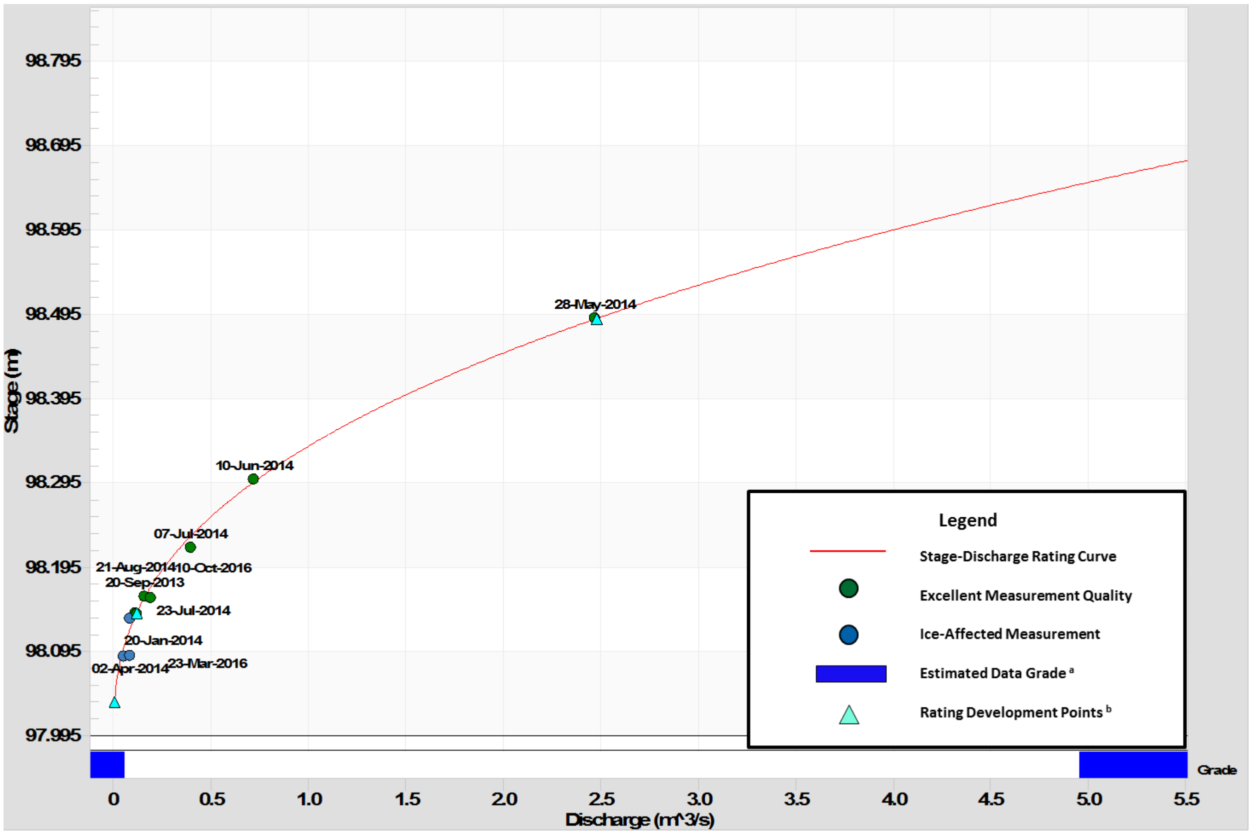
Figure 3-2 BL-H02 stage-discharge rating curve and manual measurements, October 2013 to August 2014.



[a] Estimated data grade indicated in blue at base of graph indicates that the entire rating curve is considered ‘estimated’ due to the low number of manual measurements used to develop the curve.

[b] Rating development points refer to fixed stage-discharge points that are used to develop a rating curve. These development points are analogous with the lowest and highest manually measured stage-discharge points (i.e., Rating Measurements) that were used to build the curve.

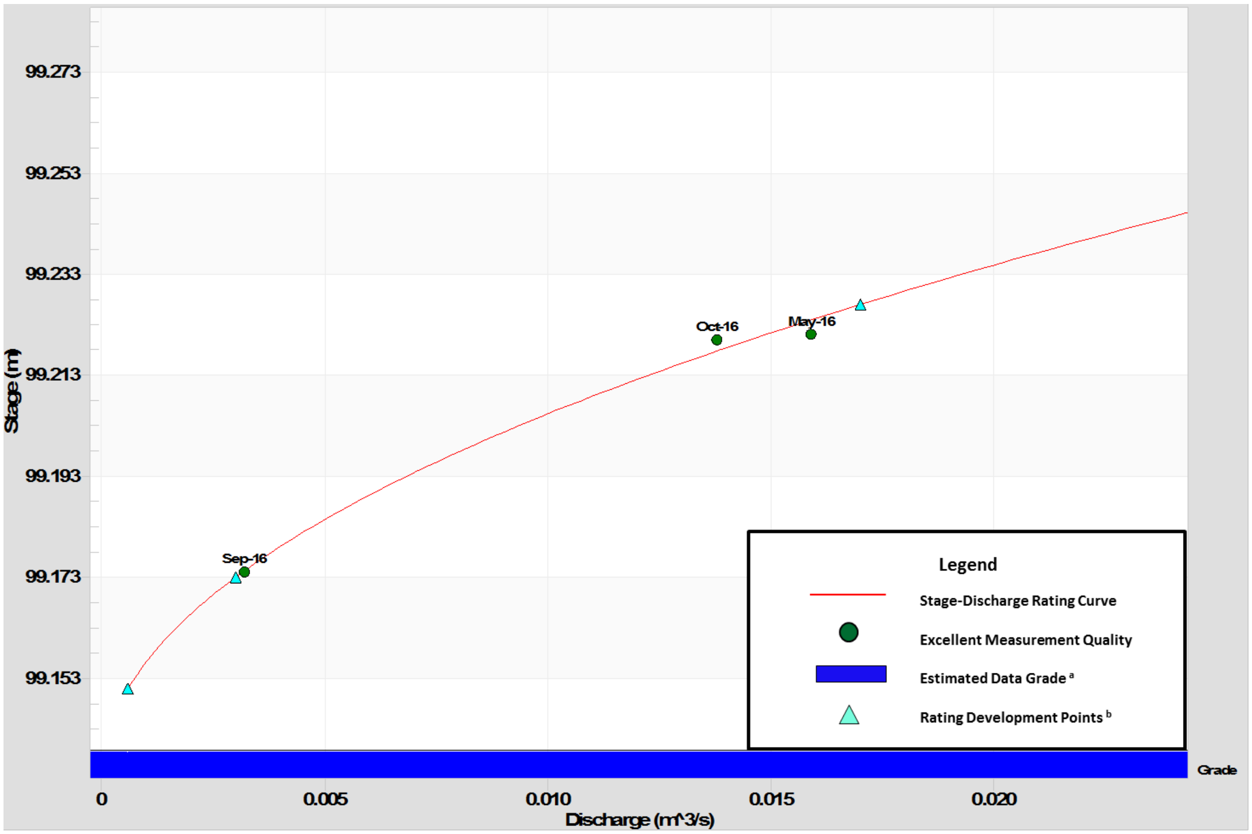
Figure 3-3 BL-0/H03 stage-discharge rating curve and manual measurements, September 2013 to October 2016.



[a] Estimated data grade indicated in blue at base of graph indicates rating curve extrapolation less than 0.5x the lowest manually measured discharge and greater than 2x the highest manually measured discharge used to develop the curve.

[b] Rating development points refer to fixed stage-discharge points that are used to develop a rating curve. These development points are analogous with the lowest and highest manually measured stage-discharge points (i.e., Rating Measurements) that were used to build the curve.

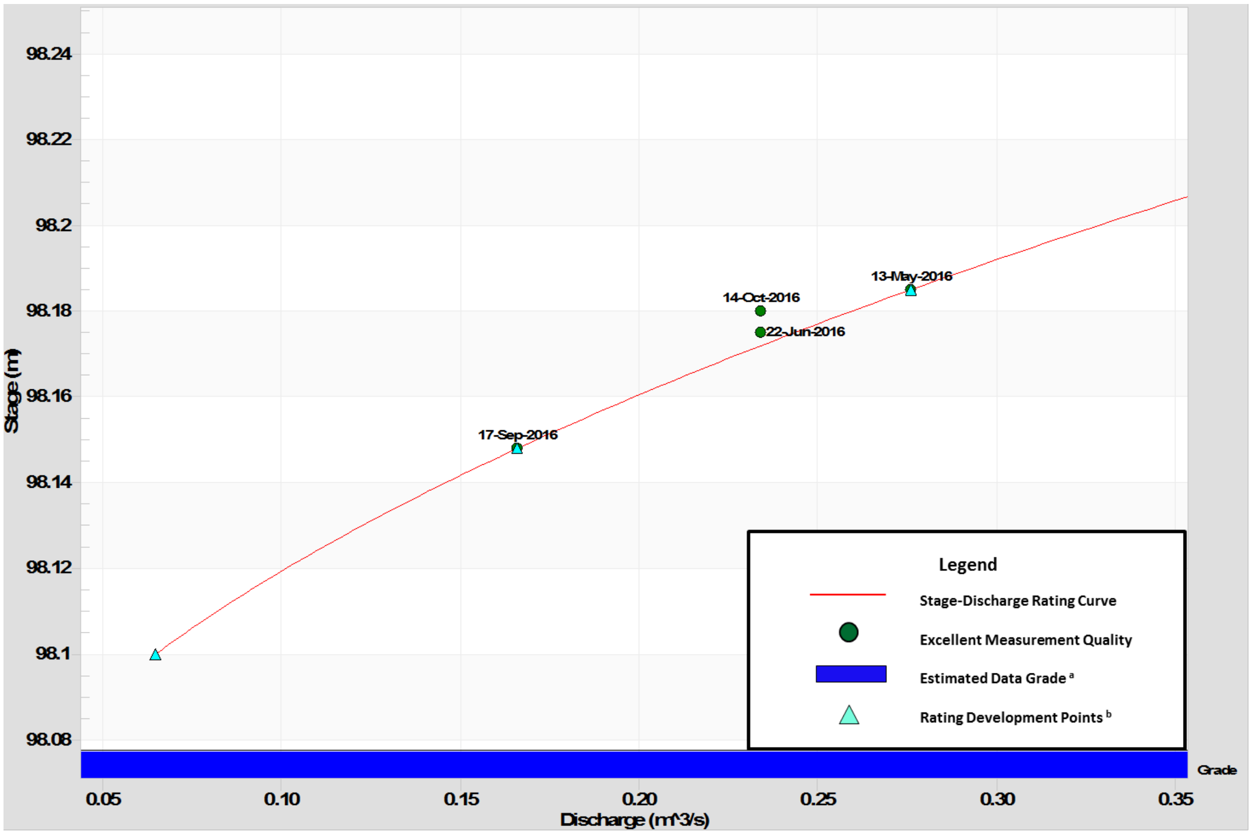
Figure 3-4 GC-27/H03 preliminary stage-discharge rating curve and manual measurements, May to October 2016.



[a] Estimated data grade indicated in blue at base of graph indicates that the entire rating curve is considered ‘estimated’ due to the low number of manual measurements used to develop the curve.

[b] Rating development points refer to fixed stage-discharge points that are used to develop a rating curve. These development points are analogous with the lowest and highest manually measured stage-discharge points (i.e., Rating Measurements) that were used to build the curve.

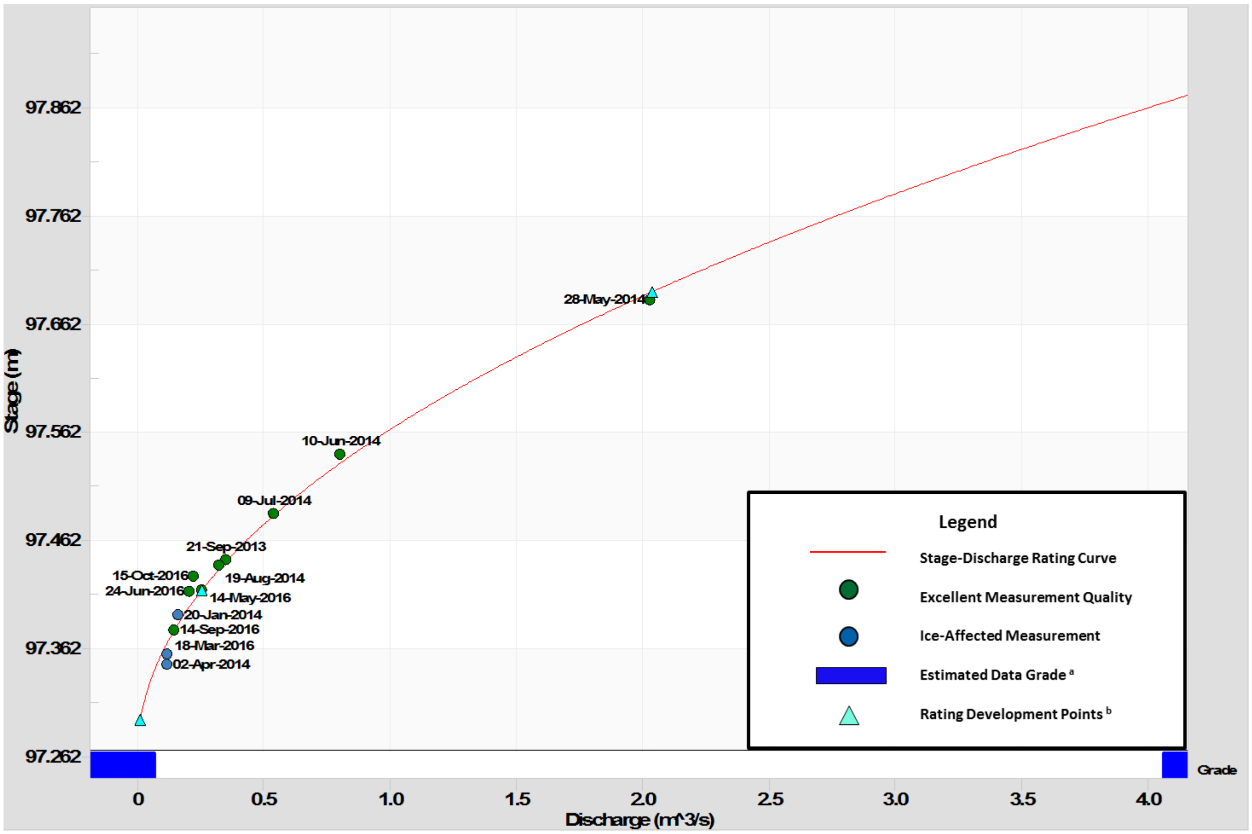
Figure 3-5 GC-11/H02 preliminary stage-discharge rating curve and manual measurements, May to October 2016.



[a] Estimated data grade indicated in blue at base of graph indicates that the entire rating curve is considered 'estimated' due to the low number of manual measurements used to develop the curve.

[b] Rating development points refer to fixed stage-discharge points that are used to develop a rating curve. These development points are analogous with the lowest and highest manually measured stage-discharge points (i.e., Rating Measurements) that were used to build the curve.

Figure 3-6 GC-7/H01 stage-discharge rating curve and manual measurements, September 2013 to October 2016.



[a] Estimated data grade indicated in blue at base of graph indicates rating curve extrapolation less than 0.5x the lowest manually measured discharge and greater than 2x the highest manually measured discharge used to develop the curve.

[b] Rating development points refer to fixed stage-discharge points that are used to develop a rating curve. These development points are analogous with the lowest and highest manually measured stage-discharge points (i.e., Rating Measurements) that were used to build the curve.

3.1.2 Stream Hydrographs

The three hydrographs each for Blairmore Creek and Gold Creek are displayed in Figure 3-7 and Figure 3-8 respectively, along with corresponding daily precipitation and air temperature data from the Pelletier Creek meteorological station (305NJ61; operated by Alberta Environment and Parks), which is located approximately 4.5 km northwest of the lower Blairmore Creek station BL-0/H01. Key statistics from each derived hydrograph are summarized in Table 3-2. Since data are only available for certain periods, statistics have only been presented for years or seasons in which sufficient data are available.

Figure 3-7 Daily mean discharge at Blairmore Creek hydrology stations, with daily total precipitation and temperature at Pelletier Creek climate station, 2013 to 2016.

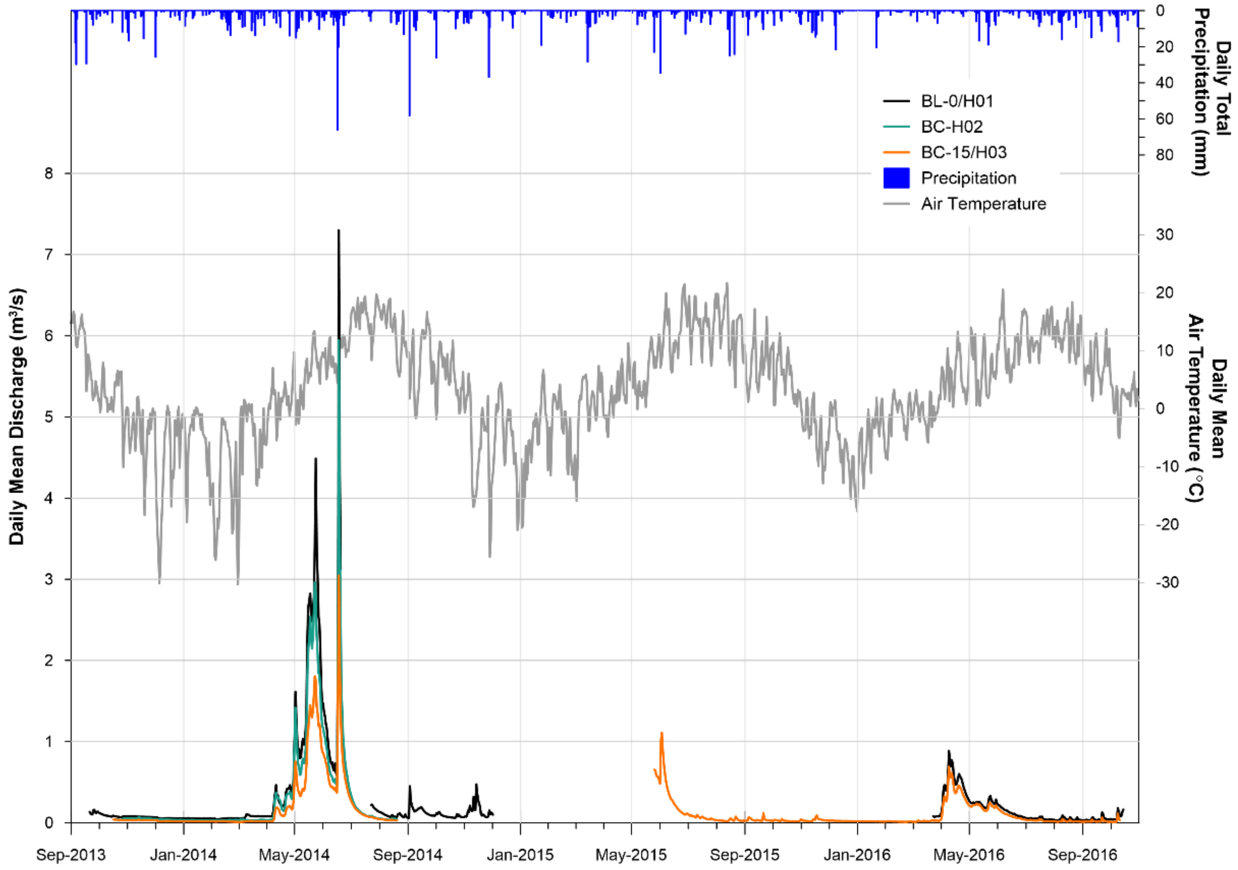


Figure 3-8 Daily mean discharge at Gold Creek hydrology stations, with daily total precipitation and temperature at Pelletier Creek climate station, 2013 to 2016.

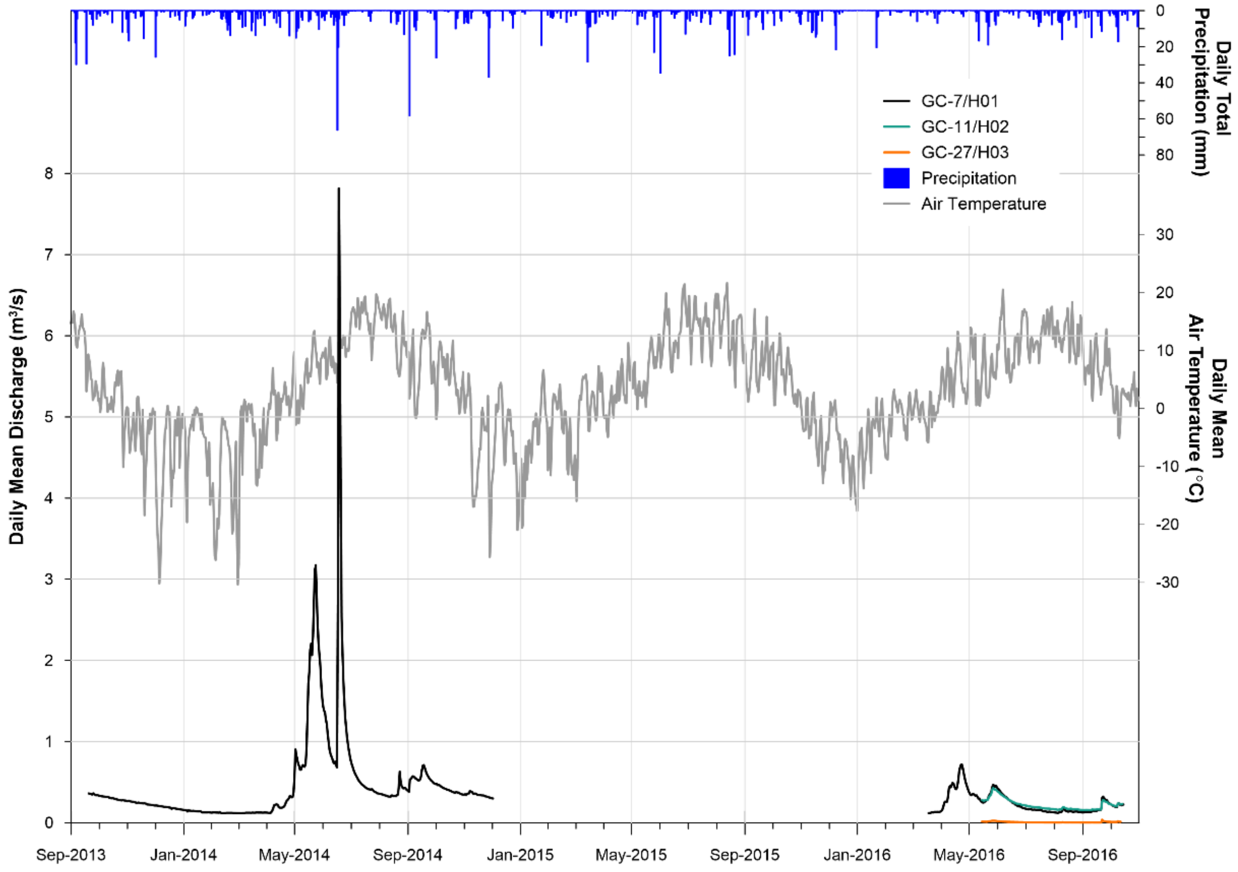


Table 3-2 Blairmore Creek and Gold Creek hydrology monitoring stations and hydrological summary data, 2014 to 2016.

ID	Name	Drainage Area (km^2)	Year	Mean Open-Water Daily Flow (m^3/s)	Mean Winter Daily Flow (m^3/s)	Mean Annual Daily Flow (m^3/s)	Max Annual Daily Flow (m^3/s)	Min Annual Daily Flow (m^3/s)
Blairmore Creek								
BC-15/H03	Blairmore Creek Upper	15.0	2014	-	-	-	3.046	-
			2016	0.116	0.023	0.075	0.692	0.010
BL-H02	Blairmore Creek Middle	23.7	2014	-	0.039	-	5.946	-
BL-0/H01	Blairmore Creek Lower	47.7	2014	-	0.063	-	1.243	-
			2016	0.161	-	-	0.887	-
Gold Creek								
GC-7/H01	Gold Creek above Morin Creek	31.5	2014	0.751	0.164	0.508	7.815	0.118
			2016	0.252	-	-	0.719	-

Notes: GC-27/H03 and GC-11/H02 were installed in May 2016; due to the short period of record available at the time of this report no summary data are presented here.

Open-water season is defined as April 1 to October 31 (the period during which streams are typically ice-free). Winter season is defined as November 1 to March 31 (the period during which streams are typically covered in ice).

-: Not available due to incomplete data coverage.

3.2 SYNTHETIC HYDROGRAPHS

Table 3-3 summarizes the combination of WSC, primary and secondary gauge locations used to derive long-term streamflow estimates at each IFA study reach on Gold and Blairmore creeks.

Table 3-3 Primary and Secondary Gauge Selection for Individual Reaches.

Stream	Corresponding Long-term WSC gauge	Reach	Primary Gauge	Secondary Gauge
Gold Creek	Gold Creek near Frank (Apr-Nov) (WSC 05AA030, drainage area 63.3 km^2) Crownsest River at Frank (Dec-Mar) (WSC 05AA008, drainage area 402.7 km^2)	9	GC-27/H03	GC-26
		8	GC-27/H03	GC-22
		7	GC-7/H01	Primary used
		6	GC-7/H01	GC-3
		5	GC-7/H01	GC-1
Blairmore Creek	Crowsnest River (Annual) (WSC 05AA008, drainage area 402.7 km^2)	5	BC-15/H03	Primary used
		4	BC-15/H03	BC-12
		3	BC-15/H03	BC-2

3.2.1 Primary Gauge Synthetic Hydrographs

3.2.1.1 Gold Creek

On Gold Creek, the GC-27/H03 gauge near the headwaters was selected as the primary gauge to represent flows upstream of the Caudron Creek confluence, in Reaches 8 to 9. The GC-7/H01 gauge near Gold Creek bridge was selected to represent flows downstream of the Caudron Creek confluence, in Reaches 5 to 7, and was preferred over the GC-11/H02 gauge based on data record (longer at GC-7/H01), proximity to Reaches 5 and 6 (closer at GC-7/H01) and conservatism (continuous flows were on average 6% lower at GC-7/H01 due to groundwater losses, and more appropriate for IFA analyses). Regression relationships were developed using these gauges and the WSC Gold Creek near Frank gauge, except for the winter period (December to March) when no data were available at the WSC gauge, and pro-rated WSC Crowsnest River at Frank data were used as replacement.

GC-7/H01

The seasonal regression relationships are shown for GC-7/H01 in Figure 3-9. During winter months, daily unit stream flows were generally higher at the WSC Crowsnest gauge than at GC-7/H01, although the relationship was very poor (R^2 = 0.18) based primarily on differences in the two catchment characteristics and limited data availability. The April relationship between GC-7/H01 and WSC Gold Creek near Frank was also quite poor (R^2 = 0.32), but this was developed using data both from April 2014 and April 2016 in which flow conditions were very different. During April 2014, significant watershed snowmelt had yet to occur, and unit runoff was generally higher at the downstream gauge (WSC Gold Creek near Frank) than at GC-7/H01. Conversely, the freshet peak occurred during April 2016, leading to a flashier response and higher unit runoff upstream (GC-7/H01) than downstream (WSC Gold Creek near Frank).

During low-flow open-water conditions (i.e., below the long-term MAD at WSC Gold Creek near Frank, May to November), the relationship was derived primarily from 2016 data and was very good (R^2 = 0.88). Unit flows below ~0.009 $m^3/s/km^2$ were generally higher at WSC Gold Creek near Frank than at GC-7/H01, and vice versa, which may be related to the increasing proportion of surface flows lost to the subsurface during very dry conditions (as was documented in Reach 6: Figure 3-4 in the IFA).

During high-flow open water conditions (i.e., above the long-term MAD at WSC Gold Creek near Frank, May to November), the relationship was derived primarily from 2014 data and was also very good (R^2 = 0.93). Unit flows at GC-7/H01 were equal to or higher than at WSC Gold Creek near Frank, since smaller catchments are more reactive to precipitation events, and hydraulic gradients between the stream channel and water table (ultimately flow losses) may have been reduced around GC-7/H01. At the highest flows, some model uncertainty was introduced by averaging across the different unit flow responses to the snowmelt-driven freshet peak (in May 2014) and rainfall-driven annual peak (in June 2014).

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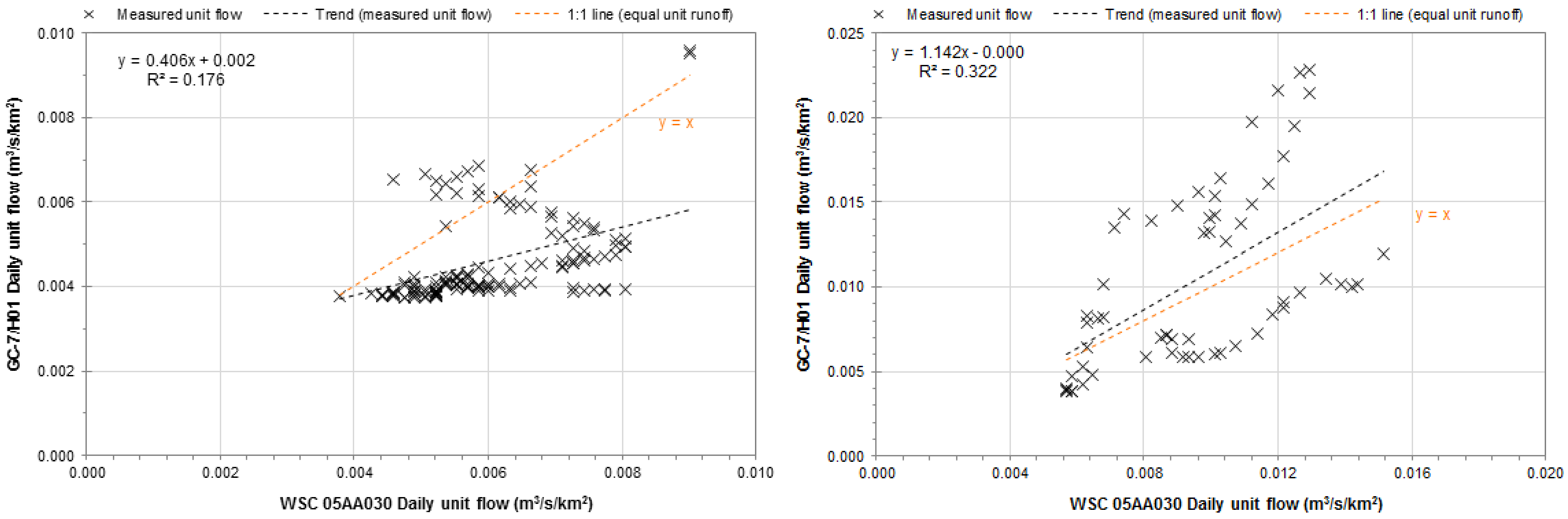
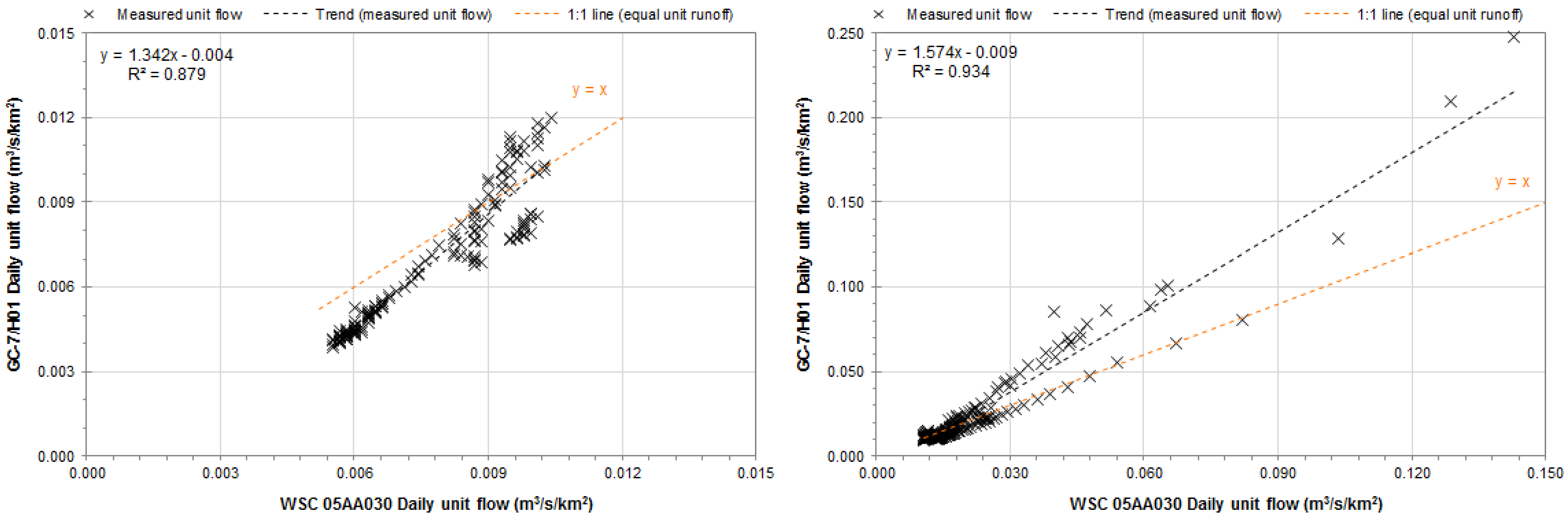
Figure 3-9 Seasonal relationships in concurrent daily unit runoff between the GC-7/H01 gauge and WSC gauges (Gold Creek near Frank from April-November, Crowsnest River at Frank from December-March).


(A) Overwinter (Dec-Mar)

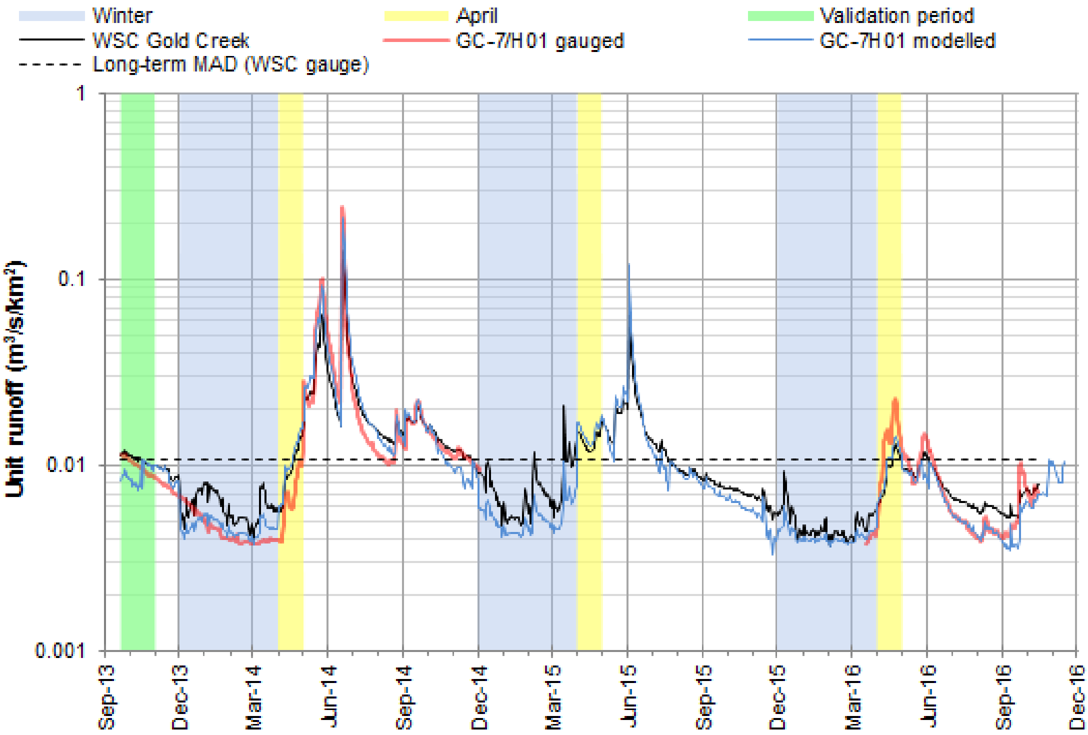
(B) April


(C) May-November (< MAD)

(D) May-November (> MAD)

Figure 3-10 presents a comparison of the gauged unit flows at GC-7/H01 (2013 to 2016) and the predicted unit flows derived by applying the appropriate seasonal regression discussed above. During the short (Sep-Oct 2013) validation period, gauged unit flows both during low-flow and high-flow conditions (spanning 16 and 26 days, respectively) were reasonably well correlated with predicted unit flows (R^2 = 0.67 and 0.77, respectively). Across all 651 days with gauged data, the gauged and predicted unit flows were very well correlated (R^2 = 0.94), and predicted flows were only 4% lower on average than gauged unit flows, implying that the long-term predicted streamflows used in IFA analyses across Reaches 5 to 7 were marginally conservative. Prediction errors increased at the highest flows but cannot be improved in the absence of separate regression relationships for different precipitation events (e.g., snowmelt, large rain events).

Figure 3-10 Comparison of gauged and simulated flows, 2013-2016, GC-7/H01.



Note: The MAD line represents the threshold between open-water low- and high-flow conditions (used to train separate regressions during these periods).

GC-27/H03

At GC-27/H03, hydrometric data were only available from May to October 2016, removing the potential for derived relationships during the winter and April periods. Separate open-water relationships during low-flows and high-flows were developed (Figure 3-11); however, flows above the long-term MAD at WSC Gold Creek near Frank only occurred during a 10-day period (May 25 to June 3), so the threshold was reduced to 0.75 MAD to increase the higher flow record. For either flow condition, unit flows at GC-27/ H03 were lower than at GC-7/H01, since the headwaters area was lower and more forested than the Caudron Creek watershed, which dominated flows through lower Gold Creek including through GC-7/H01. This information was used to modify the winter and April relationships developed at GC-7/H01 (Figure 3-9), to estimate unit flows during these periods at GC-27/H03.

Figure 3-11 Seasonal relationships in concurrent daily unit runoff between the GC-27/H03 gauge and WSC gauges (Gold Creek near Frank from April-November, Crowsnest River at Frank from December-March).

(A) Overwinter (Dec-Mar)

No concurrent data available.

Relationship used: y = 0.1015x + 0.0006

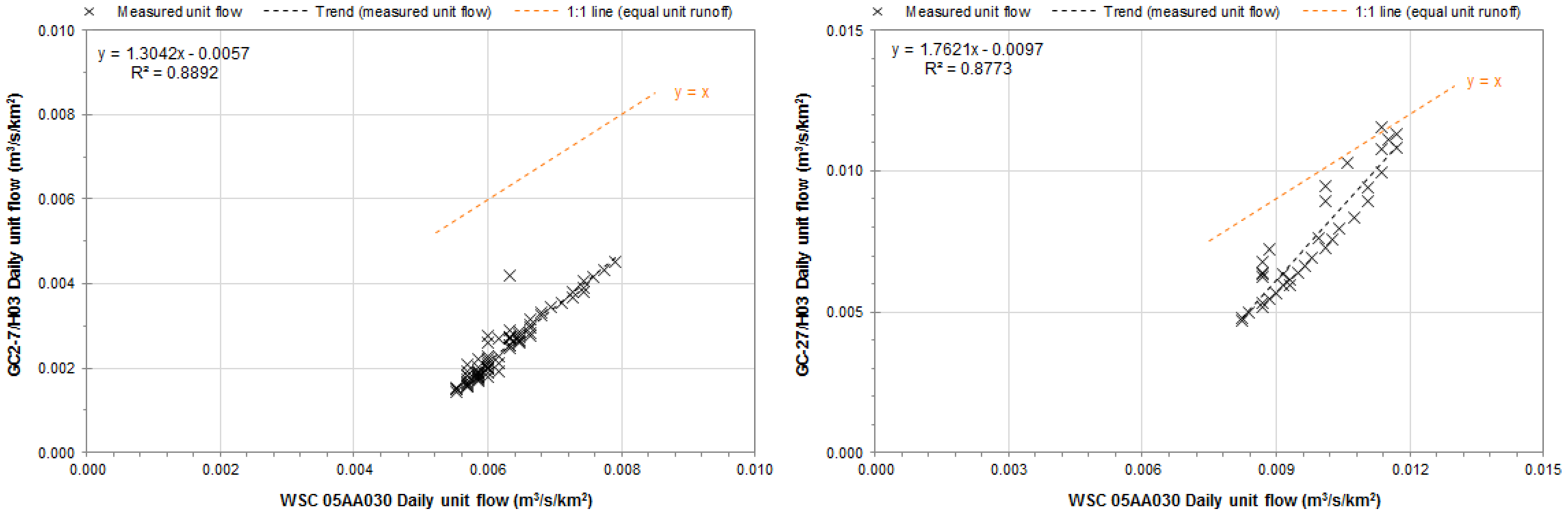
(=0.25 x coefficient values used in winter regression equation at GC-7/H01)

(B) April

No concurrent data available.

Relationship used: y = 0.3997x - 0.0002

(=0.35 x coefficient values used in April regression equation at GC-7/H01)

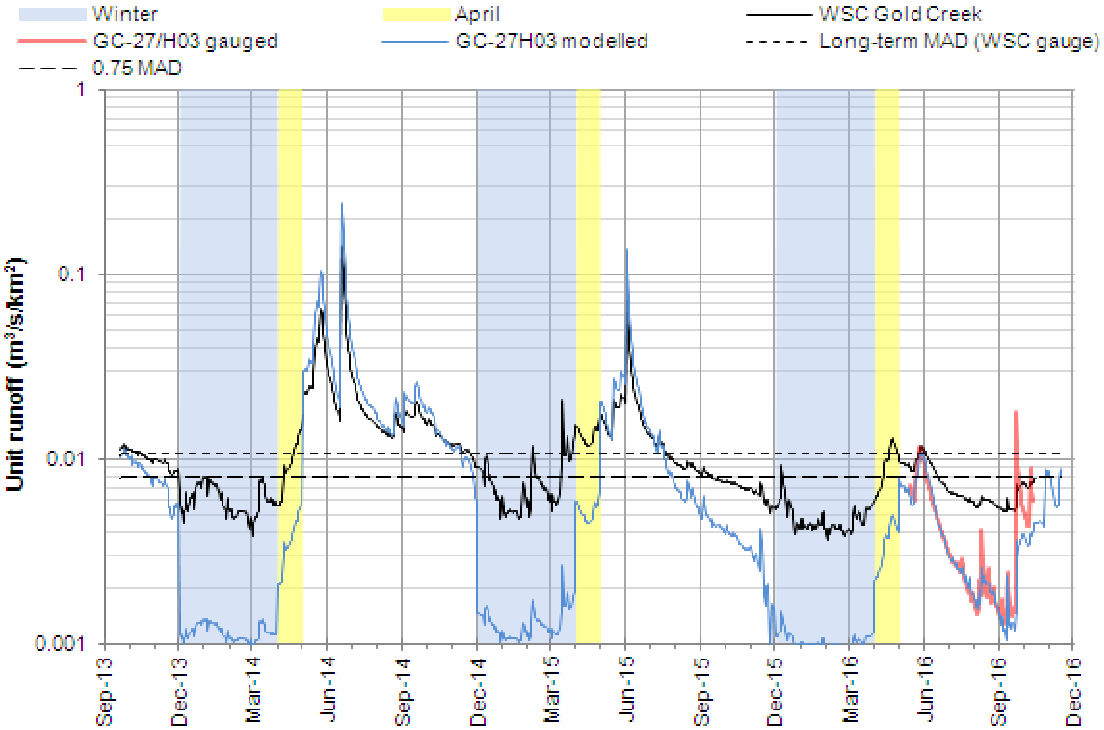


(C) May-November (< 0.75 x MAD)

(D) May-November (> 0.75 x MAD)

The overall correlation between unit flows at GC-27/H03 and WSC Gold Creek near Frank was very good both for low-flow and high-flow conditions (R^2 = 0.89 and 0.88, respectively), but prediction errors became large during a rain-event centered on September 22, 2016, which caused a flashy response in gauged GC-27/H03 flows but a more conservative response within the gauged flows at WSC Gold Creek near Frank (and ultimately the predicted flows at GC-27/H03 scaled from the WSC data; Figure 3-12). The response at GC-7/H01 was inbetween these gauges (Figure 3-10) as would be expected at an intermediate gauge. The 130 days with gauged flows prior to September 22 were very well predicted using the appropriate seasonal regression relationship discussed above (R^2 = 0.97, average 1.5% model underprediction); however, the model predictive strength dropped considerably across all 151 days with gauged flows (R^2 = 0.65, average 18% model underprediction) due to the inability of the model to simulate different watershed responses to precipitation.

Figure 3-12 Comparison of gauged and simulated flows, 2013-2016, GC-27/H03.



Note: The MAD line represents the threshold between open-water low- and high-flow conditions (used to train separate regressions during these periods).

3.2.1.2 Blairmore Creek

On Blairmore Creek, the BC-15/H03 gauge was selected as the primary gauge to represent flows in all three IFA study reaches (Reaches 3 to 5). This was preferered over the BC-H02 gauge (more centrally located between these reaches), but no data was collected at BC-H02 during 2016 which reduced the amount of data available for regression analysis (particularly during low flows). The downstream Reach 3 was equidistant between the BC-0/H01 (downstream) and BC-15/H03 (upstream) gauges, but for consistency the BC-15/H03 gauge was preferred given its application to characterize streamflows across Reaches 4 and 5. During all seasonal flow conditions, the unit flows from all three gauges on Blairmore Creek were slightly better correlated with concurrent data from the WSC Crowsnest River at Frank gauge than with the WSC Gold Creek near Frank gauge; therefore, the Crowsnest River data were used to establish the seasonal relationships and long-term streamflow estimates along Blairmore Creek. This result may be due to the lower groundwater contributions (base flows) and higher freshet flows that characterize the Blairmore and Crowsnest River watersheds, relative to Gold Creek watershed.

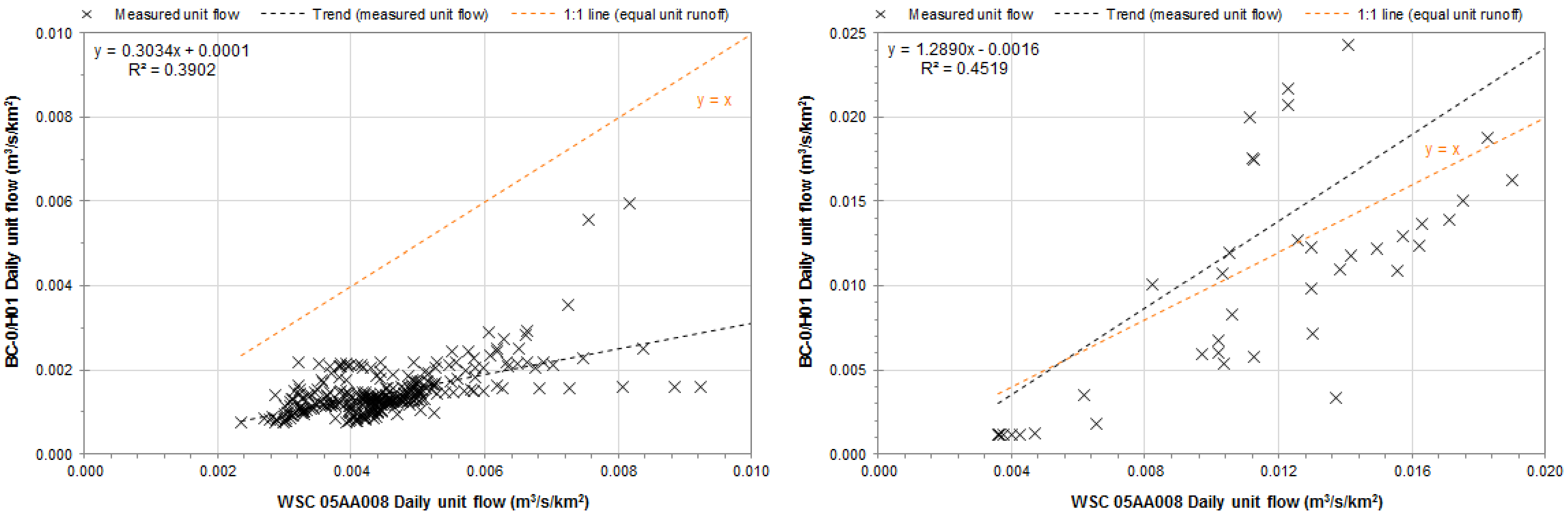
The seasonal regression relationships are shown for BC-15/H03 in Figure 3-13. Except during very high flows (above ~0.08 $m^3/s/km^2$), the unit flows were consistently lower at BC-15/H03 than at WSC Crowsnest River at Frank. The relationships developed for the Winter (November to March) and April periods remained relatively low (R^2 = 0.39 and 0.45, respectively), but these were stronger than the corresponding relationships for the Gold Creek gauges (which also used WSC Crowsnest River at Frank data during winter). During open-water conditions, a threshold of 2 x MAD was selected to more equally distribute unit flows between lower and higher flow conditions, and the derived relationships were both very good (R^2 = 0.80 and 0.88 for low and higher-flow conditions, respectively).

Figure 3-14 presents a comparison of the gauged unit flows at BC-15/H03 (2013 to 2016) and the predicted unit flows derived by applying the appropriate seasonal regression relationship discussed above. During the short (September to October 2013) validation period, gauged unit flows only occurred during a 15-day period of low-flow conditions, during which period there was moderate correlation with predicted unit flows (R^2 = 0.68). Across all 817 days with gauged data, the gauged and predicted unit flows were very well correlated (R^2 = 0.93), and predicted unit flows were only 6% lower on average than gauged unit flows, implying that the long-term predicted streamflows used in IFA analyses across Reaches 3 to 5 were marginally conservative.

Figure 3-13 Seasonal relationships in concurrent daily unit runoff between the BC-15/H03 gauge and WSC Crowsnest River at Frank gauge.

(A) Overwinter (Nov-Mar)

(B) April



(C) May-November (< 2 x MAD)

(D) May-November (> 2 x MAD)

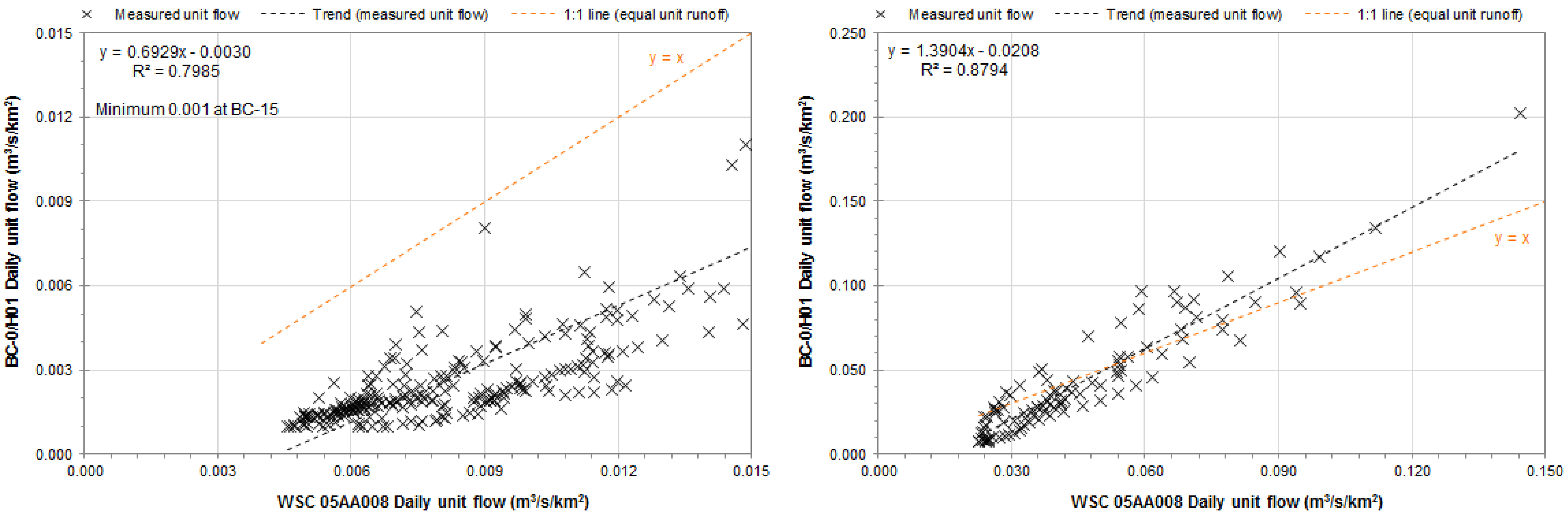
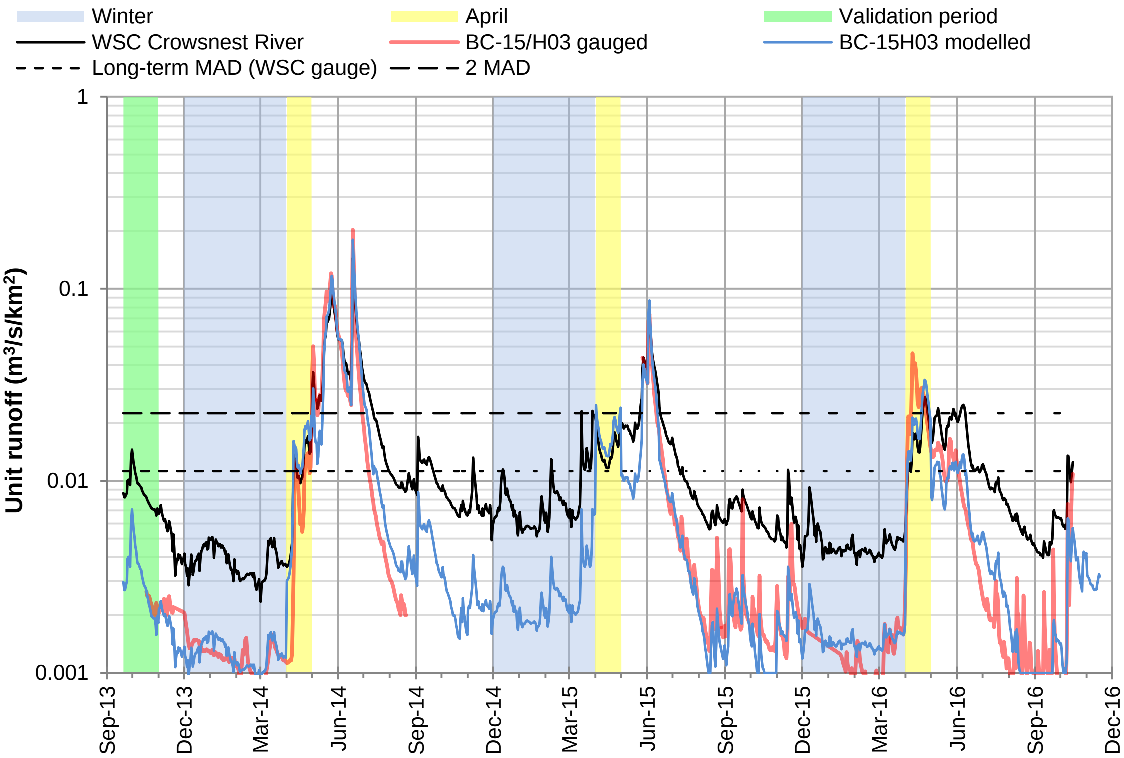


Figure 3-14 Comparison of gauged and simulated flows, 2013-2016, BC-15/H03.

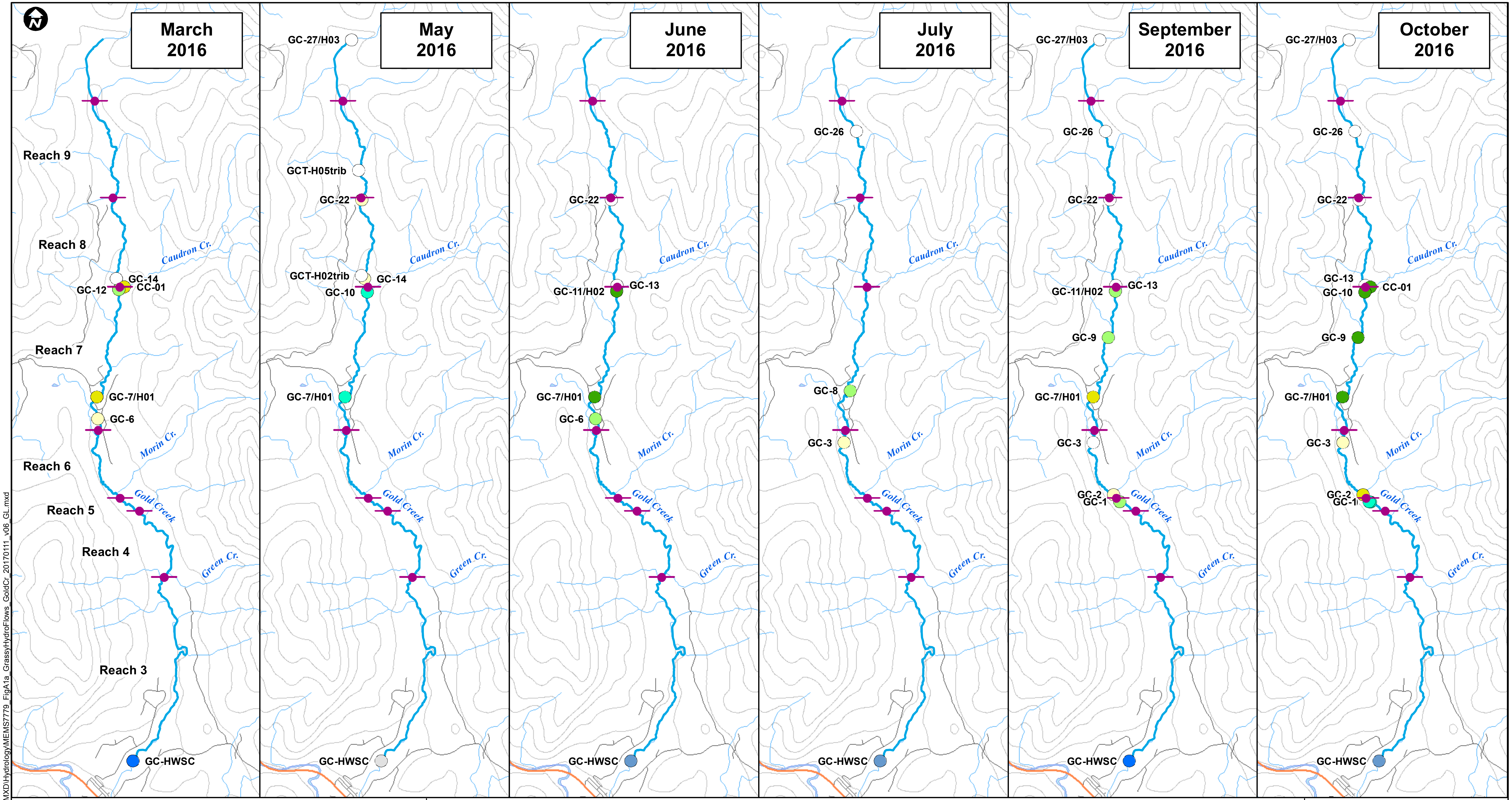


Note: The 2 MAD line represents the threshold between open-water low- and high-flow conditions (used to train separate regressions during these periods).

3.2.2 Secondary gauge synthetic hydrographs

The secondary gauges selected for adjusting primary gauge data, at six of the eight study reaches, are tabulated in Table 3-3. Streamflows across Reach 7 (Gold Creek) and Reach 5 (Blairmore Creek) were adequately characterized by the GC-7/H01 and BC-15/H03 primary gauges, respectively, and did not require adjustment using a secondary gauge.

Figure 3-15 and Figure 3-16 show a spatial comparison of measured flows at primary and secondary gauge (and selected other locations) within all 2016 surveys associated with the hydrometric station commissioning (March, May 2016) and IFA surveys (June 2016 onwards). From these data, the values used to calculate Empirical Adjustment Factors (EAFs); i.e., the ratio of mean primary gauge flow to mean secondary gauge flow in each reach are tabulated in Table 3-4. During a given survey, the period of time inbetween measurements at primary gauges and seconday gauges was kept as short as possible in order to avoid changes in time and flow conditions that may affect the ratio of flows between these gauges. With the exception of the October 2016 program, conditions remained relatively similar (i.e., absent of large precipitation events) throughout each 4-5 day period required to sample all locations in the monitoring network. During October 2016, recent snowfall (~15 cm) characterized conditions at the start of the fieldwork (Oct 10), but this began to melt during warmer conditions on Oct 12-13 and conditions were snow-free by the end of monitoring (Oct 15). Conditions were coldest at the start of Oct 12, when the flow measurement at BL-4 was conducted, and some flow was lost overnight due to ice production; surrounding measurements surveyed on Oct 11 or later on Oct 12 were higher (Figure 3-16).



LEGEND

Flow

○ 0.00 - 0.05
● 0.06 - 0.10
● 0.11 - 0.15
● 0.16 - 0.20
● 0.21 - 0.25
● 0.26 - 0.30
● 0.31 - 0.40
● 0.41 - 0.50
● 0.51 - 0.60

Macrohabitat Reach Break
Primary Highway
Road
100m Contour
Watercourse
Waterbody

PROJECT

RIVERSDALE RESOURCES

GRASSY MOUNTAIN COAL PROJECT

TITLE

MEASURED 2016 FLOWS AT HYDROMETRIC STATIONS AND SELECTED IFA CROSS-SECTIONS - GOLD CREEK

NOTES

Data Sources: Government of Canada, Government of Alberta
Datum/Projection: UTM NAD 83 Zone 11

0 1 2 4
Kilometres

Hatfield CONSULTANTS

PROJECT: 7779
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DATE: January 11, 2017

FIGURE

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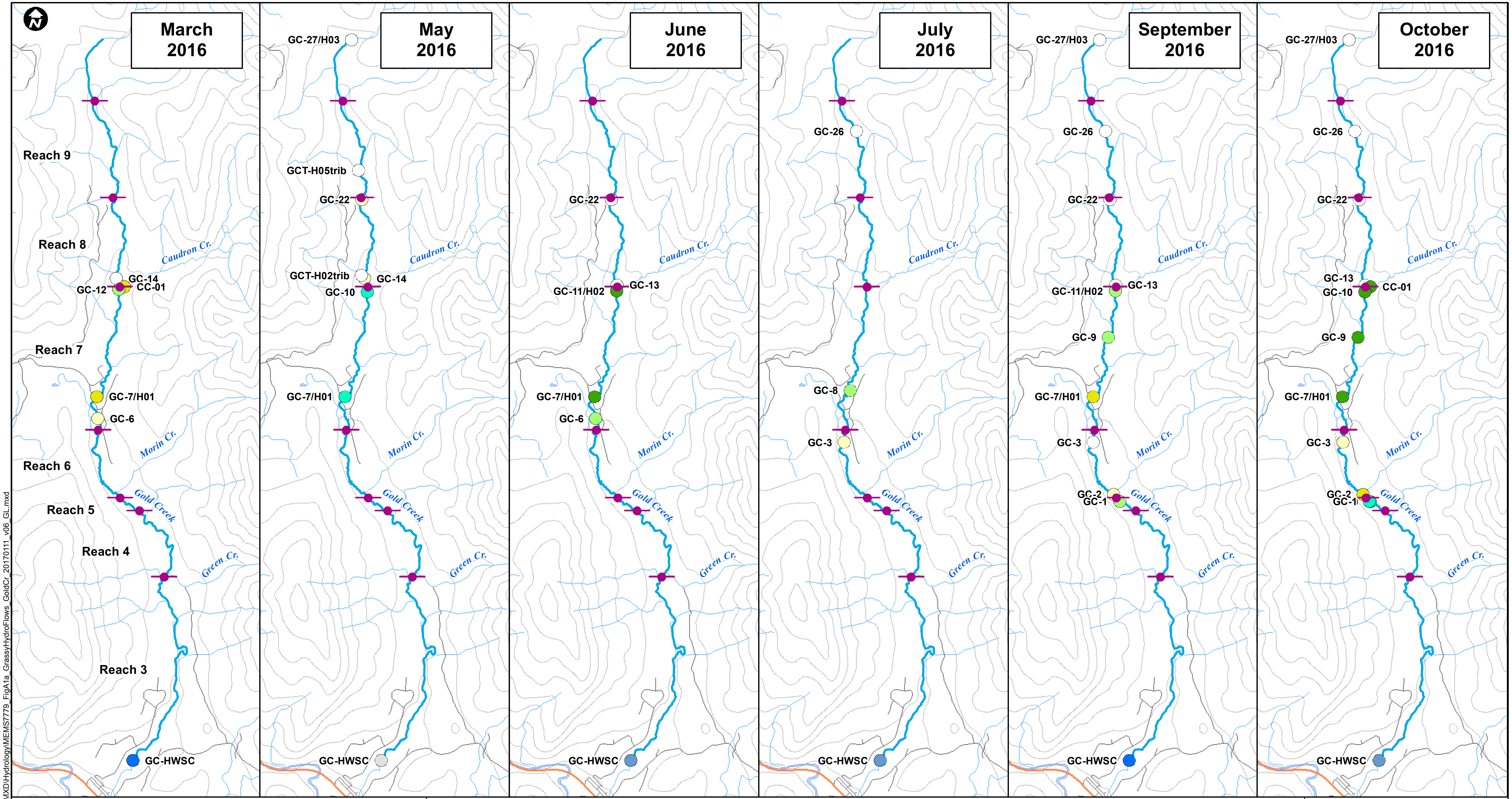

LEGEND

Flow

○	0.00 - 0.05
○	0.06 - 0.10
●	0.11 - 0.15
●	0.16 - 0.20
●	0.21 - 0.25
●	0.26 - 0.30
●	0.31 - 0.40
●	0.41 - 0.50
●	0.51 - 0.60

- Macrohabitat Reach Break
- Primary Highway
- Road
- 100m Contour
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PROJECT

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Datum/Projection: UTM NAD 83 Zone 11

0 1 2 4
Kilometres

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PROJECT: 7779
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FIGURE
3-16

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Table 3-4 Empirical Adjustment Factors (EAF) calculated between Primary and Secondary Gauge Data.

Stream	Reach	Gauge		2016 Streamflow Measurement (m^3/s)							EAF
				Mar	May	Jun	Jul	Sep	Oct	Mean	
Gold Creek	9	Primary:	GC-27/H03	-	-	-	-	0.003	0.014	**0.009**	**2.281**
		Secondary:	GC-26	-	-	-	-	0.008	0.031	**0.019**	
	8	Primary:	GC-27/H03	0.006[1]	0.016	0.009[1]	-	0.003	0.014	**0.010**	**3.293**
		Secondary:	GC-22	0.016	0.063	0.035	-	0.010	0.035	**0.032**	
	7	*Primary gauge used*		na	na	na	na	na	na	**na**	**na**
	6	Primary:	GC-7/H01	-	-	-	0.182[1]	0.147	0.222	**0.184**	**0.307**
		Secondary:	GC-3	-	-	-	0.062	0.026	0.081	**0.056**	
	5	Primary:	GC-7/H01	-	-	-	-	0.147	0.222	**0.185**	**1.146**
		Secondary:	GC-1	-	-	-	-	0.166	0.257	**0.212**	
Blairmore Creek	5	*Primary gauge used*		na	na	na	na	na	na	**na**	**na**
	4	Primary:	BC-15/H03	-	-	-	0.030	0.016	0.032	**0.026**	**1.773**
		Secondary:	BC-12	-	-	-	0.051	0.027	0.060	**0.046**	
	3	Primary:	BC-15/H03	-	-	-	0.030	0.016	0.032	**0.026**	**1.892**
		Secondary:	BC-2	-	-	-	0.056	0.039	0.053	**0.049**	

[1] Estimated value using value measured nearby or obtained from continuous data to be more concurrent with timing of secondary gauge measurement.

Calculated EAF values were higher than 1.0 in five of six reaches with secondary gauges (i.e., streamflows were higher at a secondary gauge than the primary gauge, Table 3-4), but the EAF was lower than 1.0 in Reach 6 of Gold Creek since to account for the subsurface flow losses occurring inbetween the primary gauge upstream (GC-7/H01) and secondary gauge downstream (GC-3).

The reach-specific (secondary gauge) synthetic hydrograph was then calculated as the product of the primary gauge synthetic hydrograph and the corresponding EAF value (Table 3-4).

3.2.3 Long-term flow statistics

The derived Mean Annual Discharge and Mean Monthly Discharge values for each reach were summarized in the main IFA report (Table 3-3 and Table 3-4 for Gold and Blairmore Creeks, respectively).

Additional metrics are presented below, to further characterize the historical streamflow environment estimated for each reach based on the derived synthetic flow records, including:

- Flow duration curves (Figure 3-17 to Figure 3-18);
- Monthly box-whisker plots (Figure 3-19 to Figure 3-20);
- Monthly average and exceedance statistics (Table 3-5 to Table 3-12); and,
- Annual and long-term 7-day and 30-day low flow values (Figure 3-21 to Figure 3-28).

Figure 3-17 Flow Duration Curves estimated from daily synthetic flow data (1975-2016) for Gold Creek Reaches 9 (upstream) to 5 (downstream).

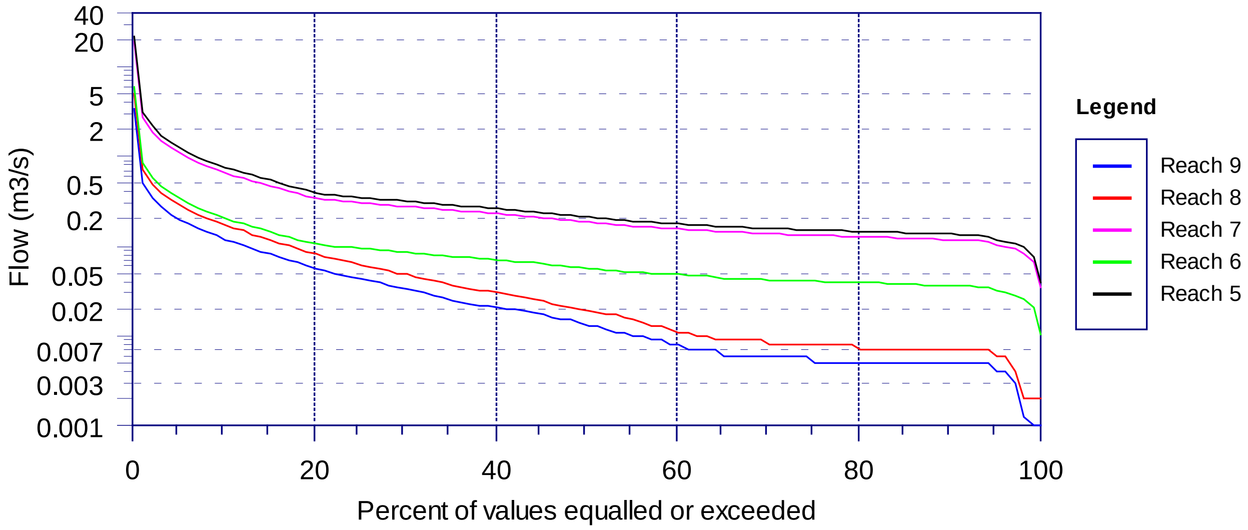


Figure 3-18 Flow Duration Curves estimated from daily synthetic flow data (1975-2016) for Blairmore Creek Reaches 5 (upstream) to 3 (downstream).

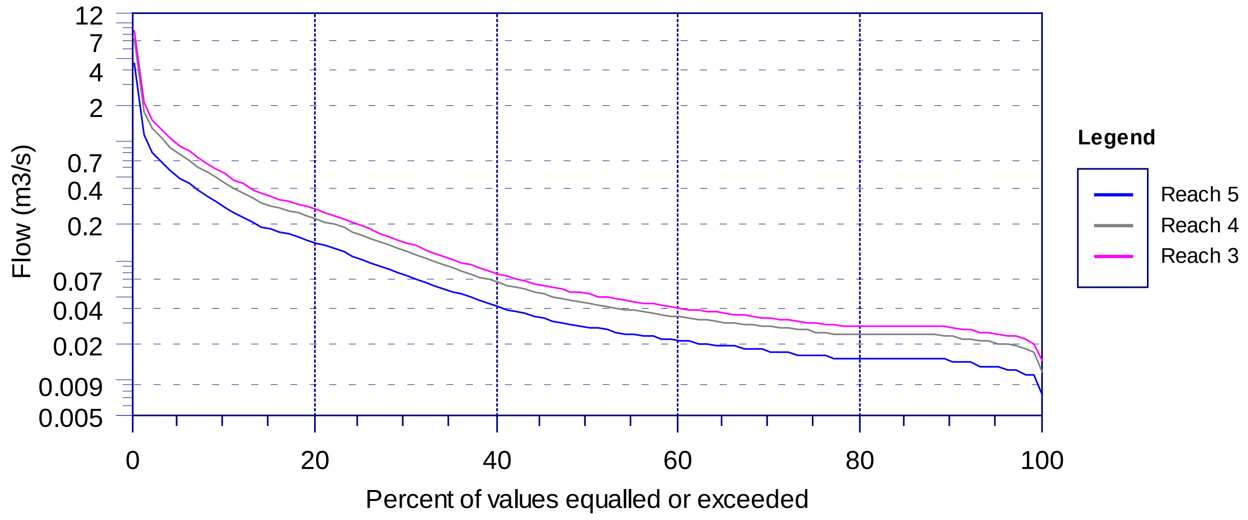
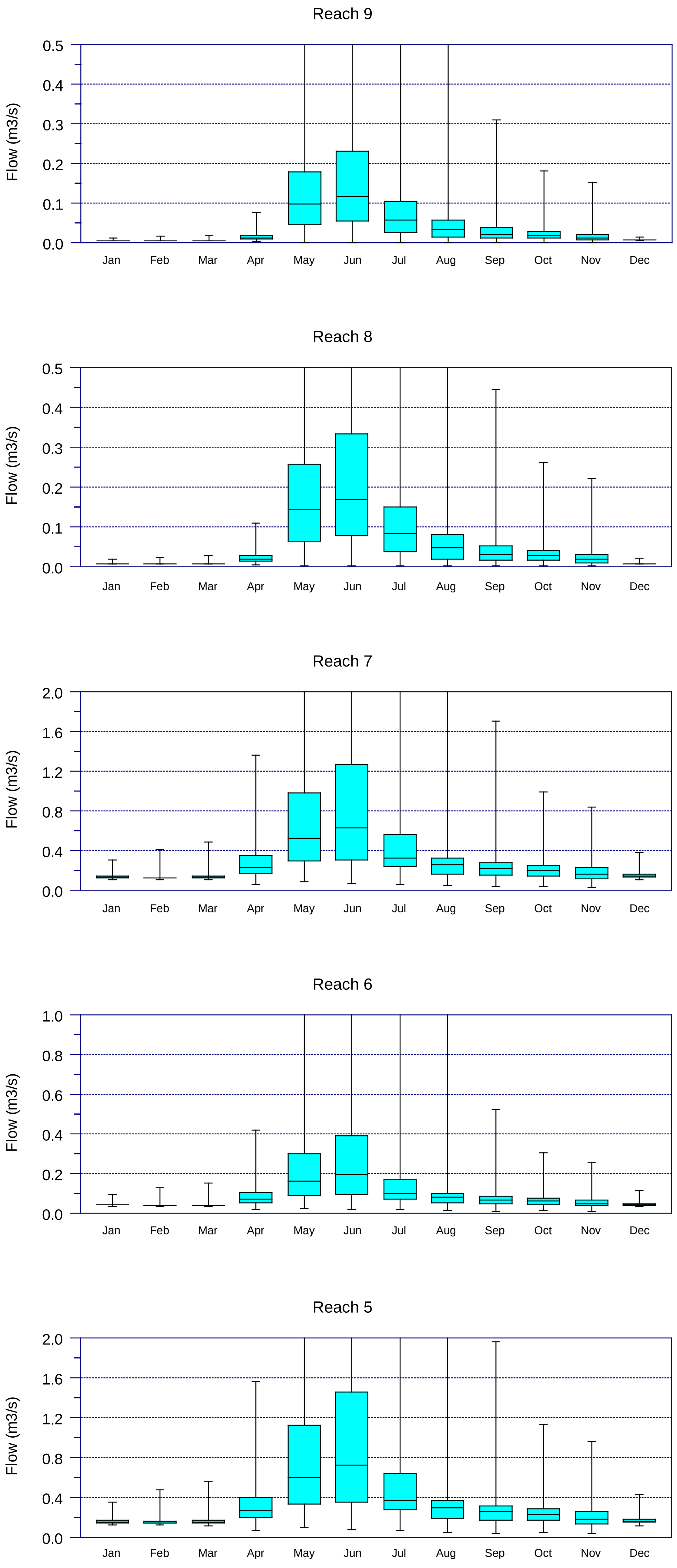
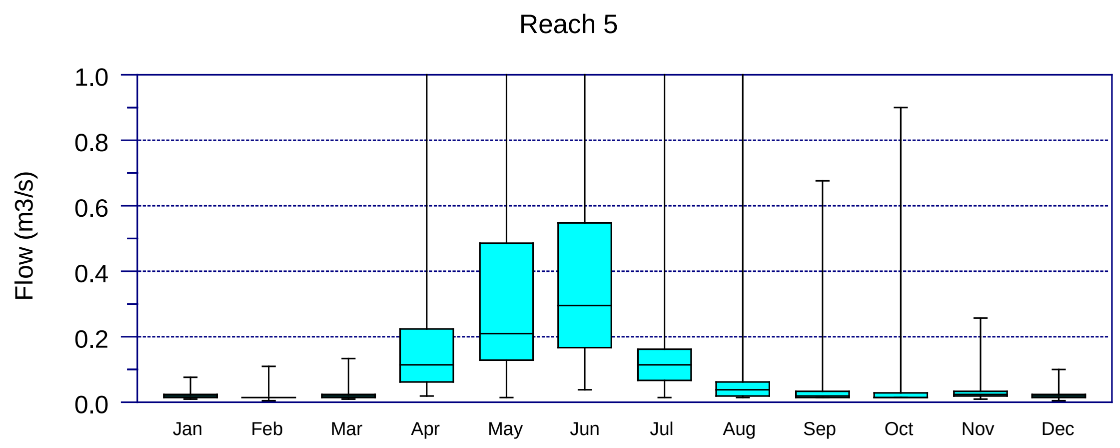


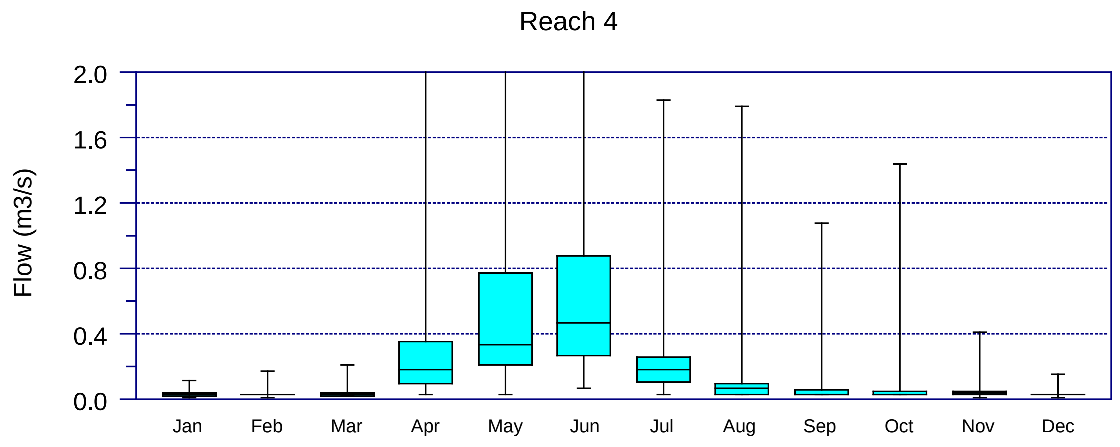
Figure 3-19 Long-term Mean Monthly Discharge statistics estimated from daily synthetic flow data (1975-2016) for Gold Creek Reaches 9 (upstream) to 5 (downstream).

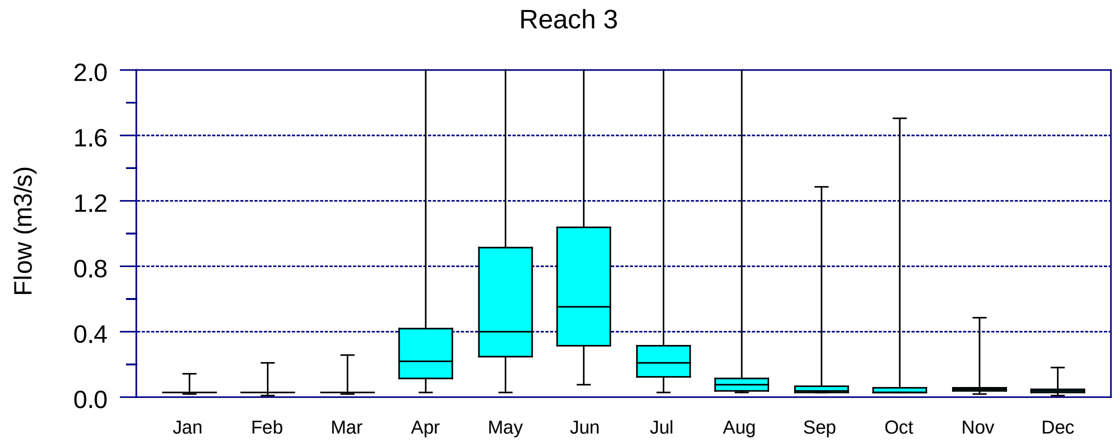


Note: Boxes show 25th and 75th percentiles, black bars median values, whiskers show minimum and maximums but these may be cut off during summer months for improved clarity at low flows.

Figure 3-20 Long-term Mean Monthly Discharge statistics estimated from daily synthetic flow data (1975-2016) for Blairmore Creek Reaches 5 (upstream) to 3 (downstream)







Note: Boxes show 25th and 75th percentiles, black bars median values, whiskers show minimum and maximums but these may be cut off during summer months for improved clarity at low flows.

Table 3-5 Monthly statistics including exceedance probabilities, Reach 9 Gold Creek.

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sample size	1271	1159	1271	1230	1271	1230	1271	1271	1245	1302	1246	1271
Minimum	0.004	0.004	0.004	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.004
Maximum	0.012	0.016	0.019	0.076	1.781	3.415	0.951	0.951	0.309	0.180	0.153	0.015
Mean	0.005	0.005	0.006	0.016	0.147	0.185	0.079	0.044	0.030	0.025	0.017	0.006
Median	0.005	0.005	0.005	0.013	0.098	0.116	0.058	0.033	0.022	0.019	0.013	0.006
90% exceedence	0.005	0.005	0.005	0.008	0.022	0.026	0.012	0.006	0.005	0.005	0.001	0.005
75% exceedence	0.005	0.005	0.005	0.010	0.045	0.054	0.026	0.014	0.012	0.011	0.007	0.005
25% exceedence	0.006	0.006	0.006	0.019	0.179	0.231	0.104	0.056	0.037	0.028	0.022	0.006
10% exceedence	0.007	0.006	0.007	0.030	0.327	0.402	0.165	0.080	0.055	0.047	0.037	0.007
Standard deviation (denom. = n-1)	0.001	0.001	0.001	0.010	0.168	0.230	0.083	0.059	0.034	0.026	0.018	0.001

Note: based on synthetic daily flow data generated for the period Sep 16 1975-Nov 16 2016.

Table 3-6 Monthly statistics including exceedance probabilities, Reach 8 Gold Creek.

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sample size	1271	1159	1271	1230	1271	1230	1271	1271	1245	1302	1246	1271
Minimum	0.006	0.006	0.006	0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.006
Maximum	0.018	0.024	0.028	0.109	2.572	4.932	1.374	1.374	0.446	0.261	0.222	0.022
Mean	0.008	0.008	0.008	0.023	0.212	0.268	0.114	0.063	0.044	0.037	0.025	0.008
Median	0.008	0.007	0.008	0.018	0.142	0.168	0.083	0.048	0.032	0.028	0.019	0.008
90% exceedence	0.007	0.007	0.007	0.011	0.032	0.037	0.017	0.008	0.007	0.007	0.002	0.007
75% exceedence	0.007	0.007	0.007	0.014	0.065	0.079	0.037	0.020	0.017	0.016	0.009	0.007
25% exceedence	0.008	0.008	0.008	0.028	0.258	0.333	0.150	0.081	0.053	0.040	0.032	0.009
10% exceedence	0.009	0.009	0.010	0.043	0.472	0.581	0.238	0.116	0.080	0.067	0.053	0.010
Standard deviation (denom. = n-1)	0.001	0.001	0.002	0.014	0.242	0.332	0.119	0.086	0.048	0.037	0.026	0.002

Note: based on synthetic daily flow data generated for the period Sep 16 1975-Nov 16 2016.

Table 3-7 Monthly statistics including exceedance probabilities, Reach 7 Gold Creek.

Season	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sample size	1271	1159	1271	1230	1271	1230	1271	1271	1245	1302	1246	1271
Minimum	0.107	0.105	0.102	0.055	0.083	0.068	0.060	0.045	0.036	0.038	0.031	0.104
Maximum	0.309	0.414	0.487	1.360	9.965	19.130	5.312	5.312	1.709	0.989	0.837	0.378
Mean	0.138	0.133	0.140	0.289	0.828	1.038	0.467	0.290	0.240	0.219	0.176	0.147
Median	0.132	0.127	0.131	0.229	0.526	0.628	0.325	0.259	0.222	0.200	0.160	0.141
90% exceedence	0.119	0.118	0.117	0.143	0.228	0.238	0.152	0.110	0.105	0.105	0.079	0.120
75% exceedence	0.124	0.121	0.122	0.173	0.293	0.309	0.238	0.166	0.152	0.147	0.117	0.129
25% exceedence	0.146	0.138	0.146	0.349	0.981	1.271	0.558	0.320	0.272	0.249	0.224	0.158
10% exceedence	0.164	0.154	0.166	0.530	1.811	2.234	0.902	0.427	0.329	0.317	0.284	0.181
Standard deviation (denom. = n-1)	0.020	0.021	0.032	0.173	0.922	1.277	0.435	0.309	0.162	0.122	0.094	0.027

Note: based on synthetic daily flow data generated for the period Sep 16 1975-Nov 16 2016.

Table 3-8 Monthly statistics including exceedance probabilities, Reach 6 Gold Creek.

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sample size	1271	1159	1271	1230	1271	1230	1271	1271	1245	1302	1246	1271
Minimum	0.033	0.032	0.031	0.017	0.025	0.021	0.018	0.014	0.011	0.012	0.009	0.032
Maximum	0.095	0.127	0.150	0.418	3.064	5.881	1.633	1.633	0.525	0.304	0.257	0.116
Mean	0.042	0.041	0.043	0.089	0.254	0.319	0.143	0.089	0.074	0.067	0.054	0.045
Median	0.041	0.039	0.040	0.070	0.162	0.193	0.100	0.080	0.068	0.061	0.049	0.043
90% exceedence	0.037	0.036	0.036	0.044	0.070	0.073	0.047	0.034	0.032	0.032	0.024	0.037
75% exceedence	0.038	0.037	0.038	0.053	0.090	0.095	0.073	0.051	0.047	0.045	0.036	0.040
25% exceedence	0.045	0.043	0.045	0.107	0.302	0.391	0.171	0.098	0.084	0.077	0.069	0.048
10% exceedence	0.050	0.047	0.051	0.163	0.557	0.687	0.277	0.131	0.101	0.097	0.087	0.056
Standard deviation (denom. = n-1)	0.006	0.006	0.010	0.053	0.283	0.393	0.134	0.095	0.050	0.038	0.029	0.008

Note: based on synthetic daily flow data generated for the period Sep 16 1975-Nov 16 2016.

Table 3-9 Monthly statistics including exceedance probabilities, Reach 5 Gold Creek.

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sample size	1271	1159	1271	1230	1271	1230	1271	1271	1245	1302	1246	1271
Minimum	0.123	0.120	0.117	0.063	0.095	0.078	0.069	0.052	0.041	0.044	0.035	0.119
Maximum	0.354	0.475	0.559	1.559	11.424	21.930	6.090	6.090	1.959	1.133	0.960	0.433
Mean	0.158	0.152	0.161	0.332	0.949	1.190	0.535	0.332	0.275	0.251	0.202	0.168
Median	0.151	0.146	0.150	0.262	0.603	0.720	0.372	0.297	0.254	0.229	0.183	0.161
90% exceedence	0.137	0.135	0.135	0.164	0.262	0.273	0.174	0.126	0.121	0.121	0.090	0.137
75% exceedence	0.142	0.139	0.140	0.198	0.335	0.355	0.273	0.190	0.175	0.168	0.134	0.148
25% exceedence	0.168	0.159	0.167	0.400	1.124	1.456	0.639	0.367	0.312	0.286	0.256	0.181
10% exceedence	0.188	0.176	0.190	0.607	2.076	2.561	1.034	0.489	0.377	0.363	0.326	0.208
Standard deviation (denom. = n-1)	0.023	0.024	0.037	0.199	1.057	1.464	0.498	0.354	0.186	0.140	0.107	0.031

Note: based on synthetic daily flow data generated for the period Sep 16 1975-Nov 16 2016.

Table 3-10 Monthly statistics including exceedance probabilities, Reach 5 Blairmore Creek.

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sample size	0.008	0.007	0.010	0.017	0.016	0.040	0.015	0.015	0.015	0.015	0.009	0.007
Minimum	0.075	0.110	0.134	1.426	2.412	4.494	1.148	1.123	0.677	0.900	0.259	0.098
Maximum	0.019	0.017	0.020	0.162	0.367	0.432	0.138	0.053	0.033	0.029	0.028	0.021
Mean	0.017	0.015	0.017	0.116	0.211	0.294	0.112	0.039	0.019	0.015	0.023	0.019
Median	0.012	0.012	0.012	0.038	0.076	0.119	0.042	0.015	0.015	0.015	0.015	0.013
90% exceedence	0.014	0.013	0.014	0.063	0.128	0.167	0.067	0.020	0.015	0.015	0.018	0.015
75% exceedence	0.022	0.019	0.022	0.222	0.485	0.548	0.164	0.062	0.035	0.029	0.032	0.025
25% exceedence	0.027	0.024	0.029	0.334	0.821	0.893	0.284	0.097	0.063	0.049	0.045	0.034
10% exceedence	0.007	0.007	0.012	0.144	0.373	0.420	0.117	0.070	0.044	0.048	0.019	0.009
Standard deviation (denom. = n-1)	0.008	0.007	0.010	0.017	0.016	0.040	0.015	0.015	0.015	0.015	0.009	0.007

Note: based on synthetic daily flow data generated for the period Sep 16 1975-Nov 16 2016.

Table 3-11 Monthly statistics including exceedance probabilities, Reach 4 Blairmore Creek.

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sample size	0.013	0.012	0.016	0.027	0.025	0.064	0.024	0.024	0.024	0.024	0.014	0.011
Minimum	0.119	0.175	0.213	2.273	3.844	7.162	1.830	1.789	1.079	1.434	0.413	0.155
Maximum	0.030	0.027	0.032	0.258	0.585	0.689	0.220	0.084	0.052	0.047	0.044	0.034
Mean	0.027	0.025	0.026	0.185	0.336	0.468	0.178	0.062	0.031	0.024	0.036	0.030
Median	0.020	0.019	0.019	0.060	0.121	0.190	0.067	0.024	0.024	0.024	0.025	0.020
90% exceedence	0.022	0.021	0.022	0.100	0.205	0.266	0.106	0.032	0.024	0.024	0.029	0.024
75% exceedence	0.035	0.030	0.035	0.354	0.772	0.873	0.261	0.099	0.056	0.046	0.050	0.040
25% exceedence	0.044	0.039	0.046	0.532	1.309	1.422	0.452	0.155	0.101	0.078	0.072	0.055
10% exceedence	0.011	0.012	0.019	0.229	0.594	0.669	0.186	0.112	0.069	0.076	0.031	0.015
Standard deviation (denom. = n-1)	0.013	0.012	0.016	0.027	0.025	0.064	0.024	0.024	0.024	0.024	0.014	0.011

Note: based on synthetic daily flow data generated for the period Sep 16 1975-Nov 16 2016.

Table 3-12 Monthly statistics including exceedance probabilities, Reach 3 Blairmore Creek.

Season	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sample size	1271	1159	1271	1230	1271	1230	1271	1271	1245	1302	1246	1271
Minimum	0.016	0.014	0.019	0.032	0.030	0.076	0.028	0.028	0.028	0.028	0.017	0.014
Maximum	0.142	0.207	0.253	2.698	4.564	8.504	2.173	2.124	1.281	1.703	0.490	0.185
Mean	0.035	0.032	0.038	0.306	0.695	0.818	0.261	0.099	0.062	0.055	0.053	0.041
Median	0.032	0.029	0.031	0.220	0.399	0.556	0.211	0.073	0.036	0.028	0.043	0.036
90% exceedence	0.023	0.022	0.023	0.072	0.143	0.225	0.080	0.028	0.028	0.028	0.029	0.024
75% exceedence	0.027	0.025	0.026	0.119	0.243	0.315	0.126	0.037	0.028	0.028	0.034	0.029
25% exceedence	0.041	0.036	0.042	0.421	0.917	1.036	0.310	0.117	0.066	0.055	0.060	0.048
10% exceedence	0.052	0.046	0.054	0.632	1.554	1.688	0.537	0.183	0.119	0.093	0.085	0.065
Standard deviation (denom. = n-1)	0.013	0.014	0.023	0.272	0.705	0.795	0.221	0.133	0.082	0.091	0.036	0.018

Note: based on synthetic daily flow data generated for the period Sep 16 1975-Nov 16 2016.

Figure 3-21 Estimated low-flow statistics, 1976-2016, Reach 9 Gold Creek.

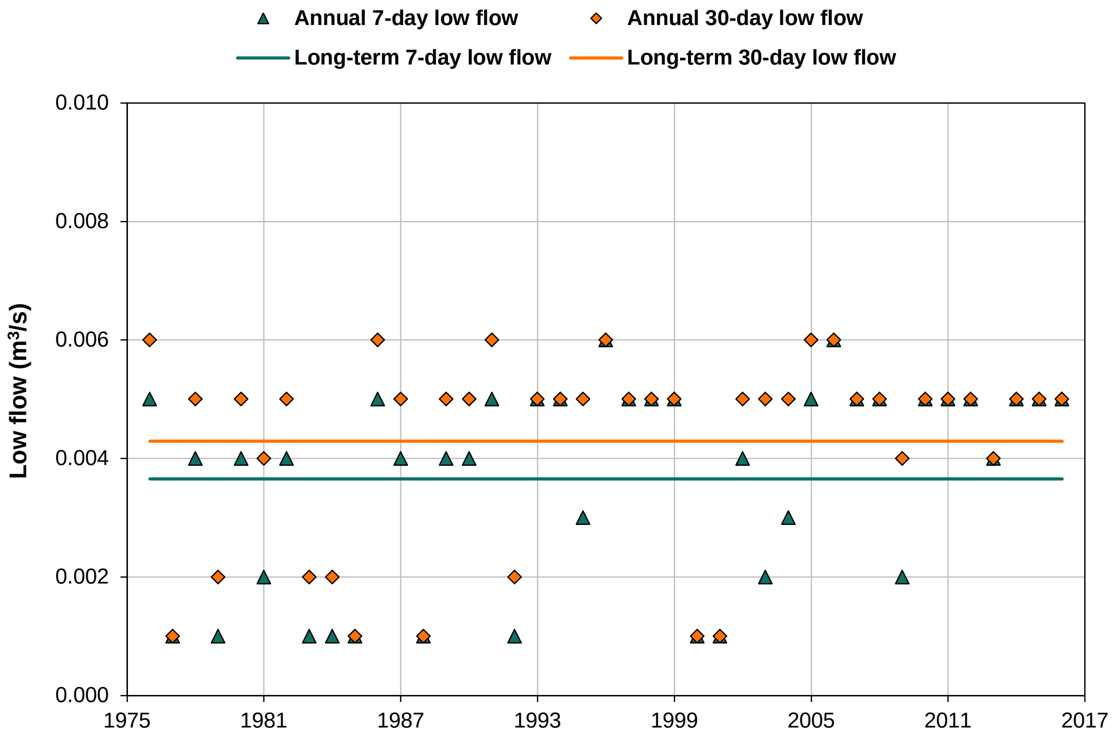


Figure 3-22 Estimated low-flow statistics, 1976-2016, Reach 8 Gold Creek.

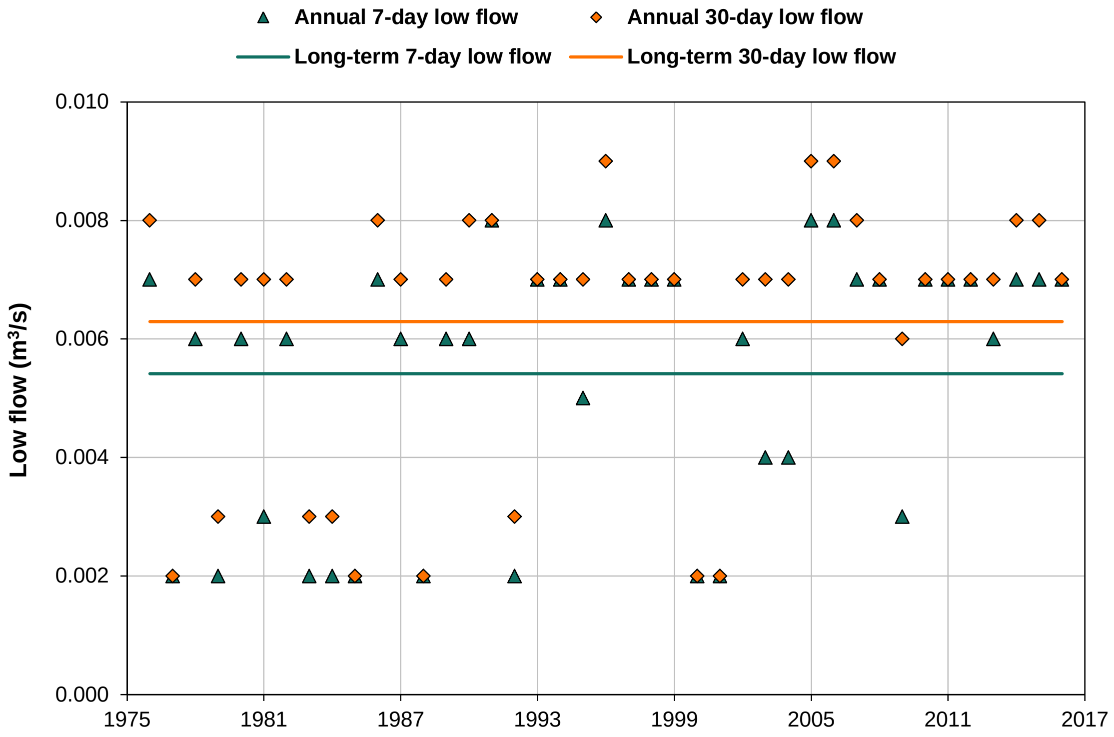


Figure 3-23 Estimated low-flow statistics, 1976-2016, Reach 7 Gold Creek.

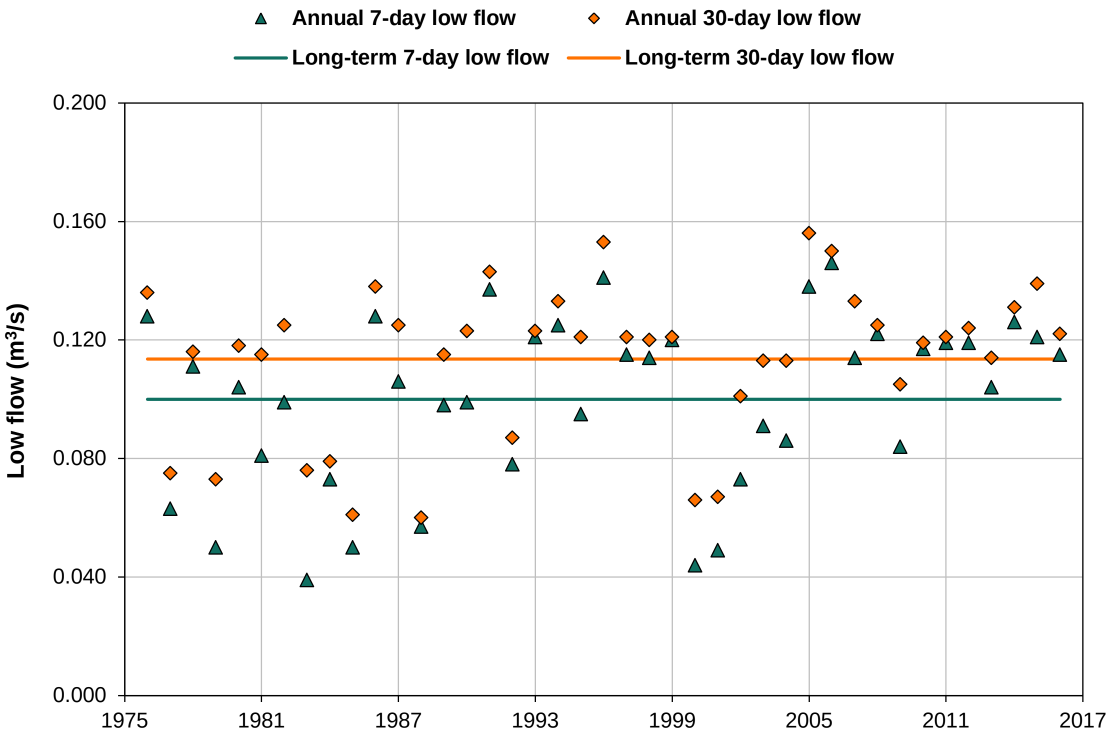


Figure 3-24 Estimated low-flow statistics, 1976-2016, Reach 6 Gold Creek.

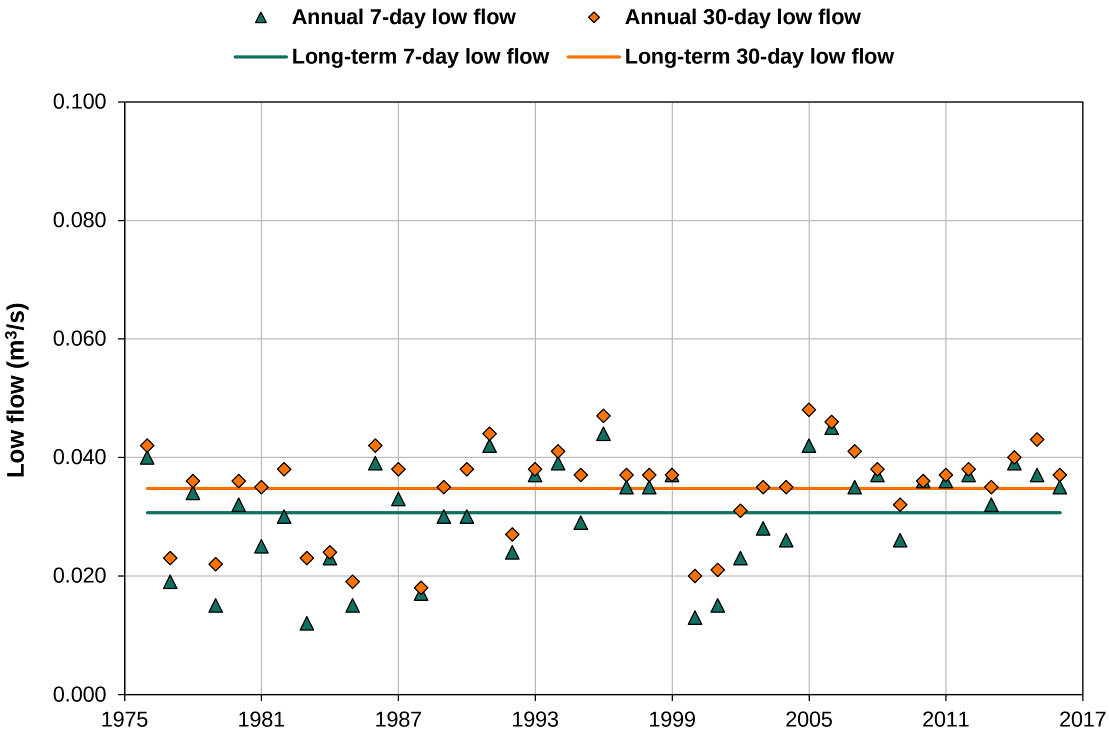


Figure 3-25 Estimated low-flow statistics, 1976-2016, Reach 5 Gold Creek.

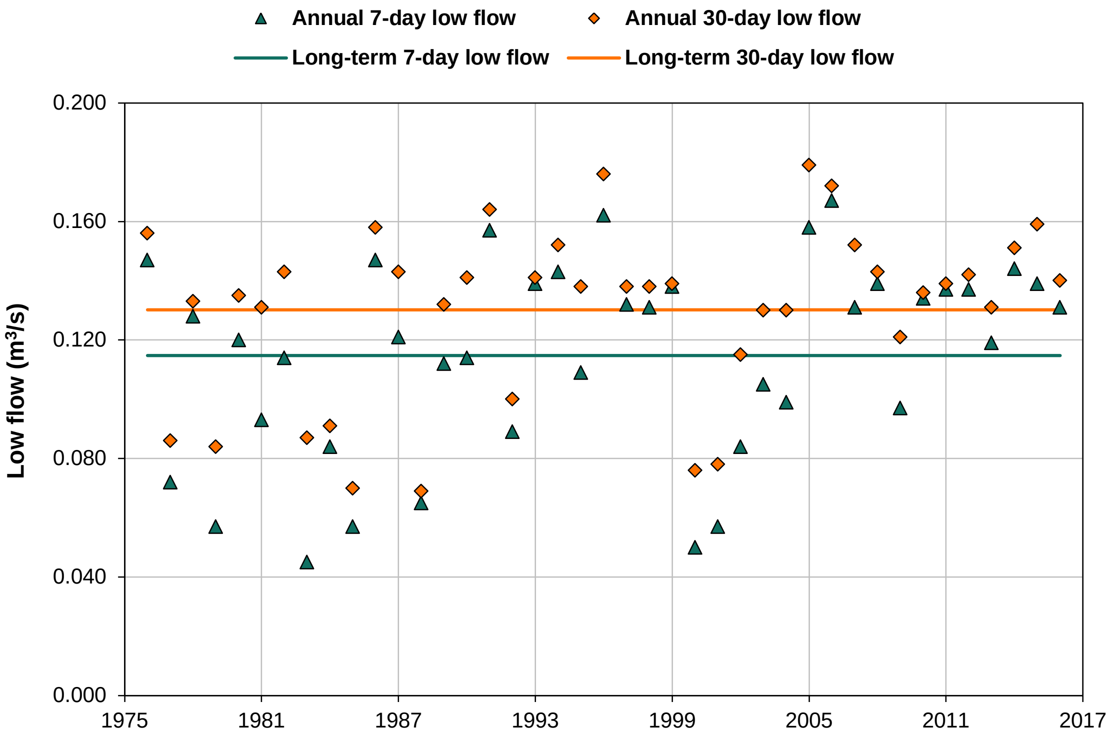


Figure 3-26 Estimated low-flow statistics, 1976-2016, Reach 5 Blairmore Creek.

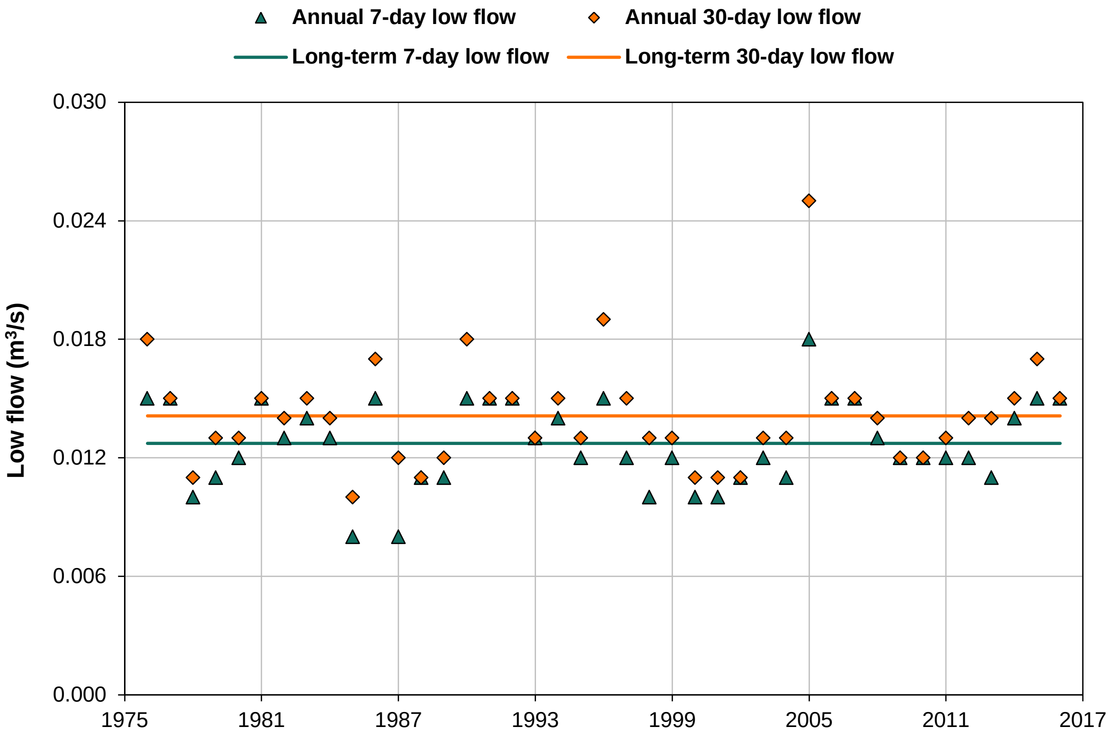


Figure 3-27 Estimated low-flow statistics, 1976-2016, Reach 4 Blairmore Creek.

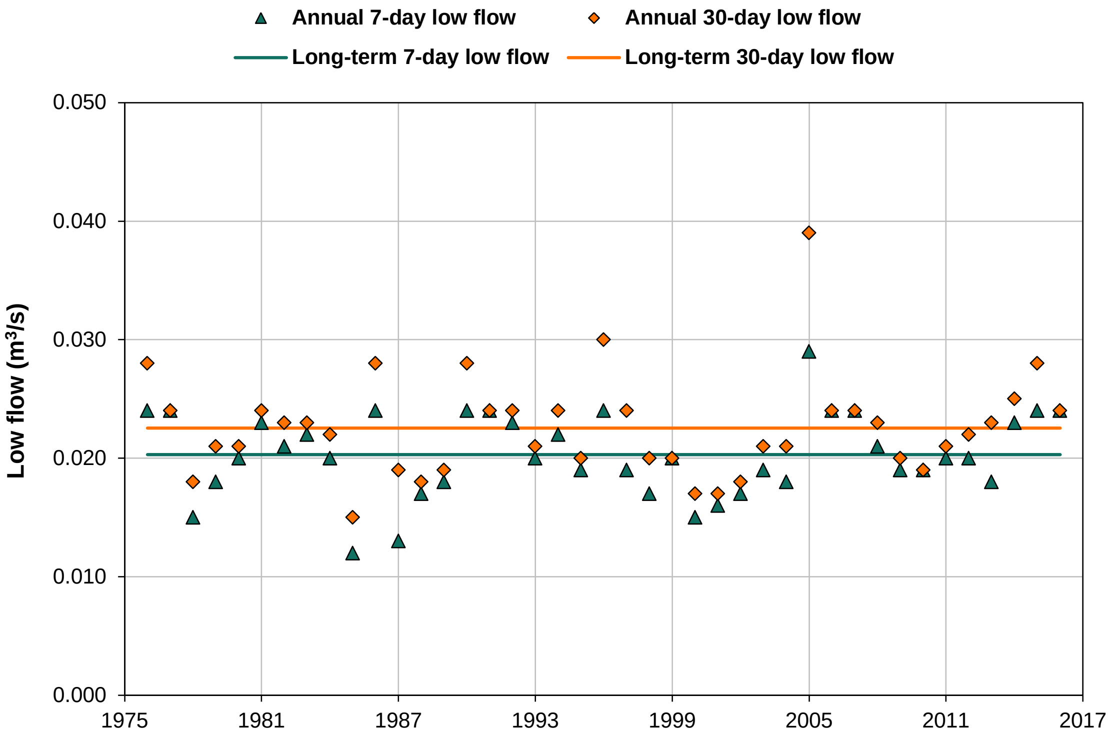
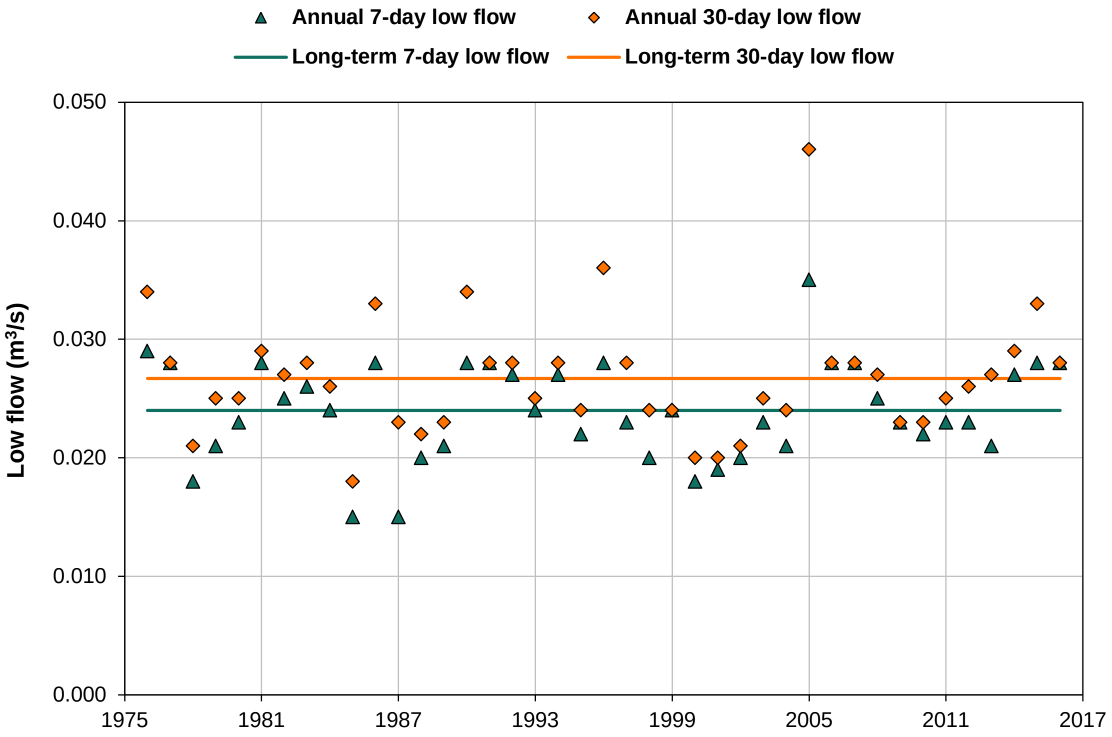


Figure 3-28 Estimated low-flow statistics, 1976-2016, Reach 3 Blairmore Creek.



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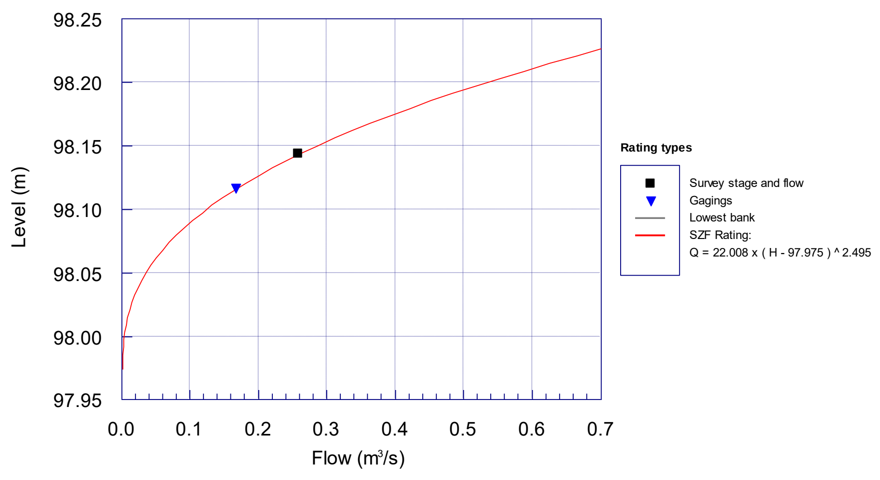
Appendix A2

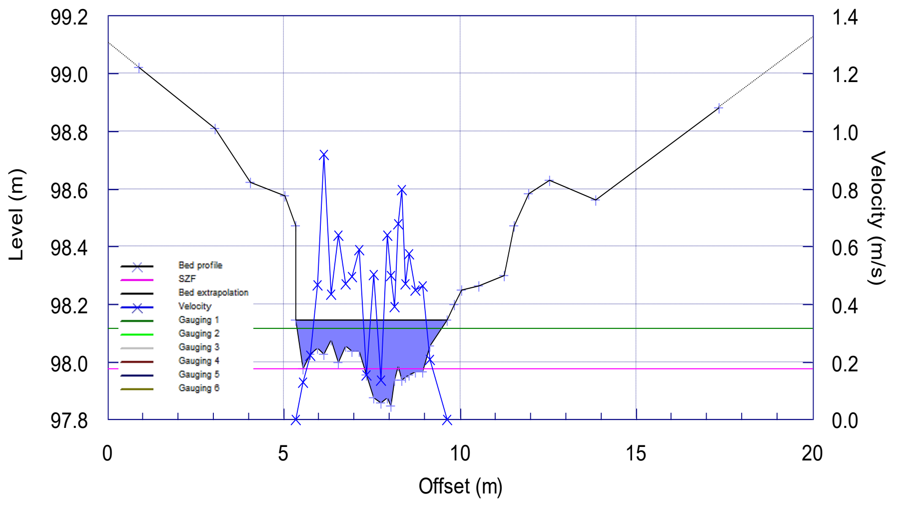
Cross-Section Summary Data and Photographs

Gold Creek

Previous View Main Menu TA and EIA Menu Addendum Menu Search

GOLD CREEK: XS GC-0
PRIMARY HABITAT UNIT: RIFFLE





Rating Curve

Survey Flow Depth/Velocity Profile

UPSTREAM

DOWNSTREAM

Not surveyed/photographed

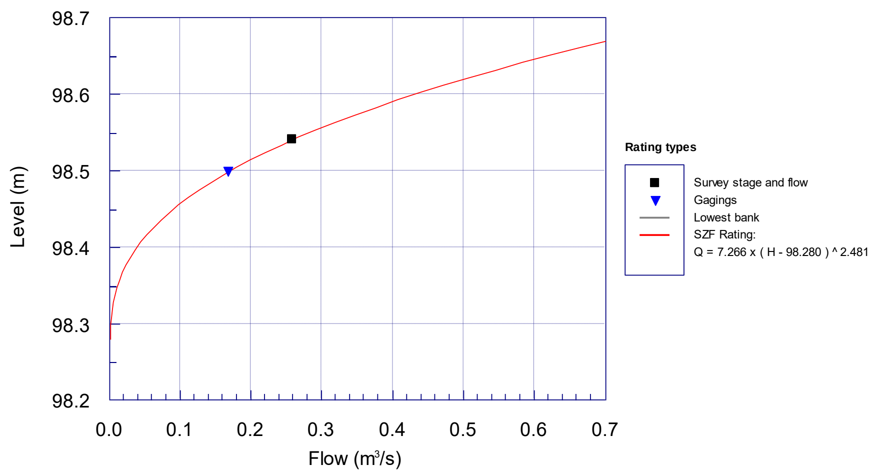
Not surveyed/photographed

June/July 2016

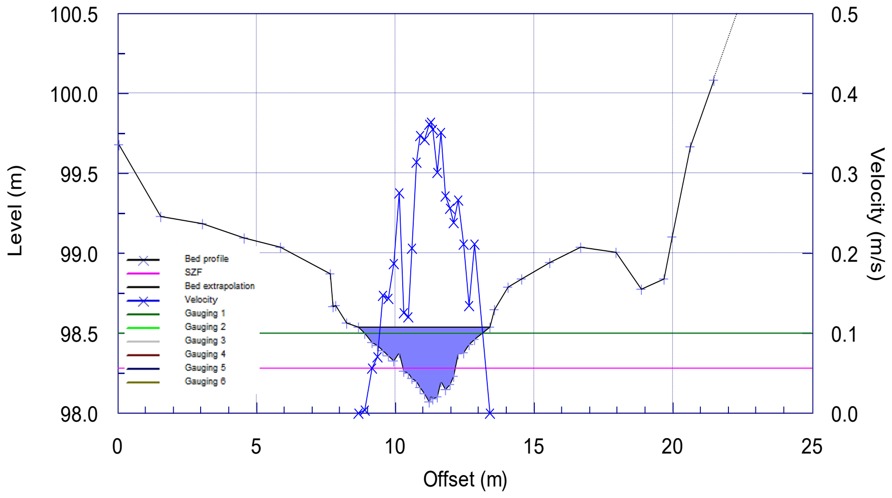
14 September 2016, WSE = 98.116 m, Q = 0.166 m^3/s

15 October 2016, WSE = 98.143, Q = 0.257 m^3/s

GOLD CREEK: XS GC-1
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM

DOWNSTREAM

Not surveyed/photographed

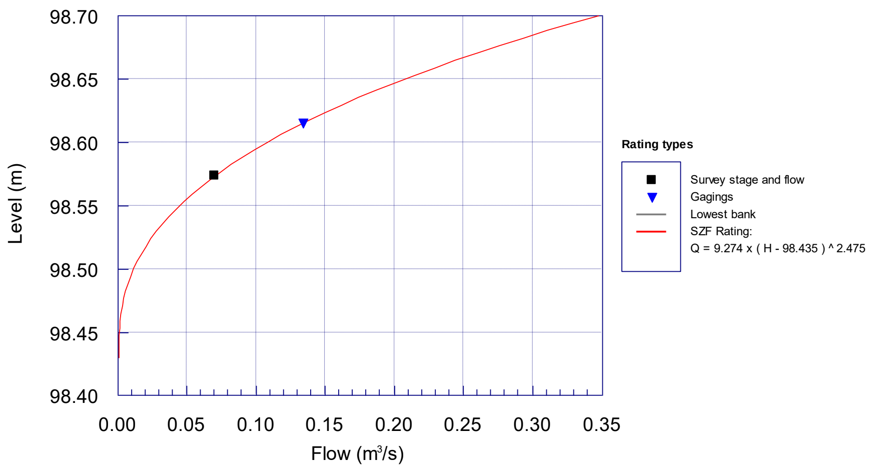
Not surveyed/photographed

June/July 2016

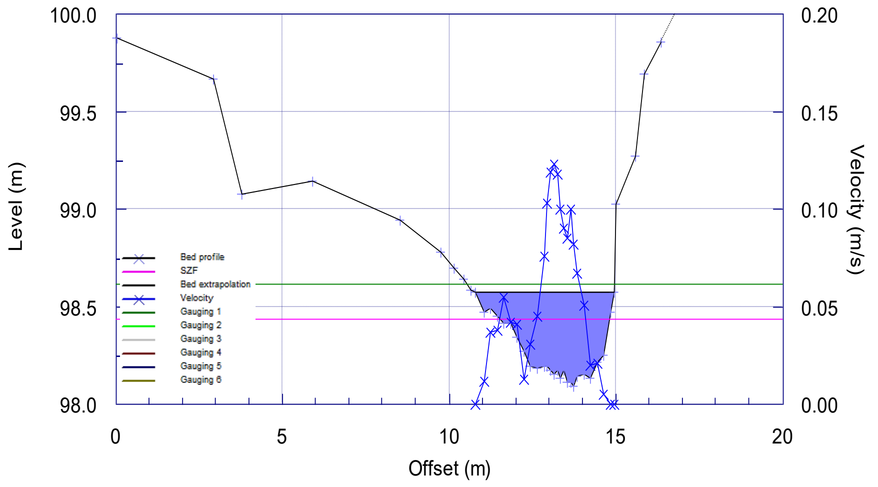
14 September 2016, WSE = 98.498 m, Q = 0.166 m^3/s

15 October 2016, WSE = 98.540 m, Q = 0.257 m^3/s

GOLD CREEK: XS GC-2
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM

DOWNSTREAM

Not surveyed/photographed

Not surveyed/photographed

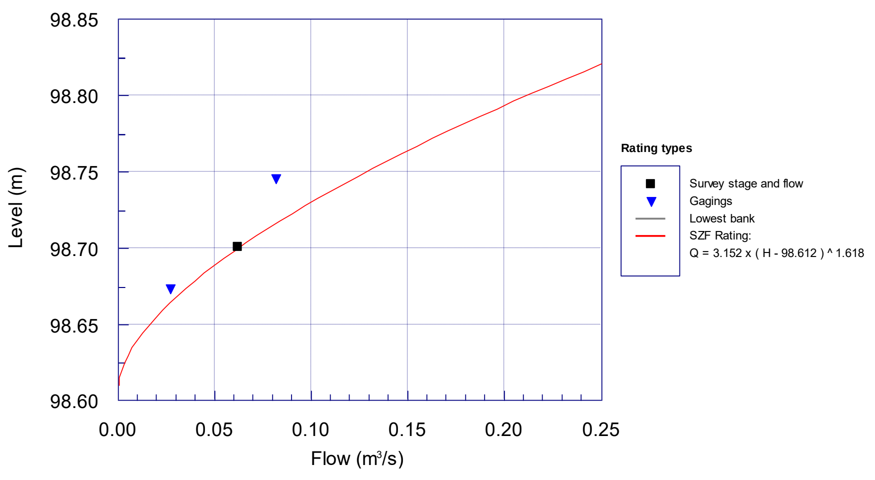
June/July 2016

14 September 2016, WSE = 98.573 m, Q= 0.069 m^3/s

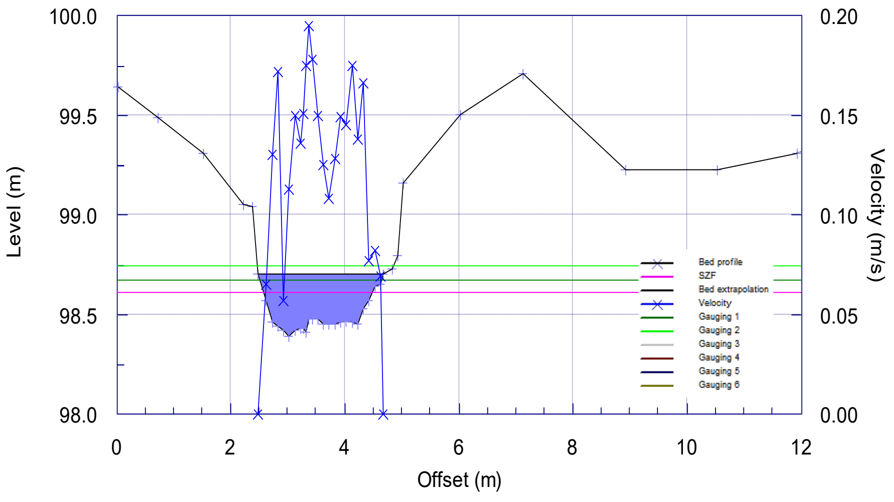
15 October 2016, WSE = 98.615 m, Q = 0.133 m^3/s

Previous View Main Menu TA and EIA Menu Addendum Menu Search

GOLD CREEK: XS GC-3
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

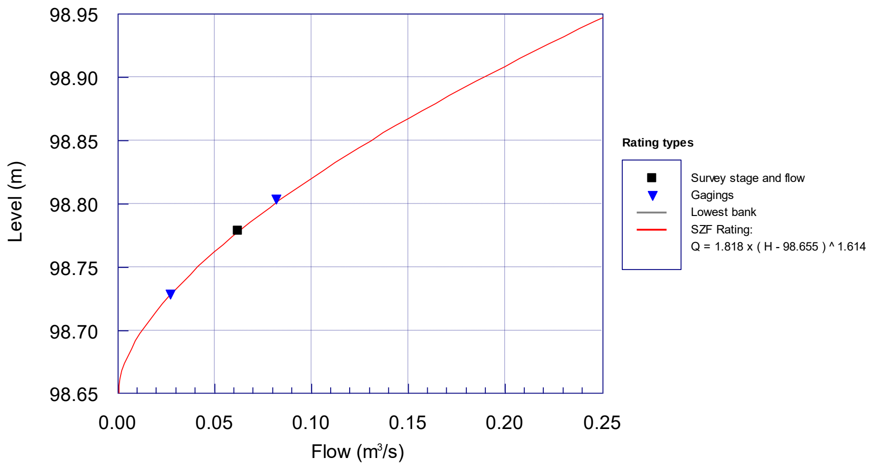
UPSTREAM **DOWNSTREAM**

8 July 2016, WSE = 98.700 m, Q = 0.062 m^3/s

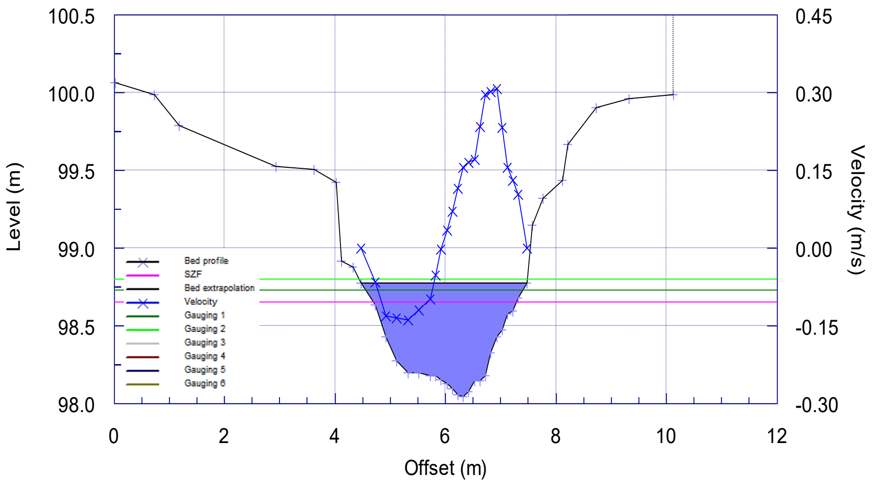
14 September 2016, WSE = 98.673 m, Q = 0.026 m^3/s

14 October 2016, WSE = 98.745 m, Q = 0.081 m^3/s

GOLD CREEK: XS GC-4
PRIMARY HABITAT UNIT: POOL



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM (photos identical to GC-5)

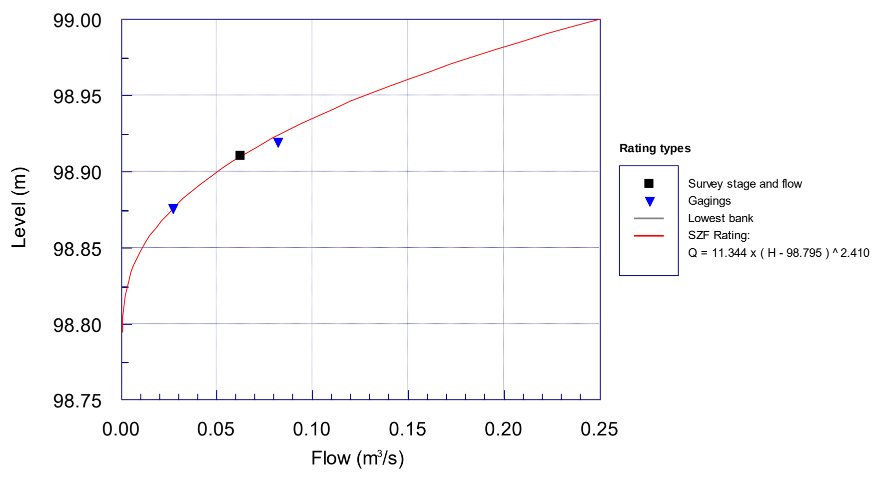
DOWNSTREAM

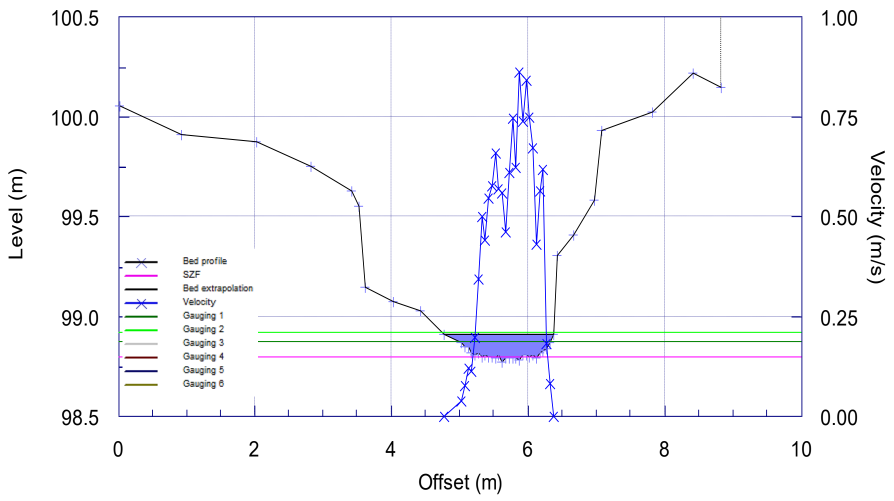
8 July 2016, WSE = 98.778 m, Q = 0.062 m^3/s

14 September 2016, WSE = 98.728 m, Q = 0.026 m^3/s

14 October 2016, WSE = 98.803 m, Q = 0.081 m^3/s

GOLD CREEK: XS GC-5
PRIMARY HABITAT UNIT: RIFFLE





Rating Curve **Survey Flow Depth/Velocity Profile**

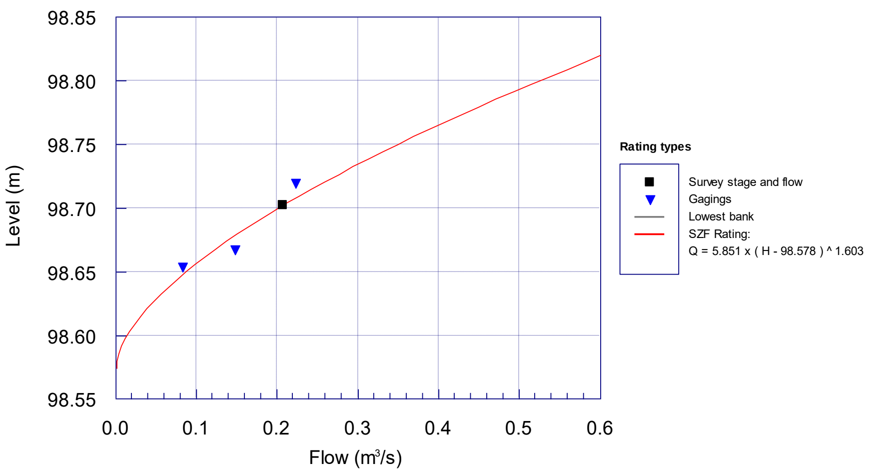
UPSTREAM **DOWNSTREAM**

8 July 2016, WSE = 98.910 m, Q = 0.062 m^3/s

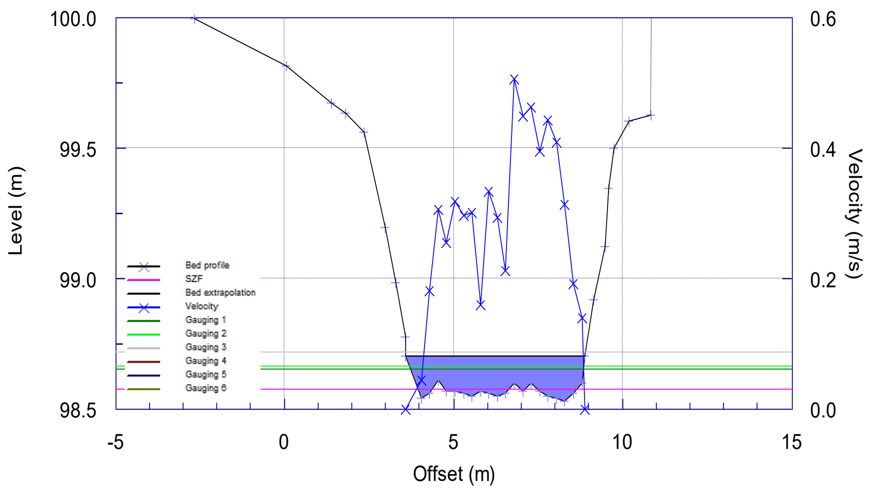
14 September 2016, WSE = 98.875 m, Q = 0.026 m^3/s

14 October 2016, WSE = 98.919 m, Q = 0.081 m^3/s

GOLD CREEK: XS GC-6
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM

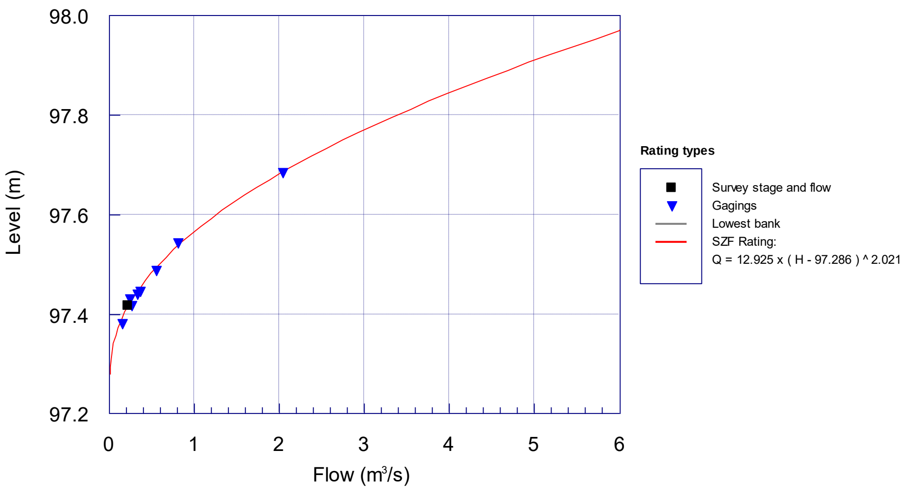
DOWNSTREAM

24 June 2016, WSE = 98.653 m, Q = 0.072 m³/s

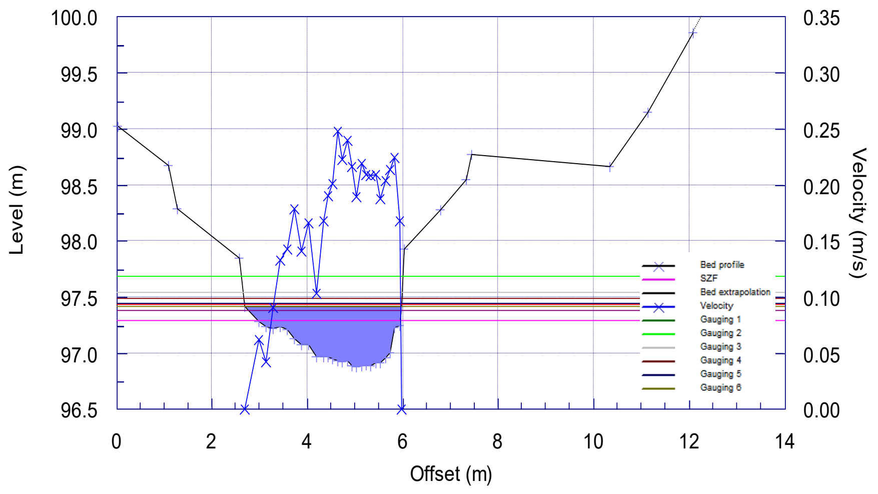
14 September 2016, WSE = 98.667 m, Q = 0.147 m³/s

14 October 2016, WSE = 98.719 m, Q = 0.222 m³/s

GOLD CREEK: XS GC-7 (HS-01)
PRIMARY HABITAT UNIT: RUN/GLIDE



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM

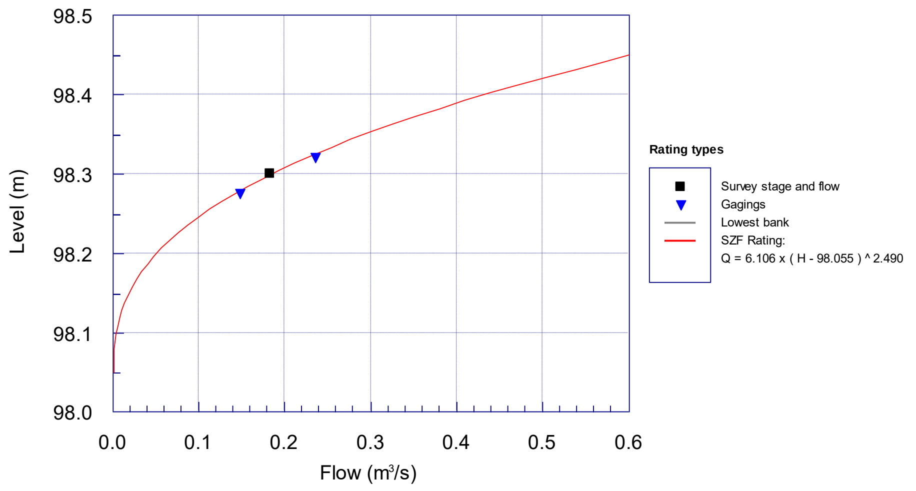
DOWNSTREAM

24 June 2016, WSE = 97.415 m, Q = 0.206 m^3/s

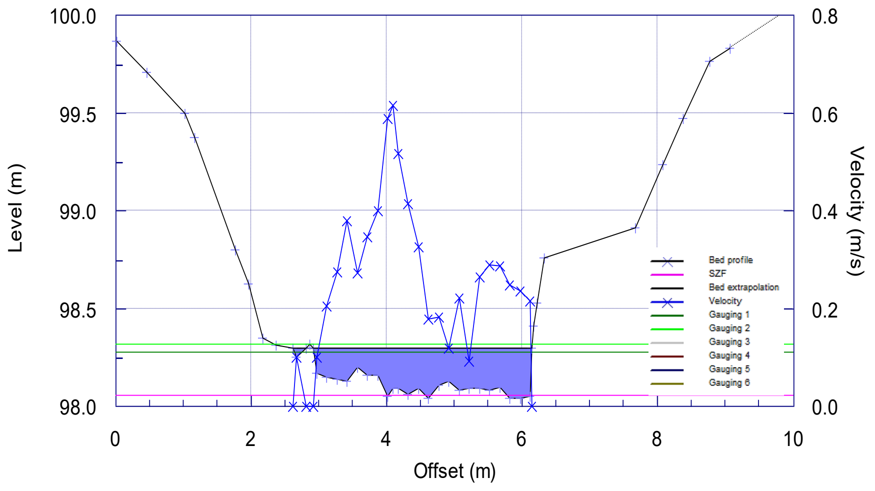
14 September 2016, WSE = 97.379 m, Q = 0.147 m^3/s

15 October 2016, WSE = 97.429 m, Q = 0.222 m^3/s

GOLD CREEK: XS GC-8
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

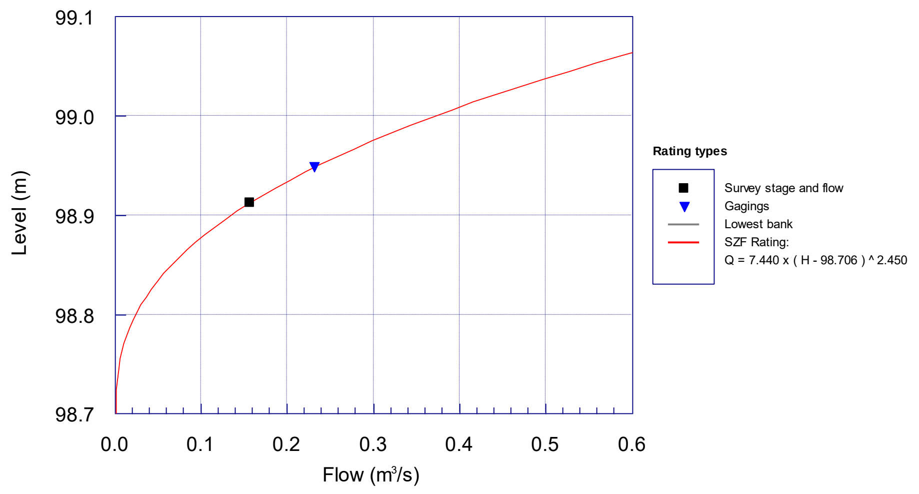
UPSTREAM **DOWNSTREAM**

8 July 2016, WSE = 98.299 m, Q = 0.182 m^3/s

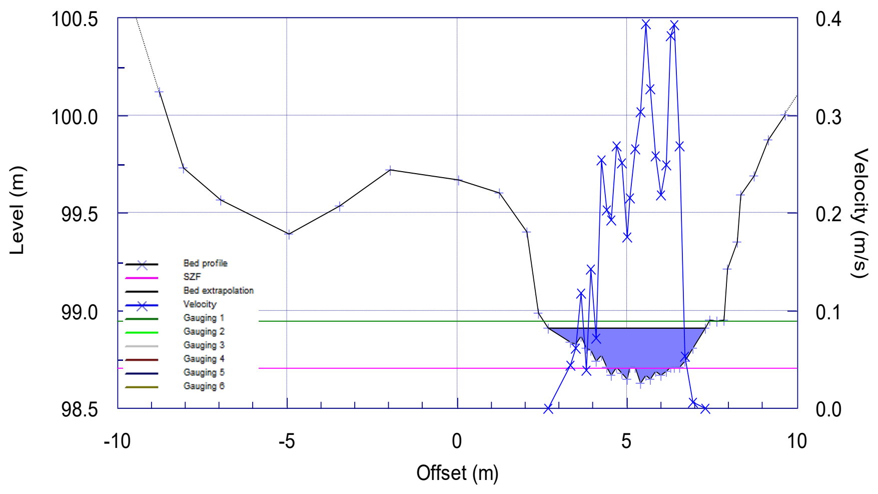
14 September 2016, WSE = 98.275 m, Q = 0.147 m^3/s

14 October 2016, WSE = 98.320 m, Q = 0.230 m^3/s

GOLD CREEK: XS GC-9
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM

DOWNSTREAM

Not surveyed/photographed

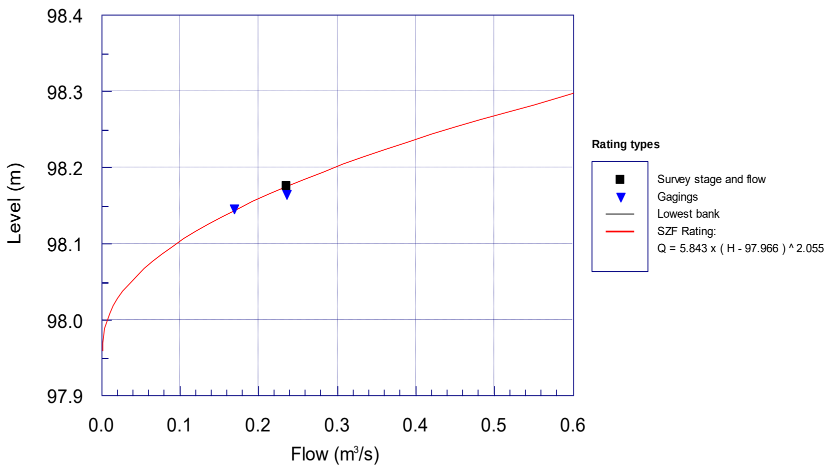
Not surveyed/photographed

June July 2016

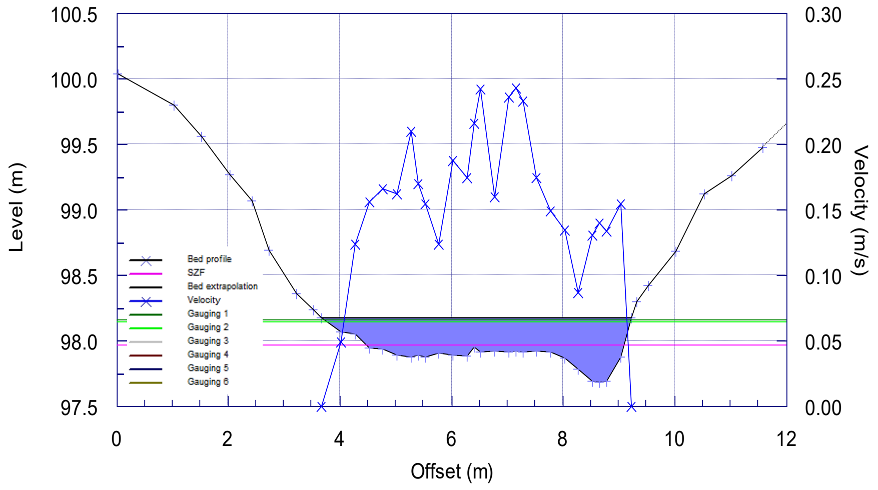
17 September 2016, WSE = 98.912 m, Q = 0.155 m^3/s

14 October 2016, WSE = 98.948 m, Q = 0.230 m^3/s

GOLD CREEK: XS GC-10
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

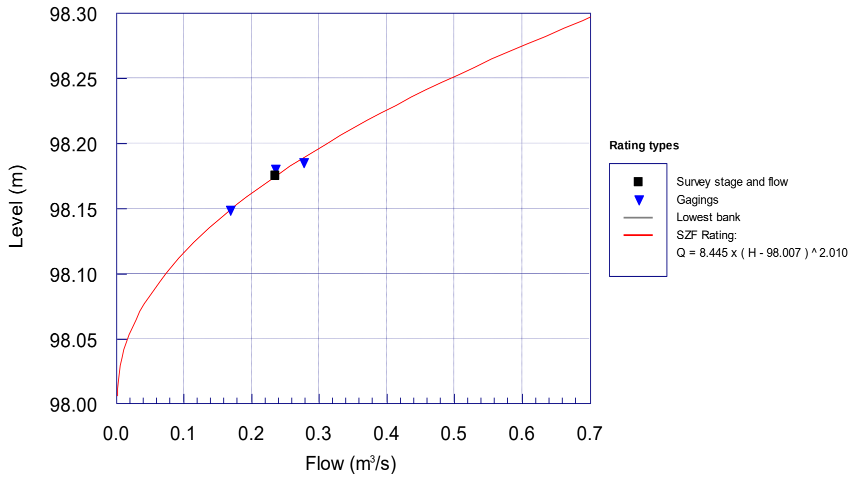
UPSTREAM

DOWNSTREAM

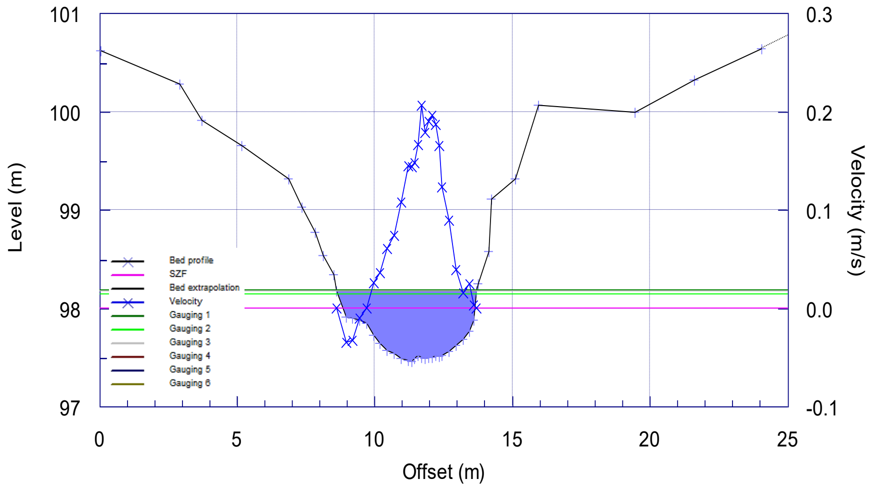
17 September 2016, WSE = 98.145 m, Q = 0.167 m^3/s

14 October 2016, WSE = 98.175 m, Q = 0.234 m^3/s

GOLD CREEK: XS GC-11 (HS-02)
PRIMARY HABITAT UNIT: POOL



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM DOWNSTREAM

22 June 2016, WSE = 98.175 m, Q = 0.234 m^3/s

17 September 2016, WSE = 98.148 m, Q = 0.167 m^3/s

14 October 2016, WSE = 98.180 m, Q = 0.234 m^3/s

Previous View
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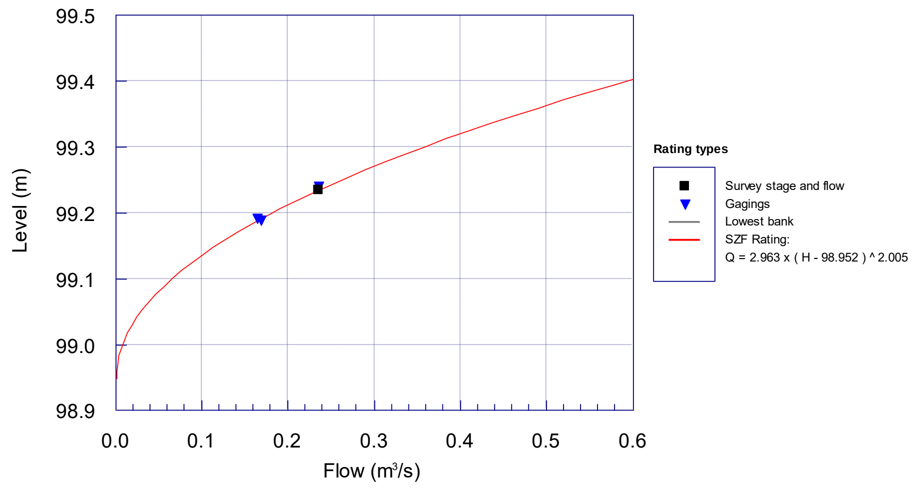
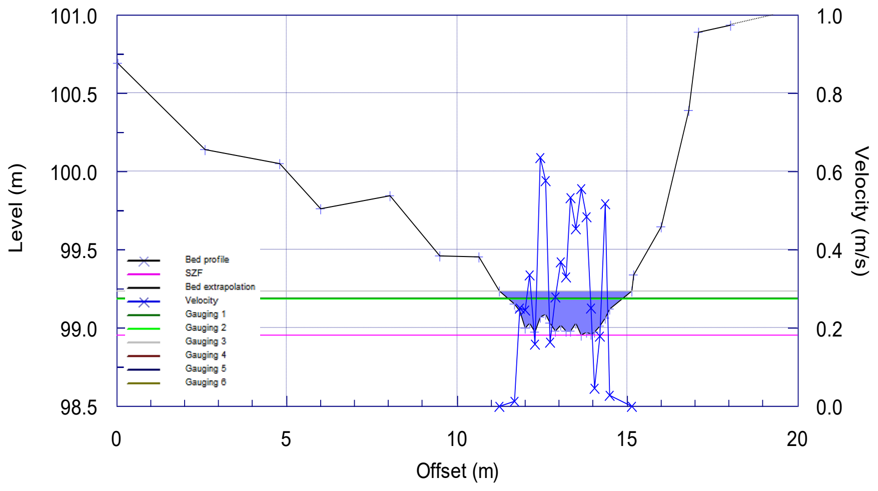
GOLD CREEK: XS GC-12
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

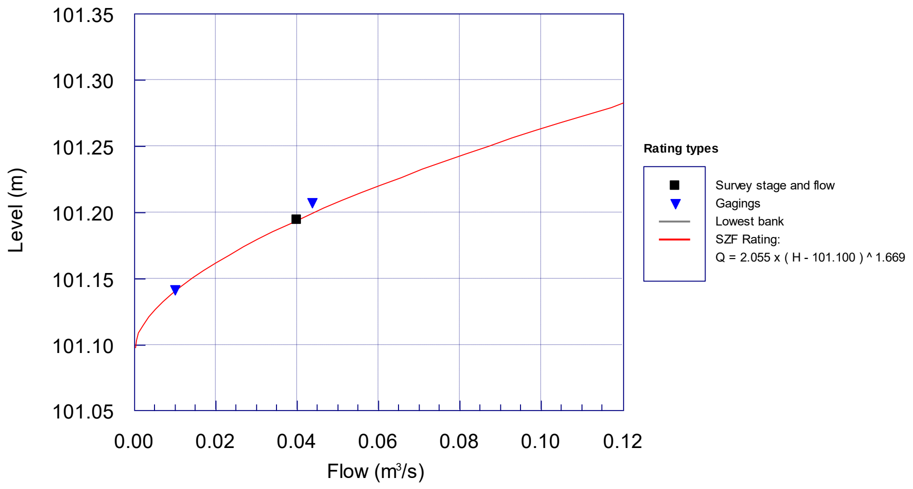
UPSTREAM **DOWNSTREAM**

22 June 2016, WSE = 99.234 m, Q = 0.234 m^3/s

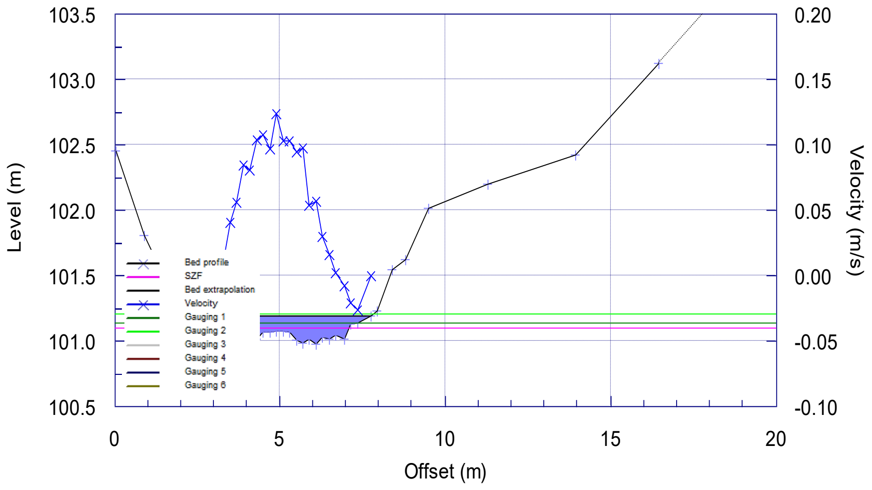
17 September 2016, WSE = 99.188 m, Q = 0.167 m^3/s

14 October 2016, WSE = 99.239 m, Q = 0.234 m^3/s

GOLD CREEK: XS GC-13
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

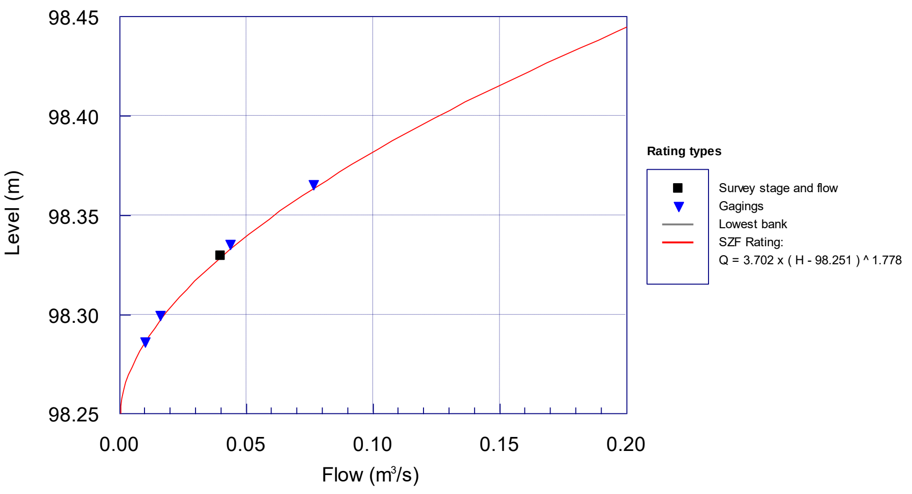
UPSTREAM **DOWNSTREAM**

22 June 2016, WSE = 101.194 m, Q = 0.040 m^3/s

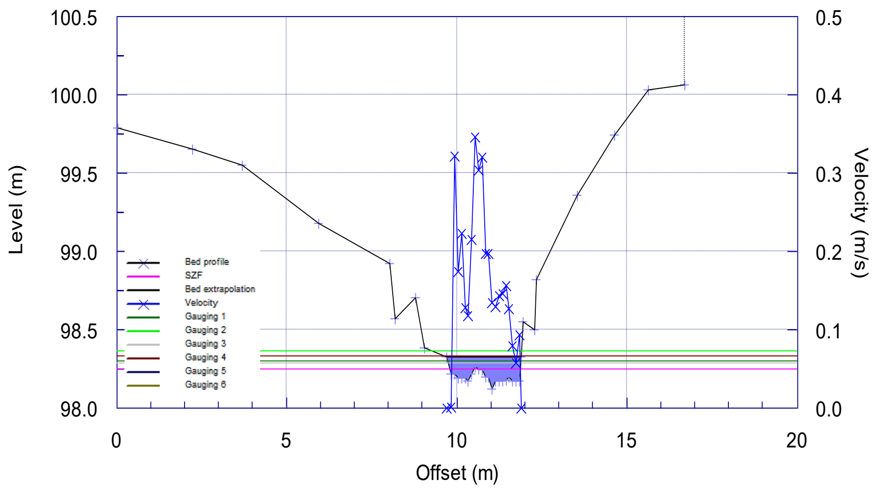
17 September 2016, WSE = 101.141 m, Q = 0.010 m^3/s

13 October 2016, WSE = 101.207 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-14
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

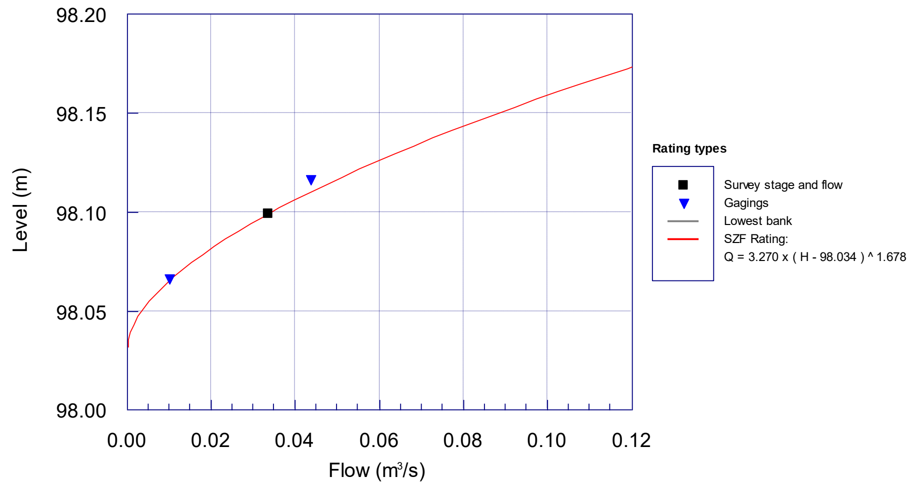
UPSTREAM **DOWNSTREAM**

22 June 2016, WSE = 98.329 m, Q = 0.040 m^3/s

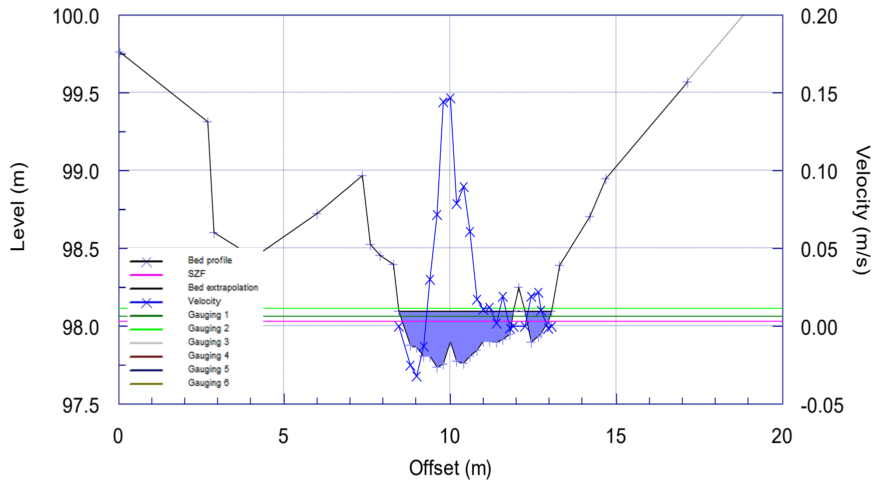
17 September 2016, WSE = 98.286 m, Q = 0.010 m^3/s

13 October 2016, WSE = 98.335 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-15
PRIMARY HABITAT UNIT: POOL



Rating Curve



Survey Flow Depth/Velocity Profile

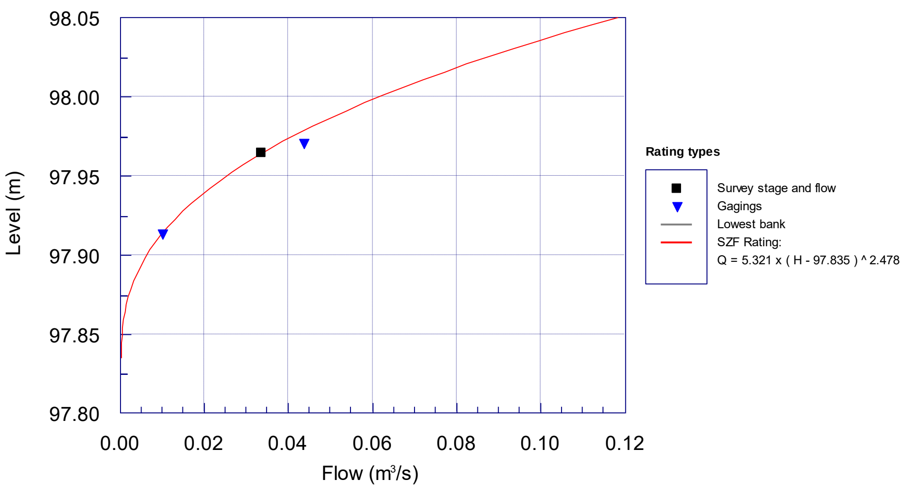
UPSTREAM **DOWNSTREAM**

22 June 2016, WSE = 98.099 m, Q = 0.033 m^3/s

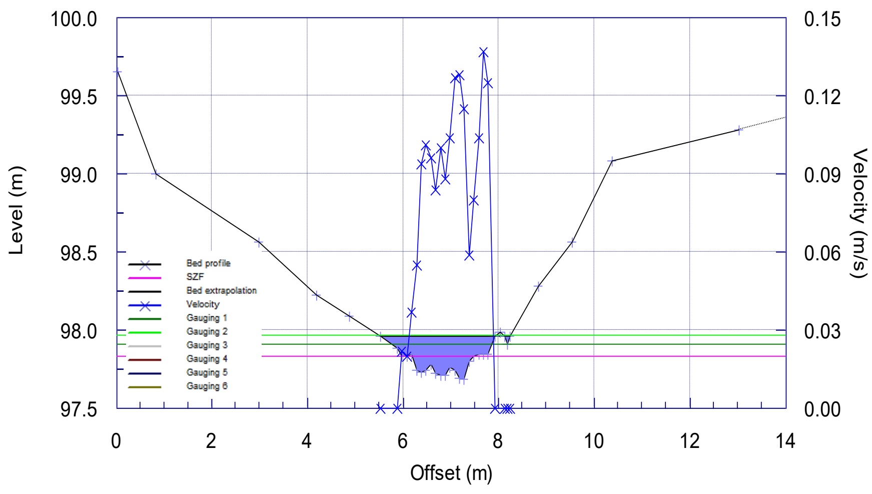
17 September 2016, WSE = 98.066 m, Q = 0.010 m^3/s

13 October 2016, WSE = 98.116 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-16
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

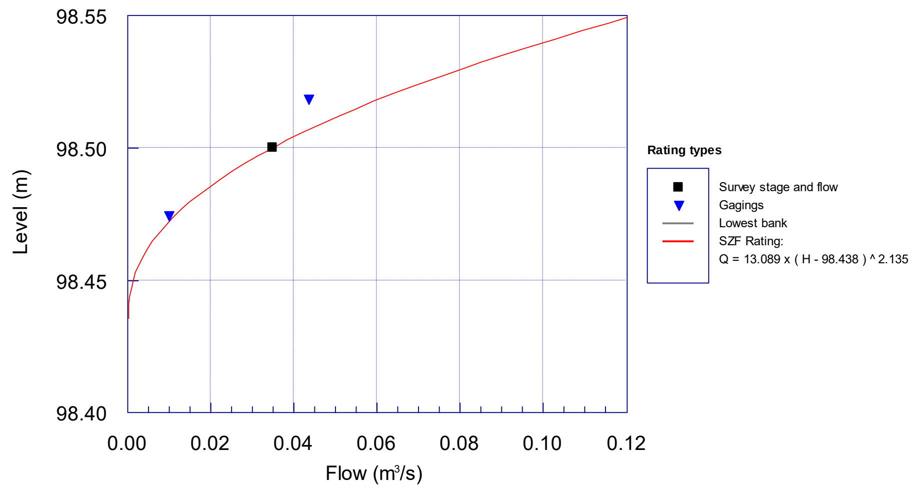
UPSTREAM **DOWNSTREAM**

22 June 2016, WSE = 97.964 m, Q = 0.033 m^3/s

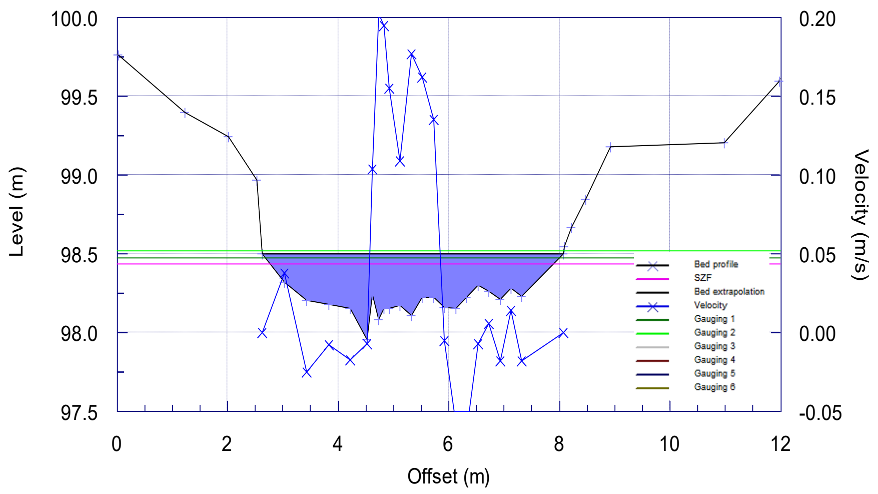
17 September 2016, WSE = 97.913 m, Q = 0.010 m^3/s

13 October 2016, WSE = 97.970 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-17
PRIMARY HABITAT UNIT: POOL



Rating Curve



Survey Flow Depth/Velocity Profile

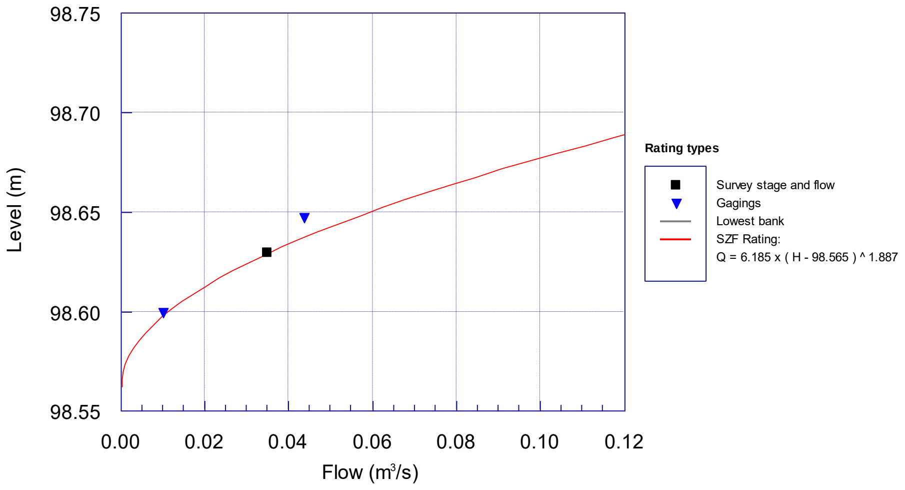
UPSTREAM **DOWNSTREAM**

23 June 2016, WSE = 98.500 m, Q = 0.035 m^3/s

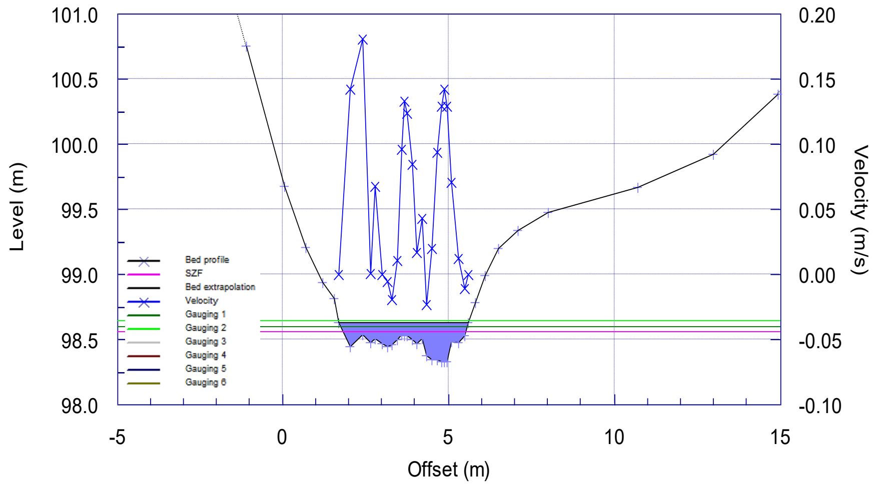
16 September 2016, WSE = 98.474 m, Q = 0.010 m^3/s

13 October 2016, WSE = 98.518 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-18
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM

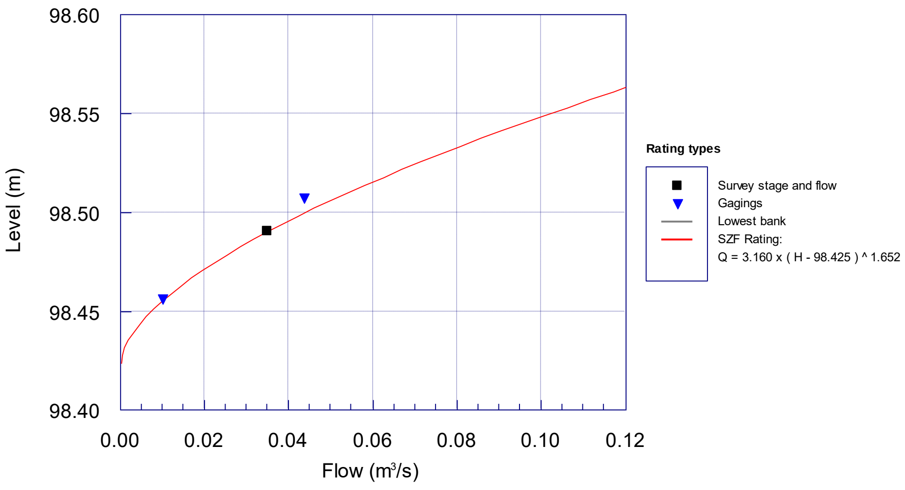
DOWNSTREAM

23 June 2016, WSE = 98.629 m, Q = 0.035 m^3/s

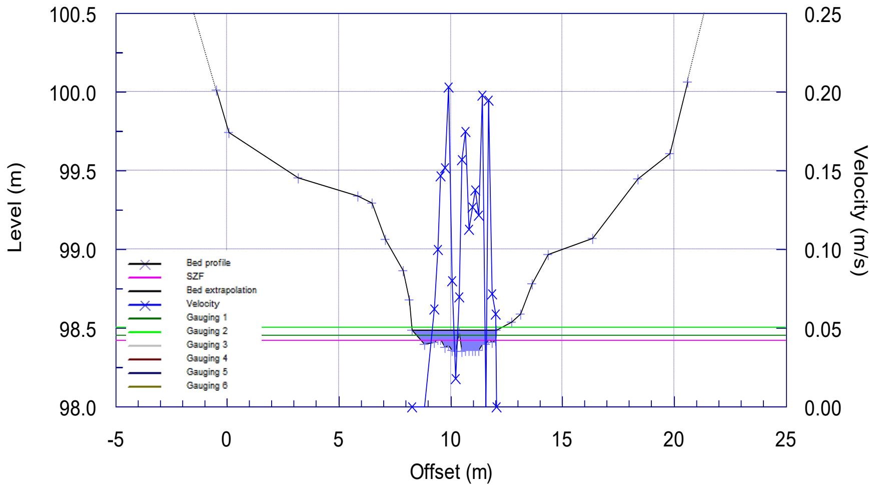
16 September 2016, WSE = 98.599 m, Q = 0.010 m^3/s

13 October 2016, WSE = 98.647 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-19
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

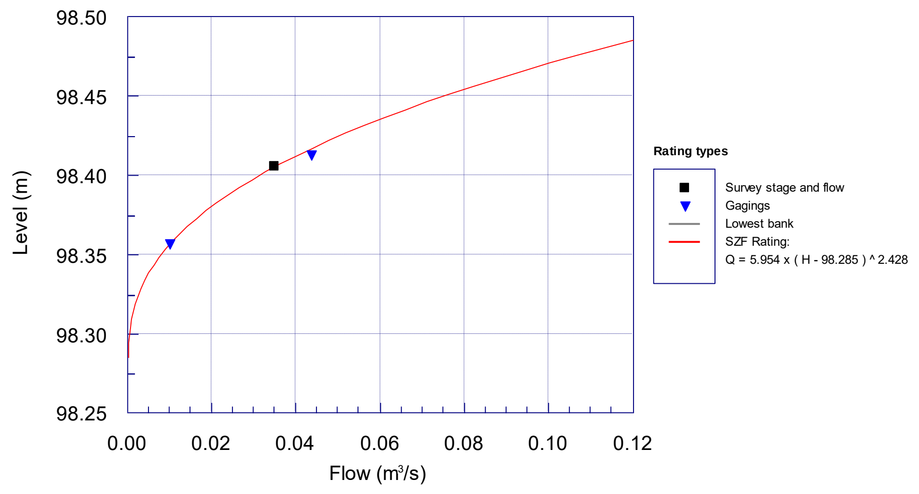
UPSTREAM **DOWNSTREAM**

23 June 2016, WSE = 98.490 m, Q = 0.035 m^3/s

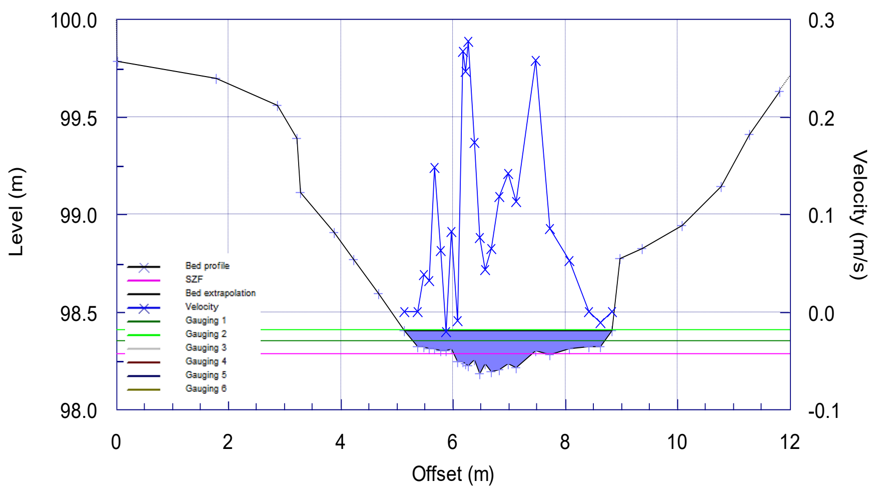
16 September 2016, WSE = 98.456 m, Q = 0.010 m^3/s

13 October 2016, WSE = 98.507 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-20
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

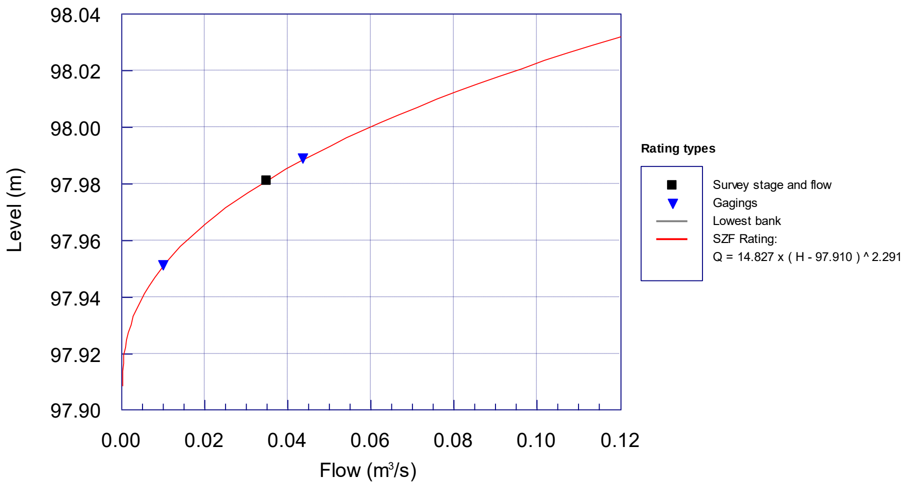
UPSTREAM **DOWNSTREAM**

23 June 2016, WSE = 98.405 m, Q = 0.035 m^3/s

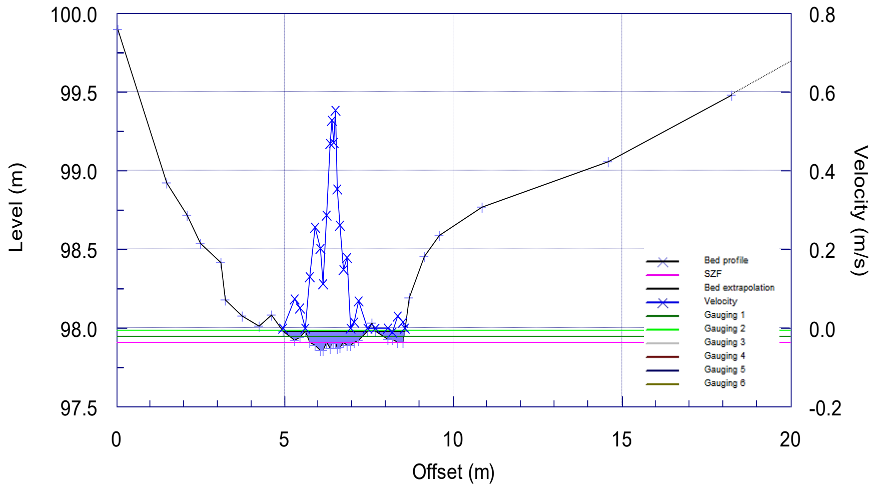
16 September 2016, WSE = 98.356 m, Q = 0.010 m^3/s

13 October 2016, WSE = 98.412 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-21
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

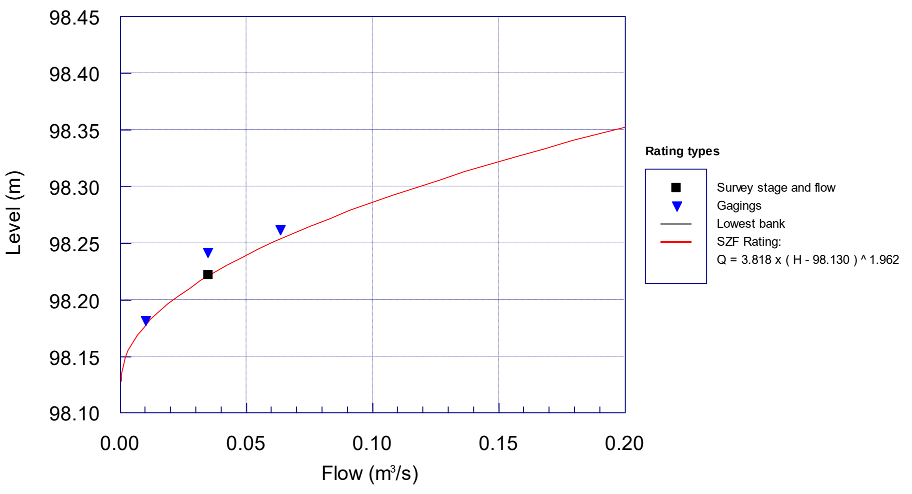
UPSTREAM **DOWNSTREAM**

23 June 2016, WSE = 97.981 m, Q = 0.035 m^3/s

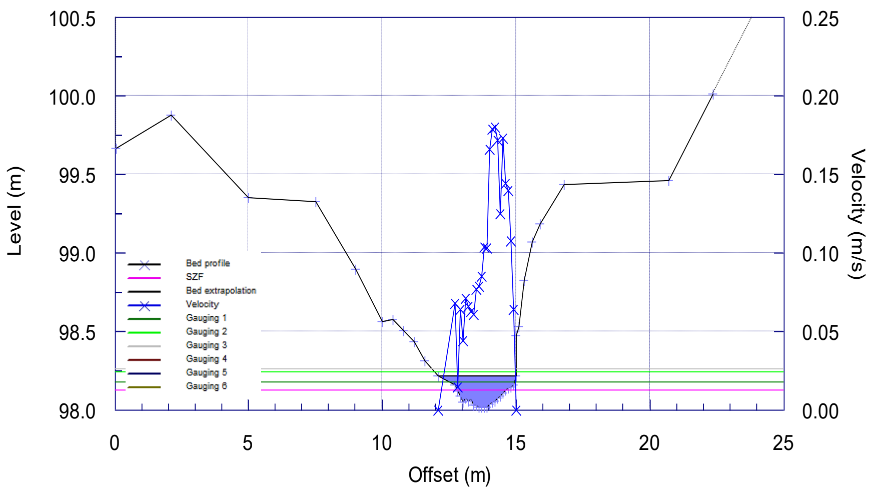
16 September 2016, WSE = 97.951 m, Q = 0.010 m^3/s

13 October 2016, WSE = 97.989 m, Q = 0.043 m^3/s

GOLD CREEK: XS GC-22
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

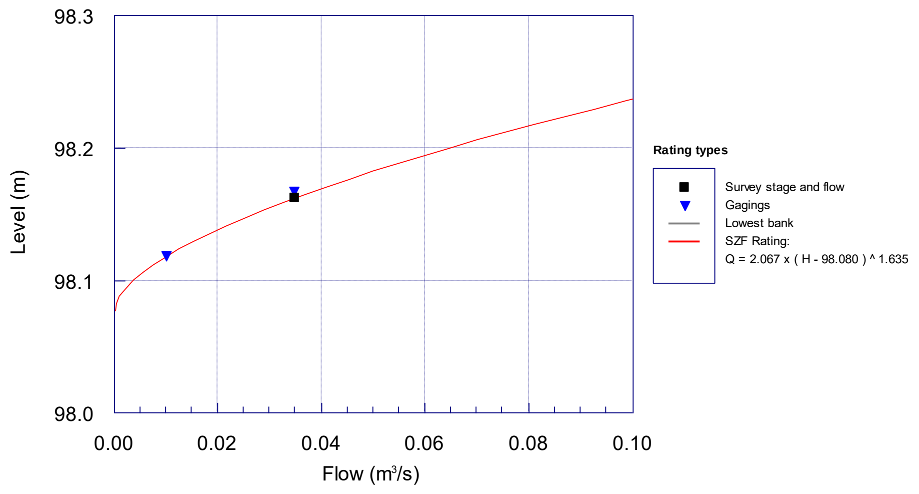
UPSTREAM **DOWNSTREAM**

23 June 2016, WSE = 98.221 m, Q = 0.035 m^3/s

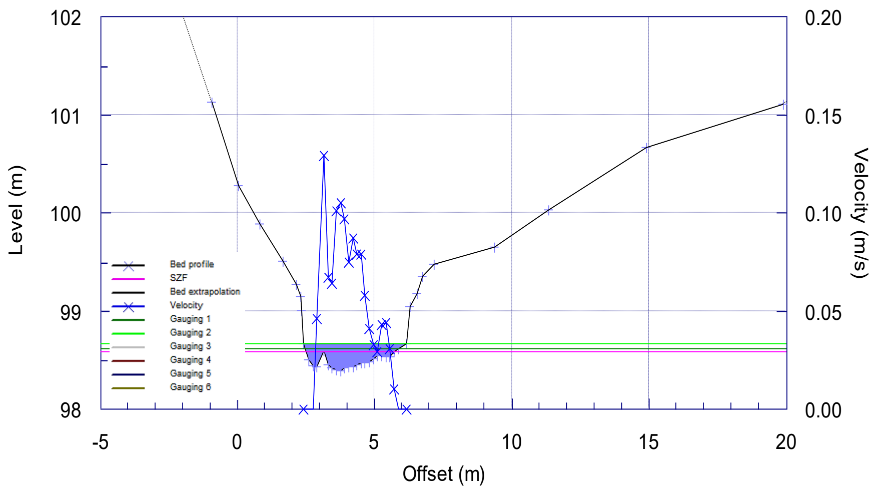
16 September 2016, WSE = 98.181 m, Q = 0.010 m^3/s

13 October 2016, WSE = 98.241 m, Q = 0.035 m^3/s

GOLD CREEK: XS GC-23
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

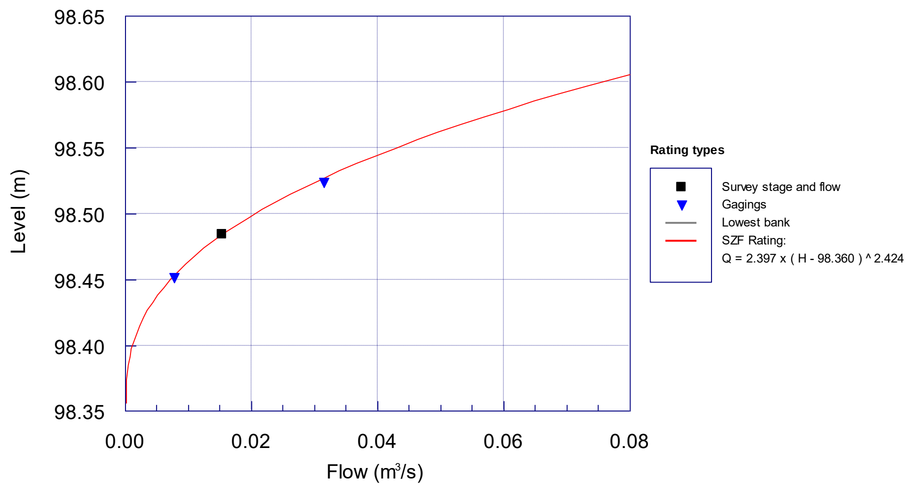
UPSTREAM **DOWNSTREAM**

23 June 2016, WSE = 98.162 m, Q = 0.035 m^3/s

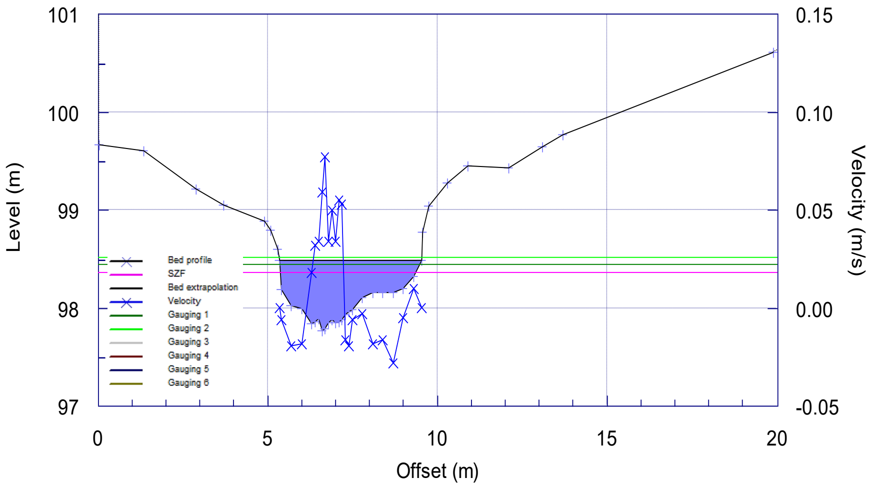
16 September 2016, WSE = 98.118 m, Q = 0.010 m^3/s

12 October 2016, WSE = 98.167 m, Q = 0.035 m^3/s

GOLD CREEK: XS GC-24
PRIMARY HABITAT UNIT: POOL

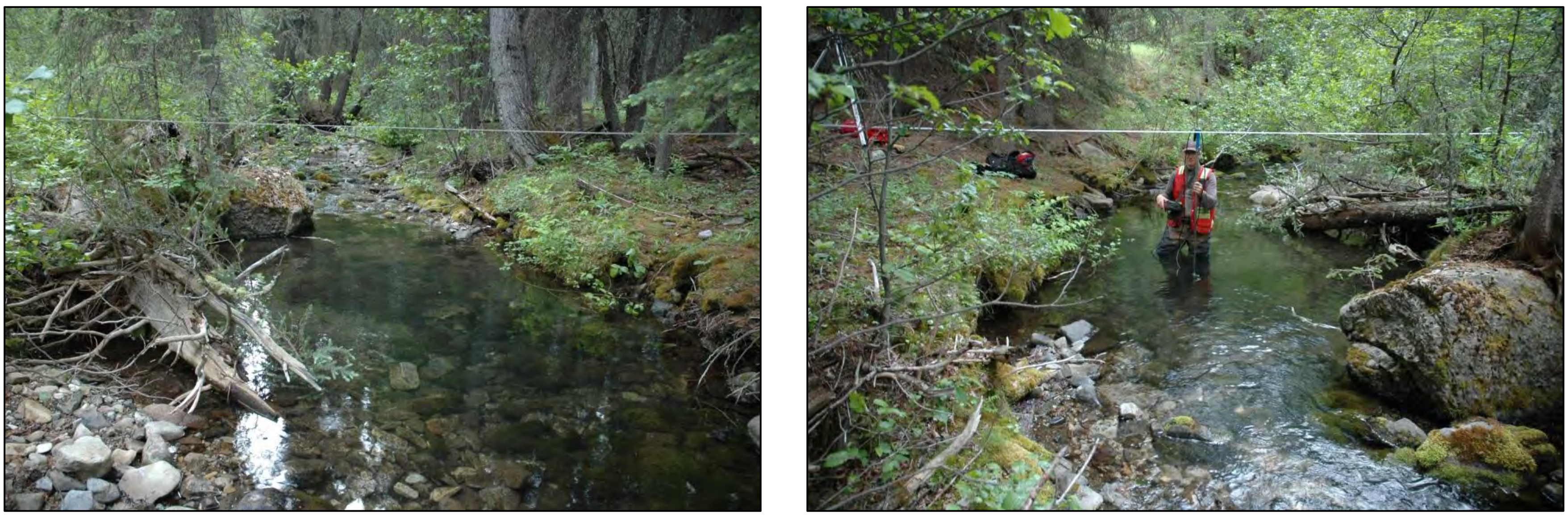


Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM DOWNSTREAM

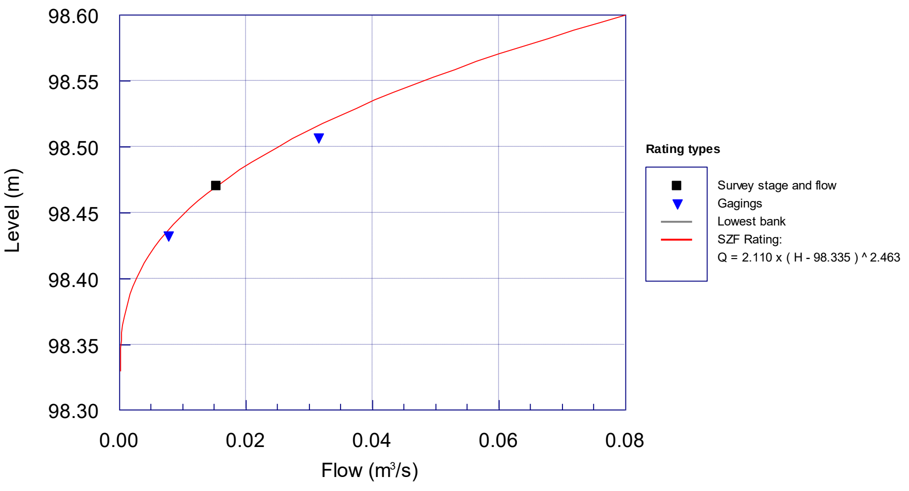


7 July 2016, WSE = 98.484 m, Q = 0.015 m^3/s

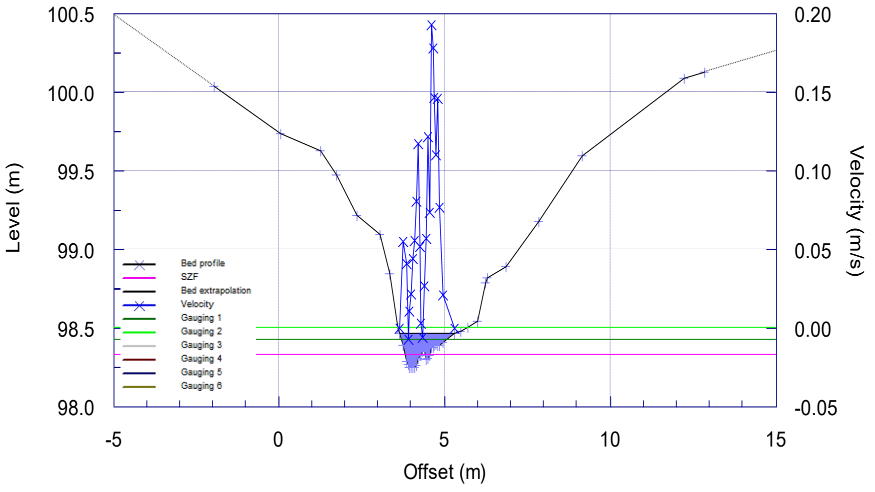
16 September 2016, WSE = 98.451 m, Q = 0.008 m^3/s

12 October 2016, WSE = 98.523 m, Q = 0.031 m^3/s

GOLD CREEK: XS GC-25
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

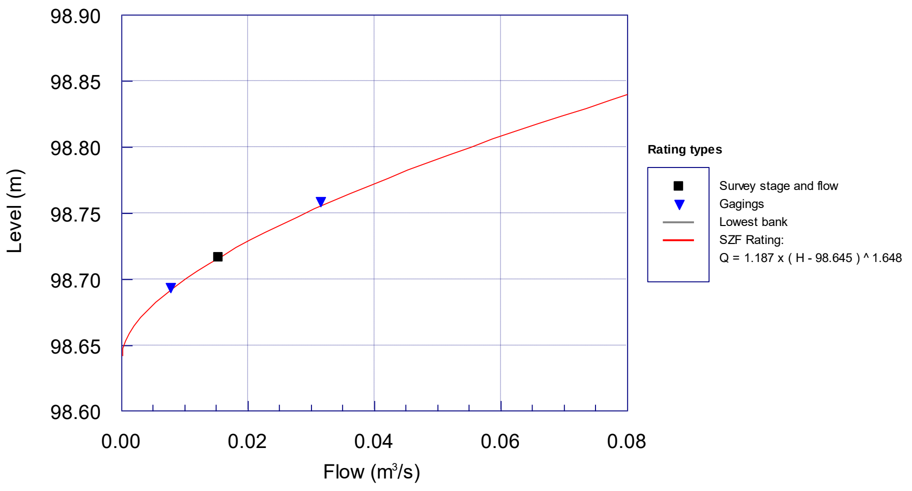
UPSTREAM **DOWNSTREAM**

7 July 2016, WSE = 98.470 m, Q = 0.015 m^3/s

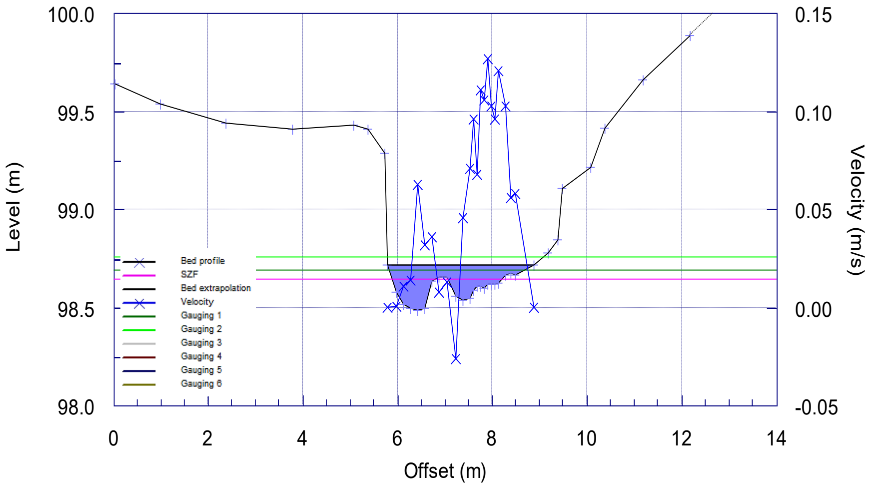
16 September 2016, WSE = 98.432 m, Q = 0.008 m^3/s

12 October 2016, WSE = 98.506 m, Q = 0.031 m^3/s

GOLD CREEK: XS GC-26
PRIMARY HABITAT UNIT: RUN



Rating Curve

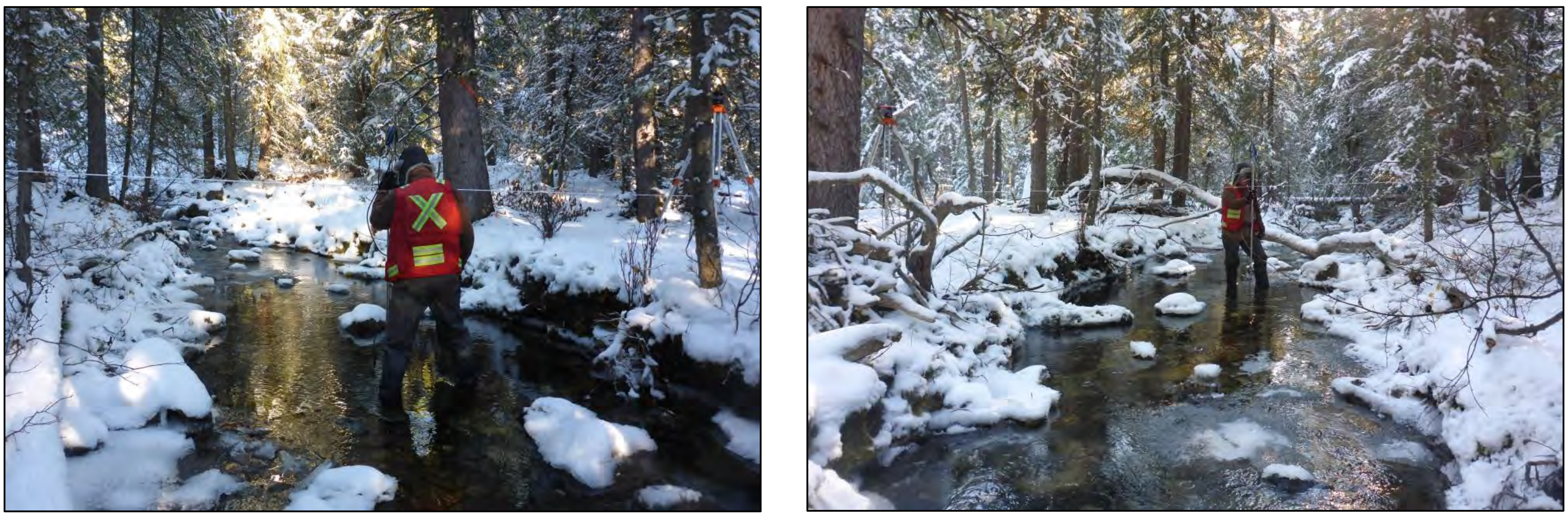


Survey Flow Depth/Velocity Profile

UPSTREAM **DOWNSTREAM**

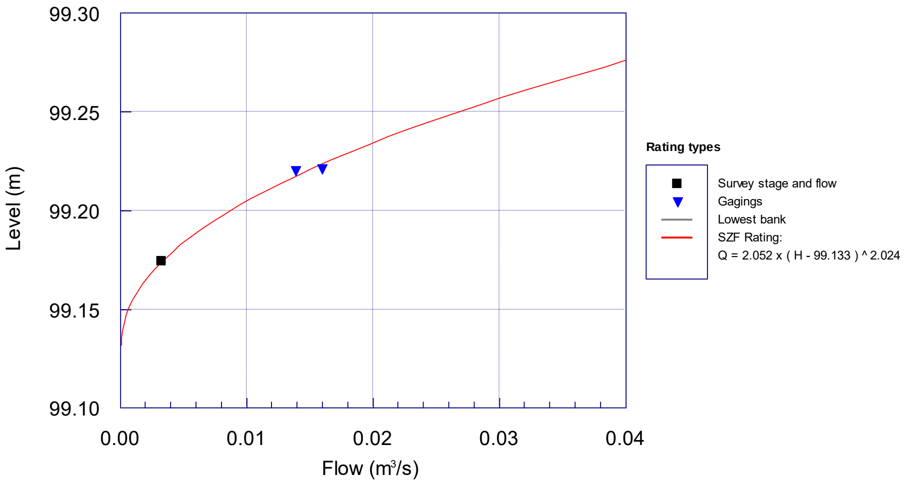
June July 2016, WSE = 98.716 m, Q = 0.015 m^3/s

September 2016, WSE = 98.693 m, Q = 0.008 m^3/s

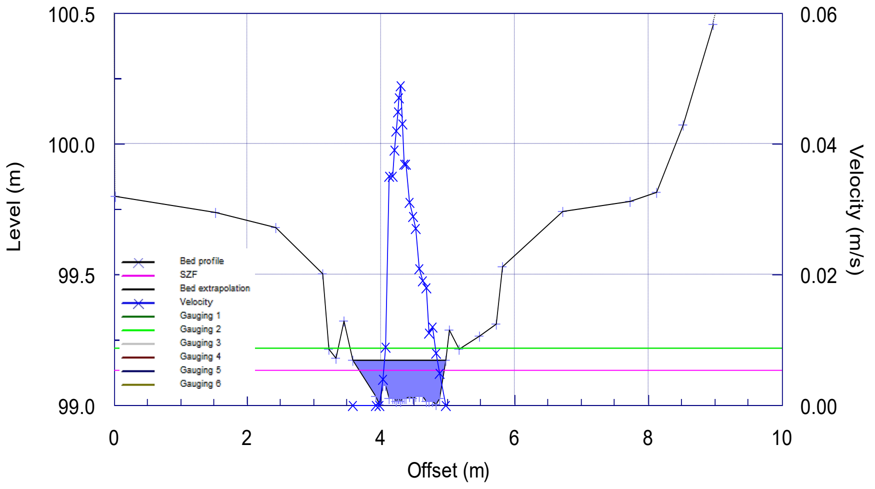


October 2016, WSE = 98.758 m, Q = 0.031 m^3/s

GOLD CREEK: XS GC-27 (HS-03)
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM **DOWNSTREAM**

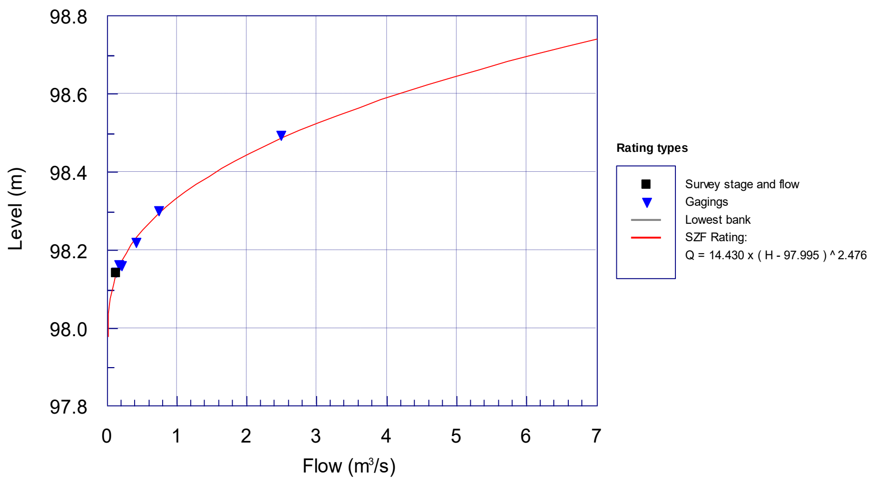
14 May 2016, WSE = 99.221 m, Q = 0.016 m^3/s

16 September 2016, WSE = 99.174 m, Q = 0.003 m^3/s

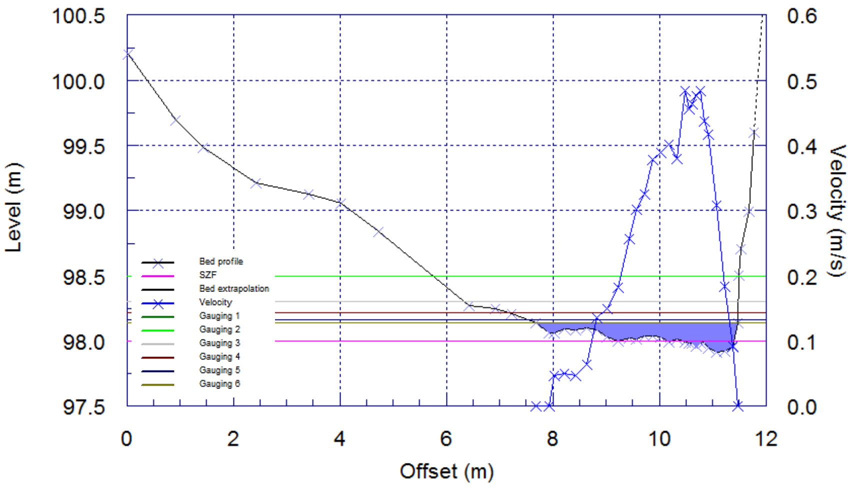
12 October 2016, WSE = 99.220 m, Q = 0.014 m^3/s

Blairmore Creek

BLAIRMORE CREEK: XS BC-0/H01
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM

DOWNSTREAM

22 March 2016, WSE = 98.132 m, Q = 0.082 m^3/s

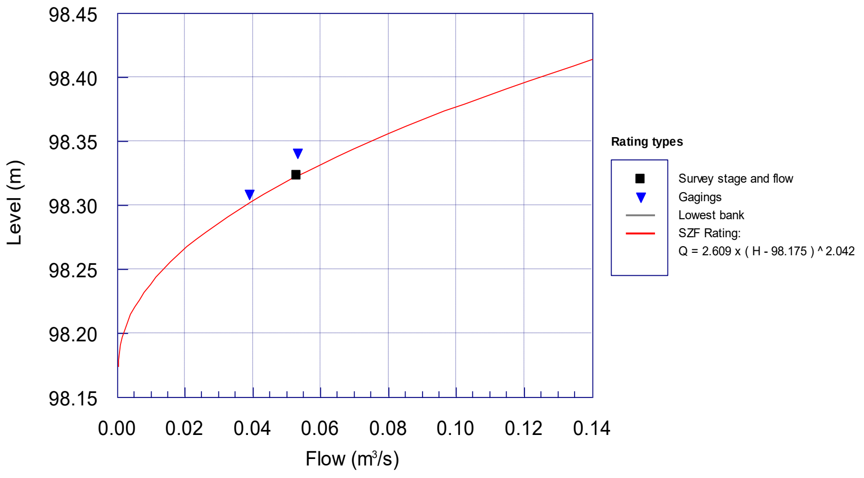
Not surveyed/photographed

Not surveyed/photographed

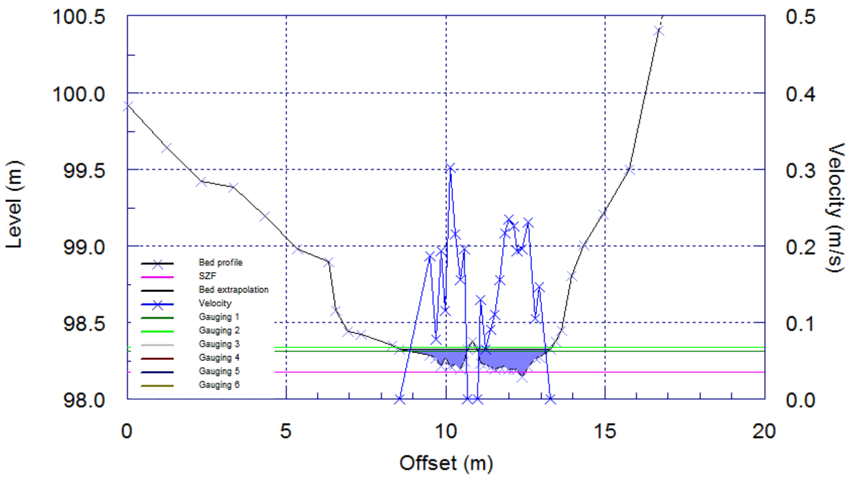
June/July/September 2016

19 October 2016, WSE = 98.140 m, Q = 0.121 m^3/s

BLAIRMORE CREEK: XS BC-1
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

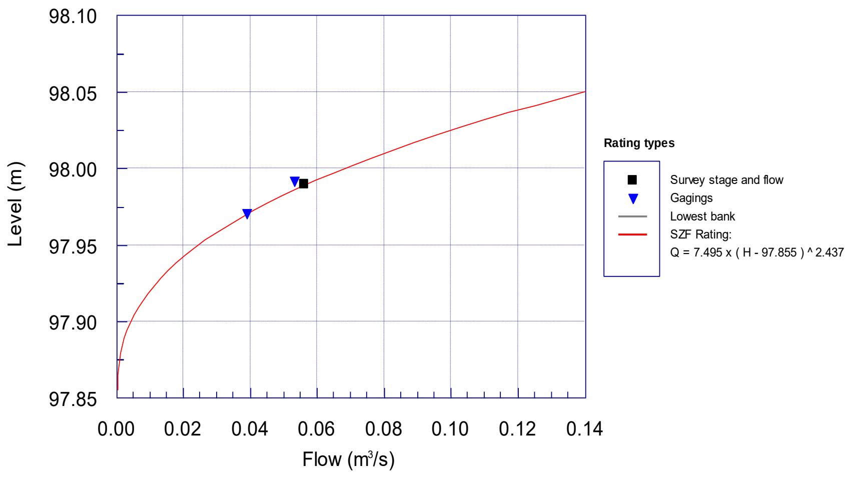
UPSTREAM **DOWNSTREAM**

5 July 2016, WSE = 98.323 m, Q = 0.053 m^3/s

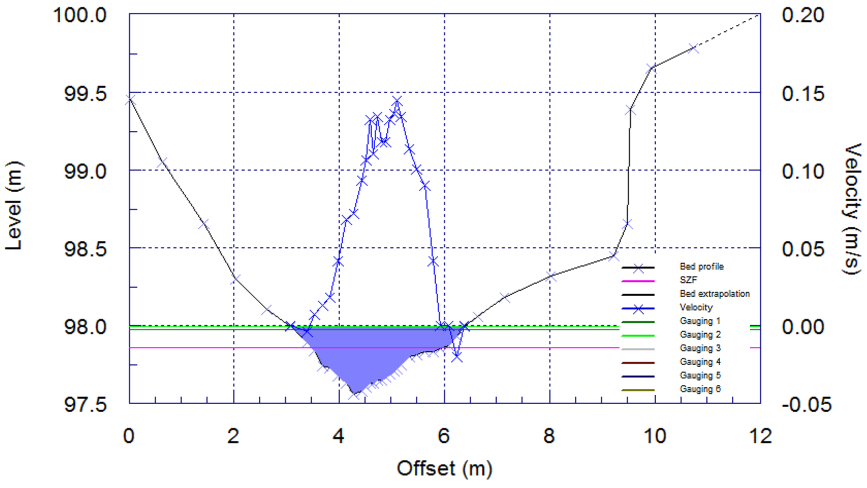
16 September 2016, WSE = 98.308 m, Q = 0.039 m^3/s

12 October 2016, WSE = 98.340 m, Q = 0.053 m^3/s

BLAIRMORE CREEK: XS BC-2
PRIMARY HABITAT UNIT: RUN/GLIDE



Rating Curve



Survey Flow Depth/Velocity Profile

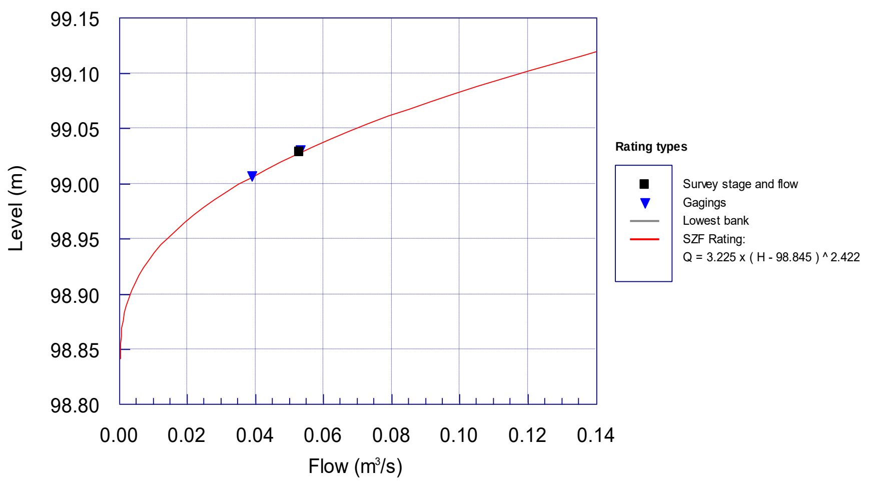
UPSTREAM **DOWNSTREAM**

7 July 2016, WSE = 97.989 m, Q = 0.056 m^3/s

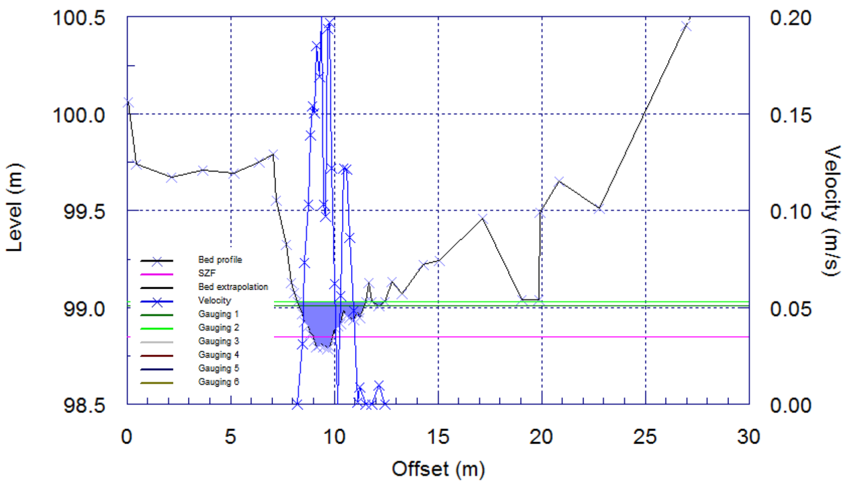
13 September 2016, WSE = 97.970 m, Q = 0.039 m^3/s

12 October 2016, WSE = 97.991 m, Q = 0.053 m^3/s

BLAIRMORE CREEK: XS BC-3
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM **DOWNSTREAM**

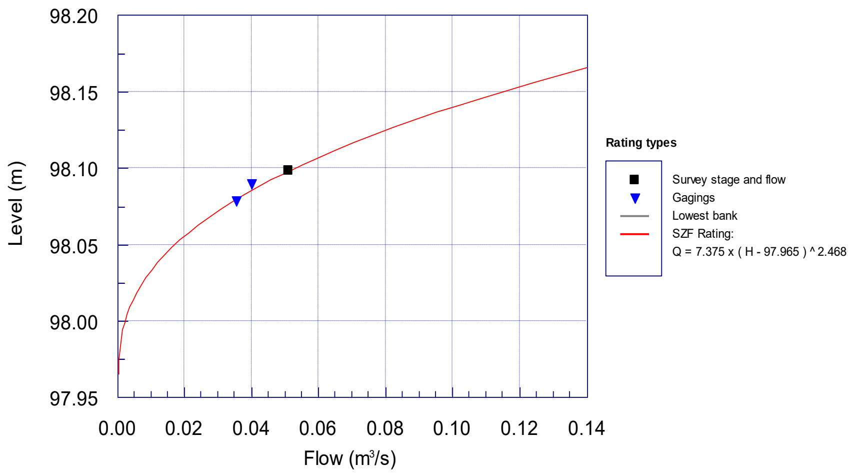
5 July 2016, WSE = 99.028 m, Q = 0.053 m^3/s

13 September 2016, WSE = 99.006 m, Q = 0.039 m^3/s

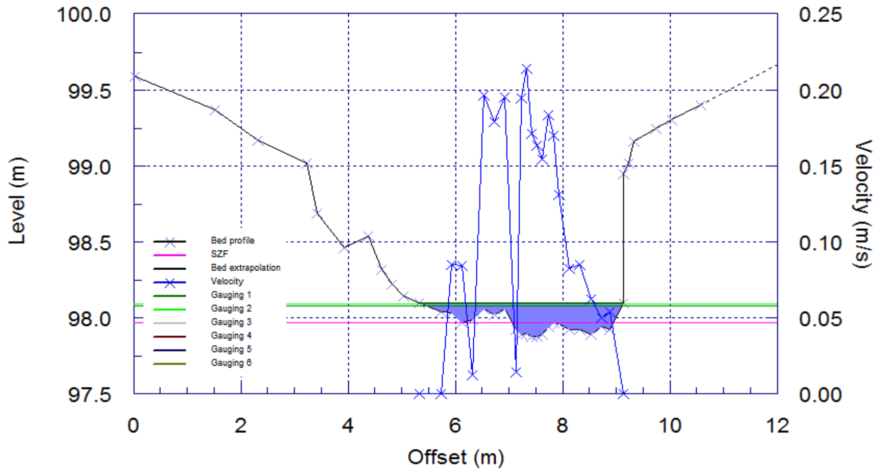
12 October 2016, WSE = 99.030 m, Q = 0.053 m^3/s

Previous View
Main Menu
TA and EIA Menu
Addendum Menu
Search

BLAIRMORE CREEK: XS BC-4
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

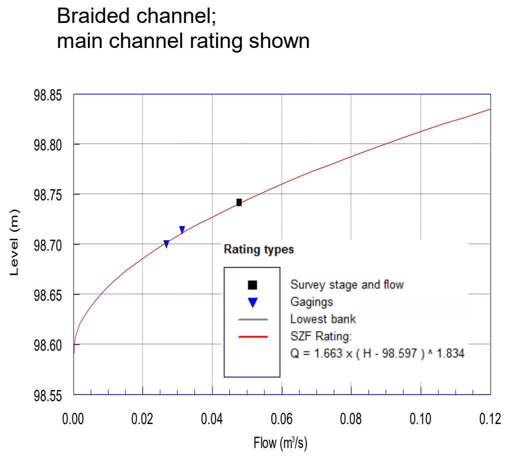
UPSTREAM **DOWNSTREAM**

5 July 2016, WSE = 98.098 m, Q = 0.051 m^3/s

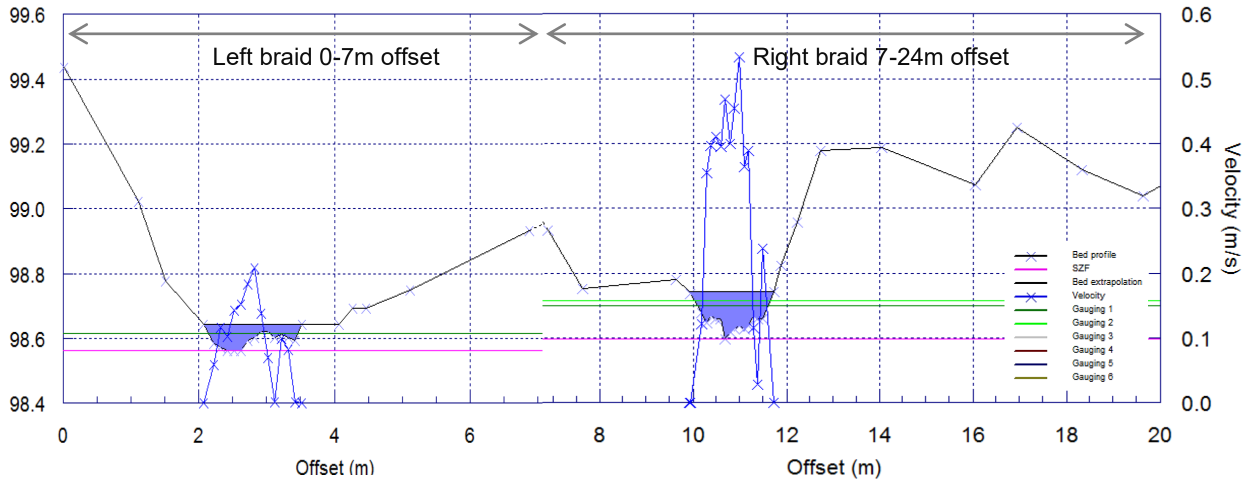
13 September 2016, WSE = 98.078 m, Q = 0.035 m^3/s

12 October 2016, WSE = 98.089 m, Q = 0.040 m^3/s

BLAIRMORE CREEK: XS BC-5
PRIMARY HABITAT UNIT: RIFFLE (BRAIDED)



Rating Curve

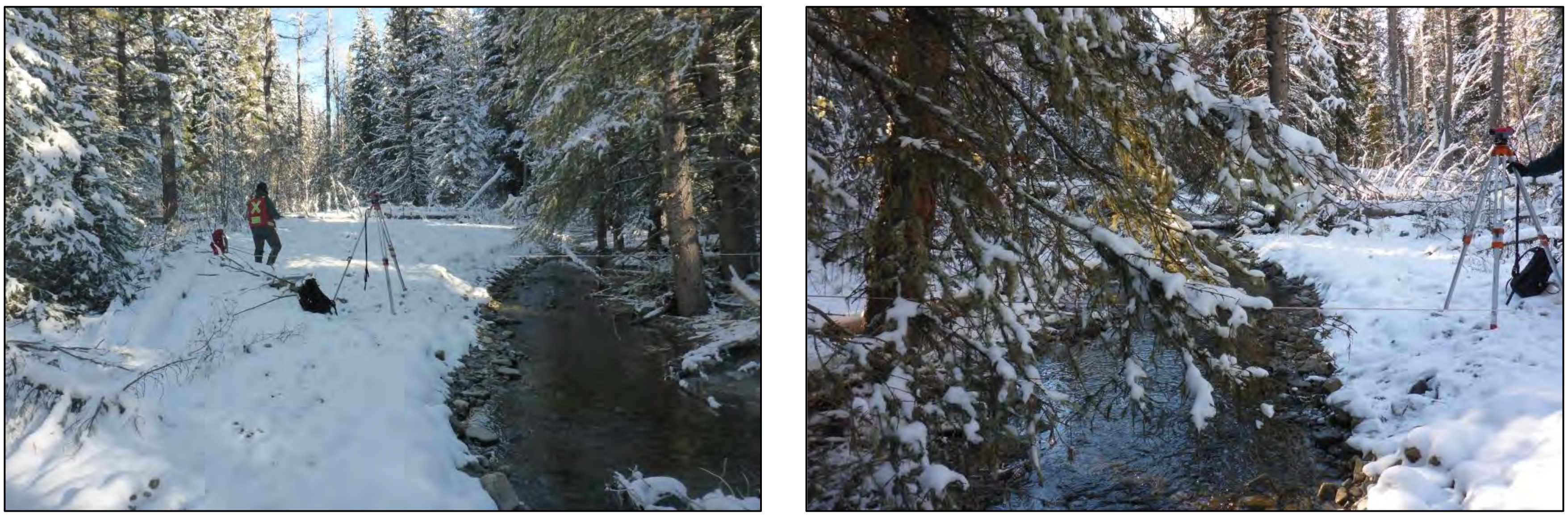


Survey Flow Depth/Velocity Profile

UPSTREAM (main channel; right-side) **DOWNSTREAM (main channel; right side)**

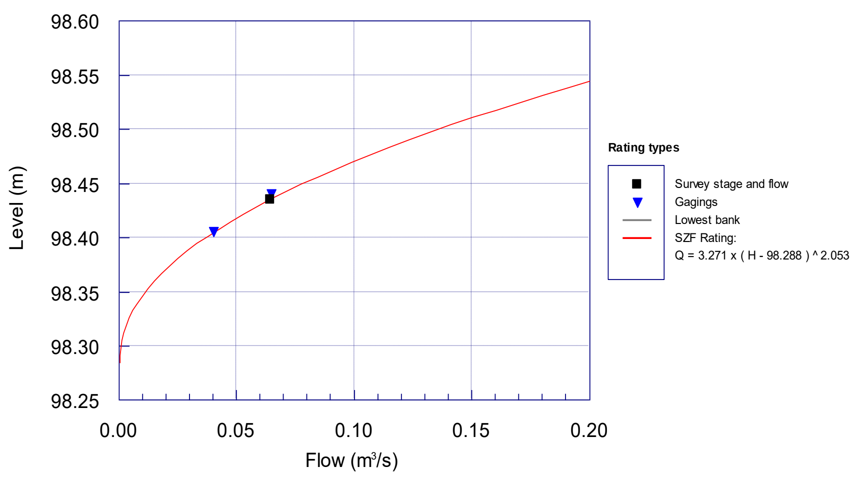
7 July 2016, WSE = 98.741 m, Q = 0.048 m^3/s

15 September 2016, WSE = 98.700 m, Q = 0.027 m^3/s

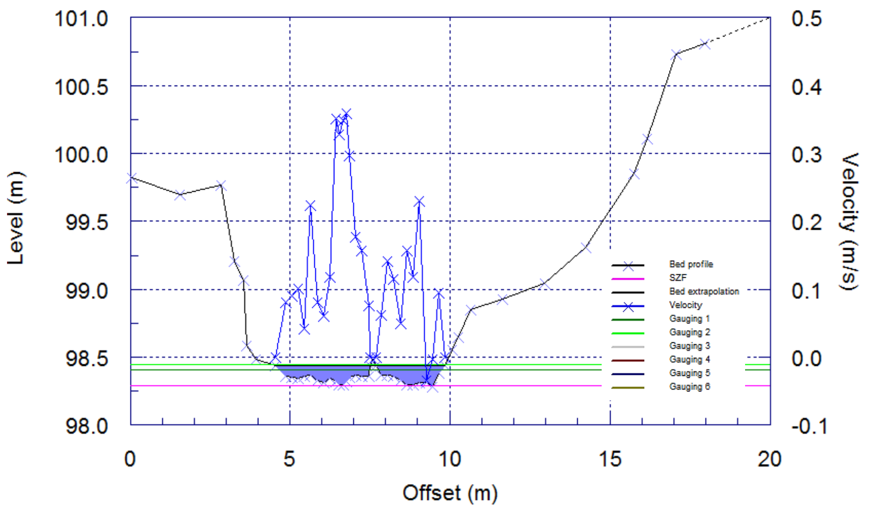


12 October 2016, WSE = 98.714 m, Q = 0.031 m^3/s

BLAIRMORE CREEK: XS BC-6
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

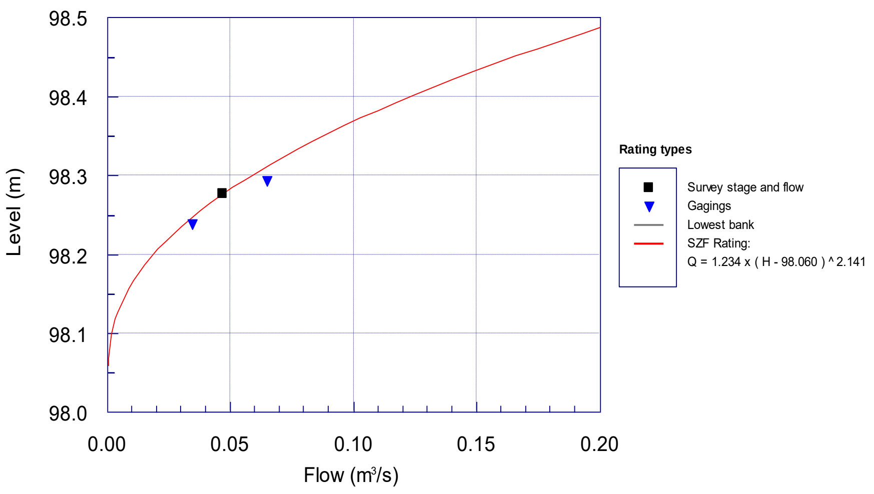
UPSTREAM **DOWNSTREAM**

6 July 2016, WSE = 98.435 m, Q = 0.064 m^3/s

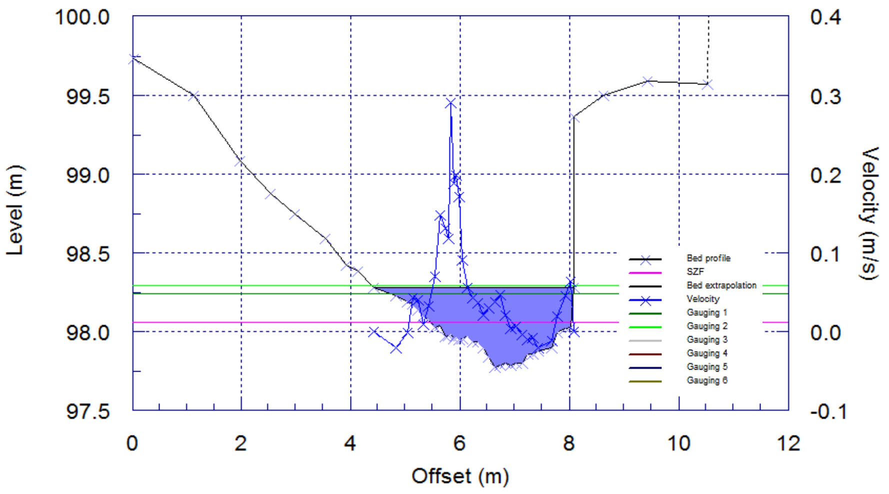
15 September 2016, WSE = 98.405 m, Q = 0.040 m^3/s

11 October 2016, WSE = 98.440 m, Q = 0.065 m^3/s

BLAIRMORE CREEK: XS BC-7
PRIMARY HABITAT UNIT: POOL



Rating Curve



Survey Flow Depth/Velocity Profile

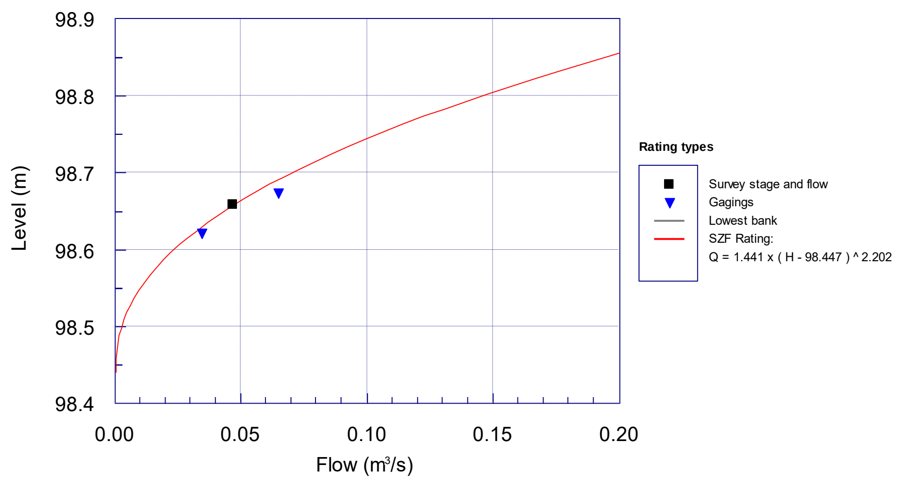
UPSTREAM **DOWNSTREAM**

7 July 2016, WSE = 98.276 m, Q = 0.046 m^3/s

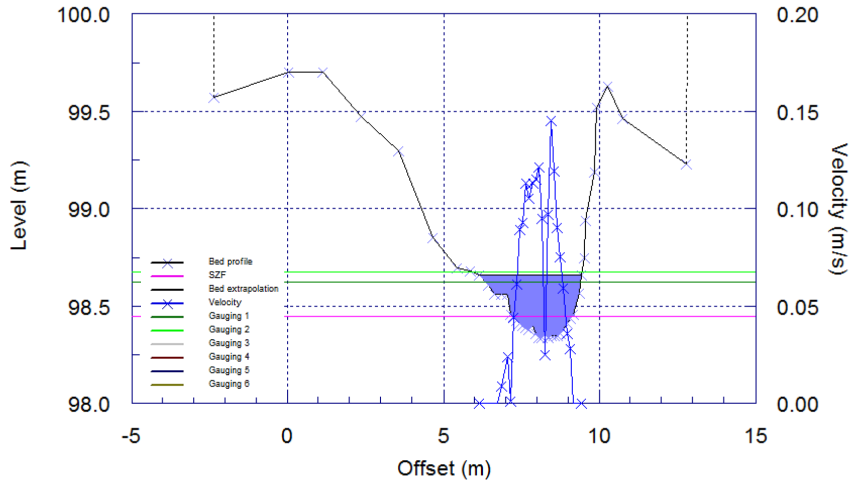
15 September 2016, WSE = 98.237 m, Q = 0.034 m^3/s

11 October 2016, WSE = 98.292 m, Q = 0.065 m^3/s

BLAIRMORE CREEK: XS BC-8
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

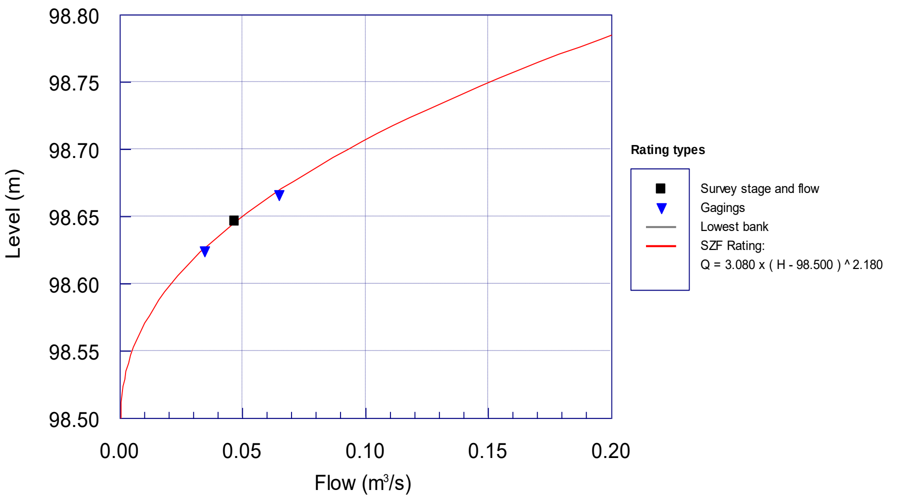
UPSTREAM **DOWNSTREAM**

6 July 2016, WSE = 98.657 m, Q = 0.046 m^3/s

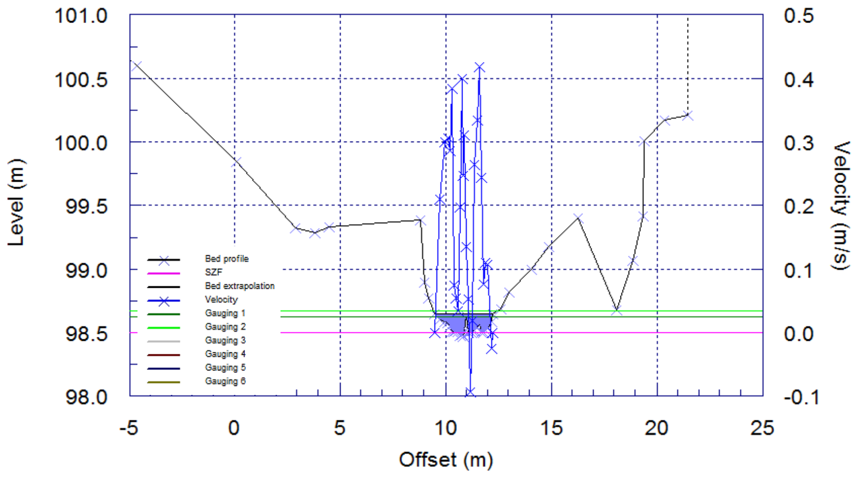
15 September 2016, WSE = 98.620 m, Q = 0.034 m^3/s

11 October 2016, WSE = 98.672 m, Q = 0.065 m^3/s

BLAIRMORE CREEK: XS BC-9
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM

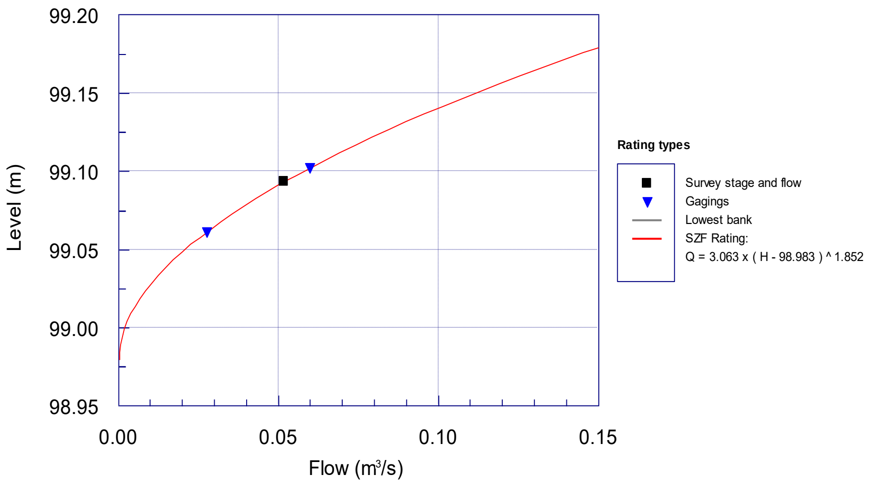
DOWNSTREAM

6 July 2016, WSE = 98.646 m, Q = 0.046 m³/s

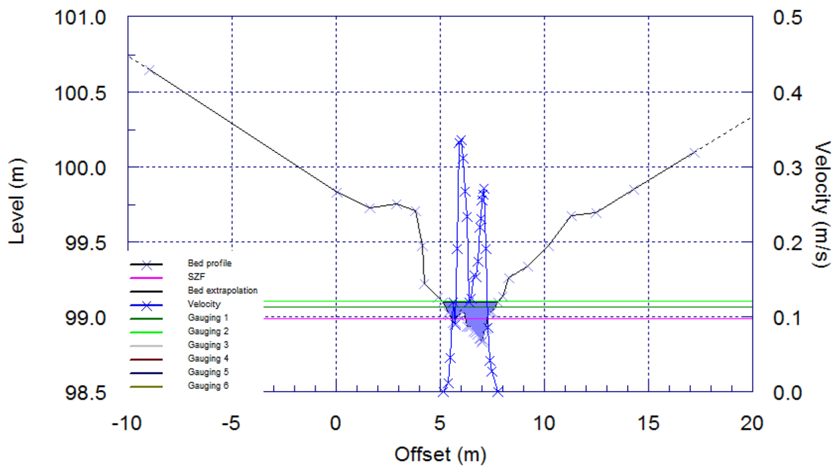
15 September 2016, WSE = 98.624 m, Q = 0.034 m³/s

11 October 2016, WSE = 98.666 m, Q = 0.065 m³/s

BLAIRMORE CREEK: XS BC-10
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM DOWNSTREAM

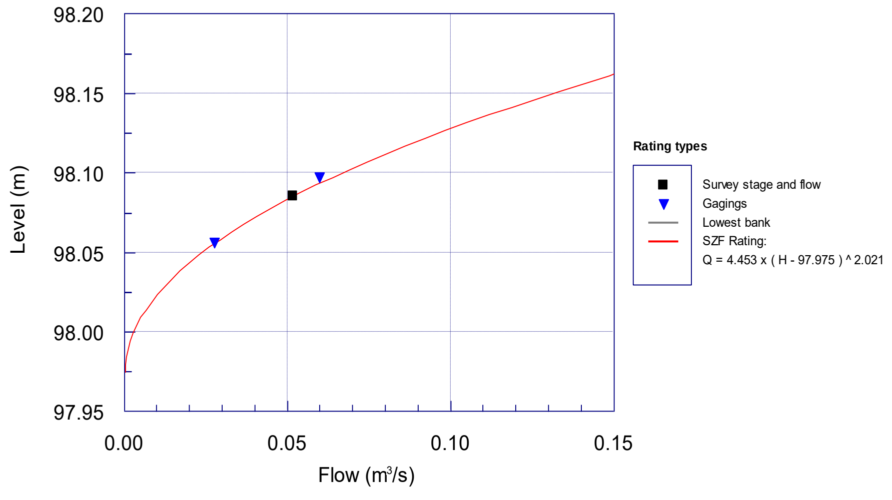
6 July 2016, WSE = 99.093 m, Q = 0.051 m^3/s

15 September 2016, WSE = 99.061 m, Q = 0.027 m^3/s

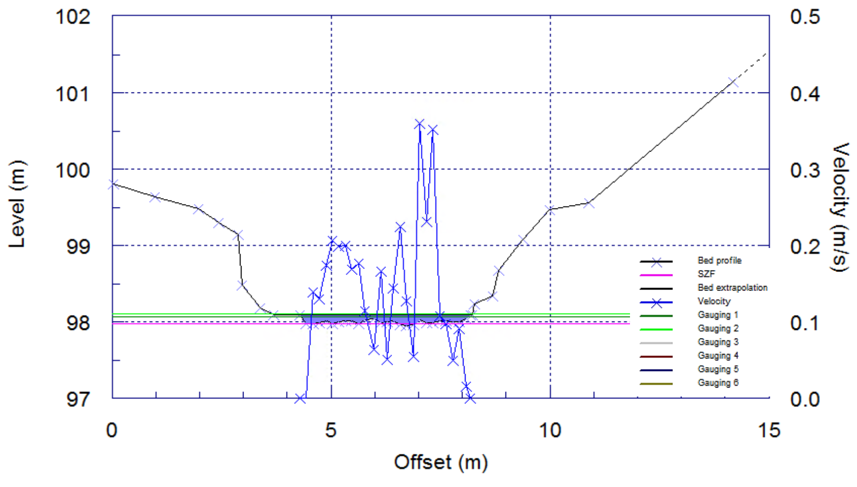
11 October 2016, WSE = 99.102 m, Q = 0.060 m^3/s

Previous View Main Menu TA and EIA Menu Addendum Menu Search

BLAIRMORE CREEK: XS BC-11
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

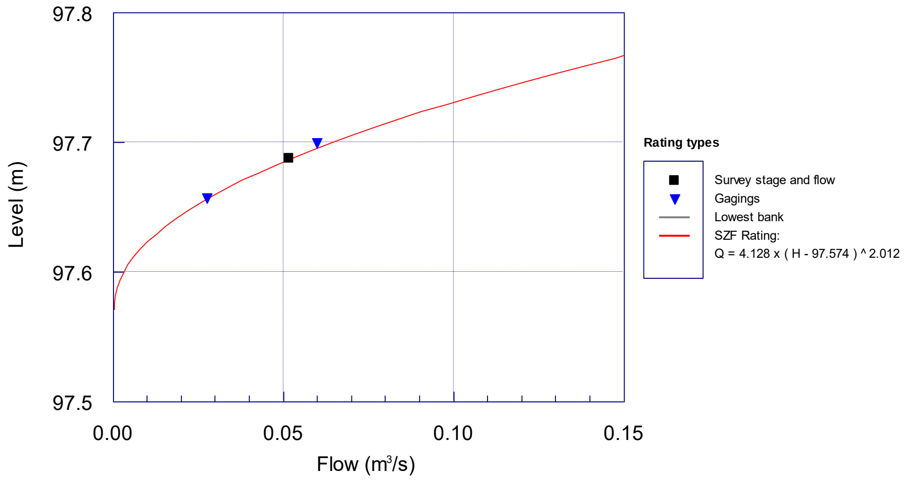
UPSTREAM **DOWNSTREAM**

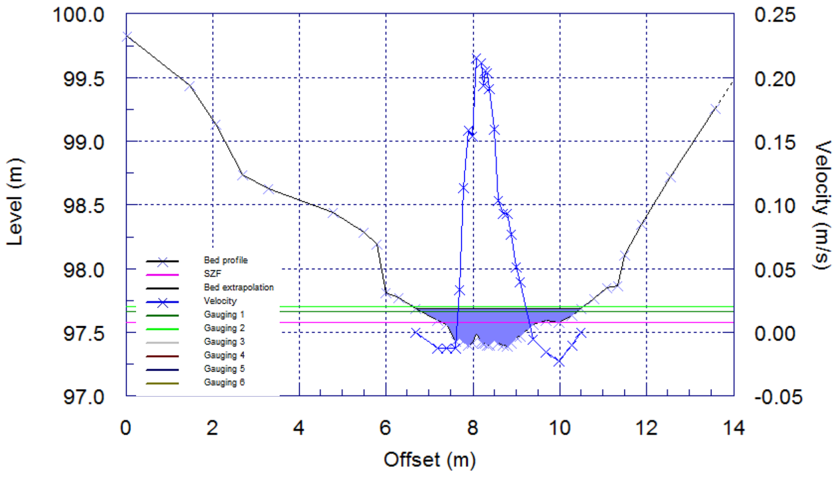
6 July 2016, WSE = 98.085 m, Q = 0.051 m^3/s

15 September 2016, WSE = 98.056 m, Q = 0.027 m^3/s

11 October 2016, WSE = 98.097 m, Q = 0.060 m^3/s

BLAIRMORE CREEK: XS BC-12
PRIMARY HABITAT UNIT: RUN





Rating Curve

Survey Flow Depth/Velocity Profile

UPSTREAM

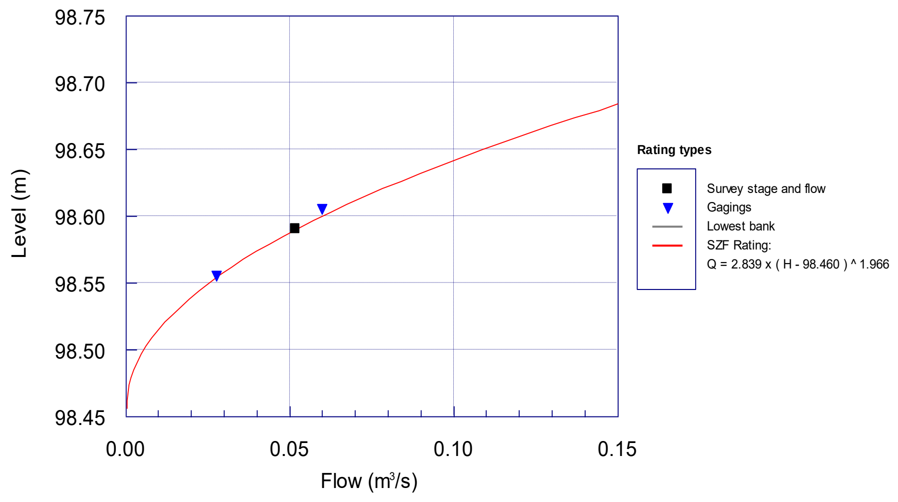
DOWNSTREAM

6 July 2016, WSE = 97.687 m, Q = 0.051 m^3/s

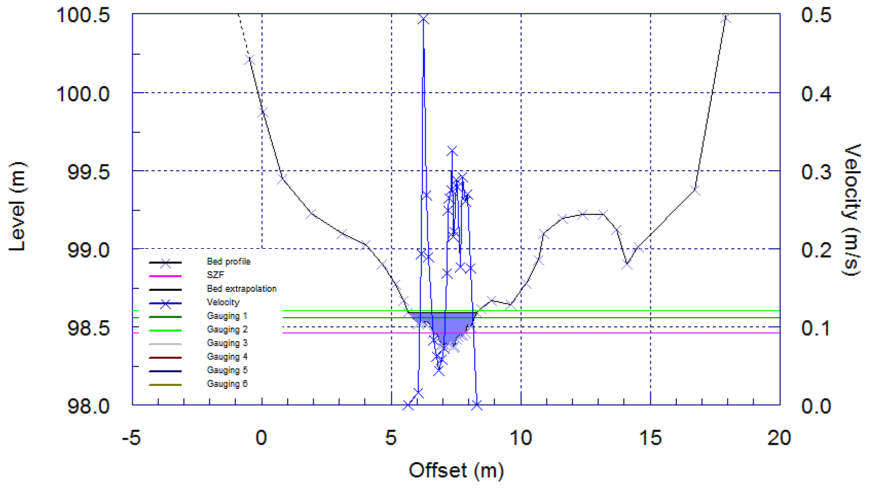
15 September 2016, WSE = 97.657 m, Q = 0.027 m^3/s

11 October 2016, WSE = 97.699 m, Q = 0.060 m^3/s

BLAIRMORE CREEK: XS BC-13
PRIMARY HABITAT UNIT: RIFFLE



Rating Curve



Survey Flow Depth/Velocity Profile

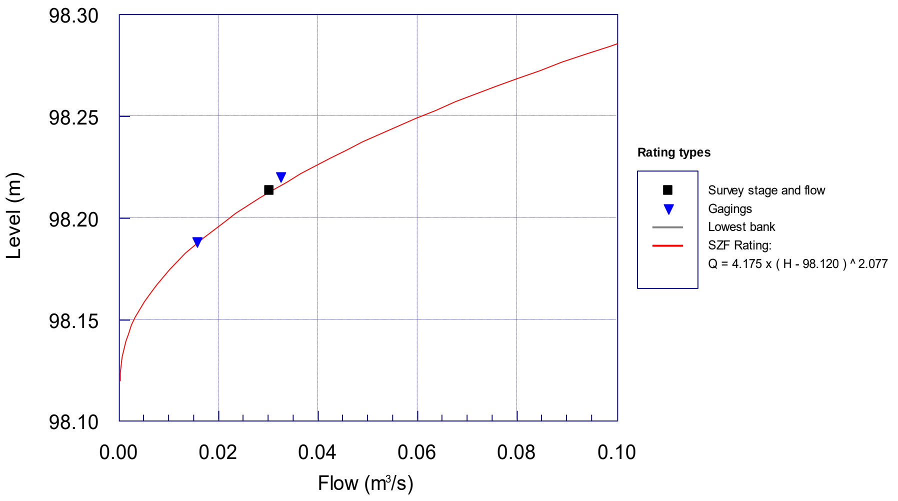
UPSTREAM **DOWNSTREAM**

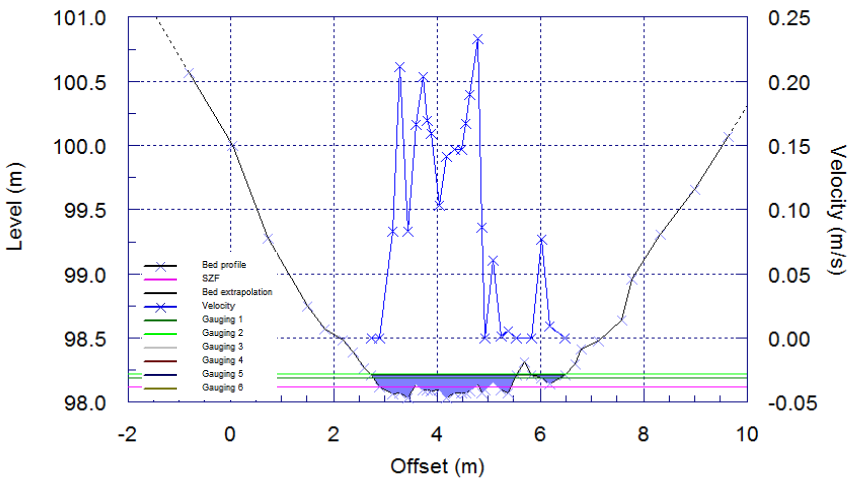
5 July 2016, WSE = 98.590 m, Q = 0.051 m³/s

15 September 2016, WSE = 98.555 m, Q = 0.027 m³/s

11 October 2016, WSE = 98.605 m, Q = 0.060 m³/s

BLAIRMORE CREEK: XS BC-14
PRIMARY HABITAT UNIT: RIFFLE





Rating Curve **Survey Flow Depth/Velocity Profile**

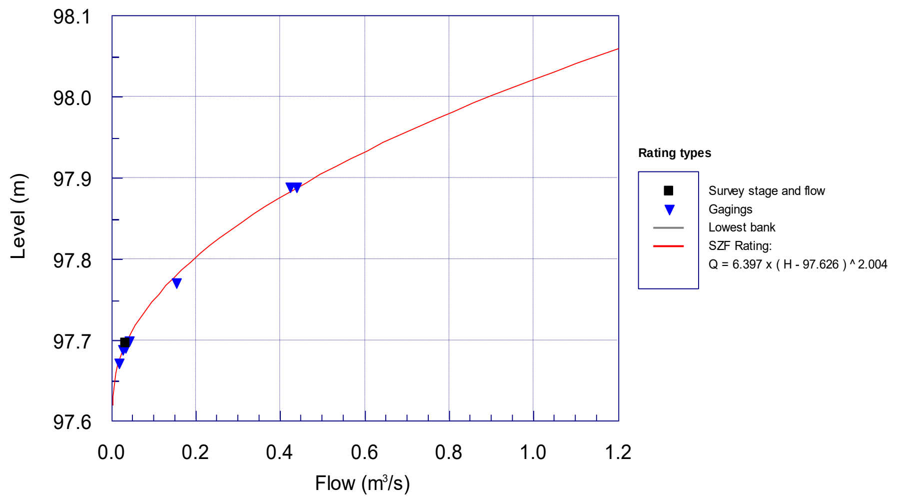
UPSTREAM **DOWNSTREAM**

5 July 2016, WSE = 98.213 m, Q = 0.030 m^3/s

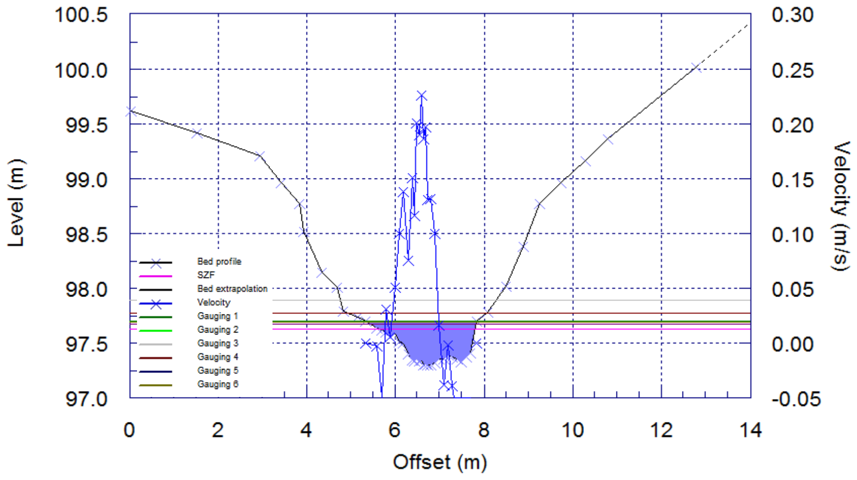
15 September 2016, WSE = 98.188 m, Q = 0.016 m^3/s

11 October 2016, WSE = 98.220 m, Q = 0.032 m^3/s

BLAIRMORE CREEK: XS BC-15/H03
PRIMARY HABITAT UNIT: RUN



Rating Curve



Survey Flow Depth/Velocity Profile

UPSTREAM **DOWNSTREAM**

5 July 2016, WSE = 97.689 m, Q = 0.030 m^3/s

15 September 2016, WSE = 97.687 m, Q = 0.024 m^3/s

11 October 2016, WSE = 97.671 m, Q = 0.016 m^3/s

Appendix A3

WSCT HSC Selection Memo

Hatfield
CONSULTANTS

MEMO

Date: December 6, 2016 HCP Ref No.: MEMS7779

From: Cory Bettles, MSc, RPBio, FP-C

To: Mike Bartlett (MEMS)

Subject: Candidate List and Selection of Westslope Cutthroat Trout Habitat Suitability Criteria (HSC) Curves

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Mike,

This memo has been prepared in response to commentary received from the Alberta Energy Regulator (AER) and Fisheries and Oceans Canada (DFO) requesting the rationale applied in the selection of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) habitat suitability criteria (HSC) curves for use in the Grassy Mountain Coal Project Instream Flow Needs (IFN) Assessment. Below is a brief summary of the steps exercised in the evaluation and selection of the preferred HSC curves:

- Westslope Cutthroat Trout (WSCT) were confirmed as the target fish species for the IFN given their presence and distribution throughout both Gold Creek and Blairmore Creek in the aquatic local study area (LSA) as well as their federal at-risk and provincial conservation designations.
- HSC literature sources specific to WSCT were identified and HSC curves for key life stages/life-history function (e.g., spawning/incubation, fry rearing, juvenile rearing, adult rearing/holding, overwintering) were compiled for comparison.
- The literature HSC curves were evaluated based on how they were generated by the authors (e.g., use of data from multiple cutthroat trout sub-species, use of only WSCT data, the geographic location of watercourses used in the development/refinement of HSC curves, the amount of data used to build the HSC curves, size and physical habitat characteristics of watercourse(s) used in developing/refining HSCs, professional peer review).
- Coarse validation of HSCs using field data collected from the target watercourses (e.g., snorkel data during spawning/overwintering/rearing surveys, evaluation of local hydrometric data during the WSCT spawning window etc.).

Attachment 1 provides a compilation of all the literature HSCs (for depth, velocity, substrate) generated for WSCT. A detailed reference list is provided, below. HSC curves were assembled from Washington Department of Fish and Wildlife (WDFW), British Columbia Ministry of Environment (BC MoE), Teck Coal Limited's Fording River Operations Swift Project Environmental Assessment (Golder 2012), and Teck Coal Limited's Line Creek Operations Phase II (Golder 2011).

While the curves from WDFW are shown, they include data from other sub-species of cutthroat trout (e.g., Coastal Cutthroat Trout), thus, are not considered as appropriate for this Project. Focus was placed on the HSC curves developed by BC MoE (2014) and Golder (2011, 2012) for key life stages/life-history functions.

Golder (2012) developed proposed (blue; presented in the attached) and final (green; presented HSC curves that underwent multiple peer reviews and were refined in a system relatively close geographically to the proposed Grassy Mountain Coal Project. Golder (2012) proposed HSC curves (blue curves) were initially vetted through the BC MoE Instream Flow Specialist (Ron Ptolemy) and further re-evaluated through a fish sub-committee (created as part of the Fording River Operations EA), which was comprised of individuals from provincial and federal governments, First Nations, and fisheries consultants. Through the sub-committee, the HSCs were refined to develop final (green curves) specific to the Fording River system. Finally, each blue and green curve was evaluated crudely using local data (e.g., hydrological, fish) collected for the Grassy Mountain Project.

Golder (2011) also developed HSC curves specific for overwintering. They were considered given the close geographic extent to this project. No other curves were considered as suitable.

The resultant HSCs were the following:

1. **Spawning/Incubation**

    - Depth HSC: Golder (2012) 'Final' (Green Curve) was selected.
    - Velocity HSC: Golder (2012) 'Proposed' (Blue Curve) was selected.
    - Substrate HSC: Golder (2012) 'Final' (Green Bars) was selected.

    Rationale: The proposed depth (blue curve) HSC remained unchanged post-evaluation from the Fording River fish sub-committee (green curve). We believe the selected HSC provides a conservative range of depth preference based on observations made during this project's WSCT spawning surveys and is relatively aligned with literature for Alberta populations of WSCT (e.g., DFO 2014). The proposed (blue curve) and final (green curve) velocity HSC were evaluated against local hydrology data from Gold Creek, fish spawning data collected during the WSCT spawning window (May, June 2016) for both Gold and Blairmore creeks, and spawning velocity preferences for Alberta WSCT (e.g., DFO 2014). Local hydrology information from Gold Creek was used as a surrogate for Blairmore Creek. We evaluated hydrometric data from locations within Gold Creek and found that velocities between May and August 2016 ranged between 0.08 m/s and 0.3 m/s in upper Gold Creek (above the Caudron Creek confluence, an important tributary to the Gold Creek watershed) and 0.1 m/s and 0.5 m/s in lower-/mid Gold Creek (below the Caudron Creek confluence). Further, we observed spawning throughout several reaches in both Gold and Blairmore creeks. Given the line of evidence, the proposed (blue curve) HSC is more appropriate for WSCT spawning in both Gold Creek and Blairmore Creek systems. The spawning substrate HSC from Golder (2012) matches that proposed by WDFW (2016), thus we have adopted this suitability criteria.

2. **Fry Rearing**

    - Depth HSC: Golder (2012) 'Final' (Green Curve) was selected.
    - Velocity HSC: Golder (2012) 'Final' (Green Curve) was selected.
    - Substrate HSC: Golder (2012) 'Final' (Green Curve) was selected.

Rationale: The final depth (green) HSC (Golder (2012) better reflects the local conditions of both Gold and Blairmore creeks compared to the proposed (blue) HSC and the HSC from BC MoE. Similar to the depth HSC, the final velocity HSC from Golder (2012) is conservative and appears to reasonably associate with observed field conditions. The Golder (2012) final (green) substrate HSC was selected given its suitability appears to better reflect the species life-stage requirements.

3. Juvenile Rearing

- Depth HSC: Golder (2012) 'Final' (Green Curve) was selected.
- Velocity HSC: Golder (2012) 'Final' (Green Curve) was selected.
- Substrate HSC: Golder (2012) 'Final' (Green Curve) was selected.

Rationale: The final depth (green) HSC (Golder (2012) better reflects the local conditions of both Gold and Blairmore creeks compared to the proposed (blue) HSC as well as the HSC from BC MoE (Ptolemy 2014). Similar to the depth HSC, the final velocity HSC from Golder (2012) is conservative and associates with observed field conditions. The Golder (2012) final (green) substrate HSC is aligned with other literature sources and is consistent with the WSCT life-stage requirements.

4. Adult Rearing/Holding

- Depth HSC: Golder (2012) 'Final' (Green Curve) was selected.
- Velocity HSC: Golder (2012) 'Final' (Green Curve) was selected.
- Substrate HSC: Golder (2012) 'Final' (Green Curve) was selected.

Rationale: The final depth (green) HSC (Golder 2012) is conservative and tends to associate with observations of habitat use in Gold and Blairmore creeks compared to the proposed (blue) HSC curve. Similar to the depth HSC, the final velocity HSC from Golder (2012) is conservative thus was selected to account for any habitat/flow variabilities between Gold and Blairmore creeks. The Golder (2012) final (green) substrate HSC was selected given its suitability appears to better reflect the species life-stage requirements.

5. Overwintering

- Depth HSC: Golder (2011) Curve was selected.
- Velocity HSC: Golder (2011) Curve was selected.
- Substrate HSC: Golder (2012) 'Final' (Green Curve) was selected.

Rationale: The Golder (2011) depth HSC curve was selected given the multiple data sources that were used to generate the suitability prior to use with Teck's Line Creek Operations Phase II project. The Golder (2011) velocity HSC curve appears to reflect local conditions of both Gold and Blairmore creeks. The Golder (2012) final (green) substrate HSC was selected given the range of suitability appears to reflect the species life-stage requirements.

Of note, I have not included discussion around the selection of the drift invertebrate HSC curves as, to my knowledge, only one set of depth and velocity curves exist (Ptolemy 2001) and will be presented in the Instream Flow Needs Assessment.

If there are any questions or concerns with respect to the selection of HSC curves for application in the Grassy Mountain Instream Flow Needs Assessment, they can be directed to myself for consideration and/or response.

Regards,

Cory Bettles, MSc, RPBio, FP-C
Fisheries and Aquatics Manager

Encl. **Attachment 1**

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Fisheries and Oceans Canada. 2014. Recovery Strategy for the Alberta populations of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) in Canada [Final]. *Species at Risk Act* Recovery Strategy Series. Fisheries and Oceans Canada, Ottawa. iv + 28 pp + Appendices.

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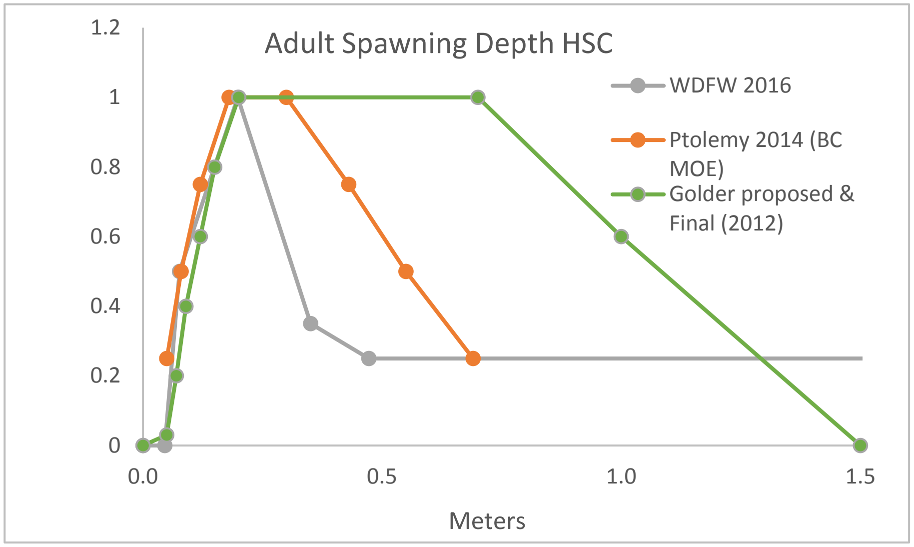
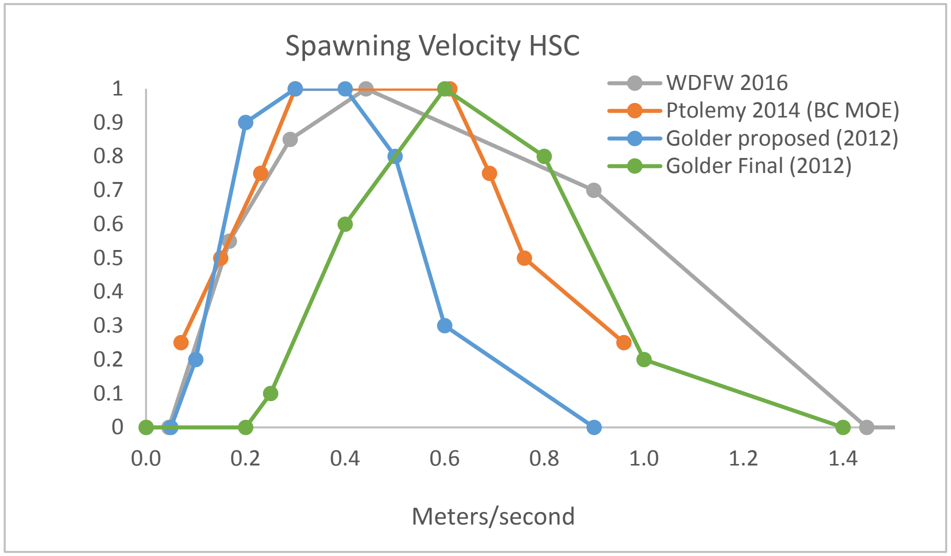
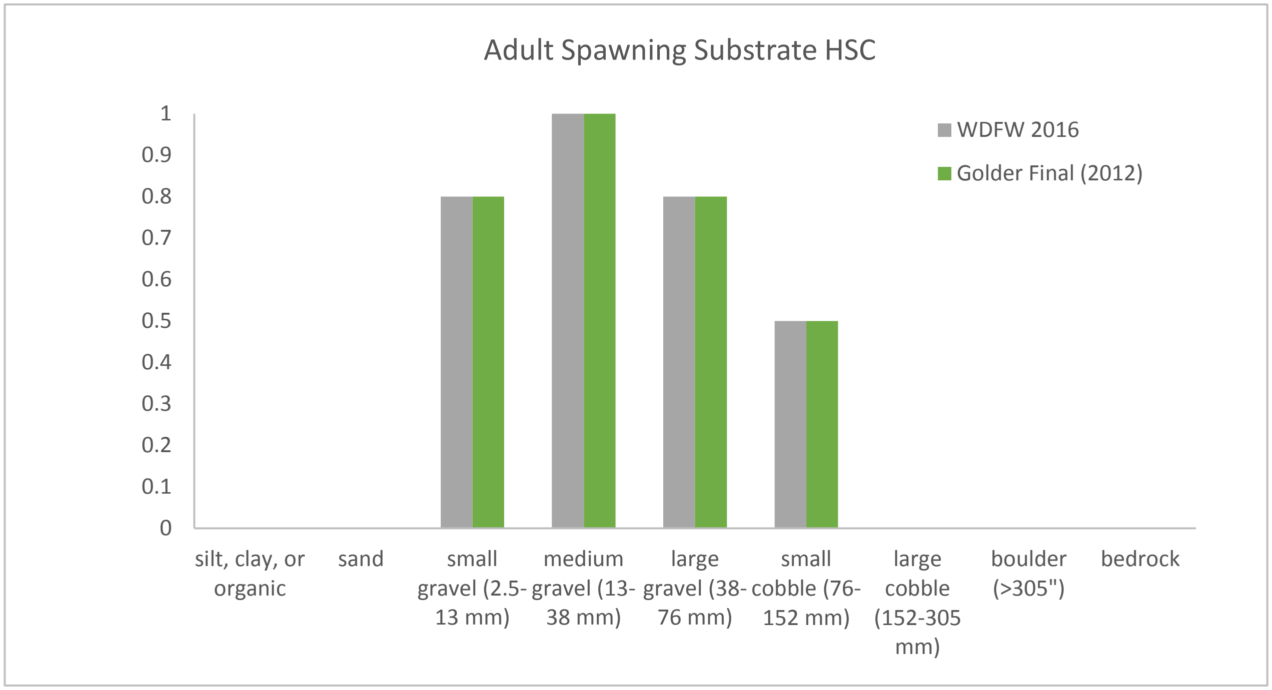
Ptolemy, R. 2001. HSI curves for benthic invertebrates. BC Ministry of Environment.

WDFW. 2004. Instream Flow Study Guidelines: Technical and habitat suitability issues including fish preference curves. Included updated versions 2008, 2013, 2016.

WSCT Spawning Habitat Suitability Criteria Curves







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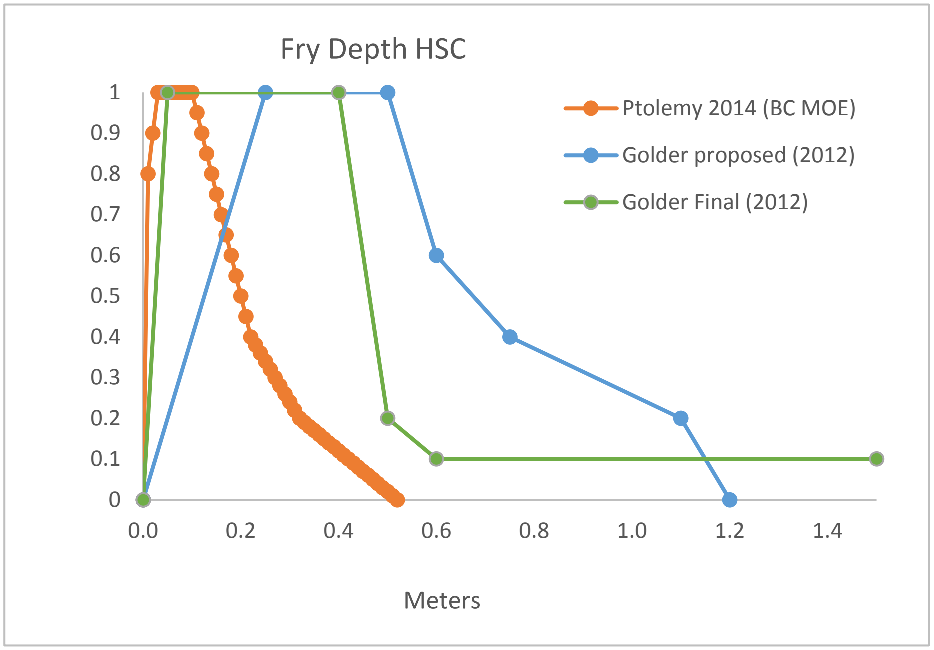
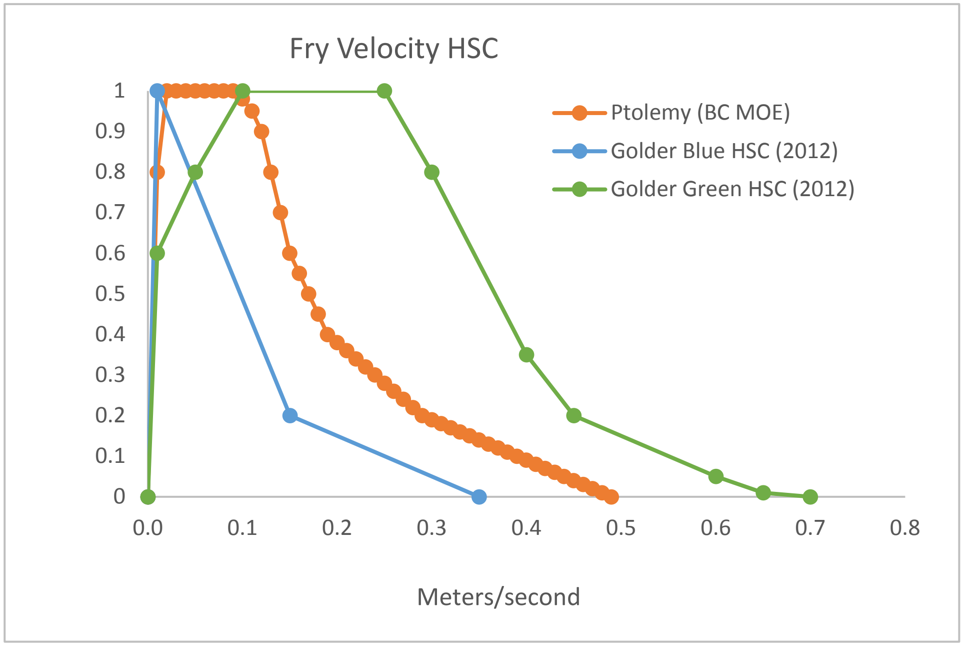
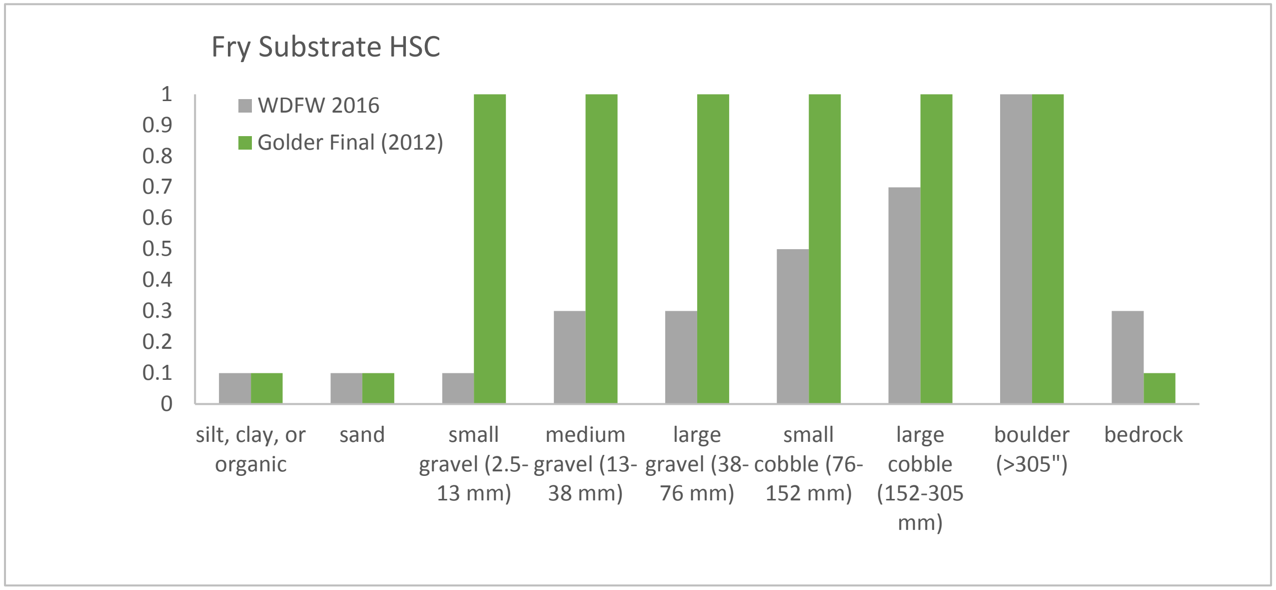
WSCT Fry (Rearing) Habitat Suitability Criteria Curves







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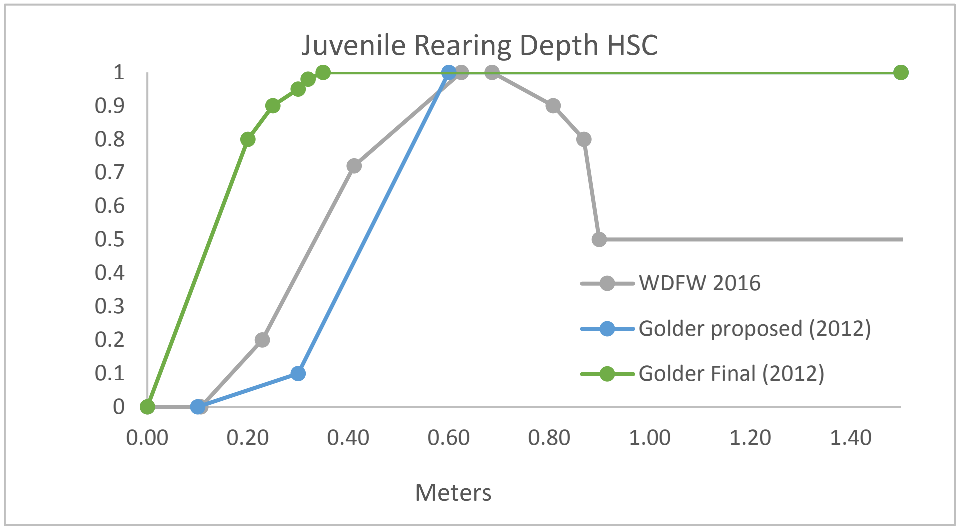
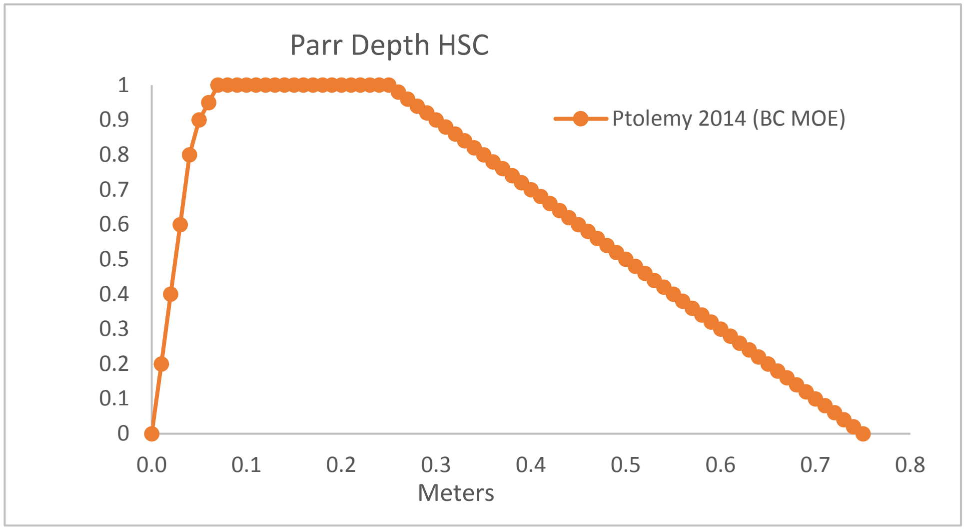
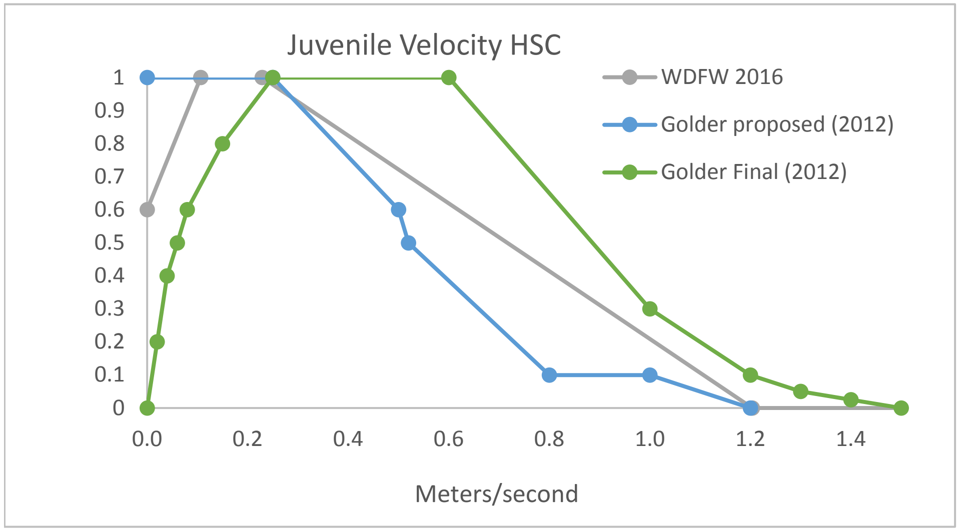
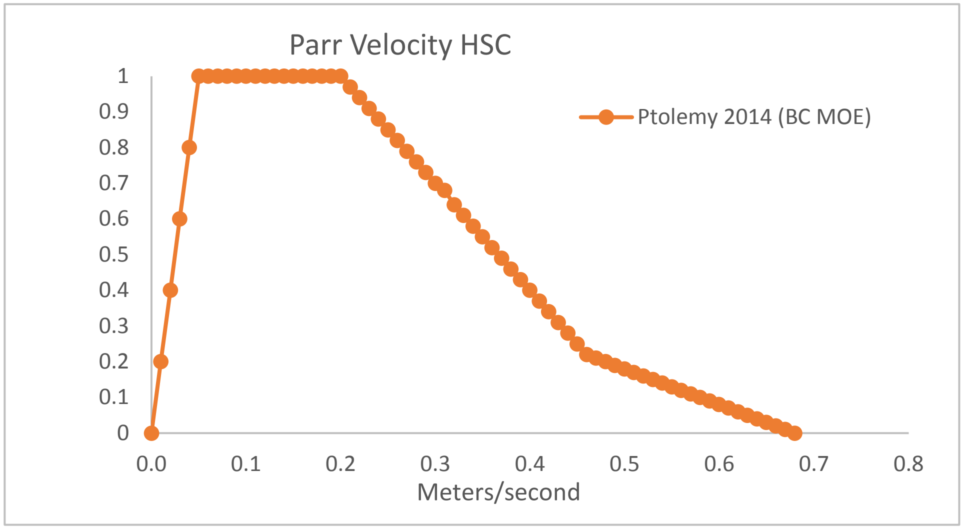
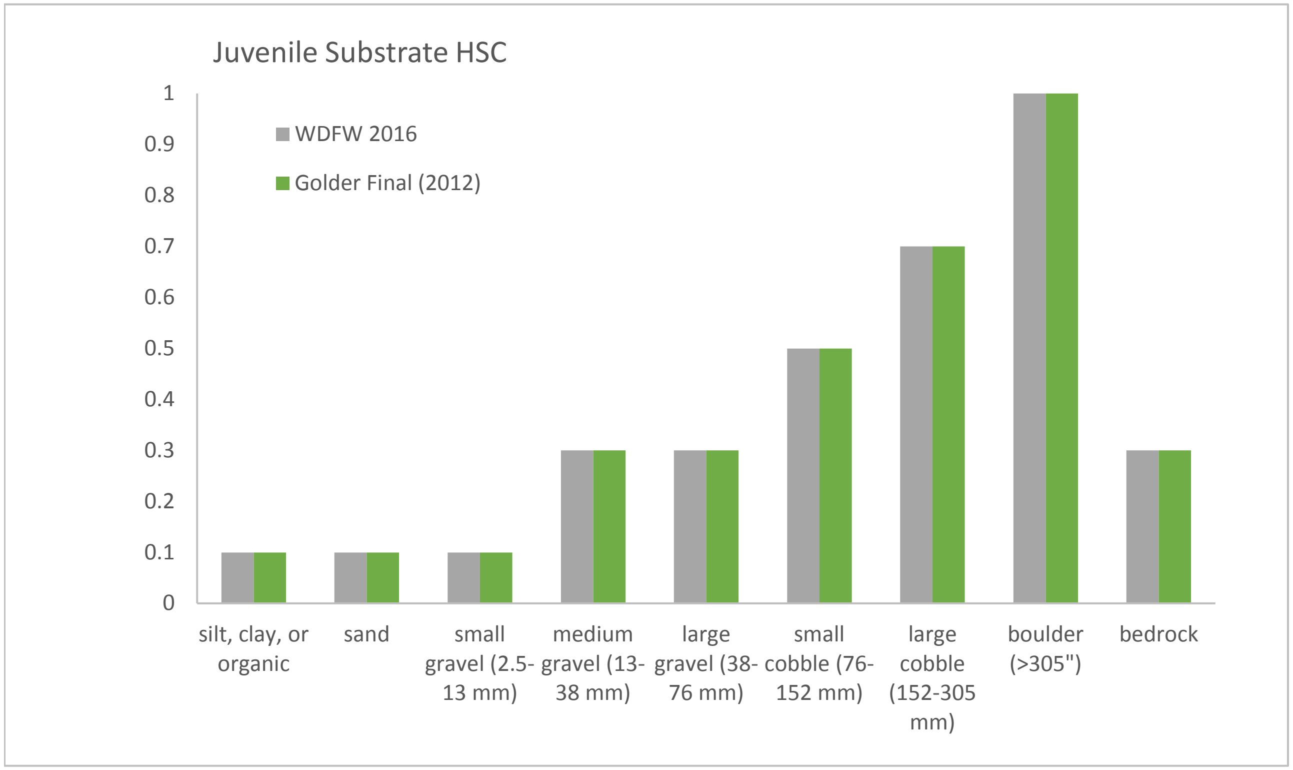








WSCT Juvenile (substrate) Habitat Suitability Criteria Curves



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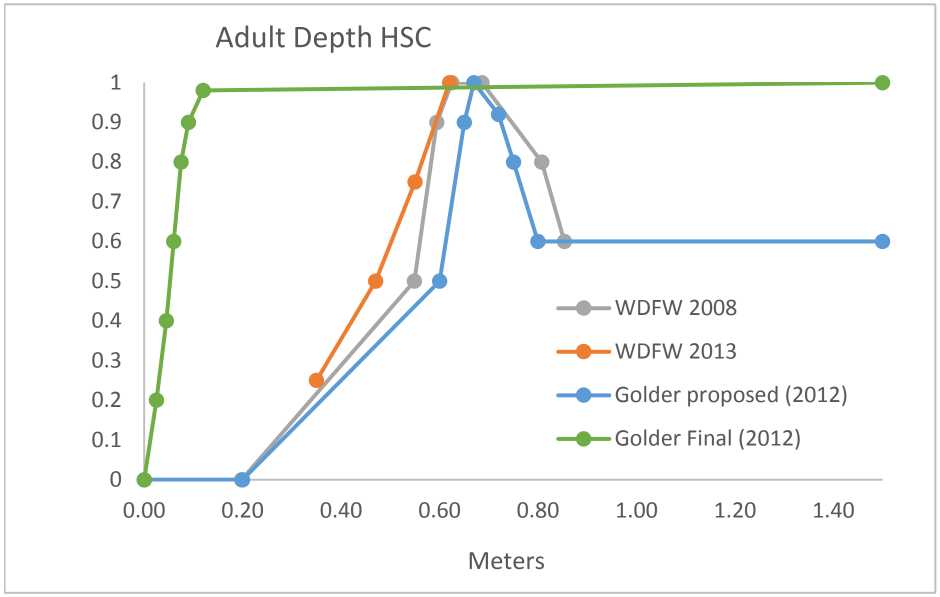
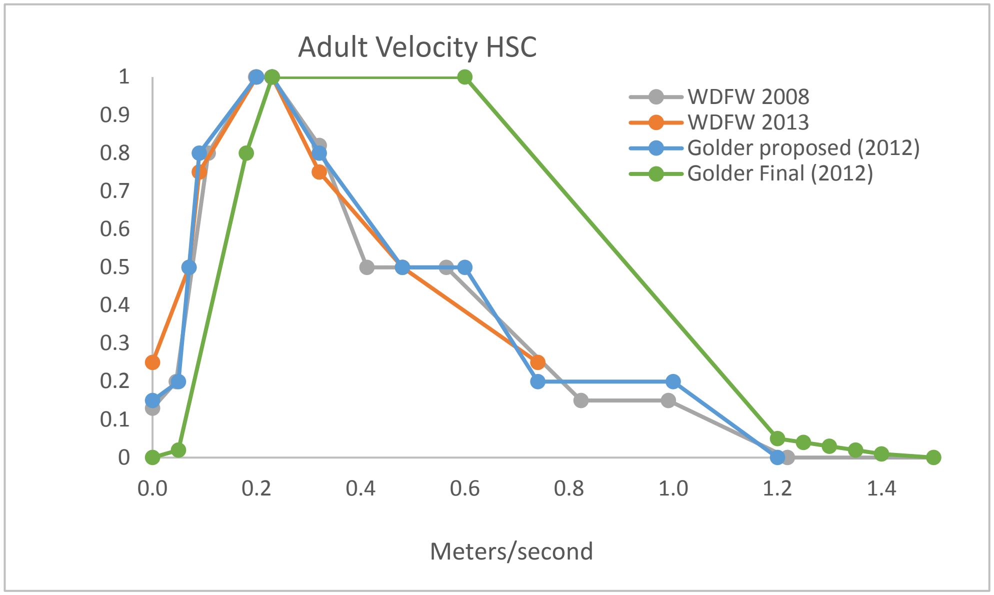
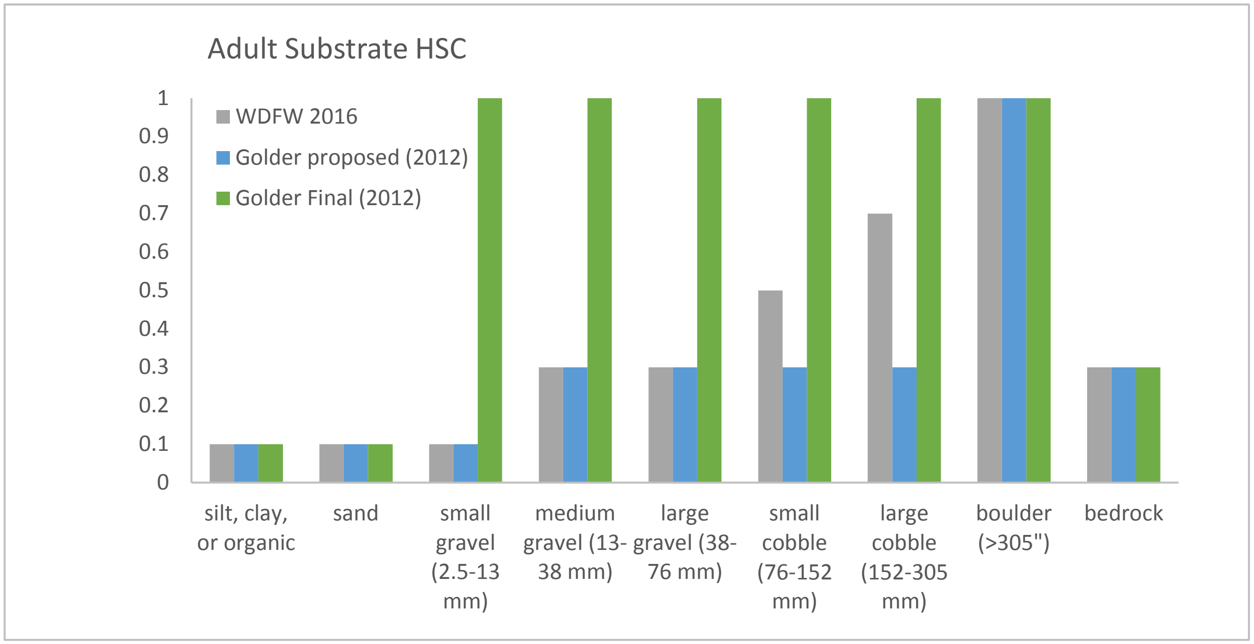
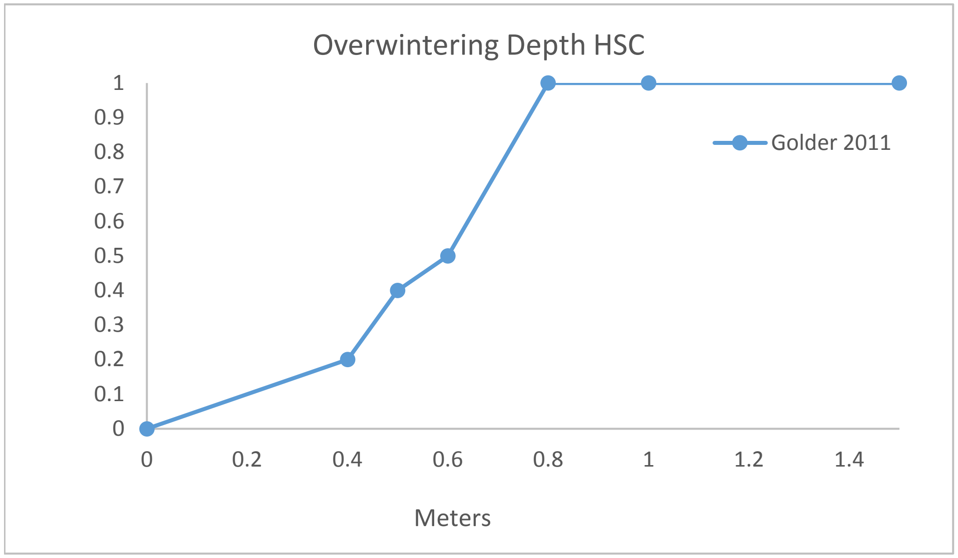
WSCT Adult (Rearing/Holding) Habitat Suitability Criteria Curves

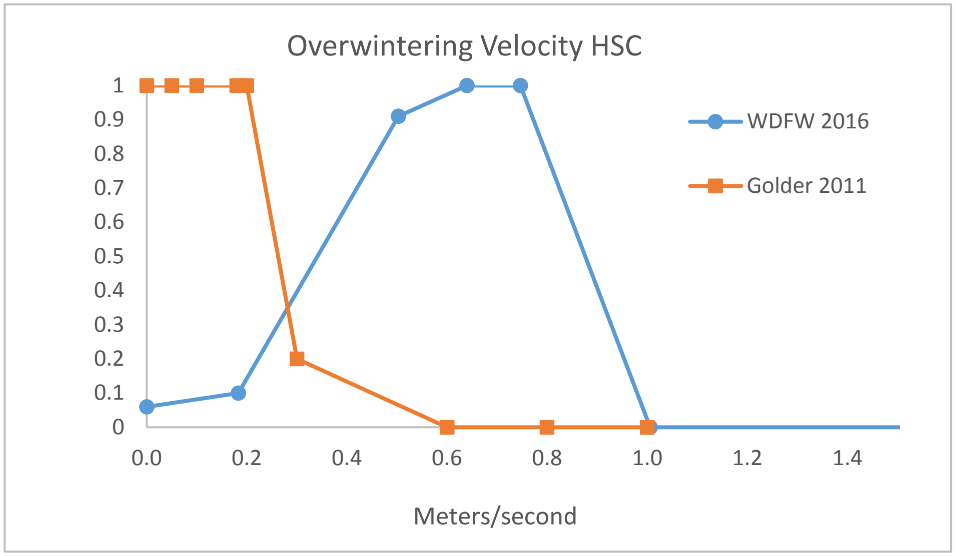


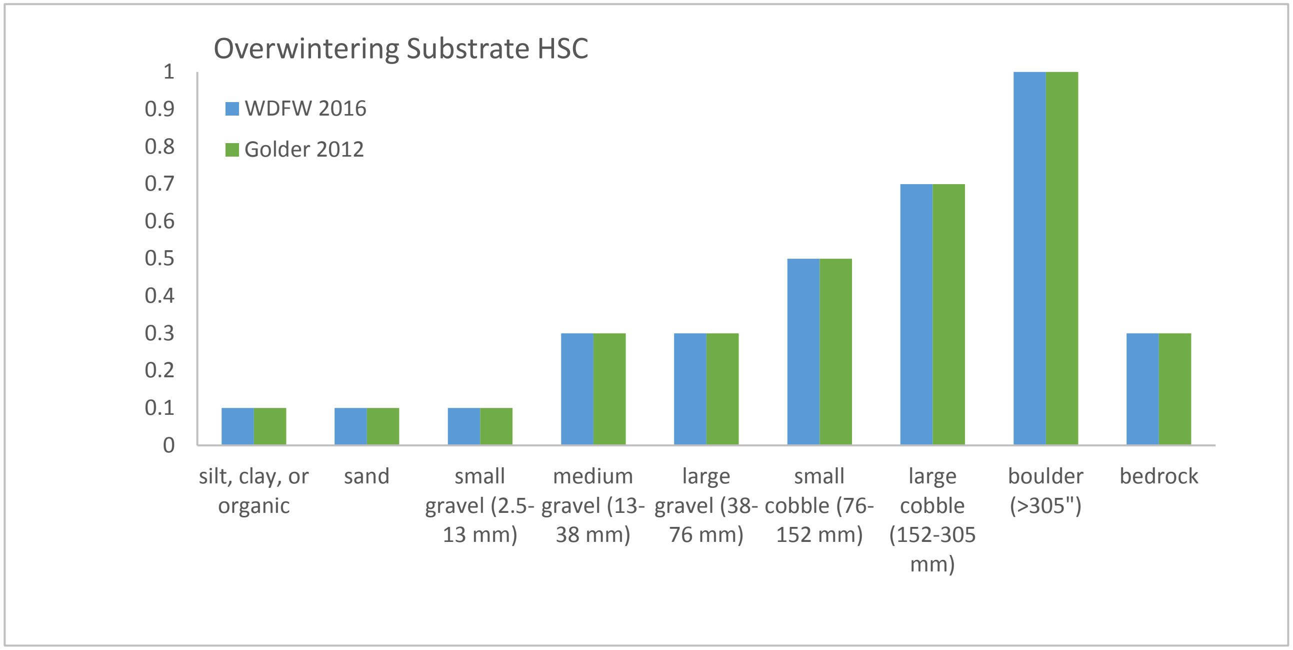




WSCT Overwintering Habitat Suitability Criteria Curves







Appendix A4

Stream Temperature Memo

WATER TEMPERATURE MODELLING USING FORECASTED FLOW CHANGES FOR GRASSY MOUNTAIN COAL MINE

Prepared for:

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Appendix A1 Forecasted Flow Data

LIST OF ACRONYMS

ACA	Alberta Conservation Association
AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
CHPP	Coal handling and preparation plant
DFO	Fisheries and Oceans Canada
LSA	Local study area
MMD	Mean monthly discharge
RMSE	Root mean square error
RSA	Regional study area
SEFA	System for environmental flow assessment
WSC	Water survey Canada
WSCT	Westslope cutthroat trout

ACKNOWLEDGEMENTS

This report was prepared for Benga Mining Limited by Hatfield Consultants. Cory Bettles (MSc, RPBio FP-C) managed the 2016 data collection and report compilation for the Project. This report was written by Jennifer Carter (MRM) and reviewed by Cory Bettles and Martin Davies (MES, RPBio). Fieldwork was conducted by Sarah Quesnelle (MSc), Cory Bettles, Jennifer Carter (MRM), and Sarah Thomasen (MSc, RPBio).

DISTRIBUTION LIST

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AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	First version of Water Temperature Modelling Using Forecasted Flow Changes for Grassy Mountain Coal Mine	20170110	(insert signature)	(insert signature)
			Martin Davies Project Director	Cory Bettles Project Manager

1.0 INTRODUCTION

Benga Mining Limited (Benga), a wholly owned subsidiary of Riversdale Resources Limited (Riversdale), is proposing to develop the Grassy Mountain Coal Project (the Project) along the eastern edge of the Rocky Mountain foothills approximately 200 km south of Calgary, Alberta in the municipality of Crowsnest Pass. The Project will involve a surface metallurgical coal mine, a coal handling and preparation plant (CHPP) with associated infrastructure, an overland conveyor system, which will parallel an existing high grade access corridor and connect to a rail load-out facility, and a new section of rail track.

The Project will result in flow changes in watercourses that support fish and other aquatic life. These watercourses include Gold Creek and Blairmore Creek, both tributaries to the Crowsnest River. Potential flow reductions may occur in Gold Creek because of water diversions, water withdrawals, and/or reductions in run-off due to capture, treatment, and storage of water by various Project components as per the Project's proposed Water Quality Management Plan (WMP) (SRK 2016a). Potential increases in flow are predicted to occur in Blairmore Creek due to the release of water through the proposed WMP.

The regional and local study areas (RSA and LSA, respectively) for assessment of fish and fish habitat, water quality, and hydrology are congruent and encompass areas where Project activities have the potential to impact aquatic habitat or fish populations and communities. As such, the following study was conducted to determine how changes in flow in Gold and Blairmore creeks could affect stream temperature, which plays a vital role in the presence/absence, life-histories, and spatial distribution of stream organisms (Hauer and Lamberti 2006, Magnuson et al. 1979). Many streams experience diel temperature flux and a range in daily temperature of more than 5°C is very common. However, the high latent heat of water can cause stream temperatures to vary much more narrowly on a daily basis than air temperatures (Hauer and Lamberti 2006). Factors such as groundwater input and riparian shading can have a large influence on stream temperature (Hauer and Lamberti 2006, Leach et al. 2012) leading to high variation in stream temperatures between habitats only a few metres apart (Hauer and Lamberti 2006, Kalb 2013). Annual fluctuations in stream temperatures are important to critical life history variables such as reproduction as well as general movement throughout the habitat, as they provide an environmental cue for activities such as spawning, egg incubation/fry emergence, and emergence of aquatic insects (Hasnain 2012, Hauer and Lamberti 2006, Jakober et al. 1998). Fish move throughout waterbodies, in response to changes in temperature: as water temperature declines in the fall, juveniles move downstream seeking out deep pool habitat and other protected areas to overwinter (Jakober et al. 1998).

Water temperature was modeled for Gold and Blairmore creeks over the lifespan of Grassy Mountain Coal mine from pre-construction to post-closure (i.e., 2017 to 2099) to determine how, during each phase of the mine, maximum monthly changes in forecasted flow (Appendix 1) could affect key bioperiods of Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*; WSCT).

2.0 METHODS

Hydrological Data

A Mean Monthly Discharge (MMD) time-series, representative of baseline conditions (2017), was generated at various nodes along each watercourse, as input data to the project Instream Flow Assessment (IFA; Hatfield 2016a) and the temperature modelling component. These were produced firstly at hydrometric gauge locations along each watercourse, based on a regression analysis of daily flows gauged concurrently between each hydrometric gauge and data collected by Water Survey of Canada (WSC) at nearby regional stations. The resulting 41-year daily flow data series (extending from 1975-2016) were then estimated for selected input stream-temperature modelling locations by applying correction factors calculated as the ratio of measured flows between hydrometric gauges and input locations. For input locations not directly measured during field sampling, the nearest available data, which provided reliable estimates of flow conditions at input locations was used (e.g., within the same reach, and no intervening tributary inflows).

The predicted Project flows were generated as follows. Monthly total flow changes were predicted by SRK (SRK 2016a) from the start of construction (2018) until the end of mine (2099), at five (5) model nodes each on Gold Creek and Blairmore Creek. These were calculated using a watershed model developed using regional precipitation data, assumptions on runoff yield between undisturbed and disturbed watershed areas, and the project WMP for controlling surface waters and groundwater affected by mine operations (SRK 2016a). Mine operations were grouped into the following main phases, including construction (2018), operations (2019-2042), decommissioning (2043-2044) and closure (2045-2099). The predicted total flow changes did not differentiate between the constituents of runoff (i.e., surface channel flow, interflow, and groundwater; therefore, for the purposes of this assessment, there was assumed to be no difference between predicted changes in total and surface channel flow.

For each discharge time-series used within the stream-temperature modelling, monthly Project flows from 2018-2099 were simulated by applying the predicted flow changes from the most appropriate SRK model node to the appropriate MMD baseline (2017) time-series outlined above. Separate datasets for each node were generated, including; (1) during average hydrologic conditions throughout 2017-2099 (integrating the MMD time series outlined above, with the SRK monthly total flow changes during ‘average’ conditions), and (2) during low-flow (drought) conditions throughout 2017-2099 (integrating a modelled, lower-flow 1-in-10-year baseline MMD time series, with the SRK monthly total flow changes during dry 1-in-10-year conditions assumed to occur every year).

Water Temperature Modelling

For each scenario (i.e., average and dry hydrologic conditions), water temperature was predicted for months March to October on both Gold and Blairmore creeks and, because of data limitations, for months January to February on Blairmore Creek only. March to October predictions incorporate flow-related temperature changes that may influence spawning, egg incubation, and rearing, while January to February predictions incorporate flow-related temperature changes that may influence overwintering. Locations for water temperature predictions were based on SRK model nodes G04 and G09 on Gold

Creek and BC03, BC07, and BL02 on Blairmore Creek. These nodes were chosen because they are located where changes in discharge as a result of mine activities would be most prominent.

Water temperature modelling was run using the *System for Environmental Flow Assessment* (SEFA) program. The Theurer Method was used to predict maximum water temperature downstream of each site (Jowett et al. 2014). Meteorological and water temperature time series data for an upstream and downstream site were used to calibrate the model. Parameters used to run the model and their associated data sources are located in Table 1. Datasets summarized in Table 2 include:

- (1) locations where monthly flow data were generated and used to approximate flows at the SRK nodes;
- (2) channel stations where the channel bed profile was surveyed for purposes of estimating the hydraulic changes (e.g., water depth) with flow;
- (3) locations with available upstream and downstream water temperature data (Hatfield 2016a); and
- (4) locations with available air temperature data (Hatfield 2016a).

Winter data (November to February) were not available for any period on Gold Creek or Blairmore Creek in 2015/2016 and were limited for the time period they were collected (2013/2014) on Blairmore Creek. As a result, water temperature during the overwintering months (November to February) was only modeled on Blairmore Creek.

Changes in water temperature were assessed by taking the difference between predicted water temperature used to calibrate the model (using baseline flows) and predicted water temperature using forecasted flow changes for each phase of the mine. To determine how predicted changes in water temperature may affect each identified bioperiod of WSCT, changes in predicted water temperature relative to observed water temperatures were then compared against literature-based optimal temperature ranges for each bioperiod (DFO 2014).

Table 1 Model parameters and associated data sources used to calibrate and run water temperature model.

Parameter	Source
Upstream Water Temperature	Hatfield hydrological stations or temperature loggers
Downstream Water Temperature	Hatfield hydrological stations or temperature loggers
Air Temperature	Hatfield temperature loggers or Alberta Agriculture and Forestry Blairmore weather station
Relative Humidity	Alberta Agriculture and Forestry Blairmore weather station
Wind Speed	Alberta Agriculture and Forestry Blairmore weather station
Ground Temperature[1]	Alberta Agriculture and Forestry Blairmore weather station

Table 1 (Cont'd.)

Parameter	Source
Daily Sun Hours	www.climatemps.com – Calgary sun hours/day
Radiation	Photovoltaic and solar resource maps on www.nrcan.gc.ca
Observed Discharge	Hatfield hydrological stations
Forecasted Discharge	Estimated percent flow changes from GoldSim Water Balance Model were applied to baseline discharge observed in 2016. Maximum monthly percent change for each mine life phase were applied (see A1).

1 Ground temperature data were not available, therefore, mean monthly air temperature were used as specified in SEFA 2014 manual.

Table 2 Station data sources for each SRK node.

SRK model node	Channel station (channel geometry)	US water temperature station	DS water temperature station	Air temperature station	Discharge station
March to October					
BC-03	BC0/HS01	BC2w	BC1w	BC2a	BC-2 (simulated)
BL-02	BC-4	BC-15/H03	BC2w	GC1a	BC-12 (simulated)
BC-07	BC-9	BC-15/H03	BC2w	G4a	BC-12 (simulated)
GC-04	GC-8	GC2w	GC1w	G1a	GC-7/HS01 (observed)
GC-09	GC-23	GC-27/H03	GC4w	G4a	GC9 (simulated)
November to January					
BC-03	BC0/HS01	BCH02	BCH01	Blairmore weather station	BC-02 (simulated)
BL-02	BC-4	BC-15/H03	BCH02	Blairmore weather station	BC-12 (simulated)
BC-07	BC-9	BC-15/H03	BCH02	Blairmore weather station	BC-H02 (simulated)

3.0 RESULTS AND DISCUSSION

Model outputs predict that forecasted flow changes throughout all phases of the mine will cause little to no change in maximum daily water temperature for both Gold and Blairmore creeks (Figure 1 to Figure 8). For Gold Creek, differences between predicted baseline water temperature (using baseline flow data) and predicted water temperature using forecasted flow data ranged from -0.32 to +0.19°C for months March to October across all mine phases and seasonal conditions. Model fit is fairly good for months March to October for all sites on Blairmore Creek (Figure 3 to Figure 5, RMSE = 1.8 to 2.0°C). Model fit was good for months March to October for site GC04 (Figure 1; RMSE = 1.7°C), but less for GC09 (Figure 2, RMSE = 2.6°C), likely a result of an influx of flows from Cauldron Creek at the observed downstream water temperature site.

For Blairmore Creek, differences between predicted baseline water temperature (using baseline flow data) and predicted water temperature using forecasted flow data range from -0.36 to +0.21°C for months March to October across all mine phases and seasonal conditions. Model fit was good for winter months on Blairmore Creek (Figure 6 to Figure 8; RMSE = 0.2 to 0.3°C). Differences between water temperature predictions for winter month's range from -0.99 to 0.21°C across all mine phases and seasonal conditions. For winter months, the maximum predicted change of -0.99°C occurred at SRK node BL02 in November during the operations phase of the mine under the dry season condition only (Figure 6), whereas all other phases result in -0.001°C to +0.21°C change in temperature.

Overall, the preferred temperature range of WSCT is 9 to 12°C (Alberta Westslope Cutthroat Trout Recovery Team 2013) and they are rarely found in waters exceeding 22°C (Behnke and Zarn 1976). More recent work by Bear et al. (2007) found the upper incipient lethal temperature of WSCT is 19.6°C. Observed baseline water temperatures in both Gold and Blairmore creeks exceeded the preferred temperature range, but did not exceed, and are not predicted to exceed, incipient lethal temperatures throughout the lifetime of the mine.

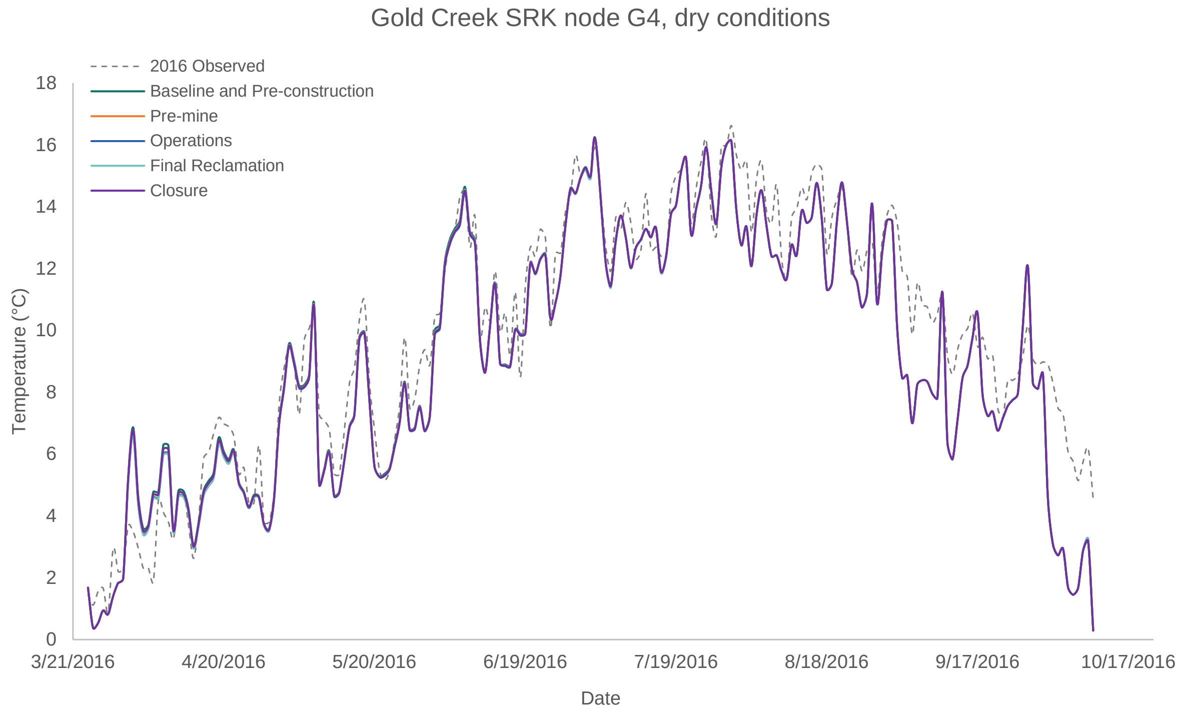
Predicted changes in water temperature were compared against optimal temperature ranges for each bioperiod (Hatfield 2016b) summarized in Table 3. Predicted increases in temperature with flow change during egg incubation (+0.20°C for Gold and +0.05°C for Blairmore) are negligible relative to baseline water temperatures at this time, which are warmer than optimal ranges for egg incubation by +6-9°C (Table 3). Thus, it is unlikely that the relatively small predictive increase in temperature will result in any incremental adverse effect on incubation (e.g., earlier emergence), and the predicted decrease in temperature (-0.17°C for Gold and -0.25°C for Blairmore) would only shift temperatures towards the species preferred incubation range. However, decreases in flow predicted in Gold Creek could lead to lower hyporheic flow, the flow through subsurface sediment and porous space adjacent to stream, and an increase of deeper groundwater, which contains less dissolved oxygen, in spawning beds. Less deoxygenated water could cause decrease of egg and larvae survival (Bradford and Heinonen 2008). However, given the low predicted reduced flow for Gold Creek (A1), this outcome is not expected.

For rearing, a maximum daily temperature between 13°C and 15°C ensures suitable thermal temperature for WSCT, with optimum growth occurring at 13.6°C. Bear et al. (2007) found that 15°C is the upper range for optimal growth of WSCT. Baseline water temperature during the rearing window is colder (-3°C) and warmer (+2°C for Gold Creek and +3°C for Blairmore Creek) than the preferred temperature range

(Table 3) and exceeds the upper range at which optimum growth for WSCT occurs, by 2-3°C. In comparison, the predicted increase in temperature of +0.09-0.13°C with changes in flow is negligible and unlikely to cause any effects on WSCT rearing (nursery, feeding, holding).

Stream temperatures during overwintering already reach near-freezing temperatures (Table 3). A further decrease in temperature could be problematic in Gold Creek given flows are projected to decrease, which could accentuate the freeze-up of overwintering habitat. Frozen conditions can further exacerbate already stressful conditions with the potential of frazil ice, which can damage gill tissues, and the availability of invertebrate food sources could be compromised (Bradford and Heinonen 2008). Potential effects to overwintering will ultimately be manioulated by the contribution(s) of groundwater influx during mine operations as the maintenance of WSCT overwintering habitat appears to be largely determined by this factor (Brown and MacKay 1995).

Figure 1 Observed and predicted water temperature for maximum monthly forecasted changes in flow over each phase of the lifespan of the mine, March to October at SRK node G4 both dry and normal season conditions.



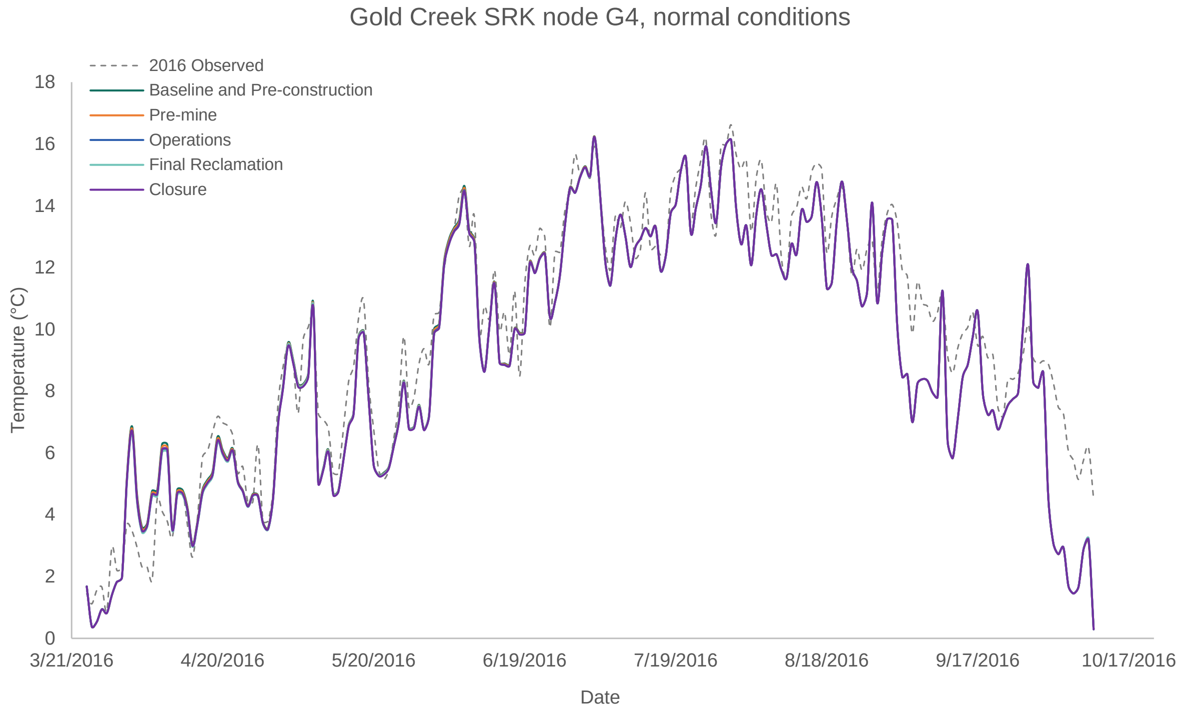
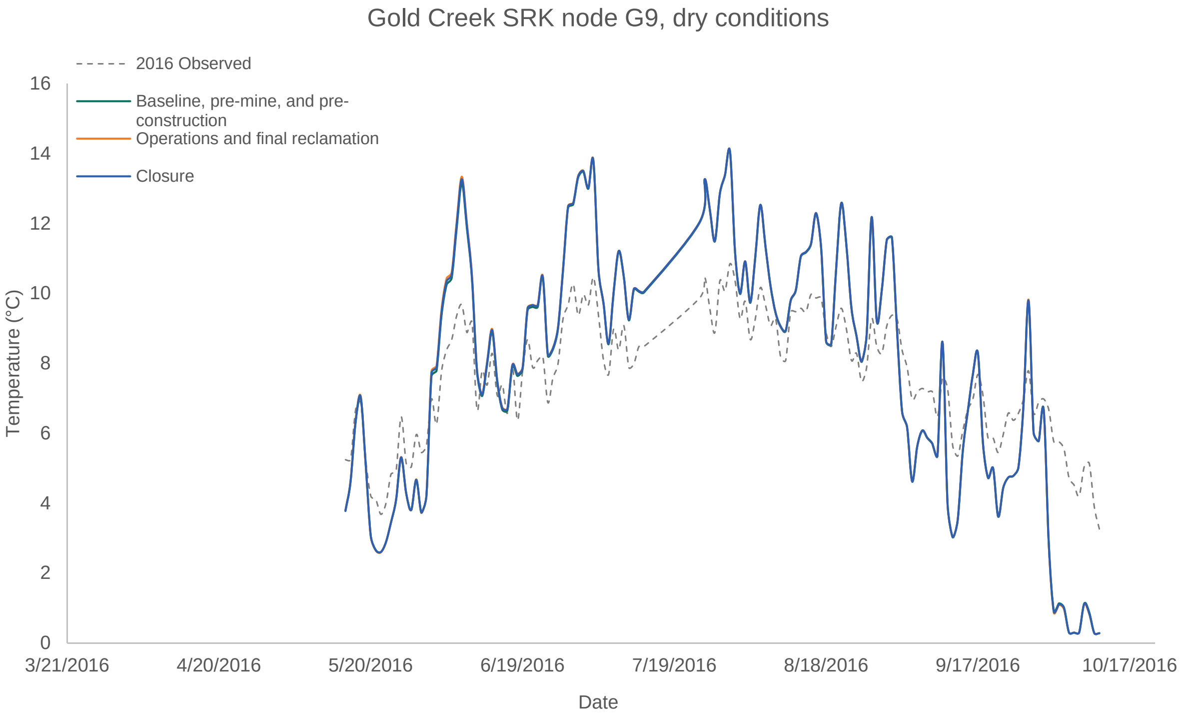


Figure 2 Observed and predicted water temperature for maximum monthly forecasted changes in flow over each phase of the lifespan of the mine, March to October at SRK node G9 both dry and normal season conditions.



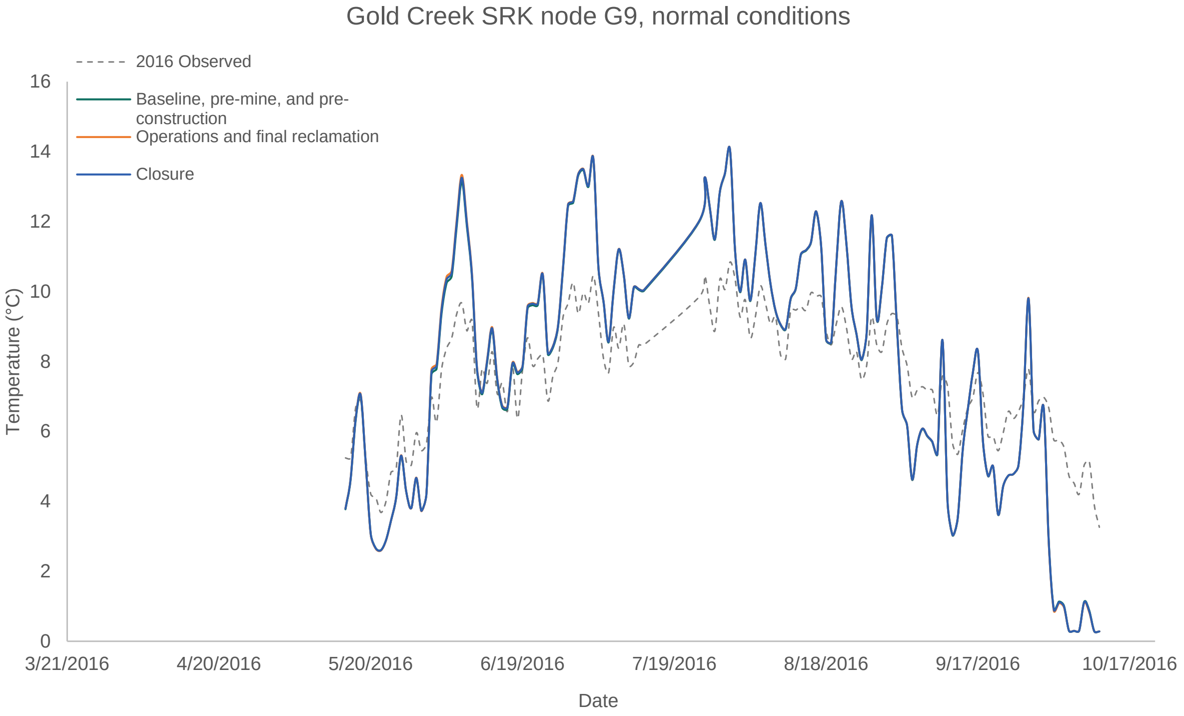
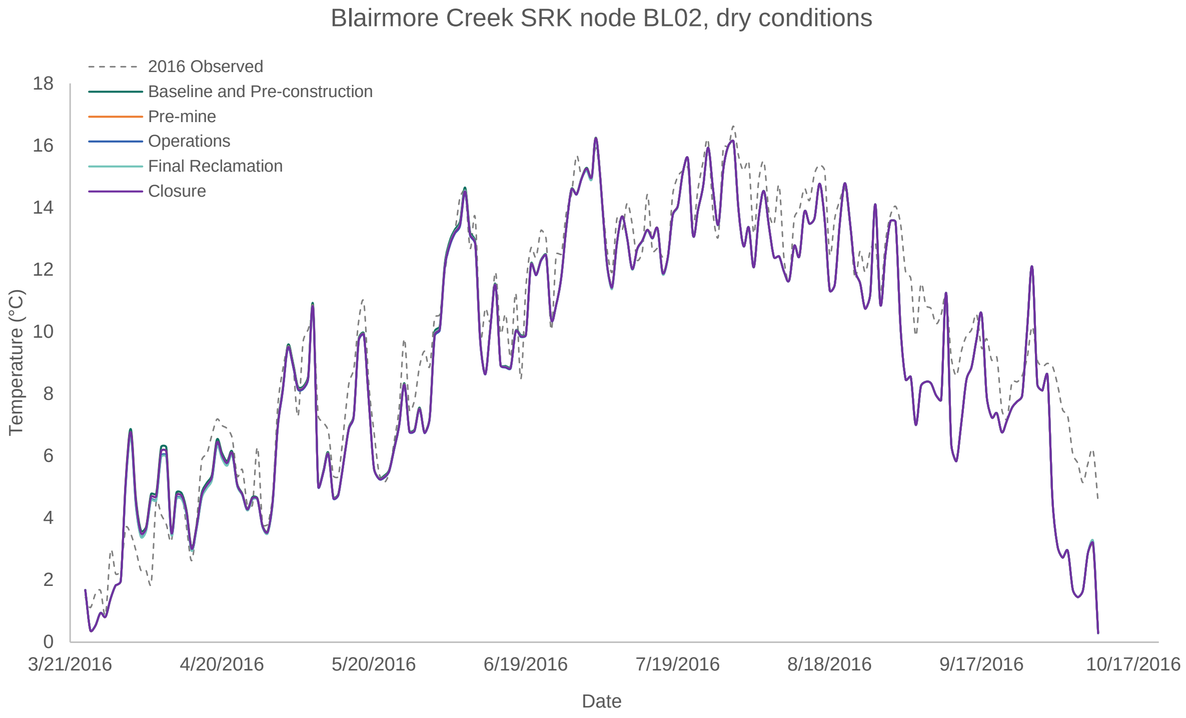


Figure 3 Observed and predicted water temperature for maximum monthly forecasted changes in flow over each phase of the lifespan of the mine, March to October at SRK node BL02 both dry and normal season conditions.


Blairmore Creek SRK node BL02, dry conditions

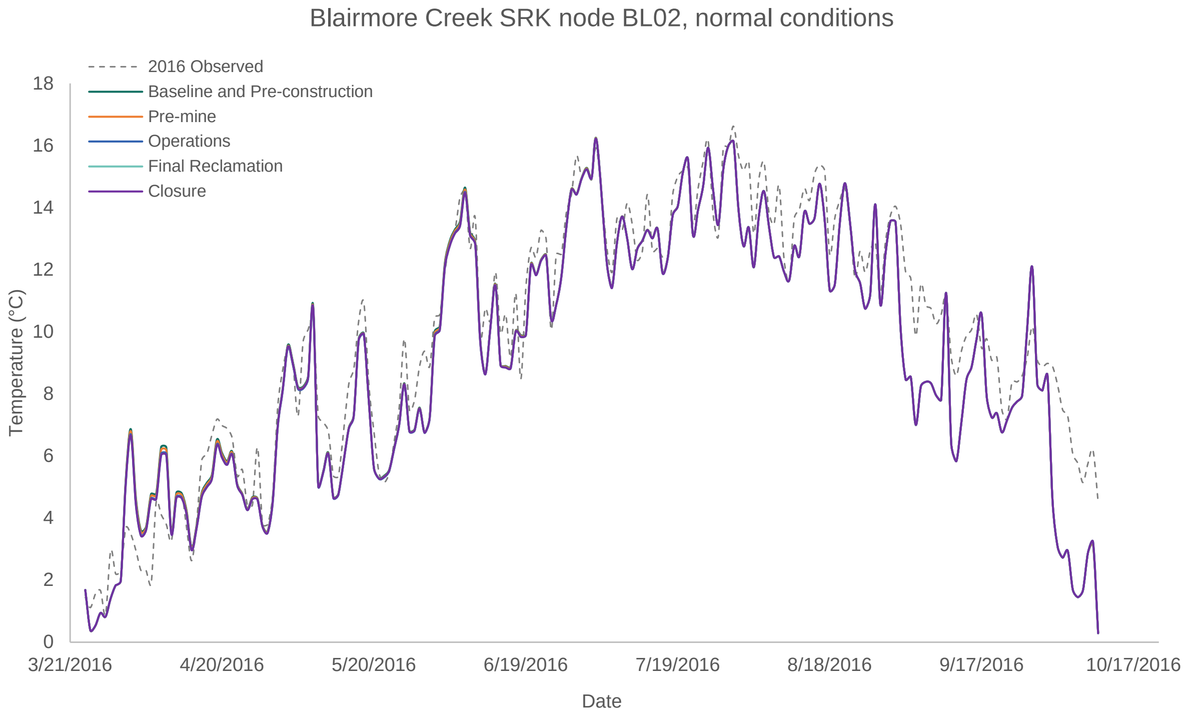
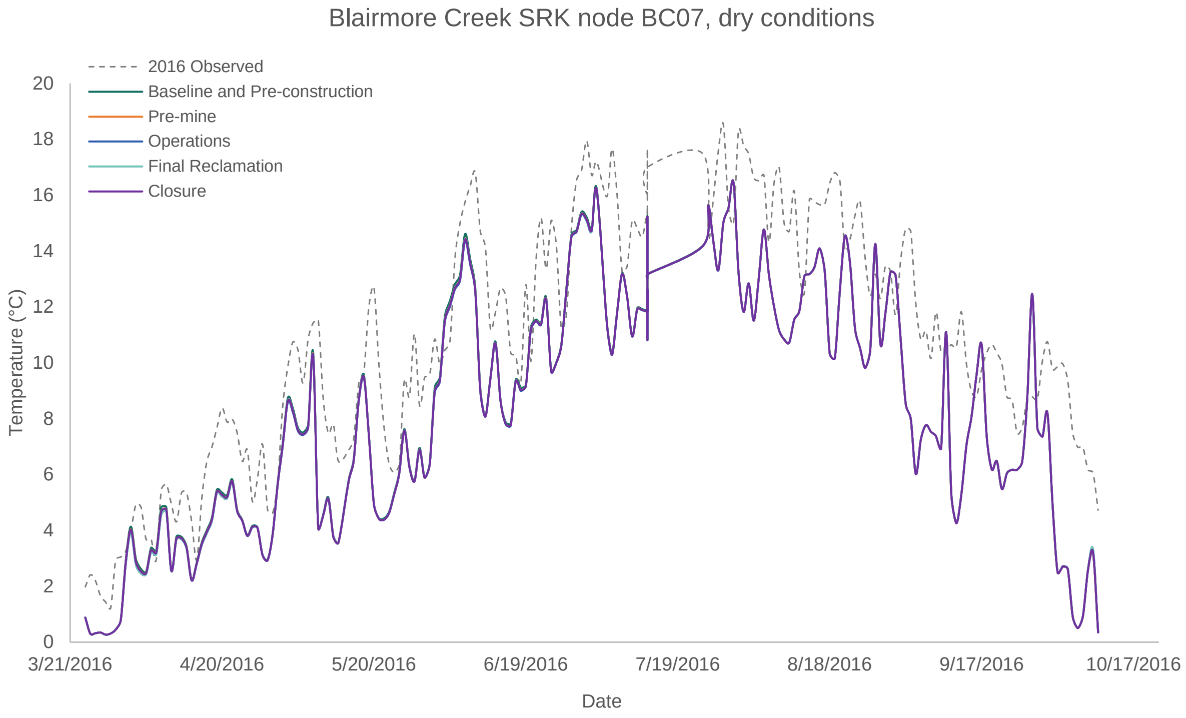
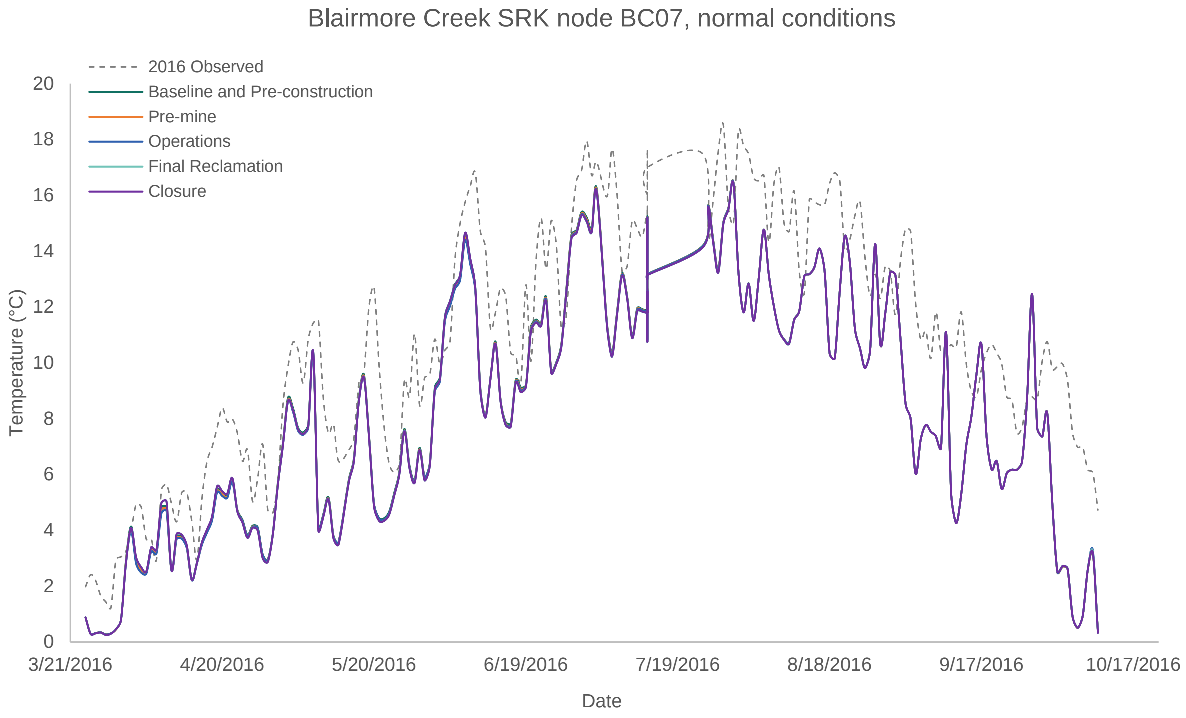

Blairmore Creek SRK node BL02, normal conditions

Figure 4 Observed and predicted water temperature for maximum monthly forecasted changes in flow over each phase of the lifespan of the mine, March to October at SRK node BC07 both dry and normal season conditions.

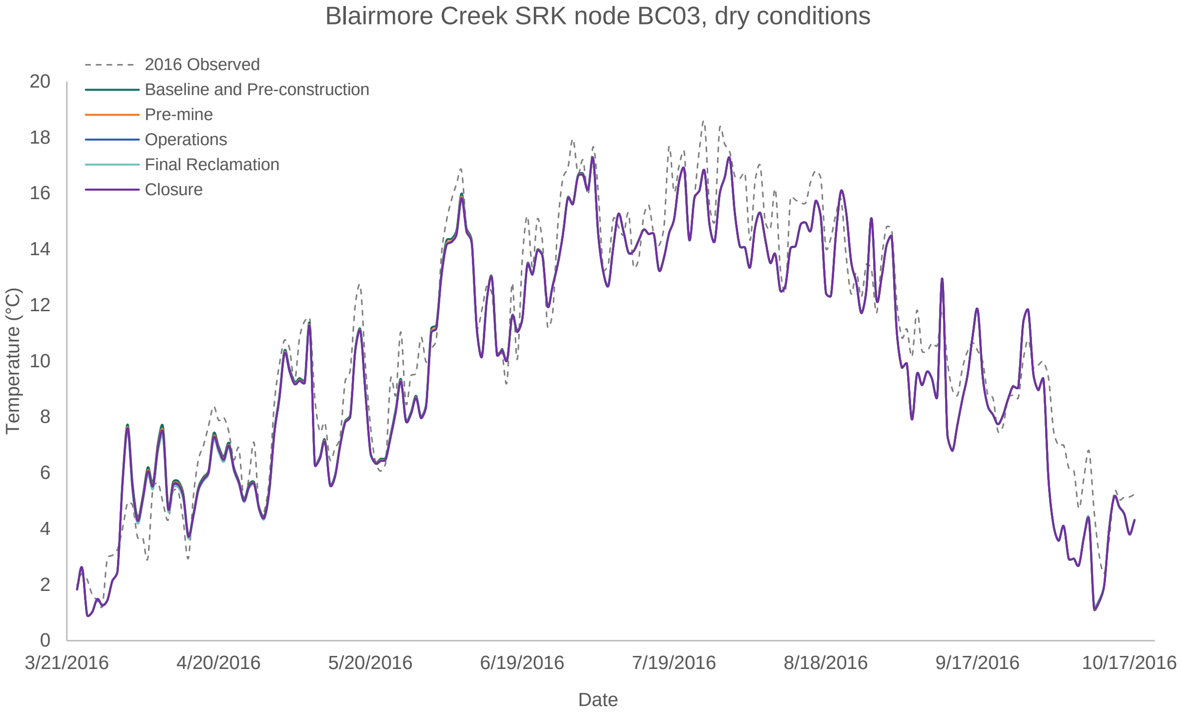


Blairmore Creek SRK node BC07, dry conditions



Blairmore Creek SRK node BC07, normal conditions

Figure 5 Observed and predicted water temperature for maximum monthly forecasted changes in flow over each phase of the lifespan of the mine, March to October at SRK node BC03 both dry and normal season conditions.



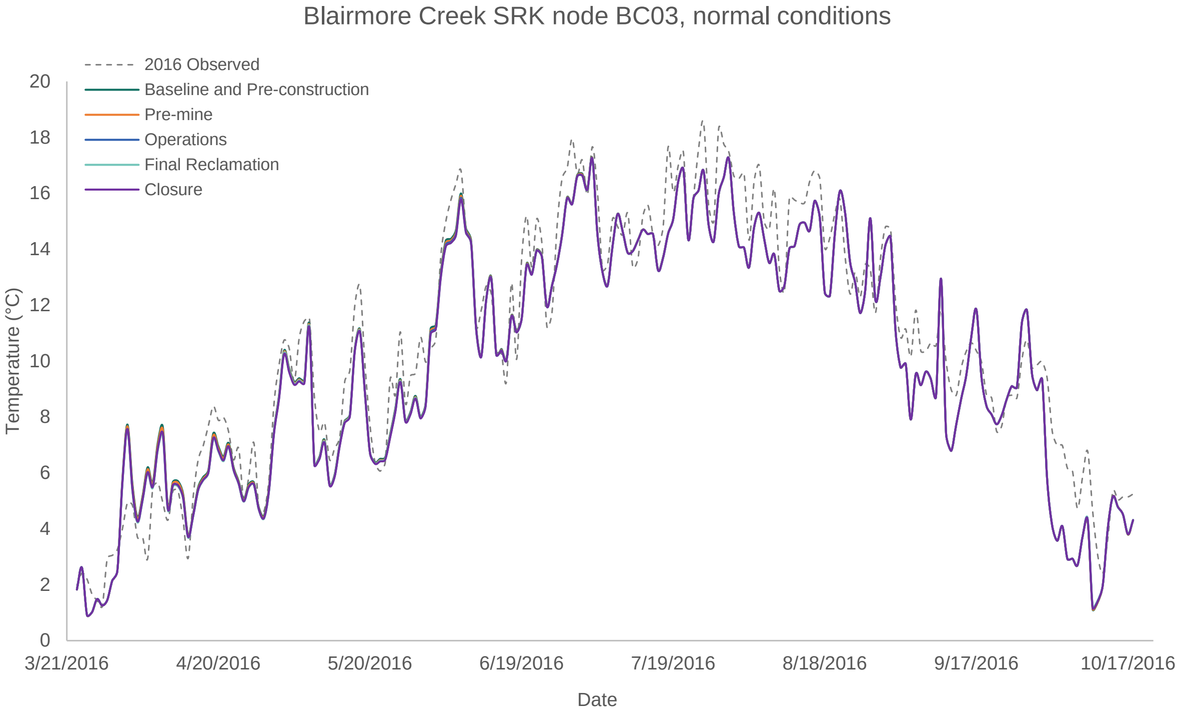
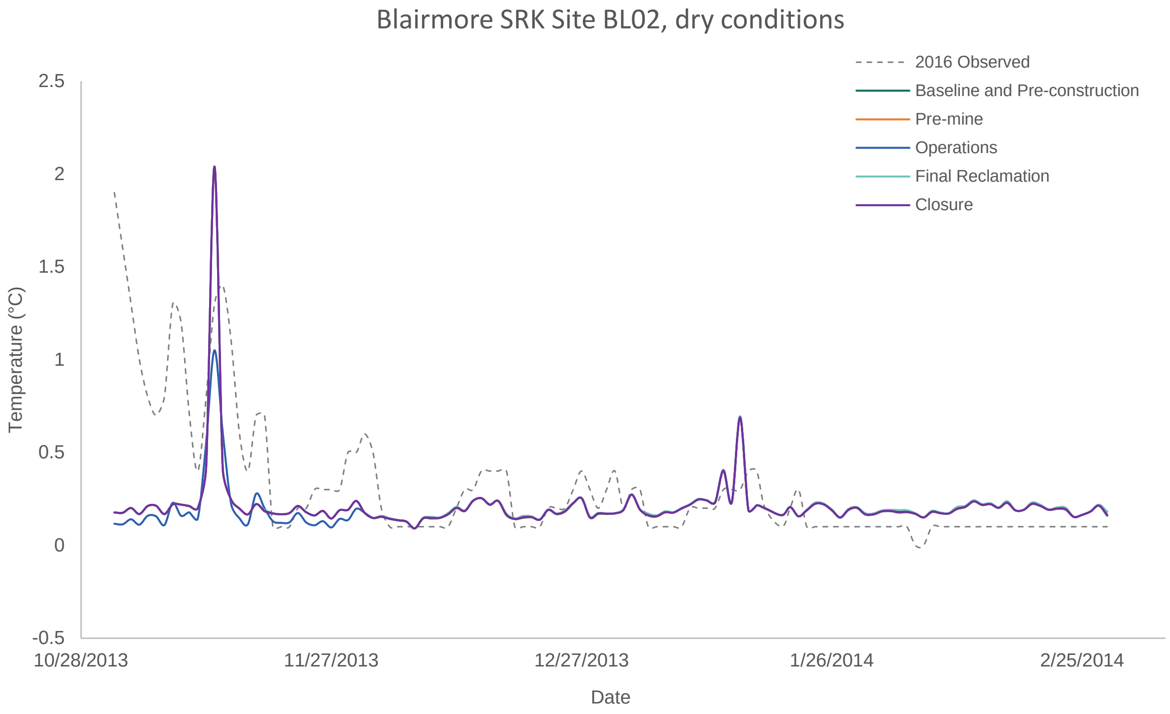


Figure 6 Observed and predicted water temperature for maximum monthly forecasted changes in flow over each phase of the lifespan of the mine, November to February at SRK node BL02 both dry and normal season conditions.



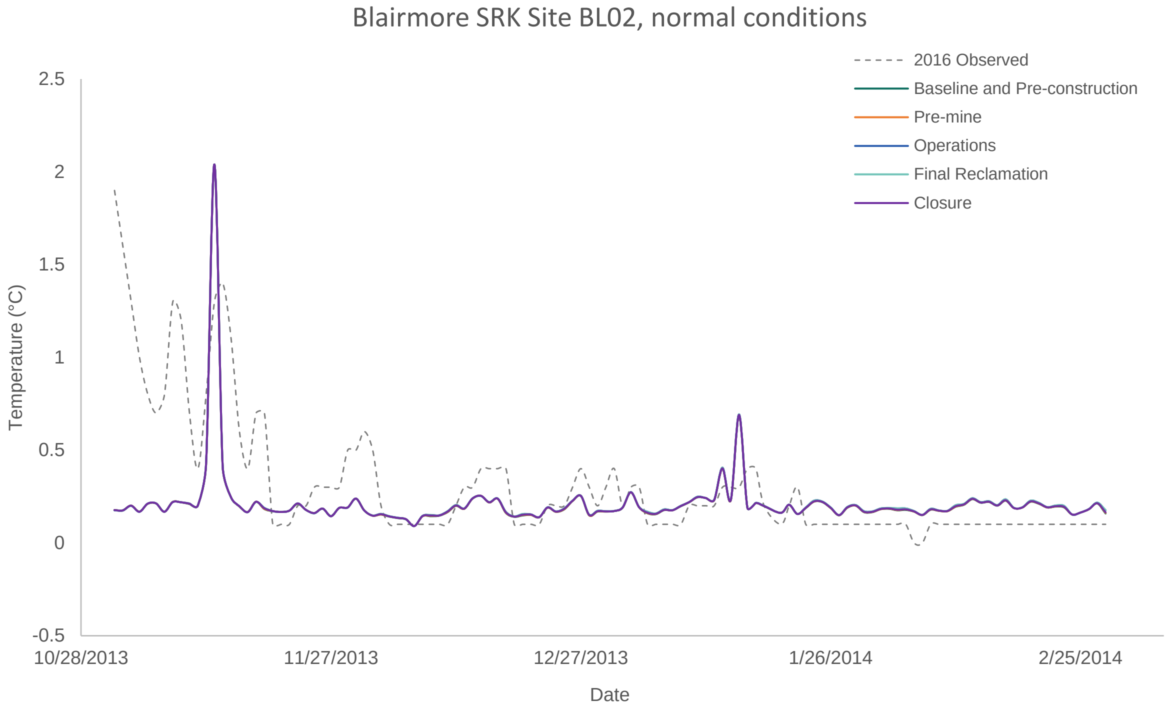
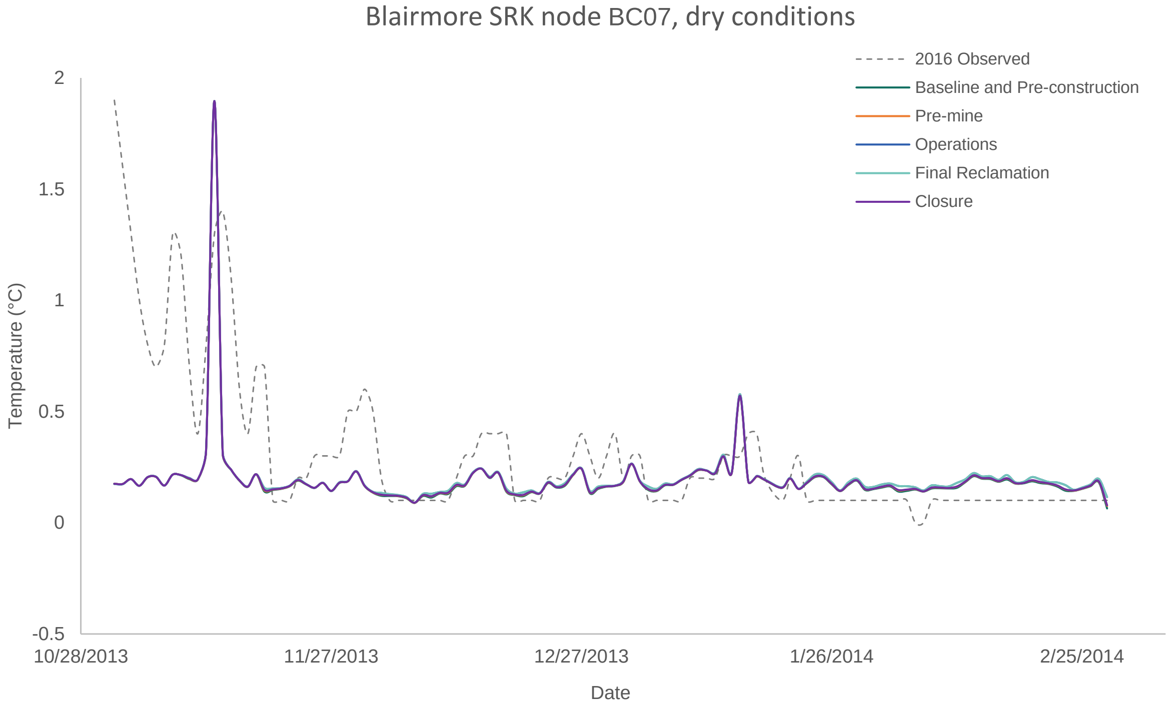


Figure 7 Observed and predicted water temperature for maximum monthly forecasted changes in flow over each phase of the lifespan of the mine, November to February at SRK node BC07 both dry and normal season conditions.



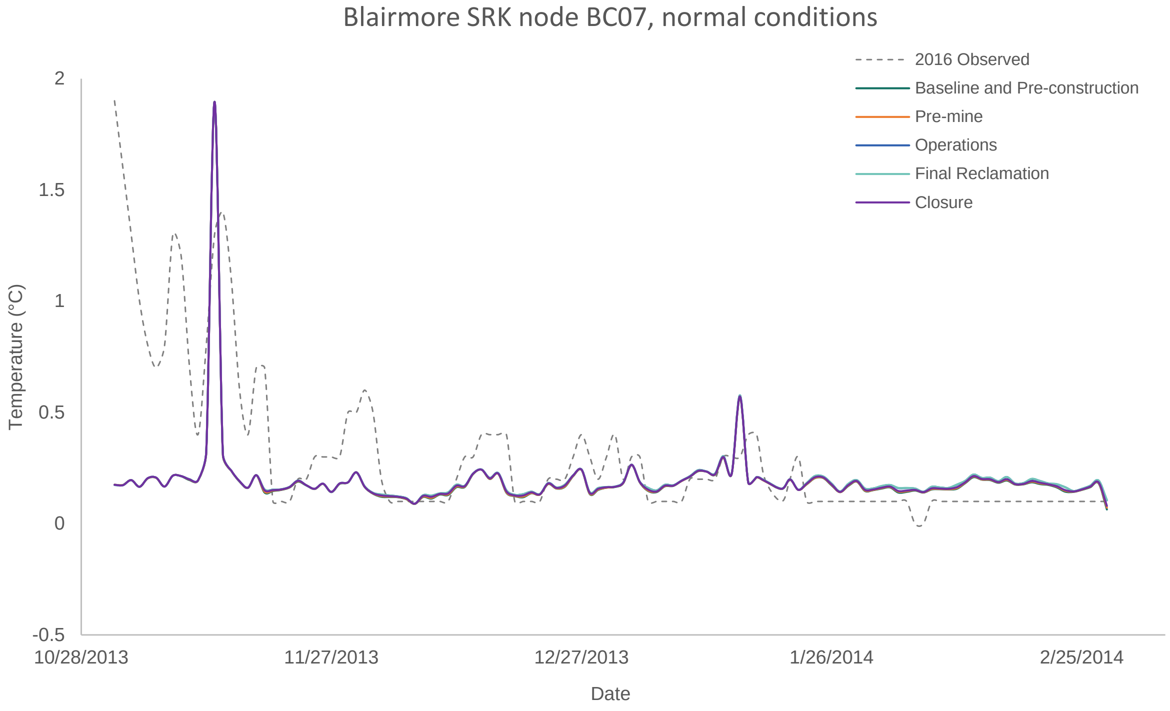
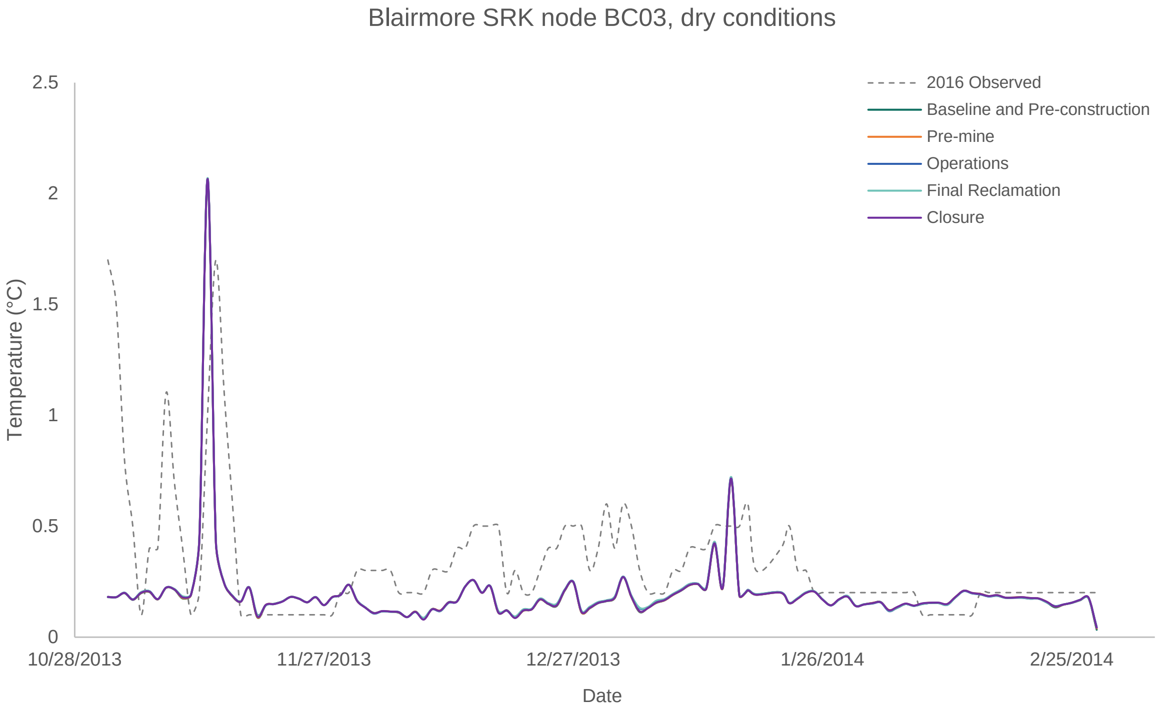


Figure 8 Observed and predicted water temperature for maximum monthly forecasted changes in flow over each phase of the lifespan of the mine, November to February at SRK node BC03 both dry and normal season conditions.



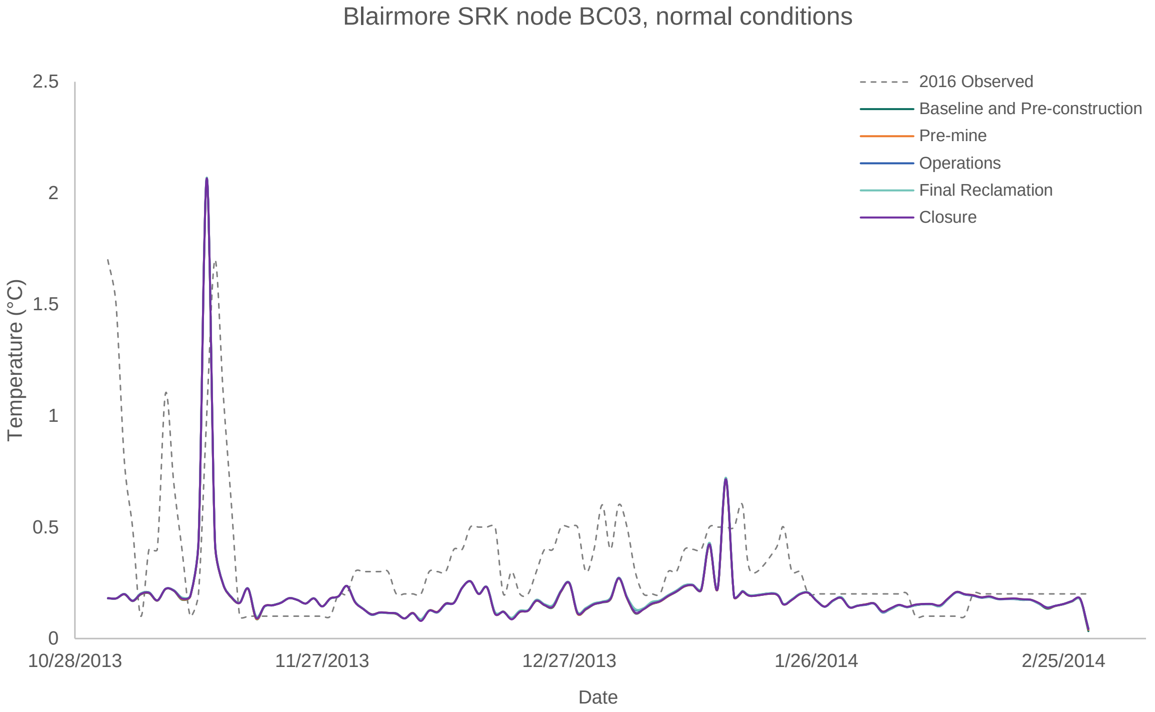


Table 3 Comparison of predicted changes in temperature for both Gold and Blairmore Creeks relative to observed and optimal temperature ranges for each bioperiod of Westslope Cutthroat Trout.

			Gold Creek		Blairmore Creek	
Bioperiod	**Biological Stanza**	**Optimal Temperature Range (°C)**	**Observed Temperature (°C)**	**Predicted Change in Temperature (°C)**	**Observed Temperature (°C)**	**Predicted Change in Temperature (°C)**
Egg Incubation	June to August	6.00 - 10.00	6.30 - 16.62	-0.17 - 0.19	8.48 - 18.52	-0.25 - 0.05
Spawning	May to July	6.00 - 10.00	3.68 - 16.62	-0.16 - 0.19	5.14 - 18.52	-0.25 - 0.05
Rearing	March to October	4.00 - 15.00	0.89 - 16.62 *	-0.32 - 0.09 *	0.89 - 18.52	-0.36 - 0.13
Overwintering	October to April	-	-	-	0.00 - 9.37	-0.99 - 0.21

* March and April data were not available for site G9. Only site G4 data were considered for these months.

4.0 CONCLUSION

Water temperature modelling suggests that flow changes will have little to no effect on WSCT bioperiods for Gold and Blairmore creeks throughout the mine lifespan. Changes in water temperature predicted by the model are negligible relative to baseline water temperature, which already exceed optimal ranges of temperature for WSCT for some bioperiods. However, decreases in temperature as a result of flow reductions during the overwintering bioperiod should be monitored due to the potential changes in groundwater influx and the possibility of increasing the freeze-up of important overwintering habitats or the incidence of frazil ice. It is important to note that water temperature monitoring on Gold and Blairmore creeks is ongoing, which will enhance current baseline data and refine predictive temperature shifts.

5.0 REFERENCES

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APPENDICES

Appendix A1

Forecasted Flow Data

Table A1 Maximum percent change in flow forecasted by month for each mine phase over the lifespan of Grassy Coal Mine relative to baseline flows measured in 2016.

Mine Phase and Years	Month	Maximum Percent Change in Flow Forecasted									
		Dry Year Scenario					Normal Year Scenario				
		BC07	BL02	BC03	GC09	GC04	BC07	BL02	BC03	GC09	GC04
Pre-construction (2017)											
	Jan	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Feb	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Mar	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Apr	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	May	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Jun	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Jul	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Aug	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Sep	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Oct	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Nov	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	Dec	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Pre-mine (2018)											
	Jan	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Feb	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Mar	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Apr	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	May	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Jun	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Jul	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Aug	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Sep	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Oct	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Nov	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%
	Dec	7%	6%	6%	0%	0%	5%	4%	4%	0%	0%

Table A1 (Cont'd.)

Mine Phase and Years	Month	Maximum Percent Change in Flow Forecasted									
		Dry Year Scenario					Normal Year Scenario				
		BC07	BL02	BC03	GC09	GC04	BC07	BL02	BC03	GC09	GC04
Operations (2019-2041)											
	Jan	45%	43%	41%	-9%	-6%	34%	32%	30%	-9%	-6%
	Feb	41%	39%	38%	-9%	-6%	31%	29%	28%	-9%	-6%
	Mar	31%	29%	27%	-9%	-6%	24%	22%	20%	-9%	-6%
	Apr	16%	13%	11%	-9%	-6%	13%	10%	11%	-9%	-6%
	May	14%	11%	10%	-9%	-6%	12%	9%	9%	-9%	-6%
	Jun	13%	11%	10%	-9%	-6%	11%	9%	9%	-9%	-6%
	Jul	14%	11%	11%	-9%	-6%	12%	9%	10%	-9%	-6%
	Aug	17%	15%	16%	-9%	-6%	14%	11%	13%	-9%	-6%
	Sep	19%	17%	17%	-9%	-6%	16%	13%	14%	-9%	-6%
	Oct	24%	22%	21%	-9%	-6%	19%	16%	17%	-9%	-6%
	Nov	24%	21%	20%	-9%	-6%	19%	16%	17%	-9%	-6%
	Dec	30%	27%	27%	-9%	-6%	23%	20%	20%	-9%	-6%
Final Reclamation (2042-2044)											
	Jan	45%	44%	46%	-9%	-6%	35%	33%	35%	-9%	-6%
	Feb	41%	40%	42%	-9%	-6%	32%	30%	32%	-9%	-6%
	Mar	31%	30%	32%	-9%	-6%	25%	23%	25%	-9%	-6%
	Apr	16%	15%	17%	-9%	-6%	13%	12%	14%	-9%	-6%
	May	8%	7%	9%	-9%	-6%	8%	6%	8%	-9%	-6%
	Jun	8%	6%	9%	-9%	-6%	13%	11%	13%	-9%	-6%
	Jul	11%	9%	12%	-9%	-6%	13%	11%	13%	-9%	-6%
	Aug	18%	16%	19%	-9%	-6%	14%	13%	15%	-9%	-6%
	Sep	20%	19%	21%	-9%	-6%	16%	15%	17%	-9%	-6%
	Oct	25%	24%	26%	-9%	-6%	19%	18%	20%	-9%	-6%
	Nov	24%	23%	25%	-9%	-6%	19%	18%	20%	-9%	-6%
	Dec	31%	30%	32%	-9%	-6%	24%	23%	25%	-9%	-6%

Table A1 (Cont'd.)

Mine Phase and Years	**Month**	**Maximum Percent Change in Flow Forecasted**									
		Dry Year Scenario					**Normal Year Scenario**				
		BC07	**BL02**	**BC03**	**GC09**	**GC04**	**BC07**	**BL02**	**BC03**	**GC09**	**GC04**
Closure (2044-2099)											
	Jan	9%	8%	10%	-2%	-3%	12%	10%	12%	-3%	-3%
	Feb	9%	7%	9%	-2%	-3%	10%	9%	11%	-3%	-4%
	Mar	7%	6%	8%	-3%	-4%	8%	7%	9%	-4%	-4%
	Apr	8%	6%	9%	-5%	-4%	10%	8%	11%	-5%	-4%
	May	9%	8%	10%	-5%	-5%	13%	11%	13%	-5%	-5%
	Jun	9%	8%	10%	-5%	-5%	13%	11%	13%	-5%	-5%
	Jul	8%	6%	9%	-5%	-5%	10%	8%	11%	-5%	-5%
	Aug	6%	5%	7%	-5%	-5%	7%	6%	8%	-5%	-5%
	Sep	7%	6%	8%	-4%	-4%	8%	7%	9%	-4%	-4%
	Oct	9%	7%	9%	-4%	-4%	10%	8%	10%	-4%	-4%
	Nov	10%	8%	11%	-3%	-4%	13%	12%	14%	-4%	-4%
	Dec	10%	8%	11%	-3%	-4%	13%	11%	14%	-3%	-4%