Appendix 5.1.2.6D
Instream Flow Study

Blackwater Gold Project

Instream Flow Study

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ACRONYMS

Abbreviations and Units of Measure	Definition
AWS	area weighted suitability (synonymous with weighted usable area)
BC	British Columbia
BC IFM	British Columbia Instream Flow Methodology
DFO	Fisheries and Oceans Canada
FFHI	Fish and Fish Habitat Inventories
FHAP	Fish Habitat Assessment Procedures
FSS	Freshwater Supply System
ha	hectare
HSC	Habitat Suitability Curve
IFIM	Instream Flow Incremental Methodology
IFN	Instream Flow Needs
IFS	Instream Flow Study
KO	kokanee
L/s	Litres per second
LSA	Local Study Area
m	metres
m^2/m	square metres per metre
m^3/s	cubic metres per second
MAD	Mean Annual Discharge
%	percent
PHABSIM	Physical Habitat Simulation System
Project (the)	proposed Blackwater Gold Project
RB	Rainbow trout
RSA	Regional Study Area
SEFA	System for Environmental Flow Analysis
SZF	stage of zero flow
TSF	tailings storage facility
VDF	velocity distribution factor
WMN	watershed model nodes
WUA	weighted usable area (synonymous with area weighted suitability)

EXECUTIVE SUMMARY

Potential changes in stream flows in Davidson Creek, Creek 661, Chedakuz Creek, and Creek 705 may result from water diversions, alteration of watershed areas (and subsequent run-off volumes), and capture of run-off by various infrastructure components required for the Blackwater Project (the Project). These project components include:

- Construction of the Tailing Storage Facility (TSF) in Davidson Creek. This TSF will capture all Davidson Creek flows upstream of the TSF dam. This will reduce the Davidson Creek Watershed area reporting to its confluence with Chedakuz Creek from 76 km^2 to 32 km^2 with a commensurate reduction in stream flow.
- Construction of the TSF, spillway channel, waste rock dumps and camp infrastructure in the upper reaches of the Creek 661 watershed. This project infrastructure will reduce the Creek 661 watershed from 56 km^2 to 50 km^2 at its confluence with Chedakuz Creek upstream of Tatelkuz Lake and reduce downstream flows in Creek 661 as a result.
- Diversion of Lake 01628LNRS, the headwater lake of Davidson Creek, to Lake 01538UEUT, one of the two headwater lakes of Creek 705. This will divert run-off from approximately 3 km^2 of upper Davidson Creek to Creek 705, increasing its watershed area from 45 km^2 prior to diversion to approximately 48 km^2 after diversion and increase flows in Creek 705.

An instream flow study (IFS) was conducted to assess the potential for flow changes to affect fish and fish habitat in these streams. The study was designed to provide a quantitative analysis of anticipated effects by predicting hydraulic conditions important for fish (i.e., stream depth, width, and water velocity) during different phases of the Project and by comparing the subsequent changes in *area weighted suitability* (AWS) to baseline over a 15-year time series of flows. AWS, expressed in metres squared, was calculated by applying species and life-stage specific *habitat suitability curves* (HSCs) to the hydraulic conditions predicted by the hydraulic habitat models, over the modelled stream sections and predicted flow time series. This was done for each project phase: construction, operations, closure, and post-closure.

Any change in the 15-year AWS time series greater than 10% was considered to be a potential residual adverse effect to rainbow trout and kokanee, the two numerically dominant fish species in the Project area. Unmitigated flows were modeled in Davidson Creek and Chedakuz Creek to show the duration and magnitude of potential adverse effects due to unmitigated flow reductions on fish and fish habitat and to show the likely effectiveness of proposed mitigation measures.

The approach used for the IFS was based on BC instream flow assessment methods. These methods are similar to, and supported by, the habitat component of the Instream Flow Incremental Methodology (IFIM). 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.

Field data were collected for the IFS models in Davidson Creek, Creek 661, Chedakuz Creek and Creek 705 during the open water seasons of 2011, 2012 and 2013. A total of 103 transects

were established and repeatedly measured over different flows to develop calibrated hydraulic habitat relationships for seven modelled sections:

- middle Davidson Creek (immediately downstream of the TSF)
- lower Davidson Creek (further downstream of the TSF and nearer the confluence with Chedakuz Creek);
- Chedakuz Creek downstream of the Davidson Creek confluence;
- Chedakuz Creek upstream of the Davidson Creek confluence (and immediately downstream of Tatelkuz Lake);
- lower Creek 661;
- lower Creek 705; and
- middle Creek 705.

Each of these sections represented a unique hydro-geomorphic section with relatively homogenous morphology, gradient, substrates, and discharge. The sections were selected because of their downstream proximity to flow-altering mine infrastructure and their use by rainbow trout for spawning and rearing and, in the cases of lower Davidson Creek, lower Creek 661, and Chedakuz Creek, by kokanee for spawning.

IFS analyses were completed for five biologically relevant time periods or stanzas. These stanzas represented the stream-resident life stages for rainbow trout and kokanee and included:

- spawning and egg incubation for kokanee;
- spawning and egg incubation for rainbow trout;
- rearing for rainbow trout fry;
- rearing for juvenile rainbow trout; and
- overwintering for juvenile rainbow trout.

Predictions from the IFS models in Creek 661 and Creek 705 indicated that, without mitigation, Project-related changes to stream flows would result in less than 10% changes in the 15-year AWS time series for rainbow trout or kokanee life stages compared to baseline. No significant adverse effects to rainbow trout or kokanee in either stream was anticipated during any Project phase due to these relatively small changes in AWS. Although not significant, the predicted flow reduction in Creek 661 and the predicted flow increase in Creek 705 would potentially result in more suitable habitat for some life stages and less suitable habitat for other life stages.

Predictions from the IFS model in Davidson Creek indicated that, without mitigation, the following reductions in the 15-year AWS time series for rainbow trout and kokanee would occur:

- Up to 61% reduction in kokanee spawning habitat;
- Up to 83% reduction in rainbow trout spawning habitat;
- 12% - 30% reduction in rainbow trout fry habitat in summer and fall; and,
- 46% - 75% reduction in rainbow trout juvenile habitat in spring, summer, and fall.

Because these reductions are greater than the 10% effect threshold, significant adverse effects to rainbow trout and kokanee are assumed to occur in absence of mitigation. These effects are unacceptable due to the value or rainbow trout and kokanee to local recreational and Aboriginal fisheries. As a result, mitigation in the form of pumping water from Tatelkuz Lake via a Freshwater Supply System (FSS) is required to provide flows protective of both species in Davidson Creek.

Instream flow needs (IFN) protective of rainbow trout and kokanee were defined for Davidson Creek for the biologically relevant stanzas, including juvenile rainbow trout rearing (December 1 to April 30), freshet flushing flows (May 1 to May 15), rainbow trout spawning (May 16 to June 30), kokanee spawning/rainbow trout egg incubation and juvenile rearing (July 1 to August 31), and kokanee egg incubation/juvenile rainbow trout rearing (September 1 to November 30). When met, these IFNs will avoid adverse effects to all stream resident life stages of the two species.

Flows to meet these IFNs will be provided by pumping water (up to 6.56 M m^3/year) from Tatelkuz Lake to Davidson Creek by the FSS. This pumping will be required during operations and closure phases only. The FSS will also supply freshwater requirements in the mill during operations and to the open pit during closure (1.05 M m^3/year). The system, as designed, has sufficient capacity to meet both IFN and these mine site requirements.

Operation of the FSS would cease at the beginning of the post-closure phase. As a result, flow changes relative to baseline would occur solely due to changes to watershed areas and the resulting re-distribution of site run-off at mine closure. These flow changes are predicted to result in >10% reductions in the 15-year AWS time-series for kokanee spawning and egg incubation habitat and juvenile rainbow trout rearing habitat in lower Davidson Creek. Because these potential adverse effects to kokanee and rainbow trout habitat in Davidson Creek occur at the end of the Project, monitoring will be used to determine whether model predictions are correct and if additional water is required to avoid these effects. Monitoring and phased closure of the TSF will provide the opportunity to develop engineering solutions, if required. Habitat offsetting options would be pursued only if no feasible engineering options are available. Contingency options in the current Fisheries Mitigation and Offsetting Plan include restoration of degraded streams in the Nechako River watershed, including Murray and Swanson creeks, two streams identified by local stream keeper groups and First Nations as previously important fish producing streams, and replacement of fish impassable culverts in the Vanderhoof Forest District.

Pumping of water from Tatelkuz Lake to Davidson Creek during operations and closure phases has the potential to create adverse effects to fish using littoral areas of Tatelkuz Lake. Based on simulated a 1:50 year dry conditions during Project operations in Year 17, withdrawals from Tatelkuz Lake would result in no more than an 11 cm reduction in lake levels. This reduction would occur in June when lake water levels are naturally highest, and are not predicted to result in significant adverse effects to littoral habitats for fish in Tatelkuz Lake. Larger percentage reductions in lake levels occur in December through March. However, these reductions are not expected to negatively affect fish in the lake because fish are typically occupying deep-water habitats in winter and not the shallower littoral habitats affected by these lower winter lake levels.

Changes in Chedakuz Creek flows downstream of Tatelkuz Lake due to pumping of water from the lake to Davidson Creek would not result in reductions in the 15-year AWS time series greater than 10%. Therefore, meeting IFN in Davidson Creek will not adversely affect fish or fish habitat in Chedakuz Creek immediately downstream of Tatelkuz Lake.

Monitoring to evaluate the accuracy of hydraulic habitat model predictions, the success of mitigation pumping via the FSS, and the potential effects of flow changes in Project-area streams will be required during the operations and closure periods. This monitoring will need to continue until long-term trends in habitat availability have been confirmed. The mitigation-pumping scheme developed for Davidson Creek is flexible and permits adaptive response to results from monitoring programs.

Conservative assumptions were incorporated into the IFS to reduce inherent uncertainties in hydraulic habitat models, in the interpretation of results for assessment of potentially significant adverse effects, and in setting of instream flow requirements for Davidson Creek. These assumptions included:

1. Predictions from the hydraulic habitat models were interpolated and not extrapolated. This was possible because hydraulic habitat models were calibrated with input data collected over the range of modeled flows;

2. Site-specific modifications of Provincial habitat suitability curves were necessary but limited because the provincial curves were based on more extensive provincial data sets that better represented habitat conditions that fish can use and not just habitats they select in the study-area;

3. Potential changes in flow, and resulting changes in the 15-year AWS time series for rainbow trout and kokanee, were considered over biologically relevant stanzas instead of over individual months or years. This allowed direct analysis of flow changes over all periods affecting annual production and recruitment of rainbow trout and kokanee;

4. The threshold for potential adverse effects to fish was set at a 10% change in AWS. We considered this a high standard of protection, because changes in AWS greater than 10% are typically necessary to cause a detectable population level effect in fish;.

5. Mean annual 30-day low flows were used to represent the habitat bottleneck that defines productivity for each species and life stage during each biological stanza. This is conservative relative to other commonly used flow criteria, such as the mean annual 7-day low flow or the mean annual 7-day low flows for each stanza, because the mean

annual 30-day low flows are higher than these alternatives, and therefore, result in higher IFN and provide greater protection of fish and fish habitat;

6. The final IFN in Davidson Creek for each biological stanza were defined as flow required to provide at least 90% of the baseline habitat at the ean annual 30-day low flow for the stanza, for all rainbow trout and kokanee life stages present. By providing flows for the species and life stage requiring the most flow in each stanza, habitat for all other life stages in the stanza are also protected; and

7. Winter IFN were conservatively defined as mean 30-day low flows in March, the lowest flow month in the historical flow time-series. This is more conservative than the often used 7-day low flow with a 10 year return period (7Q10 flow) because 30-day low flows are higher.

1.0 INTRODUCTION

The proposed Blackwater Gold Project (the Project) will result in flow changes in streams that support fish and other aquatic life. These streams include Davidson Creek, a tributary of Chedakuz Creek entering downstream of Tatelkuz Lake, Creek 661, another Chedakuz Creek tributary entering upstream of Tatelkuz Lake, Chedakuz Creek, and Creek 705, a tributary of Fawnie Creek in an adjacent watershed (Figure 1).

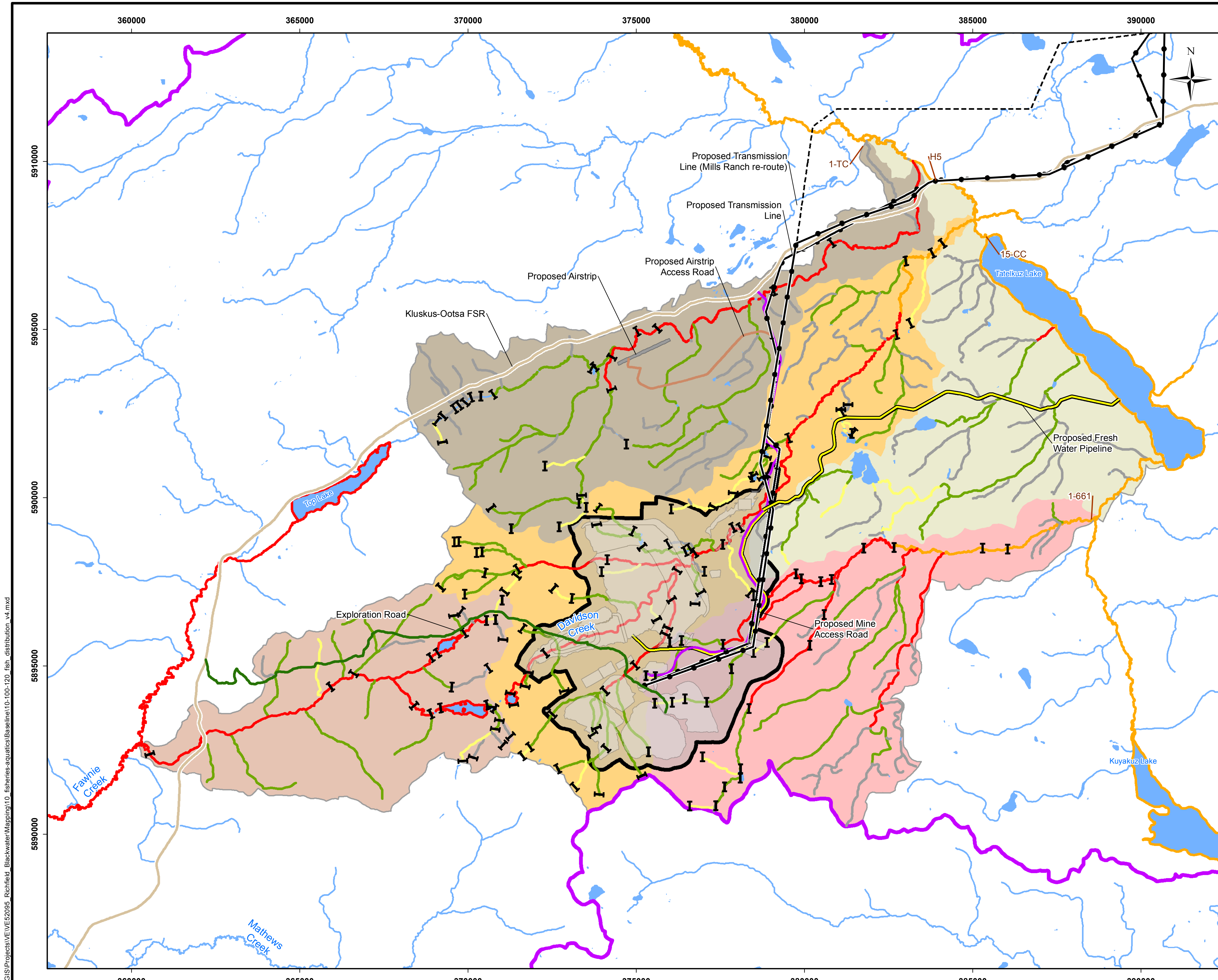
Potential flow reductions may occur in Davidson Creek, Creek 661, and Chedakuz Creek because of water diversions, water withdrawals, and/or reductions in run-off due to capture and storage of water by various Project components. Potential increases in flow may occur in Creek 705 due to proposed enlargement and diversion of the headwater lake of Davidson Creek (Lake 01682LNRS) into Creek 705 to prevent the isolation and potential extirpation of rainbow trout in this lake (see Appendix 5.1.2.6C Fisheries Mitigation and Offset Plan for details). Because of these potential changes in flow and their subsequent effects on fish, an instream flow study (IFS) was conducted to:

1. Assess the potential for flow-related effects on fish and fish habitat in these streams;
2. Determine the need for, and likely effectiveness of, mitigation measures to minimize or eliminate potential flow-related effects in these streams; and
3. Determine instream flow needs (IFN) for Davidson Creek to sustain its use by and productivity for rainbow trout and kokanee, the two most abundant and valued fish species in the aquatics local study area (LSA).

This appendix provides the detailed methods for, and results of, this IFS. It describes the assessment of potential flow changes on fish and fish habitat in the four potentially affected creeks during construction, operations, closure, and post-closure phases of the Project. It does so by comparing model-predicted indices of habitat availability and suitability in these streams 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 unmitigated and mitigated scenarios in Davidson and Chedakuz creeks. The unmitigated operations scenario is provided to show the magnitude of potential adverse effects to fish in the absence of mitigation and is the hypothetical condition in which Davidson Creek flows are those remaining following capture of upstream run-off in the Tailings Storage Facility (TSF). The mitigated operations scenario reflects Davidson Creek flows augmented by pumping water from Tatelkuz Lake via the Freshwater Supply System (FSS). This pumping would continue through the closure phase as various Project components are decommissioned after mining.

The post-closure phase includes restoration of drainage to Davidson Creek when water quality in the TSF meets water quality objectives and is safe to release to the downstream environment. Pumping of water from Tatelkuz Lake to Davidson Creek would cease during this phase of the Project.



Legend

- Reach Break
- Kluskus-Ootsa FSR
- Exploration Road
- Stream (>= 2nd order)
- Waterbody

Project Components

- Proposed Mine Access Road
- Proposed Airstrip Access Road
- Proposed Transmission Line
- Proposed Fresh Water Pipeline
- Proposed Airstrip
- Proposed Site Facilities
- Proposed Mine Site

Fish Distribution

- Known Kokanee and Rainbow Trout Distribution
- Known Rainbow Trout Distribution
- Unconfirmed Rainbow Trout Distribution
- Non Fish-bearing
- No data available

Catchments

- Chedakuz Creek Local
- Creek 661
- Creek 705
- Davidson Creek
- Tatelkuz Lake Tributaries
- Turtle Creek
- Aquatics Regional Study Area

0 0.5 1 2 3 4 5
Kilometres
Scale:1:110,000

Reference
BC Government GeoBC Data Distribution

CLIENT: newgold

PROJECT: Blackwater Gold Project

Fish Distribution

DATE: December, 2013	ANALYST: KA	**Figure 1**
JOB No: VE52277	QA/QC: MY	PDF FILE: 10-100-120_fish_distribution_v4_instream_flow.pdf
GIS FILE: 10-100-120_fish_distribution_v4.mxd		
PROJECTION: UTM Zone 10	DATUM: NAD83	amec

2.0 POTENTIAL PROJECT EFFECTS ON STREAM FLOWS AND LAKE LEVELS

Project infrastructure at the mine site includes:

- an open pit;
- two tailings storage facilities (Site C and Site D);
- two waste rock dumps (East and West);
- a low-grade ore stockpile;
- a plant site;
- a construction lay-down area;
- separate construction and operations camps;
- a sand and gravel screening plant;
- various seepage collection ditches and ponds;
- administrative buildings, warehouses, and a truck shop; and
- explosive storage facilities.

Most of these facilities are located within the headwaters of the Davidson Creek watershed. However, some of these facilities will encroach into the headwaters of the Creek 661 watershed (**Figure 2**). As a result, potential changes in stream flows in Davidson Creek and Creek 661 may occur due to construction, operation, and closure of these mine site facilities.

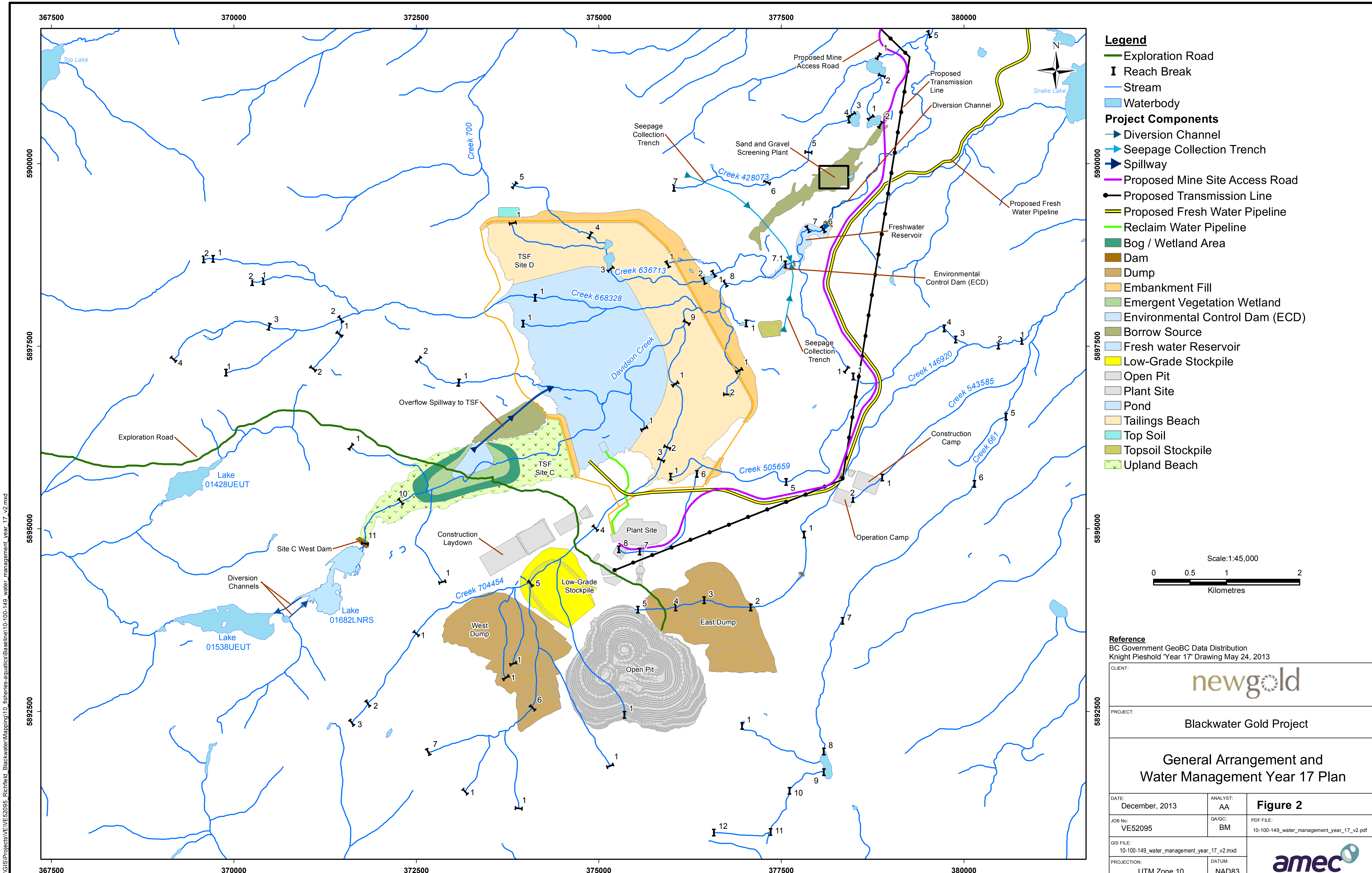
2.1 Davidson Creek

Mine site infrastructure in the Davidson Creek watershed would reduce its watershed area contributing downstream run-off at its confluence with Chedakuz Creek from 76 km^2 to 65 km^2 during the construction phase and to 32 km^2 during the operations phase (**Table 1**). This would include construction of a dam in Reach 9 of Davidson Creek to capture water in the Site D TSF and construction of a dam at the bottom of Reach 7 of Davidson Creek to capture water in the Site C TSF (**Figure 2**). The watershed area in Davidson Creek is reduced because the TSF will be operated as a zero discharge facility during the operations and closure phased of the Project.

Table 1: Changes in Total Watershed Area (km^2) by Project Phase

Watershed	Baseline	Construction	Operations	Closure	Post Closure
Davidson Creek	76.2	64.7	31.9	34.8	79.5
Chedakuz Creek[1]	593	590	590	590	590
Creek 661	56.3	55.6	51.3	50.1	50.1
Creek 705	45.3	47.9	47.9	47.9	47.9

Note: [1] Chedakuz Creek Watershed area reported at Hydrology Node H5, downstream of the project. Refer to **Figure 3** (in **Section 3** following).



Legend
Exploration Road
Reach Break
Stream
Waterbody
Project Components
Diversion Channel
Seepage Collection Trench
Spillway
Proposed Mine Site Access Road
Proposed Transmission Line
Proposed Fresh Water Pipeline
Reclaim Water Pipeline
Bog / Wetland Area
Dam
Dump
Embankment Fill
Emergent Vegetation Wetland
Environmental Control Dam (ECD)
Borrow Source
Fresh water Reservoir
Low-Grade Stockpile
Open Pit
Plant Site
Pond
Tailings Beach
Top Soil
Topsoil Stockpile
Upland Beach
Scale:1:45,000
0 0.5 1 2
Kilometres
Reference
BC Government GeoBC Data Distribution
Knight Piesold 'Year 17' Drawing May 24, 2013
CLIENT:
newgold
PROJECT:
Blackwater Gold Project
General Arrangement and
Water Management Year 17 Plan
DATE: December, 2013
ANALYST: AA
Figure 2
JOB No: VE52095
QA/QC: BM
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GIS FILE: 10-100-149_water_management_year_17_v2.mxd
PROJECTION: UTM Zone 10
DATUM: NAD83
amec
Y:\GIS\Projects\VE\VE52095_Richfield_Blackwater\Mapping\10_fisheries-aquatics\Baseline\10-100-149_water_management_year_17_v2.mxd
367500
370000
372500
375000
377500
380000
5900000
5897500
5895000
5892500
Top Lake
Snake Lake
Proposed Mine Access Road
Proposed Transmission Line
Diversion Channel
Seepage Collection Trench
Sand and Gravel Screening Plant
Creek 428073
Creek 700
Proposed Fresh Water Pipeline
Freshwater Reservoir
Environmental Control Dam (ECD)
TSF Site D
Creek 636713
Creek 668328
Davidson Creek
Seepage Collection Trench
Creek 146920
Creek 543585
Overflow Spillway to TSF
Exploration Road
Construction Camp
Creek 661
Creek 505659
TSF Site C
Lake 01428UEUT
Operation Camp
Site C West Dam
Construction Laydown
Plant Site
Diversion Channels
Creek 704454
Low-Grade Stockpile
Lake 01682LNRS
Lake 01538UEUT
West Dump
East Dump
Open Pit

The reductions in watershed area shown in **Table 1** are reasonable proxies for the potential flow reductions that would occur in middle and lower Davidson Creek without mitigation. Such significant reductions in stream flows would likely have significant adverse effects on rainbow trout and kokanee that use the lower reaches of Davidson Creek (Reaches 1 to 6 below the Site C TSF) for spawning, rearing, and overwintering in the case of rainbow trout and spawning in the case of kokanee. For this reason, mitigation measures have been included in the Project design to avoid or minimize these effects in Davidson Creek during all phases of the Project:

- During construction, all run-off will be diverted around construction sites back to Davidson Creek by coffer dams, diversion channels or pumps;
- A Freshwater Supply System (FSS) will be used to augment flows in middle and lower Davidson Creek by pumping water from Tatelkuz Lake as soon as construction of the TSF Site D dam is completed and beginning to store upstream run-off; and
- Operation of the FSS will continue throughout construction of the Site C TSF and throughout the operation and closure phases of the Project. The FSS will also provide make-up water for the processing plant and any additional water needed to fully submerge Potentially Acid Generating (PAG) waste rock in the TSFs during mine operations.

The Davidson Creek watershed area would increase during the post-closure phase when drainage from the TSF to Davidson Creek is restored and the portion of the adjacent Creek 661 watershed previously diverted into the TSF reports to Davidson Creek. The enlargement and diversion of Lake 01682LNRS into Creek 705 would remain in place at post closure.

2.2 Creek 661

Construction of camps, administrative buildings, the East Waste Rock dump, and a portion of the Site C TSF in the Creek 661 watershed would reduce its watershed area from 56 km^2 to 55 km^2 during the construction phase, to 51 km^2 during the operations phase, and to 50 km^2 during the closure and post-closure phases (**Table 1**). These reductions in watershed area and subsequent reductions in run-off volumes reporting to Creek 661 have the potential to affect rainbow trout and kokanee that spawn in the lower three reaches of Creek 661. Rainbow trout are also use habitat higher up in the Creek 661 watershed for spawning, rearing, and foraging. These include Reaches 4 and 5 of Creek 661 as well as the lower reaches of three of its headwater tributaries (Creek 543585, Creek 146920, and Creek 505659).

Besides limiting the amount of mine site infrastructure built in the Creek 661 watershed, no other mitigation measure is proposed to minimize potential flow reductions in Creek 661 or any of the fish-bearing tributaries that would be under or downstream of mine site infrastructure. Thus, potential flow reductions in headwater creeks and in the Creek 661 mainstem could occur during all phases of the Project as various components of the mine site infrastructure are built and operated within the Creek 661 watershed.

2.3 Chedakuz Creek

Potential flow changes may occur in different reaches of Chedakuz Creek during different phases of the Project. This is because of anticipated flow alterations in Davidson Creek, in Creek 661, and because of water withdrawals from Tatelkuz Lake. Overall, the watershed area of Chedakuz Creek downstream of its confluence with Davidson Creek would decrease by 3 km^2 following diversion of Lake 01628LNRS to Creek 705 (**Table 1**). Creek 705 is a tributary to Fawnie Creek not Chedakuz Creek. Therefore, diversion of water from Lake 01628LNRS to Creek 705 would result in permanent loss of this run-off to Chedakuz Creek.

Flow reductions in Chedakuz Creek in the reach between the outlet of Tatelkuz Lake and the confluence with Davidson Creek (**Figure 1**) would occur if FSS water withdrawals from Tatelkuz Lake were large enough to lower the lake water level such that outflows to Chedakuz Creek were also reduced. Rainbow trout, kokanee, mountain whitefish, and longnose suckers spawn and rear in this reach of Chedakuz Creek so any significant reductions in flow, particularly during the spring and fall spawning periods, could have adverse effects on these fish populations.

2.4 Tatelkuz Lake

Water withdrawals from Tatelkuz Lake to augment flows in Davidson Creek during mine operations and closure have the potential to lower lake levels below those that would naturally occur without operation of the FSS. Depending on the magnitude of draw-down, the time of year, and climatic conditions during the year (i.e., 1:50 wet, 1:50 dry), lake levels in Tatelkuz Lake may fall within the range of natural variability or, in severe dry years, below the lower bounds of the natural lake level range.

Any additional draw-down of Tatelkuz Lake beyond the natural intra-year and inter-year low water level has the potential to expose more littoral area than would naturally occur without withdrawals. Areas of greatest exposure would be along the shallow, low gradient littoral areas at the north and south ends of Tatelkuz Lake.

Fish species in Tatelkuz Lake that use littoral areas for foraging or juvenile rearing include mountain whitefish, rainbow trout, brassy minnow, burbot, longnose sucker, northern pikeminnow and slimy sculpin. Kokanee and mountain whitefish are species that may use exposed rocky lake shorelines to spawn, but lake spawning in Tatelkuz Lake has not been documented to date. If lake spawning does occur, these habitats are limited to the steep-sided eastern and western shorelines, which would be less affected by any draw-down caused by FSS operation than would be the sandier, weedier northern and southern shorelines. However, any draw-down beyond the natural lake level range has the potential to decrease availability of foraging, rearing, and potentially spawning habitat for the Tatelkuz Lake fish community.

2.5 Creek 705

Enlargement and diversion of Lake 01628LNRS in the headwaters of Davidson Creek to Lake 01538UEUT in the headwaters of Creek 705 is required to mitigate the potential isolation and extirpation of its resident rainbow trout population (see Appendix 5.1.2.6C Fisheries Mitigation and Offset Plan for details). This diversion will increase the watershed area of Creek 705 from 45 km^2 to 48 km^2 (Table 1). Flows in Creek 705 will increase as a result of this change in watershed area and the associated increase in run-off. Additional flows may benefit rainbow trout spawning, rearing, and overwintering in Creek 705 by alleviating potentially stressful conditions during summer and winter low flow periods. However, increased flows, particularly during the spring freshet, have the potential to adversely affect rainbow trout and other aquatic organisms in Creek 705 by increasing erosion and downstream sedimentation and by creating hydraulic conditions that may reduce the suitability of habitat for spawning and rearing.

3.0 METHODS

3.1 Approach

The hydraulic habitat component of the Instream Flow Incremental Methodology (IFIM) (Bovee 1982, Bovee et al., 1998) was used in this IFS to predict the effect of flow changes on fish habitat in all four study streams. It was also used to set minimum instream flow needs (IFN) in Davidson Creek.

This approach was 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 the 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 curves (HSCs) 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 used the *System for Environmental Flow Analysis* (SEFA) software (Payne and Jowett, 2013) which is the current state-of-the-science. 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 rainbow trout and kokanee, the two valued component (VC) fish species identified for the fish component of the Environmental Assessment (**Section 5.3.9**). These two species represented 99% of fish captures during baseline surveys conducted in the LSA and are valued fish species in recreational and Aboriginal fisheries in the Project area. HSCs for rainbow trout and kokanee were obtained from the BC Ministry of Environment (R. Ptolemy, pers. comm.). The Provincial curves were based on extensive, province-wide sampling efforts, and were validated with site-specific data collected within the LSA.

Flow data to support the IFS analyses was obtained from a Project watershed model developed by Knight Piésold (**EA Appendix 5.1.2.1B**). The model provides a time series of flows for baseline conditions and for each Project phase at locations relevant to the IFS. The locations for which flow estimates are available are termed watershed model nodes (WMN).

3.2 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 potentially affected fish species and life stage 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 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 hydro-geomorphic sections were identified in each creek based on detailed habitat mapping using *Reconnaissance Level (1:20,000) Fish and Fish Habitat Inventories* (FFHI) (Resources Inventory Standards Committee, 2001) and stream surveys following the *Fish*

Habitat Assessment Procedures (FHAP) (Johnson and Slaney, 1996). Hydro-geomorphic sections were further subdivided into three meso-habitats (i.e., glides, pools, riffles) using the FFHI and FHAP datasets. Characteristics defined by Johnson and Slaney (1996) were used to identify and map the distribution of glide, riffle and pool meso-habitats in each potentially affected stream (**EA Appendix 5.1.2.6A**).

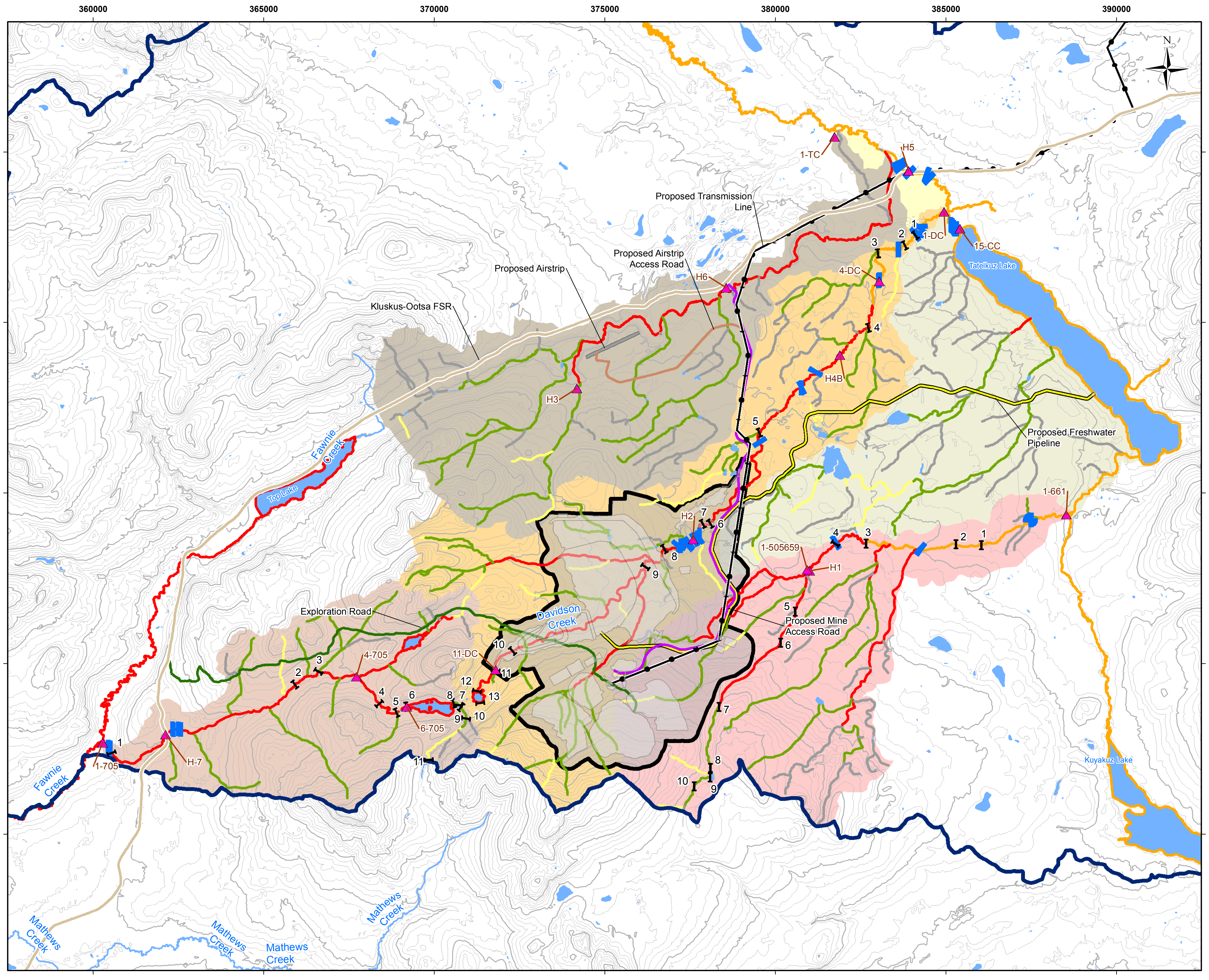
Transects were established in each of these three meso-habitat types in each hydro-geomorphic section to collect the data required for the development and calibration of hydraulic habitat models. Detailed channel cross-section, water surface elevation, substrate composition, and vertical depth and water 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.

3.2.1 Davidson Creek

Two hydro-geomorphic sections were delineated in Davidson Creek (**Figure 3**): one in lower Davidson Creek (i.e., reaches 1 to 4) near the confluence with Chedakuz Creek and one in middle Davidson Creek (i.e., reaches 5 to 6) immediately downstream of the proposed TSF. Two separate hydraulic habitat models were developed in SEFA for Davidson Creek as a result.

Habitat in the Lower Davidson Creek hydro-geomorphic section is characterized by riffle-pool morphology with abundant gravel substrates, stable banks, deep pools and cover provided by overhanging vegetation and large woody debris. As a result, habitat in this section provides good spawning habitat for rainbow trout and kokanee and high-quality rearing habitat for juvenile rainbow trout. A total of 18 transects were established in lower Davidson Creek: eight in glides, five in riffles, and five in pools (**Table 3**). Glide habitats were sampled to ensure adequate characterization of the type of habitat preferentially used by kokanee for spawning. The lower Davidson Creek section was 5,985 metres (m) long, with mean annual discharge (MAD) of approximately 0.369 metres cubed per second (m^3/s) at the upstream end (WMN 4-DC; **Figure 3**) and approximately 0.403 m^3/s at the downstream end, just upstream of the confluence of Davidson Creek with Chedakuz Creek (WMN 1-DC).

Habitat in the Middle Davidson Creek hydro-geomorphic section is characterized by riffle and glide habitat with fewer pools than in the lower section of the creek. Substrates in this middle section are characterized by a mixture of cobbles and boulders with spawning gravels present in isolated pockets. This middle section provides good quality spawning and rearing habitat for rainbow trout. However, kokanee do not migrate this high up Davidson Creek to spawn and habitat use is limited to rainbow trout. A total of 23 transects were established in middle Davidson Creek: eight in glides, nine in riffles, and six in pools (**Table 4**). The modelled stream length for the middle Davidson Creek section, downstream of Project facilities, was 7,642 m. MAD was approximately 0.281 m^3/s at the upstream end (WMN H2; **Table 2**; **Figure 3**) and 0.345 m^3/s at the downstream end (WMN H4B) of this section.



Reference
BC Government GeoBC Data Distribution

CLIENT: newgold

PROJECT: Blackwater Gold Project

Instream Flow Overview

DATE: November, 2013	ANALYST: AA	Figure 3
JOB No: VE52277	QA/QC: MY	PDF FILE: 10-100-093_v2_instream_flow_instream_flow.pdf
GIS FILE: 10-100-093_v2_instream_flow.mxd		
PROJECTION: UTM Zone 10	DATUM: NAD83	amec

3.2.2 Lower Chedakuz Creek

Two separate hydro-geomorphic sections were delineated and, therefore, two hydraulic habitat models were developed in Chedakuz Creek downstream of Tatelkuz Lake (**Figure 3**). The first section ("Lower Chedakuz 15-CC") extended 933 metres downstream from the outlet of Tatelkuz Lake to the confluence of Davidson Creek. The second section ("Lower Chedakuz H5") extended approximately 2,860 metres downstream from the confluence with Davidson Creek.

These two sections were necessary to address differences in flow-related effects potentially created upstream and downstream of the Chedakuz Creek/Davidson Creek confluence with and without the FSS. Without the FSS, potential changes in stream flow would occur only in the section of Chedakuz Creek below the Davidson Creek confluence. This is because no effects to Tatelkuz Lake water levels or outflows to Chedakuz Creek would occur under this scenario. With operation of the FSS, potential changes in stream flow would occur in the section of Chedakuz Creek between Tatelkuz Lake and the confluence of Davidson Creek. This is because of the potential for lake level reductions and subsequent reductions in outflow volumes.

Potential changes in the section of Chedakuz Creek downstream of the Davidson Creek confluence could also occur during operation of the FSS. However, these changes would be the result of changes in upstream catchment areas post-closure and not because of pumping of water from the lake to the creek. This is because pumping water from Tatelkuz Lake to Davidson Creek would only change the location where this water ultimately reached Chedakuz Creek from and not the volume of water in the creek.

The hydro-geomorphic section between Tatelkuz Lake and the confluence of Davidson Creek has an average gradient between 0% to 1% and an average bankfull width of approximately 14 m. Abundant gravels provide good quality spawning habitat for rainbow trout and kokanee while deep pools and abundant instream vegetation, under cut banks, and woody debris provide good cover and rearing opportunities for juvenile trout.

Although gradients are slightly higher downstream of Davidson Creek, similar habitat exists in Chedakuz Creek downstream of the Davidson Creek confluence. Again, both rainbow trout and kokanee use this habitat for spawning and/or rearing.

MAD at the Tatelkuz Lake outlet (WMN 15-CC) is 1.727 m^3/s with a watershed area of approximately 395 km^2 (Table 2). MAD at WMN H5, below the confluence with Davidson Creek is 2.525 m^3/s with a watershed area of approximately 593 km^2.

Eight transects were established in the Lower Chedakuz Creek section (15-CC) below Tatelkuz Lake: six in glides, one in a riffle, and one in a pool (**Table 5**). Fourteen transects were established in the Lower Chedakuz section (H5) below Davidson Creek: five in glides, five in riffles, and four in pools (**Table 5**).

3.2.3 Creek 661

A single hydro-geomorphic section was delineated and modelled in Creek 661. This section extended from the confluence of the Creek 661 mainstem with Creek 505659, one of its headwater tributaries, downstream to the confluence of Creek 661 with Chedakuz Creek upstream of Tatelkuz Lake (**Figure 3**).

Watershed model nodes are located in each of Creek 661 and Creek 505659 immediately upstream of their confluence (WMN 1-505659 and WMN H1). To simplify nomenclature, the sum of flows at these two nodes, which is the flow relevant to the IFS, is hereafter referred to as WMN H+. MAD at WMN H+ at the upstream end of this section is 0.105 m^3/s (**Table 2**). MAD at the confluence of Creek 661 with middle Chedakuz Creek is 0.283 m^3/s (WMN 1-661).

Habitat within the modeled section of Creek 661 is laterally stable with riffle-pool morphology, good cover, and high habitat complexity due to the presence of undercut banks, overhanging vegetation, and abundant small and large woody debris. High quality spawning gravels in the lower 7,525 metres of Creek 661 (Reaches 1 to 3) provide good spawning habitat for kokanee and rainbow trout. Kokanee do not migrate further upstream than the top of Reach 3 to spawn. Habitat in the upper 2,330 metres of the modeled section is only used by rainbow trout.

A total of 17 transects were established in Creek 661 for the SEFA model: six in glides, six in riffles, and five in pools (**Table 6**).

3.2.4 Creek 705

Two hydro-geomorphic sections were delineated for the IFS in Creek 705. The first was an 816 m long section (Reach 1) extending upstream from the creek’s confluence with Fawnie Creek (**Figure 3**). The second was a 6,775 m long section located at the downstream end of Reach 2 of Creek 705. MAD is 0.258 m^3/s in the lowest hydro-geomorphic section of Creek 705 (WMN 1-705) (**Table 2**). MAD is 0.239 m^3/s in the hydro-geomorphic section located further upstream in Reach 2 (WMN H7).

The channel in Reach 2 of Creek 705 is narrower and steeper than the channel in Reach 1. However, habitat in the two reaches is generally similar. Good quality rainbow trout rearing habitat is present throughout both reaches. Cover is provided by deep pools, overhanging vegetation, boulders and woody debris.

Kokanee do not spawn in Creek 705. However, good quality spawning and rearing habitat for rainbow trout exists in both modeled sections. This is particularly true near the bottom of Reach 1 near the confluence with Fawnie Creek. Spawning habitat quality is more variable moving upstream in the creek and depends on the frequency and abundance of suitably sized gravel substrates.

A total of 10 transects were established in the lower Creek 705 section (WMN 1-705): four in glides, four in riffles, and two in pools (**Table 7**). Thirteen transects were established in the middle Creek 705 section (WMN H7): five in glides, five in riffles, and three in pools.

Even though potential flow increases caused by diversion of Lake 01628LNRS to Creek 705 would be proportionally higher immediately below Lake 01538UEUT than in either of the two modeled sections, hydraulic habitat models were not developed for stream sections immediately downstream of Lake 01538UEUT. These models were not developed because:

1. The physical structure of fish habitat in Creek 705 immediately below the lake precludes the collection of accurate flow data and the development of meaningful instream flow models. Habitat here is characterized by small channel morphology, with large, post-glacial substrates (rather than fluvial substrates found in lower reaches), interspersed with sections of U-shaped channel with depositional fines and organic substrates (**Figure** 4). Discharges in summer are small with water flowing under and around large substrates in riffles and near-zero flows in glides;
2. Hydraulic habitat models do not address any physical changes that may occur to the channel and stream banks as a result of increased flow.

As a result of these constraints, only a qualitative field assessment of the potential for flow-related effects in Reach 4 of Creek 705 (the outlet of Lake 01538UEUT) was completed. Results of this analysis are presented in the Fisheries Mitigation and Offsetting Plan (**EA Appendix 5.1.2.6C**).

Figure 4: Habitat in Creek 705 downstream of Lake 01538UEUT showing large post-glacial substrates in riffle sections (left) and U-shaped channel in glide sections (right).

Table 2: Mean Monthly Flows and MAD for Selected WMN

Month	Davidson Creek					Chedakuz Creek		Creek 661				Creek 705			
	11-DC	**H2**	**H4B**	**4-DC**	**1-DC**	**15-CC**	**H5**	**H1**	**1-505659**	**H+**	**1-661**	**6-705**	**4-705**	**H7**	**1-705**
January	0	0.133	0.168	0.174	0.203	0.954	1.434	0.006	0.012	0.018	0.097	0.002	0.005	0.027	0.041
February	0	0.123	0.152	0.156	0.185	0.942	1.416	0.004	0.009	0.013	0.085	0.001	0.002	0.017	0.030
March	0	0.115	0.145	0.155	0.184	1.071	1.609	0.003	0.008	0.011	0.082	0.001	0.001	0.016	0.031
April	0.008	0.204	0.297	0.362	0.404	2.027	3.047	0.020	0.060	0.080	0.293	0.018	0.074	0.252	0.282
May	0.049	0.816	0.964	1.053	1.104	4.301	6.464	0.117	0.289	0.406	0.934	0.130	0.437	1.181	1.218
June	0.046	0.834	0.949	0.991	1.033	3.913	5.880	0.122	0.275	0.397	0.852	0.075	0.238	0.670	0.694
July	0.011	0.318	0.391	0.406	0.441	1.811	2.721	0.038	0.089	0.126	0.307	0.029	0.085	0.222	0.239
August	0.003	0.191	0.246	0.254	0.286	1.070	1.607	0.016	0.036	0.053	0.162	0.012	0.033	0.100	0.114
September	0.001	0.163	0.210	0.216	0.247	1.123	1.688	0.011	0.026	0.037	0.134	0.009	0.023	0.080	0.094
October	0.002	0.166	0.215	0.229	0.260	1.106	1.662	0.011	0.037	0.049	0.169	0.012	0.038	0.131	0.146
November	0.002	0.160	0.210	0.227	0.258	1.341	2.015	0.011	0.034	0.044	0.164	0.010	0.033	0.116	0.132
December	0	0.141	0.183	0.192	0.223	1.066	1.602	0.008	0.017	0.025	0.114	0.004	0.011	0.046	0.061
Annual Average	0.010	0.281	0.345	0.369	0.403	1.727	2.595	0.031	0.075	0.105	0.283	0.025	0.082	0.239	0.258

Note: All flows in m^3/s. WMN H+ is a calculated node at the confluence of Creek 661 with Creek 505659 and is the sum of WMN H1 and WMN 1-505659. WMN locations presented in **Figure 3**.

Table 3: Instream Flow Transect Summary for Lower Davidson Creek

Stream Section	Stream Reach	Transect Name	Habitat Unit	Total Surveys	Aug-2011	Oct-2011	May-2012	Jul-2012	Aug-2012	Sep-2012	Oct-2012	May-2013	Jun-2013
Lower	1	1-DC-1.1	Pool	**4**			√	√	√	√			
Lower	1	1-DC-1.2	Glide	**6**	√		√	√	√	√	√		
Lower	1	1-DC-1.3	Riffle	**4**			√	√	√	√			
Lower	1	1-DC-02	Glide	**5**	√			√	√	√			√
Lower	1	1-DC-3.1	Riffle	**4**			√	√	√	√			
Lower	1	1-DC-3.2	Glide	**4**			√	√	√	√			
Lower	1	1-DC-3.3	Pool	**4**			√	√	√	√			
Lower	1	1-DC-04	Glide	**5**	√			√	√	√			√
Lower	1	1-DC-05	Glide	**5**	√			√	√	√			√
Lower	3	3-DC-1.1	Glide	**6**	√	√		√	√	√			√
Lower	3	3-DC-1.2	Pool	**4**		√		√	√	√			
Lower	3	3-DC-1.3	Riffle	**5**		√		√	√	√			√
Lower	4	4-DC-1.1	Riffle	**5**		√		√	√	√			√
Lower	4	4-DC-1.2	Glide	**5**		√		√	√	√			√
Lower	4	4-DC-1.3	Pool	**5**		√		√	√	√			√
Lower	4	4-DC-2.1	Glide	**5**		√		√	√	√			√
Lower	4	4-DC-2.2	Pool	**5**		√		√	√	√			√
Lower	4	4-DC-2.3	Riffle	**5**		√		√	√	√			√

Note: √ = field data collected within indicated time period.

Table 4: Instream Flow Transect Summary for Middle Davidson Creek

Stream Section	Stream Reach	Transect Name	Habitat Unit	Total Surveys	Aug-2011	Oct-2011	May-2012	Jul-2012	Aug-2012	Sep-2012	Oct-2012	May-2013	Jun-2013
Middle	5	5-DC-1.1	Riffle	**5**		√		√	√	√			√
Middle	5	5-DC-1.2	Glide	**5**		√		√	√	√			√
Middle	5	5-DC-1.3	Pool	**5**		√		√	√	√			√
Middle	5	5-DC-2.1	Riffle	**5**		√		√	√	√			√
Middle	5	5-DC-2.2	Glide	**5**		√		√	√	√			√
Middle	5	5-DC-2.3	Pool	**5**		√		√	√	√			√
Middle	6	6-DC-1.1	Pool	**5**		√		√	√	√			√
Middle	6	6-DC-1.2	Riffle	**5**		√		√	√	√			√
Middle	6	6-DC-1.3	Glide	**5**		√		√	√	√			√
Middle	7.1	7.1-DC-01	Riffle	**6**	√			√	√	√	√		√
Middle	7.1	7.1-DC-02	Riffle	**6**	√			√	√	√	√		√
Middle	7.1	7.1-DC-3.1	Pool	**6**		√		√	√	√	√		√
Middle	7.1	7.1-DC-3.2	Riffle	**7**	√	√		√	√	√	√		√
Middle	7.1	7.1-DC-05	Riffle	**6**	√			√	√	√	√		√
Middle	8	8-DC-01	Glide	**6**	√			√	√	√	√		√
Middle	8	8-DC-2.1	Pool	**6**		√		√	√	√	√		√
Middle	8	8-DC-2.2	Riffle	**6**		√		√	√	√	√		
Middle	8	8-DC-2.3	Glide	**7**	√	√		√	√	√	√		√
Middle	8	8-DC-3.1	Riffle	**6**		√		√	√	√	√		√
Middle	8	8-DC-3.2	Glide	**7**	√	√		√	√	√	√		√
Middle	8	8-DC-3.3	Pool	**6**		√		√	√	√	√		√
Middle	8	8-DC-04	Glide	**6**	√			√	√	√	√		√
Middle	8	8-DC-05	Glide	**6**	√			√	√	√	√		√

Table 5: Instream Flow Transect Summary for Chedakuz Creek

Stream Section	Stream Reach	Transect Name	Habitat Unit	Total Surveys	Nov-2011	May-2012	Jul-2012	Aug-2012	Sep-2012	Oct-2012	May-2013	Jul-2013	Aug-2013	Sep-2013
H5	14	LCC-1.1	Riffle	**4**			√	√	√	√				
H5	14	LCC-1.2	Glide	**4**			√	√	√	√				
H5	14	LCC-2.1	Riffle	**4**			√	√	√	√				
H5	14	LCC-2.2	Glide	**4**			√	√	√	√				
H5	14	LCC-2.3	Pool	**4**			√	√	√	√				
H5	15	LCC-3.1	Riffle	**4**			√	√	√	√				
H5	15	LCC-3.2	Glide	**5**	√		√	√	√	√				
H5	15	LCC-3.3	Pool	**4**			√	√	√	√				
H5	15	LCC-4.1	Riffle	**4**			√	√	√	√				
H5	15	LCC-4.2	Glide	**5**	√		√	√	√	√				
H5	15	LCC-4.3	Pool	**4**			√	√	√	√				
H5	15	LCC-5.1	Riffle	**4**			√	√	√	√				
H5	15	LCC-5.2	Glide	**5**	√		√	√	√	√				
H5	15	LCC-5.3	Pool	**4**			√	√	√	√				
15-CC	15	C1T1-G	Glide	**4**							√	√	√	√
15-CC	15	C1T2-G	Glide	**4**							√	√	√	√
15-CC	15	C1T3-G	Glide	**4**							√	√	√	√
15-CC	15	C1T4-R	Riffle	**4**							√	√	√	√
15-CC	15	C1T5-G	Glide	**4**							√	√	√	√
15-CC	15	C1T6-P	Pool	**4**							√	√	√	√
15-CC	15	C1T7-G	Glide	**4**							√	√	√	√
15-CC	15	C1T8-G	Glide	**4**							√	√	√	√

Note: √ = field data collected within indicated time period.

Table 6: Instream Flow Transect Summary for Creek 661

Stream Section	Stream Reach	Transect Name	Habitat Unit	Total Surveys	Jul-2012	Aug-2012	Sep-2012
Lower	1	1-661-1.1	Glide	**3**	√	√	√
Lower	1	1-661-1.2	Pool	**3**	√	√	√
Lower	1	1-661-1.3	Riffle	**3**	√	√	√
Lower	1	1-661-1.4	Glide	**3**	√	√	√
Lower	1	1-661-1.5	Pool	**3**	√	√	√
Lower	1	1-661-1.6	Riffle	**3**	√	√	√
Middle	3	3-661-2.1	Glide	**3**	√	√	√
Middle	3	3-661-2.2	Riffle	**3**	√	√	√
Middle	3	3-661-2.3	Pool	**3**	√	√	√
Middle	3	3-661-2.4	Pool	**3**	√	√	√
Middle	3	3-661-2.5	Glide	**3**	√	√	√
Middle	3	3-661-2.6	Riffle	**3**	√	√	√
Upper	4	4-661-3.1	Riffle	**3**	√	√	√
Upper	4	4-661-3.2	Pool		Abandoned	-	-
Upper	4	4-661-3.3	Pool	**3**	√	√	√
Upper	4	4-661-3.4	Glide	**3**	√	√	√
Upper	4	4-661-3.5	Glide	**3**	√	√	√
Upper	4	4-661-3.6	Riffle	**3**	√	√	√

Note: √ = field data collected within indicated time period.

Table 7: Instream Flow Transect Summary for Creek 705

Stream Section	Stream Reach	Transect Name	Habitat Unit	Total Surveys	May-2013	Jul-2013	Aug-2013
Lower	1	T14-R	Riffle	**3**	√	√	√
Lower	1	T15-G	Glide	**3**	√	√	√
Lower	1	T16-P	Pool	**3**	√	√	√
Lower	1	T17-R	Riffle	**3**	√	√	√
Lower	1	T18-R	Riffle	**3**	√	√	√
Lower	1	T19-G	Glide	**3**	√	√	√
Lower	1	T20-P	Pool	**3**	√	√	√
Lower	1	T21-R	Riffle	**3**	√	√	√
Lower	1	T22-G	Glide	**3**	√	√	√
Lower	1	T23-G	Glide	**3**	√	√	√
Middle	2	T1-G	Glide	**4**	√√	√	√
Middle	2	T2-R	Riffle	**4**	√√	√	√
Middle	2	T3-G	Glide	**4**	√√	√	√
Middle	2	T4-P	Pool	**4**	√√	√	√
Middle	2	T5-G	Glide	**4**	√√	√	√
Middle	2	T6-P	Pool	**4**	√√	√	√
Middle	2	T7-R	Riffle	**4**	√√	√	√
Middle	2	T8-P	Pool	**4**	√√	√	√
Middle	2	T9-R	Riffle	**4**	√√	√	√
Middle	2	T10-C	Riffle	**4**	√√	√	√
Middle	2	T11-G	Glide	**4**	√√	√	√
Middle	2	T12-G	Glide	**4**	√√	√	√
Middle	2	T13-R	Riffle	**4**	√√	√	√

Note: √ = field data collected within indicated time period. Double mark indicates two separate visits within time period.

3.3 Field Methods

3.3.1 Verification of Habitat Suitability Curves

The HSCs applied for rainbow trout spawning, fry rearing and juvenile rearing, and for kokanee spawning were based on BC provincial curves (R. Ptolemy, BC Ministry of Environment). To validate provincial curves, depth, velocity, and substrate associations were collected for a sample of fish captured or observed in Davidson Creek, Creek 661, and Creek 705. To ensure consistency, depth, water velocity and substrate data were collected using the same methods used to develop the provincial curves (R. Ptolemy, BC Ministry of Environment, pers. comm.). Mean water column velocities were collected where fish were observed. Substrate composition as percent coverage was recorded using BC-standard substrate categories (RISC, 2001). All of these data were used to confirm that fish habitat use at the Project site was consistent with the provincial HSCs.

3.3.2 Instream Flow Study

Field practices employed for the Project IFS followed the BC IFM guidelines (Lewis et al., 2004) and BC Hydrometric Standards (BC MOE, 2009). Adjustments or additions to these methods were made only to address specific data needs for the unique site conditions or analytical approach employed.

3.3.2.1 Initial Survey Visit

Three benchmarks were established for each meso-habitat transect. Where longitudinal spacing and riparian visibility allowed, a common set of three benchmarks was established for a cluster of adjacent transects. Benchmarks were surveyed to a datum specific to each transect (or cluster of adjacent transects). Staff gauges (3/8" rebar) were installed at all transects and were surveyed to the transect datum. Water surface elevations were measured relative to the top of the staff gauge. Metal posts (3/8" rebar) were used to mark the left and right bank transect end points, which were above the bankfull stream channel.

A channel cross-section was surveyed to the transect datum. The spacing of measurements across each transect was proportional to the channel width but, in most cases, the spacing was 10 cm to 50 cm between survey points. This provided a detailed cross-section of 30 to 50 elevations for each transect cross-section.

As a check on the staff gauge measurement, water surface elevations were surveyed at the water edge on the right and left sides of the channel. Water surface elevations were also surveyed at two points (left and right sides of wetted width) approximately 20 m upstream and 20 m downstream of the transect to determine stream gradient. Where the wetted edge was not visible 20 m upstream or downstream, gradient measurements were obtained with an inclinometer and the distance from the transect recorded.

Water depth and velocity measurements were collected following the BC Hydrometric Standards (BC MOE, 2009). Vertical depth and velocity profiles were collected at no less than 25 points within the wetted width. This ensured that discharge data collected for the IFS met the requirements laid out by regulatory agencies and that flow calculations were based on more than 20 panels across the streams.

Substrate data were collected at these same locations within the wetted width of the stream and at dry locations within the bankfull width. Substrate size classes were consistent with the BC IFM and BC standardized fish habitat assessment methods (RISC, 2001; Johnson and Slaney, 1996). To ensure accurate data for transects installed during high flows or high turbidity, substrate data were re-assessed during subsequent visits when visibility improved.

Each transect was documented with a series of eight photographs as per the BC IFM guidelines. These included photos looking across the transects from the left and right banks, looking upstream and downstream from the transect, and looking at the transect from 20 m upstream and downstream.

3.3.2.2 Calibration Revisits

Hydraulic habitat modelling only required repeated measurement of water surface elevations for each transect. None of the other field data collected during the initial visits was necessary or collected. This method was consistent with SEFA guidelines (Jowett et al., 2013).

Stream discharge was measured at glide transects within each cluster of transects in each hydro-geomorphic section during each visit to each creek. This was done because glides have less turbulent flow than riffles and less stagnant water than pools. More accurate discharge measurements were collected as a result. Discharge for each cluster of transects was calculated as the average discharge in glides near the cluster. A series of standard photographs was collected at each transect during each calibration visit as well.

3.3.2.3 Field Schedule

Initial habitat mapping and transect establishment was completed in August 2011 when meso-habitat types could be easily identified. This timing was consistent with the provincial FHAP guidelines (Johnston and Slaney, 1996). Additional transect installations were completed between October 2011 and May 2012. Establishment of transects was staggered based on sampling priorities and the evolution of Project design.

Wherever possible, data collection for the initial site visit was conducted during high flows. Subsequent data collection for model calibration occurred over the range of flows necessary to calibrate the models and to eliminate extrapolation of model results beyond the constraints of the input data. Dates of the site visits and the flow volumes and percentage of MAD for flows during each visit to each creek are presented in **Annex A**. In summary, initial and calibration visits were conducted on the following dates, at the following locations and flows:

- **Lower Davidson Creek**: seven visits between August 2011 and June 2013 at flows ranging between 29% and 551% of MAD;
- **Middle Davidson Creek**: seven visits between August 2011 and June 2013 at flows ranging between 28% and 605% of MAD;

- **Chedakuz Creek (15-CC)**: four visits between May 2013 and September 2013 at flows ranging between 25% and 292% of MAD;
- **Chedakuz Creek (H5)**: five visits between November 2011 and October 2012 at flows ranging between 37% and 175% of MAD;
- **Creek 661**: three visits between July 2012 and September 2012 at flows ranging between 23% and 62% of MAD;
- **Lower Creek 705**: five visits between May 2013 and August 2013 at flows ranging between 12% and 444% of MAD;
- **Middle Creek 705**: four visits between May 2013 and August 2013 at flows ranging between 6% and 810% of MAD.

This sampling schedule was intentionally focused to provide the greatest model accuracy for the flow changes expected as a result of the Project. For Davidson Creek, Chedakuz Creek, and Creek 661, where the Project will reduce flows, data collection efforts were concentrated during summer low flows rather than spring or fall high flow periods. For Creek 705, where the Project will increase flows, data collection focused on surveying the highest flows practical.

3.3.2.4 Hydrology Input Data

Baseline and predicted Project flows for input into the hydraulic habitat models in SEFA were provided by a watershed model developed and calibrated by Knight Piésold (**EA Appendix 5.1.2.1B**). Input data for this watershed model were collected during field studies between spring 2011 and winter 2013 from seven hydrometric stations within the Project area and from a site-specific climate station operated between July 2011 and December 2012.

Output data from the watershed model were predicted stream discharges in each potentially affected stream on a monthly time step for a 15 year time series. A 15-year monthly flow time series was developed for each of seven scenarios: baseline, construction, unmitigated operations, mitigated operations, unmitigated closure, mitigated closure and post-closure (**EA Appendix 5.1.2.1C**). These data were provided for 15 different WMN relevant to the Project and the IFS (**Figure 3**). Flow predictions at two additional nodes, both in Chedakuz Creek, were developed outside the watershed model using a synthetic long-term stream flow series.

3.4 Analytical Methods

Provincial HSC were verified by comparing curves with a frequency analysis of site-specific data.

Hydraulic habitat models were developed to meet two key objectives: 1) define IFN for Davidson Creek downstream of the TSF; and, 2) evaluate the potential for effects on fish habitat resulting from flow changes in Davidson Creek, Chedakuz Creek, Creek 661, and Creek 705 during construction, operations, closure, and post-closure phases of the Project. Davidson Creek IFN were established using the calibrated hydraulic habitat models. The same models were used to assess potential flow alterations. Potential effects were assessed by comparing the predicted 15-year time-series of "*area weighted suitability*" (AWS) for each rainbow trout and kokanee life stage in each stream during each Project phase to the predicted baseline (i.e., natural, pre-construction) AWS for these same species and life stages over the same 15-year flow period. AWS is an index of available habitat area weighted by suitability for each fish species and life stage considered in the assessment. It is synonymous with the previously used term *weighted useable area* (WUA). However, because WUA is actually a weighted index of suitability, and not an area, the WUA terminology is considered misleading (I. Jowett, T. Payne, pers. comm.) and AWS was used to be more accurate.

Construction phase potential effects were examined for Davidson Creek only. This was because predicted flow changes during construction were highest in Davidson Creek compared to the three other Project area creeks and because predicted flows changes during construction in the other Project area creeks were lower than for the other Project phases.

For the operations and closure phases, both unmitigated and mitigated scenarios were assessed in Davidson Creek and Chedakuz Creek. This was done to show the magnitude and duration of potential unmitigated effects to fish and to show the effectiveness of the proposed mitigation (i.e., the FSS). Operations and closure phases were also assessed for Creek 661 because of subtle changes in water management between these phases. Predicted flow changes in Creek 705 were assessed for the operations phase only. This is because water is diverted from Lake 01682LNRS to Lake 01538UEUT in the operations phase, and because, once diverted, no further Project-related changes to drainage patterns would occur.

Predicted changes in flows were assessed for the post-closure phase in Davidson Creek, Chedakuz Creek, and Creek 661. This is the phase when the mine is decommissioned and the post-mining drainage pattern has been established. This includes the release of water from the TSF to Davidson Creek.

3.4.1 Verification and Calibration of Habitat Suitability Curves

Site-specific depth, water velocity and substrate data at locations where rainbow trout and kokanee were captured or observed were summarized using frequency histograms. These histograms were then compared to the BC provincial HSCs. Where necessary, BC provincial curves were adjusted to reflect local habitat use data.

3.4.2 Development of Hydraulic Habitat Models

Cross-section geometry, water depth, water velocity, substrate composition, and stage/discharge measurements were entered into the SEFA software package. Data quality control and quality assurance checks were performed by reviewing information summaries and plots of the cross-section depths and velocities generated in SEFA.

Stage/discharge rating curves for each cross-section were generated in SEFA using best-fit regression techniques. This was done in a three-step process. First, each rating curve was fit and reviewed. Any water surface elevation data points that appeared to be outliers were identified. Original data sheets examined to correct any data entry errors. Second, flow estimates for the calibration measurements were reviewed. Because study sections did not include significant tributary inputs, flows were assumed to be constant within each section over each day. Third, different forms of the rating curve equation were considered. Both “stage of zero flow” (SZF) rating and hydraulic rating were considered as recommended by Jowett et al. (2013).

The SZF rating is the log-log least squares fit through data points. SZF is either the section minimum or a specified value based on field surveys of the section flow control. SZF is identified according to the formula:

$$\text{Flow} = a * (\text{Stage-SZF})^{b}$$

Where a and b are real numbers.

The hydraulic rating method uses Manning's equation to calculate flow. Flows are calculated for estimated Manning’s N for each measured discharge according to the formula:

$$\text{Flow} = 1/N * A * R^{2/3} * S^{1/2}$$

Where A is cross-section area, R is the hydraulic radius, and S is the stream gradient. For this equation, S was assumed constant within each stream section.

The variation in Manning’s N with flow is calculated according to the equation:

$$N = a * \text{Flow}^{\beta}$$

Where *a* and β are real numbers.

The mean error in discharge (%) and coefficient of determination (R^2) showed the goodness of fit of the rating to the measured discharges. The mean error was the average percentage error in the discharges predicted from the rating and the measured discharges while the coefficient of determination was derived by comparing measured and predicted stages (Jowett et al., 2013). These metrics were used to evaluate the overall fit of each curve for the section. The stage of zero flow (SZF) rating curve was used unless the hydraulic rating curve provided a better fit.

SEFA calculated “velocity distribution factors” (VDFs) at each point along each transect. Similar to Manning’s N for a point measurement, VDFs represent the ratio of measured velocity at a given point to the velocity calculated. They assume uniform flow conditions across a transect and that point velocities are proportional to water conveyances at that point. VDFs are estimated according to the formula:

$$Q = K \times S^{1/2}$$

Where Q is the flow, S the slope, and K the conveyance (Jowett et al., 2013).

VDFs are calculated automatically in SEFA but can be adjusted manually. This is especially useful for streams whose banks are higher than the water level at the time of the survey. By default, these points are given VDF values equal to the nearest measured point in the water. However, changes in vegetation, locations of large wood, and longitudinal geometry may warrant adjustments to the VDFs. Photographs of the banks were used to confirm or adjust VDFs as required.

Once each hydraulic habitat model was calibrated, HSCs were used to translate the flow-based predictions of hydraulic variables into habitat indices. The primary metric of habitat generated by the hydraulic habitat models was AWS. Units of AWS were square metres of habitat per metre of stream channel length (m^2/m).

Curves of habitat (AWS) as a function of flow were developed for each fish species and life stage considered in the assessment:

- Juvenile rainbow trout rearing;
- Juvenile rainbow trout overwintering;
- Adult rainbow trout migration and spawning;
- Rainbow trout egg incubation;
- Kokanee migration and spawning; and
- kokanee egg incubation.

AWS results were multiplied by the length of each modelled section to provide an index of suitable habitat area for comparison of each Project phase to baseline “pre-construction” conditions. These section-based AWS results were calculated by weighting each transect type AWS by the relative occurrence of the meso-habitat in the section. This “habitat mapping” approach used the distribution of meso-habitats determined from FHAP surveys conducted in each stream.

3.4.3 Biological Stanzas

Predictions of AWS were made for “biologically relevant stanzas” defined for the four stream-based life stage of rainbow trout (migration/spawning, egg incubation, juvenile rearing, juvenile overwintering) and two stream-based life stages for kokanee (migration/spawning, egg incubation) present in different Project streams at different times of the year (**Table** 8). These stanzas were based on life history information (**Table 9**) verified during baseline surveys conducted in Davidson Creek in 2011 and 2012 (**EA Appendix 5.1.2.6A**) 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.

Table 8: Biologically Relevant Stanzas in Project Area Streams

Stream	Stanza	Rationale
Davidson Creek	1 December – 30 April	Juvenile overwintering
Creek 661	1 May – 15 May	Freshet flows: substrate scour and cleaning of fine sediments from spawning gravels
	16 May - 30 June	Rainbow trout migration and spawning
	1 July - 31 August	Kokanee spawning, rainbow trout egg incubation and rearing
	1 September - 30 November	Kokanee egg incubation, rainbow trout rearing
Lower Chedakuz Creek	1 December - 1 May	Juvenile overwintering
	1 May – 15 May	Freshet flows: substrate scour and cleaning of fine sediments from spawning gravels
	16 May – 30 June	Rainbow trout migration and spawning
	1 July – 31 July	Rainbow trout egg incubation and rearing
	1 August - 31 September	Kokanee spawning, rainbow trout rearing
	1 October - 30 November	Kokanee egg incubation, rainbow trout rearing
Creek 705	1 December - 1 May	Juvenile overwintering
	1 May – 15 May	Freshet flows: substrate scour and cleaning of fine sediments from spawning gravels
	16 May - 30 June	Rainbow trout migration and spawning
	1 July – 30 November	Rainbow trout egg incubation and rearing

Adult rainbow trout spawn in Project area streams between 15 May and 30 June (**EA Appendix 5.1.2.6A**). Adults return to lakes to forage and overwinter after spawning. In Davidson Creek, adults spend typically less than five days in the stream before returning to Tatelkuz Lake (**EA Appendix 5.1.2.6A**).

Rainbow trout eggs and alevins incubate in the gravel for 4 to 8 weeks (Scott and Crossman 1973). Fry typically emerge from the gravels between 1 June and 15 July. After they emerge, rainbow trout fry disperse to rearing habitat within their natal stream where they grow over the summer. As water temperatures decline in the fall, juveniles move downstream seeking out deep pools and other protected areas to overwinter. Increased day length and warming temperatures in the following spring prompt juveniles to move into areas where conditions are more conducive to growth and survival.

Juvenile rainbow trout appear to spend 1 to 2 years rearing in Project area streams before migrating downstream to nearby lakes. These include Tatelkuz Lake for Davidson Creek, Chedakuz Creek and Creek 661 rainbow trout and Top Lake or Laidman Lake for rainbow trout spawned in Creek 705 (**EA Appendix 5.1.2.6A**).

Kokanee spend most of their lives in Tatelkuz Lake. They migrate to Davidson Creek and Creek 661 to spawn between 15 July and 30 August when flows are low but stable. This is approximately one month earlier than peak spawning in Chedakuz Creek. These earlier runs are presumably due to cooler water temperatures in Davidson Creek and Creek 661 compared to Chedakuz Creek at this time of year (**EA Appendix 5.1.2.6A**). Adult kokanee die after spawning.

Kokanee eggs and embryos remain in the gravel over winter. Fry emerge in late spring and soon migrate to Tatelkuz Lake where they rear for 2 to 3 years before returning to Davidson Creek, Creek 661, or Chedakuz Creek to spawn.

The typical hydrograph of Project area streams is characterized by peak spring flows during late April or early May. These “flushing flows” largely determine the physical structure of the stream channel including maintenance of channel geometry and stream pattern, distribution and downstream transport of sediments, maintenance of riparian vegetation and floodplain connectivity, and, importantly for rainbow trout and kokanee, removal of accumulated sediments in spawning gravels. Biologically, spring freshet flows coincide with increasing water temperatures that cue spawning migrations for adult rainbow trout (Scott and Crossman, 1973).

Following the freshet, flows gradually decline over the summer months. Low flows continue to predominate during the fall with intermittent spikes due to rain events. Lowest flows occur during the winter when freezing temperatures and snowfall limits run-off.

Average baseline (i.e., natural, pre-construction) flows for each relevant biological stanza at each WMN are presented in **Table 10**. As baseline flows are available only on a monthly basis, flows for the 1 to 15 May freshet period are not presented. Instead, average baseline flows during the spring rainbow trout migration and spawning period are based on 1 May to 30 June data. Flows during April are highly variable due to differences in the onset of breakup and spring freshet. To address this, April flows were excluded from the calculation of mean flows for the juvenile rainbow trout overwintering stanza. This was considered appropriately conservative given the duration of this stanza and the effect of removing higher flow data from a low flow period.

Table 9: Species, Life History, and Periodicity for Project Area Streams

Species	Life history/behavior	Jan				Feb				Mar				Apr				May				Jun				Jul				Aug				Sep				Oct				Nov				Dec			
Rainbow Trout (DC, 661, 705)	Juvenile overwintering	x	x	x	x	x	x	x	x	x	x	x	x	x	x																															x	x	x	x
	Juvenile rearing															x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
	Juvenile migration																							x	x	x	x	x	x	x	x	x	x	x	x														
	Adult migration + spawning																			x	x	x	x	x	x																								
	Egg incubation																					x	x	x	x	x	x	x	x	x	x																		
Rainbow Trout (LCC)	Overwintering	x	x	x	x	x	x	x	x	x	x	x	x	x	x																															x	x	x	x
	Rearing															x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
	Juvenile migration																							x	x	x	x	x	x	x	x	x	x	x	x														
	Adult migration + spawning																			x	x	x	x	x	x																								
	Egg incubation																					x	x	x	x	x	x	x	x	x	x																		
Kokanee (DC, 661)	Adult migration + spawning																									x	x	x	x	x	x	x	x																
	Egg incubation	x	x	x	x	x	x	x	x	x	x	x	x	x	x													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kokanee (LCC)	Adult migration + spawning																													x	x	x	x	x	x	x	x												
	Egg incubation	x	x	x	x	x	x	x	x	x	x	x	x	x	x																	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

Note: DC = Davidson Creek; LCC – Lower Chedakuz Creek; 661 = Creek 661; 705 = Creek 705. Adult rainbow trout rear and overwinter in LCC, but do not rear or overwinter in DC.

Table 10: Mean Baseline Discharge for Biological Stanzas at Selected WMNs

	Davidson Creek					Creek 661				Creek 705			
Stanza	**11-DC**	**H2**	**H4B**	**4-DC**	**1-DC**	**H1**	**1-505659**	**H+**	**1-661**	**6-705**	**4-705**	**H7**	**1-705**
1 Dec to 31 Mar	0.000	0.128	0.162	0.170	0.199	0.005	0.012	0.017	0.095	0.002	0.005	0.027	0.041
1 May to 30 Jun	0.048	0.825	0.957	1.022	1.068	0.120	0.282	0.402	0.893	0.103	0.338	0.925	0.956
1 Jul to 31 Aug	0.007	0.254	0.319	0.330	0.363	0.027	0.062	0.089	0.234	0.021	0.059	0.161	0.178
1 Sep to 30 Nov	0.002	0.163	0.212	0.224	0.255	0.011	0.033	0.043	0.156	0.010	0.032	0.109	0.124

	Chedakuz	
Stanza	**H5**	**15-CC**
1 Dec to 31 Mar	1.515	1.008
1 May to 30 Jun	6.172	4.107
1 Jul to 31 Jul	2.721	1.811
1 Aug to 30 Sep	1.647	1.096
1 Oct to 30 Nov	1.839	1.224

Note: All flows in m^3/s. H+ is a calculated node (sum of H1 and 1-505659). WMN locations are presented in **Figure 3**.

Table 11: Mean Baseline Biological Stanza 30-day Low Flow for Selected WMNs

	Davidson Creek				
Stanza	**11-DC**	**H2**	**H4B**	**4-DC**	**1-DC**
1 Dec to 31 Mar	0	0.114	0.141	0.144	0.172
1 May to 30 Jun	0.041	0.718	0.850	0.921	0.968
1 Jul to 31 Aug	0.003	0.191	0.246	253.6	0.286
1 Sep to 30 Nov	0.001	0.147	0.189	194.7	0.224

	Chedakuz	
Stanza	**H5**	**15-CC**
1 Dec to 31 Mar	1.401	0.932
1 May to 30 Jun	4.979	3.313
1 Jul to 31 Jul	2.721	1.811
1 Aug to 30 Sep	1.272	0.847
1 Oct to 30 Nov	1.545	1.028

Note: All flows in m^3/s. WMN locations are presented in **Figure 3**.

3.4.4 Identification of Instream Flow Needs for Davidson Creek

The hydraulic habitat models developed in SEFA were used to determine instream flows needs (IFN) for rainbow trout and kokanee in Davidson Creek. The IFN were set as the minimum monthly flows required to protect fish and, by association, other aquatic values during each biologically relevant stanza.

A limiting habitat approach was taken to define IFN in Davidson Creek. This approach assumes that low flows during each biological stanza represent a potential habitat bottleneck limiting fish production (Jowett et al., 2005). It also conservatively assumes that any of the life stages present for either species could limit productivity for any stanza where they co-exist. This assumption precludes any one life stage taking precedence or having unsubstantiated influence over any other species or life stage when setting the IFN. For example, if rainbow trout spawning habitat was considered to be the habitat bottleneck, this would not necessarily indicate that the availability of fry or juvenile habitat was of lower or no concern.

IFN were set as the flows required to provide at least 90% of the habitat available for fish under baseline conditions for each of the following “biologically relevant stanzas”:

- juvenile rainbow trout rearing (December 1 to April 30);
- freshet flushing flows (May 1 to May 15);
- rainbow trout spawning (May 16 to June 30);
- kokanee spawning/rainbow trout egg incubation and juvenile rearing (July 1 to August 31); and
- kokanee egg incubation/juvenile rainbow trout rearing (September 1 to November 30).

Mean annual 30-day low flow for each stanza was defined as the flow condition limiting fish productivity, where the mean annual 30-day low flow is the lowest 30-day average flow within the stanza. This approach is conservative in comparison to alternative flow metrics such as the mean annual 7-day low flow, or 1:10 dry year mean 30-day low flow typically used for other projects because mean annual 30-day low flows are higher. IFN based on these higher flows will therefore represent more conservative habitat protection in Davidson Creek. Mean annual stanza 30-day low flows for input into the hydraulic habitat models (**Table 11**) were calculated by Knight Piésold using the data from the Project hydrometeorology report (**EA Appendix 5.1.2.1B**) and the calibrated watershed model (**EA Appendix 5.1.2.1C**).

Overwintering habitat suitability and availability has been identified as a management concern for streams in BC (Hatfield, 2012; Faulkner et al., 2012). Because hydraulic habitat models could not be developed for winter conditions, a conservative approach was taken whereby winter IFN in Davidson Creek were defined as the mean annual winter stanza 30-day low flow (**Table** 11).

3.4.5 Identification of Mitigated Flow Regime for Davidson Creek

The IFN were used to set the minimum instream flow criteria in Davidson Creek. These were the flows that must be met by flow augmentation provided by pumping water from Tatelkuz Lake via the FSS. The FSS will be designed and operated to augment remaining natural flows in Davidson Creek to meet prescribed IFN for each biological stanza during the operations and closure phases of the Project.

This mitigated flow regime also includes flushing flows in spring and transitional flows between each stanza throughout the hydrologic year. Each of these specific flows are described in the sections below. Taken together, these different flows are intended to maintain fish habitat and critical hydrological processes, and consequently, to maintain production of rainbow trout and kokanee in Davidson Creek. It is assumed that production of other aquatic resources such as periphyton and benthic macro-invertebrates will also be protected as a result.

3.4.5.1 Stanza Flows

Flows within each biological stanza were defined using the IFN calculated for middle and lower Davidson Creek. IFN for both sections were incorporated into the watershed model and mitigation flows required at the FSS outlet were defined such that IFN were met or exceeded for both sections (i.e., at both WMN H2 and WMN 1-DC). Within the range of flows considered, more flow generally produced more AWS. The only exception to this was rainbow trout fry for which optimal habitat conditions occurred at flows lower than mean baseline conditions. Therefore, the flow requirement was conservatively defined by the section (lower or middle), species, and life stage with the highest flow requirement for a given stanza.

3.4.5.2 Flushing Flows

Flushing flows are short-term flow pulses that transport fine sediment and organic material and provide the environmental cues and hydraulic conditions necessary for fish to migrate and gain access to upstream habitat. They exert enough tractive force to remove and transport fine organic matter and sediment from the stream bed gravels but are generally not strong enough to alter the alignment or morphology of the channel. Flows in the latter category are referred to as channel-forming flows (Milhous, 1998; Wald, 2009). Flushing flows provide the processes, conditions, and benefits associated with naturally occurring flows of moderately high magnitude and relatively short duration (i.e., lasting for several days).

Flushing flows are typically set based on direct observations of sediment transport within streams, on equations that enable predictions of sediment scour and transport as a function of stream power, or on stream-flow metrics that have been derived from empirical measurements made on other streams. Wald (2009) conducted an extensive review of the scientific literature on the effects of high flows on the physical characteristics of streams in Washington State and concluded that MAD can be considered a first approximation of flushing flows in high gradient, snowmelt-dominated streams. Tennant (1976) and Ptolemy and Lewis (2002) recommended flushing flows of 200% and 400% of MAD, respectively, in gravel-dominated streams. The wide range in flushing flows recommended by these researchers reflects the hydrologic and morphologic diversity that prevail in salmonid-bearing streams. It also suggests that there is no single value for appropriate flushing flows and that the magnitude of flushing flows set for any particular stream is depending on the unique channel geomorphology, slope, and dominant substrate sizes in the stream.

In its lower reaches, Davidson Creek is a low gradient, meandering stream. These characteristics generally reduce the potential for erosion and sediment transport during high flows. Therefore, flushing flows on the higher end of these estimates are likely warranted[1].

3.4.5.3 Transitional Flows

Transitional flows are meant to ensure a smooth and gradual progression of physical conditions in Davidson Creek from one flow level to the next over extended periods of time. Providing these transitional flows will provide fish with the cues and time necessary to adjust to various prescribed flow increases or decreases between stanzas during the year. For example, recently emerged fry are particularly vulnerable to stranding along stream fringes as flows recede, as well as to being displaced downstream if flows increase rapidly. Additionally, eggs and alevins in the gravels must be covered with water of sufficient depth and velocity to ensure their survival. Therefore, any reduction in flow after fish have spawned creates a scenario where eggs can become exposed to air, desiccate, and die. Transitional flows are necessary to avoid these types of occurrences and must be conservatively set[2].

For Davidson Creek, the magnitude and duration of transitional flows were set to ensure that rainbow trout and kokanee redds remain covered with water during their respective egg incubation periods through to the emergence of fry. Incubation flows for both species were considered those required to maintain flows over 90% of all redds, as inferred from the HSC. Based on the HSC for rainbow trout spawning, the majority (>90%) of rainbow trout spawn in water that is at least ten centimetres deep. Therefore, the IFN for rainbow trout egg incubation was calculated as the flow that would result in water depths no more than 10 cm lower than the depths provided during the rainbow trout spawning period.

Kokanee spawn during late summer as flows approach their lowest levels. Kokanee spawn in shallower water than rainbow trout with most (>90%) spawning in water that is at least four centimetres deep. Therefore, the IFN for kokanee egg incubation were those that would result in water depths no more than 4 cm lower than the depths provided during the kokanee spawning period.

To obtain transitional flow values for Davidson Creek between the rainbow trout and kokanee spawning and egg incubation periods, water surface elevations were calculated from the rating curve equation for WMN H2 (Knight Piésold, 2013a) associated with IFN stanza for rainbow trout and kokanee spawning using the formula:

$$Q=4.4(Y-0.38)^{2.08}$$

[1] Higher channel-forming flows such as those that occur during 2 to 10-year recurrence interval peak flows (Wald 2009) are not recommended for Davidson Creek during operations or closure because of their potential to remove spawning gravels, substrates that would not be replaced due to the captured of these substrates behind the TSF dams.

[2] Transitional flows are preferred over shorter duration ramping rates, such as those typically set below hydroelectric facilities, because they allow flows to be increased or decreased over the course of days or weeks instead of hours.

Where Q is the discharge (m^3/s); and Y is the creek stage (m). Use of the rating curve equation for WMN H2 to define incubation transitional flows was checked against estimates based on rating curves for each habitat transect in the middle Davidson Creek section. Incubation flows derived using the H2 rating curve met or exceeded the flows required based on the use of habitat transect rating curves.

3.4.6 Assessment of Potential Effects of Flow Changes in Project Area Streams

The assessment of potential effects on fish and fish habitat due to changes in flows was conducted using a time series approach. Fifteen year time series of year simulated monthly flow data predicted for baseline conditions and during each project phase (Section 3.3.2.4) were converted to a 15-year simulated monthly habitat time series for rainbow trout spawning, rainbow trout fry and juvenile rearing, and kokanee spawning in each stream. This was done using the HSCs and the hydraulic models in SEFA.

Simulated 15-year monthly habitat time series for each species life stage during each Project phase were compared to simulated 15-year monthly habitat time series during natural baseline flow conditions to assess potential flow related effects to fish in each stream. Doing so provided a direct comparison of total habitat availability over time (i.e., area under the curve) during different Project phases in each stream. Direct comparison of time series were possible because the synthetic flows used for modeling each Project phase were based on the same 15-year simulated data set used to described baseline conditions (January 1998 to December 2012).

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 in Project area stream during each Project phase. Average monthly AWS was calculated as the total stanza habitat over the 15-year time series 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 area stream was that at least 90% of total habitat availability remained over the relevant biological stanzas for kokanee and rainbow trout (i.e., no more than a 10% reduction in total AWS over the 15-year time series). This threshold was considered conservative because:

1. Conserving at least 90% of baseline total AWS during each biological stanza was unlikely to result in any detectable reduction in numbers or biomass of fish populations in these creeks;

2. Hydraulic habitat model results represent a theoretical best-case scenario that assume instant population responses to change in flow when in fact the amount of suitable habitat varies naturally with variation in flow. As a result, fish populations are always less than what they could theoretically be based on hydraulic habitat models and a modest reduction in theoretical total habitat availability (i.e., <10%) is unlikely to have a real ecological consequence;

Quantitative assessment of potential effects of predicted flow changes on overwintering fish was not possible using the hydraulic habitat models. This was because hydraulic habitat models do not accurately predict water depths or water velocities under the ice and because HSCs are not available for overwintering fish. As a result, potential effects on overwintering fish were qualitatively assessed by comparing anticipated winter low flows for each Project phase to minimum monthly winter flow under baseline conditions; and

Once built, the TSF dam will capture sediment transported from the upper Davidson Creek watershed and prevent it from reaching lower Davidson Creek. This potential effect will continue through post-closure. Capture of these sediments, and gravels in particular, has the potential to reduce the quantity of spawning habitat for rainbow trout and kokanee over time. A qualitative assessment of this potential effect was completed, and the possibility of gravel flushing was considered in the establishment of spring flushing flows for Davidson Creek.

3.4.7 Assessment of Effects of Meeting Instream Flow Needs in Davidson Creek on Tatelkuz Lake

Water withdrawn from Tatelkuz Lake to meet IFNs in Davidson Creek during mine operations and closure phases has the potential to create adverse effects for fish in Tatelkuz Lake. This is because water withdrawn from Tatelkuz Lake will lower the lake water level below what would occur naturally during the year, without operation of the FSS. Tatelkuz Lake levels naturally vary between months (i.e., high in spring and low in summer) and between years (i.e., wet years and dry years). However, any reduction in lake levels below those that naturally occur, particularly below the lowest level during the driest years, has the potential to expose more of the littoral habitats used by fish in Tatelkuz Lake for some part of their life history.

For most fish species in the lake, these littoral areas are used by juvenile fish for rearing in summer. However, fish species such as mountain whitefish and kokanee may also use specific habitat types within the littoral area for spawning. Therefore, operation of the FSS may negatively affect the production of these fish in Tatelkuz Lake if these specific littoral habitats are critical to their survival, growth, and reproduction, are in short-supply in the lake, and are located in shallow littoral areas that would be exposed due to reduced lake levels.

Any reduction in Tatelkuz Lake water levels could also negatively affect the availability and suitability of habitat in Chedakuz Creek immediately downstream of the lake. Habitat in Chedakuz Creek below the lake is suitable for spawning, rearing, foraging and overwintering of many Tatelkuz Lake fish species including rainbow trout, kokanee, and mountain whitefish. The likelihood of potential effects to fish using lower Chedakuz Creek is greatest during the low flow months of summer and winter and is largely dependent on the amount of water that needs to be provided to Davidson Creek and the natural volume of water entering Tatelkuz Lake from its upper watershed, which is dependent on annual climatic conditions (i.e., wet or dry years).

A Tatelkuz Lake routing model developed by Knight Piésold (2013b) was used to predict changes in Tatelkuz Lake surface elevation due to FSS pumping to meet mill requirements and Davidson Creek IFN. Results were calculated for average and 1:50 year dry conditions. Modelled water withdrawals from Tatelkuz Lake were those assumed for Year 17 of the Project when water is required to supply the mill (0.033 m^3/s) and to meet Davidson Creek IFN.

Supplemental water needs to keep potentially acid generating (PAG) waste rock submerged in the TSF under extreme dry conditions were not modelled.

Potential effects of the predicted changes in lake surface elevation were assessed using a littoral fish habitat model for Tatelkuz Lake described in the Fish Habitat EA (**EA Section 5.3.9**). Potential effects were assessed by comparing the area of different littoral habitat types available to fish within the 1 metre depth contour during average and 1:50 dry year conditions with operation of the FSS (i.e., operation and closure phases) to areas available under natural baseline conditions. Modelling only the first metre of littoral habitat was appropriate because the maximum extent of modelled changes in lake surface elevation was 0.11 m.

4.0 RESULTS

4.1 Habitat Suitability Curves

Project-specific data used to validate provincial HSC included 110 observations of rainbow trout fry, 95 observations of rainbow trout juveniles and 72 measurements at kokanee redds. For rainbow trout fry, observed depths were within the range indicated by the provincial HSC and no changes were made to the curves. However, almost 50% of rainbow trout fry captured in Project area streams were in zero velocity habitats and no rainbow trout fry were captured in the higher velocity habitats represented by the provincial HSC. To reflect this site-specific data, the Project rainbow trout fry HSC for water velocity was shifted slightly to the right (**Figure 5**). The substrate HSC for rainbow trout fry was altered from the provincial HSC to include fine substrates. This was because 95% of fry observed in Project area streams were associated with fine substrates (**Table 12**).

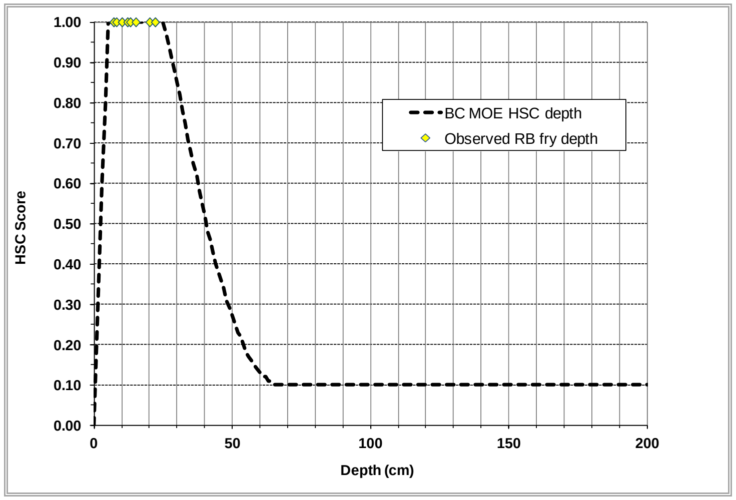
For rainbow trout juveniles, observed depths in Project area streams were shallower and slower than the provincial depth and velocity HSCs. Because of this, both curves were shifted slightly to the right (**Figure 6**). The substrate HSC for rainbow trout juveniles was also altered to reflect Project-specific habitat associations (**Table 12**). The provincial standard curves for rainbow trout spawning were used without changes (**Figure 7**; **Table 12**).

Kokanee spawning redds were observed at depths consistent with the provincial HSC and no adjustments were made as a result (**Figure 8**). However, no kokanee redds were observed at the highest water velocities included in the provincial HSC. The Project-specific curve was adjusted to the right accordingly (**Figure 8**). Spawning kokanee used gravel substrates in Project area streams which is consistent with the provincial HSCs (**Table 12**).

Table 12: Habitat Suitability Values for Substrate

Species/ Stage	Substrate							
	Vegetation	Fines	Small Gravel	Large Gravel	Small Cobble	Large Cobble	Boulder	Bedrock
RB fry	0.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2
RB juveniles	0.0	0.3	0.5	0.8	1.0	1.0	1.0	0.4
RB spawning	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0
KO spawning	0.0	0.0	1.0	1.0	0.0	0.0	0.0	0.0

Note: RB = rainbow trout; KO = kokanee. Suitability ratings range between 0 (no habitat value) to 1 (ideal habitat value)



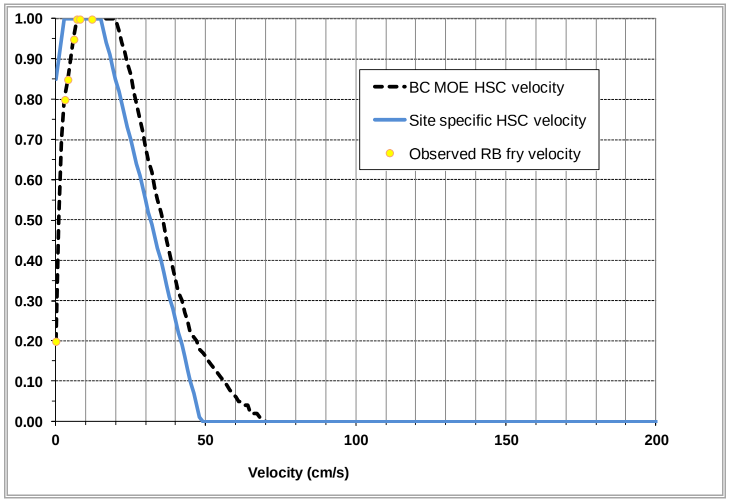
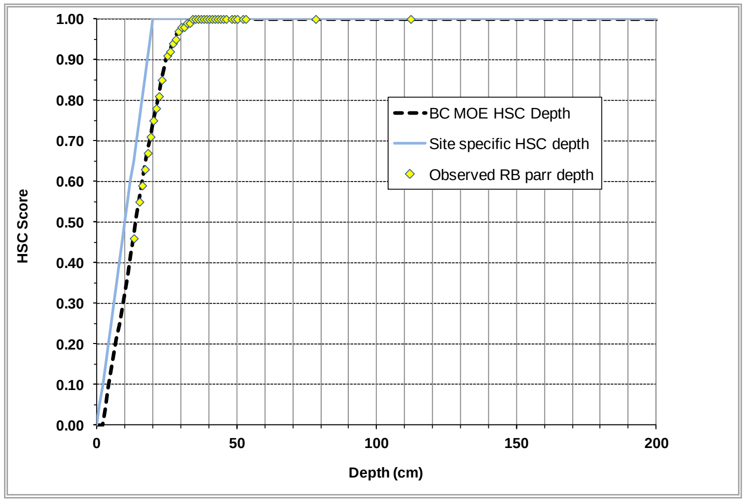


Figure 5: Depth and Velocity HSC for Rainbow Trout Fry



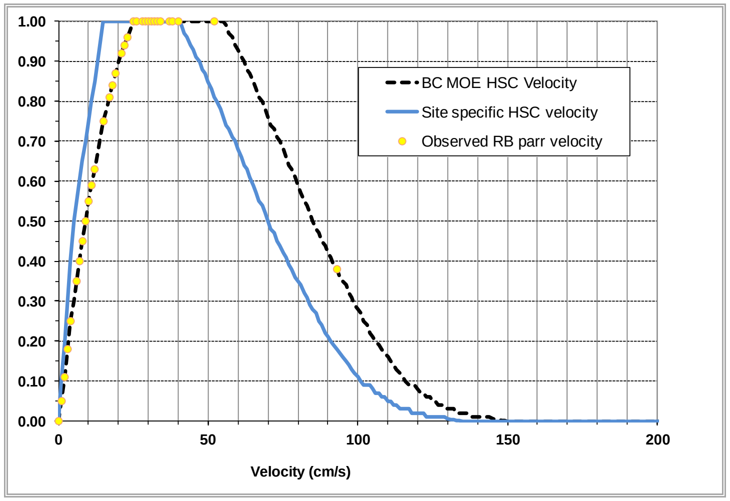


Figure 6: Depth and Velocity HSC for Rainbow Trout Parr

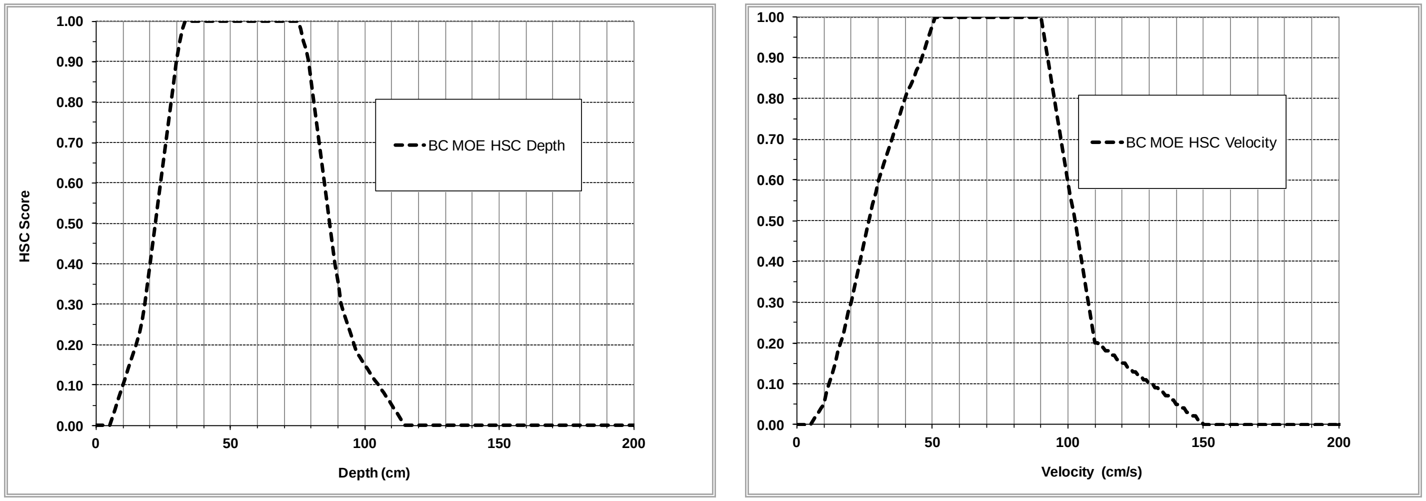


Figure 7: Depth and Velocity HSC for Rainbow Trout Spawning

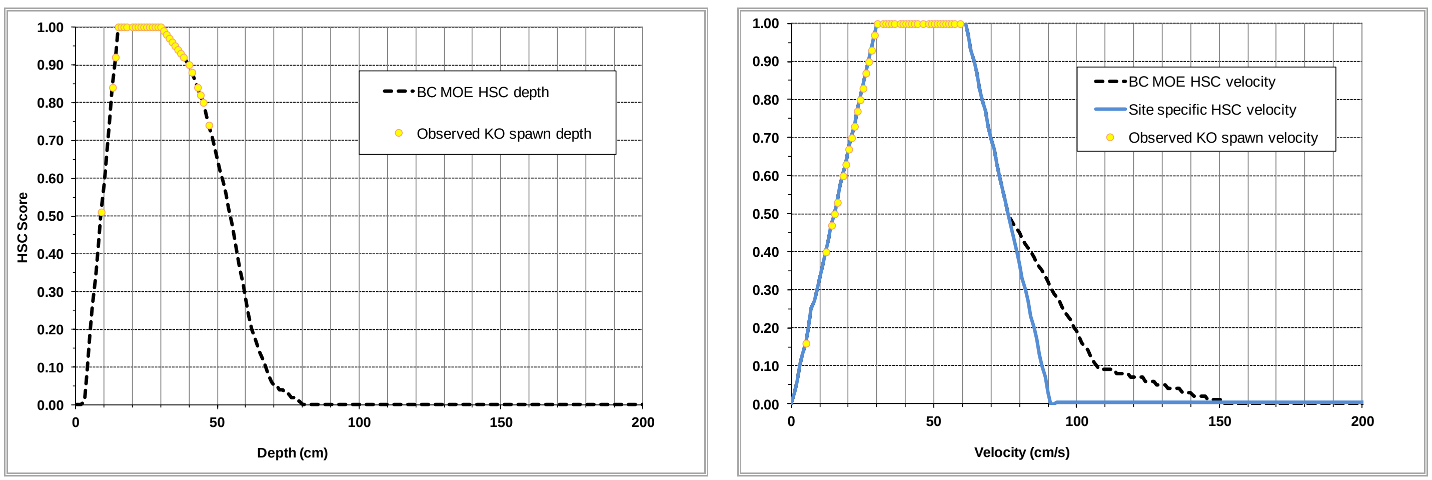


Figure 8: Depth and Velocity HSC for Kokanee Spawning

4.2 Davidson Creek Instream Flow Models

4.2.1 Lower Davidson Creek Model

Rating curves for all 18 transects in lower Davidson Creek are shown in **Figure 9**[3]. The average R^2 for all 18 transects was 0.998, and the average mean error was 2.74%. Rating curves for individual transects, surveyed cross-sections, and photographs from each site visit are presented in **Annex B**.

The relationship between flow and wetted width for each transect is presented in **Figure 10**. For most transects in this section, wetted width is relatively constant (i.e., relatively flat curve) between 0.5 m^3/s and 3.0 m^3/s with relatively linear decreases in width with decreasing discharge below 0.5 m^3/s. Only two transects, 1DC-02G and 3DC-1.2P, a transect in a glide and pool, respectively, demonstrated markedly positive relationships between wetted width and discharge at flows greater than 2.0 m^3/s.

The hydraulic habitat relationships for kokanee spawning and rainbow trout spawning, fry rearing, and juvenile rearing in this section of Davidson Creek are shown in **Figure 11**. Optimal hydraulic habitat for rainbow trout fry occurs at flows between 0 m^3/s and 0.2 m^3/s with a peak at 0.1 m^3/s. AWS decreases almost exponentially for rainbow trout fry at flows greater than 0.2 m^3/s.

The range of optimal habitat for rainbow trout juveniles is much wider than that for rainbow trout fry. This is due to their larger size and greater ability to swim against, or hold position in, higher velocity water. Optimal habitat for rainbow trout juveniles was found at intermediate flows generally ranging from 0.2 m^3/s to 1.0 m^3/s with a peak at 0.4 m^3/s. Above this, habitat quality decreases but at a much slower rate than for rainbow trout fry.

Optimal rainbow trout spawning habitat is found between 0.75 m^3/s and 1.75 m^3/s with a peak at 1.2 m^3/s. Beyond this range, suitability of rainbow trout spawning habitat decreases faster at flows <0.75 m^3/s than it does for flows >1.75 m^3/s. This observation is consistent with the need for rainbow trout redds to be located in faster areas where sedimentation rates are low and gas exchange rates are high.

The range of optimal kokanee spawning habitat is narrower lower than rainbow trout. Optimal kokanee spawning habitat occurs generally between 0.2 m^3/s and 0.9 m^3/s with a peak at 0.5 m^3/s. Similar to rainbow trout and presumably for the same reasons, the suitability of kokanee spawning habitat decreases much more quickly at flows below this optimal range than above it.

[3] The range of flows modelled for AWS (0 to 3.0 m^3/s) is larger than required for hydraulic habitat simulations using the 15-year watershed model datasets where the flow range at WMN 1-DC is 0.021 m^3/s to 2.300 m^3/s.

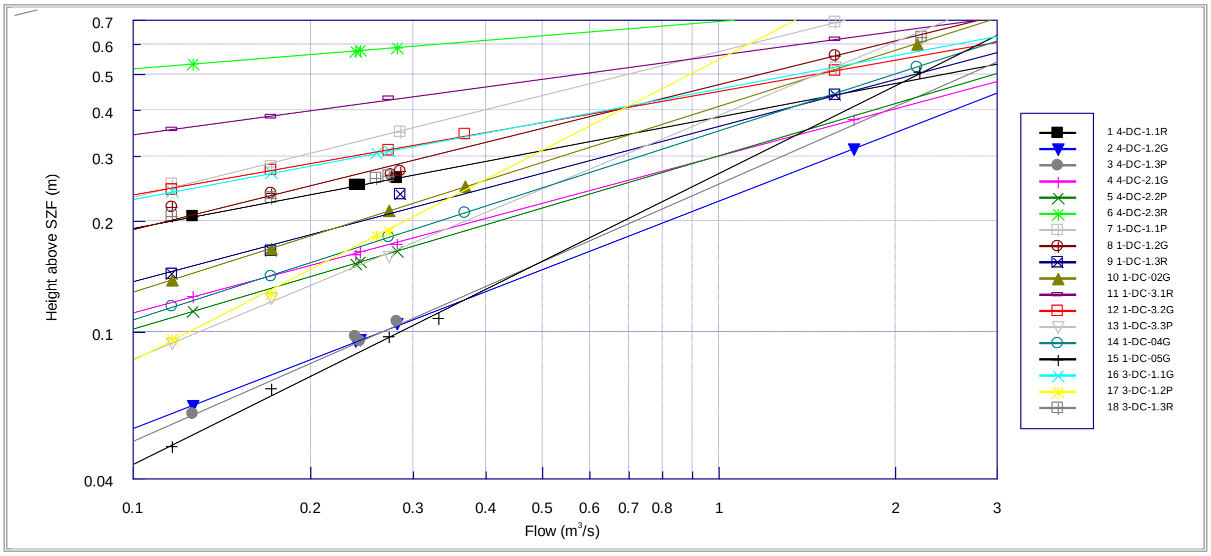


Figure 9: Rating Curves for All Transects, Lower Davidson Creek Model

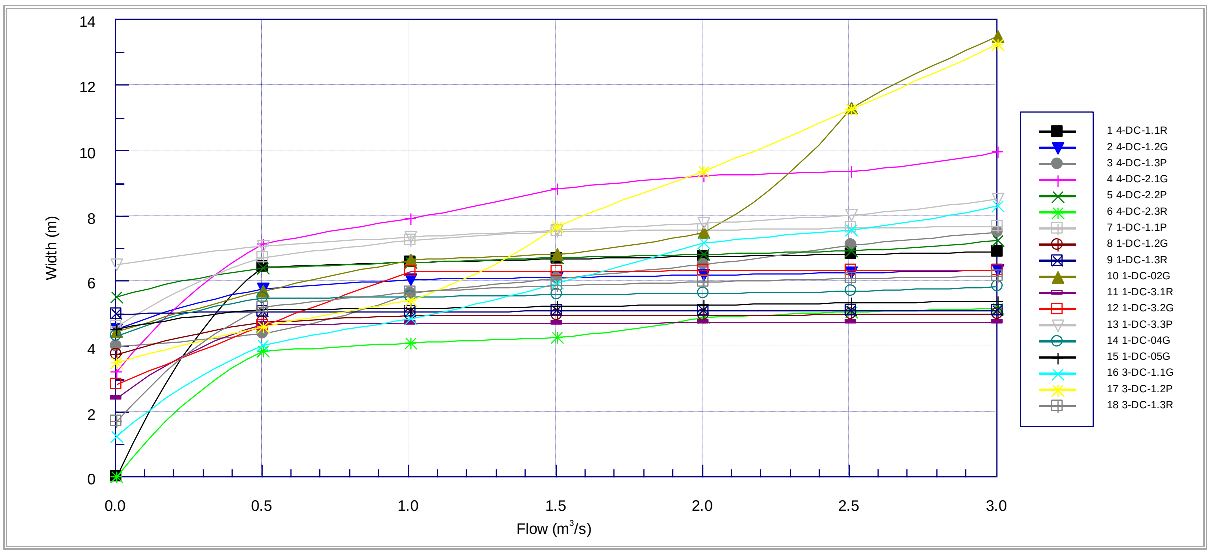


Figure 10: Wetted Width (m) as a Function of Flow (m^3/s), Lower Davidson Creek Model

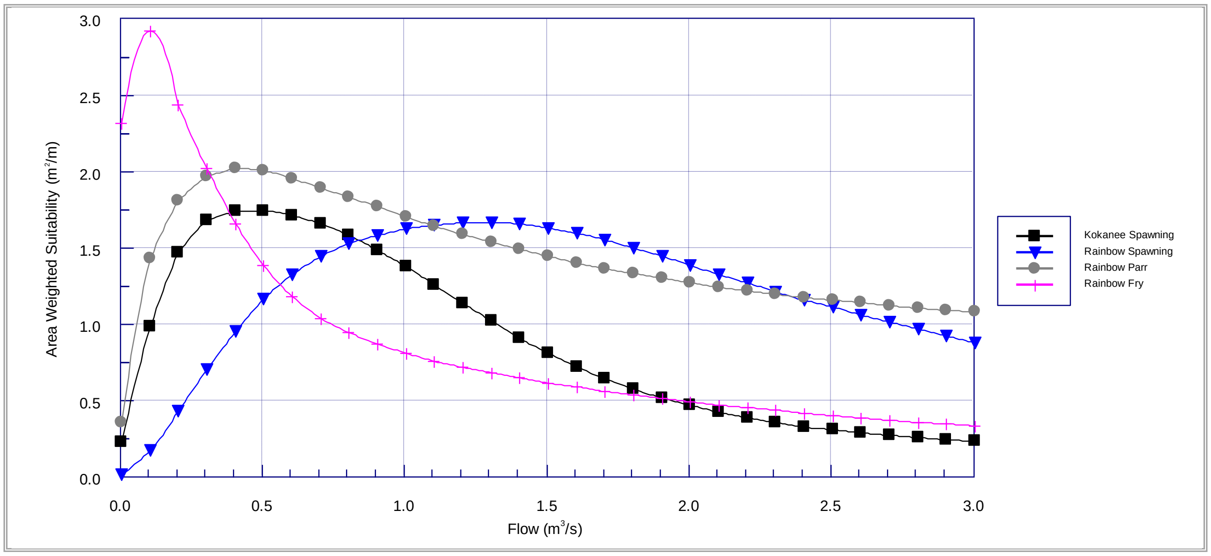


Figure 11: Habitat (AWS; m²/m) as a Function of Flow (m³/s) in Lower Davidson Creek

4.2.2 Middle Davidson Creek Model

Rating curves for the 23 transects in the Middle Davidson Creek section are shown in **Figure 12** and **Figure 13**[4]. Transects are presented in separate graphs (one for the cluster of transects in the lower portions of the section and one for the cluster in the upper portion of the section) due to the way the middle Davidson Creek model was structured within SEFA.

Average R^2 for all transects was 0.998 and the average mean error was 4.48%. Rating curves for individual transects, the surveyed cross-sections, and photographs from each site visit are presented in **Annex B**.

[4] The range of flows modelled for AWS (0 to 2.0 m³/s) is larger than required for hydraulic habitat simulations using the 15-year watershed model datasets (flow range at WMN H2 = 0 to 1.9 m³/s)

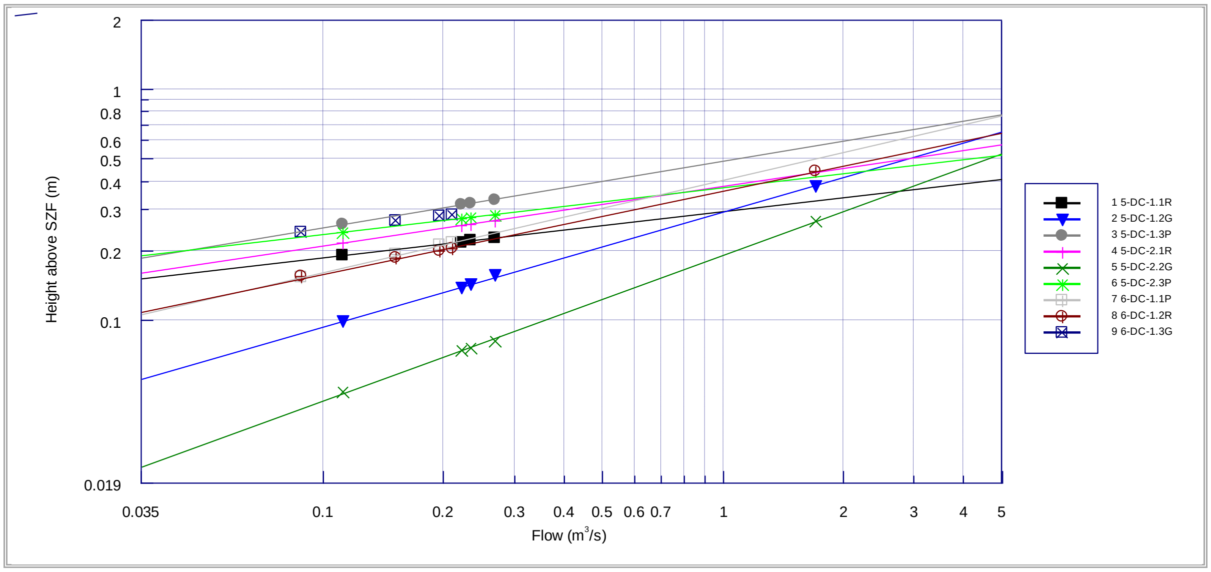


Figure 12: ***Rating Curves for Lower Transect Cluster, Middle Davidson Creek Model***

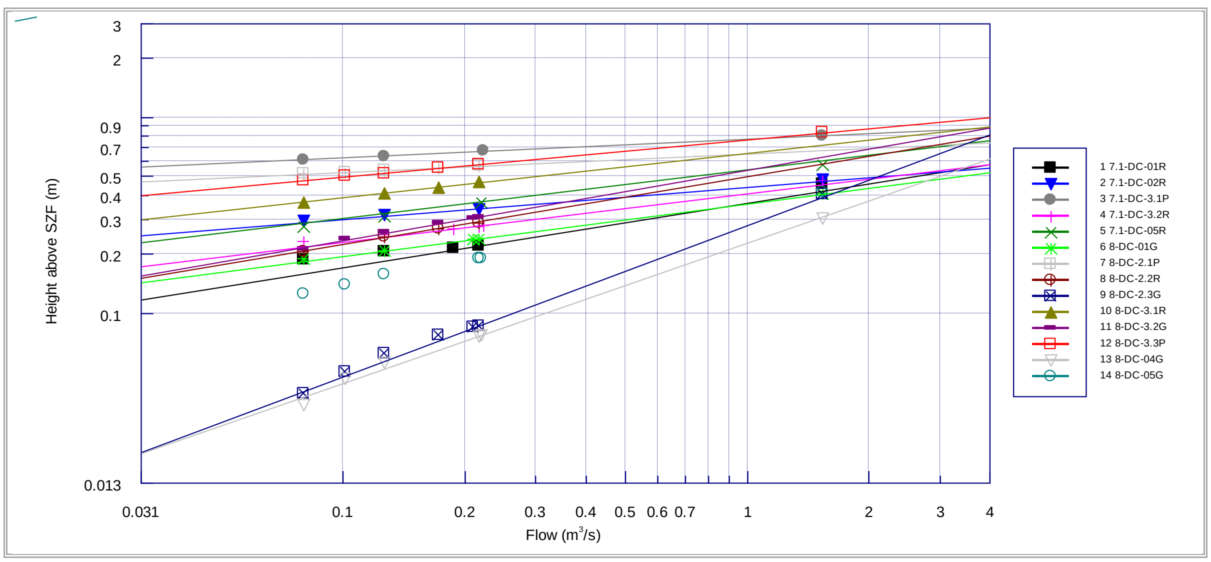


Figure 13: ***Rating Curves for Upper Transect Cluster, Middle Davidson Creek Model***

The relationship between flow and wetted width for each transect is presented in **Figure 14**. Similar to the lower Davidson Creek model, width was relatively insensitive to changes in discharge over the range of modeled flows. This is consistent with the channel geometry and morphology observed along most of the middle reaches of Davidson Creek where the creek is generally confined within well-defined banks. Only at flows <0.1 m^3/s did wetted widths decrease quickly.

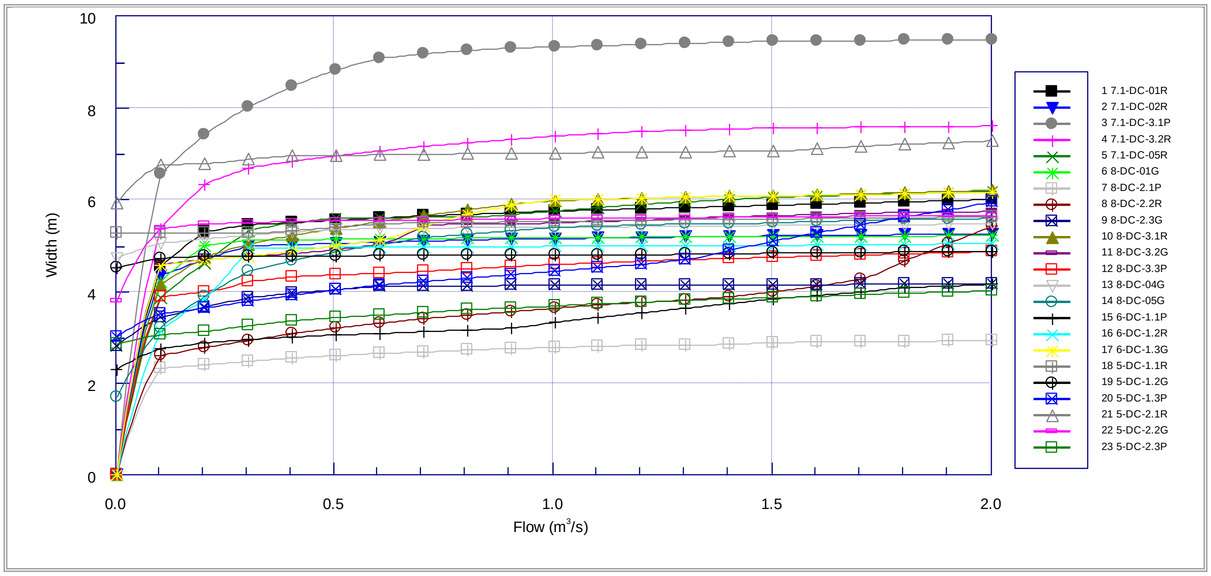


Figure 14: Wetted Width (m) as a Function of Flow (m^3/s), Middle Davidson Creek Model

The hydraulic habitat relationships for rainbow trout fry, juveniles, and spawning adults in the middle section of Davidson Creek are shown in **Figure 15**. Patterns for all three curves are similar to those in lower Davidson Creek with optimal rainbow trout fry habitat present at low flows, optimal rainbow trout juvenile habitat at more intermediate flows, and optimal rainbow trout spawning habitat at higher flows. Kokanee do not migrate this far up in Davidson Creek and a spawning curve is therefore not presented.

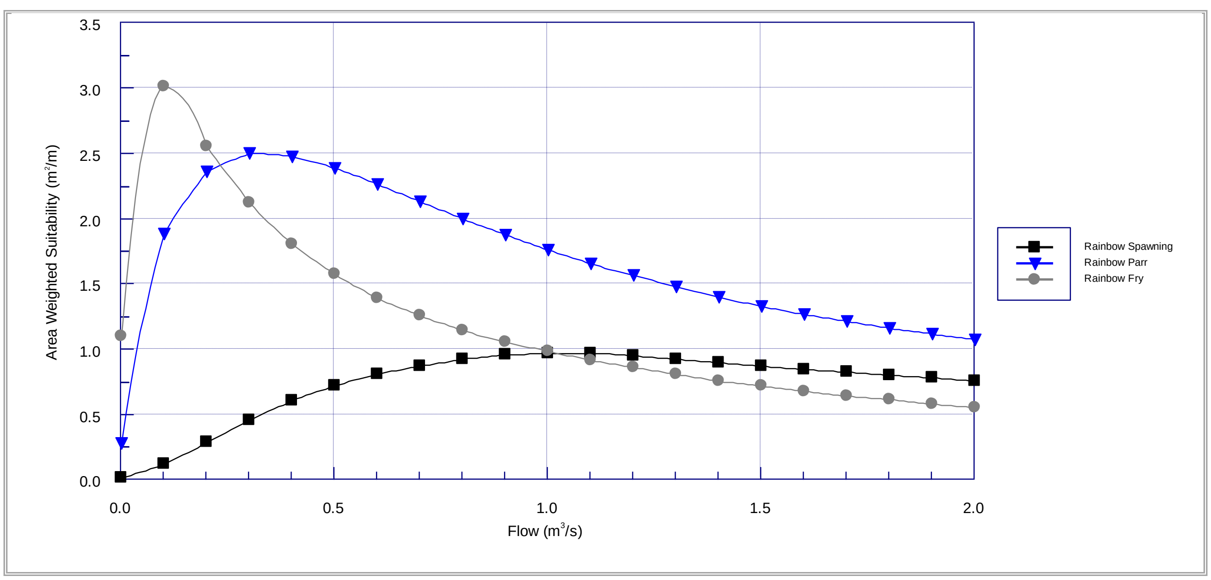


Figure 15: Habitat (AWS; m^2/m) as a Function of Flow (m^3/s), Middle Davidson Creek Model

4.3 Chedakuz Creek Instream Flow Models

4.3.1 Chedakuz Creek H5 Model

Rating curves for all 14 transects in the Chedakuz Creek H5 model (i.e., downstream of the Davidson Creek confluence) are shown in **Figure 16**. Average R^2 for all 14 transects was 0.997 and the average mean error was 2.34%. Rating curves for individual transects, the surveyed cross-sections, and photographs from each site visit are presented in **Annex B**.

The relationships between flow and wetted width for each transect are shown in **Figure 17**. For most transects, wetted widths are relatively insensitive to changes in flow between 1.0 and 10.0 m^3/s. However, wetted widths increase more rapidly with increasing discharge for two transects (LLC-3.1 and LLC-6.2) at flows >5.0 m^3/s. Wetted widths decrease quickly at all transects at flows <1.0 m^3/s.

The hydraulic habitat relationships for kokanee spawning and for rainbow trout spawning, fry rearing, and juvenile rearing are shown in **Figure 18**[5]. Optimal habitat for rainbow trout fry in this section occurs at flows between approximately 0.5 m^3/s and 1.5 m^3/s with a peak at approximately 1.0 m^3/s. Rainbow trout fry habitat decreases rapidly with increasing flows above 1.5 m^3/s.

Optimal rainbow trout juvenile habitat occurs between 1.0 m^3/s and 2.0 m^3/s. AWS for rainbow trout juvenile decreases relatively constantly with increasing flows above 2.0 m^3/s. Optimal rainbow trout spawning habitat occurs between 2.5 m^3/s and 4.5 m^3/s with a peak at approximately 3.0 m^3/s. Suitability of rainbow trout spawning habitat decreases at approximately the same rate above and below this peak.

Optimal kokanee spawning habitat occurs between 1.0 m^3/s and 2.5 m^3/s with a peak at approximately 2.0 m^3/s. Suitability of kokanee spawning habitat decreases more quickly at flows below 1.0 m^3/s than it does above 2.5 m^3/s. This because female kokanee actively select habitats with flows that will keep eggs well oxygenated and free of sediment.

[5] The range of flows modelled for AWS (0.0 to 10.0 m^3/s) is larger than required for habitat availability simulations using the 15-year watershed model datasets.

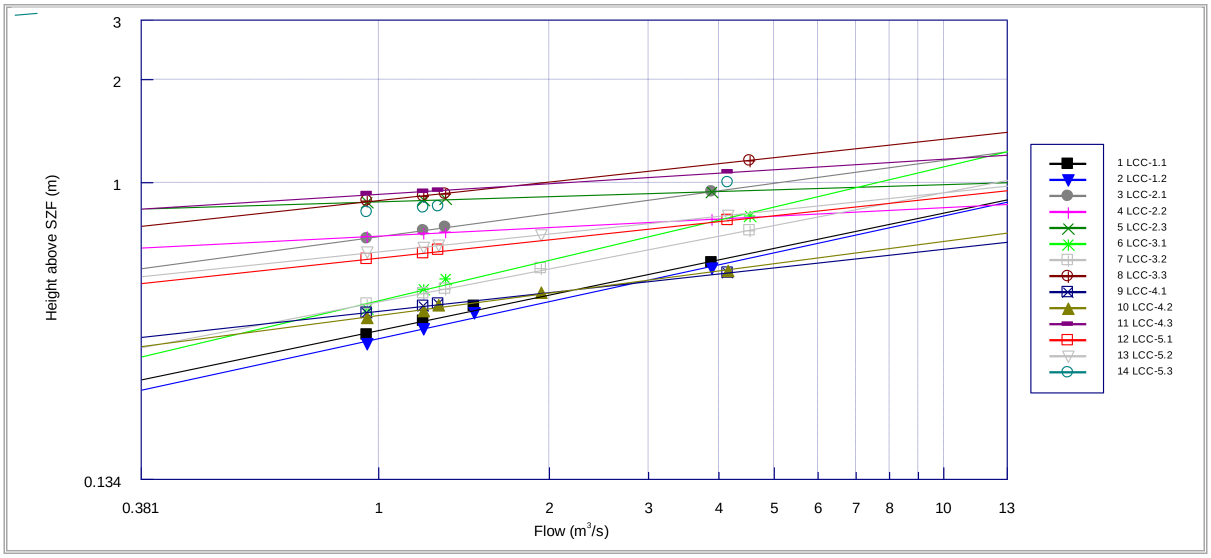


Figure 16: Rating Curves for All Transects, Chedakuz Creek H5 Model

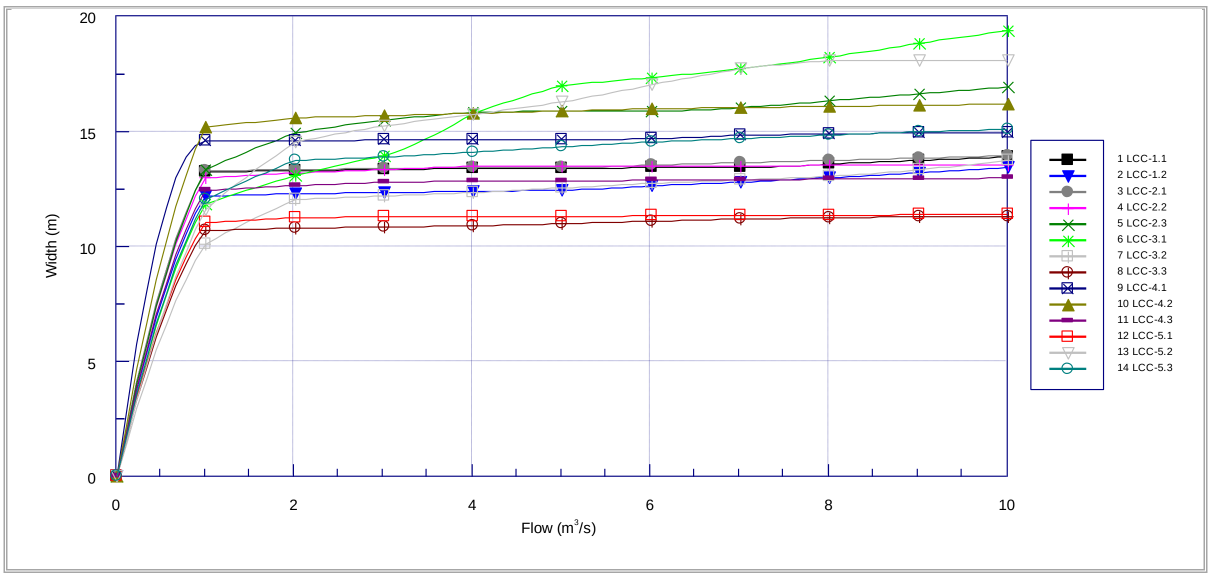


Figure 17: Wetted width (m) as a Function of Flow (m^3/s), Chedakuz Creek H5 Model

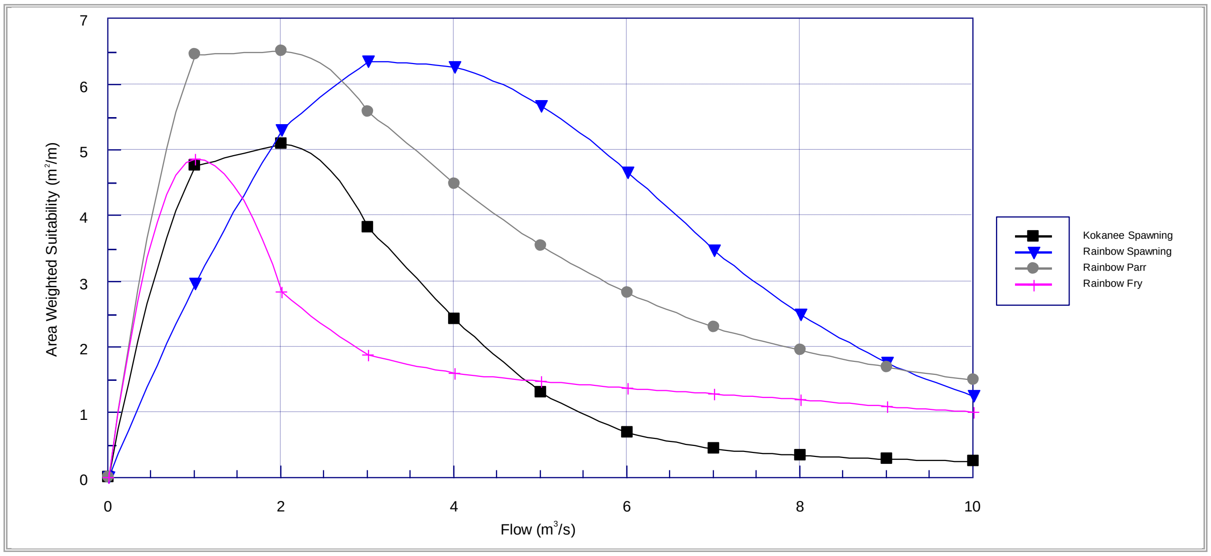


Figure 18: ***Habitat (AWS; m^2/m) as a Function of Flow (m^3/s), Chedakuz Creek H5 Model***

4.3.2 Chedakuz Creek 15-CC Model

Rating curves for all eight transects used in the Chedakuz Creek 15-CC model (i.e., immediately downstream of Tatelkuz Lake) are shown in **Figure 19**. Average R^2 for all transects is 0.989 and the average mean error is 9.40%. Rating curves for individual transects, the surveyed cross-section, and photographs from each site visit are presented in **Annex B**. The relationship between flow and wetted width for each transect is presented in **Figure 20**. The hydraulic habitat relationship for the section is shown in **Figure 21**[6].

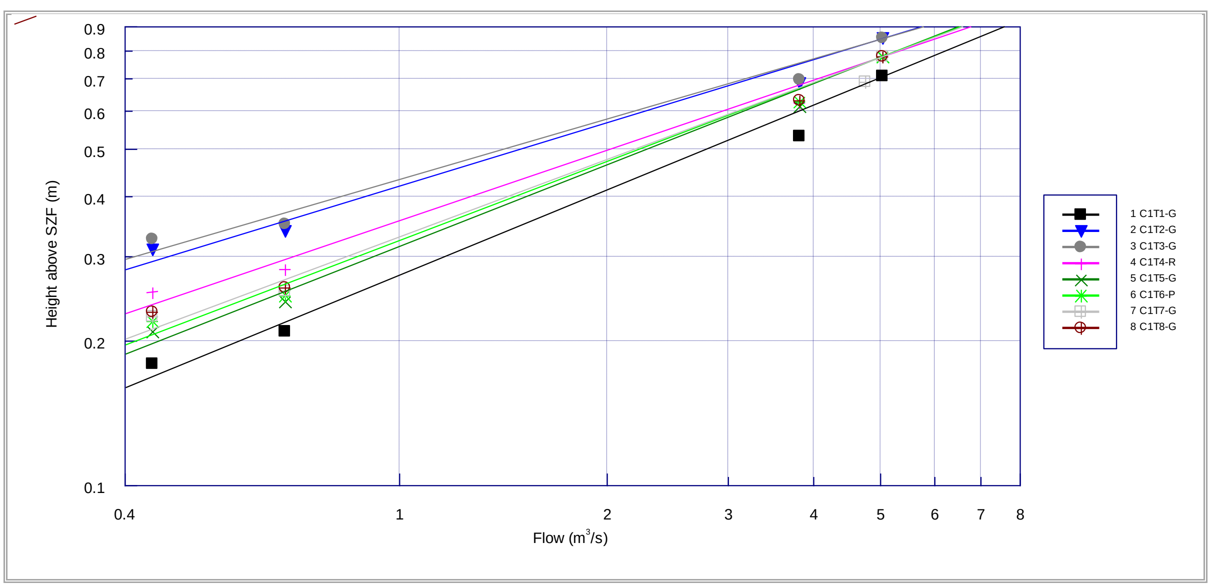


Figure 19: ***Rating Curves for All Transects, Chedakuz Creek 15-CC Model***

[6] The range of flows modelled for AWS (0.0 to 10.0 m^3/s) is larger than required for habitat availability simulations using the 15-year watershed model datasets.

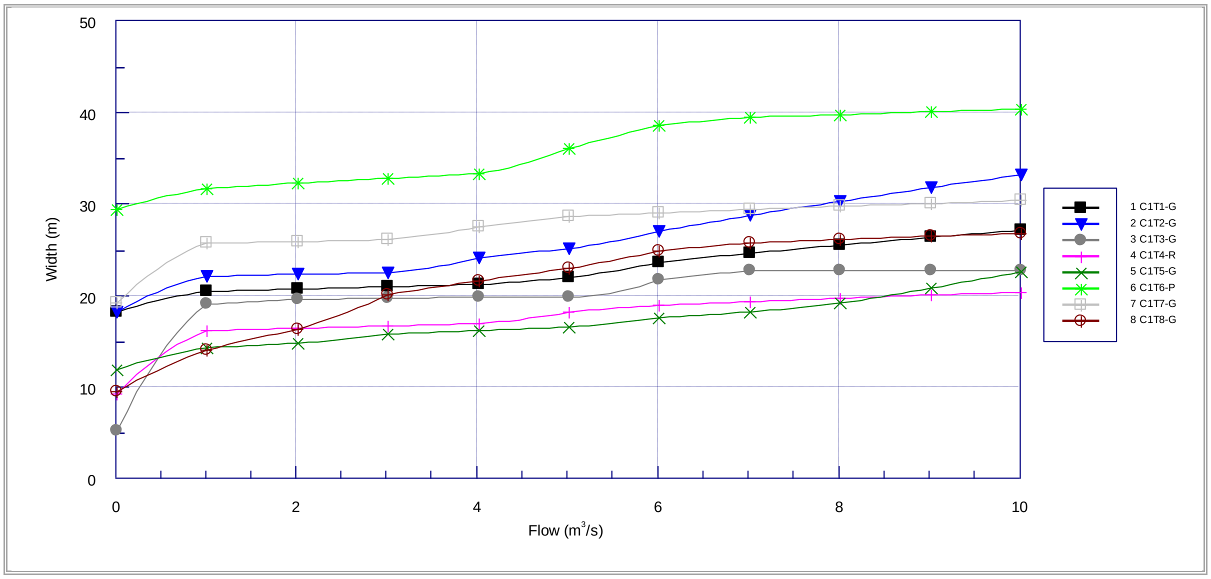


Figure 20: ***Wetted Width (m) as a Function of Flow (m^3/s), Chedakuz Creek 15-CC Model***

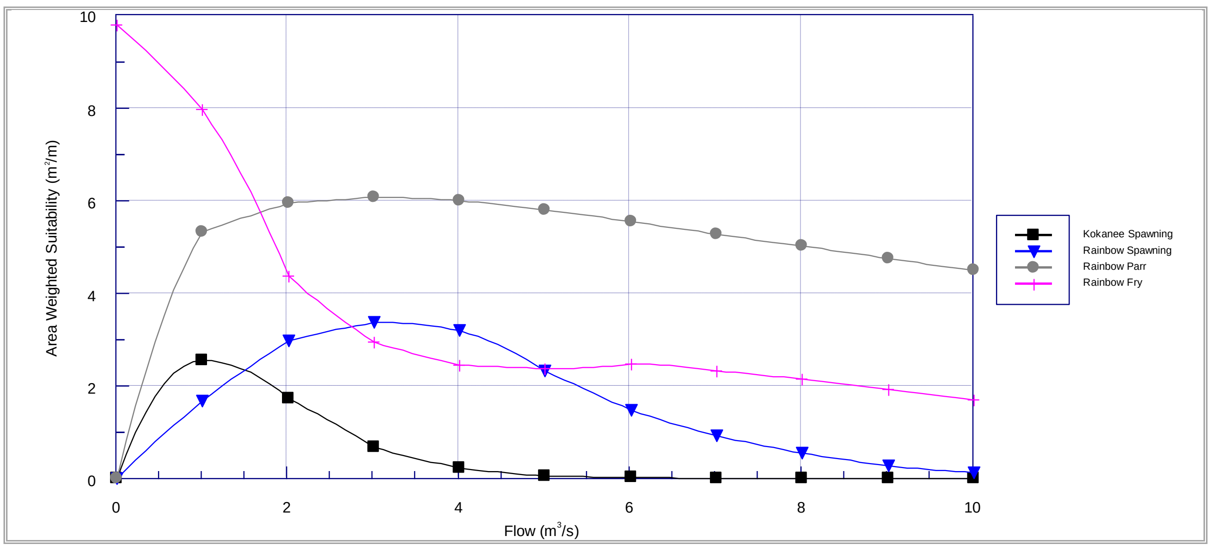


Figure 21: ***Habitat (AWS; m^2/m) as a Function of Flow (m^3/s), Chedakuz Creek 15-CC Model***

For this model, optimal habitat for rainbow trout fry occurs at zero flow with decreasing AWS with increasing discharge. Optimal habitat for rainbow trout juveniles occurs between 2 m^3/s and 4 m^3/s and remains relatively high at flows up to 10 m^3/s.

Optimal habitat for rainbow trout spawning occurs between approximately 2 m^3/s and 5 m^3/s with a peak at approximately 3 m^3/s. AWS for rainbow trout spawning decreases at approximately the same rate above and below this optimal range.

Kokanee spawning habitat is optimal at about 1 m^3/s and spawning habitat appears to remain up to approximately 3 m^3/s. These patterns reflect the physical structure of habitat in this section which is typical of medium-sized rivers rather than the smaller stream habitat represented in Davidson Creek.

4.4 Creek 661 Instream Flow Model

Rating curves for all 17 transects in the Creek 661 model are shown in **Figure 22**. Average R^2 for all transects was 0.995 and the average mean error was 2.30%. Rating curves for individual transects, the surveyed cross-section, and photographs from each site visit are presented in **Annex B**.

The relationship between flow and wetted width for each transect is presented in **Figure 23**. Wetted width is relatively insensitive to changes in discharge for most transects between 0.2 m^3/s and 2 m^3/s. However, one transect (1-661-1.3) shows a markedly positive relationship between wetted width and discharge at flow >0.6 m^3/s.

Hydraulic habitat relationships for this modeled section is shown in **Figure 24**[7]. Optimal habitat for rainbow trout fry occurs at flows between 0 m^3/s and 0.2 m^3/s. AWS decreases quickly above, 0.2 m^3/s for rainbow trout fry.

Optimal habitat for rainbow trout juveniles occurs between 0.1 m^3/s and 0.5 m^3/s with a peak at approximately 0.2 m^3/s. Above this range, habitat quality decreases but the response is slower than for fry. Optimal habitat for rainbow trout spawning occurs between 0.3 m^3/s and 0.9 m^3/s with a peak at approximately 0.4 m^3/s.

Optimal kokanee spawning habitat in this section occurs between 0.1 m^3/s and 0.4 m^3/s with a peak at approximately 0.2 m^3/s. AWS for kokanee spawning decreases more quickly below this optimal range than it does above, for reasons previously explained.

[7] The range of flows modelled for AWS (0.0 to 2.0 m^3/s) is larger than required for habitat availability simulations.

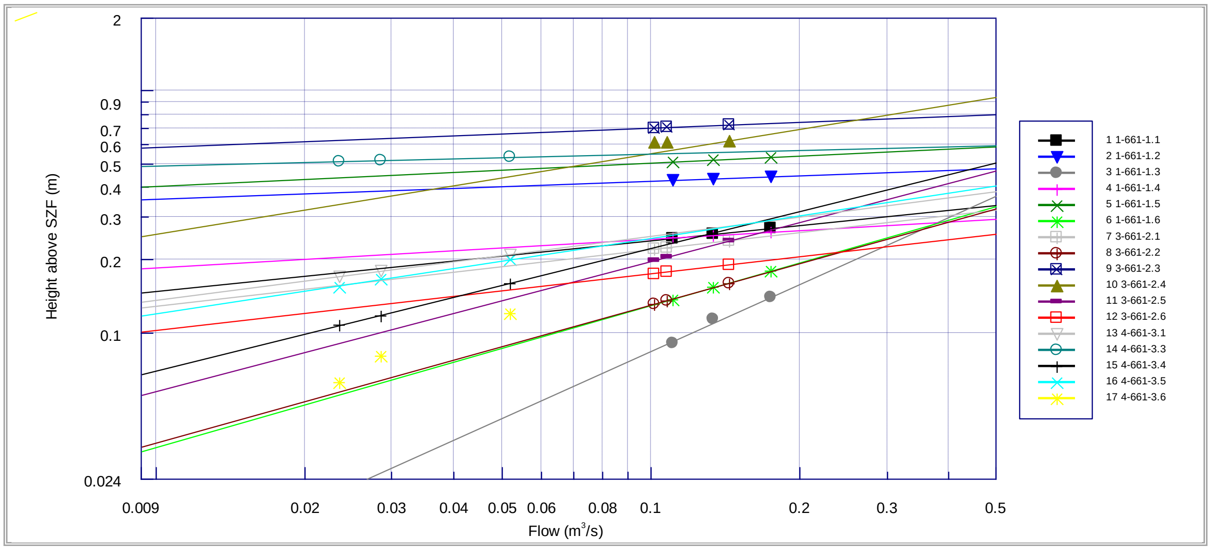


Figure 22: Rating Curves for All Transects, Creek 661 Model

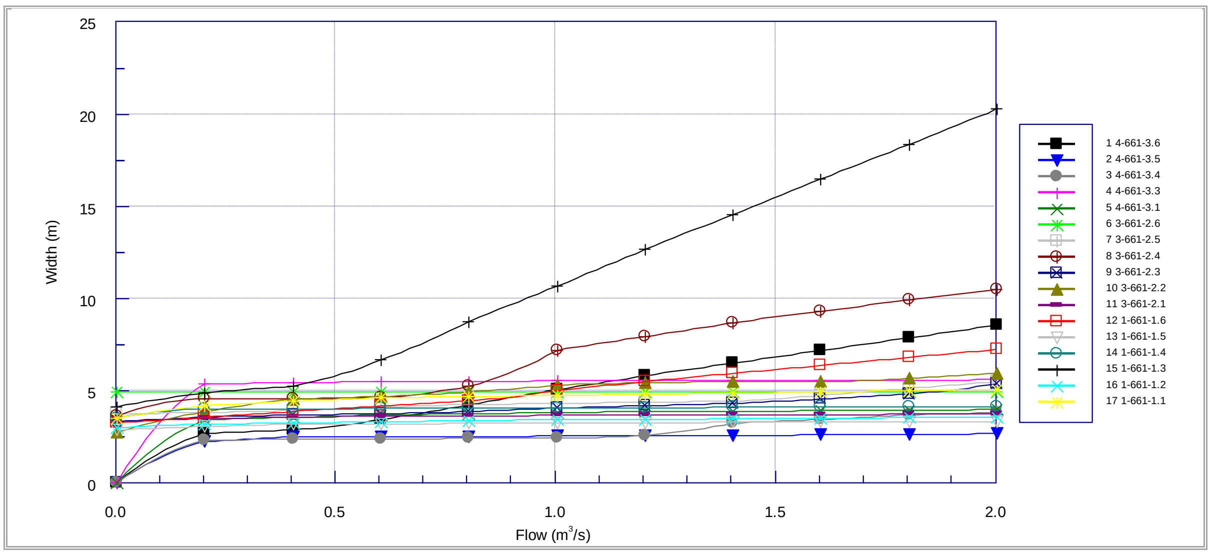


Figure 23: Wetted Width (m) as a Function of Flow (m^3/s), Creek 661 Model

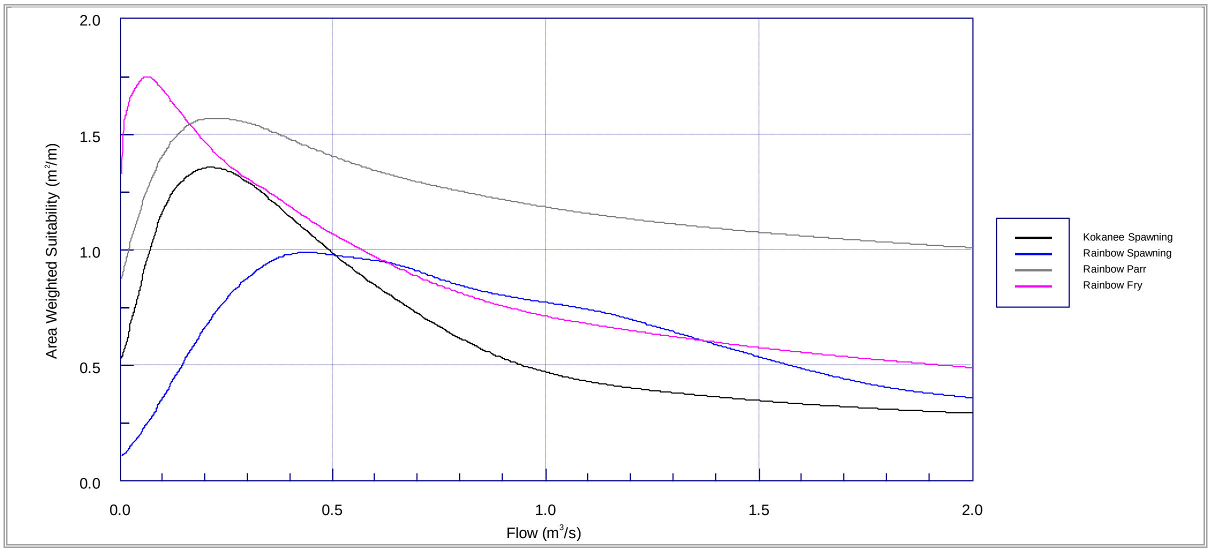


Figure 24: Habitat (AWS; m^2/m) as a Function of Flow (m^3/s), Creek 661 Model

4.5 <u>Creek 705 Instream Flow Models</u>

4.5.1 Lower Creek 705 Model

Rating curves for all 10 transects in the lower Creek 705 model are shown in **Figure 25**. Average R^2 for all transects was 0.996 and the average mean error was 4.57%. Rating curves for individual transects, the surveyed cross-section, and photographs from each site visit are presented in **Annex B**.

The relationship between flow and wetted width for each transect is presented in **Figure 26**. Above 0.1 m^3/s, the wetted width is relatively insensitive to increases in flow up to 2 m^3/s at all 10 transects.

The hydraulic habitat relationships for rainbow trout spawning, fry rearing, and juvenile rearing for this section of Creek 705 is shown in **Figure 27**[8]. Kokanee do not utilize Creek 705 and hydraulic habitat relationships for kokanee are not shown for this reason.

Optimal habitat for rainbow trout fry occurs at approximately 0.1 m^3/s. Above 0.1 m^3/s, AWS decreases exponentially with increasing flow. Optimal habitat for rainbow trout juveniles occurs between 0.2 m^3/s and 0.7 m^3/s with a peak at approximately 0.4 m^3/s. Similar to other modeled streams, the availability of suitable habitat for rainbow trout juveniles is more stable with increasing flow than it is for rainbow trout fry. Rainbow trout spawning habitat availability peaks at approximately 1.1 m^3/s but is near optimal between 0.8 m^3/s and 1.5 m^3/s.

[8] The range of flows modelled for AWS (0 to 2.0 m^3/s) is larger than required for habitat availability simulations.

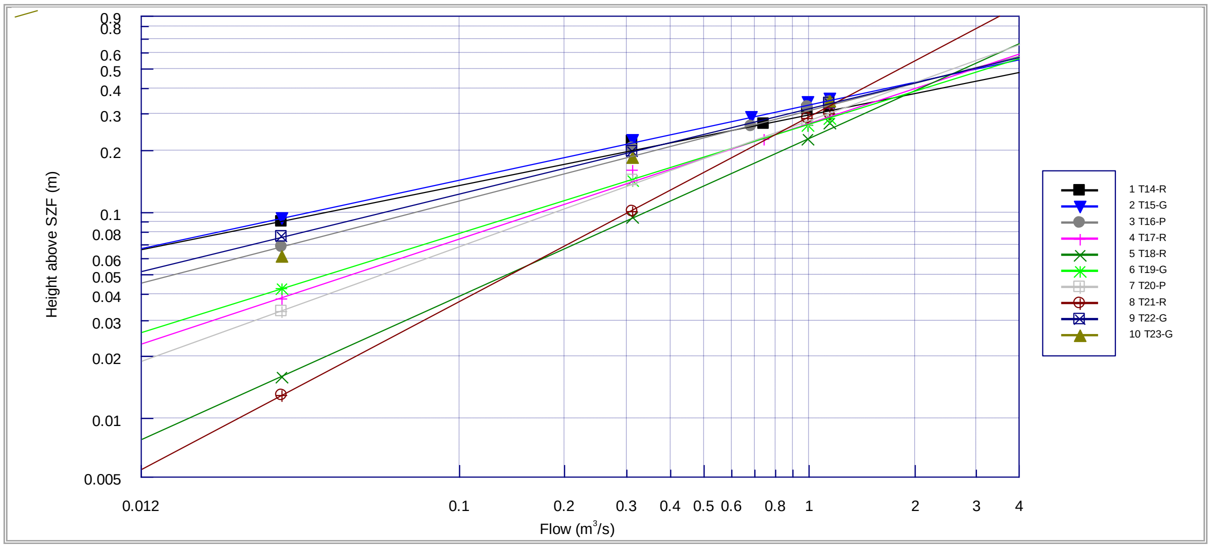


Figure 25: Rating Curves for All Transects, Lower Creek 705 Model

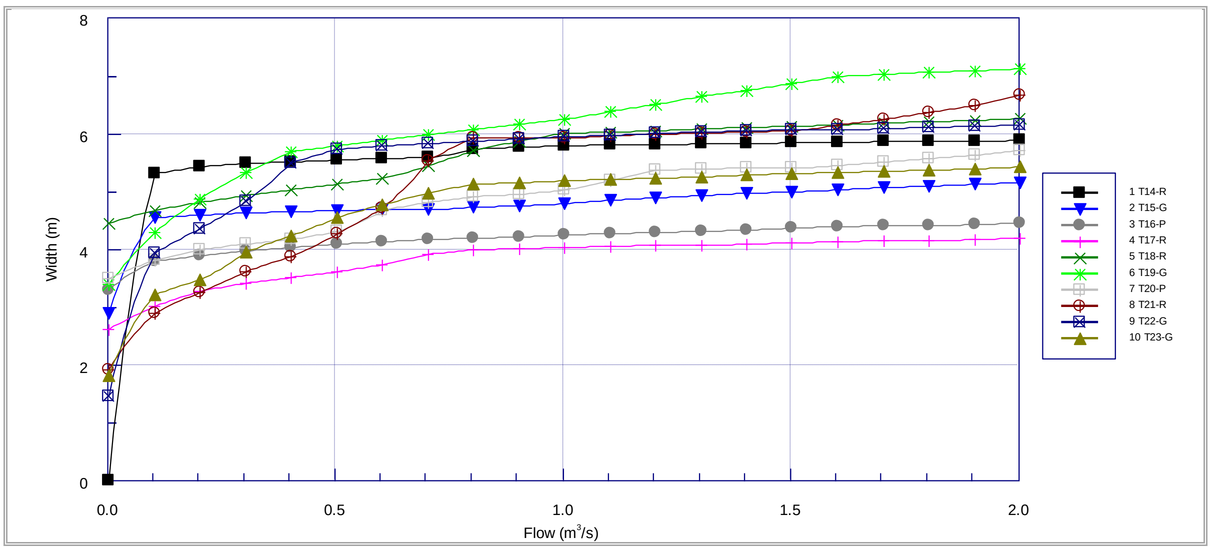


Figure 26: Wetted Width (m) as a Function of Flow (m³/s), Lower Creek 705 Model

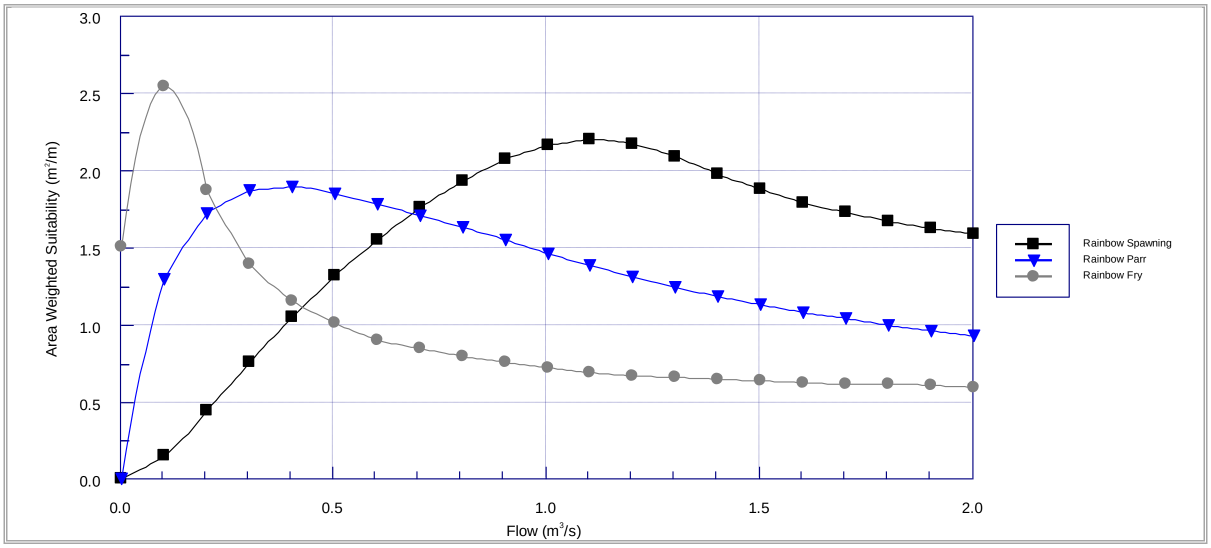


Figure 27: Habitat (AWS; m^2/m) as a Function of Flow (m^3/s), Lower Creek 705 Model

4.5.2 Upper Creek 705 Model

Rating curves for all 13 transects used in the Upper Creek 705 model are shown in **Figure 28**. Average R^2 for all transects was 0.992 and the average mean error was 9.90%. Rating curves for individual transects, the surveyed cross section, and photographs from each site visit are presented in **Annex B**.

The relationship between flow and wetted width for each transect is presented in **Figure 29**. With the exception of one transect (T8-P), wetted width was relatively insensitive to changes in flow between 0.1 m^3/s and 2 m^3/s. For transect T8-P, a positive relationship between wetted width and flow exists at flows >0.2 m^3/s.

The hydraulic habitat relationships for rainbow trout spawning, fry, and juveniles in this section of Creek 705 is shown in Figure 30[9]. Optimal fry habitat occurs between 0 m^3/s and 0.2 m^3/s with a peak at approximately 0.1 m^3/s. AWS for rainbow trout fry decreases rapidly with increasing discharge above 0.2 m^3/s.

Optimal rainbow trout juvenile rearing habitat occurs between 0.2 m^3/s and 0.7 m^3/s with a peak at about 0.4 m^3/s. Optimal rainbow trout spawning habitat is difficult to differentiate because of the relatively gradual increase in rainbow trout spawning AWS from 0 m^3/s and 0.7 m^3/s and the relatively flat relationship between rainbow trout spawning AWS and discharge above 0.7 m^3/s. However, rainbow trout spawning AWS appears to plateau in this section above 1 m^3/s.

[9] The range of flows modelled for AWS (0 to 2.0 m^3/s) is larger than required for habitat availability simulations.

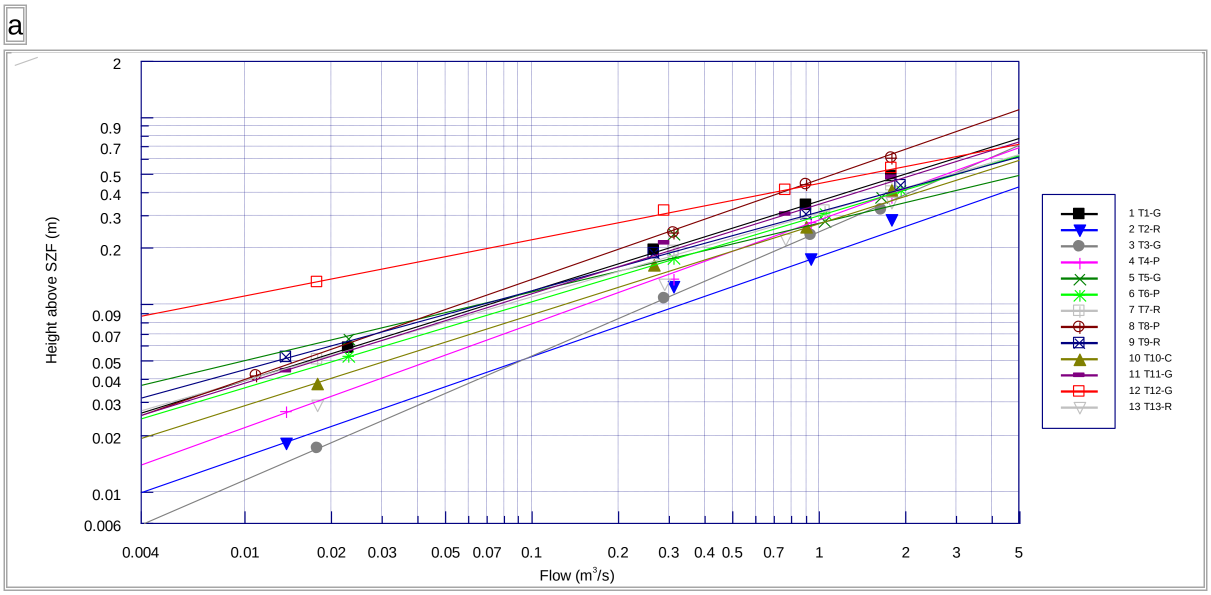


Figure 28: Rating Curves for All Transects, Upper Creek 705 Model

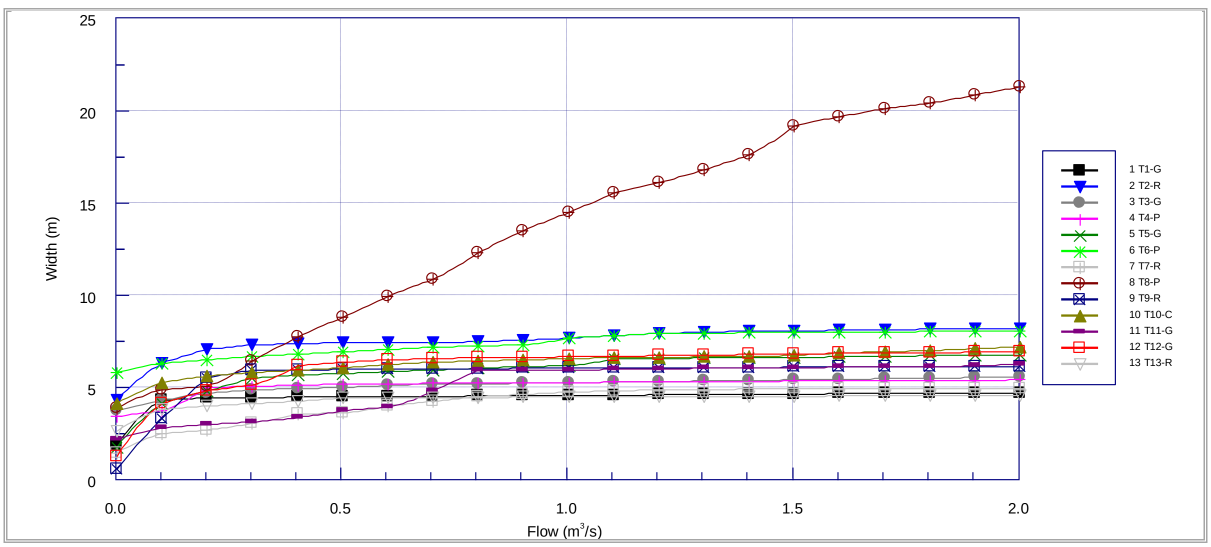


Figure 29: Wetted Width (m) as a Function of Flow (m^3/s), Upper Creek 705 Model

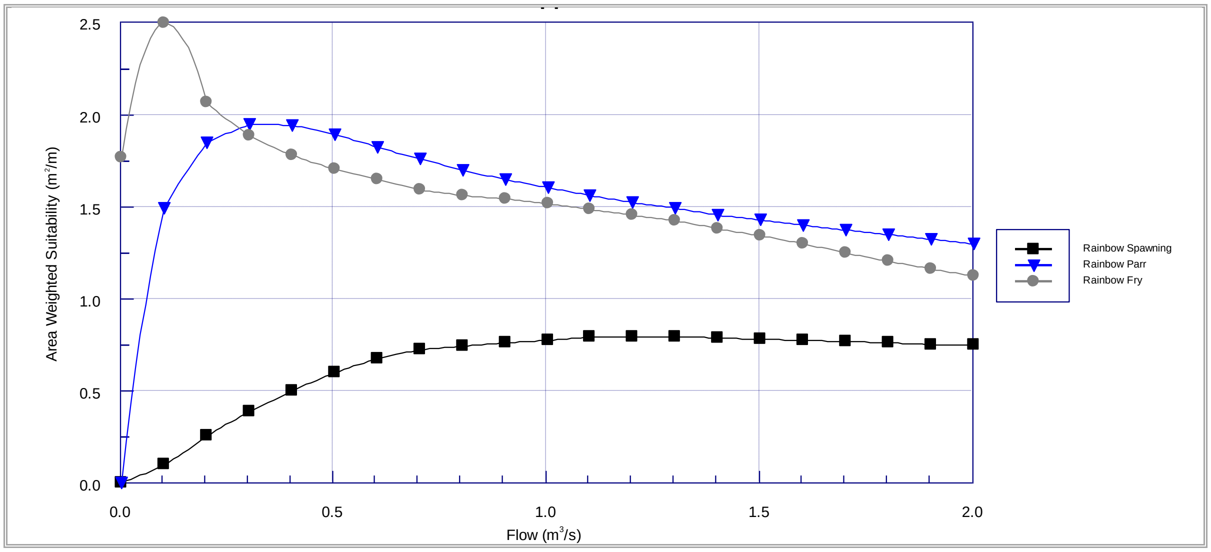


Figure 30: Habitat (AWS; m^2/m) as a Function of Flow (m^3/s), Upper Creek 705 Model

4.6 Confidence Intervals for Hydraulic Habitat Relationships

Confidence intervals for hydraulic habitat relationships for lower and middle Davidson Creek models are summarized, by species and life stage, in **Table 13**. The average range of the 80% confidence interval is presented as a percentage of the mean estimate. Average confidence interval width is presented for 1.0 m^3/s intervals. Hydraulic habitat relationships, with confidence intervals, are presented for 0.1 m^3/s intervals in **Annex C**.

Confidence intervals for kokanee spawning in lower Davidson Creek ranged from 48% to 50% of the mean across all modeled flows. Confidence intervals for rainbow trout spawning in lower Davidson Creek ranged from 46% to 56% of the mean over the modeled flows. This increased to 65% at flows <1 m^3/s and to 81% at flow >1 m^3/s but <2 m^3/s in the middle Davidson Creek section.

For rainbow trout juveniles, confidence intervals were 32%, 46%, and 52% of the estimated mean in the Lower Davidson Creek section at flows <1 m^3/s, >1 m^3/s<2 m^3/s, and >2 m^3/s, respectively. Confidence intervals were 37% and 39% of the mean estimate at flows <1 m^3/s and >1 m^3/s<2 m^3/s, respectively.

Confidence intervals for rainbow trout fry in the lower Davidson Creek section increased from 27% to 50% of the mean with increasing flow and from 38% to 46% in the middle Davidson Creek section with increasing flow.

To examine the potential for uncertainty in the hydraulic habitat relationships that would affect the accuracy of the analyses and its conclusions, rainbow trout spawning availability in the middle Davidson Creek model over the 15-year watershed model flow time series was selected as a test case. This model was selected because it had the widest confidence intervals for the Davidson Creek model and, therefore, had the lowest confidence in its predictions. For this analysis, the lower confidence bound was calculated using the 10th percentile hydraulic habitat relationship while the upper confidence bound was calculated using the 90th percentile hydraulic habitat relationship (refer to **Annex C**, **Figure C-2** for these relationships). These confidence bounds are presented in terms of average habitat availability over the 15-year habitat series in **Figure 31**.

Table 13: ***Average Width of 80% Confidence Intervals (as % of Estimate) for Flow/Habitat Relationships for Lower and Middle Davidson Creek Models***

	KO Spawning		RB Spawning		RB Parr		RB Fry	
Flow range	**LDC**	**MDC**	**LDC**	**MDC**	**LDC**	**MDC**	**LDC**	**MDC**
≤1 m^3/s	49%	-	46%	65%	32%	37%	27%	38%
1 < m^3/s ≤ 2	48%	-	56%	81%	46%	39%	41%	46%
2 < m^3/s ≤ 3	50%	-	54%	-	52%	-	50%	-

Note: KO = kokanee, RB = rainbow trout, LDC = lower Davidson Creek, MDC = middle Davidson Creek.

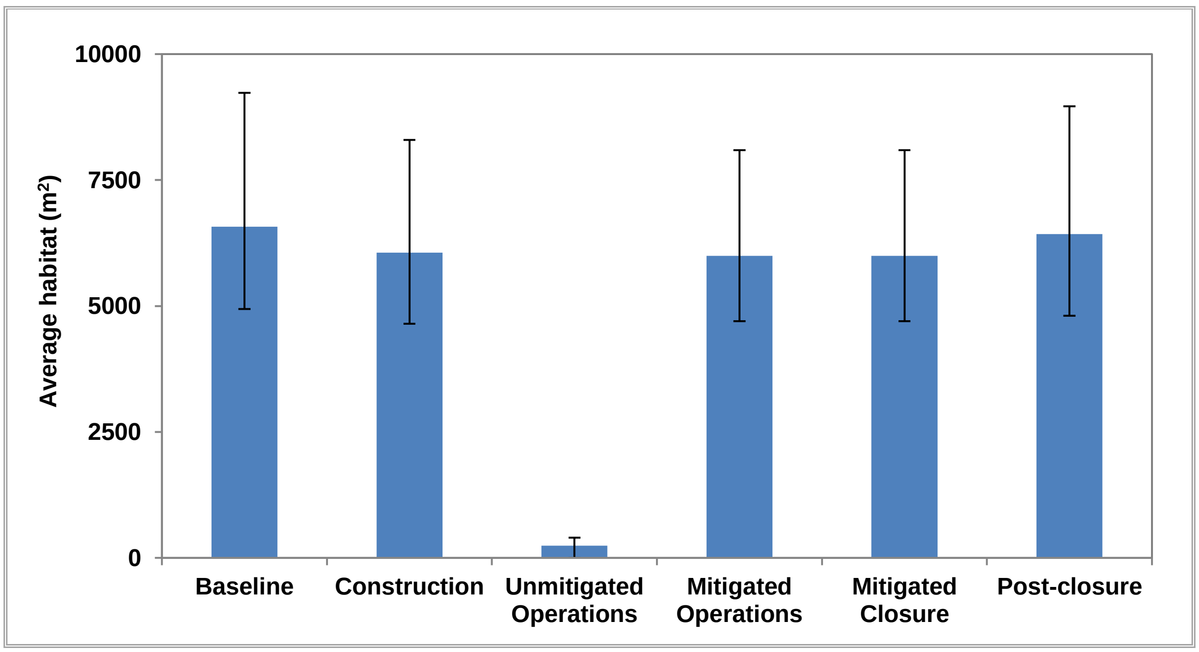


Figure 31: ***Average Middle Davidson Creek Rainbow Trout Spawning Habitat Availability by Project Phase, with Confidence Bounds***

Uncertainty in hydraulic habitat relationships confers uncertainty in AWS using the flow time series. However, this uncertainty should not result in systemic bias for any particular Project phase because error bounds are similar across the range of flow changes predicted for the Project. Therefore, uncertainty in hydraulic habitat relationships is not expected to affect the assessment of potential Project effects.

A more detailed analysis of uncertainty in the hydraulic habitat relationships using a re-sampling procedure (i.e., Monte Carlo analysis) to complete repeat random draws from the range of habitat suitability values (AWS) for each simulated flow in the time series analysis (Turner, 2012) was not completed. However, it is not expected that such an analysis would change the results or conclusions of the assessment. This is because uncertainty in the hydraulic habitat relationship for rainbow trout spawning in middle Davidson Creek is consistent across the range of modelled flows and because the range of flows predicted under baseline and Project conditions are within the range of the model input data (i.e., results can be interpolated and not extrapolated).

4.7 Identification of IFN for Davidson Creek

Table 14 summarises the derivation of IFN, by location and by biological stanza, for middle and lower sections of Davidson Creek (WMN H2 and 1-DC, respectively). The species and life stage requiring the highest flows for each biological stanza, and therefore the species and life stage defining the IFN for that biological stanza, are shown in bold. These include:

- Spawning rainbow trout require the highest flows in lower and middle sections of Davidson Creek in spring (May 16 to June 30);
- Rainbow trout juveniles required the highest flows in middle Davidson Creek in summer (July 1 to August 31);
- Spawning kokanee require the highest flows in lower Davidson Creek in summer (July 1 to August 31);
- Rainbow trout juveniles require the highest flows in lower and middle sections of Davidson Creek in fall (September 1 to November 30); and
- Overwintering IFN were conservatively defined as baseline March flows, the lowest mean monthly flows for the winter stanza.

IFN for rainbow trout fry are not included in **Table 14**. This was because the maximum habitat availability for rainbow trout fry occurs at very low flows (e.g., 0.068 m^3/s for middle Davidson Creek) and their AWS typically increases with decreasing flow. For this reason, fry habitat availability never defines IFN as flows this low would preclude the use of habitat in Davidson Creek by other all other species and life stages. Final IFN by location in Davidson Creek and by biological stanza are summarised in **Table 15**.

Table 14: Summary of IFN Statistics by Biological Stanza

Location	Biological Stanza	Baseline Mean Annual Stanza 30-day Low Flow (m^3/s)	Species and Life Stage	Flow Producing Maximum Habitat (m^3/s)	Habitat at Baseline Mean Annual Stanza 30-day Low Flow, as % Maximum Habitat	Recommended Flow (IFN) (m^3/s)	Habitat at Recommended Flow, as % Maximum Habitat
Middle Davidson	1 December – 10 May	0.114	RB juveniles	-	-	0.115	-
	16 May – 30 June	0.718	RB juveniles	0.268	77%	0.545	87%
			RB spawning	**0.784**	**99%**	**0.545**	**89%**
	1 July – 31 August	0.191	**RB juveniles**	**0.268**	**96%**	**0.130**	**87%**
	1 September – 30 November	0.147	**RB juveniles**	**0.268**	**90%**	**0.115**	**83%**
Lower Davidson	1 December – 10 May	0.172	RB juveniles	-	-	0.175	-
	16 May – 30 June	0.968	RB juveniles	0.455	88%	0.735	95%
			RB spawning	**1.180**	**97%**	**0.735**	**87%**
	1 July – 31 August	0.286	RB juveniles	0.455	94%	0.225	89%
			KO spawning	**0.525**	**92%**	**0.225**	**83%**
	1 September – 30 November	0.224	**RB juveniles**	**0.455**	**89%**	**0.155**	**79%**

Note: RB = rainbow trout. KO = kokanee.. Defining species and life stage for each stanza indicated in bold.

Table 15: Summary of Baseline Mean Annual 30-Day Low Flows and Recommended IFN by Biological Stanza

Location	Biological Stanza	Baseline Mean Annual Stanza 30-day Low Flow (m^3/s)	Recommended Flow (m^3/s)
Middle Davidson	1 December – 10 May	0.114	0.115
	16 May – 30 June	0.718	0.545
	1 July – 31 August	0.191	0.130
	1 September – 30 November	0.147	0.115
Lower Davidson	1 December – 10 May	0.172	0.175
	16 May – 30 June	0.968	0.735
	1 July – 31 August	0.286	0.225
	1 September – 30 November	0.224	0.155

4.8 Mitigated Flow Regime for Davidson Creek

The mitigation flow regime, for average flow conditions, for Davidson Creek at the FSS outfall (located in middle Davidson Creek, **Figure 32**) incorporates IFN for each biological stanza as well as flushing flows during the spring freshet and transitional flows between biological stanzas (**Figure 32**). This flow regime was used to generate the mitigated operations phase flow time series to assess potential Project effects in Davidson Creek (**Section 4.9** following).

Constant flows were defined for the FSS outfall within each stanza. However, due to the remaining natural run-off and groundwater inflows from the watershed downstream of the outfall, flows in lower Davidson Creek will exhibit higher variability than in middle Davidson Creek immediately downstream of the FSS outlet. Therefore, kokanee and rainbow trout habitat in lower Davidson Creek will be reflective of a more variable, semi-naturalized hydrograph than in middle Davidson Creek.

Provisions to reduce mitigation freshet flows in years with lower natural water availability (i.e., dry years) were included in the mitigated flow regime. This provision was intended to avoid potential effects in Tatelkuz Lake and in lower Chedakuz Creek due to water withdrawals in drier years. It was also intended to introduce variability to flushing flows similar to what naturally occurs in Davidson Creek.

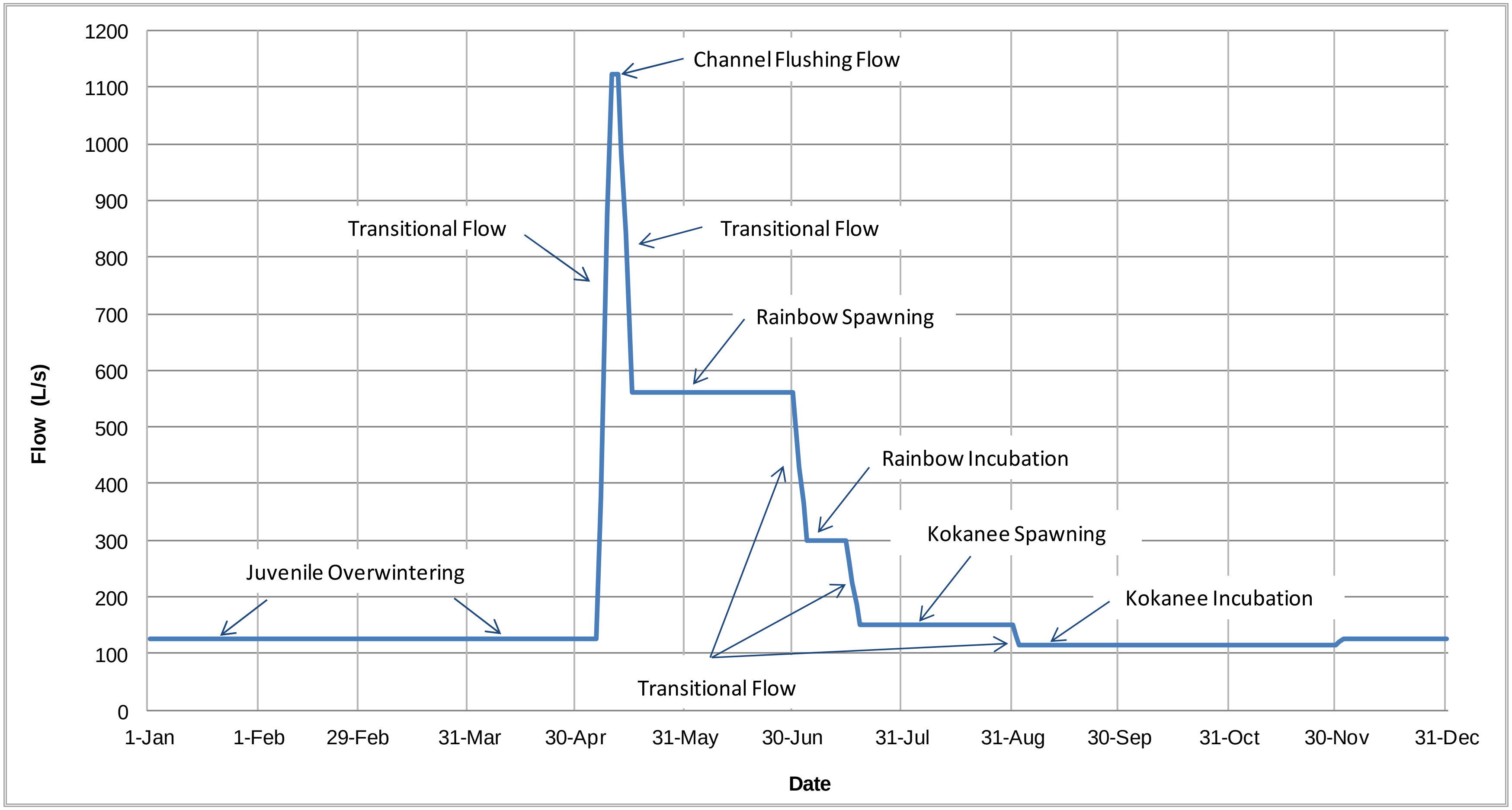


Figure 32: Mitigated Flow Regime for Middle Davidson Creek at FSS Outfall, for Average and Wet Years

4.8.1 End-of-pipe flow requirements

End-of-pipe flows at the FSS outfall required to meet IFNs in Davidson Creek are presented in **Table 16**. With the exception of the fall stanza, IFN for all stanzas were defined by the flow requirements for lower Davidson Creek (**Table 15**). This was because the prescribed flows in lower Davidson Creek were almost always greater than the prescribed flows for middle Davidson Creek (**Table 15**). This is another conservative measure to minimize the risk to fish in Davidson Creek. The fall stanza IFN is defined by the IFN for middle Davidson Creek. It is sufficiently large to also meet the IFN in the lower section.

Table 16: End–of-Pipe Requirements to Meet Davidson Creek IFN

Biological Stanza	End–of-Pipe Requirement (m^3/s)
1 December to 10 May	0.125
16 May to 30 June	0.560
1 July to 31 August	0.150
1 September to 30 November	0.115

4.8.2 Flushing Flows

Flushing flow recommendations for Davidson Creek are presented in **Table 17** and **Table 18**. A single flushing flow will be released in the spring of each year under all but the most extreme drought conditions (i.e., >1:50 dry years). Release of flushing flow volumes will coincide with the historical peak runoff period in Davidson Creek and will last for a minimum of 72 hours.

Water availability will vary during the operational phase of the Project due to natural within-year and between-year hydrologic variability. Therefore, the magnitude and duration of the flushing flow released into Davidson Creek will be varied based on water availability. The availability of water for flushing flows will be forecast based on snowpack levels measured in April. In years of average or above average snowpack, a flow equal to 400% MAD (1.120 m^3/s) will be provided over a 3-day period, typically from 7 to 9 May (**Table 17**). In years of below average snowpack, a 3-day flushing flow equivalent to 200% MAD or the recommended rainbow spawning flow of 0.560 m^3/s will be released to Davidson Creek (**Table 18**). In years of exceptionally low snowpack levels (i.e., snowpack levels lower than 90th percentile), flushing flows will not be released. Instead, water will be reserved to supply rainbow trout spawning needs (0.560 m^3/s) during the 16 May to 30 June stanza.

Physical conditions provided by these flushing flows to sustain spawning habitat for rainbow trout and kokanee in Davidson Creek will be monitored during operations, closure, and post-closure phases. This monitoring will include substrate quality, composition, and distribution and areas of scour and deposition. If necessary, the magnitude, frequency, timing, and duration of flushing flows will be adjusted to achieve desired conditions.

4.8.3 Transitional Flows

Flushing flows will be preceded and followed by transitional flows to ensure that rates of flow change are within biologically acceptable limits. Transitional flows will also occur between successive biologically-based stanza IFNs. In all but two instances, the duration of transitional flows will be three days. The exceptions are two single day adjustments on 1 September and 1 December that bridge the kokanee spawning, kokanee incubation and overwintering IFNs.

The 3-day transitional flows that connect overwintering, flushing, rainbow trout spawning, rainbow trout incubation, kokanee spawning, and kokanee incubation periods will provide a gradual increase or decrease in flows over time. The target rates of change for transitional flows range from a low of 0.0005 m^3/hour to a maximum of 0.030 m^3/hour.

These transitions may be made manually or automatically. Slower rates of change will result if the discharge is electronically monitored and adjusted on a continual basis to meet transitional flow requirements. Higher rates of change will result if flow is monitoring and adjusted manually. This is because it would be done at less frequent intervals than using an automatic system. Whichever method is used, transitional flows will be much slower than the maximum allowable ramping rate of 2.5 cm/hour used at hydroelectric facilities.

4.8.4 Biological-stanza Flows

Based on the rating curve for H2 (**Section 3.4.5.4**), the water surface elevation in Davidson Creek corresponding to the rainbow trout spawning flow of 0.560 m^3/s (Table 17) is 75 cm. Subtracting 10 cm from this stage gives an water level elevation of 65 cm. Based on the same rating curve, a flow of 0.290 m^3/s is required to maintain water surface elevations of 65 cm. This water level will ensure that redds in water depths >10 cm, the preferred water depth for rainbow trout spawning, remain wetted. However, this flow was conservatively rounded to 0.300 m^3/s to derive the recommended rainbow trout incubation flows for Davidson Creek (**Table 17**).

The kokanee spawning flow was set at 0.150 m^3/s (**Table 17**). Most kokanee (>90%) spawn in water 4 cm deep or greater. Kokanee incubation flows were therefore defined as a reduction in 4 cm water surface elevation from the kokanee spawning flow. Based on the rating curve for H2 (**Section 3.4.5.3**), a 4 cm reduction in stage would occur at a discharge of 0.095 m^3/s. Habitat modelling suggests that reducing flows to this level would affect juvenile rainbow trout rearing in Davidson Creek. For this reason, fall stanza flows were conservatively set at the higher 0.115 m^3/s flow and not 0.095 m^3/s. These higher flows will protect juvenile rainbow trout but also protect kokanee redds from being dewatered (**Table 17**). A 1-day transitional flow of 0.130 m^3/s is recommended in early September to assure a smooth reduction to the fall stanza flow.

Table 17: Recommended Flow Regime for Davidson Creek at FSS Outfall for Average or Above Average Water Years

Date	Type of Flow	Flow (m^3/s)	Implementation
2 Dec - 6 May	Rainbow Trout - Overwintering	0.125	Refer to **Table 15**
7 - 9 May	Transitional (72 hrs)		Ramp up incrementally to flushing flow over 72-hour period; target rate is 15 L/h; maximum rate is 30 L/h
10 - 12 May	Flushing Flow	1.120	400% mean annual discharge (MAD = 0.281 m^3/s)
13 - 15 May	Transitional (72 hrs)		Ramp down to rainbow trout spawning flow over 72-hour period; target rate is 8 L/h; maximum rate is 16 L/h
16 May - 30 Jun	Rainbow Trout - Spawning	0.560	Refer to **Table 15**
1 - 3 Jul	Transitional (72 hrs)		Ramp down to rainbow trout incubation flow over 72-hour period; target rate is 4 L/h; maximum rate is 10 L/h
4 - 15 Jul	Rainbow Trout - Incubation	0.300	Refer to text for details.
16 - 18 Jul	Transitional (72 hrs)		Ramp down to kokanee spawning flow over 72-hour period; target rate is 2 L/h; maximum rate is 6 L/h
19 Jul - 31 Aug	Kokanee - Spawning	0.150	Refer to **Table 15**
1 Sep	Transitional (24 hrs)	0.130	Ramp down to kokanee incubation flow over 24-hour period; target rate is 1 L/h; maximum rate is 5 L/h
2 Sep - 30 Nov	Kokanee - Incubation	0.115	Refer to **Table 15**
1 Dec	Transitional (24 hrs)	0.120	Ramp up to overwintering flow over 24-hour period; target rate is 0.5 L/h; maximum rate is 2.5 L/h

Table 18: Recommended Flow Regime for Davidson Creek at FSS Outfall for Period 2 December to 30 June during Below Average Water Years

Date	Type of Flow	Flow (m^3/s)	Implementation
2 Dec - 9 May	Rainbow Trout - Overwintering	0.125	Refer to **Table 15**
10 - 12 May	Transitional (72 hrs)		Ramp up incrementally to flushing flow over 72-hour period; target rate is 6 L/h; maximum rate is 18 L/h
13 - 15 May	Flushing Flow	0.560	200% mean annual discharge (MAD = 0.281 m^3/s)
16 May - 30 Jun	Rainbow Trout – Spawning	0.560	Refer to **Table 15**

Note: Decrease in flushing flows from 400% MAD (1.120 m^3/s) to 200% MAD (0.560 m^3/s).

4.9 Potential Effects of Meeting IFN in Davidson Creek on Tatelkuz Lake

Using the Tatelkuz Lake routing model (Knight Piésold, 2013b), the predicted maximum change in Tatelkuz Lake water levels due to pumping to meet mill requirements and Davidson Creek IFN occurs in June (**Table 19**, and see **Section 5.3.2.4.1.2** of Hydrology EA). During average conditions, this amounts to an approximately 7 cm reduction (or 6% reduction) in June lake levels (**Table 19**). During 1:50 dry year conditions, a reduction of 11 cm (or 9% reduction) is predicted (**Table 20**). These predicted changes are small relative to baseline mean annual (0.80 m) and maximum (2.0 m) lake level fluctuations. Absolute water level changes are smaller in other months of the year. No impacts to fish using littoral habitat in Tatelkuz Lake are expected as a result of changes to Tatelkuz Lake levels of up to 0.11 m.

The aggregate change in littoral habitat availability in Tatelkuz Lake during the operations and closure phases is predicted to be less than 1% under average conditions and less than 3% under 1:50 year dry conditions (see **Section 5.3.9** of Fish Habitat EA). The largest changes occur for littoral habitats with boulders, habitats that occur at higher elevations along the western and eastern shorelines and that represent less than 4% of total habitat. Reductions in this type of littoral habitat from baseline are >18% for average conditions. No change in the availability of this type of habitat would occur under 1:50 dry conditions because this type of habitat is naturally dewatered during baseline 1:50 dry conditions.

Percentage change in Tatelkuz Lake water levels are highest in winter (December to March). These include up to 20% reductions in lake levels in February during average conditions and up to 23% reduction in lake levels in February during 1:50 year dry conditions (**Table 20**). These relative changes are not expected to have a significant effect on fish in Tatelkuz Lake because fish during this time are generally using deeper water habitats which would be unaffected by these predicted water level reductions.

Table 19: Estimated Mean Monthly and Annual Tatelkuz Lake Levels with Mitigation Measures for Construction, Operations, Closure, and Post-closure Phases

Mine Phase	Estimated Mean Monthly and Annual Tatelkuz Lake Elevations												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Baseline Elevation (masl)	926.93	926.93	926.95	927.11	927.37	927.33	927.08	926.95	926.96	926.96	927.00	926.95	927.07
Estimated Baseline Fluctuation (cm)	19.6	18.5	27.9	76.2	131.2	129.3	105.6	84.3	34.3	34.5	38.9	33.0	147.8
Construction (Year -2) Elevation (masl)	926.93	926.93	926.95	927.11	927.37	927.33	927.08	926.95	926.96	926.96	927.00	926.95	927.07
Change from Baseline in cm	0.00	0.00	0.00	0.04	0.10	0.06	-0.01	-0.01	0.00	0.01	0.01	0.00	0.02
% Change from Baseline Fluctuation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Operations (Year 17) Elevation (masl)	926.89	926.89	926.92	927.09	927.30	927.26	927.03	926.91	926.93	926.93	926.98	926.92	927.02
Change from Baseline in cm	-3.61	-3.63	-3.36	-2.46	-6.72	-7.29	-4.78	-4.07	-3.12	-3.21	-2.85	-3.39	-4.25
% Change from Baseline Fluctuation	-18%	-20%	-12%	-3%	-5%	-6%	-5%	-5%	-9%	-9%	-7%	-10%	-3%
Closure (Year 20) Elevation (masl)	926.90	926.90	926.93	927.09	927.30	927.26	927.04	926.92	926.94	926.93	926.98	926.92	927.03
Change from Baseline in cm	-2.89	-2.89	-2.64	-2.04	-6.67	-7.46	-4.51	-3.49	-2.56	-2.69	-2.37	-2.75	-3.88
% Change from Baseline Fluctuation	-15%	-16%	-9%	-3%	-5%	-6%	-4%	-4%	-7%	-8%	-6%	-8%	-3%
Post-closure Elevation (masl)	926.93	926.93	926.95	927.11	927.38	927.33	927.08	926.95	926.96	926.96	927.00	926.95	927.07
Change from Baseline in cm	0.18	0.17	0.17	0.25	0.80	-0.37	-0.25	-0.08	0.08	0.12	0.05	0.15	0.12
% Change from Baseline Fluctuation	1%	1%	1%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%

Source: Lake levels and % change have been determined by AMEC using data in Knight Piésold (2013b).

Note: masl =metres above sea level; cm = centimetre; % = percent.

Table 20: Estimated 1:50–year Dry Monthly and Annual Tatelkuz Lake Levels with Mitigation Measures for Construction, Operations, Closure, and Post-closure Phases

Mine Phase	Estimated 1:50 Year Dry Monthly and Annual Tatelkuz Lake Elevations												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Baseline Elevation (masl)	926.84	926.85	926.87	926.83	926.93	926.93	926.86	926.80	926.76	926.79	926.85	926.84	926.85
Estimated Baseline Fluctuation (cm)	19.6	18.5	27.9	76.2	131.2	129.3	105.6	84.3	34.3	34.5	38.9	33.0	147.8
Construction (Year -2) Elevation (masl)	926.84	926.85	926.87	926.83	926.93	926.93	926.86	926.80	926.76	926.79	926.85	926.84	926.85
Change from Baseline in cm	0.00	0.00	0.00	0.04	0.14	0.03	-0.02	-0.01	-0.01	0.00	0.00	0.00	0.02
% Change from Baseline Fluctuation	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Operations (Year 17) Elevation (masl)	926.80	926.81	926.83	926.80	926.83	926.82	926.80	926.75	926.72	926.75	926.82	926.80	926.80
Change from Baseline in cm	-4.42	-4.32	-3.94	-3.21	-10.15	-11.06	-5.85	-5.22	-4.08	-4.07	-3.47	-4.27	-5.50
% Change from Baseline Fluctuation	-23%	-23%	-14%	-4%	-8%	-9%	-6%	-6%	-12%	-12%	-9%	-13%	-4%
Closure (Year 20) Elevation (masl)	926.81	926.82	926.84	926.80	926.83	926.82	926.81	926.75	926.73	926.76	926.82	926.81	926.80
Change from Baseline in cm	-3.54	-3.43	-3.09	-2.66	-10.00	-10.93	-5.39	-4.38	-3.27	-3.32	-2.84	-3.44	-4.87
% Change from Baseline Fluctuation	-18%	-19%	-11%	-3%	-8%	-8%	-5%	-5%	-10%	-10%	-7%	-10%	-3%
Post-closure Elevation (masl)	926.85	926.85	926.87	926.83	926.94	926.93	926.86	926.80	926.76	926.79	926.85	926.84	926.85
Change from Baseline in cm	0.14	0.15	0.17	0.20	1.05	-0.53	-0.25	-0.07	0.08	0.18	0.08	0.12	0.12
% Change from Baseline Fluctuation	1%	1%	1%	0%	1%	0%	0%	0%	0%	1%	0%	0%	0%

Source: Lake levels and % change have been determined by AMEC using data in Knight Piésold (2013b).

Note: masl = metres above sea level; cm = centimetre; % = percent.

4.10 Potential for Flow-Related Effects

4.10.1 Davidson Creek

Predicted changes in the 15-year AWS time-series in Davidson Creek are summarized for each Project phase in **Table 21**. Predicted changes in the 15-year AWS time-series for each phase are compared to baseline in **Figure 33**.

During construction, total aggregated AWS in Davidson Creek is predicted to decrease by 6% for rainbow trout spawning in spring, decrease by 3% and 7% for rainbow trout juveniles in summer and fall, and decrease by 6% for kokanee spawning in late summer (**Table 21**). However, total aggregated AWS in Davidson Creek is predicted to increase by 10% in summer and 7% in fall for rainbow trout fry and to increase by 9% for rainbow trout juveniles in spring. These predicted changes in AWS are due to water management in the upper Davidson Creek watershed during construction. However, none of the predicted reductions in AWS in Davidson Creek during the construction phase would be greater than the 10% change threshold. As a result, no significant adverse effect to rainbow trout or kokanee is predicted to occur during this phase.

Without operation of the FSS (i.e., unmitigated), predicted flow changes in Davidson Creek during mine operations would result in significant reductions in AWS for rainbow trout and kokanee (**Table 21**). These predicted reductions in AWS include:

- A 61% reduction in kokanee spawning habitat;
- An 83% reduction in rainbow trout spawning habitat;
- A 12% to 30% reduction in rainbow trout fry habitat in summer and fall, respectively;
- A 46% to 75% reduction in rainbow trout juvenile habitat in spring, summer, and fall.

Each of these predicted reductions in AWS is well above the 10% change threshold and, therefore, would be expected to cause significant adverse effects to rainbow trout and kokanee in Davidson Creek if allowed to occur. These effects would likely be manifest in the form of significant reduction in areas suitable for spawning, significant egg mortality due to desiccation, sedimentation, or reduced gas exchange, significant reductions in benthic macro-invertebrate drift, and/or significant reductions in areas with suitable depths and water velocities for fry and juveniles. Together or singly, these reductions would likely result in the extirpation of kokanee and rainbow trout from Davidson Creek. Mitigation using the FSS is therefore crucial to maintaining these fish and, by association, other aquatic organisms in Davidson Creek.

Operation of the FSS during mine operations and closure phases, successfully mitigates potential flow effects in Davidson Creek downstream of the TSF. As can be seen in **Table 21**, changes in total aggregated AWS are predicted to be no more than 6% lower for rainbow trout and kokanee spawning in spring and late fall, respectively, and only 3% and 9% lower for rainbow trout juveniles in summer and fall, respectively. Aggregated AWS for rainbow trout fry is predicted to increase by 12% in summer and 10% in fall. This is because more lower velocity habitat would be available with operation of the FSS compared to natural flows. Approximately 13% to 14% more rainbow trout juvenile habitat would exist during the spring freshet during operations and closure. This is because slightly lower discharges in spring, compared to natural flows, would create more of the lower velocity habitats preferred by juvenile rainbow trout.

During the post-closure phase when water quality in the TSF is acceptable for release to Davidson Creek and the FSS is decommissioned, aggregated AWS for rainbow trout would either increase compared to baseline conditions or be no more than 9% lower than baseline for all life stages and biological stanzas (**Table 21**). Aggregated AWS for rainbow trout spawning would be only 3% lower than baseline while aggregated AWS for juvenile rainbow trout in summer and fall would be only 9% and 5% lower than baseline. Aggregated AWS for rainbow trout fry would increase compared to baseline in summer (+18%) and fall (+5%). These changes are reflections of:

- the slight increase in watershed area of Davidson Creek at post-closure compared to baseline (~3.3 km^2 larger[10]; **Table 1**);
- the change in summer water losses due to increased evaporation from the TSF (see **Section 5.3.2** for details of the post-closure site water-balance); and
- the preferences by adult and juvenile rainbow trout for higher flows and the preference by rainbow trout fry for lower flows.

Aggregated AWS for kokanee spawning was predicted to be 13% lower than baseline during the post-closure phase (**Table 21**). This prediction is greater than the 10% change threshold conservatively set for determining potential adverse effects. As a result, a potential residual adverse effect to kokanee spawning habitat may occur in Davidson Creek during the post-closure phase.

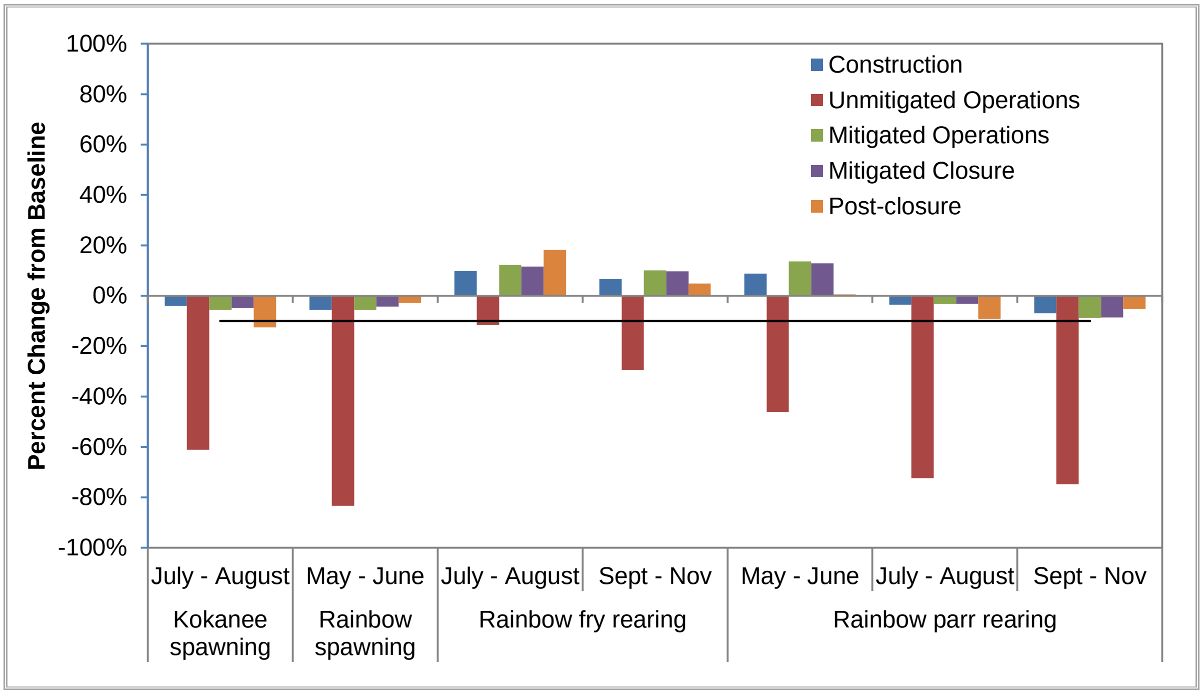
Offsetting for any lost kokanee production in Davidson Creek would be required if monitoring during the operations and closure phases shows that modeling predictions are accurate and if no further engineering solutions are found possible during these phases. However, New Gold will monitor physical and biological conditions in Davidson Creek over the 35-year operations and closure periods. Data would be used to refine model predictions and evaluate different engineered solutions. For instance, the Site C portion of the TSF will be closed in early operations. This will afford the opportunity to field-evaluate TSF closure options and to evaluate closure options for the larger, Site D portion of the TSF. If required, solutions to provide more water for kokanee spawning during post-closure would be developed using biological and engineering data obtained through the operations and closure phases. Habitat offsetting would remain an option if effective solutions to flow augmentation are not found. Contingency options in the Fisheries Mitigation and Offsetting Plan (**EA Appendix 5.1.2.6C**) include restoration of degraded streams in the Nechako River watershed, including Murray and Swanson creeks, two streams identified by local stream keeper groups and First Nations as previously important fish producing streams, and replacement of fish impassable culverts in the Vanderhoof Forest District.

[10] Net increase in watershed area after diversion of a portion of the headwaters of the Creek 661 watershed to Davidson Creek and diversion of Lake 1628LNRS in the Davidson Creek headwaters to Creek 705.

Table 21: Potential Changes in Area Weighted Suitability (m^2) for Rainbow Trout and Kokanee in Davidson Creek over the 15-year Watershed Model Flow Time Series

			Area Weighted Suitability by Project Phase										
			Baseline	Construction		Unmitigated Operations		Mitigated Operations		Mitigated Closure		Post-closure	
Model	**Species/Life Stage**	**Stanza**	**(m^2)**	**(m^2)**	**(% change)**	**(m^2)**	**(% change)**	**(m^2)**	**(% change)**	**(m^2)**	**(% change)**	**(m^2)**	**(% change)**
Lower	Kokanee spawning	Jul – Aug	8,519	8,176	-4%	3,314	-61%	8,033	-6%	8,101	-5%	7,447	-13%
	Rainbow spawning	May – Jun	9,152	8,791	-4%	2,378	-74%	8,821	-4%	9,047	-1%	8,859	-3%
	Rainbow fry rearing	Jul – Aug	11,623	12,788	10%	17,737	53%	13,396	15%	13,199	14%	14,147	22%
		Sep – Nov	14,052	15,032	7%	17,059	21%	15,810	13%	15,691	12%	15,010	7%
	Juvenile rainbow rearing	May – Jun	10,151	10,765	6%	9,952	-2%	11,147	10%	10,948	8%	10,264	1%
		Jul – Aug	11,620	11,336	-2%	6,150	-47%	11,216	-3%	11,275	-3%	10,699	-8%
		Sep – Nov	10,838	10,338	-5%	5,316	-51%	9,993	-8%	10,060	-7%	10,276	-5%
Middle	Kokanee spawning	N/A	-	-	-	-	-	-	-	-	-	-	-
	Rainbow spawning	May – Jun	6,579	6,066	-8%	245	-96%	6,007	-9%	6,007	-9%	6,432	-2%
	Rainbow fry rearing	Jul – Aug	17,855	19,583	10%	8,322	-53%	19,686	10%	19,686	10%	20,688	16%
		Sep – Nov	21,031	22,371	6%	7,673	-64%	22,804	8%	22,804	8%	21,761	3%
	Juvenile rainbow rearing	May – Jun	14,973	16,575	11%	3,592	-76%	17,401	16%	17,401	16%	14,997	0%
		July – Aug	18,234	17,479	-4%	2,071	-89%	17,645	-3%	17,645	-3%	16,415	-10%
		Sep – Nov	16,679	15,268	-8%	1,605	-90%	15,070	-10%	15,070	-10%	15,783	-5%
Total	Kokanee spawning	Jul – Aug	8,519	8,176	-4%	3,314	**-61%**	8,033	-6%	8,101	-5%	7,447	**-13%**
	Rainbow spawning	May – Jun	15,731	14,857	-6%	2,622	**-83%**	14,828	-6%	15,054	-4%	15,291	-3%
	Rainbow fry rearing	Jul – Aug	29,477	32,372	10%	26,059	**-12%**	33,082	12%	32,885	12%	34,835	18%
		Sep – Nov	35,083	37,403	7%	24,731	**-30%**	38,614	10%	38,495	10%	36,770	5%
	Juvenile rainbow rearing	May – Jun	25,125	27,340	9%	13,544	**-46%**	28,548	14%	28,349	13%	25,262	1%
		Jul – Aug	29,854	28,814	-3%	8,221	**-72%**	28,862	-3%	28,920	-3%	27,114	-9%
		Sep – Nov	27,517	25,607	-7%	6,920	**-75%**	25,063	-9%	25,130	-9%	26,059	-5%

Note: N/A = not applicable; there is no kokanee spawning in the middle Davidson Creek. % change is percent change from baseline conditions. Reductions greater than the -10% defined effect threshold are indicated in bold.



Note: Values represent comparison of predicted Project phase AWS to baseline AWS. Defined effect-threshold (-10%) indicated with black horizontal line.

Figure 33: Summary of Percent Change in Total Habitat Area for Davidson Creek Downstream of TSF, for 15-year Watershed Model Flow Series

4.10.2 Lower Chedakuz Creek

During construction, no changes in AWS for rainbow trout or kokanee are predicted to occur in Chedakuz Creek downstream of Tatelkuz Lake (i.e., lower Chedakuz 15-CC section) (**Table 22**). This is because pumping water from Tatelkuz Lake to mitigate potential flow reductions in Davidson Creek does not occur until operations.

Slight increases (~1% to 3%) in AWS for rainbow trout spawning, fry, and juvenile habitat are predicted in Chedakuz Creek downstream of the Davidson Creek confluence (i.e., lower Chedakuz H5 section) during construction (**Table 22**). This is because the slight decrease in flows caused by diversion of Lake 1628LNRS to Creek 705 creates slightly more preferable hydraulic conditions for all three life stages compared to baseline. Aggregating these two sections together, the predicted changes in AWS for rainbow trout spawning, fry, and juvenile and for kokanee spawning in Chedakuz Creek during construction are small (<4%) and no significant adverse effect would result (**Figure 34**).

No change in AWS for any rainbow trout life stage or for kokanee spawning would occur in Chedakuz Creek immediately downstream of Tatelkuz Lake during the unmitigated operations scenario (**Table 22**). This is because no pumping of water from Tatelkuz Lake would occur under this scenario. Therefore, flows and resulting AWS for both species would be similar to baseline and construction phases. However, in Chedakuz Creek downstream of the Davidson Creek confluence (H5 section), AWS for rainbow trout fry and juveniles would increase between 1%

and 13% under the unmitigated operations scenario (**Table 22**). AWS for kokanee spawning would decrease in spring but only by 3%. These changes would occur due to the slightly smaller watershed area caused by diversion of Lake 1628LNRS in the headwaters of Davidson Creek to Creek 705, by capture of flow in Davidson Creek behind the TSF, and by water requirements (0.033 m^3/s) in the mill. These effects to rainbow trout and kokanee are much smaller in Chedakuz Creek than in Davidson Creek owing to its much larger unaffected upstream watershed area. Aggregated changes in AWS for kokanee and rainbow trout life stages for the unmitigated scenario are shown in **Figure 34**.

Pumping of water from Tatelkuz Lake to Davidson Creek (i.e., mitigated operations scenario) is predicted to result in changes to AWS for rainbow trout and kokanee in Chedakuz Creek immediately downstream of the lake outlet (15-CC section in **Table 22**). These changes include:

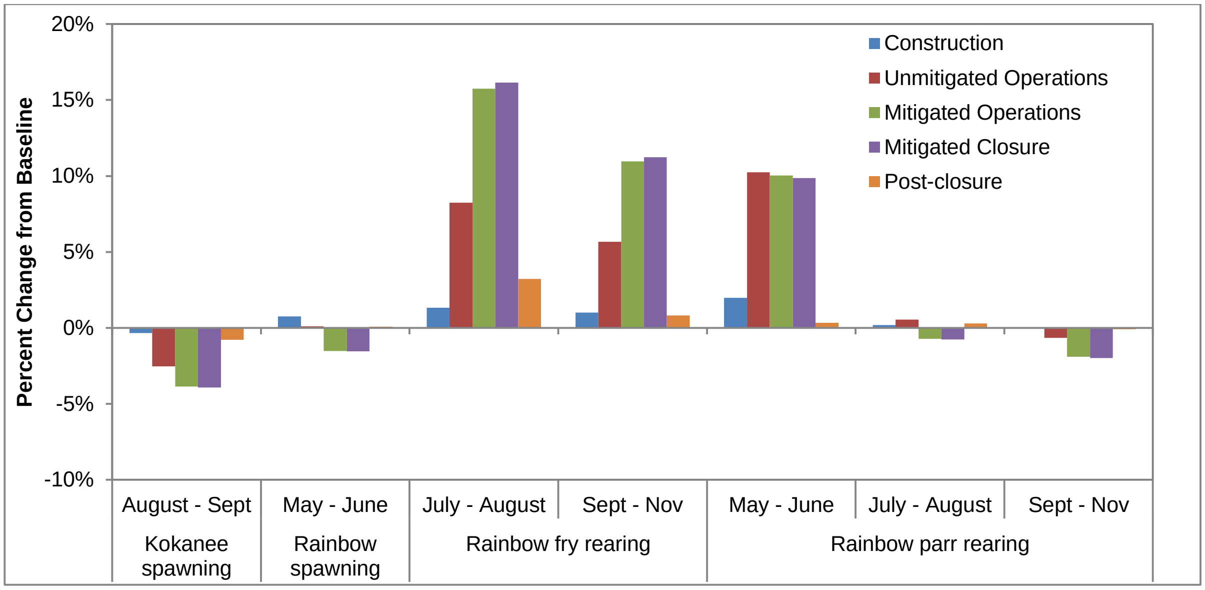
- a 9% reduction in rainbow trout spawning habitat in spring;
- 2%, 6%, and 5% reductions in rainbow trout juvenile habitat in spring, summer, and fall, respectively; and
- 5% reduction in kokanee spawning habitat in late summer.

None of these reductions in AWS are greater than 10% from baseline and, therefore no significant adverse effect to any life stage of either species is predicted to occur. AWS for rainbow trout fry is predicted to increase (11% to 16%) in summer/fall due to their preference for slower flow habitat.

During mitigated operations, the reductions in AWS for rainbow trout spawning and juveniles in Chedakuz Creek immediately downstream of Tatelkuz Lake are larger than changes in Chedakuz Creek downstream of the Davidson Creek confluence (15-CC vs. H5 sections in **Table 22**). This is due to the return of water pumped from Tatelkuz Lake to Chedakuz Creek, via the FSS and Davidson Creek. Therefore, predicted changes in AWS for rainbow trout and kokanee in Chedakuz Creek downstream of Davidson Creek during mitigated operations are due entirely to changes in upstream catchment area (**Table 1**) caused by construction of mine facilities in the upper Davidson Creek and Creek 661 watersheds.

Predicted changes in rainbow trout and kokanee AWS in Chedakuz Creek during the closure phase are identical to those predicted during the mitigated operations phase in both sections. This is because the FSS continues to operate during closure and because there are no further alterations to the Chedakuz Creek watershed area or to the run-off volumes reporting to the creek at either location.

During post-closure, AWS for rainbow trout spawning, fry, and juveniles and for kokanee spawning return to nearly pre-construction baseline levels (**Table 22** and **Figure 34**). The small decreases in kokanee spawning habitat (-1%) and small increases rainbow trout fry habitat (up to +5%) predicted in summer and late summer are a result of slightly lower flows that would occur due to the <1% decrease in total watershed area of Chedakuz Creek immediately upstream and downstream of the Davidson Creek confluence following closure of the mine.



Note: Values represent comparison of predicted Project phase AWS to baseline AWS. Defined effect-threshold (-10%) indicated by the lower extent of the y-axis.

Figure 34: Summary of Percent Change in Total Habitat Area for Chedakuz Creek, for 15-year Watershed Model Flow Series

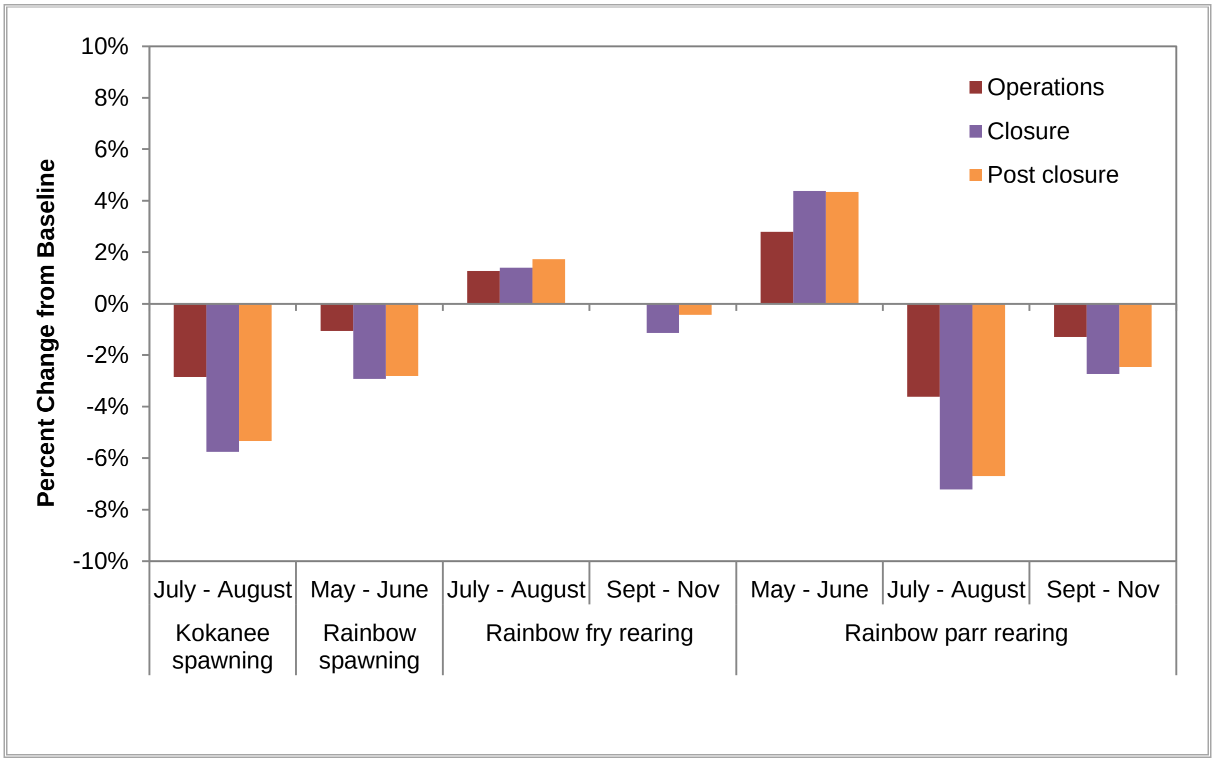
Table 22: Potential Changes in Area Weighted Suitability (m^2) for Rainbow Trout and Kokanee in lower Chedakuz Creek over the 15-year Watershed Model Flow Time Series

			Area Weighted Suitability by Project Phase										
			Baseline	Construction		Unmitigated Operations		Mitigated Operations		Mitigated Closure		Post-closure	
Model	**Species/Life Stage**	**Stanza**	**(m^2)**	**(m^2)**	**(% change)**	**(m^2)**	**(% change)**	**(m^2)**	**(% change)**	**(m^2)**	**(% change)**	**(m^2)**	**(% change)**
15-CC	Kokanee spawning	Aug – Sep	2,159	2,159	0%	2,158	0%	2,054	-5%	2,050	-5%	2,160	0%
	Rainbow spawning	May – Jun	2,457	2,458	0%	2,446	0%	2,228	-9%	2,213	-10%	2,457	0%
	Rainbow fry rearing	Jul – Aug	6,457	6,460	0%	6,522	1%	7,512	16%	7,558	17%	6,490	1%
		Sep – Nov	7,228	7,227	0%	7,260	0%	7,990	11%	8,024	11%	7,207	0%
	Juvenile rainbow rearing	May – Jun	5,398	5,398	0%	5,395	0%	5,301	-2%	5,294	-2%	5,397	0%
		Jul – Aug	5,169	5,168	0%	5,157	0%	4,894	-5%	4,882	-6%	5,163	0%
		Sep – Nov	5,023	5,023	0%	5,015	0%	4,780	-5%	4,769	-5%	5,029	0%
H5	Kokanee spawning	Aug – Sep	12,065	12,016	0%	11,708	-3%	11,620	-4%	11,615	-4%	11,954	-1%
	Rainbow spawning	May – Jun	12,502	12,615	1%	12,529	0%	12,503	0%	12,517	0%	12,515	0%
	Rainbow fry rearing	Jul – Aug	8,903	9,103	2%	10,104	13%	10,269	15%	10,283	15%	9,368	5%
		Sep – Nov	10,023	10,199	2%	10,971	9%	11,152	11%	11,166	11%	10,188	2%
	Juvenile rainbow rearing	May – Jun	10,849	11,172	3%	12,517	15%	12,575	16%	12,554	16%	10,907	1%
		Jul – Aug	17,289	17,332	0%	17,425	1%	17,403	1%	17,403	1%	17,363	0%
		Sep – Nov	17,692	17,681	0%	17,552	-1%	17,502	-1%	17,499	-1%	17,666	0%
Total	Kokanee spawning	Aug – Sep	14,224	14,175	0%	13,866	-3%	13,674	-4%	13,665	-4%	14,114	-1%
	Rainbow spawning	May – Jun	14,959	15,073	1%	14,974	0%	14,731	-2%	14,730	-2%	14,972	0%
	Rainbow fry rearing	Jul – Aug	15,360	15,563	1%	16,627	8%	17,780	16%	17,841	16%	15,858	3%
		Sep – Nov	17,251	17,426	1%	18,231	6%	19,141	11%	19,190	11%	17,395	1%
	Juvenile rainbow rearing	May – Jun	16,247	16,570	2%	17,913	10%	17,876	10%	17,849	10%	16,303	0%
		Jul – Aug	22,458	22,501	0%	22,581	1%	22,298	-1%	22,285	-1%	22,526	0%
		Sep – Nov	22,715	22,704	0%	22,567	-1%	22,282	-2%	22,267	-2%	22,695	0%

Note: % change is percent change from baseline conditions. No reductions greater than the10% threshold were predicted.

4.10.3 Creek 661

Predicted changes in AWS in Creek 661 are presented in **Figure 35** and summarized in **Table 23**. Results are presented for operations, closure, and post-closure phases only, as reductions in watershed area, and hence run-off volumes, during the construction phase is <2% (**Table 1**). Only unmitigated scenarios are shown for operations and closure phases as operation of the FSS does not affect Creek 661 and this mitigation measure is therefore specific to Davidson Creek.



Note: Values represent comparison of predicted Project phase AWS to baseline AWS. Defined effect-threshold (-10%) defined by the lower extent of y-axis.

Figure 35: Summary of Percent Change in Total Habitat Area for Creek 661, for 15-year Watershed Model Flow Series

Predicted flow reductions in Creek 661 result in relatively small (<8%) changes in AWS for rainbow trout spawning, fry, and juvenile in Creek 661 during operations, closure and post-closure phases. The largest reduction in AWS is predicted to occur during closure for rainbow trout juvenile in summer (-7%). All other reductions in AWS for other rainbow trout life stages are predicted to be <5%. Increases in AWS up to 2% for rainbow trout fry in summer are predicted during these three phases.

Reductions in AWS for kokanee spawning are predicted to occur during operations, closure, and post-closure phases in Creek 661. However, none of these reductions in AWS would be >6% from baseline and no residual adverse effects would occur as a result.

Table 23: Potential Changes in Area Weighted Suitability for Rainbow Trout and Kokanee in Creek 661 over 15-year Watershed Model Flow Time Series

Species/Life Stage	Stanza	Area Weighted Suitability by Project Phase						
		Baseline	Operations		Closure		Post-closure	
		(m^2)	(m^2)	(% change)	(m^2)	(% change)	(m^2)	(% change)
Kokanee spawning	Jul - Aug	11,006	10,693	-3%	10,373	-6%	10,419	-5%
Rainbow spawning	May – Jun	8,719	8,627	-1%	8,465	-3%	8,475	-3%
Rainbow fry rearing	Jul – Aug	16,116	16,320	1%	16,342	1%	16,394	2%
	Sep – Nov	16,381	16,375	0%	16,194	-1%	16,311	0%
Juvenile rainbow rearing	May – Jun	13,153	13,520	3%	13,729	4%	13,724	4%
	Jul – Aug	13,538	13,049	-4%	12,562	-7%	12,631	-7%
	Sep – Nov	6,288	6,206	-1%	6,116	-3%	6,133	-2%

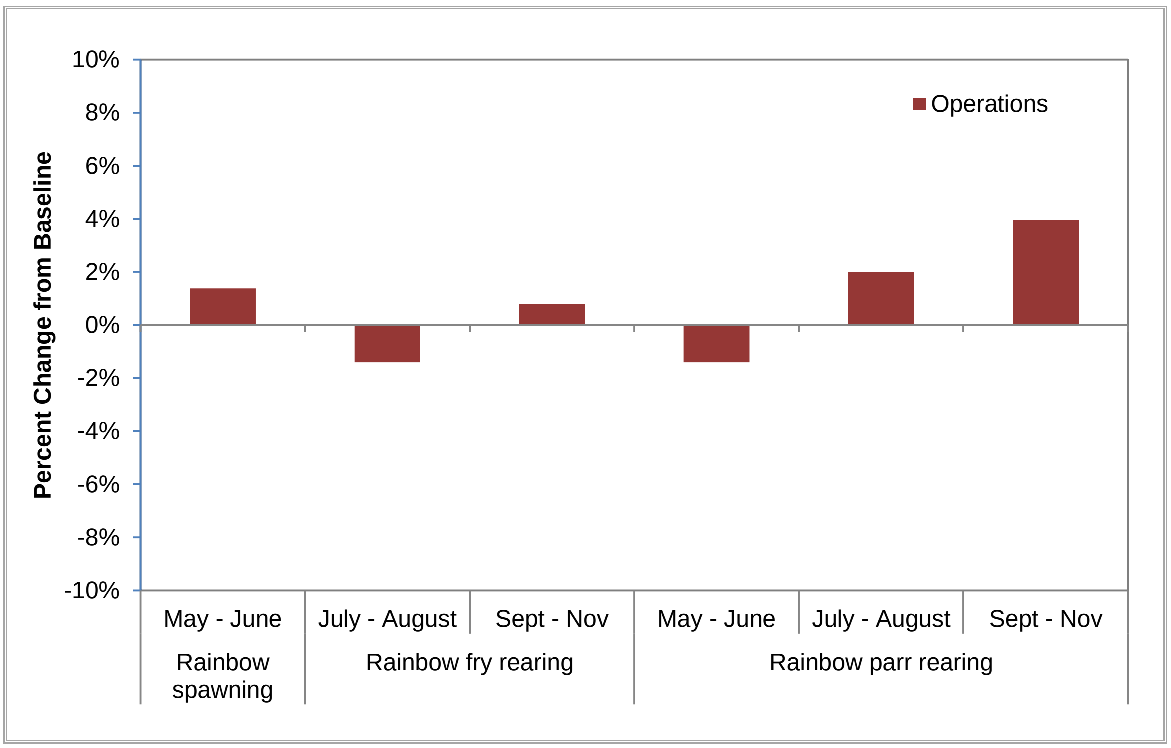
Note: % change is percent change from baseline conditions. No reductions are greater than the -10% threshold defined.

4.10.4 Creek 705

Changes in AWS for rainbow trout life stages in the lower and middle sections of Creek 705 are presented in **Table 24**. All of these changes occur due to the increased flows that would occur in Creek 705 due to the proposed diversion of Lake 01682LNRS to Creek 705 during mine construction. This diversion would result in a 2.6 km^2 (or 5%) increase in total watershed area in Creek 705 and an increase in flows in Creek 705. This diversion would be permanent in order to sustain the rainbow trout population in Lake 01682LNRS. As a result, only results for the operations phase are presented as these results are the same as for construction, closure, and post-closure phases.

Predicted increases in flow would result in small (<3%) reductions in AWS for rainbow trout fry and juveniles during summer and spring, respectively, in both the middle and lower sections of Creek 705 (**Table 24**). These reductions are lower than the 10% threshold for adverse effects.

Increases in AWS for rainbow trout spawning in spring, for rainbow trout fry in fall, and for rainbow trout juveniles in summer and fall are also predicted to occur. However, these all of these increases in AWS are small (<5% increase).



Note: Values represent comparison of predicted Project phase AWS to baseline AWS. Defined effect-threshold (-10%) defined by lower extent of y-axis.

Figure 36: Summary of Percent Change in Total Habitat Area for Creek 705, for 15-year Watershed Model Flow Series

Table 24: Potential Changes in Area Weighted Suitability for Rainbow Trout in Creek 705 over 15-year Watershed Model Flow Time Series

Model	Species/Life Stage	Stanza	Area Weighted Suitability by Project Phase		
			Baseline	Operations	
			(m^2)	(% change)	% change
Lower	Rainbow spawning	May – Jun	4,812	4,872	1%
	Rainbow fry rearing	Jul – Aug	15,719	15,512	-1%
		Sep – Nov	16,203	16,350	1%
	Juvenile rainbow rearing	May – Jun	11,276	11,129	-1%
		Jul – Aug	10,743	10,957	2%
		Sep – Nov	7,755	8,074	4%
Middle	Rainbow spawning	May – Jun	1,476	1,503	2%
	Rainbow fry rearing	Jul – Aug	1,712	1,674	-2%
		Sep – Nov	1,879	1,876	0%
	Juvenile rainbow rearing	May – Jun	1,237	1,209	-2%
		Jul – Aug	1,230	1,254	2%
		Sep - Nov	940	965	3%
Total	Rainbow spawning	May – Jun	6,288	6,375	1%
	Rainbow fry rearing	Jul – Aug	17,431	17,186	-1%
		Sep – Nov	18,082	18,226	1%
	Juvenile rainbow rearing	May – Jun	12,514	12,338	-1%
		Jul – Aug	11,973	12,211	2%
		Sep – Nov	8,695	9,039	4%

Note: % change is percent change from baseline conditions. No changes are greater than the -10% threshold defined.

The most likely effects of increased stream flows to habitat in Creek 705 immediately downstream of Lake 01538UEUT will be channel widening and bank erosion at locations where the channel is narrow and steep and the banks are soft. These areas are limited to the narrower riffle and run habitats that exist in a 2,400 m long reach of Creek 705 upstream of the tributary confluence draining Lake 01428UEUT to Creek 705. Gradient in this reach is only 1% and the erosive power of the stream is lower than other areas of Creek 705 as a result. However, banks along many of these riffle and run habitats are comprised of erodible gravels and fines and physical widening of the stream channel and redistribution of sediments is likely to occur. These changes are likely to occur over several consecutive spring freshets after which the physical characteristics of the reach will establish a new dynamic equilibrium.

Other areas of Creek 705 immediately downstream of Lake 01538UEUT are not expected to undergo significant channel modification or erosion. These include:

- The 250 m section of Creek 705 immediately downstream of Lake 01538UEUT where the gradient is low (1.5%), the channel is largely unconfined, and habitat is predominantly comprised of pools, riffles and glides with large cobble substrates, or fens created by beaver dams;

- An 800 m section that is occasionally confined with relatively steep gradient (3%) but with habitat comprised of riffles and glides with cobble-armoured channels and banks; and
- The beaver-impounded wetlands in the reach immediately upstream of the tributary confluence draining Lake 01428UEUT to Creek 705. Water depths and wetted widths in these wetlands are likely large enough to attenuate the predicted increase in stream flows, even in spring.

The effects to fish production in Creek 705 from diversion of Lake 01629LNRS, are expected to be negligible due to the small changes in habitat likely to occur in the few narrow, unarmoured riffle and run habitats that exist in Creek 705 downstream of Lake 01538UEUT. No significant adverse effects to fish or fish habitat are anticipated as a result.

4.11 Potential for Winter Effects

Minimum monthly flows for the winter stanza, for baseline and for each Project phase, is presented in **Table 25** for each relevant WMN. This information is summarized from the Surface Water Hydrology EA (**Section 5.3.2**). Comparisons to baseline are in terms of flows and not habitat because HSCs and hydraulic habitat models are not available to convert winter flow changes into habitat effects.

4.11.1 Davidson Creek

In Davidson Creek, minimum winter flows will be reduced by more than 10% during construction. This includes a potential decrease in winter flows up to 24% from baseline at middle Davidson Creek (WMN H2) and a potential decrease in winter flows up to 15% from baseline in lower Davidson Creek (WMN 1-DC). Although these reductions exceed the 10% change effect threshold, this threshold is likely conservative for potential winter effects on fish. This is because fish typically find refuge in pools during the winter and pool habitat is less sensitive to changes in flow than glides and riffles because of greater depth and slower water velocities in pools.

During operations and closure, pumping from Tatelkuz Lake to Davidson Creek would mitigate potential flow-related effects in Davidson Creek during winter (i.e., all potential flow reductions <10%). However, minimum monthly winter flows during the post-closure phase are predicted to average a 14% reduction compared to baseline. This potential adverse effect will be monitored during operations and closure to determine if additional flows are required to avoid changes in useable winter habitat for rainbow trout and kokanee. If additional flows are required, engineering alternatives to address post-closure flow reductions in Davidson Creek will be considered.

4.11.2 Chedakuz Creek

Winter flows in Lower Chedakuz Creek are predicted to be more than 10% lower than baseline during mitigated operations and closure (**Table 25**). This is due to retention of Davidson Creek run-off in the TSF and to pumping of water from Tatelkuz Lake. However, because Lower Chedakuz Creek is relatively deep and characterized by extensive pool and glide habitat, these flow reductions are not anticipated to result in adverse effects on overwintering fish.

Lower Chedakuz Creek generally remains ice-free during the winter. Therefore, the hydraulic portion of the hydraulic habitat models remain valid even in winter and the effect of winter flow reductions on water surface elevations at modelled transects can be described. For the Chedakuz 15-CC section, a reduction from 0.942 m^3/s to 0.782 m^3/s (**Table 25**) would result in an average reduction in water depth of 3 cm. For the Chedakuz H5 section, a reduction from 1.416 m^3/s to 1.245 m^3/s (**Table 25**) would result in an average reduction in water depth of less than 2 cm. Changes in depth of this magnitude (2 – 3 cm) are not expected to affect the low velocity pool habitats that fish typically use as refuge during the winter months.

4.11.3 Creek 661

Predicted winter flow reductions in Creek 661 at the upstream extent of the modeled section (i.e.,WMN H+) are predicted to exceed 20% during operations and closure phases (**Table 22**). Although these changes are large in percentage terms, the changes are small in absolute terms (i.e., approximately 0.003 m^3/s). These small changes to flows, in absolute terms, are not anticipated to make a difference to overwintering habitat availability or suitability. This is because most of the habitat this high up in the Creek 661 watershed is frozen to the bottom in winter (**EA Appendix 5.1.2.6A**). Therefore, reduced flows are not expected to affect habitat used by fish in winter this high in the watershed. Further downstream (i.e., WMN 1-661), predicted flow reductions are smaller, in percentage terms (<3% change). This reduction is not expected to significantly reduce overwintering habitat availability. This is because higher flows and larger groundwater inputs lower in the watershed (compared to the upper watershed) are expected to continue to provide flows to maintain pool and glide depths, and therefore, overwintering habitat for juvenile rainbow trout in lower Creek 661.

4.11.4 Creek 705

Winter flows in Creek 705 will increase due to the diversion of Lake 01628LNRS. However, anticipated changes are expected to be small (0.003 m^3/s; 11% at WMN 1-705). This change in flows is habitat quality is expected to result in positive changes to overwintering habitat quality, but to be undetectable at the population level.

Table 25: Summary of Minimum Monthly Winter Stanza Flows for Each Project Phase, and Comparison to Baseline Minimum Monthly Winter Stanza Flows

Stream	WMN		Baseline	Construction	Unmitigated Operations	Mitigated Operations	Closure	Post-closure
Davidson Creek	H2	Flow (m^3/s)	0.115	0.087	0	0.125	0.125	0.101
		% change		**-24%**	**-100%**	9%	9%	**-12%**
	H4B	Flow (m^3/s)	0.145	0.119	0.016	0.141	0.142	0.126
		% change		**-18%**	**-89%**	-3%	-2%	**-14%**
	4-DC	Flow (m^3/s)	0.155	0.128	0.020	0.145	0.146	0.131
		% change		**-18%**	**-87%**	-6%	-6%	**-15%**
	1-DC	Flow (m^3/s)	0.184	0.156	0.049	0.174	0.175	0.160
		% change		**-15%**	**-74%**	-6%	-5%	**-13%**
Chedakuz Creek	15-CC	Flow (m^3/s)	0.942	0.942	0.940	0.782	0.813	0.951
		% change		0%	0%	**-17%**	**-14%**	1%
	H5	Flow (m^3/s)	1.416	1.388	1.278	1.245	1.277	1.400
		% change		-2%	**-10%**	**-12%**	**-10%**	-1%
Creek 661	H+	Flow (m^3/s)	0.011	0.011		0.008	0.007	0.010
		% change		1%		**-23%**	**-32%**	-9%
	1-661	Flow (m^3/s)	0.082	0.082		0.080	0.080	0.081
		% change		0%		-3%	-3%	-1%
Creek 705	H7	Flow (m^3/s)	0.016	0.019		0.019	0.019	0.019
		% change		18%		18%	18%	18%
	1-705	Flow (m^3/s)	0.030	0.033		0.033	0.033	0.033
		% change		11%		11%	11%	11%

Note: % change refers to percent change from baseline conditions. Reductions greater than -10% indicated in bold. Data summarized from **Section 5.3.2**.

4.12 Potential for Geomorphic Effects

The TSF dams will capture sediment transported downstream from the upper Davidson Creek watershed and prevent it from reaching lower Davidson Creek. Sediments capture has the potential to reduce the quantity of spawning habitat for rainbow trout and kokanee over time. This could occur even though flushing flows have specifically been designed to avoid the extreme “channel-forming” flows that typically re-distribute substrates, including even larger cobble substrates. Although other Project-area streams immediately downstream of lakes (which also act as sediment traps) do contain extensive, high quality spawning gravels (e.g., Chedakuz Creek downstream of Tatelkuz Lake), monitoring of physical habitat changes in Davidson Creek downstream of the TSF will be conducted to determine whether occasional gravel additions are required to maintain spawning habitat quantity and quality in Davidson Creek downstream of the TMF.

5.0 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.

Monitoring to evaluate the accuracy of hydraulic habitat model predictions, the success of mitigation pumping via the FSS, and the potential effects of flow changes in Project-area streams will be required during the operations and closure periods. Monitoring will need to continue until long-term trends in habitat availability have been confirmed. FSS operations and the mitigation scheme developed for Davidson Creek are flexible and permit adaptive response to results from monitoring programs.

5.1 Hydraulic Habitat Models

This IFS uses calibrated hydraulic habitat models to represent and predict how the availability and suitability of habitat for various life stages of rainbow trout and kokanee varies with stream discharge. In Davidson Creek, these models were used to set IFN for the different stream-dwelling life stages of rainbow trout and kokanee and to assess potential effects to fish for mitigated and unmitigated Project scenarios. In Chedakuz Creek, Creek 705 and Creek 661, these models were used to assess potential effects due to flow changes only. These models rely on three sources of input data:

1. Hydraulic relationships depicting how water depths and water velocities vary with flow;
2. Habitat suitability curves that depict the preference for different water depths and velocities by different life stages of fish; and
3. A hydrological data time series that depicts baseline flows and predicts flows under different future conditions.

Uncertainty exists for each of these inputs. These uncertainties were minimized by:

1. Calibrating hydraulic models with depth, water velocity, and substrate data measured at each transect over the range of flows to be modeled. This allowed predictions to be interpolated rather than extrapolated;
2. Using Provincial habitat suitability curves, based on extensive provincial data sets that represent conditions that fish use. Site-specific modifications based on field data were used to ensure representation of site conditions;

3. Using hydrological flow time series provided by a calibrated watershed model that met or exceeded industry recognized modeling error standards.

5.2 Time-series Approach

Potential effects due to flow changes caused by construction, operation, 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. We used a 15 year flow time-series for this IFS because this was the longest series available based on appropriate regional hydrometric data (**EA Appendix 5.1.2.1B**). We consider this series to be sufficiently long to assess potential effects and to set instream flow needs for Davidson Creek because this length of time includes representative wet and dry conditions that have occurred over the 15 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 (e.g., 1:50 dry conditions). 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, and definition of IFN, so our modelling results are considered to appropriately assess and address the potential for Project-related effects.

5.3 Conservative Assumptions

Conservative assumptions were made throughout the IFS. These assumptions were made to reduce inherent uncertainties in the hydraulic habitat models, in the interpretation of results for assessment of potentially significant adverse effects, and in setting of instream flow requirements for Davidson Creek. Conservative assumptions for each of these steps are described below.

For the definition of IFN in Davidson Creek, the following conservative assumptions were used:

- The mean annual 30-day low flows were used to represent the habitat bottleneck that limits fish productivity for each species and life stage during each biological stanza. This is considered conservative relative to other commonly used flow criteria, such as the mean annual 7-day low flow or the mean annual 7-day low flows for each stanza, because the mean annual 30-day low flows are higher than these alternatives. This results in the selection of higher IFN, and therefore greater protection of fish and fish habitat.
- IFN for each species and life stage were defined as the flows required to provide at least 90% of the baseline habitat present at the mean annual 30-day low flow for each stanza. This threshold was conservative because, due to natural variation, the actual carrying capacity of habitat for fish will always be less than that predicted by hydraulic habitat relationships. A change in habitat availability or suitability of 10% from baseline is small enough that it unlikely to cause a detectable effect on fish populations. Therefore, a 10% threshold for adverse effect was considered conservative and to be highly protective of fish production in Davidson Creek.
- The final IFN for each biological stanza was selected based on the highest flow required to protect all rainbow trout and kokanee life stages present in each stream.
- Winter IFN were conservatively defined as baseline mean March flows, the lowest flow month in the historical flow time-series.

For the assessment of potential effects to fish due to flow changes caused by the Project, the following conservative assumptions were used:

- Potential changes in flow, and resulting changes in availability and suitability of habitat, were considered over biologically relevant stanzas. These stanzas were monthly based and represented periods of time during the year that were important to different life stages of fish (e.g., spawning, fry rearing, juvenile rearing). This was more conservative than considering potential changes in individual months, or over an entire year, because it allowed direct analysis of predicted flow changes over all periods affecting annual production and recruitment rainbow trout and kokanee in Project-area streams.

- Potential adverse effects to fish were considered to be only those that resulted in less than 90% of baseline area weighted suitability for each rainbow trout or kokanee life stage across each biological stanza. Thus, any reduction in AWS greater than 10% from baseline was considered significant. We consider this a very high standard for protection of fish because changes greater than 10% are typically necessary to cause a detectable population level effect in fish.
- The lowest winter period monthly flow for each Project phase was compared to the lowest winter monthly flow at baseline to assess potential effects of changes in winter flows on fish. A change of more than 10% in winter flows was considered the threshold for a potential adverse effect. This approach was considered conservative because fish tend to use refuge habitats in pools during the winter, and the relationship between flow change and habitat change is not linear in pools (i.e., a 1% change in flow tends to result in less than 1% change in available overwintering habitat area in pools).

5.4 Limitations

Hydraulic habitat relationships could not developed to quantitatively assess potential flow changes on the availability and suitability of stream habitat for overwintering fish. The qualitative approach used was considered conservative. Project-related reductions in winter flows are predicted to occur, particularly for the construction and post-closure periods, and for this reason monitoring and adaptive management of winter flows may be required to avoid potential effects on fish and fish habitat. The FSS pumping scheme is flexible and can be adapted to respond to monitoring results.

Potential effects to bed-load transport and to the spawning habitat reliant on this natural bed-load transport were considered only qualitatively in this IFS. Annual and monthly bed-load volumes in Davidson Creek are not known and models predicting the volume of bed-load captured in the TSF and deprived to lower Davidson Creek were not possible. Although channel-forming flows that would naturally displace existing spawning gravels in lower Davidson Creek (and transport new gravels from upstream) were intentionally avoided when setting flushing flows for Davidson Creek, the potential exists for significant reduction in gravel recruitment and, therefore, significant reduction in spawning habitat suitability and availability for rainbow trout and kokanee reliant on these gravels for spawning once the TSF is built. Monitoring of spawning habitat quality and gravel availability is recommended as are the development of potential mitigation measures to replace lost gravels should monitoring show significant reductions in spawning habitat quality, adult spawner use, egg survivorship, or fry abundance over time.

This report does not consider potential effects of changes in water chemistry or water temperature in Davidson Creek due to pumping of water from Tatelkuz Lake during operations and closure phases to meet IFNs. These potential effects are addressed qualitatively in the Fish and Fish Habitat EAs (**EA Section 5.3.8** and **EA Section 5.3.9**).

6.0 SUMMARY

The water requirements of the Project are identified in the Project Description (**Section 2.2.3.5** Water Management) and are based on the proposed project design and have been used to assess the potential effects of the Project.

The extreme dry conditions provided in the Application were developed to define the potential water shortfall range that might be experienced and to determine if the Project would need additional water. The potential shortfall was compared to the available pumping and delivery capacity of the freshwater supply system above and beyond normal operating conditions. This allowed for the freshwater supply system to be designed in a way that established a viable contingency to meet the project water needs, based on normal operations and supplemental withdrawal, including allowing for the continued flooding of PAG waste in the TSF.

The Project could endure one or more extreme dry years in a row without depleting the storage within the TSF supernatant pond. Use of this contingency function built into the water supply system will not supersede the minimum instream flow requirements. Surplus water to offset any shortfall experienced by the TSF supernatant pond could be drawn in wetter than average flows following extreme dry years, if required at all.

An IFS was used to assess the potential fish and fish habitat effects resulting from proposed changes to stream flows in Davidson Creek, Creek 661, Chedakuz Creek, and Creek 705 that may result from water diversions, alteration of watershed areas (and subsequent run-off volumes), and capture of run-off by various infrastructure components required for the Project. Adverse effects on Creek 661 and Creek 705 due to changes in flows are not anticipated.

During operations, the TMF will capture all flows from part of the Davidson Creek watershed. In the absence of mitigation, adverse effects would be expected in Davidson Creek downstream of the TMF. To mitigate these potential effects, water will be pumped from Tatelkuz Lake to Davidson Creek via the FSS. The IFS was used to develop and assess an augmented flow regime that will protect fish and fish habitat values in Davidson Creek. The mitigation flow regime provides flows for five biologically relevant time periods: juvenile rainbow trout overwintering, spring flushing, spring rainbow trout spawning flows, summer kokanee spawning and juvenile rainbow trout rearing, and fall kokanee egg incubation and juvenile rainbow trout rearing. Transitional flows were defined to avoid potential impacts during changes between these periods. Contingency for drier than average years was included by removing spring flushing flows, because these flows naturally occur on a periodic basis. The total withdrawals required to supply the mitigated flow regime in an average or wetter year are 6.56 M m^3/y.

The FSS will also supply continuous mine site water needs of 0.033 m^3/s (1.05 Mm^3/y) throughout the operations and closure phases of the Project. These flows are supplied to the mill during operations, and to the open pit during closure. Supplemental water from Tatelkuz Lake may also be required to address shortfalls in the site water balance under extreme dry conditions, to ensure sub-aqueous disposal of PAG tailings (between 0.98 Mm^3/y and 2.92 Mm^3/y for 5th percentile extreme dry conditions during Years 2 through 11 of mine life (**EA Section 2.2**)). The FSS has sufficient capacity to meet both IFN and mine site requirements.

Water withdrawals from Tatelkuz Lake have the potential to lower the water surface elevation of the lake and to reduce flows in the section of Chedakuz Creek between the lake outlet and the mouth of Davidson Creek. The potential for adverse effects on Tatelkuz Lake and Chedakuz Creek were assessed by modelling the effects of withdrawals on lake water surface elevations, on creek flows, and on fish habitat availability. Supplemental water needs for the TSF under extreme dry conditions were not modelled. The effects of water withdrawals are similar during operations and closure phases, and are smaller during the construction and post closure phases. Adverse effects on fish and fish habitat are not anticipated.

FSS operation would cease at the start of the post-closure phase. Flow changes relative to baseline would occur due to the distribution of site run-off at mine closure. These flow changes may result in reductions in the availability of habitat for kokanee spawning and egg incubation and for juvenile rainbow trout rearing in lower Davidson Creek that are greater than the 10% relative to baseline. Because these potential adverse effects occur at the end of the Project, monitoring will be used to determine whether model predictions are correct and if additional water is required to avoid these effects. Monitoring and phased closure of the TSF will provide the opportunity to develop engineering solutions, if required. Habitat offsetting options would be pursued only if no feasible engineering options are available.

The Proponent will include all water requirements in its application for a water license.

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ANNEXES

Annex A
Transect Survey Schedule and Surveyed Flows

Lower Davidson Creek

Transect	Habitat	MAD (m^3/s)	Surveyed flow (m^3/s)							Surveyed flow (as percent of MAD)						
			Aug-11	Oct-11	May-12	Jul-12	Aug-12	Sep-12	Jun-13	Aug-11	Oct-11	May-12	Jul-12	Aug-12	Sep-12	Sep-12
1-DC-1.1	Pool	0.403			1.580	0.286	0.172	0.116				392%	71%	43%	29%	
1-DC-1.2	Glide	0.403	0.275		1.580	0.286	0.172	0.116		68%		392%	71%	43%	29%	
1-DC-1.3	Riffle	0.403			1.580	0.286	0.172	0.116				392%	71%	43%	29%	
1-DC-02	Glide	0.403	0.368			0.273	0.172	0.116	2.184	91%			68%	43%	29%	542%
1-DC-3.1	Riffle	0.403			1.580	0.273	0.172	0.116				392%	68%	43%	29%	
1-DC-3.2	Glide	0.403	0.368		1.580	0.273	0.172	0.116		91%		392%	68%	43%	29%	
1-DC-3.3	Pool	0.403			1.580	0.273	0.172	0.116				392%	68%	43%	29%	
1-DC-04	Glide	0.403	0.368			0.273	0.172	0.116	2.184	91%			68%	43%	29%	542%
1-DC-05	Glide	0.403	0.332			0.273	0.172	0.116	2.208	82%			68%	43%	29%	548%
3-DC-1.1	Glide	0.403		0.259		0.273	0.172	0.116			64%		68%	43%	29%	
3-DC-1.2	Pool	0.403		0.259		0.273	0.172	0.116			64%		68%	43%	29%	
3-DC-1.3	Riffle	0.403		0.259		0.273	0.172	0.116	2.221		64%		68%	43%	29%	551%
4-DC-1.1	Riffle	0.369		0.243		0.282	0.239	0.126			66%		76%	65%	34%	
4-DC-1.2	Glide	0.369		0.243		0.282	0.239	0.126	1.701		66%		76%	65%	34%	461%
4-DC-1.3	Pool	0.369		0.243		0.282	0.239	0.126			66%		76%	65%	34%	
4-DC-2.1	Glide	0.369		0.243		0.282	0.239	0.126	1.701		66%		76%	65%	34%	461%
4-DC-2.2	Pool	0.369		0.243		0.282	0.239	0.126			66%		76%	65%	34%	
4-DC-2.3	Riffle	0.369		0.243		0.282	0.239	0.126			66%		76%	65%	34%	

Note: MAD = mean annual discharge.

Middle Davidson Creek

Transect	Habitat	MAD (m^3/s)	Surveyed flow (m^3/s)							Surveyed flow (as percent of MAD)						
			Aug-11	Oct-11	Jul-12	Aug-12	Sep-12	Oct-12	Jun-13	Aug-11	Oct-11	Jul-12	Aug-12	Sep-12	Oct-12	Jun-13
5-DC-1.1	Riffle	0.345		0.234	0.268	0.221	0.112				68%	78%	64%	32%		
5-DC-1.2	Glide	0.345		0.234	0.268	0.221	0.112		1.701		68%	78%	64%	32%		493%
5-DC-1.3	Pool	0.345		0.234	0.268	0.221	0.112				68%	78%	64%	32%		
5-DC-2.1	Riffle	0.345		0.234	0.268	0.221	0.112				68%	78%	64%	32%		
5-DC-2.2	Glide	0.345		0.234	0.268	0.221	0.112		1.701		68%	78%	64%	32%		493%
5-DC-2.3	Pool	0.345		0.234	0.268	0.221	0.112				68%	78%	64%	32%		
6-DC-1.1	Pool	0.281		0.195	0.210	0.152	0.088				69%	75%	54%	31%		
6-DC-1.2	Riffle	0.281		0.195	0.210	0.152	0.088		1.701		69%	75%	54%	31%		605%
6-DC-1.3	Glide	0.281		0.195	0.210	0.152	0.088				69%	75%	54%	31%		
7.1-DC-01	Riffle	0.281	0.188		0.217	0.126	0.080	0.101	1.532	67%		77%	45%	28%	36%	545%
7.1-DC-02	Riffle	0.281	0.188		0.217	0.126	0.080	0.101	1.532	67%		77%	45%	28%	36%	545%
7.1-DC-05	Riffle	0.281	0.220		0.217	0.126	0.080	0.101	1.532	78%		77%	45%	28%	36%	545%
7.1-DC-3.1	Pool	0.281		0.223	0.217	0.126	0.080	0.101	1.532		79%	77%	45%	28%	36%	545%
7.1-DC-3.2	Riffle	0.281	0.188	0.223	0.217	0.126	0.080	0.101	1.532	67%	79%	77%	45%	28%	36%	545%
8-DC-01	Glide	0.281	0.210		0.217	0.126	0.080	0.101	1.532	75%		77%	45%	28%	36%	545%
8-DC-04	Glide	0.281	0.220		0.217	0.126	0.080	0.101	1.532	78%		77%	45%	28%	36%	545%
8-DC-05	Glide	0.281	0.220		0.217	0.126	0.080	0.101	1.532	78%		77%	45%	28%	36%	545%
8-DC-2.1	Pool	0.281	0.172		0.217	0.126	0.080	0.101		61%		77%	45%	28%	36%	
8-DC-2.2	Riffle	0.281		0.172	0.217	0.126	0.080	0.101			61%	77%	45%	28%	36%	
8-DC-2.3	Glide	0.281	0.210	0.172	0.217	0.126	0.080	0.101	1.532	75%	61%	77%	45%	28%	36%	545%
8-DC-3.1	Riffle	0.281		0.172	0.217	0.126	0.080	0.101			61%	77%	45%	28%	36%	
8-DC-3.2	Glide	0.281	0.210	0.172	0.217	0.126	0.080	0.101		75%	61%	77%	45%	28%	36%	
8-DC-3.3	Pool	0.281		0.172	0.217	0.126	0.080	0.101	1.532		61%	77%	45%	28%	36%	545%

Note: MAD – mean annual discharge.

Chedakuz Creek 15-CC

Transect	Habitat	MAD (m^3/s)	Surveyed flow (m^3/s)				Surveyed flow (as percent of MAD)			
			May-13	Jul-13	Aug-13	Sep-13	May-13	Jul-13	Aug-13	Sep-13
C1T1-G	Glide	1.727	5.040	3.814	0.682	0.437	292%	221%	39%	25%
C1T2-G	Glide	1.727	5.040	3.814	0.682	0.437	292%	221%	39%	25%
C1T3-G	Glide	1.727	5.040	3.814	0.682	0.437	292%	221%	39%	25%
C1T4-R	Riffle	1.727	5.040	3.814	0.682	0.437	292%	221%	39%	25%
C1T5-G	Glide	1.727	5.040	3.814	0.682	0.437	292%	221%	39%	25%
C1T6-P	Pool	1.727	5.040	3.814	0.682	0.437	292%	221%	39%	25%
C1T7-G	Glide	1.727	5.040	4.759	0.682	0.437	292%	276%	39%	25%
C1T8-G	Glide	1.727	5.040	3.814	0.682	0.437	292%	221%	39%	25%

Note: MAD = mean annual discharge.

Chedakuz Creek H5

Transect	Habitat	MAD (m^3/s)	Surveyed flow (m3/s)					Surveyed flow (as percent of MAD)				
			Nov-11	Jul-12	Aug-12	Sep-12	Oct-12	Nov-11	Jul-12	Aug-12	Sep-12	Oct-12
LCC-1.1	Riffle	2.595		3.892	1.474	0.953	1.200		150%	57%	37%	46%
LCC-1.2	Glide	2.595		3.892	1.474	0.953	1.200		150%	57%	37%	46%
LCC-2.1	Riffle	2.595		3.892	1.310	0.953	1.200		150%	50%	37%	46%
LCC-2.2	Glide	2.595		3.892	1.310	0.953	1.200		150%	50%	37%	46%
LCC-2.3	Pool	2.595		3.892	1.310	0.953	1.200		150%	50%	37%	46%
LCC-3.1	Riffle	2.595		4.533	1.310	0.953	1.200		175%	50%	37%	46%
LCC-3.2	Glide	2.595	1.941	4.533	1.310	0.953	1.200	75%	175%	50%	37%	46%
LCC-3.3	Pool	2.595		4.533	1.310	0.953	1.200		175%	50%	37%	46%
LCC-4.1	Riffle	2.595		4.143	1.278	0.953	1.200		160%	49%	37%	46%
LCC-4.2	Glide	2.595	1.941	4.143	1.278	0.953	1.200	75%	160%	49%	37%	46%
LCC-4.3	Pool	2.595		4.143	1.278	0.953	1.200		160%	49%	37%	46%
LCC-5.1	Riffle	2.595		4.143	1.278	0.953	1.200		160%	49%	37%	46%
LCC-5.2	Glide	2.595	1.941	4.143	1.278	0.953	1.200	75%	160%	49%	37%	46%
LCC-5.3	Pool	2.595		4.143	1.278	0.953	1.200		160%	49%	37%	46%

Note: MAD = mean annual discharge.

Creek 661

Transect	Habitat	MAD (m^3/s)	Surveyed flow (m^3/s) Jul-12	Aug-12	Sep-12	Surveyed flow (as percent of MAD) Jul-12	Aug-12	Sep-12
1-661-1.1	Glide	0.283	0.175	0.134	0.111	62%	47%	39%
1-661-1.2	Pool	0.283	0.175	0.134	0.111	62%	47%	39%
1-661-1.3	Riffle	0.283	0.175	0.134	0.111	62%	47%	39%
1-661-1.4	Glide	0.283	0.175	0.134	0.111	62%	47%	39%
1-661-1.5	Pool	0.283	0.175	0.134	0.111	62%	47%	39%
1-661-1.6	Riffle	0.283	0.175	0.134	0.111	62%	47%	39%
3-661-2.1	Glide	0.258	0.144	0.102	0.108	56%	40%	42%
3-661-2.2	Riffle	0.258	0.144	0.102	0.108	56%	40%	42%
3-661-2.3	Pool	0.258	0.144	0.102	0.108	56%	40%	42%
3-661-2.4	Pool	0.258	0.144	0.102	0.108	56%	40%	42%
3-661-2.5	Glide	0.258	0.144	0.102	0.108	56%	40%	42%
3-661-2.6	Riffle	0.258	0.144	0.102	0.108	56%	40%	42%
4-661-3.1	Riffle	0.106	0.052	0.029	0.024	49%	27%	23%
4-661-3.3	Pool	0.106	0.052	0.029	0.024	49%	27%	23%
4-661-3.4	Glide	0.106	0.052	0.029	0.024	49%	27%	23%
4-661-3.5	Glide	0.106	0.052	0.029	0.024	49%	27%	23%
4-661-3.6	Riffle	0.106	0.052	0.029	0.024	49%	27%	23%

Note: MAD = mean annual discharge.

Lower Creek 705

Transect	Habitat	MAD (m^3/s)	Surveyed flow (m^3/s)					Surveyed flow (as percent of MAD)				
			May-13	May-13	May-13	Jul-13	Aug-13	May-13	May-13	May-13	Jul-13	Aug-13
T14-R	Riffle	0.258	0.739	0.989	1.145	0.313	0.031	286%	383%	444%	121%	12%
T15-G	Glide	0.258	0.681	0.989	1.145	0.313	0.031	264%	383%	444%	121%	12%
T16-P	Pool	0.258	0.681	0.989	1.145	0.313	0.031	264%	383%	444%	121%	12%
T17-R	Riffle	0.258	0.739	0.989	1.145	0.313	0.031	286%	383%	444%	121%	12%
T18-R	Riffle	0.258		0.989	1.145	0.313	0.031		383%	444%	121%	12%
T19-G	Glide	0.258		0.989	1.145	0.313	0.031		383%	444%	121%	12%
T20-P	Pool	0.258		0.989	1.145	0.313	0.031		383%	444%	121%	12%
T21-R	Riffle	0.258		0.989	1.145	0.313	0.031		383%	444%	121%	12%
T22-G	Glide	0.258			1.145	0.313	0.031			444%	121%	12%
T23-G	Glide	0.258			1.145	0.313	0.031			444%	121%	12%

Note: MAD = mean annual discharge.

Middle Creek 705

Transect	Habitat	MAD (m^3/s)	Surveyed flow (m^3/s)				Surveyed flow (as percent of MAD)			
			May-13	May-13	Jul-13	Aug-13	May-13	May-13	Jul-13	Aug-13
T1-G	Glide	0.239	0.905	1.789	0.266	0.023	379%	749%	111%	10%
T2-R	Riffle	0.239	0.939	1.789	0.313	0.014	393%	749%	131%	6%
T3-G	Glide	0.239	0.939	1.649	0.290	0.018	393%	690%	121%	8%
T4-P	Pool	0.239	0.939	1.789	0.313	0.014	393%	749%	131%	6%
T5-G	Glide	0.239	1.052	1.649	0.313	0.023	440%	690%	131%	10%
T6-P	Pool	0.239	1.052	1.936	0.313	0.023	440%	810%	131%	10%
T7-R	Riffle	0.239	1.052	1.789	0.313	0.018	440%	749%	131%	8%
T8-P	Pool	0.239	0.904	1.789	0.313	0.011	378%	749%	131%	5%
T9-R	Riffle	0.239	0.904	1.936	0.266	0.014	378%	810%	111%	6%
T10-C	Riffle	0.239	0.904	1.789	0.266	0.018	378%	749%	111%	8%
T11-G	Glide	0.239	0.762	1.789	0.290	0.014	319%	749%	121%	6%
T12-G	Glide	0.239	0.762	1.789	0.290	0.018	319%	749%	121%	8%
T13-R	Riffle	0.239	0.762	1.789	0.290	0.018	319%	749%	121%	8%

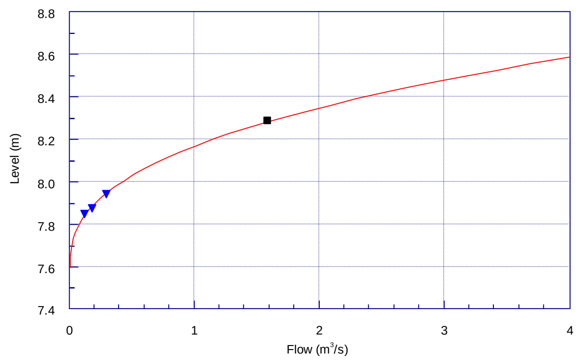
Note: MAD = mean annual discharge.

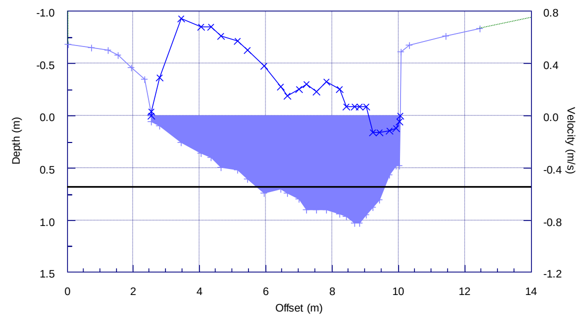
Annex B
Individual Transect Data

LOWER DAVIDSON CREEK MODEL

SZF – stage of zero flow
WSE – water surface elevation (note that all WSE measurements are relative to transect-specific benchmarks surveyed to a transect-specific datum)
Q – discharge

LOWER DAVIDSON- TRANSECT 1-DC-1.1 - POOL





SZF rating curve **Survey flow depth / velocity profile**

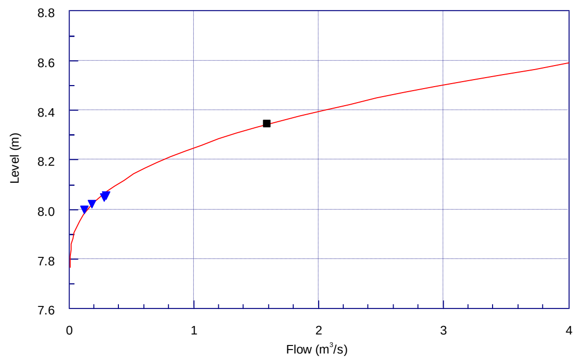
1 May 12 WSE = 8.281 Q = 1.580

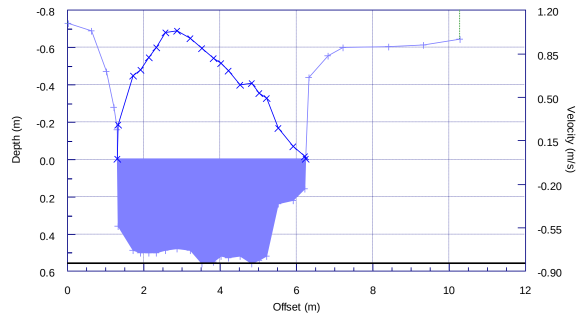
19 Jul 12 WSE = 7.940 Q = 0.286

19 Aug 12 WSE = 7.874 Q = 0.172

26 Sep 12 WSE = 7.845 Q = 0.116

LOWER DAVIDSON- TRANSECT 1-DC-1.2 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

22 Aug 11 WSE = 8.048 Q = 0.275

1 May 12 WSE = 8.342 Q = 1.580

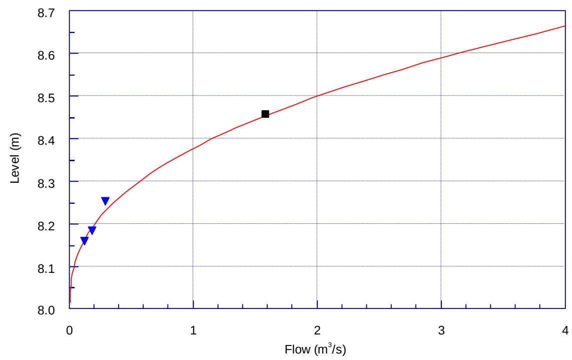
19 Jul 12 WSE = 8.054 Q = 0.286

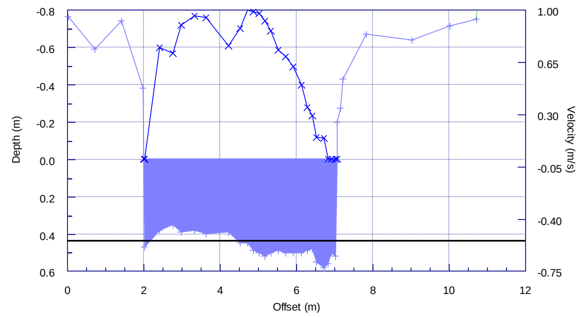
19 Aug 12 WSE = 8.019 Q = 0.172

LOWER DAVIDSON- TRANSECT 1-DC-1.2 - GLIDE PAGE 2

26 Sep 12	**WSE = 7.999**	**Q = 0.116**	No additional surveys

LOWER DAVIDSON- TRANSECT 1-DC-1.3 - RIFFLE





SZF rating curve | **Survey flow depth / velocity profile**

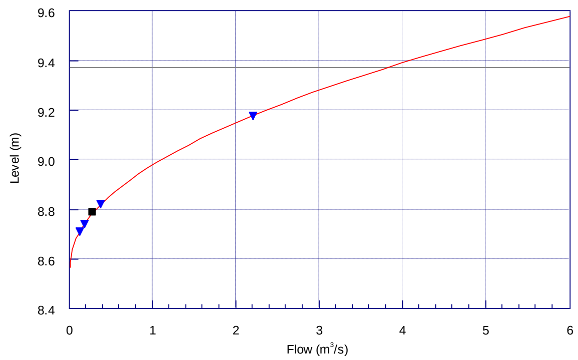
1 May 12 WSE = 8.454 Q = 1.580

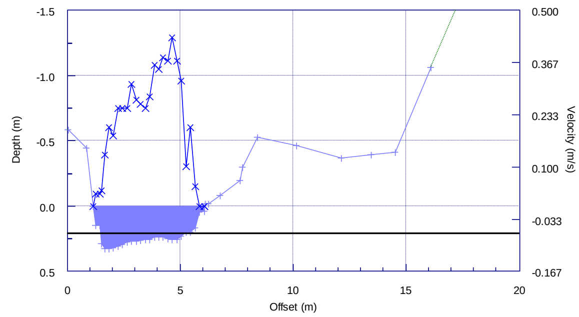
19 Jul 12 WSE = 8.251 Q = 0.286

19 Aug 12 WSE = 8.182 Q = 0.172

26 Sep 12 WSE = 8.159 Q = 0.116

LOWER DAVIDSON- TRANSECT 1-DC-02 - GLIDE





SZF rating curve | **Survey flow depth / velocity profile**

17 Aug 11 WSE = 8.820 Q = 0.368

18 Jul 12 WSE = 8.785 Q = 0.273

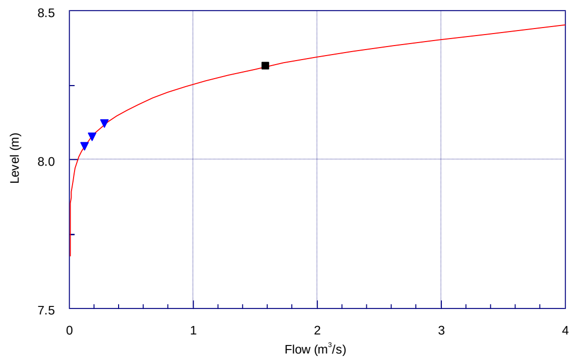
19 Aug 12 WSE = 8.740 Q = 0.172

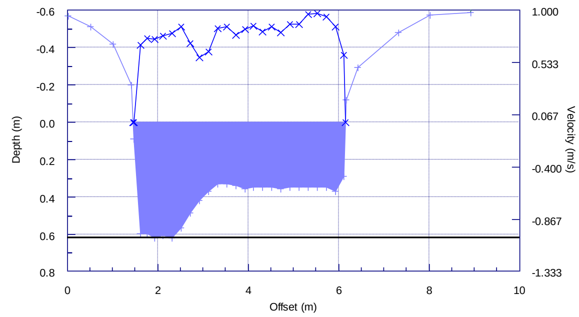
26 Sep 12 WSE = 8.710 Q = 0.116

LOWER DAVIDSON- TRANSECT 1-DC-02 - GLIDE PAGE 2

14 Jun 13 **WSE = 9.175** **Q = 2.184** No additional surveys

LOWER DAVIDSON- TRANSECT 1-DC-3.1 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

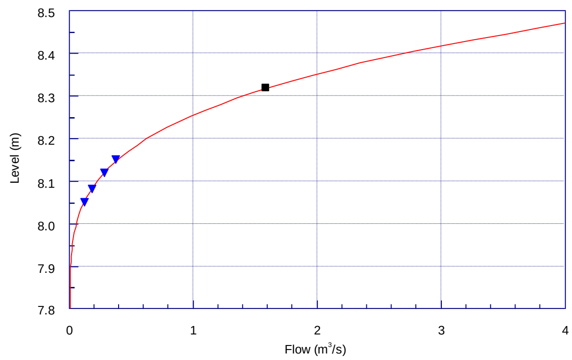
1 May 12 WSE = 8.312 Q = 1.580

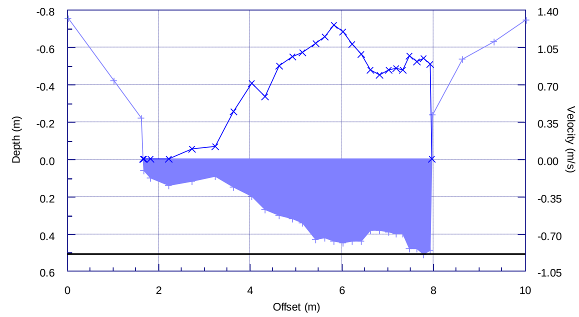
18 Jul 12 WSE = 8.120 Q = 0.273

19 Aug 12 WSE = 8.075 Q = 0.172

26 Sep 12 WSE = 8.044 Q = 0.116

LOWER DAVIDSON- TRANSECT 1-DC-3.2 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

17 Aug 11 WSE = 8.150 Q = 0.368

1 May 12 WSE = 8.317 Q = 1.580

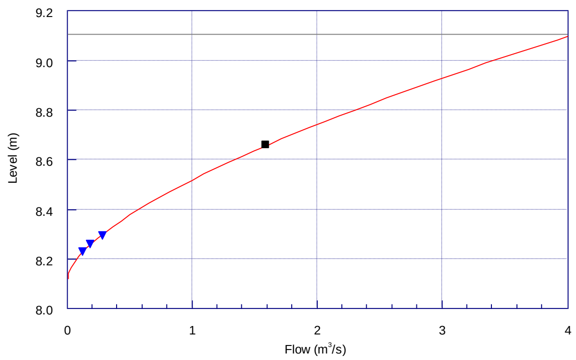
18 Jul 12 WSE = 8.118 Q = 0.273

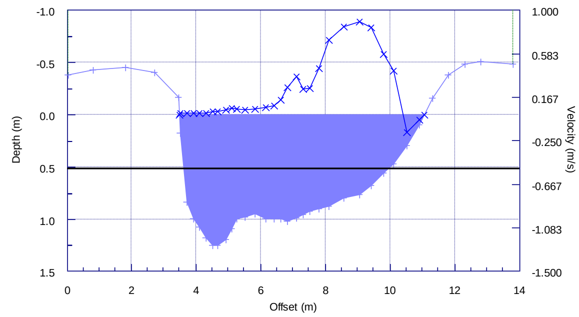
19 Aug 12 WSE = 8.081 Q = 0.172

LOWER DAVIDSON- TRANSECT 1-DC-3.2 - GLIDE PAGE 2

26 Sep 12 **WSE = 8.050** **Q = 0.116** No additional surveys

LOWER DAVIDSON- TRANSECT 1-DC-3.3 - POOL





SZF rating curve **Survey flow depth / velocity profile**

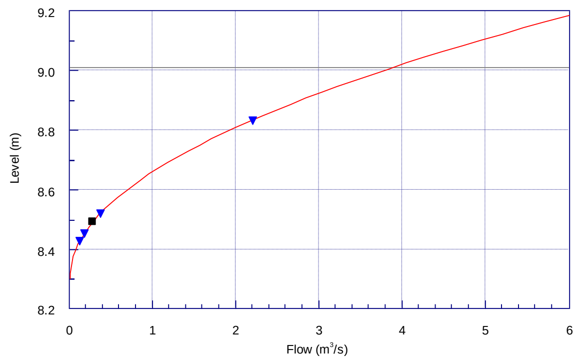
1 May 12 WSE = 8.656 Q = 1.580

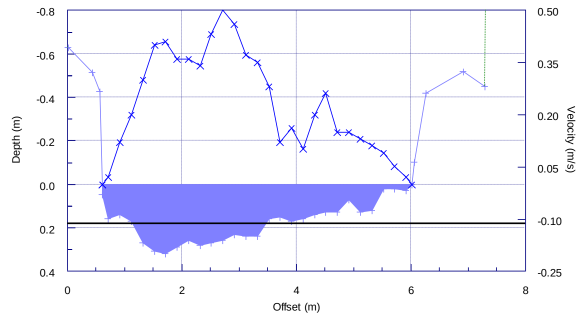
18 Jul 12 WSE = 8.295 Q = 0.273

19 Aug 12 WSE = 8.258 Q = 0.172

26 Sep 12 WSE = 8.228 Q = 0.116

LOWER DAVIDSON- TRANSECT 1-DC-04 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

17 Aug 11 WSE = 8.520 Q = 0.368

18 Jul 12 WSE = 8.491 Q = 0.273

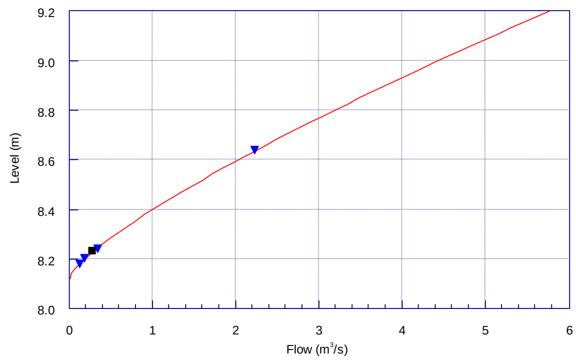
19 Aug 12 WSE = 8.451 Q = 0.172

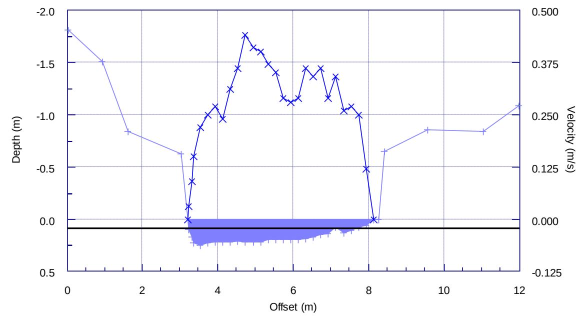
26 Sep 12 WSE = 8.427 Q = 0.116

LOWER DAVIDSON- TRANSECT 1-DC-04 - GLIDE PAGE 2

14 Jun 13	**WSE = 8.831**	**Q = 2.184**	No additional surveys

LOWER DAVIDSON- TRANSECT 1-DC-05 - GLIDE





SZF rating curve

Survey flow depth / velocity profile

15 Aug 11 WSE = 8.240 Q = 0.332

18 Jul 12 WSE = 8.228 Q = 0.273

19 Aug 12 WSE = 8.201 Q = 0.172

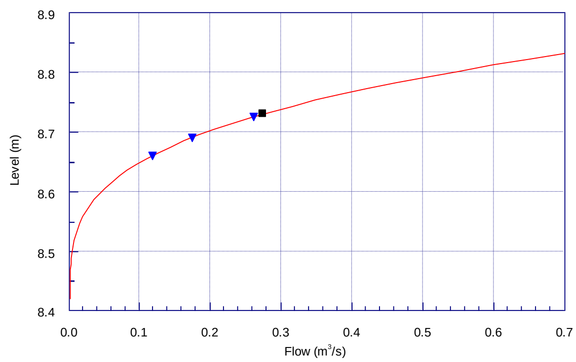
26 Sep 12 WSE = 8.180 Q = 0.116

LOWER DAVIDSON- TRANSECT 1-DC-05 - GLIDE PAGE 2

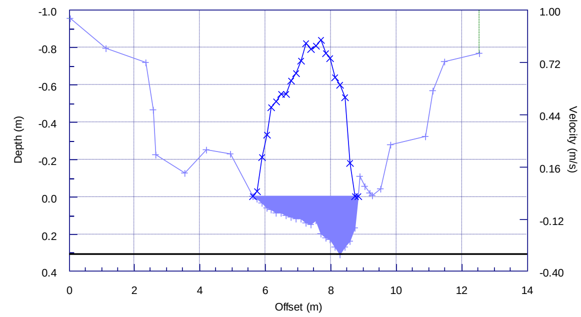
14 Jun 13 **WSE = 8.637** **Q = 2.208**

No additional surveys

LOWER DAVIDSON- TRANSECT 3-DC-1.1 - GLIDE



SZF rating curve



Survey flow depth / velocity profile

21 Oct 11 WSE = 8.725 Q = 0.259

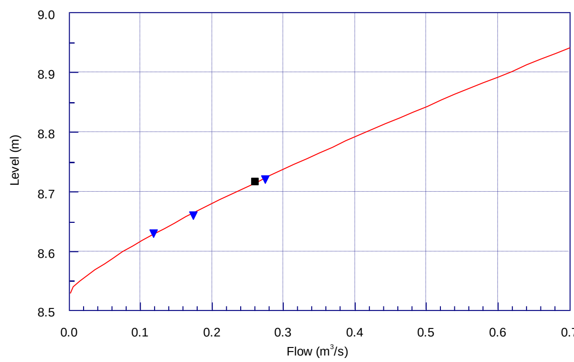
No photographs available.

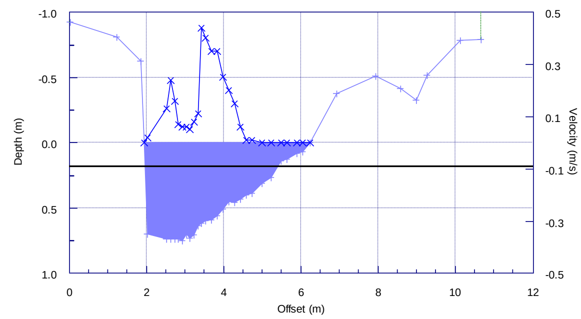
18 Jul 12 WSE = 8.730 Q = 0.273

23 Aug 12 WSE = 8.690 Q = 0.172

26 Sep 12 WSE = 8.660 Q = 0.116

LOWER DAVIDSON- TRANSECT 3-DC-1.2 - POOL





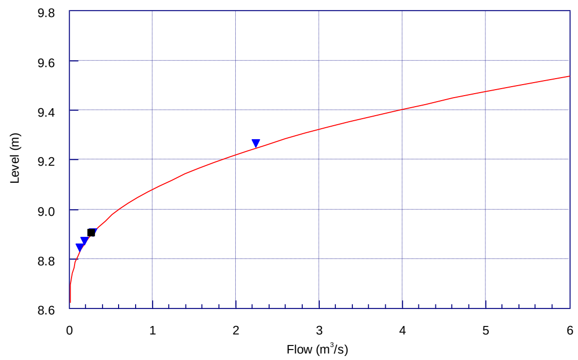
SZF rating curve **Survey flow depth / velocity profile**

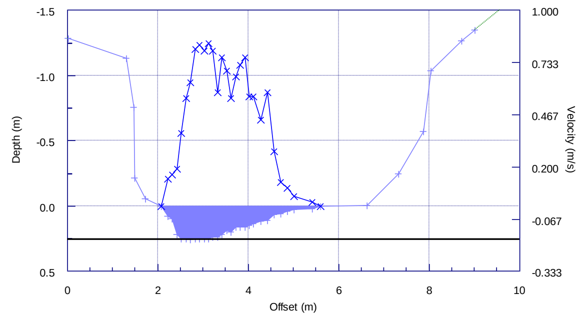
No photographs available.

21 Oct 11 WSE = 8.715 Q = 0.259 **18 Jul 12 WSE = 8.720 Q = 0.273**

23 Aug 12 WSE = 8.660 Q = 0.172 **26 Sep 12 WSE = 8.629 Q = 0.116**

LOWER DAVIDSON- TRANSECT 3-DC-1.3 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

No photographs available.

21 Oct 11 WSE = 8.900 Q = 0.259

18 Jul 12 WSE = 8.905 Q = 0.273

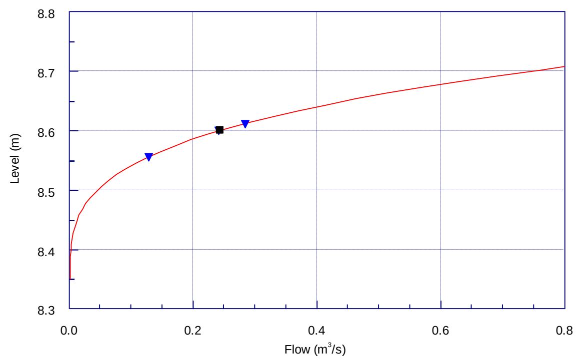
23 Aug 12 WSE = 8.870 Q = 0.172

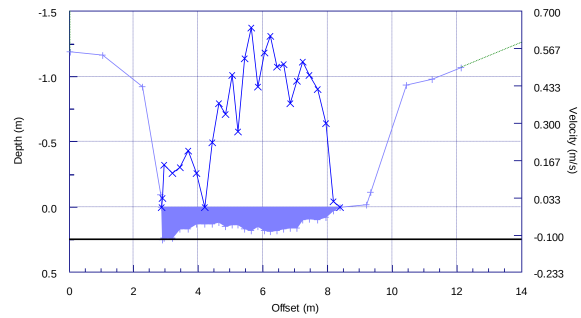
26 Sep 12 WSE = 8.845 Q = 0.116

LOWER DAVIDSON- TRANSECT 3-DC-1.3 - RIFFLE PAGE 2

14 Jun 13 **WSE = 9.266** **Q = 2.221** No additional surveys

LOWER DAVIDSON - TRANSECT 4-DC-1.1 - RIFFLE





SZF rating curve | **Survey flow depth / velocity profile**

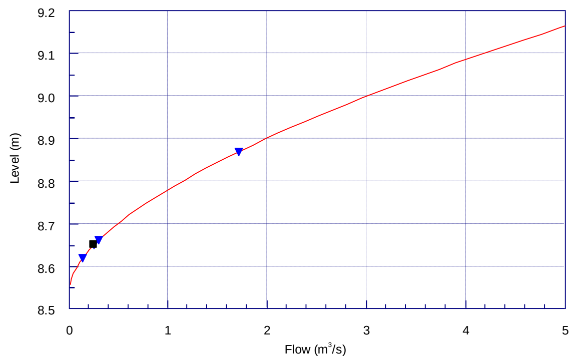
22 Oct 11 WSE = 8.600 Q = 0.243

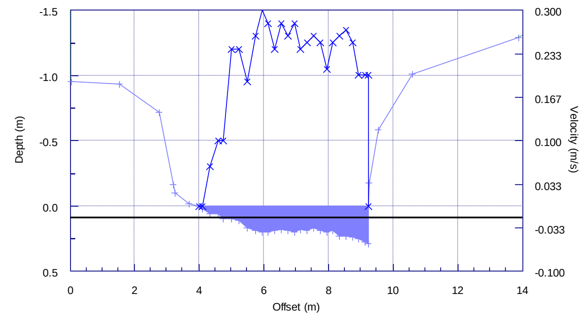
18 Jul 12 WSE = 8.610 Q = 0.282

21 Aug 12 WSE = 8.599 Q = 0.239

25 Sep 12 WSE = 8.555 Q = 0.126

LOWER DAVIDSON - TRANSECT 4-DC-1.2 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

22 Oct 11 WSE = 8.650 Q = 0.243

18 Jul 12 WSE = 8.660 Q = 0.282

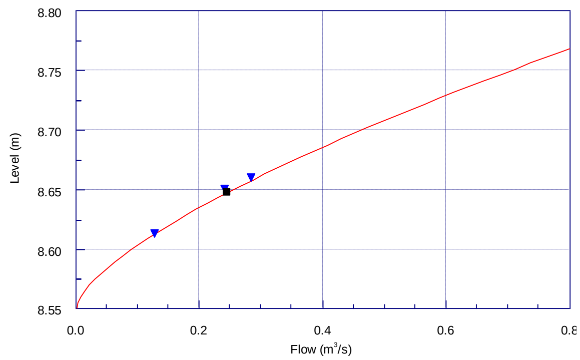
21 Aug 12 WSE = 8.649 Q = 0.239

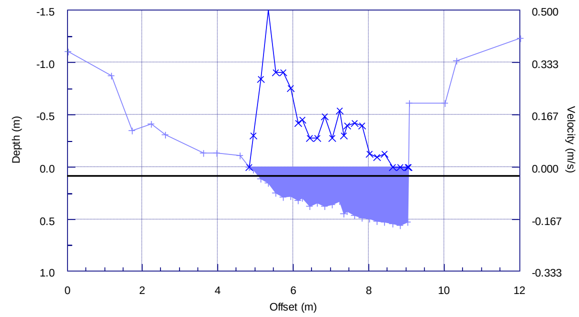
25 Sep 12 WSE = 8.618 Q = 0.126

LOWER DAVIDSON - TRANSECT 4-DC-1.2 - GLIDE PAGE 2

15 Jun 13	**WSE = 8.868**	**Q = 1.701**	No additional surveys

LOWER DAVIDSON - TRANSECT 4-DC-1.3 - POOL





SZF rating curve **Survey flow depth / velocity profile**

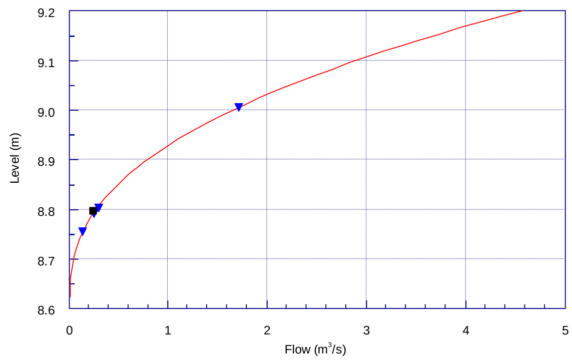
22 Oct 11 WSE = 8.647 Q = 0.243

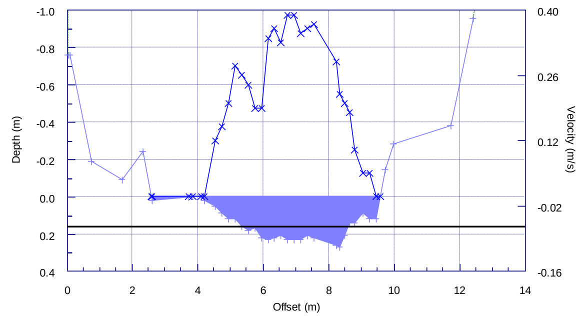
18 Jul 12 WSE = 8.660 Q = 0.282

21 Aug 12 WSE = 8.650 Q = 0.239

25 Sep 12 WSE = 8.613 Q = 0.126

LOWER DAVIDSON - TRANSECT 4-DC-2.1 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

22 Oct 11 WSE = 8.795 Q = 0.243

18 Jul 12 WSE = 8.803 Q = 0.282

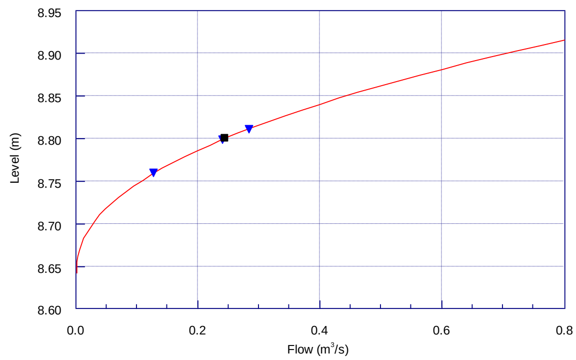
21 Aug 12 WSE = 8.792 Q = 0.239

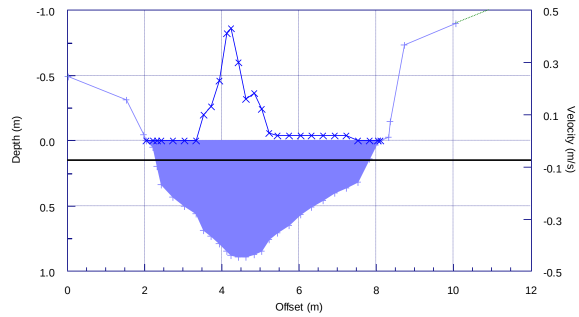
25 Sep 12 WSE = 8.755 Q = 0.126

LOWER DAVIDSON - TRANSECT 4-DC-2.1 - GLIDE PAGE 2

15 Jun 13 **WSE = 9.006** **Q = 1.701** No additional surveys

LOWER DAVIDSON - TRANSECT 4-DC-2.2 - POOL





SZF rating curve **Survey flow depth / velocity profile**

22 Oct 11 WSE = 8.800 Q = 0.243

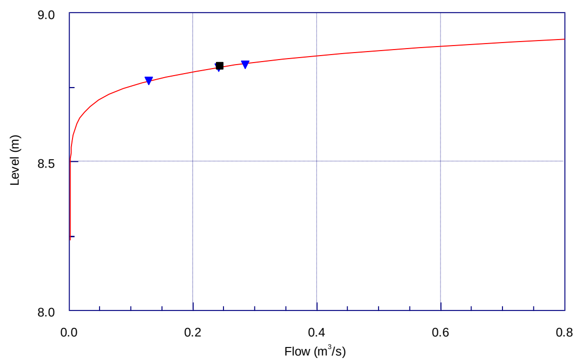
18 Jul 12 WSE = 8.811 Q = 0.282

21 Aug 12 WSE = 8.798 Q = 0.239

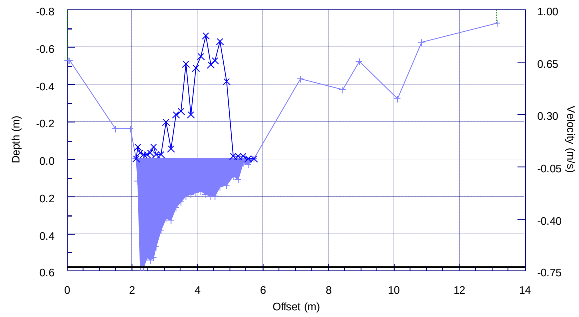
25 Sep 12 WSE = 8.759 Q = 0.126

DRAFT

LOWER DAVIDSON - TRANSECT 4-DC-2.3 - RIFFLE



SZF rating curve



Survey flow depth / velocity profile

22 Oct 11 WSE = 8.817 Q = 0.243

18 Jul 12 WSE = 8.825 Q = 0.282

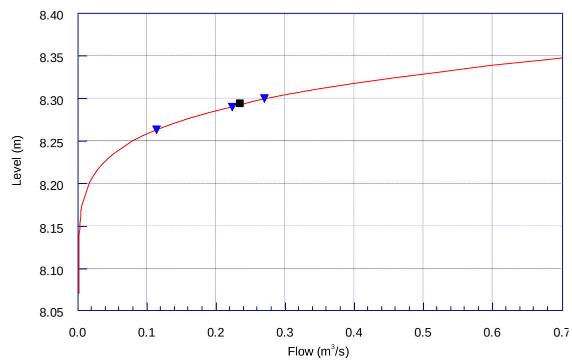
21 Aug 12 WSE = 8.815 Q = 0.239

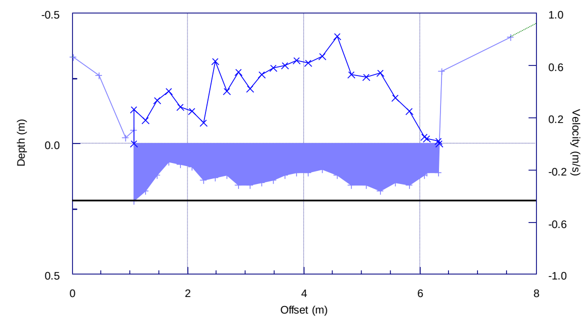
25 Sep 12 WSE = 8.770 Q = 0.126

MIDDLE DAVIDSON CREEK MODEL

SZF – stage of zero flow
WSE – water surface elevation (note that all WSE measurements are relative to transect-specific benchmarks surveyed to a transect-specific datum)
Q – discharge

MIDDLE DAVIDSON - TRANSECT 5-DC-1.1 - RIFFLE





SZF rating curve | **Survey flow depth / velocity profile**

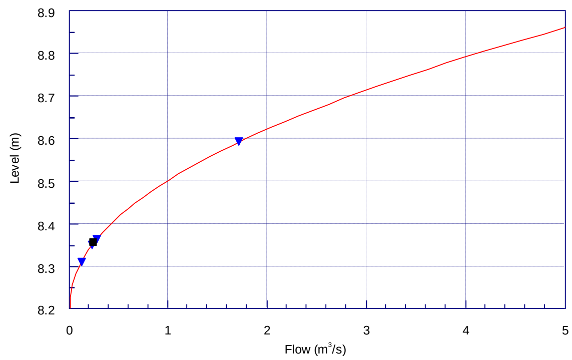
23 Oct 11 WSE = 8.293 Q = 0.234

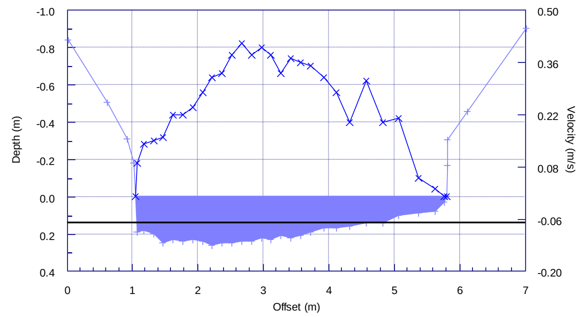
18 Jul 12 WSE = 8.300 Q = 0.268

21 Aug 12 WSE = 8.290 Q = 0.221

26 Sep 12 WSE = 8.263 Q = 0.112

MIDDLE DAVIDSON - TRANSECT 5-DC-1.2 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

23 Oct 11 WSE = 8.353 Q = 0.234

18 Jul 12 WSE = 8.362 Q = 0.268

21 Aug 12 WSE = 8.349 Q = 0.221

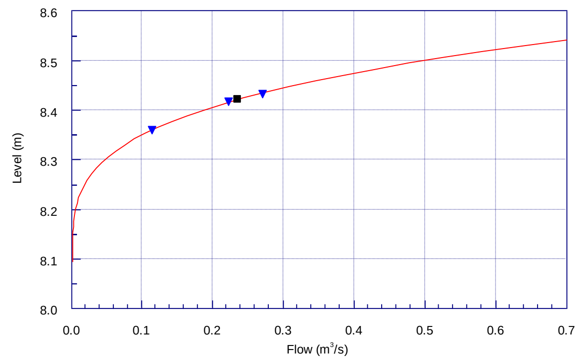
26 Sep 12 WSE = 8.310 Q = 0.112

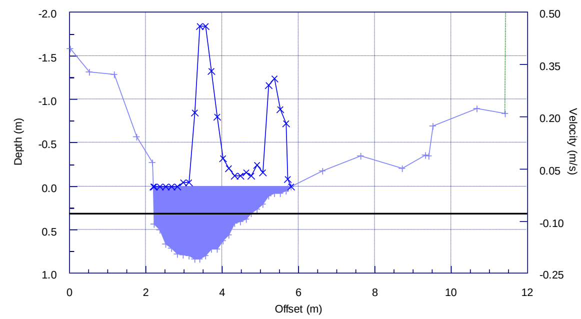
MIDDLE DAVIDSON - TRANSECT 5-DC-1.2 - GLIDE PAGE 2

15 Jun 13 **WSE = 8.592** **Q = 1.701**

No additional surveys

MIDDLE DAVIDSON - TRANSECT 5-DC-1.3 - POOL





SZF rating curve **Survey flow depth / velocity profile**

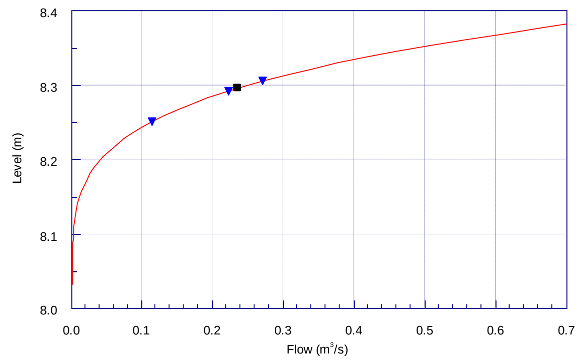
23 Oct 11 WSE = 8.421 Q = 0.234

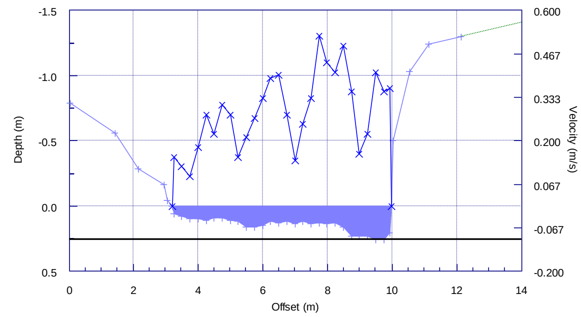
18 Jul 12 WSE = 8.432 Q = 0.268

21 Aug 12 WSE = 8.416 Q = 0.221

26 Sep 12 WSE = 8.359 Q = 0.112

MIDDLE DAVIDSON - TRANSECT 5-DC-2.1 - RIFFLE





SZF rating curve | **Survey flow depth / velocity profile**

No photographs available.

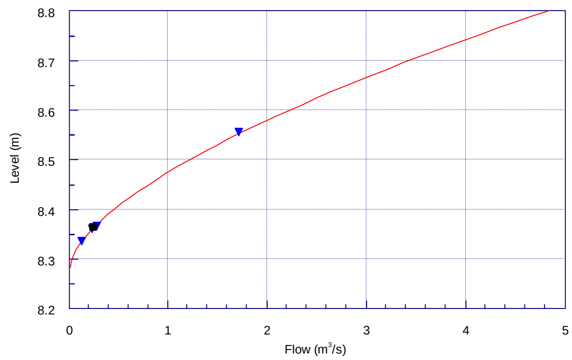
19 Oct 11 WSE = 8.296 Q = 0.234

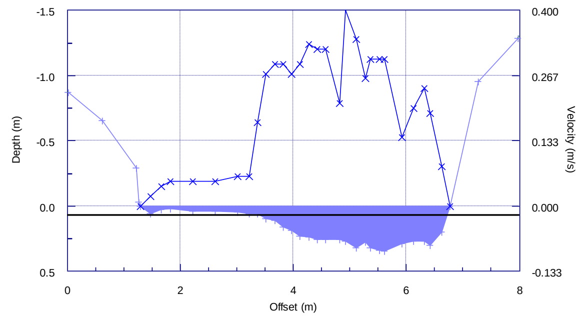
18 Jul 12 WSE = 8.306 Q = 0.268

21 Aug 12 WSE = 8.292 Q = 0.221

25 Sep 12 WSE = 8.251 Q = 0.112

MIDDLE DAVIDSON - TRANSECT 5-DC-2.2 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

No photographs available.

19 Oct 11 WSE = 8.362 Q = 0.234

18 Jul 12 WSE = 8.367 Q = 0.268

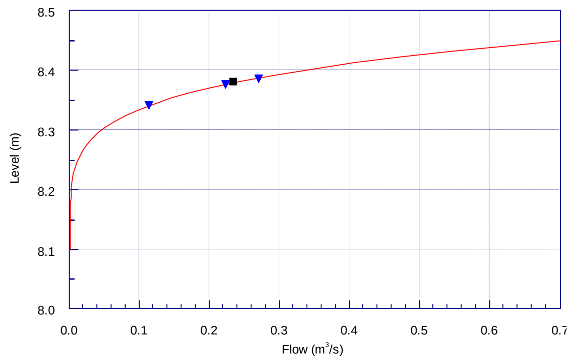
21 Aug 12 WSE = 8.360 Q = 0.221

25 Sep 12 WSE = 8.335 Q = 0.112

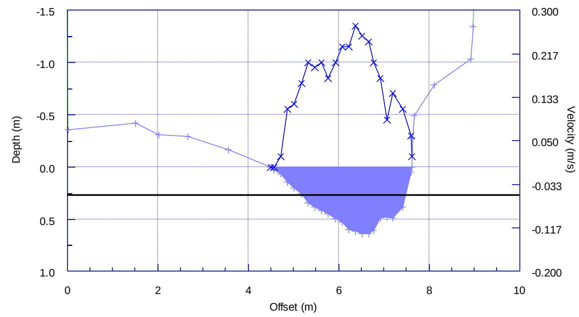
MIDDLE DAVIDSON - TRANSECT 5-DC-2.2 - GLIDE PAGE 2

15 Jun 13 **WSE = 8.555** **Q = 1.701** No additional surveys

MIDDLE DAVIDSON - TRANSECT 5-DC-2.3 - POOL



SZF rating curve



Survey flow depth / velocity profile

No photographs available.

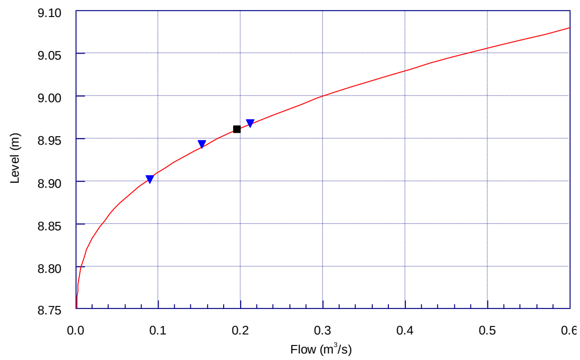
19 Oct 11 WSE = 8.379 Q = 0.234

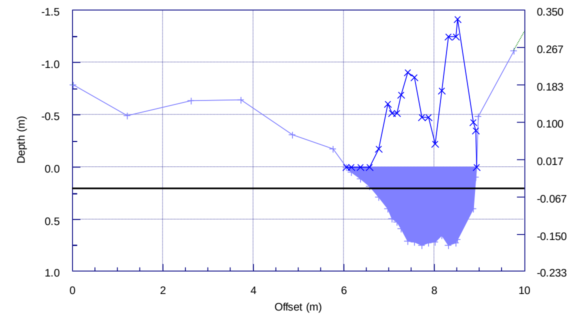
18 Jul 12 WSE = 8.385 Q = 0.268

21 Aug 12 WSE = 8.375 Q = 0.221

25 Sep 12 WSE = 8.340 Q = 0.112

MIDDLE DAVIDSON - TRANSECT 6-DC-1.1 - POOL





SZF rating curve **Survey flow depth / velocity profile**

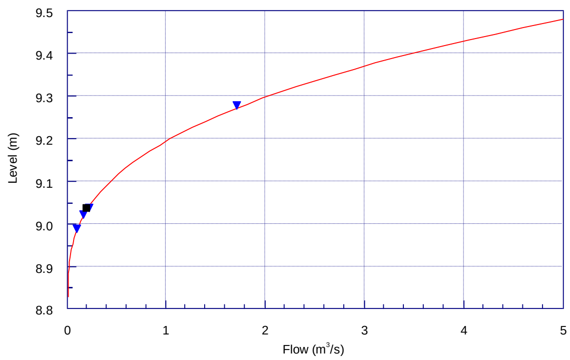
23 Oct 11 WSE = 8.960 Q = 0.195

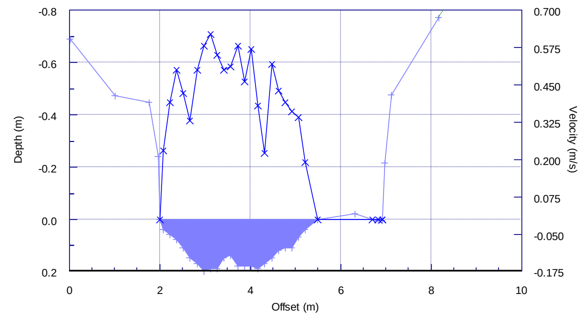
18 Jul 12 WSE = 8.967 Q = 0.210

21 Aug 12 WSE = 8.943 Q = 0.152

25 Sep 12 WSE = 8.902 Q = 0.088

MIDDLE DAVIDSON - TRANSECT 6-DC-1.2 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

23 Oct 11 WSE = 9.034 Q = 0.195

18 Jul 12 WSE = 9.037 Q = 0.210

21 Aug 12 WSE = 9.020 Q = 0.152

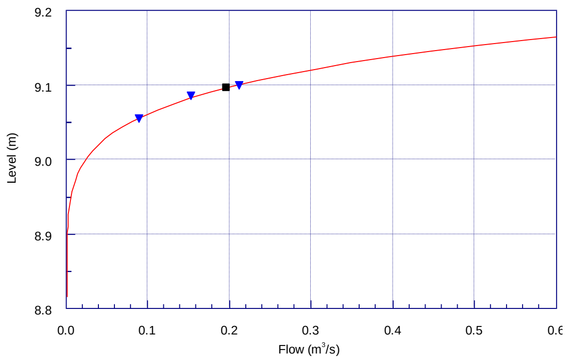
25 Sep 12 WSE = 8.988 Q = 0.088

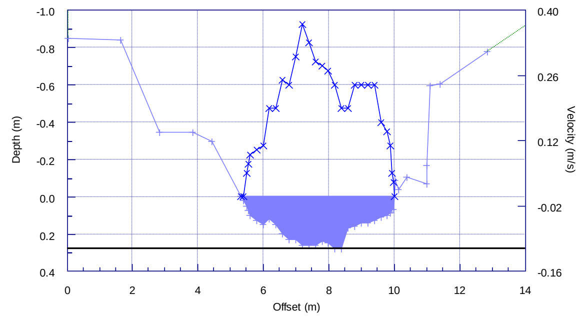
MIDDLE DAVIDSON - TRANSECT 6-DC-1.2 - RIFFLE PAGE 2

15 Jun 13 **WSE = 9.276** **Q = 1.701**

No additional surveys

MIDDLE DAVIDSON - TRANSECT 6-DC-1.3 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

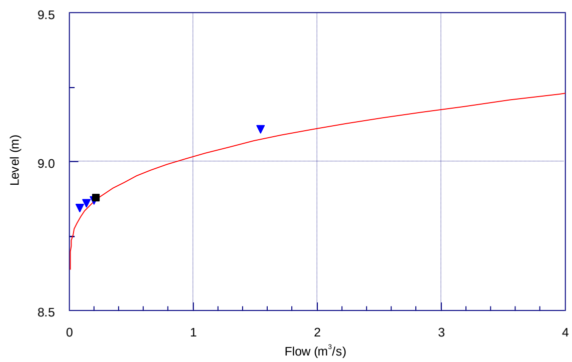
23 Oct 11 WSE = 9.096 Q = 0.195

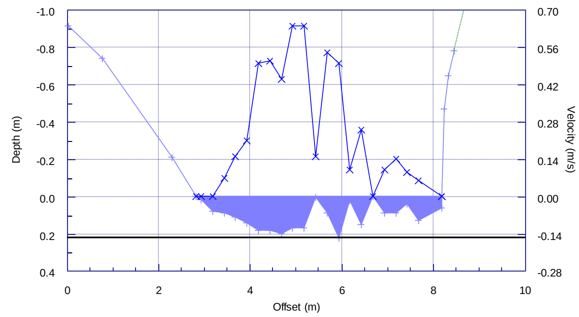
18 Jul 12 WSE = 9.100 Q = 0.210

21 Aug 12 WSE = 9.085 Q = 0.152

25 Sep 12 WSE = 9.055 Q = 0.088

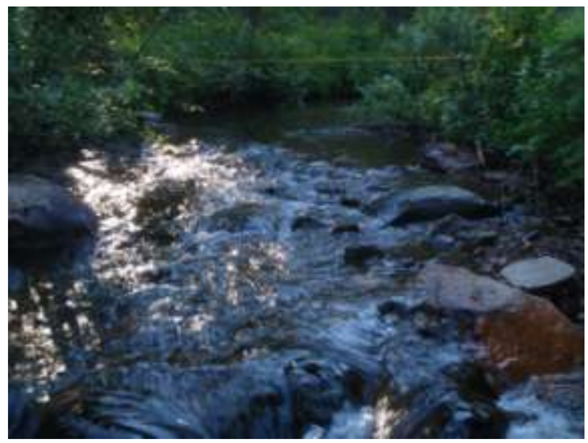
MIDDLE DAVIDSON - TRANSECT 7.1-DC-01 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

21 Aug 11 WSE = 8.871 Q = 0.188



19 Jul 12 WSE = 8.875 Q = 0.217

21 Aug 12 WSE = 8.860 Q = 0.126

25 Sep 12 WSE = 8.843 Q = 0.080

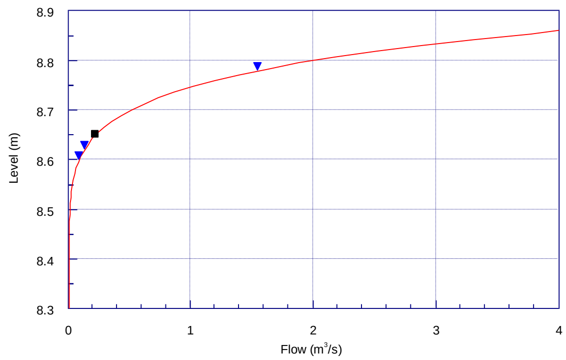
MIDDLE DAVIDSON - TRANSECT 7.1-DC-01 - RIFFLE PAGE 2

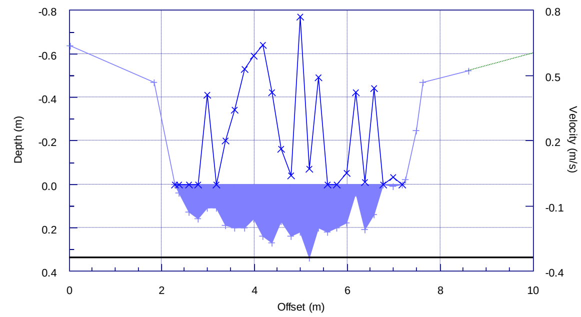
22 Oct 12 WSE = 8.937 Q = 0.101

14 Jun 13 WSE = 9.109 Q = 1.532

No additional surveys

MIDDLE DAVIDSON - TRANSECT 7.1-DC-02 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

21 Aug 11 WSE = 8.658 Q = 0.188

19 Jul 12 WSE = 8.649 Q = 0.217

21 Aug 12 WSE = 8.628 Q = 0.126

25 Sep 12 WSE = 8.607 Q = 0.080

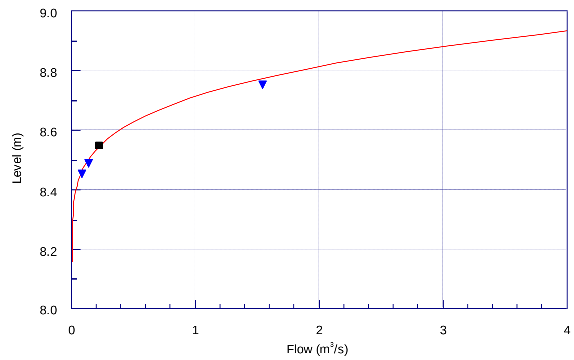
MIDDLE DAVIDSON - TRANSECT 7.1-DC-02 - RIFFLE PAGE 2

22 Oct 12 WSE = 8.714 Q = 0.101

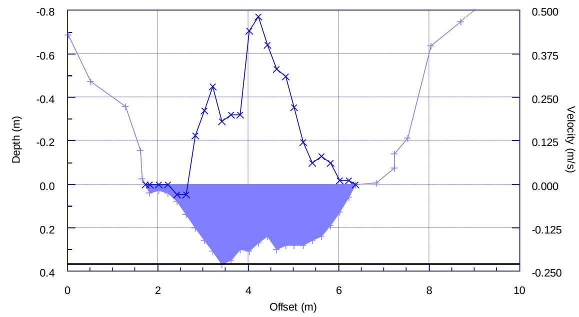
14 Jun 13 WSE = 8.788 Q = 1.532

No additional surveys

MIDDLE DAVIDSON - TRANSECT 7.1-DC-05 - RIFFLE



SZF rating curve



Survey flow depth / velocity profile

20 Aug 11 WSE = 8.546 Q = 0.220

19 Jul 12 WSE = 8.496 Q = 0.217

21 Aug 12 WSE = 8.488 Q = 0.126

25 Sep 12 WSE = 8.453 Q = 0.080

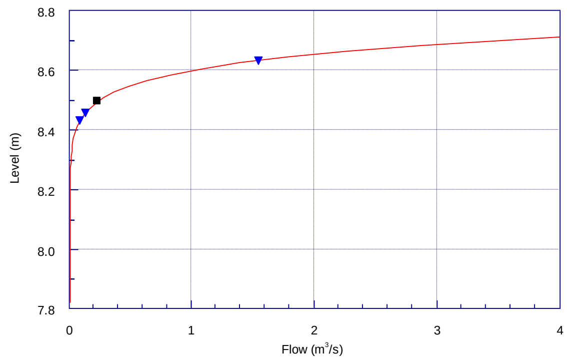
MIDDLE DAVIDSON - TRANSECT 7.1-DC-05 - RIFFLE PAGE 2

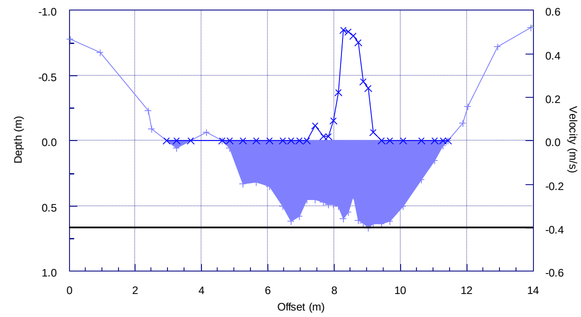
22 Oct 12 WSE = 8.588 Q = 0.101

14 Jun 13 WSE = 8.753 Q = 1.532

No additional surveys

MIDDLE DAVIDSON - TRANSECT 7.1-DC-3.1 - POOL





SZF rating curve **Survey flow depth / velocity profile**

21 Oct 11 WSE = 8.494 Q = 0.223

19 Jul 12 WSE = 8.411 Q = 0.217

21 Aug 12 WSE = 8.456 Q = 0.126

25 Sep 12 WSE = 8.429 Q = 0.080

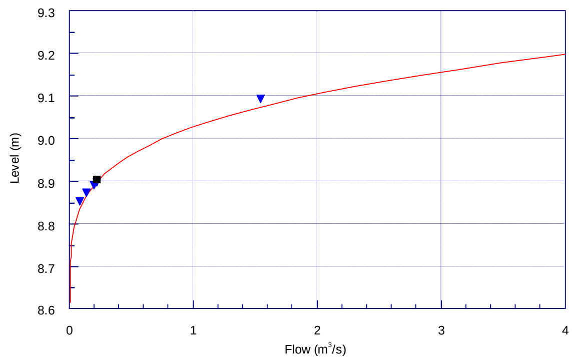
MIDDLE DAVIDSON - TRANSECT 7.1-DC-3.1 - POOL PAGE 2

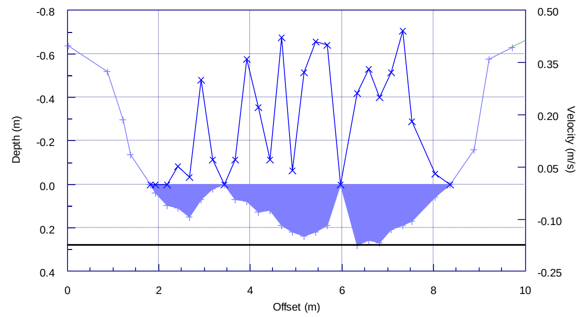
22 Oct 12 WSE = 8.486 Q = 0.101

14 Jun 13 WSE = 8.630 Q = 1.532

No additional surveys

MIDDLE DAVIDSON - TRANSECT 7.1-DC-3.2 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

21 Aug 11 WSE = 8.889 Q = 0.188

21 Oct 11 WSE = 8.900 Q = 0.223

19 Jul 12 WSE = 8.897 Q = 0.217

21 Aug 12 WSE = 8.872 Q = 0.126

MIDDLE DAVIDSON - TRANSECT 7.1-DC-3.2 - RIFFLE PAGE 2

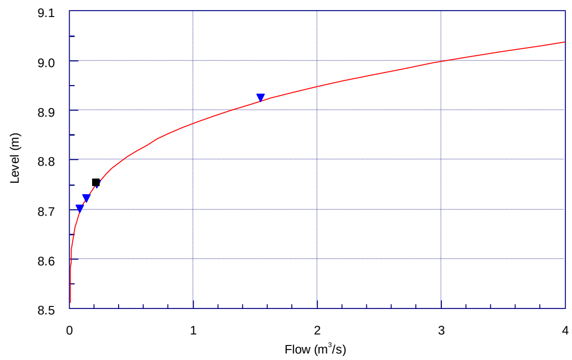
25 Sep 12 WSE = 8.852 Q = 0.080

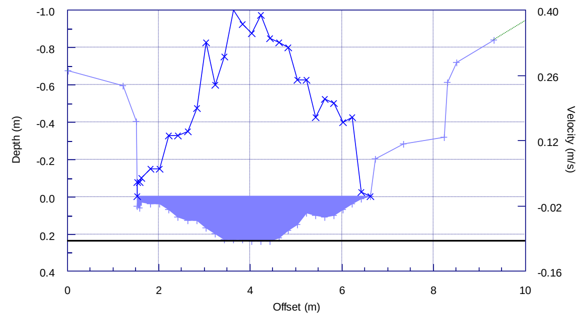
22 Oct 12 WSE = 8.927 Q = 0.101

No photographs available.

14 Jun 13 WSE = 9.092 Q = 1.532

MIDDLE DAVIDSON - TRANSECT 8-DC-01 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

19 Aug 11 WSE = 8.750 Q = 0.210

19 Jul 12 WSE = 8.752 Q = 0.217

21 Aug 12 WSE = 8.721 Q = 0.126

25 Sep 12 WSE = 8.701 Q = 0.080

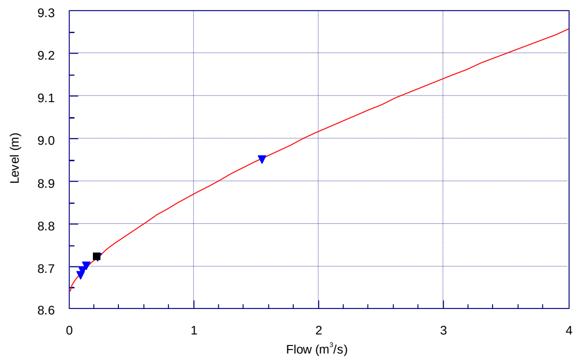
MIDDLE DAVIDSON - TRANSECT 8-DC-01 - GLIDE PAGE 2

22 Oct 12 WSE = 8.726 Q = 0.101

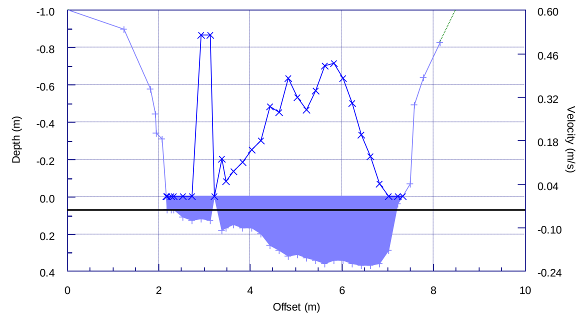
14 Jun 13 WSE = 8.924 Q = 1.532

No additional surveys

MIDDLE DAVIDSON - TRANSECT 8-DC-04 - GLIDE



SZF rating curve



Survey flow depth / velocity profile

20 Aug 11 WSE = 8.721 Q = 0.220

19 Jul 12 WSE = 8.720 Q = 0.217

21 Aug 12 WSE = 8.700 Q = 0.126

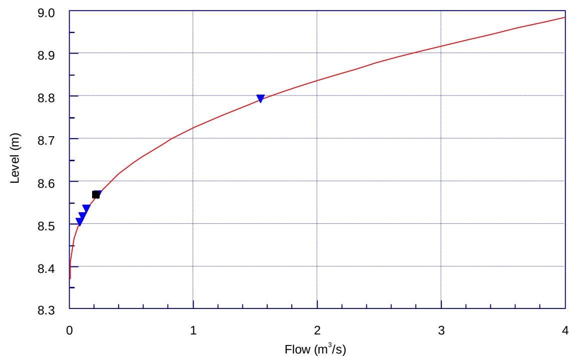
25 Sep 12 WSE = 8.678 Q = 0.080

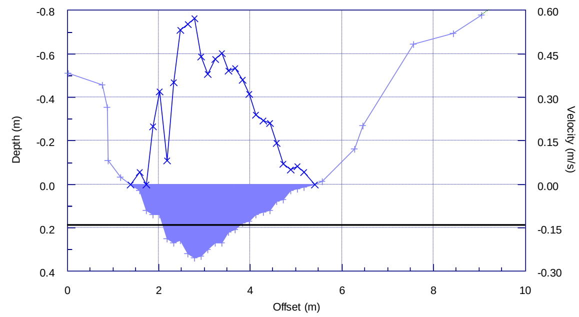
MIDDLE DAVIDSON - TRANSECT 8-DC-04 - GLIDE PAGE 2

No photographs available.

22 Oct 12	**WSE = 8.690**	**Q = 0.101**	**14 Jun 13**	**WSE = 8.949**	**Q = 1.532**

MIDDLE DAVIDSON - TRANSECT 8-DC-05 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

20 Aug 11 WSE = 8.568 Q = 0.220

19 Jul 12 WSE = 8.566 Q = 0.217

21 Aug 12 WSE = 8.534 Q = 0.126

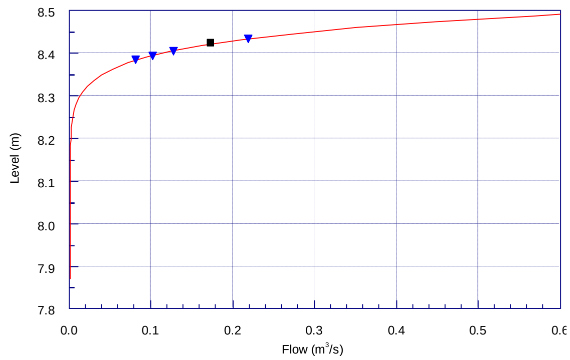
25 Sep 12 WSE = 8.503 Q = 0.080

MIDDLE DAVIDSON - TRANSECT 8-DC-05 - GLIDE PAGE 2

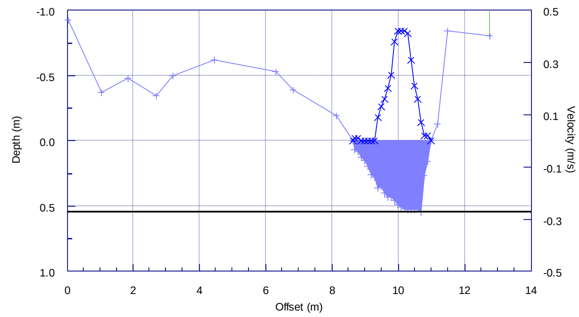
No photographs available.

22 Oct 12	**WSE = 8.516**	**Q = 0.101**	**14 Jun 13**	**WSE = 8.792**	**Q = 1.532**

MIDDLE DAVIDSON - TRANSECT 8-DC-2.1 - POOL



SZF rating curve



Survey flow depth / velocity profile

20 Oct 11 WSE = 8.421 Q = 0.172

19 Jul 12 WSE = 8.434 Q = 0.217

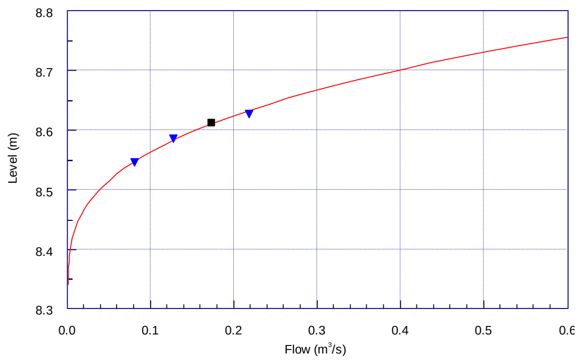
21 Aug 12 WSE = 8.405 Q = 0.126

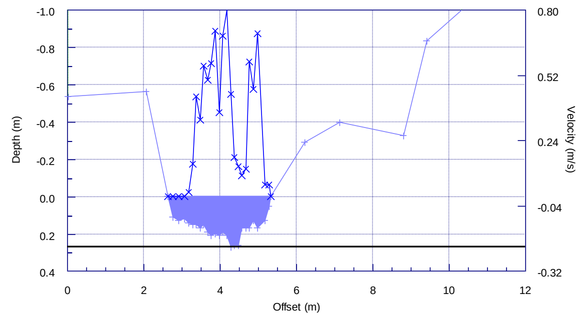
25 Sep 12 WSE = 8.383 Q = 0.080

MIDDLE DAVIDSON - TRANSECT 8-DC-2.1 - POOL PAGE 2

22 Oct 12 WSE = 8.394 Q = 0.101

MIDDLE DAVIDSON - TRANSECT 8-DC-2.2 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

20 Oct 11 WSE = 8.610 Q = 0.172

19 Jul 12 WSE = 8.627 Q = 0.217

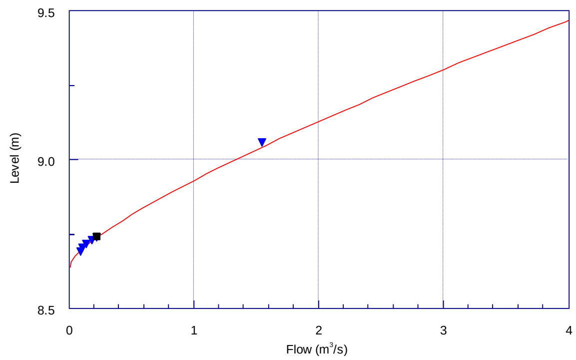
21 Aug 12 WSE = 8.585 Q = 0.126

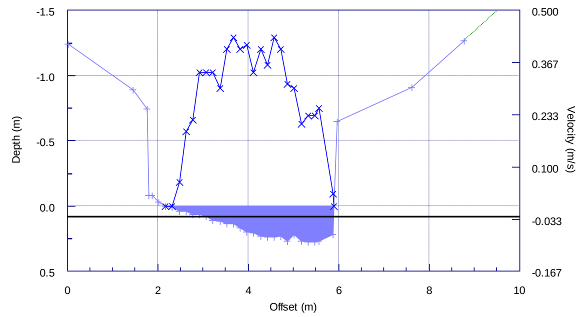
25 Sep 12 WSE = 8.545 Q = 0.080

MIDDLE DAVIDSON - TRANSECT 8-DC-2.2 - RIFFLE PAGE 2

22 Oct 12 WSE = 8.635 Q = 0.101

MIDDLE DAVIDSON - TRANSECT 8-DC-2.3 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

19 Aug 11 WSE = 8.738 Q = 0.210

20 Oct 11 WSE = 8.730 Q = 0.172

19 Jul 12 WSE = 8.739 Q = 0.217

21 Aug 12 WSE = 8.715 Q = 0.126

MIDDLE DAVIDSON - TRANSECT 8-DC-2.3 - GLIDE PAGE 2

25 Sep 12 WSE = 8.692 Q = 0.080

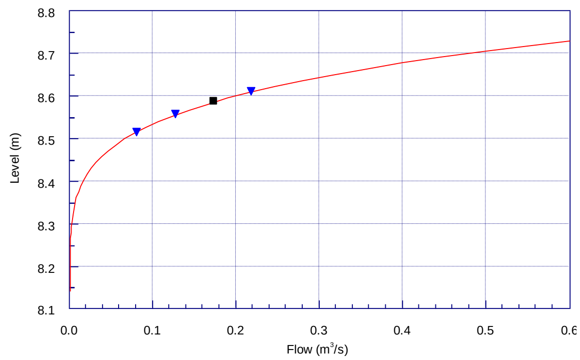
22 Oct 12 WSE = 8.703 Q = 0.101

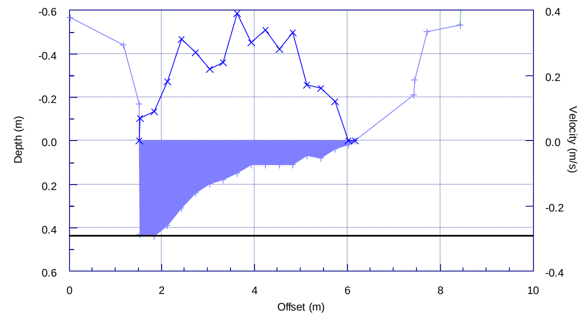
No photographs available.

14 Jun 13 WSE = 9.056 Q = 1.532

No additional surveys

MIDDLE DAVIDSON - TRANSECT 8-DC-3.1 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

20 Oct 11 WSE = 8.585 Q = 0.172

19 Jul 12 WSE = 8.611 Q = 0.217

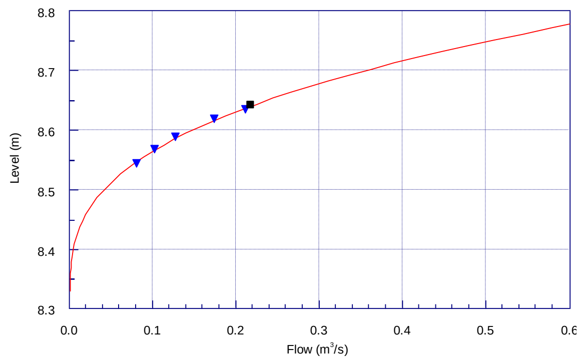
21 Aug 12 WSE = 8.556 Q = 0.126

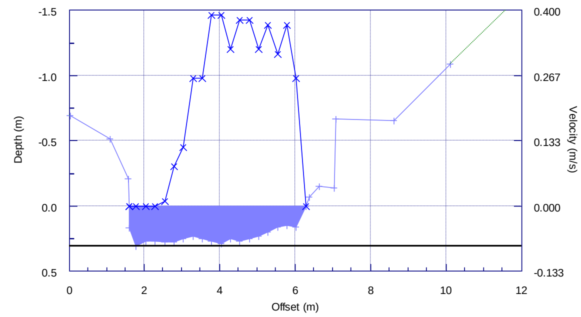
25 Sep 12 WSE = 8.515 Q = 0.080

MIDDLE DAVIDSON - TRANSECT 8-DC-3.1 - RIFFLE PAGE 2

22 Oct 12	**WSE = 8.535**	**Q = 0.101**	No additional surveys

MIDDLE DAVIDSON - TRANSECT 8-DC-3.2 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

19 Aug 11 WSE = 8.635 Q = 0.210

20 Oct 11 WSE = 8.618 Q = 0.172

19 Jul 12 WSE = 8.640 Q = 0.217

21 Aug 12 WSE = 8.588 Q = 0.126

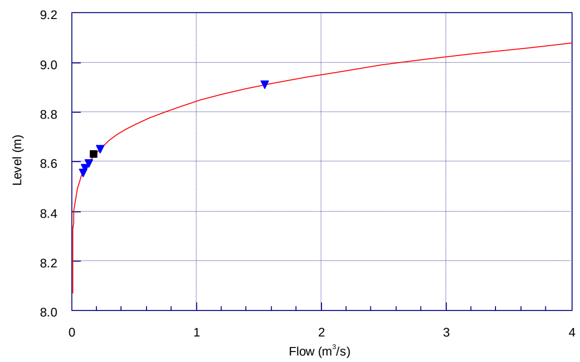
MIDDLE DAVIDSON - TRANSECT 8-DC-3.2 - GLIDE PAGE 2

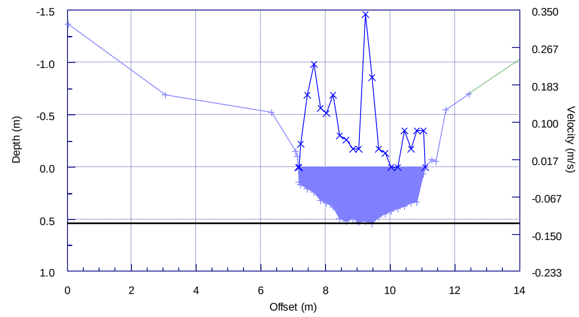
25 Sep 12 WSE = 8.543 Q = 0.080

22 Oct 12 WSE = 8.568 Q = 0.101

No additional surveys

MIDDLE DAVIDSON - TRANSECT 8-DC-3.3 - POOL





SZF rating curve **Survey flow depth / velocity profile**

20 Oct 11 WSE = 8.626 Q = 0.172

19 Jul 12 WSE = 8.648 Q = 0.217

21 Aug 12 WSE = 8.593 Q = 0.126

25 Sep 12 WSE = 8.553 Q = 0.080

MIDDLE DAVIDSON - TRANSECT 8-DC-3.3 - POOL PAGE 2

22 Oct 12 WSE = 8.575 Q = 0.101

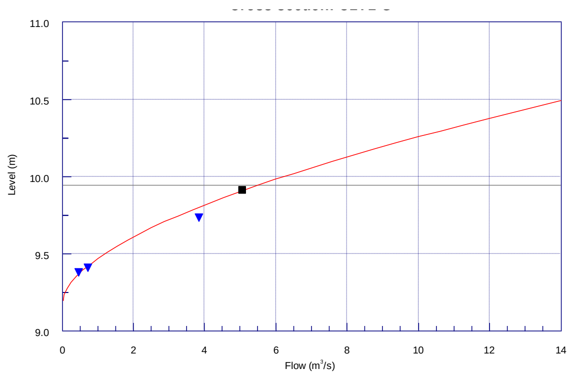
14 Jun 13 WSE = 8.911 Q = 1.532

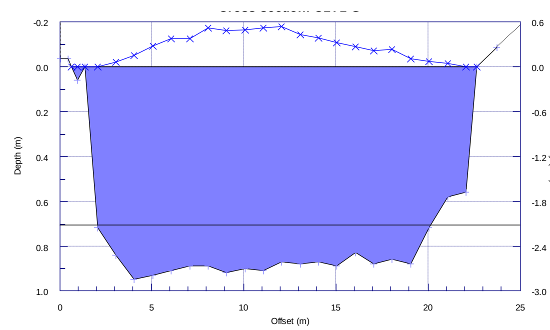
No additional surveys

CHEDAKUZ 15-CC MODEL

SZF – stage of zero flow
WSE – water surface elevation (note that all WSE measurements are relative to transect-specific benchmarks surveyed to a transect-specific datum)
Q – discharge

CHEDAKUZ 15-CC- TRANSECT C1T1-G- GLIDE





SZF rating curve **Survey flow depth / velocity profile**

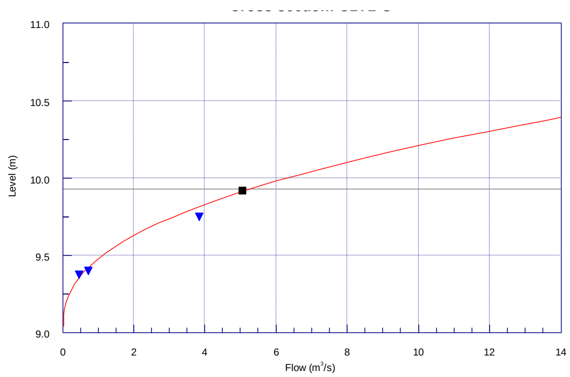
23 May 13 WSE = 9.908 Q = 5.040

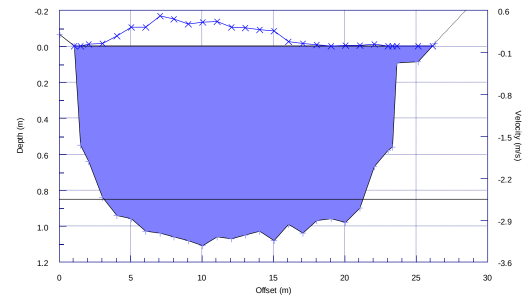
12 Jul 13 WSE = 9.731 Q = 3.814

20 Aug 13 WSE = 9.409 Q = 0.682

10 Sep 13 WSE = 9.379 Q = 0.437

CHEDAKUZ 15-CC- TRANSECT C1T2-G- GLIDE





SZF rating curve **Survey flow depth / velocity profile**

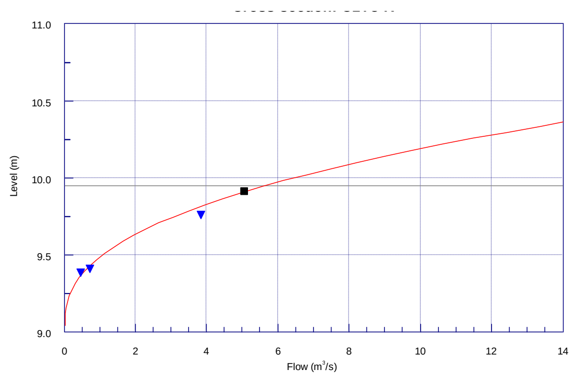
23 May 13 WSE = 9.913 Q = 5.040

12 Jul 13 WSE = 9.748 Q = 3.814

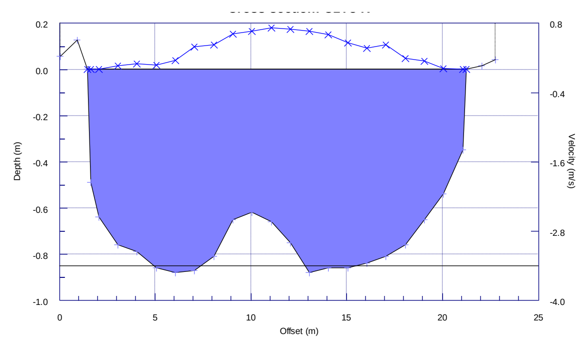
20 Aug 13 WSE = 9.401 Q = 0.682

10 Sep 13 WSE = 9.373 Q = 0.437

CHEDAKUZ 15-CC- TRANSECT C1T3-G- GLIDE



SZF rating curve



Survey flow depth / velocity profile

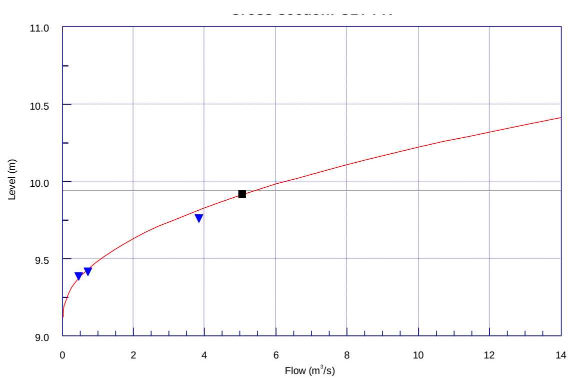
23 May 13 WSE = 9.908 Q = 5.040

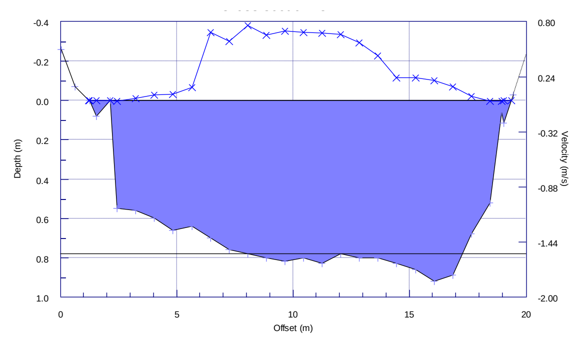
12 Jul 13 WSE = 9.756 Q = 3.814

20 Aug 13 WSE = 9.408 Q = 0.682

10 Sep 13 WSE = 9.383 Q = 0.437

CHEDAKUZ 15-CC- TRANSECT C1T4-R- RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

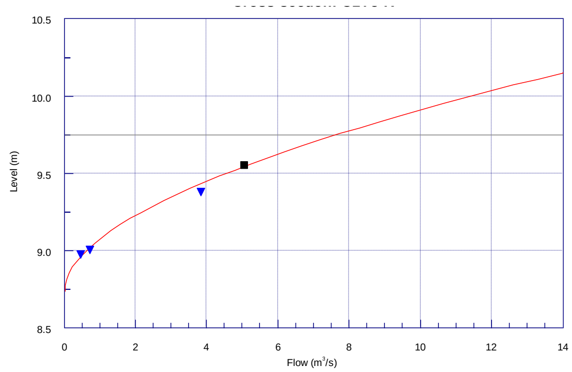
23 May 13 WSE = 9.913 Q = 5.040

12 Jul 13 WSE = 9.757 Q = 3.814

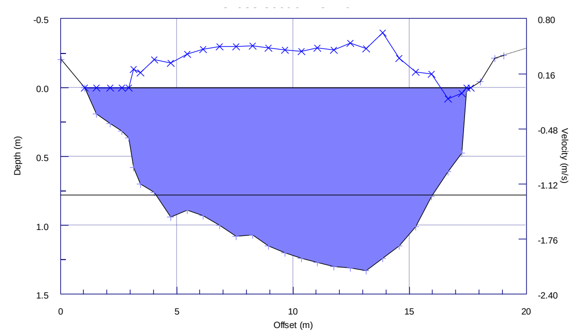
20 Aug 13 WSE = 9.415 Q = 0.682

10 Sep 13 WSE = 9.385 Q = 0.437

CHEDAKUZ 15-CC- TRANSECT C1T5-G- GLIDE



SZF rating curve



Survey flow depth / velocity profile

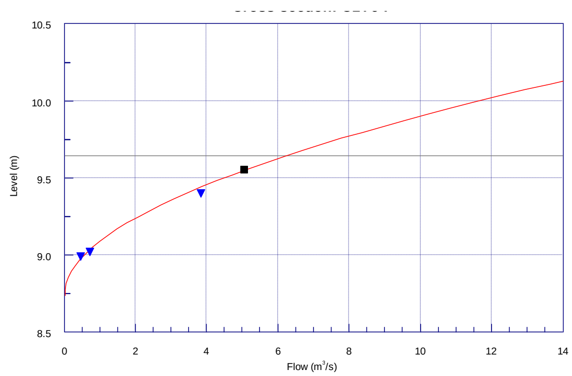
25 May 13 WSE = 9.545 Q = 5.040

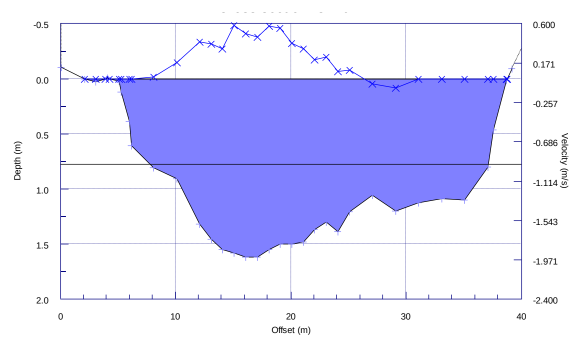
12 Jul 13 WSE = 9.380 Q = 3.814

20 Aug 13 WSE = 9.006 Q = 0.682

10 Sep 13 WSE = 8.974 Q = 0.437

CHEDAKUZ 15-CC- TRANSECT C1T6-P- POOL





SZF rating curve **Survey flow depth / velocity profile**

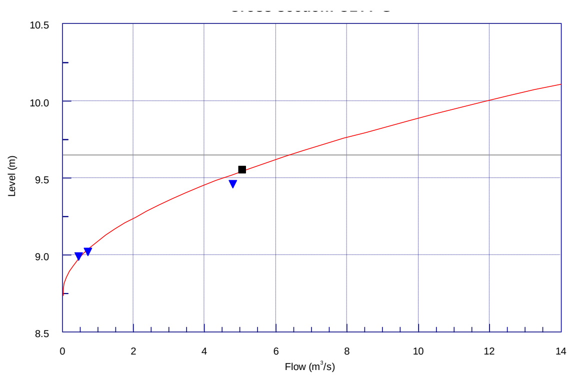
24 May 13 WSE = 9.549 Q = 5.040

12 Jul 13 WSE = 9.398 Q = 3.814

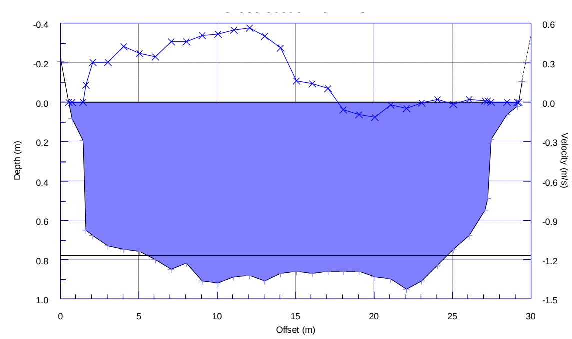
20 Aug 13 WSE = 9.017 Q = 0.682

10 Sep 13 WSE = 8.988 Q = 0.437

CHEDAKUZ 15-CC- TRANSECT C1T7-G- GLIDE



SZF rating curve



Survey flow depth / velocity profile

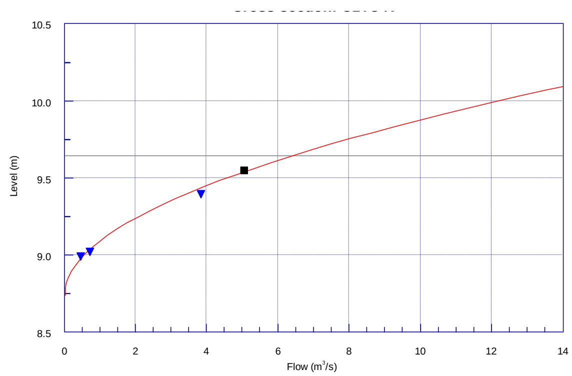
24 May 13 WSE = 9.545 Q = 5.040

9 Jul 13 WSE = 9.456 Q = 4.759

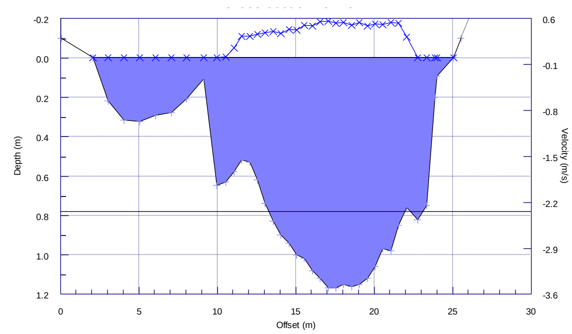
20 Aug 13 WSE = 9.019 Q = 0.682

10 Sep 13 WSE = 8.989 Q = 0.437

CHEDAKUZ 15-CC- TRANSECT C1T8-G- GLIDE



SZF rating curve



Survey flow depth / velocity profile

25 May 13 WSE = 9.540 Q = 5.040

12 Jul 13 WSE = 9.393 Q = 3.814

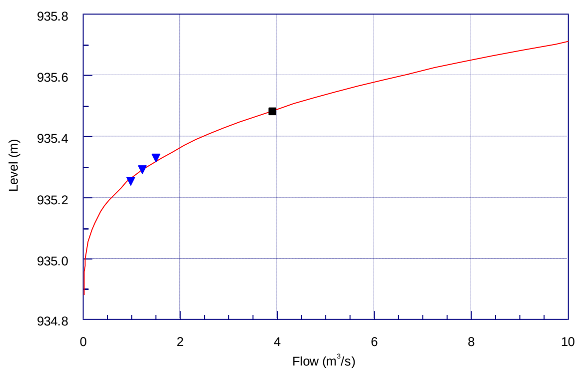
20 Aug 13 WSE = 9.018 Q = 0.682

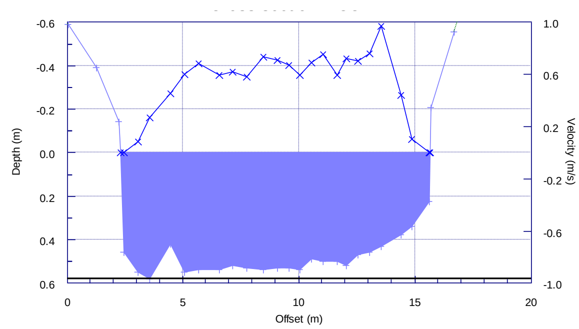
10 Sep 13 WSE = 8.990 Q = 0.437

CHEDAKUZ H5 MODEL

SZF – stage of zero flow
WSE – water surface elevation (note that all WSE measurements are relative to transect-specific benchmarks surveyed to a transect-specific datum)
Q – discharge

CHEDAKUZ H5- TRANSECT LCC-1.1 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

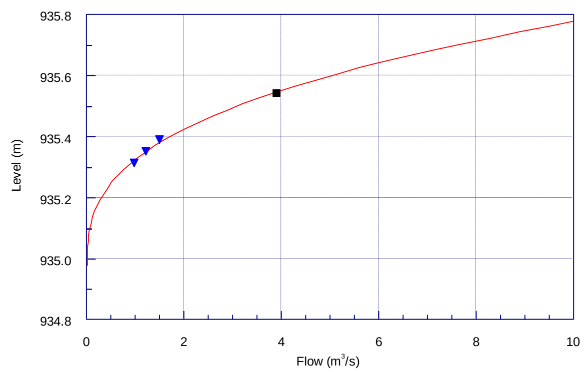
11 Jul 12 WSE = 935.478 Q = 3.892

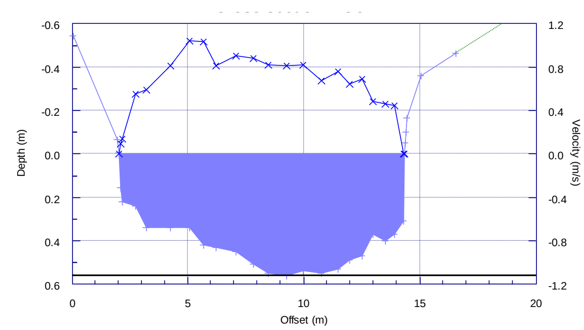
17 Aug 12 WSE = 935.330 Q = 1.474

27 Sep 12 WSE = 935.253 Q = 0.953

23 Oct 12 WSE = 935.290 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-1.2 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

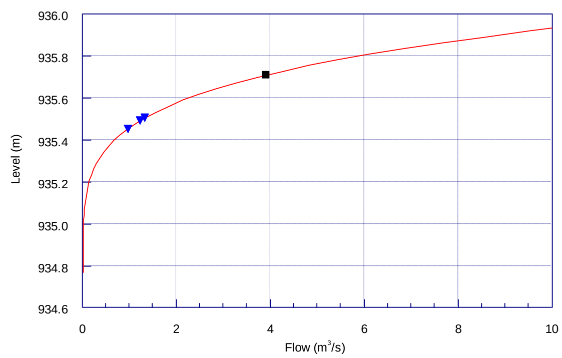
11 Jul 12 WSE = 935.539 Q = 3.892

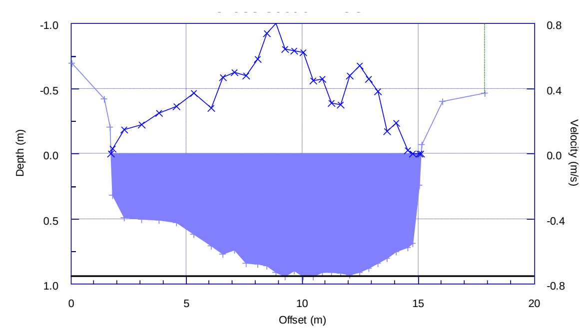
17 Aug 12 WSE = 935.390 Q = 1.474

27 Sep 12 WSE = 935.314 Q = 0.953

23 Oct 12 WSE = 935.350 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-2.1 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

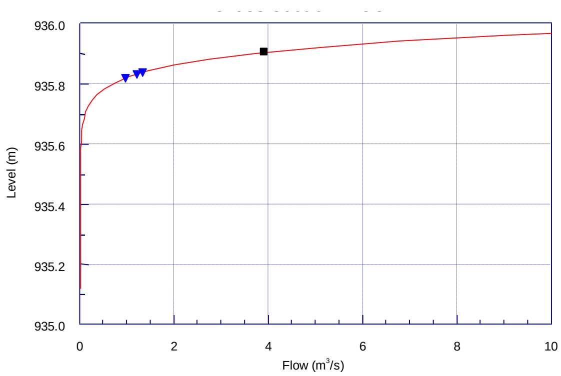
11 Jul 12 WSE = 935.707 Q = 3.892

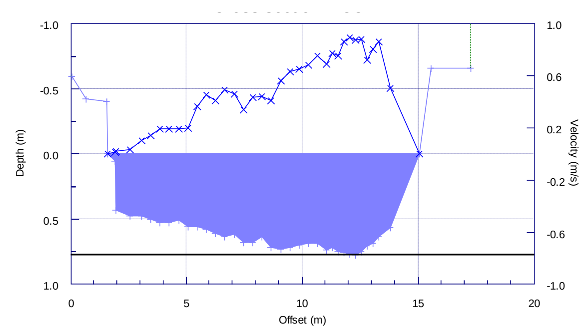
18 Aug 12 WSE = 935.507 Q = 1.310

27 Sep 12 WSE = 935.450 Q = 0.953

23 Oct 12 WSE = 935.490 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-2.2 - GLIDE



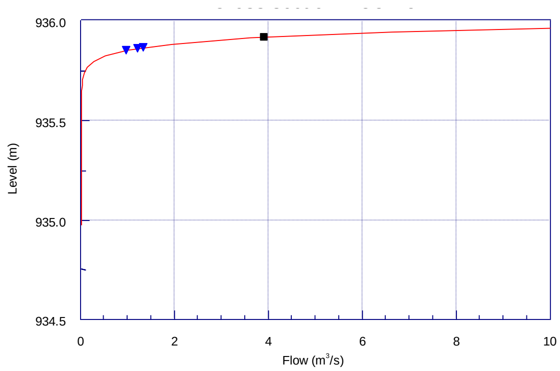


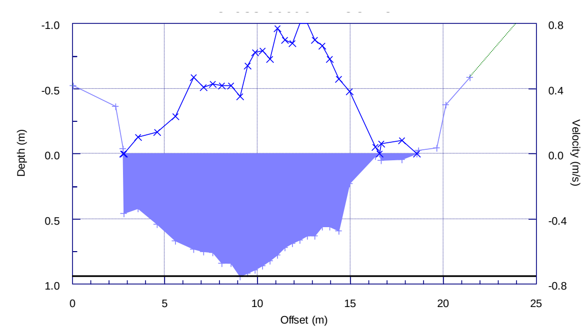
SZF rating curve **Survey flow depth / velocity profile**

11 Jul 12 WSE = 935.905 Q = 3.892 **18 Aug 12 WSE = 935.838 Q = 1.310**

27 Sep 12 WSE = 935.820 Q = 0.953 **23 Oct 12 WSE = 935.832 Q = 1.200**

CHEDAKUZ H5- TRANSECT LCC-2.3 - POOL





SZF rating curve **Survey flow depth / velocity profile**

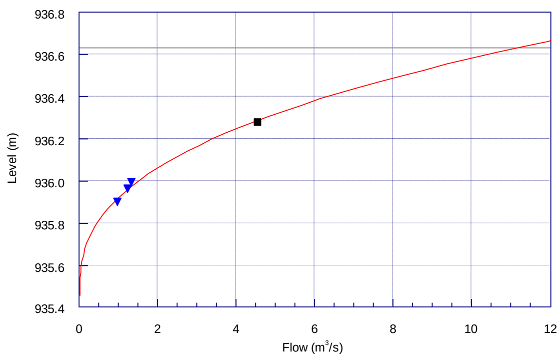
11 Jul 12 WSE = 935.915 Q = 3.892

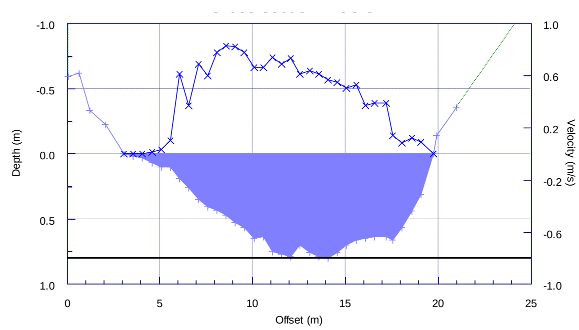
18 Aug 12 WSE = 935.868 Q = 1.310

27 Sep 12 WSE = 935.850 Q = 0.953

23 Oct 12 WSE = 935.860 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-3.1 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

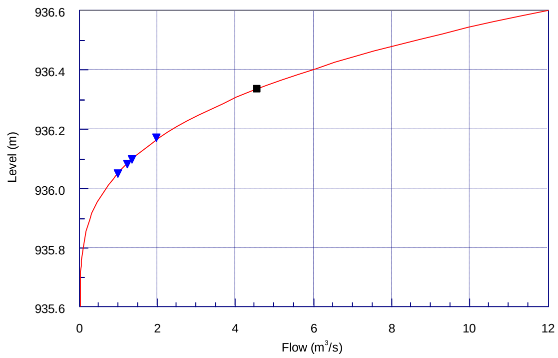
9 Jul 12 WSE = 936.275 Q = 4.533

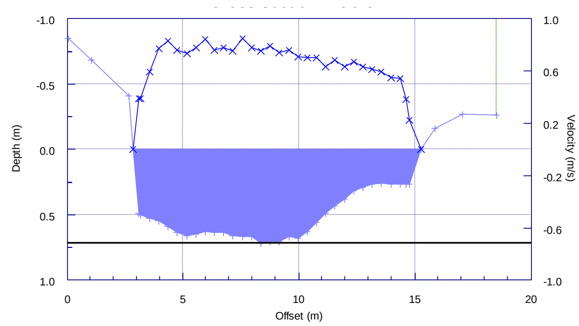
18 Aug 12 WSE = 935.994 Q = 1.310

27 Sep 12 WSE = 935.900 Q = 0.953

23 Oct 12 WSE = 935.960 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-3.2 - GLIDE





SZF rating curve | **Survey flow depth / velocity profile**

11 Oct 11 WSE = 936.170 Q = 1.941

9 Jul 12 WSE = 936.331 Q = 4.533

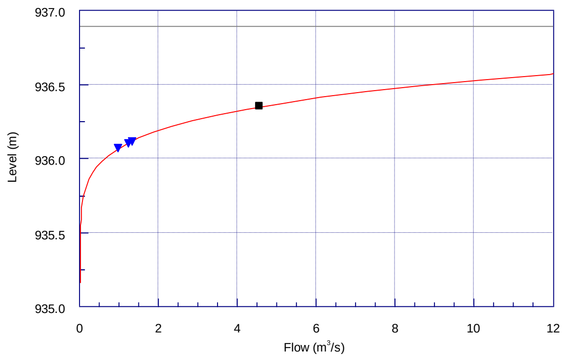
18 Aug 12 WSE = 936.097 Q = 1.310

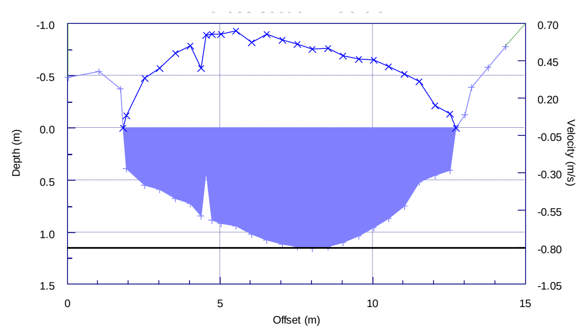
27 Sep 12 WSE = 936.050 Q = 0.953

CHEDAKUZ H5- TRANSECT LCC-3.2 - GLIDE PAGE 2

23-Oct-12 **WSE = 936.080** **Q = 1.200** No additional surveys

CHEDAKUZ H5- TRANSECT LCC-3.3 - POOL





SZF rating curve **Survey flow depth / velocity profile**

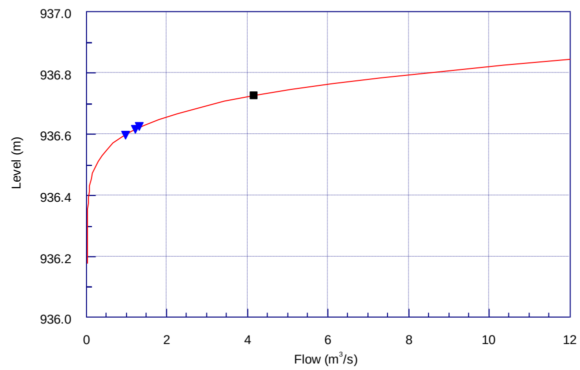
9 Jul 12 WSE = 936.350 Q = 4.533

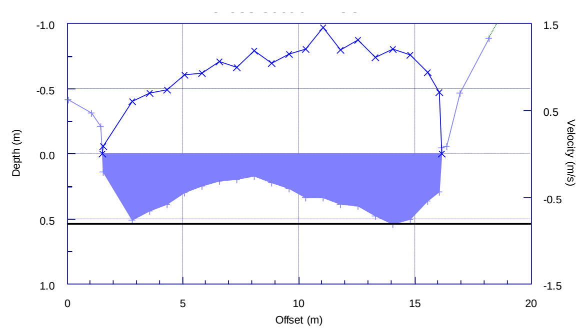
18 Aug 12 WSE = 936.112 Q = 1.310

27 Sep 12 WSE = 936.070 Q = 0.953

23 Oct 12 WSE = 936.100 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-4.1 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

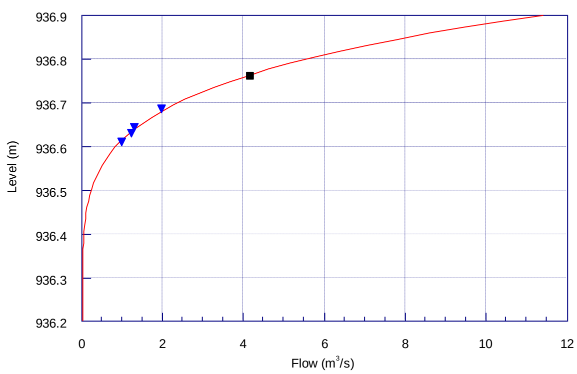
10 Jul 12 WSE = 936.724 Q = 4.143

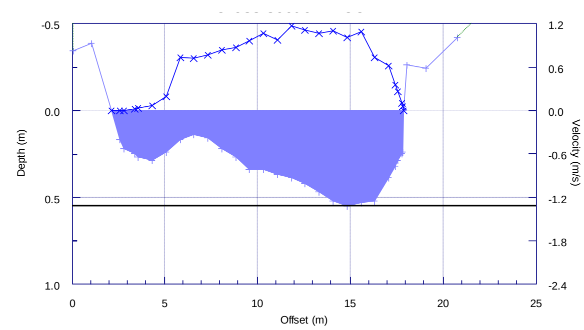
19 Aug 12 WSE = 936.624 Q = 1.278

27 Sep 12 WSE = 936.595 Q = 0.953

23 Oct 12 WSE = 936.615 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-4.2 - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

11 Oct 11 WSE = 936.685 Q = 1.941

10 Jul 12 WSE = 936.760 Q = 4.143

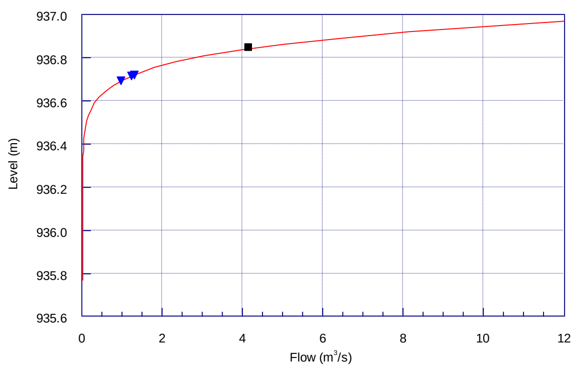
19 Aug 12 WSE = 936.644 Q = 1.278

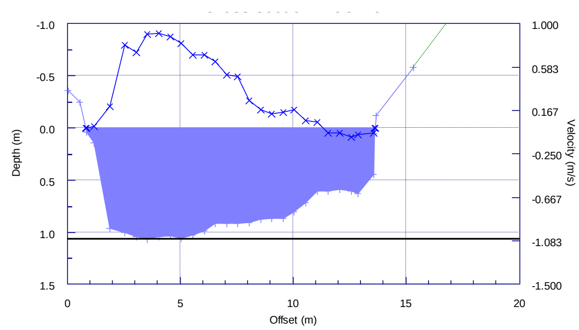
27 Sep 12 WSE = 936.610 Q = 0.953

CHEDAKUZ H5- TRANSECT LCC-4.2 - GLIDE PAGE 2

23-Oct-12 **WSE = 936.630** **Q = 1.200** No additional surveys

CHEDAKUZ H5- TRANSECT LCC-4.3 - POOL





SZF rating curve **Survey flow depth / velocity profile**

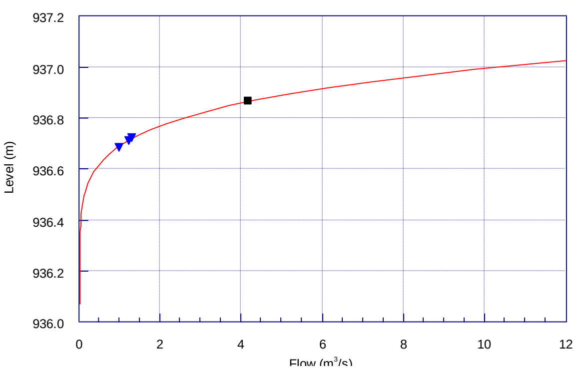
10 Jul 12 WSE = 936.842 Q = 4.143

19 Aug 12 WSE = 936.719 Q = 1.278

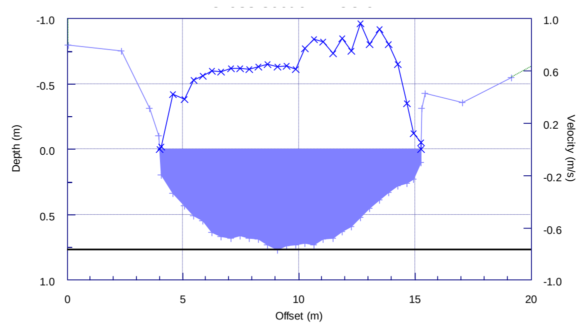
27 Sep 12 WSE = 936.694 Q = 0.953

23 Oct 12 WSE = 936.713 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-5.1 - RIFFLE



SZF rating curve



Survey flow depth / velocity profile

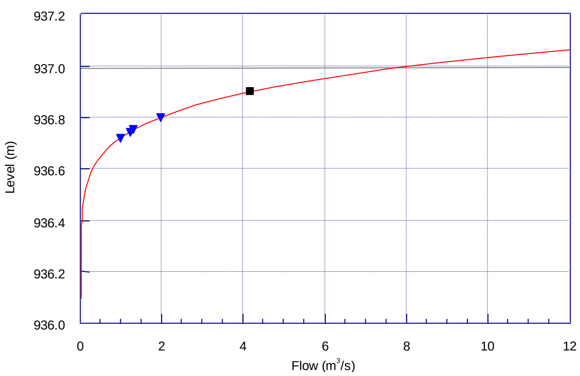
10 Jul 12 WSE = 936.862 Q = 4.143

19 Aug 12 WSE = 936.722 Q = 1.278

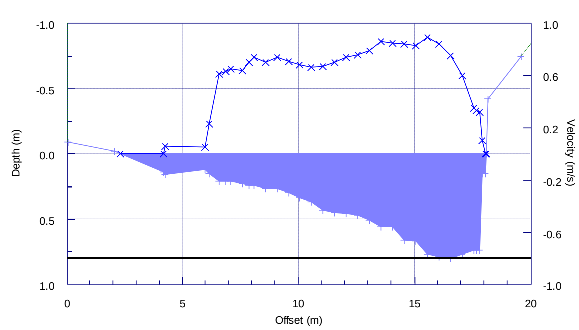
27 Sep 12 WSE = 936.684 Q = 0.953

23 Oct 12 WSE = 936.710 Q = 1.200

CHEDAKUZ H5- TRANSECT LCC-5.2 - GLIDE



SZF rating curve



Survey flow depth / velocity profile

11 Oct 11 WSE = 936.799 Q = 1.941

10 Jul 12 WSE = 936.900 Q = 4.143

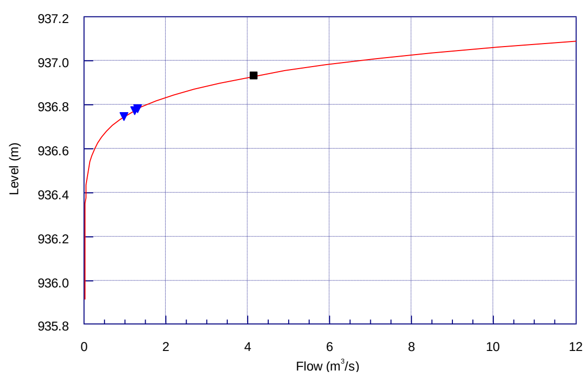
19 Aug 12 WSE = 936.754 Q = 1.278

27 Sep 12 WSE = 936.720 Q = 0.953

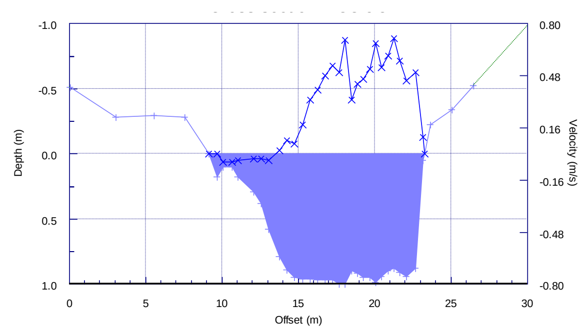
CHEDAKUZ H5- TRANSECT LCC-5.2 - GLIDE PAGE 2

23-Oct-12 **WSE = 936.740** **Q = 1.200** No additional surveys

CHEDAKUZ H5- TRANSECT LCC-5.3 - POOL



SZF rating curve



Survey flow depth / velocity profile

10 Jul 12 WSE = 936.930 Q = 4.143

19 Aug 12 WSE = 936.780 Q = 1.278

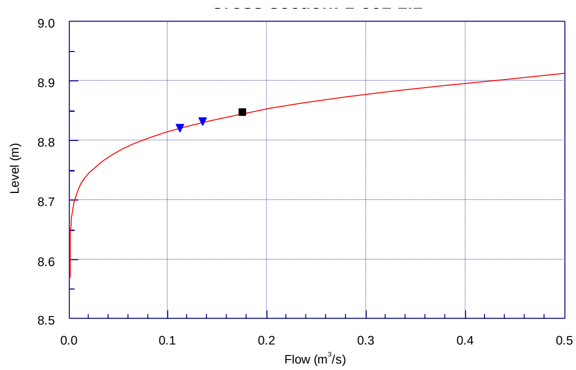
27 Sep 12 WSE = 936.744 Q = 0.953

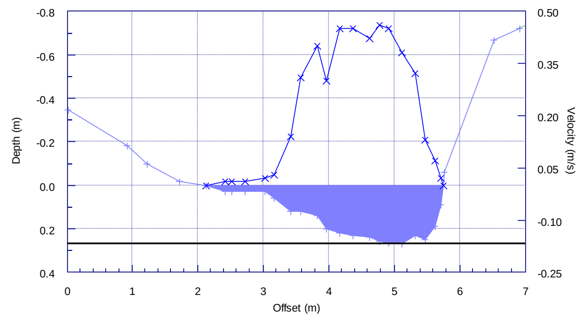
23 Oct 12 WSE = 936.770 Q = 1.200

CREEK 661 MODEL

SZF – stage of zero flow
WSE – water surface elevation (note that all WSE measurements are relative to transect-specific benchmarks surveyed to a transect-specific datum)
Q – discharge

CREEK 661- TRANSECT 1-661-1.1 - GLIDE





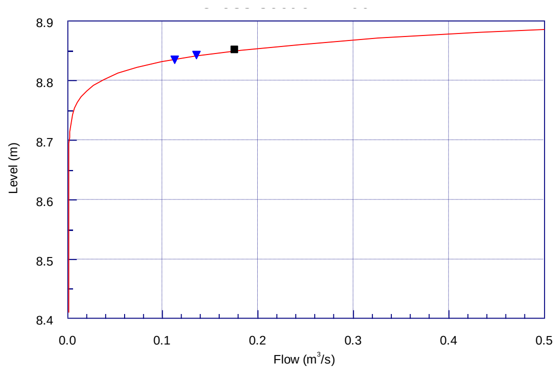
SZF rating curve **Survey flow depth / velocity profile**

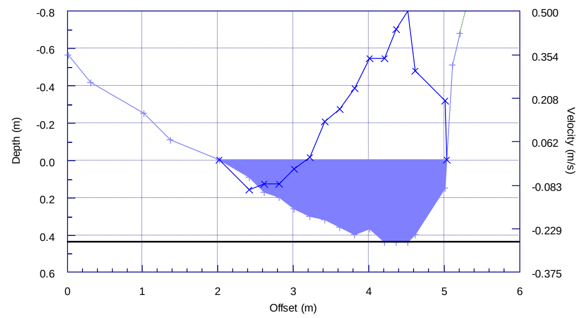
13 Jul 12 WSE = 8.845 Q = 0.175

20 Aug 12 WSE = 8.831 Q = 0.134

24 Sep 12 WSE = 8.820 Q = 0.111

CREEK 661- TRANSECT 1-661-1.2 - POOL





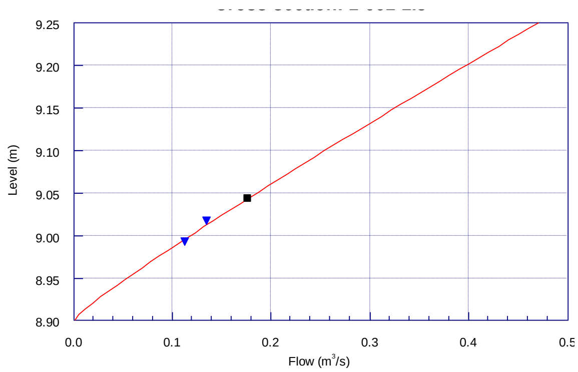
SZF rating curve **Survey flow depth / velocity profile**

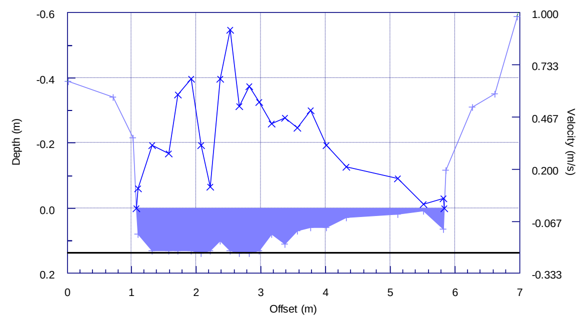
13 Jul 12 WSE = 8.850 Q = 0.175

20 Aug 12 WSE = 8.842 Q = 0.134

24 Sep 12 WSE = 8.835 Q = 0.111

CREEK 661- TRANSECT 1-661-1.3 - RIFFLE





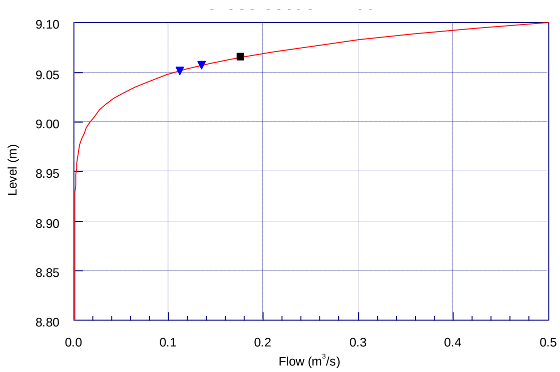
SZF rating curve **Survey flow depth / velocity profile**

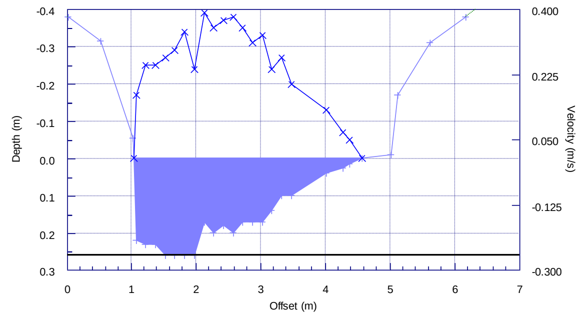
13 Jul 12 WSE = 9.043 Q = 0.175

20 Aug 12 WSE = 9.017 Q = 0.134

24 Sep 12 WSE = 8.993 Q = 0.111

CREEK 661- TRANSECT 1-661-1.4 - GLIDE





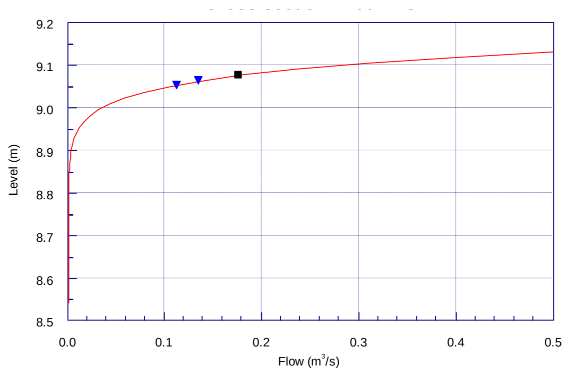
SZF rating curve **Survey flow depth / velocity profile**

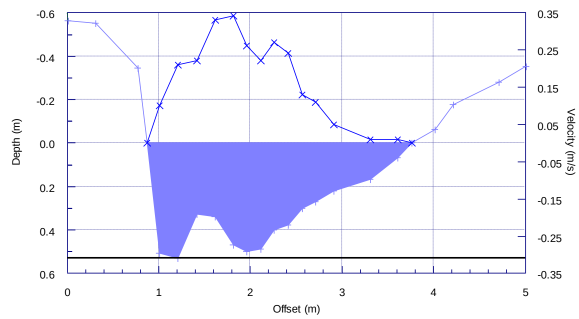
13 Jul 12 WSE = 9.065 Q = 0.175

20 Aug 12 WSE = 9.057 Q = 0.134

24 Sep 12 WSE = 9.051 Q = 0.111

CREEK 661- TRANSECT 1-661-1.5 - POOL





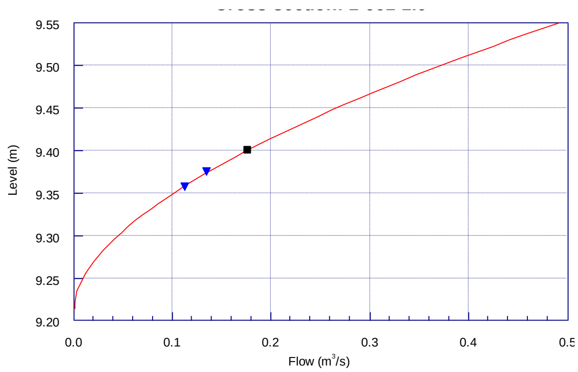
SZF rating curve **Survey flow depth / velocity profile**

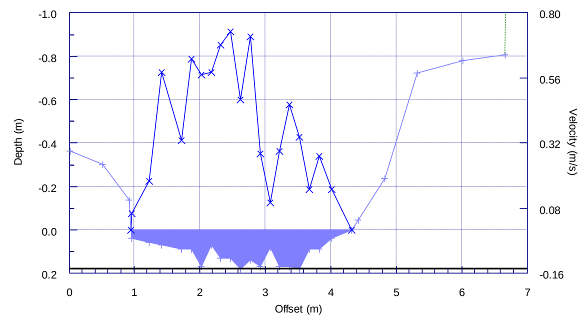
13 Jul 12 WSE = 9.075 Q = 0.175

20 Aug 12 WSE = 9.063 Q = 0.134

24 Sep 12 WSE = 9.052 Q = 0.111

CREEK 661- TRANSECT 1-661-1.6 - RIFFLE





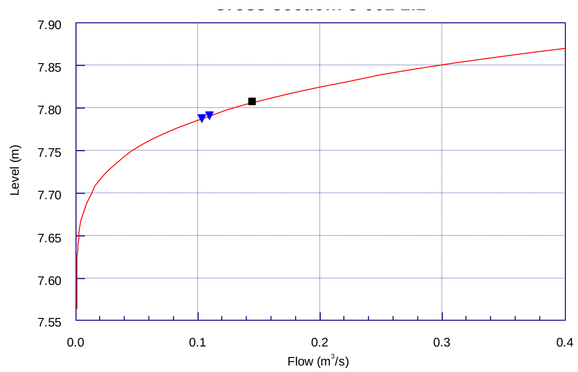
SZF rating curve **Survey flow depth / velocity profile**

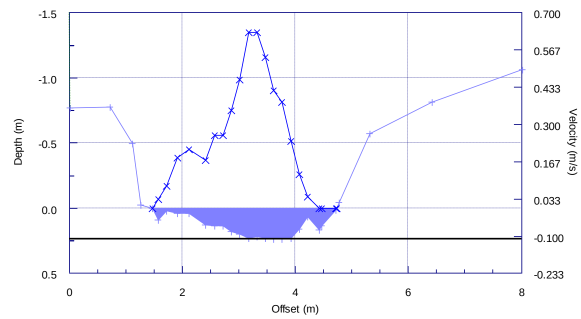
13 Jul 12 WSE = 9.400 Q = 0.175

20 Aug 12 WSE = 9.375 Q = 0.134

24 Sep 12 WSE = 9.357 Q = 0.111

CREEK 661- TRANSECT 3-661-2.1 - GLIDE





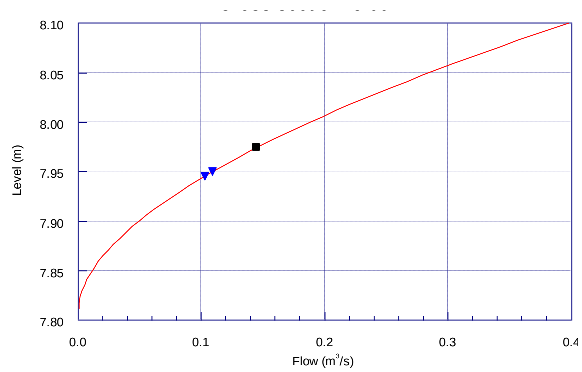
SZF rating curve **Survey flow depth / velocity profile**

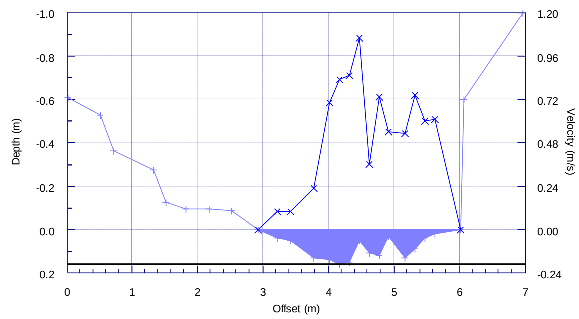
14 Jul 12 WSE = 7.806 Q = 0.144

20 Aug 12 WSE = 7.787 Q = 0.102

24 Sep 12 WSE = 7.791 Q = 0.108

CREEK 661- TRANSECT 3-661-2.2 - RIFFLE





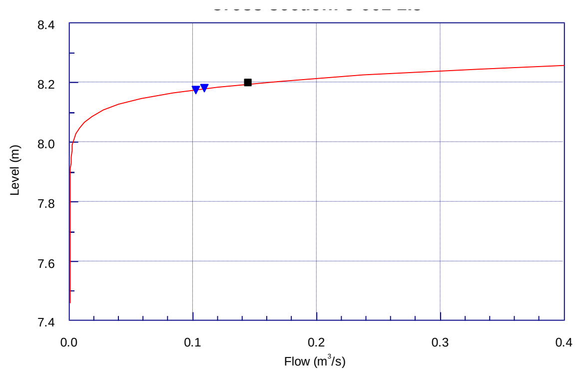
SZF rating curve **Survey flow depth / velocity profile**

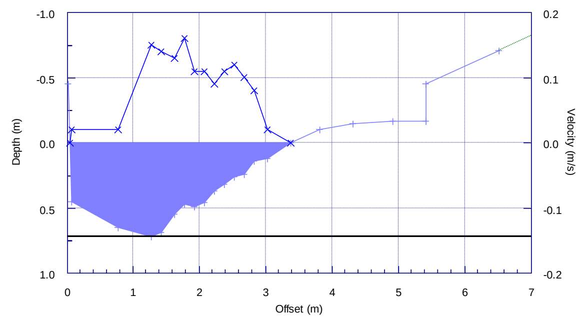
14 Jul 12 WSE = 7.974 Q = 0.144

20 Aug 12 WSE = 7.945 Q = 0.102

24 Sep 12 WSE = 7.950 Q = 0.108

CREEK 661- TRANSECT 3-661-2.3 - POOL





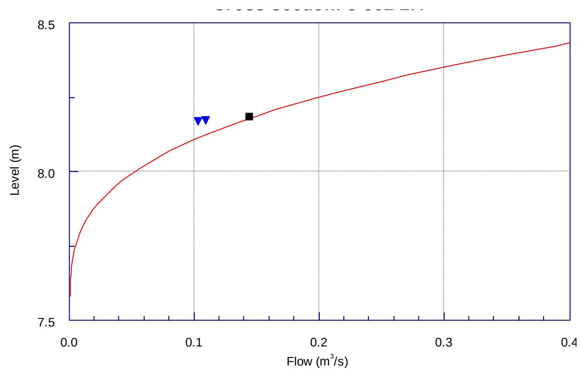
SZF rating curve **Survey flow depth / velocity profile**

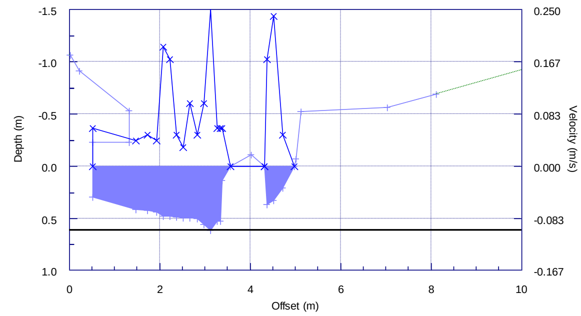
14 Jul 12 WSE = 8.195 Q = 0.144

20 Aug 12 WSE = 8.175 Q = 0.102

24 Sep 12 WSE = 8.180 Q = 0.108

CREEK 661- TRANSECT 3-661-2.4 - POOL





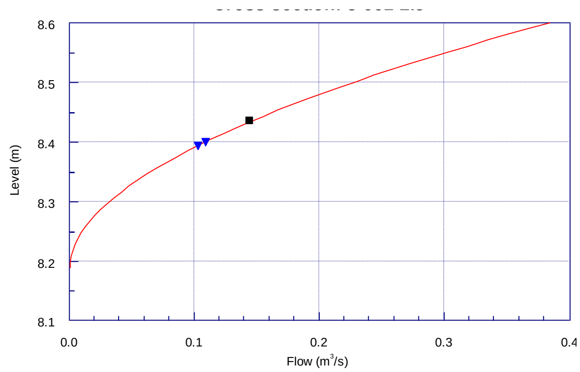
SZF rating curve **Survey flow depth / velocity profile**

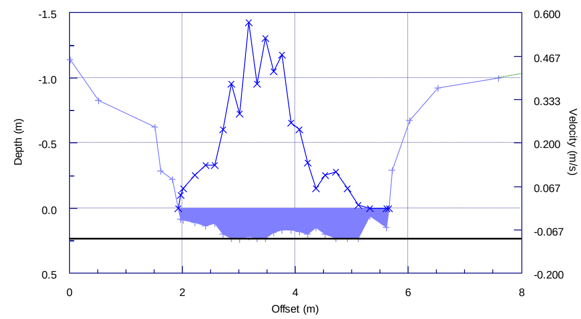
14 Jul 12 WSE = 8.180 Q = 0.144

20 Aug 12 WSE = 8.170 Q = 0.102

24 Sep 12 WSE = 8.173 Q = 0.108

CREEK 661- TRANSECT 3-661-2.5 - GLIDE





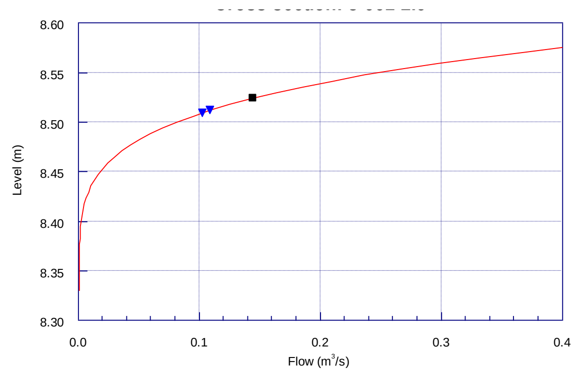
SZF rating curve **Survey flow depth / velocity profile**

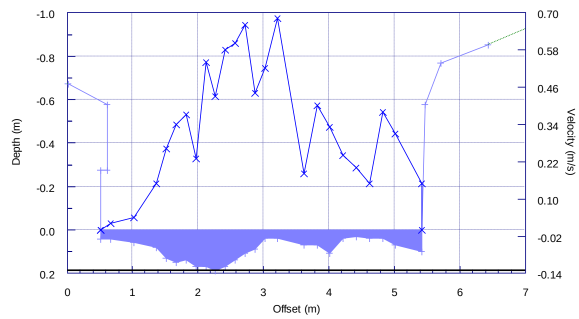
14 Jul 12 WSE = 8.434 Q = 0.144

20 Aug 12 WSE = 8.393 Q = 0.102

24 Sep 12 WSE = 8.400 Q = 0.108

CREEK 661- TRANSECT 3-661-2.6 - RIFFLE





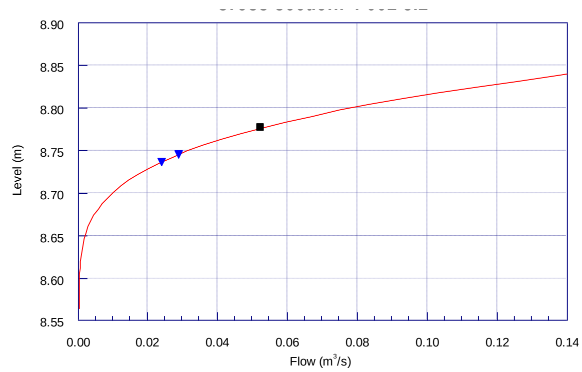
SZF rating curve **Survey flow depth / velocity profile**

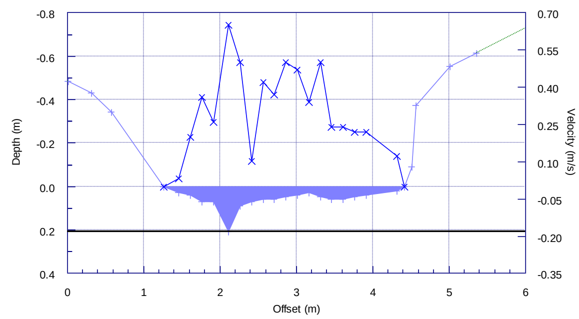
14 Jul 12 WSE = 8.524 Q = 0.144

20 Aug 12 WSE = 8.509 Q = 0.102

24 Sep 12 WSE = 8.512 Q = 0.108

CREEK 661- TRANSECT 4-661-3.1 - RIFFLE





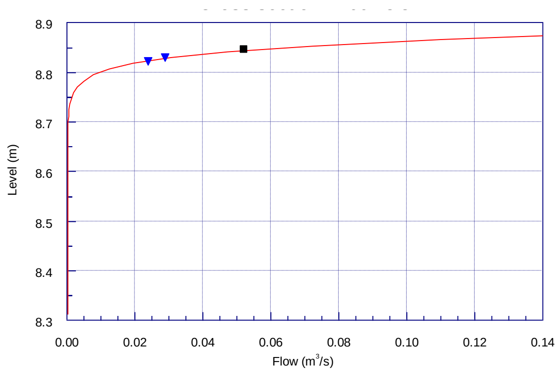
SZF rating curve **Survey flow depth / velocity profile**

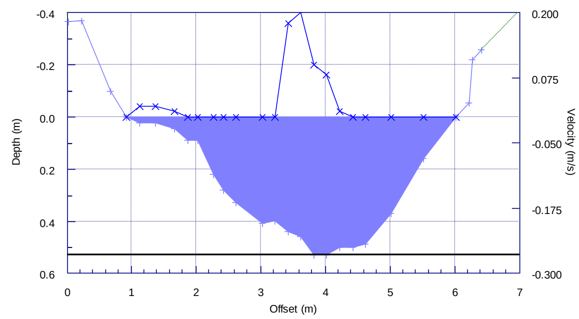
15 Jul 12 WSE = 8.776 Q = 0.052

20 Aug 12 WSE = 8.745 Q = 0.029

24 Sep 12 WSE = 8.736 Q = 0.024

CREEK 661- TRANSECT 4-661-3.3 - POOL





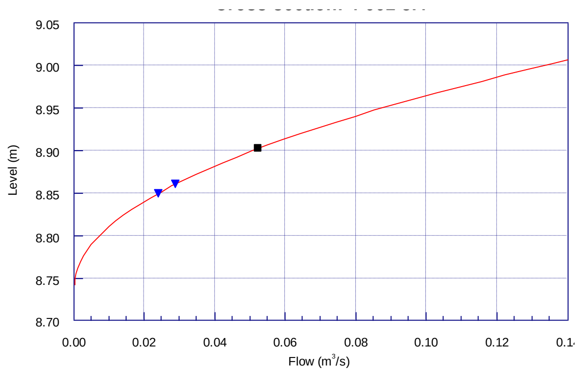
SZF rating curve **Survey flow depth / velocity profile**

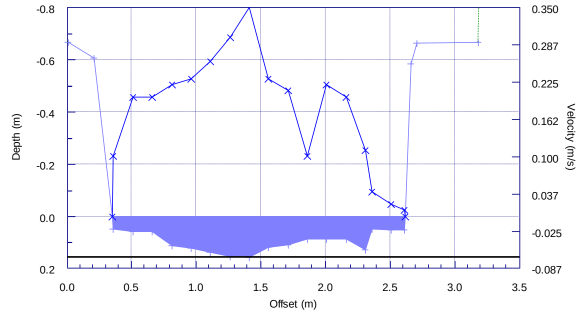
15 Jul 12 WSE = 8.844 Q = 0.052

20 Aug 12 WSE = 8.829 Q = 0.029

24 Sep 12 WSE = 8.822 Q = 0.024

CREEK 661- TRANSECT 4-661-3.4 - GLIDE





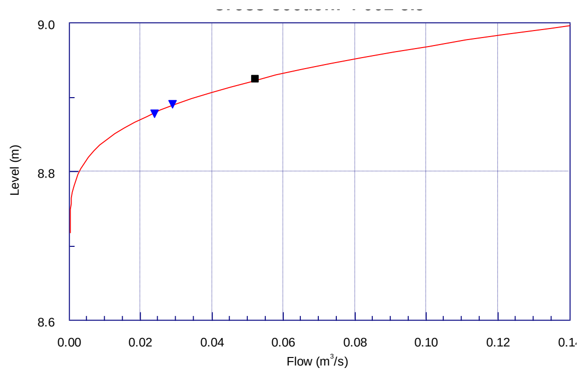
SZF rating curve **Survey flow depth / velocity profile**

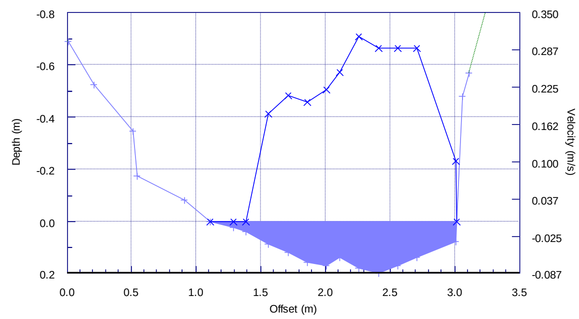
15 Jul 12 WSE = 8.902 Q = 0.052

20 Aug 12 WSE = 8.860 Q = 0.029

24 Sep 12 WSE = 8.849 Q = 0.024

CREEK 661- TRANSECT 4-661-3.5 - GLIDE





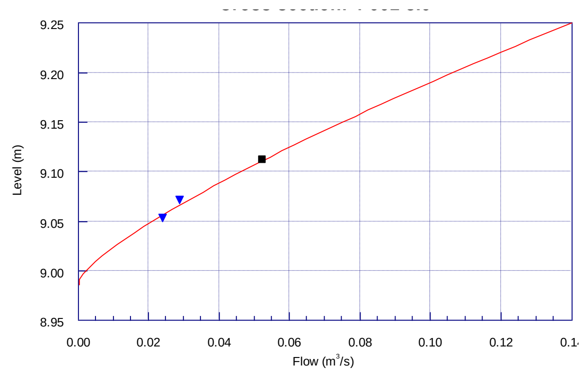
SZF rating curve **Survey flow depth / velocity profile**

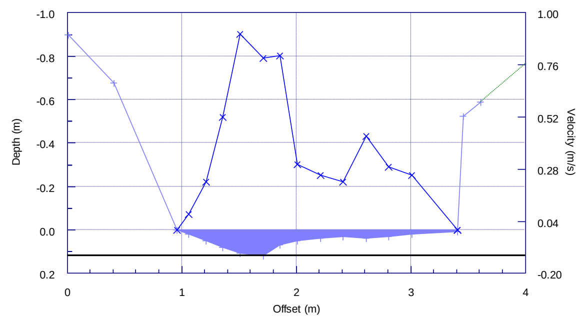
15 Jul 12 **WSE = 8.923** **Q = 0.052**

20 Aug 12 **WSE = 8.890** **Q = 0.029**

24 Sep 12 **WSE = 8.878** **Q = 0.024**

CREEK 661- TRANSECT 4-661-3.6 - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

15 Jul 12 WSE = 9.111 Q = 0.052

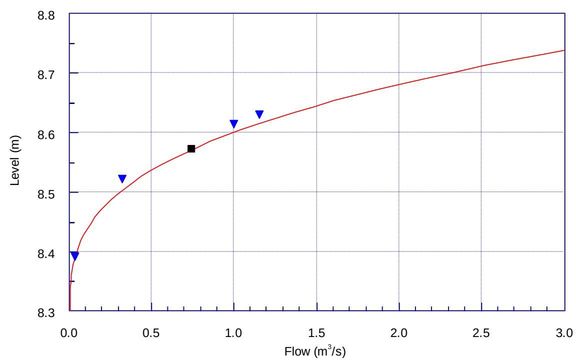
20 Aug 12 WSE = 9.071 Q = 0.029

24 Sep 12 WSE = 9.053 Q = 0.024

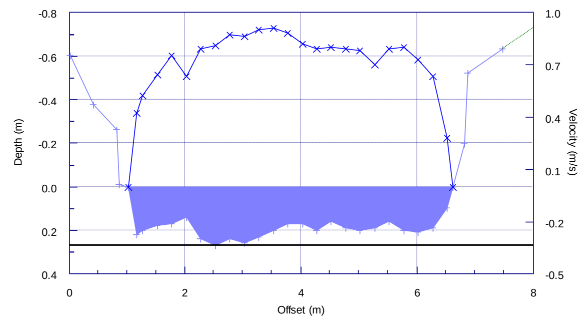
LOWER CREEK 705 MODEL

SZF – stage of zero flow
WSE – water surface elevation (note that all WSE measurements are relative to transect-specific benchmarks surveyed to a transect-specific datum)
Q – discharge

LOWER 705 - TRANSECT T14-R - RIFFLE



SZF rating curve



Survey flow depth / velocity profile

21 May 13 WSE = 8.571 Q = 0.739

22 May 13 WSE = 8.613 Q = 0.989

25 May 13 WSE = 8.629 Q = 1.145

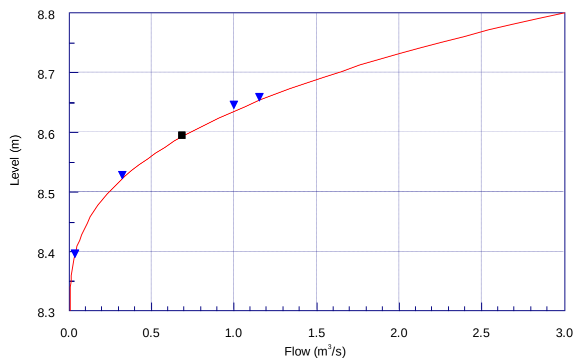
13 Jul 13 WSE = 8.522 Q = 0.313

LOWER 705 - TRANSECT T14-R – RIFFLE – PAGE 2

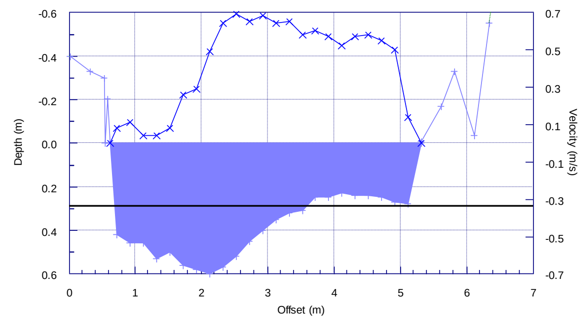
12 Aug 13 WSE = 8.391 Q =0.031

No additional surveys

LOWER 705 - TRANSECT T15-G - GLIDE



SZF rating curve



Survey flow depth / velocity profile

20 May 13 WSE = 8.592 Q = 0.681

22 May 13 WSE = 8.646 Q = 0.989

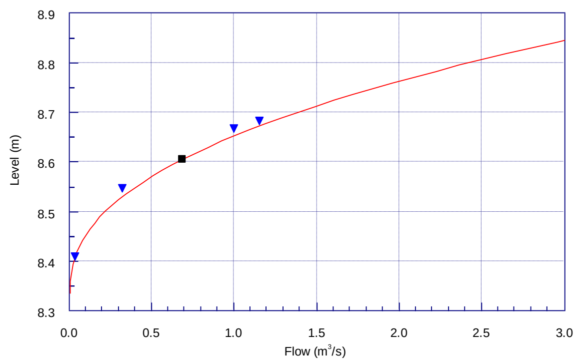
25 May 13 WSE = 8.658 Q = 1.145

13 Jul 13 WSE = 8.528 Q = 0.313

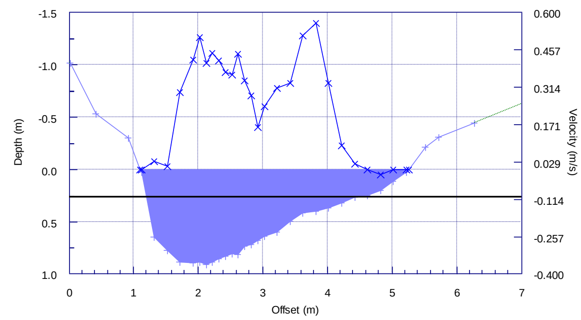
LOWER 705 - TRANSECT T15-G – GLIDE – PAGE 2

12 Aug 13 **WSE =8.396** **Q = 0.031** No additional surveys

LOWER 705 - TRANSECT T16-P - POOL



SZF rating curve



Survey flow depth / velocity profile

20 May 13 WSE = 8.605 Q = 0.681

22 May 13 WSE = 8.667 Q = 0.989

25 May 13 WSE = 8.683 Q = 1.145

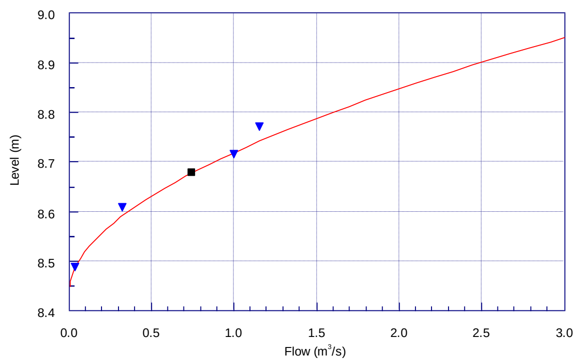
13 Jul 13 WSE = 8.546 Q = 0.313

LOWER 705 - TRANSECT T16-P – POOL – PAGE 2

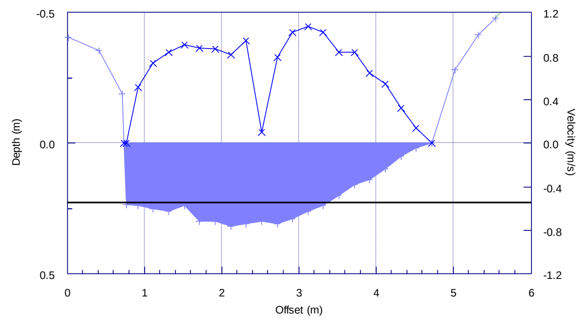
12 Aug 13 WSE =8.409 Q =0.031

No additional surveys

LOWER 705 - TRANSECT T17-R - RIFFLE



SZF rating curve



Survey flow depth / velocity profile

21 May 13 WSE = 8.677 Q = 0.739

22 May 13 WSE = 8.716 Q = 0.989

25 May 13 WSE = 8.771 Q = 1.145

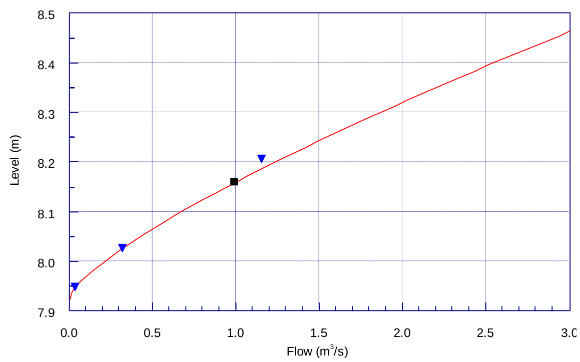
13 Jul 13 WSE = 8.609 Q = 0.313

LOWER 705 - TRANSECT T17-R – RIFFLE – PAGE 2

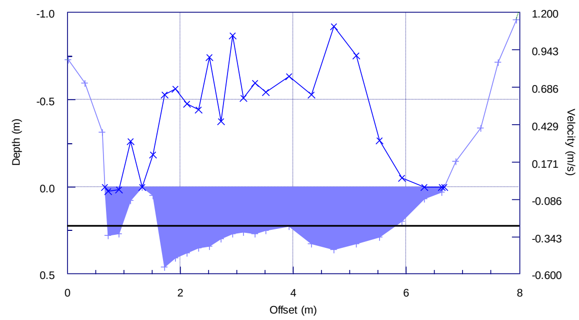
12 Aug 13 **WSE =8.487** **Q =0.031**

No additional surveys

LOWER 705 - TRANSECT T18-R - RIFFLE



SZF rating curve



Survey flow depth / velocity profile

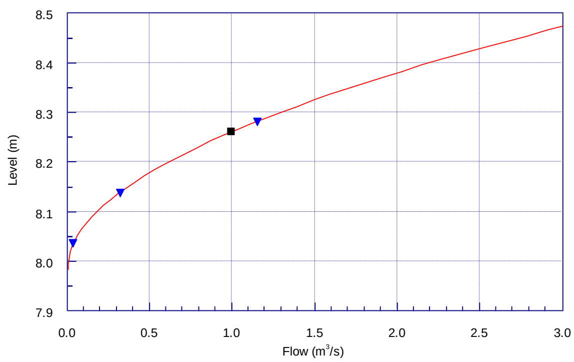
22 May 13 WSE = 8.158 Q = 0.989

25 May 13 WSE = 8.205 Q = 1.145

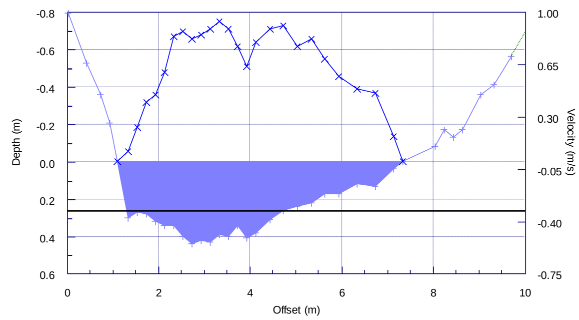
13 Jul 13 WSE = 8.026 Q = 0.313

12 Aug 13 WSE = 7.947 Q = 0.031

LOWER 705 - TRANSECT T19-G - GLIDE



SZF rating curve



Survey flow depth / velocity profile

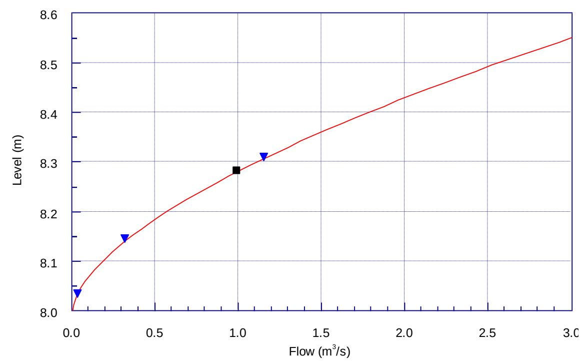
22 May 13 WSE = 8.260 Q = 0.989

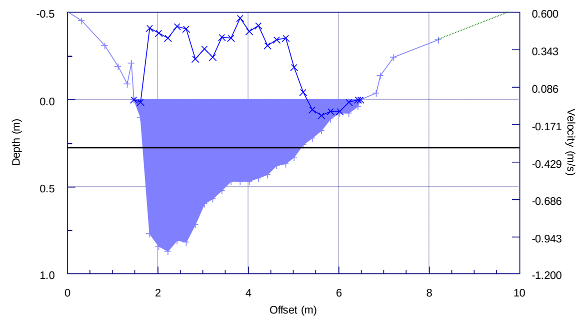
25 May 13 WSE = 8.280 Q = 1.145

13 Jul 13 WSE = 8.137 Q = 0.313

12 Aug 13 WSE = 8.036 Q = 0.031

LOWER 705 - TRANSECT T20-P - POOL





SZF rating curve **Survey flow depth / velocity profile**

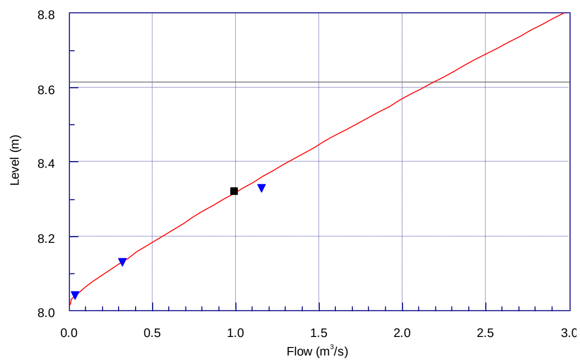
22 May 13 WSE = 8.280 Q = 0.989

25 May 13 WSE = 8.310 Q = 1.145

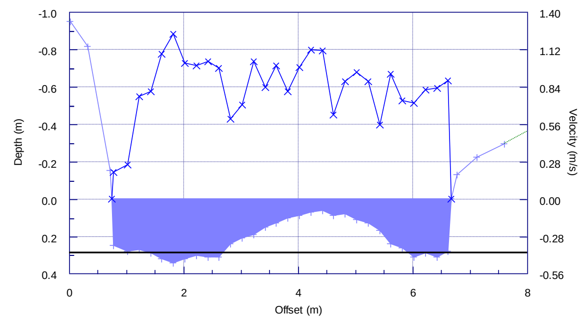
13 Jul 13 WSE = 8.145 Q = 0.313

12 Aug 13 WSE = 8.035 Q = 0.031

LOWER 705 - TRANSECT T21-R - RIFFLE

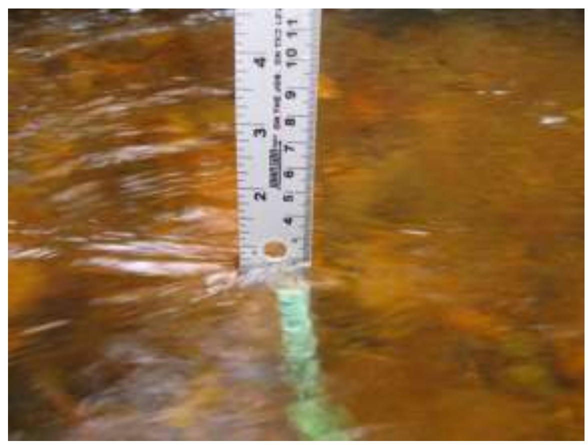


SZF rating curve



Survey flow depth / velocity profile

22 May 13 WSE = 8.318 Q = 0.989

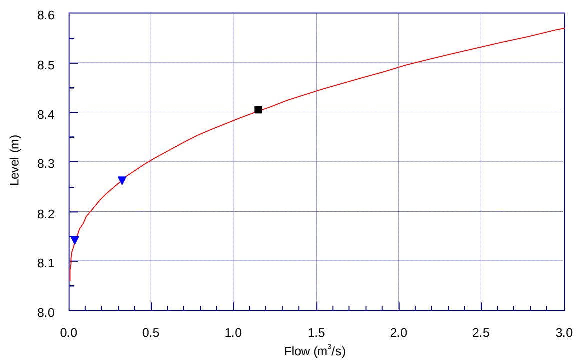


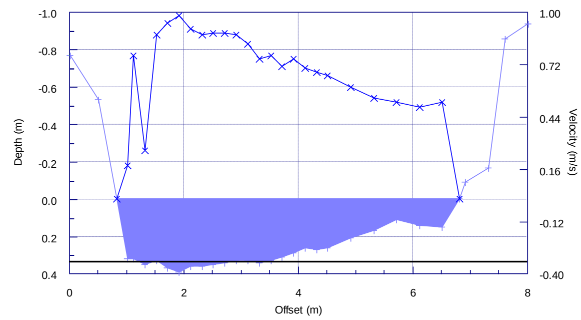
25 May 13 WSE = 8.329 Q = 1.145

13 Jul 13 WSE = 8.130 Q = 0.313

12 Aug 13 WSE = 8.042 Q = 0.031

LOWER 705 - TRANSECT T22-G - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

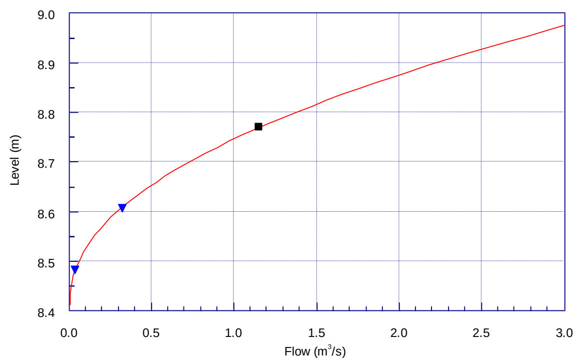
25 May 13 WSE = 8.403 Q = 1.145

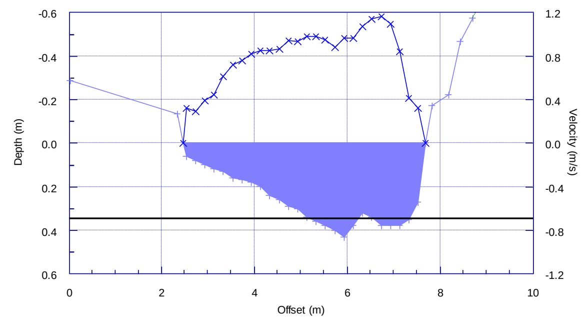
13 Jul 13 WSE = 8.262 Q = 0.313

12 Aug 13 WSE = 8.141 Q = 0.031

No additional surveys

LOWER 705 - TRANSECT T23-G - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

25 May 13 WSE = 8.769 Q = 1.145

13 Jul 13 WSE = 8.607 Q = 0.313

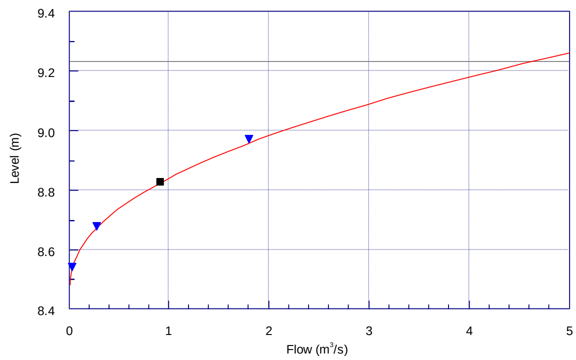
12 Aug 13 WSE = 8.483 Q = 0.031

No additional surveys

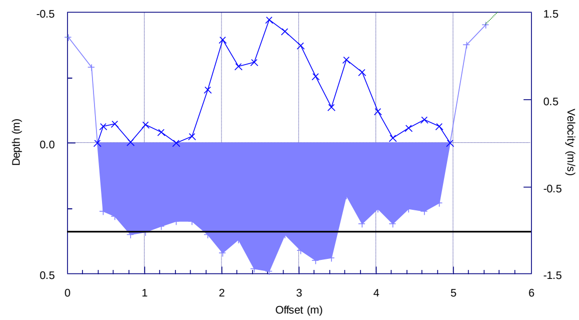
MIDDLE CREEK 705 MODEL

SZF – stage of zero flow
WSE – water surface elevation (note that all WSE measurements are relative to transect-specific benchmarks surveyed to a transect-specific datum)
Q – discharge

MIDDLE 705- TRANSECT T1-G - GLIDE



SZF rating curve



Survey flow depth / velocity profile

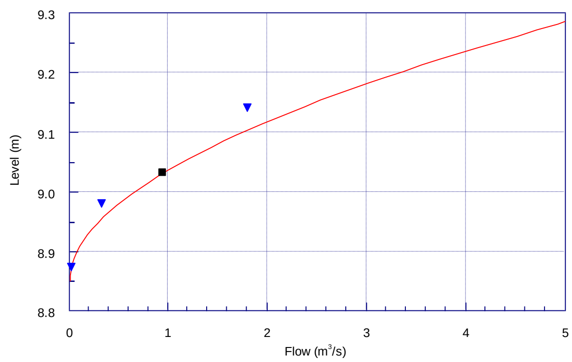
16 May 13 WSE = 8.824 Q = 0.905

26 May 13 WSE = 8.970 Q = 1.789

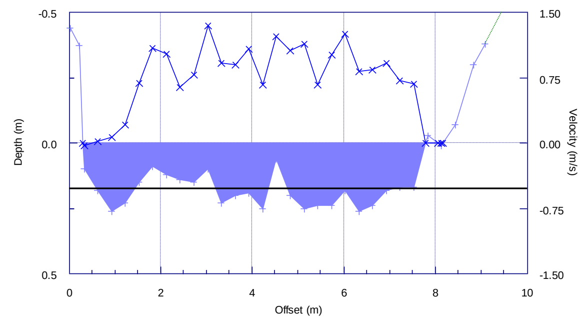
13 Jul 13 WSE = 8.677 Q = 0.266

9 Aug 13 WSE = 8.541 Q = 0.023

MIDDLE 705- TRANSECT T2-R - RIFFLE



SZF rating curve



Survey flow depth / velocity profile

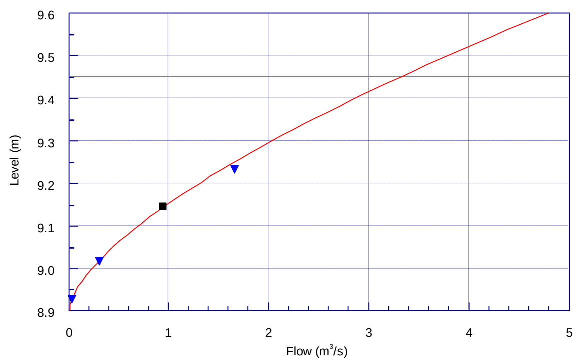
17 May 13 WSE = 9.031 Q = 0.939

26 May 13 WSE = 9.140 Q = 1.789

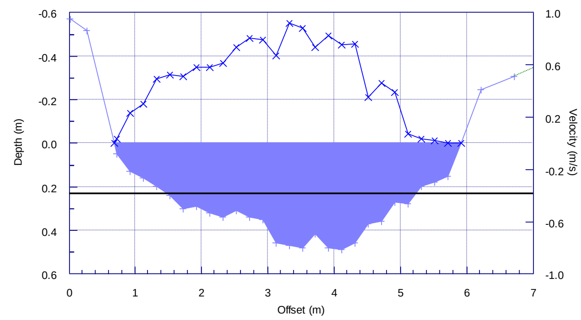
13 Jul 13 WSE = 8.980 Q = 0.313

9 Aug 13 WSE = 8.874 Q = 0.014

MIDDLE 705- TRANSECT T3-G - GLIDE



SZF rating curve



Survey flow depth / velocity profile

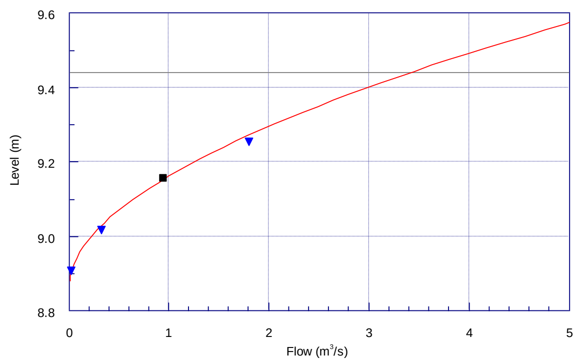
17 May 13 WSE = 9.144 Q = 0.939

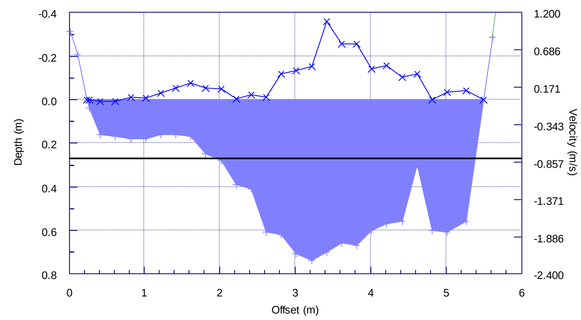
26 May 13 WSE = 9.232 Q = 1.649

13 Jul 13 WSE = 9.016 Q = 0.290

9 Aug 13 WSE = 8.926 Q = 0.018

MIDDLE 705- TRANSECT T4-P - POOL





SZF rating curve **Survey flow depth / velocity profile**

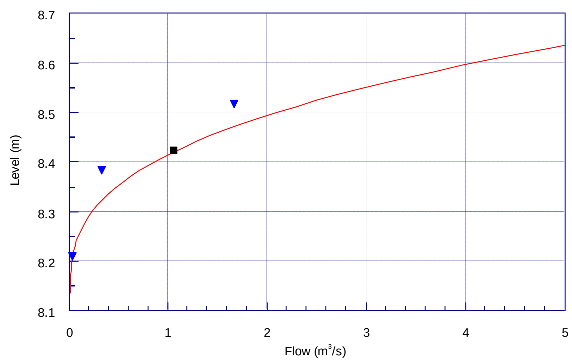
17 May 13 WSE = 9.154 Q = 0.939

26 May 13 WSE = 9.253 Q = 1.789

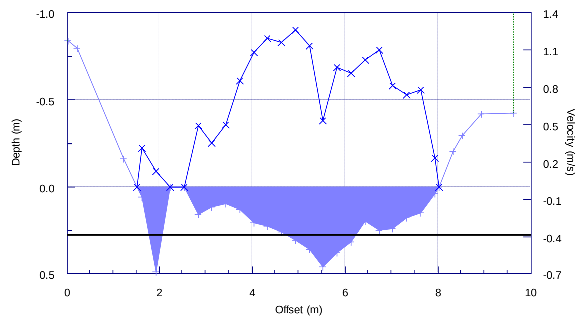
13 Jul 13 WSE = 9.017 Q = 0.313

9 Aug 13 WSE = 8.907 Q = 0.014

MIDDLE 705- TRANSECT T5-G - GLIDE



SZF rating curve



Survey flow depth / velocity profile

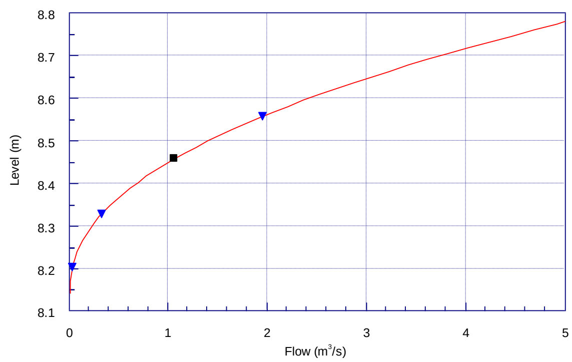
18 May 13 WSE = 8.421 Q = 1.052

26 May 13 WSE = 8.516 Q = 1.649

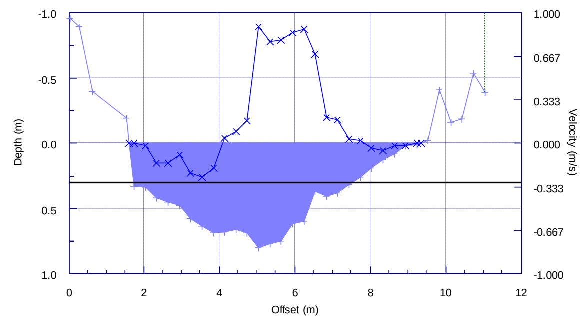
13 Jul 13 WSE = 8.383 Q = 0.313

9 Aug 13 WSE = 8.209 Q = 0.023

MIDDLE 705- TRANSECT T6-P - POOL



SZF rating curve



Survey flow depth / velocity profile

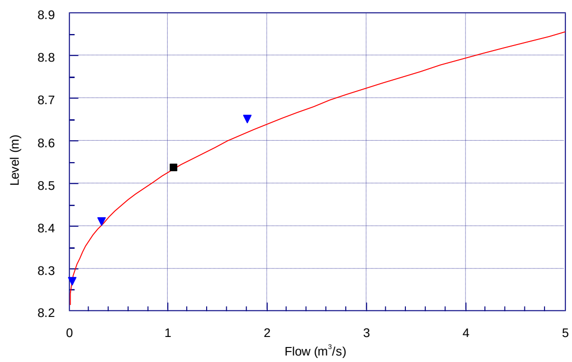
18 May 13 WSE = 8.457 Q = 1.052

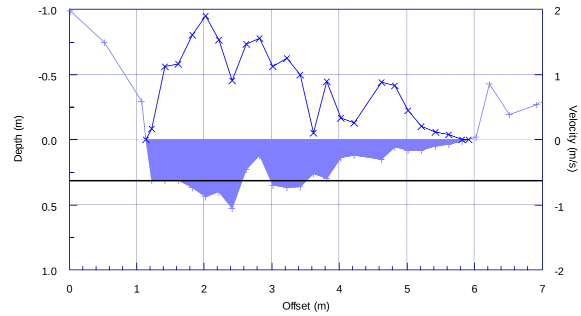
26 May 13 WSE = 8.558 Q = 1.936

13 Jul 13 WSE = 8.327 Q = 0.313

9 Aug 13 WSE = 8.203 Q = 0.023

MIDDLE 705- TRANSECT T7-R - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

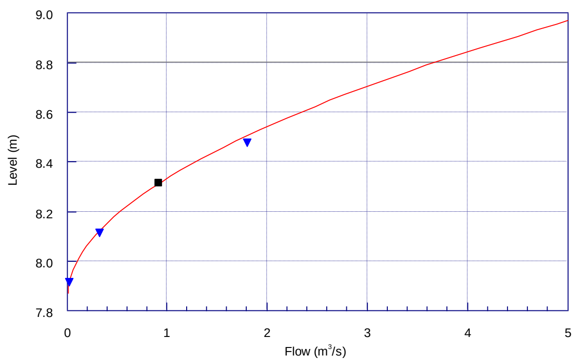
18 May 13 WSE = 8.534 Q = 1.052

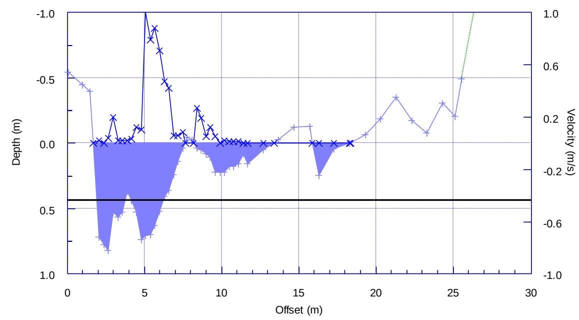
26 May 13 WSE = 8.650 Q = 1.789

13 Jul 13 WSE = 8.410 Q = 0.313

9 Aug 13 WSE = 8.268 Q = 0.018

MIDDLE 705- TRANSECT T8-P - POOL



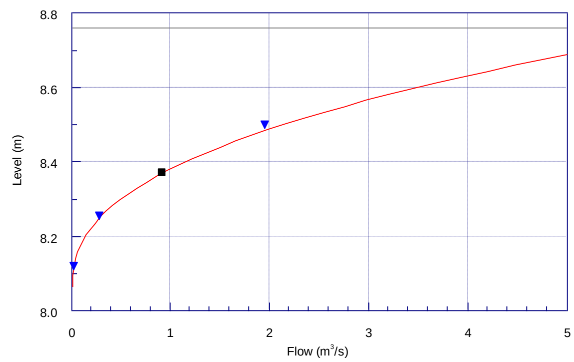


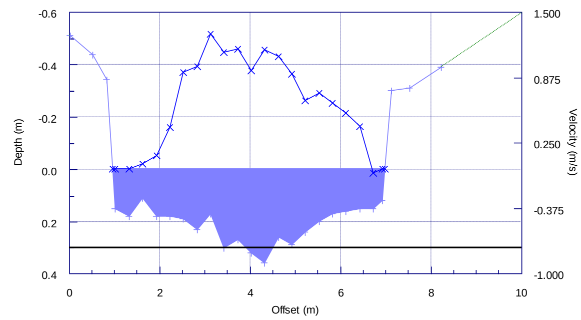
SZF rating curve **Survey flow depth / velocity profile**

19 May 13 WSE = 8.312 Q = 0.904 **26 May 13 WSE = 8.477 Q = 1.789**

13 Jul 13 WSE = 8.113 Q = 0.313 **9 Aug 13 WSE = 7.914 Q = 0.011**

MIDDLE 705- TRANSECT T9-R - RIFFLE



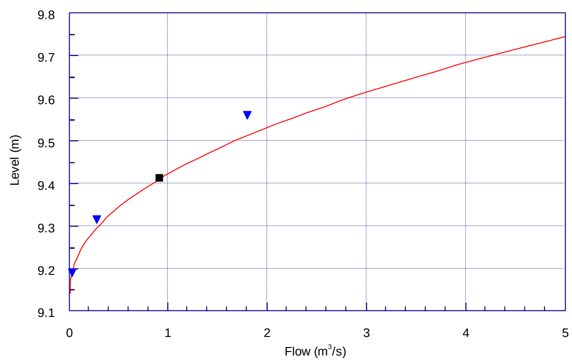


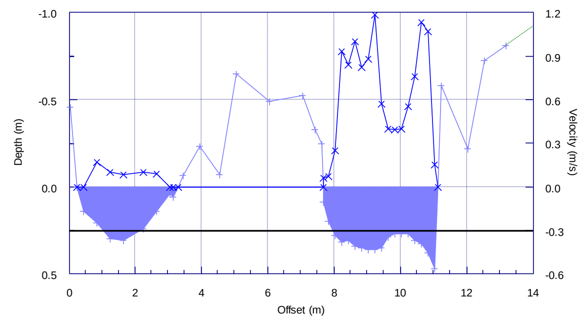
SZF rating curve **Survey flow depth / velocity profile**

19 May 13 WSE = 8.369 Q = 0.904 **26 May 13 WSE = 8.500 Q = 1.936**

13 Jul 13 WSE = 8.255 Q = 0.266 **9 Aug 13 WSE = 8.119 Q = 0.014**

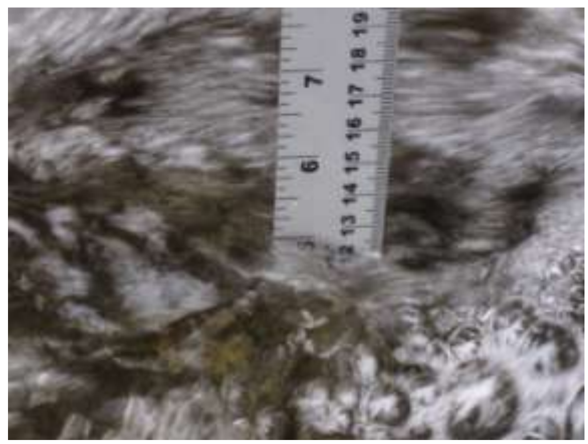
MIDDLE 705- TRANSECT T10-C - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

19 May 13 WSE = 9.410 Q = 0.904

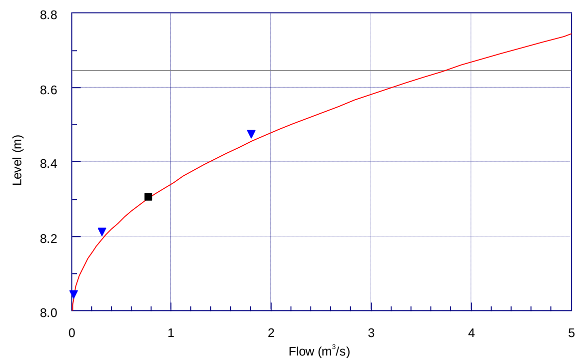


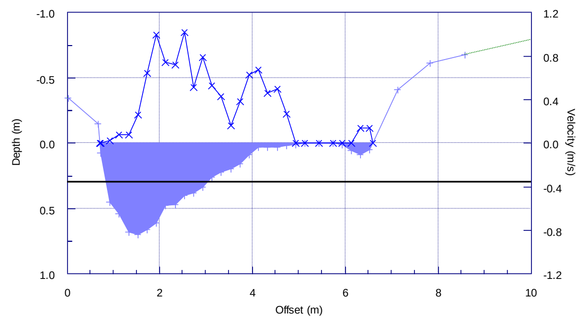
26 May 13 WSE = 9.560 Q = 1.789

13 Jul 13 WSE = 9.315 Q = 0.266

9 Aug 13 WSE = 9.190 Q = 0.018

MIDDLE 705- TRANSECT T11-G - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

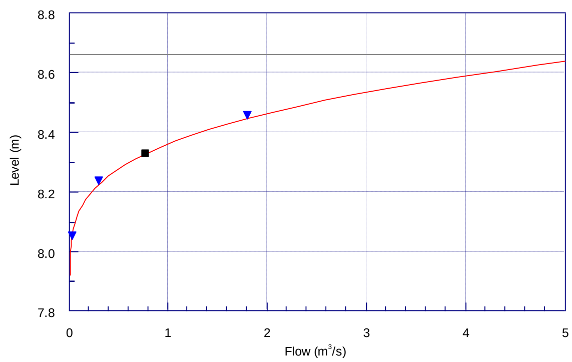
20 May 13 WSE = 8.302 Q = 0.762

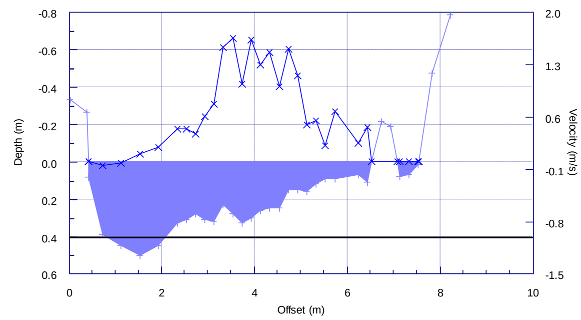
26 May 13 WSE = 8.475 Q = 1.789

13 Jul 13 WSE = 8.212 Q = 0.290

9 Aug 13 WSE = 8.044 Q = 0.014

MIDDLE 705- TRANSECT T12-G - GLIDE





SZF rating curve **Survey flow depth / velocity profile**

20 May 13 WSE = 8.327 Q = 0.762

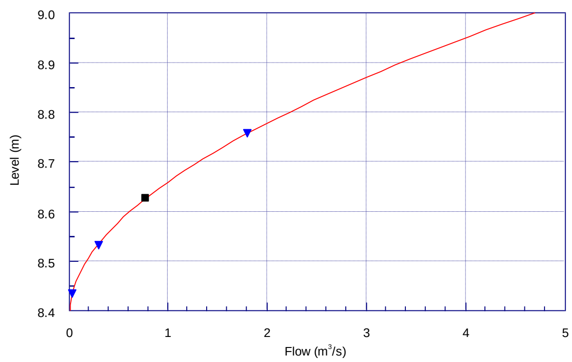
26 May 13 WSE = 8.457 Q = 1.789

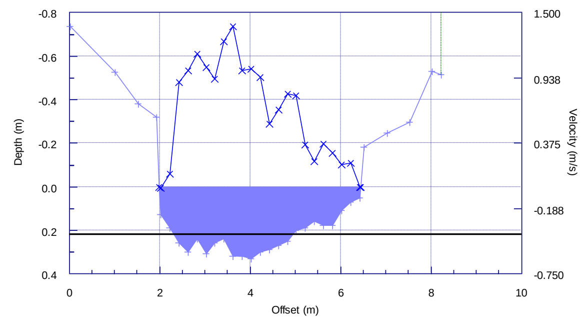
i

13 Jul 13 WSE = 8.235 Q = 0.290

9 Aug 13 WSE = 8.051 Q = 0.018

MIDDLE 705- TRANSECT T13-R - RIFFLE





SZF rating curve **Survey flow depth / velocity profile**

20 May 13 WSE = 8.626 Q = 0.762

26 May 13 WSE = 8.757 Q = 1.789

13 Jul 13 WSE = 8.532 Q = 0.290

9 Aug 13 WSE = 8.434 Q = 0.018

Annex C
Summary of Confidence in Hydraulic Habitat Model Predictions

Figure C-1: 80% Confidence Intervals for Flow/Habitat Relationships, Lower Davidson Creek Model

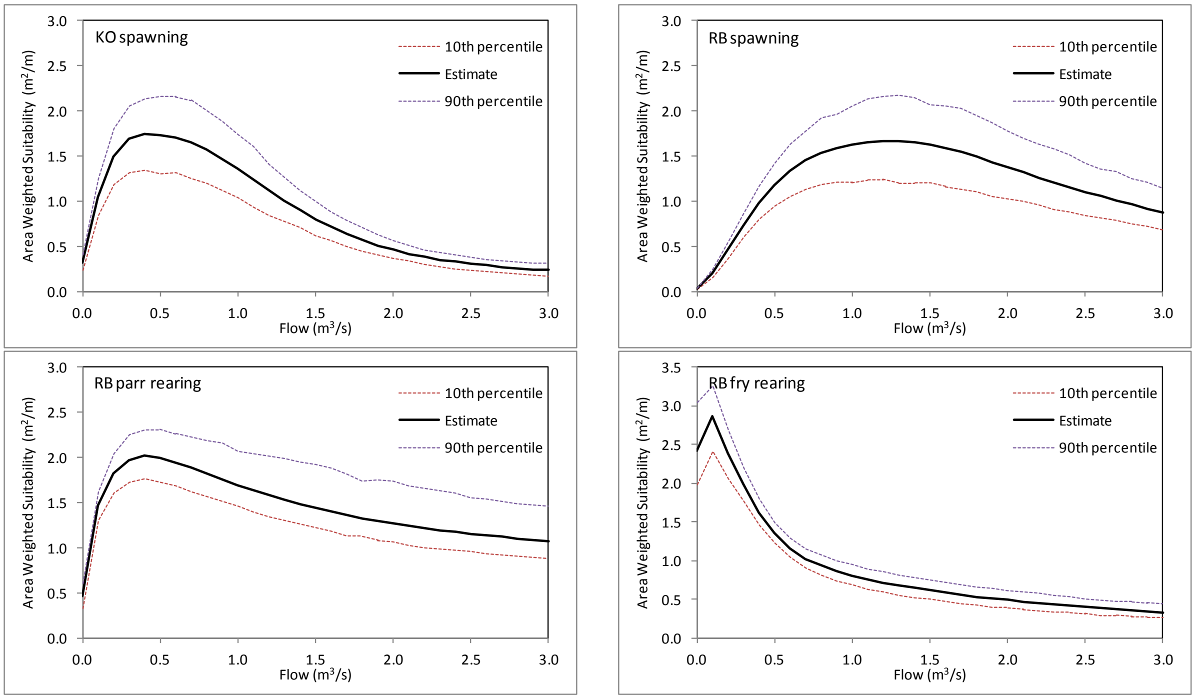


Figure C-2: 80% Confidence Intervals for Flow/Habitat Relationships, Middle Davidson Creek Model