Signature Page

April 2022

Blackwater Gold Project

Follow-up Programs for Condition 3.14 of the Blackwater Gold Project Decision Statement Issued under Section 54 of the Canadian Environmental Assessment Act, 2012

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ACRONYMS AND ABBREVIATIONS

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

AEMP	Aquatic Effects Monitoring Plan
ATU	accumulated thermal units
BC	British Columbia
Blackwater or Project	Blackwater Project or Blackwater Gold Project
BW Gold	BW Gold LTD.
CAHS	Centre for Aquatic Health Sciences
CEA Agency	Canadian Environmental Assessment Agency (now Impact Assessment Agency of Canada)
CPUE	catch-per-unit-effort
DFO	Fisheries and Oceans Canada
DS	Decision Statement
EA	Environmental Assessment
EAO	British Columbia Environmental Assessment Office
FWSS	freshwater supply system
FWR	freshwater reservoir
GAUC	Guassian Area-Under-The-Curve model
IAAC	Impact Assessment Agency of Canada
IFN	instream flow needs
Lake 15	Lake 01538UEUT
Lake 16	Lake 01682LNRS
MaxN	maximum fish count in a video frame
NAAHP	National Aquatic Animal Health Program
New Gold	New Gold Inc.
OWM	Overwintering Mortality
Project	Blackwater Gold Project
QA/QC	quality assurance and control
RT-qPCR	Real time Polymerase Chain Reaction
SOPs	Standard operating procedures
UAV	Unmanned Aerial Vehicle

1. INTRODUCTION

The Blackwater Gold Project (Project) received a Decision Statement (DS) on April 15, 2019, under the Canadian Environmental Assessment Act, 2012 (CEA Agency 2019) and an Environmental Assessment Certificate #M19-01 on June 21, 2019, under the 2002 Environmental Assessment Act (EAO 2019).

Condition 3.14 of the DS requires the BW Gold Ltd.'s (BW Gold) to develop a Fish and Fish Habitat Follow-up Program as follows:

3.14 The Proponent shall develop, prior to construction and in consultation with Indigenous groups, Fisheries and Oceans Canada (DFO), and other relevant authorities, a follow-up program to verify the accuracy of the environmental assessment and determine the effectiveness of the mitigation measures as it pertains to adverse environmental effects of the Designated Project on fish and fish habitat. The Proponent shall implement the follow-up program during all phases of the Designated Project and shall apply conditions **2.9** and **2.10** when implementing the follow-up program. As part of the follow-up program, the Proponent shall:

3.14.1 conduct parasite and pathogen inventories in Lake 01538UEUT and Lake 01682LNRS prior to enlarging Lake 01682LNRS and connecting it to Lake 01538UEUT pursuant to condition 3.13 and compare the results of the parasite and pathogen inventories for the two lakes;

3.14.2 monitor, starting when the Proponent starts to pump water into Davidson Creek and continuing through until the freshwater supply system has been decommissioned, rainbow trout (*Oncorhynchus mykiss*) and Kokanee (*Oncorhynchus nerka*) populations in Davidson Creek, including:

3.14.2.1 community composition of rainbow trout (*Oncorhynchus mykiss*) and Kokanee (*Oncorhynchus nerka*), their absolute abundance, genetic structure and diversity;

3.14.2.2 absolute abundance of overwintering rainbow trout juveniles; and

3.14.2.3 characteristics of spawner populations through surrogate monitoring metrics including size at 50% maturity, redd counts and spawner distribution.

Condition 2.9 of the DS requires follow-up programs to verify the accuracy of the environmental assessment, determine whether modified or additional mitigation measures are required, and timely implementation if required.

Condition 2.10 of the DS requires consultation with Indigenous groups on the follow-up programs regarding opportunities for participation in their implementation.

1.1 Purpose and Objectives

The purpose of Fish and Fish Habitat Follow-up Program described herein is to fulfill the condition 3.14 of the federal DS.

The Fish and Fish Habitat Follow-up Programs are designed to first characterize baseline conditions for each of the indicators listed in the condition (e.g., characteristics of spawner populations). These indicators will then be monitored during different phases of the Project to determine, to the extent possible, if (a) variation from baseline conditions is occurring, (b) mitigation measures are effective, and (c) if the environmental assessment was accurate in terms of anticipated effects on the indicators.

2. FOLLOW UP PROGRAM 3.14.1: LAKES 15 AND 16 PARASITES AND PATHOGENS STUDY

2.1 Background and Approach

Lakes 15 and 16 are located at high elevation (~1345 m), in separate sub-watersheds that are divided by a narrow (~500 m) strip of land (Figure 1), with a 0.4 m difference between lake elevations. Lake 16 is the headwater lake of Davidson Creek, which is the main creek draining the mine site. Construction of a connector channel between the Lake 16 and Lake 15 is proposed (and required under Condition 3.13 of the DS) to preserve the Rainbow Trout population in Lake 16 that would otherwise be entirely isolated by the mine development in the upper and middle reaches of Davidson Creek (Figure 1). The purpose of condition 3.14.1 is to address the risk of introducing new parasites or pathogens to either of the lakes when they are connected, which could harm the populations of Rainbow Trout in either lake.

A parasite-pathogen study was designed by the BC Center for Aquatic Health Sciences (CAHS). Due to potential low fish numbers in Lake 15 and Lake 16, a non-lethal sampling approach was used (i.e., no sampling of Rainbow Trout tissue, which would have required sacrificing of fish). The study was initiated in September 2021 with a field program to collect gill swabs and mucus samples from Rainbow Trout in Lakes 15 and 16, as well as water samples. The purpose of the study is to test the samples for a suite of viruses, bacteria, and pathogens and thereby establish the degree of overlap between the parasite and pathogens present in each lake.

2.2 Field Methods

Standard fish sampling protocols (RISC 2001) were adhered to during the September 2021 field program. Rainbow Trout in Lakes 15 and 16 were captured primarily by angling, with some initial shoreline fyke net sets.

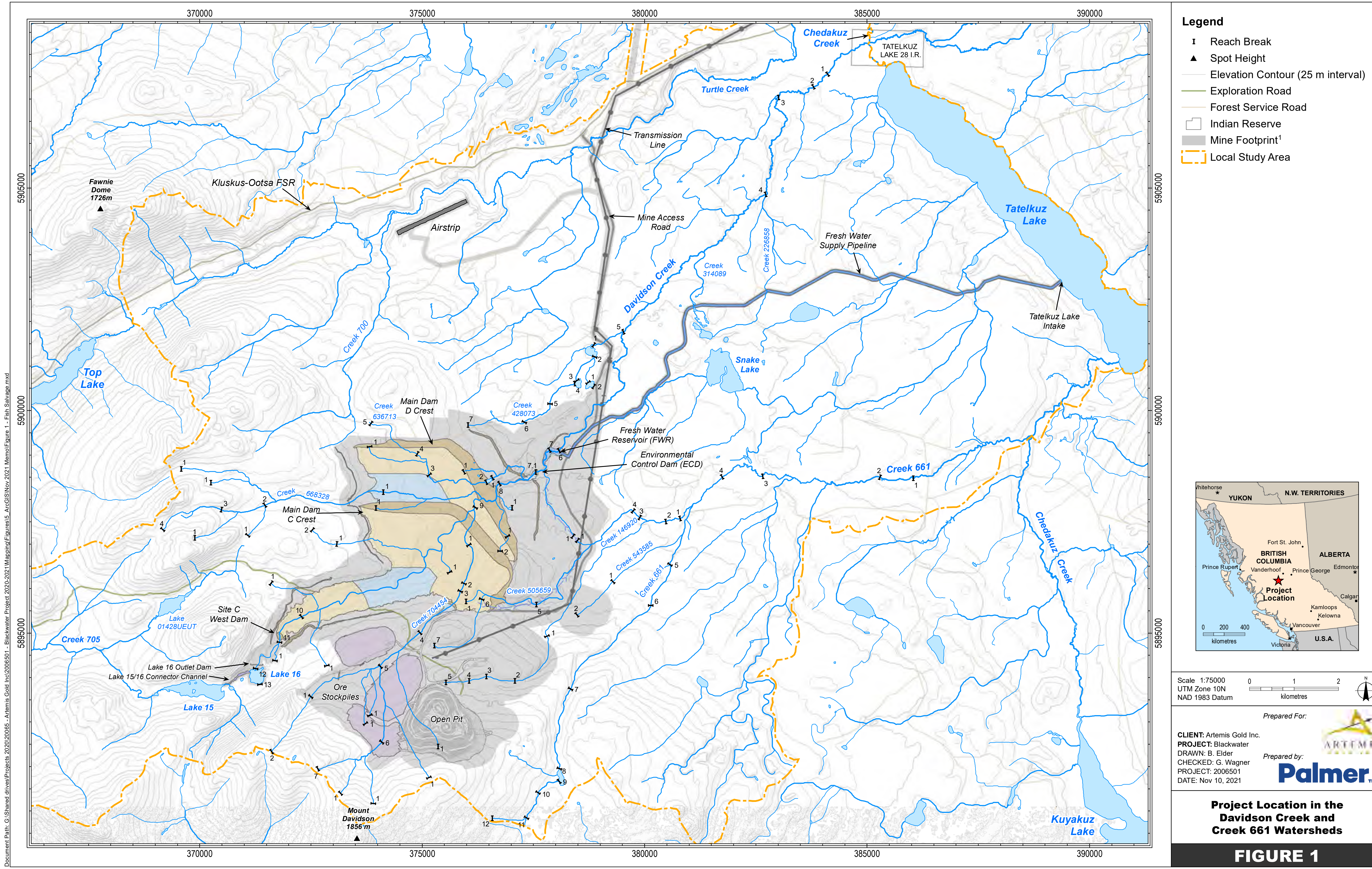
Gill swabs and mucus samples were collected from captured rainbow trout, and water samples were collected from each lake. Prelabelled microtubes and sample bags were used for each fish and swabs specific to viral or bacterial sampling were used for skin mucous and gills.

2.3 Laboratory Methods

Molecular assays for a list of NAAHP (National Aquatic Animal Health Program) parasites and pathogens of Rainbow Trout are currently being performed by CAHS. At CAHS, molecular assays are routinely used for fish screening using kidney tissues. However, these assays needed to be optimised for the non-lethal samples being used in this study which would contain low levels of parasites/pathogens genetic material relative to fish tissue samples.

A Real time Polymerase Chain Reaction (RT-qPCR) molecular assay was used that targets genetic material of the pathogen of concern. Specific primers (forward and reverse) and a probe had to be designed for each of the NAAHP diseases of concern for Rainbow Trout and Kokanee found in the lakes. Primers and probes already exist for testing samples for several well-known fish diseases, including Ceratomyxosis (*Ceratomyxa shasta*) and Whirling disease (*Myxobolus cerebralis*). Additionally, primers and probes have been developed for this study by CAHS for three major fish bacteria: *Renibacterium salmoninarum*; *Aeromonas salmonicida*; *Yersinia ruckeri*; and for four major fish viruses: Infectious Hematopoietic Necrosis Virus, Infectious Pancreatic Necrosis Virus, Infectious Salmon Anaemia Virus, and Viral Haemorrhagic Septicaemia Virus.

To prepare for analysis, each isolate was filtered and diluted 5 times in 10-fold dilution. Control swabs were dipped in each dilution to mimic the sample swabs. DNA was extracted from each swab using the Qiagen



Legend
Reach Break
Spot Height
Elevation Contour (25 m interval)
Exploration Road
Forest Service Road
Indian Reserve
Mine Footprint[1]
Local Study Area
Chedakuz Creek
TATELKUZ LAKE 28 I.R.
Turtle Creek
Transmission Line
Kluskus-Ootsa FSR
Fawnie Dome 1726m
Airstrip
Mine Access Road
Tatelkuz Lake
Fresh Water Supply Pipeline
Creek 226858
Creek 314089
Davidson Creek
Tatelkuz Lake Intake
Creek 700
Top Lake
Snake Lake
Creek 636713
Main Dam D Crest
Creek 428073
Fresh Water Reservoir (FWR)
Environmental Control Dam (ECD)
Creek 661
Creek 668328
Main Dam C Crest
Creek 146920
Creek 543585
Creek 661
Chedakuz Creek
Creek 505659
Site C West Dam
Lake 01428UEUT
Creek 705
Creek 704454
Lake 16 Outlet Dam
Lake 15/16 Connector Channel
Lake 16
Lake 15
Ore Stockpiles
Open Pit
Mount Davidson 1856 m
Kuyakuz Lake
370000
375000
380000
385000
390000
5905000
5900000
5895000
YUKON
N.W. TERRITORIES
Fort St. John
BRITISH COLUMBIA
ALBERTA
Prince Rupert
Vanderhoof
Prince George
Project Location
Kamloops
Kelowna
Vancouver
Victoria
U.S.A.
0 200 400 kilometres
Scale 1:75000
UTM Zone 10N
NAD 1983 Datum
0 1 2 kilometres
Prepared For:
CLIENT: Artemis Gold Inc.
PROJECT: Blackwater
DRAWN: B. Elder
CHECKED: G. Wagner
PROJECT: 2006501
DATE: Nov 10, 2021
Prepared by:
Palmer
Project Location in the Davidson Creek and Creek 661 Watersheds
FIGURE 1
Contains information licensed under the Open Government Licence - British Columbia and Canada.
Document Path: G:\Shared drives\Projects 2020\20065 - Artemis Gold Inc\2006501 - Blackwater Project 2020-2021\Mapping\Figures\5_ArcGIS\Nov 2021 Memo\Figure 1 - Fish Salvage.mxd

DNeasy blood and tissue kit (Cat# 69506) and as per CAHS SOP #17 v2.1. RT-qPCR was performed on the extracted DNA using the TaqMan qPCR kit (Applied Biosystems).

2.4 Reporting and Follow-up

Testing of the gill swab, mucus, and water samples from the two lakes is ongoing as of March 2022, and the results are expected to be reported in August 2022.

The report will be presented to Indigenous groups and DFO for consideration prior to construction of the connector channel between Lakes 15 and 16.

If the current study concludes that the parasite and pathogen communities in the two lakes are similar and joining them poses minimal risk of introducing new harmful parasites/pathogens to either lake, Artemis proposes that additional studies or monitoring will not be required. However, if the study is inconclusive or demonstrates that the lakes have differing parasite/pathogen communities and there is a risk of introducing one or more new parasite/pathogen to either lake, further work will be required. The scope of this future work would be developed in consultation with First Nations, DFO, and the Impact Assessment Agency of Canada (IAAC).

3. FOLLOW UP PROGRAM 3.14.2: DAVIDSON CREEK FISH POPULATIONS

3.1 Background and Approach

Development of the Project will cause a reduction in the catchment area of Davidson Creek, and, if un-mitigated, a corresponding reduction in flows in Davidson Creek downstream of mine. To mitigate this effect on flows, flow augmentation is proposed using a Freshwater Supply System (FWSS) that will pump water from Tatelkuz Lake to a freshwater reservoir (FWR) adjacent to Reach 6 of Davidson Creek (Figure 1).

For the first 5 years of mine operations, the FWR will store water diverted from the upper portions of Davidson Creek, and mine contact water that is suitable for release into Davidson Creek. Water will be released from the FWR into Davidson Creek to meet a defined Instream Flow Needs (IFN) for Rainbow Trout and Kokanee life stages.

Starting in Year 6 of Operations, water will be pumped from Tatelkuz Lake, and the FWR will also store and release water that is a mix of water diverted from the upper catchment, treated effluent, and Tatelkuz Lake water. The IFN identifies the timing of the streamflow rate in Davidson Creek that would be required to provide adequate habitat to instream aquatic species throughout the year.

The primary purpose of condition 3.14.2 follow-up program is to determine if the Project, and specifically flow augmentation from the FWSS, is affecting fish community composition, overwintering abundance and habitat use, and spawner populations during different Project phases. Several indictors require monitoring, with the aim of detecting changes that may be attributable to flow augmentation. The follow-up program currently proposes monitoring of the following:

- Community Composition
  - Young-of-year (YoY) and juvenile Rainbow Trout abundance (Condition 3.14.2.1);
  - Adult Kokanee and Rainbow Trout abundance and genetics (Condition 3.14.2.1 and 3.14.2.3);
- Rainbow Trout overwintering abundance and habitat availability (Condition 3.14.2.2);
- Spawner Populations
  - Rainbow Trout adult spawner and redd abundance (Condition 3.14.2.3);
  - Kokanee adult spawner and redd abundance (Condition 3.14.2.3); and
  - Kokanee fry outmigration assessment (surrogate metric for Condition 3.14.2.3).

Field programs were initiated in 2021 and are planned for 2022 to build upon and validate baseline information on fish populations in Davidson Creek, and to refine and select the field sampling methods that will be carried forward for the follow-up program through the life of the mine. The scope of 2022 field programs and the long-term 3.14.2 Follow-up Program study design will be further developed in consultation with First Nations.

3.2 Study Design

3.2.1 Community Composition (Sub-condition 3.14.2.1)

3.2.1.1 Davidson Creek Young-of-Year and Juvenile Rainbow Trout Abundance

To estimate absolute abundance of YoY (age 0+) and juvenile (and 1+ to 3+) Rainbow Trout, electrofishing surveys will be conducted at nine sites in Davidson Creek. At least one site will be located in each of the six reaches of Davidson Creek, as shown in **Figure 2.** At each site, sampling will include:

- Three-pass depletion electrofishing of stream sections 100 to 150 m in length, isolated with block nets;
- Identification of species and collection of length, weight, and body condition data for all fish captured;
- Measurement of channel dimensions and calculation of mean values of bankfull width, wetted width, water depth, and gradient; and,
- In-situ water quality measurements (i.e., temperature, dissolved oxygen, pH, and conductivity).

Sampling will occur during in late July, during the period after Rainbow Trout YoY emergence and before the arrival of spawning Kokanee adults in the downstream reaches of Davidson Creek. Sampling timing will be confirmed by calculating accumulated thermal units (ATU) using local stream and air temperature data. This calculated value will be compared to available emergence timing and ATU literature to estimate the timing window and variability of Rainbow Trout emergence dates. Results will be used to refine the juvenile sampling window for a given year. Observed emergence timing from field surveys will be compared to modelled emergence dates to validate and refine estimated emergence and ATU calculations.

At each site, sampling effort, electrofisher specifications, and catches will be recorded. Catch per unit effort (CPUE), relative abundance (number of fish per unit effort) and density metrics (number of fish per m^2) will be calculated and analyzed, as described in Section 3.3.1.1. Sampling frequency is described in Section 3.4.

The summer fish inventory measurement endpoints will include an inventory of the fish community and fish health (Table 3-1).

Table 3-1: Measurement and Assessment Endpoints for the Davidson Creek Young-of-Year and Juvenile Rainbow Trout Abundance

Measurement Endpoint	Assessment Endpoint
Fish inventory	Catch Per Unit Effort (CPUE) and fish density (fish/100 m^2) for each identified species, population structure
Fish health	Length, weight, condition

3.2.1.2 Davidson Creek Adult Kokanee and Rainbow Trout Abundance

Adult Rainbow Trout and Kokanee abundance will be estimated from spawner surveys, described in Section 3.2.3.

3.2.1.3 Rainbow Trout and Kokanee Genetic Structure and Diversity

The requirement (3.14.2.1) to monitor Rainbow Trout and Kokanee genetic structure and diversity will be met by employing the genetic study methodology used in the baseline studies to the extent possible and where feasible, as described in Taylor, 2012. This sampling methodology is described here, although it is recognized that adaptations may be warranted to account for advances in laboratory methods and genetic analysis techniques, based on subject matter expert guidance.

Samples of genetic material will be taken from Rainbow Trout and Kokanee populations that occur in lower Davidson Creek. As described in the Project's baseline studies, two sub-populations of Rainbow Trout are understood to occur in Davidson Creek, separated by a cascade barrier in Reach 11: one in the lower reaches (i.e., downstream of the barrier) and one in the upper reaches and Lake 16 (i.e., above the barrier). This monitoring condition is specific to the effects on fish residing in Davidson Creek downstream of the mine site. Therefore, only the lower Davidson Creek sub-population of Rainbow Trout will be assessed as part of this program. Only a single identified population of Kokanee occur in Davidson Creek, so this population will also be assessed.

Rainbow Trout tissue samples will be taken from stream-resident juvenile fish caught in Davidson Creek during summer electrofishing sampling (Section 3.2.1.1). Kokanee tissue samples will be taken from mature adult fish returning to spawn. Adult, pre-spawn Kokanee will be sampled, rather than juvenile lake-resident Kokanee, to ensure that fish sampled are part of the Davidson Creek spawning population, since Tatelkuz Like likely contains fish from multiple stream-spawning populations. Migrating pre-spawn Kokanee adults will be captured in lower Davidson Creek using seine nets over an area with no observed actively spawning fish. A minimum of 30 samples will be collected for each species (i.e., 30 Rainbow Trout and 30 Kokanee). All fish sampled will be identified to the species level, measured for length and weight, sampled for tissue, then released back into stream site from which they were captured.

Tissue samples will be adipose and/or caudal fin clips, depending on tissue analysis volume requirements. Fin clips will be immediately placed into labelled vials containing 95% ethanol to minimize DNA degradation.

Polymerase chain reactions (PCR) of microsatellite DNA will be carried out on ten microsatellite loci of Rainbow Trout and six loci of Kokanee, previously identified in the baseline genetic analysis (Taylor, 2012).

Measurement and assessment endpoints have been selected with a focus on non-lethal monitoring of the fish community to the extent possible. The genetic measurement endpoint is a deviation from a population equilibrium (i.e., allele frequency is stable between generations; Table 3-2).

Table 3-2: Measurement and Assessment Endpoints for the Davidson Creek Young-of-Year and Juvenile Rainbow Trout Abundance

Measurement Endpoint	Assessment Endpoint
Genetic structure	Deviation from population equilibrium

3.2.2 Juvenile Rainbow Trout Overwintering (Sub-condition 3.14.2.2)

DS Condition 3.14.2 requires “absolute abundance of overwintering rainbow trout juveniles”. However, sampling of fish populations under ice during winter is logistically challenging and can present risks to human and fish health. Therefore, following discussion with representatives of IAAC and DFO (17 November, 2021), a technically feasible alternate assessment strategy was developed.

Juvenile Rainbow Trout overwintering surveys will include two assessment methods:

1. Mid-winter assessment of relative fish abundance using underwater cameras and evaluation of habitat characteristics at nine sites in Davidson Creek; and
2. Fall pre-overwintering and spring post-overwintering relative abundance surveys using three-pass electrofishing at five sites in Davidson Creek.

3.2.2.1 Mid-winter Assessment

Winter surveys will be conducted to assess overwintering abundance and habitat use at nine sites in Davidson Creek (Site 1 to Site 9; **Figure 2**). Potential overwintering sites were identified using winter 2022 field survey information, field reconnaissance and drone imagery from summer 2021 surveys (Section 3.2.3 Spawner Populations), and baseline stream habitat data. The mid-winter overwintering abundance and habitat assessment program will include measurement and assessment of:

1. Juvenile Rainbow Trout overwintering abundance at each selected site using underwater cameras. Cameras and underwater lights will be placed in an overwintering deep pool habitat within each site. Stationary high-quality video will be recorded for a standardized period (e.g., 60 minutes) during daytime. The video will be reviewed to determine relative abundance using the established metric of maximum count of individuals observed simultaneously in a video frame (MaxN; Hitt et al. 2020).
2. Overwintering habitat quality measurements including:
    - Snowpack depth;
    - Ice depth;
    - Water depth;
    - Pool area;
    - Instream cover types and abundance;
    - Pool crest water depth and velocity, and;
    - In-situ water quality (i.e., temperature, dissolved oxygen, pH, and conductivity).

At each site, recording time, camera and lighting specifications, habitat measurements, and water chemistry parameters will be recorded. MaxN values will be determined and habitat suitability will assessed, as described in Section 3.3.2.1. Sampling frequency is described in Section 3.4. The mid-winter overwintering survey measurement endpoints will include assessment of fish abundance and habitat suitability (Table 3-3).

Table 3-3: Measurement and Assessment Endpoints for the Mid-winter Juvenile Rainbow Trout Overwintering Assessment

Measurement Endpoint	Assessment Endpoint
Fish abundance	Maximum count of individuals observed simultaneously in a video frame (MaxN)
Habitat suitability	Flowing water is present and dissolved oxygen levels are greater than 5 mg/L

3.2.2.2 Fall Pre-overwintering and Spring Post-overwintering Assessment

Pre-and post-overwintering surveys will include three-pass electrofishing assessments of five sites in Davidson Creek (DCOH5 to DCOH 9; **Figure 2**). The methodology will follow that previously described in Section 3.2.1.1 for summer Rainbow Trout assessment.

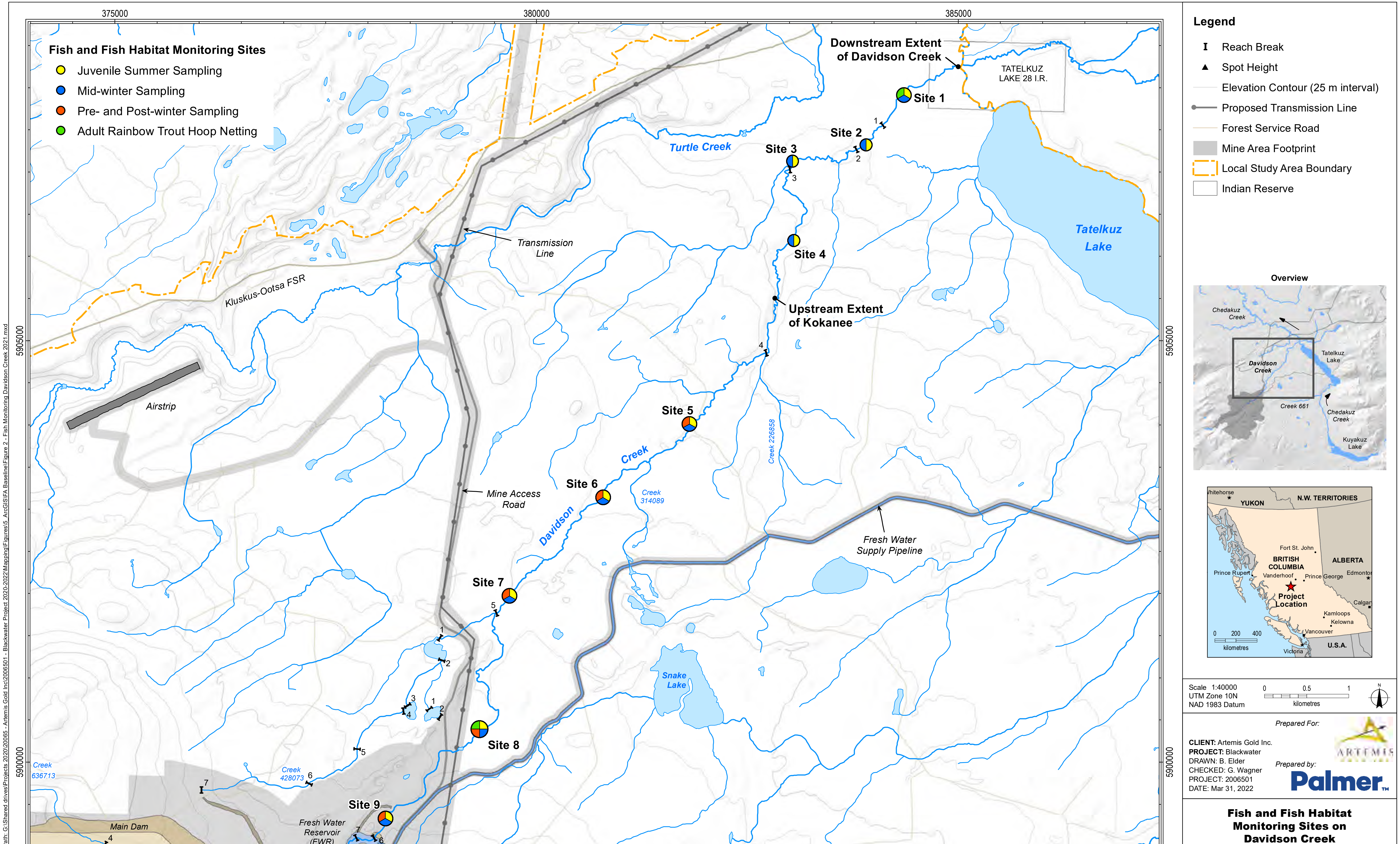
Sampling timing will vary, depending on seasonal differences in water temperature, ice cover, and discharge. Fall sampling will generally be conducted in late September, before water temperatures drop below 5°C and before ice cover forms. Spring sampling will be conducted shortly after ice-off, once temperatures reach 5°C and before spring freshet precludes effective electrofishing.

Notably, the five sites selected for assessment are less than the nine identified for summer YoY and juvenile sampling and overwintering assessment. This is due to the expected presence of incubating Kokanee embryos in the gravel substrates of the lower reaches of Davidson Creek. Electrofishing sampling will not be conducted in potential Kokanee spawning areas to minimize mortalities. Therefore, the four furthest-downstream sites (DCOH1 to DCOH 4) will not be sampled in fall or spring.

At each site, sampling effort, electrofisher specifications, and catches will be recorded. CPUE, relative abundance (number of fish per unit effort) and density metrics (number of fish per m^2) will be calculated and analyzed, as described in Section 3.3.2.2. Sampling frequency is described in Section 3.4. The pre-and post-winter overwintering survey measurement endpoints will include assessment of fish abundance and habitat suitability (Table 3-4Table 3-1).

Table 3-4: Measurement and Assessment Endpoints for Fall Pre-overwintering and Spring Post-overwintering Assessment

Measurement Endpoint	Assessment Endpoint
Fish inventory	Catch Per Unit Effort (CPUE) and fish density (fish/100 m^2) for each identified species, population structure
Fish health	Length, weight, condition



Fish and Fish Habitat Monitoring Sites on Davidson Creek

FIGURE 2

3.2.3 Davidson Creek Spawner Populations (Sub-condition 3.14.2.3)

DS Condition 3.14.3 requires assessment of "characteristics of spawner populations through surrogate monitoring metrics including size at 50% maturity". However, evaluating size at 50% maturity can require intensive lethal sampling to assess gonad development. Large-scale, annual lethal sampling is expected to negatively impact the Rainbow Trout and Kokanee population, will require an unfeasible lake and stream sampling program, and will be confounded by the migratory life history and lake-residence period of Rainbow Trout. Therefore, following discussion with representatives of IAAC and DFO (17 November, 2021) and additional consultation with First Nations and their technical consultants, an assessment of size at 100% maturity is proposed as an alternative to size at 50% maturity. To measure size at 100% maturity, body size (i.e., fork length and weight) of migrating pre-spawn fish (in the case of Rainbow Trout) or postorbital-hypural length of post-spawn mortalities (in the case of Kokanee), that are assumed to be 100% mature, will be measured and evaluated. This metric will be used to directly evaluate change in body size of mature fish that spawn in Davidson Creek.

3.2.3.1 Rainbow Trout Spawner Abundance

Adult Rainbow Trout spawner abundance and distribution will be directly assessed with two methods: capture of migrating spawners using hoop nets and visual assessment of spawners and redds.

Hoop Net Sampling

Direct sampling of migrating fish will involve intercepting mature fish during their annual pre-spawning migration into Davidson Creek. Migrating adult fish will be captured and counted using bi-directional hoop nets located at two sites: one site the furthest downstream reach of Davidson Creek, near its confluence with Chedakuz Creek (Site 1) and one site (Site 8) immediately downstream of the proposed mine access road in middle Davidson Creek (**Figure 2**).

The hoop netting program will include the following tasks:

- Installation and maintenance of bi-directional (i.e., upstream- and downstream-facing) hoop nets at each site;
- Regular (i.e., at least twice-daily) hoop net checks for fish, including:
    - Marking mature Rainbow Trout (i.e., those producing milt or eggs) with movement direction- and site-specific coloured and numbered floy tags to evaluate residence time and movement;
    - Enumeration of Rainbow Trout and measurement of weight, length, sex, and body condition; and
    - Testing for spawning ripeness (i.e., exuding milt or eggs) by lightly pressing on the abdomen.
- In-situ daily water quality measurement (i.e., temperature, dissolved oxygen, pH, and conductivity)
- Daily velocity measurements at the hoop net sites.

Fish capture data will be used to evaluate spawner numbers and distribution, as described in Section 3.3.3.1. Sampling frequency is described in Section 3.4. The Rainbow Trout spawner abundance measurement endpoints will include the number of migrating adult fish captured in hoop nets (Table 3-5).

Table 3-5: Measurement and Assessment Endpoints for Rainbow Trout Spawning Hoop Net Sampling

Measurement Endpoint	Assessment Endpoint
Fish abundance	Total number of adult spawners captured in hoop nets returning to Davidson Creek
Fish distribution	Number of adult spawners captured at each hoop net site in Davidson Creek
Fish size at 100% maturity	Weight and length of mature Rainbow Trout captured in hoop nets returning to Davidson Creek

Bank Walk Visual Assessment

Bank walk surveys also will be conducted the peak spawning period and post-spawn to estimate redd counts and identify areas of high spawning activity and the spawning distribution of Rainbow Trout within Davidson Creek.

The bank walk surveys will be completed at the two hoop netting sites in Davidson Creek, downstream of the FWR. Each survey zone will be located within the same reach as the hoop net site, although some site-specific adjustment will be needed to establish effective monitoring locations. Each survey zone will consist of a 500-m long section that contains likely spawning locations based on baseline Fish Habitat Assessment Procedure (FHAP) and RISC 1:20,000 habitat assessments from the baseline program (Johnston and Slaney 1996; RISC 2001; AMEC 2013) and field reconnaissance.

Each section will be surveyed twice during the annual Rainbow Trout spawning period: once at the ‘peak’ of spawning activity (i.e., after the furthest downstream hoop net upstream-movement catch has peaked, to assess the maximum number of fish in the assessment sections) and once post-spawning (i.e., after the furthest downstream hoop net downstream-movement catch has peaked, to assess the maximum number of redds). Exact survey time will depend on annual variability in run timing.

Each surveyed section will be walked once in an upstream direction by a pair of trained observers. Observers will record the number of redds and adult fish in each section. Geographic coordinates will be recorded for each redd (or redd complex if multiple redds occur in close proximity).

Fish and redd observation data will be used to evaluate spawner numbers and distribution, as described in Section 3.3.3.1. Sampling frequency is described in Section 3.4. The Rainbow trout bank walk assessment measurement endpoints will include assessment of fish and redd abundance and density (Table 3-6).

Table 3-6: Measurement and Assessment Endpoints for Rainbow Trout Spawning Bank Walk

Measurement Endpoint	Assessment Endpoint
Fish abundance	Number of adult spawners observed and their density at each survey sites
Fish distribution	Relative number of adult spawners observed at each survey site
Redd abundance	Relative number of redds observed and their density in each survey reach

3.2.3.2 Kokanee Spawner Abundance

Spawner Survey

Kokanee spawner surveys in Davidson Creek will include underwater camera surveys and bank walks to determine the total abundance of mature Kokanee entering Davidson Creek. The surveys will begin at the confluence of Chedakuz and Davidson creeks, extending through Reaches 1 to 4 of Davidson Creek (**Figure 2**), representing the full extent of documented Kokanee spawning.

Bank walk surveys will be conducted approximately once per week for the duration of the annual pre-spawning migration and spawning periods, typically beginning in late July and ending in early September, depending on environmental factors. Bank walk spawner and redd surveys that encompass the entire migration and spawning period allows the use of an area-under-the-curve (AUC) estimate of Kokanee spawner abundance, described further in Section 3.3.3.2.

The Kokanee spawner survey field program will include the following tasks:

- Installation of an underwater camera paired with a fish fence near the confluence of Davidson Creek and Chedakuz Creek to estimate the total abundance of fish entering Davidson Creek;
- Visual assessment of Kokanee spawners and redds via bank walks. Information collected during the bank walk surveys will include:
    - Kokanee counts (characterizing fish as either holding/migrating, spawning, spent, or carcass); and
    - Redd abundance, approximate location, and substrate type.
- Measurement of fork and postorbital-hypural lengths from carcasses;
- Collection of tissue samples (i.e., otoliths and fin clips) from carcasses; and
- In-situ water quality (i.e., temperature, dissolved oxygen, pH, and conductivity).

Surveys will be conducted in the upstream direction to reduce disturbing the sediment to maximize fish observability. As observers advance along the creek, live and dead observations will be recorded; live fish will be classified as holding/migrating (lively, fresh in appearance, absence of wear, unpaired male and female) or spawning (paired male and female) or spent (lethargic, presence of wear). Male and female mortalities will be counted and marked by chopping the fish posteriorly above the adipose fin to avoid recounts in subsequent surveys. Environmental conditions (e.g., percent bankfull, water temperature, water clarity, brightness, cloud cover, and precipitation intensity) will be documented.

A value of observer efficiency (OE) will be applied to each reach on each day to account for negative bias associated with spatial/temporal changes in observability. These correction factors are critical to AUC estimates because it allows inter- and intra-annual comparisons of fish counts within and between streams. Calibrated amongst crew members, OE will be subject to the surveyors' best judgement based on daily fluctuations of environmental conditions.

Tissue Sampling

Tissue samples collected opportunistically from carcasses and from live fish will be used for age measurement and for genetic analysis.

Otolith samples will be opportunistically gathered for age analyses to determine the age ranges of Kokanee spawners. The proposed target minimum sample size for otoliths is n=100 samples, although more samples could be collected, if carcasses are available, to increase the confidence of statistical analyses. These ageing structures will be removed and prepared (e.g., mounted, polished, or otherwise treated) as necessary. Age will determined by counting the number of annuli through a compound microscope. Age data will be analyzed to calculate a length-at-age relationship for mature fish. This information will be used to determine length and age at 100% maturity for the population.

Fin clip samples will also be taken from Kokanee spawners during the spawning survey to perform genetic analysis of the populations, as described in Section 3.2.1.3. Fin clips will be taken from live, pre-spawn, adult fish, gathered using seine net pulls from Davidson Creek. Migrating and holding fish will be targeted; no fish will be collected from active spawning areas. Fin clips will be stored in 95% ethanol for genetic analysis. PCR testing will be performed, including identification of microsatellite loci to be compared. Statistical tests will be performed on these data to estimate deviation from population equilibrium and population differentiation.

Kokanee spawner counts, redd counts, length measurements, and age data will be used to evaluate total escapement, distribution of spawners, and size at maturity, as described in Section 3.3.3.2. Sampling frequency is described in Section 3.4. The Kokanee bank walk visual assessment measurement endpoints will include assessment of fish abundance and habitat suitability (Table 3-7).

Table 3-7: Measurement and Assessment Endpoints for Kokanee Spawning Bank Walk

Measurement Endpoint	Assessment Endpoint
Fish abundance	Relative number of adult spawners and their density observed in each survey reach
Redd abundance	Relative number of redds and their density observed in each survey reach
Fish size at 100% maturity	Length and age at 100% maturity of Kokanee returning to Davidson Creek

3.2.3.3 Kokanee Fry Outmigration Survey

Kokanee fry outmigration abundance is an indicator of the success of the previous year's Kokanee spawning activity and the overwinter survival of in-gravel Kokanee embryos. As such, a spring Kokanee fry outmigration survey in Davidson Creek will be completed to assess abundance as a surrogate metric for adult Kokanee spawning success.

Kokanee fry outmigration assessment will be completed using a sub-sampling mark-recapture method. Sampling will involve deploying fine-mesh nets of known dimensions into the channel at predetermined locations, according to the methods of Fraley and Clancey (1984). Each net will be sampled at a set interval and the fry captured will be enumerated and recorded. The duration of sampling period will be adjusted based on the numbers of fry netted and/or the amount of debris present, although it is expected to last approximately four weeks, based on literature review. Data including date, time, water depth, water temperature and weather conditions will be recorded. Sampling will be conducted once per week, between 19:00 hours and 02:00 hours as most (>90%) fry emigration occurs during this period (Thorp 1987, Manson 2005).

Capture efficiency of the nets will be determined using a mark-recapture approach by marking captured fry with Bismarck Brown Y and releasing them upstream of the capture location. Recaptured marked fish will be counted and the proportion of recaptured fish will indicate the trap's effectiveness.

To inform sampling timing, accumulated thermal units (ATU) will be calculated using continuously measured stream and air temperature data. The results will be compared to available emergence timing and ATU literature to estimate the timing window and variability of Kokanee fry emergence dates. Results of this calculation will inform an approximate fry sampling window for a given year. Observed emergence timing data will be compared to modelled emergence to help validate and refine estimated emergence and ATUs.

Total fry emigration for each sampling period will be calculated and estimates for the entire emigration period extrapolated using flow rates, stream channel dimensions, and recapture rates, as described in Section 3.3.3.3. Sampling frequency is described in Section 3.4. The Kokanee fry outmigration measurement endpoints will include assessment of relative fish abundance and timing (Table 3-8).

Table 3-8: Measurement and Assessment Endpoints for Kokanee Fry Outmigration Survey

Measurement Endpoint	Assessment Endpoint
Fish abundance	Calculated total fry abundance for the outmigration period
Outmigration timing	Estimated start, finish, and peak timing of outmigration movement

3.3 Data Analysis

Statistical analyses will be used to evaluate changes over time. Power analyses have been performed, as appropriate, to support a study design that will allow for between-year comparisons and longer-term trend analysis. Between-year comparison (i.e., paired comparison between two separate annual datasets) will be completed to identify statistically differences in mean values using Analysis of Variance (ANOVA), or if the data are not normally distributed the equivalent non-parametric statistical test (e.g., Wilcoxon Signed-Rank Test). All statistical analyses will be performed using the R statistical system (R Development Core Team 2011). The significance level (α) = 0.05 will be used for all statistical tests, except as noted in specific analyses. In addition, year over year change will be assessed qualitatively, by comparing with the baseline data.

For longer time scale (i.e., five years and onwards), non-parametric Mann-Kendall temporal trends testing will be used to determine if there are significant temporal trends in any given monitoring metric, and if so, the direction and statistical significance of temporal trend. The sensitivity of the Mann-Kendall trends test increases with an increasing number of time steps (i.e., consecutive years of data) and it is considered that somewhere between five and ten time steps are a minimum requirement. Trends analyses will therefore begin following the fifth year of this monitoring program.

Additional metric-specific tests are described in the following section, where appropriate.

3.3.1 Community Composition

3.3.1.1 Davidson Creek Young-of-Year and Juvenile Rainbow Trout Abundance

Fish data will be transcribed from field notes and submitted to the ENV Fisheries Data Submission site.

Catch-Per-Unit-Effort (CPUE)

Fish community data will be summarized by calculating CPUE for each individual fishing effort and fish species captured. The CPUE will be calculated as the number of fish captured per sampling device per unit time as follows:

Electrofishing:

*CPUE=number of fish caught * [100/(electrofishing effort, hr)]*

The CPUE is an index of relative abundance that can be used to compare fish populations over time with the assumption that catch is proportional to the amount of effort for each gear-type used. For effects assessment, a Mann-Kendall temporal trends test will be undertaken for each site and compared between control and impact sites: this will require a minimum of five years of sequential monitoring data.

Density

Fish density values will be calculated by dividing the total number of fish caught in a closed site by the area of that site. Site area will be determined by multiplying a mean wetted width of the site by the length of the site. A minimum of three width values will be used to calculated mean wetted width.

Density values will be calculated for the total number of fish captured (i.e., all species), Rainbow Trout life stages (i.e., YoY and juveniles), and for any other species encountered.

Population Structure

Population structures of fish will be assessed using length and wight frequency distributions and length-weight regressions.

Fish Condition

Length-weight data will be plotted to visually assess the entire data set and to identify outliers. Once outliers are visually identified, potential explanations for the outlier values will be investigated and decisions will be made to either repair the outlier, include the outlier in data analysis, or remove the outlier from further analysis.

The length/weight data from reference sites and from historical data (Appendix 2-O, Fish and Aquatic Resources 2011 – 2012 Baseline Report; Appendix 2-P, Fish and Aquatic Resources 2013 Baseline Report) will be combined and a normal reference range will be calculated using specific length increments and the associated average weight data. The following equation will be used for definition of normal range:

$$log_{10}(W) = b * log_{10}(L) + a$$

where W = weight (g), L = length (mm), a = the intercept of the regression defined from the reference and historical data, and b = the slope of the regression defined from the reference and historical data.

The regression equation for the normal range will then used to calculate the $\log_{10}$ of expected weight as:

$$log_{10}(W_E) = b * log_{10}(L) + a$$

where W_E = expected weight (g), L = measured fork length (mm), a = the defined intercept of the regression and b = the defined slope of the regression. Residual $\log_{10}$(weight) values will then be calculated as the difference between expected and measured weight as:

$$W_R = W - W_E$$

where W_R = residual weight, W = measured weight, and W_E = expected weight. The median, 25th percentile, 75th percentile, and the interquartile range (IQR) for both negative and positive residuals will then be calculated. The upper and lower limits of the normal range of the residuals will then be calculated as:

$$NR_{UL} = 75\%ile + 1.5 \times IQR$$

$$NR_{LL} = 25\%ile - 1.5 \times IQR$$

where NR_{UL} = the upper limit of the normal range of the residuals, NR_{LL} = the lower limit of the normal range of the residuals, IQR = the interquartile range, 25%ile = 25th percentile value for the negative residuals, and 75%ile = 75th percentile value for the positive residuals.

The upper and lower limits of normal range for the length/weight linear regression will be calculated as:

$$log_{10}(W_{UL}) = (a - NR_{UL}) + b \times log_{10}(L\quad)$$

$$log_{10}(W_{LL}) = (a + NR_{LL}) + b \times log_{10}(L\quad)$$

where W_{UL} = normal range upper limit for weight (g), W_{LL} = normal range lower limit weight (g), L = fork length (mm), a = the intercept of the regression and b = the slope of the regression. The lower limit and upper limit of normal range will be used to assess the length/weight fit of fish from assessed sites relative to the normal range, both among years and among sites.

The relative condition (K_n) will be used as the metric for condition and will be calculated by comparing the measured weight to the expected weight from the measured length as:

$$K_n = \frac{W}{W_E}$$

where W = measured fish weight (g) and W_E = expected fish weight (g).

Relative condition will be statistically compared between sites. First, the distributions will be tested for normality using an Anderson-Darling test and if normally distributed, a single factor ANOVA followed by a Tukey's multiple comparison test will be computed to compare relative condition. If the data are not normally distributed, a Kruskal-Wallis test by ranks will be used with a Steel-Dwass test for multiple comparisons. Significance will be assumed when $p < 0.05$.

Site Selection Power Analysis

The number of monitoring sites was selected to provide adequate statistical power to detect a year-over-year change in the mean relative abundance value.

To inform this power calculation, the relative abundance of YoY and juvenile Rainbow Trout captured at the three 2021 survey sites are presented in Table 3-9. The two age groups were combined due to the low numbers captured in each reach.

Table 3-9. Relative Abundance of Combined Young-of-Year and Juvenile Rainbow Trout in Davidson Creek, 2021

Survey Site	Abundance (number of captured fish)	Relative Abundance (catch per unit effort)
DCJUVRB1 – Reach 1	13	0.87
DCJUVRB2 – Reach 5	32	0.56
DCJUVRB3 – Reach 6	24	0.56

To standardize the data used in this evaluation, single-pass electrofishing data was used for determining relative abundance, incorporating data from the original baseline work conducted in 2011 to 2013, and recent sampling in 2021. This data comparison provided a relative abundance mean/standard deviation (SD) from a total of 16 sites, for which ETA squared (i.e., measure of effect size that is commonly used in Analysis of Variance [ANOVA] models) was determined, as well as Cohens f statistic (i.e., a measure of standardized average effect in the population across all the levels of the independent variable; Cohen 1988) to use as an effect size derived from the sample population relative abundance data. An ANOVA was completed for CPUE by year using the Sum of Squares value for year and residuals from the ANOVA to evaluate an effect size of 0.576. Based on this value, the sample size required for 80% power (alpha = 0.05) is nine survey sites per year in Davidson Creek.

The abundance data collected using triple-pass depletion approach is expected to have a lower coefficient of variation over time when compared to the single-pass approach (used in the 2011-2013 baseline studies, and in 2021). As a result, the triple-pass approach has more statistical power to detect any trends or changes in abundance (George et al 2021). The proposed triple-pass method will lower the observed variance and allow for more powerful statistical evaluation. The data from the first pass of the triple-pass sampling also will be comparable to the single-pass baseline (2011-2013) and 2021 data to allow for historical comparison.

3.3.1.2 Davidson Creek Adult Kokanee and Rainbow Trout Abundance

Adult Kokanee and Rainbow Trout abundances are addressed in Section 3.3.3.

3.3.1.3 Rainbow Trout and Kokanee Genetic Structure and Diversity

Data analysis methods for genetic structure and diversity will broadly follow those described in Taylor (2012), summarized here. However, adjustments may be required to account for laboratory-specific analysis variation.

Tests will be performed using GENEPOP (Raymond and Rousset 2001). Tests for deviations from Hardy-Weinberg equilibrium will be performed for each locus-population combination using an exact test in which probability (P) values will be estimated using a Markov chain method. Tests for genotypic linkage disequilibrium for all combinations of locus pairs within a population will also be made using a Markov chain method with GENEPOP default values. Tests for population differentiation between all pairs of populations will be performed using FST estimated as θ (Weir and Cockerham 1984) as implemented in GENETIX (Belkhir et al. 2004). Significance levels will be determined correcting for multiple simultaneous tests following Narum (2006). Basic descriptive statistics of sample size (N), number of alleles (NA), observed (HO) and expected (HE) will be compiled using FSTAT (Goudet 2001). A factorial correspondence analysis (FCA) will be used to depict genetic similarity amongst all individuals in genetic space as inferred from variation in allele frequencies using GENETIX. A hierarchical partitioning of allele frequency variation to that between drainages, among localities within drainages, and within localities will be conducted using the analysis of molecular variance approach as implemented in ARLEQUIN (Excoffier et al. 2006).

The model-based Bayesian clustering analysis within STRUCTURE (Pritchard et al. 2000) will be used to assess population structure employing the admixture model with correlated allele frequencies and a burnin of 50,000 iterations followed by an additional 100,000 iterations, replicated three times. The simulations will be run with hypothesized numbers of populations (K) ranging from K = 1 to K = s+2 where s = the number of localities sampled (i.e., a total of K = 9). STRUCTURE HARVESTER will be used to process the results from multiple runs of STRUCTURE (Earl 2011). Given the relatively small spatial scale of the study (and an expected low level of genetic differentiation) and that fish were sampled largely within what are likely to be spawning tributaries, the STRUCTURE analysis will also use the locality prior option which employs prior knowledge of where each sample was collected to assist in clustering. The LOCPRIOR model works on the principle that individuals from the same sampling location often come from the same genetic population. Therefore, the LOCPRIOR operate to assume that the sampling locations can be informative about ancestry (Hubisz et al. 2009).

These calculations will be used to generate a description of the genetic condition of the assessed populations of Rainbow Trout and Kokanee. This data will be analyzed to evaluate change in allele frequency within the population over time.

3.3.2 Juvenile Rainbow Trout Overwintering

3.3.2.1 Mid-winter Assessment

Fish abundance will be estimated using the metric of the maximum count of individuals observed simultaneously in a video frame (MaxN), as described in Hitt et al. (2021). This value will be obtained by an observer reviewing the video footage while recording the number of fish present. Still frames will be captured to document the MaxN values.

Habitat suitability will be determined based on the presence of ice-free water beneath ice at the deepest point of the assessment site and adequate dissolved oxygen to support aquatic life. This threshold will be defined as 5 mg/L, based on BC's Approved Water Quality Guidelines for Aquatic Life for the instantaneous minimum water quality guidelines for all life stages other than buried embryo / alevin (BC MOECCS, 2021).

3.3.2.2 Fall Pre-overwintering and Spring Post-overwintering Assessment

Methods for analyzing fall pre-overwintering and spring post-overwintering data will follow those described in Section 3.2.1.1.

The fall pre-overwintering and spring post-overwintering relative abundance data will be used to determine overwintering survival. The estimated abundance and survival, will be determined with the relative abundance catch data from pre- and post-winter electrofishing effort adopting the approach of Trudel et al (2012) to determine overwinter mortality (OWM) outlined in below equation:

$$OWM = \left[1 - \frac{(CPUE_{spring})}{(CPUE_{fall})}\right] * 100$$

where $CPUE_{spring}$ and $CPUE_{fall}$, respectively, define the pre-overwintering and post-overwintering estimates of catch per unit effort.

3.3.3 Davidson Creek Spawner Populations

3.3.3.1 Rainbow Trout Spawner Abundance

Catches for each hoop net site and each movement direction (i.e., upstream and downstream) will be tabulated and used to calculate the number of Rainbow Trout spawners entering Davidson Creek.

Total adult abundance (i.e., the total number of unique adult fish captured migrating into Davidson Creek) will be determined based on the total number of unique floy tags applied to fish captured in hoop nets. Adult spawner distribution will be assessed by tabulating the relative numbers of fish captured at each hoop net site, moving each direction. Fish size at 100% maturity will be calculated by determining the mean length and weight values of all mature spawners encountered.

Bank walk survey data for each site will be evaluated to calculate relevant metrics. Total spawner abundance will be calculated for pooled and individual sites. Fish distribution will be assessed by comparing the relative number of fish observed at each site. Redd abundance will be determined by the maximum number of redds observed at each site during the survey period.

3.3.3.2 Kokanee Spawner Abundance

Spawner Abundance

An area-under-the-curve (AUC) method will be used to estimate escapement of spawning Kokanee based on periodic counts obtained through visual surveys. AUC methods calculate an escapement (E) estimate by taking the integral of the count data (expanded by observer efficiency) and dividing it by a value of survey life (SL; synonymous with residence time or stream life): E = AUC ÷ SL

Specifically, total escapement for Davidson Creek will using a gaussian area-under-the-curve (GAUC) model developed by Millar et al (2012) using the R Studio Environment (R Core Team, 2021). This method involves using a generalized linear model (GLM) with a quasi-Poisson family to fit to the OE-expanded count data. This method subsequently incorporates empirically derived stream-specific values of SL and OE and their uncertainty into the estimator. There is no historical information available for these values and their calculation would require a weir and a comprehensive study design that is outside the scope of the present study. Rather, OE was implicit through its application in periodic surveys, while a literature value of SL and its uncertainty was used similarly to Holt & Cox (2008).

This GAUC method will be used to generate estimates of total escapement and standard error, start and end dates of the spawning period, and peak spawning timing.

Redd Abundance

Redd abundance data will be tabulated for each surveyed reach and for each survey day. The highest count of redd abundance for each reach will be identified as used as the metric value for that reach. The total number of redds within Davidson Creek will be calculated as the total of maximum redd counts per reach.

Size at Maturity

Size at maturity will be calculated using the length, weight, and age data gathered for adult spawning Kokanee. Fish size at 100% maturity will be calculated by determining the mean postorbital-hypural length values of all mature spawners encountered. Age at 100% maturity will also be calculated by determining the mean age of Kokanee, based on otolith ageing.

3.3.3.3 Kokanee Fry Outmigration Survey

Total daily catch data will first be expanded, using an estimate of trapping efficiency, based on the mark-recapture-based estimate of trap effectiveness. To calculate total daily catch estimate, the following formula for the adjusted Peterson estimate will be applied (Ricker, 1975):

$$N = \frac{(M + 1) * (C + 1)}{R + 1}$$

Where: N = Daily fry estimate, C = Daily Catch, R = Number of Marks Recaptured, and M = Number of Marks Released

Kokanee fry outmigration abundance will then be estimated, based on the efficiency-adjusted daily fry estimate, using an AUC calculation method, similar to that used for adult Kokanee, described in Section 3.3.3.2.

3.4 Frequency and Duration

The monitoring programs for community composition, overwintering abundance and habitat use, and spawner populations will occur during all phases of the Project.

Starting in Construction phase, the frequency of Condition 3.14.2 FUP will initially be annual for all sampling components. However, certain monitoring components will be conducted annually initially with a framework to decrease sampling frequency by one year after each three-year period in which no effects are identified, to a minimum sampling frequency of once every three years. Once sampling frequency is decreased to once every two or three years, frequency would be increased again by one year if effects were identified, up to a maximum frequency of annually. Specifically, these components are the Rainbow Trout YoY and juvenile abundance surveys (Section 3.2.1.1) and Rainbow Trout overwintering surveys (Section 3.2.2).

Rainbow trout spawning surveys and kokanee spawning surveys and escapement surveys (Section Davidson Creek Spawner Populations (Sub-condition 3.14.2.3)3.2.3) will be completed on an annual basis for at least the two years of Construction and the first eight years of Operations, to ensure that at least two complete kokanee cohort generations are assessed. Beyond the eight-year mark of Operations, survey frequency for fish community could be reduced to once every two years, if no trend (changes) in fish community is observed.

The genetic sampling frequency (Section 3.2.1.3) will be every four years, to allow time for potential detectable genetic drift to occur, and to coincide with the four-year life cycle of Kokanee spawners.

Monitoring frequency of all FUP components for Closure and Post-Closure phases will be determined near the end of the Operations phase and will depend on monitoring results during that phase.

4. IMPLEMENTATION SCHEDULE

Follow-up Programs 3.14.1 (Parasite Pathogen Study) and 3.14.2 (Davidson Creek Populations) were initiated in 2021-2022 through field programs to select sites, refine field sampling methods, and collect baseline data prior the start of Construction. The programs will be ongoing throughout the life of the Project.

5. ADAPTIVE MANAGEMENT

The follow-up programs for Condition 3.14 described herein will evolve over time in response to the results of the monitoring, changing conditions or development at the Project, updates to methods, and through consultation with Indigenous groups, regulators, or other stakeholders. This process of continuous improvement with changing conditions is referred to as adaptive management.

Conditions 2.5 and 2.6 in the federal DS identify requirement for follow-up programs:

"2.5 The Proponent shall, where a follow-up program is a requirement of a condition set out in this Decision Statement, have a Qualified Professional, where such a qualification exists for the subject matter of the follow-up program, determine, as part of the development of each follow-up program and in consultation with the party or parties being consulted during the development, the following information:

2.5.1 the follow-up activities that must be undertaken by a qualified individual;

2.5.2 the methodology, location, frequency, timing and duration of monitoring associated with the follow-up program;

2.5.3 the scope, content, format and frequency of reporting of the results of the follow-up program;

2.5.4 the levels of environmental change relative to baseline conditions that would require the Proponent to implement modified or additional mitigation measure(s), including instances where the Proponent may require Designated Project activities to be stopped; and

2.5.5 the technically and economically feasible mitigation measures to be implemented by the Proponent if monitoring conducted as part of the follow-up program shows that the levels of environmental change referred to in condition 2.5.4 have been reached or exceeded.

2.6 The Proponent shall update and maintain the follow-up and adaptive management information referred to in condition 2.5 during the implementation of each follow-up program in consultation with the party or parties being consulted during the development of each follow-up program."

Thus, an adaptive management framework has been incorporated into the follow-up programs. Figure 3 identifies the components of the adaptive management framework.

Figure 3. Adaptive Management Framework

Plan: In collaboration with the Indigenous groups, further refine and plan Follow up Programs 3.14.1 and 3.14.2.

Do: Implement Follow-up Programs 3.14.1 and 3.14.2.

Monitor: BW Gold will review and update the follow up programs over the life of the Project. This will include:

- Review of the programs in terms of effectiveness in detecting changes with the monitoring program;
- Recommendations provided by qualified individual and Indigenous groups on the monitoring plan; and
- Engagement tracking to record input from Indigenous groups.

Adjust: BW Gold will adjust the follow-up programs (e.g. study design, field methods, data analysis methods, and reporting) based on program findings, as well as input and feedback from Indigenous groups.

5.1 Follow-Up Program Trigger Response

To determine 'the levels of environmental change relative to baseline conditions that would require the Proponent to implement modified or additional mitigation measure(s)' entails establishing levels (i.e., triggers), that, when reached, trigger a response action.

Changes in the monitoring metrics for fish populations (e.g., fish abundance, density, spawner escapement, fry emigration), may reflect natural variability and it is challenging to pinpoint whether a significant change is attributable to mine activities (namely, flow augmentation). Establishing triggers provides an early-warning system, allowing sufficient time to investigate root causes, increase monitoring, and take preventative action (i.e., implement modified or additional mitigation measure(s)).

Statistical analyses, described in Section 3.3, will be used to evaluate changes over time. Power analyses have been performed to support a study design that will allow for between-year comparisons and longer-term trend analysis. Between-year comparison (i.e., paired comparison between two separate annual datasets) will be completed to identify statistically differences in mean values. In addition, year over year change will be assessed qualitatively, by comparing with the baseline data.

For longer time scale (i.e., five years and onwards), non-parametric Mann-Kendall temporal trends testing will be used to determine if there are significant temporal trends in any given monitoring metric, and if so, the direction and statistical significance of temporal trend. The sensitivity of the MK trends test increases with an increasing number of time steps (i.e., consecutive years of data) and it is considered that somewhere between five and ten time steps are a minimum requirement. For the first four years of monitoring, temporal trends analysis will not be possible, however a Trigger Action Response Plan for fish habitat endpoints has been established that is based on triggers for flow and temperature. This is outlined in the Aquatic Effects Monitoring Program (AEMP) for the Project.

Table 5-1 identifies triggers and responses for adaptive management related to fish population monitoring as part of follow-up programs 3.14.2. There are no triggers proposed for follow-up program 3.14.1 (Parasite Pathogen Study), as the study will be completed prior to Construction and connecting of Lakes 15 and 16 the study findings will inform next steps and further actions.

Table 5-1.: Adaptive Management Triggers and Responses

Trigger	Response
No trend in monitoring metric (i.e., stable over time) or upward trend (e.g., increase in fish abundance)	Inform Indigenous groups No change to mitigation measures Consider reduction in the frequency of monitoring
Downward trend monitoring metric (e.g., decrease in fish abundance)	Inform Indigenous groups Identify potential causes and additional studies to test hypotheses Implement modified or additional mitigation measures Monitor post-implementation of the modified or additional mitigation measures and communicate results Evaluate if new mitigation or fish offsetting measures are required

In the case of negative adverse effects to fish populations that deviate from the predictions of the EA, there are limited additional mitigation measures available. Flow augmentation from the FWR/FWSS can be controlled for flow and temperature, and relative proportions of the different sources of water can be adjusted (i.e., increase the input from the diversions, reduce volume of Tatelkuz Lake water). However, BW Gold’s fish habitat offsetting plan, includes habitat creation, restoration, or enhancement projects in the Davidson Creek watershed to offset the predicted effects on fish productivity and includes measures to benefit other fish populations in the region. If effects are beyond what was predicted in the Environmental Assessment and the Fisheries Offsetting Plan (Palmer, 2021), additional offsetting may be required.

6. REPORTING

DS Conditions 2.11, 2.12 and 2.13 set out annual reporting requirements related to the implementation of conditions in the DS. Condition 2.14 sets out information sharing requirements related to the annual reports.

DS Condition 2.11 requires:

> *"The Proponent [BW Gold] shall, commencing in the reporting year during which the Proponent begins the implementation of the conditions set out in this Decision Statement, prepare an annual report that sets out:*
>
> *2.11.1 the activities undertaken by the Proponent in the reporting year to comply with each of the conditions set out in this Decision Statement;*
>
> *2.11.2 how the Proponent complied with condition 2.1;*
>
> *2.11.3 for conditions set out in this Decision Statement for which consultation is a requirement, how the Proponent considered any views and information that the Proponent received during or as a result of the consultation, including a rationale for how the views have, or have not, been integrated;*
>
> *2.11.4 the information referred to in conditions 2.5 and 2.6 for each follow-up program;*
>
> *2.11.5 the results of the follow-up program requirements identified in conditions 3.14, 3.15, 3.16, 4.5, 5.5, 6.11, 6.12, 6.13, 6.14, 8.18.6, 8.20.5, 8.21, and 8.22 if required;*
>
> *2.11.6 any update made to any follow-up program in the reporting year;*
>
> *2.11.7 any modified or additional mitigation measures implemented or proposed to be implemented by the Proponent, as determined under condition 2.9 and rationale for why mitigation measures were selected pursuant to condition 2.5.4; and*
>
> *2.11.8 any change(s) to the Designated Project in the reporting year."*

DS Condition 2.12 requires: *"The Proponent [BW Gold} will provide the draft annual report to Indigenous groups, no later than June 30 following the reporting year to which the annual report applies. BW Gold will consult Indigenous groups on the content and findings in the draft annual report."*

DS Condition 2.13 requires: *"The Proponent [BW Gold], in consideration of any comments received from Indigenous groups pursuant to condition 2.12 shall revise and submit to the Agency [Impact Assessment Agency of Canada] and Indigenous groups a final annual report, including an executive summary in both official languages, no later than September 30 following the reporting year to which the annual report applies."*

DS Condition 2.14 requires: *"The Proponent [BW Gold] shall publish on the Internet, or any medium which is publicly available, the annual reports and the executive summaries referred to in conditions 2.11 and 2.13."*

The Proponent shall keep these documents publicly available for 25 years following the end of decommissioning of the Designated Project. The Proponent shall notify the Agency and Indigenous groups of the availability of these documents within 48 hours of their publication."

Reporting in compliance with these conditions will commence when BW Gold begins to implement the follow-up programs. BW Gold will implement the follow up programs during all phases of the Project, as stipulated in the DS.

7. SUMMARY

The follow up programs herein have been developed to fulfill DS condition 3.14. This condition pertains to conducting an inventory of parasites and pathogens in two lakes that will be joined by a connector channel, and monitoring fish populations in Davidson Creek downstream of the Project. The follow up programs cover data collection during pre-construction (2021-2022), through to decommissioning.

Information from these programs will be used for comparison during long-term monitoring over the life of the Project to determine the accuracy and effectiveness of mitigation measures, as set out in Condition 2.9. Depending on the long-term monitoring results compared with threshold values for the monitoring metrics used, modified or additional mitigation measures may be required in conjunction with subsequent monitoring.

8. REFERENCES

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Blackwater Gold Project

Follow-up Programs for Condition 3.14 of the Blackwater Gold Project Decision Statement Issued under Section 54 of the Canadian Environmental Assessment Act, 2012

April 2022

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April 2022

Blackwater Gold Project

Follow-up Programs for Condition 3.14 of the Blackwater Gold Project Decision Statement Issued under Section 54 of the Canadian Environmental Assessment Act, 2012

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ACRONYMS AND ABBREVIATIONS

Terminology used in this document is defined where it is first used. The following list will assist readers who may choose to review only portions of the document.

AEMP	Aquatic Effects Monitoring Plan
ATU	accumulated thermal units
BC	British Columbia
Blackwater or Project	Blackwater Project or Blackwater Gold Project
BW Gold	BW Gold LTD.
CAHS	Centre for Aquatic Health Sciences
CEA Agency	Canadian Environmental Assessment Agency (now Impact Assessment Agency of Canada)
CPUE	catch-per-unit-effort
DFO	Fisheries and Oceans Canada
DS	Decision Statement
EA	Environmental Assessment
EAO	British Columbia Environmental Assessment Office
FWSS	freshwater supply system
FWR	freshwater reservoir
GAUC	Guassian Area-Under-The-Curve model
IAAC	Impact Assessment Agency of Canada
IFN	instream flow needs
Lake 15	Lake 01538UEUT
Lake 16	Lake 01682LNRS
MaxN	maximum fish count in a video frame
NAAHP	National Aquatic Animal Health Program
New Gold	New Gold Inc.
OWM	Overwintering Mortality
Project	Blackwater Gold Project
QA/QC	quality assurance and control
RT-qPCR	Real time Polymerase Chain Reaction
SOPs	Standard operating procedures
UAV	Unmanned Aerial Vehicle

1. INTRODUCTION

The Blackwater Gold Project (Project) received a Decision Statement (DS) on April 15, 2019, under the Canadian Environmental Assessment Act, 2012 (CEA Agency 2019) and an Environmental Assessment Certificate #M19-01 on June 21, 2019, under the 2002 Environmental Assessment Act (EAO 2019).

Condition 3.14 of the DS requires the BW Gold Ltd.'s (BW Gold) to develop a Fish and Fish Habitat Follow-up Program as follows:

3.14 The Proponent shall develop, prior to construction and in consultation with Indigenous groups, Fisheries and Oceans Canada (DFO), and other relevant authorities, a follow-up program to verify the accuracy of the environmental assessment and determine the effectiveness of the mitigation measures as it pertains to adverse environmental effects of the Designated Project on fish and fish habitat. The Proponent shall implement the follow-up program during all phases of the Designated Project and shall apply conditions **2.9** and **2.10** when implementing the follow-up program. As part of the follow-up program, the Proponent shall:

3.14.1 conduct parasite and pathogen inventories in Lake 01538UEUT and Lake 01682LNRS prior to enlarging Lake 01682LNRS and connecting it to Lake 01538UEUT pursuant to condition 3.13 and compare the results of the parasite and pathogen inventories for the two lakes;

3.14.2 monitor, starting when the Proponent starts to pump water into Davidson Creek and continuing through until the freshwater supply system has been decommissioned, rainbow trout (*Oncorhynchus mykiss*) and Kokanee (*Oncorhynchus nerka*) populations in Davidson Creek, including:

3.14.2.1 community composition of rainbow trout (*Oncorhynchus mykiss*) and Kokanee (*Oncorhynchus nerka*), their absolute abundance, genetic structure and diversity;

3.14.2.2 absolute abundance of overwintering rainbow trout juveniles; and

3.14.2.3 characteristics of spawner populations through surrogate monitoring metrics including size at 50% maturity, redd counts and spawner distribution.

Condition 2.9 of the DS requires follow-up programs to verify the accuracy of the environmental assessment, determine whether modified or additional mitigation measures are required, and timely implementation if required.

Condition 2.10 of the DS requires consultation with Indigenous groups on the follow-up programs regarding opportunities for participation in their implementation.

1.1 Purpose and Objectives

The purpose of Fish and Fish Habitat Follow-up Program described herein is to fulfill the condition 3.14 of the federal DS.

The Fish and Fish Habitat Follow-up Programs are designed to first characterize baseline conditions for each of the indicators listed in the condition (e.g., characteristics of spawner populations). These indicators will then be monitored during different phases of the Project to determine, to the extent possible, if (a) variation from baseline conditions is occurring, (b) mitigation measures are effective, and (c) if the environmental assessment was accurate in terms of anticipated effects on the indicators.

2. FOLLOW UP PROGRAM 3.14.1: LAKES 15 AND 16 PARASITES AND PATHOGENS STUDY

2.1 Background and Approach

Lakes 15 and 16 are located at high elevation (~1345 m), in separate sub-watersheds that are divided by a narrow (~500 m) strip of land (Figure 1), with a 0.4 m difference between lake elevations. Lake 16 is the headwater lake of Davidson Creek, which is the main creek draining the mine site. Construction of a connector channel between the Lake 16 and Lake 15 is proposed (and required under Condition 3.13 of the DS) to preserve the Rainbow Trout population in Lake 16 that would otherwise be entirely isolated by the mine development in the upper and middle reaches of Davidson Creek (Figure 1). The purpose of condition 3.14.1 is to address the risk of introducing new parasites or pathogens to either of the lakes when they are connected, which could harm the populations of Rainbow Trout in either lake.

A parasite-pathogen study was designed by the BC Center for Aquatic Health Sciences (CAHS). Due to potential low fish numbers in Lake 15 and Lake 16, a non-lethal sampling approach was used (i.e., no sampling of Rainbow Trout tissue, which would have required sacrificing of fish). The study was initiated in September 2021 with a field program to collect gill swabs and mucus samples from Rainbow Trout in Lakes 15 and 16, as well as water samples. The purpose of the study is to test the samples for a suite of viruses, bacteria, and pathogens and thereby establish the degree of overlap between the parasite and pathogens present in each lake.

2.2 Field Methods

Standard fish sampling protocols (RISC 2001) were adhered to during the September 2021 field program. Rainbow Trout in Lakes 15 and 16 were captured primarily by angling, with some initial shoreline fyke net sets.

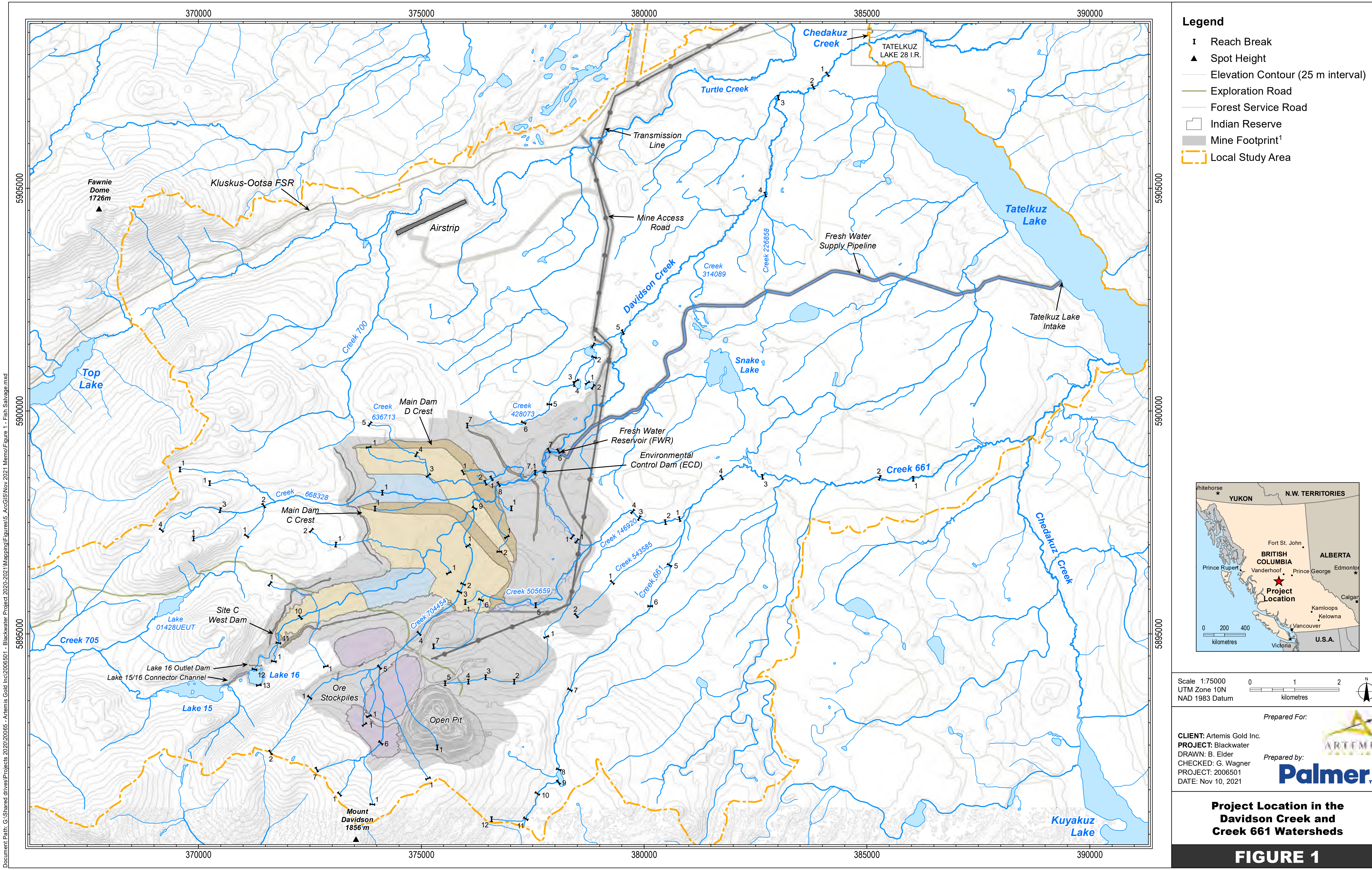
Gill swabs and mucus samples were collected from captured rainbow trout, and water samples were collected from each lake. Prelabelled microtubes and sample bags were used for each fish and swabs specific to viral or bacterial sampling were used for skin mucous and gills.

2.3 Laboratory Methods

Molecular assays for a list of NAAHP (National Aquatic Animal Health Program) parasites and pathogens of Rainbow Trout are currently being performed by CAHS. At CAHS, molecular assays are routinely used for fish screening using kidney tissues. However, these assays needed to be optimised for the non-lethal samples being used in this study which would contain low levels of parasites/pathogens genetic material relative to fish tissue samples.

A Real time Polymerase Chain Reaction (RT-qPCR) molecular assay was used that targets genetic material of the pathogen of concern. Specific primers (forward and reverse) and a probe had to be designed for each of the NAAHP diseases of concern for Rainbow Trout and Kokanee found in the lakes. Primers and probes already exist for testing samples for several well-known fish diseases, including Ceratomyxosis (*Ceratomyxa shasta*) and Whirling disease (*Myxobolus cerebralis*). Additionally, primers and probes have been developed for this study by CAHS for three major fish bacteria: *Renibacterium salmoninarum*; *Aeromonas salmonicida*; *Yersinia ruckeri*; and for four major fish viruses: Infectious Hematopoietic Necrosis Virus, Infectious Pancreatic Necrosis Virus, Infectious Salmon Anaemia Virus, and Viral Haemorrhagic Septicaemia Virus.

To prepare for analysis, each isolate was filtered and diluted 5 times in 10-fold dilution. Control swabs were dipped in each dilution to mimic the sample swabs. DNA was extracted from each swab using the Qiagen



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DNeasy blood and tissue kit (Cat# 69506) and as per CAHS SOP #17 v2.1. RT-qPCR was performed on the extracted DNA using the TaqMan qPCR kit (Applied Biosystems).

2.4 Reporting and Follow-up

Testing of the gill swab, mucus, and water samples from the two lakes is ongoing as of March 2022, and the results are expected to be reported in August 2022.

The report will be presented to Indigenous groups and DFO for consideration prior to construction of the connector channel between Lakes 15 and 16.

If the current study concludes that the parasite and pathogen communities in the two lakes are similar and joining them poses minimal risk of introducing new harmful parasites/pathogens to either lake, Artemis proposes that additional studies or monitoring will not be required. However, if the study is inconclusive or demonstrates that the lakes have differing parasite/pathogen communities and there is a risk of introducing one or more new parasite/pathogen to either lake, further work will be required. The scope of this future work would be developed in consultation with First Nations, DFO, and the Impact Assessment Agency of Canada (IAAC).

3. FOLLOW UP PROGRAM 3.14.2: DAVIDSON CREEK FISH POPULATIONS

3.1 Background and Approach

Development of the Project will cause a reduction in the catchment area of Davidson Creek, and, if un-mitigated, a corresponding reduction in flows in Davidson Creek downstream of mine. To mitigate this effect on flows, flow augmentation is proposed using a Freshwater Supply System (FWSS) that will pump water from Tatelkuz Lake to a freshwater reservoir (FWR) adjacent to Reach 6 of Davidson Creek (Figure 1).

For the first 5 years of mine operations, the FWR will store water diverted from the upper portions of Davidson Creek, and mine contact water that is suitable for release into Davidson Creek. Water will be released from the FWR into Davidson Creek to meet a defined Instream Flow Needs (IFN) for Rainbow Trout and Kokanee life stages.

Starting in Year 6 of Operations, water will be pumped from Tatelkuz Lake, and the FWR will also store and release water that is a mix of water diverted from the upper catchment, treated effluent, and Tatelkuz Lake water. The IFN identifies the timing of the streamflow rate in Davidson Creek that would be required to provide adequate habitat to instream aquatic species throughout the year.

The primary purpose of condition 3.14.2 follow-up program is to determine if the Project, and specifically flow augmentation from the FWSS, is affecting fish community composition, overwintering abundance and habitat use, and spawner populations during different Project phases. Several indictors require monitoring, with the aim of detecting changes that may be attributable to flow augmentation. The follow-up program currently proposes monitoring of the following:

- Community Composition
  - Young-of-year (YoY) and juvenile Rainbow Trout abundance (Condition 3.14.2.1);
  - Adult Kokanee and Rainbow Trout abundance and genetics (Condition 3.14.2.1 and 3.14.2.3);
- Rainbow Trout overwintering abundance and habitat availability (Condition 3.14.2.2);
- Spawner Populations
  - Rainbow Trout adult spawner and redd abundance (Condition 3.14.2.3);
  - Kokanee adult spawner and redd abundance (Condition 3.14.2.3); and
  - Kokanee fry outmigration assessment (surrogate metric for Condition 3.14.2.3).

Field programs were initiated in 2021 and are planned for 2022 to build upon and validate baseline information on fish populations in Davidson Creek, and to refine and select the field sampling methods that will be carried forward for the follow-up program through the life of the mine. The scope of 2022 field programs and the long-term 3.14.2 Follow-up Program study design will be further developed in consultation with First Nations.

3.2 Study Design

3.2.1 Community Composition (Sub-condition 3.14.2.1)

3.2.1.1 Davidson Creek Young-of-Year and Juvenile Rainbow Trout Abundance

To estimate absolute abundance of YoY (age 0+) and juvenile (and 1+ to 3+) Rainbow Trout, electrofishing surveys will be conducted at nine sites in Davidson Creek. At least one site will be located in each of the six reaches of Davidson Creek, as shown in **Figure 2.** At each site, sampling will include:

- Three-pass depletion electrofishing of stream sections 100 to 150 m in length, isolated with block nets;
- Identification of species and collection of length, weight, and body condition data for all fish captured;
- Measurement of channel dimensions and calculation of mean values of bankfull width, wetted width, water depth, and gradient; and,
- In-situ water quality measurements (i.e., temperature, dissolved oxygen, pH, and conductivity).

Sampling will occur during in late July, during the period after Rainbow Trout YoY emergence and before the arrival of spawning Kokanee adults in the downstream reaches of Davidson Creek. Sampling timing will be confirmed by calculating accumulated thermal units (ATU) using local stream and air temperature data. This calculated value will be compared to available emergence timing and ATU literature to estimate the timing window and variability of Rainbow Trout emergence dates. Results will be used to refine the juvenile sampling window for a given year. Observed emergence timing from field surveys will be compared to modelled emergence dates to validate and refine estimated emergence and ATU calculations.

At each site, sampling effort, electrofisher specifications, and catches will be recorded. Catch per unit effort (CPUE), relative abundance (number of fish per unit effort) and density metrics (number of fish per m^2) will be calculated and analyzed, as described in Section 3.3.1.1. Sampling frequency is described in Section 3.4.

The summer fish inventory measurement endpoints will include an inventory of the fish community and fish health (Table 3-1).

Table 3-1: Measurement and Assessment Endpoints for the Davidson Creek Young-of-Year and Juvenile Rainbow Trout Abundance

Measurement Endpoint	Assessment Endpoint
Fish inventory	Catch Per Unit Effort (CPUE) and fish density (fish/100 m^2) for each identified species, population structure
Fish health	Length, weight, condition

3.2.1.2 Davidson Creek Adult Kokanee and Rainbow Trout Abundance

Adult Rainbow Trout and Kokanee abundance will be estimated from spawner surveys, described in Section 3.2.3.

3.2.1.3 Rainbow Trout and Kokanee Genetic Structure and Diversity

The requirement (3.14.2.1) to monitor Rainbow Trout and Kokanee genetic structure and diversity will be met by employing the genetic study methodology used in the baseline studies to the extent possible and where feasible, as described in Taylor, 2012. This sampling methodology is described here, although it is recognized that adaptations may be warranted to account for advances in laboratory methods and genetic analysis techniques, based on subject matter expert guidance.

Samples of genetic material will be taken from Rainbow Trout and Kokanee populations that occur in lower Davidson Creek. As described in the Project’s baseline studies, two sub-populations of Rainbow Trout are understood to occur in Davidson Creek, separated by a cascade barrier in Reach 11: one in the lower reaches (i.e., downstream of the barrier) and one in the upper reaches and Lake 16 (i.e., above the barrier). This monitoring condition is specific to the effects on fish residing in Davidson Creek downstream of the mine site. Therefore, only the lower Davidson Creek sub-population of Rainbow Trout will be assessed as part of this program. Only a single identified population of Kokanee occur in Davidson Creek, so this population will also be assessed.

Rainbow Trout tissue samples will be taken from stream-resident juvenile fish caught in Davidson Creek during summer electrofishing sampling (Section 3.2.1.1). Kokanee tissue samples will be taken from mature adult fish returning to spawn. Adult, pre-spawn Kokanee will be sampled, rather than juvenile lake-resident Kokanee, to ensure that fish sampled are part of the Davidson Creek spawning population, since Tatelkuz Like likely contains fish from multiple stream-spawning populations. Migrating pre-spawn Kokanee adults will be captured in lower Davidson Creek using seine nets over an area with no observed actively spawning fish. A minimum of 30 samples will be collected for each species (i.e., 30 Rainbow Trout and 30 Kokanee). All fish sampled will be identified to the species level, measured for length and weight, sampled for tissue, then released back into stream site from which they were captured.

Tissue samples will be adipose and/or caudal fin clips, depending on tissue analysis volume requirements. Fin clips will be immediately placed into labelled vials containing 95% ethanol to minimize DNA degradation.

Polymerase chain reactions (PCR) of microsatellite DNA will be carried out on ten microsatellite loci of Rainbow Trout and six loci of Kokanee, previously identified in the baseline genetic analysis (Taylor, 2012).

Measurement and assessment endpoints have been selected with a focus on non-lethal monitoring of the fish community to the extent possible. The genetic measurement endpoint is a deviation from a population equilibrium (i.e., allele frequency is stable between generations; Table 3-2).

Table 3-2: Measurement and Assessment Endpoints for the Davidson Creek Young-of-Year and Juvenile Rainbow Trout Abundance

Measurement Endpoint	Assessment Endpoint
Genetic structure	Deviation from population equilibrium

3.2.2 Juvenile Rainbow Trout Overwintering (Sub-condition 3.14.2.2)

DS Condition 3.14.2 requires “absolute abundance of overwintering rainbow trout juveniles”. However, sampling of fish populations under ice during winter is logistically challenging and can present risks to human and fish health. Therefore, following discussion with representatives of IAAC and DFO (17 November, 2021), a technically feasible alternate assessment strategy was developed.

Juvenile Rainbow Trout overwintering surveys will include two assessment methods:

1. Mid-winter assessment of relative fish abundance using underwater cameras and evaluation of habitat characteristics at nine sites in Davidson Creek; and
2. Fall pre-overwintering and spring post-overwintering relative abundance surveys using three-pass electrofishing at five sites in Davidson Creek.

3.2.2.1 Mid-winter Assessment

Winter surveys will be conducted to assess overwintering abundance and habitat use at nine sites in Davidson Creek (Site 1 to Site 9; **Figure 2**). Potential overwintering sites were identified using winter 2022 field survey information, field reconnaissance and drone imagery from summer 2021 surveys (Section 3.2.3 Spawner Populations), and baseline stream habitat data. The mid-winter overwintering abundance and habitat assessment program will include measurement and assessment of:

1. Juvenile Rainbow Trout overwintering abundance at each selected site using underwater cameras. Cameras and underwater lights will be placed in an overwintering deep pool habitat within each site. Stationary high-quality video will be recorded for a standardized period (e.g., 60 minutes) during daytime. The video will be reviewed to determine relative abundance using the established metric of maximum count of individuals observed simultaneously in a video frame (MaxN; Hitt et al. 2020).
2. Overwintering habitat quality measurements including:
   - Snowpack depth;
   - Ice depth;
   - Water depth;
   - Pool area;
   - Instream cover types and abundance;
   - Pool crest water depth and velocity, and;
   - In-situ water quality (i.e., temperature, dissolved oxygen, pH, and conductivity).

At each site, recording time, camera and lighting specifications, habitat measurements, and water chemistry parameters will be recorded. MaxN values will be determined and habitat suitability will assessed, as described in Section 3.3.2.1. Sampling frequency is described in Section 3.4. The mid-winter overwintering survey measurement endpoints will include assessment of fish abundance and habitat suitability (Table 3-3).

Table 3-3: Measurement and Assessment Endpoints for the Mid-winter Juvenile Rainbow Trout Overwintering Assessment

Measurement Endpoint	Assessment Endpoint
Fish abundance	Maximum count of individuals observed simultaneously in a video frame (MaxN)
Habitat suitability	Flowing water is present and dissolved oxygen levels are greater than 5 mg/L

3.2.2.2 Fall Pre-overwintering and Spring Post-overwintering Assessment

Pre-and post-overwintering surveys will include three-pass electrofishing assessments of five sites in Davidson Creek (DCOH5 to DCOH 9; **Figure 2**). The methodology will follow that previously described in Section 3.2.1.1 for summer Rainbow Trout assessment.

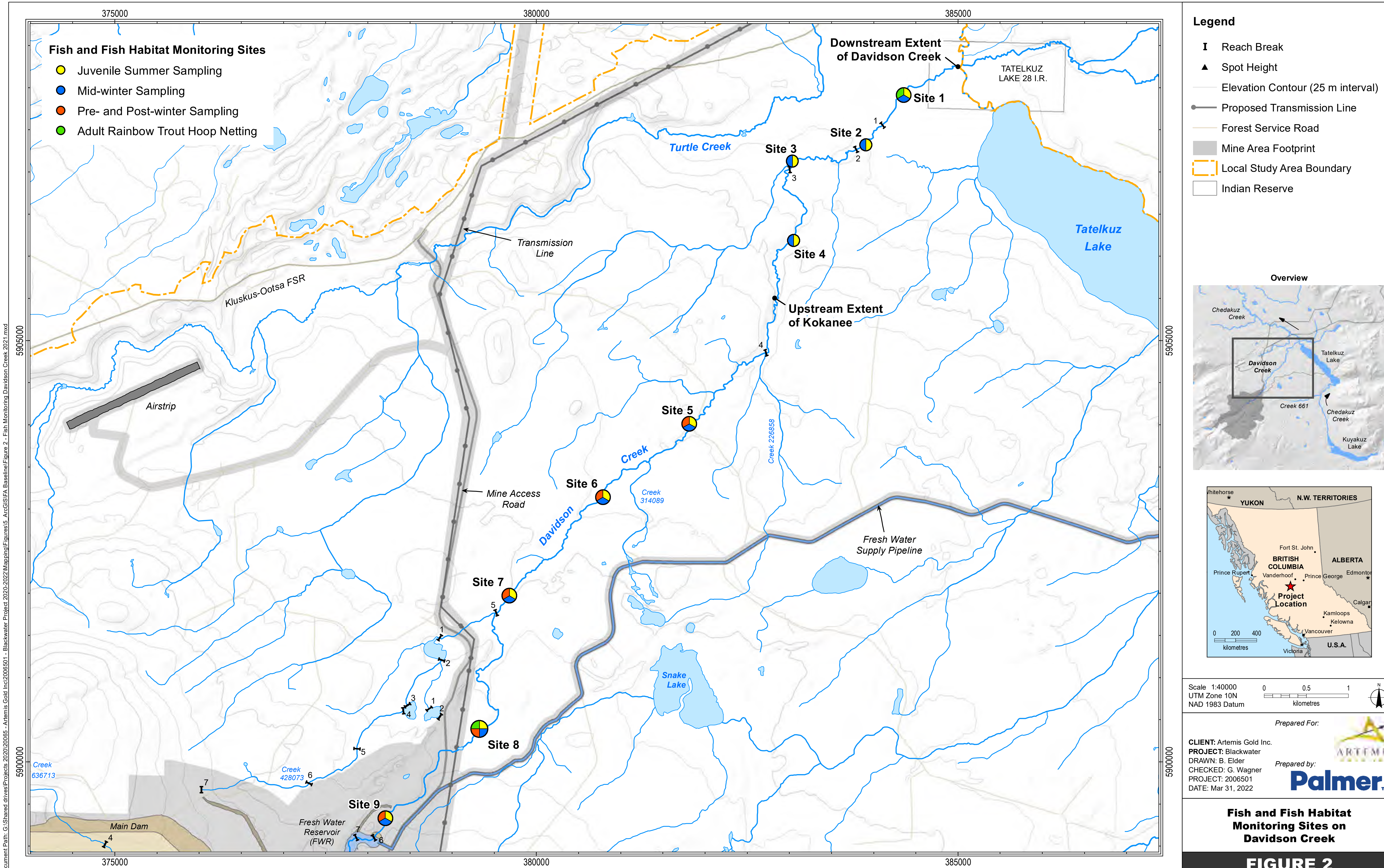
Sampling timing will vary, depending on seasonal differences in water temperature, ice cover, and discharge. Fall sampling will generally be conducted in late September, before water temperatures drop below 5°C and before ice cover forms. Spring sampling will be conducted shortly after ice-off, once temperatures reach 5°C and before spring freshet precludes effective electrofishing.

Notably, the five sites selected for assessment are less than the nine identified for summer YoY and juvenile sampling and overwintering assessment. This is due to the expected presence of incubating Kokanee embryos in the gravel substrates of the lower reaches of Davidson Creek. Electrofishing sampling will not be conducted in potential Kokanee spawning areas to minimize mortalities. Therefore, the four furthest-downstream sites (DCOH1 to DCOH 4) will not be sampled in fall or spring.

At each site, sampling effort, electrofisher specifications, and catches will be recorded. CPUE, relative abundance (number of fish per unit effort) and density metrics (number of fish per m^2) will be calculated and analyzed, as described in Section 3.3.2.2. Sampling frequency is described in Section 3.4. The pre-and post-winter overwintering survey measurement endpoints will include assessment of fish abundance and habitat suitability (Table 3-4Table 3-1).

Table 3-4: Measurement and Assessment Endpoints for Fall Pre-overwintering and Spring Post-overwintering Assessment

Measurement Endpoint	Assessment Endpoint
Fish inventory	Catch Per Unit Effort (CPUE) and fish density (fish/100 m^2) for each identified species, population structure
Fish health	Length, weight, condition



Fish and Fish Habitat Monitoring Sites on Davidson Creek

FIGURE 2

3.2.3 Davidson Creek Spawner Populations (Sub-condition 3.14.2.3)

DS Condition 3.14.3 requires assessment of "characteristics of spawner populations through surrogate monitoring metrics including size at 50% maturity". However, evaluating size at 50% maturity can require intensive lethal sampling to assess gonad development. Large-scale, annual lethal sampling is expected to negatively impact the Rainbow Trout and Kokanee population, will require an unfeasible lake and stream sampling program, and will be confounded by the migratory life history and lake-residence period of Rainbow Trout. Therefore, following discussion with representatives of IAAC and DFO (17 November, 2021) and additional consultation with First Nations and their technical consultants, an assessment of size at 100% maturity is proposed as an alternative to size at 50% maturity. To measure size at 100% maturity, body size (i.e., fork length and weight) of migrating pre-spawn fish (in the case of Rainbow Trout) or postorbital-hypural length of post-spawn mortalities (in the case of Kokanee), that are assumed to be 100% mature, will be measured and evaluated. This metric will be used to directly evaluate change in body size of mature fish that spawn in Davidson Creek.

3.2.3.1 Rainbow Trout Spawner Abundance

Adult Rainbow Trout spawner abundance and distribution will be directly assessed with two methods: capture of migrating spawners using hoop nets and visual assessment of spawners and redds.

Hoop Net Sampling

Direct sampling of migrating fish will involve intercepting mature fish during their annual pre-spawning migration into Davidson Creek. Migrating adult fish will be captured and counted using bi-directional hoop nets located at two sites: one site the furthest downstream reach of Davidson Creek, near its confluence with Chedakuz Creek (Site 1) and one site (Site 8) immediately downstream of the proposed mine access road in middle Davidson Creek (**Figure 2**).

The hoop netting program will include the following tasks:

- Installation and maintenance of bi-directional (i.e., upstream- and downstream-facing) hoop nets at each site;
- Regular (i.e., at least twice-daily) hoop net checks for fish, including:
    - Marking mature Rainbow Trout (i.e., those producing milt or eggs) with movement direction- and site-specific coloured and numbered floy tags to evaluate residence time and movement;
    - Enumeration of Rainbow Trout and measurement of weight, length, sex, and body condition; and
    - Testing for spawning ripeness (i.e., exuding milt or eggs) by lightly pressing on the abdomen.
- In-situ daily water quality measurement (i.e., temperature, dissolved oxygen, pH, and conductivity)
- Daily velocity measurements at the hoop net sites.

Fish capture data will be used to evaluate spawner numbers and distribution, as described in Section 3.3.3.1. Sampling frequency is described in Section 3.4. The Rainbow Trout spawner abundance measurement endpoints will include the number of migrating adult fish captured in hoop nets (Table 3-5).

Table 3-5: Measurement and Assessment Endpoints for Rainbow Trout Spawning Hoop Net Sampling

Measurement Endpoint	Assessment Endpoint
Fish abundance	Total number of adult spawners captured in hoop nets returning to Davidson Creek
Fish distribution	Number of adult spawners captured at each hoop net site in Davidson Creek
Fish size at 100% maturity	Weight and length of mature Rainbow Trout captured in hoop nets returning to Davidson Creek

Bank Walk Visual Assessment

Bank walk surveys also will be conducted the peak spawning period and post-spawn to estimate redd counts and identify areas of high spawning activity and the spawning distribution of Rainbow Trout within Davidson Creek.

The bank walk surveys will be completed at the two hoop netting sites in Davidson Creek, downstream of the FWR. Each survey zone will be located within the same reach as the hoop net site, although some site-specific adjustment will be needed to establish effective monitoring locations. Each survey zone will consist of a 500-m long section that contains likely spawning locations based on baseline Fish Habitat Assessment Procedure (FHAP) and RISC 1:20,000 habitat assessments from the baseline program (Johnston and Slaney 1996; RISC 2001; AMEC 2013) and field reconnaissance.

Each section will be surveyed twice during the annual Rainbow Trout spawning period: once at the ‘peak’ of spawning activity (i.e., after the furthest downstream hoop net upstream-movement catch has peaked, to assess the maximum number of fish in the assessment sections) and once post-spawning (i.e., after the furthest downstream hoop net downstream-movement catch has peaked, to assess the maximum number of redds). Exact survey time will depend on annual variability in run timing.

Each surveyed section will be walked once in an upstream direction by a pair of trained observers. Observers will record the number of redds and adult fish in each section. Geographic coordinates will be recorded for each redd (or redd complex if multiple redds occur in close proximity).

Fish and redd observation data will be used to evaluate spawner numbers and distribution, as described in Section 3.3.3.1. Sampling frequency is described in Section 3.4. The Rainbow trout bank walk assessment measurement endpoints will include assessment of fish and redd abundance and density (Table 3-6).

Table 3-6: Measurement and Assessment Endpoints for Rainbow Trout Spawning Bank Walk

Measurement Endpoint	Assessment Endpoint
Fish abundance	Number of adult spawners observed and their density at each survey sites
Fish distribution	Relative number of adult spawners observed at each survey site
Redd abundance	Relative number of redds observed and their density in each survey reach

3.2.3.2 Kokanee Spawner Abundance

Spawner Survey

Kokanee spawner surveys in Davidson Creek will include underwater camera surveys and bank walks to determine the total abundance of mature Kokanee entering Davidson Creek. The surveys will begin at the confluence of Chedakuz and Davidson creeks, extending through Reaches 1 to 4 of Davidson Creek (**Figure 2**), representing the full extent of documented Kokanee spawning.

Bank walk surveys will be conducted approximately once per week for the duration of the annual pre-spawning migration and spawning periods, typically beginning in late July and ending in early September, depending on environmental factors. Bank walk spawner and redd surveys that encompass the entire migration and spawning period allows the use of an area-under-the-curve (AUC) estimate of Kokanee spawner abundance, described further in Section 3.3.3.2.

The Kokanee spawner survey field program will include the following tasks:

- Installation of an underwater camera paired with a fish fence near the confluence of Davidson Creek and Chedakuz Creek to estimate the total abundance of fish entering Davidson Creek;
- Visual assessment of Kokanee spawners and redds via bank walks. Information collected during the bank walk surveys will include:
    - Kokanee counts (characterizing fish as either holding/migrating, spawning, spent, or carcass); and
    - Redd abundance, approximate location, and substrate type.
- Measurement of fork and postorbital-hypural lengths from carcasses;
- Collection of tissue samples (i.e., otoliths and fin clips) from carcasses; and
- In-situ water quality (i.e., temperature, dissolved oxygen, pH, and conductivity).

Surveys will be conducted in the upstream direction to reduce disturbing the sediment to maximize fish observability. As observers advance along the creek, live and dead observations will be recorded; live fish will be classified as holding/migrating (lively, fresh in appearance, absence of wear, unpaired male and female) or spawning (paired male and female) or spent (lethargic, presence of wear). Male and female mortalities will be counted and marked by chopping the fish posteriorly above the adipose fin to avoid recounts in subsequent surveys. Environmental conditions (e.g., percent bankfull, water temperature, water clarity, brightness, cloud cover, and precipitation intensity) will be documented.

A value of observer efficiency (OE) will be applied to each reach on each day to account for negative bias associated with spatial/temporal changes in observability. These correction factors are critical to AUC estimates because it allows inter- and intra-annual comparisons of fish counts within and between streams. Calibrated amongst crew members, OE will be subject to the surveyors' best judgement based on daily fluctuations of environmental conditions.

Tissue Sampling

Tissue samples collected opportunistically from carcasses and from live fish will be used for age measurement and for genetic analysis.

Otolith samples will be opportunistically gathered for age analyses to determine the age ranges of Kokanee spawners. The proposed target minimum sample size for otoliths is n=100 samples, although more samples could be collected, if carcasses are available, to increase the confidence of statistical analyses. These ageing structures will be removed and prepared (e.g., mounted, polished, or otherwise treated) as necessary. Age will determined by counting the number of annuli through a compound microscope. Age data will be analyzed to calculate a length-at-age relationship for mature fish. This information will be used to determine length and age at 100% maturity for the population.

Fin clip samples will also be taken from Kokanee spawners during the spawning survey to perform genetic analysis of the populations, as described in Section 3.2.1.3. Fin clips will be taken from live, pre-spawn, adult fish, gathered using seine net pulls from Davidson Creek. Migrating and holding fish will be targeted; no fish will be collected from active spawning areas. Fin clips will be stored in 95% ethanol for genetic analysis. PCR testing will be performed, including identification of microsatellite loci to be compared. Statistical tests will be performed on these data to estimate deviation from population equilibrium and population differentiation.

Kokanee spawner counts, redd counts, length measurements, and age data will be used to evaluate total escapement, distribution of spawners, and size at maturity, as described in Section 3.3.3.2. Sampling frequency is described in Section 3.4. The Kokanee bank walk visual assessment measurement endpoints will include assessment of fish abundance and habitat suitability (Table 3-7).

Table 3-7: Measurement and Assessment Endpoints for Kokanee Spawning Bank Walk

Measurement Endpoint	Assessment Endpoint
Fish abundance	Relative number of adult spawners and their density observed in each survey reach
Redd abundance	Relative number of redds and their density observed in each survey reach
Fish size at 100% maturity	Length and age at 100% maturity of Kokanee returning to Davidson Creek

3.2.3.3 Kokanee Fry Outmigration Survey

Kokanee fry outmigration abundance is an indicator of the success of the previous year’s Kokanee spawning activity and the overwinter survival of in-gravel Kokanee embryos. As such, a spring Kokanee fry outmigration survey in Davidson Creek will be completed to assess abundance as a surrogate metric for adult Kokanee spawning success.

Kokanee fry outmigration assessment will be completed using a sub-sampling mark-recapture method. Sampling will involve deploying fine-mesh nets of known dimensions into the channel at predetermined locations, according to the methods of Fraley and Clancey (1984). Each net will be sampled at a set interval and the fry captured will be enumerated and recorded. The duration of sampling period will be adjusted based on the numbers of fry netted and/or the amount of debris present, although it is expected to last approximately four weeks, based on literature review. Data including date, time, water depth, water temperature and weather conditions will be recorded. Sampling will be conducted once per week, between 19:00 hours and 02:00 hours as most (>90%) fry emigration occurs during this period (Thorp 1987, Manson 2005).

Capture efficiency of the nets will be determined using a mark-recapture approach by marking captured fry with Bismarck Brown Y and releasing them upstream of the capture location. Recaptured marked fish will be counted and the proportion of recaptured fish will indicate the trap’s effectiveness.

To inform sampling timing, accumulated thermal units (ATU) will be calculated using continuously measured stream and air temperature data. The results will be compared to available emergence timing and ATU literature to estimate the timing window and variability of Kokanee fry emergence dates. Results of this calculation will inform an approximate fry sampling window for a given year. Observed emergence timing data will be compared to modelled emergence to help validate and refine estimated emergence and ATUs.

Total fry emigration for each sampling period will be calculated and estimates for the entire emigration period extrapolated using flow rates, stream channel dimensions, and recapture rates, as described in Section 3.3.3.3. Sampling frequency is described in Section 3.4. The Kokanee fry outmigration measurement endpoints will include assessment of relative fish abundance and timing (Table 3-8).

Table 3-8: Measurement and Assessment Endpoints for Kokanee Fry Outmigration Survey

Measurement Endpoint	Assessment Endpoint
Fish abundance	Calculated total fry abundance for the outmigration period
Outmigration timing	Estimated start, finish, and peak timing of outmigration movement

3.3 Data Analysis

Statistical analyses will be used to evaluate changes over time. Power analyses have been performed, as appropriate, to support a study design that will allow for between-year comparisons and longer-term trend analysis. Between-year comparison (i.e., paired comparison between two separate annual datasets) will be completed to identify statistically differences in mean values using Analysis of Variance (ANOVA), or if the data are not normally distributed the equivalent non-parametric statistical test (e.g., Wilcoxon Signed-Rank Test). All statistical analyses will be performed using the R statistical system (R Development Core Team 2011). The significance level (α) = 0.05 will be used for all statistical tests, except as noted in specific analyses. In addition, year over year change will be assessed qualitatively, by comparing with the baseline data.

For longer time scale (i.e., five years and onwards), non-parametric Mann-Kendall temporal trends testing will be used to determine if there are significant temporal trends in any given monitoring metric, and if so, the direction and statistical significance of temporal trend. The sensitivity of the Mann-Kendall trends test increases with an increasing number of time steps (i.e., consecutive years of data) and it is considered that somewhere between five and ten time steps are a minimum requirement. Trends analyses will therefore begin following the fifth year of this monitoring program.

Additional metric-specific tests are described in the following section, where appropriate.

3.3.1 Community Composition

3.3.1.1 Davidson Creek Young-of-Year and Juvenile Rainbow Trout Abundance

Fish data will be transcribed from field notes and submitted to the ENV Fisheries Data Submission site.

Catch-Per-Unit-Effort (CPUE)

Fish community data will be summarized by calculating CPUE for each individual fishing effort and fish species captured. The CPUE will be calculated as the number of fish captured per sampling device per unit time as follows:

Electrofishing:

*CPUE=number of fish caught * [100/(electrofishing effort, hr)]*

The CPUE is an index of relative abundance that can be used to compare fish populations over time with the assumption that catch is proportional to the amount of effort for each gear-type used. For effects assessment, a Mann-Kendall temporal trends test will be undertaken for each site and compared between control and impact sites: this will require a minimum of five years of sequential monitoring data.

Density

Fish density values will be calculated by dividing the total number of fish caught in a closed site by the area of that site. Site area will be determined by multiplying a mean wetted width of the site by the length of the site. A minimum of three width values will be used to calculated mean wetted width.

Density values will be calculated for the total number of fish captured (i.e., all species), Rainbow Trout life stages (i.e., YoY and juveniles), and for any other species encountered.

Population Structure

Population structures of fish will be assessed using length and wight frequency distributions and length-weight regressions.

Fish Condition

Length-weight data will be plotted to visually assess the entire data set and to identify outliers. Once outliers are visually identified, potential explanations for the outlier values will be investigated and decisions will be made to either repair the outlier, include the outlier in data analysis, or remove the outlier from further analysis.

The length/weight data from reference sites and from historical data (Appendix 2-O, Fish and Aquatic Resources 2011 – 2012 Baseline Report; Appendix 2-P, Fish and Aquatic Resources 2013 Baseline Report) will be combined and a normal reference range will be calculated using specific length increments and the associated average weight data. The following equation will be used for definition of normal range:

$$log_{10}(W) = b * log_{10}(L) + a$$

where *W* = weight (g), *L* = length (mm), *a* = the intercept of the regression defined from the reference and historical data, and *b* = the slope of the regression defined from the reference and historical data.

The regression equation for the normal range will then used to calculate the $\log_{10}$ of expected weight as:

$$log_{10}(W_E) = b * log_{10}(L) + a$$

where W_E = expected weight (g), *L* = measured fork length (mm), *a* = the defined intercept of the regression and *b* = the defined slope of the regression. Residual $\log_{10}$(weight) values will then be calculated as the difference between expected and measured weight as:

$$W_R = W - W_E$$

where W_R = residual weight, *W* = measured weight, and W_E = expected weight. The median, 25th percentile, 75th percentile, and the interquartile range (IQR) for both negative and positive residuals will then be calculated. The upper and lower limits of the normal range of the residuals will then be calculated as:

$$NR_{UL} = 75\%ile + 1.5 \times IQR$$

$$NR_{LL} = 25\%ile - 1.5 \times IQR$$

where NR_{UL} = the upper limit of the normal range of the residuals, NR_{LL} = the lower limit of the normal range of the residuals, *IQR* = the interquartile range, 25%ile = 25th percentile value for the negative residuals, and 75%ile = 75th percentile value for the positive residuals.

The upper and lower limits of normal range for the length/weight linear regression will be calculated as:

$$log_{10}(W_{UL}) = (a - NR_{UL}) + b \times log_{10}(L\ \ )$$

$$log_{10}(W_{LL}) = (a + NR_{LL}) + b \times log_{10}(L\ \ )$$

where W_{UL} = normal range upper limit for weight (g), W_{LL} = normal range lower limit weight (g), L = fork length (mm), a = the intercept of the regression and b = the slope of the regression. The lower limit and upper limit of normal range will be used to assess the length/weight fit of fish from assessed sites relative to the normal range, both among years and among sites.

The relative condition (K_n) will be used as the metric for condition and will be calculated by comparing the measured weight to the expected weight from the measured length as:

$$K_n = \frac{W}{W_E}$$

where W = measured fish weight (g) and W_E = expected fish weight (g).

Relative condition will be statistically compared between sites. First, the distributions will be tested for normality using an Anderson-Darling test and if normally distributed, a single factor ANOVA followed by a Tukey's multiple comparison test will be computed to compare relative condition. If the data are not normally distributed, a Kruskal-Wallis test by ranks will be used with a Steel-Dwass test for multiple comparisons. Significance will be assumed when $p < 0.05$.

Site Selection Power Analysis

The number of monitoring sites was selected to provide adequate statistical power to detect a year-over-year change in the mean relative abundance value.

To inform this power calculation, the relative abundance of YoY and juvenile Rainbow Trout captured at the three 2021 survey sites are presented in Table 3-9. The two age groups were combined due to the low numbers captured in each reach.

Table 3-9. Relative Abundance of Combined Young-of-Year and Juvenile Rainbow Trout in Davidson Creek, 2021

Survey Site	Abundance (number of captured fish)	Relative Abundance (catch per unit effort)
DCJUVRB1 – Reach 1	13	0.87
DCJUVRB2 – Reach 5	32	0.56
DCJUVRB3 – Reach 6	24	0.56

To standardize the data used in this evaluation, single-pass electrofishing data was used for determining relative abundance, incorporating data from the original baseline work conducted in 2011 to 2013, and recent sampling in 2021. This data comparison provided a relative abundance mean/standard deviation (SD) from a total of 16 sites, for which ETA squared (i.e., measure of effect size that is commonly used in Analysis of Variance [ANOVA] models) was determined, as well as Cohens f statistic (i.e., a measure of standardized average effect in the population across all the levels of the independent variable; Cohen 1988) to use as an effect size derived from the sample population relative abundance data. An ANOVA was completed for CPUE by year using the Sum of Squares value for year and residuals from the ANOVA to evaluate an effect size of 0.576. Based on this value, the sample size required for 80% power (alpha = 0.05) is nine survey sites per year in Davidson Creek.

The abundance data collected using triple-pass depletion approach is expected to have a lower coefficient of variation over time when compared to the single-pass approach (used in the 2011-2013 baseline studies, and in 2021). As a result, the triple-pass approach has more statistical power to detect any trends or changes in abundance (George et al 2021). The proposed triple-pass method will lower the observed variance and allow for more powerful statistical evaluation. The data from the first pass of the triple-pass sampling also will be comparable to the single-pass baseline (2011-2013) and 2021 data to allow for historical comparison.

3.3.1.2 Davidson Creek Adult Kokanee and Rainbow Trout Abundance

Adult Kokanee and Rainbow Trout abundances are addressed in Section 3.3.3.

3.3.1.3 Rainbow Trout and Kokanee Genetic Structure and Diversity

Data analysis methods for genetic structure and diversity will broadly follow those described in Taylor (2012), summarized here. However, adjustments may be required to account for laboratory-specific analysis variation.

Tests will be performed using GENEPOP (Raymond and Rousset 2001). Tests for deviations from Hardy-Weinberg equilibrium will be performed for each locus-population combination using an exact test in which probability (P) values will be estimated using a Markov chain method. Tests for genotypic linkage disequilibrium for all combinations of locus pairs within a population will also be made using a Markov chain method with GENEPOP default values. Tests for population differentiation between all pairs of populations will be performed using FST estimated as θ (Weir and Cockerham 1984) as implemented in GENETIX (Belkhir et al. 2004). Significance levels will be determined correcting for multiple simultaneous tests following Narum (2006). Basic descriptive statistics of sample size (N), number of alleles (NA), observed (HO) and expected (HE) will be compiled using FSTAT (Goudet 2001). A factorial correspondence analysis (FCA) will be used to depict genetic similarity amongst all individuals in genetic space as inferred from variation in allele frequencies using GENETIX. A hierarchical partitioning of allele frequency variation to that between drainages, among localities within drainages, and within localities will be conducted using the analysis of molecular variance approach as implemented in ARLEQUIN (Excoffier et al. 2006).

The model-based Bayesian clustering analysis within STRUCTURE (Pritchard et al. 2000) will be used to assess population structure employing the admixture model with correlated allele frequencies and a burnin of 50,000 iterations followed by an additional 100,000 iterations, replicated three times. The simulations will be run with hypothesized numbers of populations (K) ranging from K = 1 to K = s+2 where s = the number of localities sampled (i.e., a total of K = 9). STRUCTURE HARVESTER will be used to process the results from multiple runs of STRUCTURE (Earl 2011). Given the relatively small spatial scale of the study (and an expected low level of genetic differentiation) and that fish were sampled largely within what are likely to be spawning tributaries, the STRUCTURE analysis will also use the locality prior option which employs prior knowledge of where each sample was collected to assist in clustering. The LOCPRIOR model works on the principle that individuals from the same sampling location often come from the same genetic population. Therefore, the LOCPRIOR operate to assume that the sampling locations can be informative about ancestry (Hubisz et al. 2009).

These calculations will be used to generate a description of the genetic condition of the assessed populations of Rainbow Trout and Kokanee. This data will be analyzed to evaluate change in allele frequency within the population over time.

3.3.2 Juvenile Rainbow Trout Overwintering

3.3.2.1 Mid-winter Assessment

Fish abundance will be estimated using the metric of the maximum count of individuals observed simultaneously in a video frame (MaxN), as described in Hitt et al. (2021). This value will be obtained by an observer reviewing the video footage while recording the number of fish present. Still frames will be captured to document the MaxN values.

Habitat suitability will be determined based on the presence of ice-free water beneath ice at the deepest point of the assessment site and adequate dissolved oxygen to support aquatic life. This threshold will be defined as 5 mg/L, based on BC's Approved Water Quality Guidelines for Aquatic Life for the instantaneous minimum water quality guidelines for all life stages other than buried embryo / alevin (BC MOECCS, 2021).

3.3.2.2 Fall Pre-overwintering and Spring Post-overwintering Assessment

Methods for analyzing fall pre-overwintering and spring post-overwintering data will follow those described in Section 3.2.1.1.

The fall pre-overwintering and spring post-overwintering relative abundance data will be used to determine overwintering survival. The estimated abundance and survival, will be determined with the relative abundance catch data from pre- and post-winter electrofishing effort adopting the approach of Trudel et al (2012) to determine overwinter mortality (OWM) outlined in below equation:

$$OWM = \left[1 - \frac{(CPUE_{spring})}{(CPUE_{fall})}\right] * 100$$

where $CPUE_{spring}$ and $CPUE_{fall}$, respectively, define the pre-overwintering and post-overwintering estimates of catch per unit effort.

3.3.3 Davidson Creek Spawner Populations

3.3.3.1 Rainbow Trout Spawner Abundance

Catches for each hoop net site and each movement direction (i.e., upstream and downstream) will be tabulated and used to calculate the number of Rainbow Trout spawners entering Davidson Creek.

Total adult abundance (i.e., the total number of unique adult fish captured migrating into Davidson Creek) will be determined based on the total number of unique floy tags applied to fish captured in hoop nets. Adult spawner distribution will be assessed by tabulating the relative numbers of fish captured at each hoop net site, moving each direction. Fish size at 100% maturity will be calculated by determining the mean length and weight values of all mature spawners encountered.

Bank walk survey data for each site will be evaluated to calculate relevant metrics. Total spawner abundance will be calculated for pooled and individual sites. Fish distribution will be assessed by comparing the relative number of fish observed at each site. Redd abundance will be determined by the maximum number of redds observed at each site during the survey period.

3.3.3.2 Kokanee Spawner Abundance

Spawner Abundance

An area-under-the-curve (AUC) method will be used to estimate escapement of spawning Kokanee based on periodic counts obtained through visual surveys. AUC methods calculate an escapement (E) estimate by taking the integral of the count data (expanded by observer efficiency) and dividing it by a value of survey life (SL; synonymous with residence time or stream life): E = AUC ÷ SL

Specifically, total escapement for Davidson Creek will using a gaussian area-under-the-curve (GAUC) model developed by Millar et al (2012) using the R Studio Environment (R Core Team, 2021). This method involves using a generalized linear model (GLM) with a quasi-Poisson family to fit to the OE-expanded count data. This method subsequently incorporates empirically derived stream-specific values of SL and OE and their uncertainty into the estimator. There is no historical information available for these values and their calculation would require a weir and a comprehensive study design that is outside the scope of the present study. Rather, OE was implicit through its application in periodic surveys, while a literature value of SL and its uncertainty was used similarly to Holt & Cox (2008).

This GAUC method will be used to generate estimates of total escapement and standard error, start and end dates of the spawning period, and peak spawning timing.

Redd Abundance

Redd abundance data will be tabulated for each surveyed reach and for each survey day. The highest count of redd abundance for each reach will be identified as used as the metric value for that reach. The total number of redds within Davidson Creek will be calculated as the total of maximum redd counts per reach.

Size at Maturity

Size at maturity will be calculated using the length, weight, and age data gathered for adult spawning Kokanee. Fish size at 100% maturity will be calculated by determining the mean postorbital-hypural length values of all mature spawners encountered. Age at 100% maturity will also be calculated by determining the mean age of Kokanee, based on otolith ageing.

3.3.3.3 Kokanee Fry Outmigration Survey

Total daily catch data will first be expanded, using an estimate of trapping efficiency, based on the mark-recapture-based estimate of trap effectiveness. To calculate total daily catch estimate, the following formula for the adjusted Peterson estimate will be applied (Ricker, 1975):

$$N = \frac{(M + 1) * (C + 1)}{R + 1}$$

Where: N = Daily fry estimate, C = Daily Catch, R = Number of Marks Recaptured, and M = Number of Marks Released

Kokanee fry outmigration abundance will then be estimated, based on the efficiency-adjusted daily fry estimate, using an AUC calculation method, similar to that used for adult Kokanee, described in Section 3.3.3.2.

3.4 Frequency and Duration

The monitoring programs for community composition, overwintering abundance and habitat use, and spawner populations will occur during all phases of the Project.

Starting in Construction phase, the frequency of Condition 3.14.2 FUP will initially be annual for all sampling components. However, certain monitoring components will be conducted annually initially with a framework to decrease sampling frequency by one year after each three-year period in which no effects are identified, to a minimum sampling frequency of once every three years. Once sampling frequency is decreased to once every two or three years, frequency would be increased again by one year if effects were identified, up to a maximum frequency of annually. Specifically, these components are the Rainbow Trout YoY and juvenile abundance surveys (Section 3.2.1.1) and Rainbow Trout overwintering surveys (Section 3.2.2).

Rainbow trout spawning surveys and kokanee spawning surveys and escapement surveys (Section Davidson Creek Spawner Populations (Sub-condition 3.14.2.3)3.2.3) will be completed on an annual basis for at least the two years of Construction and the first eight years of Operations, to ensure that at least two complete kokanee cohort generations are assessed. Beyond the eight-year mark of Operations, survey frequency for fish community could be reduced to once every two years, if no trend (changes) in fish community is observed.

The genetic sampling frequency (Section 3.2.1.3) will be every four years, to allow time for potential detectable genetic drift to occur, and to coincide with the four-year life cycle of Kokanee spawners.

Monitoring frequency of all FUP components for Closure and Post-Closure phases will be determined near the end of the Operations phase and will depend on monitoring results during that phase.

4. IMPLEMENTATION SCHEDULE

Follow-up Programs 3.14.1 (Parasite Pathogen Study) and 3.14.2 (Davidson Creek Populations) were initiated in 2021-2022 through field programs to select sites, refine field sampling methods, and collect baseline data prior the start of Construction. The programs will be ongoing throughout the life of the Project.

5. ADAPTIVE MANAGEMENT

The follow-up programs for Condition 3.14 described herein will evolve over time in response to the results of the monitoring, changing conditions or development at the Project, updates to methods, and through consultation with Indigenous groups, regulators, or other stakeholders. This process of continuous improvement with changing conditions is referred to as adaptive management.

Conditions 2.5 and 2.6 in the federal DS identify requirement for follow-up programs:

"2.5 The Proponent shall, where a follow-up program is a requirement of a condition set out in this Decision Statement, have a Qualified Professional, where such a qualification exists for the subject matter of the follow-up program, determine, as part of the development of each follow-up program and in consultation with the party or parties being consulted during the development, the following information:

2.5.1 the follow-up activities that must be undertaken by a qualified individual;

2.5.2 the methodology, location, frequency, timing and duration of monitoring associated with the follow-up program;

2.5.3 the scope, content, format and frequency of reporting of the results of the follow-up program;

2.5.4 the levels of environmental change relative to baseline conditions that would require the Proponent to implement modified or additional mitigation measure(s), including instances where the Proponent may require Designated Project activities to be stopped; and

2.5.5 the technically and economically feasible mitigation measures to be implemented by the Proponent if monitoring conducted as part of the follow-up program shows that the levels of environmental change referred to in condition 2.5.4 have been reached or exceeded.

2.6 The Proponent shall update and maintain the follow-up and adaptive management information referred to in condition 2.5 during the implementation of each follow-up program in consultation with the party or parties being consulted during the development of each follow-up program."

Thus, an adaptive management framework has been incorporated into the follow-up programs. Figure 3 identifies the components of the adaptive management framework.

Figure 3. Adaptive Management Framework

Plan: In collaboration with the Indigenous groups, further refine and plan Follow up Programs 3.14.1 and 3.14.2.

Do: Implement Follow-up Programs 3.14.1 and 3.14.2.

Monitor: BW Gold will review and update the follow up programs over the life of the Project. This will include:

- Review of the programs in terms of effectiveness in detecting changes with the monitoring program;
- Recommendations provided by qualified individual and Indigenous groups on the monitoring plan; and
- Engagement tracking to record input from Indigenous groups.

Adjust: BW Gold will adjust the follow-up programs (e.g. study design, field methods, data analysis methods, and reporting) based on program findings, as well as input and feedback from Indigenous groups.

5.1 Follow-Up Program Trigger Response

To determine 'the levels of environmental change relative to baseline conditions that would require the Proponent to implement modified or additional mitigation measure(s)' entails establishing levels (i.e., triggers), that, when reached, trigger a response action.

Changes in the monitoring metrics for fish populations (e.g., fish abundance, density, spawner escapement, fry emigration), may reflect natural variability and it is challenging to pinpoint whether a significant change is attributable to mine activities (namely, flow augmentation). Establishing triggers provides an early-warning system, allowing sufficient time to investigate root causes, increase monitoring, and take preventative action (i.e., implement modified or additional mitigation measure(s)).

Statistical analyses, described in Section 3.3, will be used to evaluate changes over time. Power analyses have been performed to support a study design that will allow for between-year comparisons and longer-term trend analysis. Between-year comparison (i.e., paired comparison between two separate annual datasets) will be completed to identify statistically differences in mean values. In addition, year over year change will be assessed qualitatively, by comparing with the baseline data.

For longer time scale (i.e., five years and onwards), non-parametric Mann-Kendall temporal trends testing will be used to determine if there are significant temporal trends in any given monitoring metric, and if so, the direction and statistical significance of temporal trend. The sensitivity of the MK trends test increases with an increasing number of time steps (i.e., consecutive years of data) and it is considered that somewhere between five and ten time steps are a minimum requirement. For the first four years of monitoring, temporal trends analysis will not be possible, however a Trigger Action Response Plan for fish habitat endpoints has been established that is based on triggers for flow and temperature. This is outlined in the Aquatic Effects Monitoring Program (AEMP) for the Project.

Table 5-1 identifies triggers and responses for adaptive management related to fish population monitoring as part of follow-up programs 3.14.2. There are no triggers proposed for follow-up program 3.14.1 (Parasite Pathogen Study), as the study will be completed prior to Construction and connecting of Lakes 15 and 16 the study findings will inform next steps and further actions.

Table 5-1.: Adaptive Management Triggers and Responses

Trigger	Response
No trend in monitoring metric (i.e., stable over time) or upward trend (e.g., increase in fish abundance)	Inform Indigenous groups No change to mitigation measures Consider reduction in the frequency of monitoring
Downward trend monitoring metric (e.g., decrease in fish abundance)	Inform Indigenous groups Identify potential causes and additional studies to test hypotheses Implement modified or additional mitigation measures Monitor post-implementation of the modified or additional mitigation measures and communicate results Evaluate if new mitigation or fish offsetting measures are required

In the case of negative adverse effects to fish populations that deviate from the predictions of the EA, there are limited additional mitigation measures available. Flow augmentation from the FWR/FWSS can be controlled for flow and temperature, and relative proportions of the different sources of water can be adjusted (i.e., increase the input from the diversions, reduce volume of Tatelkuz Lake water). However, BW Gold's fish habitat offsetting plan, includes habitat creation, restoration, or enhancement projects in the Davidson Creek watershed to offset the predicted effects on fish productivity and includes measures to benefit other fish populations in the region. If effects are beyond what was predicted in the Environmental Assessment and the Fisheries Offsetting Plan (Palmer, 2021), additional offsetting may be required.

6. REPORTING

DS Conditions 2.11, 2.12 and 2.13 set out annual reporting requirements related to the implementation of conditions in the DS. Condition 2.14 sets out information sharing requirements related to the annual reports.

DS Condition 2.11 requires:

> *"The Proponent [BW Gold] shall, commencing in the reporting year during which the Proponent begins the implementation of the conditions set out in this Decision Statement, prepare an annual report that sets out:*
>
> *2.11.1 the activities undertaken by the Proponent in the reporting year to comply with each of the conditions set out in this Decision Statement;*
>
> *2.11.2 how the Proponent complied with condition 2.1;*
>
> *2.11.3 for conditions set out in this Decision Statement for which consultation is a requirement, how the Proponent considered any views and information that the Proponent received during or as a result of the consultation, including a rationale for how the views have, or have not, been integrated;*
>
> *2.11.4 the information referred to in conditions 2.5 and 2.6 for each follow-up program;*
>
> *2.11.5 the results of the follow-up program requirements identified in conditions 3.14, 3.15, 3.16, 4.5, 5.5, 6.11, 6.12, 6.13, 6.14, 8.18.6, 8.20.5, 8.21, and 8.22 if required;*
>
> *2.11.6 any update made to any follow-up program in the reporting year;*
>
> *2.11.7 any modified or additional mitigation measures implemented or proposed to be implemented by the Proponent, as determined under condition 2.9 and rationale for why mitigation measures were selected pursuant to condition 2.5.4; and*
>
> *2.11.8 any change(s) to the Designated Project in the reporting year."*

DS Condition 2.12 requires: *"The Proponent [BW Gold} will provide the draft annual report to Indigenous groups, no later than June 30 following the reporting year to which the annual report applies. BW Gold will consult Indigenous groups on the content and findings in the draft annual report."*

DS Condition 2.13 requires: *"The Proponent [BW Gold], in consideration of any comments received from Indigenous groups pursuant to condition 2.12 shall revise and submit to the Agency [Impact Assessment Agency of Canada] and Indigenous groups a final annual report, including an executive summary in both official languages, no later than September 30 following the reporting year to which the annual report applies."*

DS Condition 2.14 requires: *"The Proponent [BW Gold] shall publish on the Internet, or any medium which is publicly available, the annual reports and the executive summaries referred to in conditions 2.11 and 2.13."*

The Proponent shall keep these documents publicly available for 25 years following the end of decommissioning of the Designated Project. The Proponent shall notify the Agency and Indigenous groups of the availability of these documents within 48 hours of their publication."

Reporting in compliance with these conditions will commence when BW Gold begins to implement the follow-up programs. BW Gold will implement the follow up programs during all phases of the Project, as stipulated in the DS.

7. SUMMARY

The follow up programs herein have been developed to fulfill DS condition 3.14. This condition pertains to conducting an inventory of parasites and pathogens in two lakes that will be joined by a connector channel, and monitoring fish populations in Davidson Creek downstream of the Project. The follow up programs cover data collection during pre-construction (2021-2022), through to decommissioning.

Information from these programs will be used for comparison during long-term monitoring over the life of the Project to determine the accuracy and effectiveness of mitigation measures, as set out in Condition 2.9. Depending on the long-term monitoring results compared with threshold values for the monitoring metrics used, modified or additional mitigation measures may be required in conjunction with subsequent monitoring.

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Appendix Q

Complementary Measures Proposal

Palmer™

470 Granville Street, Suite 630, Vancouver, BC V6C 1V5
Tel: 604-629-9075 | www.pecg.ca

Blackwater Complementary Measures Proposal

Evaluating Watershed Disturbances That Affect Fish in the Upper Fraser River

[redacted]

Palmer Project #
2006501

[redacted]

Prepared For
Blackwater Gold Inc.

July 9, 2021

Palmer™

470 Granville Street, Suite 630, Vancouver, BC V6C 1V5
Tel: 604-629-9075 | www.pecg.ca

July 9, 2021

Ryan Todd, Vice President, Environment and Social Responsibility
Blackwater Gold Inc.
Suite 3083 – 595 Burrard Street
Vancouver, B.C.
V7X 1L3

Dear Ryan Todd,

Re: Blackwater Project Complementary Measures Proposal
Project #: 2006501

Palmer, in collaboration with researchers from the University of Northern British Columbia, is pleased to submit this complementary measures research proposal in support of a *Fisheries Act* Authorization submission for the proposed Blackwater project. The proposed research is multi-disciplinary and will focus on evaluating stream temperature and aquatic ecology, sediment dynamics, hydro-climatology, and improving applied modelling techniques for evaluating watershed disturbances and fish in the upper Fraser River watershed. **This work is intended to inform future conservation and remediation initiatives by improving the understanding of watershed-scale impacts to fish in the upper Fraser River watershed.**

Our research team is excited about the potential to form a collaborative relationship to advance this work. If you or technical reviewers have any questions about this report, please feel free to contact Rick Palmer at 604-629-9075 or at rick.palmer@pecg.ca.

Yours truly,

Palmer™

<original signed by>

Rick Palmer, M.Sc., R.P.Bio.
President & CEO, Senior Fisheries Biologist

Executive Summary

Blackwater Gold Inc. (BW Gold) proposes to develop the Blackwater Project (the Project), an open pit gold mine, in central British Columbia, approximately 110 kilometres (km) southwest of Vanderhoof, and approximately 160 km west-southwest of Prince George. The proposed mine consists of an open pit, ore processing facilities, a tailings management facility, a freshwater supply system, waste rock dumps and stockpiles, camps, a transmission line, and access roads.

The Project design minimizes impacts to fish and fish habitat through re-design, refinement, and mitigation measures; however, some residual loss of fish habitat is predicted to occur due to its development. Palmer was retained by BW Gold to support the application for an Authorization under Paragraph 35(2)(*b*) of the *Fisheries Act*. In accordance with policies set by the Department of Fisheries and Oceans Canada, Palmer has developed a Fisheries Offsetting Plan to counterbalance unavoidable residual impacts to fish and fish habitat. One component of the proposed offsetting is a novel complementary measures research program that will support future conservation outcomes of the Fisheries Offsetting Plan for the Project area.

This document proposes a novel complementary measures research program relevant to the upper Fraser River region, where the Project is situated. The work will engage fisheries regulators, academics, consultants, industry partners, and local Indigenous groups in a collaborative effort to address knowledge gaps and improve current offsetting methods with the intent that this research benefit future projects in the upper Fraser River watershed. The research program is focused in two main tributaries (Davidson Creek, and the Stellako-Nautley Rivers) to leverage existing data collection networks. Given the similarity in the physiography, climate, and historical watershed disturbances across the western portion of the upper Fraser River watersh[redacted]om these studies are expected to be generalizable across the entire region.

This complementary research program is based on the premise that future conservation and remediation initiatives should target the environmental variables that have the greatest influence on fish productivity to have the greatest chance at positively influencing fish communities and fish habitat. The proposed work is intended to address gaps in the current understanding of how different watershed-level stressors are affecting fish. The research program consists of four complementary, multi-disciplinary projects that will be conducted at the wa[redacted]nd are generally relevant to fisheries management in the upper Fraser River watershed:

- **Thermal ecology of rainbow trout in the Stellako River**
  This research program will be led by Dr. Eduardo Martins of University of Northern British Columbia (UNBC). The program will characterize the spatio-temporal variability in water temperature of the Stellako River, and quantify the subsequent energetic costs of thermoregulation of rainbow trout (*Oncorhynchus mykiss*) using both field data and laboratory analyses. The findings will inform how salmonids may respond to changes in water temperatures caused by climate or land-use change, and will inform the management of rainbow trout fisheries. In addition, the proposed research has the potential to inform how changes to the watershed may affect the development of sockeye salmon (*O. nerka*) embryos and fry.

- **Impacts of fine sediment on salmonid habitats in the Nautley watershed**
  This research program will be led by Dr. Phil Owens of UNBC. The objective of the program will be to investigate fine sediment and associated contaminant dynamics in two key sub-watersheds of the Nautley watershed. The findings will identify the source of the sediment and any associated contaminants using chemical analysis and fingerprinting techniques, and will be able to inform management practices and policy advice such as soil protection measures and riparian buffers.

- **Past and future trajectory of the hydroclimate and water temperatures in the Nautley Watershed**
  This research program will be led by Dr. Stephen Déry of UNBC. The objective of the study is to evaluate a new technique to estimate streamflow in ungauged basins using temperature data and to characterize the past and potential future impacts of climate change on the hydrology and water temperatures of the Nautley Watershed. This study will produce predictions of how stream temperature and streamflow regimes may change in the future, which will allow for more informed planning and decision-making regarding fisheries and aquatic resources.

- **Improved methods for quantifying the effects of land-use change on fish**
  This research program will be led by a collaboration of scientists from Palmer. The objective of the study is to demonstrate a new modelling approaches that quantify how watershed-scale environmental changes affect fish habitat, and to use this framework to conduct a sensitivity analysis to identify the environmental variables to which rearing and spawning fish are most sensitive. This study will produce information to inform the development of restoration and management activities that target the environmental variables that have the greatest impact on fish health.

[redacted]

A key component [redacted] project is the creation of an Advisory Group, which may contribute traditional knowledge, provide oversight and direction to the project, and/or provide an avenue to coordinate engagement and the dissemination of research. Key Advisory Group members in this region may include representatives from the Lhoosk'uz Dené First Nation, Ulkatcho First Nation, Nadleh Whut'en First Nation, Saik'uz First Nation, and Stellat'en First Nation, the Nazko First Nation, and the Provincial and Federal governments.

[redacted]

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1. Introduction

Blackwater Gold Inc. (BW Gold) is proposing the development of the Blackwater Project (the Project), an open pit gold mine located in central British Columbia (B.C.), approximately 110 km southwest of Vanderhoof and 160 km southwest of Prince George. Following a joint provincial and federal review, this Project was issued an environmental assessment (EA) certificate of approval in 2019. Since the Project will entail the construction and operation of the mine within and adjacent to aquatic environments frequented by fish, its development will require a *Fisheries Act* Authorization. To support the *Fisheries Act* Authorization process, BW Gold retained Palmer to design and prepare a Fisheries Offsetting Plan for the Project. The purpose of this document is to propose a complementary measures research program, which is one of the offsetting strategies to counterbalance unavoidable residual impacts to fish and fish habitat for the Project.

The Project will consist of an open pit mine, a tailings storage facility (TSF), the construction of roads, and other mine infrastructure located within the Davidson Creek watershed. Davidson Creek supports rainbow trout (*Oncorhynchus mykiss*) and kokanee (*O. nerka*); rainbow trout and kokanee are widely distributed in the lower reaches of Davidson Creek and nearby watercourses, but only rainbow trout frequent the headwaters of Davidson Creek. The study area is currently unimpacted by industrial projects, limited to traditional and non-traditional land-uses in the lower portion, and generally undisturbed in the upper reaches of the mine site area.

The Project is located in the upper Fraser River watershed. Tributaries of the upper Fraser River provide important rearing and spawning habitat for salmonids, including Pacific salmon, trout and charr. In the upper Fraser River watershed, freshwater ecosystems are affected by climate change, logging, forest fires, agricultural development and other anthropogenic influences (Picketts et al., 2016). The impacts of logging include changes to t[redacted]me, stream temperature, and increased sediment inputs into streams (Bladon et al., 2018; [redacted]; Moore et al., 2020). Climate change is expected to result in warmer air temperatures and variable precipitation patterns (Pacific Climate Impacts Consortium [PCIC], 2013), which will affect streamflow and water temperature. Agriculture and ranching operations impact streams by reducing riparian vegetation and destabilizing stream banks. While these impacts are generally understood on a regional basis, there is often significant local variability. These environmental stressors cause changes to streamflow, water temperature, water quality, and habitat availability, all of which affect fish and fish habitat. Due to the confounding nature of these impacts, understanding the relative impacts of these environmental stres[redacted]challenging. These issues are particularly poorly understood in tributary streams that lack da[redacted]vide important rearing and spawning habitat. This region has received further stress from events such as the recent 2019 Big Bar Landslide, which blocked upstream salmon migrations and rendered many salmon populations at risk for extirpation. For example, due to the migration timing of Fraser River early Chinook salmon (*O. tshawytscha*) and early Stuart Sockeye salmon (*O. nerka*) populations coinciding with high spring flows, these populations were unable to pass the velocity barrier at the Big Bar landslide and 89% and 99% mortality, respectively, was estimated in 2019 by Fisheries and Oceans Canada officials (CBC, 2020). Collectively, these issues have caused a conservation emergency for salmon fisheries in this region and research to better understand the relationship between fish health and environmental stressors is urgently needed.

The cumulative impacts to fish and fish habitat from changes in land use, forest fires and climate change are especially concerning considering several Fraser River Pacific salmon Conservation Units (CUs) within the Middle and upper Fraser drainages have shown declining trends in abundance over recent decades (Salmon Watersheds Program, 2016). Almost half of the Fraser Sockeye CUs have been placed in the Wild Salmon Policy (WSP) 'Red status zone' (Fisheries and Oceans Canada [DFO], 2018) with most of these WSP Red CUs identified as Endangered by The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in its recent assessment (COSEWIC, 2017). Chinook salmon have shown a declining trend in abundance from Oregon to Alaska, including throughout B.C. Abundances of Chinook salmon are reaching critically low levels in southern B.C., where recent status assessments have placed over half of the assessed Chinook CUs in the WSP Red status zone and COSEWIC has determined that many of the CUs in the B.C. Interior are Endangered or Threatened, including the three CUs that spawn and rear within the Nechako River drainage (DFO, 2016; Grant et al, 2019). Fraser River Coho salmon (*O. kisutch*) have shown consistently low abundances for the past two decades and Interior Fraser River CUs (which includes the Nechako Watershed) were recently placed in the Amber WSP status zone (DFO, 2015), and identified as Threatened by COSEWIC (COSEWIC, 2016). Unfortunately, large areas of the Interior Fraser Coho distribution are data deficient, including within the Nechako River system, so true abundance and population status is not known, but inferred based on available information according to the methodology of COSEWIC (2016). Pacific salmon are a treasured resource in B.C. and many CUs, in the upper and middle Fraser River, including the Nechako River drainage, are currently imperilled. The status of these CUs demonstrates the necessity of further conservation and research efforts in the relationship of the health of these fish to the impacts of environmental stressors found in the upper and middle Fraser River regions.

In response to the dramatic declines in fish populations (Riddell et al., 2018), it is anticipated that significant Advisory Group interest will continue to be directed towards conservation and remediation initiatives in the upper Fraser River watershed in the coming years. Recently, DFO also announced a $647 million investment to fund a Pacific Salmon Strategy Initiative in the fields of conservation and stewardship, hatchery production [redacted]rmation, and integrated management and collaboration. However, there is currently sti[redacted] information available that characterizes watershed-scale stressors and how they affect fish in small- to medium-sized tributaries of the upper Fraser River, which is necessary information for designing effective conservation and remediation strategies. The salmonid populations in the upper Fraser River watershed are also an important traditional and cultural resource for local First Nations. Salmon and trout are an important food source. The declining fish populations have direct, negative impacts related to food security and health of the affected First Nations.

This complementary [redacted]ram will help fill this data gap and help address issues related to the management of sal[redacted]ood source. The overarching premise of the proposed studies is that for future conservation [redacted]ediation initiatives to have the greatest chance at positively influencing fish, they should target the environmental variables that have the greatest influence on fish productivity. The findings from these studies will support future conservation and remediation initiatives by quantifying environmental variables that present the greatest risk to fisheries in tributaries to the upper Fraser River. The outcomes of this proposed research will also provide guidance and direction to develop management actions to improve the management of salmonids and availability of salmonids as a food source for the affected First Nations.

1.1 Relevance to the Blackwater Project

The construction of the mine infrastructure on the Davidson Creek and Creek 661 watersheds may result in reduced streamflow, changes to water temperature, and changes in the sediment dynamics within the watersheds. These changes parallel many of the issues that are occurring within the western portion of the upper Fraser River watershed. Although the proposed watershed disturbance for the Project would be caused by mining, and not widespread land-use (i.e. forestry) or climate change, the Project activities highlight some of the knowledge gaps related to watershed disturbance and the methods used to characterize them in the region.

For example, to address the expected loss of fish habitat in Davidson Creek, numerous strategies are being proposed to mitigate and offset loss of fish habitat through the *Fisheries Act* Authorization submission. One component of the proposed mine design is a Freshwater Supply System (FWSS) that will augment flows in Davidson Creek, downstream of the mine footprint, with water extracted from the nearby Tatelkuz Lake. Water temperatures in Davidson Creek will also require active management so that they minimize the potential impacts to fish. The development and design of these mitigation and offsetting strategies relies on current science that describes the aquatic ecology of the region, as well as existing habitat modelling techniques that are used to quantify how environmental changes affect fish. Therefore, the quality of, and confidence in, these mitigation and offsetting strategies are dependent on the quality and applicability of current research in the region, as well as the robustness of existing modelling techniques. Any knowledge gaps, limitations, or assumptions of the current research and modelling approaches will also apply to the work conducted to evaluate the Project, as well as subsequent resource development projects.

1.2 Research [redacted]

To address the vari[redacted]ature of issues that are facing the upper Fraser River watershed, we are proposing a multi-disciplinary complementary measures research program. The research program is intended to address knowledge gaps and limitations relevant to the Project area and, more generally, the western portion of the upper Fraser River watershed. It is expected that this study will advance our knowledge of watershed stressors (sediment dynamics, streamflow regime, water temperature) that affect fish and fish ecology. Furthermore, it will advance new and innovative techniques that can be used to model how these impacts affect fish and fish habitat. Specifically, four distinct projects are proposed that focus on stream temperature[redacted]cology, sediment dynamics, hydro-climatology, and improving applied modelling technique[redacted]esearch projects are summarized below and are presented in more detail in Section 5.

- **Thermal ecology of rainbow trout in the Stellako River**. This research program will be led by Dr. Eduardo Martins of UNBC. The objective of the program will be to characterize the spatio-temporal variability in water temperature of the Stellako River, and to quantify the subsequent energetic costs of thermoregulation of rainbow trout. The findings will inform how salmonids may respond to changes in water temperatures caused by climate and land-use change, and will inform the management of rainbow trout fisheries. In addition, the proposed research may inform how changes to the watershed may affect the development of sockeye salmon embryos and fry.
- **Impacts of fine sediment on salmonid habitats in the Nautley watershed.** This research program will be led by Dr. Phil Owens of UNBC. The objective of the program will be to investigate fine

sediment and associated contaminant dynamics in two key sub-watersheds of the Nautley watershed. The findings will identify the source of the sediment and any associated contaminants, and will be able to inform management practices and policy advice such as soil protection measures and riparian buffers.

- **Past and future trajectory of the hydroclimate and water temperatures in the Nautley Watershed.** This research program will be led by Dr. Stephen Déry of UNBC. The objective of the study is to evaluate a new technique to estimate streamflow in ungauged basins and to characterize the past and potential future impacts of climate change on the hydrology and water temperatures of the Nautley Watershed. This study will produce predictions of how stream temperature and streamflow regimes may change in the future, which will allow for more informed planning and decision-making regarding fisheries and aquatic resources.
- **Improved methods to quantify the effects of land-use change on fish.** This research program will be led by a collaboration of scientists from Palmer. The objective of the study is to evaluate the performance of a novel approach that quantifies watershed-scale environmental changes, and to use this framework to conduct a sensitivity analysis to identify the environmental variables to which rearing and spawning fish are most sensitive. This study will produce information to inform the development of restoration and management activities that target the environmental variables that have the greatest impact on fish health.

Photograph 1. Measuring erosion and sediment delivery after the Shovel Lake wildfire (Photo: Dr. Phil Owens).

This work will be c[redacted]y university researchers from the University of Northern British Columbia (UNBC) and scientists from Palmer. The work will engage fisheries managers, local Indigenous groups, and interest groups (as an Advisory Group) in a collaborative effort to address key concerns of Advisory Group members and fisheries regulators, improve current offsetting methods, and improve the planning and assessment of future industrial projects in the upper Fraser River watershed.

1.3 Complementary Measures as Fisheries Offsetting

Fisheries and Oceans Canada (DFO; 2019) states that complementary measures, which are actions such as data collection and scientific research related to maintaining or enhancing fish habitat, may comprise up to 10% of required offsetting. Complementary measures must fill knowledge gaps regarding fish and fish habitat to inform fisheries management projects and restoration priorities. Additionally, complementary measures must be consistent with the following guiding principles of habitat offsetting authorized under the *Fisheries Act*, where relevant:

- Measures to offset should support fisheries management objectives and give priority to the restoration of degraded habitat.
- Benefits from measures to offset should balance the adverse effects resulting from the works, undertakings, or activities. Complementary measures, specifically, may produce findings that indirectly support conservation initiatives, but are not expected to produce measurable, on-the-ground conservation outcomes.
- Measures to offset should provide additional benefits to the ecosystem.
- Measures to offset should generate self-sustaining benefits over the long term.

The research proposed herein aligns with these criteria in the following ways:

- A key outcome of the research is to conduct work to better understand the watershed-scale stressors that are affecting fish and fish habitat. Identifying the watershed stressors that are affecting fish and fish habitat, and understanding how they are doing so, will enable the development of targeted conservation and management initiatives that are specifically intended to address these stressors.
- The research team consists of local university professors and will be supported by a scientific advisory group of local scientists and resource managers that focus on the upper Fraser River watershed region. This will ensure that research topics are closely aligned with fisheries management objectives and issues that are relevant in the region.
- The proposed research will produce publicly available data and knowledge that can be used to support and inform conservation and remediation efforts that will generate self-sustaining benefits related to fish p[redacted]proving the local aquatic ecosystems over the long term.
- The funding tha[redacted]o support this research will advance knowledge in ways that would not otherwise be possible or realistic based on current financial and research constraints.
- The research findings will facilitate the development of management actions that address salmonid-related food scarcity issues for affected First Nations throughout the upper Fraser River watershed.
- The proposed research is an important component of the comprehensive Compensation Plan that is being developed to balance the adverse impacts that would be caused by the Project.

[redacted]

2. Applicant Information

BW Gold is a wholly-owned subsidiary of Artemis Gold Inc. (Artemis), and is the applicant for the complementary measures research program, discussed herein. Contact information for the applicant is as follows:

Name and Address of Owner
BW Gold LTD.
Suite 3083 – 595 Burrard Street
Vancouver, B.C.
V7X 1L3

Authorized Contact Person
Ryan Todd
Vice President, Environment and Social Responsibility
Telephone: 604 329 8179
Email: rtodd@artemisgoldinc.com

[redacted]

[redacted]

3. Research Team

To carry out the research program, Artemis intends to support a collaborative project team comprising various organizations. Curriculum Vitae for the proposed project team members are included in Appendix A and the organizational structure for the proposed research program is presented in Figure 1.

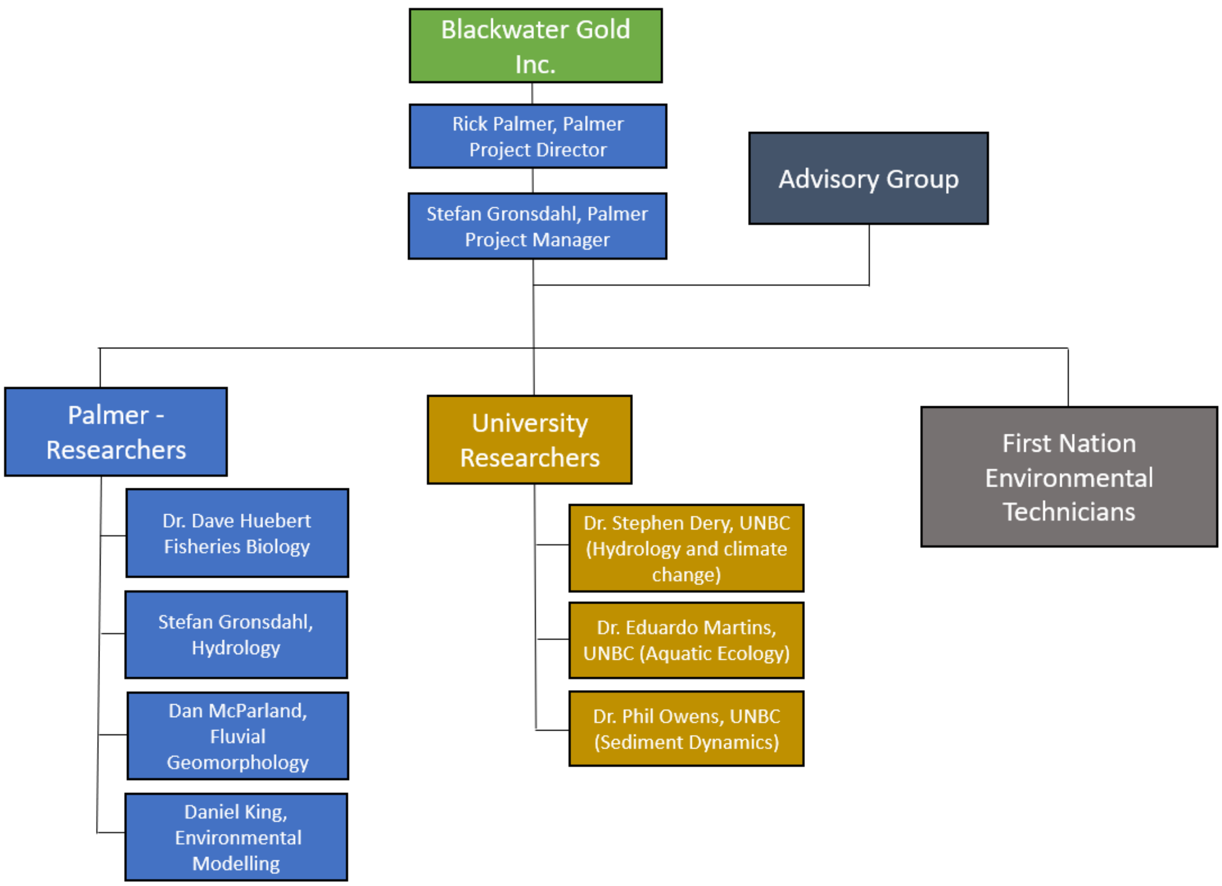


Figure 1. Proposed organizational chart of the complementary measures research team.

3.1 Palmer Scientists

Palmer scientists will be responsible for providing day-to-day project management, liaising with DFO, and administering the research program. Additionally, Palmer scientists will be involved in some components of the research program related to bioenergetic and instream flow assessments, as well as studies to synthesize the findings from the different disciplines and coordinating and leading annual reporting. The following key Palmer personnel are expected to be involved in the Project:

Rick Palmer, M.Sc., R.P.Bio, Senior Fisheries Biologist: Project Director
Rick Palmer is the President and CEO and Senior Fisheries Biologist at Palmer. Rick has over 25 years of experience undertaking and managing fisheries inventories and aquatic impact assessments for a wide

range of private, public and industry related projects. He has extensive experience with baseline/impact fish and fish habitat assessments as they relate to mining, hydroelectric and water supply developments. Rick engages Fisheries and Oceans Canada and other agencies on a regular basis to find solutions for client issues. He has been involved with environmental impact assessments, technical baseline studies, environmental monitoring programs and peer review in British Columbia, Alberta, Ontario, Yukon, NWT and Nunavut. Rick provides senior management of environmental permitting process for large-scale natural resource development projects. His technical areas of expertise include fisheries restoration and enhancement, aquatic ecology, in-stream flow modelling, environmental impact and risk. He has provided technical expertise at public hearings for issues related to aquatic environments and is considered an expert in aquatic-related provincial and federal regulations in Canada.

Stefan Gronsdahl, M.Sc., P.Geo., Hydrologist: Project Manager
Stefan Gronsdahl is a watershed hydrologist with six years of experience in watershed hydrology, hydrological processes, hydrological modeling, statistical analysis, and environmental flow needs assessments. Recently, Stefan has applied innovative and diverse analytical tools to understand and predict how snowmelt and other hydrological processes generate runoff and influence streamflow. This work has resulted in more effective seasonal flood forecasting and forest management planning in B.C. watersheds that support forestry, fisheries, and domestic and agricultural water users. Stefan is particularly interested in the impacts of resource development, forestry, and climate change on streamflow, with an emphasis on the effects on low flows and fish habitat. He regularly works at the intersection of hydrology, fluvial geomorphology, and aquatic ecology to quantify how water supply and scarcity affect aquatic habitat and to develop suitable mitigation strategies. Recently, he was a lead scientist on a study (in press) that developed innovate instream flow methodology that can be efficiently executed and can be used to predict how climate and land-use change will affect fish.

Dr. Dave Huebert, [redacted].Biol., Senior Environmental Scientist
Dr. Huebert is also an environmental scientist who has worked on a variety of projects in the mining, oil and gas, clean energy, municipal, and industrial sectors. His work has included watershed characterization, baseline characterization, environmental assessment, environmental effects monitoring plan design and implementation, adaptive management plan design and implementation, environmental compliance monitoring, development of site-specific water quality objectives, and third-party reviews of environmental assessment reports for both government and First Nations organizations. Dr. Huebert has field experience in ecology and toxi[redacted] variety of projects across the west and into the north, and includes experience conducti[redacted]ent of groundwater, assessment of upland vegetation, and assessment of surface water, vege[redacted], fish, benthic invertebrates and periphyton in the aquatic environment.

Dan McParland, M.Sc., R.P.Bio, Senior Fluvial Geomorphologist
Dan McParland has nine years of experience linked to geomorphological and hydrological assessment, fluvial hazard mitigation, and aquatic habitat enhancement. Dan has worked on numerous projects throughout B.C. and the rest of Canada assessing the impacts of land use change and flow regulation on geomorphic processes and physical habitat in watercourses. Dan's M.Sc. research at UBC examined the linkages between the physical sciences (hydrology and geomorphology) and aquatic ecology through statistical analyses and numerical models and culminated in a model Geomorphic Instream Flow Tool (GIFT) that quantifies changes in hydraulics, channel morphology, and aquatic habitat as a result of land use change (e.g. forestry) and/or climate change. During his consulting career, Dan has successfully completed numerous erosion hazard assessments, fish passage evaluations, and geomorphology peer

reviews. Dan has developed a variety of strategies for evaluating and mitigating the erosion and sedimentation risk posed to aquatic and terrestrial habitats and existing infrastructure by proposed land development and government infrastructure projects.

Daniel King, B.Sc., M.ET. Candidate, Fisheries Biologist

Daniel is a fisheries biologist with four years of experience gained through his Master's research, work for the mining sector in an academic capacity on the impacts of elevated metals on rainbow trout development, and employment with Palmer. Daniel has an extensive knowledge of British Columbia fish species, their life-stages, life history characteristics, and habitat use. Additionally, his unique academic background in fish behaviour, health, and physiology, pharmacology, and environmental toxicology, offers a view into the impacts of environmental contaminants on fish species and aquatic habitats. Daniel has a demonstrated ability in experimental design and analysis of large datasets developed during his Master's research and project experience with Palmer. Daniel has worked on extensive reviews regarding various life-stages and habitat usage for several listed species including the Fraser and Nechako River White Sturgeon, listed conservation units of Pacific salmon (e.g. Interior Fraser River Coho Salmon), Bull Trout, Northern Mountain Sucker, Salish Sucker, Brassy Minnow, Coastal Cutthroat Trout, and Westslope Cutthroat Trout. Daniel is a director of the board for a local conservation group, the Alouette River Management Society. Through this position, academic endeavors and employment with Palmer, Daniel is always seeking ways to protect and enhance fish populations and their habitat using the best-available modern and innovative methodologies.

3.2 University Researchers

Professors that specialize in watershed-scale disturbances that affect fish and fish habitat from UNBC will lead most of the res[redacted] proposed through this program through funding arrangements with BW Gold. All these [redacted]ated in Prince George and have previously conducted work within the upper Fraser River watershed and have strong relationships with local Advisory Group members, resource managers, and First Nations. By funding and supporting local researchers, this program will ensure that the research questions and topics will be relevant. It will also build on the significant, previous work that has been conducted within the watershed. The following professors will be the Principal Investigators for their respective research programs:

Professor Eduardo[redacted]., UNBC

Dr. Eduardo Martin[redacted]ssistant Professor at UNBC, where he leads the Freshwater Fish Ecology Laboratory. Dr. Martins' research lies at the interface of organismal and population ecology salmonids found in temperate and tropical environments. He is particularly interested in the thermal and movement ecology of salmonids and how they influence the dynamics of their populations. He has over 10 years of experience applying research methods such as biotelemetry (e.g., radio, acoustic) and biologging (e.g., temperature, acceleration) to collect data from wild, free-ranging fish and address a variety of questions within his research interests. The findings of his research have been published in over 60 peer-reviewed articles. Furthermore, Dr. Martins specializes in the development and application of advanced statistical and mathematical methods (e.g., mark-recapture, hierarchical, hidden Markov, matrix projection models) to analyze field data and infer ecological processes (using either frequentist or Bayesian approaches). His research program on the thermal ecology of salmonids is currently being supported by a Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant.

Professor Stephen Déry, Ph.D., UNBC

Dr. Stephen Déry is professor in the Department of Geography, Earth and Environmental Sciences and in the Natural Resources and Environmental Studies graduate program at UNBC, Prince George, B.C. As of July 1st 2019, Dr. Déry holds the NSERC/Rio Tinto Senior Industrial Research Chair in Climate Change and Water Security with a 5-year program of research focused on the Nechako watershed. His background is in atmospheric science and he has degrees from York University (BSc and MSc) and McGill University (PhD). Dr. Déry completed post-doctoral positions at the Lamont-Doherty Earth Observatory of Columbia University, New York and held a Visiting Research Scientist position at Princeton University in New Jersey. He investigates the consequences of climate change and water management on the water cycle of northern and alpine regions. A major aspect of this research is to better monitor, understand and project the water temperatures and streamflow trends in major tributaries to the upper Fraser River based on observational data and numerical simulations.

Professor Phil Owens, Ph.D., UNBC

Phil Owens is a Professor in the Department of Geography, Earth and Environmental Sciences and an Endowed Research Chair in Landscape Ecology at UNBC. He also co-directs research at the UNBC Quesnel River Research Centre. His research group is assessing how landscape disturbances impact aquatic ecosystems in B.C., focusing on sediment quantity and quality. Most of this research is based in the Quesnel and Nechako watersheds. Work in the Quesnel watershed is focusing on the impacts of the Mount Polley mine spill on aquatic ecosystems. Work in the Nechako watershed is addressing fine-grained sediment in sensitive aquatic habitats and determining its quality and its source. His research group is also investigating erosion and sediment delivery following wildfires near Kamloops (in 2003) and Vanderhoof (in 2018) including polycyclic aromatic hydrocarbons (PAHs) concentrations in soils and sediment in wildfire-affected watersheds[redacted]

3.3 First Nation Environmental Technicians

In addition, as a part of this project, BW Gold envisions an opportunity to build capacity and develop skills and experience related to environmental sciences. Mentorship and guidance would be provided by industry scientists and university researchers on field campaigns and potentially other aspects of the research. Meaningful development of technical skills is best done by supporting the growth and advancement of individuals for exten[redacted]time. Therefore, this proposal includes funding for the creation of up to three First Nation re[redacted]sistant positions to support the proposed research programs that are up to four months long. The intent of funding these positions is to recruit and support First Nation members and to provide them with paid opportunities to develop their technical, field, analytical, and writing skills.

3.4 Advisory Group

For this complementary measures research program to be successful, it is important that it answers questions that are relevant to local fisheries management initiatives and that results are disseminated to Advisory Group members.

The main avenue to coordinate engagement and disseminate research will be through an Advisory Group that will be affiliated with the proposed research program. The Advisory Group will be engaged to provide feedback and input to guide specific research questions, study locations, and other pertinent issues. The Advisory Group's involvement will be key to ensure that the proposed research addresses issues that are relevant to local fisheries and resource management.

Advisory Group meetings are proposed to be held annually, in either Prince George or Vanderhoof. These meetings will provide an opportunity for First Nations, other Advisory Group members, and researchers to discuss their programs and to disseminate findings and results, as well as to solicit feedback on planned activities. Meetings will be scheduled at a time of year that is conducive to organizing a tour of nearby field sites. Given the geographic region of the upper Fraser River watershed, significant travel to attend annual Advisory Group meetings may be necessary and could present a barrier to attendance. In recognition of this, BW Gold has included an annual budget to subsidize travel costs for members to attend Advisory Group meetings. Prospective members of the Advisory Group are fisheries and resource managers, as well as folks engaged with fish conservation and restoration efforts, who work within the upper Fraser River region.

First Nations Representatives
Invitations to join the Advisory Group will be extended to representatives from the Lhoosk'uz Dené First Nation, Ulkatcho First Nation, Nadleh Whut'en First Nation, Saik'uz First Nation, and Stellat'en First Nation, the Nazko First Nation.

Professor Mike Power, Ph.D., University of Waterloo
Dr. Power is a research biologist in the Department of Biology, University of Waterloo, with a specialization in northern salmonid ecology, population dynamics and stable isotope research. His research has focused on understanding the effects of climate-related variability on growth and thermal habitat use of fish species, such as Arctic char ([redacted]) and Atlantic salmon (*Salmo salar*), and on climate-related analyses of estuarine and sa[redacted]. His work aims specifically at melding modern analytical methods (e.g., stable isotopes) with long-term biological monitoring records to better infer likely population-level responses to climate change. Other research interests have focused on understanding the functioning of fish within northern lake and river foodwebs, determining the ecological effects of water abstraction, hydro dams and the study of ecological flow assessment techniques for flow regulation.

Zsolt Sary, M.Sc., R.P.Bio., Regional Aquatic Ecologist, B.C. Ministry of Forests, Lands, and Natural Resources
Zsolt Sary's primary [redacted] designing and implementing land designations under available legislation to protect the habitat of aquatic species at risk and regionally significant species; to review plans for development projects occurring near aquatic ecosystems to ensure flow conditions remain adequate to maintain fish habitat; and to evaluate proposed mitigation measures for avoiding or minimizing harm to lakes, rivers, and streams during construction and operation of projects. He is also involved in regional committees to develop provincial methodologies for assessing watershed health status, recover the endangered Nechako white sturgeon population, and improve stewardship practices on private and public lands. Prior to joining the Public Service in 2008, he spent 10 years in the private sector as a consultant in southern B.C., and another 7 years in the tropics studying the management of small-scale coral reef fisheries

Alexandre Bevington, M.Sc., P.Ag., Research Hydrologist, B.C. Ministry of Forests, Lands, and Natural Resources

Alex Bevington is a Research Hydrologist in the Omineca Region with the B.C. Ministry of Forests, Lands, Natural Resource Operations and Rural Development. His research integrates climate change, environmental change, and geospatial technology to better understand watersheds across large landscapes. Alex uses a combination of satellite remote sensing, geospatial modelling, and field techniques to build workflows that aim to provide tools for decision-makers that are grounded in sound scientific analysis.

[redacted]

[redacted]

4. Study Area

The tributary watersheds within the upper Fraser River watershed have experienced cumulative impacts from logging, agricultural land- and water-use, and forest fires over the last century (Figure 2). These pressures affect the streamflow regime, water temperatures, and sediment dynamics (Picketts et al., 2016). Along with other indices of environmental quality, these pressures can affect the health and viability of resident fish populations. The upper Fraser River region has also experienced an increase in extreme weather events, such as drought and flooding, which can affect the movement patterns of migratory species and reduce the quality of habitat critical for spawning, overwintering, and rearing. Additionally, rare devastating stochastic events are also problematic for the viability of salmon populations. A prime example is the 2019 Big Bar landslide that blocked fish migration to upstream spawning sites and rendered many salmon populations at risk for extinction. Collectively, these issues have caused many Pacific salmon populations within the upper and middle Fraser River, including the Nechako River drainage, to be listed as threatened or endangered (DFO, 2018; COSEWIC, 2018; DFO, 2016; Grant et al. 2019; COSEWIC, 2017; COSEWIC, 2016; DFO, 2015).

Tributaries to the Nechako River share similar physical and biological characteristics and resource management issues to other tributary streams that are primarily located on the Nechako and Cariboo Plateaus, such as those in the Blackwater River and the Nazko River watersheds. These areas are characterized by rolling terrain, coniferous forests, and cold, wet winters and warm, dry summers. The dominant hydrological event of the year is typically during the spring, when snowmelt leads to peak freshet flow. The intent of this complementary measures program is to better understand watershed-scale impacts and fisheries management issues that generally apply to tributaries of the western portion of the upper Fraser River. Given the similarity in the physiography, climate, and historical watershed disturbances across the western portion [redacted]er River watershed, they findings from these studies are expected to be generalizable ac[redacted]ion. For example, the hydrological regime of the upper Fraser River watershed is predominantly snowmelt-driven and forest types are similar, so findings related to land-use change and hydrology will likely be transferable across the region. Furthermore, anadromous salmonids with similar habitat preferences occupy the region, so findings related to aquatic ecology are also expected to be broadly generalizable to areas outside of the specific study watersheds. Therefore, findings from studies in the Stellako-Nautley watersheds are expected to be able to inform management and conservation initiatives throughout the western portion of the upper Fraser River watershed. The following study watersheds within th[redacted]tion of the upper Fraser River watershed are proposed (Figure 2).

Davidson Creek Watershed

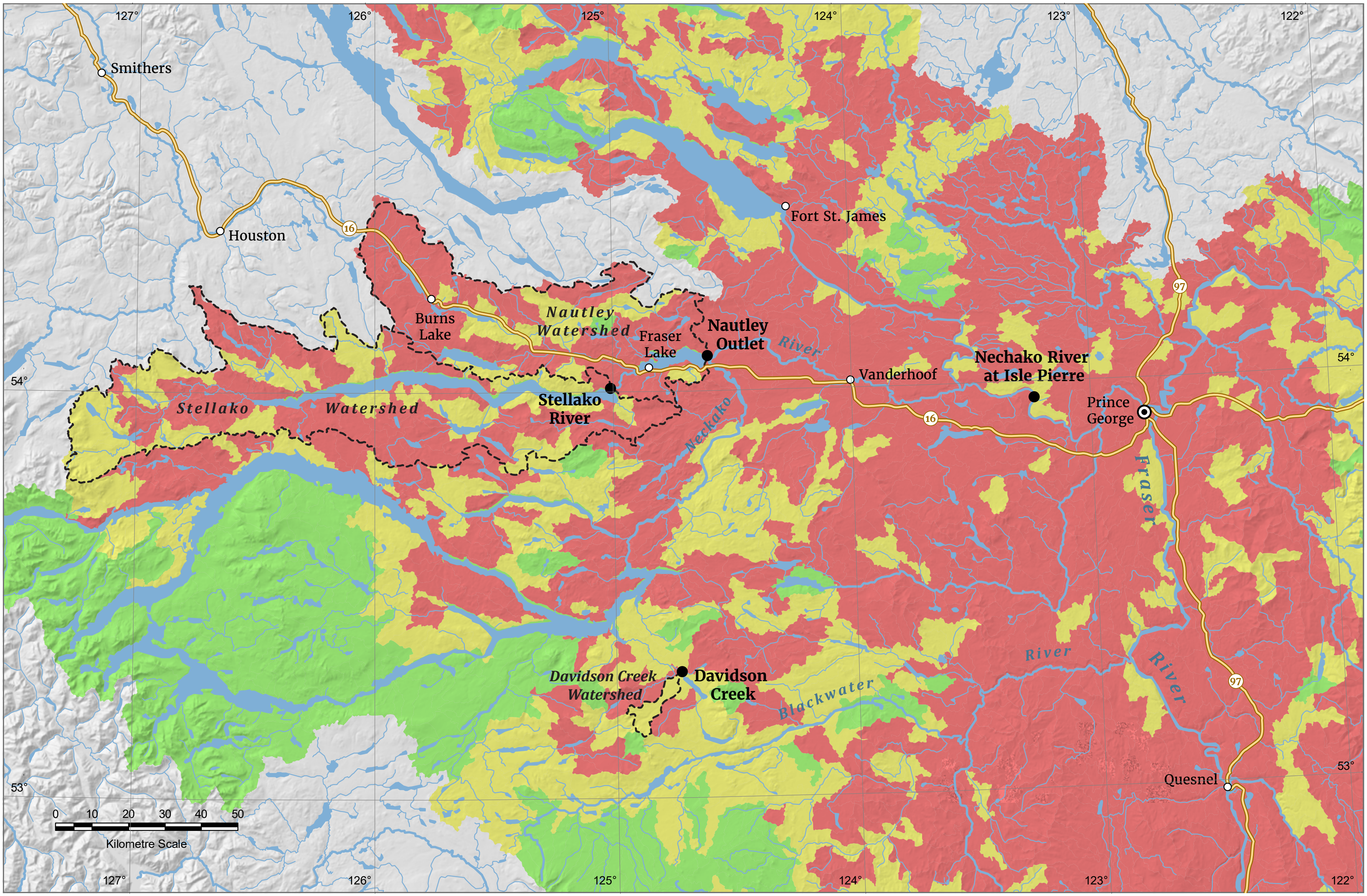
Davidson Creek is a 78 km^2 tributary to Chedakuz Creek and the Nechako River that supports both rainbow trout and kokanee. The watershed ranges from 929 to 1,821 m in elevation, and is the main watershed that would be impacted by the proposed Project. Considerable baseline data have been collected to characterize the hydrology, climate, and aquatic ecology of the Davidson Creek watershed. These data will be made available for this complementary measures research program.

Stellako – Nautley Watersheds

The Stellako – Nautley Watershed is a 6,030 km^2 tributary of the Nechako River that supports various freshwater and anadromous salmonids, including several Threatened and Endangered Sockeye, Chinook, and Coho salmon Conservation Units (COSEWIC, 2016; COSEWIC, 2017; COSEWIC, 2018). Long-term streamflow records in this river system are available from the Water Survey of Canada (WSC), and existing instrumentation has been deployed by UNBC to characterize water temperature and aquatic ecology of the river system.

[redacted]

[redacted]



LEGEND:

Cumulative Salmon Habitat Pressure

- Low
- Moderate
- High

- Highway
- Watercourse
- Watershed Boundary
- Lake

N

PROJECT NO.	2006501	REVISION:	1-1
DATE:	May 27, 2021	SCALE:	1:1500000
DRAWN:	BE	DATUM:	NAD 1983
CHECKED:	SG	PROJECTION:	BC Albers

CLIENT: ARTEMIS GOLD INC

PREPARED BY: Palmer™

PROJECT: Blackwater

TITLE: **Complementary Measures Study Area**

FIGURE 2

5. Proposed Research Programs

5.1 Thermal Ecology of Rainbow Trout in the Stellako River

5.1.1 Principal Investigator

Dr. Eduardo Martins (UNBC)

5.1.2 Background Information

Salmonids experience daily and spatial variations in water temperature ranging from a few (1-2°C) to several (3-6°C) degrees Celsius (Pincebourde et al., 2016; Kurylyk et al., 2015; Fausch et al., 2002). This daily variation in water temperature determines the times conducive for activity as well as the intensity of activity (Gunderson et al., 2016). Large variations in temperature, resulting in thermal conditions which deviate from the range preferred by individuals, will elicit thermoregulatory behaviours that can only be effective in spatially heterogeneous thermal habitat (Sears et al., 2016; Sears et al., 2019). Indeed, temperature in freshwater habitats can vary at fine spatial scales (10-100s of metres; Kurylyk et al., 2015; Dzara et al., 2019), providing fish with a range of thermal habitats in which to potentially regulate their body temperature. Theoretical work suggests that the energetic costs of thermoregulation will vary with both the amount of variability and the structure (i.e. clumped or dispersed) of thermal habitats (Sears et al., 2016), but there are no empirical studies explicitly assessing energetic costs of behavioural thermoregulation by individuals ranging freely in heterogeneous thermal habitats. Furthermore, the spatio-temporal availability of thermal habitats is one of the most important drivers of fish distribution. Indeed, determining the influence of abiotic factors such as temperature on the distribution of fish is fundamental to the effective development and implementation [redacted] programs (Allen & Singh, 2016; Cooke et al., 2016; Ogburn et al., 2017). The Stellako [redacted]hako River watershed lends itself as an excellent study system to investigate the ther[redacted]almonids. The river is home to healthy population of rainbow trout, which has been assessed annually by the Ministry of Forest, Lands, Natural Resource Operations and Rural Development (FLNRORD) for over 30 years and supports a prime recreational fishery in the Nechako watershed. The river is also the spawning grounds for one of the main populations of summer-run Fraser River sockeye salmon.

5.1.3 Objectiv[redacted]

The objective of thi[redacted] project is to investigate the thermal ecology of rainbow trout in the Stellako River. Specifically, the project will:

- Characterize the spatio-temporal variability in water temperature of the Stellako River.
- Quantify the influence of spatio-temporal variability in water temperature on the energetic costs of thermoregulation of rainbow trout.
- Quantify the influence of spatio-temporal variability in water temperature on distribution of rainbow trout.

This project builds on the research program on thermal ecology of Salmonids being led by Dr. Eduardo Martins at UNBC. Specifically, his research program on thermal ecology aims to elucidate how water temperature and its interaction with other abiotic and biotic factors influence the organismal (behaviour, survival and reproduction) and population (abundance and distribution) ecology of salmonids.

5.1.4 Research Methodology

The spatial heterogeneity of thermal habitats within the Stellako River will be determined using thermal images obtained by an infrared camera attached to an Unmanned Aerial Vehicle (UAV; Dugdale et al., 2019). The UAV will be piloted and images will be taken while floating downriver in an inflatable raft. Thermal images of the river will be obtained every 15 days over 60 days (July to August). Continuous (every 5 minutes) measurements of water temperature will be obtained by 100 temperature loggers deployed at various locations within the Stellako River. Temperature data loggers will be deployed in a stratified design informed by a pilot thermal imaging study of the two sections, which will be conducted two weeks before the commencement of the 60-day study period. The combination of thermal imaging and continuous temperature monitoring by data loggers will enable detailed characterization of the spatio-temporal variability of water temperature (thermal habitats) in the study sections of the river.

Rainbow trout will be captured by angling. Fish assigned to the field study (n = 60) will be immobilized by electro-sedation and placed in a trough with running river water, where they will be measured (fork length) and surgically implanted with a radio-transmitter equipped with acceleration and temperature sensors. Fish will be sexed by visual inspection of gonads during transmitter implantation. All tagged fish will be released at the capture site. Fish overall dynamic body acceleration (a proxy for activity and energy use) and body temperature will be continuously monitored for 60 days (July to August) by four radio-receivers. Attempts to recapture the fish and retrieve the radio transmitters will also be made at the end of the monitoring period. Snorkel surveys will be conducted bi-weekly (total of four times) to estimate the abundance and spatial distribution of rainbow trout along the Stellako River.

Fish assigned to the [redacted] (n = 20) will be transported to a field-based laboratory set up near the Stellako River, whe[redacted]laced into a holding tank (1.4 m diameter by 0.8 m height) at a temperature similar to the water temperature at the time of capture. Up to four fish will be transported and kept in the holding tank at a time. Before transfer to the holding tanks, the fish will be measured (fork length), tagged with a tag for individual identification and surgically fitted with a temperature data logger. Following sampling, the fish will be placed into a shuttle-box system that will be used to assess thermal preference (Neill et al., 1972). The shuttle-box consists of two circular tanks connected by a channel to enable fish to freely move between the tanks. Temperature in one of the tanks (warm tank) is kept consistently warmer (typically by 1 °C) t[redacted] tank (cool tank) by independent pumps connected to cold and warm water reservoirs and [redacted] by the shuttle-box software. Using a video camera connected to a computer, the shuttle-box software keeps track of the location of the fish to determine whether to cool or warm the system. The system warms the water in both tanks if the fish is located in the warm tank; but cools the water in both tanks if the fish is located in the cool tank. The fish is therefore able to control the temperature of its body (measured by data loggers implanted into the stomach) by moving between tanks, revealing its thermal preference (i.e., set-point range defined by the limits of the central 50% of the distribution of body temperatures). After being moved to the shuttle-box system to assess thermal preference, each fish will be kept in the shuttle-box tank for 12 hours under constant temperature (similar to the river temperature at the time of capture) to enable acclimation to the tank before initiation of the 24-hour thermal preference trial (Neil et al., 1972; MacNaughton et al. 2018).

5.1.5 Research Applications

Salmonids are economically, culturally and ecologically important in B.C. Improving our knowledge on and predictive capacity of their responses to temperature will be critical to inform management and conservation practices and policies in a changing climate. Although it is well known that warmer temperatures can negatively impact the survival and reproduction of salmonids, there is very limited evidence of how well fishes can explore the thermal variability in freshwater habitats to effectively thermoregulate and buffer the effects of warm waters. For example, despite the consensus that the creation of thermal refugia in aquatic environments may help mitigate the impacts of warming on freshwater organisms (Kurylyk et al., 2015), it is unknown how costly it may be for fish to use artificial refugia and therefore how effective that management approach may be. Using rainbow trout from the Stellako River, the research proposed here will address important questions regarding the ability of salmonids to effectively thermoregulate and use thermally variable environments. The findings will thus inform how salmonids may respond to changes in water temperatures caused by the exploitation of natural resources in the watershed and ongoing climate change. Furthermore, the findings on how rainbow trout respond to water temperatures may inform the management of the unique Stellako rainbow trout fishery FLNRORD recently completed a study to determine the potential impact of an earlier start to spring angling for rainbow trout on the Stellako River (Hagen et al., 2020). Recent discussions with FLNRORD biologists indicate that an earlier start may be particularly beneficial if the need emerges to close the fishery due to high temperatures in the summer. Finally, given that the Stellako River is also a spawning ground for Fraser River sockeye salmon, the research also has the potential to inform how changes to the watershed may affect thermal conditions for the development of sockeye salmon embryos and fry. Given the similarity in the physiography, climate, and historical watershed disturbances across the western portion of the upper Fraser River watershed, they findings from these studies are expected to be generalizable to Sockeye habitat management and conservation initiatives throughout the west[redacted]upper Fraser River watershed.

5.1.6 Deliverables

- Submission of two manuscripts to peer-reviewed publications
- Contributions to annual reports on complementary measures progress
- Two conference presentations (national and international)
- Publicly archived data set on water temperature to be contributed to a regional database currently in development an[redacted]the Freshwater Fish Ecology Laboratory at UNBC

5.2 Impact of Fine Sediment on Salmonid Habitats in the Nautley Watershed

5.2.1 Principal Investigator

Dr. Phil Owens, UNBC

5.2.2 Background Information

Excessive fine-grained sediment (i.e., fine sands, silts and clays) supply to streams can limit fish productivity by causing: siltation over spawning substrates, thereby decreasing the rate of oxygen diffusion into bottom substrates; causing physical damage to gills and other epithelia; increasing turbidity and thereby reducing the feeding success of visual predators; and vectoring potentially toxic metals and persistent organic contaminants (Figure 3). Many pollutants are hydrophobic and thus attached to sediment as opposed to being dissolved in water. As such, erosion and sediment delivery to aquatic habitats have been identified as a stressor to Fraser River salmonid populations (Grant et al., 2019). The U.S. Environmental Protection Agency (USEPA) has identified fine sediment as the largest polluter of rivers and lakes in the U.S., and reducing sediment delivery to aquatic systems is often central to most healthy watershed and habitat restoration and protection programs (USEPA, 2020).

There are numerous natural and anthropogenic sources of sediment and associated contaminants in watersheds. Prior work in the Nechako watershed by Owens and his research group (e.g., Gateuille et al., 2019) has identified that this includes enhanced erosion and sediment delivery due to climate change (i.e., more rainfall) and wildfires (including the 2018 Shovel Lake wildfire), as well as activities such as forest harvesting, agriculture and resource development. Recently, there has also been concern associated with the impact of fine sediment entering streams in the upper Fraser River watershed, including Ormond Creek, due to the construction of linear infrastructure projects.

This project will investigate fine sediment sources and transport dynamics and their impacts on salmonid (e.g., rainbow trout and Fraser River sockeye salmon) habitats, and will focus on two sub-watersheds which form part of the Nautley system in the Nechako watershed: the Stellako-Endako river system and Ormond Creek. These two rivers represent major inputs to Fraser Lake, which itself is an important tributary of the Nechako River via Nautley River. The Endako River is the main tributary of the Stellako and joins it just upstream of where the Stellako enters Fraser Lake. This work builds on existing research by the project team (Déry, Martins and Owens) over the last ca. 10 years and addresses new priority questions that relate to environmental str[redacted]id populations in this crucial part of the Nechako watershed.

[redacted]

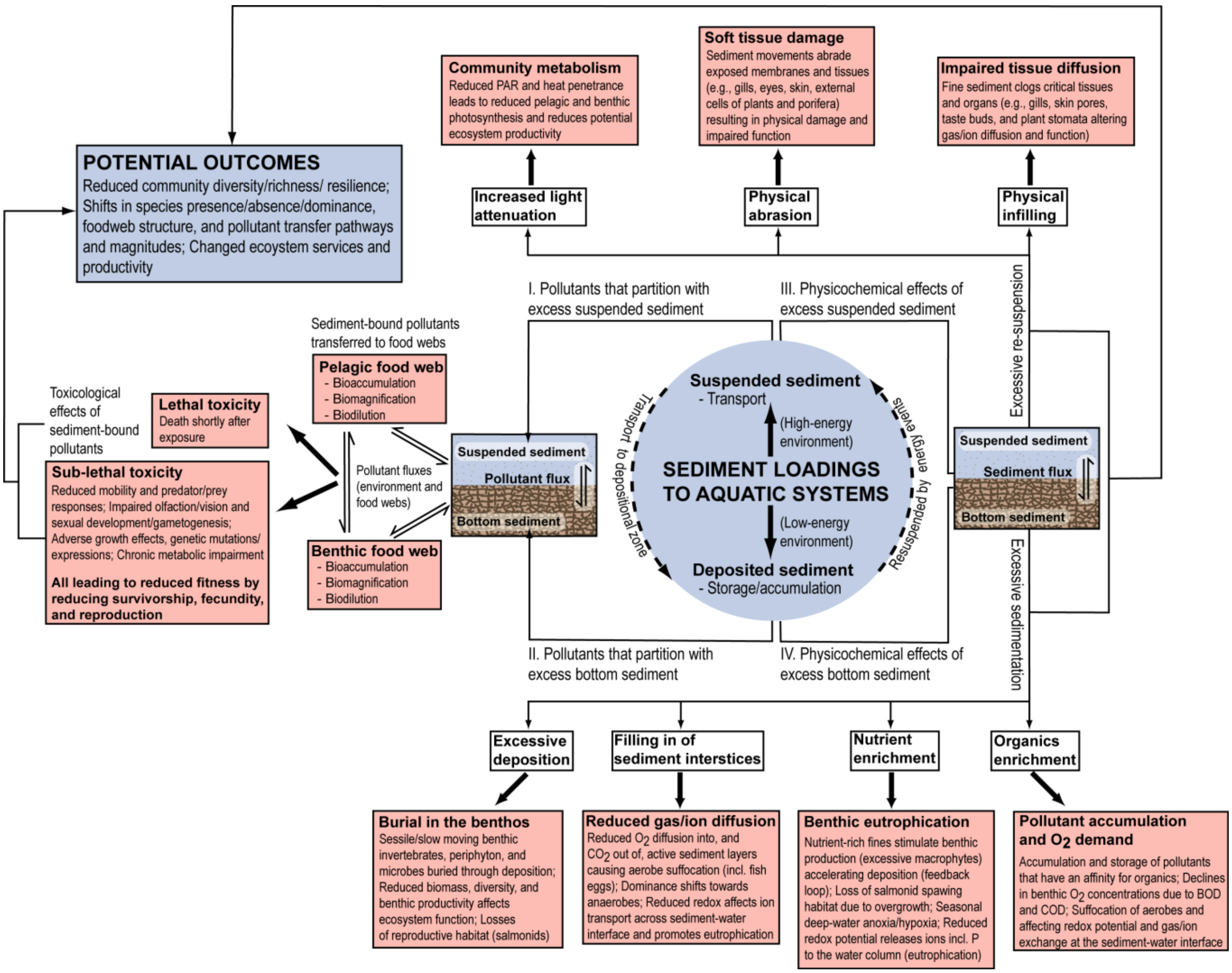


Figure 3. Some of the main physical, chemical and biological impacts on aquatic biota, including fish, due to excessive inputs of fine-grained sediment (from Owens, 2020).

5.2.3 Research [redacted]

The project will investigate fine sediment and associated contaminant dynamics in two key sub-watersheds of the Nautley watershed. Specifically, it will:

- determine the spatial variation in fine sediment transport and storage along the Stellako River and Ormond Creek with emphasis on important spawning habitats;
- determine the source of fine sediment being transported and stored in the Stellako River and Ormond Creek; and
- determine the quality of this fine sediment in terms of particle size, and nutrient (e.g., phosphorus) and contaminant content.

5.2.4 Research Methodology

5.2.4.1 Determine the Spatial Variation in Fine Sediment Transport and Storage (Objective 1)

Suspended sediment transport dynamics in the two study watersheds will be determined using probes which constantly record turbidity. Turbidity is an optical property that is closely related to the suspended sediment concentration (SSC) in the river water. In order to relate turbidity to SSC, it is necessary to collect river water samples using an ISCO sampler which can be programmed to collect 500 ml samples at regular time intervals. Comparison of turbidity (as determined by the turbidity probes) and SSC (using the ISCO samplers) at the same time enables a rating curve between the two to be established; subsequently, turbidity is used to estimate SSC via an equation. Using records of river discharge as supplied from Dr. Stephen Déry and WSC gauging stations in the study watersheds (e.g. Stellako River at Glenannan, WSC station 08JB002, record 1929 onwards; Vore et al., 2020), SSC and river discharge can be used to determine sediment loads and fluxes. In the Endako River and Ormond Creek, we (Déry and Owens) will install water level loggers to constantly record river height (stage) and use a portable SonTek Flow Tracker to determine discharge, thus enabling a stage – discharge rating curve to be established for these two rivers. Given the significant contributing area of the Endako River, it is important to determine the sediment load that it delivers to the Stellako River.

Sediment storage within river gravels at key salmonid spawning sites and critical habitats will be selected to complement the work proposed by Dr. Eduardo Martins in the Stellako River and existing work in Ormond Creek. We will use a resuspension technique (Owens et al., 2012) and gravel storage basket traps (Harper et al., 2017) to quantify the amount of fine sediment that is deposited and stored in river gravels, and how this changes during the year and between years. There is normally considerable variation on sediment storage in gravel be[redacted]s in sediment supply and river flows.

5.2.4.2 Determination of Sediment Sources and Sediment Quality (Objectives 2 and 3):

The sediment fingerprinting technique that we will use has been applied successfully in several Canadian watersheds, including the Nechako and Quesnel watersheds, that have identified sources of sediment and assessed levels of contamination (Owens et al., 2012, 2016, 2019; Koiter et al., 2013; Smith and Owens, 2014; Boudreault et al., 2018; Liu et al., 2018; Gateuille et al., 2019). In brief, the technique involves the collection of suspen[redacted]nel bed-stored fine sediment from river sites of interest over periods representing all hyd[redacted]sons. Soils and source materials from the landscape (e.g., channel banks and upland soils) tha[redacted]e potential to be delivered, by erosional and transport processes, to the study rivers are also collected. Bulk (i.e., >10 g) suspended sediment samples will be collected with a portable high-volume centrifuge system or a high-volume filtration system (i.e., instantaneous samples; Goharrokhia et al., 2020) and time-integrated samplers that composite sediments over a set time interval (Gateuille et al., 2019). This will enable us to both collect sediment samples associated with short-duration specific flow events (e.g., freshet or rainfall event) and also aggregated over longer periods of time (e.g., low-flow conditions). Channel-stored sediment will be collected using a resuspension approach and gravel basket traps, as described above (Owens et al., 2012; Harper et al., 2017). Representative landscape soils, channel bank materials and other sources (e.g., wildfire ash, mine products, road runoff etc., depending on watershed activities and conditions at the time of the project) will be collected with a standard stainless-steel hand corer. The suspended/bed sediment and landscape samples will then be dry-sieved and analyzed for biological, chemical and physical properties that would be expected, based on experience and the results of prior research (i.e., Owens et al., 2016), to be influenced by the types of disturbances/land-use types in the study watersheds.

The physical and biogeochemical properties that will be used to identify sediment sources, and assess sediment quality (i.e., contamination), are expected to include some of the following: geochemical trace elements like metals; colour properties; mineral magnetism properties; total organics vs. inorganics composition; nutrients such as carbon and phosphorus; and particle size composition. Most of the analytical work for these biogeochemical indicators will be performed in UNBC's Northern Analytical Laboratory Services (NALS) facility based on standard USEPA methods. Particle size will be determined using a Malvern Mastersizer 3000 at the UNBC Quesnel River Research Centre. Colour properties will be analysed at the Department of Soil Science, University of Manitoba, where Dr, Owens is an Adjunct Professor. The concentrations and species of PAHs (as indicators of fire history and intensity, and hydrocarbon pollution) in sediments and landscape materials will also be determined for the study watersheds; however, we will outsource these analyses to SGS AXYS Ltd. in Sidney, B.C. The biochemical and physical data will then be analyzed in a state-of-the-art R-based unmixing model which will apportion sediment contributions amongst particular landscape types and activities for each stream site (Blake et al., 2018; Gateuille et al., 2019).

We will determine if the suspended sediment and channel stored sediment is enriched in potential contaminants and nutrients relative to other samples we have collected from unimpacted or low impacted sites in the Nechako and other watersheds in B.C. (e.g. Smith and Owens, 2014; Owens et al., 2019). We will also assess if the sediment is contaminated using provincial and federal sediment quality guidelines for the protection of freshwater aquatic biota (e.g., B.C. Ministry of Environment and Climate Change Strategy, 2021).

[redacted]

Photograph 2. Installing a sediment sampler in the Nechako River (Photo: Phil Owens).

5.2.5 Research Applications

Once the source of the sediment and any associated contaminants has been identified in the study watersheds it should be possible to develop management practices and policy advice. For example, if most fine sediment and associated contaminants are being supplied by a small part of a watershed impacted by agriculture, it should be possible to develop practices to control erosion (e.g. soil protection measures) and/or establish targeted riparian buffer zones to stop delivery to rivers (e.g., Owens et al., 2007; Vanrobaeys et al., 2019). Equally, if the sediment and contaminants are being supplied from point sources, such as mining projects, or activities associated with linear infrastructure, it should be possible to develop best practices to stop such material from entering critical river channels. Similarly, the work undertaken in Ormond Creek with help to inform the impact of large wildfires (i.e. Shovel Lake fire) on the delivery of sediment and contaminants (e.g. PAHs) to fish-bearing streams.

The work on the flux and storage of fine-sediment and associated contaminants will also help to identify hot-spots within the study rivers where these materials may be stressors to fish-spawning areas and other key habitats.

The techniques developed and applied in this project – (i) estimating sediment fluxes through turbidity monitoring, sediment sampling and calibration, and river discharge estimation; (ii) determining channel bed storage of sediment and contaminants; and (iii) determining sediment and associated contaminant sources through the source fingerprinting technique – can be applied in other watershed in B.C., so as to assess land use activities and watershed disturbances on critical salmonid habitats.

5.2.6 Deliverables

- Submission of t[redacted] peer-reviewed publications.
- Contributions to annual reports on complementary measures progress
- Two conference presentations (national and international)
- Publicly archived data set on sediment sources, fluxes, storage and contaminants

5.3 Past and Future Trajectory of the Hydroclimate and Water Tempe[redacted]e Nautley Watershed

5.3.1 Principal [redacted]gator:

Dr. Stephen Déry (UNBC)

5.3.2 Objective

Tributary basins of the upper Fraser River including the Nautley watershed are now experiencing the cumulative effects of climate change, land cover disturbances and land use changes. These cumulative stressors are influencing the amount and timing of flows, erosion, sediment transport and deposition, water quality, and water temperatures. In turn, these changes in hydrology affect aquatic habitat and species. Key fish species in the Nautley, Stellako, and Nadina River system include resident rainbow and lake trout (*Salvelinus namaycush*), burbot *(Lota lota),* kokanee and anadromous sockeye salmon, which are all sensitive to hydroclimate and water temperature changes. This study will combine in situ data with model output to assess recent trends and the potential future trajectory of the hydroclimate and water temperatures in the 6030 km^2 Nautley watershed. Thus, the overarching research objective of this study is to assess recent (1950-2020) and potential future (2021-2100) changes in surface hydrology and water temperatures of the Nautley watershed. Secondary objectives include: 1) improving hydrological and water temperature monitoring in the Nautley watershed; 2) understanding the mechanisms behind historical and potential future changes in hydrology and water temperatures in the Nautley watershed.

5.3.3 Research Methodology

5.3.3.1 Observational Study

Research question: Can water temperature be used as a conservative tracer to extract streamflow in ungauged basins?

The project will include an observational component and a modelling study. Accurate simulations rely on in situ data for model calibration and validation to understand the reliability and uncertainty associated with the numerical output. Thus, the first step is identifying the observational gaps in the Nautley watershed and deploying hydrometeorological equipment to augment the current monitoring network. A principal source of information is the WSC that maintains hydrometric and water temperature gauges on the Nautley, Stellako and Nadina rivers. While the river discharge records span 1950 or 1964 to present at these sites, the associated water temperature datasets span only a few years. The Endako River and Ormond Creek, the other major tributaries to Fraser Lake feeding the Nautley River, are not currently gauged. There are no other hydrometric gauges either in the headwater tributaries upstream of Nadina Lake. Therefore, in collaboration with p[redacted]ators (Owens, Martins), we will install water level and temperature loggers in the Endak[redacted]Creek, and several headwater streams to better track freshwater and heat fluxes in this system. Using a SonTek FlowTracker to gauge flows, we will visit these sites at high, average, and low flows each project year to develop rating curves that can then yield volumetric flows based on the water level data. Combined with the water temperature data, the volumetric flows will allow to track heat transport through the river network.

A key question to be addressed using the observational data is whether water temperature can be used as a conservative tracer to extract volumetric flows from ungauged basins. For instance, using conservation of heat and mass pr[redacted]mixing model can be developed such that:

$$T_3 = \frac{T_1 Q_1 + T_2 Q_2}{Q_1 + Q_2} = \frac{T_1 Q_1 + T_2 Q_2}{Q_3}$$

Where T_1 and T_2 (°C) are the water temperatures of two tributaries while Q_1 and Q_2 (m^3/s) represent their respective volumetric flows. Then at the confluence of the two tributaries where total streamflow equals Q_3, the overall water temperature attains T_3. As water temperature is relatively easier to measure and conserved over short distances, one can then extract the volumetric flow (say Q_2) for an ungauged tributary from:

$$Q_2 = \frac{Q_1(T_3 - T_1)}{(T_2 - T_3)}$$

This approach will be tested in the vicinity of the confluence of the Endako and Stellako rivers and in headwater basins of the Nadina River. As the Endako River is not gauged by the WSC, tracking water temperatures at upstream and downstream sites of the confluence will provide the means to extract flows in the Endako River. This approach, however, will not be valid in situations when both tributaries approach the same water temperature, so that gauging data remain essential to assessing water and heat budgets in the Nautley watershed. A similar approach will be tested in headwater streams of the Nadina River. Thus, the in situ water temperature data will not only be useful to calibrate and validate a water temperature model but may yield additional discharge data for implementation of the hydrological model.

If this approach to estimate flows proves effective, it may well provide another tool to make predictions in tributary streams and small ungauged basins. This is significant because there are very few small basins that are gauged in north-central B.C. and understanding of the hydrological characteristics of these watersheds is thus relatively poor. Yet, gauging reliable volumetric flows in small to medium-sized streams remains vital in tracking the suitability of the aquatic environment for various fish species. Indeed, this could lead to an expansion of the streamflow monitoring network in north-central B.C. that would be most beneficial from a fisheries management perspective.

In collaboration with Martins, we will also explore the representativeness of the WSC water temperature record at its hydrometric gauge in the Stellako River (ID: 08JB002). We will compare the water temperature records at the ~100 sites monitored by loggers to be deployed in the Stellako River and compare these relative to the WSC's measurements near the river's source at Francois Lake.

5.3.3.2 Modelling Study

Research question [redacted]ast and potential future impacts of climate change on the hydrology and water temperatu[redacted]y watershed?

Aside from observational data, the project will make use of two numerical models: 1) the Variable Infiltration Capacity (VIC) hydrological model (Liang et al., 1994) and the Air2Stream river water temperature (Toffolon & Piccolroaz, 2015). The VIC model is currently being implemented at UNBC to establish historical (1950-2020) and potential future (2021-2100) water resources across the Nechako watershed including the Nautley River. Careful VIC model calibration and validation will be undertaken for the three long term WSC hydrometric gauges [redacted]watershed (Nautley, Stellako and Nadina Rivers). Thereafter, daily time series of routed stre[redacted]be generated along the stream network spanning 1950 to 2100. Simulations will be further validated with the field data collected in the observational component of this project. Additional output from the VIC model will be used to investigate changes in lake ice cover, lake surface temperatures and evaporation from Fraser, Francois and Nadina lakes.

In a subsequent effort, air temperature data combined with routed streamflow from the VIC model will be fed to the Air2Stream water temperature model to obtain historical and future projections of water temperatures, spanning 1950-2100. These simulations will require in situ water temperature data for model calibration and validation over a recent period. Once optimized, the Air2Stream model will be integrated for points along the Nautley / Stellako / Nadina river system for which VIC routed streamflow data are available. Based on these data, we will create the thermal history experienced by up-river migrating salmon through the Nautley watershed. This will complement the effort by Martins who will provide information on transit time for migrating sockeye salmon through the Nautley / Stellako / Nadina river system. We will also explore the frequency of days exceeding critical threshold water temperatures (e.g. > 20°C) and cumulative degree days all along the waterway. Particular attention will be given to the water temperature trends for the Stellako and Nautley rivers relative to a previous effort by Islam et al. (2019). That study reported a +0.27°C and a -0.19°C trend in the 1950 to 2015 water temperatures in the Nautley and Stellako rivers, respectively. These results are inconsistent with other sites across the Nechako and entire Fraser River Basin where the trend analysis suggested a warming of 1°C during that 66-year period. It is possible that seiching in Francois Lake may release deeper, cooler waters into the Stellako River, thereby offsetting a regional warming trend. In situ water temperature data at the source of the Stellako River near Francois Lake collected by Martins will also be used to explore whether strong wind storms induce sudden decreases of water temperatures in the Stellako River. Additionally, water level loggers will be installed at the eastern end of Francois Lake to explore whether seiching can cause sudden water level changes and releases of cool, hypolimnetic water into the Stellako River.

5.3.4 Research Applications

Aquatic habitat and species depend on optimal environmental conditions including a stable water supply over a limited range of water temperatures. This project will improve monitoring of water temperatures and flows in the Nautley watershed that then discharges into the Nechako River. The sparse observational network of stream gauges and water temperature loggers will be augmented to capture all major contributors to water and heat inputs to Fraser Lake. Observations of water temperature data combined with volumetric flows will allow computing the transport of heat through the Nautley / Stellako / Nadina river system. As well, these data will permit improved model calibrations, yielding long term time series of both routed streamflow and water temperatures. Combined information on volumetric flows and water temperatures, a heat budget for water inputs to the system will be established. Then, metrics based on the number of days e[redacted]emperature thresholds and degree days will be generated. This information will be u[redacted] potential risks to resident and anadromous fish from future exposure to heat stress in the Nautley watershed.

Future hydroclimate projections and envelopes on their uncertainties are also key data to be generated through this project. Knowledge of the potential future trajectories of the climate, volumetric flows (including their seasonality in a warmer environment) and of water temperatures, will allow more informed planning and decision-making for future management of fish across the upper Fraser River. This is particularly important as climate[redacted]cted to intensify moving into the 21st century.

Over the course of this project, we will engage local First Nations where appropriate. Data will also be provided to Advisory Group members across the watershed and be applied for training and education purposes. Finally, the observational database will be made publicly available in a long-term data archive as a legacy of this project.

5.3.5 Deliverables

All data collected in the field or as output from model simulations will be deposited into our data management system in addition to publicly accessible data repositories (e.g. Zenodo). Three peer-reviewed publications (including one "data paper") are anticipated to be submitted to peer reviewed journals as another outcome of this project. Results from this research will be disseminated at international and/or national conferences as well as during outreach activities in the Nechako watershed. Findings will also be shared with Advisory Group members across the upper Fraser River watershed through an updated website, social media postings, and quarterly newsletters targeting Advisory Group members in the Nechako watershed.

5.4 Evaluating a Novel Technique to Quantify the Effects of Land-Use Change on Fish

5.4.1 Research Team

Stefan Gronsdahl, M.Sc., P.Geo, Dan McParland, M.Sc., P.Geo., Dave Huebert, Ph.D., R.P.Bio., Daniel King, MET Candidate

5.4.2 Background

The upper Fraser River watershed has experienced watershed disturbances from logging, forest fires, climate change, and agriculture (Picketts et al., 2016). The impacts these disturbances have on the physical and biological environment is recognized but poorly understood. The impacts of logging include changes to the streamflow regime, stream temperature, and increased sediment inputs into streams (Bladon et al., 2018; Gomi et al., 2005; Moore et al., 2020). Climate change is expected to result in warmer air temperatures and variable precipitation patterns (PCIC, 2013), which will affect streamflow and water temperature. Agriculture and ranching operations reduce riparian vegetation, which destabilizes stream banks and increases summertime stream temperatures. Although these impacts are known to occur, few studies have charac[redacted]mflow response to climate and land-use change in the upper Fraser River watershed reg[redacted]ck of suitable hydrological datasets. However, innovative modelling approaches may be [redacted]these impacts. For example, Zégre et al. (2010) outline an alternative approach that can be used to detect changes in streamflow that uses hydrological models and relies less on paired watershed study designs. Chernos et al. (2017) also provide an example of how hydrological models can be used to simulate how different forest-harvesting and climate scenarios may affect streamflow.

While understanding [redacted] may change is an important factor for understanding impacts to fish populations, other [redacted]as water temperatures, prey availability, and sediment dynamics may confound the effects [redacted]nd make it challenging to quantify the potential impacts. (Moore et al., 2020). Conventional instream flow modelling and habitat assessment approaches tend to only consider the impacts of one variable in isolation of others even though multiple variables could be affecting fish. For example, instream flow assessments are often conducted to evaluate how changes in streamflow affect fish, but do not typically consider other important variables such as prey availability or water temperature, which has the potential to introduce uncertainty and error into such analyses (Naman et al., 2019).

In addition, conventional instream flow assessment techniques are field-intensive and time-consuming to implement. There here have been repeated calls for the development of new techniques that are both cost-effective and biologically robust (Lancaster and Downes, 2010; Railsback, 2016). Recent advances in various modelling techniques have been developed to address these concerns (e.g. McParland et al., 2016; Naman et al., 2020). In contrast to conventional methods, an added benefit of the bioenergetic suitability modelling technique presented by Naman et al. (2020) is that it evaluates fish habitat as a function of streamflow with added variables of water temperature, water quality, and prey availability, rather than exclusively using streamflow as a predictor of habitat quality. Since these variables are collectively used in a single model, this technique can be used to conduct a sensitivity analysis to identify which environmental variables have the greatest influence on fish productivity. The results of these sensitivity analyses could identify the environmental variables that have the greatest influence on fish productivity and can be used to inform conservation and remediation priorities that address the factors most limiting to fish. For example, if the research were to identify that logging is likely to cause decreases in summertime low flows that would limit fish habitat in the future, managers may want to prioritize the construction of headwater storage that could be used to augment instream flows during critical low flow periods. However, these techniques have not yet gained traction amongst practitioners. Therefore, the intent of this study is to showcase the application of environmental modelling techniques in the upper Fraser River watershed.

This research program will be conducted in the Davidson Creek watershed, which is 78 km^2, supports both rainbow trout and kokanee, and would be affected by the Project.

5.4.3 Objectives

The goal of this study is to quantify the different environmental stressors that are expected to affect fish habitat in the upper Fraser River watershed, using Davidson Creek as a study site, and to provide a framework for a robust and efficient modelling strategy that could be applied to other watersheds in B.C. This analysis will utilize watershed-scale and bioenergetic modelling techniques to quantify the effects of logging and forest fires, climate change, and agriculture on streamflow and fish habitat. There are two specific objectives fo[redacted]

1) To demonstrate [redacted] to quantify how watershed-scale environmental changes and climate change affect modelled fish habitat.
2) To conduct a sensitivity analysis, using bioenergetic modelling techniques, in order to identify the environmental variables to which rearing and spawning fish are most sensitive.

The intent of the research program is not to replicate baseline data collection within the watershed, nor is it intended to be a monitoring program to quantify the effects of mine development. Instead, the analysis will leverage the ri[redacted]eries and streamflow datasets that have been collected from the watershed since 20[redacted], validate, and assess the performance of the modelling study proposed as a part of this program. The study will focus on evaluating the impacts of hypothetical future climate and land-use change scenarios against the pre-disturbance, baseline conditions of Davidson Creek.

5.4.4 Proposed Methods

Although the study will focus on Davidson Creek, the proposed study will not consider the potential effects of mine development due to the confounding nature of future impacts caused by reductions in watershed contributing area, and subsequent changes to the streamflow and temperature regimes, water chemistry, and aquatic ecosystems. Instead, the proposed approach will utilize the relatively rich baseline datasets from Davidson Creek to inform the development of models that represent undisturbed conditions. Then, the analysis will impose hypothetical disturbance scenarios (e.g., climate change, land-use change) to evaluate the impacts to watershed characteristics (streamflow, water temperature, water quality). The corresponding impacts to fish productivity will be evaluated using a bioenergetic suitability model and will be compared to the 'before' scenario to quantify changes in fish productivity caused by different environmental variables. This yields a before-and-after comparison, where 'before' represents the baseline conditions and 'after' represents our series of hypothetical disturbance scenarios. Because the study will utilize pre-disturbance baseline data, its result will not be compromised by the potential confounding influences that would be caused by mine development.

A schematic of the proposed complementary measures workflow is presented in Figure 4 and described in this section.

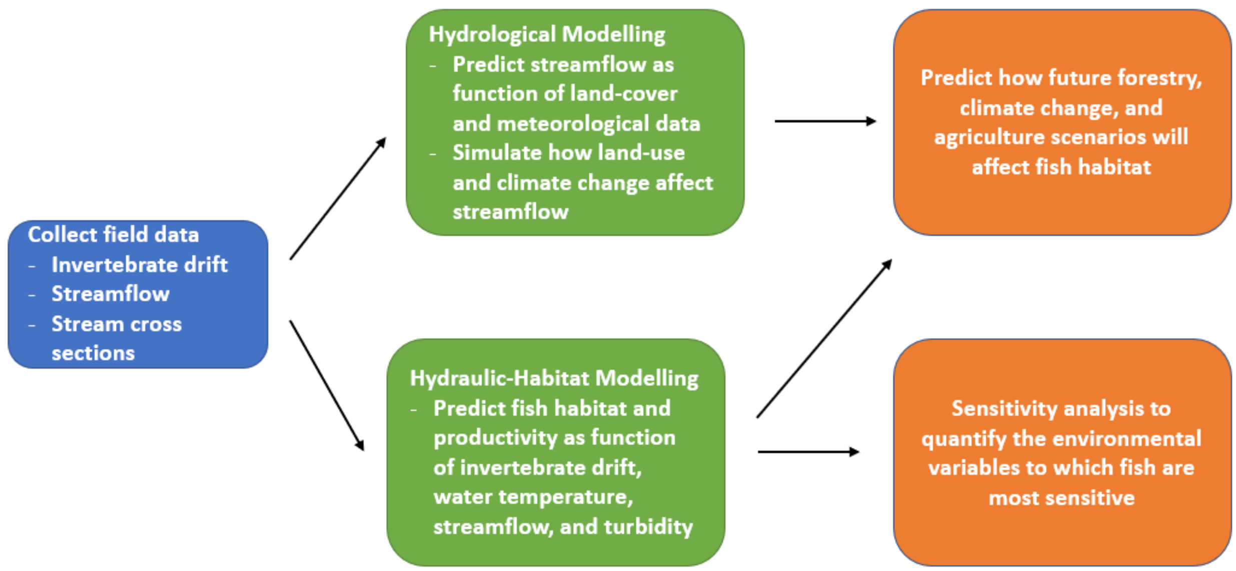


Figure 4. Workfl[redacted]arch program to evaluate the effects of watershed-scale impacts on fish [redacted] Davidson Creek.

5.4.4.1 Data Collection

This study will use the robust baseline data that were collected in Davidson Creek to support the Project. Using existing data is beneficial because it is both cost-effective, and because it allows for the integration of long-term timeseries of streamflow (2011-present) that will strengthen the analysis. A field program will be conducted to supplement existing datasets that will be used for the different modelling exercises as a part of this program. The field program is expected to focus on collecting the following data:

- **Invertebrate drift concentrations:** These data are required to characterize the prey availability for rearing fish, which is an important input for the bioenergetic suitability modelling approach.

- **Channel cross-sections:** Channel measurements are necessary inputs to characterize the hydraulic geometry of study reaches that will be used in the geomorphic instream flow tool.

5.4.4.2 Novel Modelling Approaches

Hydrological Modelling

To evaluate the impacts of logging, forest fires, and climate change, a comparative analysis of streamflow responses will be performed using physically-based hydrological models similar to those described in Chernos et al. (2017). This approach involves using meteorological timeseries to simulate daily streamflow. The first step in developing a hydrological model involves a GIS-based exercise to discretize the watershed using publicly available land-cover data (e.g., forest cover characteristics, elevation, surficial geology) into unique units that are expected to have similar hydrological characteristics (Figure 5). Then, a model structure will be developed that will simulate different hydrological processes (e.g. snowmelt, groundwater flow) using appropriate watershed model algorithms that are available as a part of the Raven modelling platform (Craig et al., 2020). Model parameters will be calibrated against historical data using the Ostrich software program (Matott, 2017) to maximize the fit between modelled daily streamflow and measured daily streamflow. Once the model calibration is deemed successful, the effects of different land-cover and climate change scenarios on streamflow will be quantified using hypothetical synthetic input datasets that will be evaluated by the model to predict how streamflow differs from a baseline scenario.

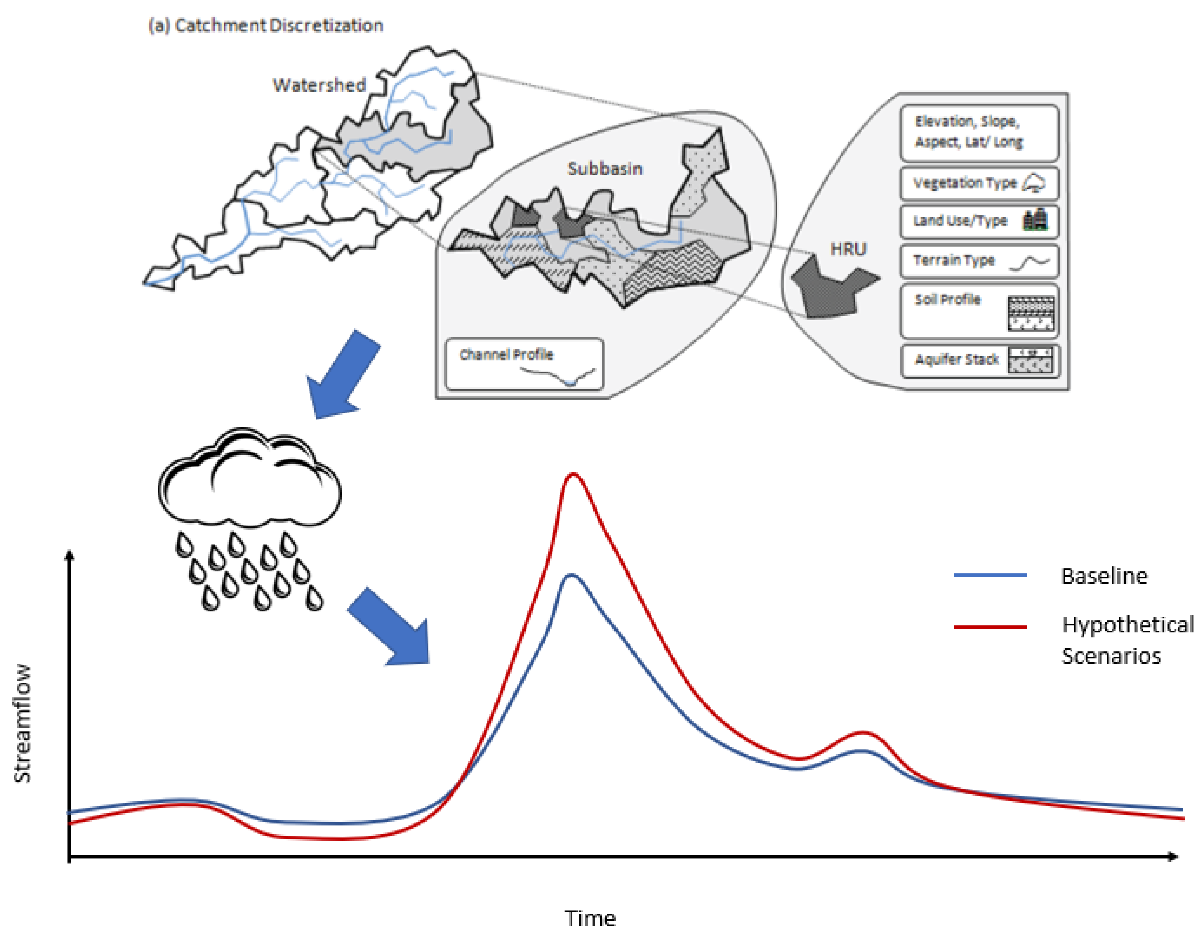


Figure 5. Conceptual hydrological modelling workflow that includes catchment discretization, meteorological input data, and the comparison of streamflow response between baseline and hypothetical scenarios.

Hydraulic-Habitat Modelling

Hydraulic-habitat models will be used to quantify physical fish habitat as a function of physical and environmental input data such as streamflow, stream temperature, turbidity, and invertebrate drift (prey availability). The models developed through this component of the program will support the sensitivity analysis, described in Section 5.4.4.3. Different hydraulic-habitat modelling techniques will be used to characterize the impacts of rearing and spawning fish since their habitat needs differ. For rearing fish, a bioenergetic suitability model (BSM) framework developed by Naman et al. (2020) will be adapted to the present study. This model incorporates water temperature, water quality, prey availability, and stream hydraulics to predict the net energy intake of rearing fish. Water temperature, water quality, and prey data collected as a part of the baseline program and the field campaign will be used as inputs to the BSM. GIFT developed by McParland et al. (2016) will be leveraged to generate hydraulic inputs related to streamflow (distributions of depths and velocities). GIFT was chosen because it provides an efficient alternative to approaches, and because it can be used to evaluate hypothetical changes to channel morphology. GIFT will also be used to evaluate the impacts of future climate and land-use scenarios, as determined by the Raven model discussed above. To characterize habitat available to spawning fish, habitat modelling will involve the use of regionally-derived habitat suitability curves for depths and velocities. These curves have been developed using data from numerous B.C. streams by the Ministry of Environment and Climate Change Strategy and are most appropriate for characterizing the habitat preferences of spawning fish.

5.4.4.3 Sensitivity [redacted]

The key input parameters for the BSM are streamflow, stream temperature, and turbidity. Through the evaluation of watershed-scale impacts discussed above, the effects that logging, climate change, and agriculture have on the streamflow regime, stream temperature, and potentially sediment inputs will be quantified under different hypothetical scenarios. These effects will then be coupled to the hydraulic-habitat models by adjusting the relevant input parameters and comparing the outputs to baseline scenarios. The results from this analysis will quantify the net energy intake available to rearing fish and changes in the suitable area for spa[redacted] these different climate and land-use scenarios.

In addition to quantifying specific climate and land-use scenarios, this evaluation will also include a sensitivity analysis, which will involve adjusting one input parameter for the habitat models at a time and systematically quantifying the impacts to the associated fish species. This will quantify the environmental variables that present the biggest risk to fish and the extent these variables are expected to change in the future in response to stressors like climate and land-use change. This will provide key information that describes environmental variables which fish are most sensitive to, and can be used for future remediation and management actions.

Photograph 3: Clear cuts within the upper Fraser River watershed (Photo: Robin McKillop).

5.4.5 Research Applications

The key outcomes of this research relate to the quantification of environmental stressors and how geographic differences or disturbance-induced changes in environmental variables affect the health and productive capacity of fish and fish habitat in the upper Fraser River watershed. Three specific research applications warrant [redacted] as a part of this program are efficient and scientifically robust methods for evaluating both the biological and hydraulic components of instream flow assessments; however, they have not been widely adopted by practitioners because few studies have showcased and tested their functionality. A key outcome of this study will be to develop a framework for conducting efficient and robust instream flow assessments and can serve as a guide for future evaluations.

1) The techniques [redacted] as a part of this program are efficient and scientifically robust methods for evaluating both the biological and hydraulic components of instream flow assessments; however, they have not been widely adopted by practitioners because few studies have showcased and tested their functionality. A key outcome of this study will be to develop a framework for conducting efficient and robust instream flow assessments and can serve as a guide for future evaluations.

2) This analysis wi[redacted]tative prediction of how different environmental stressors (i.e. logging, agriculture, clim[redacted]are expected to change physical watershed characteristics and suitability of fish habitat. T[redacted]ings will allow managers to identify and optimize restoration and conservation efforts to address these potential issues.

3) This project will support the production of datasets that characterize fish habitat and physical watershed characteristics in Davidson Creek. Examples include streamflow and water temperature records, climate change simulations, and bioenergetic fish habitat suitability models. These data and products will be made publicly available to inform future research and investigations in the region.

5.4.6 Deliverables

The following deliverables are proposed for this research program:

- Contributions to annual reports.

- Submission of an applied paper that provides specific guidance about how practitioners and water managers could collect data and implement alternative streamflow-habitat modelling techniques to a peer-reviewed journal. This document will help guide fisheries managers, consultants, and regulators to implement improved methods of fish habitat assessment such as geomorphic instream flow tools and bioenergetic suitability modeling.
- A technical report that will be catalogued in the publicly-available B.C. Ecological Reports Catalogue (EcoCat) database (or similar), and/or submitted to a peer-reviewed journal. The report will provide the results of the sensitivity analysis component of the study and will provide regionally-specific information to fisheries and watershed managers in the upper Fraser River region

[redacted]

[redacted]

6. Schedule

All four proposed research projects will be completed concurrently over a three-year period. The proposed schedule is detailed in Table 1.

Table 1. Overview of the proposed complementary measures research program schedule by quarter.

Program	Task	Year 1				Year 2				Year 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Thermal ecology	Project Initiation	O											
	Literature Review		O	O	O								
	Field Work		F	F			F	F					
	Data Processing, Analysis, Modelling				O	O		O	O	O			
	Thesis and Manuscript Preparation									O	O	O	O
	Conferences							M					
Sediment Dynamics	Project Initiation	O											
	Literature Review		O	O	O								
	Field Work		F	F	F		F	F	F				
	Data Processing, Analysis, Modelling					O		O	O	O			
	Thesis and Manuscript Preparation									O	O	O	O
	Conferences							M				M	
Hydroclimate and Water Temperature	Project Initiation	O											
	Literature Review		O	O	O								
	Field Work		F		F		F		F		F		F
	Data Processing, Analysis, Modelling			O		O		O	O	O			O
	Thesis and Manuscript Preparation									O	O	O	O
	Conferences							M				M	
Instream Flow Assessment Methodologies	Project Initiation	O											
	Literature [redacted]		O	O	O								
	Field Wor [redacted]		F	F									
	Data Proc [redacted]				O	O	O						
	Manuscript Preparation							O	O	O			
	Conferences							M					
General Tasks	Scientific Advisory Group Meeting			M				M				M	
	Annual Reporting				O				O				O

F Field-based tasks
O Office-based tasks
M Meetings and conferences

[redacted]

7. Budget

The total budget for the three-year proposed research program is **$1,014,327**, excluding applicable taxes (Table 2). All Palmer fees related to conducting research activities will be billed at cost for this project. A 20% contingency has been applied to cover potential future expenses not captured in this budget.

Table 2. Budget summary for the proposed complementary measures research program.

Program	Item	Cost ($)
Thermal Ecology	Field Equipment	60,150
	Travel Expenses	5,750
	Contractor Expenses	22,500
	M.Sc. Stipend	42,000
	UNBC Overhead (15%)	19,600
	Program Subtotal	**150,000**
Sediment Dynamics	Field Equipment	33,000
	Travel Expenses	5,000
	Lab Analysis	42,400
	M.Sc./Post-doctoral fellow stipend	50,000
	UNBC Overhead (15%)	19,600
	Program Subtotal	**150,000**
Hydroclimate and Water Temperature	Field Equipment	27,900
	[redacted]avel Expenses	22,500
	Field Tech Wage	30,000
	Post-doctoral fellow stipend	50,000
	UNBC Overhead (15%)	19,600
	Program Subtotal	**150,000**
Instream Flow Methodologies	Field Work	11,932
	Field Expenses	4,778
	Modelling, Analysis, Manuscript/Report	126,317
	Program Subtotal	**143,026**
First Nation Engagement and Capacity Building	Advisory Group Meetings	30,000
	Research Assistant Positions	60,000
	Program Subtotal	**90,000**
Project Coordination	Annual Reporting	80,154
	Project Management, Coordination, Engagement	82,092
	Program Subtotal	**162,246**
Subtotal		845,272
Contingency (20%)		169,054
Grand Total		**$1,014,327**

8. Calculation of Complementary Measures

Based on the policy detailed by DFO (2019), complementary measures may account for up to 10% of the proposed habitat offsetting for a project. The corresponding quantity of offsetting that complementary measures may provide is based on the estimated cost of implementing the other proposed offsetting measures.

The calculation break-down for the value of complementary measures is detailed in Table 3. As detailed in the Schedule 35 Application, the proposed cost of offsetting for the Blackwater project is $13,590,000, which corresponds to a total habitat gain of 185,507 habitat units. The total estimated cost of the proposed complementary measures proposal is $1,014,327 which is 7.5% of the value of the other proposed offsetting. Therefore, the corresponding value of the proposed complementary measures is equivalent to 12,924 habitat units.

Table 3. Calculation of complementary measures value.

Program	Cost ($)	Proportion of Total Offsetting Cost	Habitat Units	Proportion of Total Habitat Units
Offsetting Programs	$13,590,000	92.5 %	172,565	92.5 %
Complementary Measures	$1,014,327	7.5 %	12,924	7.5 %
Totals	$14,604,327	100 %	185,507	100 %

[redacted]

[redacted]

9. Summary of Project Outcomes

A summary of the deliverables and research applications that are expected to result from this proposed complementary measures research program are provided in Table 4.

Table 4. Summary of proposed deliverables and research applications.

Program	Deliverables	Research Applications
Thermal ecology of rainbow trout in the Stellako River	• Submission of two manuscripts to peer-reviewed publications. • Two conference presentations (national and international). • Publicly archived data set on water temperature to be contributed to a regional database currently in development and maintained by the Freshwater Fish Ecology Laboratory at UNBC.	• The findings will thus inform how salmonids may respond to changes in water temperatures caused by the exploitation of natural resources in the watershed and ongoing climate change. • Findings on how rainbow trout respond to water temperatures may inform the management of the unique Stellako rainbow trout fishery. • Inform how changes to the watershed may affect thermal conditions for the development of sockeye salmon embryos and fry.
Impact of fine sediment on salmonid habitats in the Nautley watershed	• Submission of two manuscripts to peer-reviewed publications. • Two conference presentations (national and international). • Publicly archived data set on susp[redacted]es, storage, and [redacted]	• The identification of the source of sediments and associated contaminants will help identify management practices and policy advice to mitigate sediment delivery. • Identification of sediment flux and storage will identify hot-spots that may stress spawning and other habitat. • Further development of sediment sampling and tracing techniques that can be applied throughout B.C.
Past and future trajectory of the hydroclimate and water temperatures in the Nautley watershed	• Submission of two manuscripts to peer-reviewed publications. • One 'data' paper. • Conference presentations • local outreach. • Publicly archived data set.	• Characterization of thermal regimes that can be used to assess heat-related risks to resident and anadromous fish. • Predictions of future temperature and streamflow regimes that can be used to inform planning and decision making to protect fish within the upper Fraser watershed. • Development of novel technique to estimate flows in ungauged basins within the upper Fraser River basin.
Demonstrating novel techniques to quantify the effects of land-use change on fish.	• Sub[redacted]anuscript to a peer-reviewed publication. • Preparation of a technical report that will be publicly archived. • Conference presentations and/or local outreach. • Publicly archived data set.	• Development of a framework to conduct robust instream flow assessments using improved methods. • Quantitative predictions of how different environmental stressors affect fish habitat will allow for the identification of efficient restoration and conservation efforts.
All programs	• Preparation of annual reports that encompass each research program and will provide a description of the project activities to date, a presentation of preliminary results, and a description of next steps.	• Findings will be disseminated to Advisory Group members for training and education purposes. Finally, the observational database will be made publicly available in a long-term data archive as a legacy of this project.

10. Certification

This report was prepared, reviewed, and approved by the undersigned:

Prepared By: <original signed by>

Stefan Gronsdahl, M.Sc., P.Geo.
Hydrologist

Reviewed By: <original signed by>

Ian MacLeod, B.Sc., R.P.Bio, P.Biol.
Senior Fisheries Biologist

Reviewed By: <original signed by>

Robin McKillop, M.Sc., P.Geo.
Principal, Senior Geoscientist

Approved By: <original signed by>

Rick Palmer, M.Sc., R.P.Bio
President & CEO, Senior Fisheries Biologist

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Appendix A

Project Team CVs

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Palmer™

Rick Palmer

M.Sc., R.P. Bio.

President & CEO, Senior Fisheries Biologist

Professional History

Palmer
President and CEO
Senior Fisheries Biologist
Vancouver, BC
2010 - Present

AECOM
Manager, Water and Natural Resource Practice Area Lead
BC & Yukon
2008 - 2010

Gartner Lee Limited
Manager, Natural Resources Team Lead
Vancouver, BC
2006 - 2008

Gartner Lee Limited
Senior Fisheries Biologist / Project Manager
Toronto, ON
2001 - 2006

ARC Environmental Ltd.
Senior Fisheries Biologist / Project Manager
Kamloops, BC
1999 - 2000

Triton Environmental Ltd.
Fisheries Biologist
Vancouver, BC
1996 - 1999

Summary

Rick Palmer is the President and CEO and Senior Fisheries Biologist at Palmer. Rick has over 25 years of experience undertaking and managing fisheries inventories and aquatic impact assessments for a wide range of private, public and industry related projects. He has extensive experience with baseline/impact fish and fish habitat assessments as they relate to mining, hydroelectric and water supply developments. Rick engages Fisheries and Oceans Canada and other agencies on a regular basis to find solutions for client issues. He has been involved with environmental impact assessments, technical baseline studies, environmental monitoring programs and peer review in British Columbia, Alberta, Ontario, Yukon, NWT and Nunavut.

Rick provides senior management of environmental permitting process for large-scale natural resource development projects. His technical areas of expertise include fisheries aquatic ecology, in-stream flow modelling, environmental impact and risk. He has provided technical expertise at public hearings for issues related to aquatic environments and is considered an expert in aquatic-related provincial and federal regulations in Canada.

Experience

Energy

- **Site C Clean Energy Project, BC | 2020** Senior Fisheries Biologist & Project Director for the Temporary Fishway Operation. Client: Peace River Hydro Partners (PRHP)
- **Site C Clean Energy Project, BC | 2020** Senior Fisheries Biologist & Project Director for the Fish Salvage Operation on the Peace River. Client: Peace River Hydro Partners (PRHP)
- **BRGMON-13 Seton River sockeye smoltt entrainment program, BC | 2019** Senior Fisheries Biologist and QEP. Client: BC Hydro (St'at'imc Eco-Resources Ltd)
- **Trans Northern Pipeline Inc. (TNPI), ON | 2017-present** Senior Fisheries Biologist for several crossing repairs.
- **Seton River Transmission Crossing, BC | 2018** Senior Fisheries Biologist, Fisheries Self Assessment. Client: BC Hydro
- **Blackwater Project Transmission Line Project, BC | 2015-present** Senior Fisheries Biologist, Fisheries Offsetting Plan. Client: New Gold
- **Gladstone Diversion Project, YK. | 2009-2011** Senior aquatic advisor and Fish and Aquatic Discipline Lead. Client: Yukon Energy Corporation
- **Atlin Storage and Control Structure Project, YK | 2009-2011** Senior aquatic advisor and Fish and Aquatic Discipline Lead. Client: Yukon Energy Corporation
- **Marsh Lake Fall-Winter Storage Project, YK | 2009-2011** Senior aquatic advisor and Fish and Aquatic Discipline Lead. Client: Yukon Energy Corporation

Mining

- **Elk Gold Project, BC | 2019-present** Project Director and Senior Fisheries Biologist for Environmental Baseline and MAPA. Client: Bayshore Minerals
- **Premier Gold Mine Project, BC | 2018-present** Project Director for Environmental Baseline and MAPA. Client: Ascot Resources

resume

- **Kwanika Project, BC | 2018 -2019** Project Director and Senior Fisheries Biologist for environmental baseline studies in support of a PFS. Client: Serengeti Resources
- **Elk Gold Project, BC | 2018 -2019** Project Director, Closure and Reclamation Plan. Client: Equinox Gold,
- **Blackwater Project, BC | 2015-2018** Fisheries Permitting Lead, Fish Offsetting Plan. Client: New Gold,
- **Red Mountain Project, BC | 2016-2018** Project Director for Fisheries, Aquatic Resources Client: IDM Mining
- **Casino Mine, YT | 2008-present** Project Manager and Fisheries and Aquatic Lead for Environmental Baseline and EA. Client: Western Copper and Gold
- **Cullaton Lake, NU | 2007-2009 & 2016-present** Project Director for Aquatic Risk Assessment; Closure and Reclamation Plan. Client: Barrick Gold
- **Brucejack Mine, BC | 2018** Project Manager for Bathymetric Assessment for Road upgrades and DFO Fisheries Permitting. Client: Pretium Resources,
- **Ambershaw Metals Inc. ON | 2017-2019** Project Director for Environmental Baseline Program
- **Ajax Mine, BC | 2016-2017** Fish Offsetting Plan support for EA. Client: KGHM
- **Coffee Gold, YT | 2014-2015** Project Manager, Fisheries and Aquatic Lead for Environmental Baseline. Client: Kaminak Gold
- **Elk Gold Project, BC | 2012-2014** Project Manager and Fisheries and Aquatic Lead for Environmental Baseline and Mines Act Amendment Permit. Client: Gold Mountain Mining Corporation,
- **New Polaris Mine Project, BC | 2011-2015** Project Director and Lead Fisheries Biologist for environmental baseline program, effects assessment; development of the dewatering program technical assessment report in support of a discharge permit application. Client: Canarc Resources,
- **Hushamu Project, BC | 2011-2014** Project Manager and Lead Fisheries Biologist for Baseline Programs. Client: Northisle Copper and Gold
- **Tulsequah Chief Mine, BC | 2007-2015** Project Director for Aquatic Risk Assessment; provide fisheries expertise for various environmental permitting and approvals programs; Aquatic field work for EEM and juvenile fish stranding programs. Client: Chieftain Metals,
- **High Lake Project, NU | 2007-2008** Fish and Aquatic Resource Lead for Environmental Baseline and Effects Assessment; Technical Hearing in Cambridge Bay. Client: OzMinerals,
- **Damoti Lake, NU | 2004-2006** Project Manager, Team Lead for Environmental Baseline Program. Client: Doublestar Resources
- **DO – 18 Project, NWT | 2005-2006** Project Manager, Senior Fisheries Biologist for Environmental Baseline Program Client: Peregrine Diamonds,
- **Izok Lake Project, NU | 2015** Fisheries Lead for multiple accounts analysis in support of Environmental Assessment. Client: MMG Limited,
- **Nordegg, AB | 2012** Environmental Due Diligence Project Lead. Client: NWP Coal Canada,
- Anglo American / Peace River Coal, Belcourt Saxon, BC | 2006 - 2009 Fish and Aquatic Resource Lead for Environmental Baseline Program.
- **Fish Lake Project, BC | 1994-1996** Fisheries Field Biologist for Environmental Baseline and Effects Assessment. Client: Taseko Mines

Land Development and Infrastructure

- **Mission Force Main Project, BC | 2019-present** Project Director and Senior Fisheries Biologist for obtaining a Federal Fisheries Act Authorization for an open cut & dredging project across the Fraser River. Client: City of Mission
- Alberta and BC National Park Infrastructure Projects | 2015-present Project Director and Senior Fisheries Biologist for several fisheries self- assessments and DFO requests for review for bank stabilization, bridge and culvert projects. Client: Parks Canada
- **Bank Stabilization Project, BC | 2018-present** Project Director and Senior Fisheries Biologist for bank stabilization project involving the protection of white sturgeon spawning areas Client: City of Vanderhoof
- **Ecosystems and Species Monitoring Program, BC | 2016-present** Fisheries Senior Lead. Client: Resort Municipality of Whistler
- **Dahlaks Creek Bridge Repair, BC | 2018** Senior Fisheries Lead for obtaining a Fisheries Act Authorization. Client: British Columbia Timber Sales
- **Wapiti River Coordinated Monitoring Program (CMAP), AB | 2007-present** Project Manager Client: Aquatera Utilities

- **Wapiti River Instream Flow Program, AB | 2014-2018** Designed, implemented and developed an instream flow program on the Wapiti River using a physical habitat simulation model (PHABSIM) and a River2D model to establish new instream objectives (IO) for the water licence. Client: Aquatera Utilities
- **Wapiti River Water Management Plan, AB | 2015-2018** Provided technical support to the WRWP Technical Steering Committee. Client: Aquatera Utilities
- **Wapiti River Fisheries Assessments, AB | 2007-2008** Project Manager, Fisheries Lead. Client: Aquatera Utilities
- **Lindsay Court Wells, ON | 2004** Fisheries Lead Client: Regional Municipality of Halton
- **9th Line and 16th Avenue Sanitary Sewer, ON | 2002-2005** Project Manager, Fisheries Lead. Client: York Region

Peer Review

- **Hope Bay, NU | 2011-2017** Fish and Fish Habitat Lead for Peer Review. Client: Kitikmeot Inuit Association
- **Back River, NU | 2014-2017** Fish and Fish Habitat Lead for Peer Review. Client: Kitikmeot Inuit Association
- **Madrid, NU | 2015** Fish and Fish Habitat Lead for Peer Review. Client: Kitikmeot Inuit Association
- **Jay Pipe, NU | 2015** Fish and Fish Habitat Lead for Peer Review. Client: Kitikmeot Inuit Association
- **Ivanhoe, AB | 2011-2012** Fish and Fish Habitat Lead for Peer Review. Client: Management and Solutions in Environmental Science (MSES)
- **Bootjack Creek, BC | 2012** Fish and Fish Habitat Lead for Peer Review. Client: William Lake Indian Band
- **Total A&P, AB | 2013-2015** Fish and Fish Habitat Lead for Peer Review. Client: MSES

Education

Master of Science (M.Sc.) - Fisheries
University of Waterloo, Ontario | 2006

Bachelor of Science (B.Sc.) - Biology
Simon Fraser University, British Columbia | 1996

Diploma of Technology (Dip. T) – Renewable Resource, Fish, Wildlife & Recreation
British Columbia Institute of Technology, British Columbia | 1989

Professional Development, Certifications and Associations

- Registered Professional Biologist with the College of Applied Biology (BC)
- St John's Ambulance Emergency First Aid for Industry (OFA Level 1 Equivalent)
- Supervisor backpack electrofishing certification
- Advance PADI certification

Reports and Presentations

Over 100 technical reports completed, which are available on request. Rick has presented at scientific and engineering conferences and workshops across Canada and within the USA and Europe.

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Stefan Gronsdahl

M.Sc., P.Geo.
Hydrologist

Professional History

Palmer
Hydrologist
2020-present

Polar Geoscience Ltd
Hydrologist
2018-2020

University of British Columbia
Graduate and Research Assistant
2016-2018

Associated Environmental Consultants Inc.
Environmental Scientist
2013-2016

Summary

Stefan Gronsdahl is a watershed hydrologist with six years' experience in environmental consulting throughout western and northern Canada. Stefan has a strong and diverse background in hydrology and climate baseline evaluations, watershed hydrology, hydrological modeling, and statistical analysis. Stefan's work has focused on the impacts of resource development, land-use, and climate change on streamflow, with an emphasis on the effects on low flows and fish habitat. He regularly applies his strong analytical and modelling skills to find innovative solutions to answer challenging applied questions in support of effective resource management strategies. Stefan completed a M.Sc. thesis that investigated the hydrological impacts of forestry on low-flows and fish habitat in the southern interior of B.C. Stefan is an effective, efficient, and rigorous field and office-based scientist. He focuses on clients' needs and has proven to be technically innovative. He has also developed familiarity with key legislation specific to water and environmental-related issues in western Canada.

Experience

Hydrological Modelling and Water Supply Assessments

Okanagan and Kalamalka Lakes Flood Forecasting Enhancements | 2021
Project hydrologist responsible for quality checking, processing, and gap-filling snow, meteorological, and streamflow data using appropriate statistical methods. Stefan also conducted a detailed assessment of previous iterations of the model to identify potential approaches to improve model performance. The data analysis and modelling was conducting using the 'R' programming language and the Raven modelling platform.
Client: BC River Forecast Centre

Detour Lake Water Balance Modelling | 2021
Stefan is a project hydrologist who assisted with the development of a water balance model that considers how future climate change scenarios will impact the mine-site water balance and closure plan. Data analysis and modelling was primarily conducted using the 'R' programming language and the GoldSim modelling framework.
Client: Kirkland Gold Inc.

Water Balance Modelling | 2020
Stefan helped with the development and calibration of a semi-distributed and physically based monthly water balance model of the Salmon River watershed on the west-coast of northern B.C. The model was developed in a complex watershed which is heavily glacierized and regularly experiences glacial lake outburst floods. The results from this analysis will be incorporated with groundwater and water quality models and will be used to evaluate the effects of mining operations on the downstream receiving environment.
Client: Ascot Resources Ltd.

Statistical Inflow Modelling | 2020
Stefan was the project hydrologist responsible for developing statistical models that used snowpack and climate data to predict seasonal inflows, water supply, and floods for Okanagan Lake, Kalamalka-Wood Lake, Nicola Lake, and the Nicola River, in the southern interior of B.C. He was responsible for processing

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and gap-filling snow, meteorological, atmospheric teleconnection data, and seasonal weather forecast data using appropriate statistical methods. Stefan also helped develop the empirical statistical models that will be used for real-time, operational predictions of seasonal inflow forecasts throughout the spring and early summer. Easy-to-use operational tools were developed so that inflow forecasts could be efficiently generated by the client. Analytical techniques used as a part of this project included linear and non-linear regressions, multivariate statistical modelling, principal component analysis, double-mass corrections, rating curve development, and linear and non-linear interpolation schemes.
Client: BC River Forecast Centre:

Hydrological Modelling of Snow and Runoff Generation Processes | 2019-2020
Stefan was the lead hydrologist responsible for development of a physically based hydrological model that was used to identify how snow dynamics, runoff generation, and land-use change impacts peak flows, water supply, and fish habitat in the Horsefly Watershed. Stefan was responsible for the study design, model development, calibration and validation, data analysis, and interpretation of results. Spatial data pre- and post-processing and data analysis were conducted using free, reproducible, and open-source software including the 'R' programming language and the Raven modelling framework. The results of the modelling exercise were interpreted to understand the effects of forestry on streamflow and have allowed for the development of forest management practices to minimize the impacts to infrastructure and fish habitat.
Client: Tolko Industries Ltd.

Baseline Hydrology and Climate Program | 2020-Present
Evaluated hydrometric and climate data quality in accordance with industry standards and provincial guidelines. Conducted data analysis, regional analyses, and processing including frequency analyses and the development of rating curves. Stefan provided support to field staff who are conducting hydrometric monitoring at the Premier and Red Mountain projects. Stefan also developed a training manual for field staff who are conducting regular hydrometric and climate monitoring.
Client: Ascot Resources Ltd.

Water Supply Assessment | 2018
Project Hydrologist responsible for data analysis and reporting as a part of a comprehensive water supply and demand study in the lower Fraser Valley to support the Stó:lo Nation's treaty negotiations. Hydroclimatic data analysis was conducted using the 'R' programming language.
Client: Stó:lo Xwexilmexw Treaty Association.

Environmental Flow Needs Assessment and Planning for Okanagan Lake | 2018
Project Hydrologist responsible for researching historical water licences and water consumption with the end goal of recreating naturalized hydrographs to be used to determine site-specific environmental flow needs for 18 tributaries of Okanagan Lake, BC. This work was conducted to inform the eventual development of a hydrological model intended to inform decisions regarding water supply and environmental flow needs in the Okanagan basin.
Client: Okanagan Basin Water Board

Fisheries and Instream Flow Needs

Blackwater Mine Site – Development of Instream Flow Needs | 2020
Stefan is the lead hydrologist responsible for understanding and quantifying how changes to the streamflow that will be caused by mine development will affect aquatic ecosystems in a tributary stream of the Nechako River, in central B.C. Stefan has designed and executed an analysis that incorporates hydrological model data with the results of instream flow assessments to quantify how changes in streamflow affect fish. This analysis has led to the development of a mitigated instream flow needs that will minimize impacts to aquatic ecosystems. The results of Stefan's analysis will serve as the basis for engineering design of water diversion and retention infrastructure.
Client: Artemis Gold Inc.

Instream Flow Methodology Evaluation | 2019-2020
Stefan is the lead scientist responsible for developing and validating an innovative approach for conducting instream flow assessments. The approach utilizes a cost-effective and analytically robust technique for evaluating how changes in streamflow affect physical fish habitat that would improve the quality and efficiency of instream flow assessments. This method is also an improvement on more conventional instream flow assessment techniques

because it can be used to quantify the effects of land-use and climate change on channel morphology and fish habitat.
Client: Habitat Conservation Trust Foundation

Fisheries Sensitive Watershed Assessment | 2019-2020
Project hydrologist responsible for analyzing and interpreting watershed characteristics in three watersheds in support of developing watershed management strategies to protect fish and fish habitat. This work involved characterizing channel morphology and hydraulics, reviewing aerial photographs, evaluating the past impacts of forest disturbance and road construction, and evaluating sedimentation and erosion potential.
Client: BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development

Forestry and Resources Development

Watershed Assessment | 2019-2020
Project hydrologist of a comprehensive watershed assessment of Sicamous Creek, near Sicamous, BC. Responsibilities included reviewing the relevant literature that assessed the impacts of logging on watershed hydrology, evaluating riparian conditions, sediment transport potential, and watershed runoff potential. Hydroclimatic data analysis was conducted using the 'R' programming language. Sicamous Creek is a noteworthy watershed given the presence of an active alluvial fan at the outlet of the watershed and the potential for it to negatively affect riparian conditions and nearby infrastructure.
Client: Tolko Industries Ltd

Soo River Water Quality Program | 2019-2020
Lead hydrologist responsible for conducting a surface water quality sampling program in six watersheds in response to a fertilizer treatment for regenerating cutblocks. Duties included sampling, logistics, reporting, and project management.
Client: BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development

Hydrological Assessment, Chilcotin Business Area | 2019
Project hydrologist responsible for assessing the hydrological impacts of proposed forest harvesting. Assessment methods included field observations, GIS analysis, a review of physical watershed processes, and a review of available fisheries data. The results of this assessment were specific recommendations for reducing the potential impacts of forest harvesting.
Client: Tolko Industries Ltd.

Watershed Assessment | 2017
Project hydrologist of a comprehensive watershed assessment of Quartz Creek located 30 km south of Nelson BC, near the community of Ymir, BC. Responsibilities included conducting a comprehensive literature review regarding the impacts of logging, forest disturbance, and climate change on water yields and low flows. Quartz Creek is noteworthy given the high level of community concern over water supply and quality both with respect to climate change and planned forest development.
Client: BC Timber Sales, Kootenay Business Area

Hydrogeomorphic Flood Assessment | 2018-2019
Project Hydrologist responsible for a post-flood hydro-geomorphic assessment of a watershed near Clinton, BC. The assessment focused on evaluating riparian conditions and identifying the cause of major flooding and erosion on several private properties located near the 2017 Elephant Hill Fire. Investigation methods included interviews, hydroclimatic data analysis using 'R', and aerial photograph interpretation. Recommendations were made to perform culvert upgrades to mitigate erosion and sedimentation issues.
Client: BC Attorney General's Office

Hydrogeomorphic Desktop Analysis | 2019
Responsible for the review and analysis of aerial photography, ortho-imagery, and GIS data to understand the hydrogeomorphic risk associated with 32 areas where the road crossed creeks located near Howards Pass, eastern Yukon. Evaluated the potential risk associated with landslides, debris flows, floods, and erosion.
Client: Selwyn Chihong Mining Ltd.

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Stefan Gronsdahl
M.Sc., P.Geo.
Hydrologist

Education

Master of Science
University of British Columbia | 2016-2018

Bachelor of Science, Physical Geography
University of Victoria | 2007-2013

Professional Development, Certifications and Associations

Professional Associations

- Professional Geoscientist
- Engineers and Geoscientists of B.C.
- Canadian Society for Hydrological Sciences.

Software

- Raven Hydrological Modelling Platform
- System for Environmental Flow Analysis (SEFA).
- R Statistical Analysis and Programming Language

Reports and Presentations

- **Gronsdahl, S.,** Moore, R.D., Rosenfeld, J., McCleary, R., and Winkler, R.D. 2019. Effects of forestry on summertime low flows and physical fish habitat in snowmelt-dominant headwater catchments of the Pacific Northwest. Hydrological Processes. https://doi.org/10.1002/hyp.13580
- Moore, R.D., **Gronsdahl, S**., and McCleary, R. 2020. Effects of forest harvesting on warm-season low flows in the Pacific Northwest: A review. Confluence: Journal of Watershed Science and Management. https://doi.org/10.22230/jwsm.2020v4n1a35

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Dave Huebert

Ph.D., P.Biol., R.P.Bio.
Senior Environmental Scientist

Professional History

Palmer
Senior Environmental Scientist
Vancouver, BC
2019 – present

AECOM
Senior Environmental Scientist
Burnaby, BC
2014 – 2019

Stantec Consulting
Senior Environmental Scientist
Burnaby, BC
2012 – 2014

Stantec Consulting
Senior Environmental Scientist
Winnipeg, MB
2010 – 2012

TetrEx Consultants
Environmental Scientist
Winnipeg, MB
2004 – 2010

Independent Environmental Consultant
1983 - 2004

Summary

Dave is a registered professional biologist in both Alberta and British Columbia, specializing in aquatic and terrestrial ecology and toxicology. He completed his PhD in the Department of Botany at the University of Manitoba in 1992, where he focused his studies on the interaction of environmental and chemical factors on assessment of cadmium toxicity in the duckweed, *Lemna trisulca*.

Subsequent to obtaining his PhD, he worked as an independent contract scientist with the Department of Fisheries and Oceans at the Experimental Lakes Area, and as a sessional instructor at a variety of educational institutions in Winnipeg, Manitoba.

As a consultant, initially hired in 2004 by Tetr*ES* Consultants Inc. and most recently with Palmer, He has worked on a variety of projects in the mining, oil and gas, clean energy, municipal, and industrial sectors. His work has included baseline characterization, environmental assessment, environmental and aquatic effects monitoring plan design and implementation, adaptive management plan design and implementation, environmental compliance monitoring and reporting, and third-party reviews of environmental assessment reports for both government and First Nations organizations.

His field experience in ecology and toxicology includes a variety of projects across the west and into the north, and includes experience conducting assessment of groundwater, assessment of upland vegetation, and assessment of surface water, vegetation, fish, benthic invertebrates and periphyton in the aquatic environment.

Experience

Watershed Monitoring | 2019-2020

Dave developed a watershed monitoring strategy for the CVRD, complete with a decision matrix for determination of site importance based on the existing data record, assessed risk, and location of each site within the watershed. The approach included establishing long-term monitoring sites for definition of baseline conditions and providing a strategy for developing short-term sites and aquatic monitoring programs to address emerging issues. Client: Cowichan Valley Regional District (CVRD)

Casino Mine | 2021

The Casino Mine is a proposed gold and copper mine in Yukon. Dave completed a gap analysis of existing data for surface water, hydrology, and fish and fish habitat. Subsequent to that, he coordinated production of the 2021 Work Plan and budget to address identified data gaps.
Client: Casino Mining Corp.

Shasta/Baker Mines Compliance Monitoring | 2020-2021

Dave provided senior technical review of an Aquatic Effects Monitoring Program to collect surface water and aquatics data for Permit compliance for both mine sites and then coordinated completion of two Annual Surface Water Reports and an Aquatic Effects Monitoring Report. Dave was the principal author of the Annual Reports, and the senior technical reviewer for

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the Aquatic Effects Monitoring Program report. He also helped design the Annual Surface Water sampling program for subsequent years.
Client: Talisker Resources

Elk Gold Project | 2019-2021
An assessment was required for a BC Mines Act Amendment to restart mining at Elk Gold. Dave's role was to write the Surface Water Baseline Report, to provide a senior technical review of the Fish and Aquatics Baseline Report, to write the Water Quality Effects Assessment, to provide a senior review of the Fish and Aquatics Effects Assessment, and to write the Environmental Monitoring Plan (EMP) for the Project. The EMP included an Aquatic Effects Monitoring Plan, Post-Closure Monitoring Plan, Discharge Monitoring Plan, Mine Site Water Monitoring Plan, and Environmental Monitoring Plan for compliance monitoring. Once the application had been submitted and reviewed, Dave was part of the technical team responding to the Information Requests. He also completed a senior technical review of the 2019 Elk Gold Project Annual Discharge Report for EMA Discharge Permit 106262.
Client: Bayshore Minerals

Annual Ecosystems Monitoring Program Report | 2021
Dave was the senior technical reviewer for the aquatics section of the Annual Report. His role was to review the data analysis and interpretation for the surface water, sediment, periphyton, and benthic invertebrate sections of the report. Client: Town of Whistler

Premier Gold Project | 2019-2021
An assessment was required for a BC Mines Act Amendment to restart mining for the Premier Gold Project. Dave's role was to write the Surface Water Baseline Report and to provide a senior technical review of the Fish and Aquatics Baseline Report. He also provided a senior technical review of the 2019 Aquatic Effects Monitoring Program report and provided recommendations for transition of the existing care and maintenance surface water monitoring program to operations monitoring. Once that was all complete, he wrote the Baseline Summary Reports for the Surface Water and the Freshwater Fish and Fish Habitat Valued Components, and then wrote the Effects Assessment Chapters for the same VC's. In addition, he developed and wrote the Environmental Monitoring Plan for the Project, which included an Aquatic Effects Monitoring Program and associated Adaptive Management Plan. Once the application had been submitted and reviewed, he was part of the technical team responding to the Information Requests.
Client: Ascot Resources

Tundra Mine Site Remediation | 2017-2018
The Tundra Mine is an abandoned mine site in the Northwest Territories that is being remediated. The role was to develop and write an Adaptive Management Plan for the aquatic monitoring phase once the remediation project was complete. Compiled and summarized the available environmental data preparatory to development of a site-specific water and contaminant transport model.
Client: Indigenous and Northern Affairs Canada

Yellowknife Bay Potable Water Source Selection | 2017
A new water intake structure is required for the City of Yellowknife. To facilitate construction of the project, an analysis of Yellowknife Bay water and sediment arsenic was required. The role was to compile water and sediment chemistry data, develop an approach to analysis of the data, and write an assessment to characterize arsenic in Yellowknife Bay. Managed the project and oversaw report delivery. The conclusions were presented to the City Council of Yellowknife twice.

Faro Mine Aquatic Effects Monitoring Program Workplan | 2017
The Faro Mine complex is an abandoned mine site in the Yukon Territories. The role was to develop a work plan and budget for the 2017 monitoring of the aquatic environment upstream and downstream of the site in collaboration with Golder Associates. Undertook a gap analysis of recent aquatics documents to determine what additional information might need to be collected during the 2017 aquatic monitoring program.
Client: Indigenous and Northern Affairs Canada

Pulp and Paper Cycle 7 IOS EEM Report | 2016

Provided senior review for an Investigation of Solutions (IOS) Interpretive Report for the Cycle 7 Environmental Effects Monitoring (EEM) program at the Tolko pulp and paper operations located in The Pas, Manitoba. Provided responses to Information Requests sent by Environment Canada.
Client: Tolko Industries Ltd.

Regina Master Plan | 2016

The role was to determine the scope, status and relevance of existing source water protection plans for the Regina area. Evaluated and summarized existing documents, including the Upper Qu'Appelle and Wascana Creek Watersheds Source Water Protection Plan and the Water Security Plan of the Saskatchewan Water Security Agency. Included were recommendations to the City of Regina for optimal implementation of the Protection Plans.
Client: City of Regina

Stoney Creek Water Sampling Program | 2015

AECOM was selected to complete a water chemistry and benthics sampling program in Stoney Creek over the course of one sampling year (wet and dry season). The sampling program was conducted prior to implementation of the Integrated Stormwater Management Plan (ISMP) for the Stoney Creek sub-watershed. The City of Burnaby was interested in comparison of current results with those collected previously in 1999. The objective was to develop an understanding of temporal changes (both negative and positive) in this sub-watershed. The role was to provide a technical review of the analysis and interpretation of the water chemistry and benthics data.
Client: City of Burnaby

Effects of Chlorination in Marine Downstream Receiving Waters | 2015

Marine vessels, nuclear power plants, thermal power plants, and various other marine facilities require the use of seawater for cooling or other purposes. Growth of marine organisms on and within structures exposed to seawater, called biofouling, is the inevitable result. Biofouling reduces water movement through pipes, damages infrastructure, potentially transports invasive species, and can reduce the rate of thermal exchange in cooling systems. Control of biofouling is therefore critical to the long-term maintenance and operations of vessels, structures and facilities exposed to seawater. Chlorination with sodium hypochlorite is one of the most widely used antifouling agents due to its established technology, long-term use, low cost, high reactivity and effectiveness. However, because it is both highly reactive and toxic to marine life, there is also concern regarding the effects of residual chlorine in the downstream receiving environment. The purpose of this report was to characterize the fate of chlorine, and potential environmental effects of chlorination practices in the marine environment. A follow-up report examined the toxicological relationship between marine fish and chlorine byproducts.
Client: AltaGas DCLNG General Partner Inc.

City of Kindersley Downstream Use and Impact Study | 2015

The Town of Kindersley intends to develop a new wastewater treatment plant to allow for discharge of treated wastewater to the Teo Lakes basin, which is part of the Eagle Creek sub-basin of the North Saskatchewan River. The Town of Kindersley required an analysis of the existing water treatment, wastewater treatment, sanitary sewer and storm sewer infrastructure to assess existing capacities, and to identify shortfalls for projected future growth of the Town. The purpose of the DUIS was to guide the regulatory permitting of the future upgrades to the wastewater treatment system, and in so doing establish the basis of its design in terms of the level of treatment that will be required to ensure protection of downstream uses. The role in this project was to undertake a senior technical review of the draft report.
Client: City of Kindersley

City of Melville Downstream Use and Impact Study | 2015

The existing lagoon system for the Town of Melville consists of two anaerobic primary cells and five secondary facultative cells with a discharge to Crescent Creek. The Town of Melville required an analysis of the existing water treatment, wastewater treatment, sanitary sewer and storm sewer infrastructure to assess existing capacities, and to identify shortfalls for projected future growth of the Town. The purpose of the DUIS was to guide the regulatory permitting of the future upgrades to the wastewater treatment system (WWTS), and in so doing, establish the basis of its design in terms of the level of treatment that will be required. The role in this project was to undertake a senior technical review of the draft report.
Client: City of Melville

Lac de Gras Hydrodynamic Modeling, Northwest Territories | 2014

The GNWT Department of Public Works and Services required statistical analyses of the existing water chemistry data record for Lac de Gras (LDG) in the Northwest Territories. Baseline water chemistry was defined, spatial and temporal trends in specific parameters of concern were evaluated, and relative loading rates were calculated. The analyses sought to determine whether there were cumulative effects to LDG's water quality resulting from the operation of two diamond mines within its watershed. The role was to define and manage the study, oversee data analysis, compile and write the report, and to undertake the preliminary technical review of the report.
Client: Government of Northwest Territories (GNWT)

Water Chemistry and Hydrology Data for Five Sites in the Mackenzie River Watershed | 2013

Dave wrote the proposal and managed the project team. Wrote a report using 50 years of water chemistry and hydrology data for five sites in the Mackenzie River watershed for Aboriginal Affairs and Northern Development Canada (AANDC). The objectives of the study were to define baseline conditions, examine spatial variability within the watershed, determine if conditions have altered over the past 50 years, and define seasonal periods within the watershed.
Client: Aboriginal Affairs and Northern Development Canada

Giant Mine Remediation Project | 2014

- Wrote the fish-tissue section for the Yellowknife Bay 2014 aquatics report for the Giant Mine in Yellowknife, NWT. Analysis endpoints included length distribution, fish condition, hepatosomatic index, and liver, muscle and/or whole-body metal content for Lake Whitefish, Northern Pike and Slimy Sculpin.
- Participated in a review of the Giant Mine Surveillance Network Program for surface-water chemistry. Developed an understanding of current conditions, data gaps, and data quality. Developed recommendations for a Surveillance Network Program moving forward.
- Contributed to the development of an aquatic monitoring program for the Giant Mine in Yellowknife, NWT. The task was to work as the technical aquatic lead for the project, managing all technical aspects of the aquatics program. This monitoring program is part of ongoing work at the Giant Mine site in Yellowknife, NWT.
- As part of the Statistical Advisory Group in Stantec, undertook a post hoc power analysis of water chemistry data for Phase 1 of the Yellowknife Bay/Giant Mine remediation project. The purpose of the analysis was to determine if the level of sampling effort to date was sufficient to provide a sensitive understanding of baseline conditions prior to project implementation. This report is part of an ongoing monitoring program at the Giant Mine site in Yellowknife, NWT.

Client: Aboriginal Affairs and Northern Development Canada

Water Chemistry and Hydrology Data for the Peel River Watershed | 2012

The Peel River watershed is located in the Yukon Territories and is an almost pristine wilderness, although it is currently under pressure from resource industries. The objectives of this study were to define the seasonal hydrological cycle within the watershed, to develop an understanding of baseline water chemistry, to determine and describe any seasonal differences in water chemistry, to determine spatial variability in water chemistry, particularly moving downstream, and to determine and describe any temporal trends in water chemistry and/or hydrology. Wrote the proposal, managed the project analytical team, and compiled and wrote several sections of the report.
Client: Aboriginal Affairs and Northern Development Canada

Gahcho Kue EIS Review, Northwest Territories | 2011

Reviewed sections on water quality and quantity within, and downstream of, the Gahcho Kue diamond mine project EIA. Reviewed sections on effects to fish and fish habitat downstream of the Project. The work consisted of reviewing the methods and results to identify data gaps in the current assessment. The results of the review were presented to AANDC, DFO and Environment Canada as an assessment report to assist their respective regulatory reviews of the proponent's EIS submission.
Client: Indian and Northern Affairs Canada

West Lynn Lake Habitat Assessment, Lynn Lake, Manitoba | 2010

Undertook a habitat and fisheries resources assessment for West Lynn Lake as part of a project to provide a replacement water-intake structure for the Town of Lynn Lake, MB.
Client: Ministry of Infrastructure and Transportation

Independent Review of the Manitoba Government position on Wastewater Treatment for the City of Winnipeg | 2010

Wrote a third party review of the Province of Manitoba's requirement for nitrogen and phosphorus removal for the City of Winnipeg sewage works. Concentrated the review on the risks inherent in removal of nitrogen in a nitrogen-limited aquatic ecosystem. Examined the cost-effectiveness of nitrogen removal, considering the ability of blue green algae to fix atmospheric nitrogen.
Client: City of Winnipeg

Independent Review of Wastewater Effluent Regulations | 2010

Reviewed the proposed 2010 Federal Wastewater Effluent Regulations for the City of Winnipeg, including development of the logical flow of the Regulation. This review was subsequently used by the Canadian Waste Water Association for information purposes and was posted on their national website. Presented an analysis of deficiencies within the Regulation, and discussed implications of the Regulations for wastewater treatment for the City of Winnipeg. Developed a list of suggested corrections to the identified logical or procedural deficiencies as part of the public consultation process for the Wastewater Regulation.
Client: City of Winnipeg

Infrastructure Engineering Vulnerability Assessment, Portage la Prairie, Manitoba | 2009

Wrote a climate-change effects synopsis for the Public Infrastructure Engineering Vulnerability Committee's (PIEVC) City of Portage la Prairie Water Resources Infrastructure Assessment – Pilot Study. The study was based on existing materials, of both observed and projected changes in relevant climate parameters. As part of this assessment, the Environment Canada website (www.weatheroffice.gc.ca) was accessed for historic climatic and meteorological data. An assessment of trends in these historic data was undertaken. Future climate projections, both chronic and acute, were discussed and summarized based on the recent findings of the Intergovernmental Panel on Climate Change. These climate projections were then compared to recent, historic extreme weather events as part of a discussion of how climate change may affect the severity and frequency of future extreme weather events within the Project area.
Client: PIEVC

Water-Treatment Plant Environmental Impact Assessment, Winnipeg, Manitoba | 2006

Evaluated the environmental factors involved in the development of cyanobacterial blooms in freshwater in relation to expected discharges from a proposed new water-treatment plant, as part of the Environmental Impact Assessment for the new City of Winnipeg wastewater-treatment plant.
Client: City of Winnipeg

Northwest Area Water Supply (NAWS) DEIS and SEIS Review, and Devil's Lake Outlet | 2004-2016

- Contributed to a report on Potential Biota of Concern (PBOC) as they relate to the U.S. Bureau of Reclamation's water-diversion project in North Dakota, particularly with respect to treatability of fish pathogens in municipal water-treatment plants.
- Undertook a critical review of the 2014 Supplementary EIS written by the US Bureau of Reclamation in regards to the potential effects of NAWS, which is a water-supply project designed to supply drinking water to North Dakota. The role was to identify deficiencies within the logical structure and analytical results of the SEIS in support of a pending court challenge by the Government of Manitoba in US District Court.
- Updated, compiled and edited documents produced in rebuttal of the document, 'Northwest Area Water Supply Project Draft Environmental Impact Statement.'
- Completed a wetland delineation process, including vegetation surveys at several sites along the proposed drainage canal, to support legal challenges by Manitoba and Canada of the North Dakota Water Commission's "Devils Lake Emergency Outlet Project" in North Dakota courts of the correctness of the original wetland delineations.

Client: Government of Manitoba

Education

Doctor of Philosophy (Ph.D.)
University of Manitoba

Master of Science (M.Sc.)
University of Alberta

Bachelor of Science (B.Sc.)
University of Winnipeg

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Dan McParland

M.Sc., P.Geo.

Senior Fluvial Geomorphologist

Professional History

Palmer
Senior Fluvial Geomorphologist
Toronto, ON
2016 - present

AECOM
Fluvial Geomorphologist
Guelph, ON
2013 - 2016

University of British Columbia
Research Assistant
Vancouver, BC
2011 - 2013

Queen's University
Research Assistant
Kingston, ON
2010-2011

Summary

Dan is a Senior Fluvial Geomorphologist with nine years of experience linked to geomorphological and hydrological assessment, natural channel design, fluvial hazard mitigation, storm water management, and aquatic habitat enhancement. He has completed analyses at a range of spatial scales from watershed to reach level and is skilled in both fieldwork and desktop analyses. Dan has applied his technical knowledge in watersheds throughout Canada and has experience with many different river types. He has managed over 25 geomorphology projects.

Dan completed his undergraduate studies at Queen's University and his graduate studies at the University of British Columbia. His M.Sc. research examined the linkages between the physical sciences (hydrology and geomorphology) and aquatic ecology using 2D hydrodynamic models and other numerical models.

During his consulting career, Dan has successfully completed numerous natural channel designs, fluvial hazard assessments, fish passage evaluations, and peer reviews for linear infrastructure, mining, and municipal projects. Dan has developed a variety of strategies for evaluating and mitigating the erosion and sedimentation risk posed to aquatic and terrestrial habitats and existing infrastructure by proposed land development and government infrastructure projects. He also works closely with ecologists, engineers, and environmental planners to integrate the results of geomorphological assessments with other disciplines.

Experience

Watershed Hazard Assessment and Management

- Natural Resources Canada – Channel Migration and Scour Assessment, Northeastern AB
- Government of Yukon – Channel Migration Assessment along the Dempster Highway, Northern YT
- Parks Canada – Rocky Mountain National Parks Erosion Inventory, Alberta and BC
- Yukon Energy Corporation – Aishihik Lake Generating Station Relicensing, Aishihik, YT
- City of Toronto – East Don River Scour Assessment, Toronto, ON
- Dawson Creek – Dawson Creek Fluvial Geomorphology Assessment, Dawson Creek, BC
- Trans-Northern Pipelines Inc. – Montreal Line Environmental Screening, Eastern, ON & Southern, QC
- Regional District of Kootenay Boundary – Fluvial Hazard Mapping, Kootenay Boundary, BC
- Chief Isaac Inc. – North Fork Hydro Geomorphology Assessment, Dawson, YT
- Region of Peel – Mimico Creek Scour Assessment, Brampton, ON
- District of Vanderhoof – Nechako River Migration Assessment, Vanderhoof, BC
- Parks Canada – Kootenay River Migration Assessment, Kootenay National Park, BC

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- Town of Markham – City-wide Erosion Assessment and Implementation Plan, Markham, ON
- City of Red Deer – Suspended Sediment Transport Analyses, Red Deer, AB
- Parks Canada – Rouge National Urban Park Geomorphology Asssessment, Toronto, ON
- City of Toronto – Pottery Road Pedestrian Bridge, Toronto, ON
- Yukon Geological Survey – Carmacks Community Hazards Mapping, Carmacks, YT
- Metrolinx – West Don River Rail Crossing, Vaughan, ON
- City of Toronto – Riverside Drive Erosion Assessment, Toronto, ON
- R.J. Burnside – Bear Creek Erosion Hazard Limit Assessment, Barrie, ON
- YMCA of Greater Toronto – Cedar Glen Bride Replacement, Toronto, ON
- Ontario Ministry of Transportation – McGillivray Road Extension, Vaughn, ON
- City of Pickering – Palmer Bridge Rehabilitation, Pickering, ON
- Best Seller Reality – Salt Creek Erosion Hazard Limit Assessment, Brampton, ON
- Region of Peel – Fletcher's Creek Scour Assessment, Brampton, ON
- York Region – Rehabilitation of the York Durham Sanitary System, Richmond Hill, ON
- Metrolinx – Humber River Morphodynamic Assessment, Toronto, ON

Natural Channel Design and Stream Restoration

- Town of Markham – City-wide Erosion Assessment and Implementation Plan, Markham, ON
- City of Red Deer – Suspended Sediment Transport Analyses, Red Deer, AB
- Parks Canada – Rouge National Urban Park Geomorphology Asssessment, Toronto, ON
- City of Toronto – Pottery Road Pedestrian Bridge, Toronto, ON
- Yukon Geological Survey – Carmacks Community Hazards Mapping, Carmacks, YT
- Metrolinx – West Don River Rail Crossing, Vaughan, ON
- City of Toronto – Riverside Drive Erosion Assessment, Toronto, ON
- R.J. Burnside – Bear Creek Erosion Hazard Limit Assessment, Barrie, ON
- YMCA of Greater Toronto – Cedar Glen Bride Replacement, Toronto, ON
- Ontario Ministry of Transportation – McGillivray Road Extension, Vaughn, ON
- City of Pickering – Palmer Bridge Rehabilitation, Pickering, ON
- Best Seller Reality – Salt Creek Erosion Hazard Limit Assessment, Brampton, ON
- Region of Peel – Fletcher's Creek Scour Assessment, Brampton, ON
- York Region – Rehabilitation of the York Durham Sanitary System, Richmond Hill, ON
- Metrolinx – Humber River Morphodynamic Assessment, Toronto, ON

Environmental Assessment and Planning Studies

- Town of Erin – Erin Wastewater Treatment Plant EA, Erin, ON
- Town of East Gwillimbury – Green Lane Master Environmental Servicing Plan, East Gwillimbury, ON
- Halton Region – Southwest Georgetown Subwatershed Study, Georgetown, ON
- KLM Planning Partners Ltd. – Courtice Headwater Drainage Feature Assessment, Courtice, ON
- Region of Peel – The Gore Road Widening EA, Brampton, ON
- City of Ottawa – Ottawa HWY 174/17 EA, Ottawa, ON
- York Region – Upper York Sanitary Solutions, Newmarket, ON
- Municipality of Clarington – Bennett Creek Realignment EA and Preliminary Design, Bowmanville, ON
- Town of Newmarket – Newmarket Comprehensive Stormwater Master Plan, Newmarket, ON
- City of Ottawa – East Light Rail Transit Extension EA, Ottawa, ON
- York Region – Nobleton Water and Waste Water Class EA, Nobleton, ON
- City of Brampton – Redside Dace Compensation Tool, Brampton, ON

Environmental Monitoring

- CN Rail – Credit River Erosion Protection Post-Construction Monitoring, Georgetown, ON
- Town of Oakville – North Oakville Creek Monitoring, Oakville, ON
- Municipality of Clarington – Port Granby Creek Post-Construction Monitoring, Port Hope, ON
- City of London – Tributary 'C' Environmental Monitoring, London, ON

Peer Review

- Parks Canada – Snake Indian River Avulsion Hazard Peer Review, Jasper National Park, AB
- Conservation Halton – Grindstone & Borer's Creek Peer Review, Burlington, ON
- Cook's Ferry Indian Band – Proposed Habitat Restoration for Ashcroft Coal Derailment, Ashcroft, BC
- Parks Canada – Yoho Twinning Design Review, Field, BC
- TRCA – Highland Creek Bank Stabilization, Scarborough, ON
- Taykwa Tagamou Nation – Little Long Hydro Review, Kapuskasing, Ontario

Education

Master of Science – Fluvial Geomorphology Focus
University of British Columbia | 2013

Bachelor of Science – Physical Geography
Queen's University | 2011

Reports and Presentations

- Professional Geoscientist, Association of Professional Geoscientists of Ontario (2017-present)
- Member, Canadian Geophysical Union (2011-present)
- Member, Canadian Geomorphology Research Group (2011-present)

Reports and Presentations

- Cronmiller, D.C., McParland, D.J., Goguen, K.M., & McKillop, R.J. 2020. Carmacks surficial geology and community hazard susceptibility mapping. Yukon Geological Survey Miscellaneous Report 20.
- McParland, D.J., McKillop, R.J., & Blais-Stevens, A. 2018. Adjustments in channel planform and longitudinal profile at proposed pipeline crossings of Smoky River, Deep Valley Creek, and Little Smoky River, northwestern Alberta. Geological Survey of Canada, Open File 8220.
- McKillop, R.J. & McParland, D.J. 2018. The time-limited resilience of river morphology to alteration: examples from across Canada. Presented at: Natural Channel Systems Conference, Guelph, ON, May 24, 2018.
- McKillop, R.J., McParland, D.J. and Scobie, C., 2017, When creek meets valley wall: prioritizing erosion mitigation alongside the Oshawa Landfill. Oral presentation and abstract in the 2017 TRIECA Conference, Brampton, ON, March 22-23, 2017.
- McParland, D.J., Eaton B.C., & Rosenfeld, J.S. 2016. At-a-station hydraulic geometry simulator. River Research and Application, 32(3), 399-410. doi:10.1002/rra.2851
- McKillop, R.J. Brown, C.E., McParland, D.J., Sacco, D.A., & Coates, J. 2016. Inventory of mass movement geohazards along the Dempster Highway. Yukon Geological Survey Miscellaneous Report 17.
- McParland, D.J. & Eaton, B.C. 2013. Empirical aquatic habitat assessment tools for British Columbian channels. Presented at: Canadian Geomorphologic Research Group Annual Meeting, Edmonton, AB, August 22, 2013.
- McParland, D.J. & Eaton, B.C. 2012. Statistical habitat methods for British Columbian channels. Presented at: University of Washington Hydrology Symposium, Seattle, WA, September 22, 2012.

resume

Palmer™

Daniel H. King

B.Sc. (Hons) Biochemistry, M.ET Candidate
Fisheries Biologist

Professional History

Palmer
Fisheries Biologist
February 2020 - Present

Simon Fraser University
Graduate Research Assistant
2017 - Present

Alouette River Management Society
Director of the Board
2019 - Present

Laboratory of Dr. Vicki Marlatt
Simon Fraser University
Brittania Creek Project co-author
June - August 2020

Laboratory of Dr. Vicki Marlatt
Simon Fraser University
Toxicity Assessment Assistant
2018 - 2019

Nautilus Environmental Company Inc.
Toxicity Assessment Assistant
June 2017

University of British Columbia - Okanagan
Undergraduate Research Assistant
2015 - 2016

Summary

Daniel is an fisheries biologist with experience in gained in his master's thesis, work in mining sector fish toxicity exposures and employment with Palmer. Daniel has an extensive knowledge of local fish species, their life-stages, life history characteristics, and habitat use. This combined with his unique academic background combining fish behaviour, health and physiology; with experience in pharmacology and environmental toxicology to enable a complete view of impacts of contaminants in the environment and habitat alteration and loss on aquatic species.

Daniel has a demonstrated ability in experimental design and data analysis of large datasets, including those recorded over time from long-term monitoring programs. Specific analyses include fish population trends over time, Benthic Macroinvertebrate monitoring metrics over time comparing test locations to a reference model (CABIN) and QA/QC of large-scale datasets such as water chemistry parameters. Daniel has experience in environmental monitoring, fish inventory and habitat assessments, fish biological sampling Additionally, Daniel has worked on extensive reviews of life-stages and habitat use to assist in project-specific protection of several listed species including the Fraser and Nechako River White Sturgeon, listed conservation units of Pacific salmon (e.g. Interior Fraser River Coho Salmon), Bull Trout, Northern Mountain Sucker, Salish Sucker, Brassy Minnow, Coastal Cutthroat Trout, and Westslope Cutthroat Trout.

Experience

Blackwater Gold Project | 2021

Design and implementation of several large-scale fish population monitoring programs in several different water bodies in the area each requiring a unique, tailored approach to population monitoring. Programs included modern and novel approaches to fish population monitoring associated with potential impacts of mining activities including aerial-drone based Kokanee population monitoring, solar-powered underwater cameras for Rainbow Trout and young-of-the-year Kokanee enumeration and monitoring; and the design and use of a larval light trap to monitor the potential impacts of lake drawdown to a blue-listed littoral-dwelling fish species, the Brassy Minnow. In addition to the novel methodologies, conventional approaches to fish populations assessments and monitoring were also incorporated into the various programs including hoop-net surveys, minnow-trapping, backpack electrofishing, snorkel surveys and gillnetting.
Client: Artemis Gold Inc.

Wapiti River Long-Term Aquatic Monitoring | 2021

Assisted in the compilation, organization, QA/QC and analyses of a dataset collected for Aquatera Utilties for the purpose of long-term monitoring of the aquatic ecosystem components downstream of the Aquatera Utilities Water Treatment Plant. Metrics assessed included benthic macroinvertebrates, periphyton and water chemistry parameters (e.g. total phosphorous and nitrogen). Experimental Design included several impacted sites and reference locations that required a thoughtful and sophisticated approach to the analysis and interpretation.
Client: Aquatera Utilities

resume

Upperlands Environmental Inventory | 2020

Planned and implemented a field program for an inventory of fish and herptile species 8 coastal streams within the Upperlands region of the District of West Vancouver (mountainous region below Cypress Provincial Park and above the British Properties). The inventory discovered the presence of an introduced population of Westslope Cutthroat Trout outside of their known extent in the area. Involved habitat assessments and identification of early life stages of Westslope Cutthroat Trout. Findings contributed to a larger environmental inventory to support planning and land use for the Upperlands region.
Client: District of West Vancouver

Fish Community Monitoring and Assessment | 2020

Completed the data analysis and wrote the fish community portion of the Annual Monitoring Report for three species of fish captured in five streams from annual fishing and monitoring efforts over five years (2016-2020). Assessment included five-year Mann-Kendall trends analyses on fish abundance (CPUE), relative abundance through species composition and trends in fish condition using a normal range and relative condition. Additionally, length frequency distributions were compared between sites and years using a Kolmogorov-Smirnov test to compare two frequency distributions. The results of this fish community analysis, in combination with physicochemical environmental data and a benthic invertebrate trends analysis completed by Palmer; will assist the Resort Municipality of Whistler in future community and environmental planning efforts.
Client: Resort Municipality of Whistler

Nechako River Bank Stabilization Project | 2020

Completed a literature review and wrote the fish community and effects assessment for a Fisheries and Oceans Canada Request for Review for a bank stabilization project of a municipal park on the Vanderhoof Braided Reach of the Nechako River; a reach of critical habitat for the endangered Nechako River White Sturgeon. Given the sensitive habitat and SARA-listed white sturgeon present within this area of the Nechako, the review of fish of all life stages, their habitat use and timing was exhaustive to ensure minimum impact to the white sturgeon and all other fish species present. Fish species reviewed included the Nechako River white sturgeon, chinook, sockeye and coho salmon; bull trout and rainbow trout.
Client: District of Vanderhoof

Force Main Replacement, Fraser River | 2020

Contributed to the literature review, evidence compilation and written response to concerns raised by the Leq'á:mel First Nation regarding a draft Fisheries Act Authorization submitted by Palmer on behalf of the City of Mission. Included an extensive review of Fraser River lamprey species, their life stages and habitat use; the potential impacts and mortality of the proposed dredging activity, and a review of migratory salmonids of various life stages and their migration timing windows. The Leq'á:mel First Nation and City of Mission were pleased with and accepted Palmer's official responses.
Client: City of Mission

Site C Clean Energy Project | 2020-Present

Biological operation of the Site C Clean Energy Project Temporary Upstream Fishway. Duties included site, equipment and water quality monitoring within the facility, fish processing and sampling for a variety of fish species, monitoring and transport of fish species in specially designed pods to upstream release site, weekly and annual report writing for the sub-contractor Peace River Hydro Partners (PRHP), and for BC Hydro. With Site C being such a large-scale infrastructure project with many stakeholders and sub-contractors involved, extensive collaboration with BC Hydro and PRHP staff from various departments and levels of seniority was required; with a significant level of flexibility and adaptability required to maximize the efficiency to the fishway and the health and survival of fish passing through the facility. In addition to these collaboration efforts, tours and discussion took place with the local first nation's liaison to the facility.
Client: Peace River Hydro Partners and BC Hydro

Elk Gold Mine Fish Inventory and Wetland Delineation | 2020

Participated in a fish inventory and habitat assessment for Siwash Creek and the tributary Don Creek, east of Merritt, B.C. In addition to the fish inventory and habitat assessment, field representatives surveyed the area using drone-based orthomosaic imaging and completed a wetland delineation in the area of a proposed treatment wetland.

Brittania Mine Early Life-Stage Rainbow Trout Field Experiment | 2020
Assisted in implementing and completing the field-portion of an experiment using the Environment Canada standardized biological test method: Toxicity Tests Using Early Life Stages of Salmonid Fish (EPS 1/RM/28). Rainbow trout embryos were deployed in hatch boxes in Brittania Creek until the swim-up life stage and dissected for biochemical testing on tissues, histopathology, and tissue metal concentrations. Several sites were used with varying levels of metal contamination from Brittania Mine and results will be compared to a concurrent lab-based exposure using site water from Brittania Creek. Daniel's involvement in the project will result in a co-authorship on the publication once completed.

Global Fisheries Monitoring Review | 2020
Contract completed for Palmer. Wrote a comprehensive review of modern, innovative and cost-effective approaches to fisheries catch monitoring used by fisheries management authorities around the world. Review used a combination of information from scientific literature, NGOs, fisheries management authorities and interviews with representatives from these fields. Review was completed for Fisheries and Oceans Canada (DFO) with the goal of applying the findings of the review to implement the changes outlined in the recently update Fisheries Monitoring Policy (2019). Some examples of key innovations found were related to improvements in technology such as wireless video data transfer via cellular or satellite networks, artificial intelligence and machine learning applied to catch video, and remote un-manned monitoring stations. The review was edited and co-authored by Katsky Venter.
Client: Fisheries and Oceans Canada (DFO)

Master of Environmental Toxicology Project | 2018-Present
Developed and implemented a comprehensive toxicity exposure of the sea lice pesticides SLICE ® and Ivermectin to a juvenile benthic fish species, the starry flounder, using a dosed-sediment exposure. Various exposures were used to assess effects from the biochemical level of metabolism and stress, up to the physiological and fitness impact of swimming, respiration, and camouflage ability, and lastly the behavioral level assessing the ability of the fish to perceive and avoid the contaminants. Employed a beach seine to capture wild juvenile starry flounder and in the process captured a large variety of marine an estuarine fish species and gained skills in identification of these species. Used a 16' jet boat to access harvest some harvest sites.

Alouette River Management Society | 2019-Present
Director of the Board
Involved in key decisions surrounding the protection and enhancement of the Alouette River watershed
Lobbying and collaborative efforts with multiple stakeholders including the City of Maple Ridge, BCMOE, the DFO, BC Hydro, the Katzie Nation, and other members of the community. Recently wrote ARMS's contribution to the City of Maple Ridge Integrated Stormwater Management Plan (November 2020).

Education

Master of Environmental Toxicology Candidate
Simon Fraser University, Burnaby, BC | 2017 - Present

Bachelor of Science (Honours) Biochemistry (Medical Concentration)
University of British Columbia Okanagan, Kelowna, BC | 2012 - 2016

Professional Development, Certifications and Associations

- Electrofishing Crew Supervisor Certification
- Done Pilot Certificate – Basic Operations
- Occupational First Aid Level 1
- WHMIS 2015 Certification

resume

- Pacific Streamkeepers Federation Spawner Survey and Habitat Assessment Training
- Marine fish survey and harvest methods, marine and freshwater fish identification; and salmonid sampling
- Transport Canada Pleasure Craft Operator License
- Simon Fraser University Animal Care Committee Animal User Training Course – Fish
- UBC Centre for Environmental Assessment Research - Canadian Environmental Assessment Act Workshop Certificate

Reports and Presentations

- **King, D. H.** and Venter, K. 2020. Review of Fisheries Catch Verification Tools and Technologies: A Review and Assessment of Innovative and cost effective tools and technologies used worldwide to verify fisheries catch data. ***Report for Fisheries and Oceans Canada.*** Katsky Venter Independent Consultant and Palmer
- **King, D. H.** and Kennedy, C. J. Sublethal effects of anti-sea lice pesticides SLICE ® and ivermectin on the swim performance, oxygen consumption, camouflage and avoidance behaviour of the starry flounder (*Platichthys stellatus*). ***Salish Sea Ecosystem Conference.*** International Conference. (Virtual Oral Presentation) Vancouver, BC April, 2020.
- **King, D. H.** and Kennedy, C. J. Sublethal effects of anti-sea lice pesticides SLICE ® and ivermectin on the swim performance, oxygen consumption, camouflage and avoidance behaviour of the starry flounder (*Platichthys stellatus*). ***Pacific Northwest Society of Environmental Toxicology and Chemistry Annual Conference.*** International Conference. (Oral Presentation) Vancouver, WA, USA April, 2019.
- **King, D. H.** and Kennedy, C. J. Sublethal effects of anti-sea lice pesticides SLICE ® and ivermectin on the swim performance, oxygen consumption, camouflage and avoidance behaviour of the starry flounder (*Platichthys stellatus*). ***ToxTalks Annual Graduate Symposium.*** Institutional Conference. (Oral Presentation) Vancouver, BC March, 2018 and 2019.
- **King, D. H.** and Kennedy, C. J. Sublethal effects of anti-sea lice pesticides SLICE ® and ivermectin on the swim performance, oxygen consumption, camouflage and avoidance behaviour of the starry flounder (*Platichthys stellatus*). ***Canadian Ecotoxicity Workshop.*** International Conference. (Oral Presentation) Vancouver, BC, October, 2018.
- **King, D. H.** and Deyholos, M. Kinetic characterization of a proteinacious inhibitor (*LuPMEI45*) of the enzyme Pectin Methylesterase (PME) from flax (*Linum usitatissimum*) and comparative analysis of PME activity assays. ***UBC Okanagan***. (Honours Thesis) Kelowna, BC, May 2016.
- **King, D. H.** and Deyholos, M. Kinetic characterization of a proteinacious inhibitor (*LuPMEI45*) of the enzyme Pectin Methylesterase (PME) from flax (*Linum usitatissimum*) and comparative analysis of PME activity assays. ***UBC Okanagan Undergraduate Research Conference.*** Institutional Conference. (Oral Presentation) Kelowna, BC, May 2016.

THE UNIVERSITY OF NORTHERN BRITISH COLUMBIA
Curriculum Vitae

Date: February 12, 2021 **Initials**: EGM

1. **SURNAME**: Martins **FIRST NAME**: Eduardo
MIDDLE NAME(S): Osses Guimaraes

2. **PROGRAM/LIBRARY/DEPARTMENT:** Department of Ecosystem Science and Management

3. **Faculty**: Faculty of Environment

4. **PRESENT RANK**: Assistant Professor **SINCE**: July 01, 2017

5. **POST-SECONDARY EDUCATION** (list most recent first)

University or Institution	Degree	Subject Area	Dates
Universidade Estadual de Campinas	PhD	Ecology	2004 to 2007
Universidade Estadual de Campinas	MSc	Ecology	2002 to 2004
Universidade Estadual de Campinas	BSc	Biology	1998 to 2001

6. **EMPLOYMENT RECORD**

University, Company or Organization	Rank or Title	Dates
University of Northern British Columbia	Assistant Professor	Since July 2017
BC Hydro	Natural Resource Specialist	Nov 2016 to May 2017
University of Waterloo	Liber Ero Postoctoral Fellow	Dec 2014 to Nov 2016
University of British Columbia	Research Associate	Apr 2014 to Nov 2014
Carleton University	Postdoctoral Fellow	Apr 2011 to Mar 2014
University of British Columbia	Postdoctoral Fellow	Apr 2008 to Mar 2011

7. **SUPERVISIONS**

(a) Graduate Students Supervised and/or Co-Supervised

Student Name	Program Type	Year		Principal Supervisor	Co-Supervisor(s)
		Start	Finish		
Elizabeth Hirsch	MSc NRES, UNBC	2021	in progress	Eduardo Martins	
Sebastian Dalgarno	PhD NRES, UNBC	2020	in progress	Eduardo Martins	
Avery Dextrase	MSc NRES, UNBC	2020	in progress	Eduardo Martins	
Thomas Balfour	MSc NRES, UNBC	2020	in progress	Eduardo Martins	
Joseph Bottoms	PhD NRES, UNBC	2019	in progress	Eduardo Martins	
Emily Mason	MSc NRES, UNBC	2019	in progress	Eduardo Martins	

Bryce O'Connor	MSc NRES, UNBC	2019	in progress	Eduardo Martins	
Caleb Jetter	MSc NRES, UNBC	2019	in progress	Eduardo Martins	
Daniel Larson	MSc NRES, UNBC	2018	2020 (deceased)	Eduardo Martins	Nikolaus Gantner
Gretchen Stokes	MSc Fisheries & Wildlife, Virginia Tech	2014	2016	Leandro Castello	Eduardo Martins

(b) Undergraduate Students Supervised and/or Co-Supervised

Student Name	Program Type	Year		Principal Supervisor	Co-Supervisor(s)
		Start	Finish		
Daniel Scurfield	Honors BSc, W&F, UNBC	2020	2021	Eduardo Martins	Nikolaus Gantner
Ian Clevenger	Honors BSc, W&F, UNBC	2019	2020	Eduardo Martins	
Morgan Dowd	Honors BSc, W&F, UNBC	2019	2020	Eduardo Martins	
Grayson Vanderbyl	Honors BSc, W&F, UNBC	2019	2020	Eduardo Martins	
Rioghnach Steiner	Honors BSc, W&F, UNBC	2018	2019	Eduardo Martins	

9. SELECTED GRANTS

Granting Agency	Subject	$ Per Year	Year	Principal Investigator	Co-Investigator(s)
FWCP	Spatial ecology of Arctic grayling (4^{14} year)	138,099	2022 to 2022	Eduardo Martins	Mark Shrimpton, Mike Power, Steven Cooke, Marie Auger-Methé, David Patterson
LNG Canada	Conservation and recovery research on OOlichan	~500,000 (× 5 yrs)	2020 to 2025	Mark Shrimpton	Caren Helbing, Morgan Hocking, Jonathan Moore, Mary Lesperance, Adam Lewis, Alejandro Buren, Heather Bryan, Eduardo Martins
CFI/BCKDF	Infrastructure for thermal ecology research	399,260	2020	Eduardo Martins	

FWCP	Spatial ecology of Arctic grayling (3rd year)	176,492	2020 to 2021	Eduardo Martins	Mark Shrimpton, Mike Power, Steven Cooke, Marie Auger-Methé, David Patterson
FWCP	Spatial ecology of Arctic grayling (2nd year)	184,609	2019 to 2020	Eduardo Martins	Mark Shrimpton, Mike Power, Steven Cooke, Marie Auger-Methé, David Patterson
NSERC DG	Thermal ecology of freshwater fishes	28,000 (× 5 yrs)	2018 to 2023	Eduardo Martins	
Research Council of Norway	Partnership on sustainable hydropower in Canada and Norway	179,453 (× 4 yrs)	2018 to 2022	Ingeborg Helland	Knut Alfredsen, Per-Arne Amundsen, Antti Eloranta, Michael Power, Steven Cooke, Eduardo Martins

10. **<u>SELECTED PUBLICATIONS</u>** (full list on Google Scholar)

Martins EG, Déry SJ and Patterson DA. *In press.* Fraser River. In: Rivers of North America. Volume 2. M Delong & T Jardine (eds). Elsevier Inc.

Cooke SJ, Raby GD, Bett NN, Teffer AK, Burnett, Jeffries KM, Eliason EJ, Martins EM, Miller KM, Patterson DA, Nguyen VM, Young N, Farrell AP and Hinch SG. *In press*. On conducting management-relevant mechanistic science for upriver migrating adult Pacific salmon. Pages 35-55 in Madliger, C.L., C.E. Franklin, O.P. Love and S.J. Cooke, Editors. Conservation Physiology: Applications for wildlife conservation and management. Oxford University Press, UK.

Furey NB, Martins EG and Hinch SG. 2021. Migratory salmon smolts exhibit consistent interannual depensatory predator swamping: effects on telemetry-based survival estimates. *Ecology of Freshwater Fish*, 30:18-30.

Whoriskey K, Martins EG, Auger-Methé M, Gutowsky LFG, Lennox RJ, Cooke SJ, Power M and Flemming JM. 2019. Current and emerging statistical techniques for aquatic telemetry data: A guide to analysing spatially discrete animal detections. *Methods in Ecology and Evolution* 10:935-948.

Hahn L, Martins EG, Nunes LD, Câmara LF, Machado LS and Garrone-Neto D. 2019. Biotelemetry reveals migratory behaviour of large catfish in the Xingu River, Eastern Amazon. *Scientific Reports* 9:8464.

Gutowsky LFG, Harrison PM, Martins EG, Leake A, Patterson DA, Zhu DZ, Power M and Cooke SJ. 2017. Daily temperature experience and selection by adfluvial bull trout (*Salvelinus confluentus*). Environmental Biology of Fishes 100:1167-1180.

Cooke SJ, Struthers D, Martins EG, Gutowsky LFG, Power M, Doka S, Dettmers J, Crook D, Lucas, MC, Holbrook CM and Krueger CC. 2016. A moving target – incorporating knowledge of the spatial ecology of fish into biological assessment and management of freshwater fisheries. Environmental Monitoring and Assessment 188, 239.

Harrison PM, Gutowsky LFG, Martins EG, Patterson DA, Cooke SJ and Power M. 2016. Temporal plasticity in thermal habitat selection of burbot, Lota lota, a diel-migrating winter specialist. Journal of Fish Biology 88, 2111–2129.

Gutowsky LFG, Harrison PM, Martins EG, Leake A, Patterson DA, Power M and Cooke SJ. 2016. Interactive effects of phenotypic traits on adfluvial bull trout (*Salvelinus confluentus*) movement ecology. Canadian Journal of Zoology 94, 31–40.

Drenner SM, Hinch SG, Martins EG, Furey NB, Clark TD, Cooke SJ, Patterson DA, Robichaud D, Welch D, Farrell AP, Thomson R. 2015. Environmental conditions and physiological state influence estuarine movements of homing sockeye salmon. Fisheries Oceanography 24, 307–324.

Martins EG, Gutowsky LFG, Harrison PM, Mills Flemming JE, Jonsen ID, Zhu DZ, Leake A, Patterson DA, Power M and Cooke SJ. 2014. Behavioral attributes of turbine entrainment risk for adult bull trout revealed by acoustic telemetry and state-space modeling. Animal Biotelemetry 2, 13.
Featured in FishSens Magazine: http://magazine.fishsens.com/entrainment-study-tracks-bull-trout-keep-fish-canadian-dams-turbines.htm

Gale MK, Hinch SG, Cooke SJ, Donaldson MR, Eliason EJ, Jeffries KM, Martins EG and Patterson DA. 2014. Observable impairments predict mortality of captured and released sockeye salmon at various temperatures. Conservation Physiology 2, doi:10.1093/conphys/cou029

Drenner SM, Hinch SG, Martins EG, Robichaud D, Clark TD, Thomson LA, Patterson DA, Cooke SJ and Thomson RE. 2014. Variable thermal experience and diel thermal patterns of homing sockeye salmon in coastal marine waters. Marine Ecology Progress Series 496, 109–124.

Martins EG, Gutowsky LFG, Harrison PM, Patterson DA, Power M, Zhu D, Leake A and Cooke SJ. 2013. Forebay use and entrainment rates of resident adult fish in a large hydropower reservoir. Aquatic Biology 19, 253–263.

Gutowsky LFG, Harrison PM, Martins EG, Leake A, Patterson DA, Power M and Cooke SJ. 2013. Diel vertical migration hypothesis explain size-dependent behaviour in a freshwater piscivore. Animal Behaviour 86, 365–373.

Martins EG, Hinch SG, Cooke SJ and Patterson DA. 2012. Climate effects on growth, phenology and survival of sockeye salmon (Oncorhynchus nerka): a synthesis of the current state of knowledge and future research directions. Reviews in Fish Biology and Fisheries 22, 887–914.

Johnson JE, Patterson DA, Martins EG, Cooke SJ and Hinch SG. 2012. Quantitative methods for analyzing cumulative effects on fish migration success: a review. Journal of Fish Biology 81, 600–631. (Special Issue: Fish Migration in the 21st Century: Opportunities and Challenges).

Martins EG, Hinch SG, Patterson DA, Hague MJ, Cooke SJ, Miller KM, Robichaud D, English KK and Farrell AP. 2012. High river temperature reduces survival of sockeye salmon (Oncorhynchus nerka) approaching spawning grounds and exacerbates female mortality. Canadian Journal of Fisheries and Aquatic Sciences 69, 330–342.

Drenner SM, Clark TD, Whitney CK, Martins EG, Cooke SJ and Hinch SG. 2012. A synthesis of tagging studies examining the behaviour and survival of anadromous salmonids in marine environments. PLoS ONE 7, e31311.

Jeffries KM, Hinch SG, Martins EG, Clark TD, Lotto AG, Patterson DA, Cooke SJ, Farrell AP and Miller KM 2012. Sex and proximity to reproductive maturity influence survival, final maturation, and blood physiology of Pacific salmon when exposed to high temperature during a simulated migration. Physiological and Biochemical Zoology 85, 62–73.

Martins EG, Hinch SG, Patterson DA, Hague MJ, Cooke SJ, Miller KM, Lapointe MF, English KK and Farrell AP. 2011. Effects of river temperature and climate warming on stock-specific survival of adult migrating Fraser River sockeye salmon (Oncorhynchus nerka). Global Change Biology 17, 99–114.

BIOSKETCH

Name/Affiliation: Stephen J. DÉRY, University of Northern British Columbia (UNBC)

Education/Training

2001	PhD	Atmospheric and Oceanic Sciences, McGill University
1993	MSc	Earth and Atmospheric Sciences, York University
1991	BSc	Earth and Atmospheric Sciences and Applied Mathematics, York University

Employment/Affiliations

2019-present	Professor (tenured) and NSERC/Rio Tinto Industrial Research Chair in Climate Change and Water Security, Environmental Science and Engineering Program, UNBC
2017-2020	Adjunct Professor, Civil Engineering, University of Manitoba
2015-2019	Professor (tenured), Environmental Science and Engineering Program, UNBC
2010-2015	Associate Professor (tenured) and Tier II Canada Research Chair in Northern Hydrometeorology, Environmental Science and Engineering Program, UNBC
2005-2010	Assistant Professor and Tier II Canada Research Chair in Northern Hydrometeorology, Environmental Science and Engineering Program, UNBC
2004-2005	Visiting Research Scientist, Princeton University
2000-2003	Post-Doctoral Fellow, Lamont-Doherty Earth Observatory, Columbia University
1994-1996	Project Scientist, York University
1991-1993	Meteorological Technician, Ontario Hydro

KEY AWARDS: NSERC Discovery Accelerator Supplement ($120K), 2011-2014.

DISTINCTIONS: Dr. Déry has published >100 peer-reviewed journal articles and book chapters with >4500 citations and h-index of 34 (Google Scholar®). He is Associate Editor for *Atmosphere-Ocean* and the *Journal of Hydrometeorology*. He is former co-chair of the NSERC Advancing Climate Change Science in Canada panel (2019), former member of NSERC Strategic Partnership Grants (Environment & Agriculture) panel (2018), NSERC Northern Research Supplement (2008-11) and NSERC Geosciences Evaluation (2011-14) groups, NSF Arctic Natural Science Program panel (2016), external examiner for 9 PhD theses.

Research Funding

Over the past 4 years, Dr. Déry has secured >$3M in competitive research funding such as:

- NSERC/Rio Tinto Industrial Research Chair in Climate Change and Water Security, NSERC/Rio Tinto Canada Fund, $1.5M
- Atmospheric and terrestrial rivers of western Canada in transition, NSERC Discovery Grant, $240K, 2016-2022
- Mountain Water Futures (Phases 1 & 2), Global Water Futures (GWF Pillar 3), $150K, 2017-2023
- Storms & Precipitation Across the Continental Divide Experiment (GWF Pillar 1), $112K, 2018-2020
- Evaluating the resiliency of aquatic ecosystems to a catastrophic mine tailings spill: The 2014 Mount Polley incident in the Quesnel River watershed, BC, Environment and Climate Change Canada, Environmental Damages Fund, $60K, 2016-2018
- BaySys, NSERC-Manitoba Hydro Collaborative Research and Development, $75K, 2015-2019
- Earth, Air, Wind and Fire, Tri-University Partnership Research Fund, $40K, 2019-2020
- Integrated watershed-based research in the Nechako River Basin (Phases 1 and 2), Government of BC/Nechako Environmental Enhancement Fund, $125K (2014-2017) and $125K (2018-2022)

Most significant contributions:

1. Cariboo Alpine Mesonet (CAMnet): I have spearheaded the development of CAMnet (Hernández-Henríquez et al. 2018), a network of 15 automatic weather stations deployed in remote regions of BC since 2006. Meteorological data are archived online (in a publicly accessible data repository) and shared with colleagues, supporting undergraduate and graduate student research projects. CAMnet data were critical in understanding the evolution of the sediment plume in Quesnel Lake following the catastrophic failure of a tailings pond at Mount Polley Mine, near Likely, BC (Petticrew et al. 2015). CAMnet stations have also provided unique opportunities to train many students in remote field work and data quality control.

2. Blowing snow: I have investigated blowing snow for >25 years including work on the spectral and bulk versions of the Piektuk blowing snow model (Déry et al. 1998; Déry and Yau 1999) for studies of Arctic blizzards (Déry and Yau 2001). Piektuk was then coupled to RACMO2/ANT, the first regional climate model ever to be fully coupled with a blowing snow routine, to obtain new estimates of the impact of snowdrift on Antarctic surface mass balance (SMB) over 1989-2009. Moreover, the coupled modeling system has been used to assess impacts of drifting snow on an Antarctic ice shelf and on the Greenland Ice Sheet SMB (Lenaerts et al. 2010, 2012). The model, which continues to be used worldwide, has also been applied to the study of snow transport in alpine terrain (Déry et al. 2010), across mountain glaciers and over sea ice (Déry and Tremblay 2004), as well as the Tibetan Plateau.

3. Streamflow trends in northern/western Canada: This body of work has provided better understanding of the role of climate change and flow regulation on some of Canada's principal waterways including observational evidence of intensification of the hydrologic cycle (Déry et al. 2009) and changing contributions to pan-Arctic river discharge (Déry and Wood 2005, Déry et al. 2005, 2009, 2016). A recent 19% decline in contributions of snowmelt to Fraser River discharge (Kang et al. 2014, 2016) based on VIC model simulations is expected to amplify in the 21st century, leading to significant seasonal shifts in hydrographs with earlier freshets and lower flows during summer/fall salmon migrations (Islam et al. 2017, 2019). Ongoing hydrological simulations are elucidating the roles of flow regulation versus climate change on Hudson Bay and Nechako river discharge (Déry et al. 2018; Stadnyk et al. 2020; Tefs et al. 2021) and on Fraser River water temperatures (Islam et al. 2019).

4. Northern Hemisphere snowcover extent trends: Recent efforts have explored Northern Hemisphere (NH) snowcover extent (SCE) trends given SCE is a sensitive indicator of climate change. Déry and Brown (2007) revealed significant declines in SCE during spring and summer over North America and Eurasia for 1972-2006 with impacts on the snow-albedo feedback (SAF). Hernández-Henríquez et al. (2015) expanded this study period by 8 years to uncover polar amplification of negative trends in SCE, with a 28% greater retreat of peak trends in NH snowcover relative to the previous study. There was also elevation dependence of SCE over time as statistically significant negative trends occurred at most elevations. These significant negative trends exhibited at high latitudes and elevations provided evidence of polar amplification and elevation dependence of trends in snowcover in a warming climate, suggesting a leading role of the SAF on the recent retreat of NH snowcover. Shi et al. (2011, 2013) have also surveyed the role of radiative and turbulent fluxes on the accelerating retreat of the NH snowcover. Allchin and Déry (2017, 2019) explored recent changes in the onset of snow cover and issues of concern with the NOAA SCE Climate Data Record.

5. Remote sensing of snowcover: Déry et al. (2005) provided the first application of MODIS to track snow depletion curves on the North Slope of Alaska, constraining simulations of regional hydrology. Tong et al. (2009a,b) demonstrated the potential predictability (by one month) of the timing of the spring freshet in the Quesnel River (near its outlet to the Fraser River) simply by tracking the day at which MODIS remotely sensed snowcover fraction was 0.5 across its watershed. Other work shows that passive microwave data of snow water equivalent (SWE) in the Cariboo Mountains become saturated and thus unreliable above 250-400 mm SWE (Tong et al. 2010) and allow tracking of snowmelt and liquid water content within snow in the Colorado Rockies (Kang et al. 2014).

Key recent publications (S. J. Déry: >4500 citations with h-index of 34, >2100 citations since 2016; Google Scholar®)

1) Thériault JM, Déry SJ, Pomeroy JW, Smith HM, Almonte J, Bertoncini A, Crawford R, Desroches-Lapointe A, Lachapelle M, Mariani Z, Mitchell S, Morris JE, Hébert-Pinard C, Rodriguez P, Thompson, H D 2021: Meteorological observations collected during the Storms and Precipitation Across the continental Divide Experiment (SPADE), April-June 2019, Earth System Science Data, in press.
2) Pokorny S, Stadnyk TA, Ali G, Lilhare R, Déry SJ, Koenig KA 2021: Cumulative effects of uncertainty on simulated streamflow in a hydrologic modeling environment, Elementa: Science of the Anthropocene, 9(1), 431.
3) Sharma AR, Déry SJ 2020: Linking atmospheric rivers to annual and extreme runoff in British Columbia and southeastern Alaska, Journal of Hydrometeorology, 21(11), 2457-2472.
4) Vore ME, Déry SJ, Hou Y, Wei A 2020: Climatic influences on forest fire and mountain pine beetle outbreaks and resulting runoff effects in large watersheds in British Columbia, Canada, Hydrological Processes, 34(24),4560-4575.
5) Allchin M, Déry SJ 2020: The climatological context of trends in the onset of Northern Hemisphere seasonal snowcover, 1972-2017, Journal of Geophysical Research: Atmospheres, 125, e2019JD032367.
6) Stadnyk TA, MacDonald MK, Tefs AAG, Déry SJ, Koenig K, Gustafsson D, Isberg K, Arheimer B 2020: Hydrological modeling of freshwater discharge into Hudson Bay using HYPE, Elementa: Science of the Anthropocene, 8, 43.
7) Hamilton AK, Laval BE, Petticrew EL, Albers SJ, Allchin M, Baldwin SA, Carmack EC, Déry SJ, French TD, Granger B, Graves KE, Owens PN, Selbie DT, Vagle S 2020: Seasonal turbidity linked to physical dynamics in a deep lake following the catastrophic 2014 Mount Polley mine tailings spill, Water Resources Research, 56(8), e2019WR025790.
8) Sharma AR, Déry SJ 2020: Contribution of atmospheric rivers to annual, seasonal, and extreme precipitation across British Columbia and southeastern Alaska, Journal of Geophysical Research: Atmospheres, 125(9), e2019JD031823.
9) Picketts IM, Déry SJ, Parkes MW, Sharma AR, Matthews CA 2020: Scenarios of climate change and natural resource development: complexity and uncertainty in the Nechako Watershed, The Canadian Geographer, 64(3), 475-488.
10) Sharma AR, Déry SJ 2020: Variability and trends of landfalling atmospheric rivers along the Pacific Coast of northwestern North America, International Journal of Climatology, 40(1), 544-558.
11) Lilhare R, Pokorny S, Déry SJ, Stadnyk TA, Koenig KA 2020: Sensitivity analysis and uncertainty assessment in water budgets simulated by the Variable Infiltration Capacity model in Canadian sub-arctic watersheds, Hydrological Processes, 34(9), 2057-2075.
12) Li Z, Shi X, Tang Q, Zhang Y, Gao H, Pan X, Déry SJ, Zhou P 2020: Partitioning the contributions of glacier melt and precipitation to the 1971-2010 runoff increases in a headwater basin of the Tarim River, Journal of Hydrology, 583, 124579.
13) Curry CL, Islam SU, Zwiers FW, Déry SJ 2019: Atmospheric rivers increase future flood risk in western Canada's largest Pacific River, Geophysical Research Letters, 46(3), 1651-1661.
14) Islam SU, Curry CL, Déry SJ, Zwiers FW 2019: Quantifying projected changes in runoff variability and flow regimes of the Fraser River Basin, British Columbia, Hydrology Earth System Sciences, 23, 811-828.
15) Lilhare R, Déry SJ, Pokorny S, Stadnyk TA, Koenig KA 2019: Inter-comparison of multiple hydro-climatic datasets across the Lower Nelson River Basin, Manitoba, Canada, Atmosphere-Ocean, 57, 262-78.
16) Islam SU, Hay RW, Déry SJ, Booth BP 2019: Modelling the impacts of climate change on riverine thermal regimes in western Canada's largest Pacific watershed, Scientific Reports, 9, 11398.
17) Allchin M, Déry SJ 2019: Shifting spatial and temporal patterns in the onset of seasonally snow-dominated conditions in the Northern Hemisphere, 1972-2017, Journal of Climate, 32(16), 4981-5001.

18) Déry SJ, Stadnyk TA, MacDonald MK, Koenig KA, Guay C 2018: Flow alteration impacts on Hudson Bay river discharge, Hydrological Processes, 32(24), 3576-3587.
19) MacDonald MK, Stadnyk TA, Déry SJ, Braun M, Gustafsson D, Isberg K, Arheimer B 2018: Impacts of 1.5°C and 2.0°C warming on pan-Arctic river discharge into the Hudson Bay Complex through 2070, Geophysical Research Letters, 45(15), 7561-7570.
20) Hernández-Henríquez MA, Sharma AR, Taylor M, Thompson HD, Déry SJ 2018: The Cariboo Alpine Mesonet: Sub-hourly hydrometeorological observations of British Columbia's Cariboo Mountains and surrounding area since 2006, Earth System Science Data, 10, 1655-1672.
21) Allchin M, Déry SJ 2017: A spatio-temporal analysis of trends in Northern Hemisphere snow-dominated area and duration, 1971-2014, Annals of Glaciology, 58(75pt1), 21-35.
22) Radić V, Menounos B, Shea J, Fitzpatrick N, Tessema M, Déry SJ 2017: Evaluation of different methods to model near-surface turbulent fluxes for a mountain glacier in the Cariboo Mountains, BC, Canada, The Cryosphere, 11, 2897-2918.
23) Islam SU, Déry SJ, Werner AT 2017: Future climate change impacts on snow and water resources of the Fraser River Basin, British Columbia, Journal of Hydrometeorology, 18, 473-496.
24) Islam SU, Déry SJ 2017: Quantification of uncertainties in modelling the snow hydrology of the Fraser River Basin, British Columbia, Canada, Hydrology and Earth System Sciences, 21, 1827-1847.
25) Koster R, Betts A, Dirmeyer P, Bierkens M, Bennett K, Déry SJ, Evans J, Fu R, Hernandez F, Leung R, Liang X, Masood M, Savenije H, Wang G, Yuan X 2017: Hydroclimatic variability and predictability: A survey of recent research, Hydrology and Earth System Sciences, 21, 3777-3798.
26) Hernández-Henríquez MA, Sharma AR, Déry SJ 2017: Variability and trends in runoff in the rivers of British Columbia's Coast and Insular Mountains, Hydrological Processes, 31, 3269-3282.
27) Li Z, Hao Z, Shi X, Déry SJ, Li J, Chen S, Li Y 2016: An agricultural drought index to incorporate the irrigation process and reservoir operations: A case study in the Tarim River Basin in China, Global and Planetary Change, 143, 10-20.
28) Sharma AR, Déry S 2016: Elevational dependence of air temperature variability and trends in British Columbia's Cariboo Mountains, 1950-2010, Atmosphere-Ocean, 54(2), 153-170.
29) Kang DH, Gao H, Shi X, Islam SU, Déry SJ 2016: Impacts of a rapidly declining mountain snowpack on streamflow timing in Canada's Fraser River Basin, Scientific Reports, 6, 19299.
30) Déry SJ, Stadnyk TA, MacDonald M, Gauli-Sharma B 2016: Recent trends and variability in river discharge across northern Canada, Hydrology and Earth System Sciences, 20, 4801-4818.
31) Albers SJ, Déry SJ, Petticrew EL 2016: Flooding in the Nechako River Basin of Canada: A random forest modeling approach to flood analysis in a highly regulated reservoir system, Canadian Water Resources Journal, 41(1-2), 250-260.
32) Hernández-Henríquez MA, Déry SJ, Derksen C 2015: Polar amplification and elevation-dependence in trends of Northern Hemisphere snow cover extent, 1971-2014, Environ. Research Letters, 10, 044010.
33) Petticrew EL, Albers S, Baldwin S, Carmack EC, Déry SJ, Gantner N, Graves K, Laval B, Morrison J, Owens PN, Selbie DT, Vagle S 2015: Initial observations of the impact of a catastrophic mine tailings impoundment spill into a large oligotrophic lake: Quesnel Lake, British Columbia, Canada, Geophysical Research Letters, 42, 3347-3355.
34) Leggat M, Owens PN, Stott TA, Forrester BJ, Déry SJ, Menounos B 2015: Hydro-meteorological drivers and sources of suspended sediment flux in the proglacial zone of the retreating Castle Creek Glacier, Cariboo Mountains, British Columbia, Earth Surface Processes and Landforms, 40, 1542-1559.
35) Padilla A, Rasouli K, Déry SJ 2015: Impacts of variability and trends in monthly runoff and water temperature on salmon migration in the Fraser River Basin, Canada, Hydrol. Sciences Journal, 60, 523-533.
36) Kang DH, Shi X, Gao H, Déry SJ 2014: On the changing contribution of snow to the hydrology of the Fraser River Basin, Journal of Hydrometeorology, 15, 1344-1365.

UNBC UNIVERSITY OF NORTHERN BRITISH COLUMBIA

Philip N. Owens

Quesnel River Research Centre QRRC

Name: Philip Neil Owens
Nationality: British
Status in Canada: Permanent resident
Date of birth: 9th April 1966

Work address: Environmental Science Program, Faculty of Environment, University of Northern British Columbia (UNBC), Prince George, British Columbia, Canada V2N 4Z9
Telephone: +001 250 960 6177
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E-mail: Philip.owens@unbc.ca and owensp@unbc.ca
Web site: https://www2.unbc.ca/owens
Present position: Professor in Environmental Science and FRBC Endowed Research Chair in Landscape Ecology at UNBC.
Adjunct Professor in the Department of Soil Science and the Department of Geography and Environment, University of Manitoba, Canada.
Research topics: Response of aquatic systems to landscape disturbances (e.g. agriculture, forestry, mining, urban development, wildfires, climate change); tracing sediment in river systems; sediment-associated contaminants and nutrients (e.g. phosphorus).

EDUCATION

1984-1988 Coventry Polytechnic, Coventry CV1 5FB, UK
Graduated with B.Sc. (2.1) Honours Degree in Geography
Thesis: Valley sedimentation at Slapton, Devon, and its implications for management
Supervisor: Prof. I.D.L. Foster

1988-1990 University of British Columbia, Vancouver, British Columbia, V6T 1Z2, Canada
Graduated with M.Sc. Degree in Physical Geography
Thesis: Lake sediment-based sediment yields and erosion rates in the Coast Mountains, British Columbia
Supervisor: Prof. O. Slaymaker. Funding: NSERC (Canada)

1990-1994 University of Exeter, Exeter, Devon EX4 4RJ, UK
Graduated with Ph.D. in Physical Geography
Thesis: Towards improved interpretation of caesium-137 measurements in erosion studies
Supervisor: Prof. D.E. Walling. Funding: NERC (UK)

RESEARCH PROJECTS/GRANTS (select current and recent)

- Forest Renewal British Columbia (FRBC) *Endowed Research Chair Operating Grant* (2007 – ongoing) – several projects including: sediment fingerprinting in Canadian watersheds; sources of sediment in proglacial environments; impacts of wildfire on soil erosion and fine-grained sediment dynamics in forested aquatic systems; sediment-associated contaminants in watersheds. Funds: ~$525,000.
- NSERC Discovery Grant – *Advancing techniques to fingerprint sediment sources in disturbed watersheds*. Project team: P.N. Owens, PI. Duration: 2018 – 2023 (5 years). Funds: $180,000.
- Nechako Environmental Enhancement Fund (NEEF) – *Integrated watershed research in the Nechako river basin: Phase 1 and 2*. Project team: Stephen Déry, Phil Owens, Margot Parkes and Ellen Petticrew (all UNBC). Duration: 2014 – 2023 (9 years). Funds: ~$1,000,000 from NEEF with ~$1,000,000 as matched funding from other sources.

- Environment and Climate Change Canada, Environmental Damages Fund – *Evaluating the resiliency of aquatic ecosystems to a catastrophic mine tailings spill event: the 2014 Mount Polley incident in the Quesnel River watershed, British Columbia: Phase 1 and 2*. Project team: UNBC (Ellen Petticrew (PI), Phil Owens, Stephen Déry), UBC (Sue Baldwin, Bernard Laval), U of Lethbridge (Greg Pyle). Duration 2016 – 2020 (5 years). Funds: ~$1,000,000.
- NSERC Collaborative Research and Development Grant - *Contributions of climate change and hydro-electric regulation to the variability and change of freshwater-marine coupling in the Hudson Bay System*. Project team: U of Manitoba (David Barber, PI, and others), UNBC (Stephen Déry, Phil Owens and Ellen Petticrew), University of Quebec and other institutions. Duration: 2015 – 2020 (5 years). Funds: ~$9,000,000 (50% from NSERC and matched funding from Manitoba Hydro).
- Environment Canada – Lake Winnipeg Basin Stewardship Fund (LWBSF) – *Designing and managing riparian areas to filter phosphorus and sediment*. Project team: UNBC (Phil Owens, PI) and U of Manitoba (David Lobb). Duration: 2013 – 2017 (4 years). Funds: $147,500.
- Canada Foundation for Innovation (John R Evans Leaders Fund) – *Infrastructure to support innovations in soil erosion and sedimentation research*. Project team: David Lobb (PI, U of Manitoba) and Phil Owens (co-PI). Duration 2014 – onwards. Funds: $620,000 (50% from CFI, 50% from Manitoba Research) plus other matched-funding.

PUBLICATIONS and PRESENTATIONS

a) Summary

- Total publications: >140
- Total refereed journal publications: 88
- Examples of journals: Scientific Reports, Earth-Science Reviews, Geophysical Research Letters, Environmental Research Letters, Science of the Total Environment, Advances in Agronomy, Water Research, Water Resources Research, Hydrological Processes, Journal of Hydrology
- Total conference presentations (including posters): >200
- Total invited/keynote presentations: >40
- Total media presentations and interviews (TV, radio, web and press): >50
- Metrics: Web of Science H-factor = 37 (as of March 2021)

b) Edited books

- **Owens PN,** Slaymaker O (Editors) (2004). *Mountain Geomorphology*. Hodder Arnold Publishers Ltd.
- **Owens PN,** Collins AJ (Editors) (2006). *Soil Erosion and Sediment Redistribution in River Catchments: Measurement, Modelling and Management*. CABI, Wallingford, UK.
- **Owens PN** (Editor) (2008). *Sustainable Management of Sediment Resources: Sediment Management at the River Basin Scale*. Elsevier, Amsterdam.
- Banasik K, Horowitz AJ, **Owens PN,** Stone M, Walling DE (Editors) (2010). *Sediment Dynamics for a Changing Future*. IAHS Pub.337, IAHS Press, U.K.

c) Edited journal special issues

- **Owens PN,** Rickson RJ, Clarke MA (Eds) (2006). The use of vegetation for erosion and environmental protection. *Earth Surface Processes and Landform*, **31**, 533-631.
- Church M, **Owens P**, Petticrew E, Souch C (Eds) (2006). Sediment and geochemical budgets. *Geomorphology*, **79**, 1-142.

- **Owens PN** (Ed.) (2007). Sediment linkages between the river catchment and the sea. *Journal of Soils and Sediments*, **7**, 273-350.
- **Owens PN,** Petticrew EL, van der Perk M (Eds) (2010). Sediment response to catchment disturbances. *Journal of Soils and Sediments*, 10, 591-697.

d) Refereed journal papers (since 2015)

- **Owens PN** (2020). Soil erosion and sediment dynamics in the Anthropocene: a review of human impacts during a period of rapid environmental change. Journal of Soils and Sediments, 20, 4115-4143. https//:doi.org/10.007/s11368-20-02815-9
- Hamilton AK, Laval BE, Petticrew EL, Albers SJ, Allchin M, Baldwin SA, Carmack EC, Déry SJ, French TD, Granger B, Graves KE, **Owens PN,** Selbie DT, Vagle S (2020). Seasonal turbidity linked to physical dynamics in a deep lake following the catastrophic 2014 Mount Polley mine tailings spill. Water Resources Research, 56. e2019WR025790. https://doi.org/10.1029/2019WR025790
- Goharrokhia M, Lobb DA, **Owens PN** (2020). Evaluation of high-flow rate continuous-flow centrifugation and continuous-flow filtration techniques for sampling suspended sediment. Hydrological Processes, 34, 3882-3893.
- **Owens PN,** Blake WH, Millward GE (2019). Extreme levels of fallout radionuclides and other contaminants in glacial sediment (cryoconite) and implications for downstream aquatic ecosystems. Scientific Reports, 9, 12531. https://doi.org/10.1038/s41598-019-48873-z
- Reiffarth DG, Petticrew EL, **Owens PN**, Lobb DA (2019) Spatial differentiation of cultivated soils using compound-specific stable isotopes (CSSIs) in a temperate agricultural watershed in Manitoba, Canada. Journal of Soils and Sediments, 19, 3411-3426.
- Boudreault M, Koiter AJ, Lobb DA, Liu K, Benoy G, **Owens PN,** Li S (2019). Comparison of sampling designs for sediment source fingerprinting in an agricultural watershed in Atlantic Canada. Journal of Soils and Sediments, 19, 3302-3318.
- Gateuille D, **Owens PN,** Petticrew EL, Booth BP, French TA, Déry SJ (2019). Determining contemporary and historical sediment sources in a large drainage basin impacted by cumulative effects: the regulated Nechako River, British Columbia, Canada. Journal of Soils and Sediments 19, 3357-3373.
- Vanrobaeys JA, **Owens PN,** Lobb DA, Kieta KA, Campbell JM (2019). Seasonal efficacy of vegetated filter strips for phosphorus reduction in surface runoff. Journal of Environmental Quality, 48, 880-888.
- Goharrokhia M, Pahlavanb H, Lobb DA, **Owens PN,** Clark SP (2019). Assessing issues associated with a time-integrated fluvial fine sediment sampler. Hydrological Processes, 33, 2048-2056.
- Hatam I, Petticrew EL, French TD, **Owens PN,** Laval B, Baldwin S (2019). The bacterial community of Quesnel Lake sediments impacted by a catastrophic mine tailings spill differ in composition from those at undisturbed locations – two years post-spill. Scientific Reports, 9, 2705.
- **Owens PN,** Gateuille D, Petticrew EL, Booth B, French TA (2019). Sediment-associated organopollutants, metals and nutrients in the Nechako River, British Columbia: a current study with synthesis of historical data. Canadian Water Resources Journal, 44, 42−64.
- Habibiandehkord R, Lobb DA, **Owens PN,** Flaten DN (2019). Effectiveness of vegetated buffer strips in controlling legacy phosphorus exports from agricultural land. Journal of Environmental Quality, 48, 314-321.

- Kieta KA, **Owens PN** (2019). Phosphorus release from shoots of Phleum pretense L. after repeated freeze-thaw cycles and harvesting. Ecological Engineering, 127, 204-211.
- Boudreault M, Koiter AJ, Lobb DA, Lui K, Benoy G, **Owens PN,** Danielescu D, Li S (2018). Using colour, shape and radionuclide fingerprints to identify sources of sediment in an agricultural watershed in Atlantic Canada. Canadian Water Resources Journal, 43, 347-365.
- Kieta KA, **Owens PN,** Vanrobaeys J, Lobb DA, Flaten DN (2018). Phosphorus dynamics in vegetated buffer strips in cold climates: a review. Environmental Reviews, 26, 255-272.
- Blake WH, Boeckx P, Stock B, Smith HG, Bode S, Upadahayay HR, Gaspar L, Goddard R, Lennard A, Lizaga I, Lobb DA, **Owens PN,** Petticrew EL, Kuzyk Z, Gari BD, Munishi L, Mtei K, Nebiyu A, Mabit L, Navas A, Semmens B (2018). A hierarchical Bayesian mixing model approach for river basin sediment source apportionment. Scientific Reports, 8, 13073.
- Koiter AJ, **Owens PN,** Petticrew EL, Lobb DA (2018). Assessment of particle size and organic matter correction factors in sediment source fingerprinting investigations: the example of two contrasting watersheds in Canada. Geoderma, 325, 195-207.
- Liu K, Lobb DA, Miller JJ, **Owens PN,** Caron MEG (2018). Determining sources of fine-grained sediment for a reach of the Lower Little Bow, Alberta, using a colour-based sediment fingerprinting approach. Canadian Journal of Soil Science, 98, 55-69.
- Habibiandehkord R, Lobb DA, Sheppard SC, Flaten DN, **Owens PN** (2017) Uncertainties in vegetated buffer strips functioning for controlling phosphorus export from the Canadian prairies. Environmental Science and Pollution Research, 24, 18372-18382.
- Laceby JP, Evrard O, Smith HG, Blake WH, Olley JM, Minella JPG, **Owens PN** (2017). The challenges and opportunities of addressing particle size effects in sediment source fingerprinting: a review. Earth-Science Reviews, 169, 85-103.
- Koiter AJ, **Owens PN,** Petticrew EL, Lobb DA (2017). The role of soil surface properties on the particle size and carbon selectivity of interrill erosion in agricultural landscapes. Catena, 153, 194-206.
- **Owens PN,** Blake WH, Gasper L, Gateuille D, Koiter AJ, Lobb DA, Petticrew EL, Reiffarth DG, Smith HG, Woodward JC (2016). Fingerprinting and tracing the sources of soils and sediments: Earth and oceans science, geoarchaeological, forensic, and human health applications. Earth-Science Reviews, 162, 1-23.
- Reiffarth D, Petticrew EL, **Owens PN,** Lobb DA (2016).Identification of sources of variability in fatty acid (FA) biomarkers in the application of compound-specific stable isotopes (CSSIs) to soil and sediment fingerprinting and tracing: a review. The Science of the Total Environment, 565, 8-27.
- Leggat M, **Owens PN**, Stott TA, Forrester B, Déry SJ, Menounos B. (2015). Hydroclimatic drivers and sources of suspended sediment flux in the proglacial zone of the retreating Castle Creek glacier, Caribou Mountains, British Columbia, Canada. Earth Surface Processes and Landforms, 40, 1542-1559.
- Koiter AJ, **Owens PN**, Petticrew EL, Lobb DA (2015). The role of gravel channel beds on the particle size and organic matter selectivity of transported fine-grained sediments: implications for sediment fingerprinting and biogeochemical flux studies. Journal of Soils and Sediments, 15, 2174-2188.
- Barthod LRM, Liu K, Lobb DA, **Owens PN**, Martinez-Carreras N, Koiter AJ, Petticrew EL, McCullough GK, Liu C, Gaspar L (2015). Selecting color-based tracers and classifying sediment sources in the assessment of sediment dynamics using sediment source fingerprinting. Journal of Environmental Quality, 44, 1605-1616.

- Petticrew EL, Albers SJ, Baldwin S, Carmack EC, Déry SJ, Gantner N, Graves K, Laval B, Morrison J, **Owens PN**, Selbie D, Vagle S (2015). The impact of a catastrophic mine tailings spill into one of North America's largest fjord lakes: Quesnel Lake, British Columbia. Geophysical Research Letters, 42, 3347-3355.

RECENT POSTGRADUATE AND RESEARCH PERSONNEL SUPERVISION (since 2007)

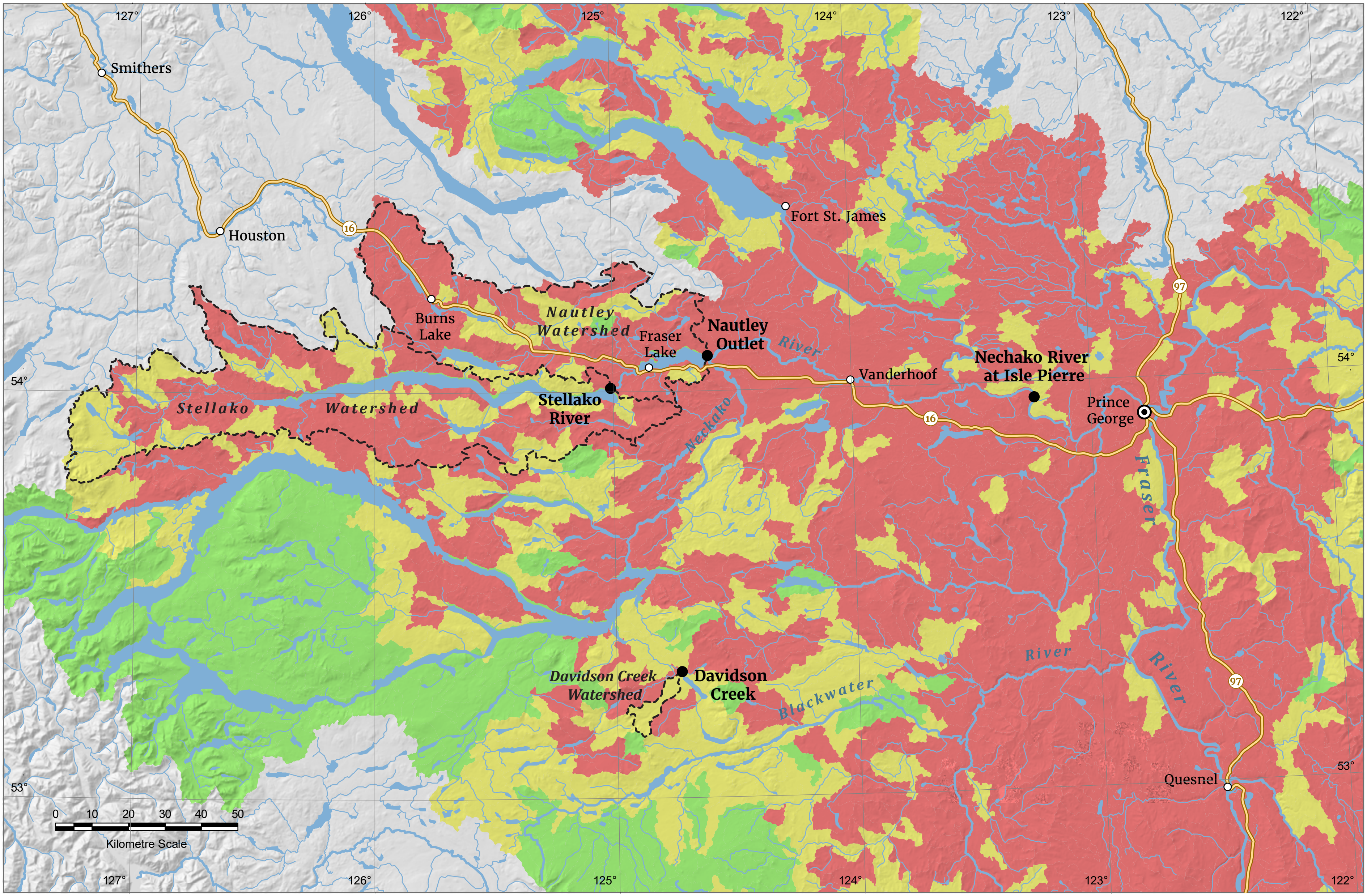
- PhD supervision (completed and on-going): 4
- MSc supervision (completed and on-going): 9
- International MSc project co-supervision (completed): 7
- Post-doctoral research fellows: 3
- Research associates and assistants: 23

TEACHING at UNBC (not all courses are taught each year)

- **BSc Geography:** *Concepts in Geomorphology* (GEOG311)
- **BSc Environmental Science:** *Introduction to Environmental Science* (ENSC111), *Introduction to Aquatic Systems* (ENSC211)**,** *Northern Contaminated Environments* (ENSC308) and *Lands and Environment of the Circumpolar North* (NORS312)
- **MSc/PhD Natural Resources and Environmental Studies (NRES):** *Processes in Geomorphology* (NRES 751)

EDITOR, WORKING GROUPS AND EXPERT GROUPS/PANELS

- Editor-in-Chief *Journal of Soils and Sediments* (2011 -)
- Member of the Steering Committee and leader of WG4/WP2 of the European Sediment Research Network (SedNet) funded by the European Union (2002-2004)
- Treasurer (2008 -) and Vice-President (2017 -) of the International Association of Sediment–Water Science (IASWS)
- Chair of the European Geosciences Union (EGU) sub-division on Erosion, Sedimentation and River Processes (2009-2012)
- Member of UK NERC Peer Review College (2005-2006)
- National Science Foundation (USA-NSF) Critical Zone Observatory Grant Panel (2007)



LEGEND:

Cumulative Salmon Habitat Pressure

- Low
- Moderate
- High

- Highway
- Watercourse
- Watershed Boundary
- Lake

N

PROJECT NO.	2006501	REVISION:	1-1
DATE:	May 27, 2021	SCALE:	1:1500000
DRAWN:	BE	DATUM:	NAD 1983
CHECKED:	SG	PROJECTION:	BC Albers

CLIENT: ARTEMIS GOLD INC

PREPARED BY: Palmer™

PROJECT: Blackwater

TITLE: **Complementary Measures Study Area**

FIGURE 2

Palmer™

Rick Palmer

M.Sc., R.P. Bio.

President & CEO, Senior Fisheries Biologist

Professional History

Palmer
President and CEO
Senior Fisheries Biologist
Vancouver, BC
2010 - Present

AECOM
Manager, Water and Natural Resource Practice Area Lead
BC & Yukon
2008 - 2010

Gartner Lee Limited
Manager, Natural Resources Team Lead
Vancouver, BC
2006 - 2008

Gartner Lee Limited
Senior Fisheries Biologist / Project Manager
Toronto, ON
2001 - 2006

ARC Environmental Ltd.
Senior Fisheries Biologist / Project Manager
Kamloops, BC
1999 - 2000

Triton Environmental Ltd.
Fisheries Biologist
Vancouver, BC
1996 - 1999

Summary

Rick Palmer is the President and CEO and Senior Fisheries Biologist at Palmer. Rick has over 25 years of experience undertaking and managing fisheries inventories and aquatic impact assessments for a wide range of private, public and industry related projects. He has extensive experience with baseline/impact fish and fish habitat assessments as they relate to mining, hydroelectric and water supply developments. Rick engages Fisheries and Oceans Canada and other agencies on a regular basis to find solutions for client issues. He has been involved with environmental impact assessments, technical baseline studies, environmental monitoring programs and peer review in British Columbia, Alberta, Ontario, Yukon, NWT and Nunavut.

Rick provides senior management of environmental permitting process for large-scale natural resource development projects. His technical areas of expertise include fisheries aquatic ecology, in-stream flow modelling, environmental impact and risk. He has provided technical expertise at public hearings for issues related to aquatic environments and is considered an expert in aquatic-related provincial and federal regulations in Canada.

Experience

Energy

- **Site C Clean Energy Project, BC | 2020** Senior Fisheries Biologist & Project Director for the Temporary Fishway Operation. Client: Peace River Hydro Partners (PRHP)
- **Site C Clean Energy Project, BC | 2020** Senior Fisheries Biologist & Project Director for the Fish Salvage Operation on the Peace River. Client: Peace River Hydro Partners (PRHP)
- **BRGMON-13 Seton River sockeye smoltt entrainment program, BC | 2019** Senior Fisheries Biologist and QEP. Client: BC Hydro (St'at'imc Eco-Resources Ltd)
- **Trans Northern Pipeline Inc. (TNPI), ON | 2017-present** Senior Fisheries Biologist for several crossing repairs.
- **Seton River Transmission Crossing, BC | 2018** Senior Fisheries Biologist, Fisheries Self Assessment. Client: BC Hydro
- **Blackwater Project Transmission Line Project, BC | 2015-present** Senior Fisheries Biologist, Fisheries Offsetting Plan. Client: New Gold
- **Gladstone Diversion Project, YK. | 2009-2011** Senior aquatic advisor and Fish and Aquatic Discipline Lead. Client: Yukon Energy Corporation
- **Atlin Storage and Control Structure Project, YK | 2009-2011** Senior aquatic advisor and Fish and Aquatic Discipline Lead. Client: Yukon Energy Corporation
- **Marsh Lake Fall-Winter Storage Project, YK | 2009-2011** Senior aquatic advisor and Fish and Aquatic Discipline Lead. Client: Yukon Energy Corporation

Mining

- **Elk Gold Project, BC | 2019-present** Project Director and Senior Fisheries Biologist for Environmental Baseline and MAPA. Client: Bayshore Minerals
- **Premier Gold Mine Project, BC | 2018-present** Project Director for Environmental Baseline and MAPA. Client: Ascot Resources

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- **Kwanika Project, BC | 2018 -2019** Project Director and Senior Fisheries Biologist for environmental baseline studies in support of a PFS. Client: Serengeti Resources
- **Elk Gold Project, BC | 2018 -2019** Project Director, Closure and Reclamation Plan. Client: Equinox Gold,
- **Blackwater Project, BC | 2015-2018** Fisheries Permitting Lead, Fish Offsetting Plan. Client: New Gold,
- **Red Mountain Project, BC | 2016-2018** Project Director for Fisheries, Aquatic Resources Client: IDM Mining
- **Casino Mine, YT | 2008-present** Project Manager and Fisheries and Aquatic Lead for Environmental Baseline and EA. Client: Western Copper and Gold
- **Cullaton Lake, NU | 2007-2009 & 2016-present** Project Director for Aquatic Risk Assessment; Closure and Reclamation Plan. Client: Barrick Gold
- **Brucejack Mine, BC | 2018** Project Manager for Bathymetric Assessment for Road upgrades and DFO Fisheries Permitting. Client: Pretium Resources,
- **Ambershaw Metals Inc. ON | 2017-2019** Project Director for Environmental Baseline Program
- **Ajax Mine, BC | 2016-2017** Fish Offsetting Plan support for EA. Client: KGHM
- **Coffee Gold, YT | 2014-2015** Project Manager, Fisheries and Aquatic Lead for Environmental Baseline. Client: Kaminak Gold
- **Elk Gold Project, BC | 2012-2014** Project Manager and Fisheries and Aquatic Lead for Environmental Baseline and Mines Act Amendment Permit. Client: Gold Mountain Mining Corporation,
- **New Polaris Mine Project, BC | 2011-2015** Project Director and Lead Fisheries Biologist for environmental baseline program, effects assessment; development of the dewatering program technical assessment report in support of a discharge permit application. Client: Canarc Resources,
- **Hushamu Project, BC | 2011-2014** Project Manager and Lead Fisheries Biologist for Baseline Programs. Client: Northisle Copper and Gold
- **Tulsequah Chief Mine, BC | 2007-2015** Project Director for Aquatic Risk Assessment; provide fisheries expertise for various environmental permitting and approvals programs; Aquatic field work for EEM and juvenile fish stranding programs. Client: Chieftain Metals,
- **High Lake Project, NU | 2007-2008** Fish and Aquatic Resource Lead for Environmental Baseline and Effects Assessment; Technical Hearing in Cambridge Bay. Client: OzMinerals,
- **Damoti Lake, NU | 2004-2006** Project Manager, Team Lead for Environmental Baseline Program. Client: Doublestar Resources
- **DO – 18 Project, NWT | 2005-2006** Project Manager, Senior Fisheries Biologist for Environmental Baseline Program Client: Peregrine Diamonds,
- **Izok Lake Project, NU | 2015** Fisheries Lead for multiple accounts analysis in support of Environmental Assessment. Client: MMG Limited,
- **Nordegg, AB | 2012** Environmental Due Diligence Project Lead. Client: NWP Coal Canada,
- Anglo American / Peace River Coal, Belcourt Saxon, BC | 2006 - 2009 Fish and Aquatic Resource Lead for Environmental Baseline Program.
- **Fish Lake Project, BC | 1994-1996** Fisheries Field Biologist for Environmental Baseline and Effects Assessment. Client: Taseko Mines

Land Development and Infrastructure

- **Mission Force Main Project, BC | 2019-present** Project Director and Senior Fisheries Biologist for obtaining a Federal Fisheries Act Authorization for an open cut & dredging project across the Fraser River. Client: City of Mission
- Alberta and BC National Park Infrastructure Projects | 2015-present Project Director and Senior Fisheries Biologist for several fisheries self- assessments and DFO requests for review for bank stabilization, bridge and culvert projects. Client: Parks Canada
- **Bank Stabilization Project, BC | 2018-present** Project Director and Senior Fisheries Biologist for bank stabilization project involving the protection of white sturgeon spawning areas Client: City of Vanderhoof
- **Ecosystems and Species Monitoring Program, BC | 2016-present** Fisheries Senior Lead. Client: Resort Municipality of Whistler
- **Dahlaks Creek Bridge Repair, BC | 2018** Senior Fisheries Lead for obtaining a Fisheries Act Authorization. Client: British Columbia Timber Sales
- **Wapiti River Coordinated Monitoring Program (CMAP), AB | 2007-present** Project Manager Client: Aquatera Utilities

- **Wapiti River Instream Flow Program, AB | 2014-2018** Designed, implemented and developed an instream flow program on the Wapiti River using a physical habitat simulation model (PHABSIM) and a River2D model to establish new instream objectives (IO) for the water licence. Client: Aquatera Utilities
- **Wapiti River Water Management Plan, AB | 2015-2018** Provided technical support to the WRWP Technical Steering Committee. Client: Aquatera Utilities
- **Wapiti River Fisheries Assessments, AB | 2007-2008** Project Manager, Fisheries Lead. Client: Aquatera Utilities
- **Lindsay Court Wells, ON | 2004** Fisheries Lead Client: Regional Municipality of Halton
- **9th Line and 16th Avenue Sanitary Sewer, ON | 2002-2005** Project Manager, Fisheries Lead. Client: York Region

Peer Review

- **Hope Bay, NU | 2011-2017** Fish and Fish Habitat Lead for Peer Review. Client: Kitikmeot Inuit Association
- **Back River, NU | 2014-2017** Fish and Fish Habitat Lead for Peer Review. Client: Kitikmeot Inuit Association
- **Madrid, NU | 2015** Fish and Fish Habitat Lead for Peer Review. Client: Kitikmeot Inuit Association
- **Jay Pipe, NU | 2015** Fish and Fish Habitat Lead for Peer Review. Client: Kitikmeot Inuit Association
- **Ivanhoe, AB | 2011-2012** Fish and Fish Habitat Lead for Peer Review. Client: Management and Solutions in Environmental Science (MSES)
- **Bootjack Creek, BC | 2012** Fish and Fish Habitat Lead for Peer Review. Client: William Lake Indian Band
- **Total A&P, AB | 2013-2015** Fish and Fish Habitat Lead for Peer Review. Client: MSES

Education

Master of Science (M.Sc.) - Fisheries
University of Waterloo, Ontario | 2006

Bachelor of Science (B.Sc.) - Biology
Simon Fraser University, British Columbia | 1996

Diploma of Technology (Dip. T) – Renewable Resource, Fish, Wildlife & Recreation
British Columbia Institute of Technology, British Columbia | 1989

Professional Development, Certifications and Associations

- Registered Professional Biologist with the College of Applied Biology (BC)
- St John's Ambulance Emergency First Aid for Industry (OFA Level 1 Equivalent)
- Supervisor backpack electrofishing certification
- Advance PADI certification

Reports and Presentations

Over 100 technical reports completed, which are available on request. Rick has presented at scientific and engineering conferences and workshops across Canada and within the USA and Europe.

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Stefan Gronsdahl

M.Sc., P.Geo.
Hydrologist

Summary

Stefan Gronsdahl is a watershed hydrologist with six years' experience in environmental consulting throughout western and northern Canada. Stefan has a strong and diverse background in hydrology and climate baseline evaluations, watershed hydrology, hydrological modeling, and statistical analysis. Stefan's work has focused on the impacts of resource development, land-use, and climate change on streamflow, with an emphasis on the effects on low flows and fish habitat. He regularly applies his strong analytical and modelling skills to find innovative solutions to answer challenging applied questions in support of effective resource management strategies. Stefan completed a M.Sc. thesis that investigated the hydrological impacts of forestry on low-flows and fish habitat in the southern interior of B.C. Stefan is an effective, efficient, and rigorous field and office-based scientist. He focuses on clients' needs and has proven to be technically innovative. He has also developed familiarity with key legislation specific to water and environmental-related issues in western Canada.

Professional History

Palmer
Hydrologist
2020-present

Polar Geoscience Ltd
Hydrologist
2018-2020

University of British Columbia
Graduate and Research Assistant
2016-2018

Associated Environmental Consultants Inc.
Environmental Scientist
2013-2016

Experience

Hydrological Modelling and Water Supply Assessments

Okanagan and Kalamalka Lakes Flood Forecasting Enhancements | 2021

Project hydrologist responsible for quality checking, processing, and gap-filling snow, meteorological, and streamflow data using appropriate statistical methods. Stefan also conducted a detailed assessment of previous iterations of the model to identify potential approaches to improve model performance. The data analysis and modelling was conducting using the 'R' programming language and the Raven modelling platform.
Client: BC River Forecast Centre

Detour Lake Water Balance Modelling | 2021

Stefan is a project hydrologist who assisted with the development of a water balance model that considers how future climate change scenarios will impact the mine-site water balance and closure plan. Data analysis and modelling was primarily conducted using the 'R' programming language and the GoldSim modelling framework.
Client: Kirkland Gold Inc.

Water Balance Modelling | 2020

Stefan helped with the development and calibration of a semi-distributed and physically based monthly water balance model of the Salmon River watershed on the west-coast of northern B.C. The model was developed in a complex watershed which is heavily glacierized and regularly experiences glacial lake outburst floods. The results from this analysis will be incorporated with groundwater and water quality models and will be used to evaluate the effects of mining operations on the downstream receiving environment.
Client: Ascot Resources Ltd.

Statistical Inflow Modelling | 2020

Stefan was the project hydrologist responsible for developing statistical models that used snowpack and climate data to predict seasonal inflows, water supply, and floods for Okanagan Lake, Kalamalka-Wood Lake, Nicola Lake, and the Nicola River, in the southern interior of B.C. He was responsible for processing

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and gap-filling snow, meteorological, atmospheric teleconnection data, and seasonal weather forecast data using appropriate statistical methods. Stefan also helped develop the empirical statistical models that will be used for real-time, operational predictions of seasonal inflow forecasts throughout the spring and early summer. Easy-to-use operational tools were developed so that inflow forecasts could be efficiently generated by the client. Analytical techniques used as a part of this project included linear and non-linear regressions, multivariate statistical modelling, principal component analysis, double-mass corrections, rating curve development, and linear and non-linear interpolation schemes.
Client: BC River Forecast Centre:

Hydrological Modelling of Snow and Runoff Generation Processes | 2019-2020
Stefan was the lead hydrologist responsible for development of a physically based hydrological model that was used to identify how snow dynamics, runoff generation, and land-use change impacts peak flows, water supply, and fish habitat in the Horsefly Watershed. Stefan was responsible for the study design, model development, calibration and validation, data analysis, and interpretation of results. Spatial data pre- and post-processing and data analysis were conducted using free, reproducible, and open-source software including the 'R' programming language and the Raven modelling framework. The results of the modelling exercise were interpreted to understand the effects of forestry on streamflow and have allowed for the development of forest management practices to minimize the impacts to infrastructure and fish habitat.
Client: Tolko Industries Ltd.

Baseline Hydrology and Climate Program | 2020-Present
Evaluated hydrometric and climate data quality in accordance with industry standards and provincial guidelines. Conducted data analysis, regional analyses, and processing including frequency analyses and the development of rating curves. Stefan provided support to field staff who are conducting hydrometric monitoring at the Premier and Red Mountain projects. Stefan also developed a training manual for field staff who are conducting regular hydrometric and climate monitoring.
Client: Ascot Resources Ltd.

Water Supply Assessment | 2018
Project Hydrologist responsible for data analysis and reporting as a part of a comprehensive water supply and demand study in the lower Fraser Valley to support the Stó:lo Nation's treaty negotiations. Hydroclimatic data analysis was conducted using the 'R' programming language.
Client: Stó:lo Xwexilmexw Treaty Association.

Environmental Flow Needs Assessment and Planning for Okanagan Lake | 2018
Project Hydrologist responsible for researching historical water licences and water consumption with the end goal of recreating naturalized hydrographs to be used to determine site-specific environmental flow needs for 18 tributaries of Okanagan Lake, BC. This work was conducted to inform the eventual development of a hydrological model intended to inform decisions regarding water supply and environmental flow needs in the Okanagan basin.
Client: Okanagan Basin Water Board

Fisheries and Instream Flow Needs

Blackwater Mine Site – Development of Instream Flow Needs | 2020
Stefan is the lead hydrologist responsible for understanding and quantifying how changes to the streamflow that will be caused by mine development will affect aquatic ecosystems in a tributary stream of the Nechako River, in central B.C. Stefan has designed and executed an analysis that incorporates hydrological model data with the results of instream flow assessments to quantify how changes in streamflow affect fish. This analysis has led to the development of a mitigated instream flow needs that will minimize impacts to aquatic ecosystems. The results of Stefan's analysis will serve as the basis for engineering design of water diversion and retention infrastructure.
Client: Artemis Gold Inc.

Instream Flow Methodology Evaluation | 2019-2020
Stefan is the lead scientist responsible for developing and validating an innovative approach for conducting instream flow assessments. The approach utilizes a cost-effective and analytically robust technique for evaluating how changes in streamflow affect physical fish habitat that would improve the quality and efficiency of instream flow assessments. This method is also an improvement on more conventional instream flow assessment techniques

because it can be used to quantify the effects of land-use and climate change on channel morphology and fish habitat.
Client: Habitat Conservation Trust Foundation

Fisheries Sensitive Watershed Assessment | 2019-2020
Project hydrologist responsible for analyzing and interpreting watershed characteristics in three watersheds in support of developing watershed management strategies to protect fish and fish habitat. This work involved characterizing channel morphology and hydraulics, reviewing aerial photographs, evaluating the past impacts of forest disturbance and road construction, and evaluating sedimentation and erosion potential.
Client: BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development

Forestry and Resources Development

Watershed Assessment | 2019-2020
Project hydrologist of a comprehensive watershed assessment of Sicamous Creek, near Sicamous, BC. Responsibilities included reviewing the relevant literature that assessed the impacts of logging on watershed hydrology, evaluating riparian conditions, sediment transport potential, and watershed runoff potential. Hydroclimatic data analysis was conducted using the 'R' programming language. Sicamous Creek is a noteworthy watershed given the presence of an active alluvial fan at the outlet of the watershed and the potential for it to negatively affect riparian conditions and nearby infrastructure.
Client: Tolko Industries Ltd

Soo River Water Quality Program | 2019-2020
Lead hydrologist responsible for conducting a surface water quality sampling program in six watersheds in response to a fertilizer treatment for regenerating cutblocks. Duties included sampling, logistics, reporting, and project management.
Client: BC Ministry of Forests, Lands, Natural Resource Operations, and Rural Development

Hydrological Assessment, Chilcotin Business Area | 2019
Project hydrologist responsible for assessing the hydrological impacts of proposed forest harvesting. Assessment methods included field observations, GIS analysis, a review of physical watershed processes, and a review of available fisheries data. The results of this assessment were specific recommendations for reducing the potential impacts of forest harvesting.
Client: Tolko Industries Ltd.

Watershed Assessment | 2017
Project hydrologist of a comprehensive watershed assessment of Quartz Creek located 30 km south of Nelson BC, near the community of Ymir, BC. Responsibilities included conducting a comprehensive literature review regarding the impacts of logging, forest disturbance, and climate change on water yields and low flows. Quartz Creek is noteworthy given the high level of community concern over water supply and quality both with respect to climate change and planned forest development.
Client: BC Timber Sales, Kootenay Business Area

Hydrogeomorphic Flood Assessment | 2018-2019
Project Hydrologist responsible for a post-flood hydro-geomorphic assessment of a watershed near Clinton, BC. The assessment focused on evaluating riparian conditions and identifying the cause of major flooding and erosion on several private properties located near the 2017 Elephant Hill Fire. Investigation methods included interviews, hydroclimatic data analysis using 'R', and aerial photograph interpretation. Recommendations were made to perform culvert upgrades to mitigate erosion and sedimentation issues.
Client: BC Attorney General's Office

Hydrogeomorphic Desktop Analysis | 2019
Responsible for the review and analysis of aerial photography, ortho-imagery, and GIS data to understand the hydrogeomorphic risk associated with 32 areas where the road crossed creeks located near Howards Pass, eastern Yukon. Evaluated the potential risk associated with landslides, debris flows, floods, and erosion.
Client: Selwyn Chihong Mining Ltd.

Stefan Gronsdahl
M.Sc., P.Geo.
Hydrologist

Education

Master of Science
University of British Columbia | 2016-2018

Bachelor of Science, Physical Geography
University of Victoria | 2007-2013

Professional Development, Certifications and Associations

Professional Associations

- Professional Geoscientist
- Engineers and Geoscientists of B.C.
- Canadian Society for Hydrological Sciences.

Software

- Raven Hydrological Modelling Platform
- System for Environmental Flow Analysis (SEFA).
- R Statistical Analysis and Programming Language

Reports and Presentations

- **Gronsdahl, S.,** Moore, R.D., Rosenfeld, J., McCleary, R., and Winkler, R.D. 2019. Effects of forestry on summertime low flows and physical fish habitat in snowmelt-dominant headwater catchments of the Pacific Northwest. Hydrological Processes. https://doi.org/10.1002/hyp.13580
- Moore, R.D., **Gronsdahl, S**., and McCleary, R. 2020. Effects of forest harvesting on warm-season low flows in the Pacific Northwest: A review. Confluence: Journal of Watershed Science and Management. https://doi.org/10.22230/jwsm.2020v4n1a35

Palmer™

Dave Huebert

Ph.D., P.Biol., R.P.Bio.
Senior Environmental Scientist

Professional History

Palmer
Senior Environmental Scientist
Vancouver, BC
2019 – present

AECOM
Senior Environmental Scientist
Burnaby, BC
2014 – 2019

Stantec Consulting
Senior Environmental Scientist
Burnaby, BC
2012 – 2014

Stantec Consulting
Senior Environmental Scientist
Winnipeg, MB
2010 – 2012

TetrEx Consultants
Environmental Scientist
Winnipeg, MB
2004 – 2010

Independent Environmental Consultant
1983 - 2004

Summary

Dave is a registered professional biologist in both Alberta and British Columbia, specializing in aquatic and terrestrial ecology and toxicology. He completed his PhD in the Department of Botany at the University of Manitoba in 1992, where he focused his studies on the interaction of environmental and chemical factors on assessment of cadmium toxicity in the duckweed, *Lemna trisulca*.

Subsequent to obtaining his PhD, he worked as an independent contract scientist with the Department of Fisheries and Oceans at the Experimental Lakes Area, and as a sessional instructor at a variety of educational institutions in Winnipeg, Manitoba.

As a consultant, initially hired in 2004 by Tetr*ES* Consultants Inc. and most recently with Palmer, He has worked on a variety of projects in the mining, oil and gas, clean energy, municipal, and industrial sectors. His work has included baseline characterization, environmental assessment, environmental and aquatic effects monitoring plan design and implementation, adaptive management plan design and implementation, environmental compliance monitoring and reporting, and third-party reviews of environmental assessment reports for both government and First Nations organizations.

His field experience in ecology and toxicology includes a variety of projects across the west and into the north, and includes experience conducting assessment of groundwater, assessment of upland vegetation, and assessment of surface water, vegetation, fish, benthic invertebrates and periphyton in the aquatic environment.

Experience

Watershed Monitoring | 2019-2020
Dave developed a watershed monitoring strategy for the CVRD, complete with a decision matrix for determination of site importance based on the existing data record, assessed risk, and location of each site within the watershed. The approach included establishing long-term monitoring sites for definition of baseline conditions and providing a strategy for developing short-term sites and aquatic monitoring programs to address emerging issues. Client: Cowichan Valley Regional District (CVRD)

Casino Mine | 2021
The Casino Mine is a proposed gold and copper mine in Yukon. Dave completed a gap analysis of existing data for surface water, hydrology, and fish and fish habitat. Subsequent to that, he coordinated production of the 2021 Work Plan and budget to address identified data gaps.
Client: Casino Mining Corp.

Shasta/Baker Mines Compliance Monitoring | 2020-2021
Dave provided senior technical review of an Aquatic Effects Monitoring Program to collect surface water and aquatics data for Permit compliance for both mine sites and then coordinated completion of two Annual Surface Water Reports and an Aquatic Effects Monitoring Report. Dave was the principal author of the Annual Reports, and the senior technical reviewer for

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the Aquatic Effects Monitoring Program report. He also helped design the Annual Surface Water sampling program for subsequent years.
Client: Talisker Resources

Elk Gold Project | 2019-2021

An assessment was required for a BC Mines Act Amendment to restart mining at Elk Gold. Dave's role was to write the Surface Water Baseline Report, to provide a senior technical review of the Fish and Aquatics Baseline Report, to write the Water Quality Effects Assessment, to provide a senior review of the Fish and Aquatics Effects Assessment, and to write the Environmental Monitoring Plan (EMP) for the Project. The EMP included an Aquatic Effects Monitoring Plan, Post-Closure Monitoring Plan, Discharge Monitoring Plan, Mine Site Water Monitoring Plan, and Environmental Monitoring Plan for compliance monitoring. Once the application had been submitted and reviewed, Dave was part of the technical team responding to the Information Requests. He also completed a senior technical review of the 2019 Elk Gold Project Annual Discharge Report for EMA Discharge Permit 106262.
Client: Bayshore Minerals

Annual Ecosystems Monitoring Program Report | 2021

Dave was the senior technical reviewer for the aquatics section of the Annual Report. His role was to review the data analysis and interpretation for the surface water, sediment, periphyton, and benthic invertebrate sections of the report. Client: Town of Whistler

Premier Gold Project | 2019-2021

An assessment was required for a BC Mines Act Amendment to restart mining for the Premier Gold Project. Dave's role was to write the Surface Water Baseline Report and to provide a senior technical review of the Fish and Aquatics Baseline Report. He also provided a senior technical review of the 2019 Aquatic Effects Monitoring Program report and provided recommendations for transition of the existing care and maintenance surface water monitoring program to operations monitoring. Once that was all complete, he wrote the Baseline Summary Reports for the Surface Water and the Freshwater Fish and Fish Habitat Valued Components, and then wrote the Effects Assessment Chapters for the same VC's. In addition, he developed and wrote the Environmental Monitoring Plan for the Project, which included an Aquatic Effects Monitoring Program and associated Adaptive Management Plan. Once the application had been submitted and reviewed, he was part of the technical team responding to the Information Requests.
Client: Ascot Resources

Tundra Mine Site Remediation | 2017-2018

The Tundra Mine is an abandoned mine site in the Northwest Territories that is being remediated. The role was to develop and write an Adaptive Management Plan for the aquatic monitoring phase once the remediation project was complete. Compiled and summarized the available environmental data preparatory to development of a site-specific water and contaminant transport model.
Client: Indigenous and Northern Affairs Canada

Yellowknife Bay Potable Water Source Selection | 2017

A new water intake structure is required for the City of Yellowknife. To facilitate construction of the project, an analysis of Yellowknife Bay water and sediment arsenic was required. The role was to compile water and sediment chemistry data, develop an approach to analysis of the data, and write an assessment to characterize arsenic in Yellowknife Bay. Managed the project and oversaw report delivery. The conclusions were presented to the City Council of Yellowknife twice.

Faro Mine Aquatic Effects Monitoring Program Workplan | 2017

The Faro Mine complex is an abandoned mine site in the Yukon Territories. The role was to develop a work plan and budget for the 2017 monitoring of the aquatic environment upstream and downstream of the site in collaboration with Golder Associates. Undertook a gap analysis of recent aquatics documents to determine what additional information might need to be collected during the 2017 aquatic monitoring program.
Client: Indigenous and Northern Affairs Canada

Pulp and Paper Cycle 7 IOS EEM Report | 2016

Provided senior review for an Investigation of Solutions (IOS) Interpretive Report for the Cycle 7 Environmental Effects Monitoring (EEM) program at the Tolko pulp and paper operations located in The Pas, Manitoba. Provided responses to Information Requests sent by Environment Canada.
Client: Tolko Industries Ltd.

Regina Master Plan | 2016
The role was to determine the scope, status and relevance of existing source water protection plans for the Regina area. Evaluated and summarized existing documents, including the Upper Qu'Appelle and Wascana Creek Watersheds Source Water Protection Plan and the Water Security Plan of the Saskatchewan Water Security Agency. Included were recommendations to the City of Regina for optimal implementation of the Protection Plans.
Client: City of Regina

Stoney Creek Water Sampling Program | 2015
AECOM was selected to complete a water chemistry and benthics sampling program in Stoney Creek over the course of one sampling year (wet and dry season). The sampling program was conducted prior to implementation of the Integrated Stormwater Management Plan (ISMP) for the Stoney Creek sub-watershed. The City of Burnaby was interested in comparison of current results with those collected previously in 1999. The objective was to develop an understanding of temporal changes (both negative and positive) in this sub-watershed. The role was to provide a technical review of the analysis and interpretation of the water chemistry and benthics data.
Client: City of Burnaby

Effects of Chlorination in Marine Downstream Receiving Waters | 2015
Marine vessels, nuclear power plants, thermal power plants, and various other marine facilities require the use of seawater for cooling or other purposes. Growth of marine organisms on and within structures exposed to seawater, called biofouling, is the inevitable result. Biofouling reduces water movement through pipes, damages infrastructure, potentially transports invasive species, and can reduce the rate of thermal exchange in cooling systems. Control of biofouling is therefore critical to the long-term maintenance and operations of vessels, structures and facilities exposed to seawater. Chlorination with sodium hypochlorite is one of the most widely used antifouling agents due to its established technology, long-term use, low cost, high reactivity and effectiveness. However, because it is both highly reactive and toxic to marine life, there is also concern regarding the effects of residual chlorine in the downstream receiving environment. The purpose of this report was to characterize the fate of chlorine, and potential environmental effects of chlorination practices in the marine environment. A follow-up report examined the toxicological relationship between marine fish and chlorine byproducts.
Client: AltaGas DCLNG General Partner Inc.

City of Kindersley Downstream Use and Impact Study | 2015
The Town of Kindersley intends to develop a new wastewater treatment plant to allow for discharge of treated wastewater to the Teo Lakes basin, which is part of the Eagle Creek sub-basin of the North Saskatchewan River. The Town of Kindersley required an analysis of the existing water treatment, wastewater treatment, sanitary sewer and storm sewer infrastructure to assess existing capacities, and to identify shortfalls for projected future growth of the Town. The purpose of the DUIS was to guide the regulatory permitting of the future upgrades to the wastewater treatment system, and in so doing establish the basis of its design in terms of the level of treatment that will be required to ensure protection of downstream uses. The role in this project was to undertake a senior technical review of the draft report.
Client: City of Kindersley

City of Melville Downstream Use and Impact Study | 2015
The existing lagoon system for the Town of Melville consists of two anaerobic primary cells and five secondary facultative cells with a discharge to Crescent Creek. The Town of Melville required an analysis of the existing water treatment, wastewater treatment, sanitary sewer and storm sewer infrastructure to assess existing capacities, and to identify shortfalls for projected future growth of the Town. The purpose of the DUIS was to guide the regulatory permitting of the future upgrades to the wastewater treatment system (WWTS), and in so doing, establish the basis of its design in terms of the level of treatment that will be required. The role in this project was to undertake a senior technical review of the draft report.
Client: City of Melville

Lac de Gras Hydrodynamic Modeling, Northwest Territories | 2014

The GNWT Department of Public Works and Services required statistical analyses of the existing water chemistry data record for Lac de Gras (LDG) in the Northwest Territories. Baseline water chemistry was defined, spatial and temporal trends in specific parameters of concern were evaluated, and relative loading rates were calculated. The analyses sought to determine whether there were cumulative effects to LDG's water quality resulting from the operation of two diamond mines within its watershed. The role was to define and manage the study, oversee data analysis, compile and write the report, and to undertake the preliminary technical review of the report.
Client: Government of Northwest Territories (GNWT)

Water Chemistry and Hydrology Data for Five Sites in the Mackenzie River Watershed | 2013

Dave wrote the proposal and managed the project team. Wrote a report using 50 years of water chemistry and hydrology data for five sites in the Mackenzie River watershed for Aboriginal Affairs and Northern Development Canada (AANDC). The objectives of the study were to define baseline conditions, examine spatial variability within the watershed, determine if conditions have altered over the past 50 years, and define seasonal periods within the watershed.
Client: Aboriginal Affairs and Northern Development Canada

Giant Mine Remediation Project | 2014

- Wrote the fish-tissue section for the Yellowknife Bay 2014 aquatics report for the Giant Mine in Yellowknife, NWT. Analysis endpoints included length distribution, fish condition, hepatosomatic index, and liver, muscle and/or whole-body metal content for Lake Whitefish, Northern Pike and Slimy Sculpin.
- Participated in a review of the Giant Mine Surveillance Network Program for surface-water chemistry. Developed an understanding of current conditions, data gaps, and data quality. Developed recommendations for a Surveillance Network Program moving forward.
- Contributed to the development of an aquatic monitoring program for the Giant Mine in Yellowknife, NWT. The task was to work as the technical aquatic lead for the project, managing all technical aspects of the aquatics program. This monitoring program is part of ongoing work at the Giant Mine site in Yellowknife, NWT.
- As part of the Statistical Advisory Group in Stantec, undertook a post hoc power analysis of water chemistry data for Phase 1 of the Yellowknife Bay/Giant Mine remediation project. The purpose of the analysis was to determine if the level of sampling effort to date was sufficient to provide a sensitive understanding of baseline conditions prior to project implementation. This report is part of an ongoing monitoring program at the Giant Mine site in Yellowknife, NWT.

Client: Aboriginal Affairs and Northern Development Canada

Water Chemistry and Hydrology Data for the Peel River Watershed | 2012

The Peel River watershed is located in the Yukon Territories and is an almost pristine wilderness, although it is currently under pressure from resource industries. The objectives of this study were to define the seasonal hydrological cycle within the watershed, to develop an understanding of baseline water chemistry, to determine and describe any seasonal differences in water chemistry, to determine spatial variability in water chemistry, particularly moving downstream, and to determine and describe any temporal trends in water chemistry and/or hydrology. Wrote the proposal, managed the project analytical team, and compiled and wrote several sections of the report.
Client: Aboriginal Affairs and Northern Development Canada

Gahcho Kue EIS Review, Northwest Territories | 2011

Reviewed sections on water quality and quantity within, and downstream of, the Gahcho Kue diamond mine project EIA. Reviewed sections on effects to fish and fish habitat downstream of the Project. The work consisted of reviewing the methods and results to identify data gaps in the current assessment. The results of the review were presented to AANDC, DFO and Environment Canada as an assessment report to assist their respective regulatory reviews of the proponent's EIS submission.
Client: Indian and Northern Affairs Canada

West Lynn Lake Habitat Assessment, Lynn Lake, Manitoba | 2010

Undertook a habitat and fisheries resources assessment for West Lynn Lake as part of a project to provide a replacement water-intake structure for the Town of Lynn Lake, MB.
Client: Ministry of Infrastructure and Transportation

Independent Review of the Manitoba Government position on Wastewater Treatment for the City of Winnipeg | 2010

Wrote a third party review of the Province of Manitoba's requirement for nitrogen and phosphorus removal for the City of Winnipeg sewage works. Concentrated the review on the risks inherent in removal of nitrogen in a nitrogen-limited aquatic ecosystem. Examined the cost-effectiveness of nitrogen removal, considering the ability of blue green algae to fix atmospheric nitrogen.
Client: City of Winnipeg

Independent Review of Wastewater Effluent Regulations | 2010

Reviewed the proposed 2010 Federal Wastewater Effluent Regulations for the City of Winnipeg, including development of the logical flow of the Regulation. This review was subsequently used by the Canadian Waste Water Association for information purposes and was posted on their national website. Presented an analysis of deficiencies within the Regulation, and discussed implications of the Regulations for wastewater treatment for the City of Winnipeg. Developed a list of suggested corrections to the identified logical or procedural deficiencies as part of the public consultation process for the Wastewater Regulation.
Client: City of Winnipeg

Infrastructure Engineering Vulnerability Assessment, Portage la Prairie, Manitoba | 2009

Wrote a climate-change effects synopsis for the Public Infrastructure Engineering Vulnerability Committee's (PIEVC) City of Portage la Prairie Water Resources Infrastructure Assessment – Pilot Study. The study was based on existing materials, of both observed and projected changes in relevant climate parameters. As part of this assessment, the Environment Canada website (www.weatheroffice.gc.ca) was accessed for historic climatic and meteorological data. An assessment of trends in these historic data was undertaken. Future climate projections, both chronic and acute, were discussed and summarized based on the recent findings of the Intergovernmental Panel on Climate Change. These climate projections were then compared to recent, historic extreme weather events as part of a discussion of how climate change may affect the severity and frequency of future extreme weather events within the Project area.
Client: PIEVC

Water-Treatment Plant Environmental Impact Assessment, Winnipeg, Manitoba | 2006

Evaluated the environmental factors involved in the development of cyanobacterial blooms in freshwater in relation to expected discharges from a proposed new water-treatment plant, as part of the Environmental Impact Assessment for the new City of Winnipeg wastewater-treatment plant.
Client: City of Winnipeg

Northwest Area Water Supply (NAWS) DEIS and SEIS Review, and Devil's Lake Outlet | 2004-2016

- Contributed to a report on Potential Biota of Concern (PBOC) as they relate to the U.S. Bureau of Reclamation's water-diversion project in North Dakota, particularly with respect to treatability of fish pathogens in municipal water-treatment plants.
- Undertook a critical review of the 2014 Supplementary EIS written by the US Bureau of Reclamation in regards to the potential effects of NAWS, which is a water-supply project designed to supply drinking water to North Dakota. The role was to identify deficiencies within the logical structure and analytical results of the SEIS in support of a pending court challenge by the Government of Manitoba in US District Court.
- Updated, compiled and edited documents produced in rebuttal of the document, 'Northwest Area Water Supply Project Draft Environmental Impact Statement.'
- Completed a wetland delineation process, including vegetation surveys at several sites along the proposed drainage canal, to support legal challenges by Manitoba and Canada of the North Dakota Water Commission's "Devils Lake Emergency Outlet Project" in North Dakota courts of the correctness of the original wetland delineations.

Client: Government of Manitoba

Education

Doctor of Philosophy (Ph.D.)
University of Manitoba

Master of Science (M.Sc.)
University of Alberta

Bachelor of Science (B.Sc.)
University of Winnipeg

Palmer™

Dan McParland

M.Sc., P.Geo.

Senior Fluvial Geomorphologist

Professional History

Palmer
Senior Fluvial Geomorphologist
Toronto, ON
2016 - present

AECOM
Fluvial Geomorphologist
Guelph, ON
2013 - 2016

University of British Columbia
Research Assistant
Vancouver, BC
2011 - 2013

Queen's University
Research Assistant
Kingston, ON
2010-2011

Summary

Dan is a Senior Fluvial Geomorphologist with nine years of experience linked to geomorphological and hydrological assessment, natural channel design, fluvial hazard mitigation, storm water management, and aquatic habitat enhancement. He has completed analyses at a range of spatial scales from watershed to reach level and is skilled in both fieldwork and desktop analyses. Dan has applied his technical knowledge in watersheds throughout Canada and has experience with many different river types. He has managed over 25 geomorphology projects.

Dan completed his undergraduate studies at Queen's University and his graduate studies at the University of British Columbia. His M.Sc. research examined the linkages between the physical sciences (hydrology and geomorphology) and aquatic ecology using 2D hydrodynamic models and other numerical models.

During his consulting career, Dan has successfully completed numerous natural channel designs, fluvial hazard assessments, fish passage evaluations, and peer reviews for linear infrastructure, mining, and municipal projects. Dan has developed a variety of strategies for evaluating and mitigating the erosion and sedimentation risk posed to aquatic and terrestrial habitats and existing infrastructure by proposed land development and government infrastructure projects. He also works closely with ecologists, engineers, and environmental planners to integrate the results of geomorphological assessments with other disciplines.

Experience

Watershed Hazard Assessment and Management

- Natural Resources Canada – Channel Migration and Scour Assessment, Northeastern AB
- Government of Yukon – Channel Migration Assessment along the Dempster Highway, Northern YT
- Parks Canada – Rocky Mountain National Parks Erosion Inventory, Alberta and BC
- Yukon Energy Corporation – Aishihik Lake Generating Station Relicensing, Aishihik, YT
- City of Toronto – East Don River Scour Assessment, Toronto, ON
- Dawson Creek – Dawson Creek Fluvial Geomorphology Assessment, Dawson Creek, BC
- Trans-Northern Pipelines Inc. – Montreal Line Environmental Screening, Eastern, ON & Southern, QC
- Regional District of Kootenay Boundary – Fluvial Hazard Mapping, Kootenay Boundary, BC
- Chief Isaac Inc. – North Fork Hydro Geomorphology Assessment, Dawson, YT
- Region of Peel – Mimico Creek Scour Assessment, Brampton, ON
- District of Vanderhoof – Nechako River Migration Assessment, Vanderhoof, BC
- Parks Canada – Kootenay River Migration Assessment, Kootenay National Park, BC

resume

- Town of Markham – City-wide Erosion Assessment and Implementation Plan, Markham, ON
- City of Red Deer – Suspended Sediment Transport Analyses, Red Deer, AB
- Parks Canada – Rouge National Urban Park Geomorphology Asssessment, Toronto, ON
- City of Toronto – Pottery Road Pedestrian Bridge, Toronto, ON
- Yukon Geological Survey – Carmacks Community Hazards Mapping, Carmacks, YT
- Metrolinx – West Don River Rail Crossing, Vaughan, ON
- City of Toronto – Riverside Drive Erosion Assessment, Toronto, ON
- R.J. Burnside – Bear Creek Erosion Hazard Limit Assessment, Barrie, ON
- YMCA of Greater Toronto – Cedar Glen Bride Replacement, Toronto, ON
- Ontario Ministry of Transportation – McGillivray Road Extension, Vaughn, ON
- City of Pickering – Palmer Bridge Rehabilitation, Pickering, ON
- Best Seller Reality – Salt Creek Erosion Hazard Limit Assessment, Brampton, ON
- Region of Peel – Fletcher's Creek Scour Assessment, Brampton, ON
- York Region – Rehabilitation of the York Durham Sanitary System, Richmond Hill, ON
- Metrolinx – Humber River Morphodynamic Assessment, Toronto, ON

Natural Channel Design and Stream Restoration

- Town of Markham – City-wide Erosion Assessment and Implementation Plan, Markham, ON
- City of Red Deer – Suspended Sediment Transport Analyses, Red Deer, AB
- Parks Canada – Rouge National Urban Park Geomorphology Asssessment, Toronto, ON
- City of Toronto – Pottery Road Pedestrian Bridge, Toronto, ON
- Yukon Geological Survey – Carmacks Community Hazards Mapping, Carmacks, YT
- Metrolinx – West Don River Rail Crossing, Vaughan, ON
- City of Toronto – Riverside Drive Erosion Assessment, Toronto, ON
- R.J. Burnside – Bear Creek Erosion Hazard Limit Assessment, Barrie, ON
- YMCA of Greater Toronto – Cedar Glen Bride Replacement, Toronto, ON
- Ontario Ministry of Transportation – McGillivray Road Extension, Vaughn, ON
- City of Pickering – Palmer Bridge Rehabilitation, Pickering, ON
- Best Seller Reality – Salt Creek Erosion Hazard Limit Assessment, Brampton, ON
- Region of Peel – Fletcher's Creek Scour Assessment, Brampton, ON
- York Region – Rehabilitation of the York Durham Sanitary System, Richmond Hill, ON
- Metrolinx – Humber River Morphodynamic Assessment, Toronto, ON

Environmental Assessment and Planning Studies

- Town of Erin – Erin Wastewater Treatment Plant EA, Erin, ON
- Town of East Gwillimbury – Green Lane Master Environmental Servicing Plan, East Gwillimbury, ON
- Halton Region – Southwest Georgetown Subwatershed Study, Georgetown, ON
- KLM Planning Partners Ltd. – Courtice Headwater Drainage Feature Assessment, Courtice, ON
- Region of Peel – The Gore Road Widening EA, Brampton, ON
- City of Ottawa – Ottawa HWY 174/17 EA, Ottawa, ON
- York Region – Upper York Sanitary Solutions, Newmarket, ON
- Municipality of Clarington – Bennett Creek Realignment EA and Preliminary Design, Bowmanville, ON
- Town of Newmarket – Newmarket Comprehensive Stormwater Master Plan, Newmarket, ON
- City of Ottawa – East Light Rail Transit Extension EA, Ottawa, ON
- York Region – Nobleton Water and Waste Water Class EA, Nobleton, ON
- City of Brampton – Redside Dace Compensation Tool, Brampton, ON

Environmental Monitoring

- CN Rail – Credit River Erosion Protection Post-Construction Monitoring, Georgetown, ON
- Town of Oakville – North Oakville Creek Monitoring, Oakville, ON
- Municipality of Clarington – Port Granby Creek Post-Construction Monitoring, Port Hope, ON
- City of London – Tributary 'C' Environmental Monitoring, London, ON

Peer Review

- Parks Canada – Snake Indian River Avulsion Hazard Peer Review, Jasper National Park, AB
- Conservation Halton – Grindstone & Borer's Creek Peer Review, Burlington, ON
- Cook's Ferry Indian Band – Proposed Habitat Restoration for Ashcroft Coal Derailment, Ashcroft, BC
- Parks Canada – Yoho Twinning Design Review, Field, BC
- TRCA – Highland Creek Bank Stabilization, Scarborough, ON
- Taykwa Tagamou Nation – Little Long Hydro Review, Kapuskasing, Ontario

Education

Master of Science – Fluvial Geomorphology Focus
University of British Columbia | 2013

Bachelor of Science – Physical Geography
Queen's University | 2011

Reports and Presentations

- Professional Geoscientist, Association of Professional Geoscientists of Ontario (2017-present)
- Member, Canadian Geophysical Union (2011-present)
- Member, Canadian Geomorphology Research Group (2011-present)

Reports and Presentations

- Cronmiller, D.C., McParland, D.J., Goguen, K.M., & McKillop, R.J. 2020. Carmacks surficial geology and community hazard susceptibility mapping. Yukon Geological Survey Miscellaneous Report 20.
- McParland, D.J., McKillop, R.J., & Blais-Stevens, A. 2018. Adjustments in channel planform and longitudinal profile at proposed pipeline crossings of Smoky River, Deep Valley Creek, and Little Smoky River, northwestern Alberta. Geological Survey of Canada, Open File 8220.
- McKillop, R.J. & McParland, D.J. 2018. The time-limited resilience of river morphology to alteration: examples from across Canada. Presented at: Natural Channel Systems Conference, Guelph, ON, May 24, 2018.
- McKillop, R.J., McParland, D.J. and Scobie, C., 2017, When creek meets valley wall: prioritizing erosion mitigation alongside the Oshawa Landfill. Oral presentation and abstract in the 2017 TRIECA Conference, Brampton, ON, March 22-23, 2017.
- McParland, D.J., Eaton B.C., & Rosenfeld, J.S. 2016. At-a-station hydraulic geometry simulator. River Research and Application, 32(3), 399-410. doi:10.1002/rra.2851
- McKillop, R.J. Brown, C.E., McParland, D.J., Sacco, D.A., & Coates, J. 2016. Inventory of mass movement geohazards along the Dempster Highway. Yukon Geological Survey Miscellaneous Report 17.
- McParland, D.J. & Eaton, B.C. 2013. Empirical aquatic habitat assessment tools for British Columbian channels. Presented at: Canadian Geomorphologic Research Group Annual Meeting, Edmonton, AB, August 22, 2013.
- McParland, D.J. & Eaton, B.C. 2012. Statistical habitat methods for British Columbian channels. Presented at: University of Washington Hydrology Symposium, Seattle, WA, September 22, 2012.

resume

Daniel H. King

B.Sc. (Hons) Biochemistry, M.ET Candidate
Fisheries Biologist

Professional History

Palmer
Fisheries Biologist
February 2020 - Present

Simon Fraser University
Graduate Research Assistant
2017 - Present

Alouette River Management Society
Director of the Board
2019 - Present

Laboratory of Dr. Vicki Marlatt Simon Fraser University
Brittania Creek Project co-author
June - August 2020

Laboratory of Dr. Vicki Marlatt Simon Fraser University
Toxicity Assessment Assistant
2018 - 2019

Nautilus Environmental Company Inc.
Toxicity Assessment Assistant
June 2017

University of British Columbia - Okanagan
Undergraduate Research Assistant
2015 - 2016

Summary

Daniel is an fisheries biologist with experience in gained in his master's thesis, work in mining sector fish toxicity exposures and employment with Palmer. Daniel has an extensive knowledge of local fish species, their life-stages, life history characteristics, and habitat use. This combined with his unique academic background combining fish behaviour, health and physiology; with experience in pharmacology and environmental toxicology to enable a complete view of impacts of contaminants in the environment and habitat alteration and loss on aquatic species.

Daniel has a demonstrated ability in experimental design and data analysis of large datasets, including those recorded over time from long-term monitoring programs. Specific analyses include fish population trends over time, Benthic Macroinvertebrate monitoring metrics over time comparing test locations to a reference model (CABIN) and QA/QC of large-scale datasets such as water chemistry parameters. Daniel has experience in environmental monitoring, fish inventory and habitat assessments, fish biological sampling Additionally, Daniel has worked on extensive reviews of life-stages and habitat use to assist in project-specific protection of several listed species including the Fraser and Nechako River White Sturgeon, listed conservation units of Pacific salmon (e.g. Interior Fraser River Coho Salmon), Bull Trout, Northern Mountain Sucker, Salish Sucker, Brassy Minnow, Coastal Cutthroat Trout, and Westslope Cutthroat Trout.

Experience

Blackwater Gold Project | 2021
Design and implementation of several large-scale fish population monitoring programs in several different water bodies in the area each requiring a unique, tailored approach to population monitoring. Programs included modern and novel approaches to fish population monitoring associated with potential impacts of mining activities including aerial-drone based Kokanee population monitoring, solar-powered underwater cameras for Rainbow Trout and young-of-the-year Kokanee enumeration and monitoring; and the design and use of a larval light trap to monitor the potential impacts of lake drawdown to a blue-listed littoral-dwelling fish species, the Brassy Minnow. In addition to the novel methodologies, conventional approaches to fish populations assessments and monitoring were also incorporated into the various programs including hoop-net surveys, minnow-trapping, backpack electrofishing, snorkel surveys and gillnetting.
Client: Artemis Gold Inc.

Wapiti River Long-Term Aquatic Monitoring | 2021
Assisted in the compilation, organization, QA/QC and analyses of a dataset collected for Aquatera Utilties for the purpose of long-term monitoring of the aquatic ecosystem components downstream of the Aquatera Utilities Water Treatment Plant. Metrics assessed included benthic macroinvertebrates, periphyton and water chemistry parameters (e.g. total phosphorous and nitrogen). Experimental Design included several impacted sites and reference locations that required a thoughtful and sophisticated approach to the analysis and interpretation.
Client: Aquatera Utilities

resume

Upperlands Environmental Inventory | 2020

Planned and implemented a field program for an inventory of fish and herptile species 8 coastal streams within the Upperlands region of the District of West Vancouver (mountainous region below Cypress Provincial Park and above the British Properties). The inventory discovered the presence of an introduced population of Westslope Cutthroat Trout outside of their known extent in the area. Involved habitat assessments and identification of early life stages of Westslope Cutthroat Trout. Findings contributed to a larger environmental inventory to support planning and land use for the Upperlands region.
Client: District of West Vancouver

Fish Community Monitoring and Assessment | 2020

Completed the data analysis and wrote the fish community portion of the Annual Monitoring Report for three species of fish captured in five streams from annual fishing and monitoring efforts over five years (2016-2020). Assessment included five-year Mann-Kendall trends analyses on fish abundance (CPUE), relative abundance through species composition and trends in fish condition using a normal range and relative condition. Additionally, length frequency distributions were compared between sites and years using a Kolmogorov-Smirnov test to compare two frequency distributions. The results of this fish community analysis, in combination with physicochemical environmental data and a benthic invertebrate trends analysis completed by Palmer; will assist the Resort Municipality of Whistler in future community and environmental planning efforts.
Client: Resort Municipality of Whistler

Nechako River Bank Stabilization Project | 2020

Completed a literature review and wrote the fish community and effects assessment for a Fisheries and Oceans Canada Request for Review for a bank stabilization project of a municipal park on the Vanderhoof Braided Reach of the Nechako River; a reach of critical habitat for the endangered Nechako River White Sturgeon. Given the sensitive habitat and SARA-listed white sturgeon present within this area of the Nechako, the review of fish of all life stages, their habitat use and timing was exhaustive to ensure minimum impact to the white sturgeon and all other fish species present. Fish species reviewed included the Nechako River white sturgeon, chinook, sockeye and coho salmon; bull trout and rainbow trout.
Client: District of Vanderhoof

Force Main Replacement, Fraser River | 2020

Contributed to the literature review, evidence compilation and written response to concerns raised by the Leq'á:mel First Nation regarding a draft Fisheries Act Authorization submitted by Palmer on behalf of the City of Mission. Included an extensive review of Fraser River lamprey species, their life stages and habitat use; the potential impacts and mortality of the proposed dredging activity, and a review of migratory salmonids of various life stages and their migration timing windows. The Leq'á:mel First Nation and City of Mission were pleased with and accepted Palmer's official responses.
Client: City of Mission

Site C Clean Energy Project | 2020-Present

Biological operation of the Site C Clean Energy Project Temporary Upstream Fishway. Duties included site, equipment and water quality monitoring within the facility, fish processing and sampling for a variety of fish species, monitoring and transport of fish species in specially designed pods to upstream release site, weekly and annual report writing for the sub-contractor Peace River Hydro Partners (PRHP), and for BC Hydro. With Site C being such a large-scale infrastructure project with many stakeholders and sub-contractors involved, extensive collaboration with BC Hydro and PRHP staff from various departments and levels of seniority was required; with a significant level of flexibility and adaptability required to maximize the efficiency to the fishway and the health and survival of fish passing through the facility. In addition to these collaboration efforts, tours and discussion took place with the local first nation's liaison to the facility.
Client: Peace River Hydro Partners and BC Hydro

Elk Gold Mine Fish Inventory and Wetland Delineation | 2020

Participated in a fish inventory and habitat assessment for Siwash Creek and the tributary Don Creek, east of Merritt, B.C. In addition to the fish inventory and habitat assessment, field representatives surveyed the area using drone-based orthomosaic imaging and completed a wetland delineation in the area of a proposed treatment wetland.

Brittania Mine Early Life-Stage Rainbow Trout Field Experiment | 2020
Assisted in implementing and completing the field-portion of an experiment using the Environment Canada standardized biological test method: Toxicity Tests Using Early Life Stages of Salmonid Fish (EPS 1/RM/28). Rainbow trout embryos were deployed in hatch boxes in Brittania Creek until the swim-up life stage and dissected for biochemical testing on tissues, histopathology, and tissue metal concentrations. Several sites were used with varying levels of metal contamination from Brittania Mine and results will be compared to a concurrent lab-based exposure using site water from Brittania Creek. Daniel's involvement in the project will result in a co-authorship on the publication once completed.

Global Fisheries Monitoring Review | 2020
Contract completed for Palmer. Wrote a comprehensive review of modern, innovative and cost-effective approaches to fisheries catch monitoring used by fisheries management authorities around the world. Review used a combination of information from scientific literature, NGOs, fisheries management authorities and interviews with representatives from these fields. Review was completed for Fisheries and Oceans Canada (DFO) with the goal of applying the findings of the review to implement the changes outlined in the recently update Fisheries Monitoring Policy (2019). Some examples of key innovations found were related to improvements in technology such as wireless video data transfer via cellular or satellite networks, artificial intelligence and machine learning applied to catch video, and remote un-manned monitoring stations. The review was edited and co-authored by Katsky Venter.
Client: Fisheries and Oceans Canada (DFO)

Master of Environmental Toxicology Project | 2018-Present
Developed and implemented a comprehensive toxicity exposure of the sea lice pesticides SLICE ® and Ivermectin to a juvenile benthic fish species, the starry flounder, using a dosed-sediment exposure. Various exposures were used to assess effects from the biochemical level of metabolism and stress, up to the physiological and fitness impact of swimming, respiration, and camouflage ability, and lastly the behavioral level assessing the ability of the fish to perceive and avoid the contaminants. Employed a beach seine to capture wild juvenile starry flounder and in the process captured a large variety of marine an estuarine fish species and gained skills in identification of these species. Used a 16' jet boat to access harvest some harvest sites.

Alouette River Management Society | 2019-Present
Director of the Board
Involved in key decisions surrounding the protection and enhancement of the Alouette River watershed
Lobbying and collaborative efforts with multiple stakeholders including the City of Maple Ridge, BCMOE, the DFO, BC Hydro, the Katzie Nation, and other members of the community. Recently wrote ARMS's contribution to the City of Maple Ridge Integrated Stormwater Management Plan (November 2020).

Education

Master of Environmental Toxicology Candidate
Simon Fraser University, Burnaby, BC | 2017 - Present

Bachelor of Science (Honours) Biochemistry (Medical Concentration)
University of British Columbia Okanagan, Kelowna, BC | 2012 - 2016

Professional Development, Certifications and Associations

- Electrofishing Crew Supervisor Certification
- Done Pilot Certificate – Basic Operations
- Occupational First Aid Level 1
- WHMIS 2015 Certification

- Pacific Streamkeepers Federation Spawner Survey and Habitat Assessment Training
- Marine fish survey and harvest methods, marine and freshwater fish identification; and salmonid sampling
- Transport Canada Pleasure Craft Operator License
- Simon Fraser University Animal Care Committee Animal User Training Course – Fish
- UBC Centre for Environmental Assessment Research - Canadian Environmental Assessment Act Workshop Certificate

Reports and Presentations

- **King, D. H.** and Venter, K. 2020. Review of Fisheries Catch Verification Tools and Technologies: A Review and Assessment of Innovative and cost effective tools and technologies used worldwide to verify fisheries catch data. ***Report for Fisheries and Oceans Canada.*** Katsky Venter Independent Consultant and Palmer
- **King, D. H.** and Kennedy, C. J. Sublethal effects of anti-sea lice pesticides SLICE ® and ivermectin on the swim performance, oxygen consumption, camouflage and avoidance behaviour of the starry flounder (*Platichthys stellatus*). ***Salish Sea Ecosystem Conference.*** International Conference. (Virtual Oral Presentation) Vancouver, BC April, 2020.
- **King, D. H.** and Kennedy, C. J. Sublethal effects of anti-sea lice pesticides SLICE ® and ivermectin on the swim performance, oxygen consumption, camouflage and avoidance behaviour of the starry flounder (*Platichthys stellatus*). ***Pacific Northwest Society of Environmental Toxicology and Chemistry Annual Conference.*** International Conference. (Oral Presentation) Vancouver, WA, USA April, 2019.
- **King, D. H.** and Kennedy, C. J. Sublethal effects of anti-sea lice pesticides SLICE ® and ivermectin on the swim performance, oxygen consumption, camouflage and avoidance behaviour of the starry flounder (*Platichthys stellatus*). ***ToxTalks Annual Graduate Symposium.*** Institutional Conference. (Oral Presentation) Vancouver, BC March, 2018 and 2019.
- **King, D. H.** and Kennedy, C. J. Sublethal effects of anti-sea lice pesticides SLICE ® and ivermectin on the swim performance, oxygen consumption, camouflage and avoidance behaviour of the starry flounder (*Platichthys stellatus*). ***Canadian Ecotoxicity Workshop.*** International Conference. (Oral Presentation) Vancouver, BC, October, 2018.
- **King, D. H.** and Deyholos, M. Kinetic characterization of a proteinacious inhibitor (*LuPMEI45*) of the enzyme Pectin Methylesterase (PME) from flax (*Linum usitatissimum*) and comparative analysis of PME activity assays. ***UBC Okanagan***. (Honours Thesis) Kelowna, BC, May 2016.
- **King, D. H.** and Deyholos, M. Kinetic characterization of a proteinacious inhibitor (*LuPMEI45*) of the enzyme Pectin Methylesterase (PME) from flax (*Linum usitatissimum*) and comparative analysis of PME activity assays. ***UBC Okanagan Undergraduate Research Conference.*** Institutional Conference. (Oral Presentation) Kelowna, BC, May 2016.

THE UNIVERSITY OF NORTHERN BRITISH COLUMBIA
Curriculum Vitae

Date: February 12, 2021 **Initials**: EGM

1. **SURNAME**: Martins **FIRST NAME**: Eduardo
MIDDLE NAME(S): Osses Guimaraes

2. **PROGRAM/LIBRARY/DEPARTMENT:** Department of Ecosystem Science and Management

3. **Faculty**: Faculty of Environment

4. **PRESENT RANK**: Assistant Professor **SINCE**: July 01, 2017

5. **POST-SECONDARY EDUCATION** (list most recent first)

University or Institution	Degree	Subject Area	Dates
Universidade Estadual de Campinas	PhD	Ecology	2004 to 2007
Universidade Estadual de Campinas	MSc	Ecology	2002 to 2004
Universidade Estadual de Campinas	BSc	Biology	1998 to 2001

6. **EMPLOYMENT RECORD**

University, Company or Organization	Rank or Title	Dates
University of Northern British Columbia	Assistant Professor	Since July 2017
BC Hydro	Natural Resource Specialist	Nov 2016 to May 2017
University of Waterloo	Liber Ero Postoctoral Fellow	Dec 2014 to Nov 2016
University of British Columbia	Research Associate	Apr 2014 to Nov 2014
Carleton University	Postdoctoral Fellow	Apr 2011 to Mar 2014
University of British Columbia	Postdoctoral Fellow	Apr 2008 to Mar 2011

7. **SUPERVISIONS**

(a) *Graduate Students Supervised and/or Co-Supervised*

Student Name	Program Type	Year		Principal Supervisor	Co-Supervisor(s)
		Start	Finish		
Elizabeth Hirsch	MSc NRES, UNBC	2021	in progress	Eduardo Martins	
Sebastian Dalgarno	PhD NRES, UNBC	2020	in progress	Eduardo Martins	
Avery Dextrase	MSc NRES, UNBC	2020	in progress	Eduardo Martins	
Thomas Balfour	MSc NRES, UNBC	2020	in progress	Eduardo Martins	
Joseph Bottoms	PhD NRES, UNBC	2019	in progress	Eduardo Martins	
Emily Mason	MSc NRES, UNBC	2019	in progress	Eduardo Martins	

Bryce O'Connor	MSc NRES, UNBC	2019	in progress	Eduardo Martins	
Caleb Jetter	MSc NRES, UNBC	2019	in progress	Eduardo Martins	
Daniel Larson	MSc NRES, UNBC	2018	2020 (deceased)	Eduardo Martins	Nikolaus Gantner
Gretchen Stokes	MSc Fisheries & Wildlife, Virginia Tech	2014	2016	Leandro Castello	Eduardo Martins

(b) Undergraduate Students Supervised and/or Co-Supervised

Student Name	Program Type	Year		Principal Supervisor	Co-Supervisor(s)
		Start	Finish		
Daniel Scurfield	Honors BSc, W&F, UNBC	2020	2021	Eduardo Martins	Nikolaus Gantner
Ian Clevenger	Honors BSc, W&F, UNBC	2019	2020	Eduardo Martins	
Morgan Dowd	Honors BSc, W&F, UNBC	2019	2020	Eduardo Martins	
Grayson Vanderbyl	Honors BSc, W&F, UNBC	2019	2020	Eduardo Martins	
Rioghnach Steiner	Honors BSc, W&F, UNBC	2018	2019	Eduardo Martins	

9. SELECTED GRANTS

Granting Agency	Subject	$ Per Year	Year	Principal Investigator	Co-Investigator(s)
FWCP	Spatial ecology of Arctic grayling (4[14] year)	138,099	2022 to 2022	Eduardo Martins	Mark Shrimpton, Mike Power, Steven Cooke, Marie Auger-Methé, David Patterson
LNG Canada	Conservation and recovery research on OOlichan	~500,000 (× 5 yrs)	2020 to 2025	Mark Shrimpton	Caren Helbing, Morgan Hocking, Jonathan Moore, Mary Lesperance, Adam Lewis, Alejandro Buren, Heather Bryan, Eduardo Martins
CFI/BCKDF	Infrastructure for thermal ecology research	399,260	2020	Eduardo Martins	

FWCP	Spatial ecology of Arctic grayling (3rd year)	176,492	2020 to 2021	Eduardo Martins	Mark Shrimpton, Mike Power, Steven Cooke, Marie Auger-Methé, David Patterson
FWCP	Spatial ecology of Arctic grayling (2nd year)	184,609	2019 to 2020	Eduardo Martins	Mark Shrimpton, Mike Power, Steven Cooke, Marie Auger-Methé, David Patterson
NSERC DG	Thermal ecology of freshwater fishes	28,000 (× 5 yrs)	2018 to 2023	Eduardo Martins	
Research Council of Norway	Partnership on sustainable hydropower in Canada and Norway	179,453 (× 4 yrs)	2018 to 2022	Ingeborg Helland	Knut Alfredsen, Per-Arne Amundsen, Antti Eloranta, Michael Power, Steven Cooke, Eduardo Martins

10. **SELECTED PUBLICATIONS** (full list on Google Scholar)

Martins EG, Déry SJ and Patterson DA. *In press.* Fraser River. In: Rivers of North America. Volume 2. M Delong & T Jardine (eds). Elsevier Inc.

Cooke SJ, Raby GD, Bett NN, Teffer AK, Burnett, Jeffries KM, Eliason EJ, Martins EM, Miller KM, Patterson DA, Nguyen VM, Young N, Farrell AP and Hinch SG. *In press*. On conducting management-relevant mechanistic science for upriver migrating adult Pacific salmon. Pages 35-55 in Madliger, C.L., C.E. Franklin, O.P. Love and S.J. Cooke, Editors. Conservation Physiology: Applications for wildlife conservation and management. Oxford University Press, UK.

Furey NB, Martins EG and Hinch SG. 2021. Migratory salmon smolts exhibit consistent interannual depensatory predator swamping: effects on telemetry-based survival estimates. *Ecology of Freshwater Fish*, 30:18-30.

Whoriskey K, Martins EG, Auger-Methé M, Gutowsky LFG, Lennox RJ, Cooke SJ, Power M and Flemming JM. 2019. Current and emerging statistical techniques for aquatic telemetry data: A guide to analysing spatially discrete animal detections. *Methods in Ecology and Evolution* 10:935-948.

Hahn L, Martins EG, Nunes LD, Câmara LF, Machado LS and Garrone-Neto D. 2019. Biotelemetry reveals migratory behaviour of large catfish in the Xingu River, Eastern Amazon. *Scientific Reports* 9:8464.

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Harrison PM, Gutowsky LFG, Martins EG, Patterson DA, Cooke SJ and Power M. 2016. Temporal plasticity in thermal habitat selection of burbot, Lota lota, a diel-migrating winter specialist. Journal of Fish Biology 88, 2111−2129.

Gutowsky LFG, Harrison PM, Martins EG, Leake A, Patterson DA, Power M and Cooke SJ. 2016. Interactive effects of phenotypic traits on adfluvial bull trout (*Salvelinus confluentus*) movement ecology. Canadian Journal of Zoology 94, 31–40.

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Featured in FishSens Magazine: http://magazine.fishsens.com/entrainment-study-tracks-bull-trout-keep-fish-canadian-dams-turbines.htm

Gale MK, Hinch SG, Cooke SJ, Donaldson MR, Eliason EJ, Jeffries KM, Martins EG and Patterson DA. 2014. Observable impairments predict mortality of captured and released sockeye salmon at various temperatures. Conservation Physiology 2, doi:10.1093/conphys/cou029

Drenner SM, Hinch SG, Martins EG, Robichaud D, Clark TD, Thomson LA, Patterson DA, Cooke SJ and Thomson RE. 2014. Variable thermal experience and diel thermal patterns of homing sockeye salmon in coastal marine waters. Marine Ecology Progress Series 496, 109–124.

Martins EG, Gutowsky LFG, Harrison PM, Patterson DA, Power M, Zhu D, Leake A and Cooke SJ. 2013. Forebay use and entrainment rates of resident adult fish in a large hydropower reservoir. Aquatic Biology 19, 253–263.

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BIOSKETCH

Name/Affiliation: Stephen J. DÉRY, University of Northern British Columbia (UNBC)

Education/Training

2001	PhD	Atmospheric and Oceanic Sciences, McGill University
1993	MSc	Earth and Atmospheric Sciences, York University
1991	BSc	Earth and Atmospheric Sciences and Applied Mathematics, York University

Employment/Affiliations

2019-present	Professor (tenured) and NSERC/Rio Tinto Industrial Research Chair in Climate Change and Water Security, Environmental Science and Engineering Program, UNBC
2017-2020	Adjunct Professor, Civil Engineering, University of Manitoba
2015-2019	Professor (tenured), Environmental Science and Engineering Program, UNBC
2010-2015	Associate Professor (tenured) and Tier II Canada Research Chair in Northern Hydrometeorology, Environmental Science and Engineering Program, UNBC
2005-2010	Assistant Professor and Tier II Canada Research Chair in Northern Hydrometeorology, Environmental Science and Engineering Program, UNBC
2004-2005	Visiting Research Scientist, Princeton University
2000-2003	Post-Doctoral Fellow, Lamont-Doherty Earth Observatory, Columbia University
1994-1996	Project Scientist, York University
1991-1993	Meteorological Technician, Ontario Hydro

KEY AWARDS: NSERC Discovery Accelerator Supplement ($120K), 2011-2014.

DISTINCTIONS: Dr. Déry has published >100 peer-reviewed journal articles and book chapters with >4500 citations and h-index of 34 (Google Scholar®). He is Associate Editor for *Atmosphere-Ocean* and the *Journal of Hydrometeorology*. He is former co-chair of the NSERC Advancing Climate Change Science in Canada panel (2019), former member of NSERC Strategic Partnership Grants (Environment & Agriculture) panel (2018), NSERC Northern Research Supplement (2008-11) and NSERC Geosciences Evaluation (2011-14) groups, NSF Arctic Natural Science Program panel (2016), external examiner for 9 PhD theses.

Research Funding

Over the past 4 years, Dr. Déry has secured >$3M in competitive research funding such as:

- NSERC/Rio Tinto Industrial Research Chair in Climate Change and Water Security, NSERC/Rio Tinto Canada Fund, $1.5M
- Atmospheric and terrestrial rivers of western Canada in transition, NSERC Discovery Grant, $240K, 2016-2022
- Mountain Water Futures (Phases 1 & 2), Global Water Futures (GWF Pillar 3), $150K, 2017-2023
- Storms & Precipitation Across the Continental Divide Experiment (GWF Pillar 1), $112K, 2018-2020
- Evaluating the resiliency of aquatic ecosystems to a catastrophic mine tailings spill: The 2014 Mount Polley incident in the Quesnel River watershed, BC, Environment and Climate Change Canada, Environmental Damages Fund, $60K, 2016-2018
- BaySys, NSERC-Manitoba Hydro Collaborative Research and Development, $75K, 2015-2019
- Earth, Air, Wind and Fire, Tri-University Partnership Research Fund, $40K, 2019-2020
- Integrated watershed-based research in the Nechako River Basin (Phases 1 and 2), Government of BC/Nechako Environmental Enhancement Fund, $125K (2014-2017) and $125K (2018-2022)

Most significant contributions:

1. Cariboo Alpine Mesonet (CAMnet): I have spearheaded the development of CAMnet (Hernández-Henríquez et al. 2018), a network of 15 automatic weather stations deployed in remote regions of BC since 2006. Meteorological data are archived online (in a publicly accessible data repository) and shared with colleagues, supporting undergraduate and graduate student research projects. CAMnet data were critical in understanding the evolution of the sediment plume in Quesnel Lake following the catastrophic failure of a tailings pond at Mount Polley Mine, near Likely, BC (Petticrew et al. 2015). CAMnet stations have also provided unique opportunities to train many students in remote field work and data quality control.

2. Blowing snow: I have investigated blowing snow for >25 years including work on the spectral and bulk versions of the Piektuk blowing snow model (Déry et al. 1998; Déry and Yau 1999) for studies of Arctic blizzards (Déry and Yau 2001). Piektuk was then coupled to RACMO2/ANT, the first regional climate model ever to be fully coupled with a blowing snow routine, to obtain new estimates of the impact of snowdrift on Antarctic surface mass balance (SMB) over 1989-2009. Moreover, the coupled modeling system has been used to assess impacts of drifting snow on an Antarctic ice shelf and on the Greenland Ice Sheet SMB (Lenaerts et al. 2010, 2012). The model, which continues to be used worldwide, has also been applied to the study of snow transport in alpine terrain (Déry et al. 2010), across mountain glaciers and over sea ice (Déry and Tremblay 2004), as well as the Tibetan Plateau.

3. Streamflow trends in northern/western Canada: This body of work has provided better understanding of the role of climate change and flow regulation on some of Canada's principal waterways including observational evidence of intensification of the hydrologic cycle (Déry et al. 2009) and changing contributions to pan-Arctic river discharge (Déry and Wood 2005, Déry et al. 2005, 2009, 2016). A recent 19% decline in contributions of snowmelt to Fraser River discharge (Kang et al. 2014, 2016) based on VIC model simulations is expected to amplify in the 21st century, leading to significant seasonal shifts in hydrographs with earlier freshets and lower flows during summer/fall salmon migrations (Islam et al. 2017, 2019). Ongoing hydrological simulations are elucidating the roles of flow regulation versus climate change on Hudson Bay and Nechako river discharge (Déry et al. 2018; Stadnyk et al. 2020; Tefs et al. 2021) and on Fraser River water temperatures (Islam et al. 2019).

4. Northern Hemisphere snowcover extent trends: Recent efforts have explored Northern Hemisphere (NH) snowcover extent (SCE) trends given SCE is a sensitive indicator of climate change. Déry and Brown (2007) revealed significant declines in SCE during spring and summer over North America and Eurasia for 1972-2006 with impacts on the snow-albedo feedback (SAF). Hernández-Henríquez et al. (2015) expanded this study period by 8 years to uncover polar amplification of negative trends in SCE, with a 28% greater retreat of peak trends in NH snowcover relative to the previous study. There was also elevation dependence of SCE over time as statistically significant negative trends occurred at most elevations. These significant negative trends exhibited at high latitudes and elevations provided evidence of polar amplification and elevation dependence of trends in snowcover in a warming climate, suggesting a leading role of the SAF on the recent retreat of NH snowcover. Shi et al. (2011, 2013) have also surveyed the role of radiative and turbulent fluxes on the accelerating retreat of the NH snowcover. Allchin and Déry (2017, 2019) explored recent changes in the onset of snow cover and issues of concern with the NOAA SCE Climate Data Record.

5. Remote sensing of snowcover: Déry et al. (2005) provided the first application of MODIS to track snow depletion curves on the North Slope of Alaska, constraining simulations of regional hydrology. Tong et al. (2009a,b) demonstrated the potential predictability (by one month) of the timing of the spring freshet in the Quesnel River (near its outlet to the Fraser River) simply by tracking the day at which MODIS remotely sensed snowcover fraction was 0.5 across its watershed. Other work shows that passive microwave data of snow water equivalent (SWE) in the Cariboo Mountains become saturated and thus unreliable above 250-400 mm SWE (Tong et al. 2010) and allow tracking of snowmelt and liquid water content within snow in the Colorado Rockies (Kang et al. 2014).

Key recent publications (S. J. Déry: >4500 citations with h-index of 34, >2100 citations since 2016; Google Scholar®)

1) Thériault JM, Déry SJ, Pomeroy JW, Smith HM, Almonte J, Bertoncini A, Crawford R, Desroches-Lapointe A, Lachapelle M, Mariani Z, Mitchell S, Morris JE, Hébert-Pinard C, Rodriguez P, Thompson, H D 2021: Meteorological observations collected during the Storms and Precipitation Across the continental Divide Experiment (SPADE), April-June 2019, Earth System Science Data, in press.

2) Pokorny S, Stadnyk TA, Ali G, Lilhare R, Déry SJ, Koenig KA 2021: Cumulative effects of uncertainty on simulated streamflow in a hydrologic modeling environment, Elementa: Science of the Anthropocene, 9(1), 431.

3) Sharma AR, Déry SJ 2020: Linking atmospheric rivers to annual and extreme runoff in British Columbia and southeastern Alaska, Journal of Hydrometeorology, 21(11), 2457-2472.

4) Vore ME, Déry SJ, Hou Y, Wei A 2020: Climatic influences on forest fire and mountain pine beetle outbreaks and resulting runoff effects in large watersheds in British Columbia, Canada, Hydrological Processes, 34(24),4560-4575.

5) Allchin M, Déry SJ 2020: The climatological context of trends in the onset of Northern Hemisphere seasonal snowcover, 1972-2017, Journal of Geophysical Research: Atmospheres, 125, e2019JD032367.

6) Stadnyk TA, MacDonald MK, Tefs AAG, Déry SJ, Koenig K, Gustafsson D, Isberg K, Arheimer B 2020: Hydrological modeling of freshwater discharge into Hudson Bay using HYPE, Elementa: Science of the Anthropocene, 8, 43.

7) Hamilton AK, Laval BE, Petticrew EL, Albers SJ, Allchin M, Baldwin SA, Carmack EC, Déry SJ, French TD, Granger B, Graves KE, Owens PN, Selbie DT, Vagle S 2020: Seasonal turbidity linked to physical dynamics in a deep lake following the catastrophic 2014 Mount Polley mine tailings spill, Water Resources Research, 56(8), e2019WR025790.

8) Sharma AR, Déry SJ 2020: Contribution of atmospheric rivers to annual, seasonal, and extreme precipitation across British Columbia and southeastern Alaska, Journal of Geophysical Research: Atmospheres, 125(9), e2019JD031823.

9) Picketts IM, Déry SJ, Parkes MW, Sharma AR, Matthews CA 2020: Scenarios of climate change and natural resource development: complexity and uncertainty in the Nechako Watershed, The Canadian Geographer, 64(3), 475-488.

10) Sharma AR, Déry SJ 2020: Variability and trends of landfalling atmospheric rivers along the Pacific Coast of northwestern North America, International Journal of Climatology, 40(1), 544-558.

11) Lilhare R, Pokorny S, Déry SJ, Stadnyk TA, Koenig KA 2020: Sensitivity analysis and uncertainty assessment in water budgets simulated by the Variable Infiltration Capacity model in Canadian sub-arctic watersheds, Hydrological Processes, 34(9), 2057-2075.

12) Li Z, Shi X, Tang Q, Zhang Y, Gao H, Pan X, Déry SJ, Zhou P 2020: Partitioning the contributions of glacier melt and precipitation to the 1971-2010 runoff increases in a headwater basin of the Tarim River, Journal of Hydrology, 583, 124579.

13) Curry CL, Islam SU, Zwiers FW, Déry SJ 2019: Atmospheric rivers increase future flood risk in western Canada's largest Pacific River, Geophysical Research Letters, 46(3), 1651-1661.

14) Islam SU, Curry CL, Déry SJ, Zwiers FW 2019: Quantifying projected changes in runoff variability and flow regimes of the Fraser River Basin, British Columbia, Hydrology Earth System Sciences, 23, 811-828.

15) Lilhare R, Déry SJ, Pokorny S, Stadnyk TA, Koenig KA 2019: Inter-comparison of multiple hydro-climatic datasets across the Lower Nelson River Basin, Manitoba, Canada, Atmosphere-Ocean, 57, 262-78.

16) Islam SU, Hay RW, Déry SJ, Booth BP 2019: Modelling the impacts of climate change on riverine thermal regimes in western Canada's largest Pacific watershed, Scientific Reports, 9, 11398.

17) Allchin M, Déry SJ 2019: Shifting spatial and temporal patterns in the onset of seasonally snow-dominated conditions in the Northern Hemisphere, 1972-2017, Journal of Climate, 32(16), 4981-5001.

18) Déry SJ, Stadnyk TA, MacDonald MK, Koenig KA, Guay C 2018: Flow alteration impacts on Hudson Bay river discharge, Hydrological Processes, 32(24), 3576-3587.
19) MacDonald MK, Stadnyk TA, Déry SJ, Braun M, Gustafsson D, Isberg K, Arheimer B 2018: Impacts of 1.5°C and 2.0°C warming on pan-Arctic river discharge into the Hudson Bay Complex through 2070, Geophysical Research Letters, 45(15), 7561-7570.
20) Hernández-Henríquez MA, Sharma AR, Taylor M, Thompson HD, Déry SJ 2018: The Cariboo Alpine Mesonet: Sub-hourly hydrometeorological observations of British Columbia's Cariboo Mountains and surrounding area since 2006, Earth System Science Data, 10, 1655-1672.
21) Allchin M, Déry SJ 2017: A spatio-temporal analysis of trends in Northern Hemisphere snow-dominated area and duration, 1971-2014, Annals of Glaciology, 58(75pt1), 21-35.
22) Radić V, Menounos B, Shea J, Fitzpatrick N, Tessema M, Déry SJ 2017: Evaluation of different methods to model near-surface turbulent fluxes for a mountain glacier in the Cariboo Mountains, BC, Canada, The Cryosphere, 11, 2897-2918.
23) Islam SU, Déry SJ, Werner AT 2017: Future climate change impacts on snow and water resources of the Fraser River Basin, British Columbia, Journal of Hydrometeorology, 18, 473-496.
24) Islam SU, Déry SJ 2017: Quantification of uncertainties in modelling the snow hydrology of the Fraser River Basin, British Columbia, Canada, Hydrology and Earth System Sciences, 21, 1827-1847.
25) Koster R, Betts A, Dirmeyer P, Bierkens M, Bennett K, Déry SJ, Evans J, Fu R, Hernandez F, Leung R, Liang X, Masood M, Savenije H, Wang G, Yuan X 2017: Hydroclimatic variability and predictability: A survey of recent research, Hydrology and Earth System Sciences, 21, 3777-3798.
26) Hernández-Henríquez MA, Sharma AR, Déry SJ 2017: Variability and trends in runoff in the rivers of British Columbia's Coast and Insular Mountains, Hydrological Processes, 31, 3269-3282.
27) Li Z, Hao Z, Shi X, Déry SJ, Li J, Chen S, Li Y 2016: An agricultural drought index to incorporate the irrigation process and reservoir operations: A case study in the Tarim River Basin in China, Global and Planetary Change, 143, 10-20.
28) Sharma AR, Déry S 2016: Elevational dependence of air temperature variability and trends in British Columbia's Cariboo Mountains, 1950-2010, Atmosphere-Ocean, 54(2), 153-170.
29) Kang DH, Gao H, Shi X, Islam SU, Déry SJ 2016: Impacts of a rapidly declining mountain snowpack on streamflow timing in Canada's Fraser River Basin, Scientific Reports, 6, 19299.
30) Déry SJ, Stadnyk TA, MacDonald M, Gauli-Sharma B 2016: Recent trends and variability in river discharge across northern Canada, Hydrology and Earth System Sciences, 20, 4801-4818.
31) Albers SJ, Déry SJ, Petticrew EL 2016: Flooding in the Nechako River Basin of Canada: A random forest modeling approach to flood analysis in a highly regulated reservoir system, Canadian Water Resources Journal, 41(1-2), 250-260.
32) Hernández-Henríquez MA, Déry SJ, Derksen C 2015: Polar amplification and elevation-dependence in trends of Northern Hemisphere snow cover extent, 1971-2014, Environ. Research Letters, 10, 044010.
33) Petticrew EL, Albers S, Baldwin S, Carmack EC, Déry SJ, Gantner N, Graves K, Laval B, Morrison J, Owens PN, Selbie DT, Vagle S 2015: Initial observations of the impact of a catastrophic mine tailings impoundment spill into a large oligotrophic lake: Quesnel Lake, British Columbia, Canada, Geophysical Research Letters, 42, 3347-3355.
34) Leggat M, Owens PN, Stott TA, Forrester BJ, Déry SJ, Menounos B 2015: Hydro-meteorological drivers and sources of suspended sediment flux in the proglacial zone of the retreating Castle Creek Glacier, Cariboo Mountains, British Columbia, Earth Surface Processes and Landforms, 40, 1542-1559.
35) Padilla A, Rasouli K, Déry SJ 2015: Impacts of variability and trends in monthly runoff and water temperature on salmon migration in the Fraser River Basin, Canada, Hydrol. Sciences Journal, 60, 523-533.
36) Kang DH, Shi X, Gao H, Déry SJ 2014: On the changing contribution of snow to the hydrology of the Fraser River Basin, Journal of Hydrometeorology, 15, 1344-1365.

Philip N. Owens

Name:	Philip Neil Owens	**Status in Canada:**	Permanent resident
Nationality:	British	**Date of birth:**	9th April 1966

Work address: Environmental Science Program, Faculty of Environment, University of Northern British Columbia (UNBC), Prince George, British Columbia, Canada V2N 4Z9
Telephone: +001 250 960 6177
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E-mail: Philip.owens@unbc.ca and owensp@unbc.ca
Web site: https://www2.unbc.ca/owens
Present position: Professor in Environmental Science and FRBC Endowed Research Chair in Landscape Ecology at UNBC.
Adjunct Professor in the Department of Soil Science and the Department of Geography and Environment, University of Manitoba, Canada.
Research topics: Response of aquatic systems to landscape disturbances (e.g. agriculture, forestry, mining, urban development, wildfires, climate change); tracing sediment in river systems; sediment-associated contaminants and nutrients (e.g. phosphorus).

EDUCATION

1984-1988 Coventry Polytechnic, Coventry CV1 5FB, UK
Graduated with B.Sc. (2.1) Honours Degree in Geography
Thesis: Valley sedimentation at Slapton, Devon, and its implications for management
Supervisor: Prof. I.D.L. Foster

1988-1990 University of British Columbia, Vancouver, British Columbia, V6T 1Z2, Canada
Graduated with M.Sc. Degree in Physical Geography
Thesis: Lake sediment-based sediment yields and erosion rates in the Coast Mountains, British Columbia
Supervisor: Prof. O. Slaymaker. Funding: NSERC (Canada)

1990-1994 University of Exeter, Exeter, Devon EX4 4RJ, UK
Graduated with Ph.D. in Physical Geography
Thesis: Towards improved interpretation of caesium-137 measurements in erosion studies
Supervisor: Prof. D.E. Walling. Funding: NERC (UK)

RESEARCH PROJECTS/GRANTS (select current and recent)

- Forest Renewal British Columbia (FRBC) *Endowed Research Chair Operating Grant* (2007 – ongoing) – several projects including: sediment fingerprinting in Canadian watersheds; sources of sediment in proglacial environments; impacts of wildfire on soil erosion and fine-grained sediment dynamics in forested aquatic systems; sediment-associated contaminants in watersheds. Funds: ~$525,000.
- NSERC Discovery Grant – *Advancing techniques to fingerprint sediment sources in disturbed watersheds*. Project team: P.N. Owens, PI. Duration: 2018 – 2023 (5 years). Funds: $180,000.
- Nechako Environmental Enhancement Fund (NEEF) – *Integrated watershed research in the Nechako river basin: Phase 1 and 2*. Project team: Stephen Déry, Phil Owens, Margot Parkes and Ellen Petticrew (all UNBC). Duration: 2014 – 2023 (9 years). Funds: ~$1,000,000 from NEEF with ~$1,000,000 as matched funding from other sources.

- Environment and Climate Change Canada, Environmental Damages Fund – *Evaluating the resiliency of aquatic ecosystems to a catastrophic mine tailings spill event: the 2014 Mount Polley incident in the Quesnel River watershed, British Columbia: Phase 1 and 2*. Project team: UNBC (Ellen Petticrew (PI), Phil Owens, Stephen Déry), UBC (Sue Baldwin, Bernard Laval), U of Lethbridge (Greg Pyle). Duration 2016 – 2020 (5 years). Funds: ~$1,000,000.
- NSERC Collaborative Research and Development Grant - *Contributions of climate change and hydro-electric regulation to the variability and change of freshwater-marine coupling in the Hudson Bay System*. Project team: U of Manitoba (David Barber, PI, and others), UNBC (Stephen Déry, Phil Owens and Ellen Petticrew), University of Quebec and other institutions. Duration: 2015 – 2020 (5 years). Funds: ~$9,000,000 (50% from NSERC and matched funding from Manitoba Hydro).
- Environment Canada – Lake Winnipeg Basin Stewardship Fund (LWBSF) – *Designing and managing riparian areas to filter phosphorus and sediment*. Project team: UNBC (Phil Owens, PI) and U of Manitoba (David Lobb). Duration: 2013 – 2017 (4 years). Funds: $147,500.
- Canada Foundation for Innovation (John R Evans Leaders Fund) – *Infrastructure to support innovations in soil erosion and sedimentation research*. Project team: David Lobb (PI, U of Manitoba) and Phil Owens (co-PI). Duration 2014 – onwards. Funds: $620,000 (50% from CFI, 50% from Manitoba Research) plus other matched-funding.

PUBLICATIONS and PRESENTATIONS

a) Summary

- Total publications: >140
- Total refereed journal publications: 88
- Examples of journals: Scientific Reports, Earth-Science Reviews, Geophysical Research Letters, Environmental Research Letters, Science of the Total Environment, Advances in Agronomy, Water Research, Water Resources Research, Hydrological Processes, Journal of Hydrology
- Total conference presentations (including posters): >200
- Total invited/keynote presentations: >40
- Total media presentations and interviews (TV, radio, web and press): >50
- Metrics: Web of Science H-factor = 37 (as of March 2021)

b) Edited books

- **Owens PN,** Slaymaker O (Editors) (2004). *Mountain Geomorphology*. Hodder Arnold Publishers Ltd.
- **Owens PN,** Collins AJ (Editors) (2006). *Soil Erosion and Sediment Redistribution in River Catchments: Measurement, Modelling and Management*. CABI, Wallingford, UK.
- **Owens PN** (Editor) (2008). *Sustainable Management of Sediment Resources: Sediment Management at the River Basin Scale*. Elsevier, Amsterdam.
- Banasik K, Horowitz AJ, **Owens PN,** Stone M, Walling DE (Editors) (2010). *Sediment Dynamics for a Changing Future*. IAHS Pub.337, IAHS Press, U.K.

c) Edited journal special issues

- **Owens PN,** Rickson RJ, Clarke MA (Eds) (2006). The use of vegetation for erosion and environmental protection. *Earth Surface Processes and Landform*, **31**, 533-631.
- Church M, **Owens P**, Petticrew E, Souch C (Eds) (2006). Sediment and geochemical budgets. *Geomorphology*, **79**, 1-142.

- **Owens PN** (Ed.) (2007). Sediment linkages between the river catchment and the sea. *Journal of Soils and Sediments*, **7**, 273-350.
- **Owens PN,** Petticrew EL, van der Perk M (Eds) (2010). Sediment response to catchment disturbances. *Journal of Soils and Sediments*, 10, 591-697.

d) Refereed journal papers (since 2015)

- **Owens PN** (2020). Soil erosion and sediment dynamics in the Anthropocene: a review of human impacts during a period of rapid environmental change. Journal of Soils and Sediments, 20, 4115-4143. https//:doi.org/10.007/s11368-20-02815-9
- Hamilton AK, Laval BE, Petticrew EL, Albers SJ, Allchin M, Baldwin SA, Carmack EC, Déry SJ, French TD, Granger B, Graves KE, **Owens PN,** Selbie DT, Vagle S (2020). Seasonal turbidity linked to physical dynamics in a deep lake following the catastrophic 2014 Mount Polley mine tailings spill. Water Resources Research, 56. e2019WR025790. https://doi.org/10.1029/2019WR025790
- Goharrokhia M, Lobb DA, **Owens PN** (2020). Evaluation of high-flow rate continuous-flow centrifugation and continuous-flow filtration techniques for sampling suspended sediment. Hydrological Processes, 34, 3882-3893.
- **Owens PN,** Blake WH, Millward GE (2019). Extreme levels of fallout radionuclides and other contaminants in glacial sediment (cryoconite) and implications for downstream aquatic ecosystems. Scientific Reports, 9, 12531. https://doi.org/10.1038/s41598-019-48873-z
- Reiffarth DG, Petticrew EL, **Owens PN**, Lobb DA (2019) Spatial differentiation of cultivated soils using compound-specific stable isotopes (CSSIs) in a temperate agricultural watershed in Manitoba, Canada. Journal of Soils and Sediments, 19, 3411-3426.
- Boudreault M, Koiter AJ, Lobb DA, Liu K, Benoy G, **Owens PN,** Li S (2019). Comparison of sampling designs for sediment source fingerprinting in an agricultural watershed in Atlantic Canada. Journal of Soils and Sediments, 19, 3302-3318.
- Gateuille D, **Owens PN,** Petticrew EL, Booth BP, French TA, Déry SJ (2019). Determining contemporary and historical sediment sources in a large drainage basin impacted by cumulative effects: the regulated Nechako River, British Columbia, Canada. Journal of Soils and Sediments 19, 3357-3373.
- Vanrobaeys JA, **Owens PN,** Lobb DA, Kieta KA, Campbell JM (2019). Seasonal efficacy of vegetated filter strips for phosphorus reduction in surface runoff. Journal of Environmental Quality, 48, 880-888.
- Goharrokhia M, Pahlavanb H, Lobb DA, **Owens PN,** Clark SP (2019). Assessing issues associated with a time-integrated fluvial fine sediment sampler. Hydrological Processes, 33, 2048-2056.
- Hatam I, Petticrew EL, French TD, **Owens PN,** Laval B, Baldwin S (2019). The bacterial community of Quesnel Lake sediments impacted by a catastrophic mine tailings spill differ in composition from those at undisturbed locations – two years post-spill. Scientific Reports, 9, 2705.
- **Owens PN,** Gateuille D, Petticrew EL, Booth B, French TA (2019). Sediment-associated organopollutants, metals and nutrients in the Nechako River, British Columbia: a current study with synthesis of historical data. Canadian Water Resources Journal, 44, 42−64.
- Habibiandehkord R, Lobb DA, **Owens PN,** Flaten DN (2019). Effectiveness of vegetated buffer strips in controlling legacy phosphorus exports from agricultural land. Journal of Environmental Quality, 48, 314-321.

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RECENT POSTGRADUATE AND RESEARCH PERSONNEL SUPERVISION (since 2007)

- PhD supervision (completed and on-going): 4
- MSc supervision (completed and on-going): 9
- International MSc project co-supervision (completed): 7
- Post-doctoral research fellows: 3
- Research associates and assistants: 23

TEACHING at UNBC (not all courses are taught each year)

- **BSc Geography:** *Concepts in Geomorphology* (GEOG311)
- **BSc Environmental Science:** *Introduction to Environmental Science* (ENSC111), *Introduction to Aquatic Systems* (ENSC211)**,** *Northern Contaminated Environments* (ENSC308) and *Lands and Environment of the Circumpolar North* (NORS312)
- **MSc/PhD Natural Resources and Environmental Studies (NRES):** *Processes in Geomorphology* (NRES 751)

EDITOR, WORKING GROUPS AND EXPERT GROUPS/PANELS

- Editor-in-Chief *Journal of Soils and Sediments* (2011 -)
- Member of the Steering Committee and leader of WG4/WP2 of the European Sediment Research Network (SedNet) funded by the European Union (2002-2004)
- Treasurer (2008 -) and Vice-President (2017 -) of the International Association of Sediment–Water Science (IASWS)
- Chair of the European Geosciences Union (EGU) sub-division on Erosion, Sedimentation and River Processes (2009-2012)
- Member of UK NERC Peer Review College (2005-2006)
- National Science Foundation (USA-NSF) Critical Zone Observatory Grant Panel (2007)

Appendix R

Offsetting Habitat Value (DFO IR #17 Memo)

R1. Response Memo
R2. Datasheet

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Memorandum

Date: April 22, 2022

Project #: 2006501

DFO File #: 21-HPAC-01447

To: Kevin deBoer, Fisheries and Oceans Canada

From: Ian MacLeod and Irene Tuite, Palmer

cc: Ryan Todd, Travis Desormeaux, BW Gold Ltd.

Re: Blackwater Gold Project Application for a *Fisheries Act* Authorization
DFO Adequacy Review Letter – Information Request #17
DFO File: 21-HPAC-01447

1. Introduction

This memorandum has been prepared in response to an Information Request (IR) provided by Fisheries and Oceans Canada (DFO) as part of the adequacy review of the previously filed Application for Authorization under the *Fisheries Act* for the Blackwater Project. Specifically, this memorandum addresses IR #17, which states:

"The amount and nature of the proposed measures to offset do not counterbalance the residual effects on fish and fish habitat. The offsetting proposal appears to substantially over-value the potential benefits from restoration and enhancement offsetting works. Please provide clarification on the following items:

a. *Including multiple species in the habitat equivalency analysis of the offset areas. This creates disparity when comparing to habitat values of stream systems supporting a single species.*
b. *The 'Index of Alteration' (IA) included in the Habitat Units calculation is limited to the specific habitat characteristics that are currently degraded and which the offsetting proposes to improve. This approach may exaggerate the difference in habitat value between before and after conditions.*
c. *Addition of the IA variable to the calculation of an offsetting Habitat Units results in a new unit that reflects the characteristics defined in the IA, and is not directly comparable to the Habitat Units defined for fish habitat affected by works related to the mine site.*
d. *The calculation of offsetting gains appears to include credit for increased habitat values in an area much greater than the footprint of the physical works proposed for offsetting.*

Provide a detailed breakdown of the calculation (including HSI and IA) of offsetting Habitat Units as presented in Table 10-3 of the application report. Provide underlying habitat assessments and calculations for establishing the Habitat Unit values from the areas provided for each offsetting site, and include detail to clarify how habitat losses during offset construction is accounted for in the habitat balance."

2. Response to DFO Information Request #17

2.1 Habitat Accounting Summary

The Project's offsetting plan provides an adequate amount of fish habitat creation and restoration/enhancement to adequately counterbalance the residual effects on fish and fish habitat. This section provides an overview of the habitat losses associated with the Project and the gains that arise from the offsetting plan, to contextualize the detailed discussion of the offsetting gain calculations provided in the subsequent sections.

Section 8.1 of the Project's *Fisheries Act* Authorization Application (FAAA) describes how fish habitat losses were quantified, using four methods:

1. Measurement of areal extent (surface area) of affected instream habitat (in m^2);
2. Application of Habitat Evaluation Procedure (HEP) to calculate Habitat Units (HU), a metric that integrates habitat quality with quantity (equivalent to m^2 of 'usable' in-stream habitat);
3. Modelling of instream flow using the System for Environmental Flow Analysis (SEFA) that is also used to calculate HUs specifically related to changes in streamflow;
4. Calculation of the riparian habitat (in m^2) using stream buffers applied to stream segments, based on fish-bearing status assessed during baseline field programs.

A summary of calculated Project losses of fish habitat, based on the four assessment methods, is shown in Table 1. Overall, the Project is anticipated to result in the loss of 121,841 m^2 of instream area, 89,916 Rainbow Trout HU, 563 Kokanee HU, 372 Food and Nutrient Production HU and 802,986 m^2 of riparian area. The methods for determining these loss values and detailed summary tables are provided in Section 8.1 (including Tables 8-3 to 8-7) and Appendix B – *Habitat Evaluation Procedure (HEP) for Blackwater Project Fisheries Offsetting Plan* of the FAAA. In addition, a detailed data table showing the calculation of the HU values for each unique stream segment affected by the Project will be provided as part of the response to DFO IRs #11 and #12.

The calculated Project gains of fish habitat following successful implementation of the offsetting measures are shown in Table 2. The offsetting measures are anticipated to result in the creation or restoration/enhancement of 212,264 m^2 of instream area, 97,881 Rainbow Trout HU, 772,794 Chinook Salmon HU, and 569,433 m^2 of riparian area. The methods for determining these loss values and detailed summary tables are provided in Sections 10.5 and 10.6 (including Table 10-3) and Appendix B – *Habitat Evaluation Procedure (HEP) for Blackwater Project Fisheries Offsetting Plan* of the FAAA. In addition, a series of detailed data tables showing the calculation of the HU values for each unique offsetting stream segment is provided in Appendix A of this memo. Detailed summaries of the offsetting design plans are provided in Table 3 and Table 4 to illustrate the extent and variety of restoration/enhancement and habitat creation approaches that support the offsetting measures.

The calculated fish habitat values presented in Tables 1 and 2 result in gain:loss ratios of 1.74:1 for instream area, 2.03:1 for combined HU, and 0.71:1 for riparian area. These ratios demonstrate that the offsetting measures will result in benefits to fish habitat that will outweigh the residual impacts of the Project.

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Table 1: Summary of Habitat Loss Quantified Using HEP, SEFA, and Linear Corridor Area Analyses

Assessment Method	Watershed	Stream	Length (m)	Instream Area (m²)	Rainbow Trout Habitat Units						Kokanee Habitat Units	Food and Nutrient Production	Riparian Area (m²)
					Spawning / Egg Incubation	Fry Summer Rearing	Juvenile Summer Rearing	Adult Summer Foraging	Overwintering	Total (All Life Stages)	Spawning / Egg Incubation		
HEP	Creek 661	661 Tributaries	794	0	0	0	0	0	0	0	0	0	0
		Creek 146920	6,841	9,452	0	0	2,362	0	0	2,362	0	0	98,369
		Creek 505659	7,974	14,653	3,555	3,018	5,115	0	1,183	12,871	0	0	181,333
		Creek 505659 Tributaries	507	1,665	0	0	112	0	0	112	0	0	4,457
	Davidson Creek	Davidson Creek Mainstem	3,847	16,958	4,013	8,026	5,978	0	4,240	22,257	0	0	115,405
		Davidson Creek Tributaries	8,157	11,659	0	852	1,634	0	852	3,338	0	144	39,316
		Creek 636713	3,086	14,265	0	2,681	4,114	0	2,681	9,476	0	0	28,634
		Creek 636713 Tributaries	1,089	2,302	0	0	179	0	0	179	0	0	10,063
		Creek 688328	5,342	7,991	1,689	2,954	2,049	0	1,140	7,832	0	0	108,065
		Creek 688328 Tributaries	6,965	4,091	0	0	1,206	0	0	1,206	0	0	48,803
		Creek 704454	3,231	8,117	933	3,683	4,087	0	1,774	10,476	0	0	70,125
		Creek 704454 Tributaries	6,518	8,641	0	0	2,411	0	0	2,411	0	228	76,834
		Creek 428073	632	22,047	0	5,512	5,512	0	5,512	16,536	0	0	3,235
	Tatelkuz Lake Tributary	Unnamed	1,365	-	0	0	0	0	0	0	0	0	13,647
	HEP Sub-Total		**56,348**	**121,841**	**10,190**	**26,726**	**34,759**	**0**	**17,382**	**89,056**	**0**	**372**	**798,286**
SEFA[1,2]	Davidson Creek	Lower Davidson Creek Mainstem	-	-	0	0	0	0	-	0	5	0	0
		Middle Davidson Creek Mainstem	-	-	0	0	396	0	-	396	-	0	0
	Creek 661	Creek 661 Mainstem	-	-	0	0	458	6	-	464	558	0	0
	SEFA Sub-Total		**-**	**-**	**0**	**0**	**854**	**6**	**-**	**860**	**563**	**0**	**0**
Linear Corridors[3]	Various Project site streams		-	-	-	-	-	-	-	-	-	0	4,700
Totals			**56,348**	**121,841**	**10,190**	**26,726**	**35,613**	**6**	**17,382**	**89,916**	**563**	**372**	**802,986**

Notes:

1. *Overwintering habitat losses are not quantified using SEFA.*
2. *Adult life stages consider foraging, migration, and spawning.*
3. *Linear corridor losses are calculated for the FWSS Pipeline, FWSS Pump Station, and the Mine Access Road.*

Table 2: Habitat Gains from Habitat Construction Offsetting Measures - Area, Habitat Units by Life Stage, and Riparian Area.

Offsetting Measure	Length (m)	Pre-restoration Area (m)	Post-restoration Area (m)	Net Area Change[1] (m^2)	Rainbow Trout Habitat Units					Chinook Salmon Habitat Units				Rainbow Trout HU Total	Chinook Salmon HU Total	HU Total	Riparian Area (m^2)
					Spawning / Egg Incubation	Fry Summer Rearing	Juvenile Summer Rearing	Adult Summer Foraging	Over-wintering	Spawning / Egg Incubation	Fry Summer Rearing	Juvenile Summer Rearing	Over-wintering				
Murray Creek	2,944	32,722	24,681	-8,041	1,093	1,219	5,652	6,629	5,059	1,640	5,649	6,084	5,616	19,652	18,989	38,641	115,576
Greer Creek – Lower	4,615	57,697	53,876	-3,821	1,208	788	4,031	4,288	3,334	1,169	4,479	4,197	5,384	13,649	15,229	28,878	119,191
Greer Creek – Middle	3,168	27,776	26,921	-856	961	788	4,758	5,942	4,459	1,047	4,906	5,860	5,784	16,908	17,597	34,505	91,738
Greer Creek – Upper	8,673	89,463	91,236	1,773	1,280	3,526	7,135	6,802	4,889	1,280	7,059	6,840	5,800	23,632	20,979	44,611	229,600
Creek 661 Pond	95	n/a	5,867	5,867	0	1,031	4,123	0	4,123	0	0	0	0	9,277	0	9,277	5,080
Lake 15/16 Connector	676	n/a	9,683	9,683	144	76	5,831	3,893	5,819	0	0	0	0	15,763	0	15,763	8,248
Complementary Measures	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	12,942	n/a
Totals	**20,171**	**207,658**	**212,264**	**4,605**	**4,686**	**7,428**	**31,530**	**27,554**	**27,683**	**5,136**	**22,093**	**22,981**	**22,584**	**98,881**	**72,794**	**184,617**	**569,433**

Notes:

1. *The loss of area in the Murray and Greer creek channels is the result of narrowing the over-widened existing banks that have been trampled by cattle. The decrease in instream area is balanced by the increase in habitat quality, demonstrated by the net gain of habitat units.*

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Table 3: Summary Table of Offsetting Measures to Improve Existing Ranchland Stream Habitats Proposed for the Blackwater Project.

Waterbody	Length (m)	Pre-Restoration Area (m^2)	Post-Restoration Area (m^2)	Restoration and Enhancement Treatments																					
				Instream Cattle Exclusion (m^2)	Total Bank Treatment Length[1] (m)		Bank Treatment Length[2] (m)										Riparian Planting (m^2)	Woody Debris Habitat		Boulder Cluster[2]	Gravel Placement (m^2)	New Clear-Span Bridges	Off-Channel Cattle Watering Stations
							Bank Regrading		Brush Layer		Woody Debris Narrowing		Restore Natural Width		Vegetated Boulder Revetment								
					Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank	Left Bank	Right Bank		Rootwad	Log				
Lower Greer Creek	4,615	57,697	53,876	53,876	1,036	1,254	510	714	1,036	785	-	-	526	540	-	114	119,191	11	3	9	-	2	3
Middle Greer Creek	3,168	27,776	26,921	26,921	1,097	998	903	808	927	832	42	38	183	183	-	-	91,738	13	9	15	620	1	5
Upper Greer Creek	8,673	89,463	91,236	91,236	1,524	1,501	1,270	927	1,320	1,187	120	292	72	282	22	22	229,600	37	43	38	4,500	2	6
East Murray Creek	803	7,939	6,860	6,860	783	783	-	-	757	757	-	-	757	757	26	26	31,524	5	5	4	420	1	1
West Murray Creek	261	2,272	1,769	1,769	265	265	-	-	265	265	-	-	265	265	-	-	10,246	1	1	2	36	0	1
Mainstem Murray Creek	1,880	22,511	16,052	16,052	1,642	1,880	-	238	1,642	1,880	-	-	1,642	1,642	-	-	73,806	7	5	8	1,035	2	5
Totals	**19,400**	**207,658**	**196,714**	**196,714**	**6,347**	**6,681**	**2,683**	**2,687**	**5,947**	**5,706**	**162**	**330**	**3,445**	**3,669**	**48**	**162**	**556,104**	**74**	**66**	**76**	**6,611**	**8**	**21**

Notes:
[1]Total Bank Treatment Length represents the full extent of bank treatments in a given waterbody. The individual bank treatment lengths described in the following columns may overlap spatially to some extent (i.e., multiple treatments applied to a single segment of bank) and do not necessarily sum to the total length provided in this column.
[2]A single boulder cluster is defined as three boulders.

Table 4: Summary Table of Offsetting Measures to Create New Habitats Proposed for the Blackwater Project.

Waterbody	Length (m)	Instream Area (m^2)	Rocky Shoal Habitat (m^2)	Shoreline/Floodplain Vegetation (m^2)	Riparian Area (m^2)	Woody Debris Structure			Cobble Connector Arm Outlet[1] (m^2)	Cobble Cluster	Boulders	Gravel Placement (m^2)
						Rootwad	Log	Deflector				
Lake 15 and 16	676	9,683	4,360	4,300	8,248	6	7	4	295	4	-	91
Creek 661 Pond	95	5,867	2,440	-	5,080	10	13	-	-	-	40	-
Totals	771	15,550	6,800	4,300	13,328	16	20	4	295	4	40	91

Notes:

[1] Connector Arm Outlet is an instream cobble transition zone that connects the deep channel arm to the low-flow channel

2.2 Response to #17a

Multiple species were included in the calculation of habitat loss and gain. Rainbow Trout (*Oncorhynchus mykiss*) and Kokanee (*O. nerka*) were identified as the representative species for habitat loss evaluation at the mine site, while Rainbow Trout and Chinook Salmon (*O. tshawytscha*) were the two species selected for habitat gain evaluation at the offsetting sites.

Two lines of reasoning support the inclusion of multiple species (i.e., Rainbow Trout, Kokanee, and Chinook Salmon) in the habitat equivalency calculations. The first reason is that the species included in the calculation represent fish communities present in the relevant watercourses. The standard Habitat Evaluation Procedure (HEP) is applied consistently, whether it is an impacted watercourse or offsetting watercourse, to provide a habitat suitability assessment of representative fish species that occur in each affected stream. The second reason is that the two species included in the offsetting gains calculations (i.e., Rainbow Trout and Chinook Salmon) occupy different ecological niches and do not significantly overlap temporally or spatially in habitat use. Habitat restoration and enhancement will benefit both species in distinct ways.

2.2.1 Species Presence

The inclusion of multiple species in the habitat equivalency calculations is reflective of the fact that the assessed systems support multiple fish species.

2.2.1.1 Davidson Creek and Creek 661

Rainbow Trout are the most abundant species in Davidson Creek and Creek 661. It was the only species encountered in stream segments directly beneath the Project footprint during baseline sampling. Both Davidson Creek and Creek 661 support other species in their downstream reaches, notably Kokanee, a species that seasonally occupies the lower reaches of these creeks for spawning and in-gravel embryo incubation. Other species, including Mountain Whitefish (*Prosopium williamsoni*), Brassy Minnow (*Hybognathus hankinsoni*), Northern Pikeminnow (*Ptychocheilus oregonensis*), Longnose Sucker (*Catostomus catostomus*), and Prickly Sculpin (*Cottus asper*) may seasonally or permanently occupy portions of Davidson Creek or Creek 661, although catches of these species were very low or zero during baseline sampling. These species were captured or historically reported in downstream waterbodies, including Chedakuz Creek and Tatelkuz Lake.

Based on the high abundance of Rainbow Trout and the seasonal presence of Kokanee, these two species were selected as the assessment species to account for Project-caused habitat losses using a combination of the HEP and System for Environmental Flow Analysis (SEFA) methods.

Calculations of habitat gains for the Creek 661 Pond and the Lake 15/16 Connector Channel offsets (located in Creek 661 and Davidson Creek watersheds, respectively) also relied on Rainbow Trout and Kokanee as the representative species. However, since neither of these offset projects offers Kokanee habitat, the Kokanee habitat gain was determined to be zero.

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2.2.1.2 Murray Creek and Greer Creek

Murray and Greer creeks are tributaries of the Nechako River, a large tributary of the Fraser River that supports a diverse community of fish.

Greer Creek supports juvenile Chinook Salmon, which were captured via minnow trapping and electrofishing by Palmer in fall 2017 and 2021 (Palmer, 2017 and 2021 unpublished data). Historical records (1980-1998) indicate the presence of sculpin species, Chinook Salmon, Coho Salmon (*O. kisutch*), Sockeye Salmon (*O. nerka*), Rainbow Trout, Mountain Whitefish, Largescale Sucker (*Catostomus macrocheilus*), Longnose Sucker, Leopard Dace (*Rhinichthys falcatus*), Longnose Dace (*R. cataractae*), Northern Pikeminnow, and Redside Shiner (*Richardsonius balteatus*) at various locations within the watershed.

Murray Creek supports Chinook Salmon, Lake Chub (*Couesius plumbeus*), Rainbow Trout, sculpin species, Bridgelip Sucker (*Catostomus columbianus*), Longnose Sucker, and Redside Shiner, according to capture records found in the FISS database (BC FISS; records date from 2008-2015). During fish salvage operations conducted prior to culvert replacement at the Larson Road crossing (upstream of the proposed restoration area), Lake Chub, juvenile Chinook Salmon, and Rainbow Trout were captured via minnow trap and dip net (AMS, 2015). Fish sampling conducted by Palmer in 2016 and 2017 using minnow traps resulted in the capture of juvenile Chinook Salmon, Redside Shiner, and Lake Chub.

Rainbow Trout and Chinook Salmon were selected for habitat gain evaluation for Murray and Greer creeks. Rainbow Trout were chosen to match the Project's habitat loss evaluation methodology. Chinook Salmon were chosen based on their similarity to Kokanee (used in the Project's habitat loss evaluation) as a highly valued and sensitive species, as well as for their documented presence in the watershed and their stream-resident life history (i.e., juveniles remain in stream environments after emergence and directly benefit from restoration works).

2.2.1.3 Summary

Computing the habitat value for all species present in all affected watercourses would likely result in the most comprehensive understanding of the overall effect on the fish communities in affected streams. However, this would be a complex and data-intensive exercise. Rather, two species were selected as representative species for the calculation of both habitat gains and losses: Rainbow Trout and Kokanee for habitat losses and Rainbow Trout and Chinook Salmon for habitat gains.

During the offsetting identification and screening process, priority was given to near-field offsetting projects that would directly benefit local fish populations (i.e., Creek 661 Pond, Lake 15/16 Connector Channel). However, potential offsetting options are limited in the vicinity of the mine. Therefore, inclusion of far-field sites was necessary to develop an adequate offsetting balance. Inclusion of potential offsetting projects that would benefit multiple species that are of recognized high value to First Nations, fisheries managers, and conservation groups was identified as a priority.

Chinook Salmon are highly coveted and important for First Nation food, social and ceremonial values. Chinook Salmon are also important for recreational angling, as food for the Endangered Southern Resident Killer Whale and for other marine mammal species. The Nechako River Chinook Salmon are part of the Middle Fraser River (Summer 5-2) Conservation Unit which are listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2019). Given the pressures on many populations of Pacific Salmon, including this and several other populations of Chinook Salmon, restoring and enhancing suitable and historically high-value habitat for this highly important species is in alignment with fisheries management objectives and the accounting procedure accurately captures the wide-ranging benefits of the offsetting projects (PSF, 2020).

The inclusion of two species in the habitat equivalency calculations for both gains (i.e., Rainbow Trout and Kokanee) and losses (i.e., Rainbow Trout and Chinook Salmon) is an appropriate expression of the expected negative and positive impacts to the fish communities in the affected watersheds. The Project's habitat balance shows a small loss of Kokanee habitat value and a much larger gain of Chinook habitat value. This is a direct result of the deliberate intent of the Project design to minimize potential loss of Kokanee habitat by implementing avoidance, mitigation, and offsetting measures, including a robust Instream Flow Needs (IFN) program to maintain water quantity to downstream Kokanee habitat. The large gain of Chinook Salmon habitat value is the result of targeted restoration and enhancement measures to support this high-value fish species.

2.2.2 Ecological Niches

Habitat value gains for Chinook Salmon and Rainbow Trout were calculated separately due to differences in habitat preferences and timing of life stages of both species.

Rempel et al (2012) evaluated habitat suitability curves for depth, velocity, and substrate types for 0+, 1+ stream-type Chinook Salmon, 0+ Rainbow Trout, and 1+ to Juvenile Rainbow Trout. It was determined that 0+ Rainbow Trout preferred shallower and lower velocity habitat than 0+ Chinook Salmon, and 1+ Rainbow Trout preferred deeper water than both 0+ and 1+ Chinook Salmon. 1+ Rainbow Trout preferred a broad range of velocities, including those preferred by 0+ and 1+ Chinook Salmon. Roper et al (1994) developed a utilization index (valued from -1 to 1) that compared the use of habitat by Chinook Salmon and Steelhead (*O. mykiss*) to the proportion of available habitat. The study found that Chinook Salmon preferred pool and glide habitat and the Steelhead preferred riffle and run habitat, regardless of its availability within a reach. These results are further supported by other habitat preference studies (Bisson et al. 1988, Everest and Chapman 1972, McPhail 2007, Rubin et al. 1991, Stein et al. 1972).

McPhail (2007) summarizes the differences in habitat use by adult, juvenile and young-of-the-year Rainbow Trout and Chinook Salmon. Adult Rainbow Trout and Steelhead can occupy all mesohabitat types but are often found in runs and glides with depths ranging from 0.4 - 1.0 m. Juvenile Rainbow Trout occupy riffles and runs (<0.25 m) and disperse widely throughout a system, and age-0 Rainbow Trout display agonistic behaviour and establish territories in shallow water along stream margins, generally in areas less than 20 cm deep. Adult Chinook Salmon, especially stream-type fish that enter during the spring and stay in deep pools during the summer, prefer high-velocity water. Juvenile Chinook Salmon prefer slower pool and off-channel habitat, particularly when overwintering. Chinook Salmon fry prefer slow edge habitat less than 30 cm deep and disperse to channel edges, sloughs, backwaters, and off-channel habitats. As the fry grow, they shift into deeper faster water, and stream-type Chinook that remain in their natal stream seek cover in pool habitat. Chinook are gregarious and are typically found schooled whereas Rainbow Trout are territorial and disperse widely throughout a stream (McPhail, 2007; Stein et al. 1972).

In addition to differences in habitat preference, the life history events of Chinook Salmon and Rainbow Trout/Steelhead are often separated temporally. Chinook Salmon adults typically migrate from spring to the fall and spawn in the late summer and fall (McPhail, 2007). Chinook Salmon spawning is temporally separated with the Rainbow Trout spawning in the spring (March-June; McPhail, 2007). Consequently, timing of embryo development, emergence, and rearing of the species also differ. Rainbow Trout swim-up and rear during the spring and summer and will overwinter (normally) whereas Chinook Salmon hatch in the winter and swim-up during the following spring (McPhail, 2007). For rearing, ocean-type Chinook Salmon emigrate to the ocean within their first year, whereas stream-type Chinook Salmon can reside in streams for longer periods and generally prefer deep and fast flowing water as they grow (McPhail, 2007; Roper et al 1994). Overall, temporal differences in key life stages leads to persistent differences in relative body size, habitat occupancy, and interaction with food sources.

To account for the differences in habitat preferences between Rainbow Trout and Chinook Salmon, the HEP calculations for Chinook Salmon were completed using an adjusted set of Habitat Suitability Index (HSI) values, based on peer-reviewed scientific literature (Raleigh et al, 1986). As described in the report titled *Habitat Evaluation Procedure (HEP) for Blackwater Project – Fisheries Offsetting Plan* (Appendix B of the Application; TGAEC 2021), HSI values for the Habitat Type/Class matrix were modified to reflect Chinook Salmon habitat preferences. Tables 3 and 5 of Appendix B of the Application (TGAEC 2021) show the Chinook-specific modifications and the resulting matrix of HSI values, respectively.

In summary, the differences in habitat preferences for the life stages of Chinook Salmon and Rainbow Trout as well as the temporal separation of each of their life stages supports the separation of the Chinook and Rainbow Trout habitat value for the offsetting accounting.

2.3 Response to #17b

The characteristics of the streams lost due to Project development and those included in the offsetting restoration/enhancement projects (i.e., Murray and Greer creeks) are different. This difference is driven largely by the ongoing destructive effects of cattle activity (e.g., trampling and grazing streamside vegetation, eroding banks) and ranching (e.g., vehicle crossings of watercourses, anthropogenic stream alteration). These ongoing destructive activities are not present at the mine site, resulting in a fundamental dissimilarity between the lost and restored/enhanced streams.

The habitat value of the stream segments lost due to Project development was quantified using a site-specific HEP method. Broadly, the HEP calculation relies on identifying stream mesohabitat (e.g., riffle, glide, pool) type and classification to assign habitat suitability values for fish life stages. The result is an estimate of the overall habitat value for a given undisturbed stream segment.

To evaluate the potential habitat gains at all offsetting sites in a manner that allowed for comparison with the mine-site habitat losses, the same mesohabitat type/classification HEP method was applied. However, to accurately quantify the fish habitat value of the significantly disturbed ranchland offsetting streams, adaptation of the HEP method by including the Index of Alteration (IA) term was needed. For the restoration sites where cattle grazing is impacting existing fish habitat, the IA reflects the lower suitability of the degraded fish habitat that is not captured by the unadjusted HEP. For consistency of analysis, the IA calculation was also applied to the created habitats in the Lake 15/16 Connector Channel and the Creek 661 Off-Channel Pond, using the same post-completion predictive approach employed for the ranchland streams.

The reliance of the unadjusted mine-site HEP method on mesohabitat type and classification renders it insensitive to changes that result from widely practiced stream restoration methods. Cattle exclusion, riparian planting, and channel restoration will improve the fish habitat in ways that are not directly quantified in the unadjusted HEP. For example, a pre-restoration Glide 2 habitat with instream cattle trampling, eroding banks, and no riparian vegetation would be assigned the same value as a post-restoration Glide 2 habitat where cattle had been excluded from the channel, eroding banks had been stabilized with plantings, and riparian vegetation had been established.

It should be noted that the variables selected for inclusion in the IA significantly overlap with aspects of habitat function that are expected to improve following restoration. This is an acknowledged limitation of the IA-adjusted HEP. However, the combination of the IA variables (i.e., riparian vegetation, riparian banks, channel condition, substrate, and cover) and the variables that are inherently included in the unadjusted HEP (e.g., channel morphology, water velocity, water depth, gradient, spawning gravel presence, instream cover, and habitat complexity) capture a broad suite of the most important aspects of fish habitat.

An example of the application of the IA calculation is given in Table 5.

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Table 5: Application of the IA to a cattle-impacted Pool 2 habitat segment and the resulting HU for juvenile Rainbow Trout. Both the existing and restored suitability indices are itemized.

Habitat Parameter	Habitat Variable[1]	Existing		Restored	
		Individual Suitability Index	Combined Variable Suitability Index	Individual Suitability Index	Combined Variable Suitability Index
Riparian Vegetation	Canopy Closure - V1	0	0.00	2	0.50
	Dominant Vegetation Type - V2lb	0		2	
	Dominant Vegetation Type - V2rb	0		0	
Riparian Banks	Percent Bank Vegetated - V3lb	2	0.67	4	0.89
	Percent Bank Vegetated - V3rb	2		4	
	Sediment Inputs - V4lb	4		4	
	Sediment Inputs - V4rb	4		4	
	Bank Composition - V5lb	0		0	
	Bank Composition - V5rb	0		0	
Channel Condition	Channel Thread -V6	1	0.25	1	0.88
	Bankfull width:depth ratio - V7	1		2	
	Disturbance - V8	0		4	
Substrate	Percent Fines - V9	0	0.00	0	0.00
	Spawning Quality - V10	0		0	
	Dominant Particle Size - V11	0		0	
Cover	Shelter Rating - V12	0	0.20	0	0.50
	Percent Unit Covered - V13	2		5	
	Off-Channel Habitat - V14	0		0	
IA			0.22		0.55
Length (m)			40		40
Width (m)			5		4
Habitat Type HSI (P2)			0.75		0.75
Rainbow Trout Juvenile HU			33.50		66.33

Notes: 1 – lb = left bank, rb = right bank

In the example habitat segment in Table 5, cattle grazing eliminated the woody riparian vegetation and widened the stream channel. The restoration includes riparian planting on the left bank, cattle exclusion, and narrowing the stream channel. The habitat improvements are captured in variables V2lb, V3lb, V3rb, V7, V8, and V13. The dominant substrate is fines, (V9, V10, and V11) and will not change from the restoration. The restoration will improve the degraded habitat from an IA of 0.22 to 0.55. The existing Rainbow Trout juvenile Habitat Unit (HU) value is calculated by multiplying the HSI times the length times the width times the IA (Equation 1). The net gain in juvenile Rainbow Trout habitat is 66.33 minus 33.50, or 32.83 HU.

In this example, the reduction in width due to the restoration reduces the area. The reduction in area is offset by the higher quality of the habitat reflected in the IA. Therefore, if the IA was not applied and the habitat type/classification did not change, the HU value post-restoration would be less than pre-restoration (i.e., the HU values would indicate that the habitat value *decreases* post restoration). This is inaccurate; while the area decreases, the quality increases. The IA accounts for this.

In an equivalent section of Pool 2 habitat on the mine site, the IA would have an assumed value of 1.0, which would result in 150 juvenile rainbow trout HU (calculated as 1.0 IA * 40 m length * 5 m width * 0.75 HSI). The application of the IA to both the pre- and post-restoration conditions at the ranchland offsetting sites numerically captures an intuitive concept: that a post-restoration segment of channel (66.33 HU) offers more fish habitat value than the same pre-restoration segment (33.50 HU), but less than an equivalent undisturbed habitat on the mine site (150 HU).

2.4 Response to #17c

Palmer/TGAEC (2021) developed an IA evaluation that describes the relative level of habitat alteration in stream habitats utilized by Rainbow Trout and Chinook Salmon. The IA assessment considers five habitat parameters: 1) riparian vegetation; 2) riparian banks; 3) channel condition; 4) substrate; and 5) cover.

The five habitat parameters are scored for each identified stream habitat segment as a suitability index from zero (bad) to one (perfect). The IA is the mean suitability index of the five variables and is multiplied by each unaltered HSI value for each affected life stage of rainbow trout and Chinook salmon to determine the degraded HU value.

The IA specifically addresses the impacts of cattle grazing and associated activities that degrade the fish habitat. In a pristine stream channel, with no cattle grazing, each of the five variables are assumed to have a suitability of one. For the mine site, where there is no cattle grazing, the IA is assumed to have a suitability of one. There is no reduction in habitat from the IA in the mine site as can be seen by Equation 1. Since IA has a suitability of one in the mine site, it can be omitted in the calculation.

Equation 1

$$HU_{u_i,sp_j,ls_k} = HSI_{u_i,sp_j,ls_k} * L_{u_i} * W_{u_i} * IA_{u_i}$$

Where:
HU = Habitat unit
HSI = Habitat Suitability Index
L = Unit Length
W = Unit Bankfull Width
IA = Index of Alteration
u_i = Habitat mapping mesohabitat unit i
sp_j= species j
ls_k= life-stage k

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2.5 Response to #17d

HEP analyses are based on the calculation of dimensionless habitat units for each evaluated species. The number of HUs in a given reach of interest is determined by multiplying the total area of available habitat (in m^2) by a species- and life stage-specific HSI (quantity * quality) (USFWS 1980).

HUs were calculated in a consistent manner to describe habitats in the Project area that will be affected by mine construction, operation, and closure activities, as well as for habitats that will be constructed and/or enhanced through implementation of offsetting measures.

Use of a consistent accounting system to assess existing and future habitat conditions facilitates the quantitative comparison between HU losses due to the Project actions and HU gains through the implementation of the above-named offsetting measures.

It may seem that the HU value is larger than the area of the physical works in square meters; however, the HU is a dimensionless unit and incorporates all the various species and life-stages evaluated. Calculation inputs for each offsetting measure are provided in Appendix A. These tables present the inputs for each stream segment that are used in the derivation of the IA and the calculation of the resulting pre- and post-offsetting HU values.

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Appendix A

Detailed HEP Data

Summary of Offsetting Net Gains in Area and Habitat Units

Offsetting Measure		Area (m²)	Habitat Units (HU)								
			Rainbow Trout					Chinook Salmon			
			Spawning	Fry	Juvenile	Adult	Overwintering	Spawning	Fry	Juvenile	Overwintering
Lower Greer Creek	Existing	57,697	2,646	9,603	14,665	12,028	7,518	3,672	12,995	12,176	2,350
	Predicted	53,876	3,854	10,391	18,696	16,315	10,851	4,840	17,474	16,374	7,735
	Net Gain	**- 3,821**	**1,208**	**788**	**4,031**	**4,288**	**3,334**	**1,169**	**4,479**	**4,197**	**5,384**
Middle Greer Creek	Existing	27,210	158	3,701	6,991	4,751	3,447	203	6,938	4,732	4,091
	Predicted	26,434	852	4,409	11,745	10,664	7,885	961	11,784	10,586	9,868
	Existing (Harlow Tributary)	566	-	24	24	-	-	-	24	-	-
	Predicted (Harlow Tributary)	487	267	105	28	29	21	288	84	7	7
	Net Gain	**- 856**	**961**	**788**	**4,758**	**5,942**	**4,459**	**1,047**	**4,906**	**5,860**	**5,784**
Upper Greer Creek	Existing	89,463	544	10,691	31,255	29,210	21,107	544	30,830	29,422	25,160
	Predicted	91,236	1,824	14,218	38,390	36,012	25,996	1,824	37,890	36,262	30,960
	Net Gain	**1,773**	**1,280**	**3,526**	**7,135**	**6,802**	**4,889**	**1,280**	**7,059**	**6,840**	**5,800**
East Murray Creek	Existing	7,939	-	925	1,659	1,502	531	-	1,659	1,502	1,299
	Predicted	6,860	244	1,135	3,325	3,283	2,203	366	3,325	3,161	2,929
	Net Gain	**- 1,079**	**244**	**210**	**1,666**	**1,781**	**1,671**	**366**	**1,666**	**1,659**	**1,630**
West Murray Creek	Existing	2,272	250	367	287	164	171	375	255	55	39
	Predicted	1,769	222	405	650	595	366	333	614	502	383
	Net Gain	**- 503**	**- 28**	**38**	**362**	**431**	**195**	**- 42**	**359**	**447**	**344**
Mainstem Murray Creek	Existing	22,511	-	1,808	3,023	1,997	850	-	3,023	1,997	1,632
	Predicted	16,052	877	2,779	6,646	6,413	4,044	1,316	6,646	5,975	5,274
	Net Gain	**- 6,459**	**877**	**971**	**3,624**	**4,417**	**3,193**	**1,316**	**3,624**	**3,978**	**3,642**
Creek 661	**Predicted Gain**	**5,867**	**-**	**1,031**	**4,123**	**-**	**4,123**	n/a	n/a	n/a	n/a
Lake 15 and 16	**Predicted Gain**	**9,683**	**144**	**76**	**5,831**	**3,893**	**5,819**	n/a	n/a	n/a	n/a

Appendix S

Vegetation Work Plan

ECOLOGIC CONSULTANTS LTD.
UNIT 2, 252 EAST 1ST STREET
NORTH VANCOUVER BC V7L 1B3
PHONE: 604 803-7146

MEMORANDUM

DATE:	February 18, 2022
TO:	Irene Tuite, M.Sc., R.P.Bio. – Aquatic Biologist Travis Desormeaux, Environmental Manager, BW Gold
FROM:	Jason Jones (Ph.D., R.P.Bio.), Jamie Fenneman (Ph.D., R.P.Bio.) and Ryan Durand (M.Sc., R.P.Bio.)
SUBJECT:	Blackwater Gold Project –2022 Vegetation Work Plan

TASK UNDERSTANDING

EcoLogic Consultants Ltd. (EcoLogic) understands that BW Gold has requested the support of vegetation and wetland specialist services related to fisheries and wetlands offsetting related to projected projest effects from development of the Blackwater Gold project(Project). BW Gold and its consultants (including Palmer) have developed fish habitat compensation and offsetting plans as well as a Wetlands Management and Offsetting Plan in accordance with provincial and federal regulatory requirements of the Project. As part of these plans, recommendations have been made with respect to vegetation management (including vegetation surveys, planting plans, invasive species management, and ecosystem protection). The workplan for the wetlands plan will be managed through a separate, but similar, work plan to be provided concurrently for review. EcoLogic has been engaged to review the existing plans, conduct a site visit to complete surveys in conjunction with some combination of project consultants (e.g. Palmer, ERM) and Aboriginal groups, Aboriginal monitors and their consultants, which would be used to evaluate the efficacy of the proposed strategies, develop construction-level documents to supplement existing compensation and offsetting plans, and to provide overall recommendations for plan improvements.

PROPOSED TEAM

Two highly experienced individuals will lead the execution of the workplan, including but not necessarily limited to proposed field work and subsequent development of construction-level documents and offsetting and compensation plan updates:

- Jamie Fenneman, Ph.D., R.P.Bio. - Dr. Fenneman has more than 20 years of experience studying flora and fauna in British Columbia, and has collected and documented plants and wildlife throughout most of the province. He specializes in botanical inventories, rare plant surveys, and mitigation strategies for rare species. He also conducts inventories and surveys of small and large mammals, invertebrates, amphibians, and birds.

- Ryan Durand, M.Sc., R.P.Bio. – Mr. Durand is ecologist/project manager with over 20 years of experience. He has worked throughout western and northern Canada, including British Columbia, Nunavut, Northwest Territories, and Saskatchewan, primarily on energy and mining projects. He specializes in vegetation inventories, wetland and ecosystem classification and mapping, and watercourse mapping and assessments. He is proficient in air photo interpretation and GIS mapping, having completed over 50 mapping projects (encompassing over 8 million hectares) including Terrestrial Ecosystem Mapping, Predictive Ecosystem Mapping, Sensitive Ecosystems Inventory Mapping, and Wildlife Habitat Suitability Mapping.

VEGETATION WORK PLAN

EcoLogic has reviewed the compensation and offset plans contained within two documents:

- Application for Authorization under Paragraphs 34.4(2)(b) and 35(2)(b) of the *Fisheries Act* (Non-Emergency Situations); and
- Fish Habitat Compensation Plan Pursuant to Section 27.1 of the Metal and Diamond Mining Effluent Regulations.

In addition, EcoLogic has reviewed comments received from Project stakeholders and reviewers on the plans.

As part of a June-July 2022 field visit (timing dependant on plant phenology), EcoLogic proposes to visit the following locations (see attached map):

- Mathews Creek,
- Murray Creek,
- Greer Creek,
- Creek 661; and
- Lake 15/16 Connection Channel.

At each location, EcoLogic will conduct the following assessments:

- An assessment of existing vegetation diversity and abundance following standard provincial protocols, such as the intuitive meander technique (a standard methodology for rare plant surveys in BC). The intuitive meander protocol was selected to align with the Province of BC's recommended survey methods for rare plants and lichens (see RISC Standards, Standards for Components of British Columbia's Biodiversity No. 43). This approach balances survey coverage with concentrating efforts in more biologically diverse or specialized ecosystems, and also permits the compilation of comprehensive species lists across multiple ecosystem strata. The intuitively controlled meander can be modified to accommodate different levels of survey intensity by varying the survey time at the survey location or proportionally in each stratum.

  - For the Murray Creek, Greer Creek, Creek 661 and Lake 15/16 locations, the focus of the vegetation assessments is to evaluate the existing re-vegatation and vegetation management plans proposed as part of fish offset and compensation planning, rather than to complete an exhaustive inventory of the floral community. This survey will provide a summary of plant species at the site to inform the selection of species that may be used in revegetation efforts. A particular focus will be placed on identifying appropriate native willow (*Salix* sp.) and graminoid species for restoration efforts so that any ecosystems that become established will be reflective of natural conditions. Surveys will be extended into areas of natural emergent and riparian vegetation adjacent to the sites to determine the species composition that would most closely resemble adjacent ecosystems, as well as identify potential sources of propagation material.
  - For Mathews Creek, in additional to achieving the previous objective, additional plot-based surveys will be completed to augment the wetland classification and mapping exercise. The survey coverage will be dictated by the selected mapping survey intensity.

- An evaluation of existing conditions that may influence the success of proposed planting or revegetation plans (e.g., evidence of livestock activity, presence and density of agronomic species).
- Documenting the location(s) and magnitude of invasive plant infestations at each site, including a summary of invasive species, their abundance, and their spatial extent (including georeferencing of population boundaries, where appropriate). The invasive plant surveys will be based around the IAPP list, and will incorporate additional species that are on the regional list Northwest Invasive Plant Council.
- All occurrences of rare or at-risk plants at the site, as well as any ecosystems that may potentially support such species, will also be recorded; these data will be submitted to the B.C. Conservation Data Centre (CDC) in accordance with their standard data submission protocols. EcoLogic recommends that any collected voucher specimens (depending on population size) and photo documentation of rare or at-risk plants be submitted to the herbarium at the University of British Columbia (UBC) or submitted to the iNaturalist citizen science platform (www.inaturalist.org), respectively.
- Documenting recommendations for potential site-specific treatments for all offsetting locations (e.g. tilling or otherwise removing the pressure from agronomic species to compete with native plants) that could be implemented prior to riparian area planting or other site vegetation planting.

Deliverables will include:

- Summary list of plant species observed at each site, with optimal species for revegetation identified.

- Georeferenced photo documentation of invasive plants and their populations. Invasive plant data will be uploaded to the provincial database.
- Georeferenced photo documentation of rare or at-risk plants and their populations.
- Spatial data, including polygons and points related to invasive, rare, or at-risk plant locations.
- Spatial recommendations for potential site treatments for all offsetting locations (including updates to existing planting plans) and associated monitoring requirements.
- Recommended changes to existing planting or revegetation measures (e.g., species selection, planting densities), including plant protection measures (e.g., livestock exclusion, browse protection).

WORKSHOPS

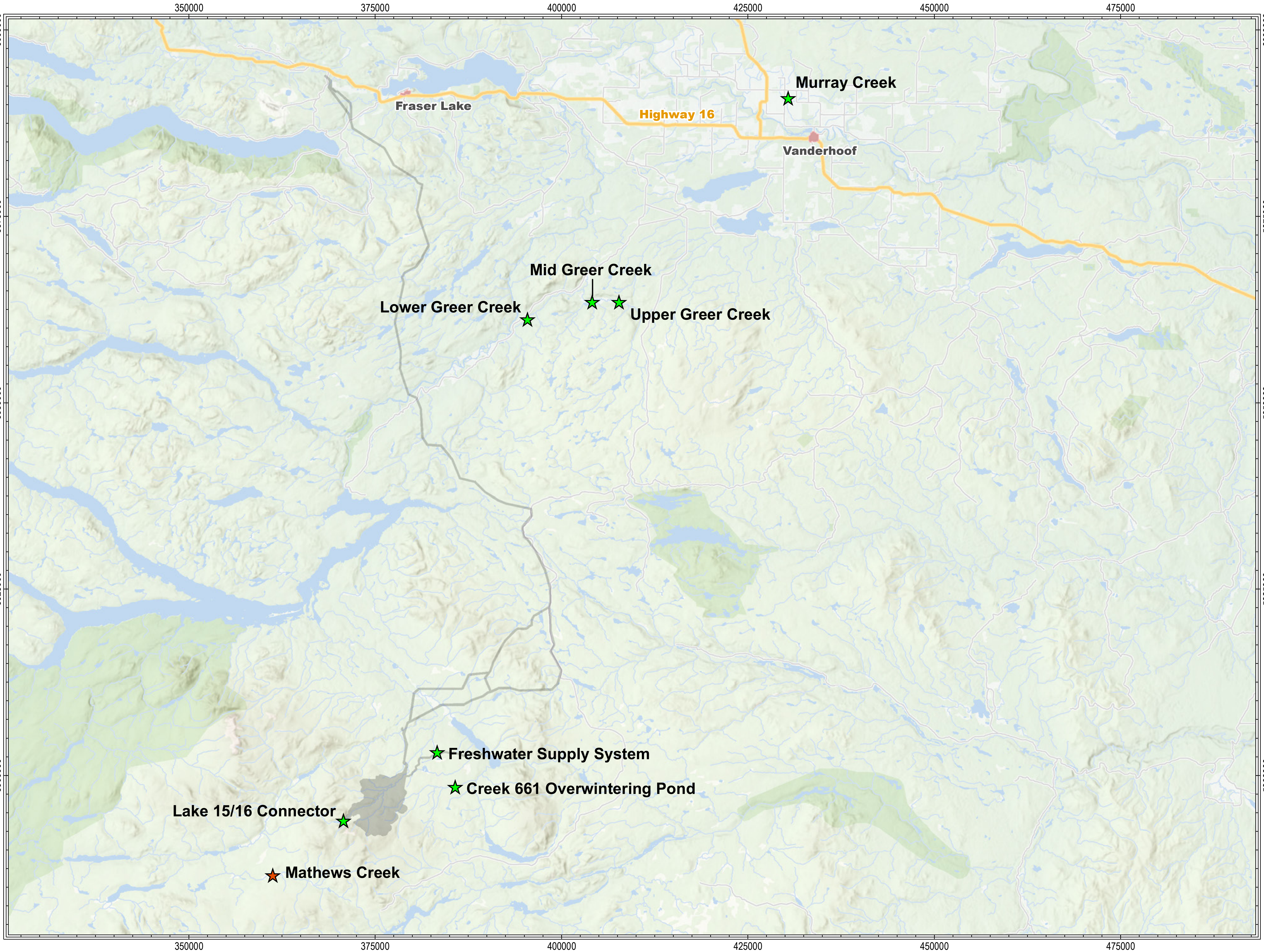
EcoLogic scientists will deliver a one-day vegetation and wetland workshop at the BW Gold project site during the middle of the field program with participation from all field work participants on wetland ecology and riparian plant identification based in the Mathews Creek area. The workshop logistics will be coordinated by BW Gold. Key topics will include:

- wetland function;
- wetland indicators (e.g., soil conditions, obligate wetland plants);
- identification and delineation of riparian areas;
- plant identification; and
- planning and executing reclamation and restoration activities.

EcoLogic will conduct an additional half-day workshop to help align all on-site consultants working on vegetation and wetland surveys on protocols and procedures.

SCHEDULE

- Review current fish offset plans and planting plans (February 2022)
- Develop workplan for vegetation field work and incorporation into overall project plans (Feb-March 2022)
- Field visit for vegetation surveys (four 10-hr days, two people) and two workshops (June-July 2022)
- Project reporting (August-September 2022)



Legend

- Proposed offsetting location (Schedule 35)
- Proposed offsetting location (Schedule 2)
- Mine area footprint
- Population centre
- Lake
- Park or protected area
- Highway
- Road
- Watercourse

Scale 1:500000
UTM Zone 10
NAD 1983 Datum

0 5 10 15 kilometres

Prepared For:

CLIENT: Artemis Gold Inc.
PROJECT: Blackwater
DRAWN: B. Elder
CHECKED: M. Sotiropoulos
PROJECT: 2006501
DATE: Mar 23, 2021

Prepared by:

Proposed Offsetting Locations

FIGURE 1

Document Path: G:\Shared drives\Projects 2020\20065 - Artemis Gold Inc\2006501 - Blackwater Project 2020\Mapping\Figures\5_ArcGIS\DFO Report\Proposed Offsetting Locations.mxd

Appendix T

Davidson Creek Temperature Normal Range Memo

470 Granville Street, Suite 630, Vancouver, BC V6C 1V5
Tel: 604-629-9075 | www.pecg.ca

Memorandum

Date: May 15, 2021
Project #: 2006501

To: Ryan Todd and Sachi de Souza, Blackwater Gold Ltd.
From: Dave Huebert, Palmer
cc: Irene Tuite, Rick Palmer, Ian MacLeod, Palmer; Boris Fichot, Greg Smyth, Knight Piesold

Re: Davidson Creek Temperature Normal Range
Assessment of Project Effects to Kokanee Spawning Habitat

1. Introduction

BW Gold Ltd. (BW Gold) is proposing to develop the Blackwater Project (the Project), which will consist of an open pit mine, a Tailings Storage Facility (TSF), and other mine-related infrastructure. The Project is situated approximately 160 km southwest of Prince George, B.C, and is primarily located within the 78 km^2 Davidson Creek watershed.

Davidson Creek flows within a thick surficial sequence of unconfined glaciofluvial sand and gravel and has been identified as a groundwater fed system (KP 2016a). Groundwater discharge has been estimated to contribute approximately 30% of the flow in Davidson Creek during spring freshet and greater than 90% of flow from September to March (KP 2014). The groundwater discharge therefore supports spawning and rearing life processes for fish and aquatic life by sustaining in-stream base-flow requirements during times of low surface runoff, and by maintaining minimum stream temperature during periods of ice-cover.

Both Kokanee Salmon (*Oncorhynchus nerka*) and Rainbow Trout (*Oncorhynchus mykiss*) spawn in Davidson Creek: however, groundwater likely plays a more important role for Kokanee Salmon, who spawn in mid-summer with eggs incubating in the gravel during the winter (when the embryos are at risk from freezing) and fry emerging from spawning gravels in the spring (May or June). Kokanee Salmon spawn in middle to lower Davidson Creek approximately 10 km to 15 km downstream of the mine infrastructure.

Construction of the Tailings Storage Facility (TSF) and other mine infrastructure is expected to reduce streamflow in Davidson Creek. This reduction in flow is anticipated to result in a measurable loss of flow in the middle to lower reaches of Davidson Creek to below in stream flow requirements. To offset the potential loss of fish habitat associated with flow reductions, BW Gold is proposing to construct a Freshwater Supply System (FWSS) to augment flows in Davidson Creek, downstream of the mine footprint. The FWSS will consist of a pipeline that will pump water from Tatelkuz Lake, and a freshwater storage reservoir (FWR) adjacent to Davidson Creek that will store water sourced from Tatelkuz Lake and from the upper portions

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of Davidson Creek. Water will then be released from the storage reservoir into Davidson Creek so that a streamflow regime downstream of the TSF will meet a defined instream flow needs (IFN) schedule (AMEC 2015; Palmer 2021). The IFN identifies the timing of the streamflow rate in Davidson Creek that will be required to provide adequate habitat to instream aquatic species throughout the year.

The use of water from Tatelkuz Lake to augment flows, however, has the potential to increase the surface water temperature in Davidson Creek to beyond normal range, particularly in September and October. This has the potential to increase the rate of egg development of Kokanee Salmon such that the alevins develop and release too early in the spring season, thus jeopardizing spawning success.

To address this concern, the objective of the following memo is to define the current (2014-2020) normal range of surface water temperature in middle to lower Davidson Creek and to compare this with the modelled temperature of water released from the FWR, particularly during September and October. The purpose is to determine whether the temperature in middle to lower Davidson Creek will be increased to the extent that egg development and spawning success of Kokanee Salmon might be affected.

2. Normal Temperature Range in Davidson Creek

2.1 Surface Water Temperature Record

The recent period of record for temperature in middle and lower Davidson Creek includes measured daily average temperatures from April 2014 to December 2020 inclusive for four sites (Table 1), although none of the sites have a complete data record for the entire period. The most upstream site discussed in this memo is site H4B, which is just downstream of the Access Road, and the most downstream is site ST-08KO, which is just upstream of the confluence with Chedakuz Creek: the distance between site H4B and site ST-08KO is approximately 5 km. The four temperature monitoring sites discussed in this memo are surface water sites located in shallow riffle sections of Davidson Creek (KP 2020).

Table 1. Middle and Lower Davidson Creek Temperature Stations

Station ID	Easting	Northing	Elevation (m)	Drainage Area (km^2)
*H4B	381893	5904051	1041	61
ST-16KO	383118	5906374	974	70
ST-15KO	383694	5907253	947	75
ST-08KO	384257	5907788	937	76

**Hydrometric Station*

Source: Knight-Piesold Fulcrum database

2.2 Spatial Correlation

The average daily surface water temperature in middle to lower Davidson Creek is highly correlated moving upstream to downstream and the closer two sites are the higher the correlation. From April to October through the period of record, the correlation coefficient for comparison of temperature was estimated at 0.962 (Figure 1) for the sites furthest apart (upstream H4B vs downstream ST-08KO), and 0.999 (Figure 2) for the sites closest together (upstream ST-15KO vs downstream ST08KO).

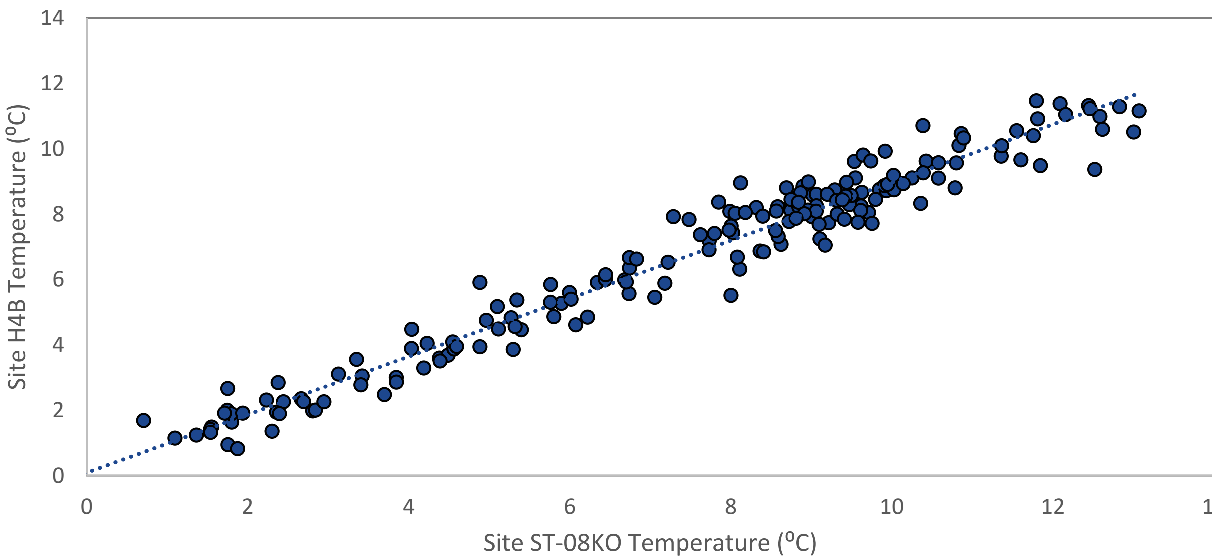

Figure 1. Median Daily Average Temperature from April to October at Upstream Site H4B vs Downstream Site ST-08KO

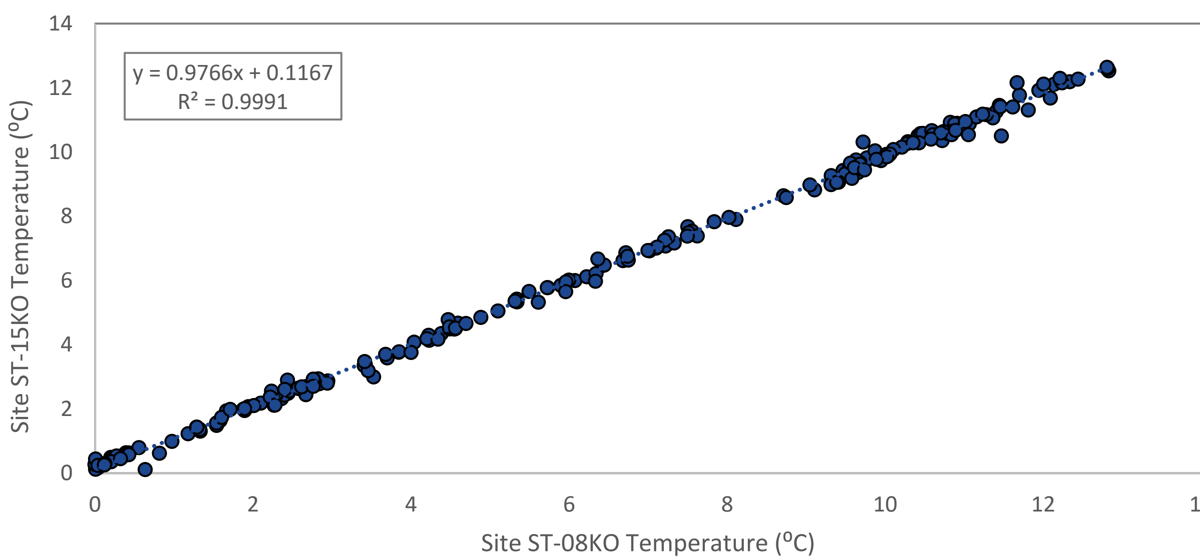

Figure 2. Median Daily Average Temperature from April to October at Upstream Site ST-15KO vs Downstream Site ST-08KO

2.3 Seasonal Cycles

Surface water temperatures in middle to lower Davidson Creek fluctuate through the seasons, with increasing daily average temperatures in spring to a temperature maximum in mid-July to mid-August (Julian Day ~195 to ~230), a fall temperature recession with steadily decreasing daily average temperatures in late summer to early fall, and with minimum daily average temperatures of approximately 0ºC through the winter months (Figure 3).

In contrast, shallow groundwater in the Davidson Creek watershed is relatively cool and does not vary seasonally to the same extent. In a 2016 study it was reported that shallow groundwater in the watershed varied from 4.0ºC to 4.5ºC, with a yearly mean of approximately 4.3ºC (KP 2016b).

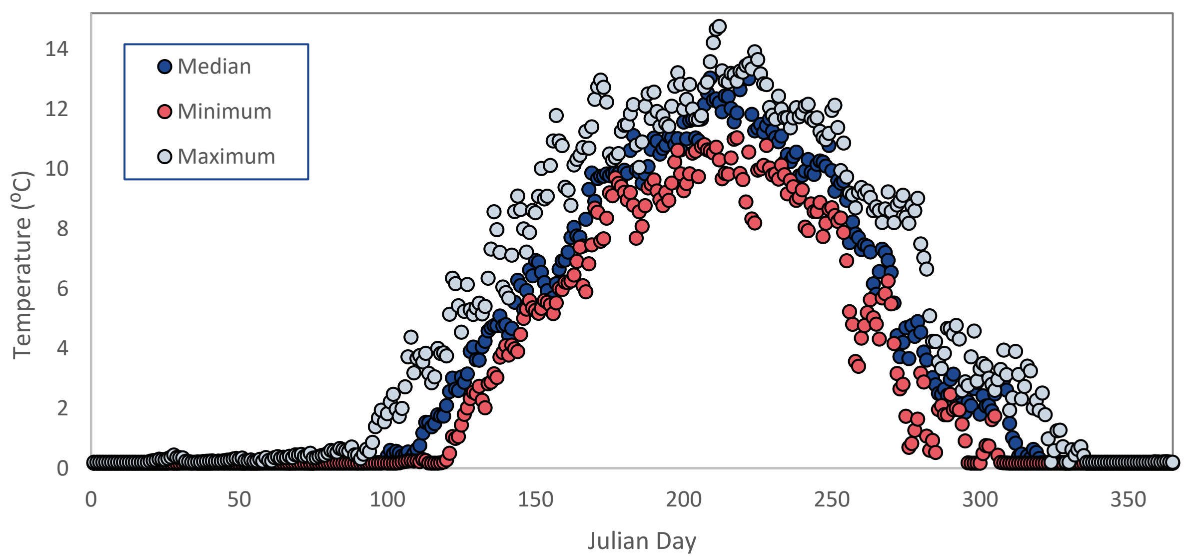

Figure 3. Daily Average Temperatures in Davidson Creek (ST-08KO) through the Period of Record (2014-2020).

The correlation in average daily surface water temperatures between monitoring sites, and the disparity between the surface water temperature data and the groundwater temperature data suggests that watershed processes, such as air temperature, rather than localized processes, such as site-specific groundwater upwelling or surface water runoff, control surface water temperature in middle to lower Davidson Creek. Regression of average daily air temperature with average daily water temperature during the fall temperature recession supports this assessment: for example, at site ST-08KO the correlation coefficient of air temperature vs water temperature was R^2=0.89 for September and October (Figure 4).

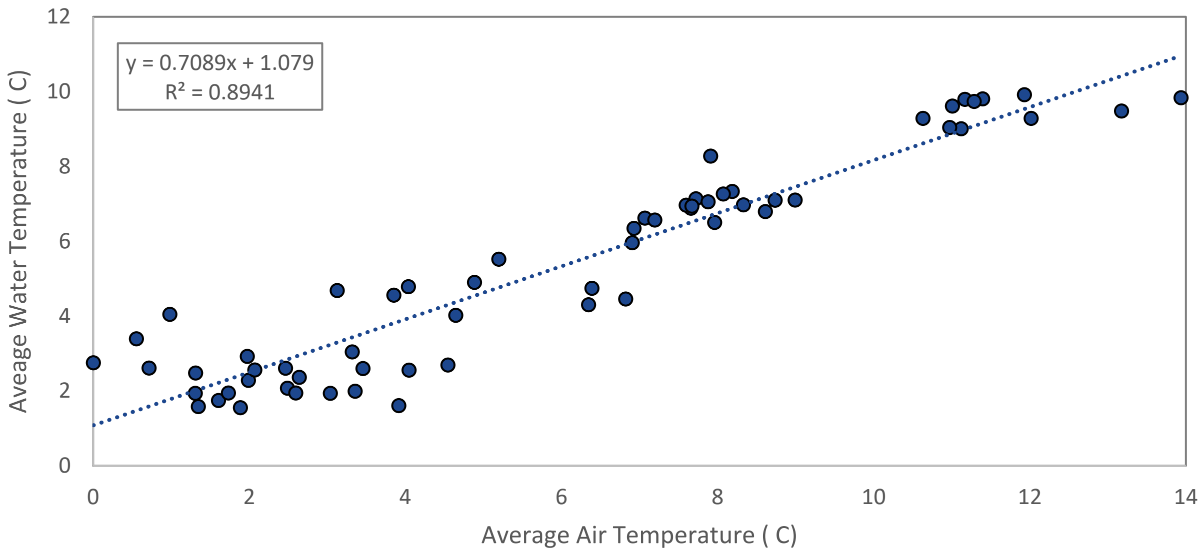

Figure 4. Average Daily Water Temperatures in Davidson Creek (ST-08KO) vs Average Daily Air Temperatures for September and October through 2016 to 2020.

2.4 Summer Maximum

There is a gradual increase in the summer maxima moving from upstream at H4B to downstream at ST-08KO, with the mean daily average temperature ranging from a low of 10.1ºC at H4B to a high of 11.5ºC at ST-08KO, and the maximum daily average temperature increasing from 12.7ºC at site H4B to 14.6ºC at Site ST-08KO (Table 2). These summertime average daily temperatures classify Davidson Creek as a cold-water environment throughout the entire middle to lower reaches of the creek (maximum daily temperature 11ºC to 15ºC; Hillman et al. 1999).

Table 2. Daily Average Temperature Summer Maxima in Davidson Creek

Station ID	Maximum Temperature (ºC)	Median Temperature (ºC)	Mean Temperature (ºC)	Standard Deviation (ºC)	Coefficient of Variation (%)
H4B	12.7	10.2	10.1	1.0	9.4
ST-16KO	13.7	10.9	10.9	1.1	10.3
ST-15KO	14.4	11.4	11.4	1.2	10.8
ST-08KO	14.6	11.5	11.5	1.2	10.9

2.5 Fall Recession

Through September (Julian Day 244 to 273) and October (Julian Day 274 to 304) there is a steady linear (R^2 = 0.92 to 0.94) decline in the maximum average daily surface water temperature through the middle to lower reaches of Davidson Creek, from approximately 10ºC to 12ºC at the beginning of September, to a low of approximately 2ºC at the end of October (Figure 5). Similar to the average daily temperature during the summer maxima (Section 1.4), the lowest temperatures are recorded at upstream site H4B and the highest temperatures are recorded at the most downstream site at ST-08KO (Figure 5).

Based on the daily average temperature data through the period of record (2014 to 2020) and the linear regressions calculated from the maximum daily average temperature (Figure 5), the upper bound of normal range for the maximum daily average temperature was calculated as the 95th percentile (%ile) of the residuals of the linear regressions. These values are estimates of the maximum average daily temperature at the upper bound of the normal range for each site for each date between September 1 and October 31 inclusive (Table 3, Table 4).

The upper bound of normal range for the maximum daily average temperature decreased steadily from approximately 12ºC at the beginning of September to approximately 9ºC at the end of September/beginning of October (Table 3, Table 4), and to approximately 5ºC at the end of October (Table 4). Similar to the average daily temperature during the summer maxima (Section 1.4), the lowest temperature occurred at upstream site H4B and the highest temperature occurred at the most downstream site at ST-08KO (Table 3 and Table 4).

The mean monthly upper bound of normal range for the maximum daily average temperature in middle to lower Davidson Creek ranged from 10.1ºC to 10.9ºC in September (Table 3), and from 6.8ºC to 7.1ºC in October (Table 4).

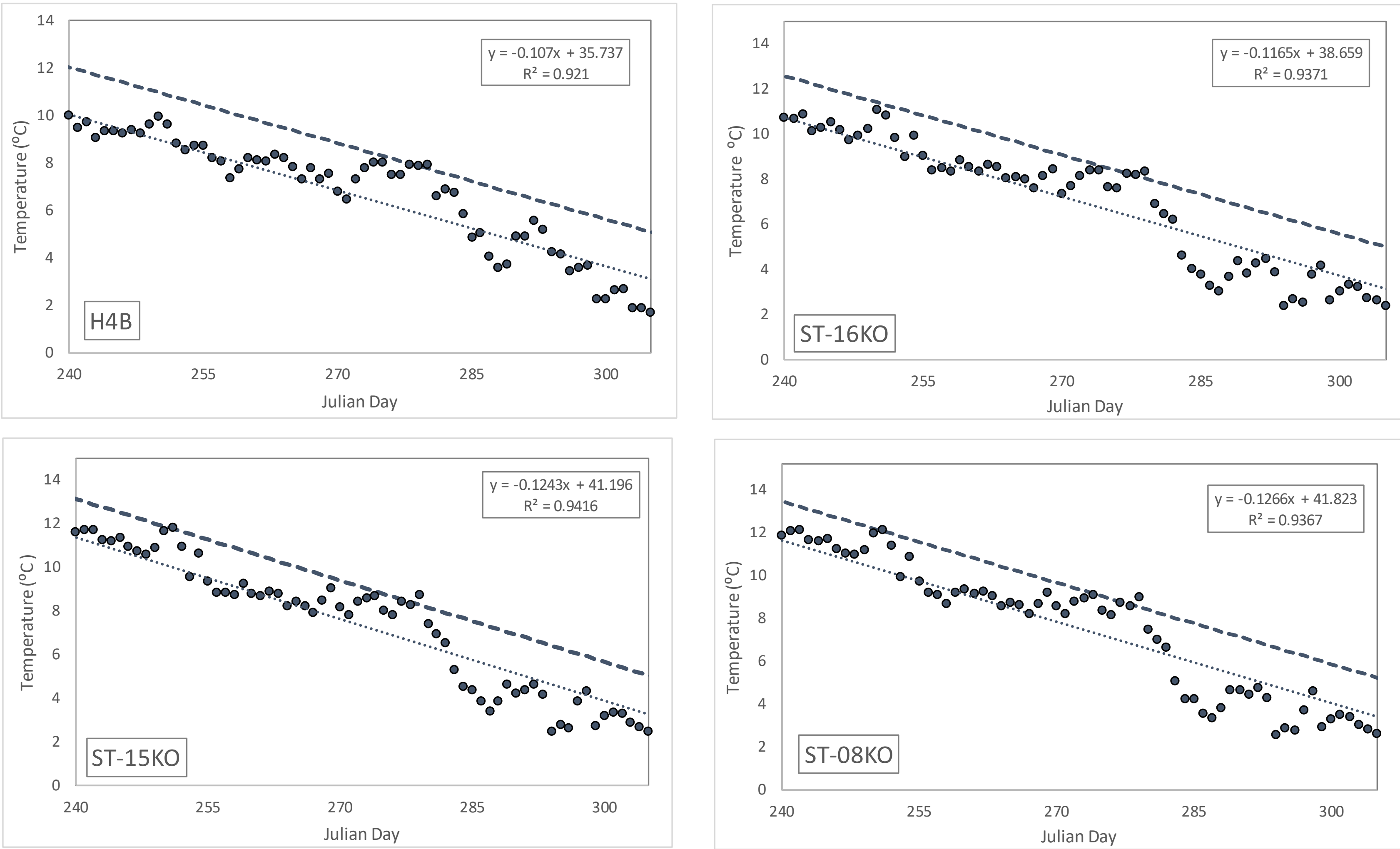

Figure 5. Maximum (dashed line = 95%ile) Average Daily Temperature During September and October in Davidson Creek

Table 3. Maximum (95%ile) Average Daily Temperature during September in Davidson Creek.

Date	Julian Day	Site ST-08KO	Site ST-15KO	Site ST-16KO	Site H4B
SEP01	244	12.8	12.6	12.1	11.6
SEP02	245	12.6	12.5	12.0	11.5
SEP03	246	12.5	12.4	11.9	11.4
SEP04	247	12.4	12.3	11.8	11.3
SEP05	248	12.3	12.1	11.6	11.2
SEP06	249	12.1	12.0	11.5	11.1
SEP07	250	12.0	11.9	11.4	11.0
SEP08	251	11.9	11.8	11.3	10.9
SEP09	252	11.7	11.6	11.2	10.8
SEP10	253	11.6	11.5	11.1	10.7
SEP11	254	11.5	11.4	10.9	10.5
SEP12	255	11.4	11.3	10.8	10.4
SEP13	256	11.2	11.1	10.7	10.3
SEP14	257	11.1	11.0	10.6	10.2
SEP15	258	11.0	10.9	10.5	10.1
SEP16	259	10.9	10.8	10.4	10.0
SEP17	260	10.7	10.6	10.2	9.9
SEP18	261	10.6	10.5	10.1	9.8
SEP19	262	10.5	10.4	10.0	9.7
SEP20	263	10.4	10.3	9.9	9.6
SEP21	264	10.2	10.1	9.8	9.5
SEP22	265	10.1	10.0	9.7	9.4
SEP23	266	10.0	9.9	9.5	9.3
SEP24	267	9.9	9.8	9.4	9.2
SEP25	268	9.7	9.6	9.3	9.1
SEP26	269	9.6	9.5	9.2	8.9
SEP27	270	9.5	9.4	9.1	8.8
SEP28	271	9.3	9.3	9.0	8.7
SEP29	272	9.2	9.2	8.8	8.6
SEP30	273	9.1	9.0	8.7	8.5
Mean	----	10.9	10.8	10.4	10.1

Table 4. Maximum (95%ile) Average Daily Temperature during October in Davidson Creek.

Date	Julian Day	Site ST-08KO	Site ST-15KO	Site ST-16KO	Site H4B
OCT01	274	9.0	8.9	8.6	8.4
OCT02	275	8.8	8.8	8.5	8.3
OCT03	276	8.7	8.7	8.4	8.2
OCT04	277	8.6	8.5	8.3	8.1
OCT05	278	8.5	8.4	8.1	8.0
OCT06	279	8.3	8.3	8.0	7.9
OCT07	280	8.2	8.2	7.9	7.8
OCT08	281	8.1	8.0	7.8	7.7
OCT09	282	8.0	7.9	7.7	7.6
OCT10	283	7.8	7.8	7.6	7.4
OCT11	284	7.7	7.7	7.4	7.3
OCT12	285	7.6	7.5	7.3	7.2
OCT13	286	7.4	7.4	7.2	7.1
OCT14	287	7.3	7.3	7.1	7.0
OCT15	288	7.2	7.2	7.0	6.9
OCT16	289	7.1	7.0	6.9	6.8
OCT17	290	6.9	6.9	6.7	6.7
OCT18	291	6.8	6.8	6.6	6.6
OCT19	292	6.7	6.7	6.5	6.5
OCT20	293	6.6	6.5	6.4	6.4
OCT21	294	6.4	6.4	6.3	6.3
OCT22	295	6.3	6.3	6.2	6.2
OCT23	296	6.2	6.2	6.0	6.1
OCT24	297	6.1	6.0	5.9	5.9
OCT25	298	5.9	5.9	5.8	5.8
OCT26	299	5.8	5.8	5.7	5.7
OCT27	300	5.7	5.7	5.6	5.6
OCT28	301	5.5	5.5	5.5	5.5
OCT29	302	5.4	5.4	5.3	5.4
OCT30	303	5.3	5.3	5.2	5.3
OCT31	304	5.2	5.2	5.1	5.2
Mean	----	7.1	7.0	6.9	6.8

3. Potential Effect of the FWR on Davidson Creek Temperature

These data provide an understanding of baseline temperature conditions in Davidson Creek and will be compared with an updated water temperature assessment that is currently being updated to reflect the most current mine plan and water management plan.

4. Certification

This report was prepared, reviewed, and approved by the undersigned:

Prepared By: <original signed by>

Dave Huebert., R.P.Bio., P.Biol., Ph.D.
Senior Environmental Scientist

Reviewed By: <original signed by>

Ian MacLeod, B.Sc., R.P.Bio., P.Biol.
Senior Fisheries Biologist

Approved By: <<original signed by>

Rick Palmer, M.Sc., R.P.Bio.
President and CEO, Senior Fisheries Biologist

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References

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Appendix U

Groundwater Seepage in Creek 661 Memo (DFO IR #14)

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Tel: 647-795-8153 | www.pecg.ca

Memorandum

Date: March 18, 2022

Project #: 2006501

To: Kevin DeBoer, Fisheries and Oceans Canada

From: Jason Cole, M.Sc., P.Geo. and Nolan Boyes, M.Sc., P.Geo., Palmer

Cc: Michael Brierley, Dan McParland, Robin McKillop, and Irene Tuite, Palmer
Ryan Todd, Travis Desormeaux, BW Gold Ltd.

Re: Blackwater Gold Project Application for a *Fisheries Act* Authorization
DFO Adequacy Review Letter – Information Request #14 Groundwater Seepage in Creek 661
DFO File: 21-HPAC-01447

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1. Introduction

On December 6, 2021, Palmer, on behalf of BW Gold Ltd (BW Gold), submitted an application to Fisheries and Oceans Canada (DFO) for a *Fisheries Act* Authorization for the Blackwater Gold Project (the Project) near Vanderhoof, British Columbia. On January 21, 2022, BW Gold received a letter from DFO acknowledging receipt of the application and requesting addition information required by DFO for the application to be complete.

The purpose of this memorandum is to fulfill the following information request (IR) #14 from DFO's letter:

Confirm that the proposed construction of the Creek 661 overwintering pond will not result in changes to groundwater levels with affects to Creek 661 mainstem flows.

Palmer is pleased to present this technical memorandum presenting quantification of estimated groundwater seepage from Creek 661 into the proposed Overwintering Pond (OWP) for the Project. An OWP has been proposed south of Creek 661 to benefit fish habitat during the winter season (**Appendix A**). Due to the proximity of the OWP to Creek 661, Fisheries and Oceans (DFO) has raised concerns regarding the potential for baseflow loss following construction of the pond as per IR #14 above and discussed at meeting (conference call) with DFO, Palmer, and BW Gold on February 22, 2022.

2. Response to DFO Information Request #14

Subsurface material in the alluvial valley is expected to consist of poorly sorted silts and sands, with some clay, gravel and cobbles, based on examination of localized exposures in creek banks and a history of beaver-related impoundments in the area. Groundwater seepage into the OWP is meant to help regulate the thermal regime and dissolved oxygen levels within the pond, especially during winter. Any storage of groundwater seepage into the OWP is temporary and will be released into Creek 661 at the outlet of the OWP such that no baseflow is lost from the creek-valley system. It is estimated that the OWP will only intercept groundwater seepage related to Creek 661 for approximately 120 m, limiting the area of influence of local groundwater levels and potential effects to Creek 661 flows. The estimated average flows of Creek 661 are 300 Litres/second (L/s), with an estimated winter low flow of 100 L/s.

To estimate the amount of groundwater likely to seep from Creek 661 into the OWP, we applied Darcy's Law (1856) for groundwater flow through a porous medium:

$$Q = KiA$$

Q	=	*Groundwater Flux or Groundwater Seepage (m^3/s)*	
K	=	*Hydraulic Conductivity (m/s)*	
A	=	*Area (m^2)*	*= 4.13 m wide * 120 m long*
			= 496 m^2
i	=	*Hydraulic Gradient (change in head divided by the change in distance):*	

dH / dL = (1053.8 mASL – 1053.13 mASL) / 20 m = 0.0335 m/m

A range of hydraulic conductivity values between $1x10^{-5}$ m/s and $1x10^{-7}$ m/s was used to represent potential variability in the surficial soils in the alluvial valley based on our understanding of the depositional environment of the OWP location. Additional soils testing is planned for spring 2022 to refine our understanding of soil composition and measure the in-situ hydraulic conductivity of the soils at the OWP location. The seepage area was calculated using the maximum depth of the pond and the approximate length of the creek adjacent to the OWP. Finally, the horizontal hydraulic gradient was calculated using groundwater elevations provided in **Appendix A** and utilizing an average distance of 20 m from the creek to the OWP.

Results of the application of Darcy's Law for groundwater seepage are provided in **Table 1**. The groundwater seepage to the OWP was calculated to range from 0.17 – 0.0017 L/s. In the most conservative scenario, applying a hydraulic conductivity value of 1 x 10^{-5} m/s representative of a 'clean' sand, the groundwater seepage into the OWP is calculated to be 0.17 L/s or only 0.17% of Creek 661 baseflow during winter low flow.

Based on these calculations, no impact to the baseflow of Creek 661 or local groundwater levels is anticipated even under the unlikely condition that the soils in the alluvial valley where the OWP is proposed are all 'clean' sand.

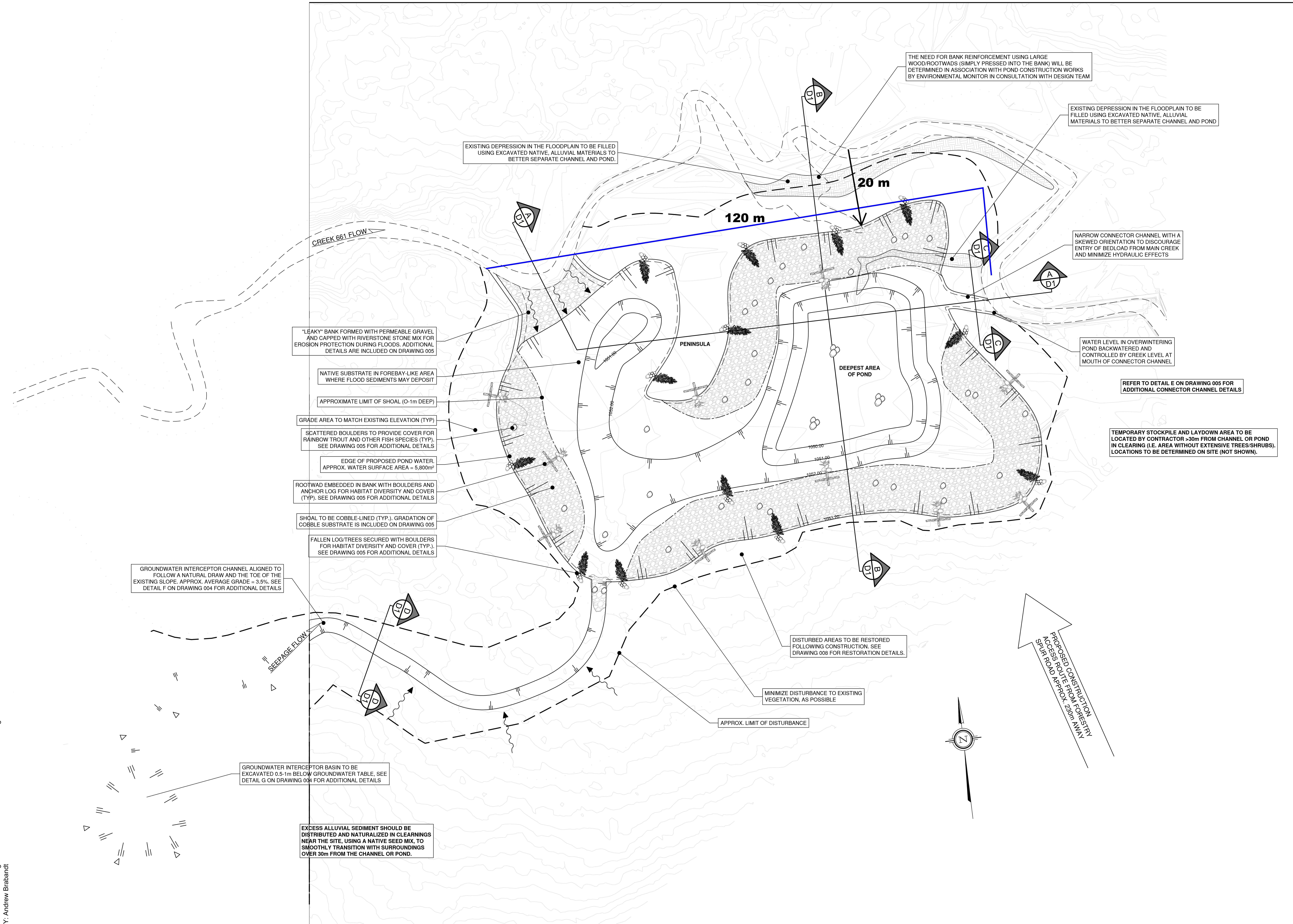
Table 1. Groundwater Seepage Summary

Hydraulic Conductivity (m/s)	Surficial Geology	Area (m^2)	Gradient (m/m)	Q (L/s)	% of Winter Low Flow
1×10^{-5}	Clean Sand	496	0.0335	**0.17**	**0.17%**
1×10^{-6}	Silty Sand	496	0.0335	**0.017**	**0.017%**
1×10^{-7}	Silt	496	0.0335	**0.0017**	**0.0017%**

Appendix A

Creek 661 Overwintering Pond Plan

NOT FOR CONSTRUCTION



LEGEND

- APPROXIMATE WATERLINE
- EXISTING EDGE OF EXTENSIVE TREES AND SHRUBS
- APPROXIMATE LIMIT OF DISTURBANCE
- APPROXIMATE LIMIT OF PROPOSED SHOAL
- PROPOSED COBBLE
- PROPOSED CONIFEROUS TREE
- PROPOSED ROOTWAD
- PROPOSED BOULDER

DESIGN OBJECTIVES & PURPOSE

OVERWINTERING HABITAT IS A KEY LIMITING FACTOR IN FISHERIES PRODUCTIVITY IN THE WATERSHED. THE PROPOSED OVERWINTERING POND IS SITUATED AT A LOCATION WITH NATURALLY HIGH GROUNDWATER TABLE AND THROUGH-FLOW TO MINIMIZE WINTER ICE COVER THICKNESS AND MAXIMIZE DISSOLVED OXYGEN. DEEP WATER (>2m), COBBLE/BOULDER SUBSTRATES AND OVERHEAD COVER ARE INCORPORATED INTO THE POND DESIGN TO MAXIMIZE THE HABITAT QUALITY. A PROPOSED GROUNDWATER INTERCEPTOR CHANNEL FOLLOWS A NATURAL DRAW IN THE VALLEY SIDE, WHERE GROUNDWATER IS CLOSEST TO THE SURFACE. THE INTERCEPTOR CHANNEL WILL BE EXCAVATED BELOW THE GROUNDWATER TABLE WITH THE AIM OF CONCENTRATING GROUNDWATER DISCHARGE INTO THE POND THROUGHOUT THE YEAR, PARTICULARLY DURING WINTER MONTHS.

DESIGN TARGETS

- WATER SURFACE AREA OF 5,800m².
- MIN. POND DEPTH OF 2m.
- WOODY DEBRIS AND BOULDER FISH HABITAT FEATURES.

NOTES:

1. SITE PLAN PREPARED BY DWB CONSULTING SERVICES LTD. BASED ON BLENDING RESULTS OF LOCAL RTK GPS SURVEY, CONDUCTED ON SEPTEMBER 8, 2016 WITH BROADER, HIGH-RESOLUTION, LIDAR-DERIVED ELEVATION DATA ACQUIRED BY EAGLE MAPPING LTD. ON AUGUST 8-9, 2011. STATIC DATA WAS OBTAINED AND CORRECTED TO CSRS-PPP (CANADIAN SPATIAL REFERENCE SYSTEM PRECISE POINT POSITIONING). COORDINATE SYSTEM NAD83 UTM ZONE 10.
2. WATERLINE AND TREELINE INTERPRETED FROM PHOTOGRAMMETRY AND RTK GPS POINTS.
3. DESIGN REVIEW AND DRAFTING BY ONSITE ENGINEERING LTD. DESIGN BY PALMER.
4. REFER TO DRAWING 004 FOR TYPICAL DETAILS FOR CONNECTOR CHANNEL AND INTERCEPTOR CHANNEL.
5. REFER TO DRAWING 005 FOR TYPICAL DETAILS FOR PROPOSED SALVAGED CONIFEROUS TREE, ROOTWAD, BOULDER, COBBLE GRADATION AND LEAKY BANK.
6. REFER TO DRAWING 006 TO 008 FOR EROSION SEDIMENT CONTROL AND SITE ISOLATION DETAILS.
7. REFER TO DRAWING 008 FOR RIPARIAN RESTORATION AND ENHANCEMENT DETAILS.

BC 1C
1-800-474-6886

REV NO	REVISIONS	DATE	DRAWN	APPR'D
A	ISSUED FOR REVIEW	MAR 15, 2021	JL	MF
B	ISSUED FOR REVIEW	APR 1, 2021	JL	MF
C	ISSUED FOR REVIEW	APR 16, 2021	JL	MF
D	ISSUED FOR PERMIT APPROVAL	MAY 26, 2021	JL	MF

BW GOLD LTD
a subsidiary company of Artemis Gold Inc

SCALE: 1:400 (0 – 8 – 24m)

DESIGNED:	DM & RM
DRAWN:	JL
CHECKED:	MF
SURVEYED:	-
DATE:	MAY 2021

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BW GOLD LTD

BLACKWATER PROJECT - SCHEDULE 35 FISHERIES OFFSETTING PLAN

CREEK 661 OVERWINTERING POND

OVERWINTERING POND PLAN

CLIENT PROJECT NO. 2006501
OEL PROJECT NO. 1824-3-10
DRAWING NO. 003
SHEET: 3 OF 10
REV D

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