Appendix 5.1.2.6E
Blackwater Gold Project
Effects Assessment of Davidson Creek Flow Augmentation on Homing of Salmonid Fish

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ACRONYMS

Abbreviations and Units of Measure	Definition
ANOVA	Analysis of Variance
Agency (the)	Canadian Environmental Assessment Agency
ECD	Environmental Control Dam
FSS	Freshwater Supply System
MDS	Multi-Dimensional Scaling
New Gold	New Gold Inc.
Project	Blackwater Gold Project
TSF	Tailing Storage facility

EXECUTIVE SUMMARY

New Gold Inc. is proposing to develop the Blackwater Gold Project (the Project); a low grade gold deposit 110 km southwest of Vanderhoof, BC. The footprint of the Project will result in the temporary containment or diversion of the headwaters of Davidson Creek and reduce the watershed area to 42% of its original condition during operations and closure. This area of containment is the minimum area required to meet the water needs of the Project, including tailings management, and provide for seepage control.

Davidson Creek provides spawning, incubation, and juvenile rearing habitat for two populations of rainbow trout (*Oncorhynchus mykiss*) and spawning and incubation habitat for one population of kokanee (*Oncorhynchus nerka*). Unmitigated flow reductions associated with the Project are expected to reduce available habitat for these populations. Flow augmentation of Davidson Creek with water pumped from Tatelkuz Lake is proposed to mitigate those effects. Incorporating water from a waterbody that is further upstream in the Chedakuz Creek Watershed will alter the water chemistry in Davidson Creek. This may reduce the ability of salmonid fish populations to recognize and home to natal spawning areas.

This report addresses these concerns by: (1) summarizing the scientific literature on salmonid imprinting and use of olfaction in homing; (2) assessing the differences in water chemistry between receiving waters (Davidson Creek) and source waters (Tatelkuz Lake); (3) identifying the vulnerability of rainbow trout and kokanee in Davidson Creek to change in water sources; (4) applying existing knowledge to determine the likelihood of effects to the homing of Davidson Creek salmonids; and (5) outlining a monitoring and adaptive management approach to document and mitigate potential impacts to Davidson Creek rainbow trout and kokanee.

This report concludes that the use of flow augmentation to mitigate effects to fish habitat is unlikely to disrupt homing of salmonids to spawning grounds in a way that has permanent effects. The maintenance of some home-stream water in Davidson Creek and the plastic nature of salmonid imprinting make it likely that Davidson Creek will continue to attract rainbow trout and kokanee spawners after construction of the project and during its operation. What is less certain is how far rainbow trout spawners will migrate upstream of the lower reaches of Davidson Creek against a decreasing olfactory gradient.

An adaptive management approach is recommended that incorporates two components: (1) monitor kokanee and rainbow trout populations in Davidson Creek to evaluate the nature of effects to homing; and (2) in the event of observed effects, apply management options such as adult or egg transfers or other contingency options that are available to ensure ongoing use of fish habitat.

1.0 INTRODUCTION

New Gold Inc. (New Gold) is proposing to mine a large, low-grade gold deposit in low relief terrain in central British Columbia, approximately 110 km southwest of Vanderhoof. The Blackwater Gold Project (the Project) will alter the hydrological characteristics of Davidson Creek. The construction phase will reduce the watershed area of Davidson Creek to approximately 42% of its pre-Project area due to the containment of waters draining the proposed mine site and diversion of watershed areas upstream of the mine. This area of containment is the minimum area required to meet the water needs of the Project, including tailings management, and provide for seepage control. The effect is temporary because water the natural drainage pattern will be restored at the end of the closure phase when the open pit is filled.

To mitigate the loss of fish habitat of the upper one-third of the watershed during construction, operations and closure phases, water will be pumped from Tatelkuz Lake through a 13.6 km-long water pipeline to a freshwater storage reservoir downstream of the Tailings Storage Facility (TSF) (**Figure 1-1**). Water from the reservoir will then be discharged into Davidson Creek to provide sufficient flows in the middle and lower sections of the creek to maintain fish habitat and fish populations at baseline levels.

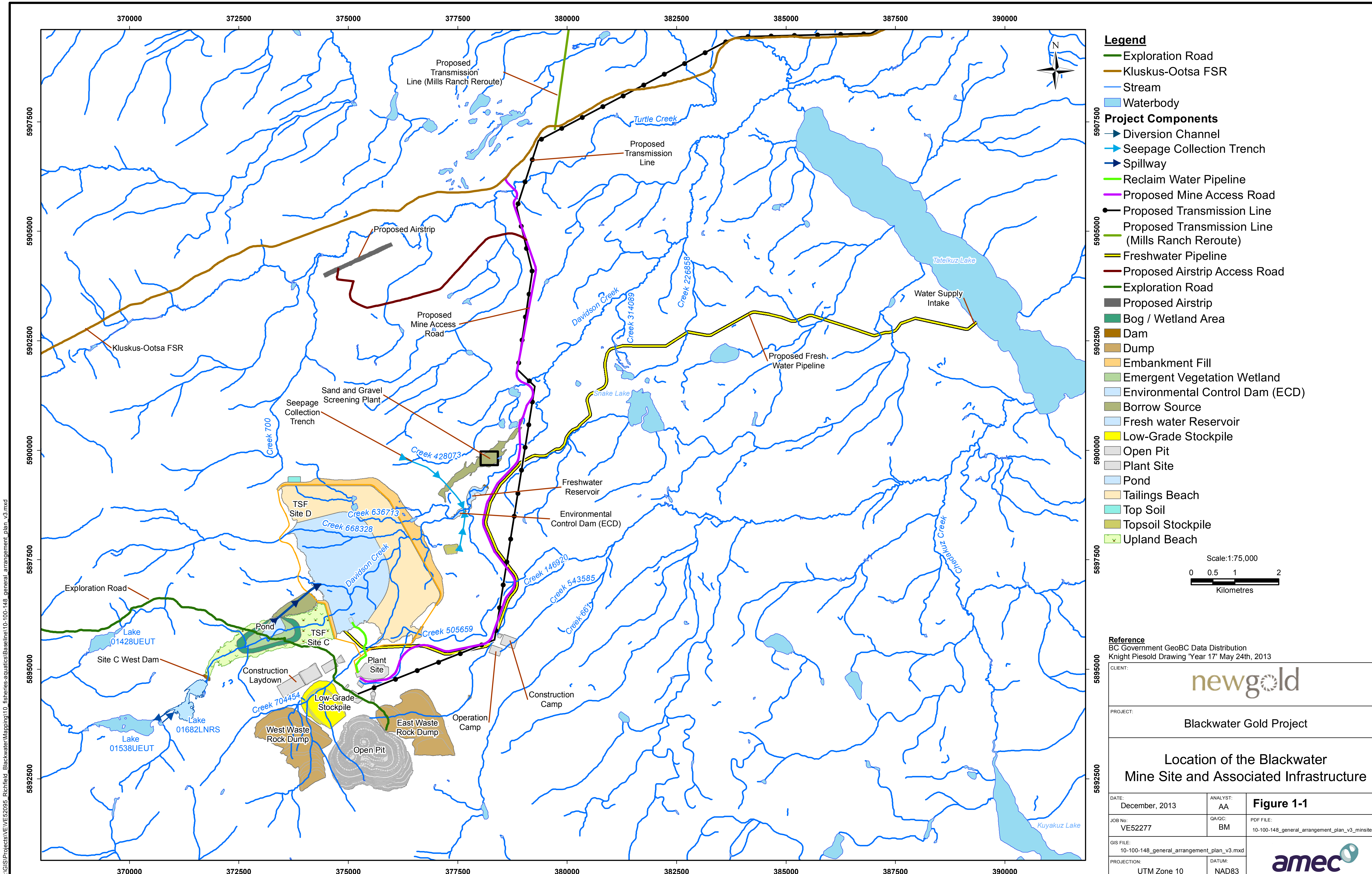
1.1 Scope and Objectives

While the flow augmentation from Tatelkuz Lake will protect fish habitat in the middle and lower sections of Davidson Creek (**Appendix 5.1.2.6D**), there are concerns that the resulting changes to water chemistry will have negative consequences to the homing ability of spawning kokanee (*Oncorhynchus nerka*) and rainbow trout (*Oncorhynchus mykiss*), which use olfaction to find their way to natal habitats (Dittman and Quinn, 1996). This assessment addresses these concerns by: (1) summarizing what is known of salmonid imprinting and use of olfaction in homing; (2) assessing the differences in water chemistry between receiving waters (Davidson Creek) and source waters (Tatelkuz Lake); (3) identifying the vulnerability of Davidson Creek fish species to olfactory disruption; (4) applying existing knowledge to determine the likelihood of effects to the homing of Davidson Creek salmonids; and (5) outlining a monitoring and adaptive management approach to document and mitigate potential impacts to Davidson Creek fish populations.

The flow augmentation to Davidson Creek also has potential ecological consequences related to altered thermal and hydrological regimes but these are addressed elsewhere in the Environmental Assessment (**Sections 5.3.2, 5.3.3, 5.3.8** and **5.3.9**).

1.2 Project Description

The major structural elements of the Project will be an open pit mine, processing plant (mill), TSF, Environmental Control Dam (ECD), access roads, transmission line, and Freshwater Supply System (FSS) (**Figure 1-1**).



Legend
Exploration Road
Kluskus-Ootsa FSR
Stream
Waterbody
Project Components
Diversion Channel
Seepage Collection Trench
Spillway
Reclaim Water Pipeline
Proposed Mine Access Road
Proposed Transmission Line
Proposed Transmission Line (Mills Ranch Reroute)
Freshwater Pipeline
Proposed Airstrip Access Road
Exploration Road
Proposed Airstrip
Bog / Wetland Area
Dam
Dump
Embankment Fill
Emergent Vegetation Wetland
Environmental Control Dam (ECD)
Borrow Source
Fresh water Reservoir
Low-Grade Stockpile
Open Pit
Plant Site
Pond
Tailings Beach
Top Soil
Topsoil Stockpile
Upland Beach
Scale:1:75,000
0 0.5 1 2
Kilometres
Reference
BC Government GeoBC Data Distribution
Knight Piesold Drawing 'Year 17' May 24th, 2013
CLIENT:
newgold
PROJECT:
Blackwater Gold Project
Location of the Blackwater Mine Site and Associated Infrastructure
DATE: December, 2013
ANALYST: AA
Figure 1-1
JOB No: VE52277
QA/QC: BM
PDF FILE: 10-100-148_general_arrangement_plan_v3_minsite.pdf
GIS FILE: 10-100-148_general_arrangement_plan_v3.mxd
PROJECTION: UTM Zone 10
DATUM: NAD83
amec
Proposed Transmission Line (Mills Ranch Reroute)
Proposed Transmission Line
Turtle Creek
Proposed Airstrip
Proposed Mine Access Road
Kluskus-Ootsa FSR
Tatelkuz Lake
Water Supply Intake
Proposed Fresh Water Pipeline
Davidson Creek
Creek 314089
Creek 226858
Snake Lake
Sand and Gravel Screening Plant
Seepage Collection Trench
Creek 700
Creek 428073
Freshwater Reservoir
Environmental Control Dam (ECD)
TSF Site D
Creek 636713
Creek 668328
Creek 146920
Creek 543585
Creek 661
Chedakuz Creek
Exploration Road
Lake 01428UEUT
Pond
TSF Site C
Creek 505659
Site C West Dam
Construction Laydown
Plant Site
Construction Camp
Creek 704454
Low-Grade Stockpile
Operation Camp
West Waste Rock Dump
East Waste Rock Dump
Open Pit
Lake 01682LNRS
Lake 01538UEUT
Kuyakuz Lake
370000 372500 375000 377500 380000 382500 385000 387500 390000
5907500 5905000 5902500 5900000 5897500 5895000 5892500
Y:\GIS\Projects\VE\VE52095_Richfield_Blackwater\Mapping\10_fisheries-aquatics\Baseline\10-100-148_general_arrangement_plan_v3.mxd

The mine site will occupy 44.3 km^2 of the headwaters of Davidson Creek Watershed. A portion of the upper watershed will not be mined and will continue to function as a lotic system. The upper reaches of Davidson Creek will be routed west to the adjacent Creek 705 Watershed. Surface and groundwater flows from mined areas of the Davidson Creek Watershed will be intercepted and directed to the TSF, which will straddle the entire midsection of the Davidson Creek Watershed when fully developed. The TSF will enable permanent storage of physically and geochemically stable tailing and waste rock at the site. No water will be discharged from the TSF until the post-closure period, which is estimated to begin in year 36 after operations begins. All groundwater from mined areas or from seepage from the TSF will be intercepted at the ECD and pumped back to the TSF.

New Gold has designed the FSS and will operate it to protect the ecological functions and values of local streams and lakes throughout the expected 17 year operation phase of the mine (year +1 to +17) and the 18 year closure phase (year +18 to +35). Post-closure will begin in year +36 when water from the TSF will begin to discharge into Davidson Creek, assuming water quality requirements will be met. At that time, water pumping from Tatelkuz Lake will cease and flow augmentation will end.

1.3 Freshwater Supply System (FSS)

The FSS is intended to provide the desired capacity and operational flexibility to meet the flow augmentation and biological objectives of the project. The FSS will consist of a water intake structure at Tatelkuz Lake, two or more in-line variable speed pumps, and a 0.6 m-diameter pipeline capable of delivering a maximum of 667 L/s. Flexibility in the system is intended to allow for pumping directly to Davidson Creek immediately below a 700,000 m^3 Freshwater Reservoir and for release from the reservoir via a spillway into Davidson Creek (**Figure 1-1**).

Water will be stored in the Freshwater Reservoir and released as needed to supplement flows in Davidson Creek. In this regard, the reservoir is designed to store and release enough water to meet high volume, rapidly varying flow requirements (i.e., flushing and channel maintenance flow needs) during the spring. The reservoir would also serve as an emergency backup water supply for Davidson Creek in the event of a breakdown in other components of the FSS.

1.4 Davidson Creek Watershed

Davidson Creek is a fourth order stream that drains 77 km^2 of the northeast slope of Mt. Davidson into lower Chedakuz Creek, just downstream of Tatelkuz Lake. Most of the Davidson Creek surface run-off comes from its headwaters because there are only a limited number of small tributary streams entering the mainstem in the middle and lower reaches. However, Davidson Creek also receives substantial groundwater inputs in its middle and lower reaches.

Davidson Creek has been divided into four sections that reflect its hydrogeomorphology and the ecology of the fish community that use the system. Lower Davidson Creek (Reaches 1 to 4 downstream of the Project site) is low gradient with riffle-pool morphology, has abundant gravel substrates and supports the only kokanee spawning grounds found in Davidson Creek (**Section 5.1.2.6**). It is also used for spawning and juvenile rearing habitat for rainbow trout.

Middle Davidson Creek (Reaches 5 to 8) is also low gradient with riffle-pool morphology. These middle reaches have productive rainbow trout spawning and rearing habitat and are predominantly cobble-boulder substrates with intermittent patches of gravel.

In the upper reaches of Davidson Creek (i.e., Reaches 9 to 10), habitat complexity and suitability of spawning and juvenile rearing habitat is lower than in the middle and lower reaches of Davidson Creek but, nevertheless, still provides fair to good habitat for rainbow trout.

Finally, the Davidson Creek headwaters, upstream of the lower boundary of Reach 11 are partially isolated by a cascade and are used seasonally by a population of rainbow trout that resides in headwater Lake 01682LNRS (**Section 5.1.2.6**). The Project site overlaps reaches 6 to 11. During construction of the Project, water from Reaches 11 and 12 will be diverted westward into Lake 01538UEUT, one of the two headwater lakes of the Creek 705 Watershed.

1.5 Davidson Creek Fish Community

The Davidson Creek fish community is numerically dominated by rainbow trout and kokanee. Davidson Creek kokanee migrate from Tatelkuz Lake via lower Chedakuz Creek to spawn in the gravels of lower Davidson Creek (Reaches 1 to 4) in July and August. Spent adults die and their eggs remain in the gravel through the winter. Fry emerge the next spring and immediately migrate out of Davidson Creek and up lower Chedakuz Creek to Tatelkuz Lake. There they rear for 3 to 4 years before undertaking their spawning migration.

Like kokanee, rainbow trout of Davidson Creek are predominantly lake residents as adults. Davidson Creek rainbow trout spawners return to spawning grounds from Tatelkuz Lake in June and migrate as far upstream as Reach 10. After spawning, those fish return to Tatelkuz Lake, completing a round-trip journey that takes an average of 18 days. After several weeks of incubation, fry emerge and rear in Davidson Creek for at least the summer, and up to 2 years, before migrating to Tatelkuz Lake to adopt an adult life style. Rainbow trout reach maturity at an age of 3 to 5 years and, unlike kokanee which spawn only once, can live to spawn multiple times over multiple years.

Analysis of microsatellite DNA showed that both kokanee and rainbow trout that spawn in Davidson Creek are reproductively isolated from other conspecifics in the Project Local Study Area (LSA) (**Section 5.1.2.6**) , although some movement likely does occur occasionally between localities that are currently interconnected. The Davidson Creek kokanee population is characterized by its early spawning run from Tatelkuz Lake, a feature that is an adaptation to the cool summer temperatures of that creek. In addition to Davidson Creek, spawners of this population are found in Creek 661 and middle Chedakuz Creek (upstream of Tatelkuz Lake). This population is genetically distinct from a population that also resides in Tatelkuz Lake but spawns later in mid-September in lower Chedakuz Creek (below Tatelkuz Lake), a feature that is an adaptation to the warmer water of lower Chedakuz Creek.

Rainbow trout of Davidson Creek are considered separate from those of adjacent watersheds in the LSA (Turtle Creek, Creek 661, and Creek 705). Based on existing baseline data (i.e., migration timing, distribution, growth rates), and the presence of a headwater lake, there are two rainbow trout populations that use habitat in Davidson Creek (**Section 5.1.2.6**). One that resides in headwater Lake 01682LNRS and spawns and rears in Reaches 11 and 12, and one that resides in Tatelkuz Lake and spawns and rears in Reaches 1 to 10.

2.0 SYNOPSIS OF LITERATURE RELATED TO HOMING AND IMPRINTING

As a group, salmonid fish are characterized by their ability to return to their home or "natal" spawning grounds. This ecological trait has permitted adaptation to local conditions, and consequently provides populations with considerable fitness advantages (Ricker, 1972; Beacham and Murray, 1989, 1993; Bryant, 2009; Dionne et al., 2009; Eliason et al., 2011). Over short distances (approximately 1 to 100 km), salmonids are guided to their natal stream by odours to which the juveniles were exposed while living in the stream prior to migration (Hasler and Scholz, 1983; Quinn, 2005). Considerable research has applied to identifying when salmonids are imprinted, to which odours they are imprinted, and how odours are used during the return migration.

Early studies identified smolt transformation as the critical period for imprinting (Wagner, 1969; Scholz et al., 1976; Dittman et al., 1996, 1997; Hasler and Scholz, 1983; Morin et al., 1989a, 1989b; Morin and Doving, 1992; Nevitt et al., 1994). This is because early studies focused on ocean-going salmonids that have a smolt stage. The smolt stage is when a salmonid undergoes the physiological transformation that allows them to live in salt water. Exclusively freshwater populations such as the kokanee and rainbow trout of the Chedakuz Creek Watershed do not have a smolt stage. Instead, fry develop into "parr" (or "fingerling") and remain in that juvenile stage until they mature into the sexually active adult stage at an age of 3 to 5 years. However, the research done on smolting fish is applicable to populations that do not smolt. As is discussed below, the stage at which the juveniles leave their natal stream for a residence lake is the freshwater equivalent of the smolt stage.

Manipulation of release locations of hatchery-reared smolts (e.g. Donaldson and Allen, 1957; Quinn et al., 1989a; Candy and Beacham, 2000) were the primary method used to inform the nature of the imprinting process. In general, salmonids used in these manipulations tended to return to the release location rather than to natal areas (Vreeland et al., 1975; Cramer, 1981; Slaney et al., 1993; Johnson et al., 1990; Kenaston et al., 2001), even if the odours from the natal hatcheries were available nearby (Quinn et al., 1989a; Brannon and Quinn, 1990). However, when salmonids were relocated downstream during their migration, they tended to return to their natal site (Ebel et al., 1973; Slatick et al., 1975; Ebel, 1980). It was believed that the physiological changes associated with smolting (Hoar, 1976; Dickhoff and Sullivan, 1987), specifically elevated levels of the hormone thyroxine, facilitated the imprinting process (Nevitt and Dittman, 1998).

This early model for imprinting, however, was not able to explain the more complex life histories of some wild individuals (Dittman and Quinn, 1996). For example, sockeye salmon (*Oncorhynchus nerka* – the anadromous versions of kokanee) emerge from natal areas and migrate to lacustrine juvenile rearing habitats, where they spend several years prior to undergoing smolt transformation and moving to sea (Quinn, 2005). If imprinting occurred solely at the smolt transformation stage, returning adults would not find natal spawning grounds. Subsequent experiments (Tilson et al., 1994, 1995; Dittman and Quinn, 1996; Nevitt and Dittman, 1998; Havey, 2008) revealed that imprinting events and associated peaks in thyroxine occur as early as the time of emergence and may continue through the smolt transformation stage. The apparent conflict of these ideas with past studies is explained by the predominant use of hatchery-raised fish in the relocation studies (Dittman and Quinn, 1996). In contrast to hatchery fish, wild fish experience complex sensory environments as they move to new environments or are exposed to seasonal variations in water chemistry. Along with development-associated events, thyroxine surges are also linked with changes in environmental conditions and provide imprinting opportunities for fish during migration and key life cycle events (Dittman and Quinn, 1996).

The composition of chemicals that fish imprint upon remains poorly understood (Nordeng, 1977; Hasler and Scholz, 1983; Stabell, 1984; Brannon and Quinn, 1990) and is complicated by the fact that chemical signatures of rivers are variable over seasonal and annual timescales and therefore can differ considerably between imprinting and return migration. Even in more extreme environmental circumstances, such as water chemistry changes following the eruption of Mt. St. Helens (Whitman et al., 1982; Leider, 1989), salmon are able to locate natal areas.

Imprinting chemicals can consist of a variety of inorganic and organic chemicals derived from a watershed's geology and its flora and fauna, but existing studies are contradictory (Idler et al., 1961; Fagerlund et al., 1963; McBride et al., 1964; Bodznick, 1978; Plate, 2001). Some studies indicate that combinations of naturally occurring amino acids (Shoji et al., 2000, 2003), including female salmonid sex pheromones (Yambe et al., 2006) can be used by homing salmonids. Along these lines, scientists became interested in the idea that odours from juveniles could direct migrating adults back to natal spawning grounds (Døving et al., 1980; Stabell, 1984, 1992). Subsequent results indicated that salmonids are able to identify the odours of their own population (Groot et al., 1986; Quinn and Tolson, 1986; Courtenay et al., 1997), but such odours do not seem to play a critical role in homing (Brannon and Quinn, 1990). An alternate hypothesis is that rivers may contain unique "olfactory bouquets" of minerals that remains sufficiently stable for salmon to use as cues for homing (Bodznick, 1978; Plate, 2001).

Several studies indicate that chemicals such as morpholine and phenylethyl alcohol can be used to artificially imprint salmon (Cooper and Hasler, 1976; Cooper and Scholz, 1976; Scholz et al., 1978; Hasler and Scholz, 1983) and enhance homing (Scholz et al., 1978; Hassler and Kucas, 1988). Such work demonstrates that salmonids can successfully home using a single element of a complex mixture and that they can imprint in a plastic manner based on chemical availability. The mechanism that allows for this trait is thought to arise from differential survival of olfactory sensory neurons during development. Specifically, those neurons that are used for the chemicals detected at crucial life stages are retained and propagated, while others are not. This leaves adult salmonids with an olfactory system that is tuned to homestream odours.

When anadromous salmonids undertake spawning migrations at sea, they rely on navigating mechanisms such as geo-magnetism in open water (Quinn, 1980; Quinn and Brannon, 1982), and shift to olfaction-based homing methods upon approaching rivers (Craigie, 1926; Madison et al., 1972; Stasko et al., 1976; Døving et al., 1985; Quinn et al., 1989b). Navigation using olfactory homing is thought to rely on sequential imprinting. In other words, salmonids are able to recreate the migratory route using a series of olfactory waypoints (Harden-Jones, 1968). This concept corresponds well with contemporary models that suggest that juvenile salmonids imprint during periods of migration and/or periods of environmental change (Dittman and Quinn, 1996; Nevitt and Dittman, 1998).

Once detected, the concentrations of imprinted odours can lead salmonids to natal streams (Fretwell, 1989). This orientation method is associated with test forays into non-natal streams (Griffith et al., 1999) and occasional overshoots of natal rivers (Ricker and Robertson, 1935). Interestingly, exposure of migrating salmonids to imprinted odours also triggers rheotactic responses such as upstream swimming (Johnsen and Hasler, 1980; Johnsen, 1982). Olfactory homing can return salmonids to very precise locations of a stream (Quinn et al., 2006), but ultimately gives way to local scale spawning site selection (females) and mate choice (males) (Blair and Quinn, 1991), where it is likely that habitat availability and competition play a role in redd placement.

Under natural conditions, most salmonids retrace the sequence of odours and return to natal areas, thus providing the conditions for local adaptation. However, a small segment of many populations stray to non-natal tributaries and rivers where they potentially play an important role in maintaining genetic diversity or in re-colonizing new habitats (Pess, 2009). Straying occurs among the kokanee populations of the Chedakuz Creek Watershed, and among rainbow trout populations in that watershed, as shown by the results of microsatellite DNA analyses (**Section 5.1.2.6**).

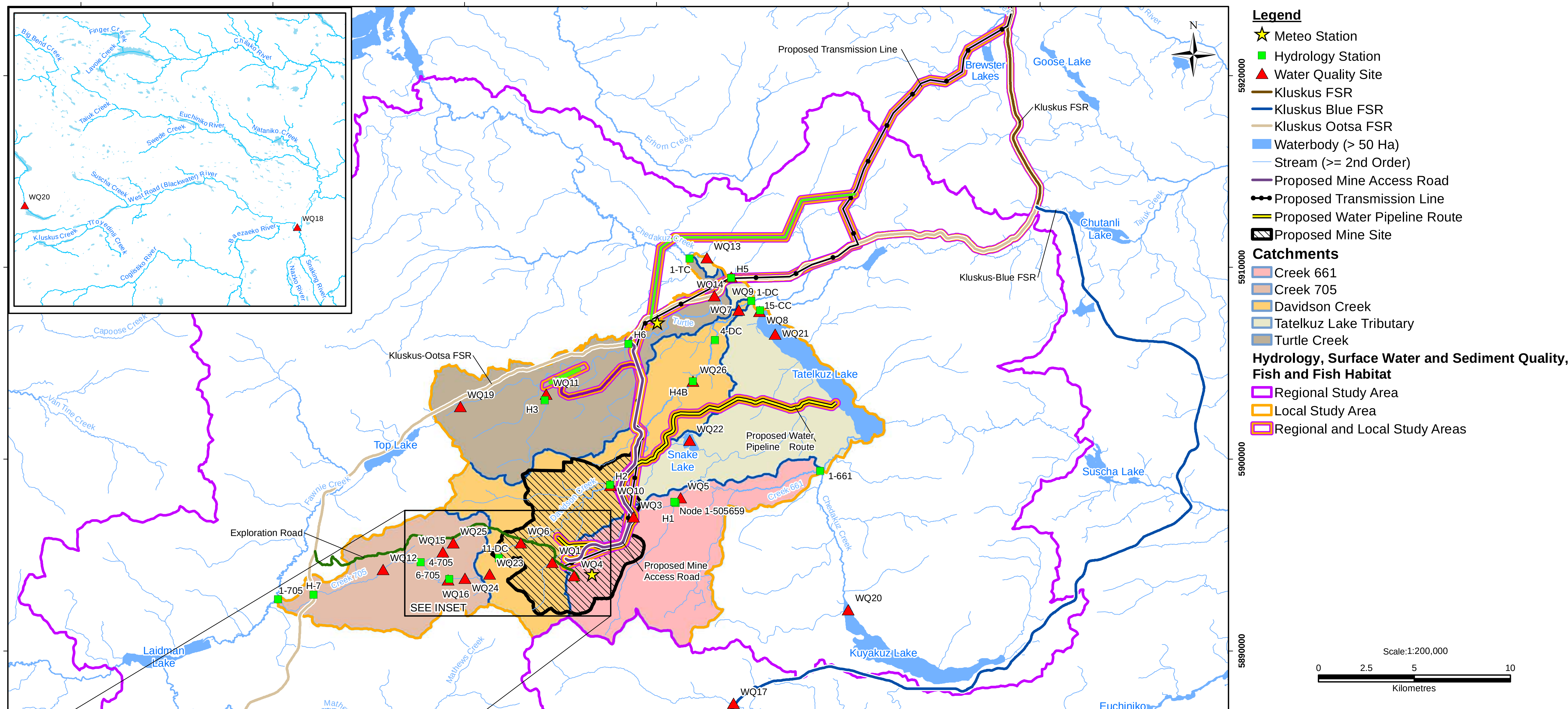
The literature on salmonid homing and imprinting is considerable and has culminated in an understanding that salmonids imprint at key developmental stages but also opportunistically when exposed to novel environmental conditions. The physiology of imprinting enables flexibility over what odours are remembered and when they are remembered and contributes to the diversity and adaptability of this species which inhabits a complex and dynamic environment (Dittman and Quinn, 1996).

3.0 DIFFERENCES IN WATER CHEMISTRY BETWEEN SOURCE AND RECEIVING WATERS

The olfactory hypothesis for homing in salmonids requires that each stream has a unique chemical composition and thus a distinct odour (Hasler and Scholz, 1983). While the chemicals used are not well understood, plasticity is considered likely, based on artificial imprinting studies and physiological studies (Nevitt and Dittman, 1999). If chemical signatures of Davidson Creek water form part of the ‘olfactory bouquet’ (i.e., Bodznick, 1978; Plate, 2001) for salmonids originating from Davidson Creek, it would be expected that differences would be maintained across seasons.

3.1 Analysis of Water Quality

To assess this, water chemistry data collected at stations in Tatelkuz Lake (WQ21), lower Chedakuz Creek (WQ8), Davidson Creek headwaters (WQ6), upper Davidson Creek (WQ10), middle Davidson Creek (WQ26), and lower Davidson Creek (WQ7) (**Figure 3-1**) were analyzed to assess if chemical signatures of basic water chemistry parameters differed spatially and persisted across seasons. Water samples were collected throughout the year in 2011 and 2012 and were analysed for nutrients, anions and total metals (**Section 5.1.2.2**). A multivariate framework was used to provide a single integrated analysis of chemical differences.



Reference
BC Government GeoBC Data Distribution

CLIENT: newgold

PROJECT: Blackwater Gold Project

Surface Water Quality Monitoring Sites

DATE: October, 2013	ANALYST: BB	Figure 3-1
JOB No: VE52095	QA/QC: MY	PDF FILE: 09-100-003_v21_SA_WQ_sites.pdf
GIS FILE: 09-100-003_v21.mxd		amec
PROJECTION: UTM Zone 10	DATUM: NAD83	

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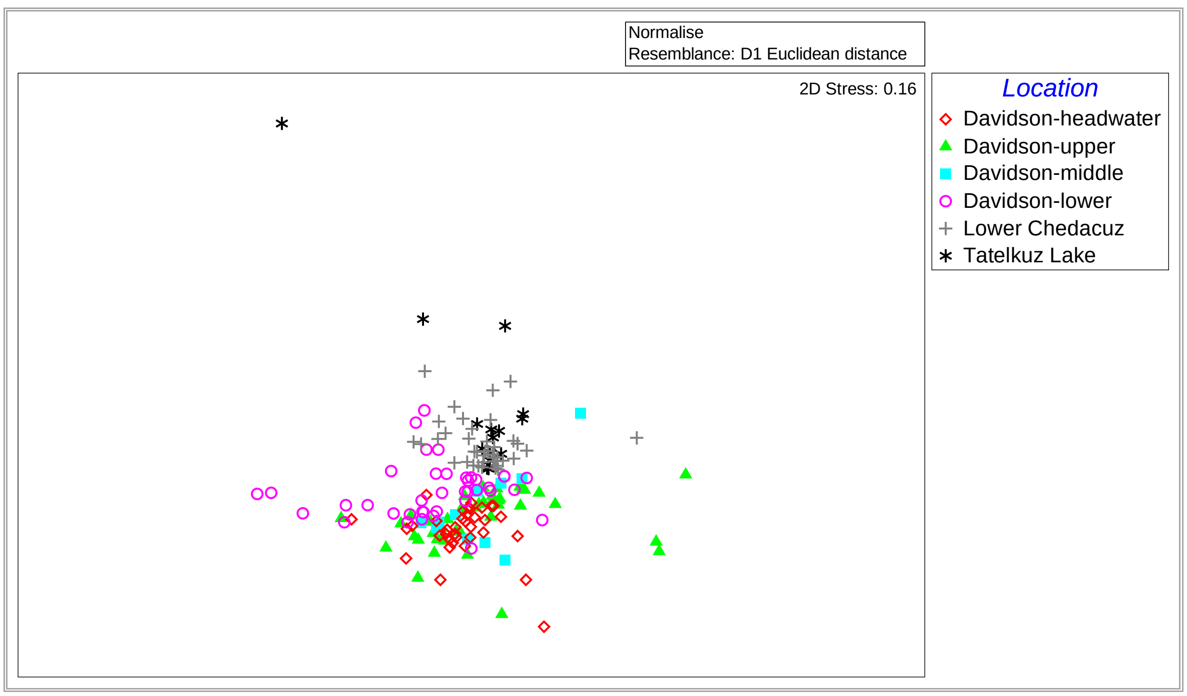
Due to incomplete representation across samples, some parameters were excluded from analysis (e.g., cyanide). Water chemistry parameters were examined for normality, corrected with log transformations where required, and normalized to a common scale (Clarke and Warwick, 2001). Where pairs of parameters were heavily correlated (r>0.95), one parameter was removed. This resulted in the exclusion of conductivity (correlated with hardness and calcium), hardness (correlated with calcium), and strontium (correlated with calcium). The resulting dataset was used to generate a matrix of Euclidean distance scores that included values for each pair of samples (Clarke and Warwick, 2001). Similarity scores were used as inputs for statistically analyzing and visualizing global differences in water chemistry. Statistical differences were assessed across and within areas using a permutation-based multivariate analog of Analysis of Variance (ANOVA) (ANOSIM, 999 permutations, Clarke and Warwick, 2001), while visualization was done using non-metric Multi-Dimensional Scaling (MDS) (PRIMER 6; Clarke and Warwick, 2001). Parameters that most characterized the differences among areas were identified using a SIMPER algorithm (PRIMER 6; Clarke and Warwick, 2001), a method that evaluates the contribution of each parameter to Euclidean distance dissimilarity values for pairs of groups.

Differences in water chemistry were apparent across areas (Global R: 0.33, P<0.001; (**Figure 3-2**), but were greatest between Davidson Creek and Tatelkuz Lake (pairwise R: 0.44; P<0.001), followed by Davidson Creek and Lower Chedakuz Creek (pairwise R: 0.33; P<0.001). Less obvious, but statistically significant differences, in water chemistry were detected between Tatelkuz Lake and its outflow (Lower Chedakuz Creek) (pairwise R: 0.17; P = 0.03).



Note: Proximity between points indicates community similarity among samples.

Figure 3-2: ***MDS ordination of Water Chemistry from Davidson Creek, Lower Chedakuz Creek and Tatelkuz Lake***

Of the top ten variables that created the observed differences between Tatelkuz Lake and Davidson Creek (41% of the observed dissimilarity), eight were metals.

Within Davidson Creek, the headwaters differed from all sites (all $P<0.015$) and Upper Davidson Creek differed slightly from Lower Davidson (pairwise R: 0.134; $P<0.001$) (**Figure 3-2**).

Since the cloud of data points for Tatelkuz Lake does not include those of Davidson Creek, water chemistry differences appear to persist across seasons. While the composition of chemicals upon which salmonids imprint is poorly understood, there is the potential for the olfactory bouquet to be altered by pumping of Tatelkuz Lake water into Davidson Creek.

3.2 Flow Dilution

The biggest Project-related differences in water chemistry of Davidson Creek will occur below the TSF, where the only source of water will be Tatelkuz Lake. Further downstream, surface run-off and groundwater originating within the Davidson Creek Watershed will mix with water derived from Tatelkuz Lake, and will contribute to the olfactory bouquet. Dilution of Tatelkuz Lake water in Davidson Creek is expected to vary in time and space. Based on monthly baseline estimates of flow in Davidson Creek and expectations of the volume of water that will be required to maintain fish habitat (**Appendix 5.1.2.6D**), water originating from Davidson Creek will comprise 17 to 42% of flows in Middle Davidson, 20 to 55% of flows in Lower Davidson and 26 to 61% of flows at the confluence of Lower Chedakuz Creek. The proportion of water originating from Tatelkuz Lake will typically be greatest during the June rainbow trout migration and spawning period and at moderate levels during kokanee spawning (**Table 3-1**).

Table 3-1: Percent of Flows Originating from Davidson Creek at Stations along Davidson Creek and in Different Time Periods

Month	Stanza	Upper	Middle	Lower
Jan	Kokanee egg incubation/rainbow trout rearing	22	25	36
Feb	Kokanee egg incubation/rainbow trout rearing	19	21	33
Mar	Kokanee egg incubation/rainbow trout rearing	19	24	36
Apr	Kokanee alevin emergence/rainbow trout rearing	43	56	62
May	Rainbow trout migration/spawning	21	30	34
Jun	Rainbow trout migration/spawning	17	22	26
Jul	Kokanee spawning/rainbow trout egg incubation and rearing	33	37	45
Aug	Kokanee spawning/rainbow trout rearing	27	30	39
Sep	Kokanee spawning and egg incubation/rainbow trout rearing	29	32	42
Oct	Kokanee egg incubation/rainbow trout rearing	30	35	45
Nov	Kokanee egg incubation/rainbow trout rearing	30	37	46
Dec	Kokanee egg incubation/rainbow trout rearing	25	29	40
Annual	Mean	24	31	38

Notes: Stanzas defined in **Appendix 5.1.2.6D**.

4.0 VULNERABILITY OF KOKANEE AND RAINBOW TROUT TO HOMING DISRUPTION

The two salmonid species that occupy Davidson Creek exhibit different life histories that will mediate their vulnerability to disruptions to imprinting, homing and spawning success. Rainbow trout have several advantages (longer lifespan, iteroparity, plastic life history) that should increase their resilience to potential effects (**Table 4-1**). For example, repeat spawning rainbow trout have multiple opportunities to find natal spawning grounds prior to senescence and their increased lifespan allows a greater window for adaptive management. On the other hand, the exclusive use of lower Davidson Creek habitats for spawning by kokanee means that that there will be no direct effects to kokanee habitat and that all kokanee will be exposed to the least altered water chemistry in Davidson Creek. Further, populations of both species occur in other unaltered habitats adjacent to Davidson Creek, which provides a safety factor for adaptive management (**Section 5.1.2.6**).

Table 4-1: Ecological Traits of Rainbow Trout and Kokanee Affecting Resilience to Disruption of Homing

Ecological Trait	Rainbow Trout	Kokanee	Ecological Consequence
Long lifespan	X	-	Increased time window for adaptive management.
Iteroparous	X	-	Increased learning/straying opportunities. Spawners spread across multiple year classes (less likely for catastrophic year class failure).
Spawner straying	X	X	Common feature of salmonids. Allows colonization of new habitat and genetic flow among adjacent populations.
Juvenile rearing in stream	X	-	Higher probability of imprinting with longer stream residence period. Also, for juveniles that stray (e.g. Anderson et al., 2008), an opportunity to imprint to areas dominated by water more similar to that of Tatelkuz Lake.
Spawn in lower reaches only	-	X	Will be less affected by declining concentrations of olfactory stimulus upstream with up to 62% of flow naturally occurring in the Creek.
Physical habitat not affected by Project development	-	X	No Project facilities will affect kokanee habitat in Davidson Creek
Other source habitats for re-colonization or restoration	X	X	Microsatellite DNA analysis indicates that other streams in the Chedakuz Creek Watershed support similar genotypes as Davidson Creek. Such source populations provide adaptive management opportunities and potential strays.
Run timing coincides with relatively high concentrations of foreign water	X	-	Potentially weaker homing signal to follow

Notes: X = ecological trait applicable to that species.

5.0 LIKELIHOOD OF EFFECTS TO THE HOMING OF DAVIDSON CREEK SALMONIDS

The likelihood of impact to homing of Davidson Creek salmonids will vary depending on species, year class, and the extent that alterations in water chemistry disrupt spawning site selection.

The plastic nature of salmonid imprinting (Dittman and Quinn, 1996; Nevitt and Dittman, 1999) suggests that individuals hatched in the flow-augmented Davidson Creek are unlikely to have their homing capability altered by flow augmentation. Furthermore, as changes to environmental conditions trigger imprinting (reviewed by Dittman and Quinn, 1996), individual rainbow trout that were hatched in Davidson Creek during baseline conditions, but experienced the new olfactory stimuli prior to migrating from Davidson Creek, would also likely be capable of homing.

There will remain year classes of fish, however, that will be imprinted during baseline conditions and will return to Davidson Creek to find an altered olfactory bouquet consisting of a mixture of Davidson Creek characteristics and Tatelkuz Lake characteristics. Successful homing for these individuals will require an ability to identify Davidson Creek where it flows into lower Chedakuz Creek and, once within Davidson Creek, identify the appropriate spawning area. There will be no Project effects on kokanee spawning habitat, and spawning habitat for rainbow trout has not been assessed as a limiting factor for population size.

Water chemistry of the migration route from Tatelkuz Lake to Davidson Creek will not be altered by the Project. At the confluence of Davidson Creek and lower Chedakuz Creek, the concentrations of the olfactory stimuli to which these fish had been imprinted will be the highest available and will therefore remain as an olfactory waypoint (Fretwell, 1989). Furthermore, it is unlikely that the “foreign” component of the water found in Davidson Creek will have an inhibitory effect on migrating salmon because it will be similar in nature to Tatelkuz Lake water and familiar to migrating adults. Therefore, it is highly probable that Davidson Creek will remain identifiable.

Once in Davidson Creek, fish will be required to move upstream against an increasing gradient of Tatelkuz Lake water. If concentration of imprinting chemicals remains a primary mechanism for continuing upstream (e.g., Fretwell, 1989), then it is possible that spawning of both species will be concentrated in the lower reaches of Davidson Creek. For kokanee, this is consistent with their natural distribution of spawning. However, for rainbow trout, which has historically used the middle and lower sections of Davidson Creek for spawning, this could result in reduced production over the uppermost 4 km of stream. This will not represent an equivalent loss of production for the whole population because spawning habitat has not been identified as a limiting factor for the Davidson Creek population.

Depending on spawning site fidelity and the amount of straying, avoidance of habitats could carry forward through generations, though studies on the re-colonization of reopened habitats suggest otherwise (Pess, 2009). Alternatively, other methods of spawning site selection may take over from olfactory-based homing when fish are in Davidson Creek. For example, straying, competition for spawning sites or other sensory cues (Hendry et al., 2001; Pess, 2009) may drive returning spawners against the olfactory gradient to natal spawning habitats.

In the unlikely event of a large decline in returning spawners related to augmented flows, a number of safeguards exist, as well as an adaptive management plan. First, given the proposed timing of start-up of the FSS and augmentation of flows at freshet in year 1 of construction, at least one year class of fish can be spawned under baseline conditions and imprinted on the modified regime. For kokanee, most of this year class will return 3 or 4 years later to spawn. Over subsequent generations, gaps in year classes will be filled as a result of this life history plasticity (i.e., variability in age at maturity). A similar plastic life history pattern holds for rainbow trout, except that the presence of repeat spawners can also contribute to filling vacant year classes. Straying is well documented in salmonids (Pess, 2009) and would also be expected to reduce the severity of long-term adverse effects of flow augmentation on salmonid homing, particularly given that unimpacted populations reside nearby (Pess, 2009). The absence of genetic differences between rainbow trout that spawn in Davidson Creek and other systems (e.g., Creek 661) suggests population mixing (i.e., straying) from natal spawning grounds occurs and that colonizing individuals are adapted to existing conditions. Reservoirs of genotypes similar to Davidson Creek, such as those found in Creek 661, also expand the options and timeframes for adaptive management and restoration (see below).

6.0 ADAPTIVE MANAGEMENT

Adaptive management is defined by the Canadian Environmental Assessment Agency (the Agency) as the "planned and systematic process for continuously improving environmental management practices by learning about their outcomes. Adaptive Management provides flexibility to identify and implement new mitigation measures or to modify existing ones during the life of a project" (Agency, 2013). Such an approach acknowledges uncertainty and requires a monitoring program to provide strategic information on which to assess the status of the system, determine the effectiveness of management measures, and inform additional management action if needed.

Monitoring the effects of flow augmentation on salmonid homing requires a strategy that is tailored to the species of interest and can be phased to capture additional information (e.g., effectiveness of mitigation measures). Adaptive management will focus on maintaining production of Davidson Creek salmonid populations and continued use of baseline spawning grounds (i.e., maintaining carrying capacity) (**Figure 6-1**). Reduced productivity could arise from homing disruptions if spawners do not return to Davidson Creek and/or if density-dependent effects take place because not all spawning habitats are used. Monitoring will be conducted in a way that is complimentary of baseline collections (redd counts, hoop netting for rainbow trout and spawner counts for kokanee, microsatellite DNA analysis, etc.) and will be augmented by other approaches as needed.

In the unlikely event that returning spawner numbers decline after flow augmentation begins, restoration options will be considered. These could entail transfers of adults or eggs of similar genotypes (e.g., rainbow trout captured in Turtle Creek and rainbow trout or kokanee captured in Creek 661) into middle Davidson Creek, where imprinting of the next generation to the modified olfactory bouquet will create a self-sustaining population. Tagging of suspected Davidson Creek spawners, migrating through lower Chedakuz Creek (e.g., early-run kokanee) could also provide insight on the fate of spawners originating from Davidson Creek.

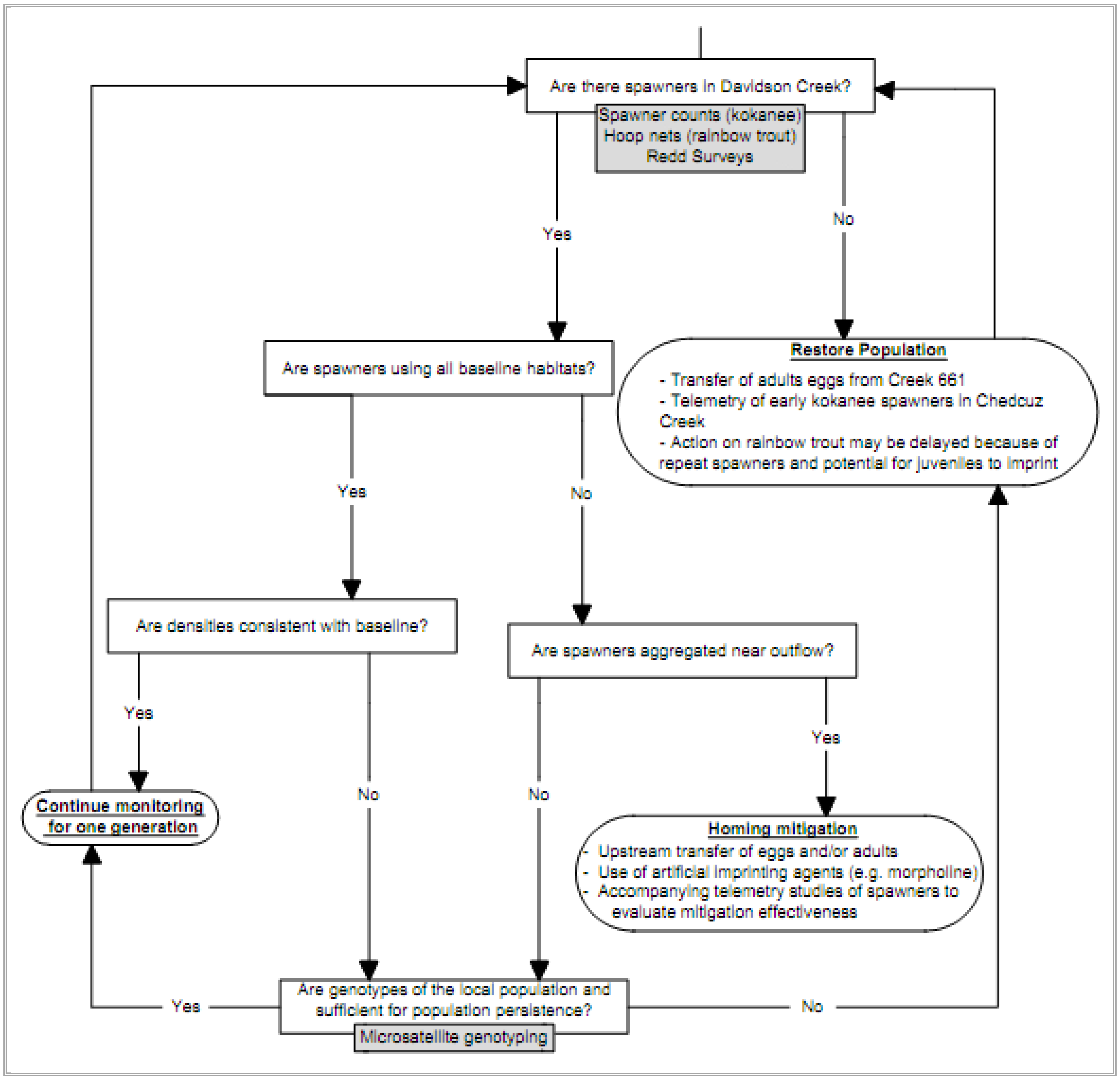


Figure 6-1: ***Adaptive Management Approach for Addressing Potential Disruptions to Salmonid Homing Caused by the Project***

A more likely consequence of homing disruption will be the absence of rainbow trout spawners in the middle reaches immediately downstream of the Freshwater Reservoir. This would be determined using the same methods as outlined above. Declines of rainbow trout spawners will trigger homing mitigation efforts. These may include the transfer of eggs and or adults from lower Davidson Creek to spawning grounds upstream and/or the use of artificial imprinting techniques (e.g., Scholz et al., 1978) directed at juveniles spawned in the lower reaches. Such techniques may require that an artificial imprinting agent such as morpholine be added to waters in existing spawning grounds to imprint juveniles. When these artificially imprinted fish are expected to return, the imprinting agent can be added to waters at the upstream extent of baseline spawning habitat to attract spawners further upstream.

Low densities of spawners may signal widespread homing disruption, with existing spawners comprised of strays. In these circumstances, genetic analysis will be considered to identify the genotypes of spawners. If spawners are not native to Davidson Creek, or spawners are so few that year class failure is likely, efforts to restore the population would be initiated.

6.1 Population Restoration

In the unlikely event that homing of salmonids is completely disrupted, restoration of the population will have to be considered. Past studies of reconnected habitats indicate that natural re-colonization of suitable habitats such as Davidson Creek will occur (Pess, 2009). The timeframe of natural re-colonization varies from years to decades and depends on source population size, distance to source, habitat area, stray rate and the adaptability of the strays to the new environment (reviewed by Pess, 2009). The circumstances in Davidson Creek will favour rapid re-colonization because there are nearby source populations of similar evolutionary history. However, in the event these timeframes are not considered acceptable, active management may be required (Young, 1999). Active management approaches will most likely entail the movement of salmonids (eggs or adults) to underutilized spawning habitats (e.g., Havey, 2008; Kirkland, 2012). The source of transferred individuals is important because salmonids are well known for local adaptation (Young, 1999). Fortunately, baseline studies on genetic structure of local salmonid populations can provide insights toward optimal source populations. The urgency to implement restorative action, if needed, will be heightened for kokanee given their life history vulnerabilities (i.e., semelparity, exclusive use of lake habitat by juveniles and pre-spawning adults). The duration and magnitude of transfers will depend on ongoing assessments of source and receiving populations, but should continue for multiple year classes of fish (Young, 1999).

6.2 Homing Mitigation

Homing mitigation will be pursued if spawners are returning to Davidson Creek but are unwilling to navigate to upstream spawning areas in the face of decreasing imprinted olfactory concentrations. Two primary options are available to restore the use of spawning habitats. First, ripe adults or eggs collected in lower reaches can be transferred to spawning habitats previously occupied during baseline surveys. Eggs hatched in the new habitats would be expected to imprint on the modified olfactory bouquet and result in self-sustaining populations in the future. If transferred adults are unwilling to remain in receiving habitats, containment devices may be required. Alternatively, gametes could be stripped from spawners downstream, fertilized and placed in egg boxes in underutilized spawning substrates. This approach can increase the specificity regarding the densities of eggs placed, but it eliminates important ecological steps (i.e., microhabitat selection, mate choice etc.) that could impact future fitness (Consuegra and Garcia de Leaniz, 2008).

An alternative to adult or egg transfers is the use of artificial imprinting agents such as morpholine, phenylethyl alcohol, and amino acids. Such chemicals have been used experimentally to understand the mechanisms of homing (Nevitt and Dittman, 1999; Ueda et al., 2007; Yamamoto et al., 2010) and to successfully enhance homing in populations of coho salmon (*Oncorhynchus kisutch*) (Cooper et al., 1976; Johnsen and Hasler, 1980; Hassler and Kucas, 1988), rainbow trout (Scholz et al., 1978) and kokanee (Tilson et al., 1993). As with the adult/egg transfers identified above, the use of artificial imprinting agents would only be required for one generation until imprinting naturally occurs with the modified water chemistry of Davidson Creek. The application of such methods are not universally successful (Rehnberg et al., 1985; Hassler and Kutchins, 1990; McLellan et al., 2001), but have the advantage of being less intrusive and less likely to negatively influence important ecological processes such as micro-scale redd site selection and mate choice. Experimental studies also show that addition of such chemicals will not inhibit migration of individuals who have not been imprinted (Rehnberg et al., 1985). Additional study would be needed to ensure that the methods are transferable to the application of Davidson Creek.

7.0 CONCLUSION

The use of flow augmentation to mitigate Project effects to fish habitat in Davidson Creek is unlikely to disrupt homing of salmonids to spawning grounds in a way that has permanent effects. The maintenance of some home-stream water in Davidson Creek and the plastic nature of salmonid imprinting make it likely that Davidson Creek will retain rainbow trout and kokanee spawners upon initiation of the Project. What is less certain is how far upstream spawners will migrate against a decreasing olfactory gradient. Application of an adaptive management and monitoring program, however, will provide options to deal with potential negative effects and to restore baseline numbers and distributions of spawners to the system.

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