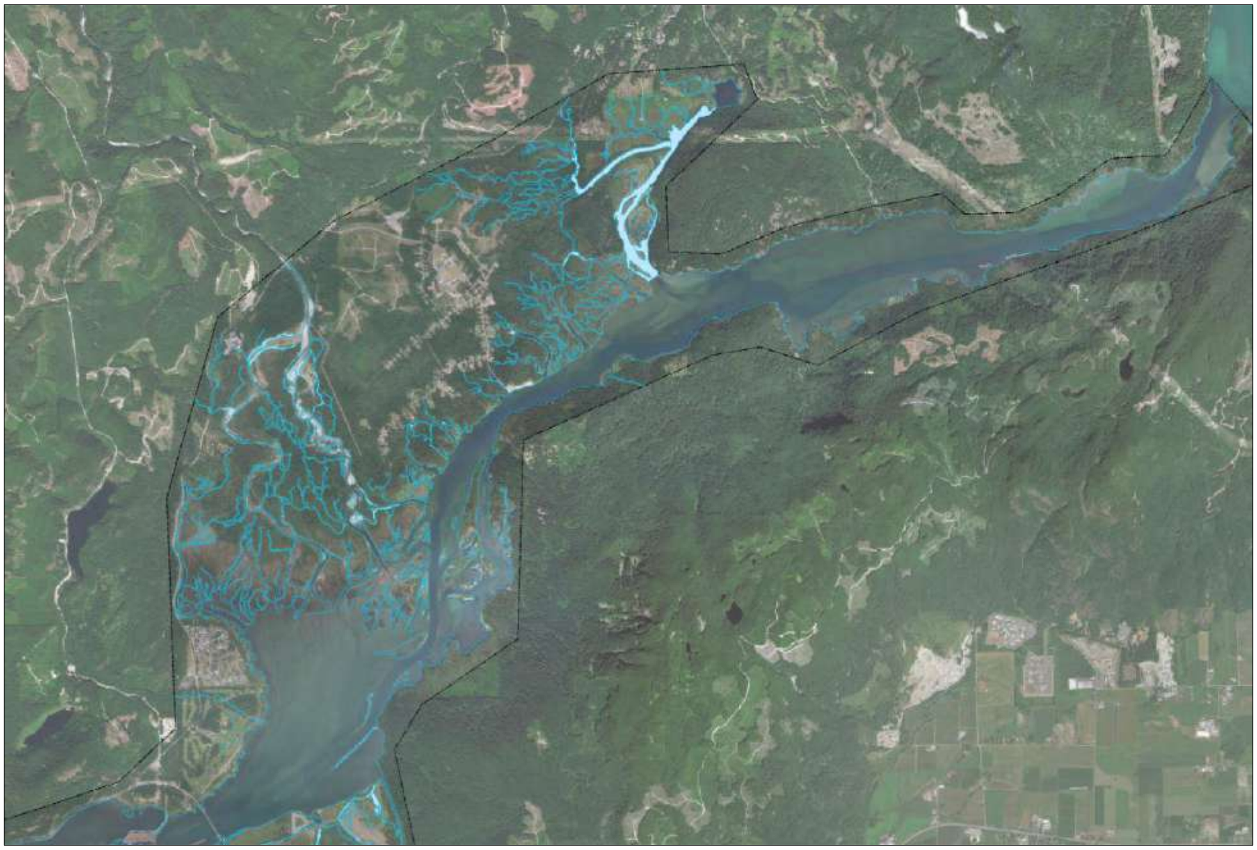
# Harrison River Tributaries Salmon Habitat Assessment



Prepared for:
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May 2017

HEMMERA

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Sts'ailes Development Corporation
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**Attn: David Moore, General Manager, Harrison Fisheries Authority, Sts'ailes and Sq'éwlets First Nations**

Dear David,

**Re: Harrison River Tributaries Salmon Habitat Assessment**

Hemmera Envirochem Inc. is pleased to provide you with a draft version of the subject report for your review and for discussion purposes. As such, the report is not signed. Please review the reports and provide Hemmera with comments and written revisions you feel are appropriate. Once comments and revision requests are received and reviewed, we will finalize the report and circulate signed copies. To aid us in finalizing reports and to avoid unofficial "draft for discussion" reports being used or referenced, we request that you delete the draft report after providing your feedback.

We have appreciated the opportunity to work with you on this project and trust that this report meets your requirements. Please feel free to contact the undersigned by phone or email regarding any questions or further information that you may require.

Regards,
**Hemmera Envirochem Inc.**

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# EXECUTIVE SUMMARY

This Executive Summary is not intended to be a "stand-alone" document, but a summary of findings as described in the following report. It is intended to be used in conjunction with the scope of services and limitations described therein.

The purpose of this project was to develop a comprehensive screening tool informed by ecological, economic and cultural filters, and to produce an interactive database identifying historic and potential salmon habitat restoration opportunities within Harrison watershed. The Project area is 50 square kilometres centred around the Harrison River; between the outlet of Harrison Lake to the north, and the confluence with the Fraser River to the south.

The Project consisted of a two-phase approach: first, the identification and mapping of potential restoration opportunities in the Lower Harrison Watershed; and second, the ranking of these opportunities based on their potential value to society. The first phase was completed through literature review, field surveys, and the acquisition of orthoimagery and LiDAR, which was used to map existing and potential fish habitat. The second phase was completed by using an ecological filter to estimate a site's contribution to fish production and the ecological health of the watershed; an economic filter to estimate the comparable net present value of a site; and a social filter to estimate cultural importance and potential value to society.

The first phase identified a total of 392 polygons that were mapped within the study area: 159 were classified as wetted areas, 94 as ephemeral channels, 69 as accreted channels, and 70 as upland features. Of the wetted areas, 125 wetted, and all accreted and ephemeral polygons were classified as potential restoration opportunities. Of the potential restoration opportunities, 20 sites (made up of multiple polygons) were selected for detailed analysis during the second phase based on restoration feasibility. Thirteen of the selected restoration opportunities were classified as potential new habitat, three were classified as enhanced habitat, and the remaining four involve a mix of new and enhanced sections. Total area of streambed in which habitat improvements are likely to occur for each project ranged from 1,038 $m^2$ to 180,952 $m^2$.

All selected opportunities are anticipated to benefit both chum and coho salmon. Estimated annual net production ranged from 420 to 87,656 adult fish for chum salmon and from 69 to 85,047 fish for coho salmon. Model generated project construction costs ranged from $15,650 to over $4,000,000. Net cumulative project value based on economic calculations over a Year 20 period ranged from $703,563 to $318,369,606.

Twenty projects were proposed in this study, based on mapping and subsequent ground-truthing; however, several more may be identified, based on the results of the habitat mapping, supplemented by local knowledge. The proposed projects may also be divided into multiple, smaller projects or phases that may be more economically feasible and/or more logistically manageable.

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# 1.0 INTRODUCTION

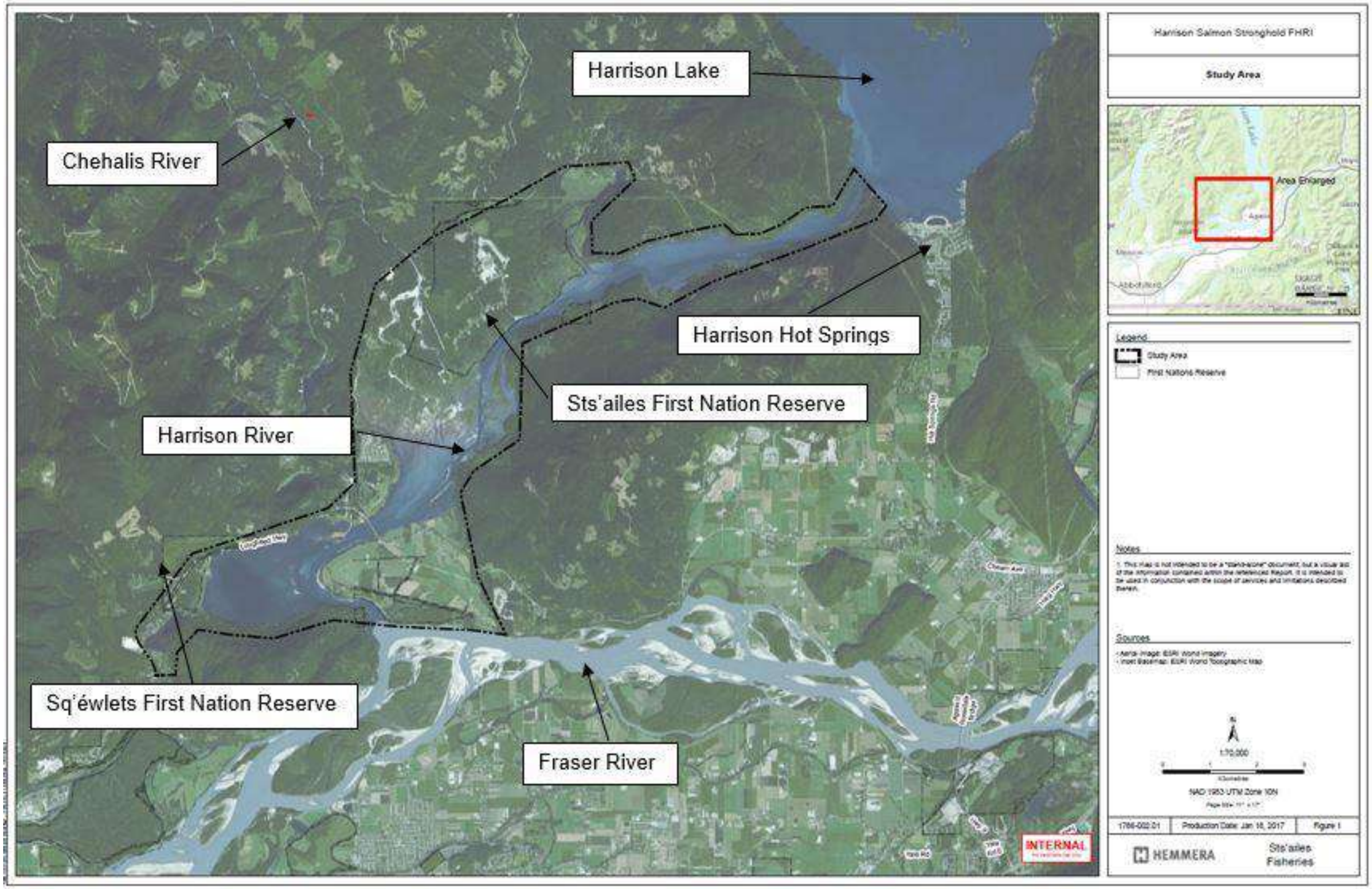
In 2010, the Harrison River, located in southern British Columbia, was designated as Canada's first International Salmon Stronghold by the North American Salmon Stronghold Partnership (PFRCC 2010). The ecological significance of this area comes from the watershed's natural diversity and productivity, which supports all five Pacific salmon species (*Oncorhynchus* spp.), including unique runs of Chinook salmon (*O. tshawytscha*) sockeye salmon (*O. nerka*) and steelhead trout (*O. mykiss*) (Ennis 2011, David Moore, pers. comm., 2017). The salmon provide a significant source of nutrients to the Harrison River and surrounding ecosystems and are at the heart of economic and cultural values for local Aboriginals. The Stronghold encompasses the Lower Harrison Watershed (LHW), including Harrison Lake and several important salmon-producing tributaries.

The LHW has been severely impacted by loss of riparian areas from forest harvesting and accretion of channels due to water management and flooding (Pearson and Chiavaroli 2010). Potential future effects from climate change, such as extreme flooding, spread of invasive species, low water levels and warmer stream temperatures may be expected (Beechie 2012). Many of the Harrison River tributaries may no longer support historical levels of salmon productivity (Ritchie and Springer, Unpublished) because of habitat loss, habitat accretion, barriers to fish passage, loss of habitat complexity, the ingress of invasive species (e.g., Eurasian watermilfoil [*Myriophyllum spicatum*] and reed canary grass [*Phalaris arundinacea*]). It is suspected these ecological losses have also resulted in socio-economic losses.

The Salmon Stronghold's approach promotes activities reinforcing the vitality of salmon ecosystems, through voluntary and locally-based initiatives, with the collaboration of government agency (Beeson 2009). The Harrison Salmon Stronghold Working Group (led by the Sts'ailes, in collaboration with other local organisations and community members, non-government organisations, as well as federal, provincial and regional governments) has fostered partnership efforts for restoring and maintaining the Harrison Salmon Stronghold. Concurrently, the Harrison Fisheries Authority (Sts'ailes - Sq'éwlets Fisheries Group) has recognized the need for an investigation of historical and current habitat values to identify and prioritize future fisheries restoration opportunities along the Harrison River.

## 1.1 PROJECT LOCATION

The Project area is 50 km$^2$ centred around the Harrison River between the outlet of Harrison Lake and Morris Lake to the north, and the confluence with the Fraser River and Lake Errock to the south (**Figure 1**). The Project area focuses on tributaries leading into the Harrison River, mainly between Morris Creek and the Chehalis River to the west and Harrison Mills to the east. The Project area was defined, in part, by the ability to acquire high resolution orthoimagery (HRO) and LiDAR to inform detailed habitat mapping and restoration designs (see **Section 3.2**).



Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Aerial Image: ESRI World Imagery
- Inset Basemap: ESRI World Topographic Map

**Figure 1 Project Location**

## 1.2 PROJECT RATIONALE

Past enhancement and restoration activities in the region have been largely reactive, including smaller projects undertaken for the purposes of offsetting emergency dike work construction (e.g., spawning channels at Ed Leon Slough) and industry driven development (e.g., spawning channels at John Mack and Log Dump sloughs). This critical area for salmonids requires a large-scale, holistic and proactive approach to future planning, management and implementation of restoration activities within the watershed. The purpose of this study is to develop a current, comprehensive, and interactive database on the state of fish habitat health in the watershed, with the long-term focus on improving overall fish productivity while promoting cultural values in the region.

## 1.3 PROJECT OBJECTIVES

The goals of this restoration database are to develop a central source of information to help identify economically feasible and culturally valuable restoration opportunities that may improve overall fisheries productivity by addressing limiting factors identified in this study. The objectives of the project are to:

1) Develop a comprehensive screening tool informed by ecological, economic and cultural filters (based on Scarfe, 1997); and
2) Produce an interactive database identifying historic and potential restoration opportunities within Harrison watershed.

This will assist resource managers and community members in identifying and prioritizing restoration opportunities.

## 1.4 PROJECT LIMITATIONS

This work was performed in accordance with Contract #: SOC 080416FHRI HEMMERA between Hemmera Envirochem Inc. ("Hemmera") and Sts'ailes Development Corporation ("Client"), dated October 18, 2016 ("Contract"). This Report has been prepared by Hemmera, based on fieldwork conducted by Hemmera, for sole benefit and use by Sts'ailes Development Corporation. In performing this work, Hemmera has relied in good faith on information provided by others, and has assumed that the information provided by those individuals is both complete and accurate. This work was performed to current industry standard practice for similar environmental work, within the relevant jurisdiction and same locale. The findings presented herein should be considered within the context of the scope of work and project terms of reference; further, the findings are time sensitive and are considered valid only at the time the Report was produced. The conclusions and recommendations contained in this Report are based upon the applicable guidelines, regulations, and legislation existing at the time the Report was produced; any changes in the regulatory regime may alter the conclusions and/or recommendations.

# 2.0 BACKGROUND

## 2.1 STUDY APPROACH

The Harrison River Watershed Habitat Assessment study consisted in a two-phase approach: first, the identification and mapping of potential restoration opportunities in the LHW (see **Section 3.0**), and second, the ranking of these opportunities based on their potential value to society. Each phase is further described in sections below, and detailed methods are provided in **Section 3.0**.

### 2.1.1 Screening Tool

Watershed-based assessments have been conducted in the LHW (Pearson and Chiavaroli, 2010) and other regions (EBA 2001; Burt and Palfrey 2011) with focus on characterising salmon habitat status and identifying potential restoration strategies and opportunities. However, any prioritization of potential restoration and enhancement projects has been mostly based on ecological factors (e.g., habitat indicators, limiting factors and conservation priorities), thus often excluding other potential benefits from the process. As noted in Anderson et al. (2003); "A watershed restoration project is as much a social undertaking as an ecological one"; the process of identifying and prioritizing which restoration projects to implement should therefore include socio-economic considerations. Such an approach was suggested by Scarfe (as cited in Slaney and Zaldokas 1997), in the context of the Watershed Restoration Program.[1] Scarfe (1997) proposed a screening approach that considers a project's value to society based on the potential environmental, economic, and social benefits the restoration project may yield. The Harrison River Watershed Habitat Assessment study used a similar approach (described in sections below and illustrated in **Figure 2**), which was adapted for the Harrison Watershed and with a focus on local communities. To produce a screening framework that reflects conditions and values specific to the LHW environment and communities, input and/or direction from the Sts'ailes and Sq'éwlets during the development of all three filters was critical.

#### *2.1.1.1 Ecological Benefits Filter*

Proposed restoration projects are first evaluated based on an ecological benefits filter, which considers primarily the potential restoration and/or enhancement of local fish populations (i.e., net gain in productivity), but also improvements to the overall ecological health of the watershed (e.g., improvements to water quality, to wildlife, riparian lands and wetlands). Projects with limited or nil net benefit to the ecology of the area, according to a predefined threshold, are filtered out of the process at this point.

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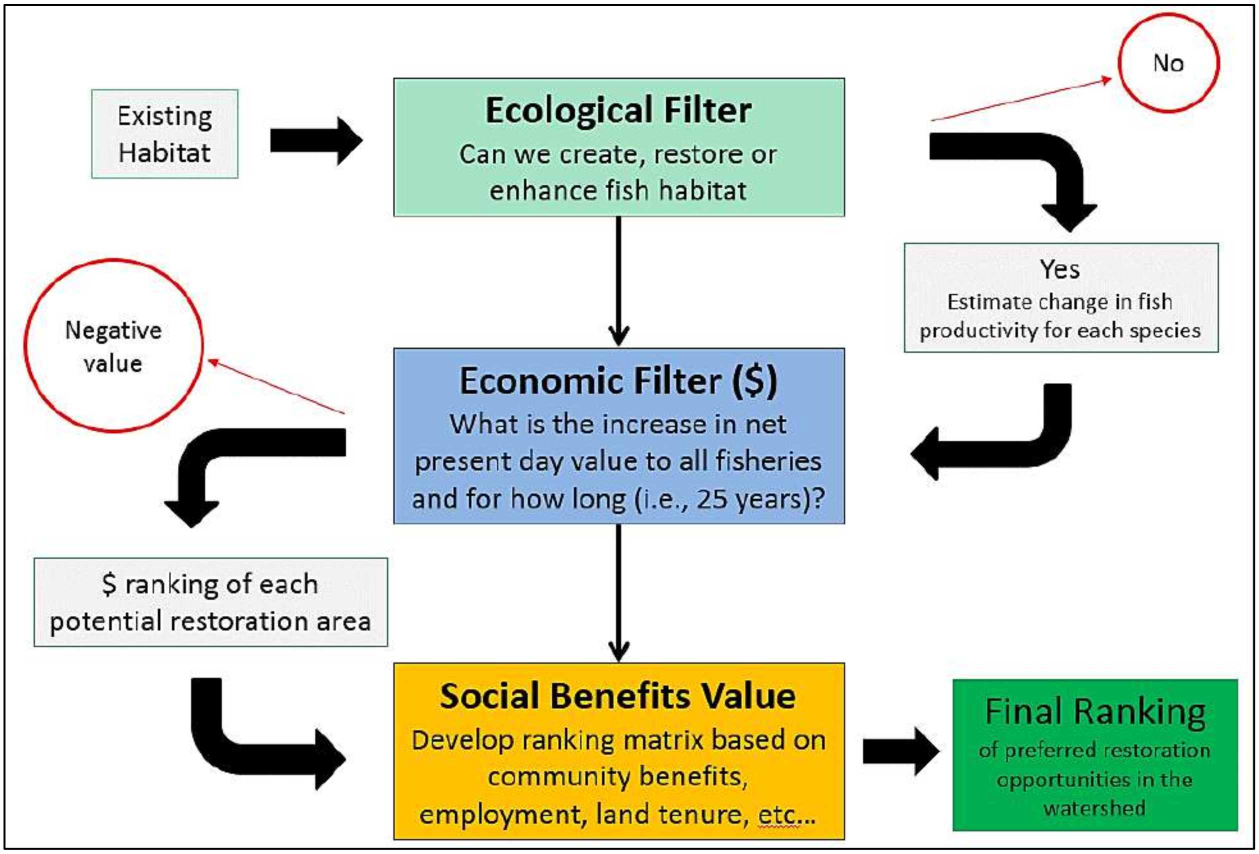
[1] The Watershed Restoration Program (WRP) was implemented in 1994 under Forest Renewal BC (a program under the Forest Practices Code Act of British Columbia) and was active until 2004 (MoE 2016). One of the Program's goals was to restore fisheries that had been impacted by logging operations, through the funding of rehabilitation projects.



**Note:** Red circles represent *end of pathway* points.

**Figure 2 Overview of the Study Approach (modified from Scarfe 1997)**

#### *2.1.1.2 Economic Benefits Filter*

After each restoration project has been ranked according to its ecological benefits, it will be re-examined through an economic benefits filter. These benefits are often time-dependent and gradual (Scarfe 1997), so all the costs and future benefits accrued throughout the lifespan of a project are brought into present values, and an appropriate real discount rate is applied. The resulting net present value (NPV) allows assessing the true potential economic benefits of a project over the its full life cycle. Once a total NPV value is determined for each Project, mangers can compare the relative ecological versus economic benefits of a restoration Project using a single metric converted to dollars.

#### *2.1.1.3 Social Benefits Filter*

As restoration projects may generate other benefits that are of value from a social perspective, a social benefits filter is also considered when assessing potential restoration projects. Such benefits include local employment, partnerships, social and cultural values, educative opportunities, etc. The social filter is complex to implement and may identify areas that have relative values (high, medium low), or binary, such as cultural sensitive areas that cannot be disturbed. The cultural filter allows for a final, and critical decision process that allows areas to be chosen or dismissed due to their significance to the local stakeholders.

## 2.2 TARGET FISHERIES

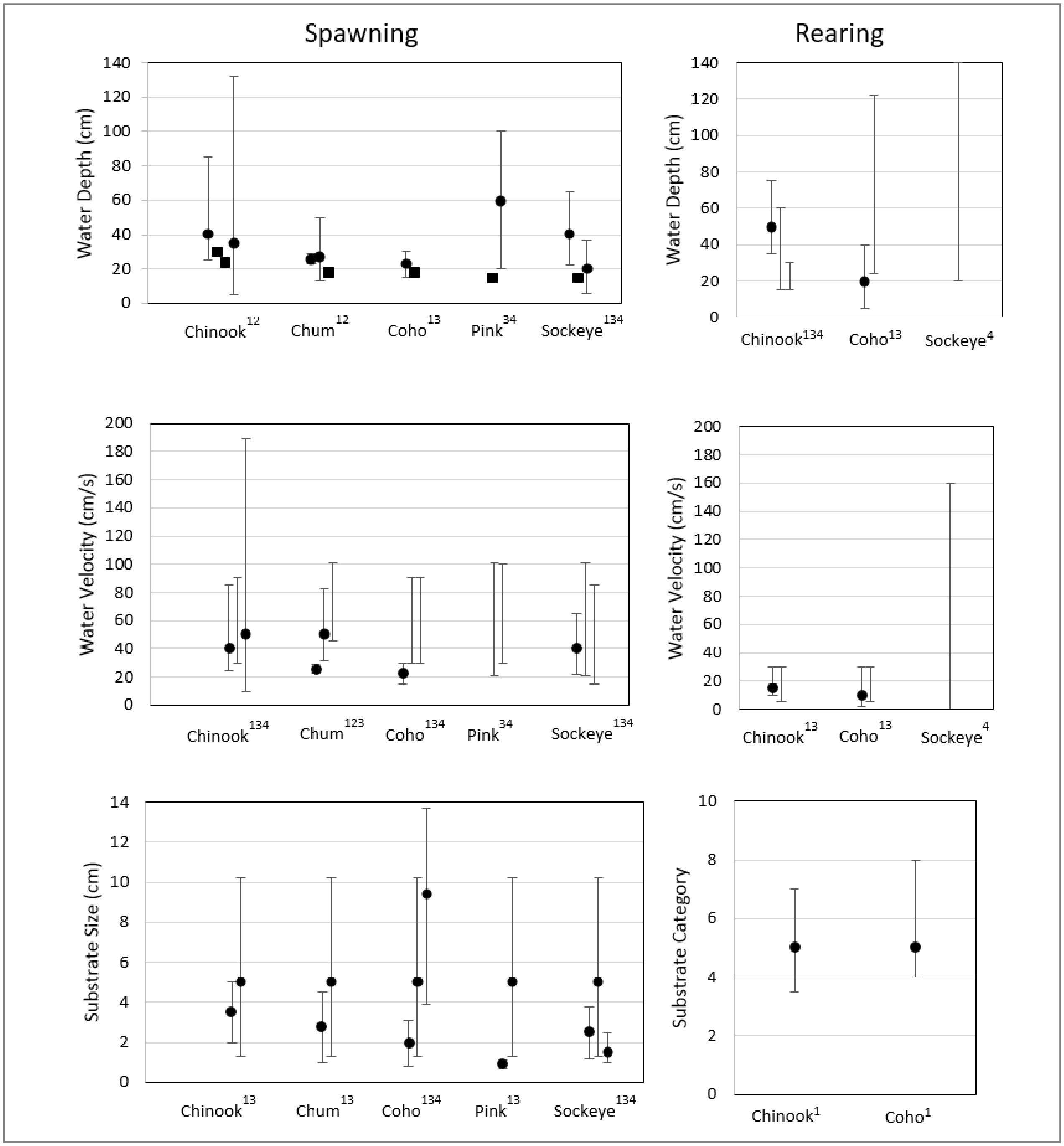
The study focuses on Pacific salmon species due to their importance to commercial, recreational, and Aboriginal (CRA) fisheries. However, several habitat requirements for trout and non-salmonid species are similar to those for salmon, thus allowing various fish species to benefit from habitat restoration. The Harrison River supports all five Pacific salmon species (i.e., Chinook, chum, coho, pink (*O. gorbuscha*), and sockeye), and several other salmonids, such as rainbow/ steelhead trout, coastal cutthroat trout (*O. clarkii clarkii*) and Dolly Varden (*Salvelinus malma*). Other ecologically and/or commercially valuable species occur in the region, such as white sturgeon (*Acipenser transmountanus*); however, they are not considered in this study. The following sections present an overview of the spawning and rearing requirements for each target species. These values will be used to develop the environmental preferences for each species to identify where habitat conditions have become degraded and what are optimal conditions to create, enhance or restore.

### 2.2.1 Overview of Spawning and Rearing Requirements

Habitat requirements for spawning and rearing Pacific Salmon are primarily associated with water depth, water velocity and substrate (**Figure 3**). Fish body size is positively related to water depth and water velocity preferences for spawning and rearing life history stages (Keeley and Slaney 1996), suggesting larger fish select deeper, faster areas of streams. Preferred spawning sites for salmonids generally have flows greater than 10 centimeter per second (cm/s) and water depth greater than 10 cm (Keeley and Slaney 1996).

Although spawning substrate preference is often correlated to fish body size (i.e., larger fish tend to build redds in larger substrate), salmonids can use a wide range of substrate sizes, given low abundance of fine sediments (e.g., silt and sand; Keeley and Slaney 1996). Territory size for spawning salmon is generally four times the redd size, with redd size being positively related to fish body size (Keeley and Slaney 1996). Bjornn and Reiser (1991) reported average redd areas are as follows: fall Chinook = 5.1 $m^2$, coho = 2.8 $m^2$, chum = 2.3 $m^2$, sockeye = 1.8 $m^2$, and pink = 0.6 $m^2$. Territory size for rearing salmon is mainly based on density and food availability.

Salmonid life history stages are also temperature-dependant. Unsuitable temperatures may delay river entry for spawning migrants, alter incubation length for eggs, and effect hatching and emergence time (Bjornn and Reiser 1991). Temperature requirements vary by species; however, all generally fall within the range of 4 - 14°C, with an upper lethal limit around 25°C.



**Note:** Circles represent means (± range), squares represent minimums. Superscript numbers indicate data sources: 1) Keeley and Slaney 1996; 2) Groot and Margolis 1991; 3) Bjornn and Reiser 1991; and 4) McPhail 2007.

**Figure 3** **Spawning and Rearing Habitat Requirements for Pacific Salmon**

#### *2.2.1.1 Chinook Salmon*

Chinook are the largest Pacific salmon, have the widest distribution, and exhibit a variety of life histories. Within the LHW, three distinct Chinook conservation units (CU)[2] have been identified (Holtby and Ciruna 2007): two stream-type and one ocean-type. Stream type rear in freshwater for one to two years before migrating to the ocean, whereas ocean-type migrate to the Fraser Estuary upon emergence or soon after (DFO 1997; Groot and Margolis 1991; McPhail 2007). The fall run ocean-type CU, designated "Harrison Chinook", spawns in the Harrison River. The spring run stream-type CU has not been recorded since the 1980's (Foy 2007 in Pearson and Chiavaroli 2010), and the summer run stream-type CU spawn in the watershed headwaters above Harrison Lake, which are beyond the project scope; therefore, these two CUs were excluded from this study.

Harrison Chinook are endemic to the Harrison River and are distinct by their white-flesh. Spawning migrants generally enter the Harrison River the first week of October (FISS 2010 in Pearson and Chiavaroli 2010). Within the Harrison River they have been documented spawning in the mainstem, along bars, and in side channels (Holtby and Ciruna 200). Spawning site conditions for chinook are highly variable (**Figure 3**). They generally spawn in larger streams with faster water and coarser substrate than other Pacific salmon species; however, they can also spawn in shallow, two to three metres wide side channels. As Chinook have the largest eggs of any Pacific salmon and require stable flow regimes for adequate oxygen supply, adequate sub-gravel flow of well-oxygenated water appears a more critical factor in spawning site selection than water depth, velocity, and substrate size (McPhail 2007). Spawning pairs may defend a 24 $m^2$ territory; approximately four times the average redd area (Bjornn and Reiser 1991).

Eggs incubate over winter and alevin emerge in the spring. Initially, fry are associated with shallow sloughs, backwaters, and off-channel habitats, with wetted depths between 15 and 30 cm and velocities less than 15 cm/s (McPhail 2007). In freshwater, their diet consists of aquatic and terrestrial insects (McPhail 2007). As they grow, juveniles drift downstream to main river channels and/or major tributaries (Groot and Margolis 1991; McPhail 2007).

#### *2.2.1.2 Chum Salmon*

Chum salmon are widely distributed and account for most of the Pacific salmon biomass (Holtby and Ciruna 2007; McPhail 2007). They are mainly a coastal species, rarely found more than 200 km away from the ocean. A single chum CU has been identified in the Harrison River (Holtby and Ciruna 2007).

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[2] Under the Wild Salmon Policy, a conservation unit is defined as: "a group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to recolonize naturally within and acceptable timeframe." (DFO 2008)

In the lower Fraser River, chum begin their spawning migration in September and may spawn as late as January. Chum are known to spawn in the Harrison River mainstem and side-channels. Preferred spawning sites are groundwater-fed channels, in reaches upstream of turbulent flows. Typical spawning sites have water depths of 13 to 50 cm and velocities between 20 and 80 cm/s, with gravel less than 15 cm in size (McPhail 2007). Eggs incubate over winter, hatch in two to three months, and fry emerge from the gravel one to two and one-half months later, depending on water temperatures. Fry begin their migration to the estuary upon emergence and; therefore, only rely briefly on freshwater habitats. Freshwater feeding is rare, but those that do eat chironomids and other aquatic insect larvae (McPhail 2007). Most chum mature after two to three years in the ocean (McPhail 2007).

#### *2.2.1.3 Coho Salmon*

Lower Fraser River coho are genetically distinct from interior stocks and a single coho CU has been identified in the Harrison River (Holtby and Ciruna 2007). Subsequently, they are the most widespread salmon throughout the Harrison watershed.

Returning coho migrate in the late fall and may spawn until mid-winter (FISS 2010 in Pearson and Chiavaroli 2010). Coho are opportunistic spawners, using a variety of spawning habitats (Diewart 2007 in Pearson and Chiavaroli 2010). Spawning sites can range from large rivers to smaller streams and side-channels no more than one metre wide. Redds are often found at the heads of riffles, where there is adequate sub-gravel flow. Recorded velocities at spawning sites may range from 30 to 91 cm/s, with substrate size ranging from 3.9 to 13.7 cm (McPhail 2007). On average, coho redds are 2.8 $m^2$ (Bjornn and Reiser 1991) and spawning pairs may defend a territory four times the size of the redd (Bruner 1951). Eggs incubate over winter, hatching in the spring, with fry emerging after one to three months, depending on water temperatures (DFO 1997; McPhail 2007).

Juvenile coho may rear in freshwater for a year or two before migrating to the ocean as smolts. They initially seek out backwaters, side channels, and small creeks, taking cover under boulders, overhanging branches, fallen trees, undercut roots and banks, and log jams (McPhail 2007; Groot and Margolis 1991). As they grow, they move into pools, then open areas, and finally, into river mainstems (Groot and Margolis 1991; McPhail 2007). Fry growth depends on population density, temperature, and food availability. Coho fry may feed in groups or individually: those feeding in groups are often associated with velocities greater than 6.0 cm/s, whereas individuals are found in velocities less than 6.0 cm/s (McPhail 2007). An increase in food availability may allow fry to grow faster and move into areas with velocities ranging from 65 to 84 cm/s (McPhail 2007). Juvenile coho are initially drift-feeders; eating aquatic insects in the water column or terrestrial insects from the surface, becoming piscivorous as they grow (McPhail 2007). Overwintering juveniles seek out off-channel areas (e.g., deep pools, beaver ponds and flooded wetlands), with abundant in-stream cover; coho production is often limited by availability of winter habitat (Holtby and Ciruna 2007). Outmigration occurs between April and June, usually after a year in freshwater. Coho spend approximately 18 months at sea before returning to spawn (McPhail 2007).

#### *2.2.1.4 Pink Salmon*

Like chum, pink salmon are less reliant on freshwater than other Pacific salmon species, as they spawn within 100 km of the ocean, and the fry out-migrate to estuaries soon after emergence (McPhail 2007). Pink salmon generally mature at two years of age, with odd and even year runs. The odd-year Fraser River run is the largest pink salmon run in BC (Diewert 2007 in Pearson and Chiavaroli 2010). A single odd-year pink CU has been identified in the Harrison River (Holtby and Ciruna 2007).

Spawning typically occurs from September to October, with the Fraser system having both early and late run segments (McPhail 2007; FISS 2010 in Holtby and Ciruna 2007). Spawners are often associated with clean, coarse, medium sized gravel and sub-gravel flow (as found in shallow riffles). Redds are often found in channels 20 to 100 cm deep (wetted depth), with a velocity ranging from 30 cm/s to 100 cm/s (McPhail 2007). Eggs incubate over-winter, hatch within one and one-half to three months, and fry emerge from the gravel after three to five months depending on water temperatures (McPhail 2007). Freshwater feeding is rare, but those that do primarily eat chironomids larvae and pupae (McPhail 2007). Of all Pacific salmon species, pink salmon spend the least amount of time rearing in freshwater. In the Fraser River system, pink salmon out-migration generally occurs between February and May.

#### *2.2.1.5 Sockeye Salmon*

Sockeye salmon have the greatest variability in life histories. Freshwater obligates (Kokanee) live entirely in freshwater, anadromous ocean-type migrate to the ocean immediately upon emergence, and anadromous lake-type rear in a nursery lake for one to two years before migrating to the ocean (Holtby and Ciruna 2007; McPhail 2007). Anadromous river-type sockeye spawn in rivers and streams, then migrate to the ocean; however, there is limited knowledge about their first year. They may migrate to the estuary soon after emergence (Diewart 2007 in in Pearson and Chiavaroli 2010; Groot and Margolis 1991; Holtby and Ciruna 2007;) or rear in streams and rivers up to a year before out-migrating (McPhail 2007). Three distinct sockeye CUs have been identified in the LHW: two lake-type and a river-type (Holtby and Ciruna 2007). The lake-type CUs spawn in tributaries outside the spatial scope of the project and rear in Harrison Lake; therefore, they were excluded from this study. The sockeye salmon belonging to the river-type CU spawn in the Chehalis and Harrison rivers are the focus of this study.

River-type sockeye in the Harrison River are late-run, beginning spawning migration in October (FISS 2010 in Pearson and Chiavaroli 2010) and spawning in mid-February (Mathes *et al.* 2010). They typically spawn in small tributaries and side channels, seeking areas of upwelling groundwater (supplying clean, oxygen-rich water), preferably in shallow riffles (Groot and Margolis 1991; McPhail 2007). Spawning sites generally have gravel ranging from 1 to 2.5 cm, with water depths of 6 to 37 cm, and velocities from 15 to 85 cm/s (McPhail 2007).

Fry aggregate in slow waters along river margins, sloughs, backwaters, and off-channel habitat. They are found in water depths of 20 to 140 cm and velocities up to 16 cm/s. Freshwater diet primarily consists of zooplankton, as well as chironomids larvae and pupae (McPhail 2007). Sockeye spend one to three years at sea before returning to spawn.

## 2.3 COMMERCIAL, RECREATIONAL AND ABORIGINAL FISHERIES

### 2.3.1 Traditional, Social and Cultural Fisheries

A Traditional Ecological Knowledge (TEK) study (Ritchie Unpublished) was undertaken by the Sts’ailes as part of this project. The study involved interviewing Sts’ailes elders and fishers regarding the historical function of the Harrison River tributaries and their traditional use of these habitats. This TEK study is available upon request. A relevant excerpt of the report is provided below.

Historically, Sts’ailes (formerly Chehalis) settlements were built along the individual sloughs between Morris Creek and the Chehalis River, where people had consistent access to salmon resources. Fishermen and community members would ensure that water in the sloughs flowed and the gravels were cleared of silts and vegetation by destroying beaver dams, cutting channels, and pulling out vegetation and debris. The Sts’ailes developed methods of selective fishing to ensure that salmon were harvested in a culturally appropriate matter that would ensure continued salmon abundance. Selective fishing was used to avoid killing female salmon that were spawning, and select fatty fish if they wanted to eat it fresh, and non-fatty fish if they wanted to preserve it. Preserving surplus salmon allowed the Sts’ailes to put food aside for winter and use the remainder for trading or gifting away at ceremonies. The Harrison River Valley was coveted for its salmon production and outside tribes would come every salmon season and pay the Sts’ailes a tribute to be permitted to fish in their waters. Bands from the upper Salish tribes and from far up and down the coast would congregate there in the fishing season.

### 2.3.2 Aboriginal Commercial Fisheries

In 2010, the Sts’ailes and Sq’éwlets (commonly referred to as Scowlitz) initiated an agreement with DFO to co-manage local salmon fisheries, under the umbrella for the Harrison Fisheries Authority (HFA; Moore, 2012). The following year, with the support from DFO’s Pacific Integrated Commercial Fisheries Initiative (PICFI), the Harrison Salmon Producers General Partnership (HSP) was formed, along with a business and training plan, which was implemented in 2012. Since 2013, the Sts’ailes and Sq’éwlets have managed and operated a “cooperative communal economic fishery” targeting pink and chum salmon that migrate into the Harrison River and adjacent Fraser River (Moore 2016).

### 2.3.3 Recreational Fishery

Recreational fishing is a popular leisure activity in BC for both local and tourist anglers and provides many socio-economic benefits to local communities. The latest available DFO Survey of Recreational Fishing in Canada provides 2010 data for BC freshwater fisheries (ESA 2010). Accordingly, the total direct expenditures made by all anglers in BC for freshwater fisheries was $247,183,428. These expenditures include costs such as transportation, food and lodging, fishing services, supplies, and equipment. In BC freshwaters, there was a total of 286,167 active anglers (335,563 licensed anglers). The average number of days fished is 13 days per angler and has remained relatively unchanged since 1995. Of all the fish caught, 26% were kept (8,949,790 caught and 2,330,638 kept). The main three fish caught were rainbow trout, freshwater salmon, and cutthroat trout in that order.

The Harrison River has been described as a salmon and trout angers dream and boasts a healthy multiple species recreational fishery. Fish can be caught year-round in the Harrison River with the most productive fishing between August and April. Coastal cutthroat and bull trout can be caught during the spring, and white sturgeon are common in the fall. Chinook, coho, and chum salmon dominate fishing activity from September to early December. **Table 1** outlines current salmon fishing regulations in the Harrison and Chehalis Rivers; however, the dates and limits listed are subject to change based on the data provided from stock assessments for each population. Though recreational fishing provides socio-economic benefits to the communities along the Harrison River, it is important to strive for a balance between the promotion of recreational fishing as a leisure activity and conservation of the resource.

**Table 1 Salmon limits, openings, and closures in BC Region 2 as of March 2017**

| Rivers | Salmon Species | Dates | Limits |
|---|---|---|---|
| Chehalis River | Coho | April 1 - March 31 | 4 hatchery marked fish per day |
| | Chinook | January 1 - May 31 | No fishing for chinook |
| | | June 1 - August 31 | 4 per day, only 2 over 50 cm |
| | | September 1 - December 31 | 4 per day, only 2 over 62 cm |
| | Chum | November 1 - November 30 | 2 per day |
| Harrison River | Chinook | until further notice | Non-retention |
| | Coho | September 1 -March 31 | 4 hatchery marked fish per day |
| | Chum | September 1 -March 31 | 2 per day |

**Note:** Table adapted from BC Freshwater Fishing Regulations, Fisheries and Oceans Canada, accessed March 2017.

## 2.4 OVERVIEW OF STRESSORS TO FISHERIES PRODUCTIVITY AND POTENTIAL RESTORATION METHODS

The following represent stressors to fisheries productivity identified through the literature review and observation during field assessments.

### 2.4.1 Forest Harvesting

Forest harvest is the most significant land use in the LHW. Although it is widely recognized the LHW has experienced adverse effects from past forest harvesting and associated road development, the extent and magnitude of these effects are uncertain (Pearson and Chiavaroli 2010). The effects of forest harvesting practices on salmon spawning and rearing streams, include: increased landslides, increased peak flows, stream bank erosion, sedimentation, reduced large woody debris recruitment, limited nutrient availability, and increased water temperatures (Slaney and Martin 1997).

**Restoration Recommendations**

Restoration efforts can be impaired by failure to restore the natural drainage patterns affected by access roads and cutblocks. Without a holistic watershed-scale approach, restoration efforts in lower streams may have limited positive effect. The most beneficial outcomes are achieved when stream rehabilitation is coupled with hillslope restoration (Slaney and Martin 1997). Restoration efforts aimed to reduce sediment transport include hillslope stabilization, road deactivation, and revegetation. However, restoration of forest harvesting areas is beyond the scope of this project.

### 2.4.2 Sedimentation

Although natural sedimentation is known to occur in the LHW because of back flooding of the Fraser and Harrison Rivers (Moore 2014), some sedimentation has been associated with land clearing activities throughout the watershed (Pearson and Chiavaroli 2010). Additionally, aquatic invasive plants, such as Eurasian watermilfoil, can promote the deposition of suspended sediments (Mossop and Bradford 2004), resulting in sediment build-up over spawning gravel.

Britwell (1999) compiled a comprehensive review of the adverse effects of sediments on fish and fish habitat. Sedimentation may cause physical effects that include gill trauma and increased stress. High levels of suspended sediment in water can kill fish directly; however, this is only likely to occur in situations with extreme sediment loads. Sedimentation also physically reduces the quality of spawning sites by infilling interstitial spaces in the gravel, resulting in detrimental effects on salmon egg, alevin, and juvenile survival. Sedimentation also reduces the density of macroinvertebrate communities by limiting light penetration, thus reducing primary production, and increasing macroinvertebrate drift rates.

**Restoration Recommendations**

Restoration efforts aimed at reducing sedimentation associated with anthropogenic activities are beyond the scope of this project. However, suggested restoration efforts include hillslope stabilization, road deactivation, and revegetation of site appropriate native plants. Once natural upstream sediment inputs have been restored, on-site sedimentation can be managed. Common sediment removal techniques include manual or mechanical scaring of the substrate. Hand tools, machinery, and water jets can all be used to disturb the sediment, so fines become suspended and get carried downstream. Another technique, employed by the Weaver Creek Spawning Channel, is to dredge once a year to remove deposited sediments. Sedimentation can be naturally dislodged by the actions of adult spawning salmon or by increasing local water velocities.

### 2.4.3 Water Quality and Flow

Tributaries in Pacific Northwest are naturally oligotrophic. Pearson and Chiavaroli (2010) summarized that the $NO_2$ and $NO_3$ levels in Harrison River tributaries are below the 100 $\mu g \bullet L^{-1}$ threshold and phosphorous levels below or at detection limits. Agricultural runoff is insignificant (approximately 0.6%) in most of the Harrison River watershed (Pearson and Chiavaroli 2010), except around the Harrison Mills area. Some tributaries in the LHW are threatened by water demand during natural summer low flows, and water withdrawals from domestic and business water licences (Pearson and Chiavaroli 2010). Summer low flows can be the result of a decreasing snow pack, increased surface runoff in the spring and increased flood flows associated with land clearing activities.

**Restoration Recommendations**

Increasing nutrient levels (i.e., through fertilization) in the Harrison River is not recommended as tributaries in the LHW are naturally oligotrophic. Nutrients are brought into the system from salmon returning from the ocean to spawn. Low flows can be restored by rehabilitating cleared land, thus reducing the associated runoff and flood flows. In some cases, it may be possible to limit water withdrawal, increase the efficiency of systems that use water, and buy back water rights. Methods of restoring water flows may include revegetating cleared areas and restoring riparian vegetation, and reconnecting isolated drainages.

### 2.4.4 Invasive Vegetation

#### *2.4.4.1 Reed Canary Grass*

Reed canary grass (*Phalaris arundinacea*) is an invasive sod-forming perennial grass. It can tolerate periods of frequent and prolonged flooding, as well as saline soils. Reed canary grass experiences two growth periods, one before seed maturation followed by summer dormancy, and one after seed maturation followed by winter dieback. Seeds are most viable immediately after maturation; however, up to 74% of new shoots arise asexually from rhizomes and rhizome fragments (GISD 2010). Reed canary grass has a high abundance of rhizomes, which form dense, impenetrable mats within a year.

Reed canary grass displaces native plants and is poor quality for use by most wildlife. Although it can provide vegetative cover for fish along streams, the grass is considered to be more detrimental than beneficial to salmon, as it reduces the quantity of available spawning gravel by blocking salmon access to channels and causing channel accretion. By promoting silt deposition, reed canary grass increases sedimentation in water channels and encroaches on waterways, which constricts channels (GISD 2010).

**Removal Recommendations**

Successful restoration from a reed canary grass infestation to a native-plant community may require two to three years, with post-remediation monitoring and maintenance to prevent reinvasion (Tu 2004). Various remediation methods may be implemented, depending on infestation level and site characteristics (Tu 2004). Manual and mechanical removal have shown to be successful techniques; manual removal is most suitable for small areas or isolated plants, while mechanical removal via tilling has shown to be successful when combined with a proper flood regime. This method is limited by site access and the ability to control water levels.

Reed canary grass is shade intolerant and; therefore, shading has proven to be successful at providing targeted control. Plants in areas shaded for an entire growing season do not survive. Successful shading materials include layered cardboard and mulch, and plastic fabric. Mowing or burning beforehand facilitates the installation of shade clothes. Reed canary grass can also be shaded out by fast growing shrubs or trees (e.g., red alder (*Alnus rubra*)); conifer canopies are ideal.

Mowing, grazing, and burning can be effective pre-treatments to tilling, herbicides, or shading; however, these methods have not shown to be effective at removing reed canary grass when used alone. Limited mowing and burning of the top layer stimulates stem growth, which is not desirable. Mowing can assist in depleting the seedbank if mowing is done prior to flowering at least five times/year for five to ten years. Reed canary grass does not burn well and prescribed burning in the Pacific Northwest is conducted during the fall, when burning would have minimal effect on reed canary grass.

Each method above often requires follow-up spot treatment of herbicides or physical removal to mitigate reinvasion. Following removal works, replanting with native grasses, sedges, and rushes is recommended, as these species often outcompete reed canary grass seed germination. A combination of methods is recommended for removal of reed canary grass in the project area, based on local conditions; limitations, such as working windows, site access, and regulations may also guide restoration efforts.

#### *2.4.4.2 Eurasian Watermilfoil*

Eurasian watermilfoil (*Myriophyllum spicatum*), herein called milfoil, is an invasive aquatic perennial plant, commonly confused with native milfoil species *M. verticillatum* and *M. exalbescens.* It grows more aggressively than native species, able to out-compete them due to its high over-wintering biomass and rapid spring growth (Smith and Barko 1990). It forms dense mats that displace most other plants within two to three years (Aiken et al. 1979). Milfoil can grow in water depths ranging from one to ten metres, but is most common in water one to three metres deep in fine inorganic, nutrient-rich sediments (Aiken et al. 1979; Smith and Barko 1990). Flowering occurs from June to September (Aiken et al. 1979). Asexual reproduction is common and colonization of new sites is done by vegetative fragmentation, which occurs at the end of winter (when small, axillary buds detach from the root crowns) and during the summer (when stems release numerous fragments that develop roots). Fragments mechanically broken off by wave action and boats are viable (Aiken et al. 1979; Smith and Barko 1990).

Milfoil may provide cover for invertebrates and fish (Smith and Barko 1990), as well as spawning and rearing sites for freshwater crustaceans, calm waters for waterfowl to rest, and it may prevent algal blooms by competing for nutrients (Aiken et al. 1979). Conversely, milfoil has negative effects on salmon; it has been associated with increased salmonid predation by providing cover for juvenile pikeminnow - a species which preys on salmonids (Mossop and Bradford 2004). Milfoil also encroaches on spawning gravel (Newroth 1985) and can contribute to the deposition of sediment (Mossop and Bradford 2004). Preliminary studies and field observations indicate milfoil can alter temperature and dissolved oxygen profiles in shallow water (Aiken et al. 1979; Unmuth et al. 2000). The effects of milfoil on salmonids are poorly understood and research opportunities are possible.

#### Removal Recommendations

Milfoil management is focused on controlling abundance, as eradication has only been documented in small lakes, and the likelihood of re-infestation is high (Newroth 1993). Mechanical removal is a common means of managing milfoil. Rototilling was shown to be the most effective control method in Cultus Lake, BC (Mossop and Bradford 2004) and the Okanagan, BC (Dunbar 2009). However, rototilling is destructive to salmon spawning areas and precautions must be taken to avoid harm to fish (e.g., working in BC MoE instream work windows). In sensitive areas, milfoil can be manually picked. Bottom barriers (e.g., polyester geotextile and nylon) have also been shown effective in spot treatments and can be used in areas inaccessible to rototillers (Mossop and Bradford 2004; Truelson 1987).

Biological control of milfoil has been focused on the native watermilfoil weevil (*Euhrychiopsis lecontei*). The decline of several milfoil populations across North America have been attributed to the weevil (Creed 2000). Weevils damage plant tissues throughout the milfoil life stages, thus reducing plant growth. Studies have shown the weevils have little effect on native milfoil species, but represent a promising biological control option for Eurasian watermilfoil (Sheldon and Creed 2003; Creed 2000).

Milfoil has shown to be susceptible to herbicides (e.g., 2,4-dichlorophenoxy acetic acid) provided there is no water movement (Aiken et al. 1979). However, herbicide use in fish-bearing waterbodies is not recommended; this option is not considered appropriate for this study.

### 2.4.5 Barriers to Fish Passage

#### *2.4.5.1 Culverts*

Poor culvert design, improper culvert instillation, or a lack of culvert maintenance may restrict the passage of adult salmon to spawning sites and prevent juvenile salmon access to off-channel over-winter habitat (Whyte et al. 1997). Culverts connecting main channels to over-wintering habitats should be designed and installed in such a way to provide low velocities required for juvenile salmon movement and migration. Fast and/or shallow water can restrict the upstream movement of salmon through the culvert. Perched or elevated culverts (i.e., at the downstream end) may also impede salmon access. Finally, culverts that do not adequately accommodate debris passage may become blocked and a barrier to fish passage (Whyte et al. 1997). The following hydraulic criteria are recommended to maintain salmon passage through culverts: an average water velocity not exceeding 1.2 m/s in culverts shorter than 24.4 m, and 0.9 m/sec in culverts longer than 24.4 m; and water depth at any point in the culvert should be no less than 0.23 m (Whyte et al. 1997).

#### Restoration Recommendations

Culverts in fish bearing channels, historically fish bearing channels, or where fish access could be reasonably expected if the culvert were made passible, that do not meet the hydraulic criteria, are too steep, have height restrictions, or are predisposed to blockages should be replaced or modified. Baffles can be installed within culverts to decrease water velocities, increase water depths, and allow for fish passage through steep culverts. Tail-water control devices can be installed to create a resting pool at the downstream end of the culvert, back-flood the culvert (which increases water depths and decreases velocities), and control downstream erosion. Culverts should be designed and installed to prevent scouring and downcutting of the streambed. New culverts should be installed 0.30 m below the natural grade line of the stream to allow natural substrates to line the culvert bottom, and should be sized to accommodate a 100-year flood. If the culvert is not designed to allow debris passage, trash racks, which would require maintenance, can be installed at the upstream end of the culvert (Whyte et al. 1997).

Beavers can be discouraged from damming culvert inlets by installing beaver fences or screening devices. In each instance, the mesh spacing should be approximately 15 cm (i.e., wide enough to allow adult fish passage). Devices are attached to culvert intakes and should be at least 0.5 m above the pond floor, to make it difficult for beavers to anchor their dam building materials (Finnigan and Marshall 1997).

Where possible, the replacement of a culvert with a free span bridge is recommended to eliminate constrictions to streamflow that encourage beaver dam building. Bridges allow for the retention of natural flow and substrate of steams, and provide a corridor for wildlife to cross.

#### *2.4.5.2 Beaver Dams*

Beavers play an important ecological role in many salmon bearing ecosystems and need to be considered in watershed restoration projects (Finnigan and Marshall 1997). Beavers colonize slower-moving sections of rivers and streams, existing ponds, and stable groundwater-fed side channels. Damming can change sections of streams into ponds, which have various physical, chemical, and biological functions that can be either beneficial or detrimental to salmon. Occupied and abandoned beaver ponds provide benefits to the ecosystem by regulating water flow, modifying the riparian zone, retaining sediment, providing salmon rearing habitat, and assisting in nutrient cycling (Finnigan and Marshall 1997). Unfortunately, many beaver dams obstruct fish passage (Finnigan and Marshall 1997) blocking migration to large areas of rearing and spawning habitats. This is particularly true along upper

Morris Creek and some of the Sts'ailes sloughs. As a result of trapping practices, beaver populations in the LHW were historically smaller than they are today. First Nations have used beaver dams as fish traps; a section of dam would be broken to allow fish into the impoundment, then a gate would be built to trap the salmon (Ritchie and Springer, Unpublished).

**Restoration Recommendations**

Beaver populations and dams have been traditionally managed by the First Nations (Ritchie and Springer, Unpublished). The problem for creating fish passage is that beavers rapidly repair breached dams, sometimes within a day. Over the course of spawning migrations, dams may need to be breached repeatedly, which is not time- or cost-effective. Dams are often not breached during periods when juvenile salmonids are seeking rearing or over-wintering habitat. Dam removal should be conducted by hand or light machinery, with suitable sediment barrier in place, and in small sections (where possible), to mitigate scouring and temperature changes. In addition, fish and/or amphibian salvages may be required prior to the works, where complete dewatering may occur.

Beaver removal is not a preferred management technique, as beavers are naturally found within the LHW and are considered contributors to watershed health. Culling may not be socially and culturally accepted by local First Nation groups and; therefore, not considered as a local control option. Relocation is not recommended because of its potential to create new beaver management conflicts elsewhere.

Various exclusion and fish passage designs are available as alternatives to beaver control and dam removal, such as the Telkwa design, which maintains constant water level in the impoundment for the beavers' hydrological needs while providing fish passage (Finnigan and Marshall 1997). The Telkwa design includes excavating a low gradient channel that goes around the beaver dam and connects the beaver pond to the downstream channel, where a fence is erected along the banks of the new channel and the channel is filled with large floating woody debris held in place by a barrier log; the fence and woody debris discourage dam-building activities while allowing fish passage (Finnigan and Marshall 1997).

### 2.4.6 Channel Loss

Many side channels and sloughs along the Harrison River no longer provide suitable salmon habitat because of either natural or artificial accretion processes resulting in partial or complete channel de-watering. Many of these accreted channels have become ephemeral, only supporting water input during periods of heavy precipitation or flooding (e.g., during spring freshet). Channels may become accreted/ dewatered from a buildup of sediment, encroachment of reed canary grass, or a lowering of the groundwater table. Channels located in alluvial floodplains (e.g., those located between Chehalis River and Morris Creek) are prone to sedimentation, which can build up over time. The accumulation of fluvial sediments increase the site elevation, making flooding less frequent and eventually drying the site out. Instream sedimentation may also promote reed canary grass encroachment (**Section 2.3.4.1**). Channels may also become dewatered by the lowering of water levels or if they are cut-off by the construction of dikes and other flood-control structures.

**Restoration Recommendations**

Excavation of accreted channels and the construction of sediment control devices (e.g., weirs) may be recommended to re-establish fish habitat. Cut-off channels can be reconnected to mainstems by incorporating connectivity through flood-control devices (e.g., installing/improving culverts beneath dikes). A clear understanding of local hydrology and sedimentation processes is important to assess whether restoration will be effective during project design.

### 2.4.7 Over-Harvesting

There is the potential for overfishing of Harrison River fish stocks. Fisheries that impact the Harrison River include recreational fisheries, which are largely based out of Harrison Hot Springs, commercial fisheries in the Fraser River, and the small Aboriginal terminal fisheries conducted under the Harrison Salmon Producers LLP. Over-fishing can be brought on by (1) over-estimating abundance and under-estimating fishing mortality; (2) the increased ability to efficiently catch fish at low abundance levels; and (3) increased discarding and nonreporting of small fish as the population declined, as exemplified by the 1993 Atlantic cod collapse (Myers et al. 1997).

Setting manageable catch limits is notoriously difficult, which may result in streams not meeting escapement targets (Price et al. 2008). Problems with setting catch limits include a lack of reliable escapement data, along with illegal, unreported, and unregulated fishing. This may take the form of recreational fishers catching their limit, and returning a second time in the same day (Slogan, personal observation with coho and chum fishers during the study). Unreported catch by local fishers or Aboriginals without licences also impact the ability of resource managers to set appropriate limits. The Harrison River fisheries are not only impacted by these actions in the LHW, but also downstream along the Fraser River where fish may be intercepted prior to making it into the watershed.

**Restoration Recommendations**

Given the ecological, economic, and cultural value of the fisheries of the Harrison River, maintaining vigilance around fishing behaviour (setting conservative catch limits) may be critical to ensuring the long-term productivity of the area. This may be achieved with increased monitoring or policing of the fishing areas along the Harrison River.

### 2.4.8 Climate Change

The effects of climate change may vary by watershed, and the response from individual salmon populations depends on stock-specific tolerances and life histories. Two main concerns in relation to climate change effects on salmon populations are associated with water temperature and stream flow.

In the Pacific Northwest, water temperatures are expected to increase by up to 4°C to 6°C (Beechie et al. 2012; Taylor and Langlois 2000 in Pearson and Chiavaroli 2010) by 2100. Such increases could raise stream temperatures above lethal threshold for salmon (e.g., during summer), and/or reduce habitat quality (e.g., increased algae production, decreased dissolved oxygen). Climate change models also predict an increase in precipitation during the fall and winter, and a decrease in the summer (Beechie et al. 2012; Taylor and Langlois 2000, in Pearson and Chiavaroli 2010). By 2100, maximum monthly flows are expected to increase by 10 to 50%, and summer low flows could decrease by 10 to 70% (Beechie et al. 2012).

#### Restoration Recommendations

Restoration activities should be considered in the context of their capacity to mitigate the effects of climate change or increase ecosystem resilience. Actions that mitigate effects may reduce fall and winter floods and peak flows, and increase summer base flows. Restoration can also aim to maintain cool water temperatures during summer months. Beechie (2012) proposed various stream restoration strategies to mitigate the effects of climate change, including: longitudinal, lateral, and vertical connectivity, stream flow regimes, erosion and sediment delivery, riparian functions, instream rehabilitation, and nutrient enrichment.

# 3.0 METHODS

## 3.1 LITERATURE REVIEW

The primary source of data for the screening tool was values determined through a literature review consisting of local and regional field studies, government technical reports, and peer-reviewed papers. The focus of the review was to acquire data values to populate the Scarfe model (Scarfe 1997; model used to predict the present value of habitat), as field investigation time was limited. The literature review focused on acquiring the following information:

1. Optimal spawning and rearing conditions (i.e., substrate type, water depth) for Pacific salmon in the LHW. Conditions were used to assess relative habitat quality and identify areas for enhancement and restoration efforts (see **Section 2.2**);
2. Potential salmonid productivity values from habitat representative of what currently exists in the LHW and what could be created in the future;
3. The mean weight of each species of fish used in the model;
4. The latest economic values of the local fisheries for commercial, recreational and Aboriginal fisheries in the LHW; and
5. Documented past and/or proposed restoration projects in the LHW.

The preference, or pedigree, for data sources were highest for local field programs and the lowest for published literature or technical reports from other regions of the country or globe as determined by professional judgement (**Table 2**).

**Table 2 Preference for data sources used to inform the model**

| Preference | Data Source |
|---|---|
| 1 | Local field program |
| 2 | Local reports from the Harrison Fisheries Groups |
| 3 | Local peer-reviewed reports |
| 4 | Regional peer-reviewed reports |
| 5 | Professional judgement |

## 3.2 HABITAT MAPPING

The process of habitat mapping consisted of three phases. The first phase of the study involved the acquisition of 47 $km^2$ of high resolution orthoimagery (HRO) and LIDAR (Light Detection and Ranging) data, thereby delineating the study area[3] (**Section 3.2.1**). The second phase consisted of desktop predictive mapping to assess fish habitat, evaluate possible limiting factors and identify preliminary areas

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[3] Orthoimagery and LiDAR were also collected for an area south of Lake Errock and the upper Miami River areas, but were not included in the study. This imagery resides with the Harrison Fisheries Authority and DFO.

for potential restoration efforts using ArcView® 10.5 (**Section 3.2.2**). Finally, field surveys were also conducted to collect local data, identify and assess fish habitat and restoration opportunities and perform quality assurance (QA) checks on desktop mapping. The habitat mapping attributes used are provided in **Appendix A**.

### 3.2.1 Acquisition of Orthoimagery and LIDAR

Terra Remote Sensing (Terra) collected LiDAR data in late October 2017 to provide a detailed and current overview of terrestrial and hydrological features in the LHW. A report was prepared by Terra (2017) that identifies the equipment, methods and data collected. This report is attached in **Appendix B**. Airborne data collection was tied to ground control survey locations to ensure accuracy of the LiDAR and elevation models. Point density was an average of greater than eight points per square meter on open hard terrain resulting in a vertical accuracy of approximately 10 cm. Digital imagery was acquired at a 10 cm pixel resolution. LiDAR was acquired as bare earth, allowing for digital elevation models of the ground below vegetation, and a second layer with the vegetation elevations.

### 3.2.2 Mapping Output in GIS

LIDAR data and orthoimagery was used to map existing and potential fish habitat at a scale of approximately 1:1000. A detailed scale of this nature is necessary to accurately identify, map, and cost restoration opportunities; many that include narrow accreted depressions less than five metres wide. Since the Project was focussed on the wetted areas of the watershed, Terra applied a "hydro-flattening" process that identifies break-lines between watercourses and the land. Where waterbodies were less than two metres wide, a line was mapped verses a polygon. In the model, lines were converted to polygons and conservatively assumed to have a wetted width of one metre. Additional polygons were created in ArcGIS that extended off the wetted polygons in areas that were identified as potential salmon habitat.

Potential habitat was determined by identifying elevation depressions in the LIDAR data that could, based on experience, be feasibly converted to fish habitat. These areas were typically historic channels cut-off from main wetted areas or accreted zones. Depressions were then cross referenced with field survey data to determine if they were viable areas for salmon habitat creation or enhancement. After reviewing the digital elevation model data and orthoimagery, polygons were also created in areas without depressions, but that could serve to connect existing channels. Lastly, polygons were created around salmon habitat stressors (e.g., culverts and beaver dams). These were identified during field surveys and from analysis of orthographic images.

Each polygon was classified using a series of attributes modified from accepted fish habitat mapping procedures in BC (Resource Inventory Standards Council (RISC) 2001 and 2008) and included important criteria for assessing restoration potential (**Appendix A**). The primary attributes used include: habitat (upland, accreted, ephemeral, wet), stressor type, and salmon usage or potential usage (life-stage). Secondary modifying attributes include: riparian vegetation type, crown closure, water velocity, channel depth, substrate type, channel morphology, and instream cover.

### 3.2.3 Field Surveys and Ground Truthing

Field surveys were conducted to collect local data, identify and assess fish habitat and restoration opportunities, and QA desktop mapping. Field surveys were targeted to occur during low water to identify ephemeral channels and areas that would not support year-round fish spawning or rearing. The surveys were also used to investigate the presence of stressors and disturbances (e.g., beaver dams and invasive plants), anthropogenic disturbances (e.g., culverts), and aquatic areas lost due to past natural disturbance (i.e., flooding leading to channel cut-off or accretion) variables. Field surveys were conducted over four trips during the period of October 5 to 7and 24 to 27, 2016, and March 15, 20 and 21, 2017. A total of 88 sites were investigated via boat, by road, and on foot. Site characteristics, as well as hydrological and water quality data, were collected on a standardized site card form.

As mentioned in **Section 3.2.2**, site characteristics were measured *in situ* or determined by "ground estimates" among the field crew, following standards similar to those outlined by the Resource Inventory Standard Committee (RISC, 2001 and 2008). Each site was georeferenced and photo-documented. Other parameters assessed during the field surveys included:

- Streambed substrate composition;
- Instream habitat complexity and cover;
- Water quality (temperature, dissolved oxygen, pH, turbidity);
- Sources of groundwater input;
- Existing riparian vegetation integrity and areas of invasive and non-native species that negatively affect fish productivity;
- Status of fish passage at identified road/dike stream crossings and flood control infrastructure within 100 m of the Harrison River and large tributary main stems. Presence of accumulated debris and barriers/obstacles to fish passage;
- Low-lying areas including depressions and gullies where it may be feasible to create new spawning and rearing habitat;
- Ease of access for future restoration works (i.e., is the site accessible by road or by boat only); and,
- Overall existing salmonid habitat values (e.g., substrate, channel depth, water velocity) for key life processes (i.e., spawning, rearing, overwintering, migration).

Attributes used during ground-truthing and the subsequent habitat mapping in ArcView® 10.5 (**Section 3.2.3**) are presented in **Appendix A**.

## 3.3 CALCULATION OF ECOLOGICAL BENEFITS VALUES

### 3.3.1 Production

As introduced in **Section 2.1.1.1**, the ecological benefits filter used in the present study was based on methods proposed by Scarfe (1997). The formula used to estimate fisheries benefit (i.e., the increase in biomass that may result from the restoration works) is as follows:

$$\mathbf{P = S*K*Y}$$

where:

**P** = the fish production or yield (i.e., new body mass per unit area).

**S** = the area ($m^2$) of streambed in which habitat improvements are likely to occur.

**K** = estimated number of adult fish, of each species, that will result from the restoration works (i.e., the impact per square metre of improved streambed).

**Y** = the average weight of an adult fish for each species included in the assessment.

The production (i.e., **P**) is the estimated growth in the biomass of the relevant fish species that may result from the restoration.

The area of streambed in which habitat improvements are likely to occur for each potential restoration opportunity (i.e., '**S**') was determined by adding areas for all the mapped polygons associated with that opportunity.

The number of adult fish that may result from the restoration works (i.e., '**K**') can be estimated in a variety of ways, with associated levels of complexity, robustness and confidence. As the main objective of this study was to develop a user-friendly screening tool that can be utilized by both decision-makers and community members to identify and prioritizing restoration opportunities, a relatively simpler method to calculate '**K**' was investigated. Keeley, Slaney and Zaldokas (1996) analyzed data from 30 studies from a literature search to evaluate the effects of restoration works on salmonid densities, and consequently, the potential resulting benefits. The authors used average changes in fish densities (based on pre-/ post- or control/ post- yields from restoration projects) and life-stage survival rates to calculate potential increases in adult production resulting from restoration works. **Table 3** summarizes the results (i.e., biostandards) from Keeley et al. (1996). Although not current, these values are considered appropriate for this study as they are based on data from several projects, each with a pre-treatment reference level or control area (providing a more robust comparison). Furthermore, the authors (well-published university and provincial biologists in BC) conducted their investigation within the context of the Watershed Restoration Program and developed the values to assist with cost-benefit analyses.

### Table 3 Estimated Fish Production Benefits

| Species | Survival Rate | | Estimated Average Production (No. adult fish/m$^2$) | | |
|---|---|---|---|---|---|
| | Fry/ Freshwater[1] | Smolts/ Marine[1] | Enhanced Channel[2] | New Channel | New Off-channel Pond |
| Chinook salmon | 0.680 | 0.041 | 0.017 | - | - |
| Coho salmon | 0.680 | 0.098 | 0.025 | 0.066 | 0.068 |
| Chum salmon | 0.069 | 0.007 | 0.470 | 1.580 | n/a |
| Pink salmon | 0.070 | 0.028 | 2.110 | - | n/a |
| Sockeye salmon | 0.093 | 0.073 | 6.330 | - | n/a |
| Steelhead trout | 0.330 | 0.160 | 0.003 | - | - |
| Rainbow trout | n/a | n/a | 0.040 | - | - |
| Cutthroat trout | n/a | n/a | 0.023 | - | - |

[1] Average survival rates from Bradford (1995), used by Keeley et al. (1996) for production estimate calculations.
[2] Values represent the net gain (i.e., post-treatment production minus pre-treatment production).

The average weights of adult salmon ('**Y**') were taken from values provided in *Guidelines for In-Stream Placement of Hatchery Salmon Carcasses for Nutrient Enrichment* (DFO, undated), which were based on mean weights from BC catch statistics (J. Bateman, pers. comm.). **Table 4** presents the suggested average weights for adult salmon in kilograms (kg). Values for rainbow trout and coastal cutthroat trout were not available.

### Table 4 Suggested Average Weights for Adult Salmon

| Species | Average Weight (kg) | Species | Average Weight (kg) |
|---|---|---|---|
| Chinook salmon | 8.5 | Sockeye salmon | 2.5 |
| Coho salmon | 3.0 | Steelhead trout | 4.0 |
| Chum salmon | 4.5 | Rainbow trout | - |
| Pink salmon | 1.5 | Coastal cutthroat trout | - |

### 3.3.2 Assumptions

The following assumptions were made in the process of developing and applying the Ecological Filter:

- The area of potential restoration (i.e., '**S**' in the SKY formula) for each identified polygon was assumed to be to the top-of-bank, although actual polygons may slightly over or underestimate actual potential wetted restoration areas;
- Survival rates used by Keeley et al. (1996) to estimate fish production benefits have not changed significantly since the study was conducted; and
- Restoration works in the studies investigated by Keeley et al. (1996) to calculate the potential number of adult fish are similar in scope to the potential opportunities in the LHW; therefore, the authors' production values (**Table 3**) may be used in the present study to estimate ecological benefits.

### 3.3.3 Limitations

The following limitations may be attributed to the process of developing and applying the Ecological Filter:

- Not all potential restoration areas were identified in detail during the study. Other areas exist that could be restored, enhanced, or created; however, the 20 areas identified were chosen as they were determined to be accessible and feasible, based on professional judgement;
- Not every potential restoration area identified via habitat mapping could be ground-truthed; therefore, some of these polygons may not represent feasible restoration opportunities, or the calculated areas ('**S**') may be over- or under-estimated;
- No data were available for production ('**K**') of Chinook, pink, sockeye and trout species in new channels; therefore, values from Keeley et al. (1996) for enhanced channels were used in the calculations;
- As there may be regional differences in the weights of adult salmon ('**Y**'), it is understood the values in this study are suggested values, which can be adjusted with local data in the future; and
- The potential ecological benefits considered in the model are mainly from a fisheries perspective (i.e., focused on salmonids); however, many other benefits may result from the restoration works, such as benefits to non-fisheries species, wildlife, birds, vegetation, and water quality. Although these are important components of overall ecosystem health, associated potential benefits are difficult to quantify and their value is considered mainly as value-added (i.e., qualitative) to the ecological benefits filter.

## 3.4 CALCULATION ECONOMIC BENEFITS VALUES

The economic benefits to fisheries were calculated as a balance between the fish productivity and the estimated cost of each potential restoration project. The benefits from restoration accumulate over the entire life of a restoration project, so Scarfe (1997) proposed converting all costs and benefits into present values. Scarfe's net present value (NPV) formula is as following:

$$NPV = B_0 - C_0 + \frac{B_1 - C_1}{1 + R} + \frac{B_2 - C_2}{(1 + r)^2} + \cdots + \frac{B_T - C_T}{(1 + R)^T}$$

where:

**$B_1$** = the aggregate benefits made available by the project in year 1, 1 = 0…T;

**$C_1$** = the costs incurred with respect to the project in the same year; and

**r** = the selected real discount rate for the study.

Scarfe (1997) proposed expressing all project cost and future benefit values in constant dollars of today's purchasing power. Therefore, future values are discounted back to the present using an inflation-adjusted rate of interest (i.e., real discount rate). The author proposed a real discount rate of 3% per annum, to account for the level of uncertainty that may be associated with restoration projects, while taking into consideration the risk to society associated with not investing in restoration and allowing the ecosystem to deteriorate. A real discount rate of 0% (r = 0.00) is proposed in the present study, as it is assumed the value of a healthy watershed (and healthy fisheries) to society will increase over time and offset future uncertainty. This 0% discount rate is considered conservative as the cost to build restoration areas, the value of the land, and the value of the resource generally all become more valuable with time. Furthermore, a negative discount rate (e.g., -1- to -3%) could be considered if the value of the project was assumed to increase significantly in the future.

The value representing aggregate benefits made available by the project is calculated by multiplying fish production ('**P**'; **Section 3.3**) by the suggested price parameters representing the intrinsic value of fish (i.e., in relation to a fisheries). The value of a fish may differ depending on the fishery (i.e., prices may vary from a commercial to an Aboriginal or recreational fishery). Because this study is focusing on the Aboriginal fisheries in the Harrison Watershed, the suggested price parameters are based on data (i.e., commercial gross values) provided by the Harrison Salmon Producers General Partnership (HSP) for their chum, pink and sockeye salmon fisheries. The suggested price points, by species, are as presented below:

| | |
|---|---|
| Chum salmon | \$5.04/ kg |
| Pink salmon | \$3.08/ kg |
| Sockeye salmon | \$4.64/ kg |

No commercial values were available from HSP for coho and Chinook salmon, as these species are only kept for social food items and not sold commercially (K. Charlie, pers. comm.). However, Chinook salmon may be occasionally sold, at a price of \$5.50/ kg (D. Moore, pers. comm.).

### 3.4.1 Assumptions

The following assumptions were made in the process of developing and applying the Economic Filter:

- The average estimated life span of a re-watered, groundwater-fed channel is 20 years (Bonnell 1991; Ward and Slaney 1979);
- The cost associated with the construction of new habitat (e.g., excavation of an accreted channel, with habitat complexing) was estimated to be \$50/m$^2$ on average, while the cost associated with the enhancement of existing fish habitat (e.g., removal of invasive aquatic vegetation, addition of large woody debris or addition of spawning gravel) was estimated at \$25/ m$^2$ on average based on professional judgement;
- A one-time cost of 5% of the total construction cost was included for adaptive management (i.e., initial monitoring with maintenance);
- Production gains from returning adults are assumed to start on Year 2 for pink salmon (Year 0 being the construction year), Year 3 for chum and coho salmon, Year 4 for chinook salmon, and Year 5 for sockeye salmon and steelhead trout; and

- Scarfe (1997) proposed economic benefits from recreational fisheries of two angler-days per adult steelhead trout produced. In this model, benefits from recreational fishery (i.e., angling) are applied to Chinook salmon, sockeye salmon and steelhead trout (at two angler-days per adult fish produced), as well as coho salmon, chum salmon, rainbow trout and coastal cutthroat trout (at one angler-day per adult fish produced).

### 3.4.2 Limitations

The following limitations may be attributed to the process of developing and applying the Economic Filter:

- The estimated costs associated with the construction of new and enhanced habitats may vary greatly based on site access, complexity of the project (i.e., the number and type of restoration activities proposed), and external factors such as cost of labor and materials. Therefore, the values utilized to calculate construction cost in the model may be under or over estimated to varying degrees; and
- A cost for project adjustments and maintenance was applied to Year 1 only; although, it is anticipated most projects will required minimal maintenance, a number may need repeated maintenance efforts over the lifespan of the project (e.g., beaver dam removal program). In addition, the model does not include costs related to effectiveness monitoring (e.g., as required under the conditions for *Fisheries Act* Authorizations).

## 3.5 CONSIDERATION OF SOCIAL BENEFITS VALUES

The primary source of information for preliminary social benefits values was traditional ecological knowledge gathered from interviews with members of the Sts'ailes community. Four Sts'ailes elders were interviewed by Morgan Ritchie in 2016; their interviews were summarized and supplemented with interviews conducted by Ritchie and Springer (Unpublished) in 2009. Research questions driving the Sts'ailes TEK interviews included:

1) What are the main salmon populations, including their spawning locations, and rearing habitat?
2) What are some traditional fishing practices, technologies, and locations?
3) What changes to important salmon spawning and rearing waterways have you observed?
4) What are some examples of traditional and contemporary management and maintenance of salmon fisheries and habitats?

Due to the complex nature of a social benefits filter, additional information needs to be gathered before the filter can be applied to the restoration sites.

## 3.6 RANKING

Identified potential restoration sites were ranked by ecological benefits (**Section 3.3**) and economic benefits (**Section 3.4**). Sites with greater ecological benefits (i.e., greater productivity) were ranked higher than those with low ecological benefits. Sites with greater economic benefits (i.e., more cost effective) were ranked higher than those with low economic benefits.

# 4.0 RESULTS

## 4.1 FIELD SURVEYS AND GROUND-TRUTHING

During preliminary field surveys, a total of 88 tributary sites were assessed. The site card forms completed for each site are provided in **Appendix C**. Following review of the LIDAR information, key sites were ground-truthed to gather additional field data for use in the mapping data base (**Section 4.2**). Some sites were not ground-truthed as a result of access, water level and weather restrictions.

## 4.2 HABITAT MAPPING OUTCOMES

A total of 392 polygons were mapped within the study area: 159 were classified as wetted areas, 94 as ephemeral channels, 69 as accreted channels and an additional 70 polygons were identified as upland features (e.g., roads, culverts, beaver dams and potential new connector channels). This information is shown on **Figures 4A** to **4C** (attached). Of the wetted areas, 34 were excluded from consideration for restoration because they were either suspected to be "healthy" (i.e., no stressors could be identified), or represented a low estimated feasibility for restoration (e.g., Harrison River mainstem). The remaining 125 wetted polygons were classified as potential restoration opportunities. Both ephemeral and accreted areas were initially identified based on elevation (i.e., visible depressions) in the LiDAR data. The ephemerality of a channel was estimated based on proximity and potential connectivity to wetted areas, as well as the absence of identifiable barriers or obstacles.

Subsequently, 20 potential restoration opportunities (often comprising multiple polygons) were selected for detailed analysis based on access, relative estimated height above the water table of wetted area, and the ability to create rearing or spawning habitat for the target fish species. These top 20 sites are shown on **Figures 5A** to **5C** (attached) along with the site stressors identified as part of the desktop and field studies. Photos for the top 20 sites (photos provided only for sites assessed in the field) are provided in **Appendix D**.

## 4.3 ECOLOGICAL FILTER OUTCOMES

The purpose of the ecological benefits filter is to assist in estimating the magnitude of the contribution the proposed restoration project may have on the ecological health of the watershed. Ecological benefit values are represented by the fish production or yield (i.e., new body mass per unit area) estimated for the restoration works (**Section 3.3**). **Table 5** provides a summary of the ecological benefits filter outcomes. Thirteen of the selected restoration opportunities were classified as potential new habitat (i.e., either accreted or isolated areas), three were classified as enhanced habitat (i.e., existing habitat with limiting factors such as lack of spawning gravel, presence of invasive aquatic vegetation or lack of in-stream cover), and the remaining four involve a mix of new and enhanced sections. Total area of streambed in which habitat improvements are likely to occur for each project ranged from 1,038 to 180,952 $m^2$ (8 out of 20 projects being smaller than 10,000 $m^2$, and only three being larger than 30,000 $m^2$).

All selected opportunities are anticipated to benefit both chum and coho salmon (detail in **Section 5.0**). Estimated net production values (i.e., based on benefits from the restoration, excluding pre-treatment production for enhanced channels) are presented in **Table 5** for each species that may benefit from the 20 proposed restoration opportunities. Estimated annual net production ranged from 420 to 87,656 adult fish for chum salmon and from 69 to 85,047 fish for coho salmon.

### Table 5 Summary of Selected Potential Restoration Opportunities and Associated Ecological Benefits

| Location | Limiting Factor(s) | Restoration Activities | Habitat Area ($m^2$) | Estimated Net Production/ Year | | |
|---|---|---|---|---|---|---|
| | | | | Target Species | Return (No. adult) | Biomass (kg) |
| Bateson Slough N. | Ephemeral channel, invasive vegetation, lack of available cover, road, culvert | Excavation, removal of invasive vegetation, add instream complexities, riparian planting, upgrade culvert | 18,423 | CM | 36,637 | 164,868 |
| | | | | CO | 1,530 | 4,591 |
| Bateson Slough S. | Ephemeral channel, invasive vegetation, lack of available cover, road, culvert | Excavation, removal of invasive vegetation, add instream complexities, riparian planting, upgrade culvert | 27,813 | CM | 56,541 | 254,437 |
| | | | | CO | 2,362 | 7,086 |
| E. Sq'éwlets Slough | Existing isolated pond, channel to pond dewaters, areas of accretion, culvert with grate blocks fish passage, invasive vegetation | Excavation, re-connection of pond, habitat complexing, replace culvert | 14,935 | CM | 4,064 | 106,189 |
| | | | | CO | 170 | 2,957 |
| E. Sq'éwlets Slough Ext. | Used as agricultural ditch, lack of connectivity, lacking riparian vegetation, multiple culverts | Improve/replace culverts, connect to adjacent sloughs, plant riparian area | 2,572 | CM | 4,064 | 18,287 |
| | | | | CO | 170 | 509 |
| Ed Leon Side Channel | Accreted areas, culvert | Excavation, habitat complexing, improve culvert | 11,307 | CM | 10,987 | 49,443 |
| | | | | CO | 459 | 1,377 |
| Harrison Mills N. Option 1 | Lack of available cover and riparian vegetation along existing wetted section; accreted section | Habitat complexing, riparian planting, excavation (re-connection to Mtn. Woodside Channel) | 15,496 | CM | 9,590 | 43,154 |
| | | | | CO | 6,771 | 20,313 |
| Harrison Mills N. Option 2 | Accreted channel (agricultural land), culvert | Excavation, habitat complexing, riparian planting, improve culvert | 2,028 | CM | 8,110 | 36,496 |
| | | | | CO | 339 | 1,016 |
| Hatchery Flats Channels | Accreted/ cutoff channels, lacking riparian vegetation and instream complexities | Excavation, leave unconnected from Chehalis, habitat complexing, allow natural riparian area to develop | 20,058 | CM | 33,276 | 149,744 |
| | | | | CO | 1,390 | 4,170 |
| | | | | CH | 358 | 3,043 |
| HR Bridge E. | Accreted/cutoff channel section, isolated channel, lack of available cover, culverts | Excavation, barrier removal, re-connection of isolated channel, habitat complexing | 5,328 | CM | 8,418 | 37,882 |
| | | | | CO | 2,685 | 1,055 |
| HR Bridge W. | Accreted channel, isolated pond | Excavation, reconnect pond, habitat complexing | 2,726 | CM | 4,307 | 19,382 |
| | | | | CO | 180 | 540 |

| Location | Limiting Factor(s) | Restoration Activities | Habitat Area ($m^2$) | Estimated Net Production/ Year | | |
|---|---|---|---|---|---|---|
| | | | | Target Species | Return (No. adult) | Biomass (kg) |
| Kilby Channel | Accreted channel | Excavation, habitat complexing, remove log jams, possibly create second entrance | 3,477 | CM | 5,494 | 24,722 |
| | | | | CO | 229 | 688 |
| Lower Chehalis Side Channel | Accreted channel, log jam | Excavation (re-connection to Chehalis River), remove log jam, create riffle-pool morphology, ensure connection redundancy to Chehalis River | 11,602 | CM | 18,331 | 82,491 |
| | | | | CO | 766 | 2,297 |
| | | | | CH | 197 | 1,677 |
| Lower Conner Creek | Barriers to fish passage (beaver dam complex) | Removal of barriers, or test Telkwa design | 48,427 | CM | 1,211 | 5,448 |
| | | | | CO | 22,761 | 68,283 |
| Morris Creek | Invasive aquatic vegetation | Removal of invasive vegetation | 180,952 | CM | 4,524 | 20,357 |
| | | | | PK | 381,809 | 572,718 |
| | | | | SK | 1,145,426 | 2,863,591 |
| | | | | CO | 85,047 | 255,145 |
| | | | | CH | 3,076 | 26,148 |
| | | | | SH | 525 | 2,099 |
| | | | | RB | 7,238 | - |
| | | | | CCT | 4,162 | - |
| Morris Creek Side Channel | Accreted channel, lack of spawning gravel, invasive vegetation | Excavation, adding/uncovering gravel, removal of invasive vegetation | 22,972 | CM | 36,296 | 163,332 |
| | | | | CO | 1,516 | 4,548 |
| | | | | CH | 391 | 3,320 |
| Unnamed Slough | Ephemeral channel section, barriers to fish passage (beaver dam), invasive vegetation, accreted channel section | Removal of barriers and invasive vegetation, excavation, habitat complexing | 5,668 | CM | 4,592 | 20,665 |
| | | | | CO | 1,508 | 4,523 |
| Upper Chehalis Side Channel | Accreted channel | Excavation, habitat complexing | 8,670 | CM | 13,699 | 61,644 |
| | | | | CO | 572 | 1,717 |

| Location | Limiting Factor(s) | Restoration Activities | Habitat Area ($m^2$) | Estimated Net Production/ Year | | |
|---|---|---|---|---|---|---|
| | | | | Target Species | Return (No. adult) | Biomass (kg) |
| Upper Connor Creek | Ephemeral channels, barriers to fish passage (likely beaver dams), possible invasive aquatic vegetation | Removal of barriers and invasive vegetation | 16,794 | CM | 420 | 1,889 |
| | | | | CO | 7,893 | 23,680 |
| West Sq'éwlets Slough | Accreted channel, lack of spawning gravel, invasive vegetation, culvert | Excavation, adding/uncovering gravel, removal of invasive vegetation, improve culvert | 67,835 | CM | 87,656 | 394,457 |
| | | | | CO | 9,549 | 28,647 |
| William Philips Pond | Accreted channel and existing isolated pond | Excavation, re-connection of pond, habitat complexing | 1,038 | CM | 1,640 | 7,380 |
| | | | | CO | 69 | 206 |

**Note:** CCT: coastal cutthroat trout; CH: Chinook salmon; CM: chum salmon; CO: coho salmon; PK: pink salmon; RB: rainbow trout; SH: steelhead

## 4.4 ECONOMIC FILTER OUTCOMES

The purpose of the economic benefits filter is to provide an estimate of the comparable net present value of a project, in the context of fisheries benefits (i.e., the Aboriginal commercial fisheries and the local recreational fishery). The model value includes the initial estimated cost of construction (Year 0), the subsequent estimated maintenance cost (Year 1), and the potential economic gains accrued over the lifetime of the restoration project (assumed to be 20 years, for the purpose of this study; **Section 3.4.1**). A second modified value was produced to adjust for site-specific efficiencies or added costs and to help differentiate costs by areas. **Table 6** provides a summary of the economic benefits filter outcomes of both the model and modified values.

Model-generated project construction costs ranged from $20,350 to over $4,000,000 (11 projects had an estimated construction cost below $500,000; cost was mainly dependent on total project area). Most projects (15 of 20) showed an model estimated net benefit at Year 3 (i.e., upon the return of the first chum and coho salmon cohorts produced by the project). The modeled net cumulative project value at Year 20 ranged from $1,879,457 to $336,725,942.

Adjusted Project construction costs ranged from $15,650 to over $3,000,000 (13 projects had an estimated construction cost below $500,000; cost was mainly dependent on total project area). Most projects (18 of 20) showed an adjusted estimated net benefit at Year 3 (i.e., upon the return of the first chum and coho salmon cohorts produced by the project). The modeled net cumulative project value at Year 20 ranged from $1,884,392 to $339,325,932.

## Table 6 Summary of Selected Potential Restoration Opportunities and Associated Economic Benefits

| Location | Cost Estimate ($) | | | | Economic Benefit Estimate ($) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year 0 Construction ($) | | Year 1 Maintenance ($) | | First Profit Year ($) | | | | Year 20 Cumulative Value ($) | | Normalized Value ($/m2) |
| | Model | Adjusted | Model | Adjusted | Year | Model | Year | Adjusted | Model | Adjusted | |
| Bateson Slough N. | 921,150 | 1,302,350 | 46,058 | 65,118 | Y3 | 907,064 | Y3 | 991,573 | 32,769,676 | 41,095,262 | 1,096 |
| Bateson Slough S. | 1,390,650 | 2,028,450 | 69,533 | 101,423 | Y3 | 1,369,384 | Y3 | 1,510,780 | 49,472,019 | 63,401,868 | 1,062 |
| E. Sq'éwlets Slough | 221,750 | 210,875 | 11,088 | 10,544 | Y3 | 571,229 | Y3 | 1,297,999 | 27,116,691 | 27,128,109 | 1,816 |
| E. Sq'éwlets Slough Ext. | 128,600 | 278,600 | 6,430 | 13,930 | Y4 | 1,286,581 | Y4 | 230,797 | 4,574,912 | 4,417,412 | 1,718 |
| Ed Leon Side Channel | 347,700 | 278,160 | 17,385 | 13,908 | Y3 | 126,633 | Y3 | 415,400 | 12,369,339 | 12,442,356 | 1,789 |
| Harrison Mills N. Option 1 | 435,200 | 750,600 | 21,760 | 37,530 | Y3 | 342,383 | Y3 | 84,158 | 8,024,578 | 14,913,060 | 477 |
| Harrison Mills N. Option 2 | 101,400 | 374,800 | 5,070 | 18,740 | Y3 | 14,237 | Y3 | 128,668 | 3,607,279 | 9,006,201 | 623 |
| Hatchery Flats Channels | 1,002,900 | 852,465 | 50,145 | 42,623 | Y3 | 987,564 | Y3 | 1,247,551 | 34,933,756 | 36,928,668 | 1,841 |
| HR Bridge E. | 140,700 | 133,200 | 7,035 | 6,660 | Y4 | 118,126 | Y3 | 944,232 | 2,245,018 | 9,616,972 | 1,805 |
| HR Bridge W. | 136,300 | 115,855 | 6,815 | 5,793 | Y3 | 134,216 | Y3 | 155,683 | 4,848,838 | 4,870,305 | 1,787 |
| Kilby Channel | 173,850 | 173,850 | 8,693 | 8,693 | Y3 | 171,191 | Y3 | 171,191 | 6,184,669 | 6,184,669 | 1,779 |
| Lower Chehalis Side Channel | 580,100 | 580,100 | 29,005 | 29,005 | Y3 | 701,510 | Y3 | 701,510 | 21,062,229 | 21,062,229 | 1,815 |
| Lower Conner Creek | 1,210,675 | 50,000 | 60,534 | 25,000 | Y4 | 2,470,955 | Y3 | 861,359 | 16,483,261 | 17,204,470 | 355 |
| Morris Creek | 4,523,800 | 150,000 | 226,190 | 100,000 | Y2 | 1,131,036 | Y2 | 1,417,661 | 336,725,942 | 339,325,932 | 1,875 |
| Morris Creek Side Channel | 1,148,600 | 1,378,320 | 57,430 | 68,916 | Y3 | 99,849 | Y3 | 889,830 | 40,861,152 | 40,619,946 | 1,770 |

| Location | Cost Estimate ($) | | | | Economic Benefit Estimate ($) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Year 0 Construction ($) | | Year 1 Maintenance ($) | | First Profit Year ($) | | | | Year 20 Cumulative Value ($) | | Normalized Value ($/m2) |
| | Model | Adjusted | Model | Adjusted | Year | Model | Year | Adjusted | Model | Adjusted | |
| Unnamed Slough | 213,250 | 213,250 | 10,663 | 25,000 | Y3 | 124,407 | Y3 | 60,069 | 6,045,834 | 5,556,496 | 980 |
| Upper Chehalis Side Channel | 433,500 | 433,500 | 21,675 | 21,675 | Y3 | 426,871 | Y3 | 426,871 | 15,421,652 | 15,421,652 | 1,779 |
| Upper Connor Creek | 839,700 | 100,000 | 41,985 | 50,000 | Y5 | 144,494 | Y3 | 92,060 | 5,275,388 | 5,057,073 | 301 |
| W Sq'éwlets Slough | 3,077,875 | 3,277,875 | 153,894 | 163,894 | Y3 | 2,647,868 | Y3 | 2,437,868 | 102,601,692 | 102,391,692 | 1,509 |
| William Philips Pond | 20,350 | 15,650 | 1,018 | 783 | Y3 | 84,234 | Y3 | 89,169 | 1,879,457 | 1,884,392 | 1,815 |

[1] summary of the economic benefits filter outcomes of both the model and modified values.

## 4.5 SOCIAL BENEFITS FILTER OUTCOMES

Due to the complex nature of a social benefits filter, one has not yet been applied to the restoration sites. However, results from the interviews with Sts'ailes members indicate all interviewees agree enhancement and ongoing maintenance of salmon spawning and rearing areas is important. These interviewees would particularly like to see the sloughs between Morris Creek and the Chehalis River cleared of vegetation and sediment so they return to their pre-deteriorated condition, and are made suitable for salmon spawning and rearing once again.

## 4.6 PRELIMINARY RANKING

The purpose of site ranking is to assist resource managers and community members in prioritizing ecologically-beneficial and economically-feasible restoration opportunities. **Table 7** provides a summary of the Ecological and Economic rankings for the top 20 habitat restoration sites. **Table 8** provides a list of the top 20 sites determined by combining the Ecological and Economic rankings (where combined rankings tied, the site with a lower ranking value (either Ecological or Economic) scored higher overall).

Four sites ranked in the top 10 for both Ecological and Economic Benefits, including: East Sq'éwlets Slough, Hatchery Flats Channels, Lower Chehalis Side Channel, and Morris Creek. Conversely, six sites ranked in the bottom 10 for both Ecological and Economic Benefits, including: E. Sq'éwlets Slough Ext., Harrison Mills N. Option 1, Harrison Mills N. Option 2, Unnamed Slough, Upper Chehalis Side Channel, and Upper Connor Creek.

**Table 7 Summary of Ecological and Economic Benefits Rankings**

| Habitat Restoration Site | Ecological Benefits (Pounds of Adult Salmonids) | Ranking | Economic Benefits ($/ m$^2$) | Ranking |
|---|---|---|---|---|
| Bateson Slough N. | 373,590 | 5 | 1,096 | 14 |
| Bateson Slough S. | 576,553 | 3 | 1,062 | 15 |
| E. Sq'éwlets Slough | 240,623 | 7 | 1,816 | 3 |
| E. Sq'éwlets Slough Ext. | 41,438 | 19 | 1,718 | 12 |
| Ed Leon Side Channel | 112,038 | 12 | 1,789 | 7 |
| Harrison Mills N. Option 1 | 139,919 | 10 | 477 | 18 |
| Harrison Mills N. Option 2 | 82,700 | 14 | 623 | 17 |
| Hatchery Flats Channels | 346,029 | 6 | 1,841 | 2 |
| HR Bridge E. | 85,841 | 13 | 1,805 | 6 |
| HR Bridge W. | 43,920 | 18 | 1,787 | 8 |
| Kilby Channel | 56,019 | 16 | 1,779 | 9 |
| Lower Chehalis Side Channel | 190,620 | 8 | 1,815 | 5 |
| Lower Conner Creek | 162,547 | 9 | 355 | 19 |
| Morris Creek | 8,245,333 | 1 | 1,875 | 1 |
| Morris Creek Side Channel | 377,429 | 4 | 1,770 | 11 |

| Habitat Restoration Site | Ecological Benefits (Pounds of Adult Salmonids) | Ranking | Economic Benefits ($/ $m^2$) | Ranking |
|---|---|---|---|---|
| Unnamed Slough | 55,529 | 17 | 980 | 16 |
| Upper Chehalis Side Channel | 139,686 | 11 | 1,779 | 10 |
| Upper Connor Creek | 56,370 | 15 | 301 | 20 |
| West Sq'éwlets Slough | 932,775 | 2 | 1,509 | 13 |
| William Philips Pond | 16,724 | 20 | 1,815 | 4 |

**Table 8 Preliminary Habitat Restoration Site Rankings**

| Habitat Restoration Site | Ranking |
|---|---|
| Morris Creek | 1 |
| Hatchery Flats Channels | 2 |
| E. Sq'éwlets Slough | 3 |
| Lower Chehalis Side Channel | 4 |
| West Sq'éwlets Slough | 5 |
| Morris Creek Side Channel | 6 |
| Bateson Slough S. | 7 |
| Bateson Slough N. | 8 |
| HR Bridge E. | 9 |
| Ed Leon Side Channel | 10 |
| Upper Chehalis Side Channel | 11 |
| William Philips Pond | 12 |
| Kilby Channel | 13 |
| HR Bridge W. | 14 |
| Lower Conner Creek | 15 |
| Harrison Mills N. Option 1 | 16 |
| E. Sq'éwlets Slough Ext. | 17 |
| Harrison Mills N. Option 2 | 18 |
| Unnamed Slough | 19 |
| Upper Connor Creek | 20 |

# 5.0 DISCUSSION

## 5.1 RESTORATION OPPORTUNITIES

Restoration opportunities in the LHW are numerous and varied, both in area and types of activity suggested to enhance fisheries productivity. Pearson and Chiavaroli (2010), identified the most severe stressors in the region as forest harvesting, increased peak flows, stream bank erosion, sedimentation, reduced large woody debris recruitment, limited nutrient availability, and increased water temperatures. However, *in situ* signs of these stressors appear as accreted channels, cut-off channels, numerous culverts with little access, turbid water, reduced riparian vegetation and increased instream non-native vegetation. A total of 88 sites were assessed during this study with most showing evidence of these stressors. Accretion was the greatest limiting factor observed among the surveyed channels, leading to complete or partial channel de-watering, reduction in available spawning gravel and/ or increase in the occurrence of suitable conditions (i.e., fine substrate) for the colonization of invasive vegetation. Beaver activity (i.e., dams) and the presence of high-density populations of invasive aquatic vegetation (i.e., Eurasian watermilfoil and reed canary grass) were also documented as significant limiting factors at several sites.

Once the stressors/ limiting factors have been identified, it is important to assess whether they can be managed (feasibly) and, if so, to evaluate the risk-benefit factors associated with restoration efforts. In the case of accreted channels, restoration may primarily involve excavation to re-establish channel grade below the winter low water level; or mechanical scarring of the substrate to increase channel depth and/or expose gravel underneath a layer of fine sediments. Although this may result in the short-term increase in habitat capacity (e.g., available spawning and rearing habitat), it may not address long-term management issues, if the driving factors for channel accretion remain. For this reason, each potential restoration opportunity must be thoroughly investigated prior to implementation; the factors driving the identified stressors must be understood and strategies to manage them, evaluated for their feasibility and likelihood of long-term sustainability. Both technical and local expertise will be required during this investigative phase; the engagement of First Nations community members (i.e., Sts'ailes and Sq'éwlets) is crucial, not only to acquire a better understanding of current local and regional conditions, but also to gain an historical perspective of the habitat capacity.

Twenty projects were proposed in this study, based on mapping and subsequent ground-truthing; however, several more may be identified, based on the results of the habitat mapping, supplemented by local knowledge. The proposed projects may also be divided into multiple, smaller projects or phases that may be more economically feasible and/or more logistically manageable. Although efficiencies can be realised by restoring larger areas under a single project, the higher cost and project duration may be limiting factors.

All 20 projects are expected to specifically benefit chum and coho salmon, by directly improving habitat conditions for these species (i.e., spawning habitat for chum salmon, and rearing and over-wintering habitats for coho; **Section 2.2.1**). The various restoration efforts are also expected to benefit other fish species through functions such as improved water quality and redundancies in migration routes. Habitat restoration may also benefit other components of the ecosystem, such as benthic macroinvertebrate communities, amphibians, birds, wildlife, riparian habitat, and native aquatic vegetation.

## 5.2 HABITAT MAP, DATABASE AND SCREENING TOOL

The habitat map, database and screening tool presented in this study were developed to assist decision-makers and community members identifying and prioritizing economically feasible and socially valuable restoration opportunities in the LHW. While the habitat map and database provide an overview of fish habitat conditions and limiting factors, the screening tool allows for potential restoration opportunities to be evaluated from an ecological, economic and (eventually) social perspective. All three tools (i.e., the map, database, and screening model) constitute a strong platform to develop a large-scale, long-term plan for fish habitat restoration in the LHW. The interactive and user-based nature of these tools will also facilitate and allow greater community engagement during the planning process by providing visual representations of existing limiting factors to fish productivity and potential restoration opportunities (i.e., the web-based map). This creates a central source of information that can be consulted and contributed to over time (i.e., the digital database); and a series of criteria based filters that projects may be evaluated and prioritized on. Although these tools were designed and developed to be as comprehensive as possible, they form only parts of a much greater endeavour (i.e., the restoration of fish habitat at a watershed level), which will require sustained effort over several years for continued development and implementation.

The model developed in this study for the purposes of screening and prioritizing restoration opportunities is relatively unique in that it provides a long-term vision of the potential benefits associated with each project. That said, like any model, it has its strengths and its limitations, and though it can be a powerful tool for restoration planning, it must be used with a clear understanding of its various assumptions and limitations (**Section 3**). Furthermore, the model is a dynamic tool, which can and should be refined and updated as new information becomes available in the future.

As there were uncertainties associated with numerous variables of the model, assumptions were made in order to allow further development of the model. For example, the model assumes an average lifespan of 20 years for both new and enhanced channels (Bonnell 1991; Ward and Slaney 1979). However, that estimate was calculated based on a variety of projects, many that involve active side channels and larger streams. As off-channels have a greater stability than larger streams, their lifespan and productivity tend to be greater (Slaney and Martin 1997). Therefore, the benefits from restoration efforts in off-channel habitat (which represents a large percentage of potential opportunities in the LHW) may be accrued for a period greater than 20 years. On the other hand, unpredictable natural events, such as a large flood event or the colonization of area by beavers, can shorten the lifespan of channel.

Another assumption that can lead to significant changes of the model outcomes is associated with the estimated net production of adult fish resulting from the restoration efforts; the model assumes constant production over the lifespan of the channel. However, Bonnell (1991) evaluated the production of chum salmon in 24 groundwater-fed side channels (built between 1978 and 1987) and found the annual fry production (at a constant number of female spawners) remained high for approximately 4 years following construction, but declined over time. This decline, however, may have been related to high spawning densities rather then channel deterioration. One could also argue production may increase over time, as the channel becomes more established.

## 5.3 RECOMMENDATIONS AND NEXT STEPS

The objectives of the project were to: (1) develop a comprehensive screening tool informed by ecological, economic and cultural filters (based on Scarfe, 1997); and (2) produce an interactive database identifying historic and potential restoration opportunities within Harrison watershed, that will assist resource managers and community members in identifying and prioritizing economically feasible and socially valuable restoration opportunities, both of which were achieved. In meeting these objectives, several recommendations for future work to further enhance this project and build from its findings can made:

- Continue support for the local Aboriginal communities to identify and assign value to their culturally significant areas to guide where restoration efforts are best conducted or left absent;
- Initiate experimental trials to manage invasive species, such as Eurasian milfoil, in the watershed, particularly in high value areas such as Morris Creek;
- Work with local stakeholders in the Harrison Mills area to enhance and restore the multiple sloughs that join the Harrison River with the Fraser River, re-establish riparian areas to reduce soil erosion, reconnect fragmented sloughs that could provide redundancy for migrating fish, and further investigate the culturally historic value these sloughs provided to the local Aboriginal groups;
- Provide funding for the Community Mapping Network to work with the authors to ensure the web-ready interactive map becomes active and accessible to the public in a manner that is consistent with established methods;
- Begin community awareness and engagement (i.e., open houses) to establish partnerships and agreement that ensure accessibility and long-term protection (i.e., secure tenure) for areas identified by the study; and
- Initiate steps to gain funding for critical, high value restoration projects for multi-species benefits such as spawning channels in in the old arm of the Chehalis River, and accreted and milfoil infested areas of Morris Creek.

Effectiveness monitoring, although not included in the model's cost calculations, is critical to assess the success of restoration activities, as well as to identify post-project issues or areas of improvement for the next project (Slaney and Zaldokas 1997). The criteria to evaluate success may vary depending on the objectives of the restoration project. For example, one project may aim at re-establishing a sustainable yield of chum salmon through the rehabilitation of spawning habitat, while another may aim at improving water quality for general ecosystem benefits and/or social benefits.

# 6.0 CLOSURE

This fisheries habitat assessment report of the Lower Harrison River and its tributaries were undertaken consistent with the agreement between Hemmera and the Sts'ailes Development Corporation. Hemmera sincerely appreciates the opportunity to have worked on such a unique and inspiring Project with you. If there are any questions on this report please do not hesitate to contact the undersigned.

Report prepared by:
**Hemmera Envirochem Inc.**

Jamie

Jamie Slogan, PhD, R.P.Bio.
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ROBERTS

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Masters Student

Report peer reviewed by:
**Hemmera Envirochem Inc.**

Trevor Welton, R.P.Bio.
Business Leader

## 7.0 REFERENCES

Aiken, S.G., P.R. Newroth, and I. Wile. 1979. The biology of Canadian weeds. 34. *Myriophyllum spicatum* L. Canadian Journal of Plant Science 59:201-215.

Anderson, J. L., R. W. Hilborn, R. T. Lackey, and D. Ludwig. 2003. Chapter 9: Watershed Restoration—Adaptive Decision Making in the Face of Uncertainty. Pages 203-232 in RC Wissmar and PA Bisson, editors. Strategies for Restoring River Ecosystems: Sources of Variability and Uncertainty in Natural and Managed Systems. American Fisheries Society, Bethesda, Maryland.

Beechie, T., H. Imaki, J. Greene, A. Wade, H. Wu, G. Press, P. Roni, J. Kimball, J. Stanford, P. Kiffney, N. Mantua. 2012. Restoring Salmon Habitat for a Changing Climate. Research and Applications

Beeson, K. 2009. Applying the Salmon Stronghold Concept in Canada. Prepared for Pacific Fisheries Resource Conservation Council.

Birtwell, I.K. 1999. Effects of Sediment on Fish and their Habitat. Department of Fisheries and Oceans Canada, Science Branch, Marine Environment and Habitat Sciences Division, West Vancouver, B.C.

Bjornn, T.C. and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. American Fisheries Society Special Publication 19:83-138

Bonnell, R.G. 1991. Construction, Operation, and Evaluation of Groundwater-Fed Side Channels for Chum Salmon in British Columbia. American Fisheries Society Symposium. 10: 109-124.

British Columbia Ministry of Environment (MoE). 2016. Watershed Restoration Program. Available online at: http://www.env.gov.bc.ca/wld/documents/watershed_restoration_program.htm

Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. United States Fishery Bulletin 61: 93-110.

Burt, D.W. and Palfrey. 2011. San Juan and Gordon River Watersheds Habitat Status Report.

Creed, R.P. 2000. The weevil-watermilfoil interaction at different spatial scales: what we know and what we need to know. J. Aquatic Plant Management. 38:78-81

DFO. 1997. Strategic Review of Fisheries Resources for the South Thompson-Shuswap Habitat Management Area. Fraser River Action Plan.

DFO. (Undated). Guidelines for In-Stream Placement of Hatchery Salmon Carcasses for Nutrient Enrichment.

Diewart, R. 2007. Habitat requirements for ten Pacific salmon life history strategies. Fisheries and Oceans Canada. Unpublished data. In, Pearson, M. and L. Chiavaroli. 2010. Harrison River Watershed Habitat Status Report. Prepared for Fisheries and Oceans Canada.

Dunbar, G. 2009. Management Plan for Eurasian Watermilfoil (Myriophyllum spicatum) in the Okanagan, British Columbia. Okanagan Basin Water Board.

Economic Analysis and Statistics (EAS) Strategic Policy. 2010. Survey of Recreational Fishing in Canada. Prepared for Department of Fisheries and Oceans (DFO). Ottawa, ON.

EBA Engineering Consultants (EBA). 2001. Gordon River Watershed Restoration Plan. Prepared by EBA Engineering Consultants for TFL Forest Ltd, Sechelt, BC. 39 p.

Ennis, G. July 2011. Harrison River Salmon Stronghold: Charting a Path for Local Implementation. Pacific Fisheries Resource Conservation Council.

Finnigan, R.J. and D.E. Marshall. 1997. Chapter 15: Managing Beaver Habitat for Salmonids: Working with Beavers. In, Slaney, P.A. and D. Zaldokas (eds.). 1997. Fish Habitat Rehabilitation Procedures. Watershed Technical Circular No. 9. Ministry of Environment, Lands and Parks, and Ministry of Forests, Vancouver.

Fisheries Information Summary System (FISS). 2010. In, Pearson, M. and L. Chiavaroli. 2010. Harrison River Watershed Habitat Status Report. Prepared for Fisheries and Oceans Canada.

Foy, M. 2007. Lower Fraser Area Salmonid Enhancement Program – 2007 Salmon Conservation Strategy "Putting the Wild Salmon Policy into Practice". Prepared for Fisheries and Oceans Canada for internal use only. 45 pp. In, Pearson, M. and L. Chiavaroli. 2010. Harrison River Watershed Habitat Status Report. Prepared for Fisheries and Oceans Canada.

Global Invasive Species Database (GISD). 2010. *Phalaris arundinacea*. Invasive Species Specialist Group (ISSG) of the IUCN Species Survival Commission.

Groot, C. and L. Margolis (eds). 1991. Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, B.C.

Holtby, B.L. and Ciruna, K.A. 2007. Conservation Units for Pacific Salmon under the Wild Salmon

Keeley, E.R. and P.A. Slaney. 1996. Quantitative measures of rearing and spawning habitat characteristics for stream dwelling salmonids: guidelines for habitat restoration. Province of British Columbia, Ministry of Environment, Lands and Parks and Ministry of Forests. Watershed Restoration Project Report No. 4: 34 p.

Keeley, E.R., P.A. Slaney and D. Zaldokas. 1996. Estimates of Production Benefits for Salmonid Fishes from Stream Restoration Initiatives. Watershed Restoration Management Report No. 4. Watershed Restoration Program, Ministry of Environment, lands and Parks and Ministry of Forests.

Mathes, M.T., Hinch, S.G., Cooke, S.J., Crossin, G.T., Patterson, D.A., LoXo, A.G. and Farrell A.P. 2010. Effect of water temperature, timing, physiological condition, and lake thermal refugia on migrating adult Weaver Creek sockeye salmon (*Oncorhynchus nerka*). Canadian Journal of Fisheries and Aquatic Sciences. 67:20-84.

McPhail, J.D. 2007. The Freshwater Fishes of British Columbia. University of Alberta Press.

Moore, D. 2016. Harrison Salmon Producers – 2015 Fraser-Harrison River Pink and Chum Economic Opportunity Fisheries. Harrison Salmon Producers LLP. March 31, 2016.

Moore, D. 2014. Proposed Off-site Fish Habitat Compensation Project for Innergex. Sts'ailes community fishers forum.

Moore, D. 2012. Harrison Salmon Producers – 2012 Fraser-Harrison River Chum Economic Opportunity Fishery. Harrison Salmon Producers GP. Harrison Salmon Producers LLP. October 28, 2012.

Mossop, B. and M.J. Bradford. 2004. Review of Eurasian watermilfoil control at Cultus Lake and recommendations for suture removals. Prepared for DFO. Available at: http://www.dfo-mpo.gc.ca/Library/344683.pdf

Myers, R. A., J. A Hutchings, and N. J. Barrowman. 1997. Why do fish stocks collapse? The example of cod in Atlantic Canada. *Ecological applications*, *7*(1), 91-106.

Newroth, P.R. 1985. A review of Eurasian water milfoil impacts and management in British Columbia. In, Anderson, L.W.J. (ed), Proceedings of the First International Symposium on watermilfoil (*Myriophyllum spicatum*) and related *Haloragaceae* species. Aquatic Plant Management Society, Washington, D.C. pp 139-153

Newroth, P.R. 1993. Application of aquatic vegetation identification, documentation, and mapping in Eurasian watermilfoil control projects. Lake Reservoir Management 7:185-196.

Pacific Fisheries Resource Conservation Council (PFRCC). 2010. BC's Harrison River designated first Canadian "Salmon Stronghold" through North American Partnership. Available online at: http://www.fish.bc.ca/bc-s-harrison-river-designated-first-canadian-salmon-stronghold-through-north-american-partnership.

Pearson, M. and L. Chiavaroli. 2010. Harrison River Watershed Habitat Status Report. Prepared for Fisheries and Oceans Canada.

Price, M.H.H., C.T. Darimont, N.F. Temple and S.M. MacDuffee. 2008. Ghost runs: management and status assessment of Pacific salmon (Oncorhynchus spp.) returning to British Columbia's central and north coasts. Canadian Journal of Fisheries and Aquatic Sciences. 65: 2712-2718

Ritchie, M. and C. Springer. Unpublished. Harrison River Chum Fishery: The Ethnographic and Archaeological Perspective. Prepared for the Chehalis Indian Band Department of Fisheries.

Ritchie, M. Unpublished. Harrison River Fishery and Habitat Enhancement: The TEK and Archaeological Perspective. Prepared for Sts'ailes Fisheries Department.

RISC (Resource Inventory Standards Committee). 2008. Reconnaissance (1:20 000) fish and fish habitat inventory: site card field guide. Ministry of Environment Ecosystem Branch. April 2008.

RISC. 2001. Reconnaissance (1: 20 000) Fish and Fish Habitat Inventory: Standards and Procedures-version 2.0. Ministry of Environment Ecosystem Branch.

Scarfe, B. 1997. Chapter 4: Screening Criteria for Restoration Projects. In: Fish Habitat Rehabilitation Procedures. Slaney, P.A. and D. Zaldokas (eds.). 1997. Watershed Technical Circular No. 9. Watershed Restoration Program. Ministry of Environment, Lands and Parks, and Ministry of Forests, Vancouver.

Sheldon, S.P. and R.P. Creed. 2003. The effect of a native biological control agent for Eurasian watermilfoil on six North American watermilfoils. Aquatic Botany 76:359-265

Slaney, P.A. and A.D. Martin. 1997. Chapter 1: Planning Fish Habitat Rehabilitation: Linking to Habitat Protection. In, Slaney, P.A. and D. Zaldokas (eds.). 1997. Fish Habitat Rehabilitation Procedures. Watershed Technical Circular No. 9. Ministry of Environment, Lands and Parks, and Ministry of Forests, Vancouver.

Smith, C.S. and J.W. Barko 1990. Ecology of Eurasian Watermilfoil. Journal of Aquatic Plant Management 28: 55-64

Taylor, E. and D. Langlois. 2000. Climate Change and the Lower Fraser Valley. Environment Canada Pacific and Yukon Region, Vancouver, B.C. In, Pearson, M. and L. Chiavaroli. 2010. Harrison River Watershed Habitat Status Report. Prepared for Fisheries and Oceans Canada.

Truelson, R.L. 1987. Assessment of the 1986 Eurasian water it control program in Cultus Lake. Prepared for BC Ministry of Environment and Parks

Tu, M. 2004. Reed Canary Grass (Phalaris arundinacea L.) Control & Management in the Pacific Northwest. The Nature Conservancy

Unmuth, J.M.L., R.A. Lillie, D.S. Dreikosen, and D.W. Marshall. 2000. Influence of dense growth of Eurasian watermilfoil on lake water temperature and dissolved oxygen. J Freshwater Ecology 15:497-504

Ward, B.R., and P.A. Slaney. 1979. Evaluation of in-stream enhancement structures for the production of juvenile steelhead trout and coho salmon in the Keogh River: progress 1977 and 1978. Province of British Columbia, Fisheries Technical Circular No. 45: 47p.

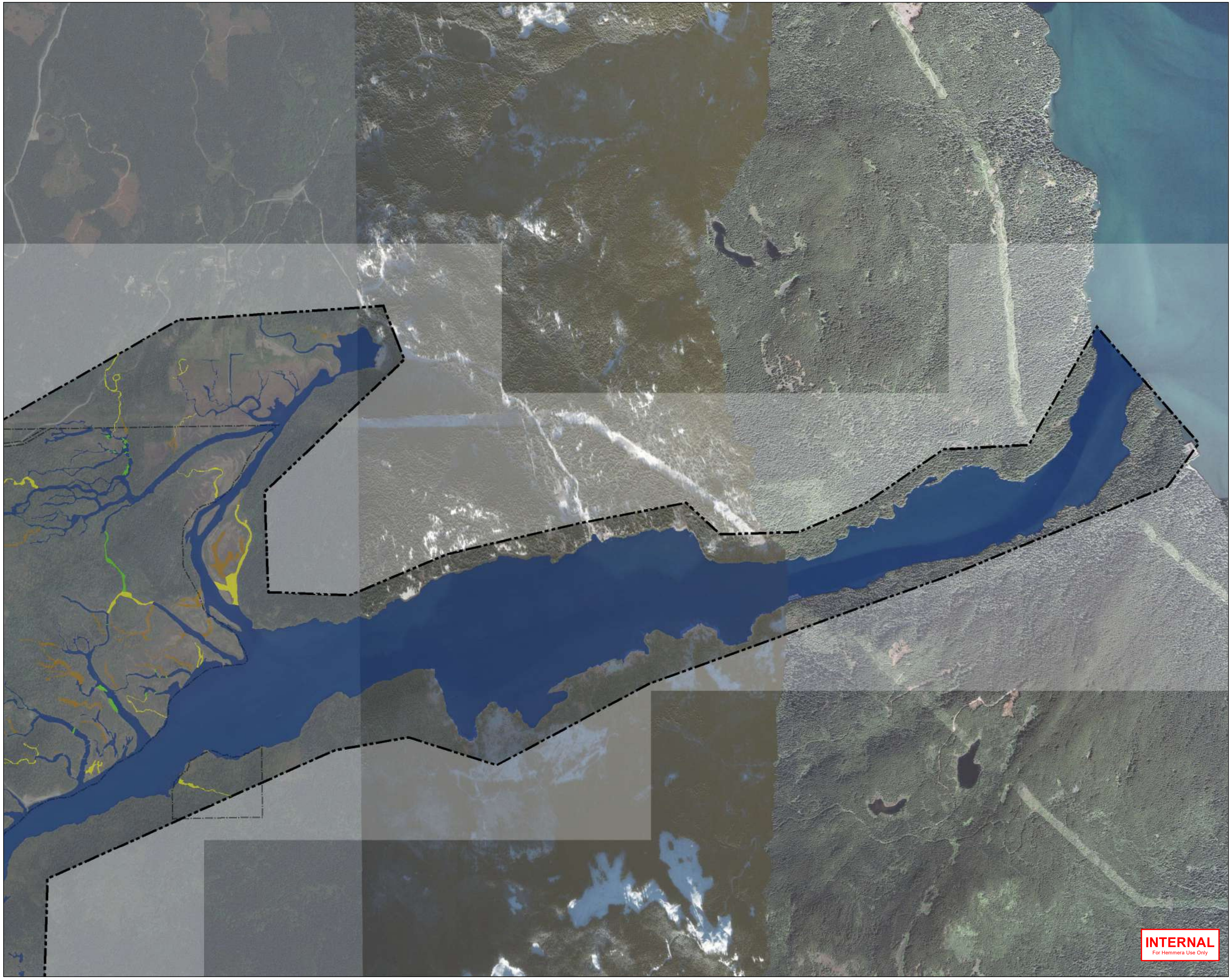
Whyte, I.W., S. Babakaiff, M.A. Adams, P.A. Giroux. 1997. Chapter 5: Restoring Fish Access and Rehabilitation of Spawning Sites. In, Slaney, P.A. and D. Zaldokas (eds.). 1997. Fish Habitat Rehabilitation Procedures. Watershed Technical Circular No. 9. Ministry of Environment, Lands and Parks, and Ministry of Forests, Vancouver.

## Personal Communication

David Moore, General Manager Harrison Fisheries Authority, Sts'ailes - Sq'éwlets, 2017

Kim Charlie, Fisheries Manager, Sts'ailes, 2017

# FIGURES



INTERNAL
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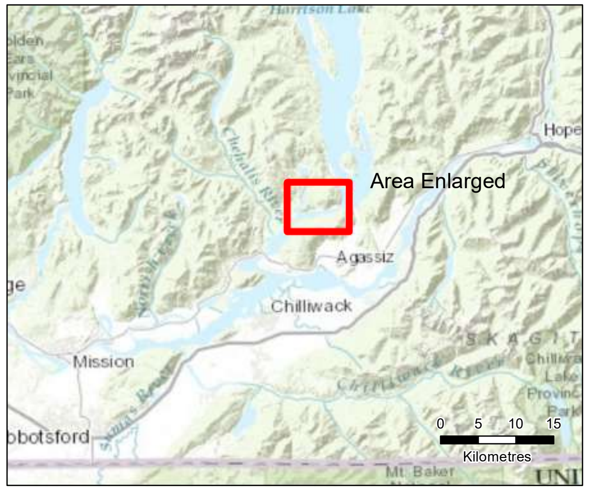
Harrison Salmon Stronghold FHRI

## Primary Habitat Classifications



Legend

| | |
|---|---|
| ⬚ | Study Area |
| ⬚ | First Nations Reserve |
| 🟩 | Upland |
| 🟫 | Accreted |
| 🟨 | Ephemeral |
| 🟦 | Wet |

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

- Study Area imagery from data from Terra Remote, 2017
- Outside of Study Area, ESRI World Imagery
- Inset Basemap: ESRI World Topographic Map

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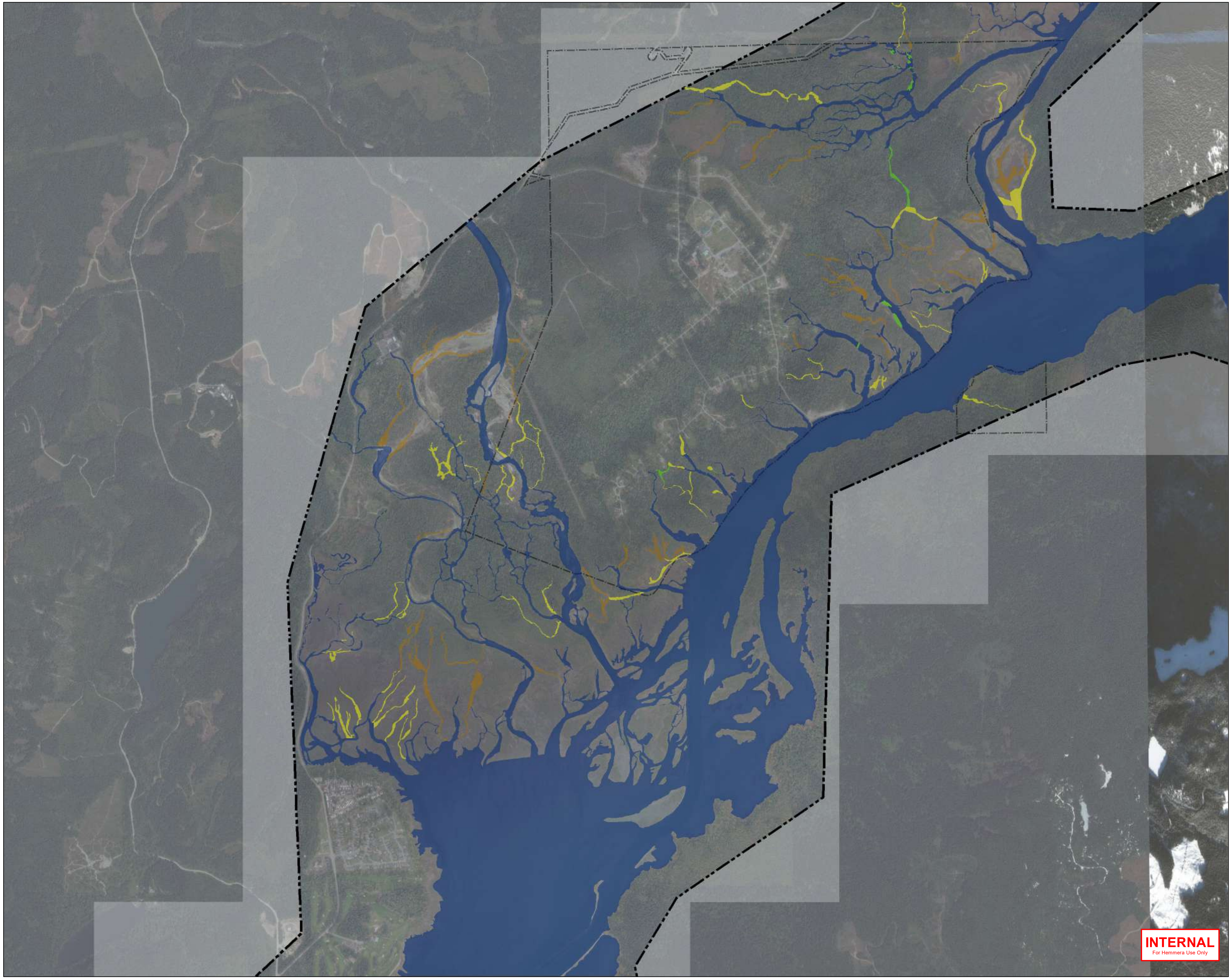
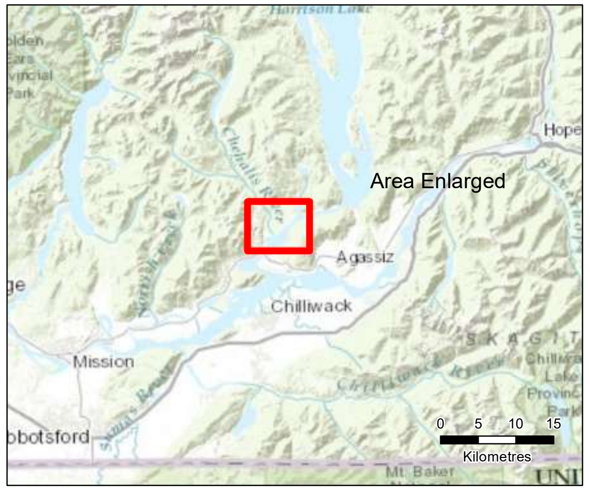


## Harrison Salmon Stronghold FHRI

## Primary Habitat Classifications



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| ⬚ | Study Area |
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| 🟨 | Ephemeral |
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Sts'ailes Fisheries

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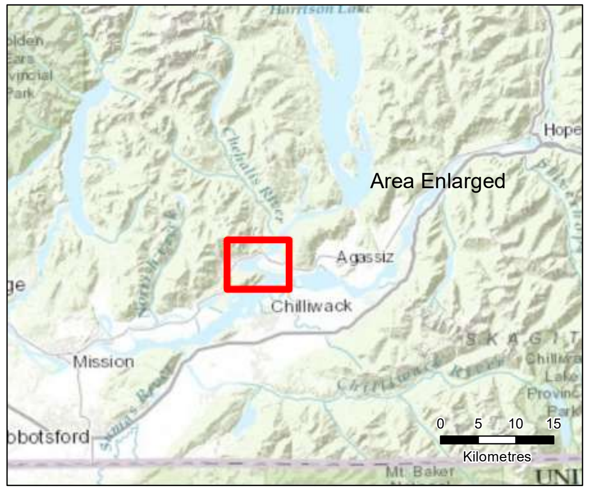
# Harrison Salmon Stronghold FHRI

## Primary Habitat Classifications



Legend

⬚ Study Area
⬚ First Nations Reserve
🟩 Upland
🟫 Accreted
🟨 Ephemeral
🟦 Wet

Notes

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

Sources

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- Outside of Study Area, ESRI World Imagery
- Inset Basemap: ESRI World Topographic Map

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| 1786-002.01 | Production Date: Apr 26, 2017 | Figure 4C |

HEMMERA

Sts'ailes Fisheries

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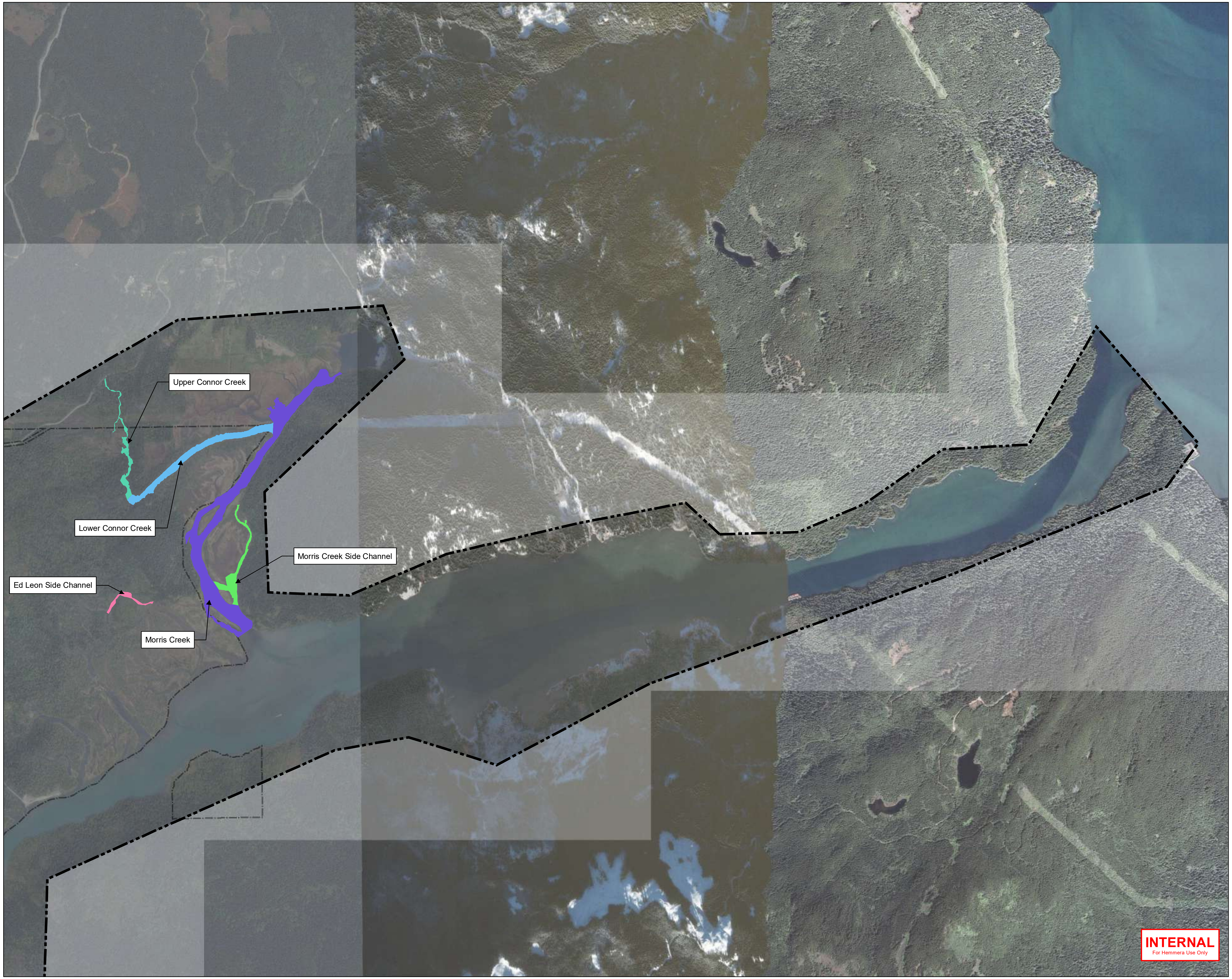
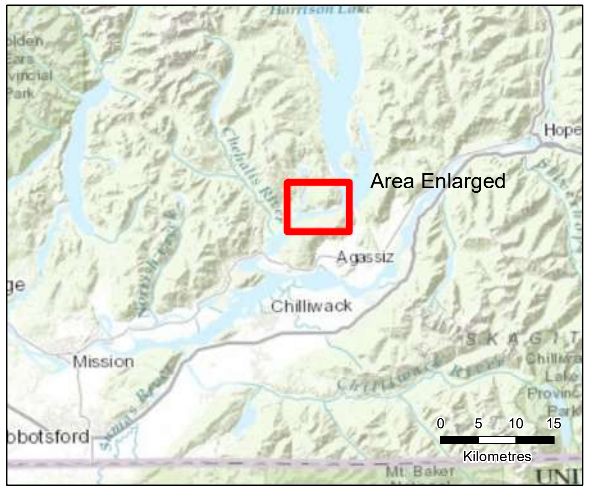
# Harrison Salmon Stronghold FHRI

## Top 20 Potential Restoration Sites and associated Stressors





**Legend**

- ⬚ Study Area
- ⬚ First Nations Reserve
- 🟦 BD
- 🟩 BD:IS
- 🟥 DW
- 🟩 DW:SE
- 🟪 IS

**Acronymns:**
BD = beaver dam
CV = culvert
DW = dewatered
IS = invasive species
SE = sedimentation

**Notes**

1. This map is not intended to be a "stand-alone" document, but a visual aid of the information contained within the referenced Report. It is intended to be used in conjunction with the scope of services and limitations described therein.

**Sources**

Study Area imagery from data from Terra Remote, 2017
- Outside of Study Area, ESRI World Imagery
- Inset Basemap: ESRI World Topographic Map

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HEMMERA

Sts'ailes Fisheries

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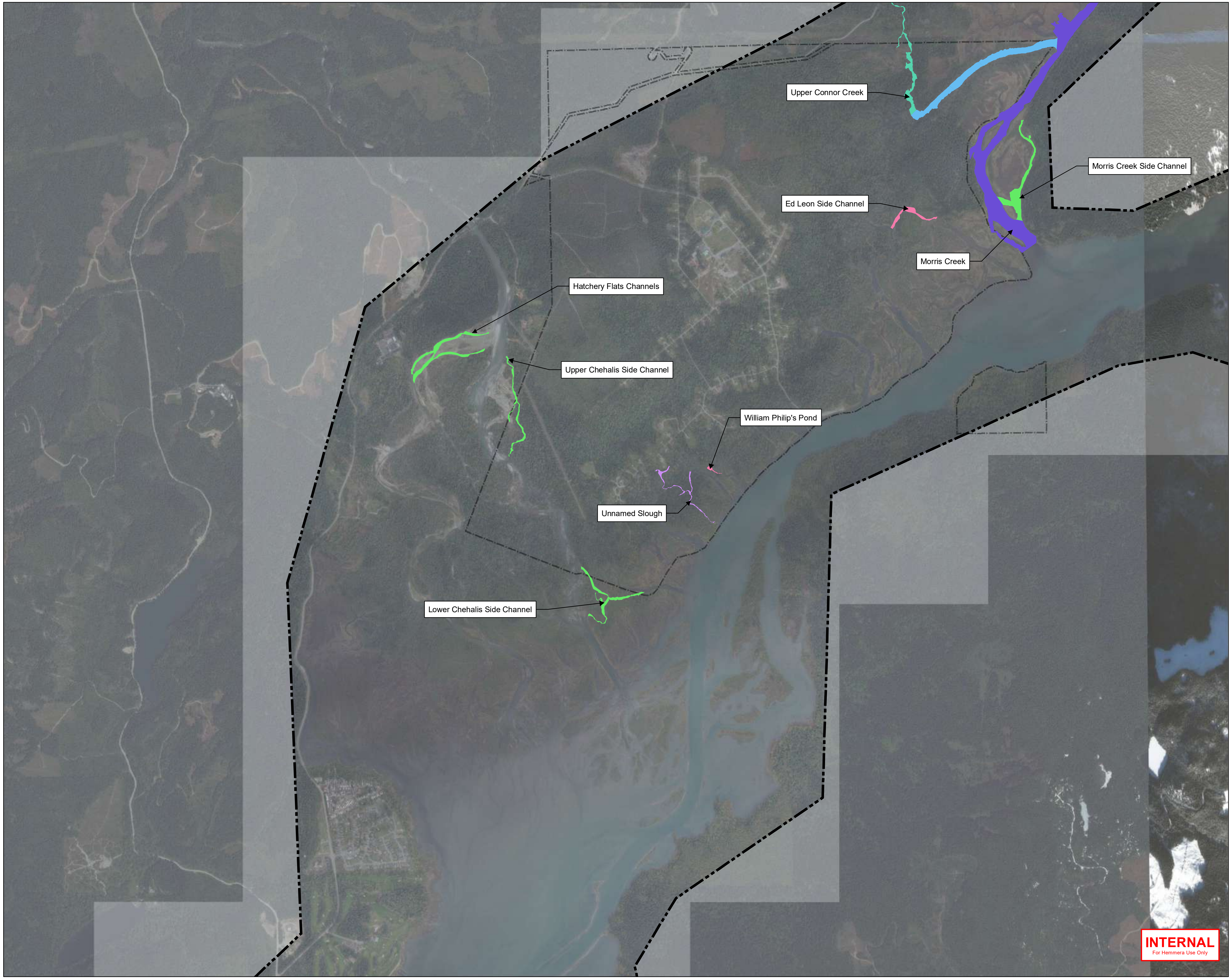
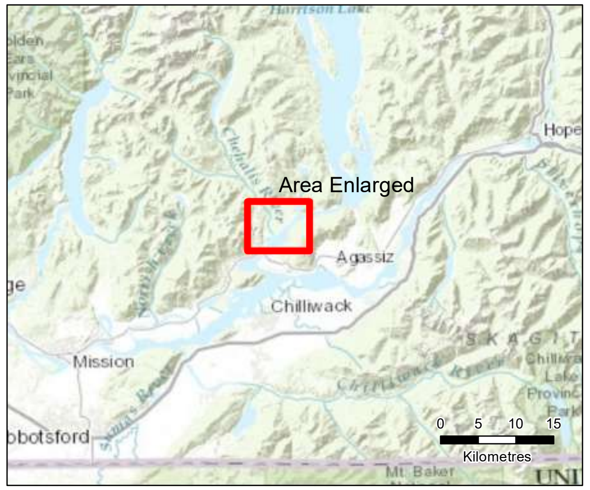


# Harrison Salmon Stronghold FHRI

## Top 20 Potential Restoration Sites and associated Stressors



### Legend

⬚ Study Area

⬚ First Nations Reserve

🟦 BD

🟩 BD:IS

🟥 DW

🟪 DW:BD

🟩 DW:SE

🟪 IS

**Acronymns:**

BD = beaver dam

CV = culvert

DW = dewatered

IS = invasive species

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### Notes

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### Sources

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- Inset Basemap: ESRI World Topographic Map

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| 1786-002.01 | Production Date: Apr 26, 2017 | Figure 5B |
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HEMMERA

Sts'ailes
Fisheries

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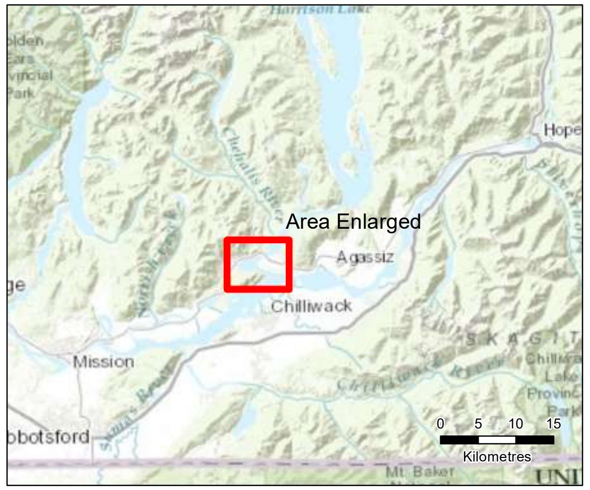
INTERNAL
For Hemmera Use Only

# Harrison Salmon Stronghold FHRI

## Top 20 Potential Restoration Sites and associated Stressors



Legend

- Study Area
- First Nations Reserve
- ▇ CV:SE
- ▇ DW
- ▇ DW:CV
- ▇ DW:IS
- ▇ DW:SE

**Acronymns:**
BD = beaver dam
CV = culvert
DW = dewatered
IS = invasive species
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Notes

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Sources

Study Area imagery from data from Terra Remote, 2017
- Outside of Study Area, ESRI World Imagery
- Inset Basemap: ESRI World Topographic Map

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Sts'ailes Fisheries

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# APPENDIX A

## Habitat Mapping Attributes

# Appendix B: Habitat Mapping Attributes

## Primary Attributes

| Habitat Type | |
|---|---|
| 0 | upland |
| 1 | accreted |
| 2 | ephemeral |
| 3 | wet |

| Fish Use | | |
|---|---|---|
| Species | | Life Stage |
| CH | Chinook | |
| CO | Coho | all |
| CM | Chum | spawning |
| SK | Sockeye | rearing |
| PK | Pink | holding |

| Stressor/Feature | |
|---|---|
| BD | beaver dam |
| CV | culvert |
| DW | dewatering |
| ER | erosion |
| SE | sedimentation |
| X | log jam |
| HA | hatchery |
| AV | avulsions |
| IS | Invasive species |
| EN | encroachment |
| R | road |
| AG | agriculture |

| Restoration | |
|---|---|
| 0 | No |
| 1 | Historical |
| 2 | Potential |

## Modifiers

| Riparian Vegetation | |
|---|---|
| N | none |
| G | graminoid |
| W | wetland |
| S | shrub < 2m |
| C | coniferous |
| D | deciduous |
| M | mixed C + D |

| Crown Closure (%) | |
|---|---|
| 0 | 0 |
| 1 | 1-20 |
| 2 | 21-40 |
| 3 | 41-70 |
| 4 | 71-90 |
| 5 | >90 |

| Water Velocity (cm/s) | | |
|---|---|---|
| 0 | none | 0 |
| 1 | negligible | < 2 |
| 2 | slow | 2-20 |
| 3 | moderate | 20 - 100 |
| 4 | fast | > 100 |

| Channel Depth (m) | | |
|---|---|---|
| 0 | ephemeral | 0 |
| 1 | shallow | < 0.5 |
| 2 | moderate | 0.5 - 1.0 |
| 3 | deep | 1.0 - 10 |
| 4 | very deep | 10+ |

| Streambed Substrate | |
|---|---|
| S | silt/fines |
| Sa | Sand |
| G | Gravel |
| C | Cobble |
| B | Boulder |

| Channel Morphology | |
|---|---|
| RP | riffle-pool |
| CP | cascade-pool |
| SC | small channel |
| LC | large channel |
| OC | off channel habitat |
| P | pool |
| D | ditch |

| Instream Cover (%) | | |
|---|---|---|
| SWD | small woody debris | 0 |
| LWD | large woody debrid | 1-5 |
| B | boulders | 5-25 |
| U | undercut banks | 26-50 |
| OV | overhanging vegetation | 50-75 |
| IN | instream vegetation | 76-100 |

# APPENDIX B

## Harrison River LiDAR Project Report

# Project Report

## Harrison River LiDAR Project
## Harrison River, BC

April 7, 2017

Submitted to:
Hemmera Envirochem Inc.
18th Floor, 4730 Kingsway, Burnaby, BC
V5H 0C6

Attn: Jamie Slogan

Submitted by:
Terra Remote Sensing Inc.
1962 Mills Road, Sidney BC,
V8L 5Y3

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Terra Project Ref.#000-2792-01
Terra Project Manager: Taylor Davis

terra remote sensing

# NOTIFICATION OF CONFIDENTIAL INFORMATION

This Report is submitted for consideration as part of Hemmera's Project completed by Terra Remote Sensing Inc. and contains proprietary and confidential information that is considered by Terra Remote Sensing Inc. and its subcontractors to represent valuable trade secrets. All information enclosed in this Report that is not supplied by Hemmera is confidential and proprietary to the proponent. By accepting and retaining the Report, Hemmera agrees to avoid publication or disclosure of such proprietary and confidential information to unauthorized third parties by employing at least the same standards and measures it customarily uses to protect its own proprietary and confidential information; provided, however, that shall be free to use, reproduce and disseminate such information contained in the Report to its employees and consultants who are involved in considering and evaluating the Report and in discussions with the submitter. Hemmera shall, nevertheless, be free to disclose such information to third parties if it is independently developed without access to the proponent's information, obtained from a third party without restriction, already in its possession without restriction, or is released in the public domain. Hemmera agrees to reproduce this confidentiality notice on any copies of the Report made in accordance with the limited rights provided herein. If a contract or other agreement is concluded between Hemmera and the proponents as a result of the Report, Hemmera may use or disclose the proprietary information contained in the Report to the extent provided for in any such resulting contract or other agreement.

# Contents

# EXECUTIVE SUMMARY

**Terra Remote Sensing Inc.** (TRSI) is pleased to submit this project report to Hemmera Envirochem Inc. for the Harrison River LiDAR survey. Contained in this report are details regarding the project specifications and overall data accuracy.

Terra Remote Sensing Inc. conducted an aerial survey of 51.58 km$^2$, located in Harrison Mills, BC. Data acquisition operations primarily occurred from the Pitt Meadows Regional Airport. The survey commenced on November 4 and finished on November 8, 2016. Data collected includes: LiDAR, color digital imagery, and static GPS control.

Using a combined GPS and inertial navigation system (INS), TRSI calculated aircraft attitude and position and incorporated laser range data to resolve spatial surface information. The calibration flight consisted of parallel and perpendicular passes over the Pitt Meadows Regional Airport runway and was performed immediately after the completion of the project. This pattern allowed TRSI to calibrate the roll, pitch, and heading of the system and refine the acquired spatial data.

A GPS base station with an aerial target was placed at the Pitt Meadows Regional Airport to provide suitable baseline lengths for the aircraft data processing. The ground survey combined with calibration flight in the project area aided in resolving and validating vertical elevations and geo-referenced aerial photos.

TRSI personnel completed all data acquisition, data post-processing, and quality analysis.

# PROJECT SPECIFICATIONS

## Project Location

The Harrison River LiDAR Project is located in Harrison Mills, BC (Figure 1).

| Project Sites | Project Size (km²) | Acquisition Date | Control Survey Date |
|---|---|---|---|
| **Total Project Area** | 51.58 | Nov 4 – 8, 2016 | November 4, 2016 |

## Geodetic Parameters

- **Horizontal Datum**: NAD83 (CSRS)
    - **Epoch**: 2002.0
- **Vertical Datum**: CGVD28
- **Geoid**: HTv2.0
- **Projection**: UTM Zone 10 N
- **Units**: Metres

## LiDAR Point Density

- 8 points per square metre (pts/$m^2$) on open hard surfaces (based on a single flight-line); aggregate point density was approximately 16 points / $m^2$.

## Orthophoto Resolution

- 10 cm pixel resolution

## Harrison River LiDAR Project Overview:

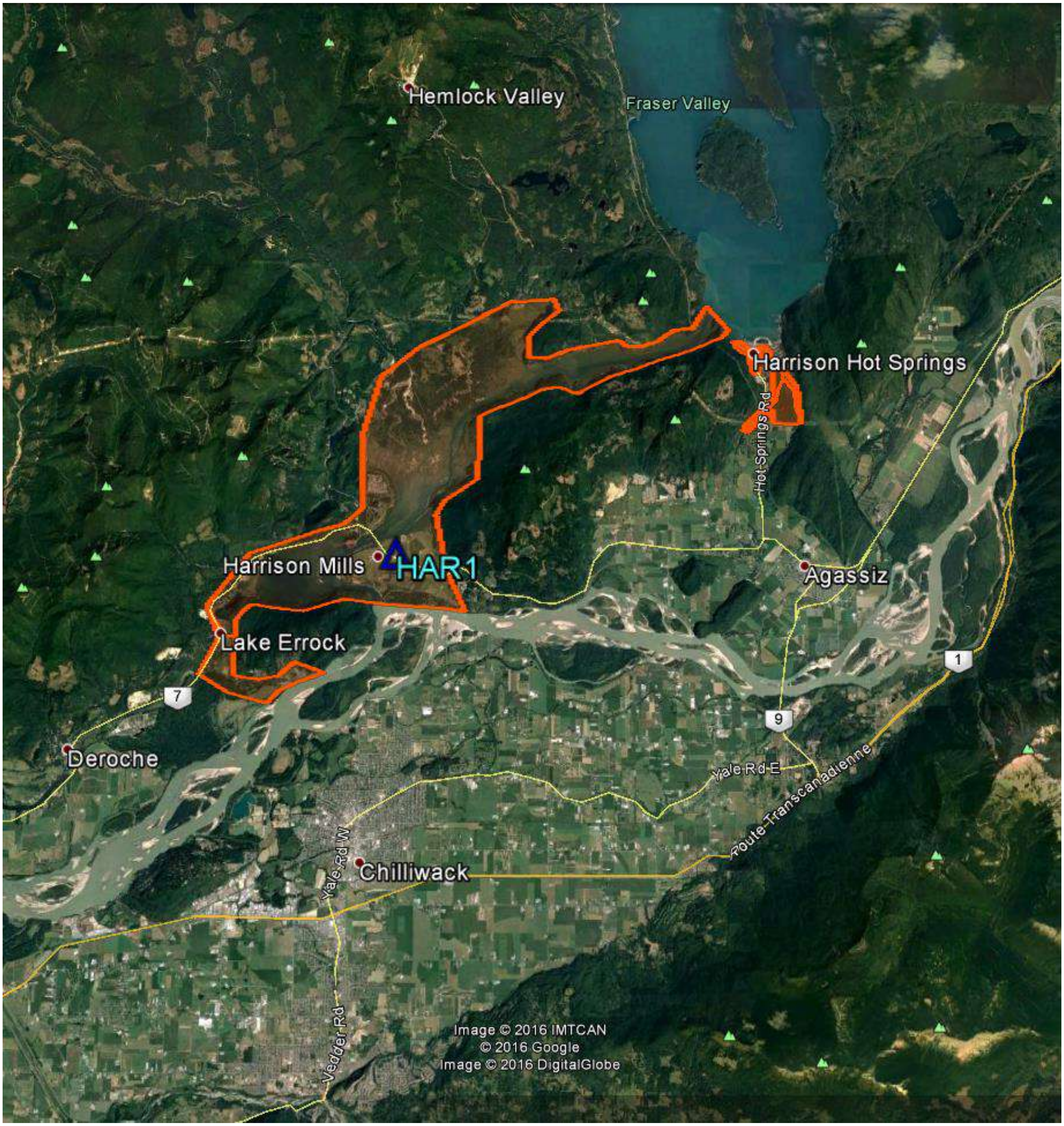


Figure 1. Google Earth image showing the project site and GPS static control location in Harrison Mills, BC

## Flight Parameters

### Rotary Wing Data Acquisition Specifications

| ACQUSITION DETAILS | |
|---|---|
| **Collection Platform** | Bell 206B |
| **Flying Height (AGL)** | 1000 m |
| **Acquisition Speed** | 90 km/h |
| **Flight Line Separation** | 440 m |
| **Lateral Flight Line Overlap** | 100 % |

## System Parameters

| LiDAR | |
|---|---|
| **Laser Type** | Riegl LMS-Q780 |
| **DIGITAL IMAGERY** | |
| **Camera Type** | Nikon D800 |

## Ground Control Summary

| Ground Control | |
|---|---|
| GPS BASE STATIONS | **GPS Base Stations:** Base stations are used for positioning kinematic trajectory.<br>• Baseline length: maximum 30 km<br>• Methodology:<br>○ Set out by air-crew at Pitt Meadows Regional Airport<br>○ Data processed using Applanix POSPAC MMS(v 8.0) software |
| CONTROL STATIONS<br> | **Control Stations:** Targeted control monuments were established to aid in calibrating the airborne data.<br>• Methodology:<br>○ All coordinates were established by static differential surveying methods and referenced to British Columbia Active Control System (BCACS) station: BCLC – City of Langley ACP<br>○ Data processed using Waypoint GrafNet (v 8.5) software. |
| GROUND SURVEY INSTRUMENTATION | Ashtech ProFlex 500 (L1/L2) dual frequency receiver |

# Monument Name: HAR1

| STATION COORDINATE SHEET | HAR1 |
|---|---|
| AGENCY | TRSI |
| DATE OF SURVEY | November 4, 2016 |
| SURVEYOR | M. Dempster |
| HORIZONTAL DATUM | NAD83 (CSRS) |
| VERTICAL DATUM | CGVD28 |
| GEOID | (HT2.0) |
| PROJECTION | UTM Zone 10 |
| LINEAR UNIT | Metres |
| EPOCH | 2002.0 |
| LATITUDE (d m s) | 49 14 30.36911 |
| LONGITUDE (d m s) | -121 56 17.39744 |
| ELLIPSOIDAL HEIGHT | -6.373 |
| EASTING | 577287.969 |
| NORTHING | 5454875.189 |
| ELEVATION | 11.306 |

| MONUMENTATION | ADJUSTMENT |
|---|---|
| TRSI SPIKE | BCACS STATION BCLC WAS HELD FIX IN THE HORIZONTAL AND VERTICAL |

**DESCRIPTION**

| | |
|---|---|
| GENERAL LOCATION: | HARRISON MILLS, BC |

TRSI CONTROL MONUMENT LOCATED ON KENNEDY RD, APPROX 60 METRES WEST FROM INTERSECTION OF LOUGHEED HWY

# DATA PROCESSING

The following section outlines the data processing sequence implemented for the project.

## LiDAR Data

### *LiDAR Calibration*

Once the final aircraft trajectory positions were obtained from the GPS and INS processing, the LiDAR data was calibrated to obtain the parameters necessary to apply to the system installation for the project.

**External Calibration (System)** - External calibration of the data involved the use of the runway calibration flights and a selection of the ground control points. These data were used to establish system offsets and nominal roll, pitch, and heading values. The position of the target features were compared with their corresponding known positions obtained through the independent GPS survey.

**Internal Calibration (LiDAR)** - Project area flight lines were then compared to one another (along with control) to make any necessary final adjustments to the applied values within individual flight lines. The objective is to achieve overall data accuracies that meets or exceeds the project accuracy requirements.

Following field operations, final data checks and adjustments were made during the calibration / pre-processing phase in the office. This stage of data processing yields the final geo-referencing of the data from which all checks to the data accuracy specifications are made. These checks included internal and external accuracy checks.

### *Ground Accuracy Testing*

**1. Internal Accuracy Checks**

Internal checks were made on flight-line overlap areas

Comparison of overlap areas for the vertical component will utilize range data and grid interpolation. Planar areas were used to minimize the effects of artifacts at feature discontinuities:

- Intra flight - minimum of one overlap area
- Inter flight / day to day – two overlap areas (where overlap exists)

Comparison of overlap areas for the horizontal component using intensity data and extraction of conjugate features such as road or building edges:

- Intra flight - minimum of one overlap area
- Inter flight / day to day – two overlap areas

TerraMatch software was also used in the internal accuracy checks. TerraMatch software produces a report listing the apparent offsets in range, roll, pitch, and heading for each flight line. The listing includes both the offset values and standard deviations. Once saved, these values were opened in Excel and sorted to determine outliers. Any offending flight lines were flagged and returned to calibration for review.

Once all of the flight lines were reviewed in TerraMatch and approved, they were released into production. This final TerraMatch report is used for verification purposes only, and therefore the flight lines are not shifted by the suggested offsets. In order for the LiDAR data to be approved and released, all of the offsets listed in the TerraMatch report will lie within established accuracy limits.

### 2. External Accuracy Checks

External checks consisted of checks performed on control stations.

The checks consisted of horizontal and vertical comparisons of the data from the following;

- Base station over-flights
- Over-flights of standard photo type targets placed throughout or near to the project area

Using the ground control points that were not included in the calibration process, the LiDAR data accuracy test consisted of a three-dimensional coordinate difference comparison between control point coordinates and a linear interpolated mapping coordinate derived from the surface of a triangular irregular network (TIN). The coordinate difference results were analyzed to obtain the RMSE values included in this report, which are contained in the Accuracy Reporting section further in this report.

# Digital Imagery

### *Digital Image Calibration*

Calibration of the digital camera consisted of two parts. First the internal camera calibration, which defines the individual camera parameters such as focal length, principle point, offset and lens distortion. These are typically initially determined using a test array of photo targets located at the Terra hanger. A process is also undertaken as required during field operations using images flown an area with natural targets which can be positively identified in each of the separate image.

Both methods use a reverse bundle adjustment strategy to extract the parameters. The derived camera model will be used from project to project but is checked at the beginning of each project using field measurements to ensure that the cameras are performing properly.

The second part of the calibration is project specific, which involves determining the boresite angles of the camera with respect the Inertial Measuring Units (IMU) frame of reference. The differences are small and cannot be measured directly but are easily determined through the calibration process. Once sufficient calibration points are collected, Terrasolid software solves for the boresite angles in a process similar the photogrammetric bundle block adjustment.

### *Digital Imagery / Orthomosaic Processing*

When the raw imagery was initially mosaicked together, colour differences can be evident at seams throughout the dataset. The seams themselves are perfectly straight lines that stand out in areas of trees or buildings. The next step was a preliminary colour balance that involved two steps: a global Intensity, saturation and contrast adjustment, followed by automated colour point routine. Colour points are sample sites in common areas of the raw imagery. A triangulated colour corrective scheme is created, which can be edited. This is a powerful tool for removing seams due to colour differences.

Once the above steps are completed, the next step is to perform a seam line improvement. The seam line improvement transformed the straight seam lines into broken irregular lines following lines of contrast. This helps hide the photo seams lines through forest areas. The product at this point is visually correct.

The final step involves going through each block looking for defects and correcting features such as bridges and buildings, which may be distorted. Since orthorectification occurs to ground level, above-ground features are not in their true orthographic position. These above-ground features were edited to achieve a visually acceptable product.

# QUALITY CONTROL REPORT

Terra is committed to ensure that the quality of our services and products at every level are continually monitored. We have recently implemented a Quality Management System based on the international QMS standard ISO9001:2008.

Terra's QC department assures that all deliveries meet or exceed the specifications and formats stated in the contract for this project.

## *Summary of quality plan*

The Terra quality plan for the project may be summarized as follows:

A. Field and Pre-processing

- Field QC of acquired data
- QA of acquired data upon return from field by calibration department
- Data calibration followed by QC of results vs. ground checks

B. Data Processing

- Internal QC (IQC) is conducted within processing department following initial data processing. Identified corrections then go through a first-edit process.
- Edited data then goes through a QC conducted by the independent QA/QC department.

C. Data Delivery

- QA of final deliverable products by the independent QA/QC department

## *Field QC / QA Processes*

**1. LiDAR and Image Data Verification** — The primary concerns with respect to quality for airborne LiDAR survey programs are data integrity, completeness, and coverage. The following QC procedures are undertaken in the field during the data acquisition process to address these concerns.

Data integrity refers to the data files being uncorrupted and able to be processed. Field procedures undertaken to ensure data integrity:

- Daily download from airborne system
- Checks that all files can be opened and contain the correct content
- Checks for corrupted files
- Create backup files of all data

Data completeness involves:

- Checks to ensure that there is a full set of files for each mission
- Checks to ensure there are no gaps in the data

- Data coverage checks are performed to determine that there is a match between each type of data to be collected and each area that is to be covered by that data type (e.g. if there are variations in the required coverage for LiDAR and digital image data).

**2. Geo-Referencing Verification**—The basic accuracy of the data is achieved primarily through a combination of the system specifications and actual operational performance and the flight procedures.

Flight procedures are subject to weather and other conditions in the air such as air traffic that may affect the way in which the project is actually flown.

While final accuracy results won't be known until the data are processed, two processes will be conducted to ensure that the data returned from the field will meet the project accuracy specifications. These processes are checks on flight data to ensure operational adherence to project specifications.

Flight data checks:

- Review of system calibration flight following installation
- Checks on actual system setting to match project specifications
- Checks on flight overlap and aircraft speed
- Checks on maximum baseline distances from aerial base stations
- Review of GPS data acquired on the base stations through network ties and redundant base station operation for checks on airborne data

Accuracy checks:

- Vertical and horizontal checks on LiDAR and image data obtained on flights over base stations and other placed targets

## *Calibration and Data Pre-processing QC / QA Processes*

Following field operations, final data checks and adjustments are made during the calibration / pre-processing phase in the office. As this stage of data processing yields the final geo-referencing of the data all checks to the accuracy specifications are made. They include internal and external accuracy checks.

1. **Internal Accuracy Checks**—Internal checks will be made on flight-line overlap areas and on the overlaps between datasets acquired on different days.
2. **External Accuracy Checks**—The external checks made by Terra consist of comparison of the LiDAR data to ties to any client supplied control and to any additional control placed by Terra in the project area.

## *Quality Control Methodology for Data Processing QC / QA Processes*

Individual departments processing various aspects of the data conduct internal QC procedures appropriate to the type of data processing being undertaken. The following are examples of QC procedures.

- Digital Image Processing

- Checks on the consistency of the image tonal quality across the project area, particularly in areas where image boundaries occur due to different flying days or different missions
- Checks on seams where individual images are mosaicked to ensure that there are no mismatches, especially as evidenced along linear features, for example, roadways

- LiDAR Processing
- Checks on ground classification through the use of shaded relief models to ensure ground is accurately defined
- Checks on the feature classes by comparing to the digital imagery to ensure all required classes are identified within the LiDAR data

## *Final Quality Assurance Procedures*

Terra maintains a separate QA division that reviews all data prior to delivery. Specific QA processes will be implemented for each type of data to be delivered. Checks will include the following:

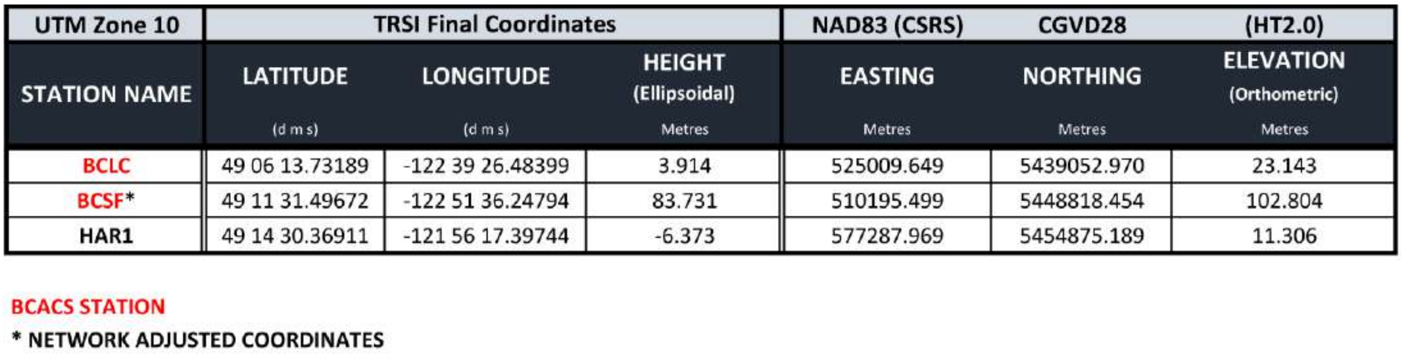
- Data format
- Map projection and datum
- File name and content matching conventions adopted for the project
- Data completeness
- Consistency of data between different types, e.g. classified LiDAR points match the features in the digital image
- Review of checks on external control
- Review of bare earth classification
- Review of above ground points to ensure noise removal

# ACCURACY REPORTING

## Final Coordinates

Final TRSI coordinates are reported in UTM Zone 10 N – NAD 83 (CSRS) – HTv2.0

## Final Coordinates



| UTM Zone 10 | TRSI Final Coordinates | | | NAD83 (CSRS) | CGVD28 | (HT2.0) |
|---|---|---|---|---|---|---|
| STATION NAME | LATITUDE (d m s) | LONGITUDE (d m s) | HEIGHT (Ellipsoidal) Metres | EASTING Metres | NORTHING Metres | ELEVATION (Orthometric) Metres |
| BCLC | 49 06 13.73189 | -122 39 26.48399 | 3.914 | 525009.649 | 5439052.970 | 23.143 |
| BCSF* | 49 11 31.49672 | -122 51 36.24794 | 83.731 | 510195.499 | 5448818.454 | 102.804 |
| HAR1 | 49 14 30.36911 | -121 56 17.39744 | -6.373 | 577287.969 | 5454875.189 | 11.306 |

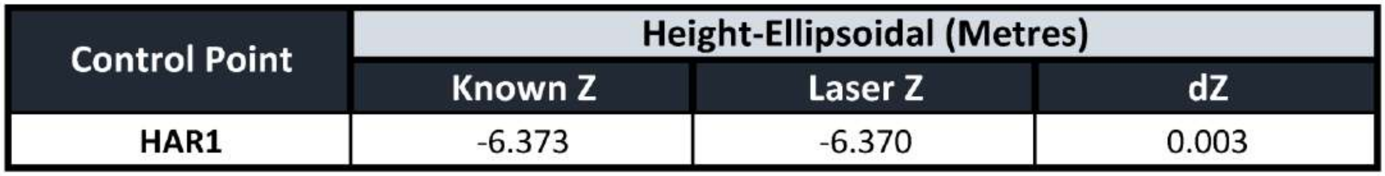
BCACS STATION

* NETWORK ADJUSTED COORDINATES

## Vertical Accuracy

The following table outlines the final accuracies obtained in the project through the comparison of the known static GPS survey locations in comparison with the bare earth LiDAR data obtained in the survey.

## Vertical Accuracy Report - Static

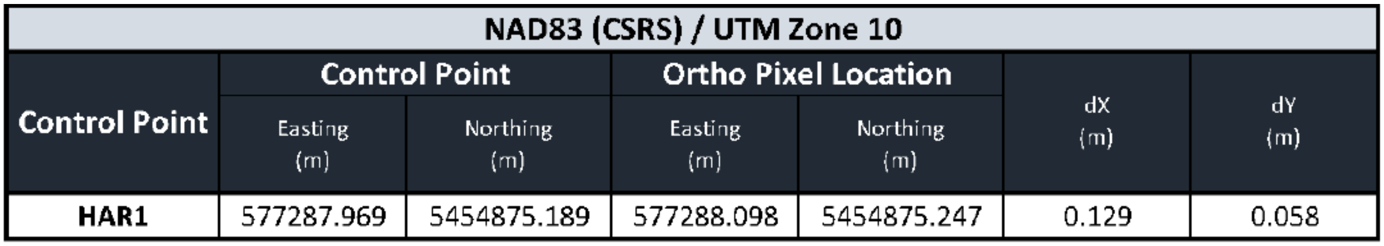


| Control Point | Height-Ellipsoidal (Metres) | | |
|---|---|---|---|
| | Known Z | Laser Z | dZ |
| HAR1 | -6.373 | -6.370 | 0.003 |

## Horizontal Accuracy

Positioning of control was situated on identifiable targets that could be distinguished in the orthophoto data. The table below summarizes the statistical results for all control points with corresponding photo targets.

### Horizontal Accuracy Report



NAD83 (CSRS) / UTM Zone 10

| Control Point | Control Point | | Ortho Pixel Location | | dX (m) | dY (m) |
|---|---|---|---|---|---|---|
| | Easting (m) | Northing (m) | Easting (m) | Northing (m) | | |
| **HAR1** | 577287.969 | 5454875.189 | 577288.098 | 5454875.247 | 0.129 | 0.058 |

# DELIVERABLES SUMMARY

| **Deliverable Product Summary** | | | | | |
|---|---|---|---|---|---|
| **Final Deliverable Coordinates** | **Projection:** | UTM Zone 10 N | | | |
| | **Datum:** | NAD 83 (CSRS) | | | |
| **Delivery Medium** | **Hard Drive** | ☐ | **FTP** | ☑ | |
| **Delivery Products** | **Description** | **Resolution** | **Format** | **In Scope** | |
| | | | | **YES** | **NO** |
| **LiDAR** | Ground | n/a | .las v1.2 | ☑ | ☐ |
| | Non-Ground | n/a | .las v1.2 | ☑ | ☐ |
| | Detailed Classification (pre-determined feature code) | n/a | .las v1.2 | ☐ | ☒ |
| | Filtered ground LiDAR points (MKP) | n/a | .las v1.2 | ☐ | ☒ |
| **DEM** | | m | .img | ☑ | ☐ |
| **DSM** | | m | .img | ☑ | ☐ |
| **CHM** | | m | .img | ☑ | ☐ |
| **3D Mesh** | | m | .dxf | ☐ | ☒ |
| **Contours** | not cartographically enhanced | m | .shp | ☐ | ☒ |
| **Hillshade Models** | | m | .tiff | ☑ | ☐ |
| **Slope / Aspect Maps** | | m | .tiff | ☐ | ☒ |
| **PLS-CADD®** | Compiled .bak model | n/a | .bak | ☐ | ☒ |
| | In-flight MET data | n/a | .csv | ☐ | ☒ |
| **Planimetry** | 2D - pre-determined feature code | n/a | .shp | ☑ | ☐ |
| | 3D - pre-determined feature code | n/a | .shp | ☐ | ☒ |
| **3D Buildings** | 3D wireframe buildings | n/a | .shp | ☐ | ☒ |
| **Tree crown polygons** | Max-diameter | n/a | .shp | ☐ | ☒ |
| **Tree-top points** | Max height point | n/a | .shp | ☐ | ☒ |
| **RGB Imagery** | Orthophoto mosaics | 10cm | .ecw | ☑ | ☐ |
| | Oblique imagery | cm | .jpg | ☐ | ☒ |
| **NIR Imagery** | Orthophoto mosaics | cm | .tiff | ☐ | ☒ |
| **Hyperspectral Imagery** | VNIR Bands - Radiometrically calibrated mosaics | m | .tiff | ☐ | ☒ |
| | SWIR Bands - Raidometrically calibrated mosaics | m | .tiff | ☐ | ☒ |
| **TIR Imagery** | Calibrated mosaics | cm | .tiff | ☐ | ☒ |
| **Video** | Nadir and Oblique digital video | n/a | .mp4 | ☐ | ☒ |
| **Plots** | | scale | .pdf | ☐ | ☒ |
| **Project Index** | Key map containing all relevant project information | n/a | .dwg | ☑ | ☐ |
| **Project Report** | Accuracy and general project reporting | n/a | .pdf | ☑ | ☐ |
| **Other** | | | | ☐ | ☒ |
| **Comments** | | | | | |

# APPENDIX A – NETWORK ADJUSTMENT:

# Network Adjustment Residuals

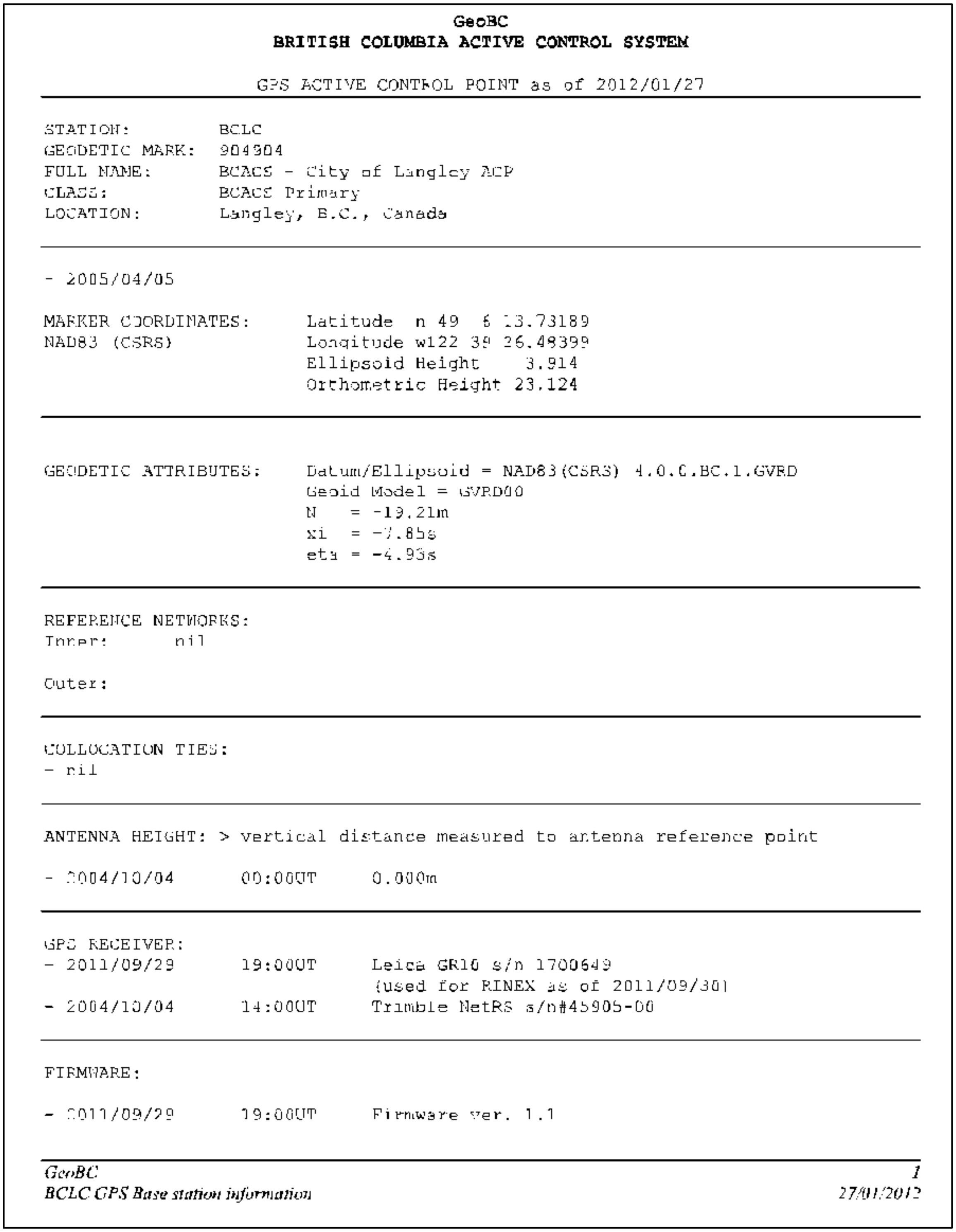
```
             ***************************************************
             * NETWORK - WEIGHTED GPS NETWORK ADJUSTMENT        *
             *                                                 *
             * (c) Copyright NovAtel Inc., (2012)              *
             *                                                 *
             * Version: 8.40.3116                              *
             *                                                 *
             * FILE: G:\000-2792 Hemmera - Harrison River
BC\Control\D309\static\proc\000-2792-01_D309_Harrison_Static.net
             ***************************************************

DATE(m/d/y): Mon.  11/21/16   TIME: 11:31:31

****************************************************************

  DATUM:            'NAD83'
  SCALE_FACTOR:     1.5576
  CONFIDENCE LEVEL: 95.00 %   (Scale factor is 2.4479)


*****************************************************************
    INPUT CONTROL/CHECK POINTS
*****************************************************************

STA_ID     TYPE    -- LATITUDE --  -- LONGITUDE --  ELLHGT -   HZ-SD   V-SD
BCLC       GCP-3D  49 06 13.73189 -122 39 26.48399      3.914 0.00001 0.00010
BCSF       CHK-3D  49 11 31.49655 -122 51 36.24849     83.735

*****************************************************************
    INPUT VECTORS
*****************************************************************

SESSION NAME           VECTOR(m)   ------ Covariance (m) [unscaled] ------
                        DX/DY/DZ          standard deviations in brackets
BCLC to BCSF (1)      -8447.2665  4.6357e-006 (0.0022)
                      14202.7366  2.1619e-006 7.6078e-006 (0.0028)
                       6481.4832  -5.0271e-006 -1.3391e-006 1.6441e-005 (0.0041)

BCLC to BCSF (2)      -8447.2683  3.5205e-006 (0.0019)
                      14202.7418  2.2795e-006 4.9917e-006 (0.0022)
                       6481.4756  -1.6605e-006 -2.6577e-006 5.7339e-006 (0.0024)

BCLC to HAR1 (1)      50534.6999  6.4650e-005 (0.0080)
                      -18202.0101  -3.6819e-005 1.6741e-004 (0.0129)
                      10022.7493  1.5607e-006 -3.8112e-005 4.2870e-005 (0.0065)

BCLC to HAR1 (2)      50534.7378  2.5524e-004 (0.0160)
                      -18202.0405  -1.9830e-004 5.5847e-004 (0.0236)
                      10022.7550  -4.2492e-005 -2.8937e-005 1.4160e-004 (0.0119)

BCSF to HAR1 (1)      58981.9785  1.0689e-004 (0.0103)
                      -32404.7297  -7.9789e-005 2.7215e-004 (0.0165)
                       3541.2780  1.2573e-005 -6.8888e-005 7.1775e-005 (0.0085)
```

```
BCSF to HAR1 (2)      58982.0001  2.7801e-004 (0.0167)
                      -32404.7348  -2.1758e-004 6.1522e-004 (0.0248)
                       3541.2504  -4.6999e-005 -3.1024e-005 1.5362e-004 (0.0124)

****************************************************************
    OUTPUT VECTOR RESIDUALS (East, North, Height - Local Level)
****************************************************************

SESSION NAME               -- RE --   -- RN --   -- RH --     - PPM -   DIST - STD -
                              (m)        (m)        (m)                  (km)    (m)
BCLC to BCSF (1)            -0.0022    -0.0017    -0.0045       0.295   17.8  0.0067
BCLC to BCSF (2)             0.0021     0.0006     0.0035       0.232   17.8  0.0047
BCLC to HAR1 (1)             0.0061     0.0095    -0.0065       0.238   54.6  0.0207
BCLC to HAR1 (2)            -0.0422     0.0099    -0.0143       0.835   54.6  0.0386
BCSF to HAR1 (1)             0.0072    -0.0123     0.0025       0.215   67.4  0.0265
BCSF to HAR1 (2)            -0.0138     0.0002     0.0283       0.467   67.4  0.0404
                         --------------------------------
               RMS           0.0186     0.0075     0.0135

 $ - This session is flagged as a 3-sigma outlier

****************************************************************
    CHECK POINT RESIDUALS (East, North, Height - Local Level)
****************************************************************

STA. NAME    -- RE --   -- RN --   -- RH --
                (m)        (m)        (m)
BCSF           0.0112     0.0053    -0.0039
            --------------------------------
RMS            0.0112     0.0053     0.0039

****************************************************************
    CONTROL POINT RESIDUALS (ADJUSTMENT MADE)
****************************************************************

STA. NAME    -- RE --   -- RN --   -- RH --
                (m)        (m)        (m)
BCLC           0.0000    -0.0000    -0.0000
            --------------------------------
RMS            0.0000     0.0000     0.0000

****************************************************************
    OUTPUT STATION COORDINATES (LAT/LONG/HT)
****************************************************************

STA_ID      -- LATITUDE --  -- LONGITUDE -- - ELLHGT -
BCLC        49 06 13.73189 -122 39 26.48399     3.9140
BCSF        49 11 31.49672 -122 51 36.24794    83.7311
HAR1        49 14 30.36911 -121 56 17.39744    -6.3734

****************************************************************
    OUTPUT VARIANCE/COVARIANCE
****************************************************************
                                             2
STA_ID      SE/SN/SUP  --------- CX matrix (m )-----------
            (95.00 %)  (not scaled by confidence level)
```

```
               (m)          (ECEF, XYZ cartesian)
BCLC           0.0000  1.3356e-009
               0.0000  1.9278e-009 3.1077e-009
               0.0002  -2.6437e-009 -4.1248e-009 5.7567e-009

BCSF           0.0032  2.8648e-006
               0.0043  1.7969e-006 4.4846e-006
               0.0071  -1.7653e-006 -2.0450e-006 5.8842e-006

HAR1           0.0237  4.7355e-005
               0.0142  -3.0565e-005 1.1624e-004
               0.0200  -1.1921e-007 -2.3043e-005 3.0678e-005

****************************************************************
    VARIANCE FACTOR = 1.0000

    Note: Values < 1.0 indicate statistics are pessimistic, while
          values > 1.0 indicate optimistic statistics. Entering this
          value as the network adjustment scale factor will bring
          variance factor to one.
****************************************************************
```

# APPENDIX B – ACTIVE CONTROL STATION REPORT:

## BCACS STATION: BCLC



GeoBC

**BRITISH COLUMBIA ACTIVE CONTROL SYSTEM**

GPS ACTIVE CONTROL POINT as of 2012/01/27

```
STATION:         BCLC
GEODETIC MARK:   904304
FULL NAME:       BCACS - City of Langley ACP
CLASS:           BCACS Primary
LOCATION:        Langley, B.C., Canada
```

---

```
- 2005/04/05

MARKER COORDINATES:      Latitude  n 49  6 13.73189
NAD83 (CSRS)             Longitude w122 39 26.48399
                         Ellipsoid Height    3.914
                         Orthometric Height 23.124
```

---

```
GEODETIC ATTRIBUTES:     Datum/Ellipsoid = NAD83(CSRS) 4.0.0.BC.1.GVRD
                         Geoid Model = GVRD00
                         N    = -19.21m
                         xi   = -7.85s
                         eta  = -4.93s
```

---

```
REFERENCE NETWORKS:
Inner:       nil

Outer:
```

---

```
COLLOCATION TIES:
- nil
```

---

```
ANTENNA HEIGHT: > vertical distance measured to antenna reference point

- 2004/10/04       00:00UT     0.000m
```

---

```
GPS RECEIVER:
- 2011/09/29       19:00UT     Leica GR10 s/n 1700649
                               (used for RINEX as of 2011/09/30)
- 2004/10/04       14:00UT     Trimble NetRS s/n#45905-00
```

---

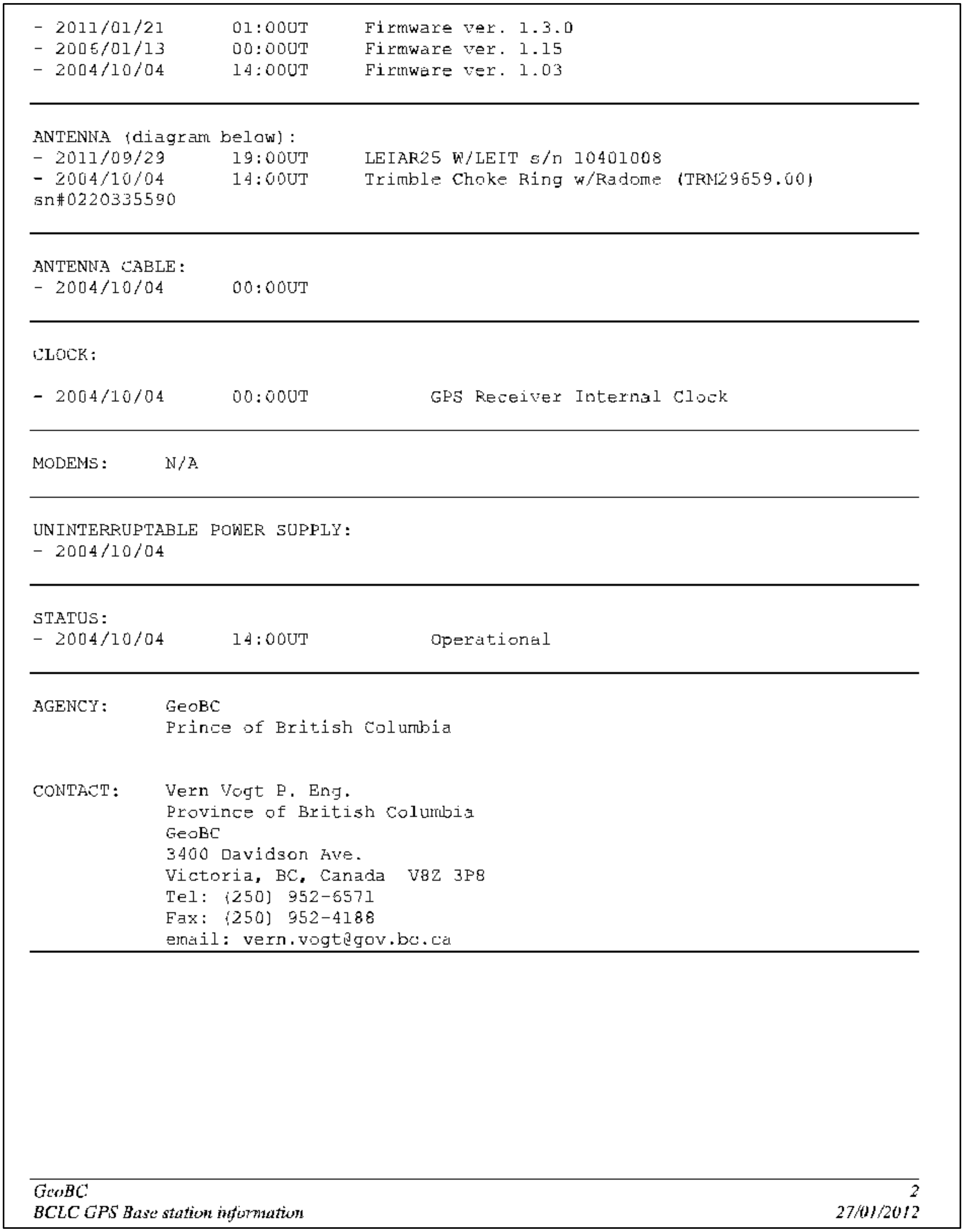
```
FIRMWARE:

- 2011/09/29       19:00UT     Firmware ver. 1.1
```

---

*GeoBC* *1*

*BCLC GPS Base station information* *27/01/2012*

Figure 1 of 4



```
- 2011/01/21      01:00UT     Firmware ver. 1.3.0
- 2006/01/13      00:00UT     Firmware ver. 1.15
- 2004/10/04      14:00UT     Firmware ver. 1.03
```

```
ANTENNA (diagram below):
- 2011/09/29      19:00UT     LEIAR25 W/LEIT s/n 10401008
- 2004/10/04      14:00UT     Trimble Choke Ring w/Radome (TRM29659.00)
sn#0220335590
```

```
ANTENNA CABLE:
- 2004/10/04      00:00UT
```

```
CLOCK:

- 2004/10/04      00:00UT           GPS Receiver Internal Clock
```

```
MODEMS:     N/A
```

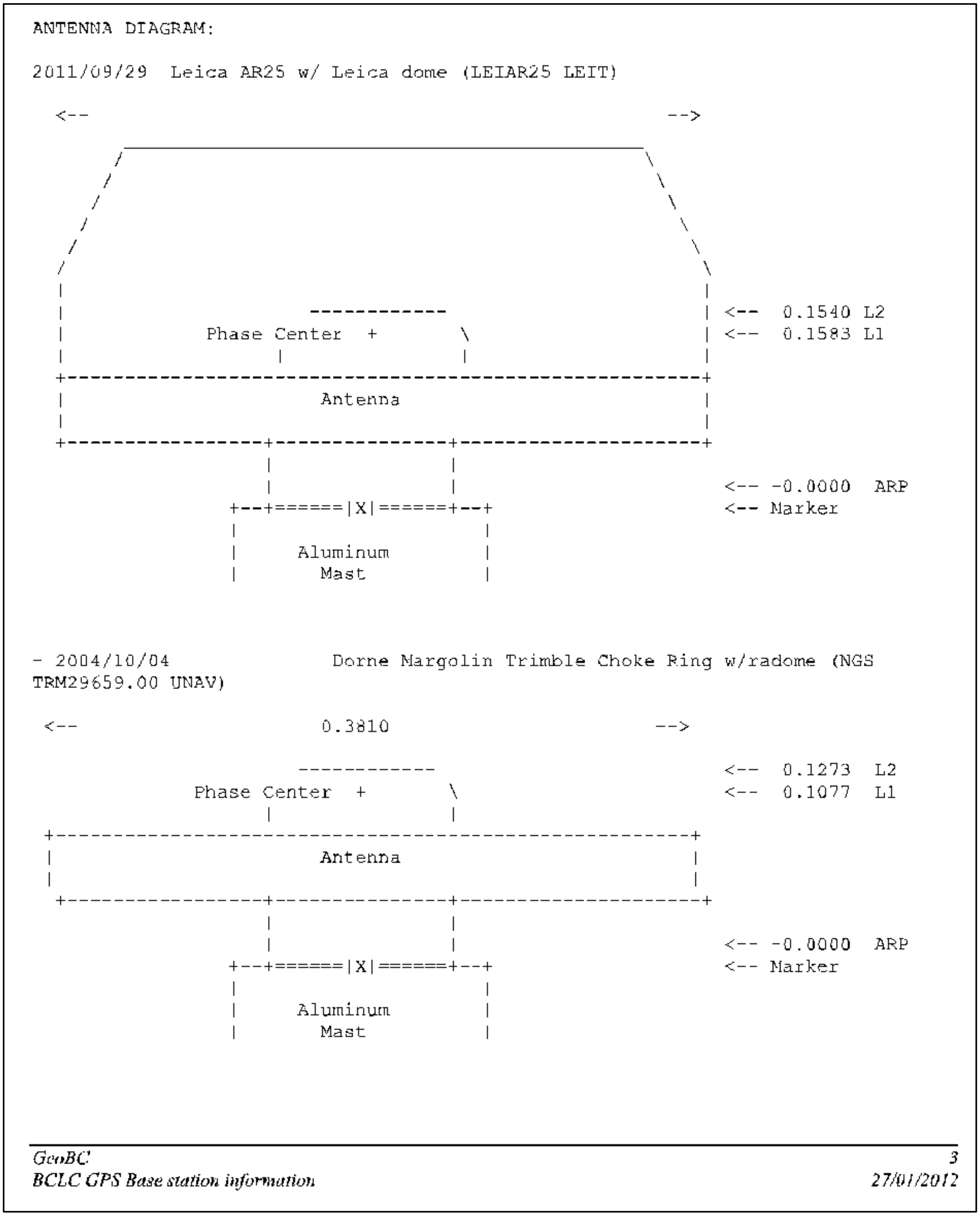
```
UNINTERRUPTABLE POWER SUPPLY:
- 2004/10/04
```

```
STATUS:
- 2004/10/04      14:00UT           Operational
```

```
AGENCY:     GeoBC
            Prince of British Columbia


CONTACT:    Vern Vogt P. Eng.
            Province of British Columbia
            GeoBC
            3400 Davidson Ave.
            Victoria, BC, Canada  V8Z 3P8
            Tel: (250) 952-6571
            Fax: (250) 952-4188
            email: vern.vogt@gov.bc.ca
```

*GeoBC* *2*
*BCLC GPS Base station information* *27/01/2012*

Figure 2 of 4

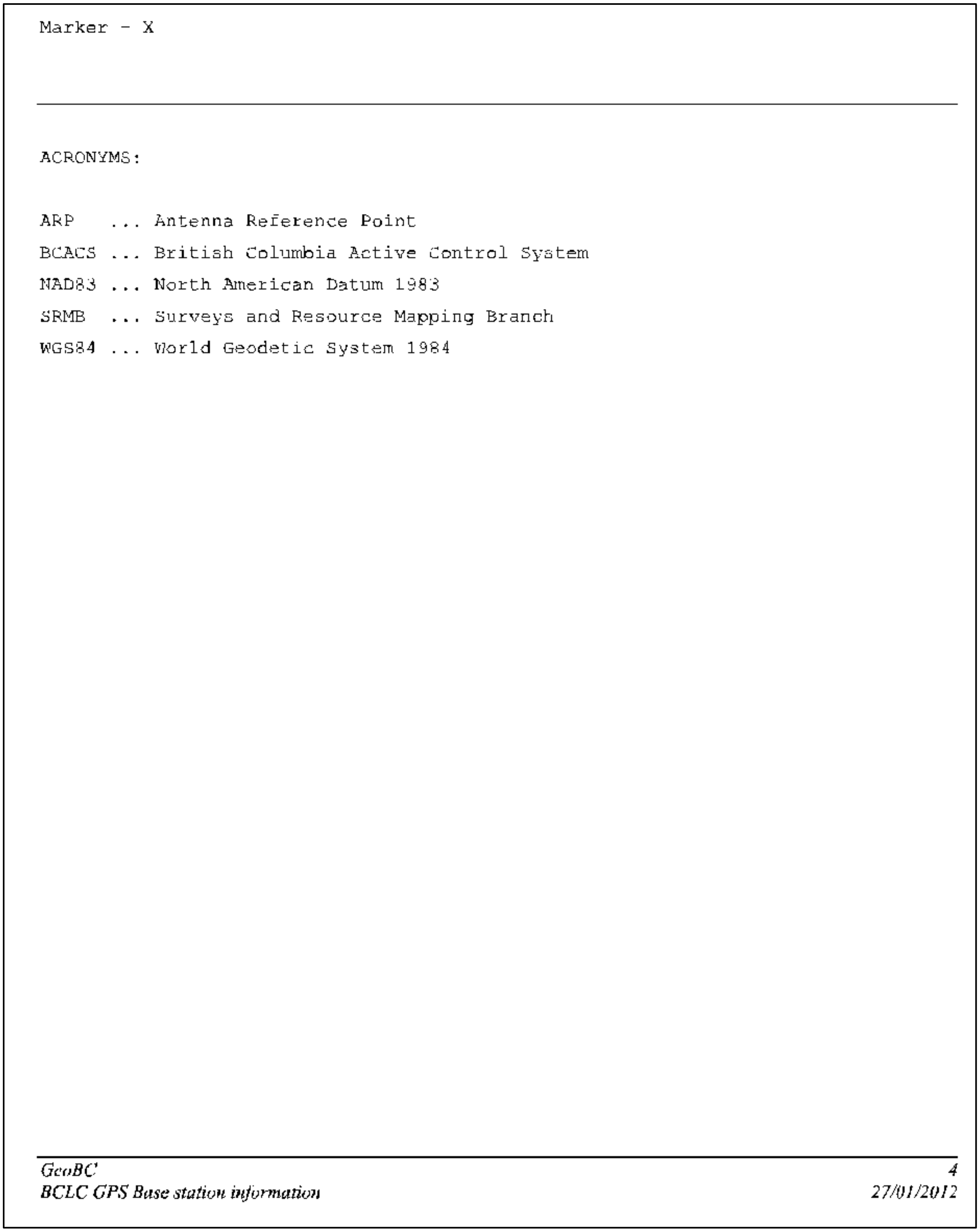


```
ANTENNA DIAGRAM:

2011/09/29  Leica AR25 w/ Leica dome (LEIAR25 LEIT)

  <--                                                  -->

        _____________________________________________
       /                                              \
      /                                                \
     /                                                  \
    /                                                    \
   /                                                      \
  /                                                        \
  |                                                        |
  |                     ------------                       | <--  0.1540 L2
  |            Phase Center  +       \                     | <--  0.1583 L1
  |                  |               |                     |
  +--------------------------------------------------------+
  |                      Antenna                           |
  |                                                        |
  +-----------------+---------------+----------------------+
                    |               |
                    |               |                        <-- -0.0000  ARP
                 +--+======|X|======+--+                     <-- Marker
                 |                     |
                 |     Aluminum        |
                 |       Mast          |



- 2004/10/04              Dorne Margolin Trimble Choke Ring w/radome (NGS
TRM29659.00 UNAV)

 <--                     0.3810                       -->

                       ------------                          <--  0.1273  L2
              Phase Center  +       \                        <--  0.1077  L1
                    |               |
 +--------------------------------------------------------+
 |                       Antenna                          |
 |                                                        |
  +-----------------+---------------+----------------------+
                    |               |
                    |               |                        <-- -0.0000  ARP
                 +--+======|X|======+--+                     <-- Marker
                 |                     |
                 |     Aluminum        |
                 |       Mast          |
```

*GeoBC*  
*BCLC GPS Base station information*

*3*  
*27/01/2012*

Figure 3 of 4



Marker - X

ACRONYMS:

ARP ... Antenna Reference Point
BCACS ... British Columbia Active Control System
NAD83 ... North American Datum 1983
SRMB ... Surveys and Resource Mapping Branch
WGS84 ... World Geodetic System 1984

*GeoBC* *4*
*BCLC GPS Base station information* *27/01/2012*

Figure 4 of 4

Reference: http://www2.gov.bc.ca/assets/gov/data/geographic/bcacs/bclc_site.pdf

# APPENDIX C – DELIVERABLE DATA INVENTORY:

```
Date       Time    Attrib      Bytes        File name
---------- -------- ------  ----------------  --------

T:\PROJ-000\000-2792 Hemmera - Harrison River BC\Deliveries
16/12/2016 3:51:54 PM AD----                   IMG
16/12/2016 3:51:24 PM AD----                   INDEX
                   -------------------
                              256  1 Files

T:\PROJ-000\000-2792 Hemmera - Harrison River BC\Deliveries\IMG
15/12/2016 3:30:59 PM A-----     1,214,935,391  HEM_UTM_CHM_SP000-2792_v1.img
15/12/2016 3:20:26 PM A-----       209,077,678  HEM_UTM_DEM_SP000-2792_v1.img
15/12/2016 3:30:31 PM A-----       208,807,221  HEM_UTM_DSM_SP000-2792_v1.img
15/12/2016 3:20:39 PM A-----        51,240,232  HEM_UTM_HILL_SP000-2792_v1.img
                   -------------------
                      1,684,060,522  4 Files

T:\PROJ-000\000-2792 Hemmera - Harrison River BC\Deliveries\INDEX
15/12/2016 9:22:11 AM A-----          333,864  000-2792_HarrisonRiver_ClientIndex_UTM10_v1.dwg
16/12/2016 3:50:48 PM A-----            8,239  000-2792_HarrisonRiver_ClientIndex_UTM10_v1.zip
                   -------------------
                          342,103  2 Files
Date       Time    Attrib      Bytes        File name
---------- -------- ------  ----------------  --------

T:\PROJ-000\000-2792 Hemmera - Harrison River BC\Deliveries\LIDAR
19/12/2016 9:14:20 AM AD----                   Ground
19/12/2016 8:54:42 AM AD----                   NonGround
                   -------------------
                               0  0 Files

T:\PROJ-000\000-2792 Hemmera - Harrison River BC\Deliveries\LIDAR\Ground
19/12/2016 8:35:36 AM A-----       17,037,501  HEM_570_5450_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:36 AM A-----        4,148,747  HEM_570_5451_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:38 AM A-----       12,449,269  HEM_570_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:38 AM A-----           59,737  HEM_570_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:39 AM A-----        4,875,871  HEM_571_5449_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:45 AM A-----       51,025,771  HEM_571_5450_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:49 AM A-----       45,763,693  HEM_571_5451_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:55 AM A-----       43,932,079  HEM_571_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:59 AM A-----       47,143,175  HEM_571_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:35:59 AM A-----        2,432,699  HEM_571_5454_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:00 AM A-----       20,031,881  HEM_572_5449_UTM10_Ground_SP000-2792_v1.laS
19/12/2016 8:36:02 AM A-----       31,453,739  HEM_572_5450_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:05 AM A-----       14,944,835  HEM_572_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:06 AM A-----       22,385,871  HEM_572_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:07 AM A-----       18,872,787  HEM_572_5454_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:10 AM A-----       32,604,775  HEM_573_5450_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:11 AM A-----       12,914,015  HEM_573_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:11 AM A-----        9,083,609  HEM_573_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:13 AM A-----       24,522,533  HEM_573_5454_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:13 AM A-----        1,787,651  HEM_574_5450_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:15 AM A-----       11,017,801  HEM_574_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:17 AM A-----       35,456,831  HEM_574_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:18 AM A-----       24,173,897  HEM_574_5454_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:19 AM A-----       10,005,281  HEM_574_5455_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:20 AM A-----        5,749,161  HEM_575_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:24 AM A-----       76,685,877  HEM_575_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:26 AM A-----       68,241,705  HEM_575_5454_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:33 AM A-----       78,166,305  HEM_575_5455_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:36 AM A-----       56,305,971  HEM_575_5456_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:38 AM A-----       49,011,135  HEM_575_5457_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:41 AM A-----       31,515,415  HEM_575_5458_UTM10_Ground_SP000-2792_v1.las
```

```
19/12/2016 8:36:43 AM A-----  16,309,085 HEM_575_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:43 AM A-----     788,391 HEM_575_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:45 AM A-----  14,765,247 HEM_576_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:49 AM A-----  87,806,427 HEM_576_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:52 AM A-----  91,948,341 HEM_576_5454_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:53 AM A-----  45,066,829 HEM_576_5455_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:55 AM A-----  86,429,597 HEM_576_5456_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:36:59 AM A-----  66,790,143 HEM_576_5457_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:07 AM A-----  57,188,441 HEM_576_5458_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:14 AM A-----  69,869,829 HEM_576_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:18 AM A-----  32,830,671 HEM_576_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:20 AM A-----  18,968,871 HEM_577_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:24 AM A----- 104,030,717 HEM_577_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:27 AM A-----  79,070,127 HEM_577_5454_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:30 AM A-----  44,431,641 HEM_577_5455_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:32 AM A-----  59,908,441 HEM_577_5456_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:35 AM A-----  66,733,635 HEM_577_5457_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:41 AM A-----  52,112,275 HEM_577_5458_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:49 AM A-----  46,152,755 HEM_577_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:54 AM A-----  61,433,205 HEM_577_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:55 AM A-----  11,134,931 HEM_577_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:56 AM A-----  15,595,765 HEM_578_5452_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:37:57 AM A-----  13,221,205 HEM_578_5453_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:00 AM A-----  18,946,125 HEM_578_5456_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:02 AM A-----  49,247,537 HEM_578_5457_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:07 AM A-----  54,507,643 HEM_578_5458_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:15 AM A-----  60,231,373 HEM_578_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:20 AM A-----  75,232,887 HEM_578_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:24 AM A-----  33,276,649 HEM_578_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:24 AM A-----      15,707 HEM_578_5462_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:24 AM A-----   2,132,853 HEM_579_5458_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:28 AM A-----  51,225,997 HEM_579_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:34 AM A-----  52,644,341 HEM_579_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:39 AM A-----  44,833,589 HEM_579_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:40 AM A-----  16,330,641 HEM_579_5462_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:43 AM A-----  39,332,729 HEM_580_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:46 AM A-----  61,553,769 HEM_580_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:49 AM A-----  30,556,343 HEM_580_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:51 AM A-----  31,019,865 HEM_580_5462_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:56 AM A-----  22,226,921 HEM_581_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:59 AM A-----  67,841,899 HEM_581_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:38:59 AM A-----     283,797 HEM_581_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:00 AM A-----   5,782,685 HEM_581_5462_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:01 AM A-----  10,436,673 HEM_582_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:03 AM A-----  87,818,837 HEM_582_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:04 AM A-----   6,216,899 HEM_582_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:06 AM A-----  60,746,337 HEM_583_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:07 AM A-----   6,409,373 HEM_583_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:09 AM A-----  24,620,861 HEM_584_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:10 AM A-----  22,930,755 HEM_584_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:11 AM A-----   2,028,541 HEM_585_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:13 AM A-----  49,040,783 HEM_585_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:13 AM A-----   2,483,495 HEM_585_5462_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:14 AM A-----       6,561 HEM_586_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:17 AM A-----  19,141,965 HEM_586_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:17 AM A-----   6,619,697 HEM_586_5462_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:18 AM A-----  13,172,143 HEM_587_5458_UTM10_Ground_SP000-2792_v1.las
```

```
19/12/2016 8:39:18 AM A-----       5,587,865  HEM_587_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:20 AM A-----      26,881,861  HEM_587_5460_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:20 AM A-----      11,483,941  HEM_587_5461_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:23 AM A-----      15,208,471  HEM_588_5458_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:29 AM A-----      36,047,037  HEM_588_5459_UTM10_Ground_SP000-2792_v1.las
19/12/2016 8:39:31 AM A-----      12,261,249  HEM_588_5460_UTM10_Ground_SP000-2792_v1.las
                        -------------------
                          3,142,752,880  94 Files

T:\PROJ-000\000-2792 Hemmera - Harrison River BC\Deliveries\LIDAR\NonGround
19/12/2016 8:43:00 AM A-----     517,457,457  HEM_570_5450_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:01 AM A-----     125,206,903  HEM_570_5451_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:04 AM A-----     303,928,889  HEM_570_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:04 AM A-----       1,363,059  HEM_570_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:06 AM A-----     243,501,233  HEM_571_5449_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:18 AM A-----   1,512,059,899  HEM_571_5450_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:27 AM A-----   1,223,691,585  HEM_571_5451_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:38 AM A-----   1,470,222,797  HEM_571_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:45 AM A-----     856,429,195  HEM_571_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:46 AM A-----      82,845,827  HEM_571_5454_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:48 AM A-----     186,628,957  HEM_572_5449_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:52 AM A-----     559,003,213  HEM_572_5450_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:57 AM A-----     598,875,863  HEM_572_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:43:59 AM A-----     250,817,999  HEM_572_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:02 AM A-----     402,851,447  HEM_572_5454_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:06 AM A-----     464,970,569  HEM_573_5450_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:09 AM A-----     357,949,721  HEM_573_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:09 AM A-----       9,145,523  HEM_573_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:13 AM A-----     496,770,905  HEM_573_5454_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:14 AM A-----      40,730,163  HEM_574_5450_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:17 AM A-----     442,394,501  HEM_574_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:21 AM A-----     429,934,895  HEM_574_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:23 AM A-----     254,812,523  HEM_574_5454_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:26 AM A-----     349,190,539  HEM_574_5455_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:27 AM A-----     234,223,313  HEM_575_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:34 AM A-----     814,647,785  HEM_575_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:38 AM A-----     465,924,507  HEM_575_5454_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:49 AM A-----   1,510,354,289  HEM_575_5455_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:57 AM A-----     894,341,915  HEM_575_5456_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:44:59 AM A-----     330,453,241  HEM_575_5457_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:06 AM A-----     853,234,147  HEM_575_5458_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:10 AM A-----     450,601,285  HEM_575_5459_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:10 AM A-----      10,610,855  HEM_575_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:13 AM A-----     397,011,199  HEM_576_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:21 AM A-----     987,108,263  HEM_576_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:27 AM A-----     630,032,205  HEM_576_5454_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:28 AM A-----     195,635,693  HEM_576_5455_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:32 AM A-----     393,099,839  HEM_576_5456_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:40 AM A-----     997,356,679  HEM_576_5457_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:45:57 AM A-----   1,961,288,163  HEM_576_5458_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:46:13 AM A-----   1,790,182,755  HEM_576_5459_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:46:22 AM A-----     945,323,861  HEM_576_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:46:25 AM A-----     426,883,803  HEM_577_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:46:32 AM A-----     738,026,881  HEM_577_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:46:39 AM A-----     817,217,063  HEM_577_5454_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:46:46 AM A-----     719,669,873  HEM_577_5455_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:46:50 AM A-----     452,009,939  HEM_577_5456_UTM10_NonGround_SP000-2792_v1.las
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19/12/2016 8:47:26 AM A-----   2,030,028,173  HEM_577_5459_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:47:37 AM A-----   1,232,214,773  HEM_577_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:47:39 AM A-----     249,346,615  HEM_577_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:47:41 AM A-----     198,811,293  HEM_578_5452_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:47:43 AM A-----     209,450,199  HEM_578_5453_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:47:49 AM A-----     741,075,423  HEM_578_5456_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:47:55 AM A-----     648,137,341  HEM_578_5457_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:48:05 AM A-----   1,065,423,897  HEM_578_5458_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:48:20 AM A-----   1,752,895,771  HEM_578_5459_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:48:31 AM A-----   1,325,661,257  HEM_578_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:48:39 AM A-----     860,589,333  HEM_578_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:48:39 AM A-----         358,597  HEM_578_5462_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:48:40 AM A-----     120,171,401  HEM_579_5458_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:48:49 AM A-----     999,747,321  HEM_579_5459_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:03 AM A-----   1,572,211,917  HEM_579_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:13 AM A-----   1,129,063,193  HEM_579_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:16 AM A-----     303,154,471  HEM_579_5462_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:22 AM A-----     729,802,145  HEM_580_5459_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:29 AM A-----     709,322,143  HEM_580_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:34 AM A-----     639,805,811  HEM_580_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:40 AM A-----     609,625,847  HEM_580_5462_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:49 AM A-----   1,049,788,759  HEM_581_5459_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:49:57 AM A-----     846,584,325  HEM_581_5460_UTM10_NonGround_SP000-2792_v1.las
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19/12/2016 8:42:15 AM A-----     159,710,205  HEM_582_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:19 AM A-----     595,568,377  HEM_583_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:21 AM A-----     202,975,511  HEM_583_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:23 AM A-----     390,659,557  HEM_584_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:25 AM A-----     342,858,209  HEM_584_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:26 AM A-----      69,397,229  HEM_585_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:29 AM A-----     582,680,405  HEM_585_5461_UTM10_NonGround_SP000-2792_v1.las
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19/12/2016 8:42:34 AM A-----     714,024,989  HEM_586_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:34 AM A-----      19,591,785  HEM_586_5462_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:36 AM A-----     279,275,285  HEM_587_5458_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:37 AM A-----      65,495,015  HEM_587_5459_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:39 AM A-----     386,928,261  HEM_587_5460_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:40 AM A-----     150,474,887  HEM_587_5461_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:44 AM A-----     603,877,195  HEM_588_5458_UTM10_NonGround_SP000-2792_v1.las
19/12/2016 8:42:53 AM A-----   1,507,790,417  HEM_588_5459_UTM10_NonGround_SP000-2792_v1.las
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                      56,848,622,378  94 Files
Date      Time  Attrib     Bytes       File name
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T:\PROJ-000\000-2792 Hemmera - Harrison River BC\Deliveries\ORTHO
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02/01/2017 11:41:34 AM A-----       1,281,219  HEM_570_5451_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:54 AM A-----         887,344  HEM_570_5452_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:13 AM A-----          36,567  HEM_570_5453_UTM10_10cmRGB_SP000-2792_v1.ecw
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02/01/2017 11:40:58 AM A-----     3,077,863  HEM_571_5452_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:18 AM A-----     1,812,747  HEM_571_5453_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:37 AM A-----       428,616  HEM_571_5454_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:42:08 AM A-----     2,917,962  HEM_572_5449_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:41:03 AM A-----       943,423  HEM_572_5452_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:22 AM A-----     1,164,795  HEM_572_5453_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:42 AM A-----     4,234,206  HEM_572_5454_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:41:54 AM A-----     7,911,012  HEM_573_5450_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:41:07 AM A-----       728,940  HEM_573_5452_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:27 AM A-----       702,429  HEM_573_5453_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:47 AM A-----     7,743,351  HEM_573_5454_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:41:59 AM A-----       635,099  HEM_574_5450_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:41:12 AM A-----       751,926  HEM_574_5452_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:31 AM A-----     1,559,587  HEM_574_5453_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:52 AM A-----     8,149,865  HEM_574_5454_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:16 AM A-----     1,641,742  HEM_574_5455_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:41:16 AM A-----       487,468  HEM_575_5452_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:36 AM A-----     3,271,799  HEM_575_5453_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:58 AM A-----     8,266,759  HEM_575_5454_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:22 AM A-----    10,473,355  HEM_575_5455_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:02 AM A-----     7,631,821  HEM_575_5456_UTM10_10cmRGB_SP000-2792_v1.ecw
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02/01/2017 11:38:15 AM A-----     5,551,957  HEM_575_5458_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:34 AM A-----     3,625,207  HEM_575_5459_UTM10_10cmRGB_SP000-2792_v1.ecw
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02/01/2017 11:40:03 AM A-----     9,488,803  HEM_576_5454_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:28 AM A-----     9,459,366  HEM_576_5455_UTM10_10cmRGB_SP000-2792_v1.ecw
03/01/2017 12:12:52 PM A-----    20,632,779  HEM_576_5456_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:46 AM A-----     8,395,877  HEM_576_5457_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:21 AM A-----     9,709,175  HEM_576_5458_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:40 AM A-----    10,598,875  HEM_576_5459_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:44 AM A-----     5,038,785  HEM_576_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:41:25 AM A-----     1,121,932  HEM_577_5452_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:45 AM A-----     4,280,963  HEM_577_5453_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:09 AM A-----     8,278,527  HEM_577_5454_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:33 AM A-----     7,440,046  HEM_577_5455_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:07 AM A-----     9,057,167  HEM_577_5456_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:51 AM A-----     9,682,265  HEM_577_5457_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:26 AM A-----     8,775,806  HEM_577_5458_UTM10_10cmRGB_SP000-2792_v1.ecw
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02/01/2017 11:41:29 AM A-----       544,289  HEM_578_5452_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:40:49 AM A-----       466,473  HEM_578_5453_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:39:12 AM A-----     7,660,191  HEM_578_5456_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:57 AM A-----    10,238,528  HEM_578_5457_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:31 AM A-----     6,305,520  HEM_578_5458_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:51 AM A-----     9,597,989  HEM_578_5459_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:56 AM A-----    10,323,861  HEM_578_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:35:57 AM A-----     7,222,510  HEM_578_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
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02/01/2017 11:37:01 AM A-----        9,848,754  HEM_579_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:03 AM A-----        9,511,974  HEM_579_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:35:17 AM A-----        2,736,200  HEM_579_5462_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:01 AM A-----        3,674,868  HEM_580_5459_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:06 AM A-----        5,586,482  HEM_580_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:08 AM A-----        6,533,816  HEM_580_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:35:25 AM A-----        5,478,549  HEM_580_5462_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:06 AM A-----        4,166,903  HEM_581_5459_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:11 AM A-----        5,718,094  HEM_581_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:13 AM A-----          122,479  HEM_581_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:35:32 AM A-----        1,585,384  HEM_581_5462_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:38:10 AM A-----        1,855,254  HEM_582_5459_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:16 AM A-----        5,959,303  HEM_582_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:18 AM A-----        1,068,998  HEM_582_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:21 AM A-----        5,563,601  HEM_583_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:24 AM A-----        1,130,085  HEM_583_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:25 AM A-----        3,276,705  HEM_584_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:28 AM A-----        2,753,525  HEM_584_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:37:30 AM A-----          621,448  HEM_585_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:36:34 AM A-----        5,365,609  HEM_585_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:35:40 AM A-----          662,748  HEM_585_5462_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:35:03 AM A-----           33,451  HEM_586_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:35:07 AM A-----        4,279,769  HEM_586_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:35:47 AM A-----          718,739  HEM_586_5462_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:34:31 AM A-----        2,422,914  HEM_587_5458_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:34:44 AM A-----          933,943  HEM_587_5459_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:34:54 AM A-----        3,741,130  HEM_587_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:34:58 AM A-----        1,465,940  HEM_587_5461_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:34:35 AM A-----        3,909,901  HEM_588_5458_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:34:40 AM A-----        9,474,084  HEM_588_5459_UTM10_10cmRGB_SP000-2792_v1.ecw
02/01/2017 11:34:49 AM A-----        3,161,673  HEM_588_5460_UTM10_10cmRGB_SP000-2792_v1.ecw
                            -------------------
                                441,714,763  93 Files
Date      Time   Attrib      Bytes       File name
---------- -------- ------   ----------------  --------

C:\1 JOBS\000-2792
06/02/2017 11:35:33 AM A-----                5  000-2792_HarrisonRiver_Lakes_UTM10_v1.cpg
06/02/2017 11:35:33 AM A-----            2,258  000-2792_HarrisonRiver_Lakes_UTM10_v1.dbf
06/02/2017 11:35:33 AM A-----              425  000-2792_HarrisonRiver_Lakes_UTM10_v1.prj
06/02/2017 11:35:33 AM A-----              852  000-2792_HarrisonRiver_Lakes_UTM10_v1.sbn
06/02/2017 11:35:33 AM A-----              156  000-2792_HarrisonRiver_Lakes_UTM10_v1.sbx
06/02/2017 11:35:33 AM A-----        2,657,904  000-2792_HarrisonRiver_Lakes_UTM10_v1.shp
06/02/2017 11:35:33 AM A-----              676  000-2792_HarrisonRiver_Lakes_UTM10_v1.shx
06/02/2017 11:36:29 AM A-----                5  000-2792_HarrisonRiver_Rivers_UTM10_v1.cpg
06/02/2017 11:36:29 AM A-----            6,548  000-2792_HarrisonRiver_Rivers_UTM10_v1.dbf
06/02/2017 11:36:29 AM A-----              425  000-2792_HarrisonRiver_Rivers_UTM10_v1.prj
06/02/2017 11:36:29 AM A-----            2,196  000-2792_HarrisonRiver_Rivers_UTM10_v1.sbn
06/02/2017 11:36:29 AM A-----              228  000-2792_HarrisonRiver_Rivers_UTM10_v1.sbx
06/02/2017 11:36:29 AM A-----          215,468  000-2792_HarrisonRiver_Rivers_UTM10_v1.shp
06/02/2017 11:36:29 AM A-----            1,820  000-2792_HarrisonRiver_Rivers_UTM10_v1.shx
06/02/2017 2:03:32 PM A-----       204,508,355  000-2792__HarrisonRiver_DEM_UTM10_v1.img
                            -------------------
                                207,397,321  15 Files

Summary of C:\1 JOBS\000-2792
```

| | | |
|---|---|---|
| Directories | = | 1 |
| Files | = | 15 |
| Bytes | = | 207,397,321 |

# APPENDIX C

## Completed Site Cards

7610000593

## SITE CARD

STREAM NAME (gaz.) HR - 11 (local)

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE YY MM DD TIME AGENCY CREW FISH FORM Y ☐ N ☐

| CHANNEL | mthd | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CHANNEL WIDTH (m) | 17.7 | | | | | | | |
| WETTED WIDTH (m) | dry | | | | | | | |
| RES. POOL DEPTH (m) | | | | | | | | |

GRADIENT % MTD

$W_b$ Dp (m) 1.345 MTD

STAGE L M H

No Vis. Ch. ☐ Dry/Int. ☐ DW ☐ Tribs. ☐

EMS MTD REQ # MTD

TEMP °C COND. µS/cm

pH TURB. T M L C

WATER

FLD SNS

BED MATERIAL Dominant Subdom.

D95 (cm) D (cm) Morph.

DISTURBANCE INDICATORS

| beavdam | aban ch | erdbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| 01 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

PATTERN TM ME IM IR SI ST

ISLANDS N O I F S AN

BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

MORPHOLOGY

COVER Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | | | | | | | |
| LOC | | | | | | | |

CROWN CLOSURE

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | > 90% |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |

LWD FNC N F A DIST C E INSTREAM VEG N A M V

LB SHP U V S O RB SHP U V S O

TEXTURE F G C B R A TEXTURE F G C B R A

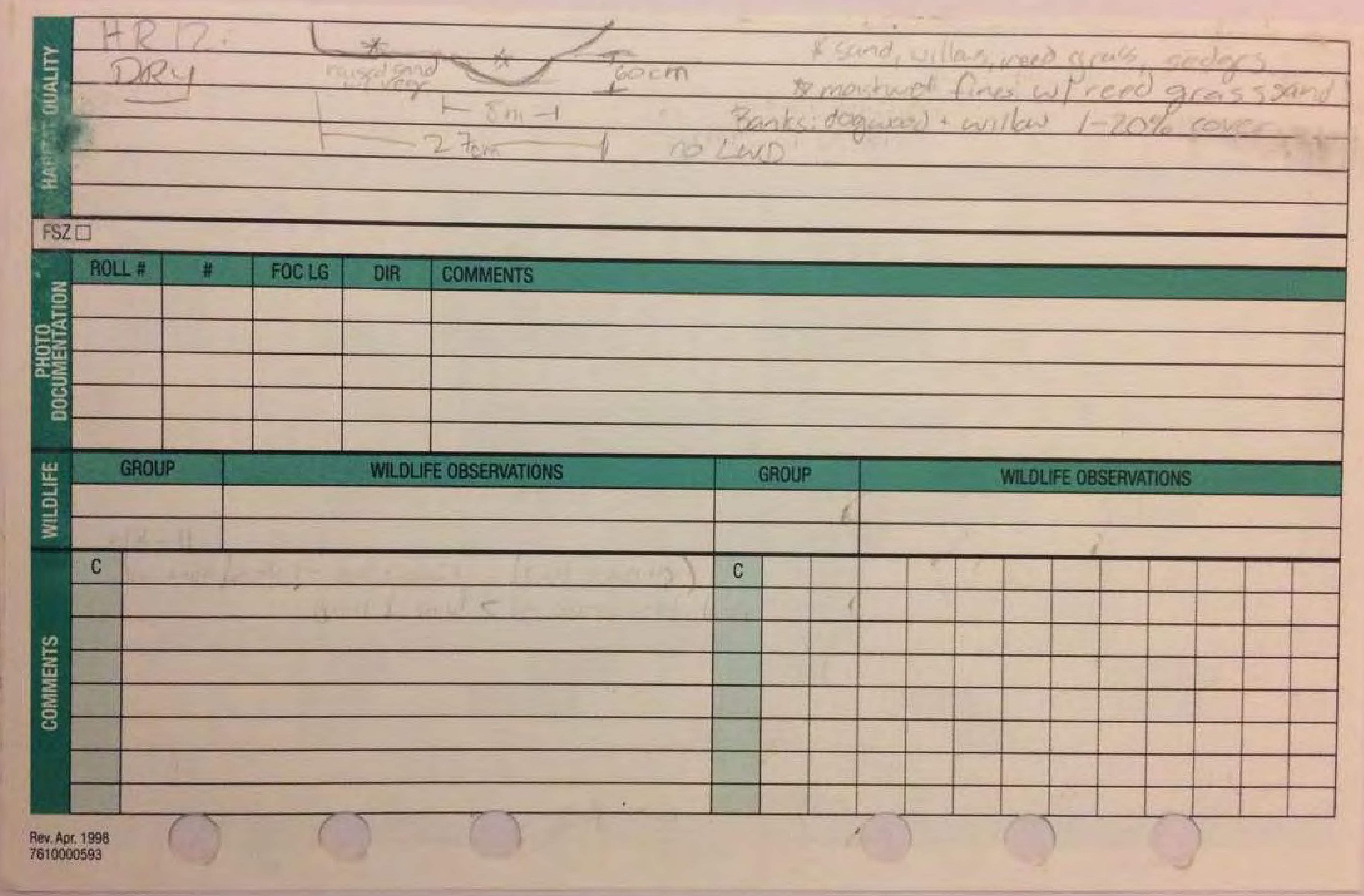
RIP. VEG. N G S C D M W RIP. VEG. N G S C D M

STAGE INIT SHR PS YF MF NA STAGE INIT SHR PS YF MF NA

COVER

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM MTD |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R__ F__ | gravel + sand | |
| | | | | | | R__ F__ | <1m above | |
| | | | | | | R__ F__ | water table | |
| | | | | | | R__ F__ | | |

FEATURES



**HABITAT QUALITY**

HR 12:
DRY

mixed sand w/ veg
60cm
8m
27cm

* sand, willow, reed grass, sedges
* moist-wet fines w/ reed grass sand
Banks: dogwood + willow 1-20% cover
no LWD

FSZ ☐

**PHOTO DOCUMENTATION**

| ROLL # | # | FOC LG | DIR | COMMENTS |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**WILDLIFE**

| GROUP | WILDLIFE OBSERVATIONS | GROUP | WILDLIFE OBSERVATIONS |
|---|---|---|---|
| | | | |
| | | | |

**COMMENTS**

C

C

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**HABITAT QUALITY**

FSZ ☐

**PHOTO DOCUMENTATION**

| ROLL # | # | FOC LG | DIR | COMMENTS |
|---|---|---|---|---|
| | | | | Flow @ "~~A~~B" ~~Mono Creek~~ @ 10m = 0.01 |
| | | | | ~~A~~ B @ 76m = 40% = 0.01 m/sec |
| | | | | 60% = 0.03 ~~m~~ m/sec |
| | | | | |
| | | | | |

**WILDLIFE**

| GROUP | WILDLIFE OBSERVATIONS | GROUP | WILDLIFE OBSERVATIONS |
|---|---|---|---|
| | | | |
| | | | |

**COMMENTS**

| C | |
|---|---|
| | "C" = flow 0.06 |

| C | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

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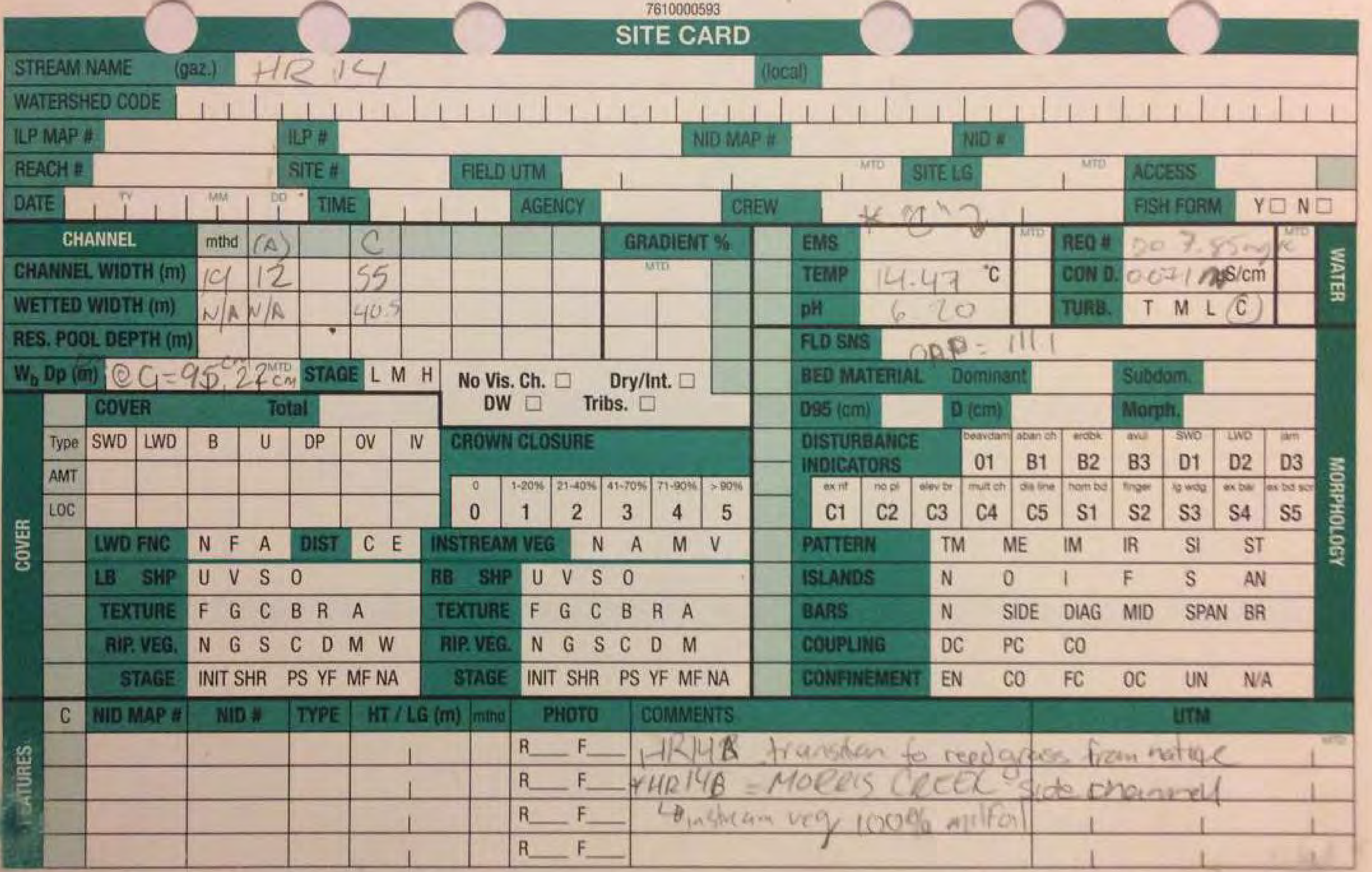


7610000593

## SITE CARD

| | | | |
|---|---|---|---|
| STREAM NAME (gaz.) | HR 14 | (local) | |
| WATERSHED CODE | | | |
| ILP MAP # | | ILP # | |
| NID MAP # | | NID # | |
| REACH # | | SITE # | |
| FIELD UTM | MTD | SITE LG | MTD |
| ACCESS | | | |
| DATE | YY MM DD | TIME | |
| AGENCY | | CREW | *[illegible] |
| FISH FORM | Y ☐ N ☐ | | |

| CHANNEL | mthd | (A) | | C | | | | |
|---|---|---|---|---|---|---|---|---|
| CHANNEL WIDTH (m) | 19 | 12 | | 55 | | | | |
| WETTED WIDTH (m) | N/A | N/A | | 40.5 | | | | |
| RES. POOL DEPTH (m) | | | | | | | | |

GRADIENT % MTD

$W_b$ Dp (m) @G=95.27cm MTD

STAGE L M H

No Vis. Ch. ☐ Dry/Int. ☐ DW ☐ Tribs. ☐

| WATER | | | | | |
|---|---|---|---|---|---|
| EMS | | MTD | REQ # | DO 7.85mgk | MTD |
| TEMP | 14.47 °C | | CON D. | 0.071 mS/cm | |
| pH | 6.20 | | TURB. | T M L [✓ C] | |

FLD SNS ORP = 111.1

| MORPHOLOGY | | | |
|---|---|---|---|
| BED MATERIAL Dominant | | Subdom. | |
| D95 (cm) | | D (cm) | |
| Morph. | | | |

DISTURBANCE INDICATORS

| beavdam | aban ch | erdbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| 01 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| PATTERN | TM | ME | IM | IR | SI | ST |
| ISLANDS | N | O | I | F | S | AN |
| BARS | N | SIDE | DIAG | MID | SPAN | BR |
| COUPLING | DC | PC | CO | | | |
| CONFINEMENT | EN | CO | FC | OC | UN | N/A |

COVER Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | | | | | | | |
| LOC | | | | | | | |

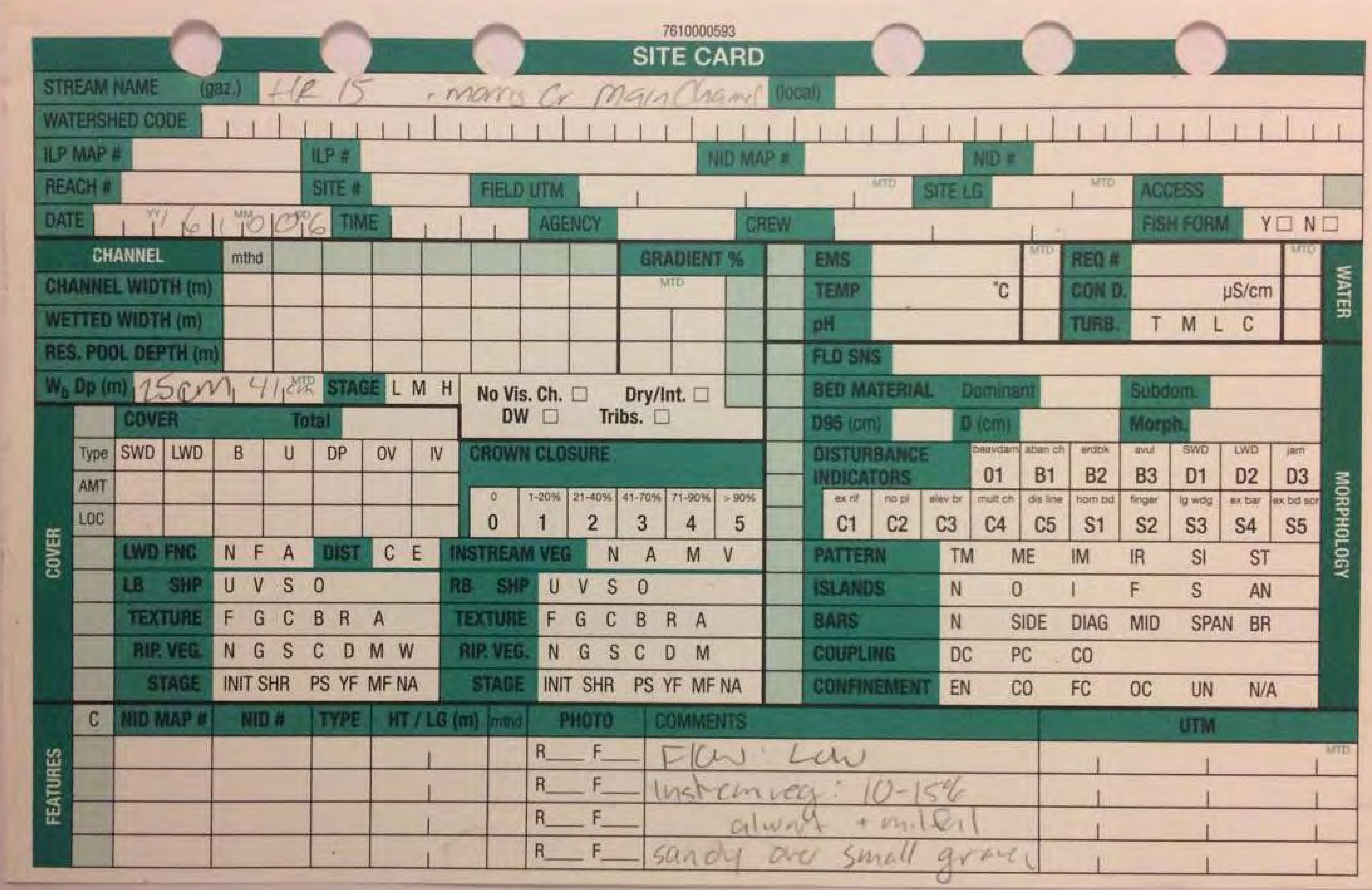
CROWN CLOSURE

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | >90% |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |

| | | | |
|---|---|---|---|
| LWD FNC | N F A | DIST | C E |
| INSTREAM VEG | N A M V | | |
| LB SHP | U V S O | RB SHP | U V S O |
| TEXTURE | F G C B R A | TEXTURE | F G C B R A |
| RIP. VEG. | N G S C D M W | RIP. VEG. | N G S C D M |
| STAGE | INIT SHR PS YF MF NA | STAGE | INIT SHR PS YF MF NA |

FEATURES

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R__ F__ | HR14B transition to reedgrass from native | MTD |
| | | | | | | R__ F__ | *HR14B = MORRIS CREEK side channel | |
| | | | | | | R__ F__ | ↳ instream veg 100% milfoil | |
| | | | | | | R__ F__ | | |



7610000593

# SITE CARD

STREAM NAME (gaz.) HR 15 . Morris Cr MainChannel (local)

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE YY 6 MM 10 DD 06 TIME AGENCY CREW FISH FORM Y ☐ N ☐

| CHANNEL | mthd | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CHANNEL WIDTH (m) | | | | | | | | |
| WETTED WIDTH (m) | | | | | | | | |
| RES. POOL DEPTH (m) | | | | | | | | |

$W_b$ Dp (m) 15cm, 41 MTD cm STAGE L M H

GRADIENT % MTD

No Vis. Ch. ☐ Dry/Int. ☐ DW ☐ Tribs. ☐

| | | | | | |
|---|---|---|---|---|---|
| EMS | | MTD | REQ # | | MTD |
| TEMP | °C | | CON D. | µS/cm | |
| pH | | | TURB. | T M L C | |

WATER

FLD SNS

BED MATERIAL Dominant Subdom.

D95 (cm) D (cm) Morph.

COVER Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | | | | | | | |
| LOC | | | | | | | |

CROWN CLOSURE

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | > 90% |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 |

DISTURBANCE INDICATORS

| beavdam | aban ch | erdbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| O1 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

COVER

LWD FNC N F A DIST C E

INSTREAM VEG N A M V

LB SHP U V S O

TEXTURE F G C B R A

RIP. VEG. N G S C D M W

STAGE INIT SHR PS YF MF NA

RB SHP U V S O

TEXTURE F G C B R A

RIP. VEG. N G S C D M

STAGE INIT SHR PS YF MF NA

MORPHOLOGY

PATTERN TM ME IM IR SI ST

ISLANDS N O I F S AN

BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

FEATURES

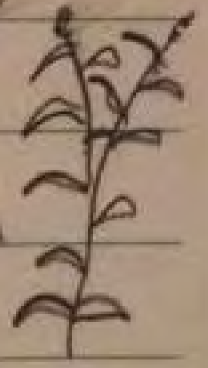
| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R__ F__ | Flow: Low | MTD |
| | | | | | | R__ F__ | Instream veg: 10-15% | |
| | | | | | | R__ F__ | algae + milfoil | |
| | | | | | | R__ F__ | sandy over small gravel | |

Oct 6 /16 Harrison River w/ Jamie Sloggan
by Boat (Frank 604-

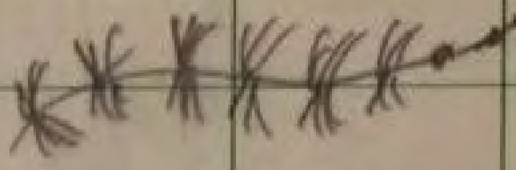
Veg found Oct 5.

Awlwort - subularia aquatica

clasping leaved pondweed - potamogeton
richardsonii



european water milfoil - myriophyllum spicatum
↳ invasive?



Shallows HR_16
Depth : 1056 cm flow 0.06
Quality pH 7.40 Temp 16.37°C
DO 11 mg cond 0.044 ms
LWD - few (1) fine sand over small gravel
instream veg: alwart (5-10%)

HR_16B Depth 97 cm Flow 0.06 m/s
pH : 7.81 Temp: 16.37 DO: 10.8 Conductivity 0.042
veg: 15% alwart patches, clasping pondweed
ORP 146.9

HR 16C   Depth 86cm Flow 0.08 m/s
pH 8.00   Temp 16.40   DO 16.63 Cond. .042
ORP 139   103 DO sat
veg ~~&~~ same as HR 16B

Oct 7th Truck access
HR-18 channel parallel to road.
depth 65cm, 80cm
wet width 5m, low flow
beaver dam @ E end   sediment: fines.
Wood; SWD: mod, LWD: low
cover veg: 1-20%.
- hardhack, willow on N side, & sedge
- sitka spruce on S side
instream veg: lillies + rush
- easy access, difficult to construct

GPS Point: "Clear" heading SW
from beaver dam (H18)

**HABITAT QUALITY**

FSZ ☐

**PHOTO DOCUMENTATION**

| ROLL # | # | FOC LG | DIR | COMMENTS |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**WILDLIFE**

| GROUP | WILDLIFE OBSERVATIONS | GROUP | WILDLIFE OBSERVATIONS |
|---|---|---|---|
| | | | |
| | | | |

**COMMENTS**

C Flagging visible along channel.

C

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## SITE CARD

STREAM NAME (gaz.) HK 17 Dry Creek off road(s) (local)

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE YY MM DD TIME AGENCY CREW FISH FORM Y☐ N☐

**CHANNEL** mthd

CHANNEL WIDTH (m) 9.6

WETTED WIDTH (m)

RES. POOL DEPTH (m)

$W_b$ Dp (m) 35cm MTD STAGE L M H

**GRADIENT %** MTD

No Vis. Ch. ☐ Dry/Int. ☑ DW ☐ Tribs. ☐

**COVER** Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | H | L | | | | | |
| LOC | | | | | | | |

**CROWN CLOSURE**

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | > 90% |
|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | [✓ 4] | 5 |

LWD FNC N F A DIST C E INSTREAM VEG N A M V

| | LB | RB |
|---|---|---|
| SHP | [✓ U] V S O | U V S O |
| TEXTURE | F G C B R A | F G C B R A |
| RIP. VEG. | N G S C D [✓ M] W | N G S C D M |
| STAGE | INIT SHR PS YF [✓ MF] NA | INIT SHR PS YF MF NA |

**WATER**

EMS MTD REQ # MTD

TEMP °C CON D. µS/cm

pH TURB. T M L C

**MORPHOLOGY**

FLD SNS Dom 13cm / 60cm for boulders

BED MATERIAL Dominant Cobble Subdom. gravel/b

D95 (cm) D (cm) Morph.

DISTURBANCE INDICATORS

| beavdam | aban ch | erdbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| 01 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

PATTERN TM ME IM IR SI ST

ISLANDS N O I F S AN

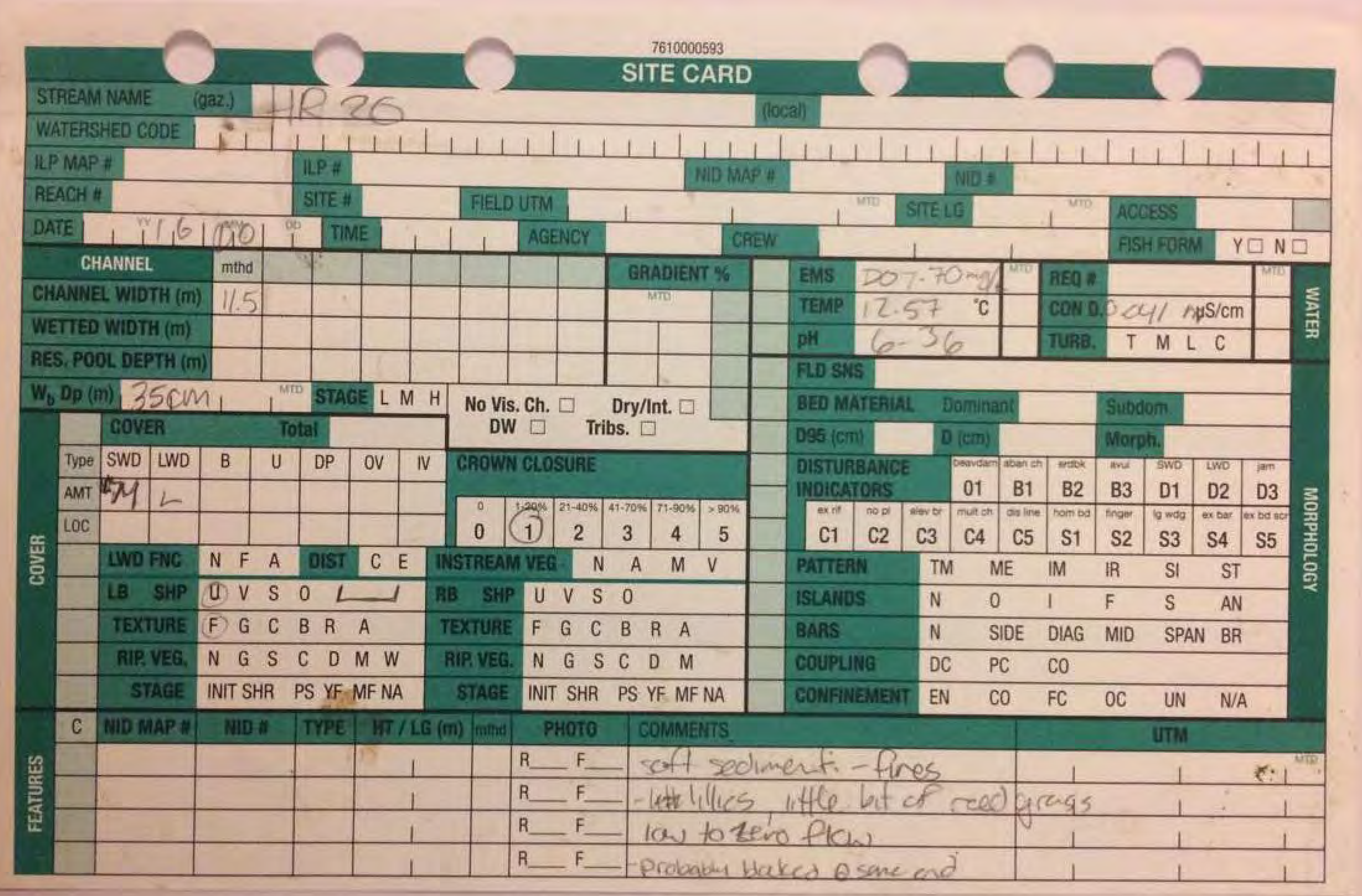
BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

**FEATURES**

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R__ F__ | Dom. substrate: cobble | |
| | | | | | | R__ F__ | veg: cedar, alder, maple | |
| | | | | | | R__ F__ | sword fern understory | |
| | | | | | | R__ F__ | | |



7610000593

## SITE CARD

STREAM NAME (gaz.) HR 26 (local)

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE YY 16 MM 10 DD TIME AGENCY CREW FISH FORM Y ☐ N ☐

| CHANNEL | mthd | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| CHANNEL WIDTH (m) | 11.5 | | | | | | | |
| WETTED WIDTH (m) | | | | | | | | |
| RES. POOL DEPTH (m) | | | | | | | | |

GRADIENT % MTD

$W_b$ Dp (m) 35cm MTD STAGE L M H

No Vis. Ch. ☐ Dry/Int. ☐ DW ☐ Tribs. ☐

**WATER**

| | | | | | |
|---|---|---|---|---|---|
| EMS | D07-70mg/L | MTD | REQ # | | MTD |
| TEMP | 12.57 °C | | CON D. | 0.041 mS/cm | |
| pH | 6-36 | | TURB. | T M L C | |

**COVER**

COVER Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | M | L | | | | | |
| LOC | | | | | | | |

CROWN CLOSURE

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | > 90% |
|---|---|---|---|---|---|
| 0 | [✓ 1] | 2 | 3 | 4 | 5 |

LWD FNC N F A DIST C E INSTREAM VEG N A M V

LB SHP [✓ U] V S O RB SHP U V S O

TEXTURE [✓ F] G C B R A TEXTURE F G C B R A

RIP. VEG. N G S C D M W RIP. VEG. N G S C D M

STAGE INIT SHR PS YF MF NA STAGE INIT SHR PS YF MF NA

**MORPHOLOGY**

FLD SNS

BED MATERIAL Dominant Subdom

D95 (cm) D (cm) Morph.

DISTURBANCE INDICATORS

| beavdam | aban ch | ersbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| 01 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

PATTERN TM ME IM IR SI ST

ISLANDS N O I F S AN

BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

**FEATURES**

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R__ F__ | soft sediment - fines | MTD |
| | | | | | | R__ F__ | - little lillies, little bit of reed grass | |
| | | | | | | R__ F__ | low to zero flow | |
| | | | | | | R__ F__ | - probably blocked @ some end | |

7610000593

## SITE CARD

STREAM NAME (gaz.) HR 20-C (local)

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE YY 16 MM 10 DD 07 TIME AGENCY CREW FISH FORM Y ☐ N ☐

| CHANNEL | mthd | | | | | | |
|---|---|---|---|---|---|---|---|
| CHANNEL WIDTH (m) | 16m | | | | | | |
| WETTED WIDTH (m) | 2.2 | | | | | | |
| RES. POOL DEPTH (m) | | | | | | | |

GRADIENT % MTD

W$_b$ Dp (m) 98cm MTD STAGE L M H

No Vis. Ch. ☐ Dry/Int. ☐ DW ☐ Tribs. ☐

**WATER**

EMS MTD REQ # MTD

TEMP °C CON D. µS/cm

pH TURB. T M L C

COVER Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | H | M-H | | | | | |
| LOC | | | | | | | |

CROWN CLOSURE

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | > 90% |
|---|---|---|---|---|---|
| 0 | 1 | 2 | [✓ 3] | 4 | 5 |

LWD FNC N F A DIST C E

INSTREAM VEG N A M V

LB SHP [✓ U] V S O

RB SHP U V S O

TEXTURE [✓ F] G C B R A organic

TEXTURE F G C B R A

RIP. VEG. N G S C D M W

RIP. VEG. N G S C D M

STAGE INIT SHR PS YF MF NA

STAGE INIT SHR PS YF MF NA

**MORPHOLOGY**

FLD SNS

BED MATERIAL Dominant Subdom.

D95 (cm) D (cm) Morph.

DISTURBANCE INDICATORS

| beavdam | aban ch | erdbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| 01 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

PATTERN TM ME IM IR SI ST

ISLANDS N O I F S AN

BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

**FEATURES**

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM MTD |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R__ F__ | cover: cedar, alder, maple, spruce | |
| | *ground water pond | | | | | R__ F__ | Flow Ø | |
| | ↳ dog pit | | | | | R__ F__ | veg: duckweed | |
| | | | | | | R__ F__ | reed grass | |

7610000593

# SITE CARD

STREAM NAME (gaz.) 29 HR-24B (local) CONNOR CREEK

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE 2016 MM 10 DD 07 TIME AGENCY CREW TR, TS FISH FORM Y ☐ N ☐

| CHANNEL | mthd | | | | | | |
|---|---|---|---|---|---|---|---|
| CHANNEL WIDTH (m) | 22m | | | | | | |
| WETTED WIDTH (m) | 22m | | | | | | |
| RES. POOL DEPTH (m) | | | | | | | |

W<sub></sub>b Dp (m) 1m MTD STAGE L M H

GRADIENT % MTD

No Vis. Ch. ☐ Dry/Int. ☐ DW ☐ Tribs. ☐

EMS MTD REQ # DO 6.25 MTD

TEMP 11.82 °C CON D. .062 µS/cm

pH 6.50 TURB. T M L [✓ C]

FLD SNS tea colored water

BED MATERIAL Dominant Be Subdom.

D95 (cm) D (cm) Morph.

COVER Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | H | H | | | | | |
| LOC | | | | | | | |

CROWN CLOSURE

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | > 90% |
|---|---|---|---|---|---|
| 0 | 1 | 2 | [✓ 3] | 4 | 5 |

DISTURBANCE INDICATORS

| beavdam | aban ch | erdbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| 01 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

LWD FNC N F A DIST C E

INSTREAM VEG N A M V

LB SHP [✓ U] V S O

RB SHP U V S O

TEXTURE F G C B R A

TEXTURE F G C B R A

RIP. VEG. N G S C D M W

RIP. VEG. N G S C D M

STAGE INIT SHR PS YF [✓ MF] NA

STAGE INIT SHR PS YF MF NA

PATTERN TM ME IM IR SI ST

ISLANDS N O I F S AN

BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

WATER

MORPHOLOGY

COVER

FEATURES

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM MTD |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R__ F__ | canopy cover - w alder + slough sedge | |
| | | | | | | R__ F__ | sitka spruce | |
| | | | | | | R__ F__ | no flow (beaver dams below + above) | |
| | | | | | | R__ F__ | instream: sedge, hardhack, native grass | |

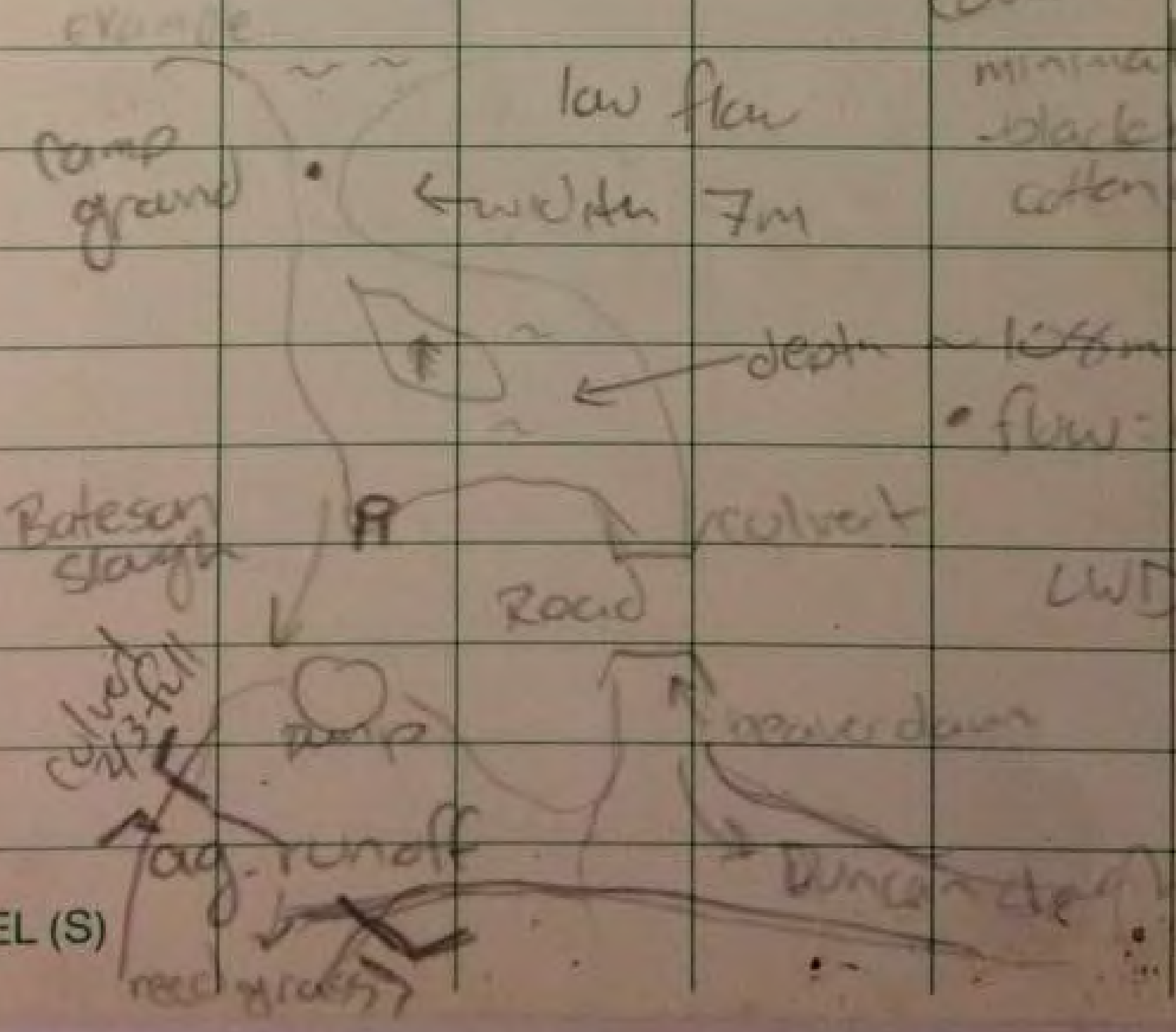
Oct 5/16 Harrison River w/ Jaimie Slogan 778 985 6984
by boat

GoPro - start @ HR mouth
-GPS track "HR V01"
↳ end waypoint "215"

Oct - low water

Map 3 - sediment sample/picture
-sand w/ some gravel 1piece bigger-ish cobble
↳ 1piece veg

STOP. HR 01 "Duncan Slough"
-Scowlitz F.N. RV Park - channel
-low H2O ~~q~~ quality, turbid
↳ erod/erosion
-sandy substrate
-culvert/pump station/dam
↳ fish barrier



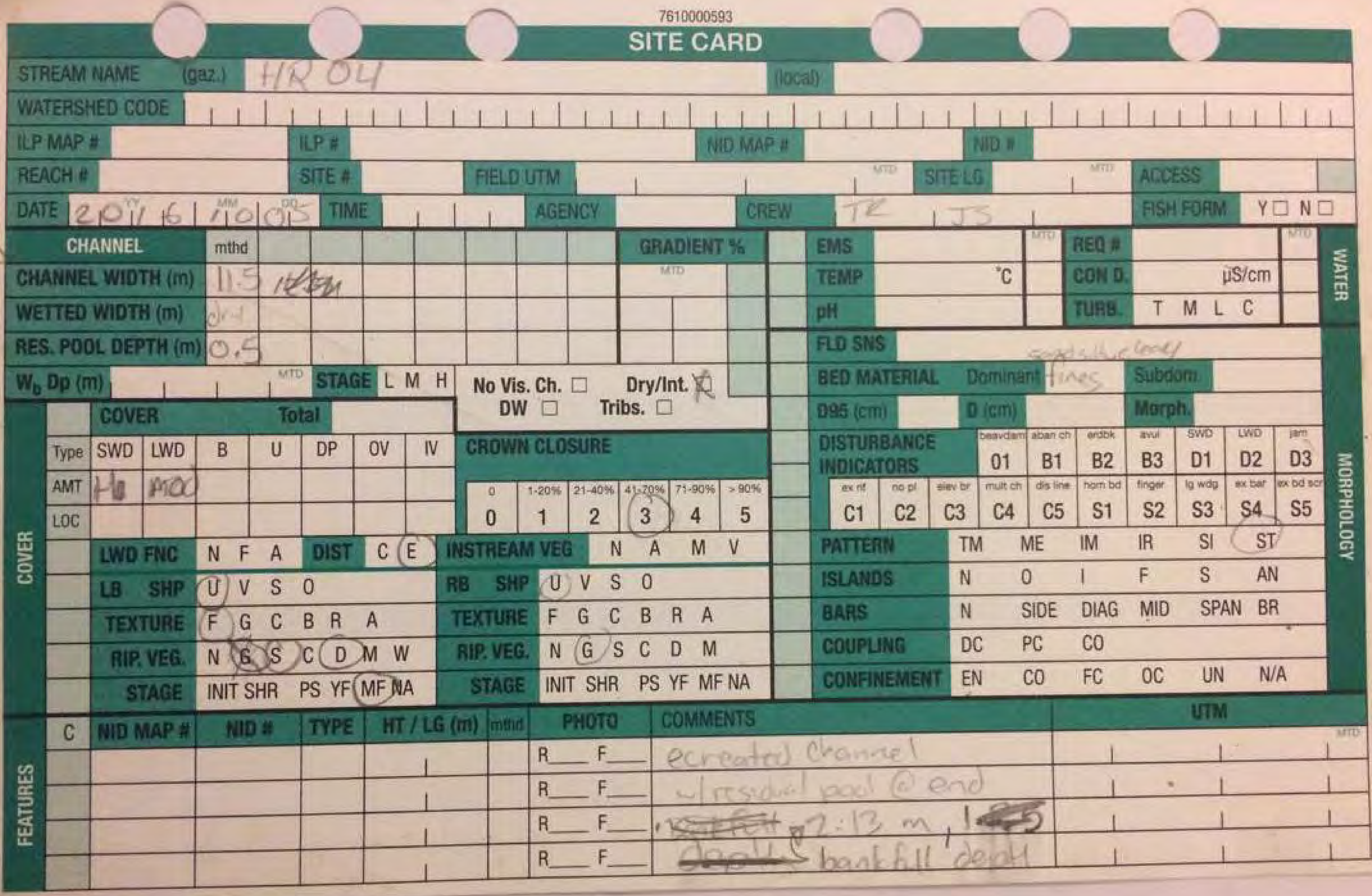
low flow
← width 7m
depth ~ 105m
cover:
minimal
-blackberry,
cottonwood
• flow: 0.01
LWD <1

HR-02 dry channel w raised 1m high ridge
upstream
~~right~~ N of Harrison Bridge
width: 2.96m
depth: 55cm
veg: sedge (water), row of cottonwoods
dogwood, alder, blackberry on slope
-comes out onto small stagnant slough
↳ may be fish trap right now
-approx 10 x 30m

HR-03 downstream side of Harrison Bridge
-back channel parallel to river -sedge
-& doored culvert → agri runoff? watermain?

HR-04 basically same as HR-03
-closer to bridge -culvert door
-mainly reed grass w/ cottonwood
-ends in stagnant pool ~ 20m wide
-KW -

HR-05 d.s. of train bridge
-long all the way to train tracks
-wildlife: Heron, frog x3



7610000593

## SITE CARD

STREAM NAME (gaz.) HR 04 (local)

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE YY 2011 MM 6 / 10 DD 05 TIME AGENCY CREW TR JS FISH FORM Y ☐ N ☐

dry

| CHANNEL | mthd | | | | | | |
|---|---|---|---|---|---|---|---|
| CHANNEL WIDTH (m) | 11.5 ~~[illegible]~~ | | | | | | |
| WETTED WIDTH (m) | dry | | | | | | |
| RES. POOL DEPTH (m) | 0.5 | | | | | | |

GRADIENT % MTD

$W_b$ Dp (m) MTD STAGE L M H

No Vis. Ch. ☐ Dry/Int. ☒ DW ☐ Tribs. ☐

EMS MTD REQ # MTD

TEMP °C CON D. µS/cm

pH TURB. T M L C

WATER

FLD SNS sand/silt/clay

BED MATERIAL Dominant fines Subdom.

D95 (cm) D (cm) Morph.

| DISTURBANCE INDICATORS | beavdam 01 | aban ch B1 | erdbk B2 | avul B3 | SWD D1 | LWD D2 | jam D3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ex rif C1 | no pl C2 | elev br C3 | mult ch C4 | dis line C5 | hom bd S1 | finger S2 | lg wdg S3 | ex bar S4 | ex bd scr S5 |

PATTERN TM ME IM IR SI [✓ ST]

ISLANDS N O I F S AN

BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

MORPHOLOGY

COVER

| COVER | | | | | | | Total |
|---|---|---|---|---|---|---|---|
| Type | SWD | LWD | B | U | DP | OV | IV |
| AMT | H | mod | | | | | |
| LOC | | | | | | | |

LWD FNC N F A DIST C [✓ E]

LB SHP [✓ U] V S O

TEXTURE [✓ F] G C B R A

RIP. VEG. N [✓ G] [✓ S] C [✓ D] M W

STAGE INIT SHR PS YF [✓ MF] NA

CROWN CLOSURE 0: 0 · 1-20%: 1 · 21-40%: 2 · [✓ 41-70%: 3] · 71-90%: 4 · >90%: 5

INSTREAM VEG N A M V

RB SHP [✓ U] V S O

TEXTURE F G C B R A

RIP. VEG. N [✓ G] S C D M

STAGE INIT SHR PS YF MF NA

FEATURES

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM MTD |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R___ F___ | ecreated channel | |
| | | | | | | R___ F___ | w/ residual pool @ end | |
| | | | | | | R___ F___ | , ~~[illegible]~~ 2:13 m, 1~~[illegible]~~ | |
| | | | | | | R___ F___ | ~~depth~~ bankfull depth | |

**HABITAT QUALITY**

FSZ ☐

**PHOTO DOCUMENTATION**

| ROLL # | # | FOC LG | DIR | COMMENTS |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**WILDLIFE**

| GROUP | WILDLIFE OBSERVATIONS | GROUP | WILDLIFE OBSERVATIONS |
|---|---|---|---|
| | | | |
| | | | |

**COMMENTS**

C May need structure to deflect/protect from woody debris accumulation

Wildlife: Heron
- unidentified frog x3

C

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## SITE CARD

STREAM NAME (gaz.) HR05 (local)

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE 2016/10/05 TIME AGENCY CREW TR, JS FISH FORM Y ☐ N ☐

**CHANNEL** mthd

CHANNEL WIDTH (m) 1.4 1.25 1.2

WETTED WIDTH (m) dry

RES. POOL DEPTH (m)

$W_b$ Dp (m) MTD STAGE L M H

GRADIENT % MTD

No Vis. Ch. ☐ Dry/Int. ☒

DW ☐ Tribs. ☐

EMS MTD REQ # MTD

TEMP °C CON D. µS/cm

pH TURB. T M L C

FLD SNS

BED MATERIAL Dominant Subdom.

D95 (cm) D (cm) Morph.

**WATER**

**COVER**

COVER Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | | | | | | | |
| LOC | | | | | | | |

CROWN CLOSURE

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | > 90% |
|---|---|---|---|---|---|
| 0 | 1 | 2 | [✓ 3] | 4 | 5 |

LWD FNC N [✓ F] A DIST [✓ C] E

INSTREAM VEG N A M V

LB SHP [✓ U] V S O

RB SHP U V S O

TEXTURE [✓ F] G C B R A

TEXTURE F G C B R A

RIP. VEG. N [✓ G] [✓ S] C [✓ D] M W

RIP. VEG. N G S C D M

STAGE INIT SHR PS YF [✓ MF] NA

STAGE INIT SHR PS YF MF NA

**MORPHOLOGY**

DISTURBANCE INDICATORS

| beavdam | aban ch | erdbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| 01 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

PATTERN TM ME IM IR SI [✓ ST]

ISLANDS N O I F S AN

BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

**FEATURES**

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM MTD |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R height F | Bankfull = 1.2 m, 1.25, 1.22 m | |
| | | | | | | R___ F___ | High accum of LWD in 1/3 of channel | |
| | | | | | | R___ F___ | excavated channel w/ reed grass upstream | |
| | | | | | | R___ F___ | -rush & sedge @ confluence | |

**HABITAT QUALITY**

Water Quality : 12.06 °C DO 6.8mg
pH 5.26 Turbid 0.27 ms

veg dominated by reed grass
willow + hardhack + dogwood)

FSZ ☐

**PHOTO DOCUMENTATION**

| ROLL # | # | FOC LG | DIR | COMMENTS |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

**WILDLIFE**

| GROUP | WILDLIFE OBSERVATIONS | GROUP | WILDLIFE OBSERVATIONS |
|---|---|---|---|
| | muskrat/beaver prints | | |
| | golden/bald eagle | | |

**COMMENTS**

C

eroding banks
in flood plain

chum at bottom of channel (adults)
-stickleback below

C

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## SITE CARD

STREAM NAME (gaz.) HR-10 (local)

WATERSHED CODE

ILP MAP # ILP # NID MAP # NID #

REACH # SITE # FIELD UTM MTD SITE LG MTD ACCESS

DATE 2016 | 10 | 06 TIME AGENCY CREW TR | JS FISH FORM Y ☐ N ☐

| CHANNEL | mthd | | | | | | |
|---|---|---|---|---|---|---|---|
| CHANNEL WIDTH (m) | 22.8 | | | | | | |
| WETTED WIDTH (m) | 20.7 | | | | | | |
| RES. POOL DEPTH (m) | | | | | | | |

$W_b$ Dp (m) 1.09 1.20 MTD STAGE L M H

GRADIENT % MTD

No Vis. Ch. ☐ Dry/Int. ☐ DW ☐ Tribs. ☐

EMS MTD REQ # MTD

TEMP °C CON D. µS/cm

pH TURB. T M L C

**WATER**

FLD SNS @ 14m ¥

BED MATERIAL Dominant 6cm B Subdom. Fines

D95 (cm) D (cm) Morph.

**COVER**

COVER Total

| Type | SWD | LWD | B | U | DP | OV | IV |
|---|---|---|---|---|---|---|---|
| AMT | L | L | | | | | |
| LOC | | | | | | | |

CROWN CLOSURE

| 0 | 1-20% | 21-40% | 41-70% | 71-90% | > 90% |
|---|---|---|---|---|---|
| 0 | [✓ 1] | 2 | 3 | 4 | 5 |

DISTURBANCE INDICATORS

| beavdam | aban ch | erdbk | avul | SWD | LWD | jam |
|---|---|---|---|---|---|---|
| 01 | B1 | B2 | B3 | D1 | D2 | D3 |

| ex rif | no pl | elev br | mult ch | dis line | hom bd | finger | lg wdg | ex bar | ex bd scr |
|---|---|---|---|---|---|---|---|---|---|
| C1 | C2 | C3 | C4 | C5 | S1 | S2 | S3 | S4 | S5 |

LWD FNC N F A DIST C E INSTREAM VEG N A M V

LB SHP U V S O RB SHP U V S O

TEXTURE F G C B R A TEXTURE F G C B R A

RIP. VEG. N [✓ G] [✓ S] C D M W RIP. VEG. N G S C D M

STAGE INIT SHR PS YF MF NA STAGE INIT SHR PS YF MF NA

PATTERN TM ME IM IR SI ST

ISLANDS N O I F S AN

BARS N SIDE DIAG MID SPAN BR

COUPLING DC PC CO

CONFINEMENT EN CO FC OC UN N/A

**MORPHOLOGY**

**FEATURES**

| C | NID MAP # | NID # | TYPE | HT / LG (m) | mthd | PHOTO | COMMENTS | UTM MTD |
|---|---|---|---|---|---|---|---|---|
| | | | | | | R___ F___ | Flow V, @7m = 0.00 D=42cm | |
| | | | | | | R___ F___ | V2 @14m = 0.02 D=44 cm | |
| | | | | | | R___ F___ | | |
| | | | | | | R___ F___ | instream veg ≈ 30% milfoil | |

# APPENDIX D

## Photo Log for the Top 20 Sites

**Photo 1:** Bateson Slough North. Facing North with a view of the de-watered channel choked with vegetation. Photo taken October 27, 2016.

**Photo 2:** Bateson Slough North. Facing South with view of culvert that connects to Bateson Slough South under Lougheed Highway. Photo taken October 27, 2016.

**Photo 3:** Bateson Slough South. Facing North with view of the de-watered channel choked with vegetation. Photo taken October 27, 2016.

**Photo 4:** East Sq'éwlets Slough. Facing South with a view of the de-watered, entrenched channel leading to a culvert with mesh screen that runs under a dike to the Fraser River. Photo taken October 27, 2016.

**Photo 5:** East Sq'éwlets Slough. Facing North with view of de-watered channel between the existing pond and culvert to the Fraser River. Photo taken October 27, 2016.

**Photo 6:** East Sq'éwlets Slough. Facing North with view of the existing pond. Photo taken October 27, 2016.

**Photo 7:** Harrison Mills North Option_1. Facing south with view of the existing channel that lacks instream complexity and riparian vegetation. Photo taken October 27, 2016.

**Photo 8:** Harrison Mills North_Option 1. Facing south with view of the accreted channel connecting to the Mtn. Woodside channel. Photo taken October 27, 2016.

**Photo 9:** Hatchery Flats Channel. Standing at the Chehalis River facing West with view of the accreted and isolated channel. Photo taken October 27, 2016.

**Photo 10:** Hatchery Flats Channel. Standing at the hatchery channel facing east with view of accreted and isolated channel. Photo taken October 27, 2016.

**Photo 11:** Lower Chehalis Side-channel. Facing North-East with view of the de-watered channel choked with vegetation. Photo taken October 5, 2016.

**Photo 12:** Lower Connor Creek. Facing west with a view of beaver dams. Photo taken October 28, 2016.

**Photo 13:** Morris Creek. Facing east with view of the aquatic vegetation and accreted channel. Photo taken October 5, 2016.

**Photo 14:** Morris Creek Side-channel. Facing North with view of the de-watered channel. Photo taken October 5, 2016.

**Photo 15:** Unnamed Slough. Facing north with a view of the encroaching instream vegetation. Photo taken October 25, 2016.

**Photo 16:** Upper Chehalis Side-channel. Facing south with a view of de-watered channel. Photo taken October 25, 2016.

**Photo 17:** Upper Connor Creek. Facing east with view of wetland and encroaching reed canary grass. Photo taken October 7, 2016.

**Photo 18:** West Sq'éwlets Slough. Facing North with view of existing pond from the dike. Photo taken October 28, 2016.

**Photo 19:** West Sq'éwlets Slough. Facing South with view of culvert that runs under the dike to the Fraser River. Photo taken October 28, 2016.