INSTREAM FISHERIES RESEARCH INC.

Gates Creek Level 2 Fish and Riparian Habitat Survey (COA-F18- F-2438)

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Summary

In 2015, a Level 1 Fish Habitat survey (FHAP) was conducted on the entire length of Gates Creek, a tributary of the Seton-Anderson Watershed. The purpose of the FHAP was to assess the quantity and quality of fish habitat in Gates Creek. FHAP surveys also identify “disturbances” that pose risks to fish habitat. Through the FHAP, pool habitat, off-channel habitat, and large woody debris (LWD) were determined to be limited in Gates Creek.

In the fall of 2017, a Level 2 FHAP was conducted on Gates Creek. In the Level 2 FHAP, prescriptions are developed to improve, create, enhance, or protect fish habitat at specific sites. Restoring ecosystem processes such as watershed connectivity (fish access), sedimentation, water quality, flood plain connectivity or riparian plant communities may also be addressed in prescription development. This project addresses the priority action 13 “BRG.RLR.RI.13.01 Assess the feasibility for creation of off-channel or side channel habitat-P1” in the Bridge-Seton Action Plan (FWCP 2017).

For Gates Creek, the survey team developed a set of habitat restoration prescriptions to create or enhance fish and riparian habitat. As the majority of Gates Creek flows through private land, sites were selected based on a combination of findings of the Level 1 FHAP and the potential for landowner co-operation in restoration. Specifically, sites were selected if habitat deficiencies (*e.g.,* lack of instream or overstream cover, sedimentation issues, bank erosion, poor fish access, or lack of connection to natural flood plain) were identified.

A concern for at least two potential restoration sites was the presence of reed canary grass (*Phalaris arundinacea*). Reed canary grass forms a monoculture of dense grass mats, preventing the establishment of a native riparian plant community. The removal of grasses and replanting of riparian vegetation is suggested for these sites. In addition, historical agricultural practices across much of the valley have contributed to a reduction in bank stability, instream cover, and pool habitat for juvenile salmonid rearing. Riparian planting can help to improve bank stabilization. Placement of LWD habitat structures is recommended to increase instream cover for species such as Bull Trout and Coho Salmon. Two properties, owned by the Fish & Wildlife compensation program, offer opportunities for construction of off-channel fish accessible wetland habitat to increase the abundance of rearing habitat for salmonids.

Acknowledgements

We are grateful for the funding support of the Fish & Wildlife Compensation Program and Aboriginal Fund for Species at Risk (AFSAR). We also thank N’Quatqua Fisheries, Lillooet Tribal Council, St’at’imc Eco-Resources, and Dave Polster for their knowledge and co-operation in the project.

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1.0 Introduction

1.1 Background

Gates Creek is an important salmon and trout bearing stream on the south coast of British Columbia. The watershed is located in the traditional territory of the N'Quatqua First Nation. Gates Creek is part of the Seton-Anderson Watershed a tributary of the Fraser River (Figure 1).

Fish habitat in Gates Creek has been degraded by multiple land use activities (*i.e.* logging, agriculture, rail and road development) beginning in the early 1900's. Migratory fish, such as Pacific salmon and Bull Trout, have also been affected by hydro-electric developments on the Seton and Fraser Rivers and the slides at Hell's Gates in the early 1900's (Talbot 1950; Andrew and Green 1958).

An artificial spawning channel was built for Sockeye Salmon adjacent to Gates Creek near D'Arcy to compensate for impacts to Sockeye Salmon incurred from the building of the Seton Dam and Hell's Gate slides (Figure 1). The spawning channel has been in operation since its construction in 1965. The channel was originally built by the International Pacific Salmon Fisheries Commission (later re-named the International Pacific Salmon Commission) and operated in collaboration with the Department of Fisheries and Ocean (DFO). Since 1981 the channel has been operated by the N'Quatqua First Nation Fisheries Department (N'Quatqua Fisheries) in partnership with DFO.

Due to the economic and social importance of the Gates Creek Sockeye Salmon population, significant investments have been made in monitoring the Sockeye Salmon population in the Seton-Anderson watershed by DFO and BC Hydro. Most recently, a five-year study estimated Sockeye Salmon egg to fry survival and juvenile abundance in Gates Creek and the spawning channel (Lingard et al., 2016). The DFO has also monitored Sockeye Salmon spawner abundance annually since the 1930's (DFO unpublished data). BC Hydro currently implements multiple Sockeye Salmon monitors as part of the Bridge River Water Use Plan (BC Hydro 2011). Adult Sockeye Salmon passage at the Seton Dam as well as post passage mortality are monitored under BRGMON-14 (Effectiveness of Cayoosh Flow Dilution, Dam Operation, and Fishway Passage on Delay and Survival of Upstream Migration of Salmon in the Seton-Anderson Watershed). Sockeye Salmon smolt abundance in the Seton River and entrainment rates though the Seton generating station are monitored under BRGMON-13 (Seton River Sockeye Smolt Monitoring).

Data regarding habitat use and population status of other salmonid species, such as Coho Salmon and Bull Trout, in Gates Creek are limited compared to Sockeye Salmon. In 2012, late summer and fall habitat use by Coho Salmon juveniles in Gates Creek and D'Arcy Creek was assessed using minnow trapping (Hillaby et al., 2012). In 2016, a pilot study was implemented to evaluate habitat use and densities of juvenile Coho Salmon, Bull Trout and Rainbow Trout using open site electro-fishing (Lingard et al., 2016). However, both these studies provided only a single year of data regarding juvenile salmonid behaviour and abundance in Gates Creek and represent only a snap shot of the condition of these populations in the watershed. Longer term (5-10 years) studies are required to assess the factors limiting individual species within a watershed (Korman et al., 1997).

Although data is limited regarding Bull Trout and Coho Salmon in the Gates Creek watershed, they are of high interest for enhancement through habitat restoration by the Fish & Wildlife Compensation program (FWCP 2017). Bull Trout and interior Coho Salmon are important species to aquatic environments and both are of conservation concern in British Columbia. Bull Trout are listed as "of special concern" by the Province of British Columbia and the Committee on the Status of Endangered Wildlife in Canada

(COSEWIC) (COSEWIC 2012). Interior Fraser Coho are listed as threatened by COSEWIC (COSEWIC 2016).

Bull Trout are considered to be especially sensitive to the expected effects of climate change in Pacific Northwest watersheds due to their long-life span, low densities, and preference for cold water (>15°C) (Baxter and McPhail 1996; Reiman et al., 2007). Adult fluvial Bull Trout are documented to spawn in high gradient tributaries of large watersheds with groundwater or hyporheic upwelling (Bean et al., 2015). Juvenile Bull Trout prefer habitats with instream cover (*i.e.* boulder, cobble, wood, cut banks) for rearing (Baxter and McPhail 1996). Pool habitat with cover is favored by multiple life stages of fluvial Bull Trout (Baxter and McPhail 1996).

Habitat loss and degradation from human land use, such as logging and agriculture, are listed as major threats to the interior Fraser River Coho Salmon population (COSEWIC 2016). Coho Salmon juveniles typically spend one-year rearing in stream environments prior to their seaward migration and prefer slow water habitats with ample cover (Sandercock 1991). Juvenile Coho Salmon are often found in off-channel sloughs and ponds in winter (Nickelson et al., 1992). Adult salmon return to watersheds to spawn between October and February.

Habitat for rearing juvenile salmon and resident trout species, such as pools and large woody debris, have been identified as limited in Gates Creek through multiple habitat assessments (Creekside Resources 2001; Hillaby 2012; Lingard et al., 2015). Functional large woody debris (LWD) is particularly important to both Coho Salmon and Bull Trout due to its ability to encourage pool formation through scour as well as provide instream cover (Carlson et al., 1990; Cederholm et al., 1997; Rich et al., 2003). Riparian vegetation and stream shading are also limited in some areas of Gates Creek due to removal of native vegetation and planting of agricultural grasses and lawns. The importance of riparian vegetation to freshwater ecosystems and salmonid populations is well documented and services provided include: stream shading, nutrient input, and channel stabilization (Sweeny et al., 2004; Baker et al., 2006; Broadmeadow et al., 2010).

1.3 Habitat Restoration Principles and Process

Ecosystems and habitats can become degraded directly from human activities such as logging or farming. Human activities that cause major disturbances on the landscape can cause a cascade of indirect effects that inhibit an ecosystems natural processes and, therefore, its ability to naturally recover to its previous state. These stressors result in drastically altered habitats. Habitat restoration is the process of returning an ecosystem to a previous functional state through the removal of stressors and the restoration of ecological process that have been damaged or lost (Apfelbaum and Haney 2009).

In riverine habitats stressors can include: altered patterns of sedimentation and nutrient input from human land use and development (Ward et al., 2009), simplified aquatic and riparian habitat (Ralph et al., 1994), or decreased water quality (Nearbonne and Vonderacek 2001).

Two common approaches to restoration of salmon habitat and populations are undertaken in the Pacific Northwest. Limiting factor analysis is a bottom up approach that uses studies such as the Level 1 FHAP to identify habitat features that are in short supply in watersheds. This approach typically focuses on site specific conditions and a “build it and they will come” ideology. Process-based restoration is a top down approach that focuses on restoring ecosystem functions. In stream restoration for salmon, process-based restoration can include addressing: sedimentation, re-connecting flood plains, riparian ecosystem functions, water quality, or hydrology patterns (Booth et al., 2016). In freshwater ecosystems in British

Columbia the general process of habitat restoration using the limiting factor approach consists of four steps:

1- A Level 1 Fish Habitat Survey (FHAP) the objective of which is to assess the quantity and quality of fish habitat, as well as identify stressors or disturbances to fish habitat.
2- Review of Level 1 FHAP to identify sites with specific deficiencies.
3- Level 2 FHAP field visits to identify sites, map and evaluate the potential to remove or mitigate stressors.
4- Development of prescriptions to address site specific stressors or deficiencies.

Prescriptions are site specific plans that may entail: removing stressors (*e.g.,* chemical pollutants, erosion, refuse, or invasive species), creating new habitat (*e.g.,* off-channel habitat, side channels, wetlands, spawning channels), improving access to existing habitat, or enhancing existing habitat (*e.g.,* wood structures, or replacing substrate).

The focus of this Level 2 Fish Habitat Survey was to develop prescriptions which remove or mitigate the effects of stressors in Gates Creek to enhance or create rearing habitat for both Coho Salmon and Bull Trout. Stressors were identified in the Level 1 FHAP completed in 2015 and include: limited pool habitat, degraded riparian habitat, lack of functional large woody debris. However, the prescriptions are expected to benefit multiple species of fish as well as other taxa including birds, invertebrates, amphibians and terrestrial mammals through restoration of riparian and aquatic ecosystem processes. Identification of areas for building new off-channel habitat protected from extreme flood was also an important focus of this survey.

1.4 Goals and Objectives

Goals for this Level 2 FHAP include development of habitat prescriptions as a baseline to build future proposals for restoration projects in Gates Creek. Specific to FWCP, this project will address priority action BRG.RLR.RI.13.01(Assess the feasibility for creation of off channel or side channel habitat-P1) in the Bridge-Seton Action Plan. The results of this survey will provide the information needed to develop proposals for Priority Action BRG.RLR.HB.17.04(Implement habitat restoration protective measures Anderson Lake &tributaries including Gates Creek-P1), also in the Bridge- Seton Action Plan.

2.0 Methods

2.1 Study Area

Gates Creek is a major salmon-bearing tributary of the Seton-Anderson watershed that extends 17 km from Gates Lake to Anderson Lake and drains approximately 345 km^2 (Komori 1997) (Figure 1). The Seton-Anderson watershed is located approximately 200 km north of Vancouver in the rain shadow of the southern Coast Mountains. No glaciers are present in the watershed; however, Gates and Anderson Lakes provide storage. Anderson Lake is connected to Seton Lake via Portage Creek, and Seton Lake drains into the Fraser River via Seton River (Figure 1). Gates Creek supports seven species of salmonids: Sockeye Salmon, Coho Salmon, and Pink Salmon, Rainbow Trout, Bull Trout, Dolly Varden (*Salvelinus malma*), and Mountain White Fish (*Proposium williamsoni*).

The upper most reach of Gates Creek leaving Gates Lake is characterized as a small 3rd order stream with high habitat heterogeneity and mature riparian habitat. Average bankfull channel width and gradient for this reach are 8.8 m and 1.4%, respectively (Lingard et al., 2015).

The section of Gates Creek between Eight Mile Creek and Spruce Creek flows entirely through private land. This middle section of Gates Creek downstream of the confluence of Eight Mile Creeks has an average gradient of 0.3% and average bankfull width of 10.1 m (Lingard et al., 2015). The majority of habitat in this reach is glide with fine substrate. The riparian habitat in this region has been extensively altered for agricultural and residential land use.

Gates Creek, downstream of the confluence of Spruce Creek to the mouth at Anderson Lake, represents the known Sockeye Salmon spawning area. The Gates Creek is widest (13.7 m bankfull width) in this reach (Lingard et al., 2015). Habitat in this reach is a mixture of riffles and glides. The average gradient in this section is 1.2% (Lingard et al., 2015). The majority of substrate in this cobble or gravel with limited fines. In many areas the channel is confined by either road, rail, dike or a combination of these features.

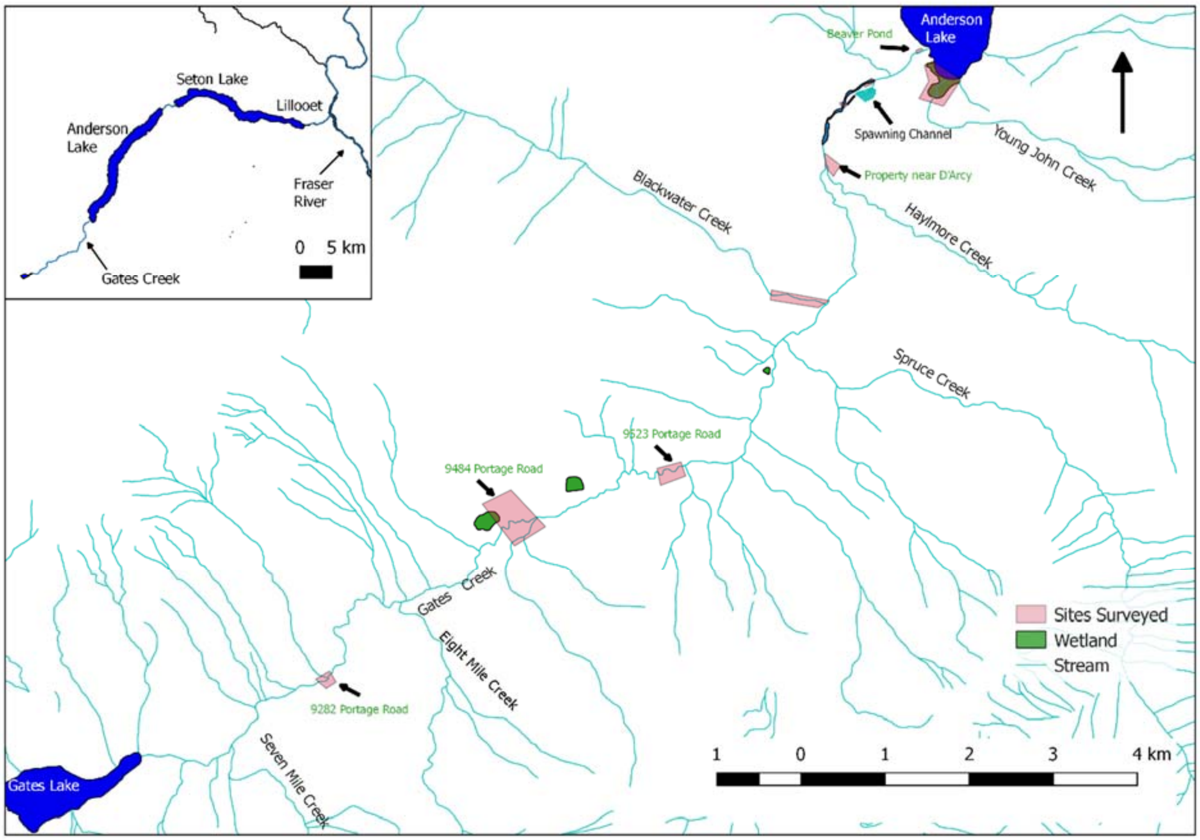

Figure 1. Map of Gates Creek watershed flowing from Gates Lake to Anderson Lake. Areas highlighted in red were surveyed in 2017 for development of habitat restoration prescriptions. Inset shows location of Gates Creek in Seton-Anderson watershed flowing towards the Fraser River.

2.2 General Methods for Prescription Development

In October 2017, a team of restoration and fisheries specialists surveyed specific sites along the entire length of Gates Creek to develop habitat restoration prescriptions. An important goal of this restoration planning project was identifying stressors hindering the function or recovery of riparian and aquatic ecosystems. The second step of the survey was to develop measures to assist the natural successional recovery process of altered habitats (Polster 2011). The team consisted of a vegetation restoration specialist (David Polster), fisheries restoration specialist (Peter Fredriksen), fisheries biologists (Stephanie

Lingard and Jennifer Buchannan), St'at'imc fisheries technicians (Gage Berkner, and Kevin Alec) and the N'Quatqua Fisheries manager (Harry O'Donaghey).

Restoration opportunities along Gates Creek are constrained by private land ownership. Due to the complications of obtaining landowner participation, this survey focused on two properties purchased for restoration by FWCP, projects within the natural channel of Gates Creek or nearby tributaries, or properties to which an invitation had been extended by landowners. Projects proposed in this study will, hopefully, serve as examples to surrounding landowners, and encourage involvement in additional restoration projects in future years.

Prior to the field survey, sites were selected based on the findings of the 2015 Level 1 FHAP (Lingard et al., 2015) and recommendations by Hillaby (2012). Sites selected consisted of areas of poor fish passage, areas with potential for improving fish habitat (*e.g.,* adding cover or substrate), or areas where construction of additional habitat may be possible due to known landowner interest. Survey methods varied depending on the individual needs of a site. In general, the team identified and mapped stressors at each site. Details recorded for each site included: riparian vegetation structure, invasive species, habitat stability, fish habitat quality and complexity, and fish access.

2.2.1 Fish Habitat

In general, there are natural and existing anthropogenic templates available for the restoration of fish habitat (Slaney and Zaldokas 1997), which can be utilized in specific areas of watersheds, provided the application is appropriate in scale and site location. This study selected methods deemed to be the most suitable based on tested restoration activities undertaken in the Pacific Northwest. Several methods and prescriptions described in this document will also require more detailed topographic survey data, and consultation with engineers or hydrologists prior to work commencing.

Fish habitat prescriptions were suggested for four areas along Gates Creek: 9484 Portage Road, 9523 Portage Road, Black Water Creek and Young John Creek wetland. In general, the focus of fish habitat prescriptions was either to provide additional habitat (instream cover structures, pools and wetlands), access to habitat, or enhance existing habitat (*e.g.,* add overstream cover or preferred substrates). Assessment methods varied by site and are detailed in the corresponding sections of this report.

LWD Structures

The LWD structure design suggested are ballasted, bank-attached logs (20-50 cm diameter) preferably with root-wads for both the mainstem of Gates Creek and in constructed off-channel habitat (Figure 2). General design of LWD structures is as follows:

<u>To resist frontal hydraulic drag forces:</u>

- The bank end of the wood buried in the bank and anchored with large diameter cuttings
- Depending on the site there may be a need to use more traditional anchoring of logs to large boulders 3-5 meters from the top of the bank.

<u>To resist buoyancy forces:</u>

- The logs are angled into the off-channel habitat or mainstem where they are attached with sufficient boulder ballast to hold the large woody debris in place under high flow events.

- The ballast boulders will be attached to the placed log structure utilizing ½" galvanized cable and clamps or glue (as described in Slaney and Zaldokas 1997 pg. 9-11).
- Structures will protrude no more than 2/3rd of the wetted width of the excavated off-channel habitat.
- Structures will protrude no more than 1/3rd of the wetted width of the flowing channel.
- Root wads will be placed fully into the off-channel habitat and submerged using the boulder ballast method.

To promote pool scour:

- If the toe of the structure is less than 0.5 m depth at base flows, it will be excavated to approximately 1 m deep.
- The armour layer of the bed will be scarified to promote scour off the downstream ends of the structure placement.

Miscellaneous techniques:

- If possible, root wads will be left attached to stems, and placed so that the base the stem faces upstream to deflect flows into the center of the channel and away from the bank.
- If the root wad is not attached to a stem, it will be placed in an upright position within the structure to increase juvenile refuge and cover.
- Structures will be constructed in a manner to allow low flows along the bank and deflect higher flows back to the center channel.
- Structures can be alternated from left to right bank, to promote thalwag movement in the channel (Figure 2).

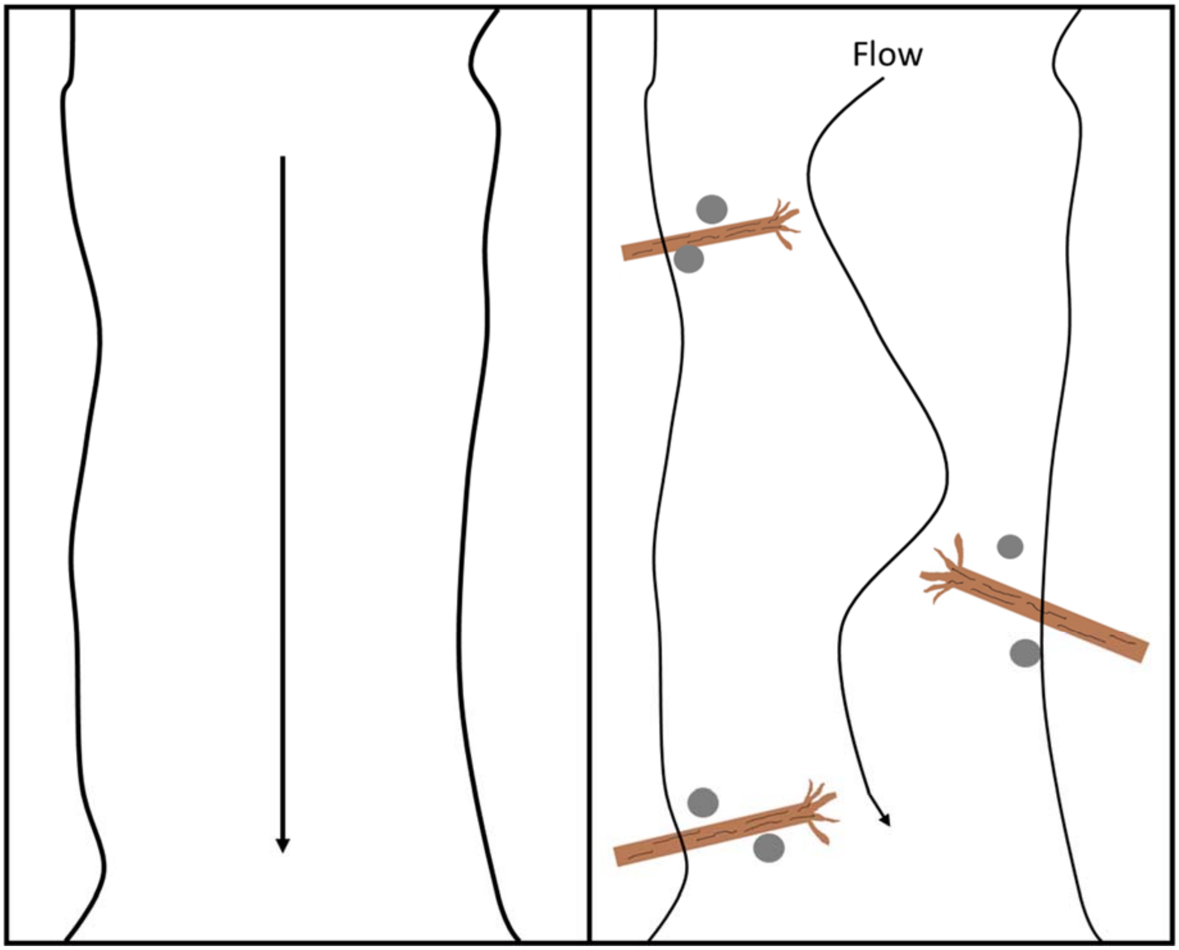

Figure 2. Schematic drawing of single log-root wad and boulder structures that could be used in Gates Creek to increase instream cover and hydraulic complexity of both mainstem and off-channel habitat.

Boulder Placement Prescription

If sufficient large woody debris cannot be obtained to complex off-channel habitat or provide instream cover in the mainstem of Gates Creek, boulder clusters could be used as an alternate measure to slow velocity and create complexity. The advantage of this technique is that there will be no risk to water conveyance structures such as culverts and bridges that LWD structures pose.

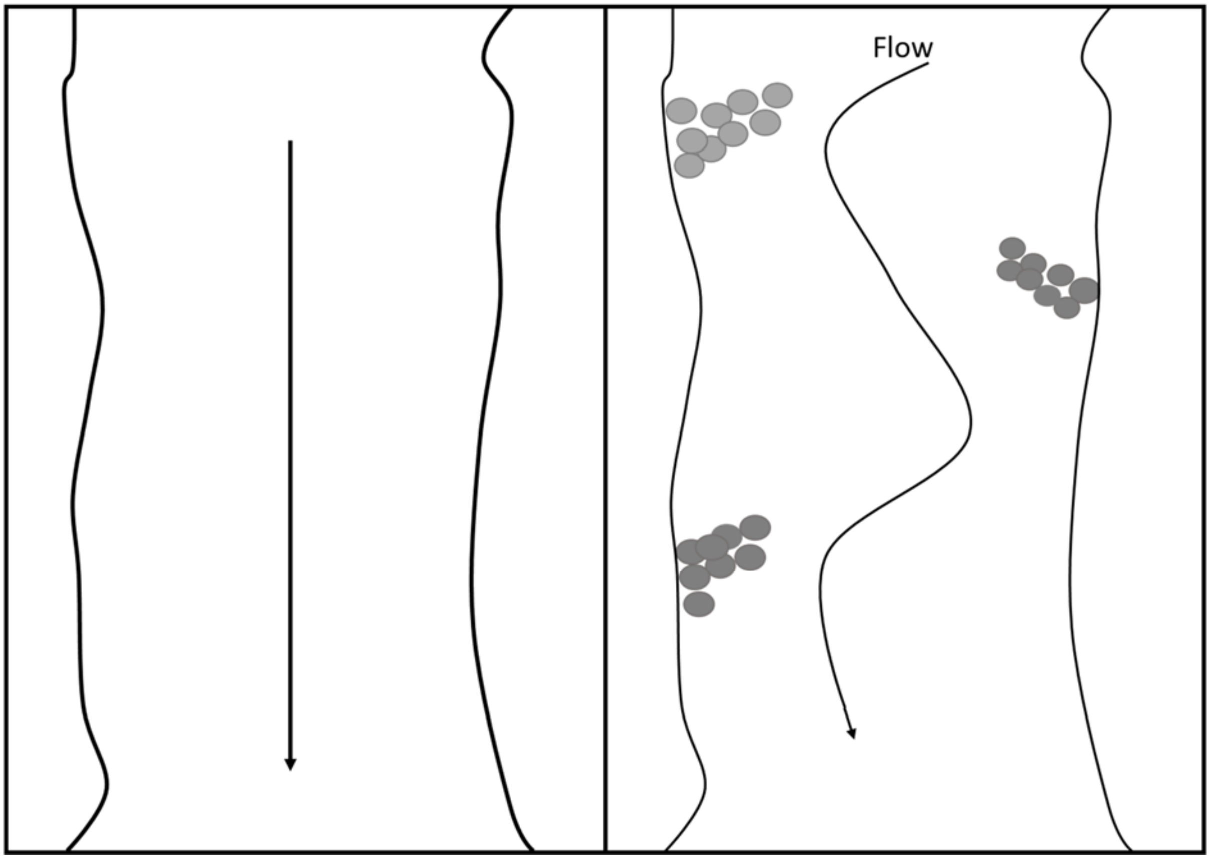

Figure 3. Schematic of how boulder clusters could be used to increase instream cover and habitat complexity in Gates Creek.

Off-Channel Habitat

Off-channel wetland habitat favored by rearing Coho Salmon juveniles is limited in Gates Creek due to infilling of the flood plain for agriculture and urban development. Low-flow, groundwater fed wetland ponds, often created by beavers (*Castor canedensis*), are well documented to benefit Coho Salmon (Swales et al., 1989; Giannico and Hinch 2003; Pollock et al., 2004). Therefore, some of the prescriptions have been proposed to take advantage of the existing high-water table to create off-channel ponds and channels with connections to Gates Creek.

The groundwater nature of these channels and ponds will resemble natural wetlands (example in Figure 4). Depths of ponds and channels will depend on the amount of local ground water available but should be sufficient for rearing Coho Salmon juveniles (0.5- 3.0 m in depth). The off-channel habitats will be complexed with large woody debris as described in the section above to provide habitat heterogeneity. Substrates would typically consist of locally present material. Supplementation with suitably sized spawning gravel may also be possible if desired by stakeholders in future projects.

<u>General targets for characteristic of off-channel habitat:</u>

- Pond depth of 1-3 m
- Pond width of 3-5 m

- Channel widths 3-5 meters
- Channel depths 0.5-1.5 m
- Abundance instream cover (LWD or instream and/or riparian vegetation)
- Perennially wetted

Figure 4. Example of ground water wetland pond.

2.2.2 Riparian Habitat Treatment Types and Estimated Costs

Vegetation and soil engineering prescriptions were developed by David Polster. Two treatments were suggested for the stressors specific to Gates Creek.

Reed Canary Grass Treatment

Reed canary grass (*Phalaris arundinacea L.*) was the primary stressor in the riparian and flood plain areas of 9484 and 9523 Portage Road properties. Reed canary grass is a popular agricultural grass; however, it is not native to the riparian ecosystems in of the south coast of British Columbia. The grass grows in thick monospecific matts with a sod layer depth of roughly 50 cm. Reed canary grass invasion in riparian and wetland ecosystems results in a loss of bio-diversity in plant and animal communities (Spyreas et al., 2010) as well as a homogenization of soil conditions (Dassonville et al., 2008). Reed canary grass is not shade tolerant and emerging methods of suppression have been developed to shade the grass with cuttings of native trees and shrubs (Kim et al., 2006).

The recommended treatment of sites covered by reed canary grass consists of using an excavator to peel back the grass and flipping the matt over with the root mass upward immediately behind the stripped area. The bare soil areas exposed from the flipping of the grass are then planted with 2-3 cm diameter cuttings of Balsam Poplar (*Populus balsamifera ssp. balsamifera*), Willow (*Salix sp.*) and

Red-osier Dogwood (*Cornus sericea*) (Polster 2017). Live stakes should be spaced at approximately 30 cm to provide dense shading of the grass in the immediate future. Habitat diversity can be also be improved by creating islands of higher elevation for establishing more drought tolerant vegetation and bird habitat.

Rough and Loose Soil Treatments

Roughening and loosening soils is done to encourage establishment of native vegetation in areas of soil compaction. This treatment is completed with an excavator to open holes in the site and re-placing the loosened soil from the excavation. The treatment consists of digging holes at 10 m spacing. Dirt is returned to the holes after it has been removed and loosened. An elevational difference of 1.25 m to 1.5 m should be established between the tops of the mounds and the adjacent land surface.

Woody debris (logs and root wads) may also be added to sites as part of this treatment at a rate of 100 m^3/ha. The woody debris provide perches for birds. As birds migrate into the site they will expel seeds in their excrement to accelerate re-vegetation. The benefit of birds in the re-establishment of wild vegetation at disturbed sites has been well documented (Garcia et al., 2010; McClanahan and Wolfe 1993) and may aid in successional recovery of bare soils, as well as reduce the need to replant or aid in successional recovery of bare soils.

3.0 Sites Surveyed

A total of nine sites were visited as part of this survey (Figure 1). Details of the surveys techniques and site characteristics of each site are detailed in the following sections.

3.1 9523 Portage Road

The 9523 Portage Road property was previously used as a grazing area for bison and cattle. The property was purchased in the mid 2000's by FWCP for conservation purposes. According to the Gates Creek Properties Management Plan (BCRP 2007), this parcel encompasses a total of 31.0 hectares. Approximately 500 linear metres (m) of Gates Creek flows through the property, with Portage Road located on the north side of the channel and the Canadian National (CN) railway line on the south side of the channel (Figure 5). The property is accessible from both Portage Road or the rail line. The portion of the property south of the CN rail line goes uphill to a meadow-woodland habitat. The parcel north of the rail line contains Gates Creek and flood plain habitat. Within the parcel boundaries, one (1) third order, and two (2) first order tributaries enter the channel from the south. Another unmapped drainage originating alongside Portage Road enters the channel from the north.

Although the entire length of the Gates Creek channel within the property was examined for this assessment, the primary area of focus for instream prescription development was a section of channel approximately 150 m long upstream of the bridge. No discharge measurements were collected for this assessment. Stage at the time of the survey was deemed to be low given the timing of the survey (early fall) and lack of recent rainfall. Within the area surveyed a series of 13 channel cross sections were established to document the existing channel conditions (Appendix 1). The average wetted width of perpendicular cross sections was 8.6 m, and the channel width was 9.8 m. The average maximum depth of all transects was 1.6 m (range 1.25 - 2.25 m). Channel banks and bottom substrate were comprised almost entirely of fines. Most of the channel had near vertical banks with some areas of undercutting and evidence of banks sloughing into the channel. Riparian vegetation was dominated by reed canary grass, although there were clusters of immature deciduous trees and shrubs (Figure 6). Sedges were also present in lower elevation areas subject to frequent inundation. Channel gradient was < 1% and velocities, although not measured, were estimated to be less than 0.3 m/sec in the thalweg of the channel during the survey. Instream cover was almost non-existent and limited to undercut banks and occasional pieces of small woody debris. Overstream cover was also limited by the dominant vegetation present along the banks (grass).

Prescriptions to habitat restoration at 9523 Portage Road are discussed in section 4.1.

Figure 5. Overview of FWCP owned property at 9523 Portage Road. While lines indicate depth-velocity transects from October 2017. Blue lines indicate mapped drainages. Green lines indicate property boundaries, and yellow lines indicate observed drainage locations.

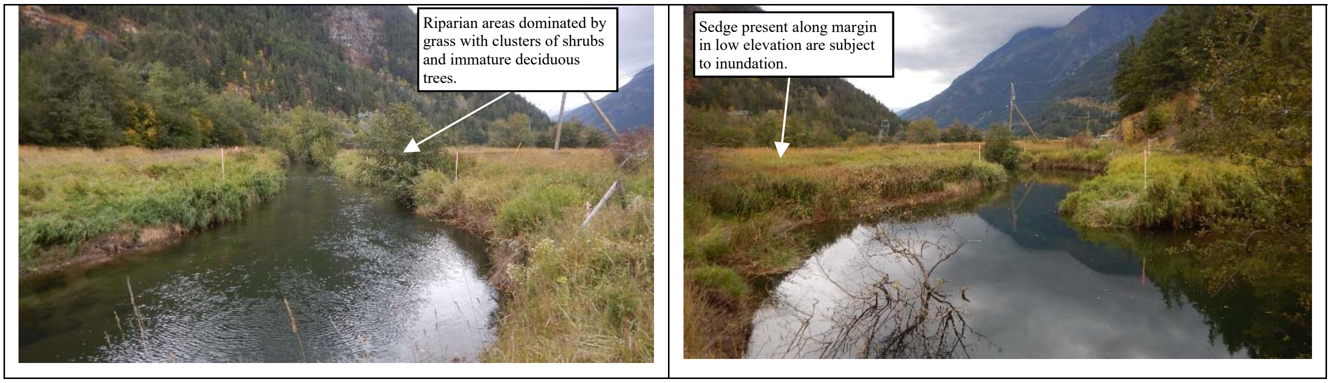

Figure 6. Riparian vegetation at 9523 Portage Road in October 2017. Left: view of typical channel and riparian habitat conditions at 9523 Portage Road. Right: view of typical channel and riparian habitat conditions at 9523 Portage Road.

3.2 9484 Portage Road

According to the Gates Creek Properties Management Plan (BCRP 2007) this 9484 Portage Road parcel encompasses a total of 63.5 hectares; however, background information reviewed for this assessment[1] was unable to confirm the actual limits of property owned by FWCP. The total area stipulated in the management plan did not correspond with total area for these two district lots shown on provincial mapping sources[2] (Figure 7), and therefore some assumptions were made about the presumed property limits.

The portion of the property north of the rail line was the site of an old farm home that was removed in recent years (between 2015 and 2017). This northern portion of the property has a number of productive fruit trees that are frequented by bears. Agricultural grasses are present on this portion of the property; however, the mix of deciduous trees and native shrubs also indicates this area is recovering naturally.

Within the presumed property limits, Gates Creek flows approximately 300 m south of Portage Road and 200 m south of the CN railway. There are at least 700 linear metres of the Gates Creek mainstem flowing through the property and possibly more than 1,700 m (depending on the actual property limits, Figure 7). Access to the site is available from a driveway at 9484 Portage Road, which terminates at the CN track near milepost 118 of the CN Squamish Sub-division. There did not appear to be any road access to the Gates Creek channel through the property, although, a historical road bed leading to what appeared to be a washed-out bridge was identified and used for foot access (machine access along this route is not currently possible as there is no access over the CN track and no crossing of the adjacent ditch). In summary, access to the main channel of Gates Creek for equipment to conduct restoration work was considered poor.

Although this survey only looked at a portion of the main channel, immature deciduous trees and shrubs, were present in the riparian area along Gates Creek, and seemed to be recovering naturally. Considering the poor access conditions for equipment, and the relatively good condition of riparian habitat along the main channel, this assessment was focused on the large upland areas of grass (*i.e.*, agricultural fields and pasture) dominating the property.

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[1] The Sept 25, 2007 version of the Gates Creek Properties Management Plan (Draft EBT #4) provided for this assessment was incomplete, and did not include maps or other appendices.

[2] Cadastral information reviewed from iMpaBC, and Data BC Web Map Library used with GoogleEarth Pro.

Elevation varies little variation in elevation across the property. The property had saturated soil conditions, open wetlands, high grasses and constructed drainages that made access for this survey difficult (*i.e.,* due to inability to see the ground while walking).

The only mapped drainage from the north within the assessment area is a second order tributary originating from the north side of Portage Road and shown to drain due south to Gates Creek (Figure 7). However, the mapped drainage pattern (Figure 7) did not coincide with field observations (Figure 8). Field observations indicate water from this drainage is intercepted and conveyed east along the CN track by a channel/ditch paralleling the track. This channel had a top width of approximately 5 m and depths ranging from 2 m to 3 m, with typical wetted widths between 1 m and 2 m, and wetted depth of 0.3 m to 0.5 m. A series of open water wetlands were also observed west of the driveway connecting to the ditch, on both sides of the CN track (Figure 8). Beaver activity was observed both north and south of the CN track, including recent dam construction in the ditch and partial blockage of the culvert draining under the CN track (Figure 9). The installation of a plastic beaver proof add-on structure (BPAO[3]), combined with multiple beaver traps alongside the track indicate recent beaver activity causing drainage concerns for the rail line. The area south of this channel to Gates Creek is dominated by large fields of grass, with small pockets of cattail, native shrubs, and/or immature deciduous trees. This area appears to have been historically used for agricultural production (*e.g.,* grazing, or hay fields). Saturated soil, and open wetlands were observed at various locations in the fields along with standing water along both sides of what appeared to be a historical road bed running from the driveway to Gates Creek (Figure 8). Most of the area surveyed was dominated by large tracts reed canary grass (former agricultural fields) which is suppressing the successional recovery of native vegetation.

Adjacent to the fields of reed canary grass lies a functioning wet meadow habitat. Wet meadows are areas of poorly drained soils typically vegetated with water tolerant grasses, sedges, and rushes and other hydrophilic species. Though standing water is present only at seasonally high conditions, the water table keeps water saturated year-round. Wet meadows provide value by collecting runoff and removing any excess nutrients within the water and trapping them in the soils. This nutrient-rich environment provides food and habitat for insects, amphibians, reptiles, birds and mammals (EPA, 2018).

Wet meadow habitats are frequently associated with farming as the soils are attractive due to their nutrient richness. For farming to occur, draining of the habitat must happen through the installation of drainage tiles. It is likely that the adjacent field was once wet meadow and excavation would reveal drainage tiles. Removing the drainage structures, would allow that area to become saturated again. The increase of water in the soil may naturally inhibit the growth of reed canary grass and allow for the natural colonization of native hydrophilic species from the adjacent wet meadow. Due to the high value of this wet meadow habitat, water table elevations should be collected prior to planning of projects at this site to ensure new construction will not destroy functioning habitat. Concepts to restore and construct fish and wildlife habitat at 9484 Portage Road are discussed in section 4.2

[3] Beaver proof add-on (BPAO https://www.bpao.ws/) designed/intended to reduce beaver blockages and allow fish passage through an easy to clean structure that limits flooding by incorporating an overflow component.

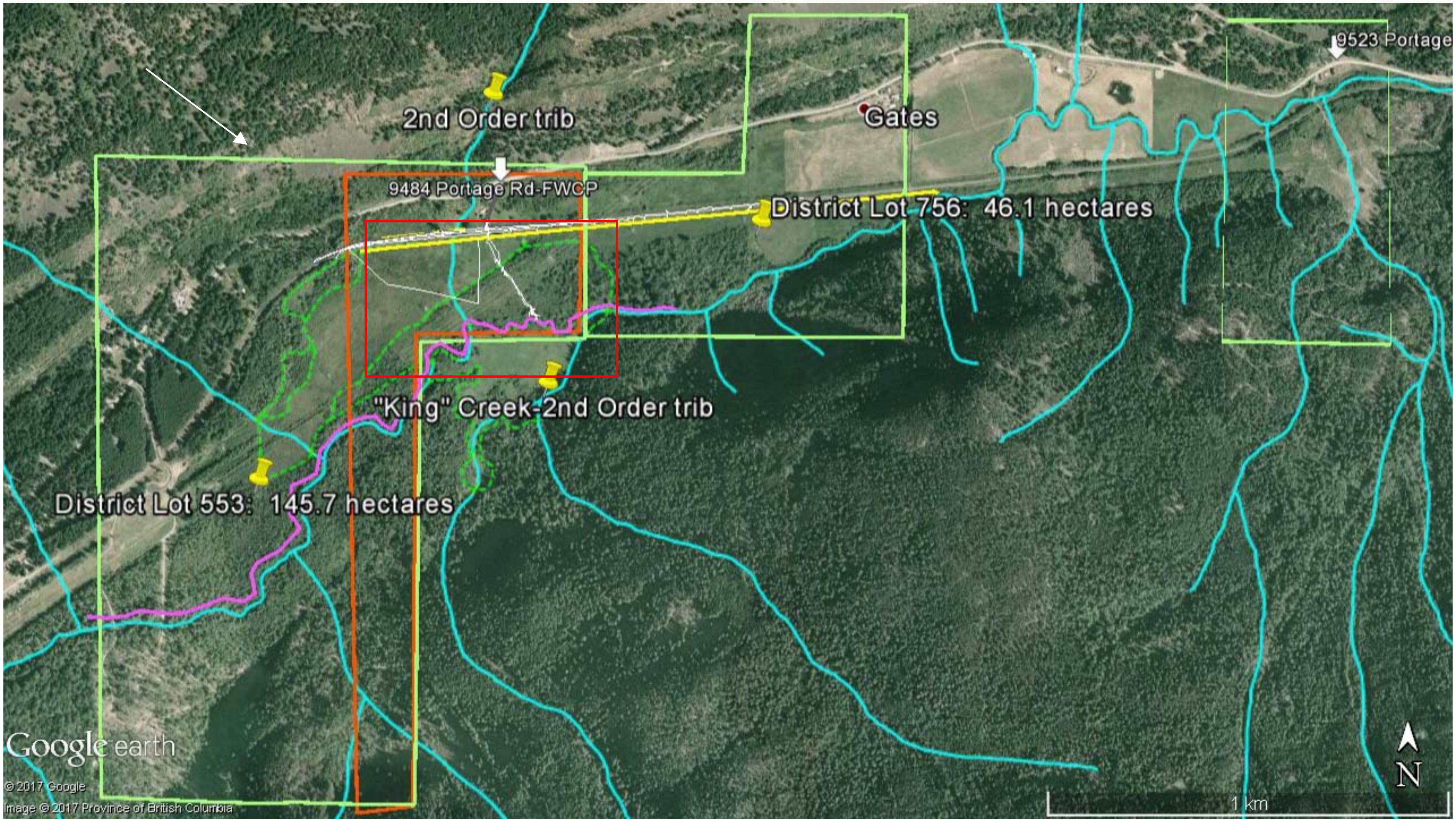

Figure 7. Overview of FWCP property at 9484 Portage Road, and surrounding area. Green lines indicate mapped boundaries of DL 553 and 756. Orange line indicates "presumed" limit of FWCP ownership for this survey. Red rectangle indicates primary survey area. Blue lines indicate scale mapped drainages. Yellow lines indicate observed drainage locations. Purple line indicates left (north) bank of Gates Creek. Dashed green line indicates mapped wetlands. White line indicates GPS tracks from field survey. Data from imapBC.

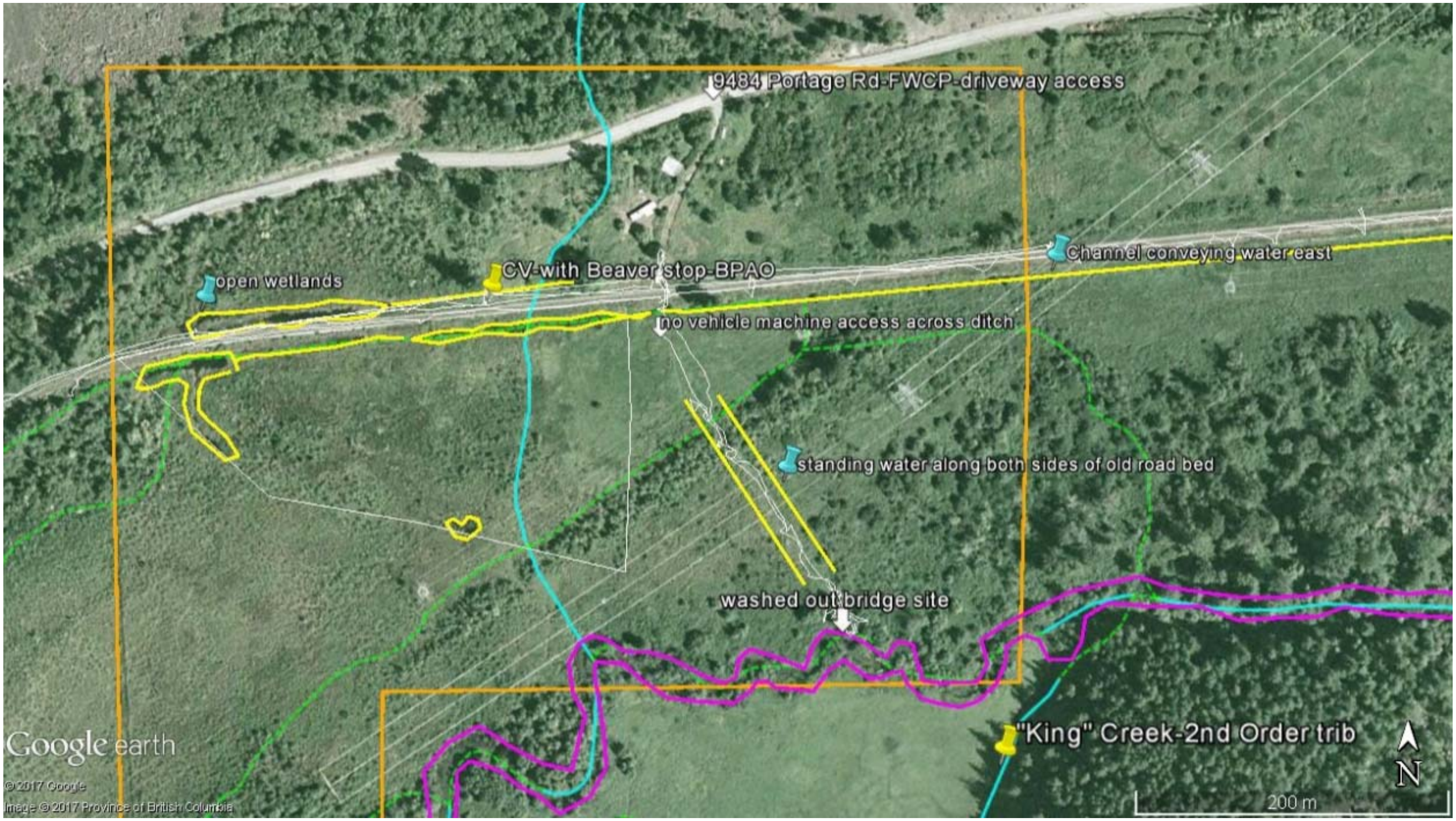

Figure 8. Overview of primary survey area and drainage at 9484 Portage Road. Orange line indicates "presumed" limit of FWCP ownership for this survey. Blue lines indicate scale mapped drainages. Dashed green lines indicate mapped wetlands. Yellow lines indicate observed drainage locations, and open wetlands. Purple line indicates TOB for Gates Creek from air photos. White line indicates GPS tracks from field survey. Data from imapBC.

Figure 9. Left: open water wetland upstream (north) of the CN Track on 9484 Portage Road, and west of the BPAO. A second wetland is also located on the south side of the track in this area. Right: Beaver proof add-on (BPAO) attached to the upstream end of the CN culvert. Despite the name this structure is still affected by beaver activity. s

3.3 Blackwater Creek Fish Passage

The fish passage assessment in Blackwater Creek included visual inspection of three culverts and the bridge associated with the Blackwater Cr Forest Service Road (Figure 10). Although the culvert inspections did not specifically follow all the procedures outlined in the Field Assessment for Determining Fish Passage Status of Closed Bottom Structures (BC MOE 2011), the assessment did collect enough information to characterize fish passage conditions.

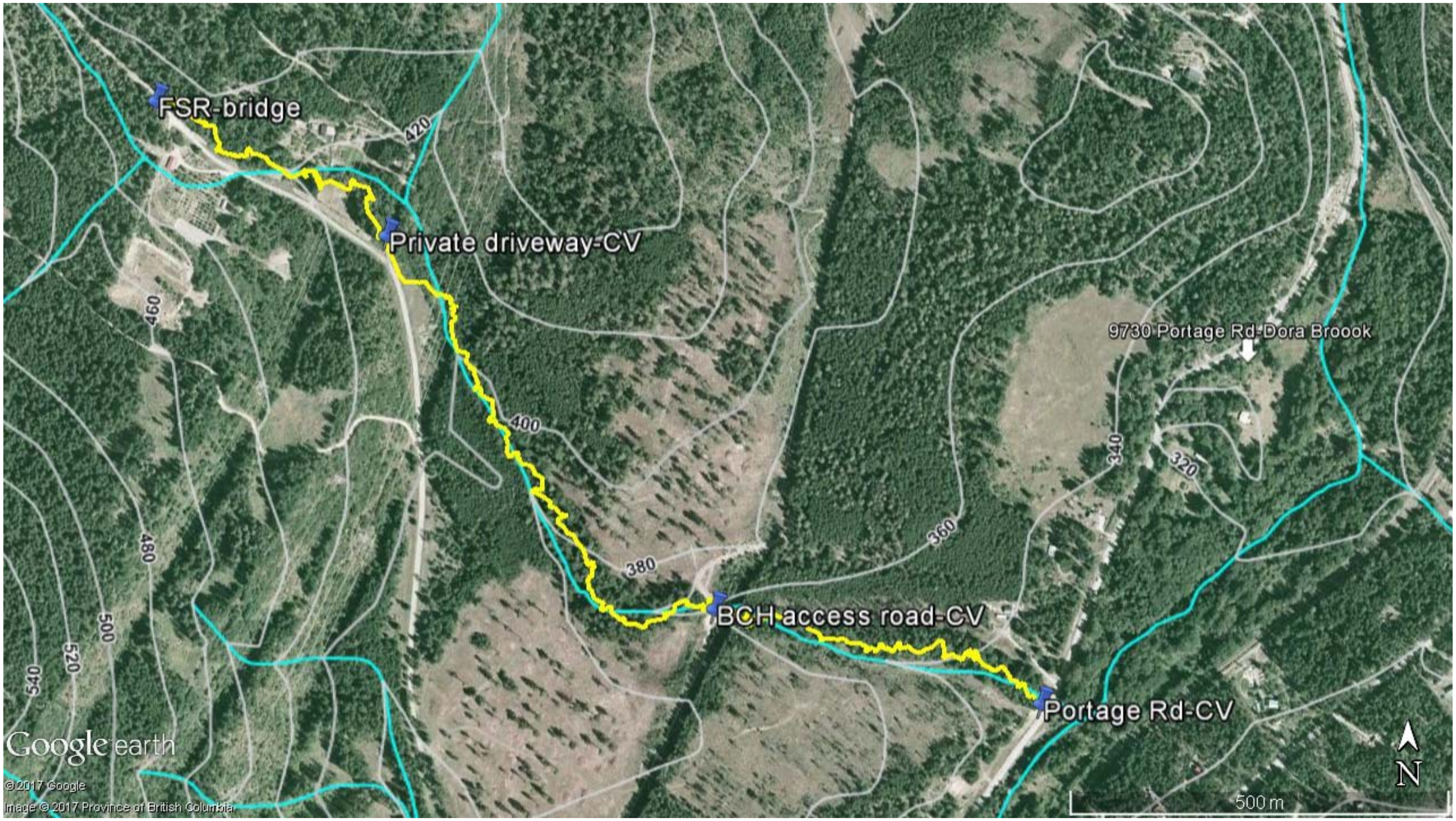

Figure 10. Overview of Blackwater Creek and fish passage assessment locations. Blue lines indicate mapped drainages. Yellow line indicates GPS track of Blackwater Cr from field survey

9690 Portage Road

The Portage Road crossing of Blackwater Creek consists of a 21 m long corrugated metal pipe (CMP) culvert, with a diameter of 1,550 mm. At the time of the survey, culvert slope did not appear to be causing an impediment to fish passage as the culvert had a relatively consistent depth (0.3 - 0.4 m) with moderate velocity (Figure 11), and no drop existed at the culvert outfall. Downstream of the culvert outfall a series of weirs have been constructed to improve fish passage (Figure 11). These weirs have been constructed with a combination of natural substrate and concrete blocks with drop heights ranging from 0.4 m to 0.7 m. Pool depth to drop height ratios were between 0.43:1 and 1.73:1 (Figure 12) for individual steps. While these weir structures may be passable by some species and/or age classes at various stream stages, most of the jump heights[4], and pool depth to jump height ratios[5] measured during this survey did not meet published criteria for fish passage of salmonids (Whyte et. al. 1997).

Figure 11. Left: Observed depth and velocity conditions inside the Portage Road crossing of Blackwater Creek appeared to meet criteria for fish passage. Right: Drop heights, and pool depth to jump height ratios associated with weirs downstream of the Portage Road crossing of Blackwater Creek did not meet criteria for fish passage.

[4] Jump heights for 50 mm to 130 mm juveniles approximately 0.3 to 0.6 m (some variances by species)

[5] "the ability to jump a vertical obstacle is also related to the depth of water from which a fish can leap. A pool depth of at least 1.25 times the height of the obstacle provides for ideal leaping conditions".

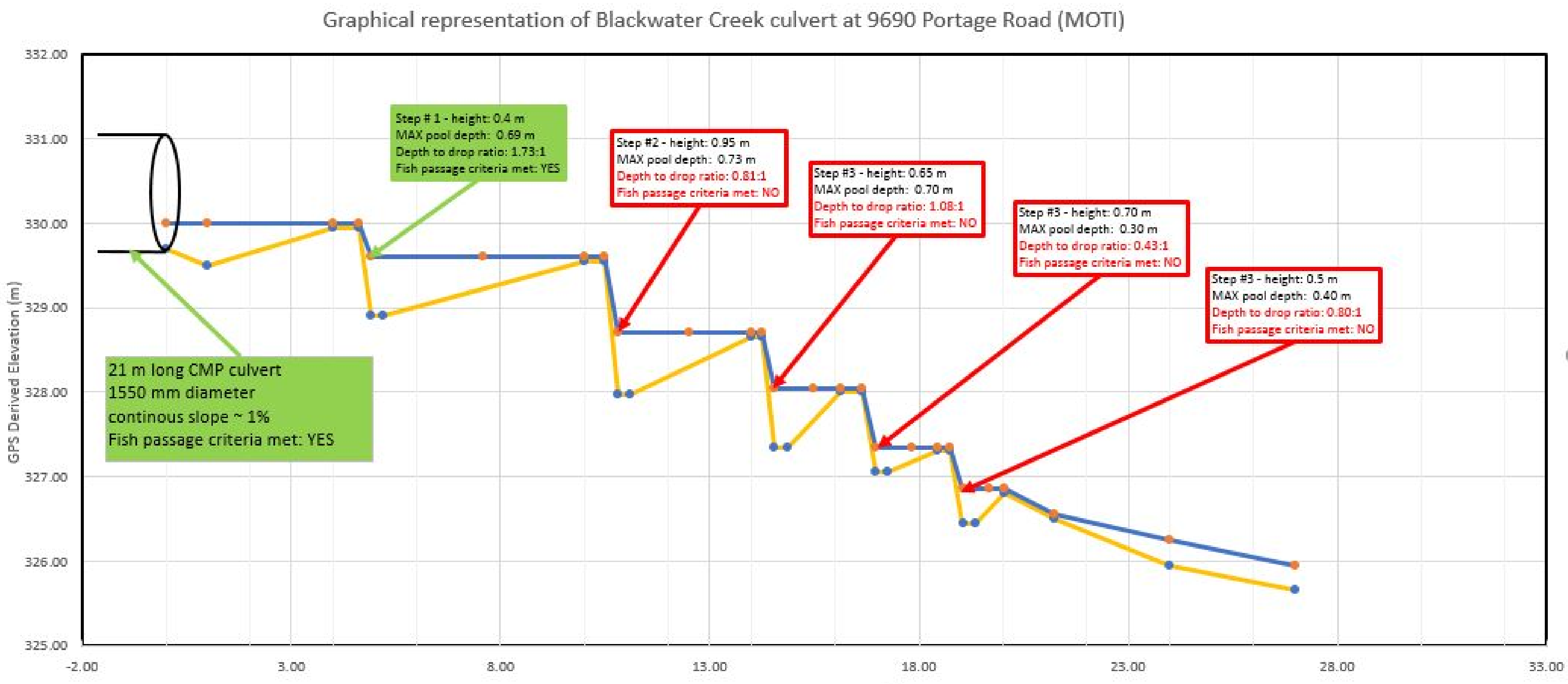

Figure 12. Graphical representation of Blackwater Creek culvert at 9690 Portage Road (MOTI)

BC Hydro transmission line ROW

The BC Hydro (BCH) transmission line right of way (RoW) road crossing of Blackwater Creek consists of a 7.5 m long CMP culvert, with a diameter of 1,200 mm. The culvert had an average velocity of 2.4 m/sec over the full length of the culvert. Culvert slope (up to 10%) was identified as an impediment to fish passage due to sheet flow conditions (Figure 13) created in the upstream half of the culvert (*e.g.,* depth < 10 cm and velocity 3.5 to 4.0 m/sec[6], Figure 14). There was no drop at the culvert outfall, however, downstream of the culvert outfall a series of three (3) weirs have been constructed to improve fish passage (Figure 13). These weirs were also constructed with a combination of natural substrate and concrete blocks. Drop heights for the weirs range between 0.5 m and 0.65 m. Pool depth to jump height ratios were between 0.87:1 and 1.00:1 (Figures 13 & 14). While the weir structures may be passable by some species and/or age classes of fish at various stream stages, the jump heights, and pool depth to jump height ratios, measured during this survey did not meet published criteria for fish passage of either adult or juvenile salmonids (Whyte et. al. 1997).

[6] Prolonged swimming speed (*i.e.,* swimming velocities that can be maintained for passage through difficult areas) of juveniles varies from 0.3 to 0.7 m/sec (depending on age class and species), and from 1.8 to 3.2 m/sec for adults (depending on species).

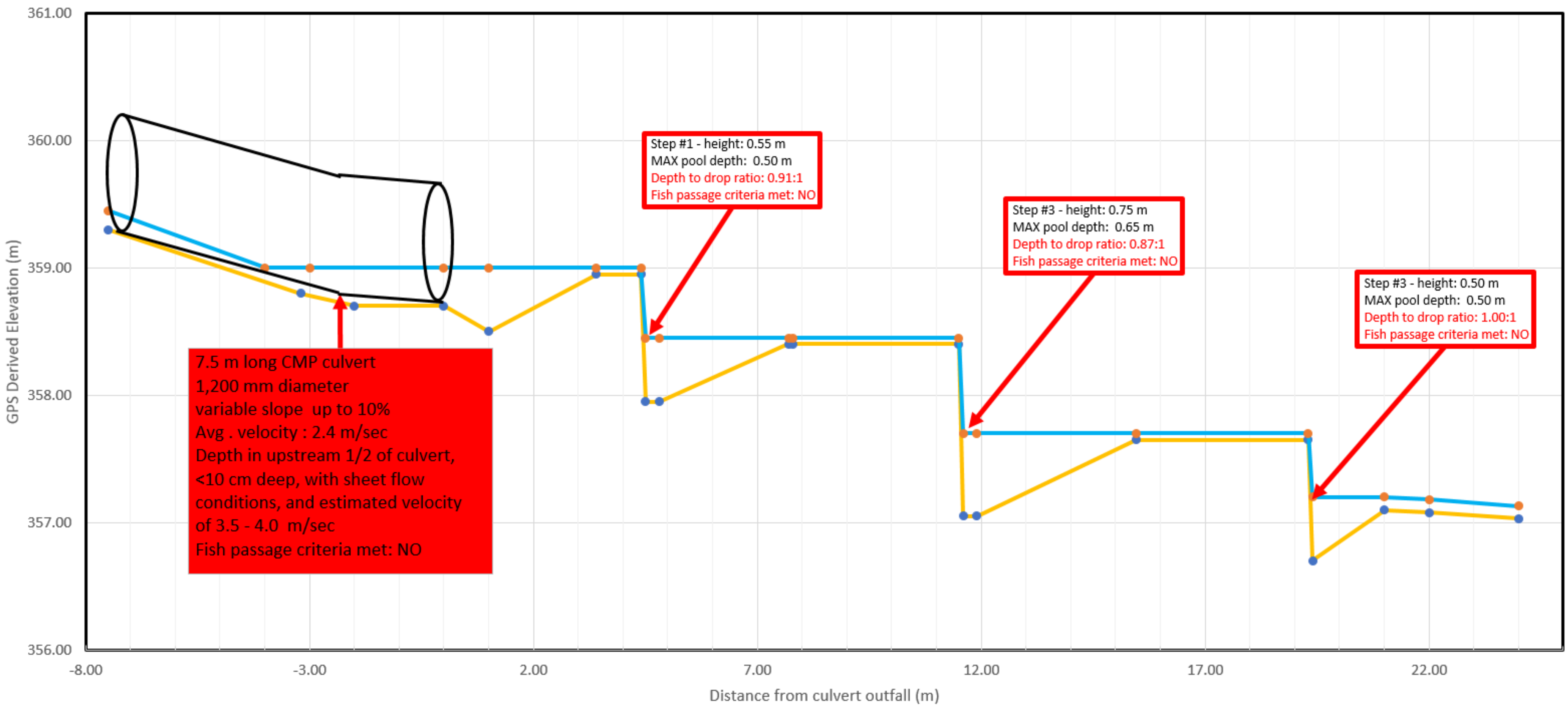

Figure 13. Graphical representation of the BCH ROW culvert crossing of Blackwater Creek


Figure 14. Left: Depth and velocity conditions inside the BCH RoW crossing of Blackwater Creek were characterized by sheet flow conditions, which did not meet criteria for fish passage. Right: Drop heights, and pool depth to jump height ratios associated with weirs downstream of the BCH RoW crossing of Blackwater Creek did not meet criteria for fish passage.

3465 Blackwater Road – private driveway

The private driveway crossing of Blackwater Creek located near 3465 Blackwater Lake Road consists of a 7.5 m long CMP culvert, with a diameter of 1,200 mm. The culvert slope (up to 10%) was identified as an impediment to fish passage (Figure 15). The culvert had an average velocity of 2.4 m/sec over the full length of the culvert. In addition, the culvert slope created sheet flow conditions in the upstream half of the culvert (*e.g.*, depth <10 cm and velocity 3.5 to 4.0 m/sec; Figure 15). Velocity at the culvert outfall was also high and there was a drop of approximately 10 cm (Figure 15, Figure 16). There were no weirs or gradient barriers observed upstream or downstream of the culvert. While the crossing may be passable by some species and/or age classes of fish at other stream stages, conditions during this survey did not meet published criteria for fish passage of salmonids (Whyte et. al. 1997).


Figure 15. Left- Depth and velocity conditions inside the driveway crossing of Blackwater Creek were characterized by sheet flow conditions, which did not meet criteria for fish passage. Right- The outfall of the driveway crossing of Blackwater Creek was indicative of the high culvert velocity which did not meet criteria for fish passage

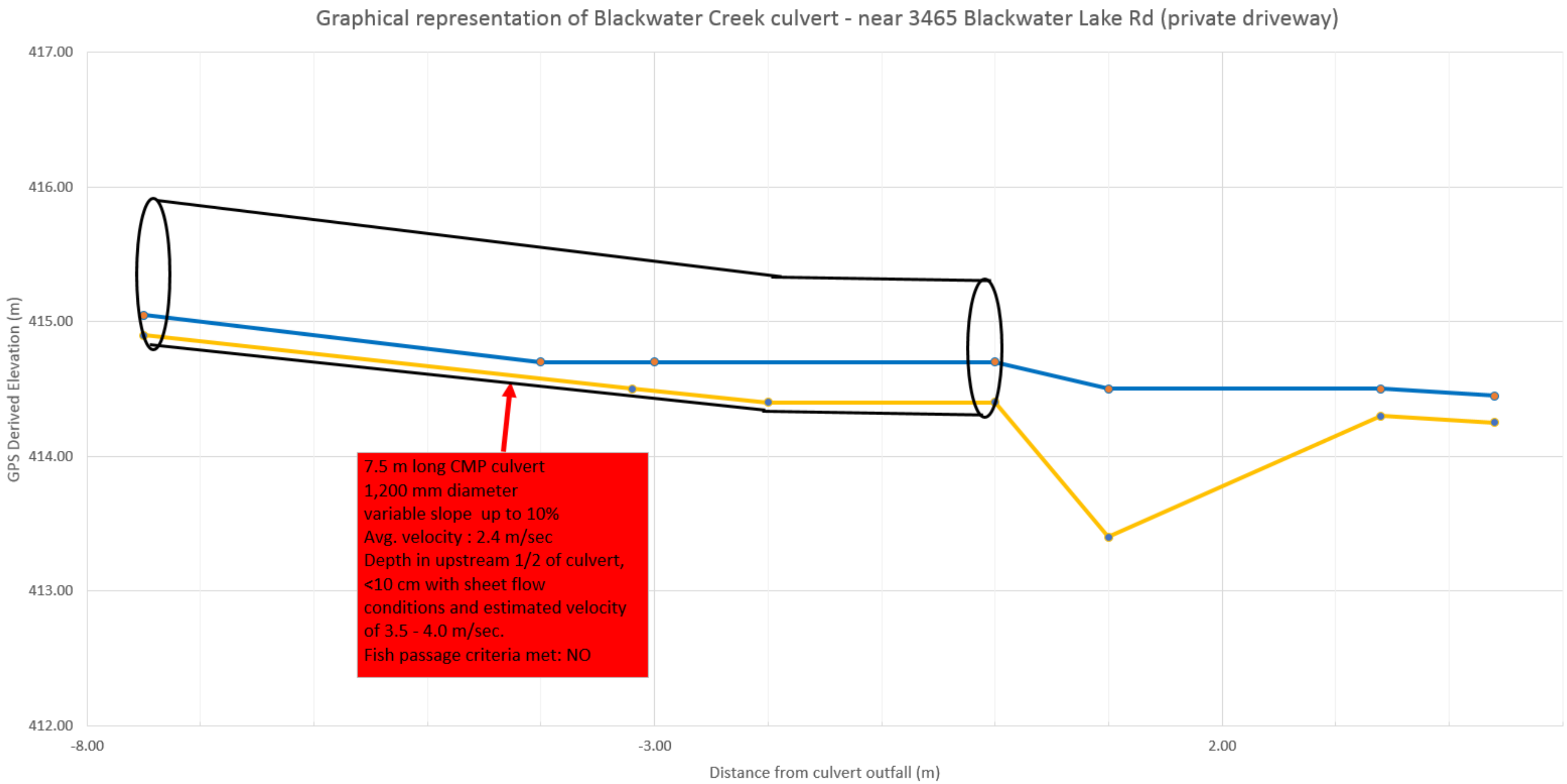

Figure 16. Graphical representation of the private driveway crossing of Blackwater Creek.

3500 Blackwater Road

The Blackwater Creek Forest Service Road crossing of Blackwater Creek was comprised of a clear span bridge. No fish passage issues were identified at this crossing.

Concepts to restore fish access at the three culvert crossings in Black Water Creek are discussed in section 4.3.

3.4 Young John Creek Wetland

The Young John Creek wetland complex is located adjacent to the southwest shore of Anderson Lake and encompasses an area of approximately 6 hectares (Figure 17). The wetland complex starts approximately 150 m southeast of the Gates Creek confluence, although the main wetted entrance is approximately 375 m from Gates Creek. Young John Creek is a 3rd order mapped drainage with a watershed area of approximately 540 hectares[7]. Hillaby (2012), indicated there is no defined stream channel that would allow fish passage or any movement of aquatic organisms into the upper watershed. It appears the stream goes subsurface for several hundred meters, before reaching the wetland complex.

The wetland contains a number of large ground water ponds (Figures 17 & 18). Hillaby (2012) identified the Anderson Lake foreshore including the wetland complex and ponds as a rearing area for juvenile Coho Salmon. Spawning Coho Salmon have been observed in the channels between the ground water ponds in the wetland complex (Harry O'Donaghey pers. comm). However, it is unlikely the few adults observed spawning produced the number of juvenile Coho Salmon captured during the Hillaby (2012) study. Therefore, it is speculated that Coho Salmon juveniles from Gates Creek disperse into the Young John Creek wetland and ponds. Adult Pink Salmon were observed at the time of this survey (October 2017).

Although the Young John Creek wetland was visited it was evident from the brief site visit that the area would be difficult to evaluate from a ground level survey. Any survey of this area to evaluate habitat or restoration opportunities, would greatly benefit from high resolution aerial photographs to better identify channels, and channel connectivity. A general discussion of potential enhancement opportunities is presented in section 4.4.

[7] Stream network and watershed area information from the Data BC Web Map Library, combined with measuring tools in Google Earth Pro, November 27, 2017.

Figure 17. Overview of D'Arcy and location of Young John Creek wetland complex. Blue lines indicate 1:20,000 scale mapped drainages. Dashed green line indicates mapped wetland boundary. White line indicates GPS tracks from field survey.

Figure 18. Example of large ground water ponds found in Young John Creek wetland.

3.5 Debris Flow at 9282 Portage Road

A debris flow occurred on Falls Creek (local name) in September of 2015. Debris from this event entered the channel of Gates Creek at 9282 Portage Road (Figures 1 and 19). The mixed deciduous and conifer forest, that stood on the property prior to the debris flow, was heavily impacted. At the time of this survey (2017), the majority of the vegetation was dead as a results of burial. Dead timber was harvested following the debris flow. The substrate on site was dominated by fine materials (clay, silt and sand).

At the time of our survey (October 2017), The site was at early successional stages with deciduous shrub seedlings beginning to establish across the site. Early successional species such as Balsam Poplar and Thimbleberry (*Rubus parviflorus*) were present.

Roads and trails used to harvest dead trees were still visible during this survey. The areas that had experienced vehicle traffic were visibly compacted, which appeared to be suppressing natural succession. Harvesting wood has also smoothed the surface of the ground as the large logs were yarded across the fresh debris flow surface. The compacted roads and smoothed ground surfaces associated with the timber harvesting limit rainfall absorption, and instead cause the rainsplash erosion (Polster 2011), to mobilize and carry the sediment into Gates Creek. The patterns of smooth surfaces and areas that have remained rough from the original debris flow can be seen in the patterns of vegetation establishment. Vegetation has started to establish in areas where the surface remained rough while areas that were smoothed by log yarding have limited vegetation (Figure 19).

Figure 19. Photograph of 9282 Portage Road property on October 5th, 2017 (two years after debris flow event). Areas near woody debris had patches of denser vegetation while areas with-out woody debris or with obvious soil compaction have lower densities of seedlings.

3.6 Off-channel Beaver Ponds near Anderson Lake

A series of off-channel ponds were identified along the north side of Gates Creek, near the confluence with Anderson Lake (Figure 20). An overhead visual assessment indicated these ponds were primarily formed by beaver dams, although the ponds also appeared to be intermittently connected to the floodplain through high flow channels that entered the pond complex at several locations from Gates Creek. The visual survey suggested the off-channel habitat could already be providing good habitat for juvenile Coho Salmon rearing. The riparian area was well established, the ponds had areas of variable depth (up to 1 m or greater), and LWD was present at multiple locations (Figure 21). However, beaver activity, that created the ponds, was also identified as a potential limiting factor to habitat productivity. While beaver can create large complexes of wetlands, providing excellent rearing habitat, the dams themselves can also limit the ability of fish to enter the pond complex, and may prevent juveniles from migrating out in the spring. In summary, the assessment indicated this off-channel beaver habitat appears to be functioning to provide habitat for juvenile fish.

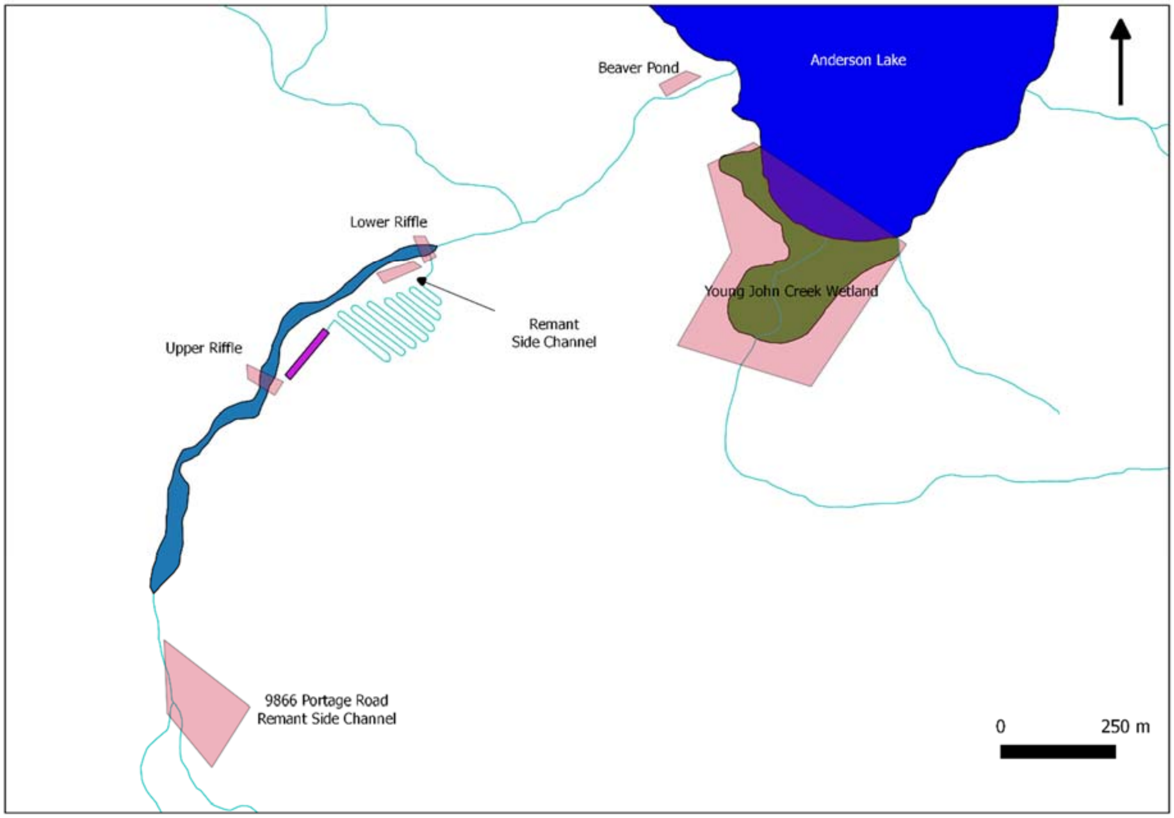

Figure 20. Sites surveyed in lower Gates Creek and Young John Creek wetland near D'Arcy.

Figure 21. Photo of pond created by beavers adjacent to Gates Creek approximately 200 m upstream of the confluence with Anderson Lake.

3.7 Fish Passage at Gates Creek Spawning Channel Intake and Outlet

There are two channel wide riffles in lower Gates Creek constructed to facilitate operation of the Sockeye salmon spawning channel (Figure 22). The downstream riffle was constructed to direct returning adults towards the outlet of the spawning channel (Figure 22). The upstream riffle was constructed to provide head for channel operation by raising the water level (Figure 22). These riffles create gradient conditions estimated at 5 to 7% over a linear stream distance of approximately one channel width (*i.e.*, 20 to 30 m). At some discharge levels these constructed riffles could create conditions that impede upstream fish passage particularly for young-of-year fry, and rearing juveniles. These conditions include; increased velocities, hydraulic jumps created by boulders, and sheet flow conditions created by the upstream control weirs (Figure 22).

Fish passage concerns associated with these riffles has been identified in multiple studies since at least 2003 (Thevarge 2004; Hillaby 2012). Hillaby (2012), identified fish passage issues at the upper riffle for stream resident species such as Rainbow Trout and Bull Trout and suggested annual fish passage observations and evaluation be undertaken. The upstream riffle was modified in 2014 to improve passage for adult Sockeye Salmon; however, it still does not appear to be functional for smaller salmonids.

Issues have been raised by N'Quatqua Fisheries staff regarding the current design of the downstream riffle and its impediment of natural migratory behaviour for Sockeye Salmon as well as other species of salmonids in Gates Creek. Currently, during the Sockeye Salmon migration period, all fish are forced to enter the bottom of the spawning channel and migrate through counters into either Gates Creek or the spawning channel as directed by DFO. The remainder of the year, fish are forced to migrate through the boulder step pools (Figure 22). An alternative design was developed by DFO for the downstream riffle (Thevarge, 2004); however, no modifications have been made to date at the downstream riffle.

Despite the concerns regarding fish passage at these two riffles, no modifications to either of these riffles are proposed at this time due to the potential impact on the spawning channel functionality.

Figure 22. Left: Downstream view of riffle constructed to direct adult Sockeye into the spawning channel. Note sheet flow conditions at the upstream control weir, as well as hydraulic jumps, and increased velocity through the riffle. Right: Downstream view of riffle constructed as part of the spawning channel intake. Note hydraulic jumps, and increased velocity created by the riffle, and the concrete fish ladder along the right margin.

3.8 Off-channel habitat – Sockeye spawning channel

During a tour of the Sockeye Salmon spawning channel facility, the survey team identified a high-flow side-channel along the south margin of Gates Creek approximately 100 m downstream of the spawning channel intake (Figure 23). This area could potentially be modified to provide perennial habitat in the form of an active side channel, or as off-channel refuge habitat.

The existing channel is approximately 60 m long, and 10 m wide. Based on observed conditions (*i.e.,* bed scour, Figure 23) the channel is active during typical high-water events and freshet, although it was dry at the time of the survey. Excavating the channel to intercept the water table and adding habitat features (*e.g.,* LWD), could extend the seasonal range of habitat availability in this channel for salmonids. However, modifications to deepen and extend the seasonal availability of habitat could also result in a change to channel dynamics in this area, and or channel morphology. If the enhanced channel is protected from high flows (*i.e.,* with an upstream berm to create off-channel refuge), the modifications could result in increased velocities in the main channel during high water events and changes to the opposing bank. If the channel is excavated to make the channel active at all stages, it could result in a shift in channel morphology.

In summary, no modifications are proposed at this time, due to the potential impact on the channel morphology in this area.

Figure 23. Left: Upstream view of an existing side channel near the Sockeye spawning channel that could be enhanced to extend the seasonal availability of this habitat. Right: Yellow line indicates approximate extent of potential off-channel area that could be enhanced along the right (south) margin.

3.9 Gates Creek near D'Arcy

This area of Gates Creek was brought to the attention of the survey team by a local landowner who expressed interest in potentially cooperating, and/or accommodating restoration projects within their property. The property is situated on the river-right (east) margin of Gates Creek near the confluence of Haylmore Creek, which is the largest tributary to Gates Creek (Figure 24). Access to the property is by a privately owned one lane clear span bridge over Gates Creek, which the owner acknowledged was a structure that may require modification in the future (*i.e.*, abutment repairs due to channel scour).

Gates Creek in this area consists of a single, sinuous channel, semi-confined between linear infrastructure (i.e., Portage Road and CN track) on one or both margins and the D'Arcy property, all of which are elevated approximately 8 m above the river level (Figure 25). The wetted width of Gates Creek was approximately 20 m (Figure 25), with a typical bankfull channel width of approximately 25 m (determined based on the presence of stable, mature vegetation close to the wetted edge). However, the river has low natural banks, providing an 80 m wide floodplain corridor, between the higher banks created by the linear transportation corridors and private property. Substrate in both Gates Creek and Haylmore Creek is coarse, dominated by boulder, cobble, and gravel, and is indicative of the gradient (2-3%) and semi-confined nature of the channels (Figure 25).

Figure 24. Overview of property near D'Arcy. Red shading indicates DL boundary. Light blue lines indicate mapped drainages. Yellow line indicates dry secondary channel. Dark blue area at top of map indicates widening of Gates Creek and provincial polygon for Gates Creek.

Figure 25. Left: Downstream view of Gates Creek in vicinity of Haylmore Creek confluence and private clear span bridge (visible in the background on the left). Right: East margin of Gates Creek showing stable, mature vegetation, near wetted edge but low bank height providing a wide floodplain.

Off-channel habitat

The most promising opportunity from a restoration perspective on the property was what appeared to be a relic or high-water side channel on the river-right (east) margin of Gates Creek. The channel starts near the confluence with Haylmore Creek and continues parallel to the river for approximately 150 m before rejoining Gates Creek at the bridge crossing (Figure 24). There was little or no scour to alluvium that might be indicative of frequent inundation. However, the presence of a continuous depression combined with evidence of rafted debris, and sediment deposition indicated the area has conveyed water in the past or may convey water during extremely high-water events.

Haylmore Creek

Haylmore Creek is a sixth order stream with a watershed area of approximately 115 km^2. Field observation indicate the channel has a higher gradient than Gates Creek (3-4% typical) with a typical wetted width of 7-10 m and a channel width of approximately 15 m. There were indicators of instability within the channel (recent morphology changes identified by the landowner), and in the forested area adjacent to the channel (immature vegetation and cobble deposits indicative of old relic channels). At one location, the survey team observed a side channel area situated approximately 1.5 m below the water surface elevation of the adjacent main channel < 5 m away. However, despite the difference in elevation, there was almost no water in the side channel (Figure 26).

In summary, field observations indicate that Haylmore Creek channel is unstable, and subject to changes in channel morphology. In addition, observations in the side channel area, indicates the area has poor sub-surface flow conditions, despite the channel gradient and large substrate. In combination these factors would seem to limit the feasibility of any habitat enhancement such as excavating off-channel habitat, or channel manipulations to install structures and/or increase pool habitat.

Figure 26. Left: The base of this log jam at the upstream end of a side channel in Haylmore Cr was approximately 1.5 m below the water surface of the adjacent main channel < 5 m away. Right: Despite the observed difference in elevation from the adjacent main channel (Photo 27) there was only a limited amount of flow in the side channel.

4.0 Results and Outcomes: Site Specific Prescriptions

4.1 9523 Portage Road

Fish habitat at the property owned by FWCP at 9523 Portage Road has been negatively impacted by agricultural practices. These practices have resulted in the removal of native riparian vegetation, and channelization of Gates Creek. These changes have reduced bank stability, channel complexity, and instream cover. There has also been a loss of off-channel and wetland habitat. The objective of the proposed restoration project is to aid in the recovery of the riparian habitat back to a functioning forest and increase channel complexity, instream cover, and channel stability. Techniques proposed to achieve these objectives should focus on accelerating natural recovery by improving conditions for early successional vegetation. Channel complexity could be increased by the installation of LWD features, and excavation of the off-channel habitat (Figure 27). The restoration measures outlined in this report currently encompass the low land-flood plain area of the property. The upland sections are recovering naturally and do not require intervention at this time.

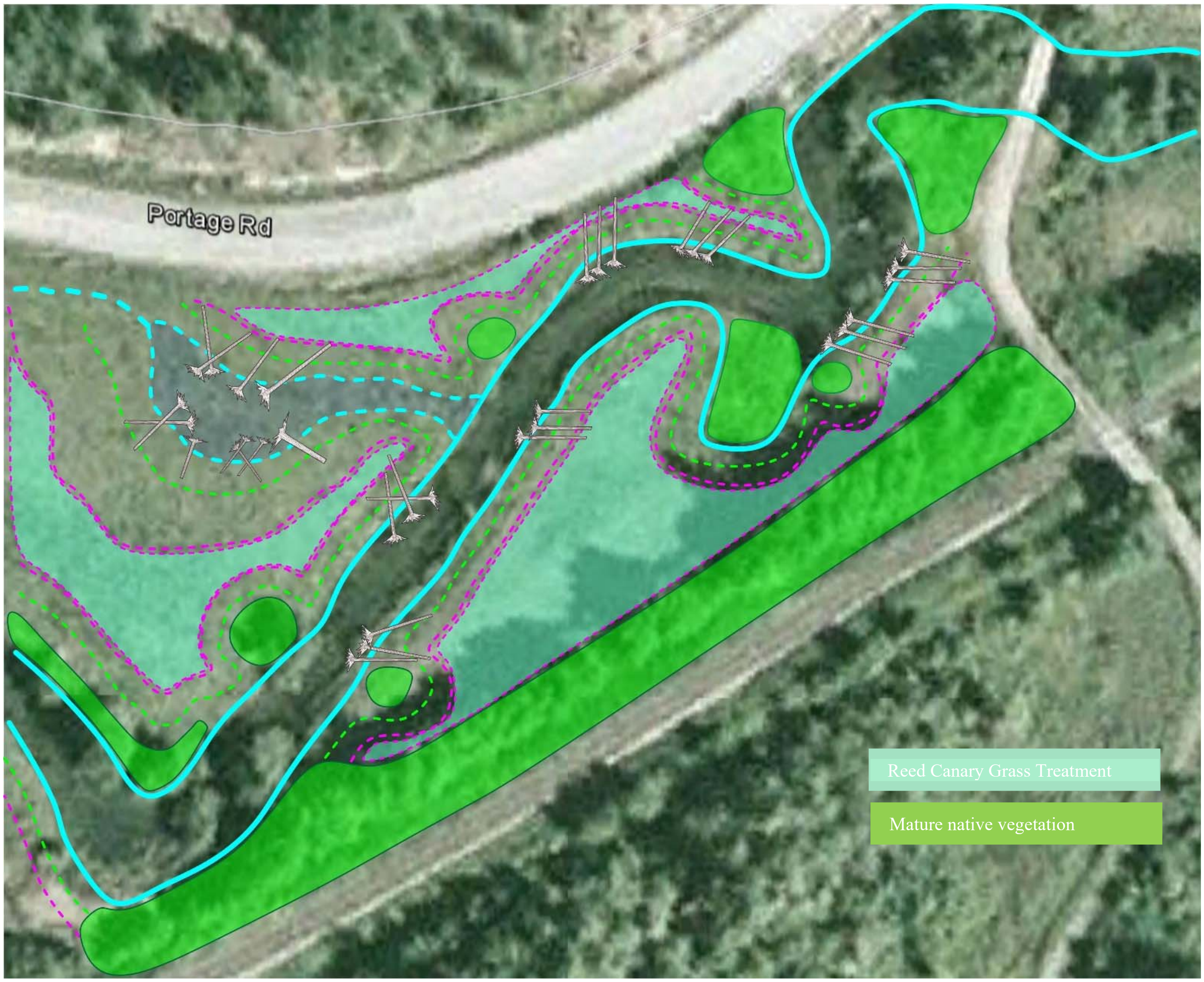

Figure 27. Overview of proposed restoration measures at 9523 Portage Road Solid blue lines indicate Gates Creek Top of Bank (TOB). Dashed blue line indicates proposed off-channel habitat. Dashed green line indicates approximate limit of vegetation stripping at TOB. Dashed purple line infilled with mint-green shading indicates approximate limit of reed canary grass treatment. Bright-green shading indicates area of mature native riparian vegetation to be retained.

4.1.1 Fish and Riparian habitat

Proposed fish habitat restoration measures include modifying the riparian zone to suppress the existing reed canary grass and re-planting with cuttings from native species. In the channel, clusters of large woody debris (LWD, Appendix 2, Figure A2-1) will be installed at strategic locations along the bank. The diameter of LWD would fall roughly between 20 and 50 cm to provide instream cover and scour pool areas for Coho Salmon as well as Bull Trout juveniles and adults. LWD would be partially buried in the bank and anchored with cables to ballast rock (Figure 2). Additional anchoring would be provided by using larger diameter cuttings (5 -10 cm) around the wood structure (Figures A3-1, A3-2 and A3-3).

An off-channel area has also been proposed to intersect with the unmapped drainage coming from Portage Road. Once excavated, this area will also be complexed with LWD in 15 m cells. The target depth of the off-channel area would be 0.5-1.5 m. The channel target length would be approximately 60 m. This would be a low flow channel targeting Coho Salmon rearing and overwintering (Sandercock 1991; Slaney and Zaldokas 1997). After the installation of LWD, the areas along the bank will be planted with cuttings as described in section 2.2.1 and 2.2.2.

After the initial phase of LWD installation and off-channel habitat building, the treatment of reed canary grass could be repeated for the entire section of the property between the rail line and Portage Road (Figure 27). An example of project design, including preliminary construction specifications and sequencing are provided in Appendix 2 for 9523 Portage Road.

4.1.2 Project Costs

The proposed project would be undertaken in several phases to treat all wetland habitat affected by reed canary grass. The first phase would focus on the 150 m long section of Gates Creek (shown in Figure 24) and include using an excavator to create the off-channel habitat and strip a 3 m section along the bank of Gates Creek to permit installation of LWD structures. Once LWD and off-channel habitat are in place, treatment of the reed canary grass in the remaining area between Portage Road and the rail line would be undertaken.

Approximate costs for the reed canary grass treatment include excavator time as well as cutting preparation and planting. Excavator time is roughly $1,200 per day. An estimate of 1800 m^2 of grass can be flipped per day (approximately $ 0.66 m^2). Cost per cutting (installed) is estimated to be $2. A rate of 6 cuttings per m^2 are proposed; therefore cost, per m^2 is estimated at $12.00. Total cost per unit area is estimated to be $12.66 per m^2 or approximately $120,000 per hectare.

The installation of LWD and building of off-channel habitat and treatment of surrounding vegetation would cost approximately $150,000 for the purposed 150 m section (Table 1).

The remaining lowland portion of the property and banks of Gates Creek would also could also benefit from treatment of the reed canary grass. The lowland portion of 9523 Portage Road is approximately 2 ha. Of the total lowland area roughly 1.8 hectares of reed canary grass would require treatment in phase 2 of the project. To apply the $120,000 ha cost of the reed canary grass treatment and staking treatment of the entire wetland area is expected to cost between $225,000 and $275,000.

Total estimated costs to restore the riparian and wetland habitat and enhance instream fish habitat at 9523 Portage Road fall in the range of $400,000-$500,000.

Costs are uncertain due to several uncertain estimates:

- Engineering cost for bridge assessment and requirements for other design components (*e.g.,*, LWD anchoring),
- Traffic control costs for material deliveries along Portage Road,
- Availability and cost to acquire, and deliver LWD,
- Additional costs for alternate access (*i.e.,* from CN track) if the bridge is deemed unsuitable for machine access or material deliveries.

The above estimate does not include costs for pre-and/or post construction fish abundance surveys, or post construction surveys to monitor physical stability, and riparian survival. Monitoring of cutting survival, re-establishment of grasses, fish colonization and use of sites, as well as structure stability is suggested for at least two to three years post construction.

Table 1. Estimate of approximate cost break down for phase 1 of purposed restoration activities at 9523 Portage Road

Expense	**Description**	**Estimated Cost**
Professional Fees	Project planning, permitting, reporting, project design.	$15,000
Labour	Includes collecting and installing cuttings, site preparation	$40,000
Accommodation costs	Per diems, accommodation	$20,000
Engineer Assessment	Preparation of drawings and bridge assessment	$5,500
Excavator	Digging channels, excavating reed canary grass	$25,000
Materials	Chain saw, LWD, post augers, tools, water pump and hose, erosion control fencing	$25,000
Traffic Control	Flagging and signage	$3,200
Transportation	Mileage and/or vehicle rental	$4,000

4.2 9484 Portage Road

4.2.1 Fish and Riparian Habitat

The conceptual restoration plan developed as part of this assessment for 9484 Portage Road would include expanding accessible off-channel habitat and creating conditions to accelerate natural recovery of native vegetation (Figure 28). Protection of existing high-value wetland habitat located in the south west corner of the property during restoration should also be an important aspect of project planning.

Coho Salmon as well as multiple species of wildlife would benefit from this project. The conceptual design for the off-channel habitat would include re-establishing a more natural drainage pattern (*i.e.,* across the valley rather than along the CN track). To accomplish this, a series of fish accessible wetland ponds would be excavated around the property with drainage channels to collect and store water (Figure 28). Depth and width of ponds and connecting channels will be dictated by the amount of available water to supply the wetland with sufficient flow for aeration. However, the proposed target width of the channels would be 3 - 5 metres of wetted with. Target wetted depth of the connecting channels would be 0.5 m. Target depth of the ponds would be 1.5 m deep. Single log (20 - 50 cm diameter) and rootward

LWD structures will be installed in ponds to provide instream cover. LWD would be partially buried in the bank for anchoring. Due to low flow nature of the channels and ponds, no ballast rocks would be required for anchoring. The excavation of wetland ponds would also serve to reduce areas of reed canary grass, and create soil mounds, which would then be planted with native cuttings or seed to accelerate the natural succession of these areas back to forested habitat.

A major challenge of this project will be designing to manage potential beaver dam building activity. Building sections of the wetland complex greater than 1 m in depth may aid in deterring dam building by providing suitable habitat for beaver lodges (Hartman and Tornlov 2006). Planting of less palatable species to beavers in the riparian area may also serve to reduce beaver dam building (e.g., cascara or twinberry) (Washington Department of Wildlife); however, many of the species listed as less preferred by beavers do not grow in the interior climatic zone around Gates Creek. Some restoration professionals, in the nearby Bridge River watershed, have found red-osier dogwood to be less favorable to beavers (Kim North pers.comm.). Consultation with a specialist in beaver ecology is recommended during project development to ensure the project would not result in additional flooding concerns for the CN rail line.

As noted this a conceptual plan, and any final design should also consider the need to retain access to the BCH transmission towers for maintenance. In addition, it may also be advisable to incorporate an access route to the Gates Creek channel during project planning should air photos identify suitable options for future projects in Gates Creek. N'Quatqua First Nation has also expressed interest in having a pedestrian access route to IR4 on the south bank of Gate Creek (Harry O'donaghey pers. Comm). However, due to the bear activity on the property wider public access would not be advisable.

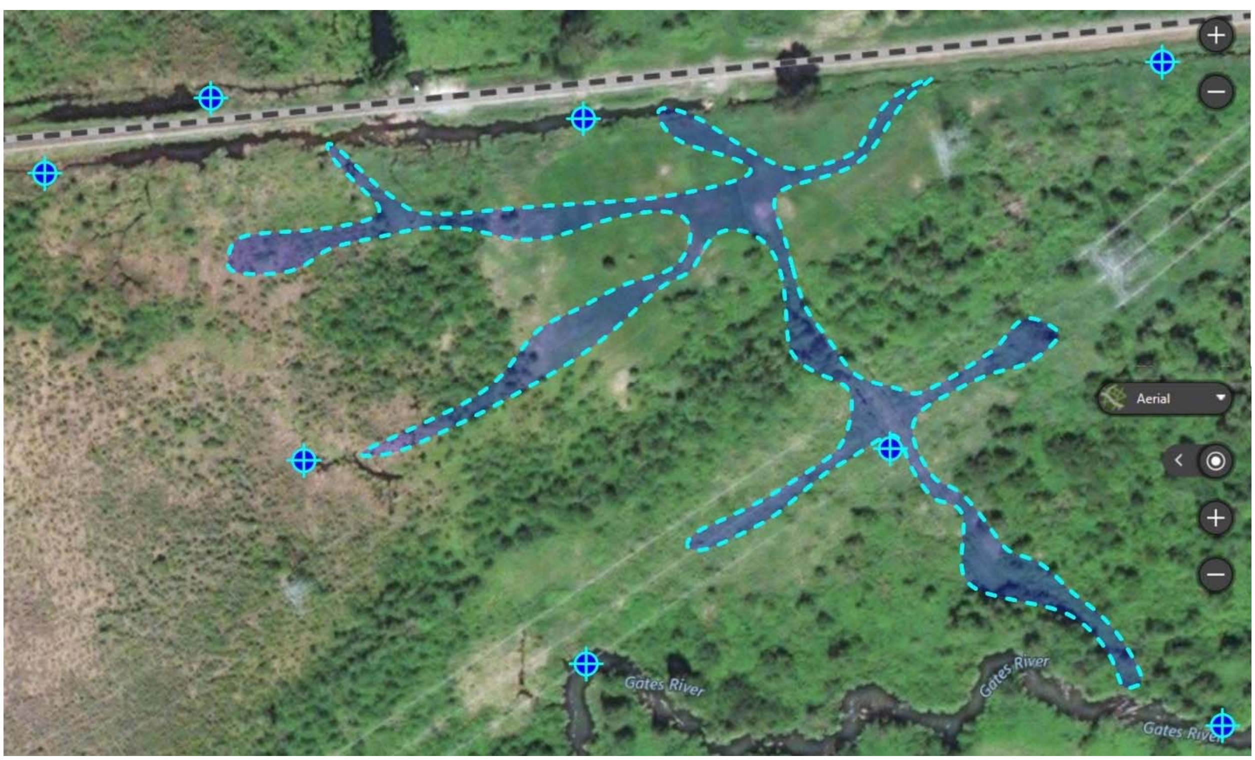

Figure 28. Overview of 9484 Portage Road restoration concept. Blue cross-hairs indicate recommended areas for collection of elevation data. Channel and Pond target wetted depth will be 0.5-1.5 m. Target wetted widths will be will be 3 m – 5 m.

4.2.2 Estimated Costs

Although a conceptual design was developed as part of this assessment (Figure 28), project costs and construction sequencing have not been determined for this project as there are uncertainties regarding project feasibility. Elevation data is required to determine target channel and pond depths required to ensure excavated areas will provide water storage and increase wetted off-channel habitat without lowering water levels in Gates Creek and adjacent wetlands. Elevation data at each location should include, but not necessarily be limited to, ground and water surface elevations, as well as water depth at the time of the survey. In addition to elevation data, current high resolution aerial imagery is recommended for project planning at this location to ensure protection of existing wetlands and vegetation. Estimated costs of surveying are $10,000. Aerial photography for 9484 Portage Road and Young John Creek wetland, discussed in the following sections, are estimated to be $10,000.

Due to uncertainties surrounding project feasibility, itemized costing of the project is not provided. However, the area of interest for this project is approximately 4 ha in size and the costs for similar prescriptions at 9523 Portage Road can be used to ball park estimate costs. Reed canary-grass treatment and construction of fish accessible wetland ponds will likely cost in the range of $300,000 to $600,000 (based on the area and costs for similar project type and size at 9523 Portage Road). Additional monitoring of the property after construction would be required to assess beaver activity and address potential risks of flooding to the CN rail line.

4.3 Blackwater Creek

4.3.1 Fish Habitat

Observations and field measurements for this assessment indicate the three culverts surveyed do not meet the criteria for passage of salmonids. Although it may be possible for adults to navigate some of the culverts under conditions other than those observed (*i.e.,* higher stage), consistent fish access seems unlikely considering the observed jump height to pool depth ratios, culvert slope, water velocity and sheet flow conditions.

Restoring fish passage at these crossings would restore fish access to an estimated 8 linear kilometers of channel in Blackwater Creek (~12,000 m^2 based on an average wetted width of 1.5 m). Rainbow Trout have been documented in the Fisheries Information Summary System (FISS) and there are historical accounts of resident rainbow trout in Blackwater Creek (Harry O'Donaghey pers. comm).

9690 Portage Road

The Portage Road culvert crossing of Blackwater Creek, did appear to meet fish passage criteria; however, the six weirs constructed downstream of the crossing did not. Jump heights were too high for juvenile salmonids[8] and pool depth to jump height ratios indicated the weirs were also an obstruction to adult migration.

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[8]Jump heights for 50 mm to 130 mm juveniles approximately 0.3 to 0.6 m (some variances by species),

"the ability to jump a vertical obstacle is also related to the depth of water from which a fish can leap. A pool depth of at least 1.25 times the height of the obstacle provides for ideal leaping conditions".

To improve fish passage for all life stages of salmonids the following criteria should be met (Whyte *et. al.*, 1997):

- Culvert velocities should be reduced to 0.3 m/sec, or less,
- Weir jump heights should be reduced to 30 cm (0.3 m) or less,
- Pool depth should be increased to at least 1.25 times the jump height (*e.g.,* for 30 cm jump height, the minimum pool depth should be 37.5 cm).

Field measurements indicate a 4 m change in elevation within 28 m of the culvert outfall, before the stream gradient decreases. To meet the recommended criteria for fish passage, a total of 13 to 14 weirs are recommended at a spacing of approximately 2.1 m within this distance (Figure 29). In addition, it is also recommended the concrete curbs used in construction of the existing weirs be removed and replaced with boulders. Boulder weirs provide a more natural alternative for habitat restoration and would increase hydraulic diversity within the channel. The proposed design would improve fish passage by creating resting areas for fish and natural scour areas to maintain adequate pool depths. The cost to modify the weirs to improve fish passage has been estimated at approximately $70,000 (Table 2).

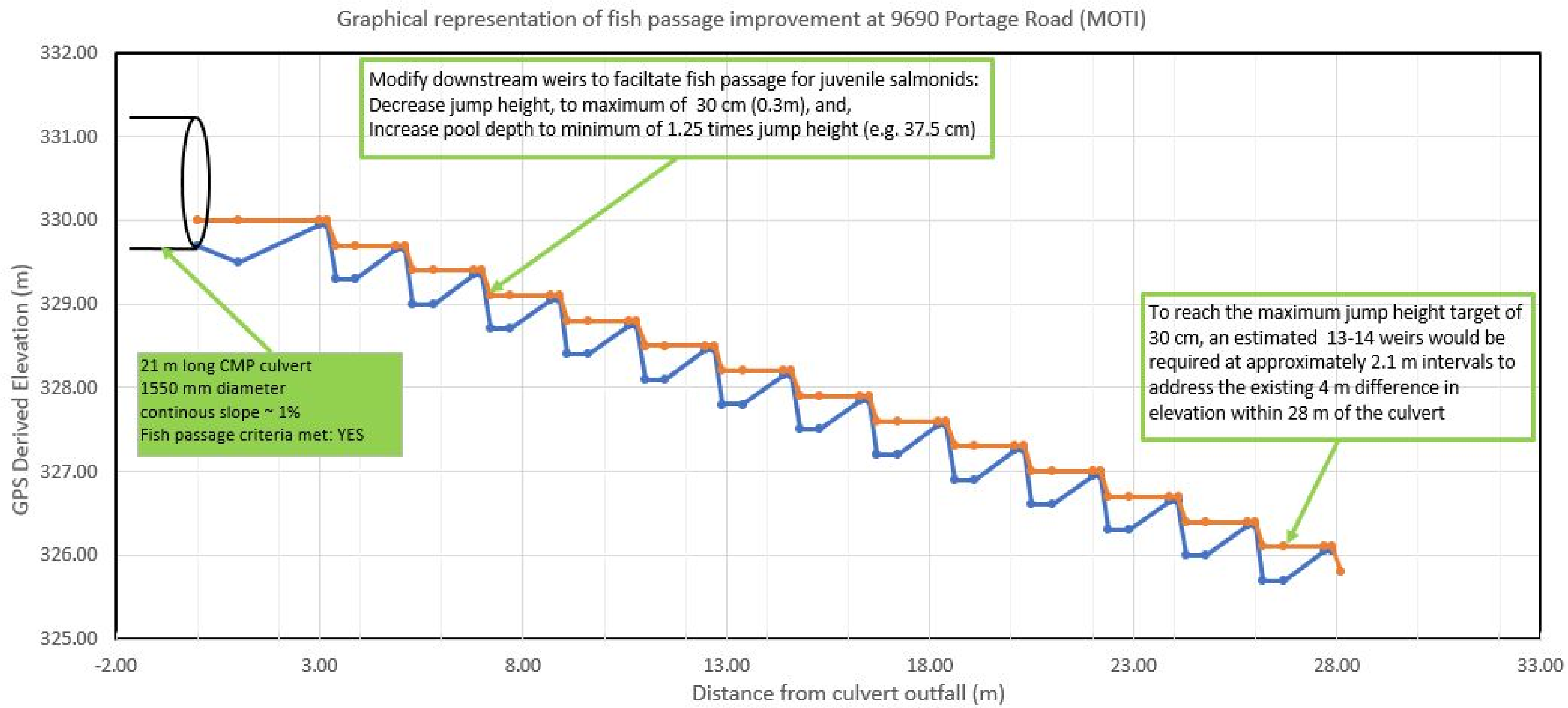

Figure 29. Recommended weir configuration to provide fish passage for all life stages

BC Hydro transmission line Right Of Way (RoW)

The BCH transmission line RoW culvert crossing of Blackwater Creek, did not meet fish passage criteria, and the three weirs constructed downstream of the crossing were also identified as an obstruction to fish passage. Water velocity in the culvert as well as jump heights were too high for juvenile salmonids[9]. Pool depth to jump height ratios were also identified as an obstruction to migration for all age classes of fish. To reduce culvert velocities for fish passage, the existing culvert would need to be modified to reduce slope, and this may require replacing it with a larger diameter structure.

Field measurements indicate a 2 m change in elevation within 22 m of the culvert outfall before the stream gradient decreases. To meet the recommended criteria for fish passage, described in the above section for 9690 Portage Road, at total of 7 weirs, at 3.1 m intervals are recommended within this distance. In addition, it is recommended the concrete curbs used in construction of the existing weirs be removed and replaced with boulders to provide hydraulic heterogeneity. The cost to replace the existing culvert and modify the weirs has been estimated at approximately $90,000 (Table 2).

3465 Blackwater Road – private driveway

The private driveway crossing of Blackwater Creek also did not meet fish passage criteria. This site differs from the other two road crossings of Blackwater Creek in that no weirs upstream or downstream of this culvert affect fish passage. Culvert conditions at this site (*i.e.,* slope, water depth and water velocity) were identified as an obstruction to all life stages of salmonids.

To improve fish passage for all life stages culvert velocities must be reduced to less than 0.3 m/sec (Whyte *et. al.*, 1999). The existing outfall drop should also be eliminated. To reduce culvert velocities for fish passage, the slope of the culvert will must be reduced which will likely require an upgrade to a larger diameter structure. The cost to replace the existing culvert has been estimated at approximately $65,000 (Table 2).

4.3.2 Estimated Costs

The total cost for all three crossings is estimated to be approximately $226,000 (Table 2). Construction specifications are not provided due to the unknown interest by owners of each crossing in moving forward with fish access upgrades. Construction specifications are not provided due to the unknown interest by owners of each crossing in moving forward with the recommended fish access upgrades. While all three crossings need to be addressed to restore watershed connectivity, improvements to fish passage at a single crossing of Blackwater Creek should not be discouraged. As fish passage is improved at each crossing, it increases the value of addressing fish passage problems with the remaining structures. Furthermore, a phased approach (e.g., modifying one crossing per year), could allow for iterative learning on project design and implementation.

Table 2. Simple breakdown of costs for repairing three fish passage structures on Blackwater Creek

	Description	Portage Road	BC Hydro RoW	Private Drive
Machinery	Dump truck, excavator, low bed	$ 15,000	$ 15,000	$7,800
Professional fees	Planning, permitting, project design and reporting	$ 12,800	$ 12,000	$8,600

[9]Jump heights for 50 mm to 130 mm juveniles approximately 0.3 to 0.6 m (some variances by species),

"the ability to jump a vertical obstacle is also related to the depth of water from which a fish can leap. A pool depth of at least 1.25 times the height of the obstacle provides for ideal leaping conditions".

Labour	Fish salvage, restoration planting, reporting	$ 11,000	$ 10,000	$5,500
Accommodation		$ 8,000	$ 8,000	$3,000
Per diems		$ 5,000	$ 5,000	$3,000
Materials	Culvert, tools, erosion control fencing, weir components	$ 2,000	$ 24,000	$22,000
Dewatering	Isolating site for safe work	$ 10,000	$ 10,000	$10,000
Engineer fees	Approval of design and drawings	$ 1,600	$ 6,400	$3,200
Traffic control	Flagging and signage	$ 4,800	$ 1,600	$800
Approximate Total Cost		**$ 70,200**	**$ 92,000**	**$ 63,900**

4.4 Young John Creek Wetland

4.4.1 Fish Habitat

To best evaluate restoration opportunities and develop prescriptions it is recommended high resolution aerial photographs (*e.g.*, 3-10 cm pixel imagery) be collected of the Young John Creek wetland complex. Aerial photography would provide valuable information about channel connectivity, and opportunities for connecting or expanding the channel network. In addition, precise water surface elevation data (*i.e.*, +/- 1 cm accuracy) should be collected at numerous locations to evaluate relationships between channels in the wetland, and what the implications or benefits might be of channel and/or water elevation modifications (Figure 30). Additional information is also needed regarding land ownership surrounding the area to determine what partnerships are required to facilitate enhancement work in this area. At least one landowner (Harry O'Donaghey) is interested in undertaking habitat restoration in this area.

Enhancement/restoration opportunities in the wetland complex itself include but may not be limited to:

- Channel modifications to increase depth and/or improve connectivity within the wetland
- Installation of habitat cover structures (*e.g.*, LWD) such as logs with root wads as described in section 2.2.1)
- Riparian planting to increase shade and overhead cover (red-osier dogwood, willow, balsam poplar).
- Improving culverts associated with the wetland complex
- Adding substrate for spawning and rearing (*i.e.*, gravel and cobble).

Figure 30.Young John Wetland – blue cross hairs indicate recommended areas for collection of elevation data

4.4.3 Estimated Costs

A cost estimate to complete habitat restoration work at Young John Creek was not completed as part of this assessment due to the information gaps identified, and subsequent uncertainties about project feasibility. Aerial photographs and elevations of land and water surfaces are required for next steps of project planning. Estimated costs for additional data collection for Young John Creek and 9484 Portage Road are estimated to be $20,000.

4.5 Debris Flow at 9282 Portage Road

4.5.1 Fish Habitat

No fish habitat prescriptions are recommended for this area. Gates Creek, through natural high-water events, has transported sediment that may have entered the stream out of this area and the channel appears natural with no extensive sediment wedges. No barriers to fish passage were present or debris jams which might cause erosion concerns were observed during the survey.

4.5.2 Riparian and Upland Habitat

The smooth and compacted areas at the 9282 Portage Road debris fan could be treated through machine loosening of the soil and addition of woody debris for bird perches. The objective of the soil loosening is to decrease sediment raindsplash and thereby reduce transport of mobilized sediment into Gates Creek, as well as increase the rate of successional plant community establishment.

4.5.3 Estimated Costs

Approximately 4.5 hours of machine time are required per hectare (10,000 m^2) of soil roughening treatment. At a rate of $1,200 per day for machine time this results in an approximate cost of $675 per hectare ($0.675 per m^2). The property is approximately 1.5 hectares in size equating to an approximate cost of $1,200 in machine time. There would be additional costs of approximately $4,000 for permitting, professional service fees, traffic control. In total costs to loosen the soil and place or redistribute existing woody debris will likely fall between $5,000 to $7,000.

4.6 Off-channel Beaver Ponds

4.6.1 Fish Habitat

The visual survey conducted for this assessment indicated the off-channel beaver pond habitat near the confluence with Anderson Lake is functioning to provide rearing habitat for juvenile fish. No habitat enhancement is proposed at this time.

4.7 Fish Passage at Gates Creek Spawning Channel

As previously noted in Section 3.7, no modifications to either of the riffles associated with operation of the Sockeye Salmon spawning channel are proposed in this report due to potential impacts on the spawning channel functionality.

However, juvenile fish passage through the riffles is an uncertainty that should be evaluated and monitored. It is possible juvenile Coho Salmon, Rainbow Trout and Bull Trout move downstream during high discharge events and are unable to migrate back upstream to preferred rearing habitat. Rearing habitat is limited below the spawning channel riffles and survival of salmonids rearing in Gates Creek may be affected by the lack of access to upstream habitats. Therefore, enhancing habitat downstream of the riffles or improving fish passage at the riffles should be future considerations for DFO and N'Quatqua Fisheries.

4.8 Off-channel Habitat at the Gates Creek Sockeye Spawning Channel

4.8.1 Fish Habitat

No modifications to the high flow side channel along the right (southeast) margin of Gates Creek downstream of the spawning channel intake are proposed at this time. Uncertainties remain regarding the stability and value of enhancing the channel and the potential to draw groundwater away from the spawning channel. Given the potential impacts on local channel morphology and proximity to residential structures, hydrological survey and modelling should be undertaken before considering channel alterations within this area.

4.9 Gates Creek Near D'Arcy

4.9.1 Fish Habitat

No habitat enhancement plans were developed for the D'Arcy property. Consultation with DFO engineers is required to evaluate potential for habitat restoration options that would benefit both fish and the landowners desire to protect the bridge crossing.

The most promising enhancement potential identified by this assessment at the D'Arcy property was the 200 m long relic channel area along the river-right (east) margin of Gates Creek. This area could potentially be excavated to create perennial off-channel habitat. However, preliminary calculations suggest it would be necessary to remove 4,000 to 5,000 cubic metres of material to create a 5 m wide wetted channel. The costs to remove and dispose of such a large volume of material may prove prohibitively expensive. Observations along Haylmore Creek also indicated sub-surface flow in this area of the valley are poor. Furthermore, channel gradient and confinement as well as the presence of linear transportation infrastructure on the opposing bank present additional challenges to restoration. Despite challenges identified from during this survey, the interest of the landowner in partnering in restoration is highly valuable. Therefore, the availability of ground water may be worth investigating further by hydrological experts and DFO restoration experts.

Haylmore Creek

This assessment did not identify any enhancement/restoration opportunities for Haylmore Creek. Field observations indicated the channel, in the area surveyed, is unstable and subject to changes in morphology. The channel appeared to be natural, had functional mature riparian forest and ample natural fish habitat. Observations indicated the area has poor sub-surface flow conditions that would limited the feasibility of excavating of off-channel habitat. In combination, these factors indicated off-channel habitat enhancement is unlikely to be beneficial to this stream.

4.9.2 Estimated Costs

No costs were estimated for off-channel habitat construction at the property near D'Arcy at this time. This area could provide a viable opportunity for constructing off-channel habitat; however, assessment by DFO restoration staff as well as further information gathering is required to evaluate the feasibility of projects. Next steps for this property would involve consultation with DFO resource restoration staff as well as collection of ground water elevations and sub-surface flow volumes by hydrological experts.

5.0 Discussion and Next Steps

5.1 Priority Setting

This analysis has typically followed a limiting factor approach to restoration planning. However, all proposed projects will affect ecosystem processes in Gates Creek. For example, restoring riparian vegetation will improve water quality, and primary productivity of the watershed through the filtration of run off through root systems and addition of organic nutrients from leaf litter (Wallace et al., 1997). Roughening soils and aiding in the natural succession of vegetation at 9282 Portage Road would be expected to reduce suspended sediments entering Gates Creek during rain events.

A total of six potential restoration projects were identified for the Gates Creek watershed. Each project has unique challenges and benefits associated with the proposed treatments. To prioritize projects in the watershed, we evaluated projects based on:

1. Landowner interest in restoration
2. Potential gain in ecological health
3. Ease of access
4. Risk Factors
    a. CN
    b. Road

c. Private infrastructure

5. Ability to engage public

Each criterion had a possible score of 1 to 5. Criteria 4 (Risk factors) was given negative scores (-1 to -5) as they complicate the feasibility of a project. The project with the highest score was determined to be of highest priority (Table 3). While cost is an important factor in project feasibility and can be prohibitive, costs were not included in this ranking due to the unknown cost of multiple projects included in the assessment. Scores were assigned subjectively based on the opinion of the survey team.

Table 3. Rating of priority of prescribed restoration projects for Gates Creek watershed.

Project	Landowner interest	Ease of Access	Potential Ecological Gain	Risk factor	Ability to Engage Public	Score
9523 Portage Road	5	4	5	-1	2	15
9484 Portage Road	5	2	5	-3	0	9
Blackwater Creek	0 (unknown)	5	5	0	3	13
Young John Creek	3	3	2	0	4	12
Gates Creek near D'Arcy	3	5	0 (feasibility unknown)	-2	5	10
9282 Portage	0 (unknown)	5	3	0	2	9

Based on this analysis, the highest priority project was 9523 Portage Road (Table 3). Access to Gates Creek is possible by both the CN rail line and Portage Road. Potential ecological value was considered high. Bull Trout adults are often observed in the pool at 9523 Portage, and the addition of instream and overstream cover would increase the quality of habitat. The proposed project would also create new habitat for Coho Salmon juveniles. In addition, the slow water off-channel habitat would benefit aquatic birds, amphibians and invertebrates. Replanting the site with native shrubs will provide habitat for multiple species of wildlife. In addition, the project includes an option for public engagement, though the creation of a small interpretive area in the existing drive way, also exists due to the proximity to Portage Road.

The second highest priority project is improving fish passage in Blackwater Creek (Table 3). For a modest financial investment, connectivity to the 8 km of natural habitat in Blackwater Creek can be restored for fish in Gates Creek. Although Blackwater Creek is a high gradient tributary, no natural barriers were found between the three crossings proposed. While this stream is not known to be used by Coho Salmon or Bull Trout, providing fish access through out natural watersheds is essential to restoring proper ecosystem function. Furthermore, it is unknown how long Blackwater Creek has been inaccessible to salmonids. Visual observations indicate Blackwater Creek has characteristics of a stream that would support stream resident Bull Trout and the creek is known to support populations of resident Rainbow Trout. The potential for public engagement is moderate. At least one crossing on private land would require securing landowner co-operation. Engaging with BC Hydro and the Ministry of Transport and Infrastructure will also be necessary for project success.

The remaining projects in the Young John Creek wetland and 9484 Portage Road require further data collection. As mentioned, elevation data is required to assess project feasibility, and aerial photographs are recommended to better plan the project and assess connectivity between water bodies in both areas. Total costs for aerial photography and surveying for both these properties is expected to be roughly $20,000. In addition, aerial photography could easily be expanded to a larger area of the watershed for a relatively small incremental increase in cost. This small cost increase would provide substantial benefits to project assessment and planning in opportunities other areas of the watershed.

The Young John Creek wetland provides an interesting opportunity. Both adult and juvenile salmon have been observed using the network of ground water ponds. However, additional cover and appropriate substrate (gravel and cobble) are needed in the ponds and connecting streams. This project could be a relatively cost-effective measure for providing additional rearing and spawning habitat for multiple species of salmon. There is a large potential for public involvement in this project due to its proximity to the community of D'Arcy/ N'Quatqua. At least one landowner is interested in undertaking this project. The ecological benefits of the project are unknown as the degree to which fish use the ponds is not well documented; although, information collected by Hillaby (2012) suggests this area is important to rearing Coho Salmon.

The 9484 Portage Road property is of high priority for further data collection and the next steps of project planning. This property provides a large potential area for the construction of off-channel habitat for fish and wildlife. The existing wet meadow habitat provides additional diversity in this landscape. However, the presence of beavers in the area and proximity to CN rail line are significant challenges to consider in project planning. The soft-terrain and high-water table may also present challenges for machine access. Off-channel habitat is likely to be dammed by beavers in the area. Although beavers may reduce fish access to off-channel habitat, wetland ponds would provide ideal habitat for birds, amphibians and other wildlife. Looking beyond our focus on Coho Salmon and Bull Trout habitat enhancement in this assessment, 9484 Portage Road has significant potential for riparian and flood plain restoration.

Should restoration at 9484 Portage Road be undertaken, it is not recommended that public access in the form of trails or interpretive information areas be included in the site design to protect wildlife. Bear activity is apparent on the portion of the property between the rail line and Portage Road where a derelict orchard continues to produce fruit. However, N'Quatqua First Nation should be consulted regarding project design and access to IR4.

Although not necessarily of high priority, the roughening of soils at 9282 Portage Road is a relatively low effort, cost effective project and that could accelerate the establishment of successional vegetation on the disturbed site. Re-establishment of vegetation on the site may help reduce rainsplash and mobilization of fine sediment into Gates Creek. Additionally, increasing the porosity of the soil in the short term may result in a lower degree of run-off. Land-owner interest in restoration is unknown.

Finally, the property near D'Arcy at the Haylemore Creek- Gates Creek confluence was deemed our lowest priority due to the uncertainty of project feasibility and low water table in the area. However, this project is interesting given the opportunity given the location and available landowner co-operation. Next steps for this site include fostering discussion between the Resource Restoration Unit at the Department of Fisheries and Oceans and the landowners. Evaluations of the possibilities for private infrastructure protection and habitat enhancement from hydrological and engineering specialists will be required at this site.

5.2 Recommendations and Next Steps

The next steps in moving towards habitat restoration in the Gates Creek watershed are to confirm landowner interest and secure partnerships for funding applications.

Should FWCP be interested in moving forward with restoration at 9523 Portage Road, a multi-stakeholder meeting to discuss proposal development would be extremely helpful. Both provincial (Ministry of Forests, Lands and Natural Resources) and federal agencies (Department of Fisheries and Oceans) as well as First Nation stakeholders, and FWCP should be included in project planning and funding proposal development. Other potential funding partners include CN and MOTI.

Partnerships should be developed with all necessary stake holders (Ministry of Environment, BC Hydro, DFO, private landowners, N'Quatqua First Nation) to address fish access in Blackwater Creek and restore watershed connectivity.

Further data collection including aerial photographs as well as land and water surface elevations are recommended as next steps for Young John Creek and 9484 Portage Road. Many of the organizations described above could also benefit from higher resolution aerial photographs in the valley, and all of these organizations should be consulted about potential funding partnerships for aerial photography.

Although not discussed in this report, ownership of some of the properties surrounding D'Arcy Creek has changed since 2012. Therefore, and it may be valuable to re-assess community interest (Harry O'Donaghey pers. comm).

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7.0 Appendix 1- Channel Cross sections measured at 9523 Portage Road

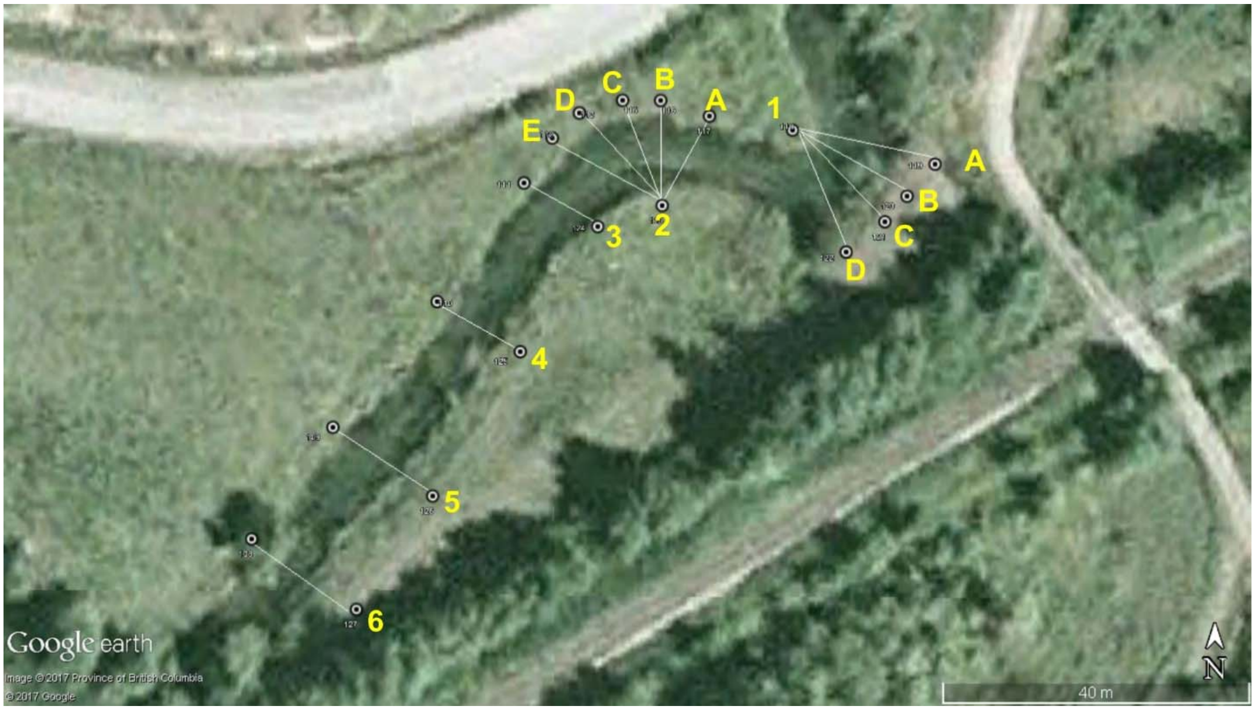
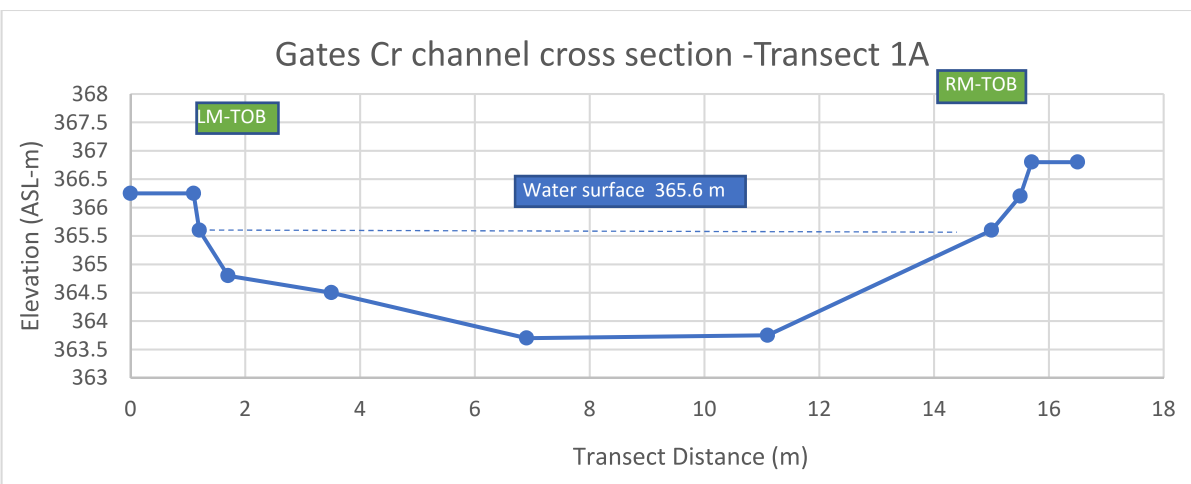
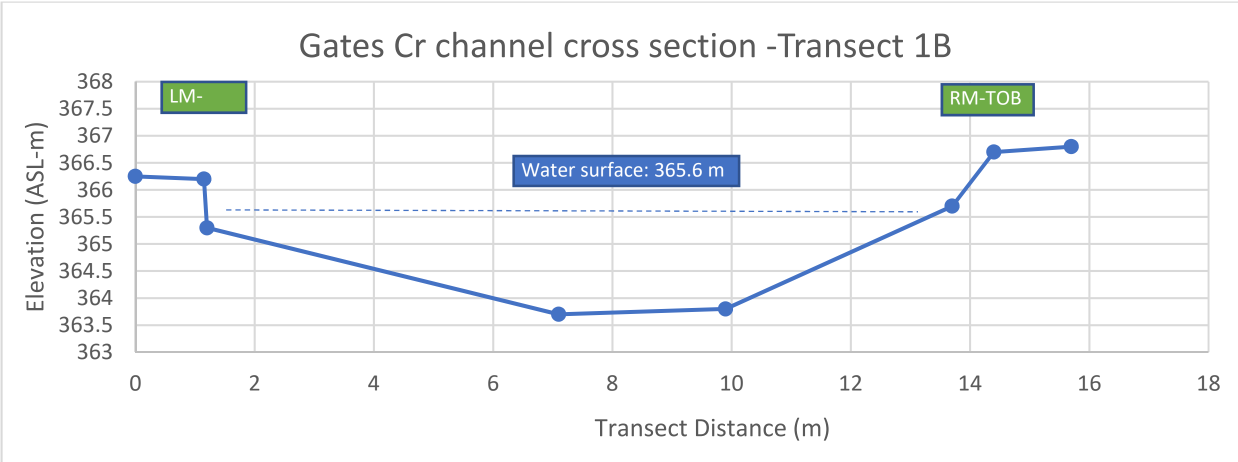
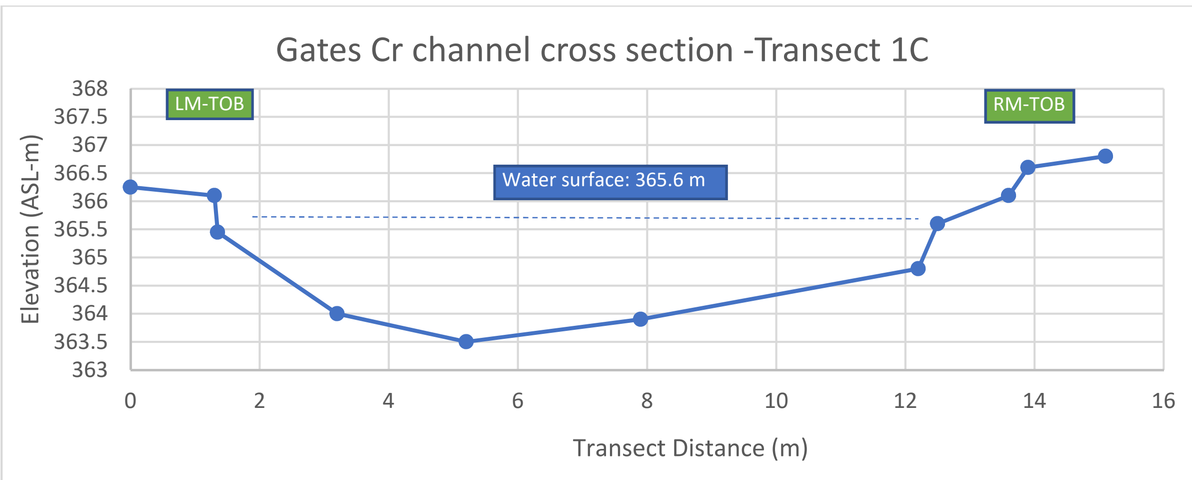
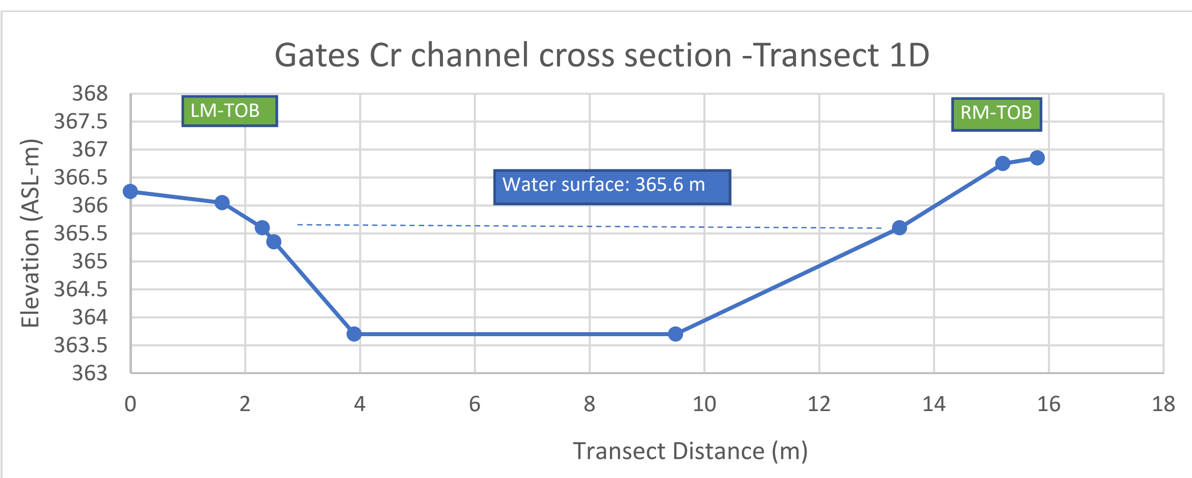


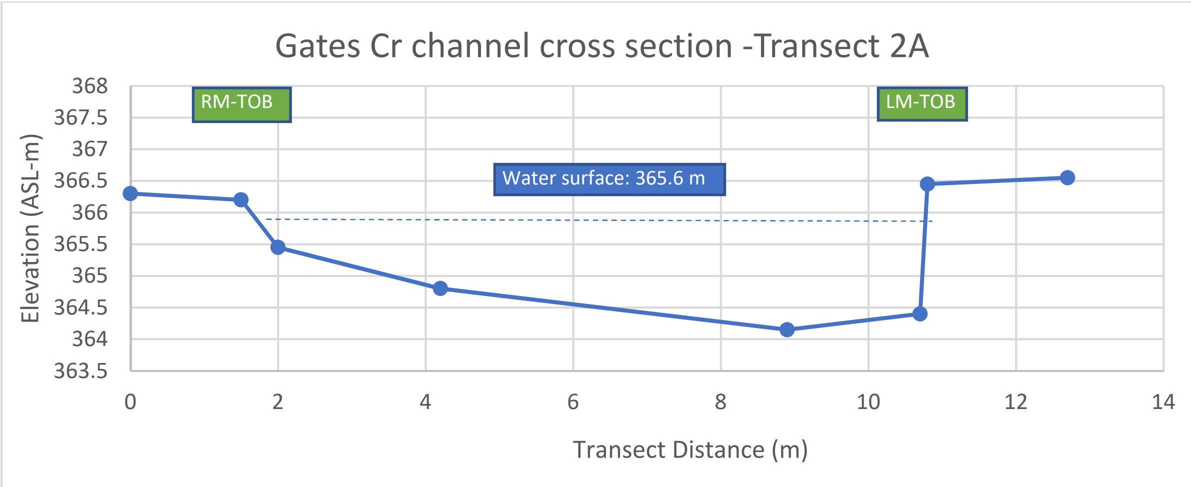
Figure A-1 9523 Portage rd – Transect locations in Gates River

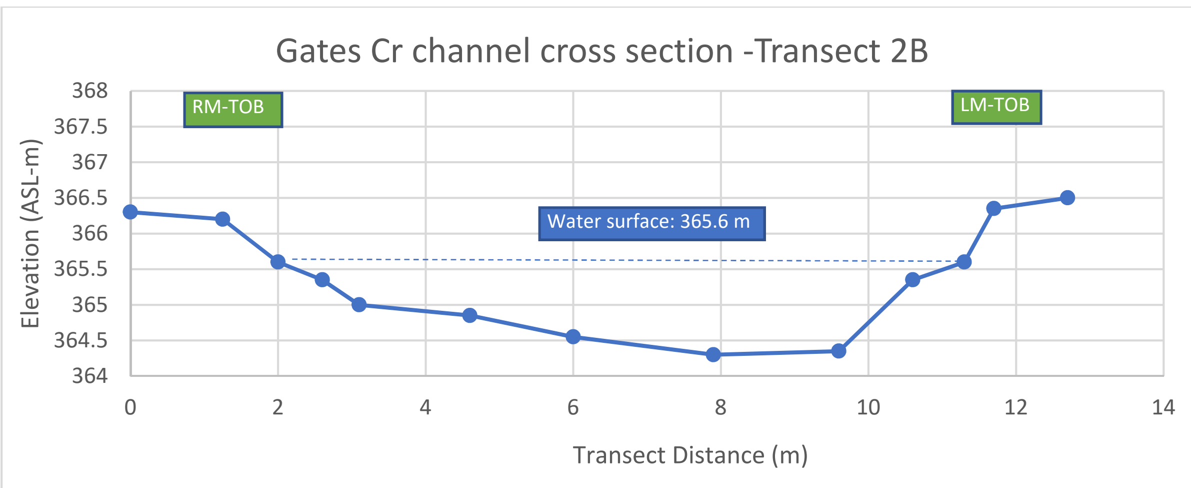


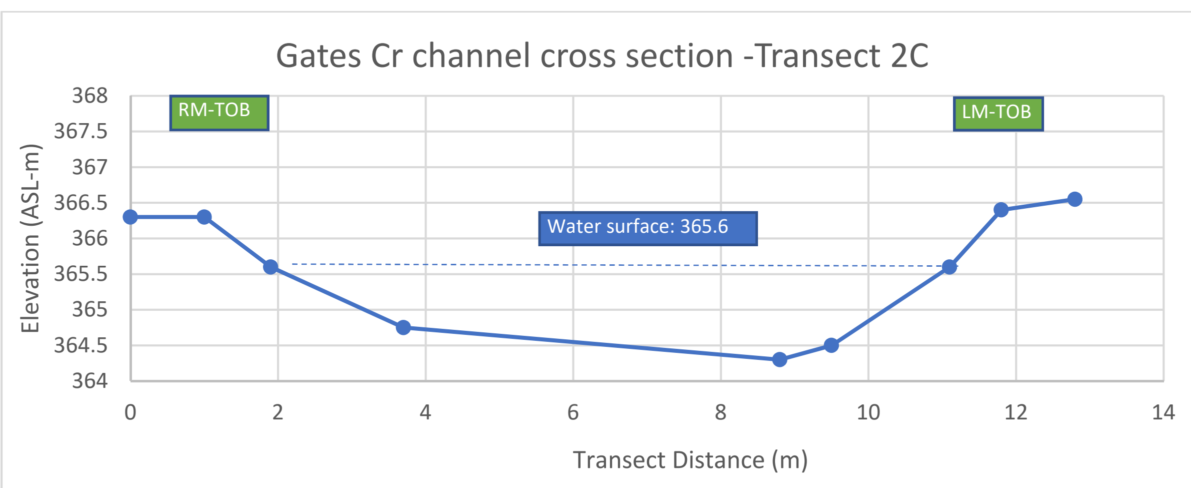

Gates Cr channel cross section -Transect 1B
LM-
RM-TOB
Water surface: 365.6 m
Elevation (ASL-m)
Transect Distance (m)
368
367.5
367
366.5
366
365.5
365
364.5
364
363.5
363
0
2
4
6
8
10
12
14
16
18

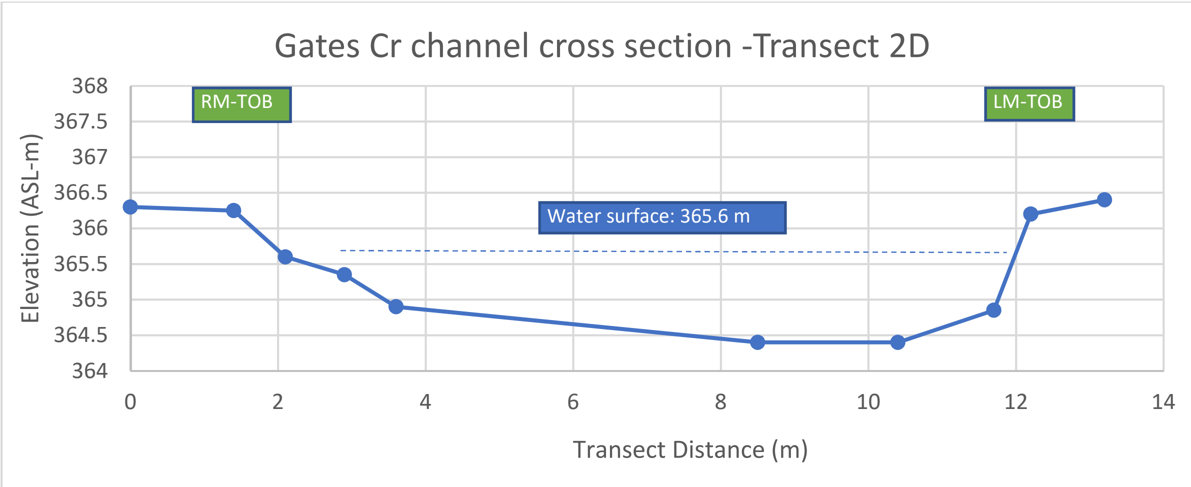

Gates Cr channel cross section -Transect 1C
LM-TOB
RM-TOB
Water surface: 365.6 m
Elevation (ASL-m)
Transect Distance (m)
368
367.5
367
366.5
366
365.5
365
364.5
364
363.5
363
0
2
4
6
8
10
12
14
16

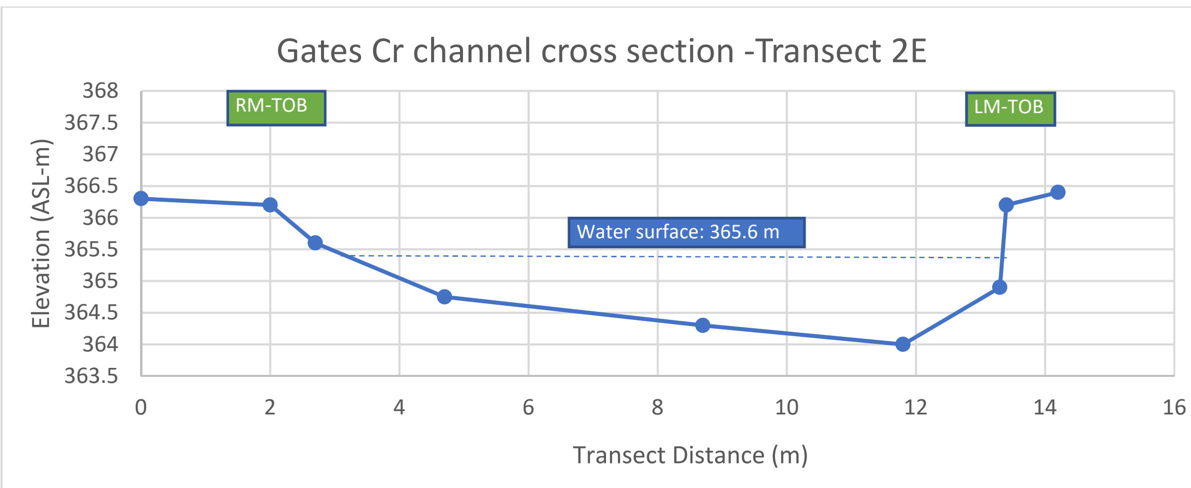

Gates Cr channel cross section -Transect 1D
LM-TOB
RM-TOB
Water surface: 365.6 m
Elevation (ASL-m)
Transect Distance (m)
368
367.5
367
366.5
366
365.5
365
364.5
364
363.5
363
0
2
4
6
8
10
12
14
16
18

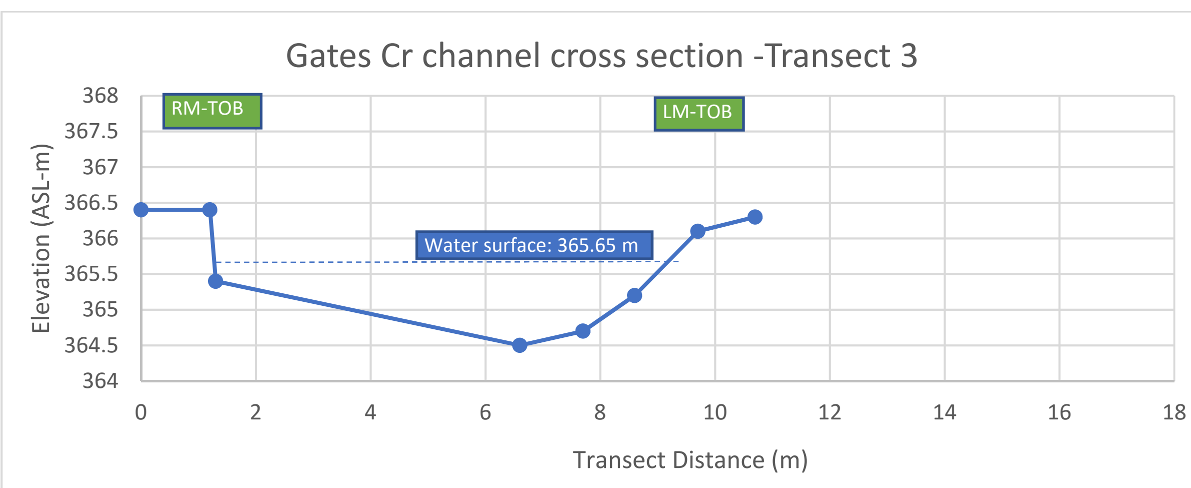

Gates Cr channel cross section -Transect 2A
RM-TOB
LM-TOB
Water surface: 365.6 m
Elevation (ASL-m)
368
367.5
367
366.5
366
365.5
365
364.5
364
363.5
0
2
4
6
8
10
12
14
Transect Distance (m)

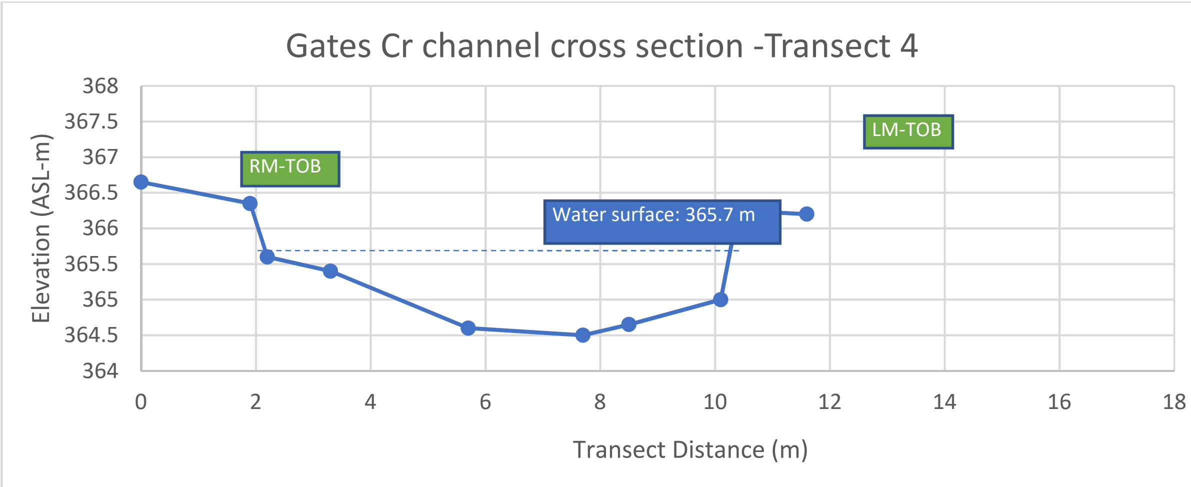

Gates Cr channel cross section -Transect 2B
RM-TOB
LM-TOB
Water surface: 365.6 m
Elevation (ASL-m)
368
367.5
367
366.5
366
365.5
365
364.5
364
0
2
4
6
8
10
12
14
Transect Distance (m)

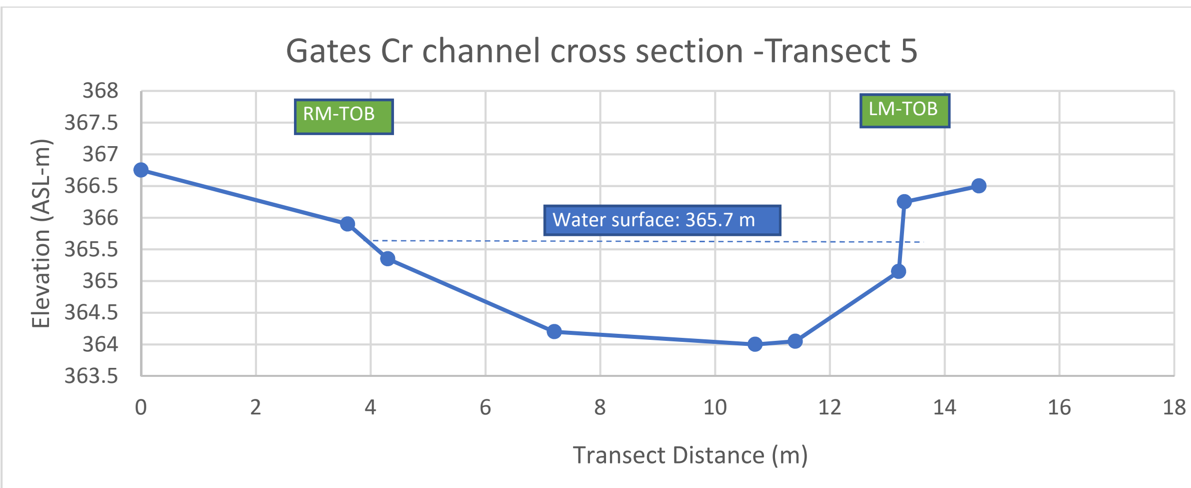

Gates Cr channel cross section -Transect 2C
RM-TOB
LM-TOB
Water surface: 365.6
Elevation (ASL-m)
368
367.5
367
366.5
366
365.5
365
364.5
364
0
2
4
6
8
10
12
14
Transect Distance (m)

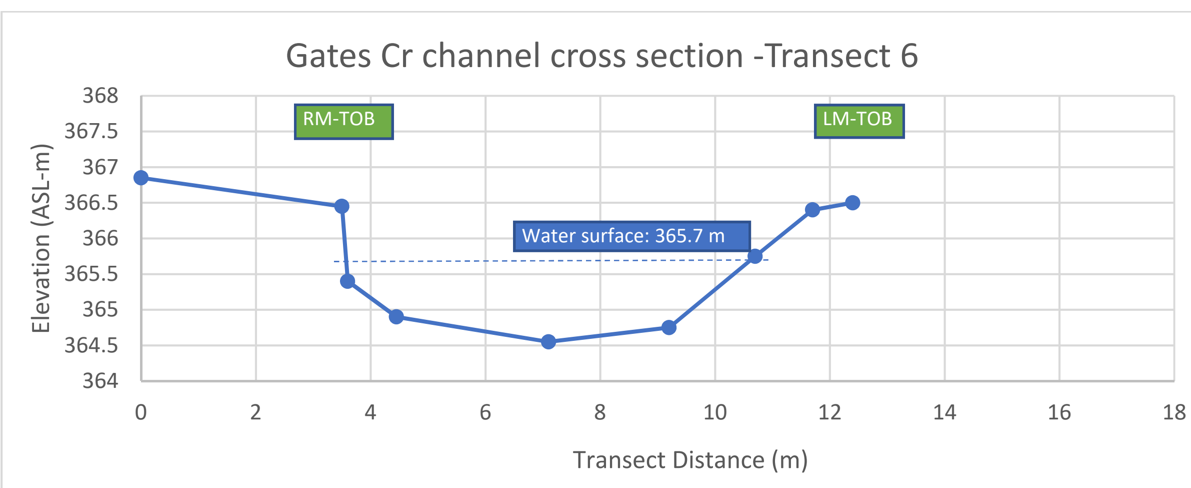

Gates Cr channel cross section -Transect 2D
RM-TOB
LM-TOB
Water surface: 365.6 m
Elevation (ASL-m)
Transect Distance (m)


Gates Cr channel cross section -Transect 2E
RM-TOB
LM-TOB
Water surface: 365.6 m
Elevation (ASL-m)
Transect Distance (m)


Gates Cr channel cross section -Transect 3
RM-TOB
LM-TOB
Water surface: 365.65 m
Elevation (ASL-m)
Transect Distance (m)


Gates Cr channel cross section -Transect 4
368
367.5
367
366.5
366
365.5
365
364.5
364
Elevation (ASL-m)
RM-TOB
LM-TOB
Water surface: 365.7 m
0
2
4
6
8
10
12
14
16
18
Transect Distance (m)


Gates Cr channel cross section -Transect 5
368
367.5
367
366.5
366
365.5
365
364.5
364
363.5
Elevation (ASL-m)
RM-TOB
LM-TOB
Water surface: 365.7 m
0
2
4
6
8
10
12
14
16
18
Transect Distance (m)


Gates Cr channel cross section -Transect 6
368
367.5
367
366.5
366
365.5
365
364.5
364
Elevation (ASL-m)
RM-TOB
LM-TOB
Water surface: 365.7 m
0
2
4
6
8
10
12
14
16
18
Transect Distance (m)

8.0 Appendix 2 -Project specifications and construction sequencing for 9523 Portage Road:

Project planning

PRE-FIELD PLANNING AND PERMITTING (12 - 18 months before construction)

- Conduct site meeting with DFO Resource restoration staff to review conceptual and finalize design details based on feedback/comments.
- Submit application/notification information to regulatory agency for instream work and fish sampling/salvage permits.
- Conduct site meeting with staff from Canadian National Railway Company (CN) and Ministry of Transportation and Infrastructure (MOTI) to discuss proposed project and consider any design concerns from adjacent transportation authorities, and property or right of way boundaries. Review and determine requirements for approvals to access site adjacent properties (if required).
- Conduct spring and fall minnow trapping to evaluate pre-enhancement fish presence in proposed enhancement area.
    - (*e.g.*,, use existing transect stakes and install two traps at each stake, using pre-determined consistent depth (*e.g.*,, 50 cm) for all traps.
    - Consider establishing similar fish presence sampling control station upstream or downstream of enhancement area for future comparison, using same/similar number of traps and depth criteria.
- Conduct engineering assessment of existing to bridge to evaluate feasibility of using bridge for equipment access. If bridge is not acceptable, project will need to establish access partnership with CN.

Habitat Enhancement

Site Preparation (15-30 days before construction):

1. Identify areas of existing native vegetation and mark/protect areas with natural successional regeneration during subsequent stages of construction to maximize bank stability and preserve local seed banking
2. Mow or mechanically cut proposed enhancement areas containing reed canary grass with hand brush cutters to reduce vegetation height and thereby reduce potential for re-growth after stripping and filling.

Stripping – (final timing to be determined)

3. Strip reed canary grass to a depth of 20 cm along 1.5 m wide section from top of Bank (TOB; Figure A3-1) using excavator with clean-up bucket **(NOTE: Actual stripping depth to be reviewed and finalized prior to construction (*e.g.*,, through consultation with DFO Resource restoration) some adjustments may be required depending on specific locations and relative height of bank above low water level (LWL)).**
4. Stripped reed canary grass to be flipped back on itself to cover adjacent areas of similar monoculture reed canary grass (*e.g.*,, area approximately 1.5 to 3.0 m from Top of Bank)
5. Exposed areas stripped of rooted vegetation to be covered with biodegradable erosion control blanket (ECB) or burlap yardage to reduce erosion (*e.g.*,, rainsplash), and shade out re-growth prior to vegetation establishment. Timing of ECB installation should be coordinated with LWD installation in specific locations.

LWD structure installation

Proposed LWD structures to be comprised of conifer tree species (5 - 6 metres long with 20-30 cm diameter)

6. Prior to installation prepare willow and/or poplar cuttings for structure anchoring – cuttings to be minimum length of 1.5 m and 5 cm diameter.
7. Excavate trench at 45 degree slope angle and perpendicular or angled upstream to current.
   a. If necessary remove ECB prior to installing LWD structures
   b. To minimize soil disturbance and improve structure anchoring **trench must be excavated with trenching bucket or other attachment less than 0.5 m wide**.
8. Place LWD stem in trench with rootwad protruding into current.
   a. Rootwads/LWD not to extend more than 33% of LWL channel width (typical LWL channel width 8-10 m).
9. Install minimum of two (2) anchor cuttings across stem approximately 30 cm above LWL, at top of excavated trench, and 1 m from end of stem.
10. Backfill trench and compact soil in lifts during backfill.
11. Re-install or install ECB over buried LWD stem/structure
12. Following installation of LWD structure install typical willow and red osier dogwood cuttings (*e.g.,*, 2-3 cm by 1 m long) at double normal density (*e.g.,*, > 4 stems per sq metre) over top of any buried LWD stems, to maximize anchoring/soil stability with increased stem and root density over structures

Cuttings

Example of specifications for cutting collection and installation adapted from:

http://coloradoriparian.org/a-guide-for-harvesting-storing-and-planting-dormant-willow-cuttings-2/

Harvesting and preparation of cuttings

Tools: Lopping shears, hand pruning shears, small wood saws or brush cutters, twine, labels, buckets.

- Harvest cuttings during the dormant season (between leaf fall and bud break):
- Locate a collection site near the project site with similar willow species, comparable site conditions (*e.g.,*, hydrology, landscape position, elevation), and abundant, vigorous willow stands.
- Obtain landowner permission to collect from the site.
- Choose healthy stems (*i.e.,* “green” wood in cross section) that are: relatively straight, covered in smooth bark (*i.e.,* not furrowed or damaged), and free of insect/pathogen damage.
- Follow ethical harvest guidelines to conserve health of the donor stand: ◦Remove no more than 1/3rd of the branches from any single willow or red-osier dogwood.
  - Never remove more than 40% of the overall canopy cover.
  - Harvest stems evenly through the stand (*e.g.,*, not from one side of the shrub only).
- Select stems ½ to 1¼ inches in diameter for most cutting projects.
  - Some project activities (*e.g.,* LWD anchoring) may require stems that are 1 to 3 inch in diameter or 3 to 6 inches in diameter where longer or stronger poles are needed. In general, Red-osier Dogwood (*Cornus stolonifera Michx*.), and Willows (*Salix* spp.) are more appropriate for smaller diameter cuttings while larger diameter cuttings should be Balsam Poplar (*Populus balsamifera L*.).

- Cut stems to length, as determined by specific project needs (*e.g.*,, depth to late-summer water table, severity of erosion and flood damage).
    - In general, harvest cuttings in 18-24 inch lengths, though some project activities may need cuttings up to 5 feet long.
    - Remove the cutting with a clean diagonal cut near its base, as low as you can remove it from the plant stem and still harvest a healthy cutting.
    - The diagonal cut is used to differentiate the rooting-end from the above ground end, and to aid installation.
    - The top should be prepared with a horizontal cut.
- Prepare cuttings by clipping the terminal bud (unless a tree-like form is desired) with a horizontal cut and removing all lateral branches along the stem as close to the stem as possible.
    - Use caution and avoid damaging the stem while clipping the lateral branches.
    - Removing lateral branches helps maintain an appropriate root to shoot ratio and creates a cutting that is easier to install.
    - Cut the top end of the stem horizontally to create a flat pounding surface if necessary.
- Bundle and tag cuttings by species, size, date, and site. Keep bundles cool, moist, and shaded during transportation and on-site storage.
- Prior to planting, soak willows in water for 5-14 days to increase speed of root formation.
    - Willows can be soaked in buckets, a stream, or a lake with well-oxygenated water.
    - Roughly 50 to 80% of the length of the cutting should be in contact with water while soaking.
    - Under hydrologic conditions that are highly favorable to the establishment of willow cuttings, pre-soaking may not be necessary.
- Planting willow cuttings
- Tools: planting bars (dibbles), rebar, rubber or wooden mallet, post-hole diggers, electric hammer-drills, soil augers, pick mattocks, power stingers, shovels, buckets, lopping shears.
- Locate and flag planting sites, and determine planting densities based on knowledge of hydrology, location of existing willow populations, and specific site objectives.
    - Areas where the water table drops more than 3 ft during the growing season or with large fluctuations in water-table depths are problematic for survival of willow cuttings.
    - In areas with low erosion potential, space cuttings 1-3 feet apart. On steeper slopes, or where there is a greater threat of soil erosion, denser plantings may be appropriate.
- Optimal time of willow planting varies by region.
    - Typically, willow cuttings are installed after spring thaw but before bud break, or in fall after leaves change color and/or fall.
    - If planting in fall, be sure to install cuttings deep enough (at least 2 feet deep) to avoid them from being lodged out of the ground by winter freeze-thaw cycles.
- Prepare pilot holes, if necessary, for willow cuttings by pounding in rebar, using a pick mattock or other appropriate tools.
    - Mechanical devises (*i.e.,* stingers or augers) can also be used to prepare deeper holes in difficult soils.
    - Pilot holes allow for easier installation without damaging the cuttings. In soft soils, pilot holes may not be necessary.
- Plant willow stakes into prepared "pilot" holes or directly into substrates by hand-pressure or tapping with a rubber mallet.

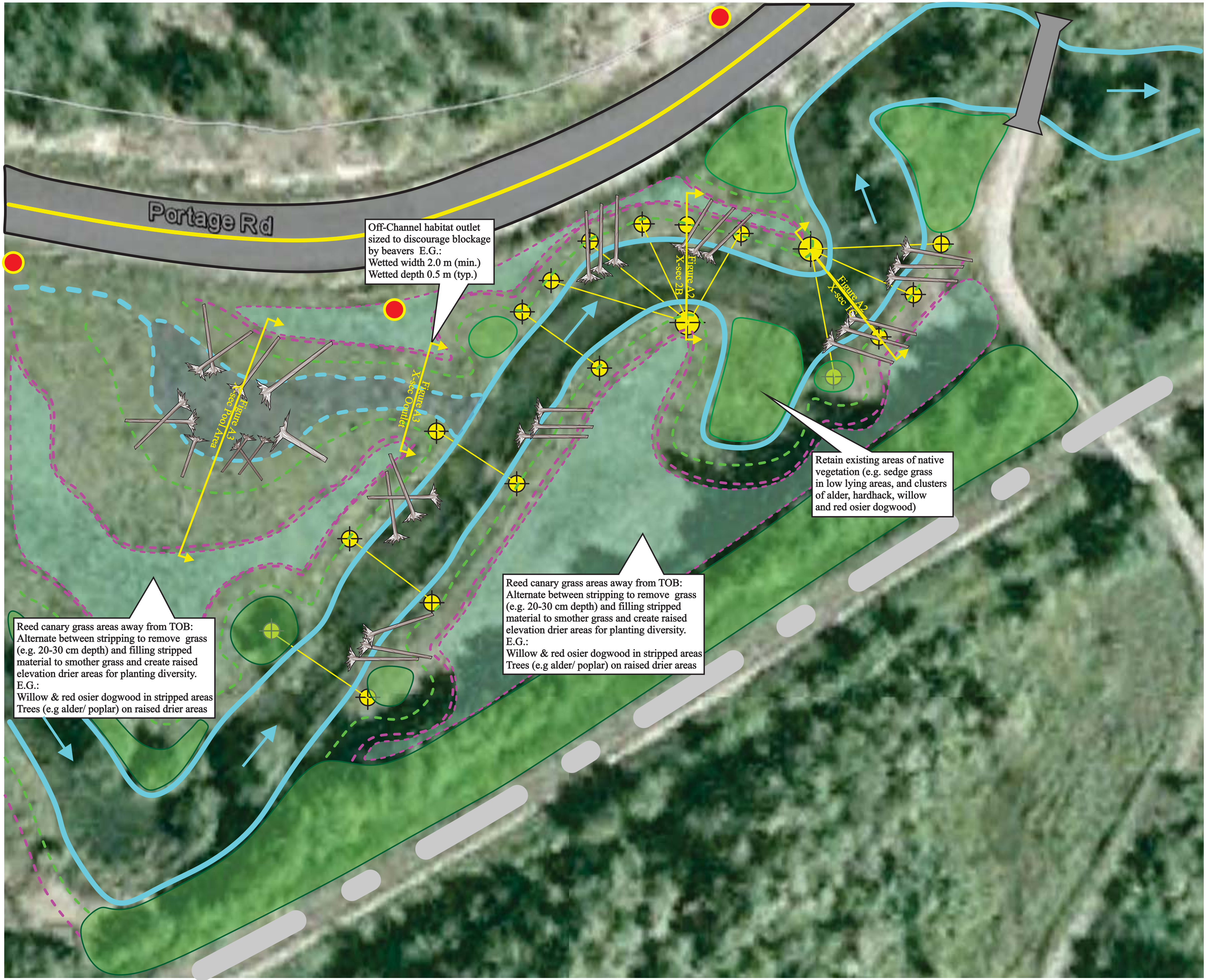
    - The bottom 6-8 inches of the cutting should be installed below the expected dry-season water table. Generally, 50-80% of the cutting is buried and at least 4 to 6 inches should remain above ground, or enough to overtop competing herbaceous vegetation.
    - At least 2 lateral stem buds (and preferably 3 or 4) should be present on the above-ground portion of the stem.
    - Be sure that pointy tips on lateral buds point sky-ward and that the diagonally cut end, usually the thicker end of the cutting, is inserted into the ground.
    - Multiple stakes may be placed in a single hole.
    - If the tops of the cuttings were damaged (cut or mangled) during installation, trim the top cleanly with a horizontal cut at least one inch below the longest split. Cracked or heavily damaged tops can hasten drying of the stem and increase susceptibility to pest damage, decreasing survival rates.
- If the stems dry out during transportation, remove the bottom 2 to 3 inches of the cutting to recreate a "fresh" end just before installation.
- Backfill around cuttings, when necessary, and tamp soil around cuttings to insure good soil to stem contact (*i.e.*, without air pockets).
    - Alternatively, pour a syrup-like slurry of soil and water into the hole, allowing sediment to displace any air pockets as water leaches into underlying soil. **NOTE: Poor soil-to-stem contact is a leading cause of willow stake death**

Environmental Management

- Construction works should be carried out in accordance with applicable Best Management Practices (BMPs) identified in:
    - Develop with Care Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia (BC Ministry of Environment): http://www.env.gov.bc.ca/wld/documents/bmp/devwithcare/)
    - Land Development Guidelines for the Protection of Aquatic Habitat, 1992 (Fisheries and Oceans Canada: http://www.dfo-mpo.gc.ca/Library/165353.pdf)
    - Standards and Best Practices for Instream Works, 204 (Ministry of Water Land and Air Protection: http://www.env.gov.bc.ca/wld/documents/bmp/iswstdsbpsmarch2004.pdf)
- All work to be carried out in accordance with any approvals, authorizations, or permits issued for the project.
- All work to be monitored by an appropriately qualified environmental professional (QEP)
- Vegetation removal boundaries to be delineated in advance jointly by the EM and the contractor, to ensure vegetation disturbance is limited to designated areas.
- Vegetation removal to be conducted outside of bird nesting and breeding windows identified by Environment Canada, and/or Ministry of Forests Land and Natural Resource Operations., to ensure compliance with Section 35 of the Provincial Wildlife Act and Section 5, 6, and 12 of the Federal Migratory Birds Convention Act.
- Prior to construction contractor to prepare the following plans for review and approval by the contract administrator and Environmental Monitor (EM):
    - Erosion and Sediment Control Plan (ESCP)
    - Spill Prevention and Emergency Response Plan (SPERP)

- Contractor to implement ESCP and SPERP, as outlined in approved documents, and to maintain spill response equipment on-site appropriate to the volume and nature of materials being handled and/or stored for project activities.
- Construction equipment is not to enter flowing water at any time
- Construction equipment to be fueled at least 30 m from any watercourse or waterbody.
- Disturbed areas to be stabilized and planted with native vegetation as soon as possible following construction.

Appendix 2. Figure A2-1. Overview of Conceptual Enhancement Plan for FWCP property - 9523 Portage Road



LEGEND

- Existing wetted edge/ Top of Bank (TOB)
- Existing native vegetation - Retained
- Flow direction
- Portage Road
- Utility Pole (BCH/Telus)
- Existing bridge (to be inspected/approved for access)
- Canadian National Railway (alternative access)
- Pre-construction Cross section transect point(s)

ENHANCEMENTS

- Cut Line for reed canary grass stripping E.G.: from 0 to 1.5 m from TOB Strip to elevation (ASL) 366.5 m (typ.)
- Fill Line for reed canary grass stripping E.G.: from 1.5 to 3.0 m from TOB Fill to elevation (ASL) 367-368 m (typ.)
- Area to be alternately stripped and filled to clear reed canary grass and create planting mounds.
- Off channel pond excavation Bottom elevation (ASL) 364 m (typ.)
- LWD/Rootwad 20 - 30 cm DBH x 5-6 m length (typ.) Variable sizing in off-channel habitat

Scale:

0 5 10 20 30 metres

NO.	DATE (dd/mm/yyyy)	REVISION	BY
1	22 Oct 2017	Preliminary concept plan for discussion	PF
2	25 Nov 2017	Updated concept plan for discussion	PF
3	24 Jan 2018	Updated concept plan for report	PF
4	08 Mar 2018	Re-mumbered for final draft report	PF

Basemap Source:
Google Earth Pro, 2005 Aerial imagery
Elevations from local survey with GPS derived (assumed) baseline elevation - (ASL)

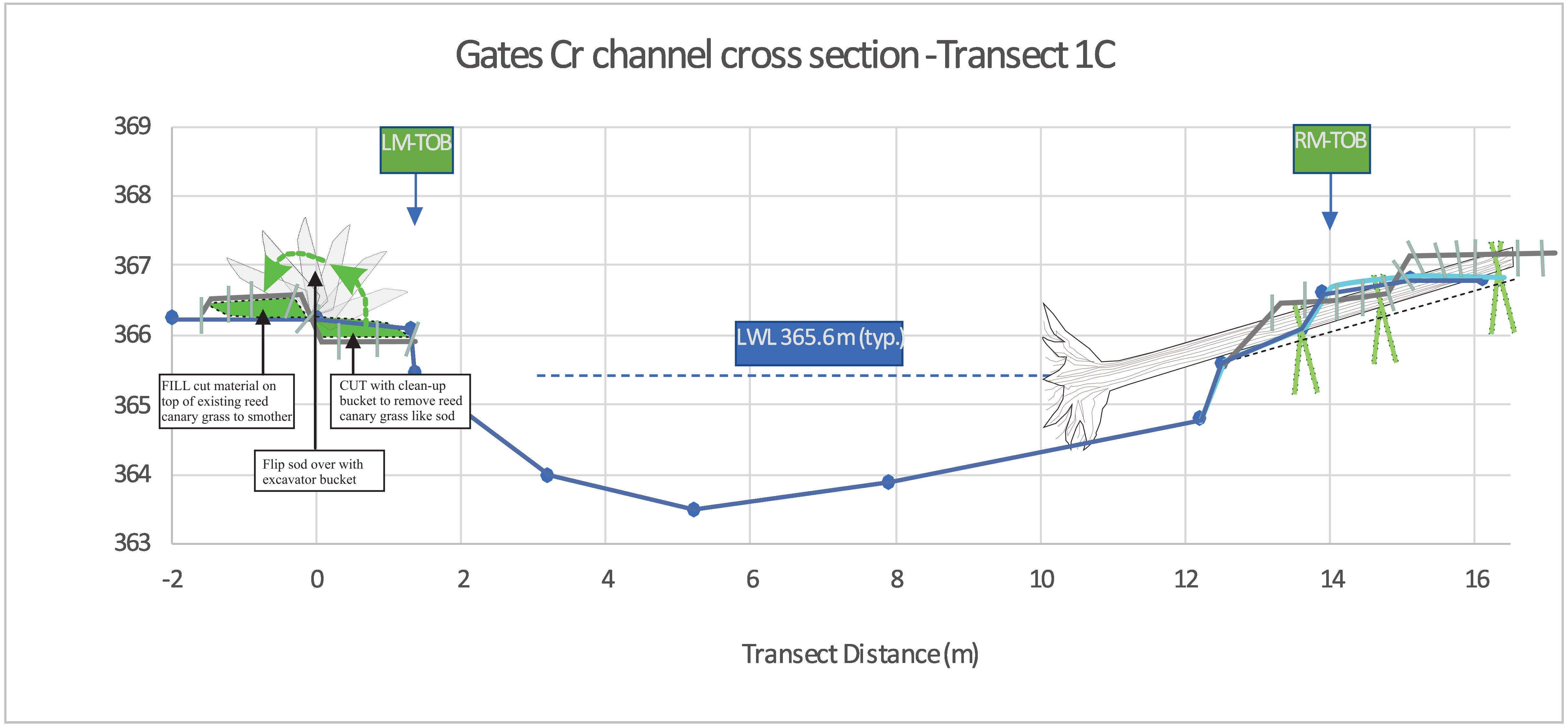
Map Datum: Baseline elevation from hand held GPS (Garmin Map 64S)

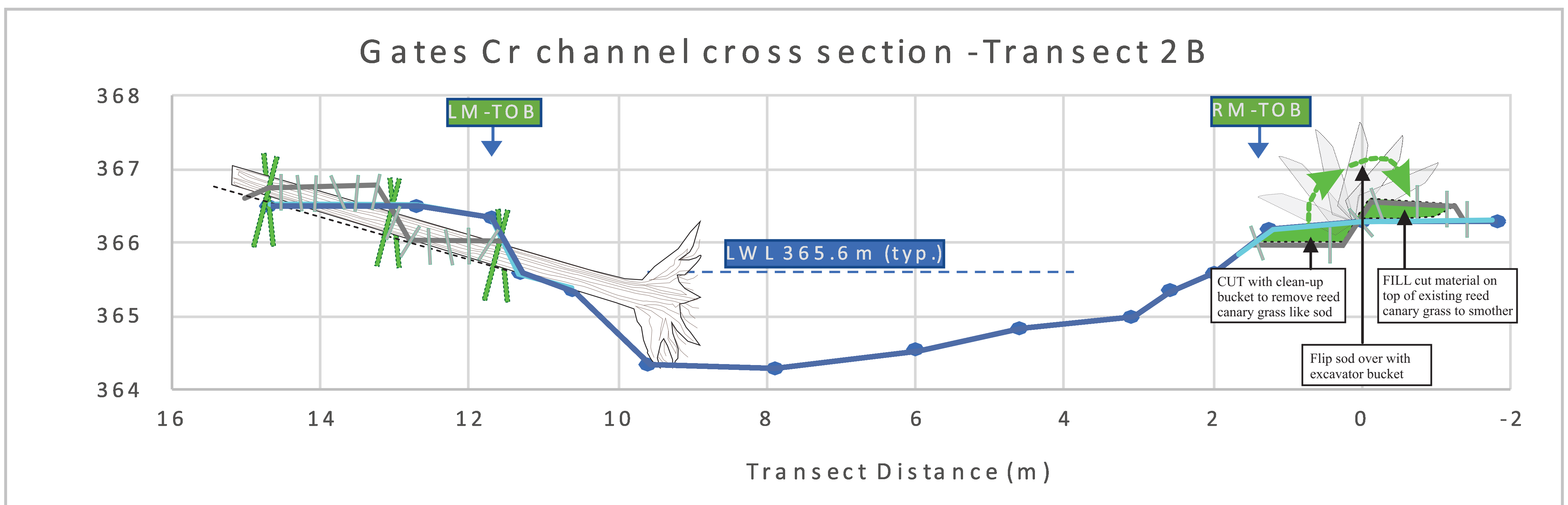
Project # 2027-01:

File name:9523 Concept Plan Rev4-FigA1

POLARIS Environmental Consultants

Appendix 2. Figure A2-2. Example channel cross sections - Gates Creek Enhancement Plan: 9523 Portage Road





LEGEND

- Measured channel cross section
- Low water level (LWL), Oct 2017 survey
- Existing shoreline in work area

PROPOSED ENHANCEMENTS

- Proposed new shoreline in work area
- Trench / cut line (LWD installation)
- Cut/ fill area: reed canary grass stripping
- Structure anchor cuttings (willow/polpar) 5 cm diameter x 1.5 - 2.0 m long (typ.)
- Revegetation cutting (willow/red osier) 1-3 cm diameter x 0.5 - 1.0 m long (typ.)
- LWD/Rootwad 20 - 30 cm DBH x 5-8 m length (typ.) Variable sizing in off-channel habitat

General arrangement drawing for information and discussion only. Not intended for construction. Final design details may differ.

Scale:

As shown

NO.	DATE (dd/mm/yyyy)	REVISION	BY
1	22 Oct 2017	Gates Creek channel cross sections for Enhancement Concept Plan	PF
2	03 Mar 2018	Re-numbered for final draft report	PF

Basemap Source: October 5, 2017 transect survey

Map Datum: Baseline elevation from hand held GPS (Garmin Map 64S)

Project # 2027-01:

File name: 9523 Concept Plan X-sec-Rev2-FigA2-8Mar2018

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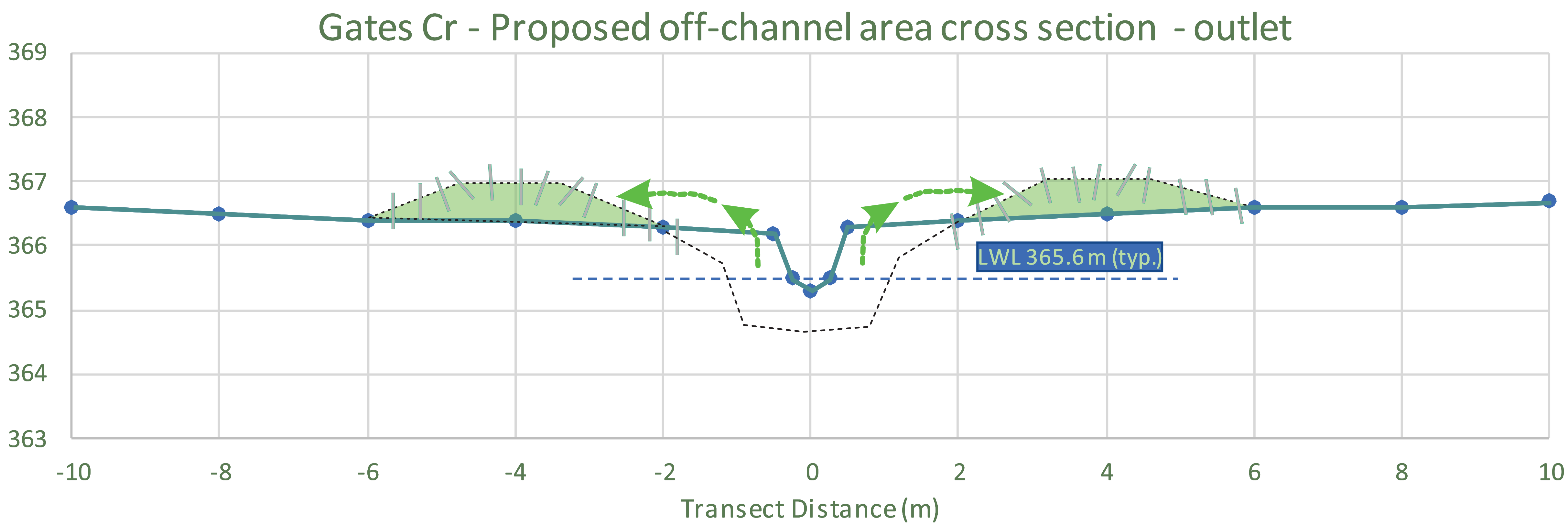
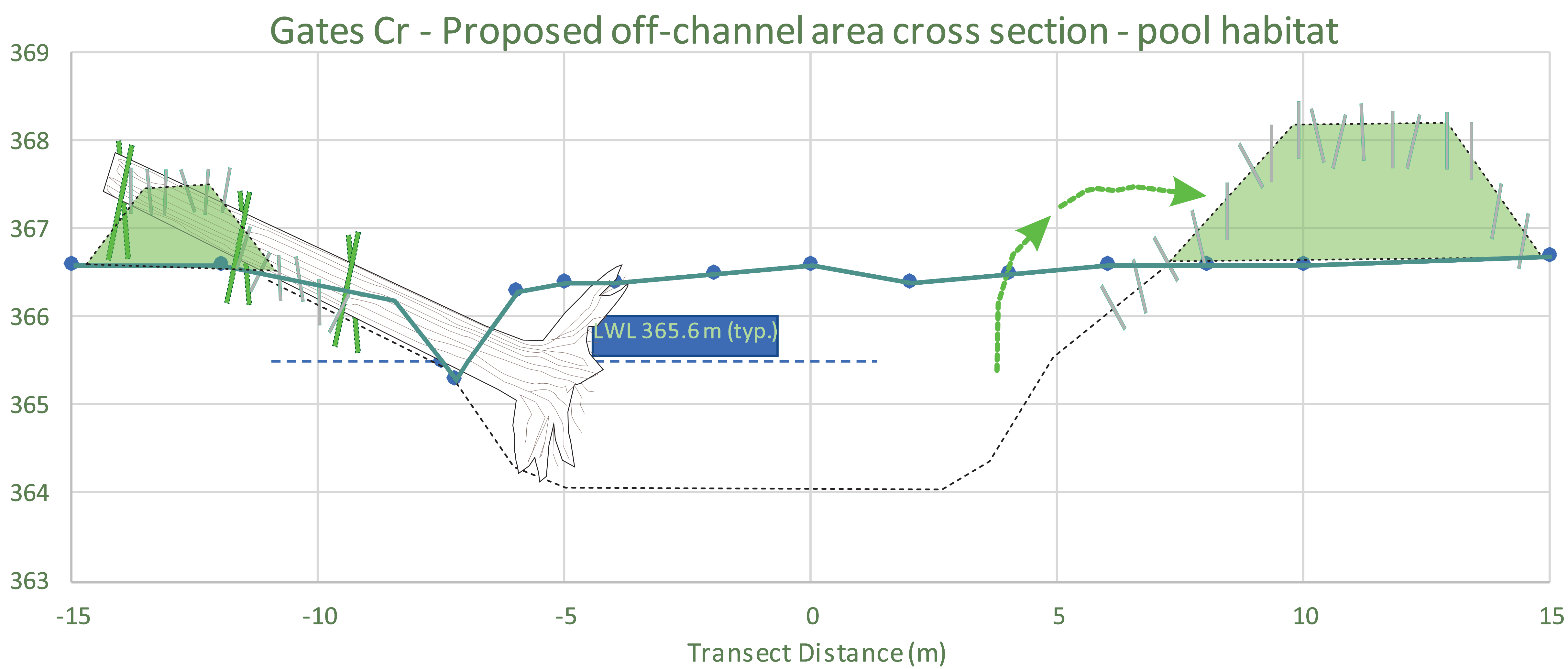
Appendix 2. Figure A2-3.
Example off-channel cross sections - Gates Creek Enhancement Plan: 9523 Portage Road





LEGEND

Existing channel cross section (not measured, but representative)

Low water level (LWL), Oct 2017 survey

PROPOSED ENHANCEMENTS

Proposed new shoreline in work area

Cut line (Pool/channel excavation & LWD installation)

Cut/ fill area: reed canary grass stripping

Structure anchor cuttings (willow/polpar) 5 cm diameter x 1.5 - 2.0 m long (typ.)

Revegetation cutting (willow/red osier) 1-3 cm diameter x 0.5 - 1.0 m long (typ.)

LWD/Rootwad
20 - 30 cm DBH x 5-8 m length (typ.)
Variable sizing in off-channel habitat

General arrangement drawing for information and discussion only. Not intended for construction. Final design details may differ.

Scale: As shown

NOTE: Scales differ between cross sections and individual horizontal and vertical scales also differ

NO.	DATE (dd/mm/yyyy)	REVISION	BY
1	22 Oct 2017	Gates Creek - Examples cross sections of proposed off-channel	PF
2	08 Mar 2018	Re-numbered for final draft report	PF

Basemap Source: October 5, 2017 transect survey

Map Datum: Baseline elevation from hand held GPS (Garmin Map 64S)

Project # 2027-01:

File name:
9523 Concept-Plan-off channel X-sec-Rev2-FigA3

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