Peace Project Water Use Plan

WILLISTON TRIBUTARIES HABITAT

Implementation Year 10

Reference: GMSMON-17

Study Period: 2011 – 2020

LGL Limited environmental research associates
9768 Second Street
Sidney, BC, V8L 3Y8

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PEACE PROJECT WATER USE PLAN

Program No. GMSMON-17

Williston Trial Tributaries




Final Report

Prepared for

BC Hydro

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CELEBRATING 50 YEARS

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Cover photos:

From left to right: Ole Creek constructed Berm B, Ole Creek debris catchers and planted vegetation on Berm A, Six-Mile Creek planted vegetation on Berm J, Six-Mile Creek embedded Large Woody Debris along Berm D. All photos © Shane Johnson, LGL Limited on May 28 and 29, 2019.

EXECUTIVE SUMMARY

Under project GMSMON-17 (Williston Trial Tributaries and Tributary Habitat Review), six management questions and associated hypotheses were developed to direct the study design and monitoring program. This report presents the results of the 10-year monitoring program. The purpose of the Ole and Six Mile Creek enhancements was to prevent extensive braiding and thus maintaining Ole and Six Mile Creeks throughout the draw down zone (DDZ) in one fish-passable channel at spring water levels. In 2020, all habitat restoration or enhancement works in the estuaries of Ole and Six Mile Creeks were inspected for the last time under GMSMON-17, six years after works installation, and deemed functional.

Training Berms: The berms constructed at both creeks were still preventing creek braiding and the related shallow and high velocity creek morphology which can pose an obstacle to fish migration. While berm erosion did not appear to have progressed, settlement of fines and sand on the berm crests was observed but may not need to be addressed since this may be enforcing berm stability and function. At the conclusion of the monitoring program, all berm works appeared to be stable and are expected to remain in good condition for a few years to come although the possibility of future erosion from ice and floating log scouring at changing reservoir elevations cannot be ruled out.

Embedded Large Woody Debris (LWD) Structures: The embedded LWD structures were still providing their primary function of stabilizing the toes of constructed banks and berms. With regard to their secondary purpose of initiating scouring of holding pools and providing shading and cover to fish, the erosion of the trained channels has lowered the thalweg and the water surface levels in both creeks leaving the embedded LWD structures perched above the creek surfaces. Without direct contact to creek flow, even at spring discharge levels, the LWD structures cannot initiate or maintain pool scour or provide shading and submerged cover for fish. Regardless, since the creek channel was prevented from braiding and no obstacles to fish migration were identified, the need for LWD structures to provide low current velocity and shaded fish holding habitat in the DDZ did not appear to be essential for allowing fish access to their spawning streams through the DDZ.

Debris Catchers: In general, the installed debris catchers were still preventing driftwood accumulation in the stream channels, log jam creation and fish migration obstacles from forming. Nevertheless, small amounts of driftwood have started to penetrate the creek channel and may need to be removed in the future. A good portion of the driftwood inside the debris catchers had a length and weight that may make it possible to be removed manually. The debris catcher logs were starting to weather and it is unclear what their functional life span will be.

Flow Velocity, Discharge and Water Depths as an Obstacle to Fish Migration: Arctic Grayling and Rainbow Trout can typically sustain swimming speeds of 0.1 – 0.5 m/s for longer periods of time. These discharge velocities were found at the margins of Ole Creek in water depths from 10-20 cm at the discharge measurement location on May 29, 2020. Flow velocities in deeper water were higher. Discharge and flow velocities across Six-Mile Creek could not be measured in 2020 due to high water conditions that made it unsafe to cross the creek. In addition to the

sustained swimming speeds of 0.1 – 0.5 m/s for Rainbow Trout and Arctic Grayling, the maximum burst speeds for the two species are reported as approximately 1.6 m/s for Arctic Grayling and 1.47 m/s for Rainbow Trout with a fork length of <40 cm. Therefore, both species would likely be able to cross short stretches of high velocity areas in deeper water by seeking out low velocity areas on the creek margins to recover. At discharges higher than encountered in 2020, migration for both species would likely be impeded by current velocities exceeding maximum burst swimming speeds throughout all depth > 10 cm.

Vegetation: The successful growth and establishment of the planted vegetation was directly correlated with period of reservoir inundation during the growth season from May to October. Establishment of vegetation at lower elevations, which were close to being permanently inundated, was generally not successful while vegetation planted at higher elevations was successful in stabilizing berms and creating shade. Natural vegetation was establishing itself alongside the planted vegetation on the constructed berms.

Songbirds: No consistent pattern was revealed in how the enhancements affected songbird utilization around tributaries. During the post-enhancement monitoring, no difference in species richness or abundance could be ascertained at Ole Creek (treatment) and Factor Ross Creek (control); therefore, the enhancements at Ole Creek did not appear to have an effect on songbird species. Likewise, while species richness appeared to increase over time at Six Mike Creek (treatment) post-enhancement, a similar trend was recorded at Lamonti Creek (control).

Amphibians: The abundance of amphibians of the various species recorded in areas potentially affected by the enhancement remained relatively low and stable through time (pre- and post-enhancement) and there was no evidence of changes to amphibian abundance and diversity within areas influenced by the enhancement at each site.

Final status of GMSMON-17

Management Question	Summary of Key Monitoring Results
MQ-1: Does access for spring spawners (i.e., Rainbow Trout and/or Arctic Grayling) improve as a result of enhancement?	Summary of Findings The original channels of Ole and Six Mile Creeks in the Williston Reservoir DDZ were heavily braided with very shallow water depths, possibly perched channels and a heavy load of large woody debris. The accumulation of large woody debris in the DDZ is typical for Williston Reservoir tributaries based on the large amount of driftwood. Roscoe et al. (2014) reported that habitat quality throughout the DDZ was generally poor and not suitable for salmonid spawning or holding. The access for spring spawners to their spawning streams crossing the DDZ in both creeks appeared to have improved six years after construction measures were completed. The formerly heavily braided channels have been trained into one non-perched channel with higher water depth throughout the DDZ. In addition to increased depths, current velocities in the trained portion of both creeks appeared to allow for salmonid migration at flows as measured in from 2018-2020 in Ole Creek while the installed debris catchers mainly prevented log jam formations and related creek channel blockage Sources of Uncertainties Depths and current velocities in Six Mile Creek were only safe for wading in one of three years from 2018-2020 and therefore discharge could not be reliably measured in two out of three years. The potential addition of a small and stable watercraft, such as a pack-raft, that could be used as platform for discharge measurements at high flow rates should be considered for future site inspections. Comments Based on visual assessments, the creek portions on both sides of the centre thalweg portion appeared suitable for migration of Rainbow Trout and Arctic Grayling and therefore access for spring spawners appeared to have improved as a result of the enhancement.

Management Question	Summary of Key Monitoring Results
MQ-2: Is the area and quality of fish habitat created by the tributary enhancement maintained over time?	Summary of Findings The area and quality of fish habitat created by the tributary enhancement measures was mainly maintained from 2014 to 2020. The berms and debris catchers constructed throughout the DDZ of Ole and Six Mile Creek in 2014 were still fully functional in 2020, six years after their creation. These structures maintained the trained creeks in their planned unbraided channels. The root wads installed into the toes of the berms to create back eddies along the trained channel and thus provide current refuges for fish were mainly perched (due to scour) above the water level. The plantings on berms in both creeks have established permanent and thriving vegetation above the Williston Reservoir inundation elevation. Plantings below the annual inundation elevations were not successful and have disappeared. Sources of Uncertainties The logs installed as debris catchers were starting to deteriorate and should be inspected within the next three years since they are essential for the prevention of log accumulation and related erosion and scour on the constructed berms during changing reservoir levels. Comments The root wads perched above the water level do neither have a hydrological function nor do they provide submerged cover anymore. If back eddies, current refuges, scour pools and submerged cover were desired features, new LWD structures would need to be installed reaching into the newly formed stream channels.

Management Question	Summary of Key Monitoring Results
MQ-3: Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?	Summary of Findings Vegetation cover appeared to have increased on the enhancement structures since their construction, but this was most notable for the herb layer. An increase in vegetation abundance at control sites was not observed during the same monitoring periods, which suggested the observed increases at the treatment sites was not due to other environmental factors (e.g., climate, reservoir operations). However, no noticeable differences in species richness (i.e., diversity) were observed between treatment and control sites when multiple years of data were compared. Sources of Uncertainty/Limitations Data collection in 2011 occurred before the location of the treatment (enhancement) sites were known. Vegetation data collection was suspended until this information was know, but only re-commenced after the construction of the enhancements in 2014. Vegetation data were collected immediately after the construction period, when vegetation composition at the time was comprised of the live willow stake and grass seed that were applied as part of the site stabilization. Because of the variation in data collection methods and the location of survey transects between Year 1 and subsequent years of monitoring, comparisons of vegetation data from pre-construction to post-construction conditions was not possible; however, these circumstances did not impede the ability to address MQ3. Comments Riparian vegetation appeared to be trending to an increase in diversity and abundance; however, the enhancement areas are influenced by variation in annual reservoir influx and elevations, which is likely affecting the establishment of this riparian vegetation.

Management Question	Summary of Key Monitoring Results
MQ-4: Does abundance and diversity of songbirds (passerines) around tributaries change as a result of enhancement?	Summary of Findings No consistent pattern was revealed in how the enhancements affected bird utilization around tributaries. During the post-enhancement monitoring, no difference in species richness or abundance could be ascertained at Ole Creek (treatment) and Factor Ross Creek (control); therefore, the enhancements at Ole Creek did not appear to have an effect on songbird species. Likewise, while species richness appeared to increase over time at Six Mike Creek (treatment) post-enhancement, a similar trend was recorded at Lamonti Creek (control). No observable effect was recorded that would address this management question. Sources of Uncertainty/Limitations A number of factors limited the utility of using songbird data to assess the effectiveness of tributary enhancements. Survey methods varied between the pre-enhancement and post-enhancement periods and the specific methods used limited the ability to associate the recorded data to the specific enhancements. Comments Overall, the results of the songbird monitoring from GMSMON-17 had low statistical power to detect changes in songbird abundance and diversity around the tributaries due to the small number of sampling plots (i.e., 1 or 2) and limited number of songbird observations in each survey. A longer time series of data is required to answer this management question; however, songbird utilization of the enhanced areas will be a function of the persistence and succession of vegetation. The results to date do not indicate a change in songbird abundance or diversity as a result of the enhancement; however, it is expected that songbird habitat conditions would improve over the long-term as vegetation is further established in the enhanced areas.

Management Question	Summary of Key Monitoring Results
MQ-5: Does amphibian abundance and diversity in tributaries change as a result of enhancement?	Summary of Findings No substantial differences were noted in amphibian species diversity within the drawdown zone before and after the enhancements for both the treatment and control sites. For areas above the drawdown zone species diversity increased post-enhancement at all locations, but this is likely a reflection of survey effort. Western toads appeared to be using all drawdown zone sites, both pre- and post-enhancement. All other amphibian detections made during this program were within terrestrial habitat or wetland habitat. The abundance of amphibians of the various species recorded in areas potentially affected by the enhancement remained relatively low and stable through time (pre- and post-enhancement) and there was no evidence of changes to amphibian abundance and diversity within areas influenced by the enhancement at each site. Sources of Uncertainty/Limitations Monitoring for amphibians was completed in the first six years of the program; however, the survey methods varied across the years. Given this variation in survey methods across years, it was determined that the amphibian data could not be analyzed in the context of a before-after-control-impact (BACI) design as originally planned. Few surveys were completed pre-enhancement in relevant areas of the drawdown zone at the two treatment sites, and the diversity and numbers of amphibians using the areas pre-enhancement were not well established. In addition, survey and/or amphibians data was not consistently collected each year, which resulted in data gaps that limited the ability to standardize data for multiple years to allow for cross-year comparisons. Comments The variability of the amphibian data did not allow a quantitative answer to this management question; however, this project has shown use of the drawdown zone adjacent to the enhancement works at each site by a relatively stable diversity of amphibians throughout the course of the project (pre- and post-enhancement), so the collection of further amphibian data is not necessary.

Management Question	Summary of Key Monitoring Results
MQ-6: Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?	Summary of Findings Evidence of breeding in the drawdown zone was limited to a long-toed salamander egg mass in a small pool at Six Mile Creek in 2011, and western toads in amplexus in a slow flow inlet created by an earth berm at Six Mile Creek in 2015. Other detections of amphibian breeding and amphibian breeding habitat were recorded from more permanent wetland habitats on the margin of the drawdown zone at Six Mile Creek, and possibly at Factor Ross Creek. Overall, there was no change in the quality of amphibian breeding habitat over time. Since suitable breeding habitat appeared to be sparse at the enhancement sites prior to construction, and monitoring for amphibians did not continue throughout the program, it was challenging to determine if this habitat was maintained over time.. Sources of Uncertainty/Limitations The primary objective of studying amphibians in GMSMON-17 was to determine whether or not amphibian abundance and diversity changed as a result of enhancement work (BC Hydro 2015). As such, amphibian data collection focused on documentation of amphibian egg masses, larvae and metamorphs (sub-adults and adults). Morphometric data were collected on identification, sex (where feasible), developmental stage, and snout-vent length (SVL) (adults only). Other than observations of breeding evidence, no actual quantitative data on breeding habitat (e.g., persistence of water bodies, water temperature, water depth, substrate, aquatic vegetation) were collected. Comments The quality of the breeding habitat at this site can only be inferred from amphibian use of the area through time. In 2015, occupancy was modelled occupancy by dividing the number of plots where any species of amphibian was detected by the total number of sites that were surveyed, under the premise that occupancy is related to abundance. However, these results were highly variable with standard deviations nearly as large as the estimates of occupancy; therefore, there was insufficient sampling time and effort to address this management question based on detection data. Regardless, the area of amphibian breeding habitat was general low in the pre-enhancement condition and even less so in the post-enhancement period, so the enhancements are expected to have little effect on the regional amphibian population.

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1 INTRODUCTION

The annual reservoir cycling in Williston Reservoir created a drawdown zone of approximately 450 km^2 that was unproductive in both the inundated state as aquatic habitat and in the drawdown state as terrestrial habitat (BC Hydro 2003). The Peace Water Use Plan Committee (hereafter known as the Committee) recognized that the largely unproductive drawdown zone (DDZ) on Williston Reservoir contributed to low fishery productivity, a lack of riparian and wildlife habitat, and potentially increased predation risk for wildlife. In addition, large amounts of woody debris, mainly originating from the initial flooding, is annually deposited on most beaches when the water level is falling in the fall and re-floated in the spring at rising water levels. In some bays the large amounts of woody debris have blocked fish passage into creeks and are scouring the shore while destroying emerging vegetation.

To address all of these issues, the Committee recommended the Riparian and Wetland Habitat management plan to improve foreshore habitat for fisheries, wildlife, and riparian areas. As part of this habitat management plan, BC Hydro conducted a 10-year monitoring program to assess the effectiveness of tributary enhancement sites constructed under a related project (GMSWORKS-19: Williston Trial Tributaries) on the Williston Reservoir (Appendix 1). The program, GMSMON-17: Williston Trial Tributaries, monitored the effect of two constructed sites for enhancing fish access and habitat as well as the enhancement to vegetation and wildlife habitat.

The following tributary enhancements were constructed in 2014 at two locations:

- Six Mile Creek is a tributary to the Parsnip Reach of the Williston Reservoir, emptying into Six Mile Bay approximately 40 km north of Mackenzie. Enhancement work at Six Mile Creek consisted of a series of seven geogrid soil wrap berms along the left bank of the existing channel, two of which were vegetated with live willow stakes to enhance riparian vegetation. In addition to the constructed works, a significant volume of accumulated large wood debris was removed from in and around the creek channels within the reservoir drawdown zone.

- Ole Creek is on the west side of the reservoir, approximately 180 km northwest of Mackenzie. Enhancement work at Ole Creek consisted of the construction of a series of four gravel training berms along both banks of the existing creek channel, two of which included wood debris catchers. Live willow stakes were planted, and local grass seed was applied to the upstream-most berms.

- Additionally, nearby Factor Ross and Lamonti Creeks were used as control creeks during the first three years of the program. These control creeks are believed to have provided sufficient information and little additional benefit is expected; therefore, no further monitoring at these control creeks was conducted since 2013.

Pre-construction monitoring on all four creeks occurred from 2011 to 2013. Monitoring continued in 2014, during the construction period, and the post-construction monitoring occurred from 2015 to 2020. Annual reports were prepared and submitted to BC Hydro as part of the Williston Reservoir Management Plan. The annual report for Year 10 of GMSMON-17 is provided in Appendix 2.

2 STUDY AREA

2.1 Williston Reservoir

Williston Reservoir is located in northeastern British Columbia and was created by construction of the W.A.C. Bennett Dam at the head of the Peace River Canyon, about 20 km west of Hudson's Hope, B.C (BC Hydro 2015a). The reservoir extends for about 260 km along the Rocky Mountain Trench from the Finlay River in the north to the Parsnip River in the south. The reservoir is generally divided into three geographic regions (from north to south): Finlay Reach, Peace Reach and Parsnip Reach (BC Hydro 2015a).

Since 1971, reservoir elevations have ranged between 654 m and 672 m, with reservoir elevations fluctuating from year to year, driven by inflow and system generation needs. Inflows to the reservoir are primarily driven by snowmelt in the Peace River watershed and are much higher in summer than in winter. The reservoir is typically ice covered between the end of January and the beginning of May and generally reaches an annual minimum elevation in April or May, followed by reservoir refilling in the spring freshet. The reservoir generally reaches the maximum elevation in July or August and is then drafted through the winter as generation is increased to meet peak winter loads (Figure 1). The Normal Maximum Reservoir Level (NMRL) is 672 m and BC Hydro normally maintains a minimum elevation of approximately 655 m (BC Hydro 2015a).

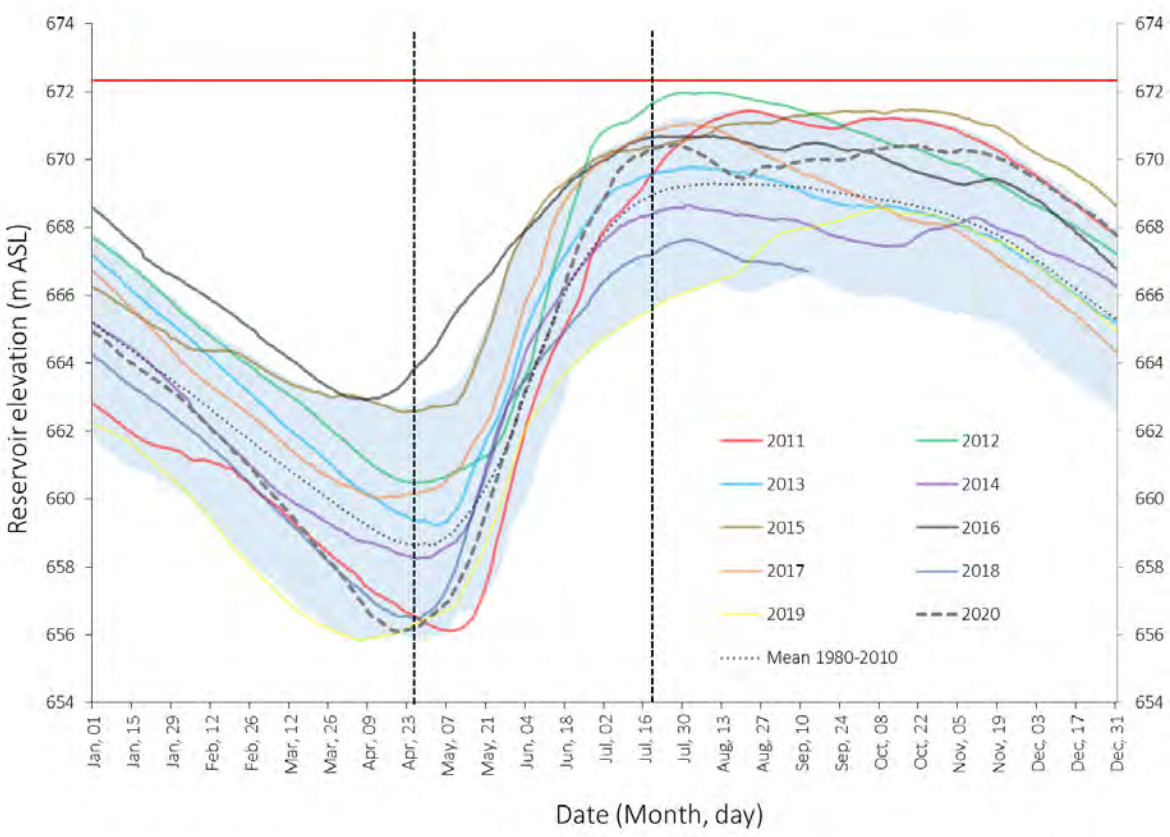

Figure 1. Williston Reservoir elevations from 2011 to 2020. The shaded area represents the 10th and 90th percentile for the period 2011 to 2019; the horizontal red line is the normal operating maximum. Vertical dashed lines indicated the typical start and end dates of field sampling.

2.2 Physiography

The Williston Reservoir is nestled between the Hart Range of the Northern Rockies Mountain on its east and the Omenica Mountains on its west, which lie in a north-northwest to south-southeast orientation (

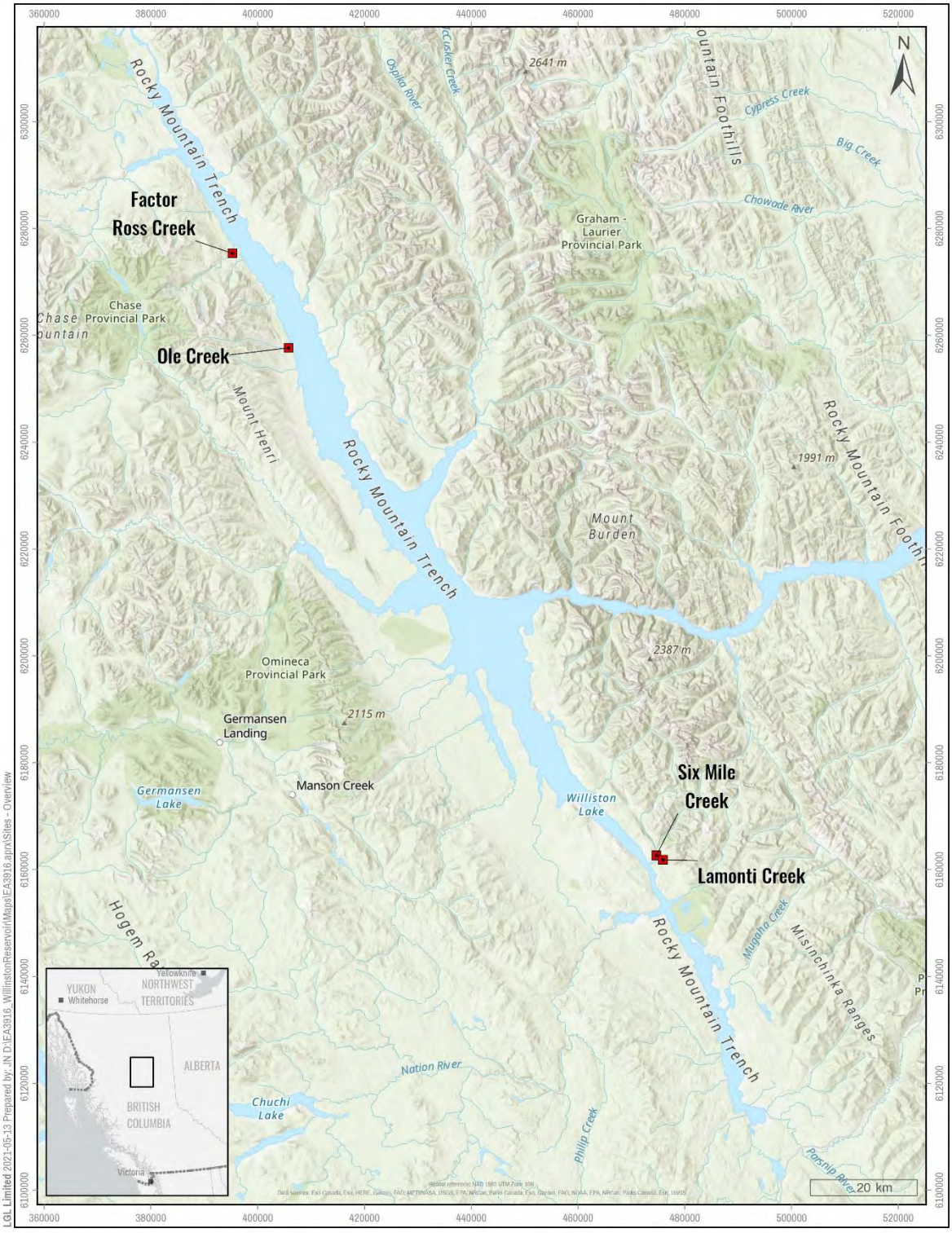

Figure 2). The Finlay and Parsnip Reaches lie within the wide, flat-bottomed Rocky Mountain Trench and the former stream channels are deeply incised. Glacial till is the most abundant surficial deposit in the region.

The reservoir is located within the Sub-Boreal Spruce and Boreal White and Black Spruce biogeoclimatic zones (Meidinger and Pojar 1991). The Sub-Boreal Spruce zone is the dominant zone and occurs as two subzones and variants at lower elevations along most of the reservoir (Meidinger and Pojar 1991). The Boreal White and Black Spruce zone occurs only at the northern end of the reservoir in the Finlay Arm (Meidinger and Pojar 1991). The drawdown zone consists of large areas of mud, sand, and gravel flats with stranded large woody debris. Limited amounts of vegetation occur even following extended periods of drawdown.

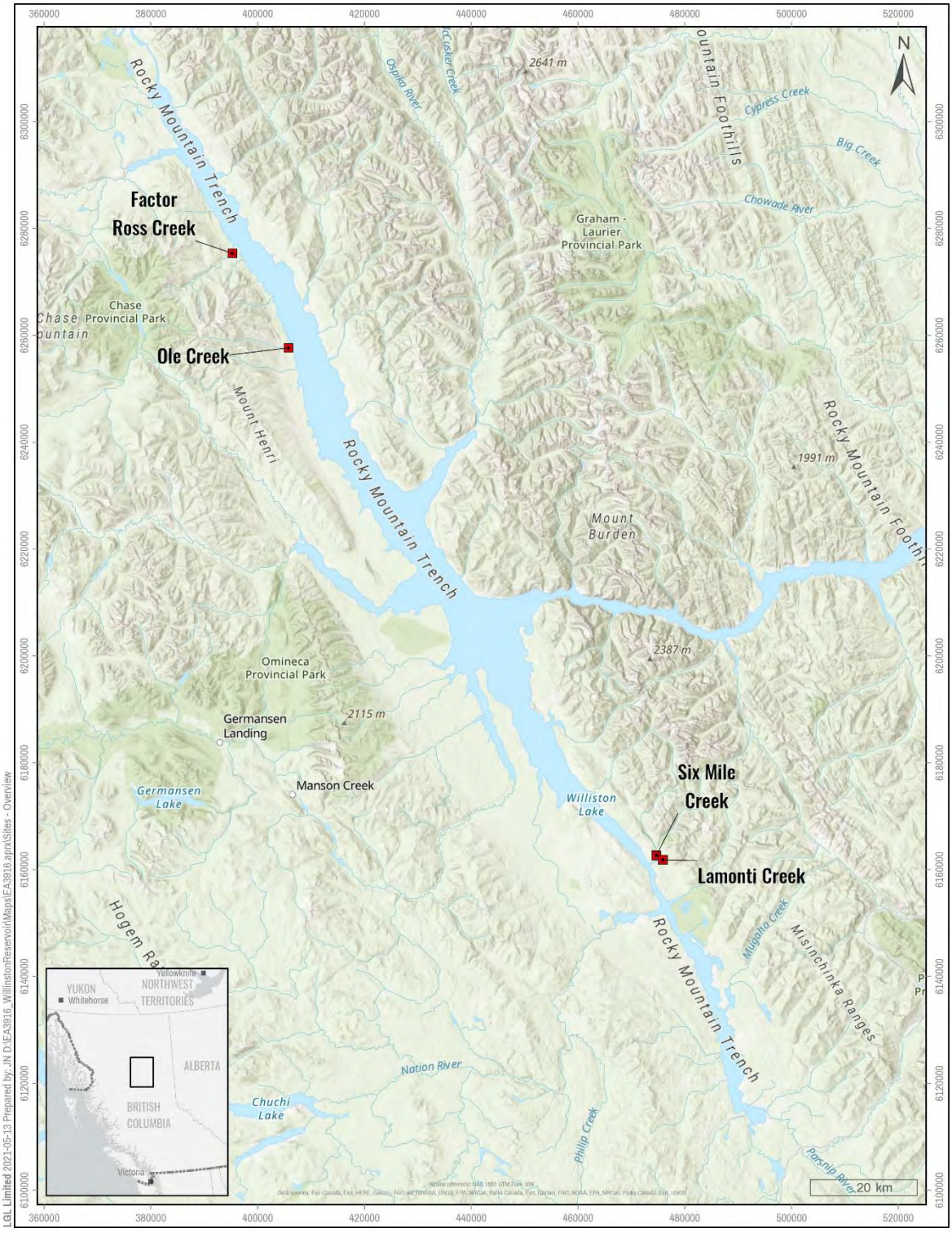

Figure 2. Location of Ole Creek in the Finlay Reach and Six Mile Creek in Parsnip Reach at Williston Reservoir.

2.3 Climatology

Daily weather in the region is influenced by middle-latitude cyclones that typically move from southwest to northeast British Columbia that respond to large scale features of the Rocky Mountains (Whiteman 2000, Klock and Mullock 2001). These lows tend to move over mountains and produce a widespread area of precipitation as well as unstable air where bands of clouds and showers develop. The middle-latitude cyclones dominate the weather during the fall through spring, while convection dominates during the summer months. The lows can become very slow moving and result in large amounts of precipitation in one place (Klock and Mullock 2001); combined with moist air that originates over the Pacific Ocean, that makes its way eastward through the narrow and deep valleys that occur through the Rocky Mountains (Vickers et al. 2001). The region experiences long, cold winters and ice formation on the reservoir begins as early as November and can extend into the beginning of May. Annual precipitation ranges between 40 cm to 50 cm with snowfall accounting for 35-45% of the annual precipitation. The Williston Reservoir receives and stores most of its hydrologic input from snowmelt. The large spring runoff typically begins in mid-May and peaks in June (Stockner et al. 2005).

2.4 Physical Works

Tributaries of the Williston Reservoir had become inaccessible to fish due to alluvial barriers and interference from wood debris. Alluvial barriers become exposed to varying degrees when the reservoir is drawn down from its high pool elevation, resulting in channel braiding. Woody debris becomes stranded in tributary mouths from a combination of prevailing winds and drawdown history (BC Hydro 2015). For both Six Mile and Ole Creeks, the habitat enhancement works were constructed with the objective to stabilize the channel and improve fish access in the DDZ. Construction was implemented under the guidance of Environmental Protection Plans (DWB 2014a, 2014b).

2.4.1 Six Mile Creek

Enhancements at Six Mile Creek included the construction of a series of geogrid soil wrap berms along the left bank of the existing creek channel. The purpose of the berms was to cut off existing flow bifurcations and concentrate and confine creek flow to within a single main channel to provide a depth of flow suitable for fish migration. From the mouth of Six Mile Creek into Williston Reservoir approximately 650 m of stream construction work was completed in the DDZ. All construction was guided by and Environmental Protection Plan (DWB, 2014a, 2014b). The construction works included three main components (Kerr Wood Leidal and Associates Ltd 2011; DWB 2014a, 2014b; Kerr Wood Leidal and Associates Ltd 2015):

1) Lower reservoir berms were constructed of one tonne grain bags filled with gravel and sand. Large woody debris (LWD) pieces, gravel and rocks were used to fill voids. The berms were covered with a vegetated geogrid.

2) Woody revetment log jams, comprised of stream bed material (cobble, gravel and sand) were moored and armoured the berms.

3) Upper reservoir berms were comprised of willow wattles layered along the stream bank edge surrounded by shoreline soil, sand, gravel. These were weighted with LWD, boulders, rocks and gravel. A gravel berm toe was constructed with a riprap base and the berms were topped with a vegetated geogrid, live willow stakes, and grass seed. :

The Six Mile enhancements were confined to the eastern bank in parallel with the main channel and to prevent continued braiding of the channel through the DDZ. Field fit changes were made to the planned design and this resulted in an extension of the earth berm around a small beaver pond. The beaver pond is located along the eastern bank of the main channel at the northern-most transition of the DDZ. Large root wads were placed into the riparian area of the pond to potentially improve habitat for amphibians. Fish salvage was not required, but amphibians were salvaged from the pond and stream riparian area during active construction of the berm (DWB, 2014a, 2014b).

2.4.2 Ole Creek

Enhancements at Ole Creek consisted primarily of the construction of a series of gravel training berms along both banks of the existing creek channel, with the intent of blocking the existing flow bifurcations and confining creek flow to within a single main channel to provide a depth of flow suitable for fish migration. In addition, a significant volume of accumulated large wood debris was removed from in and around the creek channel in the DDZ. The construction works at Ole Creek had an approximate length of 250 m within the DDZ. Parts of the channel were isolated during construction and a single Rainbow Trout was salvaged. Surveys for amphibians were conducted and a single long-toed salamander was detected in a south bank debris pile approximately 10 m from debris clearing and berm construction site (DWB, 2014a, 2014b). Field fit changes were made to the planned design as the channel had shifted from previous surveys. The construction works included three main components (Kerr Wood Leidal and Associates Ltd 2011, 2014; DWB 2014a, 2014b):

1) Lower reservoir berms constructed with gravel and rock revetments.

2) Upper reservoir berms layered with LWD, vegetated geogrid, grass seed and live willow stakes.

3) Woody debris catcher constructed with Imported LWD pieces staked into the upper gravel-rock berm with the length extended vertically and on slope.

3 METHODS

GMSMON-17 was a study focused on monitoring the success of tributary enhancements at two sites on the Williston Reservoir to improve fish habitat and access, as well as increasing the abundance and diversity of riparian vegetation and wildlife. A variety of sampling techniques were used for the various components during the 10-year program; although, specific surveys for

certain components were not completed every year. Sampling methods for the various components are described below.

3.1 Fish Habitat

Visual Surveys: Surveys of the condition of the constructed berms, the embedded LWD structures and embedded live willow cuttings were carried out visually and in comparison to their condition of the last inspection. At the same time, it was visually assessed whether the berm structural materials such as coir (coconut fibre based) matting or 1 m^3 bulk bags were still covered and, if visible, whether these were structurally supportive.

For the embedded LWD structures, it was also visually assessed whether they scoured the creek bed to create pools and whether they provided submerged cover and shading for fish. If LWD structures were observed to be elevated above the creek surface at high discharge they were assumed to not create scour pools, submerged cover or shading.

Similarly, woody debris catchers (WDCs) were assessed visually for their structural integrity and their functionality was based on the accumulation of woody debris or driftwood on the creek side or the zone between the WDCs and in the creek bed. Vegetation was also visually assessed, and results were reported in relation to the success of the 2015 plantings and vegetation that established itself naturally along the berms.

Discharge Measurements and Channel Depth Assessments: The discharge measurement followed the instructions described in "Chapter 4.2.5.1 Measuring by Wading" (p. 78-83) in the Manual of British Columbia Hydrometric Standards – Version 1.0 (2009). For the current velocity and depth measurements a current meter was used in combination with a four-piece calibrated wand (Swoffer Model 2100 Current Velocity Meter). Discharges were measured when it was safe to wade in the creeks. Discharge in Ole Creek was measured at Berm 'A (Lat: 56°27'15.42"N; Long: 124°31'46.95"W). A permanent discharge survey point was not established for Ole Creek but since discharge for a creek should be independent of the location it is measured locations can be changed from year to year based on accessibility and wadeability.

Data Entry and Analysis: Data was collected on printed data forms in the field and transcribed into Microsoft Excel. GPS waypoint and photographs were labelled accordingly. Other than the results of the habitat classification, data analysis presented in this report is for data that was collected in Year 10 only. As this report represents the final year of the monitoring program, the null hypotheses are discussed.

3.2 Vegetation Surveys

A combination of air photo interpretation and ground sampling of terrestrial vegetation was used to describe terrestrial vegetation communities at the project sites during the pre- and post-enhancement periods. Sampling efforts for vegetation in the latter years of the program focused on visual surveys.

3.2.1 Habitat Classification

Habitat class descriptions and their spatial distribution were prepared in Year 4 (2014) of the program; the year enhancements were constructed (MacInnis et al. 2015). A combination of air photo interpretation and ground sampling of terrestrial vegetation was used to describe terrestrial vegetation communities at the project sites (Province of British Columbia 2010, RISC 2010). Photo interpretation was completed in 2D soft copy using ArcGIS (version 9.3, ESRI 2008) and a habitat classification scheme based on RISC (2010) was developed to capture all the habitat classes in the study area visible at the air photo resolution that was available. Digital ortho-rectified low and high resolution air photos taken of the project sites, provided by BC Hydro (approx. 100 cm pixel resolution; 2011) and JR Canadian Mapping (5 cm pixel resolution; 2014-2015).

Each habitat class was identified based on a common plant species assemblage or substrate and elevation position within the drawdown zone. In addition to habitat classification, an enhancement classification scheme was also developed for Six Mile and Ole Creeks, using the high resolution air photos collected during Year 4 (MacInnis et al. 2015). The objective of the classification scheme was to identify and differentiate artificial structures and surfaces from undisturbed habitats at the enhancement sites. Any new structures, or areas where ground disturbance resulted in alterations to surface materials, were identified as enhancement structures and were designated with an enhancement class (Appendix 3). Overall, the map scale varied roughly between 1:1000 and 1:200 throughout the interpretation process depending on the size of the habitat polygon and the resolution of the air photo. The delineation of habitat and enhancement class polygons included all non-flooded areas within the drawdown zone (from an elevation above the full pool level to below the pool level present during ground surveys and air photo collection).

In Year 6, a qualitative assessment of the abundance and distribution of habitat and enhancement classes was completed in place of a more detailed re-delineation of habitat and enhancement class polygons (Thompson and Carson 2017). The qualitative assessment of abundance and distribution of habitat and enhancement classes was based on observations made during ground sampling and review of orthophotos from an unmanned aerial vehicle. Vegetation cover and surface features were recorded, and representative photographs of notable features were taken.

No further assessment of habitat or enhancement classes was conducted after Year 6 (2016). A review of the collected data was conducted in 2019 (Hilton 2019a) where it was concluded that vegetation mapping could be repeated in Year 10 to compare the extent and area of the different vegetation communities; however, this could be costly to acquire aerial imagery (Appendix 4). Therefore, a qualitative comparison of enhancement structures (i.e., berms) was completed by mimicking representative photographs of the structure taken immediately after construction in Year 10 (Section 3.3.3).

3.2.2 Ground Sampling

Data on terrestrial (riparian) vegetation were collected in Years 1, 4, 5, 6, and 10. Data were collected from the enhancement sites (Ole Creek, Six Mile Creek) each of these years, but only collected at the control sites (Factor Ross Creek, Lamonti Creek) for the first four years. However, data collection methods varied in the first year compared to the remainder of the monitoring program.

Data from 2011 (Year 1) were collected at two locations, on each side of the creek. Paired 15 m survey transects positioned perpendicular to the creek were surveyed where the creek flowed into the reservoir. The second pair of transects was approximately 150 m upstream. Data was collected on species coverage (measured linearly). In addition, the percent cover and size of trees was measured in 5 m by 5 m quadrats at the start of each transect (Poupard et al. 2012). Data collected from these transects did not provide information on the pre-enhancement conditions in areas where enhancement would later occur (Hilton 2019a).

Survey methods changed from 2014 to 2016. Data were collected along transects located on the enhancements structures (berms) or in areas that were disturbed by the construction at Six Mile and Ole Creeks. Similar transects were established in the riparian areas along the control creeks. Transects were 20 m in length and consisted of ten 2 m by 0.5 m quadrats to allow for sub-sampling and to increase the accuracy of vegetation cover estimates. Within each quadrat, vegetation was identified to species and the percent cover of each species was recorded (MacInnis et al. 2015, MacInnis et al. 2016, Thompson and Carson 2017). Data collected in 2014 represented the condition of the enhancement structures immediately after construction. Data collected in 2015 and 2016 represented the first- and second-years post-enhancement, respectively (Hilton 2019a). Species richness and percent cover of each vegetation layer was recorded for each transect.

Data were collected in 2020 (Year 10) following the same methods employed in 2014 to 2016; however, data was only collected along transects at Six Mile and Ole Creeks. Three transects were surveyed at each location. Data was not collected from the control sites as it was determined sufficient information from these sites had been collected and little additional benefit was expected from further monitoring (Hilton 2019a).

3.2.3 Visual Surveys and Photographic Review

Visual surveys of the condition of the constructed berms, the embedded live willow cuttings and the embedded LWD structures were carried out visually in Year 8 (2018) and again in Year 9 (2019) to assess their condition (Plate et al. 2019, Plate et al. 2020).

Photographs of the physical works features at the time of construction were taken by Kerr Wood Leidal. Select photographs of each feature along with the approximate location of where each photograph was taken, and the photograph orientation were determined. These locations were visited in Year 10 (2020) and the photographs were re-created (Appendix 5). The amount of

change of vegetation composition and structure was visually assessed to provide a qualitative comparison on the enhanced areas.

3.3 Songbird Surveys

A summary and analysis of songbird data collected under GMSMON-17, including multi-year comparisons of bird survey data, was completed in 2019 (Hilton 2019b). A summary of the methods is taken from this report as well as the description of the relevant dataset and the interpretation of the applicable management question. A copy of the Hilton (2019b) report is included in Appendix 6.

Songbird data was collected in 2011, 2014, 2015 and 2016. In 2011 (Year 1), Golder Associates Ltd. used variable radius point count surveys every 200 m along each stream, with the first location chosen within what was anticipated to be the treatment area (Poupard et al. 2012). Point count stations were five minutes in duration. The number of survey stations and sampling frequency (i.e., replicates) varied across the different creeks:

- At Six Mile Creek and Lamonti Creek (a treatment/control dyad), three replicates were completed of each of the five point count stations, with the first survey of each station completed in early May, the second survey of each station in mid-May, and the third survey of each station in early June.

- At Factor Ross Creek, six stations were visited in the morning and again in the afternoon on the same day in mid-May only. Two of the transects at Factor Ross Creek were revisited in the afternoon two days later. At Ole Creek, eight stations were surveyed once in mid-May.

In 2014, DWB Consulting Services Ltd. and Cooper Beauchesne and Associates Ltd. established new point count stations within the drawdown zone along each of the four tributaries (MacInnis et al. 2015). Two stations were established at Six Mile Creek (one overlapped an enhancement area), and two stations were established at Lamonti Creek. Only one station was sampled at each of Ole Creek and Factor Ross Creek. Timing of surveys varied across years:

- In 2014 (construction year) and 2015 (post-enhancement), each station was replicated on two consecutive days within a 4-day period in mid-June (MacInnis et al. 2015, MacInnis et al. 2016).

- In 2016, (post-enhancement) the same stations were replicated on two days in late May (Thompson and Carson 2017).

From 2014 to 2016, songbird surveys lasted for 30 minutes at each station and all birds recorded within and outside a 75 m radius were recorded.

3.4 Amphibian Surveys

A summary and analysis of amphibian data collected under GMSMON-17, including multi-year comparisons of amphibian survey data, was completed in 2019 (Hilton 2019c). A summary of the methods is taken from this report as well as the description of the relevant dataset and the interpretation of the applicable management question. A copy of the Hilton (2019c) report is included in Appendix 7.

Data on amphibians was collected from 2011 to 2016. In 2011 and 2012, Golder Associates Ltd. completed area-based surveys within small ponds and wetland in the vicinity of each tributary. Encountered amphibians were identified to species, snout-vent-length measured, sex determined (when possible) and developmental stage recorded. Surveys were completed during mid-May, early June and/or mid-August (Poupard et al. 2012). In 2012, many of the same locations were surveyed as in 2011 and effort at each location was similar, although no location information was reported, and surveys were completed during a single site visit in early July (Golder 2013). In 2013, Golder altered survey methods to target areas that were most likely to be affected by habitat enhancements. Time-constrained surveys were completed rather than area-based searches (Golder 2014)

From 2014 to 2016, DWB Consulting Services Ltd. established circular plots (200 m^2) in various locations; some close to the tributaries within the drawdown zone and some in upland areas (e.g., >500 m from the tributaries). Transect surveys and spot checks were also completed. Data on species, number, snout-vent length, weight, sex and development stage were collected (MacInnis et al. 2015, MacInnis et al. 2016, Thompson and Carson 2017).

Further data on amphibian species was not collected after 2016, since it was concluded that additional data would not influence the ability to effectively answer management questions #5 and #6 (Hilton 2019c).

4 Datasets

Below, we provide a summary of the sampling design including temporal replication, key parameters that were considered, sites surveyed, and number of samples or sampling points that were comprised in the various datasets.

4.1 Dataset 1: Visual Surveys (Fish habitat)

Observations of the fish habitat conditions were made annually and qualitatively compared to the conditions observed in the previous year. In this regard, the condition of the original construction materials, and their structural integrity and functionality were assessed. Noted annual changes were used to predict future conditions and recommendations for ongoing inspections.

4.2 Dataset 2: Discharge Measurements and Channel Depth Assessments

Annual measurements of current velocity and tributary depth provided empirical data on conditions suitable for fish movement. Although, these conditions could not be measured each

year due to the high water flows creating unsafe conditions for field staff. The location of survey points varied annually so that independent measurements of creek discharge could be collected, taking into account annual variation in conditions.

4.3 Dataset 3: Vegetation – Habitat and Enhancement Classification

The objective of the classification scheme was to identify and differentiate artificial structures and surfaces from undisturbed habitats at the enhancement sites. Changes to the distribution and abundance of habitat classes over time provided information on the effects of the enhancement structures to improve the conditions for riparian vegetation.

A total of ten habitat classes describing vegetation communities at the tributary enhancement and control sites were identified and mapped, including ten habitat classes at Six Mile Creek, seven classes at Lamonti Creek, six classes at Ole Creek and seven at Factor Ross Creek (MacInnis et al. 2015). A total of seven classes describing the enhancement works and initial reclamation at Six Mile Creek and Ole Creek were identified and mapped, including five classes at Six Mile Creek and five at Ole Creek (MacInnis et al. 2015). Data is presented on the number of polygons and the total area covered for each class between Year 4 (2014) and Year 6 (2016) at the two treatment sites (Appendix 3).

4.4 Dataset 4: Vegetation – Ground Surveys

Ground sampling of terrestrial vegetation was conducted to support the interpretation of habitat classes and provide a description of plant communities (e.g., species diversity) at the sites. In 2011, four survey transects were completed at each site; one pair where the stream entered the reservoir and one pair 150 m upstream. These transects were orientated perpendicular to the stream flow and data was collected on the linear distance (in centimeters) covered by each species as the observer walked from the edge of the stream to the upland areas. In addition, 5 m by 5 m quadrats were placed at the start of each transect and percent cover and height of tree species were recorded.

From 2014 to 2016, plus in 2020, ground surveys provided data on the species composition and percent cover of vegetation layers (e.g., moss, herbs, shrubs, trees). Belt transects were conducted at the sites, but the number of transects surveyed varied each year (Table 1). Transect locations were selected to represent the various riparian features and ground conditions (i.e., soil substrates) located at each of the sites. The location of each transect was selected so that different habitat types at each site were sampled. Transects at the enhancement sites were located on the earth berm structures or on areas disturbed by construction and surface substrates generally consisted of mineral soils. Transects at the reference sites were located on natural features (i.e., benches and floodplains) and surface substrates consisted of both organic and mineral soils (Thompson and Carson 2017). Species richness and percent cover from each transect were compared across years to measure changes in the abundance and diversity (Appendix 8).

Table 1. Vegetation transects surveyed between 2014 and 2020 for the GMSMON-17 project.

Site	Transect	Start UTM (E/N)	End UTM (E/N)	Years Surveyed			
				2014	2015	2016	2020
Six Mile Creek	SC2	474668/6162655	474670/6162676	✓	✓	✓	
	SC3	474697/6162745	474712/6162753		✓	✓	✓
Lamonti Creek	LC1	475082/6162074	475098/6162065	✓			
	LC2	475169/6162056	475187/6162058	✓	✓	✓	
	LC4	475181/6161997	475192/6162013	✓	✓	✓	
Ole Creek	OC1	405833/6257636	405831/6257638	✓	✓	✓	✓
	OC2	405887/6257660	405867/6257657	✓	✓	✓	✓
	OC3	405863/6257675	405844/6257664		✓		✓
Factor Ross Creek	FC1	395521/6275897	395511/6275884	✓	✓	✓	
	FC3	395380/6275938	395363/6275929	✓	✓	✓	

4.5 Dataset 5: Vegetation – Visual Surveys and Photographic Review

Photographs taken of enhanced sites in 2014 were compared to photographs taken of the same locations in 2020 to provide a qualitative comparison of vegetation growth in the enhanced areas through time. At Six Mile Creek, 14 photo points were selected on the six enhancement structures (i.e., berms) so that there were 2-3 photos from each berm. At Ole Creek, six photo points were selected on the four enhancement structures (i.e., 1-2 photos per berm).

4.6 Dataset 6: Bird Surveys

Songbird data were summarized in terms of species richness within and outside the 75 m radius point count stations to allow comparisons between sites and between years. Bird data collected in 2011 were compared between sites and treatments. Bird data collected between 2014 (construction year) and 2016 (post-enhancement) were compared between sites, treatments and years. Since new bird survey stations were selected in 2014, and stations were longer in duration (30 minutes), data from surveys completed in 2014 onwards could not be easily compared with data collected in 2011.

4.7 Dataset 7: Amphibian Surveys

Originally, this project was intended to have a BACI (Before-After-Control-Impact) design, with two treatment sites and two control sites; however, there were few pre-enhancement surveys completed in relevant areas of the drawdown zone at the two treatment sites. Consequently, a treatment-control comparison was not meaningful. Rather, a subset of survey stations was selected from Ole Creek and Six Mile Creek that were in areas potentially affected by the enhancement activities. Habitat mapping completed as part of the vegetation component of the project was used as a base mapping layer so that amphibian survey locations could be examined in relation to habitat types and locations of enhancement structures. Data from this subset were examined to determine if there were any trends in species detected or number of individuals captured throughout the monitoring program.

5 Management Questions

5.1 MQ1: Does access for spring spawners (i.e., Rainbow Trout and/or Arctic Grayling) improve as a result of enhancement?

The original channels of Ole and Six Mile Creeks in the Williston Reservoir DDZ were heavily braided with very shallow water depths, possibly perched channels and a heavy load of large woody debris. The accumulation of large woody debris in the DDZ is typical for Williston Reservoir tributaries based on the large amount of driftwood. Roscoe et al. (2014) reported, based on visual observations, that fish access to either creek was not blocked by perched channels or log jams (although a large amount of logs had accumulated in the mouths of both rivers) before habitat enhancement measures were undertaken, but that habitat quality throughout the DDZ was generally poor and not suitable for salmonid spawning or holding.

The suitability as salmonid holding and spawning habitat of both creeks in the DDZ appeared to have improved six years after construction measures were completed. The former heavily braided channels have been trained into one non-perched channel with greater water depth throughout the DDZ. In addition to increased depths, current velocities in the trained portion of both creeks were suitable for salmonid migration along the margins of both creek sections through the DDZ. Even in years when discharge at one of the two creeks could not be measured all across the creek width due to safety concerns, flows and depths at the margins and throughout the DDZ were suitable for salmonid migration. in 2018-2020 in Six Mile and Ole Creeks. The installed debris catchers prevented log jam formations and related creek channel blockage. Only very few and smaller logs were deposited inside the debris catcher corridor.

Based on visual assessments, the creek portions on both sides of the centre thalweg portion appeared suitable for migration of Rainbow Trout and Arctic Grayling and therefore access for spring spawners appeared to have improved as a result of the enhancement.

5.1.1 Challenges and Opportunities

From 2011-2014, electrofishing and mark-recapture methods were used to estimate the fish abundance in the habitat restoration zone before as a before construction baseline. After the first year of electrofishing (EF), a decision was made to switch to a mark-recapture sampling program to provide fish juvenile productivity estimates. The changes were implemented in the 2012-2014 field season, but low detection limited the effectiveness of the changes. Based on the field results, and a review of the power associated with the previous study design, it was confirmed that electrofishing and mark-recapture were unlikely to detect a change in fisheries productivity related to the enhancements (MacInnis et al. 2015). An internal review resulted in a change to the measurement of habitat features rather than fish abundance in Terms of Reference for GMSMON 17.

Depths and current velocities in Six Mile Creek were only safe for wading in one of three years from 2018-2020 and therefore discharge could not be reliably measured in two out of three years. The potential addition of a small and stable watercraft, such as a pack-raft, that could be used as

a platform for discharge measurements at high flow rates should be considered for future site inspections.

The logs used to create the debris catchers were starting to deteriorate and their structural integrity should be monitored at least every three years. Without functional debris catchers, all progress made on the channel training through constructed berms and vegetation establishment could be destroyed by large amounts of floating logs entering the stream channel areas and eroding the constructed berms.

5.2 MQ2: Is the area and quality of fish habitat created by the tributary enhancement maintained over time?

The berms and debris catchers constructed throughout the DDZ of Ole and Six Mile Creek in 2014 were still fully functional in 2020, six years after their creation. These structures maintained the trained creeks in their planned unbraided channels. The root wads installed into the toes of the berms to create back eddies along the trained channel and thus provide current refuges for fish were now mainly perched (due to scour) above the water level. The plantings on berms in both creeks have established permanent and thriving vegetation above the Williston Reservoir inundation elevation. Plantings below the annual inundation elevations were not successful and have disappeared.

The area of habitat that was created was to our knowledge never accurately quantified but in general an approximate 650 m stretch of Six Mile Creek and 400 m stretch of Ole Creek flowing through the DDZ were modified to improve fish passage. At an approximate average width of 10 m at non-runoff flows rough estimate of fish habitat created would therefore be 6500 m^2 for Six Mile Creek and 4000 m^2 for Ole Creek.

5.2.1 Challenges and Opportunities

The logs installed as debris catchers were starting to deteriorate and should be inspected within the next three years since they are essential for the prevention of log accumulation and related erosion and scour on the constructed berms during changing reservoir levels. Large numbers of drifting and eroding logs would also nullify all progress made on vegetation establishment on the constructed berms. Therefore, the debris catchers should be monitored and replaced if necessary.

In addition, the root wads that were buried at the toes of berms were perched above the water level have neither a hydrological function nor do they provide submerged cover anymore. If back eddies, current refuges, scour pools and submerged cover were desired features, new LWD structures would need to be installed reaching into the newly formed stream channels.

For future plantings, we recommend using the average reservoir level as a measure to decide the lowest planting elevation. Only areas that are above the average water level from May to October (> 670 masl) should be planted. Areas below that level will likely be inundated for the growth period and terrestrial vegetation will therefore not survive.

5.3 MQ3: Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?

Riparian vegetation was predominantly herbaceous species that were observed during the ground sampling. The cover of herbs appeared to have increased on the enhancement structures since their construction. An increase in vegetation abundance was not observed at control sites during the same monitoring periods, which suggested the observed increases at the treatment sites was not due to other environmental factors (e.g., climate, reservoir operations). However, no noticeable differences in species richness (i.e., diversity) were observed between treatment and control sites when multiple years of data were compared.

5.3.1 Habitat classification

At Six Mile and Ole Creeks, non-vegetated habitat classes (e.g., basin silt, gravel and sand) dominated the riparian areas along the tributaries in the downstream areas where the creeks enter the reservoir. There were notable changes (i.e., increase) in the cover of basin silt at each site between 2014 and 2016, which was matched by an equal decrease in the aquatic habitat class (e.g., streams and ponds). The enhancements converted braided habitat to a channelized tributary; thereby reducing that area that was classified as aquatic habitat and increasing the unvegetated non-aquatic habitats (e.g., basin silt) two years following project implementation. Habitat classification was last assessed in 2016 but based on visual assessments of the treatment sites in 2018 and 2019 (Plate et al. 2019, Plate et al. 2020) the overall stability of the enhancement areas has remained despite periods of flooding from fluctuations in the reservoir elevation.

5.3.2 Ground sampling of vegetation

Enhancements were constructed in 2014 and transects at the treatment sites (Ole Creek and Six Mile Creek) were located on newly created enhancement structures or in areas that were disturbed by construction (MacInnis et al. 2015). These transects were re-surveyed in 2015, 2016 and 2020 and represented the first-, second-, and sixth-year post-enhancement, respectively. Data were collected on the percent cover of herb, shrub, moss and tree species; only the herb and shrub layer data were consistently gathered across the survey years, and therefore are most relevant to addressing the management question. An increase in shrub cover was recorded at both treatment sites in 2020, compared to previous years (Appendix 8). Although, shrub cover remained relatively sparse and was limited mostly to *Alnus sinuata* (sitka alder) and *Salix bebbiana* (Bebb's willow). In both cases, shrub growth was at the sapling stage where plants were approximately 1 m in height.

The percent cover for the herb layer increased substantially in 2016 (two years after the enhancements) at both sites, but in 2020 the response diverged at these two sites for the portions of the transects not submerged at the time of the fieldwork. A decline in coverage was recorded at Ole Creek in 2020 and the opposite was observed at Six Mile Creek.

There were no clear trends in herb species richness between treatment and control sites when multiple years of data (e.g., 2014 to 2016) were compared. It is likely that climatic factors or reservoir operations affected species persistence across the years. The percent cover of herbs at

the control sites varied across the years sampled but was generally higher than what was observed at the treatment sites, which was likely due to the relative natural conditions (i.e., no disturbance) at the control sites.

While the riparian vegetation appeared to be trending to an increase in diversity and abundance, the enhancement areas are influenced by variation in annual reservoir influx and elevations, which is likely affecting the establishment of this riparian vegetation.

5.3.3 Visual Surveys and Photographic Review

Comparison of riparian vegetation growth on the enhancement structures in the final year of the program to previous years was partially possible. When photographs were taken in July of 2020, reservoir elevations were relatively high, compared to previous years (Figure 1), and several of the enhancement structures were submerged. However, a proportion of the structures at Six Mile Creek and Ole Creek could be surveyed (Appendix 5), and vegetation in the early stages of becoming established was observed, indicating that riparian vegetation is becoming enhanced by the project. Fireweed (*Chamaenerion angustifolium*) had become prevalent on several berms (e.g., photo J2 Appendix 5). This pioneer species typically takes hold on disturbed sites and helps to prepare the substrate for other plant species.

5.3.4 Challenges and Opportunities

Data collection in 2011 occurred before the location of the treatment (enhancement) sites were known. Vegetation data collection was suspended until this information was know, but only re-commenced after the construction of the enhancements in 2014. Vegetation data were collected immediately after the construction period, when vegetation composition at the time was comprised of the live willow stake and grass seed that were applied as part of the site stabilization. Because of the variation in data collection methods and the location of survey transects between Year 1 and subsequent years of monitoring, comparisons of vegetation data from pre-construction to post-construction conditions was not possible; however, these circumstances did not impede the ability to address MQ3.

Survey methods during the post-construction period were sufficiently consistent to address MQ3; although, observers varied as did the actual number of transects surveyed, which likely contributed to some variability in the vegetation data. Also, the number of transects at each treatment site (i.e., three) represents a small sample size, which created a challenge, especially during years of higher reservoir elevations when transects were submerged. Finally, while photographs of the enhancement structures were taken immediately after construction to document to the work, the photographic review was not discussed until early 2020 (i.e., in the final year of the monitoring program). If the photographic review was planned in advance, specific photo-points could have been established and an additional number of representative photographs could have been used. Further, by establishing specific photo-points, a more quantitative approach to the review would have been possible and photos could have been reviewed annually to track the success of the treatment sites for increasing riparian vegetation.

It is anticipated that inspection of the enhancement structures will continue in the future. This presents an opportunity to continue with the photographic review. Photo-points are now established and any crews conducting the inspection could re-create the sample photographs at no additional cost

5.4 MQ4: Does abundance and diversity of song birds (passerines) around tributaries change as a result of enhancement?

No consistent pattern was revealed in how the enhancements affected bird utilization around tributaries. First of all, the songbird data collected in 2011 were not very useful as a pre-enhancement dataset when compared to the data collected in 2014 through 2016 due to the variation is sampling methods. During the post-enhancement monitoring, no difference in species richness or abundance could be ascertained at Ole Creek (treatment) and Factor Ross Creek (control); therefore, the enhancements at Ole Creek did not appear to have an effect on songbird species. Likewise, while species richness appeared to increase over time at Six Mike Creek (treatment) post-enhancement, a similar trend was recorded at Lamonti Creek (control). No observable effect was recorded to show that a change in the abundance and diversity of songbirds occurred after the enhancements. Therefore, it can be concluded the project had minimal effect on songbirds. Further descriptions of individual species recorded at each site is presented in Appendix 6.

5.4.1 Challenges and Opportunities

A number of factors limited the utility of using songbird data to assess the effectiveness of tributary enhancements. Survey methods varied between the pre-enhancement and post-enhancement periods and the specific methods used limited the ability to associate the recorded data to the specific enhancements.

Variable radius point counts were used to record all birds within and outside a 75 m radius. Five minute recording periods were used in 2011, whereas 30 minute periods were used in 2014 through 2016. The latter, longer observation periods are more useful when conducting spot mapping, where bird observations are directly linked to habitats and/or breeding areas. In addition, sampling methods that employ line transects can be used to record species that utilize the treatment areas, which in this case may have been preferable given the way the treatment areas were constructed (i.e., lateral berms). Bird observations are typically recorded at distance gradients from the centre of the transect (e.g., 0-10 m, 11-25 m, 26-50 m, >50 m) so that songbird utilization of treatment areas could be differentiated from bird use of adjacent habitats. Songbird data was summarized as species richness and abundance within and outside of 75 m, so the results may have influenced by adjacent upland habitats (Hilton 2019).

Overall, the results of the songbird monitoring from GMSMON-17 had low statistical power to detect changes in songbird abundance and diversity around the tributaries due to the small number of sampling plots (i.e., 1 or 2) and limited number of songbird observations in each survey. Songbird utilization of the enhanced areas will be a function of the persistence and succession of vegetation. The results to date do not indicate a change in songbird abundance or diversity as a

results of the enhancement and it is expected that conditions would either improve over the long-term or not negatively effect songbirds; therefore, further monitoring of songbirds in the enhancement areas is not recommended or required.

5.5 MQ5: Does amphibian abundance and diversity in tributaries change as a result of enhancement?

In consideration of the outcome of the site enhancement work, the variability of the amphibian data did not allow a quantitative answer to this management question; however, this project has shown use of the drawdown zone, adjacent to the enhancement works, at each site by a relatively stable diversity of amphibians throughout the course of the project (pre- and post-enhancement). While the abundance of amphibians of the various species recorded in areas potentially affected by the enhancement remained relatively low and stable through time (pre- and post-enhancement) and there was no evidence of changes to amphibian abundance and diversity within areas influenced by the enhancement at each site.

Monitoring for amphibians was completed in the first six years of the program but the survey methods varied across the years. From 2011 through 2013, Golder Associates Ltd. completed surveys in the drawdown zone and at upland locations >200 m from the drawdown zone at each site. Few locations were surveyed at each site, and it was unclear which of the locations were revisited each year. In 2014, DWB Consulting Services Ltd. changed the methods and surveyed plots or searches in the drawdown zone, upland areas <200 m from the drawdown zone, and upland areas >200 m from the drawdown zone. In 2015 and 2016, DWB Consulting Services Ltd. repeated these methods, but also added in transects within the drawdown zone that were surveyed at night. Given the variation in survey methods across years, it was determined that the amphibian data could not be analyzed in the context of a before-after-control-impact (BACI) design (Hilton 2019). Despite these limitations, there were some trends worth noting.

Amphibians were only recorded within a tributary during the post-enhancement monitoring in 2015; therefore, this discussion will focus on amphibian abundance and diversity within and above the drawdown zone during the pre-enhancement and the post-enhancement periods. No substantial differences were noted in the species diversity within the drawdown zone before and after the enhancements for both the treatment and control sites. Western toads appeared to be using all drawdown zone sites, both pre- and post-enhancement. Wood Frog was observed at the bottom of Six Mile Creek during fish spawning surveys in 2015 (MacInnis et al. 2015). All other amphibian detections made during this program were within terrestrial habitat or wetland habitat (see Section 5.6).

5.5.1 Challenges and Opportunities

Originally, this project was intended to have a BACI design. However, there were few pre-enhancement surveys completed in relevant areas of the drawdown zone at the two treatment sites; it was determined that a before-after enhancement comparison was not possible. In addition, some of the locations that were surveyed by Golder Associates Ltd. were not surveyed by DWB Consulting Services Ltd. (MacInnis et al. 2015). Further, the locations of searches (that

did not yield amphibian detections) were lacking for 2014 so it was not possible to determine where surveys occurred that year. Some of the locations surveyed in 2014 were revisited in 2015 and 2016, but many survey locations appeared to be new.

Few surveys were completed pre-enhancement in relevant areas of the drawdown zone at the two treatment sites, and the diversity and numbers of amphibians using the areas pre-enhancement were not well established. In addition, survey and/or amphibians data was not consistently collected each year, which resulted in data gaps that limited the ability to standardize data for multiple years to allow for cross-year comparisons. For instance, data on amphibian captures (e.g., weight, SVL and age class) are incomplete preventing a multi-year examination of relationships between these variables and capture location or time of year. Likewise, data on amphibian life stages were not consistently collected and the survey locations for amphibians were not consistently visited during each year of the monitoring. The number of amphibians captured per unit of time or per searched area could not be computed for most years of the project and the relationships between environmental conditions and amphibian detections could not be explored. Therefore, a comparison to amphibian data post-enhancement was not deemed appropriate (Hilton 2019c).

5.6 MQ6: Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?

The area and quality of amphibian breeding habitat did not substantially change over time as a result of the tributary enhancements. Evidence of breeding in the drawdown zone was limited to a long-toed salamander egg mass in a small pool at Six Mile Creek in 2011, and western toads in amplexus in a slow flow inlet created by an earth berm at Six Mile Creek in 2015. Other detections of amphibian breeding and amphibian breeding habitat were recorded during the monitoring for GMSMON-17, but these were from more permanent wetland habitats on the margin of the drawdown zone at Six Mile Creek, and possibly at Factor Ross Creek and not in areas that were influenced by the enhancements.

For the enhancements to change the area and quality of amphibian breeding habitat, these would first have to result in conditions that either enhance or detract from suitable breeding habitat. Drawing upon the observations noted above, the small pool in the basin silt habitat at Six Mile Creek was first surveyed in 2011 and then not surveyed again until 2016. This suggested that the pool persisted over the years. The suitability of this pool as breeding habitat likely varied annually depending on the climatic conditions, vegetation succession, and fluctuations in the reservoir elevation. A similar scenario can be described for the slow flow inlet created by the earth berm at Six Mile Creek. The construction of the tributary enhancements was not expected to affect the amphibian breeding habitat that was documented above the drawdown zone; although, these areas were flooded by reservoir operations in 2015 and 2016 (post-enhancement).

5.6.1 Challenges and Opportunities

Other than observations of breeding evidence, no actual quantitative data on breeding habitat (e.g., persistence of water bodies, water temperature, water depth, substrate, aquatic

vegetation) were collected. Quality of the breeding habitat at this site can only be inferred from amphibian use of the area through time. In 2015, DWB Consulting Services Ltd. modelled occupancy by dividing the number of plots where any species of amphibian was detected by the total number of sites that were surveyed, under the premise that occupancy is related to abundance. These results were highly variable with standard deviations nearly as large as the estimates of occupancy. Plus, when assuming a low detection probability, the estimates of occupancy suggested that between 150 and 500 sites would need to be resampled six times at each location to achieve any significant power to detect a change in occupancy (MacInnis et al. 2016). Using this approach there was insufficient sampling time and effort to address this management question.

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Appendix 1
Timeline of GMSMON-17

Year	Activities
2008	The Terms of Reference for the Peace River Water Use Plan Monitoring Program: Tributary Habitat Review (GMSMON-17) was prepared. The objective of the monitoring program was to address the management questions by collecting the data necessary to draw inferences and to test the hypotheses. The general approach to the monitoring program is a before-after-impact study that will consist of annual fish surveys, fish habitat assessment, riparian vegetation assessment, songbird survey, as well as amphibian and amphibian-habitat inventory assessments
2011	First year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Fish habitat delineation • Reconnaissance snorkel and angling fish surveys • Kick net sampling for fish eggs • Fish spawning survey • Removal depletion fish surveys Vegetation: • Paired line intersect transects • Quadrat sampling Birds: • Breeding bird point counts Amphibians: • Time constrained amphibian searches • Area constrained amphibian searches
2012	Second year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Installation of stream gauging stations and discharge measurements at Six Mile and Ole creeks • Spawning surveys • Juvenile and small-bodied fish population estimates • Discharge measurements at stream gauging stations Amphibians: • Time constrained amphibian searches • Area constrained amphibian searches
2013	Third year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Maintenance of stream gauging stations and discharge measurements at Six Mile and Ole creeks • Visual assessment of fish passability at tributary mouths • Spawning surveys • Discharge measurements at stream gauging stations • Juvenile and small-bodied fish population estimates Amphibians: • Time constrained amphibian searches • Area constrained amphibian searches
2014	Construction of the enhancement structures at Six Mile Creek and Ole Creek.

	Fourth year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Tributary access assessment and fish habitat • Drawdown zone fish sampling • Spawner surveys • Juvenile fish surveys • Fry surveys Vegetation • Habitat classification – description of vegetation communities • Ground sampling - belt line quadrat transects Amphibians: • Time constrained amphibian searches • Area based surveys targeting wetlands Birds: • Breeding bird point counts • Scans for waterfowl and shorebirds
2015	Update to the Terms of Reference based on the review of the 2011-2013 dataset. A change to the Management Question and an updated approach was identified to better meet the objectives of the study as originally described in the Water Use Planning process. Fifth year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Tributary access assessment and fish habitat • Drawdown zone fish sampling • Spawner surveys • Juvenile fish surveys • Fry surveys Vegetation • Habitat classification – description of vegetation communities • Ground sampling - belt line quadrat transects Amphibians: • Time constrained amphibian searches • Area based surveys targeting wetlands • Night-time transect surveys Birds: • Breeding bird point counts • Scans for waterfowl and shorebirds
2016	Sixth year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Stream velocity, stage and discharge measurements • Habitat assessment through aerial imaging • Tributary access assessment and fish habitat • Spawner surveys Vegetation

	• Habitat classification – description of vegetation communities • Ground sampling - belt line quadrat transects Amphibians: • Time constrained amphibian searches • Area based surveys targeting wetlands • Night-time transect surveys Birds: • Breeding bird point counts • Scans for waterfowl and shorebirds
2017	Seventh year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Visual surveys of the constructed berms • Discharge measurements and channel depth assessments Vegetation Visual surveys
2018	Eight year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Visual surveys of the constructed berms • Discharge measurements and channel depth assessments Vegetation • Visual surveys
2019	Sixth year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Visual surveys of the constructed berms • Discharge measurements and channel depth assessments Vegetation • Visual surveys
2020	Sixth year of monitoring and baseline data collection. Field surveys were comprised of: Fish: • Visual surveys of the constructed berms • Discharge measurements and channel depth assessments Vegetation • Ground sampling - belt line quadrat transects • Photographic review

Appendix 2: Williston Trial Tributaries – Implementation Year 10 - GMSMON 17
Study Period: April 2020 to December 2020

Peace Project Water Use Plan

WILLISTON TRIAL TRIBUTARIES

Implementation Year 10

Reference: GMSMON-17

Study Period: April 2020 to December 2020

LGL Limited environmental research associates
9768 Second Street
Sidney, BC, V8L 3Y8

December 2020

EA3916

PEACE PROJECT WATER USE PLAN

Program No. GMSMON-17

Williston Trial Tributaries

Final Report Year 10 (2020)

Prepared for

BC Hydro

BC Hydro Generation
Peace River Water Use Plan
6911 Southpoint Drive
Burnaby, BC

BC Hydro Reference # EC13-490459

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December 2020

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Cover photos:

From left to right: Ole Creek constructed Berm B, Ole Creek debris catchers and planted vegetation on Berm A, Six-Mile Creek planted vegetation on Berm J, Six-Mile Creek embedded Large Woody Debris along Berm D. All photos taken on May 28 and 29, 2020 © Chu Cho Environmental and LGL Limited.

EXECUTIVE SUMMARY

Under project GMSMON-17 (Williston Trial Tributaries and Tributary Habitat Review), six management questions and associated hypotheses were developed to direct the study design and monitoring program. This report presents the results of the tenth year of the program and the third year of monitoring carried out by Chu Cho Environmental and LGL Limited. The purpose of the Ole and Six Mile Creek enhancements is to prevent extensive braiding and thus maintaining Ole and Six Mile Creeks throughout the draw down zone (DDZ) in one fish-passable channel at spring water levels. In 2020, all habitat restoration or enhancement works in the estuaries of Ole and Six Mile Creeks were inspected and deemed functional.

Training Berms: The berms constructed at both creeks were still preventing creek braiding and the related shallow and high velocity creek morphology which can pose an obstacle to fish migration. While berm erosion did not appear to have progressed, settlement of fines and sand on the berm crests was observed but may not need to be addressed since this may be enforcing berm stability and function.

Embedded Large Woody Debris (LWD) Structures: The embedded LWD structures are still providing their primary function of stabilizing constructed banks and berms. With regards to their secondary purpose of initiating scouring of holding pools and providing shading and cover to fish, the erosion of the trained channels has lowered the thalweg and the water surface levels in both creeks leaving the embedded LWD structures elevated above the creek surfaces. Without direct contact to creek flow, even at spring discharge levels, the LWD structures cannot initiate or maintain pool scour or provide shading and submerged cover for fish. Since the creek channel was prevented from braiding and no obstacles to fish migration were identified, the LWD triggered creation of low flow and shaded fish holding habitat in the DDZ did not appear to be essential.

Debris Catchers: In general, the installed debris catchers were preventing driftwood accumulation, log jam creation and fish migration obstacles from forming. Nevertheless, small amounts of driftwood have started to penetrate the creek channel and may need to be removed in the future. A good portion of the driftwood inside the debris catchers had a length and weight that may make it possible to be removed manually.

Vegetation: The successful growth and establishment of the planted vegetation was directly correlated with period of reservoir inundation during the growth season from May to October. Establishment of vegetation at lower elevations, which were close to being permanently inundated, was generally not successful while vegetation planted at higher elevations was successful in stabilizing berms and creating shade. Natural vegetation was establishing itself alongside the planted vegetation on the constructed berms.

Flow Velocity, Discharge and Water Depths as an Obstacle to Fish Migration: Arctic Grayling and Rainbow Trout can typically sustain swimming speeds of 0.1 – 0.5 m/s for longer periods of time. These discharge velocities were found at the margins of Ole Creek in water depths from 10-20 cm at the discharge measurement location on May 29, 2020. Flow velocities in deeper water were much higher. Discharge and flow velocities across Six-Mile Creek could not be measured in 2020 due to high water conditions that made it unsafe to cross the creek. In addition to the sustained swimming speeds of 0.1 – 0.5 m/s for Rainbow Trout and Arctic Grayling, the maximum burst speeds for the two species are reported as approximately 1.6 m/s for Arctic Grayling and 1.47 m/s for Rainbow Trout with a fork length of <40 cm. Therefore, both species would likely be able to cross short stretches of high velocity areas in deeper water by seeking out low velocity areas on the creek margins to recover. At discharges higher than

encountered in 2020, migration for both species would likely be impeded by current velocities exceeding maximum burst swimming speeds throughout all depth > 10 cm.

Table 2 Year 10 (2020) status of the GMSMON-17 management questions and management hypothesis

Management Question (MQ)	Management Hypothesis	Year 10 (2020) Status
MQ1: Does access for spring spawners (i.e., Rainbow Trout and/or Arctic Grayling) improve as a result of enhancement?	H_{01}: Access to spawning habitat in the spring period – as measured by the proportion of modified channel with sufficient depth for target fish passage – increases following enhancements to tributaries.	In Year 10, the depth of the modified channels throughout the DDZ in both creeks is still sufficient for target fish passage.
MQ2: Is the area and quality of fish habitat created by the tributary enhancement maintained over time?	H_{02}: Total rearing area for fish increases following enhancement to tributaries.	Yes, when compared to the 2016 results, the increase of rearing habitat following enhancement has been maintained in 2020.
MQ3: Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?	H_{03}: Riparian vegetation abundance and diversity along the tributaries increases following enhancement to tributaries.	In general, riparian vegetation has increased as a result of enhancement in the higher elevation locations but was not successful at the lower (mostly inundated) elevations.
MQ4: Does abundance and diversity of song birds (passerines) around tributaries change as a result of enhancement?	H_{06}: Song bird abundance and diversity near tributaries increases following tributary enhancement.	Songbird assessments were not planned for 2020 (as per contract).
MQ5: Does amphibian abundance and diversity in tributaries change as a result of enhancement?	H_{04}: Amphibian abundance and diversity in and near tributaries changes following tributary enhancement.	Amphibian monitoring or sampling was not planned for 2020 as per contract.
MQ6: Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?	H_{05}: Total amphibian breeding area changes following enhancement.	Amphibian monitoring or sampling was not planned for 2020 as per contract.

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    d. Physical habitat enhancement works at the mouths of Six Mile Creek Ole Creek
- Methods
    a. Visual Surveys
    b. Discharge Measurements and Channel Depth Assessments
    c. Data Entry and Analysis

2 RESULTS

2.1 Reservoir Conditions

During the 2020 field season, the elevation of Williston Reservoir ranged from a daily average low of 656.1 m ASL on April 20 to a daily average high of 670.4 masl on July 27 (Table). On May 28 and 29, 2020, reservoir elevations (661.49 and 661.69 masl, respectively) allowed for inspection of all constructed works in the mouth of Ole and Six -Mile Creek in the dry. Therefore, habitat enhancement works could be visually assessed at the field inspection dates since they were not obscured by high reservoir levels or snow.

Table 1 Dates and reservoir elevations of for the 2020 field sessions for GMSMON-15

Field Session	Project	2020		Reservoir Elevation (masl)*		
		Start Date	End Date	On Inspection Date	2019 Max	2019 Min
Six-Mile Creek Works Inspection	GMSMON- 17	May 28	May 28	661.49	670.4	656.1
Ole Creek Works Inspection	GMSMON- 17	May 29	May 29	661.69	670.4	656.1

*elevations where the Ole and Six Mile Creeks works begin to get inundated: Ole Creek=663.3 masl; Six Mile Creek = 664.8 masl.

In 2020, the reservoir levels were lower (656.1 masl 2020 versus 658.6 masl 1980-2010 average) than most previous years, reaching minimum elevations slightly earlier (April 20 in 2020 versus May [1980-2010 average]) (Figure 3). The timing (July 27 in 2020 versus Aug 10 [1980-2010 average]) of the maximum elevation in 2020 was earlier than average but the elevation height (670.4 masl versus 669.3 masl [1980-2010 average]) was very similar to the average.

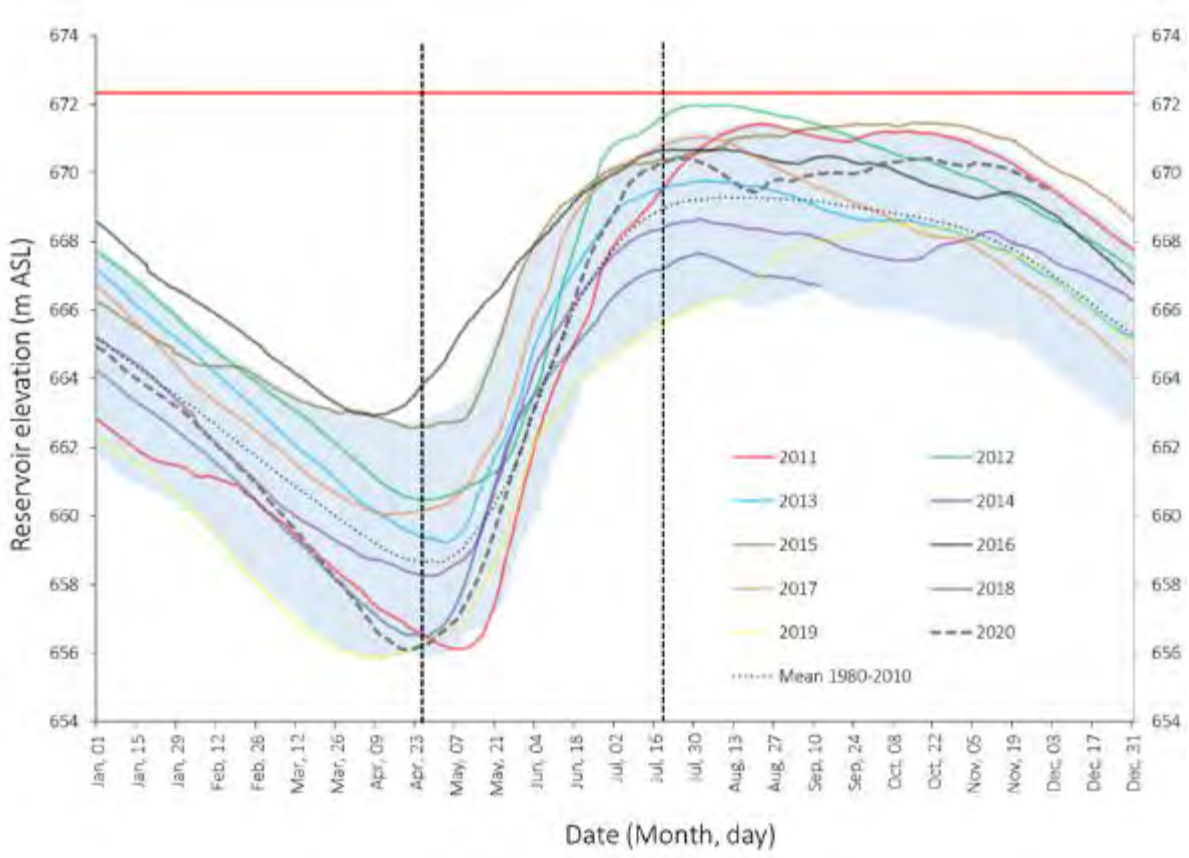

Figure 3 Williston Reservoir elevations from 2011 to 2020. The shaded area represents the 10th and 90th percentile for the period 2011 to 2019; the horizontal red line is the normal operating maximum. Vertical dashed lines indicated start and end dates of GMSMON-15 and GMSMON-17 sampling in 2020.

2.2 Environmental Conditions

The average daily temperatures in 2020 were initially, in early April, below and for the rest of the sampling season similar to the range of variability of the daily mean temperatures during the previous years of monitoring (Figure 4).

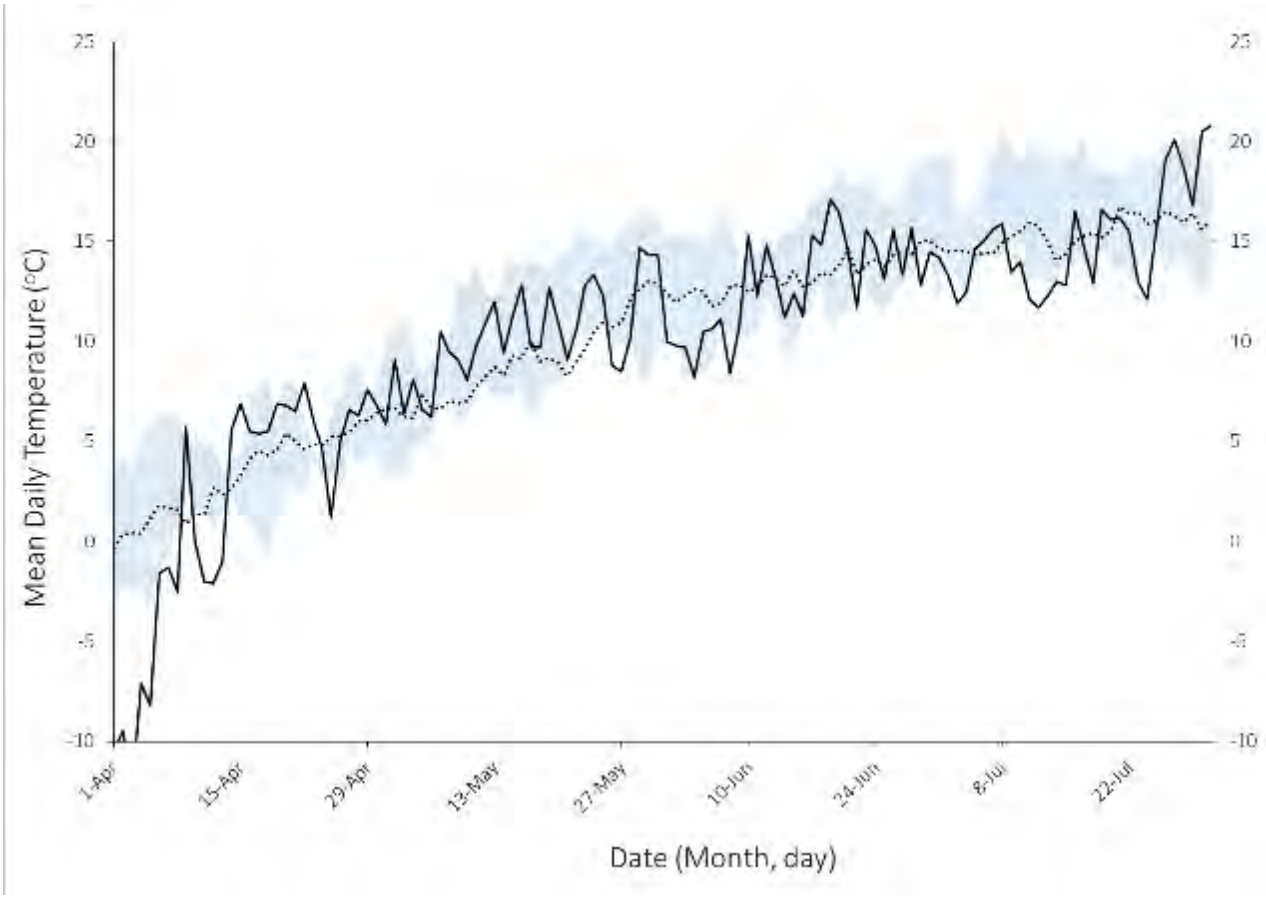

Figure 4 Daily mean air temperature for 2020 (black line) in the study region for the monthly periods when field surveys occurred. The shaded area represents the standard deviation (+/-) of the daily mean air temperatures for Years 1-9 (2011-2019) of the monitoring program. Dotted line represents the average mean temperature from 1980-2010.

Cumulative precipitation during the survey period in 2020 was typically within the range of variability measured during the previous years of monitoring in April and May (Figure 5). At the end of June and throughout July 2020 precipitation was substantially higher than average conditions.

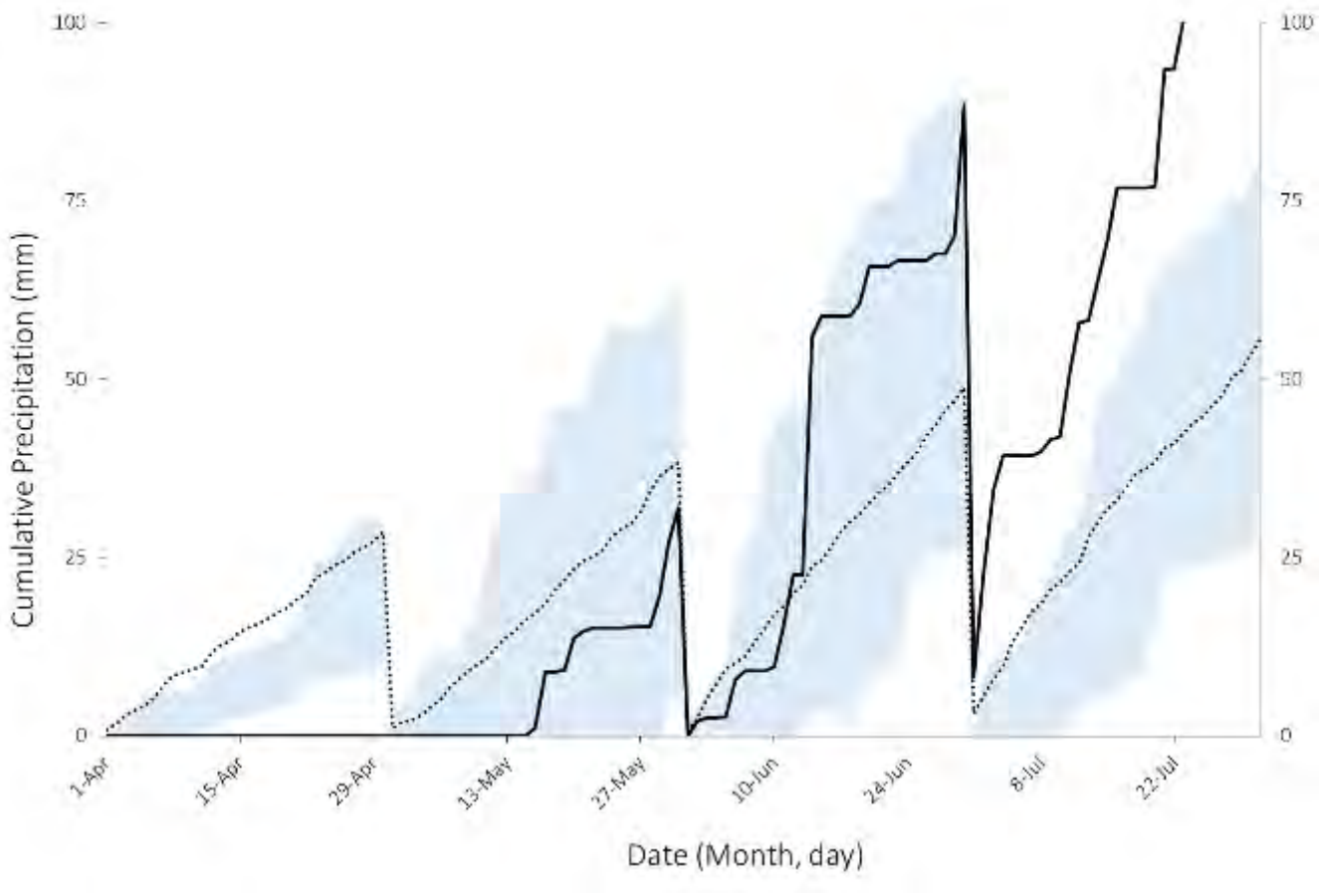

Figure 5 Cumulative monthly total precipitation for 2020 (black line) in the study region for the monthly periods when field surveys occurred. The shaded area represents the standard deviation (+/-) of the cumulative monthly total precipitation for Years 1-9 (2011-2019) of the monitoring program. The dotted line represents the average cumulative precipitation from 1980-2010.

2.3 Ole Creek

During the May 29, 2020 Ole Creek site inspection none of the structures constructed in 2014 were inundated by Williston Reservoir (reservoir level = 661.69 m), all snow had melted, and vegetation had started to grow. In addition, Ole Creek discharge was high and the creek was not safe to wade. Therefore, conditions during the 2020 site inspection were ideal for the survey of all constructed structures but not to measure discharge. An overview orthophoto showing the location of all enhancement structures as originally constructed is provided in Figure 6.

Maintenance of an Unbraided Single Channel and Fish Access: In general, Ole Creek works adequately met the performance objective of maintaining a single thread channel as designed. Within this single channel, water depth and velocity, measured during the site inspection, may allow for access of Rainbow Trout and Arctic Grayling into Ole Creek for spawning and rearing based on the current velocity values measured on May 29, 2020 and shown in Table 2.

Table 2 Current velocities and water depths for discharge measurement undertaken at Ole Creek on May 29, 2020.

Field Survey Distance (m)	Water Depth (m)	velocity (m/s)	Area (m^2)	Discharge (m^3/s)	Total Discharge (m^3/s)
0.75	0.00	0.00	0.000	0.000	
1.00	0.20	0.68	0.075	0.051	
1.50	0.20	0.96	0.100	0.096	
2.00	0.20	1.27	0.109	0.138	
2.50	0.27	1.01	0.189	0.191	
3.00	0.25	0.79	0.178	0.140	**0.97**
3.50	0.20	0.76	0.156	0.119	
4.00	0.15	0.97	0.081	0.079	
4.50	0.15	1.07	0.069	0.074	
5.00	0.1	0.78	0.094	0.073	
5.50	0.15	0.22	0.032	0.007	
5.51	0	0.00	0.001	0.000	

Erosion of or Settlement on Berms: During the May 5, 2016 and the June 12, 2018 site surveys, there appeared to be some settlement / erosion on the right bank (looking downstream) berm crest, but this does not appear to have progressed over the last three years.

Plantings: As in 2019, all but very few of the willow stakes planted in 2014 had withered; although, a number of natural willows had established.

Seeded Erosion Control Matting: The seeded erosion control matting (ECM) was showing promising growth of grass, clover and other natural vegetation. To maintain this development additional seeding may need to occur in future years.

LWD Structures: The embedded LWD structures were still stabilizing the toe of the constructed berms but the LWD structures were neither creating scour pools, nor did they provide fish cover or shading at the creek level. It appeared as if Ole Creek may have lowered its thalweg through erosion, leaving the LWD structures elevated above creek levels at all but the highest discharges. The observation that the creek thalweg has been lowered, will need to be confirmed through a detailed elevational survey.

Detailed and Structure-Specific Assessment Results: Detailed May 29, 2020 inspection results for all Ole Creek structures are shown in Table and Table 4Table and related photographs are shown in Figure 7 and Figure 8.

An Ole Creek enhancement structure overview is shown in Figure 6.

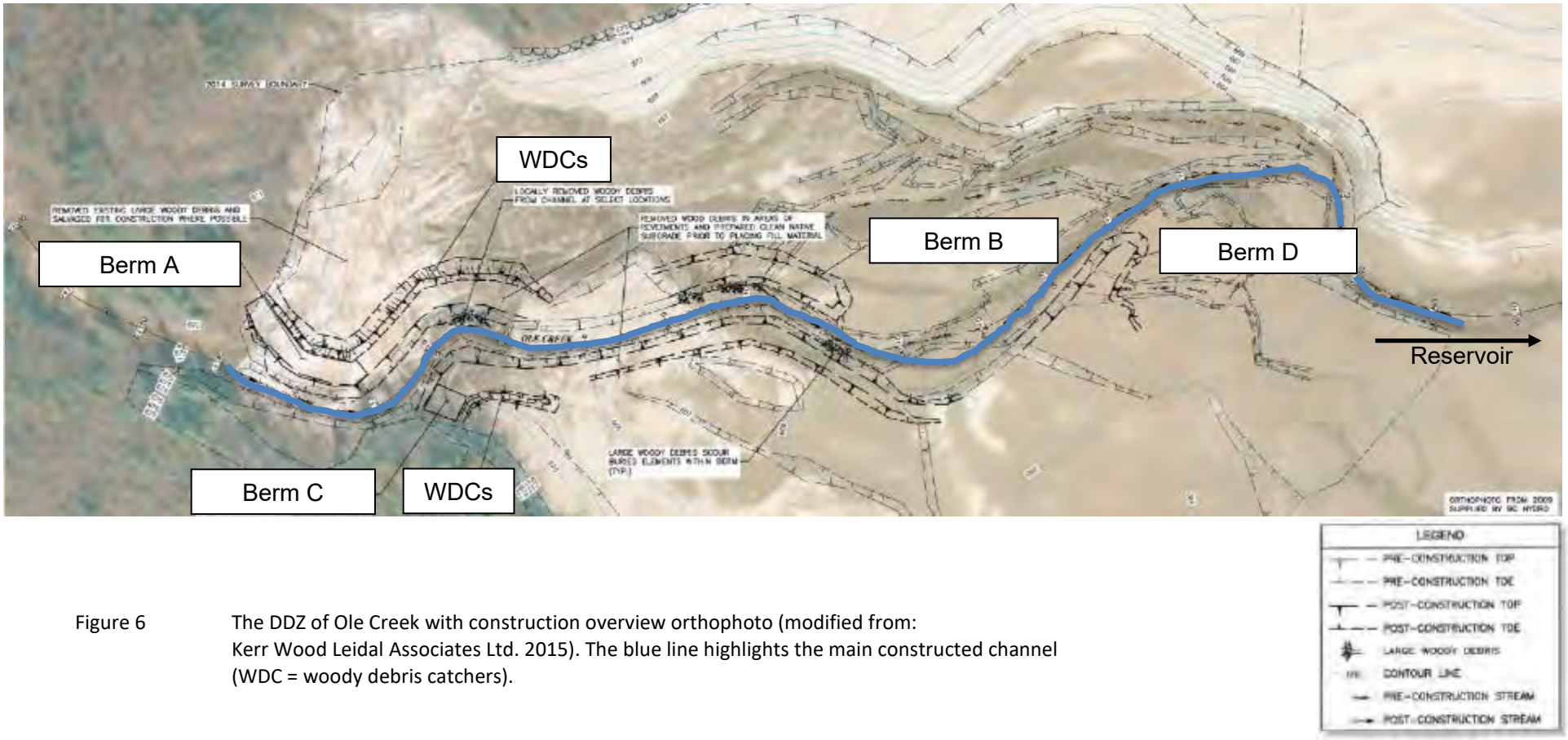

Figure 6 The DDZ of Ole Creek with construction overview orthophoto (modified from: Kerr Wood Leidal Associates Ltd. 2015). The blue line highlights the main constructed channel (WDC = woody debris catchers).

Table 3 Summary table for detailed 2020 observations made at Ole Creek structures Berms D, B and C built in 2014 (woody debris catchers=WDC).

Structure	2020 Structural Integrity	Likely Deterioration Cause	2020 Ecological Function	Action Needed
Berm D: Low gravel-cobble berm	Berm structurally sound; we observed a small amount of cobble erosion and movement as well as fines accumulation on the berm crest	Driftwood, ice movement, rising and falling reservoir	Berm D maintained a single channel	None at this point
Berm B: Low gravel-cobble berm; embedded LWD	Berm structurally sound; embedded LWD structures were present and stable	None observed	Berm B maintained a single channel; embedded LWD stabilized berm toe but created little scour, cover or shading because they were elevated above the creek	Elevational survey to assess whether the thalweg is lowering
Berm C: Low gravel-cobble berm, embedded LWD; WDC	Berm structurally sound; embedded LWD structures present and stable; woody debris catchers were intact; a small amount of erosion and cobble movement on the crest of the downstream berm portion	Driftwood, ice movement, rising and falling reservoir	Berm C maintained a single channel; embedded LWD stabilized berm toe but created little scour, cover or shading because it was elevated above the creek; WDC intact and functional; small amount of driftwood inside WDC did not interfere with works yet	Elevational survey to assess whether Thalweg is lowering

Figure 7 From left to right, Berm D (left, looking upstream), Berm B (looking downstream) and Berm C with WDC structures (Ole Creek, May 29, 2020).

Table 4 Summary table for detailed 2020 observations made at Ole Creek structures Berm A, a log jam and for discharge, water velocities and depths

Structure	2020 Structural Integrity	Likely Deterioration Cause	2020 Ecological Function	Action Needed
Berm A: Low gravel-cobble berm; WDC; embedded LWD; planted willow stakes	Berm structurally sound; small amount of cobble erosion at base of upright WDC logs; small amount of driftwood inside of WDC; embedded LWD present and stable; all but two willow plantings failed; little natural vegetation seen in 2019 had disappeared in 2020.	Driftwood, ice movement, rising and falling reservoir	Berm A maintained a single channel; embedded LWD stabilized berm toe but created little scour, cover or shading because it was elevated above the creek; WDC intact and functional; small amount of driftwood inside WDC did not interfere with works yet	Elevational survey to assess whether the thalweg is lowering; possible manual removal of driftwood inside of WDC
Log Jam at Long.: 124°31'48.53"W; Lat.: 56°27'15.54"N;	The previously (2016, 2018) reported log jam was removed.	None	None	Future inspection to assess log jam presence
Current velocities, water depths, discharge (14.6 m^3/s) at 56°27'14.00"N; 124°31'43.73"W	Based on visual assessment, Ole Creek current velocities and water depths through the DDZ may have been suitable for fish migration on May 29, 2020 based on a minimum thalweg depth of 0.5 m and velocity breaks behind cobbles and boulders.	None observed	Facilitated fish migration	Inspection in 2020

Figure 8 From left to right: Berm A with WDC; site of removed log jam (Ole Creek, May 29, 2020).

2.4 Six Mile Creek

During the May 28, 2020 Six Mile Creek inspection, none of the structures constructed in 2014 were inundated by Williston Reservoir (reservoir level=661.49 masl), all snow had melted, vegetation had started to grow, and inspection conditions were ideal. Nevertheless, Six Mile Creek discharge was too high to wade safely and instead of a full discharge measurement, point discharge measurements were carried out in two locations. An overview orthophoto showing the location of all enhancement structures as originally constructed is provided in Figure 9.

Maintenance of an Unbraided Single Channel and Fish Access: In general, the Six Mile Creek works adequately met the performance objective of maintaining a single thread channel as designed. Within this single channel, water depth and velocity appeared to allow for access of Rainbow Trout and Arctic Grayling into Six Mile Creek for spawning and rearing based on visual assessment in lieu of a discharge measurement.

Erosion of or Settlement on Berms: A small amount of erosion and fines accumulation was observed on the Six Mile Creek berms. The observed erosion did not appear to be affecting the hydrological of ecological function of the berms. The coir (coconut husk) of the soil wraps continues to hold up well and no bulk bags (white material) were exposed.

Plantings: Stakes embedded horizontally into the longer inundated Berm C did not sprout and grow while the horizontally embedded stakes on the higher elevation Berm J did sprout and grow and provided shading and cover for fish. Similarly, willow stakes vertically planted on Berm J sprouted and grew along with planted grasses to form a stabilizing vegetation root system. The seeded erosion control matting (ECM) was successful in establishing grass, clover and other vegetation, but additional seeding may need to occur. Good natural grass recruitment was observed since the previous inspection (June 13, 2019).

LWD Structures: The embedded LWD structures were still stabilizing the toe of the constructed berms but the LWD structures were neither creating scour pools, nor did they provide fish cover or shading at the creek level. It appeared as if Six Mile Creek may have lowered its thalweg through erosion, leaving the LWD structures elevated above creek levels at all but the highest discharges. The observation that the creek thalweg has been lowered, will need to be confirmed through a detailed elevational survey.

Detailed and Structure-Specific Assessment Results: Detailed May 28, 2020 inspection results for all Six Mile Creek structures are shown in Table 5Table, Table 6Table and Table7 and related photographs are shown in Figure 10, Figure 11 and Figure 12. An overview orthophoto showing the location of all enhancement structures is provided in Figure 9 .

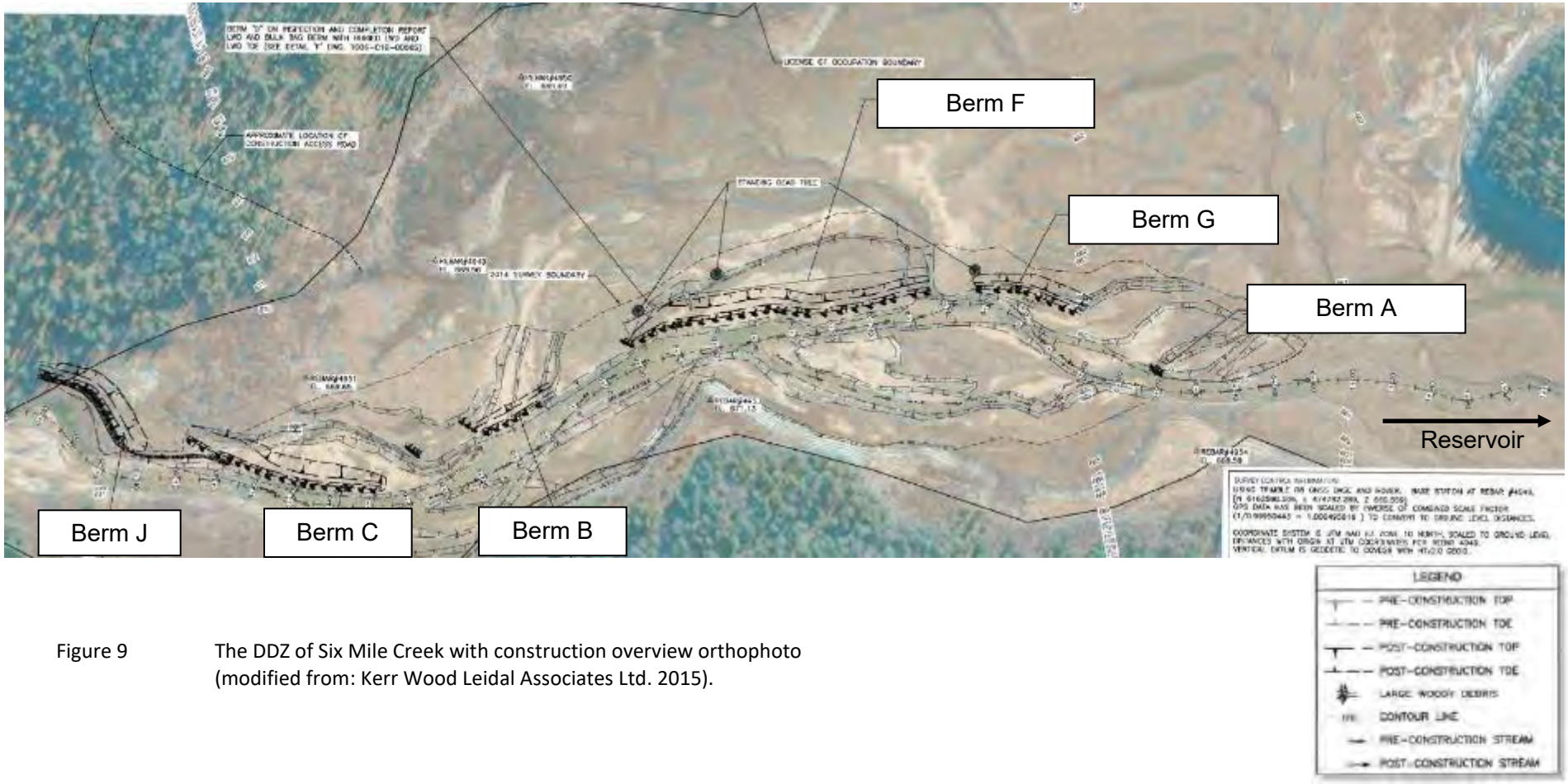

Figure 9 The DDZ of Six Mile Creek with construction overview orthophoto (modified from: Kerr Wood Leidal Associates Ltd. 2015).

Table 5 Summary table for detailed 2020 observations made at Six Mile Creek structures Berm A, Berm F and Berm D built in 2014.

Structure	2020 Structural Integrity	Likely Deterioration Cause	2020 Ecological Function	Action Needed
Berm A: Large buried bulk bag berm with embedded LWD	Berm A appeared structurally sound but mild continuous erosion along all of the berm crest was observed (needs to be confirmed through a detailed elevational survey)	Erosion due to logs, ice movement, rising and falling reservoir	Berm A was still functioning in maintaining a single channel	Elevational survey to assess whether the berm crest is eroding
Berm G: A buried bulk bag berm with embedded LWD	Berm G structurally sound; embedded LWD structures present and stable; coir material used in soil wraps was in good condition and stable	None	Berm G maintains a single channel; embedded LWD stabilized the berm toe	None
Berm F: Non-vegetated geogrid soil wrap berm with embedded LWD	Berm F structurally sound; embedded LWD structures present and stable; coir material used in soil wraps was in good condition and stable; fines settlement on crest	Fines due to ice movement, rising and falling reservoir; perched LWD due to erosion of thalweg	Berm F maintains a single channel; embedded LWD stabilized the berm toe and used to create scour (2016) but scouring function was lost	Detailed elevational survey (to monitor potential accumulations of fines or erosion on berm crest)

Figure 10 From left to right: Berm A; Berm F and Berm G (in background) with embedded LWD (Six Mile Creek, May 28, 2020).

Table 6 Summary table for detailed 2020 observations made at Six Mile Creek structures Berm B and C built in 2014.

Structure	2020 Structural Integrity	Likely Deterioration Cause	2020 Ecological Function	Action Needed
Berm B: Non-vegetated geogrid soil wrap berm with embedded LWD	Berm B structurally sound; embedded LWD structures present and stable; coir material was in good condition and stable	None from the reservoir; perched LWD due to erosion of thalweg	Berm B maintained a single channel; embedded LWD stabilized the berm toe but did not provide fish habitat because it was above water	None
Berm C: vegetated geogrid soil wrap berm with embedded LWD, willow stake plantings and rock spur	Berm C structurally sound; embedded LWD structures present and stable; willow live stakes withered away but grass cover appears healthy; rock spur was structurally sound; coir material in good condition and stable; tie-in to beaver pond was stable	None from the reservoir; perched LWD due to erosion of thalweg	Berm C and the rock spur maintained a single channel; embedded LWD stabilized the berm toe but did not provide fish habitat because it was above water; no larger plants for shading established	Possible re-planting of willow stakes

Figure 11 From left to right: Berm B with embedded LWD; Berm C with embedded stakes and rock spur; (Six Mile Creek, May 28, 2020).

Table 7 Summary table for detailed 2020 observations made at Six Mile Creek Berm J built in 2014.

Structure	2020 Structural Integrity	Likely Deterioration Cause	2020 Ecological Function	Action Needed
Berm J: vegetated geogrid soil wrap berm with embedded LWD and stakes with willow stake plantings	Berm J structurally sound; embedded LWD present and stable; embedded stakes sprouted; planted willow shoots and other vegetation growing well; coir material in good condition and deteriorating as planned; small amount of fines settled on crest	None observed	Berm J maintained a single channel; embedded LWD stabilized the berm toe; embedded stakes were sprouting and providing shade and cover; willow stakes on berm were growing well and provided shade	None
Current velocities, water depths, discharge were not measured on May 28, 2020 due to unsafe conditions	Based on visual assessment, current velocities and water depths in Six Mile Creek throughout the works in the DDZ were suitable for fish migration with a minimum thalweg depth of 0.5 m and velocity breaks behind cobbles and boulders	None observed	Facilitated fish migration	None

Figure 12 From left to right: Berm J with embedded LWD on June 13, 2018 (left picture) and on May 28, 2020 (right picture).

3 DISCUSSION

GMSMON-17, initiated in 2011, is a long-term monitoring program that aims to understand the effectiveness of Ole Creek and Six Mile Creek habitat enhancement demonstration projects in improving creek access for fish in spring during low reservoir levels. Data collected in 2020 represented the last year of the 10-year monitor. The habitat enhancements on both creeks were completed in 2014, so data collected in Year 10 represented the conditions six years after construction. Year 10 also represented the third year that data were collected at the sites by Chu-Cho Environmental and LGL Limited. Previous data collection was completed by Cooper Beauchesne and Associates Ltd. For the most part, the methods employed in previous years of the monitoring program were used in Years 8, 9 and 10.

3.1 Discussion of GMSMON-17 Management Question 1: Does access for spring spawners (i.e., Rainbow Trout and/or Arctic Grayling) improve as a result of enhancement?

The original channels of Ole and Six Mile Creeks in the Williston Reservoir DDZ were heavily braided with very shallow water depths, possibly perched channels and a heavy load of large woody debris. The accumulation of large woody debris in the DDZ is typical for Williston Reservoir tributaries based on the large amount of driftwood.

Roscoe et al. (2014) reported, based on visual observations, that fish access to either creek was not blocked by perched channels or log jams (although a large amount of logs had accumulated in the mouths of both creeks) before habitat enhancement measures were undertaken, but that habitat quality throughout the DDZ was generally poor and not suitable for salmonid spawning or holding.

The suitability as salmonid holding and spawning habitat of both creeks in the DDZ appeared to have improved six years after construction measures were completed. The formerly heavily braided channels have been trained into one non-perched channel with higher water depth throughout the DDZ. In addition to increased depths, current velocities in the trained portion of both creeks appeared to allow for salmonid migration at flows as measured in 2020 in Ole Creek, while the installed debris catchers mainly prevent log jam formations and related creek channel blockage. Depths and current velocities in Six Mile Creek were not safe for wading and were therefore not measured in 2020, but based on visual assessment the creek portions on both sides of the centre thalweg portion appeared suitable for migration of Rainbow Trout and Arctic Grayling.

3.2 Discussion of GMSMON-17 Management Question 2: Is the area and quality of fish habitat created by the tributary enhancement maintained over time?

The berms and debris catchers constructed throughout the DDZ of Ole and Six Mile Creek in 2014 were still functional and maintained the trained creeks in their planned unbraided channels. The root wads installed into the toes of the berms to create back eddies along the trained channel and thus provide current refuges for fish were mainly perched (due to scour) above the water level and therefore did not provide a hydrological function. Additional placement of anchored LWD structures reaching into the creeks at all flows should be considered to provide current refuges and fish holding habitat.

The plantings on berms in both creeks, as expected, have established permanent and thriving vegetation above the Williston Reservoir inundation elevation. Plantings below the annual inundation elevations were not successful and have disappeared.

3.3 Environmental Conditions

Reservoir operations and annual environmental conditions affect the exposure of habitat enhancements to air, water, driftwood and the potential resulting damage caused by these factors on the enhancement works. Therefore, factors such as reservoir elevations and environmental conditions were considered when analyzing the success and perseverance of the constructed habitat features in allowing access to spawning creeks at low reservoir levels in the spring. A final analysis to account for possible confounding effects of reservoir operations and environmental conditions on the function and perseverance of the enhancement works is provided in the main body of this report.

In general, the conditions during the 2020 site visits were ideal for the assessment of all structures on May 28 at Six Mile Creek and May 29 at Ole Creek where none of the structures were inundated. Obscuring snow cover was completely absent, and vegetation had sprouted which allowed for a quick visual assessment of vegetation condition. In future years all restoration structures should be inspected at reservoir levels below 663 masl to allow for inspection in the dry and without being inundated.

3.4 Vegetation

In 2020, and as per the contract with BC Hydro, the vegetation assessment included observations of the continued presence and function the vegetation planted in 2014 under GMSWORKS-19 and vegetation that established itself naturally. Please see detailed inventory of all plant species and their abundances in the main body of this report.

While none of the vegetation planted or embedded below a reservoir level of approximately 666 masl (elevation needs to be confirmed by a survey) sprouted or grew, vegetation planted or embedded above this level grew well and provides shading and cover for fish, in addition to stabilizing constructed banks and berms.

3.5 Fish Presence

In Year 2020 (Year 10), the monitoring of fish presence was not part of GMSMON-17.

3.6 Depth, Current Velocity and Fish Access

The depths and current velocities (shown in Table 2 for Ole Creek and assessed visually for Six-Mile Creek) even at the most restricted channel locations of the constructed channels at both creeks appeared to allow for fish migration at the measured flows in 2020. Arctic Grayling have a maximum burst (>20 sec) swimming speed of approximately 1.6 m/s while a swimming speed of approximately at 0.5 m/s can be maintained of periods of up to 20 minutes (Cahoon et al. 2018, Mac Phee and Watts 1975). Rainbow Trout have a maximum swimming speed of 1.47 m/s and average prolonged speeds of 0.4-0.8 m/s, for fish >0.41 m fork length, which overlaps with the length of Rainbow Trout that are spawning in Ole and Six Mile Creeks (Katopodis and Gervais 2016). Based on these swim speed values, migration along the margins of both creeks in water depth of 10-15 cm should have been possible at the discharges measured in May of 2020. Discharge measurements as per Resource Inventory Standards (Manual of British Columbia Hydrometric Standards – Version 1.0. March 12, 2009) are carried out at one third of the water depth where current velocities are typically much higher than close to the bottom as can be seen in Figure 13 on an example of a culvert where currents at one third of the water depth were approximately 2 m/s while the current velocity close to the culvert bottom was much slower at 0.3-0.8 m/s. In a natural creek with rougher bottom substrate the differences between one third

depth and bottom current velocity are likely even more pronounced. We therefore assume that in addition to using the creek margins for migration in depth of 10-15 cm, migration may also have been possible in slightly deeper water close to the bottom.

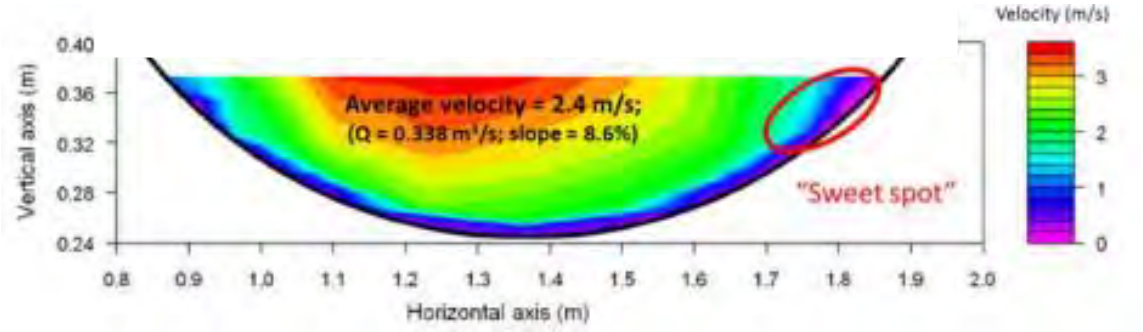

Figure 13 Current velocities measured in a culvert at different depths and distance from the bottom (from: Katopodis and Gervais 2016).

Nevertheless, additional scour pools created by adding LWD structures, which are either anchored in the stream channel or embedded in the berms at an elevation that allows them to be in the water, are recommended for any future installations. These added LWD structures would create additional low current and resting areas between the long runs and rifles that may pose physical exhaustion for smaller fish.

4 CONCLUSIONS

Vegetation development and establishment can be a relatively slow ecological process, so the longer time series (i.e., 10 years) was necessary. Vegetation was successfully established at elevations that are inundated for only short annual periods of time. Natural vegetation established on the constructed berms at the same elevations. We therefore recommend surveying the lowest elevation for successful vegetation establishment as a guideline for future plantings.

The berms built to contain both creeks in a single channel to avoid the formation of shallow fast flowing and braided channels that can become an obstacle to fish passage are in good condition and fully functional. The same is true for the constructed Woody Debris Catchers that are still intact and kept the majority of driftwood out of the creek channels. The manual removal of small amounts of driftwood inside of the Woody Debris Catchers should nevertheless be considered in the future.

The embedded LWD structures are still functioning in preventing or slowing erosion of berm toes but are now elevated above creek level for most of the year and therefore will not create scour pools or provide low velocity refuges for fish. LWD structures anchored to reach below the creek surface level or the addition of boulders and general complexing of the creek channels may be needed to create low current velocity pockets in the future.

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Appendix 3
Habitat Classification

Habitat class descriptions and the comparison between the total area classified in 2014 to 2016.

			Six Mile						Ole					
			2014			2016			2014			2016		
Habitat Class	**Habitat Class Name**	**Habitat Class Description**	**No. Polygons**	**Area (ha)**	**% Area**	**No. Polygons**	**Area (ha)**	**% Area**	**No. Polygons**	**Area (ha)**	**% Area**	**No. Polygons**	**Area (ha)**	**% Area**
BS	Basin Salt	Lacustrine surface material with a plain surface expression and low to minimal coarse woody debris cover. Vegetation cover within the basin areas is mainly absent; however, occasional herbaceous germinants may be observed in the early spring, prior to flooding. Soils are mainly silt and sand textured. Groundwater is the main water source.	5	2.51	17.90	7	6.55	35.78	3	0.98	11.76	2	2.61	32.02
GS	Gravel and Sand	Fluvial and glaciofluvial surface materials with undulating or gently sloping surface expressions and low coarse woody debris cover. Vegetation cover is sparse to absent, with the exception of occasional patches localized to surface depressions within intermittent water channels and coarse woody debris structures. Soils are coarse textured, consisting of gravel and sand. Precipitation and stream subirrigation are the main water sources.	12	0.55	3.96	12	0.93	5.05	13	1.00	12.05	10	1.35	16.60
OV	Organic Veneer	Organic surface material with a gently sloped surface expression and low coarse woody debris cover. Vegetation cover is sparse to low; species commonly observed include bluejoint, sedges and purslane speedwell. Soils appear to be remnant of past forest cover, with an organic horizon overlaying silt and clay mineral horizons. Groundwater is the main water source.	5	0.8	5.75	9	1.49	8.16	N/A	N/A	N/A	N/A	N/A	N/A
SD	Shoreline Driftwood	Organic and glacialfluvial surface materials (depending on location and slope within the drawdown zone) on gently sloped surface expression with moderate to high coarse woody debris cover. Vegetation cover is low to moderate on organic surface materials and sparse to absent on glaciofluvial surfaces (i.e., gravel and sand). Species commonly observed include bluejoint, common horsetail (in wet depressions), marsh yellow cress (*Rorippa palustris*), tower mustard and Norwegian cinquefoil. Soils are either remnant of past forest cover (gentle slopes) or gravel and sand substrates (moderate slopes) occurring in the upper drawdown zone. Precipitation and groundwater are the main water sources.	10	1.03	7.33	9	1.47	8.04	6	0.50	6.06	3	0.56	6.89
SF	Shoreline Forest	Undisturbed forest cover above the upper limits of the drawdown zone. Forest cover at the study sites is representative of the Williston variant for the moist cool subzone of the Sub-boreal Spruce Biogeoclimatic zone (SBSmk2). At Six Mile, Lamonti and Factor Ross Creek study sites, the tree cover along the shoreline is primarily coniferous; dominant tree species include lodgepole pine (Pinus contorta var. latifolia), subalpine fir (Abies lasiocarpa) and hybrid white spruce (Picea glauca x engelmannii), with Black Spruce (Picea mariana) occurring on wet sites. At Ole Creek, tree cover along the shoreline is primarily deciduous and diverse (shown in representative photographs above); species include trembling aspen (Populus tremuloides), black cottonwood (Populus balsamifera ssp. trichocarpa), paper birch (Betula papryifera), hybrid spruce, subalpine fir and lodgepole pine; large willow (Salix spp.) and Sitka alder (Alnus viridis ssp. sinuata) also occur within the tree canopy.	4	3.00	21.40	4	3.42	18.66	2	2.86	34.40	2	2.69	32.99

			Six Mile						Ole					
			2014			2016			2014			2016		
Habitat Class	**Habitat Class Name**	**Habitat Class Description**	**No. Polygons**	**Area (ha)**	**% Area**	**No. Polygons**	**Area (ha)**	**% Area**	**No. Polygons**	**Area (ha)**	**% Area**	**No. Polygons**	**Area (ha)**	**% Area**
		Groundwater and precipitation are the main water sources and reservoir flooding is not expected to occur.												
SW	Shoreline Willow	Organic surface materials on plain to gently sloping surface expressions with low to moderate coarse woody debris cover. Vegetation cover is moderate to high and consists of willow dominated shrub cover and a grass dominated (i.e., bluejoint) herbaceous cover. Reservoir flooding is expected to be frequent to rare.	10	0.90	6.42	12	0.99	5.41	1	0.05	0.59	1	0.04	0.55
SP	Streams and Ponds	Areas of perennial water cover, including creeks, small streams, ponds and the reservoir.	5	4.35	31.04	3	2.45	13.39	1	2.91	35.08	1	0.89	10.90
WH	Wetland Horsetail	Gently sloping areas within the upper drawdown zone that experience seepage from uphill perennial water sources, as well as along the edges of small streams. Vegetation cover is moderate to high and is dominated by bryophytes and swamp horsetail. Other herbaceous species observed includes yellow monkey flower (*Mimulus gluttatus*) and bluejoint. Groundwater is the main water source.	4	0.23	1.62	3	0.20	1.09	N/A	N/A	N/A	N/A	N/A	N/A
WS	Wetland Sedge	Organic surface materials with a plain surface expression and low to sparse coarse woody debris cover. Vegetation cover is high and dominated by graminoids (e.g., grasses, sedges and rushes). Species observed include sedges, bluejoint, swamp horsetail, common horsetail, dwarf scouring-rush, marsh yellow cress and willows. Groundwater is the main water source and reservoir flooding is expected to be frequent to not occurring.	5	0.17	1.21	6	0.33	1.81	N/A	N/A	N/A	N/A	N/A	N/A
WW	Wetland Willow	Organic surface materials on a plain surface expression with sparse to absent coarse woody debris cover. Vegetation cover is high and dominated by bryophytes (e.g., sphagnum mosses) and willows. Black spruce may also be present. Groundwater is the main water source and reservoir flooding is expected to be frequent to rare.	1	0.48	3.40	1	0.48	2.63	N/A	N/A	N/A	N/A	N/A	N/A

Appendix 4
GMSMON-17 Tributary Habitat Review
Vegetation Data Compilation and Analyses

Peace River Water Use Plan

GMSMON-17 Tributary Habitat Review

Vegetation Data Compilation and Analyses

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September 2019

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1 Introduction

Situated in the northern interior of BC near the towns of Mackenzie and Hudson's Hope, Williston Reservoir is the largest reservoir in BC, with a surface area of 1,773 square kilometres. Water levels in the reservoir are controlled by one of the world's largest earth-filled structures, the WAC Bennett Dam, which since completed in 1968, regulates the flow of the Peace River.

Water levels within Williston Reservoir fluctuate throughout the year due to dam operations for power generation. During the winter, the reservoir is drawn down resulting in a large mostly unvegetated floodplain ("drawdown zone") around the perimeter of the reservoir. When the reservoir is low, shallow channels with excessive braiding occur where tributaries flow over the exposed drawdown zone. The reservoir is typically at its lowest level in late April and early May (BC Hydro 2003). Reservoir levels increase in late spring due to snow melt, with the reservoir reaching its maximum elevation ("full pool") in July each year (BC Hydro 2003). Reservoir levels stay high throughout the summer months and much of the fall.

Large woody debris (LWD) is introduced into the reservoir every year due to logging and erosion, adding to an accumulation of debris from the original filling of the reservoir (BC Hydro 2008a). This debris accumulates in the bays where the tributaries empty into the reservoir (BC Hydro 2008a). The woody debris in tributary mouths may scour the banks of the tributaries and the reservoir thereby reducing natural littoral and/or riparian vegetation that may be growing there and increasing sedimentation (BC Hydro 2008b; Cubberley and Hengeveld 2010).

BC Hydro implemented a trial tributary mitigation plan to improve fish access to tributaries affected by large woody debris accumulations and/or shallow water depths due to stream braiding through the drawdown zone in spring. Cubberley and Hengeveld (2010) selected two mitigation trial sites and paired these with control sites (Table 1). Six Mile Creek was selected as a trial mitigation site due to a perched mouth caused by sediment accumulation. Lamonti Creek was selected as a paired control for Six Mile Creek. Chichouyenily Creek was selected as a second trial mitigation site but was later abandoned in favour of Ole Creek. Ole Creek had high accumulations of large woody debris at the tributary mouth, which spread tributary flow laterally across the drawdown zone at low reservoir levels (Kerr Wood Leidal 2011). Factor Ross Creek was selected as a paired control for Ole Creek. Mitigation recommendations for Six Mile Creek and Ole Creek included renovating the stream channels within the drawdown zone and use of retention structures to increase vegetation growth along the high-water mark (Cubberley and Hengeveld 2010).

Table 1. Summary of GMSMON-17 project design.

Treatment Creek	Treatment Goal	Control Creek
Six Mile Ck.	Restore fish passage past perched creek mouth	Lamonti Ck.
Ole Ck.	Restore fish passage past woody debris accumulations	Factor Ross Ck.

A Tributary Habitat Review monitoring program was initiated to assess the effectiveness of the tributary enhancement in improving fish and wildlife habitat. The enhancement was expected to improve fish access to tributaries during low reservoir elevations, when the tributaries are used for spring spawning (BC Hydro 2008b). Riparian vegetation recruitment along the banks was expected to improve after mitigation. In addition to fish and vegetation, songbirds and amphibians were selected for monitoring to determine if they were positively or negatively affected by the enhancement.

A set of six management questions were established to guide the GMSMON-17 monitoring program (BC Hydro 2008b, BC Hydro 2015):

1) Does access for spring spawners (i.e., rainbow trout and/or arctic grayling) improve as a result of enhancement?
2) Is the area and quality of fish habitat created by the tributary enhancement maintained over time?
3) Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?
4) Does abundance and diversity of song birds (passerines) around tributaries change as a result of enhancement?
5) Does amphibian abundance and diversity in tributaries change as a result of enhancement?
6) Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?

To address all management questions, field surveys for fish, vegetation, songbirds and amphibians at the enhancement sites and control sites were initiated in 2011 under the GMSMON-17 program. Data collected between 2011 and 2013 were baseline pre-enhancement data for each site (Table 2). Enhancement of the trial tributaries occurred in 2014 under the GMSWORKS-19 program; data on fish, vegetation, songbirds and amphibians were collected during the construction year. Post-enhancement data on fish, vegetation, songbirds and amphibians were collected from 2015 onwards.

Table 2. Data collection by project phase for the GMSMON-17 project.

Project Phase	Year(s) Data Collected
Pre-enhancement	2011 - 2013
Enhancement (construction)	2014
Post-enhancement	2015 - present

This report will provide summaries and analyses of the vegetation data collected to date under GMSMON-17, including multi-year comparisons of vegetation survey data and vegetation mapping. Management question #3 will be considered using the vegetation data collected to date. Recommendations for vegetation sampling (methods, locations) in the final year of the monitoring program will be provided.

2 Vegetation Data Collection - Background

Two different consultants have collected vegetation data for the project, separated by a two-year break:

- 2011: Golder Associates Ltd.
- 2012 – 2013: no data collection
- 2014 – 2016: DWB Consulting Services Ltd.

Different methods were used for vegetation surveys by the different consultants, as summarized below and in
Table 3.

In 2011, paired line transects were established at each of the four study sites (Six Mile Creek, Lamonti Creek, Ole Creek and Factor Ross Creek). One pair of transects was situated where the stream entered the reservoir at the time of surveying (mid-August) and the other pair was situated 150 m upstream. Each pair of transects started at the bank of the stream on opposite sides and ran perpendicular to the stream for 15 m towards the upland habitat on each side. Locations of vegetation transects and quadrats at each site can be found in Appendix E (yellow points on maps; each pair of points represents the start and end location for each transect; quadrats were completed at the start point for each transect, which is the point closest to the creek for each pair). Surveyors collected information on the species encountered along each transect, and the distance along the transect covered by each species. Quadrat sampling (5 m x 5 m quadrats) was also completed at the start of each transect to collect data on trees greater than 10 m in height, including % cover of the quadrat, estimated height of trees and diameter of trees. The consultant recommended that no further vegetation sampling occur until the year of enhancement treatments, so transects were not sampled again in 2012 or 2013. A full description of the methods used for the vegetation sampling in the first year of the project can be found in the year-end report (Golder 2012).

Table 3. Vegetation survey methods used throughout the first six years of the GMSMON-17 project.

Year	Consultant	Methods			
		Survey Type	**Location**	**Timing of Data Collection**	**Type of Data Collected**
2011	Golder Associates Ltd.	Paired line intersect transects, 15 m in length, perpendicular to the stream	4 transects completed at each site, with one pair situated where the stream enters the reservoir (in August) and one pair 150 m upstream	mid-August	distance along the transect (in cm) covered by each species
		Quadrat sampling (5m x 5m)	quadrat located at the start of each transect (4 quadrats per site)	mid-August	tree species (>10m height only), % cover of the quadrat, height of trees, diameter (dbh)

Year	Consultant	Methods			
		Survey Type	**Location**	**Timing of Data Collection**	**Type of Data Collected**
2014	DWB Consulting Services Ltd.	Belt-line quadrat transects, 20 m in length, containing ten 2m x 0.5m quadrats	transects in riparian habitats and on enhancement structures, in different locations than in 2011; 8 transects completed in total (Six Mile = 1, Lamonti = 3, Ole = 2, Factor Ross = 2)	mid-June	% cover by species in each quadrat along each transect
		Habitat mapping	non-flooded areas within the drawdown zones of each site	spring 2014	habitat classes and enhancement feature classes; polygons drawn using photo interpretation and ground sampling; area of each polygon calculated
2015	DWB Consulting Services Ltd.	Belt-line quadrat transects, 20 m in length, containing ten 2m x 0.5 m quadrats	most of the transects established in 2014 were revisited, and two additional transects were surveyed; 9 transects completed in total (Six Mile = 2, Lamonti = 2, Ole = 3, Factor Ross = 2)	mid-June	% cover by species in each quadrat along each transect; % cover by each layer (tree, shrub, herb, bryophyte) in each quadrat
		Habitat mapping	non-flooded areas within the drawdown zones of each site	spring 2015	habitat classes and enhancement feature classes; polygons drawn using photo interpretation and ground sampling; area of each polygon calculated
2016	DWB Consulting Services Ltd.	Belt-line quadrat transects, 20 m in length, containing ten 2m x 0.5 m quadrats	most of the transects surveyed in 2015 were revisited; 8 transects completed in total (Six Mile = 2, Lamonti = 2, Ole = 2, Factor Ross = 2)	late May	% cover by species in each quadrat along each transect

In 2014 through 2016, new vegetation sampling transects were established. The enhancement treatments were initiated and completed in 2014, and vegetation transect locations were selected to overlap some of the enhanced areas at Six Mile Creek and Ole Creek. Locations of vegetation transects at each site can be found in Appendix F. Transects were 20 m in length and contained ten 2 m x 0.5 m quadrats along that length. Within the quadrats, the species name and percent cover of the quadrat were recorded. A full description of the methods used for the transect sampling can be found in year-end reports for the project (MacInnis et al. 2015, MacInnis et al. 2016).

The vegetation transects sampled at each site between 2014 and 2016 are shown in Table 4. Many transects were sampled for multiple years. Data collected in 2015 and 2016 represent post-enhancement data.

Table 4. Vegetation transects surveyed between 2014 and 2016 of the GMSMON-17 project. Enhancement occurred in 2014; data collected in 2015 & 2016 are post-enhancement data.

Site	Transect	Start UTM (E/N)	End UTM (E/N)	Years Surveyed		
				2014	2015	2016
Six Mile Creek	SC2	474668/6162655	474670/6162676	✓	✓	✓
	SC3	474697/6162745	474712/6162753		✓	✓
Lamonti Creek	LC1	475082/6162074	475098/6162065	✓		
	LC2	475169/6162056	475187/6162058	✓	✓	✓
	LC4	475181/6161997	475192/6162013	✓	✓	✓
Ole Creek	OC1	405833/6257636	405831/6257638	✓	✓	✓
	OC2	405887/6257660	405867/6257657	✓	✓	✓
	OC3	405863/6257675	405844/6257664		✓	
Factor Ross Creek	FC1	395521/6275897	395511/6275884	✓	✓	✓
	FC3	395380/6275938	395363/6275929	✓	✓	✓

In addition to the transect sampling, habitat mapping was completed at each site in 2014 (enhancement year) and 2015 (post-enhancement). A habitat classification scheme based on RISC (2010) was developed to capture all the habitat classes visible using air photos of the study sites. An enhancement classification scheme was also developed for Six Mile Creek and Ole Creek to identify and differentiate artificial structures and surfaces from undisturbed habitats at the enhancement sites. Air photos were used to delineate habitat polygons and ground sampling was used to help describe terrestrial vegetation communities (Province of British Columbia 2010, RISC 2010). Habitat and enhancement area mapping were completed on either side of the channel within all non-flooded areas of the drawdown zone at the time of air photo collection. A full description of the methods used for the habitat mapping can be found in year-end reports for the project (MacInnis et al. 2015, MacInnis et al. 2016).

3 Vegetation Data Analyses

3.1 Methods

Vegetation data collected in the first 6 years of the GMSMON-17 project (2011 to 2016) were obtained from BC Hydro. When data were not available electronically, they were acquired from year-end report tables or appendices. Data were closely examined to understand the nature of the data and how to best organize it for consistency between years. New Excel files were created for each year of the project, and the raw data were imported or entered. Data were standardized across sites and years in terms of transect names and worksheet layout. Raw data were summarized in various ways (e.g., % cover by layer for the transect, species richness) to allow comparisons between sites and between years. Table 5 provides a summary of the tasks completed and data analyses done with each year of vegetation data

from the project. Once Excel spreadsheets were complete, the vegetation data from all years of the project were imported into a single Access database.

Table 5. Data analyses of vegetation data from the first six years of the GMSMON-17 project.

Year(s)	Data Type	Data Analyses Tasks Completed
2011	Transect data	original data contained within an Appendix to the 2011 report; legibility of some of the scanned data sheets was poor, and species names were deciphered using cross-references to species code lists found online
		for each species and each transect, total distance covered was calculated by summing all recorded values; this sum was divided by 1500 cm to get the % cover of the transect for each species
		% cover by layer (tree = A, shrub = B, herb = C, bryophyte = D) was calculated for each transect by summing the % cover for each species in each layer; % cover for bare ground, coarse woody debris (CWD) and water were also calculated
		# of species was counted for each layer (A, B, C, D) to get a measure of species richness for each transect
		data were entered in an Excel spreadsheet with a worksheet for each analysis; column headings and format were standardized across worksheets
		data were imported into an Access database containing all vegetation data for the project
2011	Quadrat data	original data contained within an Appendix to the 2011 report; legibility of some of the scanned data sheets was poor
		data were entered in an Excel spreadsheet
		data were imported into an Access database containing all vegetation data for the project
2014 - 2016	Transect data	data included % cover by species for each quadrat along each transect
		reformatted 2015 data to remain consistent with 2014 and 2016 data; this included replacing species names with 7-letter codes
		% cover by layer (A, B, C, D) for each section was calculated
		% cover by layer (A, B, C, D) for each transect was calculated by adding % cover for each layer/section, then dividing by 10 sections
		# species was counted for each section and transect to get a measure of species richness
		data were entered in an Excel spreadsheet for each year, with a worksheet for each analysis; column headings and format were standardized across worksheets and years
		data were imported into an Access database containing all vegetation data for the project
2014	Habitat	2014 data included area of each individual mapped polygon

Year(s)	Data Type	Data Analyses Tasks Completed
and 2015	Mapping	2015 data were taken from summary data tables in year-end report; no data on areas of individual polygons
		added together areas of polygons of the same class code (2014 data)
		added enhancement mapping areas to the worksheets with habitat mapping data to get a complete dataset of mapped areas for each site
		standardized habitat class and enhancement codes across all sites and years, and added null values for area where necessary
		data were entered in an Excel spreadsheet with worksheets for each site and data analysis; column headings and format were standardized across sites and years
		data were imported into an Access database containing all vegetation data for the project

3.2 Results

Data analyses that were not used to answer the management questions are provided in Appendices to this report:

- 2011 Vegetation Transects: these transects were located at the edge of the drawdown zone, or upstream of the drawdown zone, and did not provide data on pre-enhancement conditions in areas where enhancement would later occur; analyses are provided in **Appendix A**
- 2011 Vegetation Quadrats: these quadrats were only completed in 2011, and were not in locations that would provide pre-enhancement data; analyses are provided in **Appendix B**
- 2014 – 2016 Vegetation Transects: analyses of data from individual years are provided in **Appendix C**
- 2014 – 2015 Vegetation Mapping: analyses of data from individual years are provided in **Appendix D**

A comparison between sites, treatments and years for vegetation transect data collected between 2014 and 2016 is presented below. A comparison between years for the vegetation mapping data collected in 2014 and 2015 is also presented below.

3.2.1 Vegetation Transects

2014 – 2016 Vegetation Transects (Enhancement Year and Post-enhancement)

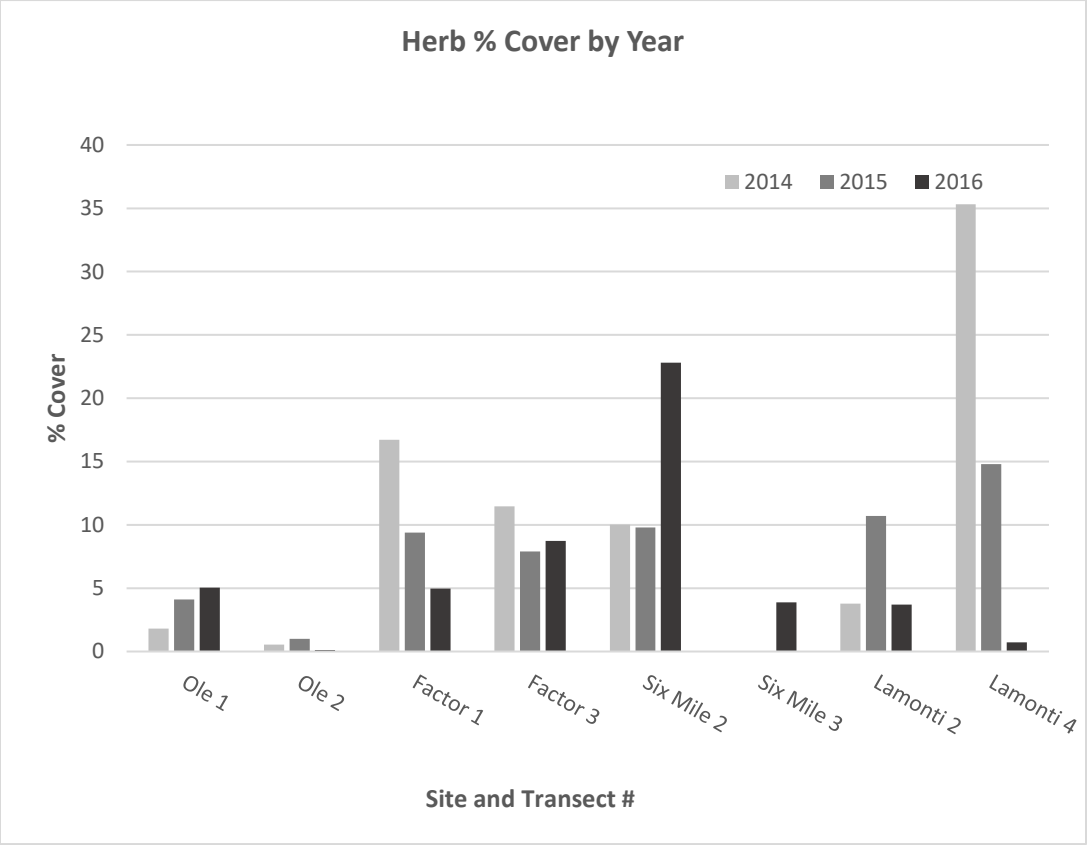
Enhancement took place in 2014 and transects at the treatment sites (Ole Creek and Six Mile Creek) were located on newly created enhancement structures or in areas that were disturbed by construction (MacInnis et al. 2015). Transects completed in 2015 and 2016 represent the first- and second-years post-enhancement, respectively.

A comparison of the percent cover by herbs at each site and transect that was repeatedly sampled between years is shown in Figure 1. At Ole Creek (treatment site), herb percent cover increased each year at transect 1. At Ole Creek transect 2, herb percent cover increased from 2014 to 2015, but then decreased in 2016. At Six Mile Creek (treatment site), herb percent cover increased from 2014 to 2016

at both transects, although the most dramatic increase was observed at transect 2. Note that Six Mile Creek transect 3 was not sampled in 2014, so Figure 1 only shows data for 2015 and 2016.

At Factor Ross transect 1 and Lamonti Creek transect 4 (control sites), there was a decrease in herb percent cover between 2014 and 2016. No clear trend in herb percent cover by year is evident at Factor Ross transect 3 and Lamonti Creek transect 2: at Factor Ross transect 3, the lowest herb percent cover was recorded in 2015, while at Lamonti Creek transect 2, the highest herb percent cover was recorded that same year.

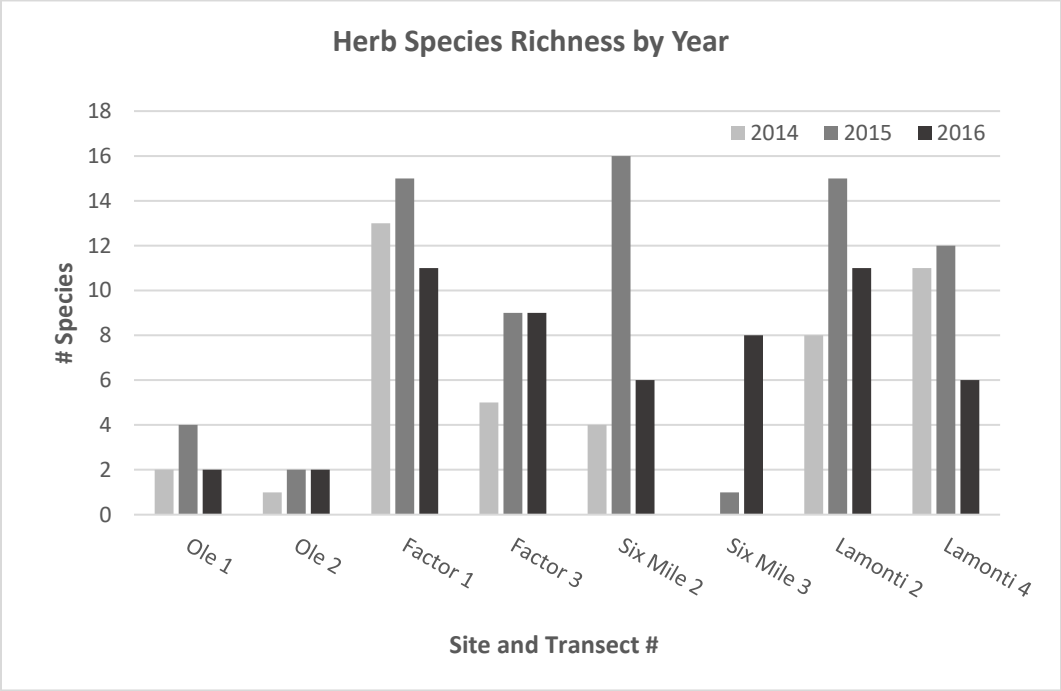
Figure 1. Herb percent cover for each site and transect repeatedly sampled between 2014 and 2016. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.



The data suggest that there may be some positive effect of the treatment on herb percent cover, with three of the four transects at treatment sites showing an increase in herb percent cover with increasing time post-construction. The same trend is not seen at control sites, suggesting the increase in herb percent cover at treatment sites is not due to other environmental factors (climate, reservoir operations, etc.). Additional data collection in year 10 of the project can be used to determine if this trend continues.

Species richness of the herb layer can be compared between 2014 and 2016 (Figure 2). At many sites, herb species richness decreased in 2016 compared to 2015 (Ole Creek transect 1, Factor Ross Creek transect 1, Six Mile Creek transect 2, Lamonti Creek transects 2 and 4). At two sites (Ole Creek transect 2 and Factor Ross Creek transect 3), herb species richness increased after 2014, but remained the same in 2015 and 2016. At one site (Six Mile Creek transect 3), herb species richness increased in 2016 relative to 2015.

Figure 2. Herb species richness for each site and transect repeatedly sampled between 2014 and 2016. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.



There are no clear trends in herb species richness between treatment and control sites when multiple years of data are compared. It's possible that climatic factors or reservoir operations may have favoured an increase in species establishment in 2015 at all sites, but some of those species could not persist until 2016. This was most dramatically seen at Six Mile Creek transect 2, with 16 herb species recorded in 2015, and only 6 herb species recorded in 2016.

3.2.2 Vegetation Mapping

2014 – 2015 Vegetation Mapping – (Enhancement Year and Post-enhancement)

Vegetation mapping was first completed in 2014, the year enhancement took place at treatment sites. Vegetation mapping was repeated in 2015, the first year post-enhancement. Vegetation maps completed in 2014 are provided in Appendix F.

Ten habitat classes were identified in total across all sites, although not all habitat classes were present at each site.

The proportions of several habitat classes in the habitat mapping at Ole Creek differed between 2014 and 2015 (treatment site; light green bars in

Figure 3). In 2014, the streams & ponds habitat class made up a high proportion (>30%) of the map area, while in 2015 this habitat class only made up 10% of the habitat map area. There was an increase in the proportion of the basin silt habitat class from 10% of the map in 2014 to 28% in 2015.

The proportions of several habitat classes in the habitat mapping at Factor Ross Creek also differed between 2014 and 2015 (paired control to Ole Creek; blue bars in

Figure 3). In 2014, the basin silt habitat class made up a high proportion (>37%) of the map area, while in 2015 this habitat class only made up 17% of the habitat map area. There was an increase in the proportion of the streams & ponds habitat class from 4% of the mapped area in 2014 to 24% of the mapped area in 2015.

In comparison to Ole Creek, the habitat map at Factor Ross Creek had a much higher proportion of basin silt in 2014 and a much lower proportion of basin silt in 2015. This was reversed for streams & ponds: the habitat map at Factor Ross Creek had a lower proportion of streams & ponds in 2014 compared to that at Ole Creek but had a much higher proportion of streams & ponds in 2015.

The total area mapped at Ole Creek and Factor Ross Creek in 2014 and 2015 remained constant, and it is assumed that the map boundaries did not change. Therefore, this change in habitat composition between years is assumed to be due to environmental factors (reservoir flooding, climate) driving habitat change.

The proportions of several habitat classes in the habitat mapping at Six Mile Creek differed between 2014 and 2015 (treatment site; yellow bars in

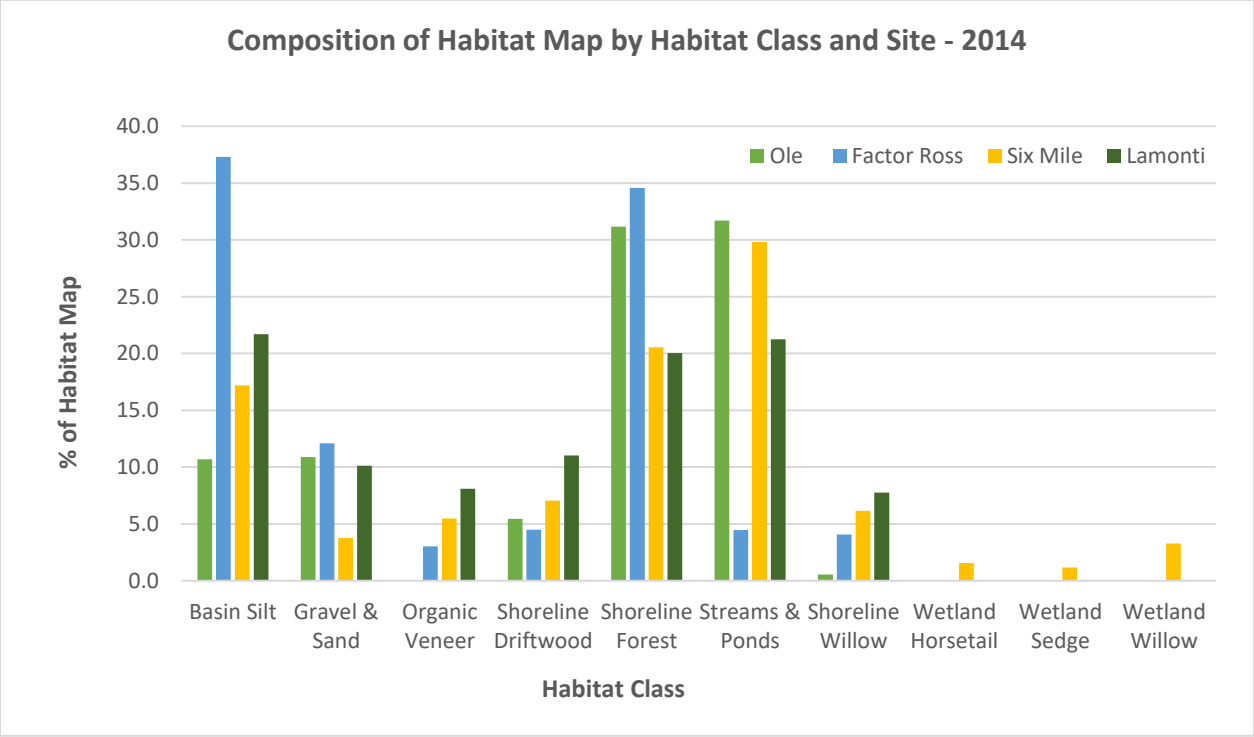
Figure 3). In 2014, the streams & ponds habitat class made up a high proportion (>29%) of the map area, while in 2015 this habitat class only made up 13% of the habitat map area. There was an increase in the proportion of the basin silt habitat class from 17% of the map in 2014 to 34% in 2015. These were similar differences as those observed at Ole Creek, the other treatment site. Six Mile Creek was the only site with wetland habitat within the mapped area, therefore it is the only site with wetland horsetail, wetland sedge and wetland willow habitat classes both years.

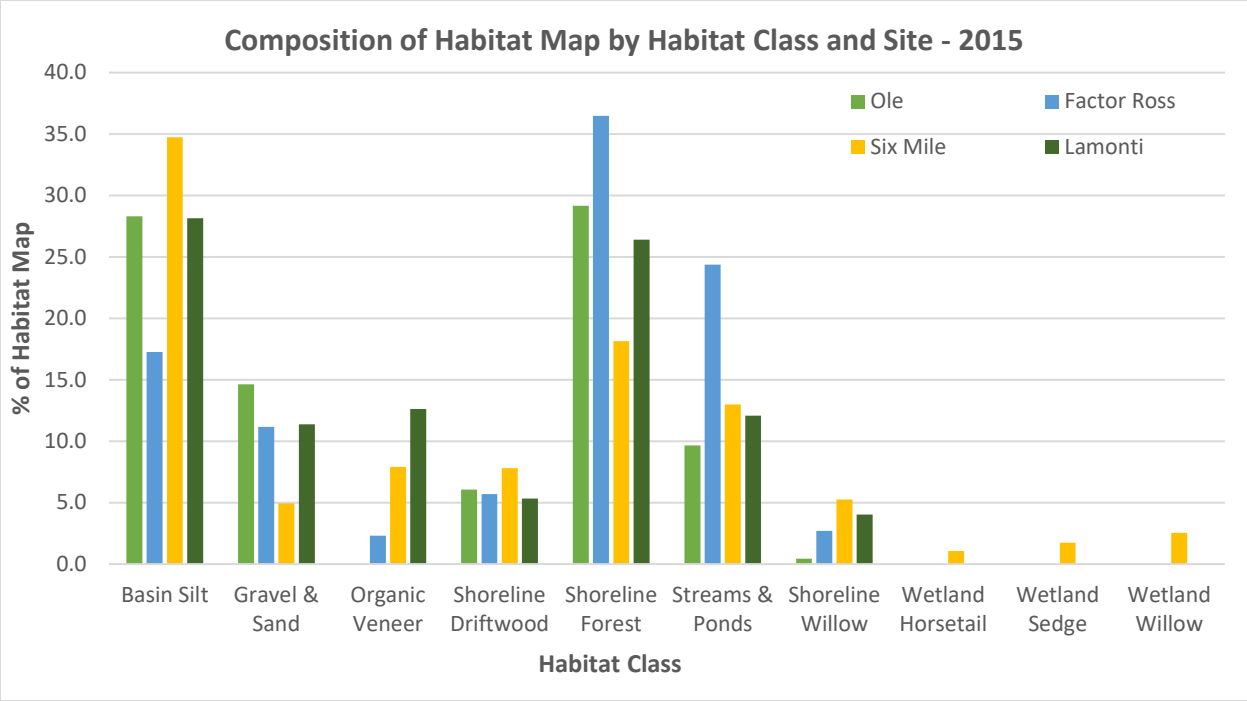
At Lamonti Creek (paired control to Six Mile Creek; dark green bars in

Figure 3), the proportion of the streams & ponds habitat class decreased between 2014 and 2015 from 21% to 12%. There was a slight increase in the proportion of shoreline forest in 2015, and a slight decrease in the proportion of shoreline driftwood.

The total area mapped at Six Mile Creek did increase from 14.6 ha in 2014 to 18.9 ha in 2015. At Lamonti Creek, the area mapped also increased from 8.9 ha in 2014 to 16.5 ha in 2015. It is possible that the newly mapped areas at both sites accounted for some of the shift in habitat composition between years.

Figure 3. Habitat map composition by habitat class for each site mapped in 2014 and 2015. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.





The proportions of the Ole Creek and Six Mile Creek habitat maps comprised of enhancement habitat classes remained relatively constant between 2014 and 2015 (Appendix D). There was a reduction in the proportion of overburden at Six Mile Creek from 2% in 2014 to 1% in 2015. Two additional enhancement classes were added to the Six Mile Creek map in 2015 (stump armor and silt) which were not present in the 2014 map.

3.3 Sources of Error

For the vegetation transect data presented above and in the Appendices, the values for percent cover by each vegetation layer do not account for layering of the vegetation along the transect or within the quadrat. Percent cover was collected for individual species during field data collection. The percent cover for species within the same vegetation layer (A=trees, B=shrubs, C=herbs, D=bryophytes) were then added up for each transect or section along a transect. Vegetation that is more layered (meaning the plants overlap each other in space) will have a percent cover for the section or transect that exceeds what covers the ground of the transect. For this same reason, we also occasionally have percent cover values exceeding 100% (e.g., 2011 transect data).

Surveyors collecting vegetation data differed from year to year of the project, and within a year at different sites. There could also be slight differences in methods used between years, even when the same transects are sampled. Some transects sampled in 2014 and 2015 went from having herbs only in 2014 to having herbs and bryophytes in 2015. It's possible that surveyors in 2014 were not classifying bryophytes (differing methods), or that there were differences in skill sets in terms of ability to identify

bryophytes. Even within the same year, some transects had bryophytes identified to species, while others had bryophytes classified by genus only.

There were likely errors in data entry between field notes and spreadsheets. For the 2011 vegetation data, scanned field data sheets provided as an Appendix to the year-end report were the only available source of data. In some cases, the scanned data sheets were very blurry and hard to decipher. It's possible some errors were made when transcribing the 2011 data to digital spreadsheets. For the 2014-2016 vegetation data, digital data was provided by BC Hydro. It's possible some errors were made when the field data was originally entered in spreadsheets; the original field data is not available for those years of the project for comparison.

4 Discussion

The transects completed in 2011 were not placed in locations where enhancement would later occur, but the data showed that there was very little tree cover at most of the sites (Factor Ross Creek was an exception). The shrub layer provided the most cover along most transects, although a few transects had greater coverage by herbs than shrubs. Most sites had the greatest species richness in the herb layer.

In 2014, a new sampling design was initiated with transects at enhancement sites (Six Mile Creek and Ole Creek) placed in locations where enhancement would occur. Data collected in the enhancement year showed that the transects at Ole Creek had very low percent cover by herbs, with only one to two species present. At Six Mile Creek, only one transect was completed and it had 10% cover by four herb species. Transects completed at the control sites (Factor Ross Creek and Lamonti Creek) all had greater species richness than their paired treatment sites.

In 2015, the first year post-enhancement, percent cover did not change much for the treatment sites. At the control sites, percent cover by herbs decreased at Factor Ross Creek and one of the Lamonti Creek transects (#4) but increased at the other Lamonti Creek transect (#2) (Figure 1). Species richness improved at treatment sites in 2015, with the largest increase observed at Six Mile Creek transect 2 where four herb species were recorded in 2014 and sixteen herb species were recorded in 2015 (Figure 2). An increase in species richness was also noted at one of the Lamonti Creek transects (#2) and at one of the Factor Ross transects (#3), both of which doubled their herb species richness from 2014 to 2015 (Figure 2). Species richness remained relatively constant at other sites between 2014 and 2015. Bryophytes were recorded for the first time in 2015; it is not known if these species were newly established in 2015, or whether they were simply not recorded in 2014. The year-end report for 2015 noted that survival of planted willow stem cuttings at Six Mile Creek was low to moderate, while at Ole Creek all the stem cuttings died (MacInnis et al. 2015). It was suggested that survival of the willow cuttings on enhancement structures was likely related to how or where the cuttings were planted (hard ground, cuttings pounded into soil and potentially damaged, shallow depth of soil; MacInnis et al. 2016).

In 2016, the second year post-enhancement, the percent cover by herbs increased at three of the treatment transects and decreased at one treatment transect (Ole Creek #2). By comparison, at control sites, herb percent cover decreased at three of the transects and remained relatively constant at one transect (Figure 1). These data suggest that there may be some positive effect of the treatment on herb

percent cover and suggests there is some value to continued monitoring of control sites for comparison to treatment sites.

Species richness declined in 2016 at most transects, with the exception of Six Mile Creek transect 3, which had an increase from one herb species in 2015 to eight herb species in 2016 (Figure 2). A shrub species was noted for the first time at one of the Ole Creek transects in 2016. The decrease in species richness at many transects in 2016 suggests that climatic factors or reservoir operations may have favoured species establishment in 2015, but that some of these species could not persist in 2016. The year-end report for 2016 noted that native plant species (e.g., Norwegian cinquefoil and marsh water cress) were colonizing some of the enhancement structures at Six Mile and Ole Creek (MacInnis et al. 2016). They note the change in diversity at the northern-most enhancement berm at Six Mile Creek in 2016 (location of transect 3), with fireweed, thimbleberry, lady's thumb, smooth hawksbeard, common horsetail and Bicknell's geranium recorded along the transect (MacInnis et al. 2016).

The habitat mapping completed in 2014 and 2015 showed that both treatment sites had a decrease in area of the streams & ponds habitat class between years, and an increase in area of the basin silt habitat class. These differences were quite large and similar between treatment sites: at Six Mile Creek, the streams & ponds habitat class decreased from 29% to 13% of the habitat map and at Ole Creek the same class decreased from 30% to 10% of the habitat map between 2014 and 2015. At Six Mile Creek, the basin silt habitat class increased from 17% to 34% of the habitat map and at Ole Creek the same class increased from 10% to 28% of the habitat map between 2014 and 2015. In contrast, the proportion of the habitat map comprised of the basin silt habitat class decreased at Factor Ross Creek and increased very slightly at Lamonti Creek between those same years. This suggests some effect of the habitat enhancements on the proportions of these habitat classes at the treatment sites and suggests there is some value in continuing to monitor control sites for comparison to the treatment sites. It is likely that the increased channelization of the treatment streams and the corresponding reduction in stream braiding across the drawdown zone resulted in the observed trends in the two habitat classes mentioned above.

Management question #3 asks "Does riparian vegetation along tributaries increase in abundance and diversity as a result of the enhancement?". The transect data collected between 2014 and 2016 suggest that there has been a positive effect of the enhancement on abundance and richness of vegetation. While the successful establishment of much of the planted vegetation was low, native species were beginning to colonize the enhancement structures in 2016. Although this newly established vegetation may not provide much structural diversity for wildlife use this soon after establishment, these plants may help further stabilize the substrates along the enhancement structures, thereby allowing further colonization by native plants in the future.

5 Recommendations for Future Sampling

BC Hydro could consider three potential methods for finalizing the vegetation monitoring in Year 10 of the project:

1) Vegetation mapping could be repeated using previous methods (see MacInnis et al. 2015, 2016): this would allow a comparison of the area and extent of different vegetation communities between 2014/2015 and Year 10;
2) Vegetation transects sampled in 2014 and 2015 could be re-sampled using previous methods (see MacInnis et al. 2015, 2016): this would allow quantitative comparisons of % cover and species richness between 2014/2015 and Year 10;
3) Photographs taken of enhanced sites in 2014 could be compared to photographs taken of the same locations in Year 10: this would allow qualitative, and possibly quantitative, comparisons to be made of the vegetation in the enhanced areas through time.

Each of these methods have pros and cons (Table 6). Given that there was little terrestrial/riparian vegetation vulnerable to negative impacts from this project, and that creating new riparian habitat was not a primary goal of this project, it is questionable how much effort is warranted in Year 10 of the project.

Table 6. Pros and cons of vegetation sampling methods that might be used in Year 10 of the GMSMON-17 project.

Method	Pros	Cons
Vegetation mapping	Allows quantitative comparisons between years	Costly (updated aerial imagery needed)
	Allows landscape level changes to be assessed	Among-year consistency in mapping can be challenging to obtain
Vegetation transects	Allows quantitative comparisons between years	Few transects completed within each site in 2014 & 2015, so there are limited data with which to compare Year 10 data
	Inexpensive to collect data	May not capture landscape level changes effectively
Photographic comparisons	Inexpensive to collect data	Methods to allow quantitative comparisons could be more time consuming
	Allows qualitative (possibly quantitative) comparisons between years	
	Easy to interpret	

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Appendices

Appendix A: Vegetation transect data analyses - 2011.

2011 Vegetation Transects (Pre-enhancement)

A graph summarizing the percent cover of each transect by vegetation layer, bare ground and coarse woody debris (CWD) for vegetation transects sampled in 2011 is shown in Figure A1. Note that percent cover does exceed 100% in some cases since percent coverage values for individual species in each layer were added together. It is likely that percent cover values by vegetation layer are overestimated in some cases due to layering of the vegetation (see comments in Section 3.3 of this report on potential sources of error).

Most of the vegetation transects did not have any tree (A layer) coverage; exceptions were the upstream transects at Ole Creek (Ole 3 & Ole 4) and all transects at Factor Ross Creek (Figure A1). The upstream transects at Factor Ross Creek (Factor 3 & 4) were the only transects with trees as the dominant layer. All transects had coverage in the shrub layer (B layer), with transects at Ole Creek having the highest shrub percent coverage. All sites had high percent coverage of shrubs at transects close to the reservoir (transects 1 and 2; transects 1 & 4 at Lamonti Creek); Ole Creek had slightly higher shrub percent coverage at transects upstream from the reservoir (Ole 3 & 4), whereas the other sites generally had lower percent coverage by shrubs at upstream transects. At Lamonti Creek (transects 3 & 4) and Six Mile Creek (transects 2 & 3), the herb layer (C layer) was the most dominant vegetation coverage. Herb layer percent coverage appears to be inversely related to shrub layer percent coverage: at sites with higher shrub coverage, there is generally lower herb coverage, likely due to shrub coverage limiting light availability at ground level. However, there are several sites that have shrub coverage exceeding 60% which do also have herb layer coverage exceeding 50% (e.g., Six Mile 2 & 3, Ole 4, Lamonti 1, 2 & 3). All transects did have a bryophyte layer (D layer), with the highest percent coverage by that layer found at Factor Ross Creek (transects 1, 3 & 4). Bare ground was recorded along most transects. Ole Creek transects had the highest percent coverage by bare ground; three transects at Ole Creek had the highest shrub percent coverage, suggesting a possible link between shrub coverage and bare ground coverage at that site. All transects with shrub coverage exceeding 80% also had bare ground coverage exceeding 30%. Most sites had some coarse woody debris (CWD) coverage; percent coverage by CWD was greater at Lamonti Creek and Factor Ross Creek, the two control sites for the monitoring program.

A graph showing the species richness by vegetation layer for transects sampled in 2011 is shown in Figure A2. Only Factor Ross Creek and upstream transects at Ole Creek had more than one species in the tree layer (A layer). All sites had several species in the shrub layer (B layer), but no clear trends can be seen within or between sites. All sites also had several species in the herb layer (C layer), with richness in the herb layer often exceeding the richness of the other layers; exceptions to this include transect 1 at Ole Creek, which had the greatest number of species in the bryophyte layer (D layer) and transect 4 at Ole Creek, which had the greatest number of species in the shrub layer (B layer). When sites are compared, Six Mile Creek and Lamonti Creek (paired treatment and control sites) appear to have greater herb layer richness than Ole Creek and Factor Ross Creek. All sites had bryophyte species (D layer), but Ole Creek and Factor Ross Creek had the greatest richness of the bryophyte layer. For all sites, richness of the bryophyte layer generally declined for transects upstream from the reservoir (transects 3 & 4, transects 2 & 3 at Lamonti Creek).

Figure A1. Percent cover by vegetation layers (A=tree, B=shrub, C=herb, D=bryophyte), bare ground and coarse woody debris (CWD) for each transect sampled at each site in 2011. Transect numbers 1 & 2 are at the edge of the reservoir for most sites (transects 1 & 4 at Lamonti Creek); other transects at each site are 150 m upstream from the reservoir. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.

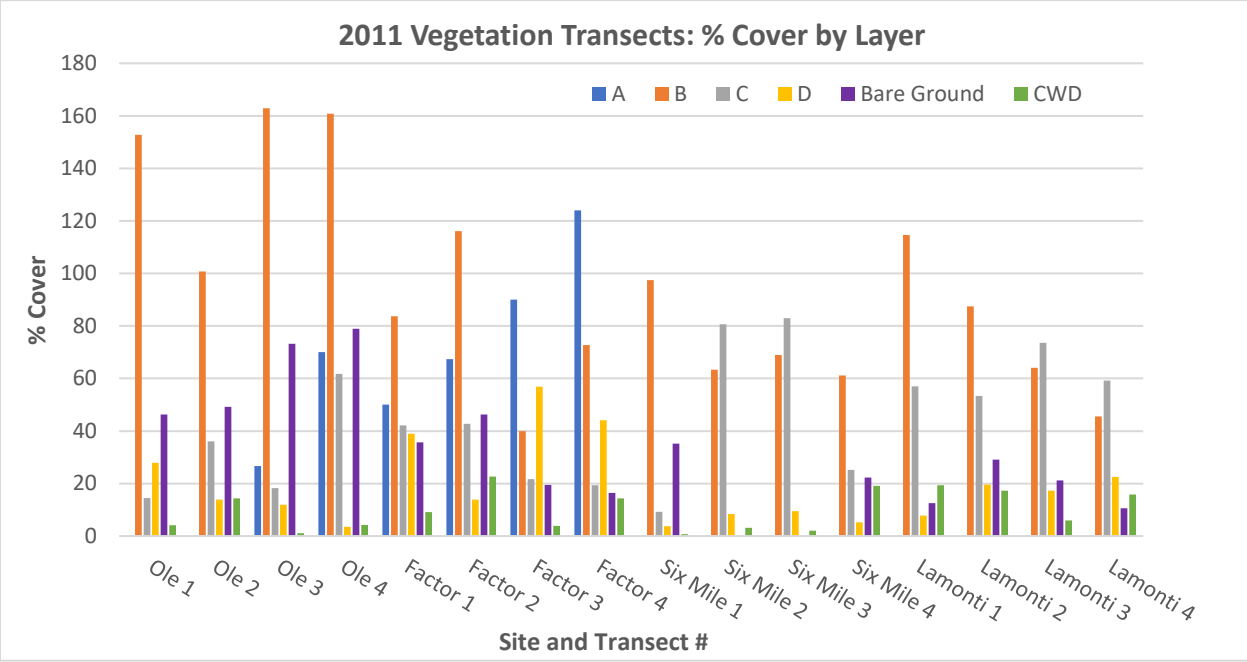
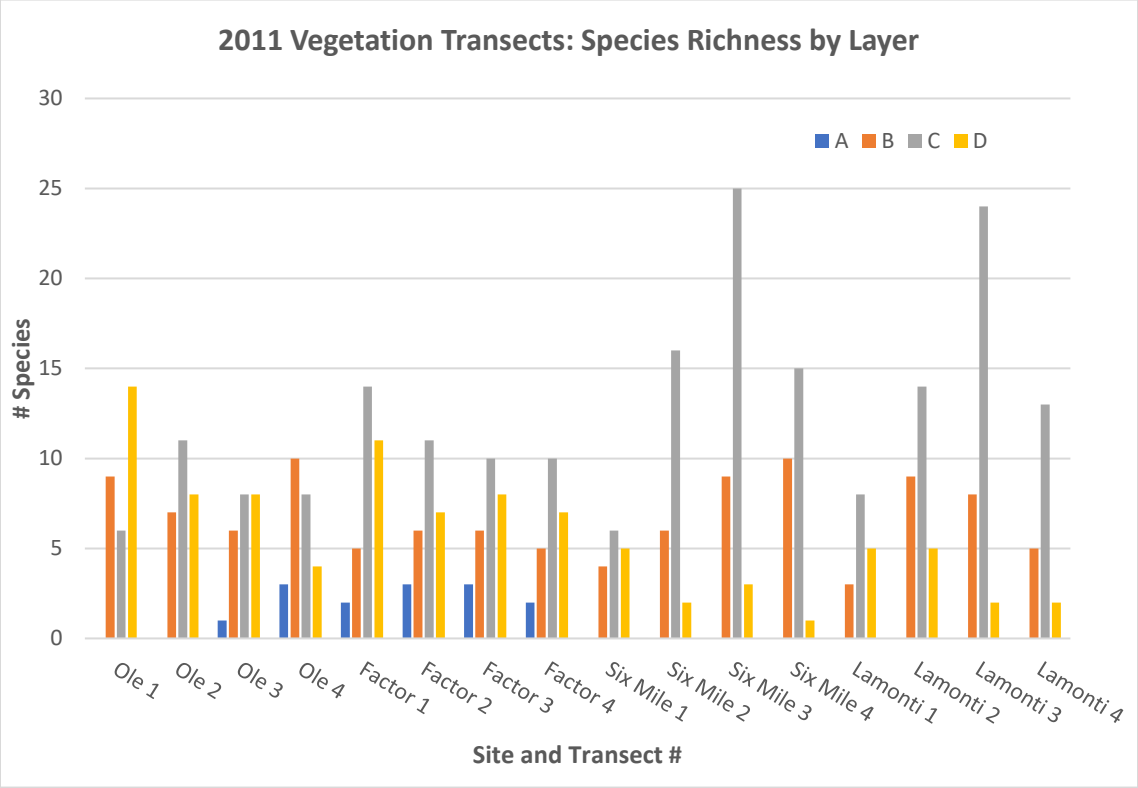


Figure A2. Species richness by vegetation layers (A=tree, B=shrub, C=herb, D=bryophyte) for each transect sampled at each site in 2011. Transect numbers 1 & 2 are at the edge of the reservoir for most sites (transects 1 & 4 at Lamonti Creek); other transects at each site are 150 m upstream from the reservoir. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.



Appendix B: Vegetation quadrat data analyses - 2011.

Vegetation quadrats were only completed in 2011 at the start of every transect (4 per site). The quadrats were 5m x 5m but only trees greater than 10 m in height were recorded within the plot. Notes were made about the occurrence of trees smaller than 10 m in height. The data are shown in Table B1. Few trees were located within the quadrats, and several quadrats (e.g., Lamonti) did not have any trees greater than 10 m in height.

The species of trees recorded in each quadrat differed by site (Table B1). At Six Mile Creek, only one species was recorded in one of the quadrats: subalpine fir was recorded in quadrat SV-4. Spruce hybrids that were smaller than 10 m in height were recorded in two other Six Mile Creek quadrats (SV-2 and SV-3). Quadrats at Lamonti Creek did not contain any trees greater than 10 m in height, but various species were recorded that were under the 10 m height cut-off (poplar, subalpine fir and spruce hybrid). Each quadrat at Ole Creek and Factor Ross Creek contained trees greater than 10 m in height. Ole Creek quadrats contained spruce hybrids and paper birch. Factor Ross had the greatest tree diversity in the quadrats, with 4 species recorded (poplar, lodgepole pine, paper birch and subalpine fir).

Table B1. Vegetation quadrat data collected in 2011. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.

Site	Station ID	Species	% Cover	Est. Height (m)	DBH (cm)	Notes
Six Mile	SV-1	none	0	0	0	
Six Mile	SV-2	none	0	0	0	1 spruce hybrid 4.7 m in height
Six Mile	SV-3	none	0	0	0	4 spruce hybrid <10m in height
Six Mile	SV-4	subalpine fir	15	15	15.4	
Six Mile	SV-4	subalpine fir	15	17.5	23.3	
Lamonti	LV-1	none	0	0	0	dense mix of poplar 8m in height
Lamonti	LV-2	none	0	0	0	mix of subapline fir and spruce hybrid <10m in height (1-3m tall)
Lamonti	LV-3	none	0	0	0	mix of subapline fir and spruce hybrid <10m in height (1-4m tall)
Lamonti	LV-4	none	0	0	0	1 spruce hybrid 7m in height
Ole Creek	OV-1	spruce hybrid	25	22	19.9	
Ole Creek	OV-1	spruce hybrid	45	30	37.9	
Ole Creek	OV-2	spruce hybrid	40	10	13.5	also 1 spruce <10m in height and 1 clump of paper birch
Ole Creek	OV-3	paper birch	50	25	27.8	also 1 spruce hybrid and 6 subalpine fir <10m in height
Ole Creek	OV-3	paper birch	5	10	11.7	
Ole Creek	OV-3	paper birch	5	10	11.3	
Ole Creek	OV-4	unknown	40	15		7 spruce hybrid <10m in height; writing on datasheet illegible
Factor Ross	FV-1	poplar	70	35	34	also many (~13) alder <10m in height (~8.5m tall)
Factor Ross	FV-2	poplar	5	35	46	also many (~13) alder <10m in height (7-8m tall)
Factor Ross	FV-3	lodgepole pine	5	27	28.5	dead

Site	Station ID	Species	% Cover	Est. Height (m)	DBH (cm)	Notes
Factor Ross	FV-3	lodgepole pine	2	17	22.6	dead
Factor Ross	FV-3	paper birch	2	20	15.2	
Factor Ross	FV-4	subalpine fir	40	15	18.7	

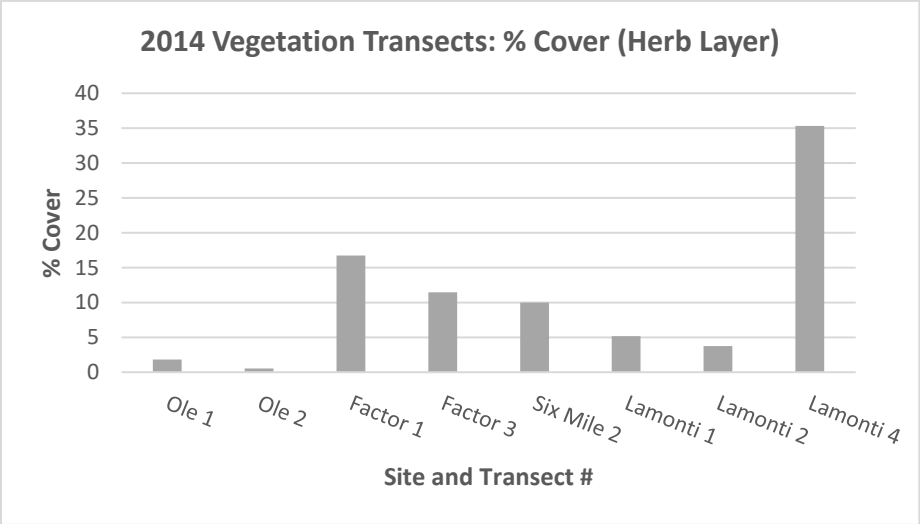
Appendix C: Vegetation transect data analyses by year - 2014 to 2016.

2014 Vegetation Transects (Enhancement Year)

A graph summarizing the percent cover of each transect for vegetation transects sampled in 2014 is shown in Figure C1. In 2014, no tree, shrub or moss species (A, B or D layers) were detected on any of the transects; only herbs (C layer) were found. Therefore, Figure C1 shows the percent cover by the herb layer on each transect.

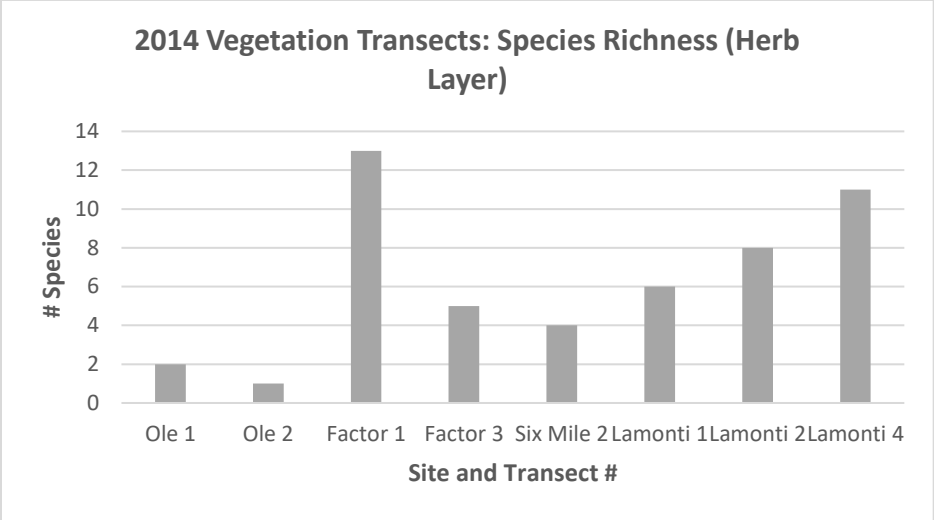
In 2014, vegetation transects were completed immediately after construction of the enhancement structures at Six Mile Creek and Ole Creek; the transects were located on the newly created enhancement structures or in areas that were disturbed by construction (MacInnis et al. 2015). Transects at Ole Creek had lower percent cover by herbs than its paired control site, Factor Ross Creek. It is more difficult to see a clear trend in herb percent cover at Six Mile Creek (treatment) and Lamonti Creek (control): herb percent cover is higher at the single transect sampled at Six Mile Creek than at two of the transects at Lamonti Creek. However, transect 4 at Lamonti Creek had the highest percent cover by herbs of any transect.

Figure C1. Percent cover by the herb layer for each transect sampled at each site in 2014. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.



A graph showing the species richness of the herb layer for transects sampled in 2014 is shown in Figure C2. In general, trends in species richness between sites and transects (Figure C2) mirror trends in percent cover (Figure C1). One exception is transect 2 at Lamonti Creek: percent cover was slightly lower than transect 1 at Lamonti Creek, yet species richness was slightly higher than transect 1 at Lamonti Creek. The transect with the highest species richness was Factor Ross transect 1, yet this was not the site with the highest percent cover by herbs. Both treatment sites (Ole Creek and Six Mile Creek) had lower species richness than their paired controls (Factor Ross Creek and Lamonti Creek, respectively).

Figure C2. Species richness of the herb layer for each transect sampled at each site in 2014. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.



2015 Vegetation Transects (Post-enhancement)

A graph summarizing the percent cover of each transect for vegetation transects sampled in 2015 (one year post-enhancement) is shown in Figure C3. In 2015, no tree or shrub species (A or B layers) were detected on any of the transects. Ole Creek (treatment site) had lower percent cover than its paired control site, Factor Ross Creek. Transect 2 at Six Mile Creek (treatment site) had similar percent cover to transect 2 at Lamonti Creek, while transect 3 at Six Mile Creek had almost no vegetation cover (0.01% cover by one herb species). Transect 4 at Lamonti Creek had the highest percent cover of any transect. Only four transects had any percent cover by bryophytes (D layer): Factor Ross Creek transect 3, Six Mile Creek transect 2 and Lamonti Creek transects 2 and 4.

A graph showing the species richness by vegetation layer for transects sampled in 2015 is shown in Figure C4. In general, trends in species richness between sites and transects (Figure C3) mirror trends in percent cover (Figure C4). Exceptions include Ole Creek transect 3, which had low percent cover by the herb layer, but had higher species richness than the other two transects at Ole Creek, and Lamonti Creek transect 4, which had higher percent cover than transect 2, but had lower species richness. The transect with the highest species richness was Six Mile transect 2, closely followed by Factor Ross Creek transect 1 and Lamonti Creek transect 2.

Figure C3. Percent cover by vegetation layers (A=tree, B=shrub, C=herb, D=bryophyte) for each transect sampled at each site in 2015. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.

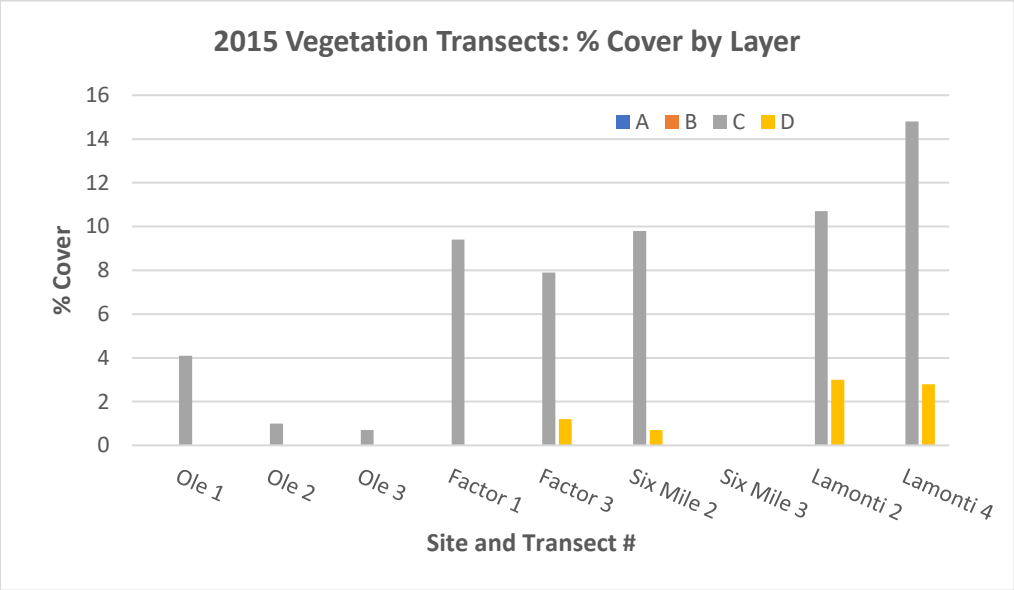
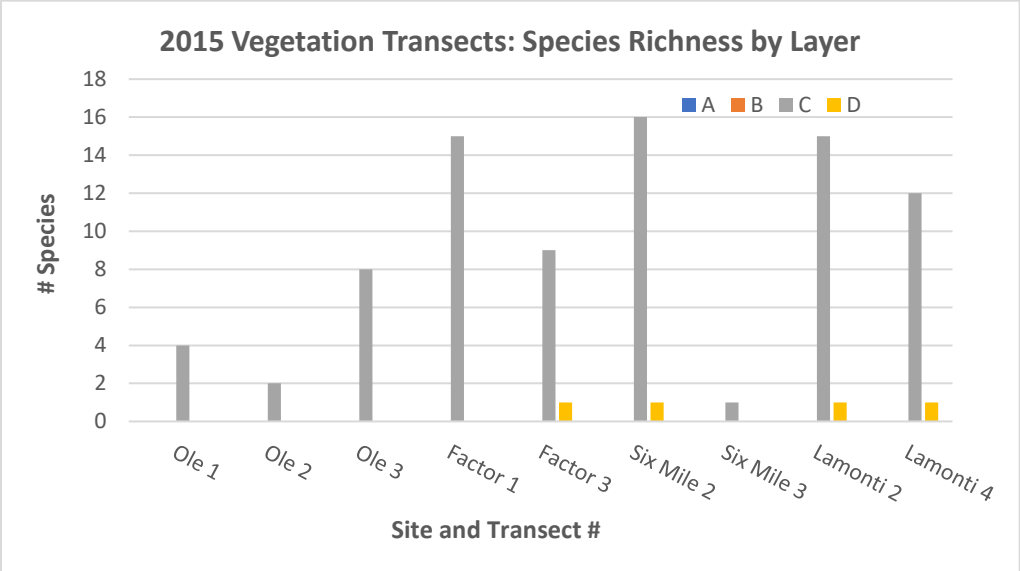


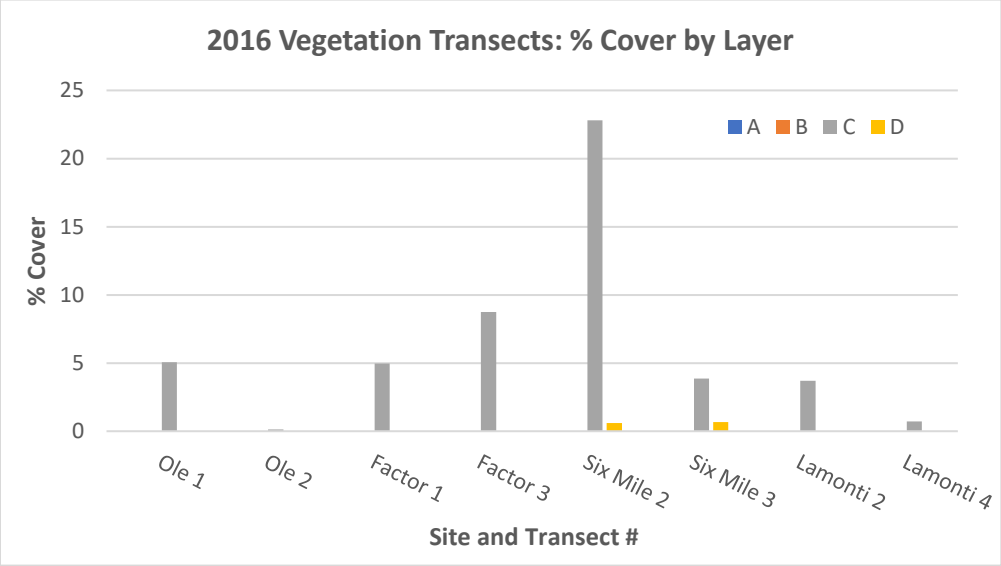
Figure C4. Species richness by vegetation layers (A=tree, B=shrub, C=herb, D=bryophyte) for each transect sampled at each site in 2015.



2016 Vegetation Transects (Post-enhancement)

A graph summarizing the percent cover of each transect for vegetation transects sampled in 2016 (two years post-enhancement) is shown in Figure C5. In 2016, no tree species (A layer) were detected on any of the transects, and a shrub species (B layer) was only recorded on Ole Creek transect 2 (treatment site). The highest percent cover by the herb layer was recorded at Six Mile Creek transect 2 (treatment site), with more than double the herb coverage of all the other transects sampled. Only two transects had more than 5% herb cover: Factor Ross Creek transect 3 and Six Mile Creek transect 2. When percent cover by herbs at treatment sites (Ole Creek and Six Mile Creek) are compared to those at control sites (Factor Ross Creek and Lamonti Creek), there are no clear trends: there appears to be a lot of variability on a transect-by-transect basis. Only the two transects at Six Mile Creek had any percent cover by bryophytes (D layer).

Figure C5. Percent cover by vegetation layers (A=tree, B=shrub, C=herb, D=bryophyte) for each transect sampled at each site in 2016. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.

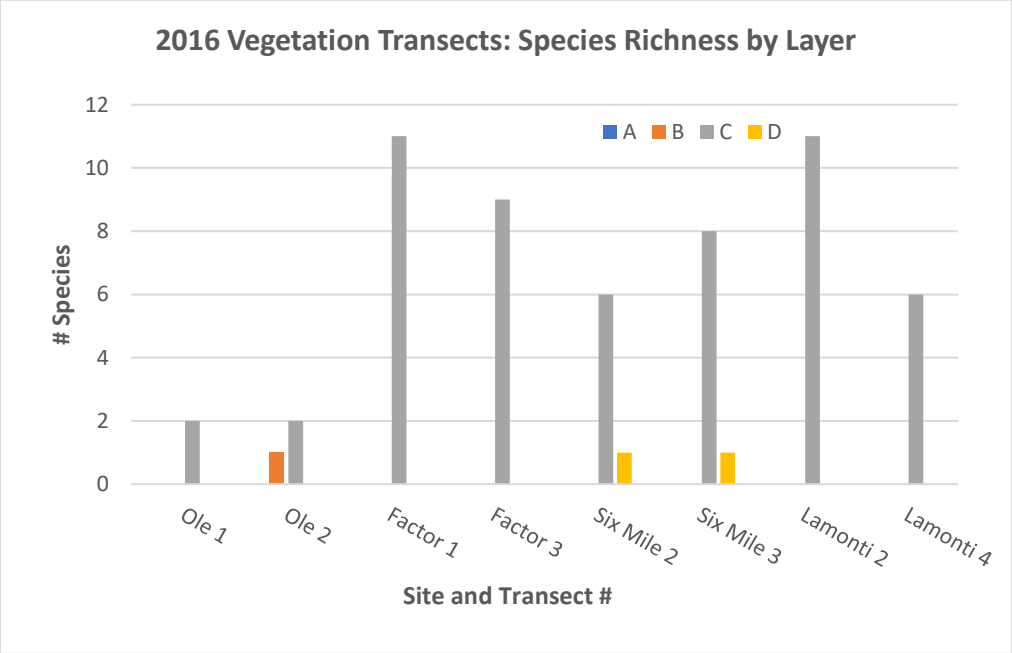


A graph showing the species richness by vegetation layer for transects sampled in 2016 is shown in Figure C6. Both transects at Ole Creek (treatment site) had low species richness of the herb layer compared to all other sites and transects. The two sites with the highest species richness in the herb layer were Factor Ross Creek transect 1 and Lamonti Creek transect 2, both control sites. Ole Creek transect 2 was the only transect within which a shrub species was recorded. The two transects at Six Mile Creek were the only ones where bryophyte species were recorded.

Relationships between species richness and percent cover between sites and transects are opposite to what might be expected (Figure C5 & Figure C6). The transect with the highest percent cover by herbs (Six Mile Creek transect 2 = 22.8% cover) did not have the highest herb species richness (6 species). Six Mile Creek transect 3 had one of the lower herb percent coverages (3.9% cover) yet had 8 herb species

(Figures C5 & C6). Similarly, Lamonti Creek transect 2 only had herb cover of 3.7% but had 11 herb species. Lamonti Creek transect 4 only had herb cover of 0.7% but had 6 herb species. At Factor Ross Creek, the transect with the higher herb cover (transect 3 = 8.7% cover) had the lower species richness (9 herb species) compared to the other transect at the site.

Figure C6. Species richness by vegetation layers (A=tree, B=shrub, C=herb, D=bryophyte) for each transect sampled at each site in 2016. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.



Appendix D: Vegetation mapping analyses - 2014 and 2015.

2014 Vegetation Mapping (Enhancement Year)

Vegetation mapping was first completed in 2014, the year enhancement took place at treatment sites. Vegetation maps of each site are provided in Appendix F.

A graph comparing the composition of the habitat maps by habitat class at each site in 2014 is shown in Figure D1. Paired treatment and control sites are displayed side-by-side in Figure D1 (e.g., Ole Creek = treatment, Factor Ross = paired control) for ease of comparison. Ten habitat classes were identified in total across all sites, although not all habitat classes were present at each site.

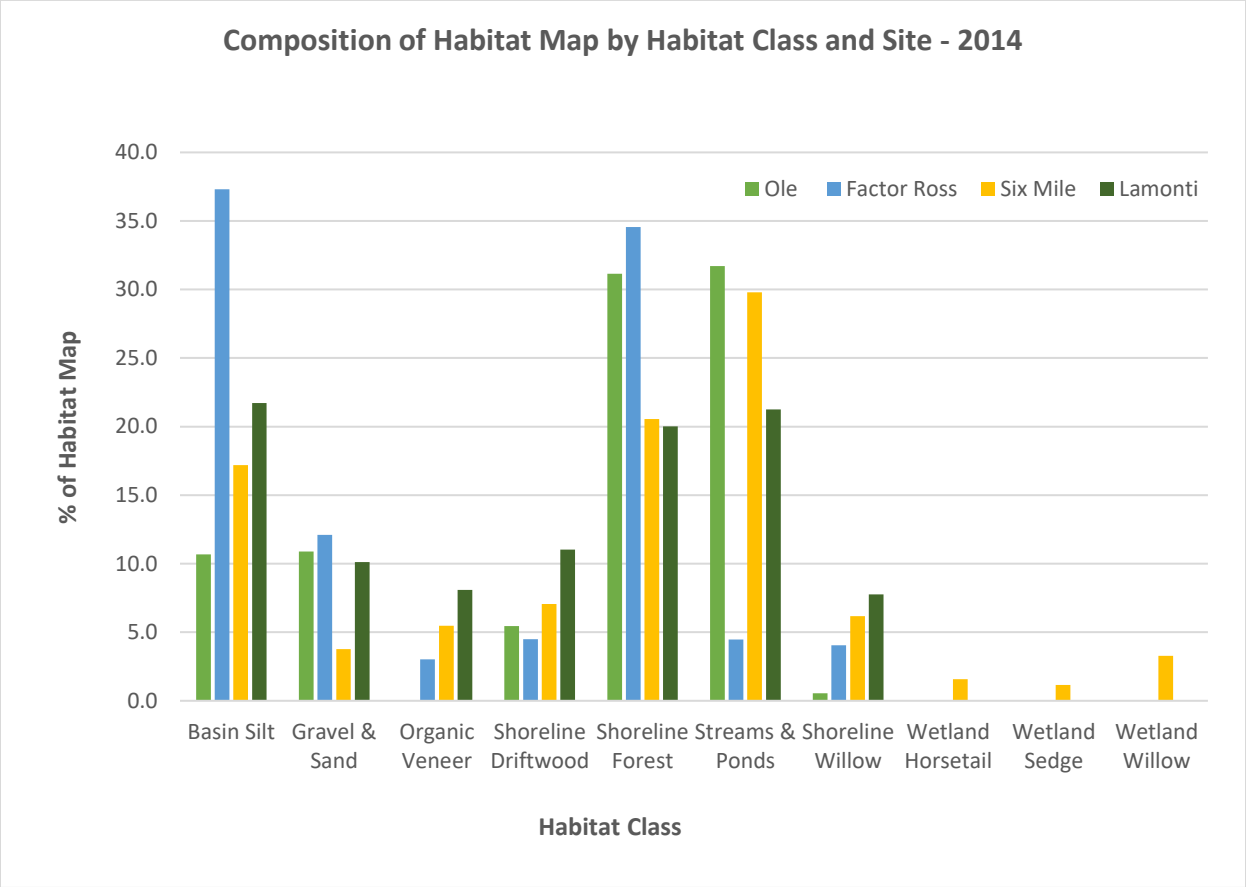
The habitat map for Ole Creek was comprised of six habitat classes, with two habitat classes (shoreline forest and streams & ponds) comprising more than 60% of the map area (light green bars in Figure D1). Ten percent of the Ole Creek habitat map was comprised of basin silt, and another 10% was comprised of gravel & sand. The shoreline driftwood habitat class was present across 5% of the habitat map. A very small proportion of the habitat map was comprised of shoreline willow (0.5%).

The habitat map for Factor Ross Creek, the paired control for Ole Creek, was comprised of seven habitat classes with two habitat classes (basin silt and shoreline forest) making up more than 70% of the habitat map area (blue bars in Figure D1). The Factor Ross Creek habitat map was comprised of 12% gravel & sand; the remaining habitat classes (organic veneer, shoreline driftwood, streams & ponds, shoreline willow) were each less than 5% of the habitat map area. In comparison to Ole Creek, the habitat map at Factor Ross Creek had a much higher proportion of basin silt and a much lower proportion of streams & ponds.

The habitat map for Six Mile Creek was comprised of all ten habitat classes, with two habitat classes (shoreline forest and streams & ponds) comprising more than 50% of the map area (yellow bars in Figure D1). Seventeen percent of the Six Mile Creek habitat map was comprised of basin silt. Organic veneer, shoreline driftwood and shoreline willow were each present across 5-7% of the habitat map. Six Mile Creek was the only site with wetland habitat within the mapped area, therefore it is the only site with wetland horsetail, wetland sedge and wetland willow habitat classes. A small proportion of the habitat map (<4% each) was made up of gravel & sand and the three wetland habitat classes.

The habitat map for Lamonti Creek, the paired control for Six Mile Creek, was comprised of seven habitat classes with three habitat classes (basin silt, shoreline forest and streams & ponds) making up more than 60% of the habitat map area (dark green bars in Figure D1). The Lamonti Creek habitat map was comprised of roughly 10% each of gravel & sand and shoreline driftwood, and roughly 8% each of organic veneer and shoreline willow. The habitat map for Lamonti Creek had many similarities to the habitat map for Six Mile Creek in terms of proportions of many of the habitat classes.

Figure D1. Habitat map composition by habitat class for each site mapped in 2014. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.

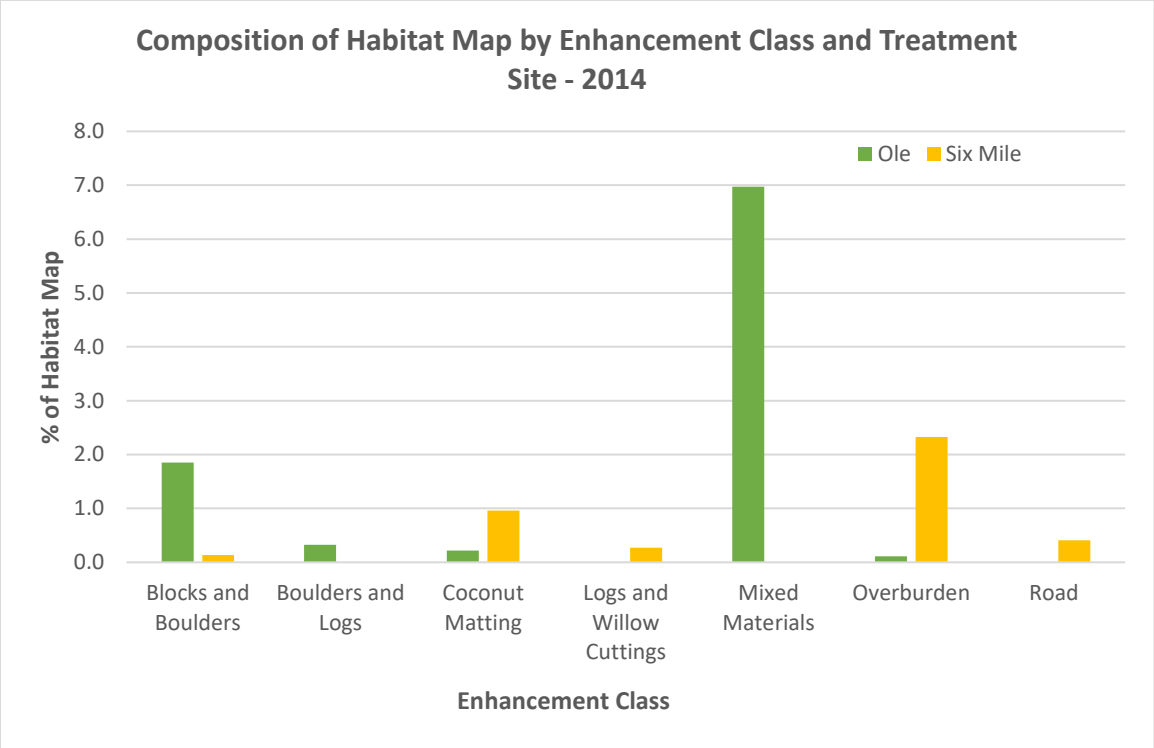


In 2014, seven enhancement classes were mapped at treatment sites, although several classes were not present at both sites (Figure D2). Enhancement classes made up a small proportion of the habitat maps for each site (generally less than 2% of the habitat map for each class); an exception was the mixed materials enhancement class, which made up 7% of the Ole Creek habitat map.

The Ole Creek habitat map had five enhancement classes (light green bars in Figure D2). Three of these classes (boulders & logs, coconut matting and overburden) each made up less than 1% of the habitat map area. Two percent of the Ole Creek habitat map was comprised of blocks & boulders, and 7% was mixed materials.

Enhancement classes at Six Mile Creek made up a smaller proportion of the habitat map compared to Ole Creek, with three classes each making up less than 0.5% of the habitat map area (yellow bars in Figure D2). The enhancement class that made up the greatest proportion of the Six Mile Creek habitat map was overburden, but that class only made up 2% of the habitat map area.

Figure D2. Habitat map composition by enhancement class for the two treatment sites, Ole Creek and Six Mile Creek, as mapped in 2014.



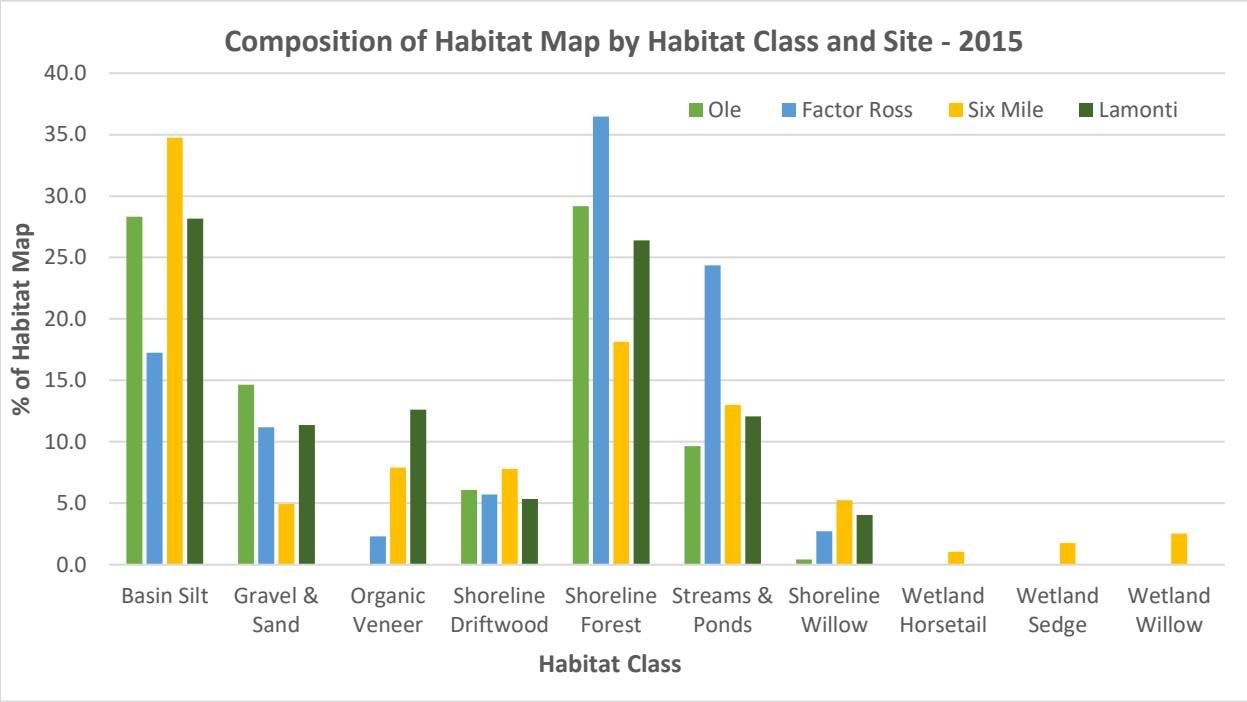
2015 Vegetation Mapping (Post-enhancement)

A graph comparing the composition of the habitat maps by habitat class at each site in 2015 is shown in Figure D3. Ten habitat classes were identified in total across all sites, although not all habitat classes were present at each site.

The habitat map for Ole Creek was comprised of six habitat classes, with two habitat classes (basin silt and shoreline forest) comprising more than 55% of the map area (light green bars in Figure D3). Fifteen percent of the Ole Creek habitat map was comprised of gravel & sand, and another 10% was comprised of streams & ponds. The shoreline driftwood habitat class was present across 6% of the habitat map. A very small proportion of the habitat map was comprised of shoreline willow (0.5%).

The habitat map for Factor Ross Creek, the paired control for Ole Creek, was comprised of seven habitat classes with two habitat classes (shoreline forest and streams & ponds) making up 60% of the habitat map area (blue bars in Figure D3). The Factor Ross Creek habitat map was comprised of 11% gravel & sand; the remaining habitat classes (organic veneer, shoreline driftwood, streams & ponds, shoreline willow) were each less than 6% of the habitat map area. In comparison to Ole Creek, the habitat map at Factor Ross Creek had a much higher proportion of streams & ponds and a lower proportion of basin silt.

Figure D3. Habitat map composition by habitat class for each site mapped in 2015. Treatment creeks: Ole and Six Mile; control creeks: Factor Ross and Lamonti.

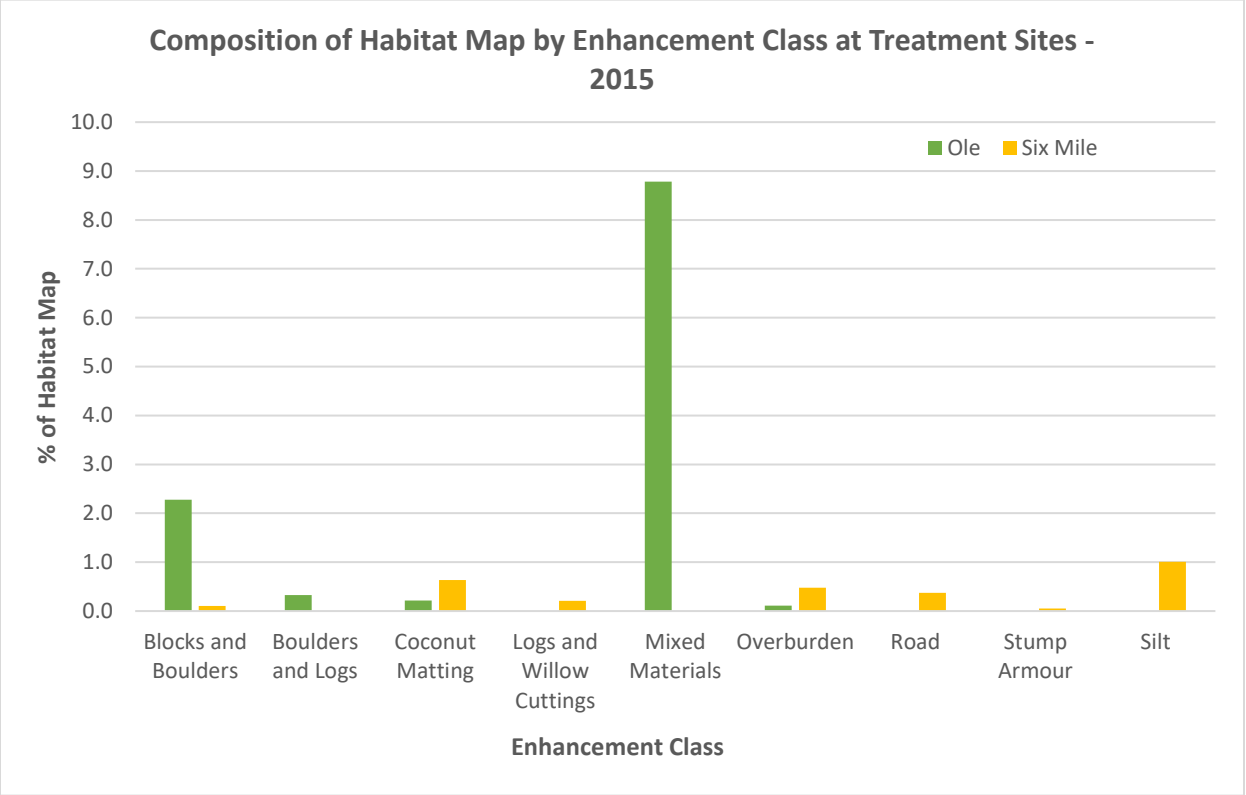


The habitat map for Six Mile Creek was comprised of all ten habitat classes, with one habitat class (basin silt) comprising 34% of the map area (yellow bars in Figure D3). Eighteen percent of the Six Mile Creek habitat map was comprised of shoreline forest, and 13% was comprised of streams & ponds. Gravel & sand, organic veneer, shoreline driftwood and shoreline willow were each present across 5-8% of the habitat map. As in 2014, Six Mile Creek was the only site with wetland habitat within the mapped area, therefore it is the only site with wetland horsetail, wetland sedge and wetland willow habitat classes. A small proportion of the habitat map (<3% each) was made up of the three wetland habitat classes.

The habitat map for Lamonti Creek, the paired control for Six Mile Creek, was comprised of seven habitat classes with two habitat classes (basin silt and shoreline forest) making up 54% of the habitat map area (dark green bars in Figure D3). The Lamonti Creek habitat map was comprised of roughly 12% each of gravel & sand, organic veneer, and streams & ponds. Roughly 5% of the habitat map was comprised of each of shoreline driftwood and shoreline willow. The habitat map for Lamonti Creek had many similarities to the habitat map for Six Mile Creek in terms of proportions of many of the habitat classes.

In 2015, nine enhancement classes were mapped at treatment sites, although several classes were not present at both sites (Figure D4). Enhancement classes made up a small proportion of the habitat maps for each site (generally less than 2% of the habitat map for each class); an exception was the mixed materials enhancement class, which made up 8% of the Ole Creek habitat map.

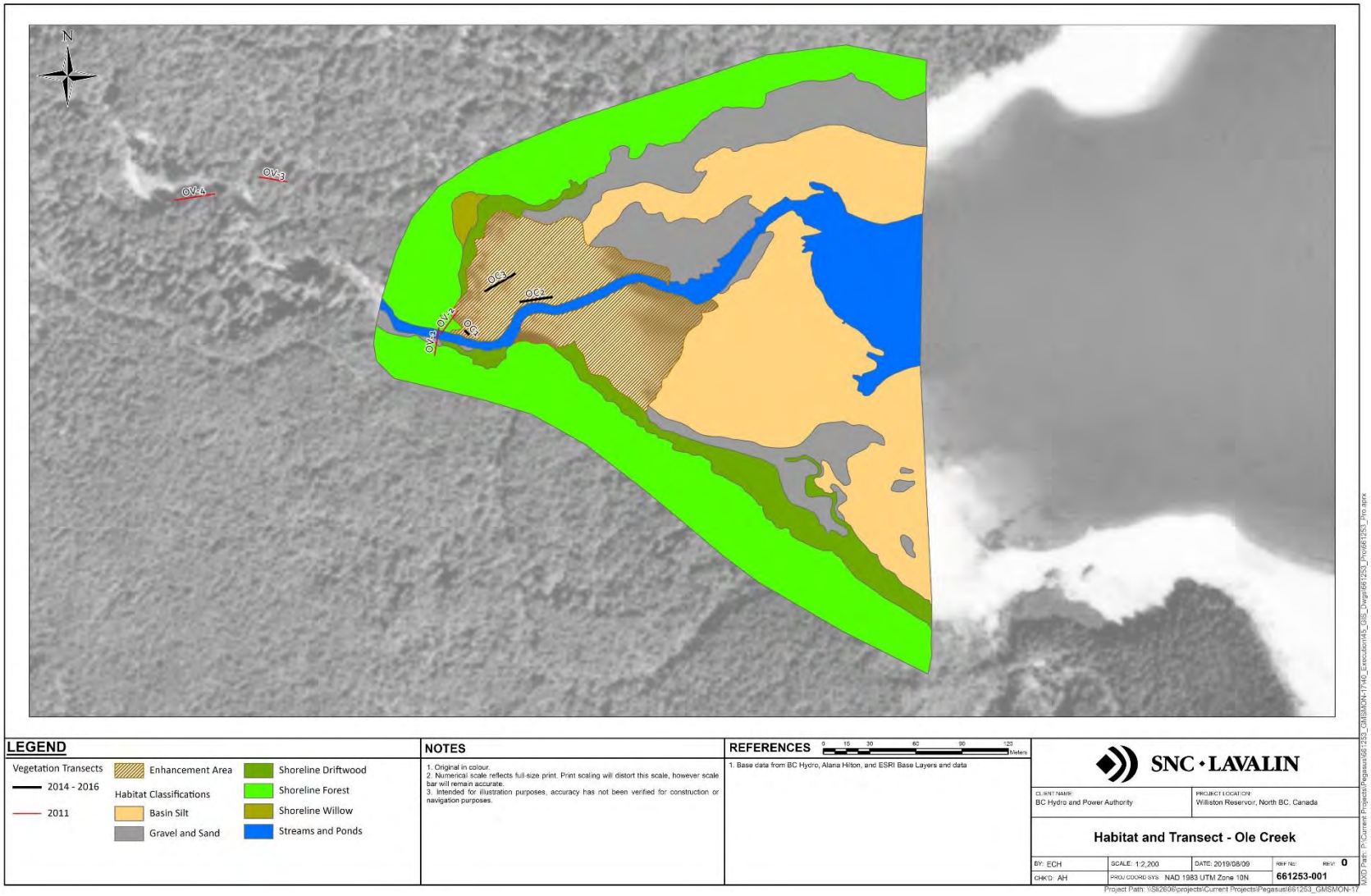
Figure D4. Habitat map composition by enhancement class for the two treatment sites, Ole Creek and Six Mile Creek, as mapped in 2015.



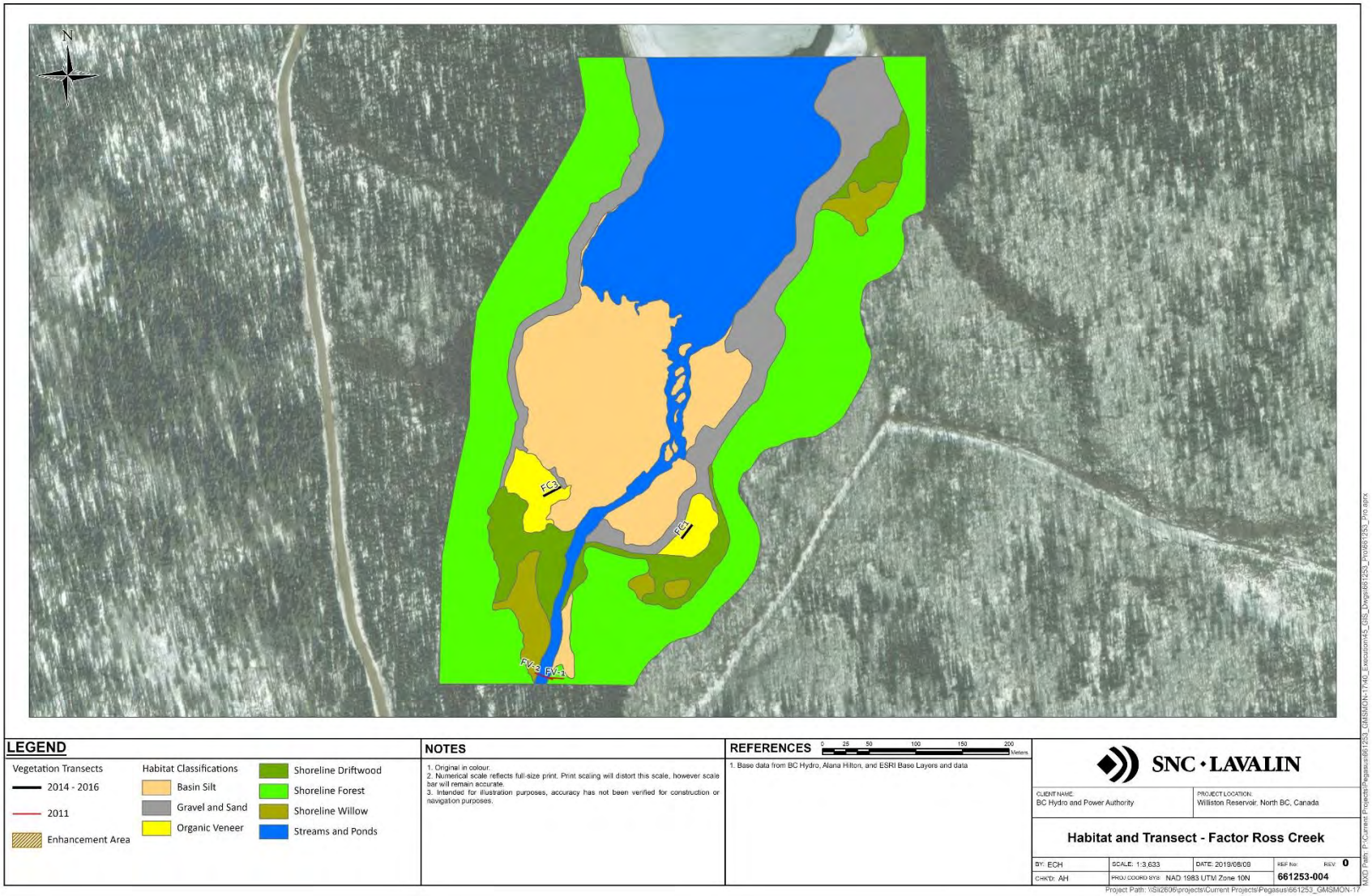
The Ole Creek habitat map had five enhancement classes (green bars in Figure D4). Three of these classes (boulders & logs, coconut matting and overburden) each made up less than 1% of the habitat map area. Two percent of the Ole Creek habitat map was comprised of blocks & boulders, and 8% was mixed materials.

Enhancement classes at Six Mile Creek made up a smaller proportion of the habitat map compared to Ole Creek, with six classes each making up less than 0.6% of the habitat map area (yellow bars in Figure D4). The enhancement class that made up the greatest proportion of the Six Mile Creek habitat map was silt, but that class only made up 1% of the habitat map area.

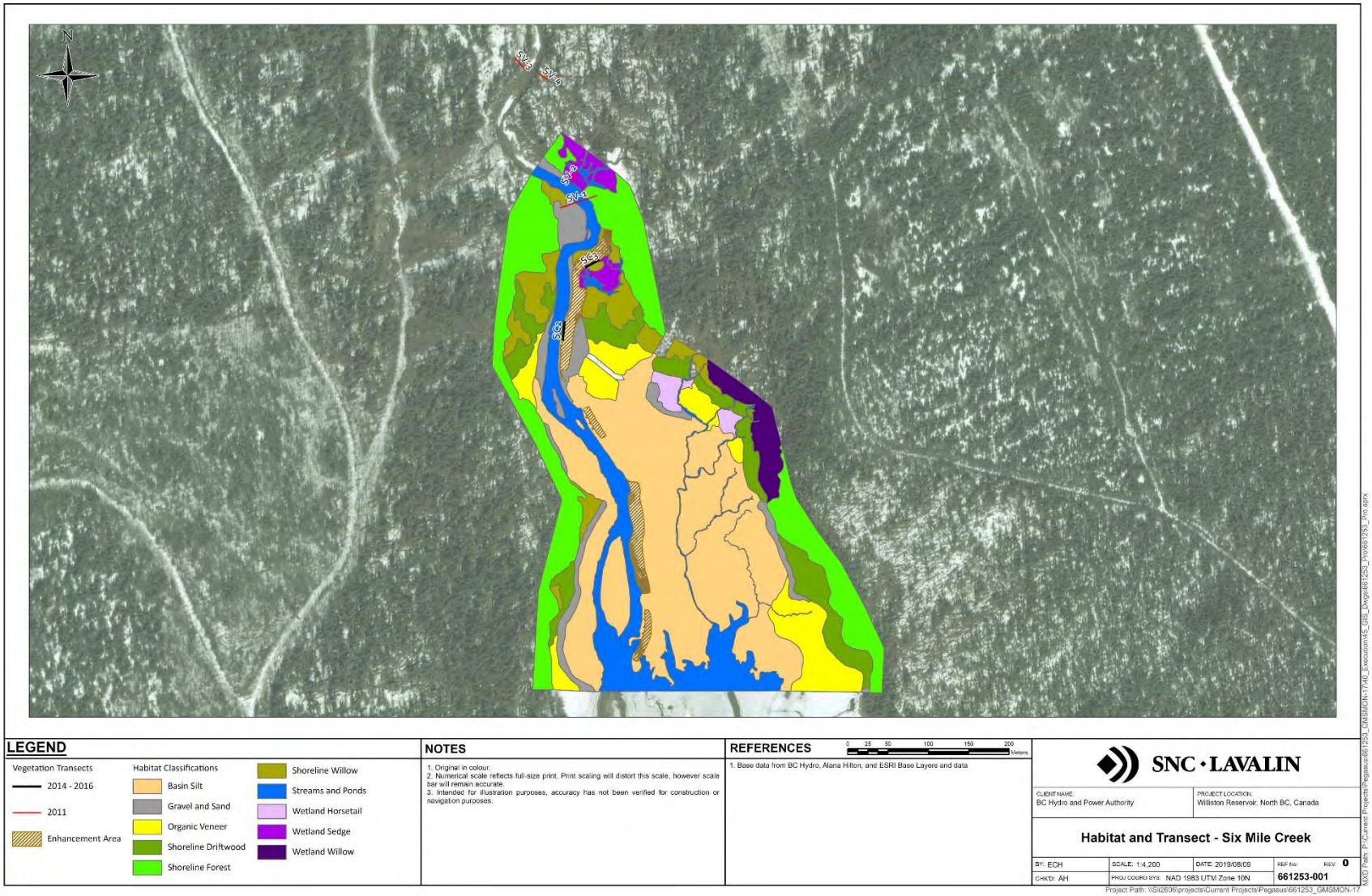
Appendix E: Vegetation mapping and locations of vegetation transects completed in 2011 and 2014 – 2016.



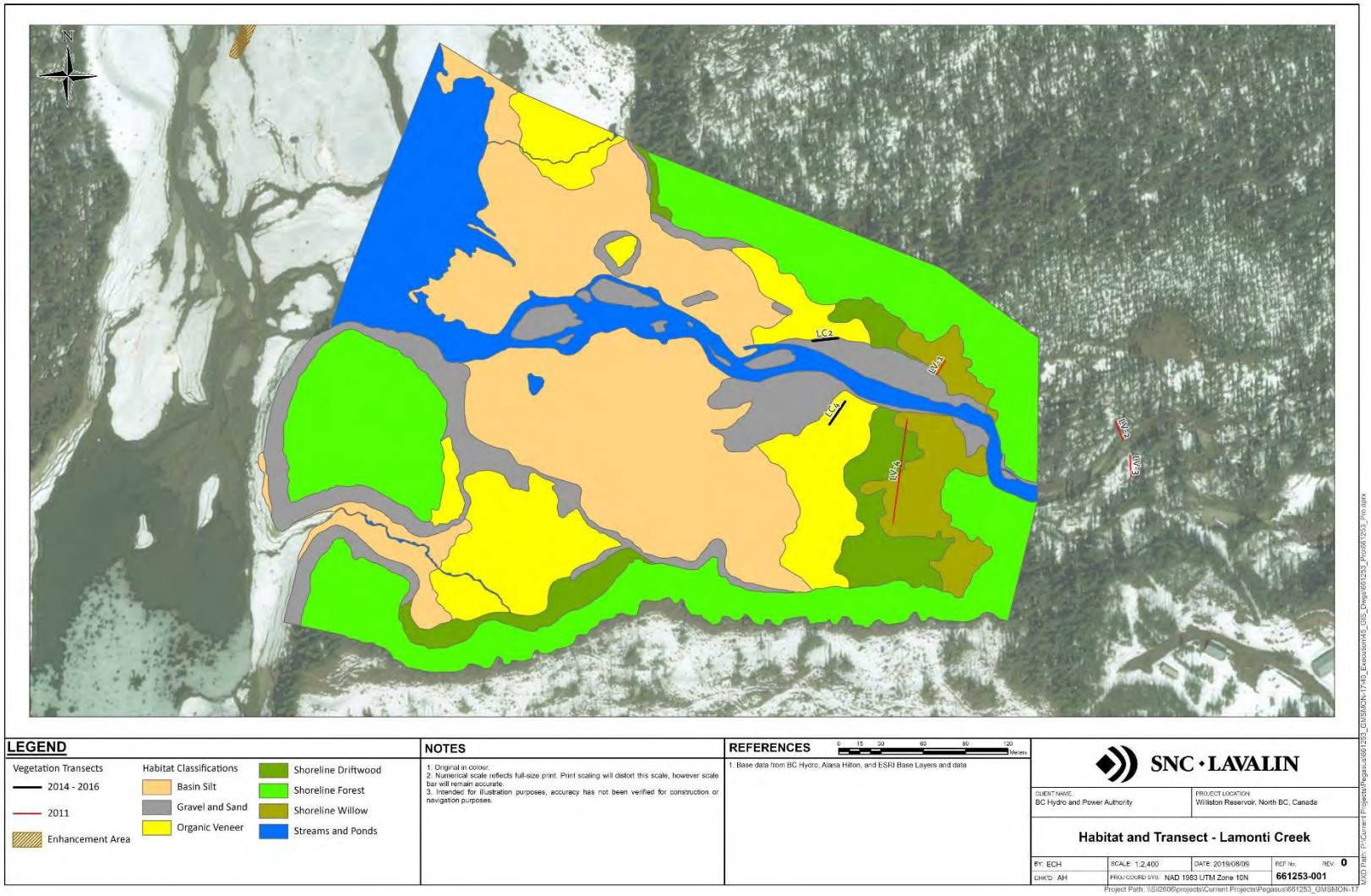
Habitat classes and transect locations at Ole Creek.



Habitat classes and transect locations at Factor Ross Creek.



Habitat classes and transect locations at Six Mile Creek.



Habitat classes and transect locations at Lamonti Creek.

Appendix 5
Vegetation Photo Review

Introduction

Photographs are a simple and useful tool to monitor changes in vegetation growth over time. Information on the extent and condition of vegetation can be qualitatively or quantitatively assessed using ground-based photographs that record a particular site at a particular time.

Photographs of the enhancement structures were taken at the time of construction by Kerr Wood Leidal. Select photographs of each structure, along with the approximate location and photograph orientation were determined. These locations were visited in Year 10 (2020) and the photographs were re-created. The amount of change of vegetation composition and structure was visually assessed to provide a qualitative comparison on the enhanced areas to address Management Question #3.

Methods

Representative photographs taken of the enhanced sites at Six Mile and Ole Creek were selected, and their approximate location and orientation were determined (Tables A5.1 and A5.2). These locations were re-visited in 2020 and new photograph were taken. A qualitative comparison of the vegetation growth and coverage from the original photographs to the recent photographs was completed.

Table 1. Geographic locations of reference photographs at Six Mike Creek 2020.

Photo	Zone	Easting	Northing
A-1	10 U	474733	6162225
A-2	10 U	474726	6162215
B-1	10 U	474690	6162568
B-2	10 U	474694	6162560
B-3	10 U	474709	6162534
C-1	10 U	474669	6162667
C-2	10 U	474669	6162618
C-3	10 U	474681	6162680
DF-1	10 U	474739	6162492
DF-2	10 U	474756	6162431
G-1	10 U	474773	6162313

G-2	10 U	474773	6162282
J-1	10 U	474723	6162774
J-2	10 U	474713	6162758

Figure 1. Overview of Six Mile Creek physical work features with locations of select photographs (red arrows). Arrow direction indicates the photograph orientation. The three vegetation transects (green) to be surveyed in 2020 are indicted for reference.

Table 2. Geographic locations of reference photographs at Ole Creek.

Photo	Zone	Easting	Northing
A-1	10 V	405854	6257641
A-2	10 V	405861	6257643
B-1	10 V	405950	6257736
B-2	10 V	405938	6257669
C-1	10 V	405888	6257645
D-1	10 V	406020	6257690

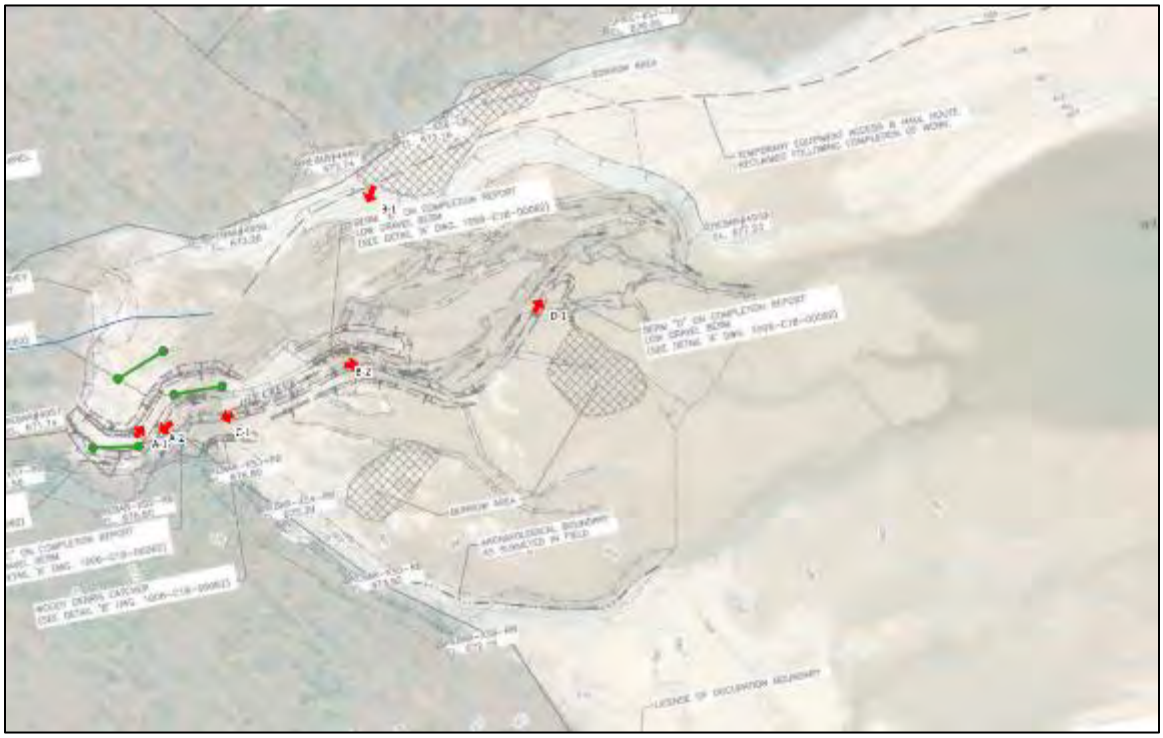


Figure 2. Overview of Six Mile Creek physical work features with locations of select photographs (red arrows). Arrow direction indicates the photograph orientation. The three vegetation transects (green) to be surveyed in 2020 are indicted for reference.

Dataset

Photographs taken of enhanced sites in 2014 were compared to photographs taken of the same locations in 2020 to provide a qualitative comparison of vegetation growth in the enhanced areas through time. At Six Mile Creek, representative photographs were used from 14 photo points on the on the six enhancement structures (i.e., berms) so that there were 2-3 photos from each berm. At Ole Creek, six photo points were selected on the four enhancement structures (i.e., 1-2 photos per berm).

Analysis

Overall, vegetation growth on the enhancement structures has been slow with relatively little change between the time of construction (2014) and the final year of GMSMON-17 (2020; Appendix 4). Therefore, a qualitative assessment of the change in vegetation composition and structure was conducted. At the time of the survey in 2020 the reservoir elevation was high and several of the enhancement structures at Six Mile Creek and Ole Creek were submerged, making direct comparisons difficult to impossible.

Results

Comparison of photographs taken in 2014 and 2016 to the photographs taken in 2020.

Six Mile Creek

Photo A-1. Berm A with water level just below crest elevation. Date taken: May 22, 2014.

Berm A was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm A is likely inhibiited by sporadic flooding conditions.

Photo A-2. Berm A – finished berm at ~0+900. The two front bulk bags to be removed. Date taken: May 20, 2014.

Berm A was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm A is likely inhibiited by sporadic flooding conditions.

Photo B-1. Berm B – Upstream and downstream of berm B. Date taken: June 11, 2014.

Berm B was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm B is likely inhibiited by sporadic flooding conditions.

Photo B-2. Berm B – Upstream end of berm B. Date taken: June 11, 2014.

Berm B was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm B is likely inhibiited by sporadic flooding conditions.

Photo B-3. Berm B – Downstream end of berm B, after ECM covered with granular fill. Date taken: June 11, 2014.

Berm B was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm B is likely inhibiited by sporadic flooding conditions.

Photo C-1. Berm C – Upstream end of berm C and downstream end of berm J. Date taken: June 11, 2014.

Photo C-1. Berm C – Upstream end of berm C and downstream end of berm J. Date taken: July 4, 2020.

Herb layer is dominated by *Chamerion angustifolium* (fireweed) and moss species, which are more prevalent along the sides of the berm. The geogrid material remains sparsely vegetated in 2020. Willow stakes that were embedded horizontally into Berm C did not sprout and grow.

Photo C-2. Berm C – Downstream end of berm C with granular fill placed on the back side. Date taken: June 11, 2014.

Photo C-2. Berm C – Downstream end of berm C with granular fill placed on the back side. Date taken: July 4, 2020.

Herb layer is dominated by *Chamerion angustifolium* (fireweed) and moss species, which are more prevalent along the sides of the berm. Willow stakes that were embedded horizontally into Berm C did not sprout and grow; this area is fully submerged in 2020.

Photo C-3. Berm C – Upstream end of berm C and downstream end of berm J. Date taken: June 11, 2014.

Photo C-3. Berm C – Upstream end of berm C and downstream end of berm J. Date taken: July 4, 2020.

Herb layer is dominated by *Chamerion angustifolium* (fireweed) and grass species, which are more prevalent along the sides of the berm. Here (i.e., the upstream sections of the berm) the geogrid material is more vegetated compared to the downstream sections, potentially due to less annual flooding from the reservoir.

Photo DF-1. Berm D/F – Upstream end of berm D looking downstream at berm F. Date taken: May 30, 2014.

Berm D/F was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm D/F is likely inhibiited by sporadic flooding conditions.

Photo DF-2. Berm D/F – Midway along berm F looking at berm G. Date taken: May 30, 2014.

Berm D/F was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm D/F is likely inhibiited by sporadic flooding conditions.

Photo G-1. Berm G – Upstream end of berm G, before all construction stakes were inserted. Date taken: May 26, 2014.

Berm G was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm G is likely inhibiited by sporadic flooding conditions.

Photo G-2. Berm G – Midway along berm G looking downstream. Date taken: May 26, 2014.

Berm G was fully submerged at the time of the site visit in 2020. Photo taken at the downstream end of Berm C.

Vegetation growth on Berm G is likely inhibiited by sporadic flooding conditions.

Photo J-1. Berm J – Looking downstream on berm J with berm C in the background. Date taken: June 11, 2014.

Photo J-1. Berm J – Looking downstream on berm J with berm C in the background. Date taken: July 2, 2020.

Herb layer is dominated by *Chamerion angustifolium* (fireweed) and grass species, which are prevalent along the top of the berm. Embedded willow stakes and shoots are growing along the sides of the berm. Overall, vegetation cover is highest on Berm J compared to the other enhancement sites.

Photo J-2. Berm J – Midway along berm J looking downstream. Date taken: June 11, 2014.

Photo J-2. Berm J – Midway along berm J looking downstream. Date taken: July 4, 2020.

Herb layer is dominated by *Chamerion angustifolium* (fireweed) and grass species, which are prevalent along the top of the berm. Embedded willow stakes and shoots are growing along the side of the berm. Overall, vegetation cover is highest on Berm J compared to the other enhancement sites.

Ole Creek

<table>
<tr>
<td> 
Photo A-1. Berm A – Downstream end of berm A, ECM use above EL. 671.0 m. Date taken: May 28, 2014.</td>
<td> 
Photo A-1. Berm A – Downstream end of berm A, ECM use above EL. 671.0 m. Date taken: July 4, 2020.</td>
</tr>
<tr>
<td colspan="2">Berm A remains sparely vegetated and was inundated with large woody debris. Willow plantings that were installed at the time of construction have not become established.</td>
</tr>
</table>

Photo A-2. Berm A – Upstream end of berm A. Date taken: May 28, 2014.

Photo A-2. Berm A – Upstream end of berm A. Date taken: July 4, 2020.

Berm A remains sparely vegetated and was inundated with large woody debris. Willow plantings that were installed at the time of construction have not become established. A small proportion of grass species have naturally established.

Photo B-1. Berm B – Site overview showing part of berm A, berm B, and most of berm C. Date taken: May 28, 2014.

Photo B-1. Berm B – Site overview showing part of berm A, berm B, and most of berm C. Date taken: July 4, 2020.

Berm B was mostly submerged at the time of the site visit in 2020. Vegetation species were not noted during visual inspections completed in 2018 and 2019.

Photo B-2. Berm B – (Panoramic) Berm B looking downstream on left side of photo and Berm D at right side. Date taken: May 5, 2016.

Photo B-2. Photo taken from the north side of the Ole Creek inlet looking across Berm B (submerged) to Berm C. Date taken: July 4, 2020.

Berm B was submerged at the time of the site visit in 2020. Vegetation species were not noted during visual inspections completed in 2018 and 2019.

<table>
<tr>
<td> 
Photo C-1. Berm C – Upstream end of berm C with woody debris catcher. Date taken: May 28, 2014.</td>
<td> 
Photo C-1. Berm C – Upstream end of berm C with woody debris catcher. Date taken: July 4, 2020.</td>
</tr>
<tr>
<td colspan="2">A small patch of Equisetum (horsetail) was present on Berm C in 2020, which is visible in the foreground of the photo. Willow saplings are becoming established and are 0.5 m to 1.0 m in height. Large woody debris and rocks and boulders dominate the enhancement structure.</td>
</tr>
</table>

Photo D-1. Berm D – Berm D looking downstream. Date taken: May 5, 2016.

Photo D-1. Berm D – Berm D looking downstream. Date taken: July 4, 2020.

Berm D was submerged at the time of the site visit in 2020. Trace amounts of grass and willow are visible in the foreground of the photo.

Appendix 6
GMSMON-17 Tributary Habitat Review
Bird Data Compilation and Analyses

Peace River Water Use Plan

GMSMON-17 Tributary Habitat Review

Bird Data Compilation and Analyses

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June 2019

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1 Introduction

Situated in the northern interior of BC near the towns of Mackenzie and Hudson's Hope, Williston Reservoir is the largest reservoir in BC, with a surface area of 1,773 square kilometres. Water levels in the reservoir are controlled by one of the world's largest earth-filled structures, the WAC Bennett Dam, which since completed in 1968, regulates the flow of the Peace River.

Water levels within Williston Reservoir fluctuate throughout the year due to dam operations for power generation. During the winter, the reservoir is drawn down resulting in a large mostly unvegetated floodplain ("drawdown zone") around the perimeter of the reservoir. When the reservoir is low, shallow channels with excessive braiding occur where tributaries flow over the exposed drawdown zone. The reservoir is typically at its lowest level in late April and early May (BC Hydro 2003). Reservoir levels increase in late spring due to snow melt, with the reservoir reaching its maximum elevation ("full pool") in July each year (BC Hydro 2003). Reservoir levels stay high throughout the summer months and much of the fall.

Large woody debris (LWD) is introduced into the reservoir every year due to logging and erosion, adding to an accumulation of debris from the original filling of the reservoir (BC Hydro 2008a). This debris accumulates in the bays where the tributaries empty into the reservoir (BC Hydro 2008a). The woody debris in tributary mouths may scour the banks of the tributaries and the reservoir thereby reducing natural littoral and/or riparian vegetation that may be growing there and increasing sedimentation (BC Hydro 2008b; Cubberley and Hengeveld 2010).

BC Hydro implemented a trial tributary mitigation plan to improve fish access to tributaries affected by large woody debris accumulations and/or shallow water depths due to stream braiding through the drawdown zone in spring. Cubberley and Hengeveld (2010) selected two mitigation trial sites and paired these with control sites (Table 1). Six Mile Creek was selected as a trial mitigation site due to a perched mouth caused by sediment accumulation. Lamonti Creek was selected as a paired control for Six Mile Creek. Chichouyenily Creek was selected as a second trial mitigation site but was later abandoned in favour of Ole Creek. Ole Creek had high accumulations of large woody debris at the tributary mouth, which spread tributary flow laterally across the drawdown zone at low reservoir levels (Kerr Wood Leidal 2011). Factor Ross Creek was selected as a paired control for Ole Creek. Mitigation recommendations for Six Mile Creek and Ole Creek included renovating the stream channels within the drawdown zone and use of retention structures to increase vegetation growth along the high-water mark (Cubberley and Hengeveld 2010).

Table 1. Summary of GMSMON-17 project design.

Treatment Creek	Treatment Goal	Control Creek
Six Mile Ck.	Restore fish passage past perched creek mouth	Lamonti Ck.
Ole Ck.	Restore fish passage past woody debris accumulations	Factor Ross Ck.

A Tributary Habitat Review monitoring program was initiated to assess the effectiveness of the tributary enhancement in improving fish and wildlife habitat. The enhancement was expected to improve fish access to tributaries during low reservoir elevations, when the tributaries are used for spring spawning

(BC Hydro 2008b). Riparian vegetation recruitment along the banks was expected to improve after mitigation. In addition to fish and vegetation, songbirds and amphibians were selected for monitoring to determine if they were positively or negatively affected by the enhancement.

A set of six management questions were established to guide the GMSMON-17 monitoring program (BC Hydro 2008b, BC Hydro 2015):

1) Does access for spring spawners (i.e., rainbow trout and/or arctic grayling) improve as a result of enhancement?
2) Is the area and quality of fish habitat created by the tributary enhancement maintained over time?
3) Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?
4) Does abundance and diversity of song birds (passerines) around tributaries change as a result of enhancement?
5) Does amphibian abundance and diversity in tributaries change as a result of enhancement?
6) Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?

To address all management questions, field surveys for fish, vegetation, songbirds and amphibians at the enhancement sites and control sites were initiated in 2011 under the GMSMON-17 program. Data collected between 2011 and 2013 were baseline pre-enhancement data for each site (Table 2). Enhancement of the trial tributaries occurred in 2014 under the GMSWORKS-19 program; data on fish, vegetation, songbirds and amphibians were collected during the construction year. Post-enhancement data on fish, vegetation, songbirds and amphibians were collected from 2015 onwards.

Table 2. Data collection by project phase for the GMSMON-17 project.

Project Phase	Year(s) Data Collected
Pre-enhancement	2011 - 2013
Enhancement (construction)	2014
Post-enhancement	2015 - present

This report will provide summaries and analyses of the bird data collected to date under GMSMON-17, including multi-year comparisons of bird survey data. Management question #4 will be considered using the bird data collected to date. Recommendations for bird sampling (methods, locations) in the final year of the monitoring program will be provided.

2 Bird Data Collection - Background

Two different consultants collected bird data for the project, separated by a two year break:

- 2011: Golder Associates Ltd.
- 2012 – 2013: no data collection

- 2014 – 2016: DWB Consulting Services Ltd./Cooper Beauchesne and Associates Ltd.

Different methods were used for bird surveys by the different consultants, as summarized below and in Table 3.

Golder Associates Ltd. (2011 only) used variable radius point count surveys every 200 m along each stream, with the first location chosen within what was anticipated to be the treatment area. Point count stations were five minutes in duration. The sampling schedule used in 2011 differed across creeks:

- At Six Mile Creek and Lamonti Creek (a treatment/control dyad), three replicates were completed of each of the five point count stations, with the first survey of each station completed in early May, the second survey of each station in mid-May, and the third survey of each station in early June.
- At Factor Ross Creek, six stations were visited in the morning and again in the afternoon on the same day in mid-May only. Two of the transects at Factor Ross Creek were revisited in the afternoon two days later. At Ole Creek, eight stations were surveyed once in mid-May.

The bird stations sampled at each site in 2011 are shown in Table 4. A full description of the methods used for the bird sampling in the first year of the project can be found in the year-end report for the project (Golder 2012).

In 2014, DWB Consulting Services Ltd./Cooper Beauchesne and Associates Ltd. established new bird point count stations within the drawdown zone along each of the four tributaries. Two stations were established at Six Mile Creek (one overlapped an enhancement area), and two stations were established at Lamonti Creek. Only one station was sampled at each of Ole Creek and Factor Ross Creek. Timing of surveys varied across years:

- In 2014 (construction year) and 2015 (post-enhancement), each station was replicated on two consecutive days within a 4-day period in mid-June.
- In 2016, (post-enhancement) the same stations were replicated on two days in late May.

Stations lasted for 30 minutes and all birds recorded within and outside a 75 m radius were recorded. The bird stations sampled at each site between 2014 and 2016 are shown in Table 5. A full description of the methods used for the bird sampling in 2014 through 2016 can be found in year-end reports for the project (MacInnis et al. 2015, MacInnis et al. 2016, Thompson and Carson 2017).

Table 3. Bird survey methods used throughout the first six years of the GMSMON-17 project.

Year	Consultant	Methods				
		Point Count Obs. Period	Location	Number of Replications	Timing of Data Collection	Type of Data Collected
2011	Golder Associates Ltd.	5-minute stations	Stations spaced 200 m apart along the main creek at each site; first station was located in what was anticipated to be the treatment area	Six Mile Creek (5 stations) = 3 replications; Lamonti Creek (5 stations) = 3 replications	early May, mid-May, mid-June	birds within and outside a 75 m radius
				Factor Ross Creek (6 stations) = 2 replications (once in morning and once in afternoon); 2 stations revisited 2 days later	mid-May	
				Ole Creek = 1 replication	mid-May	
2014 - 2016	DWB Consulting Services Ltd. & Cooper Beauchesne and Associates Ltd.	30-minute stations	Single station within the drawdown zone along each tributary; additional station in enhanced habitat at Six Mile Creek; additional station at Lamonti Creek	2 replications each year, spaced 1-2 days apart	2014 and 2015 - mid-June; 2016 - late May	all birds (including waterbirds and shorebirds) within and outside a 75 m radius

Table 4. Bird stations surveyed in 2011 of the GMSMON-17 project.

Site	Station ID	UTM (E)	UTM (N)	Survey Timing		
				Survey #1	Survey #2	Survey #3
Ole Creek	OPC-1	404827	6257614	mid-May	n/a	n/a
	OPC-2	405000	6257640			
	OPC-3	405154	6257795			
	OPC-4	405232	6257867			
	OPC-5	405442	6257894			
	OPC-6	405591	6257779			

Site	Station ID	UTM (E)	UTM (N)	Survey Timing		
				Survey #1	Survey #2	Survey #3
	OPC-7	405788	6257673			
	OPC-8	406033	6257749			
Factor Ross Creek	FRPC-1	395408	6276074	mid-May (morning)	mid-May (same day as survey #1, afternoon)	mid-May (2 days after survey #1, afternoon)
	FRPC-2	395352	6275882			
	FRPC-3	395328	6275707			n/a
	FRPC-4	395337	6275555			
	FRPC-5	395287	6275389			
	FRPC-6	395222	6275259			
Six Mile Creek	SMPC-1	474729	6162616	early May	mid-May	early June
	SMPC-2	474709	6162830			
	SMPC-3	474552	6162878			
	SMPC-4	474639	6163035			
	SMPC-5	474580	6163187			
Lamonti Creek	LPC-1	475286	6161990	early May	mid-May	early June
	LPC-2	475412	6161997			
	LPC-3	475484	6161924			
	LPC-4	475610	6161932			
	LPC-5	475718	6161951			

Table 5. Bird stations surveyed between 2014 and 2016 of the GMSMON-17 project.

Site	Station	UTM (E)	UTM (N)	Survey Timing		
				2014	2015	2016
Ole Creek	OB1	405907	6257669	June 10 to 14	June 7 to 11	May 24 to 30
Factor Ross Creek	FB1	395465	6275927			
Six Mile Creek	SB1	474766	6162501			
	SB2	474684	6162680			
Lamonti Creek	LB1	475077	6162077			
	LB2	475103	6161974			

3 Bird Data Analyses

3.1 Methods

Bird data collected in the first 6 years of the GMSMON-17 project (2011 to 2016) were obtained from BC Hydro. When data were not available electronically, they were acquired from year-end report tables or appendices. Data were closely examined to understand the nature of the data and how to best organize it for consistency between years. New Excel files were created for each year of the project, and the raw

data were imported or entered. Data were standardized across sites and years in terms of transect names and worksheet layout. It was not possible to standardize the data between years of the project: times of bird detections were not recorded, so it was not possible to separate out birds recorded within the first 5 minutes of the longer point count stations completed between 2014 and 2016. Raw data were summarized in terms of species richness within and outside the 75 m radius point count stations to allow comparisons between sites and between years. Table 4 provides a summary of the tasks completed and data analyses done with each year of bird data from the project. Once Excel spreadsheets were complete, the bird data from all years of the project were imported into a single Access database.

Table 4. Data analyses of bird data from the first six years of the GMSMON-17 project.

Year(s)	Data Type	Data Analyses Tasks Completed
2011	Point Count Stations	original field data point count plots contained within an Appendix to the 2011 report; legibility of some of the scanned data sheets was poor, and species names were deciphered using cross-references to species code lists found online
		data included location, station start/end time, weather conditions, species names (4-letter codes) and a plotted location with respect to the plot centre; sex of individuals was occasionally recorded; habitat features of interest nearby the station were occasionally drawn on the diagram (e.g., creek location, treeline)
		data were entered into an Excel spreadsheet
		# of individuals of each species within and outside the 75 m radius point count station was summarized for each station; survey locations within the drawdown zone were summarized separately from the survey locations upstream from the reservoir
		total number of unique species at each site (within drawdown zone and within the point count station radius) was tallied by visit
		data were imported into an Access database containing all bird data for the project
2014 - 2016	Point Count Stations	data for all three years of bird surveys was contained within an Appendix to the 2016 report
		data included location, station start/end time, weather conditions, species names (4-letter codes), type of observation (visual, call or song), and a distance class from the observer; habitat features of interest at the bird location were occasionally noted (e.g., drawdown zone)
		# of individuals from each species was tallied for each pair of survey days each year; birds recorded inside and outside 75 m radius analyzed separately
		data were imported into an Access database containing all bird data for the project

Bird data collected within the 75 m radius point count stations in the drawdown zone are presented below. Data collected outside the 75 m radius point count stations in the drawdown zone, and data

collected further from the reservoir, are summarized in Appendix A (2011 data) and Appendix B (2014 – 2016 data). Bird data collected in 2011 were compared between sites and treatments. Bird data collected between 2014 (construction year) and 2016 (post-enhancement) were compared between sites, treatments and years. Since new bird survey stations were selected in 2014, and stations were longer in duration (30 minutes), data from surveys completed in 2014 onwards cannot be easily compared with data collected in 2011.

3.2 Results

3.2.1 2011 Bird Surveys (pre-implementation)

At Ole Creek, one bird station was sampled within the drawdown zone once in mid-May. In total, six individuals from four species were recorded within the 75 m radius point count station (Table 5). The most abundant species was the Tree Swallow. The treeline did pass through a portion of this plot, and three of the species recorded (Yellow-bellied Sapsucker, Hammond's Flycatcher and Yellow-rumped Warbler) were using the upland forested habitat. The other species, Tree Swallow, is an aerial insectivore that will forage over the drawdown zone but is unlikely to be impacted by the Ole Creek habitat restoration as it nests in tree cavities.

Table 5. Bird results within the point count station (75 m radius) in the drawdown zone at Ole Creek in 2011, prior to project implementation.

Ole Creek		
Species	**May 11, 2011 (morning)**	**1 station**
Yellow-bellied Sapsucker	1	
Hammond's Flycatcher	1	
Tree Swallow	3	
Yellow-rumped Warbler	1	
Total	6	

At Factor Ross Creek (control to Ole Creek), two bird stations within the drawdown zone were sampled three times in mid-May. During the first visit to the site, four individuals from four species were recorded within the 75 m radius point count station (Table 6). At the second visit to the site in the early evening of the same day, four individuals from three species were recorded (Table 6). On the third visit to the site, two birds from two species were recorded within the 75 m radius point count station (Table 6).

Table 6. Bird results within the point count station (75 m radius) in the drawdown zone at Factor Ross Creek in 2011 (control), prior to project implementation at Ole Creek. Species in bold type is one that might use drawdown habitats for foraging and/or nesting.

Factor Ross Creek				
Species	**May 15, 2011 (morning) 2 stations**	**May 15, 2011 (evening) 2 stations**	**May 17, 2011 (mid-day) 2 stations**	**Total**
Yellow-bellied Sapsucker		1		1
Hammond's Flycatcher			1	1
Tree Swallow		2		2
Yellow-rumped Warbler	1	1		2
Chipping Sparrow	1		1	2
Dark-eyed Junco	1			1
Purple Finch	1			1
Total	4	4	2	10

At Six Mile Creek, one bird station within the drawdown zone was sampled twice in mid-May and was sampled a third time in early June. During the first survey of the site, two individuals of one species (Song Sparrow) were recorded within the 75 m radius point count station (Table 7). At the second visit to the site in mid-May, no birds were recorded (Table 7). On the third visit to the Six Mile Creek drawdown zone in early June, six individuals from six species were recorded within the 75 m radius point count station (Table 7).

Table 7. Bird results at Six Mile Creek in 2011, prior to project implementation. Species in bold type is one that might use drawdown habitats for foraging and/or nesting.

Six Mile Creek				
Species	**May 11, 2011 (morning) 1 station**	**May 13, 2011 (morning) 1 station**	**June 8, 2011 (morning) 1 station**	**Total**
Spotted Sandpiper			1	1
Pacific Wren			1	1
Swainson's Thrush			1	1
Tennessee Warbler			1	1
Wilson's Warbler			1	1
Yellow-rumped Warbler			1	1
Song Sparrow	2			2
Total	2	0	6	8

At Lamonti Creek (control to Six Mile Creek), one bird station within the drawdown zone was sampled twice in mid-May and was sampled a third time in early June. During the first survey of the site, three individuals from three species were recorded within the 75 m radius point count station (Table 8). At the

second visit to the site, two individuals from one species (Hammond's Flycatcher) were recorded (Table 8). During the third visit to Lamonti Creek drawdown zone in early June, four individuals from four species were recorded within the 75 m radius point count station (Table 8).

Table 8. Bird results at Lamonti Creek in 2011 (control), prior to project implementation at Six Mile Creek.

Lamonti Creek				
Species	**May 11, 2011 (morning) 1 station**	**May 13, 2011 (morning) 1 station**	**June 7, 2011 (morning) 1 station**	**Total**
Hammond's Flycatcher		2	1	3
Pacific Wren	1			1
Golden-crowned Kinglet	1			1
American Robin			1	1
Wilson's Warbler	1			1
Yellow-rumped Warbler			1	1
Purple Finch			1	1
Total	3	2	4	9

Between-Site Comparisons

Due to differences in survey methods between the northern sites (Ole Creek and Factor Ross Creek) and the southern sites (Six Mile Creek and Lamonti Creek) in terms of survey timing and replication of surveys, it is not useful to compare bird survey results between these geographic locations. However, comparisons can be made between treatment and control sites at each location.

Fewer species were recorded within the drawdown zone at Ole Creek (treatment site; 4 species) compared to Factor Ross Creek (paired control; 7 species). All species detected at Ole Creek were also recorded at Factor Ross Creek during at least one of the surveys. Bird species detected in this study that could be impacted by the nature of this drawdown zone project due to their foraging and/or nesting habitats (e.g., Song Sparrow, Spotted Sandpiper and Chipping Sparrow) were not recorded during the Ole Creek survey. Chipping Sparrow was recorded during two surveys at Factor Ross Creek; Spotted Sandpiper and Song Sparrow were not recorded at Factor Ross Creek.

At Six Mile Creek and Lamonti Creek, the species assemblage was quite different in early May. Pacific Wren, Wilson's Warbler and Yellow-rumped Warbler were recorded at both sites by the end of the third survey at both sites; the other species were only recorded at one of the two sites. Two bird species that could be impacted by the nature of this drawdown zone project due to their foraging and/or nesting habitats were recorded at Six Mile Creek during one of the three surveys (Spotted Sandpiper and Song Sparrow); none were recorded during the three surveys at Lamonti Creek.

3.2.2 2014 - 2016 Bird Surveys (post-implementation)

At Ole Creek, one station was sampled on two consecutive days in spring of 2014, 2015 and 2016. In 2014, only one individual was recorded (enhancement year; Table 9). In the following years, thirteen species were recorded over two survey days in 2015 (this may include species recorded outside the 75 m radius point count station; see Discussion), and six species were recorded in 2016. Chipping Sparrow and Dark-eyed Junco had the highest number of detections when all years of data were considered. Chipping Sparrow is a species that may use habitat in the drawdown zone for foraging and/or nesting. This species was only recorded at this station in 2015 and was possibly recorded >75 m from the point count station centre. It was recorded >75 m from the point count station centre in both 2014 and 2016 (see Appendix B). Spotted Sandpiper, which commonly use the drawdown zone habitat for foraging and/or nesting, was only recorded post-construction (2016). Most species were only recorded in one of the survey years; species recorded across more than one survey year included Northern Waterthrush, Yellow Warbler and Dark-eyed Junco.

Table 9. Bird results at Ole Creek between 2014 and 2016 after project implementation. Species in bold type are those that might use drawdown habitats for foraging and/or nesting.

Ole Creek (within 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 12)	Survey #2 (June 13)	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (May 28)	Survey #2 (May 30)	Total
Spotted Sandpiper						2	2
Northern Flicker			1				1
Alder Flycatcher			1				1
Dusky Flycatcher				1			1
Tree Swallow			1	1			2
Black-capped Chickadee			1				1
Swainson's Thrush			1	1			2
Warbling Vireo			1				1
American Redstart			1				1
Northern Waterthrush			1			1	2
Tennessee Warbler				1			1
Wilson's Warbler					1		1
Yellow Warbler				1		1	2
Yellow-rumped Warbler						2	2
Chipping Sparrow			3				3
Dark-eyed Junco		1	1	1			3
Western Tanager						1	1
Total	0	1	12	6	1	7	27

At Factor Ross Creek (control site), one station was sampled on two consecutive days in spring of 2014, 2015 and 2016. In 2014, only one individual was recorded (Table 10). Nine species were recorded over two survey days in both of 2015 and 2016. Spotted Sandpiper, which commonly uses the reservoir drawdown zones for foraging and nesting, was only detected at this station in 2016. Chipping Sparrow,

which may also use the habitat in the drawdown zone for foraging and nesting, was only recorded at this station in 2015. Most species were only recorded in one of the survey years; species recorded across more than one survey year included American Redstart and Tennessee Warbler.

Table 10. Bird results at Factor Ross Creek (control) between 2014 and 2016 following project implementation at Ole Creek. Species in bold type are those that might use drawdown habitats for foraging and/or nesting.

Factor Ross Creek (within 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 12)	Survey #2 (June 13)	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (May 29)	Survey #2 (May 30)	Total
Spotted Sandpiper					2	2	4
Bald Eagle		1					1
Dusky Flycatcher			1				1
Hammond's Flycatcher				1			1
American Robin				1			1
Swainson's Thrush				1			1
American Redstart				1	1		2
Orange-crowned Warbler					1		1
Tennessee Warbler			2		1		3
Yellow Warbler			1				1
Yellow-rumped Warbler			1				1
Chipping Sparrow			1				1
Dark-eyed Junco					1		1
Western Tanager					1		1
Total	0	1	6	4	7	2	20

At Six Mile Creek, two stations were sampled in spring of 2014, 2015 and 2016. At Station 1, three species were recorded in 2014 (enhancement year), and four species were recorded in each of 2015 and 2016 (post-enhancement; Table 11). At Station 1, Spotted Sandpiper and Tree Swallow had the highest number of detections when all years of data were considered. Most species were only recorded in one of the survey years; species recorded across more than one survey year included Spotted Sandpiper, Tree Swallow, and Dark-eyed Junco. Spotted Sandpiper is a species that may use the drawdown zone habitat for foraging and/or nesting and was only recorded at this station post-construction (2015 and 2016).

Table 11. Bird results at Six Mile Creek, Station 1, between 2014 and 2016 post project implementation. Species in bold type is one that might use drawdown habitats for foraging and/or nesting.

Six Mile Creek - Station 1 (within 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Spotted Sandpiper			2		2	1	5
Northern Flicker	1						1
Barn Swallow						1	1
Northern Rough-winged Swallow		2					2
Tree Swallow	1	1		2			4
American Robin					2	1	3
Tennessee Warbler			1	1			2
Dark-eyed Junco				1		1	2
White-throated Sparrow							0
Total	2	3	3	4	4	4	20

Only one survey was completed at Six Mile Creek Station 2 in 2014. This station was added to sample bird use of the vegetation planted as part of the enhancement. At Station 2, five species were recorded in 2014 (enhancement year); eleven species were recorded in 2015, and ten species were recorded in 2016 (post-enhancement; Table 12). At Station 2, Tennessee Warbler and Lincoln's Sparrow had the highest number of detections when all years of data were considered. Eight species were recorded across more than one survey year, including Alder Flycatcher, Warbling Vireo, Northern Waterthrush, Tennessee Warbler, Yellow Warbler, Yellow-rumped Warbler, Lincoln's Sparrow and White-throated Sparrow. Song Sparrow may use habitats within the drawdown zone for foraging and/or nesting; this species was only recorded at this station in 2014 (enhancement year) and was not recorded post-enhancement.

Table 12. Bird results at Six Mile Creek, Station 2, between 2014 and 2016, post project implementation. Species in bold type is one that might use drawdown habitats for foraging and/or nesting.

Six Mile Creek - Station 2 (within 75 m radius point count)						
	2014	2015		2016		
Species	Survey #1 (June 10)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Alder Flycatcher			1	1		2
Hammond's Flycatcher			1			1
Swainson's Thrush					1	1
Cassin's Vireo		1				1
Warbling Vireo		1		1		2
Magnolia Warbler		1	1			2
Northern Waterthrush			1		1	2

Six Mile Creek - Station 2 (within 75 m radius point count)						
	2014	2015		2016		
Species	Survey #1 (June 10)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Orange-crowned Warbler				1		1
Tennessee Warbler	2	3	2	1	1	9
Wilson's Warbler				1		1
Yellow Warbler		1	1	1		3
Yellow-rumped Warbler			1	1	1	3
Dark-eyed Junco	1					1
Lincoln's Sparrow	1		1	1	2	5
Song Sparrow	2					2
White-throated Sparrow	1	1				2
Total	7	8	9	8	6	38

At Lamonti Creek (control site), two stations were sampled in spring of 2014, 2015 and 2016. At Station 1, two species were recorded in 2014 (Table 13). Ten species were recorded in 2015 and nine species were recorded in 2016. Only one survey was completed at Lamonti Creek Station 2 in 2014. At Station 2, one species was recorded in 2014; twelve species were recorded in 2015, and nine species were recorded in 2016 (Table 14). At both Stations 1 and 2, Spotted Sandpiper had the highest number of detections when all years of data were considered; this species, which may use the drawdown zone for foraging and/or nesting, was only recorded post-enhancement (2015 and/or 2016). Most species were only recorded in one of the survey years; at Station 1, species recorded across more than one survey year included Northern Flicker and Western Tanager. At Station 2, species recorded across more than one survey year included Spotted Sandpiper, Belted Kingfisher, Tree Swallow and Lincoln's Sparrow.

Table 13. Bird results at Lamonti Creek (control), Station 1, between 2014 and 2016, following implementation of the Six-Mile Creek project. Species in bold type is one that might use drawdown habitats for foraging and/or nesting.

Lamonti Creek - Station 1 (within 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Lesser Scaup			1				1
Common Merganser			2				2
Lesser Yellowlegs					2		2
Spotted Sandpiper					3	1	4
American Kestral			1				1
Belted Kingfisher			1				1
Northern Flicker				1	1		2
Hammond's Flycatcher			1				1
American Robin					1		1
Ruby-crowned Kinglet			1				1
American Pipit						3	3

Lamonti Creek - Station 1 (within 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Warbling Vireo			1	1			2
American Redstart	1	1					2
Blackpoll Warbler	1	1					2
Northern Waterthrush				1			1
Orange-crowned Warbler					1	1	2
Yellow-rumped Warbler						1	1
Lincoln's Sparrow					1		1
Western Tanager				1	1		2
Total	2	2	8	4	10	6	32

Table 14. Bird results at Lamonti Creek, Station 2, between 2014 and 2016. Species in bold type are those that might use drawdown habitats for foraging and/or nesting.

Lamonti Creek - Station 2 (within 75 m radius point count)						
	2014	2015		2016		
Species	Survey #1 (June 10)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Canada Goose					1	1
Green-winged Teal			2			2
Spotted Sandpiper			3	2	2	7
Bald Eagle		1				1
Belted Kingfisher	1		1			2
Alder Flycatcher			1			1
Barn Swallow					2	2
Tree Swallow		2			1	3
American Robin				1	3	4
American Redstart		1				1
Northern Waterthrush				1		1
Orange-crowned Warbler			1			1
Tennessee Warbler			1			1
Yellow Warbler			1			1
Yellow-rumped Warbler				1		1
Chipping Sparrow		1				1
Dark-eyed Junco					1	1
Lincoln's Sparrow			1		1	2
Total	1	5	11	5	11	33

Between Site Comparisons

When survey results from Ole Creek (treatment site) are compared to those from Factor Ross Creek (control site), ten bird species were recorded at both sites throughout the course of the three survey years (Table 15). Seven species were only recorded at Ole Creek, and four species were only recorded at Factor Ross Creek.

Two bird species that could be impacted by the nature of this drawdown zone project due to their foraging and/or nesting habitats (Spotted Sandpiper and Chipping Sparrow) were recorded at both Ole Creek and Factor Ross Creek. At both sites, Spotted Sandpiper was only recorded in 2016 and Chipping Sparrow was only recorded in 2015. Since the same pattern of observation occurred at both treatment and control sites, a treatment effect is not apparent when these species are considered.

Fewer species and individuals were recorded in the enhancement year (2014) compared to post-enhancement (2015 & 2016) at both Ole Creek and Factor Ross Creek. Since this trend occurred at both treatment and control sites, it is not likely due to an enhancement effect.

Table 15. Species comparison between sites, Ole Creek and Factor Ross Creek; data from 2014 - 2016. Species in bold type are those that might use drawdown habitats for foraging and/or nesting.

Species	Ole Creek only	Factor Ross Creek only	Both Sites
Spotted Sandpiper			X
Bald Eagle		X	
Northern Flicker	X		
Alder Flycatcher	X		
Dusky Flycatcher			X
Hammond's Flycatcher		X	
Tree Swallow	X		
Black-capped Chickadee	X		
American Robin		X	
Swainson's Thrush			X
Warbling Vireo	X		
American Redstart			X
Northern Waterthrush	X		
Orange-crowned Warbler		X	
Tennessee Warbler			X
Yellow Warbler			X
Yellow-rumped Warbler			X
Wilson's Warbler	X		
Chipping Sparrow			X
Dark-eyed Junco			X
Western Tanager			X

When survey results from Six Mile Creek (treatment site; both stations combined) are compared to those from Lamonti Creek (control site; both stations combined), fifteen bird species were recorded at both sites throughout the course of the three survey years (Table 16). Seven species were only recorded at Six Mile Creek, and fourteen species were only recorded at Lamonti Creek.

One bird species that could be impacted by the nature of this drawdown zone project due to its foraging and/or nesting habitats (Spotted Sandpiper) was recorded at both Six Mile Creek and Lamonti Creek. This species was only recorded post-enhancement (2015 and/or 2016) at both sites, suggesting there is negative no treatment effect.

Song Sparrow and Chipping Sparrow, which also use habitats that might be impacted by this project, were only recorded at Six Mile Creek and Lamonti Creek, respectively. Song Sparrow was only recorded during the enhancement year (2014) at Six Mile Creek. Chipping Sparrow was only recorded in 2015 at Lamonti Creek and may have been located >75 m from the point count station centre (see Discussion). It is not possible to determine treatment effects with so few detections of these species.

Fewer species and individuals were recorded in the enhancement year (2014) compared to post-enhancement (2015 & 2016) at both Six Mile Creek and Lamonti Creek. Since this trend occurred at both treatment and control sites, it is not likely due to an enhancement effect.

All species that could have been negatively or positively influenced by the project were uncommon and only detected sporadically and in low numbers. This suggests that any positive or negative consequence of the projects were likely of low biological significance.

Table 16. Species comparison between sites, Six Mile Creek and Lamonti Creek; data from 2014 - 2016.

Species	Six Mile Creek	Lamonti Creek	Both Sites
Canada Goose		X	
Green-winged Teal		X	
Lesser Scaup		X	
Common Merganser		X	
Lesser Yellowlegs		X	
Spotted Sandpiper			X
Bald Eagle		X	
American Kestral		X	
Belted Kingfisher		X	
Northern Flicker			X
Alder Flycatcher			X
Hammond's Flycatcher			X
Barn Swallow			X
Northern Rough-winged Swallow	X		
Tree Swallow			X
American Robin			X
Swainson's Thrush	X		

Species	Six Mile Creek	Lamonti Creek	Both Sites
Ruby-crowned Kinglet		X	
American Pipit		X	
Cassin's Vireo	X		
Warbling Vireo			X
American Redstart		X	
Blackpoll Warbler		X	
Magnolia Warbler	X		
Northern Waterthrush			X
Orange-crowned Warbler			X
Tennessee Warbler			X
Wilson's Warbler	X		
Yellow Warbler			X
Yellow-rumped Warbler			X
Dark-eyed Junco			X
Chipping Sparrow		X	
Lincoln's Sparrow			X
Song Sparrow	X		
White-throated Sparrow	X		
Western Tanager		X	

3.3 Sources of Error

Survey results at some stations surveyed in 2011 were likely affected by creek noise. This would prevent the surveyors from hearing birds at greater distances from the station centre and may have resulted in an underestimation of the richness of birds within or outside the 75 m radius station.

It's assumed that individual birds were not double-counted at stations. This could have been a larger issue at the longer 30-minute stations completed between 2014 and 2016, as it may have been difficult to track individual bird movements for that length of time and distinguish new birds to the station. This error would only affect the number of individuals recorded, not the species present.

Bird data for 2014 through 2016 was obtained from an Appendix to the 2016 report (Thompson and Carson 2017). The dataset included four distance classes to distinguish distance of each detected bird from the observer. Using a comparison of the dataset to the written results in year-end reports for 2014, 2015 and 2016, it appeared that the distance classes each represented the following radii of a point count station: distance class 1 = 0 – 20 m, distance class 2 = 20 – 40 m, distance class 3 = 40 – 75 m, and distance class 4 = >75 m. For the analyses done in this report, distance class 4 was assumed to be outside 75 m (data presented in Appendices to this report), and distance classes 1 – 3 were assumed to be within 75 m (data presented in Section 3.2.2).

For the 2015 data included in the Appendix to the 2016 year-end report, there were no detections listed outside of the 75 m radius point count stations. However, the 2015 report mentions four species that

were recorded outside of the 75 m radius point count stations (MacInnis et al. 2016). It is not known if other data is missing from the bird results table included as an Appendix to the 2016 report.

4 Discussion

Survey stations at paired treatment and control sites should have been placed in similar habitat at each site so that a comparison of bird species between sites could be made. If slightly different habitats were sampled at treatment and control sites, the bird species assemblage would be expected to be different. If there were differences between stations or sites in terms of ability to detect birds at certain distances from the point count station, due to topography or ambient noise, this may have affected the survey results. Both of the above would contribute to increased variability in the bird data, which would make it difficult to ascertain treatment effects.

It is likely that slightly different survey methods were used in 2015 compared to 2014 and 2016, making comparisons between years post-construction problematic. No birds were recorded as being outside any 75 m radius point count station in 2015, which differed from 2014 and 2016. It is possible that the surveyors in 2015 did not differentiate between birds less than and greater than 75 m from the point count station centre. If so, the number of detections and species recorded in 2015 will be artificially inflated compared to 2014 and 2016 due to inclusion of birds that were outside the 75 m radius station.

While this report focuses on bird data within the 75 m radius point count stations within the drawdown zone, it is likely that the station radii overlapped habitats that may not be considered drawdown zone habitat. It is not possible to determine which bird detections in the data were relevant when considering the potential effects of this project. We have identified three bird species as potentially sensitive to changes to drawdown zone habitat along the edges of the tributaries due to their foraging and/or nesting habitats: Spotted Sandpiper, Chipping Sparrow and Song Sparrow (e.g., see Craig et al. 2018). When trends in detections of these species through time and between treatment and control sites are considered, there does not appear to be a treatment effect at either of the paired sites.

Management question #4 asks “Does abundance and diversity of songbirds (passerines) around tributaries change as a result of enhancement?”. Since the 2011 data was collected differently than the 2014 through 2016 data, the 2011 data is not very useful as a pre-enhancement dataset when compared to the data collected in 2014 through 2016. Data collected from 2014 through 2016 showed that Ole Creek (treatment site) and Factor Ross Creek (control site) were identical in terms of the number of species recorded through time (if 2015 data is ignored), and abundance was very similar between sites in 2014 and 2016. There were no differences between these sites in terms of detections of species that might be considered sensitive to habitat changes within the drawdown zone (Spotted Sandpiper and Chipping Sparrow). The data collected to date has not shown any obvious effect of the enhancement on bird species at Ole Creek.

Data collected from 2014 through 2016 at Six Mile Creek showed that the number of detections through time at both stations were similar, although there was an increase in species richness post-construction at Station 2 (the station added to sample bird use of the vegetation planted as part of the enhancement). At Lamonti Creek (paired control to Six Mile Creek), there was an increasing number of detections in 2015 and 2016, as well as increases in species richness with time. Since species richness

increased at both treatment and control sites post-enhancement, a treatment effect is not well supported. Spotted Sandpiper was only recorded at both sites post-enhancement, indicating that there has not been a treatment effect for this species at these sites; rather, the observed change is more likely a reflection of general fluctuations of the population in the region.

5 Recommendations for Future Sampling

Because the abundance and diversity of bird species that utilize drawdown zone habitats is small (e.g., 3 or less species in low density), and bird response to this project has been undetectable to date (even as a weak trend), and because the vegetation response to this project has been minimal (Hilton 2019), it is likely that any impact to bird habitat suitability caused by the project is not biologically significant. Therefore, at this time it is recommended that no further bird sampling is required; however, further sampling would be welcomed if done opportunistically during other sampling tasks (e.g., Year 10 vegetation monitoring).

Birds might be expected to make use of new habitats that establish post-enhancement, once vegetation has matured to a point that the habitat provides some value to birds. Further bird sampling in year 10 of the project would allow more time for vegetation establishment and maturation. However, it is possible that vegetation will not have matured sufficiently by year 10 to see any clear response by birds.

If bird sampling is repeated in year 10 of the project, it is recommended that the same bird stations sampled in 2011 (drawdown zone stations only) and 2014 through 2016 be re-sampled. For all stations, sampling could occur in mid-June and stations replicated twice within a short time frame (e.g., one to two days apart). For the 2011 stations, birds within and outside the 75 m point count radius should be recorded for 5 minutes; for the 2014 - 2016 stations, birds within and outside the 75 m point count radius should be recorded for 30 minutes. If possible, surveyors should note which bird detections are in drawdown zone habitat that may have been impacted by this project. Bird sampling should only be repeated in year 10 if vegetation sampling is being repeated; if possible, relationships between changes in vegetation at treatment sites and bird results should be examined.

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Appendices

Appendix A: Bird point count station data analyses – 2011

2011 Bird Point Count Stations (Pre-enhancement)

Drawdown Zone

Birds recorded within the 75 m radius point count stations in the drawdown zone in 2011 are reported in Section 3.2.1 of this report. Birds recorded outside the 75 m radius point count stations in the drawdown zone are reported below. These detections are reported separately from the detections inside the point count station radius as it is possible that these detections represent birds using habitats outside of the drawdown zone and in the adjacent forest habitat.

No birds were recorded outside the point count station radius within the drawdown zone at Ole Creek (treatment site). At Factor Ross Creek (the paired control to Ole Creek), eight species were recorded over three surveys of two stations within the drawdown zone (Table A1).

Table A1. Bird results outside the 75 m radius point count station at Factor Ross Creek in 2011.

Factor Ross Creek (drawdown zone, outside 75 m station radius)				
Species	**May 15, 2011 (morning) 2 stations**	**May 15, 2011 (evening) 2 stations**	**May 17, 2011 (mid-day) 2 stations**	**Total**
Pacific Wren	1	1		2
Hammond's Flycatcher	1			1
Ruby-crowned Kinglet		1		1
American Robin	1			1
Yellow-rumped Warbler			1	1
Chipping Sparrow			1	1
Dark-eyed Junco	1			1
Purple Finch	1			1
Total	5	2	2	9

At Six Mile Creek (treatment site), four species were recorded over three surveys of one station within the drawdown zone (Table A2). At Lamonti Creek (the paired control to Six Mile Creek), two species were recorded over three surveys of one station within the drawdown zone (Table A3). These same two species were recorded outside the point count station radius at Six Mile Creek.

Table A2. Bird results outside the 75 m radius point count station at Six Mile Creek in 2011.

Six Mile Creek (drawdown zone, outside 75 m station radius)				
Species	**May 11, 2011 (morning) 1 station**	**May 13, 2011 (morning) 1 station**	**June 8, 2011 (morning) 1 station**	**Total**
Ruby-crowned Kinglet	1			1
Varied Thrush	1	1	1	3
American Robin	1	1		2

Six Mile Creek (drawdown zone, outside 75 m station radius)				
Species	**May 11, 2011 (morning) 1 station**	**May 13, 2011 (morning) 1 station**	**June 8, 2011 (morning) 1 station**	**Total**
Yellow-rumped Warbler	1			1
Total	4	2	1	7

Table A3. Bird results outside the 75 m radius point count station at Lamonti Creek in 2011.

Lamonti Creek (drawdown zone, outside 75 m station radius)				
Species	**May 11, 2011 (morning) 1 station**	**May 13, 2011 (morning) 1 station**	**June 7, 2011 (morning) 1 station**	**Total**
Varied Thrush	1	1		2
Yellow-rumped Warbler	1			1
Total	2	1	0	3

Above Drawdown Zone

Several bird count stations were completed above the drawdown zone along the tributary at each site. Results from these surveys are shown below. Detections within and outside the 75 m radius point count station have been combined for these tables.

At Ole Creek (treatment site), seven point count stations were completed along the creek on one day in mid-May; four species were detected (Table A4). Hammond's Flycatcher and Yellow-rumped Warbler were recorded most frequently. At Factor Ross Creek (paired control to Ole Creek), four point count stations were completed along the creek on one day in mid-May (one survey in the morning and one in the evening). Fourteen species were recorded; the highest number of detections were for Hammond's Flycatcher and Pacific Wren (Table A5).

Table A4. Bird results above the drawdown zone at Ole Creek in 2011.

Ole Creek (above drawdown zone)	
Species	**May 11, 2011 (morning) 7 stations**
Hammond's Flycatcher	3
Golden-crowned Kinglet	2
Yellow-rumped Warbler	4
Purple Finch	1
Total	10

Table A5. Bird results above the drawdown zone at Factor Ross Creek in 2011.

Factor Ross Creek (above drawdown zone)			
Species	**May 15, 2011 (morning) 4 stations**	**May 15, 2011 (evening) 4 stations**	**Total**
Ruffed Grouse	1	1	2
Three-toed Woodpecker	1		1
Yellow-bellied Sapsucker		4	4
Hammond's Flycatcher	3	3	6
Pacific-slope Flycatcher	1		1
Black-capped Chickadee	1		1
Mountain Chickadee	1		1
Brown Creeper	1		1
Red-breasted Nuthatch	2		2
Pacific Wren	3	3	6
Golden-crowned Kinglet		2	2
Ruby-crowned Kinglet	1		1
Varied Thrush	1	2	3
Purple Finch	1		1
Total	17	15	32

At Six Mile Creek and Lamonti Creek (paired treatment and control sites, respectively), four point count stations were completed along each creek on two days in mid-May and one day in early June. At Six Mile Creek, eighteen species were recorded; the highest number of detections were for Hammond's Flycatcher, Varied Thrush and Yellow-rumped Warbler (Table A6). At Lamonti Creek, seventeen species were recorded; the highest number of detections were for Hammond's Flycatcher, Pacific Wren, Varied Thrush, Wilson's Warbler and Yellow-rumped Warbler (Table A7).

Table A6. Bird results above the drawdown zone at Six Mile Creek in 2011.

Six Mile Creek (above drawdown zone)				
Species	**May 11, 2011 (morning) 4 stations**	**May 13, 2011 (morning) 4 stations**	**June 8, 2011 (morning) 4 stations**	**Total**
Spotted Sandpiper			2	2
Red-tailed Hawk			1	1
Rufous Hummingbird			1	1
Belted Kingfisher			1	1
Northern Flicker	1		1	2
Hammond's Flycatcher		3	5	8
Red-breasted Nuthatch	2			2
Pacific Wren	1	6		7

Six Mile Creek (above drawdown zone)				
Species	**May 11, 2011 (morning) 4 stations**	**May 13, 2011 (morning) 4 stations**	**June 8, 2011 (morning) 4 stations**	**Total**
Golden-crowned Kinglet	2		1	3
Swainson's Thrush			3	3
Varied Thrush	3	3	1	7
American Robin		1	2	3
Tennessee Warbler			1	1
Wilson's Warbler			2	2
Yellow-rumped Warbler	1	3	7	11
Dark-eyed Junco			1	1
Song Sparrow	1			1
White-throated Sparrow			2	2
Total	11	16	31	58

Table A7. Bird results above the drawdown zone at Lamonti Creek in 2011.

Lamonti Creek (above drawdown zone)				
Species	**May 11, 2011 (morning) 4 stations**	**May 13, 2011 (morning) 4 stations**	**June 7, 2011 (morning) 4 stations**	**Total**
Northern Flicker	1			1
Yellow-bellied Sapsucker			1	1
Hammond's Flycatcher		3	3	6
Gray Jay	1			1
Red-breasted Nuthatch		1		1
Pacific Wren	5	4	3	12
Golden-crowned Kinglet	1	1	1	3
Ruby-crowned Kinglet	1	1		2
Swainson's Thrush			2	2
Varied Thrush	3	6	2	11
American Robin	1		2	3
Wilson's Warbler	1	3	3	7
Yellow-rumped Warbler	2	1	5	8
Dark-eyed Junco		1		1
Chipping Sparrow			1	1
White-throated Sparrow			2	2
Purple Finch		1		1
Total	16	22	25	63

Appendix B: Bird point count station data analyses – 2014 through 2016

Birds recorded within the 75 m radius point count stations in the drawdown zone in 2014 through 2016 are reported in Section 3.2.2 of this report. Birds recorded outside the 75 m radius point count stations in the drawdown zone are reported below. These detections are reported separately from the detections inside the point count station radius as it is possible that these detections represent birds using habitats outside of the drawdown zone and in the adjacent forest habitat.

At Ole Creek (treatment site), six species were recorded outside the point count radius in 2014, and nine species were recorded outside the point count radius in 2016 (Table B1). All species recorded in 2014 were also recorded in 2016. No birds were recorded outside the 75 m point count radius in 2015.

Table B1. Bird results outside the 75 m radius point count station at Ole Creek, 2014 - 2016.

Ole Creek (outside 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 12)	Survey #2 (June 13)	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (May 28)	Survey #2 (May 30)	Total
Hammond's Flycatcher						1	1
American Robin		1				1	2
Swainson's Thrush		1			1	1	3
Warbling Vireo	1	1				1	3
American Redstart		1			1	1	3
Northern Waterthrush	2	1			1		4
Yellow-rumped Warbler					1	1	2
Chipping Sparrow	1	1			1		3
Western Tanager						1	1
Total	4	6	0	0	5	7	22

At Factor Ross Creek (paired control to Ole Creek), seven species were recorded outside the point count radius in 2014, and nine species were recorded outside the point count radius in 2016 (Table B2). Three of the species recorded in 2014 were also recorded in 2016. No birds were recorded outside the 75 m point count radius in 2015.

Table B2. Bird results outside the 75 m radius point count station at Factor Ross Creek, 2014 - 2016.

Factor Ross Creek (outside 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 12)	Survey #2 (June 13)	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (May 29)	Survey #2 (May 30)	Total
Spotted Sandpiper					2		2
Belted Kingfisher		1					1
Northern Flicker						1	1

Factor Ross Creek (outside 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 12)	Survey #2 (June 13)	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (May 29)	Survey #2 (May 30)	Total
Hammond's Flycatcher		1				2	3
American Crow						1	1
American Robin		1					1
Swainson's Thrush		1					1
Northern Waterthrush						1	1
Orange-crowned Warbler						1	1
Tennessee Warbler	1	1					2
Chipping Sparrow	1	1			1	1	4
Dark-eyed Junco	1	1				1	3
Western Tanager						1	1
Total	3	7	0	0	3	9	22

At Six Mile Creek (treatment site) Station 1, nine species were recorded outside the point count radius in 2014, and three species were recorded outside the point count radius in 2016 (Table B3). All species recorded in 2016 were newly recorded outside that point count station. At Six Mile Creek Station 2, two species were recorded outside the point count radius in 2014, and eleven species were recorded outside the point count radius in 2016 (Table B4). No birds were recorded outside the 75 m point count radius at either station in 2015.

Table B3. Bird results outside the 75 m radius point count station at Six Mile Creek Station 1, 2014 - 2016.

Six Mile Creek - Station 1 (outside 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Spotted Sandpiper					2	3	5
Olive-sided Flycatcher		1					1
Western Wood-pewee	1						1
American Robin	1	1					2
American Redstart		1					1
Blackpoll Warbler	1	1					2
Orange-crowned Warbler		1					1
Tennessee Warbler	1	1					2

Six Mile Creek - Station 1 (outside 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Yellow Warbler	1	1					2
Clay-colored Sparrow						1	1
Dark-eyed Junco					1		1
White-throated Sparrow		1					1
Total	5	8	0	0	3	4	20

Table B4. Bird results outside the 75 m radius point count station at Six Mile Creek Station 2, 2014 - 2016.

Six Mile Creek - Station 2 (outside 75 m radius point count)						
	2014	2015		2016		
Species	Survey #1 (June 10)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Northern Shoveler				1		1
American Robin	1				2	3
Swainson's Thrush				2		2
American Redstart					1	1
Common Yellowthroat				1		1
Magnolia Warbler				1		1
Orange-crowned Warbler					1	1
Tennessee Warbler					1	1
Yellow Warbler	1					1
Lincoln's Sparrow				1		1
White-throated Sparrow				1		1
Western Tanager				1		1
Total	2	0	0	8	5	15

At Lamonti Creek (paired control to Six Mile Creek) Station 1, two species were recorded outside the point count radius in 2014, and ten species were recorded outside the point count radius in 2016 (Table B5). Neither species recorded in 2014 was recorded outside that point count station in 2016. At Lamonti Creek Station 2, eight species were recorded outside the point count radius in 2014, and thirteen species were recorded outside the point count radius in 2016; only two of the species were recorded both years (Table B6). No birds were recorded outside the 75 m point count radius at either station in 2015.

Table B5. Bird results outside the 75 m radius point count station at Lamonti Creek Station 2, 2014 - 2016.

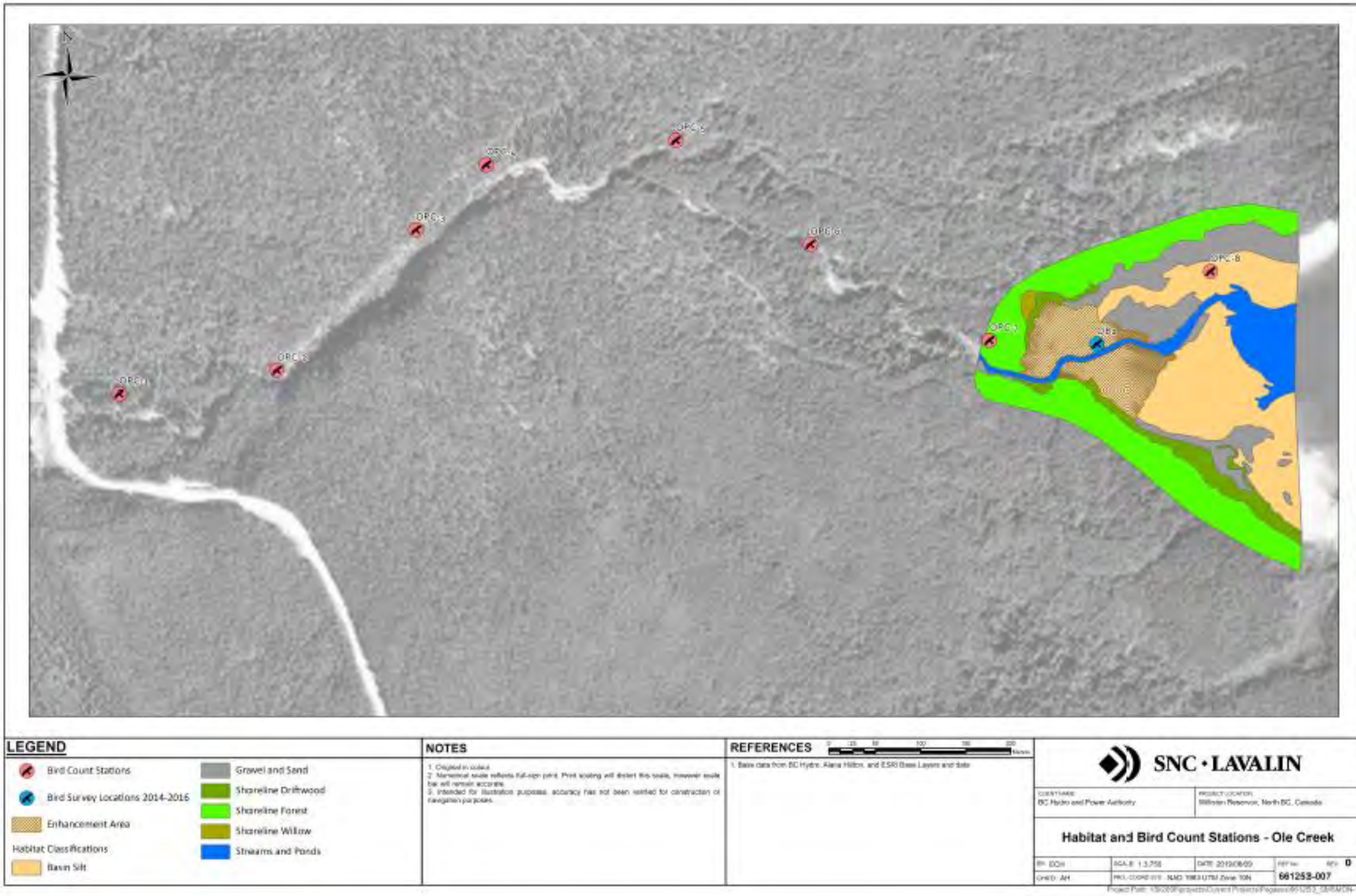
Lamonti Creek - Station 1 (outside 75 m radius point count)							
	2014		2015		2016		
Species	Survey #1 (June 10)	Survey #2 (June 11)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Spotted Sandpiper						1	1
Hammond's Flycatcher					1		1
Barn Swallow					2		2
American Robin					1		1
Golden-crowned Kinglet					1		1
Ruby-crowned Kinglet						1	1
Swainson's Thrush		1					1
American Redstart						1	1
Tennessee Warbler		1					1
Yellow-rumped Warbler					1		1
Dark-eyed Junco						1	1
Lincoln's Sparrow						1	1
Total	0	2	0	0	6	5	13

Table B6. Bird results outside the 75 m radius point count station at Lamonti Creek Station 2, 2014 - 2016.

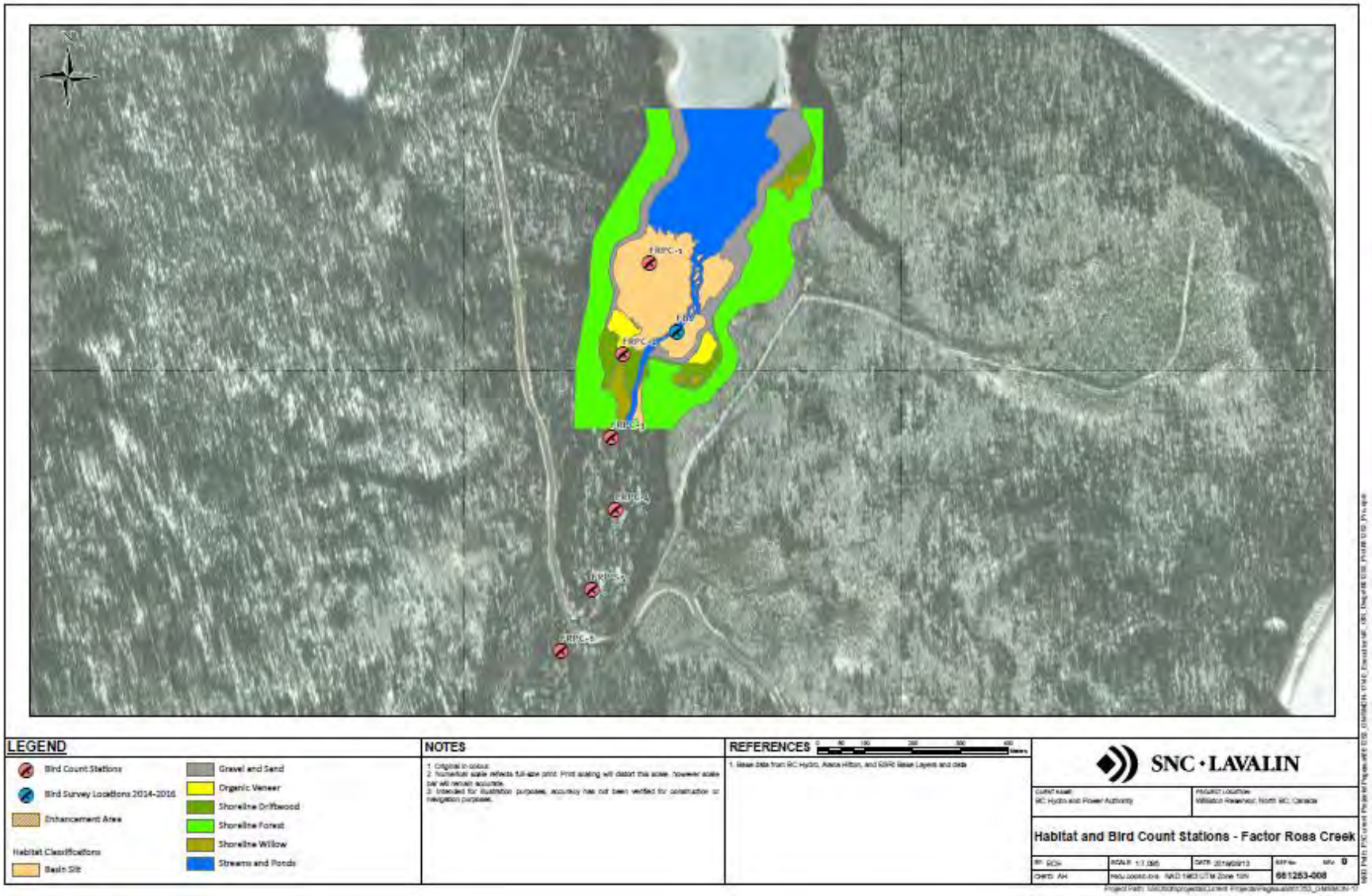
Lamonti Creek - Station 2 (outside 75 m radius point count)						
	2014	2015		2016		
Species	Survey #1 (June 10)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Lesser Yellowlegs				1		1
Spotted Sandpiper					1	1
Black-backed Woodpecker	1					1
Alder Flycatcher	1					1
Common Raven	1					1
American Robin					1	1
Ruby-crowned Kinglet					1	1
Swainson's Thrush	1			1		2
Warbling Vireo	1					1
American Redstart	1				1	2
Blackpoll Warbler	1					1
Orange-crowned Warbler				1	1	2

Lamonti Creek - Station 2 (outside 75 m radius point count)						
	2014	2015		2016		
Species	Survey #1 (June 10)	Survey #1 (June 7)	Survey #2 (June 8)	Survey #1 (May 25)	Survey #2 (May 26)	Total
Tennessee Warbler	1					1
Yellow Warbler					1	1
Chipping Sparrow					1	1
Dark-eyed Junco					1	1
Lincoln's Sparrow				1		1
White-throated Sparrow				1		1
Western Tanager					1	1
Total	8	0	0	5	9	22

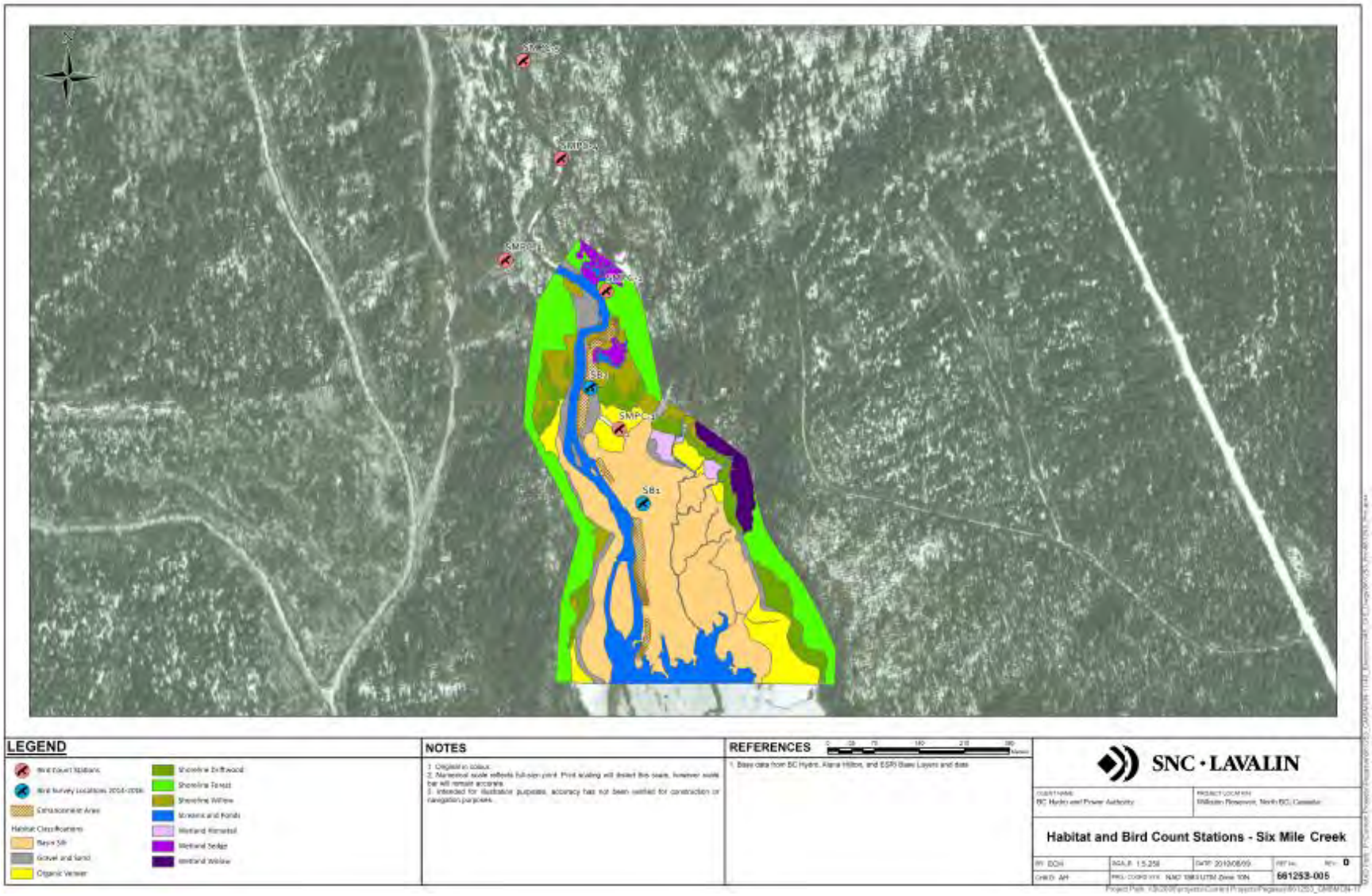
Appendix C: Locations of bird stations sampled in 2011 and 2014 – 2016.



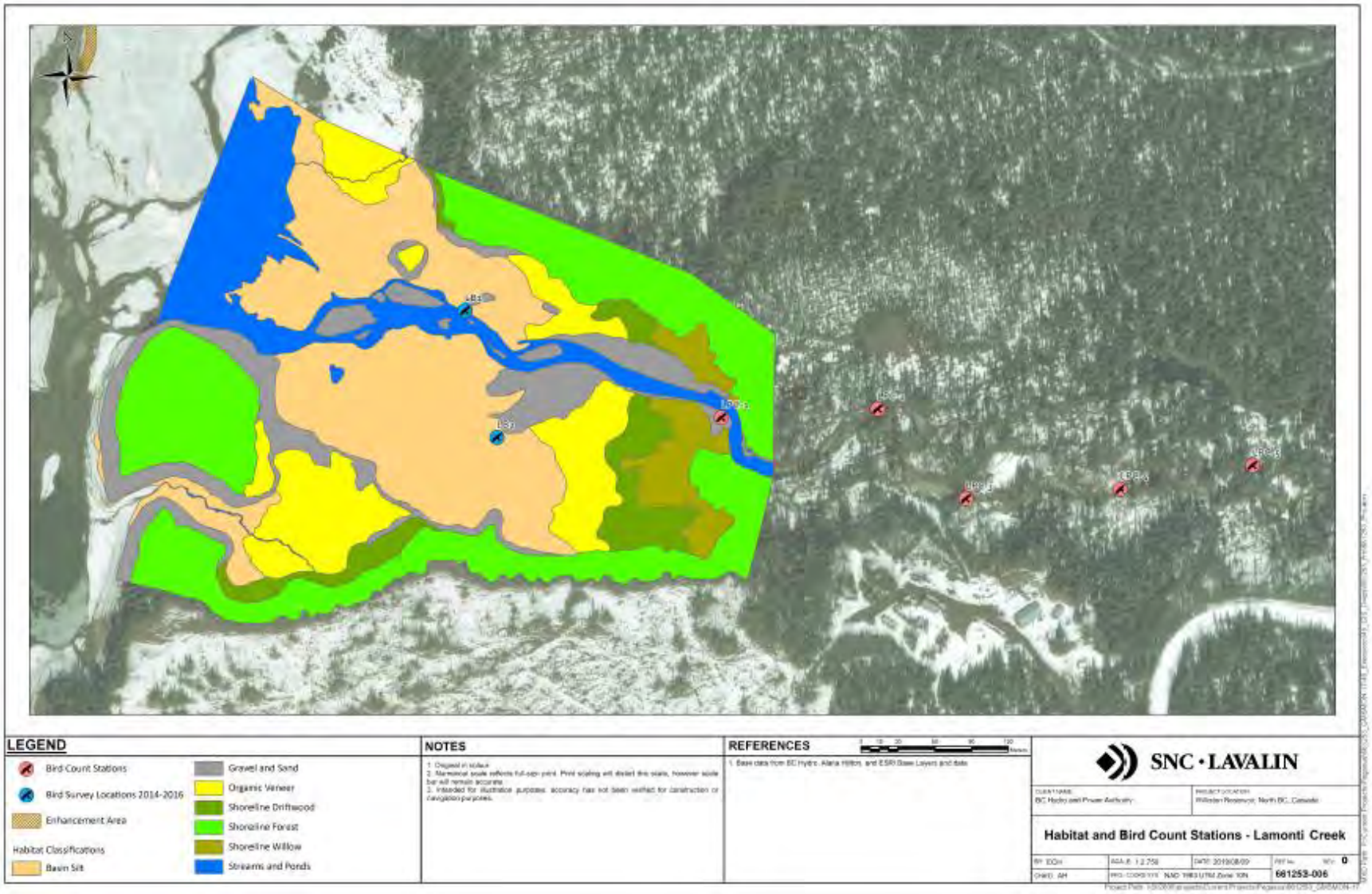
Bird point count survey locations at Ole Creek. Red bird count stations are those locations surveyed in 2011. Blue bird survey locations are those surveyed in 2014-2016.



Bird point count survey locations at Factor Ross Creek. Red bird count stations are those locations surveyed in 2011. Blue bird survey locations are those surveyed in 2014-2016.



Bird point count survey locations at Six Mile Creek. Red bird count stations are those locations surveyed in 2011. Blue bird survey locations are those surveyed in 2014-2016.



Bird point count survey locations at Lamonti Creek. Red bird count stations are those locations surveyed in 2011. Blue bird survey locations are those surveyed in 2014-2016.

Appendix 7
GMSMON-17 Tributary Habitat Review
Amphibian Data Compilation and Analyses

Peace River Water Use Plan

GMSMON-17 Tributary Habitat Review

Amphibian Data Compilation and Analyses

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November 2019

Executive Summary

BC Hydro implemented a trial tributary mitigation plan at Williston Reservoir to improve fish access to tributaries affected by large woody debris accumulations and/or shallow water depths due to stream braiding through the drawdown zone in spring. Two trial tributaries and two control tributaries were selected for the project so that a Before-After-Control-Impact (BACI) analysis could be completed. A Tributary Habitat Review monitoring program was initiated to assess the effectiveness of the tributary enhancement in improving fish and wildlife habitat. Amphibians were one of the wildlife groups selected for monitoring to determine if they were positively or negatively affected by the enhancement.

Two management questions were asked relating to amphibians: management question #5 asked "Does amphibian abundance and diversity in tributaries change as a result of enhancement?", and management question #6 asked "Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?".

Two different consultants collected amphibian data for this project between 2011 and 2016. Pre-enhancement amphibian data were collected by one consultant from 2011 – 2013. Construction of the project occurred in 2014; amphibian data were collected by a new consultant from 2014 – 2016. Survey locations visited by the two consultants varied. Few pre-enhancement surveys were completed in relevant areas of the drawdown zone at the two treatment sites, and amphibian diversity and numbers of amphibians using the areas pre-enhancement were not well established. Therefore, it was determined that a before-after enhancement comparison was not possible. Consequently, a treatment-control comparison was not meaningful.

Amphibian data within relevant areas of the drawdown zone at the two treatment sites (Ole Creek and Six Mile Creek) indicated that Western Toads used the margins of the reservoirs in small numbers pre- and post-enhancement. It is possible that the margins of the drawdown zone are providing foraging habitat for this species; toads are likely using vegetated habitat with woody debris cover in these areas. A wetland adjacent to the enhancement at Six Mile Creek was used for breeding by multiple amphibian species (Columbia Spotted Frogs, Western Toads and Long-toed Salamanders) pre- and post-enhancement. There was little evidence of other amphibian breeding use of drawdown zone areas; most amphibian detections within the drawdown zone during this project were of adult or juvenile amphibians using terrestrial habitat along the reservoir margins. Amphibian tadpoles and larvae are easier to detect than terrestrial amphibians, so we are confident that breeding activity was not missed by the consultants.

Management question #5 asks about changes to amphibian abundance and diversity in tributaries. Amphibians were only recorded within a tributary twice throughout this project: three pairs of Western Toads were observed in amplexus (mating) at Six Mile Creek in 2015, in a slow flow inlet formed by the earth berm barrier that separated the area from the fast flow of Six Mile Creek (MacInnis et al. 2015). In addition, a Wood Frog was observed at the bottom of Six Mile Creek during fish spawning surveys in 2015 (MacInnis et al. 2015). Since amphibian use

of the tributaries (streams) at each site appears to be rare, changes to the stream as part of the enhancement project (e.g., channelization, creation of pools, etc.) is not expected to affect amphibians negatively.

We considered evidence of changes to amphibian abundance and diversity within areas influenced by the enhancement at each site, rather than just within the tributaries themselves. The variability of the amphibian data did not allow a quantitative answer to this question; however, this project has shown use of the drawdown zone adjacent to the enhancement works at each site by a relatively stable diversity of amphibians throughout the course of the project (pre- and post-enhancement). The abundance of amphibians of the various species recorded in areas potentially affected by the enhancement remained relatively low and stable through time (pre- and post-enhancement). Therefore, it can be concluded that there did not appear to be a negative impact to amphibian diversity or abundance in areas potentially influenced by the enhancement.

Management question #6 can only be addressed at the wetland adjacent to the enhancement at Six Mile Creek, since there was little evidence of other breeding use of the drawdown zone. Data on habitat area and habitat suitability (e.g., water temperatures) of this wetland were not collected pre-enhancement. Amphibian surveys showed breeding use of this wetland in the year of project construction but flooding of the wetland due to reservoir operations reduced or prevented post-enhancement surveys. The enhancement at Six Mile Creek is not expected to have negatively affected the breeding habitat suitability of this wetland; it may have had a positive impact on habitat suitability through preventing inundation of the wetland early in the spring by Six Mile Creek. However, this is not possible to prove due to lack of data collected on habitat conditions in the wetland pre-enhancement.

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1 Introduction

Situated in the northern interior of BC near the towns of Mackenzie and Hudson's Hope, Williston Reservoir is the largest reservoir in BC, with a surface area of 1,773 square kilometres. Water levels in the reservoir are controlled by one of the world's largest earth-filled structures, the WAC Bennett Dam, which was completed in 1968. The Peace River is the primary outflow from the reservoir.

Water levels within Williston Reservoir fluctuate throughout the year due to dam operations for power generation. During the winter, the reservoir is drawn down resulting in a large unvegetated muddy floodplain ("drawdown zone") around the perimeter of the reservoir. When the reservoir is low, shallow channels with excessive braiding occur where tributaries flow over the exposed drawdown zone. The reservoir is typically at its lowest level in late April and early May (BC Hydro 2003). Reservoir levels increase in late spring due to snow melt, with the reservoir reaching its maximum elevation ("full pool") in July each year (BC Hydro 2003). Reservoir levels stay high throughout the summer months and much of the fall.

Large woody debris (LWD) is introduced into the reservoir every year due to logging and erosion, adding to an accumulation of debris from the original filling of the reservoir (BC Hydro 2008a). This debris accumulates in the bays where the tributaries empty into the reservoir (BC Hydro 2008a). The woody debris in tributary mouths may scour the banks of the tributaries and the reservoir thereby reducing natural littoral and/or riparian vegetation that may be growing there and increasing sedimentation (BC Hydro 2008b; Cubberley and Hengeveld 2010).

BC Hydro implemented a trial tributary mitigation plan to improve fish access to tributaries affected by large woody debris accumulations and/or shallow water depths due to stream braiding through the drawdown zone in spring. Cubberley and Hengeveld (2010) selected two mitigation trial sites and paired these with control sites (Table 1).

Mitigation recommendations for Six Mile Creek and Ole Creek included renovating the stream channels within the drawdown zone and use of retention structures to increase vegetation growth along the high-water mark (Cubberley and Hengeveld 2010).

Table 1. Summary of GMSMON-17 project design.

Treatment Creek	Treatment Goal	Control Creek
Six Mile Ck.	Restore fish passage past perched creek mouth	Lamonti Ck.
Ole Ck.	Restore fish passage past woody debris accumulations	Factor Ross Ck.

A Tributary Habitat Review monitoring program was initiated to assess the effectiveness of the tributary enhancement in improving fish and wildlife habitat. The enhancement was expected to improve fish access to tributaries during low reservoir elevations, when the tributaries are used for spring spawning (BC Hydro 2008b). Riparian vegetation recruitment along the banks was expected to improve after mitigation. In addition to fish and vegetation, songbirds and amphibians were selected for monitoring to determine if they were positively or negatively affected by the enhancement.

A set of management questions were established to guide the monitoring program (BC Hydro 2008b, BC Hydro 2015). The key questions were:

1) Does access for spring spawners (i.e., rainbow trout and/or arctic grayling) improve as a result of enhancement?
2) Is the area and quality of fish habitat created by the tributary enhancement maintained over time?
3) Does riparian vegetation along tributaries increase in abundance and diversity as a result of enhancement?
4) Does abundance and diversity of song birds (passerines) around tributaries change as a result of enhancement?
5) Does amphibian abundance and diversity in tributaries change as a result of enhancement?
6) Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?

To address all management questions, field surveys for fish, vegetation, songbirds and amphibians at the enhancement sites and control sites were initiated in 2011 under the GMSMON-17 program. Data collected between 2011 and 2013 were baseline pre-enhancement data for each site (Table 2). Enhancement of the trial tributaries occurred in 2014 under the GMSWORKS-19 program; data on fish, vegetation, songbirds and amphibians were collected during the construction year. Post-enhancement data on fish, vegetation, songbirds and amphibians were collected from 2015 – 2016.

Table 2. Data collection by project phase for the GMSMON-17 project.

Project Phase	Year(s) Data Collected
Pre-enhancement	2011 - 2013
Enhancement (construction)	2014
Post-enhancement	2015 - 2016

This report will provide summaries and analyses of the amphibian data collected to date, including multi-year comparisons of amphibian survey data. Management questions #5 and #6 will be considered using the amphibian data collected to date.

2 Amphibian Data Collection - Background

Two different consultants have collected amphibian data for the project: Golder Associates Ltd. completed amphibian surveys from 2011 to 2013, and DWB Consulting Services Ltd. completed amphibian surveys from 2014 to 2016. Different methods were used for amphibian surveys by the different consultants, as summarized in Table 3.

Table 3. Amphibian survey methods used throughout the first six years of the GMSMON-17 project.

Year	Consultant	Methods			
		Survey Type	**Location**	**Timing of Data Collection**	**Type of Data Collected**
2011	Golder Associates Ltd.	Area-based surveys (search time recorded)	Small ponds and wetlands along the lower reaches of each tributary	mid-May, early June, mid-August	species, sex, developmental stage, snout-vent-length (SVL)
2012				early July	
2013		Time-constrained surveys	Small ponds and wetlands near stream mouths	spring (dates not available)	
2014	DWB Consulting Services Ltd.	Time-constrained surveys of plots, systematic searches	200 m^2 circular plots in 4 locations: near tributary, 50 m and 200 m into adjacent forest, and >500 m upstream from reservoir; searches of wetland/ponded areas in drawdown zone	mid-May, mid-June, mid-August	species, weight, SVL
2015	DWB Consulting Services Ltd.	Time-constrained surveys of plots, systematic searches		early June, early August	species, (weight & SVL collected, but data unavailable)
		Night-time transect surveys in drawdown zone of Six Mile and Ole			
2016	DWB Consulting Services Ltd.	Time-constrained surveys of plots, systematic searches	Plots established in 2014 & 2015 revisited IF amphibians had been previously detected there	mid-May (Six Mile & Lamonti only), late May, late July	species, (weight & SVL collected, but data unavailable)
		Night-time transect surveys in drawdown zone of all sites	Transects established using habitat mapping, with 2 x 20 m transects in each habitat type		

In 2011, Golder Associates Ltd. completed area-based surveys of small ponds and wetlands along the lower reaches of each tributary, with time spent during each search documented. Encountered amphibians were identified to species, snout-vent-length measured, sex determined (when possible) and developmental stage recorded (Golder 2012). Surveys were completed during mid-May, early June and/or mid-August (Golder 2012). Appendix A provides the locations and timing of each survey completed within the drawdown zone and Appendix C provides the locations and timing of each survey completed >200 m from the drawdown zone in 2011 (no surveys were completed <200 m from the drawdown zone).

In 2012, Golder Associates Ltd. completed area-based searches within small ponds and wetlands in the vicinity of each tributary, with survey duration recorded. Many of the same locations were surveyed as in 2011 and effort at each location was similar to 2011 (Golder 2013), although no location information is available for the surveys completed in 2012. In 2012, surveys were completed during a single site visit in early July (Golder 2013).

In 2013, the methods were altered to target areas that were most likely to be affected by habitat enhancements (Golder 2014), and time-constrained surveys were used instead of area-based surveys. The approximate area of habitat searched was recorded for comparison to previous study years. These surveys were completed in spring, but the survey dates were not available in the data included as part of the year-end report (Golder 2014).

In 2014 through 2016, DWB Consulting Services Ltd. added many more amphibian survey locations at each site. Circular plots (200 m^2) were established in various locations, some close to tributaries or within the drawdown zone, and as in previous years, some further removed from the tributaries (>500 m; MacInnis et al. 2015, MacInnis et al. 2016, Thompson and Carson 2017); unlike previous years, some upland habitats were monitored within 50 – 200 m of the reservoir. Transect surveys and spot checks were also completed in some areas.

No exact locations surveyed from 2011 through 2013 by Golder were re-surveyed by DWB in 2014 through 2016. All survey locations had new UTMs, although it is likely that there was overlap in the general areas surveyed within the drawdown zone and along tributaries between 2011-2013 and 2014-2016.

Table 3 lists the timing of data collection in 2014 through 2016; although multiple survey periods are listed for each year, most survey locations were not sampled more than once within a year. Although time-constrained surveys were completed in 2014 (MacInnis et al. 2015), the amount of time spent at each station was not reported or provided to BC Hydro. In 2015 and 2016, the time spent at each station was reported for many survey locations, but these data are missing for some locations.

Appendix A provides the UTMs for survey locations and dates for all surveys completed within the drawdown or along the edge of the drawdown zone for all years of the project. Maps showing the locations of the survey stations within the drawdown zone at each site are provided in Appendix B. Appendix C provides the UTMs for survey locations and dates for all surveys completed within 200 m of the edge of the drawdown for all years of the project. Effects of the enhancement are unlikely for these locations; however, since these survey locations are in closer proximity to the reservoir, they are tabulated separately from those much further removed from the reservoir (i.e., those found in Appendix D). Appendix D provides the UTMs for survey locations and dates for all surveys completed more than 200 m from the edge of the drawdown zone for all years of the project. Effects of the enhancement are unlikely for these locations.

At each survey location, encountered amphibians were identified to species. In 2014, snout-vent-length and weight were also measured for many captured amphibians; these data were apparently collected in 2015 and 2016 (MacInnis et al. 2016, Thompson and Carson 2017), but the raw data were not included as part of the year-end reports and were not submitted to BC Hydro.

3 Amphibian Data Analyses

3.1 Methods

Amphibian data collected in the first 6 years of the GMSMON-17 project (2011 to 2016) were obtained from BC Hydro. When data were not available electronically, they were acquired from year-end report tables or appendices. Data were closely examined to understand the nature of the data and how to best organize it for consistency between years. New Excel files were created for each year of the project, and the raw data were imported or entered. Once Excel spreadsheets were complete, the amphibian data from all years of the project were imported into a single Access database.

As per the Monitoring Program Terms of Reference (Revision 2.0; BC Hydro 2017), amphibian data were consolidated into three tables:

(1) Sampling location data table, including:
   a. Site name
   b. Unique ID related to survey location: a 2-letter code to depict the site (Ole Creek = OA, Factor Ross Creek = FA, Six Mile Creek = SA, Lamonti Creek = LA) followed by a number for each unique location, starting at one and increasing sequentially through the year and continuing in the subsequent years
   c. UTM for each survey location
   d. Sampling mode: type of survey completed, such as area search, transect, spot check
   e. Position relative to the drawdown zone:
      i. located within, or on the edge of, the drawdown zone
      ii. located <200 m from the edge of the drawdown zone
      iii. located >200 m from the edge of the drawdown zone
   f. Position with respect to habitat enhancements

(2) Survey data table, including:
   a. Survey location ID (from above)
   b. Unique ID related to survey occasion: the survey location ID with a dash and the survey occasion at that location, e.g., OA1-2 would be the ID for the second survey at location OA1
   c. Date
   d. Start and end time
   e. Survey duration (minutes)
   f. Sampling mode
   g. Area searched (m^2)
   h. Number of people surveying
   i. Environmental conditions: temperature, cloud cover, precipitation, water temperature
   j. Day vs. night survey

(3) Detection data table, including:
   a. Survey occasion ID (from above)
   b. Unique ID related to the detection: survey occasion ID followed by a letter in alphabetical order for each detection; e.g., OA1-2A would be the first animal captured at location OA1 on the second survey of that spot

c. UTM for the survey location (same as above)
d. Species
e. Number of amphibians observed
f. Age class (egg, larvae, juvenile, adult)
g. Snout-vent-length (SVL)
h. Weight (g)
i. Behaviour

Some of the above information was unavailable in certain years of the project. Table 4 provides a summary of data gaps in the acquired amphibian data. These data gaps limit the ability to standardize data from multiple years to allow cross-year comparisons. For instance, number of amphibians captured per unit of time or per searched area cannot be computed for most years of the project. Relationships between environmental conditions and amphibian detections cannot be explored. Data on amphibian captures (weight, SVL and age class) are incomplete preventing a multi-year examination of relationships between these variables and capture location or time of year.

Table 4. Amphibian data gaps from the first six years of the GMSMON-17 project. Highlighted cells show where data gaps exist.

Table Name	Information	2011	2012	2013	2014	2015	2016
Sampling Location Table	Site name	Yes	Yes	Yes	Yes	Yes	Yes
	Search location ID	Yes	No	Yes	Yes	Yes	Yes
	Search location UTM	Yes	No	Yes	Yes	Yes	Yes
	Sampling mode	Yes	No	Yes	No	Yes	Yes
	Position relative to drawdown zone	Yes	No	Yes	Yes	Yes	Yes
	Position relative to habitat enhancements	n/a	n/a	n/a	Yes	Yes	Yes
Survey Data Table	Survey location ID	Yes	No	Yes	Yes	Yes	Yes
	Survey occasion ID	Yes	No	No	Yes	Yes	Yes
	Date	Yes	No	No	Yes	Yes	Yes
	Start and end time	No	No	No	No	Start only	Start only (some missing)
	Survey duration	Yes	No	No	No	Some (not for many wetlands, spot checks and transects)	Some (not for some transects or spot checks)
	Sampling mode	Yes	No	No	No	Yes	Yes
	Search area	Yes	No	No	No	Only for plots	Only for plots
	# of surveyors	Yes	No	No	No	Yes	Yes

Table Name	Information	2011	2012	2013	2014	2015	2016
	Environmental conditions	Some air temp and water temp	No	No	No	No	No
	Day vs night survey	Yes	No	No	No	Yes	Yes
Detection Data Table	Survey occasion ID	Yes	No	No	Yes	Yes	Yes
	Detection ID	Yes	Yes	Some	Yes	Yes	Yes
	UTM	Yes	No	Ole Creek only	Yes	Yes	Yes
	Species	Yes	Yes	Yes	Yes	Yes	Yes
	# observed	Yes	Yes	Yes	Yes	Yes	Yes
	Age class	Yes	Yes	No	No	No	No
	SVL	Yes	Yes	Yes	Some	No	No
	Weight	Some	Some	Yes	Some	No	No
	Behaviour notes	Yes	No	No	No	Some	No

Amphibian survey locations within the drawdown zone from all years of the project (2011 – 2016) were plotted on maps of each site (Appendix B). Habitat mapping completed as part of the vegetation component of the project was used as a base mapping layer so that survey locations could be examined in relation to habitat types and locations of enhancement structures.

Originally, this project was intended to have a BACI (Before-After-Control-Impact) design, with two treatment sites and two control sites. However, there were few pre-enhancement surveys completed in relevant areas of the drawdown zone at the two treatment sites; it was determined that a before-after enhancement comparison was not possible. Consequently, a treatment-control comparison was not meaningful: this comparison would usually be done in a BACI design to assess whether changes that are observed through time at treatment sites are also observed at control sites.

A subset of survey stations was identified at Ole Creek and Six Mile Creek that were in areas that were potentially affected by the enhancement at these sites (i.e., stations in the enhancement polygons, stations in areas potentially protected by enhancement structures, and stations in areas downstream of the enhancement that may be affected by channelization of the stream; Tables 5 & 6). Station labels that appear more than once in Tables 5 & 6 were surveyed more than once during different time periods of the project. Data from this subset of survey locations were examined to determine if there were any trends in species detected or number of individuals captured through time. Data from night surveys were summarized separately from daytime surveys.

Table 5. Amphibian survey locations at Ole Creek in areas of the drawdown zone that could potentially be affected by the enhancement. UTMs of survey locations are in Appendix A; a map showing the location of these survey stations is provided in Appendix B.

Habitat Type	Pre-enhancement (2011-2013)	Construction Year (2014)	Post-enhancement 2015 - 2016 (day)	Post-enhancement 2015-2016 (night)
Enhancement area (both sides of the creek)	OA6	OA8, OA11	OA8, OA13, OA32	OA41, OA54, OA55, OA56, OA57
Basin Silt				OA52
Gravel & Sand				OA64, OA65, OA66
Shoreline driftwood			OA14	

Table 6. Amphibian survey locations at Six Mile Creek in areas of the drawdown zone that could potentially be affected by the enhancement. UTMs of survey locations are in Appendix A; a map showing the location of these survey stations is provided in Appendix B.

Habitat Type	Pre-enhancement (2011-2013)	Construction Year (2014)	Post-enhancement 2015 - 2016 (day)	Post-enhancement 2015-2016 (night)
Enhancement area		SA13	SA13, SA20, SA36	SA39, SA45
Basin Silt	SA1		SA15, SA16, SA17	SA47, SA50
Gravel & Sand			SA18, SA19	SA46
Organic Veneer				SA29, SA44
Shoreline driftwood				SA43
Shoreline willow		SA8		
Wetland	SA4	SA7, SA9	SA9	SA42

3.2 Results

Amphibian survey results from the subset of identified survey locations at Ole Creek and Six Mile Creek are provided below. Nighttime survey results are presented separately from daytime survey results. Results from all other survey locations are summarized in Appendix E (drawdown zone survey results) and Appendix G (upland survey results). Maps of amphibian detections within the drawdown zone at each site are provided in Appendix F; maps of detections in upland areas at each site are provided in Appendix H).

Ole Creek

Table 7 provides the results for daytime surveys within areas of the drawdown zone at Ole Creek that could potentially be affected by the enhancement; a map showing locations of amphibian detections in the entire drawdown zone at Ole Creek is included in Appendix F.

Prior to project construction, only one amphibian observation was made with relevance to the physical works project at Ole Creek. Twelve metamorphosed Wood Frogs and one Western Toad were recorded in 2013 in an area that would undergo enhancement the following year. These detections were made adjacent to where Ole Creek enters the reservoir at high reservoir levels, in terrestrial vegetation along the reservoir shoreline (ref). No surveys were completed in relevant areas of the drawdown zone at Ole Creek in 2011 and 2012.

Project construction occurred in 2014, and it is not known how the timing of amphibian surveys in 2014 related to construction activities. In 2014, two Western Toads were recorded at two locations within one of the enhancement polygons during June and August.

Following the year of project completion, four Western Toads were recorded at one of the same locations in June 2015 where they were noted in 2014 (OA8). In addition, a Wood Frog and another Western Toad were recorded at two other survey locations in 2015; the Wood Frog was located in one of the enhancement polygons and the Western Toad was located in shoreline driftwood habitat adjacent to the enhancement area. No daytime surveys were completed in areas of the Ole Creek drawdown zone that could potentially be affected by the enhancement in 2016.

Table 8 provides the results for nighttime surveys within areas of the drawdown zone at Ole Creek that could potentially be affected by the enhancement. Only one location was surveyed at night in 2015 (on the edge of the enhancement polygon), and three Western Toads were recorded. No information was provided on the life stage of these amphibians (e.g., juveniles or adults). In 2016, eight locations were surveyed at night; amphibians were only recorded at two of the eight locations. Three Western Toads were recorded at two night survey locations in July 2016, both of which were in a gravel and sand polygon downstream of the enhancement.

Only two species were consistently found in areas of the Ole Creek drawdown zone that could potentially be affected by the project: Western Toads and Wood Frogs. It is not clear what habitat was being surveyed at OA6 in 2013, but it is possible that a small pool was surveyed with some Wood Frog tadpoles or eggs. This location was not revisited in subsequent years and was in an area where enhancement occurred. Western Toads were located within the enhancement area in 2014 and 2015, including a detection of four Western Toads in 2015. The habitat being surveyed at OA8 and the life stage of the four Western Toads were not recorded. This area was not surveyed pre-enhancement to determine if there was any change due to the project; however, the detections in 2015 were post-enhancement indicating continued use of the area. No amphibians were recorded in the enhancement polygons during night surveys in 2016 despite multiple survey locations in those areas.

Six Mile Creek

Table 7 provides the results for daytime surveys within areas of the drawdown zone at Six Mile Creek that could potentially be affected by the enhancement. A map showing locations of amphibian detections in the entire drawdown zone at Six Mile Creek is included in Appendix F.

In May 2011, a Long-toed Salamander egg mass was found in basin-silt habitat downstream of the proposed enhancement; this detection was likely in a temporary pool and provided some of the only evidence during this project that amphibians may breed within the pools of the drawdown zone. An adult Western Toad was also recorded in a large wetland on the edge of the drawdown zone in 2011. No surveys were completed in relevant areas of the drawdown zone in 2012 or 2013.

In 2014, the year implementation of the enhancement occurred, 31 daytime detections of four species were recorded within the drawdown zone or along the edge of the drawdown zone (Table 7). Most of the detections were from the large wetland complex at the edge of the drawdown zone (surveyed at stations SA7 and SA9). Columbia Spotted Frogs and Western Toads were recorded at the wetland in May, June and August, including a record of nine Western Toads in May, which were not tadpoles (MacInnis et al. 2015). Long-toed Salamanders were recorded at the wetland in May and August; the three detections in August may represent larvae. A Wood Frog was recorded at the wetland in August. A Wood Frog and Western Toad were recorded in May in shoreline willow habitat adjacent to the wetland. Four Wood Frogs were recorded in the enhancement polygon in June 2014; it is not known what habitat these Wood Frogs were using.

In 2015, the first year following project completion, all daytime detections were either within the wetland at Six Mile Creek (survey location SA9) or on the edge of the enhancement polygon adjacent to the wetland (survey location SA36), despite surveys in many other locations (Table 7). Two Western Toads and an unidentified frog were recorded at the wetland in June; a Western Toad was recorded there in August, although the wetland was flooded by August, making surveying difficult. Surveys were not completed early in the season (i.e., May) in 2015, which could explain the lack of breeding evidence in the wetland in 2015. Adjacent to the wetland (SA36), two Western Toads, two Columbia Spotted Frogs and one unidentified frog were recorded in August 2015.

In 2016, only three relevant locations within the drawdown zone were surveyed during the daytime, and no amphibians were recorded at any of these locations. Survey location SA20 was the closest survey location to the wetland that yielded many amphibian detections in 2014 and 2015, but no amphibians were recorded there in May 2016. It is not clear why survey location SA9 was not surveyed in May 2016; the wetland was reported to be flooded when crews visited in late July 2016, preventing them from surveying the habitat (Thompson & Carson 2017). This likely contributed to fewer detections at Six Mile Creek in 2016.

Table 8 provides the results for nighttime surveys within areas of the drawdown zone at Six Mile Creek that could potentially be affected by the enhancement. One transect was surveyed at night in June 2015 and thirteen Western Toads and one Columbia Spotted Frog were recorded. Six of the Western Toad detections were from three breeding pairs observed in amplexus in a slow flow inlet formed by the earth berm barrier and separated from the fast flow of Six Mile Creek (MacInnis et al. 2016). Adult toads

were also observed migrating along the periphery of the water and on the constructed earth berm itself (MacInnis et al. 2015). It is not clear exactly where the surveyors went during this night-time transect, as only one UTM was provided, which was likely the start location. Therefore, the exact locations of these detections are unknown. In May 2016, eight locations within the drawdown zone at Six Mile Creek were surveyed at night, but only two Western Toads were recorded at two of the stations (SA39 and SA44). Survey location SA39 was on the enhancement polygon adjacent to the wetland, and SA44 was in gravel and sand habitat protected by the enhancement.

In comparison to Ole Creek, a greater diversity of amphibian species was recorded within the drawdown zone at Six Mile Creek, with four species each recorded multiple times. The wetland habitat at Six Mile Creek likely explains this difference in diversity between sites; this wetland likely provides yearly breeding habitat for amphibians. No similar wetland habitat was present at Ole Creek. Many amphibians were recorded at Six Mile Creek in 2014, the year implementation of the enhancement occurred. Fewer amphibians were recorded post-enhancement; however, that is likely due to the later timing of surveys in 2015 (perhaps missing some breeding activity) and reservoir operations resulting in the wetland being flooded (and therefore not surveyed) as rigorously post-enhancement. Amphibians were recorded within the enhancement area post-enhancement, and Western Toads were recorded using habitat created by the earth berm constructed as part of the enhancement works.

Table 7. Amphibian daytime survey results at Ole Creek and Six Mile Creek in areas of the drawdown zone that could potentially be affected by the enhancement. Timing (month) for each detection or nil result is listed if the information is available. Cells with light grey shading indicate that no surveys occurred at that location in those years. Abbreviations used for species are as follows: CSF = Columbia Spotted Frog, LTS = Long-toed Salamander, unID = unidentified frog, WF = Wood Frog, WT = Western Toad. All UTMs are in Zone 10.

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
Ole Creek	OA6	405841	6257650			12 WF, 1 WT			
	OA8	405864	6257666				1 WT (Jun)	4 WT (Jun)	
	OA11	405895	6257707				1 WT (Aug)		
	OA13	405879	6257639					none (Aug)	
	OA14	405898	6257621					1 WT (Aug)	
	OA32	405882	6257644					1 WF (Jun)	
Six Mile Creek	SA1	474773	6162544	1 LTS egg mass (May)					
	SA4	474718	6162718	1 adult WT (Jun)					
	SA7	474697	6162724				2 CSF (Aug), 2 WT (Aug)		
	SA8	474702	6162709				1 WF (May), 1 WT (May)		

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
	SA9	474691	6162719				2 LTS (May), 9 WT (May), 2 CSF (May), 3 WT (Jun), 1 CSF (Jun), 3 LTS (Aug), 1 WF (Aug)	2 WT (Jun), 1 unID (Jun), 1 WT (Aug - flooded)	
	SA13	474680	6162694				4 WF (Jun)	none (Jun)	
	SA15	474708	6162583					none (Aug - flooded)	
	SA16	474708	6162583					none (Jun)	none (May)
	SA17	474687	6162610					none (Jun)	
	SA18	474701	6162639					none (Jun)	
	SA19	474693	6162672					none (Jun)	
	SA20	474686	6162723					none (Jun)	none (May)
	SA29	474736	6162622						none (May)
	SA36	474724	6162788					2 WT (Aug), 2 CSF (Aug), 1 unid (Aug)	

Table 8. Amphibian nighttime survey results at Ole Creek and Six Mile Creek in areas of the drawdown zone that could potentially be affected by the enhancement. Timing (month) for each detection or nil result is listed if the information is available. Cells with light grey shading indicate that no surveys occurred at that location in those years. Abbreviations used for species are as follows: CSF = Columbia Spotted Frog, LTS = Long-toed Salamander, unID = unidentified frog, WF = Wood Frog, WT = Western Toad. All UTMs are in Zone 10.

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
Ole Creek	OA41	405836	6257682					3 WT (Aug)	
	OA52	406050	6257760						none (May)
	OA54	405881	6257702						none (May)
	OA55	405930	6257626						none (May)
	OA56	405920	6257680						none (May)
	OA57	405894	6257652						none (May)
	OA64	405942	6257741						none (Jul)
	OA65	405981	6257761						2 WT (Jul)
	OA66	405919	6257735						1 WT (Jul)
Six Mile Creek	SA29	474736	6162622					13 WT (Jun), 1 CSF (Jun)	
	SA39	474699	6162751						1 WT (May)
	SA42	474719	6162747						none (May)
	SA43	474719	6162671						none (May)

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
	SA44	474705	6162643						1 WT (May)
	SA45	474667	6162627						none (May)
	SA46	474682	6162621						none (May)
	SA47	474699	6162582						none (May)
	SA50	474772	6162550						none (May)

4 Discussion

Throughout the course of this project, the approach for addressing the amphibian management questions has changed. In 2011 through 2013, Golder Associates Ltd. completed surveys in the drawdown zone and at upland locations >200 m from the drawdown zone at each site. Few locations were surveyed at each site, and it is unclear which of the locations were revisited each year. In 2014, DWB Consulting Services Ltd. changed the approach for the amphibian component of the project and completed plots or searches in the drawdown zone, upland areas <200 m from the drawdown zone, and upland areas >200 m from the drawdown zone. In 2015 and 2016, DWB Consulting Services Ltd. continued the approach started in 2014, but also added in transects within the drawdown zone that were surveyed at night. Some of the locations that were surveyed by Golder Associates Ltd. were surveyed by DWB Consulting Services Ltd. (MacInnis et al. 2015), although locations of searches that did not yield amphibian detections are lacking for 2014 so it not possible to determine where surveys occurred that year. Some of the locations surveyed in 2014 were revisited in 2015 and 2016, but many survey locations appeared to be new; this is likely due to use of an approach of surveying adjacent, undisturbed areas on return visits to a location (MacInnis et al. 2015). In addition, ephemeral pools in the drawdown zone may not occur in the same location each year, so it is likely that slightly different locations were surveyed each year of the project.

As a result of the above, it was determined that the data could not be analyzed in the context of a BACI design. Few surveys were completed pre-enhancement in relevant areas of the drawdown zone at the two treatment sites, and amphibian diversity and numbers of amphibians using the areas pre-enhancement were not well established. Therefore, a comparison to amphibian data post-enhancement was not deemed appropriate. Since the Before-After comparison was not possible, the Control-Impact comparison was not meaningful. Therefore, much of the data collected as part of this project is reported in Appendices to this report as it cannot be used to answer the management questions related to amphibians.

Despite the above limitations, there are some trends in the amphibian data that are worth noting. First, Western Toads appear to be using all drawdown zone sites, both pre- and post-enhancement. Detections have not been limited to spring when Western Toads might be searching for breeding locations; at all sites Western Toads were recorded along the margins of the reservoirs in small numbers in June through August (Table 7, Table 8, Appendix E, Appendix F). It is possible that some habitats along the margin of the drawdown zone are providing foraging habitat for this species; toads are likely using vegetated habitat with woody debris cover in these areas.

Second, the amphibian assemblage at Six Mile Creek likely reflects the use of the wetland habitat on the edge of the drawdown zone (survey locations SA7 and SA9). This habitat type is not present near the drawdown zone at any other site; therefore, it is difficult to compare the drawdown zone results at Six Mile Creek to those of the other sites. This wetland has been shown to be important for amphibian breeding, with likely breeding use by Columbia Spotted Frogs, Western Toads and Long-toed Salamanders. Wetlands were likely surveyed in some upland locations at each site (although habitat mapping is not available for the upland areas) based on detections of multiple species from single survey locations (e.g., OA3, FA32, FA34, FA35). The diversity of amphibians recorded at the wetland on the edge of the drawdown zone at Six Mile Creek is the same as that recorded at upland wetlands surveyed during this project (e.g., FA32 and FA34, Appendix G). The number of amphibian detections at the wetland at Six Mile Creek in 2015 is very similar to the number of detections at FA32 in 2015. There were more amphibian detections made at FA34 compared to the wetland at Six Mile Creek.

4.1 Management question 5: Does amphibian abundance and diversity in tributaries change as a result of enhancement?

Comparing amphibian abundance and diversity in an area before and after a treatment is challenging for several reasons. Terrestrial amphibians are difficult to detect during surveys due to their cryptic habits (they are not usually moving in the open during the daytime) and they use habitats that are not easily searched (e.g., subterranean areas, under and within woody debris, etc.). Amphibians may be more clumped in areas that provide less habitat, skewing survey results in poorer habitats (i.e., survey results may suggest that more amphibians use the poorer habitat; Corn and Bury 1990). It can be difficult to find quantitative and qualitative trends in amphibian data unless data sets are large over a sufficiently long time period. For this project, changes in the sampling methodology through time (different locations surveyed within a site each year, differences in survey timing year to year, changes to consultants) likely contributed to a further increase in the variability of the data, making the data even harder to analyze.

Management question #5 asks about changes to amphibian abundance and diversity in tributaries. Amphibians were only recorded within a tributary twice throughout this project: three pairs of Western Toads were observed in amplexus (mating) at Six Mile Creek in 2015, in a slow flow inlet formed by the earth berm barrier that separated the area from the fast flow of Six Mile Creek (MacInnis et al. 2015). In addition, a Wood Frog was observed at the bottom of Six Mile Creek during fish spawning surveys in 2015 (MacInnis et al. 2015). All other amphibian detections made during this project were within terrestrial habitat or wetland habitat (the latter only occurred at the edge of the drawdown zone at Six Mile Creek). Since amphibian use of the tributaries (streams) at each site appears to be rare, changes to the stream as part of the enhancement project (e.g., channelization, creation of pools, etc.) is not expected to affect amphibians negatively. The detection of Western Toads using a slow flow inlet created by the earth berm barrier is evidence of potential amphibian habitat creation by the enhancement project. Detections in this habitat were not repeated in 2016; this could be due to the timing and location of surveys in 2016 or because toads were not using the habitat that year (perhaps due to availability of other habitats as a result of climate differences between years).

Rather than address management question #5 as written, we can ask whether there has been evidence of changes to amphibian abundance and diversity within areas influenced by the enhancement at each site. In this interpretation, we are asking whether the changes to the stream flow (channelization) and construction works have caused changes to habitat adjacent to the streams that may be used by amphibians. These habitat changes could come from reduction of seasonal flooding by the stream, from compaction of habitat due to machinery use adjacent to the streams, from loss of habitat due to creation of berms, and from changes to locations of woody debris (intentional placement of woody debris or changes to where woody debris naturally accumulates post-enhancement). The variability of the amphibian data collected for this project (mentioned above) does not allow an answer to this question quantitatively; however, this project has shown use of the drawdown zone adjacent to the enhancement works at each site by a relatively stable diversity of amphibians throughout the course of the project (pre- and post-enhancement). In this respect, it can be concluded that there did not appear to be a negative impact to amphibian diversity in areas potentially influenced by the enhancement. It is more difficult to qualitatively address effects of the enhancement on abundance of amphibians. However, the number of amphibians of the various species recorded in areas potentially affected by the enhancement remained relatively low and stable through time (pre- and post-enhancement). Amphibian detections were highest at the wetland at Six Mile Creek (adjacent to the enhancement works), which provides breeding habitat for several amphibian species. Amphibians were recorded breeding at this site in the year of project construction (2014) and one year post-enhancement (2015). Unfortunately, this wetland flooded due to reservoir operations in summer 2015 and 2016, which prevented rigorous post-enhancement surveys. Therefore, comparisons of abundance of amphibians using this wetland habitat through time are not possible with the current data.

Despite variable methods, management question #5 can be considered addressed and collection of further amphibian data is not deemed necessary.

4.2 Management question 6: Does tributary enhancement change the area and quality of amphibian breeding habitat over time? If so, is the area and quality maintained over time?

There was very little evidence of amphibian breeding in the drawdown zone in this project. Long-toed Salamanders were recorded breeding in a small pool in the drawdown zone at Six Mile Creek in 2011 but were not recorded breeding in the drawdown zone in subsequent years of the project. Western Toads were recorded in amplexus in a slow flow inlet created by the earth berm barrier at Six Mile Creek in 2015, but it is not known if they ultimately laid eggs in this habitat. All other amphibian breeding detections (i.e., tadpoles or larvae recorded) were made in areas on the margin of the drawdown zone that likely had more permanent pools (e.g., two wetlands at Six Mile Creek, possibly within shoreline willow habitat at Factor Ross Creek).

Although the methods used for amphibian data collection for this project did change through time in terms of timing and location of surveys, it is expected that the surveyors would have searched any potentially suitable breeding habitat that they encountered while on site. Furthermore, tadpoles and larvae are more easily observed than terrestrial amphibians (especially Western Toad tadpoles, which congregate in shallow margins of pools in warmer water) and it is not likely that they would have been

easily missed by surveyors. Tadpoles and larvae remain in pools for several months before metamorphosing, so timing of surveys is less critical (as compared to timing surveys to record egg masses). Therefore, we can conclude based on the data collected for this project that there is very low use of the drawdown zone for amphibian breeding, except in areas where permanent water features (e.g., wetlands) exist.

Management question #6 asks whether the enhancement changed the area and quality of amphibian breeding habitat over time. Since the data suggests that the only important breeding habitats are the permanent wetlands on the margins of the drawdown zones, we need to consider whether the enhancement has changed the area and quality of that wetland habitat through time. The only wetland that this applies to is the wetland closer to the drawdown zone at Six Mile Creek (surveyed at SA7 and SA9), as it is adjacent to the enhancement area and may be affected in some way by changes to flow patterns of the tributary due to berm creation. It is possible that the berm created at Six Mile Creek may have prevented introduction of stream water into the wetland (due to high water in spring). If this is the case, the enhancement may have allowed water temperatures within the wetland to remain higher, which could have a positive impact on amphibian egg and larval development. To ascertain whether there have been changes in quality at this breeding site through time, one would need to have good knowledge of the habitat attributes that are important for breeding success of each of the species that might use this wetland to breed, and data on those attributes would need to be collected pre- and post-enhancement for comparison. Physical data on this wetland were not collected pre-enhancement, making it difficult to address this aspect of Management Question #6.

Quality of the breeding habitat at this site can only be inferred from amphibian use of the area through time. Amphibians were recorded breeding in this wetland pre-enhancement. This wetland was flooded by the reservoir earlier in the summer of 2015 and 2016 (post-enhancement) due to reservoir operations (not due to the enhancement project). Due to the flooding, surveys of the wetland post-enhancement were either reduced (2015) or not completed (2016). Consequently, it is not possible to determine if there were any changes to amphibian breeding use of the wetland post-enhancement. An answer to Management Question #6 is not possible with the data collected during this project.

5 Recommendations

Although Management Question #6 cannot be conclusively answered with the data collected as part of this project, additional field survey effort is not recommended. One additional year of amphibian surveys at the wetland at Six Mile Creek could be completed to determine if amphibians are still using the area as a breeding site post-enhancement. However, field surveys are costly due to the remote location of the project, and due to the need for multiple survey visits within a season to obtain reliable data. Since additional data should only be used to compare the diversity of species using the wetland as a breeding site pre- and post-enhancement, these surveys are not likely worth the cost. The diversity of species breeding at the wetland through time may not tell us about the quality of the wetland as a breeding site, which is what Management Question #6 asks.

If aerial imagery of the wetland at Six Mile Creek is available pre-enhancement, it could be compared to aerial imagery taken post-enhancement to determine if the area of the wetland has changed; this may

help partially answer Management Question #6. Aerial imagery was taken in 2014 and 2015 and was used to complete habitat mapping for the Six Mile Creek drawdown zone. It is not known if construction of the enhancement had already commenced at the time of the 2014 imagery. It is possible that earlier (pre-2014) aerial imagery may exist in BC Hydro's archives. Acquiring additional aerial imagery post-construction is not recommended for the sole purpose of answering Management Question #6; however, if the aerial photographs are planned for another reason, they may be examined and compared to any earlier pre-enhancement imagery of the site to determine whether there are changes in area of the wetland. Aerial photographs pre- and post-enhancement would have to be taken at roughly the same time of year to allow valid comparisons in wetland area to be made.

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Appendices

Appendix A. Amphibian survey locations within the drawdown zone or on the edge of the drawdown zone, and dates they were surveyed between 2011 and 2016 of the GMSMON-17 project.

Table A1. Amphibian survey locations within the drawdown zone surveyed between 2011 and 2013 of the GMSMON-17 project. All UTMs are in Zone 10.

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2011	2012	2013
Ole Creek	OA1	405816	6257701	16-May-11	Unsure which locations were surveyed, but surveys took place July 3-6, 2012	n/a
	OA4	405807	6257698	16-Aug-11		n/a
	OA6	405841	6257650	n/a		spring
Factor Ross Creek	FA1	395389	6275959	14-May-11		n/a
	FA4	395338	6275905	15-May-11		n/a
	FA6	395361	6275869	n/a		spring
Six Mile Creek	SA1	474773	6162544	11-May-11		n/a
	SA2	474625	6162593	11-May-11		spring
	SA4	474718	6162718	07-Jun-11		n/a
	SA5	474669	6162829	09-Aug-11		n/a
	SA6	474695	6162855	11-Aug-11		spring
Lamonti Creek	LA3	475220	6161980	n/a		spring

Table A2. Amphibian survey locations within the drawdown zone or on the edge of the drawdown zone, and dates they were surveyed between 2014 and 2016 of the GMSMON-17 project. Grey-highlighted dates denote night-time surveys.

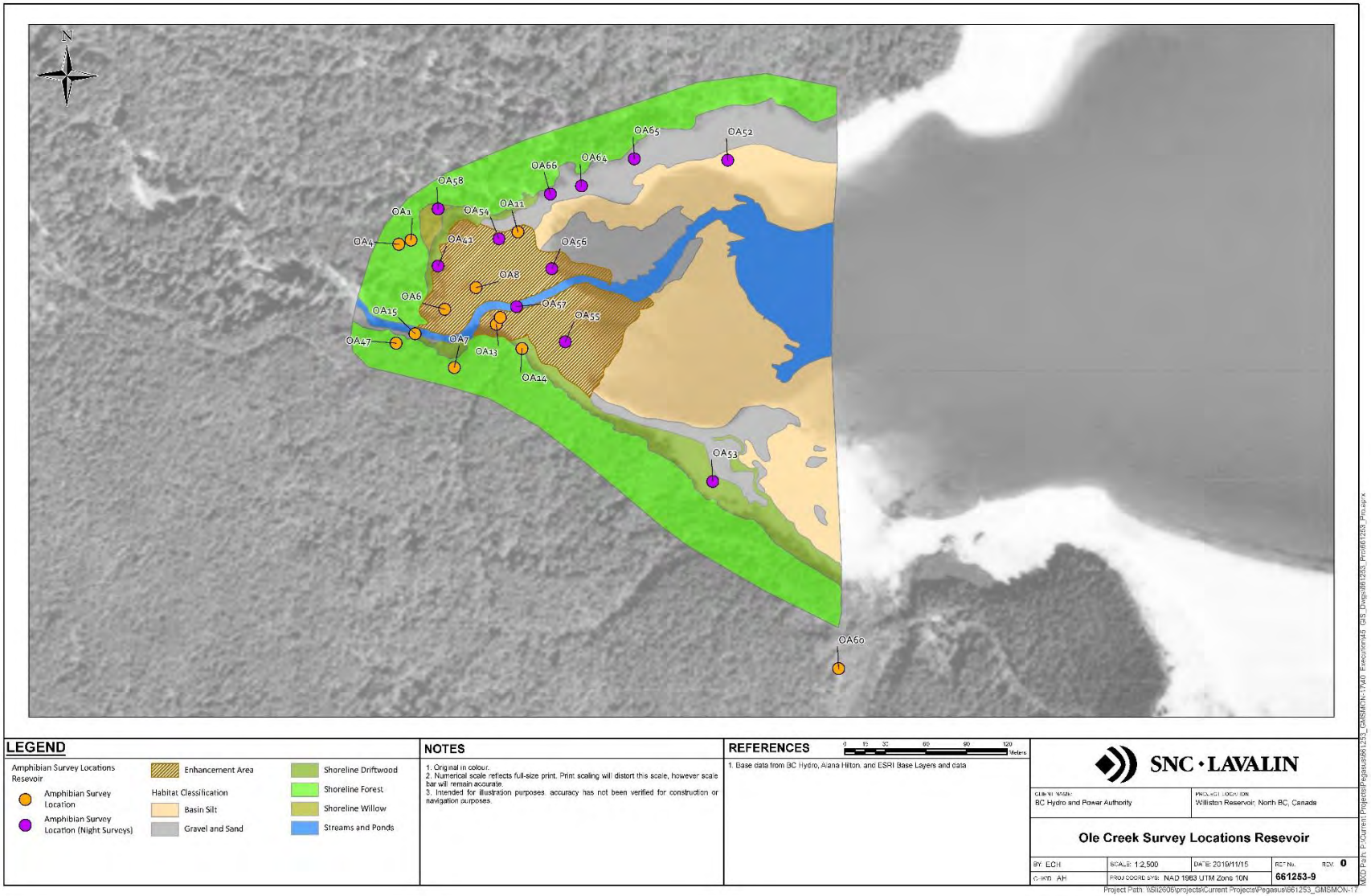
Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
Ole Creek	OA7	405848	6257607	14-May-14	17-Jun-15	n/a
					06-Aug-15	
	OA8	405864	6257666	18-Jun-14	17-Jun-15	n/a
	OA11	405895	6257707	14-Aug-14	n/a	n/a
	OA13	405879	6257639	n/a	06-Aug-15	n/a
	OA14	405898	6257621	n/a	17-Jun-15	n/a
					06-Aug-15	
	OA15	405819	6257632	n/a	07-Aug-15	n/a
	OA32	405882	6257644	n/a	17-Jun-15	n/a
	OA41	405836	6257682	n/a	06-Aug-15	n/a
	OA47	405805	6257625	n/a	n/a	28-May-16
	OA52	406050	6257760	n/a	n/a	28-May-16
	OA53	406039	6257523	n/a	n/a	29-May-16
	OA54	405881	6257702	n/a	n/a	28-May-16
	OA55	405930	6257626	n/a	n/a	28-May-16
	OA56	405920	6257680	n/a	n/a	28-May-16
	OA57	405894	6257652	n/a	n/a	28-May-16

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
	OA58	405836	6257724	n/a	n/a	28-May-16
	OA60	406132	6257385	n/a	n/a	29-May-16
	OA64	405942	6257741	n/a	n/a	22-Jul-16
	OA65	405981	6257761	n/a	n/a	22-Jul-16
	OA66	405919	6257735	n/a	n/a	23-Jul-16
Factor Ross Creek	FA6B	395475	6275837	15-May-14	14-Jun-15	22-Jul-16
				19-Jun-14	05-Aug-15	
				14-Aug-14		
	FA10	395341	6275833	18-Jun-14	14-Jun-15	n/a
				14-Aug-14	05-Aug-15	
	FA11	395524	6275838	18-Jun-14	n/a	n/a
	FA12	395508	6275817	18-Jun-14	14-Jun-15	22-Jul-16
					05-Aug-15	
	FA13	395489	6275874	14-Aug-14	n/a	n/a
	FA14	395373	6275726	14-Aug-14	n/a	n/a
	FA15	395555	6275876	n/a	14-Jun-15	n/a
					05-Aug-15	
	FA16	395373	6275726	n/a	05-Aug-15	n/a
	FA36	395334	6275850	n/a	n/a	30-May-16
	FA37	395337	6275851	n/a	n/a	30-May-16
	FA38	395502	6275836	n/a	n/a	31-May-16
	FA39	395485	6275816	n/a	n/a	30-May-16
	FA40	395457	6275838	n/a	n/a	30-May-16
	FA41	395315	6275953	n/a	n/a	30-May-16
	FA43	395305	6275922	n/a	n/a	30-May-16
	FA44	395492	6275855	n/a	n/a	31-May-16
	FA45	395319	6276057	n/a	n/a	30-May-16
	FA46	395427	6275903	n/a	n/a	31-May-16
	FA47	395314	6275813	n/a	n/a	30-May-16
	FA48	395497	6275832	n/a	n/a	31-May-16
	FA50	395322	6275819	n/a	n/a	21-Jul-16
	FA51	395302	6275939	n/a	n/a	21-Jul-16
	FA52	395315	6275940	n/a	n/a	22-Jul-16
Six Mile Creek	SA7	474697	6162724	08-May-14	n/a	n/a
	SA8	474702	6162709	08-May-14	n/a	n/a
	SA9	474691	6162719	12-May-14	03-Jun-15	n/a
				05-Jun-14		
				12-Jun-14	10-Aug-15	
				13-Aug-14		

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
	SA13	474680	6162694	16-Jun-14	03-Jun-15	n/a
	SA15	474708	6162583	n/a	10-Aug-15	n/a
	SA16	474708	6162583	n/a	03-Jun-15	15-May-16
	SA17	474687	6162610	n/a	03-Jun-15	n/a
	SA18	474701	6162639	n/a	03-Jun-15	n/a
	SA19	474693	6162672	n/a	03-Jun-15	n/a
	SA20	474686	6162723	n/a	03-Jun-15	15-May-16
	SA29	474736	6162622	n/a	04-Jun-15	15-May-16
	SA31	474785	6162619	n/a	03-Jun-15	n/a
	SA32	474912	6162446	n/a	04-Jun-15	15-May-16
	SA33	474947	6162384	n/a	04-Jun-15	15-May-16
	SA35	474767	6162674	n/a	10-Aug-15	n/a
	SA36	474724	6162788	n/a	10-Aug-15	n/a
	SA37	474873	6162535	n/a	04-Jun-15	15-May-16
	SA39	474699	6162751	n/a	n/a	25-May-16
	SA40	474830	6162552	n/a	n/a	25-May-16
	SA41	474824	6162547	n/a	n/a	25-May-16
	SA42	474719	6162747	n/a	n/a	16-May-16
	SA43	474719	6162671	n/a	n/a	24-May-16
	SA44	474705	6162643	n/a	n/a	16-May-16
						24-May-16
	SA45	474667	6162627	n/a	n/a	16-May-16
	SA46	474682	6162621	n/a	n/a	16-May-16
	SA47	474699	6162582	n/a	n/a	16-May-16
	SA48	474787	6162594	n/a	n/a	16-May-16
						24-May-16
	SA49	474785	6162578	n/a	n/a	16-May-16
	SA50	474772	6162550	n/a	n/a	16-May-16
	SA51	474870	6162520	n/a	n/a	16-May-16
Lamonti Creek	LA4B	475168	6162018	17-Jun-14	n/a	n/a
	LA5	475233	6161975	n/a	09-Aug-15	n/a
	LA19	475122	6162105	n/a	04-Jun-15	15-May-16
	LA20	475161	6162063	n/a	04-Jun-15	15-May-16
	LA25	475142	6162056	n/a	n/a	17-May-16
	LA26	475198	6162056	n/a	n/a	17-May-16
	LA27	475212	6162030	n/a	n/a	17-May-16
	LA28	475090	6162088	n/a	n/a	17-May-16
	LA29	475238	6162022	n/a	n/a	17-May-16
	LA30	475254	6162022	n/a	n/a	15-May-16

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
	LA33	475237	6161968	n/a	n/a	26-Jul-16
	LA34	474791	6162648	n/a	n/a	17-May-16

Appendix B. Maps of amphibian survey locations within the drawdown zone at Ole Creek, Factor Ross Creek, Six Mile Creek and Lamonti Creek.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OA65
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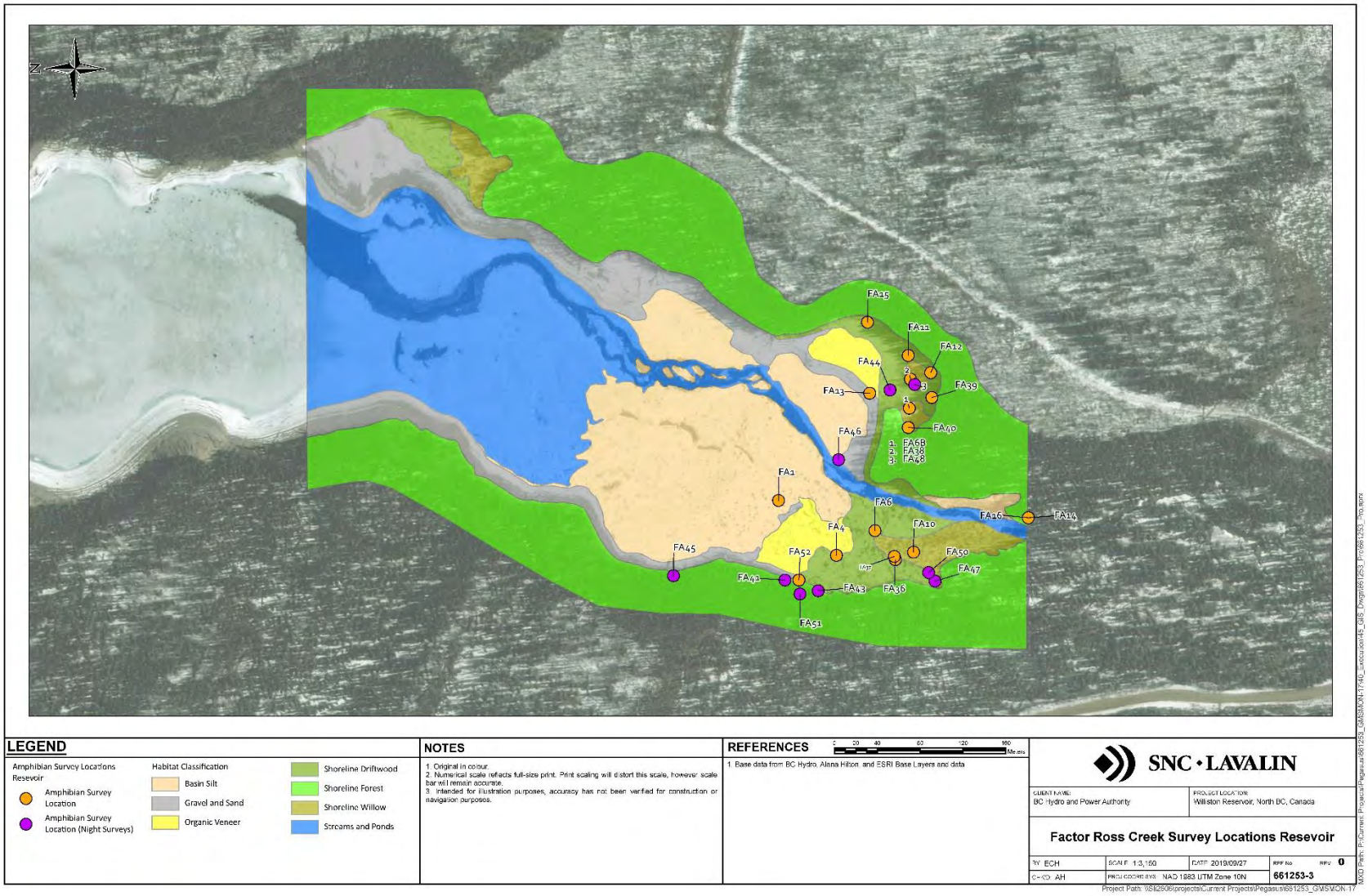
OA66
OA64
OA58
OA11
OA1
OA54
OA4
OA42
OA56
OA8
OA6
OA57
OA15
OA55
OA47
OA7
OA13
OA14
OA53
OA60
LEGEND
Amphibian Survey Locations Resevoir
Amphibian Survey Location
Amphibian Survey Location (Night Surveys)
Enhancement Area
Habitat Classification
Basin Silt
Gravel and Sand
Shoreline Driftwood
Shoreline Forest
Shoreline Willow
Streams and Ponds
NOTES
1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes. accuracy has not been verified for construction or navigation purposes.
REFERENCES
0 15 30 60 90 120 Meters
1. Base data from BC Hydro, Alana Hilton, and ESRI Base Layers and data
SNC·LAVALIN
CLIENT NAME: BC Hydro and Power Authority
PROJECT LOCATION: Williston Reservoir, North BC, Canada
Ole Creek Survey Locations Resevoir
BY: ECH
SCALE: 1:2,500
DATE: 2019/11/15
REF No. 661253-9
REV. 0
CHKD: AH
PROJ COORD SYS: NAD 1983 UTM Zone 10N
MXD Path: P:\Current Projects\Pegasus\661253_GMSMON-17\40 Execution\45 GIS_Dwgs\661253_Pro\661253_Pro.aprx
Project Path: \\Sl2608\projects\Current Projects\Pegasus\661253_GMSMON-17



LEGEND

Amphibian Survey Locations Reservoir
- Amphibian Survey Location
- Amphibian Survey Location (Night Surveys)

Habitat Classification
- Basin Silt
- Gravel and Sand
- Organic Veneer
- Shoreline Driftwood
- Shoreline Forest
- Shoreline Willow
- Streams and Ponds

NOTES

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REFERENCES

0 20 40 60 120 160 Metres

1. Base data from BC Hydro, Alena Hilton and ESRI Base Layers and data

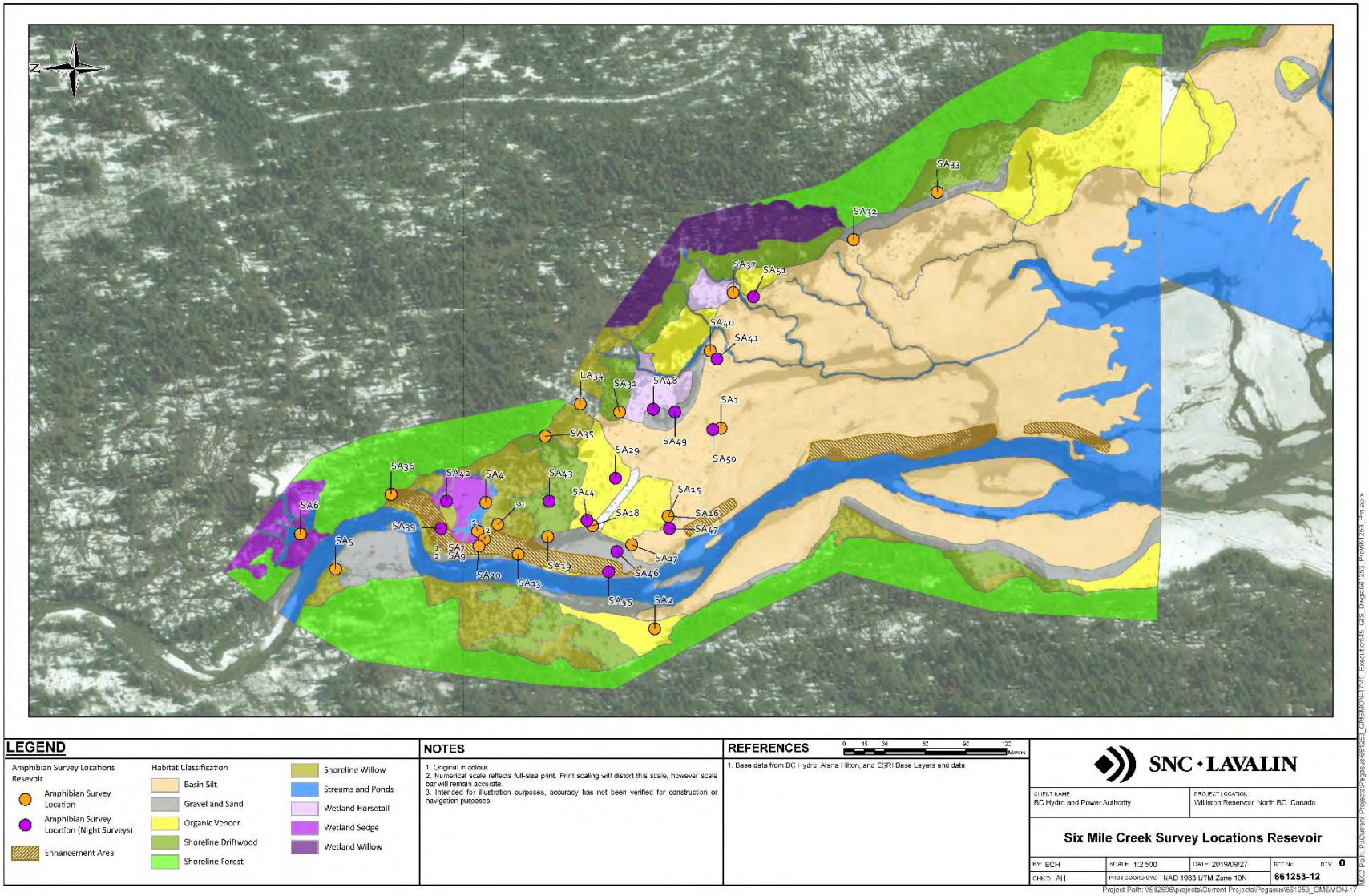
SNC·LAVALIN

CLIENT NAME: BC Hydro and Power Authority
PROJECT LOCATION: Williston Reservoir, North BC, Canada

Factor Ross Creek Survey Locations Reseveir

BY: ECH | SCALE: 1:3,150 | DATE: 2019/09/27 | REF No. | REV: 0
C-CK: AH | PROJ COORD SYS: NAD 1983 UTM Zone 10N | 661253-3

MXD Path: P:\Current Projects\Pegasus\661253_GMSMON-17\40_calculation\45_GIS_Data\661253_Project.aprx
Project Path: \\Sil2508\projects\Current Projects\Pegasus\661253_GMSMON-17


N
SA33
SA32
SA37
SA51
SA40
SA41
LA34
SA31
SA48
SA1
SA35
SA49
SA50
SA29
SA36
SA42
SA4
SA43
SA44
SA15
SA6
SA18
SA16
SA39
SA47
SA5
SA7
SA9
SA17
SA19
SA46
SA20
SA13
SA45
SA2
LEGEND
Amphibian Survey Locations Resevoir
Amphibian Survey Location
Amphibian Survey Location (Night Surveys)
Enhancement Area
Habitat Classification
Basin Silt
Gravel and Sand
Organic Veneer
Shoreline Driftwood
Shoreline Forest
Shoreline Willow
Streams and Ponds
Wetland Horsetail
Wetland Sedge
Wetland Willow
NOTES
1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.
REFERENCES
0 15 30 60 90 120 Meters
1. Base data from BC Hydro, Alaska Hilton, and ESRI Base Layers and data
SNC·LAVALIN
CLIENT NAME: BC Hydro and Power Authority
PROJECT LOCATION: Williston Reservoir, North BC, Canada
Six Mile Creek Survey Locations Resevoir
BY: ECH
SCALE: 1:2,500
DATE: 2019/09/27
REF No: 661253-12
REV: 0
CHKD: AH
PROJ COORD SYS: NAD 1983 UTM Zone 10N
Project Path: \\Sll2606\projects\Current Projects\Pegasus\661253_GMSMON-17
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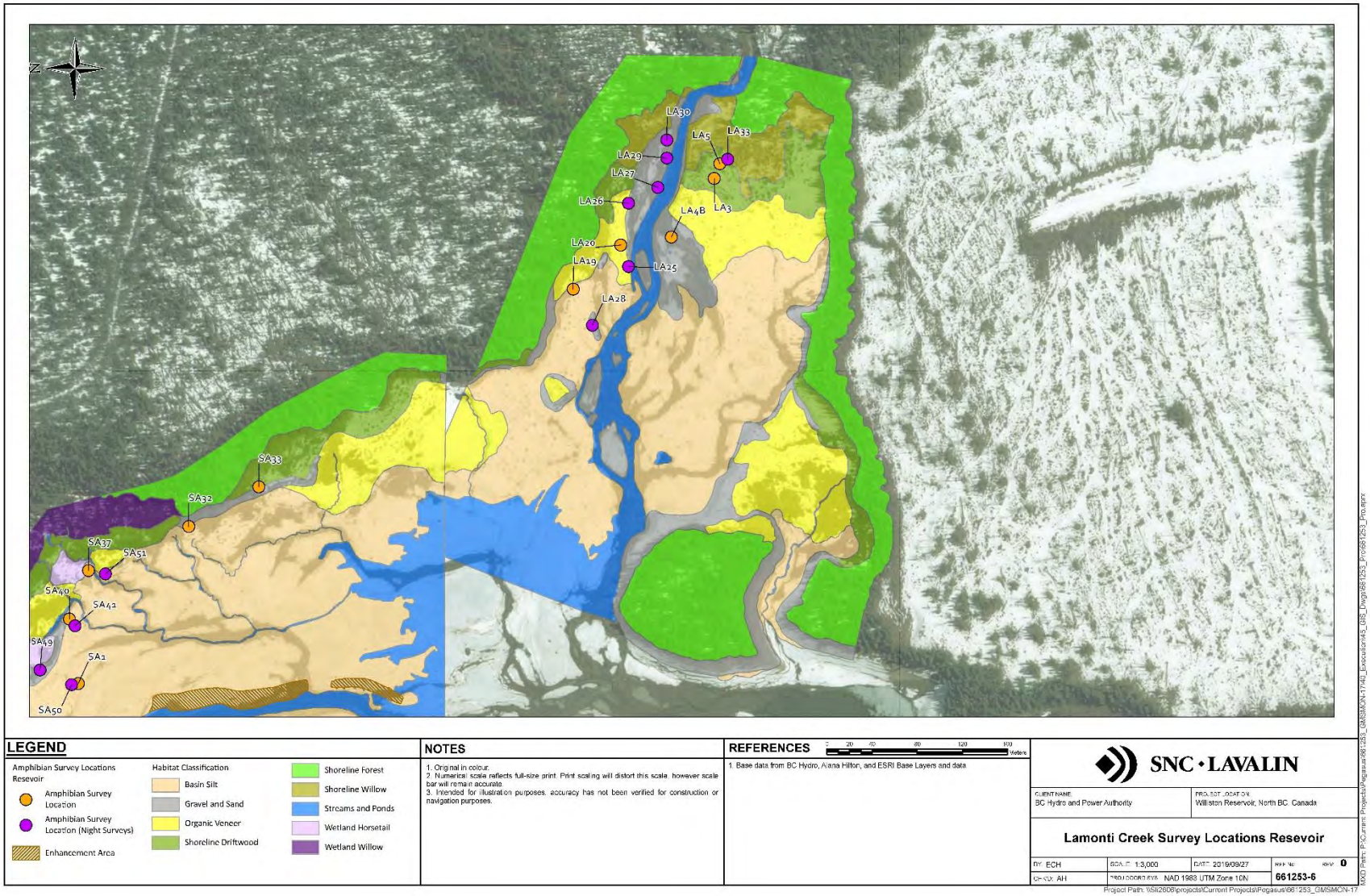

N
LA30
LA5
LA33
LA29
LA27
LA26
LA3
LA4B
LA20
LA19
LA25
LA28
SA33
SA32
SA37
SA51
SA40
SA41
SA49
SA1
SA50
LEGEND
Amphibian Survey Locations Resevoir
Amphibian Survey Location
Amphibian Survey Location (Night Surveys)
Enhancement Area
Habitat Classification
Basin Silt
Gravel and Sand
Organic Veneer
Shoreline Driftwood
Shoreline Forest
Shoreline Willow
Streams and Ponds
Wetland Horsetail
Wetland Willow
NOTES
1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes. accuracy has not been verified for construction or navigation purposes.
REFERENCES
0 20 40 80 120 160 Meters
1. Base data from BC Hydro, Alana Hilton, and ESRI Base Layers and data
SNC·LAVALIN
CLIENT NAME
BC Hydro and Power Authority
PROJECT LOCATION
Williston Reservoir, North BC. Canada
Lamonti Creek Survey Locations Resevoir
BY: ECH
SCALE: 1:3,000
DATE: 2019/09/27
REF No: 661253-6
REV: 0
CHK'D: AH
PROJECTION: NAD 1983 UTM Zone 10N
Project Path: \\Sll26D8\projects\Current Projects\Pegasus\661253_GMSMON-17

Appendix C. Amphibian survey locations at upland locations within 200 m of the edge of the drawdown zone, and dates they were surveyed between 2011 and 2016 of the GMSMON-17 project.

Table C1. Amphibian survey locations at upland locations within 200 m of the edge of the drawdown zone, and dates they were surveyed between 2011 and 2016 of the GMSMON-17 project. Grey-highlighted dates denote night-time surveys.

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
Ole Creek	OA9	405690	6257644	14-Aug-14	n/a	n/a
	OA10	405677	6257740	14-Aug-14	n/a	n/a
	OA16	405781	6257634	n/a	17-Jun-15	n/a
					07-Aug-15	
	OA17	405731	6257647	n/a	17-Jun-15	n/a
					07-Aug-15	
	OA18	405714	6257602	n/a	17-Jun-15	n/a
					07-Aug-15	
	OA19	405746	6257587	n/a	17-Jun-15	23-Jul-16
					07-Aug-15	
	OA20	405782	6257588	n/a	17-Jun-15	n/a
					07-Aug-15	
	OA21	405835	6257599	n/a	17-Jun-15	23-Jul-16
					06-Aug-15	
	OA22	405875	6257536	n/a	17-Jun-15	23-Jul-16
					06-Aug-15	
	OA23	405913	6257543	n/a	17-Jun-15	n/a
					06-Aug-15	
	OA24	405731	6257697	n/a	18-Jun-15	n/a
	OA28	405676	6257617	n/a	18-Jun-15	n/a
					07-Aug-15	
	OA35	405898	6257779	n/a	18-Jun-15	n/a
	OA43	405848	6257595	n/a	n/a	28-May-16
	OA44	405726	6257587	n/a	n/a	29-May-16
	OA45	405838	6257576	n/a	n/a	28-May-16
	OA46	405835	6257540	n/a	n/a	29-May-16
Factor Ross Creek	FA7B	395376	6275687	15-May-14	n/a	n/a
				14-Aug-14		
	FA8	395423	6275738	15-May-14	14-Jun-15	n/a
					05-Aug-15	
	FA17	395390	6275636	n/a	14-Jun-15	n/a
					05-Aug-15	
	FA18	395416	6275696	n/a	14-Jun-15	n/a
	FA19	395430	6275792	n/a	14-Jun-15	n/a
					05-Aug-15	
	FA29	395327	6276703	n/a	14-Jun-15	n/a

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
	FA30	395384	6275734	n/a	14-Jun-15	n/a
	FA31	395330	6275526	n/a	15-Jun-15	n/a
	FA42	395207	6275799	n/a	n/a	30-May-16
Six Mile Creek	SA10	474618	6162912	12-May-14	03-Jun-15	15-May-16
					10-Aug-15	
	SA11	474740	6162851	12-May-14	n/a	n/a
	SA12	474623	6162940	12-May-14	03-Jun-15	n/a
					10-Aug-15	
	SA21	474700	6162854	n/a	03-Jun-15	n/a
	SA22	474740	6162851	n/a	10-Aug-15	29-Jul-16
	SA23	474650	6162992	n/a	03-Jun-15	n/a
					10-Aug-15	
	SA24	474665	6163034	n/a	03-Jun-15	n/a
					10-Aug-15	
	SA25	474895	6162494	n/a	03-Jun-15	n/a
					10-Aug-15	
	SA26	474879	6162563	n/a	03-Jun-15	n/a
					10-Aug-15	
	SA27	474935	6162722	n/a	04-Jun-15	n/a
					10-Aug-15	
	SA28	474933	6162690	n/a	04-Jun-15	n/a
					10-Aug-15	
	SA30	475012	6162706	n/a	09-Aug-15	n/a
	SA34	474616	6162922	n/a	03-Jun-15	n/a
	SA38	474627	6162932	n/a	n/a	29-Jul-16
Lamonti Creek	LA6	475274	6161948	n/a	04-Jun-15	n/a
					09-Aug-15	
	LA7	475313	6161931	n/a	04-Jun-15	n/a
					09-Aug-15	
	LA8	475356	6161920	n/a	04-Jun-15	n/a
					09-Aug-15	
	LA9	475215	6162105	n/a	04-Jun-15	n/a
	LA10	475335	6162013	n/a	04-Jun-15	28-Jul-16
	LA16	475378	6162037	n/a	09-Aug-15	28-Jul-16
	LA17	475247	6162097	n/a	09-Aug-15	n/a
	LA18	475378	6162037	n/a	04-Jun-15	n/a
	LA24	475337	6162026	n/a	n/a	15-May-16
	LA31	475291	6161984	n/a	n/a	27-Jul-16

Appendix D. Amphibian survey locations at upland locations greater than 200 m from the edge of the drawdown zone, and dates they were surveyed between 2011 and 2016 of the GMSMON-17 project.

Table D1. Amphibian stations at upland locations >200 m from the drawdown zone surveyed between 2011 and 2013 of the GMSMON-17 project. All UTMs are in Zone 10.

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2011	2012	2013
Ole Creek	OA2	405393	6257899	16-May-11	Unsure which locations were surveyed, but surveys took place July 3-6, 2012	n/a
	OA3	404730	6257579	16-May-11		n/a
	OA5	404814	6257734	17-Aug-11		n/a
Factor Ross Creek	FA2	395235	6275308	15-May-11		n/a
				15-Aug-11		n/a
	FA3	395352	6275424	15-May-11		n/a
	FA5	395327	6275425	17-May-11		n/a
	FA7	395257	6275292	n/a		spring
Six Mile Creek	SA3	474580	6163254	13-May-11		n/a
				08-Jun-11		n/a
Lamonti Creek	LA1	475712	6161955	13-May-11		n/a
				07-Jun-11		n/a
	LA2	475733	6161929	11-Aug-11		n/a
				12-Aug-11		n/a
	LA4	475754	6161941	n/a		spring

Table D2. Amphibian stations at upland locations >200 m from the drawdown zone surveyed between 2014 and 2016 of the GMSMON-17 project. All UTMs are in Zone 10.

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
Ole Creek	OA12	404740	6257554	15-Aug-14	n/a	n/a
	OA25	405519	6257192	n/a	18-Jun-15	n/a
					07-Aug-15	
	OA26	405700	6257237	n/a	18-Jun-15	n/a
					07-Aug-15	
	OA27	405671	6257466	n/a	18-Jun-15	23-Jul-16
					07-Aug-15	
	OA28	405676	6257617	n/a	18-Jun-15	n/a
					07-Aug-15	
	OA29	405492	6256588	n/a	18-Jun-15	n/a
					07-Aug-15	
	OA30	405339	6256542	n/a	18-Jun-15	n/a
					07-Aug-15	
	OA31	405174	6256614	n/a	18-Jun-15	n/a
					07-Aug-15	

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
	OA33	405914	6256670	n/a	18-Jun-15	n/a
	OA34	404743	6257568	n/a	18-Jun-15	n/a
	OA36	405556	6256336	n/a	18-Jun-15	n/a
	OA37	405963	6256148	n/a	18-Jun-15	n/a
	OA38	406001	6256529	n/a	18-Jun-15	n/a
	OA39	404719	6257578	n/a	18-Jun-15	n/a
	OA40	403820	6256523	n/a	18-Jun-15	n/a
	OA42	406933	6257735	n/a	18-Jun-15	n/a
	OA48	405651	6257384	n/a	n/a	23-Jul-16
	OA49	405673	6257247	n/a	n/a	23-Jul-16
	OA50	405494	6257586	n/a	n/a	29-May-16
	OA51	405355	6257470	n/a	n/a	29-May-16
	OA59	404728	6257548	n/a	n/a	29-May-16
	OA61	405446	6257393	n/a	n/a	23-Jul-16
	OA62	405596	6257585	n/a	n/a	23-Jul-16
	OA63	405387	6257578	n/a	n/a	23-Jul-16
Factor Ross Creek	FA9	395306	6275254	15-May-14	15-Jun-15 04-Aug-15	n/a
	FA20	395290	6275209	n/a	13-Jun-15 04-Aug-15	n/a
	FA21	395294	6275167	n/a	13-Jun-15 04-Aug-15	n/a
	FA22	395237	6275202	n/a	13-Jun-15 04-Aug-15	22-Jul-16
	FA23	395226	6275255	n/a	13-Jun-15 04-Aug-15	22-Jul-16
	FA24	394181	6274126	n/a	15-Jun-15 05-Aug-15	n/a
	FA25	394610	6274588	n/a	15-Jun-15 06-Aug-15	n/a
	FA26	394731	6274776	n/a	15-Jun-15 06-Aug-15	n/a
	FA27	395740	6275009	n/a	15-Jun-15	n/a
	FA28	395293	6275192	n/a	13-Jun-15	n/a
	FA32	395866	6274948	n/a	15-Jun-15 06-Aug-15	n/a
	FA33	394866	6276788	n/a	14-Jun-15 05-Aug-15	n/a
	FA34	393696	6273035	n/a	14-Jun-15	n/a

Site	Location ID	UTM (N)	UTM (E)	Survey Date(s)		
				2014	2015	2016
					05-Aug-15	
					05-Aug-15	
	FA35	396660	6273498	n/a	15-Jun-15	n/a
	FA49	395318	6275506	n/a	n/a	30-May-16
Six Mile Creek	SA14	474564	6163419	16-Jun-14	n/a	n/a
Lamonti Creek	LA3B	475964	6161870	13-May-14	n/a	n/a
				17-Jun-14		
	LA11	475758	6161922	n/a	04-Jun-15	16-May-16
					09-Aug-15	
	LA12	475811	6161907	n/a	04-Jun-15	16-May-16
					09-Aug-15	
	LA13	475827	6161880	n/a	04-Jun-15	16-May-16
					09-Aug-15	
	LA14	475907	6161814	n/a	04-Jun-15	n/a
					09-Aug-15	
	LA15	475970	6161867	n/a	04-Jun-15	16-May-16
					09-Aug-15	
	LA21	475803	6161969	n/a	n/a	16-May-16
	LA22	475787	6161899	n/a	n/a	27-Jul-16
	LA23	475778	6161910	n/a	n/a	27-Jul-16
	LA32	475606	6161709	n/a	n/a	27-Jul-16

Appendix E. Amphibian survey results at survey stations within the drawdown zone that are not likely affected by the enhancement (Ole Creek and Six Mile Creek) and at all drawdown zone survey stations at control sites (Factor Ross Creek and Lamonti Creek).

Although surveys were completed within the drawdown zone at Ole Creek, Factor Ross Creek and Six Mile Creek in 2011, amphibians were only recorded at Ole Creek and Six Mile Creek (Table E1). Seven juvenile Western Toads were observed in mid-May at Ole Creek; that was the only detection in the drawdown zone at that site. These would have been individuals hatched the previous year, as Western Toads breed in mid-spring and juveniles leave breeding ponds in late summer (Corkran and Thoms 1996). No amphibians were recorded at the other survey location at Ole Creek in 2011 (OA4). Two adult Columbia Spotted Frogs and a Wood Frog were observed in early August in the drawdown zone at Six Mile Creek (Table E1). No amphibians were recorded at two other survey locations at Six Mile Creek in 2011 (SA2 and SA6) and at two survey locations at Factor Ross Creek (FA1 and FA4).

In 2012, two Western Toads were observed at Ole Creek, both juveniles and likely young from the previous year. A Western Toad and a juvenile Wood Frog were observed at Factor Ross Creek; this juvenile Wood Frog was likely hatched the previous year. At Six Mile Creek, the only species to be recorded was the Columbia Spotted Frog: adults and tadpoles. The timing of these surveys in early July is consistent with the expected timing of Columbia Spotted Frogs tadpoles in water bodies (Corkran and Thoms 1996). This species was not recorded at any of the other sites in 2012. At Lamonti Creek, a Western Toad was observed. Overall, a similar species assemblage was recorded in 2012 compared to 2011. The only species not recorded in 2012 was the Long-toed Salamander.

In 2013, locations (UTMs) and dates of detections were not recorded. At Six Mile Creek, both survey locations were within the drawdown zone; however, it is not possible to determine where within that area each of the detections were obtained. Six Columbia Spotted Frogs and nine Columbia Spotted Frog tadpoles were recorded within the drawdown zone at Six Mile Creek (Table E1). It is likely that these detections were made at the wetland at SA6, upstream of the enhancement. At Factor Ross Creek and Lamonti Creek, there were two survey locations in 2013: one in the upland and one in the drawdown zone. Amphibians were recorded at Factor Ross and Lamonti Creek in 2013, but it is not clear which station they were recorded at (upland or drawdown zone); therefore the results are listed as unknown in Table E1.

In 2014 (the year implementation occurred), amphibians were detected within the drawdown zone or along the edge of the drawdown zone at all four sites (Table E1). At Ole Creek, one Long-toed Salamander was recorded on a survey visit in mid-May. No amphibians were recorded at the other survey location at Ole Creek in 2014 (OA15). Many amphibians were recorded at Factor Ross Creek, the paired control for Ole Creek: Long-toed Salamanders were recorded six times and Wood Frogs were recorded sixteen times. It is possible that some of these detections were of the same individuals seen on multiple visits to the site. Some of the Wood Frog detections were likely tadpoles (e.g., 8 individuals observed in mid-June), although that information was not provided in the data. Wood Frogs were only recorded on surveys in June and August (not in mid-May), suggesting a slightly later timing of activity for this species. Long-toed Salamanders were recorded on all survey visits. No amphibians were recorded at two other stations at Factor Ross Creek in 2014 (FA15 and FA16). Since survey information is not available for 2014, it is unknown if there was a big difference in survey effort at Factor Ross Creek compared to Ole Creek, or if the differences in the number of amphibians recorded at each site is related to habitat suitability.

No surveys of areas of the drawdown zone away from the proposed enhancement were completed at Six Mile Creek in 2014. At Lamonti Creek, the paired control site for Six Mile Creek, only one amphibian was recorded in the drawdown zone in 2014: a Western Toad was observed in mid-June. No amphibians were recorded at the other survey location in the Lamonti Creek drawdown zone in 2014 (LA5).

In 2015, no amphibians were recorded at five survey locations within the drawdown zone at Ole Creek, including at two night-time surveys (Table E1). Wood Frogs were recorded at Factor Ross Creek, and Western Toads were recorded at Six Mile Creek and Lamonti Creek (Table E1). It's likely that the seven Wood Frogs recorded in mid-June at Factor Ross Creek represent tadpoles. No amphibians were recorded at one survey location in the drawdown zone at Six Mile Creek (SA35).

In 2016, no surveys of areas of the drawdown zone away from the proposed enhancement were completed at Ole Creek. Western Toads and Wood Frogs were recorded at Factor Ross Creek; amphibians were not recorded at eleven other drawdown zone survey locations at Factor Ross Creek, including eight locations that were surveyed at night. Western Toads had not been recorded in the drawdown zone at Factor Ross Creek in previous years of the project. Western Toads were recorded at Six Mile Creek and Lamonti Creek. Amphibians were not recorded at six other drawdown zone survey locations at Six Mile Creek (three of which were night survey locations) and at seven locations at Lamonti Creek (five of which were night survey locations). At Lamonti Creek, three Western Toads were recorded; the same number were recorded in the drawdown zone in 2015.

Table E1. Amphibian survey results from stations within the drawdown zone that are not expected to be affected by the enhancement (Ole Creek and Six Mile Creek) and all stations within the drawdown zone at Factor Ross Creek and Lamonti Creek. Timing (month) for each detection or nil result is listed if the information is available. Cells with light grey shading indicate that no surveys occurred at that location in those years. Location IDs with darker grey shading indicate locations where night surveys occurred. Abbreviations used for species are as follows: CSF = Columbia Spotted Frog, LTS = Long-toed Salamander, unID = unidentified frog, WF = Wood Frog, WT = Western Toad. All UTMs are in Zone 10.

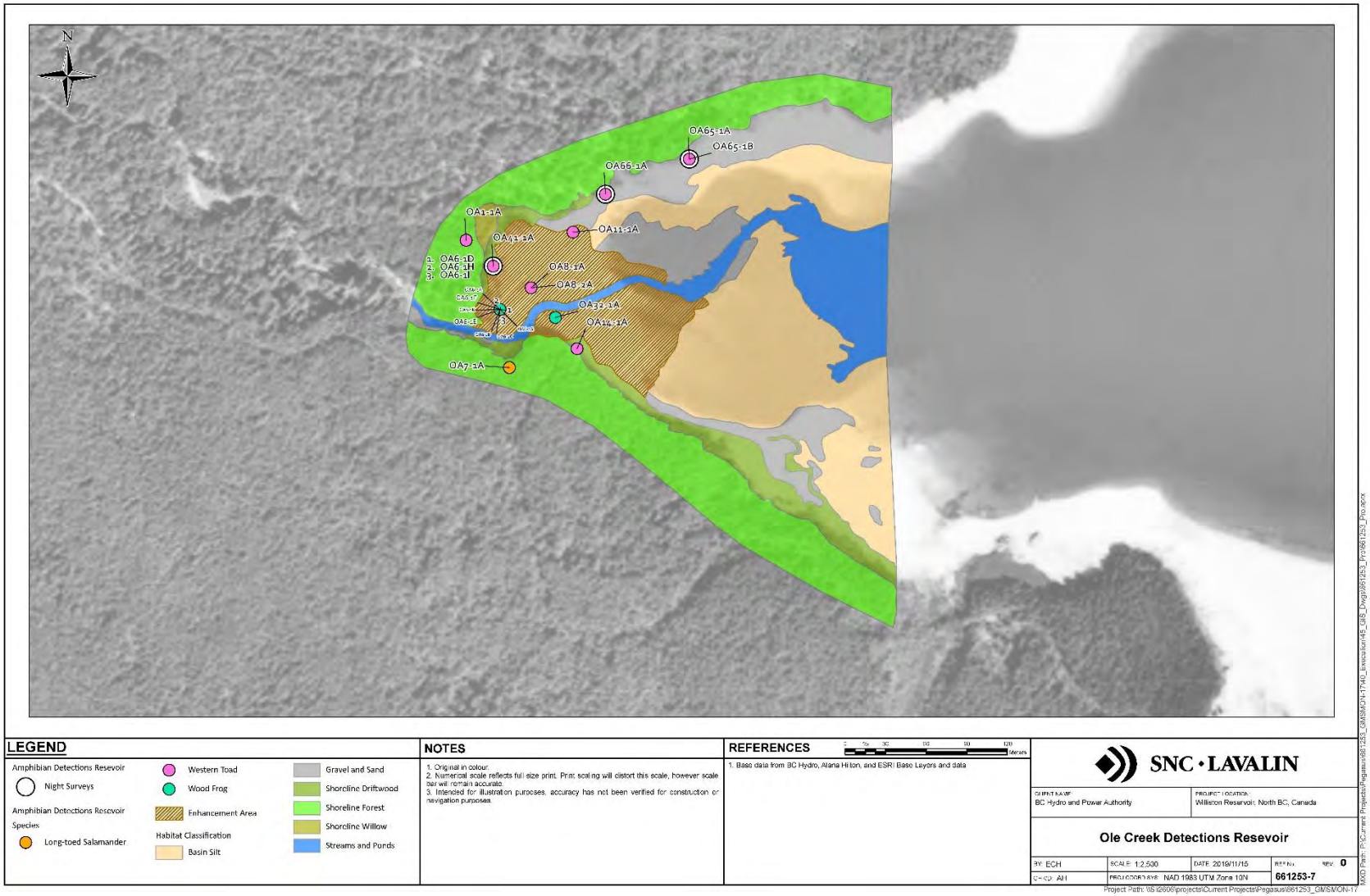
Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
Ole Creek	OA1	405816	6257701	7 juvenile WT (May)					
	OA4	405807	6257698	none (Aug)					
	unknown				2 juvenile WT (July)				
	OA7	405848	6257607				1 LTS (May)	none (June or Aug)	
	OA15	405819	6257632				none (Aug)		
	OA47	405805	6257625					none (May)	
	OA53	406039	6257523					none (May)	
	OA58	405836	6257724					none (May)	
	OA60	406132	6257385					none (May)	
Factor Ross Creek	FA1	395389	6275959	none (May)					
	FA4	395338	6275905	none (May)					
	FA6	395361	6275869			unknown (spring)			
	unknown				1 WT (July); 1 juvenile WF (July)				
	FA6B	395475	6275837				2 LTS (May), 1 LTS (June), 3 LTS (Aug), 1 WF (June & Aug)	none (June), 1 WF (Aug)	none (July)

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
	FA10	395341	6275833				8 WF (June), 2 WF (Aug)	7 WF (June), flooded (Aug)	
	FA11	395524	6275838				1 WF (June)		
	FA12	395508	6275817				1 WF (June)	1 WF (June), 2 WF (Aug)	none (July)
	FA13	395489	6275874				1 WF (Aug)		
	FA14	395373	6275726				1 WF (Aug)		
	FA15	395555	6275876				none (Jun & Aug)		
	FA16	395373	6275726				none (Aug)		
	FA36	395334	6275850						1 WT (May)
	FA37	395337	6275851						1 WF (May)
	FA38	395502	6275836						1 WT (May)
	FA39	395485	6275816						none (May)
	FA40	395457	6275838						none (May)
	FA41	395315	6275953						none (May)
	FA43	395305	6275922						none (May)
	FA44	395492	6275855						none (May)
	FA45	395319	6276057						none (May)
	FA46	395427	6275903						none (May)
	FA47	395314	6275813						none (May)
	FA48	395497	6275832						none (May)
	FA50	395322	6275819						none (Jul)
	FA51	395302	6275939						2 WT (Jul), 1 WF (Jul)
	FA52	395315	6275940						1 WT (Jul)
Six Mile Creek	SA2	474625	6162593	none (May)		unknown (May)			

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
	SA5	474669	6162829	2 adult CSF (Aug), 1 WF (Aug)					
	SA6	474695	6162855	none (May)		6 CSF, 9 CSF tadpoles			
	unknown				3 adult CSF (July), 2 CSF (July), 6 CSF tadpoles (July)				
	SA31	474785	6162619					1 WT (June)	
	SA32	474912	6162446					1 WT (June)	none (May)
	SA33	474947	6162384					1 WT (June)	none (May)
	SA35	474767	6162674					none (Aug)	
	SA37	474873	6162535					1 WT (June)	none (May)
	SA40	474830	6162552						1 WT (May)
	SA41	474824	6162547						1 WT (May)
	SA48	474787	6162594						none (May)
	SA49	474785	6162578						none (May)
	SA51	474870	6162520						none (May)
Lamonti Creek	unknown				1 WT (Aug)				
	LA3	475220	6161980			unknown (May)			
	LA4B	475168	6162018				1 WT (June)		
	LA5	475233	6161975				none (Aug)		
	LA19	475122	6162105					1 WT (June)	none (May)
	LA20	475161	6162063					2 WT (June)	none (May)
	LA25	475142	6162056						none (May)

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
	LA26	475198	6162056						none (May)
	LA27	475212	6162030						none (May)
	LA28	475090	6162088						none (May)
	LA29	475238	6162022						none (May)
	LA30	475254	6162022						1 WT (May)
	LA33	475237	6161968						1 WT (Jul)
	LA34	474791	6162648						1 WT (May)

Appendix F. Maps of amphibian locations in the drawdown zone at all four sites between 2011 – 2016.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OA65-1B
OA66-1A
OA1-1A
OA11-1A
OA11-1A
OA6-1D
OA6-1H
OA6-1I
OA8-1A
OA8-1A
OA12-1A
OA11-1A
OA7-1A
LEGEND
Amphibian Detections Resevoir
Night Surveys
Amphibian Detections Resevoir
Species
Long-toed Salamander
Western Toad
Wood Frog
Enhancement Area
Habitat Classification
Basin Silt
Gravel and Sand
Shoreline Driftwood
Shoreline Forest
Shoreline Willow
Streams and Ponds
NOTES
1. Original in colour.
2. Numerical scale reflects full size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes. accuracy has not been verified for construction or navigation purposes.
REFERENCES
1. Base data from BC Hydro, Alana Hilton, and ESRI Base Layers and data
Meters
SNC·LAVALIN
CLIENT NAME:
BC Hydro and Power Authority
PROJECT LOCATION:
Williston Reservoir, North BC, Canada
Ole Creek Detections Resevoir
BY: ECH
SCALE: 1:2,500
DATE: 2019/11/15
REF No.
661253-7
REV. 0
CHKD: AH
PROJECTION & DATUM: NAD 1983 UTM Zone 10N
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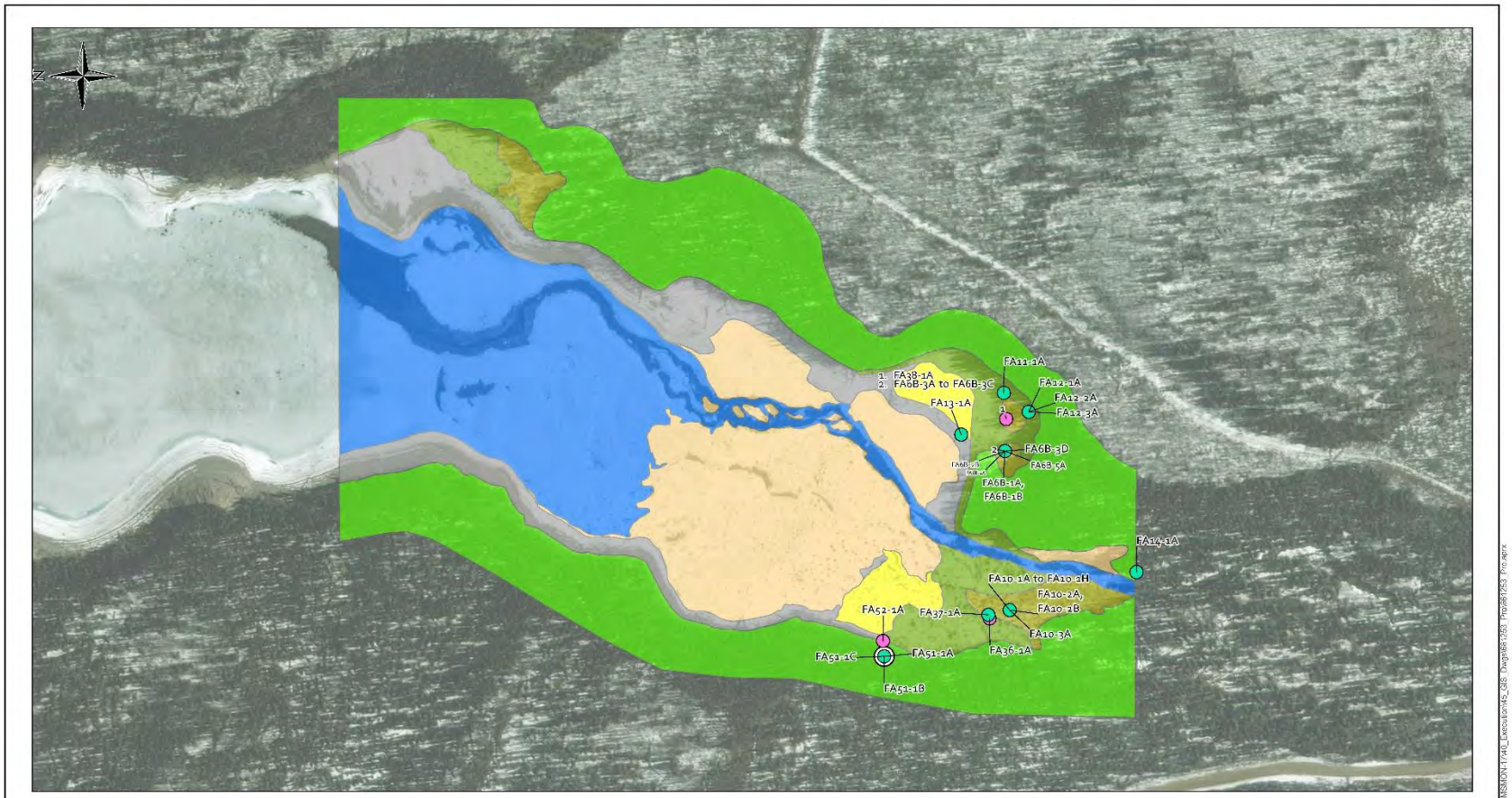

LEGEND

Amphibian Detections Resevoir
- Night Surveys

Amphibian Detections Resevoir Species
- Long-toed Salamander
- Western Toad
- Wood Frog

Habitat Classification
- Basin Silt
- Gravel and Sand
- Organic Veneer
- Shoreline Driftwood
- Shoreline Forest
- Shoreline Willow
- Streams and Ponds

NOTES

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.

REFERENCES

0 20 40 80 120 160 Meters

1. Base data from BC Hydro, Alana Hilton, and ESRI Base Layers and data

SNC·LAVALIN

CLIENT NAME: BC Hydro and Power Authority

PROJECT LOCATION: Williston Reservoir, North BC, Canada

Factor Ross Creek Detections Resevoir

BY: ECH	SCALE: 1:3,150	DATE: 2019/09/27	REF No: 661253-1	REV: 0
CHKD: AH	PROJ COORD SYS: NAD 1983 UTM Zone 10N			

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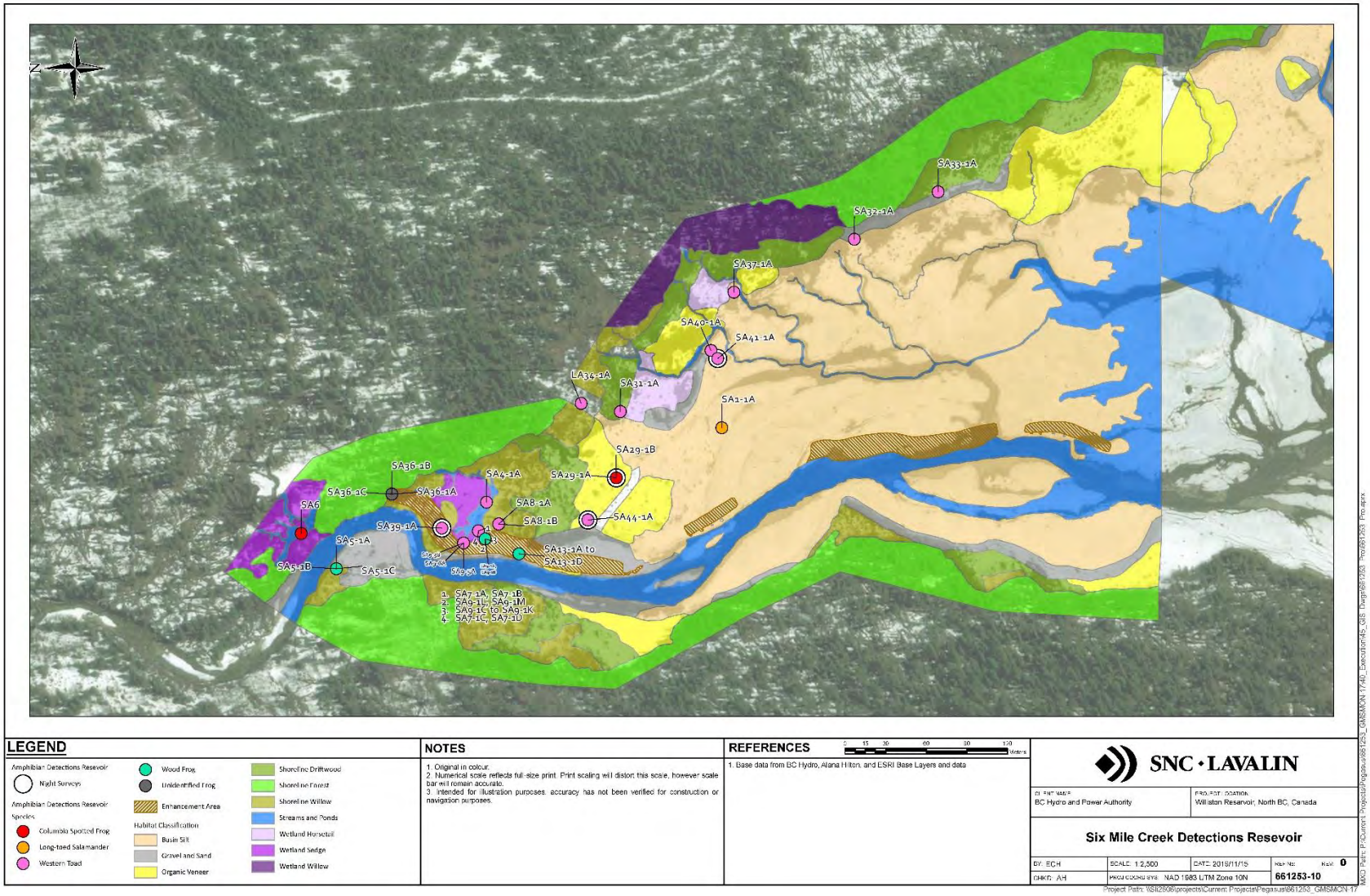

LEGEND

Amphibian Detections Reservoir
- Night Surveys

Amphibian Detections Reservoir Species
- Columbia Spotted Frog
- Long-toed Salamander
- Western Toad
- Wood Frog
- Unidentified Frog
- Enhancement Area

Habitat Classification
- Basin Silt
- Gravel and Sand
- Organic Veneer
- Shoreline Driftwood
- Shoreline Forest
- Shoreline Willow
- Streams and Ponds
- Wetland Horsetail
- Wetland Sedge
- Wetland Willow

NOTES

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes: accuracy has not been verified for construction or navigation purposes.

REFERENCES

0 15 30 60 90 120 Meters

1. Base data from BC Hydro, Alana Hilton, and ESRI Base Layers and data

SNC·LAVALIN

CLIENT NAME: BC Hydro and Power Authority

PROJECT LOCATION: Williston Reservoir, North BC, Canada

Six Mile Creek Detections Resevoir

BY: ECH	SCALE: 1:2,500	DATE: 2019/11/15	REF No:	REV: 0
CHKD: AH	PROJECTION SYS: NAD 1983 UTM Zone 10N		661253-10	

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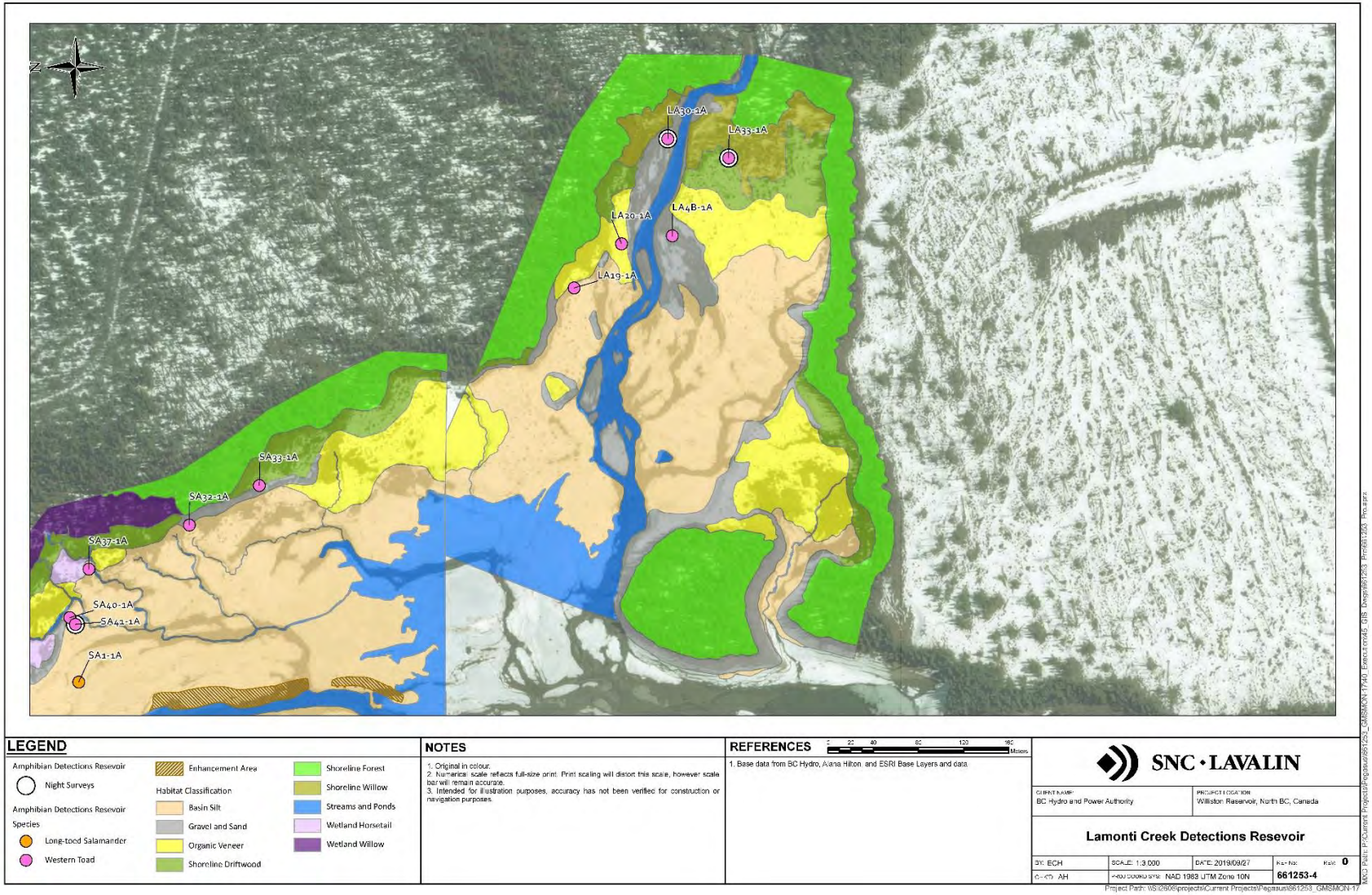
N
LA30-1A
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LA4B-1A
LA19-1A
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SA32-1A
SA37-1A
SA40-1A
SA41-1A
SA1-1A
LEGEND
Amphibian Detections Reservoir
Night Surveys
Amphibian Detections Reservoir Species
Long-toed Salamander
Western Toad
Enhancement Area
Habitat Classification
Basin Silt
Gravel and Sand
Organic Veneer
Shoreline Driftwood
Shoreline Forest
Shoreline Willow
Streams and Ponds
Wetland Horsetail
Wetland Willow
NOTES
1. Original in colour.
2. Numerical scale refects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.
REFERENCES
1. Base data from BC Hydro, Alana Hilton and ESRI Base Layers and data.
Meters
SNC·LAVALIN
CLIENT NAME: BC Hydro and Power Authority
PROJECT LOCATION: Williston Reservoir, North BC, Canada
Lamonti Creek Detections Resevoir
BY: ECH
SCALE: 1:3,000
DATE: 2019/09/27
REV: 0
CHK'D: AH
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661253-4
Project Path: \\S\2606\projects\Current Projects\Pegasus\661253_GMSMON-17

Appendix G. Amphibian survey results at upland survey stations <200 m from the drawdown zone in 2014 – 2016, and at upland survey stations >200 m from the drawdown zone between 2011 – 2016.

Amphibian Results at Upland Locations <200 m from the Drawdown Zone

The results of amphibian surveys completed in upland areas <200 m from the drawdown zone in 2014 are shown in Table G1. The species assemblage at each site was different. Three Western Toads were detected at two different locations at Ole Creek in mid-August. Two Long-toed Salamanders were recorded in mid-May at two locations at Factor Ross Creek. A Wood Frog was recorded at one of the two locations at Factor Ross Creek in mid-August. At Six Mile Creek, two Columbia Spotted Frogs were recorded at two locations in mid-May, and no amphibians were recorded at a third location. Survey effort for Lamonti Creek in 2014 is unknown, and it is possible that no surveys were completed within this distance of the reservoir at Lamonti Creek.

In 2015, two Long-toed Salamanders and two Western Toads were recorded at Ole Creek in mid-June (Table G1). Amphibians were not recorded at seven other survey locations at Ole Creek, several of which were sampled more than once. Amphibians were not recorded in August at three locations at Ole Creek with a detection during the June surveys. At Factor Ross Creek, three Long-toed Salamanders and a Wood Frog were recorded in mid-June 2015; this same species assemblage was recorded at this site in 2014, although at different survey locations. No amphibians were recorded at four other survey locations at Factor Ross Creek, three of which were surveyed twice in 2015. At Six Mile Creek, a Western Toad was recorded in early June, and Columbia Spotted Frogs and Western Toads were recorded in mid-August. It is possible that the Western Toads recorded in mid-August (6 detections) were juveniles; these detections were made during a night-time survey. In 2014, no Western Toads were recorded in upland areas <200 m from the drawdown zone at Six Mile Creek, but survey timing at that site was mid-May in 2014 compared to early June and mid-August in 2015. No amphibians were recorded at nine other survey locations at Six Mile Creek, eight of which were surveyed twice in 2015. At Lamonti Creek, three Western Toads and a Wood Frog were recorded in early June, and a Columbia Spotted Frog was recorded in mid-August. No amphibians were recorded at five other survey locations at Lamonti Creek, three of which were surveyed twice in 2015. No surveys were completed in upland areas <200 m from the drawdown zone at Lamonti Creek in 2014 for comparison.

Fewer surveys were completed in upland areas <200 m from the drawdown zone in 2016 compared to 2015 (Appendix C). The number of amphibians recorded in 2016 was reduced compared to 2014. Seven stations were completed at Ole Creek, one station was completed at Factor Ross Creek, and three stations were completed at Six Mile Creek in 2016 (Appendix C). No amphibians were recorded at Ole Creek, Factor Ross Creek or Six Mile Creek at survey locations <200 m from the drawdown zone (Table G1). Two Western Toads were recorded at Lamonti Creek in late July; no amphibians were recorded at two other survey locations at Lamonti Creek. In 2015, Wood Frogs and a Columbia Spotted Frog were also recorded in upland areas <200 m from the drawdown zone at Lamonti Creek.

Table G1. Amphibian survey results from upland stations <200 m from the drawdown zone between 2014 and 2016. Timing (month) for each detection or nil result is listed if the information is available. Cells with light grey shading indicate that no surveys occurred at that location in those years. Location IDs with darker grey shading indicate locations where night surveys occurred. Abbreviations used for species are as follows: CSF = Columbia Spotted Frog, LTS = Long-toed Salamander, unID = unidentified frog, WF = Wood Frog, WT = Western Toad. All UTMs are in Zone 10.

Site	Location ID	UTM N	UTM E	Implementation	Post-enhancement	
				2014	2015	2016
Ole Creek	OA9	405690	6257644	1 WT (Aug)		
	OA10	405677	6257740	2 WT (Aug)		
	OA16	405781	6257634		none (Jun & Aug)	
	OA17	405731	6257647		none (Jun & Aug)	
	OA18	405714	6257602		none (Jun & Aug)	
	OA19	405746	6257587		1 LTS (Jun); none (Aug)	none (Jul)
	OA20	405782	6257588		none (Jun & Aug)	
	OA21	405835	6257599		1 LTS (Jun); none (Aug)	none (Jul)
	OA22	405875	6257536		1 WT (Jun); none (Aug)	none (Jul)
	OA23	405913	6257543		none (Jun & Aug)	
	OA24	405731	6257697		none (Jun)	
	OA28	405676	6257617		none (Jun & Aug)	
	OA35	405898	6257779		1 WT (Jun)	
	OA43	405848	6257595			none (May)
	OA44	405726	6257587			none (May)
	OA45	405838	6257576			none (May)
	OA46	405835	6257540			none (May)
Factor Ross Creek	FA7B	395376	6275687	1 LTS (May), 1 WF (Aug)		
	FA8	395423	6275738	1 LTS (May)	none (Jun & Aug)	
	FA17	395390	6275636		none (Jun & Aug)	
	FA18	395416	6275696		none (Jun)	
	FA19	395430	6275792		none (Jun & Aug)	
	FA29	395327	6276703		1 WF (Jun)	
	FA30	395384	6275734		2 LTS (Jun)	

Site	Location ID	UTM N	UTM E	Implementation	Post-enhancement	
				2014	2015	2016
	FA31	395330	6275526		1 LTS (Jun)	
	FA42	395207	6275799			none (May)
Six Mile Creek	SA10	474618	6162912	2 CSF (May)	none (Jun & Aug)	none (May)
	SA11	474740	6162851	2 CSF (May)		
	SA12	474623	6162940	none (May)	none (Jun & Aug)	
	SA21	474700	6162854		none (Jun)	
	SA22	474740	6162851		1 CSF (Aug), 1 unID (Aug)	none (Jul)
	SA23	474650	6162992		none (Jun & Aug)	
	SA24	474665	6163034		none (Jun & Aug)	
	SA25	474895	6162494		none (Jun & Aug)	
	SA26	474879	6162563		none (Jun & Aug)	
	SA27	474935	6162722		none (Jun & Aug)	
	SA28	474933	6162690		none (Jun & Aug)	
	SA30	475012	6162706		6 WT (Aug)	
	SA34	474616	6162922		1 WT (Jun)	
	SA38	474627	6162932			none (Jul)
Lamonti Creek	LA6	475274	6161948		none (Jun & Aug)	
	LA7	475313	6161931		none (Jun & Aug)	
	LA8	475356	6161920		none (Jun & Aug)	
	LA9	475215	6162105		none (Jun)	
	LA10	475335	6162013		3 WT (Jun)	1 WT (Jul)
	LA16	475378	6162037		1 CSF (Aug)	none (Jul)
	LA17	475247	6162097		none (Aug)	
	LA18	475378	6162037		1 WF (Jun)	
	LA24	475337	6162026			none (May)
	LA31	475291	6161984			1 WT (Jul)

Amphibian Results at Upland Locations >200 m from the Drawdown Zone

In 2011, amphibians were detected at three of the four upland sites surveyed that were >200 m from the drawdown zone (Table G2). At Ole Creek, a Wood Frog egg mass was recorded in mid-May, and a Western Toad adult was recorded in mid-August. Wood Frogs lay eggs between late February and March in more southern areas, with eggs hatching by April (Corkran and Thoms 1996). The later egg observation date in 2011 likely reflects the later arrival of suitable temperatures for amphibian activity at this northern location. No amphibians were recorded at two other upland survey locations at Ole Creek. At Factor Ross Creek, an adult Western Toad was observed in mid-May; no amphibians were recorded at two other upland survey locations at Factor Ross Creek. No amphibians were recorded at an upland survey location at Six Mile Creek which was surveyed twice in 2011. At Lamonti Creek, a juvenile Western Toad was observed in mid-August. This timing is consistent with the juvenile toad being a young of the current year. No amphibians were recorded at another upland survey location at Lamonti Creek which was surveyed twice in 2011.

In 2014, a Western Toad and a Wood Frog were recorded in the same survey location in mid-August at Ole Creek (Table G2). At Factor Ross Creek, two Long-toed Salamanders were recorded in mid-May. At Six Mile Creek, a single Western Toad was recorded in mid-June. At Lamonti Creek, and a Western Toad was recorded in mid-May, and a Western Toad and a Columbia Spotted Frog were recorded at the same location in mid-June. This detection of a Columbia Spotted Frog is the first of this species outside of Six Mile Creek since surveys began in 2011.

In 2015, many survey stations were completed in upland areas >200 m from the drawdown zone at three of the sites (Appendix D), and many amphibians were recorded (Table G2). At Ole Creek, Western Toads were recorded at two locations in mid-June, Wood Frogs and Columbia Spotted Frogs were also recorded at Ole Creek in mid-June, including four Columbia Spotted Frogs that may have been tadpoles. No amphibians were recorded at five other upland survey locations at Ole Creek, all of which were surveyed twice in 2015.

At Factor Ross Creek, five Long-toed Salamanders were recorded in upland areas >200 m from the drawdown zone in mid-June of 2015; it's possible that some of these detections (e.g., three detections at FA23) represent larvae. Many Western Toads were recorded in upland areas at Factor Ross Creek, including three locations (FA32, FA34, FA35) at which multiple detections were made in mid-June, likely representing tadpoles. One of these sites (FA34) was resurveyed in early August and seven Western Toads were recorded; these likely represent recently metamorphosed juveniles. Surveys were completed at FA32 in mid-August, but no Western Toads were recorded. Many Columbia Spotted Frogs were recorded in upland areas at Factor Ross Creek in 2015. At survey location FA32, one Columbia Spotted Frog was recorded in both mid-June and early August. At survey locations FA33 and FA34, multiple Columbia Spotted Frogs were recorded in mid-June, likely representing tadpoles. Many Columbia Spotted Frogs were still recorded at survey location FA34 in mid-August. Many unidentified frogs were also recorded in upland areas at Factor Ross Creek, many of which were likely tadpoles (e.g., records at FA32 and FA34 in June). No amphibians were recorded at seven other upland survey locations at Factor Ross Creek, six of which were surveyed twice in 2015.

No surveys were completed in 2015 in upland areas >200 m from the drawdown zone at Six Mile Creek. At Lamonti Creek, two Western Toads and one Long-toed Salamander were recorded in upland areas >200 m from the drawdown zone in early June 2015. No amphibians were recorded at two other upland survey locations at Lamonti Creek, both of which were surveyed twice in 2015. No amphibians were recorded in August surveys at three upland survey locations at Lamonti Creek where amphibians were detected in June.

In 2016, only one amphibian was recorded in an upland area >200 m from the drawdown zone in 2016: a single Western Toad at Lamonti Creek (Table G2). In comparison to results from 2014, when fewer surveys were completed in upland areas >200 m from the drawdown zone, this is a reduction in the number of individuals and species richness at each site. Amphibians were not recorded at eight upland locations at Ole Creek, one upland location at Factor Ross Creek, and seven upland locations at Lamonti Creek in 2016. No surveys were completed in upland locations >200 m from the drawdown zone at Six Mile Creek in 2016.

Table G2. Amphibian survey results from upland stations >200 m from the drawdown zone between 2011 and 2016. Timing (month) for each detection and nil result is listed if the information is available. Cells with light grey shading indicate that no surveys occurred at that location in those years. Abbreviations used for species are as follows: CSF = Columbia Spotted Frog, LTS = Long-toed Salamander, unID = unidentified frog, WF = Wood Frog, WT = Western Toad. All UTMs are in Zone 10.

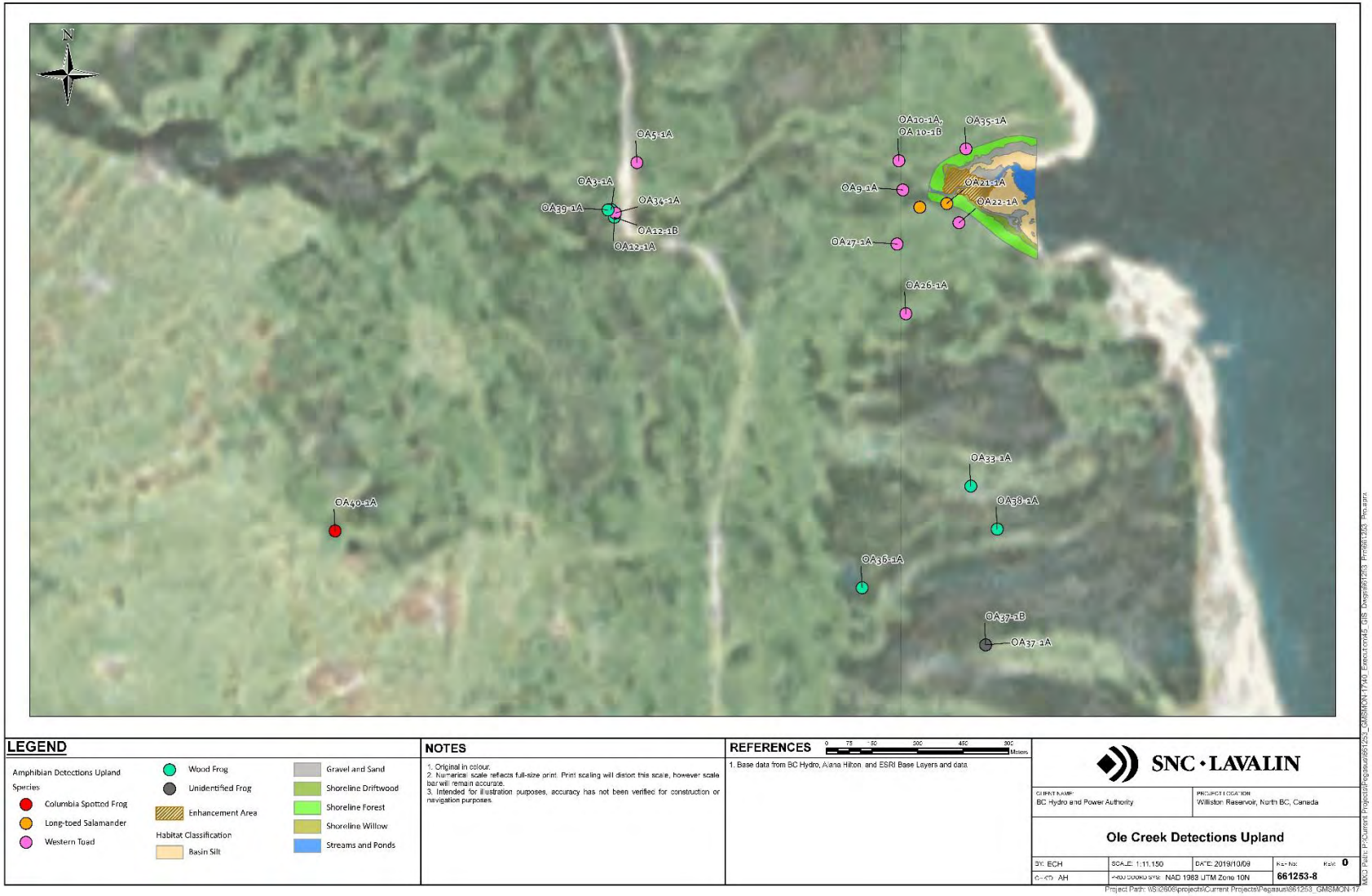
Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
Ole Creek	OA2	405393	6257899	none (May)					
	OA3	404730	6257579	1 WF egg mass (May), 1 adult WT (Aug)					
	OA5	404814	6257734	none (Aug)					
	OA12	404740	6257554				1 WT (Aug), 1 WF (Aug)		
	OA25	405519	6257192					none (Jun & Aug)	
	OA26	405700	6257237					none (Jun); 1 WT (Aug)	
	OA27	405671	6257466					1 WT (Jun); none (Aug)	
	OA28	405676	6257617					none (Jun & Aug)	
	OA29	405492	6256588					none (Jun & Aug)	
	OA30	405339	6256542					none (Jun & Aug)	
	OA31	405174	6256614					none (Jun & Aug)	
	OA33	405914	6256670					1 WF (Jun)	
	OA34	404743	6257568					1 WT (Jun)	
	OA36	405556	6256336					1 WF (Jun)	
	OA37	405963	6256148					1 WF (Jun), 1 unID (Jun)	
	OA38	406001	6256529					1 WF (Jun)	
	OA39	404719	6257578					2 WF (Jun)	

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
	OA40	403820	6256523					4 CSF (Jun)	
	OA48	405651	6257384						none (Jul)
	OA49	405673	6257247						none (Jul)
	OA50	405494	6257586						none (May)
	OA51	405355	6257470						none (May)
	OA59	404728	6257548						none (May)
	OA61	405446	6257393						none (Jul)
	OA62	405596	6257585						none (Jul)
	OA63	405387	6257578						none (Jul)
Factor Ross Creek	FA2	395235	6275308	none (May & Aug)					
	FA3	395352	6275424	none (May)					
	FA5	395327	6275425	1 adult WT (May)					
	FA7	395257	6275292			none (spring)			
	FA9	395306	6275254				2 LTS (May)	none (Jun & Aug)	
	FA20	395290	6275209					none (Jun & Aug)	
	FA21	395294	6275167					none (Jun & Aug)	
	FA22	395237	6275202					1 LTS (Jun); none (Aug)	
	FA23	395226	6275255					3 LTS (Jun); none (Aug)	
	FA24	394181	6274126					none (Jun & Aug)	
	FA25	394610	6274588					none (Jun & Aug)	
	FA26	394731	6274776					none (Jun & Aug)	
	FA27	395740	6275009					none (Jun)	
	FA28	395293	65275192					1 WF (Jun)	

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
	FA32	395866	6274948					1 LTS (Jun), 6 WT (Jun), 1 CSF (Jun), 1 WF (Jun), 5 unID (Jun), 1 CSF (Aug), 1 WF (Aug)	
	FA33	394866	6276788					3 CSF (Jun), 2 unID (Aug)	
	FA34	393805	6273005					19 WT (Jun), 15 CSF (Jun), 11 WF (Jun), 10 unID (Jun), 7 WT (Aug), 18 CSF (Aug)	
	FA35	396660	6273498					8 WT (Jun), 1 unID (Jun)	
	FA49	395318	6275506						none (May)
Six Mile Creek	SA3	474580	6163254	none (May & Jun)					
	SA14	474564	6163419				1 WT (Jun)		
Lamonti Creek	LA1	475712	6161955	none (May & Jun)					
	LA2	475733	6161929	1 juv. WT (Aug)					
	LA3B	475964	6161870				1 WT (May), 1 WT (Jun), 1 CSF (Jun)		
	LA4	475754	6161941			none (spring)			
	LA11	475758	6161922					1 WT (Jun); none (Aug)	none (May)
	LA12	475811	6161907					1 LTS (Jun); none (Aug)	none (May)

Site	Location ID	UTM N	UTM E	Pre-enhancement			Implementation	Post-enhancement	
				2011	2012	2013	2014	2015	2016
	LA13	475827	6161880					none (Jun & Aug)	none (May)
	LA14	475907	6161814					none (Jun & Aug)	
	LA15	475970	6161867					1 WT (Jun); none (Aug)	none (May)
	LA21	475803	6161969						none (May)
	LA22	475787	6161899						none (Jul)
	LA23	475778	6161910						none (Jul)
	LA32	475606	6161709						1 WT (Jul)

Appendix H. Maps of amphibian locations in upland areas at all four sites between 2011 – 2016.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OA34-1A
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OA22-1A
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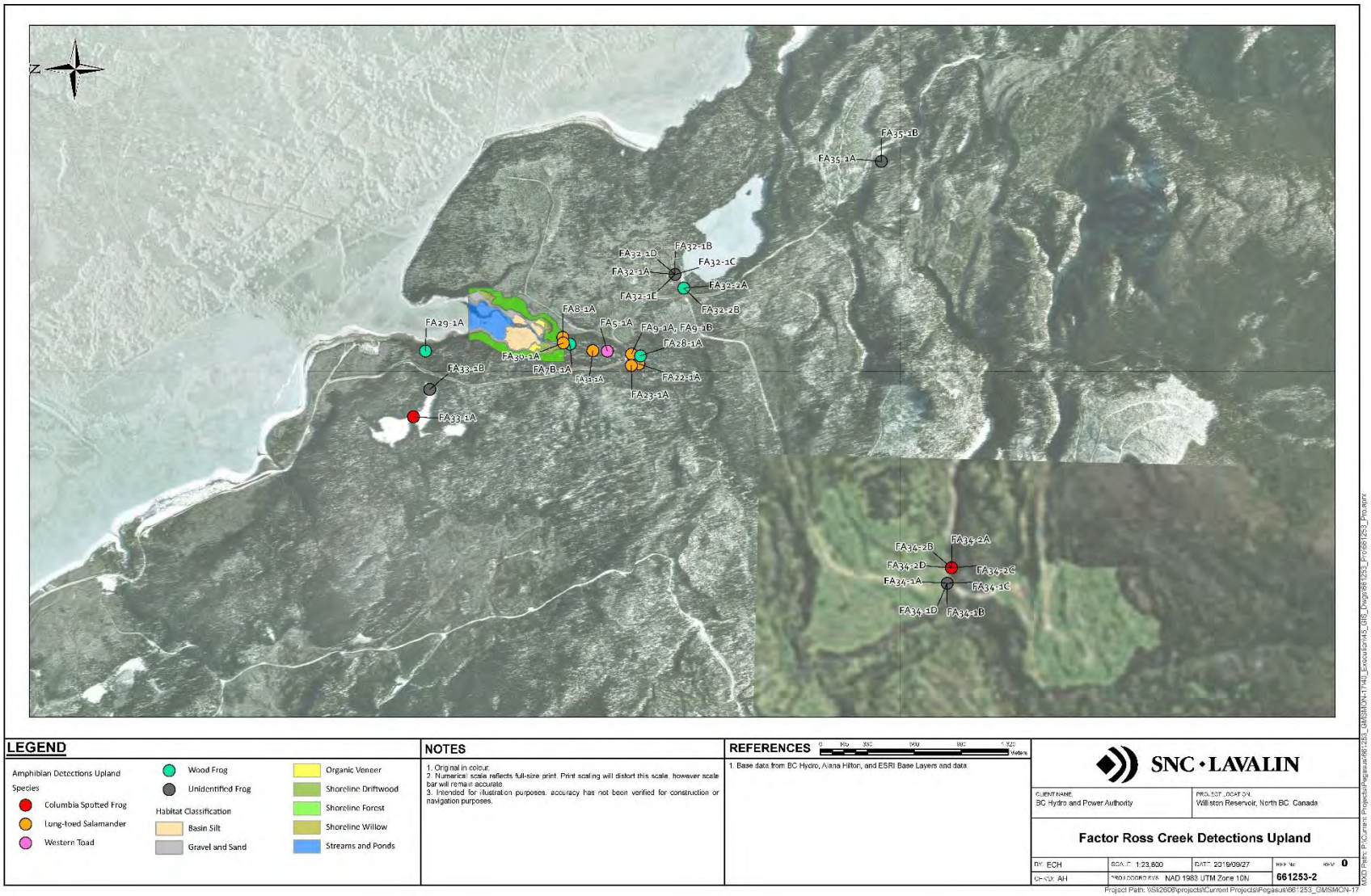
OA21-1A
OA22-1A
OA27-1A
OA26-1A
OA33-1A
OA38-1A
OA40-1A
OA36-1A
OA37-1B
OA37-1A
LEGEND
Amphibian Detections Upland
Species
Columbia Spotted Frog
Long-toed Salamander
Western Toad
Wood Frog
Unidentified Frog
Enhancement Area
Habitat Classification
Basin Silt
Gravel and Sand
Shoreline Driftwood
Shoreline Forest
Shoreline Willow
Streams and Ponds
NOTES
1. Original in colour.
2. Numerical scale refracts full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.
REFERENCES
1. Base data from BC Hydro, Alana Hilton and ESRI Base Layers and data
SNC·LAVALIN
CLIENT NAME:
BC Hydro and Power Authority
PROJECT LOCATION:
Williston Reservoir, North BC, Canada
Ole Creek Detections Upland
DR: ECH
CK: AH
SCALE: 1:11,150
HORIZONTAL SYS: NAD 1983 UTM Zone 10N
DATE: 2019/10/09
PROJECT No: 661253-8
REV: 0



LEGEND

Amphibian Detections Upland

Species

- Columbia Spotted Frog
- Long-toed Salamander
- Western Toad
- Wood Frog
- Unidentified Frog

Habitat Classification

- Basin Silt
- Gravel and Sand
- Organic Veneer
- Shoreline Driftwood
- Shoreline Forest
- Shoreline Willow
- Streams and Ponds

NOTES

1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes. accuracy has not been verified for construction or navigation purposes.

REFERENCES

0 150 300 600 900 1,200 Meters

1. Base data from BC Hydro, Alana Hilton, and ESRI Base Layers and data

SNC·LAVALIN

CLIENT NAME: BC Hydro and Power Authority

PROJECT LOCATION: Williston Reservoir, North BC Canada

Factor Ross Creek Detections Upland

BY: ECH	SCALE: 1:23,600	DATE: 2019/09/27	REF No.	REV: 0
CHK: AH	PROJECTION: NAD 1983 UTM Zone 10N		661253-2	

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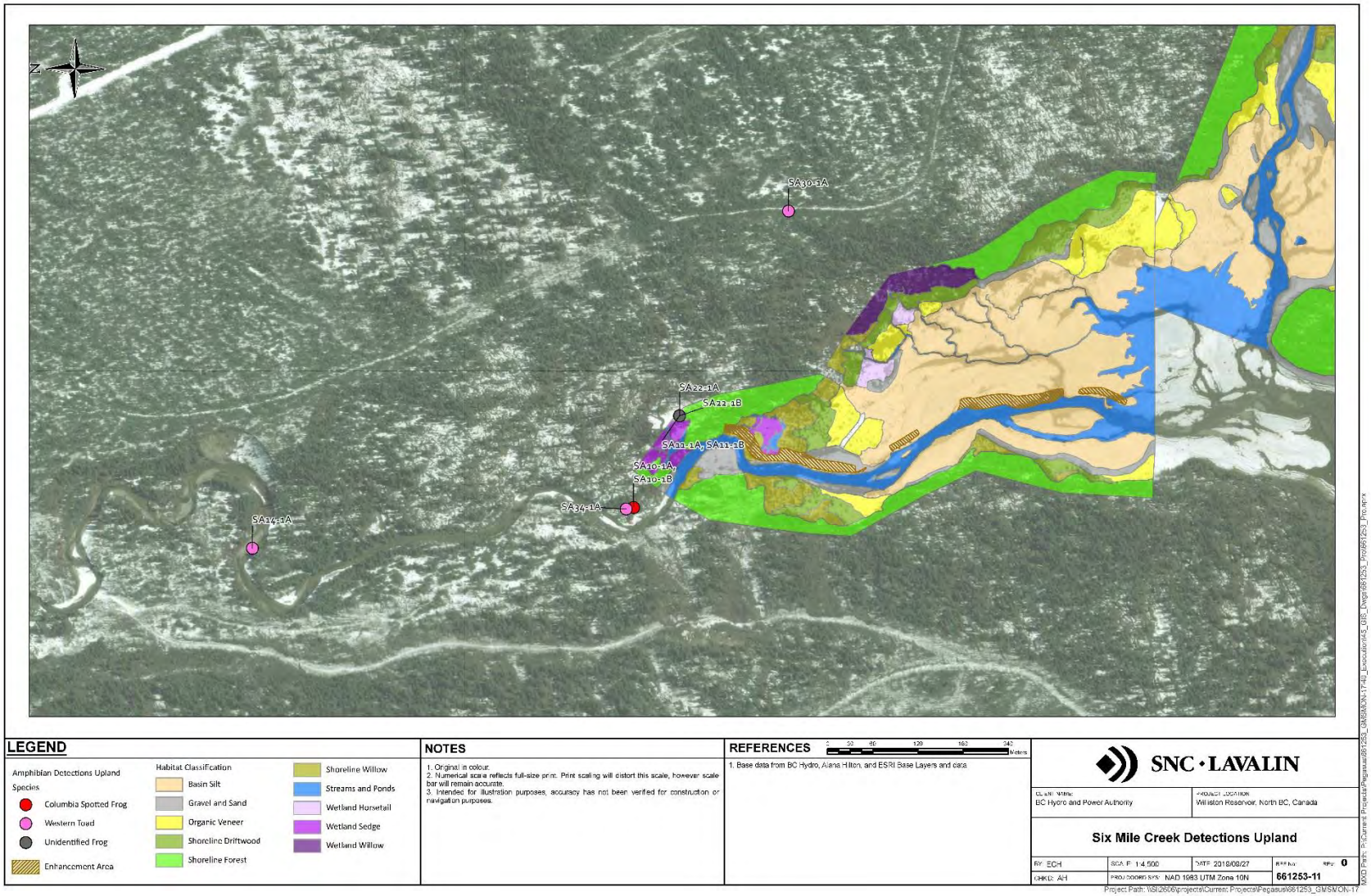
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SA22-1A
SA22-1B
SA33-1A, SA11-1B
SA10-1A
SA10-1B
SA34-1A
SA34-1A
LEGEND
Amphibian Detections Upland
Species
Columbia Spotted Frog
Western Toad
Unidentified Frog
Enhancement Area
Habitat Classification
Basin Silt
Gravel and Sand
Organic Veneer
Shoreline Driftwood
Shoreline Forest
Shoreline Willow
Streams and Ponds
Wetland Horsetail
Wetland Sedge
Wetland Willow
NOTES
1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.
REFERENCES
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Meters
1. Base data from BC Hydro, Alana Hilton, and ESRI Base Layers and data.
SNC·LAVALIN
Client: Name
BC Hydro and Power Authority
Project Location
Williston Reservoir, North BC, Canada
Six Mile Creek Detections Upland
BY: ECH
SCALE: 1:4,500
DATE: 2019/09/27
REF No.
REV: 0
CHKD: AH
PROJECTION SYS: NAD 1983 UTM Zone 10N
661253-11
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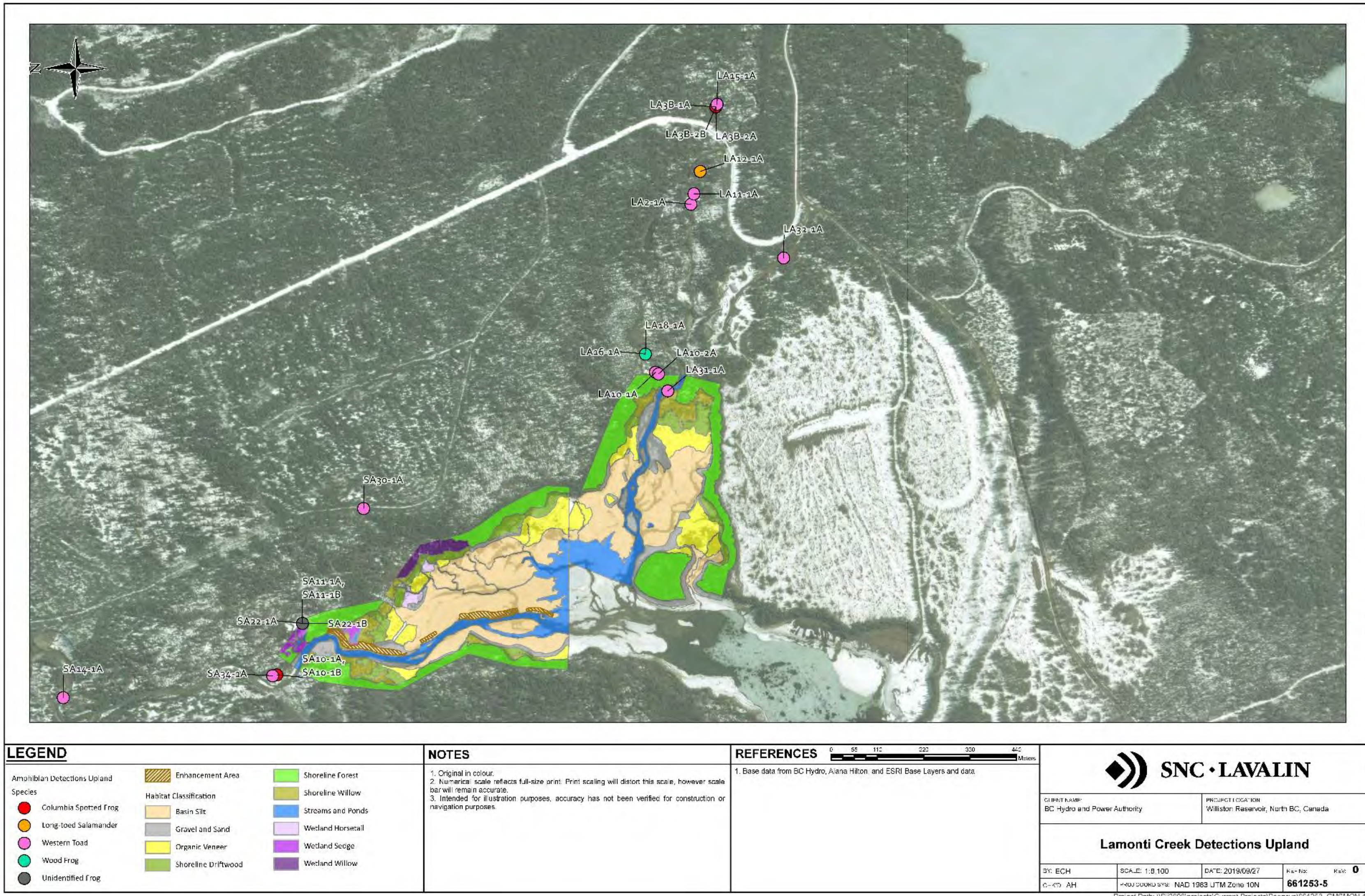
LA15-1A
LA3B-1A
LA3B-2B
LA3B-2A
LA12-1A
LA11-1A
LA2-1A
LA32-1A
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LA26-1A
LA10-2A
LA31-1A
LA10-1A
SA30-1A
SA11-1A,
SA11-1B
SA22-1A
SA22-1B
SA10-1A,
SA10-1B
SA14-1A
SA34-1A
LEGEND
Amphibian Detections Upland
Species
Columbia Spotted Frog
Long-toed Salamander
Western Toad
Wood Frog
Unidentified Frog
Enhancement Area
Habitat Classification
Basin Silt
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Shoreline Forest
Shoreline Willow
Streams and Ponds
Wetland Horsetail
Wetland Sedge
Wetland Willow
NOTES
1. Original in colour.
2. Numerical scale reflects full-size print. Print scaling will distort this scale, however scale bar will remain accurate.
3. Intended for illustration purposes, accuracy has not been verified for construction or navigation purposes.
REFERENCES
1. Base data from BC Hydro, Alana Hilton and ESRI Base Layers and data.
SNC·LAVALIN
BC Hydro and Power Authority
Williston Reservoir, North BC, Canada
Lamonti Creek Detections Upland
BY: ECH
SCALE: 1:8,100
DATE: 2019/09/27
REV: 0
CHKD: AH
NAD 1983 UTM Zone 10N
661253-5

Appendix 8
Summary analysis from ground sampling for vegetation

Data in the following charts shows the average percent cover of herb and shrubs across the various survey transects at the enhancement locations.

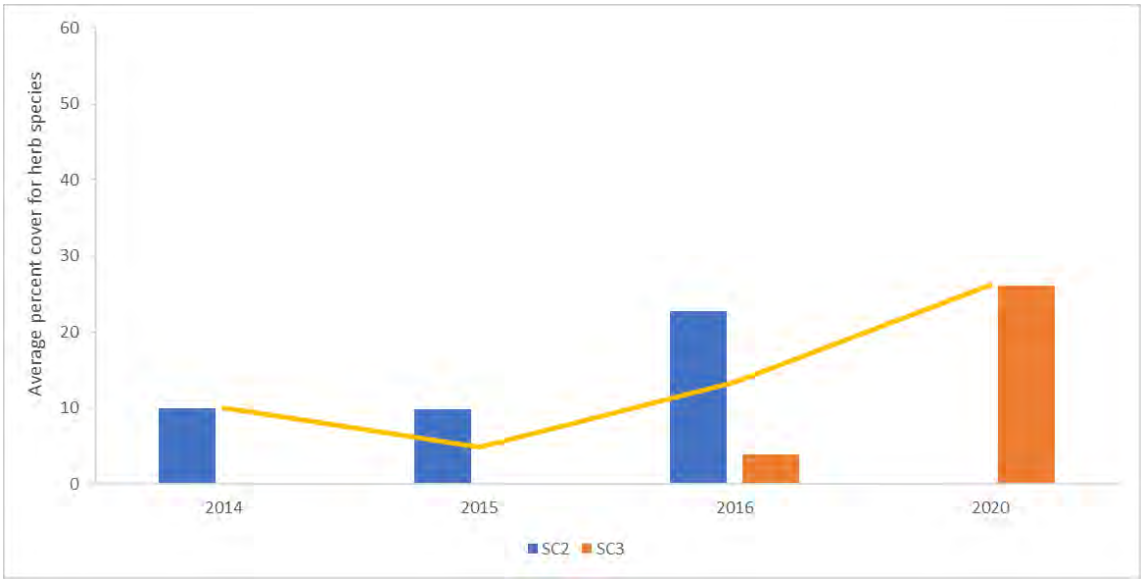

Figure 1. Average percent cover for herb species along the sampling transects at Six Mile Creek. The yellow line indicates the combined average for all transect each to show the overall trend within the sites.

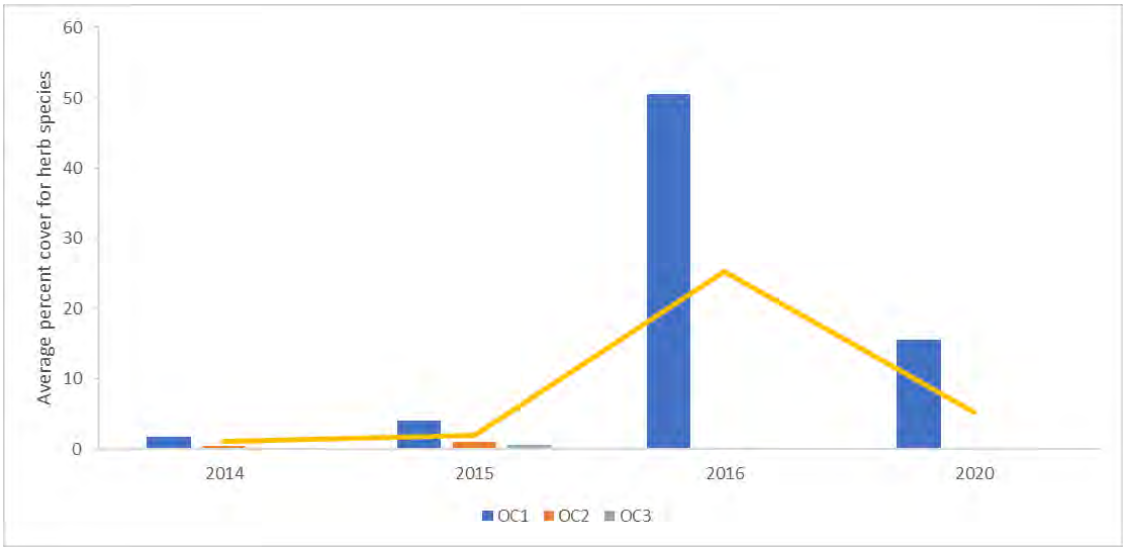

Figure 2. Average percent cover for herb species along the sampling transects at Ole Creek. The yellow line indicates the combined average for all transect each to show the overall trend within the sites.

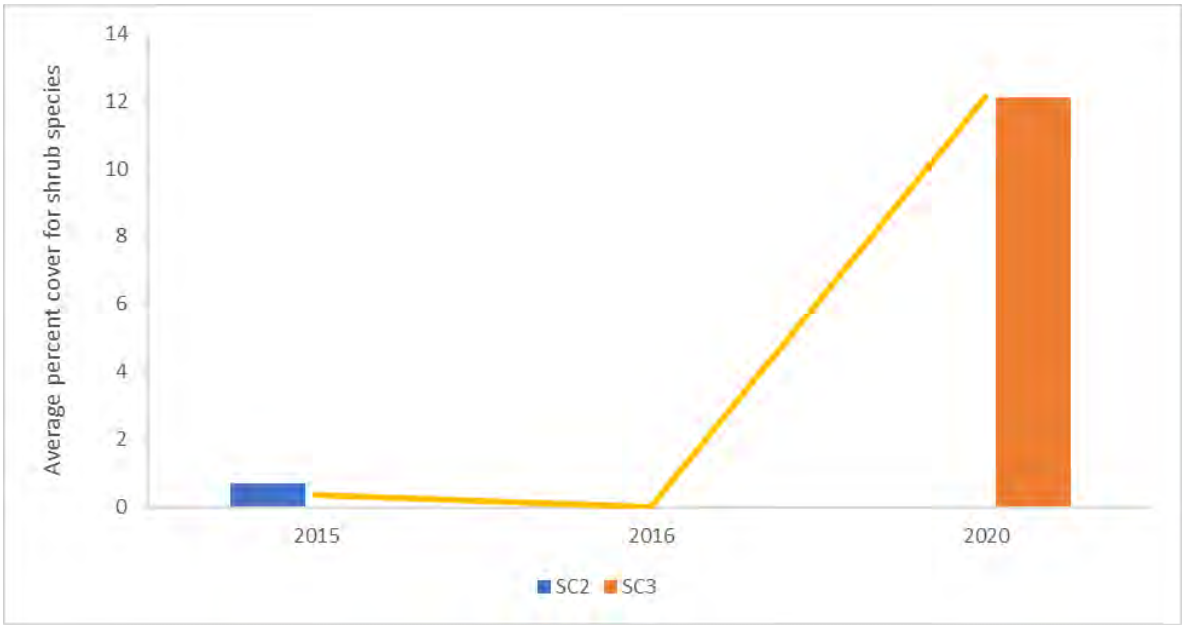

Figure 3. Average percent cover for shrub species along the sampling transects at Six Mile Creek. The yellow line indicates the combined average for all transect each to show the overall trend within the sites.

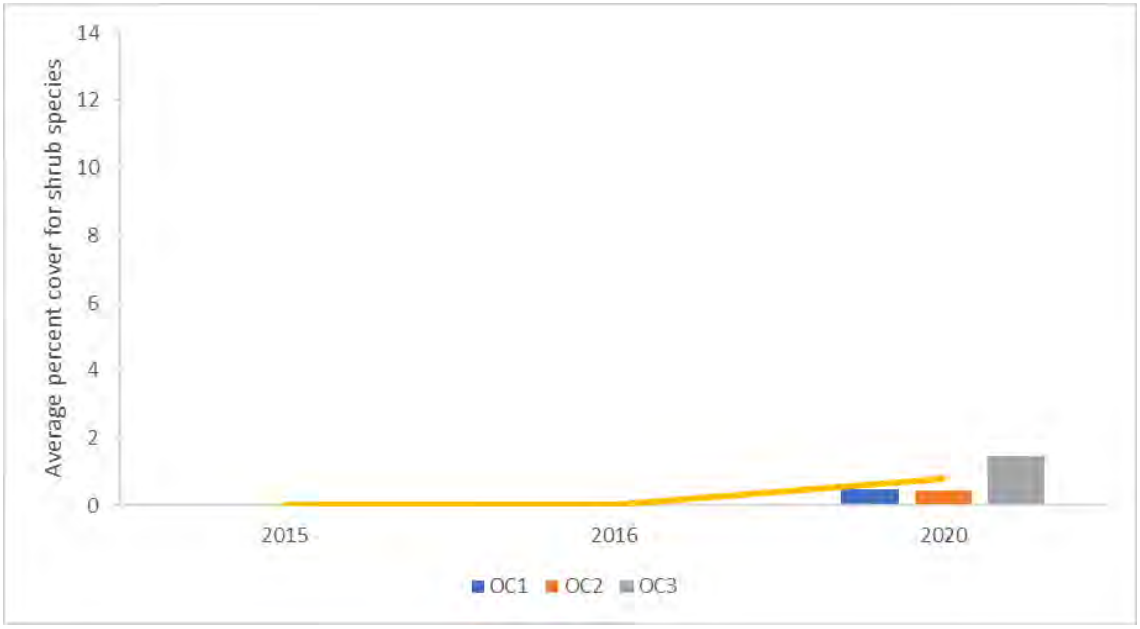

Figure 4. Average percent cover for shrub species along the sampling transects at Ole Creek. The yellow line indicates the combined average for all transect each to show the overall trend within the sites.