Site C Clean Energy Project

Peace River Riparian Vegetation Monitoring Program (Mon-5)

Construction Year 5 (2019)

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REPORT

Peace River Riparian Vegetation Monitoring Program (Mon-5)

2019 Investigations

Submitted to:

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Fort St. John, BC

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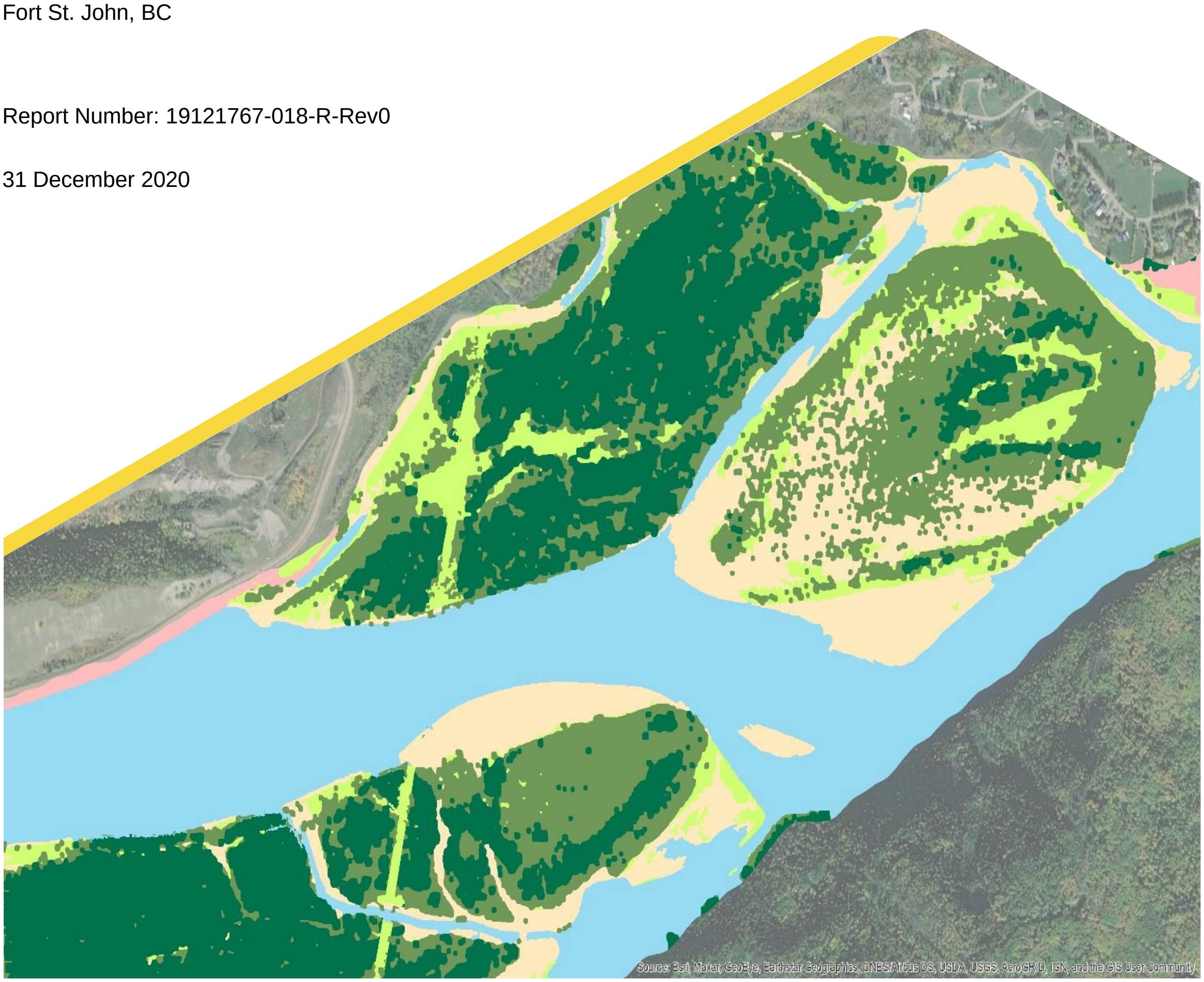

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Executive Summary

In accordance with Provincial Environmental Assessment Certificate Condition No. 7[1] and Federal Decision Statement Condition Nos. 8.4.3[2] and 8.4.4[3] for BC Hydro's Site C Clean Energy Project (the Project), BC Hydro has developed the Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP[4]). The Peace River Riparian Vegetation Monitoring Program (Mon-5) represents one component of the FAHMFP and is designed to monitor the response of riparian vegetation communities to the construction and operation of the Project and detail how those responses may change fish habitat downstream of the Project. More specifically, Mon-5 will assist in diagnosing causes of observed changes in the Peace River fish community, as identified through other components of the FAHMFP, by identify changes in the riparian vegetation community that may influence the quality of habitats available to fish. Riparian vegetation is known to contribute to fish habitat by producing Large Woody Debris (LWD), by providing localized bank stability and lateral channel stability, shade production, and as a source for litter fall and insect drop.

Two spatial boundaries were selected for Mon-5: the "upstream study area" and "downstream study area". The upstream study area includes the 16 km long portion of the Peace River from the Project downstream to the Pine River's confluence with the Peace River. The downstream study area includes the 15 km long portion of the Peace River between the Pine River confluence and Six Mile Creek's confluence with the Peace River. The upstream study area is a treatment site, while the downstream study area will serve as a control site.

This report presents the results of the first year of Mon-5 (2019) and will represent a summary of the baseline conditions in the study area prior to the development of the Project. Mon-5 is tentatively scheduled to be conducted during years 2, 4, 6, 8, 10, 15, 20, and 25 of Project operation. Results from subsequent Mon-5 surveys will be compared to the baseline conditions presented in this report.

A canopy height model, elevation data, orthorectified satellite-based high spectral resolution imagery, ground-truthing plot data, photo interpretation, and a supervised artificial intelligence image classifier were used to identify and circumscribe six riparian vegetation types in each of the two study areas. These riparian vegetation types included the following: 1) open water; 2) floodplain forest; 3) tall shrub; 4) gravel bar-exposed soil; 5) low shrub-herb/grass; and 6) anthropogenic.

Key results from the 2019 study period are summarized as follows:

- The most common riparian vegetation types in the study area are floodplain forest (28% to 35%) and tall shrub (14% to 18%), while low shrub-herb/grass (4%) and gravel bar-exposed soil (6% to 7%) are the least common riparian vegetation types.
- Open water accounts for 27% to 33% of the study area, while anthropogenic disturbance accounts for 10% to 13% of the study area.

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[1] The EAC Holder must develop a Fisheries and Aquatic Habitat Monitoring and Follow-up Program to assess the effectiveness of measures to mitigate Project effects on healthy fish populations in the Peace River and tributaries, and, if recommended by a QEP or FLNR, to assess the need to adjust those measures to adequately mitigate the Project's effects.

[2] "The plan shall include: an approach to monitor changes to fish and fish habitat baseline conditions in the Local Assessment Area."

[3] "The plan shall include: an approach to monitor and evaluate the effectiveness of mitigation or offsetting measures and to verify the accuracy of the predictions made during the environmental assessment on fish and fish habitat."

[4] Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program available at https://www.sitecproject.com/document-library/environmental-management-plans-and-reports.

- Overall, analyses conducted in 2019 were successful in identifying plant community structure and identity. The 88% accuracy level of the riparian vegetation types is considered good[5]. This high accuracy level indicates that the 2019 Mon-5 results provide a good baseline understanding of riparian vegetation types in the study area.

During future study years, parallel versus non-parallel changes between the downstream study area (i.e., control) and the upstream study area (i.e., treatment) should be considered to control for changes in the riparian vegetation community that are unrelated to the Project (e.g., changes due to annual changes in precipitation rates). Non-parallel changes in the riparian vegetation community over time may lead to the rejection of Mon-5's null hypothesis; however, linking changes in the riparian vegetation community to changes in fish habitat will be difficult. The Project's Environmental Impact Statement did not identify a pathway whereby the Project would result in changes to the riparian vegetation community at a magnitude that would be expected to influence downstream fish habitat. As such, Mon-5 will need to identify substantial and unexpected changes to the riparian vegetation community before noticeable changes to fish habitat would be expected or observed.

[5] Zhang, L., Liu, S., Sun, P., Wang, T., Wang, G., Zhang, X. and Wang, L., 2015. Consensus forecasting of species distributions: The effects of niche model performance and niche properties. PloS one, 10(3), p.e0120056. Zurlini G, Riitters K, Zaccarelli N, Petrosillo I, Jones KB, and Rossi L. 2006. Disturbance patterns in a socio-ecological system at multiple scales. ecological complexity, 3(2), pp.119-128.

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym	Description
CHM	Canopy Height Model
DEM	Digital Elevation Model
DSM	Digital Surface Model
EIS	Environmental Impact Statement
FAHMFP	Fisheries and Aquatic Habitat Monitoring and Follow-up Program
LiDAR	Light Detection and Ranging
LWD	Large Woody Debris
Mon-5	Peace River Riparian Vegetation Monitoring Program
NDVI	Normalized Difference Vegetation Index
Project	Site C Clean Energy Project
RT	Random tree
SID	Spectral Image Differencing
TEM	Terrestrial Ecosystem Mapping

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1.0 INTRODUCTION

1.1 Overview

The operation of W.A.C. Bennett Dam and Peace Canyon Dam has reduced annual flood flows, increased winter flows, and changed the seasonal timing and magnitude of flooding in the Peace River, which has impacted the structure, identity, and distribution of the riparian vegetation community (Church et al. 1997; MacInnis et al. 2011, 2013; North and Church 2015). At upper elevations of the river floodplain "colonizing herb and shrub communities have encroached on exposed river bars due to reduced flood flows, and have progressed to early riparian forest stands"[6]. At lower floodplain elevations, "successional processes have been delayed due to inundation during elevated spring and winter flows"[7].

BC Hydro's Site C Clean Energy Project (the Project) is being constructed on the Peace River approximately 5 km southwest of Fort St. John (Figure 1). The Project's Environmental Impact Statement (EIS) did not identify a pathway whereby the Project would result in changes to the riparian vegetation community at a magnitude that would be expected to influence downstream fish habitat. This is mainly because riparian habitat contributions are limited in wide, alluvial river systems, such as the Peace River, when compared with smaller stream environments. Further, if changes to the riparian vegetation community do occur over time, discerning whether those changes are in response to the Project or are ongoing changes in response to existing flow regulation activities, as detailed above, would be difficult.

In accordance with Provincial Environmental Assessment Certificate (EAC) Condition No. 7[8] and Federal Decision Statement Condition Nos. 8.4.3[9] and 8.4.4[10] for the Project, BC Hydro developed the Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program (FAHMFP[11]) (BC Hydro 2015). The FAHMFP is meant to monitor for changes in indicator fish species (i.e., Arctic Grayling [*Thymallus arcticus*], Burbot [*Lota lota*], Bull Trout [*Salvelinus confluentus*], Goldeye [*Hiodon alosoides*], Mountain Whitefish [*Prosopium williamsoni*], Rainbow Trout [*Oncorhynchus mykiss*], and Walleye [*Sander vitreus*]) that may be attributed to interactions with the Project. The Peace River Riparian Vegetation Monitoring Program (Mon-5) represents one component of the FAHMFP and is designed to monitor for a response in the riparian vegetation community that may be attributed to the construction and operation of the Project.

Riparian vegetation contributes to fish habitat through the following means (MFLNRORD 2019):

1) The production of Large Woody Debris (LWD), which provides physical habitat for fish and helps maintain channel morphology.
2) Provides localized bank stability, which reduces erosion.
3) Provides area for channel movement and contributes to lateral channel stability.
4) Provides shade, which influences water temperatures and contributes to physical cover for fish.
5) Provide litter fall and insect drop, which contributes nutrients to the stream and food items for fish.

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[6] Site C EIS, Volume 2, Section 11.1.2.2.

[7] Site C EIS, Volume 2, Section 11.1.2.2.

[8] The EAC Holder must develop a Fisheries and Aquatic Habitat Monitoring and Follow-up Program to assess the effectiveness of measures to mitigate Project effects on healthy fish populations in the Peace River and tributaries, and, if recommended by a QEP or FLNR, to assess the need to adjust those measures to adequately mitigate the Project's effects.

[9] The plan shall include: an approach to monitor changes to fish and fish habitat baseline conditions in the Local Assessment Area.

10 The plan shall include: an approach to monitor and evaluate the effectiveness of mitigation or offsetting measures and to verify the accuracy of the predictions made during the environmental assessment on fish and fish habitat.

[11] Site C Fisheries and Aquatic Habitat Monitoring and Follow-up Program available at https://www.sitecproject.com/document-library/environmental-management-plans-and-reports.

Specifically, Mon-5 will assist in diagnosing causes of observed changes in the Peace River fish community, as identified through other components of the FAHMFP, by identify changes in the riparian vegetation community that may influence the quality of habitats available to fish (Beaudrie et al. 2017). It is uncertain if changes to the riparian vegetation community, as measured under Mon-5, will result in measurable changes to fish habitat.

This report presents the results of the first year of Mon-5 (2019) and represents a summary of the baseline conditions of riparian vegetation types in the study area prior to the development of the Project.

1.2 Study Objective and Scope

The objective of Mon-5 is to test the following null hypothesis (BC Hydro 2015):

> H_1: The construction and operation of the Project does not affect riparian vegetation on the Peace River floodplain between the Project and the Pine River as it relates to fish habitat.

Rejecting the null hypothesis may trigger further investigations to answer the following management questions:

1) How does the construction and operation of the Project affect riparian vegetation in the Peace River downstream of the Project as it relates to fish habitat?

2) Can the effects of on-going succession from previous hydroelectric facilities upstream, floodplain natural variability, and climate change be identified separately from the effects that may be attributable to Project construction or operation?

Management Question #2 recognizes the challenges associated with assigning cause to observed changes, given the natural variability, the influence of existing flow regulation, and directional changes to be expected with or without the construction or operation of the Project.

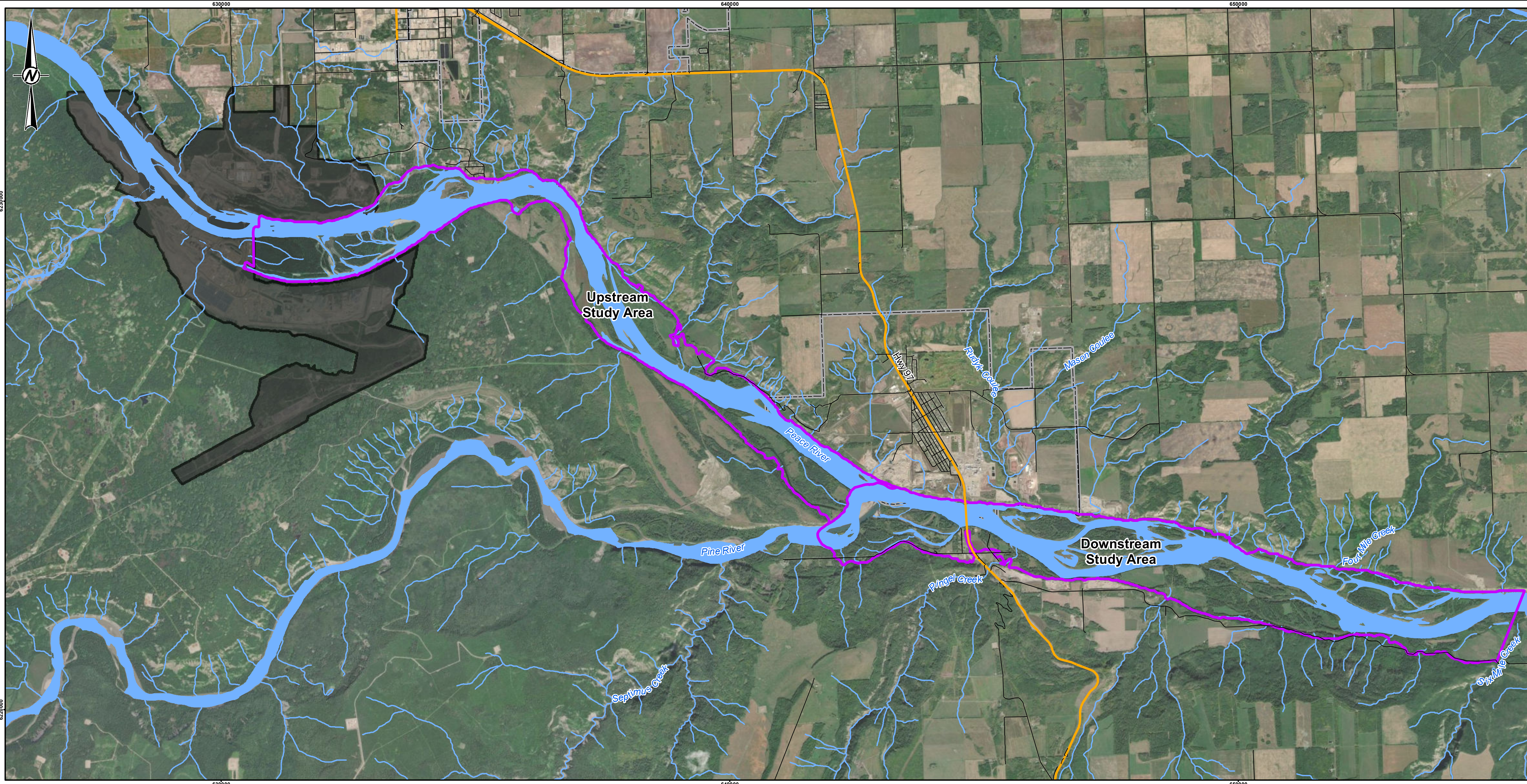
The temporal scope of this report is restricted to a single monitoring year (2019) and the scope of work is as follows:

- establishing repeatable monitoring methods and a study design for mapping, classifying, and quantifying riparian vegetation types downstream of the Project that can be implemented during future study years to test the null hypothesis
- establishing the baseline extent and structure of riparian vegetation types under pre-Project conditions prior to river diversion

2.0 STUDY AREAS

Two spatial boundaries were selected for Mon-5: the “upstream study area” and “downstream study area”. The upstream study area includes the 16 km long portion of the Peace River from the Project downstream to the Pine River’s confluence with the Peace River. The downstream study area encompasses the 15 km long portion of the Peace River between the Pine River confluence and Six Mile Creek’s confluence with the Peace River (Figure 1).

The upstream study area represents the area where the Project's effects on riparian vegetation types are expected to be greatest. It is assumed that input from the Pine River will partially mitigate anticipated Project interactions with riparian vegetation types because inputs from this river are not regulated (Water Survey of Canada 2020; Station 07FB001 1961-2016; Church 2015; Prowse et al. 2002). As a result, the upstream study area is considered the treatment site and the downstream study area is considered the control site. While the treatment and control sites are not independent, the anticipated magnitude of Project interactions with riparian vegetation types in these two study areas are anticipated to differ enough to be suitable for testing the null hypothesis.



LEGEND

- RIVER RIPARIAN VEGETATION MONITORING PROGRAM (MON-5) STUDY AREAS
- DAM SITE AREA
- MUNICIPALITY
- HIGHWAY
- ROAD
- WATERCOURSE
- RIVER

0 1,500 3,000

1:75,000 METRES

REFERENCE(S)

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APPROVED	DF

PROJECT
PEACE RIVER RIPARIAN VEGETATION MONITORING PROGRAM (MON-5)

TITLE
OVERVIEW OF THE PEACE RIVER RIPARIAN VEGETATION MONITORING PROGRAM (MON-5) STUDY AREA, 2019

PROJECT NO.	CONTROL	REV.	FIGURE
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25mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

3.0 METHODS

Field-verified terrestrial ecosystem mapping (TEM) was completed for the upstream and downstream study areas in support of the Project's EIS (Andrusiak and Simpson 2012). Bioterrain polygons are the foundation of TEM and are manually drawn using photo interpretation methods and field data. A TEM is completed by a qualified vegetation biologist, who manually assigns vegetation attributes to each bioterrain polygon. The Project's TEM was completed following provincial standards (RIC 1998) and was suitable for the purposes of the EIS; however, TEM is impractical when temporally continuous sampling and mapping are required. Observed differences in TEM over time may be due to differences in how analysts interpret and manually draw bioterrain polygons and how vegetation biologists manually assign vegetation attributes to those polygons. As a result, TEM is not suitable for testing Mon-5's null hypothesis.

To test Mon-5's null hypothesis, a remote sensing workflow was developed as an alternative to TEM. The remote sensing workflow produces a repeatable, defensible, objective, and cost-effective map of riparian vegetation types (Dekker et al. 2008; Anstee et al. 2015) that is suitable for testing Mon-5's null hypothesis. The remote sensing workflow includes the following components:

- developing digital elevation (DEM), digital surface (DSM), and canopy height (CHM) models
- Satellite Image Processing
- determining normalized difference vegetation indices (NDVI)
- semi-automated riparian vegetation classification

Each step of the remote sensing workflow is described in the following sections.

3.1 Digital Elevation, Digital Surface, and Canopy Height Models

Three models were developed using light detection and ranging (LiDAR) point cloud data (BC Hydro 2019):

1) a digital elevation model (DEM)
2) a digital surface model (DSM)
3) a canopy height model (CHM)

Each model has a resolution of 0.25 m and are raster files comprising pixels, with each pixel assigned an elevation. The raw LiDAR files (BC Hydro 2019) were initially processed using the "Create LAS Dataset" tool in Arc GIS 10.8 (ESRI 2021). The "LAS Dataset to Raster" tool in ArcGIS was used to create the DEM using last returns from LiDAR point cloud data. The DEM represents the surface of bare ground without vegetation, buildings, or other non-landscape objects.

The DSM was created using first returns from LiDAR point cloud data using the "LAS Dataset to Raster" tool in ArcGIS. The DSM depicts all above-ground features on the landscape, regardless of what they are. Areas of the DSM without vegetation are identical to the same area in the DEM (i.e., bare ground); however, areas of the DSM with above ground objects differ from the same area in the DEM. For example, a DSM will represent trees, shrubs, and buildings while a DEM will not.

The CHM was created using the “raster calculator minus” tool in ArcGIS to subtract elevation values in the DEM from elevation values in the DSM. Each pixel in the CHM raster files were then automatically assigned a height above bare ground based on this calculation. Using the height above bare ground, each pixel was assigned to one of three canopy height classes:

1) vegetation less than 2.0 m in height
2) vegetation between 2.0 and 10.0 m in height
3) vegetation greater than 10.0 m in height

Areas of water were removed from the CHM and assigned a height of 0 m.

Black cottonwood (*Populus balsamifera*) and white spruce (*Picea glauca*) are the most common tree species greater than 10.0 m tall in the study areas and they have an average crown diameter of 5.0 m (North and Church 2015). To accurately represent tree canopy diameters in vegetation greater than 10.0 m tall, an average crown diameter of 5.0 m was applied to the model (i.e., 0.25 m pixel size x 20 pixels = 5.0 m). The “boundary clean” operation in ArcGIS was performed three times to smooth interfaces between canopy height classes.

3.2 Satellite Image Processing

Satellite images of the study areas were acquired from WorldView-2 (Maxar Technologies, Westminster, CO). The satellite images included eight multispectral bands (red, blue, green, near-infrared 1, near-infrared 2, red edge, coastal, and yellow), and one panchromatic band. The multispectral bands had a resolution of 2 m, and the panchromatic band had a resolution of 0.5 m. These data were captured on 18 September 2019 and were provided as view-ready, un-orthorectified satellite images. The satellite image acquisition date was selected based on quality (i.e., cloud free), availability, and the anticipated timing of the peak vegetation growing season.

ENVI 5.0 (Exelis Visual Information Solutions, Boulder, CO; ENVI 2021) was used to process the satellite images as follows:

- The satellite images were orthorectified using the “RPC Orthorectification” tool in ENVI 5.0. Orthorectification is the process of georeferencing and correcting images so that all parts of the image appear to be viewed from directly overhead (i.e., not at an oblique angle). Orthorectified satellite images are required to make direct and accurate measurements of distances, angles, positions, and areas.
- Panchromatic sharpening was performed to improve the resolution of the multispectral bands (i.e., the satellite image) using the “Gramm-Schmidt PAN Sharpening” tool with the cubic convolution resampling method. Panchromatic sharpening fuses the relatively high resolution (i.e., 0.5 m) panchromatic image with the lower resolution (i.e., 2.0 m) eight multispectral bands to create a “sharpened” (i.e., clearer) georeferenced satellite image while preserving the spectral attributes. The 2.0 m resolution resulted in some small polygons only containing a single tree or polygons limited to a small opening in a forest. This effect was reduced by merging groups of pixels that were less than 144 m^2 in area.
- Scattering and haze effects were reduced using the “Radiometric Calibration” tool with the “Radiance” option to improve the quality of the satellite images. Subsequently, a “Dark Object Subtraction” correction was applied using “Band Minimum Subtraction” to further improve image quality.

3.3 Normalized Difference Vegetation Index (NDVI)

Normalized difference vegetation index (NDVI) is an indicator of plant health and vegetation type. A vegetation type with the same health will have the same NDVI value. Most land plants that photosynthesize appear green because chlorophyll uses photons in the visible part of the electromagnetic spectrum to fix carbon. Specifically, photons in the blue and red part of the electromagnetic spectrum are captured by chlorophyll to fix carbon, so those photons do not reflect from healthy photosynthesizing land plants; however, photons in the green part of the electromagnetic spectrum are not captured by chlorophyll and reflect off of healthy photosynthesizing land plants.

The "Band Math" tool in ArcGIS was used to calculate the NDVI value for each pixel in the study areas. This tool used two bands from the processed satellite images, near-infrared 1 and visible red, to calculate NDVI using the following formula:

$$NDVI = \frac{(\mathrm{near} - \mathrm{infrared}\ 1) - (visible\ red)}{(\mathrm{near} - \mathrm{infrared}\ 1) + (visible\ red)}$$

Photons in the near-infrared 1 part of the electromagnetic spectrum are not used for photosynthesis, so they are reflected from healthy photosynthesizing land plants. Photons in the visible red part of the electromagnetic spectrum are absorbed by healthy photosynthesizing land plants. Generally, unhealthy non-photosynthesizing land plants, bare earth, and above ground structures reflect photons in the near-infrared 1 and visible light parts of the electromagnetic spectrum. As a result, areas with a dense cover of healthy photosynthesising plants will reflect small amounts of photons in the visible red part of the electromagnetic spectrum and relatively large amounts of photons in the near-infrared part of the electromagnetic spectrum. Areas with bare earth and above ground structures will reflect photons in the near-infrared 1 and visible red parts of the electromagnetic spectrum. Using the above formula for calculating NDVI, areas with a dense cover of healthy photosynthesising plants have a maximum NDVI value of 1, while areas without vegetation and high cover of bare earth and above ground structures have an NDVI value of -1.

3.4 Riparian Vegetation Classification

The following six riparian vegetation types were identified based on the CHM, photo interpretation of the processed satellite images, and existing plot data (Andrusiak and Simpson 2012; Jones 2019):

- anthropogenic
- gravel bar-exposed soil
- low shrub-herb/grass
- open water
- tall shrub
- floodplain forest

The low shrub-herb/grass riparian vegetation type includes vegetation less than 2.0 m in height in the CHM. The tall shrub riparian vegetation type includes vegetation between 2.0 to 10.0 m tall. The floodplain forest riparian vegetation types includes vegetation greater than 10.0 m tall in the CHM.

Photo interpretation was used to check the accuracy of the anthropogenic riparian vegetation type because cultivated fields and roads where difficult to distinguish from the low shrub-herb/grass and gravel bar-exposed soil riparian vegetation types.

Training sample polygons were manually drawn within a subset of each of the six riparian vegetation types using the “Training Samples Manager” pane in ArcGIS (Table 1). The training sample polygons included three raster layers “stacked” on top of each other. The first raster layer was a true colour composite consisting of the red, blue, and green bands of the processed satellite image. The second raster layer was a near-infrared false-colour processed satellite image comprising near-infrared 1, red, and green bands. The third raster consisted of the NDVI layer.

Table 1: Summary of the six riparian vegetation types and training sample polygons used in the supervised vegetation classification during the Peace River Riparian Vegetation Monitoring Program (Mon-5), 2019.

Riparian Vegetation Type	Number (and Area) of Training Sample Polygons
Open water	9 (210,604 m^2)
Floodplain forest	4 (237,925 m^2)
Tall shrub	4 (251,256 m^2)
Gravel bar-exposed soil	3 (102,644 m^2)
Low shrub-herb/grass	6 (164,808 m^2)
Anthropogenic	n/a[1]

[1] n/a = not applicable; areas were delineated based on photo interpretation.

Training sample polygons were created for the “Train Random Trees Classifier” tool in ArcGIS. This tool drew from a family of artificial intelligence algorithms called “random trees” (RT) to classify pixels in the processed satellite images. The RT classification method is a “supervised machine-learning classifier” because it draws from preselected training data to classify pixels in an image. In this case, pixels in each of the three raster layers contained within the training sample polygons (i.e., true colour composing, near-infrared false-colour image, and NDVI) were randomly selected and used to classify the riparian vegetation type for each pixel in the study areas. This process was repeated numerous times and created a multitude of random decision trees for each pixel in the study areas; however, the most frequent tree output was used to classify each pixel while controlling for overfitting to the training sample polygons (ESRI 2022).

Ultimately, the Train Random Trees Classifier generated a “RT riparian vegetation map” of the study areas by assigning each pixel in the satellite images to one of the six riparian vegetation types based on the attributes of the raster files in the training sample polygons. The CHM was overlaid onto the RT riparian vegetation map and discrepancies between the CHM and RT riparian vegetation map were manually corrected. For example, some tall shrub and floodplain forest riparian vegetation type polygons had intermediate true colour composing, near-infrared false-colour image, and NDVI values. This led to misclassifications in some cases, which were largely corrected by accounting for the CHM in the classification. Also, some anthropogenic riparian vegetation was misclassified as gravel bar/exposed soil. In those cases, the riparian vegetation types were manually changed to anthropogenic.

Riparian vegetation type polygons less than 5.0 m^2 were merged with adjacent riparian vegetation type polygons using the “eliminate” tool in ArcGIS. Lastly, the “topology check” tool was used to validate the RT riparian vegetation map’s topology and the final RT riparian vegetation map was split into upstream and downstream study areas.

3.5 Accuracy Assessment

An accuracy assessment was undertaken to assess “users’ accuracy”, which is the rate at which the riparian vegetation types in the final RT riparian vegetation map represent what was found in the field. The accuracy assessment entailed a comparison of the final vegetation map classes, based on output from the RT algorithm, and data from 84 usable field-verification sites detailed in Andrusiak and Simpson (2012; 10 sites) and Jones (2019; 74 sites). Of the 84 field-verification sites, 74 were assessed within 39 days of the satellite imagery collection date.

4.0 RESULTS

4.1 Riparian Vegetation Classification

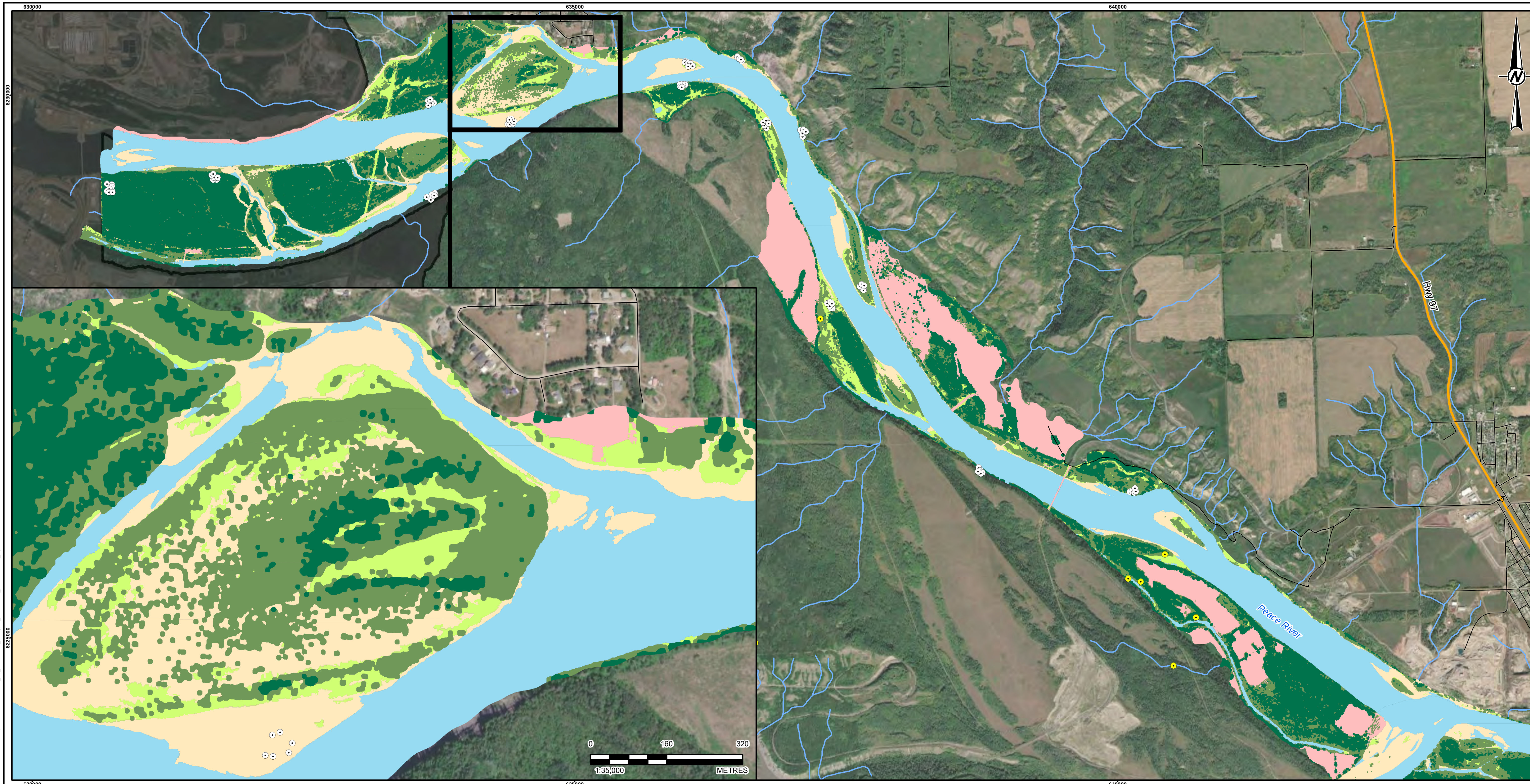
Excluding open water, floodplain forest was the most common riparian vegetation type in both the upstream study area (Figure 2) and the downstream study area (Figure 3). The proportions of each riparian vegetation type within the upstream and downstream study areas differed by less than 6.5% (Table 2).

Table 2: Summary of riparian vegetation types in the upstream and downstream study areas of the Peace River Riparian Vegetation Monitoring Program (Mon-5), 2019.

Riparian Vegetation Classification	Upstream Study Area		Downstream Study Area		Percent Difference (%)
	Area (ha)	Area (%)	Area (ha)	Area (%)	
Open water	451.1	32.9	475.9	27.1	5.8
Floodplain forest	389.3	28.4	612.7	34.9	-6.5
Tall shrub	191.2	14.0	312.6	17.8	-3.8
Gravel bar-exposed soil	97.3	7.1	110.2	6.3	0.8
Low shrub-herb/grass	58.0	4.2	65.6	3.7	0.5
Anthropogenic	182.2	13.3	176.3	10.1	3.2

4.2 Quality Assessment

Of the 84 field-verification sites assessed, 74 were described in a manner consistent with the final RT riparian vegetation map, resulting in a users' accuracy of 88%. The 88% accuracy level of the final RT riparian vegetation map is considered good (Zhang et al. 2015; Zurlini 2006). Vegetation community changes over time can result in disagreements between field assessments and image interpretation. An example of this could be a vegetation community change in response to a water level change between the time the imagery was collected and the time the site was assessed in the field. During the 2019 study, these types of disagreements were minimal and largely limited to transitional zones between the tall shrub and low shrub-herb/grass riparian vegetation types.
Further training data for these riparian vegetation types is expected to improve the ability to classify transition zones correctly.



LEGEND

- DAM SITE AREA
- HIGHWAY
- ROAD
- WATERCOURSE
- FIELD VERIFICATION POINT - ANDRUSIAK AND SIMPSON 2012
- FIELD VERIFICATION POINT – JONES 2019

VEGETATION CLASSIFICATIONS

- ANTHROPOGENIC
- GRAVEL BAR-EXPOSED SOIL
- LOW SHRUB-HERB/GRASS
- TALL SHRUB
- FLOODPLAIN FOREST
- OPEN WATER

0 700 1,400

1:35,000 METRES

NOTE(S)

HIGH WATER FLOW WAS MODELED BASED ON 991 m^3/s FLOW RATE. KNOWN ELEVATIONS FOR THIS FLOW RATE AT TWO WATER SURVEY OF CANADA (WSC) SURVEY STATIONS WERE OBTAINED AND THE RIVER SLOPE OF THE THALWAG WAS CALCULATED. BASED ON THE THALWAG SLOPE, ELEVATIONS WERE CALCULATED AT MULTIPLE LOCATIONS UPSTREAM AND DOWNSTREAM FROM THE WSC STATIONS. A HIGH WATER SURFACE WAS CREATED BASED ON THESE ELEVATIONS.
THE HIGH WATER SUMMARY AREA WAS DEVELOPED FROM THE NON-WATER VEGETATION TYPES WITHIN THE HIGHWATER BOUNDS AND A 50m INSTREAM BUFFER WAS ALSO CREATED ALONG THE HIGH WATER FLOW BANKS.

REFERENCE(S)

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COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT
BC HYDRO

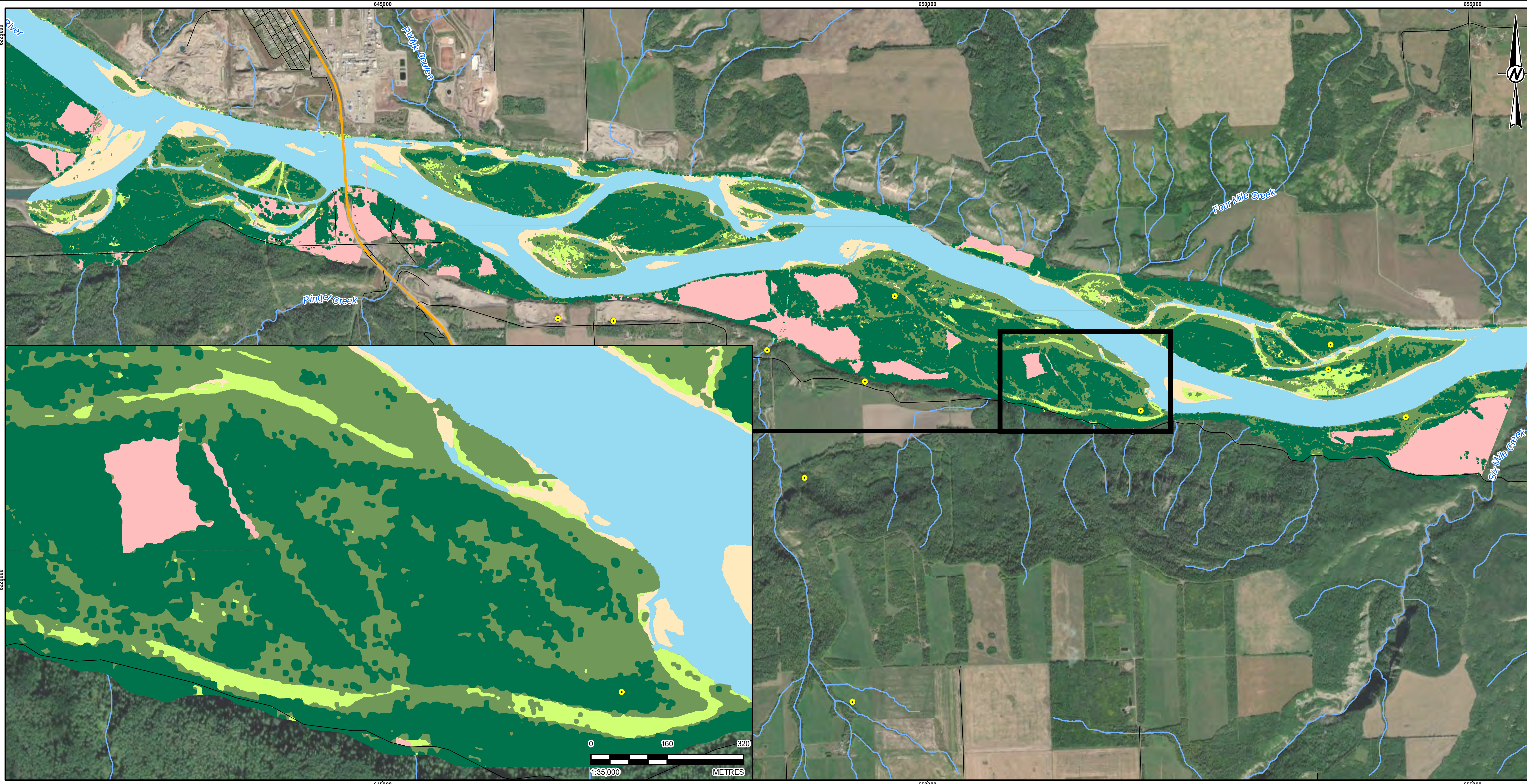
CONSULTANT
GOLDER MEMBER OF WSP

YYYY-MM-DD	2022-11-13
DESIGNED	SB
PREPARED	JP
REVIEWED	DF
APPROVED	DF

PROJECT
PEACE RIVER RIPARIAN VEGETATION MONITORING PROGRAM (MON-5)

TITLE
RIPARIAN VEGETATION TYPES IN THE UPSTREAM STUDY AREA OF THE PEACE RIVER RIPARIAN VEGETATION MONITORING PROGRAM (MON-5), 2019

PROJECT NO.	CONTROL	REV.	FIGURE
19121767	11	0	2



LEGEND

- HIGHWAY
- ROAD
- WATERCOURSE
- FIELD VERIFICATION POINT - ANDRUSIAK AND SIMPSON 2012
- FIELD VERIFICATION POINT – JONES 2019

VEGETATION CLASSIFICATIONS

- ANTHROPOGENIC
- GRAVEL BAR-EXPOSED SOIL
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NOTE(S)

HIGH WATER FLOW WAS MODELED BASED ON 991 m^3/s FLOW RATE. KNOWN ELEVATIONS FOR THIS FLOW RATE AT TWO WATER SURVEY OF CANADA (WSC) SURVEY STATIONS WERE OBTAINED AND THE RIVER SLOPE OF THE THALWAG WAS CALCULATED. BASED ON THE THALWAG SLOPE, ELEVATIONS WERE CALCULATED AT MULTIPLE LOCATIONS UPSTREAM AND DOWNSTREAM FROM THE WSC STATIONS. A HIGH WATER SURFACE WAS CREATED BASED ON THESE ELEVATIONS.
THE HIGH WATER SUMMARY AREA WAS DEVELOPED FROM THE NON-WATER VEGETATION TYPES WITHIN THE HIGHWATER BOUNDS AND A 50m INSTREAM BUFFER WAS ALSO CREATED ALONG THE HIGH WATER FLOW BANKS.

0 700 1,400
1:35,000 METRES

REFERENCE(S)

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COORDINATE SYSTEM: NAD 1983 CSRS UTM ZONE 10N

CLIENT
BC HYDRO

CONSULTANT
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YYYY-MM-DD	2022-11-13
DESIGNED	SB
PREPARED	JP
REVIEWED	DF
APPROVED	DF

PROJECT
PEACE RIVER RIPARIAN VEGETATION MONITORING PROGRAM (MON-5)

TITLE
RIPARIAN VEGETATION TYPES IN THE DOWNSTREAM STUDY AREA OF THE PEACE RIVER RIPARIAN VEGETATION MONITORING PROGRAM (MON-5), 2019

PROJECT NO.	CONTROL	REV.	FIGURE
19121767	11	0	3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

5.0 DISCUSSION

LiDAR CHMs can document and quantify, in a repeatable and consistent way, changes in vegetation structure over time. Remote sensing methods presented here can provide evidence of dynamic shifts among riparian vegetation types and provide context and direction for further inquiry into interpreting these changes. Results from this 2019 assessment will serve as the baseline dataset for which future comparisons will be made to identify changes in the riparian vegetation community over time.

Overall, the supervised classification of spectral imagery and CHM data was successful in identifying plant community structure. The 88% accuracy level of the assigned riparian vegetation type is considered good (Zhang et al. 2015; Zurlini 2006). This high accuracy level indicates that the 2019 Mon-5 results provide a good baseline understanding or riparian vegetation in the upstream and downstream study areas. When testing the Mon-5 null hypothesis during future monitoring years, it will be important to obtain satellite imagery under environmental and plant health conditions like those that occurred in mid-September 2019.

Implementing a concept of parallel versus non-parallel change over time between the downstream study area (i.e., control) and the upstream study area (i.e., treatment) can control for differences between monitoring years that are unrelated to the Project or to testing Mon-5's null hypothesis. For example, natural regional climatic variation between monitoring years (e.g., differences in precipitation or temperature over time) may cause changes in the distribution of observed riparian vegetation types. Such observed changes over time would be the results of differences in natural regional climatic variation, not interactions between the Project and riparian vegetation. The upstream and downstream study areas are likely to be subjected to the same natural regional climatic variations. As a result, related observed changes in riparian vegetation over time would be expected to be as pronounced in the downstream study area as the upstream study area and occur in lockstep (i.e., parallel over time). The null hypothesis cannot be rejected under this hypothetical scenario; however, non-parallel changes in riparian vegetation in the downstream and upstream study areas over time may lead to the rejection of Mon-5's null hypothesis. A collection of hypothetical parallel and non-parallel outcomes that could be documented under Mon-5 are provided in Figure 4.

Image differencing techniques, such as the one described by Lu et al. (2004), should be used in future study years to compare 2019 results to future monitoring years. Image differencing identifies change in riparian vegetation types over time with minimal supervision (Desclée et al. 2006; Tewkesbury et al. 2015). Pixel-based or object-based change detection would be performed by directly comparing images defined by a threshold (Chen et al. 2012). Selecting threshold difference values to indicate actual riparian vegetation type change is a decision-making process that can be modified based on field verification and interactive image interpretation. Since these threshold difference values are often intuitively defined by researchers, a bias may be introduced; however, thresholding NDVI differences, based upon standard deviation values, can reduce this bias (Coppin and Bauer 1996) as it allows threshold values to be implemented in a consistent way. As an example, an arbitrary RT classification threshold values at plus and minus one standard deviation from zero difference could be used to discriminate the classes of change from no-change over time (Coulter et al. 2011).

Detecting changes in riparian vegetation types between two or more satellite images from different dates can be accomplished by spectral image differencing (SID), a widely applied change-detection algorithm. SID techniques transform two original satellite images into a new single-band or multi-band image in which the areas of change are highlighted. This is accomplished by subtracting one satellite image from a second satellite image, typically taken on a different date. Difference values exceeding a selected threshold (e.g., one standard deviation) are considered “changed”. This approach eliminates the need to identify vegetation classification in areas where no substantial spectral change occurred between the two images/dates (e.g., Coppin et al. 2004; Klemas 2013).

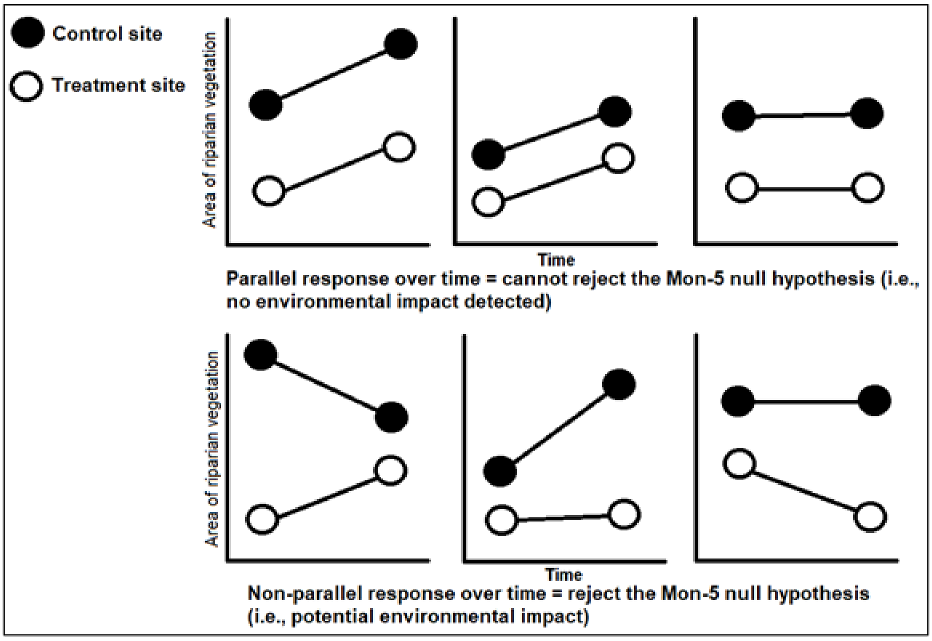

Figure 4: Hypothetical examples of parallel and non-parallel responses of riparian vegetation types over time that could be identified during the Peace River Riparian Vegetation Monitoring Program (Mon-5).

During future surveys, linking changes to the riparian vegetation community to specific changes in Peace River fish habitat will be difficult. The Project's EIS did not identify a pathway whereby the Project would result in changes to the riparian vegetation community as result of the Project at a magnitude that would be expected to influence downstream fish habitat. As such, Mon-5 would need to identify substantial and unexpected changes to the riparian vegetation community before noticeable changes to fish habitat would be expected or observed.

6.0 CLOSURE

We trust the information contained in this report is sufficiently detailed for your review purposes. Please do not hesitate to contact us should you have any questions or require clarification.

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https://golderassociates.sharepoint.com/sites/107993/project files/6 deliverables/issued to the client_for wp/19121767-018-r-rev0/19121767-018-r-rev0-2019 mon_5 riparian_vegetation 31dec_20.docx

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