Falls River Project Water Use Plan

Big Falls Reservoir Sedge Habitat Maintenance Monitoring

Implementation Year 5

Reference: FLSMON-4

Final Year Report

Study Period: 2017

Khtada Environmental Services LP
3210 Apsley Street,
Terrace, BC

April 4, 2018

Falls River Water Use Plan Monitoring: Sedge Habitat Maintenance Monitoring

Year 5

BC Hydro

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Executive Summary

In 2003, during the planning stage of the Falls River Water Use Plan (WUP), the Consultative Committee (CC) recommended specific operating regimes for the Falls River hydroelectric dam. These operating regimes were intended to create beneficial conditions for fish and wildlife within the reservoir, and were reflected in the 2006 Falls River WUP (BC Hydro, 2006).

The CC also recommended an operating regime specifically to maintain the sedge community that was present on the eastern region of the reservoir. The sedge community was identified as having high ecological value by the CC. The CC recommended installing flashboards (i.e., modular bulkheads placed across the crest of the spillway to increase reservoir height and water storage) to maintain the reservoir sedge community (BC Hydro, 2006a). The flashboards would increase the reservoir elevation to a flooding level in the spring and decrease the reservoir elevation following flooding to allow for sedge regeneration.

In 2007, the first year of the Sedge Habitat Maintenance Monitoring Project was completed by Cambria Gordon Ltd. and the Metlakatla Fisheries (Cambria Gordon Ltd., 2007). This study collected baseline field data and completed an air photo analysis of the distinct vegetation communities present within the Study Area of the Big Falls Reservoir. The field surveys included conducting line intercept transects, quadrats, elevational surveys, and ground level photo monitoring. The elevation range of the sedge community was determined from the field surveys; the total sedge habitat area within the overall Study Area was determined through the air photo analysis.

In 2007, the flashboards were installed for a short time. However, shortly after installation a dam safety issue was identified with their use and they were discontinued. Therefore, the specific operating regime recommended by the CC to support and maintain the existing sedge habitat community was not implemented. The discontinuation of the flashboards occurred after the completion of the 2007 study and report.

In 2017, Khtada Environmental Services LP (Khtada) was contracted to conduct the second year of Sedge Habitat Maintenance Monitoring Project. The key management question is whether the current operations of the Big Falls Reservoir maintain the sedge grass community (BC Hydro, 2006a). Information obtained from monitoring will be used to reduce the uncertainty associated with the current reservoir operations and its effect on the sedge community, and inform future planning of the area.

The primary null hypothesis and sub-hypothesis tested in this study are:

H_1: The area of the sedge community will not change as a consequence of reservoir operations.

- H_{1a}: The species composition of the sedge grass community will not change as a consequence of reservoir operations.

The methods of the Year 2 study mirrored the Year 1 methods to ensure that results were comparable with results of the 2007 study. The field surveys included navigating back to the same locations for each transect, elevational survey, photo point, and completing quadrats in the same vegetation polygons as 2007. The same methods were used for the air photo analysis.

Two methods were used to determine if there was a difference in sedge area between the 2007 and 2017 studies. First, the total area of each distinct vegetation community polygon from 2007 and 2017 were compared. This difference analysis showed that there was a total decrease in sedge area (ha) of 23% with a corresponding increase in shrub/herb area of 17% from 2007 to 2017.

Second, an analysis of the line intercept transect surveys and elevational surveys was completed. A paired t-test was used to determine if there was a significant difference between the lengths of sedge habitat encountered along each of the five transects completed in 2007 and 2017. A significant difference was measured (p-value=0.02199, t=3.6389, df=4); the average difference in sedge habitat (m) encountered along each of the 2017 line transect surveys was 12.5 m less than the sedge habitat (m) encountered at the same transects in 2007.

The results of the difference analysis and paired t-test indicate that the alternative hypothesis is true and that there has been a change in sedge habitat area from 2007 to 2017. It is likely that the early successional shrub/herb plant species are encroaching into areas previously dominated by sedge due to the differing reservoir operating regimes from pre-2007 to post-2007.

Disclaimer

This report is rendered solely for the use of BC Hydro in connection with the 2017 Big Falls Reservoir Sedge Monitoring Project and no person may rely on it for any other purpose without Khtada Environmental Services LP's (Khtada) prior written approval. Should a third party use this report without Khtada's approval, they may not rely upon it. Khtada accepts no responsibility for loss or damages suffered by any third party as a result of decisions made or actions taken based on this report.

The objective of this report is to address the following scope requirements for BC Hydro:

1. Reduce the uncertainty of the effects of existing reservoir operations on reservoir vegetation in the Big Falls Reservoir.
2. Map the distribution of reservoir vegetation within the drawdown zone of the eastern region of the Big Falls Reservoir.
3. Assess the changes of reservoir vegetation over time within the drawdown zone of the Big Falls Reservoir.
4. Summarize the results of both the 2007 and 2017 studies within this final report after data has been collected.

This report is based on facts and opinions contained within the referenced documents, including the results of any data collection programs carried out in relation to this report. We have attempted to identify and consider facts and documents relevant to the scope of work, accurate as of the time period during which we conducted this analysis. However, the results, our opinions, or recommendations may change if new information becomes available or if information we have relied on is altered.

The following assumptions were relied on during the preparation of this report:

1. The study level of effort was consistent throughout both the 2007 and 2017 years.
2. The methods and standards used to capture the 2017 air photos are consistent with the air photos captured in 2007.
3. Changes in the sedge habitat area are due to the current reservoir operating regime.
4. Assumed the 2007 GPS points of interest (i.e., transect locations) were accurate enough to navigate to during the 2017 field study.

We applied accepted professional practices and standards in developing and interpreting data. While we used accepted professional practices in interpreting data provided by BC Hydro or third party sources, we did not verify the accuracy of any such data.

This report must be considered as a whole; selecting only portions of this report may result in a misleading view of the results, our opinions, or recommendations.

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1.0 Introduction

1.1 Background

The Falls River Dam is located approximately 50 km south of Prince Rupert, BC, Canada, above the confluence of the Falls River and the Ecstall River. The Falls River Dam has one reservoir, the Big Falls Reservoir, located to the east of the dam. BC Hydro has owned and operated the Falls River Dam since the mid-1960s. The dam currently generates 49.5 GWh/a (approximately 0.1% of BC Hydro's total system production) (BC Hydro, 2006a).

In 2002, the CC for the Falls River WUP identified the area of sedge habitat as being of high ecological value. The CC acknowledged that changes to the operation of the Big Falls Reservoir could affect the area of sedge habitat in the drawdown area. The CC recommended the installation of flashboards (modular bulkheads placed across the crest of the spillway) during certain times of the year to increase the weir height, inundate the reservoir vegetation, and reduce the encroachment of shrubs/herbs into the sedge habitat (BC Hydro, 2016). The flashboards were installed for a short period in 2007 and then a dam safety issue led to their complete discontinuation at the dam.

In 2007, the first year of the monitoring program was completed by Cambria Gordon Ltd. and Metlakatla Fisheries. The monitoring program collected data on the distribution and characteristics of the vegetation communities within the drawdown zone. These data were collected with the goal of informing future reservoir operations required to maintain the area of sedge habitat. This initial study was completed prior to the identification of the dam safety issue that led to their discontinued use (Cambria Gordon Ltd., 2007).

In 2017, Khtada was contracted to provide sedge habitat maintenance monitoring services for BC Hydro at the Big Falls Reservoir. During Year 2 of the study, the field and data analysis methods mirrored the 2007 methods to ensure that results of the 2017 study were comparable to 2007. The goal of the 2017 study was to determine if the operating regime of the Big Falls Reservoir post-2007 maintained the area of sedge communities within the eastern region of the Big Falls Reservoir.

1.2 Reservoir Operating Regimes

1.2.1 Operating Regimes Background

Historically, the Big Falls Reservoir has operated under several different regimes. The main difference between the reservoir operating regimes was the timing of the flashboard installation. Periodically flooding the reservoir shoreline vegetation communities was considered a key action to reduce the succession of non-wetland herbs and shrubs into the ecologically valuable sedge community (BC Hydro, 2016).

Reservoir operating levels can be categorized into four stages (Table 1):

1. Pre-2002 Historic operations
2. Post-2002 dam safety review operations
3. Mid-2006 to 2007 WUP operations
4. 2007-Current existing operations

Table 1. Timing of flashboard installation for each of the four stages of reservoir operations

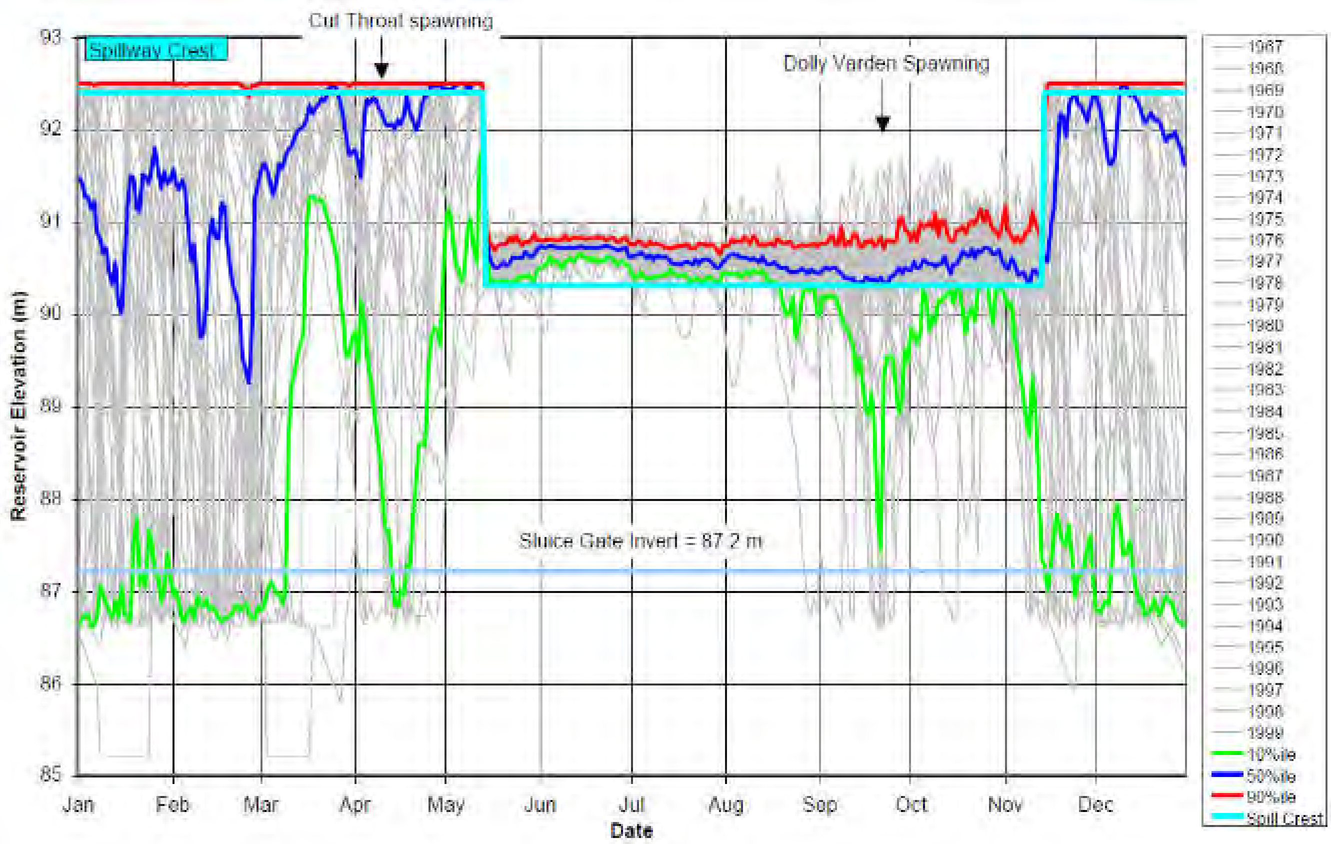
Operation Regime	***Flashboards Installed (Earliest)***	***Flashboards Installed (Latest)***	***Years Implemented***
Pre-2002 Historic operations	~15-Nov	~15-May	Up to 2002
Post-2002 dam safety review operations	Not installed	Not installed	2002 through mid-2006
Mid-2006 to 2007 CC recommended operations	15 Feb to 15 Mar	1 May to 15 May	Planned: beginning mid-2006 Actual: a short period in early 2007
2007-current operations	Not installed	Not installed	Mid-2007 to present

Source: (BC Hydro, 2016)

1.2.2 Reservoir Elevations

Up to 2002, flashboards were installed on the dam spillway crest. The spillway crest was raised from approximately 90.4 m to 92.4 m from mid-November to mid-May (Figure 1). The resulting reservoir elevations saw large annual water level fluctuations in response to the changed elevation of the spillway crest.

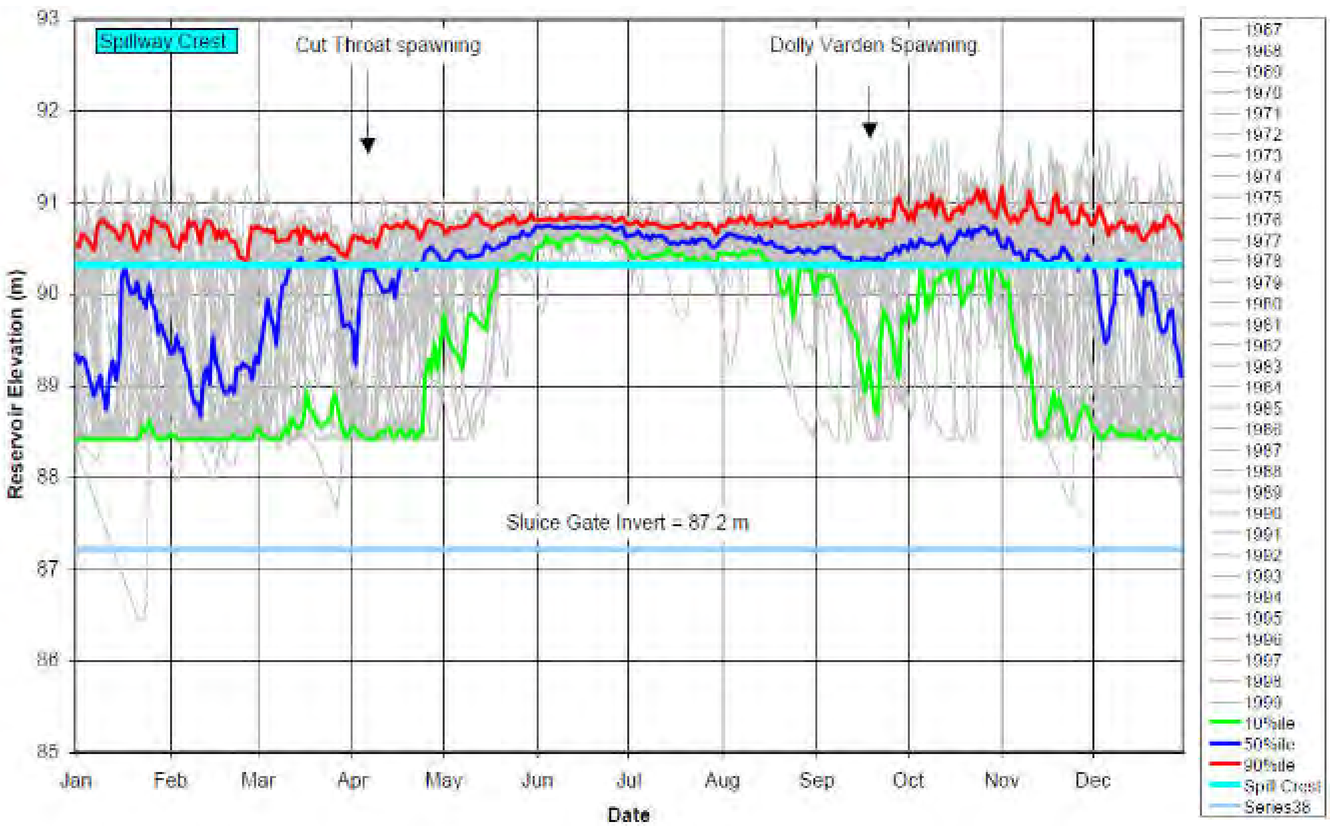
Figure 1. Big Falls Reservoir elevations under the Pre-2002 Historic Operations Regime based on modelled historic inflows



Source: From Figure 4-1 of the BC Hydro FLSMON-4 Terms of Reference report (BC Hydro, 2016)

However, in 2002 a dam safety review of operations at the Big Falls Reservoir identified a safety concern related to the flashboards. The installation period was initially reduced to a short period of time; however, a further examination of the economics of flashboard installation led to a discontinuation of their use from 2002 to early 2007. The spillway crest was at a constant approximate elevation of 90.4 m (Figure 2). In response, the reservoir elevations fluctuated less than the pre-2002 historic operations.

Figure 2. Big Falls Reservoir elevations under the Post-2002 Dam Safety Review Operations Regime based on modelled historic inflows

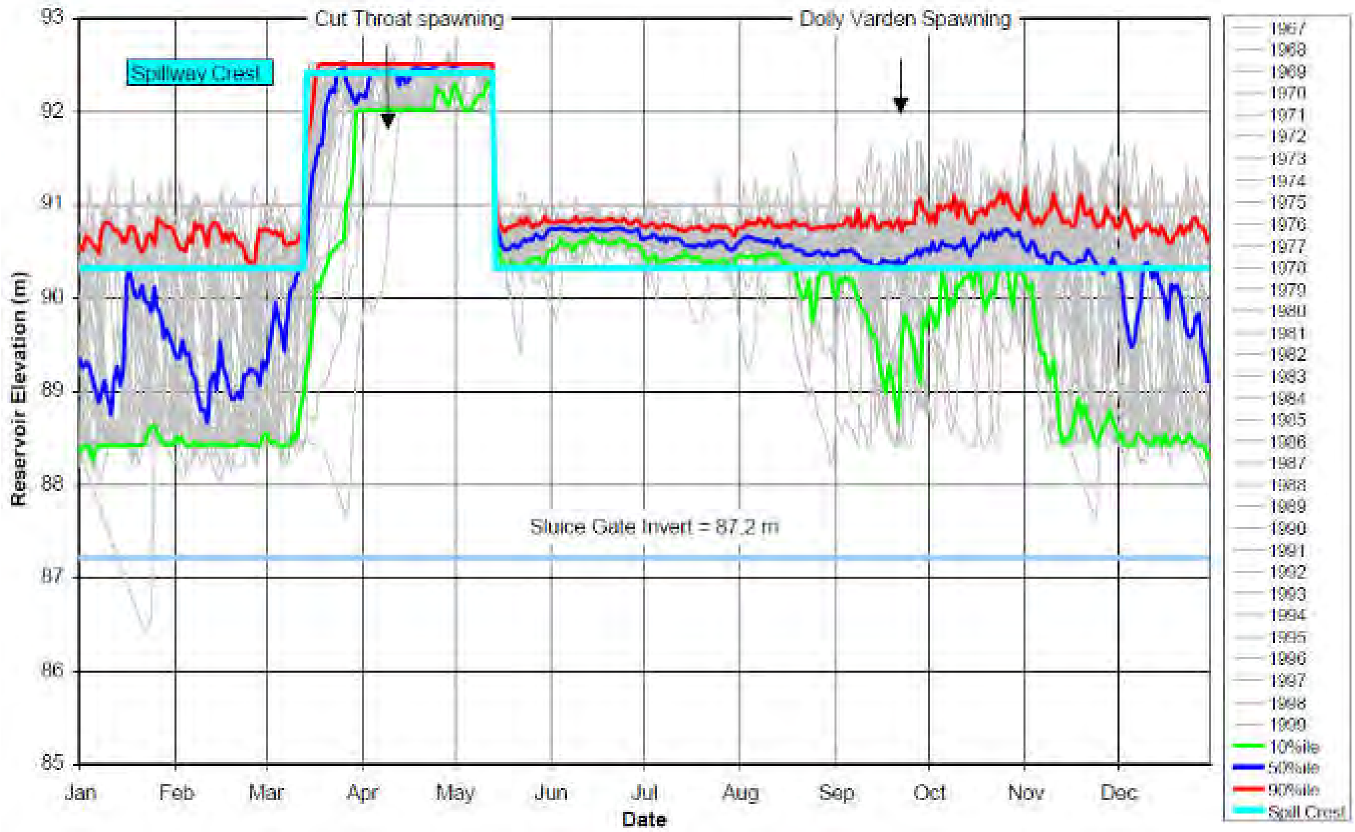


Source: From Figure 4-2 of the BC Hydro FLSMON-4 Terms of Reference report (BC Hydro, 2016).

In 2006, during the planning of the Falls River WUP, the CC recommended that the flashboards be installed from approximately February 15 to May 15 to maintain the sedge habitat area. The installation of flashboards was scheduled to begin February 2007.

The flashboards were installed during a short period of time in early 2007 (Figure 3). However, mechanical issues were encountered while the flashboards were installed. A dam safety review of the use of flashboards concluded that their use was unsafe and they were discontinued indefinitely post-2007. Consequently, the reservoir operations recommended by the CC were not possible to implement.

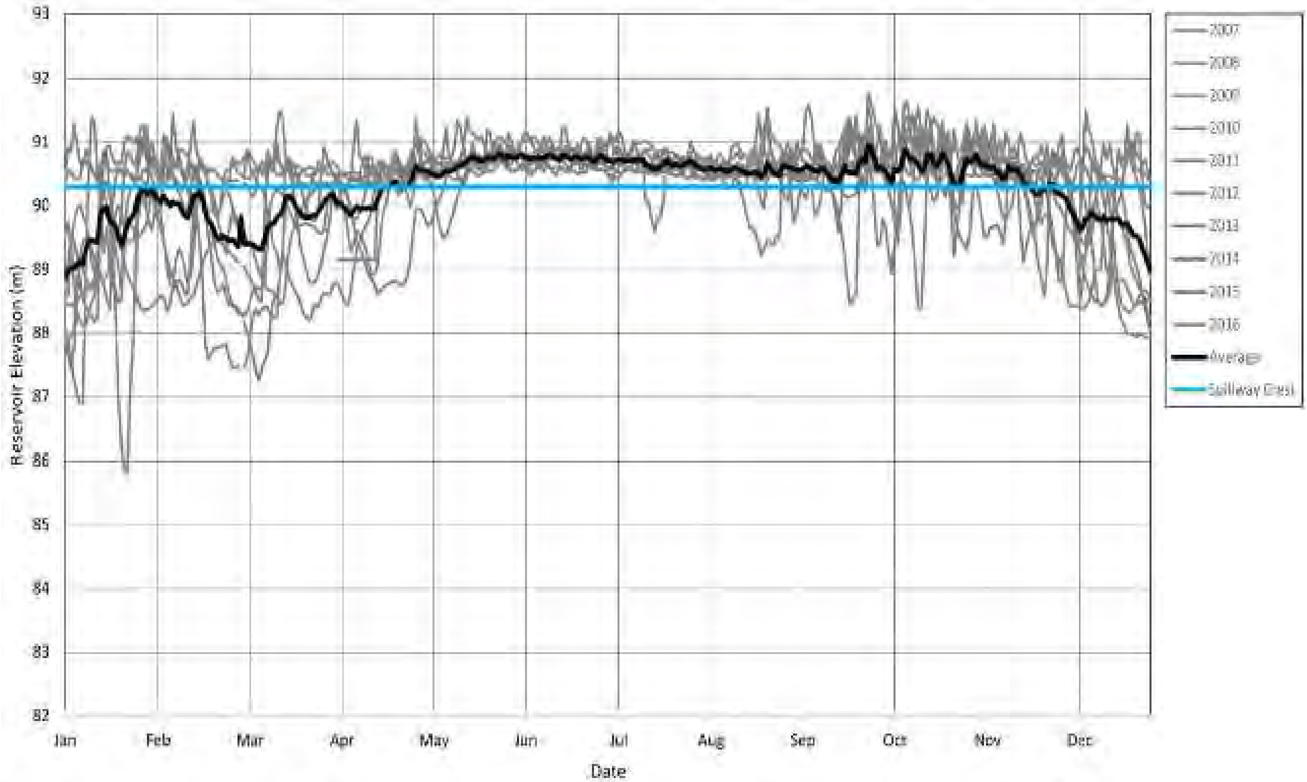
Figure 3. Big Falls Reservoir elevations under the Mid-2006 to 2006 WUP operations regime based on modelled historic inflows



Source: From Figure 4-3 of the BC Hydro FLSMON-4 Terms of Reference report (BC Hydro, 2016)

Following the dam safety review in 2007 and the discontinuation of the flashboards, actual reservoir elevations from 2006 to 2017 were similar to those of the post-2002 to 2006 elevations. The spillway crest was at a constant elevation of approximately 90.4 m. The average elevation range was from approximately 89.0 to 91.0 m (Figure 4).

Figure 4. Big Falls Reservoir elevations under the 2007-current operations regime based on average daily elevation



Source: From Figure 4-4 of the BC Hydro FLSMON-4 Terms of Reference report (BC Hydro, 2016)

1.3 Purpose

The area of the sedge community can be influenced by the reservoir operating regime (BC Hydro, 2016). The results of this study will assess the effects of existing (i.e., 2007 to 2017) reservoir operations on the extent of the sedge community within the eastern portion of the reservoir.

The primary null hypothesis and sub-hypothesis tested in this study are:
H_1: The area of the sedge community will not change as a consequence of reservoir operations.

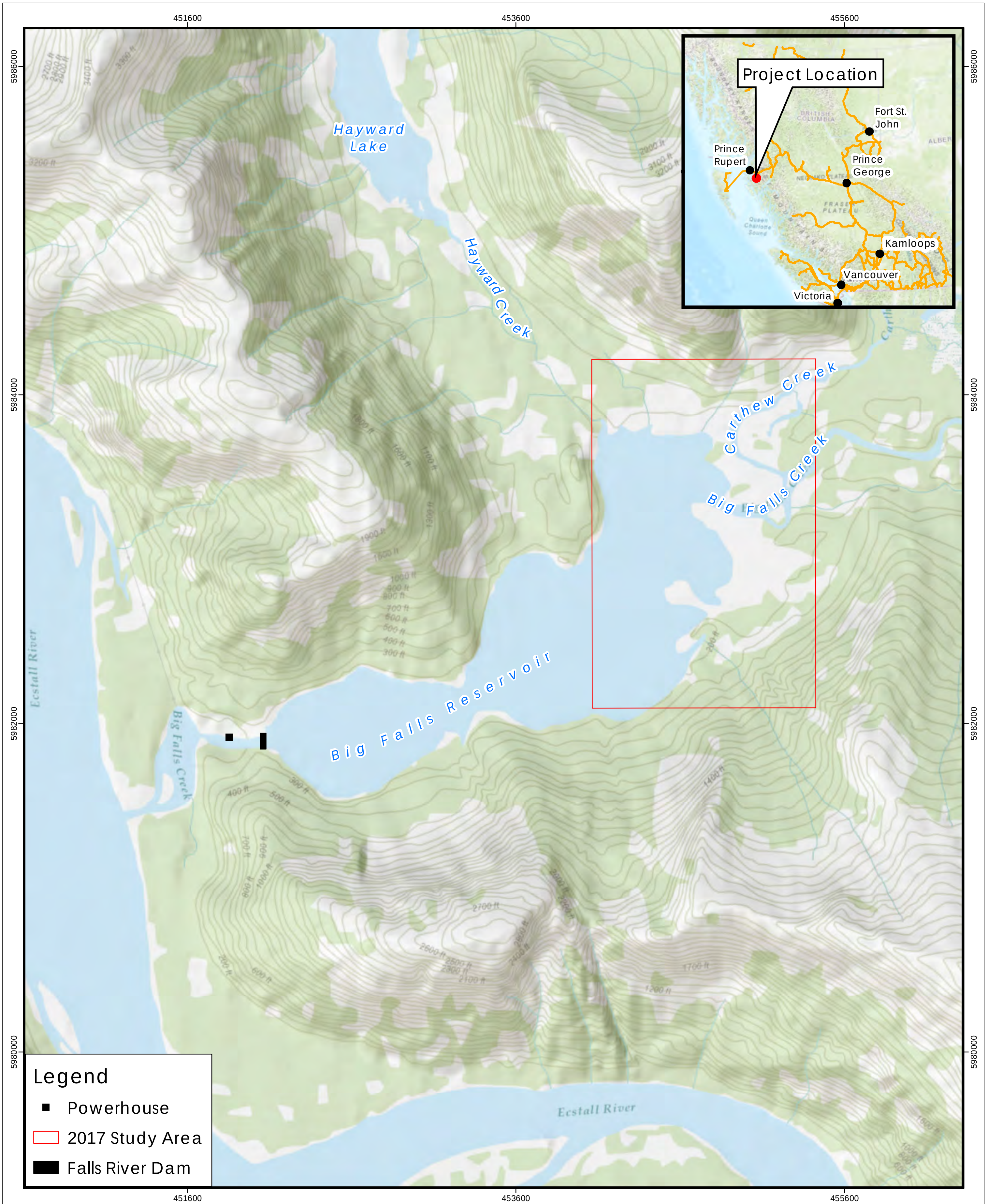
- H_{1a}: The species composition of the sedge grass community will not change as a consequence of reservoir operations.

The main objective of this study was to reduce the uncertainty related to the effects of current reservoir operations on the Big Falls Reservoir vegetation (BC Hydro, 2016).

2.0 Study Area

The Big Falls Reservoir is located approximately 50 km southeast of Prince Rupert, BC (Figure 5). In 2006, the water surface area of the reservoir (i.e., reservoir water level elevation was 92.4 m) was 340 hectares (BC Hydro, 2006b). The elevation of the reservoir fluctuates between approximately a minimum of 85.0 m to a maximum of 92.0 m above sea level (BC Hydro, 2006a).

The Big Falls Reservoir is primarily fed by the inflows of Hayward Creek, Carthew Creek, and Big Falls Creek (Figure 6). The reservoir flows over the Falls River dam and into the Ecstall River to the west. The Ecstall River then flows into the Skeena River which eventually flows into the Pacific Ocean.



BC Hydro Falls River Sedge Monitoring

0 125 250 500 750 1,000 1,250
Meters
Scale:1:30,000

File Path:
N:\ACTIVE\5853_BCH_FallsRiverSedgeMonitoring\MXD\5853_PL_20171205.mxd

Figure 5 - Location Map, Big Falls Reservoir

Project No:	5853
Date:	Dec 05, 2017
Basemap Source:	ESRI World Topographic Map
Map Datum:	NAD 1983 UTM Zone 9N

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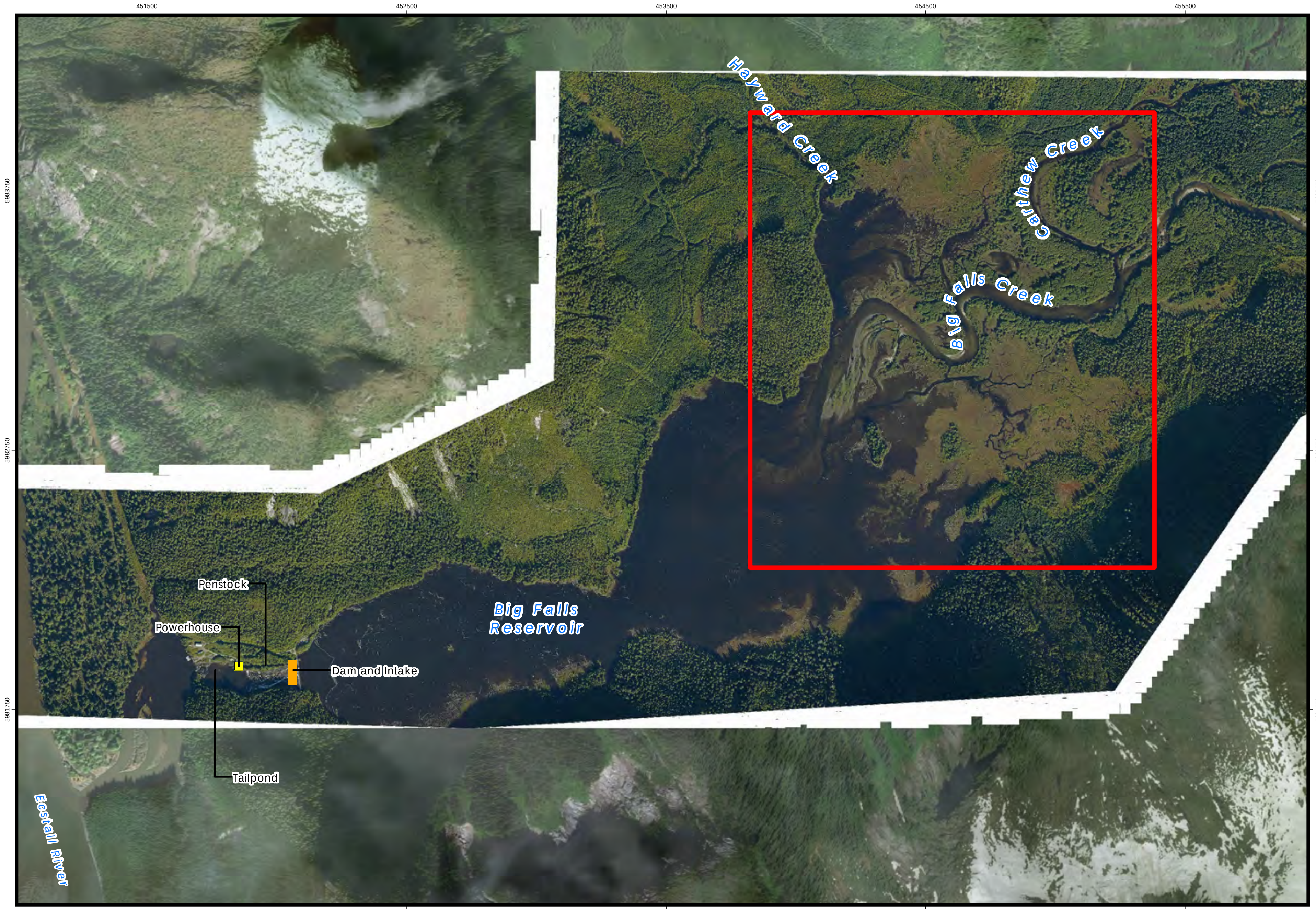

BC Hydro Falls River Sedge Monitoring

Figure 6 - Aerial Photo Mosaic of the Big Falls Reservoir

Legend

- Powerhouse
- 2017 Study Area
- Falls River Dam/Intake

0 75 150 300 450 600 750
Meters
Scale: 1:20,000

N / E / S / W

File Path:
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Project No:	5853
Date:	Dec 15, 2017
Basemap Source:	Orthophoto/ESRI World Imagery
Map Datum:	NAD 1983 UTM Zone 9N

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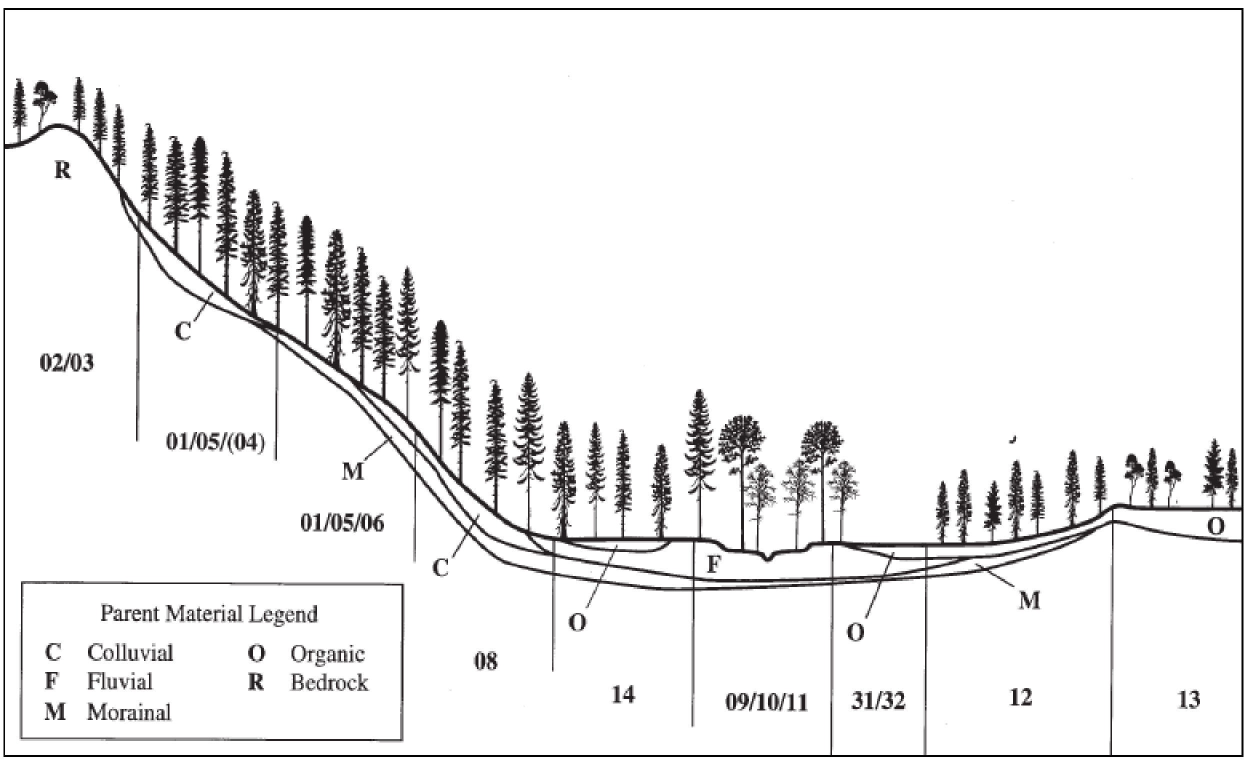
The Big Falls Reservoir is within the Coastal Western Hemlock, Very Wet Maritime, Submontaine variant (CWHvm1) biogeoclimatic (BEC) zone (Government of British Canada, 2016). On the mainland, this BEC zone is located from 0 to 400 m above sea level along the western slopes of the coastal and Kitimat mountain ranges.

The CWHvm1 BEC zone is divided into different site series. These site series are differentiated based on the elevation, vegetation, precipitation, and hydrologic regime of the site. The Study Area within the Big Falls Reservoir could be characterized as both a floodplain site, a non-forested site, and a wet site (Government of British Columbia, 2007).

The floodplain site series is (09) Salmonberry that occurs on a high fluvial bench (Figure 7). This site series occurs on elevated floodplain sites that experience seasonal fluctuations in the water table, but not annual flooding. Typical vegetation includes salmonberry and ferns in the understory and herb layer. Soil characteristics include poorly developed Brunisols or Regosols (Government of Canada, 2017).

Figure 7. Landscape profile of the CWHvm1 BEC Zone



Source: (Government of British Canada, 2016)

The non-forested site series for the Study Area are (31) Non-Forested Bogs and (32) Fens/Marshes. The bogs are uncommon throughout the zone, while fens and marshes are present near water channels and small lakes. Vegetation within the bogs are typically sphagnum sp. dominant, while the marshes are composed dominantly of sedge and rushes. The wet forest region of the CWHvm1 BEC zone contains six different site series (i.e., 05 Foamflower, 06 Deer fern, 08 Devil's club, 12 Goldthread, 13 Sphagnum, and

14 Skunk Cabbage) all of which could be present within the Study Area (Figure 7) (Government of British Canada, 2016).

The CWHvm1 BEC zone is characterized by a very wet, humid, and mild climate. The mild climate contributes to an extended cool growing season and less snow than the surrounding zones during the winter months (Government of British Columbia, 2007).

The Canadian Climate Normals (i.e., data averaged from 1981-2010) for the nearest weather station with a similar elevation of 90 m is the 'Prince Rupert R Park' Station. The average annual rainfall for the station is 2,847.7 mm, while the average annual snowfall is 95.4 cm (Government of Canada, 2017). No temperature data were available from this station. The 'Prince Rupert A' Station, located at 30 m in elevation, did collect temperature data from 1981-2010. The daily average temperature is 7.5°C, the daily maximum temperature is 10.8°C, and the daily minimum temperature is 4.2°C (Government of Canada, 2017).

Most of the Big Falls Reservoir contains steep, mountainous slopes (Figure 8). However, the Study Area is located within the eastern portion of the Big Falls Reservoir which is gently sloped, containing mostly marsh and low-lying shrub habitat. The Study Area is located on the fluvial fan that has developed at the inflow of Hayward, Big Falls, and Carthew Creek into the reservoir. The sedge habitat that developed in this region is located within a thin elevation band of approximately 1.5 to 2.0 m (Cambria Gordon Ltd., 2007) throughout the Study Area.

Figure 8. Steep mountainous slope of the Big Falls Reservoir (2017)

3.0 Methods

The methods of the 2017 Sedge Maintenance Monitoring Project were designed to replicate Year 1 of the study completed in 2007 (Cambria Gordon Ltd., 2007). The field data sheets from Year 1 of the study were also used in 2017.

3.1 Air Photo Analysis and Vegetation Mapping

To map the vegetation communities of the Big Falls Reservoir, the 2017 low level spatially geo-referenced colour mosaic air photos were stereoscopically analyzed. Distinct vegetation community boundaries within the Study Area of the Falls River Reservoir were characterized and defined. The vegetation communities were characterized following the structural stages descriptions of the BC RISC Standard for Terrestrial Ecosystem Mapping (Province of British Columbia, 1998). The polygon boundaries were drawn on the air photos and then digitized into a GIS map.

Each polygon was numbered as similarly as possible to the 2007 study. The extent of the 2017 Study Area was also kept consistent with the 2007 boundary (i.e., using the 2007 GIS polygon shapefile boundaries) as much as practical to ensure consistency and comparability.

3.2 Ground-truthing

Four data collection tasks were completed in the field which replicated the 2007 study methods:

1. Vegetation transects
2. Quadrat (Plot) sampling
3. Surveying for transect elevations
4. Ground-level photo monitoring

3.2.1 Vegetation Transects

During the 2007 study, five transect locations were established within nine vegetation polygons. These transects were located at key sites to determine site topography, species composition, and extent of vegetation within the Study Area. The GPS location of each transect start and end point was collected.

During the 2017 study, the locations of the permanent transects were located using the 2007 start and end point GPS coordinates. Transects started at or near the shoreline and ran perpendicular to the shore through different vegetation communities. The length of each transect corresponded to the 2007 study.

Species composition and percent coverage of vegetation along each transect were determined using the 'line intercept' method (Cummings, 2000). For this method, each transect was broken into segments and the plants which crossed the vertical plane of the transect line were identified. The proportion of each species along a segment was recorded. Cover of each plant species per segment was then calculated as the percent of the transect line covered by that species. The survey methods for the line intercept transect were as follows:

1. Use the GPS coordinates provided from the 2007 field study to navigate to the transect start point.
2. Extend an Eslon tape from the start point along the same bearing as in 2007 to the permanent end point.
3. Determine the interval length for distinct vegetation communities along the transect line. For homogenous communities (i.e., when one vegetation type such as sedge comprised >80% of the entire line transect), the interval length was up to 10 m, while in heterogeneous communities (i.e., when species were intermixed with one another and a vegetation type dominated <80% of the entire line transect), the interval length was between 1 and 2 m.
4. Next, determine an intercept length for each species within an interval. The intercept length was considered the distance along the transect line (i.e., Eslon tape) that was intercepted by a projection of plant foliage.

Percent cover for each of the species encountered along the transect was then calculated using the equation:

$$\%Cover = \left(\frac{Total\ intercept\ lengt\quad of\ a\ species\ (m)}{Total\ intercept\ lengt\quad (m) of\ transect}\right)\ x\ 100$$

3.2.2 Quadrat (Plot) Sampling

During the 2007 study, eight vegetation quadrats were also collected in seven different vegetation community polygons within the Study Area. The quadrats were completed to augment the species encountered within each polygon that might not have been encountered during the line intercept transect survey.

In 2017, 13 quadrats were completed within the same seven vegetation community polygons as the 2007 study. The five additional quadrats captured during the 2017 field study were collected within polygons with a high species diversity.
The quadrat frame was thrown at random locations within distinct vegetation polygons along each transect line and at two points of interest. Consistent with the 2007 study, a circle hula-hoop of 0.86 m in diameter (0.58 m^2) was used as the quadrat plot. All plant species that fell within the quadrat were recorded on the quadrat data sheet.

The percent coverage of each plant species within the quadrat was visually estimated and recorded as cover class (Table 2). Plants that were not rooted in the quadrat were also counted. Overlapping canopy cover was included in the estimation, so total cover could exceed 100%.

Table 2. Cover class categories for percent cover used in quadrat sampling

Cover Class	Percent Cover
1	0-5%
2	5-25%
3	25-50%
4	50-75%
5	75-95%
6	95-100%

3.2.3 Surveying for Transect Elevations

In 2007, five different locations within the Study Area were surveyed for elevation. The elevational survey captured the location and elevation of distinct vegetation communities, their boundaries and transitions, and geographical points of interest. The 2017 survey locations and lengths were consistent with the 2007 field survey.

The elevations were captured using a stadia rod and survey level. Consistent with the 2007 field study, the reservoir water level was used as the benchmark for each survey line. During the ground-truthing survey conducted September 22-24, 2007, the reservoir elevation varied hourly between 90.7 m and 91.15 m. During the September 7, 2017, ground-truthing, the reservoir elevation varied hourly between 90.37 m and 90.43 m. Reservoir elevations were provided by BC Hydro in 2007 and 2017. The survey line started at the water's edge, or the edge of the sedge within the water. For transects with sedge communities that were present below the water surface, the lowest elevation range of the sedges was captured while maintaining safe work practices.

The survey line often extended past the line intercept transect to capture elevation changes within as many vegetation polygons as possible. The boundaries between each vegetation community were used to verify the accuracy and precision of the air photo analysis and vegetation mapping.

3.2.4 Ground Level Photo Monitoring

Seven photo stations were established during the 2017 field study. Each photo station location was within the same polygon as the photo stations from 2007 study; however, the GPS locations of the exact 2007 photo station locations were not available. The photo stations were captured near the start of the transect or survey line or at a transition zone from one vegetation polygon to another, consistent with the 2007 study.

Once a photo station was navigated to or established during the 2017 field study, a photo was captured in each cardinal direction. A final photo of the ground at the 2017 photo point was taken.

4.0 Results

4.1 Air Photo Analysis and Vegetation Mapping

During the 2007 study, air photos of the Big Falls Reservoir were captured on August 30, 2007, from 3,000 and 7,000 feet. Air photo analysis revealed that the drawdown zone of the Big Falls Reservoir was composed of large distinct vegetation communities. These vegetation communities existed due to the specific hydrological, disturbance, slope, and elevation characteristics of the area. In 2007, six distinct vegetation communities were defined according to RISC standards through air photo analysis (Table 3).

Table 3. BC RISC standards for Terrestrial Ecosystem Mapping structural stage

Structural and Sub-stage	*Structural and Sub-stage Description*
Graminoid (sedge dominated)	Herbaceous communities dominated (greater than half of the total herb cover) by grasses, sedges, reeds, and rushes.
Bryoid (Bryophyte dominated)	Bryophyte- and lichen-dominated communities (greater than half of total vegetation cover).
Shrub/herb	Early successional stage or shrub communities maintained by environmental conditions or disturbance; dominated by shrubby vegetation; tree layer cover less than 10%, shrub layer cover greater than 20% or greater than or equal to one third of total cover.
Pole Sapling	Trees greater than 10 m tall, typically densely stocked, with overtopped shrub and herb layers; self-thinning and vertical structure not yet evident in the canopy; time since disturbance is usually less than 40 years for normal forest succession.
Young Forest	Self-thinning has become evident and the forest canopy has begun differentiation into distinct layers (dominant, main canopy, and overtopped); vigorous growth and a more open stand than in the pole/sapling stage.
Mature Forest	Trees established after the last disturbance have matured; a second cycle of shade-tolerant trees may have become established; understories become well developed as the canopy opens up.

Source: (Province of British Columbia, 1998)

On September 14, 2017, between 11:30 and 12:00 hours, a second round of air photos of the Big Falls Reservoir was captured. No further information on the methods or standards used while capturing the 2017 air photos were provided by BC Hydro.

Following stereoscopic analysis, no new vegetation communities were discovered beyond the six identified during the 2007 study (Table 3).

4.2 Ground-truthing

On September 7, 2017, two Khtada employees and one BC Hydro representative conducted the ground-truthing tasks within the Study Area of the Falls River reservoir.

4.2.1 Line Transects

During both the 2007 and 2017 field studies, five line transects were completed in the eastern region of the Big Falls Reservoir. Transects 1-1, 1-2, and 10-1 were completed along Carthew Creek, upstream of its inflow into Big Falls Creek. Transect 8-1 was completed along the Falls River upstream of its inflow into the Big Falls Reservoir. Transect 9-1 was completed within the Big Falls Reservoir (Appendices 1 and 2).

Each transect was summarized and the results displayed in elevation profiles (Figures 8 to 12). The raw data were entered into a Microsoft Access database. In 2007, the average elevation range of the sedge community was between 89.7 m and 91.7 m. In 2017, the average elevation range of the sedge community was from 89.8 m to 91.7 m.

In both 2007 and 2017, the highest amount of species diversity was found within the young forest and bryoid (i.e., moss and lichens vegetation communities). In 2007, 15 species were encountered in the young forest community and 16 species in the bryoid community. In 2017, 16 species were encountered in the young forest community and 12 species in the bryoid community.

Plant species observed during the 2007 transect survey are outlined in Appendix 3. Plant species observed during the 2017 survey are shown in Table 4. The 2017 line transect data are in Appendix 4. Transition zones referenced in Figures 9 to 14 refer to areas where no distinct vegetation community is prevalent (i.e., where shrub/herbs are intermixed with sedges/grasses or young forest species are intermixed with shrub/herbs).

Table 4. Transect sampling species diversity for each sampled vegetation polygon (2017)

Polygon #	*Transect #*	*Vegetation Community Type*	*Species (Common Name)*	*Species (Scientific Name)*
1	1-1	Graminoid Dominated Herb (Sedge)	spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			small-flowered bulrush	*Scirpus microcarpus*
			upland grass	--
4	1-1	Young forest	spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			fireweed	*Epilobium angustifolium*
			small-flowered bulrush	*Scirpus microcarpus*
			beaked sedge	*Carex utriculata*
			upland grass	--
			bracken fern	*Pteridium aquilinum*

Polygon #	Transect #	Vegetation Community Type	Species (Common Name)	Species (Scientific Name)
			red elderberry	*Sambucus racemosa*
			salmonberry	*Rubus spectabilis*
			red alder	*Alnus rubra*
			moss spp.	--
			Pacific water parsley	*Oenanthe sarmentosa*
			common horsetail	*Equisetum arvense*
1	1-2	Graminoid Dominated Herb (Sedge)	Sitka/beaked sedge	*Carex sitchensis/Carex utricualata*
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			aster sp.	Aster sp.
			small-flowered bulrush	*Scirpus microcarpus*
2	1-2	Shrub/herb	Sitka/beaked sedge	*Carex sitchensis/Carex utricualata*
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
8	8-1	Shrub/herb	Sitka/beaked sedge	*Carex sitchensis/Carex utricualata*
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			aster sp.	*Aster* sp.
			thimble berry	*Rubus parviflorus*
			red alder	*Alnus rubra*
			red elderberry	*Sambucus racemosa*
			cow parsnip	*Heracleum*
			salmonberry	*Rubus spectabilis*
9	8-1	Graminoid Dominated Herb (Sedge)	Sitka/beaked sedge	*Carex sitchensis/Carex utricualata*
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			cow parsnip	*Heracleum*
			aster sp.	*Aster* sp.
			small-flowered bulrush	Scirpus microcarpus
9	9-1	Graminoid Dominated Herb (Sedge)	small-flowered bulrush	Scirpus microcarpus
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			cinquefoil	*Potentilla* sp.
13	9-1	Bryoid	Sitka/beaked sedge	*Carex sitchensis/Carex utricualata*
			small-flowered bulrush	*Scirpus microcarpus*

Polygon #	Transect #	Vegetation Community Type	Species (Common Name)	Species (Scientific Name)
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			upland grass	--
			buckbean	*Menyanthes trifoliata*
			cinquefoil	*Potentilla* sp.
			bog cranberry	*Vaccinium oxycoccos*
			Sphagnum sp.	--
			Labrador tea	*Ledum groenlandicum*
			round-leaved sundew	*Drosera rotundifolia*
			bog rosemary	*Andromeda polifolia*
15	9-1	Shrub/herb	western redcedar	*Thuja plicata*
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			cinquefoil	*Potentilla* sp.
			upland grass	--
10	10-1	Graminoid Dominated Herb (Sedge)	Sitka/beaked sedge	*Carex sitchensis/Carex utricualata*
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*
			fireweed	*Epilobium angustifolium*
			bedstraw	*Galium* sp.
		Shrub/herb - Young forest transition zone	red elderberry	*Sambucus racemosa*
			salmonberry	*Rubus spectabilis*
			bracken fern	*Pteridium aquilinum*
			lady fern	*Athyrium filix-femina*
			red alder	*Alnus rubra*
			upland grass	--
6	10-1	Young forest	western hemlock	*Tsuga heterophylla*
			Sitka spruce	*Picea sitchensis*
			bracken fern	*Pteridium aquilinum*
			lady fern	*Athyrium filix-femina*
			red alder	*Alnus rubra*
			upland grass	--
			red elderberry	*Sambucus racemosa*
			salmonberry	*Rubus spectabilis*
			common horsetail	*Equisetum arvense*
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*

4.2.1.1 Transect 1-1

In 2007, Transect 1-1 began at the water's edge, went through a sedge community, and transitioned into a young forest. The elevation range of the sedge community was between approximately 91.1 m and 91.7 m. The reservoir elevation at the time of the transect survey was approximately 91.0 m (Figure 9).

In 2017, Transect 1-1 started at the water's edge and from 0 to 6 m went through a transition zone of grasses intermixed with shrub species (Figure 10). After the transition zone, the transect ran through a small sedge community and then transitioned into a young forest community. The elevation range of the sedge community was between 91.1 m and 91.7 m. The reservoir elevation at the time of the transect survey was 90.42 m (Figure 9).

Figure 9. Comparison of Transect 1-1 2007 and 2017 cross-sectional profiles

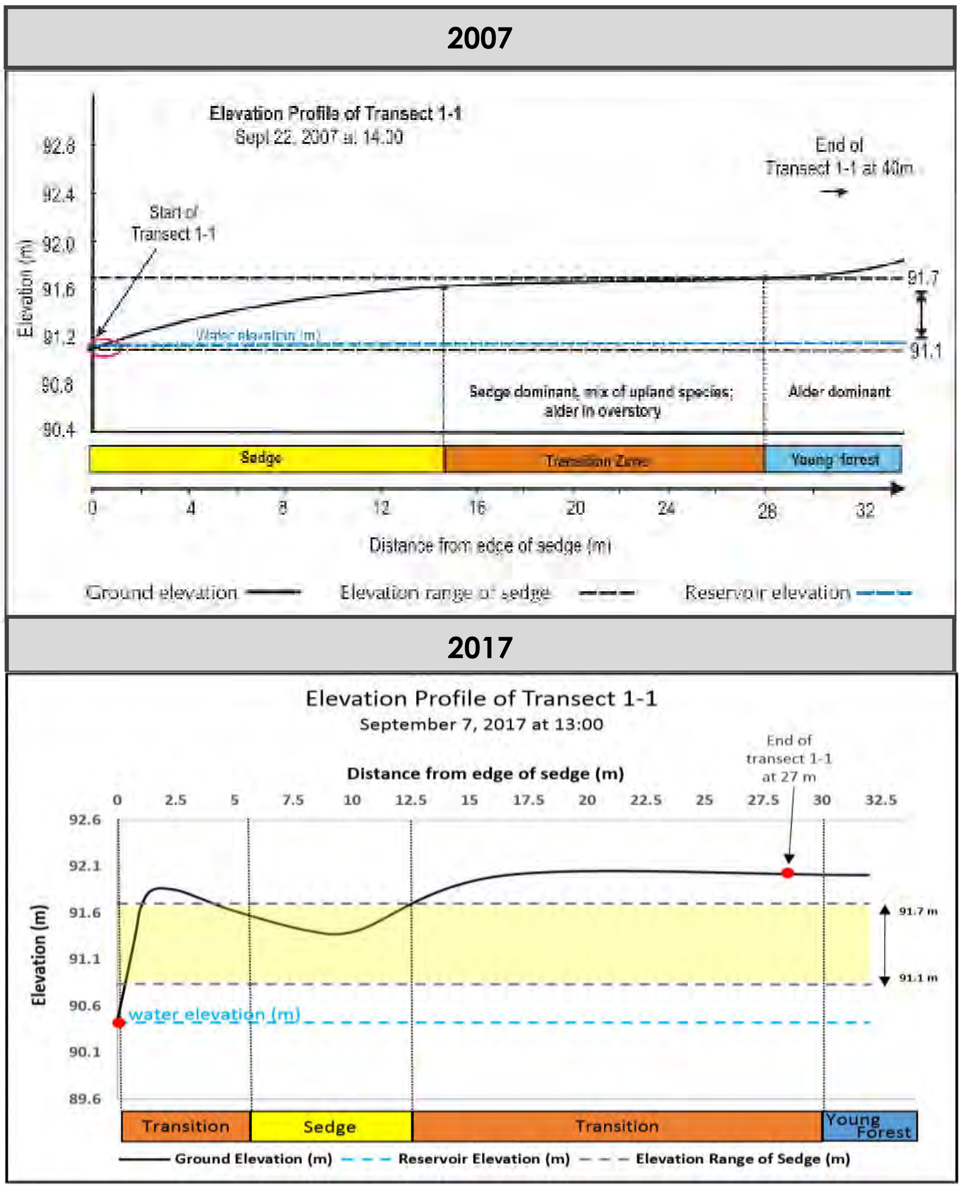


Figure 10. View of a typical transition zone near the water's edge (red box)

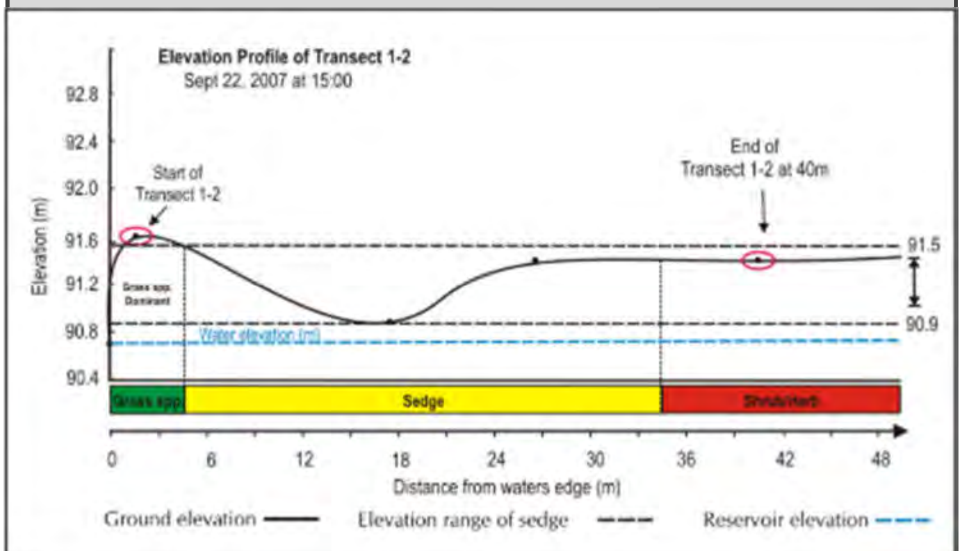
4.2.1.2 Transect 1-2

In 2007, Transect 1-2 started in a small grass band, passed through a sedge community, and ended at a shrub/herb dominated polygon. The elevation range of sedge habitat was between 90.9 m and 91.5 m. The reservoir elevation was approximately 90.7 m (Figure 11).

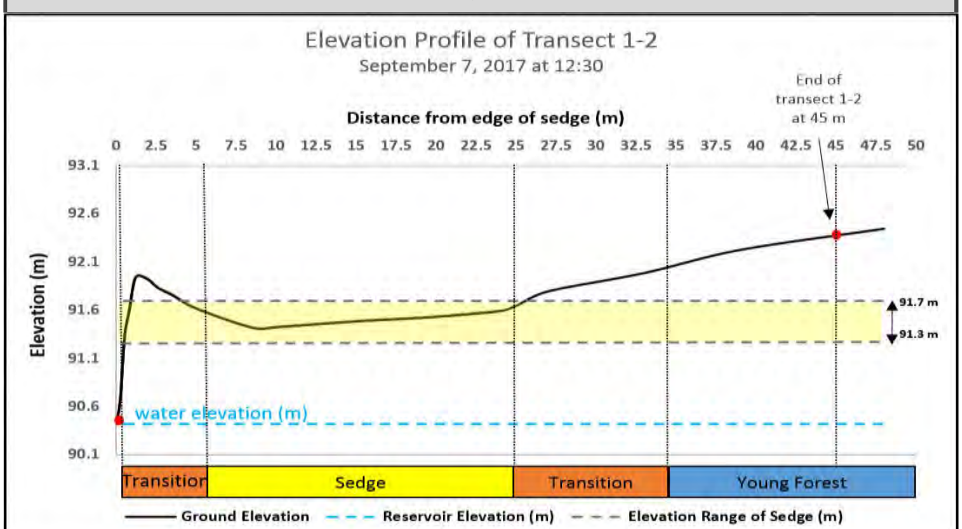
In 2017, Transect 1-2 started at the water's edge and from 0 to 5 m went through a transition zone of grass species intermixed with a spiraea dominated shrub community. Then the transect went through a sedge meadow and transitioned into a young forest community. The elevation range of the sedge community was 91.3 to 91.7 m. The reservoir elevation at the time of the survey was 90.42 m (Figure 11).

Figure 11. Comparison of Transect 1-2 2007 and 2017 cross-sectional profiles

2007



2017



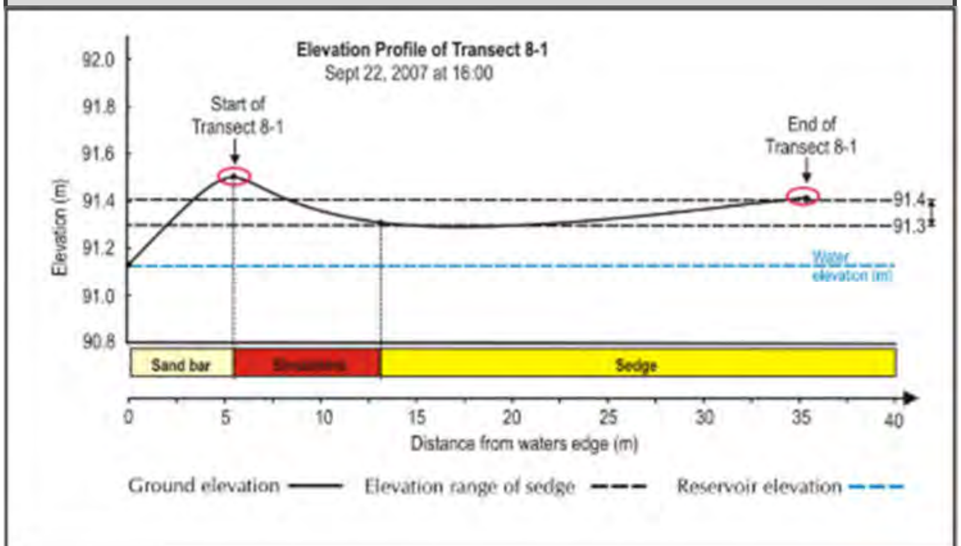
4.2.1.3 Transect 8-1

In 2007, Transect 8-1 started after the sand bar, went through a shrub/herb community, and finally through a large sedge community. The elevation range of the sedge community was between 91.3 m and 91.4 m. The reservoir elevation was approximately 91.15 m (Figure 12).

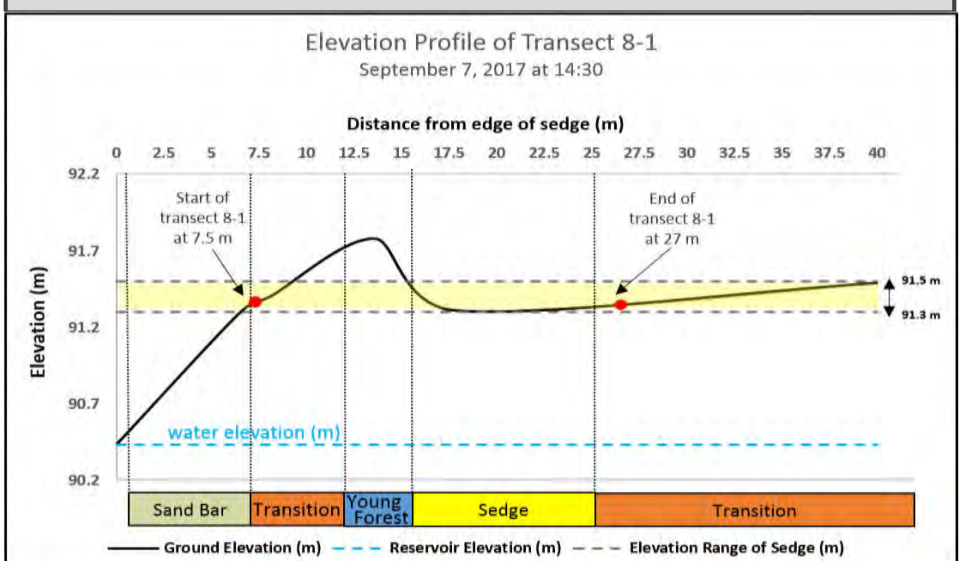
The 2017 survey started after the sand bar, went through a transition into an alder dominated young forest, through a sedge meadow, and ended in a transition area of spiraea intermixed with sedges. The elevation range of the sedge community was between 91.3 m and 91.5 m. The reservoir elevation was 90.43 m (Figure 12).

Figure 12. Comparison of Transect 8-1 2007 and 2017 cross-sectional profiles

2007



2017

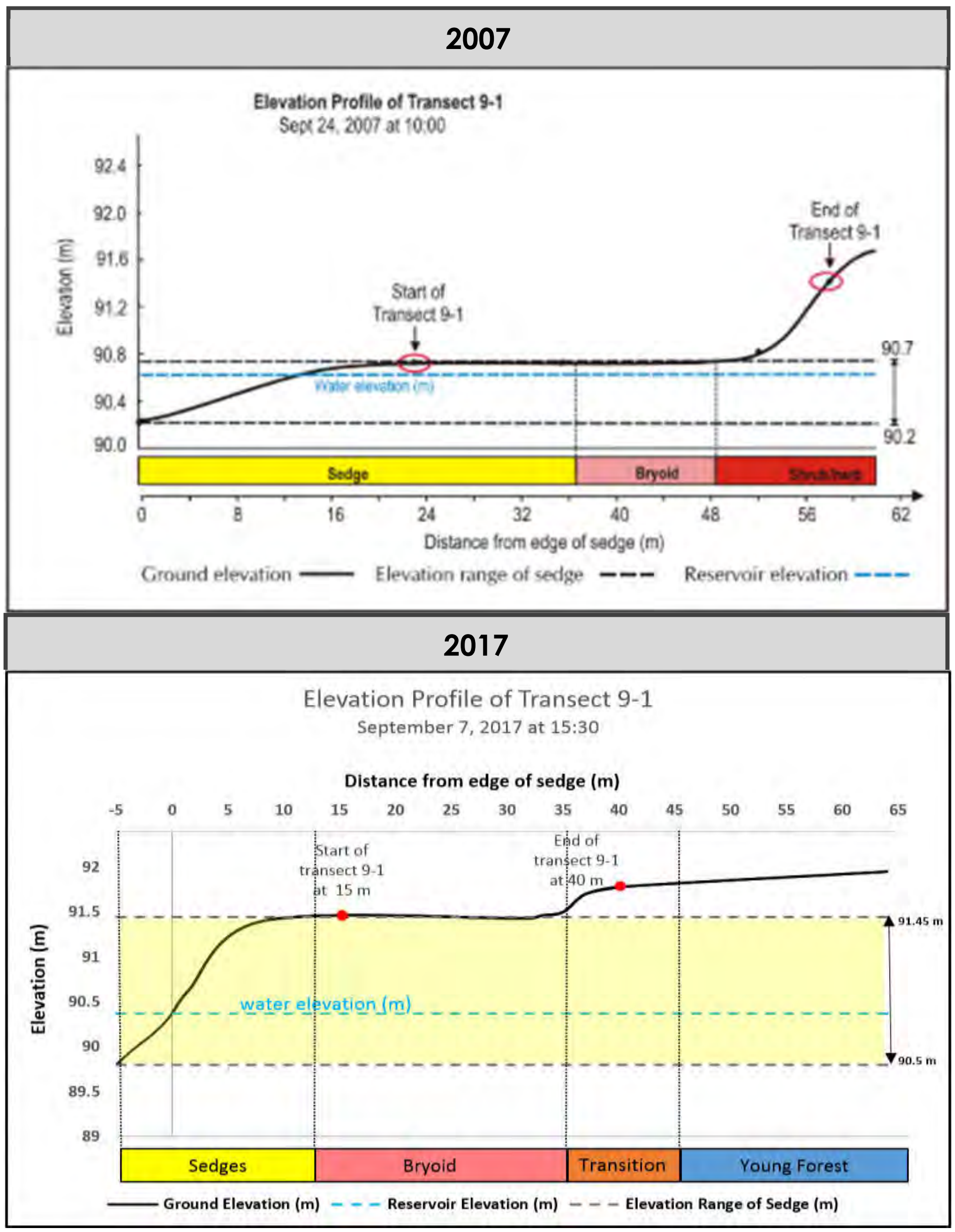


4.2.1.4 Transect 9-1

In 2007, Transect 9-1 started in a sedge dominated community, went through a bryoid community, and finally ended in a shrub/herb community. The elevation range of the sedges was between 90.2 m and 90.7 m. The reservoir elevation was approximately 90.7 m (Figure 13).

In 2017, Transect 9-1 started at the start of the sedges (i.e., 5 m within the reservoir from the shoreline), went through a sedge band and bryoid community, and then ended at the start of a young forest community. The elevation range of the sedge community was between 89.8 and 91.45 m. The reservoir elevation survey was 90.37 m (Figure 13).

Figure 13. Comparison of Transect 9-1 2007 and 2017 cross-sectional profiles

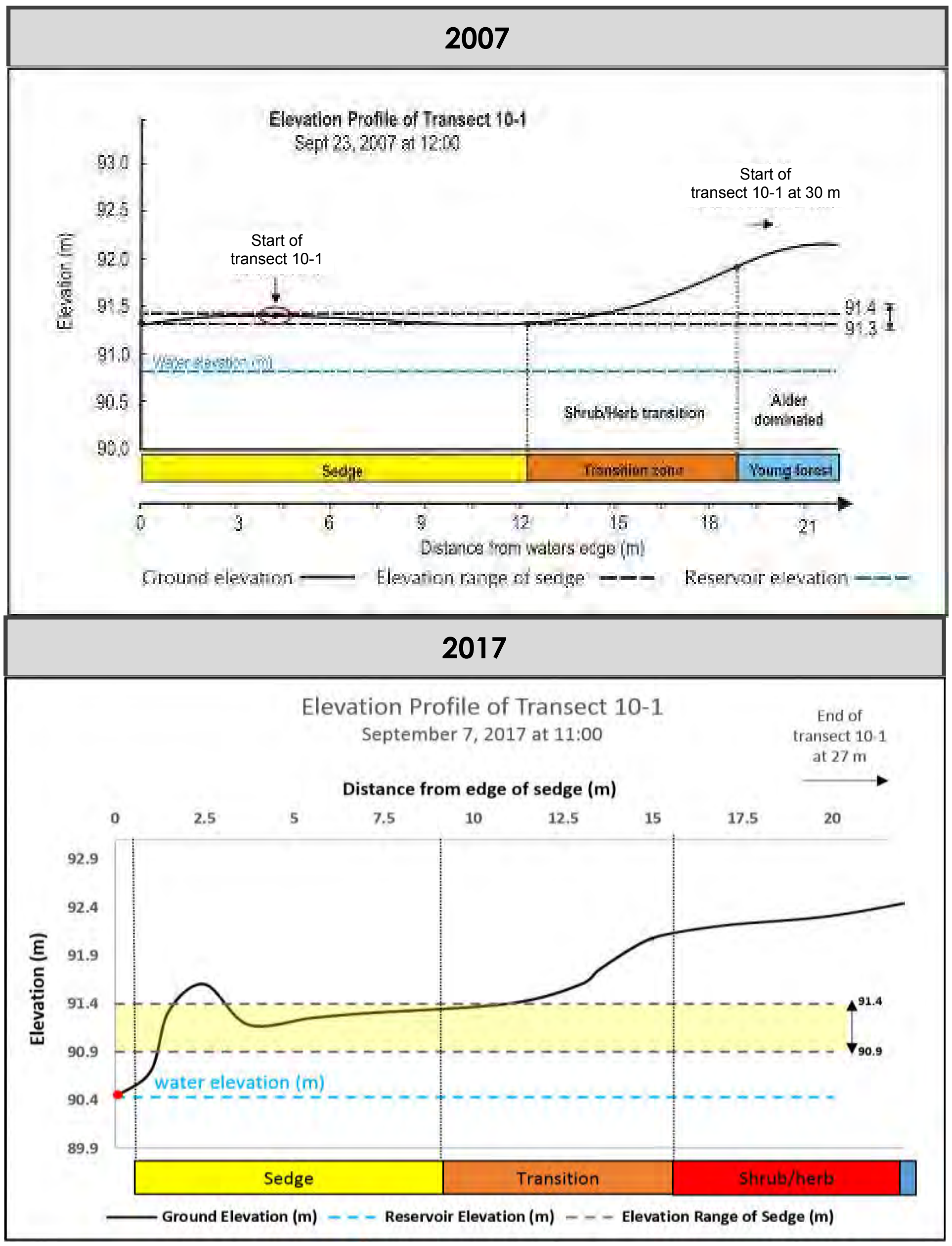


4.2.1.5 Transect 10-1

In 2007, Transect 10-1 started in a sedge community, went through a shrub/herb transition zone and ended in a young forest community. The elevation range of sedges was between 91.3 m and 91.4 m. The reservoir elevation was approximately 90.7 m (Figure 14).

In 2017, Transect 10-1 started at the water's edge, went through a small sedge pocket, and transitioned into shrubs/herbs, and finally a young forest community. The elevation range of the sedge pocket was between 90.9 m and 91.4 m. The reservoir elevation at the time of the survey was 90.43 m (Figure 14).

Figure 14. Comparison of Transect 10-1 2007 and 2017 cross-sectional profiles



4.2.2 Quadrat Sampling

In 2007, quadrat data revealed that the highest species diversity was encountered within the young forest and bryoid communities (i.e., six species each), consistent with the transect results (Appendix 3).

Consistent with the 2007 findings, the highest species diversity was found within the young forest and bryoid communities (Table 5) (i.e., seven species in young forest and six in bryoid communities), consistent with the transect results (Table 4).

Table 5. Quadrat sampling species assemblage for each sampled polygon (2017)

Polygon #	***Vegetation Community Type***	***Quadrat #***	***Species (Common Name)***	***Species (Scientific Name)***	***% Cover***
1	Graminoid Dominated (Sedge)	1	small-flowered bulrush	*Scirpus microcarpus*	95-100
			upland grass spp.	--	<5
		5	Sitka/beaked sedge mix	*Carex sitchensis/utriculata*	95-100
			spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*	5-25
			small-flowered bulrush	*Scirpus microcarpus*	5-25
		7	spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*	95-100
			Sitka/beaked sedge mix	*Carex sitchensis/utriculata*	5-25
2	Shrub/Herb	2	spiraea (hardhack)	*Spiraea douglasii* ssp. *Douglasii*	95-100
			Sitka/beaked sedge mix	*Carex sitchensis/utriculata*	<5
			upland grass spp.	--	2-25
		6	salmonberry	*Rubus spectabilis*	95-100
			red elderberry	*Sambucus racemosa*	<5
			aster sp.	--	25-50
		8	salmonberry	*Rubus spectabilis*	5-25
			red elderberry	*Sambucus racemosa*	25-50
			bracken fern	*Pteridium aquilinum*	25-50
6	Young Forest	4	salmonberry	*Rubus spectabilis*	50-75
			red alder	*Alnus rubra*	95-100
			western hemlock	*Tsuga heterophylla*	<5
			red elderberry	*Sambucus racemosa*	5-25
			bracken fern	*Pteridium aquilinum*	<5
			upland grass spp.	--	<5
			common horsetail	*Equisetum arvense*	<5
9	Graminoid Dominated (Sedge)	14	moss spp.	--	75-95
			sitka sedge	*Carex sitchensis*	5-25
			green sedge	*Carex viridula*	5-25
			cinquefoil	*Potentilla* sp.	5-25

Polygon #	Vegetation Community Type	Quadrat #	Species (Common Name)	Species (Scientific Name)	% Cover
10	Graminoid Dominated (Sedge)	3	Sitka/beaked sedge mix	*Carex sitchensis/utriculata*	95-100
			bedstraw	*Galium* sp.	<5
11	Shrub/Herb	9	salmonberry	*Rubus spectabilis*	5-25
			red elderberry	*Sambucus racemosa*	25-50
			bracken fern	*Pteridium aquilinum*	25-50
13	Bryoid Dominated	13	sphagnum	*sphagnum* spp.	95-100
			bog cranberry	*Oxycoccus oxycoccus*	5-25
			buckbean	*Menyanthes trifoliata*	<5
			upland grass spp.	--	5-25
			bog rosemary	*Andromeda polifolia*	5-25
			Labrador tea	*Ledum groenlandicum*	5-25

4.2.3 Ground Level Photo Monitoring

Seven photo points were established during the 2017 field study. Results from each photo station are presented in Appendix 5.

4.3 Contrasting 2007 and 2017 Results

4.3.1 Sedge Community Elevations

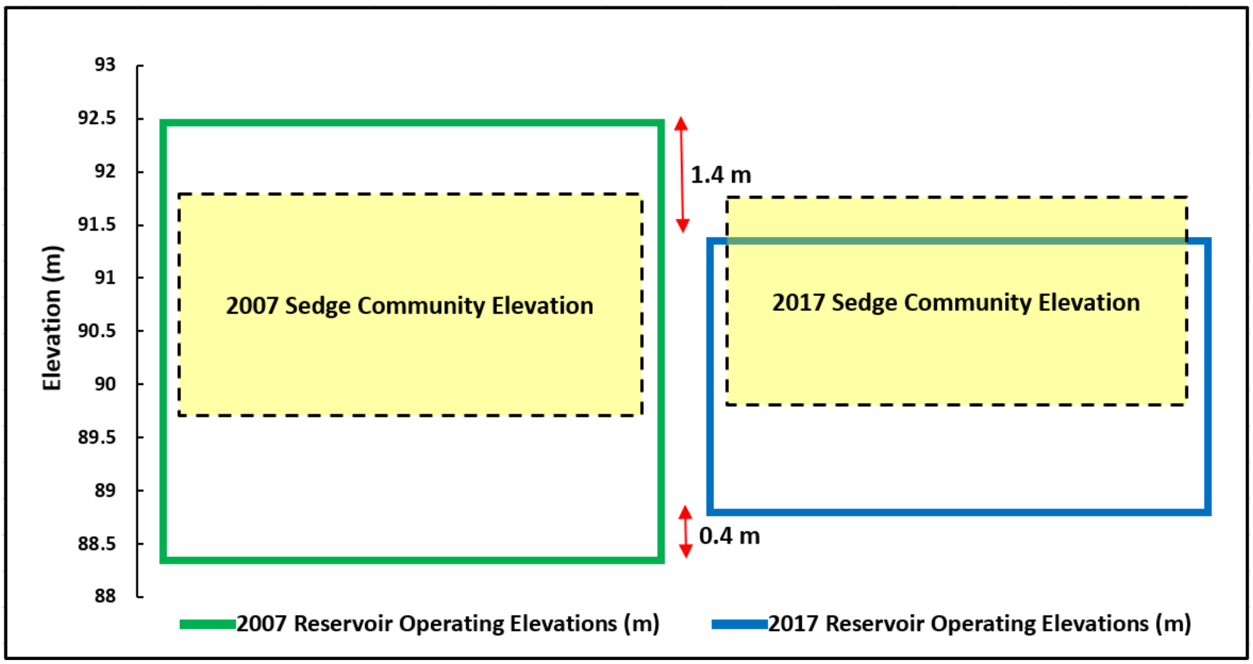
From 2007 to 2017 there were changes in the typical reservoir operating range (BC Hydro, 2006a). In 2007, the reservoir operating range was between 88.4 m and 92.4 m. The weir crest height was from 90.3 m to 92.4 m (i.e., lower limit with the flashboard removed; upper limit with the flashboard installed). The ground-truthed sedge community occurred in that range between 89.7 m and 91.7 m (Table 6).

Table 6. Comparison of 2007 and 2017 reservoir and sedge community elevations

	Elevation (m) ASL			
	2007		*2017*	
	Lower Limit (m)	Upper Limit (m)	Lower Limit (m)	Upper Limit (m)
Typical Reservoir Operating Range (BC Hydro, 2006a) and (BC Hydro, 2016)	88.4	92.4	88.9	91.0
Weir Crest Height	90.3	92.4	90.3[1]	90.3[1]
Sedge habitat community (ground-truthed in 2007 and 2017)	89.7	91.7	89.8	91.7

The actual average operating regime from 2006 to 2017 was between 88.9 m and 91.0 m (BC Hydro, 2016). The use of flashboards was discontinued in 2007 resulting in a constant weir crest height (i.e., spillway crest height) of 90.3 m. The sedge community that was ground-truthed in 2017 occurred in an elevation band of 89.8 m and 91.7 m (Table 6).

Figure 15. 2007 and 2017 reservoir operating elevations and sedge community elevations



Reservoir operations between 2007 and 2017 decreased the average maximum reservoir water level by 1.4 m and the average minimum reservoir water level by 0.4 m. In 2017, the sedge community upper limit was consistent with 2007; however, the lower limit had contracted by 0.1 m to 89.8 m.

4.3.2 Vegetation Community (Polygon) Areas

In 2007, there were 55 polygons within six vegetation community types outlined in the Study Area (Appendix 1; Table 7). The polygons ranged in area from 0.05 ha to 32.6 ha. There were twenty-four sedge habitat polygons identified with a total area of 63.1 ha.

The two largest (i.e., making up 84% of sedge habitat) sedge polygons were #9 at 32.6 ha and #11 at 20.4 ha (Table 8). The majority of the sedge habitat was located on the eastern end of the reservoir within the Study Area.

In 2017, there were 83 polygons of six different vegetation community types delineated within the Study Area (Appendix 2; Table 7). The polygons ranged in area from 0.01 ha to 21.34 ha. Thirty sedge habitat polygons were identified with a total area of 44.77 ha. The two largest polygons (i.e., making up 69% of total sedge habitat) were #9 at 21.34 ha and #11 at 8.26 (Table 8). Consistent with the 2007 findings, the majority of the sedge habitat was located on the eastern end of the reservoir within the Study Area.

Table 7. Summary of vegetation community types and areas from 2007 and 2017

Polygon Type (Structural Stage)	***Number of Polygons***		***Total Area (ha)***	
	2007	**2017**	**2007**	**2017**
Bryoid (moss)	2	2	0.9	1.32
Graminoid Dominated Herb (Sedge)	24	31	63.1	42.59
Shrub/Herb	17	31	7.12	28.36
Pole Sapling	3	4	3.3	7.81
Young Forest	6	12	20.58	29.09
Mature Forest	3	3	14.1	14.03
Total	**55**	**83**	**109.1**	**123.2***

*Total study area increased from 2007 to 2017 by 14.1 ha

The decrease in reservoir operating level resulted in the exposure of elongated sand bars at the western portion of the Study Area near the interior of the reservoir. These exposed bars were colonized by sedge species, resulting in six new sedge polygons compared to 2007 (Appendix 1). These new sedge polygons added a total area of approximately 1.96 ha (Table 8). Note that the numbering of the 2007 and 2017 polygons may not be exactly the same.

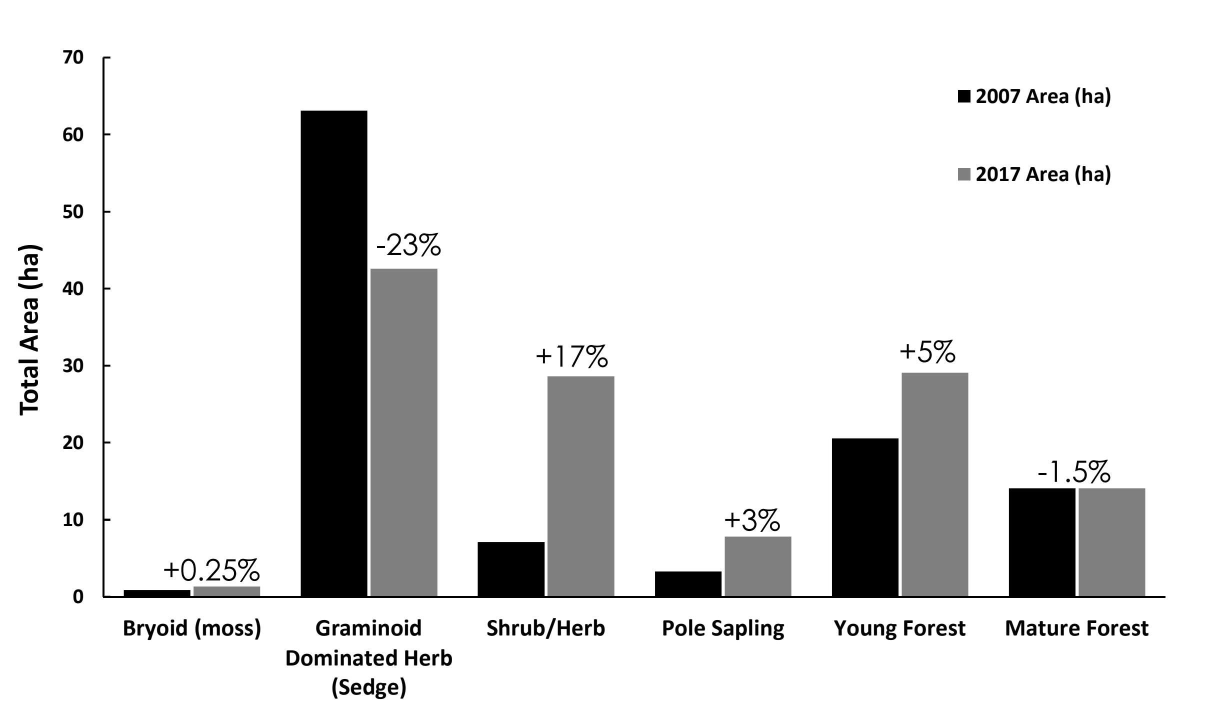
In 2007, the total number of sedge polygons was 24, with a total area of 63.1 ha or 57.8% of the Study Area. In 2017 the number of sedge polygons was 31 with a total area of 44.77 ha or 31.0% of the Study Area (Table 8). Overall, the sedge habitat area decreased from 2006 to 2017 by 23% (Figure 16). This value may not reflect the actual value as the Study Area between 2007 and 2017 increased (i.e., 2007 total area = 109.1 ha and 2017 total area = 144.66 ha). From 2007 to 2017 the study area increased by 14.1 ha.

Table 8. Comparison of the 2007 and 2017 sedge polygon numbers and areas

2007		***2017***	
Polygon #	**Area (ha)**	**Polygon #**	**Area (ha)**
1	0.86	1	1.09
3	0.18	3	0.22
9	32.57	9	21.34
10	0.37	10	0.78
11	20.39	11	8.26
12	3.04	12	2.62
21	0.52	23	0.07
22	0.22	24	0.07
23	0.25	26	0.08
24	0.18	29	0.42
26	0.04	30	2.31
27	0.12	38	0.27
28	0.40	39	0.3
28	1.91	40	0.71
30	0.17	41	1.27
38	0.18	56	0.09
39	1.33	57	0.07
41	0.11	58	0.05
48	0.10	59	0.13
50	0.02	60	0.07
51	0.02	62	0.06
52	0.03	64	0.55
53	0.05	65	0.21
54	0.04	67	0.03
		68	0.01
		70	0.74
		72	0.03
		74	0.01
		80	0.12
		81	0.62
Sedge area total (ha): 63.10		**Sedge area total (ha): 42.6**	

Excluding the mature forest community, all other vegetation communities increased in size (i.e., mature forest decreased by 1.5% from 2007 to 2017) (Figure 16). The largest increases were in the shrub/herb and young forest polygons (i.e., increased 17 and 5% respectively). Less than a 1% change was observed in the bryoid community.

Figure 16. 2007 and 2017 total vegetation community polygon areas (ha)



4.3.3 <u>Sedge Habitat Areas</u>

To study the difference in ground-truthed sedge habitat, the total length of sedge habitat (m) encountered for each 2007 transect was contrasted to total sedge habitat length (m) encountered for each 2017 transect (Table 9).

Table 9. Raw data of sedge community (m) encountered during 2007 and 2017 transects

Transect #	*2007 Sedge Habitat Length (m)*	*2017 Sedge Habitat Length (m)*
1-1	14.5	5.0
1-2	29.0	19.0
8-1	27.0	10.0
9-1	36.0	13.0
10-1	12.0	9.0

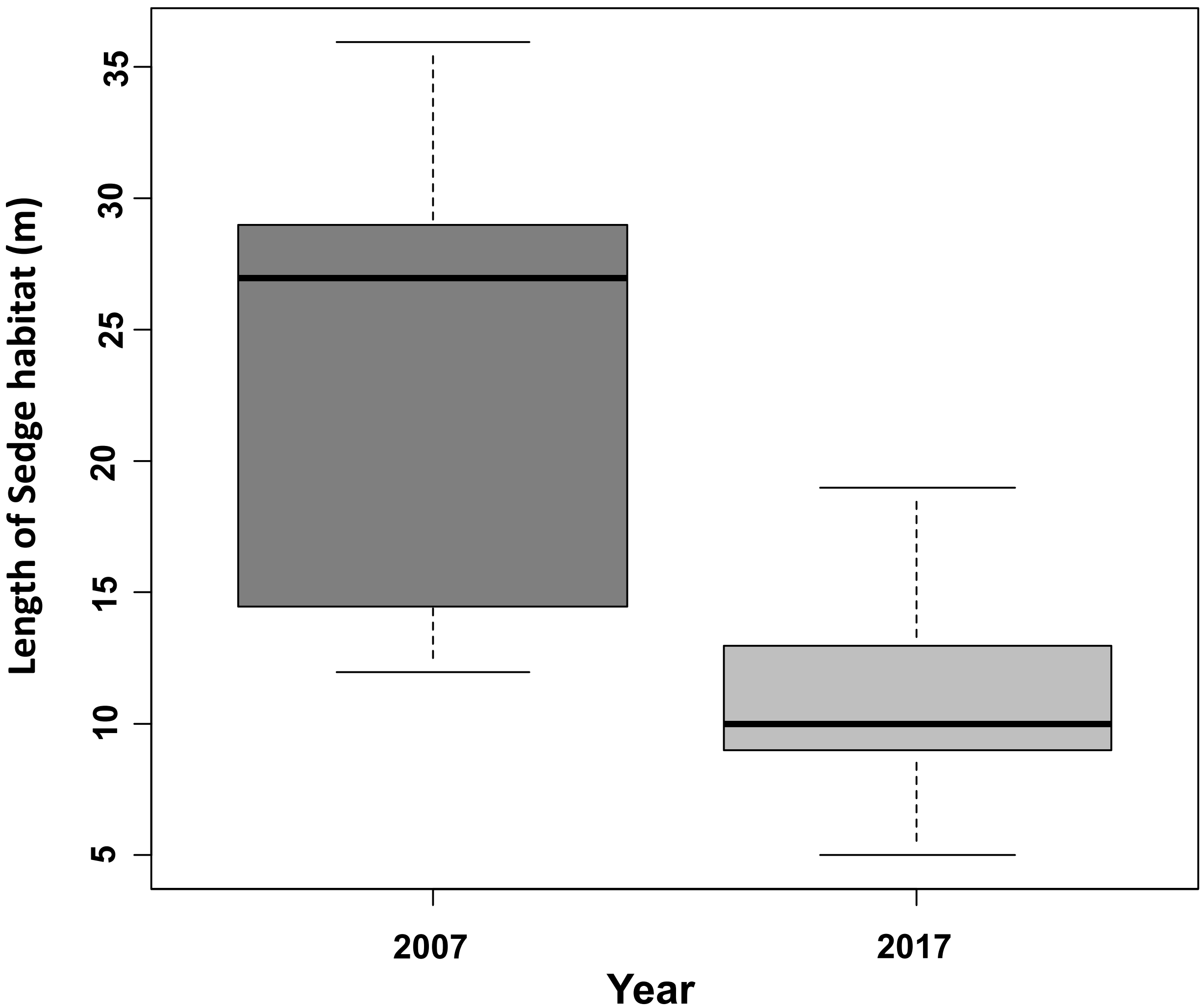
The transect sedge habitat length data was tested for normality using the Shapiro-Wilk test, where H_0: sample x_i comes from a normally distributed population (alpha=0.05). The 2007 sedge length (m) yielded a p-value of 0.7279. The 2017 sedge length (ha) yielded a p-value of 0.7583. Following the successful test for normality, a paired t-test was used to contrast total sedge area (m) within the five 2007 transects and the five 2017 transects.

H_0: There is no difference in the 2007 sedge habitat length (m) and 2017 sedge habitat length (m).

H_A: The difference between the two sedge length means (m) is not equal to 0.

There was a significant difference in the total 2007 and 2017 transect sedge area (p-value=0.02199, df=4, t=3.6389). The mean of the differences between the paired transects was 12.5 (m). A boxplot was created to explore the differences between the two datasets (Figure 17).

Figure 17. Boxplot comparing total 2007 and 2017 transect sedge habitat length (m)



In 2007, the median sedge habitat length encountered along each of the transect lines was 27.0 m. The minimum length was 12.0 m and the maximum 36.0 m.

In 2017, the median sedge habitat length encountered along each of the transect lines was 10.0 m. The minimum length was 5.0 m and the maximum was 19.0 m.

5.0 Discussion

5.1 Sedge Community Characteristics

In 2007, the three dominant sedge species identified in the Big Falls Reservoir were Sitka sedge, beaked sedge, and small flowered bulrush. The sedge community formed the dominant vegetation canopy cover on the eastern region of the reservoir. The elevation range of the sedge community was a 2 m band occurring between 89.7 and 91.7 m.

Consistent with the 2007 findings, the three dominant sedge species encountered during the 2017 study were also Sitka sedge, beaked sedge, and small flowered bulrush. In 2017, the elevation range of the sedge community was a 1.2 m band between 89.8 m and 91.7 m.

The 2017 sedge community elevation was within the same elevation range as the 2007 findings; however, the lower elevation range had contracted by 0.1 m. This indicates that the sedge community is still present within the same elevation range and has not shifted in elevation range considerably as a response to the lower water level within the reservoir. During the 2017 field study, the sedge dominated vegetation communities were not as prevalent along the water's edge as during the 2007 study. In many instances, sedges were intermixed with shrub and herb species such as spiraea (Figure 18).

Figure 18. Shoreline community of sedges intermixed with shrub/herb species (2017)

This indicates that although the elevation range of the sedge community has not shifted significantly within the last decade, the species composition within the previously sedge dominated communities has shifted toward a mixture of shrub and sedge communities.

This is a result of natural succession as the previously wetted areas became drier and the vegetation community shifted to a shrub and young forest ecosystem.

5.2 Study Limitations

The results from Year 1 of the study were considered the baseline values for this report. As such, the results of this study can only assess the change over time from 2007 to 2017. Baseline ecological data prior to Year 1 of the study in 2007 were not available.

The field study was restricted by several factors. These include a time limitation, the number of crew members, and site access. The vegetation sampling (i.e., line transect and quadrats) provided a snapshot into a subset of the vegetation communities within the Big Falls Reservoir. The sedge community elevation determined during the 2017 study could have been restricted by the current reservoir elevations.

The air photo analysis was also restricted by several limitations. The 2017 georeferenced air photo did not align with the 2007 georeferenced air photo. The misalignment of the air photos created some inconsistencies in the digitization process of both the 2007 and 2017 vegetation community polygons. Therefore, the 2017 vegetation community polygons do not match the 2007 vegetation community polygons, which may have contributed to an increase in size of the 2017 study area (i.e., 109.1 ha in 2007 to 123.2 ha in 2017). The vegetation community boundaries determined by stereoscopic analysis could contain error due to interpretation or digitizing into a GIS format. Although the BC RISC standards (Province of British Columbia, 1998) for terrestrial ecosystem mapping were followed, in some instances non-distinct boundaries were encountered and the resulting boundary could be considered subjective.

Interpretation of the effects of current reservoir operations on the sedge community was limited by available data. No data currently exist for the exact elevation, timing, duration, and frequency of inundation required to maintain the sedge community, except the 28-day inundation performance measure recommended by the CC during the planning stages of the Falls River WUP (Cambria Gordon Ltd., 2007). Data on the exact elevation, timing, duration, and frequency of inundation during the post-2007 current reservoir operations were not available for consideration.

6.0 Conclusion

The Falls River CC conducted a literature review of the Project to determine the most effective timing and extent of flooding required to maintain the sedge habitat within the reservoir. They concluded that annual inundation lasting at least 28 days (i.e., not necessarily consecutive) in the spring would prevent succession and maintain the sedge habitat area (Cambria Gordon Ltd., 2007). Following 2007, and the discontinued use of flashboards at the dam, this inundation timeline may not have been reached each year.

The difference in the reservoir operating level due to the discontinuation of the flashboards could be contributing to the encroachment of shrub/herb species into the previously sedge dominant communities.

The difference between the sedge areas was measured both through air photo analysis and ground-truthing to test the following null and sub-hypothesis:

H_1: The area of the sedge community will not change as a consequence of reservoir operations.

- H_{1a}: The species composition of the sedge grass community will not change as a consequence of reservoir operations.

The first analysis was a difference calculation based on GIS analysis. It showed that from 2007 to 2017 there had been a 23% decrease in sedge habitat area (m). There was a corresponding 17% increase in shrub/herb polygon area from 2007 to 2017. These numbers may not be precise because the total vegetation community polygon area increased from 109.1 ha in 2007 to 123.2 ha in 2017. During GIS analysis the Study Area was kept consistent as much as practical.

The second method to measure difference was a paired t-test comparing each of the total sedge habitat lengths (m) from the five 2007 and five 2017 transects. This measured the ground-truthed sedge habitat length encountered along each transect. There was a significant difference found between the sedge area of each 2007 and corresponding 2017 transect. The average difference in sedge habitat (m) encountered during the 2017 line transect survey was 12.5 m lower than the sedge habitat (m) encountered at the same transects in 2007.

The above tests show that the main alternative hypothesis is true and there is a significant difference in the amount of sedge community from 2007 to 2017.

7.0 References

BC Hydro. 2006a. *Falls River Project Water Use Plan Monitoring Terms of Reference.*

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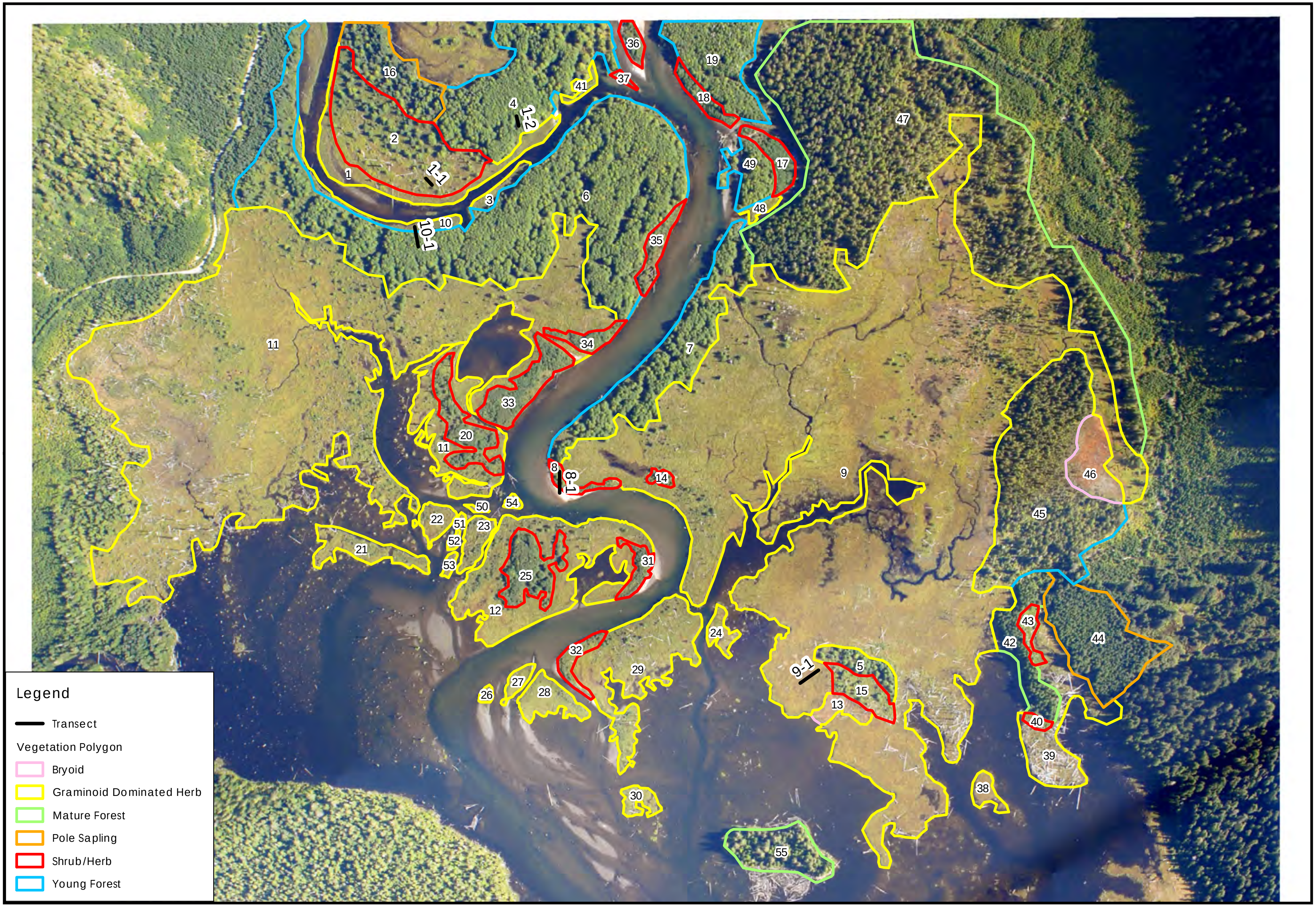
APPENDIX 1

2007 VEGETATION POLYGONS MAP



BC Hydro Falls River Sedge Habitat Monitoring

2007 Vegetation Polygons

0 30 60 120 180 240 300
Meters
Scale: 1:8,000

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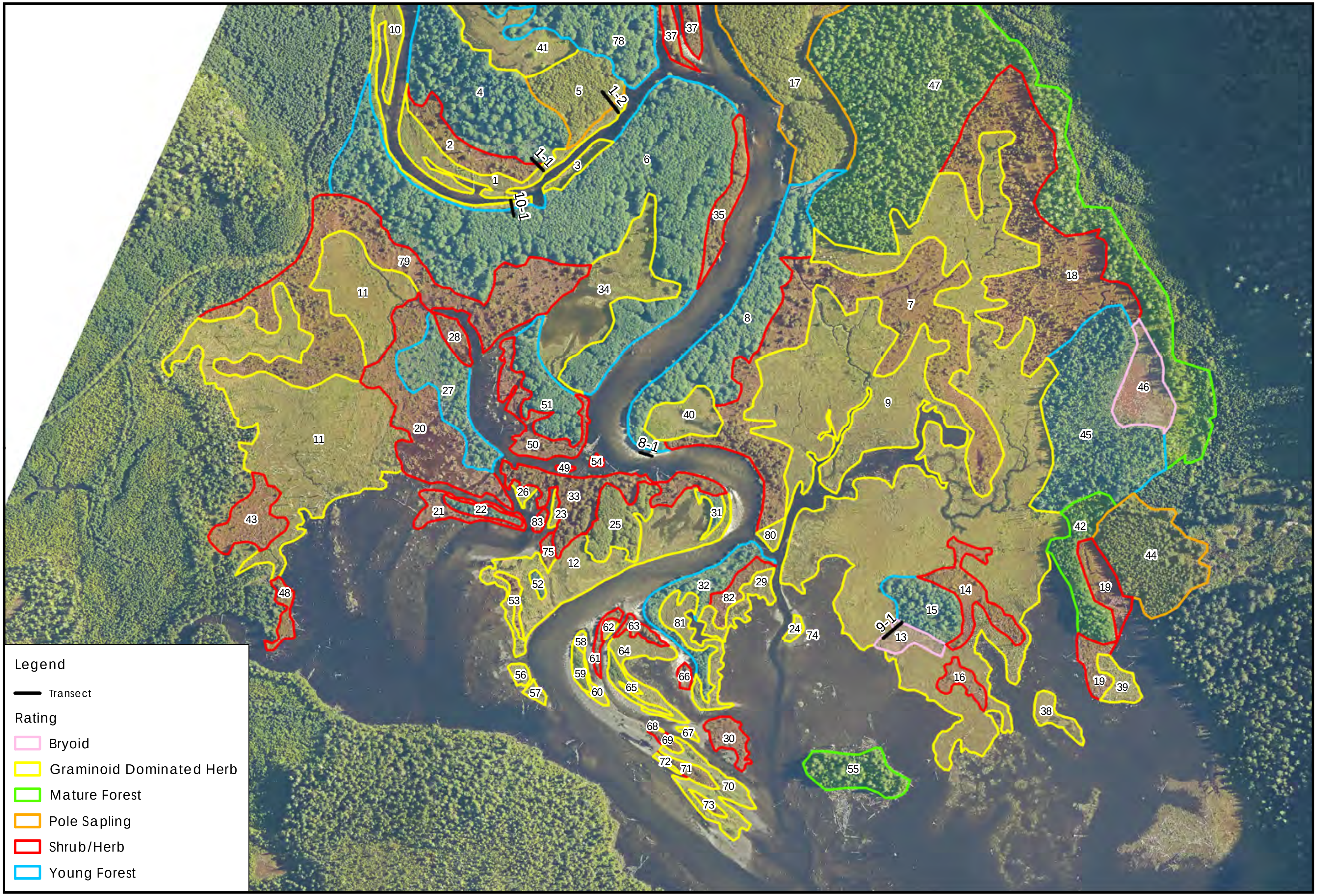
Project No:	5853
Date:	Dec 14, 2017
Basemap Source:	Orthophoto
Map Datum:	NAD 1983 UTM Zone 9N

TRITON Environmental Consultants

APPENDIX 2

2017 VEGETATION POLYGONS MAP



BC Hydro Falls River Sedge Habitat Monitoring

2017 Vegetation Polygons

0 30 60 120 180 240 300
Meters
Scale: 1:8,000

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Project No:	5853
Date:	Dec 08, 2017
Basemap Source:	Orthophoto
Map Datum:	NAD 1983 UTM Zone 9N

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APPENDIX 3

2007 TRANSECT AND QUADRAT SPECIES DIVERSITY RESULTS

2007 Line Intercept Transect species diversity results

Polygon #	Transect #	Vegetation Community Type	Species (common name)	*Species (scientific name)*
1	1-1	Graminoid Dominated Herb (Sedge)	spiraea (Hardhack)	*Spiraea douglasii ssp. Douglasii*
			small-flowered bulrush	*Scirpus microcarpus*
			upland grass[12].	–
4	1-1	Young forest	spiraea (hardhack)	*Spiraea douglasii ssp. Douglasii*
			small-flowered bulrush	*Scirpus microcarpus*
			fireweed	*Epilobium angustifolium*
			upland grass	–
			ladyfern	*Athyrium filix-femina*
			common horsetail	*Equisetum arvense*
			Pacific water-parsely	*Oenanthe sarmentosa*
			elderberry	*Sambucus racemosa*
			salmonberry	*Rubus spectabilis*
			moss[13]	–
1	1-2	Graminoid Dominated Herb (Sedge)	upland grass	–
			Sitka/beaked sedge mix	*Carex sitchensis/Carex utriculata*
			spiraea (hardhack)	*Spiraea douglasii ssp. Douglasii*
			bedstraw	*Galium sp.*
			stinging nettle	*Urtica dioca*
			moss	–
			Western hemlock	*Tsuga heterophylla*
2	1-2	Shrub/herb	Sitka/beaked sedge mix	*Carex sitchensis/Carex utriculata*
			spiraea (hardhack)	*Spiraea douglasii ssp. Douglasii*
8	8-1	Shrub/herb	red alder	*Alnus rubra*
			thistle	*Cirsium sp.*
			small-flowered bulrush	*Scirpus microcarpus*
			Aster /daisy	*Aster sp.*
			upland grass	–
			common horsetail	*Equisetum arvense*
			salmonberry	*Rubus spectabilis*
			bedstraw	*Galium sp.*
9	8-1	Graminoid Dominated Herb (Sedge)	spiraea (hardhack)	*Spiraea douglasii ssp. Douglasii*
			small-flowered bulrush	*Scirpus microcarpus*
			Aster/daisy	*Aster sp.*
			Common horsetail	*Equisetum arvense*
			Bedstraw	*Galium sp.*
			Rush sp.	*Juncus sp.*
			Violet sp.	*Viola sp.*
9	9-1	Graminoid Dominated Herb (Sedge)	Sitka sedge	*Carex sitchensis*
			spiraea (hardhack0	*Spiraea douglasii ssp. Douglasii*
			cinquefoil	*Potentilla sp.*
			green sedge	*Carex viridula*

Polygon #	Transect #	Vegetation Community Type	Species (common name)	Species (scientific name)
13	9-1	Bryoid	Sitka sedge	*Carex sitchensis*
			spiraea (hardhack)	*Spiraea douglasii ssp. Douglasii*
			cinquefoil	*Potentilla sp.*
			green sedge	*Carex viridula*
			Aster / daisy	*Aster sp.*
			bog cranberry	*Oxycoccus oxycoccus*
			Sphagnum spp.	*Sphagnum spp.*
			buckbean	*Menyanthes trifoliata*
			upland grass	–
			Western redcedar	*Thuja plicata*
			beaked sedge	*Carex utriculata*
			Merten's rush	*Juncus mertensianus*
			bog-rosemary	*Andromeda polifolia*
			Labrador tea	*Ledum groenlandicum*
			skunk cabbage	*Lysichiton americanum*
15	9-1	Shrub/herb	Sitka sedge	*Carex sitchensis*
			cinquefoil	*Potentilla sp.*
			upland grass	–
			red alder	*Alnus rubra*
			ladyfern	*Athyrium filix-femina*
			spiraea (hardhack)	*Spiraea douglasii ssp. Douglasii*
10	10-1	Graminoid Dominated Herb (Sedge)	Sitka/beaked sedge mix	*Carex sitchensis/Carex utriculata*
			bedstraw	*Galium sp.*
			fireweed	*Epilobium angustifolium*
			spiraea (hardhack)	*Spiraea douglasii ssp. Douglasii*
		Sedge - Young Forest (4-7 m transition zone)	elderberry	*Sambucus racemosa*
			upland grass	-
			red alder	*Alnus rubra*
			Sitka spruce	*Picea sitchensis*
			ladyfern	*Athyrium filix-femina*
			western hemlock	*Tsuga heterophylla*
			mountain sweet-cicely	*Osmorhiza chilensis*
			trailing black current	*Ribes laxiflorum*
			salmonberry	*Rubus spectabilis*

Source: (Cambria Gordon Ltd., 2007)

2007 Quadrat sampling species diversity results

Polygon Number	Vegetation Community Type	Quadrat Number	Species (common name)	Species (scientific name)	% Cover
1	Graminoid Dominated Herb (Sedge)	Q1-2	beaked sedge	*Carex utriculata*	75-95
		Q1-1	Sitka/beaked sedge mix	*Carex sitchensis/Carex utriculata*	25-50
			Spiraea (Hardhack)	*Spiraea douglasii ssp. Douglasii*	25-50
			upland grass	--	<5
2	Shrub/herb	Q2	Spiraea (hardhack)	*Spiraea douglasii ssp. Douglasii*	50-75
			beaked sedge	*Carex utriculata*	5-25
6	Young forest	Q6	trailing black current	*Ribes laxiflorum*	25-50
			lady fern	*Athyrium filix-femina*	5-25
			moss	--	5-25
			Pacific water-parsly	*Oenanthe sarmentos*	<5
			upland grass	--	<5
			salmonberry	*Rubus spectabilis*	<5
9	Graminoid Dominated Herb (Sedge)	Q9	Sitka sedge	*Carex sitchensis*	25-50
			common horsetail	*Equisetum arvense*	<5
10	Graminoid Dominated Herb (Sedge)	Q10	Sitka sedge	*Carex sitchensis*	75-95
11	Graminoid Dominated Herb (Sedge)	Q11	Sitka/beaked sedge mix	*Carex sitchensis/Carex utriculata*	75-95
13	Bryoid (Bryophyte dominated)	Q13	Sphagnum spp.	*Sphagnum spp.*	>95
			pale sedge	*Carex livida*	5-25
			beaked sedge	*Carex utriculata*	5-25
			buckbean	*Menyanthes trifoliate*	5-25
			bog cranberry	*Oxycoccus oxycoccus*	<5
			crowberry	*Empetrum nigrum*	<5

Source: (Cambria Gordon Ltd., 2007)

APPENDIX 4

2017 SURVEY DATA RESULTS

Date	Time	Polygon #	Transect	Station	Distance from start of transect (m)	Water Elev (m) ASL = BM	BS (+)	FS (-)	HI (BM+BS)	BS or FS adjustment	Elevation (M) ASL
07-Sep-17	10:00	1	No Transect	Edge of water	-	90.436	*		*	0	90.436
07-Sep-17		1	Quadrat data	At Quadrat 1	-			*			Unknown
07-Sep-17		1		At Quadrat 2	-			*			Unknown
07-Sep-17	13:10	1	1-1	Water level	0	90.422	2.46		93.292	0.014	90.422
07-Sep-17		1	1-1	Upper bank	0.5			1.446			91.846
07-Sep-17		4	1-1	Depression	8.2			1.886			91.406
07-Sep-17		4	1-1	Trans. To Spiraea	16.6			1.286			92.006
07-Sep-17		4	1-1	Trans. To Pole Sapling	47.2			0.686			92.606
07-Sep-17	14:35	8	8-1	Water's edge	0	90.429	2.78		93.209	0	90.429
07-Sep-17		8	8-1	Sandy beach	6.54			1.91			91.299
07-Sep-17		9	8-1	Trans. to pole sapling	13.62			1.43			91.779
07-Sep-17		9	8-1	Small sedge meadow	17.78			1.9			91.309
07-Sep-17		9	8-1	Trans. To Spiraea	28.12			1.72			91.489
07-Sep-17	11:10	10	10-1	Water level	0	90.431	3.03		93.461	0	90.431
07-Sep-17		10	10-1	Top of bench/bank	3.72			2.28			91.181
07-Sep-17		10	10-1	Transition to Spiraea	5.49			2.21			91.251
07-Sep-17		6	10-1	Start of Pole Sapling	15.19			1.36			92.101
07-Sep-17	12:30	1	1-2	Water level	0	90.422	2.88		93.302	0	90.422
07-Sep-17		1	1-2	Top of bank	1.2			1.36			91.942
07-Sep-17		1	1-2	Depression	8.55			1.9			91.42
07-Sep-17		2	1-2	Trans. To young forest	23.87			1.71			91.592
07-Sep-17	15:37	9	9-1	Sedge edge in water	-20.63	90.366		2.3	91.966		88.766
07-Sep-17		9	9-1	Water level	-15.63			1.6		0	90.366
07-Sep-17		13	9-1	Top of bank	14.21			1.34			90.626
07-Sep-17		15	9-1	Trans. To Pole Sapling	37.55			0.88			91.086

*Operator error

APPENDIX 5

2017 GROUND LEVEL PHOTO MONITORING

PHOTO POINT 1

Photo 1: Facing north at transition from polygon 1 to 2. September 7, 2017 10:00.

Photo 2: Facing east at transition from polygon 1 to 2. September 7, 2017 10:00.

Photo 3: Facing west at transition from polygon 1 to 2. September 7, 2017 10:00.

Photo 4: Facing south at transition from polygon 1 to 2. September 7, 2017 10:00.

Photo 5: View of groundcover at transition to shrub/herb species. September 7, 2017 10:00.

Description
Located 35 m east (i.e. bearing of 87˚)from the edge of Carthew Creek. Near the transition from the sedge bench to spiraea dominated shrub/herbs.

Polygons
North and East view = polygon 2
West and South view = polygon 1

UTM Coordinates
Easting: 454956.43 m
Northing: 5983789.70 m

PHOTO POINT 2

Photo 1: Facing north at the start of the elevation survey. September 7, 2017 11:30.

Photo 2: Facing east at the start of the elevation survey. September 7, 2017 11:30.

Photo 3: Facing west at the start of the elevation survey. September 7, 2017 11:30.

Photo 4: Facing south at the start of the elevation survey. September 7, 2017 11:30.

Photo 5: View of groundcover at start of survey line. September 7, 2017 11:30.

Description
Located at the start of transect 10-1, 1 m west (i.e. bearing of 260˚) from the edge of Carthew Creek. In a sedge community transitioning into a young forest.

Polygons
North and east views = polygon 10
West and south views = toward polygon 6

UTM Coordinates
Easting: 454933.83 m
Northing: 5983645.25 m

PHOTO POINT 3

Photo 1: Facing north at the start of the elevation survey. September 7, 2017 10:00.

Photo 2: Facing east at the start of the elevation survey. September 7, 2017 10:00.

Photo 3: Facing west at the start of the elevation survey. September 7, 2017 10:00.

Photo 4: Facing south at the start of the elevation survey. September 7, 2017 10:00.

Photo 5: View of groundcover at start of survey line. September 7, 2017 10:00.

Description
Located at the start of Transect 1-2, 3 m northeast (i.e. bearing of 20˚) from the edge of Carthew Creek. On top of the small band of shrub/herbs intermixed with sedge.

Polygons
North, east, and west views = polygon 1
South view = polygon 1 with spiraea intermixed

UTM Coordinates
Easting: 455134.88 m
Northing: 5983545.05 m

PHOTO POINT 4

Photo 1: Facing north at the start of the elevation survey. September 7, 2017 10:00.

Photo 2: Facing east at the start of the elevation survey. September 7, 2017 10:00.

Photo 3: Facing west at the start of the elevation survey. September 7, 2017 10:00.

Photo 4: Facing south at the start of the elevation survey. September 7, 2017 10:00.

Photo 5: View of groundcover at start of survey line. September 7, 2017 10:00.

Description
Located at the start of Transect 1-1, 3 m northeast (i.e. bearing of 50˚) from the edge of Carthew Creek. On top of the small band of shrub/herbs intermixed with sedge.

Polygons
East and west views = polygon 1
North view = towards polygon 2 and 4

UTM Coordinates
Easting: 454956.43 m
Northing: 5983789.70 m

PHOTO POINT 5

Photo 1: Facing north at the start of the young forest. September 7, 2017 10:00.

Photo 2: Facing east at the transition to young forest. September 7, 2017 10:00.

Photo 3: Facing west at the start of the young forest. September 7, 2017 10:00.

Photo 4: Facing south at the transition to young forest. September 7, 2017 10:00.

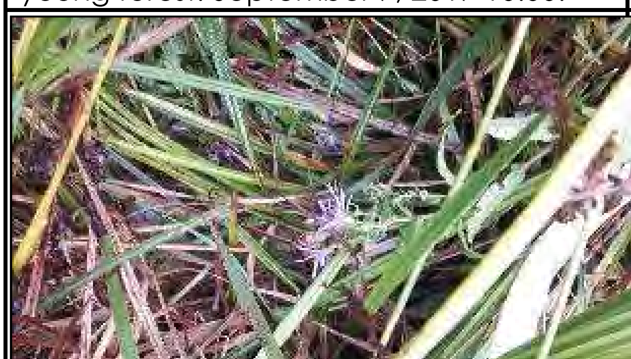

Photo 5: View of groundcover at transition to young forest. September 7, 2017 10:00.

Description
Located 130 m southwest (i.e. bearing of 245˚) from the edge of Carthew Creek. Near the transition from the shrub/herb dominated commuity to the young forest.

Polygons
North and west views = polygon 6 (YF)
East and south views = polygon 11 (S/H)

UTM Coordinates
Easting: 454792.34 m
Northing: 5983655.70 m

<table>
<tr><th colspan="2">PHOTO POINT 6</th></tr>
<tr><td>
Photo 1: Facing north at the start of the elevation survey. September 7, 2017 10:00.</td><td>
Photo 2: Facing east at the start of the elevation survey. September 7, 2017 10:00.</td></tr>
<tr><td>
Photo 3: Facing west at the start of the elevation survey. September 7, 2017 10:00.</td><td>
Photo 4: Facing south at the start of the elevation survey. September 7, 2017 10:00.</td></tr>
<tr><td>
Photo 5: View of groundcover at start of survey line. September 7, 2017 10:00.</td><td>Description
Located near the end of Transect 8-1, 25 m northeast (i.e. bearing of 50˚) from the edge of Carthew Creek. In small transition zone from young forest into sedge dominated zone.

Polygons
North and east views = toward polgon 40.
West and south view = toward polygon 8

UTM Coordinates
Easting: 454660.97 m
Northing: 5983291.66 m</td></tr>
</table>

PHOTO POINT 7

Photo 1: Facing north at the start of the elevation survey. September 7, 2017 10:00.

Photo 2: Facing east at the start of the elevation survey. September 7, 2017 10:00.

Photo 3: Facing west at the start of the elevation survey. September 7, 2017 10:00.

Photo 4: Facing south at the start of the elevation survey. September 7, 2017 10:00.

Photo 5: View of groundcover at start of survey line. September 7, 2017 10:00.

Description
Located at the start of Transect 9-1, 15 m east (i.e. bearing of 90˚) from the edge of the Big Falls Reservoir. In a sedge dominated zone transitioning into bryoid community.

Polygons
West, north, and south views = polygon 9
East views = polygon 13

UTM Coordinates
Easting: 454522.31 m
Northing: 5982823.36 m