Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoirs Revegetation Management Plan

Monitoring Wetland and Riparian Habitat in Revelstoke Reach in Response to Wildlife Physical Works

Implementation Year 6

Reference: CLBMON-11b4

Year 6 Annual Report

Study Period: 2018

Okanagan Nation Alliance, Westbank, BC
and
LGL Limited environmental research associates Sidney, BC

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CLBMON-11B4 Monitoring Wetland and Riparian Habitat in Revelstoke Reach in Response to Wildlife Physical Works




Final Annual Report
Year 6
2018

Prepared for

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BC Hydro Generation
Water Licence Requirements
6911 Southpoint Drive
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Prepared by

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Cover photos

From left to right: Site 6A, Eurasian water-milfoil (*Myriophyllum spicatum*) in Cartier Bay, Site 15A, Airport Marsh. Photos © LGL Limited: Virgil Hawkes and Doug Adama.

EXECUTIVE SUMMARY

BC Hydro commissioned CLBMON-11B4 (*Monitoring Wetland and Riparian Habitat in Revelstoke Reach in Response to Wildlife Physical Works*) in 2010 to assess the effectiveness of wildlife physical works (WPW) projects undertaken through CLBWORKS-30A at protecting or enhancing wetland and wildlife habitat in Revelstoke Reach (Arrow Lakes Reservoir). Specifically, CLBMON-11B4 assesses erosion processes and the vegetation and physicochemical characteristics of wetland and riparian habitat following the implementation of WPW-6A (Airport Outflow, completed in 2013) and WPW-15A (Cartier Bay, completed in 2016). WPW-6A aimed to stabilize the east arm of an erosion channel that had developed in the floodplain of Revelstoke Reach near the outlet of Airport Marsh, an important wetland and wildlife habitat. WPW-15A was designed to protect the high wetland and wildlife values in Cartier Bay by stabilizing a collapsed box culvert at the wetland's outflow.

Pre-works (baseline) monitoring occurred in 2010, 2011, 2012, and and in 2016 (for WPW-15A only). Post-works monitoring began in 2016 for WPW-6A, and in 2018 for WPW-15A, with repeated annual monitoring scheduled up to and including 2020. Here we report summary results from post-works monitoring in 2018. Fieldwork was carried out in May, in line with the timing of pre-works (2011-2013) monitoring.

Erosion monitoring at WPW-6A consisted of a visual assessment, survey measurements, Bank Erosion Hazard Index (BEHI) assessment, and air photo imagery assessment of erosion in the east and west erosion channels. Erosion monitoring at WPW-15A consisted of a visual assessment and survey measurements, only. Results indicate that the physical works carried out at WPW 6A in 2013 appear to have arrested erosion in the east erosion channel. There were no signs of erosion or slumping along the perimeter of the riprap, although slumping was observed and measured at the mouth channel where the channel bank remains exposed. A small degree of soil movement occurred at this location and was attributed to undercutting of the channel bank. BEHI scores were very low (<5) for the east channel and high (>25) for the west channel. The difference in BEHI scores was due to higher bank height, bank angle, surface protection, and bank material scores in the west channel than in the east channel.

An assessment of aerial images found that the east channel increased in area from 221.1 to 261 m^2 between 2008 and 2012 (4.4 per cent rate of annual increase) and increased in length by 1.0 m annually. Following the implementation of physical works in 2013, the east channel ceased expanding and decreased slightly in area (0.8 per cent) from 2014 to 2016. In contrast, the west erosion channel continued to increase in area at a rate of 2.6 per cent annually from 344.4 m^2 in 2008 to 426.5 m^2 in 2016 and increased in length by 10.4 meters during this period. Annual loss of soil in the west channel was estimated to be between 17.2 to 26.4 m^3/yr, which is similar to soil loss in the east channel before WPW construction. Due to the lack of recent aerial imagery, we were not able to assess soil loss in 2018.Our visual assessment and survey of WPW-15A did not reveal any noticeable or measurable amounts of erosion. The elevation of the swale was estimated to be 434.051 m based on survey measurements, which compares favourably with the values reported by Watson Engineering of 434.045 m following the implementation of physical works in 2016.

Vegetation and physicochemical attributes were monitored at Cartier Bay (Site 15A) only. To characterize conditions in the shallow open water areas, 104 random samples of aquatic macrophyte presence and abundance, as well water depth, water turbidity, dissolved oxygen, pH, conductivity, and temperature, were collected. Riparian plant communities adjacent to the shallow open water wetland were characterized using 29 terrestrial 50-m^2 vegetation plots, 13 of which had been previously established as part of the CLBMON-33 (*Arrow Lakes Reservoir Inventory of Vegetation Resources*) program.

At Cartier Bay, measurements of turbidity (Secchi depth), dissolved oxygen (DO), pH, conductivity (µS/cm), and temperature (°C) fell within the range of variation observed during the baseline monitoring period.

Consistent with the baseline monitoring period, Eurasian water-milfoil, common hornwort, stonewort (an algae species), and small pondweed were the most frequently encountered aquatic macrophytes in Cartier Bay in 2018; each was present in over a quarter of samples. Pondweeds (*Potamogeton* spp.) were the most biodiverse group of macrophytes but tended to be relatively less dominant locally (as measured by the sample volume x cover metric, VC). Eurasian water-milfoil, Richardson's pondweed, and stonewort showed a trend of increasing frequency since 2013, while common hornwort, small pondweed, and water smartweed were less common in samples compared to 5 years earlier.

Because the post-works data time series is, as of 2018, limited to a single year, it is too early in the monitoring process to test for significance in any of these trends or to attempt any direct before-after comparisons. Such analyses will be deferred until the final summary report (scheduled for 2020).

Six different riparian vegetation community types or VCTs were identified during terrestrial sampling. PC-Sedge and PC-Reed canarygrass are the dominant VCTs on the north and west shorelines of the Cartier Bay wetland, while the BG, PC-Shrub, RR, and SS VCTs are generally confined to the south and east shorelines. PC-Sedge, the most widely encountered vegetation type, supported both relatively high species richness and relatively high plant covers. The highest plant cover was associated with PC-Reed canarygrass, but this vegetation type was heavily dominated by a single species (reed canarygrass).

There is no strong expectation at present that the physical works will have a notable effect on upland conditions in Cartier Bay. This is because the objective of the works was to maintain the status quo with respect to the maximum depth and areal extent of the permanently wetted area. However, if a change in riparian boundaries or key characteristics is detected by the end of the monitoring period (e.g., through aerial imagery analysis), terrestrial species covers obtained during the post-works period can be compared against analogous data obtained during the pre-works period, with the aim of identifying which plants or vegetation types have contributed substantially to the observed change, and via what mechanism(s).

The status of CLBMON-11B4 after Year 6 (2018) with respect to the main study management questions (MQs) is summarized in table form below.

Management Question (MQ)	Summary of Key Results
MQ1. Are the wildlife physical works projects effective at protecting wildlife habitat quality and quantity for nesting and migratory birds and other wildlife?	**<u>Summary Findings</u>** Initial monitoring results suggest that wildlife physical works methods have so far been effective, and therefore hold potential to protect wildlife habitat in Revelstoke Reach. In 2018, estimates of aquatic macrophyte composition, distribution, and abundance, and of physicochemical variables (water depth, turbidity, DO, pH, conductivity, temperature) at Site 15A were comparable to those obtained during the pre-works (baseline) monitoring period (2011-2013). Erosion abatement in the east erosion channel at Site 6A appears to have been successful in the short-term. Advance of the east erosion channel in the floodplain ceased following physical works implementation in 2013. Erosion continues unabated in the main and west channel at Site 6A, reducing habitat and wildlife values of the floodplain. Halting erosion in the west and main channels should be considered if WPW 6A is deemed successful. We recommend at least one more monitoring session with high-resolution imagery before making this determination. No signs of erosion were evident at Site 15A, and the elevation of the swale (434.051 m) was comparable to the construction specification (434.045 m). **<u>Sources of Uncertainty/ Limitations</u>** Because the post-works data time series is, as of 2018, limited to a single year, it is too early in the monitoring process to test for significance in any trends or to attempt direct pre- and post-works comparisons. Such analyses will be deferred until the final summary report (scheduled for 2020). Due to the natural variability of the system (environmental noise), the study may have low power to detect minor changes in habitat attributes within the given time frame. In 2018, the Cartier Bay wetland compartments became inundated by the reservoir as sampling was being completed. This precluded sampling riparian and emergent vegetation at the riparian interface with the permanent wetland. It also prevented mapping of the wetland perimeter. Erosion (bank undercutting and soil movement) was observed at the mouth of the east channel. Continued erosion at this site may result in erosion between the riprap and former channel bank. It is not known if Site 15A has affected dyke porosity, which in turn may affect the water holding capacity of the dyke. **<u>Comments</u>** Due to the high natural annual variability in macrophyte distribution and abundance, only very large project-related effects are likely to be detected within the given monitoring time frame. No such large impact has yet been observed, nor is one predicted based on initial observations. Alternatively, monitoring for changes in wetland aerial extent or (using the available time series of ortho-photos) could serve as a potential complement to monitoring of lower-level habitat responses. Erosion monitoring should be continued both at Site 6A and 15A in order to fully address the management question.

Management Question (MQ)	Summary of Key Results
MQ1a. What were the pre-existing conditions at the wildlife physical works Sites 6A and 15A in terms of wetland and associated riparian habitat productivity and habitat suitability for nesting and migratory birds and other wildlife?	**Summary Findings** Data on pre-existing conditions at Site15A were collected between 2010 and 2013 under CLBMON-11B4 (reported in Miller and Hawkes 2014, and earlier annual reports) as well as through various associated WLR studies involving Revelstoke Reach. Many relevant findings were summarized in detail by Hawkes et al. (2015). **Sources of Uncertainty/ Limitations** The baseline study phase of CLBMON-11B4 did not closely monitor riparian habitat conditions at Cartier Bay, being primarily focused on characterizing shallow open water habitat conditions. Some data pertaining to Site 15A on riparian habitat productivity and suitability for nesting and migratory birds and other wildlife are available through associated WLR studies involving Revelstoke Reach. Site 6A occurs within a reed canarygrass-dominated floodplain and does not support wetland conditions *per se*. The site was not directly monitored as part of the CLBMON-11B4 baseline study (which instead focused on characterizing conditions in the adjacent Airport Marsh). Some data pertaining to Site 6A on habitat productivity and suitability for nesting and migratory birds and other wildlife are available through associated WLR studies involving Revelstoke Reach.
MQ1b. Did the wildlife physical works at Cartier Bay Site 15A affect the function and productivity of adjacent wetland and associated riparian wildlife habitat as indicated by biomass and species richness of macrophytes and abiotic indices of productivity?	**Summary Findings** The general comments for MQ1, above, also applies to this MQ. There is no evidence thus far that wildlife physical works have affected the quality or diversity of wetland and riparian vegetation in Revelstoke Reach. **Sources of Uncertainty/ Limitations** The general comments for MQ1, above, also apply to this MQ.
MQ1c. How did the wildlife physical works projects affect the suitability of wetland and associated riparian habitat for nesting and migratory birds and other wildlife?	**Summary Findings** The general comment for MQ1, above, also applies to this MQ. **Sources of Uncertainty/ Limitations** The general comments for MQ1, above, also apply to this MQ. **Comments** The results of CLBMON-11B4 will be interpreted in light of results and with data from other relevant studies including some or all of: CLBMON-11B3, CLBMON-37, CLBMON-11B2, CLBMON-36, CLBMON-39, and CLBMON-40.

Management Question (MQ)	Summary of Key Results
MQ2. Which wildlife physical works methods or techniques (including those not yet implemented) are likely to be most effective at enhancing or protecting the productivity and suitability of wetland and associated riparian wildlife habitat in the drawdown zone at Revelstoke Reach?	**Summary Findings** WPW at Site 6A indicate early success in arresting floodplain erosion protecting habitat values in Airport Marsh. WPW at 15A indicate early success in maintaining water levels in Cartier Bay by reinforcing the integrity of the dyke. **Sources of Uncertainty/ Limitations** Long-term success of the WPW is not known. **Comments** Continued monitoring of WPW 6A and 15A is required to fully address the management question.

KEYWORDS: Arrow Lakes Reservoir; wildlife physical works; effectiveness monitoring; wildlife; wetlands; erosion; aquatic macrophytes; riparian habitat; physicochemistry.

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1.0 INTRODUCTION

The Columbia River Water Use Plan (WUP) was developed as part of a multi-stakeholder consultative process to determine how to best operate BC Hydro's Mica, Revelstoke and Keenleyside facilities to balance environmental values, recreation, power generation, cultural/heritage values, navigation and flood control. During the WUP process, the Consultative Committee (CC) supported the implementation of revegetation and wildlife physical works in the Columbia River in lieu of changes to reservoir operations to help mitigate the impacts of Arrow Lakes Reservoir operations on wildlife and wildlife habitat. The CC suggested using an adaptive approach to create habitat for native wildlife, including nesting habitat for birds. In addition, the CC recommended monitoring to assess the effectiveness of these physical works at enhancing or protecting habitat for wildlife (BC Hydro 2005).

Potential Wildlife Physical Works (WPW) projects in Revelstoke Reach were identified and refined through CLBWORKS-29A, a two-year study that evaluated the feasibility of wildlife physical works in the Upper Arrow Reservoir. From an initial list of 44 potential projects, two, WPW-6A (Airport Outflow) and WPW-15A (Cartier Bay), have been implemented to date. The objective of these two WPW projects is to maintain existing shallow wetland habitat at Airport Marsh and Cartier Bay, respectively. Implementation of the projects was carried out under CLBWORKS-30A. Construction of the works at the Airport Outflow WPW-6A was completed in the fall of 2013. Construction of the works at Cartier Bay WPW-15A was completed in October 2016.

CLBMON-11B is a suite of monitoring programs (modules) that together monitor the effectiveness of wildlife physical works at protecting or enhancing wetland and riparian wildlife habitat, and at benefitting the wildlife that utilize it. CLBMON-11B4 specifically assesses erosion processes and the vegetation and physicochemical characteristics of wetland and riparian habitat. Wildlife usage is monitored under CLBMON-11B2 (spring migrant songbirds); CLBMON-36 (nesting birds); CLBMON-37 (reptiles and amphibians); CLBMON-39 (fall migrant songbirds); and CLBMON-40 (water birds and raptors).

CLBMON-11B4 was initiated in 2010. The monitoring involves sampling before-works and after-works characteristics of the affected wetlands. Pre-works monitoring occurred in 2010, 2011, 2012, and 2013 (for WPW-6A and WPW-15A; Hawkes et al. 2011; Fenneman and Hawkes 2012; Miller and Hawkes 2013; 2014). Post-works monitoring occurred in 2016 (for WPW-6A; Hawkes and Adama 2017) and in 2018 (for WPW-6A and 15-A), with repeated annual monitoring scheduled up to 2020.

Pre-works Monitoring of Wetlands (2010-2013)

During Year 1 (2010), a wetland monitoring protocol was developed, and a pilot study conducted to evaluate the study design and sampling methodology. Reconnaissance-level sampling of biotic and abiotic conditions at three wetland sites—Airport Marsh, Montana Slough, and Cartier Bay—was also undertaken (Hawkes et al. 2011). WPW-6A and WPW-15A were not themselves directly assessed at this time.

Collection of baseline ecological and physical data continued in Years 2 and 3 (2011 and 2012), enabling a description of the diversity and relative abundance/density of aquatic and emergent (and some terrestrial) plant communities at Airport Marsh, Montana Slough, and Cartier Bay, as well as the associated pelagic and benthic invertebrate communities

(Fenneman and Hawkes 2012, Miller and Hawkes 2013). As well, in 2012 the study scope was expanded to include reconnaissance-level sampling of two additional, potential enhancement sites in mid and lower Arrow Lakes Reservoir: Beaton Arm Beaver Ponds and Lower Inonoaklin Creek (Miller and Hawkes 2013).

In Year 4 (2013), pre-construction monitoring was continued at Airport Marsh and Cartier Bay, as well as at Beaton Arm Beaver Ponds and Lower Inonoaklin Creek. Montana Slough, which previous years' work had shown to support relatively few aquatic macrophytes and macroinvertebrates, was not resampled in 2013.

Changes to TOR

Initially, all CLBMON-11B modules were conducted under a single Terms of Reference (TOR). During the initial monitoring under CLBMON-11B some indicator species or sampling approaches proposed in the original TOR were found to be ineffective or to lack biological relevance in assessing the effectiveness of revegetation and wildlife physical works. Plans and schedule for wildlife physical works projects have also evolved. Consequently, the TORs for CLBMON-11B drafted in 2009 required updating to reflect improvements to approaches, the addition of modules, and to more correctly identify the differing specifics relevant to each project module.

For example, aquatic macroinvertebrates were formerly sampled at each wetland via two methods: epipelagic sampling with a dip net; and benthic sampling with a hand-held Ponar grab (Miller and Hawkes 2014). Due to low sample sizes, high variability, and high cost of taxonomic sorting, this program will not be implemented for post-works monitoring. Likewise, at Airport Outflow WPW-6A, post-works monitoring will focus primarily on erosion monitoring. Unless erosion continues to a point where the erosion channel interacts with the Airport Marsh hydrology (e.g., cutting through old Arrow Head highway into the Machete Ponds), post-works monitoring will not include wetland parameters at Airport Marsh.

This report describes the approaches and methods that ONA and LGL Limited used to implement the revised (2018) TOR for CLBMON-11B4, including approaches and methods for addressing the newly revised objectives and management questions specific to the next implementation years (2018-2020).

2.0 WILDLIFE PHYSICAL WORKS (WPW) 6A and 15A

WPW-6A (Airport Outflow)

WPW-6A is a small erosion channel (120 m in length) that has developed in the floodplain of the Arrow Lakes Reservoir north of Machete Island (Figure 2-1). The channel begins at the northwest edge of Machete Island and runs northeast towards the Old Arrowhead Highway before splitting into two side channels (east and west) forming a “Y” like configuration. Erosion occurs in the spring during run-off and in the summer or fall when the reservoir recedes from elevations above 438 m ASL.

WPW-6A was the first project to be implemented following a two-year consultation process with local stakeholders and agencies (Golder Associates 2009a; Golder Associates 2009b). Viewed as habitat maintenance project as opposed to enhancing wildlife and/or fisheries values, the goal of the project was to stop erosion along the east channel to protect existing values of adjacent habitats. The east erosion channel was selected for WPW because the direction of erosion of this feature was towards the old Arrowhead Highway/CPR rail bed which, if breached, could result in a new drainage route for water from the Airport Marsh and impact water levels presently impounded by the bed of the Arrowhead Highway/CPR rail bed. Airport Marsh is an important wetland area that supports migratory and resident populations of waterfowl, marsh birds, Great Blue Heron (*Ardea herodias*), Osprey (*Pandion haliaetus*), Bald Eagles (*Haliaeetus leucocephalus*), shorebirds, and Western Painted Turtles (*Chrysemys picta*).

The east channel was also selected due to it’s proximity to Machete Island. Machete Island provides important riparian habitat that is uncommon in Revelstoke Reach that is heavily utilized by resident and migratory songbirds (Golder Associates 2009a; CBA 2018). In addition, the floodplain also offers recreational opportunities for hiking, dog walking, nature watching, cycling, and provides access to the river for fishing. Halting erosion in the floodplain would help maintain these recreational values in Revelstoke Reach (Lees + Associates 2008).

Another objective of the project was to provide a learning opportunity for assessing the effectiveness of erosion treatments in Revelstoke Reach. Leaving the west channel unmodified as a control would allow for follow up monitoring to compare rates of erosion between the two channels. Based on the success of the treatment effectiveness, the knowledge gained could be modified and adapted in other areas in Revelstoke Reach and Arrow Lakes Reservoir.

The WPW-6A project was implemented in the fall of 2013 by Landmark Solutions Ltd, and LGL Limited was retained for environmental monitoring during construction. Golder Associates (2014) provided additional recommendations for monitoring WPW-6A and in2016, LGL Limited undertook a post-construction assessment of the site (Hawkes and Adama 2017). The assessment indicated that the riprap was integrating into the channel bank and that erosion appears to have been arrested in the east channel. However, a potential erosion point at the tip of the east channel was noted. Continued erosion, slumping and mass wasting were reported in the west and main erosion channels.

Figure 2-1: Aerial image of the WPW-6A "Y shaped" erosion channel. Scale 1:500. Inset show the location of the channel south of Revelstoke, BC. Image date May 2016.

WPW-15A (Cartier Bay)

The Cartier Bay wetland consists of an existing slough/shallow open water complex that historically may have been an oxbow of the Columbia River. The main wetland consists of two compartments separated by a gap in an old roadbed that bisects a large 24.3 ha pond. The outflow of this wetland is through a gap in the old Arrowhead highway roadbed, where a collapsed wooden box culvert exists at the downstream terminus of the wetland (WPW-6A; Figure 2-2). The persistence of water in the pond is a result of this plugged box culvert creating a rudimentary dike.

WPW-15A was designed to protect the high wetland and wildlife values in Cartier Bay by stabilizing the collapsed box culvert. Golder Associates (2009b) recommended replacing the box culvert due to ongoing erosion and the risk of catastrophic failure, which would drain much of the marsh that occupies Cartier Bay. The original project design was revised in 2015, and the new design opted for stabilizing the dyke with the addition of riprap and filter blanket on the downstream side of the dyke at the box culvert. Construction began on October 17 and was completed on October 22, 2016. The dyke elevation, original box culvert and adjacent steel culvert were undisturbed. The lowest point of the dyke was maintained at 434.045 m above sea level (ASL).

To our knowledge, a post-construction inspection has not been completed to assess for site disturbance, erosion, settlement, and spread of weeds. Environmental monitoring reports were not provided to identify or assess environmental concerns raised during construction.

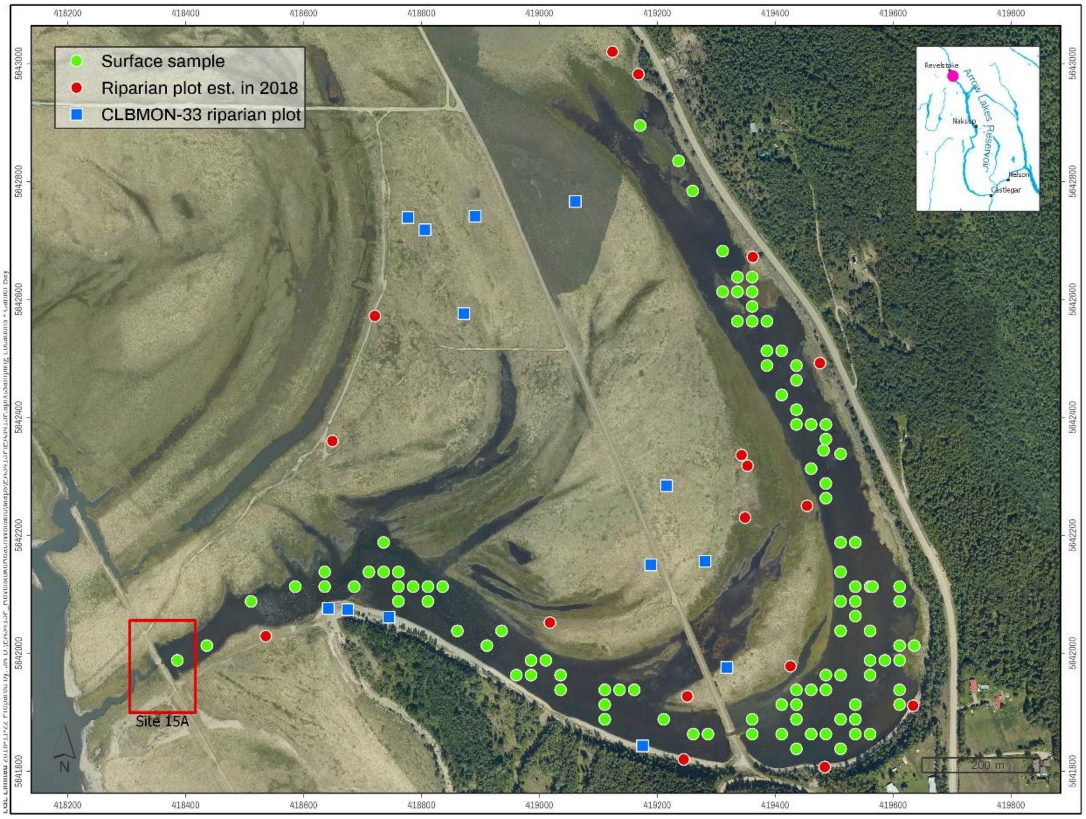

Figure 2-2: **Location of the WPW-6A relative to Cartier Bay.** Sample locations for 2018 are shown as dots (aquatic surface samples) and triangles (riparian terrestrial samples). Image date: May 30 2016. Reservoir elevation: 433.79 m ASL

3.0 MONITORING OBJECTIVES AND MANAGEMENT QUESTIONS

3.1 Monitoring Objectives

The objectives of this study are to:

1. Assess the effectiveness of wildlife physical works projects at protecting and maintaining wetland and associated riparian habitat in the drawdown zone of Revelstoke Reach in upper Arrow Lakes Reservoir.
2. Provide recommendations about which wildlife physical works methods or techniques are most likely to be effective at protecting or enhancing the productivity of wetland and associated riparian habitat in the drawdown zone of Revelstoke Reach.
3. Provide information on wetland habitat characteristics at potential wildlife physical works sites to assist in refining works designs, as appropriate (outcomes are reported in Hawkes et al. 2015b).

3.2 Management Questions

The revised management questions for CLBMON-11B4 are:

1. Are the wildlife physical works projects effective at protecting wildlife habitat quality and quantity for nesting and migratory birds and other wildlife?
    a. What were the pre-existing conditions at the wildlife physical works Sites 6A and 15A in terms of wetland and associated riparian habitat productivity and habitat suitability for nesting and migratory birds and other wildlife?
    b. Did the wildlife physical works at Cartier Bay Site 15A affect the function and productivity of adjacent wetland and associated riparian wildlife habitat as indicated by biomass and species richness of macrophytes and abiotic indices of productivity?
    c. How did the wildlife physical works projects affect the suitability of wetland and associated riparian habitat for nesting and migratory birds and other wildlife? To address this management question, the results of CLBMON-11B4 will be interpreted in light of results and with data from other relevant studies including some or all of: CLBMON-11B3, CLBMON-37, CLBMON-11B2, CLBMON-36, CLBMON-39, and CLBMON-40.
        i. Did the wildlife physical works at Cartier Bay Site 15A alter the area (m^2) or suitability of wetland and associated riparian wildlife habitat for nesting birds?
        ii. Did the wildlife physical works at Cartier Bay Site 15A alter the area (m^2) or suitability of wetland and associated riparian wildlife habitat for reptiles and amphibians?
        iii. Did the wildlife physical works at Airport Outflow WPW-6A alter the area (m^2) or suitability of wetland and associated riparian wildlife habitat for nesting birds?
        iv. Did the wildlife physical works at Airport Outflow WPW-6A alter the area (m^2) or suitability of wetland and associated riparian wildlife habitat for reptiles and amphibians?
        v. Did the wildlife physical works at Cartier Bay Site 15A affect: erosion; aerial extent of wetland habitat; cover, species richness, and evenness of undesirable macrophyte species; water depth and turbidity?
        vi. Did the wildlife physical works at Airport Outflow WPW-6A affect: physical signs of erosion; aerial extent of wetland habitat?
2. Which wildlife physical works methods or techniques (including those not yet implemented) are likely to be most effective at enhancing or protecting the productivity and suitability of wetland and associated riparian wildlife habitat in the drawdown zone at Revelstoke Reach?

4.0 METHODS

A description of the methods used in 2018, the initial year of post-works monitoring, provided below. For detailed accounts of methods used during pre-works (2010-2013) monitoring and the outcomes of that monitoring, please refer to earlier annual reports for CLBMON-11B4 (Hawkes et al. 2011; Fenneman and Hawkes 2012; Miller and Hawkes 2013; 2014).

4.1 Sampling Approach

Post-works monitoring is designed to assess for impacts accruing to the quality and extent of shallow water habitat and associated vegetation in Revelstoke Reach as a result of wildlife physical works. Specifically, the study entails:

1. Conducting erosion monitoring at WPW-6A and WPW-15A via annual visual checks, standardized annual photo documentation each year, and physical marking (e.g., stakes) to identify how the extent of erosion is changing over time.
2. Mapping shallow wetland habitat extent at Cartier Bay upstream of WPW-15A using updated aerial photo-imagery in conjunction with GIS and comparing extent pre- and post-works. Photo-based assessments will be undertaken in 2019 or 2020, once updated imagery is available.
3. Taking measurements on physicochemical attributes in the east and west compartments of the main Cartier Bay pond and assessing for changes related to the implementation of WPW.
4. Sampling macrophyte (aquatic plant) composition and abundance in the east and west compartments of the main Cartier Bay pond and assessing for changes related to the implementation of WPW.
5. Using updated aerial photo-imagery, in conjunction with ground surveys, to sample riparian (non-aquatic) plant community composition and cover at the edge of Cartier Bay wetland and assessing for changes related to the implementation of WPW. Photo-based assessments will be undertaken in 2019 or 2020, once updated imagery is available.
6. Obtaining depth measurements for the east and west compartments of the main Cartier Bay pond and generating an updated bathymetric map.
7. Deploying data loggers at selected locations in Cartier Bay wetland to monitor dissolved oxygen, conductivity and water temperature over time.

4.2 Erosion Monitoring at WPW-6A (Airport Outflow)

Our assessment on May 8th, 2018 of WPW-6A included: (1) measurements of survey pins and stakes established in 2016; (2) a bank erosion hazard assessment; and (3) a visual assessment of the installed channels and riprap (installed in the east channel). An assessment of channel erosion using aerial imagery was conducted using 2008, 2010, 2012, 2014, and 2016 imagery. Assessing erosion between 2016 and 2018 using aerial imagery was not possible as new images were not acquired in 2018. The methodology of the four assessments are described below.

4.2.1 Visual Inspection of Riprap

The interface between the riprap and the channel bank was inspected for signs of erosion such as head-cutting, rill, and gully erosion. Minor settlement of riprap is expected over time and settlement may contribute to channel formation along the riprap and channel bank interface or to the exposure of the filter blanket. Loss of sidewall material at the interface may cause lateral displacement of riprap into new erosion channels formed at the riprap and channel bank interface. To record our visual assessment, photographs were taken at each survey stake and at various locations along the channel where erosion was observed.

4.2.2 Survey measurements

Reference pins and survey stakes installed along the perimeter of the east and west channel in 2016 were located, inspected, and again georeferenced. Pins were originally located on the planar surface of the floodplain near the slope break of the channel (Figure 4-1 and Figure 4-2). Measurements to the nearest centimetre were taken using a tape measure between the survey stakes and reference pins. Distances between the survey stakes and reference pins were compared to the measurements taken in 2016 to assess for slumping along the channel banks. An increase in distance indicated slumping as the horizontal distance between the pins and the stakes increased as soil slumped down the channel bank. Channel depth was measured at the thalweg[1] between each pair of pins (1-1 and 1-9, 1-2 and 1-8, etc.).

Figure 4-1: East erosion channel at WPW-6A, May 2018 The stake in the foreground is 122 cm behind pin 1-5 located at the margin of the riprap – channel bank interface (circle).

[1] Thalweg is the lowest elevation within a valley or watercourse in a given cross-section between two points

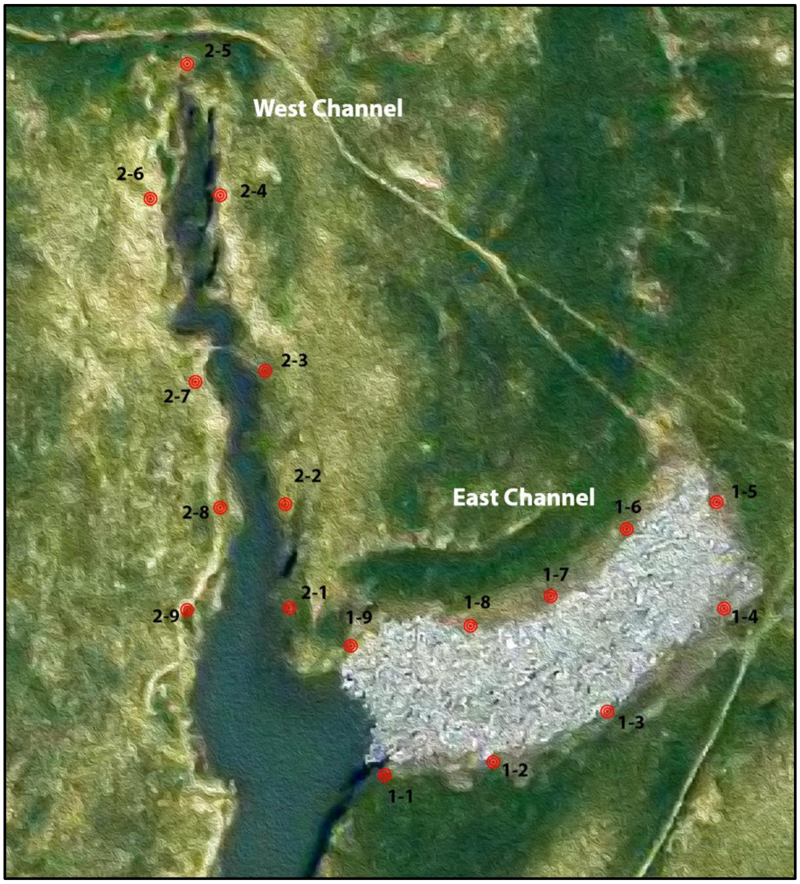

Figure 4-2: **Image showing the arrangement of survey pins around the perimeter of the erosion channels.** Thalweg measurements were taken between adjacent pins.

4.2.3 Bank Erosion Hazard Index (BEHI)

Calculating a Bank Erosion Hazard Index (BEHI) is an evaluative process to determine bank susceptibility to erosion using variables that are known to affect bank erosion rates (Rosgen 2001; Rathbun, 2008; Netwon and Drenten 2015). Bank erosion of the east and west erosion channels were assessed and compared using a modified BEHI based on four metrics:

1. **Ratio of root depth to bank height (RDH)**: the ratio of the average plant root depth to the bank height, expressed as a percentage. Given the uniformity of the site, root depths were assumed to be the same at all pin locations, and root depth was averaged across several measurements made in the west channel.
2. **Bank angle (BA):** is the angle of the bank (as measured with a clinometer) from the base of the bank to the top of the bank. Bank angles greater than 90 degrees occurred on undercut banks.
3. **Surface protection (SP):** is the percentage of the bank surface covered (and therefore protected) by plant roots, downed logs, branches, rocks, etc.
4. **Bank Material (BM):** the composition of the bank affects its erodibility and scores are adjusted based on the type of material.

Values for the four metrics were scored against modified Rosgen's BEHI indices (Table 4-1). Bank erosion hazard index (BEHI) values were calculated at each pin location and averaged to provide an overall rating for each channel. The total score was then assigned an overall hazard rating adapted from Rosgen (2001; Table 4-2).

Table 4-1: BEHI metrics and categories scores.

BEHI Category	RDH Density (%)	RDH Score	Surface Protection	SP Score	Bank Angle (deg.)	BA Score	Bank Material	BM Score
Very Low	90 - 100	1	80 - 100	1	0 - 20	1	Cobble > 6.5 cm	-10
Low	50 - 89	2.5	55 - 79	2.5	21 - 60	2.5	Clay	0
Moderate	30 - 49	5	30 - 54	5	61 - 80	5	Gravel 0.5 to 6.5 cm	5
High	15 - 29	7.5	15 - 29	7.5	81 - 90	7.5	Sandy Gravel	7.5
Very High	0 – 14	10	0 – 14	10	90+	10	Non-plastic sand and silts	10

Table 4-2: BEHI ratings (adapted from Rosgen 2001).

BEHI Category	Total Score
Very Low	≤ 5
Low	5 – 15
Moderate	15 – 25
High	> 25

4.2.4 Aerial Imagery

Aerial imagery taken every second year between 2008 and 2016 was used to assess erosion in the east and west channels. Perimeters of the erosion channels were delineated manually in GIS and channel lengths and areas were compared among years. Current (2018) aerial imagery was not available so this assessment covered the period 2008 to 2016 only.

4.3 Erosion Monitoring at WPW-15A: Cartier Bay

Our assessment of WPW-15A included a visual inspection of the installed riprap blanket and dyke, and survey measurement of the swale. Surveys elevations were taken from the top of the dyke and referenced to survey points established previously by Watson Engineering (2016) on a nearby culvert (Table 4-3 and Figure 4-3). Multiple measurements were taken at the deepest point of the swale to determine the swale elevation. Monitoring the swale elevation and depth over time will determine if the swale erodes.

Table 4-3: The location and elevation of survey points established at WPW-15A by Watson Engineering (2016).

Survey Point	UTM Northing	UTM Easting	Elevation (m ASL)
CN15A	641997.52	418352.03	435.236
CS15A	641995.25	418347.21	435.04

Figure 4-3: Location of survey reference point CS15A established by Waston Engineering on a culvert near Site 15A.

Visual inspection of WPW-15A include the following:

- **Inspection of riprap**. Settlement of placed riprap is expected at over time, which may reduce the integrity of the riprap blanket and its ability to stabilize the dyke. Settlement may also contribute to channel formation along riprap and dyke interface.
- **Inspection of riprap interface**. The interface between the riprap and the surrounding material will be inspected for signs of erosion such as head-cutting, rill, and gully erosion.

An assessment using aerial imagery of WPW-15A was not possible as new images were not acquired in 2018. No BEHI was attempted as the procedure is not applicable to WPW-15A.

4.4 Wetland and Riparian Habitat Monitoring at WPW-15A (Cartier Bay)

4.4.1 Design

The basic design of the effectiveness monitoring is a before-after physical works comparison, with new randomly selected points sampled each year. There are no control sites. Pre-works monitoring of wetland habitat parameters at Cartier Bay was conducted in 2010 (pilot study), 2011, 2012 and 2013. Pre-works monitoring specifically focused on aquatic wildlife habitat, and the primary response variables measured were aquatic macrophyte and macroinvertebrate composition and abundance. Point data on water physicochemistry were also collected. The rationale for the approach and the sampling design is described by Hawkes *et al.* (2011).

The study uses point-intercept samples of aquatic vegetation and water physicochemistry collected from a boat, as well as samples of riparian vegetation collected from shoreline (terrestrial) sample plots. Submersed plants are sampled indirectly by deploying a double-headed rake and obtaining benthic grabs of species rooted in the water. The point of intercept in this case is the area of substrate that is combed with the rake—a predefined linear distance of ~1 m. To increase sampling precision, multiple drags (one on each side of the boat) are made. Point source physicochemical data were collected annually at macrophyte sample locations in Cartier Bay during the baseline (2011-2013) sample period, and this sampling procedure will be repeated for the post-works (2018-2020) sample period. In addition to point source data, during post-works monitoring continuous water physicochemical data will also be collected in Cartier Bay using permanently deployed dataloggers.

Initial monitoring efforts were focused on aquatic habitats; therefore, pre-works data on riparian habitat characteristics at Cartier Bay were not systematically collected as part of CLBMON-11B4. To assess changes to riparian conditions resulting from implementation of WPW-15A, we will rely on a combination of: (a) prior ground inspection data collected as part of the associated vegetation monitoring programs CLBMON-33; (b) the time series of aerial images of Cartier Bay captured in 2010, 2012, 2014, and 2016 in conjunction with CLBMON-33; and (c) post-works aerial imagery as it comes available.

For delineating wetland boundary extents, aerial imagery will be used in conjunction with GPS tracks recorded on foot. The GPS-recorded wetland boundary (post-works) will be compared with the wetland extent during the pre-works period as determined through historical orthophoto interpretation and will also serve as a georeferenced baseline for future trend monitoring.

Data analysis will follow a before-after design. Biotic and abiotic measurements for the period 2011-2013 (pre-works) will be compared to measurements for the period 2018-2020 (post-works) to determine if implementation of WPW-15A had a measurable impact on wetland habitat characteristics at Cartier Bay. With respect to macrophyte and water chemistry data, several alternative trend scenarios will be considered for best fit:

1) No trend, prior to or after the project (= no project effect);
2) Linear trend, commencing prior to the project (= no project effect). Modelled using linear regression;
3) Linear trend with breakpoint, with breakpoint coinciding with project implementation (= possible project effect). Modelled using multiple regression;
4) Non-linear monotonic trend, i.e., no or minimal trend prior to the project followed by a stronger trend after project implementation (= possible project effect). Modelled using linear regression with log or other transformations; and
5) Step change (i.e., large sudden change), coinciding with project

implementation (= project effect). Modelled using *t-test* or *Analysis of Variance*.

Miller and Hawkes (2013; 2014) observed a high level of natural year-to-year variability in macrophyte abundance in Cartier Bay prior to physical works implementation. It is thus likely that any project-related effect would have to be very large in order to be statistically detectable. If the power to detect impacts on aquatic vegetation is unacceptably low because of background environmental (year-to-year) noise, an argument could be made for placing higher emphasis on monitoring detectable changes in the wetland extent or, alternatively (and more simply), water levels within the wetland compartments themselves. This shift in emphasis would be predicated on the presumption that wetland extent/water levels can stand in as a reasonable environmental surrogate for lower-level habitat responses.

4.4.2 Data Collection

Fieldwork was carried out by a team of two researchers and occurred over four days in May 2018 (May 20-23). Work was timed to occur as late as possible in the growing season but before reservoir inundation occurred, to allow for maximal vegetation development. In 2018 the reservoir elevation surpassed 434.045 m (the height of the repaired box culvert and approximate threshold for Cartier Bay inundation) on 18 May. This was slightly earlier than anticipated based on initial forecasts, with the result that river water began to breach the culvert just as the four-day sampling session commenced. The encroachment of fresh river water into the two main Cartier Bay compartments was initially gradual and did not unduly hamper surface sampling efforts. However, rising water levels obscured the previous shoreline and thus precluded delineating the current permanent wetland extent by walking the wetted perimeter and recording a GPS track. That procedure was consequently deferred until 2019.

Prior to fieldwork, 100 surface sample points in Cartier Bay were randomly placed using GIS (Figure 2-2). Water depths of sample points at the time of sampling ranged from < 1 m to 2.3 m. The methods implemented at each point are described below under the following subheadings: **Aquatic Macrophyte Sampling** (4.4.2.1); **Riparian Vegetation Sampling** (4.4.2.2); and **Water Depth and Chemistry Sampling** (4.4.2.3).

4.4.2.1 *Aquatic Macrophyte Sampling*

Two benthic rake drags were made, one on each side of the canoe. Following each rake drag, the contents of the rake were examined (Figure 4-4) and the species composition of the macrophyte sample was recorded.

The total volume of the vegetation sample was described on a categorical scale from 1 to 3 (Table 4-4), and each macrophyte species in the sample was assigned a relative cover class (**Error! Reference source not found.**5). For analysis, local abundance was estimated f or each species and sample point using the volume x cover (VC) metric (Miller and Hawkes 2014). To derive this value, we multiplied the total sample volume by the relative cover class of each species to produce a single numeric value (VC) representing the abundance of the species at each sampling point. Volume classes ranged from 1 through 3, and relative abundance classes ranged from 0.1 (for trace) to 1 through 5 (Table 4-4). For each sample point, the values were averaged across two rake grabs. Thus, the minimum possible volume value was 0.5 and the minimum possible relative cover value was 0.05. The minimum possible (non-zero) value for the volume x cover metric was then 0.5 x 0.05 = 0.025, and the maximum possible value for the volume x cover metric was 3 x 5 = 15.

Per cent frequency was calculated as the number of samples points in which a species was recorded divided by the total number of samples and served as a measure of ubiquity and a proxy for overall cover (Madsen 1999).

Figure 4-4: Rake sample of aquatic macrophytes, Cartier Bay wetland, May 22, 2018.

Table 4-4. Volume classes for macrophyte samples.

Volume Class	Sample Volume	Definition
1	Trace	Sample is restricted to one or very few strands of vegetation
2	Small	Sample fills less than half of the tines of the sampling rake
3	Large	Sample fills half or more of the tines of the sampling rake

Table 4-5. Relative cover classes for macrophyte samples.

Cover Class	Definition
T	Species is present but contributes negligibly (< 1 per cent) to the sample volume
1	Species contributes less than 10 per cent of the sample volume
2	Species contributes 11–20 per cent of the sample volume

3	Species contributes 21–50 per cent of the sample volume
4	Species contributes 51–75 per cent of the sample volume
5	Species contributes 76–100 per cent of the sample volume

Floating-leaved and emergent macrophytes, when present, were sampled using a buoyant 1-m^2 quadrat frame constructed from PVC pipe. Using this frame, one short (2-m x 1-m) belt transect was laced on each side of the boat (total 4-m^2). The per cent cover of the water surface occupied by each floating or emergent macrophyte species was recorded for each of the four quadrats. For analysis, the per cent cover value of each species was averaged among the four quadrats (Miller and Hawkes 2014).

4.4.2.2 *Riparian Vegetation Sampling*

This entailed resampling 13 10-m x 5-m (50-m^2) terrestrial vegetation plots within the Cartier Bay floodplain which were originally established and sampled under the landscape-scale study CLBMON-33 (Enns et al. 2008, Miller et al. 2018). UTM coordinates corresponding to the original plot centres were employed for this purpose (Figure 2-2). To support orthophoto-based assessments of changes over time in wetland extent and riparian community composition, 16 additional 50-m^2 riparian plots were also established and sampled in 2018 to supplement the CLBMON-33 samples (Figure 2-2; Figure 4-5).

Vegetation within plots was assessed for plant species composition/cover and vegetation community type, or VCT. Community typing followed that used for CLBMON-33 (Table 4-6). Per cent covers, measured as the percentage of the ground surface covered when the crowns are projected vertically, were visually estimated and rounded as follows: traces = 0.1%; <1% rounded to 0.5%; 1-10% rounded to nearest 1%; 11-30% rounded to nearest 5%; 31-100% rounded to nearest 10%. A VCT category was assigned to the plot following the drawdown zone community classification system developed by Enns *et al.* (2008) and subsequently modified by Miller *et al.* (2018).

Figure 4-5: Supplemental riparian vegetation plot in a reed canarygrass-dominated community, Cartier Bay, May 21, 2018.

Table 4-6. **Vegetation community types (VCTs) of Arrow Lakes Reservoir.** Classification from Enns *et al.* (2008), as modified by Miller e*t al.* (2018). Not all VCTs (e.g., BB, SF, IN) are typically vegetated. Codes in bold type correspond to types commonly found in riparian zone habitat around Cartier Bay wetland.

VCT code	Description
BB	Boulder slope
BE	Sandy beach
BG	Gravelly beaches, typically on alluvial or fluvial outwash, consisting of gravel and cobbles of various sizes, usually sloped or gently sloped. May be adjacent to creeks and seepage. Due to washing of fine materials over the surfaces, grit can collect between boulders, and some very drought and inundation tolerant plants occur, including willows, horsetail, reed canarygrass, sorrel, and redtop. Vegetation is generally sparse.
CL	Cliffs and rock outcrops
CR	Riparian cottonwood forest
Shrub riparian	Riparian shrub strip bordering cottonwood stands
IN	Industrial/ residential/ recreational
LO	Log zone

VCT code	Description
PA	Redtop upland.
PC–Willow	Reed canarygrass with willow thickets
PC–Reed canarygrass	Formerly included with the PC–Reed Canarygrass mesic, this modifier is used to denote the (nearly) pure stands of reed canarygrass that dominate large segments of the drawdown zone at mid and upper elevations in Revelstoke Reach and, to a lesser extent, Arrow Lakes. Characterized by dense cover of reed canarygrass, low species diversity, and heavy thatch cover at ground level.
PC–Foxtail/horsetail	Low-elevation reed canarygrass - little meadow-foxtail – horsetail association.
PC–Sedge	Formerly included with "PC–Reed Canarygrass mesic," this refinement of the PC type describes the widespread, mixed stands of reed canarygrass, Kellogg's sedge and/or Columbia sedge found mainly at mid elevation. Rushes (*Juncus* spp.) are also a frequent component.
PE–Foxtail	Low elevation sedge - little meadow-foxtail association.
PE–Sedge	Formerly included with "PE–Horsetail lowland," this designation is assigned to the characteristic, Kellogg's sedge-dominated, "tussocked" phase of the original PE–Horsetail lowland VCT. Found mainly at low to middle elevations, often in depressional topography on relatively compacted, non-aerated substrate. Species composition includes inundation-tolerant annuals and perennials.
PO	Pond / wetland.
RR	The "reed–rill" VCT is associated with continuous sources of fresh water from streams or seeps originating from upslope. Materials usually have some fine textured and compacted components, often boulders with silts in interstitial spaces. The silts are usually also mixed with sands, and these can be cemented and embedded with fine to coarse gravels. The RR type usually has dense, but patchy cover of mixed semi-aquatic or riparian species, with some barren areas. Species include rushes, reeds, and sedges, swamp horsetail and occasionally woody shrubs. The type can be species poor, if recent scouring has taken place.
RS	Willow stream entry
SF	Failing slope
SS	Steep sand. Steep sandy banks, often with peeling or failing slopes. Stepped patterns may occur that correspond to the typical full pool events in the reservoir. Supports just a few species of plants at low covers, such as reed canarygrass and common horsetail.
WR	River entry

4.4.2.3 *Water Chemistry and Depth Sampling*

Concurrent with macrophyte sampling, the following point source physicochemical attributes were collected at each surface sampling station:

- Water depth (via weighted tape measure)
- Turbidity (via Secchi disk)
- Dissolved Oxygen (DO; mg/l)
- Conductivity (µS/cm)
- Water Temperature (°C)
- pH

Water temperature, dissolved oxygen, conductivity, and pH were recorded at a depth 30 cm below the water surface using a multi-metric meter.

The set of randomly located depth sound measurements was pooled with similar depth data obtained in previous (2011-2013) implementation years to produce an updated bathymetric figure for the Cartier Bay wetland compartments.

5.0 RESULTS and DISCUSSION

5.1 Erosion Monitoring at WPW-6A (Airport Outflow)

5.1.1 Visual Inspection

A visual inspection of the east channel indicated that the riprap has become well integrated into the surrounding soils. In places, sediment has accumulated along the margin of the riprap, and reed canarygrass has ingressed into the channel riprap (Figure 5-1). As observed in 2016, active erosion was evident at the southwest terminus of the east channel (Figure 5-2). Fresh clumps of sod that had broken off the overhanging bank were observed on the floor of the channel indicating active bank undercutting. No other signs of erosion were observed along the perimeter of the east channel.

Extensive slumping was observed in the untreated west channel (Figure 5-3). Again, fresh clumps of sod were observed on the floor of the channel indicating ongoing active erosion and undercutting of the channel banks.

Figure 5-1: Reed canarygrass (in the foreground) ingressing into the riprap along the margin of the WPW-6A east erosion channel, May 2018.

Figure 5-2: Soil movement, slumping, and bank undercutting at the mouth of the east channel of WPW-6A, May 2018. The arrow indicates the location and direction of soil movement and slumping.

Figure 5-3: Extensive slumping and mass wasting in the WPW-6A west erosion channel, May 2018.

5.1.2 Survey measurements

Comparison of survey measurements taken in 2018 and 2016 indicated little to no slumping or erosion in the east channel, whereas soil movement,slumping, and mass wasting was evident in the west channel (

Table 5-1). Average movement between the stake and the pin was 1.5 cm in the east channel and 13.4 cm in the west channel, indicating that soils along the west channel were slumping into the erosion channel at a greater rate than in the east channel.

In the east channel, soil movement was observed at two pins (1.1 and 1.2;

Table 5-1) with distances increasing by 7 cm and 4.5 cm, respectively, over two years. Soil movement at pin 1.1 was due to slumping at the mouth of the east channel (Figure 5-2). Soil movement at pin 1.2 did not appear to be due to erosion and was likely a result of bank settlement along the margin of the channel. Little to no soil movement (≤1 cm) was observed at the remainder of the pins along the bank of the east channel (

Table 5-1).

In the west channel, soil movement was evident at all but two pins (

Table 5-1). Pins 2.5, 2.6, 2.7, and 2.9 had slumped down the bank from undercutting and mass failure (Figure 5-4). Pin 2.5, located at the head of the channel, was found on the floor of the channel, indicating aggressive head cutting had occurred over the two years.

Table 5-1: Mean and standard deviation of differences of 2016 and 2018 stake to pin measurements along the east and west Channels.

Channel	Stake-Pin Array	2018 Pin to Stake Distance (cm)	2016 Pin to Stake Distance (cm)	Difference = Soil Movement (cm)
East	1.1	129	122	7
	1.2	126.5	122	4.5
	1.3	123	122	1
	1.4	122	122	0
	1.5	120	120	0
	1.6	122.5	122	0.5
	1.7	122	122	0
	1.8	120	120	0
	1.9	122.5	122	0.5
			Mean SD	**1.5** **2.5**
West	2.1	122	122	0
	2.2	122	122	0
	2.3	124.5	122	2.5
	2.4	134	122	12
	2.5	193	122	71
	2.6	135.5	122	13.5
	2.7	137.5	122	15.5
	2.8	125	122	3
	2.9	125.5	122	3.5
			Mean SD	**13.5** **22.4**

Figure 5-4: Autumn Solomon (ONA) searching for erosion pin 2.7 on an undercut bank in the west erosion channel at WPW-6A, May 2018.

5.1.3 Bank Erosion Hazard Index

Unsurprisingly, BEHI scores were very low (4.3) for the east channel and high (28.7) for the west channel. The difference in scores was due to higher scores in bank height, bank angle, surface protection, and bank material in the west channel than in the east channel (Table 5-2). Root depth was given the same score for all pin locations, as per section 4.2.3.

Although BEHI scores were not obtained prior to construction, the BEHI score and rating in the east channel prior to the 2013 physical works would have been similar to the high value and rating obtained for the west channel in 2018. We are therefore confident in stating that the WPW-6A site reduced both the BEHI scores and potential for bank erosion in the east channel. While the merits of the BEHI can be debated, the BEHI provides a rapid semiquantitative measurement of erosion potential that is based on known factors of bank erosion and allows for comparisons over time and among sites (Allmanová and Matúš 2016).

Table 5-2: Bank Erosion Hazard Index (BEHI) scores for the east and west erosion channels.

Channel	Pin	Bank Height	Root Depth	RDH Score	Surface Protection (%)	SP Score	Bank Angle (degree)	BA Score	Bank Material Score	Total Score
East	1.1	35	45.7	7.5	90	1	16	1	0	8
East	1.2	15	45.7	7.5	90	1	12	1	0	3
East	1.3	10	45.7	7.5	95	1	10	1	0	3
East	1.4	5	45.7	7.5	100	1	18	1	0	3
East	1.5	5	45.7	7.5	85	1	7	1	0	3
East	1.6	10	45.7	7.5	100	1	7	1	0	3

East	1.7	30	45.7	7.5	80	1	15	1	0	3
East	1.8	40	45.7	7.5	100	1	25	2.5	0	4.5
East	1.9	50	45.7	7.5	100	1	14	1	5	8
Mean Values		**22.2**		**7.5**		**1**		**1.2**	**1.1**	**4.3**
West	2.1	197	45.7	7.5	100	1	45	2.5	10	21
West	2.2	235.5	45.7	7.5	85	1	30	2.5	10	21
West	2.3	259	45.7	7.5	80	1	38	5	10	23.5
West	2.4	257	45.7	7.5	20	7.5	90+	10	10	35
West	2.5	245.5	45.7	7.5	50	5	90+	10	10	32.5
West	2.6	250.5	45.7	7.5	50	5	80	5	10	27.5
West	2.7	254	45.7	7.5	40	5	90+	10	10	32.5
West	2.8	243.5	45.7	7.5	50	5	65	10	10	32.5
West	2.9	189.5	45.7	7.5	30	5	90+	10	10	32.5
Mean Values		**236.8**		**7.5**		**3.9**		**7.2**	**10**	**28.7**

5.1.4 Aerial Imagery Interpretation

Analysis of channel delineation from aerial orthoimages indicated that both channels increased in size between 2008 and 2016 (Table 5-3; Figure 5-5 and Figure 5-6). During this period, the east-channel increased in area by approximately 50 per cent (from 221.1 to 324.3 m^2) and increased in length by 4.1 meters. Prior to construction (2008 to 2012), the channel was increasing in size by 4.4 per cent annually. A large increase in channel area occurred between 2012 to 2014, which was largely due to the excavation of undercut banks, slope contouring, and riprap placements associated with the WPW site construction in 2013. From 2014 to 2016, the east channel decreased slightly in area, which was likely due to the integration of the riprap into the surrounding soils and the ingress of reed canarygrass into the channel footprint.

Over the same period, the west channel increased in area by 24 per cent (from 344.4 to 426.5 m^2) and increased in length by 10.4 meters. The west channel increased in area by between 2.0 to 3.7 per cent annually advancing approximately 1.3 meters per year into the floodplain. Annual soil loss was estimated to be between 17.2 and 26.4 m^3/yr based on an average channel depth of 2 meters. This equates to a loss of 2.1 to 3.3 dump trucks (8 m^3 capacity) of soil in the west channel per year.

Table 5-3: **Length and area of the east and west erosion channels at WPW-6A obtained from aerial imagery between 2008 and 2016.**

Image Year	Sample Year*	Channel	Channel Length	Channel Area (m^2)	Annual percentage change of channel Area (%)	Volume of lost soil (m^3/yr) **
2008	> 2008	East	35.6	221.1	-	-
2010	2008 – 2009		35.8	238.7	4.0	17.6
2012	2010 – 2011		37.7	261.8	4.8	23.1
2014	2012 – 2013		39.6	328.0	12.6	66.2
2016	2014 – 2015		39.6	324.3	-0.6	-
2008	> 2008	West	49.5	344.4	-	-
2010	2008 – 2009		49.5	361.5	2.5	17.2
2012	2010 – 2011		55.4	388.0	3.7	26.4
2014	2012 – 2013		57.5	409.8	2.8	21.8
2016	2014 – 2015		59.9	426.5	2.0	16.8

* Due to the timing of aerial photography, erosion rates apply to the years preceding the image year. For example, the erosion rate estimated due to differences in area and volume in 2016 image apply to 2014 and 2015 as the image in 2016 was taken before the reservoir was inundated.
** Based on an average channel depth of 2 meters.

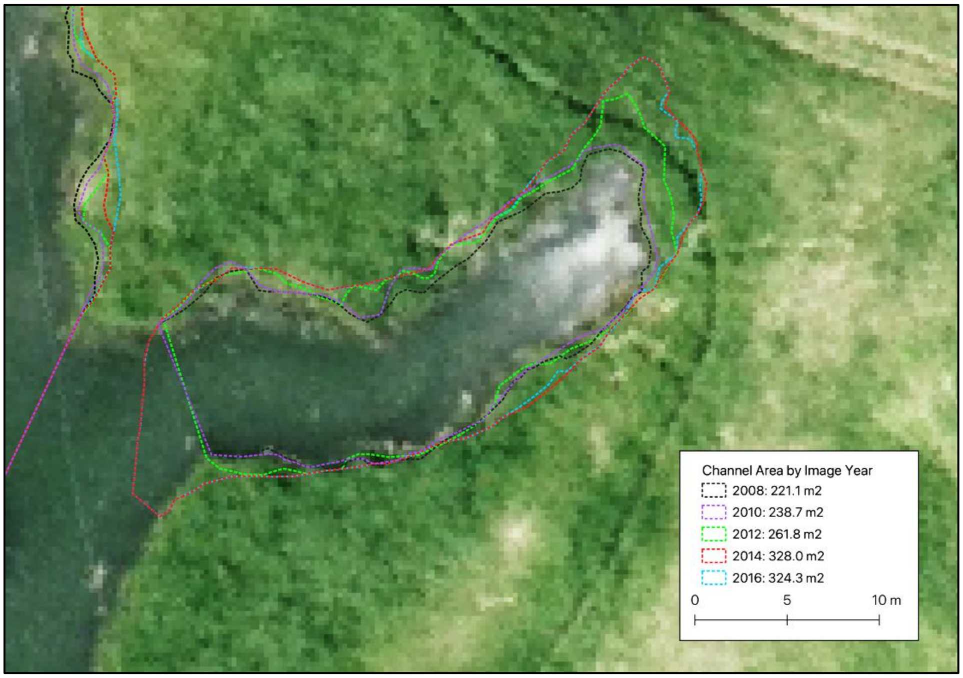

Figure 5-5: Size of the east erosion channel delineated by year. Background image year is from 2008

Figure 5-6: Size of the west erosion channel delineated by year. Background image year is from 2008.

5.2 Erosion Monitoring at Site WPW-15A

We found no evidence of erosion during our visual assessment of site WPW-15A (Figure 5-7). Average elevation of the swale was estimated to be 434.051 m based on survey measurements referenced to permanent reference points established on the old culvert (Figure 4-3). This compares favourably with the values reported by Watson Engineering (2016) of 434.045 m, indicating that no measurable amount of erosion has occurred in the swale since construction.

Figure 5-7: Images of the WPW-15A wildlife physical works at Cartier Bay, May 2018.

5.3 Wetland and Riparian Habitat Monitoring at WPW-15A

5.3.1 Water Depth and Chemistry

Average water depth at surface sample points, after correcting for daily reservoir elevations,[2] was 0.88 m (Table 5-4). Average measured depths tended to be greater in the west compartment of Cartier Bay (1.0 m) than in the east compartment (0.83 m). Depths in the east compartment ranged from 0.1-1.5 m; those in the west, from 0.3-1.9 m; Figure 5-8).

An updated bathymetric map for Cartier Bay, generated from all depth measurements (*n*=166) collected during surface sampling between 2011 and 2018, shows the distribution of shallow and deep areas within the wetland (Figure 5-9).

Measurements of turbidity (Secchi depth), dissolved oxygen (DO), pH, conductivity (µS/cm), and temperature (°C) recorded in the 2018 point samples fell within the range of variation obtained for the pre-works monitoring period (Table 5-4). In the context of this study, water physicochemical variables are only inherently ecologically significant if they are shown to have changed in response to wildlife physical works, and if these changes can be correlated with a change in aquatic plant abundance and distribution. Therefore, further exploration of physicochemical data will be deferred until 2020 when a more complete time series of post-works conditions has been obtained.

Table 5-4. Mean (*SD*) water depth, Secchi depth (relative turbidity), dissolved oxygen (DO), pH, conductivity (µS/cm), and water temperature (°C) measured in surface samples taken at Cartier Bay wetland from 2013 to 2018.

Year (*n*)	Water depth (m)	Secchi depth (m)	DO (mg/l)	pH	µS/cm	°C
2011 (19)	1.01 (0.56)	n/a	9.32 (1.85)	8.5 (0.37)	203.23 (57.92)	19.54 (1.36)
2012 (13)	1.03 (0.51)	79.62 (15.0)	9.24 (0.32)	n/a	106.42 (13.55)	14.33 (1.24)
2013 (15)	1.43 (0.44)	195 (n/a)	11.82 (1.35)	8.81 (0.38)	114.12 (8.17)	17.25 (1.68)
2018 (104)	0.88 (0.36)	91.81 (17.59)	9.11 (1.03)	8.12 (0.26)	169.7 (20.69)	19.65 (1.83)

[2] During correction, depending on year, base elevation for the west compartment of Cartier Bay was set either to 434.045 m ASL (reported elevation of WPW 15A post-physical works) or to 433.8 m ASL (reported elevation of WPW pre-physical works). Base elevation for the east compartment was estimated at 434.8 m ASL, to accommodate the fact that water entering the east compartment must also pass over an eroded roadbed, which sits at a slightly higher elevation than WPW 15A. If the daily reservoir elevation was <434.8 ASL on the day of sampling, no depth correction was applied to samples in the east compartment. The base estimate of 434.8 m ASL will be adjusted accordingly if more precise elevation information for the secondary roadbed becomes available at a later date.

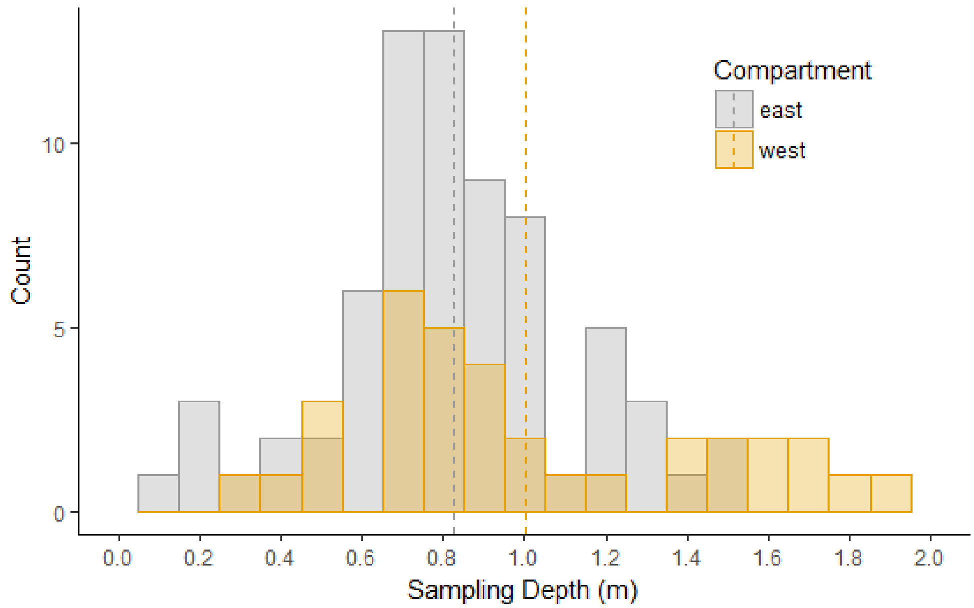

Figure 5-8. **Sampling depth distributions for the east and west compartments of Cartier Bay wetland in 2018.** "East" compartment refers to the area east of the eroded roadbed bisecting the wetland; "west" compartment refers to the area west of the roadbed and east of WPW-6A (Figure 2-2). Dashed lines represent the average sampled depths.

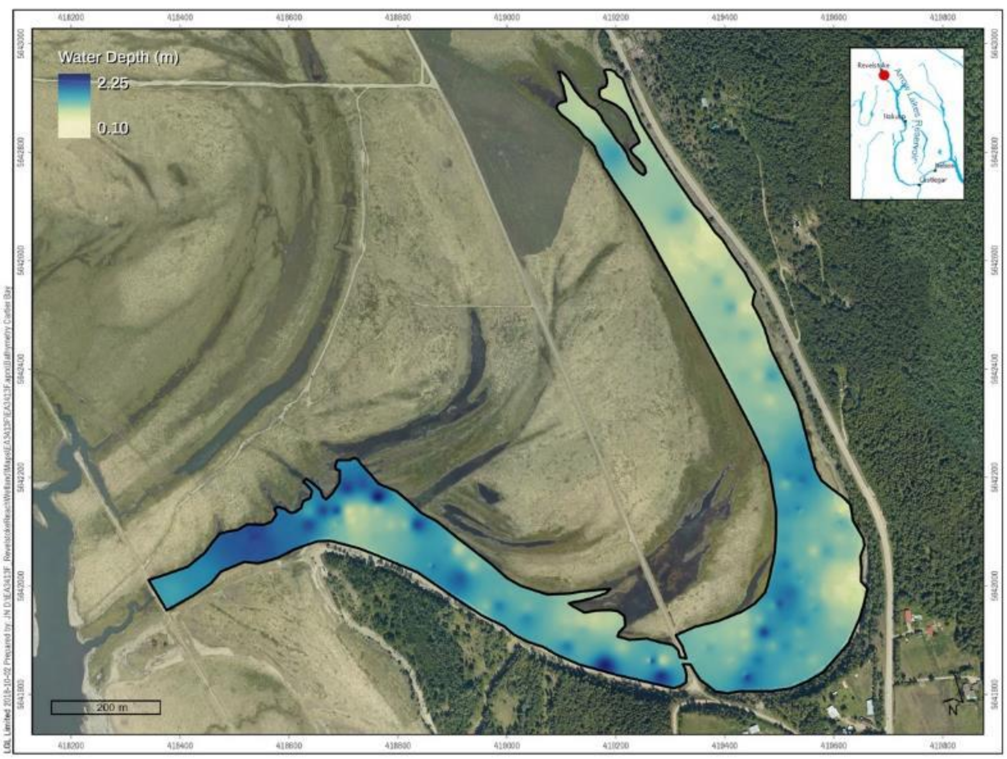

Figure 5-9: **Bathymetric map of Cartier Bay wetland, based on depth sound measurements made during surface sampling in 2011, 2012, 2013, and 2018 (*n*=165).** All depth data were back-corrected using historical records of daily reservoir elevations, to correct for overestimates on sample days when the wetland was inundated by the reservoir.

5.3.2 Aquatic Macrophytes

In 2018, the initial year of post-works monitoring, per cent frequency of macrophytes at Cartier Bay (Figure 5-10) ranged from nil (for floating-leaved pondweed) to highs of 84, 83, and 63 per cent (for stonewort, Eurasian water-milfoil, and common hornwort, respectively). Water smartweed, as well as two other pondweeds (Richardson's and eel-grass) were only encountered sporadically. Eurasian water-milfoil, Richardson's pondweed, and stonewort showed a trend of increasing frequency since 2013, while common hornwort, small pondweed, and water smartweed were less common in samples compared to 5 years earlier (Figure 5-10).

Common hornwort, Eurasian water-milfoil, and stonewort (an algae species) tended to have the highest local biomass volume as measured by the VC (sample volume x relative cover) metric. Pondweeds (*Potamogeton* spp.) were the most biodiverse group of macrophytes in Cartier Bay but tended to be relatively less dominant locally (Figure 5-11). VC for common hornwort, a native species, indicates a slight declining trend since 2011, while that of the non-native species Eurasian water-milfoil may have increased somewhat (Figure 5-11). Several of these species provide habitat structure and/or food for wildlife and can be viewed as indicators of habitat condition to some degree (see Appendix 8.1 for a brief review of the ecology of key macrophyte species found in Revelstoke Reach).

Because the post-works data time series is, as of 2018, limited to a single year, it is too early in the monitoring process to test for significance in any of these trends or to attempt any direct pre- and post-works comparisons. Such analyses will be deferred until the final summary report (scheduled for 2020).

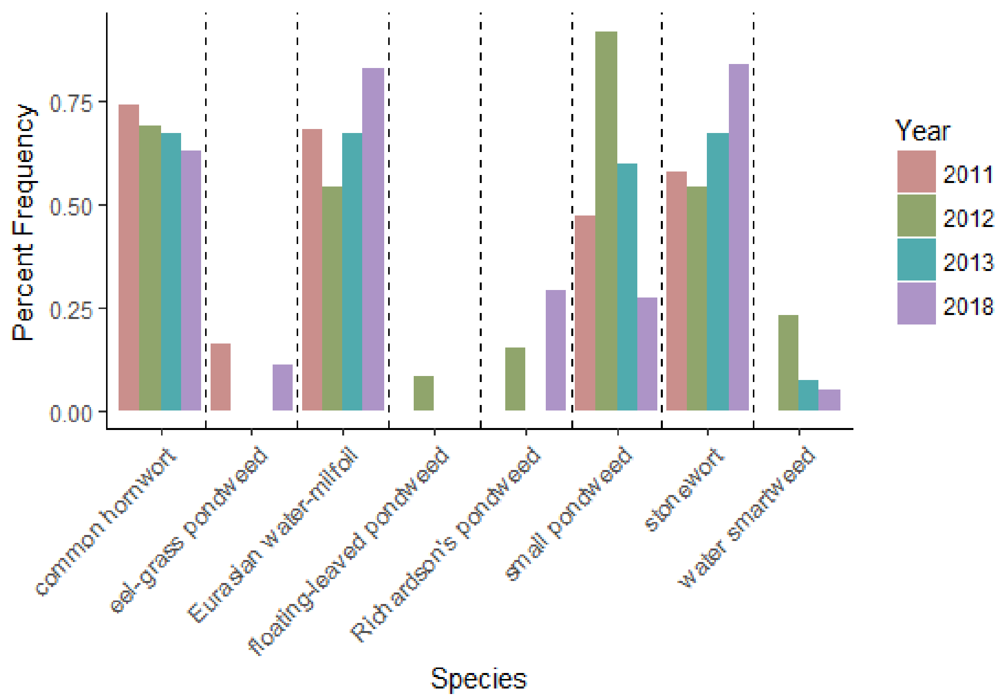

Figure 5-10. **Proportion of samples (per cent frequency) in which aquatic macrophyte species were recorded in random surface samples (rake grabs) at Cartier Bay wetland, from 2011 to 2018.** *n* = 19, 13, 15, and 104 in 2011, 2012, 2013, and 2018 respectively.

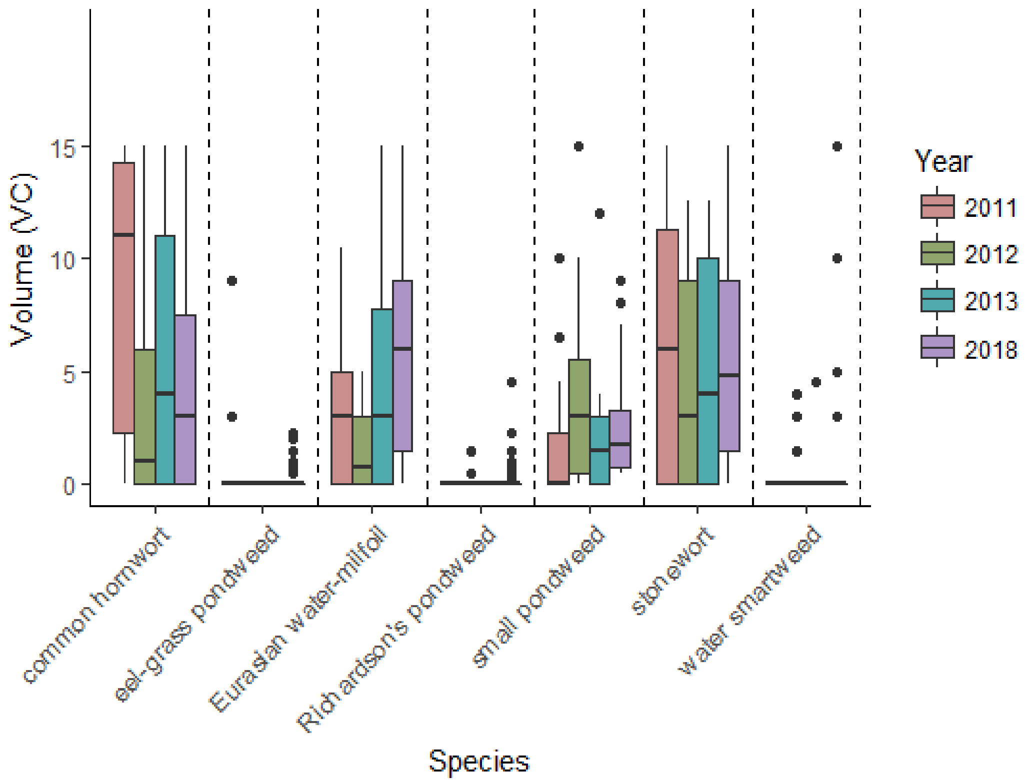

Figure 5-11. Local abundance, as represented by the VC (sample volume x relative cover) metric, of aquatic macrophytes in random surface samples (rake grabs) at Cartier Bay wetland, from 2011 to 2018. *n* = 19, 13, 15, and 104 in 2011, 2012, 2013, and 2018 respectively.

5.3.3 Riparian Vegetation

Six different riparian vegetation community types or VCTs (Figure 5-12) were identified during terrestrial sampling (*n*=29 plots). PC-Sedge and PC-Reed canarygrass are the dominant VCTs on the flat to undulating north and west shorelines of the Cartier Bay wetland, while the BG, PC-Shrub, RR, and SS VCTs are generally confined to the steeper, south and east shorelines.

PC-Sedge, the most widely encountered vegetation type, supported both relatively high species richness and relatively high plant cover. RR plots were also relatively speciose, but plant covers were lower. The highest plant cover was associated with PC-Reed canarygrass, but this vegetation type was heavily dominated by a single species (reed canarygrass). BG, PC-Shrub, and SS all supported relatively low species richness along with modest plant covers (Figure 5-12).

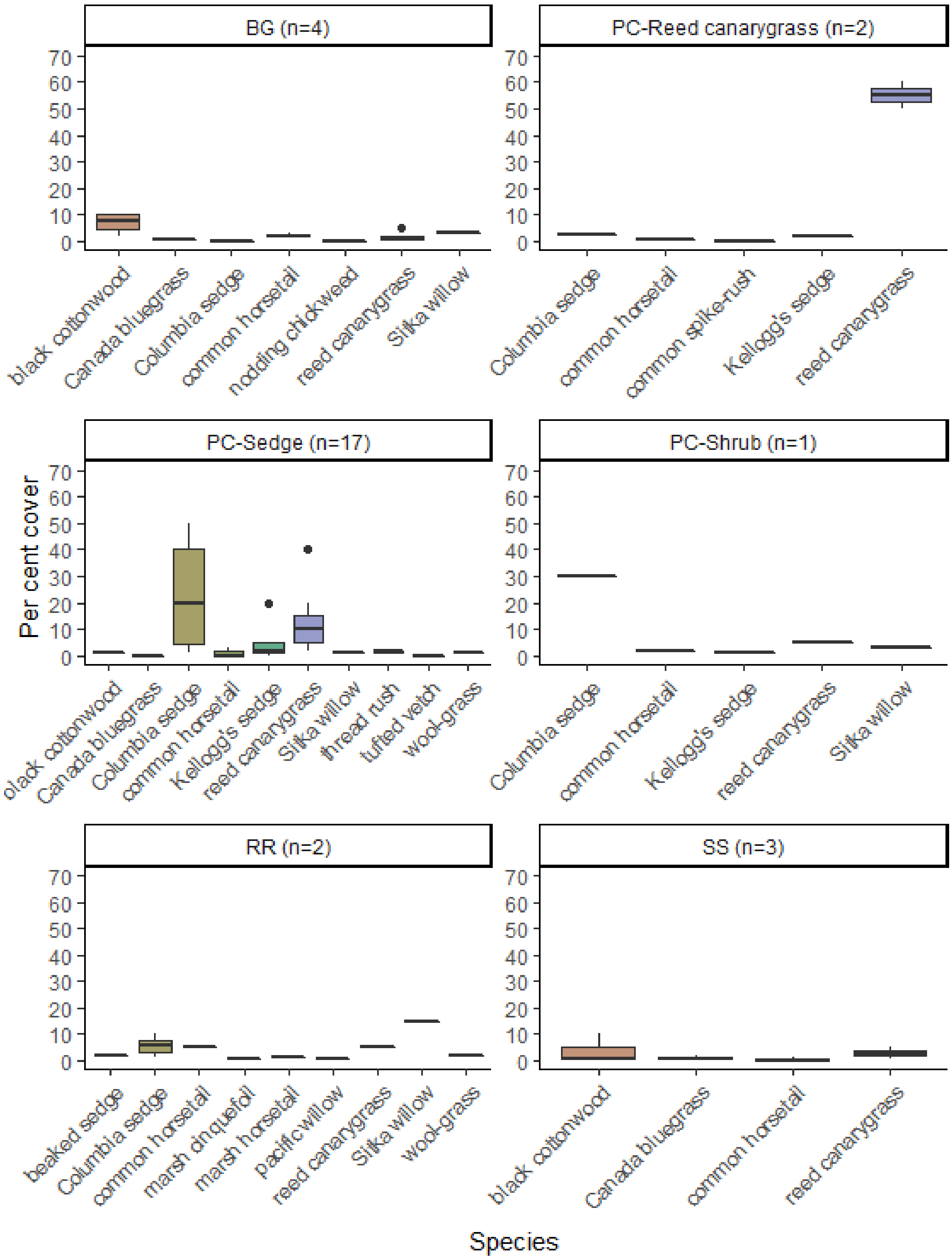

Figure 5-12. Plant species and covers for different riparian vegetation community types (VCTs) sampled around the perimeter of the Cartier Bay wetland on May 20-23, 2018. See Figure 2-2 for sample locations. See Table 4-6 for VCT code definitions and descriptions.

This sample provides a representative, not a comprehensive, accounting of the vegetation types occurring around the perimeter of Cartier Bay wetland. The primary purpose of the 2018 sample was to characterize existing riparian conditions in the immediate post-physical works period, and to provide field verification for any subsequent orthophoto monitoring of riparian vegetation changes near the wetland-terrestrial interface in response to the Site 15A WPW.

There is no strong expectation at present that the physical works will have a notable effect on upland conditions in Cartier Bay. This is because the objective of the works was to maintain the status quo with respect to the maximum depth and areal extent of the permanently wetted area. However, if a change in riparian boundaries or key characteristics is detected by the end of the monitoring period, species cover obtained during the post-works period can be compared against analogous data obtained during the pre-works period (as part of CLBMON-33). A before-after comparison of cover type could assist in identifying which plants or vegetation types have contributed substantially to the observed change, and via what mechanism(s).

6.0 SUMMARY AND RECOMMENDATIONS

This report presents summary results from the first of three years of post-physical works monitoring at Revelstoke Reach (Airport Outflow WPW-6A and Cartier Bay WPW-6A) under the CLBMON-11B4 program. CLBMON-11B4 is part of a suite of monitoring programs that together monitor the effectiveness of wildlife physical works at protecting or enhancing wetland and riparian wildlife habitat, and at benefitting the wildlife that utilizes it.

6.1 Erosion Monitoring

The installation of riprap in the east channel at WPW-6A appears to have arrested erosion in this channel. There were no signs of erosion, slumping, or mass wasting along the perimeter of the riprap, although slumping was observed at the channel mouth where the channel bank remains exposed (Figure 5-2). A small degree of soil movement occurred at this location and was attributed to undercutting the channel bank, causing the sod to slump down the bank. Continued erosion monitoring should be conducted to assess the rate of erosion at this location.

The BEHI rating obtained for the WPW-6A east channel was very low (BEHI score < 5), further underscoring the success of the project. Although BEHI scores were not obtained prior to construction, in comparison to the score obtained for the west channel in 2018, we conclude that the erosion risk has been greatly reduced as a result of the WPW.

Our analysis of aerial imagery allowed us to estimate rates of erosion in the two channels. Prior to the implementation of WPW at Site 6A, the rates of erosion in the two channels were remarkably similar both in terms of percentage area (ha) change, and rate of channel lengthing. Following the WPW, bank erosion ceased in the east channel but continued in the west channel at a rate of approximately 20 m^3/yr of soil loss annually, and a 1.3 m increase in length annually.

Our visual assessment and survey of WPW-15A did not reveal any noticeable or measurable amounts of erosion.

6.2 Habitat Productivity and Suitability

In terms of wetland and associated riparian habitat productivity and habitat suitability for nesting birds, reptiles, and amphibians at Cartier Bay, the 2018 survey of aquatic and riparian vegetation, and water physicochemical attributes, yielded no immediate indication that the repairs made to the roadbed (WPW-6A) are failing in their objective to protect existing wildlife habitat quality and quantity. Aquatic macrophyte vegetation in the Cartier Bay wetland appears to be both compositionally and quantitively like that which existed in the bay prior to 2016 (the year that physical works were implemented). Abiotic water indices (e.g., turbidity, DO, pH, and conductivity) also fell within the general range of variability recorded during the 2011-2013 baseline monitoring period. However, because the post-works data time series is at present limited to a single year, it is too early in the monitoring process to test for significance in any trends, or to attempt any direct, statistical pre- and post-works comparisons. These analyses will be deferred until the final summary report (scheduled for 2020).

6.3 Recommendations

To improve the study moving forward, we make the following recommendations for the remaining implementation years:

1. Vegetation and water sampling at Cartier Bay should be completed in the spring just before the Columbia River breaches the Site 15A dike. In 2018, sampling commenced around the same date that river water began to inundate the west compartment. This did not materially impact aquatic vegetation sampling, but it did preclude sampling riparian and emergent vegetation at the riparian interface with the permanent wetland. It also prevented mapping of the wetland perimeter. This vegetation zone is the one most likely to be affected by subtle changes in wetland extent due to changing permanent water levels, thus best efforts should be made to monitor for significant changes here. The challenge with timing lies in balancing the need to allow enough growing time in May for maximum vegetation development and ensuring that sampling occurs prior to inundation (the exact date of which fluctuates from year to year).

2. Due to the high natural annual variability in macrophyte distribution and abundance, only very large project-related effects are likely to be detected within the given monitoring time frame. No such large impact has yet been observed, nor is one predicted based on initial observations. An alternative approach is to monitor for any notable changes in the extent of the permanent wetland area itself. Monitoring for changes in wetland aerial extent could provide a less environmentally sensitive (more stable) complement to monitoring for lower-level habitat responses. One way to accomplish this would be by using available time series of aerial orthoimages (the most current available imagery is from 2019) to visually compare wetland extents pre- and post-physical works.

3. Continue erosion monitoring at WPW-6A following the methods described in this report. This includes visual assessment, survey measurements, and image interpretation. We recommend particular attention be paid to the undercut bank at the mouth of the east erosion channel as well as expanding the surveys to include the main erosion channel. We also recommend using a drone to capture

higher resolution imagery at WPW-6A as higher resolution images will improve the accuracy in delineating the channel banks and in calculating annual rates of erosion.

4. Continue erosion monitoring of WPW 15A including visual assessments of the riprap and riprap-dyke interface, and survey measurements of the swale for monitoring changes in swale depth.

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8.0 APPENDIX

8.1 Vegetation Indicators of Habitat Condition in Revelstoke Reach Wetlands

Several wetland plants occurring in Cartier Bay and/or Airport Marsh provide positive or negative benefits for wildlife and can be viewed as indicators of habitat condition to some degree. These include **floating-leaved pondweed** (8.1.1), **Richardson's** and **eel-grass pondweeds** (8.1.2), **common hornwort** (8.1.3), **water smartweed** (8.1.4), **Rocky Mountain pond-lily** (8.1.5), **greater bladderwort** (8.1.6), and **Eurasian water-milfoil** (8.1.7).

8.1.1 Floating-leaved Pondweed (*Potamogeton natans*)

Positive or negative indicator. Floating-leaved pondweed communities occur in quiet waters on peat sediment in oligotrophic and mesotrophic lakes and can often be found in deeper waters adjacent to pond-lily communities. This species forms a dense canopy and the understory is frequently sparse. Bladderworts and milfoils are common associates (Mackenzie and Moran 2004). It can be an important component of acidic ponds with organic substrates where few other species grow (Warrington 1983).

Floating-leaved pondweed sometimes forms dense beds of floating leaves and tough stems from a depth of at least 4 m, but it also grows in shallow areas and occasionally becomes stranded on wet mud. There is considerable open water under a patch of floating-leaved pondweed that affords shelter to aquatic organisms.

Floating-leaved pondweed is sometimes an important food for ducks, which browse on the rootstocks and, later in the season, on the nutlets. *Potamogeton* species in general are a favourite food of waterfowl, with some eating whole plants and others preferring certain parts of the plant (especially the nutlets/seeds). They are staple food for ducks, which utilize all species. They are also attractive to marsh birds and shorebirds, and are often heavily browsed by muskrats, beaver, deer, and moose. They provide food, shelter, and shade for fish and small animals and are a haven for insects, which in turn provide food for fish populations. Some species have been found to soften the water by removing lime and carbon dioxide and depositing marl (Warrington 1983).

8.1.2 Richardson's and Eel-grass Pondweeds (*Potamogeton richardsonii*, *P. zosteriformis*)

Positive or negative indicator. Unlike floating-leaved pondweed, these species are typically fully submergent, although plants may reach the surface from 4-5 m depth. Richardson's pondweed grows in relatively deep, less nutrient-rich waters, often on mineral sediments with some water movement, whereas eel-grass pondweed tends to occur in shallower and more nutrient-rich water. In places, these species can form the understory to canopies of floating-leaved pondweed (Mackenzie and Moran 2004). Both species provide browse for ducks (Warrington 1983).

8.1.3 Common Hornwort (*Ceratophyllum demersum*)

Positive or negative indicator. The submergent common hornwort thrives in eutrophic conditions, surviving in water up to 5 m deep. An obligate hydrophyte, it cannot survive even brief drying in air, although it tolerates fluctuating water levels and turbidity very well. The plants have no roots and, instead, develop modified leaves with a rootlike appearance to anchor the plant to the bottom or to other objects in the water. Early in the season, plants are mostly erect with the lower part anchored; later most are in floating mats at the surface.

Caddisfly larvae utilize hornwort leaves and waterfowl eat the fruits. The plants provide shelter for young fish, crustaceans, and other small animals, and support insects valuable as fish food. Mostly the seeds, but sometimes the foliage, are an important food for waterfowl and, occasionally, muskrats. Hornwort can sometimes crowd out other plants (Warrington 1983).

8.1.4 Water Smartweed (*Persicaria amphibia*)

Positive or negative indicator. Water Smartweed communities occur in larger lakes in 0.5-1.5 m deep water on sandy substrates where currents limit accumulation of organic matter and fines. Plants can form a dense floating cover associated with scattered floating-leaved pondweed and overtopping submerged species such as Eurasian watermilfoil (Mackenzie and Moran 2004). This species can grow in a truly aquatic fashion in deep water but also has marginal or terrestrial forms. In areas with highly fluctuating water levels, it tends to form floating mats (Warrington 1983).

This and related species produce nutlets, which are the only part commonly eaten; however, these nutlets can be important food for waterfowl, upland game birds, shorebirds, and songbirds. Seed production is copious and waterfowl often congregate in areas where multiple species are found (Warrington 1983).

8.1.5 Rocky Mountain Pond-lily (*Nuphar polysepala*)

Positive or negative indicator. There are several shallow-water wetland types classified with *Nuphar lutea* (a formerly used name for *N. polysepala*) as a dominant component (Mackenzie and Moran 2004). These pond-lilys occur in a wide variety of aquatic sites, ranging from deep (5 m) lakes with gravel substrates to shallow acidic pools with peat substrates (Mackenzie and Moran 2004). The substrate is often an organic ooze that is anaerobic for at least part of the year; rhizomes survive by utilizing anaerobic respiration and accumulating ethanol until free oxygen again becomes available. Optimum oxygen levels are low (around 2 ppm), with higher levels detrimental to growth. Dense colonies will cover virtually the entire surface of the water and shade out other species. Dense colonies can form and restrict water flow at 1 to 2 m depth, contributing to the oxygen deficit of the sediments and encourage silting in outlet channels of lakes (Warrington 1983). The extensive leaf litter produced by a Rocky Mountain Pond-lily bed contributes to the organic and anaerobic conditions of the sediments (Warrington 1983).

Deer graze on the leaves and petioles in shallow water, ducks eat the seeds (which are produced in generous amounts), and muskrats and beavers browse on the rhizomes. Some larval insects have been found to feed on *Nuphar* leaves but seem to do so only late in the season when the leaves are beginning to die (Warrington 1983).

8.1.6 Greater Bladderwort (*Utricularia macrorhiza*)

Positive or negative indicator. Greater Bladderwort is a widespread and successful species found in many shallow aquatic habitats. It often grows in close association with Rocky

Mountain pond-lily; the latter forms an open canopy with greater bladderwort in the understorey. This widespread shallow-water wetland ecosystem type (Mackenzie and Moran 2004) occurs in dystrophic and oligotrophic waters 20-200 cm deep, especially on guano-based and peat sediments. These sites are typically relatively species-poor (Mackenzie and Moran 2004). Within the study area it occurs primarily in Airport Marsh, where it is largely restricted to the protected waters within emergent colonies of cattail and bulrush.

Free-floating mats of greater bladderwort can become entangled in other rooted aquatic plants and impede water flow in irrigation and drainage ditches. The species is carnivorous and utilizes small crustaceans and other minute aquatic animals that it traps in bladders on the leaves. It is not believed to be an important food source for wildlife, although it can provide food and cover for fish and the mats provide breeding areas for mosquitoes (Warrington 1983).

8.1.7 Eurasian Water-milfoil (*Myriophyllum spicatum*)

Negative indicator. The non-native Eurasian water-milfoil generally grows in fresh water but can tolerate salinity up to 10 ppm. It can take on a dwarfed semiterrestrial form when stranded along receding shorelines. The species can reach the surface when rooted as much as 5 m underwater. Birds eat the seeds and, to a limited extent, the vegetation. Snails graze on the plants and caddisfly larvae build cases from the leaves. The plants provide shelter for fish and invertebrates. High population densities can supersaturate the water with oxygen in daylight and deplete the levels to almost zero at night. These fluctuations are detrimental to fish populations. In the fall, large beds can die off and cause significant oxygen deficits that are detrimental to fish and produce large masses of rotting vegetation on shorelines (Warrington 1983).

Given the potential of Eurasian water-milfoil to exert a detrimental effect on wetland health, eradication/control was investigated as a potential component of wetland creation or restoration in Revelstoke Reach. A variety of options for control or eradication of Eurasian water-milfoil have been identified (e.g. Washington State Department of Ecology 2010), but these have variable applicability to the conditions at Cartier Bay. The options range from manual pulling and harvesting to the application of chemical treatments and herbicides (e.g., Fluridone). Manual removal treatments have shown poor success rates elsewhere. Although Fluridone application has shown some success in eliminating Eurasian water-milfoil from lakes in Washington State, its effects on wildlife and other species are either marginally detrimental or unknown. Of particular concern to this study, there are no data on the ability of amphibians, which are notoriously sensitive to water chemistry, to withstand its application. Cartier Bay is one of the most significant breeding sites for Western Toad in Revelstoke Reach (see Hawkes et al. 2015a). As Western Toad is a federal species of Special Concern and the driving force behind much of the restoration activities planned for the area, it was deemed inappropriate to administer such an untested chemical due to the potential for catastrophic effects on this population. Indeed, it is possible that the success of the breeding toad population may be related to the abundance of cover provided to the eggs and developing tadpoles by the dense stands of water-milfoil, and their removal may render amphibians more susceptible to predation by fish and birds.

8.2 Field Data Form used for WPS-15A Wetland Monitoring

Below is a sample data form used for post-works (2018) sampling of aquatic conditions at Cartier Bay.

DATE: ______-______-______ (dd-mmm-yy) **TIME:** ____:____ **SITE:** ______________ **COMMUNITY TYPE:** Submergent ☐ Floating ☐ Emergent ☐ Riparian ☐

SURVEYORS: _______________ **PLOT NUMBER:** _______________ **UTM:** 11U E _______________ N _______________ **VEGETATION PRESENT?** Y ☐ N ☐

SAMPLING COMPLETED: Rake drag (rel. abundance) ☐ Surface quadrat (cover) ☐ Terrestrial plot (cover) ☐ VCT_______________

WATER DEPTH (cm): _______ **SECCHI DEPTH:** _______ **WATER TEMP:** _______ **DO:** _______ **CONDUCTIVITY:** _______ **PH:** _______ **PHOTOS:** _______________

STRUCTURAL STAGE†: _____________ SLOPE__________ ASPECT__________ SOIL MOISTURE†:_____________ GEN. SURF. TOPOG†: _______________

SURFACE SUBSTRATE (%): ROCK (>7.5 CM) ______ MINERAL (<7.5 CM)_______ ORG.________ WOOD_______ WATER________

MICROTOPOG†: _______________ ROOTING ZONE TEXTURE – COARSE FRAG†:_________ ROOTING ZONE TEXTURE – FINE†:_______________________

PRIM. WATER SOURCE†:_____________________ DISTURBANCE†:_____________________________________ PHOTOS:___________________

Aquatic Point Samples					Riparian Plots			
Sample #	* Vol.	Species	**Rel. Ab.	%Cover	Species	%Cover	Layer	Notes

***Sample Vol.**

1 Trace
2 Small
3 Large

****Relative Abundance in Sample**

T Trace
1 <10%
2 10-20%
3 20-50%
4 50-75%
5 75-100%

†Use key in CLBMON-12 (2017) data form for this field