Columbia River Project Water Use Plan

Arrow Lakes Reservoir Wildlife Management Plan

Arrow Lakes Reservoir: Implementation of Wildlife Physical Works

Implementation Year 2

Reference: CLBWORKS-30

Ecological Impact Assessment – Wildlife Physical Works Projects 14 & 15A

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Westbank, BC
and
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BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

CLBWORKS-30 Ecological Impact Assessment – Wildlife
Physical Works Project 14 & 15A

Prepared for

BC Hydro Generation
Water Licence Requirements
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Burnaby, BC

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Cover photos

From left to right: Cartier Bay in spring 2014, low lying land between sites 14 and 15A, Cartier Bay in August 2014, and Cartier Bay as seen in fall 2012. Photos courtesy of Alan Peatt, and Harry van Oort.

Executive Summary

This is a scientific review of the best available information on the hydrology, physical geography, ecology, flora, and fauna of Cartier Bay as it relates to the potential ecological benefits and risks of proposed physical works (called Site 14 and Site 15A) to raise the bay's water level and change its time of flooding. Guiding this review were experts in wetland ecology, water resources, plant ecology, and bird, reptile and amphibian biology, with additional valuable insights from local stakeholders.

The consensus is that there is a high degree of uncertainty regarding the ecological outcomes of the proposed works. Notwithstanding these uncertainties, the further consensus is that the Site 15A project appears to incur a high level of ecological risk relative to expected benefits and thus its implementation is not currently justified on scientific grounds. In contrast, the ecological risks associated with the Site 14 project appear to be relatively modest.

Summary of current habitat suitability* and predicted changes to habitat suitability with implementation of physical works at Sites 14 and 15A:

Flora and Fauna Summary	Site 14		Site 15A	
Component	**Current state**	With works	**Current state**	With works
Terrestrial vegetation	Low diversity	🟨 ⇔	Intermediate diversity	🟨 ⇔ or ⇩ 🟥
Aquatic macrophytes	Intermediate diversity	🟨 ⇔ or ⇩	Intermediate diversity	🟨 ⇔ or ⇩ 🟥
Waterfowl	Little to no use	🟨 ⇔ or ⇧ 🟩	High use	🟨 ⇔
Songbirds	Little to no use	🟨 ⇔ or ⇧ 🟩	High use	🟨 ⇔ or ⇩ 🟥
Amphibians (Western Toad)	Little to no use	🟨 ⇔ or ⇧ 🟩	Important habitat	🟨 ⇔ or ⇩ 🟥
Reptiles (Western Painted Turtle)	Little to no use	🟨 ⇔	Little use	🟨 ⇔
Aquatic Invertebrates	No Data	🟨 ?	Intermediate diversity	🟨 ?

Green triangle: consider proceeding; Yellow Triangle: reassess or do not proceed; red triangle: do not proceed with physical works. Arrows indicate direction of predicted change in habitat suitability (increase, decrease, or no effect).

* Habitat suitability is the capacity for a given habitat to support a selected species in its current state.

The current state of each assessed component at Site 14 ranges from no data available (Aquatic Invertebrates) to intermediate diversity (Aquatic Macrophytes[1]). Currently available habitat at Site 14 is of little to no use for all other assessed components. On the basis of available information, implementing the proposed physical works at Site 14 is predicted to result in habitat suitability remaining:

- unchanged for Terrestrial Vegetation and Western Painted Turtle;
- unchanged or possibly increasing for Waterfowl, Songbirds, and Western Toad; and
- unknown for Aquatic Invertebrates until more data are collected.

The current state of each assessed component at Site 15A ranges from intermediate diversity (Aquatic Invertebrates, Terrestrial Vegetation and Aquatic Macrophytes) to high use (Waterfowl and Songbirds). Both Waterfowl and Songbirds use the Site 15A wetlands to a high degree relative to other areas in Revelstoke Reach. The Site 15A wetlands also provide important habitat for Western Toad. Western Painted Turtles do not regularly use the Site 15A wetlands. On the basis of available information, implementing the physical works at Site 15A is predicted to have:

- likely negative effect on habitat suitability for Terrestrial Vegetation, Aquatic Macrophytes, Songbirds, and Western Toad;
- uncertain effect on habitat suitability for Waterfowl and Western Painted Turtle;
- an unknown effect on habitat suitability for Aquatic Macrophytes.

We recommend that the current condition of the Site 15A wetland be maintained, which aligns with the primary objective of the proposed physical works to maintain current wildlife habitat suitability in Cartier Bay. Maintaining the current condition of the wetland may require some work at Site 15A to stabilize its current elevation. We do not support completion of the more involved physical works for Site 15A as proposed by Golder (2009b).

If BC Hydro is interested in assessing the ecological impacts of physical works in the form of an in situ experiment, proceeding with works at Site 14 in a modified manner would accomplish this objective. The wetland habitat associated with Site 14 is not as important to the plants and wildlife of Cartier Bay as the area impounded by Site 15A. Manipulating the Site 14 area could provide an opportunity to investigate how wetland plants and wildlife respond to raised water levels and increased wetted area in the drawdown zone of the Arrow Lakes Reservoir. If this approach is taken, additional water budget data will be required to ensure an accurate assessment of the total area that would be flooded, and of the capacity of the newly impounded area to sustain the targeted water levels over the long term.

Implementing the originally proposed physical works at Sites 14 and 15A is not certain to result in a net ecological benefit to Cartier Bay. However, other physical works such as creation of shallow ponds and ditches would increase habitat diversity and have a high probability of improving the overall suitability of Cartier Bay for a variety of wetland plants and wildlife.

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[1] Aquatic macrophytes are all aquatic plants large enough to be visible to the eye without a magnifying lens.

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1 Introduction

In 1968, the Hugh Keenleyside Dam impounded the Columbia River near Castlegar creating the Arrow Lakes Reservoir (ALR). Operation of this reservoir results in seasonal inundation of grassland, riparian, and wetland habitats within the drawdown zone (DDZ). Habitats within the DDZ are utilized by many species of birds, mammals, reptiles and amphibians, and by humans for recreational enjoyment and other pursuits.

To help mitigate the impact of the ALR on wildlife and wildlife habitat, the BC Water Comptroller requires BC Hydro to undertake “physical works” to improve wetland and wildlife habitats within the DDZ (in lieu of making operational changes under the Columbia Water Use Plan). BC Hydro investigated 44 sites on the Arrow Lakes Reservoir in a Wildlife Physical Works feasibility study (Golder 2009a). Three sites were selected for enhancement including creation of additional wetlands at two shoreline sites, 14 and 15A, located east of the main channel of the Columbia River in Cartier Bay. Cartier Bay is within Revelstoke Reach, a 40 km long section of the Columbia River flowing north to south from Revelstoke Dam to the historical town site of Arrowhead on Upper Arrow Lake. Cartier Bay currently contains significant wetland wildlife habitat seasonally valuable to waterfowl, shorebirds, amphibians and other wildlife and wetland organisms.

The proposed project at Site 14 involves filling in a breach in a former railway grade to permanently retain water behind the grade as a way of creating wetland value. The project at Site 15A involves removal of a collapsed wooden box culvert and the raising of the same rail grade by almost one meter to (i) delay inundation from the ALR as reservoir elevations rise in the spring; and (ii) retain additional water behind the grade (or dike) as reservoir elevations decline in the fall.

Wildlife experts familiar with the area generally consider Cartier Bay to be currently providing some of the best wetland habitat in Revelstoke Reach. Although the two physical works projects were designed with intent to benefit amphibians, waterfowl and other water birds no scientific support was provided to give confidence to this outcome. Concerns exist regarding the projects’ net ecological effect. Concerns include:

1. Whether adding water to Cartier Bay will diminish its habitat value to ducks and geese;
2. Whether the utility to wildlife of current shoreline physical and biological attributes would be lost, and whether it would take an extended time, if ever, to develop similar attributes at higher elevation;
3. Whether further flooding of about 26 hectares of dense Reed Canarygrass would lead to its death and decomposition, potentially increasing biochemical oxygen demand in the area to an undesirable extent for a long time;
4. Whether the timing of winter ice formation and thawing might be altered, potentially diminishing the area’s current suitability to support such species as Western Toad; and
5. Whether there would be an overall net loss of area and/or function of habitat types that some wildlife species currently utilize at Cartier Bay.

Local residents and naturalists have also expressed their concerns regarding the ecological impact of increasing water levels in Cartier Bay by ~1 m. For example, local resident observations indicate that the Cartier Marsh shallows are the first wetland habitats in the Revelstoke area to become ice-free in the spring—by as much as three weeks prior to other valuable local wetlands (Maltby, unpubl. rpt., 2014). Some believe that Cartier Marsh is ice free early because the water is shallow; there are substantive ground- and surface-water inputs; the ice is not as thick as ice elsewhere; and as the sun heats the substrate the thinner ice melts first. The proposed physical works at Cartier Bay are intended to deepen water at this location. There is a concern that deeper water will cause ice break up to occur later in the spring, negatively affecting habitat availability for waterbirds, Great Blue Heron (*Ardea Herodias Herodias*) and other aquatic species including Western Toad (*Anaxyrus boreas*, Maltby, pers. comm.).

In response to these concerns, and following further consultations with scientists and residents familiar with the area, BC Hydro requested that an Ecological Impact Assessment be conducted consisting of a desktop synthesis, assessment, and analysis of the best currently available data and expertise relevant to evaluating the short and long term ecological implications of raising the water level in the Cartier Bay impoundment from 433.8 m to 434.75 m. This document is the outcome of that assessment. It is intended to (a) address the concerns above to the extent that existing data allow; (b) identify and describe the magnitude of remaining uncertainties and potential risks; and (c) integrate existing data and expertise from multiple disciplines to provide an overall assessment of the potential ecological risks and benefits of proceeding with this project.

This review provides a multi-disciplinary expert assessment of whether, on balance, the two physical works projects proposed at Cartier Bay are likely to have a net positive ecological effect on the hydrology, physiography, ecology, flora, and fauna of Cartier Bay. BC Hydro will use this review to inform a scientifically sound decision about whether the potential benefits of the projects will outweigh the associated ecological risks and uncertainties.

2 Objectives

This study synthesizes and assesses the best available data and expert opinion relevant to evaluating the short- (<10 years) and long-term (>10 years) ecological implications of raising winter and spring water levels in the impoundable area of Cartier Bay by almost one meter. A brief, multi-disciplinary expert assessment will be provided to meet the following objectives:

- Determine whether, on balance, the Site 14 and Site 15A projects will have a net positive ecological impact on wildlife habitat at Cartier Bay;
- Address the identified concerns to the extent that existing data will allow;
- Identify and describe the magnitude of remaining uncertainties and identifiable risks;
- Provide an overall assessment of the potential ecological risks and benefits of implementing the Site 14 and Site 15A projects as planned;
- Present suggestions, preferred options or recommendations as appropriate; and
- Be written in clear, concise language appropriate to a reasonably informed public audience.

3 Methods

For this study, we reviewed and synthesized pertinent information on Cartier Bay including:

a) data previously collected and expertise previously developed through other BC Hydro projects such as:

CLBMON-11B2: Wildlife Effectiveness Monitoring of Revegetation and Wildlife Physical Works on Spring Migrants in Revelstoke Reach

CLBMON-11B3: Wildlife Effectiveness Monitoring of Western Painted Turtles in Revelstoke Reach

CLBMON-11B4: Wetland Effectiveness Monitoring for Wildlife Physical Works

CLBMON-12: Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

CLBMON-33: Arrow Lakes Reservoir Inventory of Vegetation Resources

CLBMON-36: Kinbasket and Arrow Lakes Reservoirs: Nest Mortality of Migratory Birds Due to Reservoir Operations.

CLBMON-37: Arrow Lakes Reservoir: Amphibian and Reptile Life History and Habitat Use Assessment

CLBMON-39: Arrow Lakes Reservoir: Neotropical Migrant Use of the DDZ

CLBMON-49: Lower Columbia River Effects on Wintering Great Blue Herons

CLBWORKS-29A: Arrow Lakes Reservoir: Wildlife Physical Works Feasibility Study

CLBWORKS-30: Arrow Lakes Reservoir: Implementation of Wildlife Physical Works

CLBWORKS-2: Mid-Columbia and Arrow Lakes Reservoir Revegetation

b) external and internal expertise and published or technical literature including agency and other authorities, local naturalists or concerned citizens, a Syilx knowledge keeper, and academics.

We focused, as appropriate, on terrestrial and aquatic plant communities, birds, and herpetofauna (amphibians and reptiles), as well as plant and animal species at risk (BC red/blue or COSEWIC-listed), other species of local or regional significance, and certain invasive species such as Eurasian Water-milfoil and Reed Canarygrass. We Identified ecologically meaningful performance measures underpinning predictions about future ecological condition, similar to that used previously in CLBMON 11B4 (Miller and Hawkes 2014).

A hydrological assessment of Cartier Bay was also conducted, in which we reviewed the current status of hydrological data and identified the numerous knowledge gaps relating to hydrology that are impeding accurate predictions around the frequency, duration, and magnitude of wetland inundation following implementation of the proposed physical works.

4 STUDY AREA

4.1 Arrow Lakes Reservoir

the ALR is a ~230 km long section of the Columbia River drainage between Revelstoke and Castlegar, B.C. It has a north-south orientation and is set in the valley between the Monashee Mountains to the west and the Selkirk Range to the east (see Appendix 10-1 for descriptions of regional physiography, climate, and biogeoclimatic zones). The Hugh Keenleyside Dam, located 8 km west of Castlegar, spans the Columbia River and impounds the ALR. The ALR has a licensed storage volume of 7.1 million acre-feet (MAF; BC Hydro 2007), and the normal operating range of the reservoir is between 440.1 m and 418.64 m ASL (Figure 4-1).

Cartier Bay is situated within Revelstoke Reach at the north end of the ALR (Figure 4-2). Revelstoke Reach contains several large wetland complexes, large open sedge/grass habitats and several willow-shrub complexes. The combination of elevation, limited topographical relief, and undulating terrain has contributed to the development of important bird, reptile and amphibian habitats within the seasonally inundated drawdown zone (DDZ) of the ALR, particularly in Montana Slough and Cartier Bay.

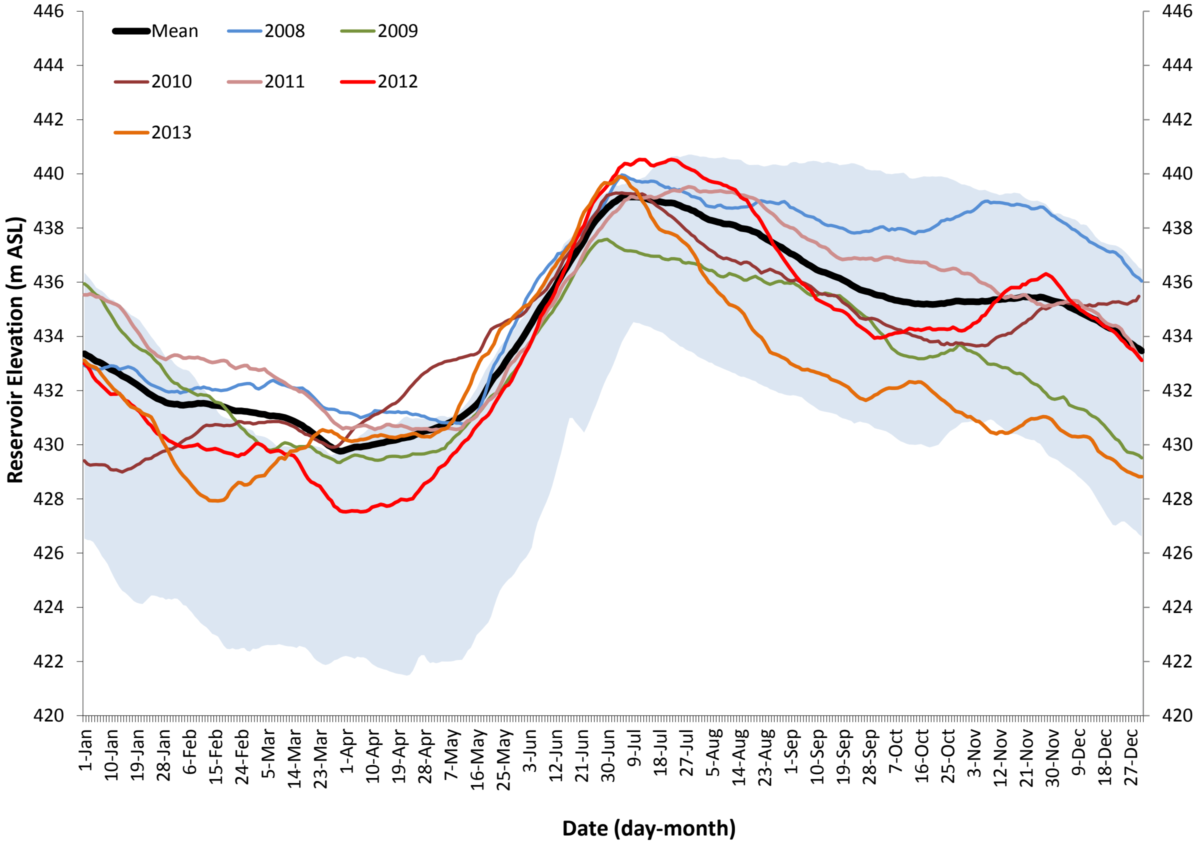


Figure 4-1: Arrow Lakes Reservoir hydrograph for the period 2008 through 2013. The shaded area represents the 10th and 90th percentile for the period 1969 to 2013

Figure 4-2: Location of Cartier Bay in Revelstoke Reach, Arrow Lakes Reservoir

4.2 Cartier Bay

Positioned approximately 6 m below the full pool elevation of the ALR (440.1 m ASL), and submerged for more than half the year, the Cartier Bay wetland (Figure 4-3) has a highly modified ecology. The wetland is devoid of emergent vegetation, and only a minor amount of willow shrub grows on the elevated ridge (436 m ASL) separating the main pond from the low mud draws to the northwest. The outer (southeast) banks of the pond are steep, and characterized by course materials (boulders, gravels) or sand, with intermittent growth of Reed Canarygrass. The inner shorelines have gentle slopes made of clay, soil, and sand, and are vegetated extensively by a low layer of sedge and grass. Like other habitats positioned at a similar elevation in the reservoir DDZ (~434 m ASL), the Cartier Bay wetland has a highly reduced vegetation assemblage. But despite reservoir impacts, this wetland still sustains considerable ecological function.

Within the ALR, Cartier Bay is likely the most important ecological asset within the 433 to 435 m elevation band, and is known to be the single most important stopover site for migrating dabbling and diving ducks in Revelstoke Reach. The main pond has two compartments (east and west) and within these there can be considerable growth of submergent vegetation, including introduced milfoil. The shallow ponded area on the eastern compartment of the wetland is a key breeding area for the SARA listed Western Toad. Other species of amphibians and reptiles have been recorded using the wetland including the Long-toed Salamander, Columbia Spotted Frog, Pacific Chorus Frog and the Western Painted Turtle. The pond is a favoured foraging habitat for Great Blue Herons, Osprey and for a variety of Shorebirds during their migration.

The utilization of Cartier Bay is highly seasonal. Migrating water fowl quickly populate the wetland each spring as the ice thaws. The community of wildlife utilizing this wetland diminishes greatly as the ALR impounds this site in spring (late May or early June), only to return again as water levels diminish in the late summer or early fall. During the winter, the site remains locked in ice and covered by snow. Western Toads congregate at the site to breed in the spring (typically late April or early May), with adults spending approximately two to three weeks in the wetland before dispersing to upland summer habitats. Western Toad eggs develop into tadpoles and eventually emerge as metamorph toadlets in late July or early August, following the inundation of Cartier Bay by the ALR. Despite this inundation, the fecundity of Western Toad appears to be relatively high.

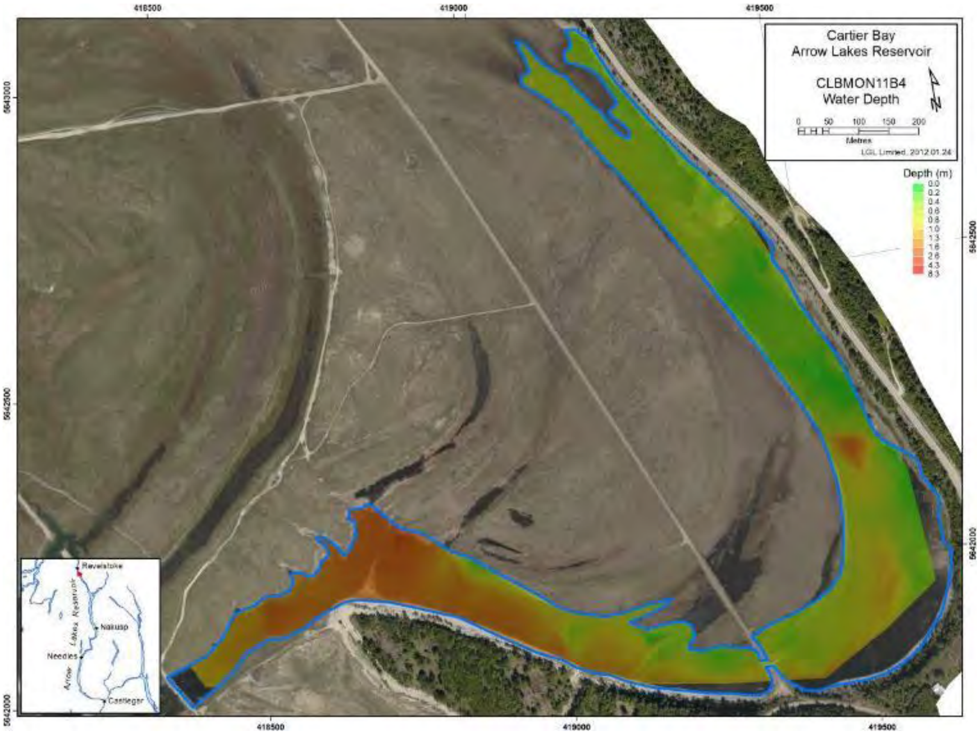


Figure 4-3: **Bathymetric map of existing Cartier Bay wetland (from Miller and Hawkes 2013)**

4.3 Proposed Physical Works – Project Descriptions

The following project descriptions were extracted from Golder Associates (2009) and Miller and Hawkes (2013).

4.3.1 Site 14: Cartier Bay

Site 14 is located eight kilometers south of Revelstoke on the east side of the reservoir. A deep gap in a former rail grade exists allowing open water drainage when the floodplain is not inundated by the reservoir (Figure 4-4). The proposed physical works are predicted to result in the creation of deep-water pond (> 1 m in depth) habitat in the collection channel adjacent to the rail grade and shallow pond habitat (< 1 m in depth) in the low lying land and shallow depressions upstream of the rail grade when not inundated by the reservoir.

Figure 4-4: **Location of the proposed physical works sites 14 and 15A relative to Cartier Bay. Image date: May 30 Reservoir Elevation: 433.79 m ASL**

The main objectives of the proposed physical works at Site 14 are:

1. Flood shallow depressions providing breeding habitat for amphibians including Western Toad, Pacific Chorus Frog (*Pseudacris regilla*), and possibly Long-toed Salamander (*Ambystoma macrodactylum*), and migratory shorebirds and waterfowl in the spring and fall during low water years. Deep pond habitat is expected to add habitat complexity to the area and provide stopover habitat for migratory diving ducks;
2. Reduce degradation caused by off-road vehicles to wetted areas upslope of the rail grade (a larger, deeper water-filled channel will restrict floodplain access east of the rail grade); and
3. Establish aquatic vegetation similar to that existing in the Cartier Bay area (Site 15A).

The proposed design at Site 14 will re-contour the existing breach in the abandoned railway grade by constructing a low maintenance hard surfaced dike with a swale to a proposed elevation of 434 m ASL, an increase of 3.2 m above the elevation of the existing breach. An existing culvert located south of the proposed dike will be removed. The new dike will occupy a footprint of approximately 3,200 $m^2$and will impound water upslope of the rail grade. Based on GPS mapping of low lying ground upstream of the proposed structure, the new dike will create approximately 3.8 ha (or more) of additional wetted habitat. Considering mean reservoir levels from 1969 to 2008, the construction will, on average, impound water from late November to approximately mid-June and will be inundated by the ALR for approximately 165 days per year through summer and fall (Golder 2009a).

4.3.2 Site 15A: Cartier Bay

Site 15A is situated about 300 m south of Site 14 (Figure 4-4). Similar to Site 14, a gap in the former rail grade allows water drainage from upslope (the east) when the floodplain is not inundated by the ALR. An ad hoc dike buried and plugged a collapsed wooden box culvert located in the gap. The result was a swale that largely controls the water elevations in two compartments of Cartier Bay (west and east of the former Arrowhead Highway; collectively called “Cartier Marsh”). Currently, Cartier Marsh is ~23.4 ha in size.

The proposed physical works at Site 15A would replace the ad hoc dike and wooden box culvert (currently at elevation ~433.8 m) with a stable, 4,500 m^2 engineered dike to eliminate the possibility of further sagging or catastrophic failure of the existing structure. In addition, the elevation of the new dike’s outlet swale would be 434.75 m, or about~ 1 m higher than current outlet. Raising the outlet would be intended to increase water storage and extent of shallow open water habitat in Cartier Marsh. An existing culvert located just north of the proposed dike would also be removed.

The proposed works at Site 15A also have three objectives:

1. Maintain existing wildlife habitat values by replacing the existing ad hoc dike with a more secure structure to ensure persistence of the pond/wetland complex;
2. Increase shallow open water habitat (<1 m deep) by raising the invert dike elevation by roughly 1 m; and
3. Increase water storage capacity of the compartment to maintain water during dry years, when reservoir levels remain low through the summer. Additional water storage will also facilitate flooding of the potential impoundment area of Site 14, particularly if Site 14 and 15A are in fact connected by a small depression between the two areas as available digital elevation data appears to indicate.

Golder (2009b) estimated that the depth of the water in the west compartment of Cartier Marsh would increase by 1 m resulting in a doubling of the total area of the existing wetted area in Cartier Marsh to ~ 51 ha. Golder anticipated that with greater impoundment, the former rail grade might leak water initially, but that leakage would become reduced as silts and organic layers build up.

Based on historical patterns, in an “average” year wetland habitat in Cartier Marsh would be available (i.e., not inundated by ALR) between late November to approximately mid-June and inundated the remainder of the year, or ~ 156 days (based on averages calculated between 1969 and 2008) However, there is considerable variation around these dates from year to year (Golder 2009a).

Figure 4-5. Current photos of Site 14 (left) and 15A (right), Cartier Marsh box culvert and swale outlet (September 8, 2014, reservoir elevation 433.62 m ASL)

5 Results and Discussion

5.1 Analysis 1: Post-works Habitat Availability

The physical works projects proposed for sites 14 and 15A are predicted to approximately double the total wetted area (Golder 2009b). For this assessment, we analysed a time series of aerial photos dating from the 1960s to the present to examine how the Cartier Bay wetland has changed over time, as well as to compare early and late season inundation regimes. In this time span, the size of Cartier Bay wetland has varied considerably (Figure 5-1, Figure 5-2, Figure 5-3) and its current area (pre-physical works) is about twice now than it was in 1968 (which represents the pre-impoundment condition). Comparing spring levels for Cartier Bay in 2012 (when reservoir elevation was 433.27 m and thus not affecting the bay) and late August levels in 2014 (when reservoir elevation had receded to 434.32 m, or ~0.5 m higher than the current rail grade, but almost 0.5 m less than the proposed invert swale elevation of 434.75 m) provides a conservative approximation of the change in inundated area that would result should the physical works be implemented. In spring 2012, the inundated area of Cartier Bay was 29 ha, compared to 59 ha in late summer 2014 (Figure 5-2, Figure 5-3), suggesting that the total wetland area should at least double (with a larger increase quite possible) following the completion of the physical works.

Furthermore, the August 2014 imagery of Cartier Bay (Figure 5-3) was obtained when reservoir elevation was 434.32 m, or close to the 434 m target elevation of the invert swale at Site 14 (Golder 2009b). Examination of this image shows a wetted area that is considerably larger than the delineated projections of Golder (2009b) for Site 14. A new impoundment here could potentially extend beyond the two main channels identified in the original feasibility study (Golder 2009b). This assumes that the rail bed is impermeable, that there isn't excessive loss to groundwater seepage, and that inputs from rain and snow and groundwater are constant over time. As with the variation in the size of Cartier Bay observed over time, we suspect that the total potential wetland area resulting from the physical works at sites 14 and 15A will vary from year to year.

We also compared habitat availability with and without physical works by estimating the number of additional days in the spring that Cartier Bay would be protected from the ALR inundation, assuming project implementation (Section 5.3.5.2). Based on the average inundation period over the last 10 years, increasing the swale elevation to 434.75 m ASL is expected to shorten the duration of inundation by 20 days, assuming a current swale elevation of 433.8 m ASL. However, if the existing swale elevation is greater than 433.8 m ASL, as field observations of water inflow to Cartier Bay (Site 15A) suggest (V. Hawkes, pers. comm.), the effect of increasing the swale elevation on the duration of inundation is expected to be much less (i.e., 6 days based on a current swale elevation of 434.15 m ASL; see Section 5.3.5.2).

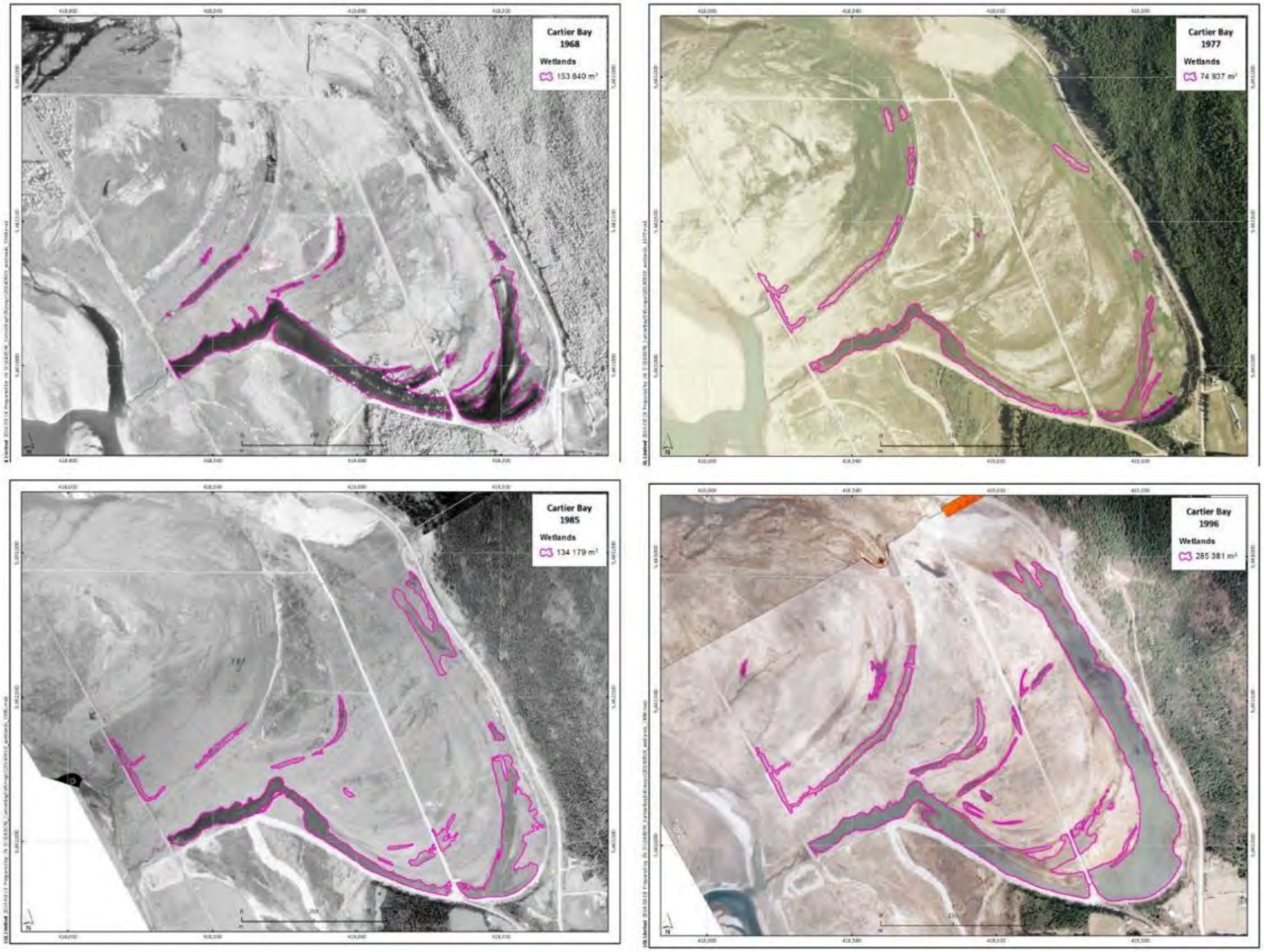


Figure 5-1: **Cartier Bay wetland delineation for 1968, 1977, 1985, and 1996.** 1968 Represents the pre-impoundment condition. Reservoir elevations in 1977 were maintained below 430 m ASL. The reservoir elevation in 1985 is unknown, but presumed to be <430 m ASL and the elevation of Arrow Lakes Reservoir was 428.68 m ASL in 1996. Total wetland area delineated in each year is shown on each figure

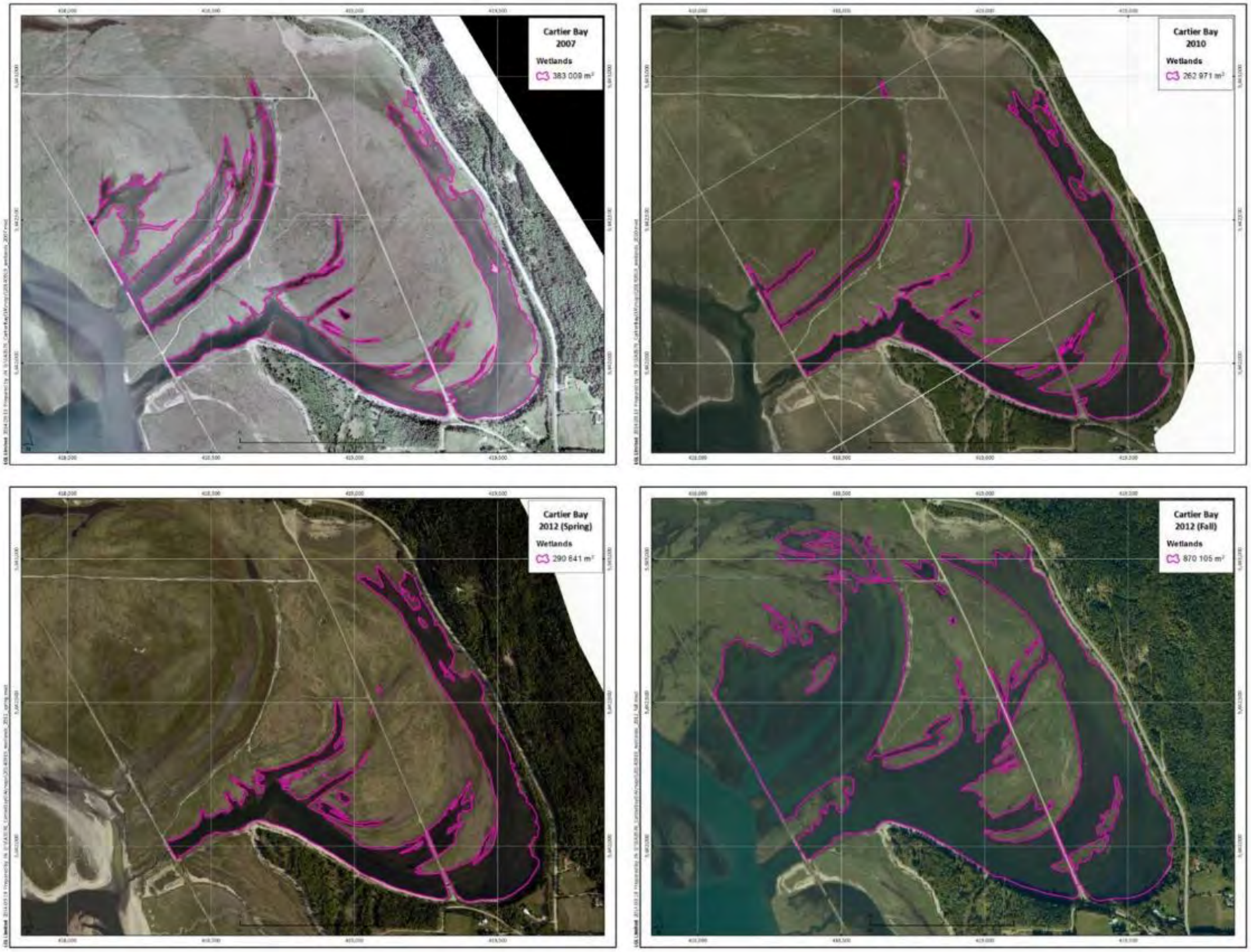


Figure 5-2: **Cartier Bay wetland delineation for 2007, 2010, 2012 (spring), and 2012 (fall).** Reservoir elevations in each year were: 2007: 434 m ASL; 2010: 433.27 m, 2012 (spring): 430.69; 2012 (fall) assumed to be > 434.75 m. Total wetland area delineated in each year is shown on each figure

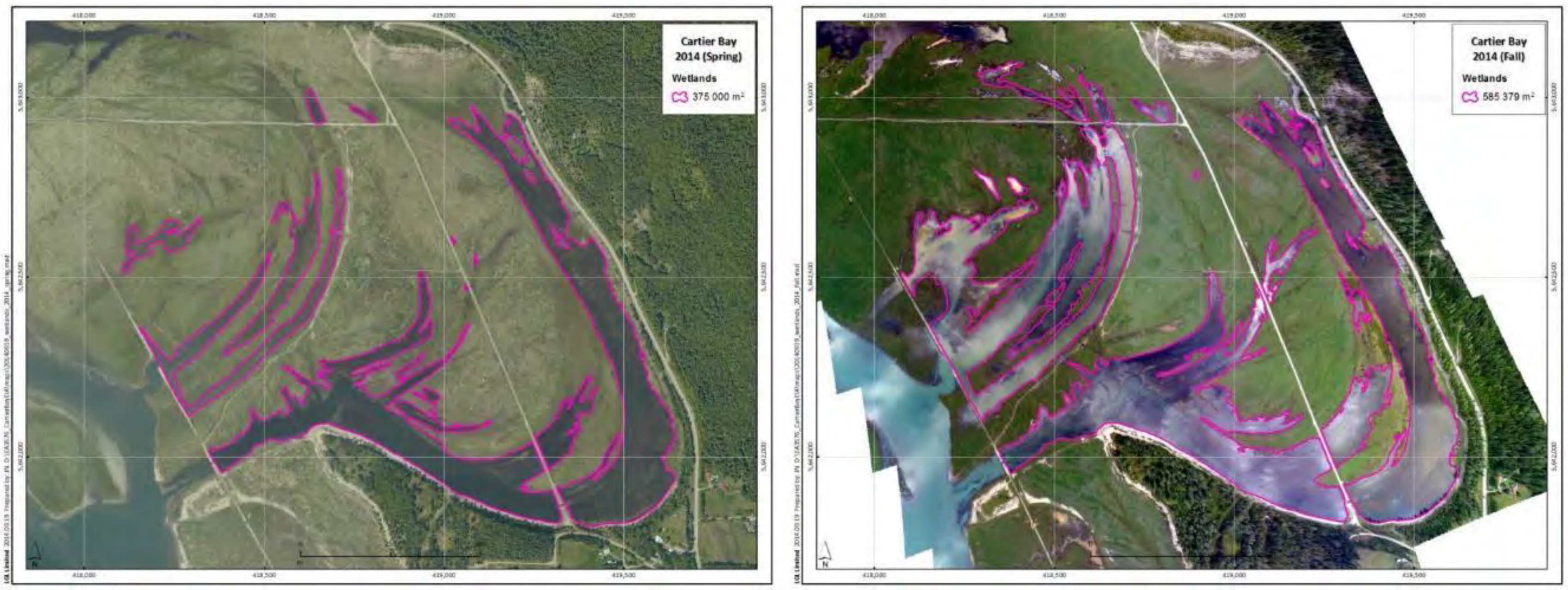


Figure 5-3: **Cartier Bay wetland delineation for 2014 (spring), and 2014 (fall). Reservoir elevations spring 2012 were 433.65 m ASL and in fall, 434.32 m ASL.** Total wetland area delineated in each year is shown on each figure

5.2 Analysis 2: Other Wetland Enhancement Projects

There has been increasing interest in creating or restoring wetland habitats in the Kootenay Region of British Columbia to restore habitat for waterfowl, wading birds, and shorebirds, and to provide habitat for less common species such as the Western Toad, Western Painted Turtle, Columbia Spotted Frog, and in some areas, grizzly bear. Creating or restoring wetlands can also help to control erosion, improve water quality, replenish groundwater, and reduce flooding (Biebighauser 2014). Most wetlands proposed for creation or restoration are upland wetlands and do not occur in the drawdown zone of a hydroelectric reservoir.

There are unique challenges and problems associated with impounding a large volume of water behind a road or rail grade not built to be a dam, which is the situation at Cartier Bay. It is possible that water will flow under the road and rail grade when the elevation of water on the upstream side is raised. It is uncertain whether either the former rail grade or the former highway at Cartier Bay were made from soil high in clay. It is important to consider that most dams are made from soil that is high in clay, and that such clay is compacted. Dams are based on an impermeable foundation that is made by digging a deep core trench. The core trench is then filled with clay that is compacted to form a groundwater dam. The groundwater dam is critical to preventing water from flowing under the dam. Dams of all sizes and elevations can fail when water flows under them, and this failure can be catastrophic (Biebighauser, pers. comm.).

Managers at Smith and Bybee Wetlands Natural Area (SBW), an 800-ha preserve in Portland, Oregon, recently installed a water control structure to suppress invasive Reed Canarygrass (*Phalaris arundinacea*) with spring and summer flooding (Jenkins et al. 2008). As far as is known, only one wetland has been built in the drawdown zone of a hydroelectric reservoir in British Columbia—at Jordan River on Vancouver Island (Hawkes and Fenneman 2010). This wetland was built to create wetland habitat, not enhance existing wetland habitat. By all accounts, the construction of new wetland habitat was successful. Elsewhere, in 2014 a log boom was installed around a wetland in Canoe Reach near Valemount, B.C. to protect the wetland from potential scour from woody debris (V. Hawkes, pers. comm.). The installation of the log boom qualifies as a form of habitat protection, which in this context refers to the formal exclusion of activities that may negatively affect the structure and/or functioning of habitats or ecosystems and does not involve habitat enhancement *per se* (Hawkes 2007, Johnson et al. 2003).

In short, while there is an extensive literature around wetland restoration projects in North America, there are few regionally relevant examples of wetland enhancement involving a similar suite of biophysical characteristics to Cartier Bay that might inform the present assessment.

5.3 Analysis 3: Hydrology of Cartier Bay

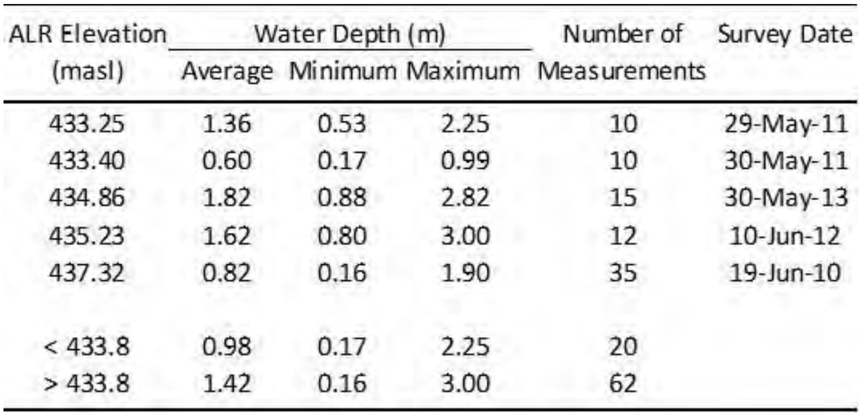
Understanding the hydrology of a wetland is critical to ensure that physical alterations to the wetland maintain or enhance the wetland biological structure and biogeochemical and ecological function (Richardson 1994, Mitsch and Gosselink 2000). The proposed physical works for Cartier Bay Site 15A, include “increasing the invert elevation of the swale of the constructed dike by 1 m” to increase the extent of shallow open water habitat behind the dike for amphibians and waterbirds, and to increase the water storage capacity in Cartier Bay (Golder 2009b). At Cartier Bay Site 14, the proposed project design is to "construct a dike with swale to close the gap in the rail grade to retain water and flood low lying ground upstream of the proposed dike" (Golder 2009b). To evaluate the potential short and long term ecological implications of raising the water elevation in Cartier Bay, the existing hydrologic conditions of Cartier Bay need to be understood.

5.3.1 Data Available and Limitations

The hydrologic data available for Cartier Bay are limited, and inadequate to fully characterize the hydrology of Cartier Bay. Golder (2009b) provides a brief description of the physical and hydrological conditions of Cartier Bay; however, water depth of the embayment was not assessed, sources of surface-water and groundwater inflows were not confirmed, surface outflow was measured on only one occasion (May 14, 2009), and the effects of direct precipitation and evapotranspiration on the water level and surface area of the bay were not discussed.

Water depths in Cartier Bay were measured during wetland surveys in 2010-2013 (Table 5-1 Figure 5-4), and during a survey on August 21, 2014, when the ALR elevation was 434.32 m ASL. Due to unknown water surface elevation during the 2011 survey and limited number of depth measurements during the 2010, 2012, and 2013 surveys, depth data from these surveys are not sufficient to accurately determine the change in storage and surface area of Cartier Bay with the bay water level. Without accurate bay bathymetry, as well as inflow and outflow data, it is difficult to predict how the water level in Cartier Bay varies after the ALR level recedes below the rail grade outlet at Site 15A. Moreover, there is uncertainty about the invert elevation of that outlet. Golder (2009b) reported the swale invert elevation to be 433.8 m ASL, but field observations of water inflow to Cartier Bay (at Site 15A) suggest that the swale elevation is higher than 433.92 m ASL, and likely 434.14 m ASL (Hawkes, pers. comm. 2014a). For this assessment, a swale invert elevation of 433.8 m ASL was assumed, to be consistent with Golder (2009b).

Table 5-1: The ALR elevations and average, minimum, and maximum water depth measured during wetland surveys from 2010-2013. Also shown are the statistics of water depth measurements collected when the ALR was less than the assumed swale elevation of 433.8 m ASL and when the ALR was greater than 433.8 m ASL



ALR Elevation (masl)	Water Depth (m)			Number of Measurements	Survey Date
	Average	Minimum	Maximum		
433.25	1.36	0.53	2.25	10	29-May-11
433.40	0.60	0.17	0.99	10	30-May-11
434.86	1.82	0.88	2.82	15	30-May-13
435.23	1.62	0.80	3.00	12	10-Jun-12
437.32	0.82	0.16	1.90	35	19-Jun-10
< 433.8	0.98	0.17	2.25	20	
> 433.8	1.42	0.16	3.00	62	

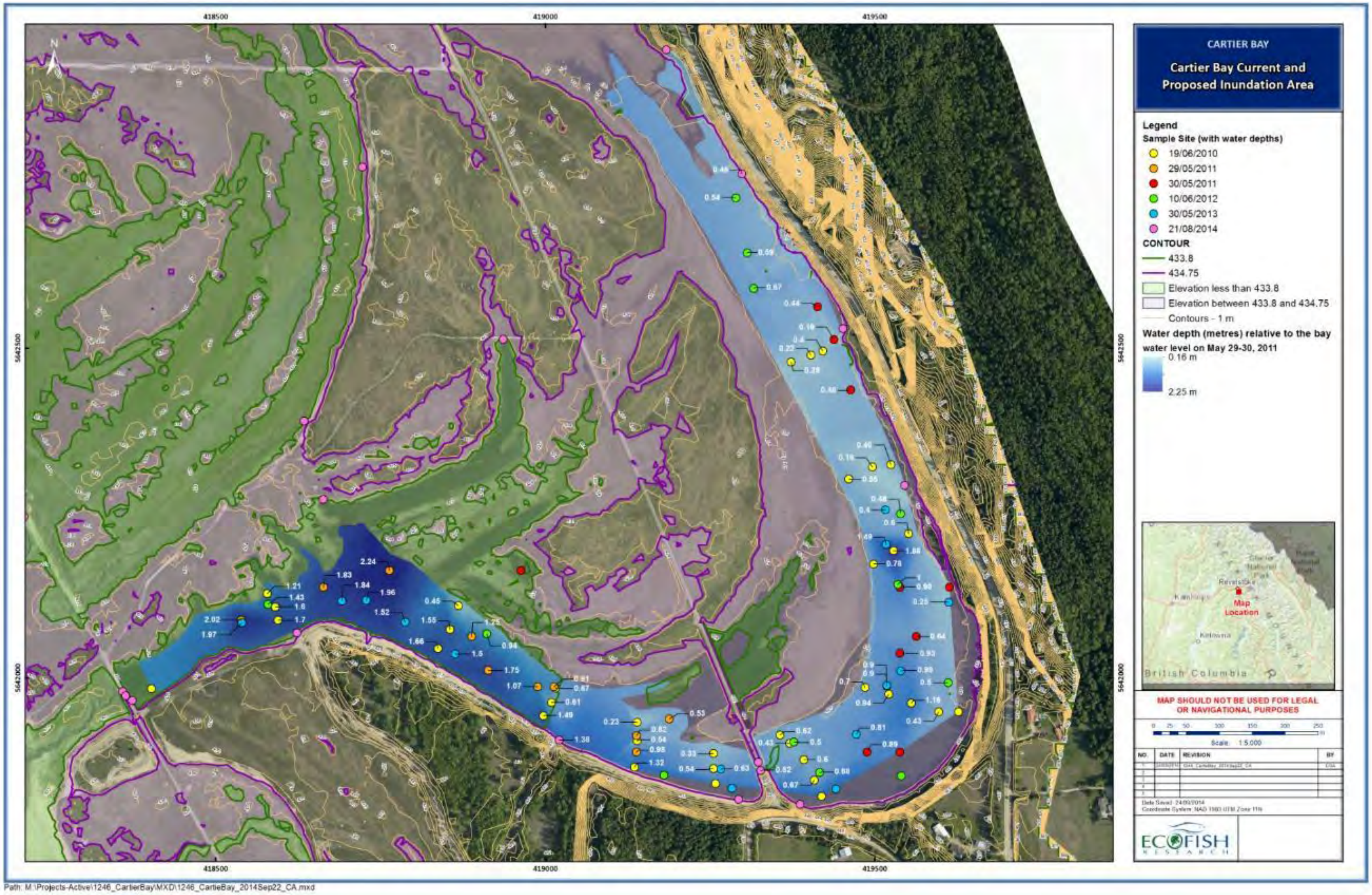


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Figure 5-4: Cartier Bay current and proposed inundated area, showing sampled water depths

5.3.2 Wetland Water Budget

A water budget is used to characterise the hydrology of wetlands and examine how changes to hydrologic conditions could potentially alter wetland structure and function. The wetland water budget determines the change in water storage in the wetland from the balance of inflows and outflows. The water budget is given by:

$$\frac{dV}{dt} = P + S_i + G_i - ET - S_o - G_o$$

where dV/dt is the change in water storage (V) per unit time (t), P is precipitation, S_i is surface-water inflow, G_i is ground-water inflow, ET is evapotranspiration, S_o is surface-water outflow, and G_o is ground-water outflow. The relative importance of each component in maintaining wetlands varies with time and geographic location, but all these components interact to create the hydrology of an individual wetland.

A water budget of Cartier Bay can be used to simulate how the bay water level varies from the time the ALR elevation drops to the swale elevation of the existing dike, to the time when the ALR level rises to the swale elevation of the existing dike. However, estimating a reasonably accurate water budget of Cartier Bay is not possible at this time due to the lack of data. There are no surface and ground water inflow data, and no groundwater outflow data. Surface outflow would have to be assumed as 0.0096 m^3/s based on the only measurement of surface outflow taken on March 14, 2009 (Golder 2009b). Further, available depth data are not sufficient to develop accurate hypsometric curves, which are needed for the water budget calculations. Moreover, continuous records of water level in Cartier Bay are not available to validate the results of the water budget.

5.3.3 Atmospheric Components of the Water Budget

5.3.3.1 Precipitation

The water budget for Cartier Bay requires estimation of water volumes exchanged with the atmosphere including inflow due to precipitation and outflow due to evapotranspiration. To estimate atmospheric inputs to Cartier Bay, total daily precipitation data for 2004 to 2013 were obtained from Environment Canada Revelstoke A weather station, which is located ~5.5 km north of Cartier Bay (Environment Canada 2014). From 2004-2013, total annual precipitation averaged 904.4 mm, and varied from 658.5 mm (2013) to 1048.6 mm (2004) (Table 5-2). The highest monthly precipitation totals generally occurred from October through January, and was up to 4.4 times greater than the lowest monthly precipitation totals, which generally occurred in July and August (Table 5-2). Based on air temperature data from the Revelstoke A weather station, precipitation generally falls as snow from November through March.

Actual precipitation inputs to Cartier Bay may be greater or less than what are presented here, and depend on the differences in site conditions (e.g., elevation, topography, and surface cover) between Cartier Bay and the Revelstoke A weather station. In addition, some of the rain that falls will be intercepted by vegetation over the wetland. The percentage of rainfall that is intercepted by emergent macrophytes at maximum plant growth is likely similar to that of grasslands (10 to 20 percent of gross precipitation) (Dunne and Leopold 1978).

Table 5-2: **Total monthly and annual precipitation (mm) at Environment Canada Revelstoke A weather station for 2004 to 2013**

	Precipitation (mm)									
Month	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Jan	164.5	186.5	127.0	98.0	87.0	146.5	120.5	143.5	150.0	64.3
Feb	38.5	27.5	120.0	54.5	60.5	39.0	43.5	107.5	112.1	14.5
Mar	82.5	35.5	39.5	153.0	48.0	53.0	47.5	108.0	107.5	92.7
Apr	43.0	37.5	56.5	36.0	40.5	24.5	28.5	85.9	103.2	49.6
May	71.5	37.5	52.5	16.0	55.0	39.0	37.0	51.5	40.0	45.3
Jun	74.0	86.5	40.0	96.5	86.5	34.0	65.5	73.0	146.3	102.6
Jul	63.5	42.0	39.5	37.5	39.5	11.5	34.5	84.0	44.8	3.8
Aug	88.5	47.0	32.0	34.0	98.5	22.0	38.0	26.5	29.0	50.6
Sep	76.5	120.5	39.5	60.0	30.5	56.0	129.5	33.0	12.8	69.8
Oct	93.5	129.0	51.0	121.0	112.0	145.0	30.5	102.5	138.6	16.5
Nov	137.1	48.5	230.5	92.0	102.5	126.0	101.0	113.0	152.9	84.2
Dec	115.5	80.0	96.5	240.5	97.5	67.0	109.0	55.0	68.4	64.6
Total	1048.6	878.0	924.5	1039.0	858.0	763.5	785.0	983.4	1105.6	658.5

5.3.3.2 *Evapotranspiration*

The effect of precipitation depends not so much on the absolute amount but on the relationship between rainfall and evaporation from water and plant surfaces. There are no direct measurements of evapotranspiration in Cartier Bay, and continuous measurements of net radiation, windspeed, and humidity are not available to compute the energy budget and estimate evapotranspiration from the bay. Due to this lack of data, the Thornthwaite formula (Thornthwaite 1948) was used to estimate monthly total potential evapotranspiration for Cartier Bay based on air temperature. The Thornthwaite formula is an empirical formula that is commonly used to estimate evaporation from wetlands when data are sparse and is given by,

$$ET_i = 16\left(\frac{10T_i}{I}\right)^{\propto}$$

where ET_i is potential evapotranspiration for month i (mm/month); T_i is mean monthly air temperature (°C), obtained from Revelstoke Station A (Environment Canada 2014); I is the local heat index given by,

$$I = \sum_{i=1}^{12} \left(\frac{T_i}{5}\right)^{1.514}$$

and the coefficient $\alpha = (0.675 \times I^3 - 77.1 \times I^2 + 17{,}920 \times I + 492{,}390) \times 10^{-6}$. The formula is for a month with 30 days and requires an adjustment for latitude and number of days in month by multiplying the calculated ET_i by a correction factor (Dunne and Leopold 1978, Table 5-2).

The results show that potential evapotranspiration (PET) varied seasonally, with the lowest average monthly PET in December and January, and the highest average monthly PET in August (Table 5-3). For the period 2004-2013, the average daily PET from May to September was 3.56 mm d^{-1}, and the average total PET was 109.3 mm; this is expected for a well-watered marsh (e.g., Roulet et al. 1997, Lafleur 2008). Over the 10-year period, total annual PET averaged 596.3 mm, and varied from 574.5 mm (2008) to 614.8 mm (2006) (Table 5-3).

Thornthwaite's formula estimates evaporation when there is no soil moisture stress. Hence, this method tends to overestimate evaporation when water levels are low. In addition, water losses to the atmosphere in winter are not fully accounted for when using the Thornthwaite formula, which assumes that no evaporation occurs for months when the monthly mean temperatures are sub-zero; water loss by sublimation may occur during this time.

5.3.3.1 Net Atmospheric Flux

Precipitation minus evapotranspiration ($P - PET$) is the net flux of water from the atmosphere to the earth's surface. On a monthly time scale, precipitation was generally greater than the computed PET (Table 5-4). However, there were months where total PET was greater than P (Table 5-4). In 2009, P was less than PET in both July and August (Table 5-4; Figure 5-5). There were greater fluctuations in $P - PET$ on a daily scale (Figure 5-5), and PET tended to be greater than P during the months of May through September (Table 5-4). A negative balance between atmospheric inputs and outputs during the summer months decreases the water storage and surface level in Cartier Bay. The effect of this negative balance may be counteracted by surface inflows from the ALR, when the ALR elevation rises above the swale elevation of the bay (Figure 5-5); however, this cannot be verified without continuous water level data from Cartier Bay.

Table 5-3: **Total monthly and annual potential evapotranspiration (mm) from 2004-2013, computed from the Thornthwaite formula (1948) and air temperature data recorded at the Environment Canada Revelstoke A weather station**

	Potential Evapotranspiration (mm)									
Month	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Jan	0.0	0.0	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	0.0	0.0	0.0	0.0	0.0	0.0	4.2	0.0	0.0	2.3
Mar	12.6	18.6	9.9	13.7	8.5	1.7	21.3	8.7	2.1	12.6
Apr	48.1	49.5	46.2	38.7	29.5	33.3	45.7	31.2	42.8	38.2
May	79.0	92.5	80.9	83.7	84.4	76.2	75.5	78.5	74.3	85.8
Jun	118.3	106.5	117.6	110.1	110.0	116.9	110.1	108.4	98.0	105.7
Jul	134.9	125.0	140.7	145.3	125.6	142.7	129.4	115.7	127.2	138.4
Aug	120.2	115.7	109.2	108.4	107.7	120.1	110.3	111.7	116.4	116.3
Sep	64.5	64.1	75.9	68.4	67.4	76.9	67.8	79.5	75.9	76.3
Oct	30.1	31.5	29.8	28.4	29.5	22.5	38.6	32.5	31.2	26.1
Nov	4.6	7.4	0.0	1.3	12.0	9.9	0.5	2.1	11.6	0.7
Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	612.2	610.7	614.8	597.9	574.5	600.0	603.3	568.3	579.3	602.4

Table 5-4: **Total monthly and annual precipitation (P) minus potential evapotranspiration (PET) (mm) for 2004 to 2013**

	P - PET(mm)									
Month	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Jan	164.5	186.5	122.4	98.0	87.0	146.5	120.5	143.5	150.0	64.3
Feb	38.5	27.5	120.0	54.5	60.5	39.0	39.3	107.5	112.1	12.2
Mar	69.9	16.9	29.6	139.3	39.5	51.4	26.2	99.4	105.4	80.1
Apr	**-5.1**	**-12.0**	10.3	**-2.7**	11.0	**-8.8**	**-17.2**	54.7	60.4	11.4
May	**-7.5**	**-55.0**	**-28.4**	**-67.7**	**-29.4**	**-37.1**	**-38.5**	**-27.0**	**-34.3**	**-40.5**
Jun	**-44.3**	**-20.0**	**-77.6**	**-13.6**	**-23.5**	**-82.9**	**-44.6**	**-35.4**	**48.4**	**-3.1**
Jul	**-71.4**	**-83.0**	**-101.2**	**-107.8**	**-86.1**	**-131.2**	**-94.9**	**-31.7**	**-82.4**	**-134.6**
Aug	**-31.7**	**-68.7**	**-77.2**	**-74.4**	**-9.2**	**-98.1**	**-72.3**	**-85.2**	**-87.4**	**-65.7**
Sep	12.0	56.4	**-36.4**	**-8.4**	**-36.9**	**-20.9**	**61.8**	**-46.5**	**-63.1**	**-6.5**
Oct	63.4	97.5	21.2	92.6	82.5	122.5	**-8.1**	70.0	107.4	**-9.6**
Nov	132.5	41.1	230.5	90.7	90.5	116.1	100.5	110.9	141.3	83.5
Dec	115.5	80.0	96.5	240.5	97.5	67.0	109.0	55.0	68.4	64.6
Total	436.4	267.3	309.8	441.1	283.5	163.5	181.7	415.1	526.3	56.1

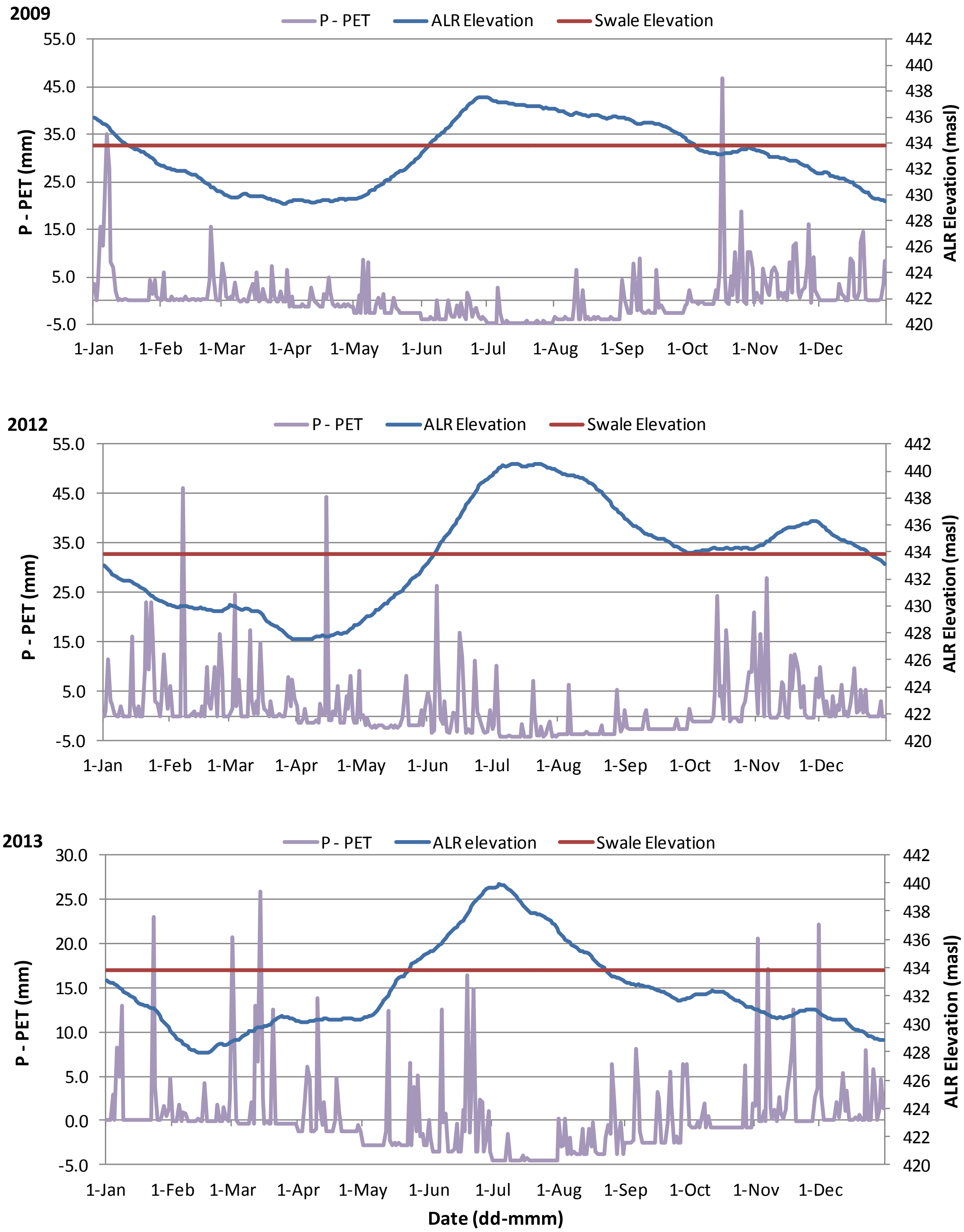


Figure 5-5: **Total daily precipitation (P) minus total daily potential evapotranspiration (PET) (mm) plotted with the ALR elevation (m ASL) for 2009, 2012 and 2013.** Cartier Bay is inundated when the ALR elevation rises above the swale elevation (433.8 m ASL). Note the different y-axis scale in 2013

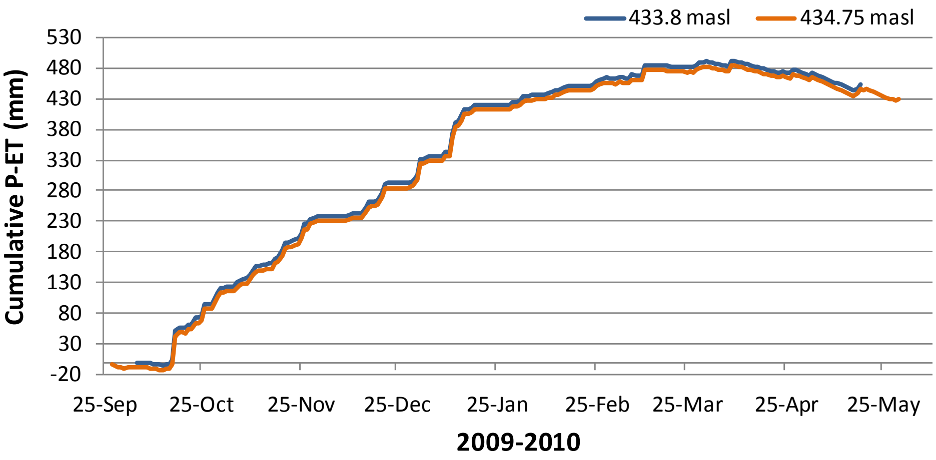
5.3.4 Change in Bay Water Level

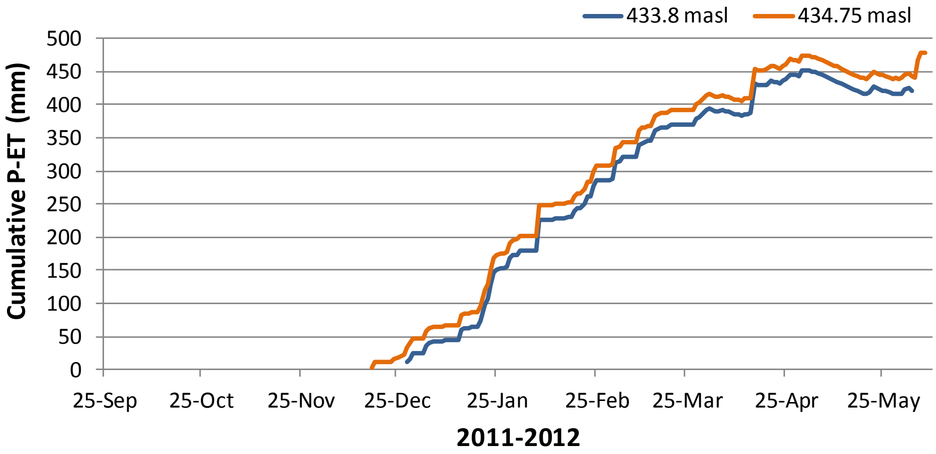
The available data are not sufficient to compute the change in water storage from the balance of inflows and outflows. However, the cumulative net atmospheric flux provides a solution to the simplified water budget, given by,

$$\frac{dh}{dt} = P - ET - S_o$$

where dh/dt is the water level over time. The cumulative net atmospheric flux ($P - ET$) was computed from the time when the ALR level drops below the swale invert, to the time when the ALR level rises to the swale elevation of the existing dike, and was computed for the existing swale elevation as Site 15A (433.8 m ASL) and its proposed swale elevation (434.75 m ASL); the results for 2009-2010, 2011-2012 and 2012-2013 are shown in Figure 5-6. Note that surface outflow (S_o) was measured only once, as 0.0096 m^3/s (Golder 2009b). This value is insignificant to the overall budget, and thus not included in the cumulative net atmospheric flux computation.

The cumulative net atmospheric flux was 57.2 mm greater for the proposed swale (478.6 mm) than the existing swale (421.4 mm) for the 2011-2012 period (Figure 5-6). A similar difference, 40.8 mm, was computed for the 2012-2013 period (168.8 mm and 128.0 mm for the proposed and existing swales respectively) (Figure 5-6). In contrast, the cumulative net atmospheric flux in 2009-2010 was 429.1 mm for the proposed swale, and 453 mm for the existing swale resulting in 23.9 mm less water computed at the proposed swale elevation than for the current swale elevation (Figure 5-6). In 2009, the ALR level dropped below the swale elevation earlier (September) than in 2011 and 2012 (December); at a time when the net atmospheric flux was negative, and because the ALR level dropped below the proposed swale elevation one week earlier than the existing swale elevation, the atmospheric flux was in a negative balance for longer. Thus, the timing of inundation is important when considering the potential effects of raising the invert swale elevation of the dike.





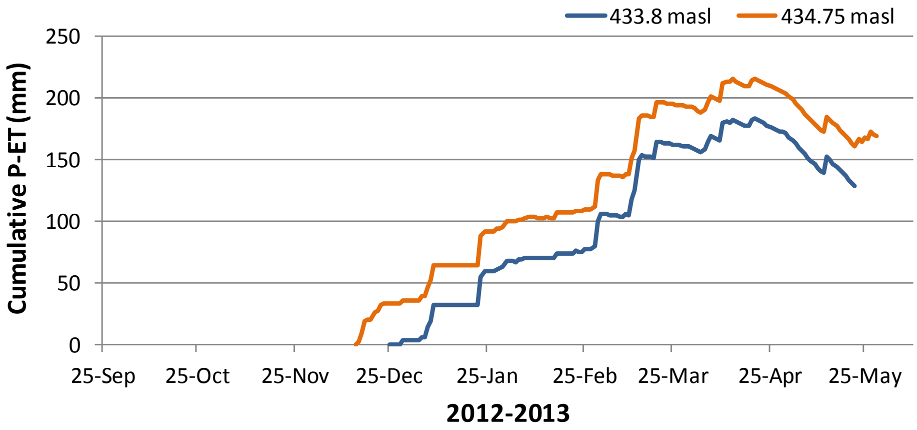


Figure 5-6: **Cumulative total daily precipitation (P) minus total daily potential evapotranspiration (PET) (mm) computed from the day when the ALR elevation dropped to the swale elevation of the existing dike (433.8 m ASL), to the day when the ALR level rose to the swale elevation of the existing dike, for the years 2009-2010, 2011-2012 and 2012-2013.** Similarly, P minus ET was also computed for the proposed dike elevation (434.75 m ASL). Note the different y-axis scale in the plots

5.3.5 Predicted Effects to Hydrology

The lack of data makes it difficult to predict the hydrological effects of raising the swale invert elevation at Site 15A by 0.95 m (assuming a change in elevation from 433.8 m ASL to 434.75 m ASL). Using the limited data available, we assessed the frequency, duration, and magnitude of wetland inundation by the ALR to help determine if it will be reduced by an ecologically meaningful extent. In doing so, we address the probability that the objectives described in Golder (2009b) are likely to be met. These objectives include increasing the extent of shallow open water habitat, and to increase the water storage capacity in Cartier Bay.

5.3.5.1 Frequency of wetland inundation

One of the objectives for increasing water depths was to increase the wetland storage capacity to maintain water during dry years, when reservoir levels remain low through the summer (Golder 2009b). Building the dike 0.95 m higher than the existing gap in the rail grade will increase the water storage capacity; however, it increases the probability that Cartier Bay would not be inundated in more years than under existing conditions. For example, if a dike with the proposed swale invert of 434.75 m ASL at Site 15A existed in 1992, 1994 and 2005, Cartier Bay would not have been inundated for longer than 1 day, as the maximum water level in these years would be at or below the swale invert (Figure 5-6). In contrast, Cartier Bay was inundated in 1992, 1994 and 2005 as the gap in the rail grade had an invert level of 433.8 m ASL, lower than the maximum the ALR level during these years (Figure 5-6). Cartier Bay was not inundated in 1973, 1977 and 2001 because the maximum the ALR level during these years was lower than the invert swale elevation (Figure 5-6). If the swale elevation is increased, there is a greater potential for periodic years with no inundation from the ALR; these inflows to the bay may be off-setting losses when ET is greater than P (Section 5.3.3.1). Compared to the existing dike swale, the higher dike swale will initially increase water storage in Cartier Bay after the ALR level drops below the swale. However, the available data are not sufficient to confirm that the bay will maintain this storage until the bay is inundated again by rising the ALR level.

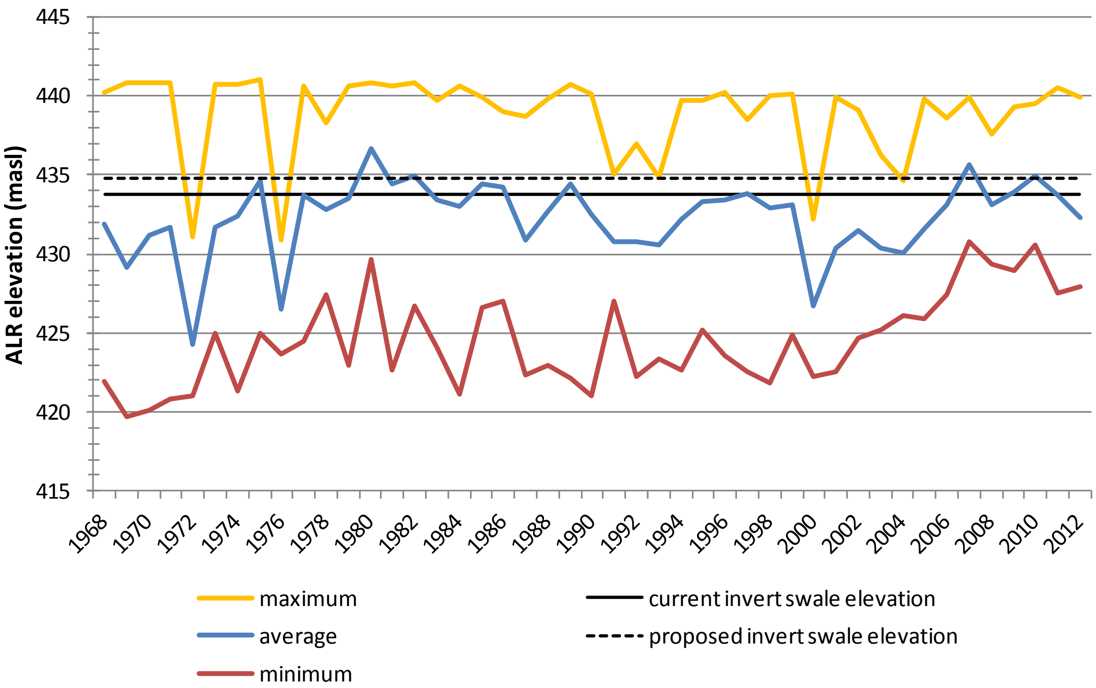


Figure 5-7: **Annual ALR elevation statistics (m ASL) from 1969 to 2013 compared to the Site 15A outlet swale**

5.3.5.2 Duration of wetland inundation

The average duration of inundation has decreased by 60 days in the last decade (2004-2013) compared to the average duration of inundation for the 34 years prior (1969-2003) (Figure 5-8). Increasing the swale elevation to 434.75 m ASL is expected to shorten the duration of inundation by 20 days, based on the average inundation period over the last 10 years (2004-2013) (Figure 5-8). Note that if the existing swale elevation is actually 434.15 m ASL as suspected, the effect of increasing the swale elevation to 434.75 m on the duration of inundation is expected to be only 6 days.

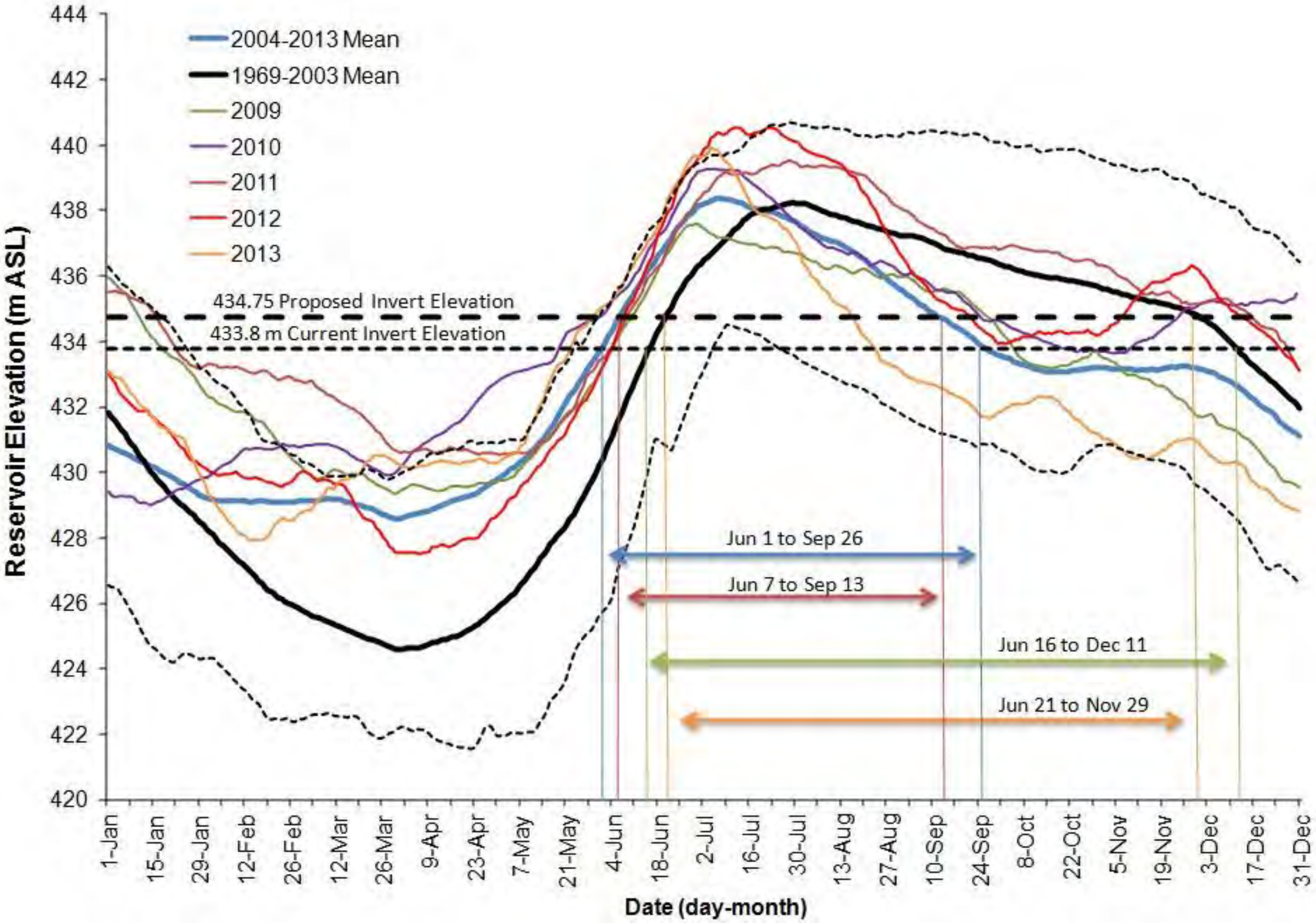


Figure 5-8: **Daily mean the ALR elevation (m ASL) from 2009 to 2013 and the 10 year mean (2004-2013) and 44 year mean (1969-2013) reservoir elevation (m), relative to the current (433.8 m ASL) and proposed (434.75 m ASL) invert swale elevation.** Arrows show the period when Cartier Bay is inundated by the ALR for the existing and proposed dikes

5.3.5.1 Magnitude of wetland inundation

With limited data, it is difficult to reliably predict how the bay water level will vary behind the proposed dike. Lack of precise knowledge about the seasonal pattern of the water level of Cartier Bay, and the elevation of Cartier Bay during spring and fall relative to the height of the existing swale, are major obstacles for determining potential effects to the magnitude of wetland inundation. From the available data, a map was created showing the current (assuming 433.8 m ASL at Site 15A) and predicted (434.75 m ASL) water elevation contours, and bay water depths sampled during amphibian surveys in 2010-2013, overlaid on a triangular irregular network (TIN) image of water depths collected in 2011 (Figure 5-4). Increasing water depths in Cartier Bay will expand the area of the bay and may provide more shallow wetland areas at the margins of the wetland, but at the expense of current shallow habitats, which will be made deeper.

Physical restoration works at Cartier Bay Site 15A may also impact the hydrology at Cartier Bay Site 14, and vice versa. The proposed physical works for Site 14 are to construct “a dike with swale to close the gap in the rail grade to retain water and flood low lying ground upstream of the proposed dike” (Golder 2009b). The rail grade at Site 14 is at a slightly lower elevation (434.8 m ASL) than at Site 15A (435.25 m ASL), and the two impounded areas are separated by a “ridge of higher land (between 434 and 436 m ASL)” (Golder 2009b). Given that the rail grade is lower at Site 14 than 15A, it is probable that additional water at Site 15A could top the ridge between the two sites and flood the newly created shallow water habitat at Site 14. Changes to the water levels at sites 15A and 14 due to the proposed dikes may alter seepage patterns between the two sites and affect their water budgets.

One of the objectives for increasing water depths was to increase the wetland storage capacity to maintain water during dry years, when reservoir levels remain low through the summer (Golder 2009b). However, Golder (2009b) does not provide evidence that Cartier Bay will maintain water during years when the ALR level does not overtop the proposed dike and inundate Cartier Bay. Petrone et al. (2003) found that restoration techniques that resulted in a higher water table, higher soil moisture, and the re-emergence of vascular plants, created higher ET losses than in an adjacent unrestored site. We may presume that a higher swale elevation would result in less surface inflows from the ALR in some years; this could potentially exacerbate the effects of increased ET on bay elevation; however, this cannot be confirmed without continuous measurements of water level.

5.3.1 Recommendations

The available hydrologic data are insufficient to support reliable predictions of water levels in Cartier Bay after an increase in swale elevation at Site 15A and/or construction of a dike swale at Site 14. The seasonal pattern of water level of Cartier Bay, and the elevation of Cartier Bay during spring and fall relative to the height of the existing swale are required for determining potential effects to the magnitude, frequency, and duration of wetland inundation. We recommend continuous monitoring of water level in Cartier Bay to establish a reliable water balance for the bay. Water level gauges should be surveyed to a common datum so that data can be directly compared with ALR water level and the invert swale elevation (the latter requires confirmation). We recommend accurate surveying of Cartier Bay bathymetry. This survey should include Site 14, Site 15A, and the bay area between and around these sites. The survey for the bay may be done after ALR floods Cartier Bay and the bay is deep enough to run boat transects with high-accuracy echo sounder and differential global positioning system.

5.4 Analysis 4: Cartier Bay Vegetation

5.4.1 Overview of Cartier Bay Vegetation

Existing vegetation in Cartier Bay is predominantly herbaceous (graminoids and forbs) with a minor component of woody shrubs and trees near the shoreline. Species diversity is relatively low. Vegetation can be generally grouped into three broad, somewhat overlapping, functional guilds: flood-tolerant terrestrial plants, facultative aquatic species, and obligate aquatic plants (here termed macrophytes). The first category includes riparian shrubs such as willows (*Salix* spp.) and graminoids such as Reed Canarygrass (*Phalaris arundincacea*) and Lenticular Sedge (*Carex lenticularis* var. *lipocarpa*). Facultative aquatics are those adapted for growing in or near water but which may complete at least some of their life cycle on drying ground above the waterline. These plants tend to establish in drying depressions and on mud flats at the edge of the receding shoreline (e.g. Spring Water-starwort, *Callitriche palustris*). Included with this group is Water Smartweed (*Persicaria amphibia* var. *stipulaceum*), a species which can grow both aquatically and terrestrially but which at Cartier Bay occurs mainly in its terrestrial form.

Macrophytes are plants normally found growing in association with standing water whose level is at or above the soil surface. These include a variety of taxonomic groups and can be further separated into categories depending on their habit of growth: floating, submersed, and emergent. Floating macrophytes (e.g. Rocky Mountain Pond-lily, *Nuphar polysepala*) have submergent stems but leaves that float on the surface. Submersed plants (e.g. Stonewort, *Chara* sp.) are those with all parts below the surface of the water. Emergent macrophytes (e.g. Swamp Horsetail, *Equisetum fluviatale*) are those whose roots normally grow underwater, but whose stems and leaves extend above the water surface.

Vegetation development at Cartier Bay is a direct product of the prevailing hydrological regime and exhibits obvious zonation patterns predicated on elevational gradients and associated hydroperiods. Below 433.8 m ASL, a permanent horseshoe-shaped wetland supports macrophytes such as Eurasian Water-milfoil (*Myriophyllum spicatum*) and Common Hornwort (*Ceratophyllum demersum*). Within the zone of seasonal reservoir flooding (above 433.8 m ASL), which includes the extensive grass flats behind the Cartier Bay rail grade, flood-tolerant Reed Canarygrass forms dense stands over much of the area, interspersed with patches of Lenticular Sedge, Columbia Sedge (*Carex aperta*), and Water Smartweed. Some isolated pools and ponds also occur here, in areas that would be inundated if the physical works project results in the raising of the dike by an additional 1 m. The current shoreline (of the extant wetland) varies in character around the perimeter, with shrub and horsetail associations characterizing the rocky east bank; steep, largely unvegetated sand and cobble banks on the southern perimeter (grading into Black Cottonwood and willow stands higher up the bank); and terrestrial and facultative aquatic herbaceous plants such as Spring Water-starwort, Lady's-thumb (*Persicaria maculata*), Little Meadow Foxtail (*Alopecurus aequalis*), Lenticular Sedge, Purple-stem Monkey Flower (*Mimulus floribundus*), and Reed Canarygrass occupying the low gradient, soft-soiled, west and north shorelines (i.e. the inner portions of the "horseshoe;" Figure 4-3).

5.4.2 Research Summary

Little information is available on the vegetation conditions that prevailed at Cartier Bay prior to construction of ad hoc dikes in the rail grade and the breaching of the old Arrowhead highway by parties unknown at least 15 years ago. Three separate BC Hydro projects are currently underway to monitor vegetation trends at the site (as components of wider studies). In order of commencement, these are: (1) CLBMON-33 Arrow Lakes Reservoir Inventory of Vegetation Resources; (2) CLBMON-12 Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis; and (3) CLBMON-11B4 Wetland Effectiveness Monitoring for Wildlife Physical Works. CLBMON-33 and CLBMON-12 target vegetation communities above the permanently wetted zone, while CLBMON-11B4 focuses on wetland macrophytes and macroinvertebrates in the open water zone.

The primary objective of CLBMON-33 is to monitor landscape level changes in spatial extent, structure and composition of vegetation community types (VCTs) within the 434–440 m ASL DDZ of the ALR, and to assess if any observed changes are attributable to the soft constraints operating system. The study is designed to span a period of ten years (2007–2016), with sampling occurring in 6 of those years (2007, 2008, 2010, 2012, 2014, and 2016). Work completed during years 1, 2, 4, 6 (Enns 2007, Enns et al. 2007, 2008, 2010, Enns and Overholt 2012) and 8 (ONA and LGL, results pending) used aerial photograph interpretation and field sampling to monitor landscape-level changes in the defined VCTs (Enns et al. 2007, 2012).

Aerial photos for selected regions of the ALR DDZ have been captured along predetermined flight lines at low water levels in each of the CLBMON-33 implementation years (up to and including 2014) except 2008, when flight lines were flown in the fall at high water levels. Aerial photos from each year are stitched together to form ortho mosaics. Polygons representing different VCTs (or VCT clusters) are demarcated on the ortho mosaics and used as the primary metric for tracking vegetation trends over time, with ground-based field sampling used primarily to ground-truth the vegetation classification derived from aerial imagery. The primary metrics monitored are the distribution, spatial extents, and structure of vegetation communities across elevation bands in the DDZ. Explanatory variables assessed include topo-edaphic site conditions (elevation, slope, aspect, primary water source, soil moisture and texture, substrate type), operational variables (timing, frequency, duration and depth of inundation) and environmental variables such as number of days (per annum) inundated, exposure to wave action and scouring, total accumulated precipitation, and average annual temperature.

The primary purpose of CLBMON-12 is to assess the long-term effectiveness of the revegetation program CLBWORKS-2 at expanding the quality (as measured by diversity, distribution and vigour) and quantity (as measured by cover, abundance and biomass) of vegetation in the DDZ for ecological and social benefits. CLMBON-12 also assesses changes in existing vegetation communities at the site (local) level in response to the soft constraints operating regime of the ALR. The study is designed to span a period of ten years (2008–2017), with sampling occurring in 6 of those years (2008, 2009, 2011, 2013, 2015, and 2017). Work completed during years 1, 2, 4, and 6 (Gibeau and Enns 2008, Enns et al. 2009, Enns and Enns 2012, Enns and Overholt 2013) used repeat sampling of vegetation plots (including revegetated and untreated plots) to monitor changes in species composition, cover, abundance, biomass, diversity, and distribution within identified vegetation communities (Enns et al. 2007, 2012). Since at Cartier Bay no revegetation prescriptions were applied under CLBWORKS-2, vegetation work at this site has been limited to the monitoring of existing vegetation.

CLBMON-11B4 was commissioned by BC Hydro in 2010 under the Water Use Plan and is the only project of the three specifically designed to monitor the impacts of reservoir operations and physical works projects on aquatic habitat within the DDZ. The mandate of this project included the following components: 1) develop a monitoring program to assess the effectiveness of wildlife physical works projects (CLBWORKS-30) at enhancing wetland habitat in Revelstoke Reach; 2) monitor the appropriate physical parameters and biological response variables to assess the effectiveness of the wildlife physical works programs at enhancing wildlife habitat in Revelstoke Reach; and 3) assess the effectiveness of wildlife physical works projects at enhancing wetland habitat (at the both the site and landscape level). Following a pilot study and sampling protocol development in 2010 (Hawkes et al. 2011), boat-based monitoring of the Cartier Bay wetland commenced in 2011 with repeat sampling conducted in 2012 and 2013 (Fenneman and Hawkes 2012, Miller and Hawkes 2013, 2014). Primary metrics monitored were the presence, distribution, abundance, and diversity of macrophytes and aquatic macroinvertebrates. Secondary metrics included hydrological and physicochemical parameters such as water depth, water temperature, substrate, pH, conductivity, and turbidity (Hawkes et al. 2011).

CLBMON-11B4 was conceived as a before-after impact study, with phase 1 being the characterization of baseline (i.e. pre-impact) conditions and phase 2 being the monitoring of ecological outcomes following implementation of proposed physical works at Cartier Bay (and nearby Airport Marsh; Golder 2009b). The original schedule anticipated one year of pre-construction baseline monitoring (2011); however, as physical works were not immediately implemented, this phase of the monitoring was extended to include the two subsequent years as well (2012 and 2013). No work was conducted in 2014. The three baseline study years (in addition to the 2010 pilot study year) afforded the opportunity to quantitatively assess levels of naturally occurring, inter-annual variability in key dependent variables such as macrophyte frequency, abundance, and biomass, and to assess the statistical significance of this variability. They also allowed for testing of the project methodology to determine if it could detect changes in measured variables with the desired accuracy (Miller and Hawkes 2013, 2014).

5.4.3 Vegetation Objectives and Performance Measures for Cartier Bay Physical Works

The feasibility study for the physical works projects (Golder 2009b) identified the following goals for the two sites:

1. For Site 14, the eventual establishment of an ecological community similar to that growing in Cartier Bay within the current area of inundation.
2. For Site 15A, expansion of the existing wetland community by increasing the amount of flooded area (Golder 2009b).

These initial objectives were general in scope, and lacked specific performance measures. Performance measures provide a means to evaluate whether or not objectives are being met, and for reporting on progress. They are also a tool to gauge the efficacy of the monitoring approach and guide its improvement. Therefore, as part of the wetland sampling and protocol development for CLBMON-11B4, Hawkes et al. (2011) proposed a more specific set of qualitative and quantitative performance measures to help guide the monitoring program. Where required for hypothesis testing, the accepted standard for statistical power was set at 0.80 or greater. These performance measures will be used to inform (in part) our synthesis of information surrounding the potential vegetation outcomes of proceeding with the 1 m elevation increase in Cartier Bay (below).

1. Site 14: creation of at least 1 ha of new wetland habitat within one year following the implementation of the physical works.
2. Site 15A: measurable increase of at least 10 per cent in areal extent (hectares or square metres) of existing shallow wetland habitat within one year following the implementation of the physical works.
3. Measurable increase in wetland productivity:
    a. Successful natural establishment of native macrophytes into newly created wetlands within ten years. “Successful establishment” is here defined as continuous species presence for at least five years.
    b. Increases of at least 25 per cent from baseline conditions in cover and diversity (species richness and evenness) of native macrophytes within 10 years. This includes species that occur in the wetlands and those that become successfully established.
    c. Successful natural establishment of native macroinvertebrates into newly created wetlands within ten years. “Successful establishment” is here defined as continuous species presence for at least five years.
    d. Measurable increases of at least 25 per cent from baseline conditions in biomass and diversity (species richness and evenness) of native macroinvertebrates within ten years. This includes species that occur in the wetlands and those that become successfully established.

4. No measurable increases greater than 25 per cent from baseline conditions in cover and diversity (species richness and evenness) of key undesirable macrophyte species over 10 years. Undesirable macrophytes include any introduced species, particularly those that are considered invasive. In the case of Revelstoke Reach, this term refers primarily to Eurasian Water-milfoil, which is the dominant invasive plant of aquatic habitats within the DDZ.
5. No measurable increases greater than 25 per cent from baseline conditions in biomass and diversity (species richness and evenness) of key undesirable macroinvertebrate species over 10 years.
6. No erosion or other structural failure of the dikes following the completion of the physical works, and no indication that such events should be expected in the future. This is based on an assessment of the structural integrity of the physical works during the final year of monitoring to ensure that they are sound.

5.4.4 Information Synthesis

5.4.4.1 Seasonally Inundated Zone

The following descriptions apply to that portion of the Cartier Bay flood plain that is exposed (not flooded) for a portion of the year, and which supports vegetation that can be classified as terrestrial (or riparian or semi-aquatic) rather than strictly aquatic.

5.4.4.1.1 Vegetation Communities

Enns et al. (2012 and earlier reports) developed a general classification for landscape level vegetation communities found in the DDZ of the ALR, including Revelstoke Reach. These VCTs were defined based on a combination of similar topography, soils, and vegetation features. The following VCTs were recognized:

BB: Non-vegetated boulders, steep
BE: Beach non-to sparely vegetated sands or gravels
BG: Non-vegetated boulders, gentle slopes
CL: Saskatoon – rock or cliffs upper elevation
CR: Cottonwood riparian
IN: Industrial / residential / recreation
LO: Blue Wildrye log zone
PA: Reed Canarygrass – Redtop upland
PC: Reed Canarygrass – Lenticular Sedge Mesic; midslope
PE: Reed Canarygrass – Horsetail middle to lower slope
PO: Waterlily – Potamogeton open water
RR: Reed – rill (upslope ground water supplies)
RS: Willow – Red Osier Dogwood – stream entry
SS: Non-vegetated sand and/or gravels, steep
WR: Silverberry – river

Of the 15 VCTs defined, 10 have been identified as occurring within or bordering the projected zone of impact of the proposed physical works at Cartier Bay (information extracted from BC Hydro unpubl. data). These are: BE, BG CR, IN, PA, PC, PE, PO, RR, and SS. A brief description of each of these VCTs (from Enns et al. 2008) follows.

BE: This VCT consists of flat to gently undulating, fine-textured sands with a mixed silt content. It usually occurs at all elevations, and appears to be scoured by water currents. It is possible that BE is simply a frequently inundated low elevation PC types. Dust issuing from this type is a common occurrences. This vegetation type is very sparsely vegetated to non-vegetated. Annual Bluegrass, Reed Canarygrass, Pineapple Weed and Common Horsetail are some of the species that occur.

BG: This VCT is typically an alluvial or fluvial outwash plain, consisting of boulders of various sizes, located always on gentle to flat areas of the reservoir. It may be adjacent to creeks and seepage that may provide water in the hot period of exposure in spring, summer or fall. 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, sourweeds, and Redtop. Vegetation is almost always very sparse or absent.

CR: This VCT mostly occurs near the 440 m ASL, but also throughout all elevations, especially in Revelstoke Reach, if the site is sheltered from scouring the soils are either remnants of, or persistent features of, well-drained alluvial fans. The CR vegetation type is often dominated by Black Cottonwood, with Trembling Aspen and occasionally very large specimens of Western Red Cedar, Douglas-fir and Western White Pine. Ponderosa pine occurs at the southern end of the Arrow Lakes portion of the reservoir, and Lodgepole Pine occurs at the northern end. There are highly variable assemblages of non-vascular and vascular plants in the CR, including horticultural species. A range of forested vegetation from wet to very dry forest types occurs, including Falsebox, Oregon-grape, Pinegrass, Trailing Bramble, bedstraws, peavines, and various mosses, liverworts, lichens. This type may be an important seed source for lower elevation sites.

IN: This type occurs across all elevation bands in the DDZ. It is characterized by heavily disturbed soils and vegetation due to roads and a variety of land uses, including past settlement. Soils are variable, but are always compacted, and have weedy margins. This type is probably a major source of weed invasion into other vegetation types in the reservoir. It is dominated by a mix of drought and/or inundation tolerant opportunistic native and weedy vegetation, such as sourweed spp., Red and White Clover, Sweet Clover, knapweed spp., Cheatgrass, Pineappleweed and others.

PA: This vegetation type occurs on raised, well drained microtopography (i.e. convex and moisture shedding) and can occur at a range of elevations including at the 433m elevation, although it is more common above 437m. It is relatively frequent, but often too small to map at the landscape level, and occurs on sloped or on well drained, sandy gravelly materials. It is physically disjunct from the CR type, which is usually flat or sloping but seldom convex. This type is usually somewhat variable, but displays a relatively high species richness compared to PC or PE, due to the presence of drought tolerant weedy species. While this type is often dominated by Reed Canarygrass, the species composition always includes at least a few species of agronomic and native grasses, including Redtop, Creeping Bentgrass, Blue Wildrye, Canad Bluegrass, Kentucky Bluegrass, and others. Various pasture and ditch weeds, such as sourweed, chickweed, Chicory, Oxe-eye Daisy also occur, in addition to somewhat dry forest-type mosses, such as Red-stemmed Feather Moss and Palm-tree Moss. Trees and shrubs usually occur.

PC: The Reed Canarygrass – Lenticular Sedge vegetation type is the mesic vegetation in the ALR and is both very common and widespread, occurring in all the map areas. It is relatively variable, and can be influenced by drainage, moisture regime, and slope position. Materials vary somewhat, but usually consist of gently sloping to flat anoxic, compacted sandy-silty to silty-sandy materials, often with quite coarse sand. Gravel depositional areas can have openings, which result in a few more species than the usual species composition for this VCT. The PC covers large parts of individual polygons and is dominated by Reed Canarygrass with minor amounts of Lenticular Sedge, Common Horsetail, and Pennsylvania Bitter-cress. Reed Canarygrass can be monospecific and form very dense, mostly pure stands of 1 ha or larger in size, especially in Revelstoke Reach. This type has been heavily grazed by geese in the Arrow Lakes, and in this this condition it can be invaded by several species of sedges, grasses, cranesbill, bedstraw, and other inundation-tolerant or requiring plants.

PE: This vegetation type occurs mainly at low to middle elevations. Physical site characteristics differ from RR sites (below) in that PE occurs in depressional topography, and water is not continuously supplied from upslope via ground water supplies, but rather mainly from reservoir water. PE can be boulder, but is always relatively compacted, non-aerated and has significantly higher silt fractions in the soil compared to its typical neighbor, the more mesic PC type. PE is less common throughout the reservoir than PC, usually occurs down-slope of PC and is less variable. Species richness is medium, dominated by Lenticular Sedge, Purslane Speedwell, Annual Bluegrass, Reed Canarygrass, and horsetails. It can have very low covers of several inundation tolerant plants including Shortawn Foxtail, and Nodding Chickweed. It appears that annual plants occur sporadically in this type and the species composition varies both annually and seasonally.

PO: This type occurs in backwaters, large deep depressional areas, cut-off oxbows or channels, and very rarely on flat stretches of beach. POs vary in water depth, but are usually deep enough to comprise permanent to semi-permanent features, i.e. they are not just shifting minor depressional areas caused by scouring, but possible old ponds or wetlands. They have standing brackish to slow moving water present most of the year. The areas may dry out in very dry successive years. The vegetation can be species poor and mainly consists of edge-dwelling and aquatic macrophytes. Species include Floating-leaved Pondweed, Common Spike-rush, Balitic Rush, Rocky Mountain Pond-lily, Marsh Cinquefoil, Water Smartweed, Eurasian Water-milfoil, and other semi-emergent to emergent plants.

RR: This type is always associated with continuous sources of fresh water as an underground stream or seep entering the reservoir. It is usually topographically depressional. Water may originate from open streams upslope, but may also continuously percolate through surficial materials in the DDZ. Materials usually have some fine textured and compacted component, 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 barren areas. Species include rushes, reeds, and sedges, Swamp Horsetail and occasionally willows. The type can be species poor, if recent scouring has taken place.

SS: With the exception of the Lower Arrow Lake narrows, this VCT is not common, occurring only in small areas throughout the reservoir. It consists of steep, sandy banks, often with peeling or failing slopes. Stepped patterns may occur that correspond to the typical full pool events in the reservoir. This type consist of only a few species of plants, with very low cover, including Reed Canarygrass, Common Horsetail, and Short-awn Foxtail.

The distribution and frequency of VCTs in the ALR is represented by mapped polygons (stored as GIS shape files), with each polygon containing one to three VCTs (Enns et al. 2007). VCT distributions and frequencies, and the extent to which these have changed over time since 2007, have been described for the ALR as a whole, though not for Cartier Bay specifically (Enns and Overholt 2012 and earlier reports). For the present report we extracted details on Cartier Bay vegetation communities (for seasonally inundated, non-wetland portions of the potential impact zone) by reviewing the raw databases associated with the aforementioned reports. These are summarized below.

5.4.4.1.2 VCT Distribution and Frequency

As noted above, a total of 10 VCTs occur within the seasonally inundated zone of potential impact from the proposed physical works at Cartier Bay. Of these, the PC (Reed Canarygrass – Lenticular Sedge) VCT easily predominates in terms of total aerial coverage. Precise figures on VCT covers are lacking; however, the PC VCT occupies most visible convex and upland surface areas within the inner portion of the horseshoe formed by Cartier Bay (inner area), as well as substantial portions of the outer riparian perimeter (Figure 5-9,Table 5-5). The PC occurs in 28 of 45 identified polygons (62 per cent) and is the dominant type in 21 (47 per cent) of the polygons. In seven polygons, it is the only identified feature (Table 5-5).

Near the margins of the existing wetland and at numerous interspersed swales and depressional features within the inner area, the PC VCT intergrades with the PE (Reed Canarygrass – Horsetail), RR (Reed – rill) and/or PO (pond) types. After PC, PE and PO are the most widely distributed community type within the inner area, occurring within 31 and 29 per cent of polygons, respectively. PE is the dominant type in four polygons, while PO is the dominant type in seven polygons. Aside from the large pond/wetland occupying the south and east margins Cartier Bay, most ponds (PO) in the inner area are small seasonal features. These ponds have not been assessed botanically and there is no information available as to their composition (though they may be too small and ephemeral to support much if any aquatic vegetation [i.e. macrophytes]). Due to their location in low-lying wet areas and relatively fragile nature, the PE and PO VCTs have been heavily impacted by recreational ATV use (i.e. "mud bogging"). Due to its concentration around existing wetland margins (i.e. lower riparian zone), the PE VCT would be the community type most immediately impacted by a 1 m increase in water levels. In addition to these four VCTs, the IN VCT (consisting mainly of roads and ATV tracks) also occurs in the inner area (Figure 5-9, Table 5-5).

The outer riparian perimeter of Cartier Bay (here defined as the south, east, and northeast boundary) supports a mix of vegetation types including steep, mostly unvegetated sand/cobble slopes, moisture-receiving herbaceous flats, creek rills, and upland woody (shrub and tree) associations. At low elevations, the southwest riparian perimeter consists predominantly of beach and steep sand slopes (BE and SS VCTs) supporting a light cover of herbaceous vegetation. At higher elevations, these community types intergrade with the PA VCT (Figure 5-9, Table 5-5). The southeast perimeter (map obj. 1951, Figure 5-9, Table 5-5) is a boulder-gravel shoreline that transitions upslope to a riparian Cottonwood stand (CR VCT). The eastern shoreline of Cartier Bay consists of predominantly herbaceous flats (PC and PE VCTs) at low elevations, with steep boulders and shrubs (BB and PA VCTs) predominating upslope. That said, this shoreline has not been thoroughly assessed from a vegetation perspective and detailed information on species composition and structure, particularly with respect to the upland shrub community, is lacking.

The northeast riparian perimeter is a somewhat disturbed, shrub and grass community type (PA VCT) situated at the upper edge of a gradually sloped alluvial plain (BG VCT; Figure 5-9, Table 5-5). As most of this area sits at or above 436 m ASL, this portion of the riparian zone should be minimally influenced by increased water levels resulting from the physical works. At this location, the 434 m contour straddles a combination of PE and PC community types (map objs. 1623 and 1631), the former of which would be mostly inundated by a 1 m increase in water level (Figure 5-9).

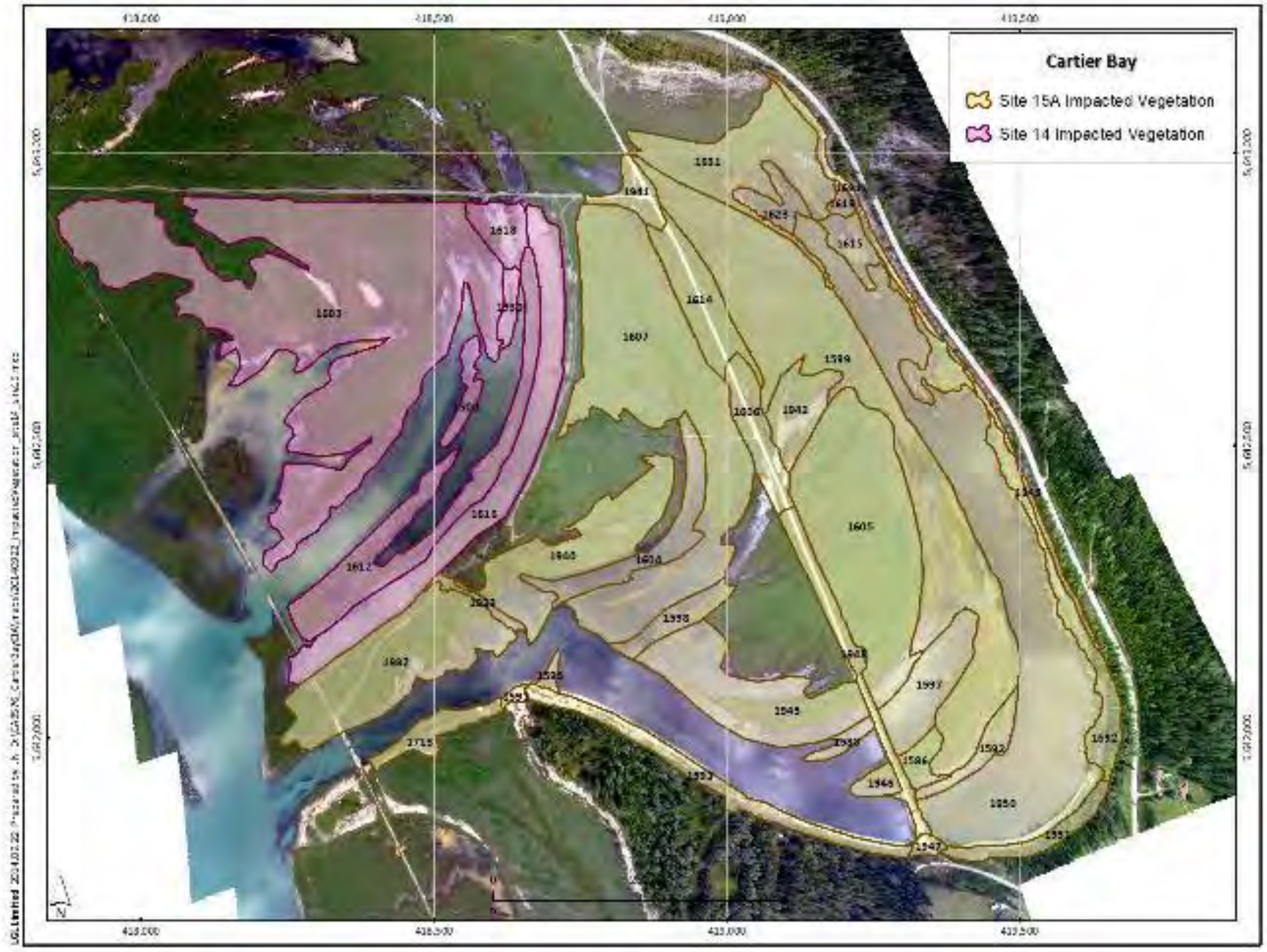


Figure 5-9: **Map of assessed vegetation polygons for the potential impact zones associated with Site 14 and 15A.** Each mapped polygon can contain up to three distinct vegetation community types (VCTs); these are indicated in the companion table, Table 5-5. Note that the channels immediately east of Site 14 and 15A lack designation (representing a gap in the data). Data extracted from BC Hydro unpubl. data)

Table 5-5: **Companion table to Figure 5-9, indicating Vegetation Community Types (VCTs) found within the potential impact zone of proposed physical works at Cartier Bay.** Each polygon can contain up to three distinct VCTs. VCT 1, VCT 2, and VCT 3 are the primary, secondary, and tertiary VCTs within each polygon respectively. The proportion (%) of each polygon occupied by a given VCT is shown in parentheses. See text for VCT definitions. Data extracted from BC Hydro unpubl. data

Map ID	Polygon	VCT 1 (%)	VCT 2 (%)	VCT 3 (%)	Area (ha)
1500	1292	PC (100)	--	--	0.4922
1586	1250	PC (90)	PE (10)	--	0.9427
1588	1252	PE (90)	PO (10)	--	0.3322
1591	1255	SS (80)	IN (20)	--	0.1017
1592	1256	PO (70)	PC (30)	--	0.6931
1593	1257	SS (80)	PA (20)	--	1.8583
1595	1262	PC (100)	--	--	0.1393
1597	1267	PC (40)	PE (40)	PO (20)	1.4276
1598	1271	PO (60)	PC (40)	--	0.7998
1599	1272	PC (100)	--	--	1.9109
1603	1282	PC (100)	--	--	8.6882
1604	1283	PO (70)	PE (30)	--	1.6556
1605	1285	PC (80)	PO (10)	PE (10)	7.9271
1606	1288	PC (60)	IN (30)	PE (10)	2.0523
1607	1290	PC (90)	PE (10)	--	4.1943
1612	1298	PC (90)	PE (10)	--	3.7921
1614	1301	PC (70)	IN (20)	PA (10)	2.4463
1615	1302	PE (70)	PO (30)	--	0.6579
1616	1304	PO (100)	--	--	4.4333
1618	1309	PO (50)	PC (30)	IN (20)	0.9908
1619	1311	PO (100)	--	--	0.1731
1623	1316	PE (80)	PC (10)	PO (10)	0.6532
1631	1324	PC (90)	PE (10)	--	3.7819
1691	1393	BB (90)	PA (10)	--	0.484
1692	1394	PE (50)	PC (40)	RR (10)	4.2032
1713	1796	PC (50)	BE (40)	PA (10)	0.7944
1930	1282	PC (100)	--	--	8.6882
1932	1263	PC (80)	IN (20)	--	1.9884
1933	1263	RR (80)	IN (20)	--	1.9884
1940	1263	PC (100)	--	--	1.9884
1941	1301	PC (70)	IN (30)	--	2.4463
1942	1293	PC (70)	PE (30)	--	8.3014
1945	1285	PC (80)	PO (10)	PE (10)	7.9271
1946	1250	PC (100)	--	--	0.9427
1947	1257	SS (80)	IN (20)	--	1.8583
1948	1265	IN (90)	PC (10)	--	0.692
1949	1394	PC (40)	BB (40)	PA (20)	4.2032
1950	1394	PO (100)	--	--	4.2032
1951	1394	BG (50)	CR (40)	PC (10)	4.2032

5.4.4.1.3 Species Composition

No comprehensive plant species list has been compiled for the terrestrial portions of Cartier Bay; however, the majority of terrestrially occurring species have been documented during the course of monitoring long-term study plots as part of the ongoing CLBMON vegetation projects (CLBMON 12, 33, and 11B4). These are tabled in Appendix 10-2. Most of these species are uncommon in the potential impact zone, occurring in fewer than 10 per cent of plots sampled from 2008 to 2011 under CLBMON 33, 12, and 11B4 (Figure 5-10). Reed Canarygrass (*Phalaris arundinacea*) is by far the most widely distributed species, occurring in almost 90 per cent of sampled plots. Lenticular Sedge (*Carex lenticularis*) occurs in over 60 per cent of plots, while Columbia Sedge (*Carex aperta*) and Common Horsetail (*Equisetum arvense*) each occurs in over 40 per cent of plots. Other frequently encountered taxa include mosses, Black Cottonwood (*Populus basmifera*), Nodding Chickweed (*Cerastium nutans*), and Marsh Horsetail (*Equisetum palustre*; Figure 5-10). All of these species are relatively widespread in the reservoir. No rare or provincially listed plant Species at Risk are known to occur in Cartier Bay. However, in 2014 the Red-listed species Moss Grass (*Coleanthus subtilis*) was discovered growing on mud flats at low elevations in the DDZ a few km south of Cartier Bay (M. Miller, pers. observation). A thorough survey for this species should be undertaken at Cartier Bay prior to commencement of any physical works. If present, this species, which appears to possess specific hydrological requirements, would likely be negatively impacted by the proposed changes to the current flooding regime (M. Miller, pers. communication).

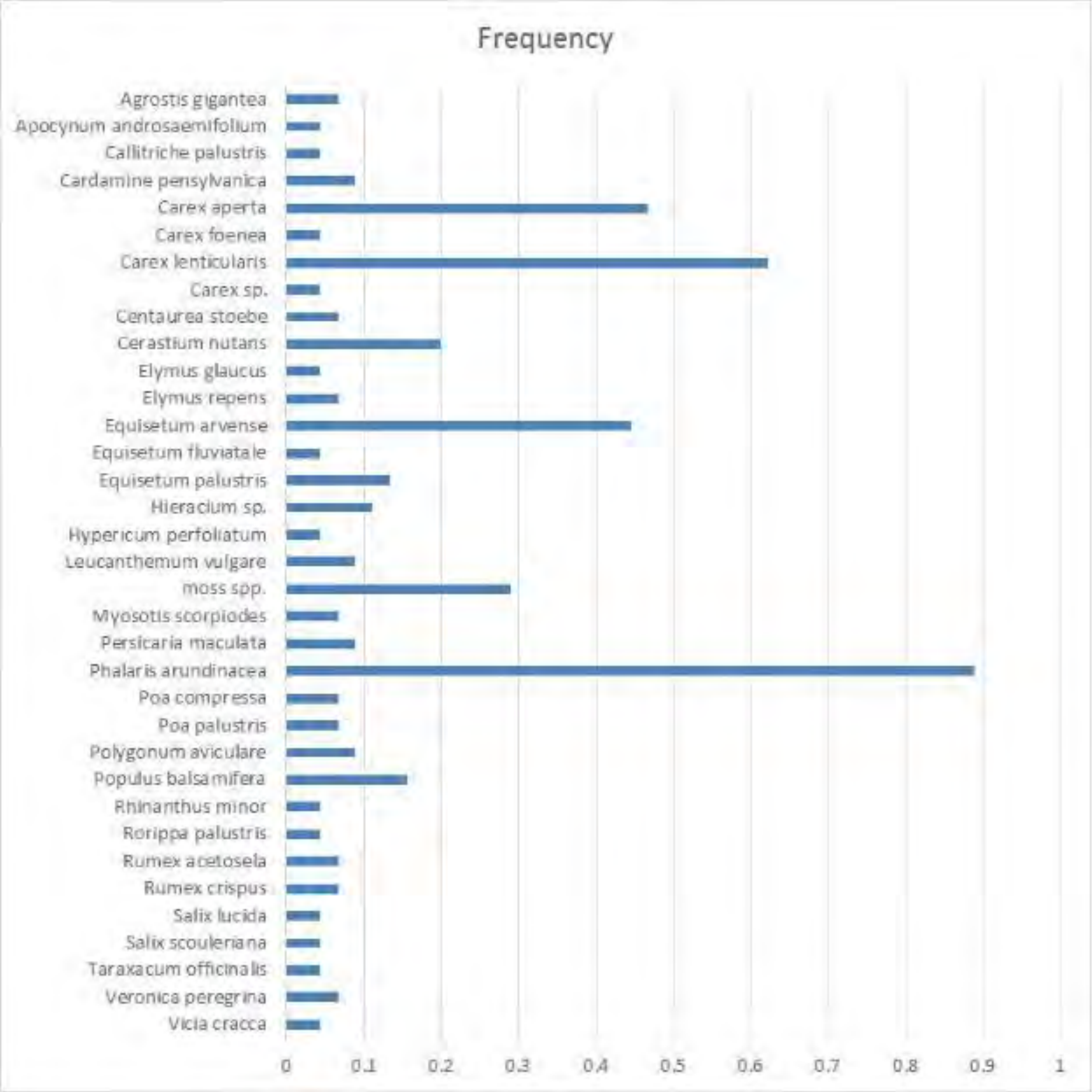


Figure 5-10: Frequency of non-aquatic plant species at Cartier Bay, as measured by their frequency of occurrence within terrestrial/riparian study plots sampled under the BC Hydro vegetation monitoring studies CLBMON 33, 12, and 11B4. For the sake of figure legibility, only those species (of the total list shown in Appendix 10-2) occurring in at least four per cent of sampled plots are displayed

5.4.4.1.4 Vegetation Cover

Some raw (unanalysed) terrestrial plant cover data exist for portions of Cartier Bay, collected as part of reservoir-wide sampling regime under the two projects CLBMON 12 and 33 (Enns and Overholt 2012, 2013 and earlier reports). Because these data collections were designed with much larger areas in mind, the associated sampling methodologies do not take into account required stratification or sample sizes at the scale represented by Cartier Bay. For example, by random chance no sample plots have been assessed within the potentially affected areas immediately adjacent to Site 14. For this reason, we feel the available data cannot be reliably used to extrapolate species-specific cover values for this particular subregion of the DDZ. A general indicator of relative species abundance at Cartier Bay is probably best obtained by reviewing species occurrence frequencies across existing sample plots (previous section).

5.4.4.2 Existing Wetland Zone

The following descriptions apply to that portion of the Cartier Bay flood plain that is inundated throughout the year, and which supports vegetation that can be classified as aquatic or semi-aquatic rather than terrestrial.

5.4.4.2.1 Aquatic macrophytes: Submergent and Floating Vegetation

The composition, distribution, and abundance of aquatic macrophytes in the Cartier Bay wetland were monitored each year from 2010 to 2013 as part of CLBMON 11B4 (Hawkes et al. 2011, Fenneman and Hawkes 2012, Miller and Hawkes 2013, 2014). Vegetation was sampled from an open boat using a combination of floating 1 m^2 quadrats (for floating vegetation) and a rake grapple (for submergents). Sampling was conducted at pre-determined random locations (point intercepts) throughout the wetland. A different set of random locations was sampled each year.

Based on this work, the wetland is known to support eight submergent or floating macrophyte taxa (Figure 5-11; see Appendix 10-3 for more information on selected species autoecology and community roles). In terms of species diversity, this places Cartier Bay at an intermediate level with respect to the other two major wetlands in Revelstoke Reach, Airport Marsh (more diverse) and Montana Slough (less diverse). However, in terms of dominant species covers, evenness of distribution, and average plant biomass, the open water habitat at Cartier Bay is more densely vegetated than the open water habitat at either Airport Marsh or Montana Slough (Hawkes et al. 2011, Miller and Hawkes 2014).

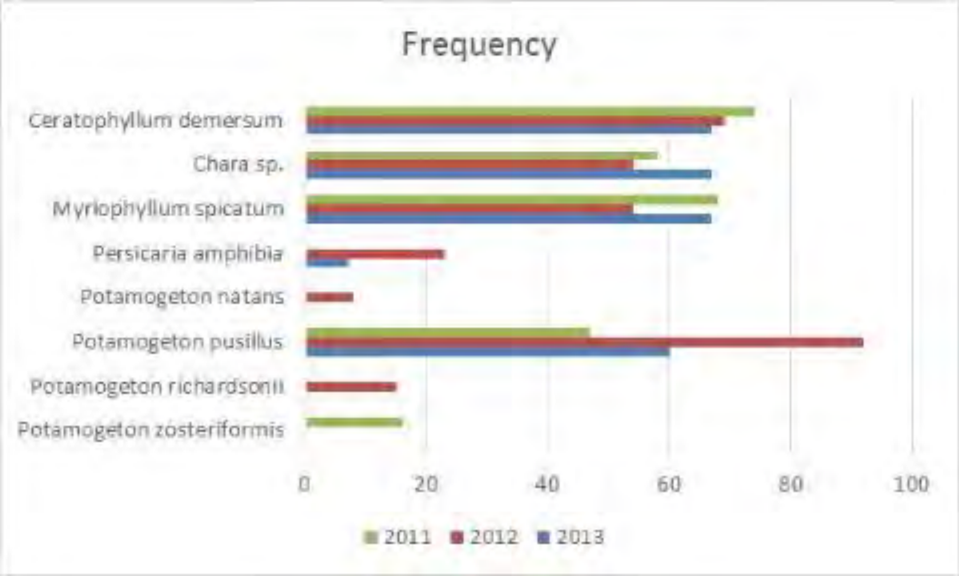


Figure 5-11 **Per cent frequency of aquatic macrophyte species detected in random samples (surface samples and rake grabs) during three sequential years (2011-2013) of May/June boat-based sampling at Cartier Bay wetland (Site 15A)**

The Cartier Bay habitat is characterized by a dense submersed canopy of Common Hornwort (*Ceratophyllum demersum*) and the introduced invasive Eurasian Water-milfoil (*Myriophyllum spicatum*) in the upper water column, with Small Pondweed (*Potamogeton pusillus*) and Stonewort (*Chara* sp.) the dominant species below (and occasionally within) the milfoil-hornwort canopy. Each of these species was typically present in 50 to 70 per cent of point intercept samples recorded over the three years (Figure 5-11). Other pondweeds (Richardson's Pondweed and Eelgrass Pondweed) made up the remaining submersed flora and were encountered at lower rates. The current dominance of the four commonest species could be inhibiting the spread of these species as well as the establishment of other submergents.

Two floating-leaved species, Water Smartweed (*Persicaria amphibia*) and Floating-leaved Pondweed (*Potamogeton natans*) form scattered beds on the water surface but in terms of relative frequency are rarely dominant (Figure 5-11). This contrasts with Airport Marsh, where the floating macrophyte community is relatively well developed with numerous large but patchily distributed beds of Water Smartweed, Floating-leaved Pondweed, and Rocky Mountain Pond-lily (*Nuphar polysepala*). At Cartier Bay, the fast rising the ALR water levels during the spring growing season likely prevents the establishment of extensive floating macrophyte beds. Here, it appears the rooted stems cannot elongate quickly enough to keep pace with rising water levels, leaving the upper leafy portions of developing plants inundated before they can form a surface bed (Miller and Hawkes, 2014).

5.4.4.2.2 Cover and Distribution

Many macrophyte occurrences at Cartier Bay are at depths > 1-2 m in turbid water, making it very challenging to obtain visual point cover estimates from the surface. For this reason, cover and abundance estimates have been made indirectly using rake grapple grabs (Hawkes et al. 2011). Fenneman and Hawkes (2012) derived a metric, VC (volume x cover) that considered both the relative cover and sample volume of each species as estimated by rake grabs at each sample point. VC analyses for the four commonest submergents (Eurasian Water-milfoil, Common Hornwort, Stonewort, and Small Pondweed) indicate that these submergents tend to be patchily distributed at the local scale within in the wetland, but that overall abundances for each species do not vary much on an annual basis (Miller and Hawkes 2013, 2014). Moreover, there has been no notable turnover (losses or additions) of species since 2010 (the failure of some relatively uncommon pondweeds, such as Richardon's Pondweed, to appear in all survey years is likely due to random chance associated with the sampling design). In other words, it appears that the structure and composition of the macrophyte community at Cartier Bay is being maintained by current operations in relatively stable state at least on a short term (e.g., three to five year) time scale.

Distribution maps for each macrophyte species recorded at Cartier Bay (Appendix 10-4 to Appendix 10-11) show that, for most species, cover tends to be concentrated in the southern portion of the bay, on either side of the old highway grade. The exception is Small Pondweed, which is distributed throughout the wetland but with highest local abundance in the northeast arm of Cartier Bay (Appendix 10-8). Eurasian Water-milfoil has a similar distribution pattern to Common Hornwort, with greatest concentrations in the south arm, but has a lower local density than Common Hornwort (Appendix 10-4, Appendix 10-5). In terms of overall sample frequency combined with local abundance and extent of distribution, the dominant macrophyte species in the wetland appears to be Common Hornwort, followed by Stonewort ((Appendix 10-4, Appendix 10-6).

5.4.4.2.3 Substrate

The benthic substrate supporting macrophyte growth in the Cartier Bay wetland is a mix of soft (largely anaerobic) organic sediment (i.e. "muck"), sand, and coarse organic detritus, with the former material prevailing in most portions of the wetland (Hawkes et al. 2011, unpubl. data). No formal soil nutrient assays have been undertaken to date.

5.5 Analysis 5: Cartier Bay Wildlife

5.5.1 Birds

5.5.1.1 Research Summary

Bird data was primarily collected under three WLR monitoring programs: CLBMON-40, CLBMON-11B-2, and CLBMON-36.

Source project data: CLBMON-40 (waterfowl)

CLBMON-40 is an ongoing wetland bird project that has generated considerable data on waterfowl abundance during the spring and fall migrations (CBA 2013a). There were two types of waterfowl survey data from this study that were examined in this report: aerial and land-based surveys.

Aerial waterfowl surveys were used to monitor waterfowl abundance over the entire DDZ of Revelstoke Reach. Each aerial survey attempted to conduct a complete census of waterfowl and partition abundance into polygons previously delineated on a map. Aerial surveys occurred sporadically during the spring and fall migration, with the goal being to make observations evenly over a wide range of reservoir elevations, during both migrations. For this study, we used aerial data only to assess the proportion of waterfowl counted in the Cartier Bay wetland, compared with other wetlands, and elsewhere within Revelstoke Reach.

Land-based waterfowl surveys occurred on a weekly schedule from September through May each year, and twice per week during the brood-rearing season (June 15 through July). Waterfowl were identified to species, counted, and mapped from fixed observation stations at Airport Marsh, Montana Slough, Cartier Bay, and several smaller wetlands in Revelstoke Reach. Because these surveys occurred often and regularly, and monitored the most populated wetland sites, the data were appropriate for assessing temporal variation in abundance. Land-based survey data also provided the most detailed account of usage at Cartier Bay in terms of numeric variation and species composition. In this study, we used the most current dataset (August 2014) to (1) document the biodiversity of waterfowl, (2) to model temporal variation in waterfowl abundance throughout the year, and (3) for assessing distributions of waterfowl within the Cartier Bay wetland area.

In addition to monitoring waterfowl at Cartier Bay, CLBMON-40 also monitored usage by Northern Harriers, and Short-eared Owls, and conducts nest searches for Bald Eagle and Osprey in the nearby forest. CLBMON-40 also monitored shorebird migration in the fall, but not at Cartier because this site is typically under water during the fall migration.

CLBMON-40 was initiated late in the spring of 2008, but the data collection was adjusted and formalized in 2009. In most cases, data considered in this report spans from spring of 2009 through summer of 2014. Further detail on the CLBMON-40 data collection is detailed in several reports (CBA 2013a, 2014a p. 40).

Source project data: CLBMON-11B-2 (spring migration of songbirds)

CLBMON-11B-2 was a WLR project that focussed on the effectiveness monitoring of wildlife physical works and revegetation with respect to the spring migration of songbirds in Revelstoke Reach. Monitoring at the Cartier Bay wetland included two types of weekly sampling: shoreline transects around the edge of the main Cartier pond (CBA 2011a), and plot sampling within the Site 14 footprint (CBA 2010).

The **shoreline transect** surveys were designed specifically to monitor usage of the main Cartier wetland shoreline by migrating songbirds with the intent that these data could be compared with similar data collected after the Site 15A project altered the shoreline habitat. Shoreline transect sampling took place during the 2011 spring songbird migration (April 28 to June 8). The encounter transect surveys followed the inner (northern/western) shoreline of the Cartier Bay wetland. One observer walked slowing along the water's edge and documented all birds detected, except waterfowl and birds flying overhead. An attempt was made to not double-count birds - this issue could be easily identified when birds flushed and landed a short distance down the shoreline, but this was an uncommon occurrence, and it was our impression that double counting was not a large source of error in our counts. Waterfowl were not recorded because they were not the focus of the study, were numerous, and were being monitored by CLBMON-40. These detections were mapped in the field by marking way points in a hand-held GPS, and noting the bearing and distance from the observer. The observer also documented whether birds were within 1, 5 or 10 m of the water's edge.

Plot sampling occurred in Site 14 footprint area. During the 2010 spring migration (April 21 - June 2, or 7 weeks), weekly songbird sampling occurred at 15 fixed plots (each 50 m x 50 m) located within the Site 14 footprint area (CBA 2010). Each plot was monitored for 5 minutes on each of 7 occasions (7 occasions X 5 minutes X 15 plots = 8.75 hours of observation). All bird species were recorded, including those flushed from the plots upon approach.

Source project data - CLBMON-36 (nesting birds)

CLBMON-36 is an ongoing project monitoring birds nesting in the Revelstoke Reach DDZ. CLBMON-36 has specifically monitored sites at the Cartier Bay wetland and surrounding area. Because the Cartier basin floods early in the breeding season, there are very few nesting records. CLBMON-36 data therefore have low relevance to this exercise, but general knowledge of the nesting community is reviewed. In this report, we do not directly analyze data from CLBMON-36, but the project has provided considerable knowledge of the wetland with respect to its value as a breeding habitat. CLBMON-36 was initiated in 2008 and is on-going. Further detail on the CLBMON-36 data collection is detailed in several reports (CBA 2013b, 2014b).

GIS analysis of waterfowl distribution

Land-based survey field map polygons/points were individually digitized in Google Earth following field surveys, and batch converted into shapefile polygons (or points) using a python script with cross-referencing to the quantitative data on species composition and bird abundance. To examine how waterfowl distributions were impacted by water levels, we considered three groups of birds that were the most abundant type of waterfowl at the Cartier Bay wetland (Canada Goose, diving ducks, and dabbling ducks), and two habitat conditions. The first habitat condition (control; n = 85 survey occasions) was when the Cartier Bay wetland was not impounded or affected in any direct way by reservoir operations; the second habitat condition (treatment; n = 18 survey occasions) was when the Arrow Lakes Reservoir water surface elevation was greater than the Cartier Bay wetland elevation (433.8 m ASL) but less than the elevation of water proposed for the Site 15A project (434.75 m ASL).

Raster generation was performed by spatially joining each occasion (for each guild) to a 10m grid and assigning the point attribute to each cell. This 10m grid was then converted to a raster, with the value field being the number of birds represented by each point. The resulting rasters were then summed together to give the total number of birds using each 10m cell for flooded vs non-flooded conditions.

Statistical modelling of waterfowl count data

To assess the use of the Cartier Bay wetland by waterfowl and its importance in this respect, we focussed on diving ducks and dabbling ducks for the quantitative analysis. These two guilds of waterfowl were chosen because they were shown to select the Cartier Bay wetland as a stop-over site, and because the Site 15A project was designed to increase habitat for these two groups of birds (Golder Associates 2009).

Count data were analyzed with two models. (1) Seasonal abundance was estimated to assess timing of migrations, and control for this factor in other analyses. This non-linear function was estimated using a General Additive Model (GAM), fit using the gam() function from the mgcv package (Wood 2001). When modelling seasonal abundance throughout the year, a cyclical quadratic smoothing spline was specified to assure that counts estimated at the year's end were similar to counts estimated at the year's beginning. (2) We examined the effect of reservoir inundation (water depth) on counts to determine if reservoir operations impacted waterfowl counts. For this second model, the predicted counts from the seasonal model (above) was included as a covariate to control for time of year. We modelled our count data with negative binomial error distributions, and in all cases found no evidence of over-dispersion.

5.5.1.2 Key Findings

The existing Cartier Bay wetland is the most important wetland in Revelstoke Reach for migrant waterfowl

With the exception of diving ducks in the fall, the Cartier Bay wetland was the most utilized wetland by waterfowl (Figure 5-12). Cartier was highly important for dabbling ducks in both migrations, and for Canada Goose in the fall (Figure 5-12).

A high diversity of birds use the existing Cartier Bay wetland

The land-based waterfowl surveys resulted in observations of 31 waterfowl species including 10 dabbling duck, and 11 diving duck species at Cartier Bay (Appendix 10-12). Canada Goose was the most numerous waterfowl species (46%) followed by American Wigeon (29%), Mallard (10%), Common Merganser (3%), Ring-necked Duck (2%), and Green-winged Teal (2%). In addition to the waterfowl species recorded during surveys, Ross' Goose has been observed at Cartier Bay.

Ten species of shorebird have been observed at Cartier Bay. Killdeer and Spotted Sandpiper were most commonly noted shorebirds, both known to breed in the vicinity. Other shorebirds occasionally observed include Greater Yellowlegs, Lesser Yellowlegs, Solitary Sandpiper, Pectoral Sandpiper, Least Sandpiper, Long-billed Dowitcher, Wilson's Snipe and Semipalmated Plover.

Great-blue Heron were commonly observed at Cartier Bay, and was the only wading bird noted during waterfowl surveys; however, both Sandhill Crane and White-faced Ibis have been observed at a pond associated with the Cartier Bay wetland near 6 Mile (pond 8 in Figure 5-19).

Osprey have been regularly seen foraging at the Cartier Bay ponds, and Bald Eagle to a lesser degree. During migration, Northern Harrier and Short-eared Owl have been occasionally observed foraging at Cartier when the grasslands are exposed, but these species are more commonly found in other parts of Revelstoke Reach.

American Pipit commonly foraged along the shoreline of the Cartier ponds during the spring migration (see below); this species, and Savannah Sparrow are both known to forage in the Cartier basin grasslands during their migrations. The airspace above the Cartier Bay wetland is heavily used by aerial insectivores during the spring migration (e.g., Vaux's Swift, Tree Swallow, Violet-green Swallow, Northern Rough-winged Swallow, etc.).

During the early breeding season, Killdeer, Savannah Sparrow and Spotted Sandpiper commonly utilize the Cartier basin, prior to inundation by the Arrow Lakes Reservoir. Other species that have been noted using the Cartier area include Belted Kingfisher, and Turkey Vulture.

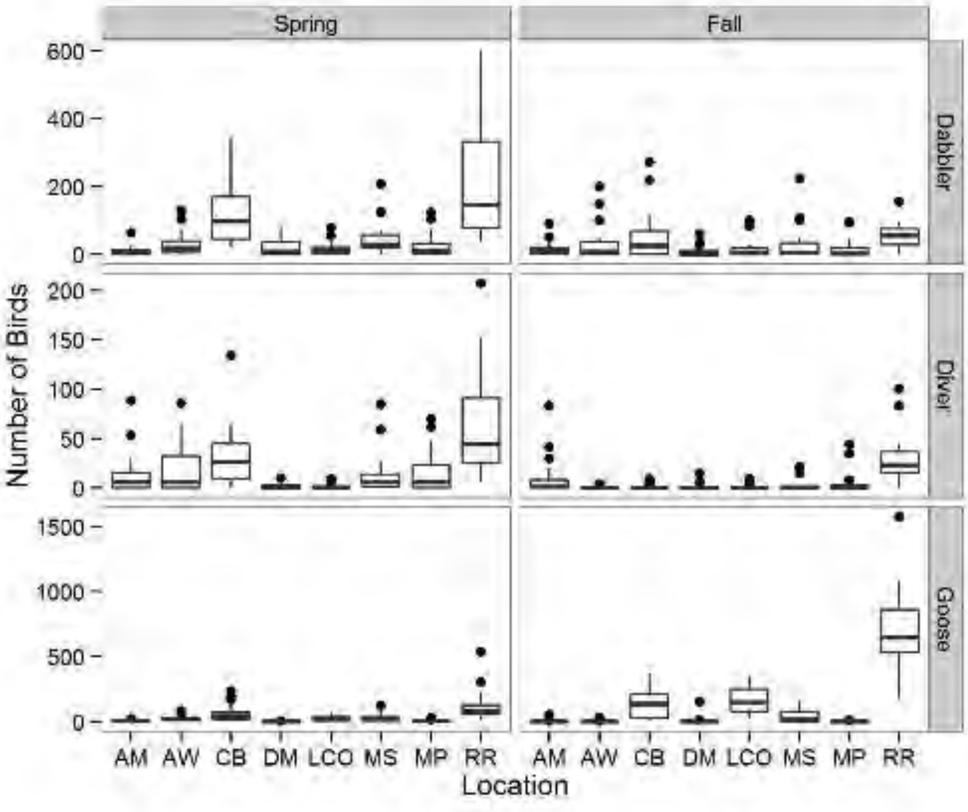


Figure 5-12: Numbers of waterfowl counted during complete aerial census counts throughout Revelstoke Reach. The 'Diver' category includes all diving ducks (merganser, scaup, goldeneye, scoter, etc.). The 'Goose' category is primarily comprised of Canada Goose but also includes Cackling Goose. Each location is a distinct wetland area: AM = Airport Marsh, AW = Airport West, CB = Cartier Bay,

DM = Downie Marsh, LCO = Locke's Creek Outflow, MS = Montana Slough, MP = Machete Ponds, RR = all other parts of Revelstoke Reach

Spatial distribution of waterfowl

The mapping of waterfowl distribution showed widespread use of the Cartier Bay pond (Figure 5-13). When reservoir elevations were between 433.8 and 434.75, dabbling ducks continued to concentrate in the permanent ponded area, but their distribution within the pond shifted away from the deepest parts of the pond (Figure 5-13). Diving ducks were uncommonly observed when the wetland was impounded (Appendix 10-13).

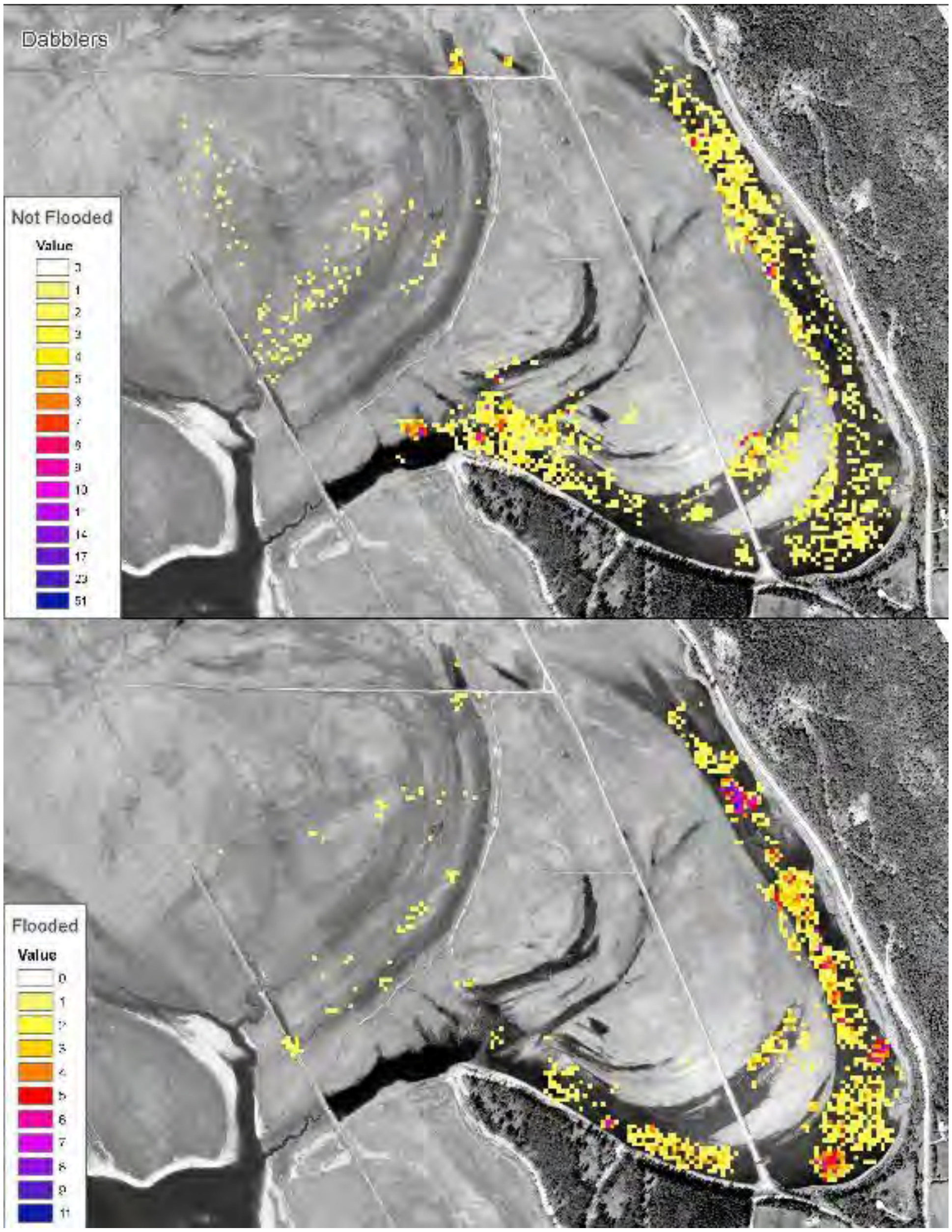


Figure 5-13: **Mapped distribution of dabbling ducks in conditions unaffected by reservoir operations (top) and when reservoir elevations are between 433.8 and 434.75 (bottom)**

Seasonality - timing of duck migrations in Revelstoke Reach

The seasonal modulation of waterfowl counts was similar in timing for dabbling and diving ducks (hereafter 'ducks'), and the data were pooled to estimate one cyclical quadratic smoothing spline of seasonality estimated with a negative binomial error distribution (Model.1; Figure 5-14).

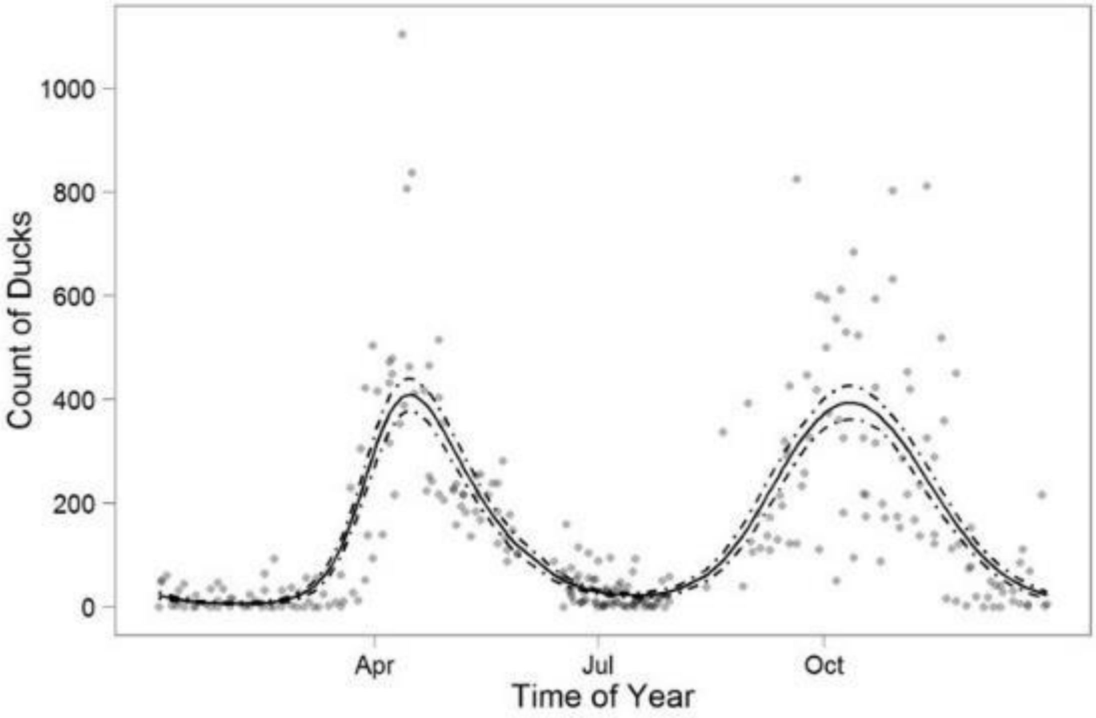


Figure 5-14: Negative binomial cyclical GAM (Model.1) estimating counts (± SE) of ducks (diving and dabbling ducks) at the Revelstoke Reach wetlands observed over 6.5 years. The count data are plotted in the background

Spring Migration: ice, not reservoir operations, impact use by ducks

In six years of monitoring where ice cover was noted at Cartier Bay, the date when Cartier Bay wetland was first observed to be ice-free varied over a span of 26 days, depending on the year, with the earliest break-ups occurring in 2010 and 2013, and the latest in 2009 and 2011. Duck counts were minimal prior to ice break up, but the date of peak migration of these birds occurred shortly after open water was present, often before the ice-free date, (Figure 5-15). The reservoir did not influence the Cartier Bay wetland until a month or more after the migration peaked (Figure 5-15). There were insufficient data to assess whether the timing of the spring thaw influenced the total amount of usage of the Cartier Bay wetland during the spring migration. Figure 5-16 provides a visual of ducks and geese on Cartier Bay on March 30, 2012, which correlates well with data presented in Figure 5-15.

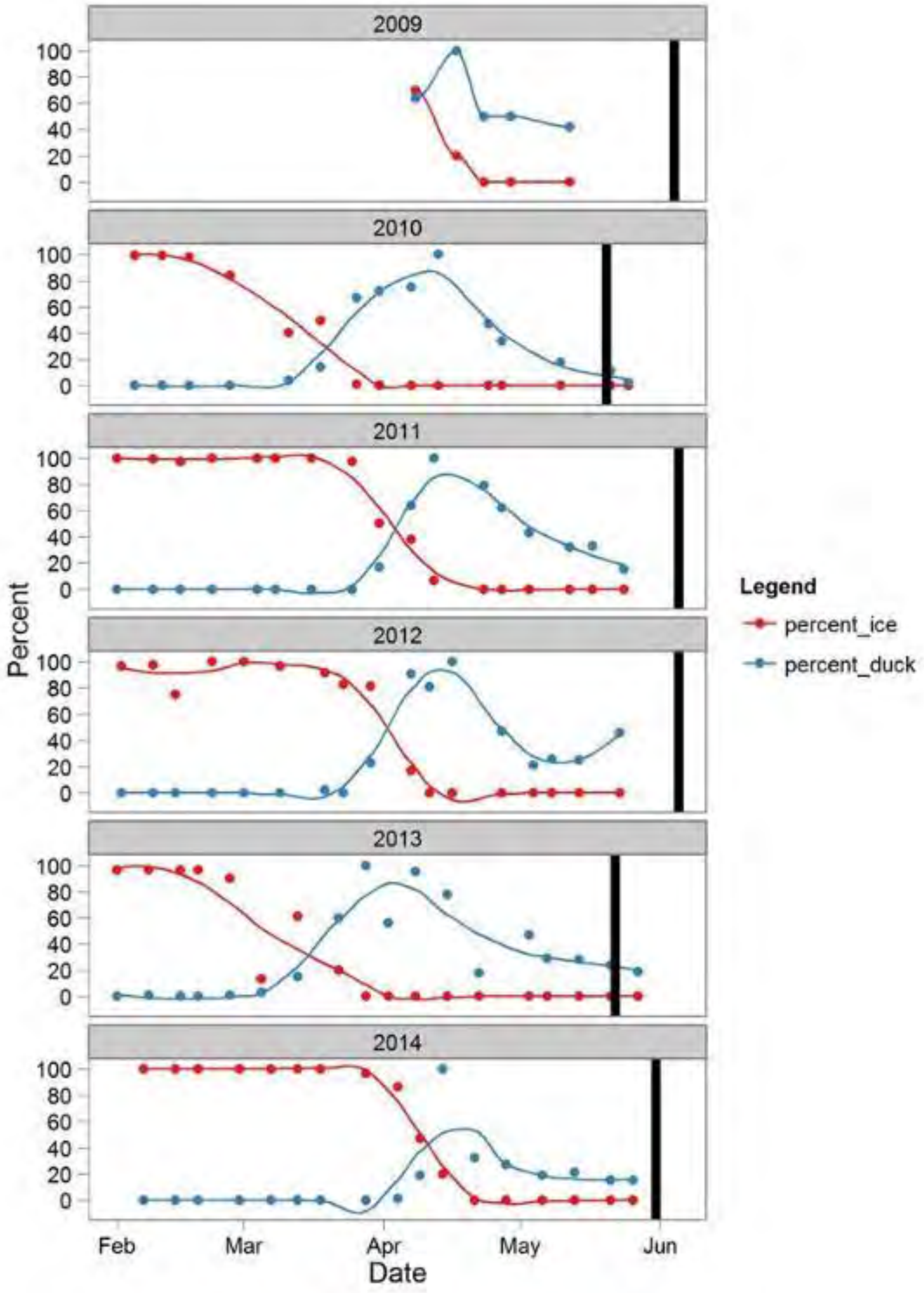


Figure 5-15: **The percentage of ice cover at the Cartier Bay wetland and the observed percentage of the annual maximum number of recorded ducks is graphed over time for each year of study.** The date when the ALR first exceeded 433.8 m ASL is plotted as a black line (typically after the spring survey season). Loess smoothers are plotted to aide interpretation

Figure 5-16: **Ducks and Geese in the shallows area of Cartier Marsh (east side) near Airport Road on March 30, 2012 (photos by Francis Maltby)**

Fall Migration: Reservoir operations and duck abundance

To test the effect of water depth on dabbling duck counts, during the fall migration, we considered data between September 1 and November 30. To control for the intensity of migration, we included the fit from the seasonal model (using the predict () function on Model.1 above), in addition to the main effect of water depth. The GLM model was fit with a negative binomial error distribution (Model.2), which showed strong declines in duck counts associated with increasing water depth at the Cartier Bay wetland (β = -0.79, $p < 0.0001$; Figure 5-17).

While Model.2 suggests that the greatest change in dabbling duck abundance occurs at water elevations lower than that suggested for Site 15A (left of vertical line - Figure 5-17), re-fitting Model.2 with the subset of data taken when the ALR elevation was less than 434.75 resulted in loss of significance for the effect of water depth.

We then re-fit this model for diving ducks, but the effect of water depth was non-significant.

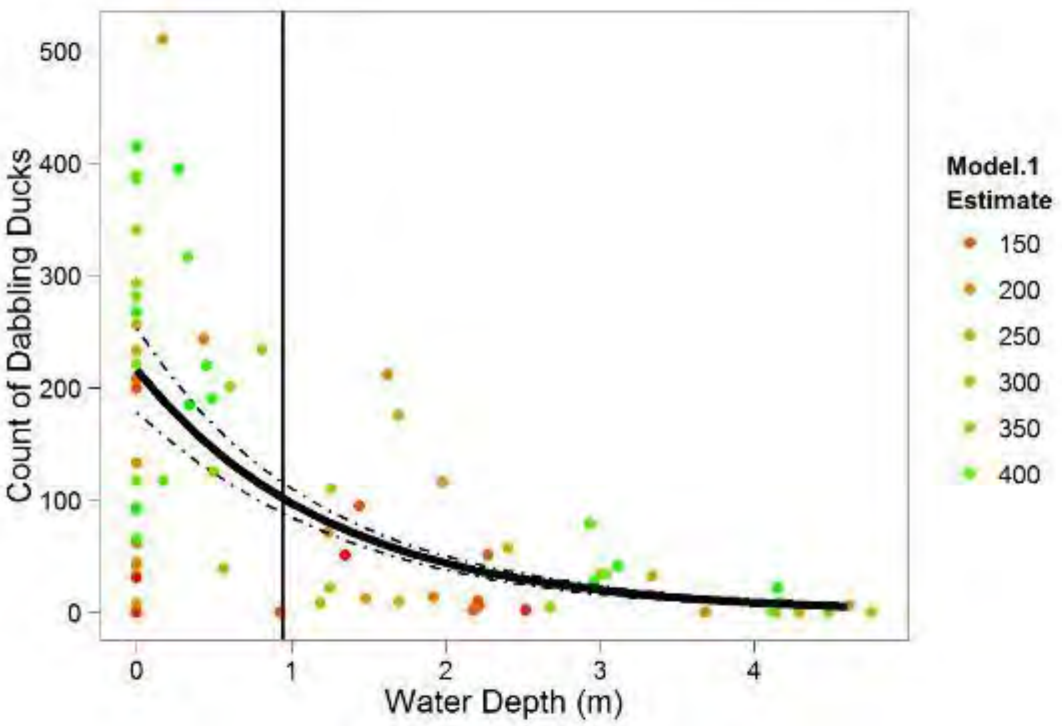


Figure 5-17: Impact of reservoir water depth over the Cartier Bay wetland on count of dabbling ducks predicted with a negative binomial GLM (Model.2) controlling for seasonal abundance (Model.1 Estimate). The estimate (± SE) illustrated was calculated assuming migration at moderate intensity (mean Model.1 Estimate). Raw data are plotted with colour indicating their timing with respect to migration (Model.1 Estimate). The vertical line represents water levels at 434.75 m ASL

Spring Songbird Migration: the existing shoreline is important for American Pipits

Seven shoreline encounter transects in spring of 2011 documented eight bird species utilizing the shoreline of the Cartier Bay wetland. American Pipit (AMPI) was the most numerous of these species, accounting for 94.5% of these records (988 birds over 7 surveys). Following AMPI, Killdeer where most commonly observed (19 records) followed by one observation of 12 Least Sandpipers, Spotted Sandpiper and Wilson's Snipe (5 records each), Savannah Sparrow (4 records), Dowitcher (2 records), and Lesser Yellowlegs (1 record). Five unidentified shorebirds, and five unidentified sparrows were also counted.

AMPI records peaked in early May and the species was not recorded after May 19 in these surveys (Figure 5-18). All detections were classified as being within 1 m of the water's edge, within 5 m of the water's, within 10 m of water's edge, or greater. For AMPI, 193 (20%) were located within 1 m of the shoreline, 404 (41%) were detected within 5 m, and 649 (66%) were detected within 10 m of the shoreline; the remaining 339 AMPI (34%) were detected in the grass > 10 m from the water. A buffer of 1, 5 and 10 m was used to calculate density for AMPI on each survey occasion, indicating well more than double the density of AMPI within 1 m of the shoreline (Figure 5-18).

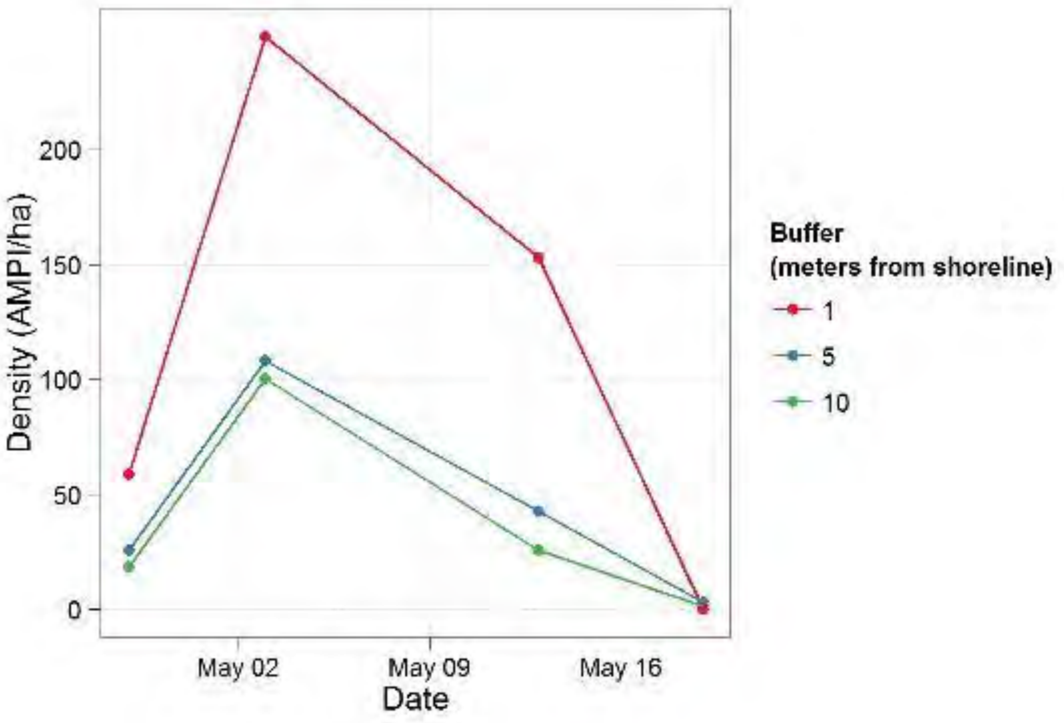


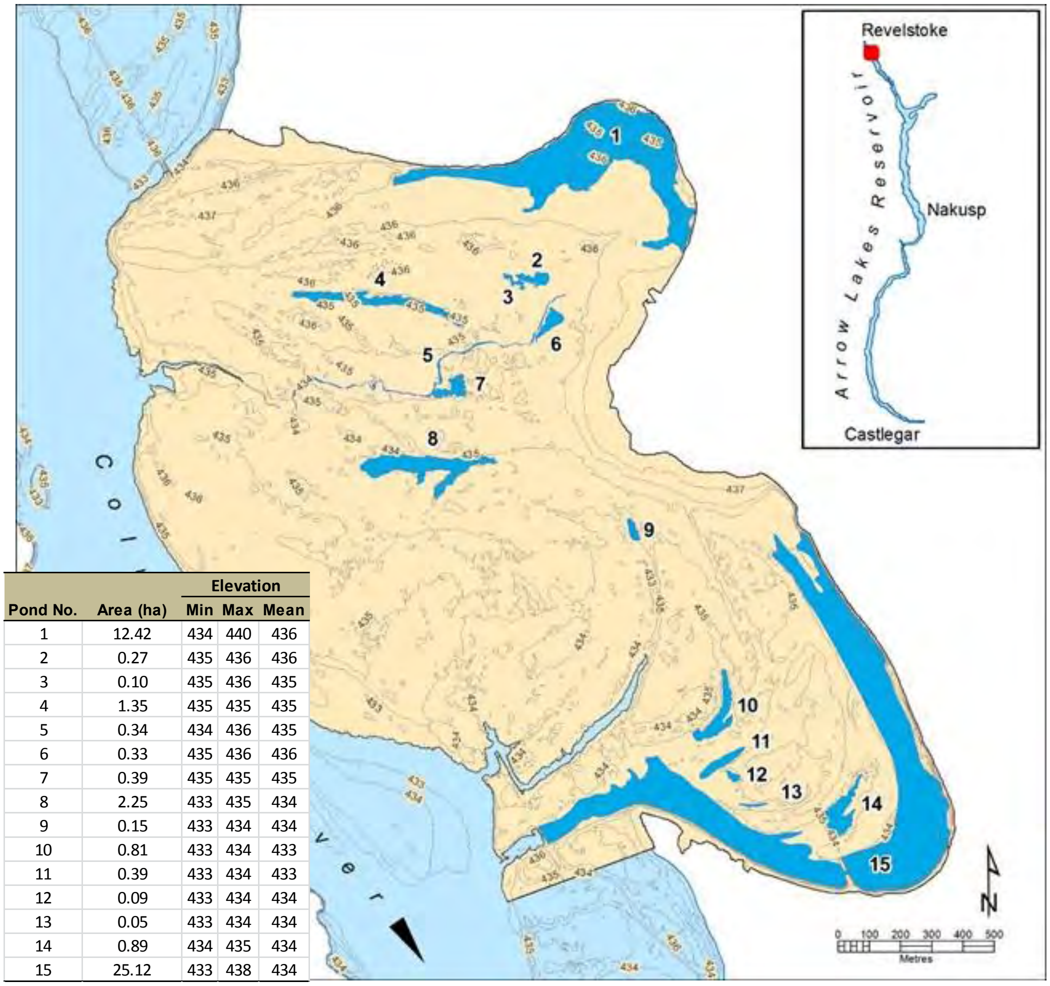
Figure 5-18: **Density of American Pipits (AMPI) calculated over three buffer widths along the shoreline of the main Cartier Bay wetland.** These data show higher densities near-shore (1 m) indicating selection for the shoreline that is proposed to be inundated by the Site 15A project

Very few birds were documented at the Site 14 impoundment. After 7 weeks of monitoring at 15 plots, four species were observed. American Pipet was the most common species (5 observations, 19 total), followed by Savannah Sparrow (13 total), Mallard (5 total), and Sora (1 total). The density of birds documented on each occasion varied from 0.2 to 4.2 birds per ha during these surveys, with peak densities being observed in late April and early May.

5.5.2 Amphibians and Reptiles

Pond-breeding amphibians use the DDZ of the ALR. Small, isolated wetlands can be critical to the persistence of amphibians with complex life cycles (Hopkins 2007). In the spring, these species migrate to ponds, breed, lay eggs, and then move into their spring and summer foraging habitat. In some locations, ponds are common features in the DDZ of ALR and are affected on an annual basis to varying degrees by reservoir operations depending on the elevation at which they are situated. The location, distribution (relative to elevation), and number of ponds available in the DDZ has been mapped for the Cartier Bay / Montana Slough region of Revelstoke Reach (Figure 5-19). The ponds mapped in this area range in size from 0.05 ha to 25.1 ha ($\bar{x}$ = 2.99; SD = 6.86 ha; Figure 5-19). Most of the pond area (~64 per cent, 28.8 ha) is situated at ~433 m ASL, an additional 30 per cent (13.6 ha) at 434 m ASL and ~ 5 per cent (~2.5 ha) at 435 m ASL. The elevation at which these habitats occur is such that all are available to amphibians for breeding in the spring.

Wetland size is a poor indicator of amphibian and reptile diversity (Gill 1978; Hecnar and M'Closkey 1996; Snodgrass et al. 2000). A majority of wetlands are small (< 4 ha) and are typically a critical source of juvenile amphibians (Semlitsch and Brodie 1998). Research has emphasized the value of small (0.2 to 0.3 ha), temporal ponds for several amphibian species (Semlitsch and Brodie 1998; Snodgrass et al. 2000; Wind 2002) and for providing amphibian diversity (Semlitsch et al. 1996; Snodgrass et al. 2000). Furthermore, the shorter/more variable hydroperiod of small wetlands may support unique species that are absent from larger, permanent wetlands (Snodgrass et al. 2000). Smaller wetlands that periodically dry provide reduced predator pressure from fish and invertebrates, which prey on larval amphibians (Semlitsch 2002). Additionally, small wetlands are important for breeding and dispersal of many amphibians (Semlitsch and Brodie 1998). Given the relationship between wetland size, hydroperiod, predator pressure, and amphibian richness, it is important to consider whether the proposed changes to Cartier Bay will influence current carrying capacity and habitat quality for amphibians.



		Elevation		
Pond No.	Area (ha)	Min	Max	Mean
1	12.42	434	440	436
2	0.27	435	436	436
3	0.10	435	436	435
4	1.35	435	435	435
5	0.34	434	436	435
6	0.33	435	436	436
7	0.39	435	435	435
8	2.25	433	435	434
9	0.15	433	434	434
10	0.81	433	434	433
11	0.39	433	434	433
12	0.09	433	434	434
13	0.05	433	434	434
14	0.89	434	435	434
15	25.12	433	438	434

Figure 5-19: Delineation of 15 ponds in the drawdown zone at Cartier Bay (pond 15) and Montana Slough (pond 1). The ponds delineated are based on 2011 imagery (figure from Hawkes and Tuttle 2013)

Amphibians and reptiles use habitats situated between ~431 m ASL and 440.1 m ASL (i.e., the normal operating range) of the ALR, but they are not confined to this area, occupying habitats at elevations approaching 452 m ASL (Figure 5-20). Western Toads (ANBO) have been documented from elevations ranging from 431 m ASL to >450 m ASL.

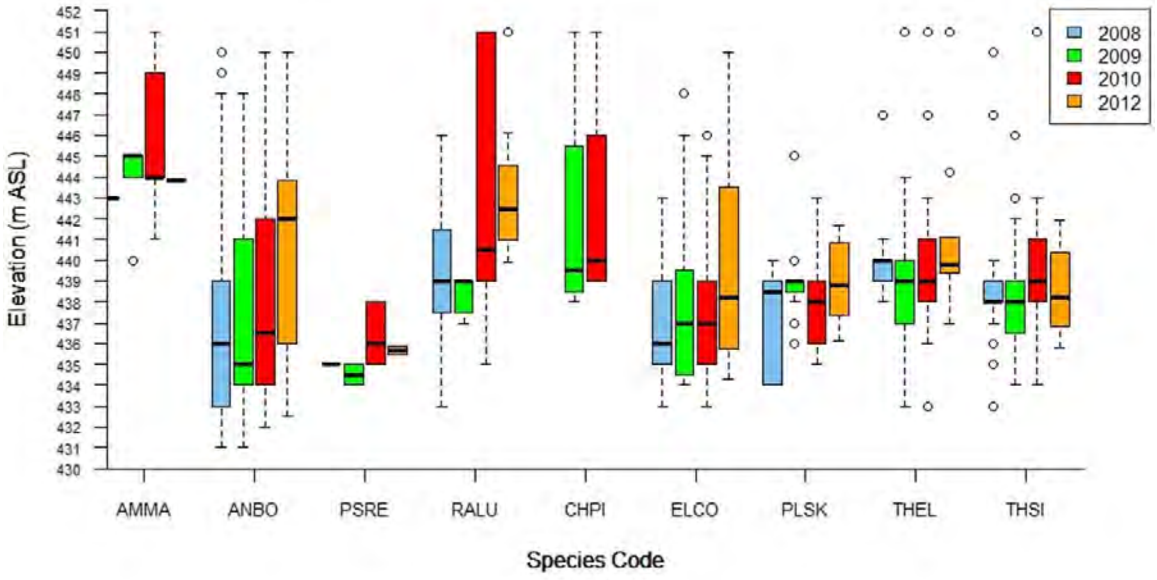


Figure 5-20: **Distribution of amphibians and reptiles (all life stages) relative to elevation and year in and adjacent to the DDZ of Arrow Lakes Reservoir.** AMMA = *Ambystoma macrodactylum*; ANBO = *Anaxyrus boreas*; PSRE = *Pseudacris regilla*; RALU = *Rana luteiventris*; CHPI = *Chrysemys picta*; ELCO = *Elgaria coerulea*; PLSK = *Plestiodon skiltonianus*; THEL = *Thamnophis elegans*; THSI = *Thamnophis sirtalis*

5.5.2.1 *Western Toad*

Western Toads use Cartier Bay during the spring, summer, and fall with most use associated with the spring breeding season. Cartier Bay is one of the more important sites within the DDZ of the ALR for toads as it provides important shallow water breeding habitat (water < 50 cm deep). Although it is difficult to quantify the use (in terms of the number of individuals using the area), large numbers of egg strings (in the 100's) are observed annually and while a population estimate has been difficult to obtain, we counted approximately 40 pairs of toads in amplexus in 2014 (that represents the maximum count made on one night). Large aggregations of Western Toad toadlets have been observed in Cartier Bay in all years of monitoring associated with CLBMON-37 (2008, 2010, 2012, and most recently, 2014).

Telemetry conducted in 2014 indicates that adult toads use Cartier in the spring, breed, and remain in the area for approximately 2 weeks (LGL/ONA unpublished data). Following this period, adult toads migrate from Cartier Bay to adjacent upland habitats to the north, east, and south. There is evidence to suggest that some adult toads return to the Cartier Bay area in August. Western Toads are not likely to overwinter in the DDZ, instead selecting upland forested sites for overwintering. Habitat upslope from Cartier Bay is considered to be suitable for overwintering and telemetry data collected in 2014 support this hypothesis. However, overwintering locations have not been verified.

5.5.2.2 *Western Painted Turtle*

The Western Painted Turtle (*Chrysemys picta belli*) is a provincially blue-listed species and the intermountain population is listed as Special Concern under Schedule 1 of SARA (COSEWIC

2006). During the Columbia River Water Use Plan (WUP), the Western Painted Turtle was identified as a species that may be vulnerable to fluctuating water levels resulting from operations of the ALR (BC Hydro 2005). The population that occurs near Revelstoke, BC is one of the most northern populations and has regional importance (Schiller and Larsen 2012a and 2012b; Maltby 2000). Furthermore, the Western Painted Turtle was identified as a species that may benefit from habitat enhancement via physical works (Golder 2009a and 2009b).

Western Painted Turtles are found in shallow water ponds, lakes, sloughs, and slow-moving streams or rivers (e.g., the Columbia River). Like many aquatic reptiles they require three types of habitats corresponding to their life history needs. These include: 1) summer habitat with muddy substrates, an abundance of emergent vegetation, and numerous basking sites; 2) nearby nesting habitat with loose, warm, well-drained soils; and 3), aquatic overwintering habitat that does not freeze to the bottom or become severely hypoxic (COSEWIC 2006).

Turtle occupancy and detection rates are low for Cartier Bay

Few turtles have been observed using Cartier Bay in the past four years of the CLBMON-11B3 study. The turtle population of Revelstoke Reach has been monitored in three DDZ sites: Airport Marsh, Montana Slough, and Cartier Bay. Through the use of radio-telemetry, we have tracked turtle movements year-round in the study area and no turtles were found to consistently use Cartier Bay. In fact, observations of turtles in Cartier Bay have been uncommon (five observations of three individual turtles) and sparse (only in June 2011 and August 2013), amounting to only 0.2% of all turtle observations (Figure 5-21). Additionally, turtle detections were an order of magnitude lower at Cartier Bay than adjacent sites, when detections were standardized per unit of effort (Table 5-6).

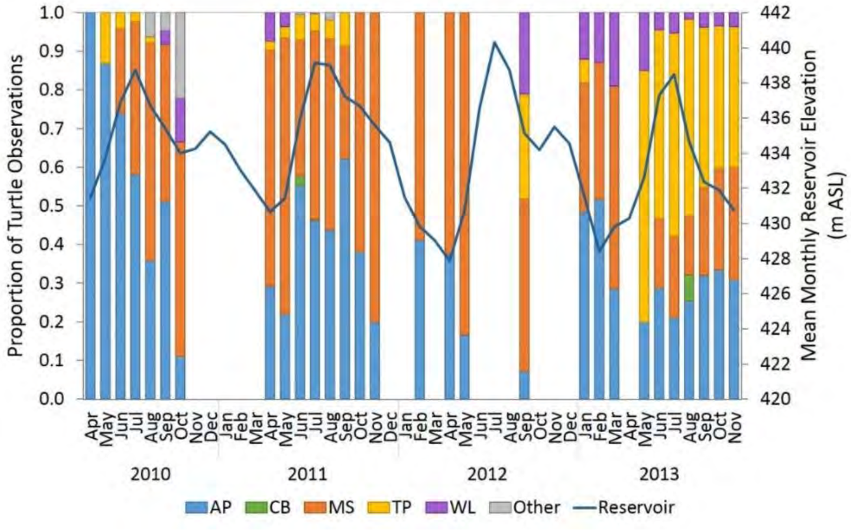


Figure 5-21: Proportion of turtles occupying each site from April 2010 to November 2013 (bars) with corresponding mean monthly reservoir elevation (line). AP= Airport Marsh, MS= Montana Slough, TP = Turtle Pond, WL = Williamson Lake, CB = Cartier Bay, Other = sites not visited in current year (Robs Willow, 9-Mile, 12-Mile, McKay Creek). Data from visual encounter surveys, traps, and telemetry surveys combined

Table 5-6: **Western Painted Turtle detections by site for the 2013 telemetry session.** Catch per unit effort is given per survey (CPUEsurvey) and per hour of telemetry survey (CPUEhour)

Site	No. of Turtles	No. of Surveys	No. of Survey Hours	CPUE$_{\text{survey}}$	CPUE$_{\text{hour}}$
Airport Marsh	59	12	49.97	4.917	1.181
Cartier Bay	2	5	10.92	0.400	0.183
Montana Slough	47	12	46.23	3.917	1.017

The low site occupancy and detection rate for Western Painted Turtles at Cartier Bay compared to neighboring Montana Slough (~2 km north) suggests that the habitat may have low suitability in its current state. This could be due to landscape-level factors (e.g. spatial proximity/connectivity to other wetlands, disturbance history) or site-level factors (e.g., water depth, physicochemistry, topography, soil substrate, vegetation, forage/prey availability, nest site availability, overwintering habitat suitability, reservoir inundation patterns, etc.). We are unable to advise whether the Site 14 and Site 15A Cartier Bay physical works projects would result in an increase in site occupancy by Western Painted Turtles.

Water depth is an important aspect of habitat suitability for Western Painted Turtles

Currently, Western Painted Turtles are found at a wide range of pond depths in Revelstoke Reach. The vertical distribution of turtles varies throughout the year, with turtles generally occurring on the bottom substrate in the winter (January-March), when ice was present and water levels were lowest (Figure 5-22). In some cases, turtles occurred in very little water. For example, in February at Montana Slough, a turtle was present in 5 cm of water, beneath a sheet of ice measuring 34 cm thick (Figure 5-22). The mean water depth of turtle locations was 100.2 cm, with a maximum water depth of 393 cm occurring in Williamson Lake (an upland reference site) in October.

The vertical distribution of Western Painted Turtles has been documented in few studies. However, all support that shallow water is critical for the species. The most suitable lake or pond has at least 80 per cent of its water depth ≤ 3 m (Orchard 1986). This would reduce dive time of turtles from the pond surface to bottom substrate, compared to deeper lakes, which is important for energy expenditure and predator avoidance. The warmer temperatures and higher productivity of shallow waters may also enhance foraging and growth rates for painted turtles in the spring and summer (COSEWIC 2006). Consistently, we found that over 99 per cent of all turtle observations were in water depths < 3 m in 2013 telemetry sessions (Figure 5-23). Despite that deeper, open water was available in ponds, overwintering turtles were located on average in shallower water (mean = 35.7 cm) compared to random locations (mean depth = 53.9 cm; Hawkes and Tuttle 2013; Wood and Hawkes 2014). Congdon et al. (1992) also reported that shallow water was of particular importance to young turtles in the summer foraging period; they occupy deeper water as they increase in size and mature. Consistent with other studies, we found that Western Painted Turtles occupied the bottom substrate of shallow pond areas during the winter and were more active throughout the water column the rest of the year.

The proposed Cartier Bay Site 15A physical works may result in an increase in existing pond water depth, by ~95 cm. Although turtles were found at a wide range of water depths, current understanding is that shallow water habitat is paramount and thus we find no support for an obvious benefit to Western Painted Turtles from the proposed physical works at Site 15A. Depending on location, Cartier Bay water depths affected by Site 15A already reach a maximum of ~2.2 m when not inundated by the reservoir (Figure 5-4), and provides a large area of shallow (≤ 3 m) water habitat that would correspond to moderate or high habitat suitability in terms of water depth alone. In contrast, the proposed Site 14 physical works will likely increase the area of shallow water habitat, and thus could provide a neutral to positive effect on habitat suitability for Western Painted Turtles.

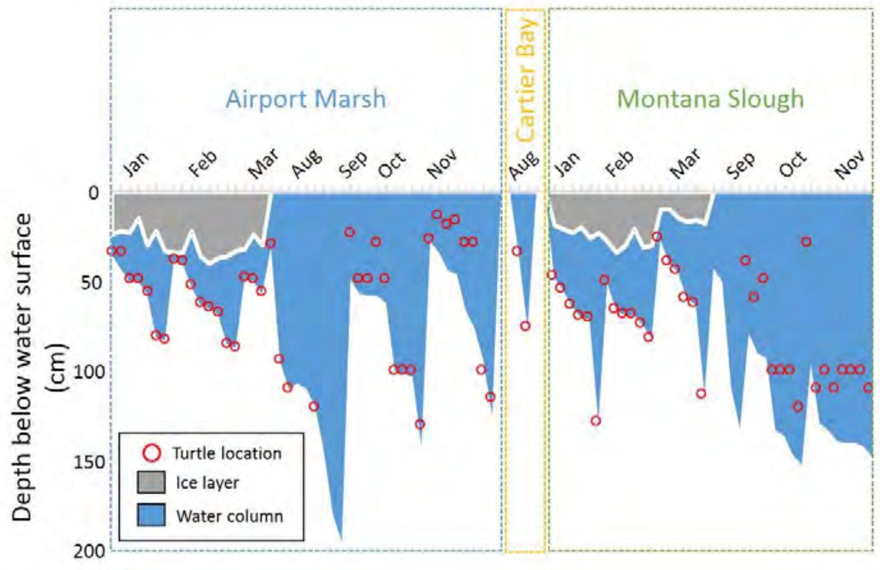


Figure 5-22: **Vertical profile of ice thickness, water depth, and turtle depth at locations of radio-tagged turtles in 2013 at three wetland sites in the DDZ of Arrow Lakes Reservoir**. Each data point represents one observation, with some months yielding more observations than others. Data are limited for Cartier Bay due to the low number of turtle observations at that site. For most observations in summer months, measurements of turtle depth were not possible due to high activity (e.g., swimming)

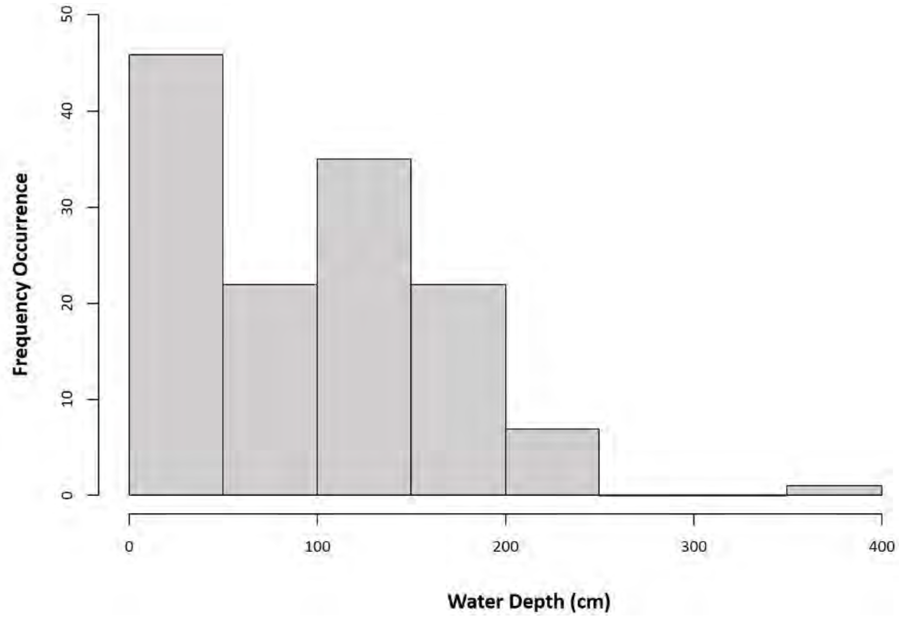


Figure 5-23: Histogram of water depth (cm) at locations of Western Painted Turtles during 2013 telemetry sessions. Data were pooled from all study sites, including Airport Marsh, Montana Slough, Cartier Bay, Turtle Pond, and Williamson Lake

Western painted turtles tolerate wide ranges in water temperature and dissolved oxygen

Water quality characteristics could be important determinants of turtle distribution and site occupancy patterns, particularly during the overwintering period. Key attributes of overwintering sites include high dissolved oxygen levels, cold-water temperatures, and ponds or wetlands that do not freeze to the bottom (Rollinson et al. 2008).

Therefore, we compared the water conditions (temperature, dissolved oxygen, and ice thickness) associated with radio-transmitter tagged turtles at each study site. A suite of water quality characteristics were also summarized for pond locations where turtles were present and random locations within the same ponds in winter 2013 (Hawkes et al. 2013; Wood and Hawkes 2014). No turtles were found overwintering at Cartier Bay. In other areas of Revelstoke Reach, hibernating turtles occurred at 429.0 m (Montana Slough) to 469.5 m elevation (Williamson Lake and Turtle Pond), and were found on average at 441.3 m elevation from January through March, 2013.

Water temperature at turtle locations varied from 0.0 to 4.7 °C in the overwintering period (mean = 1.1 °C, January-March) and 10.3 through 25.3 °C during the active period (mean = 16.5 °C, August-October; Figure 5-24). Dissolved oxygen content was found to be very low during the overwintering period, where DO conditions fell to hypoxic levels (i.e., DO < 2.0 mg/L; min= 0.36 mg/L; Figure 5-24). However, Western Painted Turtles are known to be capable of surviving up to four months under conditions of exceptionally low oxygen at near freezing temperatures (Ultsch and Jackson 1982).

Ice thickness did not appear to influence turtle locations during the winter. Overwintering ponds in the DDZ had a mean ice thickness of 26 cm (min = 10 cm, max = 40 cm; see Figure 5-22), and thus only the shallow pond margins froze solid. Ice thickness at turtle locations in February 2013 (mean = 32.5 cm) were comparable to other available (randomly selected) pond locations (mean = 36.0 cm; Hawkes and Tuttle 2013; Wood and Hawkes 2014).

From current data, painted turtles appear to tolerate a wide range of water physicochemical conditions, which is consistent with the published literature (e.g., Bickler and Buck 2007). Characteristics of sites used by turtles were highly variable throughout the year, in terms of temperature, dissolved oxygen, and ice thickness. We expect that the proposed physical works projects for Cartier Bay would not produce ecologically meaningful effects through changes in water temperature, dissolved oxygen, and ice thickness relative to painted turtle.

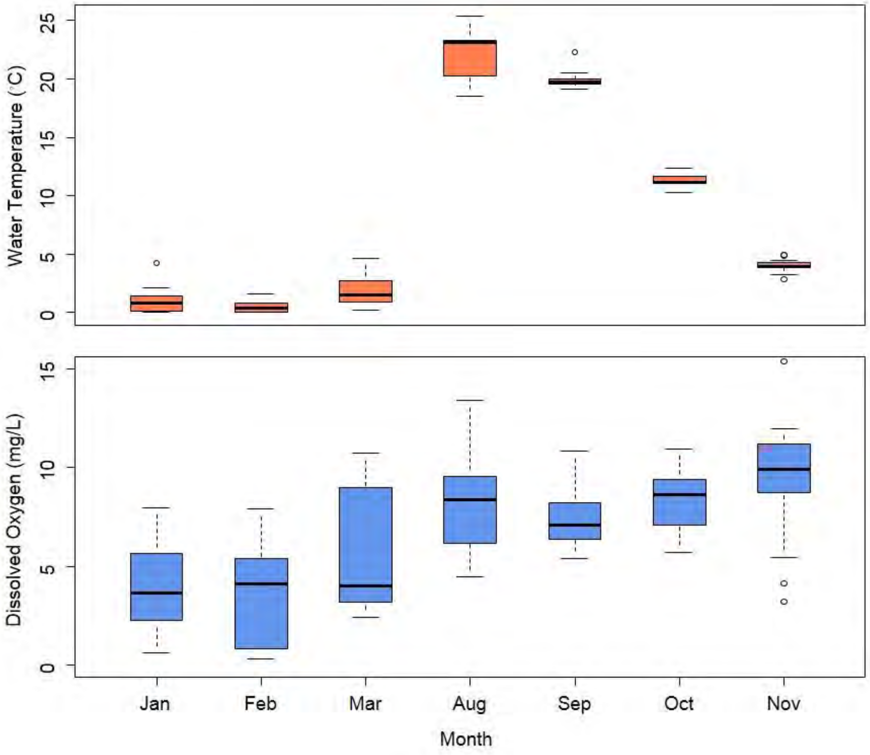


Figure 5-24: **Variation in water temperature (°C) and dissolved oxygen (mg/L) at the location of turtles detected during each month of 2013 telemetry sessions at Airport Marsh, Montana Slough, Cartier Bay, Turtle Pond, and Williamson Lake (data pooled)**

5.5.3 Fish

There are no substantive data on fish utilization of Cartier Bay for use in this assessment.

5.5.4 Macroinvertebrates

The CLBMON 11B4 study (Hawkes et al. 2011 and later reports) recorded aquatic macroinvertebrate occurrences (both benthic and pelagic) concurrently with vegetation sampling. Based on this work, Cartier Bay wetland is known to support the following macroinvertebrate taxa (classes, orders, and families): Acari (freshwater mites), Cladocera (water fleas), Copepoda (copepods), Oligochaeta (worms), Diptera (flies), Chironomidae (non-biting midges), Collembola (springtails), Daphnidae (water fleas), Ostracoda (seed shrimp), and Gastropoda (snails). As with macrophyte diversity, macroinvertebrate diversity at Cartier Bay appears to be intermediate between Airport Marsh (more diverse) and Montana Slough (less diverse). Based on current information, we are unable to advise whether the Site 14 and Site 15A Cartier Bay physical works projects would result in changes (positive or negative) to macroinvertebrate abundance or diversity.

5.6 Analysis 6: Ecological Risk Assessment I: Water temperature and Ice

The hydrological and thermal regimes of wetlands are closely linked; differences in water depth can affect freeze-thaw timing and the thickness and extent of ice-cover, which in turn, impacts wetland hydrology (Woo 1986; Kane et al. 2009; Wright, 2009). To evaluate how the timing of freeze-thaw may be impacted by raising the water elevation of Cartier Bay, the available water temperature and ice data were reviewed. The existing hydrologic conditions of Cartier Bay, as assessed from the available data, and limitations of this data and our understanding of the bay hydrology, are described earlier in Section 5.3

5.6.1 Water Temperature

Water temperature of Cartier Bay was recorded in 2010 and 2011 using two Tidbit data loggers installed at a depth of 0.5 m (Hawkes, pers. comm. 2014b). Figure 5-25 presents the average daily water temperature data for 2010 and 2011, and shows how water temperature is affected by stream (reservoir) water overtopping the swale elevation at Cartier Bay (Site 15A). Water temperature would normally remain high throughout the summer months due to high solar radiation inputs; however, temperatures at Cartier Bay decrease within a month of inundation and are at the lowest summer values when the ALR elevation is at its annual maximum (Figure 5-25). As the ALR elevation plateaus and/or declines, bay temperatures increase again before declining in mid to late September (Figure 5-25). Note that water temperature varies with depth, and the results described above are for temperatures at a depth of 0.5 m.

The water temperature data are limited, and it is difficult to find insight into the effects of the ALR elevation on freeze-thaw timing from the available temperature data. The maximum ALR elevation was greater than the swale invert elevation (presumed 433.8 m ASL) from 5 May 2010 to 22 January 2011, with the exception of a 17 day-period, from 23 October to 09 November 2010, when the ALR water level was lower than the swale invert (Figure 5-7). This differs from the winter of 2009-2010, when the ALR water level dropped below the swale invert on 5 October 2009 and remained below the swale elevation until 5 May 2010 (Figure 5-7). Based on the difference in inundation periods, it could be assumed that the bay had more water to freeze in the winter of 2010 than in 2009, and thus, it would take longer for the bay to freeze in the winter of 2010 and thaw in the spring of 2011. There are no water temperature data for the winter of 2009 to determine if freeze-up may have occurred later in 2010. The average water temperature at 0.5 m depth increased above 1°C three weeks later in the spring of 2011 compared to 2010, which may have been partially due to more water in the bay during freeze-up; though this cannot be confirmed. However, it may also have been due to differences in air temperature, precipitation, and snow pack depth. For example, average daily air temperature recorded at the Environment Canada Revelstoke "A" weather station (Environment Canada 2014), was 3.28 °C colder from January to April 2011 (-2.28 °C) than for the same period in 2010 (1.28 °C). Average daily water temperature at 0.5 m depth for the same period was similarly different (0.39 °C in 2011 and 2.54 °C in 2010).

Bay water temperatures may also be impacted by surface water input and the upwelling of groundwater. Surface and groundwater input to the bay was recorded by Maltby in November 2007 (Figure 5-26) and again in 2014 prior to spring melt. The groundwater upwelling observed in 2014 was in an area of 0.38 m to 0.5 m anchor ice, and were some of the first areas to later become open water habitat (i.e., ice-free) (Maltby 2014).

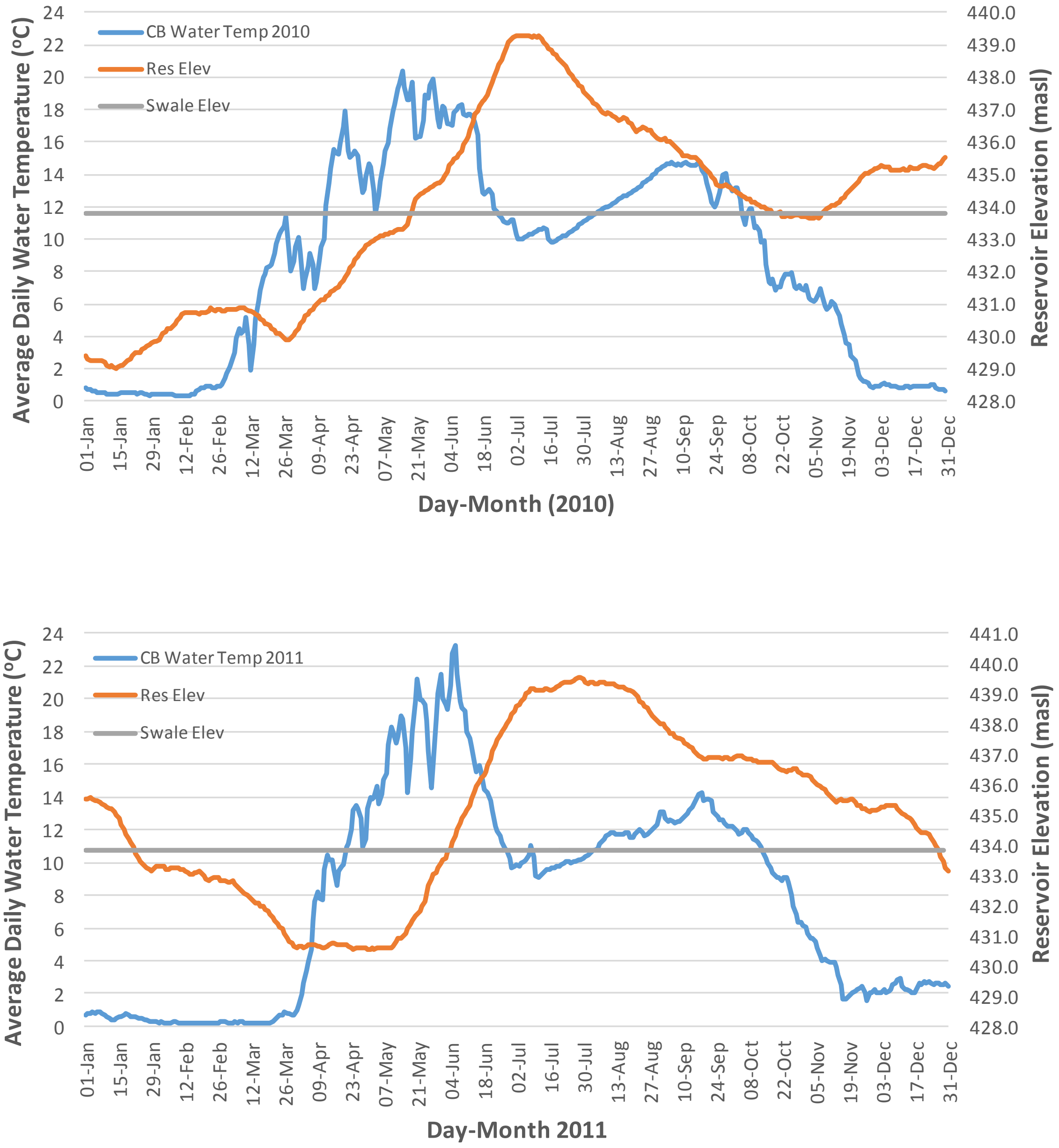


Figure 5-25: **Average daily water temperature (°C) of Cartier Bay (CB) and average daily Arrow Lakes Reservoir elevation (m ASL) recorded in 2010 and 2011 ().** The swale elevation is 433.8 m ASL

Figure 5-26: Surface water (culvert #16) inflow and groundwater upwelling in Cartier Marsh; November 26, 2007 (photo by Francis Maltby)

5.6.2 Ice Cover

From fall 2009 through spring 2014, the Cartier wetland was largely frozen over between November 20 and 21 December each year; thaw dates varied from March 28 to April 23. Four ice thickness and water depth measurements were made at Cartier Bay in 2013 and 2014. From the data available, ice presence and thickness was first measured in November and ice was not observed after April 15. Water was found in the majority of bore holes where ice was present.

Increasing the depth of water in Cartier Bay as a result of the Site 15A proposed physical works may affect the timing of thawing. Duguay et al. (2003) indicate that, for small shallow sub-arctic lakes (with depth <4m), lake depth affects the timing of ice cover breakup. Williams et al. (2004) examined ice-cover data for 143 lakes in Canada and the United States and found that, compared to lakes with smaller surface and depth, ice-on and ice-off dates were later for lakes with greater surface area and depth. However, Williams et al. (2004) indicated that these trends are weak.

Gao and Stefan (1999) examined ice cover simulated with a 1D vertical model for ten lakes in Minnesota with large surface area of 5.5 km^2 to 1515 km^2 and with depths of 1.3m to 49.1m. These authors found that the simulated ice-on dates were later for lakes with greater mean depth. Applying the results of Gao and Stefan (1999) to Cartier Bay indicates that ice-on dates would be delayed by only ~1 day if the mean depth of the bay is increased from 0.5 m to 1.0 m.

An ice thickness survey was carried out at Cartier Bay in 2014 by a local resident of Revelstoke (Maltby 2014). The bore hole data show that the ice was grounded to the bed (i.e., there was anchor ice) in areas where water is generally shallow (assumed if no water was shown below the ice), so as the bay water level rises due to snowmelt and local spring melt runoff from adjacent slopes, the ice cannot rise and water comes over top of the ice promoting a faster melt (Jasek 2014). Increasing the depth of current shallow water areas may reduce the area of anchor ice, potentially delaying thaw in areas that currently provide early open water habitat for waterfowl and other waterbirds, or it may simply transfer the area of bottom-fast ice to other areas that are currently dry in winter. Much of this area appears to be at the margins of the bay, which is sloped and may also be influenced by snowmelt runoff from upslope areas.

5.6.3 Summary Recommendations

The available baseline water temperature and ice data are limited and do not allow reliable application of numerical models to predict the effect of proposed physical works 14 and 15A on timing of freezing and thawing in Cartier Bay; application of numerical models requires data for calibration and validation. Further, the limited baseline data do not facilitate monitoring project effects after the project is implemented; baseline data are needed for comparison to operational data that should be collected after project implementation. We recommend installing temperature loggers at multiple locations and depths to properly characterize the thermal regime of Cartier Bay. The data from these loggers can be used to calibrate and validate a one-dimensional vertical model to predict changes in the bay thermal regime and ice cover due to increased water depth. The loggers should be surveyed to a common datum, as the bay water level varies with time, and the depth of the loggers will vary accordingly.

5.7 Analysis 7: Ecological Risk Assessment II: Flora and Fauna

5.7.1 Vegetation

5.7.1.1 Site 15A

5.7.1.1.1 Impacts to Non-Aquatic and Riparian Vegetation

An obvious immediate impact of raising water levels upstream of Site 15A by 1 m will be the permanent inundation and loss of those terrestrial VCTs or portions of VCTs presently occupying the affected elevation band of 433.8 to 434.75 m ASL (primarily PC, PE, PO, RR, PA, BG, and BE). Of these, the PE (Reed Canarygrass), BE (sandy beach), and PO (pond) VCTs will be the most disproportionately affected due to their concentration within this elevation band. Extensive areas of PC (Reed Carnarygrass-Lenticular Sedge) will be inundated, but these areas represent a relatively small fraction of the total PC persisting in adjacent higher areas within the bay area. Likewise, some low lying sections of PA (Reed Canarygrass – Redtop upland) along the eastern perimeter of Cartier Bay will be flooded, slightly reducing this shrubby riparian community type where it extends to the current foreshore, though possibly with only minor impacts to the surrounding vegetation as this VCT extends uphill to the highway.

The vegetation impact of flooding existing small ponds (PO) should be minimal as these habitats are lightly vegetated compared to the adjacent existing wetland. From a vegetation perspective their loss should, in principle, be offset by the expansion of and resulting connection with, the existing wetland. Note, however, that these shallow ephemeral ponds may support breeding- and security-habitat for amphibians as well as foraging habitat for shore birds that differs in character from the deeper wetland habitats which may be created through proposed physical works at Site 15A.

The vegetation impact of losing a portion of the lower BE or sandy beach shoreline (at the south perimeter of Cartier Bay) is also projected to be relatively minor, since this habitat is sparsely vegetated and provides little currently in the way of wildlife plant forage. The current beach also extends well above the proposed water line, so only a portion of this habitat would be inundated. However, higher water levels along the southern shore could produce increased erosion of the lower bank, affecting existing vegetation and potentially the long term bank stability along this section.

Loss of existing shoreline (PE) habitat poses a risk

The projected loss of shoreline (low elevation) PE habitat may be more problematic from a functional standpoint. The PE, which is distinguished by low- and medium-statured herbs adapted to growth on low gradient, seasonally receding, wet shorelines (e.g. Nodding Chickweed, Winged Water-starwort, Purslane Speedwell, Lenticular Sedge, Swamp Horsetail, Toad Rush), produces a unique type of productive open shoreline habitat not represented within the other community types. Shorebirds, migrating songbirds, and amphibians utilize this early- through late-spring and summer habitat, which tends to occupy the interface between open water wetland and taller and denser vegetation types at higher elevations within the bay (primarily PC and PA). Once water levels are raised to 434.75 m, this spring and summer habitat interface will be flooded and replaced in most areas by either a Reed Canarygrass-dominated shoreline (throughout much of the central area and eastern perimeter) or by shrubs and/or cobble (portions the northern, eastern, and southern perimeters).

The PC community, with its tendency towards tall grass monocultures, in particular represents a potentially less diverse and lower habitat suitability replacement for PE. As described by Hawkes et al. (2011), "Reed Canarygrass competitively excludes other native plant species and limits the biological and habitat diversity of host wetland and riparian habitats. Unlike native wetland vegetation, dense stands of Reed Canarygrass have little value for wildlife. Few species eat the grass, and the stems grow too densely to provide adequate cover for small mammals and waterfowl (Maia 1993).” Along with the predicted changes to the riparian interface, we expect there will be associated changes (likely reductions) in riparian wildlife utilization, though the exact nature of these changes will not be known until after physical works implementation.

Oxygen depletion resulting from decomposing vegetation poses a risk

The flooding of an area of approximately 26 ha covered primarily by Reed Canarygrass could have other unintended consequences. This perennial species is currently well established in areas of Cartier Bay that receive periodic inundation, where it forms extensive rhizomatous sods. As noted by Hawkes et al. (2011), “A concern is that as these vegetated areas become permanently flooded the resulting die-off of Reed Canarygrass will result in dense mats of dead thatch that prevent establishment of desirable macrophytes. The subsequent decomposition of large amounts of dead plant material could potentially decrease the amount of dissolved oxygen available to other organisms or otherwise modify water and soil chemistry, which could have cascading effects on the trophic web of the created wetland. As one of the goals of the physical works program is to improve wetland function, implementing the physical works in the absence of Reed Canarygrass removal [or control] could diminish their efficacy.”

We concur with this assessment and reiterate the possibility that the flooding of Reed Canarygrass stands will lead to their gradual decomposition and thus increase biological oxygen demand within Cartier Bay over an extended time period. This is a potential concern because prolonged exposure to low dissolved oxygen levels (<5 to 6 mg/l) may not directly kill an organism, but will increase its susceptibility to other environmental stresses. Exposure to < 30% saturation (<2 mg/l oxygen) for one to four days may kill most of the biota in a system (Gower 1980).

Evidence from a variety of wetland ecosystems suggests that, in general, litter decomposition is more rapid at sites that are inundated for at least a portion of the growing season than at sites that are never flooded (Neckles and Neill 1994, Xiong and Nilsson 1997). However, inundation affects decomposition in different ways depending on the specific environment: on the soil surface where oxygen is readily available, flooding hastens decomposition by increasing moisture availability. Belowground, flooding creates anoxic conditions that slow decay (Neckles and Neill 1994). This suggests that the current hydrologic pattern at upper elevations in Cartier Bay, namely summer flooding followed by winter/spring exposure, may facilitate decomposition rates by permitting rapid decomposition aboveground in standing water while annually alleviating soil anoxia via drawdown. Altering the hydroperiod to one of year-round inundation will, presumably, retard and thus prolong the decomposition process in the shallow water habitats affected. Additional research will be needed to determine if this change in pattern will lead to biologically significant oxygen deficits for the system. However, we note that the annual summer/winter flooding event flushes copious oxygenated water into the system each year and this influx may be sufficient to counter any temporary dissolved oxygen deficits resulting from local organic decomposition.

Mechanical control of the standing Reed Canarygrass crop prior to inundation via mowing or stripping could be an effective way to mitigate risks associated with introducing excessive organic matter. Several methods are effective at suppressing Reed Canarygrass (Stannard and Crowder 2001). Two such methods are tilling or stripping and defoliation (e.g. by mowing). Most rhizomes are in the upper 15 to 20 cm of the soil. Tilling kills top growth so eventually below ground energy reserves are exhausted. Several tillage operations at about 2-week intervals are usually required (Stannard and Crowder 2001). Potential disadvantages of this method are that it serves to turn up dormant seed beds of invasives such as Eurasian Water-milfoil for subsequent germination; and it leaves the soil unprotected, increasing erosion potential until the site is revegetated. Mowing is effective in so far as it depletes carbohydrate reserves in the rhizomes, inhibiting active growth and forcing translocation of resources to develop new tillers for photosynthesis (Stannard and Crowder 2001). Mowing by itself does not kill Reed Canarygrass, although it serves to knock back the cover temporarily. In fact, if mowing only occurs once or twice per year will actually stimulate additional stem production. Mowing in conjunction with shading (using a ground cover such as a weed barrier) may produce more favorable results than mowing alone (Forman 1998).

Persistence (or proliferation) of Reed Canarygrass in newly flooded areas poses a risk

Another, competing possibility is that Reed Canarygrass may not die out in the newly flooded areas but instead persists there, perhaps as the dominant vegetation type. Hawkes et al. (2011) note that Canarygrass thrives with periodic inundation and aggressively invades stream banks, floodplains, wet meadows, pastures, marshes, lakeshores, and rights-of-way, and seems particularly well-adapted to poorly drained soils and seasonally inundated sites (Stannard and Crowder 2001). Given this adaptability, flooding has shown mixed success as a means of controlling Canarygrass (Farelly 2012). As reviewed by Farelly (2012), "Some studies have found that flooding results in increased vegetative growth, tillers, and nodes (Lefor 1987, Rice and Pinkerton 1993, Coops et al. 1996). Kercher and Zedler (2004) found that *Phalaris* outgrew all other perennial species in four different flood regimes and had the greatest amount of root air space of all the species studied. Other studies have shown decreased above- and below-ground biomass and stem density with flooding as shallow as 5 to 30 cm (Coops et al. 1996, Miller and Zedler 2003). Cooke (1997) asserted that *Phalaris* will not persist under water for an entire season. Coops and van der Velde (1995) found that *Phalaris* germinated and grew best in exposed/drained soils, and that growth slowed or stopped under submerged conditions."

In an experiment with direct relevance for the Cartier Bay project, Farelly (2012) monitored the long-term responses of Canarygrass and bottomland vegetation to managed flooding in a wetland complex adjoining the Columbia River in northwest Oregon. Here, wetland managers installed a water control structure between the wetland and the Columbia Slough/River system to impound winter rainfall and thus approximate the ecological benefits that natural flooding provided as well as reduce the abundance of Canarygrass. The wetland was monitored in the year prior to the physical works and at years 1, 5, and 6 following establishment of the dike (Farelly 2012). Results showed a reduced cover of Canarygrass in areas experiencing at least 0.6 meters of inundation and an increased cover of native plant communities when compared to baseline data (Farelly 2012). Canarygrass declined by over one-third from 44.4% to 28.1% cover following water management. Since hydrology management began, the native Water Smartweed species community has replaced Canarygrass as the dominant species in the emergent zone, while Columbia Sedge cover increased seven-fold from 0.3% to 2.3%. In areas with greater than 1.2 m of maximum inundation, Canarygrass cover began to drop off exponentially to the point where it was almost completely eliminated. However, in areas with less than 0.6 meters of maximum inundation there was a slight, but significant, increase in Canarygrass cover (Farelly 2012).

Thus, while it seems highly likely that Reed Canarygrass would be eliminated from deeper (> 1 m) areas of the Cartier Bay wetland within two or three years, this assumption might not hold for some shallower created areas. Indeed, we expect that the gentle topographical gradients that characterize much of the proposed impact area upstream of Site 15A (and possibly upstream of Site 14 also) will produce extensive areas of shallow flooded ground < 0.6 m deep. These newly created shallow water areas could well provide suitable conditions for stands of Canarygrass to persist in their current form for a number of years (as opposed to being replaced by native wetland vegetation). A similar ability to tolerate prolonged shallow flooding has been observed in areas of coastal BC (D. Polster, pers. comm. 2014). That said, the relatively harsh conditions encountered at Carter Bay—deep seasonal inundation, a long-lasting spring snowpack, along with wave action and freeze-thaw cycles during the dormant season—could act to eliminate or reduce inundated Reed Canarygrass stands more quickly, or at shallower water depths, here compared to coastal regions. Determining the actual direction of this outcome will require post-impact monitoring of the affected area.

5.7.1.1.2 Impacts to Aquatic (Macrophyte) Vegetation

Predicting the outcomes of the proposed physical works at Site 15A for the existing macrophyte community is challenging due to the number of potentially interacting factors at play. On the one hand, increasing the aerial extent of the current wetland upland of Site 15A should, in theory, increase the total amount of available habitat for aquatic plant growth, resulting in long term benefits for wetland plant productivity (with concomitant benefits for associated invertebrate and vertebrate fauna). This is of course one of the original rationales for proceeding with the proposed physical works (Hawkes et al. 2011). On the other hand, the underlying (and unproven) hypothesis is that native macrophyte species will expand into and occupy the newly available habitat, while maintaining their current abundance in the existing habitat.

Suitability of the newly inundated substrate for colonization is unknown

Whether and how soon the colonization of newly inundated substrate occurs will depend, firstly, on whether newly created substrates consisting initially of decomposing terrestrial plant matter (thatch) can provide the necessary conditions for macrophyte establishment and growth. Given the density of live and dead plant cover (mainly Reed Canarygrass) covering much of the proposed impact area, we deem this to be rather unlikely for at least several years following dike construction. Once this plant matter becomes well decomposed in subsequent years, substrates may begin to resemble those of the existing wetland permitting the eventual ingrowth of macrophytes over time. However, we have no solid basis on which to posit a time frame for this process. Succession should be more rapid in areas currently occupied by the PE vegetation type, since these habitats are typically much lower in vegetation and thatch cover and tend already to support substantial open mineral soils which could serve as a suitable macrophyte substrate. Likewise, we expect that small existing ponds outside of the main pond (Figure 5-19) will be among the first habitats colonized by macrophytes, because favourable substrate conditions for macrophyte establishment should already exist.

Macrophyte responses to 1 m increase in water depth may vary

Secondly, the extent to which the current community is maintained or enhanced will depend on the respective tolerances of individual taxa for the deeper water conditions (+ 1 m increase) that will prevail in the existing wetland following physical works implementation. All macrophyte species are depth limited to some extent, commonly occurring in water 1 – 3 m deep (Aiken et al. 1979, Harrington 1983), with some being less constrained by this variable than others. For example, Eurasian Water-milfoil and Common Hornwort are able to grow in water depths up to 5 m, and occasionally grows in even deeper water if water clarity is high (Wells et al. 1997, Madsen 2005, Appendix 10-3). In the clear waters of Okanagan Lake, Eurasian Water-milfoil has been observed in water 8 m deep (Newroth 1975). The depths at which macrophytes can grow are in part a function of available light, which in turn is influenced by the water clarity, and of species' ability to harvest light, which is related to growth form (Middelboe and Markager 1997). Other things being equal, the more turbid the water body, the less deeply a species will be able to penetrate (Middelboe and Markager 1997). Miller and Hawkes (2014) recorded Secchi depths (a type of water turbidity measure) for Cartier Bay ranging from 60 cm to > 200 cm, with considerable year to year variation in this variable observed (e.g. turbidity was notably higher in 2012 than in 2013; unpubl. data). However, Secchi depths roughly correspond to the late spring water depths (when sampling occurred), implying that light is able to penetrate most of the way to the lake bottom during the primary growing season in most cases and thus does not pose a major limiting factor at current depths.

We do not know how this balance might change once water levels are increased by 1 m, though water depths will still be within the range of ecological tolerances of most species (Appendix 10-3) except possibly in the deepest sections of Cartier Bay. One possible outcome is that some species less tolerant of deep turbid water will migrate towards the shallower margins of the newly created wetland as they are excluded from deeper areas, resulting in a neutral net gain in cover. Because Eurasian Water-milfoil forms a dense surface canopy of leaves and branches, light can be collected from near the surface in even relatively turbid waters (Madsen 2005). Vegetative fragments of Eurasian Water-milfoil become established in water 2-3 m deep, and later invade shallower and deeper water (Aiken et al. 1979). This and other relatively depth-tolerant species such as Common Hornwort will likely not be negatively impacted by the change in levels and may be enhanced by the opportunity to occupy a taller water column.

Change in hydroperiod may benefit floating macrophyte beds

To the extent they are able to tolerate the deeper water levels, some floating-leaved species (e.g. Water Smartweed, Floating-leaved Pondweed) could benefit from the change in hydroperiod itself. As noted previously, fast rising reservoir levels during the spring growing season may be precluding the establishment of extensive floating macrophyte beds such as those observed at Airport Marsh. This is because the rooted stems of these species often cannot elongate quickly enough to keep pace with the rising water, leaving the upper leafy portions of developing plants inundated before they can form a surface bed (Miller and Hawkes 2014). A longer spring growing period such as that prevailing at Airport Marsh might allow these floating beds to develop to a greater extent than in the past. Given this, we anticipate that one of the eventual effects of delaying early season flooding and extending the fall impoundment period through proposed physical works could be increased cover of floating vegetation mats at Cartier Bay. Such a response would have ecological benefits. The open water under floating macrophyte beds affords shelter to various aquatic organisms and are a haven for insects, which in turn provide food for fish populations. Floating-leaved Pondweed is sometimes an important food for ducks, which browse on the rootstocks and, later in the season, on the nutlets. Pondweeds in general are a favourite food of waterfowl and are also attractive to marsh birds and shorebirds, and are often heavily browsed by muskrats, beaver, deer, and moose. Likewise, the copious nutlets of Water Smartweed can provide important food for waterfowl, shorebirds, and songbirds (Appendix 10-3).

Increased competition from Eurasian Water-milfoil is a risk

Thirdly, the ultimate response of the macrophyte community to wetland expansion may be skewed by the response of one of its co-dominant species, Eurasian Water-milfoil (Appendix 10-5). The concern exists that this species, because of its highly invasive habit and tendency to propagate from vegetative fragments rather than seeds (Aiken et al. 1979), may be the first to colonize any new habitat and thereby impede establishment of native macrophytes, altering community balance in the process. While asexual reproduction is more important for Eurasian Water-milfoil than sexual reproduction, the species is also capable of germinating from seed under right conditions and produces persistent viable seed banks (Xiao et al. 2009). Seeds remain dormant while buried or submerged but germinate readily upon exposure to light and air (Xiao et al. 2009), a trait that may enable this species to quickly preempt microsites that are available only at the very beginning of the growing season, such as the margins of wetlands following seasonal drawdown (Xiao et al. 2009).

This is not to say that Eurasian Water-milfoil cannot make a meaningful contribution to wetland productivity; its stems and leaves provide habitat structure for macroinvertebrates and cover for fish. Birds eat the seeds and, to a limited extent, the vegetation. Snails graze on the plants and caddisfly larvae build cases from the leaves (Warrington 1983). However, the species is known to reduce vegetation diversity by competing aggressively with native plants. 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). Consequently, the benefits of increasing overall macrophyte cover upstream from the proposed physical works at Site 15A must be weighed against the risks of increasing the local dominance of a noxious weed species.

5.7.1.2 Site 14

In contrast to the situation at Site 15A, there is no existing functioning wetland upstream of the proposed Site 14 project (Golder 2009b). This area instead consists of a channel that collects water from three shallow basins within the floodplain upstream of the rail grade. Vegetation adjacent to the channel consists primarily of Reed Canarygrass. There is limited information on the vegetation composition within the channel itself, though the bottom of the channel has a mostly unvegetated silty substrate (Golder 2009b). Thus, while some of the predictions and considerations outlined in the previous section (e.g. possible oxygen deficits resulting from decomposition of organic sod mats) may apply to Site 14, others (e.g. potential negative effects on existing macrophyte communities) likely do not.

Because the channel upstream of Site 14 is steep-sided, permanent flooding should result in relatively deep (> 0.6 m) ponds from which Canarygrass is effectively excluded, reducing one of the main concerns associated with the Site 15A proposal. However, in the absence of additional control measures, there is a good probability that Canarygrass will continue to persist at the margins of the channel and in the newly shallow flooded areas (< ~0.6 m deep), particularly if the flooding regime varies much from year to year. The anticipated persistence of Canarygrass in these marginal areas (along with associated thatch and sod substrates) suggests that the newly created shallow habitat may not be suitable for wildlife species such as breeding toads which prefer soft mud substrates or submergent vegetation.

Oxygen deficiencies resulting from decomposing vegetation remain a potential concern in the impoundment channel, especially considering that there appears to be some sporadic habitat utilization by fish currently (Golder 2009b). However, the impounded water will remain stagnant for only a portion of the year, if at all; the annual influx of oxygenated water from surface runoff, groundwater, spring snowmelt, and summer reservoir flooding should provide adequate relief from oxygen deficiency. Given the low rates of use by other fauna and flora at present, the overall risk to current and future ecosystem function from this outcome seems quite moderate.

Aside from possible seed banks, there is no existing pool of aquatic plant propagules at the present impact site. Development of a wetland plant community will likely necessitate the immigration of propagules (presumably during high summer/fall flood levels) from the adjacent Cartier Bay wetland. In other words, seeds and vegetative stem or root fragments of macrophytes must disperse into the channel at a time of year when most of the floodplain is inundated, then successfully settle there. This process might occur rapidly under the right circumstances, although we think it more likely, given the random nature of dispersal and the relatively small "target" area involved, that significant colonization and establishment by macrophytes via immigration from adjacent wetlands could take several seasons, unassisted. That said, it would be a relatively straightforward matter to "kick-start" the colonization process by harvesting vegetative propagules (stems and roots) of desirable species from the existing wetland and transferring them by hand to the newly created wetland.

A primary concern, as with Site 15A, is that Eurasian Water-milfoil will prove to be the initial aggressive colonizer, supplanting the available habitat for native macrophytes before they can become established. However, the opportunity may exist in this case to undertake control measures early in the restoration process in order to limit the probability of such an outcome. This could be as straightforward as mechanically removing nascent patches of milfoil during the first year or two following inundation (Wile 1978, Aiken 1979), while facilitating the initial colonization of desirable species through hand transportation of native macrophyte propagules from the adjacent wetland into the new site.

5.7.1.3 Risk-Benefit Summary (Vegetation)

From a vegetation standpoint, do the ecological benefits of proceeding with the 1 m elevation increase outweigh the associated risks and uncertainties? In the case of Site 15A, we believe the answer to this question is most probably "No." Based on current information and knowledge, we are unable to confidently predict many of the outcomes, including: (i) the biological and physicochemical impact(s) of shallowly flooding large tracts of Reed Canarygrass at Cartier Bay; (ii) the impacts to wildlife of removing existing riparian habitat, and specifically of replacing existing open shoreline vegetation with a “wall” of Canarygrass; (iii) the likelihood that existing submergent vegetation in Cartier Bay will naturally expand into the newly flooded areas; and (iv) the impact of creating additional habitat that could facilitate expansion of the introduced invasive Eurasian Water-milfoil within the existing wetland, to the potential detriment of native wetland species. The safest and most beneficial course of action, from our point of view, would be to seek to maintain the status quo at Site 15A by undertaking any necessary repairs to the existing dike to ensure it does not erode further away, while allowing for the continuation of water levels at their current depth.

In contrast to Site 15A, the proposed inundation area upstream of Site 14 does not support an existing developed wetland. The vegetation is primarily terrestrial and consists largely of low diversity Reed Canarygrass associations (PC vegetation community type) with few identified outstanding vegetation values. Because the site is relatively small and contained, many of the risks described for Site 15A can be relatively easily managed for and mitigated. For example, tilling and stripping the area prior to inundation is a technologically simple measure that could be taken to reduce the risks of oxygen depletion resulting from localized vegetative decomposition, while potentially enhancing the substrate for aquatic vegetation establishment. Likewise, the introduction of Eurasian Water-milfoil, which we view as an inevitable outcome here as at Site 15A, can possibly be temporarily slowed via mechanical control (e.g. hand pulling or harvesting) during initial years to allow for the timely establishment of native macrophytes into the system. This management measure could be carried out on an experimental trial basis (e.g. by treating half of the impounded area and leaving the other half as a control) to gauge its effectiveness.

Site 14 presents a small-scale, and relatively low risk, opportunity to experiment with wetland creation and to test many of the hypotheses regarding the potential benefits and risks of expanding the larger, existing wetland at Cartier Bay through physical works. In the case of Site 14, there appears to be little to lose from a vegetation standpoint, and possibly something to gain, by proceeding with the proposed physical works, or a modified version (e.g. multiple lower berms to form several elevationally-stepped wetlands east of the rail grade [Maltby, pers. comm.]) Given the uncertain water budget, smaller wetlands of overall reduced volume may be more likely to remain flooded longer in the season during periods of water shortage (Maltby, pers. comm.).

5.7.2 Birds

5.7.2.1 Risks to Birds

Regarding impacts to birds, the analyses of avian monitoring data suggest that the risks are large and significant for the Site 15A project, but minimal for the Site 14 project. To be clear, the risks posed by the Site 15A project to birds is entirely due to the proposal to raise water levels. The analysis demonstrated that the existing wetted area is heavily selected by migrant waterfowl (e.g., dabbling and diving ducks), and that the shoreline provides a highly important foraging habitat for American Pipit during their spring migration. The existing Cartier Bay wetland is likely the most important habitat feature in the region for these two groups during their spring migrations. For both groups, the proposal to raise water levels in Cartier Marsh (Site 15A) will largely destroy the existing habitat values. Site 15A would need to be highly effective at creating suitable habitat in a short time frame in order to replace/match, or improve upon the suitability of the existing habitat. Because this is uncertain, the risk for waterfowl and pipit associated with Site 15A should be considered as extremely high with respect to the alteration of habitat quality in terms of both probability of failure and magnitude of impact.

For Site 15A, our analysis clearly showed that usage of the Cartier Bay wetland is limited by ice thaw dates each spring. In the fall, waterfowl utilize the site until freeze-over (HvO unpublished data). The potential for Site 15A to alter the freeze/thaw dates at the Cartier Bay wetland constitutes a second risk associated with this project. If the date of thawing is delayed as a consequence of raising the water depth, this will have a negative impact to migrant waterfowl. While there is considerable uncertainty that this would be the case, previous studies suggest this deeper ponds tend to thaw more slowly (Williams et al 2004; see Section 4.7.2).

These two major risks for birds, associated with the Site 15A project, are not associated with the Site 14 project. The available data and considerable amounts of anecdotal observation indicate that the Site 14 impoundment area has minimal value for birds in its existing state. The Site 14 project will not impact the habitat quality at the existing pond because the proposed impoundment for Site 14 has a lower elevation than the existing pond.

5.7.2.2 Benefits to Birds

The proposed physical works at Site 15A would likely provide some benefit to waterfowl by reducing the time span during which the wetland is inundated by the operations of the ALR during fall migration. The analysis (Model.2) showed robust evidence that the inundation of the Cartier Bay wetland by the ALR in the fall negatively influenced usage of this site by migrant waterfowl. The magnitude of this relationship was greatest in the first meter of inundation, with decreasing influence of additional water depth. Consequently, raising the water level will provide some benefit by reducing the period of time during which the wetland is inundated and by reducing the depth of inundation. Because the spring migrations occur prior to the reservoir impoundment each year, the benefit will only be realized in the fall. Annually, it is predicted that Site 15A will reduce inundation time by as much as 20 days per year, but considerably less if the elevation of the current swale is underestimated (see Section 4.3.5.2 Duration of wetland inundation). This difference would be primarily realized in the fall because the reservoir elevations change more slowly during the fall draft, compared with the spring draw (Figure 5-8).

A second benefit of Site 14 and Site 15A is a reduction in nest flooding caused by reservoir operations. Killdeer and Spotted Sandpiper occasionally nest near the Site 15A footprint area (CBA 2011b) and suffer nest failure due to reservoir operations. Nesting habitat is abundantly available for these species outside of the Cartier Bay area. Impounding these areas will likely cause these shorebirds to nest in other locations where the risk of nest flooding is reduced. Due to the low number of nests that are built in the Cartier basin, this benefit has minor ecological importance.

The Cartier Bay wetland is not known to be valuable for brood-rearing (CBA 2013a). This was likely because the site is deeply impounded by reservoir during the brood rearing season. Site 14 and Site 15A will not raise the existing wetland elevation enough to mitigate this impact, so it is unlikely that there will be a benefit to brood-rearing waterfowl.

It was originally assumed that these projects would provide benefits to dabbling and diving ducks by creating additional deep and shallow ponded areas (Golder 2009b); however it is entirely uncertain if this benefit would be realized. A distinction needs to be made between quantity and quality. While it may be true that impounding these basins will increase access to deep and shallow pond habitat, it is entirely uncertain that (1) these habitats are currently limiting for waterfowl, or that (2) the newly created habitats will match or exceed the existing habitat in terms of quality. As such, with respect to Site 15A, it is entirely possible that these projects will create an excess of low suitability shallow and deep pond habitat, at the cost of destroying the existing high quality shallow and deep pond habitat, causing a net loss of habitat suitability and value. Because Site 14 would only impound low suitability habitat, it is more probable that habitat suitability will improve by creating additional ponded area.

5.7.2.3 Risks versus Benefits Summary

For birds, the most salient issue for Site 15A is the question of how successful the project will be at creating suitable waterfowl habitat. The proposed impoundment would modify existing habitat that is currently viewed as very high quality - with particular suitability for dabbling ducks and diving ducks; it is therefore more probable that habitat quality will diminish following manipulation, rather than increase. If habitat suitability diminishes, the ecological benefit accruing from reduced reservoir influence will be of minor significance.

The opposite is true for Site 14. In the latter case, the proposed Site 14 impoundment has very low current value so it is probable that the habitat manipulation will improve the habitat suitability for birds. While these predictions are based on low prior predictive information, we believe they are appropriate (Lindegarth and Chapman 2001).

Taken together, the risks and benefits of implementing the Site 14 and Site 15A impoundments (summarized in Table 5-7) suggest that Site 14 may provide some benefits to birds with low risk of negative impacts, while Site 15A incurs too much risk, relative to low expected benefit, so this latter project is not worth pursuing.

Table 5-7: Summary of risks and benefits to birds of the Site 14 and Site 15A impoundments.

	Site 14	Site 15A	Effect size
Risks:			
habitat degradation	Low probability	High probability	Large
postponed ice thaw	NA	Moderate probability	Large
Benefits:			
advanced ice thaw	NA	Unlikely	Moderate
mitigation of reservoir operations	Low probability	High probability	Moderate
removal of low elevation nesting habitat	High probability	High probability	Small
Increase wetland size	High probability	High probability	Small
habitat enhancement	High probability	Unlikely	Small

5.7.3 Amphibians and Reptiles

5.7.3.1 Western Toad

5.7.3.1.1 Existing Conditions: Source or Sink?

Western Toads use habitats in the DDZ of the ALR to fulfill their life requisites and all life stages of Western Toad have been observed in Cartier Bay. Hawkes and Tuttle (2013) discussed the uncertainty regarding whether habitats in the drawdown zone of hydroelectric reservoirs function as sources or sinks (as per Dias 1996) for amphibian populations. It is plausible that certain habitats in the drawdown zone function as sinks (poor quality habitat leading to demographic deficit) while others functions as sources (good quality habitat contributing to population growth). With respect to Cartier Bay, it is likely that current conditions and reservoir operations contribute to the maintenance of the local Western Toad population (i.e., a source); however, we do not know if the population of Western Toads is maladapted to Cartier Bay, which could result in a declining population over time. Additionally, it is possible for a population to be maintained in a state of persistent maladaptation (Dias 1996). In other words, the population of Western Toads using Cartier Bay might breed on an annual basis suggesting some form of population maintenance, but given the quality of habitat provided by Cattier Bay, it may never reach its full potential.

Given that we know little about the dispersal of Western Toads within Revelstoke Reach (current telemetry data are insufficient to determine if toads move between breeding areas), our ability to assess the Western Toad population as a source or sink is further limited because we don't know anything about dispersal patterns of juveniles or adults (Bansaye and Lambert 2013). However, it may be that knowledge of the dispersal patterns is irrelevant because the population of Western Toad using Cartier Bay appears to persist. As such, in its current state, Cartier Bay meets the criteria of an ecological source.

5.7.3.1.2 Post-Physical Works Conditions

Following the implementation of the proposed physical works, the total area of Cartier Bay is predicted to almost double in size while continuing to provide shallow wetland habitat of < 1 m depth (Golder 2009b). Prior to inundation in the spring, the depth of Cartier Bay ranges from ~ 0.2 cm to > 2 m with much of the eastern compartment of Cartier Bay comprised of water between ~ 0.2 and 1.4 m (Figure 4-3). For Western Toads, shallow water between 5 and 30 cm is required for breeding and this habitat type is currently well-represented in the eastern compartment. The availability, distribution, and potential suitability of similar shallow wetland habitats following the implementation of the proposed physical works is unknown. We currently have no way of assessing whether the physical works will result in a net increase of shallow wetland habitat that would be suitable for breeding Western Toads. There is also no guarantee that the total area impounded by the physical works would be as predicted as there are several unknowns including the permeability of the road and rail bed, loss due to ground water seepage, evaporation, and overall ability of the rail bed to act as an impermeable dam.

5.7.3.1.2.1 Effects of Changing Water Temperature

If the physical works were implemented in Cartier Bay there will be a predicted increase in water depth and in the total area of shallow wetland habitat. As proposed, the physical works would have a mitigating effect on the timing of inundation of Cartier Bay by the ALR from between six and 20 days. Under current conditions, the ALR inundates Cartier Bay between late May and mid-June when reservoir elevations exceed 433.8 (the current "official" height of the swale). When inundation happens, there is a cooling effect on the water of Cartier Bay, which is exemplified using data from 2010 and 2011. In 2010, the ALR started inundating Cartier Bay on 19 May and on June 4 in 2011 (Figure 5-25).

Because a key feature of breeding sites is water temperature, with higher temperatures accelerating tadpole growth (Ultsch et al. 1999), it is necessary to consider the potential effects of water cooling due to inundation on the development of Western Toad tadpoles. If Western Toad tadpoles were sedentary and used the water column at the depth of the temperature data logger there would be an impact on their developmental rate (i.e., it would be slowed); however, as Hawkes and Wood (2014) point out, tadpoles are mobile and seek out the warmest part of the water column, which is typically near the edge of a water body. In the case of Cartier Bay, tadpoles are observed each year in the warm and shallow margins of the bay and metamoprhs have been observed migrating from Cartier Bay to upland overwintering habitat (V.C. Hawkes, pers. obs.). Either this is a behavioural adaptation or it suggests there is little to no effect of water temperature on the developmental rate of Western Toads. As such, a change in water temperature associated with the proposed physical works is likely to have little to no impact on the development of Western Toad tadpoles. However, one cannot assume that the newly created shallow water margins will provide a level of habitat suitability required to support the same or greater number of tadpoles and toadlets.

5.7.3.1.2.2 Effects of Changing Water Levels

Another key feature of Western Toad breeding habitat is shallow water, usually between 5 and 30 cm in depth. These shallow water breeding habitats tend to be relatively devoid of vegetation and have soft, often muddy substrates. Data collected for CLBMON-37 between 2007 and 2014 indicate that Western Toad egg strings are most often deposited in water between 10 and 30 cm deep and are typically observed in May and early June in habitats with little to no vegetation and soft substrates (Hawkes and Tuttle 2010, 2011, 2012, 2013). Others have reported that toad egg strings are rarely deposited at depths > 15 cm (Hammerson 1999); Corn (1998) summarized ovipositon sites used by Western Toads and reported that they have been known to deposit eggs at depths ranging from 5 cm and 2 m, but depths < 1m were more typical. In other regions of the Pacific Northwest and British Columbia Western Toad egg strings are most frequently deposited in water ranging from 5 to 30 cm in depth on soft mud substrates or submergent vegetation (E. Wind, K. Ovaska, D. Olson, pers. comm.). The physical works will reportedly increase the total surface area of Cartier Bay and create shallow wetland habitat at the margins of the new wetland. This may appear to be a benefit to Western Toads because an increase in the total area of shallow wetland habitat should (in theory) increase the availability of breeding habitat. However, we do not currently know 1) how much shallow wetland habitat exists in Cartier Bay, 2) how the shallow wetland habitat is distributed, 3) whether Western Toads will use any shallow wetland habitat, and 4) whether the physical works will in fact result in a net increase, decrease, or no change in the extent of suitable, shallow wetland habitat. With respect to whether toads will breed in newly created shallow wetland habitat, we know that toads deposit eggs in several locations within Cartier Bay on a regular (annual) basis particularly in the east compartment adjacent to Airport Road.

If the proposed physical works was implemented in Cartier Bay there are several possible outcomes for Western Toads in terms of the availability and suitability of shallow wetland habitat: 1) no change; 2) reduction (negative); or 3) increase (positive).

From a risk assessment perspective, there is potential risk to Western Toads arising from the physical works that is associated with unknown changes in habitat availability, suitability, and distribution (particularly for shallow wetland habitat) following the implementation of the proposed physical works. Without sufficient data to address these unknowns, the implementation of the proposed physical works is not recommended at this time.

5.7.3.1.2.3 Timing of Reservoir Operations

Western Toad breeding habitat in Cartier Bay is situated between 433 and 435 m ASL. In three of the four years of monitoring these habitats have been inundated in May and completely flooded by June (Figure 5-27). Western Toad egg strings are generally laid between the mid to end of April and early June with tadpole development through the middle of August. Young toadlets leave the breeding pond during August and into early September. The elevation at which Western Toads were observed in each month (all life stages) relative to reservoir elevations indicates that toads are using habitats in the DDZ (i.e., at elevations <440.1 m ASL) during most months of the year. Furthermore, Western Toad toadlets have been observed annually at monitoring locations in Revelstoke Reach suggesting that breeding by this species is not impacted by timing of reservoir operations, but this has not been quantified. We do not know if habitats in the DDZ function as a source or sink for Western Toad (or other amphibian) populations (see discussion in Section 5.7.3.1.1), but at present it does not appear that minor adjustments to reservoir operations would reduce impacts on amphibians and reptiles. It is more probable that a major change in reservoir operations (e.g., maintain elevations < 433 m ASL through August) would be needed to optimally support amphibian and reptile populations.

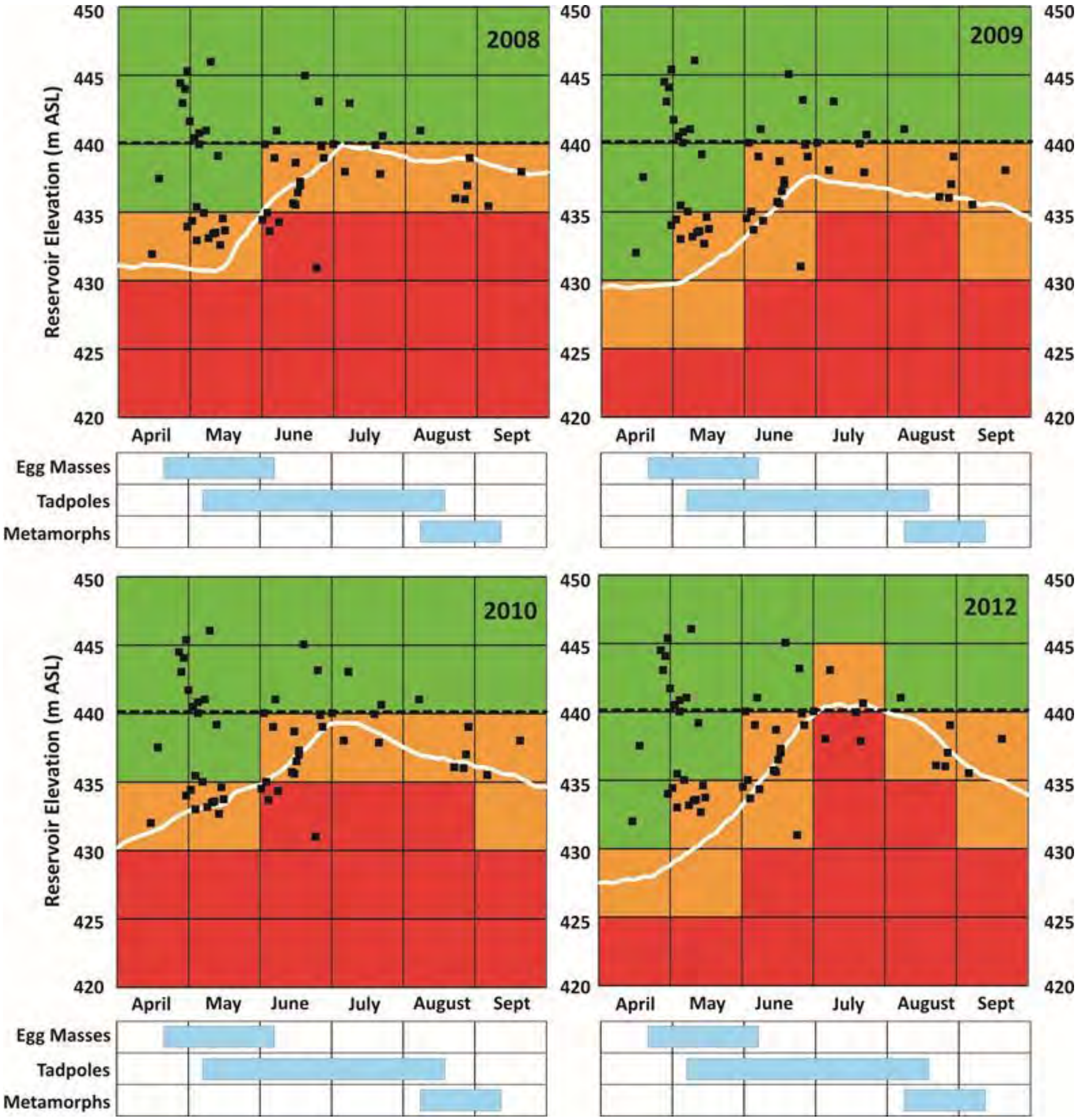


Figure 5-27: **Risk matrix portraying the mortality risk of increasing reservoir elevations to Western Toad and their habitat at various elevations in the DDZ of Arrow Lakes Reservoir.** Reservoir elevation data from April 1 through September 30, for each year are plotted (solid white line) and the normal operating maximum is plotted (doted black line). The phenology of various amphibian life stages are shown relative to date and elevation. The colours represent high risk (red), moderate risk (orange) and no risk (green). Risk is assessed relative to habitat availability as a function of reservoir inundation: red not available; orange: partially available, and green: available

5.7.3.2 *Western Painted Turtle*

As indicated previously, Western Painted Turtles have rarely been observed in Cartier Bay and current data suggest that Cartier Bay does not provide nesting or over-wintering habitat for this species. At present, it does not appear that Cartier Bay is an important habitat for this species relative to other regions of Revelstoke Reach (Montana Slough, Airport Marsh) or adjacent habitats (Turtle Pond, Williamson Lake). The proposed Cartier Bay Site 15A physical works project may result in an increase in existing water depth in Cartier Marsh of almost 1 m. Although turtles tolerate a wide range of water depths, current understanding is that shallow water habitat is paramount. Depending on location, Cartier Bay water depths affected by Site 15A already reach a maximum of ~2.2 m when not inundated by the reservoir, and provides a large area of shallow (≤ 3 m) water habitat that would correspond to moderate or high habitat suitability in terms of water depth alone. Consequently, we find no support for an obvious benefit to Western Painted Turtle from the proposed physical works at Site 15A. In contrast, it is possible that the proposed Site 14 physical works will substantially increase the area of shallow water habitat in that area, and thus could provide a neutral to positive effect on habitat suitability for Western Painted Turtles, provided Reed Canarygrass is eliminated or greatly reduced as result of the additional flooding.

5.7.3.2.1 Risk-Benefit Summary (Amphibians and Reptiles

There are no data to support a net-benefit to amphibians or reptiles due to the implementation of the proposed physical works at site 14 or 15A. Currently, Cartier Bay supports a healthy population of Western Toads and is not considered high-value habitat for Western Painted Turtle. There are potential risks associated with the proposed physical works, primarily associated with changes in the suitability of habitats used by toads for breeding. The lack of detailed characterization of those habitats contributes to an inability to properly assess the net loss or gain of highly suitability habitats following the implementation of physical works. Taking all current data into consideration coupled with information from the literature, there is little support for implementing the physical works at sites 14 or 15A as currently proposed.

The data we have suggest that there is little in the way of use of site 14 by either amphibians or reptiles (turtles), which presents an opportunity to assess the ecological response of wetland habitat in the drawdown zone of Arrow Lakes Reservoir. However, all areas in the drawdown zone will continue to be inundated by Arrow Lakes Reservoir, albeit for potentially fewer days each year. Unless reservoir elevations are maintained at elevations lower than the proposed invert swales, all sites will be continue to be impacted by reservoir inundation and will likely never reach their full ecological potential.

6 Summary

This paper presents a multi-disciplinary, scientific review of the best available information on the hydrology, physical geography, ecology, flora, and fauna of Cartier Bay, as it relates to the potential benefits and risks associated with proposed physical works at Site 14 and 15A. Guiding this review were experts in the fields of wetland ecology, hydrology, plant ecology, and bird, reptile and amphibian biology, with additional valuable insights from local stakeholders. The informed consensus resulting from this review is that there is a high degree of uncertainty regarding the ecological outcomes of permanently raising the water level and altering the timing of flooding of the existing Cartier Bay wetland (i.e. Site 15A).

This Ecological Impact Assessment does not support a conclusion of net ecological benefit to Cartier Bay should the originally proposed physical works at Sites 14 and 15A be implemented. This position is supported by the various sources of uncertainty, many of which will not be resolved because of the somewhat predictable and ever changing reservoir elevations. Despite this, there are options for other physical works in Cartier Bay such as creation of shallow ponds and ditches that would increase habitat diversity and have a high probability of improving overall suitability of Cartier Bay for a variety of wetland vegetation and wildlife.

The ecological effects of the proposed physical works on select flora and fauna is summarized in

Table 6-1. The current state of each component at Site 14 ranged from no data (Aquatic Invertebrates) to intermediate diversity for Aquatic Macrophytes. The current suitability of habitat at Site 14 was assessed as little to no use for all other components. By implementing the physical works at Site 14, habitat suitability is predicted to remain unchanged for two components (Terrestrial Vegetation and Western Painted Turtle); remain unchanged or possibly increase for Waterfowl, Songbirds, and Western Toad; and will remain unknown for Aquatic Invertebrates until more data are collected.

The current state of the same components at Site 15A differed markedly from Site 14. In its current state, the diversity of three components (Aquatic Invertebrates, Terrestrial Vegetation, and Aquatic Macrophytes) was assessed as intermediate. Both Waterfowl and Songbirds use Site 15A to a higher degree relative to other areas in Revelstoke Reach. The wetlands impounded by Site 15A also provide important habitat for Western Toad. Western Painted Turtle does not regularly use the wetlands at Cartier Bay; there are only two observations of a single turtle in this wetland since 2010. Implementing the physical works at Site 15A was predicted to have an overall negative effect on habitat suitability for Terrestrial Vegetation, Aquatic Macrophytes, Songbirds, and Western Toad. Changes in habitat suitability for Waterfowl and Western Painted Turtle were unclear. It is currently unknown how the Site 15A physical works (if implemented) would affect habitat suitability for Aquatic Macrophytes.

Notwithstanding these uncertainties, the further consensus is that the Site 15A project appears to incur a high level of ecological risk relative to expected benefits. Thus, its implementation is not currently justified on scientific grounds. In contrast, the ecological risks associated with the Site 14 project appear to be relatively modest. As a comparatively small and controlled exercise in wetland creation with a number of possible benefits, the Site 14 project may be worth pursuing with some modification to the present design.

Table 6-1: Summary of current habitat suitability* and predicted changes to habitat suitability with the implementation of physical works at Sites 14 and 15A. Green triangle: consider proceeding; Yellow Triangle: reassess or do not proceed; red triangle: do not proceed with physical works. Arrows indicated direction of predicted change in habitat suitability (increase, decrease, or stay the same).

Flora and Fauna Summary	**Site 14**		**Site 15A**	
Component	**Current state**	With works	**Current state**	With works
Terrestrial vegetation	Low diversity	△ ⇔	Intermediate diversity	△ ⇔ or ⇩ 🔺
Aquatic macrophytes	Intermediate diversity	△ ⇔ or ⇩	Intermediate diversity	△ ⇔ or ⇩ 🔺
Waterfowl	Little to no use	△ ⇔ or ⇧ ▲	High use	△ ⇔
Songbirds	Little to no use	△ ⇔ or ⇧ ▲	High use	△ ⇔ or ⇩ 🔺
Amphibians (Western Toad)	Little to no use	△ ⇔ or ⇧ ▲	Important habitat	△ ⇔ or ⇩ 🔺
Reptiles (Western Painted Turtle)	Little to no use	△ ⇔	Little use	△ ⇔
Aquatic Invertebrates	No Data	△ ?	Intermediate diversity	△ ?

*Habitat suitability is the capacity for a given habitat to support a selected species in its current state.

Hydrology

From a hydrology perspective, it is unclear what the effects on water depth will be of raising the height of the existing rail grade at the two locations in Cartier Bay. Temporal changes in water depth will be influenced not just by the height of the impoundment structure but also by factors such as precipitation, surface-water inflow and outflow, ground-water inflow and outflow, evapotranspiration, and bathymetry. Long term data on most of these variables are lacking. The limited water budget information available for Cartier Bay is inadequate to support reliable predictions around changes to the magnitude, frequency, and duration of wetland inundation.

Further, we lack data on the seasonal pattern of water level of Cartier Bay relative to the height of the existing swale. Data on surface water elevations during spring prior to inundation are needed to determine how much new area would be flooded. The estimate provided in Golder (2009b) does not appear to be substantiated by observations made in fall 2014 when Arrow Lakes Reservoir was ~ 434.75 m ALS (or the approximate height of the proposed invert swale at Site 15A). Not knowing where, and in what proportion, the newly created shallow and deep water features will be situated precludes a calculation of habitat gain, which limits our ability to estimate habitat suitability pre- and post-physical works.

In addition to these knowledge gaps, uncertainties remain regarding:

- rail grade permeability (given the ad hoc nature of the primary barrier, will impounded water be retained, or will it seep under/through into the main river channel? This question is especially relevant For Site 14, because if a permanently wetted minimum water level is not maintained, the desired vegetation may not develop or be sustained).
- the accuracy of the reported height of 433.8 for the existing Site 15A swale (field observation suggest the actual height may be higher), which will influence the magnitude of changes with respect to inundation timing, duration, and depth.
- the consequences of flood failure on wetland hydrology in those years when reservoir elevations do not exceed the new swale height of 434.75 m.
- the risk posed by water overflowing from the Site 15A impoundment into the new impoundment at Site 14 (which is lower in elevation).
- the magnitude and direction of changes to the wetland thermal regime and ice cover due to increased water depth (there is some likelihood that deeper water could lead to delayed ice breakup in the spring, with negative consequences for wildlife).

Vegetation

Site 15A impacts on riparian and aquatic vegetation are projected to be neutral at most, and potentially detrimental in the long term. At this time our projections regarding riparian vegetation are largely speculative, because detailed data on riparian vegetation are lacking. Previous vegetation studies focused on the on-the-ground conditions and did not consider how changes in reservoir elevations at the scale proposed might impact the riparian community.

That said, we expect that the existing herb and sedge dominated communities that partially occupy the receding shoreline along the inside of the current wetland will be largely replaced by a Reed Canarygrass-dominated riparian interface. This will likely result in overall lower habitat values for the wildlife (primarily amphibians and shore birds) observed to utilize these areas. Because Canarygrass has a known capacity to persist and even thrive in shallowly wetted areas, we have low confidence that the new interface will soon revert to the original habitat type or that the newly created shallow wetted areas will provide a suitable substrate for the development of wetland vegetation. These outcomes are less of a concern for Site 14, as there is little open riparian habitat here to start with and this area does not currently appear to be much utilized by wildlife.

We do not expect there to be many notable changes in the composition or quality of aquatic vegetation as a result of raising water levels upstream of Site 15A. Delaying the seasonal reservoir inundation by a few weeks in the spring may allow for increased development of floating macrophyte beds, which would be a beneficial outcome for the aquatic community as these are currently in limited supply in Cartier Bay. Some submergent macrophytes may be able to exploit the deeper water column and increase in abundance and distribution, although these already occur in high abundance and there is little to suggest that they are ecologically limiting at present. As a corollary to this response, there is a high risk that increasing the extent and depth of the existing Cartier Bay wetland will mainly serve to expand the available habitat niche for the introduced invasive macrophyte, Eurasian Water-milfoil. An increase in the density of this already dominant species could result in displacement of native macrophytes while increasing biological oxygen demand within the wetland.

We feel it is more likely that that the creation of a permanent wetland at Site 14 will have a beneficial outcome with respect to wetland vegetation, mainly because this site does not currently support such. Over time, we expect that the composition of the aquatic macrophyte community here could come to resemble that of the primary Cartier Bay wetland, although as with Site 15A there is a risk that Eurasian Water-milfoil will pre-empt any new habitat niches before native macrophyte species can become established. However, it may be possible to mitigate or minimize this risk using interventions such as mechanical control combined with the manual introduction of desired macrophytes.

Wildlife

Western Toads use Cartier Bay during the spring, summer, and fall with most use associated with the spring breeding season. Cartier Bay is one of the more important sites within the DDZ of the ALR for toads as it provides important shallow water breeding habitat (water < 50 cm deep). For Western Toads, shallow water between 5 and 30 cm is required for breeding and this habitat type is currently well-represented in the eastern compartment of Cartier Bay. The availability and distribution of similar shallow wetland habitats following the implementation of the proposed physical works is unknown and we currently have no way of assessing whether the physical works will result in a net increase of shallow wetland habitat that would be suitable for breeding Western Toads.

Although there is no proven risk to Western Toads arising from the physical works that could be attributed to changing water levels in Cartier Bay, if the existing Reed Canarygrass does not rapidly die in the newly created shallow margins, the habitat for breeding toads will likely not be suitable. The unknowns associated with habitat availability and distribution (particularly for shallow wetland habitat) coupled with the known changes to Cartier Bay and unlikely increases in total area associated with the east compartment of Cartier Bay suggest that there is no compelling reason to proceed with the physical works as proposed.

Recent observation records indicate that Western Pained Turtles rarely utilize Cartier Bay suggesting that the habitat may have low suitability in its current state. This could be due to a combination of landscape-level and site-level factors (e.g. spatial proximity/connectivity to other wetlands, water depth, water physicochemistry, topography, soil substrate, vegetation, forage/prey availability, nest site availability, overwintering habitat suitability, reservoir inundation patterns, etc.). We are unable to advise whether the Site 14 and Site 15A Cartier Bay physical works projects would result in an increase in site occupancy by Western Painted Turtles.

It is well documented that the Cartier Bay wetland is important habitat for birds. In particular, the existing wetted area is heavily selected by migrant waterfowl (e.g., dabbling and diving ducks), while the shoreline provides a highly important foraging habitat for American Pipit during their spring migration. The wetland is likely the most important habitat feature in the region for these two groups during their spring migrations. On one hand, the Site 15A project could provide some benefit to waterfowl by reducing the time span during which the wetland is inundated by the operations of the Arrow Lakes Reservoir during the fall migration. Impounding these basins would also increase access to deep and shallow pond habitat, which could also be a benefit.

On the other hand, there is little evidence that (1) habitat availability or suitability is currently limiting for waterfowl, or that (2) the newly created habitats will match or exceed the existing habitat in terms of quality. Rather, there is a high risk that the proposal to raise water levels in the main pond (Site 15A) will exert a detrimental effect on the existing habitat values for both groups. Specifically, the risk is that this project will create an excess of low suitability shallow and deep pond habitat, at the cost of destroying the existing high quality shallow and deep pond habitat, resulting in a net loss of habitat value. If habitat suitability diminishes, the ecological benefit accruing from reduced reservoir influence will be of minor significance. In contrast, because Site 14 would only impound low suitability habitat, it is more probable that habitat suitability will be improved through the creation of a new ponded area.

Further, analysis has shown that usage of the Cartier Bay wetland is limited by ice thaw dates each spring; in the fall, waterfowl utilize the site until freeze-over. The potential for Site 15A to alter the freeze/thaw dates at the Cartier Bay wetland constitutes an additional risk. If the date of thawing is delayed as a consequence of raising the water depth, spring migration could be negatively impacted. Consequently, Site 15A would need to be highly effective at creating suitable habitat in order to replace/match, or improve upon the suitability of the existing habitat, but we have no compelling evidence that this the case.

Taken together, the risks and benefits of implementing the Site 14 and Site 15A impoundments suggest that Site 14 may provide some benefits to birds with low risk of negative impacts, while Site 15A incurs too much risk, relative to low expected benefit, thus is not recommended.

7 Other Options

Given the relative uncertainty regarding the ecological benefits of the physical works proposed for Cartier Bay it is reasonable to investigate alterative options to enhance habitats in the drawdown zone. Some examples are provided below, primarily as discussion points. Prior to implementing any physical works in Cartier Bay these options should be considered relative to reservoir elevations, existing elevation survey data, ecological benefits, and cost.

1. Consider the construction of two or three berms across the north channel of Cartier Bay to assist with the maintenance of water levels should site 14 be implemented. This suggestion was made by Mr. F. Maltby of Revelstoke, B.C. and has merit for further investigation. If required, the berms would create a series of step-pool marshes at varying elevations with those at the highest elevations being available longer (i.e., not inundated) than lower ones (see Hawkes and Fenneman 2010). The area around the berms could be the focus of revegetation efforts to increase habitat heterogeneity.
2. Consider level-ditching and the creation of shallow ponds in the expanse of Reed Canarygrass in Cartier Bay through experimentation and low-impact removal (see Hawkes et al. 2011). Spoil mounding could be considered, but some form of armouring is likely required to ensure these mounds aren't eroded and simply wash away with inundation. The shallow ponds, which could range from several centimetres to ~ 1 m could provide additional habitat for pond-breeding amphibians, reptiles (garter snakes and possibly Western Painted Turtle) and water-associated birds (if large enough).
3. Consider revegetation trials that focus on live stakes (balsam poplar) of varying diameters and lengths, planted at varying depths in the drawdown zone and elevations, and at different times of the year. For example, plant some in the spring and fall (if reservoir elevations permit) and assess the efficacy of the various methods to inform future larger-scale plantings.
4. Five species of ducks nest in tree cavities: Common Merganser (*Mergus merganser*), Hooded Merganser (*Lophodytes cucullatus*), Wood Duck (*Aix sponsa*), Common Golden-Eye (*Bucephala clangula*), Barrow Golden-Eye (*Bucephala islandica*), and Bufflehead (*Bucephala albeola*). These species nest in tree cavities created by woodpeckers or from natural decay; they nest in both coniferous and deciduous trees larger than 30 cm diameter. The creation and operation of the Arrow Lakes Reservoir limits the establishment of larger trees along the valley floor, which in turn limits the availability of suitable nesting habitat for cavity nesters. To mitigate this impact, the

Wildlife Physical Works Committee recommended the installation of cavity nesting duck boxes (next boxes) to increase wildlife use in the reservoir; nest boxes are widely used to enhance populations of cavity-nesting birds including waterfowl and occupancy rates are typically moderate to high (50 to 90 per cent). Nest boxes have been installed in Revelstoke Reach, including Cartier Bay (Kellner 2013, 2014), but additional boxes and location may be beneficial.

5. Cartier Bay provides important Western Toad breeding habitat that is adjacent to important upland summer and winter habitat. Each year toads are killed on the road that bisects these two important habitats and consideration of a toad crossing structure is suggested to decrease road-based mortality. Although upland habitat is not the purview of BC Hydro, the location of important breeding habitat in the drawdown zone of Cartier Bay suggests that some form of mitigation to reduce mortality be considered. Drift nets and culverts could be used to funnel toads through culverts under the road and community based volunteer initiatives during the breeding season could be used to move toads off the road.
6. Consider addition of loafing logs or floating island to Cartier Bay and adjacent wetland habitats.
7. Consider the addition of other wildlife enhancements or habitat creation to benefit wildlife including Osprey nest poles, a high elevation gravel bed to provide nesting habitat for Killdeer, and nest boxes for swallows.

8 Recommendations and Conclusions

We recommend that the current condition of the Cartier Bay wetland be maintained, which aligns well with the primary objective of the proposed physical works to maintain the current suitability of wildlife habitat. This will require some modified physical works at Site 15A to stabilize the eroding box culvert to ensure it maintains its current elevation of approximately 433.8 m ASL. We do not support the completion of the physical works for Site 15A as proposed by Golder (2009b). The rationale for this recommendation is based on the demonstrated ecological benefits that Cartier Bay provides for various flora and fauna, including waterfowl and amphibians, and the lack of demonstrable net ecological benefit accruing from Site 15A to the flora and fauna of the area. A cautionary approach, such as the one we advocate, is supported by the data currently available. Cartier Bay provides valuable wetland habitat for many species throughout the spring, summer, and fall. We believe there are substantial risks in manipulating the depth and total area of this important habitat, since doing so will likely result in an overall loss, rather than a gain, in habitat values.

If BC Hydro is interested in assessing the ecological impacts of physical works in the form of an in situ experiment, proceeding with Site 14 in a modified manner would accomplish this objective. The wetland habitat associated with Site 14 is not as important to the flora and fauna of Cartier Bay as the area impounded by Site 15A. Manipulating the Site 14 area could provide an opportunity to investigate how flora and fauna respond to an increase in water depth and area resulting from physical works in the drawdown zone of Arrow Lakes Reservoir. If this approach is taken, additional water budget data will be required to ensure an accurate assessment of the total area that would be flooded, and of the capacity of the newly impounded area to sustain the targeted water levels over the long term.

Other recommendations include:

- Assess the rate of erosion at Site 15A;
- Consider a simplified approach to physical works at Site 15A that includes adding fill material at the site to shore up the existing berm; avoid hard-engineered approaches;
- Obtain LiDar data for Revelstoke Reach and specifically, Cartier Bay to better understand how the proposed physical works would alter the total wetted area of Cartier Bay;
- Formally assess the timing of ice formation, thickness, and duration relative to water depth and location in Cartier Bay;
- Obtain baseline water temperature data by installing data loggers at multiple locations and depths to better predict changes in water temperature and ice formation with increasing water depth;
- Conduct terrestrial vegetation surveys at the site scale. Current data associated with CLBMON-33 is not suitable for making site-level assessments; and
- Improve the state of the knowledge with respect to aquatic invertebrates at Site 14 and Site 15A (and in Cartier Bay) as this taxonomic group is likely to be affected by any changes made at either site or through other physical works that may create or expand the total wetted area in Cartier Bay.

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10 Appendices

Appendix 10-1: Study area physiography, climate, and BEC zones.

Physiography

The Columbia Basin in southeastern British Columbia is bordered by the Rocky, Selkirk, Columbia and Monashee mountains. The headwaters of the Columbia River are at Columbia Lake in the Rocky Mountain Trench, and the river flows northwest along the trench for ~250 km before emptying into Kinbasket Reservoir behind Mica Dam (BC Hydro 2007). From Mica Dam, the river continues southward for about 130 km to Revelstoke Dam. The river then flows almost immediately into the ALR behind Hugh Keenleyside Dam. The entire drainage area upstream of Hugh Keenleyside Dam is approximately 36,500 km^2. The Columbia Basin is characterized by steep valley side slopes and short tributary streams that flow into Columbia River from all directions.

The Columbia River valley floor elevation extends from approximately 800 m near Columbia Lake to 420 m near Castlegar. Approximately 40 per cent of the drainage area within the Columbia River Basin is above 2000 m elevation. Permanent snowfields and glaciers are widespread in the northern high mountain areas above 2500 m elevation, and about 10 per cent of the Columbia River drainage area above Mica Dam exceeds this elevation.

Climate

Precipitation in the Columbia Basin occurs from the flow of moist low pressure weather systems that move eastward through the region from the Pacific Ocean. More than two-thirds of the precipitation in the basin falls as winter snow. The persistence of below freezing temperatures, in combination with abundant precipitation, results in substantial snow accumulations at middle and upper elevations in the watersheds. Summer snowmelt is reinforced by rain from frontal storm systems and local convective storms.

Air temperatures across the basin tend to be more uniform than precipitation. With allowances for temperature lapse rates, station temperature records from the valley can be used to estimate temperatures at higher elevations. The summer climate is usually warm and dry, with the average daily maximum temperature for June and July ranging from 20° to 32°C. The average daily minimum temperature ranges from 7° to 10°C. The coldest month is January, when the average daily maximum temperature in the valleys is near 0°C and average daily minimum is near -5°C.

During the spring and summer months, the major source of water in the Columbia River is water stored in large snowpacks that developed during the previous winter months. Snowpacks often continue to accumulate above 2000 m elevation through May, and continue to contribute runoff long after the snowpack has become depleted at lower elevations. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. Severe summer rainstorms are not unusual in the Columbia Basin. Summer rainfall contributions to runoff generally occur as short-term peaks superimposed on high river levels caused by snowmelt. These rainstorms may contribute to annual flood peaks under the current Columbia River Treaty operations. The mean annual local inflows for the Mica, Revelstoke and Hugh Keenleyside projects are 577 m^3/s, 236 m^3/s, and 355 m^3/s, respectively.

Biogeoclimatic Zones

Two biogeoclimatic zones occur at the lower elevations surrounding the ALR: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF). Most of the reservoir area occurs within the ICH, with three subzones and four variants represented (Table 10-1). The IDF is restricted to the southernmost portion of the area and consists of a single subzone (IDFun); this area is outside of the study area of this project. The subzones are a reflection of increasing precipitation from the dry southern slope of Deer Park to the wet forests near Revelstoke (Enns et al. 2008). The the ALR study is situated primarily within the Arrow Boundary Forest District, but a small portion of its northerly area is in the Columbia Forest District.

Most of the Columbia Basin watershed remains in its original forested state. Dense forest vegetation thins above 1500 m elevation and tree line occurs at ~2,000 m elevation. The forested lands around the ALR have been and continue to be logged, with active logging (2007/2008) occurring on both the east and west sides of the reservoir.

Table 10-1: Biogeoclimatic zones, subzones and variants that occur in the Arrow Lakes Reservoir study area

Zone Code	Zone Name	Subzone/Variant Description	Forest Region & District
ICHdw1	Interior Cedar – Hemlock	West Kootenay Dry Warm	Nelson Forest Region (Arrow Forest District)
ICHmw2	Interior Cedar – Hemlock	Columbia-Shuswap Moist Warm	Nelson Forest Region (Columbia Forest District)
ICHmw3	Interior Cedar – Hemlock	Thompson Moist Warm	Nelson Forest Region (Columbia Forest District)
ICHwk1	Interior Cedar – Hemlock	Wells Gray Wet Cool	Nelson Forest Region (Arrow Forest District)
IDFun	Interior Douglas-fir	Undefined	Nelson Forest Region (Arrow Forest District)

Appendix 10-2: Partial (non-aquatic) species list for Cartier Bay, derived from study plot data (2008-2011) obtained as part of the BC Hydro vegetation monitoring studies CLBMON 33, 12, and 11B4

Species	Species
Agrostis gigantea	*Leucanthemum vulgare*
Alopecurus aequalis	*Mimulus floribundus*
Antennaria neglecta	moss spp.
Apocynum androsaemifolium	*Myosotis scorpiodes*
Betula papifyra	*Persicaria maculata*
Callitriche palustris	*Phalaris arundinacea*
Cardamine pensylvanica	*Phleum pratense*
Carex aperta	*Pinus monticola*
Carex foenea	*Plantago lanceolata*
Carex lenticularis	*Plantago major*
Carex pachystachya	*Poa annua*
Carex sitchensis	*Poa compressa*
Carex sp.	*Poa palustris*
Centaurea stoebe	*Poa* sp.
Cerastium fontanum	*Polygonum aviculare*
Cerastium nutans	*Populus balsamifera*
Eleocharis sp.	*Prosartes hookeri*
Elymus glaucus	*Prunella vulgaris*
Elymus repens	*Pteridium aquilinum*
Equisetum arvense	*Ranunculus acris*
Equisetum fluviatale	*Rhinanthus minor*
Equisetum hyemale	*Rorippa palustris*
Equisetum palustre	*Rubus pedatus*
Equisetum variegatum	*Rumex acetosela*
Erigeron sp.	*Rumex crispus*
Eurybia sibirica	*Salix lucida*
Festuca sp.	*Salix scouleriana*
Galium trifidum	*Symphoricarpos albus*
Geranium sp.	*Taraxacum officinalis*
Hieracium sp.	*Trifolium pratense*
Hypericum perfoliatum	*Veronica officinalis*
Juncus bufonis	*Veronica peregrina*
Juncus sp.	*Vicia cracca*

Appendix 10-3: Ecology notes on selected aquatic macrophytes found at Cartier Bay (adapted from Hawkes et al. 2011). The facultative wetland species Reed Canarygrass, though not technically a macrophyte, is treated here as well.

Floating-leaved Pondweed (*Potamogeton natans*)

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 Rocky Mountain 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, organic ponds 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 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).

Richardson’s and Eel-grass Pondweeds (*P.richardsonii, P.zosteriformis*)

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).

Common Hornwort (*Ceratophyllum demersum*)

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).

Water Smartweed (*Persicaria amphibia*)

Water Smartweed communities occur in larger lakes in 0.5 to 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 Water-milfoil (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 where in areas where multiple species are found (Warrington 1983).

Eurasian Water-milfoil (*Myriophyllum spicatum*)

Eurasian Water-milfoil generally grows in fresh water, but can tolerate salinity up to 10 ppm. It can apparently 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). 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).

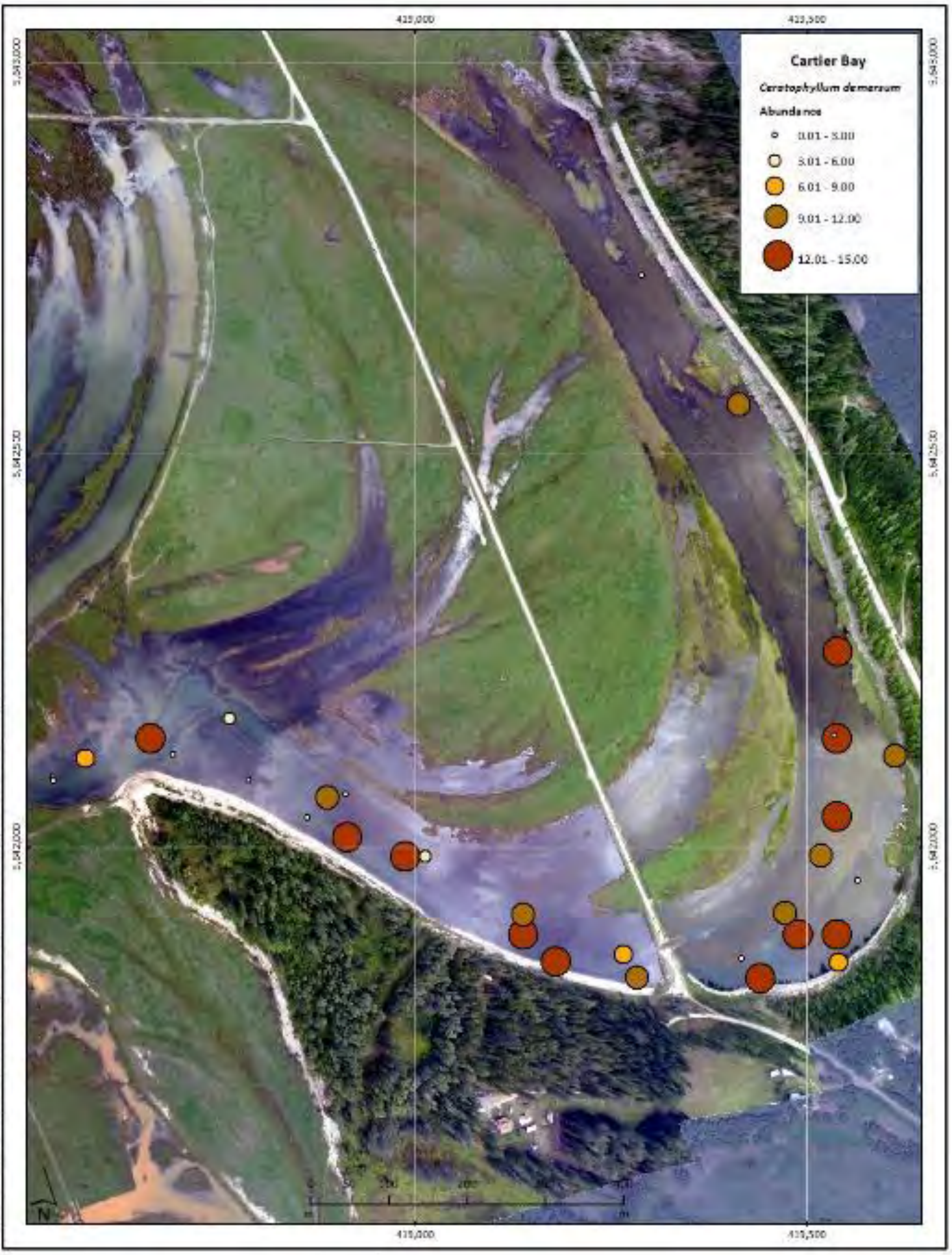
Eurasian Water-milfoil is already widespread in inundated portions of Cartier Bay, with smaller populations elsewhere throughout the study area, and thus is expected to become quickly established in any newly-created wetland habitats having connectivity to these extant wetlands. It is currently one of the dominant species at Cartier Bay, and occurs at densities that may exclude the establishment of some native species. If monitoring reveals a rapid increase in the dominance of this species that is out of proportion to its present level of dominance in the project areas, remedial action may be required. Newly created habitats should be monitored to determine its rate of spread into these areas where it did not previously have a presence. Some control efforts may be required prior and/or subsequent to proposed physical works projects in order to mitigate the likelihood that this population will act as a source population for invasion into newly-created habitats.

Reed Canarygrass (*Phalaris arundinacea*)

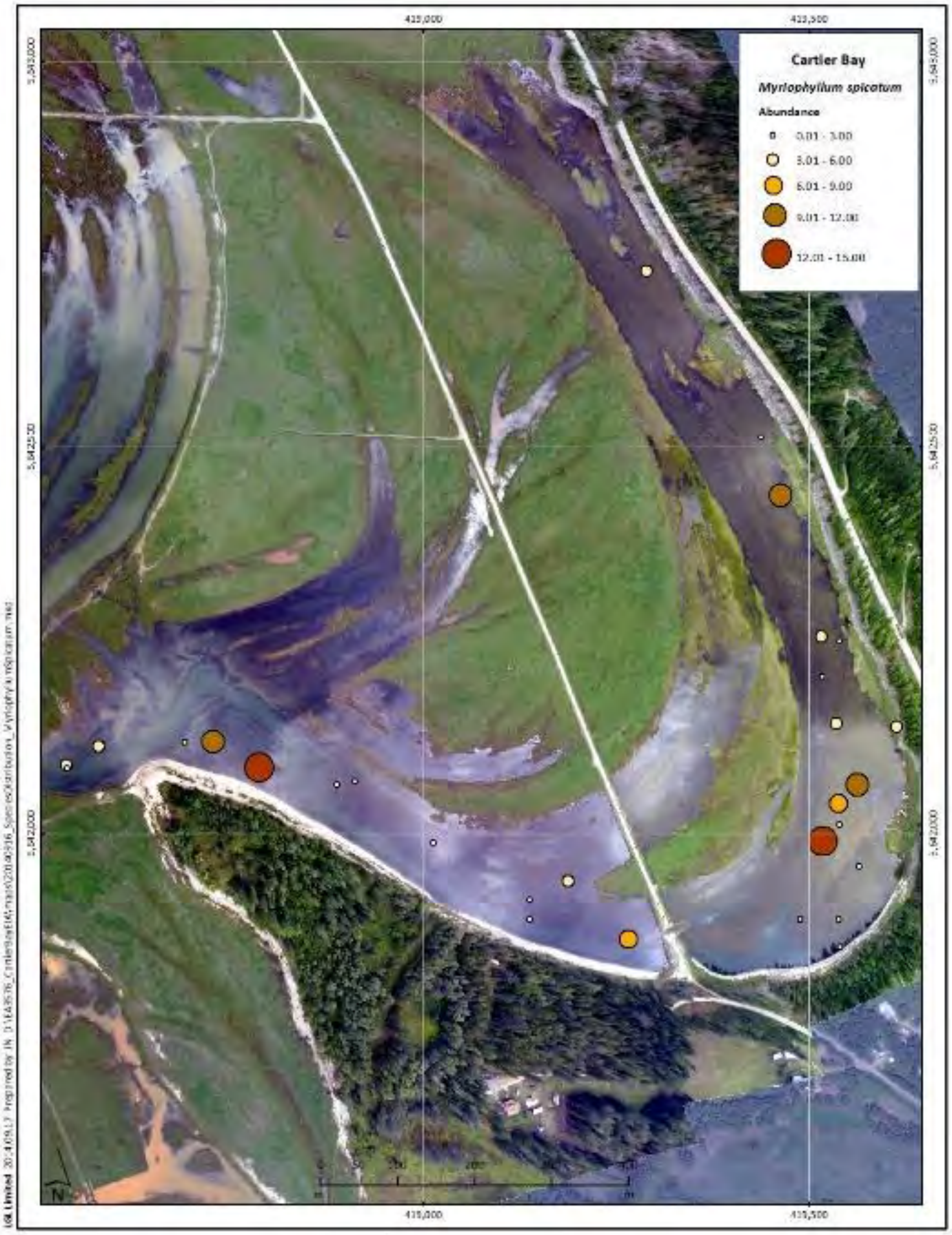
Reed Canarygrass competitively excludes other native plant species and limits the biological and habitat diversity of host wetland and riparian habitats. Unlike native wetland vegetation, dense stands of Reed Canarygrass have little value for wildlife. Few species eat the grass, and the stems grow too densely to provide adequate cover for small mammals and waterfowl (State of Washington Dept. of Ecology 2010). Reed Canarygrass thrives with periodic inundation and aggressively invades streambanks, floodplains, wet meadows, pastures, marshes, lakeshores, and rights-of-way, and seems particularly well-adapted to poorly drained soils and seasonally inundated sites (Stannard and Crowder 2001). However, it may only tolerate deep inundation (at least 30 cm of water) for two years before it succumbs (Antieu 1998). Stevens and Vanbianchi (1993) report that permanently flooding areas with more than 150 cm of water for at least three growing seasons has successfully eliminated Reed Canarygrass stands. The length of time this species can withstand deep inundation depends on temperature, current, and silt content of the water (Wheaton 1993).

Reed Canarygrass is currently well established in most regions of Revelstoke Reach that receive only periodic inundation, forming extensive rhizomatous patches that effectively out-compete all other plants. A concern is that as these vegetated areas become permanently flooded the resulting die-off of Reed Canarygrass will result in dense mats of dead thatch that prevent establishment of desirable macrophytes. In turn, this would likely affect the species of macroinvertebrates associated with wetlands, another potentially important indicator group. Further, the subsequent decomposition of large amounts of dead plant material could potentially decrease the amount of dissolved oxygen available to other organisms or otherwise modify water and soil chemistry, which could have cascading effects on the trophic web of the created wetland. As one of the goals of the physical works program is to improve wetland function, implementing the physical works in the absence of Reed Canarygrass removal or control could diminish their efficacy.

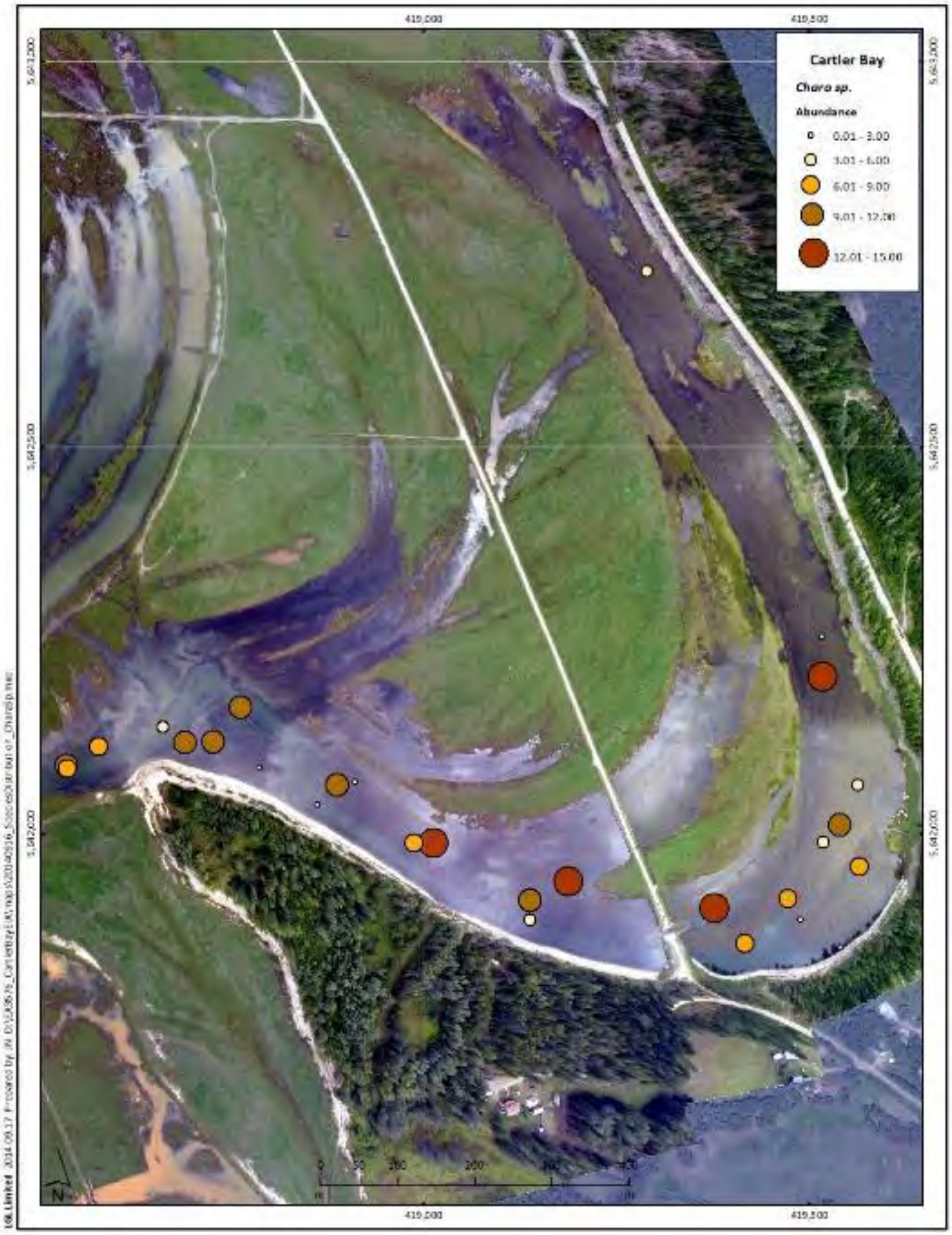
Appendix 10-4: Distribution and abundance of Common Hornwort (*Ceratophyllum demersum*) at Cartier Bay, obtained from random point samples conducted in 2011, 2012, and 2013 (data pooled). Abundance ranges are derived from the volume x cover (VC) metric, which integrates the relative cover and sample volume of each species as estimated by rake grabs at each sample point (Fenneman and Hawkes 2012). Note that the displayed distributions are representative only, since not every location was sampled; lack of a dot does not necessarily imply species absence from that location.



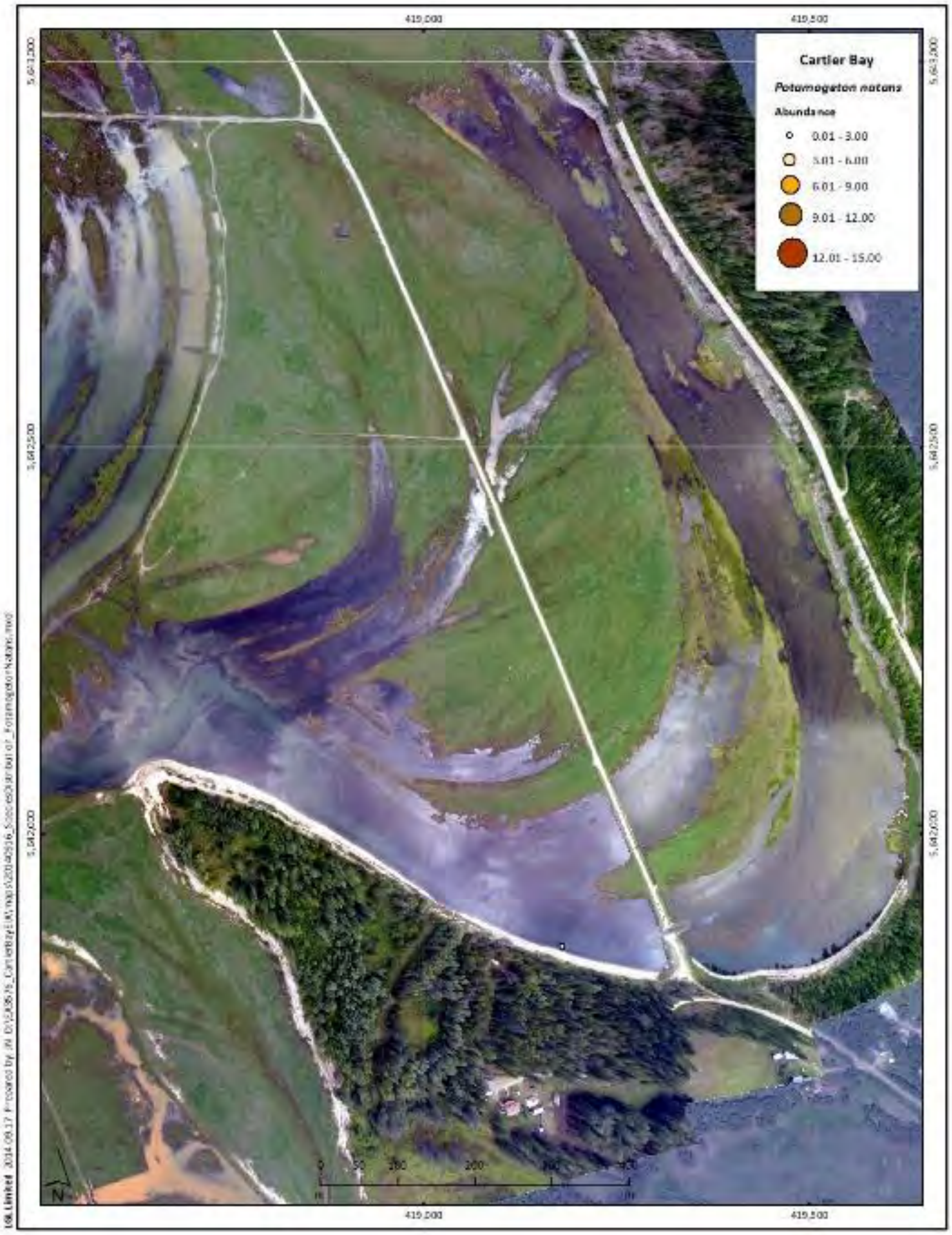
Appendix 10-5: Distribution and abundance of Eurasian Water-milfoil (*Myriophyllum spicatum*) at Cartier Bay, obtained from random point samples conducted in 2011, 2012, and 2013 (data pooled). Abundance ranges are derived from the volume x cover (VC) metric, which integrates the relative cover and sample volume of each species as estimated by rake grabs at each sample point (Fenneman and Hawkes 2012). Note that the displayed distributions are representative only, since not every location was sampled; lack of a dot does not necessarily imply species absence from that location.



Appendix 10-6: Distribution and abundance of Stonewort (*Chara* sp.) at Cartier Bay, obtained from random point samples conducted in 2011, 2012, and 2013 (data pooled). Abundance ranges are derived from the volume x cover (VC) metric, which integrates the relative cover and sample volume of each species as estimated by rake grabs at each sample point (Fenneman and Hawkes 2012). Note that the displayed distributions are representative only, since not every location was sampled; lack of a dot does not necessarily imply species absence from that location.



Appendix 10-7: Distribution and abundance of Floating-leaved Pondweed (Potamogeton natans) at Cartier Bay, obtained from random point samples conducted in 2011, 2012, and 2013 (data pooled). Abundance ranges are derived from the volume x cover (VC) metric, which integrates the relative cover and sample volume of each species as estimated by rake grabs at each sample point (Fenneman and Hawkes 2012). Note that the displayed distributions are representative only, since not every location was sampled; lack of a dot does not necessarily imply species absence from that location.



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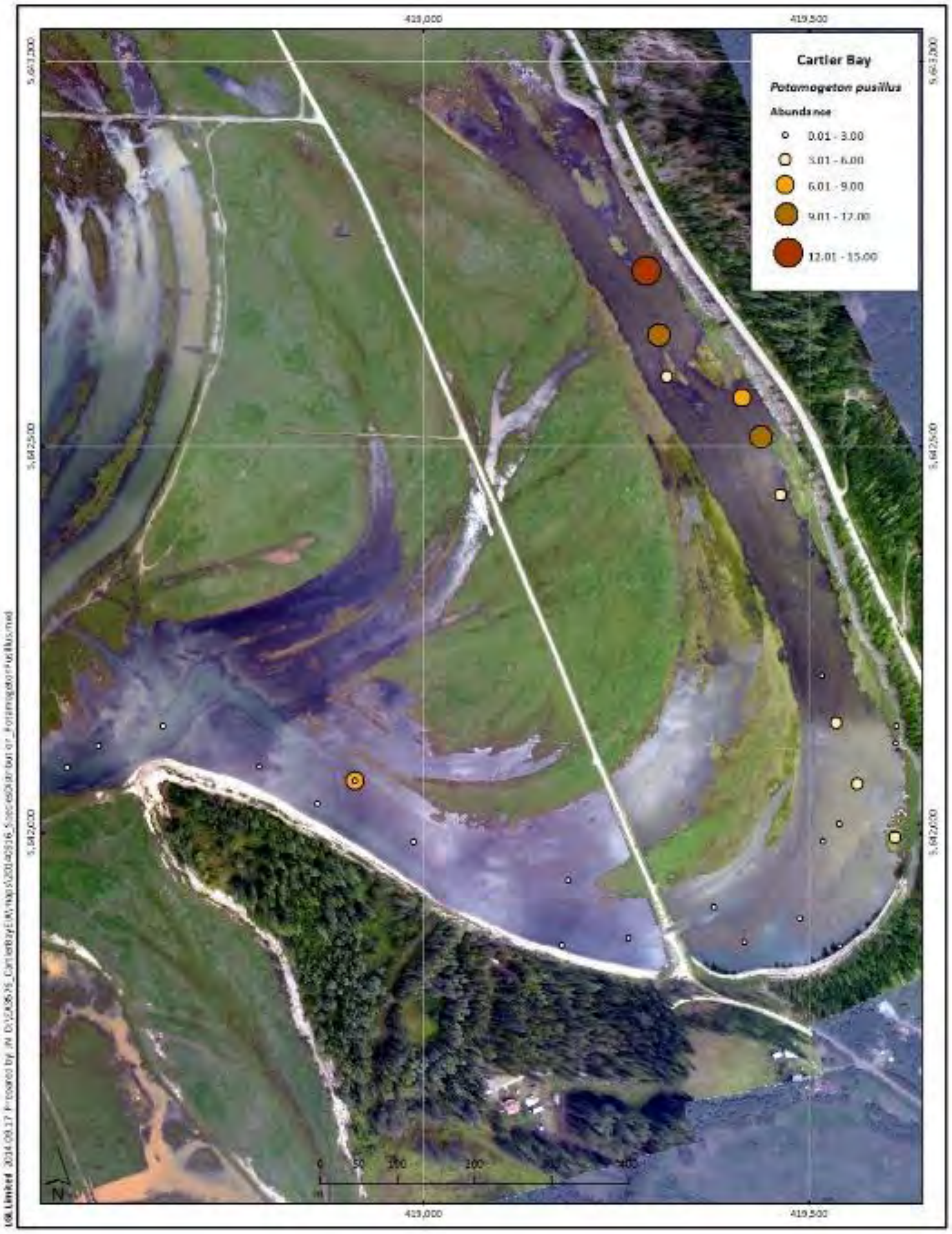
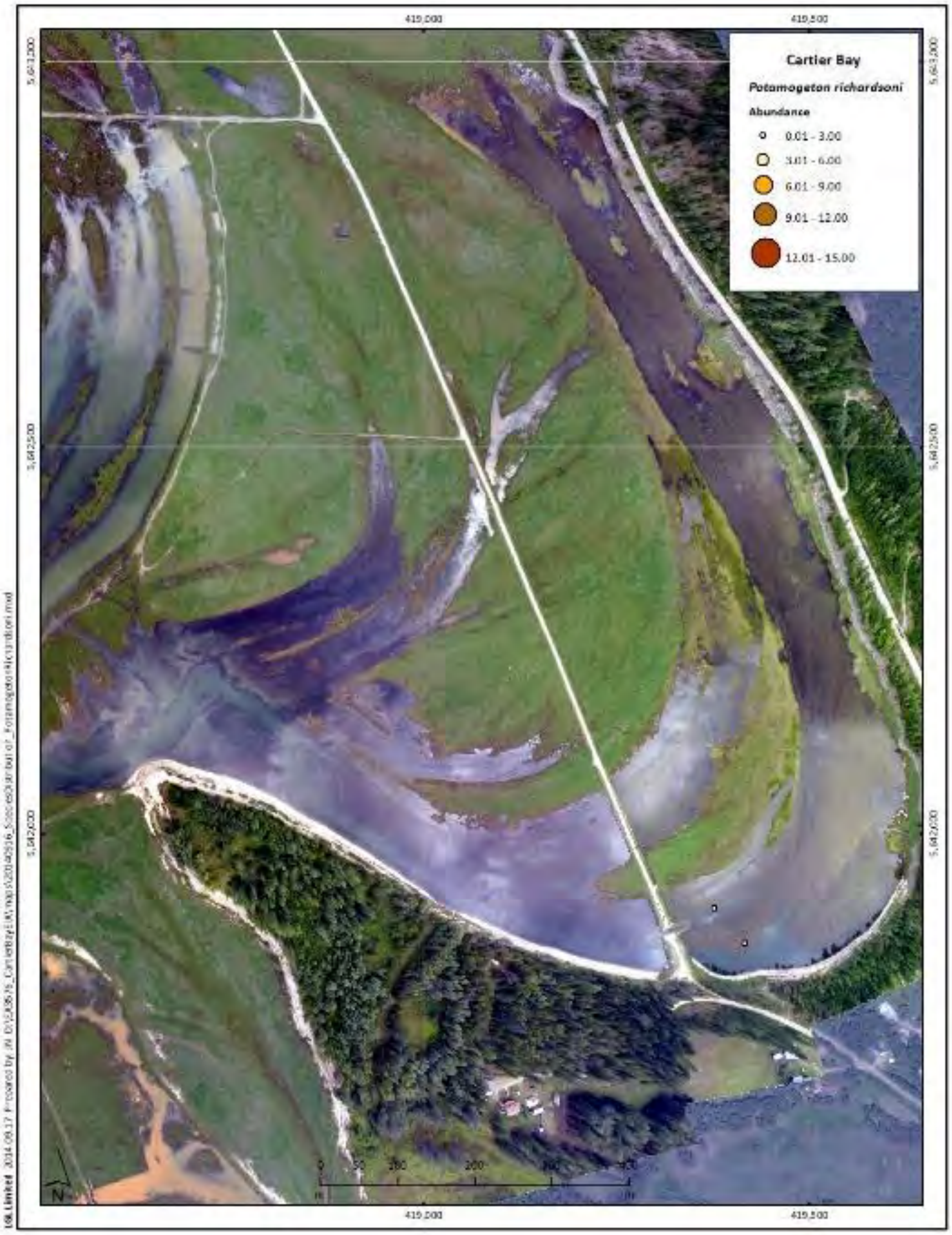
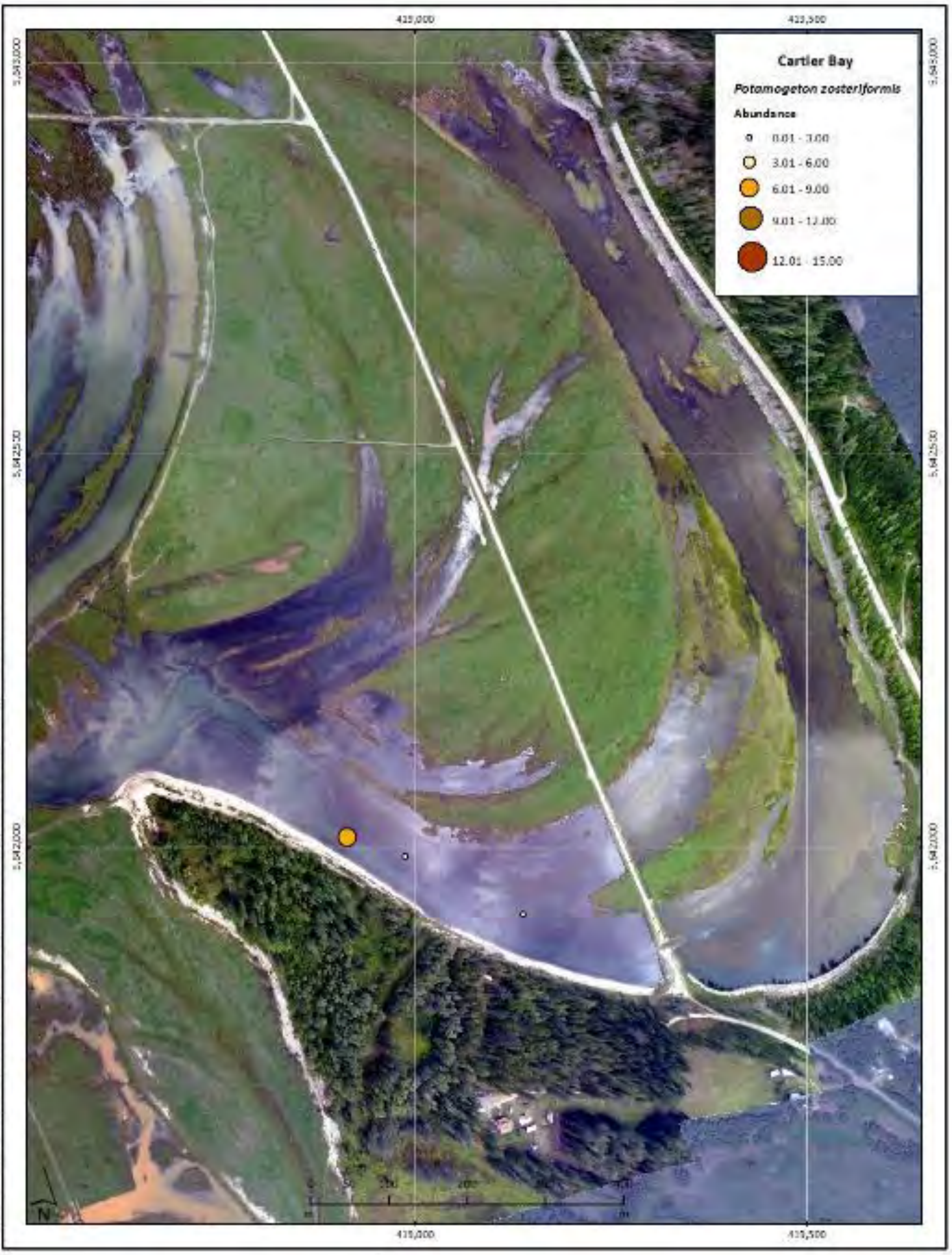
Appendix 10-8: Distribution and abundance of Small Pondweed (*Potamogeton pusillus*) at Cartier Bay, obtained from random point samples conducted in 2011, 2012, and 2013 (data pooled). Abundance ranges are derived from the volume x cover (VC) metric, which integrates the relative cover and sample volume of each species as estimated by rake grabs at each sample point (Fenneman and Hawkes 2012). Note that the displayed distributions are representative only, since not every location was sampled; lack of a dot does not necessarily imply species absence from that location.



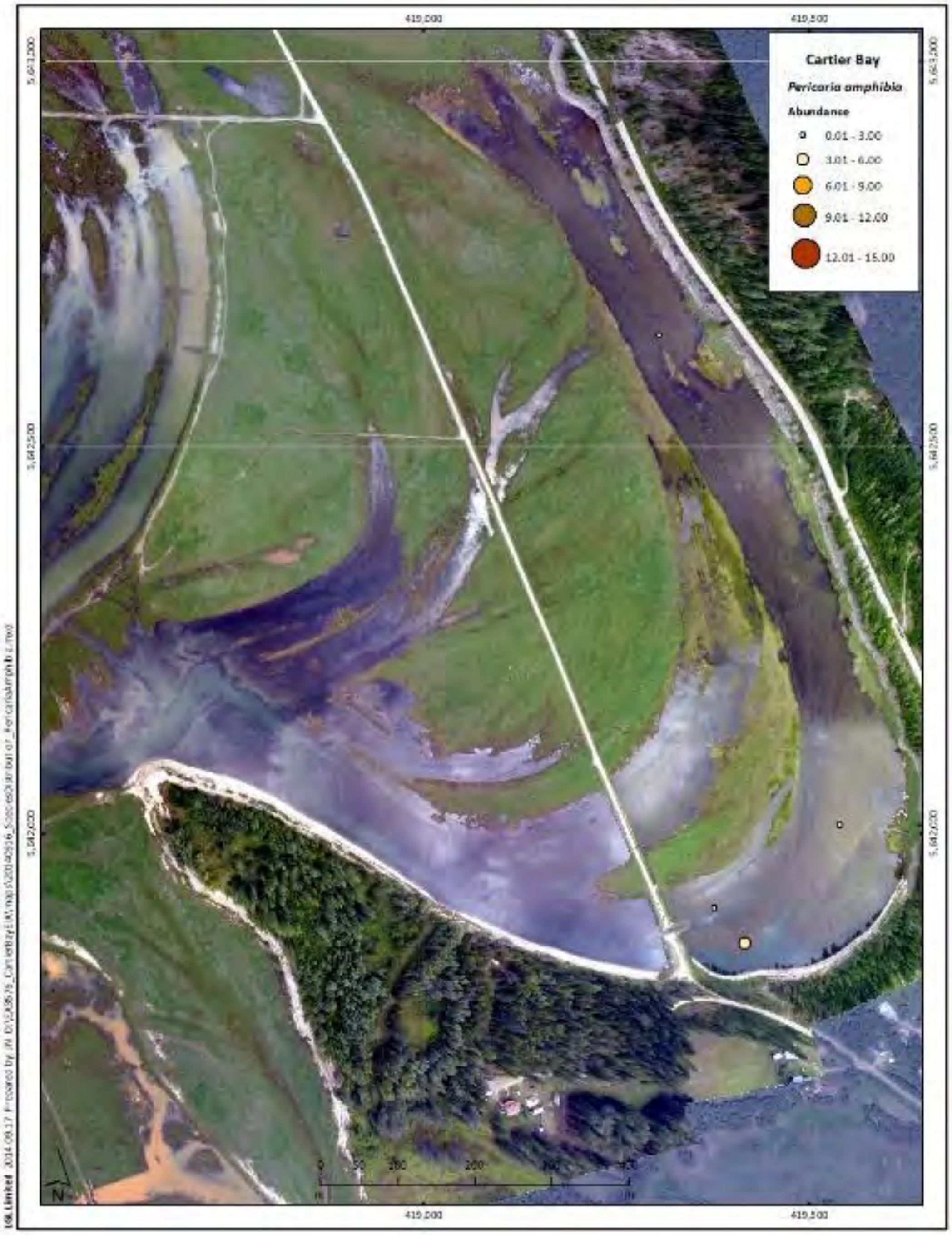
Appendix 10-9: Distribution and abundance of Richardson's Pondweed (*Potamogeton richardsonii*) at Cartier Bay, obtained from random point samples conducted in 2011, 2012, and 2013 (data pooled). Abundance ranges are derived from the volume x cover (VC) metric, which integrates the relative cover and sample volume of each species as estimated by rake grabs at each sample point (Fenneman and Hawkes 2012). Note that the displayed distributions are representative only, since not every location was sampled; lack of a dot does not necessarily imply species absence from that location.



Appendix 10-10: Distribution and abundance of Eel-grass Pondweed (*Potamogeton zosteriformis*) at Cartier Bay, obtained from random point samples conducted in 2011, 2012, and 2013 (data pooled). Abundance ranges are derived from the volume x cover (VC) metric, which integrates the relative cover and sample volume of each species as estimated by rake grabs at each sample point (Fenneman and Hawkes 2012). Note that the displayed distributions are representative only, since not every location was sampled; lack of a dot does not necessarily imply species absence from that location.



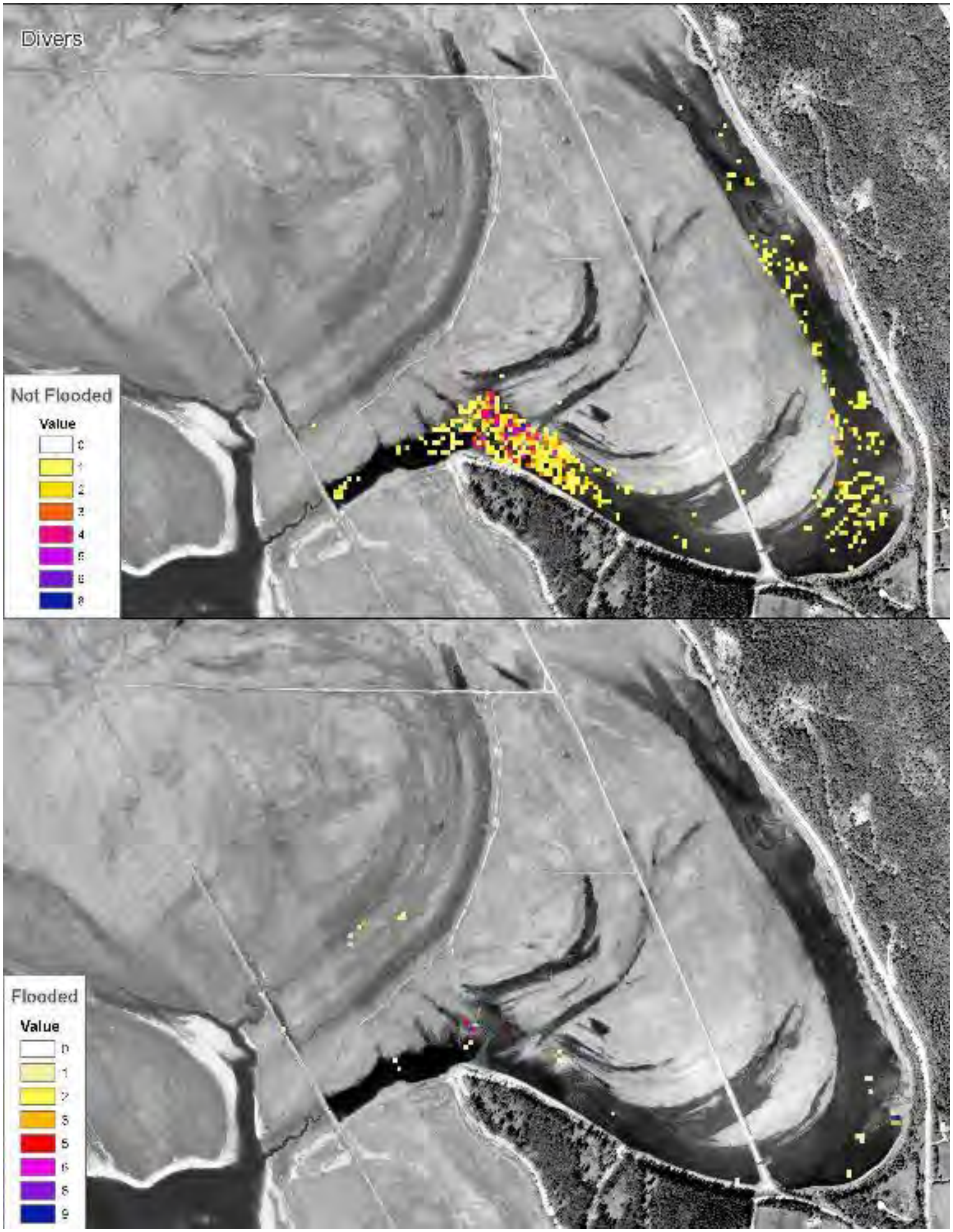
Appendix 10-11: Distribution and abundance of Water Smartweed (*Persicaria amphibia*) at Cartier Bay, obtained from random point samples conducted in 2011, 2012, and 2013 (data pooled). Abundance ranges are derived from the volume x cover (VC) metric, which integrates the relative cover and sample volume of each species as estimated by rake grabs at each sample point (Fenneman and Hawkes 2012). Note that the displayed distributions are representative only, since not every location was sampled; lack of a dot does not necessarily imply species absence from that location.



Appendix 10-12: List of waterfowl observed at the Cartier Bay wetland during land-based waterbird surveys (May 2008 to July 2014).

Common Name	Dabbling Duck	Diving Duck	Frequency	Percent
Canada Goose			16579	46
American Wigeon	●		10268	29
Mallard	●		3661	10
Common Merganser		●	1021	3
Unidentified Waterfowl Sp.			875	2
Ring-necked Duck		●	865	2
Green-winged Teal	●		710	2
Northern Pintail	●		295	1
Bufflehead		●	220	1
Barrow's Goldeneye		●	181	1
Common Goldeneye		●	152	0
Blue-winged Teal	●		147	0
Northern Shoveler	●		132	0
Wood Duck	●		113	0
Cinnamon Teal	●		79	0
Scaup Sp.		●	69	0
Tundra Swan			61	0
American Coot			53	0
Goldeneye Sp.		●	51	0
Lesser Scaup		●	50	0
Pied-billed Grebe			47	0
Common Loon			44	0
Trumpeter Swan			36	0
Hooded Merganser		●	36	0
Greater Scaup		●	21	0
Unidentified Swan			20	0
Red-necked Grebe			17	0
Gadwall	●		15	0
Unidentified Teal	●		13	0
Western Grebe			10	0
Snow Goose			9	0
Redhead		●	8	0
Eurasian Wigeon	●		8	0
Unidentified Grebe			7	0
Canvasback		●	7	0
Horned Grebe			6	0
Ruddy Duck		●	3	0

Appendix 10-13: **Mapped distributions of diving ducks during conditions when the reservoir was not influencing the Cartier Bay (top panels), and when the reservoir elevation was between 433.8 and 434.75 m ASL.**



Appendix 10-14: **Mapped distributions of geese during conditions when the reservoir was not influencing the Cartier Bay (top panels), and when the reservoir elevation was between 433.8 and 434.75 m ASL.**