EA3285

Monitoring of the Constructed Wetland at Diversion Reservoir, Jordan River Watershed, Southern Vancouver Island

Final Report **- BC Hydro Reference No. 11.W.JOR.01**

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Cover Photograph

Red-legged Frog (*Rana aurora*) in the lower pond of the constructed wetland at Diversion Reservoir, Jordon River Watershed, Vancouver Island, B.C. Photo © Krysia Tuttle, LGL Limited.

Executive Summary

Constructed wetlands are one example of habitat restoration that can be effectively used to mitigate for the loss of aquatic habitat and to offset the impacts of human activities such as hydroelectric development. The strategic water plan for coastal BC Hydro identified the loss of wetland habitat as having a major impact on wildlife in the Jordan River Watershed on southern Vancouver Island (BC Hydro 2001). In 2009, as part of a habitat restoration strategy developed for BCRP for the Jordan River Watershed, LGL Limited designed and built a two-tiered wetland on the edge of Diversion Reservoir to compensate for habitat that was lost during the impoundment of Jordan River in 1911. This constructed wetland monitoring project builds on amphibian species-at-risk surveys (2005) and work completed under grant 06.W.JOR.01: Jordan River Integrated Wildlife Habitat Restoration Plan and Constructed Wetland Design (2006). The wetland construction was a proof-of-concept build that if successful, can be applied to other watersheds that comprise the Bridge Coastal system.

The implemented constructed wetland design included a lower pond of 3,300 m^2 and an upper pond of ~4,050 m^2. The constructed wetland is situated entirely within the drawdown zone of Diversion Reservoir and earthen berms were constructed to retain water with an expectation that the berms would be overtopped by Diversion Reservoir at certain times of the year. Although the wetland was built (2009) and initial re-vegetation was completed (2010), two very important aspects of this wetland project remained: 1) the evaluation of revegetation efforts; and 2) a minimum of one-year of monitoring of the constructed wetland to obtain metrics of success and to determine the utility of the design for potential future wetland construction projects within the Bridge Coastal area.

Site visits in 2010 and monthly monitoring surveys in 2011 revealed that the process of plant succession is occurring naturally, mostly with aquatic and terrestrial plants native to the area. A total of 55 plants were documented in the footprint area of the constructed wetlands in 2011: 15 aquatic and 40 terrestrial. Ten non-native plants were recorded, some of which are invasive, mainly in the disturbed areas along the northern edge of the wetland. Removal of these invasive plant species occurred in September 2011 and should continue in the future.

Results of the wildlife monitoring in 2011 indicated that multiple species are using the newly constructed wetland habitat. For example, we documented, four species of amphibian and one species of garter snake, several songbird species (including several breeding occurrences), mammal tracks and scat, and several species of bat, all of which were either using the wetland itself or habitats immediately adjacent to the wetland area (e.g., Diversion Reservoir, upland forest).

The success of this constructed wetland provides a model that could be applied to other watersheds in BC affected by the impoundment of rivers and creation of reservoirs. To further ensure success of this wetland over time, we recommend additional monitoring surveys to target specific groups over a period of five years, with a decreased monitoring frequency over time. Suggested monitoring includes spring amphibian surveys targeting species at risk (e.g., Red-legged Frog [*Rana aurora*], Western Toad [*Anaxyrus boreas*]), the monitoring of bats (Townsend's Big-eared Bat [*Corynorhinus townsendii*], Little Brown Myotis [*Myotis lucifugus*]), rare plant surveys, and general monitoring of wetland and berm integrity. We also recommend the removal of invasive plant species that were documented at the site to improve the integrity of the wetland, riparian areas and terrestrial surroundings.

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1.0 Introduction

Wetland ecosystems are valuable natural resources that provide habitat for many plant and animal species, as well as contribute to important biological processes (e.g., nutrient cycling; MacKenzie and Shaw 2000). Due to various human activities such as urban, agricultural, and hydroelectric development, wetland ecosystems have been severely impacted throughout North America over the past five decades, changing landscape habitat and ecosystem hydrology, as well as displacing organisms that rely on these sensitive habitat ecosystems (Bishop and Pettit 1992; Nilsson and Berggren 2004). Restoration of wetland areas to pre-disturbance conditions or the creation of new wetland habitat are conservation strategies that help mitigate for the decline in aquatic ecosystems in our natural world (Cairns 1991). Amphibian species are of particular interest to wetland restoration projects, in part because of the diversity of species that occur on Vancouver Island, but also due to their world-wide decline in numbers (Houlahan et al. 2000; Hopkins 2007). Amphibians are animals that rely on moisture during most stages of their lifecycles, thus rely on either wetland/riparian habitat, or moist conditions, such as those found in BC coastal forests.

The strategic plans developed for the 15 watersheds within the BC Hydro's Bridge Coastal system in Western British Columbia include restoration as one method to mitigate for habitat lost during the impoundment of rivers and the creation of reservoirs (BC Hydro 2001). BC Hydro identified the loss of wetland habitat as having a major impact on wildlife in the Jordan River Watershed on southern Vancouver Island. Documented effects of hydroelectric developments in the Jordan River watershed include the near (or complete) extirpation of salmon runs from the lower Jordan River (formerly totaling 5,000-10,000 Chum [*Oncorhynchus keta*] and Pink [*O. kisutch*] salmon) and the loss of wetland habitat for locally breeding amphibian populations (Hawkes 2005, 2007), including the provincially and federally-listed Red-legged Frog (*Rana aurora*) (Hawkes 2005). Additional impacts on terrestrial environments, including the loss of old-growth coniferous forests and riparian habitats, are also known (Hawkes 2005).

In 2007, BC Hydro's Bridge Coastal Restoration Program (now called the Fish and Wildlife Compensation Program – Coastal [FWCP]) funded a project to construct a wetland within the drawdown zone of Diversion Reservoir on Southern Vancouver Island (Hawkes and Fenneman 2010). The construction of the wetland followed a feasibility study (Hawkes 2007) that ranked and prioritized various restoration options of wildlife and their habitat in the Jordan River Watershed. The wetland construction was also a proof-of-concept design to demonstrate the utility and effectiveness of wetland construction adjacent to the drawdown zones of reservoirs established for the production of electricity in B.C.

In 2009, LGL Limited designed and built a two-tiered wetland on the edge of Diversion Reservoir within the Jordon River Watershed and this report summarizes the results of one year of post-construction monitoring of the new wetland in 2011. This was accomplished by the collection of environmental and ecological conditions (e.g., flora and fauna, biophysical data) at the Diversion Reservoir constructed wetlands and by an assessment of the level of success associated with the proof-of-concept wetland build based on a variety of performance measures that can be compared in future years of monitoring.

1.1 Project Background and Timeline

The seeds for this project were sown in 2005, when a report outlining the status of the Red-legged Frog (a provincial and federal species of conservation concern) in the Jordan River watershed was produced by LGL Limited (Hawkes 2005). This report suggested that breeding habitat for this species was limited in the watershed, and most of what had originally occurred had been lost during the creation of the Diversion and Bear Creek Reservoirs.

In 2007, LGL Limited developed an Integrated Wildlife Habitat Restoration Plan (IWHRP), which included a proposal to develop a constructed wetland along the shoreline of Diversion Reservoir in the Jordan River watershed (Hawkes 2007). The intent of the proposed design was to create shoreline wetland habitat and thereby help to offset some of the historical wetland habitat losses that occurred with the impoundment of the reservoir. Habitat creation was deemed as the action with the greatest potential to mitigate footprint impacts resulting from impoundment of the Jordan River. This was consistent with the stated wildlife restoration objectives that were presented by BCRP in the Jordan River watershed plan, most notably Objective 2: “Rehabilitate reservoir drawdown zones to enhance productivity and wildlife habitat” (Bridge Coastal Fish and Wildlife Restoration Program 2010).

As a mitigation strategy, the report proposed that the development of a created wetland along the shoreline of Diversion Reservoir would greatly enhance breeding habitat for this species, as well as other wetland-dependent species that had faced similar reductions in available habitat. The wetland was constructed during 2009, and subsequently visited in 2010 to initiate the revegetation process and to assess the status of this newly-created habitat. LGL Limited received additional funds from FWCP to conduct one year of monitoring of the wetlands in 2011.

The following provides a more detailed timeline for this project:

- **February 2002:** Jordon River Water Use Plan (WUP) was submitted by BC Hydro to Comptroller of Water Rights.
- **November 2003:** Grant application to investigate the distribution of Red-legged Frog habitat in the Jordan River Watershed submitted to BCRP by LGL Limited.
- **May 2005:** LGL Limited submitted the report “Distribution of Red-legged Frog (*Rana aurora*) breeding habitat in the Jordan River Watershed, Vancouver Island, British Columbia” to BCRP, which suggested that a constructed wetland along the shore of Diversion Reservoir would greatly enhance the available habitat for this listed amphibian species.
- **November 2005:** Grant application for the development of an integrated wildlife habitat management plan and development of proof-of-concept wetland design for the Jordan River Watershed submitted to BCRP by LGL Limited.
- **November 2006**: Grant application to build a constructed wetland as a proof-of-concept in the drawdown zone of Diversion Reservoir submitted.
- **August 2007:** LGL submits report entitled “Integrated wildlife habitat restoration plan for the Jordan River watershed, southern Vancouver Island, British Columbia.” This report further summarized the ecological impacts of hydroelectric

developments and provided recommendations for remediation and restoration activities that could help offset these impacts, including the construction of wetland.

- **July 2009**: Site selection for the proof-of-concept wetland build. The site did not require the construction of instream works and was entirely within the drawdown zone of Diversion Reservoir.
- **Sept – Oct 2009**: Construction of berms and creation of wetland habitat by LGL Limited in partnership with Kerr-wood Lidel and TimberWest.
- **April – Aug 2010:** LGL Limited conducted a site visits to assess the water retention capabilities of the berms, the vegetation regrowth and document wildlife use of the constructed ponds. Selected areas around the perimeter of the wetland were planted with willow stakes.
- **November 2010:** Grant application for the monitoring of constructed wetland and proof-of-concept assessment at Diversion Reservoir submitted to BCRP by LGL Limited.
- **April – Sept 2011**: One year post-monitoring of constructed wetland, including wetland integrity, flora establishment and wildlife use of the area.
- **November 2011:** Grant application for the continued monitoring of constructed wetland and proof-of-concept assessment at Diversion Reservoir submitted to BCRP by LGL Limited.

2.0 Goals and Objectives

The constructed wetland at Diversion Reservoir was built in 2009 and initial re-vegetated (with native willows) of the area surrounding the wetland occurred in 2010 (Hawkes and Fenneman 2010). However, two very important aspects of this wetland restoration project remained:

1. To evaluate the 2010 revegetation efforts and to continue the revegetation process replanting any areas that did not take using native plants; and
2. To monitor the wetland to obtain metrics of success and to determine the success of the wetland design for potential future wetland construction projects within BC Hydro's Bridge Coastal area.

The primary objective of this project was to conduct a one year post-construction assessment of the ecological conditions (e.g., flora and fauna diversity and richness, wetland integrity and hydrology of the site) of the newly created wetland at Diversion Reservoir. A variety of performance measures were selected to indicate success for the wetland, and these measures can be compared in future years to ensure that the project is meeting its intended goal of the creation of habitat in the Jordon River Watershed.

3.0 Study Area

3.1 Jordon River Watershed

The Jordan River is located within the Capital Regional District, along the southwest coast of Vancouver Island, approximately 72 km by road from Victoria, B.C. The 25 km long river flows southwesterly between the Sooke Hills and the Seymour Mountain range into the Juan De Fuca Strait at the community of Jordan River (Figure 1). The watershed drains an area of approximately 165 km^2, flowing westward to empty into the Pacific Ocean along the northern coast of the Strait of Juan de Fuca. Jordan River is a steep, incised watercourse with several barriers to fish migration, including a series of boulder obstructions 1.2 km from the mouth of the river (Wright and Guimond 2003). High water inflows from snowmelt occur between May and July, with August and September generally very dry. Heavy rain also can cause immediate high flows between October and March.

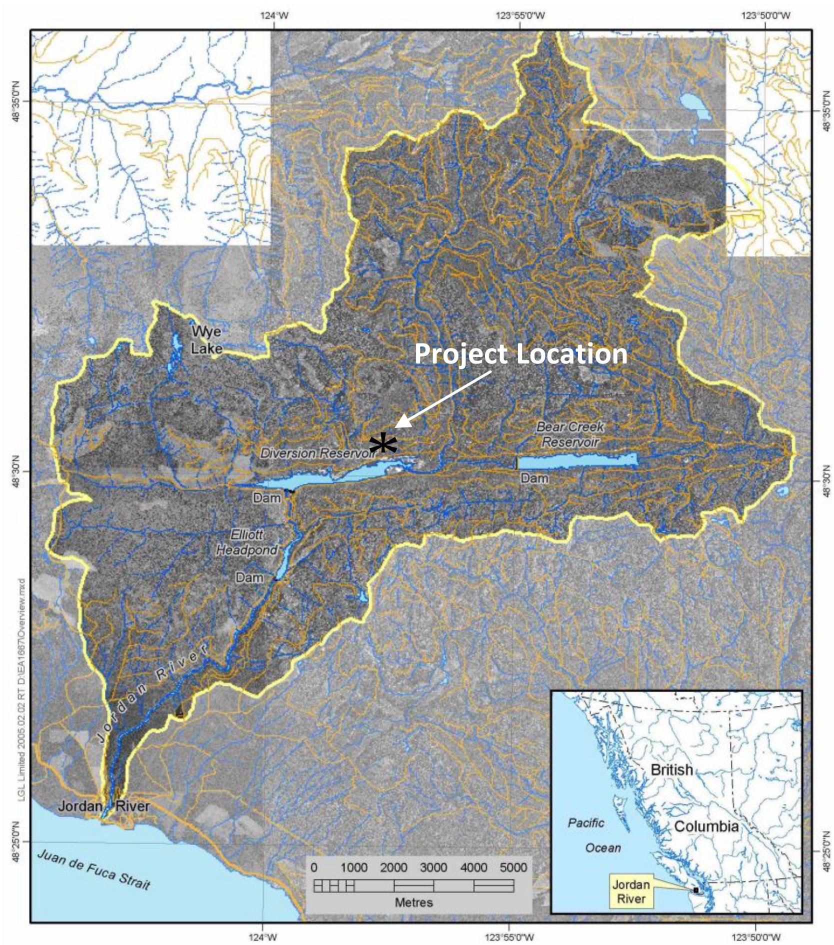

Figure 1: **Location of constructed wetlands within the Jordon River Watershed on Southern Vancouver Island.**

The Jordan River Watershed is part of the Coast and Mountains Ecoprovince, the Western Vancouver Island Ecoregion, and the Windward Island Mountains Ecosection (Demarchi 1996). Within the Windward Island Mountains Ecosection, the project area is contained within 4 variants of the Coastal Western Hemlock (CWH) biogeoclimatic zone, which covers much of Vancouver Island (Table 1).

Table 1: **Biogeoclimatic zones, subzones, and variants occurring within the Jordan River Watershed.**

Label	Zone	Subzone	Variant
CWHvm1	Coastal Western hemlock	Very wet maritime	submontane
CWHvm2	Coastal Western hemlock	Very wet maritime	montane
CWHmm1	Coastal Western hemlock	Moist maritime	submontane
CWHmm2	Coastal Western hemlock	Moist maritime	montane

The CWH is characterized by cool summers and mild winters and the highest average rainfall of all biogeoclimatic zones (Pojar et al. 1991). Within the CWH, Western Hemlock (*Tsuga heterophylla*) is the dominant coniferous tree species with Douglas-fir (*Pseudotsuga menziesii* ssp.*menziesii*) being widespread. Western Redcedar (*Thuja plicata*), Amabilis Fir (*Abies amabilis*) and Yellow-cedar (*Chamaecyparis nootkatensis*) are also common, the latter two species being restricted primarily to higher elevations (especially on southern Vancouver Island). Bigleaf Maple (*Acer macrophyllum*), Red Alder (*Alnus rubra*), and Black Cottonwood (*Populus balsamifera* ssp.*trichocarpa*) are common in riparian zones throughout the CWH (Pojar et al. 1991). Characteristic floristic features of zonal ecosystems in the CWH are:

a) prominence of western hemlock;
b) sparse herb layer; and
c) predominance of several moss species (especially *Hylocomium splendens* [step moss] and *Rhytidiadelphus loreus* [lanky moss]).

3.2 Diversion Reservoir

Initial impoundment occurred in the Jordan River watershed as early as 1909, and by 1913 two large reservoirs (Bear Creek Reservoir and Diversion [=Jordan] Reservoir) had been created above the townsite of Jordan River. The Elliot Headpond, a small reservoir below Diversion Reservoir, was added in 1971. The construction of these dams resulted in the flooding of almost 200 ha of riparian and wetland habitats in the Jordan River watershed, directly affecting over 20 km of the lower Jordan River. In addition, continued input of copper-contaminated water from the legacy of over 80 years of mining activities that took place in the watershed, as well as over 120 years of logging and the associated ecological impacts, have augmented the negative impacts of the hydroelectric developments and had some serious measurable effects on the health of the Jordan River (Wright and Guimond 2003).

The Jordon Diversion hydroelectric dam impounds the 18 km long Diversion Reservoir with a licensed storage volume of 20.5 x 10^6 m^3 and a surface area of 179.8 ha (BC Hydro 2006). The normal operating range of the reservoir is between 367.9 m and 386.2 m elevation and monthly reservoir elevations follow a typical pattern with fluctuations based largely upon rainfall driven run-off feeds into the reservoir primarily in December through March (Figure 2). Inflows vary considerably throughout the year (BC Hydro 2003).

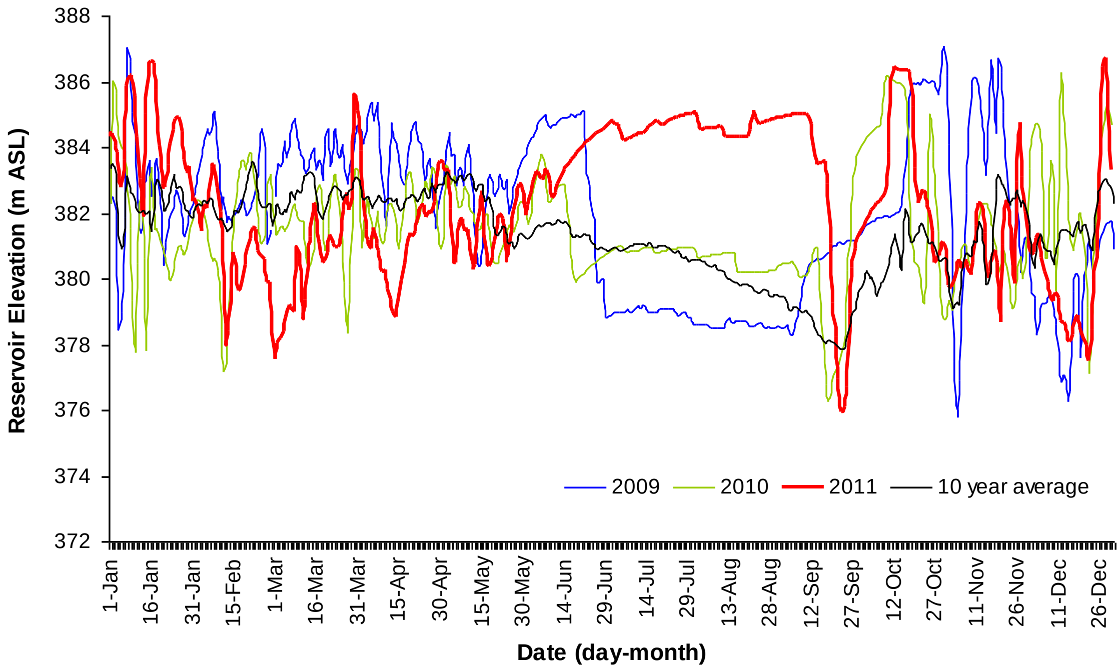

Figure 2: Daily average reservoir elevations for Diversion Reservoir for the period 2009–2011. Ten year average shown in black; 2011 (study year) shown in bold red.

3.3 Wetland Design

Prior to wetland construction, the area consisted of a small seeping stream that flowed into Diversion Reservoir, large tree stumps, an abundance of coarse woody debris, and ground cover vegetation that consisted largely of herbaceous and graminoid plants (Figure 3). The constructed wetland is comprised of two wetted areas: a lower pond (~ 3,300 m^2) and an upper pond (~ 4,050 m^2) for a total wetland area of 7,350 m^2 (Figure 4). The easternmost (upper) pond is situated approximately 1m higher in the drawdown zone than the westernmost (lower) pond. The top elevation of the lower berm was built to 383.2 m ASL, the middle berm to 384.4 m ASL and the upper berm to 384.5 m ASL. Total edge habitat created (i.e., the perimeter of the ponds) was ~551.3 m (lower pond: ~263.2 m; upper pond: 288.1 m. The depth profile of the two ponds differs substantially. The lower pond is deeper with steeper side slopes than the upper pond, with some areas of the lower pond exceeding 2 m in depth. The upper pond is relatively flat-bottomed with depth ranging from 0.5–1.0 m, with the exception of some areas towards the retaining berm that approach 2 m in depth.

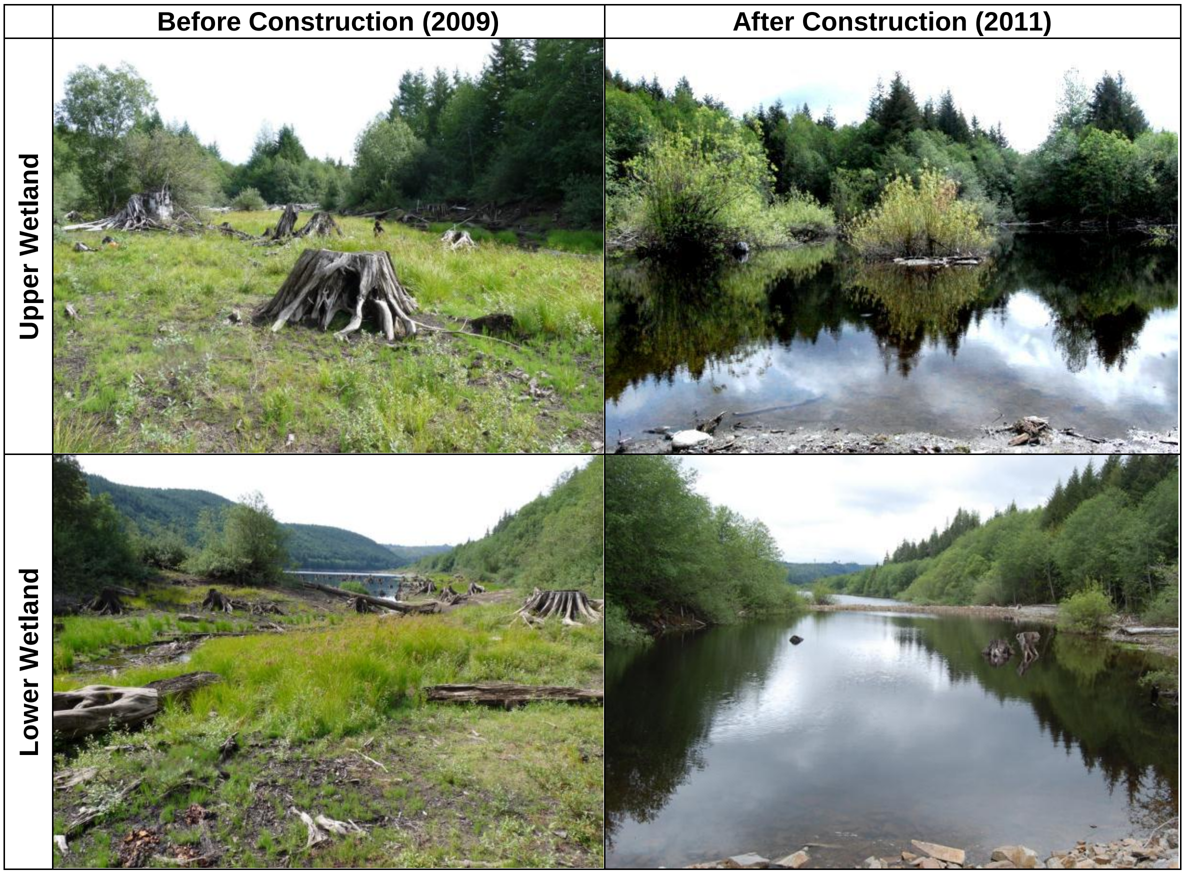

Figure 3: Photographs of wetland site location before and after construction, Diversion Reservoir, Jordon River Watershed, 2009-2011. Photo credits: Virgil Hawkes (2009) and Krysia Tuttle (2011).

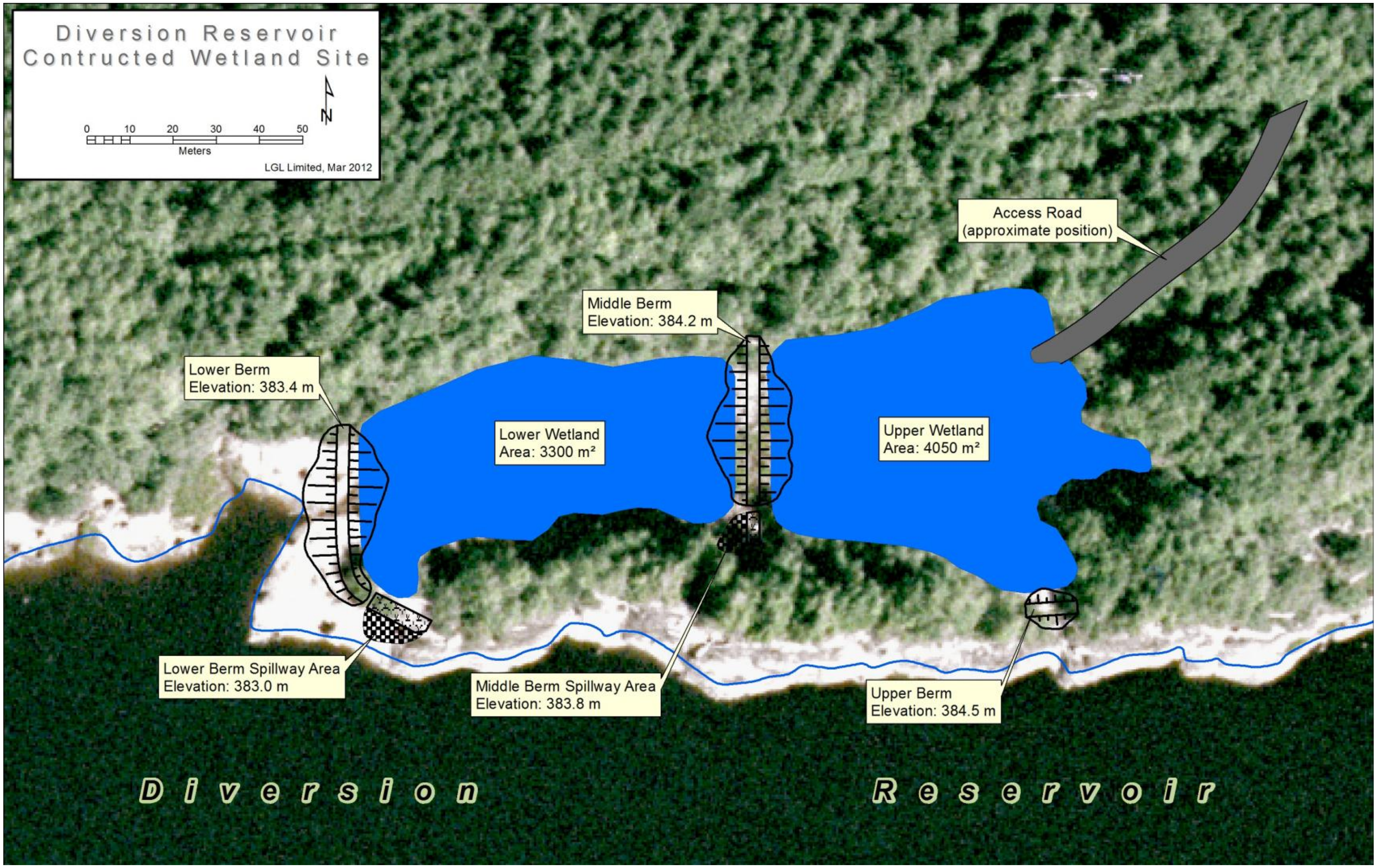

Figure 4: **Location of the three berms, spillways and wetted areas (upper and lower) of constructed wetland at Diversion Reservoir.** The total area of wetland habitat created is shown in blue and the access road in grey. Image created by Kerr Wood Leidel Consulting Engineers (2009) and was modified by LGL Limited (2011) for this report.

4.0 Methods

4.1 Field Schedule

Seven site visits were made by LGL Limited staff members from May to September 2011 to collect wildlife, habitat and hydrological data to give an overall post-restoration assessment of the area (Block et al. 2003).). Timing of these surveys was a function of available funding and based upon coinciding with the active seasons of the targeted species groups (Table 2). Wildlife monitoring surveys were aimed at documenting the presence of amphibian (e.g., salamanders and frogs), reptile (e.g., lizards, snakes), bird (e.g., songbirds, raptors, marsh birds, etc.), mammal (e.g., small mammals, mustelids, ungulates), and invertebrate (e.g., terrestrial molluscs, dragonflies) present in the immediate area of the constructed wetlands. Wetland integrity (e.g., berm integrity), composition (e.g., vegetation communities), and bio-physical habitat (e.g., water physicochemistry) data were also collected for the site. All work is based on standardized methodologies (i.e., Resources Inventory Standards Committee standards).

Table 2: Timing methods for monitoring surveys of constructed wetlands at Diversion Reservoir in 2011. A = amphibian/reptile, B = bird (songbird, waterfowl, incidental), M = mammal (scat, track, browse, bat), V = vegetation (native or invasive), W = wetland characteristic (water levels, water chemistry).

	Target Group						
Date	A	B	M	V	W	**Specific Methods**	**References**
April 13th	X	X			X	Amphibian Egg Mass Surveys Waterfowl Surveys	RIC 1998a, RIC 1998b RIC 1999a
May 4th	X	X		X	X	Amphibian Egg Mass Surveys Songbird Pointcounts	RIC 1998a RIC 1999b
May 16th	X	X	X	X	X	Tadpole Amphibian Surveys Incidental Mammal Sign	Campbell et al. 2001 Murie and Elbroch 2005
June 13th	X	X		X	X	Tadpole Amphibian Surveys Vegetation Surveys	Gosner 1960 Elzinga et al. 1998
July 11th	X			X	X	Tadpole Amphibian Surveys Vegetation Surveys	Gosner 1960 Elzinga et al. 1998
August 9th	X		X	X	X	Metamorph Amphibian Surveys Bat Detectors Incidental Plant Surveys	Wildlife Acoustics 2010 Elzinga et al. 1998
Sept. 7th				X	X	Invasive Species Removal	RSBC 1996

4.2 Survey Types

During site visits we recorded general environmental and site conditions, such as weather conditions using a Kestrel® 4500 pocket weather tracker, total survey time (i.e., sampling effort), survey area (e.g., upper or lower pond, reservoir and/or habitat type) and notable conditions that may have affected the survey results (e.g., rainfall during egg mass surveys). All field survey data (e.g., species observations) were georeferenced using a handheld Garmin® GPSMap 60Csx handheld receiver. During field visits to the constructed wetland we identified all flora and fauna to species (see Appendix A and B).

The following sections describe the specific methods used to survey for vegetation, amphibians, waterfowl and birds, and bats (Figure 5). All other plant and wildlife observations were recorded as incidental. We also documented wetland characteristics, including berm conditions, assessing water levels, and water physiocochemistry.

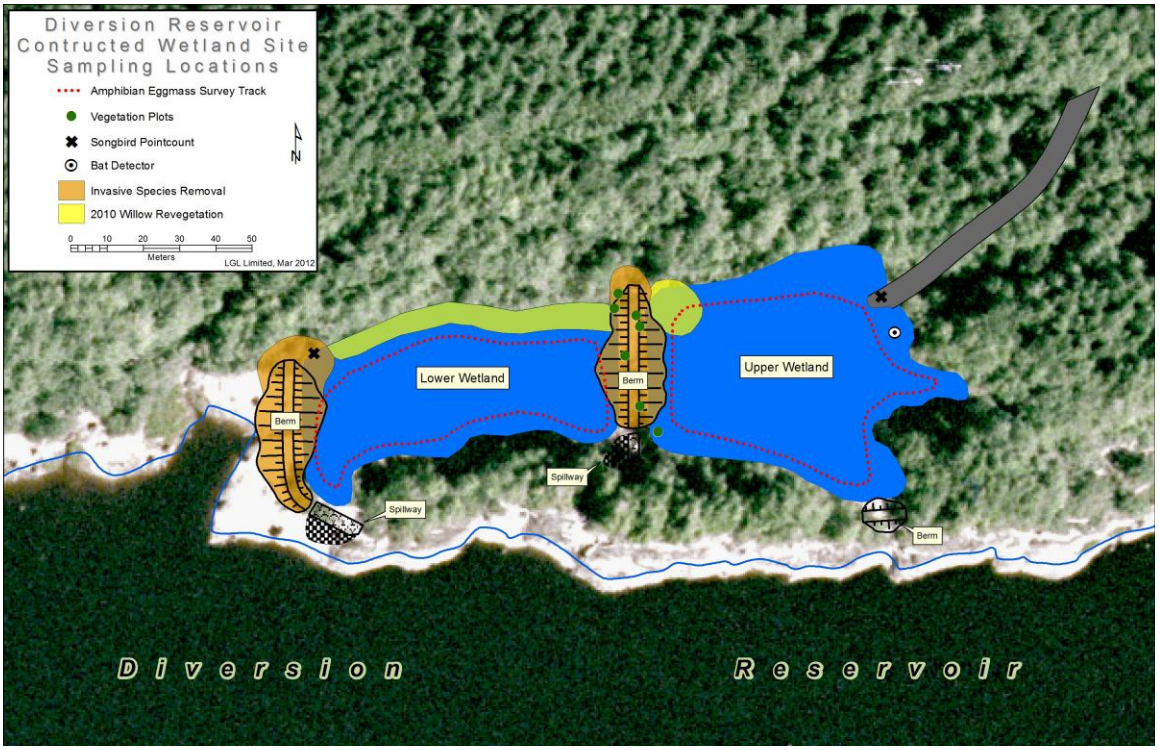

Figure 5: **Sampling locations at constructed wetlands, Diversion Reservoir in 2011.** Water chemistry sampling locations and incidental wildlife and plant survey tracks are not plotted on map, but cover the full extent of the wetlands and surrounding riparian areas.

4.2.1 Wetland Characteristics

Each wetland (labelled hereafter as upper and lower pond) was photographed from several angles to document wetland seasonal progression and water levels relative to the constructed berms and riparian vegetation. Constructed berms were photographed to document general condition over time (e.g., integrity, soil deposition). Daily reservoir elevations were obtained from BC Hydro to determine the period length of inundation to the wetlands from Diversion Reservoir. Water conditions such as dissolved oxygen (mg/L), pH, conductivity (μS/cm), and temperature (^{o}C) were documented with a YSI 85 water metre during each visit in the upper and lower ponds of the wetland and for Diversion Reservoir.

4.2.2 Vegetation

Surveys for plants included general incidental observations and quadrat plots documenting all aquatic and terrestrial native plants at the constructed wetland, as well as monitoring the overwintering success of the willow stakes planted during 2010.

General plant surveys: General plant surveys, in which each species of plant that occurs in and around the wetlands was noted, were completed in 2011. All plants were identified to species, photographed, and referenced by pond, and subsequent seasons should see this species list continue to grow as more species become established at the site. These surveys also enabled an assessment of the relative diversity of exotic plants to native species at the site, which will provide an opportunity for managers to intervene in future seasons if the establishment of exotic species is considered to be at unacceptably high levels.

Quadrat plant surveys: A total of seven vegetation plot surveys were completed in July 2011. These quadrats consisted of a 0.75 x 0.75 m (0.5 m^2) square within which the percent cover of all species of plants was estimated. In addition, the overall cover of vegetation and other habitat variables (rock, soil, woody debris) were recorded within each quadrat to better describe the overall habitat conditions that are present. Quadrat surveys were completed both on the berms (which now support some vegetation) as well as in terrestrial environments around the perimeter of the wetlands. Quadrats were not completed in aquatic habitats as these are not suited to this particular methodology. These quadrats can be re-sampled in future seasons to detect changes in the establishing vegetation communities over time.

Revegetation with willow stakes: In 2010, the initial steps of revegetation included the establishment of shrub habitat around the perimeter of the wetland, particularly those areas covered with the layer of organic material, as well as on the access road on the north side of the wetland. Approximately 376 willow stakes, including both Sitka Willow (246 stakes) and Pacific Willow (n = 130 stakes), were collected from the fringes of the newly-formed wetland and planted in bare, disturbed areas along the northern edge of the wetland, especially in the area around the northern end of the middle berm. Subsequent site visits in 2010, confirmed that virtually all of the planted willow stakes had become established and were growing vigorously, with only a small number (~10) in the driest areas showing evidence of mortality.

Survivorship of planted willow stakes: Planted willow stakes were examined for both bud growth and overall condition, including mortality. The total number of planted stakes was recorded, with each stake classified as either live or dead based on its appearance during the survey period (some individuals that appeared dead may in fact begin to produce new growth in the future once their root system has become better established). If these surveys suggest that survivorship rates are low, augmentation may become an option to improve establishment rates.

4.2.3 Amphibians and Reptiles

Amphibian surveys occurred via several techniques: 1) diurnal call surveys; 2) egg mass and larval surveys; and 3) visual encounter surveys (Donnelly et al. 1994). Amphibian call surveys are typically nocturnal based when frogs are most likely to be calling; however, Pacific Chorus Frogs (*Pseudacris regilla*) can also be heard calling during the day time during breeding season. Upon first arrival to the site we listened for five minutes at the edge of the wetland for amphibian activity. Aquatic searches for egg masses were conducted by visually scanning the surface and pond-bottom substrate within the wetland footprint. Egg masses were identified to species, photographed and georeferenced. Tadpoles were counted and staged using the Gosner Index (Gosner 1960). Visual encounter surveys (VES) were used for the detection and capture of conspicuous (e.g. Red-legged Frog, Western Toad, etc.) species of amphibian. Searches occurred in riparian habitats, within wetlands or under vegetative cover (e.g., CWD, leaf litter, sword fern). Reptiles, such as garter snakes, were recorded on an incidental basis and morphometric data was collected (e.g., snout-vent length, weight, sex).

4.2.4 Birds

Bird observations were made via songbird pointcounts (May surveys only) and on an incidental basis (remainder of survey times). Surveyors scanned each pond for bird activity with binoculars and listened for five minutes upon first arriving at the site. Birds were identified to species, and further documented by number (where possible), activity (e.g., calling, nesting, flyover, etc.), and macrohabitat (e.g., wetland, riparian, forest, reservoir, etc.).

Water birds: An inventory of waterfowl and allied species occurred during site visits; methods followed RIC standards (1999a) but were primarily of an incidental nature. The wetland was systematically slowly scanned in a semicircle radius, with the scanning direction matching the direction of travel in order to minimize double counting. Scans were made using the naked eye, binoculars and spotting scopes as appropriate to detect, identify and count species. Observers spent sufficient time scanning to ensure that diving birds had resurfaced and were not missed. Flyovers were recorded as such.

Songbird Pointcounts: Songbird pointcount surveys were conducted on May 4th 2011. Rainy weather did not permit point count surveys that were planned for May 16th 2011. The standard methodology for variable radius point-counts followed RIC (1999b) and Breeding Bird Atlas procedures (BCBBA 2009). The pointcount stations were established at either end of the wetland separated by ~200 m to avoid counting birds twice. Surveys occurred at approximately 30 minutes prior to daybreak and were five minutes in duration. Surveyors first scanned each pond for bird activity with binoculars upon first arriving at the site and then observations began approximately 1 minute after. Flyovers (i.e., birds seen or heard flying overhead but not directly associated with the terrestrial environment at the wetland site) were identified as such.

4.2.5 Bat Sampling

A Song Meter SM2BAT 192kHz Stereo Ultrasonic Recorder unit (Wildlife Acoustics, Inc.) was used to record bats at the constructed wetland between August 9th and September 7th 2011. The bat detector was programmed to record between 19:30 PM (approximate sunset time) and 1:00 AM and then again from 5:00 AM (approximately an hour before sunrise) to 6:00 AM. The detector was placed at the western edge of the upper pond pointing towards the lower pond and reservoir.

Files were uploaded in September and bat calls were first run through Wildlife Acoustics' WAC2WAV 3.0.0 software, which removes most noise segments and generates time-stamped .wav files containing bat detections. These audio clips were then processed in SonoBat 3.01 WA (Washington) west, which utilizes a decision engine based on quantitative analysis from reference calls. The program classified and sorted the .wav files based on several parameters that describe the time-frequency and time-amplitude trends of each bat call. Within call sequences, only calls exceeding a call quality of 80 per cent and discriminant probability threshold of 90 per cent were used to identify the bat to species. SonoBat 3.01 generated an output table that was imported to Excel for further analysis, including relative abundance of each species, site richness, activity by time period and total number of detections (methods taken from Hawkes et al. 2010).

4.3 Richness, Diversity and Productivity Measures

Species richness, productivity (amphibians only), and diversity measures were determined from data collected during wildlife and vegetation surveys in 2011. The number of species documented at the constructed wetland site was used as a measure of species richness. Productivity is related to the fecundity of the population being sampled. To determine productivity of amphibian populations, we reported on the number of egg masses observed for each species, and the estimated number of tadpoles and metamorphs observed in each pond of the wetland, as well as in the pitted ponds (created during materials extraction for the constructed berms).

We used an information statistic, Shannon's Diversity Index (H_s), to analyze the diversity of the plant and wildlife communities in the constructed wetlands. Shannon's diversity index is the probability that two randomly selected individuals will be members of the same species taking rare species into account. A community is considered more diverse when the probability of randomly selecting different species is low (Krebs 1999). A higher H_s indicates a higher community diversity; natural communities typically have values between 1.5 to 3.5.

4.4 Performance Measures

Post-construction monitoring of the Diversion Reservoir constructed wetland involved monitoring the characteristics (e.g., integrity, biophysical conditions) of the wetland itself and the effectiveness of the wetland in meeting the ecological objectives of the project (e.g., providing aquatic and riparian habitat for wildlife in the Jordon River watershed).

We collected data associated with the following performance measures to assess the success of the constructed wetland at Diversion Reservoir:

1. Creation of ~ 7,500 ha of new wetland habitat.
2. Water retention into early summer in at least one pond of the wetland. Water retention is also related to the depth profile of the wetland, whereby a water depth of greater than 1 m in some areas of both the upper and lower pond is maintained.
3. Water physicochemistry conditions (e.g., pH, DO, conductivity) within the acceptable range for aquatic life.
4. Little to no erosion or deterioration of the berms as determined by incidental visual post-construction monitoring and potentially formal integrity checks by a qualified engineer (on an as needed basis as part of future monitoring).
5. Less than > 50% accumulation of coarse woody debris (CWD) in the upper and lower wetland ponds throughout the summer (estimated as a percentage of surface cover: 0%; 1 to 25%, 26 to 50%, 51 to 75%, 76 to 100%).
6. Plant and wildlife species richness and diversity at the wetland.
    a. Successful natural establishment of native plant (i.e., macrophytes) into newly created wetlands within five years. "Successful establishment" is defined here as continuous species presence for at least two years. Includes a ratio of native to invasive plant species.
    b. Successful natural establishment of native wildlife species into newly created wetlands within 5 years. "Successful establishment" is defined here as continuous species presence for at least two years. This will be determined by assessing overall species richness and diversity, through the documentation of use by pond-breeding amphibians (e.g., Red-legged Frogs), riparian songbirds, waterfowl and other water-associated birds

(e.g., Great Blue Heron), mammals (e.g., bats), and insects (e.g., dragonflies).

7. Evidence of breeding at the wetland by amphibians (e.g., egg mass counts), riparian songbirds, waterfowl and other water-associated birds (e.g., nesting activity, presence of fledglings).
8. A measureable increase in productivity within five years of the implementation of the wetland construction. A measureable change will be assumed to be a change of 25 percent or greater.
    a. A measurable increase in native aquatic plant (i.e., macrophyte) cover and diversity (species richness and evenness) within five years. This will include the cover of all layers of aquatic macrophytes including submerged, rooted and floating, floating, and emergent macrophytes.
    b. Measurable increases from baseline conditions in productivity of amphibian egg masses (specifically Red-legged Frogs) within five years (in this case, baseline will be 2011). The number of egg masses should be counted on an annual basis. Egg development should be tracked to determine if eggs metamorphose into froglets.
9. The extent and survivorship of re-colonized vegetative cover, includes survivorship of planted willow stakes from 2010. No measurable increases greater than 25 percent from baseline conditions of diversity (species richness and evenness) of key undesirable plant species over 10 years. Key undesirable species include Scotch Broom (*Cytisus scoparius*), Himalayan Blackberry (*Rubus armeniacus*), and thistle species (*Cirsium* spp.).

5.0 Results

5.1 Wetland Characteristics

5.1.1 Wetland Retention and Integrity

Water retention in each pond of the constructed wetland was documented during all site visits in 2012; both upper and lower ponds maintained water levels (i.e., depth profiles) of greater than 1 m in a portion of the wetland from April to September. In particular, the southern edges of each pond are notably deep (e.g., > 2 m in some areas). Daily reservoir elevations were obtained from BC Hydro to compare the period of inundation throughout the year. Based on the wetland design, the lower of the two ponds was inundated more frequently and for longer periods than the upper pond, throughout the year (Figure 6). The lower wetland was completely inundated from mid-June to Mid-September.

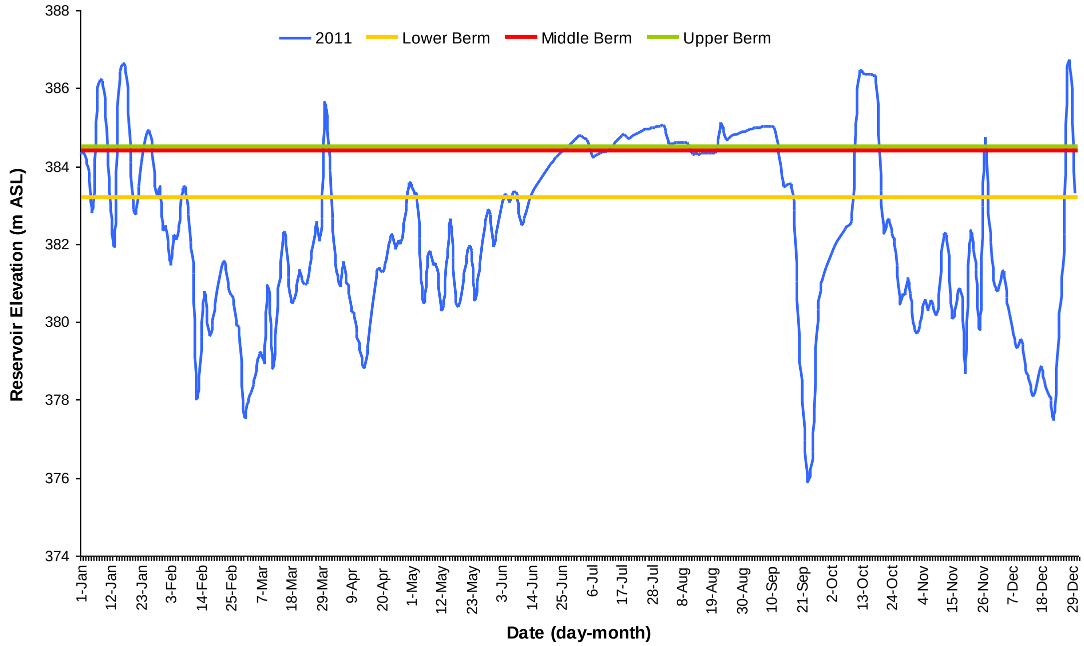

Figure 6: Daily reservoir elevations for Diversion Reservoir (blue line) and berm heights for the constructed wetlands showing the period of reservoir inundation for 2011.

Incidental observations of soil deposition on the berms were documented during the site visits: berms appeared to receive increased soil deposition throughout the year, with the lower berm receiving the most and the upper berm receiving the least (Figure 7). The western reaches of the upper pond (including the upper berm) received large deposits of coarse woody debris (CWD), presumably left behind as the reservoir levels dropped. The floating CWD (estimated at < 25%) remained in the wetland for the remainder of the summer months.

Figure 7: Photographs of middle berm at Diversion Reservoir constructed wetland in May (left) and September (right) 2011.

5.1.2 Water Physicochemistry

We collected point data for water physiocochemistry (water temperature, dissolved oxygen, pH and conductivity) from five sampling locations at the constructed wetlands in

Diversion Reservoir (Table 3). The ponds all exhibited water characteristics similar to those of other wetlands of similar types (Hawkes and Tuttle 2010) and measured variables fell within the acceptable range of values that will support aquatic life (e.g., aquatic macroinvertbrates, fish and amphibians).

Table 3: Mean water characteristics for the constructed wetland (upper and lower ponds) and Diversion Reservoir for the period April through September 2011. * indicates a single measurement rather than an average.

Location / Month	Dissolved Oxygen (mg/L)	Conductivity (µS/cm)	pH	Water Temperature (°C)
Lower Wetland	8.70	21.55	7.91	11.05
Upper Wetland	7.80	19.26	8.04	12.60
Reservoir	9.27	11.80	7.85	11.66
Pit Pond 1*	1.91	19.30	6.45	18.10
Pit Pond 2*	2.25	15.20	6.72	18.30
April	11.47	25.23	7.89	6.40
May	11.30	12.63	8.58	8.87
June	11.30	12.63	N/A	8.87
July	2.16	21.40	7.12	18.13
August	6.13	18.75	7.03	20.10
September*	1.24	1.40	8.51	16.80
Overall Average	7.77	17.25	7.73	12.62

The constructed wetlands appeared to provide suitable habitat for wildlife based on the some of the physiocochemistry data collected. Water temperature varied greatly across the seasons from 6.4°C in the spring to over 20°C in the summer. pH levels remained fairly consistent across the sampling period. Dissolved oxygen levels were higher in the spring and decreased as the summer progress (likely due to increased algal growth and plant decomposition). In general, developing amphibians that rely on oxygen in the water column tend to be found in ponds with higher dissolved oxygen levels (Dale et al. 1985; Duellman and Trueb 1986); the dissolved oxygen levels for these wetlands in the spring fall within those ranges (7.1 and 11.5 mg/L). Conductivity is likely to be affected by a number of factors, including time of day, season and air temperature; thus, the biological significance of any variability is difficult to assess.

5.2 Plants and Wildlife

A total of 102 species (i.e., species richness) were located or observed during the monitoring surveys: 55 plants species and 47 wildlife species (plus at least five species of dragonflies). Only three provincial or federally-listed plants and animals were documented in 2011, but an additional 26 could occur at this site (see Section 5.2.2.4 below). Diversity of the plant and wildlife communities at the wetland varied by month and by group (Table 4). Wildlife diversity (H_s = 0.92) was lower overall compared to plant diversity (H_s = 3.72), but when analyzed separately the bird community had a high diversity index (H_s = 3.23). Plant diversity increased throughout the summer, while wildlife diversity was highest in June and then in August.

Table 4: Species richness and community diversity for plants and wildlife documented by month at the constructed wetland at Diversion Reservoir in 2011. Richness = number of species; diversity = Shannon Index (H_s; Information statistic that takes rare species into account).

	Plants		Wildlife	
Month	Richness	Diversity	Richness	Diversity
April	12	2.48	15	1.97
May	17	2.77	31	1.4

June	19	2.94	16	2.44
July	30	3.40	19	1.14
August	37	3.61	11	2.4
Total	**55**	**3.72**	**42**	**0.92**

The following sections describe each group in detail and see Table 12 and Table 13 in the Appendix for a complete list of plants and wildlife documented by habitat at the constructed wetlands in 2011.

5.2.1 Vegetation

5.2.1.1 Vegetation Community

Diversion Reservoir is situated within the CWHmm1 (Moist Maritime Coastal Western Hemlock zone, submontane variant) biogeoclimatic zone. The year-round availability of spring-fed water from the adjacent northern forested slope, as well as from Diversion Reservoir, maintains high moisture content in the soil and allows for the continued existence of a wetland community. Prior to the creation of the wetland, the vegetation was characterized by species that were widespread within the drawdown zone of the reservoir. Dominant herbaceous plants at the site included Wool-grass (*Scirpus cyperinus*) and Kellogg's Sedge (*Carex lenticularis* var.*lipocarpa*), with willows (Sitka Willow [*Salix sitchensis*] and Pacific Willow [*S. lucida* ssp. *lasiandra*]) forming the dominant riparian vegetation around the fringes of the bay. Upland habitats around the site are composed of mid-seral second-growth coniferous forests that are dominated by Douglas-fir (*Pseudotsuga menziesii* var.*menziesii*), Western Hemlock (*Tsuga heterophylla*), and Western Redcedar (*Thuja plicata*), with Red Alder (*Alnus rubra*) and Black Cottonwood (*Populus trichocarpa*) occurring primarily on wetter microsites. Understory vegetation of upland habitats includes species such Sword Fern (*Polystichum munitum*), Salmonberry (*Rubus spectabilis*), Red Huckleberry (*Vaccinium parvifolium*), and Vanilla-leaf (*Achlys triphylla*), all of which are common and characteristic plant species throughout much of the CWH biogeoclimatic zone.

A total of 55 species of vascular plant were documented at the constructed wetland from April to September 2011 (see Table 12 in Appendix A for a complete plant list for the area), including 45 native and 10 introduced species. No species at risk were documented at the site during the 2011 surveys, although one blue-listed species (Vancouver Island Beggarticks [*Bidens amplissima*]) was documented in 2010 (photograph of species in Hawkes and Fenneman 2010). Most of the plants that occurred within the footprint of the wetland area were herbaceous or forb species (n = 32), although graminoid (n = 9), shrub (n = 11) and tree (n = 3) species were also common around the periphery of the wetland and in the surrounding riparian forest. Due to the high elevation of the area, the majority of the plant growth occurred from May to July (later than at sea level), and as a result vegetation surveys were conducted in June to coincide with the peak growing season.

Common aquatic plant species (n = 8) that had colonized the wetland included American Brooklime (*Veronica beccabunga*), Marsh Speedwell (*V. scutellata*), Pacific Water-parsley (*Oenanthe sarmentosa*), Spring Water-starwort (*Callitriche palustris*), and Small-flowered Forget-me-not (*Myosotis laxa*). Immediately around the edges of the wetland, rush and grass species (n = 7) such as Common Rush (*Juncus effusus*), Spreading Rush (*Juncus supiniformis*), Wool-grass (*Scirpus cyperinus*), and Kellogg's Sedge (*Carex lenticularis* var.*lipocarpa*) grew in areas with increased sun exposure and high soil moisture. Other common herbaceous species at the site include Giant Horsetail

(*Equisetum telmateia*), Broad-leaved Dock (*Rumex obtusifolius*), and Purple-leaved Willowherb (*Epilobium ciliatum*). The most commonly occurring riparian tree and shrub species around the wetland were Red Alder (*Alnus rubra*), Salmonberry (*Rubus spectabilis*), and both willow species (Pacific Willow [*Salix lucida* ssp. *lasiandra*] and Sitka Willow [*S. sitchensis*]).

5.2.1.2 Introduced Plant Species

Several exotic plant species were noted at the study site, some of which are considered invasive in that they often outcompete or displace native vegetation. Scotch Broom (*Cytisus scoparius*), Canada Thistle (*Cirsium arvense*), and Bull Thistle (*Cirsium vulgare*) were the most abundant invasive species, particularly on the slightly drier microsites that were typically associated with small areas of disturbance; all three of these species are considered invasive in British Columbia. Most of the introduced species at the site occurred in the disturbed areas (e.g., road access points, constructed berms), often as single plants or small groups. These species were not generally present in the natural forested habitats at the site or within the aquatic habitats of the constructed wetland, at least not in densities that would be cause for concern.

5.2.1.3 Survivorship of Willow Stakes

Early site visits to the wetland in 2011, included an evaluation of the willow stakes planted in 2010 (Figure 8). Planted stakes were counted, of which 211 were budding (101 adjacent to the upper pond; 110 adjacent to the lower pond), 68 were dead, and 111 were broken along the main stem, likely by a human since the breaks were all of similar nature (broken/alive n = 67; broken/dead n = 44). Survivorship of the living stakes was ~ 75% (~ 71% if the broken stakes were included).

Virtually all living stakes were putting out new green vegetative shoots, and most individuals had developed reproductive structures. Red Alder seedlings had also naturally revegetated the inner face of the middle berm, creating a band of seedlings above the lower band of herbaceous vegetation. Due to the rapid establishment of native aquatic and terrestrial plants at the constructed wetlands, no additional planting of willows or transplanting of other native plants to the wetland was carried out in 2011.

 

Figure 8: Photographs of overwintering survivorship of the willow stake revegetation along the northern shoreline of the constructed wetland at Diversion Reservoir in 2011. Left = broken willow stake, presumably broken by a human; right = summer growth of willow stakes.

5.2.2 Wildlife

5.2.2.1 Amphibians and Reptiles

Four species of pond breeding amphibian were documented using the ponds and riparian edges at the constructed wetlands in 2011: Red-legged Frog; Northwestern Salamander (*Ambystoma gracile*); Pacific Chorus Frog (*Pseudacris regilla*); and Rough-skinned Newt (*Taricha granulosa*). Overall, the number of pond-breeding amphibian species was high for this site compared to the number of species that occur on Vancouver Island (n = 4 and 6, respectively) (Figure 9; Shannon's Diversity Index = 1.92). Most notably, numerous egg masses, tadpoles, and five adult Red-legged Frogs were observed in and around the periphery of the wetland, including one large, adult female laying an egg mass (see cover photo).

Figure 9: Species and life stages of pond breeding amphibians documented at the constructed wetlands at Diversion Reservoir from 2009 to 2011. Top row = egg mass stage; middle row = metamorph stage; bottom row = adult life stage for the following species from left to right: Red-legged Frog, Pacific Chorus Frog, Rough-skinned Newt, Northwestern Salamander, and Western Toad. Empty spaces represent life stage not documented. Photo credits = Krysia Tuttle and Virgil Hawkes.

We documented a total of 149 amphibian egg masses within the constructed wetland ponds, as well as an additional five egg masses in the reservoir (Table 5). The observed egg masses were from three species of pond-breeding amphibian including Pacific Chorus Frog (n = 4), Red-legged Frog (n = 124), and Northwestern Salamander (n = 21). In most cases, amphibian egg masses were located in shallow to moderate depths of water (10 to 90 cm) and attached to vegetation (e.g., willow branches or underwater sedges) near the edges of the pond. Numerous Pacific Chorus Frog tadpoles (n = ~ 200) were also observed in the pitted ponds that were created nearby during the construction phase.

Table 5: Number of pond-breeding amphibians by species and life stage identified at the constructed wetlands, Diversion Reservoir in 2011.

Species	Scientific Name	Life Stage	# per Pond Lower	# per Pond Upper	Total # Egg Masses
Red-legged Frog	*Rana aurora*	Egg Mass	67	57	124
		Tadpole	~25	~75	
		Adult	1	4	
Northwestern Salamander	*Ambystoma gracile*	Egg Mass	14	7	21
Pacific Chorus Frog	*Pseudacris regilla*	Egg Mass	-	4	4
		Metamorph	2	10	
		Adult	1	5	
Rough-Skinned Newt	*Taricha granulosa*	Metamorph	-	1	0
		Adult	-	1	

Pacific Chorus Frogs were heard calling in both riparian and forested habitat, and bred in both the upper and lower ponds of the constructed wetlands (egg masses and tadpoles observed). Six adult Pacific Chorus Frogs were documented in the floating mats of coarse woody debris, at the western edge of the upper wetland pond. Three of these individuals were males that were found dead, with bloated stomachs, but the reasons for these deaths were unknown. Rough-skinned Newts were encountered in riparian habitats (e.g., both under cover; coarse woody debris) immediately adjacent to the upper pond and likely use the constructed wetland for breeding. Rough-skinned Newt eggs are typically laid singly on the underside of vegetation and therefore difficult to locate (Matsuda et al. 2006).

Several desiccated Red-legged Frog and Northwestern Salamander egg masses were found out of the water in the rocks at the edge on the middle berm and around the closest edge of Diversion Reservoir. These masses were between 30 cm to over 2 m from the water edge; the reasons for this were presumably due to fluctuating reservoir elevations (e.g., water level had rapidly decreased since the time of laying; thereby exposing the eggs).

Two other species of pond-breeding amphibian could occur in the area, and potentially benefit from the creation of new wetland habitat: Western Toad (*Anaryxus boreas*), which is a federally designated species of special concern and is included on Schedule 1 of the Species at Risk Act; and Long-toed Salamander (*Ambystoma macrodactylum*). One adult Western Toad was documented from the site in 2009, but no evidence of toads using the constructed wetlands has been documented since that time. Two species of terrestrial salamanders are also likely to use habitats adjacent to the constructed wetland including Western Red-backed Salamander (*Plethodon vehiculum*) and Ensatina (*Ensatian eschscholtzii*). Both of these species have been found close by and are known to occur in the Jordan River watershed (Hawkes 2007; Matsuda et al. 2006).

One Common Garter Snake (*Thamnophis sirtalis*) was documented on the middle berm between the upper and lower ponds foraging on Pacific Chorus Frog tadpoles. Western Terrestrial Garter Snakes (*Thamnophis elegans*) have previously been observed at the wetland and it is likely that Northwestern Garter Snakes (*Thamnophis ordinoides*) could also occur at the site. Northern Alligator Lizards (*Elgaria coerulea*) could potentially move into the site (as there is sufficient rock and vegetation cover available) provided that there is a source population for this species in the area.

5.2.2.2 Birds

Thirty-three species of bird were documented during visits to the constructed wetlands in 2011; these numbers being a drastic increase from the numbers recorded in 2009 (pre-construction) and 2010 (1^{st} year post-construction). Of these species, only two (Great Blue Heron [*Ardea Herodias*; blue-listed and special of special concern] and Barn Swallow [*Hirundo rustica*; blue-listed]) are assessed as a species at risk. In addition to the species detected during the site visits, other species at risk that could be expected at the site include Green Heron (*Butorides virescens*), Olive-sided Flycatcher (*Contopus cooperi*), and Band-tailed Pigeon (*Patagioenas fasciata*).

The constructed wetland site is important both for nesting, migrating, and wintering songbirds (n = 27), as well as water birds and shorebirds (n = 4) that are associated with wetland and lake habitats. Sixteen species of bird were recorded at songbird pointcounts and 17 additional incidental observations were made both within the wetland footprint and in the surrounding forested area (Table 6). Nesting activity was noted on several occasions near the wetlands, and fledgling American Robins (*Turdus migratorius*) and Cedar Waxwings (*Bombycilla cedrorum*) were documented feeding in the area during the summer. American Robin and Song Sparrow (*Melospiza melodia*) were the most frequently observed species, with 15 and 9 individuals (respectively) detected from the wetland and riparian areas.

Table 6: Species of bird observed at the constructed wetlands, Diversion Reservoir during 2011. PC = pointcount observation, I = incidental observation.

Common Name	Species Name	No. of Individuals PC	No. of Individuals I	Activity	Habitat Type
Waterfowl (Anatidae)					
Canada Goose	*Branta canadensis*		6	Swimming	Upper Wetland Reservoir
Barrow's Goldeneye	*Bucephala islandica*		2	Swimming	Upper Wetland
Shorebirds (Scolopacidae)					
Spotted Sandpiper	*Actitis macularius*		2	Visual	Wetland
Kingfishers (Cerylidae)					
Belted Kingfisher	*Megaceryle alcyon*		1	Feeding	Wetland
Owls (Strigidae)					
Barred Owl	*Strix varia*		2	Visual	Forest
Woodpeckers (Picidae)					
Red-breasted Sapsucker	*Sphyrapicus ruber*		1	Visual	Forest
Hairy Woodpecker	*Picoides villosus*		1	Calling	Forest
Flycatchers (Tyrannidae)					
Pacific-slope Flycatcher	*Empidonax difficilis*		3	Calling	Forest
Vireos (Vireonidae)					
Warbling Vireo	*Vireo gilvus*	1	2	Calling	Forest
Jays & Crows (Corvidae)					
Common Raven	*Corvus corax*	1	2	Flyover	Reservoir
Stellar's Jay	*Cyanocitta stelleri*	2	3	Calling	Forest
Swallows (Hirundinidae)					
Barn Swallow	*Hirundo rustica*		1	Feeding	Upper Wetland
Chickadees (Paridae)					
Chestnut-backed Chickadee	*Poecile rufescens*		5	Calling	Forest
Treecreepers (Certhiidae)					
Brown Creeper	*Certhia americana*	1	4	Calling	Forest
Wrens (Troglodytidae)					
Pacific Wren	*Troglodytes pacificus*	2	7	Calling	Forest
Kinglets (Regulidae)					
Ruby-crowned Kinglet	*Regulus calendula*	1	1	Calling	Forest
Golden-crowned Kinglet	*Regulus satrapa*	3	5	Calling	Forest
Hummingbirds (Trochilidae)					
Rufous Hummingbird	*Selasphorus rufus*	2	2	Calling	Riparian
Thrushes (Turdidae)					
American Robin	*Turdus migratorius*	6	9	Calling	Wetland, Rip
Varied Thrush	*Ixoreus naevius*	1	4	Calling	Forest
Swainson's Thrush	*Cyanocitta stelleri*		3	Visual	Riparian
Hermit Thrush	*Catharus guttatus*	1		Visual	Lower Wetland
Waxwings (Bombycillidae)					
Cedar Waxwing	*Bombycilla cedrorum*		3	Feeding	Riparian
Warblers (Parulidae)					
Yellow-rumped Warbler	*Dendroica coronata*	1	2	Calling	Riparian
Yellow Warbler	*Dendroica petechia*		1	Calling	Riparian
Wilson's Warbler	*Wilsonia pusilla*		2	Song	Forest
Townsend's Warbler	*Dendroica townsendi*		2	Song	Forest
Orange-crowned Warbler	*Vermivora celata*	2		Calling	Forest
Sparrows (Emberizidae)					
Song Sparrow	*Melospiza melodia*	3	6	Calling	Wetland
Dark-eyed Junco	*Junco hyemalis*	4	2	Feeding	Wetland, Forest
Chipping Sparrow	*Spizella passerina*		1	Feeding	Riparian
Fox Sparrow	*Passerella iliaca*	1	1	Calling	Wetland

Finches (Fringillidae)				
Evening Grosbeak	*Coccothraustes vespertinus*	1	Song/Calling	Forest
Red Crossbill	*Empidonax difficilis*	5	Flyover	Wetland

5.2.2.3 Mammals

Mammal use of the constructed wetland site was determined via the documentation of tracks, scat, and browse sign, as well as by acoustic bat monitoring. Nine mammal species were documented at the constructed wetlands during the 2011 site visits, including Black Bear (*Ursus americanus*), Raccoon (*Procyon lotor*), Columbian Black-tailed Deer (*Odocoileus hemionus columbianus*), and several species of bat (Table 7). Columbian Black-tailed Deer likely used the area frequently as pellets were noted and tracks were observed making their way across the middle berm between the upper and lower wetland ponds. Black bear scat was found at the edge of the upper wetland, and Raccoon tracks were observed near the edge of the excavated pond.

Diversion Reservoir is within the distributional range of several large mammals, such as Grey Wolf (*Canis lupus*), Cougar (*Felis concolor*), and Roosevelt Elk (*Cervus canadensis roosevelti*; tracks were documented nearby in 2010 but not in 2011), and despite the lack of detections during 2011, these species would be expected to occur in the vicinity regularly given its isolated setting and distance from urban areas. Smaller mammal species expected to occur within the area include Deer Mouse (*Peromyscus maniculatus*), shrews (*Sorex* spp.), Townsend's Vole (*Microtus townsendii*), Red Squirrel (*Tamiasciurus hudsonicus*), Short-tailed Weasel (*Mustela erminea*), etc.

In August 2011, we deployed a Wildlife Acoustics Songmeter SM2BAT ultrasonic recorder at the site for 8 nights. There are potentially 10 species of bat using habitats associated with Diversion Reservoir, including the newly constructed wetland (Table 7). Hawkes (2007) reported the capture of a single Townsend's Big-eared Bat adjacent to Diversion Reservoir < 1,000m from the wetland construction site. The results of our August 2011 sample indicate that bats were flying over the newly created wetland. These bats can be categorized into two groups: big bats and small bats, with the groupings based on the acoustic signatures obtained by the SM2BAT detector. Based on the data obtained, the acoustic signatures could be associated with three large bats and three small bats; acoustic recording are variable and can only be associated with potential species, some to higher degree of certainty than others. Mist-netting and/or harp trapping are required to determine exactly which species are using the newly constructed wetland habitat.

Table 7. Large and small bat species that could potentially occur in the Jordan River watershed. Those with an asterisk (*) are the species that could be associated with the acoustic signatures obtained by the SM2BAT detector deployed during August 2011.

Large Bats		Small Bats	
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
*Big Brown Bat	*Eptesicus fuscus*	California Myotis	*Myotis californicus*
*Silver-haired Bat	*Lasionycteris noctivagans*	*Long-eared Myotis	*Myotis evotis*
*Hoary Bat	*Lasiurus cinereus*	Keen's Myotis	*Myotis keenii*
Townsend's Big-eared Bat	*Corynorhinus townsendii*	*Little Brown Myotis	*Myotis lucifugus*
		Long-legged Myotis	*Myotis volans*
		*Yuma Myotis	*Myotis yumanensis*

5.2.2.4 Species at Risk

The CDF biogeoclimatic zone supports a disproportionate abundance of both provincial and federal species of concern, and supports some of the most threatened ecosystems in Canada. For example, the British Columbia Conservation Data Centre (BC CDC) lists a total of 318 species of flora and fauna in the Southern Island Forest District that have provincial status as species of risk, including both red-listed (Endangered, Threatened) and blue-listed (Special Concern) species and ecological communities. Similarly, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), which assesses the status of species at the federal level, has classified 92 species in the southern Vancouver Island region (which includes Diversion Reservoir) as species at risk (species that are considered Extinct, Extirpated, Endangered, Threatened, or Special Concern in Canada). Extensive human development within this region contributes additional ecological pressures, significantly affecting these populations of these species at risk.

Wetland communities such as the constructed ones at Diversion Reservoir typically support a unique assemblage of species (some of which could be species at risk). Immediately adjacent to the wetland, a second-growth coniferous forest stand (dominated by Douglas-fir and Western Redcedar) exists, which also has the potential to house additional species at risk, including Red-legged Frogs. Two visual (and one potential) observations of species at risk were made at the site during 2011 visits, and three other species have been recorded in the past (Vancouver Island Beggarticks [2010], Great Blue Heron [2010], Western Toad [2009]). To emphasize the importance of the site Table 8 lists the species at risk that may potentially be present, including species that have been confirmed at the site.

Table 8: Species at risk that could occur in or near the constructed wetland at Diversion Reservoir based on known distribution and habitat preferences. Species that have been confirmed for the wetland area are bolded and marked with an asterisk (*). Note that not all species have been assessed at the federal level, and thus do not receive a conservation status from COSEWIC. COSEWIC codes: E (Endangered); T (Threatened); SC (Special Concern); NAR (Not at Risk); and DD (Data Deficient).

Scientific Name	Common Name	Provincial Status (BC CDC)	Federal Status (COSEWIC)
Vascular Plants			
Hydrophyllum tenuipes	Pacific Waterleaf	Red	
Bidens amplissima*	**Vancouver Island Beggarticks**	Blue	SC
Claytonia washingtoniana	Washington Spring-beauty	Red	
Invertebrates (Dragonflies and Terrestrial Molluscs)			
Pachydiplax longipennis	Blue Dasher	Blue	
Erythemis collocata	Western Pondhawk	Blue	
Sympetrum vicinum	Autumn Meadowhawk	Blue	
Carychium occidentale	Western Thorn	Blue	
Monadenia fidelis	Pacific Sideband	Blue	
Nearctula sp.	Threaded Vertigo	Blue	SC
Pristiloma johnsoni	Broad-whorl Tightcoil	Blue	
Vertigo andrusiana	Pacific Vertigo	Red	

Reptiles and Amphibians			
Anaryxus boreas	Western Toad	Blue	SC
Rana aurora*	**Red-legged Frog**	Blue	SC
Aneides vagrans	Wandering Salamander	Blue	
Birds			
Ardea herodias fannini*	**Great Blue Heron**	Blue	SC
Chordeiles minor	Common Nighthawk	Yellow	T
Contopus cooperi	Olive-sided Flycatcher	Blue	T
Dendragapus fuliginosus	Sooty Grouse	Blue	
Falco peregrinus anatum	Peregrine Falcon, *anatum* ssp.	Red	SC
Falco peregrinus pealei	Peregrine Falcon, *pealei* ssp.	Blue	SC
Falco peregrinus tundrius	Peregrine Falcon, *tundrius* ssp.	Unknown	SC
Glaucidium gnoma swarthi	Northern Pygmy-Owl, *swarthi* ssp.	Blue	
Hirundo rustica*	**Barn Swallow**	Blue	
Hydropronge caspia	Caspian Tern	Blue	NAR
Megascops kennicottii kennicottii	Western Screech-Owl, *kennicottii* ssp	Blue	SC
Patagioenas fasciata	Band-tailed Pigeon	Blue	SC
Mammals			
Sorex palustris brooksii	American Watershrew, *brooksii* ssp		
Corynorhinus townsendii	Townsend's Big-eared Bat	Blue	
Myotis keenii	Keen's Myotis	Red	DD
Myotis lucifugus*	**Little Brown Myotis**		E

5.3 Proof-of-Concept Example

This constructed wetland came from a project originating in 2005 that examined the status of Red-legged Frogs (a provincial and federal species of conservation concern) in the Jordan River Watershed. The resulting report suggested that breeding habitat for this species and other pond-breeding amphibians was limited in the watershed, and most of what had originally occurred had been lost during the creation of the Diversion and Bear Creek Reservoirs (Hawkes 2005).

The following example tracks the status of Red-legged Frogs at this site and uses amphibians as a representative group to determine proof-of-concept for the constructed wetland at Diversion Reservoir. Amphibians can be viewed as umbrella species for this project, because not only do they use wetland habitat (which has a diversity of plant species associated with it) for breeding, foraging and overwintering, but the habitats that amphibians occur in are also used by a variety of other wildlife species groups (e.g., birds, mammals, aquatic insects); therefore creating amphibian habitat benefits many other species.

Monitoring surveys in 2011 revealed the presence of four species of amphibian (Red-legged Frog, Pacific Treefrog, Northwestern Salamander, Rough-skinned Newt), which indicate that the constructed wetland was successful in providing habitat for pond-breeding amphibians. Furthermore, each of these species was documented to have bred in the wetland, as evidenced by the four stages of amphibian development (egg mass, tadpole/larvae, metamorph, and adult). The productivity of Red-legged Frogs was especially notable in both the upper and lower ponds of the wetland, with over 100 egg masses, numerous tadpoles and several adults (see Table 5).

Table 9 outlines the proof-of-concept wetland, relating the parameters monitored during the 2011 surveys to the various performance measures indicative of success associated with amphibians and the creation of pond-breeding wetland habitat.

Table 9: Proof-of-concept of wetland success using amphibians as a representative group at the constructed wetland in Diversion Reservoir.

Concept	Performance Measure	Performance Measure Result (i.e., Proof)	Successful for Amphibian Species
Habitat Creation	Wetland Size	~ 7500 ha of wetland created in 2009 and is still existing in 2011.	Net gain of wetland habitat in the reservoir drawdown zone.
Wetland Integrity	Water Retention	Water retention in both wetlands was maintained throughout 2011. Berms are holding an adequate amount of water in both the upper and lower pond.	Amphibians are able to breed in water that will remain for the duration of larval development through to metamorphosis.
	Depth Profile	Depth profile of the wetland provided enough variability to promote proper wetland function (e.g., 0 to > 2 m).	Variety of depths provides different aquatic habitat for egg laying, tadpole development and foraging opportunities.
	Coarse Woody Debris	Under 25% CWD floating in upper pond of wetland from May to September.	Provides habitat (e.g., basking sites, cover from predators) and foraging substrate (e.g., algal growth on wood surface) for various life stages of amphibians.
Habitat Quality	Dissolved Oxygen	Wetland was oxygen rich (average DO = 7.77 mg/L)	Wetland has suitable levels of oxygen to support developing larvae.
	Water Temperature	Water temperatures ranged from 6 to 20 ^{o}C.	Water temperatures were within the range required for amphibians to develop.
Wetland Community	Plant Richness and Diversity	High aquatic and terrestrial plant richness (n = 55) and diversity (H_2 = 3.72) documented at the wetland.	The number and diversity of plant species provides structurally diverse cover from predators, substrate for attaching egg masses, habitat for prey items, structure to prevent erosion and turbidity.
	Wildlife Diversity and Richness	Four species of amphibians, 1 species of snake, 33 species of bird, and ~10 species of mammal using the wetland and riparian habitat.	Creation of an ecosystem with various trophic levels (includes both prey and predator species for amphibians).
	Amphibian Productivity	Four of the six species of pond-breeding amphibian bred in constructed wetlands in 2011 (number of egg masses = 149).	Such high numbers of egg masses, especially for species at risk, such as Red-legged Frogs, infers high productivity and habitat quality.

6.0 Discussion

Constructed wetlands are one example of a habitat restoration technique that can be effectively used to mitigate the loss of aquatic habitat and to offset the impacts of hydroelectric development on wildlife. The strategic water use plan for coastal BC Hydro identified the loss of wetland habitat as having a major impact on wildlife in the Jordan River Watershed on southern Vancouver Island (BC Hydro 2001). The creation (2009), revegetation (2010), and monitoring (2011) of the constructed wetland at Diversion Reservoir has begun to address the two major footprint impacts associated with hydroelectric development in the Jordon River Watershed including the loss of wetland and riparian habitats in the valley bottoms of the watershed and the potentially resulting reduced productivity of plants and wildlife in the area.

The loss of wetlands in flooded valley bottoms (Bear Creek) represents a net loss of riparian habitat in the Jordan River Watershed. Results of the preliminary monitoring surveys in 2010 and monthly surveys in 2011 revealed that the newly created wetlands are maintaining their structure (e.g., berm integrity, water retention) and function (e.g., creation of wildlife habitat); thereby representing a net gain of habitat (~7,350 m^2) in the Jordon River Watershed for pond-breeding amphibians, waterbirds, terrestrial mammals, bats, and insects. Results of the plant and wildlife monitoring in 2011 revealed a high diversity of plant species (n = 55; H_s = 3.72) and indicated that multiple wildlife species (n = 47) were using the newly constructed wetland habitat. For example, we documented, four species of amphibian and one species of garter snake, 17 songbird species (including several breeding occurrences), mammal tracks and scat, and six potential species of bat, all of which were either using the wetland itself or in habitats immediately adjacent to the wetland area (e.g., Diversion Reservoir, upland forest).

6.1 Project Objectives

The two main objectives of this created wetland restoration project were: 1) the evaluation of revegetation efforts; and 2) a minimum of one-year of monitoring of the constructed wetland to obtain metrics of success and to determine the utility of the design for potential future wetland construction projects within the Bridge Coastal area.

6.1.1 Task 1: Revegetation Efforts

The ultimate goals of the revegetation plan for Diversion Reservoir were to: 1) revegetate the bare and disturbed areas around the periphery of the wetland during created during construction, as well as areas that are prone to inundation due to reservoir operations; and 2) develop a self-sustaining system with a diverse plant community. Post-construction site visits in 2010 and 2011 provided evidence that native vegetation was establishing itself at the site, both within the actual wetland itself as well as on the disturbed terrestrial areas around the perimeter. For example, native aquatic plants such as Marsh Speedwell, pondweed (*Potamogeton* spp.), Spreading Rush, and Spring Water-starwort appeared sporadically within the wetland, while terrestrial species such as Wool-grass, Dagger-leaved Rush (*Juncus ensifolius*), and Kellogg's Sedge were re-establishing themselves in areas that had been disturbed by construction activities.

Site visits to the wetland in 2011, revealed a 75% survivorship rate of willow stakes that had been planted in 2010 (n = ~390). Red Alder seedlings had naturally revegetated the inner face of the middle berm, creating a band of seedlings above the lower band of herbaceous vegetation. Aquatic plants and a variety of graminoind and forb species had also established themselves along the shoreline of both the upper and lower wetland ponds (Figure 10).

Figure 10: Revegetation process occurring naturally (left) and by replanting (right) at the constructed wetland at Diversion Reservoir.

Three areas of potential concern for the future of plant communities at the constructed wetland are: 1) the establishment of exotic species; 2) noticeable Canada Goose browse on shoreline vegetation; and 3) the stress of prolonged periods of reservoir inundation. As discussed in the results, 10 species of non-native plants were documented at the site, four of which are invasive. Currently, growth of these exotic plants is restricted to the disturbed areas near the berms and access road, and continued removal by hand should keep most of these plants in check. Future monitoring efforts aimed at improving the conditions at the site should attempt to monitor and control/eradicate these species to slow or prevent their spread. Other than egg addling in the spring, not much can be done about the grazing impact of Canada Goose on growing vegetation. Similarly, the constructed wetland is frequently flooded by Diversion Reservoir, and as a result, it may take a few years to determine the effects of prolonged water exposure on survivorship of recently established plants.

Given the fact that multiple species of native plants, both aquatic and terrestrial have been present for two years post-construction in the wetland area, it is anticipated that the establishment of a natural vegetation community within the wetland will be successful within a relatively short time span (< 5 years). However, some long-term maintenance is still required for the plant communities at the constructed wetland, especially with regards to the removal of exotic species and the control of Canada Goose browsing. With the continued removal of invasive plant species, revegetation of the wetland with native aquatic and terrestrial plants should occur naturally. Additional vegetation monitoring (e.g., aquatic and terrestrial vegetation cover plots) over time will reveal if the wetland is continuing to progress along its current trajectory (i.e., natural succession occurring) towards a self-sustaining ecosystem.

In five years, if there are noticeable declines in the performance measures outlined for plants (e.g., decreased plant species richness and diversity, decreased vegetation cover, increased ratios of non-native to native plants, decreased survivorship in willow stakes) within the wetland and/or within the adjacent riparian community, then a revegetation plan can be developed at that time and different options for mitigation can be considered. Two potential options include: 1) more drastic methods for exotic species removal (especially in case of Scotch Broom) may need to be employed; or 2) additional planting or transplanting of native species to augment the communities that are already established. Plants that are used to revegetate portions of the drawdown zone in the future will need to be able to withstand a certain amount of wet and dry stress for the inundation and withdrawal of Diversion Reservoir, respectively. A suggested list of native plants (aquatics, semi-aquatics, shrubs) that should be used to create habitat features within and adjacent to the constructed wetland is provided in Table 10.

Table 10: Suggested native plants that could be used in future revegetation plans for the constructed wetland at Diversion Reservoir.

Vegetation Type	Common name	Scientific Name
Shrubs	Salmonberry	*Rubus spectibilis*
	Thimbleberry	*Tubus parviflorus*
	Red-osier dogwood	*Cornus stolonifera*
	High-bush cranberry	*Viburnum edule*
	Red elderberry	*Sambucus racemosa*
Wetland Plants	Cattail	*Typha latifolia*
	Marsh cinquefoil	*Potentilla palustris*
	Beaked Sedge	*Carex utriculata*
	Slough Sedge	*Carex obnupta*
	Creeping spike-rush	*Eleocharis palustris*
	Yellow-pond lily	*Nuphar polysepalum*
	Small-flowered bulrush	*Scirpus microcarpus*
	Watershield	*Brasenia schreberi*
	Pondweed	*Potamogeton* spp.

6.1.2 Task 2: Monitoring and Determining Proof-of-Concept

Because this wetland was built as a proof-of-concept, it was necessary to determine its success. Success was determined through monitoring a variety of performance measures (see section in the methods for the complete list) assessing the integrity of the wetland itself and the effectiveness of the wetland in meeting the ecological objectives of the project (e.g., providing aquatic and riparian habitat for wildlife in the Jordon River watershed). Results from the 2011 monitoring surveys provide a clear indication that the constructed wetland is currently progressing towards a self-sustaining natural ecosystem with a high degree of plant and wildlife diversity (n = 102 species), structural integrity, and does not appear to be adversely effected by current Diversion Reservoir operations. The diversity and richness of wildlife and plants documented at the wetland presumably infers appropriate habitat quality to support plants and wildlife. In particular, the high use of this wetland by pond-breeding amphibians for breeding (e.g., 149 egg masses) exemplifies the success of this proof-of-concept for the constructed wetland at Diversion Reservoir (see Table 5; Table 9).

Table 11 outlines the performance measures for this project, the level of success achieved for this proof-of-concept constructed wetland and considerations for the future of this wetland.

Table 11: Summary of proof-of-concept of wetland design using performance measures to indicate success at the constructed wetland in Diversion Reservoir.

Concept	Performance Measure	Performance Measure Result (i.e., Proof)	Success Achieved	Future Monitoring Considerations
Habitat Creation	Wetland Size	~ 7500 ha of wetland created in 2009 and is still existing in 2011.	Net gain of wetland habitat in the reservoir drawdown zone.	Does wetland area change over time?
Wetland Integrity	Water Retention	Water retention in both wetlands was maintained throughout 2011. Berms are holding an adequate amount of water in both the upper and lower pond.	Wetland habitat was available for aquatic plants, macroinvertebrates and wildlife (e.g., amphibians, birds, bats, insects) to use for the active season (e.g., April to September).	Is water retained in both ponds of the wetland over time? In the future with any deceases in reservoir elevations, does the wetland still retain water throughout the year?
	Depth Profile	Depth profile of the wetland provided enough variability to promote proper wetland function (e.g., 0 to > 2 m).	Variety of depths provides different aquatic habitat for aquatic plants, macroinvertebrates and wildlife that inhabit the wetland.	Does depth in the ponds vary from year to year? How is this influenced by reservoir operations?
	Coarse Woody Debris	Under 25% CWD floating in upper pond of wetland from May to September.	Provides habitat (e.g., basking sites, cover from predators) and foraging substrate (e.g., algal growth on wood surface) for wildlife using the pond.	Does the abundance of CWD change over time? Increased levels of > 50% surface coverage are not ideal for wetland health.
Habitat Quality	Dissolved Oxygen	Wetland was oxygen rich (average DO = 7.77 mg/L)	Wetland had suitable levels of oxygen to support developing aquatic life.	Does this change seasonally? From year to year?
	Water Temperature	Water temperatures ranged from 6 to 20 ^{o}C.	Water temperatures were within the range required for amphibian development.	Does this change seasonally? From year to year?
Wetland Community	Plant Richness and Diversity	High aquatic and terrestrial plant richness (n = 55) and diversity (H_2 = 3.72) documented at the wetland.	The number and diversity of plant species provided a structurally diverse plant community for a variety of wildlife uses: cover from predators, substrate for attaching egg masses, foraging, structure to prevent erosion and turbidity.	Is plant richness and diversity increasing over time? Are exotic plants increasing in coverage over time?
	Wildlife Diversity and Richness	Four species of amphibians, one species of snake, 33 species of bird, and ~10 species of mammal using the wetland and riparian habitat.	Creation of an ecosystem with various trophic levels (both prey and predator species).	Is wildlife richness and diversity increasing over time?
	Amphibian Productivity	Four of the six species of pond-breeding amphibian bred in constructed wetlands in 2011 (egg mass n = 149).	High numbers of egg masses, especially for species at risk, such as Red-legged Frogs, infers high productivity and habitat quality.	Is the number of Red-legged Frogs egg masses increasing or decreasing over time?

7.0 Recommendations

Monitoring of the constructed wetland site in 2011 indicates that this project has been successful in creating habitat for wetland-associated species (particularly amphibians) and has provided a habitat type that is rare or infrequent in the watershed since the creation of the Diversion and Bear Creek Reservoirs flooded similar valley-bottom habitats. The success of this constructed wetland provides a model that could be applied to other watersheds in BC affected by the impoundment of rivers and creation of reservoirs.

A critical component of all wetland restoration projects is the ability for adaptive management following the completion of the construction and revegetation phases to increase the likelihood of success associated with the project (Patten 2006). Periodic monitoring of the site following its completion enables the architects of the wetland to follow the maturation of the habitat and, should problems arise such as poor germination of revegetated areas or invasion of exotic plants, the managers are able to identify the problem, quantify the magnitude its impact, and come up with solutions to bring the wetland back to a natural and healthy state. The chances of success of the project drop significantly in the absence of such an adaptive management scheme.

To further ensure success of this wetland over time, we recommend long-term (~5 to 10 year) monitoring of the site in order to ensure that the trajectory of the established ecosystem is proceeding in a direction that is consistent with the outlined performance measures for this project and to ensure that it is meeting its stated goal of providing habitat for native wildlife, such as the Red-legged Frog and other pond-breeding amphibians. Although initial results from 2010 and 2011 indicate that this wetland is on the right track, the project can only be considered a success if the resulting ecosystems can be shown to be self-sustaining and to provide habitat for native plant and wildlife species over time. Such a designation requires periodic assessments of the site into the short term (5 years of annual visits), with occasional assessments into the longer term (10 years). These assessments will allow managers to employ adaptive management techniques such as removal of invasive exotic species (Scotch Broom, Himalayan Blackberry, etc.) or the augmentation of native plant populations with additional planted individuals if the conditions at the site are found to require such interventions. For example, a number of Scotch Broom seedlings were detected on the middle berm during both 2010 and 2011 site visits (and were subsequently removed), indicating that this will likely be an issue that requires continued attention into both the near-term and long-term future.

The following describes a proposed monitoring scheme, with additional monitoring or site visits advisable if intervention is required:

- Regular (3-4 visits per year) monitoring for the first 3 years (2010 – 2012)
- Less frequent (2 visits per year) monitoring for years 4-5 (2013 – 2014)
- Occasional (~1 visit per year) monitoring for years 6-10 (2015 – 2019)

7.1 Influences of Logging on the Constructed Wetland

A notable change to the habitat surrounding the constructed wetland occurred in July 2011 with logging of the northern slope of forested area, immediately adjacent to the wetland (Figure 11). Although a riparian buffer of approximately 30 to 40 m of forested land was established during the logging process, there is a potential for these activities to influence wetland conditions over time. Potential impacts to the wetland could include:

- decline of Red-legged Frog population using the constructed wetlands, as the surrounding upland forested habitat was likely used by adult individuals during the fall and winter for foraging and hibernation;
- changes in the diversity or abundance of other wildlife species that use both the wetland and bordering forested areas;
- changes in environmental or chemical conditions in the wetland and immediate riparian areas (e.g., temperature, water inputs, pH, dissolved oxygen, etc.); and/or
- changes in sedimentation or turbidity in wetland ponds.


Figure 11: Photographs of recent logging activities immediately north of the constructed wetland at Diversion Reservoir, 2011. Constructed wetland located left down the access road in the left photograph.

It will be important to monitor any changes in the constructed wetland that may result over time as a result of this forestry activity. Unfortunately, it may be difficult to distinguish between any changes to wetland productivity and success that occur due to the clear cut from the natural wetland succession that would have happened over time without the influence of this change of habitat.

7.2 Performance Measures over Time

In addition to the performance measures monitoring in 2011, a variety of other metrics and factors could be monitored in the future. The ultimate goal is to examine these performance measures over time, in order to compare the conditions at the wetland site against desired conditions and determine if natural ecosystems are becoming established. The results of these assessments will enable monitors to recognize any concerns with the wetland ecosystem establishment and potentially identify opportunities for intervention. Recommended factors to be investigated during future assessments include:

Established Performance Measures:

- general monitoring of wetland integrity (e.g., berm integrity, water retention, CWD accumulation) and water chemistry characteristics (e.g., pH, conductivity, temperature, dissolved O_2)
- total species diversity of plants and wildlife over time;
- survivorship of willow stakes;
- total cover of native vs. introduced plant species;

- presence of Red-legged Frogs and abundance (e.g., productivity, diversity) of breeding amphibians (using egg mass counts); and
- length of period of inundation by Diversion Reservoir.

Additional Performance Measures:

- surveys targeting species at risk to produce long-term population datasets;
- the presence/absence of Western Toad at the site (diversity and productivity);
- ongoing placement of bat detectors and additional mist net surveys (diversity and productivity);
- browse impact by Canada Geese to native riparian vegetation (invasive species impacts);
- fish presence, species richness and diversity in the wetland;
- biomass surveys for aquatic and terrestrial plants (i.e., macrophytes)
- diversity and abundance of aquatic invertebrates (diversity and productivity);
- rare plant surveys (e.g., Vancouver Island Beggarticks) ; and/or
- other general water chemistry characteristics (e.g., turbidity, sedimentation).

Regular assessments and adaptive monitoring are the final, but one of the most critical, components of this project. By reassessing the conditions at the constructed wetland site on an annual basis and providing opportunities to remedy undesired conditions (e.g., higher ratio of non-native to native plants, presence of American Bull Frogs [*Lithobates catesbeianus*], increased water turbidity or sedimentation, > 50% coarse woody debris in ponds, berm failure or erosion, etc.) or augment beneficial conditions (e.g., high quality wetland habitat for breeding amphibians, high species richness and diversity for plants and wildlife, established populations of native and rare plant populations, eradication of invasive plant species, etc.), the potential for success of the project and its ability to meet the initial objectives is greatly enhanced. As this project was a proof-of-concept, adaptation of the design and methods also allows for fine-tuning so that, should the concept be taken into other watersheds, its chances of success will be increased even further.

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10.0 Appendices

Appendix A. List of plant species for the constructed wetlands at Diversion Reservoir.

Table 12: List of plant species documented in 2011. Plants are categorized as tree, shrub, graminoid, forb, or aquatic and classified as native or introduced.

Species	Common Name	Plant Form	Category	Native/Introduced
Alnus rubra	Red Alder	Tree	Terrestrial	Native
Pseudotsuga menziesii	Douglas-fir	Tree	Terrestrial	Native
Salix lucida ssp.lasiandra	Pacific Willow	Tree	Terrestrial	Native
Salix sitchensis	Sitka Willow	Tree	Terrestrial	Native
Thuja plicata	Western Redcedar	Tree	Terrestrial	Native
Tsuga heterophyla	Western Hemlock	Tree	Terrestrial	Native
Cytisus scoparius	Scotch Broom	Shrub	Terrestrial	Introduced
Gaultheria shallon	Salal	Shrub	Terrestrial	Native
Rubus armeniacus	Himalayan Blackberry	Shrub	Terrestrial	Introduced
Rubus spectabilis	Salmonberry	Shrub	Riparian	Native
Rubus ursinus	Trailing Blackberry	Shrub	Riparian	Native
Sambucus racemosa	Red Elderberry	Shrub	Terrestrial	Native
Symphoricarpos albus	Common Snowberry	Shrub	Terrestrial	Native
Vaccinium parvifolium	Red Huckleberry	Shrub	Terrestrial	Native
Agrostis stolonifera	Creeping Bentgrass	Graminoid	Terrestrial	Introduced
Callitriche palustris	Spring Water-starwort	Graminoid	Aquatic	Native
Callitriche stagnalis	Pond Water-starwort	Graminoid	Aquatic	Introduced
Carex lenticularis	Kellogg’s Sedge	Graminoid	Terrestrial	Introduced
Juncus articulatus	Tapered Rush	Graminoid	Aquatic	Native
Juncus bufonius	Toad Rush	Graminoid	Aquatic	Native
Juncus effusus	Common Rush	Graminoid	Aquatic	Native
Juncus ensifolius	Swordleaf Rush	Graminoid	Aquatic	Native
Juncus supiniformis	Spreading Rush	Graminoid	Aquatic	Native
Poa pratensis	Kentucky Bluegrass	Graminoid	Terrestrial	Introduced
Scirpus cyperinus	Wool-grass	Graminoid	Aquatic	Native
Athyrium filix-femina	Lady Fern	Forb	Terrestrial	Native
Blechnum spicant	Deer Fern	Forb	Terrestrial	Native
Boykinia occidentalis	Coast Boykinia	Forb	Terrestrial	Native
Cirsium arvense	Canada Thistle	Forb	Terrestrial	Introduced
Cirsium vulgare	Bull Thistle	Forb	Terrestrial	Introduced
Epilobium angustifolium	Fireweed	Forb	Terrestrial	Native
Epilobium ciliatum	Purple-leaved Willowherb	Forb	Terrestrial	Native
Equisetum arvense	Common Horsetail	Forb	Aquatic	Native
Equisetum telmateia	Giant Horsetail	Forb	Aquatic	Native
Galium trifidum	Small Bedstraw	Forb	Terrestrial	Native
Geum macrophyllum	Large-leaved Avens	Forb	Terrestrial	Native
Gnaphalium uliginosum	Marsh Cudweed	Forb	Terrestrial	Introduced
Lysichiton americanum	Skunk Cabbage	Forb	Terrestrial	Native
Maianthemum dilatatum	False Lily-of-the-valley	Forb	Terrestrial	Native
Mimulus guttatus	Yellow Monkey-flower	Forb	Aquatic	Native
Myosotis laxa	Small-flowered Forget-me-not	Forb	Aquatic	Native
Oenanthe sarmentosa	Pacific Water-parsley	Forb	Aquatic	Native
Polygonum persicaria	Lady’s-thumb	Forb	Terrestrial	Introduced
Potamogeton foliosus	Leafy Pondweed	Forb	Aquatic	Native
Prunella vulgaris	Self Heal	Forb	Terrestrial	Native
Rorippa curvisiliqua	Western Yellow-cress	Forb	Terrestrial	Native
Rorippa palustris	Marsh Yellow-cress	Forb	Terrestrial	Native
Rumex obtusifolius	Broad-leaved Dock	Forb	Terrestrial	Introduced
Scutellaria lateriflora	Blue Skullcap	Forb	Terrestrial	Native
Spergularia rubra	Red Sand-spurry	Forb	Terrestrial	Introduced

Spirea douglasii	Hardhack	Forb	Terrestrial	Native
Streptopus lanceolatus	Rosy Twistedstalk	Forb	Terrestrial	Native
Taraxacum officinale	Common Dandelion	Forb	Terrestrial	Introduced
Veronica beccabunga	American Brooklime	Forb	Aquatic	Native
Veronica scutellata	Marsh Speedwell	Forb	Aquatic	Native

Appendix B. List of wildlife species for the constructed wetlands at Diversion Reservoir.

Table 13: Wildlife species observed during 2011 field visits to constructed wetlands at Diversion Reservoir. Wildlife observations are categorized by group. FO = Flyover; FOR = Forest; RES = Reservoir; RIP = Riparian; WET = Wetland.

Common Name	Species Name	Group	Habitat	Sign
Northwestern Salamander	*Ambystoma gracile*	Amphibian	WET, RIP	Visual
Pacific Chorus Frog	*Pseudacris regilla*	Amphibian	WET, RIP	Visual
Red-Legged Frog	*Rana aurora*	Amphibian	WET, RIP	Visual
Rough-Skinned Newt	*Taricha granulosa*	Amphibian	WET, RIP	Visual
American Robin	*Turdus migratorius*	Bird	WET, RIP	Visual
Barn Swallow	*Hirundo rustica*	Bird	WET, RIP	Visual
Barred Owl	*Strix varia*	Bird	FOR	Visual
Barrow’s Goldeneye	*Bucephala islandica*	Bird	WET	Visual
Belted Kingfisher	*Megaceryle alcyon*	Bird	WET	Visual
Brown Creeper	*Certhia americana*	Bird	FOR	Call
Canada Goose	*Branta canadensis*	Bird	WET, RES	Visual
Cedar Waxwing	*Bombycilla cedrorum*	Bird	WET, RIP	Visual
Chestnut-backed Chickadee	*Poecile rufescens*	Bird	FOR	Visual
Chipping Sparrow	*Spizella passerina*	Bird	RIP	Visual
Common Raven	*Corvus corax*	Bird	FO	Visual
Dark-eyed Junco	*Junco hyemalis*	Bird	RIP, FOR	Visual
Evening Grosbeak	*Coccothraustes vespertinus*	Bird	FOR	Call
Fox Sparrow	*Passerella iliaca*	Bird	RIP	Visual
Golden-crowned Kinglet	*Regulus satrapa*	Bird	RIP, FOR	Visual
Hairy Woodpecker	*Picoides villosus*	Bird	FOR	Call
Hermit Thrush	*Catharus guttatus*	Bird	WET, RIP	Visual
Orange-crowned Warbler	*Vermivora celata*	Bird	FOR	Call
Pacific Wren	*Troglodytes pacificus*	Bird	FOR	Call
Pacific-slope Flycatcher	*Empidonax difficilis*	Bird	FOR	Call
Red Crossbill	*Loxia curvirostra*	Bird	FO	Visual
Red-breasted Sapsucker	*Sphyrapicus ruber*	Bird	FOR	Call
Ruby-crowned Kinglet	*Regulus calendula*	Bird	RIP, FOR	Call

Rufous Hummingbird	*Selasphorus rufus*	Bird	RIP	Visual
Song Sparrow	*Melospiza melodia*	Bird	WET, RIP	Visual
Spotted Sandpiper	*Actitis macularius*	Bird	WET, RIP	Visual
Stellar's Jay	*Cyanocitta stelleri*	Bird	RIP, FOR	Visual
Swainson's Thrush	*Catharus ustulatus*	Bird	WET, RIP	Visual
Townsend's Warbler	*Dendroica townsendi*	Bird	FOR	Call
Varied Thrush	*Ixoreus naevius*	Bird	FOR	Call
Warbling Vireo	*Vireo gilvus*	Bird	RIP	Call
Wilson's Warbler	*Wilsonia pusilla*	Bird	RIP, FOR	Visual
Yellow Warbler	*Dendroica petechia*	Bird	WET, RIP	Call
Yellow-rumped Warbler	*Dendroica coronata*	Bird	WET, RIP	Visual
Black Bear	*Ursus americanus*	Mammal	RIP	Scat
Columbian Black-tailed Deer	*Odocoileus hemionus columbianus*	Mammal	WET, RIP	Tracks
Raccoon	*Procyon lotor*	Mammal	WET, RIP	Tracks

Appendix C. Seasonal photographs of the constructed wetlands at Diversion Reservoir, 2011.

Figure 12: Constructed wetlands at Diversion Reservoir, April 13th 2011. Photograph on left shows upper wetland; photograph on right shows upper and lower wetlands (left to right), reservoir in distance, and constructed berms.

Figure 13: Constructed wetlands at Diversion Reservoir, May 4th 2011. Photograph on left shows upper wetland; photograph on right shows lower wetland and reservoir (left to right), and constructed berm.

Figure 14: Constructed wetlands at Diversion Reservoir, June 13th 2011. Photograph on left shows upper wetland; photograph on right shows lower wetland and berm with Diversion Reservoir in the distance.

 

Figure 15: Constructed wetlands at Diversion Reservoir, July 11th 2011. Photograph on left shows upper wetland; photograph on right shows lower wetland (which has been inundated by Diversion Reservoir).

 

Figure 16: Constructed wetlands at Diversion Reservoir, August 9th 2011. Photograph on left shows upper wetland; photograph on right shows lower wetland (which has been inundated by Diversion Reservoir).

 

Figure 17: Constructed wetlands at Diversion Reservoir, September 7th 2011. Photograph on left shows upper wetland; photograph on right shows berm between lower and upper wetland that has been inundated by Diversion Reservoir.

Appendix D. Final Report Forms: Financial Statement (I); Performance Measures – Actual Outcomes (II); and Confirmation of BCRP/FWCP Recognition (III).