Columbia River Project Water Use Plan

KINBASKET RESERVOIR FISH AND WILDLIFE INFORMATION PLAN

Wetland Vegetation

Implementation Year 1

Reference: CLBMON-61

Kinbasket Reservoir: Mica Unit 5 Wetlands Monitoring Program

Study Period: 2012

LGL Limited
environmental research associates
Sidney, BC

August 19, 2013

EA3398

KINBASKET AND ARROW LAKES RESERVOIRS

Monitoring Program No. CLBMON-61

Kinbasket Reservoir Wetlands Monitoring Program




Year 1–2012
Final Report

Prepared for

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Cover photos

Kinbasket Reservoir from left to right: Reference wetland near Bush Arm km79 marshes; inundated wetlands at Bush Arm km79 marshes; Valemount Peatland; Bush Arm Causeway © Krysia Tuttle and Virgil Hawkes, LGL Limited.

EXECUTIVE SUMMARY

The construction of hydroelectric dams and reservoirs has resulted in the loss of vast areas of wetland habitat in the Columbia Basin. CLBMON-61 is a monitoring program to assess the impacts of elevated reservoir levels on wetland habitats in Kinbasket Reservoir associated with the installation of two turbines at Mica Dam. Generalized Optimization Modeling predicted reservoir levels will increase an additional 0.6 meters in every three years out of ten, and that the impacts, if any, will occur in the 753 to 754 meter elevation band of the reservoir. The management questions to be addressed by the monitoring program include:

- What are the short-term effects of water level changes on wetland vegetation composition or productivity, with emphasis on the 753 to 754 m elevation band?

- If negative changes in wetland vegetation composition or wetland productivity are detected, which are directly imputable to Mica 5 operations, are there operational changes or mitigative measures that could be implemented to improve wetland integrity (combination of composition and productivity) in Kinbasket Reservoir?

The Terms of Reference for this study calls for a Before-After-Impact-Control (BACI) design to test the following null hypotheses:

H_{01}: There are no changes in wetland composition in Kinbasket Reservoir over the course of the monitoring period.

H_{1A}: Wetland composition is not affected by reservoir operations.

H_{02}: There are no changes in wetland productivity in Kinbasket Reservoir over the course of the monitoring period.

H_{2A}: Wetland productivity is not affected by reservoir operations.

CLBMON-61 will determine baseline conditions over a two-year period (2012 and 2013) prior to the installation of the turbines. Post-installation monitoring will occur in 2015, 2016, and 2017. Metrics to be assessed include wetland area, composition, primary productivity, and secondary productivity.

The objectives in Year 1 of study were to:

a) provide a general description of wetlands in the upper elevation of Kinbasket Reservoir;

b) describe and justify the methods used to select index sites for monitoring; and,

c) review the study approach and methods (both field and analytical) to ensure they are appropriate for addressing the management questions and hypotheses.

In 2012 (Year 1), a site review was undertaken using GIS and existing data to delineate wetland habitats in Kinbasket Reservoir for sampling. Based on the spatial extent of the vegetation communities mapped previously (Hawkes et al. 2007, 2010), 102.8 hectares of wetland habitat exist between 751 and 755 m ASL, with 34.1 hectares occurring in the target elevation band (753–754 m ASL). During the site review, 25 aquatic and 50 terrestrial wetland sites were identified for sampling including 12 aquatic and 13 terrestrial wetland reference sites located outside the reservoir. Aquatic wetlands were defined as permanent shallow waters (i.e., ponds and shallow lakes) and terrestrial wetlands include bog, fen, swamp, or marsh wetland classes as defined by MacKenzie and Moran (2004).

In situ monitoring commenced in 2012 and data were collected on general wetland characteristics, wood debris accumulation, community composition, water physicochemistry, primary productivity (i.e., macrophytes biomass), and secondary productivity (i.e., aquatic macroinvertebrates). Sampling was carried out between July 7 and August 22, 2012 in three reaches of Kinbasket Reservoir: Bush Arm, Mica Arm, and Canoe Reach. Terrestrial wetlands were stratified by four elevation bands: 752 – 753 m ASL, 753 – 754 m ASL, 754 – 755 m ASL, and above 755 m ASL (for reference communities). Aquatic wetlands were stratified as either within the reservoir or outside/above; all but one reservoir pond were between 751 and 754 m ASL. During the sampling period, water levels in Kinbasket Reservoir rose rapidly and flooded many of the sites precluding sampling. Consequently, only 16 aquatic wetlands and 15 terrestrial wetland sites were sampled. Despite this, sufficient data were collected to characterize the wetlands in and adjacent Kinbasket Reservoir.

Nine terrestrial and twelve aquatic wetland communities were identified using the classifications of Pierce and Jensen (2001), MacKenzie and Moran (2004), and Hawkes et al. (2007). In terrestrial wetlands, species richness and diversity decreased with elevation from 755 to 752 m ASL. Lower elevation communities tended to be either Willow–Sedge communities or Swamp Horsetail communities and upper elevation communities were either Willow–Sedge communities, or flood, marsh, and fen associations. Decreasing shrub cover was also observed across the elevation gradient while pteridophyte (e.g., *Equisetum* spp.) and sedge cover increased at the lower elevations (752 –753 m ASL).

In aquatic wetlands, beaver activity, water depth, water physicochemistry, and organic accumulation (including wood debris) appeared to influence the distribution of aquatic communities. Beaver activity was apparent in 75 per cent of the ponds sampled and appears to be an important wetland forming process in the study area. Ponds associated with beaver activity also tended to be deeper and supported *Nuphar* and *Potamogeton* communities. pH and conductivity values differed significantly across the study area, which was likely due to geological differences among the three reaches. This difference in water physicochemistry was reflected in the distribution of at least one aquatic community: the *Chara spp*. *Chara* a macroalga that occurs in mineral rich, alkali waters and occurred exclusively in Bush Arm.

A higher frequency of wood debris was observed in the benthic sediment of ponds within the reservoir than in reference ponds. This is likely due to the large amounts of wood debris that accumulate annually in the upper elevation of the reservoir. The accumulation of wood debris is detrimental to wetlands as it displaces existing vegetation and causes physical disturbance to established vegetation. Further, leachate from wood accumulation can be toxic to aquatic life.

Macrophyte biomass was obtained as an index of primary productivity. Macrophyte biomass did not differ significantly between ponds within the reservoir and reference ponds; however, we suggest that comparing productivity levels among sites may be inappropriate. Bogs and floating fens perform essential ecological services but can have very low productivity and it would be erroneous to conclude that these wetland types are impaired. An alternative approach is to monitor primary productivity as a state variable as an index of ecological stress, in which case either a decrease or increase in productivity would be interpreted as a negative impact.

Pelagic macroinvertebrates were sampled as an index of secondary productivity. In general, the number of pelagic macroinvertebrate taxa in reservoir ponds did not differ from reference ponds with the exception of Canoe Reach, where the number of taxa documented from ponds within the reservoir were lower than the upland reference ponds. Differences in diversity and evenness values were not statistically significant. In almost all cases the relative abundance of the individual taxa detected in 2012 did not differ significantly between the reservoir and reference ponds sampled. The one exception was the Trichoptera (caddisflies), which were more abundant in the reference ponds than in ponds within the reservoir.

In future years, we recommend continuing the stratified sampling design that was established in Year 1. This includes stratifying by wetland type (terrestrial and aquatic), by elevation band, and by reach. We also recommend focusing the monitoring to four index sites: Valemount Peatland, the Sprague Bay wetlands, the km88 wetlands in Bush Arm, and the wetland complex at the Bush River Causeway,

We further recommend that an Index of Wetland Integrity (IWI) be developed for wetlands occurring within the index sites using metrics to assess taxonomic diversity and richness, structural stage, community structure, primary productivity, secondary productivity, and disturbance. Methods to assess ecological conditions of wetlands are modeled after the Index of Biological Integrity (IBI; Karr 1997; Gernes and Helgen 1999) and are well suited for assessing change in wetland conditions in response to environmental stressors (Cronk and Fennessy 2001).

Finally, we suggest that the BACI approach that was prescribed for this study is not appropriate. A BACI design entails sampling a variable (or variables) at control and impact sites before and after a disturbance to determine if the impact site has changed relative to the control sites (Smith 2002). During the initial year of the study (the pre-impact period), the operation of Kinbasket Reservoir was altered to accommodate the installation of the new units and reservoir levels reached 754.68 m ASL, which is 3.9 m above the mean and 30 cm more than the normal operating maximum. The high reservoir levels in 2012 impeded access to many sites within the reservoir, preventing the collection of the necessary pre-impact baseline data. Based on past observations of vegetation response to inundation (Hawkes et al. 2010), the water levels observed in 2012 will likely be detrimental to vegetation in the upper elevations of the reservoir. This will prohibit an assessment of pre-impact conditions and the ability to carry out BACI analyses. Since the wetland vegetation was impacted during the first year of the study, the BACI design cannot be continued and should be replaced by a long term monitoring program with annual sampling.

ACKNOWLEDGMENTS

Margo Dennis of BC Hydro administered this project. Margo Denis and Guy Martel completed a QA and Safety audit of CLBMON-61 in July 2012. LGL Staff Doug Adama, Mike Miller, Krysia Tuttle, Bryce McKinnon, Jamie Fenneman, Jeremy Gatten, and Virgil Hawkes collected field data. Janean Sharkey oversaw macroinvertebrate identification and vegetation biomass processing. Dave Robichaud provided assistance with statistical analyses. Robin Tamasi (LGL) and Lucia Ferreira completed the GIS analyses associated with this project.

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1.0 INTRODUCTION

Hydroelectric dams regulate the flow of most of the world's large river systems (Rosenberg et al 1997; Nilsson 2005) and their construction and operation dramatically alters aquatic and terrestrial ecosystems both upstream and downstream of the dam (Nilsson et al. 1991; Hill et al. 1998; Rosenberg et al 2000). Consequently, vast areas of wetland and riparian habitats are severely degraded or are eliminated outright (Nilsson and Keddy 1988; Rosenberg et al 1997; Finlayson and Davison 1999).

Completed in 1973, Mica Dam was built under the Columbia River Treaty to provide water storage for power generation and flood control. Construction of the dam flooded 42,650 ha resulting in the loss of 15,526.5 ha of riparian, 5,863 ha of wetland, and 555 ha of shallow pond habitats (Utzig and Schmidt 2011). Mica Dam was originally constructed and licensed as a six-unit facility; however, BC Hydro deferred the installation of Units 5 and 6 until additional capacity was needed.

In 2008, BC Hydro undertook an Environmental Impact Assessment (EIA) for the construction and operation for the two additional units (BC Hydro 2009). During the stakeholder engagement process, concerns were raised over the impacts that the additional units may have on wildlife and wildlife habitat in the upper elevations of Kinbasket Reservoir. During the EIA, it was identified that changes to reservoir operations could impact the success of vegetation and negatively impact wetlands and wetland dependent species during the summer re-fill period. A General Optimization Model (GOM) predicted that reservoir levels would be 0.6 m higher in July and August in every three years out of ten (KCB 2009). The model also predicted that the impacts would be restricted to the elevation band spanning 753 to 754 m Above Sea Level (ASL). Concerning wetland vegetation in Kinbasket Reservoir, the Mica 5/6 Core Committee provided the following recommendations:

1) Augment the existing WLR Kinbasket Vegetation Inventory (i.e., CLBMON-10) program with: A) a modeling exercise to simulate the potential effect of increased water levels into the upper elevation band (753–754 m ASL); and B) an additional year of vegetation inventory post Mica 5 installation in 2018.

2) Develop a new WLR study to investigate the potential for effects on the different representative wetland types that exist across the reservoir in the upper elevation band.

In January 2012, a Terms of Reference for a multi-year monitoring program (CLBMON-61) was prepared by BC Hydro to address potential impacts to wetlands resulting from the installation of the two additional turbines (BC Hydro 2011) – item 2 above. The premise of the study is to assess potential changes in wetland composition and productivity in Kinbasket Reservoir and to determine if any change can be associated with reservoir operations. Following an open call for tenders, LGL Limited was awarded a contract to deliver CLBMON-61 and Year 1 of the study was initiated in 2012. This report provides the annual progress report for Year 1 of the study.

2.0 MANAGEMENT QUESTIONS AND HYPOTHESES

2.1 Management Questions

To address the uncertainties relating to changes in reservoir operation following the installation of Mica Units 5 and 6, this monitoring program will focus on:

- Obtaining measurements of wetland area, composition and productivity that can also be used as parameters for modeling the effects of inundation on plant communities in the 753 to 754 m range (as specified under CLBMON 10); and
- Determining key indicators of change in wetland composition and productivity.

The key management questions to be addressed by the monitoring program are:

- What are the short-terms effects of water level changes on wetland vegetation composition or productivity, with emphasis on the 753 to 754 m elevation band?
- If negative changes in wetland vegetation composition or wetland productivity are detected which are directly imputable to Mica 5 operations, are there operational changes or mitigative measures that could be implemented to improve wetland integrity (combination of composition and productivity) in Kinbasket Reservoir?

2.2 Management Hypotheses

To assess the effects of reservoir operations associated with Mica Unit 5 and 6 on wetland composition and productivity, the following null hypotheses will be tested:

H_{01}: There are no changes in wetland composition in Kinbasket Reservoir over the course of the monitoring period.

H_{1A}: Wetland composition is not affected by reservoir operations.

H_{02}: There are no changes in wetland productivity in Kinbasket Reservoir over the course of the monitoring period.

H_{2A}: Wetland productivity is not affected by reservoir operations.

2.3 Key Water Use Decision

Implementation of the proposed monitoring program will provide information to support decisions around the need to balance storage in Kinbasket Reservoir with impacts on wetland integrity (composition and productivity). Specifically, the program will provide information required to support future decisions around maintaining the current operating regime or modifying operations through adjusting minimum or maximum elevations to sustain reservoir wetlands. The intent is to ensure that wetlands in the upper elevations of the reservoir drawdown area are not adversely affected by incremental changes in reservoir operations attributable to the fifth and possibly the sixth turbines in Mica Dam.

3.0 STUDY AREA

3.1 Physiography

The Columbia River begins at Columbia Lake in the Rocky Mountain Trench and flows northwest for 180 km before it empties into Kinbasket Reservoir near Donald, BC. At 216 km in length, Kinbasket Reservoir extends from Donald to Valemount, BC and is flanked by the Rocky Mountains to the east and the Selkirk and Monashee Mountain Ranges to the west (Figure 3-1). The shoreline of the reservoir is generally steep and rocky; however, low-lying land occurs on alluvial fans and fluvial or lacustrine terraces. The reservoir consists of seven reaches[1]: Beaver Mouth, Kinbasket Reach, Bush Arm, Sullivan Arm, Mica Cr., Wood Arm, and Canoe Reach.

3.2 Climate

Easterly movement of damp air from the Pacific Ocean dominate the climate. The climate near Valemount is continental and is characterized by seasonal extremes of temperature. Winters are snowy and severe, while summers are relatively warm and moist but short. The annual precipitation is 440–900 mm. The climate at Bush Arm is typified by cool-wet winters, and warm-dry winters. The distribution of precipitation is affected by the north-south trend of the mountain systems. Mean annual precipitation ranges from 500 to 1400 mm of which 25 to 50 per cent falls as snow (Braumandl an Curran 2002).

In winter, polar air masses moving south into Alberta often spill through passes into the Rocky Mountain Trench resulting in cooler and drier conditions than what is observed to the west in the Columbia Mountains. The snow pack accumulates above 2,000 m elevation through the month of May and continues to contribute runoff long after the snow pack has melted at lower elevations. Summer snowmelt is reinforced by rain from frontal storm systems and local convective storms. Runoff begins to increase in April or May and usually peaks in June to early July, when approximately 45 per cent of the runoff occurs. Mean annual temperatures range from 4.7 to 5.2°C (Environment Canada 2013).

3.3 Reservoir Operations

Kinbasket Reservoir was created in 1975 following the construction of Mica Dam. Located 135 km north of Revelstoke, the dam consists of an earthfill dam, low-level outlets, and a chute spillway. The first two turbines were commissioned in 1974, and in 1977 two more were installed bringing the total capacity of the powerhouse to 1,805 MW. Another two 500 MW generators will be installed in 2014/2015 for a total generating capacity of 2,805 MW.

BC Hydro is authorized by Conditional Water Licences No. 27068 and 39432 to store a maximum of 7 MAF [2]and 5 MAF, respectively. Licence No. 27068 applies to the volume of water stored under the Columbia River Treaty and Licence No. 39432 applies to the volume of water stored under Non-Treaty Storage (NTS).

[1] These are subdivisions of the commonly recognized Columbia and Canoe Reaches.

[2] MAF = million acre-feet.

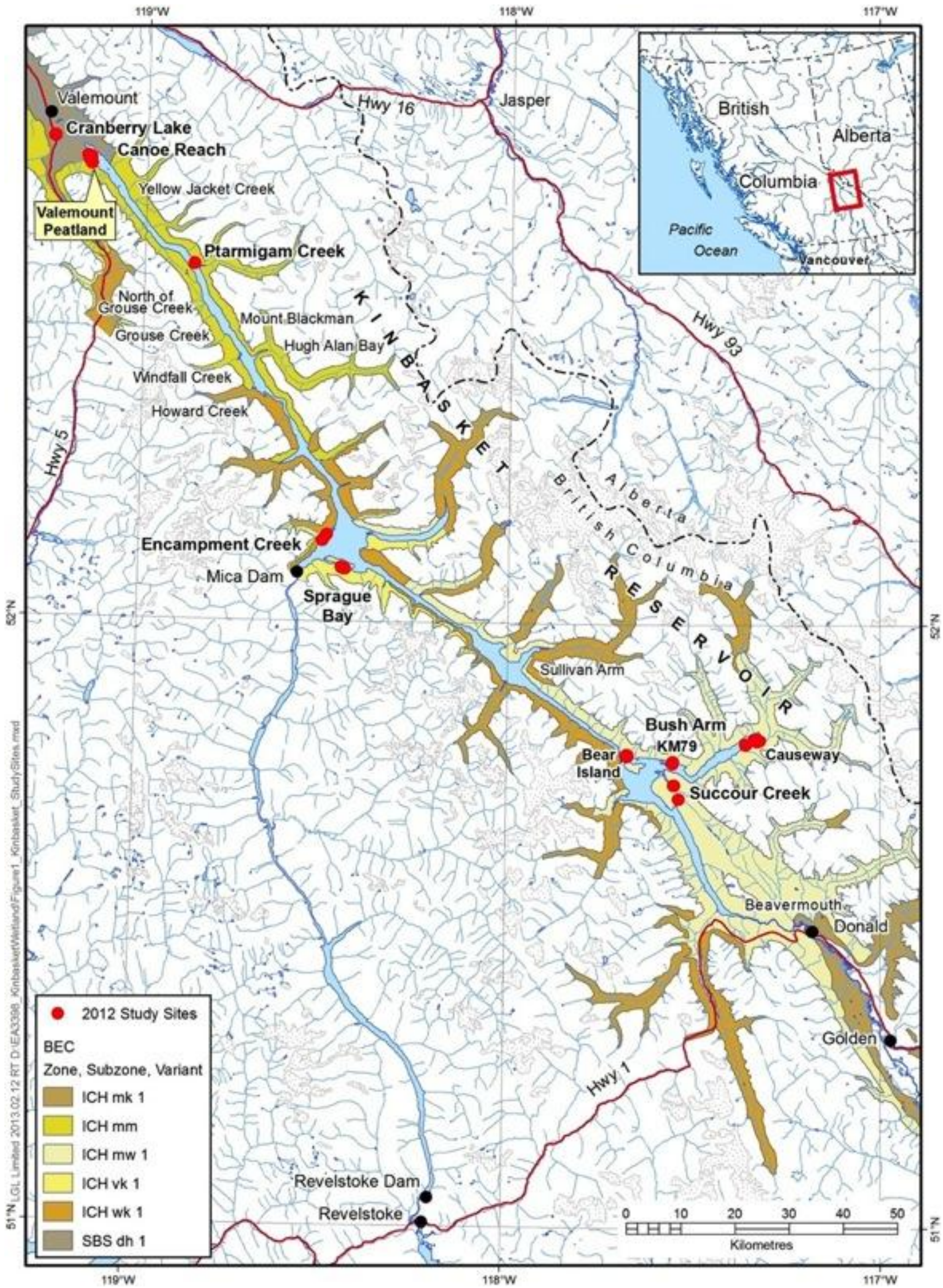

Figure 3-1: Location of CLBMON-61 sampling locations in 2012. Red markers indicate the location of sampling sites.

The normal operating range of the reservoir is between elevations 707.0 m ASL (2319.42 ft) and 754.4 m ASL (2475.0 ft); however, applications may be made to the Comptroller of Water Rights for additional storage for environmental or other purposes if there exists a high probability of spill.

3.4 Biogeography

The reservoir is located predominately within the Interior Cedar-Hemlock (ICH) biogeoclimatic (BEC) zone and is represented by four subzone/variants (Table 3-1). The ICH occurs along the valley bottoms and is typified by cool, wet winters and warm dry winters. A small portion of the reservoir extends into the Sub-Boreal Spruce (SBS) BEC zone near Valemount. The climate of the SBS is continental, and is characterized by seasonal extremes of temperature; severe, snowy winters; relatively warm, moist, and short summers; and moderate annual precipitation (Braumandl an Curran 2002).

The southern end of the reservoir includes Bush Arm and the Beaver Mouth. The Bush Arm extends east from the Columbia River into the Central Park Ranges of the Canadian Rockies (Figure 3-1). Bush Arm is characterized by an abundance of habitats on flat or gently sloping terrain that was created by sedimentation from Bush River and other inflowing streams. Another feature of these habitats is their protection from wind and wave action by the islands and peninsulae that protrude along the shoreline. This combination creates the largest variety of valuable wildlife habitat in the reservoir. Extensive fens and other wetlands have been identified that support diverse plant communities (Hawkes et al. 2007).

Canoe Reach lies in the Rocky Mountain Trench between the Rocky Mountains and the Monashees (Figure 3-1). An extensive wetland complex at the northern end of the reservoir (known as the Valemount Peatland) supports the greatest diversity and abundance of wildlife in Canoe Reach. Historically, the Valemount Peatland was likely a combination of sedge and horsetail fen and a swampy forest dominated by spruce (Ham and Menezes 2008, Yazvenko 2008a, pers. obs.). The wildlife habitat in the peatland varies from highly productive riparian and wetland habitat to highly degraded sites. Large areas are devoid of vegetation and are covered by wood debris and a mass of wood fragments that are the result of the breakdown and decay of floating logs (Hawkes et al. 2007).

The third geographical area of interest is Mica Arm, which lies between the northern terminus of the Selkirk Mountains and the eastern slopes of the Northern Monashees. High quality wildlife habitats occur in Mica Arm at Sprague Bay and Encampment Creek. Sprague Bay is located on the south shore of Mica Arm in the Selkirk Mountains and Encampment Creek is located on the north shore of Mica Arm in the Monashees (Figure 3-1).

Table 3-1: Biogeoclimatic Zones, subzones and variants occurring in the Kinbasket Reservoir study area (Braumandl and Curran 2002)

BEC Code	Zone Name	Subzone & Variant	Subzone/Variant Description	Forest Region & District
ICHmm	Interior Cedar–Hemlock	mm	Moist Mild	Prince George (Robson Valley Forest District)
ICHwk1	Interior Cedar–Hemlock	wk1	Wells Gray Wet Cool	Prince George (Robson Valley Forest District) and Nelson Forest Region (Columbia Forest District)
ICHmw1	Interior Cedar–Hemlock	mw1	Golden Moist Warm	Nelson Forest Region (Columbia Forest District)
ICHvk1*	Interior Cedar–Hemlock	vk1	Mica Very Wet Cool	Nelson Forest Region (Columbia Forest District)
ICHmk1*	Interior Cedar–Hemlock	Mk1	Kootenay Moist Cool	Nelson Forest Region (Columbia Forest District)
SBSdh1	Sub-Boreal Spruce	dh1	McLennan Dry Hot	Prince George (Robson Valley Forest District)

4.0 METHODS

4.1 Definitions

Definitions are provided to ensure that the terminology used in this report is understood. The definitions are presented in logical, not alphabetical, order.

Wetland – “land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation and various kinds of biological activity which are adapted to a wet environment” (National Wetlands Working Group 1988).

For this study, we distinguish between two types of wetlands that do not occur under the BC or Canadian wetland classification systems (Table 4-1):

1) Terrestrial wetland – includes the bog, fen, swamp, or marsh wetland classes as defined under the Canadian Wetland Classification Scheme (National Wetlands Working Group 1988) and MacKenzie and Moran (2004).

2) Aquatic wetland – Aquatic wetlands are permanently flooded “shallow-water” wetlands that are dominated by rooted, submerged and floating aquatic plants (Moran and MacKenzie 2004). These communities typically occur in standing water less than 2 m deep and are associated with permanent still or slow-moving water bodies such as ponds, shallows lake or lake margins. The term pond is used interchangeably with aquatic wetland.

Pond – used interchangeably with aquatic wetland and includes shallow lakes (< 2m deep).

Reach – Seven reaches within Kinbasket Reservoir are recognized: Canoe Reach, Mica Arm, Wood Arm, Sullivan Arm, Kinbasket Reach, Beaver Mouth, and Bush Arm. Canoe Reach, Mica Arm, and Bush Arm are the focus of this study.

Position – refers to whether a wetland, site, or transect is located within the footprint of Kinbasket Reservoir (elevation ≤ 754.4 m ASL) or outside/above (> 754.4 m ASL).

Site The term “site” applies to either an aquatic wetland (such as discrete pond) or a terrestrial vegetation community within a discrete elevation band.

Target Site/Target Wetland – wetlands or sites within the 753 to 754 m ASL elevation band (Figure 4-1).

Control Site – (not to be confused with a BACI "Control") wetlands within the reservoir but not within the 753 to 754 m ASL elevation band. In terrestrial wetlands control sites are located in either the 752 to 753 or 754 to 755 m ASL elevation bands.

Upper Control – wetlands within the 754 to 755 m ASL elevation band.

Lower Control – wetlands within the 752 to 753 m ASL elevation band.

Reference Site/Reference Wetland – wetlands above 755 m ASL.

Table 4-1: The relationship between the CLBMON-61 wetland type and the Canadian and BC wetland classification systems (National Wetlands Working Group 1988; MacKenzie and Moran 2004).

CLBMON 61 Wetland Type	NWWG Site Class	BC Wetland Associations*	Environmental Characteristics	Vegetation Types
Terrestrial Wetland	Bog	Wb associations (e.g., Wb01)	Ombrotrophic pH < 5.5 > 40 cm fibric/mesic peat	Sphagnum mosses, ericaceous shrubs, and conifers
	Fen	Wf associations (e.g., Wf01)	Groundwater-fed pH > 5.0 > 40 cm fibric/mesic peat	Deciduous shrubs, sedges, and brown mosses
	Swamp	Ws associations (e.g., Wb01)	Mineral soils or well-humified peat Temporary shallow flooding (0.1–1.0 m) Significant water flow	Conifers, willows, alders, forbs, grasses, leafy mosses
	Marsh	Wm associations (e.g., Wb51)	Mineral soils or well-humified peat Protracted shallow flooding (0.1–2.0 m)	Large emergent sedge, grass, forb, or horsetail species
Aquatic Wetlands (ponds)	Shallow Waters	Various descriptions	Permanent deep flooding (0.5–2 m)	Floating and submerged macrophytes; emergent vegetation < 10% cover

***MacKenzie and Moran (2004)**

Figure 4-1: Sampling strata of an index monitoring site showing target, control, and reference elevation bands

Index Site – wetlands to be monitored under CLBMON-61 including wetlands within the drawdown zone that will be impacted by reservoir activity as well as reference wetlands. For aquatic wetlands, an index site will be a discrete pond. For terrestrial wetlands, an index site will include the control, target and reference elevation bands.

Vegetation Communities – plant assemblages characterized by similar species composition and per cent cover. Vegetation communities are delineated into vegetation polygons. Includes definition of dominant species.

Transect – sampling unit for sampling terrestrial wetlands.

Sample stations – Sampling location within aquatic wetlands/ponds.

Wetland integrity – To have integrity, a wetland should be relatively unimpaired across a range of characteristics and spatial and temporal scales. Ecological integrity can also be defined as the "structure, composition, and function of an ecosystem as compared to reference ecosystems operating within the bounds of natural or historic disturbance regimes" (Faber-Langendoen et al 2008).

Wetland composition – The relative abundance of different flora and fauna species that characterize the structure of the biological community of a wetland. Composition can be expressed as per cent cover, per cent biomass, or the relative abundance (per cent) of species.

Wetland productivity – Primary productivity is the capture and storage of solar energy by autotrophic plants via photosynthesis. Secondary productivity involves the transfer and storage of primary production to higher trophic levels (e.g., heterotrophs). For the purposes of CLBMON-61, we use vegetative biomass as a measure of primary productivity and the diversity and abundance of aquatic macroinvertebrates as a measure of secondary productivity. Adapted from Sala and Austin (2000).

BACI (Before-After-Control-Impact) – A repeated measures study design with spatial replication of treatment and control sites and temporal replication with measurements before and after a treatment application or impact. Under CLBMON-61, “target” sites can be thought of as “treatment sites” for the purposed of the BACI study design.

Control (BACI) – A “control” under a BACI study is a spatial replicate of a treatment (target) site.

4.2 Approach

Potential ecological impacts resulting from changes in reservoir operations associated with the installation of Mica Units 5 and 6 include: 1) changes to water physicochemistry; 2) changes in patterns of erosion; 3) physical impacts to vegetation, 4) changes in wetland soils or sediment; 5) changes to wetland productivity and integrity, 6) changes to vegetation abundance, diversity, community composition, and structure, and 7) changes in patterns of wildlife use. As prescribed by BC Hydro (BC Hydro 2012), these impacts are to be assessed using a Before-After-Control-Impact (BACI) design with two years of pre-impact sampling in 2012 and 2013 and three years post- impact sampling in 2015, 2016, and 2017. The study will employ a repeated measures model to compare community composition, primary productivity, secondary productivity, and physiochemical parameters collected over the study period. Comparisons will be made across “target”, “control”, and “reference” sites (see definitions Section 4.1). The study is divided into two stages: a review stage to identify potential index sites, and a field stage consisting of ground truthing and monitoring.

The focus for Year 1 (2012) was to select and characterize wetlands, initiate baseline monitoring, and describe and refine the study design.

The focus of work in Year 2 (2013) will be to summarize the productivity and composition of the index sites sampled in both years, with an emphasis on key findings. The summary will provide preliminary insight into expected changes associated with wetland composition and productivity, discuss the relative importance of the independent variables being studied to those changes, and discuss the effect size and current trends of the data collected.

Years 3 and 4 of CLBMON-61 will report on general trends, while Year 5 (2017) will fully address each of the management objectives, questions and hypotheses. The analyses in Year 5 will focus on identifying differences in key metrics between the before and after study periods as they relate to operational changes, independently of environmental drivers. A summary of tasks associated with CLBMON-61 is provided in Figure 4-2.

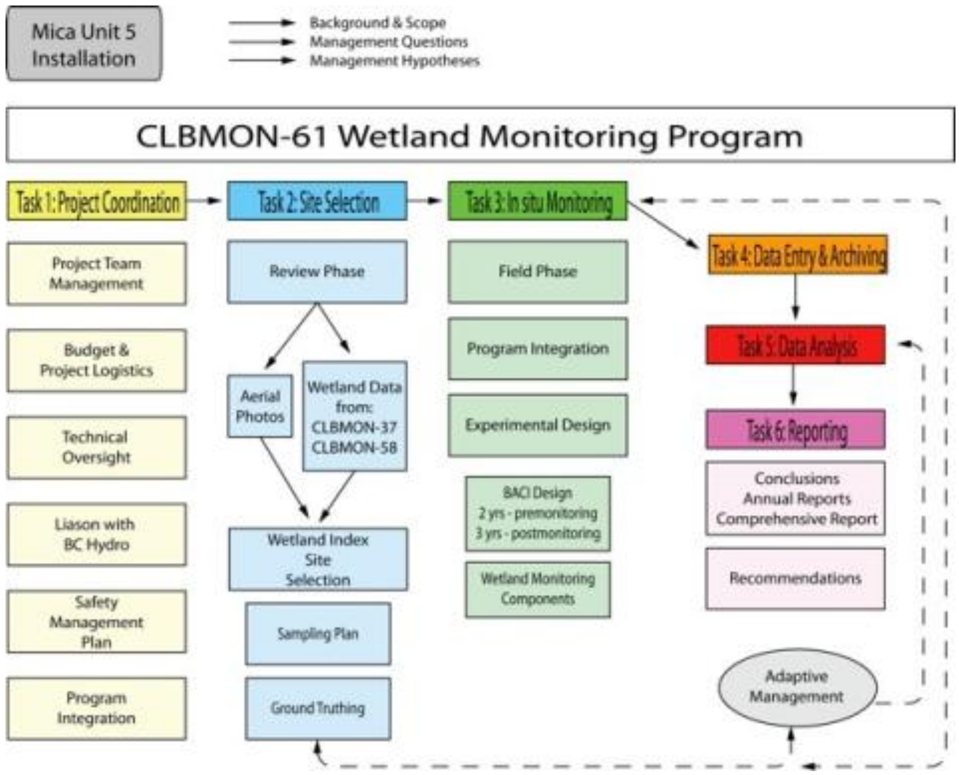

Figure 4-2: Conceptual diagram of LGL's proposed approach to the six tasks associated with the scope of CLBMON-61

4.3 Year 1 Objectives

The primary objectives in Year 1 of CLBMON-61 were to :

a) provide a general description of Kinbasket Reservoir wetlands ecosystems affected by the predicted changes in elevation;

b) describe and justify the methods used to select index sites for monitoring; and,

c) review the study approach and methods (both field and analytical) to ensure they are appropriate for addressing the management questions and hypotheses.

A suite of parameters was sampled in 2012 to characterize wetlands in Kinbasket Reservoir and to collect baseline data (Appendix 9.1). The relationship between the data collected and the general study design is provided in Figure 4-3.

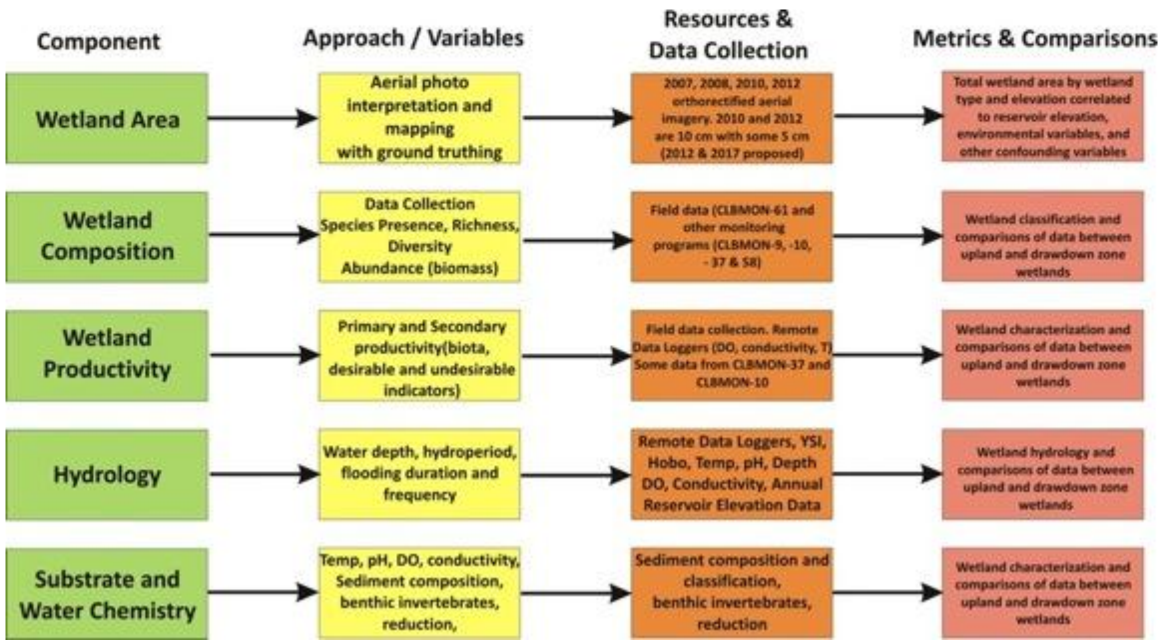

Figure 4-3: Relationship between data collected and overall study design

4.4 Site Selection

The site selection phase of CLBMON-61 (Figure 4-2) was divided into two components. A desktop review of aerial photographs and existing BC Hydro WLR data (e.g., CLBMON-09, CLBMON-10, and CLBMON37) was completed to identify potential sampling sites; it was followed by a field phase to ground truth the sites. Although site selection phase was broken into two components, the process was iterative.

4.4.1 Desktop Review

Literature Review and Data Mining

A literature review was completed for CLBMON-61 prior to the initiation of the first year of study. Information was gathered and reviewed from a number of sources including the University of Victoria Library Databases, Ministry of Environment (MOE), Canadian Wildlife Service (CWS), the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP), and other Water License Requirements projects. This information has been incorporated into this report.

Review of Spatial Data

A desktop review was undertaken using 1:5,000 orthorectified imagery (orthoimagery) from 2010 and 2008, 1:15,000 B&W orthoimagery from 2002, Google Earth™, Bing™, CLBMON10 data, and CLBMON37/58 pond delineation mapping. The GIS layer of 93 shallow water ponds developed for CLBMON-37/58 (Hawkes and Tuttle 2012) was used to identify most of the aquatic wetlands for sampling. This layer of pond features was created in 2010 using a combination of sub-metre GPS data and manually delineated polygons from 10 cm pixel digital orthoimagery. Aquatic wetlands were identified using GIS by overlaying the digital elevation model (DEM) on the existing pond layer and orthoimagery to locate wetlands in the focal elevation bands (752–753 m, 753–754 m, 754–755 m). Aquatic wetlands outside the reservoir were identified using

Bing™ and Google Earth™ imagery

The terrestrial wetland sites were selected with the aid of the CLBMON-10 vegetation community polygons. Using GIS, we constrained the vegetation community layer using the five-wetland community types described under CLBMON-10 (Table 4-2). The digital elevation model (DEM) was then used to select potential index sites spanning the focal elevation bands. Where coverage existed, the orthoimagery was used to identify reference wetlands (aquatic and terrestrial) adjacent to the reservoir. Bing™ and Google Earth™ imagery was used where orthoimagery was not available. Despite the size of Kinbasket Reservoir the process of selecting sites was performed manually. Although the reservoir is large (42,650 ha), most of the shoreline is too steep for wetlands to occur; therefore, identifying the sites manually in GIS was manageable. After wetlands were identified, they were prioritized for sampling in 2012 based on their elevation, representativeness, access, and distance to reference sites.

Table 4-2. Wetland plant communities of Kinbasket Reservoir as defined under CLBMON-10 (Hawkes et al 2007)

Code	Common Name	Scientific Name	Drainage	Description
LL	Lady's thumb-Lamb's quarter	*Polygonum persicaria-Chenopodium album*	Imperfect to moderately well	lowest vegetated elevations
BS	Buckbean - Slender Sedge	*Menyanthes trifoliata-Carex lasiocarpa-Scirpus atrocinctus / microcarpus*	very poor to poor	wetland association
WB	Wool-grass - Pennsylvania Buttercup	*Scirpus atrocinctus-Ranunculus pensylvanicus*	imperfectly to poor	wetland association
SH	Swamp Horsetail	*Equisetum variegatum, E. fluviatile, E. palustre*	poor	wetland association
WS	Willow - Sedge wetland	*Salix - Carex* species	very poor to poor	wetland association

4.4.2 Field Assessment

Field assessments were conducted to ensure the study wetlands occur within the elevation range of interest and they are representative of wetlands found within the reservoir. For efficiency and to ensure integration across the pertinent WLR studies, field assessments were coordinated with sampling for CLBMON-37 and CLBMON-10. The assessments were conducted over April 26 to May 3 (Canoe Reach), May 15 to 18 (Bush Arm), and Sprague Bay (June 25 to 27).

4.5 Terrestrial Wetland Monitoring

4.5.1 Terrestrial Wetland Sampling

Following the approach of Hawkes et al. (2007, 2010, and 2012), a modified belt-line transect quadrat method was used to sample terrestrial wetland communities both within and above the reservoir. The location of the transects were established a priori using GIS and a pair of sampling transects was positioned in each elevation band. An example of this layout is shown in (Figure 4-4).

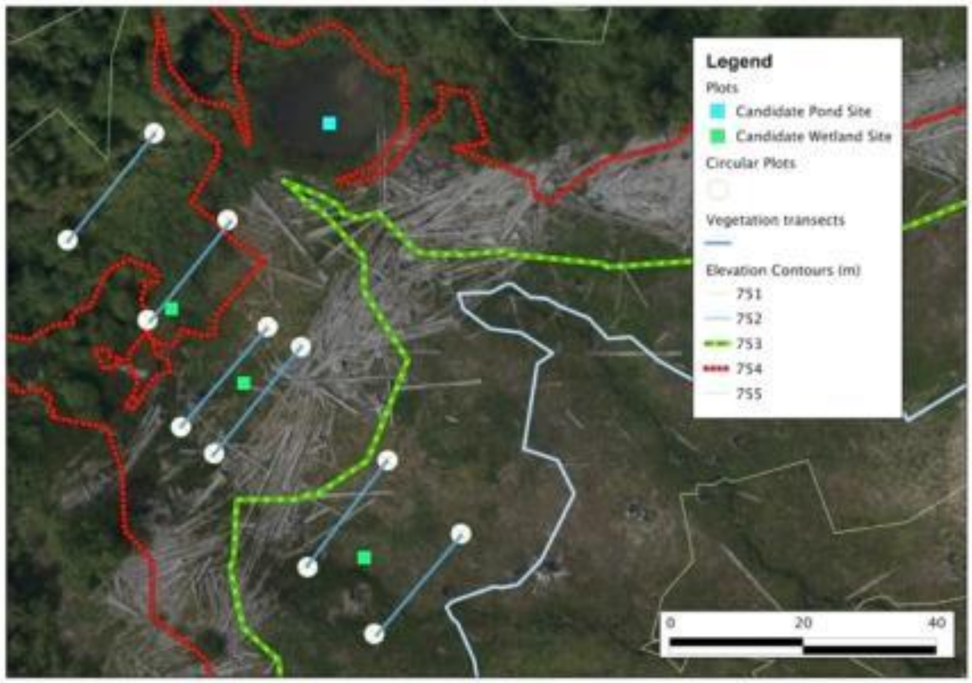

Figure 4-4: Layout of paired 20-meter vegetation transects in Kinbasket Reservoir across three elevation bands (752-753 m, 753-754 m, 754-755 m). A similar pair of transects was established for reference sites outside the reservoir (not shown)

Each belt transect was 20 m long and was sampled along the entire length using ten 2 m X 0.5 m quadrats (Figure 4-5). To better assess forest and shrub cover, at each transect end a circular 100 m^2 plot was established using a tape measure, and the cover of woody species within the circular plots was visually estimated (Figure 4-5). The location of each transect endpoint (0 m and 20 m) was georeferenced using a Garmin GPSmap 60cx handheld GPS unit. Rebar was pounded into the ground at the transect endpoints.

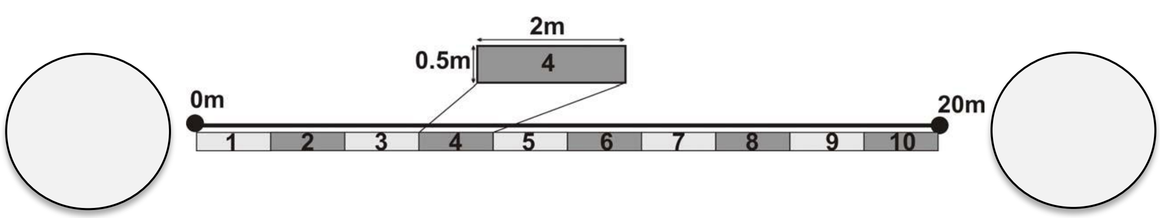

Figure 4-5: Schematic of the belt-line transect quadrat method and 100m^2 circular plots (5.64 m radius) used to sample wetland communities in Kinbasket reservoir. Note: not drawn to scale

Data collection was based on the FS882 (3) Vegetation Form (RISC 2010). Vegetation within each quadrat was identified to species, or in some cases, to genus, and the per cent cover to the nearest 5 per cent was visually estimated. The total cover of each non-woody species was averaged across the ten quadrats to derive a mean per cent cover for each species along each transect. For woody species, total cover was averaged across 12 quadrats (where each circular plot was treated as one additional, larger quadrat). Cover estimates were stratified by the following vegetation layers:

B1: Tall Shrubs (woody plants 2 m to 10 m tall)
B2: Low Shrubs (woody plants less than 2 m tall)
C: Herbs (forbs and graminoids)
D: Moss, lichen, and seedlings

The ground surface was categorized as either bare soil (mineral, sand, or fines), coarse woody debris, rock, dead organic material, live organic material, or water, and the per cent cover of each surface type recorded for each quadrat. In addition, a shallow soil sample was collected at one end of each transect using a soil auger. Samples were bagged and labeled for future nutrient analysis.

Photographs were taken along the length of each transect to provide a visual portrayal of vegetation conditions and included close-ups of plant species and general views of each transect. Photos taken of the same vegetation communities over time will provide visual evidence of vegetation and soil changes. The file numbers of all photos of a particular transect were recorded on the data forms. A sample data form is provided in Appendix 9.2.

Site access occurred via truck and walk-ins or via boat. Sampling occurred during three field sessions: 12–19 June, 17–22 July, and 21 August 2012. In 2012, the reservoir filled more rapidly than previous years, limiting the number of wetlands that could be sampled, particularly in the 752 to 754 m ASL range. We succeeded in sampling at 15 sites across a total of seven wetland complexes in Bush Arm, Canoe Reach, and Encampment Creek. Maps of all sites sampled are provided in Appendix 9.3..

4.5.2 Wetland Classification

Wetlands were initially classified following the classification developed under CLBMON-10 (Hawkes et al. 2007, and 2010). Five communities described under CLBMON-10 were identified as having the characteristics of wetland associations (Table 4-2). One of the identified communities (the Buckbean-Slender Sedge association) shared close similarities with an existing vegetation type described in Mackenzie and Moran (2004), but others had not been previously described (Hawkes *et al.* 2007). For reference terrestrial wetlands, we followed the site series approach of MacKenzie and Moran (2004), where possible. We could find, as our knowledge base of terrestrial wetlands increases with further study, that one or both of these classification systems is inappropriate for the study. In that case a new and novel system of wetland classification will be developed specifically for this project.

4.6 Aquatic Wetland Monitoring

Aquatic wetlands (ponds) were sampled over the periods of July 7 to July 11 (Canoe Reach), July 13 to July 14 (Mica Arm), July 16 to July 25 (Bush Arm), and August 21 to August 23, 2012 (Bush Arm). Sites were accessed via truck (e.g., Bush Arm; Valemount Peatland, Ptarmigan Creek; Sprague Bay) or by boat (Bush Arm, Encampment Creek). Sampling within ponds was performed using a small 2.5 m inflatable boat. Relatively light in weight (36 kg), the boat was easy to transport for two people and provided a stable and safe platform for sampling.

At a minimum, three sampling stations were established in each pond. In small ponds less than 0.5 ha, sample stations were typically established along a transect that bisected the wetland; in mid-sized ponds (<0.5 to 2.0 hectare), stations were established long two transects that ran parallel to the shoreline; and in large ponds (>2.0 ha) stations were established in representative habitats (Figure **4-6**). Due the variation in the size of wetlands sampled, distance between sample stations varied from 5 m to 400 m. A sample data sheet is provided in Appendix 9.2.

4.6.1 Physical Characteristics

Wetland area, hydrology, and chemistry are essential data for assessing changes in wetland integrity and provide valuable information for interpreting biological data, verifying wetland classification, and diagnosing potential stressors (Finlayson 1999; US EPA 2008, Mitsch and Gosselink 2007). Parameters monitored in 2012 included wetland area, water depth, water transparency, temperature, pH, conductivity, and dissolved oxygen.

The size of aquatic wetlands was obtained either from the 2010 digital orthoimagery, Google Earth, or from GPS. GPS data were collected in field or previously under CLBMON-37 using a handheld GPS (Garmin GPS Map 60CSx and SXBlue II). For complex wetlands with floating vegetation mats (e.g., Sprague Bay, km79 reference wetland), wetland size was obtained for open water areas and floating mats were mapped as a terrestrial wetland community.

At each station, depths were measured using a weighted tape measure and recorded to the nearest centimeter. Water transparency was recorded as Secchi depth (cm); however, due to the shallow depth (<2 m) at most stations Secchi depths simply reflected the depth of the pond and did not provide a measure of water transparency. In future years, it is recommended that a transparency tube be used, as they are less likely to be influenced by water depth (Dahlgren et al 2004).

Where possible, organic muck depth was estimated by pushing a D-net handle into the sediment as a probe until met with stiff resistance. In deeper water often it was not possible to obtain these measurements as the combined muck and water depth exceeded the length of our probe (2.75 m). The presence of wood debris in benthic substrate was determined by probing the surface of the substrate and recording whether the probe struck wood. Four wood probes were taken at each station at each corner of the boat. Additional sediment information was also obtained from a Ponar grabs (see Section 4.6.6) including texture, colour, and sediment type: muck (OM), wood (LWD), coarse organic matter (CO), or mineral sediment (MS).

Wetland forming processes were noted either as depressional basin, beaver dam, or anthropogenic excavation. Where multiple processes were apparent, they were designated as either primary or secondary based on the influence of the hydrogeomorphic processes.

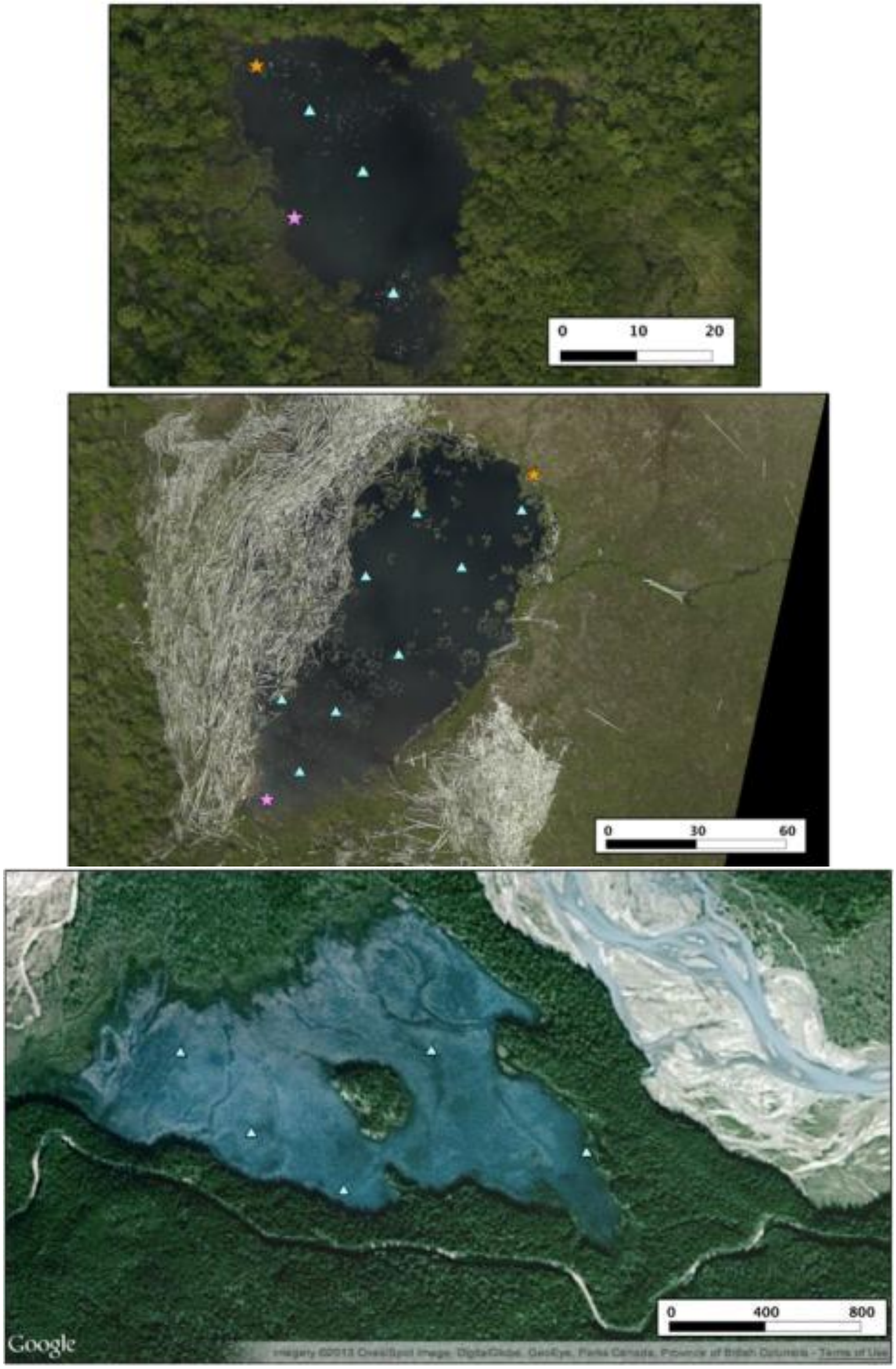

Figure 4-6: **Examples of sampling configurations for aquatic wetlands of various sizes (Pond P03 above, 0.08 ha; Pond P05 middle, 0.8 ha, and Pond P18 lower: 6.9 ha).** Distances between sample locations varied with wetland size and ranged from 20 to 500 meters. Stars indicate the location of dataloggers

Photographs were taken of each wetland community sampled. Where feasible photos were taken from the north, south, east, and west shoreline of the wetland; however, some ponds were too large or too irregular in shape to be photographed this way. Photographs were catalogued by project name and date, and can be easily cross-referenced back to our field forms and the project data for retrospective inspection.

4.6.2 Water Physicochemistry

Point samples of water temperature, dissolved oxygen, conductivity, and pH were recorded at depths of 10 cm and 30 cm below the surface of the water. Water temperatures, dissolved oxygen, and conductivity measurements were obtained using a YSI model 85 digital multi-parameter meter. pH was obtained using an Oakton 35423-10 EcoTestr pH2.

Nine conductivity (Onset U24-001) and five dissolved oxygen (PME MiniDOT) dataloggers were installed in select wetlands to collect continuous data. The dataloggers were installed between 37 cm and 50 cm below the waters surface in depths of 65 to 80 cm. The units were affixed to ¾" rebar (125 cm in length) using a pipe clamp and the rebar was fitted with an orange plastic safety cap for easy relocation (Figure 4-7). The dataloggers were factory programmed to record data every 10 minutes. They were retrieved from the field between Oct. 18 and Oct. 21, 2012 and data was downloaded using the manufacture's software (Onset Hoboware and PME miniDOT software). Data collected from the dataloggers spanned 31 to 129 days. Unfortunately, due to a firmware bug in the PME MiniDOT dataloggers, four of the five units failed prematurely after 31 to 41 days of operation. Although the manufacturer has since replaced the units, in future years quality assurance testing should be performed on the dataloggers before deploying them in the field. For quality assurance, we compared the values obtained from the dataloggers to the point sample data acquired simultaneously.

Figure 4-7: Image showing a dissolved oxygen and conductivity datalogger assembly installed in Kinbasket Reservoir

Temperature was also monitored at 14 sites by temperature dataloggers (Onset

Tidbit UTBI-001) installed for CLBMON-58 in May and June of 2011. A list of all dataloggers deployed in Kinbasket Reservoir by LGL Limited is provided in Appendix 9.4.

4.6.3 Macrophyte Sampling

Aquatic wetland plants occur in three growth forms (emergent, floating, and submergent) making it impossible to sample them using a single technique. Consequently, two sampling methods were employed.

Submergent Communities

Submergent plant communities were sampled using a macrophyte grapnel. Although imperfect, this method provides a practical and efficient way to sample submerged aquatic vegetation without requiring SCUBA (Schaumburg 2004; Alberta Environment 2006; Hawkes et al. 2011; Yin and Kreiling 2011). The grapnel was constructed from two garden rakes fastened together with the rake tines facing in opposite directions. With a 5-m rope attached, the grapnel was tossed 1.5 m from the boat and was allowed to settle on the bottom of the pond. Once on the bottom, the grapnel was dragged for ~1 m capturing submergent vegetation within the tines of the rakes. Upon hauling the grapnel into the boat, overall vegetation abundance was estimated in per cent cover based on amount of vegetation that passed across the plane of the rake tines. The relative abundance of each species was determined by sorting through the vegetation and estimating its contribution to the total amount collected. At each sample station, two samples were collected, one on each side of the boat. Samples were bagged and labeled separately for biomass estimate (Section 4.6.5).

Floating and Emergent Communities

Floating and emergent communities were sampled using a 0.50 cm x 2 m quadrat along the edge of the boat. The overall percent cover of vegetation occurring within the transect was recorded along with the individual cover of each species and growth form: floating, emergent, and submerged.

Taxonomies used in the identification of aquatic wetland plant species included:

- George W. Douglas, Del Meidinger and Jim Pojar. 1998-2002. Illustrated Flora of British Columbia.
- Brayshaw, T. C. 2000. Pondweeds, bur-reeds and their relatives of British Columbia: aquatic families of monocotyledons. Royal British Columbia Museum.
- Johnson, D., L. Kershaw, A. MacKinnon, and J. Pojar. 1995. Plants of the western boreal forest and aspen parkland. Lone Pine Publishing, Edmonton, Alta.

4.6.4 Macrophyte Community Classification

At each sampling station, macrophyte communities were typed using the grapnel and visual quadrat data and the classifications of Mackenzie and Moran (2004) and Pierce and Jensen (2001) [3]. The Wetland and Riparian Ecological

[3] The CLBMON-10 classification (Hawkes et al 2007 and 2010) could not be used as it does

Classification (WREC) of Mackenzie and Moran (2004) is a hierarchical system based on the provincial Biogeoclimatic Ecosystem Classification (Pojar et al. 1987) and the Canadian Wetland Classification System (CWCS; Warner and Rubec 1997). The WREC nests the Site Series and Site Association units of the BEC under "Wetland Class" of the Canadian Wetland Classification System, creating a single hierarchal framework. While this framework integrates well with the existing provincial and national systems, the emphasis of the WREC classification is on terrestrial wetlands: bogs, fens, marshes, swamps, estuaries, and flood associations. Mackenzie and Moran (2004) provide only a preliminary description of shallow water communities (aquatic wetlands) based on "local classifications, descriptive accounts, and observations", and communities had to be typed prudently using the WREC system.

The Pierce and Jensen (2001) system is a hierarchical, floristic classification based on macrophyte foliar cover data collected in natural and man-made water bodies in northern Idaho and northwestern Montana. Although this classification provides a summary of the abiotic attributes associated with the communities, it does not include the detailed ecological community descriptions found in MacKenzie and Moran (2004) and was consequently more challenging to use. Further, Pierce and Jensen (2001) focus exclusively on aquatic plant communities; thus both classification systems were required for typing wetland communities.

4.6.5 Primary Productivity–Aquatic Macrophytes

Aquatic macrophyte biomass was collected as an index of primary productivity. Samples were obtained using the macrophyte grapnel as described in Section 4.6.3 and samples were stored in an ice cooler until the end of the field day when they were then transferred to a refrigerator. In the lab, the samples were dried at 75 °C for 72 hours. Dry weight (g) of each sample was obtained from a digital balance.

4.6.6 Secondary Productivity–Macroinvertebrates

Benthic and pelagic invertebrates were sampled at each station as an index of secondary productivity.

Pelagic sampling

Zooplankton were sampled using a fine-meshed aquarium net following the methodology outlined in Fenneman and Hawkes (2012). At each sampling point, ten 1 m sweeps were performed at a depth of ~20-30 cm, five on each side of the boat. Samples were pooled into a single Whirl-Pak bag and preserved in 85 per cent ethanol.

Benthic sampling

Benthic invertebrates were sampled using a 2.4 L Ponar benthic grab. At each station, the Ponar was dropped to the bottom of the pond to obtain a sample of the upper substrate. The characteristics of this sample (substrate type, texture,

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include aquatic communities.

and colour) were recorded and a 500 ml sample of benthic material was obtained from the Ponar after straining the substrate using a 500 micron nytrex mesh. The samples were preserved in 85 per cent ethanol for laboratory analysis.

4.7 Laboratory Methods

4.7.1 Pelagic Macroinvertebrates

All samples were kept cool to reduce the chance of specimen deterioration. The samples were removed from the Whirl-Pak® sample bags and strained through 400 µm mesh to remove detritus (e.g., sticks, leaves, vegetation). Detritus and mesh were thoroughly washed with water and inspected under a VanGuard Model 1200-ZDPC-2 dissecting microscope for remaining invertebrates. A 1 ml sample was placed in a Petri dish under the microscope and individuals were counted as they were removed. In some instances the number of invertebrates was estimated due to the relatively large numbers in the sample. Damaged individuals were counted only if identification to taxonomic group was certain. To avoid double counting, only individuals with heads attached were included in the tally unless the taxon was unique to the sample.

Invertebrates were sorted to the lowest practical taxonomic group (Order, Family) and life stage was recorded. Digital and hard copy taxonomic guides were used to sort taxa (see below).

- Aquatic Invertebrates of Alberta. Hugh F. Clifford. http://sunsite.ualberta.ca/Projects/Aquatic_Invertebrates/index.php
- Cavanagh, N., R.N. Nordin, L.W. Pommen, and L.G. Swain. 1998a. Guidelines for designing and implementing a water quality monitoring program in British Columbia. BC Ministry of Environment, Lands and Parks. Resources Information Benthic Invertebrate Sampling Guidelines Ministry of Environment 22 Standards Committee, Victoria BC. 80p. http://srmwww.gov.bc.ca/risc/pubs/aquatic/design/index.htm
- Digital Key to Aquatic Insects of North Dakota. Valley Sate University Macro-Invertebrate Lab. http://www.waterbugkey.vcsu.edu/orderlist.htm
- Flash Cards of Common Freshwater Invertebrates of North America. The McDonald & Woodward Publishing Company, Granville, Ohio
- Key to Macroinvertebrates. Copyright © 2013 New York State Department of Environmental Conservation. http://www.dec.ny.gov/animals/35772.html
- Merritt, R.W and K.W. Cummins.1996 An Introduction to the Aquatic Insects of North America.3rd ed. Kendall Hunt. Dubuque, Iowa
- Picture Guide to the Common Aquatic “Bugs” of Saskatchewan. Prepared by Dale Parker, AquaTax Consulting, 2012. http://www.aquatax.ca/BugGuide.html

4.7.2 Benthic Macroinvertebrates

Benthic samples were stored in 85 per cent ethanol and kept cool until sampled. A 1 ml subsample of benthic sediment was extracted from the original 500 ml sample for sorting. The sorting procedure followed the procedures used for the pelagic samples. If no invertebrates were observed a second, and sometimes a third sub-sample was evaluated. As the samples evaluated did not have any observable macroinvertebrates, further sorting was ceased. Only the results of associated with the pelagic data are presented.

4.8 Data Analysis

The primary objective in 2012 was to characterize wetland communities in the upper elevations of Kinbasket Reservoir and describe baseline conditions with respect to species richness, relative abundance, occurrence, distribution, and community similarity in relation to reach and treatment. As such, analyses are largely descriptive and aim to identify differences between wetlands within the reservoir and reference sites, and across reaches.

4.8.1 Terrestrial Wetland Data

The per cent cover of all vegetation species recorded over the ten quadrats, plus two circular plots, sampled per transect were averaged to derive an estimate of total cover and per species for each transect. Hence, for this aspect of the study, the transect (not each quadrat) was used as the basic statistical unit in all analyses. General characteristics of the vegetation data sampled per transect, elevation band, and vegetation community were described with a series of tables and figures.

Plant species were classified by general growth form (e.g., perennial herb, annual herb, sedge, deciduous shrub, pteridophytes, etc.), and the relative abundances of each growth form compared across elevations and sampling strata (target wetland, lower reference, upper reference, and above drawdown reference) using box plots. Box plots show dispersion and skewness of data without making assumptions about their underlying statistical distributions. Boxes represent between 25 per cent and 75 per cent of the ranked data. The horizontal line inside the box is the median. The length of the boxes is the interquartile range. A small box indicates that most data are found around the median (small dispersion of the data). The opposite is true for a long box: the data are dispersed and not concentrated around the median. Whiskers are drawn from the top of the box to the largest observation within 1.5 interquartile range of the top, and from the bottom of the box to the smallest observation within 1.5 interquartile range of the bottom of the box.

Species richness, diversity, and evenness were assessed for each transect sampled by location and elevation. Species richness was defined as the number of species occurring along a transect. Diversity was computed as Shannon's entropy and corresponded to a measure of species composition, combining both the number of species and their relative abundances (Legendre and Legendre 1998). For each transect, diversity was computed as:

$$\mathbf{H = -\Sigma\ (pi\ log\ pi),}$$

where pi is the relative frequency or proportion (on a scale 0–1) of species observations (*i*).

A value of 0 means that the sampling unit contains only one species; H increases with the number and abundance of species recorded in the sampling unit. A high value of H means that many species were recorded. The diversity value calculated by Shannon's Entropy index (H) does not indicate how species are distributed within the transects established in each vegetation community. To determine the distribution of species by transect, vegetation community, and landscape unit, Pielou's evenness was computed (Pielou 1966):

J=H/Hmax= (-Σ (pi log pi))/ log q, where q is species richness.

The more J tends towards 1, the more evenly species are distributed throughout the community. Conversely, a value of J close to zero means that the community is dominated by a relatively small number of species (i.e., the distribution is uneven).

4.8.2 Aquatic Wetland Physicochemistry

Differences in water physicochemistry (water temperature, dissolved oxygen, pH, and conductivity) between aquatic wetlands were explored using box plots and tested using a restricted maximum likelihood mixed-effects model. This model estimates the random-effect parameters (i.e., standard deviations) averaged over the values of the fixed-effect parameters and is the preferred analytic method for nested-multi-stage sampling (Picquelle and Mier 2011). To test for differences between reference ponds and ponds within the reservoir (position), we assigned position as the fixed effect and ponds as the random effect. To test for differences in the water physicochemistry parameters among reach (Mica Arm, Canoe Reach, and Bush Arm), we assigned reach as the fixed effect and ponds as the random effect. Separate analyses were performed on the data collected at depths of 10 cm and 30 cm. These analyses were performed using JMP (2012).

Continuous dissolved oxygen, temperature, and conductivity data were plotted between mid-June to the end of August to visually assess the data for any obvious trends and to identifying any anomalies in the data. The timing of inundation was determined using daily reservoir levels recorded at Mica Dam and the elevation of each sites based on the 2002 digital elevation model provided by BC Hydro. As there are likely some inaccuracies in the digital elevation model and discrepancies between the reservoir elevation between Mica Dam and the sampling stations, the inundation dates are only an approximation. Differences in water physicochemistry immediately before and following inundation were explored using box plots and differences in individual ponds were tested using a t-test.

To assess the amount of wood debris in ponds within and above the reservoir, the frequency that wood debris was encountered by probing the bottom of the ponds was tested using a nested mixed-effects model using a binomial error-structure. Reservoir position was used as the fixed effect and ponds as the random effect. This analysis was performed in R (v. 2.15.1 R development team 2012) using the lme4 package (Bates and Maechlet 2009).

4.8.3 Aquatic Vegetation Data

Wetland communities were typed using the classification of MacKenzie and Moran (2004) and Peirce and Jensen (2001) in the field, or upon further inspection of the data. As the intent in Year 1 was to provide a general description of wetland communities using accepted criteria, no further analysis was performed on the community composition data. Community composition analyses will be performed in 2013 following more intensive vegetation sampling at the index sites.

Differences in macrophyte biomass were tested using a restricted maximum likelihood mixed-effects model as described for the water physicochemistry analysis. To test for differences across reaches, we assigned reach as the fixed effect and ponds as the random effect. To test for differences between sites situated within or outside the reservoir (position), we assigned position as the fixed effect and ponds the random effect.

4.8.4 Macroinvertebrate data

The number of aquatic macroinvertebrate taxa was assessed for each sampling location and species richness, diversity, and evenness metrics were calculated as defined above (Section 4.8.1). Differences in species richness, diversity, and evenness values were assessed using a t-test. Linear regression was used to assess the relationship between taxa and surface temperature (collected at a depth of 10 cm), in deep water (30 cm) and relative to pH. Multivariate analysis of variance (MANOVA) was used to test for the effect of habitat on relative abundance by taxon. MANOVA tests whether mean differences among groups on a combination of dependent variables are likely to have occurred by chance. In MANOVA, a new dependent variable that maximizes group differences is created from the set of dependent variables. The new dependent variable is a linear combination of measured by dependent variables, combined so as to separate the groups as much as possible (Tabachnick & Fidell, 2007).

5.0 RESULTS

5.1 Site Review

Despite the size of Kinbasket Reservoir, the amount of wetland habitat that occurs in the upper elevation bands is limited. Based on the CLBMON-10 vegetation mapping (Hawkes et al 2007; Hawkes et al 2010), 102.8 hectares of wetland-associated vegetation occurs between 751 and 755 m ASL with 34.1 hectares occurring in the target elevation band (753–754 m ASL; Table 5-1). Most wetland vegetation occurs in Bush Arm (49 per cent) or in Canoe Reach (45 per cent) but small areas of wetland vegetation occur in Mica Arm (4.6 per cent), Succour Creek (0.9 percent), and Windfall Creek (0.5 per cent). Although not extensive in area, these wetlands provide critical habitat for a suite of wetland dependent species including waterfowl, shorebirds, raptors, amphibians, reptiles, and mammals (Hawkes and Tuttle 2012; van Oort et al 2012). It should be noted that these estimates are restricted to the portions of the reservoir that have been mapped using 1:5,000 orthoimagery for vegetation monitoring (e.g., CLBMON-09, and CLBMON-10) and restoration planting (CLBWORKS-01). Wetland vegetation occurring outside the exiting vegetation mapping was not included;

however, based on an visual assessment of black and white orthoimagery from 2002 (1:15,000) and Google Earth imagery, the extent is negligible.

In total, 25 aquatic wetland and 50 terrestrial wetland sites were identified for sampling in 2012. Of the 25 aquatic wetland sites identified, seven were positioned in the target elevation band (753 to 754 m ASL), six were positioned between 748.5 to 753 m ASL, and twelve potential reference ponds were identified between 755 to 800 m ASL. Of the 50 terrestrial wetlands sites identified for sampling in 2012, 12 were positioned between 752 to 753 m ASL, 13 positioned between 753 to 753 m ASL, 11 were positioned between 745 to 755 m ASL, and 13 were reference sites between 755 to 773 m ASL.

Table 5-1. Amount (hectares) and distribution of CLBMON-10 wetland associated communities in Kinbasket Reservoir by Region (Hawkes et al 2010)

Region	Elevation Bands					
Community	751	752	753	754	755	Total (ha)
Bush Arm	**2.6**	**9.9**	**14.1**	**5.9**	**18.1**	**50.5**
Lady's thumb-Lamb's quarter			3.7		18.1	21.8
Swamp Horsetail	2.6	9.9	1.1			13.5
Willow - Sedge wetland			9.3	5.9		15.2
Canoe Reach	**31.7**		**14.3**			**46.0**
Swamp Horsetail	31.7					31.7
Willow - Sedge wetland			14.3			14.3
Sprague Bay			**4.8**			**4.8**
Willow - Sedge wetland			4.8			4.8
Succour Creek			**0.9**			**0.9**
Willow - Sedge wetland			0.9			0.9
Windfall Creek	**0.5**					**0.5**
Swamp Horsetail	0.5					0.5
Total	**34.8**	**9.9**	**34.1**	**5.9**	**18.1**	**102.8**

Field assessments were conducted as part of the site selection process over the following periods: April 26 to May 3, 2012 (Canoe Reach), May 15 to 18, 2012 (Bush Arm), and June 25 to 27 (Sprague Bay; Figure 5-1). Priority areas identified for sampling in 2012 included: the Bush River Causeway, km79, km88 in Bush Arm; Sprague Bay and Encampment Creek in Mica Arm; and the Valemount Peatland in Canoe Reach (Figure 3-1). Ptarmigan Creek and Succour Creek were identified as secondary sites for sampling.

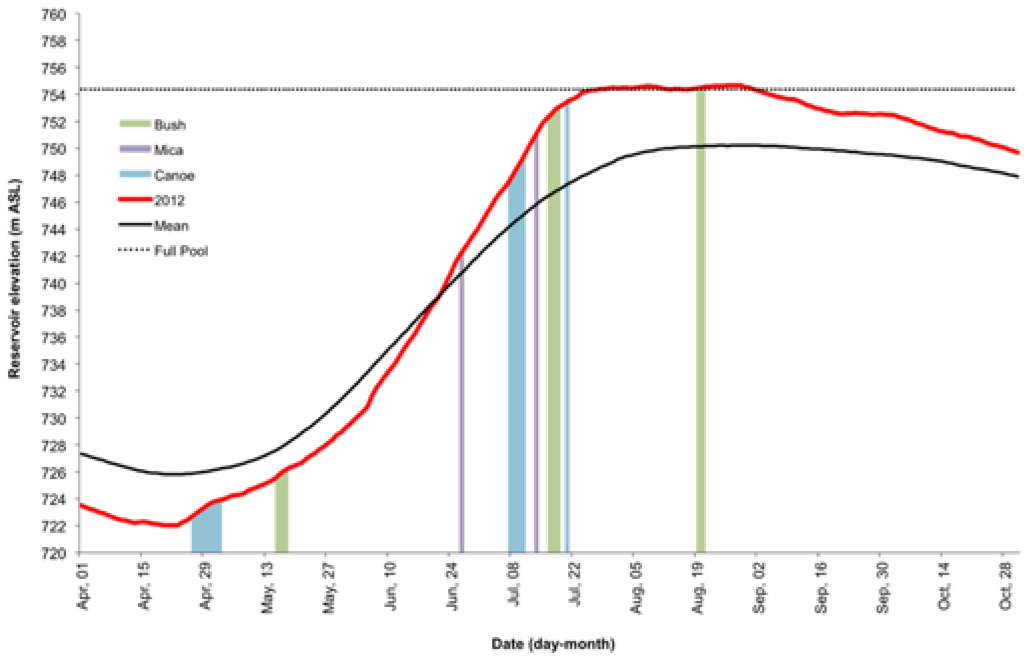

Figure 5-1: Kinbasket Reservoir elevations and the timing of field reconnaissance (April–June) and in situ monitoring (July–August) in 2012. Mean reservoir elevations were calculated from data collected between 1977 –2012.

5.2 In situ Monitoring

Sampling occurred over five periods (Figure 5-1): July 7 to July 11 (Canoe Reach), July 13 to July 14 (Mica Arm), July 16 to July 18 (Bush Arm), July 19 to 25 (Mica Arm and Canoe Reach), and August 21 to August 23 (Bush Arm). Sites were accessed via truck (e.g., Bush Arm; Valemount Peatland, Ptarmigan Creek; Sprague Bay) or by boat (Bush Arm, Encampment Creek). Due to a high snowpack and the seven month shut down of Mica Dam, Kinbasket Reservoir reached full pool on July 20, 2012 and reached a maximum elevation of 754.68 m ASL. The high reservoir levels prevented access to sampling sites within the reservoir, and, due to the closure of the causeway at Bush Arm, limited access to reference sites. Temperatures during the sampling periods were higher than the 1971 to 2000 climate norms **(**Figure 5-2**)**. The July sampling period was particularly warm with temperatures rising above 30ºC between July 7th and 14th.

Of the sites that were initially proposed for sampling, approximately 62 per cent of the ponds and 30 per cent of terrestrial wetlands were sampled. Table 5-2 provides a tally of the ponds and wetlands sampled in 2012 by reach and elevation band.

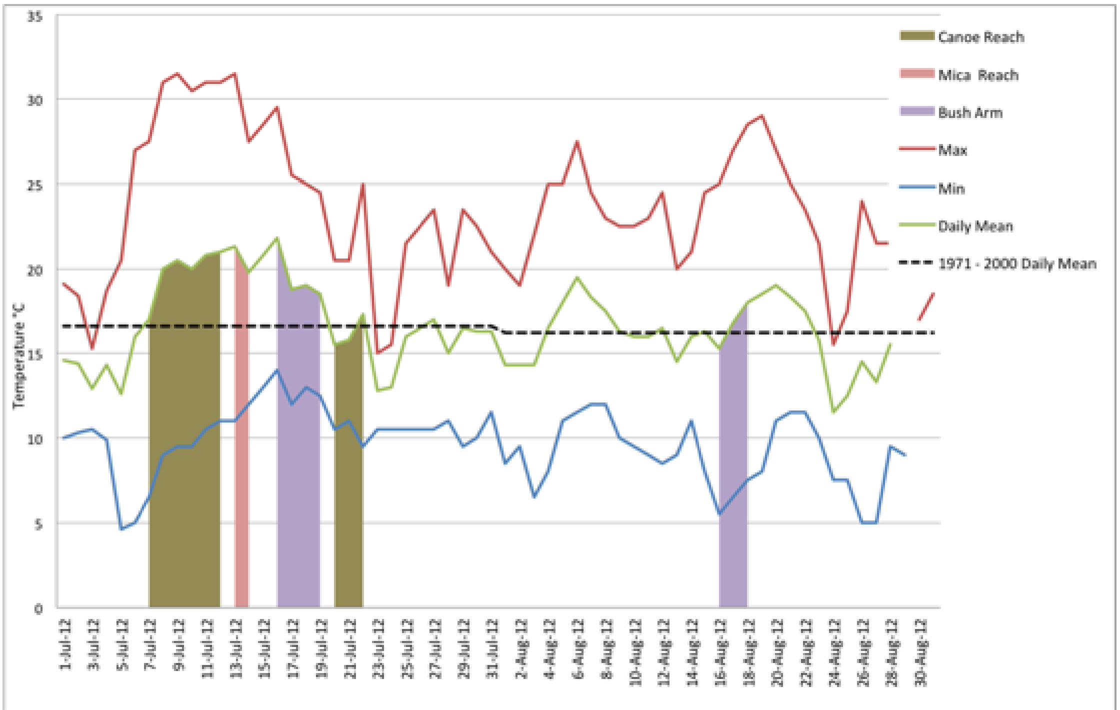

Figure 5-2: Daily minimum, mean, and maximum temperatures at Mica Creek during July and August 2012. Shading indicates the timing of sampling sessions and location

Table 5-2. Distribution of terrestrial and aquatic wetlands sampled in 2012 by reach, wetland type, and elevation band

Wetland Type/ Elevation band (m ASL)	Reach Bush	Canoe	Mica	Total
Terrestrial Wetland	**10**	**1**	**4**	**15**
Lower Control: 752-753	2			2
Target: 753-754	3		1	4
Upper Control: 754-755	2		2	4
Reference: > 755	3	1	1	5
Aquatic Wetlands	**6**	**7**	**3**	**16**
Below 753		3	1	4
Target: 753-754	2	2	1	5
Reference: > 755	4	2	1	7
Grand Total	**16**	**8**	**7**	**31**

5.3 Terrestrial Wetland Field Sampling

5.3.1 Terrestrial Wetland Classification

The unusually high reservoir levels meant that a number of pre-selected transects in the reservoir were inundated before they could be sampled. Road washouts further hampered access to some sites. Consequently, sampling of terrestrial wetland habitats within the reservoir was limited to 15 sites in Bush Arm, Canoe Reach and Encampment Creek (Table 5-2). Four target wetlands were sampled (n = 6 transects), along with two lower control wetlands (n = 2 transects) and four upper control wetlands (n = 5 transects). Another five wetlands outside the reservoir were sampled as reference sites (n = 6 transects). One high-elevation transect (transect 96) sampled as part of the CLBMON-10 program was included as an additional reference transect.

5.3.2 Terrestrial Wetland Communities

Sampling from transects in 2012 included an array of wetland associations spanning the four elevation bands. Most terrestrial wetlands were keyable to community using the classifications of Hawkes *et al*. (2007). A few "upper control" wetlands situated just above the normal operating maximum of 754.38 m ASL, and hence less affected by reservoir influences, appeared to be better captured by the classification of MacKenzie and Moran (2004) and were typed using this approach (Table 5-3).

Of the four target wetland communities sampled within the 753 to 754 m ASL elevation band, one keyed out as WS (Willow–Sedge) and two as SH (Swamp Horsetails). The community represented by a fourth transect (61.40 at Bush Arm Causeway) did not key out as an obvious wetland association. This transect, which lacked any obligate hydrophytes (i.e., close wetland affiliates) and was dominated by Slimstem Reedgrass with a significant contingent of weedy perennial grasses and forbs (e.g., Reed Canarygrass, Canada Bluegrass, Dandelion, and Clover), was assigned to the CO (Clover–Oxeye Daisy) community (Hawkes et al. 2007).

Of the two lower control transects sampled within the 752 to 753 m ASL elevation band, one was located within a BS (Buckbean–Slender Sedge) community and the other within a SH community (although the latter transect was already partially inundated at the time of sampling and could not be definitively keyed). Upper control wetlands sampled within the 754 to 755 m ASL elevation band were classified either as WS (Willow–Sedge), Fl04 (Sitka Willow–Red-osier Dogwood–Horsetail Flood), or Ws06 (Sitka Willow–Sitka Sedge Swamp) associations (Table 5-3).

The reference wetlands each represented a different Site Association (MacKenzie and Moran 2004). The reference at Km 88 was classified as Wf07 (Scrub Birch–Buckbean–Shore Sedge Fen). The Km 79 reference was transitional between Wm01 (Beaked Sedge–Water Sedge Marsh) and an upland forest. The Valemount Peatland reference was typed as Wb11 (Black Spruce–Buckbean–Peatmoss Bog). The Encampment 2 reference was typed as a Ws10 (Western Redcedar–Spruce–Skunk Cabbage Swamp), and the Succour Creek reference as a Wf01 (Water Sedge–Beaked Sedge Fen) Site Association (Table 5-3).

A description of each of these wetland types, based on Hawkes et al. (2007) and MacKenzie and Moran (2004), is provided in Appendix 9.5. Specific descriptions for each of the wetland communities sampled in 2012 are provided in Appendix 9.6.

Table 5-3. Terrestrial wetland sites, transects (with elevation in m ASL) and corresponding wetland associations sampled in Kinbasket Reservoir in 2012

Reach	Site	Transect (m ASL)	Sampling Stratum	Wetland Community Code	Wetland Descriptor	Source
Bush Arm	Km 88	61.20 (752.5)	Lower Control	BS	Buckbean–Slender Sedge Association	Hawkes *et al.* 2007
Bush Arm	Km 88	61.18 (753.5)	Target	WS	Willow–Sedge Association	Hawkes *et al.* 2007
Bush Arm	Km 88	61.16 (754.5)	Upper Control	WS	Willow–Sedge Association	Hawkes *et al.* 2007
Bush Arm	Km 88	96* (757)	Reference	WS	Willow–Sedge Association	MacKenzie and Moran 2004
Bush Arm	Km 79	61.27 and 61.28 (753.2)	Target	SH	Swamp Horsetails Association	Hawkes *et al.* 2007
Bush Arm	Km 79	61.98 and 61.99 (760)	Reference	Wm01	Beaked Sedge–Water Sedge Marsh (transitioning to upland forest)	MacKenzie and Moran 2004
Bush Arm	Causeway	61.38** (752.5)	Lower Control	SH?	Swamp Horsetails Association	Hawkes *et al.* 2007
Bush Arm	Causeway	61.40 (753.4)	Target	CO	Clover–Oxeye Daisy Association	Hawkes *et al.* 2007
Bush Arm	Causeway	61.42 (754.7)	Upper Control	Fl04	Sitka Willow–Red-osier Dogwood–Horsetail Flood Association	MacKenzie and Moran 2004
Canoe Reach	Valemount Peatland	61.07 (755) & 61.08 (755.5)	Reference	Wb11	Black Spruce–Buckbean–Peatmoss Bog	MacKenzie and Moran 2004
Encampment Creek	Encampment 1	61.46 (753.7) & 61.45 (753.8)	Target	SH	Swamp Horsetails Association	Hawkes *et al.* 2007
Encampment Creek	Encampment 1	61.44 (754.1)	Upper Control	WS	Willow–Sedge Association	Hawkes *et al.* 2007
Encampment Creek	Encampment 1	61.43 (754.8)	Upper Control	Ws06	Sitka Willow–Sitka Sedge Swamp	MacKenzie and Moran 2004
Encampment Creek	Encampment 2	61.54 (754.7)	Upper Control	Ws06	Sitka Willow–Sitka Sedge Swamp	MacKenzie and Moran 2004
Encampment Creek	Encampment 2	61.56 (756.1)	Reference	Ws10	Western Redcedar–Spruce–Skunk Cabbage Swamp	MacKenzie and Moran 2004
Bush Arm	Succour Creek	61.72 (772)	Reference	Wf01	Water Sedge–Beaked Sedge Fen	MacKenzie and Moran 2004

* CLBMON-10 transect
** Inundated at time of sampling; partially sampled only

5.3.3 Terrestrial Wetland Communities by Elevation Band

Because of operational constraints in 2012, a contiguous sampling of all four focal elevation bands was achieved for only one location (Km 88; Table 5-3), precluding any attempt to correlate community types to specific elevation bands or other environmental gradients on a local scale. Km 88 does however provide us with one example of the sort of community transitions encountered as one progresses upwards in elevation through a single wetland complex.

Here, a low-diversity plant association (BS) consisting primarily of Buckbean characterizes the lower 752 – 753 m ASL elevation band (Figure 5-3). Perennial forbs, sedges, and horsetails dominate the overall plant cover, while shrub cover is almost non-existent (Figure 5-4). Wet conditions prevail, as evidenced by the presence of obligate hydrophytes such as Common Cattail, Shore Sedge, Water Sedge, Flat-leaf Bladderwort, and Buckbean (Figure 5-3; Appendix 9.6).

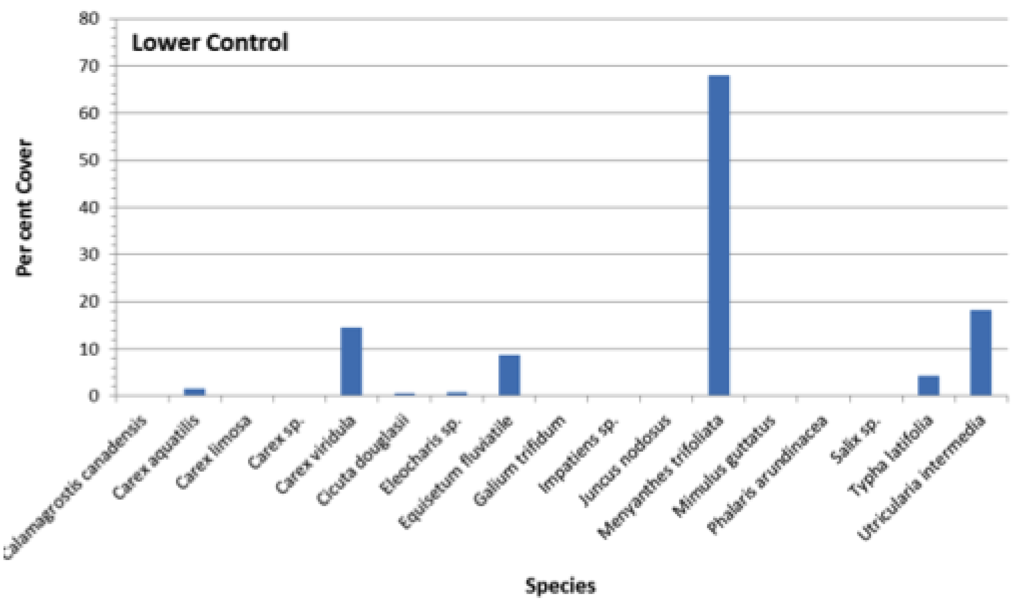

Figure 5-3: Per cent cover of plant species recorded in 2012 in transect 61.18 (target wetland) at Km 88, Bush Arm

Directly above this band, at the target elevation of 753 – 754 m ASL, the wetland complex transitions into a shrub – sedge association (WS) which, while still largely dominated by Buckbean, is significantly more speciose with a mix of both obligate wetland and terrestrial species (Figure 5-5; Appendix 9.6). Several shrub species occur although overall shrub cover remains relatively sparse (Figure 5-4). The presence of terrestrial species in association with hydrophytes implies a level of edatopic complexity (possibly resulting from microsite variations in moisture level due to hummocking) not present in the lower elevation band.

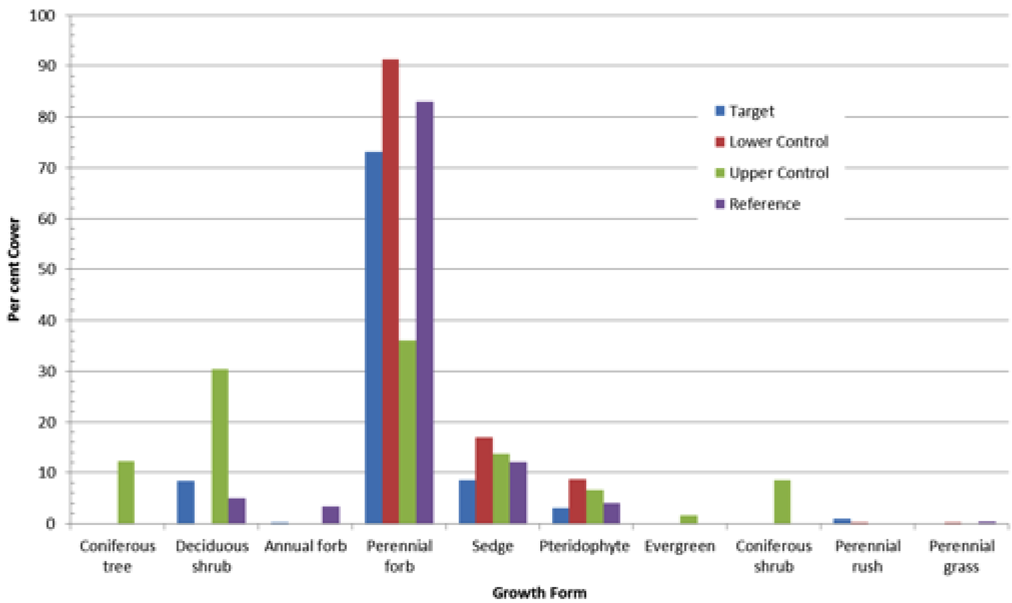

Figure 5-4: Per cent cover, by growth form, of plant species recorded in 2012 across four elevation bands (sampling strata) at Km 88, Bush Arm. Elevation bands are 752 to 753 m ASL (lower control), 753 to 754 m ASL (target), 754 to 755 m ASL (upper control), and >755 m ASL (reference). For each stratum, n = 1 transect sampled

Species richness and structural complexity continue to increase into the upper control elevation band (754 – 755 m ASL) at the interface between the drawdown zone and the upland zone. The Willow – Sedge (WS) wetland at this site experiences less frequent inundation than the adjacent lower elevation bands (Hawkes et al. 2010), and the species composition appears to reflect its ecotonal position. Here, Buckbean is still abundant but less relatively dominant compared to lower elevations; shrubs such as Scrub Birch now account for just as much cover (Figure 5-6). In addition to various sedges, bog-fen associates such as Roundleaf Sundew (*Drosera rotundifolia*) and Sticky False Asphodel (*Triantha glutinosa*) are present. A few of the species present (e.g., Mountain Death-camas [*Zigadenus elegans*]) are indicative of calcareous soil conditions (Appendix 9.6). In terms of plant growth forms, this is the most structurally diverse wetland. Perennial forbs are still the dominant feature; however, the site also supports a combination of coniferous trees and shrubs, deciduous shrubs, sedges, pteridophytes (horsetails), and evergreen herbs (Figure 5-6).

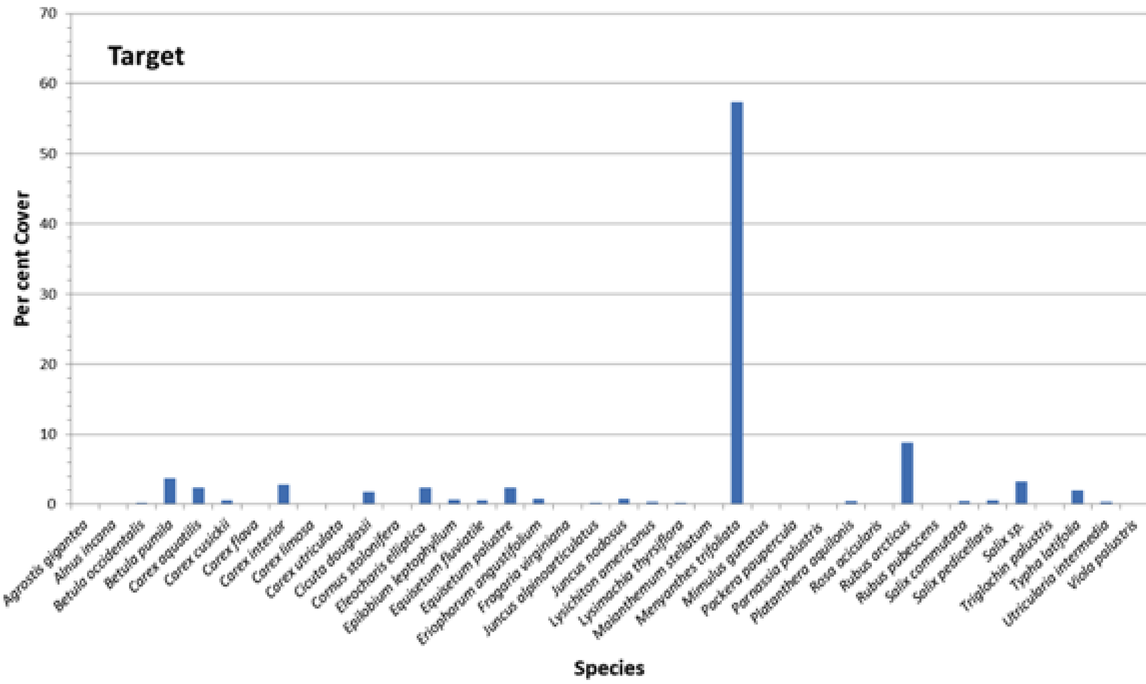

Figure 5-5: **Per cent cover of plant species recorded in 2012 in transect 61.18 (target wetland) at Km 88, Bush Arm**

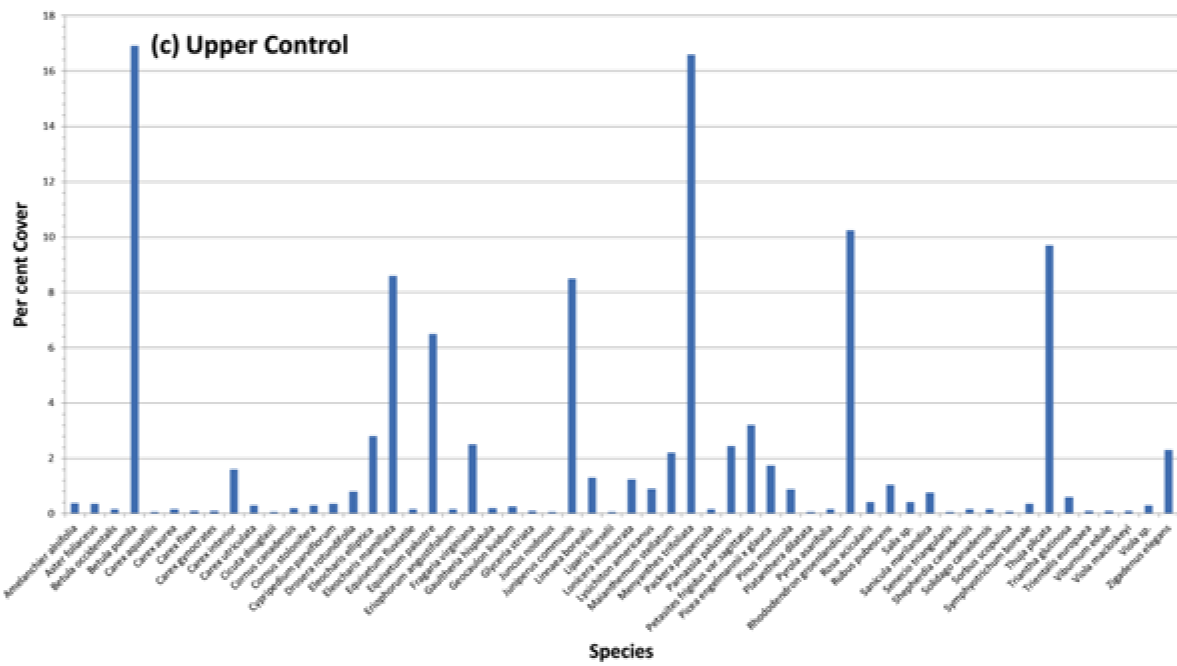

Figure 5-6: **Per cent cover of plant species recorded in 2012 in transect 61.16 (upper control wetland) at Km 88, Bush Arm**

At the reference site situated above the reservoir, the wetland complex reverts again to a sub-hydric, Buckbean-dominated community. A moderate diversity of herbs, including both obligate hydrophytes (e.g., Common Cattail) and terrestrial species (e.g., Mountain Death-Camas) species, contribute to the total plant cover (Figure 5-7). Classified here as a WS association (Table 5-3), this community shares affinities with the Scrub Birch – Buckbean – Shore Sedge Fen Site Association of MacKenzie and Moran (2004; Appendix 9.6). Structurally and compositionally, it is similar to the wetland in the target elevation band of the reservoir, with perennial forbs providing the dominant cover and deciduous shrubs, sedges, and horsetails providing secondary cover (Figure 5-4). Both wetlands appear to be less complex and diverse than the upper control wetland. In the case of this index site, the reference site should thus provide an informative basis of comparison for the target wetland with which it has been matched. In this example, wetland structure and composition appear to change more or less in step with elevation across the upper elevation bands of the reservoir, while the relationship to elevation becomes less clear above the reservoir boundary. At other locations similarly, lower elevation communities tended to be low-diversity, swamp horsetail habitats while upper elevation communities could usually be classed as either Willow – Sedge communities, or flood, marsh, and fen associations (Table 5-3).

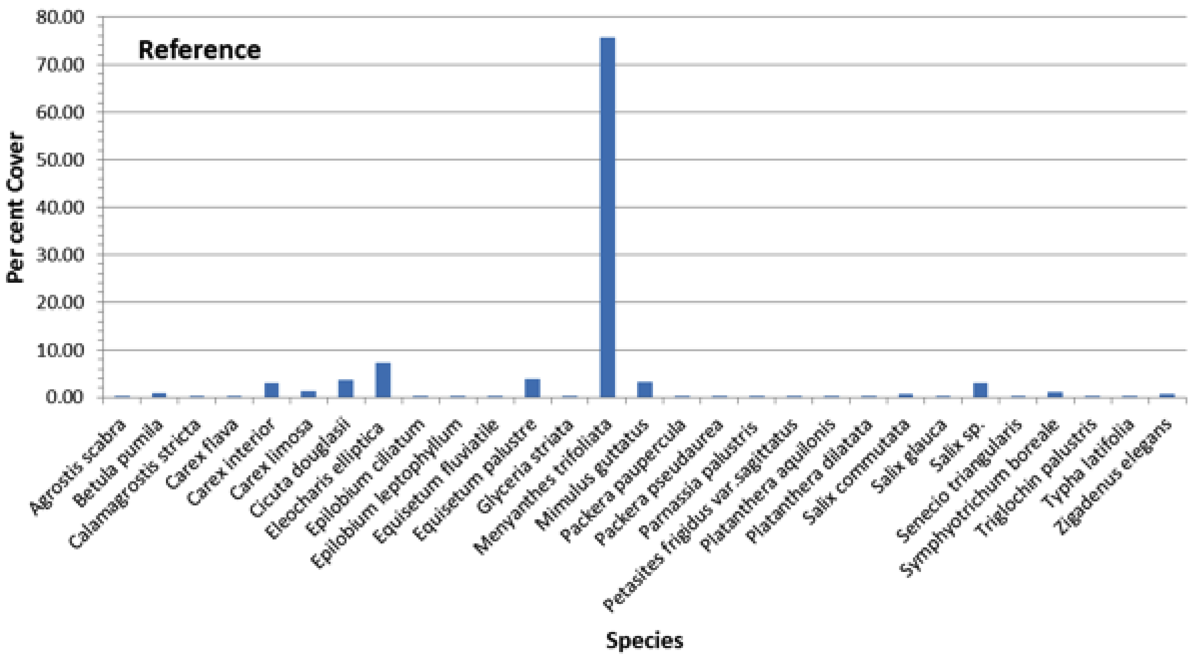

Figure 5-7: Per cent cover of plant species recorded in 2012 in transect 96 (reference wetland) at Km 88, Bush Arm

To obtain a summary picture of vegetation structure differences across sampling strata at the landscape scale (acknowledging the small sample sizes available for this purpose), per cent covers for various plant growth forms were calculated for each transect in the four elevation bands containing the target, lower control, upper control, and reference wetlands (Figure 5-8). Perennial forbs accounted for much of the cover across all four sampling strata, followed in importance by pteridophytes, sedges and sedge-like plants, and deciduous shrubs. Annual forbs, evergreen herbs, and rushes made negligible contributions to cover.

The relative importance of each growth form varied among sampling strata, suggesting (not surprisingly) an interaction between vegetation structure and elevation. For example, pteridophytes (mostly horsetails) were abundant in the target stratum, and less so in the lower control and reference strata. Sedges appeared to be more abundant in the upper control and reference wetlands than in the lower control and target wetlands. The upper control wetlands had prominent deciduous shrub cover, as did the reference wetlands. However, shrubs were less abundant in the target wetlands and had negligible cover in the lower control wetlands. Coniferous tree species composed some of the cover at the upper margins of the reservoir as well as in wetlands situated above the reservoir, but were generally absent from the lower control and target wetlands (Figure 5-8).

5.3.4 Species Richness, Diversity, and Evenness

Based on the limited sample sizes available for 2012, species richness increased with elevation at all locations (Figure 5-9). Among locations, species richness was greatest at the Km 88 site for each of the elevation bands sampled. The upper control wetland community (WS) at Km 88, represented by transect 61.16, had the highest individual species richness. Diversity (H') followed much the same pattern as species richness, except that transect 61.20, a lower control transect at Km 88, was by far the least diverse (H') even though it contained more species than some of the other transects (Figure 5-9). Transect 61.20 also had the lowest evenness value (Figure 5-9), reflecting the fact that although this transect is moderately speciose; the herb cover is largely dominated by one species, Buckbean (Figure 5-4). Other species are present but occur infrequently along the transect, suggesting that interspecific competition may be high.

Species richness/diversity/evenness was also assessed for just woody-stemmed species (Figure 5-10). There were only two sites, both in Bush Arm, where woody species were sampled in multiple elevation bands (Km 88 and Causeway), limiting the number of possible comparisons. However, there was an obvious trend of increasing richness with elevation, as would be expected given the generally lower tolerance of woody species to prolonged inundation (Hawkes et al. 2010). There was similar trend for diversity (H'), and no obvious trend for evenness (Figure 5-10), although the available samples were too limited to deduce general patterns.

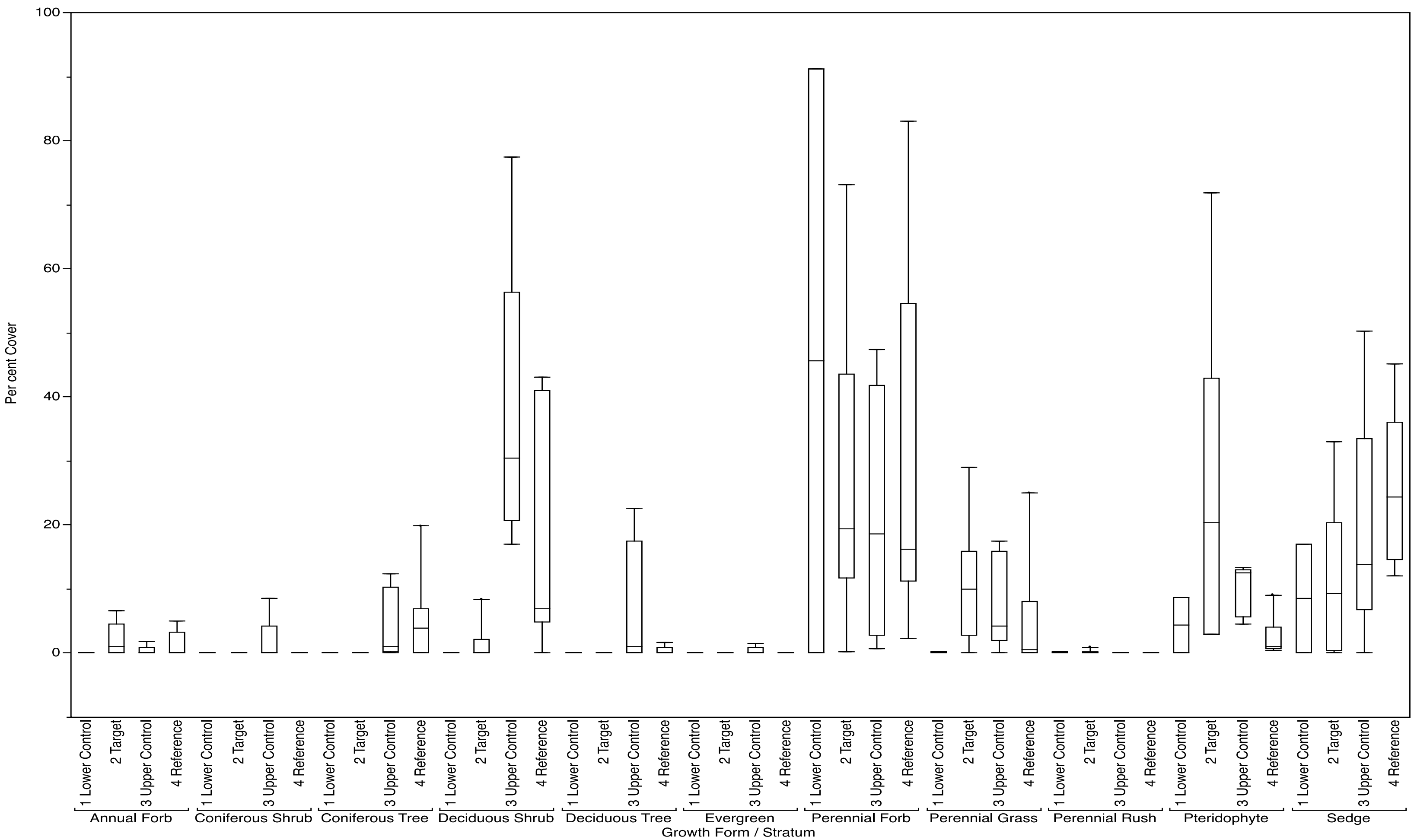

Figure 5-8: Per cent cover, by growth form, of plant species recorded in 2012 across four elevation bands (sampling strata) in Kinbasket Reservoir. Elevation bands are 752 to 753 m ASL, 753 to 754 m ASL, 754 to 755 m ASL, and >755 m ASL for lower control, target, upper control, and reference wetlands, respectively. *N* = 2, 6, 5, and 7 transects for lower control, target, upper control, and reference wetlands, respectively

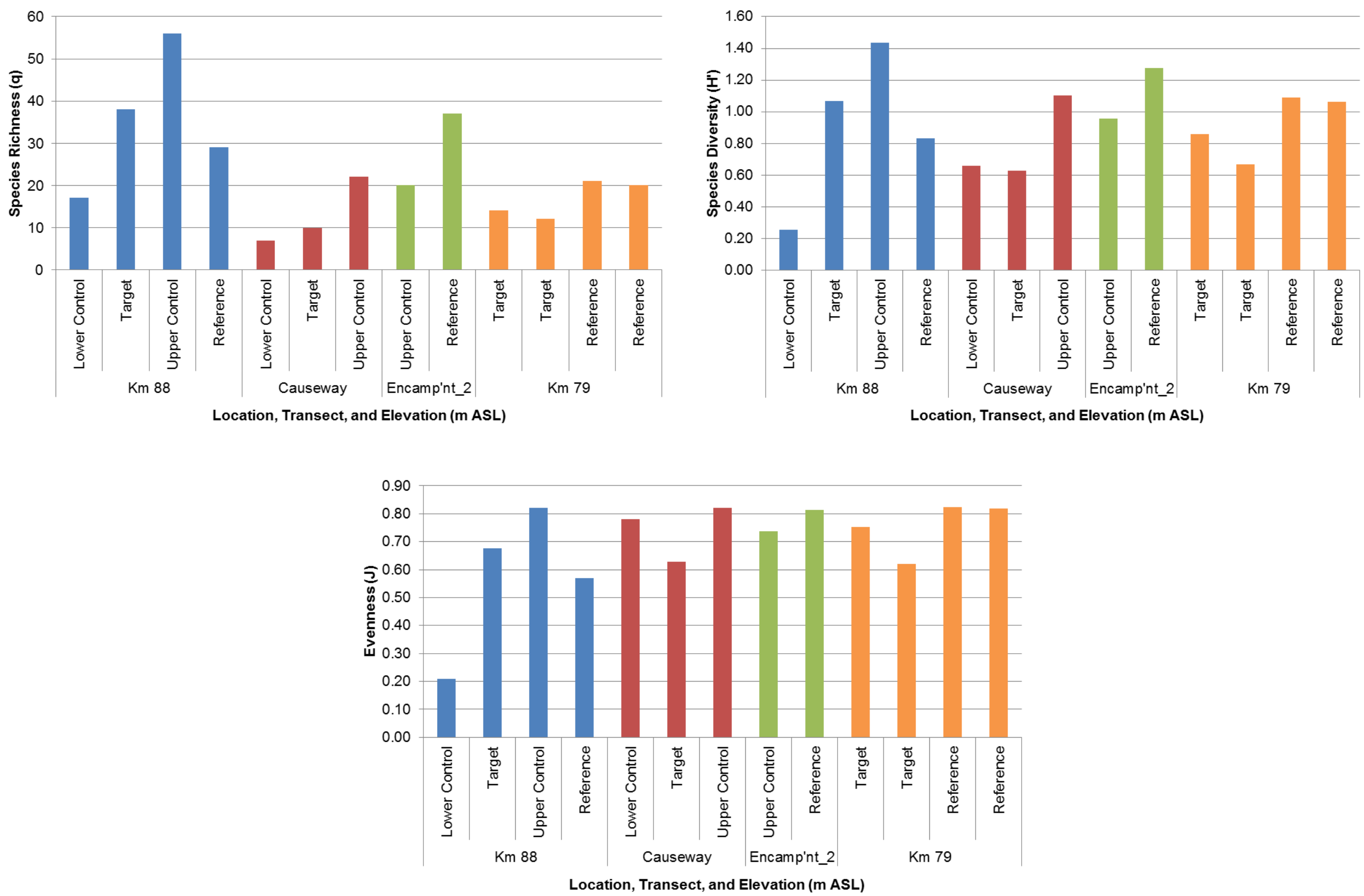

Figure 5-9: Species richness, diversity (Shannon's H), and evenness (J) per transect and elevation band at selected locations in Kinbasket Reservoir. Only those four sites where a minimum of two or more elevation bands were represented in the 2012 sampling (Table 5-1) are included for comparative purposes. For a given site, transects are ordered by elevation (m ASL) from lowest to highest

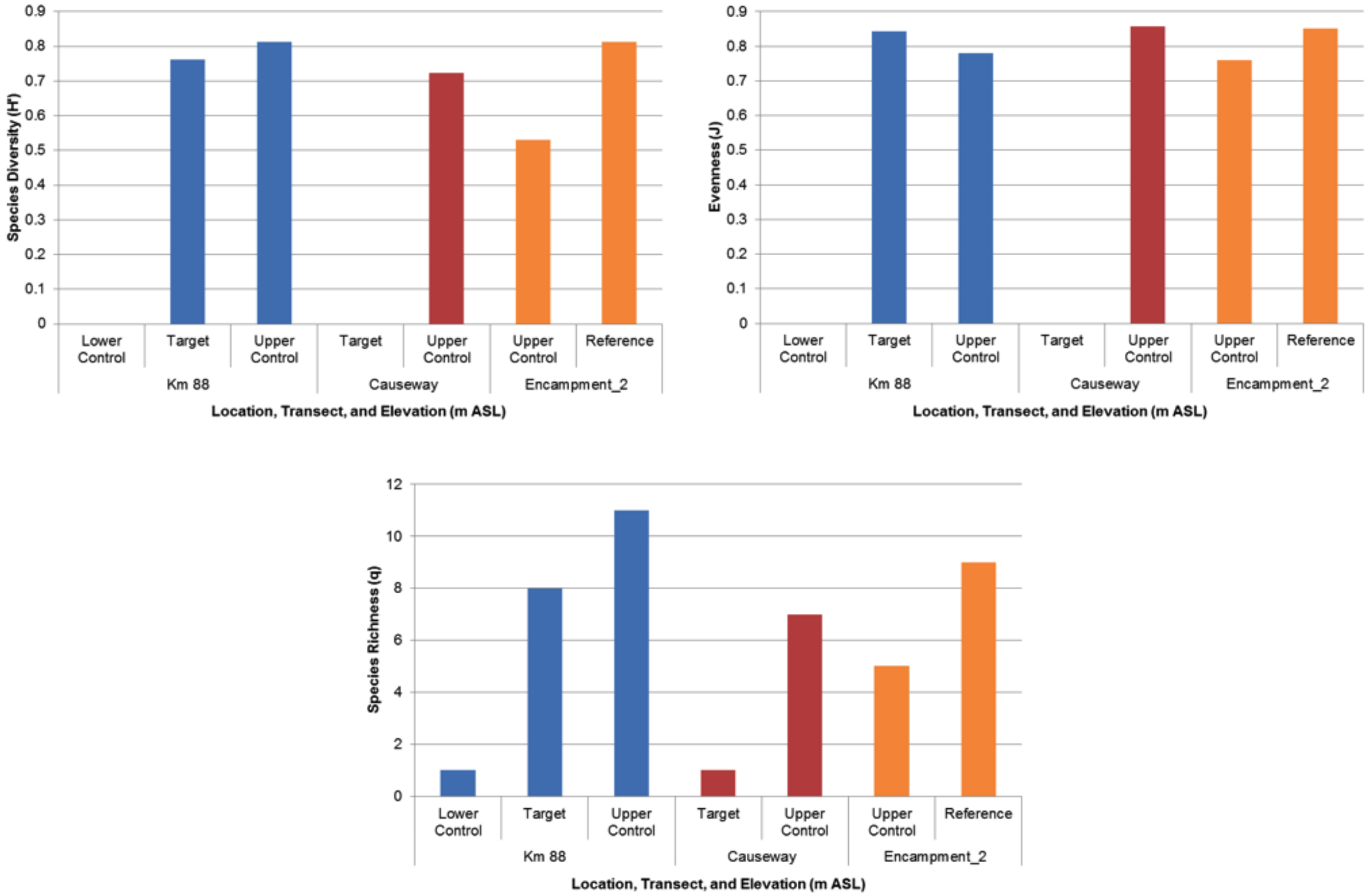

Figure 5-10: Species richness, diversity (Shannon's H), and evenness (J) of deciduous shrubs per transect and elevation band at selected locations in Kinbasket Reservoir. For comparative purposes, only the sites (Table 5-1) where deciduous shrubs were sampled at a minimum of two or more elevation bands in 2012 are shown. For a given site, transects are ordered by elevation (m ASL) from lowest to highest.

5.4 Aquatic Wetland Sampling

5.4.1 General Wetland Characteristics

A total of 16 aquatic wetlands were sampled in 2012. The elevation of wetlands sampled ranged from 748.45 to 799.7 m ASL (Table 5-4): five were positioned in the target elevation band of 753 to 754 m ASL, four between 748.5 to 752.0 m ASL, and seven between 755.5 to 799.7 m ASL. The lowest elevation pond that was sampled was at Ptarmigan Creek and, although well below the target elevation band, this pond was sampled because it is an important Western Toad breeding site (John Krebs, pers. com; Hawkes et al 2013) and is the only functional aquatic wetland in Canoe Reach that exists outside of the Valemount Peatland.

All but two of the aquatic wetlands sampled in 2012 were between 105 and 9,251 m^2 (Figure 5-11). The Bush Lake (P18) and Cranberry Lake (P21) were 48,747 m^2 (4.9 ha) and 69,475 m^2 (6.9 ha) respectively and both were sampled as reference wetlands outside Kinbasket Reservoir.

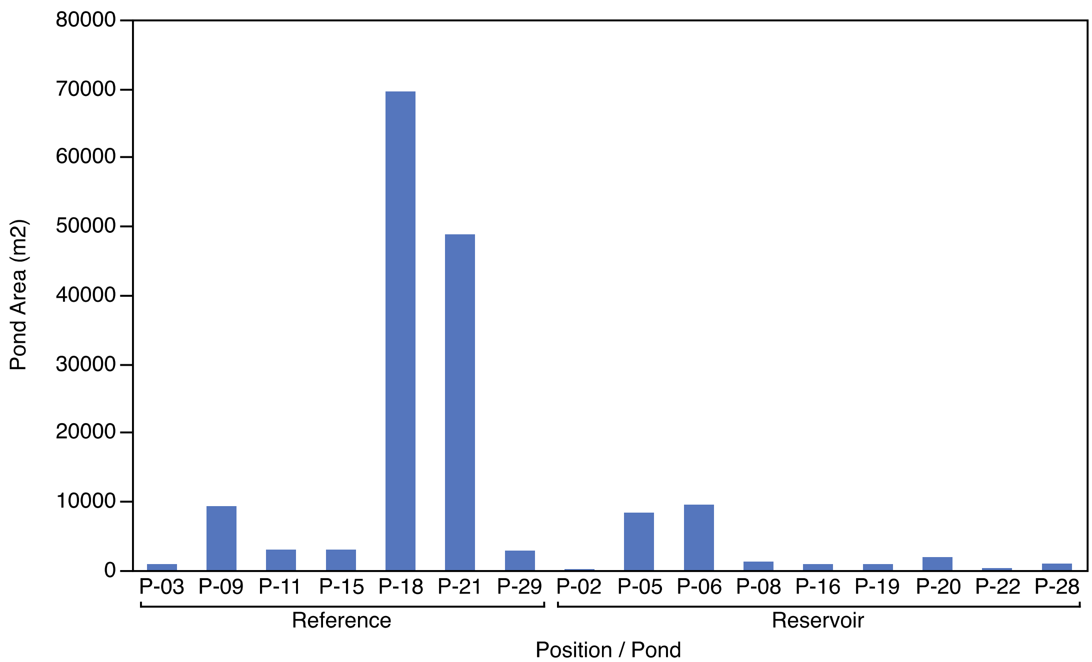

Figure 5-11: The size in area (m^2) of aquatic wetlands (ponds) sampled in 2012 grouped by position: within Kinbasket reservoir (Reservoir) or outside (Reference)

Table 5-4. Elevation, wetland size, and water physicochemistry of aquatic wetlands sampled in 2012 by reach and position

Reach/Position/ Pond Name	Survey Date	Elev. (m)	Area (m^2)	Mean Depth (cm)	Mean Sediment Depth (cm)	Mean Temp (°C) @ 10 cm	Mean Temp (°C) @ 30 cm	Mean DO (mg/l) @ 10 cm	Mean DO (mg/l) @ 30 cm	Mean pH @ 10 cm	Mean pH @ 30 cm	Mean Conductivity (µS/cm) @ 10 cm	Mean Conductivity (µS/cm) @ 30 cm	Sediment Type*	Wetland Forming Process
Bush				104.8	32.4	17.4	16.4	8.31	8.42	8.24	8.21	266.7	253.1		
Reference		766.2	27867	102.1	39.0	16.9	16.1	8.06	7.83	8.19	8.15	248.6	234.9		
km40 Ref Pond (P11)	Aug 23	761.5	2966	100.3	36.5	9.2	9.1	11.04	11.09	8.54	8.52	226.5	226.6	MS	Beaver
km79 Ref Pond (P15)	July 18	764.8	2966	60.0	68.0	11.7	10.6	9.56	9.92	8.13	8.09	44.1	43.2	OM	Beaver
Bush Lake Ref Pond (P18)	Aug 22	761.5	69475	125.3	23.0	20.9	20.9	8.60	8.54	8.41	8.39	253.0	257.4	MS	Basin
Esplanade Ref Pond (29)	Aug 23	777.8	2807	100.3	18.0	20.5	18.3	4.02	2.92	7.64	7.57	360.7	351.3	MS/OM/CO	Beaver
Reservoir		752.3	857	119.3	9.5	20.0	18.2	9.58	11.37	8.48	8.50	357.5	349.9		
km79 DDZ Pond (P16) †	July 17	751.8	826	-**		-**	-**	-**	-**	-**	-**	-**	-**	OM	Beaver††
km88 DDZ Pond (P28)	July 16	752.7	887	119.3	9.5	20.0	18.2	9.58	11.37	8.48	8.50	357.5	349.9	OM/MS	Beaver
Canoe				76.4	83.8	20.7	18.2	7.57	6.74	7.21	7.31	89.2	93.6		
Reference		786.4	34365	118.3	82.3	22.1	20.2	8.88	8.88	7.63	7.58	93.7	89.3		
Peatland Ref Pond (P03)	July 08	755.5	829	87.3	104.3	15.3	13.1	9.63	9.49	7.07	7.02	40.6	38.8	OM	Beaver
Cranberry Lake (P21)	July 10	799.7	48737	131.6	60.3	25.0	23.3	8.56	8.62	7.87	7.83	116.5	111.0	OM/MS	Basin
Reservoir		751.8	5375	55.5	84.3	20.1	16.4	6.95	4.79	7.00	7.05	86.7	97.4		
Peatland DDZ Excavation (P02)	July 08	753.1	105	88.7	64.0	21.5	18.1	2.08	0.55	6.64	6.57	118.7	142.6	WD/OM	Excavation
Peatland DDZ Pond (P05)	July 09	753.5	8337	76.0	101.7	18.7	15.8	7.10	6.38	7.23	7.24	83.6	80.5	OM	Beaver††
Ptarmigan DDZ Pond (P06)	July 07	748.5	9457	50.3	67.3	22.8	-**	10.74	-**	6.58	-**	87.1	-**	OM	Unknown
Peatland DDZ Pond (P19)	July 11	751.2	825	21.0	79.7	20.2	-**	5.21	-**	7.11	-**	101.7	-**	OM/CO	Basin
Peatland DDZ Pond (P20)	July 11	751.0	1852	16.0	78.0	18.7	-**	8.11	-**	7.09	-**	46.8	-**	OM/CO	Basin
Mica				139.2	97.0	24.3	22.0	3.24	2.77	6.12	6.04	34.9	33.9		
Reference		756.0	9251	174.0	118.0	23.9	22.9	3.39	2.65	5.88	5.81	22.7	22.2		
Sprague Bay Ref Pond (P09)	July 13	756.0	9251	174.0	118.0	23.9	22.9	3.39	2.65	5.88	5.81	22.7	22.2	OM/MS	Beaver
Reservoir		753.6	302	89.4	94.0	24.6	21.4	3.12	2.87	6.29	6.19	43.7	42.3		
Sprague Bay DDZ Pond (P08)	July 13	753.9	354	90.4	93.2	26.0	21.9	3.56	3.33	6.24	6.14	40.5	37.7	OM/MS	Beaver
Sprague Bay Lower Pond (P22)	July 14	753.0	172	87.0	96.0	21.1	20.2	0.95	0.52	6.43	6.33	51.7	53.9	OM/MS	Beaver

* sediment types: M = Organic Muck; MS = Mineral Sediment; CO = Coarse Organic; WD = Wood Debris
**values not obtained.
† inundated at the time of sampling
†† remnant Beaver pond

Pond depths (estimated from three or more depth sounds in each pond) ranged from 16 to 174 cm (Table 5-4) and the depth within ponds varied greatly (Figure 5-12). Reference ponds were significantly deeper than ponds within the reservoir [4] (F_1 = 5.96, p = 0.03). The shallowest ponds (P19 and P20) were observed in the Valemount Peatland at 752 m ASL and are representative of over 30 small shallow ponds that occur between 751 to 753 m ASL at the north end of Canoe Reach. These ponds are likely remnant features of an old fen complex that has degraded following the flooding of the reservoir. At 174 cm deep, the deepest pond sampled was P09, a reference pond at Sprague Bay in Mica Arm. This pond is a floating fen complex maintained by a series of beaver dams extending from 756 m ASL down into the reservoir to below 753 m ASL.

Beaver ponds were deeper than ponds created by other wetland forming processes (t_{11} = 3.63, p <0.004*[5]). Beaver activity (either recent or old) was observed in most ponds sampled (n=12) and was the primary wetland forming process in nine ponds (Table 5-4). While most of the recent beaver activity was observed in ponds outside of the reservoir, activity was observed in the reservoir at Sprague Bay (P08, P22) and km88 (P28). Although this was not tested, fluctuating water levels likely limit beaver activity in the reservoir, which may in turn influence pond depth and the vegetation communities that establish.

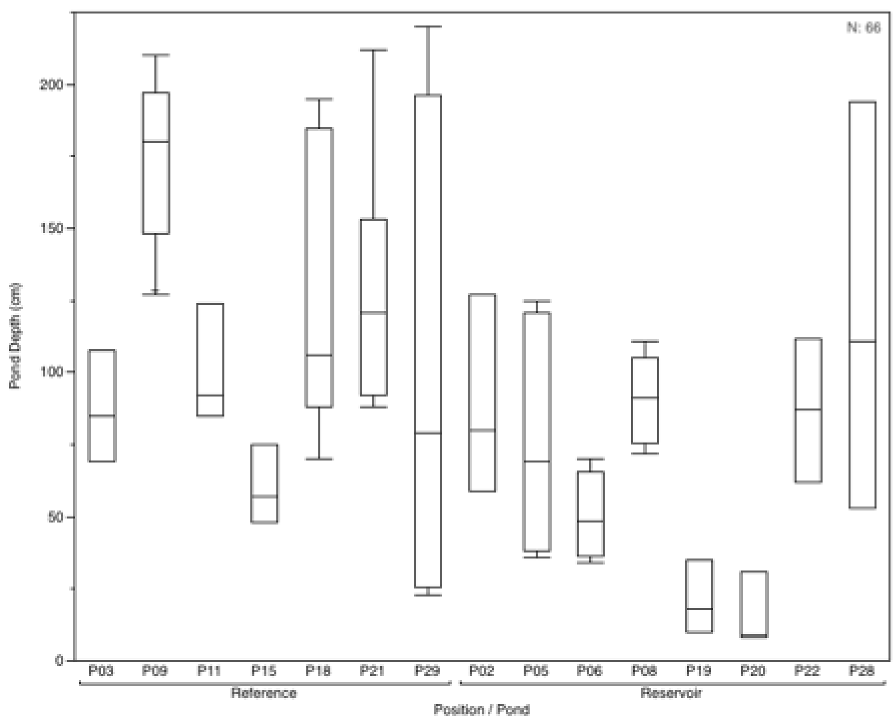

Figure 5-12: Water depths (cm) of aquatic wetlands (ponds) sampled in 2012.

[4] Pond P16 was excluded from this analysis as it was already inundated at the time of sampling

[5] This analysis excluded the two shallow lakes that were sampled (P18 and P21).

5.4.2 Sediment and Wood Debris

Pond sediments observed in aquatic wetlands included organic muck, coarse organic matter (e.g., peat and vegetation), mineral soil, and wood debris (Table 5-4). Efforts to characterize the texture and colour (hue and chroma) of sediment from Ponar benthic samples were unreliable due to the mixing of organic and mineral layers. In the future, alternative methods (e.g., hand corer) should be explored so that the organic and mineral layers can be separated and reliably characterized.

Organic muck depth (Figure 5-13), as assessed by probing the sediment using a D-Net handle, did not differ significantly between reservoir and reference ponds ($F_1 = 0.88$, $p = 0.37$). However, organic muck depth did differ among reaches ($F_2 = 9.32$, $p < 0.01$). A Tukey's pairwise comparison indicated that organic muck depth in Bush Arm differed from both Mica Arm ($p < 0.01$) and Canoe Reach ($p < 0.01$). These results are not unexpected as the ponds sampled in Mica Arm (i.e., Sprague Bay) and several ponds in Canoe Reach (i.e., Valemount Peatland) were associated with floating fen communities, which accumulate deep organic layers, whereas pond sediment in Bush Arm tended to have a higher mineral component (Table 5-4).

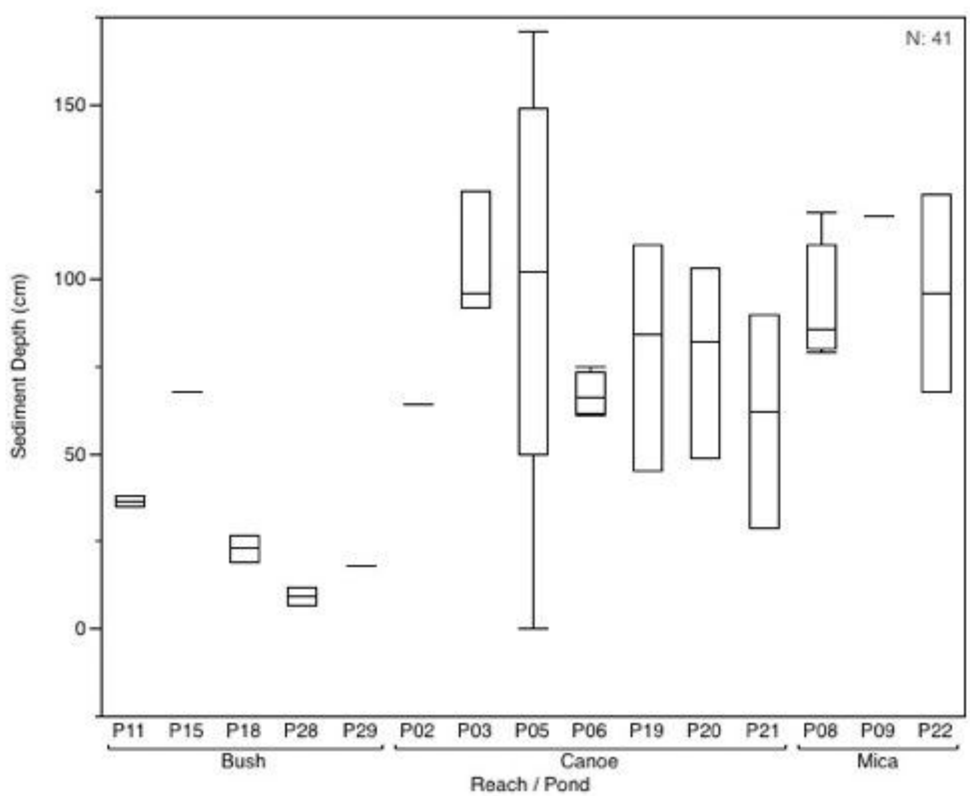

Figure 5-13: Organic muck depth (cm) in aquatic wetlands (ponds) sampled in 2012

The amount of wood debris in pond substrate was assessed by probing the bottom of the ponds using a D-net handle. Wood was encountered more frequently in the substrate of reservoir ponds than in reference ponds (p = 0.02). The overall frequency at which wood debris was encountered was 30.6 per cent in ponds located within the reservoir and 3.4 per cent in reference ponds (n = 234; Figure 5-14). The occurrence of wood debris in the reservoir is not unexpected given the large amount of wood debris that accumulates in the upper elevations of the drawdown zone annually, particularly at the north end of Canoe Reach and in Bush Arm (Figure 5-15).

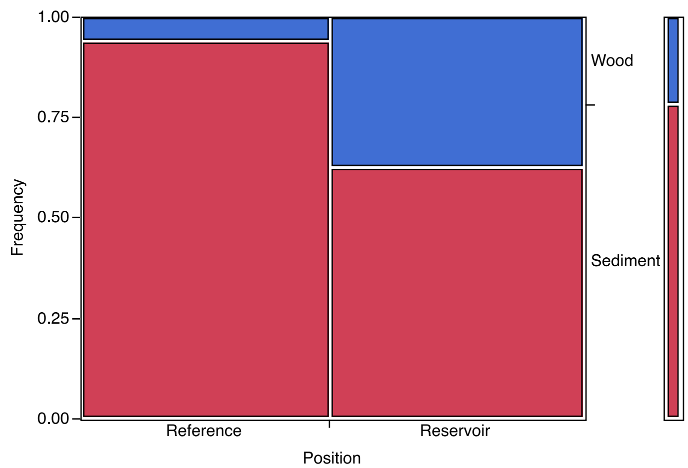

Figure 5-14: Frequency of wood encountered in the sediment of ponds sampled within Kinbasket Reservoir and in reference ponds (n = 234). The overall mean is shown on the right hand bar

Figure 5-15: Accumulation of wood debris at the Bush Arm Causeway (above) and in pond P05 in Valemount Peatland (below) over a 5-year period (2007 to 2012, left to right)

5.4.3 Water Physicochemistry: Point Sample Data

Point samples of water temperature, dissolved oxygen, pH, and conductivity were obtained from 15[6] wetlands sampled. Most ponds (n=12) were sampled between July 7 and 19th 2012; however, three reference ponds (P11, P18, P29) were sampled between August 19 to 21, 2012. Of the four variables sampled, pH and conductivity differed significantly across the three reaches (Mica, Canoe, and Bush Arm) while none of the variables differed significantly between ponds located within the reservoir and ponds located outside the reservoir (reference ponds).

Mean pond temperatures ranged from 9.0 ºC to 28.7 ºC and temperatures in ponds P11 and P15 were colder than in all other ponds sampled (Table 5-4, Figure 5-16). These ponds are influenced by beaver activity, are surrounded by coniferous forests, and are fed by streams, all of which likely contribute to the lower temperatures. High water temperatures were observed at P08, P09, and P21 (Table 5-4), which may have been a function of the extreme temperatures observed during the sampling period when maximum daily temperatures exceeded 30 ºC (Figure 5-2). Despite the temperature extremes observed, water temperatures were not significantly different between ponds located in the reservoir or above the reservoir ($F_{1\ @10cm} = 1.68$, $p_{@10cm} = 0.22$; $F_{1\ @\ 30cm} = 0.48$, $p_{@30cm} = 0.51$), or among reaches ($F_{2\ @10cm} = 3.13$, $p_{@10cm} = 0.08$; $F_{2\ @30cm} = 1.94$, $p_{@30cm} = 0.20$).

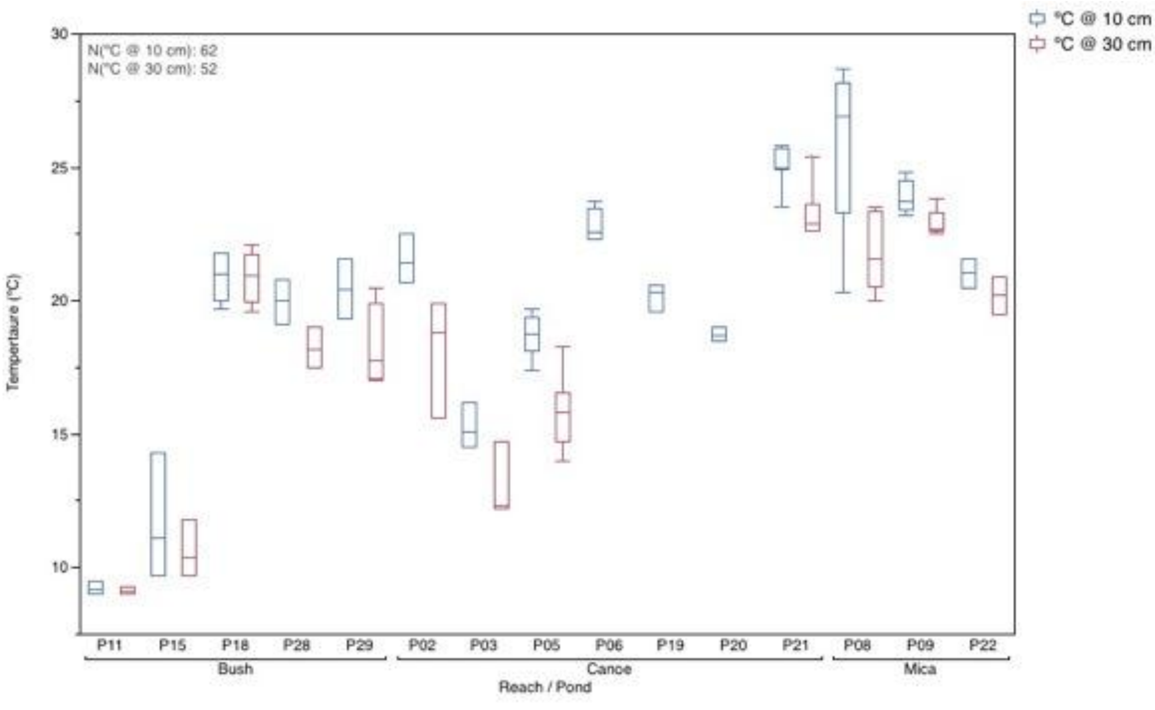

Figure 5-16: Water temperatures obtained in ponds sampled at depths of 10 cm and 30 cm in 2012

[6] Pond P16 was excluded from most analyses as it was already inundated at the time of sampling

Mean dissolved oxygen concentrations ranged from 0.38 to 11.27 mg/l (Table 5-4, Figure 5-17). Ponds with low dissolved oxygen concentrations included the Sprague Bay ponds (P08, P09, and P22) in Mica Arm, the excavated pond in the Valemount Peatland (P02), and a reference pond in Bush Arm (P29). Despite the low dissolved oxygen concentrations, the Sprague Bay ponds and pond P02 are known to support populations of amphibians including the Western Toad (*Anaxyrus boreas*), Columbia Spotted Frog (*Rana luteiventris*), and Long-toed Salamander (*Ambystoma macrodactylum*) (Hawkes and Tuttle 2012). Dissolved oxygen concentrations in the other aquatic wetlands sampled were in excess of 5 mg/l, which is an important threshold for many fish species (Davis 1995).

Dissolved oxygen measurements taken at 10 cm depths differed significantly among reaches ($F_{2\ @10cm} = 4.83$, $p_{@10cm} = 0.03$). There were significant differences between the sites sampled in Bush Arm and Mica Arm (Tukey's pairwise comparison; $p = 0.03$; Figure 5-17). Differences in dissolved oxygen concentrations between Mica Arm and Bush Arm were likely indicative of the types of aquatic wetlands sampled in the two reaches. The floating fen complex in Sprague Bay (Mica Arm) is an oligotrophic complex with high organic accumulation, so the low dissolved oxygen levels are not unexpected. Except for pond P29, most of the ponds in Bush Arm were associated with flowing water (e.g., P11, P15, P16, P28) and would be expected to yield higher dissolved oxygen concentrations.

Dissolved oxygen concentrations in ponds taken at 30 cm did not differ among reaches ($F_{2\ @30cm} = 3.57$, $p_{@30cm} = 0.07$) and dissolved oxygen concentrations at either depth did not differ between reference and reservoir ponds ($F_{1\ @10cm} = 1.23$, $p_{@10cm} = 0.29$; $F_{1\ @30cm} = 1.88$, $p_{@30cm} = 2.01$).

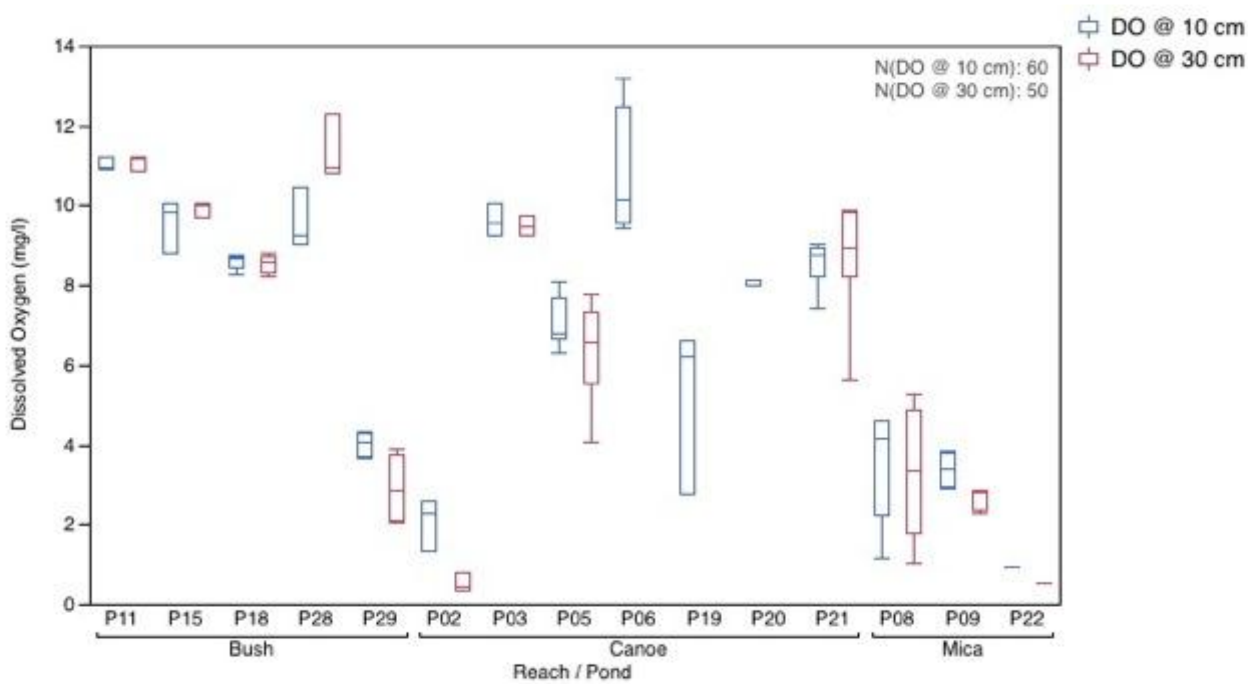

Figure 5-17: Dissolved oxygen concentrations (mg/l) in aquatic wetlands (ponds) sampled in 2012 at 10 cm and 30 cm depths.

Mean pH values in ponds ranged from 5.88 to 8.54 (Table 5-4, Figure 5-18). Mean pH in Bush Arm, Canoe Reach, and Mica Arm were 8.21 (SD 0.37), 7.31 (SD 0.42), and 6.04 (SD 0.28). Differences in pH among reaches were significant ($F_{2\ @10cm}$ = 28.12, $p_{@10cm}$ <0.001; $F_{2\ @30cm}$ = 24.17, $p_{@30cm}$ <0.001) and there were significant differences in pH among all three reaches (Tukey's pairwise comparisons; Bush–Mica: $p_{@10cm}$ <0.001 and $p_{@30cm}$ <0.001; Bush-Canoe: $p_{@10cm}$ <0.001 and $p_{@30cm}$ <0.001; Canoe-Mica: $p_{@10cm}$ = 0.01 and $p_{@30cm}$ = 0.01).

Differences in pH among reaches likely reflect regional differences in surficial geology as well as wetland biochemistry. The high pH values observed in Bush Arm are likely due to calcareous soils and parent material in the Rocky Mountains, whereas the low pH values observed in the Sprague Bay (Mica Arm) were likely due to the organic acids that form during the decomposition of the organics in this floating fen complex. pH did not differ significantly between reference ponds and ponds within the reservoir ($F_{1\ @10cm}$ = 1.88, $p_{@10cm}$ = 0.20; $F_{1\ @30cm}$ = 1.34, $p_{@30cm}$ = 0.27).

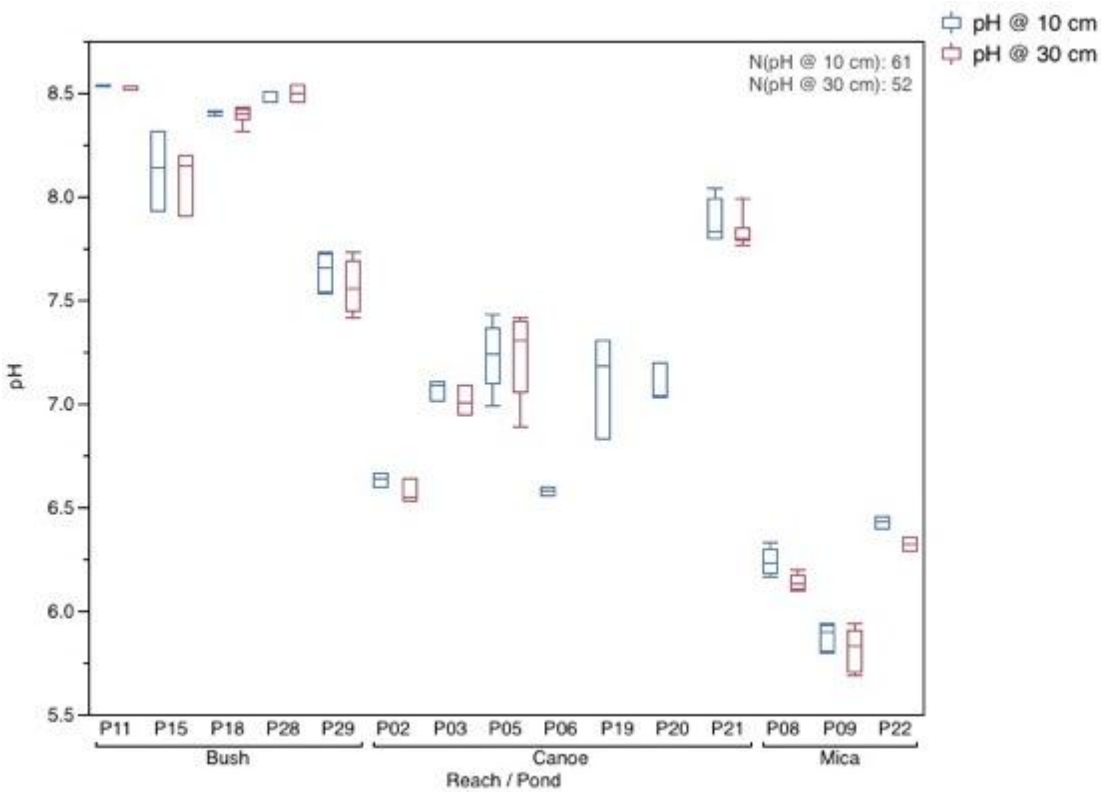

Figure 5-18: pH values in aquatic wetlands (ponds) sampled in 2012 at 10 cm and 30 cm depths.

Mean conductivity values ranged from 8.5 to 360.7 µS/cm (Table 5-4, Figure 5-19). Conductivity values were high in P11, P18, P28, and P29, which are all in Bush Arm. Differences in conductivity values among reaches were significant ($F_{2\ @10cm}$ = 9.09, $p_{@10cm}$ <0.01; $F_{2\ @30cm}$ = 6.19, $p_{@30cm}$ = 0.02) and a Tukey's pairwise comparison indicates that conductivity levels taken at depths of 10cm in Bush Arm differed significantly from both the ponds in Canoe Reach and Mica Arm (Bush–Mica: $p_{@10cm}$ < 0.01; Bush-Canoe: $p_{@10cm}$ = 0.01) but conductivity levels taken at depths of 30cm in Bush Arm differed significantly only from Mica Creek

(Bush–Mica: $p_{@30cm}$ = 0.03). As with pH, differences in water conductivity between reaches are likely a function of surficial geology. Conductivity did not differ between reference ponds and ponds within the reservoir ($F_{1\ @10cm}$ = 0.47, $p_{@10cm}$ <0.51; $F_{1\ @30cm}$ = 0.05, $p_{@30cm}$ = 0.82).

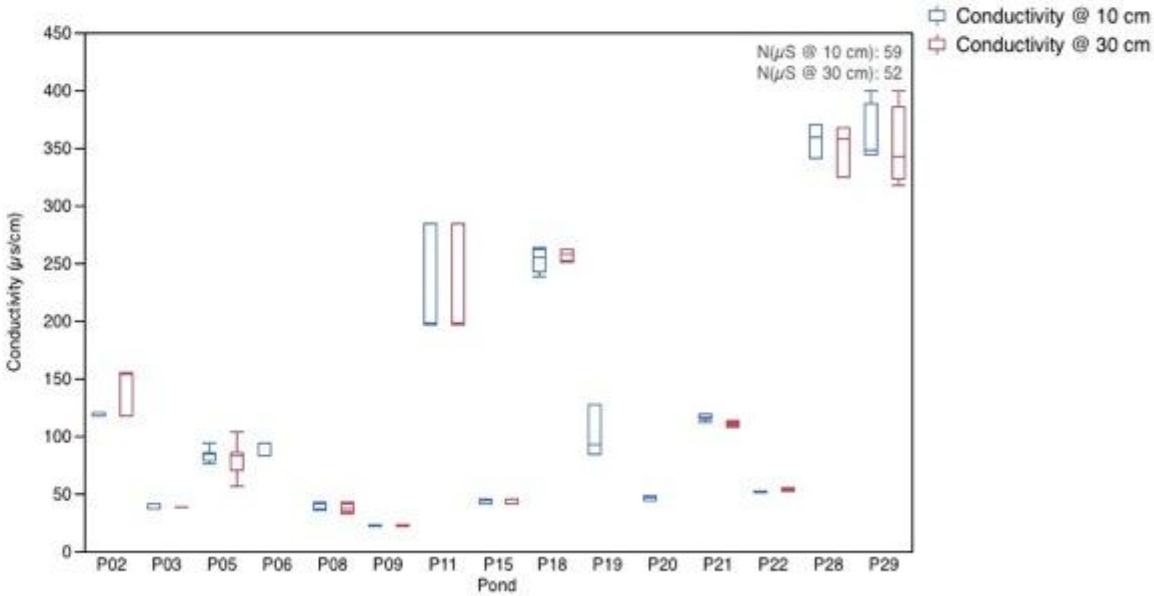

Figure 5-19: Conductivity of ponds sampled in 2012 at 10 cm and 30 cm depths. Ponds are grouped by Reach

5.4.4 Water Physicochemistry: Continuous Data

Inundation by the reservoir did not affect mean daily water temperatures in aquatic wetlands but did affect the amount water temperature fluctuated daily (maximum temp minus minimum temp). In most ponds monitored, daily mean water temperatures did not change following inundation (Figure 5-20). Only in two ponds was a significant change observed: P16 (located in the reservoir at km79) increased in temperature (8.1 to 11.3 ºC; t_{21} = 8.65, p <0.001), while P17 (located in the reservoir at the Bush Arm Causeway) decreased in temperature (19.0 to 8.5 ºC; t_{21} = 13.92, p <0.001) – this was likely due to the back flooding of Bush River. Although daily mean temperatures remained similar in most ponds, inundation attenuated the daily water temperature fluctuations in all ponds monitored within the reservoir (t_8 = 8.65, p <0.001; Figure 5-21; Appendix 9.7: Figure 9-11).

Water conductivity also appeared to change before and after inundation (t_6 = 3.08, p = 0.008; Figure 5-22; Appendix 9.7, Figure 9-11, 9-13, and 9-14); however, a similar response was also observed in the reference ponds (t_7 = 1.29, p = 0.88). This suggests that conductivity either responded to an external environmental factor other than inundation (e.g., temperature or precipitation), that the samples size was too small, or both. Nevertheless, conductivity generally increased in ponds that had an initial low conductivity and decreased in ponds that had an initial high conductivity (Figure 5-22). Unfortunately the premature failure of the PME MiniDOT dataloggers precluded a comparison to dissolved oxygen concentrations before and after inundation.

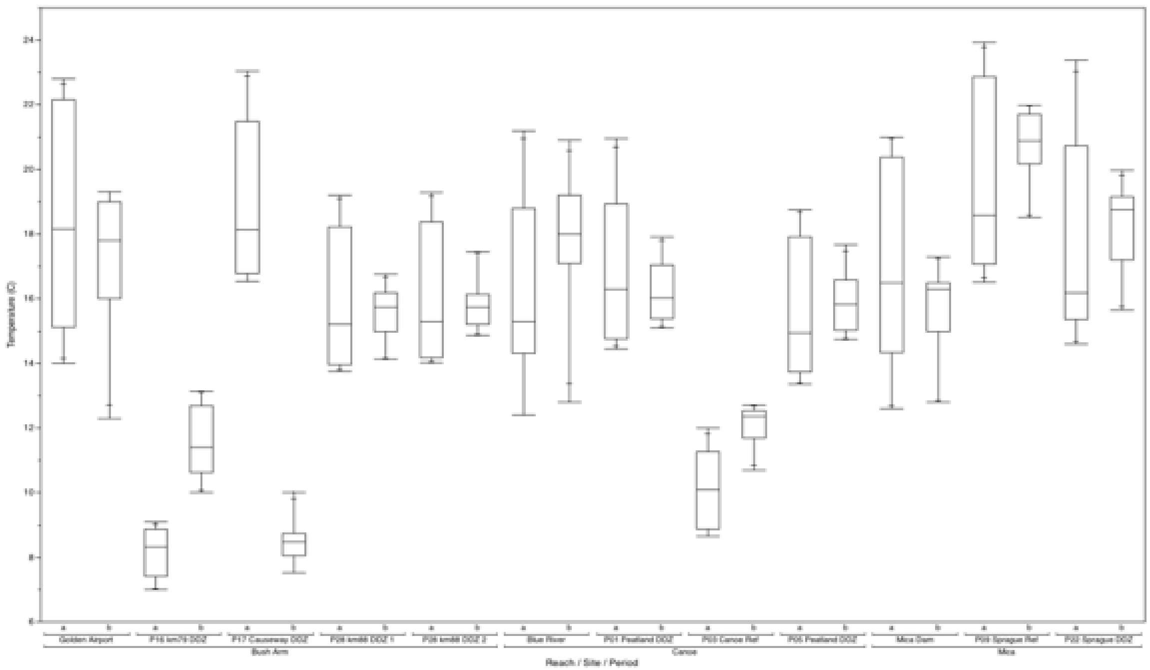

Figure 5-20: Mean water temperature of ponds within and adjacent Kinbasket Reservoir prior to inundation (period a: July 1 to 12, 2012) and immediately following inundation (period b: July 21 to July 31, 2012). Mean air temperatures at weather stations at the Golden Airport, Blue River, and Mica Dam are provided for additional reference

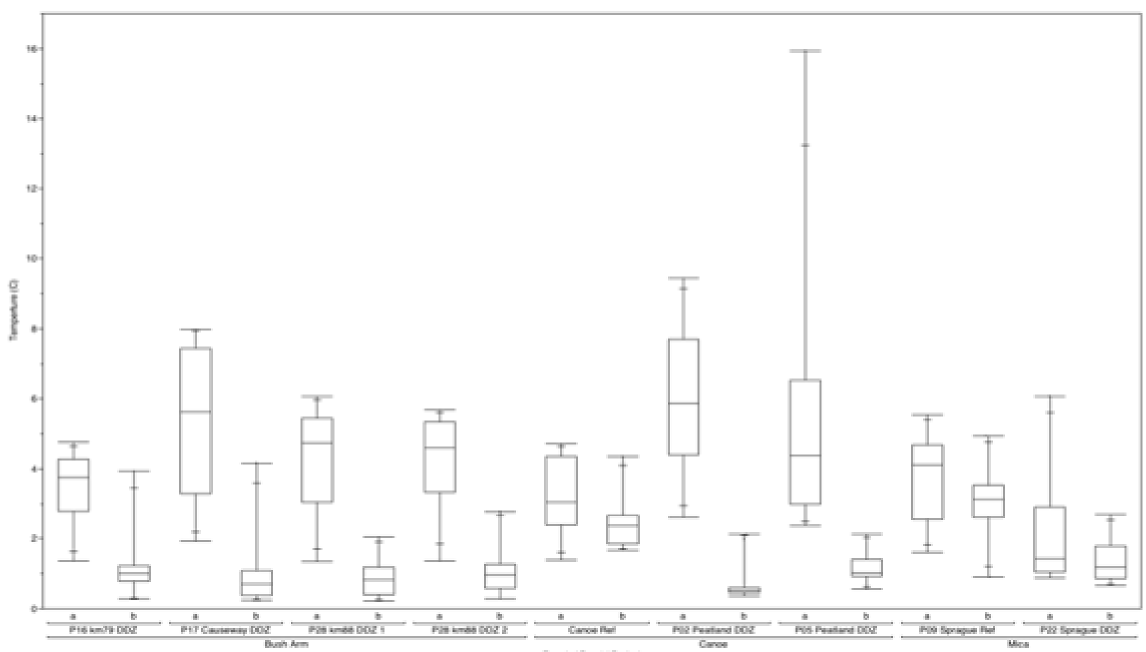

Figure 5-21: Daily water temperature fluctuations (daily max – daily min) of ponds within and adjacent Kinbasket Reservoir prior to inundation (period a: July 1 to 12, 2012) and immediately following inundation (period b: July 21 to July 31, 2012)

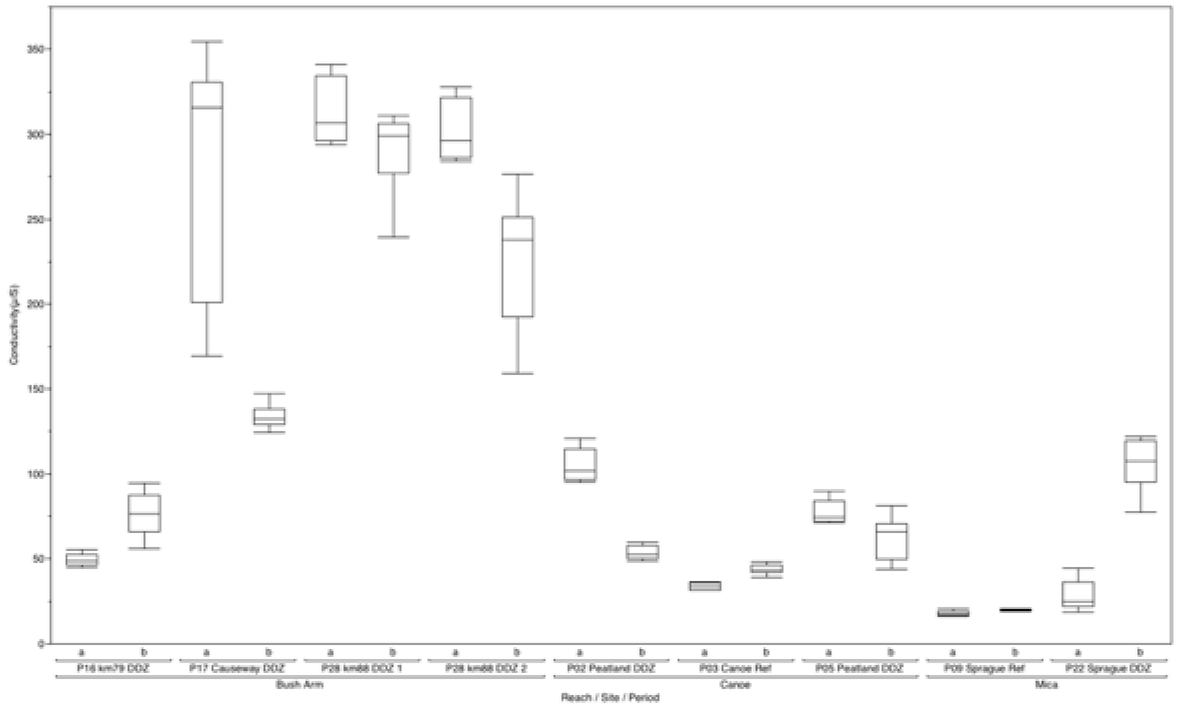

Figure 5-22: Conductivity of ponds within and adjacent Kinbasket Reservoir prior to inundation (period a: July 1 to 12, 2012) and immediately following inundation (period b: July 21 to July 31, 2012)

In addition to the results above, anomalous fluctuations in water physicochemistry were also recorded by the dataloggers. On June 24, 2012, a dramatic drop in temperature and conductivity were observed in P16 and P17 (Figure 9-11) and, after further investigation, the event was attributed to a high rainfall event resulting in an influx of cool, low-mineral water. Another unusual event occurred at P22 in Sprague Bay between July 15 to 20, 2012 (Figure 9-12). During this period the conductivity drop to zero and the daily temperature spiked to 40 ºC. Pond P22 is a small beaver pond that is positioned at 753 m ASL in the reservoir. The beaver dam likely drained or collapsed prior to inundation, exposing the datalogger to open air until Kinbasket Reservoir inundated the pond.

5.4.5 Macrophyte communities

The diversity of macrophytes in ponds sampled in the Kinbasket were low; 31 taxa were identified from the grapnel and transect sampling. The number of species detected within ponds ranged from 0 (P22) to 11 species (P29; Figure 5-23), and a mean of 4.38 (SD = 2.85) species were detected per pond. The highest number of species was recorded in Bush Arm (n = 23) followed by Canoe Reach (n= 18); only six species were document in ponds in Mica Arm (Figure 5-24). Although the numbers of species observed within the reservoir and reference ponds were similar among sites (21 and 23 species, respectively), we did not compare species diversity and evenness. Appendix 9.8 provides a list of plant species detected in the ponds sampled and describes their origin (exotic or native), habitat, and growth form.

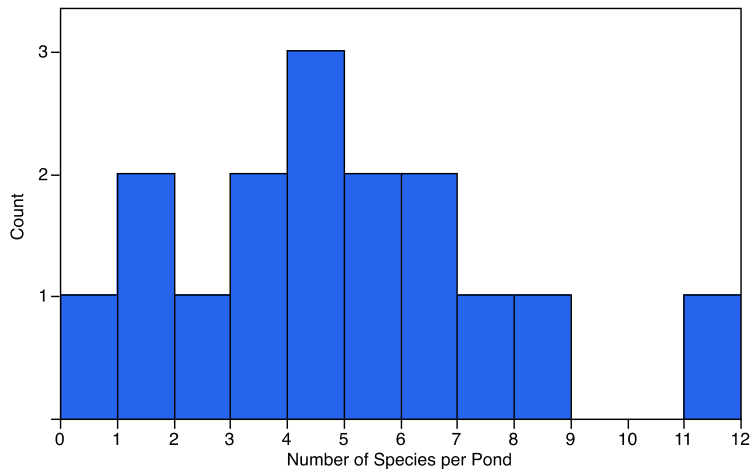

Figure 5-23: Total number of plant species detected per pond from pooled grapnel and visual quadrat data

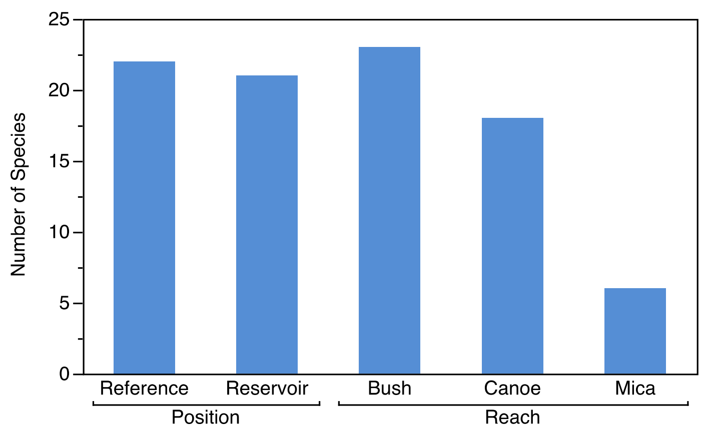

Figure 5-24: Number of plant species detected in ponds stratified by position (left) and by reach (right)

The most common species encountered were *Potamogeton pusillus* (small pondweed), *Nuphar polysepala* (Rocky Mountain Pond-lily) *Potamogeton sp.* (unidentified species), *Sparganium angustifolium* (Narrow-leaved Bur-reed), *Myriophyllum spp.* (Eurasian Water-Milfoil/Siberian Water Milfoil), and *Equisetum fluviatile* (Swamp Horsetail) (Figure 5-25). These species were wide-spread across the three reaches and occurred in ponds both within and above the reservoir. Over half of the species detected were observed in three or fewer stations. The frequency of plant species detected in ponds sampled under CLBMON-61 in 2012 is provided in Appendix 9.8.

Thirteen of the fifteen [7] aquatic wetlands sampled were typed using the classification of Mackenzie and Moran (2004) or Pierce and Jensen (2001); (Table 5-5). Despite their limitations, both classifications were applied fairly consistently across the majority of ponds sampled. Appendix 9.9 provides a brief description of the communities that were typed. These descriptions are based primarily on Mackenzie and Moran (2004), supplemented by Pierce and Jensen (2001) and our own observations.

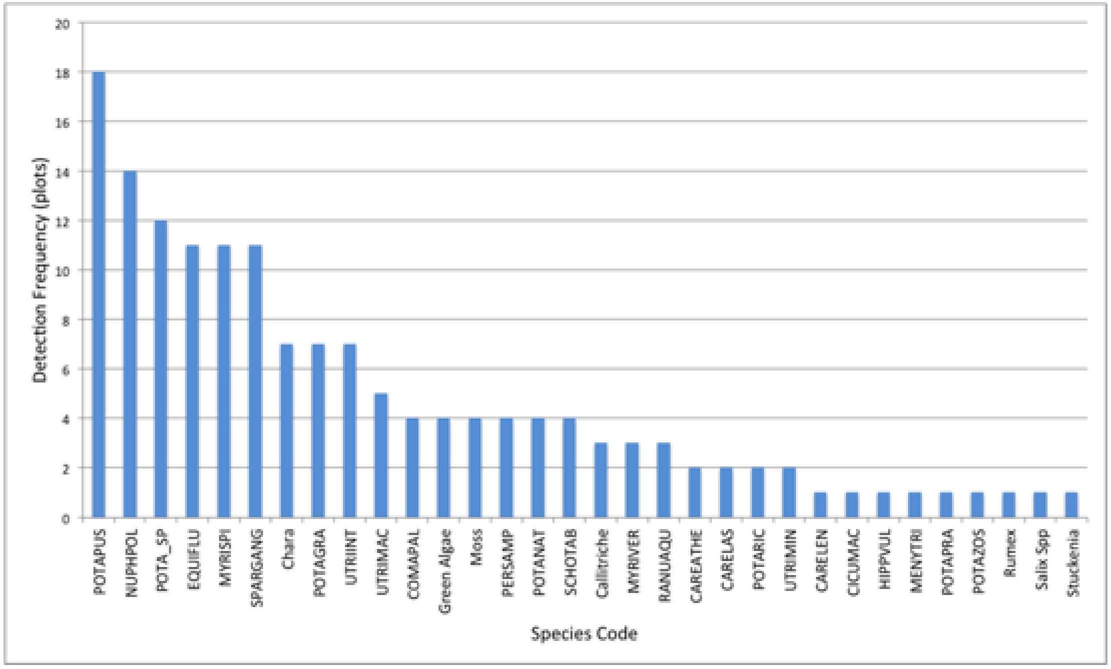

Figure 5-25: Detection frequency of wetland plants at aquatic sampling stations in 2012

Despite the preliminary nature of our assessment, water physicochemistry appeared to play a role in the distribution of macrophytes in the study area. *Chara spp.*, in particular, was detected only in Bush Arm. *Chara* is a macroalga that occurs in mineral rich alkali waters. Its distribution reflects the high mineral content of water that flows out of the Central Rockies, which are rich in calcium carbonate due to their limestone, dolomite, and shale geology. The distribution of macrophytes also appeared to be influenced by water depth and the presence of beaver activity. Beaver activity (i.e., beaver lodges and dams) was observed in 75 per cent of the ponds sampled and appeared to be an important wetland forming process in the study area (Table 5-4 and Table 5-5). Ponds associated with beaver activity tended to be deeper (Section 5.4.1) and supported floating macrophytes (e.g., *Nuphar* and *Potamogeton spp*), whereas shallow ponds tended to support emergent and submerged macrophytes (e.g., *Carex* and *Utricularia spp*).

[7] P16 could not be typed as it was inundated at the time of sampling.

Table 5-5. Classification of aquatic and semi-aquatic wetland communities from macrophyte grapnel and visual quadrat following Mackenzie and Moran (2004) and Pierce and Jensen (2002). Several ponds were represented by more than one community as indicated in brackets. Asterisks denote classification based on casual observation

Reach	Position	Pond	Species	Comment	Classification Scheme	
					Mackenzie and Moran	Pierce and Jensen
Bush	Reference	P11	Chara, POTAZOS, RANUAQU, Stuckenia	Beaver Pond, Cold Water	*(1) Chara spp. (2) Ranunculus aquatilis*	*(1) Chara spp. (2) Ranunculus aquatilis*
		P15	MYRIVER, Green Algae	Beaver Pond, Cold Water	-	*Myriophyllum* spp.
		P18	SCHOTAB, POTARIC, Chara, NUPHPOL, POTANAT	Large Lake	*(1)* Wm06 Great bulrush *(2) Nuphar lutea–Potamogeton richardsonii (3) Chara spp.*	*(1) Nuphar lutea (2) Chara spp.*
		P29	EQUIFLU, COMAPAL, CAREATHE, CARELAS, POTANAT, HIPPVUL, POTAPUS, NUPHPOL, PERSAMP, MYRIVER, CICUMAC	Beaver Pond	*(1)* Wm02 Swamp horsetail–Beaked sedge Wm06 Great bulrush *(2) Nuphar lutea–Potamogeton richardsonii*	*Nuphar lutea*
	Reservoir	P16*	POTAPUS, Chara, Moss, MYRISPI, SPARGANG, UTRIMAC	Inundated	-	-
		P28	SPARGANG, POTAPUS, RANUAQU, MYRISPI, UTRIMIN	Beaver Pond	*Ranunculus aquatilis*	*Ranunculus aquatilis*
Canoe	Reference	P03	NUPHPOL	Beaver Pond	*(1) Nuphar lutea–Potamogeton richardsonii*	*Nuphar lutea*
		P21	POTAGRA, UTRIINT, SCHOTAB, NUPHPOL, PERSAMP, POTA_SP	Large Lake	*(1)* Wm06 Great bulrush *(2) Polygonum amphibium (3*) Nuphar lutea–Potamogeton richardsonii*	*(1) Potamogeton gramineus (2) Nuphar lutea (3) Polygonum amphibium*
		P02	POTA_SP, EQUIFLU, Green Algae, COMAPAL, Salix Sp	Excavated Pond, LWD substrate, Low DO	-	-
	Reservoir	P05	NUPHPOL, POTA_SP, POTANAT, UTRIMAC, MYRISPI, PERSAMP, CARELEN, POTAGRA	Beaver Pond	*(1) Nuphar lutea–Potamogeton richardsonii (2) Nuphar lutea–Utricularia macrorhiza*	*Nuphar lutea*
		P06	MYRISPI, POTA_SP, POTAPRA	Low Elevation Pond, Ptarmigan Cr.	-	*Myriophyllum* spp.
		P19	EQUIFLU, UTRIINT, MENYTRI,	Low elevation shallow pond	Wm02 Swamp horsetail–Beaked sedge	-
		P20	SPARGANG, Callitriche, EQUIFLU, Moss	Low elevation shallow pond	-	-
Mica	Reference	P09	POTAPUS	Beaver Pond	*(1*) Nuphar lutea–Utricularia macrorhiza*	*(1) Potamogeton pusillus (2*) Nuphar lutea*
	Reservoir	P08	POTAPUS, SPARGANG, NUPHPOL, EQUIFLU, UTRIMIN, Rumex	Beaver Pond	*(1) Sparganium angustifolium (2) Nuphar lutea–Utricularia macrorhiza*	*(1) Sparganium angustifolium (2) Nuphar Lutea (3) Potamogeton pusillus*
		P22	None	Beaver Pond	*(1*) Sparganium angustifolium; (2*) Nuphar lutea–Utricularia macrorhiza*	**(1) Sparganium angustifolium *(2) Nuphar Lutea*

* grapnel sample only.

5.4.6 Macrophyte biomass

Mean pond biomass (dry weight in grams) ranged from 0.01 to 20.7 g and there were no significant differences in macrophyte biomass across reaches (F_2 = 0.98, p = 0.40) or between reservoir and references ponds (F_1 = 0.18, p = 0.68). Macrophyte biomass values were highest in P06, P11, and P2 (Figure 5-26); however, the timing of sampling across July and August may bias the data. Both ponds P29 and P11 were collected in August 23, 2012, whereas all other biomass samples except for P18 were collected between July 7^{th} and 18^{th}, 2012. In addition, the macrophyte samples.

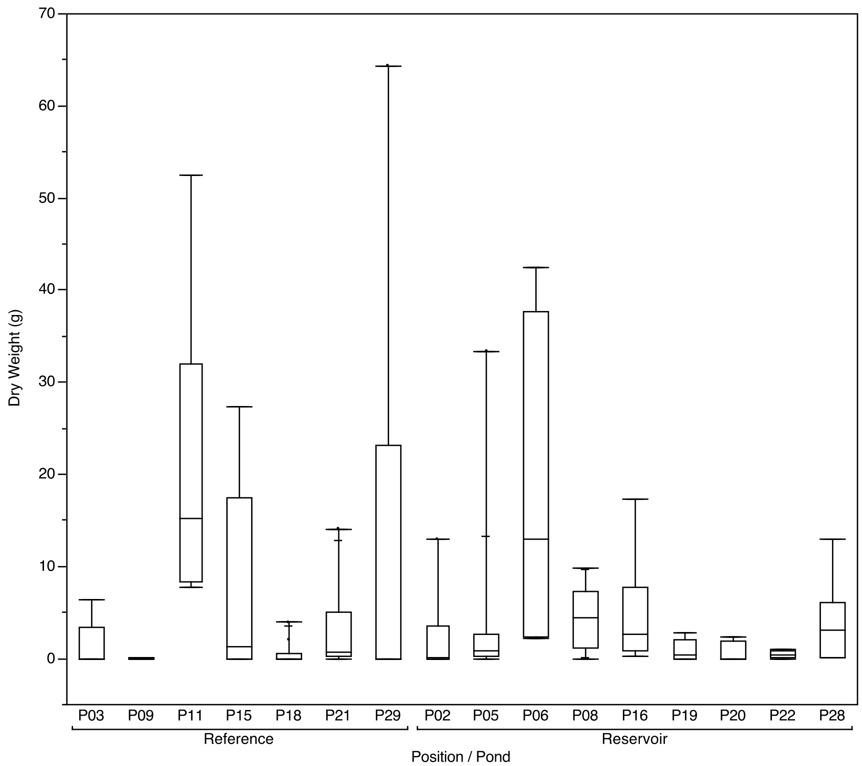

Figure 5-26: Dry weight (grams) of macrophyte biomass samples of ponds sampled in 2012

5.4.7 Pelagic Macroinvertebrates

Aquatic macroinvertebrates were sampled during July and August 2012 and data were pooled to characterize the pelagic aquatic macroinvertebrate fauna at each site. Fifty-five samples were obtained from 16 locations within and outside the reservoir (reservoir: 9 locations, 28 samples; reference: 7 locations, 27 samples; Table 5-6) resulting in an unbalanced data set.

Table 5-6: Distribution of aquatic macroinvertebrate sampling locations by reach relative to the reservoir (i.e., outside or inside)

	Drawdown Zone Sites, by Reach									Reference Sites, by Reach						
	Bush		Canoe						Mica	Bush				Canoe		Mica
	km79 DDZ pond	km88 monitoring pond2	Excavated Pond (1)	Nuphar Pond (12)	Pond 30	Pond 5	Ptarmigan Cr. Pond	Sprague Monitoring pond	Sprague Control pond	Bush FSR km40 Pond Reference Pond	Bush Lake pond reference	Esplanade Reference Pond	km79 Beaver pond reference pond	Cranberry Lake	Peatland Beaver Pond	Sprague Reference Pond
Pond Label	P16	P28	P02	P05	P20	P19	P06	P08	P22	P11	P18	P29	P15	P21	P03	P09
Plots	**1**	**3**	**3**	**7**	**3**	**3**	**3**	**3**	**2**	**3**	**5**	**4**	**2**	**7**	**3**	**3**

Nineteen taxa were documented from all ponds with six taxa occurring at ≥10 sampling locations (Table 5-7). Cladocerans (water fleas) were the most ubiquitous and generally the most abundant taxon, occurring at 15 of 16 locations sampled. Copepoda (freshwater crustaceans) occurred at 13 of 16 sites sampled and Hemiptera (true bugs) were documented at 12 sites. These three groups tend to be common and locally abundant when present and their dominance of the data set is not surprising. Cladocerans did not occur at one of the upland reference ponds in Bush Arm (km 79 Beaver Pond, P15) and it is not immediately obvious why. Temperature was lower than in most ponds (Figure 5-16), but there did not appear to be a relationship between temperature, pH, or conductivity (μS/cm) and the relative abundance of the taxa sampled in 2012 (Figure 5-27).

Table 5-7: The relative abundance (number per plot) of aquatic macroinvertebrates sampled at each pond in 2012

	Drawdown Zone Sites, by Reach									Reference Sites, by Reach							
	Bush		Canoe						Mica	Bush				Canoe		Mica	
Taxon	km79 DDZ pond	km88 monitoring pond2	Excavated Pond (1)	Nuphar Pond (12)	Pond 30	Pond 5	Ptarmigan Cr. Pond	Sprague Monitoring pond	Sprague Control pond	Bush FSR km40 Pond Reference Pond	Bush Lake pond reference	Esplanade Reference Pond	km79 Beaver pond reference pond	Cranberry Lake	Peatland Beaver Pond	Sprague Reference Pond	**Total Sites**
Acari	1.0	0.3	6.0	0.1	0.3	1.0	1.7	1.7		0.3		3.5		1.6			**11**
Amphipoda	5.0					0.3		0.3			9.2	2.5		0.3	0.3		**7**
Annelida		17.3	2.3	0.6	1.7			0.3		1.7				0.3	1.0		**8**
Anostraca				0.1													**1**
Cladocera	6.0	0.7	1548.7	13.7	9.0	62.7	6.7	3.0	9.5	2.0	3.2	87.0		102.4	24.0	0.7	**15**
Cnidaria		0.7		0.7		1.0				0.7							**4**
Coleoptera				0.1								0.3		1.1	0.3		**4**
Collembolla		1.7		0.1		4.3		0.3	1.5	0.3		0.3	1.0	0.4	0.7		**10**
Conchostraca			2.0	0.1		5.3								0.4	0.3		**5**
Copepoda		0.7	6.3	33.4	5.7	14.3	4.7		2.0	2.0	27.6	52.3		60.3	14.3	2.0	**13**
Ephemeroptera		9.0	1.7			2.7		1.0		3.0		18.5	0.5	9.4	2.0		**9**
Hemiptera	7.0	0.7	6.3	1.1		1.7		0.7	1.5	0.3		2.3	1.0	4.1	3.7		**12**
Hymenoptera															0.3		**1**
Megaloptera												0.3					**1**
Mollusca		0.7		0.6		1.3	1.7			3.0		3.8		0.7			**7**
Odonata		1.3	0.3	0.4		2.7				0.7		34.8		1.9			**7**
Ostracoda	5.0	1.7	4.7			6.7		1.7	2.5	0.3		59.0		1.0	2.7		**10**
Pelecypoda															0.3		**1**
Trichoptera						0.3				1.0		0.5		0.3	0.3	0.3	**6**
Taxa per Location	**5**	**11**	**9**	**12**	**4**	**13**	**4**	**8**	**5**	**12**	**3**	**13**	**3**	**14**	**13**	**3**	

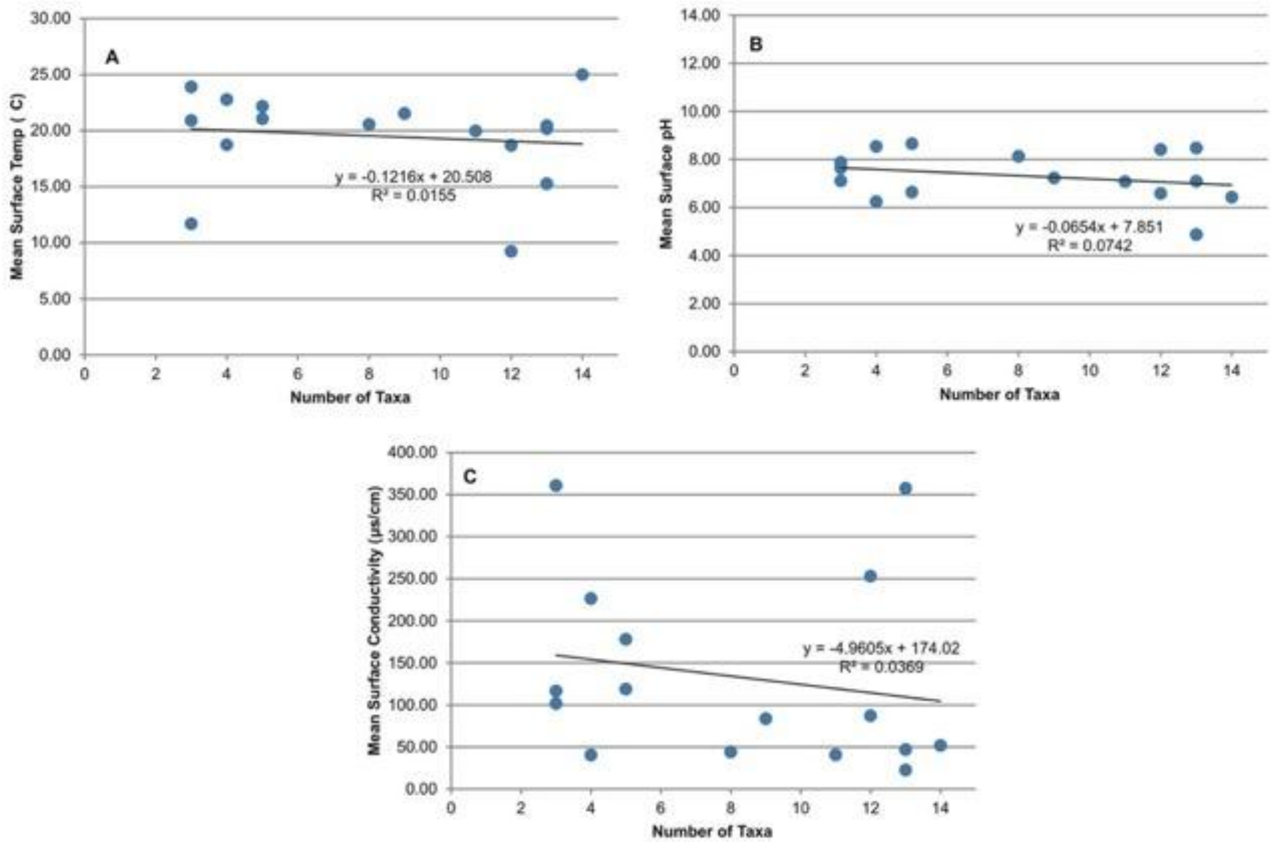

Figure 5-27: The number of taxa relative to the mean surface temperature (°C) (A), pH (B), and conductivity (µS/cm, C) measured at a depth of 10 cm at each location sampled in 2012

Rare taxa included Hymenoptera (sawflies, wasps, bees, and ants), Megaloptera (fishflies, alderflies and dobsonflies), and Pelecypoda (bivalves), with each documented from only one location. These taxa are either not considered to be sensitive to habitat changes (Hymenoptera), may be more abundant in productive ponds (Megaloptera), or are not typically associated with the water column (Pelecypoda). As such, their relative rarity is not of immediate concern, but future sampling is suggested to determine the distribution and occurrence of these taxa. Particular attention should be paid to Megaloptera, which may be a suitable indicator of productivity (see below).

In almost all cases the relative abundance of taxa did not differ significantly between the reservoir and upland ponds sampled (Table 5-8). The one exception was Trichoptera (caddisflies), which were more abundant in reference ponds than in ponds in the reservoir ($t = -2.42$; $P = 0.03$). Sample size may have influenced some of these results, particularly for taxa documented from < 10 sites (Table 5-7). The reduced level of effort associated within the reservoir in 2012 must also be considered when assessing habitat-related differences.

Table 5-8: Results of MANOVA examining the effect of pond location (within the reservoir or in reference ponds) on the relative abundance (number per plot) of arthropod families.

Taxon	t	*P*	Taxon	t	*P*
Acari	0.6000	0.556	Ephemeroptera	-1.2600	0.228
Amphipoda	-0.8900	0.388	Hemiptera	0.4100	0.687
Annelida	0.9400	0.365	Hymenoptera	-1.1500	0.271
Anostraca	0.8700	0.396	Megaloptera	-1.1500	0.271
Cladocera	0.7800	0.448	Mollusca	-1.0300	0.321
Cnidaria	0.9300	0.370	Odonata	-1.1200	0.283
Coleoptera	-1.6700	0.117	Ostracoda	-0.9000	0.383
Collembolla	0.9500	0.359	Pelecypoda	-1.1500	0.271
Conchostraca	1.0400	0.317	Trichoptera	-2.4200	**0.030**
Copepoda	-1.7200	0.108			

Species richness, diversity, and evenness varied among sites and between habitats (reservoir and upland) and by reach (Table 5-9). Species richness (the number of taxa) ranged from a low of three at several reference sites to a maximum of 14, also at reference sites (Table 5-9). In general, the number of taxa documented from reservoir ponds did not differ from upland ponds with the exception of Canoe Reach, where the number of taxa was lower in the reservoir ponds than in the reference ponds (p = 0.06). Differences in diversity and evenness values among reaches were not statistically significant (Table 5-10)

Table 5-9: Species richness (q), diversity (H'), and evenness (J) calculated for the aquatic macroinvertebrate taxa detected in each sampling location in 2012. *N* refers to sample size

		Sample Location	*N*	q	H'	J
Drawdown Zone Sites, by Reach	**Bush**	P16 km79 DDZ pond	1	5	0.65	0.93
		P18 km88 monitoring pond	3	11	0.67	0.64
	Canoe	P02 Excavated Pond (1)	3	9	0.06	0.06
		P05 Nuphar Pond (12)	7	12	0.43	0.40
		P19 Peatland Pond (30)	3	4	0.44	0.73
		P20 Peatland Pond (5)	3	13	0.64	0.57
		P06 Ptarmigan Cr. Pond	3	4	0.53	0.88
	Mica	P08 Sprague Monitoring pond	3	8	0.78	0.86
		P22 Sprague Control pond	2	5	0.56	0.80
Reference Sites, by Reach	**Bush**	P11 Bush km40 Reference Pond	3	12	0.95	0.88
		P18 Bush Lake reference	5	3	0.35	0.72
		P29 Esplanade Reference Pond	4	13	0.74	0.67
		P15 km79 Beaver pond reference	2	3	0.46	0.96
	Canoe	P21 Cranberry Lake	7	14	0.50	0.44
		P03 Peatland Beaver Pond	3	13	0.66	0.59
	Mica	P09 Sprague Reference Pond	3	3	0.37	0.77

Table 5-10: Results of t-tests (*P*-values) assessing differences in species richness (q),

diversity (H’). and evenness (J) calculated for the aquatic macroinvertebrate taxa detected in each sampling location in 2012. *N* refers to sample size; values are *P*-values of a one-way analysis of species richness (q), diversity (H’). and evenness (J) assuming unequal variance for each reach. Small sample size associated with Mica precluded statistical analyses

	Reach			
Index	**Bush**	**Canoe**	**Mica**	**Pooled**
Richness, q	0.96	0.055	.	0.73
Diversity, H'	0.82	0.27	.	0.67
Evenness, J	0.90	0.94	.	0.57

Of the 19 taxa documented, six (Amphipoda, Ephemeroptera, Megaloptera, Odonata, Pelecypoda, and Trichoptera) are known to be sensitive or moderately sensitive to habitat changes[8] including changes in dissolved oxygen and turbidity, both of which are likely to result from the installation of Mica 5/6. These taxa were either rare in the 2012 sample or not present in all sites sampled. The sensitivity of these taxa to habitat change may make one or more of them a suitable indicator regarding the effects of Mica 5/6 on secondary productivity. As discussed above, the Pelecypoda are not typically associated with the water column.

Table 5-11: Distribution and relative abundance (number per plot) of taxa moderately sensitive (MS) or sensitive (S) to habitat change in 2012

	Drawdown Zone Sites, by Reach									Reference Sites, by Reach							
	Bush		Canoe					Mica		Bush				Canoe		Mica	
Taxon	km79 DDZ pond	km88 monitoring pond2	Excavated Pond (1)	Nuphar Pond (12)	Pond 30	Pond 5	Ptarmigan Cr. Pond	Sprague Monitoring pond	Sprague Control pond	Bush FSR km40 Pond Reference Pond	Bush Lake pond reference	Esplanade Reference Pond	km79 Beaver pond reference pond	Cranberry Lake	Peatland Beaver Pond	Sprague Reference Pond	Total Sites
Amphipoda (MS)	5.0					0.3		0.3			9.2	2.5		0.3	0.3		7
Ephemeroptera (S)		9.0	1.7			2.7		1.0		3.0		18.5	0.5	9.4	2.0		9
Megaloptera (S)												0.3					1
Odonata (MS)		1.3	0.3	0.4		2.7				0.7		34.8		1.9			7
Pelecypoda (MS)															0.3		1
Trichoptera (S)						0.3				1.0		0.5		0.3	0.3	0.3	6

Of the six moderately sensitive or sensitive taxa documented in 2012, Odonata, Megaloptera, and Ephemeroptera may be suitable indicators of habitat change or productivity. This is based on their (1) relative ease of identification (e.g., Odonata vs. Amphipoda, which can be difficult to distinguish at the family level), (2) association with relatively stable environments (Megaloptera larvae pupate under rocks and logs near wetland or pond shorelines, so changes to the structure of these habitats is likely to impact this taxon), or (3) their propensity to spend several years as aquatic insects (Ephemeroptera), necessitating stable and suitable conditions to persist. The utility of one or all of these taxa as indicators of habitat change or productivity will be explored in future years.

[8] Taxonomic sensitivity from http://lakes.chebucto.org/ZOOBENTH/BENTHOS/tolerance.html

6.0 DISCUSSION

The objectives of Year 1 of CLBMON-61 were to:

a) provide a general description of wetlands in the upper elevation of Kinbasket Reservoir;

b) describe and justify the methods used to select index sites for monitoring; and,

c) review the study approach and methods (both field and analytical) to ensure they are appropriate for addressing the management questions and hypotheses.

In undertaking the site review, the need to differentiate between terrestrial and aquatic wetlands was apparent. From an ecological perspective, standing water favours plants that are specially adapted to an aquatic environment and the communities that establish in a permanent aquatic environment are markedly different from those occur on saturated or even seasonally flooded sites (Cronk and Fennessy 2001). From a sampling perspective, standing water requires techniques that are more typical of limnological studies such as sediment and water physicochemistry sampling. Conveniently, we found the distinction of aquatic and terrestrial wetland types to correspond favourably to the existing classifications (Warner and Rubec 1997; Mackenzie and Moran 2004; Pierce and Jensen 2001), and we recommend continuing this dichotomy for classifying and sampling wetlands in future years.

6.1 Terrestrial Wetlands

Unusually high reservoir levels in 2012 allowed for only a partial sampling of wetlands within the reservoir before they were inundated. While this limited our ability to compare wetland vegetation across elevation bands, we were able to provide a preliminary characterization of the wetland communities likely to be encountered within each of the four focal sampling strata. Lower control wetlands and target wetlands tended to be either Willow–Sedge (WS) communities or Swamp Horsetail (SH) communities (using the classification of Hawkes et al. [2007]). Upper control wetlands were either WS communities (Hawkes et al. 2007) or flood associations (MacKenzie and Moran 2004). Reference wetlands included both fen and swamp associations with an occasionally prominent deciduous shrub component. In contrast to most communities in the reservoir, these could generally be typed using the provincial wetland classification of MacKenzie and Moran (2004).

Species richness and diversity tended to decrease with elevation, likely reflecting the reduced habitat stability within the reservoir, although neither measure was necessarily greater in wetlands above the reservoir than in the highest elevation bands within the reservoir. The most diverse band was the upper control elevation band, which interestingly, also tends to have the lowest overall plant cover. This elevation band spans the normal operating maximum of the reservoir (754.38 m ASL) and as such occupies a transitional zone between the reservoir and adjacent upland habitats. In most years, this elevation band is not affected by reservoir operations, but in some years (e.g., 2010, 2012) it is. The periodic but irregular disturbance regime (by inundation) within this band may be acting to slow the process of habitat saturation by individual species while maintaining sufficient open habitat niches for a diversity of species and growth forms to become established.

In contrast, the target wetlands, which occupy the next lower elevation band (753-754 m ASL), appear to be more highly saturated communities with an herbaceous cover exceeding 80 per cent in places. The plant cover of some of these wetlands also tends to be dominated by a single species (often Buckbean), suggesting that interspecific competition is high.

A prominent feature of wetlands in the target elevation is the high cover of horsetails, which are second only to perennial forbs in their contribution to total cover. The most abundant horsetail, Swamp Horsetail (*Equisetum fluviatile*), is an obligate hydrophyte occurring in shallow water at margins of water bodies and in marshes, bogs, and wet ditches. Its relative abundance in the target wetland habitats speaks to the highly saturated conditions that generally prevail on these flat, poorly drained and often somewhat topographically depressed sites. In contrast, the upper control wetlands, which lie just one metre in elevation above the target wetlands, have only a modest cover of horsetails but a far greater predominance of woody deciduous shrubs, reflecting the lower inundation frequency at this elevation. Higher shrub cover could also suggest that soil conditions are in general less hydric and/or the ground surface is more varied, with more raised hummocks suitable for woody shrub establishment and survival at the latter elevation.

The annual flooding regime in recent years has been somewhat anomalous compared to the half decade previous, in that there have been four full pool or near full pool events since 2007, whereas prior to 2007 there had been no full pool event for eight years (Hawkes et al. 2013). The most recent full pool event, in 2012, exceeded the normal operating maximum for several weeks, the first time this had occurred since 1997. Following the 2007 full pool event, there was a notable die-off of woody shrubs in reservoir wetland communities such as the WS (Hawkes et al. 2010), a trend in declining shrub cover that has likely been exacerbated by high water events in 2010, 2011, and 2012 (Hawkes et al. 2013). Any comparison of vegetation cover and composition (and particularly of shrub cover and composition) both among wetland communities and across elevation bands thus needs to take these recent events into account. For example, the perceived differences in shrub cover noted above between target and upper control wetlands could be an artefact of recent flooding events and may not accurately reflect the vegetation structure existing in years prior. Nevertheless, based on the above observations, we can offer some preliminary predictions about the impact that operational changes associated with the introduction of Mica Units 5 & 6 could have on target wetland communities.

We anticipate that as the frequency of annual flooding increases at the 753-754 m ASL elevation band, the wetland communities at this elevation will, over time, come to resemble communities presently found in the adjacent lower elevation bands. For existing SH (Swamp Horsetail) wetlands, a shift toward a lower community type could entail little actual change since SH communities are widespread already at lower elevations and thus can presumably tolerate more prolonged and frequent inundation. However, although a more frequent cycle of inundation may not be sufficient mechanism to bring about a state shift in these wetlands, we predict a drop in species diversity and possibly in evenness as some hydrophytic species (such as Buckbean and Swamp Horsetail), that are better suited to the altered conditions, begin to out-compete some of the less adapted terrestrial species. Likewise, the shrub component that currently makes up part of the SH association at this elevation will likely be reduced due to the increased flooding, and may even be eliminated over time.

The target wetland (Willow–Sedge) community at Km 88 (Bush Arm) provides a good subject for monitoring impacts from the implementation of Mica Units 5 & 6 to an existing open shrub habitat. We predict that this wetland community will be substantially altered over time by a higher annual flooding regime; willows and other woody shrubs, along with some terrestrial herbs, are likely to be knocked back from their current levels under the new regime, while obligate hydrophytes such as Buckbean, Water Sedge, and Common Cattail are likely to increase. As there are currently a number of hydrophytes already established at this site, reducing the likelihood of a major state shift to a completely different ecosystem, the transition to a new community type will likely be subtle and gradual.

Given the small samples sizes and lack of replication in 2012, in the next implementation year we will strive to establish additional replicate transects at the index sites to increase our power to detect changes.

6.2 Aquatic Wetlands

Twelve distinct aquatic communities were identified within or adjacent the reservoir using the classifications of MacKenzie and Moran (2004) and Pierce and Jensen (2001). Factors that appear to influence the distribution of macrophyte communities include hydrology (e.g., water depth), pH, conductivity, the accumulation of organics, and reservoir elevation; however, the relationships were not explicitly tested.

Water depth influences the distribution of aquatic plants by limiting light availability, which in turn is influenced by water colour and turbidity (Lacoul and Freedman 2006). As water transparency decreases or as depth increases, the amount of light available for photosynthesis diminishes until plant growth is no longer supported. The ability of macrophyte to survive under low light conditions is reflected in their growth forms. In shallow waters, emergent species dominate often as expansive monocultures (e.g., *Typha sp*., and *Schoenoplectus sp*.), while in deeper water submerged and floating communities occur that are typically species poor – thus, distinct macrophyte communities occur across a gradient of water depths and these communities are typically dominated by a few prominent species.

The pattern of low macrophyte diversity occurring across a depth gradient was prevalent in many ponds. Examples of this were observed in several of reference ponds (P18, P21, and P29) where the communities transitioned from upland communities, to flood tolerant emergent communities (i.e., *Schoenoplectus*), and then to deeper water pond communities (i.e., *Nuphar lutea–Potamogeton richardsonii*). In ponds within the reservoir, the transition from terrestrial wetlands to pond communities appeared to be more abrupt (P05, P06, and P18) as the flood tolerant emergent communities were reduced or absent (with exception of the Swamp Horsetail community). This suggests that the diversity of wetland communities that occur across the hydrological gradient may provide a potential measure of wetland integrity.

6.3 Wood Debris

Data collected on pond sediment indicated higher amounts of wood debris in the substrate of ponds within the reservoir than in reference ponds. These results are not surprising given the large amount of wood debris that accumulates along the shoreline of Kinbasket Reservoir (Figure 5-15). The accumulation of wood debris can be detrimental to wetlands for several reasons. First, wood debris displaces existing terrestrial and aquatic vegetation as it accumulates over time affecting the surface and the bottom of ponds. Second, vertical and lateral movement of large wood debris due to fluctuating water levels can cause mechanical damage to established vegetation. Third, the leachate from the large accumulations of wood material can be highly coloured, acidic, of very high oxygen demand, and toxic to aquatic life (Tao 2005).

Following the installation of Mica units 5 and 6, the frequency of inundation within the target elevation range is predicted to increase. A parallel increase in the accumulation of wood debris in wetlands (both aquatic and terrestrial) in the target elevation band is therefore expected. Consequently, future monitoring should include monitoring of wood debris accumulation in the upper elevation bands using a combination of GIS and ground surveys.

6.4 Water Physicochemistry

Water physicochemistry differed across the study area underscoring the need to stratify the study area by reach. Differences in pH and conductivity observed among wetlands across the study area likely reflect differences in regional geology and wetland biogeochemical processes. The high pH ($\bar{x}$ = 8.2) and conductivity ($\bar{x}$ = 266.7 μS/cm) values observed in Bush Arm reflect its location in the Central Park Ranges of the Canadian Rockies, which are composed primarily of limestone, dolomite, and shale (Holland and Coen 1982; Wittneben and Lacelle 1986). As limestone erodes, calcium carbonate and minerals are released into solution increasing both the conductivity and pH. In contrast, low pH ($\bar{x}$ = 6.1) and conductivity ($\bar{x}$ = 34.9 μS/cm) values were observed in the Sprague Bay wetlands. Sprague Bay is located in the Selkirk Mountains, which are igneous and metamorphic in origin (Perkins 1983) and lack the calcium carbonate and minerals present in sedimentary limestone. The moderate pH ($\bar{x}$ = 7.2) and conductivity (89.2 μS/cm) values observed in Canoe Reach, which lies in the Rocky Mountain Trench between the Monashee and Rocky Mountains, likely reflects the influence of both mountain ranges on surficial geology with calcareous materials originating from till and outwash from the Rockies and non-calcareous clastic materials from the Monashees (Gadd 1995).

Inundation by the reservoir appeared to have only a limited impact on water physicochemistry; however, interpreting the continuous data was hampered by equipment failure, stochastic events, and a small sample size. To this end, all equipment should be tested rigorously prior to deployment. Setting up remote cameras at each pond would help identify stochastic events such as those observed in 2012 and would be useful in determining the timing of inundation – currently this has to be estimated using the DEM and reservoir levels at Mica Dam. In addition, remote weather stations in each reach would be helpful in correlating the water physicochemistry data to local weather events. Unfortunately, due to the limited number of aquatic wetlands in the upper elevation of Kinbasket reservoir, increasing the sample size is not feasible.

6.5 Primary Productivity

Our results did not reveal differences in macrophyte biomass between ponds within the reservoir and reference ponds. This is likely due to the small sample size, which reflects the limited number and types of ponds available for sampling (both within and adjacent the reservoir). Most of the reference ponds sampled were deeper beaver ponds, bog-like fens, or oligotrophic shallow lakes, which limits the type of vegetation that can establish (e.g., *Potamogeton spp.* and *Nuphar*). While these ponds can have low primary productivity relative to shallow ponds, which are typically characterized by communities of submergent and emergent macrophytes, they still perform essential ecological services by supporting wildlife and rare plants or function as storage sites for water and peat (Warner and Rubec 1997; Conk and Fennessy 2001). Hence, primary productivity may not be a good indicator of wetland integrity although positive or negative changes in wetland productivity can be indicative of ecological stress (Conk and Fennessy 2001). Consequently, we recommend that primary productivity be monitored as a state variable for indicating ecological stress rather than a measure of ecological integrity. In monitoring primary productivity as a state variable, either a decrease or increase in productivity would be interpreted as a negative impact.

One of the challenges in obtaining macrophyte biomass samples was using the grapnel sampler. We found that its effectiveness was greatly influenced by operator skill and water depth. The procedure entails dragging the grapnel along the bottom for approximately 1-meter, and in deep water (> 1.5 m) it can be difficult to estimate a 1 m interval. Another drawback of the method is that its effectiveness is also dependent on plant morphology and growth form. Species with floating leaves and long stems (e.g., *Nuphar* and *Potamogeton spp*.) are often missed in the sample while submerged filamentous species such as *Ranunculus aquatilis, Myriophyllum spp*, and *Chara spp* are more readily collected in the tines of the grapnel. The most effective method for sampling macrophytes is using SCUBA (Cronk and Fennessy 2001; Pierce and Jensen 2001); however, given the remoteness of the study area and safety considerations SCUBA not practical.

An alternative measure for primary productivity can be obtained from diurnal changes in dissolved oxygen concentrations (Odum 1956). This approach is based on the fact that oxygen is released into the water through photosynthesis during the day and is consumed through autotrophic and heterophytic respiration. Notwithstanding the issues we had with the dissolved oxygen dataloggers, net primary production can be estimated from continuous dissolved oxygen data using (1) rates of change in oxygen concentrations during the daytime as a measure gross of production and (2) hourly rate of respiration as determined from oxygen decrease during the night. Thus, net primary production is the difference between gross production and community respiration.

6.6 Secondary Productivity

Aquatic macroinvertebrates are commonly utilized as indicators of environmental change, particularly those that are known to be sensitive to changes in the physical or chemical attributes of their preferred habitats. There are many advantages to using macroinvertebrates to monitor the status or change of ecosystems. In particular, they are excellent indicators of site-specific conditions and because of their long lifecycles they can illustrate the history of water quality issues or extent of a disturbance. Aquatic macroinvertebrates are generally ubiquitous in freshwater ecosystems, can be long-lived (i.e., live 3 to 5 years), encompass a broad range of niches and provide a primary food source for other animals such as fish. The popularity of using macroinvertebrates to monitor water quality trends over time is due to the understanding that this method surpasses traditional water chemical tests and capabilities (Gaufin 1973). The change in the abundance, presence and even morphology of sensitive organisms combined with the presence and abundance of tolerant organisms may be indicative of habitat change.

The installation of Mica 5/6 is not likely to change the aquatic macroinvertebrate fauna from one dominated by shredders and lotic filter feeders, grazers and predators to herbivores and lentic filter feeders and predators (as per Rosenburg 1998)–this change is likely to have happened already (given that Kinbasket Reservoir was created in 1976). However, there are likely to be measurable changes in the presence, abundance, and distribution of the aquatic macroinvertebrate fauna that will be influenced by the installation of Mica 5/6.

Anticipated changes to the drawdown zone includes changes associated with sedimentation and erosion, increased deposition of wood debris, changes to the macrophyte communities (which will influence aquatic macroinvertebrates), and changes to the physicochemical properties of drawdown zone wetlands. These changes are likely to interact to affect the productivity of wetlands in the drawdown of Kinbasket Reservoir.

6.6.1 Pelagic Macroinvertebrates

Of the aquatic macroinvertebrate taxa sampled, six appear to be suitable candidates as focal species. These taxa include Trichoptera (Caddisflies), Ephemeroptera (Mayflies), Megaloptera (Fishflies, Alderflies and Dobsonflies), Odonata (Dragonflies and Damselflies), Amphipoda (Scuds) and Pelecypoda/Bivalves (Clams). Of these, Odonata, Megaloptera, and Ephemeroptera may be suitable indicators of habitat change or productivity. This is based on their (1) relative ease of identification (e.g., Odonata vs. Amphipoda, which can be difficult to distinguish at the family level), (2) association with relatively stable environments (Megaloptera larvae pupate under rocks and logs near wetland or pond shorelines, so changes to the structure of these habitats is likely to impact this taxon), or (3) their propensity to spend several years as aquatic insects (Ephemeroptera), necessitating stable and suitable conditions to persist.

The following section provides a brief overview of each taxa and the rationale for considering the taxa as a possible indicator of wetland productivity.

Trichoptera (Caddisflies)

These holometabolous insects are closely related to and resemble moths. Adults have “hairy wings”(trichoptera=hairy wing) instead of the scales that moths posses. Almost all larvae are aquatic, have a single pair of hooks on a single pair of prolegs at the end of the body, produce silk and build cases armoured with found materials instead of cocoons. Larvae of this diverse family are common on substrate in all types of streams and rivers but some species are associated with cold flowing rivers and streams and are restricted to these habitats, such as members of the family Rhyacophilidae (Mandaville 2002). This family is very important to biomonitoring programs as certain species are susceptible to environmental disturbances. Caddisflies were documented from one reservoir location in 2012 (Table 5-11). Additional sampling within the reservoir is required before selecting the Trichoptera as a focal taxon with which to assess habitat changes associated with the installation of Mica 5/6.

Given the fairly specific habitat associations of this group, changes to water temperature, dissolved oxygen, flow rates, and sedimentation could combine to generate negative effects.

Ephemeroptera (Mayflies)

Adult Mayflies are ephemeral, they do not possess functional mouth parts and may live for less than a day. Adults exhibit synchronized emergence, reproduce then die. Mayfly larvae are hemimetabolous and may spend several years as aquatic insects. They are distinguished from similar looking stonefly or dragonfly larvae by abdominal gills, which can be covered by flaps or a carapace. They also have a single claw on the end of their hind leg while stoneflies have two (Marshall 2006). Larvae are typically grouped by behaviour (e.g. burrowing, creeping, swimming or flattened), feeding method (e.g., collecting-gather, scraping, shredding) and habitat requirements (Needham 1996). Their prolonged aquatic phase suggests that this group could be monitored for several years.

Changes in the presence or abundance of Mayflies, if correlated with changes in the physical or chemical attributes of the wetlands sampled resulting from the installation of Mica 5/6 may be indicative of an adverse impact on wetland productivity.

Megaloptera (Fishflies, Alderflies and Dobsonflies)

Megaloptera larvae are the largest aquatic insects and are easily recognized by large wings, short mandibles and many thin tapered gills. Larvae of the family Corydalidae (Dobsonflies and Fishflies) are commonly referred to as hellgrammites. Members of the Corydalidae are predacious and live in clear water (Mandaville 2002) and referred to as either clingers or climbers. The larvae of Sialidae (Alderflies) are similar to hellgrammites except they appear to have a tapered ‘tail’ (Marshall 2006), are generally smaller, live in more turbid water and are classified as burrowers. Their lifecycle is between 2-5 years with most of the time spent underwater as larvae. Larvae pupate under rocks and logs near the shoreline (Marshall, 2006). The adults are sexually dimorphic with males possessing very large exaggerated mandibles. Females lay eggs on emergent vegetation. Both families are intolerant of pollution (Mandaville 2002) but may occur in a variety of habitats from well oxygenated rivers to productive ponds. *Salis* spp. are considered to be more tolerant than the corydalids but cannot tolerate extremes.

Changes to water temperature, turbidity, and alterations to the flora of wetlands in the drawdown zone that are related to increased reservoir elevations and woody debris accumulation are likely to negatively affect the Megaloptera.

Odonata (Dragonflies and Damselflies)

The Odonata are split into two sub-orders Anisoptera (Dragonflies) and Zygoptera (Damselflies) although it is not uncommon to refer to the whole order as dragonflies. All life stages are predaceous and the order is named after the nymphs unique jaw structure (Odona=toothed jaws). They have a hemimetabolous lifecycle where most of their lifecycle is spent under water as a nymph with only a portion as an adult. Adult dragonflies are unique when compared to other orders in that they can migrate and may live several years as adults. One of the ways that the two families differ as nymphs (larvae) is that damselflies are generally narrow with three gill lamellae off the tip of the abdomen while anisopterans are bulky and retain the gills internally and need to expand and contract their abdomen to push water over the gills (Marshall 2006).

They are sensitive and easily observed indicators of water quality (Marshall, 2006). Most spend at least a year in the nymphal stage before emerging.

Presently, the study method proposed (pelagic sweeps) is not optimal for sampling these taxa. The sampling methodology should be reassessed to sample specifically for the proposed indicator taxa.

6.6.2 Benthic Macroinvertebrates

No data were obtained from the benthic macroinvertebrate samples. In hindsight, this is not unexpected since the substrate of many of ponds sampled had a deep layer of organic anoxic muck often in excess of 1–meter. As most macroinvertebrates are highly sensitive to dissolved oxygen and low-dissolved oxygen concentrations (<3 mg/l) are known to limit aquatic invertebrate life (Davis 1975; Tarr et al 2005), few invertebrate are likely to be present in most of the ponds sampled.

Sampling macroinvertebrates was proposed as a measure of wetland productivity and integrity; however, both the lack of data obtained as well as the life requirements of benthic invertebrates suggests that future sampling should be re-evaluated. Sorting benthic samples is labour intensive and expensive and there are likely more appropriate and cost effective methods for assessing secondary productivity (e.g., pelagic invertebrates, bird use, and amphibian use).

6.7 Study Design

The main purpose of this monitoring program is to determine the impacts on wetland integrity (i.e., wetland composition and productivity) in the upper elevations of Kinbasket Reservoir stemming from the installation of Mica Units 5 and 6. A modified-BACI design was prescribed with two years of pre-impact monitoring and three years of post-impact monitoring (BC Hydro 2012). Temporal replication is achieved by monitoring before and after the installation of the new turbines and spatial replication is achieved by sampling at multiple sites throughout the reservoir. Moreover, sampling at 1m above and 1m below the target elevation band and at reference sites outside Kinbasket Reservoir will help control for natural variability. Further, stratifying across elevation bands within the reservoir will enable us to test the assumption that the impacts, if any, are restricted to the 752–753 m ASL elevation band.

A primary limitation of the study design is the BACI approach prescribed that calls for two years of pre-impact monitoring to establish a baseline based on the "normal" operating regime of the reservoir. Unfortunately, the "normal" operating regime was altered during the first year of the study due to a high snow pack from the previous winter and a seven-month shutdown of the turbines to allow for work on the gas insulated switchgear in preparation of the new turbines. In 2012, Kinbasket Reservoir was surcharged to an elevation of 754.68 m ASL, which was 3.9 m higher than the mean maximum levels and the highest levels observed since the reservoir was first filled in 1975. The implication of the high reservoir levels is problematic because (1) the magnitude of the surcharge is substantially greater (3.9 meters) than the impact predicted following the installation of Mica 5 and 6 (0.6 m), and (2) reservoir levels hampered the collection of data. Sites within the reservoir were inundated more quickly than anticipated and access to some sites was not feasible.

Based on the observations made by Hawkes et al (2010), the high water levels in 2012 will likely affect wetland vegetation, which may confound our ability to detect impacts following the BACI design. Because reservoir levels were altered during the pre-treatment period, establishing a baseline from normal reservoir operations will not be possible prior to Mica 5 coming on line. To mitigate for this, a long term annual monitoring program will be required.

A second limitation of the BACI approach is the limited timeframe for post-impact monitoring. Notably, the GOM predicted that the impacts would only occur every three years in ten; however, monitoring is scheduled to occur in only three years post-impact. Thus, the time frame for the CLBMON-61 study will not be long enough to determine if there are impacts. Consequently, annual monitoring is recommended for 10-year period following the installation of Mia 5 and 6. This should allow for sufficient time to assess the impacts of Mica 5 and 6 as predicted by the GOM model as well as address the lack of pre-impact data as required under a BACI.

6.8 Index Sites

In total, 25 aquatic wetland and 50 terrestrial wetland sites were identified for sampling in 2012. Despite only sampling a subset of these sites, sufficient data were collected to characterize wetlands in and adjacent Kinbasket Reservoir. In future years, we recommend focusing the *in situ* monitoring to just four index sites:

1. The central portion of the Valemount Peatland (Figure 6-1);
2. Sprague Bay wetlands (Figure 6-2);
3. km88 wetland complex in Bush Arm (Figure 6-3);
4. Bush River Causeway wetland complex (Figure 6-4)

These sites are recommended as they represent both the geographic distribution of wetlands across the study area and the broad range of environmental conditions under which they occur. Aside from being widely spread across the study area, the vegetation communities in Canoe Reach, Mica Arm, and Bush Arm appear to be influenced by the surficial geology providing a natural form of stratification at the landscape level.

A second reason for focusing on these sites is that both the aquatic and terrestrial wetland types occur at each site and suitable references for both wetland types occur nearby. This will facilitate more efficient sampling. Another feature of these sites is that they occur across a relatively low elevation gradient. This is beneficial, as it will facilitate more intensive sampling (i.e., more transects) in the terrestrial wetlands within each elevation band since the available habitat within the elevation bands increases as the gradient decreases. In addition to the physical characteristics, all the index sites were sampled in 2012 minimizing the loss of data that would occur if new sites were proposed. Terrestrial sampling occurred at each site except Sprague Bay and most of the aquatic wetlands were sampled.

Finally, sampling at these locations will reduce the need to extrapolate potential impacts to other high value wetland habitats as these sites have some of the highest wildlife value in the reservoir (Hawkes et al 2012, van Oort 2012). While km79 in Bush Arm also shares many of these same features, we feel that establishing index sites at km88 and the Bush Arm causeway captures a higher diversity of wetland types than would be achieved by sampling km79 in lieu of either km88 or the causeway. In limiting the number of sample sites to four, we will be able to sample these more intensively than would be possible with the additional of another index site.

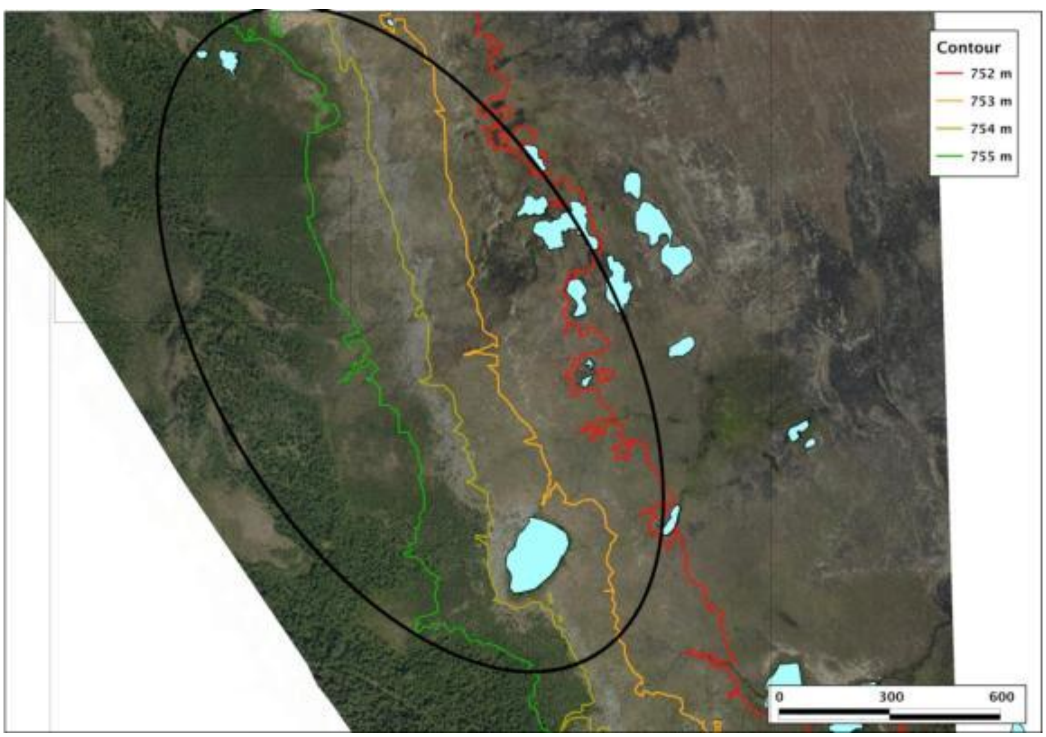

Figure 6-1: Location of the Valemount Peatland index site in Canoe Reach. Monitoring of terrestrial and aquatic wetlands will occur with the black polygon. Reference sites will be positioned above the 755 m ASL elevation band

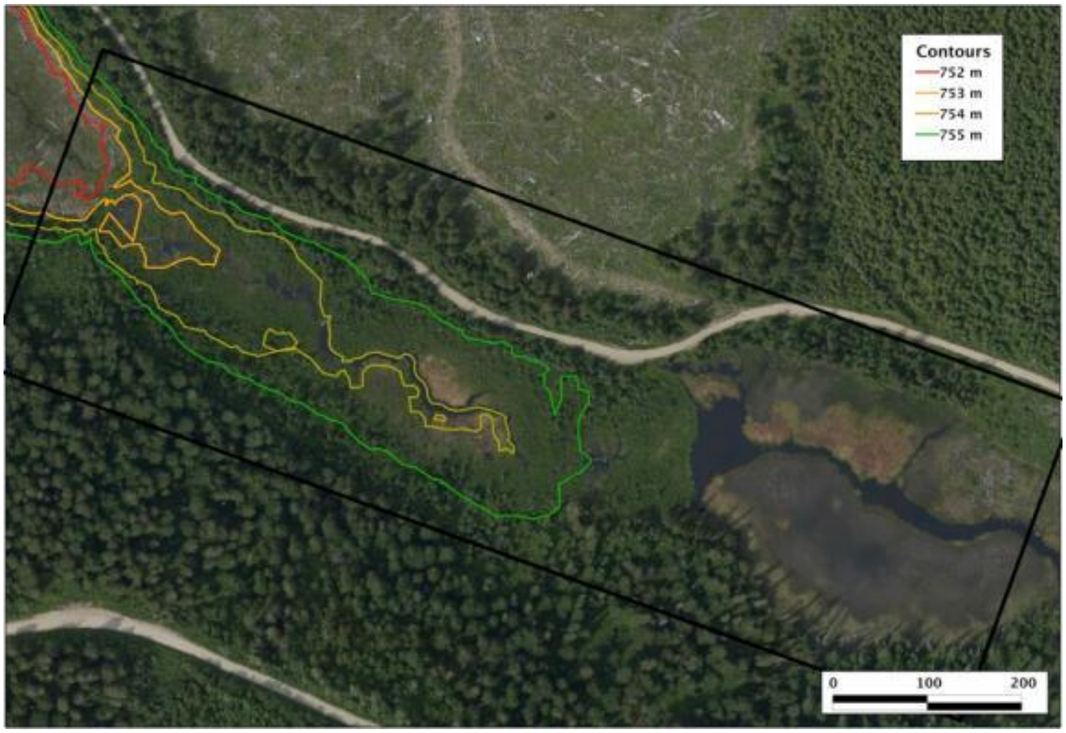

Figure 6-2: Location of the Sprague Bay index site in Mica Arm. Monitoring of terrestrial and aquatic wetlands will occur with the black polygon. Reference sites will be positioned above the 755 m ASL elevation band

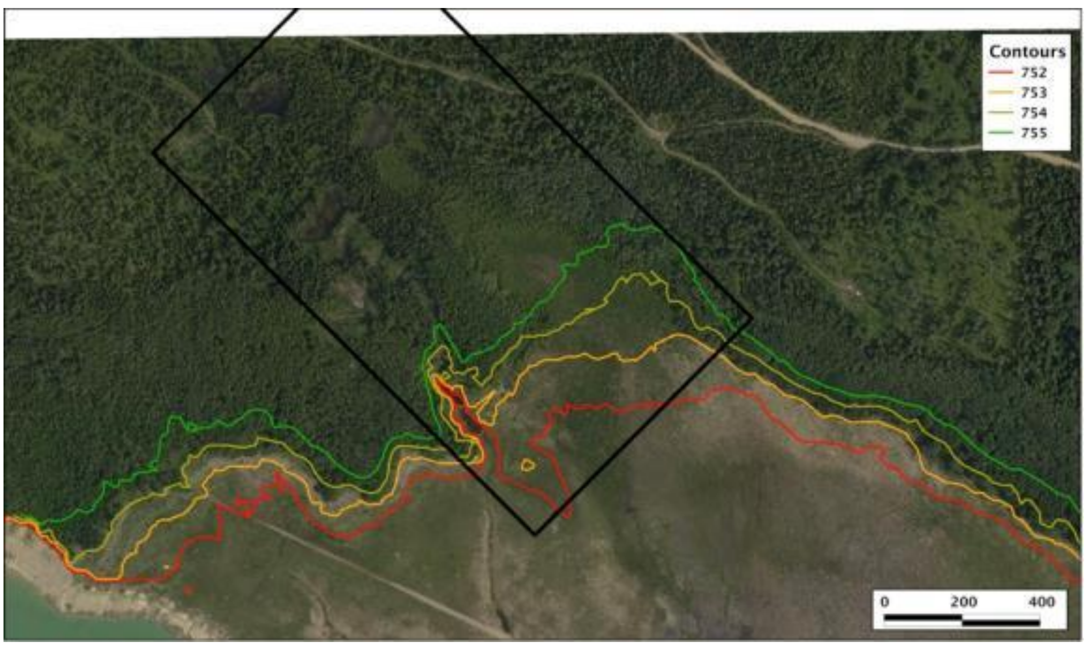

Figure 6-3: Location of the km88 index site in Bush Arm. Monitoring of terrestrial and aquatic wetlands will occur with the black polygon. Reference sites will be positioned above the 755 m ASL elevation band

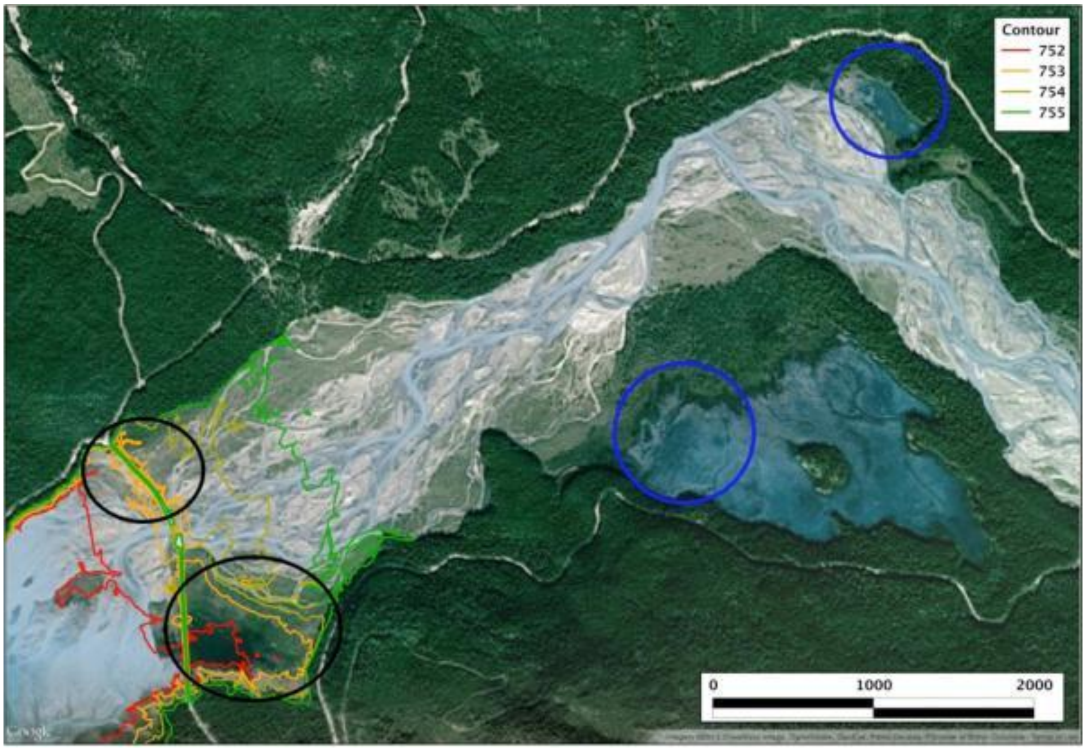

Figure 6-4: Location of the Bush Arm causeway index site. Monitoring of terrestrial and aquatic wetlands will occur with the black polygon. Reference sites will be positioned above the 755 m ASL elevation band (blue polygons).

6.9 Index of Wetland Integrity

To assess changes in wetland integrity over time, we recommend developing an Index of Wetland Integrity (IWI) tailored to each index site using metrics to assess taxa richness, structural stage, community structure, primary and secondary productivity, and habitat disturbance (e.g., presence of wood debris, invasive species). Methods to assess the ecological condition of wetlands are modeled after the Index of Biological Integrity (IBI) developed by Karr (1991) and Index of Vegetation Integrity (IVI) (Cronk and Fennessy 2001). The premise of this approach is based on the identification of reliable metrics that are predicted to respond across a disturbance gradient. Such metrics can include data directly obtained from field observation (e.g., per cent cover), from more sophisticated analysis (e.g., community composition), or from GIS (e.g. cover of wood debris from orthoimagery). The index combines several of these metrics into a composite value that allow for comparisons over time and to reference and control sites. Although the index can provide a composite value of integrity, its power lies in the ability to assess each metric independently overtime, which can lead to further hypothesis testing. Another advantage in developing an IWI is that, unlike a retrospective approach, the IWI will allow for a direct comparison to data collected in previous years.

6.10 Recommendations

Recommendations made throughout the report are summarized below. We also introduce additional recommendations for consideration.

Study Design

1. As the requirements of a BACI study design cannot be met (Section 6.7), we recommend that a long-term (10 year) annual monitoring program be implemented as an alternative approach. As an option, we suggest that an additional year of monitoring be implemented in 2014 to the current study, which calls for monitoring in 2012, 2013, 2015, 2016, and 2017. In 2017, when the final report is due, it can be determined whether additional monitoring is required.

2. For the duration of the study, we recommend focusing the monitoring to four index sites: the Bush Arm causeway wetlands, km88 wetlands, Sprague Bay wetlands, and the wetland complex in the central portion of the Valemount Peatland. Focusing the monitoring on a select number of representative index sites (rather than attempting to sample many different index sites at low intensity in hopes of maximizing coverage) will increase the likelihood of detecting subtle impacts, while making more efficient use of available resources.

3. To assess the change in wetland integrity over time, we recommend developing an Index of Wetland Integrity (IWI) using metrics to assess taxa richness, structural stage, community structure, primary and secondary productivity, and habitat disturbance (e.g., presence of wood debris, invasive species).

Methods

1. The two-headed grapnel is a tool for sampling species composition and richness in open water ponds; however, its effectiveness declines with increasing water depths (especially at depths over about 1.5 m). Biomass (and cover estimates) made from grapnel samples can vary widely both within and between vegetation types. Prior to the next study year, the appropriateness of the rake grab method for collecting biomass samples in pond habitats will be assessed and, if needed, alternative methods considered (i.e., diurnal dissolved oxygen concentrations).

2. The Secchi disk did not provide a reliable measure of transparency in shallow waters. Although slightly more time consuming to operate, we recommend that a transparency tube be used for such measurements, as water depths do not affect their use.

3. Characterizing the organic and mineral sediments of ponds using benthic samples obtained with a Ponar grab was unsuccessful due to the mixing of the organic and mineral layers. For 2013, we suggest an exploring an alternative approach for obtaining sediment samples.

4. Quality assurance testing should be performed on the dataloggers (and other sampling equipment) prior to deployment.

5. Pelagic sweeps are not optimal for sampling the invertebrate orders identified as potential indicators. The sampling methodology should be reassessed to sample specifically for the proposed indicator taxa.

7.0 CONCLUSION

The objectives in Year 1 of study were to:

a) provide a general description of wetlands in the upper elevation of Kinbasket Reservoir;

b) describe and justify the methods used to select index sites for monitoring; and,

c) review the study approach and methods (both field and analytical) to ensure they are appropriate for addressing the management questions and hypotheses.

The results from Year 1 confirm that wetlands in Kinbasket Reservoir are largely restricted to Bush Arm, Canoe Reach, and Mica Arm. We estimate that only 102.8 hectares of wetland-associated vegetation occurs between 751 and 755 m ASL with 34.1 hectares occurring in the target elevation band (753–754 m ASL). Most wetland vegetation occurs in Bush Arm (49 per cent) or in Canoe Reach (45 per cent) but small areas of wetland vegetation occur in Mica Arm (4.6 per cent), Succour Creek (0.9 percent), and Windfall Creek (0.5 per cent).

In developing general descriptions of the wetlands in the upper elevation of Kinbasket Reservoir, the need to differentiate between terrestrial and aquatic wetlands was apparent. Conveniently, we found the distinction of aquatic and terrestrial wetland types and communities to correspond favourably to existing classifications (Warner and Rubec 1997; Pierce and Jensen 2001, Mackenzie and Moran 2004; Hawkes et al 2007; Hawkes et al 2010) and all communities were typed using these classifications.

An assessment of wetland vegetation in 2012 suggests that community composition and vegetation structure in terrestrial and aquatic wetlands may respond to impacts associated with the new turbines and that factors such as woody debris accumulation should be incorporated into the monitoring program. To improve the study design, we recommend focusing the sampling to just four index sites and that an Index of Wetland Integrity by developed as a means of assessing wetland integrity overtime. Finally, because the requirements of a BACI design cannot be met, we recommend that the BACI design be replaced with a long-term annual monitoring program.

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9.0 APPENDIX

Appendix 9-1: A list of data collected under CLBMON-61 in 2012.

Table 9-1. List of variable collected during in situ monitoring of wetlands in 2012

Study Component	Field / Variable	Type of Data	Metadata	Relevant Hypothesis	Timing / Frequency
General	Project Name	Header	Mica Unit 5 Wetland Monitoring Program	n/a	n/a
General	BC Hydro Reference	Header	CLBMON-61	n/a	n/a
General	Reservoir	Header	Kinbasket Reservoir	n/a	n/a
General	Year	Header	Current Year	n/a	Each visit
General	Survey Date	Header	Current Date	n/a	Each visit
General	Survey Time	Header	Current Time	n/a	Each visit
General	Number of Surveyors	Header	Numeric value	n/a	Each visit
General	Surveyors Names	Header	Names of people working	n/a	Each visit
General	Season	Header	Spring, Summer, Fall	n/a	Each visit
General	Start time	Header	Time survey started	n/a	Each visit
General	End Time	Header	Time survey ended	n/a	Each visit
General	Weather	Header	General environmental conditions	n/a	Each visit
Location	Survey location	Mapping	Bush Arm, Canoe Reach, Sprague Bay, Succour Creek	n/a	Each visit
Location	Survey site	Mapping	Bush Arm Causeway, Valemount Peatland, etc.	n/a	Each visit
Location	GPS	Mapping	Type of GPS (SXBlue II, Garmin GPSMap 60Csx)	n/a	Each visit
Location	GPS Accuracy	Mapping	Submetre, > 1 m, < 5m, > 5m	n/a	Each visit
Location	Wetland No.	Mapping	Numeric value	n/a	Once (start)
Classification	Wetland Type	Classification	Treatment or Reference	n/a	Once (start)
Location	Wetland Area	Mapping	Numeric value (m^2)	n/a	Twice yearly
Location	Transect Number	Sampling	Transect Number	n/a	Each visit
Location	Transect Start UTM	Sampling	UTM Easting and northing, zone 11	n/a	Each visit
Location	Transect End UTM	Sampling	UTM Easting and northing, zone 11	n/a	Each visit
Classification	Wetland Classification	Classification	Classification Code	n/a	Annually or biannually
Composition and Productivity	Sample Number	Sampling	Unique Sample number	n/a	Each visit
Composition and Productivity	Sample UTM	Sampling	UTM Easting and northing, zone 11	n/a	Each visit

Study Component	Field / Variable	Type of Data	Metadata	Relevant Hypothesis	Timing / Frequency
Composition and Productivity	Collection Made	Sampling	Binary - Yes or no	n/a	Each visit
Composition and Productivity	Collection Number	Sampling	Unique identifier for collection	n/a	Each visit
Composition and Productivity	Vegetation Present	Biological	Binary - Yes or no	H01 H02	Each visit
Composition	Vegetation Species 1	Biological	Species of first plant	H01	Each visit
Composition	Relative abundance of veg Species 1	Biological	Relative abundance of Species 1 (abundance classes 0-5)	H01	Each visit
Composition	Percent cover species 1	Biological	percent cover of species 1 (estimated from 1m^2 area)	H01 H02	Each visit
Composition	Vegetation Species 2	Biological	Species of second plant	H01	Each visit
Composition	Relative abundance of veg Species 2	Biological	Relative abundance of Species 1 (abundance classes 0-5)	H01	Each visit
Composition	Percent cover species 2	Biological	percent cover of species 2 (estimated from 1m^2 area)	H01 H02	Each visit
Composition	Vegetation Species N	Biological	Continue for all plants at sample location	H01	Each visit
Composition	Relative abundance of veg Species N	Biological	Relative abundance of Species N (abundance classes 0-5)	H01	Each visit
Composition	Percent cover species N	Biological	percent cover of species N (estimated from 1m^2 area)	H01 H02	Each visit
Productivity	Veg Sample volume	Biological	Estimate of volume of vegetation sample (placed into size classes 1 to 3)	H02	Each visit
Productivity	Veg Sample wet weight	Biological	Grams (g)	H02	Each visit
Productivity	Veg Sample dry weight	Biological	Grams (g)	H02	Each visit
Productivity	Aquatic Invertebrates Present	Biological	Binary - Yes or no	H02	Each visit
Productivity	Invert Species 1	Biological	First invertebrate taxon	H02	Each visit
Productivity	Invert Abundance Species 1	Biological	Abundance class (0-5)	H02	Each visit
Productivity	Invert Species 2	Biological	Second invertebrate taxon	H02	Each visit
Productivity	Invert Abundance Species 2	Biological	Abundance class (0-5)	H02	Each visit
Productivity	Invert Species N	Biological	N Invertebrate taxon	H02	Each visit
Productivity	Invert Abundance Species N	Biological	Abundance class (0-5)	H02	Each visit
Composition	Fish present?	Biological	Binary - Yes or no	H01	Incidental
Composition	Fish Species	Biological	Species of fish if present	H01	Incidental
Physicochemistry	Water Depth	Physiological	Water depth to nearest cm	H01 H02	Each visit
Physicochemistry	Riparian Soil Type	Physiological	Classification code	H01 H02	Annually or

Study Component	**Field / Variable**	**Type of Data**	**Metadata**	**Relevant Hypothesis**	**Timing / Frequency**
					biannually
Physicochemistry	Bottom Substrate	Physiological	Cobble, rock, mud, fines, sand, mix, wood, other (describe)	H01 H02	Each visit
Physicochemistry	Water Condition	Water chemistry	Secchi depth (cm)	H01 H02	Each visit
Physiochemistry	Water Temperature	Water chemistry	Degrees Celsius (°C)	H01 H02	Continuous
Physiochemistry	Water Conductivity	Water chemistry	Microsiemens (µS/cm)	H01 H02	Continuous
Physiochemistry	Water Dissolved Oxygen	Water chemistry	Milligrams per litre (mg/L)	H01 H02	Continuous
Physiochemistry	Water pH	Water chemistry	Numeric value (0-14)	H01 H02	Each visit
Physiochemistry	Tidbit installed?	Water chemistry	Binary - Yes or no	n/a	Each visit
Physiochemistry	Tidbit location	Water chemistry	UTM Easting and northing, zone 11	n/a	Each visit
Comments	Comments	Incidental	Free form notes, incidental observations, species seen (e.g., birds, herps)	n/a	Each visit

Appendix 9-2: Example of data cards used to record vegetation and associated site-specific information in terrestrial and aquatic wetlands in 2012

Project ID	CLBMON-10: Kinbasket Reservoir Inventory of Vegetation Resources						
Date		Transect #		Quadrat #		Tran Brg	
Surveyors		VCC (2007 / 08)		Photo Nos.			

Vegetation Cover	%	TREE LAYER (A)									
Tree Layer (A)		Spp	A1	A2	A3	Tot	Spp	A1	A2	A3	Tot
Shrub Layer (B)											
Herb Layer (C)											
Moss / Seedling (D)											

SHRUB LAYER (B)											
Spp Code	B1	B2	Tot	Spp Code	B1	B2	Tot	Spp Code	B1	B2	Tot

HERB LAYER (C)						Moss Layer		NOTES
Spp Code	%	Spp Code	%	Spp Code	%	Spp Code	%	

SUBSTRATE (Must Equal 100%) Type (General) Rock ☐ Cobble ☐ Gravel ☐ Sand ☐ Silt ☐ Fines ☐ Wood ☐							
Organic Matter – Live		Organic Matter - Dead		Decay Wood		Bedrock	
Rock		Mineral Soil		Water		Other	

LGL PROJECT: EA3398 **SURVEY:** CLBMON-61 Kinbasket Wetlands Assessment **DATE:** ________-________-________ **TIME:** ______:______

SURVEY CODE: ____________ **STUDY AREA:** ____________________ **POND/WETLAND #:** ______________ **PLOT #:** ______________

LOCATION: **WAYPOINT #:** ____________ **UTM:** 11 ________________ / ________________ **SURVEYORS:** ________________

WATER PHYSIOCOCHEMISTRY:
SURFACE: DO: ___________ **WATER TEMP:** ____________ **CONDUCTIVITY:** ___________ **pH:** ______________
DEPTH: (CM) __________ **DO:** ___________ **WATER TEMP:** ____________ **CONDUCTIVITY:** ___________ **pH:** ______________

WATER DEPTH: ________________ **SUBSTRATE DEPTH:** ________________ **TOTAL DEPTH :** ____________ **SECCHI DEPTH :** __________
SUBSTRATE TYPE : ______________ **PROBE: NORTH:** ____________ **EAST:** ____________ **SOUTH:** ____________ **WEST:** ______________

INVERT COLLECTION LABELS: BENTHIC:________________ PELAGIC: ____________________
BIOMASS COLLECTION? Y ☐ N ☐ **BIOMASS COLLECTION LABEL:** ____________________

VEGETATION PRESENT? Y ☐ N ☐ **FISH PRESENT?** Y ☐ N ☐ **AMPHIBIANS PRESENT?** Y ☐ N ☐ **SPECIES :** ____________________

Type	#	*VEG ABUND	% Cover	SPECIES	**REL ABUND	% COVER	Strata Code

Substrate Codes

F = Fines (Clay/Silt)
S = Sand
SG = Small Gravel
LG = Large Gravel
C = Cobble
B = Boulder
BR = Bedrock
M = Muck
CO = Coarse Organic Detritus
W = Wood

Abundance Codes

*VEG ABUNDANCE

1 Trace
2 Small
3 Large

**Relative Abundance in Sample

T Trace
1 <10%
2 10-30%
3 30-50%
4 50-75%
5 75-100%

Strata Codes

B = Benthic
S = Submerged
F = Floating
E = Emergent

Appendix 9-3: Maps of CLBMON-61 aquatic and terrestrial sampling sites for 2012.

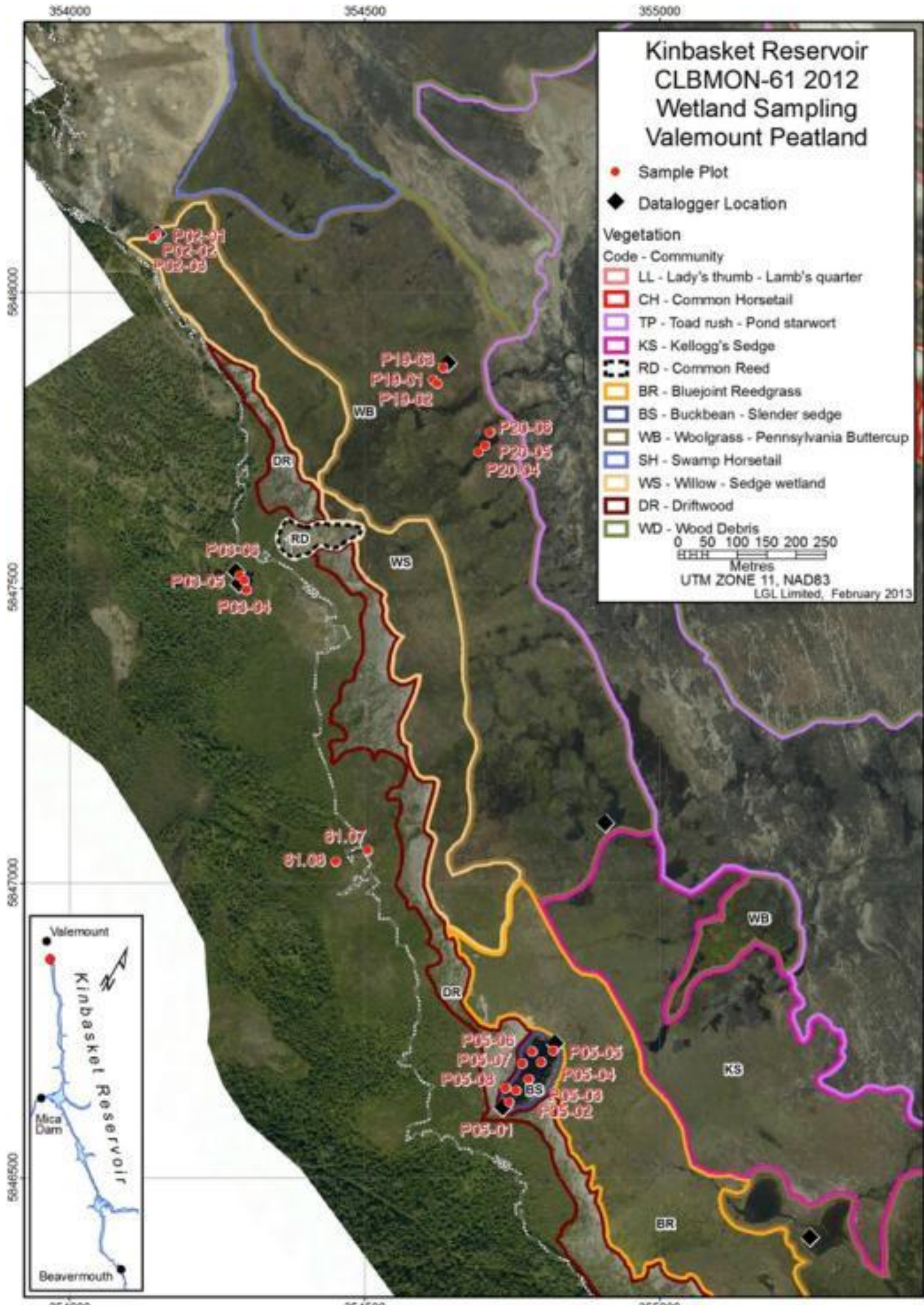


Figure 9-1: The location of the aquatic and terrestrial wetland sampling sites in the Valemount Peatland in 2012. Points identified with the prefix "P" indicate aquatic sampling stations and points identified numerical as xx.xx indicate terrestrial wetland transects. The location of temperature, conductivity, and dissolved oxygen dataloggers are shown as black diamonds.

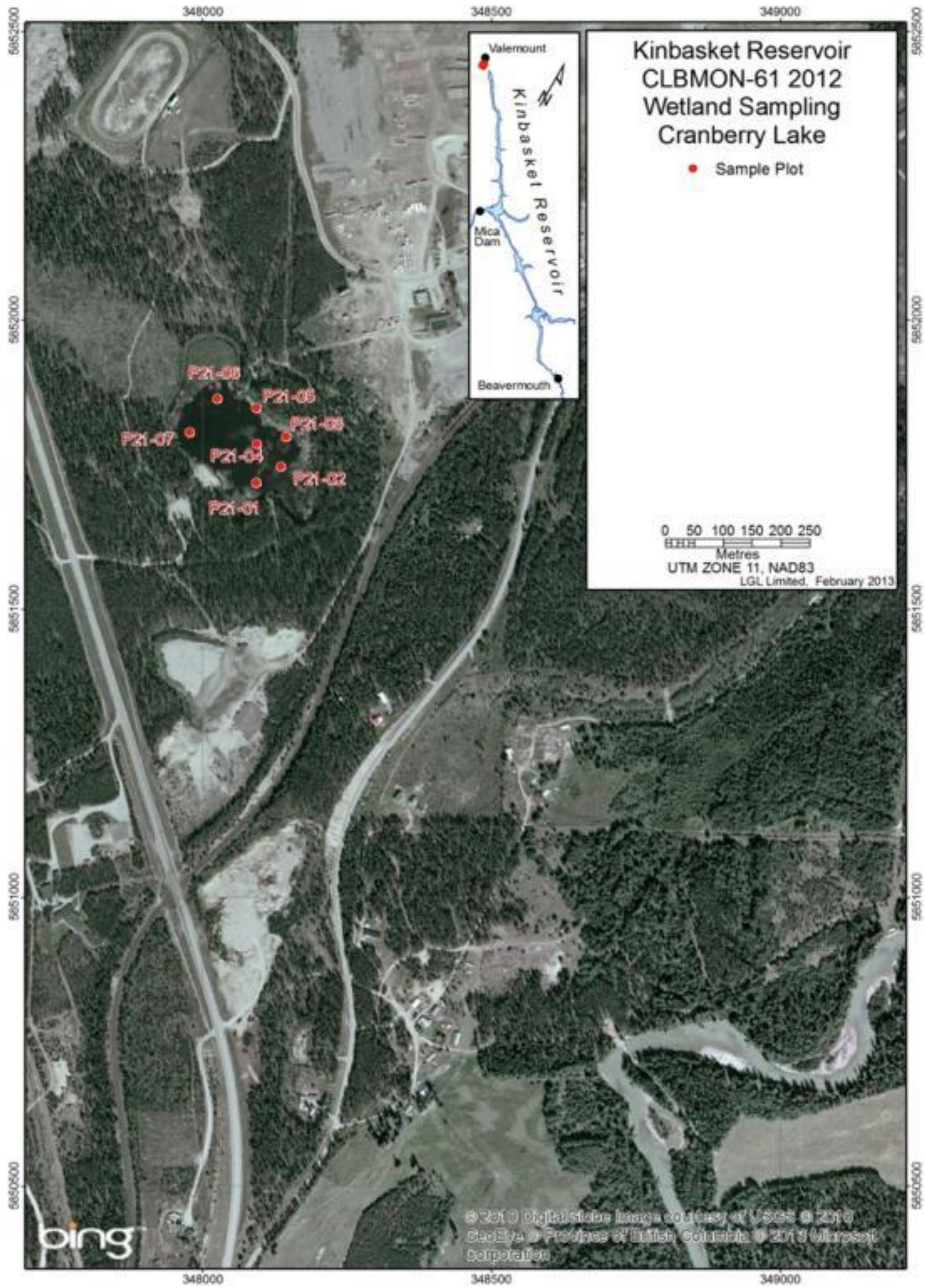


Figure 9-2: The location of the aquatic wetland sampling stations in Cranberry Lake (P21), near Valemount B.C. in 2012. Points identified with the prefix "P" indicate the location of aquatic sampling stations.

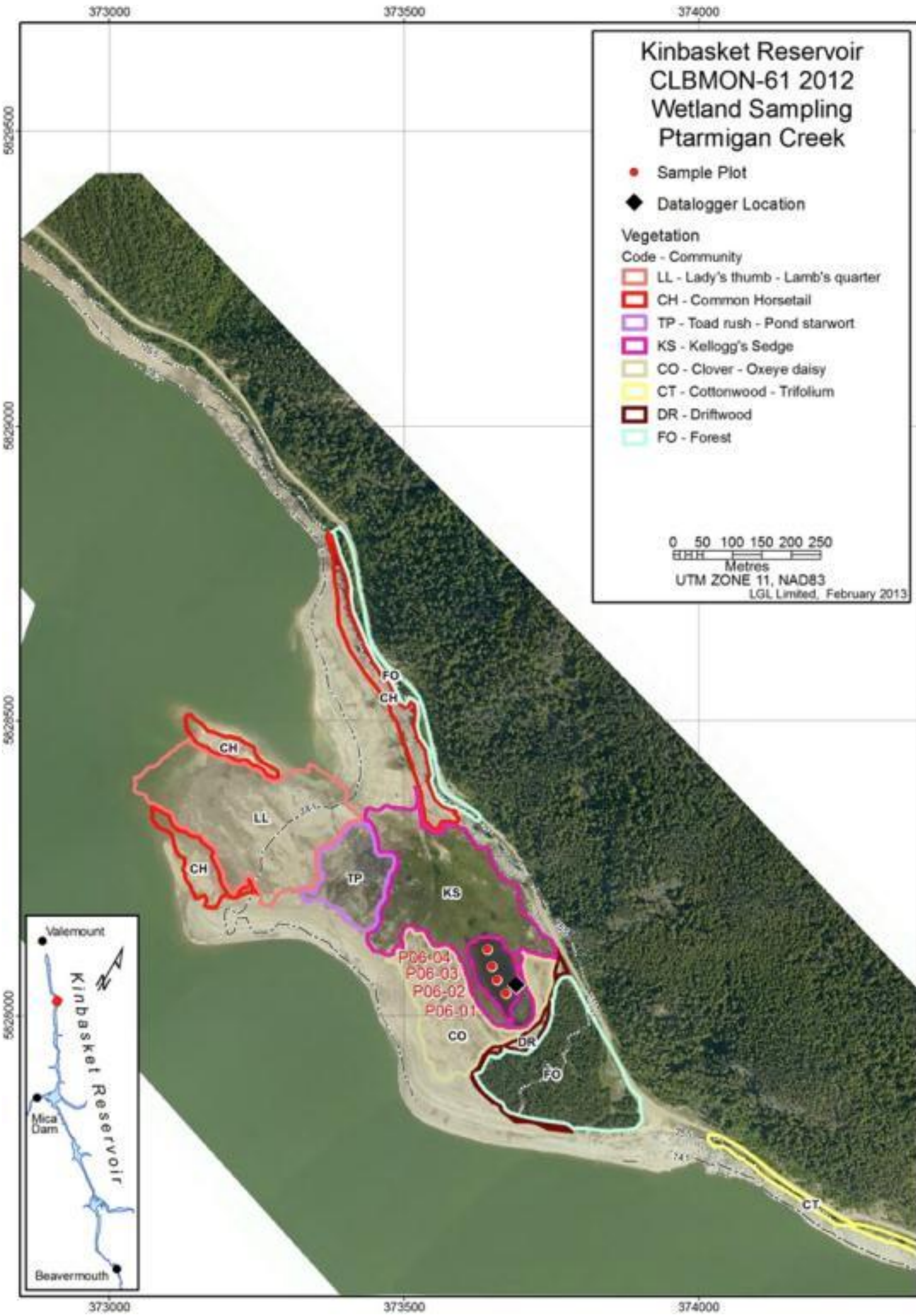


Figure 9-3: The location of aquatic wetland sampling stations at P06 at Ptarmigan Creek in 2012. Points identified with the prefix "P" indicate aquatic sampling stations. The location of a temperature datalogger is shown as black diamonds.

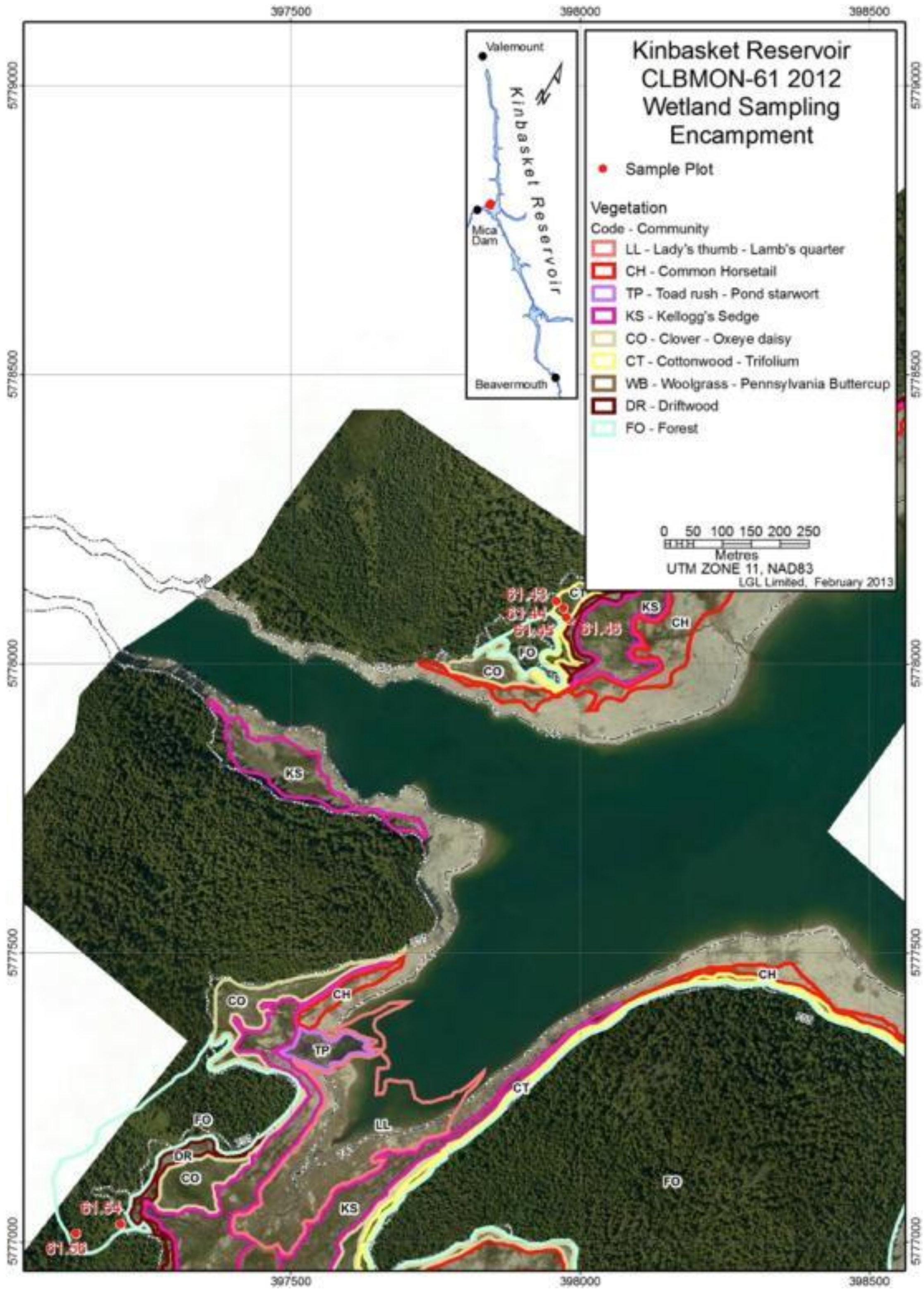


Figure 9-4: The location of terrestrial wetland transects at Encampment Creek in Mica Arm (2012). Points identified numerical as xx.xx indicate terrestrial wetland transects.

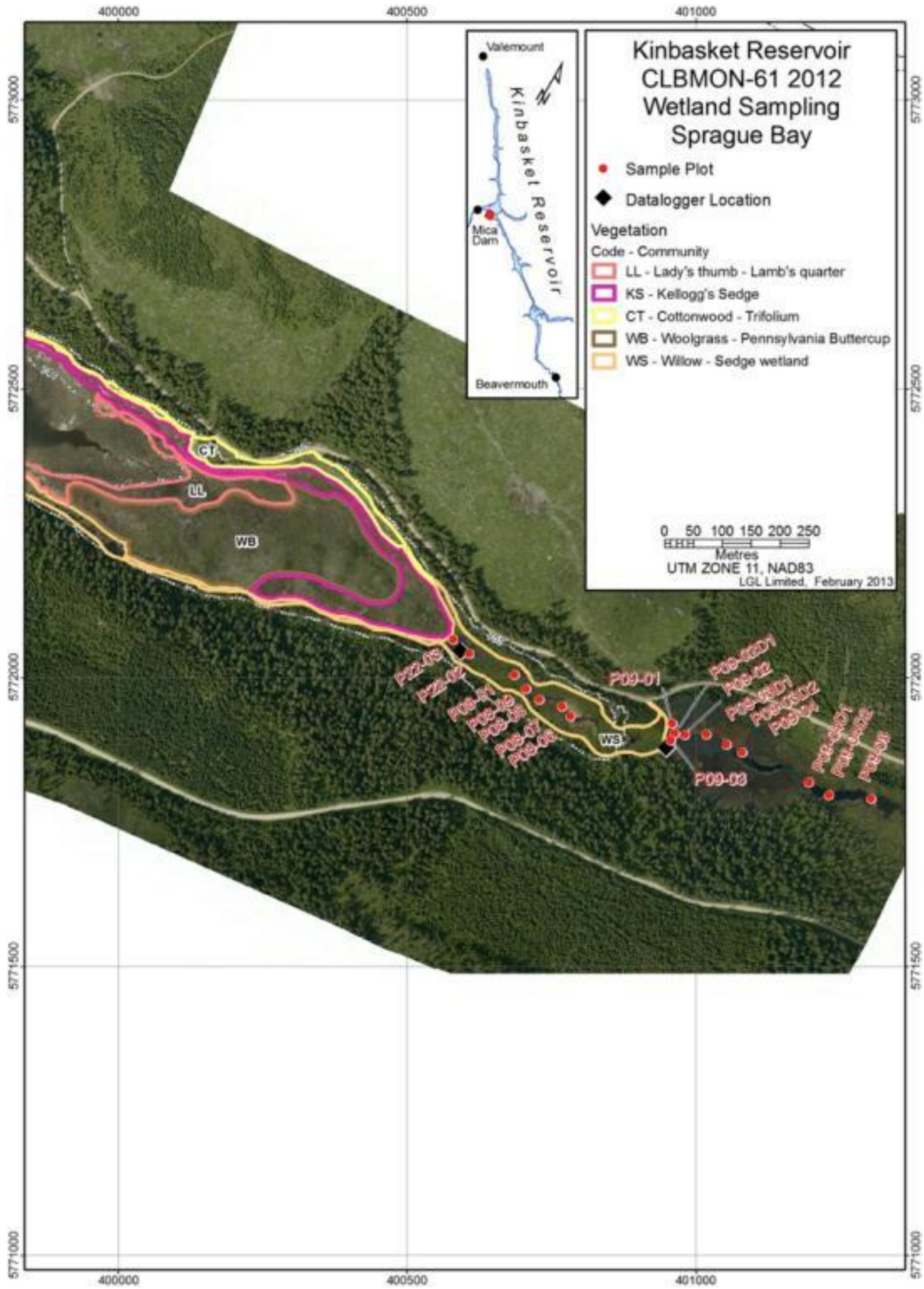


Figure 9-5: The location of aquatic wetland sampling stations at Sprague Bay in Mica Arm (2012). Points identified with the prefix "P" indicate aquatic sampling stations. The location of conductivity, and dissolved oxygen dataloggers are shown as black diamonds.

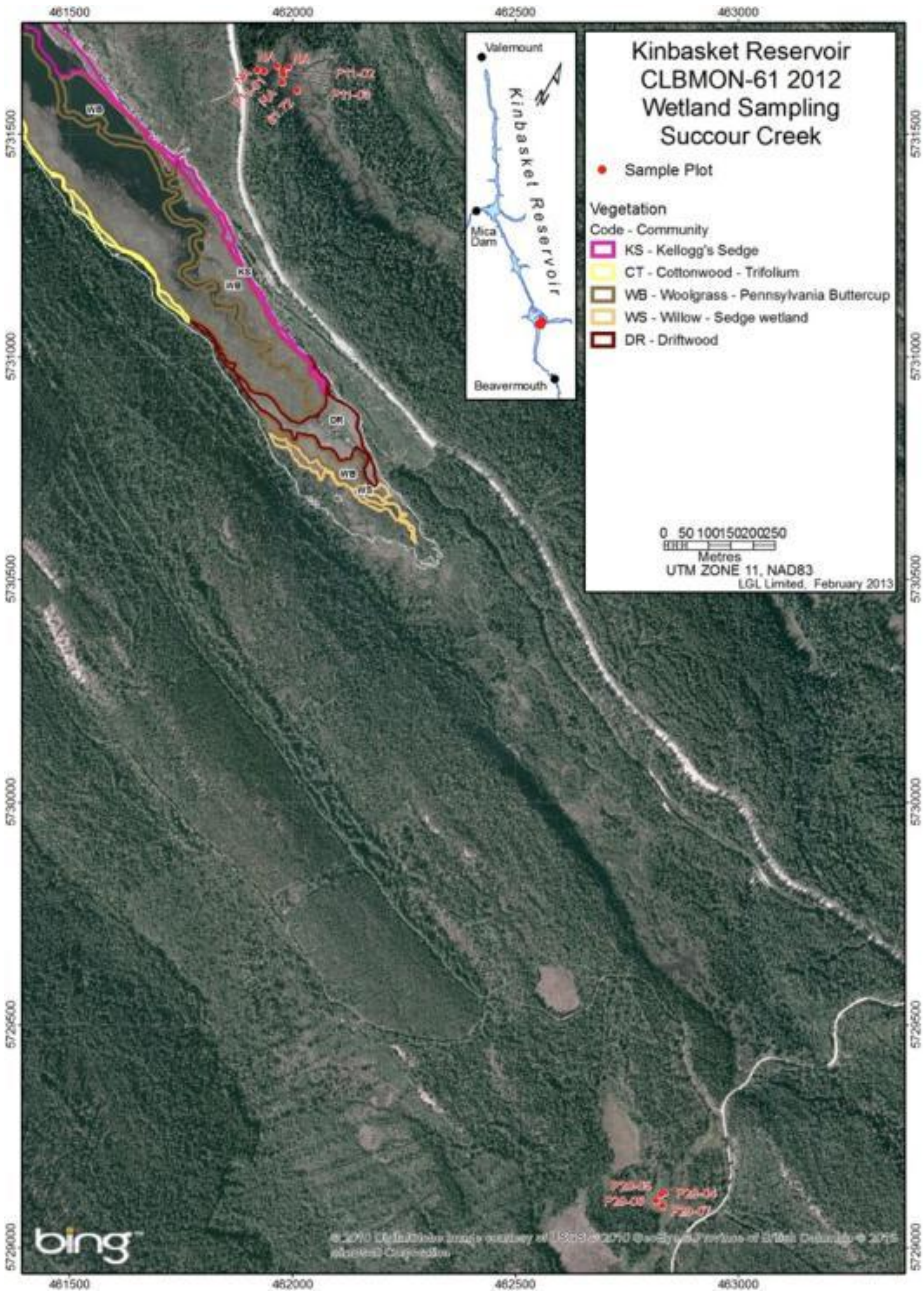


Figure 9-6: The location of aquatic and terrestrial wetland sampling sites in the Succour Creek (P11) and Esplanade Bay (P29) in Bush Arm (2012). Points identified with the prefix “P” indicate aquatic sampling stations and points identified numerical as xx.xx indicate terrestrial wetland transects. Sites within the reservoir adjacent P11 were identified but not sampled due to high reservoir levels.

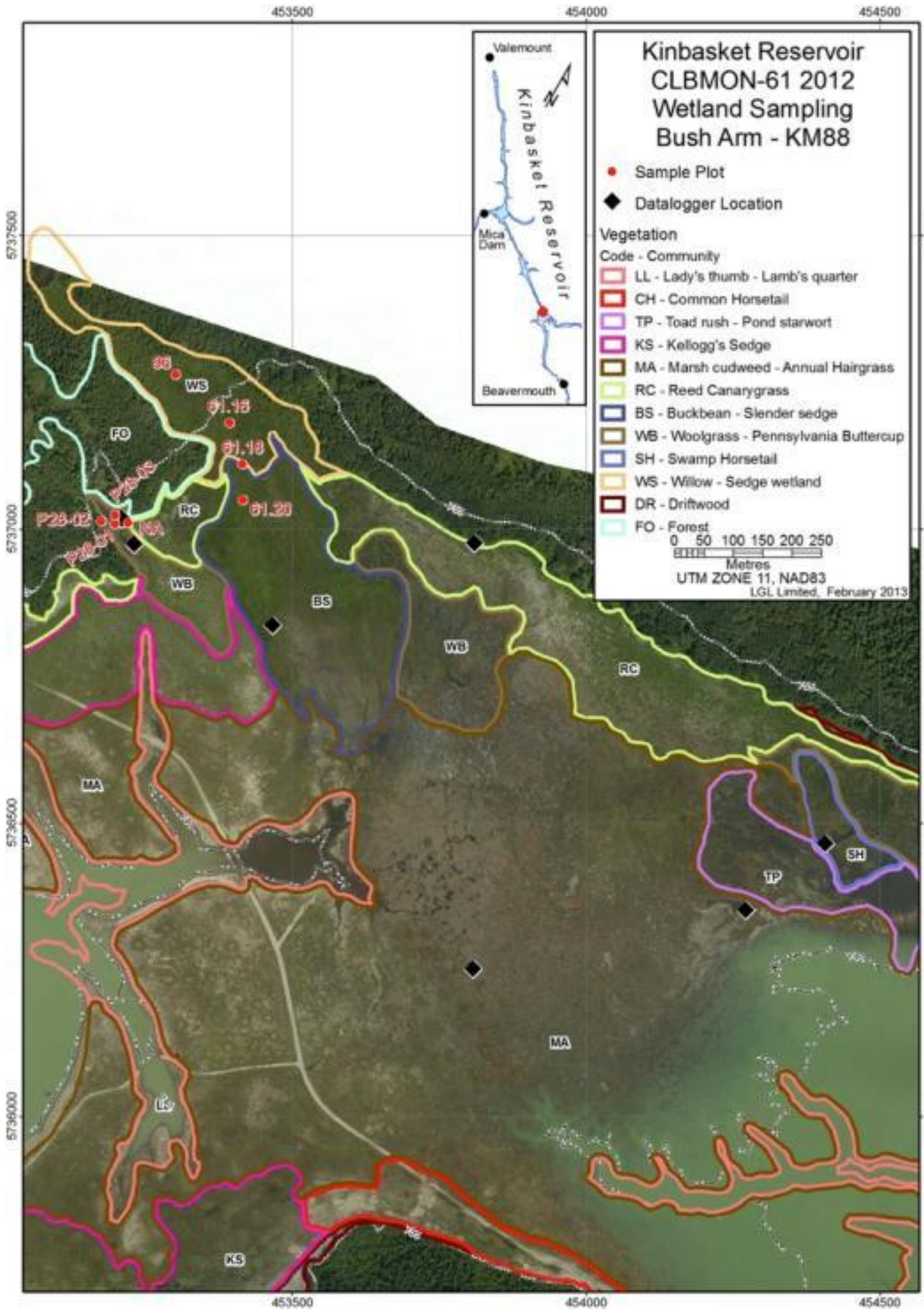


Figure 9-7: The location of aquatic and terrestrial wetland sampling sites at km88 in Bush Arm (2012). Points identified with the prefix "P" indicate aquatic sampling stations and points identified numerical as xx.xx indicate terrestrial wetland transects. The location of temperature, conductivity, and dissolved oxygen dataloggers are shown as black diamonds.

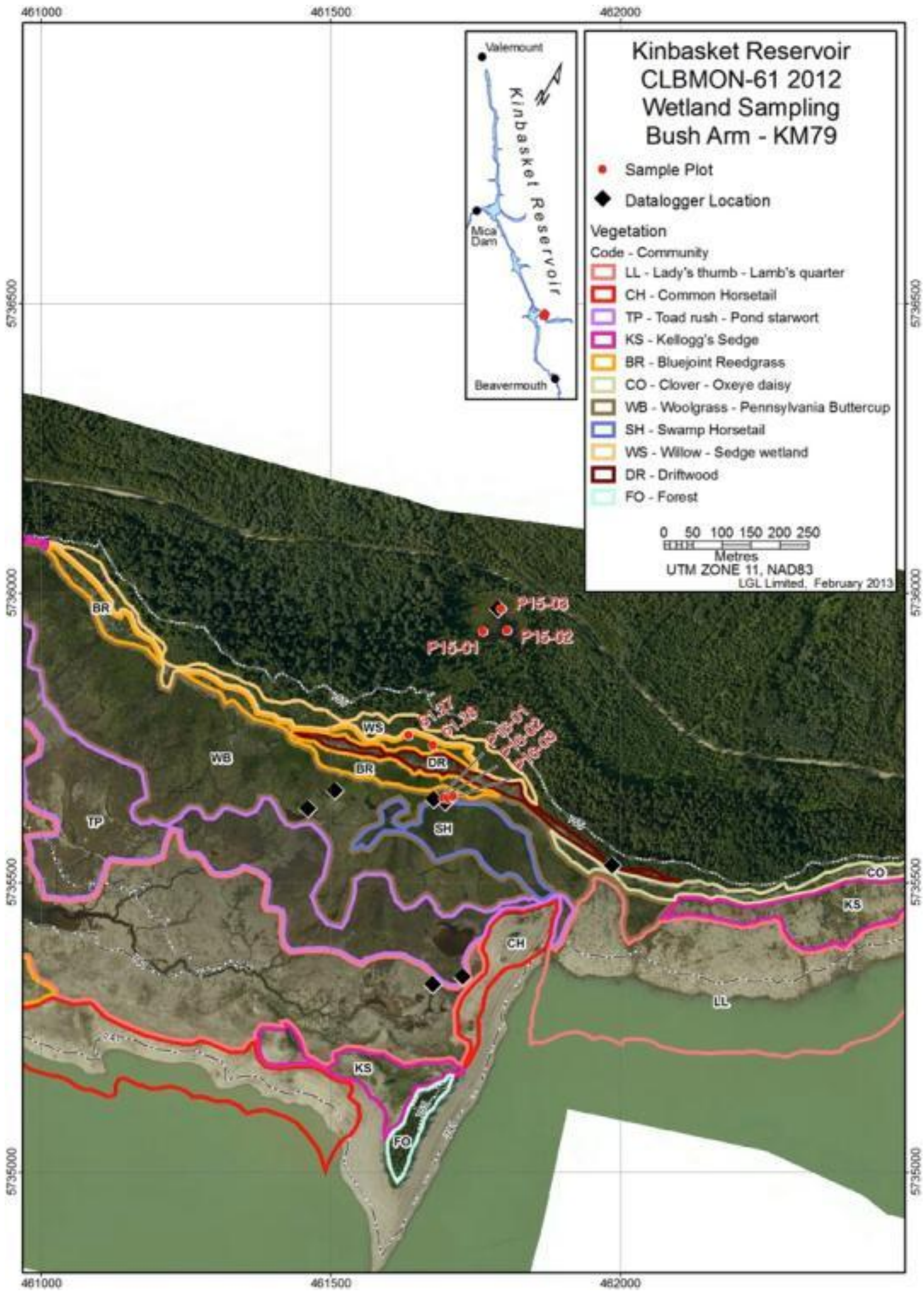


Figure 9-8: The location of aquatic and terrestrial wetland sampling sites at km79 in Bush Arm (2012). Points identified with the prefix "P" indicate aquatic sampling stations and points identified numerical as xx.xx indicate terrestrial wetland transects. The location of temperature, conductivity, and dissolved oxygen dataloggers are shown as black diamonds.

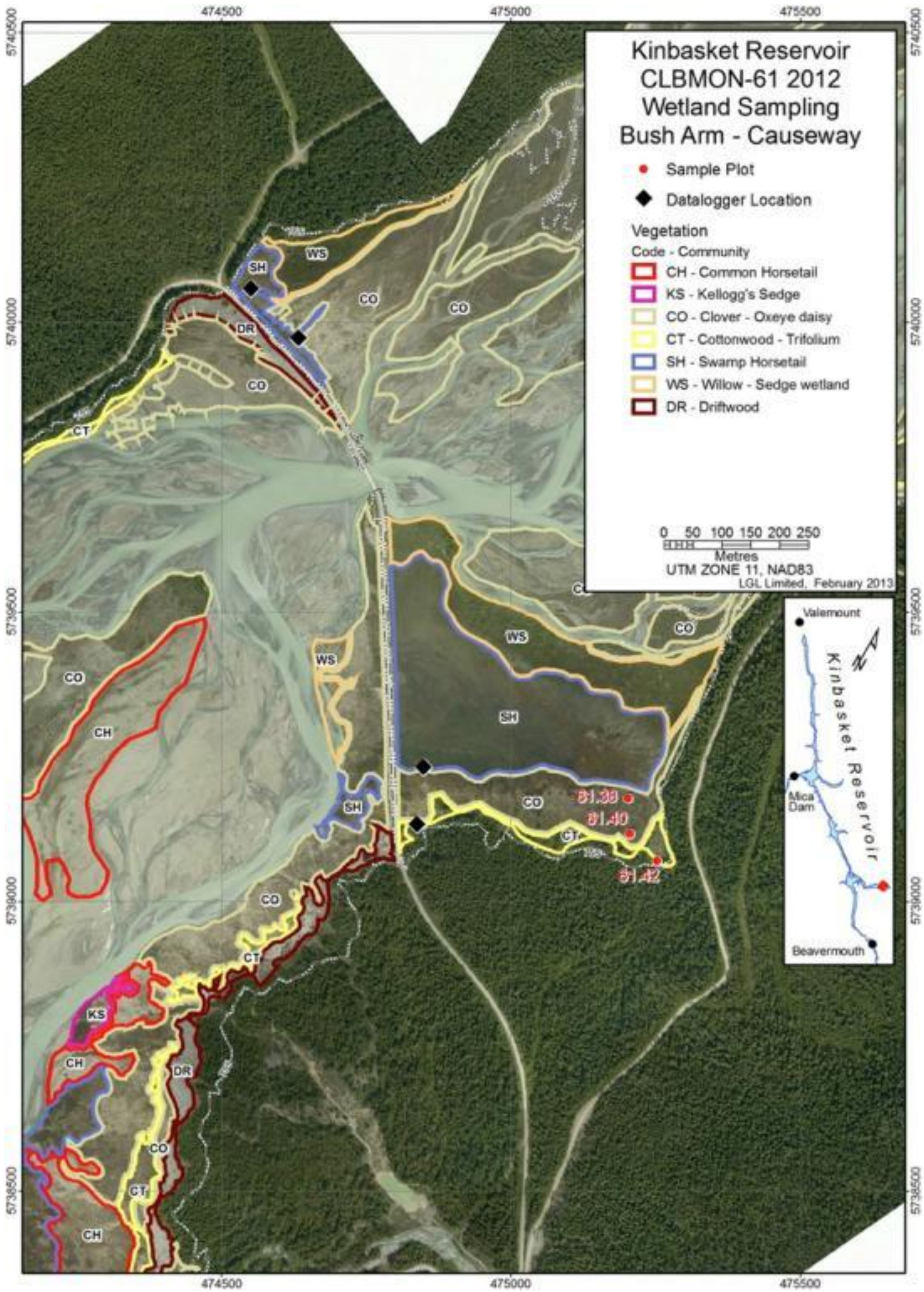


Figure 9-9: The location of terrestrial wetland sampling transects at the Bush Arm causeway (2012). Points identified numerical as xx.xx indicate terrestrial wetland transects. The location of temperature, conductivity, and dissolved oxygen dataloggers are shown as black diamonds.

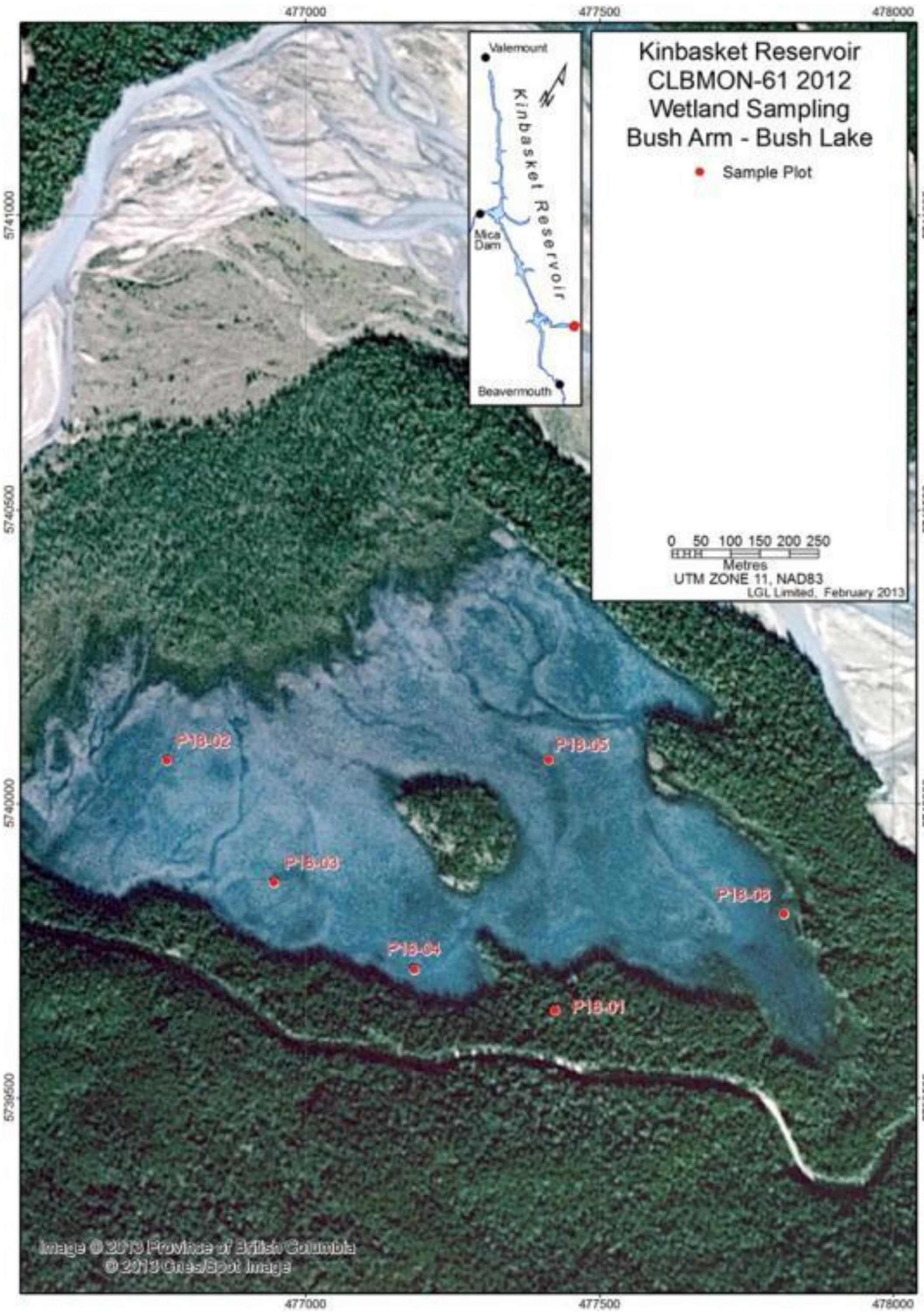


Figure 9-10: The location of aquatic wetland sampling stations at Bush Lake (2012). Points identified with the prefix "P" indicate aquatic sampling stations and points identified numerical as xx.xx indicate terrestrial wetland transects

Appendix 9-4: Dataloggers installed in Kinbasket Reservoir by LGL Limited

Table 9-2. Location and installation and retrieval dates of temperature, dissolved oxygen and conductivity dataloggers installed in Kinbasket Reservoir

Data Logger #	Parameter	Make-Model	Launch Date	Date Retrieved	Reach	Location1	Position
2315358	Temp	Onset UTBI-001	2-Jun-11	17-May-12	Bush Arm	km88	DDZ
2315359	Temp	Onset UTBI-001	2-Jun-11	17-May-12	Bush Arm	km88	DDZ
9765550	Temp	Onset UTBI-001	2-Jun-11	17-May-12	Bush Arm	km88	DDZ
9765551	Temp	Onset UTBI-001	14-May-11	17-May-12	Bush Arm	km88	DDZ
9898352	Temp	Onset UTBI-001	2-Jun-11	17-May-12	Bush Arm	km88	DDZ
2321332	Temp	Onset UTBI-001	2-Jun-11	15-May-12	Bush Arm	Causeway	Reference
2413655	Temp	Onset UTBI-001	14-May-11	16-May-12	Bush Arm	Causeway	DDZ
2413651	Temp	Onset UTBI-001	14-May-11	18-May-12	Bush Arm	km79 Perched Wetland	Reference
2321304	Temp	Onset UTBI-001	2-Jun-11	16-May-12	Bush Arm	km79	DDZ
9898378	Temp	Onset UTBI-001	2-Jun-11	16-May-12	Bush Arm	km79	DDZ
9898380	Temp	Onset UTBI-001	2-Jun-11	16-May-12	Bush Arm	km79	DDZ
9902742	Temp	Onset UTBI-001	22-Jun-11	27-Apr-12	Canoe	Ptarmigan Creek	DDZ
9902743	Temp	Onset UTBI-001	22-Jun-11	28-Apr-12	Canoe	Valemount Peatland	DDZ
9898393	Temp	Onset UTBI-001	22-Jun-11	28-Apr-12	Canoe	Valemount Peatland	DDZ
DO #307	DO	PME MINIDOT V1	12-Jun-12	19-Oct-12	Bush Arm	Causeway P17	DDZ
10089805	Conductivity	Onset U24-001	12-Jun-12	19-Oct-12	Bush Arm	Causeway P17	DDZ
DO #302	DO	PME MINIDOT V1	12-Jun-12	19-Oct-12	Bush Arm	km79 P16	DDZ
10086811	Conductivity	Onset U24-001	12-Jun-12	19-Oct-12	Bush Arm	km79 P16	DDZ
10089809	Conductivity	Onset U24-001	12-Jun-12	19-Oct-12	Bush Arm	km88 P28	DDZ
10089804	Conductivity	Onset U24-001	12-Jun-12	19-Oct-12	Bush Arm	km88 P28	DDZ
10086813	Conductivity	Onset U24-001	14-Jun-12	21-Oct-12	Mica	Sprague Bay P09	Reference
DO #288	DO	PME MINIDOT V1	14-Jun-12	21-Oct-12	Mica	Sprague Bay P21	DDZ
10086806	Conductivity	Onset U24-001	14-Jun-12	21-Oct-12	Mica	Sprague Bay P21	DDZ
DO #281	DO	PME MINIDOT V1	20-Jun-12	18-Oct-12	Canoe	Peatland P05	DDZ
10086810	Conductivity	Onset U24-001	20-Jun-12	18-Oct-12	Canoe	Valemount P05	DDZ
10086812	Conductivity	Onset U24-001	20-Jun-12	18-Oct-12	Canoe	Beaver pond P03	Reference

Appendix 9-5: Terrestrial Wetland Community Summary Attributes

WS Community

The Willow – Sedge community described by Hawkes et al. (2007) is a widespread community restricted primarily to the higher elevation bands of the reservoir (752 – 753 m to 754 – 755 m ASL). One of the more speciose communities catalogued for the reservoir, WS is characterized by high deciduous shrub cover (primarily willows) in association with various sedge (*Carex*) species. Willow species (e.g., *Salix commutata, S. bebbiana*, *S. brachycarpa*, *S. discolour*, *S. drummondiana, S. lucida* spp. *lasiandra*, *S. pedicellaris*, *S. pseudomyrsinites, S. sitchensi*) occur in association with other shrubs such as Red-osier Dogwood (*Cornus stolonifera)*, Mountain Alder (*Alnus incana*), and Prickly Rose (*Rosa acicularis*). Sedge species include Slender Sedge (*C. lasiocarpa*), Kellogg's Sedge (*C. lenticularis*), Sawbeak Sedge (*Carex stipata*) and Crawford's Sedge (*C. crawfordii*). Associated herb species include Marsh Horsetail (*Equisetum palustre*), Swamp Horsetail (*E. fluviatile*), Blue Wildrye (*Elymus glaucus*), Bluejoint Reedgrass (*Calamagrostis canadensis*), Douglas' Water-hemlock (*Cicuta douglasii*), Yellow Monkey-flower (*Mimulus guttatus*), Small Bedstraw (*Galium trifidum*), Purple-leaved Willowherb (*Epilobium ciliatum*) and Buckbean (*Menyanthes trifoliata*). Sites are characterized by poor to very poor drainage, saturated soils, occasional surface water, and organics near the soil surface (Hawkes et al. 2007).

SH Community

The Swamp Horsetails community described by Hawkes et al. (2007) is a marshy wetland type commonly encountered at various elevation bands in the reservoir drawdown zone. SH is a floristically simple association dominated by one or both of Swamp Horsetail and/or Marsh Horsetail. Sites are flat to depressed, poorly drained, and generally wet. Associated species include sedges such as Water Sedge, Kellog's Sedge and Beaked Sedge, as well as Bluejoint Reedgrass, Reed Canarygrass, Small Bedstraw, Marsh Cinquefoil (*Comarum palustre*), Common Horsetail (*Equisetum arvensis*), Woolgrass (*Scirpus atrocinctus*), Small-flowered Bulrush (*S. microcarpus)*, and Buckbean.

BS Community

The Buckbean – Slender Sedge community described by Hawkes et al. (2007) is an uncommon association found primarily at mid elevations in the Bush Arm area of the reservoir. The association is primarily herbaceous, although a sparse shrub layer can occur, with Buckbean and Slender Sedge (*Carex lasiocarpa*) being the characteristic herbs. Species richness is moderate. Associated species include Marsh Cinquefoil, Wool-grass, Douglas' Water-hemlock, Knotted Rush (*Juncus nodosus*) and Beaked Sedge. Sites are flat to depressed and poorly drained. Very wet, saturated soil conditions prevail. The BS community described for Kinbasket Reservoir compares closely to the Slender Sedge – Buckbean Site Association (Wf06) described by Mackenzie and Moran (2004). The latter occurs on floating mats adjacent to small lakes and peatland ponds, or where there is permanent surface saturation and shallow inundation. As the shallow peat layer rises and falls with fluctuating water levels, the duration of surface flooding is apparently reduced. Sites are often hummocked, with Buckbean occurring in the wet depressions and Slender Sedge occurring on mounds. Nutrient availability is poor to moderate.

BS Community

The Sitka Willow – Red-osier Dogwood – Horsetail Site Association) is considered a flood association rather than a wetland per se (Mackenzie and Moran 2004). In general terms, a flood association is a non-wetland ecosystem that occurs on regularly flooded riparian sites with well-drained soils. Sites can be tall shrub, deciduous forest, or coniferous forest depending on whether they are low bench, middle bench, or high bench (Mackenzie and Moran 2004). The Fl04 occurs primarily on levees or bars in the active floodplains of sluggish, low-gradient streams. Frequently encountered shrubs are willows (especially Sitka Willow [*Salix sitchensis*]), Red-osier Dogwood, Black Twinberry (*Lonicera involcrata*), and Mountain Alder. Soils are generally sandy and well drained, though they may remain saturated at depth for extended periods (MacKenzie and Moran 2004).

Ws06 Site Association

The Sitka Willow – Sitka Sedge Site Association is a swamp ecosystem usually associated with low elevation fluvial systems that experience prolonged saturation and early season flooding (MacKenzie and Moran 2004). The characteristic shrub is Sitka Willow. The herb layer is primarily Sitka Sedge and Common Horsetail, although Small-flowered Bulrush replaces Sitka Sedge as the site dominant on some Ws06 sites. Associated shrubs include Pacific Willow, Mountain Alder, Black Twinberry, Pink Spirea, and Red-osier Dogwood. Herbs include Bluejoint Reedgrass, Water Sedge, Beaked Sedge, Common Horsetail, Lady Fern (*Athyrium felix-femina*), and Skunk Cabbage (*Lysichiton americanus*) (Mackenzie and Moran 2004). Swamps are often transitional to upland ecosystems and can have a mix of terrestrial and wetland microhabitats (MacKenzie and Moran 2004).

Wm01 Site Association

The Beaked Sedge – Water Sedge Marsh Site Association is a widespread marsh ecosystem, occurring in a variety of landscape positions such as flooded beaver ponds, lake margins, floodplains, and palustrine basins (MacKenzie and Moran 2004). Species richness is low, with Beaked Sedge and Water Sedge making up most of the cover, although diversity increases on drier sites. Associated species include Swamp Horsetail, Marsh Cinquefoil, Bluejoint Reedgrass, bladderwort (*Utricularia* spp.), Water Smartweed (*Persicaria amphibia*) and Tufted Hairgrass (*Deschampsia cespitosa*). The Wm01 is distinguished from the compositionally similar Wf01 fen association by its mineral (as opposed to peat) substrate, a more dynamic hydrology, and a higher cover of Beaked Sedge.

Wb11 Site Association

The Black Spruce – Buckbean Peat-moss Bog Site Association is an uncommon association found in small infilled basins or on edges of larger peatlands (MacKenzie and Moran 2004). Black Spruce and/or Lodgepole Pine are always present, and Buckbean is also prominent along with a diversity of graminoids and shrubs. Sites can be hummocky with standing water occurring in depressions. Soils of the WB11 are typically peat. Associated shrubs include Scrub Birch and Labrador Tea (*Rhododendron groenlandicum*). Associated herbs include Water Sedge, Shore Sedge, Marsh Cinquefoil, Swamp Horsetail, and Bog Cranberry (*Oxycoccus oxycoccos*).

Ws10 Site Association

The Western Redcedar – Spruce – Skunk Cabbage Swamp Site Association is a forested swamp ecosystem found on toe slopes, peatland margins, and low-lying floodplains (Mackenzie and Moran 2004). The tree layer includes Spruce, Western Redcedar, and Western Hemlock. Varied microtopography can result in species-rich, well developed shrub and herb layers. Skunk Cabbage is characteristic along with herbs such as Lady Fern, Common Horsetail, Bunchberry, and Oak Fern (*Gymnocarpium dryopteris*).

Wf01 Site Association

The Water Sedge – Beaked Sedge Fen Site Association is a widespread community found in a variety of landscape positions but most often in palustrine basins (Mackenzie and Moran 2004). Species richness is low with scattered forbs, aquatics, and mosses in the understory. Plant cover consists primarily of Water Sedge and Beaked Sedge on wetter sites, with grasses such as Bluejoint Reedgrass becoming more prominent on drier, meadow-like sites. Wf01 sites typically have less Beaked Sedge and fewer aquatics than the otherwise compositionally similar Wm01 marsh association (above).

Appendix 9-6: Terrestrial Wetland Communities Sampled in 2012

Target Elevation Band 753 to 754 m ASL

The wetland (WS) in the target elevation at Km 88 (Bush Arm), as represented by transect 61.18, is a wet, species-rich, moderately shrubby site with a thick herb layer dominated primarily by Buckbean. A prominent moss layer was also observed, as were patches of open water. Shrubs include willows (*Salix pedicillaris, S. commutata*), Prickly Rose (*Rosa acicularis*), and Bog Birch (Betula pumila). Sedges include Water Sedge (*Carex aquatilis*), Inland Sedge (*C. interior*), Yellow Sedge (*C. flava*), and Beaked Sedge (*C. utriculata*). The presence of obligate hydrophytes such as Common Cattail (*Typha latifolia*), Bog Willow (*S. pedicillaris*), Shore Sedge (*C. limosa*), Water Sedge, and Buckbean speak to the generally wet conditions prevailing at the site. With respect to the relative cover of different plant growth forms, perennial forbs dominate at >70 per cent cover, followed by deciduous shrubs and sedges at slightly under 10 per cent cover each. Pteridophytes (e.g., horsetails) also make up a minor component of the plant cover. The WS community type has, in general, been shown to be vulnerable to periodic high water events resulting from reservoir operations, due to the presence of shrubby species that are intolerant of prolonged flooding (Hawkes et al. 2010, 2012). It is possible that a recent series of full pool and near full pool events (in 2007, 2010, and 2011) has knocked the shrub component of this site back considerably from previous levels, contributing to the relatively low shrub cover observed in 2012.

The wetland (SH) community in the target elevation at km 79 (Bush Arm), as represented by transects 61.27 and 61.28, is a wet, moderately species-rich site dominated by Swamp Horsetail, Common Horsetail, and Buckbean, with an additional cover of Yellow Monkey-flower (*Mimulus guttatus*), Douglas' Water-hemlock, Field Mint (*Mentha arvensis*), Bluejoint Reedgrass, Small-flowered Bulrush, Spotted Touch-me-not (*Impatiens capensis*), (*Potentilla norvegica*), Norwegian Cinquefoil, and various sedges (e.g., *Carex crawfordii*). This reservoir-generated wetland was formerly the site of an upland old growth forest stand, as evidenced by the presence of large stumps. The stumps and their decaying roots have created a hummocky micro-topography with low, wet microsites interspersed with less saturated, raised microsites, allowing for the establishment of non-obligate wetland species (e.g., Common Horsetail and Spotted Touch-me-not) alongside the more typically hydrophytic species such as Swamp Horsetail and Buckbean. The surface layer is a mix of organics (live matter, litter, and decaying wood) in conjunction with approximately 30 per cent open water.

The wetland (SH) community in the target elevation at Encampment 1 (Encampment Creek), as represented by transects 61.45 and 61.46, is dominated by Swamp Horsetail and Small-flowered Bulrush with an associated herb cover of Purple-leaved Willowherb (*Epilobium ciliatum*), Bluejoint Reedgrass, Douglas' Water-hemlock, various sedges (e.g., Crawford's Sedge; *Carex crawfordii*), Common Cattail, and Wood Horsetail (*Equisetum sylvaticum*). Pink Spiraea (*Spiraea douglasii*), a deciduous shrub, is also present in low density. As in the case above, microsite variations in moisture level due to hummocking has allowed certain non-wetland obligates (e.g., Rattlebox [*Rhinanthus minor*], Common Horsetail, Wood Horsetail, Hemp-nettle [*Galeopsis tetrahit*]) to establish alongside more typical marsh-associated species. With respect to the relative cover of different plant growth forms, pteridophytes and sedges co-dominate with ~50 per cent cover each, while perennial forbs and grasses each contribute ~20 per cent cover. Annual forbs and shrubs also make up a minor component of the plant cover. The surface layer consists of organics (live matter, litter and decaying wood) and, to a lesser extent, open mineral soil.

Lower Control Wetlands

The lower control wetland (BS) community at km 88 (Bush Arm), as represented by transect 61.20, is a wet, relatively non-diverse site with a thick herb layer dominated by Buckbean (Figure 5-5). A prominent moss layer occurs interspersed with patches of open water. There is a sparse cover of willow (*Salix sp.*), but no other shrubs. Sedges include Water Sedge, Shore Sedge, and Yellow Sedge. Other associated species with notable cover include Swamp Horsetail, Common Cattail, and Flat-leaf Bladderwort (*Utricularia intermedia*). The presence of obligate hydrophytes such as Common Cattail, Shore Sedge, Water Sedge, Flat-leaf Bladderwort, and Buckbean speak to the generally wet conditions prevailing at the site. With respect to the relative cover of different plant growth forms, perennial forbs dominate at >90 per cent cover, followed by sedges at slightly under 20 per cent cover and pteridophytes at slightly under 10 per cent cover (**Figure 5-4**). Perennial grasses (Bluejoint Reedgrass) and rushes make up a very minor component of the plant cover (**Figure 5-4**).

The lower control wetland (SH?) community at the Causeway (Bush Arm), as represented by transect 61.38, is a low-diversity, sparsely vegetated marsh-type habitat dominated by horsetails and graminoids (Northern Scouring Rush [*Equisetum variegatum*], Common Horsetail, Reed Canarygrass, Fowl Bluegrass, and Crawford's Sedge). Patches of Northern Scouring Rush form the highest cover at 13 per cent, followed by Canary Reedgrass at nine per cent and Common Horsetail at three per cent. The few other species recorded along the transect occurred in trace amounts. This site was already partially inundated by rising reservoir levels at the time of survey, preventing a complete enumeration of the plant species in the transect, which may have partly contributed to the low species numbers recorded. Abiotic site characteristics such as moisture regime and substrate character could not be determined due to the water levels. Consequently, we were unable to assign a wetland type with confidence. We have suggested a preliminary classification of SH (Table 5-3) but this needs to be confirmed through subsequent surveys.

Upper Control Wetlands

The upper control wetland (WS) community at km 88 (Bush Arm), as represented by transect 61.16, is a species-rich, shrubby site with a diverse herb assemblage characterized by a cover of Buckbean, various sedges and sedge-like plants (e.g. Interior Sedge, Slender Spike-rush [*Eleocharis elliptica*]), horsetails (e.g. Marsh Horsetail), various orchids (e.g. Yellow Lady's Slipper [*Cypripedium parviflorum*], Yellow Wide-lip Orchid [*Liparis loeselii*]), and other bog-fen associates such as Roundleaf Sundew (*Drosera rotundifolia*) and Sticky False Asphodel (*Triantha glutinosa*). Some of the species present (e.g., Mountain Death-camas [*Zigadenus elegans*]), though not all of them, are indicative of calcareous soil conditions. Wide-lip Orchid (S1) and Slender Spike-rush (S2S3) are both provincially rare species tracked by the BC Conservation Data Center. Situated at 754.5 m ASL, this wetland lies slightly above the normal operating maximum of the reservoir (754.38 m ASL), and although here we have typed it using the drawdown zone-specific classification of Hawkes et al. (2007), it could also be a candidate for typing using the classification of Mackenzie and Moran (2004).

The upper control transect at the Causeway (Bush Arm) is situated slightly above the normal operating maximum elevation and was tentatively typed as Fl04 (Sitka Willow – Red-osier Dogwood – Horsetail Site Association), a flood association, using the classification of MacKenzie and Moran (2004). The transect (transect 61.42) is in a young deciduous Black Cottonwood (*Populus balsamifera* ssp. *trichocarpa*) stand adjacent to coniferous forest, with a deciduous shrub layer of Black Twinberry, Red-osier Dogwood, willows (Sitka Willow, Bebb's Willow [*S. bebbiana*]), Prickly Rose, Birch-leaved Spirea (*Spiraea betulifolia*), and Saskatoon (*Amelanchier alnifolia*). The herb layer consists primarily of riparian and terrestrial species including Bunchberry (Cornus Canadensis), Trailing Raspberry (*Rubus pubescens*), and Common Horsetail. Hydrophytes are generally absent. The tree layer represents ~8 per cent cover, the shrub layer ~40 per cent cover, and the herb layer ~10 per cent cover. The surface layer consists of organics and fines with a significant cover of litter and woody debris.

The upper control wetland (WS) community at Encampment 1 (Encampment Creek), as represented by transect 61.44, is a wet, moderately species-rich, shrubby community dominated in the shrub layer by Sitka Willow and in the herb layer by Bluejoint Reedgrass, Small-flowered Bulrush, and Crawford's Sedge. Associated shrubs include Pussy Willow (*Salix discolor*), Pacific Willow (*S. lucida*), and Mountain Alder. Associated sedges include Kellogg's Sedge and Thick-headed Sedge (*Carex pachystachya*). Forbs include Marsh Cinquefoil, Small-flowered Bedstraw, Large-leaved Avens (*Geum macrophyllum*), and Purple-leaved Willowherb. The shrub layer represents ~60 per cent cover and the herb layer ~40 per cent cover. The surface layer consists of organics and fines with a significant cover of litter along with some exposed mineral soil.

A second upper control wetland community (transect 61.43) was also sampled at Encampment 1 (Encampment Creek) but from a slightly higher elevation (754.8 m ASL) than transect 61.44. This wetland was tentatively typed as the swamp ecosystem Ws06 (Sitka Willow – Sitka Sedge Site Association) using the classification of MacKenzie and Moran (2004). This is a treed site (Black Cottonwood and Western Red Cedar) with a shrub-dominated understory of Sitka Willow, Red Raspberry (*Rubus idaeus*), Black Twinberry, Mountain Alder, and Thimbleberry (*Rubus parviflorus*). A diverse herb layer is characterized by a cover of Bluejoint Reedgrass and Small-flowered Bulrush and includes various sedges (e.g., Grey Sedge [*Carex canescens*]), Swamp Horsetail, Lady Fern, Common Cattail, and Tall Mannagrass (*Glyceria elata*). The tree layer represents ~3 per cent cover, the shrub layer ~30 per cent cover, and the herb layer ~60 per cent cover. The surface layer consists of organics and litter with a partial cover of decaying wood. Based on the graminoid-dominated understory, this is likely a nutrient-medium site where groundwater flow and/or elevated microsites allow growth of trees and shrubs under subhydric conditions.

The upper control wetland community at Encampment 2 (Encampment Creek), another high elevation wetland, was likewise typed as Ws06 (Sitka Willow – Sitka Sedge Site Association) using the classification of MacKenzie and Moran (2004). As represented by transect 61.54, this is a treed site (Western Red Cedar, Western White Pine, Engelmann Spruce, Black Cottonwood) with a well-developed shrub layer of Sitka and Pussy Willow, Black Twinberry, Mountain Alder, and Thimbleberry. The herb layer is fairly species-poor and dominated by various sedges including Sitka Sedge (~30 per cent cover), Small-flowered Bulrush, and Swamp Horsetail. The tree layer represents <1 per cent cover, the shrub layer ~17 per cent cover, and the herb layer ~66 per cent cover. The surface layer consists of organics and litter interspersed with open mineral soil and patches of open water covering ~20 per cent of the transect. Like the Ws06 wetland at Encampment 1, the high sedge cover suggests that this is a nutrient-medium site where groundwater flow and/or elevated microsites allow growth of trees and shrubs under subhydric conditions.

Reference Wetlands

The reference wetland (WS) community at km 88 (Bush Arm), as represented by transect 96, is situated at 756.6 m ASL and therefore is not affected by normal reservoir operations. Transect 96 was originally established for CLBMON-10 and has been monitored since 2008. This wetland was classified for CLBMON-10 as a WS (Willow – Sedge) community. For the sake of continuity with the CLBMON-10 study, the same classification has been retained here, although using the classification of MacKenzie and Moran (2004), this wetland appears to key out as the fen association Wf07 (Scrub Birch – Buckbean – Shore Sedge Fen Site Association). An open shrub layer includes Scrub Birch and willows (*Salix commutata*, *S. glauca*, *Salix* sp.). The herb layer is dominated by Buckbean at ~75 per cent cover. However, a diversity of other herbs, primarily hydrophytes (e.g., Slender Spike-rush, Douglas' Water-hemlock, Interior Sedge, Shore Sedge, Marsh Horsetail, Common Cattail, Tall Mannagrass) but also terrestrial species (e.g., Mountain Death-camas), contribute to the total vascular plant cover. There is also a well-developed bryophyte layer. With respect to the relative cover of different vascular plant growth forms, perennial forbs dominate at >80 per cent cover, followed by sedges at ~12 per cent cover and both shrubs and pteridophytes at ~5 per cent cover. Grasses make up a very minor component of the plant cover. The surface layer is mainly moss interspersed with open water patches, suggesting the presence of a permanently high water table.

The reference site at Km 79 (Bush Arm), represented by transects 61.97 and 61.98, is a small Beaked Sedge – Water Sedge marsh (Wm01 Site Association) at the margins of an open water pond. A tree and shrub layer consisting of coniferous and deciduous tree species relates this wetland to the surrounding upland coniferous forest and indicates that it is somewhat transitional. The herb layer is dominated by Beaked Sedge (with *Carex retrorsa* largely replacing *C. utriculata* in this instance). Other prominent herbs include Marsh Cinquefoil, Skunk Cabbage, Monkey Flower, Lady Fern, Bluejoint Reedgrass and Purple-leaved Willowherb. Among different growth forms, sedges dominate the vascular plant cover at ~35 per cent cover, followed by perennial forbs at ~15 per cent cover, deciduous shrubs at ~10 per cent cover and shrub-sized coniferous trees at ~5 per cent cover. Pteridophytes and grasses account for <5 per cover each. The surface layer consists of organic material (mosses and litter) interspersed with frequent open water patches.

The reference site at Valemount Peatland (Canoe Reach), represented by transects 61.07 and 61.08, is a Black Spruce – Buckbean – Peatmoss bog (Wb11 Site Association). Buckbean is the most prominent species in a non-diverse herb layer that features various sedges (e.g., Sitka Sedge, Shore Sedge, Interior Sedge) along with Roundleaf Sundew and White Bog Orchid (*Platanthera dilatata*). The relatively diverse shrub layer is dominated by Scrub Birch and includes Black Spruce, Mountain Alder, Bog Cranberry, Labrador Tea, and Sweet Gale (*Myrica gale*). Among different growth forms, forbs dominate the vascular plant cover at ~50 per cent cover followed by deciduous shrubs (~40 per cent cover), sedges (~20 per cent cover), horsetails (~5 per cent cover), and coniferous trees (<5 per cent cover). Grasses and rushes are also present, but in low abundance. There is a well developed moss layer (including sphagnum mosses). The surface layer consists of organic material (moss and litter) with open water occurring in some depressions.

The reference site at Encampment 2 (Encampment Creek), represented by transect 61.56, is a Western Redcedar – Spruce – Skunk Cabbage Swamp (Ws10 Site Association). This is a forested site with an herbaceous understory dominated by Small-flower Bulrush (36 per cent cover) and Bluejoint Reedgrass (23 per cent cover). Associated herbs include Skunk Cabbage, Lady Fern, Oak Fern, Great Northern Aster (*Canadanthus modestus*), Fowl Bluegrass, and Tall Mannagrass. The tree layer includes Subalpine Fir, Spruce, Western Redcedar, Western Hemlock, and Black Cottonwood. These same species, along with some small Western White Pine, compose the shrub layer. Among different growth forms, sedges and sedge-like plants are the most prominent vascular growth form at ~35 per cent cover, followed by grasses (~25 per cent cover), coniferous trees (~20 per cent cover), forbs (~10 per cent cover), and deciduous shrubs (~5 per cent cover). Deciduous trees and pteridophytes contribute <5 per cent cover. The surface layer consists of organic material (herbs, moss, and litter) and some open mineral soil.

The reference site at Succour Creek (Bush Arm), represented by transect 61.72, is a Water Sedge – Beaked Sedge fen (Wf01 Site Association). The site is characterized by moderately high sedge cover, low species richness, and an absence of woody species. Sedge species (primarily Beaked Sedge) occur in association with both aquatic and terrestrial herbs including Tufted Hairgrass, Marsh Cinquefoil, Swamp Horsetail, Marsh Horsetail, Norwegian cinquefoil (*Potentilla norvegica*), Wild Strawberry (*Fragaria vesca*), Lindley's Aster (*Symphyotrichum ciliolatum*), Toad Rush (*Juncus bufonis*), Marsh Skullcap (*Scutellaria galericulata*), Purple-leaved Willowherb, and Pearly Everlasting (*Anaphalis margaritacea*). Among different vascular growth forms, sedges contribute the most cover at ~20 per cent, followed by perennial grasses (~8 per cent cover). Forbs, pteridophytes (horsetails), and rushes also make up a minor component of the plant cover. The surface layer consists almost entirely of thatch (decaying litter).

Appendix 9-7: Water Physicochemistry: Continuous Data

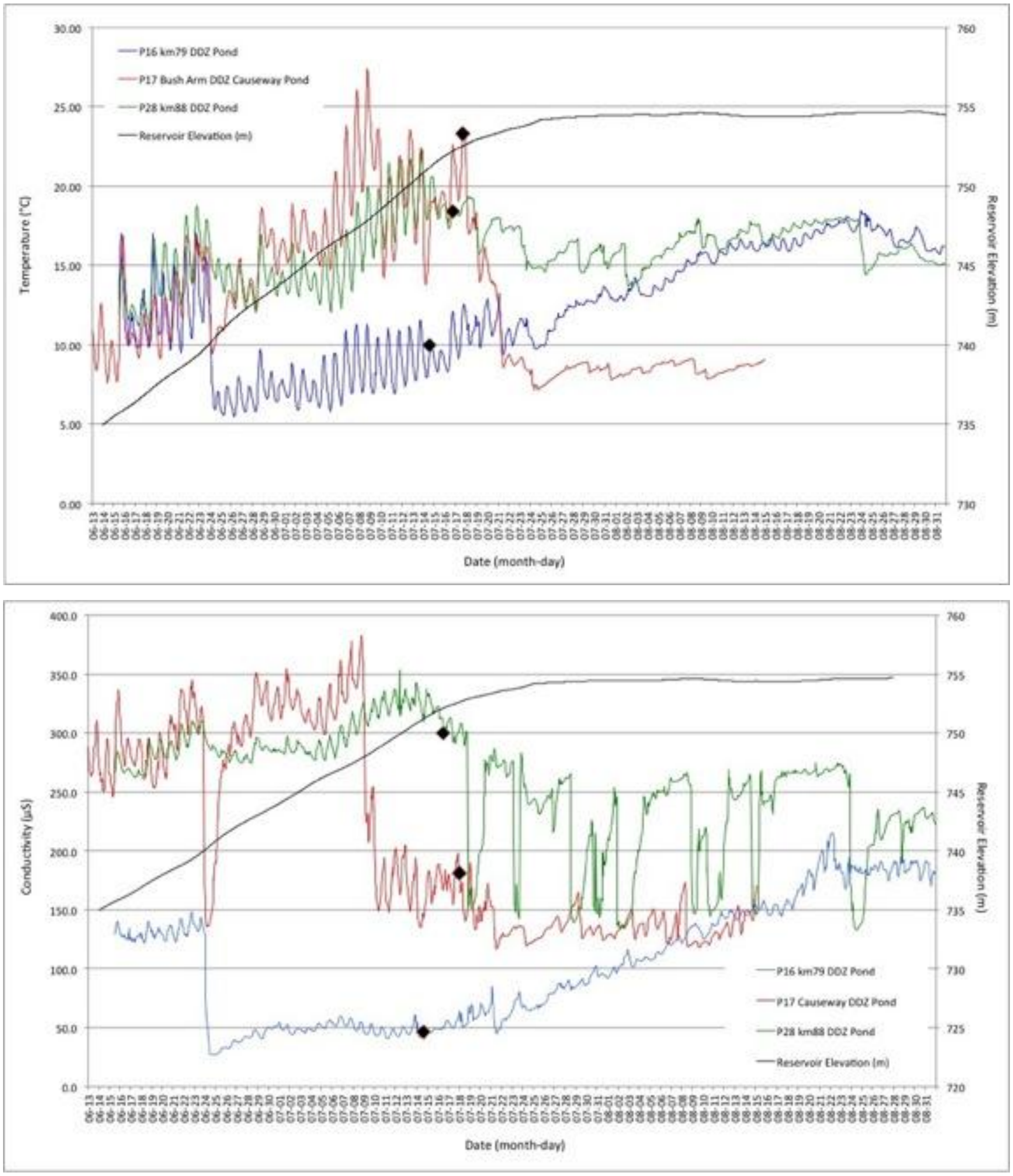
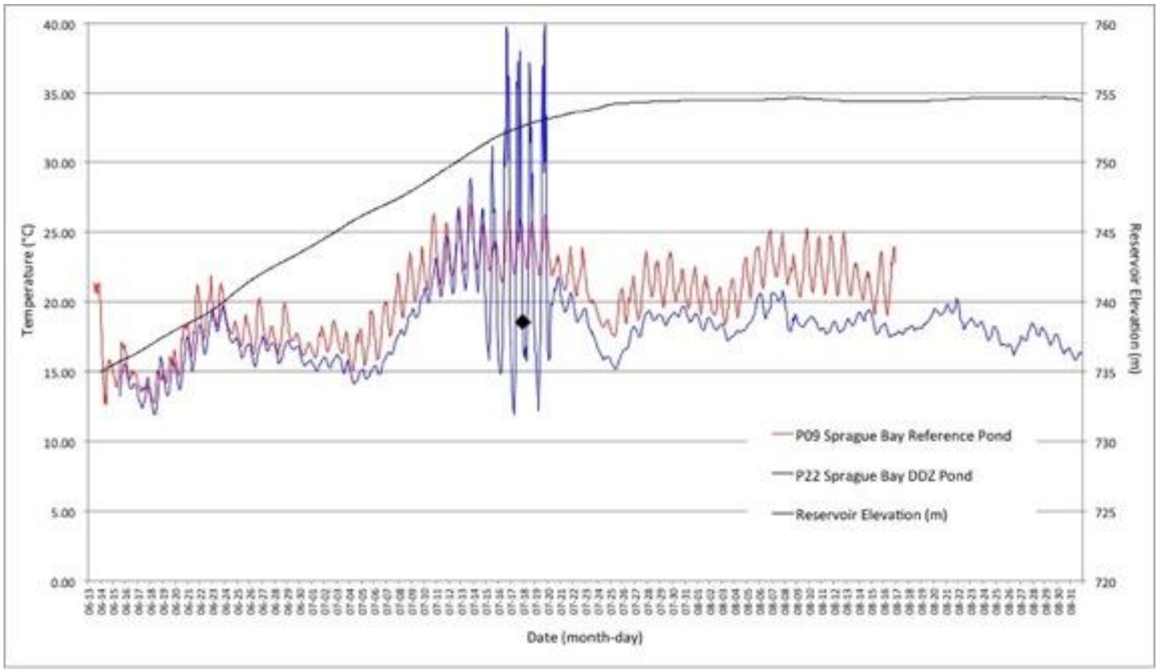


Figure 9-11: Continuous temperature (ºC; above) and conductivity levels (µS/cm; below) from dataloggers installed in Bush Arm ponds. Markers indicate the approximate timing of when ponds became inundated by Kinbasket Reservoir. The markers are based on a digital elevation model and hourly reservoir levels at Mica Dam. Reservoir levels are shown as a black line and elevation is shown in the right axis



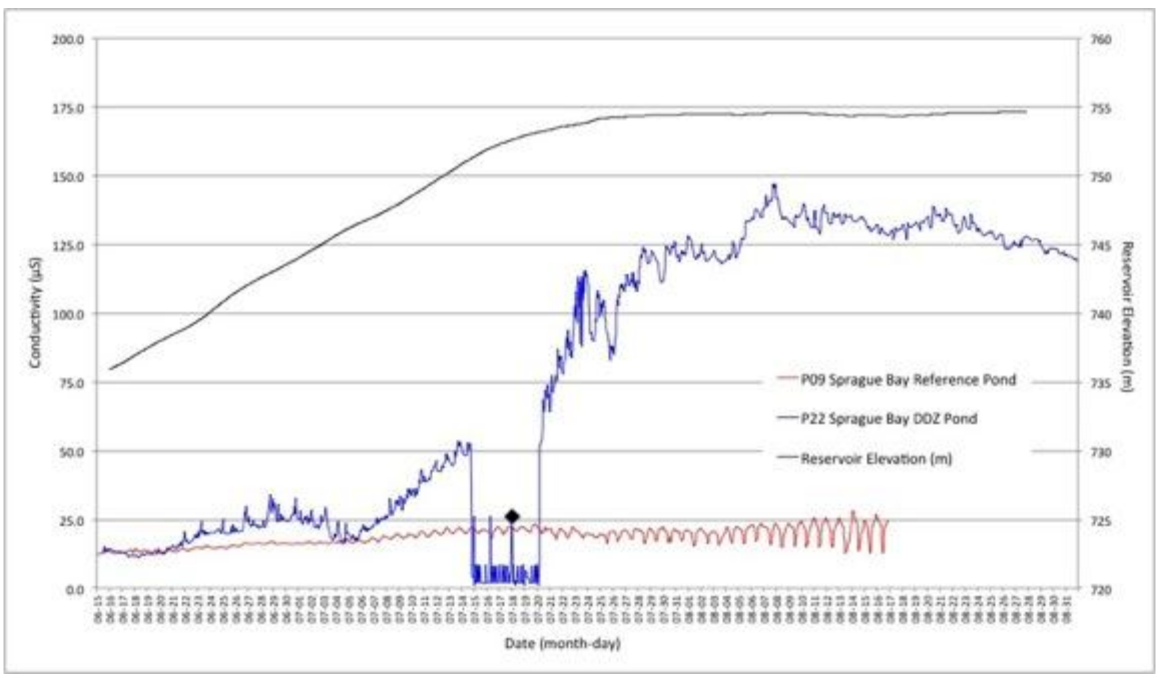
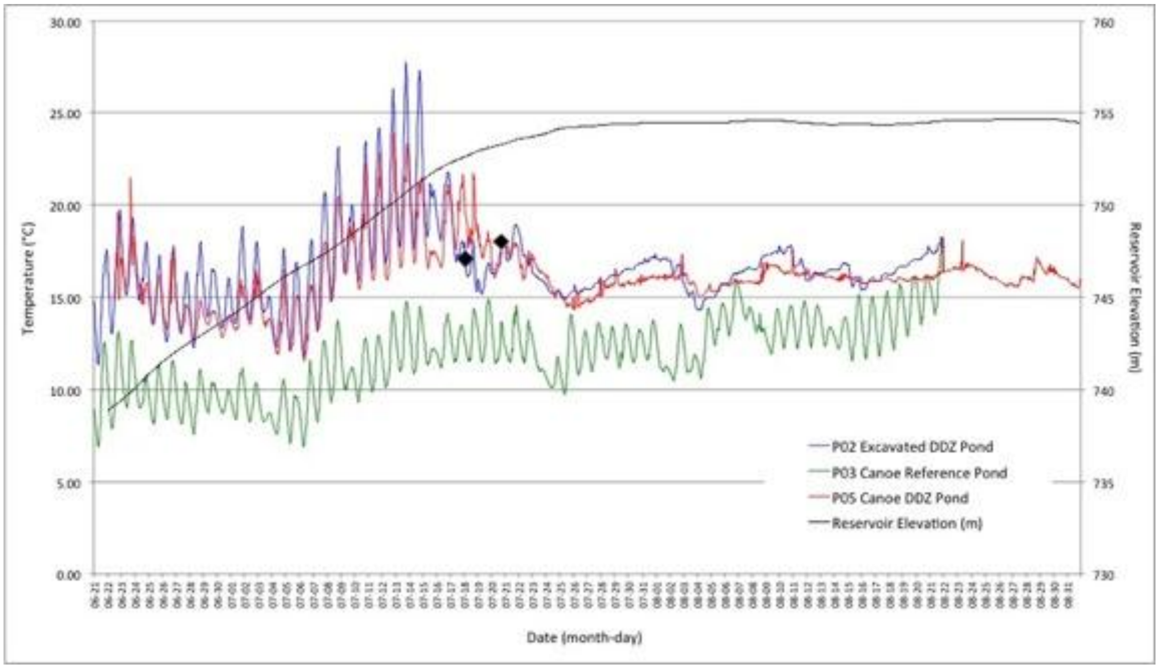


Figure 9-12: Continuous temperature (ºC; above) and conductivity levels (µS/cm; below) from dataloggers installed in Mica Arm ponds. Markers indicate the approximate timing of when ponds became inundated by Kinbasket Reservoir. The markers are based on a digital elevation model and hourly reservoir levels at Mica Dam. Reservoir levels are shown as a black line and elevation is shown in the right axis



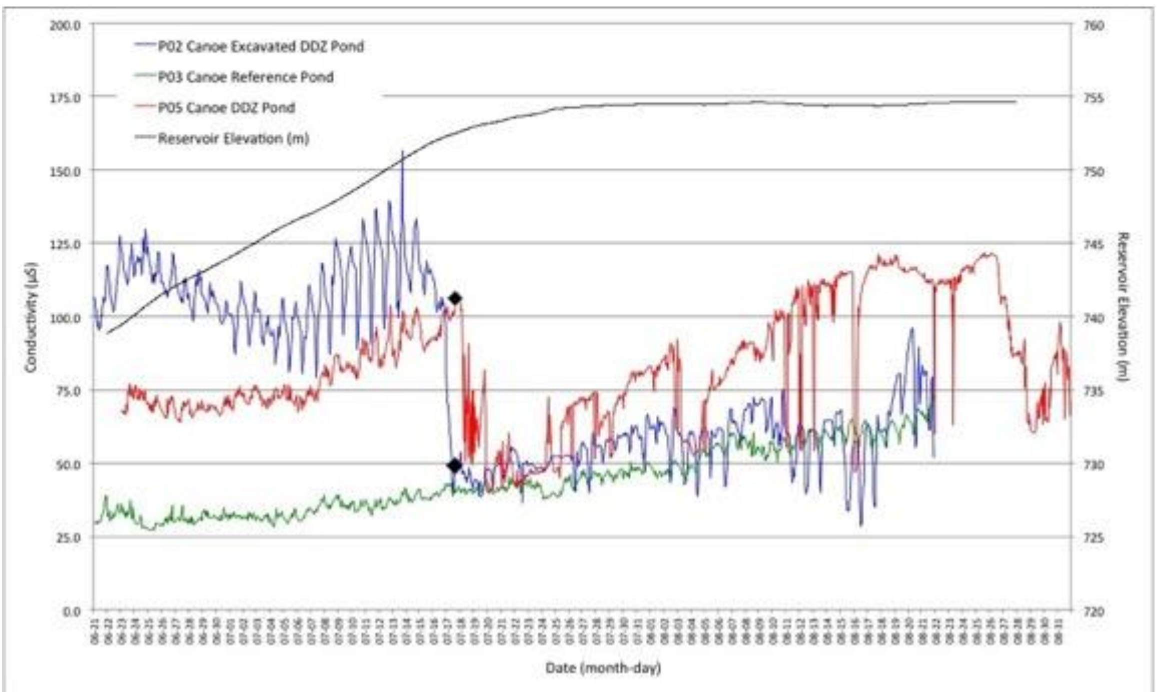


Figure 9-13: Continuous temperature (ºC; above) and conductivity levels (µS/cm; below) from dataloggers installed in Canoe Reach ponds. Markers indicate the approximate timing when the ponds became inundated by the reservoir**.** Reservoir levels are shown as a black line and elevation is shown in the right axis

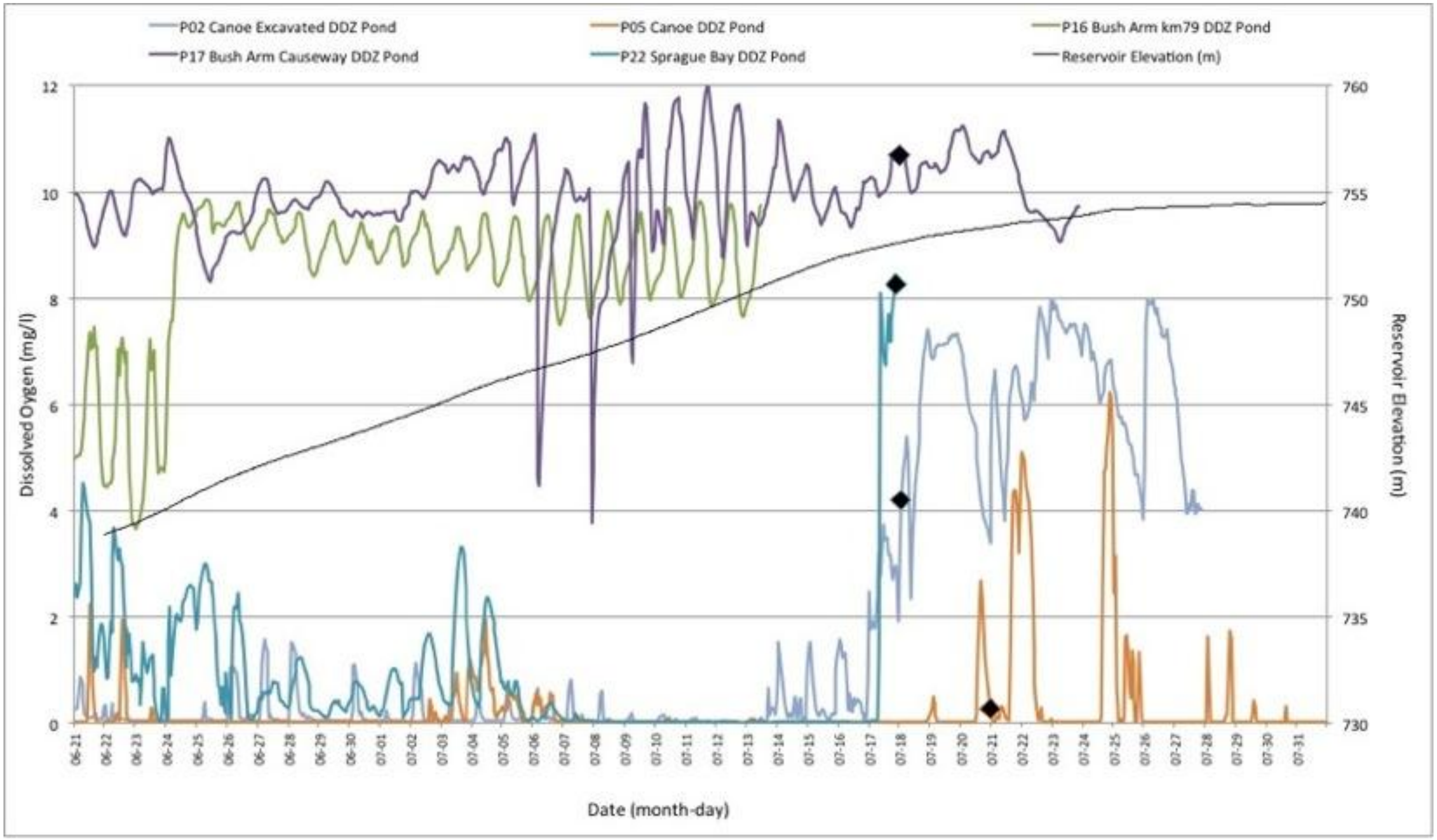


Figure 9-14: Dissolved oxygen (mg/l) levels from dataloggers installed in five ponds, June 22 to August 31, 2012. Markers indicate the approximate timing of when the ponds became inundated by Kinbasket Reservoir. Reservoir levels are shown as a black line and elevation is shown in the right axis

Appendix 9-8: Species lists

Table 9-3. Wetland species observed in terrestrial wetland transects, 2012.

Group	Species Code	Latin Name	Origin
Evergreen	GAULHIS	*Gaultheria hispidula*	Native
	LINNBOR	*Linnaea borealis*	Native
		Linnaea borealis	Native
Forb-ann	BIDECER	*Bidens cernua*	Native
	Cerastium sp.	*Cerastium sp.*	Native
	COLLLIN	*Collomia linearis*	Native
	GALETET	*Galeopsis tetrahit*	Exotic
	IMPACAP	*Impatiens capensis*	Native
	Impatiens sp.	*Impatiens sp.*	Native
	MATRDIS	*Matricaria discoidea*	Native
	MIMUGUT	*Mimulus guttatus*	Native
	POLYPER	*Polygonum persicaria*	Native
	POTENOR	*Potentilla norvegica*	Native
	RANUPEN	*Ranunculus pensylvanicus*	Native
	RHINMIN	*Rhinanthus minor*	Native
	RORIPAL	*Rorippa palustris*	Native
Forb-per	ACTARUB	*Actaea rubra*	Native
	ANAPMAR	*Anaphalis margaritacea*	Native
	ASTEFOL	*Aster foliaceus*	Native
	CANAMOD	*Canadanthus modestus*	Native
	CASTMIN	*Castilleja miniata*	Native
	CICUDOU	*Cicuta douglasii*	Native
	CICUMAC	*Cicuta maculata*	Native
	CIRCALP	*Circaea alpina*	Native
	CIRSARV	*Cirsium arvensis*	Native
	CIRSIUM sp.	*Cirsium sp.*	Native
	CIRSVUL	*Cirsium vulgare*	Native
	COMAPAL	*Comarum palustre*	Native
	CORNCAN	*Cornus canadensis*	Native
	CYPRPAR	*Cypripedium parviflorum*	Native
	DROSROT	*Drosera rotundifolia*	Native
	EPILANG	*Epilobium angustifolium*	Native
	EPILCIL	*Epilobium ciliatum*	Native
	EPILLEP	*Epilobium leptophyllum*	Native
	ERIGPHI	*Erigeron philadelphicus*	Native
	ERIOANG	*Eriophorum angustifolium*	Native
	FRAGVES	*Fragaria vesca*	Native
	FRAGVIR	*Fragaria virginiana*	Native
	GALIBOR	*Galium boreale*	Native
	GALILAB	*Galium labradoricum*	Native
	GALITRD	*Galium trifidum*	Native
	GALITRF	*Galium triflorum*	Native
	GEOCLIV	*Geocaulon lividum*	Native
	GEUMMAC	*Geum macrophyllum*	Native
	HIERPRA	*Hieracium praealtum*	Exotic
	HIPPVUL	*Hippuris vulgaris*	Native
	LEUCVUL	*Leucanthemum vulgare*	Exotic
	LIPALOE	*Liparis loeselii*	Native
	LYSIAME	*Lysichiton americanus*	Native
	LYSITHY	*Lysimachia thyrsiflora*	Native
	MAIASTE	*Maianthemum stellatum*	Native
	MAIATRI	*Maianthemum trifolium*	Native
	MENTARV	*Mentha arvensis*	Native
	MENYTRI	*Menyanthes trifoliata*	Native
	OSMODEP	*Osmorhiza depauperata*	Native
	PACKPAP	*Packera paupercula*	Native
	PARNPAL	*Parnassia palustris*	Native
	PETASAG	*Petasites fridigus ssp. sagittatus*	Native
	PLATAQU	*Platanthera aquilonis*	Native

	PLATDIL	*Platanthera dilatata*	Native
	PYROASA	*Pyrola asarifolia*	Native
	RUBUARC	*Rubus arcticus*	Native
	RUBUPUB	*Rubus pubescens*	Native
	RUMEX sp.	*Rumex sp.*	Native
	SANIMAR	*Sanicula marilandica*	Native
	SCUTGAL	*Scutellaria galericulata*	Native
	SENETRI	*Senecio triangularis*	Native
	SOLICAN	*Solidago canadensis*	Native
	SPAREME	*Sparganium emersum*	Native
	STELBOR	*Stellaria borealis*	Native
	STELLON	*Stellaria longifolia*	Native
	STRELAN	*Streptopus lanceolatus*	Native
	SYMPBOR	*Symphyotrichum boreale*	Native
	SYMPCII	*Symphyotrichum ciliolatum*	Native
	SYMPPUN	*Symphyotrichum puniceum*	Native
	TARAOFF	*Taraxacum officinale*	Exotic
	TRIAGLU	*Triantha glutinosa*	Native
	TRIEEUR	*Trientalis europaea*	Native
	TRIFDUB	*Trifolium dubium*	Native
	TRIFHYB	*Trifolium hybridum*	Exotic
	TRIFPRA	*Trifolium pratense*	Native
	TRIFREP	*Trifolium repens*	Native
	TRIGMAR	*Triglochin maritima*	Native
	TRIGPAL	*Triglochin palustris*	Native
	TYPHLAT	*Typha latifolia*	Native
	UTRIINT	*Utricularia intermedia*	Native
	VEROBEC	*Veronica beccabunga*	Native
	VIOLA sp.	*Viola sp.*	Native
	VIOLMAC	*Viola macloskeyi*	Native
	VIOLPAL	*Viola palustris*	Native
	ZIGAELE	*Zigadenus elegans*	Native
Grass-per	AGROGIG	*Agrostis gigantea*	Native
	AGROSCA	*Agrostis scabra*	Native
	BROMCIL	*Bromus ciliatus*	Native
	CALACAN	*Calamagrostis canadensis*	Native
	CALASTR	*Calamagrostis stricta*	Native
	DESCCES	*Deschampsia cespitosa*	Native
	ELYMREP	*Elymus repens*	Native
	GLYCELA	*Glyceria elata*	Native
	GLYCGRA	*Glyceria grandis*	Native
	GLYCSTR	*Glyceria striata*	Native
	PHALARU	*Phalaris arundinacea*	Native
	PHLEPRA	*Phleum pratense*	Native
	POA COM	*Poa compressa*	Native
	POA PAL	*Poa palustris*	Native
	POA PRA	*Poa pratensis*	Native
Pterid	ATHYFIL	*Athyrium filix-femina*	Native
	BOTRMUL	*Botrychium multifidum*	Native
	BOTRVIR	*Botrychium virginianum*	Native
	EQUIARV	*Equisetum arvense*	Native
	EQUIFLU	*Equisetum fluviatile*	Native
	EQUIPAL	*Equisetum palustre*	Native
	EQUISCI	*Equisetum scirpoides*	Native
	EQUISYL	*Equisetum sylvaticum*	Native
	EQUIVAR	*Equisetum variegatum*	Native
	GYMNDRY	*Gymnocarpium dryopteris*	Native
Rush	JUNCUS sp.	*Juncus sp.*	Native
Rush-ann	JUNCBUF	*Juncus bufonius*	Native
Rush-per	JUNCALP	*Juncus alpinoarticulatus*	Native
	JUNCNOD	*Juncus nodosus*	Native
	TRICALP	*Trichophorum alpinum*	Native
Sedge	CAREAQU	*Carex aquatilis*	Native
	CAREAUR	*Carex aurea*	Native
	CAREBEB	*Carex bebbii*	Native
	CARECAN	*Carex canescens*	Native

	CARECHO	*Carex chordorrhiza*	Native
	CARECRA	*Carex crawfordii*	Native
	CARECUS	*Carex cusickii*	Native
	CAREDIA	*Carex diandra*	Native
	CAREFLA	*Carex flava*	Native
	CAREGYN	*Carex gynocrates*	Native
	CAREINT	*Carex interior*	Native
	CARELAE	*Carex laeviculmis*	Native
	CARELAS	*Carex lasiocarpa*	Native
	CARELEN	*Carex lenticularis ssp.lipocarpa*	Native
	CARELIM	*Carex limosa*	Native
	CAREMAG	*Carex magellanica*	Native
	CAREPAC	*Carex pachystachya*	Native
	CAREROST	*Carex rostrata*	Native
	CARESIT	*Carex sitchensis*	Native
	CAREUTR	*Carex utriculata*	Native
	CAREVIR	*Carex viridula*	Native
	CAREX sp.	*Carex sp.*	Native
	ELEOCHARIS sp.	*Eleocharis sp.*	Native
	ELEOELL	*Eleocharis elliptica*	Native
	ELEOMAM	*Eleocharis mamillata*	Native
	ERIOVIR	*Eriophorum viridicarinatum*	Native
	SCIRATR	*Scirpus atrocinctus*	Exotic
	SCIRMIC	*Scirpus microcarpus*	Native
Shrub-con	JUNICOM	*Juniperus communis*	Native
Shrub-dec	ACERGLA	*Acer glabrum*	Native
	ALNUCRI	*Alnus viridis ssp.crispa*	Native
	ALNUINC	*Alnus incana*	Native
	AMELALN	*Amelanchier alnifolia*	Native
	BETUOCC	*Betula occidentalis*	Native
	BETUPUM	*Betula pumila*	Native
	CORNSTO	*Cornus stolonifera*	Native
	LEDUGRO	*Rhododendron groenlandicum*	Native
	LONIINV	*Lonicera involucrata*	Native
	MENZFER	*Menziesia ferruginea*	Native
	MYRIGAL	*Myrica gale*	Native
	OXYCOXY	*Oxycoccus oxycoccos*	Native
	RIBELAC	*Ribes lacustre*	Native
	ROSAACI	*Rosa acicularis*	Native
	RUBUIDA	*Rubus idaeus*	Native
	RUBUPAR	*Rubus parviflorus*	Native
	SALIBEB	*Salix bebbiana*	Native
	SALICOM	*Salix commutata*	Native
	SALIDIS	*Salix discolor*	Native
	SALILUC	*Salix lucida ssp.lasiandra*	Native
	SALIPED	*Salix pedicellaris*	Native
	SALIPRO	*Salix prolixa*	Native
	SALISCO	Salix scouleriana	Native
	SALISIT	Salix sitchensis	Native
	SALIX sp.	Salix sp.	Native
	SHEPCAN	Shepherdia canadensis	Native
	SORBSCO	Sorbus scopulina	Native
	SPIRBET	Spiraea betulifolia	Native
	SPIRDOU	Spiraea douglasii	Native
	VACCMEM	Vaccinium membranaceum	Native
	VACCOVA	Vaccinium ovalifolium	Native
	VIBUEDU	Viburnum edule	Native
Tree-con	ABIESLAS	Abies lasiocarpa	Native
	PICEENE	Picea engelmannii x glauca	Native
	PICEMAR	Picea mariana	Native
	PINUMON	Pinus monticola	Native
	THUJPLI	Thuja plicata	Native
	TSUGHET	Tsuga heterophylla	Native
Tree-dec	BETUPAP	Betula papyrifera	Native
	PICEENG	Picea engelmannii	Native
	POPUTRI	Populus balsamifera ssp. trichocarpa	Native

Table 9-4. Wetland species observed during aquatic wetland sampling in 2012.

Code	*Scientific Name*	Origin	Habitat	Form	Common Name
Callitriche	Callitriche palustris	Native	Aquatic	Floating - Rooted	water -starwort
CAREATHE	Carex atherodes	Native	Wetland	Emergent	sedge
CARELAS	Carex lasiocarpa	Native	Wetland	Emergent	sedge
CARELEN	Carex lenticularis ssp.lipocarpa	Exotic	Wetland	Emergent	sedge
Chara sp.	Chara spp.	Native	Aquatic	Submerged	muckgrass
CICUMAC	Cicuta maculata	Native	Terrestrial	Forb	spotted water hemlock
COMAPAL	Comarum palustre	Native	Wetland	Emergent	marsh cinquefoil
EQUIFLU	Equisetum fluviatile	Native	Wetland	Emergent	swamp horsetail
Green Algae	Algae sp.		Aquatic	Submerged	
HIPPVUL	Hippuris vulgaris	Native	Wetland	Emergent	mares' tail
MENYTRI	Menyanthes trifoliata	Native	Wetland	Emergent	bogbean
Moss	Moss sp.		Terrestrial	Moss	
MYRI_SP	Myriophyllum sp.		Aquatic	Submerged	milfoil
MYRISPI	Myriophyllum spicatum	Exotic	Aquatic	Submerged	eurasian water-milfoil
MYRIVER	Myriophyllum verticillatum	Native	Aquatic	Submerged	bracted water-milfoil
NUPHPOL	Nuphar polysepala	Native	Aquatic	Floating - Rooted	Rocky Mountain Pond-lily
PERSAMP	Persicaria amphibia	Native	Aquatic	Floating - Rooted	water smartweed
POTA_SP	Potamogeton sp	Native	Aquatic	Submerged	pondweed
POTAGRA	Potamogeton gramineus	Native	Aquatic	Submerged	grass-leaved pondweed
POTANAT	Potamogeton natans	Native	Aquatic	Submerged	floating-leaved pondweed
POTAPRA	Potamogeton praelongus	Native	Aquatic	Submerged	long-stalked pondweed
POTAPUS	Potamogeton pusillus	Native	Aquatic	Submerged	small pondweed
POTARIC	Potamogeton richardsonii	Native	Aquatic	Submerged	richardson's pondweed
POTAZOS	Potamogeton zosteriformis	Native	Aquatic	Submerged	eel-grass pondweed
RANUAQU	Ranunculus aquatilis	Native	Aquatic	Submerged	water crowfoot
Rumex	Rumex occidentalis	Native	Wetland	Emergent	dock
Salix Spp	Salix sp.		Terrestrial	Shrub	
SCHOTAB	Schoenoplectus tabernaemontani	Native	Wetland	Emergent	soft-stemmed bulrush
SPARG_SP	Sparganium sp		Aquatic	Submerged	
SPARGANG	Sparganium angustifolium	Native	Aquatic	Submerged	narrow-leaved bur-reed
Stuckenia	Stuckenia sp.	Native	Aquatic	Submerged	pondweed
UTRIINT	Utricularia intermedia	Native	Aquatic	Submerged	flat-leaved bladderwort
UTRIMAC	Utricularia macrorhiza	Native	Aquatic	Submerged	greater bladderwort
UTRIMIN	Utricularia minor	Native	Aquatic	Submerged	lesser bladderwort

Table 9-5. Plant species detected in ponds sampled under CLBMON-61 in 2012. Data is expressed as a frequency of detections from pooled rake and visual quadrat samples. Ponds are grouped by reach and position (reference or within reservoir).

Reach			**Bush**						**Canoe**								Count
Position		**Reference**			**Reservoir**		**Reference**				**Reservoir**			**Reference**	**Reservoir**		
Pond	**P11**	**P15**	**P18**	**P29**	**P16**	**P28**	**P03**	**P21**	**P02**	**P05**	**P06**	**P19**	**P20**	**P09**	**P08**	**P22**	
# Species	**4**	**2**	**5**	**11**	**6**	**5**	**1**	**6**	**4**	**8**	**3**	**3**	**4**	**1**	**6**	**0**	
Callitriche													1.00				1
CAREATHE				0.50													1
CARELAS				0.50													1
CARELEN										0.13							1
Chara	1.00		0.33		0.67												**3**
CICUMAC				0.25													1
COMAPAL				0.50					0.67								**2**
EQUIFLU				0.75					0.67			1.00	0.33		0.40		**5**
Green Algae		0.67							0.67								2
HIPPVUL				0.25													1
MENYTRI												1					1
Moss					1.00								0.33				2
MYRISPI					0.67	0.67				0.38	1.00						**4**
MYRIVER		0.67	0.17	0.25													3
NUPHPOL				0.25			0.67	0.29		0.88					0.20		**5**
PERSAMP				0.25				0.29		0.13							3
POTA_SP								0.29	0.67	0.63	0.75						4
POTAGRA								0.86		0.13							**2**
POTANAT			0.17	0.25						0.25							3
POTAPRA											0.25						1
POTAPUS				0.25	1.00	0.67								0.50	1.40		**5**
POTARIC			0.33														1
POTAZOS	0.33																1
RANUAQU	0.33					0.67											2
Rumex sp															0.20		1
SCHOTAB			0.50					0.14									**2**
SPARGANG					0.33	0.67							1.00		1.00		**4**
Stuckenia	0.33																1
UTRIINT								0.57				1.00					2
UTRIMAC					0.33					0.50							2
UTRIMIN					0.33	0.33									0.20		3

Appendix 9-9: Aquatic Wetland Communities

YELLOW POND-LILY *(Nuphar)* Communities

Nuphar communities occurred in beaver ponds or lakes that were in excess of 1.5 meters in depth and across a range of dissolved oxygen, pH and conductivity values. Pierce and Jensen (2002) described a single highly variable *Nuphar* community dominated by *Nuphar polysepala* (10 to 60 percent foliar coverage), which was associated with sites that were relatively high in organic carbon. This concurs with our observations except at Bush Lake (P18), which is an oligotrophic shallow lake. The Nuphar community that was present in Bush Lake occurred in isolated areas along the shoreline, where organic matter tends to accumulate. MacKenzie and Moran (2004) further subdivide the Nuphar community into several plant associations, two of which we documented.

Nuphar lutea–Potamogeton richardsonii (NLPR)

The NLPR was documented in one pond in the reservoir (P05) and in three reference sites including the two shallow lakes sampled (P21 and P18), and a small Beaver pond (P03) above the reservoir adjacent the Valemount Peatland. This community typically occurs on mineral sediments with some water movement where *N. polysepala* forms a dense canopy with scattered *Potamogeton natans* and *Polygonum amphibium. Potamogeton richardsonii* and *Myriophyllum spicatum* typically occur in the understory.

Nuphar lutea–Utricularia macrorhiza (NLUM)

The NLUM community was documented in four ponds, three of which occurred in the Sprague Bay wetland complex (P08, P09, and P22) between 753 to 756 m ASL. NLUM was also recorded in pond P05, where it occurred sympatrically with the NLPR community. This community is widespread across British Columbia and occurs dystrophic and oligotrophic waters 20–200 cm deep on gyttja and peat sediments. Sites are relatively species-poor. *Nuphar polysepala* forms an open canopy with *Utricularia macrorhiza* and *Chara* spp. common in the understory.

Muskgrass – *Chara spp.*

Muskgrass is a macroalga that occurs in stagnant, alkali waters. *Chara* spp. are efficient at using bicarbonate for photosynthesis and this precipitates large quantities of calcium carbonate (marl). Pierce and Jensen (2002) reported *Chara* spp. in ponds with a conductivity of > 100 µS/cm.

The Muskgrass community occurred in two alkaline (> 8.0 pH) reference sites in the Bush Arm (P11, P18) with conductivity levels above > 200 µS/cm. *Chara* spp was detected in a grapnel sample in pond P16 in the reservoir; unfortunately, higher than normal reservoir levels had already inundated the pond prevented us from typing the community.

White water-buttercup (WWB) – *Ranunculus aquatilis*

The WWB community occurs throughout the Pacific Northwest in mesotrophic to eutrophic waters on firm to soft mineral substrates. Water depths can be shallow to moderately deep (150 cm) and often with some current. Peirce and Jensen (2002) found WBB communities in deep water (200 to 430 cm) with pH 7.6 and conductivity of 140 µS/cm.

The WWB occurred at two ponds in Bush Arm–one above and one within Kinbasket Reservoir (P11 and P28). Both ponds were associated with flowing water over moderate depth (> 1 m) and beaver activity; pH and conductivity were high (> 8.0 pH; conductivity levels above > 200 µS/cm).

Narrow-leaved bur-reed (NLBR) – *Sparganium angustifolium*

Narrow-leaved bur-reed occurs throughout the province in small ponds and protected embayments. MacKenzie and Moran (2004) report that NLBR prefer cold waters 20–100 cm in depth with soft mucky bottoms and non-acid waters; however, this was inconsistent with our data. eFloras (2013) described the habitat for NLBR as oligotrophic waters of lakes, ponds, ditches, and streams, usually in shallow waters but to 2.5 m deep. In Sprague Bay (P08, 09, and P22), we found NLBR in warm (174 cm), deep water with low pH (5.81 to 6.43).

Large-leaved pondweed (LLP) – *Potamogeton amplifolius*

Large-leaved pondweed occurs throughout southern British Columbia. LLP typically occurs in deeper water (> 1.0 meters) with (WS few other species.

Water smartweed – *Polygonum amphibium* (WSW)

These communities occur in larger lakes in 0.5 –1.5 m deep water on sandy nitrogen-poor substrates where currents limit accumulation of organic matter and fines. *Polygonum amphibium* can form a dense floating cover with scattered *Potamogeton natans*. Submerged species such as *Myriophyllum spicatum* and *Potamogeton foliosus* are common.

Great bulrush *(*WM06*)* – *Schoenoplectus spp.*

WM06 communities were documented in the two large lakes sampled: Bush Lake in Bush Arm and Cranberry Lake near Valemount, B.C. This community occurs widely in climates with relatively warm and dry summers in waters up to 1.5 m deep. Wave-exposed lake embayments with significant water movements, and grassland potholes with occasional substrate exposure (conditions that provide abundant aeration and limit organic accumulations), are the most common locations for this Site Association. Plant diversity is low; typically, *Schoenoplectus acutus* or *S. tabernaemontani* are the only species with significant cover.

Schoenoplectus spp. are tolerant of alkali soils and often dominate in brackish potholes. They occur on Gleysols and Humic Gleysols, and occasionally Terric Humisols.

Swamp Horsetail (WM02)

This community occurred in a shallow pond (P19) at 752 m ASL in the Valemount peatland. The pond was only 16 cm deep and was surrounded by dense stands of *Equisetum fluviatile*. Many of these small shallow ponds occur in the Valemount peatland and are used extensively by *Rana luteiventris* as breeding ponds (Hawkes and Tuttle 2013). A more complete community description is provided in Appendix 9.5.

Myriophyllum spp., Potamogeton pusillus, and Potamogeton gramineus

Three communities (*Myriophyllum* spp., *Potamogeton* pusillus, and *Potamogeton gramineus*) that were sampled are not recognized in MacKenzie and Moran

(2004) and are floristically identified but not described by Pierce and Jensen (2002). These communities occurred sporadically across a range of sites (e.g., P06, P09, and P21) but further sampling is required to develop satisfactory community descriptions.