Columbia River Project Water Use Plan

Kinbasket and Arrow reservoirs Revegetation Management Plan

Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

Implementation Year 5

Reference: CLBMON-09

Final Annual Report

Study Period: 2015

LGL Limited environmental Research Associates, Sidney, BC

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KINBASKET AND ARROW LAKES REVEGETATION MANAGEMENT PLAN

Monitoring Program No. CLBMON-09
Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

Implementation Year 5 – 2015
Final Report

Prepared for

BC Hydro Generation
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Castlegar, BC

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Cover photos

From left to right: looking north up Canoe Reach; east Canoe *Equisetum* wetlands; Mica Dam; Bush Arm in fall 2007. Photos © Virgil C. Hawkes.

EXECUTIVE SUMMARY

The operation of Kinbasket Reservoir for power generation negatively impacts vegetation in the upper elevations of the reservoir. In 2007, a reservoir wide revegetation program (CLBWORKS-1) was initiated to offset the operational impacts to benefit littoral productivity, wildlife habitat, shoreline erosion, archaeological site protection, and shoreline aesthetics. CLBMON-9 was initiated in 2008 to monitor the effectiveness of the revegetation program at enhancing sustainable vegetation growth in the drawdown zone. Since 2009, effectiveness monitoring has occurred in alternating years, with 2015 marking the fifth year of monitoring under the CLBMON-9 program.

Because previous monitoring work indicated that most initial planting treatments had failed to establish, reducing the need for continued monitoring, the focus of CLBMON-9 in 2015 shifted to effectiveness monitoring of three new vegetation enhancement projects undertaken since 2012:

(1) wood debris removal and log boom exclosure trials at Canoe Reach;
(2) sedge planting trials at Km 88, Bush Arm;
(3) mound and windrow construction trials at Bush Arm Causeway, Bush Arm.

At Canoe Reach, we monitored short-term vegetation responses to the mechanical removal of wood debris at five drawdown zone sites, one of which (VP-N) was additionally protected by the installation of a log boom exclosure. At most sites, vegetation on driftwood-covered shorelines responded positively to the removal of debris within two months of clearing, with short-term increases in both total cover and species richness observed relative to untreated controls.

During the subsequent inundation cycle some sites were buried again by debris and, as a result, plant cover and richness had declined again by 2015. However, at VP-N, a previously highly impacted, remnant wetland site, the log boom exclosure was successful at preventing debris from re-encroaching. Here, the native plant community continued to show rapid recovery between 2014 and 2015. A floristic inventory of VP-N in July 2015, one year after debris removal, yielded 62 established and regenerating vascular plant species—nearly half the cumulative total of 128 species recorded to date for the entire Canoe Reach drawdown zone. It is thus apparent that targeted wood debris removal has the potential to be an effective management technique for enhancing vegetation growth in the drawdown zone, particularly if it is supplemented by placement of protective log boom exclosures (or other measures to protect the shoreline) in areas with active wood debris drifting.

At Km 88, the survival of sedge plugs two years after planting ranged from 43 to 100 per cent, with an overall survival of 74 per cent. The estimated establishment rate of approximately 17,000 sedge plants per hectare thus far appears to be exceeding the targeted objective, as proposed in the planting prescription, of between 5,000 and 15,000 plants per hectare. The high survival rate to date can likely be ascribed to a combination of site selection (Km 88 was specifically chosen for its ecological suitability as a receptor site) and the utilization of older (2-yr old versus 1-yr old), more robust nursery stock.

While getting new sedges to establish is an important step in expanding the vegetation cover at Km 88, more time will be needed to determine if these introductions have the ability on their own to alter the successional trajectory of the sites toward something more resembling a mature KS (Kellogg's Sedge) community type. Nevertheless, localized increases in sedge cover may already be providing ancillary wildlife services; we saw indications in 2015 that local waterfowl populations (most likely Canada geese) have begun to utilize the sedge plantings as a spring food source.

For the mound and windrow trials, pre-impact baseline data on vegetation and substrate conditions were collected at five proposed construction sites in 2015: Bush Arm Causeway (north and south), Chatter Creek, Goodfellow Creek, and Hope Creek. The five sites differed with respect both to substrate composition and the plant species currently supported, differences that will need to be factored in when eventually assessing the effectiveness of physical works. For example, the north Causeway site, which sits in the lower floodplain of the Bush River, had the highest vascular plant richness, whereas Chatter Creek appeared to be the most nutrient-rich site with relatively high concentrations of both nitrogen (N) and organic carbon (TOC).

In late September 2015, the first debris structures under the physical works program, CLBWORKS-1, were installed at the north and south Bush Arm Causeway sites. A total of seven mounds were constructed. In addition, three wood-choked ponds at the north Causeway site were cleaned of debris. Three other sites (Chatter Creek, Goodfellow Creek, and Hope Creek) were not treated in 2015 due to access and time constraints. The efficacy of the mounds and windrows in promoting vegetation establishment and increasing local diversity will be assessed over time, commencing in 2017 after at least one growing season has passed.

Key Words: CLBMON-9, CLBWORKS-1, revegetation, effectiveness monitoring, sedge, wood debris, log boom exclosure, mounds, drawdown zone, Kinbasket Reservoir

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1.0 INTRODUCTION

1.1 Summary

This annual summary report describes the 2015 implementation of CLBMON-9 (Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis). Work in 2015 had three main components: (1) effectiveness monitoring of the 2014 wood debris removal trials at Canoe Reach; (2) effectiveness monitoring of recently treated (planted) areas at Km 88 (Bear Island); and (3) pre-treatment (baseline) vegetation sampling of proposed (2015) mounding trials in Canoe Reach.

1.2 Background

CLBMON-9, initiated in 2008, is a long-term vegetation monitoring project that aims to assess the efficacy of physical works prescriptions, primarily revegetation (i.e., CLBWORKS-1), in enhancing the quality and quantity of vegetation in the drawdown zone of Kinbasket Reservoir for ecological and social benefits (BC Hydro 2008). Monitoring during the first six years was designed to coincide with revegetation treatments applied in 2008, 2009, and 2011 (Keefer *et al*. 2010; 2011; Keefer Ecological Services Ltd. 2012). Various metrics associated with plant communities (e.g., diversity, biomass, cover) were assessed annually and compared between control and treatment plots to determine the overall effectiveness of revegetation to improve ground cover in the Kinbasket Reservoir drawdown zone (Yazvenko 2008; Yazvenko *et al.* 2009; Fenneman and Hawkes 2012, Hawkes *et al.* 2013). The following specific management questions were addressed:

1. What is the quality and quantity of vegetation in revegetated areas compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?
2. What are species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?
3. What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the remediation and expansion of vegetation communities in the drawdown zone?
4. What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-1, at increasing the quality and quantity of vegetation in the drawdown zone?
5. Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?
6. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the site level in the future?

Table 1-1 summarizes the status of the management questions at the end of the 2013 monitoring year. Despite some early high survivorship (e.g. one year post-treatment), most plantings (seedling plugs and live stakes) failed to survive beyond three years. High attrition rates were attributed to a combination of wet and dry stress, erosion, sedimentation, and impacts from wood debris accumulation (Hawkes *et al.* 2013). By the end of the 2013 monitoring period it was evident that few of the initial treatments were establishing successfully to any meaningful degree. Moreover, treatments showed no statistically significant effects on per cent cover of vegetation, species richness, or species diversity within the drawdown zone (Hawkes *et al.* 2013).

Table 1-1: Status of CLBMON-9 management questions and hypotheses in 2013 (adapted from Hawkes *et al*. 2013b)

Management Question (MQ)	Has MQ been addressed?	Data Required	2013 Status	Preliminary Results
1. What is the quality and quantity of vegetation in revegetated areas compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass, and cover?	Yes	Field data (cover and biomass quadrats); lab data	Ongoing, but approaching ability to answer this MQ (anticipated response: “NO SIGNIFICANT DIFFERENCE”)	Some sedge plugs surviving in limited areas, but no significant differences detected in quality or quantity of vegetation between treated and untreated sites.
2. What are species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?	Partially	Field data (survivorship data for different treatment types); controlled experimental data for separating out potentially confounding factors	Ongoing, but approaching ability to answer this MQ (anticipated response: “LOW TO ZERO SURVIVAL”)	Steep decline in survivorship of plug seedlings and live stakes each year following planting; ~4 per cent of plugs surviving 4 yrs. after planting; large-scale mortality of live stakes.
3. What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the remediation and expansion of vegetation communities in the drawdown zone?	Partially	Field data, including time series data from CLBMON-10 (minimum of 5 years times series data), hydrological data	Ongoing, but approaching ability to identify limiting conditions (anticipated response: “THE CURRENT OPERATING REGIME IS THE MOST IMPORTANT, THOUGH NOT THE ONLY, VARIABLE LIMITING REVEGETATION SUCCESS IN THE DRAWDOWN ZONE”); several more years of field data, and likely a change in research direction, needed to identify environmental conditions (e.g., wood debris removal) that would improve remediation and expansion of vegetation communities	Under the current operating regime, revegetation success has been low and declining over time for all combinations of region, elevation, and planting prescription. Revegetation success of CLBWORKS-1 is likely limited by a combination of timing, frequency, duration and depth of inundation; erosion, sedimentation, and wood debris accumulation and scouring; choice of species used for revegetation; and choice of sites targeted for revegetation.
4. What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-1, at increasing the quality and quantity of vegetation in the drawdown zone?	Partially	Field data (cover and biomass quadrats, survivorship plots); lab data	Ongoing, but approaching ability to answer this MQ (anticipated response: “ALL ARE INEFFECTIVE”); statistical assessment hampered by small sample sizes and lack of replication/stratification associated with CLBWORKS-1. A review of the effectiveness of the current revegetation program is presented in this report	Widely variable results among individual sites and treatments, but the sedge plug treatment (PS) appears to be the only treatment type to have achieved moderate success in limited locales.

Management Question (MQ)	**Has MQ been addressed?**	**Data Required**	**2013 Status**	**Preliminary Results**
5. Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?	Partially	Time series field data (including data from CLBMON-10) specifically targeting natural colonization in response to physical works (no such data currently available)	Ongoing, but approaching ability to answer this MQ (anticipated response: “NO”). A review of the effectiveness of the current revegetation program is presented in this report.	There has been a small amount of moderately successful plug establishment in limited areas, indicating that the revegetation program has resulted in a minor net benefit with respect to size and productivity of some vegetated areas. However, opportunities may exist for facilitating natural colonization processes through targeted physical works that could potentially create greater benefits than the revegetation program. For example, reducing woody accumulation and taking other measures to promote natural regeneration may be a more effective long-term approach to achieving revegetation objectives than out-planting, as discussed in Sections 6.0 and 7.0 of this report.
6. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the site level in the future?	Partially	Review of existing literature, past reports, and current status of the revegetation program; data on the effectiveness alternative shoreline management options	Ongoing, but approaching ability to answer this MQ (anticipated response: “NO”). It is unlikely that modifying operations at this point will have any desired effects, because the revegetation treatments have already largely failed.	Under the current operating regime, revegetation success has been low and declining over time for all combinations of region, elevation, and planting prescription. Preliminary results suggest that adjusting the timing and reducing the duration and depth of inundation could translate into increased success for future revegetation attempts.

1.3 Recent Revegetation Approaches

Based on these results, Hawkes *et al.* (2013) made several suggestions for increasing revegetation effectiveness moving forward. Among these was a recommendation that revegetation prescriptions be specifically developed for areas of the drawdown zone where plants are most likely to survive and grow. This could include currently vegetated sites, protected bays, seepage areas, wet depressions, areas with abundant topographic featuring, soil accumulation zones, areas protected from sediment loading, and areas free of wood debris scouring.

In 2013, such an approach was taken in the stocking of 3.3 hectares of drawdown zone habitat at Km 88, a shallowly-sloped bay in Bush Arm that is partially protected from wave action and wood debris scouring due to its location on the leeward side of Bear Island (Adama 2015). Plantings consisted of plugs of Kellogg’s sedge (*Carex lenticularis* var. *lipocarpa*) and Columbia sedge (*C. aperta*), two species found naturally occurring at the site. Treatments were distinguished from previous iterations of CLBWORKS-1 by the use of older (>1-year-old), larger nursery stock, planted over a larger area and at higher densities (Adama 2015). Initial post-treatment monitoring at Km 88 suggested that survival rates during the first year were high (Adama 2015). Revegetation effectiveness monitoring at this site continued under CLBMON-9 in 2015. Further monitoring of other CLBWORKS-1 planting treatments judged to have nil or minimal prospects of long-term success was not carried out in 2015.

A second recommendation was to explore the potential efficacy of reducing wood debris accumulations in facilitating natural colonization and regeneration processes (Hawkes *et al.* 2013). Wood debris is removed from the drawdown zone of Kinbasket Reservoir annually as part of CLBWORKS-16. Removal is generally accomplished through in-situ piling and burning. In 2014, an opportunity was identified (Addendum #3 to CLBWORKS-1 Kinbasket Revegetation Physical Work) to conduct a trial to assess the effects of debris removal and debris exclusion on natural revegetation through the strategic placement of a debris exclusion boom in a small inlet located in the Valemount Peatland (Canoe Reach).

For this trial, wood debris deposits were mechanically cleared from five pre-selected locations in Canoe Reach. At the aforementioned Valemount Peatland site, removal of wood debris was paired with the installation of a log boom to reduce the amount of wood resettling on the site over the winter. Subsequent to the debris removal, treated sites were paired with control and reference (non-drawdown zone) sites, and vegetation monitoring transects were established in each. The transects were initially sampled in 2014 and again in 2015 under CLBMON-9. Results of that sampling are summarized in this report.

Thirdly, five new physical works sites in Bush Arm were identified for pre-treatment baseline sampling in 2015 (Figure 4-4). These are sites recently chosen under CLBWORKS-1 (Debris Mound and Wind Row Construction Pilot Program) to serve as trial areas for testing the effectiveness of artificial mounding at increasing topographic heterogeneity (and, in the process, vegetation establishment) within the drawdown zone (BC Hydro 2015b, Hawkes 2016). The five sites are Bush Causeway (north and south ends), Goodfellow Creek, Hope Creek, and Chatter Creek (Figure 4-4). At each site, locally available wood debris and substrate material (soil) are being or will be used to construct mounds to a height exceeding the maximum operating elevation of the reservoir, with the aim of creating a series of small non-inundated islands and peninsulas where vegetation can establish and which could eventually provide added habitat value for wildlife (Hawkes 2016).

1.4 2015 Monitoring Scope

Accordingly, the 2015 scope of services for CLBMON-9 (BC Hydro 2015a) entails several key changes in approach from previous project phases. A primary focus in 2015 was to implement a revegetation monitoring study that will:

- monitor the response of existing vegetation communities at wood debris-removal sites and to the placement of debris exclusion booms;
- monitor the success of new (2013) sedge plantings at Km 88 (Bush Arm);
- document the species composition of existing vegetation communities adjacent to and under the proposed debris mounds and windrows locations prior to construction;
- monitor the establishment of vegetation (both natural and planted) on top of and adjacent to constructed debris mounds and windrows to:
    - (a) assess natural establishment of vegetation on the physical works;
    - (b) assess success of planted vegetation on the physical works;

(c) assess erosion and wave action effects on the physical works.

2.0 STUDY AREA

The approximately 216 km long Kinbasket Reservoir is located in southeastern B.C., and is surrounded by the Rocky and Monashee Mountain ranges. The Mica hydroelectric dam, located 135 km north of Revelstoke, B.C., spans the Columbia River and impounds Kinbasket Reservoir. The Mica powerhouse, completed in 1973, has a generating capacity of 1,805 MW, and Kinbasket Reservoir has a licensed storage volume of 12 million acre feet (MAF; BC Hydro 2007). The normal operating range of the reservoir is between 707.41 m and 754.38 m elevation, but can be operated to 754.68 m ASL with approval from the Comptroller of Water Rights.

Since 2008, vegetation sampling for CLBMON-9 has occurred in 15 specific regions or "landscape units" of Kinbasket Reservoir (Figure 3-1). Some, though not all, of the regions correspond to revegetation treatment areas (CLBWORKS-1); other areas represent locations of aerial photo acquisition under CLBMON-10. For 2015, sampling was confined to Canoe Reach and Bush Arm (northwest and southeast portions of Figure 3-1), including wood debris removal and log boom sites in Canoe Reach, the 2013 sedge trials at Km 88, and five locations of proposed physical works in Bush Arm (Figure 3-2).

3.0 OBJECTIVES AND MANAGEMENT QUESTIONS

3.1 Objectives

The objectives of CLBMON-9, as per the project terms of reference (BC Hydro 2008) and as updated in the 2015 scope of services (BC Hydro 2015a), are as follows:

1. Determine the species composition (i.e., diversity, distribution and vigour) of existing vegetation communities (as classified by Hawkes *et al.* 2007) to identify species that have been successfully surviving long-term inundation.
2. Evaluate the cover, abundance and biomass of existing vegetation communities (as classified by Hawkes *et al.* 2007) relative to elevation in the drawdown zone (across the elevation gradient of 741 m–754 m ASL).
3. Monitor the response of existing vegetation communities at the local (site) level to the continued implementation of the normal operating regime for Kinbasket Reservoir and other environmental variables.
4. Assess the long-term effectiveness of the revegetation program to expand the quality (as measured by diversity, distribution and vigour) and quantity (as measured by cover, abundance and biomass) of vegetation in the drawdown zone for ecological and social benefits.
5. Assess the costs and benefits of the revegetation prescriptions applied under CLBWORKS-1 (Kinbasket Reservoir Revegetation Program Physical Works) by monitoring the response of revegetated communities to different treatments in the drawdown zone of the reservoir.

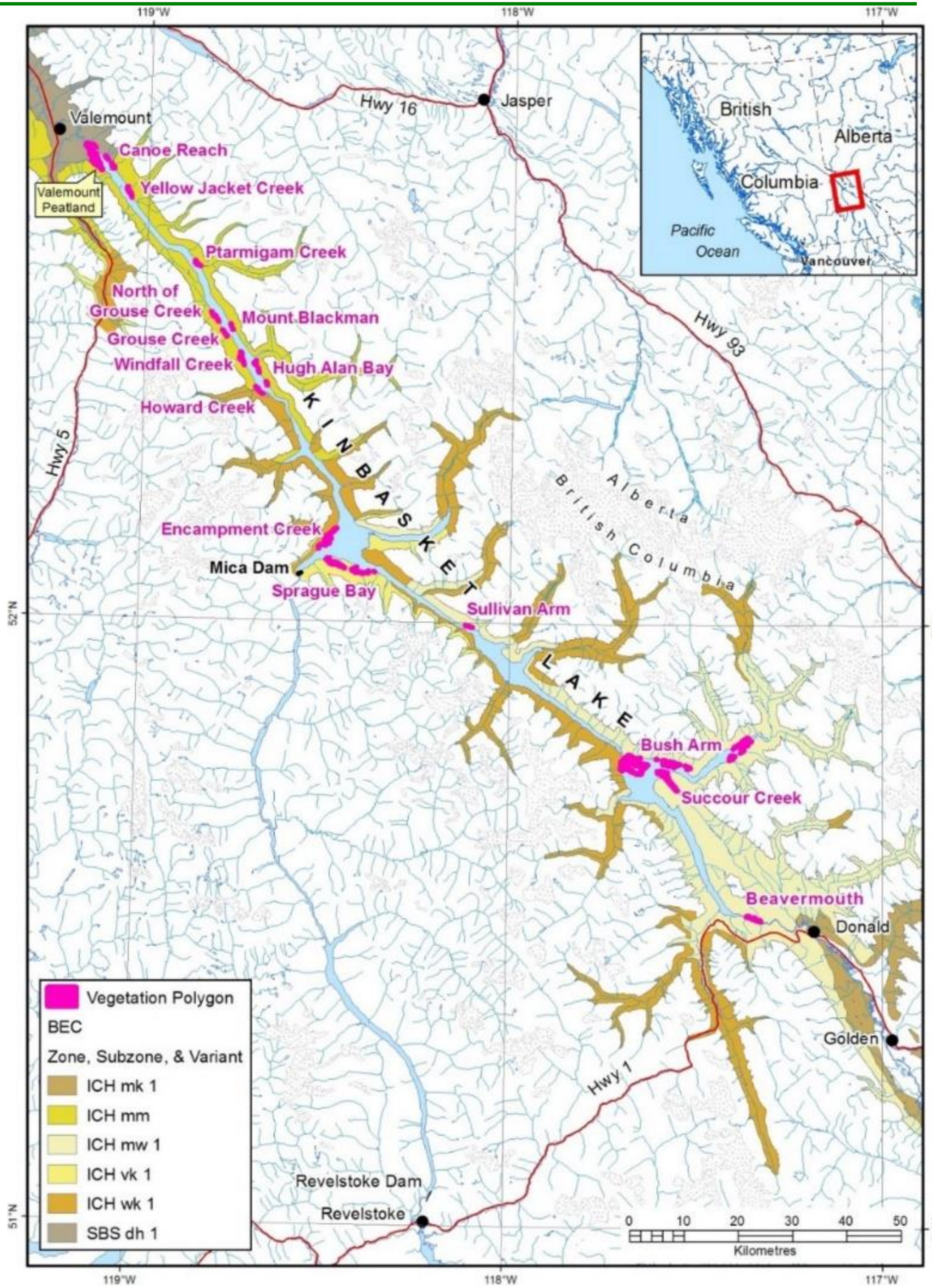

Figure 3-1: **Location of Kinbasket Reservoir and historical CLBMON-9 monitoring locations (pink).** Landscape unit names (e.g., Beavermouth, Encampment Creek) were assigned to each area sampled in 2007. Pink areas also denote the locations of aerial photograph acquisition. BEC (Biogeoclimactic Ecosystem Classification) zones after Braumandl and Curran (2002)

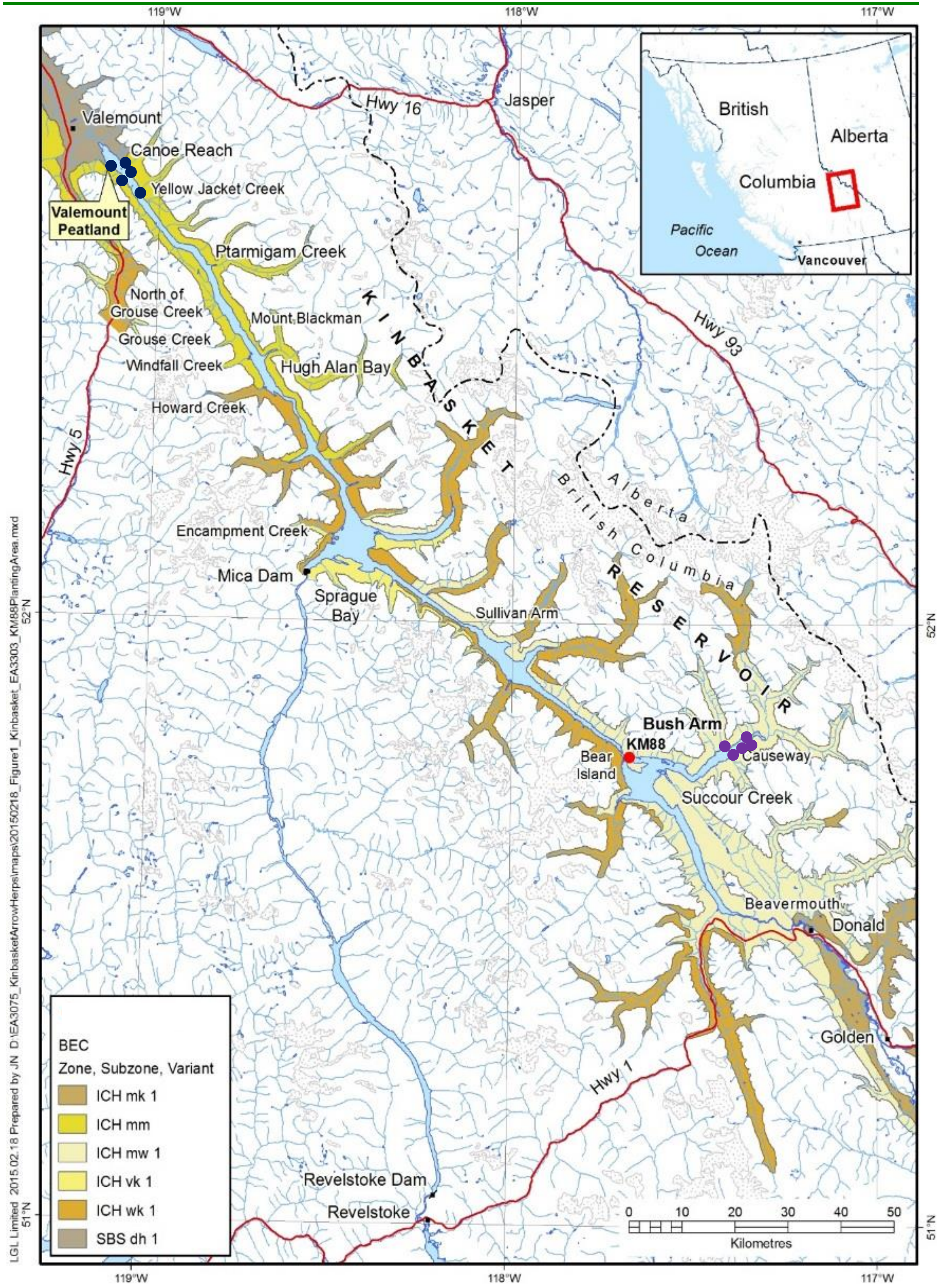

Figure 3-2: **General location of the wood debris removal experimental treatments in Canoe Reach (blue dots), the Km 88 sedge planting area (red dot), and the Bush Arm physical works sites (purple dot)**

6. Test the response of constructed wood debris and soil mounds/ windrows in full reservoir pool conditions including:
    (a) Inform BC Hydro on how reservoir operations affect the structural integrity of mounds and windrows and determine if mitigation strategies can be developed to reduce these impacts (i.e. the effectiveness of the mounds and windrows in increasing topographic heterogeneity in the drawdown zone);
    (b) Monitor natural establishment of vegetation and success of planted vegetation on constructed wood debris and soil mounds/ windrows; and
    (c) Inform BC Hydro on to what extent constructed wood debris and soil mounds/ windrows exclude floating wood debris from the parts of the drawdown zone shoreward of the constructed islands and windrows.

The CLBMON-9 program was designed for simultaneous monitoring of both revegetated sites and existing vegetation areas (i.e., areas of natural vegetation occurring within the same strata as, but not directly associated with, the revegetation trials). However, objectives 1, 2, and 3 are currently largely being addressed through the associated project CLBMON-10 (Kinbasket Reservoir Inventory of Vegetation Resources). While the primary focus of CLBMON-10 is on inter-community changes in existing vegetation communities at the landscape scale, monitored using aerial photography, that study also monitors existing vegetation at the site (local) scale (Hawkes *et al.* 2013a, Hawkes *et al.* 2015, draft). Therefore, since 2011 the main focus of CLBMON-9 has been on assessing the effects of revegetation efforts at the site level through plot-based monitoring (Hawkes *et al.* 2013b). Together, data from CLBMON-9 and -10 will inform on the effectiveness of the revegetation program (and other physical works) in maximizing vegetation growth in the drawdown zone and facilitating the development of long-term self-sustaining riparian vegetation.

To better reflect recent changes to the program scope, the following modifications to objectives 4 and 5 above are introduced (in bold):

4. Assess the long-term effectiveness of the revegetation **or other physical works** trials to expand the quality (as measured by diversity, distribution and vigour) and quantity (as measured by cover, abundance and biomass) of vegetation in the drawdown zone for ecological and social benefits.
5. Assess the costs and benefits of the revegetation prescriptions **or other physical modifications** applied under CLBWORKS-1 (Kinbasket Reservoir Revegetation Program Physical Works) by monitoring the response of revegetated communities to different treatments in the drawdown zone of the reservoir.

The inclusion of physical works trials in the objectives is intended to cover activities such as wood debris removal, log boom installation, modification to the drawdown zone via mounding, creation of wind rows out of logs and soil, revegetating with locally common plants, and any combination thereof. Other types of physical works not mentioned here, but that are designed and implemented to improve wildlife habitat suitability in the drawdown zone of Kinbasket Reservoir, should also be evaluated for their effectiveness.

3.2 Management Questions

To meet the objectives of the monitoring program, BC Hydro (2008) identified several management questions designed to help address the study objectives. The six management questions pertaining specifically to physical works effectiveness in Kinbasket Reservoir are:

1. What is the quality and quantity of vegetation in revegetated areas compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?
2. What are species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?
3. What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the remediation and expansion of vegetation communities in the drawdown zone?
4. What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-1, at increasing the quality and quantity of vegetation in the drawdown zone?
5. Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?
6. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the site level in the future?

4.0 METHODS

4.1 Study Design

Sampling in 2015 focused on areas cleared of wood debris and at the log boom installation site in Canoe Reach; on the 2013 sedge planting treatment at Km 88; and on five proposed physical works sites in Bush Arm (Figure 3-2). Sampling approaches varied slightly for the different treatment types and are described under separate headings below.

4.1.1 Wood Debris Removal and Boom Exclosure Sites

An excavator was used to clear accumulated surface wood debris from five drawdown zone sites in Canoe Reach in the late spring of 2014 (Figure 4-1). The cleared sites were at Valemount Peatland (North and South), Packsaddle Creek (North and South), and Yellowjacket Creek. Areas identified for wood debris removal were all situated near the top of the drawdown zone between 752 m ASL and 755 m ASL (the primary zone of deposition). At Valemount Peatland-North, a log boom exclosure was also installed around the cleared area to prevent re-encroachment of debris (Figure 4-1).

Monitoring plots (20 m belt transects) were established and sampled in June to capture any initial within-season vegetation response. The same five sites were resampled in June 2015 to document responses one-year post-treatment.

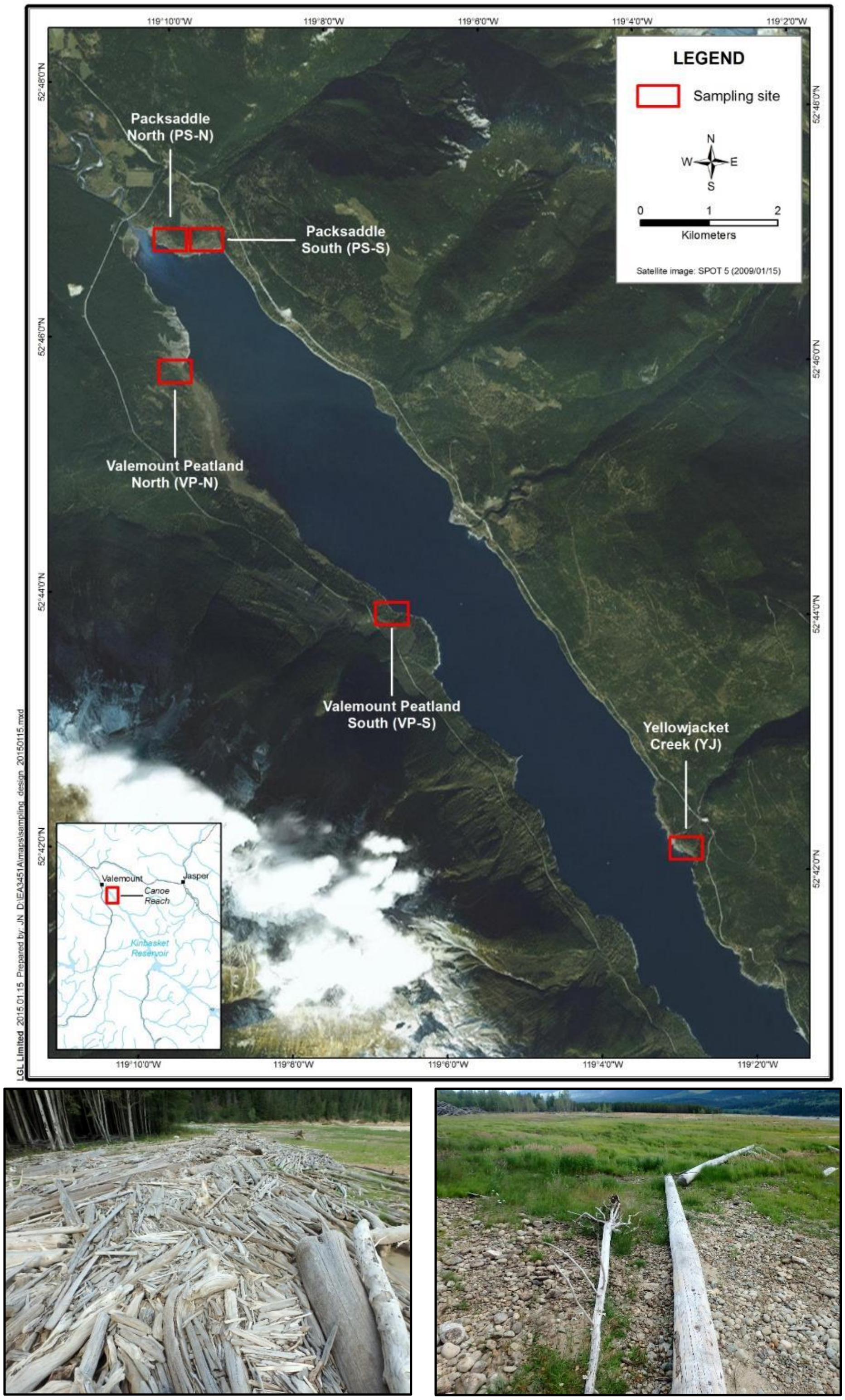

Figure 4-1: **Location of wood debris removal sites in Canoe Reach, Kinbasket Reservoir, 2014.** Lower left: wood debris accumulation at Packsaddle Creek. Lower right: log boom installation at Valemount Peatland-North to prevent re-encroachment of wood debris following spring wood removal. Wood debris pile from removal operation is partly visible at upper left of photo

Sampling at each of the five sites was replicated among treated (cleared), control, and upland forest reference transects spanning an approximately 300 m linear area of shoreline. At each site, three belt transects were overlaid across the cleared area, orientated in a linear line parallel to the elevation contour. Three matching control transects were situated in the untreated accumulation zone immediately adjacent and at a similar elevation to the cleared area. Finally, three reference transects were established in mature forest immediately upslope of the treatment and control sites. These were chosen to be representative of the non-drawdown zone, forested condition, and were located adjacent to the corresponding pitfall trap arrays set out for invertebrate sampling under CLBMON-11A (Wood *et al.* 2015, draft).

Belt transects were 20 m x 0.5 m, divided into 10 contiguous 1-m^2 quadrats to allow for sub-sampling and to increase accuracy of vegetation cover estimates.[1] The location of each transect endpoint (0 m and 20 m) was georeferenced using a Garmin handheld GPS.

All vegetation within or overhanging each quadrat was identified to species, or in some cases to genus. Per cent cover (vertical crown projection) of each taxon was visually estimated and rounded as follows: <1% - traces; 1-10% - rounded to nearest 1%; 11-30% - rounded to nearest 5%; 31-100% - rounded to nearest 10%. For the forested reference sites, low shrubs were recorded but tall shrubs and trees were not, as the latter vegetation layers rarely occur in the drawdown zone and hence serve limited comparative purpose.

In 2015, sampling entailed relocating the belt transects established in 2014, re-recording species covers, characterizing substrates, and collecting soil samples for subsequent lab analysis. The upland forest reference plots were not resampled in 2015 as these are not expected to change significantly year over year.

The prevailing terrain texture was classed as boulders, cobble, gravel, loam, sand, fines, wood, or organics. The top three constituents of each quadrat were noted and ranked as primary, secondary, or tertiary (1-3).

The ground cover (per cent area) of each quadrat was apportioned among substrate classes as follows: dead organic, coarse woody debris, rock, mineral soil, bedrock, and water (standing and flowing).

Soil samples were obtained for both treatment and control sites. Samples were collected from a location immediately adjacent to the transect by excavating the upper 20 cm of the substrate with a spade. A subsample of each soil sample (enough to fill a medium-sized Ziploc bag) was then collected and bagged. Samples were stored in a cooler during the field session and shipped to the lab (Maxxam Analytics, Burnaby) for nutrient analysis following the completion of fieldwork.

During the June survey, it was noted that the area protected behind the log boom exclosure appeared especially lush and showed a diversity of regenerating species. As some late-summer species were still emerging, it was decided to conduct a second follow-up visit in July so that a more comprehensive list of regenerating species could be compiled. This floristic survey was conducted on 20

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[1] For 2015, the sample dimension was changed to 5 contiguous 2-m^2 quadrats in order to reduce estimation time.

July, and consisted of a resampling of one of the spring transects (species list only) along with a detailed inventory of all vascular plant species occurring in the area.

4.1.2 Revegetation treatments (Km 88)

Sampling at Km 88 followed monitoring procedures previously established by Hawkes (2010) and subsequently modified by Adama (2015). For 2015, the aim was to assess the 2-year survival rates and revegetation effectiveness of the 2013 sedge plug planting trials. The stated restoration objectives (Adama 2015) was to establish between 5,000 and 15,000 sedges (*Carex lenticularis* and *C. aperta*) per hectare (depending on treatment unit) and increase the aerial extent of the Kellogg's Sedge (*C. lenticularis*) community type in the drawdown zone (Table 4-1, Table 4-2).

In 2014, sedge plug survivorship was sampled using temporary 1 x 1 m plots located throughout the planted portions of the treatment units. The quadrats were positioned by tossing a 1-m^2 sampling frame at a random (i.e. haphazard) distance and direction while traversing the planted polygons. The number of planted plugs and native sedge plants were counted in each 1-m^2 plot. Average densities of surviving plugs were estimated and these estimates compared against the initial planting densities to obtain survivorship estimates (Adama 2015).

Table 4-1: Vegetation community types identified within Kinbasket Reservoir (after Hawkes *et al.* [2007], modified by Hawkes and Gibeau [2015])

Code	Common name	Scientific name
BR	Bluejoint Reegrass	*Calamagrostis canadensis*
BS	Buckbean – Slender Sedge	*Menyanthes trifoliata – Carex lasiocarpa – Scirpus atrocinctus/microparpus*
CH	Common Horsetail	*Equisetum arvensis*
CO	Clover – Oxeye Daisy	*Trifolium* spp. – *Leucanthemum vulgare*
CT	Cottonwood – Trifolium	*Populus balsamifera* ssp. *trichocarpa – Trifolium* spp.
DI	Disturbance	
DR	Driftwood	Long, linear bands of driftwood, limited vegetation
FO	Forest	Any forested community above DDZ (>756 m ASL)
KS	Kellogg's Sedge	*Carex lenticularis* spp. *lipocarpa*
LH	Lodgepole Pine – AnnualHawksbeard	*Pinus contorta – Crepis tectorum*
LL	Lady's Thumb – Lamb's Quarter	*Persicaria maculata – Chenopodium album*
MA	Marsh Cudweed – Annual Hairgrass	*Gnaphalium uliginosum – Deschampsia danthonoides*
MC	Mixed Conifer	*Pinus monticola, Pseudotsuga menziesii, Picea engelmannii x glauca, Tsuga heterophylla, Thuja plicata*
RC	Reed Canarygrass	*Phalaris arundinacea*
RD	Common Reed	*Phragmites australis*
SH	Swamp Horsetails	*Equisetum variegatum, E. fluviatile, E. palustre*
TP	Toad Rush – Spring Water-starwort	*Juncus bufonius – Callitriche palustris*
WB	Wool-grass – Pennsylvania Buttercup	*Scirpus atrocinctus – Ranunculus pennsylvanicus*
WD	Wood Debris	Thick layers of wood debris, minimal vegetation
WS	Willow – Sedge Wetland	*Salix – Carex* species

Table 4-2: Treatment Unit (TU) objectives and current, target, and stocking densities (from Adama 2015)

TU	Comm. Type	Elevation Range (m ASL)	Area (ha)	Target Density (sph)*	Stocking Density (sph)*	Treatment Unit Objectives
1	KS/MA	746- 750	2.0	10,000 - 15,000	20,000 - 30,000	• Increase the abundance of *C. lenticularis* in the TU • Extend the KS community down to 746 m ASL into the adjacent MA community
2	KS/MA	747-748	-	-	-	• Do not plant. Retain as control.
3	KS/MA	746-748	2.36	10,000 - 15,000	20,000 - 30,000	• Increase the abundance of *C. lenticularis* in the TU • Extend the KS community down to 746 m ASL into the adjacent MA community
4	RC/KS	747-749	0.6	10,000 - 15,000	20,000 - 30,000	• Increase the abundance of *C. lenticularis* in the TU • Extend the KS community down to 747 m ASL into the adjacent MA community
5	RC/KS	748-751	0.6	5,000 - 10,000	10,000 - 20,000	• Increase the abundance of *C. aperta* in the TU • Establish *C. aperta* among openings in the RC community. • Extend the KS community up to 751 m ASL into the adjacent RC community.

*sph = seedlings per hectare

†Community Type: Reed Canary Grass (RC), Kellogg's Sedge (KS), Marsh Cudweed-Annual Hairgrass (MA)

Commencing in 2015, monitoring was conducted within fixed 5 x 5 m (25-m^2) plots. Using GIS, the distribution of the 2013 revegetation treatment units (Figure 4-2) was projected with reference to the updated Kinbasket digital elevation model (DEM; Hawkes and Gibeau 2015). Plot locations were determined in the office prior to field work using a stratified random approach. The objective was to select sample sites representative of the various combinations of elevation and revegetation prescription. A total of 30 UTM points (10 for each of the three treatment units) were selected to serve as plot centres.

Once at the site, surveyors counted the number of live sedge plants in each plot. The vigour[2] and height (cm) of each plant was also recorded, along with the total number of reproductive (flowering) plants. The same vegetation cover and substrate information was recorded as described above for belt transects at Canoe Reach (4.1.1).

Sampling was initially scheduled to occur in late June. However, due to the unanticipated rapid rise in reservoir levels in early June (Figure 4-3), an impromptu pre-survey was conducted on 11 June to capture as many data points as possible before the site became inundated for the season. All 30 of the pre-determined coordinates were sampled during this one-day survey. To allow for a rapid assessment, the dimension of sample plots was reduced to 1-m^2. Sedge reproductive status was not recorded. A second, follow-up survey was conducted on 27 June. During this survey, seven non-inundated plots were resampled using the prescribed 25-m^2 plot dimension, and reproductive status was recorded.

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[2] Vigour was assessed using a qualitative scale of (i) good to moderate; (ii) poor; and (iii) dead, following Adama (2015).

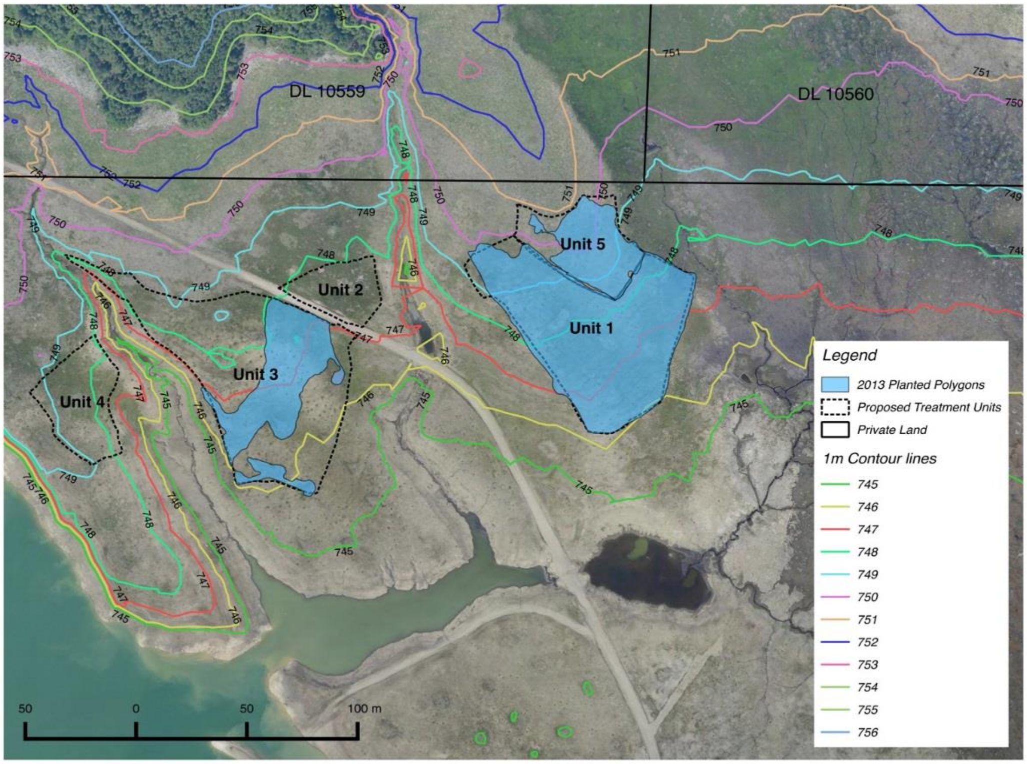

Figure 4-2: **Proposed treatment unit (TU) boundaries and areas actually planted in 2013, Kinbasket Reservoir (from Adama *et al.* [2015])**

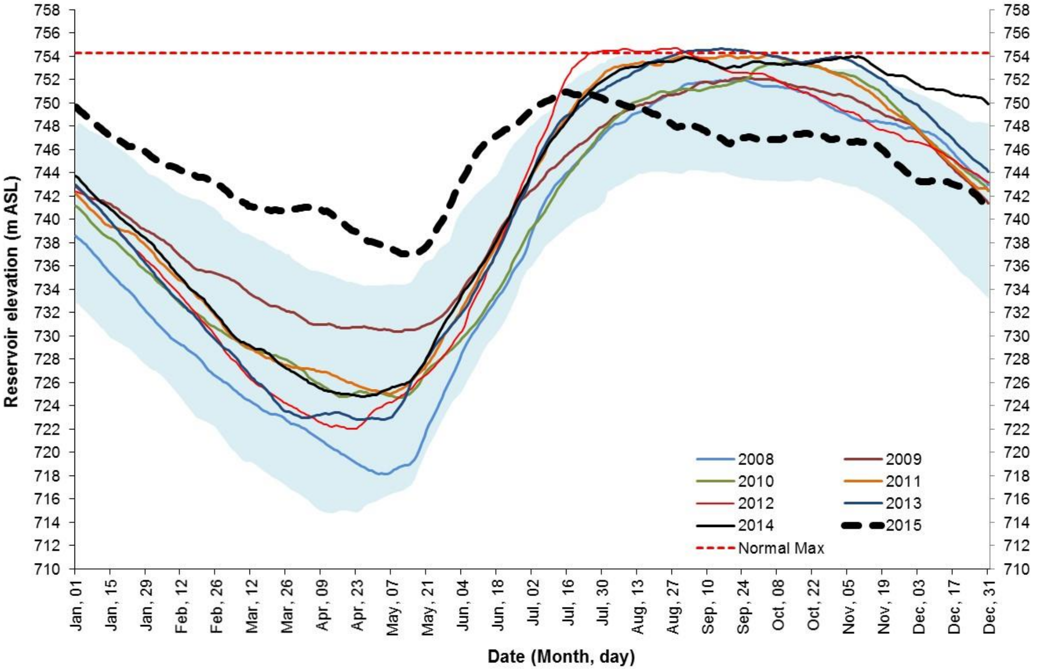

Figure 4-3: **Kinbasket Reservoir elevations 2008 to 2015.** The shaded region delineates the 10th and 90th percentile in reservoir elevation

4.1.3 Proposed physical works sites, Bush Arm

For this component, the objective in 2015 was to record pre-treatment (baseline) conditions at five proposed physical works sites in Bush Arm. The proposed sites were at Bush Arm Causeway-North, Bush Arm Causeway-South, Goodfellow Creek, Hope Creek, and Chatter Creek (Figure 4-4). The sampling approach was similar to that for wood debris removal sites and boom exclosures in Canoe Reach, modified to take advantage of the pre-treatment status of this site by implementing an experimental block (BACI) design.

Using GIS, a treatment polygon was delineated in each of the five proposed treatment areas. A second, adjoining polygon was delineated adjacent to the treatment polygon to serve as a control. The control polygon was similar in terms of elevation, substrate type, and vegetative cover to the treatment polygon (Hawkes 2016; Figure 4-4).

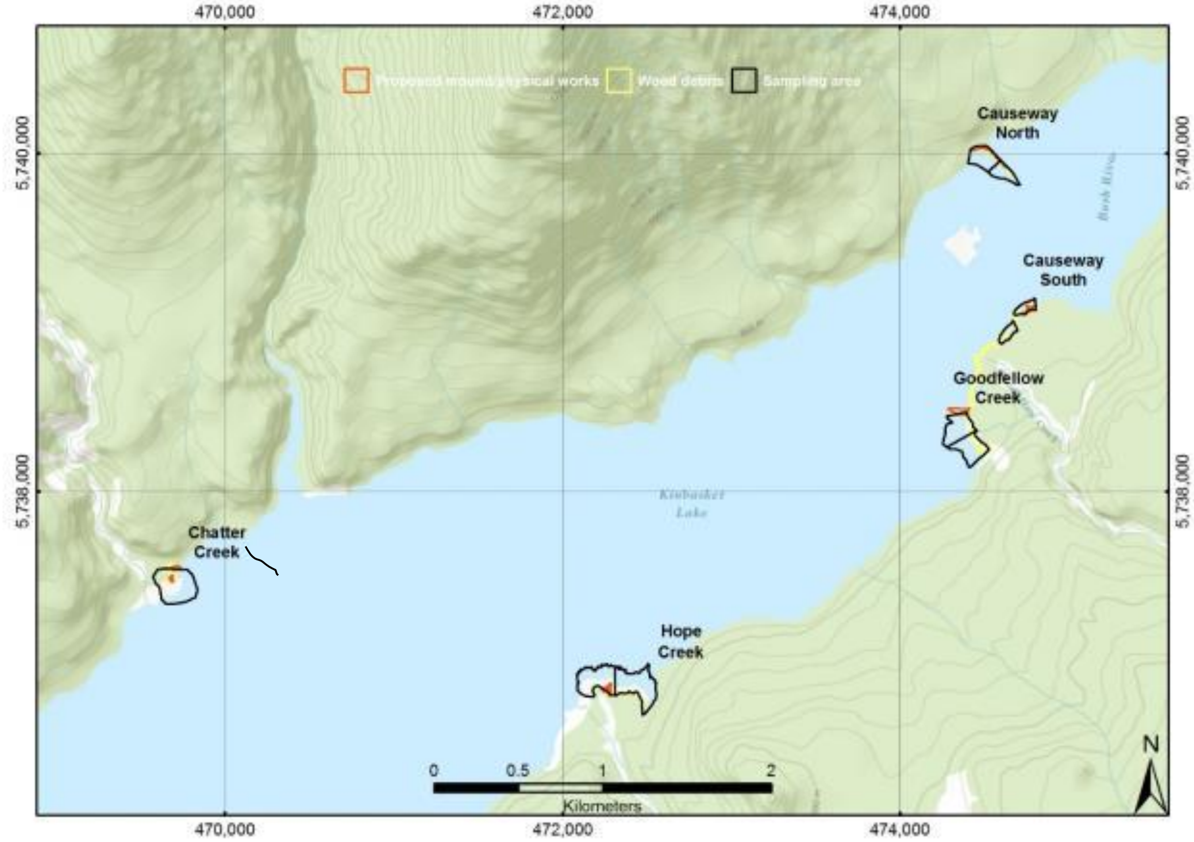

Figure 4-4: Location of proposed physical works locations in Bush Arm, Kinbasket Reservoir (from Hawkes [2016])

Vegetation and soils within each treatment and control polygon were sampled within a series of belt transects, following a similar approach used to sample wood debris removal treatments (4.1.1). Belt transects were 20 m x 0.5 m, divided into 5 contiguous 2-m^2 quadrats to allow for sub-sampling and to increase accuracy of plant cover estimates. Sampling entailed establishing transects (parallel to the contour line), recording the per cent cover of all plant species, characterizing substrates, and collecting soil samples for later lab analysis.

The number of transects assessed at each site was a function of polygon size and the local elevational gradient. Where possible, the two 2-m elevation bands between 750 m ASL and 754 m ASL (750-752 m and 752-754 m) were sampled at each location, with a target of six replicates established per band. In cases where the polygon size or elevational gradient was insufficient to sample both elevation bands at the targeted transect density (e.g., the two Bush Arm Causeway sites), a smaller number of replicates were sampled within each band (Table 4-3).

Because the proposed physical works projects for Bush Arm were still in the initial planning stages at the time of the 2015 survey, the exact configuration and extent of these projects had not yet been determined.[3] For this reason, the focus of sampling was on characterizing the overall pre-treatment conditions at each proposed site, rather than on attempting to characterize conditions within the exact project footprint.

Table 4-3: Proposed Bush Arm physical works sites, elevation bands sampled in each control and treatment polygon, and total number of transects sampled in 2015

Site	**Elevation bands sampled**	**No. of transects established**		**Total transects**
		Treatment polygon	**Control polygon**	
Bush Arm Causeway-North	750-752 m	1		12
	752-754 m	5	6	
Bush Arm Causeway-South	750-752 m	1		12
	752-754 m	5	6	
Goodfellow Creek	750-752 m	6	4	24
	752-754 m	6	6	
	754-755 m		2	
Hope Creek	750-752 m	4	4	24
	752-754 m	8	8	
Chatter Creek	750-752 m		7	13
	>752 m	6		

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[3] Mound construction commenced in September 2015, two months after baseline sampling was completed (Hawkes 2016). Due to low reservoir levels, only two of the five proposed sites (Bush Arm Causeway-North and -South) were treated in 2015. Water levels were too low to barge machinery in to some sites (Hope and Chatter Creek). Furthermore, because this is a pilot project, it was deemed desirable to delay construction of additional mounds until the integrity of the existing new mounds can be tested under full pool conditions (Hawkes 2016).

4.2 Statistical Analyses

For each wood debris removal area, differences in plant cover (total cover and cover by vegetation layer) and species richness between treated and control vegetation were tested with a series of two-way unbalanced analyses of variance (ANOVAs). ANOVAs were tested with 9,999 permutations. Due to the high natural variability of measurements, significance level was set at $\alpha=0.1$. Post-hoc (t-tests) were carried out to test specifically for site-specific differences in cover and richness between the 2015 treatment and control transects.

Differences were summarized visually using a series of boxplots. Boxplots display the variations among groups of data without making any assumptions about their underlying statistical distributions while showing their dispersion and skewness (Massart *et al*. 2005; further details in Hawkes *et al.* 2013a).

For the sedge treatments at Km 88 and the proposed physical works sites near the Bush Arm Causeway, summary descriptive results are reported for the baseline data collected in 2015.

5.0 RESULTS

5.1 Canoe Reach Wood Debris Removal and Boom Exclosure Sites

A proportional graph of surface substrate composition illustrates the difference in the amount of driftwood cover at the Canoe Reach study sites (pre- and post-clearing; Figure 5-1). Wood accounted for almost all of the surface cover in the uncleared controls whereas it was largely absent from the treated sites—until it began to reintrude onto some of the latter sites in 2015 (Figure 5-1). Following clearing, substrate compositions were similar for Packsaddle Creek-North (PS-N) and Yellowjacket Creek (YJ; primarily mineral soil and rock), and for the two Valemount Peatland sites (primarily organics with a component of open water at VP-N). The substrate at Packsaddle Creek-South (PS-S) was a combination of mineral soil and decaying organic material (consisting primarily of finely ground wood chips; Figure 5-1).

One to two months following the clearing of wood debris in the spring of 2014, the cover of herbs (non-woody vascular plants) in cleared areas appeared to be higher relative to controls at PS-N, while it was similar at PS-S and appeared to lag non-treated controls at both VP-N and YJ; Figure 5-2).

The total number of herb species present (species richness) exhibited an increase relative to controls at three of the five treated sites (PS-N, PS-S, and VP-N; Figure 5-3). At PS-N, the median species richness of treated transects immediately following clearing was around six-fold that of untreated transects (Figure 5-3. At Yellowjacket Creek, the opposite trend was observed with fewer herb species recorded in treated than in control transects (Figure 5-3). The cover and richness trends at Valemount Peatland-South (VP-S) one and two years post-clearing were unknown due to the lack of a study control (non-cleared area) at this site.

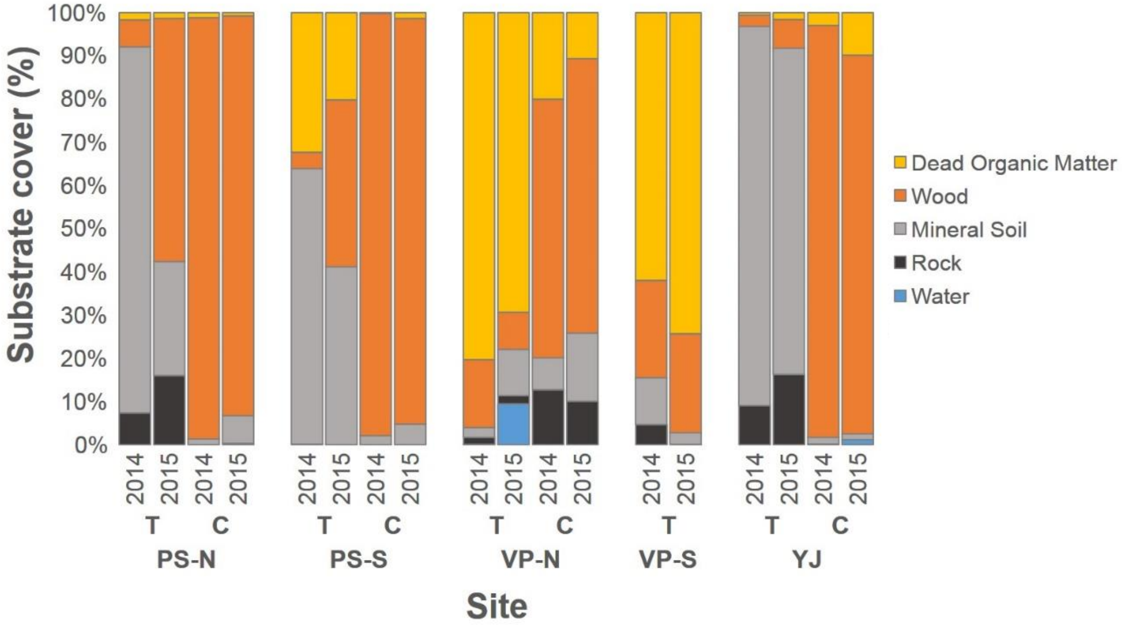

Figure 5-1: **Proportion of ground covered by each class of substrate (organic matter, decaying wood, mineral soil, rock, water) in sample transects at each of the Canoe Reach debris removal sites, 2015.** PS-N: Packsaddle Creek-North; PS-S: Packsaddle Creek-South; VP-N: Valemount Peatland-North; VP-S: Valemount Peatland-South; YJ: Yellowjacket Creek. No untreated control area was available for sampling at VP-S

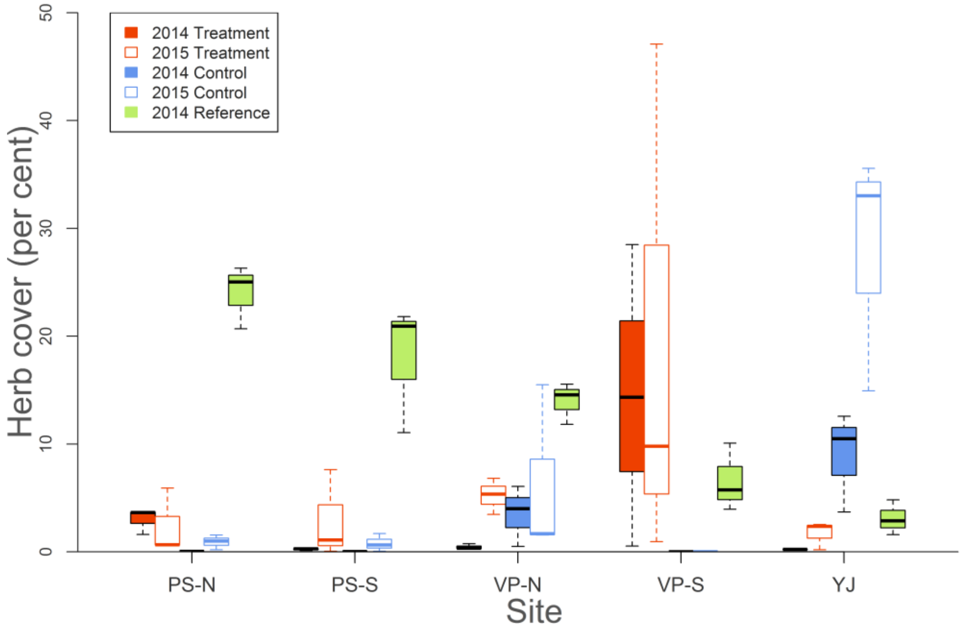

Figure 5-2: **Variation in per cent cover of the herb layer in control, treatment, and forest reference transects at the five wood debris removal sites in Canoe Reach, in 2014 and 2015**

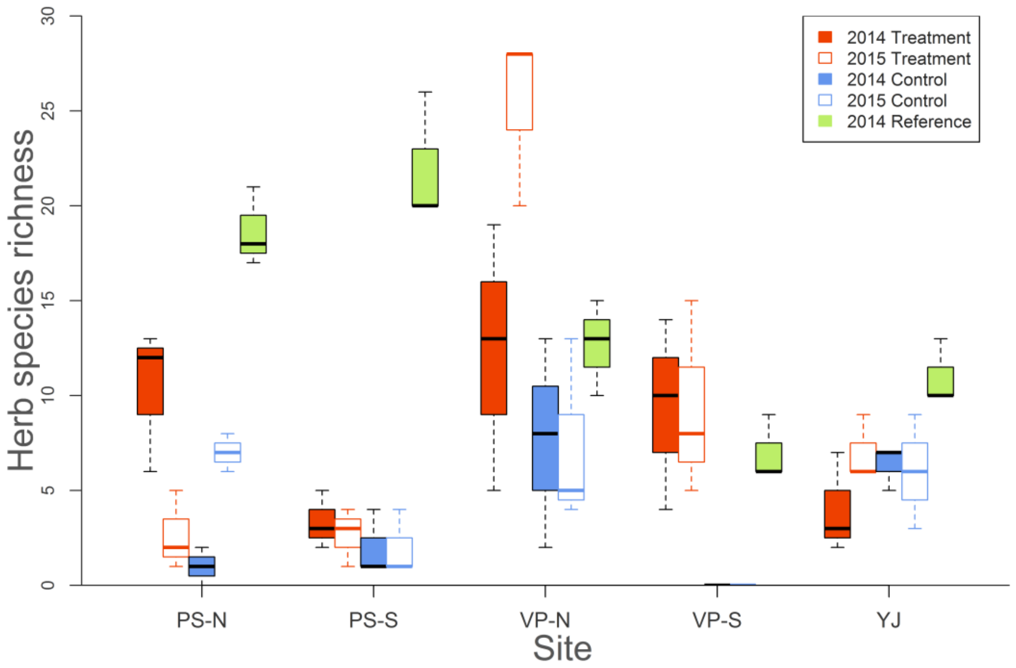

Figure 5-3: Variation in the richness of species in the herb layer of control, treatment, and forest reference transects at the five wood debris removal sites in Canoe Reach, in 2014 and 2015

Shrubs were rarely encountered in sample transects but tended to be slightly less abundant with a lower species diversity in the treated than in the control transects (Appendix 8.1). This result may be due to chance differences in initial site conditions. Alternatively, it may be the outcome of mechanical damage (crushing or scouring) inflicted on woody stems during the debris-removal process, which was accomplished using heavy machinery.

Differences in average cover of herbs between cleared and uncleared sites were statistically significant between years (F=3.8, p=0.048) and treatments (F=3.9, p=0.047). Interactions were not significant. Richness differences were not statistically significant between years at α=0.1, but were significant between treatments (F=3.8, p=0.051).

Post-hoc, independent-samples t-tests (log-transformed) were subsequently used to test the hypothesis that richness differed significantly between the 2015 treated and control transects on a site-by-site basis (excluding VP-S which lacked a control). The difference was statistically significant only for VP-N (the boom exclosure site; t=4.61, p=0.046).

The differences at some other sites, such as at PS-N, also appeared to be substantial (Figure 5-3); however, the variation within samples was large relative to sample size (n=3), which may have masked differences between treatment types. These early results suggest that wood debris removal will be more effective at restoring species diversity if the site is afforded subsequent protection from the re-incursion of debris.

The somewhat inverted response observed at Yellowjacket Creek (Figure 5-3) was likely largely due to the relative high productivity of the control site, as evidenced by the rather vigorous plant growth occurring up through the dense log cover

(Figure 5-4). Underneath the wood debris at this site, which occurs on a natural seepage area, the largely wetland vegetation was supported by moist to wet, organic soils. By comparison, the treated substrate was drier, rockier, lower in organic content (Figure 5-1), and relatively unproductive (Figure 5-4). One year following the debris removal (2015), the treated area was exhibiting a comparable level of species richness to the non-treated area (Figure 5-3). However, the year-to-year increase in overall herb cover lagged that of the non-treated area (Figure 5-2). These results suggest that the immediate effects of removing wood debris are likely to vary from site to site and will be strongly influenced by the initial starting conditions (e.g., presence/absence of a soil seed bank).

Figure 5-4: Left: vegetation growing through wood debris deposits at Yellowjacket Creek control site, Canoe Reach, Kinbasket Reservoir. Right: regenerating treatment site, Yellowjacket Creek. Photographed 21 June, 2015

During the winter of 2014/2015, substantial amounts of wood debris were redeposited onto some previously cleared areas, especially at PS-N and PS-S (Figure 5-5, Figure 5-1). As a result, some of the 2014 gains with respect to species richness did not carry over into 2015. At PS-N, this trend was actually reversed; herb richness declined in the treated site relative to both the 2014 value and to the control (Figure 5-3).

In contrast, at VP-N—the site where a log boom exclosure was installed in conjunction with wood debris removal—species richness was substantially higher in 2015, both compared to the control and to the 2014 values (Figure 5-3). Herb cover at this site also appeared to increase more rapidly in cleared than in non-cleared areas between 2014 and 2015 (Figure 5-2). This site, which receives seepage inflows from an existing shrubby wetland just outside the drawdown zone, is both wetter and more nutrient (N and K) rich than the other drawdown zone sites. The soil here is also very high in total organic carbon (TOC; Figure 5-6). These factors could help account for our observation that one year following debris removal, VP-N was beginning to show signs of rapid recovery toward a functioning semi-wetland community (Figure 5-7). A detailed floristic survey of the entire log boom exclosure area, conducted on 20 July 2015, yielded a total of 62 established and regenerating vascular plant species (Appendix 8.1).

Figure 5-5: **Fresh (winter 2014/2015) wood debris deposits on previously cleared site at Packsaddle Creek-South (PS-S).** This site was mechanically cleared of debris in the spring of 2014. Photographed 21 June 2015

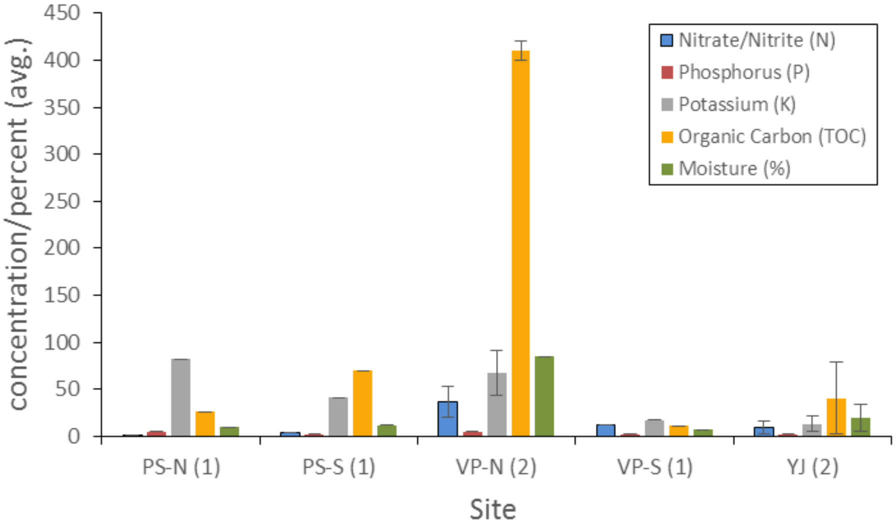

Figure 5-6: **Nutrient concentrations and soil moisture values obtained from soil samples collected at the Bush Arm proposed physical works sites, June 2015.** For PS-N and PS-S, data correspond to forest reference sites; other data are from sites in the drawdown zone**.** Sample sizes shown in () after the site name. Standard error bars displayed for n>1. Units for N, P, K: mg/kg. Units for TOC: g/kg. Units for moisture: per cent

The initial (within-season) positive response of species richness to clearing at some sites suggests that the removal of dense debris accumulations (Figure 4-1) had an immediate beneficial effect on seed germination (through release of the dormant seed bank) and/or encouraged the re-emergence of dormant rhizomes. Of the herb species recorded in the June 2014 transects (control and treated combined, VP-S excluded), 17 were unique to the treated transects. About half of these were annual species and about half were perennials (Table 5-1).

Of the herb species recorded in the June 2015 transects (control and treated combined, VP-S excluded), 36 were unique to the treated transects, two thirds of which were perennials. In terms of broad taxonomic groupings, two thirds were forbs, and one third were graminoids (i.e., grasses and sedges; Table 5-1). Furthermore, in 2015 we recorded 27 new additions to the treated transects—species that were not observed in the same transects in 2014. A similar proportion (about two thirds) of these were perennials, although the ratio of grasses to forbs was slightly higher (Table 5-2).

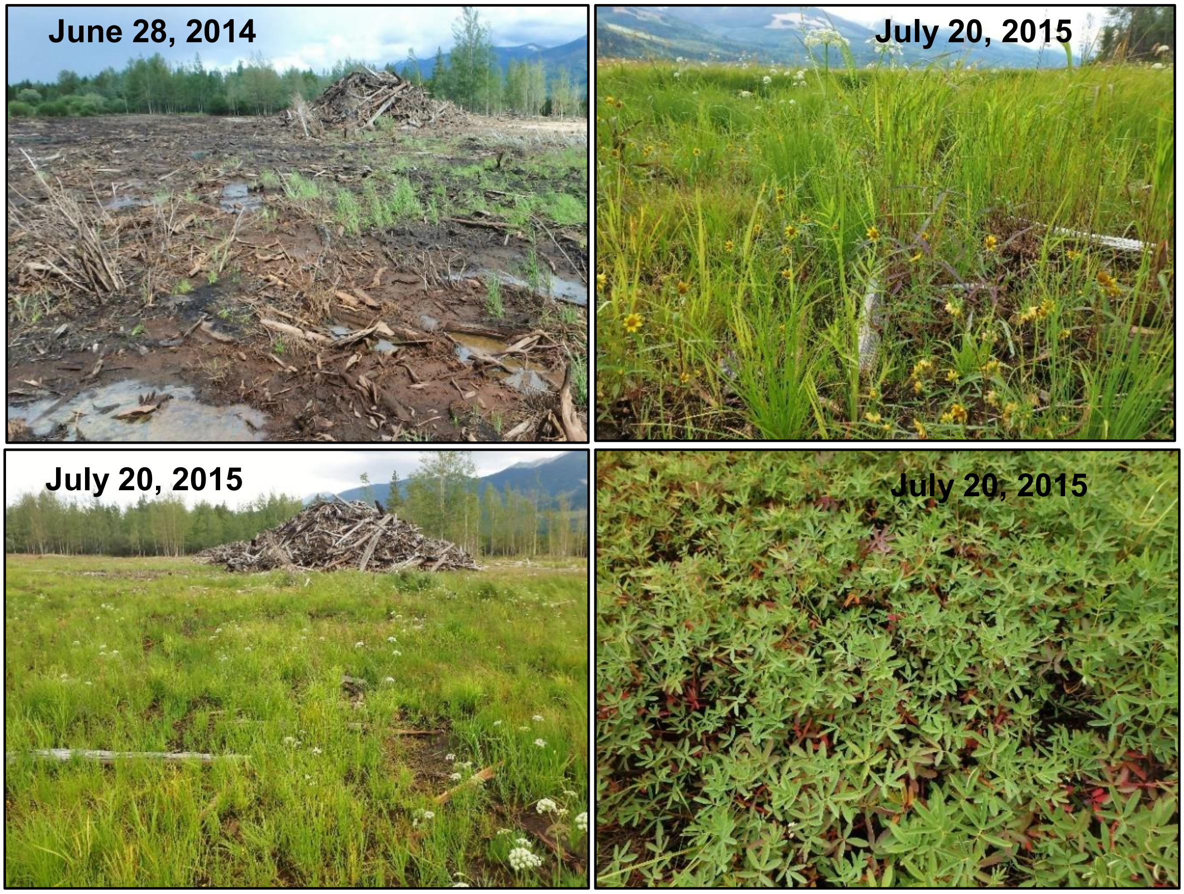

Figure 5-7: Vegetation recovery two months (upper left panel) and 15 months (other panels) following removal of wood debris at the Valemount Peatland-North (VP-N) site, Canoe Reach. Upper right panel: nodding beggarticks (*Bidens cernua*) and Douglas' water-hemlock (*Cicuta douglasii*). Lower right panel: marsh cinquefoil (*Comarum palustre*)

Table 5-1: Herb species absent from control (uncleared) transects but recorded in treated (cleared) transects in 2014 and 2015 surveys at Canoe Reach, Kinbasket Reservoir. Perennial species are shown in bolded text

Species		
2014 sample	**2015 sample**	
Cardamine pensylvanica	***Agrostis stolonifera***	*Persicaria maculosa*
Chenopodium album	*Bidens cernua*	***Poa compressa***
Cicuta douglasii	*Callitriche palustris*	***Potamogeton pusillus***
Cirsium vulgare	*Cardamine pensylvanica*	***Ranunculus gmelinii***
Crepis tectorum	***Carex crawfordii***	*Ranunculus pensylvanicus**
Erysimum cheiranthoides	***Cicuta douglasii***	*Ranunculus sceleratus*
Juncus ensifolius	***Deschampsia cespitosa***	*Rorippa palustris**
Mimulus guttatus	*Deschampsia danthonioides*	***Rumex crispus***
Poa compressa	***Eleocharis mamillata***	***Scirpus atrocinctus***
Polygonum aviculare	***Epilobium ciliatum***	***Sium suave***
Persicaria maculosa	*Galum trifidum*	***Sparganium emersum***
*Rorippa palustris**	***Glyceria striata***	***Trifolium pratense***
Rumex acetosela*	***Juncus alpinoarticulatus***	***Trifolium repens***
Trifolium pretense	*Juncus bufonius*	***Triglochin palustris***
Utricularia intermedia	***Juncus ensifolius***	***Typha latifolia***
Veronica beccabunga	***Leucanthemum vulgare***	***Utricularia intermedia***
Viola macloskeyi	***Lysimachia thyrsiflora***	***Veronica beccabunga***
	Myosotis scorpioides	***Viola macloskeyi***

*May occur as annual or perennial

Table 5-2: New herb additions to treated (cleared) transects, first recorded during the 2015 survey at Canoe Reach, Kinbasket Reservoir. Perennial species are shown in bolded text

Species		
Agrostis gigantea	***Eleocharis mamillata***	***Rumex crispus***
Agrostis stolonifera	***Epilobium ciliatum***	***Scirpus microcarpus***
Bidens cernua	***Equisetum hyemale***	***Sium suave***
Callitriche palustris	*Galium trifidum*	***Sparganium emersum***
Carex brunnescens	***Glyceria striata***	***Triglochin palustris***
Carex crawfordii	***Juncus alpinoarticulatus***	***Typha latifolia***
Carex stipata	***Leucanthemum vulgare***	
Cerastium fontanum	*Persicaria maculosa*	
Deschampsia cespitosa	***Potamogeton pusillus***	
Deschampsia danthonioides	*Ranunculus gmelinii*	
Galium trifidum	*Ranunculus pensylvanicus**	

*May occur as annual or perennial

5.2 Revegetation Treatments (Km 88)

Two years following planting, the sedge seedling plugs at Km 88 (Figure 5-8) continue to perform well both in terms of survivorship and reproductive development. In random quadrat samples at each of the three treatment units (TU-1, TU-3, and TU-5; Figure 4-2), average estimated surviving plug densities (per ha) were approximately 29,000, 15,000, and 9,000 respectively (Table 5-3). In the case of TU-1, sample densities were similar to the original stocking densities reported by Adama (2015; Table 5-3), indicating that mortality has been negligible to date. The establishment rate at TU-1 appears thus far to be exceeding the targeted project goal of 10,000-20,000 individuals/ha (Figure 5-9).

Figure 5-8: Sedge planting treatment at Km 88, Bush Arm. Planted plugs are visible mixed with an existing ground cover of annual forbs, primarily Scouler's popcorn flower (*Plagiobothry scouleri*). Photographed 11 June 2015

Table 5-3: Estimated density of sedge plugs per hectare at time of planting in 2013, estimated surviving densities in 2014 and 2015, and estimated per cent survival two years after planting (± 90% confidence interval). 2013 and 2014 data from Adama (2015)

Treatment unit	**2013 stocking density/ha**	**2014 surviving plugs/ha**	**2015 surviving plugs/ha**	**Estimated per cent survival (2015)**
TU-1	25,454 ± 4,345	23,750 ± 3,834	29,000 ± 8,834	100%
TU-3	25,000 ± 4,234	24,286 ± 4,696	15,000 ± 6832	60%
TU-5	20,714 ± 7,300	21,000 ± 8,834	9,000 ± 6379	43%
All	23,738 ± 1,952	n/a	17,666 ± 4,657	74%

At TU-3 and TU-5, sample densities in 2015 were lower than the original stocking densities (Table 5-3), implying that some attrition has occurred in the first two years following planting. For TU-5, mortality was estimated at 57 per cent. However, for both areas the densities of surviving plugs were still well within the project's targeted range of 10,000-20,000 plugs/ha (for TU-3) and 5,000-10,000 plugs/ha (for TU-5; Figure 5-9).

The relatively high mortality estimates for TU-3 and TU-5 are somewhat at odds with those of Adama in 2014 (Adama 2015), who reported 97 to 100 per cent seedling survivorship for these TUs one year after planting. This discrepancy is likely an artifact of sampling method. In 2014, sampling was focused on areas within the treatment units that were known to have been planted (that is, sampling was informally stratified to exclude non-planted patches; D. Adama, pers. comm. 2016). However, in 2015, sample quadrats were located randomly through the treatment units without regard to specific planting patterns. Consequently, some of the predetermined sample locations may have included patches left untreated 2013, possibly resulting in underestimates of survivorship. Thus, the survival rates reported here should be regarded as conservative estimates.

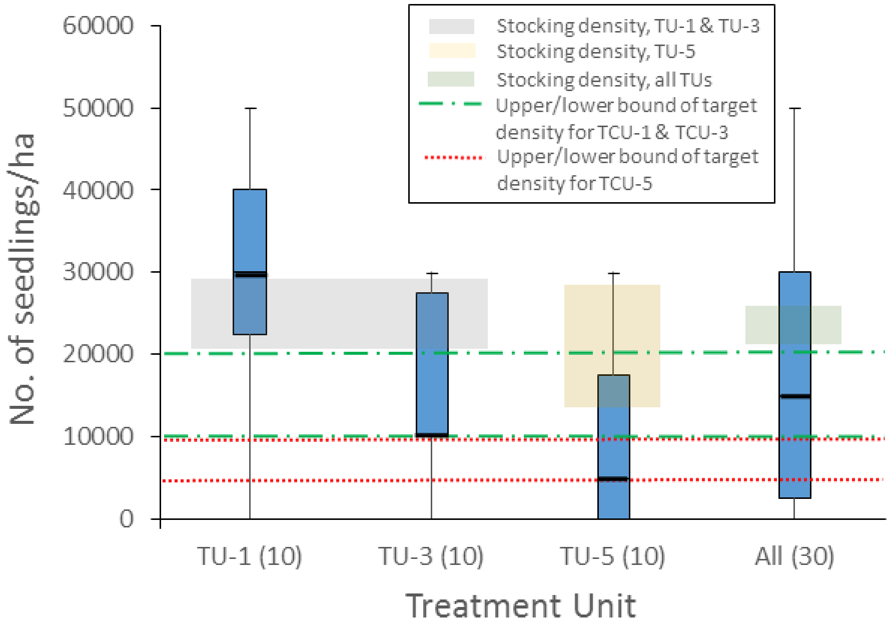

Figure 5-9: Estimated number of surviving sedge seedlings per hectare at Km 88 in 2015 (two years post-planting). The number/ha was extrapolated from recorded densities in a sample of 1-m^2 randomly placed quadrats. Sample size shown in () after TU number**.** Overlain are the original stocking densities (ranges shown by solid color bands) and targeted densities (ranges bounded by coloured dashed lines) for each sampled treatment unit (TU). For planting prescription details refer to Table 4-2

As a measure of developmental maturity, the proportion of reproductive plants (those with flowering stems) in sample quadrats at TU-1 in 2015 averaged 15.2 per cent (± 9.5, n=3). The equivalent proportion at TU-5 was 41.4 per cent (± 22.2, n=5). TU-3 was already inundated at the time of sampling and was not assessed for reproductive status. The substantially lower reproductive success at TU-1 (the lower site) compared to TU-5 (the higher site) may largely be explained by a single external factor: grazing by waterfowl. During the initial June 11 survey, it was observed that most Kellogg's sedge plants occurring in the area near to the waterline at TU-1 and TU-3 had been recently and heavily browsed, most likely by Canada geese. It was very evident that this disturbance had resulted in the seasonal loss of a high proportion of flowering stems from the treatment population.

As previously noted by Adama (2015), sedge plugs in TU-5 also appeared to be growing more rapidly than in TU-1 and TU-3. While there were advancements in plant height at all three treatment units between 2014 and 2015, plugs in TU-5 continued to be the tallest (Figure 5-10). Height differences between units in 2015 were statistically significant at α=0.1 (F=9.38, p=0.0003). General plant vigour, as represented on a qualitative scale of "good," "moderate," and "poor," also tended to be higher in TU-5 (Figure 5-11). The relative proportion of plants in each vigour class differed significantly across treatment units in 2015 (χ^2=8.83, p=0.065). Vigour appeared to decrease in TU-1 between 2014 and 2015, with far fewer plugs but appeared to increase at both TU-3 and TU-5 (Figure 5-11). The yearly differences were less apparent when values were averaged across treatment units (Figure 5-11).

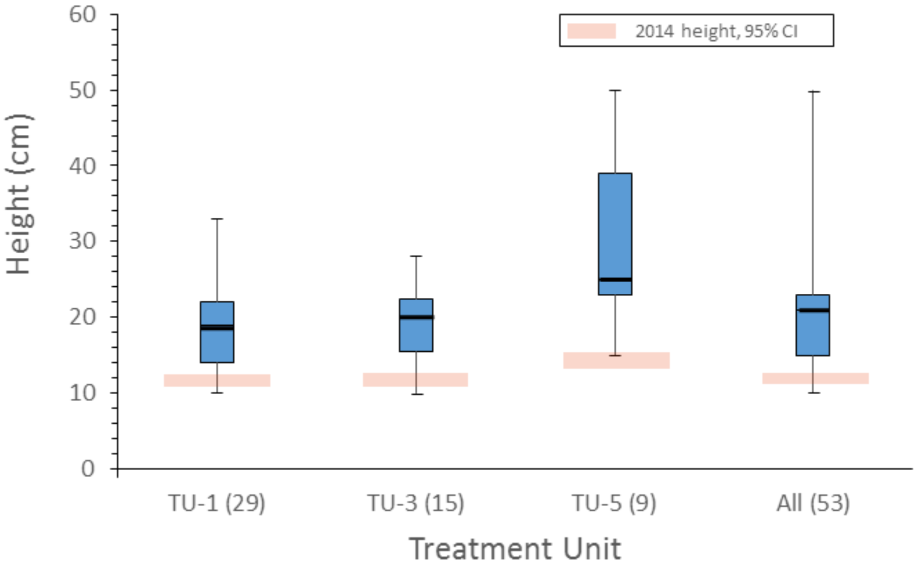

Figure 5-10: Sedge plant heights (cm) at Km 88 in 2015 (two years post-planting). Sample size shown in () after TU number**.** Overlain are the 2014 heights (bands representing the 90 per cent confidence intervals) from Adama (2015)

Differences in the timing and duration of inundation affecting the different treatment units may help account for some of the variation in sedge plug performance since 2013. In 2013, the higher planted elevation bands (748-749 m), corresponding to TU-5, were inundated from 143 to 153 days, while the lower elevation bands (746-747 m), corresponding to TU-1 and TU-3, were inundated for 161 to 167 days, a differential of 13 to 18 days (Table 5-4). In 2014, the higher planted elevation bands were inundated from 171 to 180 days, while the lower elevation bands were inundated for 189 to 204 days, a difference of about 20 days (Table 5-4). In both years, the total inundation period for all elevations exceeded the 30-year baseline norm by a substantial margin (Table 5-4). These inundation patterns imply that the sedge plantings at Km 88 have so far experienced somewhat truncated growing seasons—and potentially higher physiological stresses related to prolonged inundation—compared to those experienced over time by the established native vegetation.

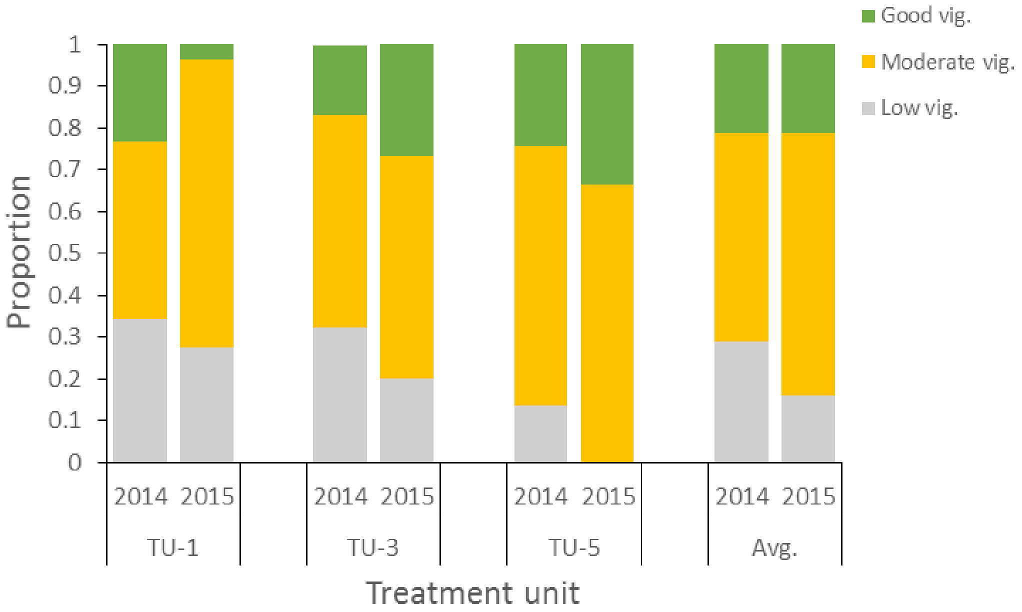

Figure 5-11: Vigour of sedge plants at Km 88 in 2015 (two years post-planting). Vigour was classified on a scale of "good," "moderate," or "poor." Shown are the proportions of sedge plants in each vigour category for each treatment unit, as well as the overall average, in 2014 and 2015

The disparity in inundation time between TU-1 (& 3) and TU-5 was magnified in 2015, when the reservoir elevation peaked in early July at 750.79 m ASL, more than 3.5 m below the normal operating maximum of 754.38 m ASL (Figure 4-3). As a result, the higher planted elevation bands (748-749 m) were only inundated from 56 to 80 days, which was between 9 and 19 days less than the 30-year baseline, and a half to a third less than in 2013 or 2014 (Table 5-4). In contrast, lower elevation bands (746-747 m) were inundated for 130 to 188 days, a shorter duration than in 2014 but still well over the historical norm. Moreover, the reservoir began to fill earlier than usual in 2015, such that the timing of inundation at lower elevations was strongly skewed toward the early part of the summer (late May and early June; Figure 4-3), a critical time for plant growth in the drawdown zone.

Table 5-4: The number of days seedlings were inundated by elevation band in 2013, 2014, and 2015. Difference between days inundated in each year and the 30-year baseline (1977 to 2006) provided in brackets

Elevation (m ASL)	2013	2014	2015	30-year baseline
745	175 (47)	213 (85)	201 (73)	128
746	167 (50)	204 (87)	188 (71)	117
747	161 (56)	189 (84)	130 (25)	105
748	153 (64)	180 (91)	80 (-9)	89
749	143 (68)	171 (96)	56 (-19)	75
750	131 (66)	163 (98)	30 (-35)	65
751	119 (66)	143 (90)	0 (-53)	53
Mean	150 (60)	180 (90)	98 (8)	90

Because the main 2015 data collection occurred on June 11, shortly prior to inundation, the 2015 results were not affected by, or reflective of, the subsequent flood events. A preliminary assessment of the effect of the atypical 2015 hydroperiod on sedge plug performance was made during a subsequent fall (October) sampling session, after the reservoir had receded. Findings from the fall 2015 survey are still being compiled and will be conveyed in a subsequent report.

5.3 Proposed Physical Works Sites, Bush Arm

Although the five proposed physical works sites in Bush Arm are all in relative close proximity to one another (Figure 4-4), they differ with respect both to substrate composition and the plant species they currently support—baseline differences that will need to be taken into account when assessing the effectiveness of physical works.[4]

Surface substrate composition was similar among Chatter Creek (CHT), Goodfellow Creek (GDF), and Hope Creek (Hope), with mineral soils making up the primary component, along with a component of rock cover that was generally absent from either than at either Bush Arm Causeway-North (BAC-N) or Bush Arm Causeway-South (BAC-S; Figure 5-12). BAC-N was distinguished from the other sites by its occasional standing water cover, while BAC-S relatively high proportional cover of wood debris and decaying organic matter (Figure 5-12).

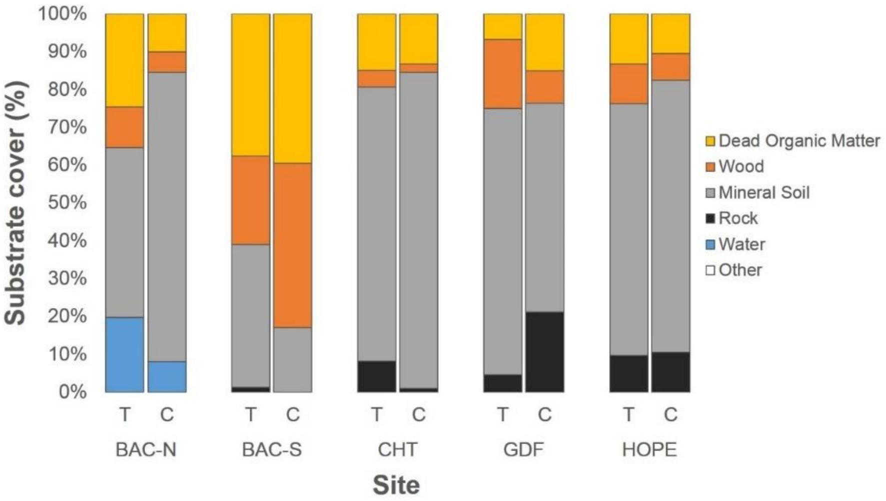

Figure 5-12: Proportion of ground covered by each class of substrate (organic matter, decaying wood, mineral soil, rock, water) in sample transects at each of the Bush Arm proposed physical works sites, 2015. BAC-N: Bush Arm Causeway-North; BAC-S: Bush Arm Causeway-South; CHT: Chatter Creek; GDF: Goodfellow Creek; Hope: Hope Creek

Mineral soils at BAC-N are very fine-textured and possess a high clay content; those at GDF and Hope are coarse and consist mainly of sand, gravel, and cobble. The substrate at CHT is predominantly silty-sandy, while that at BAC-S is a fairly balanced mix of silt, sand, organics, and fines (Figure 5-13).

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[4] Physical works projects were initiated at two of the proposed sites (Bush Arm Causeway–North and Bush Arm Causeway–South) in late September 2015 (Hawkes 2016)

CHT appears to be the most nutrient rich of the sites, with relatively high nitrate/nitrate (N) and total organic carbon (TOC) concentrations, while soils at GDF are relatively low in N (Figure 5-14). The wettest soil conditions tend to occur at BAC-N (Figure 5-14), which receives regular water inputs (both ground and surface water) due to its location in the floodplain of the Bush River.

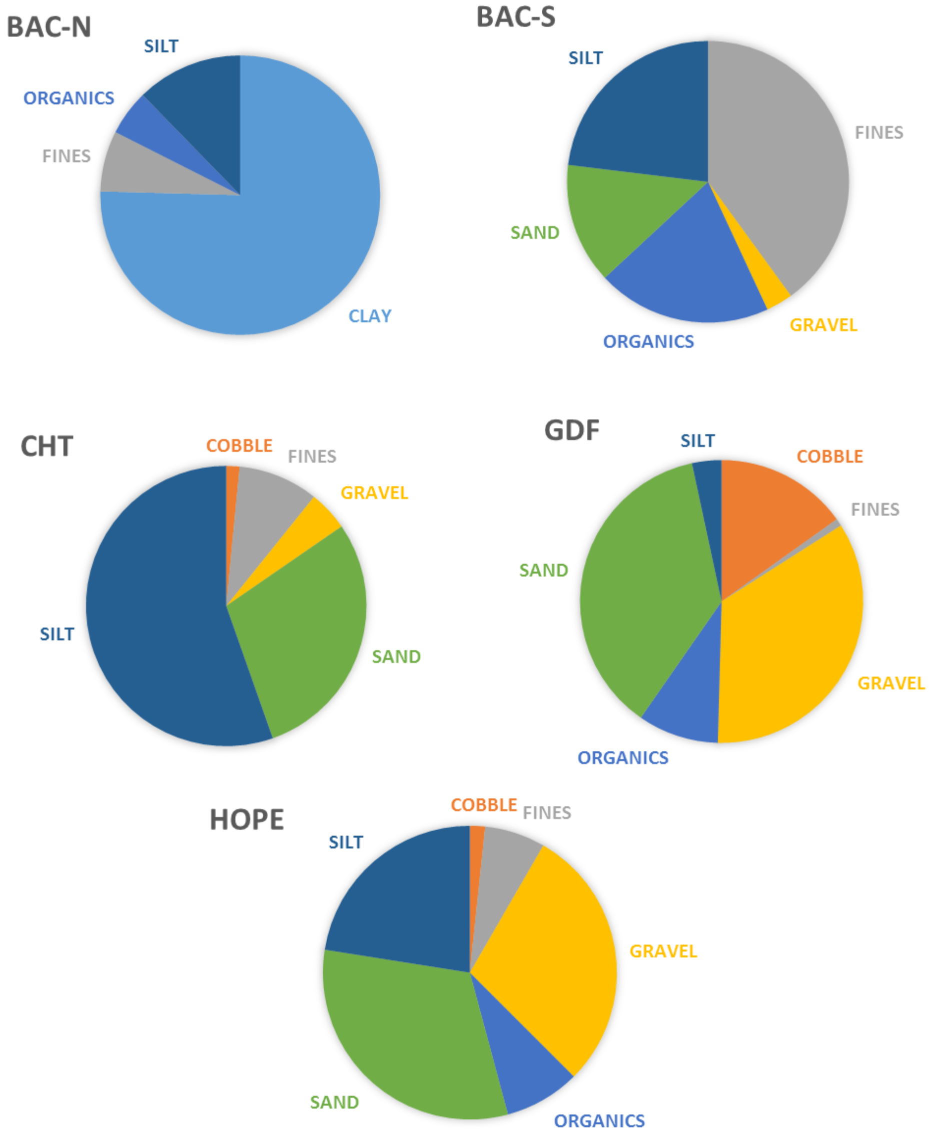


Figure 5-13: Relative frequency with which different substrate textures were recorded as the dominant mineral soil texture within 1x1 m quadrat subsamples at each of the Bush Arm proposed physical works sites, 2015. BAC-N: Bush Arm Causway (north); BAC-S: Bush Arm Causeway-South; CHT: Chatter Creek; GDF: Goodfellow Creek; Hope: Hope Creek

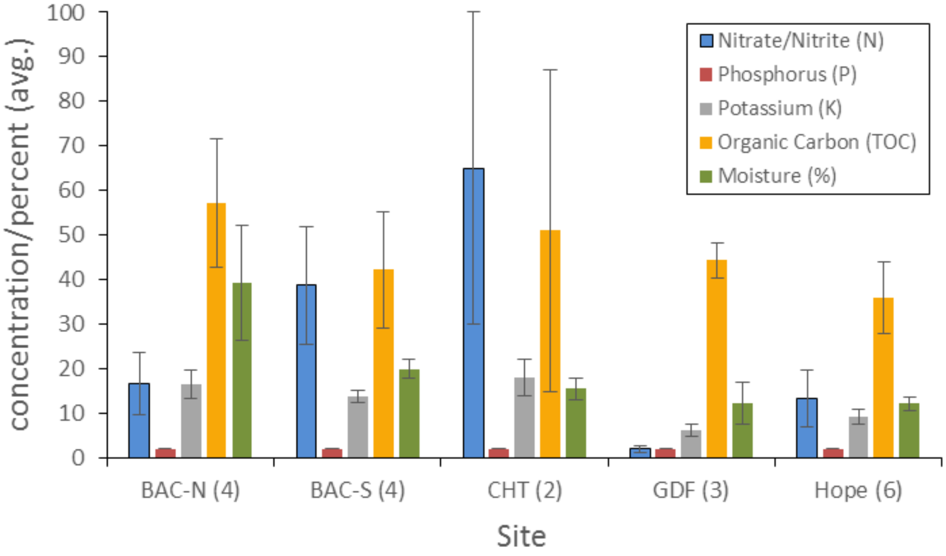
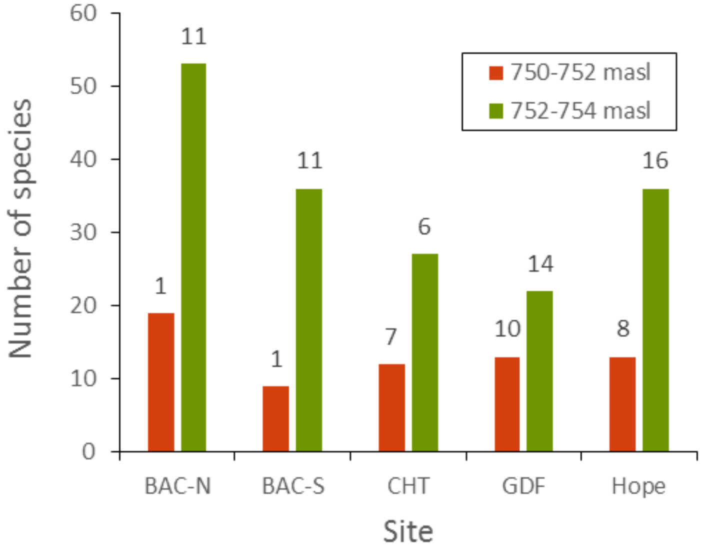


Figure 5-14: Nutrient concentrations and soil moisture values obtained from soil samples collected at the Bush Arm proposed physical works sites, June 2015. Sample sizes shown in () after the site name. Units for N, P, K: mg/kg. Units for TOC: g/kg. Units for moisture: per cent. BAC-N: Bush Arm Causway (north); BAC-S: Bush Arm Causeway-South; CHT: Chatter Creek; GDF: Goodfellow Creek; Hope: Hope Creek

BAC-N yielded the highest total number of vascular plant species in sample transects, for both low and high elevation transects. BAC-S and Hope were moderatly speciose while GDF was the least speciose site (Figure 5-15). At all sites, species richness tended to increase with elevation (Figure 5-15). Forbs made up the highest proportion of species at all sites, followed either by shrubs and sedge-like plants (BAC-N and CHT) or shrubs and grasses (BAC-S, GDF, and Hope; Figure 5-15, Appendix 8.3).

A comparison of baseline vegetation data from stratified random treatment (pre-impact) and control transects at each site reveals some existing variation between the two sample areas (polygons), implying that future (post-impact) comparisons between the two areas will need to account for the possible differences in starting conditions. For example, the herb layer (a group that includes forbs, grasses, sedge-like plants, and pteridophytes) at CHT and GDF appeared to be more speciose in the treatment than in the matching control polygons (Figure 5-16). In terms of shrub richness, control transects at BAC-S exhibited higher average values than the matching treatment transects, whereas at CHT shrubs were present in treatment transects but absent from control transects (Figure 5-16).

Cover values for the herb layer were relatively consistent between treatment and control polygons with the exception of GDF, where cover appeared to be lower in the control than the treatment polygon (Figure 5-17). Shrub cover appeared highest in the control polygon at BAC-S compared to other sampled areas, whereas shrub cover was notably sparse at both GDF polygons and in the control polygon at Hope (Figure 5-17).



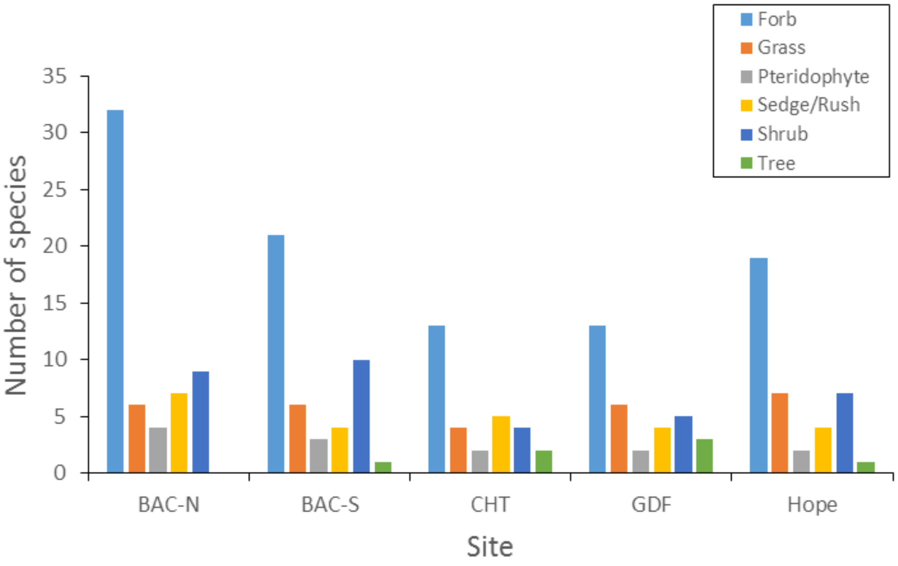


Figure 5-15: Top: Total number of vascular plant species recorded in 2015 sample transects at each of five proposed physical works sites in Bush Arm, stratified by low (750-752 m) and high (752-754 mm) elevation bands. Sample sizes shown above the bars. Bottom: Total number of vascular plant species by plant functional group. BAC-N: Bush Arm Causway (north); BAC-S: Bush Arm Causeway-South; CHT: Chatter Creek; GDF: Goodfellow Creek; Hope: Hope Creek

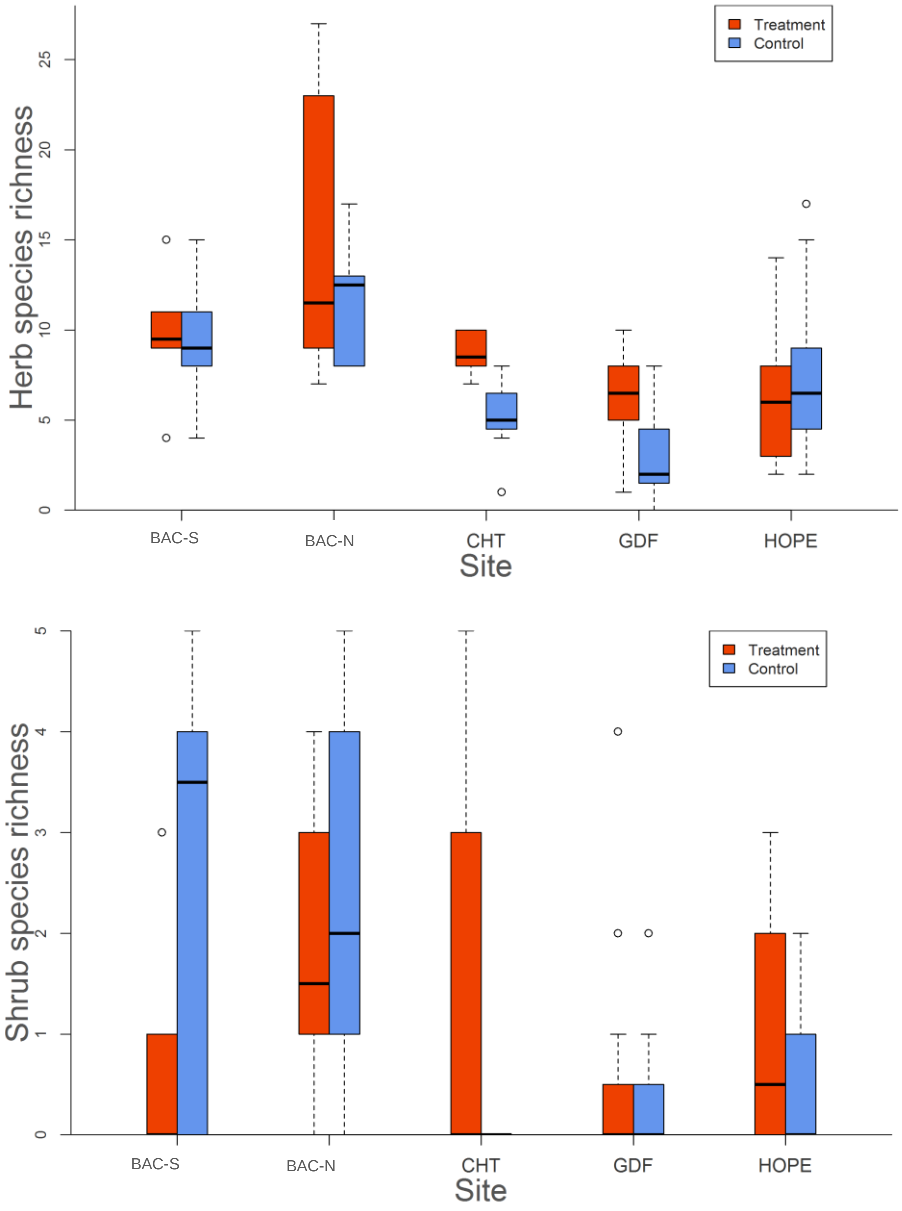


Figure 5-16: **Variation in the total species richness of herbs (top) and shrubs (bottom) in sampled transects within control and treatment polygons at the five proposed physical works sites in Bush Arm, 2015.** The herb layer includes forbs, grasses, pteridophytes, and sedge-like plants. BAC-N: Bush Arm Causway (north); BAC-S: Bush Arm Causeway-South; CHT: Chatter Creek; GDF: Goodfellow Creek; Hope: Hope Creek

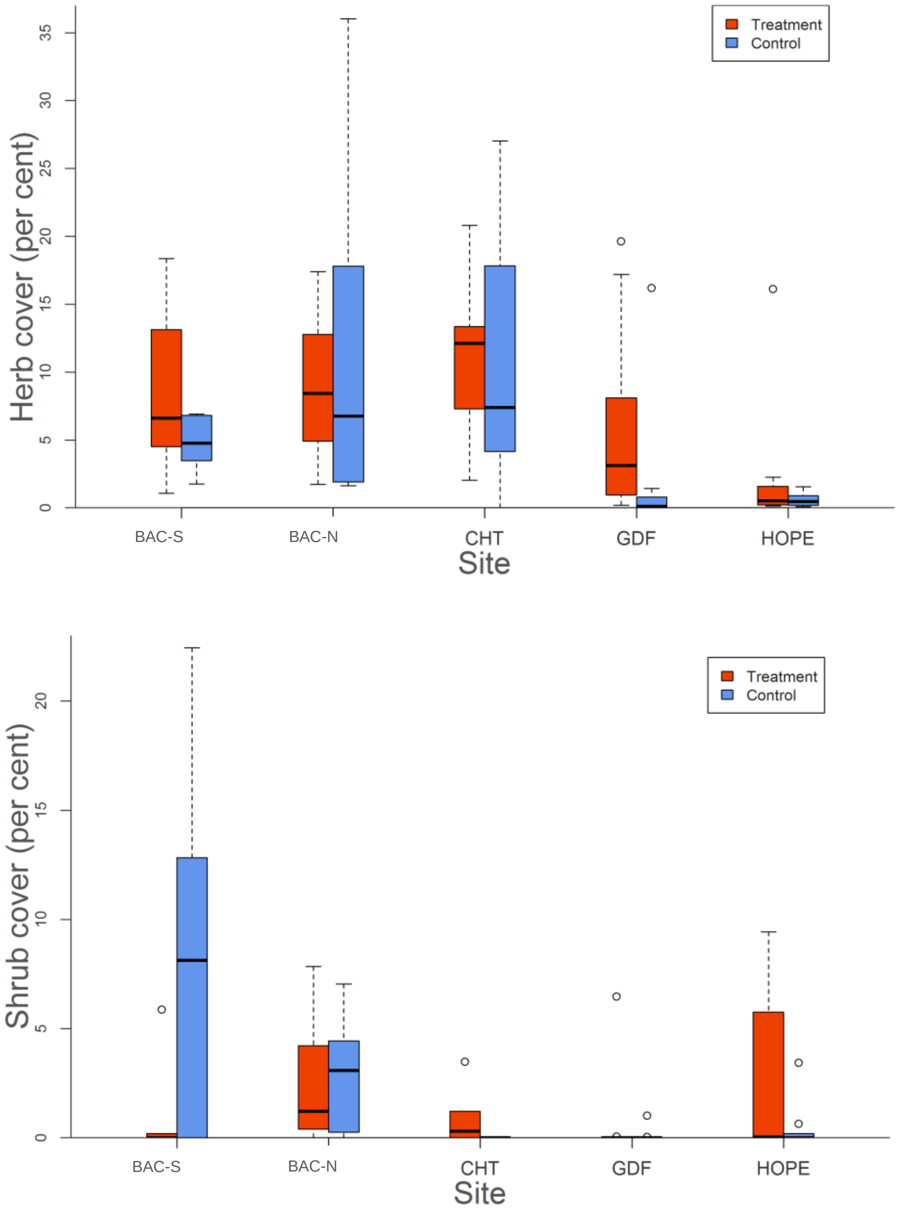


Figure 5-17: Variation in the percent cover of the herb layer (top) and shrub layer (bottom) in sampled transects within control and treatment polygons at the five proposed physical works sites in Bush Arm, 2015. The herb layer includes forbs, grasses, pteridophytes, and sedge-like plants. BAC-N: Bush Arm Causway (north); BAC-S: Bush Arm Causeway-South; CHT: Chatter Creek; GDF: Goodfellow Creek; Hope: Hope Creek

6.0 Discussion

Previous implementations of the CLBMON-9 monitoring program assessed the effectiveness of revegetation efforts implemented under CLBWORKS-1 from 2009 to 2011 (Yazvenko *et al*. 2009, Fenneman and Hawkes 2011, Hawkes *et al*. 2013). For 2015, the CLBMON-9 scope was modified to include effectiveness monitoring and baseline data collection for three additional physical works projects initiated post-2011. The new projects were: (1) the 2014 wood debris removal and boom installation trials at Canoe Reach; (2) the 2013 sedge planting trials at Km 88; and (3) the proposed 2015 installation of debris mounds and windrows at Bush Arm Causeway.

Study of the wood debris removal/exclusion trials at Canoe Reach was initiated in 2014, with 2015 representing the second year of data collection. In the case of both the Km 88 sedge trials and the Bush Arm Causeway physical works, 2015 represented the first year of sampling under CLBMON-9. Thus, most of the findings described here are of a preliminary, baseline nature.

6.1 Canoe Reach Wood Debris Removal and Boom Exclosure Sites

Various authors have observed or suggested impacts on benthic and riparian plant communities associated with the rafting or stranding of logs (Pease 1974; Bell and Kallman 1976c; Conlan 1977; Duval *et al*. 1980; Sedell and Duval 1985). Impacts on plant communities may result from scouring of both hard and soft substrates, compaction of soft substrates, shading and other alterations in the light environment, deposition of bark and wood debris, and toxic or sublethal effects associated with increased oxygen demand and release of log leachates (Sedell and Duval 1985). Bell and Kallman (1976) reported that logs stored in the Nanaimo River estuary had adverse impacts on eelgrass (*Zostera marina*) meadows as well as on macrobenthic and microbenthic algae. Damage to emergent vegetation has also been observed in coastal areas used for log handling (Duval *et al*. 1980).

In Kinbasket Reservoir, floating wood debris frequently accumulates as thick deposits on shoreline areas as a result of wave and wind action or during the winter drawdown cycle. These deposits have the ability to scour or bury existing drawdown zone vegetation, inhibiting both short and long term growth potential, and can also seriously impact on revegetation efforts (Hawkes *et al*. 2013). Mechanically removing these debris accumulations from selected sites with the aim of facilitating natural regeneration and colonization processes may be a more effective habitat restoration strategy than more conventional revegetation approaches attempted thus far with limited success (Hawkes *et al*. 2013). However, because wood debris tends to accumulate in many of the same areas each year, debris removal may only be effective for restoration purposes if actions are simultaneously taken to protect the cleared sites from subsequent re-incursions of debris.

To test this idea, we monitored short-term vegetation responses to the mechanical removal of wood debris at five drawdown zone sites in Canoe Reach, one of which (Valemount Peatland-North) was additionally protected by the installation of a log boom exclosure.

In transects sampled two months post-clearing and again one year post-clearing, we found that vegetation showed a positive response overall to debris removal, with increases observed in both per cent cover and species richness at most treated sites. As might be expected, the strength of the initial response (relative to non-treated controls) varied from site to site, likely reflecting idiosyncratic differences in existing substrates (e.g., soil texture and nutrient regimes), water inputs, and the prior presence of seed banks and/or remnant vegetative propagules (e.g., rhizomes). The most marked positive response was at Valemount Peatland-North, a highly impacted, remnant wetland site with moist, nutrient-rich, highly organic soils supported by seepage inflows from an adjacent upslope wetland and, judging by the diversity of recently-emerged species, possessing an active seed/propagule bank. A floristic inventory of this area in July 2015, one year after debris removal, yielded 62 established and regenerating vascular plant species—nearly half the cumulative total of 128 species recorded to date for the entire Canoe Reach drawdown zone (Hawkes and Gibeua 2015) and on par with some of the more productive sites in Kinbasket Reservoir.

By comparison, driftwood sites where the initial vegetation response to debris removal was more muted (i.e., Packsaddle and Yellowjacket Creek sites) tended to be sandy/gravelly beach-type habitats with relatively xeric, nutrient-poor soils and naturally limited vegetation development. Two months post-clearing, species recorded in treated transects but not in control transects consisted primarily of ruderal species such as lambs-quarters (*Chenopodium album*), lady's-thumb (*Persicaria maculosa*), common knotweed (*Polygonum aviculare*), and clovers (*Trifolium* spp.). In some sample plots, most notably Packsaddle Creek-North, species cover and richness actually appeared to undergo a decline between the time of the 2014 survey and the 2015 re-survey, likely as a consequence of the plots being partially to completely reburied by wood debris during the 2014-2015 fall/winter inundation cycle. In contrast, at the protected log boom exclosure site (Valemount Peatland-North), plant cover and richness continued to increase dramatically between 2014 and 2015.

While it is still too soon to draw definitive conclusions, results from this initial monitoring period indicate that targeted wood debris removal has the potential to be an effective management technique for enhancing vegetation growth in the drawdown zone. It is also evident that the supplemental placement of protective log boom exclosures can be an effective tool for preventing driftwood from resettling on a site following clearing—an important consideration given the inherent risks posed to regenerating vegetation by the redeposition of debris. This added measure may not be necessary in all cases, but may be critical for facilitating the recovery process in areas with active winter drifting. Because the log boom exclosure at Valemount Peatland has been in place for only one year, its long-term structural integrity in the face of wave action and other reservoir effects has not yet been fully tested and further monitoring will be needed to assess its effectiveness over a longer time frame.

Further, we consider that these approaches are likely to be most effective when paired with the selection of treatment areas that show indications of being naturally productive in the absence of debris loading. For example, experience suggests that certain community types, such as WS (Willow – Sedge Wetland), BS (Buckbean – Slender Sedge), and SH (Swamp Horsetails) are likely to respond more rapidly to clearing than more sparsely vegetated habitat types such as CH (Common Horsetail) or CT (Cottonwood – Trifolium). The former types are all associated with moist to wet soil conditions (i.e., wetlands) while the latter tend to be associated with drier, coarse, rocky sites.

The recent outcome at the Yellowjacket Creek location (YJ), where the control area produced higher relative gains in total cover than the treatment area, provides a case in point. Here, the area left experimentally uncleared was on a productive moist seepage site that, despite being heavily impacted by driftwood, was supporting a diverse complex of willows and graminoids (many of them wetland indicator species). In contrast, the area cleared was on a course gravel-cobble substrate that supported a mainly ruderal species assemblage more characteristic of the CT community type. From an experimental perspective, these inherent differences imply that the two sites were probably not an ideal pairing. From a management perspective, it seems likely that the immediate restoration payoff would have been greater had the control site been cleared of its debris, rather than vice versa.

Thanks to the previous vegetation characterizations and mapping that have already occurred under CLBMON-9 and 10, good information is currently available on the general distribution and frequency of the different community types within the reservoir drawdown zone and could be used to identify sites with high recovery potential. On a more summary level, potential treatment areas can be said to include wetlands and other formerly vegetated sites where a viable seed bank is likely to persist; shallow ponds and depressional areas; protected bays and inlets; sites with nutrient-rich, moist soils; and sites where wood deposition does not recur on a regular basis (i.e., located outside of the primary deposition zones). Cueing off coarse biophysical filters such as these, it should be relatively straightforward to identify potential target areas using historical and recent aerial photo records. Promising areas could subsequently be ground-surveyed to confirm community type, substrate quality, and seed bank or other regenerative potential, then catalogued for future management reference.

6.2 Revegetation Treatments (Km 88)

In the spring of 2013, 3.3 hectares (ha) of drawdown zone habitat at Km 88 site were planted with nursery-raised seedlings (plugs) of Kellogg's sedge (*Carex lenticularis* var. *lipocarpa*) and Columbia sedge (*C. aperta*) at a stocking density of approximately 23,000 plugs per ha. The stock consisted of unused plugs leftover from the initial phase of the revegetation program, which was postponed after 2012 due to poor plant survival and establishment (Adama 2015). The goal of the Km 88 planting prescription was to introduce seedlings at a site (or sites) in the reservoir where they would have a high chance of establishment. Specific objectives were to increase the density of sedge in three treatment units at Km 88 to between 5,000 and 15,000 sedges per ha and to increase the spatial extent of the Kellogg's Sedge (KS) community at Km 88 (Adama 2013, 2015).

The 2015 monitoring results are summarized below in relation to specific management questions (Section 3.2) as they pertain to the Km 88 project. For the current status of the management questions (MQs) as they pertain to the wider Kinbasket revegetation program, please refer to Table 1-1.

6.2.1 MQ1: What is the quality and quantity of vegetation in revegetated areas compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?

This MQ has not been addressed yet for Km 88 because insufficient time has past since the planting operation for community responses to be realistically assessed.

Anecdotal observations indicate that the treated communities retain the same overall vegetation characteristics with respect to species composition and diversity as they did prior to planting, aside from the obvious addition of the two sedge species to areas where these did not grow before (e.g., the low-elevation Marsh Cudweed—Annual Hairgrass community type in Treatment Units 1 and 3). While establishing Kellogg's and Columbia sedge is an important step in expanding the vegetation cover at Km 88, several more years of monitoring will be needed to determine if these introductions have the ability on their own to alter the successional trajectory of the sites toward something more resembling a mature KS (Kellogg's Sedge) community type. That association includes several additional species including Wool-grass (*Scirpus atrocinctus*), Yellow Sedge (*Carex flava*) and Toad Rush (*Juncus bufonius*), clover (*Trifolium* spp.), and Narrow-leaved Collomia (*Collomia linearis*) (Hawkes *et al* 2008). Thus, the planting of additional species may be required to reach the targeted objective, an action that could be considered if the 2013 seedlings demonstrate reasonable survivorship (25 to 50 per cent) over the next 5 years (Adama 2015).

6.2.2 MQ2: What are species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?

Survival one year after planting was between 93 and 100 per cent (Adama 2015). Two years after planting, survival ranged from 43 to 100 per cent, with an overall survival across the three TUs of 74 per cent (possibly an under-estimate related to the sampling protocol employed in 2015). The overall estimated establishment rate of approximately 17,000 sedge plants per hectare thus far appears to be exceeding the targeted objective of between 5,000 and 15,000 plants per hectare.

This positive result is encouraging in light of the unusually long inundation periods that prevailed in 2013 and 2014 and which led to predictions of elevated mortality for 2015 (Adama 2015). Two factors that may be contributing to the relatively high initial survival rates are site selection and plant size. The identification of ecologically suitable and capable transplant sites was a central focus of prescription development (Adama 2013), and as a result transplanted plugs have likely benefited from the comparatively moderate environmental conditions prevailing at the Km 88 site—a gently-sloped, sheltered, debris-free bay on the lee side of Bear Island supporting an existing cover of Kellogg's and Columbia sedge (as well as other species). Additionally, because of the extra year spent in nursery storage, the plugs outplanted at Km 88 were a year older and larger than those employed in earlier revegetation trials (Keefer *et al*. 2010). Larger seedlings are likely to have greater leaf area, higher root and shoot biomass, and greater root growth potential. Under stress (such as prolonged inundation), such traits could confer a survival advantage (Steed and Dewald 2003; Hough-Snee 2010, Adama 2015).

6.2.3 MQ3: What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the remediation and expansion of vegetation communities in the drawdown zone?

At Km 88, the factors most likely to limit transplant establishment success are the timing and duration of inundation, both of which have varied markedly on an annual basis since 2013. In both 2013 and 2014, total inundation time at all planted elevation bands substantially exceeded (by >70 days in the case of lower elevations) the previous 30 year norms, implying that the sedge plantings at Km

88 have so far experienced somewhat truncated growing seasons—and potentially higher physiological stresses related to prolonged inundation—compared to those experienced over time by the established native vegetation. Plugs in the lower elevation bands, which were inundated for 13 to 20 days longer than the higher bands, have experienced particularly long inundations. While this does not yet appear to have impacted on survival rates (which remain very high), the lower elevation plantings are growing more slowly and possess lower overall vigour than the adjacent higher elevation plantings.

A non-operational effect worth noting is the possible negative impact that grazing by waterfowl (likely Canada geese) is having on the demographic success of sedge plugs at low elevations. We observed that the majority of plugs situated near the May/June waterline had been heavily browsed in 2015, resulting in the seasonal loss of both photosynthetic foliage as well as reproductive structures (flowering stems). The extent to which grazing pressure may be interacting with inundation timing and duration to limit long term establishment success is at present unclear.

6.2.4 MQ4: What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-1, at increasing the quality and quantity of vegetation in the drawdown zone?

Initial monitoring results suggest that both wood debris removal, which represents an indirect form of revegetation, and the direct outplanting of sedges can be employed effectively to increase the quality and quantity of plant cover in the drawdown zone. However, the effectiveness of either approach will be limited by the original quality and condition of sites targeted for treatment (Hawkes *et al*. 2013b, Adama 2015). Because it focuses on facilitating the regeneration of existing vegetation, as opposed to introducing new vegetation, targeted wood debris removal (in combination with debris exclusion measures) appears to offer greater immediate ecological returns (with a lower up-front investment). On these grounds, we feel it could be a cost-effective alternative to direct stocking for treating multiple sites over a wide geographic area in a short time frame.

Given that debris removal has only been attempted on a trial basis since 2014, and the Km 88 treatment was only initiated in 2013, these conclusions are admittedly speculative. Nevertheless, if additional opportunities for debris removal are identified in the near term with the potential to mimic results achieved at Valemount Peatland in Canoe Reach, we believe this option should be given first priority.

The third revegetation approach covered by this report—construction of debris mounds and windrows to create topographic heterogeneity—was still in the early implementation phase in 2015 and has not yet been monitored for effectiveness.

6.2.5 MQ5: Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?

In 2013, a total of 3.3 ha at Km 88, covering three treatment units, were stocked at a density of approximately 23,000 plants per ha. Two years later, the density of surviving plants was estimated to be around 17,000/ha, or approximately 1.7 m plants per m^2. By this measure, implementation of the revegetation program at Km 88 has so far resulted in greater immediate benefits than could be achieved through natural colonization alone. A large number of individuals in the treatment population were reproductively mature in 2015 (i.e., plants were initiating inflorescences and setting seed), which can be taken as a sign that they are growing well and possess good vigour. However, no instances of seedling recruitment have been observed and it remains to be seen whether the population will be self-sustaining over the long term. It is also too early to know if the treatments will succeed at advancing community succession, either by modulating local environmental conditions and/or by facilitating the establishment of other species.

The Km 88 treatments were (intentionally) applied to an area of the drawdown zone that already supported well-established vegetation communities (spanning the KS, MA, and RC community types; Table 4-2). Thus, while treatments may have succeeded in elevating species richness and cover at the local scale, they have not necessarily produced larger vegetated areas than existed before. The main ecological effect to date has likely been to tilt the balance of community composition toward a more graminoid-intensive phase, particularly at the lower sites which otherwise tend to be dominated by short-statured annuals (Figure 5-8). Localized increases in sedge cover, even if these turn out to be ephemeral at a time scale of five or more years, may already by providing some ancillary wildlife services in the form of increased habitat structure and cover (for both aquatic as well as terrestrial organisms), shading, and browse. For example, we found indications in 2015 that local waterfowl populations (most likely Canada geese) have been preferentially utilizing sedge plantings in some of the treatment units as a spring food source.

6.2.6 MQ6: Is there an opportunity to modify operations to more effectively maintain revegetated communities at the site level in the future?

From a reclamation standpoint, opportunities still exist for enhancing the development of existing revegetation treatments through operational modifications. With respect to the hydroperiod, program experience to date suggests the following tentative precepts:

(i) To facilitate development of functional riparian ecosystems, periodic, brief inundation at low elevations (i.e., 746-750 m) is likely needed to recharge soil moisture, protect establishing plants from summer drought, and maintain suitable growing conditions for adapted riparian species and communities.

(ii) Frequent full pool events will limit the capacity for shrub and tree establishment at upper elevations (i.e., >452 m).

(iii) Extended, deep inundation is unnecessary and probably detrimental for all revegetation taxa.

(iv) Late summer and fall inundation can inhibit seed-set and dispersal for key reclamation species such as Kellogg’s sedge, resulting in lost reproductive opportunity and reduced establishment (and hence reclamation) potential.

In effect, the more that inundation cycles resemble natural spring/summer freshet cycles in both timing and duration, the more beneficial to revegetated communities they are likely to be. Operational adjustments will be most effective at maintaining revegetated communities to the extent they are employed to limit not just the depth but also the duration of inundation during the summer and early fall growing season. The inundation regime of 2015, which saw Kinbasket Reservoir peak in mid-July after reaching a relatively low annual maximum of 750.79 m ASL (Figure

4-3), appeared to benefit vegetation in several respects and could provide a useful template for operations moving forward. We predict that, if sustained over time, this inundation pattern will lead to higher cover of grasses and deciduous shrubs at mid to upper elevations, and higher sedge and annual herb cover at lower elevations.

The non-experimental nature of the planting program, combined with the recent history of variable reservoir operations (also unreplicated in space and time), limits our ability to test hypotheses or to recommend specific targets around inundation timing, frequency, duration and depth. Annually replicated planting treatments in conjunction with a succession of different inundation cycles are needed to address this question fully.

6.3 Proposed Physical Works Sites, Bush Arm

Baseline vegetation and soil conditions were assessed at five proposed debris mound installation sites in north-east Bush Arm in 2015: Bush Arm Causeway (north and south) and Chatter, Goodfellow, and Hope creeks. The sites differed with respect both to substrate composition and the plant species they currently support. For example, Bush Arm Causeway-North, which sits in the lower floodplain of the Bush River, supported the highest plant species diversity, while Chatter Creek had some of the highest nutrient (N, TOC) concentrations. Hope and Goodfellow creeks, with gravelly nutrient-poor soils, supported relatively low plant covers and species richness. These baseline differences will need to be taken into account when eventually assessing the effectiveness of physical works.

Physical works trials were initiated at the two Causeway sites in late September 2015, two months after the baseline surveys were conducted (Hawkes 2016). The trials were undertaken to test the ability of constructed debris mounds and windrows to function as receptor sites for both natural and planted vegetation and to protect habitats cleared of wood debris. The affect of reservoir operations on the structural integrity of mounds will also be assessed, following the next high water year in Kinbasket Reservoir (Hawkes 2016).

A total of seven mounds and/or windrows were installed at the two Causeway locations. In addition, three wood-choked ponds at the north Causeway site were cleaned of debris. Approximately 50 live deciduous stakes (mainly black cottonwood) were planted and an around the mound at the south Causeway site, and a number of salvaged sedge plants were transplanted onto the margins of one of the cleared ponds at the north Causeway site (Hawkes 2016).

The initial performance of the live stakes and sedge transplants will be assessed in spring 2016 to assess the utility of either or both of these methods for jumpstarting the revegetation process on the mounds and in the drawdown zone surrounding the mounds. The efficacy of the mounds and windrows in promoting vegetation establishment and increasing local diversity will be assessed over time, commencing in 2017 after at least one growing season has passed. Depending on the initial success of Bush Arm Causeway trials, consideration may be given to constructing mounds at the remaining selected trial sites at Chatter, Hope, and Goodfellow Creeks.

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8.0 APPENDICES

8.1 Shrub cover and richness, Canoe Reach Wood Debris Removal and Boom Exclosure Sites

With the exception of Valemount Peatland-South, shrub cover was much higher in forest reference transects, situated above the drawdown zone, than in drawdown zone transects (Figure 8-1). Differences in shrub cover between cleared and uncleared (control) sites were not statistically significant between years at α=0.1, but were between treatments (F=9.7, p=0.0003), with slightly higher covers recorded in the control transects. Year-site interactions were not significant.

Shrub species richness was also low in the drawdown transects, generally being limited to a single or two species (typically willow or rose spp.). Differences in richness between cleared and uncleared (control) sites were not statistically significant between years (p>0.1), but were significant between treatments (F=11.6, p=0.0007). Year-site interactions were not significant.

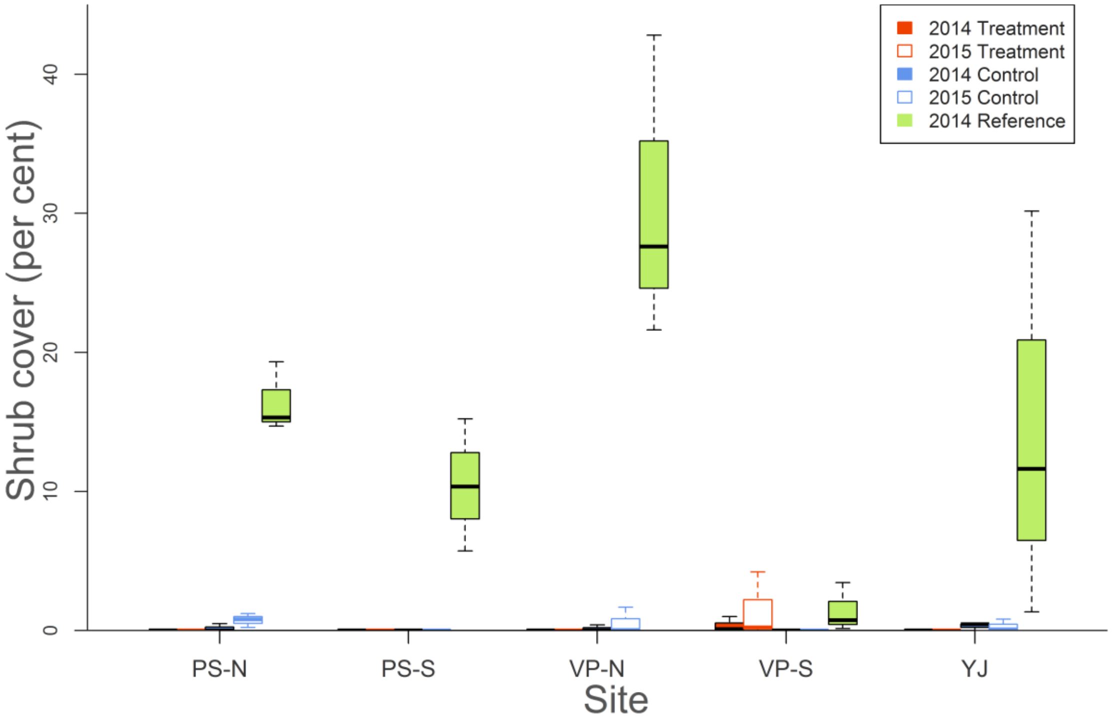

Figure 8-1: **Variation in per cent cover of the low shrub layer in control, treatment, and forest reference transects at the five wood debris removal sites in Canoe Reach, in 2014 and 2015**

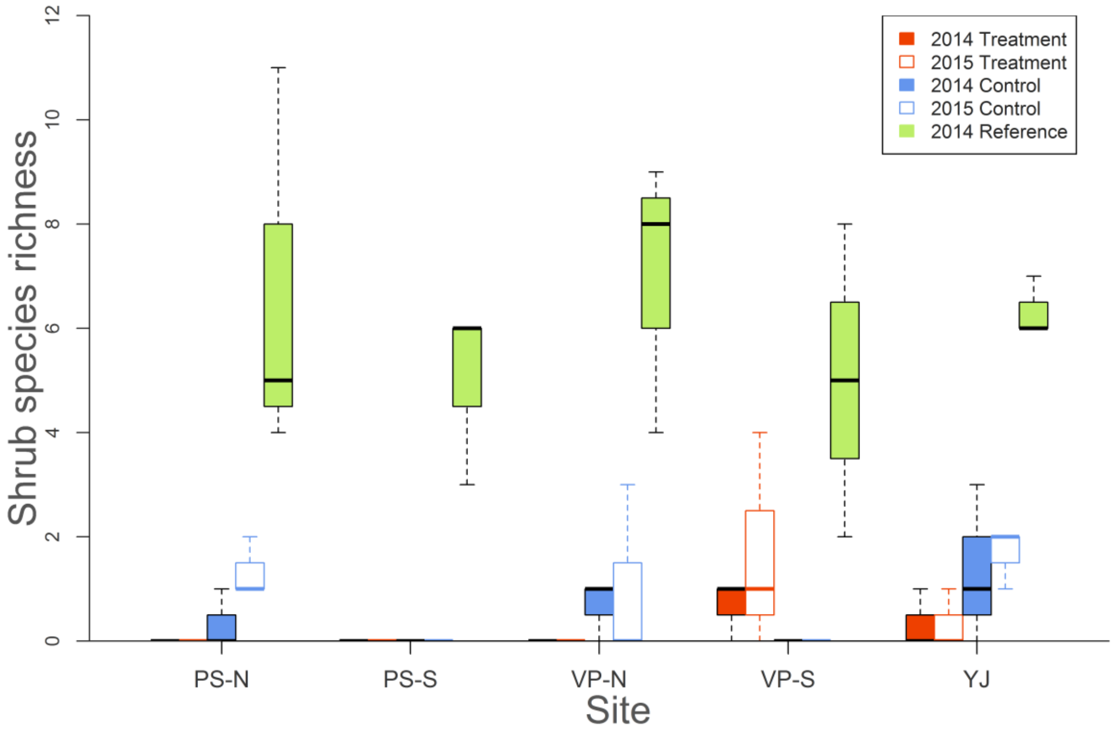

Figure 8-2: **Variation in richness of species in the shrub layer in control, treatment, and forest reference transects at the five wood debris removal sites in Canoe Reach, in 2014 and 2015.**

8.2 Log Boom Exclosure Species List, Valemount Peatland-North

Table 8-1: **Vascular plant species list resulting from the mid-summer (July 20 2015) floristic inventory of the log boom exclosure site at Valemount Peatland-North (VP-N), Canoe Reach**

Species	
Agrostis scabra	*Glyceria striata*
Agrostis stolonifera	*Juncus alpinoarticulatus*
Alopecurus aequalis	*Juncus bufonius*
Arnica chamissonis	*Juncus ensifolius*
Bidens cernua	*Leucanthemum vulgare*
Calamagrostis canadensis	*Lysimachia thyrsiflora*
Calamagrostis stricta	*Myosotis scorpioides*
Callitriche palustris	*Myriophyllum sibiricum*
Cardamine pensylvanicus	*Persicaria amphibia*
Carex aquatilis	*Persicaria maculosa*
Carex bebbii	*Poa compressa*
Carex crawfordii	*Poa palustris*
Carex flava	*Potamogeton obtusifolius*
Carex lenticularis	*Potentilla norvegica*
Carex stipata	*Ranunculus gmelinii*

Cerastium fontanum	*Ranunculus pensylvanicus*
Cicuta douglasii	*Ranunculus sceleratus*
Cirsium vulgare	*Rorippa palustris*
Comarum palustre	*Rumex crispus*
Crepis tectorum	*Sagina procumbens*
Deschampsia cespitosa	*Salix planifolia*
Eleocharis mamillata	*Scirpus atrocinctus*
Epilobium ciliatum	*Sium suave*
Equisetum arvense	*Sparganium emersum*
Equisetum fluviatile	*Sparganium natans*
Equisetum palustre	*Taraxacum officinale*
Euphrasia nemorosa	*Trifolium aureum*
Galeopsis tetrahit	*Trifolium hybridum*
Galium trifidum	*Typha latifolia*
Glyceria boreale	*Utricularia intermedia*
Glyceria grandis	*Viola macloskeyi*

8.3 Bush Arm Physical Works Sites Species List

Table 8-2: List of vascular plant species lists recorded in sample transects at five proposed physical works site in Bush Arm, June/July 2015. BAC-N: Bush Arm Causeway-North; BAC-S: Bush Arm Causeway-South; CHT: Chatter Creek; GDF: Goodfellow Creek; Hope: Hope Creek

Site	Species
BAC-N	*Agrostis gigantea* *Agrostis scabra* *Alisma triviale* *Braya humilis* *Calamagrostis canadensis* *Calamagrostis stricta* *Carex aquatilis* *Carex lasiocarpa* *Carex saxatilis* *Carex utriculata* *Carex viridula* *Coeloglossum viride* *Cornus stolonifera* *Deschampsia cespitosa* *Eleocharis elliptica* *Eleocharis mamillata* *Epilobium latifolium* *Equisetum arvense* *Equisetum fluviatile* *Equisetum palustre* *Equisetum variegatum* *Fragaria virginiana* *Galium trifidum* *Glyceria striata* *Juncus alpinoarticulatus* *Leucanthemum vulgare* *Lobelia kalmia* *Lysimachia thyrsiflora* *Medicago lupulina* *Mentha arvensis* *Packera plattensis* *Parnassia parviflora* *Phalaris arundinacea* *Poa palustris* *Poa sp.* *Potentilla anserina* *Potentilla norvegica* *Prunella vulgaris* *Rhinanthus minor* *Rosa acicularis* *Salix brachycarpa* *Salix farriae* *Salix lucida ssp.lasiandra* *Salix maccalliana* *Salix melanopsis* *Salix prolixa* *Salix sp.* *Sisyrinchium montanum* *Solidago lepida* *Symphyotrichum ciliolatum* *Symphyotrichum subspicatum* *Taraxacum officinale* *Triantha glutinosa* *Trifolium aureum* *Trifolium hybridum* *Vicia cracca* *Viola macloskeyi* *Viola sp.* *Zigadenus elegans*

BAC-S	*Agrostis gigantea*	*Galium trifidum*	*Rubus pubescens*
	Calamagrostis canadensis	*Hierochloe hirta*	*Salix bebbiana*
	Calamagrostis stricta	*Leucanthemum vulgare*	*Salix brachycarpa*
	Carex crawfordii	*Lysimachia thyrsiflora*	*Salix commutata*
	Carex lasiocarpa	*Medicago lupulina*	*Salix farriae*
	Carex lenticularis ssp. lipocarpa	*Medicago sativa*	*Salix maccalliana*
	Carex viridula	*Packera plattensis*	*Salix prolixa*
	Cornus stolonifera	*Persicaria maculosa*	*Salix sitchensis*
	Deschampsia cespitosa	*Phalaris arundinacea*	*Salix sp.*
	Elymus repens	*Poa compressa*	*Taraxacum officinale*
	Equisetum arvense	*Poa palustris*	*Trifolium hybridum*
	Equisetum pratense	*Populus trichocarpa ssp. balsamifera*	*Trifolium pratense*
	Equisetum variegatum	*Potentilla norvegica*	*Trifolium repens*
	Erucastrum gallicum	*Prunella vulgaris*	*Verbascum thapsus*
	Erysimum cheiranthoides	*Rhinanthus minor*	
	Fragaria virginiana	*Rosa acicularis*	
GDF	*Agrostis gigantea*	*Dryas drummondii*	*Poa palustris*
	Betula occidentalis	*Elymus repens*	*Populus trichocarpa ssp. balsamifera*
	Betula papyrifera	*Equisetum arvense*	*Potentilla norvegica*
	Calamagrostis canadensis	*Equisetum variegatum*	*Prunella vulgaris*
	Calamagrostis stricta	*Erucastrum gallicum*	*Rosa acicularis*
	Carex aquatilis	*Galeopsis tetrahit*	*Rubus parviflorus*
	Carex lasiocarpa	*Leucanthemum vulgare*	*Rubus pubescens*
	Carex lenticularis ssp. lipocarpa	*Medicago lupulina*	*Salix brachycarpa*
	Carex saxatilis	*Melilotus alba*	*Trifolium hybridum*
	Cornus stolonifera	*Persicaria maculosa*	*Trifolium pratense*
	Deschampsia cespitosa	*Phalaris arundinacea*	*Verbascum thapsus*
Hope	*Agrostis gigantea*	*Equisetum arvense*	*Prunella vulgaris*
	Anaphalis margaritacea	*Equisetum variegatum*	*Rosa acicularis*
	Anemone drummondii	*Erysimum cheiranthoides*	*Salix brachycarpa*
	Braya humilis	*Fragaria virginiana*	*Salix commutata*
	Calamagrostis canadensis	*Glyceria striata*	*Salix farriae*
	Calamagrostis stricta	*Leucanthemum vulgare*	*Salix lucida ssp. lasiandra*
	Carex aperta	*Medicago lupulina*	*Salix sp.*
	Carex flava	*Packera pauciflora*	*Symphyotrichum ciliolatum*
	Carex lasiocarpa	*Packera plattensis*	*Taraxacum officinale*
	Carex lenticularis ssp. lipocarpa	*Persicaria maculosa*	*Trifolium hybridum*
	Cornus stolonifera	*Phalaris arundinacea*	*Trifolium repens*
	Danthonia spicata	*Poa palustris*	*Verbascum thapsus*
	Deschampsia cespitosa	*Populus trichocarpa ssp. balsamifera*	

	Dichanthelium acuminatum	*Potentilla norvegica*	
CHT	*Calamagrostis canadensis*	*Equisetum variegatum*	*Populus tremuloides*
	Cardamine pensylvanica	*Erysimum cheiranthoides*	*Populus trichocarpa ssp.balsamifera*
	Carex aperta	*Leucanthemum vulgare*	*Potentilla norvegica*
	Carex crawfordii	*Medicago lupulina*	*Rorippa palustris*
	Carex lasiocarpa	*Melilotus alba*	*Rosa acicularis*
	Carex lenticularis ssp. lipocarpa	*Persicaria maculosa*	*Salix commutata*
	Carex saxatilis	*Phalaris arundinacea*	*Salix sitchensis*
	Collomia linearis	*Poa compressa*	*Trifolium aureum*
	Elymus repens	*Poa palustris*	*Trifolium hybridum*
	Equisetum arvense		*Verbascum thapsus*