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 6

Reference: CLBMON-9

Period: 2018

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Prepared for
BC Hydro Generation
Water Licence Requirements 6911
Southpoint Drive Burnaby, 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




Year 6 Report

Year 6: Part 1
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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-01) 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. 2018 marks the sixth year of monitoring under the CLBMON-9 program. The findings described in this interim report are preliminary in nature. A more comprehensive analysis and summary will be provided in the final (2019) comprehensive report.

Previous implementations of the CLBMON-09 monitoring program assessed the effectiveness of revegetation efforts implemented under CLBWORKS-01 from 2009 to 2011 (Yazvenko *et al*. 2009, Fenneman and Hawkes 2011, Hawkes *et al*. 2013). For 2015, the CLBMON-09 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 (Hawkes and Miller 2016).

The main objectives for the 2018 CLBMON-09 field program were: (i) to continue monitoring recent (post-2012) physical works projects undertaken to enhance vegetation at Bush Causeway, Km 88, and Valemount Peatland; and (ii) to conduct a comprehensive survey of original (2008-2011) CLBWORKS-01 revegetation treatments to fill in existing data gaps around revegetation survivorship/establishment and topo-edaphic site conditions. As part of the latter assessments, soil samples were collected from microsites representing both revegetation successes and failures. The soils data will be used in subsequent comparative nutrient analyses aimed at further identifying potential site-limiting factors.

At the Bush Causeway, artificial mounds constructed in 2015 out of local wood debris and mineral soil are currently showing evidence of successful plant colonization (both natural and via planted live cottonwood stakes), with over 70 species recorded in 2018. Stake survivorship three years following planting is estimated at 46 %. Adjacent wood-choked ponds that were cleaned of wood debris during mound construction are also showing indications of vegetative recovery, with various sedge species as well aquatic macrophyte genera (e.g., *Sparganium*, *Persicaria*, *Potamogeton*, *Alisma*) being observed to have established in or adjacent the ponds. However, because reservoir levels have remained relatively low since 2015, as yet there has been no opportunity to assess effects of erosion and wave action on the constructed mounds and windrows or to monitor the effectiveness of the log-booms at excluding woody debris. For the same reason, vegetation responses to mound inundation are also unknown.

At Valemount Peatland, vascular plant species richness behind the log-boom exclosure has increased steadily since 2014, the year the site initially underwent woody debris clearing. However, as in the case of the Bush Causeway treatments, the Valemount Peatland log-boom has not yet been tested by high reservoir levels and it is currently unknown how effective the exclosure will be at protecting the regenerating vegetation at this site from heavy wood deposition during full pool events.

At Km 88, the 2013 sedge plug treatments continue to perform well both in terms of survivorship and reproductive development. 2018 establishment estimates were slightly below the targeted densities of 10,000-15,000 plugs per ha for TU-1 and TU-3, and in line with the target density of 5,000-10,000 per ha for TU-5. Estimated per cent survival was around 35% for all TUs. Sedge vigour was rated “good” overall for TU-1 and TU-3, and “moderate to good” for TU-5.

During our extensive survey of original CLBWORKS-01 revegetation polygons, we recorded several instances of vigorous, surviving plug transplants at locations not previously known to have had successful establishment. This includes treatments in both Canoe Reach (e.g., Yellow Jacket, Ptarmigan Creek) and Bush Arm (e.g., Chatter Creek, Km 77, Km 79, Km 88 peatland). A few surviving plugs were also recorded at Canoe River Mouth, Windfall Creek, Prattle Creek, and Hope Creek. These new (and unexpected) observations of treatment survivorship, while generally highly localized, nevertheless suggest that the rate of revegetation establishment in Kinbasket has been somewhat underestimated previously (Hawkes et al. 2013, 2018). These newly-obtained data will be used to inform models of species-specific responses to site conditions and reservoir operations in Kinbasket and Arrow Lakes that are currently under development as part of CLBMON-35 (Hawkes et al. 2018).

If Kinbasket Reservoir fills in 2019, a research crew will mobilize immediately to assess the impacts of inundation on physical works at Bush Causeway and Valemount Peatland, both during and following high water. Monitoring will be carried out through ground inspections and via remote sensing. For the latter, a drone will be used to obtain aerial photos, which will be compared to historical aerial data to determine how the size/shape of the mounds changes as a result of inundation. During the subsequent (2020) growing season, covers of plant species growing behind the two log-boom exclosures will be monitored within previously-established transects, and the short-term responses of mound/windrow vegetation (both planted and naturally establishing) will be visually assessed. Field sessions in both 2019 and 2020, if they occur, are anticipated to be relatively brief.

The final (2019) CLBMON-09 report will include a more fulsome discussion of next steps regarding monitoring inundation effects on physical works. An upcoming revegetation technical review may also provide a forum for reviewing results to date and engaging in discussions around the preferred monitoring response to a single or multiple full pool event.

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1.0 INTRODUCTION

1.1 Summary

This interim report summarizes the fieldwork that was completed in 2018 to implement Year 6 (Part 1) of CLBMON-09 (Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis). As an interim report, this document does not directly address the program management questions (Section 1.2). MQs will instead be answered in the final (2019) report.

Work in 2018 had four main components: (1) effectiveness monitoring of existing revegetation treatments in Canoe Reach and Bush Arm, including the 2013 sedge plantings at KM 88; (2) vegetation monitoring of wood debris removal trials at Canoe Reach; (3) vegetation monitoring of debris boom enclosures and constructed debris mounds and windrows at Bush Arm Causeway; and (4) pre-works, baseline vegetation monitoring of future planned physical works sites in Bush Arm.

If Kinbasket Reservoir reaches full pool in the upcoming summer or subsequent summers, additional field monitoring of the physical works at Bush Causeway and Valemount Peatland is anticipated.

1.2 Background

During the Columbia River Water Use (WUP) planning process, the WUP Consultative Committee (WUP CC) recognized the value of vegetation for improving aesthetic quality, controlling dust, protecting cultural heritage sites from erosion and human access, and enhancing littoral productivity and wildlife habitat (BC Hydro 2014). The WUP CC further recognized that the most significant opportunity for accomplishing these objectives lay in restoring and expanding riparian and wetland vegetation in the reservoir drawdown zone. In lieu of operational changes during the growing season, the WUP CC supported a reservoir-wide planting and enhancement program to maximize vegetation growth in the drawdown zone and to facilitate the development of long-term self-sustaining riparian vegetation (Adama 2015). CLBMON-09, initiated in 2008, is a long-term vegetation monitoring project that aims to assess the efficacy of physical works prescriptions, including revegetation (i.e., CLBWORKS-01), 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 four implementation years of CLBMON-09 focused on assessing the effectiveness of revegetation treatments applied in 2008, 2009, and 2011 (Keefer *et al*. 2010; 2011; Keefer Ecological Services Ltd. 2012; Figure 1-1). Various metrics associated with plant communities (e.g., diversity, biomass, cover) were measured bi-annually and compared between control and treatment plots to determine the overall effectiveness of revegetation at improving ground cover of various community types in the 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)?

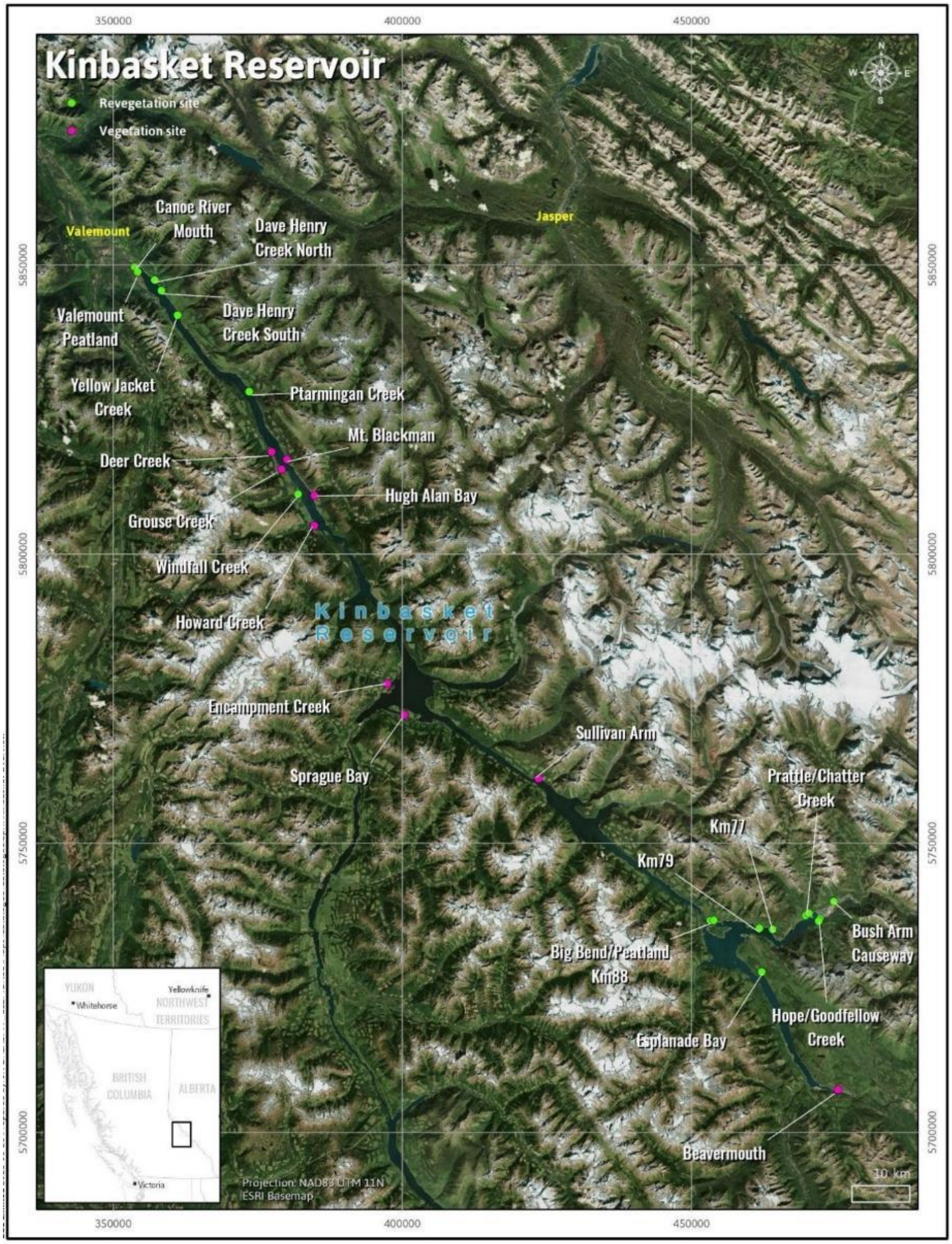

Figure 1-1: **Location of CLBWORKS-01 revegetation sites (green) in Kinbasket Reservoir.** Pink dots represent monitoring locations for existing vegetation under CLBMON-10.

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-01, 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?

Despite some initial high survivorship (e.g., one-year post-treatment), most monitored 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 many initial treatments had failed to establish successfully. Moreover, the randomly selected 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).

Hypothesis testing required that a random sampling design be employed during monitoring. However, the outcome of this approach was that some areas with relatively good revegetation performance were (through random chance) not monitored over the entire course of the study. One of the objectives for 2018 (Section 1.4: 2018 Monitoring Scope) was to reassess all or most of the original CLBWORKS-01 revegetation treatments (rather than just a random sample) to fill in some of the existing data gaps around overall revegetation performance 7 to 10 years post-treatment.

1.3 Recent Revegetation Approaches

Based on the early monitoring 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; Figure 1-2). 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-01 by the use of older (>1-year-old), larger nursery stock, planted over a larger area and at higher densities. 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 (Hawkes and Miller 2016). Further monitoring of other CLBWORKS-01 planting treatments judged to have nil or minimal prospects of long-term success was not carried out in 2015.

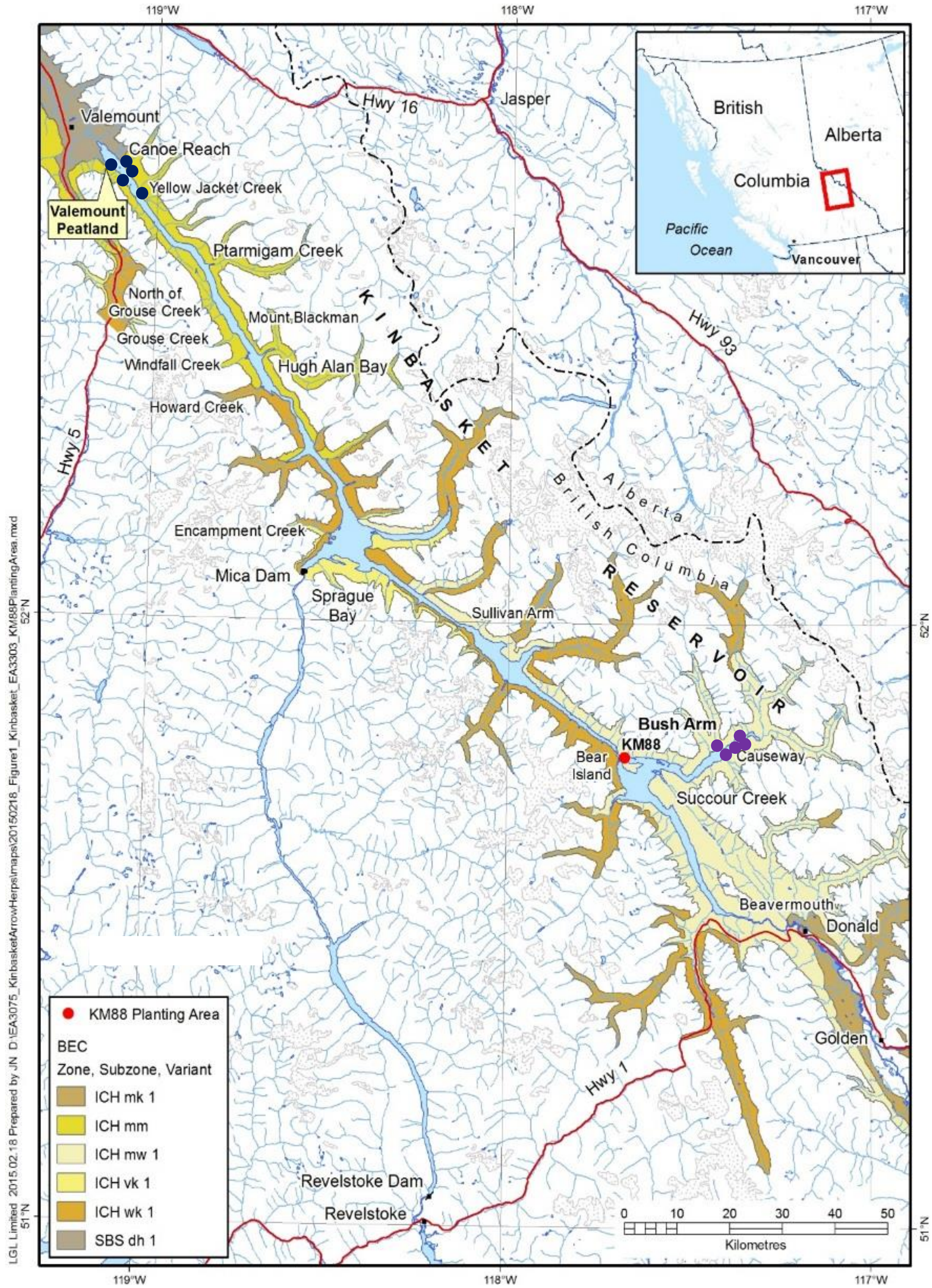

Figure 1-2: General location of the wood debris removal experimental treatments in Canoe Reach (blue dots), the Km 88 sedge planting area (red dot), and the Bush Arm physical works sites (purple dot).

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-016. Removal is generally accomplished through in-situ piling and burning. In 2014, an opportunity was identified (Addendum #3 to CLBWORKS-01 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 (Figure 1-2, Figure 1-3). 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 this sampling are summarized in Hawkes *et al*. (2016).

A BC Hydro technical review of revegetation efforts in Kinbasket and Arrow Lakes Reservoirs was held in December 2014 to look at past and new approaches to revegetation. Both CLBMON-09 and the associated monitoring project for Arrow Lakes (CLBMON-12) were discussed during this meeting as ecological context for the site-specific revegetation projects in both reservoirs. One of the new approaches put into place as an outcome of the technical review was the construction of wood debris structures (mounds and windrows) at Bush Arm as a pilot project under CLBWORKS-01 (Debris Mound and Wind Row Construction Pilot Program; BC Hydro 2015).

As part of this initiative, five sites in Bush Arm were identified as potential locations for mound and windrow construction (Hawkes 2016). The five sites were Bush Causeway (north and south ends), Goodfellow Creek, Hope Creek, and Chatter Creek (Figure 1-2, Figure 1-4). Pre-treatment baseline sampling occurred at each site in 2015. In the fall of 2015, the first pilot project was implemented at Bush Causeway. Locally available wood debris and substrate material (soil) were 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 could establish, and which could eventually provide added habitat value for wildlife. A total of seven mounds in two locations were constructed, along with windrows at one location. In addition, three previously wood-choked ponds were cleared of debris. Live stakes (black cottonwood and red-osier dogwood) were planted in the mounds, and locally salvaged sedge plugs were transplanted into suitable substrates at the base of some of the mounds (Hawkes 2016).

To protect wetland habitats and constructed mounds at the Bush Causeway North site, a 312 m long log-boom was installed in June 2016. The log-boom was designed to prevent free-floating wood debris from redepositing into the recently cleared ponds or impinging on the mounds during periods of high water (Hawkes 2017).

The areas treated in 2015 were evaluated in 2016 for erosion, live stake survival, and sedge transplant survival. Because reservoir levels remained below the elevation of the mounds in 2015 and 2016 (and again in 2017 and 2018), effects of reservoir inundation on the integrity of the mounds could not be assessed (Hawkes 2017).

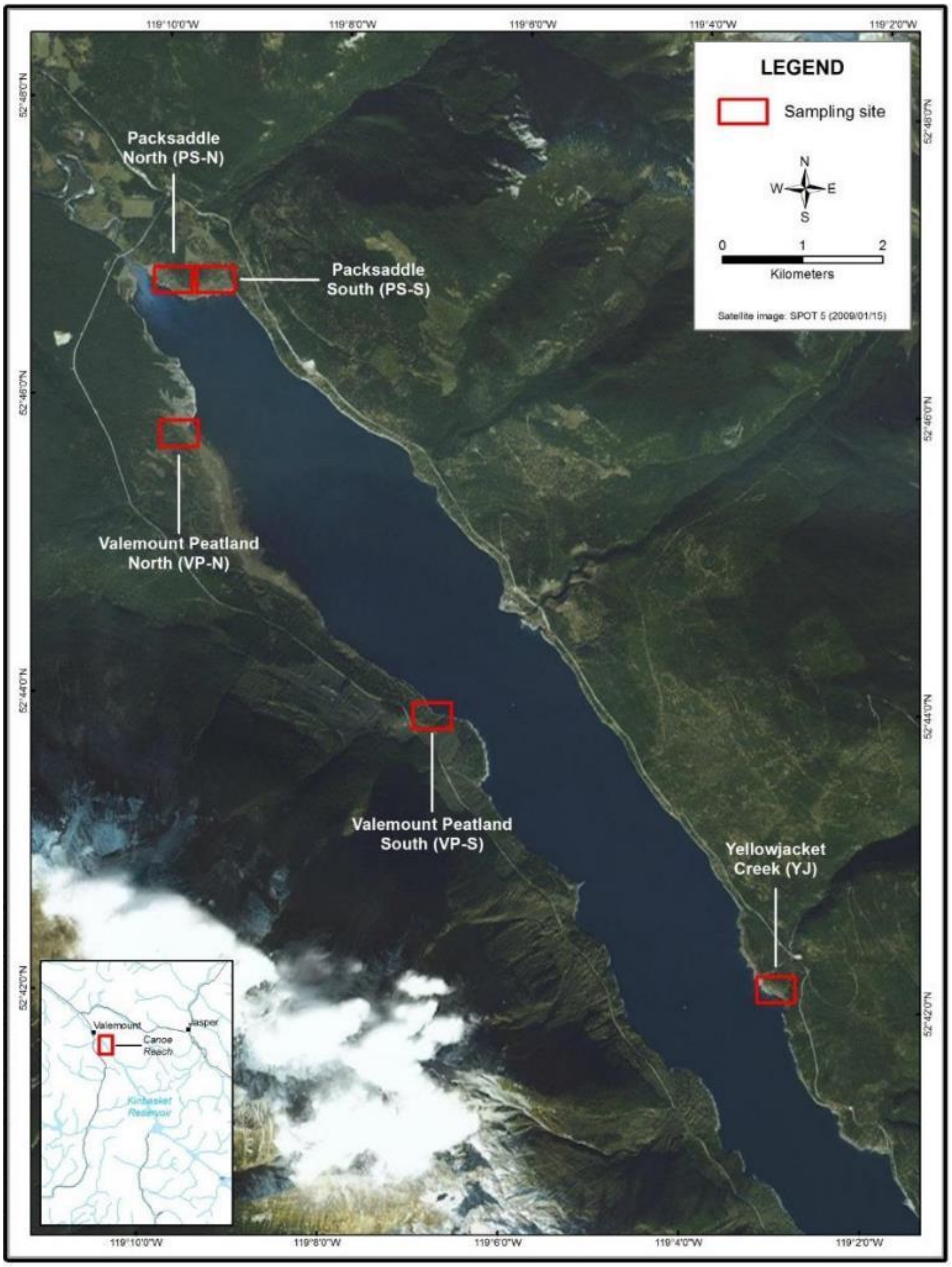

Figure 1-3: Location of wood debris removal sites in Canoe Reach, Kinbasket Reservoir, 2014.

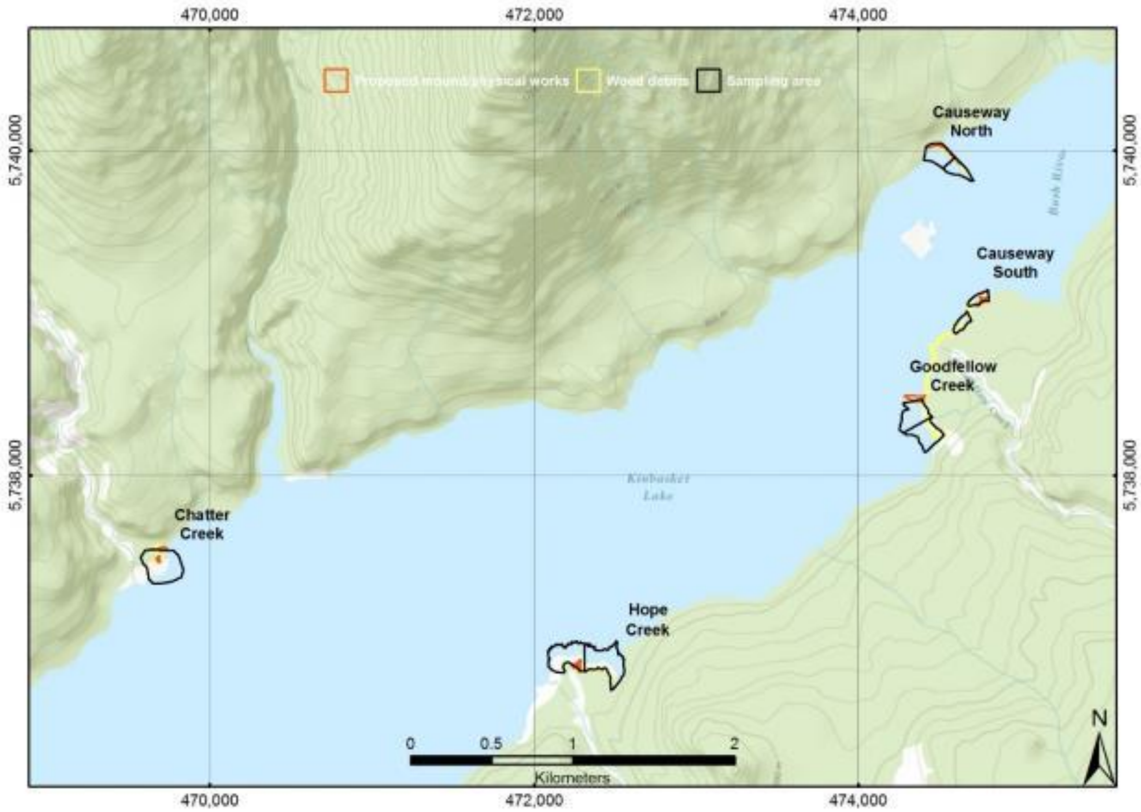

Figure 1-4: Location of proposed physical works locations in Bush Arm, Kinbasket Reservoir (from Hawkes 2016)

1.4 2018 Monitoring Scope

The Year 6 (2018) scope of work continued the 2016 monitoring work (Hawkes et al. 2017), the aim of which was to implement a revegetation monitoring study that will:

- monitor the response of existing vegetation communities to woody debris removal and the installation of debris exclusion booms (Canoe Reach and Bush Arm);
- monitor the establishment of vegetation (both natural and planted) on top of and adjacent to constructed debris ds and windrows at Bush Arm Causeway to:
    - (a) assess natural establishment of vegetation on and adjacent to the physical works;
    - (b) assess success of planted vegetation on the physical works;
    - (c) assess erosion and wave action effects on the physical works.
    - (d) assess woody debris deposition adjacent to physical works.
- collect baseline (pre-works) data on the status of existing vegetation communities adjacent to and under the proposed debris mounds and windrows locations at other Bush Arm sites prior to construction.
- monitor the effectiveness of the 2013 sedge plantings at Km 88 (Bush Arm);

In addition, a major objective established for 2018 was to visit all or most of the original CLBWORKS-01 revegetation treatments to fill data gaps around overall revegetation performance 7 to 10 years post-treatment. A similar retrospective assessment was made in 2017 for the Arrow Lakes Reservoir (CLBWORKS-2) revegetation treatments (Miller *et al.* 2018). That study revealed several instances of successful transplant establishment that previous random samples of the study area had failed to detect. Information from this assessment is also intended to help fill data gaps associated with CLBMON-35 (Arrow Lakes and Kinbasket Reservoirs Plant Response to Inundation; Hawkes et al. 2018). Fieldwork for this component entailed:

(a) enumerating transplant survivorship at each original CLBWORKS-01 site;

(b) describing the topo-edaphic site conditions at each CLBWORKS-01 site;

(c) collecting soil samples from a selection of successful and unsuccessful CLBWORKS-01 revegetation sites for future comparative soil nutrient analyses.

1.5 2019 Projected Monitoring Scope

In 2018, the elevation of Kinbasket Reservoir peaked on Aug. 20 at 747.25 m ASL, which was once again below the elevation of the physical works trials at Bush Causeway. This means that since construction occurred in 2015, there have been no opportunities yet to assess effects of erosion and wave action on the constructed mounds and windrows or to monitor the effectiveness of log-booms (here or at Valemount Peatland) at excluding woody debris. Vegetation responses to mound inundation also remain unknown. Consequently, BC Hydro has temporarily extended the CLBMON-09 project through 2019 to enable monitoring of the effects of reservoir operations on physical works at Bush Arm and Valemount Peatland should a full pool event occur within the next year.

If the reservoir fills in 2019, a research crew will mobilize immediately to assess the impacts of inundation, both during and following high water. Monitoring will be carried out through ground inspections and via remote sensing. For the latter, a drone will be used to obtain aerial photos, which will be compared to historical aerial data to determine how the size/shape of the mounds changes as a result of inundation. During the subsequent (2020) growing season, covers of plant species growing behind the log-boom exclosures at Bush Causeway and Valemount Peatland will be monitored within previously-established transects, and the short-term responses of mound/windrow vegetation (both planted and naturally establishing) will be visually assessed. Field sessions in both 2019 and 2020, if they occur, are anticipated to be relatively short.

The final CLBMON-09 report will be drafted later in 2019 and will include a more fulsome discussion of next steps regarding monitoring inundation effects on physical works. An upcoming revegetation technical review may also provide a forum for reviewing results to date and engaging in discussions around the preferred monitoring response to a single or multiple full pool event.

2.0 2018 Methods and Work Completed

Field data collection occurred over two sessions: 19-28 June and 13-19 July.

2.1 Wood Debris Removal, Constructed Mounds, Boom Exclosure, and Pre-Construction Sites

At the Canoe Reach and Bush Arm physical works sites, 172 previously established vegetation belt transects (Hawkes and Miller 2016) were relocated with GPS and sampled. Survey areas included pre-implementation sites at Bush Arm (Goodfellow Ck., Hope Ck., and Chatter Ck.), the two debris removal + log-boom exclosures at Bush Causeway and Valemount Peatland, and the constructed mounds at Bush Causeway. 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 vegetation cover estimates. For each quadrat, the % cover of each plant species was recorded, along with terrain texture. The prevailing texture was classed as rock, cobble, gravel, sand, fines, dead organics, wood, or water. The top three constituents of each quadrat were noted and ranked as primary, secondary, or tertiary (1-3). Sampling at each site was replicated among treated (cleared or cleared + log-boom) and control (reference) transects.

Monitoring of vegetation establishment (both planted and natural) was conducted for four of the constructed mounds at Bush Causeway. All species present, and their per cent covers, were recorded. Covers were estimated for three separate elevation strata (base, mid, and upper). The number and vigour of surviving live stakes on the four mounds was also recorded. The same set of topo-edaphic characteristics described below for the Km 88 sample plots (2.2) was recorded for five mounds (base, mid, and upper strata).

A brief visual assessment was made of the three cleared ponds at Bush Causeway. This included compiling a cursory list of aquatic macrophytes re-establishing in two of the ponds and recording photos of the recovering habitats.

2.2 2013 Sedge Treatments (Km 88)

In 2015, sampling of the three Km 88 sedge treatment units (Adama 2015; Figure 2-1) was conducted using randomly located 1-m^2 or 25-m^2 subplots. A total of 30 subplots (10 in each treatment unit) were sampled. The number of live sedge plants (Kellogg's and Columbia sedge) in each plot was recorded, together with plant height and vigour and the total number of reproductive (flowering) plants. The same vegetation cover and substrate information was recorded as described above for belt transects at Bush Arm/Canoe Reach. Surviving numbers were estimated by extrapolating live densities within the subplots to the entire treated area (Hawkes and Miller 2016).

In 2018, to increase count estimation accuracy, surviving plugs were enumerated within a single large (1000-m^2) polygon covering a large portion of each treated area. Three smaller (50-m^2) subplots were then established near the centre point of each polygon). At three of the subplots, soil was collected at rooting level from three representative locations within the subplot using a soil corer. The three soil subsamples from each subplot were then combined into a single sample for future lab nutrient analyses. For comparative purposes, soil samples were also collected from two sites in adjacent, non-treated vegetation (TU 4; Figure 2-1). One of these samples was intentionally situated in a vigorous vegetation patch having high covers of both sedge species; the other sample was taken from relatively unproductive microsite with minimal sedge cover.

Soil samples were later tested (in lab) for the following parameters: Calcium (mg/Lsoil dry); total, inorganic, and organic Carbon (% dry); Potassium (mg/Lsoil dry) Magnesium (mg/Lsoil dry); Sodium (mg/Lsoil dry); total Nitrogen (mg/Lsoil dry); organic matter (% dry); and soil particle size (texture).

At each 50-m^2 subplot, regardless of whether a soil collection was made, the following site information was recorded:

- Number and vigour of surviving sedge plugs (Kellogg's and Columbia sedge)
- Associated plant species covers
- Vegetation structural stage (sparse/pioneer, herb, low shrub, tall shrub)
- Aspect and slope
- General surface topography (straight, convex, concave)
- Microtopography (smooth, channelled, gullied, mounded, terraced)
- Primary water source (precipitation, stream flooding, stream sub-irrigation, surface seep)
- Soil moisture regime (xeric to hydric)
- Surface substrate (% rock, mineral soil, organics, wood, water)
- Rooting zone texture (fragmental, sandy, coarse-loamy, coarse-silty, fine-silty, fine-clayey, very-fine-clayey)
- Evidence of non-operational disturbance.

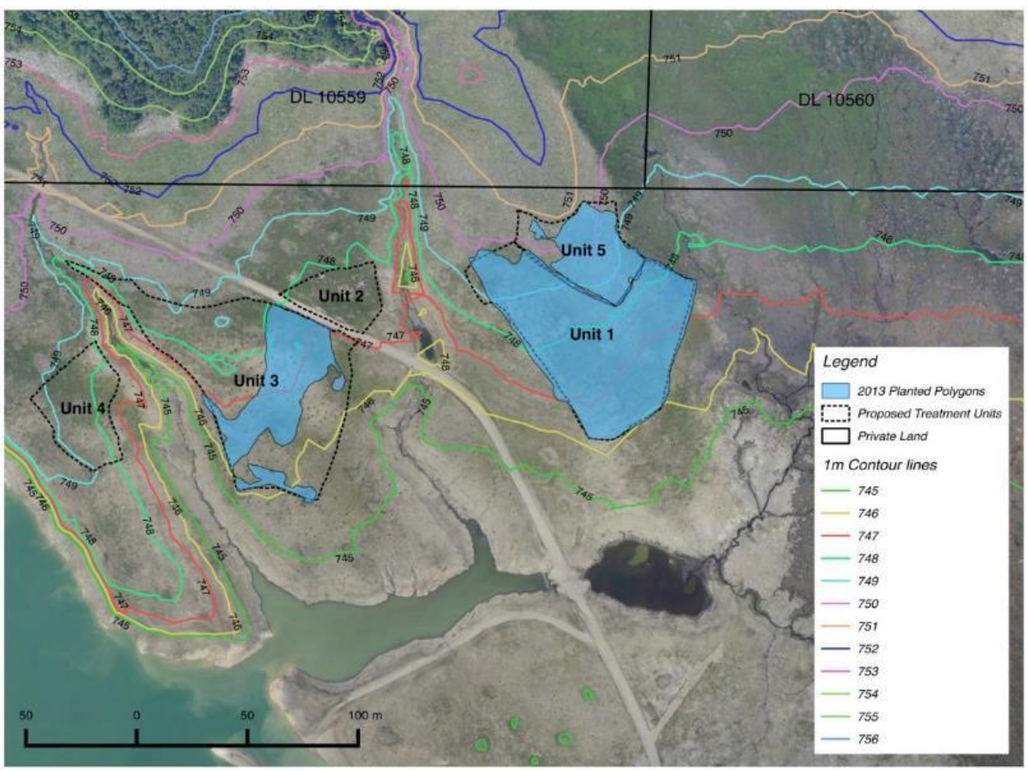

Figure 2-1: **Treatment unit (TU) boundaries showing areas planted with sedges in 2013, Kinbasket Reservoir (from Adama 2015)**

2.3 2008-2011 Revegetation Treatments

For this component, the objective in 2018 was to carry out as comprehensive a survey as logistically possible of the original CLBWORKS-01 revegetation polygons to assess transplant performance (survivorship and vigour) seven to 10-years post-treatment. The survey included some revegetation polygons that had not been previously monitored under the CLBMON-09 program. Assessments included the conducting of ground inspections to characterize site-specific vegetation and topo-edaphic conditions; and the collection of soil samples to gain a better understanding of potentially limiting site factors.

A total of 85 CLBWORKS-01 revegetation polygons were assessed in 2018, encompassing both Canoe Reach and Bush Arm. From west to east, general areas visited were: Canoe River Mouth, Valemount Peatland, Dave Henry Creek North, Dave Henry Creek South, Yellow Jacket Creek, Ptarmigan Creek, Windfall Creek, Km 88 Peatland, Km 79, Km 77, Prattle/Chatter Creeks, and Hope/Goodfellow Creeks.

The presence or absence of signs of successful revegetation was noted for each assessed polygon. For each polygon that exhibited successful establishment, a set of one to 10 50-m^2 sample plots was subjectively located within a representative area or areas of establishment. Polygon size and/or terrain heterogeneity was used to determine the number of plots sampled. For each sample plot, the number and vigour of surviving plugs and stakes were recorded, and site information pertaining to associated vegetation and topo-edaphic features was recorded as described above for Km 88 (2.2). For a selection of sample plots, a soil collection was made following the same procedure described above (2.2). For comparative purposes, some 50-m^2 plots were also established in adjacent microsites representing minimal or failed revegetation establishment, where the same site information was recorded. Paired soil samples were also collected from these poorly performing microsites for future soil nutrient comparisons with successful microsites.

For additional comparative purposes, 12 supplemental soil-sample plots were established within notably vigorous natural *Carex* patches at Canoe River Mouth, Yellow Jacket Creek, and Ptarmigan Creek.

A total of 165 50-m^2 plots were sampled in Canoe Reach and Bush Arm (including Km 88, above), from which a total of 69 soil samples were collected and submitted for lab nutrient analyses.

3.0 RESULTS

Here we report summary results only for the 2018 fieldwork. As per the project Work Order, detailed results and findings will be presented in the comprehensive synthesis report at the end of 2019, following one more year of (opportunistic) log-boom and constructed mound monitoring.

3.1 Bush Causeway Constructed Mounds, Boom Exclosure, and Woody Debris Removal

As of July 2018, a variety of plant species had colonized the constructed mounds at Bush Causeway (Figure 3-1). The lower fringes of the mounds (including the recovering mound construction footprints) supported the greatest array of establishing plants, with about 70 taxa recorded. Of these, 17 (~25%) were naturalized exotic species. The middle portions of mounds supported about 50 species, while the tops of mounds supported about 40 species (Table 3-1). Anecdotal observation indicated that individual mounds varied with respect to plant cover, with narrower mounds (windrows) tending to show sparser establishment than the more rounded mounds.

Most species occurring on mounds were ones occurring in the immediate drawdown zone area and presumably sprouted from the seed/rhizome bank contained in the original mound fill. In the case of willows (*Salix* spp.), some informal (non-enumerated) translocation of rootstock occurred through a combination of hand and excavator placement during soil transfer. Both herbaceous and woody species (e.g., willows) were present on all zones of the mounds; thus, the mound substrate mix (wood debris combined with mineral soil) appears to be generally supportive of different plant structural stages. However, the constructed habitats are situated at high elevation in the drawdown zone and have yet to experience reservoir inundation (due to the series of relatively low water years in Kinbasket that has followed mound construction). Consequently, the physical and vegetation responses of the mounds to seasonal inundation remain untested and unknown.

A total of 36 surviving, and 42 non-surviving, cottonwood stakes were counted within sample polygons on three constructed mounds (Figure 3-1), for an estimated stake survival rate (to date) of 46%.

The three Bush Causeway ponds that were cleaned of wood debris and subsequently protected behind a log-boom placement are exhibiting signs of vigorous regrowth with respect to both riparian and aquatic macrophyte vegetation. Wetland-associated genera observed in or along the edges of ponds in 2018 included *Carex*, *Potamogeton*, *Hippuris*, *Sparganium*, *Myriophyllum*, *Alisma*, *Equisetum*, and *Persicaria* (Figure 3-2Figure 3-2). As in the case of the mounds, the log-boom has not yet been exposed to a full-scale inundation event; therefore, there has been no opportunity yet to assess its long-term effectiveness at excluding wood debris from reaccumulating in the upstream ponds. Similarly, the biophysical responses of the ponds to seasonal inundation remain untested and unknown.

Figure 3-1. **Constructed mounds, Bush Causeway (north site), illustrating current state of establishing planted and natural vegetation.** Leaf-bearing live stakes are visible in the top left and bottom right panels. Photographed July 2018.

Table 3-1. Plant species recorded on constructed mounds and adjacent mound footprints at Bush Causeway in July 2018. Species were recorded for three loosely-defined elevation bands (bottom, middle, and upper). Species lists pooled across mounds. Exotic species are indicated by *.

Position on constructed mound (elevation band)		
Bottom	Middle	Upper
*Agrostis gigantea**	*Agrostis gigantea**	*Agrostis gigantea**
Agrostis scabra	*Agrostis scabra*	*Agrostis scabra*
Anaphalis margaritacea	*Anaphalis margaritacea*	*Anaphalis margaritacea*
Betula papyrifera	*Calamagrostis canadensis*	*Calamagrostis canadensis*
Brassicaceae	*Calamagrostis stricta*	*Calamagrostis stricta*
Calamagrostis canadensis	*Carex flava*	*Carex aquatilis*
Calamagrostis stricta	*Carex kelloggii*	*Carex bebbiana*
Carex aquatilis	*Carex lasiocarpa*	*Carex kelloggii*
Carex aurea	*Cirsium vulgare*	*Carex lasiocarpa*
Carex bebbiana	*Comarum palustre*	*Cirsium vulgare**
Carex flava	*Cornus stolonifera*	*Cornus stolonifera*
Carex interior	*Danthonia spicata*	*Danthonia spicata*
Carex lasiocarpa	*Deschampsia cespitosa*	*Deschampsia cespitosa*
Carex saxatilis	*Dryas drummondii*	*Dichanthelium acuminatum*
Carex utriculata	*Elymus repens**	*Elymus repens**
Chamerion angustifolium	*Epilobium ciliatum*	*Epilobium latifolium*
*Cirsium vulgare**	*Equisetum arvense*	*Equisetum arvense*
Comarum palustre	*Equisetum variegatum*	*Erigeron philadelphicus*
Cornus stolonifera	*Erigeron philadelphicus*	*Erucastrum gallicum**
Danthonia spicata	*Erucastrum gallicum**	*Fragaria virginiana*
Deschampsia cespitosa	*Fragaria virginiana*	*Glyceria striata*
Dryas drummondii	*Hierochloe hirta*	*Leucanthemum vulgare**
Elymus glaucus	*Leucanthemum vulgare**	*Lobelia kalmii*
*Elymus repens**	*Lysimachia thyrsiflora*	*Lysimachia thyrsiflora*
Epilobium latifolium	*Medicago lupulina**	*Mentha arvensis*
Equisetum arvense	*Mentha arvensis*	*Packera plattensis*
Equisetum variegatum	*Packera plattensis*	*Phalaris arundinacea**
Erigeron philadelphicus	*Phalaris arundinacea**	*Poa compressa**
*Erucastrum gallicum**	*Poa palustris*	*Poa palustris*
Fragaria virginiana	*Poa pratensis*	*Poa pratensis*
*Galeopsis tetrahit**	*Poaceae*	*Populus balsamifera* ssp. *trichocarpa*
Glyceria striata	*Populus balsamifera ssp.*	*Potentilla norvegica**
Lamium sp.	*Potentilla anserina*	*Rosa acicularis*
*Leucanthemum vulgare**	*Potentilla norvegica**	*Rubus idaeus*
Lobelia kalmii	*Primula mistassinica*	*Salix bebbiana*
Lysimachia thyrsiflora	*Rhinanthus minor*	*Salix brachycarpa*
*Medicago lupulina**	*Rosa acicularis*	*Salix lucida ssp.lasiandra*
Mentha arvensis	*Rubus arcticus*	*Sisyrinchium montanum*

Position on constructed mound (elevation band)		
Bottom	Middle	Upper
Packera plattensis	*Rubus idaeus*	*Symphyotrichum ciliolatum*
Parnassia parviflora	*Rubus parviflorus*	*Taraxacum officinale**
Persicaria amphibia	*Salix brachycarpa*	*Trifolium pratense**
*Phalaris arundinacea**	*Salix farriae*	*Verbascum thapsus**
*Plantago major**	*Salix lucida* ssp.*lasiandra*	
Platanthera stricta	*Salix planifolia*	
*Poa compressa**	*Salix scouleriana*	
Poa palustris	*Scutellaria galericulata*	
Poa pratensis	*Shepherdia canadensis*	
Populus balsamifera ssp. *trichocarpa*	*Solidago lepida*	
Potentilla anserina	*Symphyotrichum ciliolatum*	
*Potentilla norvegica**	*Taraxacum officinale**	
*Prunella vulgaris**	*Trifolium hybridum**	
Ranunculus sceleratus	*Trifolium pratense**	
Rhinanthus minor	*Verbascum thapsus**	
Rosa acicularis	*Viola sp.*	
Rubus idaeus		
Rubus parviflorus		
Rubus sp.		
Salix brachycarpa		
Salix farriae		
Salix lucida ssp.lasiandra		
Salix pedicellaris		
Salix scouleriana		
Scutellaria galericulata		
Sisyrinchium montanum		
Sium suave		
Solidago lepida		
Symphyotrichum ciliolatum		
*Taraxacum officinale**		
*Trifolium aureum**		
*Trifolium hybridum**		
*Trifolium pratense**		
*Verbascum thapsus**		

Figure 3-2. **Regenerating wetland vegetation in ponds cleaned of wood debris in 2015 at Bush Causeway.** Clockwise from top left: overview of cleaned pond with log-boom (in background), *Carex utriculata*, *Alisma gramineum*, *Carex aquatilis*, *Sparganium* sp. Photographed July 2018.

3.2 Valemount Peatland Boom Exclosure and Woody Debris Removal

A total of 18 vegetation cover transects (nine treatment and nine control) were sampled at the Valemount Peatland woody debris removal and log-boom exclosure site in 2018. Sixty-five vascular plant species were recorded in the log-boom protection area, including 34 forb and pteridophyte species, 23 graminoid species, and seven woody species. These numbers represent a substantial increase (>100%) in species richness compared to the richness recorded just after the physical works were implemented in 2014 (Figure 3-3). Species richness also increased since 2016 for all species groups, though at a slower pace than in the years immediately following installation of the log-boom. In contrast to the trial at Bush Causeway, the reservoir maximum was high enough in 2016 to briefly inundate the Valemount Peatland log-boom. However, the log boom has not yet been tested by high reservoir levels and it is currently unknown how effective the exclosure will be at protecting the regenerating vegetation at this site from heavy wood deposition during full pool events. Future analyses will compare trends in richness, diversity, cover, and composition over time between the treated (log-boom) site and an adjacent, unprotected control site.

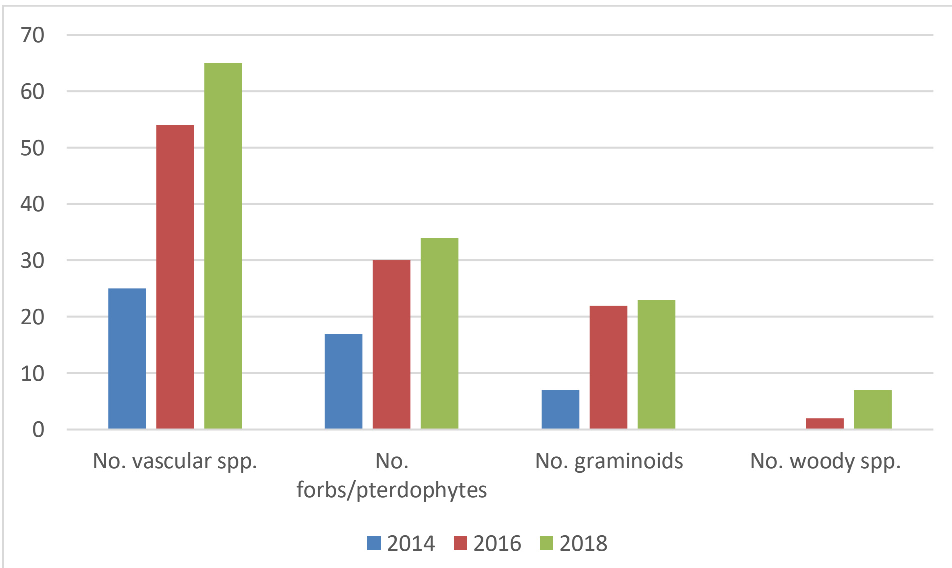

Figure 3-3. Changes in vascular plant species richness at Valemount Peatland woody debris removal and log-boom exclosure site between 2014 (two months post-treatment) and 2018.

3.3 2013 Sedge Treatments (Km 88)

Five years following planting, the sedge seedling plugs at Km 88 (Figure 3-4) continue to perform well both in terms of survivorship and reproductive development. In sample polygons at each of the three treatment units (TU-1, TU-3, and TU-5), estimated surviving plug densities (per ha) were approximately 7,190, 9,310, and 8,440 respectively. These establishment rates are slightly below the targeted densities of 10,000-15,000 plugs per ha for TU-1 and TU-3, and in line with the target density of 5,000-10,000 per ha for TU-5 (Adama 2015). Based on the reported initial stocking densities, this places the estimated survival rate for all TUs at ~35% after five years. By comparison, survivorship at several other Kinbasket sites was nil or minimal after a similar period (Hawkes et al. 2018), making this one of the more successful revegetation initiatives under CLBWORKS-01. Sedge vigour was rated “good” overall for TU-1 and TU-3, and “moderate to good” for TU-5.

Figure 3-4: Sedge planting treatment at Km 88, Bush Arm. Planted plugs of Kellogg’s sedge are visible mixed with an existing ground cover of annual forbs, primarily Scouler’s popcorn flower (*Plagiobothrys scouleri*). Photographed 28 June 2018.

Table 3-2: Estimated density of sedge plugs per hectare at time of planting in 2013, estimated surviving densities in 2018, and estimated per cent survival five years after planting. 2013 data from Adama (2015).

Treatment unit	2013 stocking density/ha	2015 surviving plugs/ha	2018 surviving plugs/ha	Estimated per cent survival
TU-1	25,454 ± 4,345	29,000 ± 8,834	7,190	28%
TU-3	25,000 ± 4,234	15,000 ± 6832	9,310	37%
TU-5	20,714 ± 7,300	9,000 ± 6379	8,440	41%
All	23,738 ± 1,952	17,666 ± 4,657	8,313	35%

The estimated surviving plug densities were lower than in 2015, when estimates ranged from ~17,666 to ~29,000 (Hawkes and Miller 2016; Table 3-2). Since there were no obvious signs of recent die-off of sedge plugs, this discrepancy is most likely an artifact of differing sampling approaches. In 2015, sampling was conducted on sets of randomly located 1-m^2 and 50-m^2 subplots within each TU, whereas in 2018, plugs were enumerated within a single large (1000-m^2) polygon established at a representative (non-random) location within each TU. Despite the non-random nature of the 2018 counts, they encompassed a large fraction of each TU and are likely a more accurate representation of true densities.

3.4 2008-2011 Revegetation Treatments

Our more extensive 2018 inventory of original CLBWORKS-01 revegetation treatments yielded informative new data on treatment polygons, some of which had not been previously assessed under the CLBMON-09 random sampling design. Most notably, we recorded several instances of vigorous, surviving plug transplants at locations not previously known to have had successful establishment (Figure 3-5,Figure 3-6). This includes treatments in both Canoe Reach (e.g., Yellow Jacket, Ptarmigan Creek) and Bush Arm (e.g., Chatter Creek, Km 77, Km 79, Km 88 peatland). Surviving plugs were also recorded at Canoe River Mouth, Windfall Creek, Prattle Creek, and Hope Creek, though at lower densities and/or lower vigour relative to the other locations. Kellogg's sedge was the most widely recorded transplanted graminoid species, but successful instances of Columbia sedge (e.g., Km 77), wool-grass (e.g., Km 88 peatland), water sedge (e.g., Hope Creek), and bluejoint reedgrass (e.g., Ptarmigan Creek, Yellow Jacket Creek) were also observed (Table 3-3).

These new (and unexpected) observations of treatment survivorship, while generally highly localized, nevertheless suggest that the rate of revegetation establishment in Kinbasket has been somewhat underestimated previously (Hawkes et al. 2013, 2018). Importantly, these newly-obtained data can be used to inform models of species-specific responses to reservoir operations in Kinbasket and Arrow Lakes that are currently under development as part of CLBMON-35 (Hawkes et al. 2018).

Figure 3-7 shows a comparison of soil parameters (average texture and nutrient content values) between sample plots with at least some successful revegetation establishment and those where revegetation treatments failed to take hold. Successful microsites tended to have slightly higher silt and clay content, and slightly lower sand and gravel content, than unsuccessful microsite, implying that soil water holding capacity may be a limiting factor influencing plug establishment. Successful microsites also had higher average volumes of Potassium (K), Magnesium (Mg), and Sodium (Na), suggesting that these elements may be nutritionally limiting. In contrast, unsuccessful microsites tended to have higher average total Carbon (C) and higher Nitrogen (N) content, implying that these elements are not limiting. Note that this very preliminary comparison does not distinguish among different revegetation species nor account for sample variation or differing establishment densities. It also does not consider other potentially influential topo-edaphic factors such as slope, aspect, water source, and soil moisture regime. A more comprehensive analysis of soil nutrient and other site limiting factors will be undertaken as part of the comprehensive report.

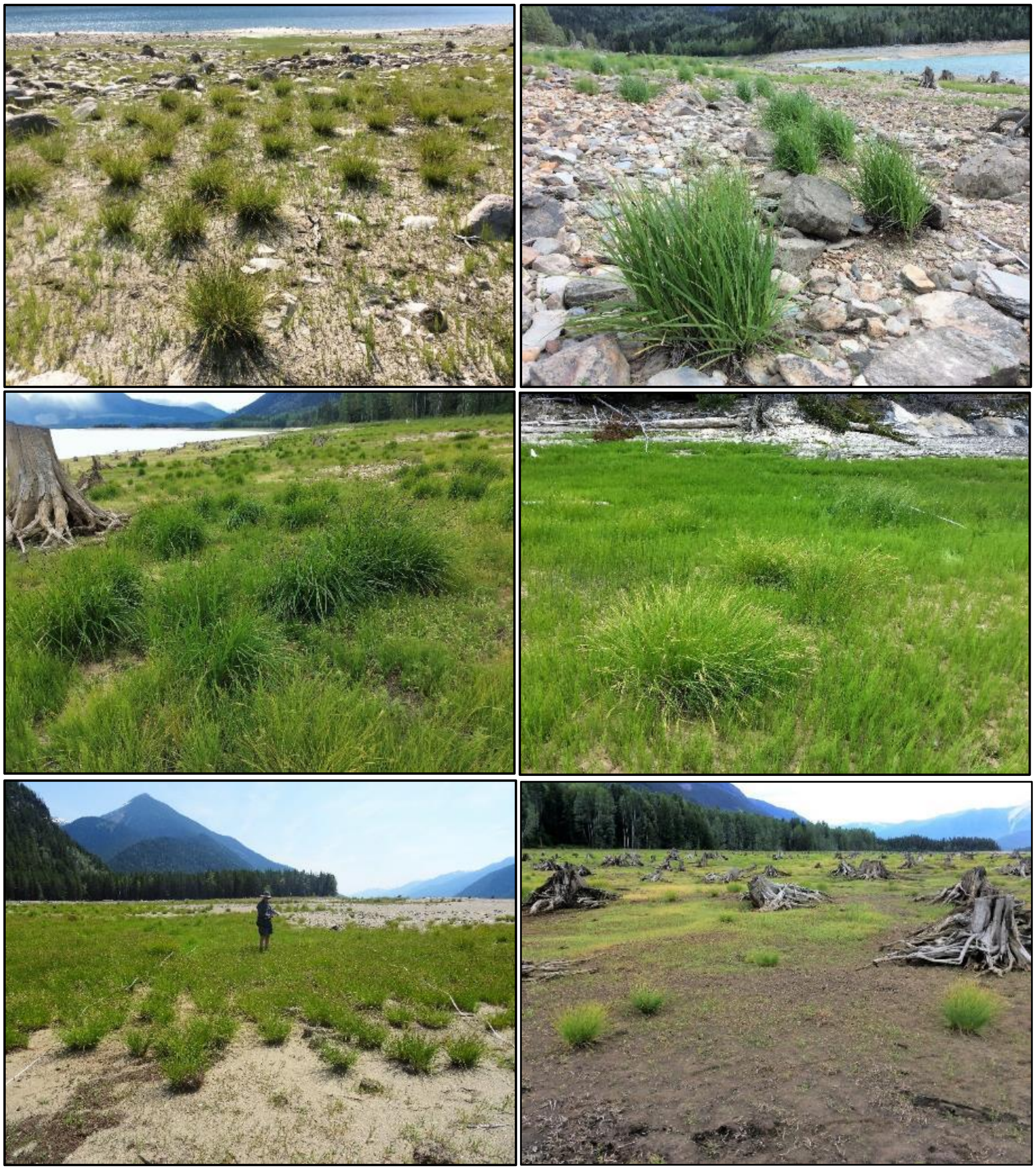

Figure 3-5. **Examples of sedge establishment associated with the CLBWORKS-01 (2008-2011) revegetation treatments.** Clockwise from top left: Kellogg's sedge, Yellow Jacket Creek; Columbia sedge, Km 77; Kellogg's sedge, Chatter Creek; Kellogg's sedge, Km 88 peatland; Kellogg's sedge, Ptarmigan Creek; Kellogg's sedge, Km 77. Photographed June 2018.

Figure 3-6. **Examples of sedge establishment associated with the CLBWORKS-01 (2008-2011) revegetation treatments.** Clockwise from top left: water sedge, Hope Creek; Kellogg's sedge, Hope Creek; Kellogg's sedge, Km 79; Columbia sedge, Km 79; Kellogg's sedge, Ptarmigan Creek; Kellogg's sedge, Yellow Jacket Creek. Photographed June 2018.

Table 3-3. **Revegetation treatments exhibiting survivorship at sites surveyed in 2018, listed by CLBWORKS-01 polygon (2008-2011) or MC unit.** MC numbers correspond to the original treatment units defined by Moody and Carr (2005) in the Columbia Water Use Plan (BC Hydro 2005).

Location	CLBWORKS-01 Polygon#/MC#	Revegetation Species Observed	Highest Recorded Density (50-m^2 plot)	Highest Recorded Vigour
Canoe River Mouth	67	Kellogg's sedge	9	3
Canoe River Mouth	80	speckled alder	3	3
Chatter Creek	85	Kellogg's sedge	62	3
Dave Henry South	30	Kellogg's sedge	2	2
Dave Henry South	85	Columbia sedge	1	2
Goodfellow Ck.	88I	black cottonwood	2	2
Hope Ck.	8, 26A, 26C, 31, 34A, 35B,	Kellogg's sedge	40	3
Hope Ck.	23, 26A, 34A, 34C	water sedge	16	2
Hope Ck.	35B	wool-grass	60	2
Hope Ck.	87C	red-osier dogwood	2	4
Hope Ck.	87C	black cottonwood	14	2
Km 77	84	Kellogg's sedge	45	3
Km 77	84	Columbia sedge	20	4
Km 79	83F, 83G	Kellogg's sedge	50	3
Km 79	83G	Columbia sedge	1	3
Km 79	83F	black cottonwood	27	3
Km 88 (peatland)	2, 3, 32D, 32E	Kellogg's sedge	12	3
Km 88 (peatland)	2	Columbia sedge	7	4
Km 88 (peatland)	2, 3, 32D, 32E	wool-grass	7	4
Km 88 (peatland)	32E	water sedge	1	2
Prattle Ck.	86	Kellogg's sedge	10	2
Ptarmigan Ck.	11, 13	Kellogg's sedge	50	4
Ptarmigan Ck.	11, 13	bluejoint reedgrass	6	3
Ptarmigan Ck.	12	water sedge	2	3
Ptarmigan Ck.	13	Columbia sedge	3	2
Windfall Ck.	7	Kellogg's sedge	4	1
Windfall Ck.	6	bluejoint reedgrass	1	2
Yellow Jacket Ck.	18, 19	Kellogg's sedge	60	4
Yellow Jacket Ck.	19, 21	Columbia sedge	2	4
Yellow Jacket Ck.	18	bluejoint reedgrass	3	4

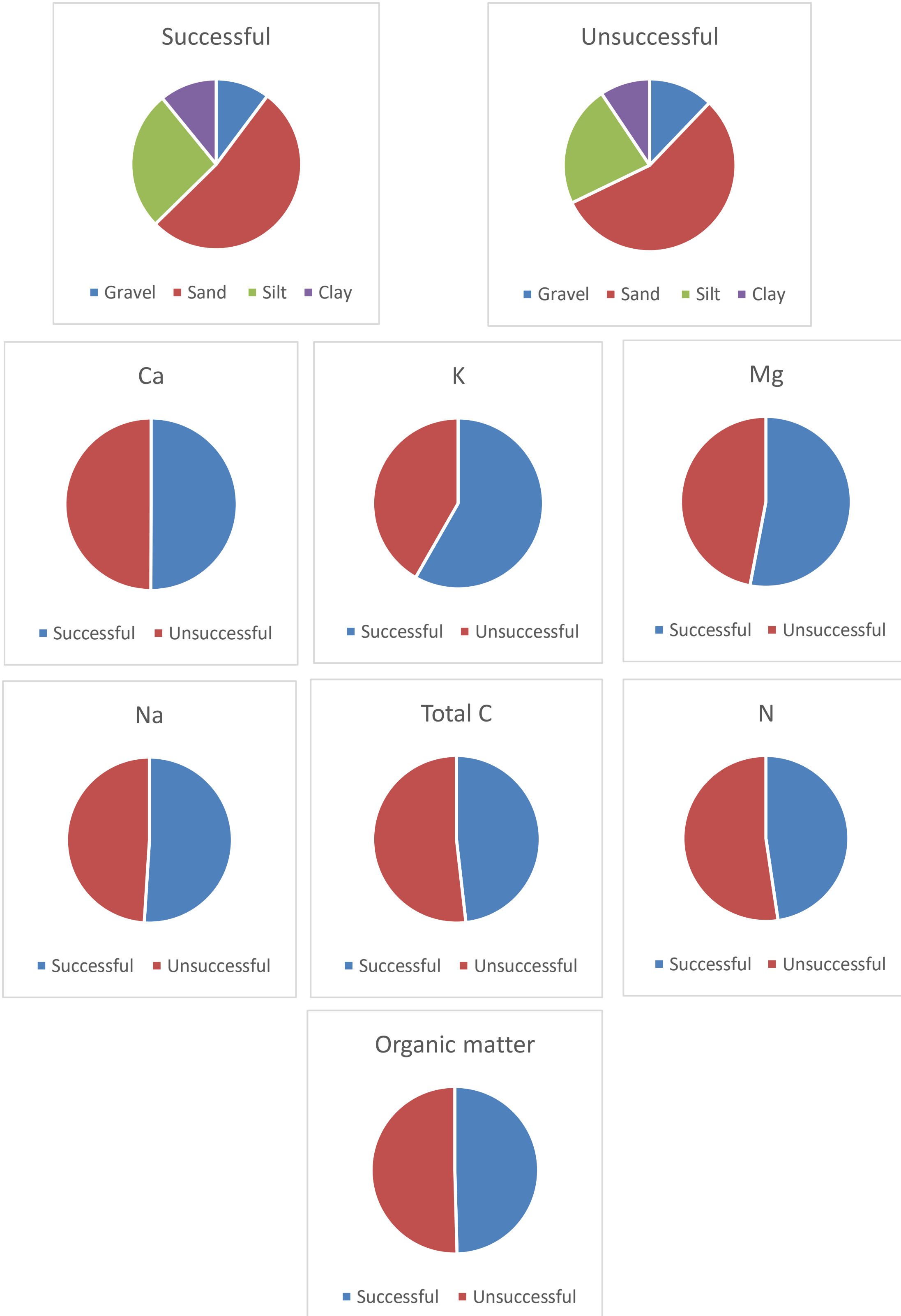

Figure 3-7. Preliminary comparison of soil parameters (average texture and nutrient content) between microsites supporting some successful revegetation establishment in 2018, and microsites with no apparent surviving revegetation.

4.0 Summary

In 2018, the CLBMON-09 field program had two primary foci: (i) monitoring recent (post-2012) physical works projects undertaken to enhance vegetation at Bush Causeway, Km 88, and Valemount Peatland; and (ii) conducting a comprehensive survey of original (2008-2011) CLBWORKS-01 revegetation treatments to fill in existing data gaps around revegetation survivorship/establishment and the topo-edaphic site conditions prevailing at the different treatment sites. As part of the latter assessments, soil samples were collected from microsites representing revegetation successes and failures; these samples will be used in subsequent comparative nutrient analyses aimed at further identifying potential site-limiting factors.

At the Bush Causeway, artificial mounds constructed in 2015 out of local wood debris and mineral soil are currently showing evidence of successful plant colonization (both natural and via planted live stakes), with over 70 species recorded in 2018. Adjacent wood-choked ponds that were cleaned of wood debris during mound construction are also showing indications of vegetative recovery, with various sedge species as well aquatic macrophyte genera (e.g., *Sparganium*, *Persicaria*, *Potamogeton*, *Alisma*) being observed to have established in or adjacent the ponds.

At Valemount Peatland, vascular plant species richness behind the log-boom exclosure has increased steadily since 2014, indicating that the exclosure continues to be effective at protecting the naturally occurring vegetation at this site from the negative impacts of heavy woody debris deposition.

At Km 88, the 2013 sedge plug treatments continue to perform well both in terms of survivorship and reproductive development. 2018 establishment estimates were slightly below the targeted densities of 10,000-15,000 plugs per ha for TU-1 and TU-3, and in line with the target density of 5,000-10,000 per ha for TU-5. Estimated per cent survival was around 35% for all TUs. Sedge vigour was rated "good" overall for TU-1 and TU-3, and "moderate to good" for TU-5.

During our extensive survey of original CLBWORKS-01 revegetation polygons, we recorded several instances of vigorous, surviving plug transplants at locations not previously known to have had successful establishment. This includes treatments in both Canoe Reach (e.g., Yellow Jacket, Ptarmigan Creek) and Bush Arm (e.g., Chatter Creek, Km 77, Km 79, Km 88 peatland). A few surviving plugs were also recorded at Canoe River Mouth, Windfall Creek, Prattle Creek, and Hope Creek. These new (and unexpected) observations of treatment survivorship, while generally highly localized, nevertheless suggest that the rate of revegetation establishment in Kinbasket has been somewhat underestimated previously (Hawkes et al. 2013, 2018). These newly-obtained data will be used to inform models of species-specific responses to site conditions and reservoir operations in Kinbasket and Arrow Lakes that are currently under development as part of CLBMON-35 (Hawkes et al. 2018).

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