Columbia River Project Water Use Plan

Kinbasket and Arrow Reservoir Revegetation Management Plan

Kinbasket Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

Implementation Year 11

Reference: CLBMON-9

2021 Post-Surcharge Survey of Vegetation Monitored Under CLBMON-9: Yearly Report

Study Period: 2021

LGL Limited environmental research associates, Sidney, BC

Contact: Virgil Hawkes (vhawkes@lgl.com)

May 25,2022

Mike Miller
9768 Second Street
Sidney, BC CANADA V8L 3Y8
Tel: (250) 656-0127 Fax: (250) 655-4761 www.lgl.com

25 May 2022

Mark Sherrington
Natural Resource Specialist, Water License Requirements
BC Hydro
6911 Southpoint Drive, 11th Floor
Burnaby, BC V3N 4X8

Re: 2021 Post-Surcharge Survey of Vegetation Monitored Under CLBMON-9: Summary Report

Dear Mr. Sherrington,

This memo summarizes the fieldwork that LGL Limited undertook in 2021 to assess post-inundation conditions at various physical works sites in Bush Arm and Canoe Reach (Kinbasket Reservoir). The primary objective of surveys was to carry out a follow-up assessment of the status of vegetation growing within log-boom exclosures (Bush Causeway and Valemount Peatland) and on constructed mounds and windrows (Bush Causeway) following the high-water (surcharge) event that took place in August and September of 2020 (Figure 1). Due to the sequence of low-water years that has prevailed in Kinbasket Reservoir since 2015, the 2020 surcharge event was expected to provide the first effective 'test' by the reservoir of these constructed features and woody debris removal treatments since their installation in 2014 (Canoe Reach log boom), 2015 (Bush Causeway log-boom, mounds, and windrows), and 2018 (Pond 12 [Canoe Reach] woody debris removal) (Miller and Hawkes 2020). The 2021 fieldwork also included a site visit to Bear Island (Bush Arm) to reassess two recent (2020) woody debris removal treatments initially assessed in 2020; and establishment of baseline transects at several new (2021) woody debris removal treatment locations in Canoe Reach (Figure 2-Figure 4).

Site visits were carried out by Mike Miller and Riley Waites and occurred between 19 June and 27 June, 2021. The completed 2021 sampling, and our summary findings, are described on a site-by-site basis below.

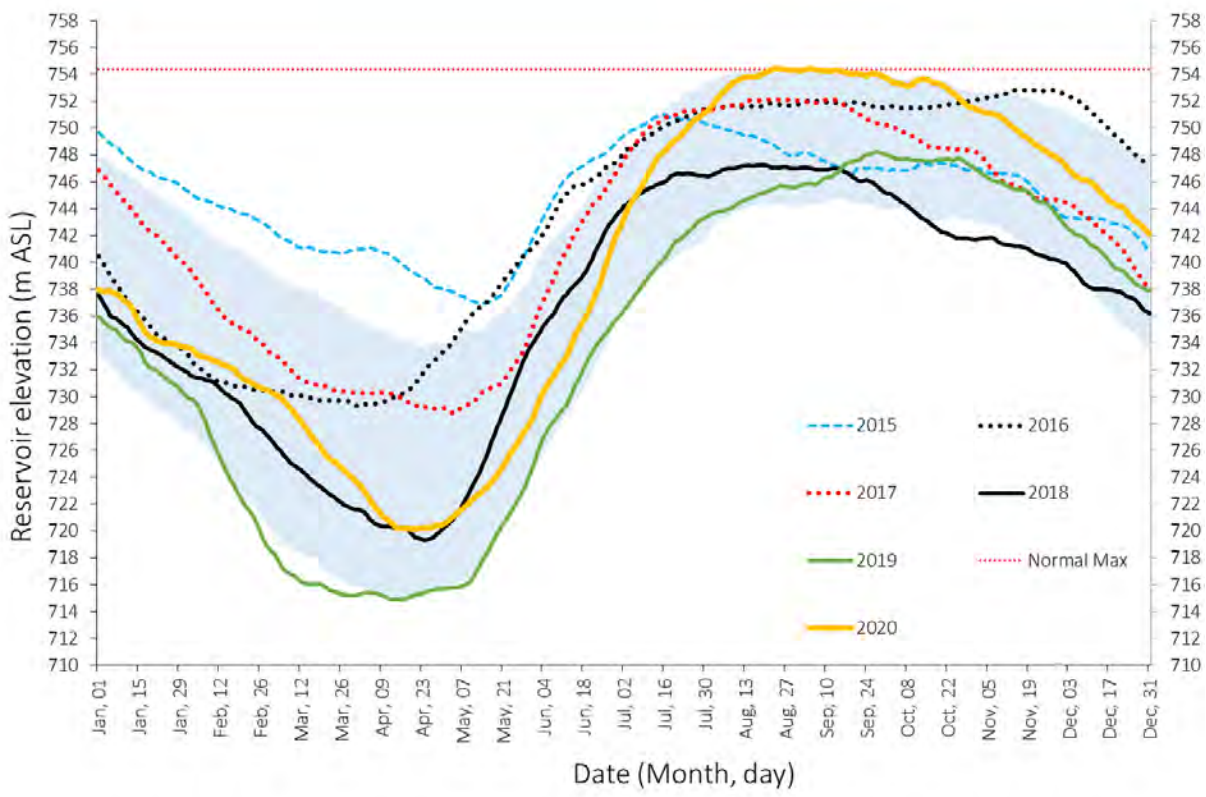

Figure 1. Hydrograph for Kinbasket Reservoir, 2015-2020, with 2020 surcharge levels indicated (period exceeding the normal operating maximum, shown by the horizontal dotted line).

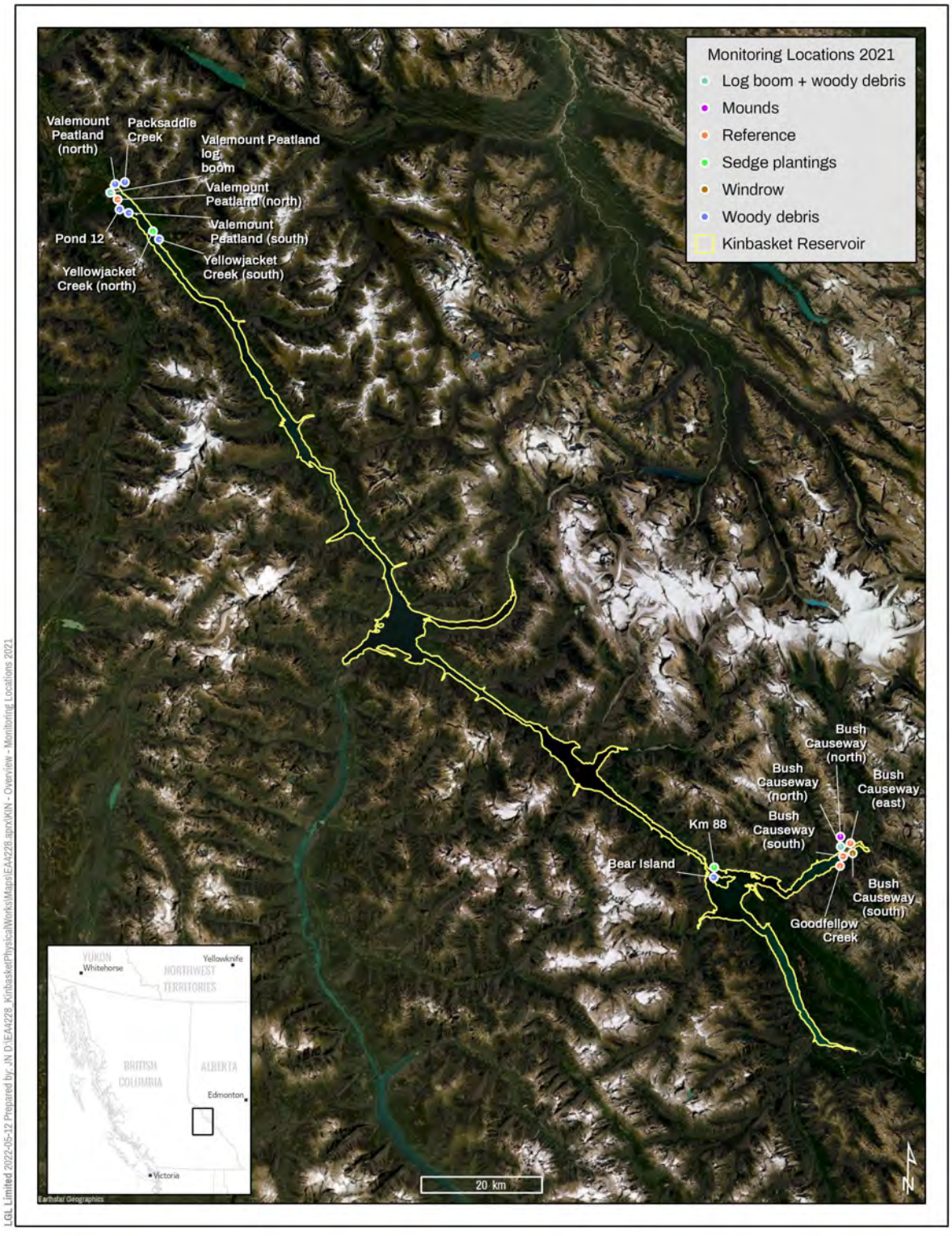

Figure 2. Reservoir-wide overview of 2021 monitoring locations.

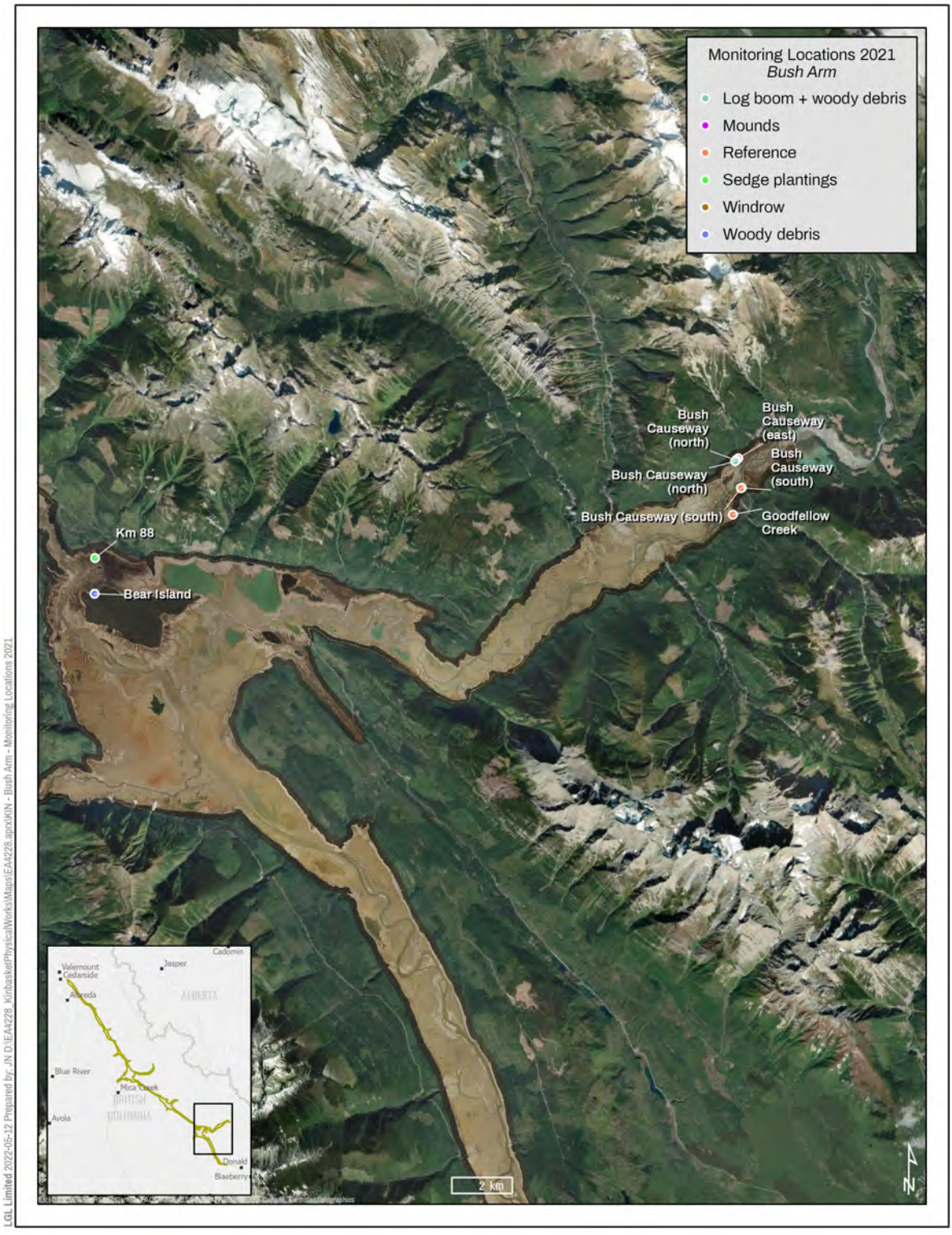

Figure 3. Bush arm monitoring locations.

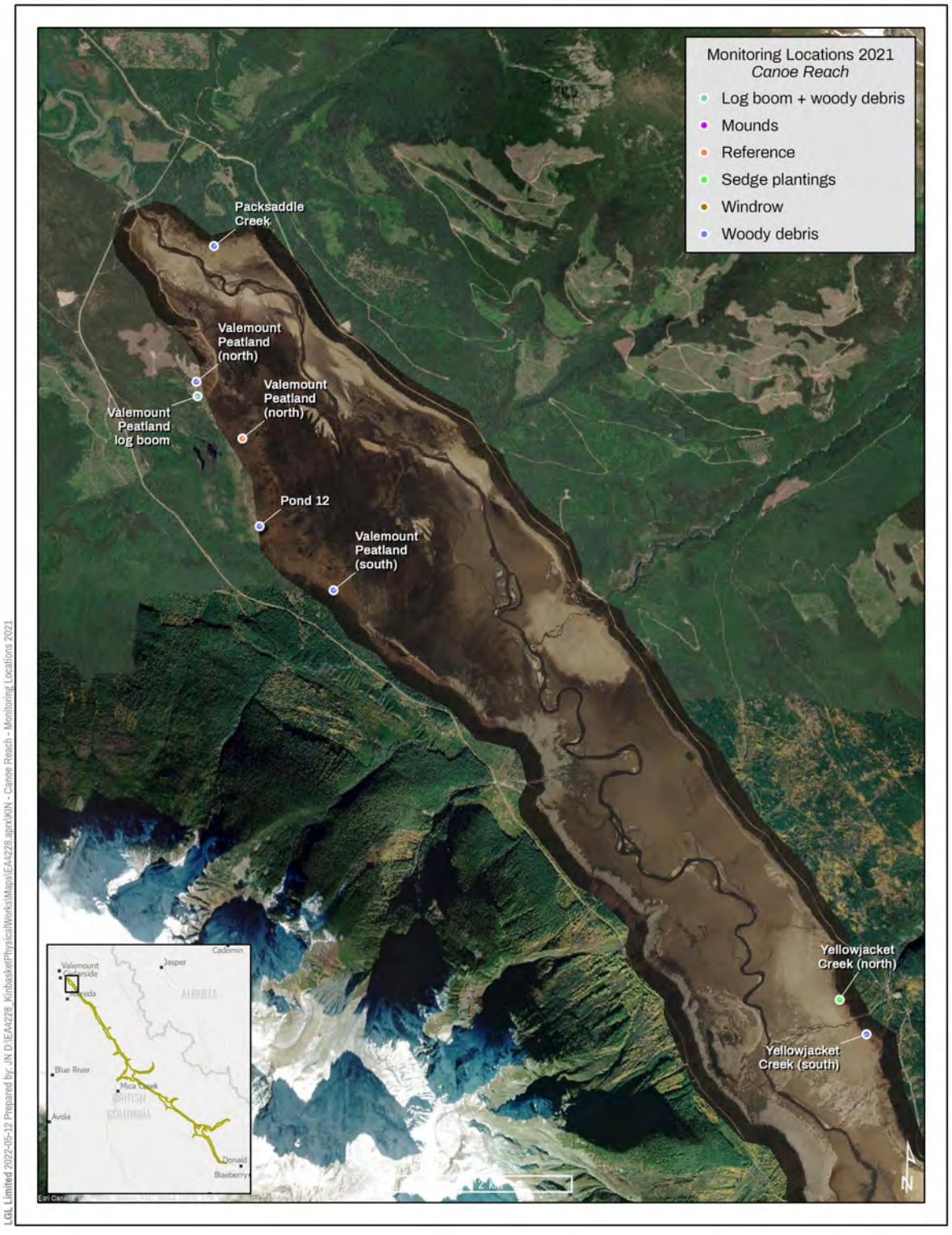

Figure 4. Canoe Reach monitoring locations.

Methods

Bush Causeway (north)

The following assessments were conducted at Bush Causeway (north) (UTM: 11U 474556 5739972):

- Vegetation covers (by species) were recorded for each of the five constructed mounds. In contrast to prior data collection, when sampling was stratified across three elevation bands or sections of the mound (lower, middle, and upper/crest), the 2021 assessments were largely focused on the tops of mound since these were the only microsites where plant growth persisted to any degree. Lower and middle mound elevations were assumed to have zero vegetation cover and were not assessed for cover. The species richness of different vegetation groups (forbs, graminoids, shrubs, etc.) occurring on the mounds was determined and compared with similar data from 2017, 2018, and 2020 (prior to inundation).
- Two mounds that were treated in 2015/2016 with live staked shrubs (willow and/or cottonwood) were reassessed for stake survival. All visible stakes were identified to species and their status (live/dead) recorded. Where numbered tags were visible on the stems, the stake number was also recorded. The number of remaining live stakes was compared to the number from 2020, prior to inundation.
- The newly cleared ponds behind the log-boom were resurveyed for plant species composition and compared with the species list that was obtained in 2020, prior to inundation and the redeposition of woody debris (due to failure of the log boom) in late 2020.
- Five reference transects near the mounds and within the log-boom exclosure area that were initially established in 2015 (prior to physical works) were resampled to maintain the time series of data collected in 2015, 2017, 2018, and 2020.
- Supplemental vegetation data for the log-boom exclosure area were obtained by resampling a selection of three transects established for the (now completed) CLBMON-61 monitoring program (Adama 2019). Each transect was represented by four circular 10 m^2 subplots (total of 12 subplots). These subplots provide multiple years (2013-2017, 2020, 2021) of cover data pertaining specifically to woody shrubs, one of the plant groups expected to respond most sensitively to changing inundation condition.

Bush Causeway (south)

The following assessments were conducted at Bush Causeway (south) (UTM: 11U 474742 5739063):

- Vegetation covers (by species) were recorded for each of the two constructed windrows. The species richness of different vegetation groups (forbs, graminoids, shrubs, etc.) occurring on the mounds was determined and compared with similar data from 2017, 2018, and 2020 (prior to inundation).
- Both windrows were reassessed for live stake survival. All visible stakes were identified to species and their status (live/dead) recorded. The number of remaining live stakes was compared to the number from 2020, prior to inundation.
- Four reference transects adjacent to the windrows that were initially established in 2015 (prior to physical works) were resampled to maintain the time series of data collected in 2015, 2017, 2018, and 2020.

Bear Island

At Bear Island, we conducted brief boat-assisted surveys of two recent (fall 2019) woody debris removal sites (UTM: 11U 453330 5735558 and 11U 454827 5735420) to assess the early responses of vegetation

to clearing. Three 20 x 0.5 m transects, established in 2020, were revisited at the first (northwest) location. For the second (north) location, a species list only was compiled (repeating the approach of 2020).

Km88 Big Bend

The boat-assisted trip to Bear Island (above) was combined with a same-day survey of the 2013 sedge trials at Km88 Big Bend (UTM: 11U 453342 5736738). There, we resampled a subset of existing revegetation monitoring plots in the three different sedge treatment units TU-1, TU-3, and TU-5 (Adama 2015, Miller and Hawkes 2020). Species covers (all species) were recorded, and the numbers of surviving stems of Kellogg's and/or Columbia sedge enumerated, in 11 5 x 5 m plots. From the count data, total surviving sedge density/ha was estimated. The percent cover data complemented similar data collected in 2015 and 2018, while the stem counts continued the existing time series of counts from 2015, 2018, and 2020.

Canoe Reach Log-boom Exclosure

At the log-boom exclosure site in Canoe Reach (Valemount Peatland North, UTM: 11U 354048 5848158), we resampled nine permanent CLBMON-9 transects within the boom exclosure along with eight reference transects located outside the exclosure area.

Just outside the log-boom exclosure, three new transects were established at a newly cleared (in spring 2021) woody debris removal site to monitor vegetation response to clearing. This clearing/burning work took place in an upland habitat above the peatland on gravelly, unproductive substrate overlapping with an access road (UTM: 11U 354034 5848318). The transects will be reassessed for changes in 2022.

Valemount Peatland

Similar to the Bush Causeway area, we obtained supplemental baseline shrub data for the Peatland by resampling a selection of CLBMON-61 transects (Adama 2019). A total of 6 transects, each represented by four circular 10 m^2 subplots (total of 12 subplots), were sampled (UTM: 11U 354542 5847693, 11U 354034 5848318.

Pond 12 (Canoe Reach) Woody Debris Removal

At Pond 12 (UTM: 11U 354732 5846724), a formerly wood-choked wetland in Valemount Peatland that underwent a woody debris removal trial in 2018, we resampled five 20 x 0.5 m transects around the pond perimeter that were originally established in 2020.

Yellowjacket Creek (south) Woody Debris Removal

We resampled three existing transects at Yellowjacket Creek (South), the site of a 2014 woody debris removal trial (UTM: 11U 361440 5841118).

Yellowjacket Creek (north) Revegetation Trials

At Yellowjacket Creek (north), a brief visual and photographic reassessment was made of the original (2009) CLBWKS-1 graminoid revegetation treatments (UTM: 11U361140 5841500).

Packsaddle Creek Woody Debris Removal

At Packsaddle Creek, three new transects were established at a newly cleared (in spring 2021) woody debris removal site to monitor vegetation response to clearing. These will be reassessed for changes in 2022 (UTM: 11U 354229 5849816).

Valemount Peatland (south) Woody Debris Removal

At Valemount Peatland South, six new transects were established south of Pond 12 at a newly cleared (in spring 2021) woody debris removal site to monitor vegetation response to clearing (UTM: 11U 355645 5845941). These will be reassessed for changes in 2022.

Results

Bush Causeway (north)

A windstorm event in August 2020, when the reservoir was in surcharge, led to a breakage in the log-boom at Bush Causeway (north). This breach resulted in a large volume of woody debris being redeposited around the area of the constructed mounds and previously cleared ponds (Figure 5). A supplementary clearing operation was undertaken in late 2020, resulting in the removal of much of the newly deposited debris. However, the subsequent 2021 survey revealed that the structural integrity of all mounds had been heavily degraded since the last site visits in June 2020. The soil on the sides of the mounds had mostly been washed away by the 2020 high-water (surcharge) event (Figure 1), leaving behind only the interlocking wood "skeleton" along with a thin veneer of soil on the mound tops. Due to the losses of incorporated mound soil, the overall volumes of the mounds also appeared to have been substantially reduced, resulting in noticeably narrower and lower structures (Figure 6, Figure 7).

Most mounds continued to support a low-density cover of naturally established native and non-native vegetation (Figure 8, Appendix: Table 1), consistent with findings from previous survey years (Miller and Hawkes 2020, 2021). However, the canopy coverage of the different plant groups (forbs, graminoids, shrubs, etc.) was substantially reduced compared to 2020 as was the overall species richness of plant groups such as forbs, graminoids, and shrubs (Figure 9, Figure 10 [top panel]). Some naturally established woody species that were found still growing on the mound tops included red-osier dogwood (*Cornus stolonifera*), prickly rose (*Rosa acicularis*), red raspberry (*Rubus ideaus*), short-fruited willow (*Salix brachycarpa*), MacCalla's willow (*S. maccalliana*), dusky willow (*S. melanopsis*), and Mackenzie willow (*S. prolixa*).

Overall, we recorded only seven living cottonwood stakes and four living willow stakes on two mounds (out of the original 40 planted; Figure 11). This compares to 12 cottonwood and 11 willow stakes recorded as alive in 2020 (Miller and Hawkes 2021), indicating a decline of 52 %.

Shrub covers within the CLBMON-61 (circular plot) transects (Figure 12) fell markedly in 2021 compared to 2020 (Figure 13, top panel), likely in direct response to the 2020 high-water (surcharge) event (Figure 1). The average shrub cover in the topmost elevation band (753-754 m) dropped from ~25% to ~15% (a 40% decline). A similar trend occurred within the 752-753 m elevation band. This decline is in contrast to the steady trend of increasing average covers observed between 2014 and 2020, the period coinciding with the sequence of lower reservoir inundation years prior to 2020 (Figure 1). The difference among years in shrub cover at Bush Arm was statistically significant (ANOVA: $F=5.65$, $p=0.0004$).

In 2021, shrub diversity within the same transects was not significantly different from previous years, suggesting that most previously documented species were still present in the plots, albeit at reduced densities (Figure 14, ANOVA: $p>0.05$).

Figure 5. Aerial image of the log-boom breach at Bush Arm following a windstorm in August 2020. Image obtained by Murray Chapple, Sterling Lumber Co Ltd.

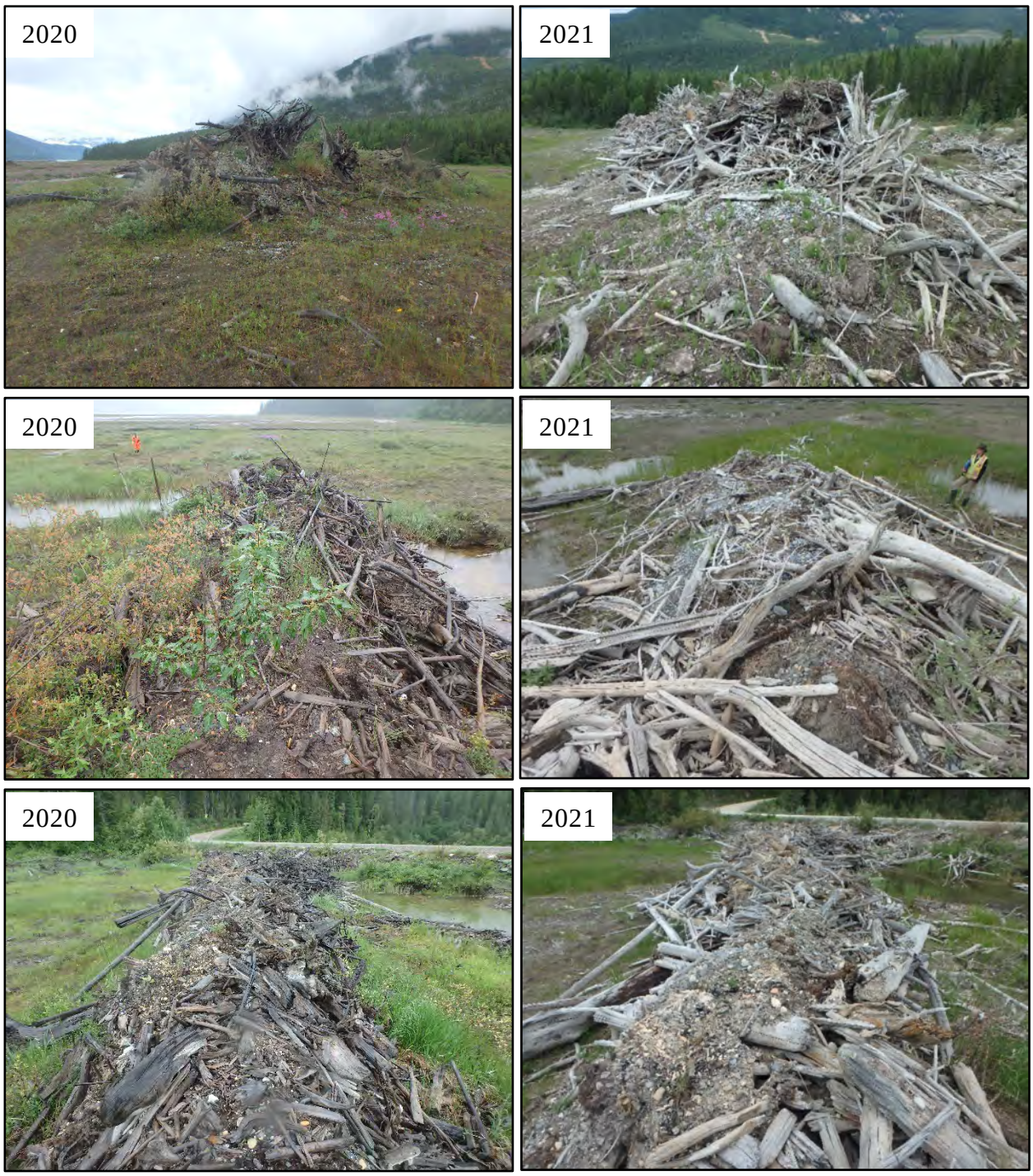

Figure 6. Constructed (2015) mounds at Bush Causeway (north), showing a side-by-side structural comparison in 2020 and 2021.

Figure 7. Constructed (2015) mounds at Bush Causeway (north), showing examples of the general condition in 2021.

Figure 8. Examples of naturally established vegetation still persisting on the summits of the Bush Causeway mounds in 2021.

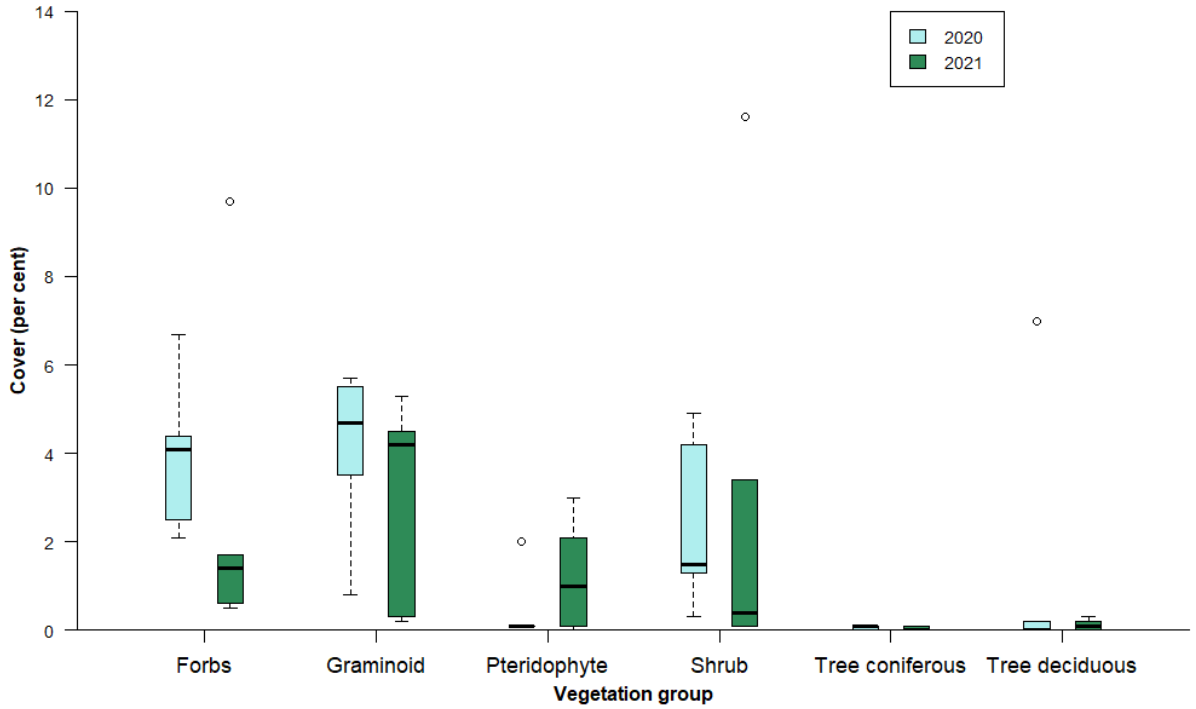

Figure 9. Per cent canopy cover of different plant functional groups on the Bush Causeway (north) mounds in 2020 and 2021.

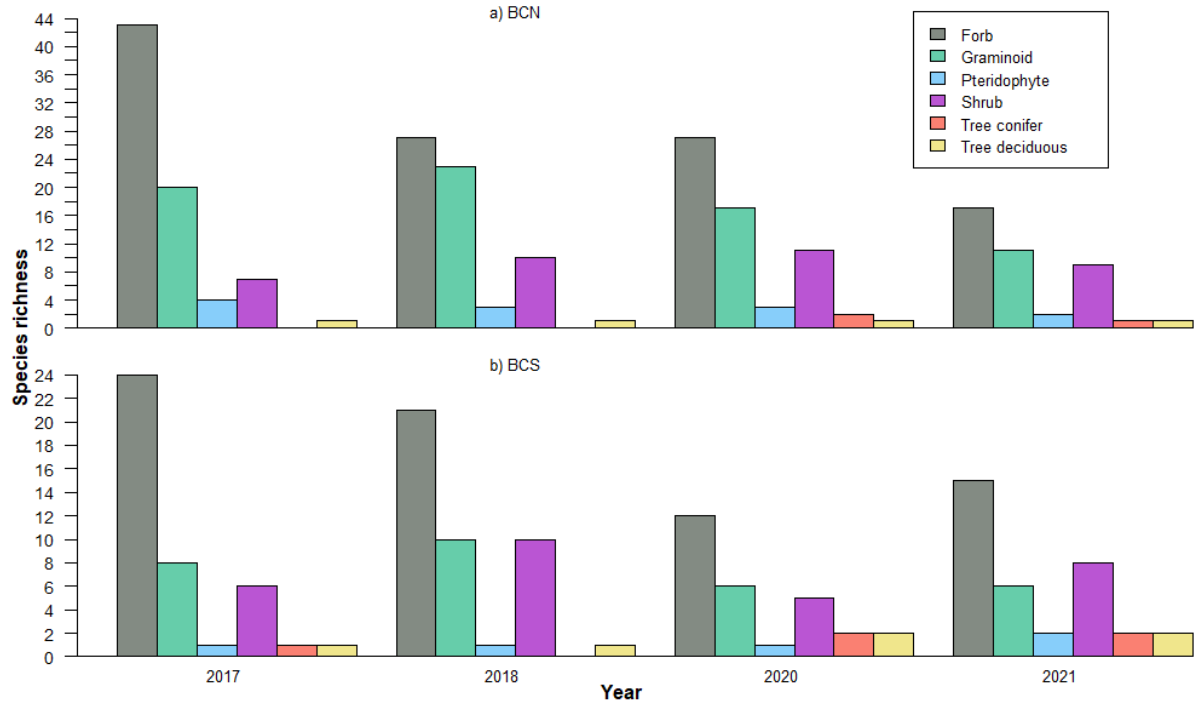

Figure 10. Number of species per plant functional group recorded on the Bush Causeway mounds from 2017 to 2021. (a) Bush Causeway north (BCN) mounds; (b) Bush Causeway south (BCS) windrows.

Figure 11. Condition in 2021 of some of the live stakes (black cottonwood) planted in 2015.

Figure 12. Examples of shrub circular plots at Bush Causeway first established as part of the CLBMON-61 program and currently being monitored under CLBMON-9.

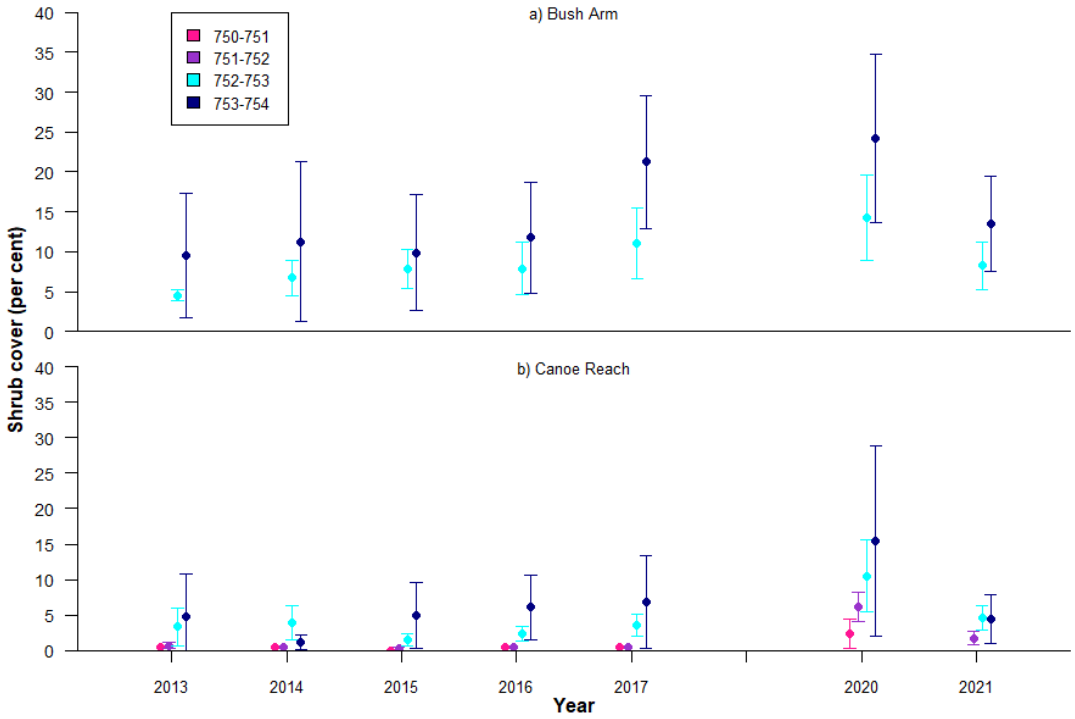

Figure 13. Box plots showing the variation in woody shrub cover over time (2013-2021) at different elevations of the drawdown zone, as recorded in sample plots at (a) Bush Causeway (Bush Arm) and (b) Valemount Peatland (Canoe Reach).

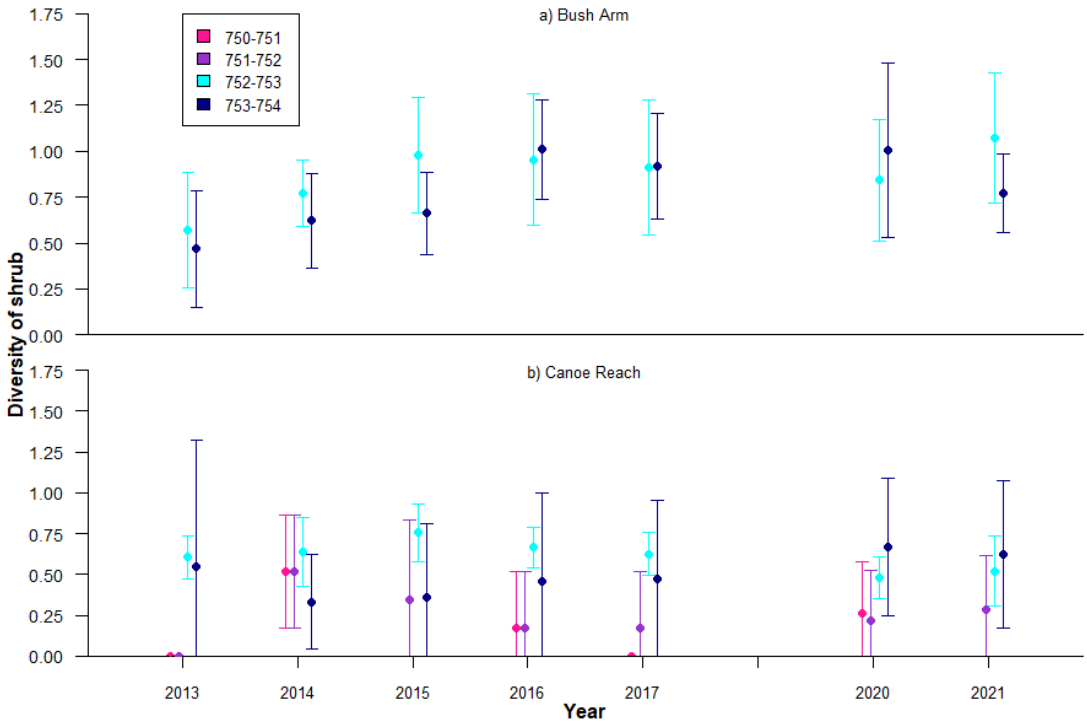

Figure 14. Box plots showing the variation in shrub species diversity over time (2013-2021) at different elevations of the drawdown zone, as recorded in sample plots at Bush Causeway (Bush Arm) and Valemount Peatland (Canoe Reach).

The 2020 high-water (surcharge) event (Figure 1) and associated woody debris deposition appeared to have set back somewhat the vegetation recovery of the ponds (Figure 15), as there was a substantial drop (of 40%) in the number of wetland species present from one year to the next (14 species in June 2021 compared to 23 in June 2020). Wetland species observed in 2021 included American water-plantain (*Alisma triviale*), water sedge (*Carex aquatilis*), yellow bog sedge (*C. gynocrates*), slender sedge (*C. lasiocarpa*), marsh cinquefoil (*Comarum palustre*), and common mare's-tail (*Hippuris vulgaris*). Species present in 2020 but not observed in 2021 included Crawe's sedge (*Carex crawei*), marsh horsetail (*Equisetum fluviatile*), tufted loosestrife (*Lysimachia thyrsiflora*), and seaside arrow-grass (*Triglochin palustris*) (Appendix: Table 2).

On a wildlife-related note, several dozen Columbia Spotted Frog tadpoles were noted in two of the cleared ponds during the June 2021 survey, implying that the ponds had retained some of their newly-gained function as wildlife habitat despite the recent disturbances.

Figure 15. Examples of wetland vegetation in cleared ponds at Bush Causeway, June 2021.

Bush Causeway (south)

The CLBWORKS-1 windrows at Bush Causeway south (BCS) did not appear to have been strongly affected by the 2020 high-water (surcharge) event (likely reflecting their slightly higher elevational position in the drawdown zone). Neither feature exhibited any recent erosion or associated water-energy damage, and species richness (Figure 10, bottom panel) and covers (Figure 15) were on par with previous years. As in prior years, the more southerly of the two windrows had by far the most well-developed vegetation establishment (Figure 17). Young pioneering tree species on this feature included Engelmann spruce (*Picea engelmannii*), western redcedar (*Thuja plicata*), and paper birch (*Betula papyrifera).* Establishing shrubs included red-osier dogwood, thimbleberry (*Rubus parviflorus*), red raspberry, and Farr's willow (*Salix farriae*) (Appendix: Table 3). Many of the species here appear to have originated from propagules dispersing from the adjacent forest community. This dispersal and

establishment may be helping to put this constructed feature on a successional trajectory towards a functional riparian forest stand that, over time, has the potential to extend the existing forest further down into the drawdown zone at this location.

Overall, we recorded six surviving live stakes on the two windrows, down slightly from the eight recorded in 2020 (out of an original total of 66 planted).

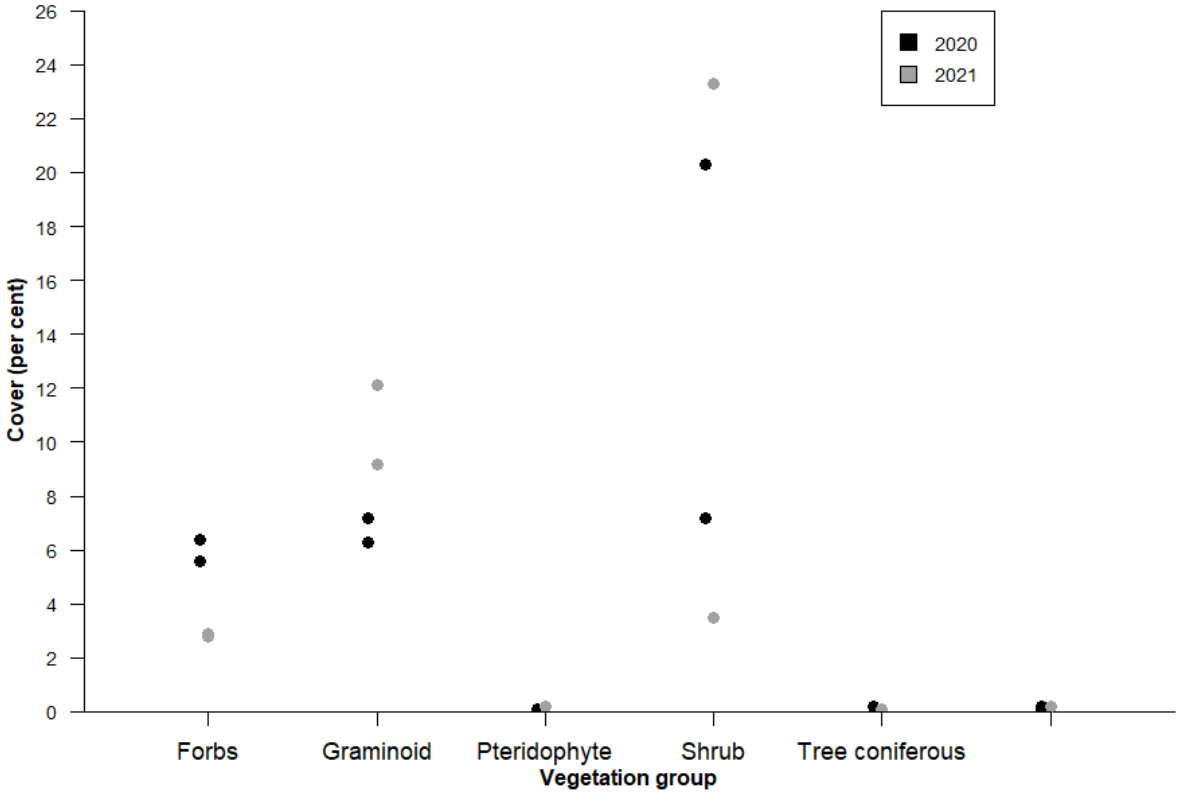

Figure 16. Per cent canopy cover of different plant functional groups on the Bush Causeway (south) windrows in 2020 and 2021. The same-coloured dots within a year correspond to the two different windrows (south windrow and north windrow). In each case, the higher cover value corresponds to the south windrow. For example, shrub cover increased on the south windrow between 2020 and 2021, but decreased over the same period at the north windrow.

Figure 17. Representative vegetation on the south windrow at Bush Causeway (south) in 2021. Clockwise from top left: general vegetation, prickly rose, Engelmann spruce seedling, paper birch seedling, thimbleberry, planted willow stake.

Bear Island

At Bear Island, the 2019-cleared site on the west side of the island had been completely re-covered by woody debris, rendering moot the follow-up transect sampling in 2021 (Figure 18). The 2019-cleared site on the north side of the island was still clear in 2021. Here, as in 2020, we observed a modest

amount of vegetation regrowth and establishment, with a total of eight species (native and non-native combined) recorded.

Figure 18. Bear island woody debris removal site, showing condition in 2020 shortly after clearing and in 2021 following redeposition of wood.

Km88 Big Bend

At Km88, plugs of Kellogg's and Columbia sedge continue to grow and seed vigorously eight years post-planting (Figure 19). In 2021, the estimated plug density (treatment units and species combined) was ~15,236 plants/ha. This compared favourably with estimated densities from 2020 (~16,160 plants/ha) and 2018, although, as might be expected, stem numbers appear to have declined somewhat since 2015 (Figure 20). However, the canopy cover provided by sedges has been on a significantly increasing trend since 2015, from ~2% cover in 2015 to ~11% cover in 2021 (Figure 21), reflecting a steady growth in the size of individual clumps as well as, perhaps, the lateral recruitment of new stems through rhizomatous spread or seedling recruitment. (Seedling recruitment was not directly assessed in 2021 but will be studied in more detail in 2022). The change in per cent cover since 2015 was significant (ANOVA: $F=15.9$, $p=0.0001$). A GLM (generalized linear model) fitted on log(Cover) ~ Year, with year as a fixed factor, also indicated an increase in cover in 2018 and 2021 relative to 2015 (by a factor of 4.8x and 7.8x, respectively).

Figure 19. Planted sedges at Km88 (2013 revegetation treatment) in 2021.

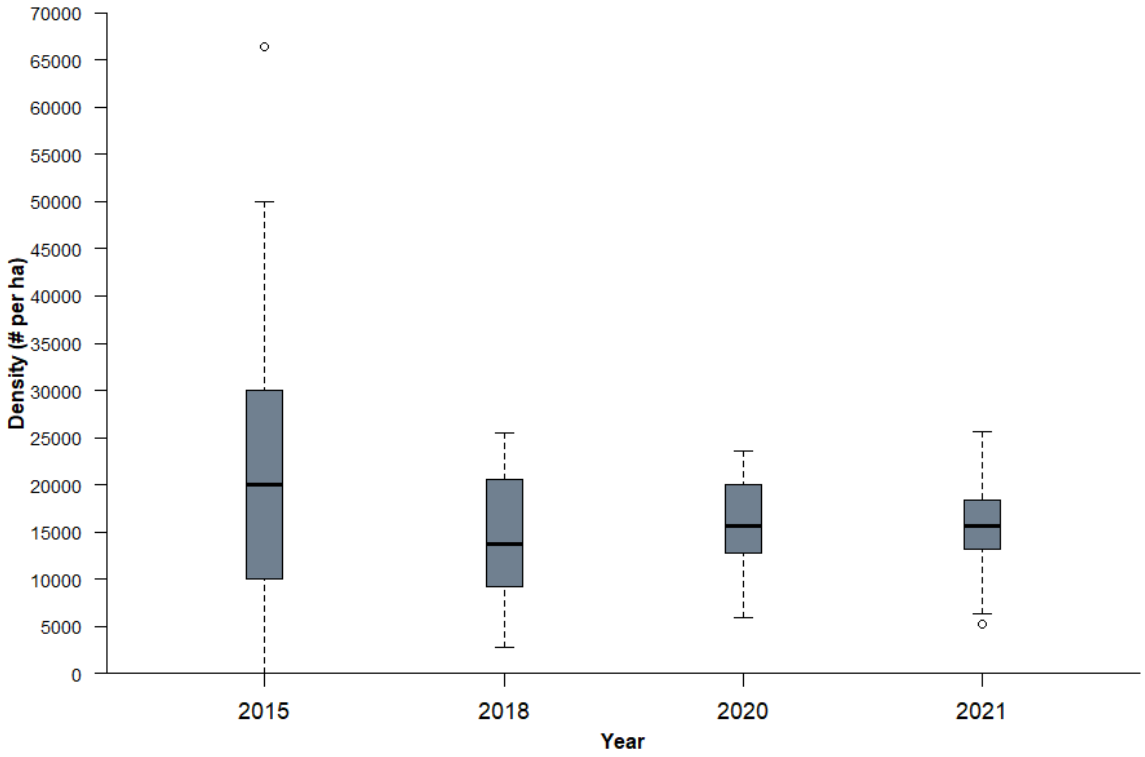

Figure 20. Estimated density per hectare of surviving sedge plugs (Kellogg's and Columbia sedge combined) at Km88 in 2015, 2018, 2020, and 2021.

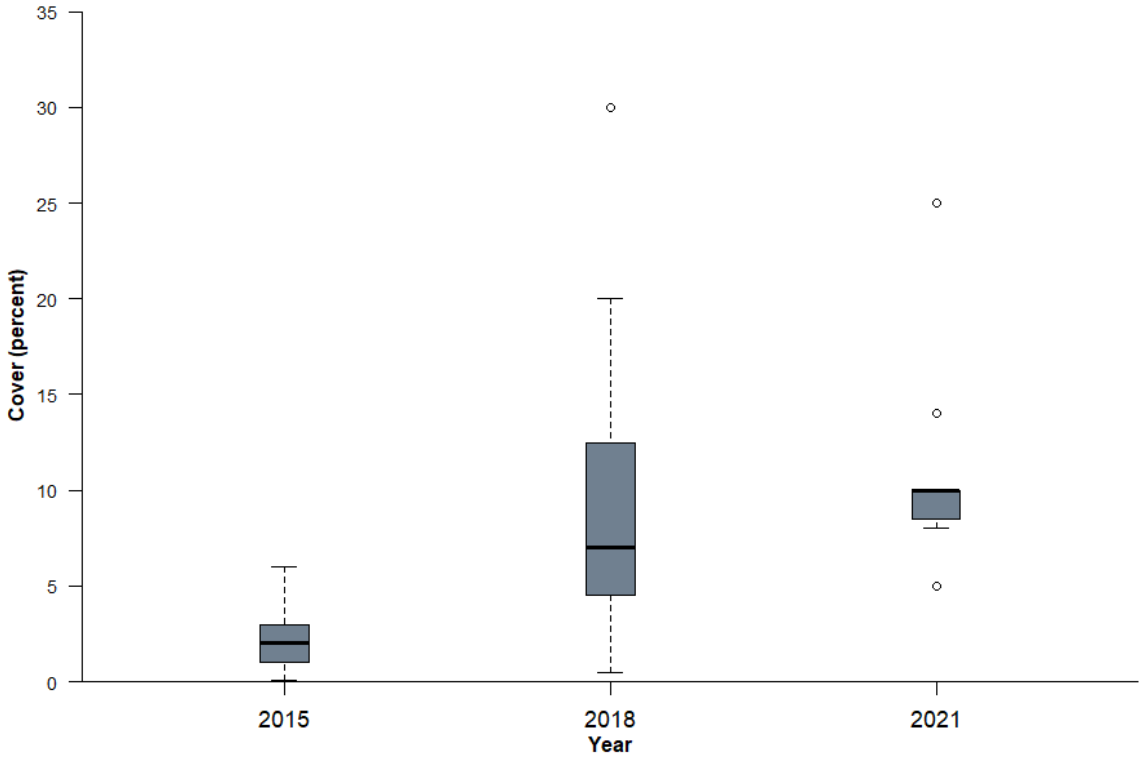

Figure 21. Percent canopy cover of Kellogg's and Columbia sedge at Km88 in 2015, 2018, and 2021 (cover data not recorded in 2020).

Canoe Reach Log-boom Exclosure

At Canoe Reach, the recovering log-boom wetland, which we have been monitoring since 2014 (Hawkes and Miller 2016; Miller and Hawkes 2020), was still wood-free in 2021 and in very good vegetation condition (Figure 22). A total of 36 different species were recorded in transects in 2021, down from 64 in 2020 and ~100 in 2017, the year when species richness peaked following several years of steady increase beginning in 2014 (the year of clearing; Appendix: Table 4). As in 2020, there was more standing water than in previous years and the community continues to be in the process (initially noted in 2020) of transitioning from a shallow, semi-terrestrial wet meadow with a diverse herb assemblage to a less diverse, deeper marsh habitat largely dominated by graminoids including water sedge, beaked sedge, and sporadic stands of common cattail.

The change in the relative importance of different species groups over time is shown in Figure 23. Of note is the steady decline in native forb cover since 2017, along with the increase between 2017 and 2020 in the cover of graminoids and shrubs. This figure also shows that overall vegetation covers appear to have declined between 2020 and 2021, possibly in response to the 2020 inundation. One-way ANOVA for forbs indicated a significant difference in average cover among years ($F=12.3$, $p=0.0001$), while GLM (fitted on log (Cover) ~ Year, with year as a fixed factor) indicated declines of 0.41x, 0.23x, and 0.067x in 2018, 2020, and 2021 (respectively) relative to 2017. For graminoids, one-way ANOVA indicated significant difference in average cover for at least one year ($F=4.03$, $p=0.012$), while GLM indicated that the only significant decline, relative to 2017, occurred in 2021 (0.52x).

Transects established at the 2021-cleared site upslope of the log-boom exclosure supported minimal cover of regenerating vegetation in June 2021 (Figure 24) and will be reassessed for vegetation development in 2022.

Figure 22. Log-boom exclosure area at Valemount Peatland, resurveyed 24 June 2021. A selection of CLBMON-9 transects were resampled here. Expanding clumps of *Typha latifolia* (common cattail) (bottom left) as well as open water areas (middle) are indicative of increasingly hygric conditions at this site.

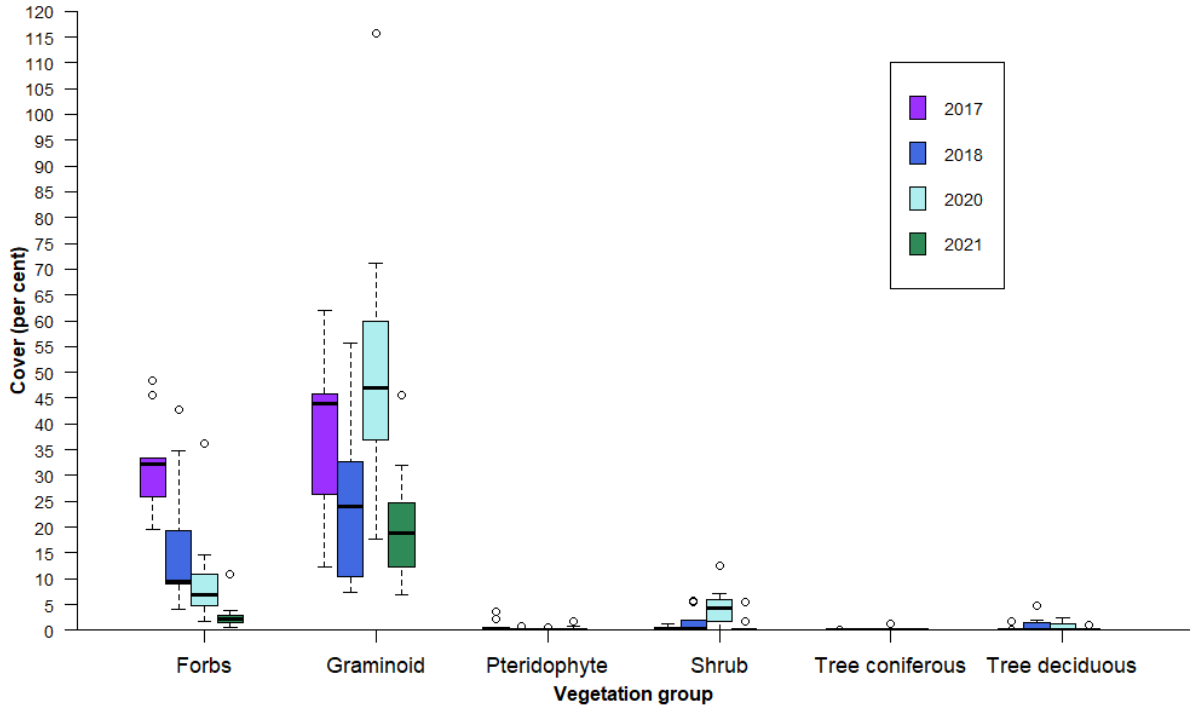

Figure 23. Per cent canopy cover of different plant functional groups in the Canoe Reach log-boom exclosure area in 2017, 2018, 2020, and 2021

Figure 24. New (2021) woody debris removal monitoring transects adjacent to the Canoe Reach log-boom exclosure.

Valemount Peatland

The assessments of shrub cover and diversity at Valemount Peatland (Figure 25) yielded similar findings as for Bush Causeway, above. Shrub covers were notably lower in 2021 than in 2020 (Figure 13, bottom panel), coinciding with prolonged late summer inundation in 2020. The average shrub cover in the topmost elevation band (753-754 m) dropped from ~17% to ~5% (a 70% decline). Similar patterns of change were observed within the lower elevation bands. The decline from 2020 to 2021 is in contrast to the steady trend of increasing average covers observed between 2015 and 2020, the period coinciding with the sequence of lower reservoir years prior to 2020. The difference among years was statistically significant (ANOVA: F=5.65, p=0.0004).

As in the case of Bush Causeway, shrub diversity within the same transects did not differ significantly among years, suggesting that most previously documented species were still present in the plots, albeit at reduced densities (Figure 14, ANOVA: $p>0.05$).

Figure 25. Examples of shrub circular plots at Valemount Peatland first established as part of the CLBMON-61 program and currently being monitored under CLBMON-9.

Pond 12 (Canoe Reach)

Transects sampled within the recovering riparian plant community at Pond 12 contained fewer species in 2021 (17) than in 2020 (41) (Appendix: Table 5). The immediate explanation for this reduction of richness in the predominantly herbaceous vegetation at this location is unclear, as the habitat appeared to be in otherwise healthy, vigorous condition with no notable signs of recent woody debris deposition (Figure 26). The prolonged inundation of 2020 could be a contributing factor. Another possible explanation for this result is that the transect locations established in 2020 were partially submerged in 2021 due to higher water levels in the pond at the time of the June survey, which made an accurate re-sampling of the transects more difficult (i.e., some species may have been present but unobserved in 2021).

Figure 26. Monitoring transects at Pond 12 (Canoe Reach). The high water level of the pond in June 2021 (relative to 2020) made resampling of some transects challenging (left photo).

Yellowjacket Creek (south) Woody Debris Removal

Yellowjacket Creek has been periodically monitored since 2014 when it was initially cleared of woody debris. While never a highly productive site, until 2021 it supported a developing plant community dominated by graminoids (native and exotic) and horsetails, along with a sparse cover of regenerating woody species consisting primarily of *Populus trichocarpa* (cottonwood), *Betula papyrifera* (birch), and *Rubus idaeus* (raspberry) (Appendix: Table 6). However, the site was re-treated for woody debris using heavy equipment in the spring of 2021, resulting in the scraping off or burying of most of the vegetation cover at this location (Figure 27). While BC Hydro debris removal planning includes avoidance of archaeology, key wildlife habitat timing (breeding season) and revegetation, at this particular location revegetation plots were not avoided during debris clearing work. The status of this site will be reassessed in 2022.

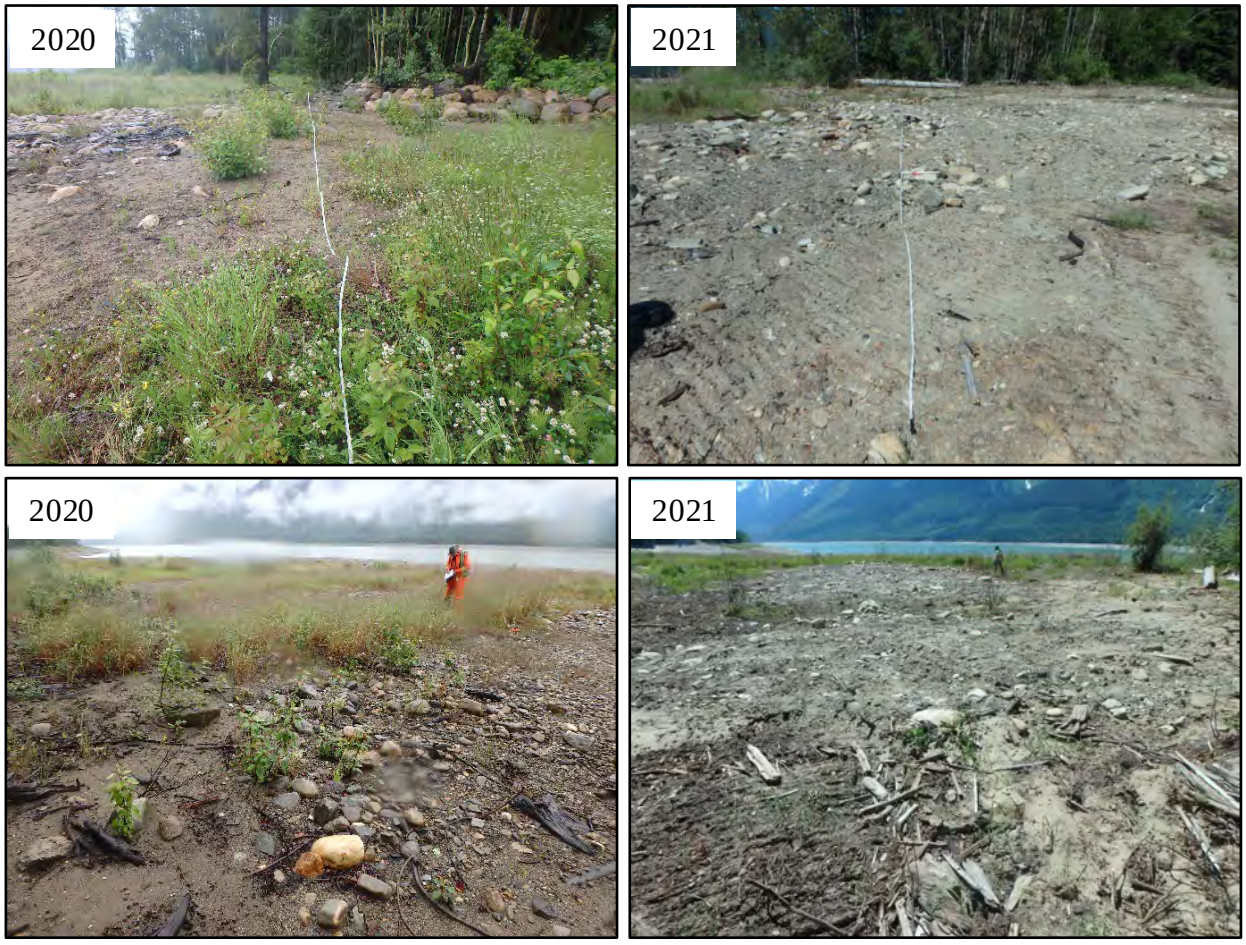

Figure 27. Woody debris removal site at Yellowjacket Creek (south), showing a side-by-side comparison in 2020 (site in recovery) and 2021 (following new disturbance from the 2021 woody debris removal operation).

Yellowjacket Creek (north) Revegetation Trials

Consistent with our 2018 (Miller and Hawkes 2020) and 2020 (Miller and Hawkes 2021) observations, the original CLBWORKS-1 sedge plantings at this location continued to show very high vigour (Figure 28), making this location the best example of successful revegetation under the CLBWORKS-1 2008-2011 planting program.

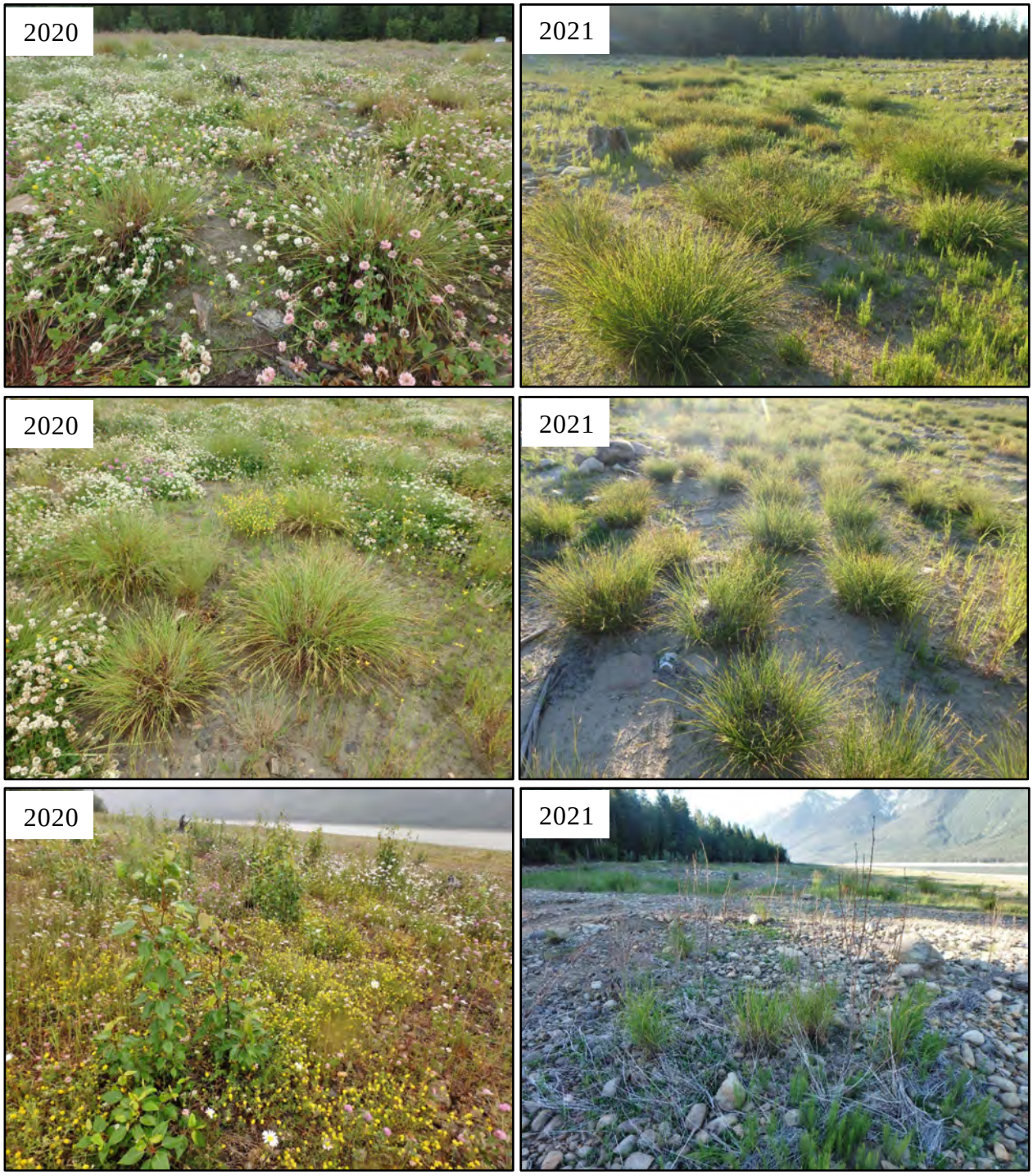

Figure 28. 2009 sedge plantings at Yellowjacket Creek (north), showing a side-by-side comparison of conditions in 2020 and 2021. Note the reduced cover of associated herbaceous vegetation in 2021. At bottom left is natural shrub establishment in 2020, following several years of no inundation. At bottom right is the same site in 2021, after inundation in 2020.

In 2020, we had noted a newly-developed herbaceous community (consisting predominantly of clovers) occurring in association with the plantings here (Miller and Hawkes 2021). The recent establishment of this community was likely a response to the series of low water years occurring prior to 2020. We also noted, in 2020, substantial natural cottonwood and other tree and shrub regeneration at slightly higher elevations. However, in 2021, the clover community had been largely reduced and replaced by horsetail and a low ground cover of annuals, possibly in response to the recent high-water (surcharge) event (Figure 1). Similarly, we observed a significant level of woody stem dieback affecting both deciduous and coniferous species (Figure 28). Some of these woody stems had died back only to the base (indicating they might survive and regrow), but a substantial number appeared to be fully dead (presumably drowned).

Packsaddle Creek Woody Debris Removal

Transects established at the 2021-cleared Packsaddle Creek site supported a modest cover of regenerating vegetation in June 2021 (Figure 29; Appendix: Table 7) and will be reassessed for vegetation development in 2022.

Figure 29. New (2021) woody debris removal monitoring transects at Packsaddle Creek.

Valemount Peatland (south) Woody Debris Removal

Transects established at the 2021-cleared site south of Pond 12 in Valemount Peatland supported a modest cover of regenerating vegetation in June 2021 (Figure 30; Appendix: Table 8) and will be reassessed for vegetation development in 2022.

Figure 30. New (2021) woody debris removal monitoring transects at south Valemount Peatland.

Summary

In 2021, we conducted a series of surveys of revegetation treatments, mounds, woody debris removal treatments, and reference sites in Bush Arm and Canoe Reach. This work took place a few months after reservoir surcharge (in 2020) and follows the pre-inundation, baseline surveys undertaken in 2020 (Miller and Hawkes 2021). Surveyed sites included Bush Causeway, Bear Island, Km88 Big Bend, the Canoe Reach log-boom exclosure, Valemount Peatland, Pond 12, Yellowjacket Creek, and Packsaddle Creek. The aim was to continue the various data time series that have been maintained for several of these locations since 2015 and to assess initial impacts of inundation on revegetation trials in the upper elevation bands of the drawdown zone following several years of non-inundation.

In 2020, we found that many plant species, and especially woody species, in the upper elevation bands had responded in a positive direction to the release from reservoir inundation over the prior five-year period (Miller and Hawkes 2021). Our 2021 follow-up surveys indicated that inundation had knocked back shrub covers within the log-boom exclosure while also substantially reducing the structural integrity of the constructed mounds at Bush Causeway north. These mounds had also suffered significant functional loss in the form of reduced vegetation cover. By contrast, the windrows at Bush Causeway south did not appear to have been much affected by the recent surcharge event, possibly due to their slightly higher position in the inundation zone. At the Km88 sedge trial, plug densities remained generally unchanged from previous years while sedge canopy cover appeared to remain on a steady upward trajectory. However, one of the two woody debris removal sites on Bear Island had been completely re-buried by debris and thus exhibited no vegetation recovery.

The log-boom exclosure in Valemount Peatland (Canoe Reach) was still intact in 2021 and there was no evidence of new wood deposition. This site remains on a strong developmental trajectory towards a functional marsh wetland. Nevertheless, following the 2020 inundation, covers of herbs, graminoids, and shrubs were reduced relative to previous years. Shrub covers were also substantially down within upper elevation bands in the Valemount Peatland at large, as well as at upper elevations on the opposite side of the reservoir at Yellowjacket Creek. Pond 12 showed good vegetation growth and still appeared to be benefiting from the original woody debris removal operation. The 2009 graminoid plantings at Yellowjacket Creek also continued to exhibit very high vigour, although there appeared to have been a decline in the cover of associated herbaceous vegetation (especially clover).

In summary, we found there to be a net negative impact of recent reservoir surcharge on physical works projects and associated vegetation recovery in the upper elevation bands of the drawdown zone. Upcoming surveys in 2022, which will reassess conditions after the return in 2021 of more moderate water levels (2021 maximum: 752.7 m ASL), will assist in determining whether the recent observed responses were transitory or reflective of a longer-term trend.

References

Adama, D. 2015. CLBWORKS-01 Kinbasket Reservoir Revegetation Program, 2014 Post-planting Report. Unpublished report by LGL Limited environmental research associates, Sidney, BC, for BC Hydro Generations, Water License Requirements, Burnaby, BC. 20 pp + Appendices.

Adama, D. 2019. CLBMON-61 Kinbasket Reservoir Wetlands Monitoring Program, Year 6 Annual Report—2012 to 2017. Draft Report. LGL Project EA3398. Unpublished report by LGL Limited, Sidney, BC. For BC Hydro, Water License Requirements, Burnaby, BC. 68 pp + Appendices.

Hawkes, V.C and P. Gibeau. 2017. CLBMON-10 Kinbasket Reservoir Inventory of Vegetation Resources. Annual Report–2016. LGL Report EA3532D. Unpublished report by LGL Limited environmental research associates, Sidney, B.C., for BC Hydro Generations, Water License Requirements, Burnaby, B.C. 62 pp + Appendices.

Hawkes, V.C. and M.T. Miller. 2016. CLBMON-09 Kinbasket Reservoir monitoring of revegetation efforts and vegetation composition analysis: year 5 – 2015. Annual Report. Unpublished report by LGL Limited, Sidney, BC, for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 41 pp. + Appendices.

Miller, M.T. and V.C. Hawkes. 2020. CLBMON-9 Kinbasket Reservoir monitoring of revegetation efforts and vegetation composition analysis: Final Report—2008-2019. Unpublished Report by LGL Limited, Sidney, BC, for BC Hydro Generation, Water Licence Requirements, Burnaby, BC. 59 pp. + App.

Miller, M.T. and V.C. Hawkes. 2021. CLBMON-9 Kinbasket Reservoir monitoring of revegetation efforts and vegetation composition analysis. 2020 Summary Note for BC Hydro.

Appendix

Table 1. Species recorded in survey years from 2017 to 2021, Bush Causeway north mounds. Species are listed by plant functional group (forbs, graminoids, pteridophytes, shrubs, coniferous trees, deciduous trees).

Plant Group	Year			
	2017	2018	2020	2021
Forb				
Anaphalis margaritacea	X	X	X	
Anthoxanthum hirtum	X	X		
Arabis pycnocarpa	X		X	X
Brassica sp.			X	
Braya humilis	X		X	X
Campanula rotundifolia	X			
Cerastium fontanum	X			
Chamerion angustifolium		X		
Cicuta douglasii			X	
Cirsium vulgare	X			
Comarum palustre	X	X		X
Dryas drummondii	X	X	X	X
Epilobium latifolium	X	X	X	
Erigeron philadelphicus	X	X	X	
Erucastrum gallicum	X	X	X	X
Fragaria virginiana	X	X	X	X
Galeopsis tetrahit		X		
Galium trifidum	X			
Lactuca biennis	X			
Lamium sp.		X		
Leucanthemum vulgare	X	X	X	X
Lobelia kalmii	X	X		
Lysimachia thyrsiflora	X	X	X	X
Medicago lupulina	X			
Mentha arvensis	X	X		
Muhlenbergia glomerata	X			
Packera plattensis	X	X	X	X
Parnassia palustris	X			
Parnassia parviflora		X		
Persicaria amphibia	X	X		X
Platanthera stricta		X		
Potentilla anserina	X	X	X	X
Potentilla biennis	X			
Potentilla norvegica		X	X	X

Primula mistassinica	X	X		
Prunella vulgaris	X	X	X	X
Ranunculus sceleratus	X	X		
Rhinanthus minor	X	X		
Rorippa palustris	X			X
Saxifraga aizoides	X		X	
Scutellaria galericulata	X	X	X	
Sisyrinchium montanum		X		
Sium suave		X		
Solidago lepida		X	X	
Symphyotrichum ciliatum	X	X		
Symphyotrichum ciliolatum	X		X	
Symphyotrichum eatonii	X		X	X
Taraxacum erythrospermum	X			
Taraxacum officinale	X	X	X	X
Triantha glutinosa	X			
Trifolium hybridum		X		
Unknown sp.	X	X		
Verbascum thapsus	X	X	X	
Viola nephrophylla	X			
Viola sp.	X			
Graminoid				
Agrostis gigantea	X	X	X	X
Agrostis scabra	X	X		
Anthoxanthum hirtum			X	
Bromus sp.				X
Calamagrostis canadensis	X	X	X	X
Calamagrostis stricta	X	X		X
Carex aquatilis	X	X	X	X
Carex aurea		X	X	
Carex bebbii	X	X	X	
Carex crawei	X			
Carex flava		X		
Carex garberi				X
Carex interior		X		
Carex kelloggii		X		
Carex lasiocarpa	X	X	X	X
Carex saxatilis	X	X		
Carex sp.			X	
Carex unilateralis	X			
Carex utriculata	X	X	X	X

Carex viridula	X			
Danthonia spicata	X	X		
Deschampsia cespitosa	X	X	X	
Dichanthelium acuminatum		X		
Elymus repens		X		
Festuca rubra	X			
Glyceria striata	X	X	X	X
Juncus alpinoarticulatus	X			
Phalaris arundinacea	X	X	X	X
Poa compressa	X	X		
Poa palustris	X	X		
Poa pratensis		X	X	
Poaceae		X	X	
Schizachne purpurascens			X	
Pteridophyte				
Cystopteris fragilis		X		
Equisetum arvense	X	X	X	X
Equisetum fluviatile	X			
Equisetum palustre	X			
Equisetum variegatum	X	X	X	X
Shrub				
Cornus stolonifera	X	X	X	X
Rosa acicularis	X	X	X	X
Rubus idaeus	X	X	X	X
Salix bebbiana		X		
Salix brachycarpa	X	X	X	X
Salix farriae	X	X	X	
Salix lasiandra var. *lasiandra*		X		
Salix maccalliana			X	X
Salix melanopsis	X		X	X
Salix pedicellaris		X		
Salix prolixa	X		X	X
Salix scouleriana		X		
Salix sitchensis			X	
Salix sp.				X
Shepherdia canadensis		X	X	
Tree-con				
Picea engelmannii x glauca			X	X
Pinaceae			X	
Tree-dec				
Betula papyrifera				X

Populus trichocarpa		X	X	X

Table 2. Wetland plant species recorded in debris-cleared ponds at Bush Causeway north in 2020 and 2021.

Species	Year	
	2020	2021
Alisma triviale	X	X
Carex aquatilis	X	X
Carex aurea	X	
Carex crawei	X	
Carex crawfordii	X	
Carex flava	X	
Carex gynocrates		X
Carex interior	X	
Carex lasiocarpa	X	X
Carex saxatilis	X	X
Carex utriculata	X	X
Carex viridula	X	X
Chara sp.		X
Comarum palustre		X
Eleocharis elliptica	X	
Eleocharis sp.		X
Equisetum fluviatile	X	
Equisetum palustre		X
Equisetum variegatum	X	
Eriophorum angustifolium	X	X
Hippuris vulgaris	X	X
Juncus alpinoarticulatus	X	
Juncus ensifolius	X	
Lysimachia thyrsiflora	X	
Parnassia palustris	X	
Sparganium emersum	X	
Triantha glutinosa	X	X
Triglochin palustris	X	

Table 3. Species recorded in surveys year from 2017 to 2021, Bush Causeway south mounds. Species are listed by plant functional group (forbs, graminoids, pteridophytes, shrubs, coniferous trees, deciduous trees).

Plant Group	Year			
	2017	2018	2020	2021
Forb				
Anaphalis margaritacea		X		
Anthoxanthum hirtum	X			
Arabis pycnocarpa	X		X	X
Boraginaceae		X		
Brassica sp.		X		
Cerastium fontanum	X			
Cerastium nutans	X			
Cirsium arvense	X			X
Cirsium vulgare	X	X	X	
Dryas drummondii		X		X
Epilobium ciliatum	X	X		
Erucastrum gallicum	X	X	X	
Fragaria virginiana		X	X	X
Hieracium pilosella				X
Leucanthemum vulgare	X	X	X	X
Lysimachia thyrsiflora		X		X
Medicago lupulina	X	X		
Melilotus alba	X			
Packera plattensis		X	X	
Paxistima myrsinites				X
Persicaria amphibia	X			
Plantago major	X	X		
Potentilla biennis	X			
Potentilla norvegica		X		
Prunella vulgaris			X	X
Rhinanthus minor	X	X		
Rorippa palustris			X	X
Rubus pubescens	X		X	
Scutellaria galericulata	X	X		X
Symphyotrichum ciliatum	X			
Taraxacum officinale	X	X		X
Thlaspi arvense				X
Trifolium aureum		X	X	
Trifolium hybridum	X	X	X	
Trifolium pratense	X	X		X
Verbascum thapsus	X	X	X	

Vicia cracca	X			X
Graminoid				
Agrostis gigantea	X	X	X	X
Agrostis scabra	X	X		
Anthoxanthum hirtum			X	X
Bromus sp.				X
Calamagrostis canadensis	X	X	X	X
Calamagrostis stricta	X	X		
Carex kelloggii			X	
Elymus glaucus		X		
Elymus repens	X	X		
Phalaris arundinacea	X	X	X	X
Poa compressa	X	X		
Poa palustris		X		
Poa pratensis	X	X	X	X
Pteridophyte				
Equisetum arvense	X	X	X	X
Lycopodium dendroideum				X
Shrub				
Cornus stolonifera	X	X	X	X
Rosa acicularis	X	X	X	X
Rubus arcticus		X		
Rubus idaeus		X	X	X
Rubus laciniatus				X
Rubus parviflorus	X	X		X
Rubus sp.		X		
Salix bebbiana			X	X
Salix brachycarpa		X		
Salix farriae				X
Salix melanopsis	X			
Salix planifolia		X		
Salix prolixa			X	
Salix scouleriana		X		
Salix sitchensis	X			X
Tree-con				
Picea engelmannii x glauca	X		X	
Picea sp. x Picea sp.				X
Thuja plicata			X	X
Tree-dec				
Betula papyrifera		X	X	X
Populus trichocarpa			X	X

Table 4. Species recorded in transects at the Canoe Reach log-boom exclosure, 2014 to 2021. Species are listed by plant functional group (forbs, graminoids, pteridophytes, shrubs, coniferous trees, deciduous trees).

Plant Group	Year						
	2014	2015	2016	2017	2019	2020	2021
Forb							
Anaphalis margaritacea					X	X	
Bidens cernua		X	X	X	X		
Bidens sp.					X		
Calla palustris		X					
Cardamine pensylvanica	X	X		X			
Cerastium fontanum		X	X	X			
Cerastium nutans				X			X
Chamerion angustifolium				X	X		
Cicuta douglasii	X	X	X	X		X	X
Cirsium vulgare	X		X	X		X	
Comarum palustre	X		X	X	X	X	X
Conyza canadensis				X			
Crepis tectorum				X			
Drosera rotundifolia			X	X	X	X	
Epilobium ciliatum		X	X	X	X		
Epilobium palustre							X
Erythranthe guttata	X						
Euphrasia nemorosa			X	X	X		
Fragaria virginiana				X		X	
Galeopsis tetrahit	X	X		X			X
Galium boreale						X	
Galium trifidum		X	X	X	X		X
Galium triflorum	X					X	
Geum macrophyllum			X	X	X	X	
Hieracium caespitosum			X				X
Hieracium glomeratum						X	
Hieracium maculatum				X			
Hieracium piloselloides			X	X	X		
Hypericum boreale				X			
Hypericum canadense				X		X	
Hypericum majus			X				
Juncus alpinoarticulatus		X		X	X		
Leucanthemum vulgare		X	X	X	X	X	X
Lycopus americanus				X			
Lysimachia thyrsiflora	X	X	X	X	X	X	X
Mentha arvensis				X			

Menyanthes trifoliata			X	X	X	X	X
Myosotis laxa				X			
Myosotis scorpioides	X	X					
Parnassia palustris			X	X	X	X	
Persicaria amphibia				X	X	X	X
Persicaria maculosa	X	X					X
Plantago major				X	X		
Potamogeton pusillus		X					
Potentilla biennis				X			
Potentilla norvegica	X	X	X	X	X		X
Ranunculus gmelinii		X		X			
Ranunculus pensylvanicus		X	X	X	X		
Ranunculus sceleratus	X	X					
Rhinanthus minor				X	X		
Rorippa palustris	X	X	X	X			
Rumex crispus		X	X	X			
Sagina procumbens			X	X			
Scirpus atrocinctus				X			
Sium suave		X	X	X	X		
Sparganium angustifolium				X	X		
Sparganium emersum		X	X	X	X		
Sparganium natans				X		X	
Stellaria longifolia				X		X	
Symphyotrichum ciliatum				X	X		
Trifolium aureum				X	X	X	
Trifolium hybridum		X	X	X	X	X	
Trifolium pratense					X	X	
Trifolium repens		X					X
Trifolium sp.						X	
Triglochin palustris		X					
Typha latifolia		X	X		X		
Utricularia intermedia	X	X	X	X	X	X	X
Veronica beccabunga	X	X					
Veronica peregrina var. *xalapensis*			X	X			
Vicia americana						X	
Vicia cracca				X	X		X
Viola macloskeyi	X	X	X	X	X	X	X
Graminoid							
Agrostis gigantea				X	X	X	X
Agrostis scabra			X	X	X		
Agrostis stolonifera		X	X	X			

Bromus sp.							X
Calamagrostis canadensis	X	X	X	X	X	X	X
Calamagrostis stricta					X	X	
Carex aquatilis			X	X	X	X	X
Carex bebbii			X	X	X	X	
Carex brunnescens		X			X		
Carex canescens			X	X	X	X	
Carex crawfordii		X	X	X		X	
Carex flava				X		X	
Carex interior			X	X	X	X	
Carex kelloggii	X	X	X	X	X	X	X
Carex lasiocarpa				X		X	
Carex limosa				X			
Carex pachystachya	X						
Carex rossii						X	
Carex sitchensis						X	X
Carex sp.							X
Carex stipata		X	X	X	X	X	
Carex tonsa				X			
Carex utriculata				X	X	X	X
Carex viridula			X	X			
Deschampsia cespitosa		X					
Deschampsia danthonioides	X						
Eleocharis mamillata		X	X	X	X	X	
Elymus repens			X	X	X	X	
Glyceria borealis				X	X		
Glyceria grandis				X	X		
Glyceria striata		X	X	X	X	X	
Hieracium piloselloides					X		
Hordeum jubatum				X			
Juncus alpinoarticulatus			X	X		X	
Juncus bufonius	X	X					
Juncus dudleyi			X				
Juncus ensifolius	X	X	X	X	X	X	X
Juncus filiformis					X		X
Juncus nodosus			X				
Poa compressa		X	X	X	X	X	X
Poa palustris	X	X	X	X	X	X	
Poa pratensis				X	X	X	
Scirpus atrocinctus	X	X	X	X	X	X	X
Scirpus microcarpus		X					

Typha latifolia				X		X	X
Pteridophyte							
Athyrium filix-femina				X			
Cystopteris fragilis				X		X	
Equisetum arvense	X	X	X	X	X	X	X
Equisetum fluviatile			X	X		X	X
Equisetum palustre				X	X		X
Equisetum scirpoides				X			
Potentilla norvegica					X		
Shrub							
Acer glabrum		X					
Alnus incana				X	X	X	
Myrica gale						X	
Rosa acicularis				X			
Rubus idaeus			X	X		X	
Salix bebbiana				X	X	X	X
Salix planifolia				X	X	X	X
Salix prolixa					X		
Salix sitchensis				X		X	
Salix sp.			X	X			
Subshrub							
Arctostaphylos uva-ursi						X	
Tree-con							
Picea engelmannii x glauca				X			
Pinus contorta						X	
Tree-dec							
Betula papyrifera				X	X	X	
Populus tremuloides				X	X	X	X
Populus trichocarpa				X	X	X	

Table 5. Species recorded in transects at Pond 12 (Canoe Reach) in 2020 and 2021. Species are listed by plant functional group (forbs, graminoids, pteridophytes, shrubs, coniferous trees, deciduous trees).

Plant Group	Year	
	2020	2021
Forb		
Cicuta douglasii	X	
Comarum palustre	X	X
Epilobium ciliatum	X	
Galium boreale	X	
Galium trifidum		X
Geum macrophyllum	X	
Lysimachia thyrsiflora	X	X
Mentha arvensis	X	
Persicaria amphibia	X	X
Ranunculus pensylvanicus	X	
Rhinanthus minor	X	
Rumex sp.	X	
Scutellaria galericulata	X	
Stellaria longifolia	X	
Unknown sp.	X	
Utricularia intermedia	X	X
Viola macloskeyi	X	X
Graminoid		
Calamagrostis canadensis	X	X
Carex aquatilis	X	X
Carex bebbii	X	
Carex canescens	X	
Carex interior	X	
Carex kelloggii	X	X
Carex lasiocarpa	X	X
Carex rossii	X	
Carex sitchensis	X	
Carex stipata	X	
Carex utriculata	X	X
Glyceria grandis	X	
Glyceria striata	X	
Phalaris arundinacea	X	
Poa palustris	X	
Scirpus atrocinctus	X	X
Scirpus microcarpus	X	
Pteridophyte		

Cystopteris fragilis	X	
Equisetum arvense		X
Equisetum fluviatile	X	
Equisetum palustre	X	X
Shrub		
Alnus incana	X	
Myrica gale	X	X
Rubus idaeus	X	
Salix bebbiana	X	X
Salix planifolia	X	X
Salix sp.	X	

Table 6. Species recorded in transects at Yellowjacket Creek (Canoe Reach) in 2020 and 2021, before and after disturbance from 2021 debris-clearing operations. Species are listed by plant functional group (forbs, graminoids, pteridophytes, shrubs, coniferous trees, deciduous trees).

Plant Group	Year	
	2020	2021
Forb		
Crepis tectorum	X	
Galeopsis tetrahit		X
Hieracium pilosella	X	
Leucanthemum vulgare	X	
Potentilla norvegica	X	
Trifolium aureum	X	
Trifolium hybridum	X	
Trifolium pratense	X	
Trifolium repens		X
Graminoid		
Agrostis gigantea	X	
Agrostis scabra	X	
Agrostis stolonifera	X	
Calamagrostis canadensis	X	X
Carex foenea	X	
Carex kelloggii	X	X
Carex mertensii	X	
Juncus tenuis	X	
Phleum pratense	X	
Poa compressa	X	X
Pteridophyte		
Equisetum arvense	X	X
Shrub		
Rubus idaeus	X	
Tree-con		
Pinus contorta	X	
Tree-dec		
Betula papyrifera	X	
Populus tremuloides	X	
Populus trichocarpa	X	X

Table 7. Species recorded in new transects at the 2021-woody debris removal site at Packsaddle (Canoe Reach) in 2021. Species are listed by plant functional group (forbs, graminoids, pteridophytes, shrubs, coniferous trees, deciduous trees).

Plant Group	Year
	2021
Forb	
Chenopodium album	X
Galeopsis tetrahit	X
Galium boreale	X
Persicaria amphibia	X
Potentilla norvegica	X
Rorippa palustris	X
Graminoid	
Calamagrostis canadensis	X
Phalaris arundinacea	X
Pteridophyte	
Equisetum arvense	X
Shrub	
Rosa acicularis	X
Salix bebbiana	X
Salix prolixa	X
Tree-dec	
Populus trichocarpa	X

Table 8. Species recorded in new transects at the 2021-woody debris removal site at Valemount Peatland south (Canoe Reach) in 2021. Species are listed by plant functional group (forbs, graminoids, pteridophytes, shrubs, coniferous trees, deciduous trees).

Plant Group	Year
	2021
Forb	
Cirsium arvense	X
Comarum palustre	X
Epilobium ciliatum	X
Galeopsis tetrahit	X
Galium trifidum	X
Lysimachia thyrsiflora	X
Persicaria amphibia	X
Persicaria maculosa	X
Potentilla norvegica	X
Trifolium repens	X
Utricularia intermedia	X
Viola macloskeyi	X
Graminoid	
Calamagrostis canadensis	X
Carex aquatilis	X
Carex kelloggii	X
Carex utriculata	X
Juncus tenuis	X
Phalaris arundinacea	X
Scirpus atrocinctus	X
Scirpus microcarpus	X
Pteridophyte	
Equisetum arvense	X
Equisetem fluviatile	X
Shrub	
Salix bebbiana	X
Salix planifolia	X