Columbia River Project Water Use Plan

Kinbasket and Arrow Lakes Revegetation Management Plan

Implementation Year 5

Reference: CLBMON-12

Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

Study Period: 2015

Okanagan Nation Alliance, Westbank, BC
and
LGL Limited environmental Research Associates, Sidney, BC

January 28, 2016

KINBASKET AND ARROW LAKES RESERVOIRS

Monitoring Program No. CLBMON-12

Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis




Implementation Year 5 – 2015

Final Report

Prepared for

BC Hydro Generation

Water Licence Requirements
Burnaby, BC

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Cover photos

From left to right: Kellogg's sedge plugs, Edgewood; dead cottonwood stakes, Edgewood; live cottonwood stakes, Edgewood; cottonwood seedlings, 12 Mile. All photos © Michael T. Miller, LGL Limited.

EXECUTIVE SUMMARY

The Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis (CLBMON-12) is a Water Licence Requirement project initiated in 2008 to assess the effectiveness of revegetation treatments applied to the reservoir drawdown zone between 2009 and 2011 under the CLBWORKS-2 program.

The primary objectives of this study are: (1) to assess the short-term effectiveness of the revegetation program at expanding the quality (as measured by diversity, distribution and vigour) and quantity (as measured by cover, abundance and biomass) of vegetation in the drawdown zone within the 434 to 440 m ASL elevation band; and (2) to assess whether revegetation establishment is facilitated by the implementation of the soft constraints operating regime. Soft constraints are operational targets developed by the Columbia Water Use Planning Consultative Committee (WUP CC) for the benefit of various interests (vegetation, wildlife, fish, culture and heritage, recreation, erosion, and power generation). Each target identifies the ideal/preferred reservoir operations (water level over the year) for a specific interest. The degree to which individual objectives are met varies by year and the requirements of competing objectives. Results of the CLBMON-12 program will help determine whether changes to the reservoir's soft constraints operating regime (or, in lieu of operational changes, additional physical works) may be required to maintain or enhance planted shoreline vegetation and the ecosystems it supports.

Data collection in 2015 entailed resampling vegetation composition and cover within previously established and monitored long-term plots stratified by region, elevation band, and treatment type (Enns and Overholt 2013a). Twenty-two areas were sampled on both sides of Arrow Lakes Reservoir between Deer Park and Revelstoke, B.C. in May and June 2015. In response to unusually low summer water levels in 2015, a second, follow-up survey of selected sites was conducted in October to assess the within-season impacts of a lack of inundation (prolonged drought) on plant cover, height, vigour, and reproduction.

Our overall conclusions are consistent with those reached following previous study years (Enns *et al*. 2009; Enns and Enns 2012; Enns and Overholt 2013a): revegetation efforts to date have achieved mixed success. A portion of the stock (primarily Kellogg's sedge and black cottonwood) planted between 2008 and 2011 has survived and taken root and, in limited areas, is growing vigorously. The plantings in these areas may now be providing some ancillary ecological services such as increased erosion control, forage for waterfowl, and perches for birds.

Regression tree analyses identified substrate, microtopography, water energy, aspect, and soil moisture as potentially important predictors of long-term planting survival. For example, cottonwood stakes tended to perform relatively well on moderately moist to dry soils with some silt content; on substrates with low to moderate sand content; and on sandier substrates combined with cool (northerly) aspects. Sedge survival tended to be relatively high in those sample plots characterized by tussocked microsites (implying prior presence of other clumping graminoids) and somewhat gravelly substrates, and also in plots with a northerly aspect and minimal exposure to erosion and sedimentation.

In several areas, survival of plantings has been minimal or has failed. Failures can probably be ascribed to a combination of environmental factors including prolonged inundation, infertile or unstable substrates, wave action and erosion/deposition, and soil moisture deficits. In areas where revegetated plants have taken hold, a lack of new recruits indicates that ecological filters preventing natural succession have not been adequately addressed and suggests that revegetated populations may not be self-sustaining over the long term. These areas may require additional physical works (i.e., site alterations such as tilling, diking, windrows, mounding) or repeat planting entries to maintain the presence of vegetation over time.

At the community level, revegetation activities seem to have had a neutral impact overall on associated vegetation development (as represented by such metrics as total cover, biomass, and species diversity). This could be because not enough time has elapsed since treatments were applied for successional effects to manifest themselves (particularly in the case of developing cottonwood stands). Nevertheless, it is becoming evident that for many barren regions of the drawdown zone, additional physical modifications aimed at ameliorating site conditions will likely be applied in concert with revegetation prescriptions if lasting community changes are to be achieved.

From an operational standpoint, opportunities also exist for advancing vegetation establishment by using soft constraints to control the timing, and limit the depth and duration, of summer inundation. With respect to reservoir hydroperiod, program experience to date suggests the following tentative "axioms":

- To facilitate development of functional riparian ecosystems, periodic, brief inundation at low elevations (i.e., 434-436 m) is likely necessary (to recharge soil moisture, protect establishing plants from summer drought, and maintain suitable growing conditions for adapted riparian species and communities).
- Frequent full pool events can limit the capacity for shrub and tree establishment at upper elevations (i.e., >436 m).
- Extended, deep inundation is likely detrimental for all revegetation taxa.
- Late summer and fall inundation can inhibit seed-set and dispersal for key reclamation species such as Kellogg's sedge, resulting in lost reproductive opportunity and reduced establishment (and hence reclamation) potential.

The status of CLBMON-12 after Year 8 (2015) with respect to the management questions and management hypotheses is summarized below.

Management Question (MQ)	Has MQ been addressed?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where appropriate	
1. What is the quality and quantity of vegetation in revegetated areas between elevations 434 m to 440 m compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?	Partially	As of 2015, there were no statistically significant differences in vegetation quantity or quantity between treated and untreated areas.	Consider expanding the survey design to include more sample replication within and among treatments. In the final implementation year, a retrospective analysis of yearly plot data should be conducted to compare trajectories in species composition over time within treated and control plots, to more clearly distinguish treatment from background effects	The relatively short time (4 to 7 years) that has passed since the application of the revegetation prescriptions limits our ability to comment on their respective successional trajectories.
2. What are species-specific survival rates under current operating conditions (i.e. what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?	Partially	The estimated survivorship of sedge plugs 4 to 7 years after planting was, on average, about 21 per cent, while that of cottonwood stakes was about 64 per cent. Local survival rates varied greatly across locations, with numerous samples showing minimal to no survival and others indicating relatively high establishment success.	Current samples are based on repeat monitoring of permanent plots established by Enns *et al*. (2007 and subsequent). The available sample size could be increased through development of a comprehensive catalogue of survivorship at all previous treatment sites, using original stocking densities for each site where known. This would assist in identifying specific treatments that appear to be working and which could benefit from expanded testing. Some promising instances of revegetation have already been identified. Resources permitting, these high-potential treatments should be targeted for expanded testing as soon as possible under CLBWORKS-1.	Survivorship was estimated indirectly based on the number of visible live plantings at each sample plot and the average reported stocking rates for each species or treatment type. In numerous instances, planted vegetation could not be distinguished with certainty from natural vegetation. Thus, estimates are approximate and should be taken as relative indicators only.
3. What environmental conditions, including the current operating regime (i.e. timing, frequency, duration and depth of inundation), may limit or improve the restoration and expansion of vegetation communities in the drawdown zone?	Partially	Revegetation performance appears to be correlated to a range of environmental factors including inundation, infertile or unstable substrates, wave action and erosion, sedimentation, and soil moisture deficits. All aspects of the operating regime have the potential to limit or improve the restoration and	There is insufficient treatment replication in the CLBWORKS-2 revegetation program to address specific hypotheses around inundation timing, frequency, duration and depth. In order to relate revegetation performance directly to these operational components, which vary annually, the treatments themselves would need to be	Limited treatment replications (both spatially and temporally) limit our ability to directly correlate revegetation performance to different soft constraints components (i.e., timing, frequency, duration and depth of inundation), and to

Management Question (MQ)	Has MQ been addressed?	Scope		Sources of Uncertainty
		Current supporting results	**Suggested modifications to methods where appropriate**	
		expansion of vegetation communities. Timing of inundation determines the ability of restored vegetation to set roots, grow, and reproduce within the annual cycle. Frequency of inundation can affect establishment rates, especially of woody species at upper elevations. Duration and depth of inundation determine the levels of anoxia that plants must endure and the degree of seasonal exposure to wave action, erosion, sedimentation, and woody debris.	replicated each year of the study across the full elevational gradient of the targeted portion of the drawdown zone.	separate soft constraints effects from other, non-operational effects.
4. What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-2, at increasing the quality and quantity of vegetation in the drawdown zone?	Partially	Cottonwood stakes have survived better, and are providing more new cover, than graminoid plugs. However, none of the treatments has yet shown to be effective at increasing the quality and quantity of associated vegetation. This may be because not enough time has elapsed since planting for beneficial effects to become evident.	It could require many more years of stand development before changes at the community level become detectable. At this stage of the study, it may be beneficial to redirect the focus of monitoring away from the assessment of community responses (which are negligible so far) and toward identification of the specific conditions or filters (both physical and methodological) acting to limit or enhance the establishment and long-term survival of individual planting treatments. Such information is needed to help guide future physical works projects in the drawdown zone. This could be accomplished through a more extensive cataloguing and survey of existing treatment areas (see comment above for MQ2).	A longer time series of data is required to address this question adequately. .
5. Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?	Partially	Yes, the program has shown modest benefits beyond what would occur through natural colonization, primarily relating to the establishment of young cottonwood trees at some high elevation sites. There has been relatively little success in getting herbaceous	N/A	A longer time series of data is required to address this question adequately.

Management Question (MQ)	Has MQ been addressed?	Scope		Sources of Uncertainty
		Current supporting results	**Suggested modifications to methods where appropriate**	
		vegetation to establish on barren sites, and much of the gains there appear transitory (due to a lack of ongoing recruitment).		
6. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the landscape and site level in the future?	Yes	Yes, opportunities exist for modifying operations to help restoration goals. Experience with the revegetation program to date suggests that soft constraints will be most effective at maintaining revegetated communities to the extent they are employed to limit not just the depth but also the duration of inundation during the summer and early fall growing season. As noted above (MQ 3), limited treatment replications (both spatially and temporally) limit our ability to directly correlate revegetation performance to different soft constraints components (i.e., timing, frequency, duration and depth of inundation). Thus, supporting results to date are mostly observational in nature. The unusually low reservoir maximum (435 m) experienced in 2015 should eventually help to shed light on this question especially if it is replicated on a regular basis in subsequent years.	N/A	The non-experimental nature of the planting program, combined with the recent history of variable reservoir operations (also unreplicated in space and time), limits our ability to test hypotheses or to recommend specific targets around inundation timing, frequency, duration and depth. A longer time series of data, in conjunction with annually replicated planting treatments, is required to this question adequately.

KEYWORDS: Arrow Lakes Reservoir; soft constraints operating regime; vegetation community; revegetation; diversity; biomass; Kellogg's sedge; black cottonwood; effectiveness monitoring; drawdown zone; reservoir elevation.

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ACRONYMS AND DEFINITIONS

Control plot – sample plot in an revegetated area of the drawdown zone that serves as a statistical control for a corresponding **treated plot** (see below). Control plots and their paired treated plots share a similar elevation, topography, substrate, and **vegetation community type** (see below).

Diversity – a measure of the species diversity within a sample of study plots that incorporates both species richness (see below) and species evenness (the relative abundance of species within the sample).

Elevation band – for monitoring purposes, the drawdown zone between 434 and 440 m is stratified into three separate elevation bands: 434-436 m ASL, 436-438 m ASL, and 438-440 m ASL.

Existing vegetation plot – sample plot in an area of the drawdown zone that was not revegetated using the revegetation prescriptions developed for CLBWORKS-2 and not specifically paired with a treated plot. Along with treated and control plots, these plots are monitored on an ongoing basis and serve as additional background reference sites for trends occurring within treated and control areas.

Landscape unit – one of two general geographic regions of the Arrow Lakes Reservoir; Revelstoke Reach (northern section) and Arrow Lakes (southern section).

Plot – primary sampling unit for obtaining field data within each treated, control, and existing vegetation area. Plots are permanently located for long-term monitoring and have a dimension of 10 m x 5 m (50 m^2).

Richness – the number of vascular plant species present in a sample of study plots.

Stake polygon – additional temporary plot for assessing live stake survival densities over a larger area than that provided by the long-term plots. Stake polygons are rectangular and usually located adjacent to existing plots, with dimensions determined by the extent of the treated area and by terrain features, typically ranging in size from 200 m^2 to 1,500 m^2.

Study area – one of 43 designated monitoring sites in the Arrow Lakes Reservoir selected by BC Hydro for which aerial photos have been acquired biennially beginning in 2007, and for which base mapping was created by delineating polygons on aerial photographic mosaics.

Treated plot – sample plot in an area of the drawdown zone that was revegetated using one of the revegetation prescriptions developed for CLBWORKS-2.

Vegetation community type (VCT) – a general classification for vegetation communities found in the drawdown zone of the Arrow Lakes Reservoir, consisting of habitats that share similar vegetation, substrates, and topography. The 16 currently recognized VCTs (Enns *et al.* 2010) are described in Appendix 10.1.

1.0 INTRODUCTION

Reservoirs managed for hydro-electric power production typically experience extreme fluctuations in water levels, with associated drawdown zones measuring vertically in the tens of metres (Abrahams 2006; Lu *et al*. 2010). These drawdown zones (defined as the exposed part of the shoreline below the top water line) are generally challenging environments for most plant species; alternating cycles of flooding and exposure produce repeated cycles of disturbance, colonization (during low water levels), and recession (during high water levels). The extreme magnitude of water fluctuations can lead to long-term declines in plant species richness, a loss of rare plant associations, and invasions by exotic species (Hill *et al*. 1998; Yang *et al*. 2012). Steep and unstable banks, long fetches with associated wave action that reduces the substrate's organic matter and prevents plant growth, low levels of soil nutrients, accumulating large woody debris and its associated scouring, and high rates of erosion and sediment deposition provide additional challenges to vegetation establishment in the drawdown zones reservoirs (Johnson 2002; Abrahams 2006; Yang *et al*. 2012).

Arrow Lakes Reservoir, in southeastern British Columbia, is 232 km long and holds a licensed volume of 7.1 million acre feet (MAF; BC Hydro 2005). Water level elevations are managed under a regime that permits a normal annual reservoir minimum of 419.9 m above sea level (ASL) and a normal reservoir maximum of 440.1 m ASL—a difference of 20.2 m. The large variations in water levels result in only sparse vegetation cover throughout much of the drawdown zone, which in turn impacts ecosystem functioning, wildlife values, and aesthetics. These cumulative impacts on reservoir shoreline vegetation communities had not been addressed until BC Hydro entered into the planning process for the Columbia River Water Use Plan (WUP) in 2001. During this planning process, the WUP Consultative Committee (WUP CC) recognized the value of vegetation in improving aesthetic quality, controlling dust storms, protecting cultural heritage sites from erosion and human access, and enhancing littoral productivity and wildlife habitat (BC Hydro 2005).

In lieu of operational changes such as maintaining lower reservoir elevations, the WUP CC recommended that a revegetation program be undertaken in Arrow Lakes Reservoir (BC Hydro 2005). The first phase of the revegetation program (CLBWORKS-2: Mid Columbia and Arrow Lakes Reservoir Revegetation) was conducted in the reservoir over four years from 2008 to 2011 between the locations of Revelstoke and Renata, B.C. The revegetation approach included planting of sedge (*Carex lenticularis* var. *lipocarpa* and *C. aperta*), black cottonwood (*Populus balsamifera* subsp. *trichocarpa*), and willow (*Salix* spp.) at prescribed areas of the drawdown zone between 434 m and 440 m ASL, as well as some repeated treatments over multiple years to facilitate the growth of vegetative cover in areas thought to have good potential to become self-sustaining. A total of 108 hectares were planted over this period, encompassing approximately 17 sites and 80 treatment areas (Keefer *et al*. 2008; 2009; Keefer Ecological Services 2010; 2011).

The decision of the WUP CC to support a revegetation program for the reservoir was predicated on the assumption that the soft constraints operating regime (inundation cycles) would be effective in maintaining current levels of vegetation, and that revegetation activities would be a more cost-effective means of remediating and expanding vegetation cover for ecological and social benefits than imposing hard constraints on the operation of the reservoir (BC Hydro 2005). Soft constraints are operational targets developed by the WUP CC for the benefit of various interests (vegetation, wildlife, fish, culture and heritage, recreation, erosion, and power generation). Each target identifies the ideal/preferred reservoir operations (water level over the year) for a specific interest. The degree to which an individual objective is met varies by water year and the requirements of competing objectives. The soft constraint targets identified for vegetation (BC Hydro 2005) were to:

- Maintain lower reservoir water levels during the vegetation growing season to preserve current levels of vegetation, with priority given to maintaining existing vegetation at and above 434 m (1424 ft) elevation.
- Maintain lower reservoir levels during the late growing season if vegetation is showing signs of stress as a result of inundation during the early growing season (May to July).

To verify the assumption that soft constraints are effective at maintaining drawdown zone vegetation, and to evaluate how effectively revegetation efforts are meeting the multiple objectives set by the WUP CC, the Committee recommended several effectiveness monitoring programs, including the following two vegetation monitoring programs:

- CLBMON-33 Arrow Lakes Reservoir Inventory of Vegetation Resources
- CLBMON-12 Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis

CLBMON-33 is a 10-year program to assess the impacts of the soft constraints operating regime on existing vegetation in the drawdown zone of Arrow Lakes Reservoir. The primary objective of this project, which was initiated in 2007, is to monitor landscape level changes in the spatial extent, structure, and composition of vegetation communities within the 434-440 m ASL elevation band of the drawdown zone, and to assess if any observed changes are attributable to the soft constraints operating regime. Results of this program will help determine whether changes to the reservoir's operating regime may be required to maintain or enhance existing shoreline vegetation and the ecosystems it supports.

CLBMON-12 is a 10-year program to evaluate planting survivorship and the effectiveness of various revegetation treatments in Arrow Lakes Reservoir at increasing the quantity and quality of self-sustaining vegetation within the drawdown zone. CLBMON-12 is designed to span the period from 2008 to 2017 and to occur in alternating years from 2009 onward. Work completed during the first six years (2008, 2009, 2011, and 2013) is described in Gibeau and Enns (2008), Enns *et al*. (2009), Enns and Enns (2012) and Enns and Overholt (2012; 2013a; 2013b). Here, we report results at the project's 8-year mark (2015 study year).

2.0 PROGRAM OBJECTIVES AND MANAGEMENT QUESTIONS

The primary objective of CLBMON-12 is to assess the short-term effectiveness of the revegetation program at expanding the quality (as measured by diversity, distribution and vigour) and quantity (as measured by cover, abundance and biomass) of vegetation in the drawdown zone for ecological and social benefits (BC Hydro 2005). The specific management questions (MQs) for this monitoring program address whether the continued implementation of the soft constraints allows for the establishment and expansion of vegetation at the site level through a revegetation program in the drawdown zone of Arrow Lakes Reservoir (BC Hydro 2008):

MQ1: What is the quality and quantity of vegetation in revegetated areas between elevations 434 m to 440 m compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?

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

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

MQ4: What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-2, at increasing the quality and quantity of vegetation in the drawdown zone?

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

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

Initially, this monitoring program also assessed the intra-community response of existing vegetation communities to the soft constraints operating regime at the local (site) level (Enns *et al*. 2007). However, commencing in 2015, MQs dealing exclusively with existing vegetation (as opposed to revegetation effectiveness) will instead be addressed by the associated study CLBMON-33, following the recommendations of Enns and Overholt (2013a) and Okanagan Nation Alliance and LGL Limited (2014). This will help reduce the amount of overlap between the two studies, which currently share similar objectives and MQs pertaining to existing vegetation (these being differentiated only by scale, with one set focused on landscape changes and one set focused on local changes). By combining landscape and site level dynamics in a single study (CLBMON-33) and making CLBMON-12 a stand-alone study on revegetation effectiveness, the study designs will also achieve greater alignment with the two analogous vegetation studies CLBMON-10 and CLBMON-9 taking place in Kinbasket Reservoir (Hawkes *et al*. 2013).

2.1 MANAGEMENT HYPOTHESES

Monitoring for the CLBMON-12 project is designed to test the following null hypothesis and associated sub-hypotheses:

H_{01}: Revegetation treatments between elevation 434m and 440m support continued natural recolonization of the drawdown zone.

H_{01A}: There is no significant difference in vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) at control versus treatment locations.

H_{01B}: There is no significant difference in the cover of vegetation in control versus treatment locations.

H_{01C}: There is no significant difference in the cover of vegetation communities and vegetation establishment (based on species distribution, diversity, vigour, biomass and abundance) arising from different revegetation prescriptions.

H_{02}: Reservoir operating conditions have no significant effect on vegetation establishment in revegetated areas between elevation 434m and 440m.

H_{02A}: Vegetation establishment (based on species cover, distribution, diversity, vigour, biomass and abundance) is not significantly affected by the timing of inundation at control and treatment sites.

H_{02B}: Vegetation establishment (based on species cover, distribution, diversity, vigour, biomass and abundance) is not significantly affected by the frequency of inundation at control and treatment sites.

H_{02C}: Vegetation establishment (based on species cover, distribution, diversity, vigour, biomass and abundance) is not significantly affected by the duration of inundation at control and treatment sites.

H_{02D}: Vegetation establishment (based on species cover, distribution, diversity, vigour, biomass and abundance) is not significantly affected by the depth of inundation at control and treatment sites.

3.0 STUDY AREA

Arrow Lakes Reservoir is situated on the Columbia River between Revelstoke and Castlegar, BC (Figure 4-1). The reservoir is ~230 km long and was formed in 1968 by the completion of Hugh Keenleyside Dam, 8 km west of Castlegar. The reservoir includes three main sections: Lower and Upper Arrow Lakes in the south, and Revelstoke Reach in the north. It has a north-south orientation and lies between the Monashee Mountains in the west and the Selkirk Mountains in the east. Two Biogeoclimatic zones occur within the study area: the Interior Cedar Hemlock (ICH) and the Interior Douglas-fir (IDF). Further details on study area climate, physiography, and geology are provided in Enns *et al.* (2007).

4.0 METHODS

4.1 Study Design

Work completed during years 1 to 6 (2008 to 2013) used field sampling and statistical analyses to monitor within-community changes in vegetation composition and abundance, with similar emphasis given to assessing existing vegetation areas and revegetated areas (Gibeau and Enns 2008; Enns *et al*. 2009; Enns and Enns 2012; Enns and Overholt 2013a). This approach, which was a feature of the original terms of reference (BC Hydro 2008), has resulted in some overlap in methods and reported results between CLBMON-12 and its partner study CLBMON-33. This is because the latter program, which is explicitly designed to assess landscape-level dynamics, also incorporates community trend data from local study plots (Enns *et al*. 2007).

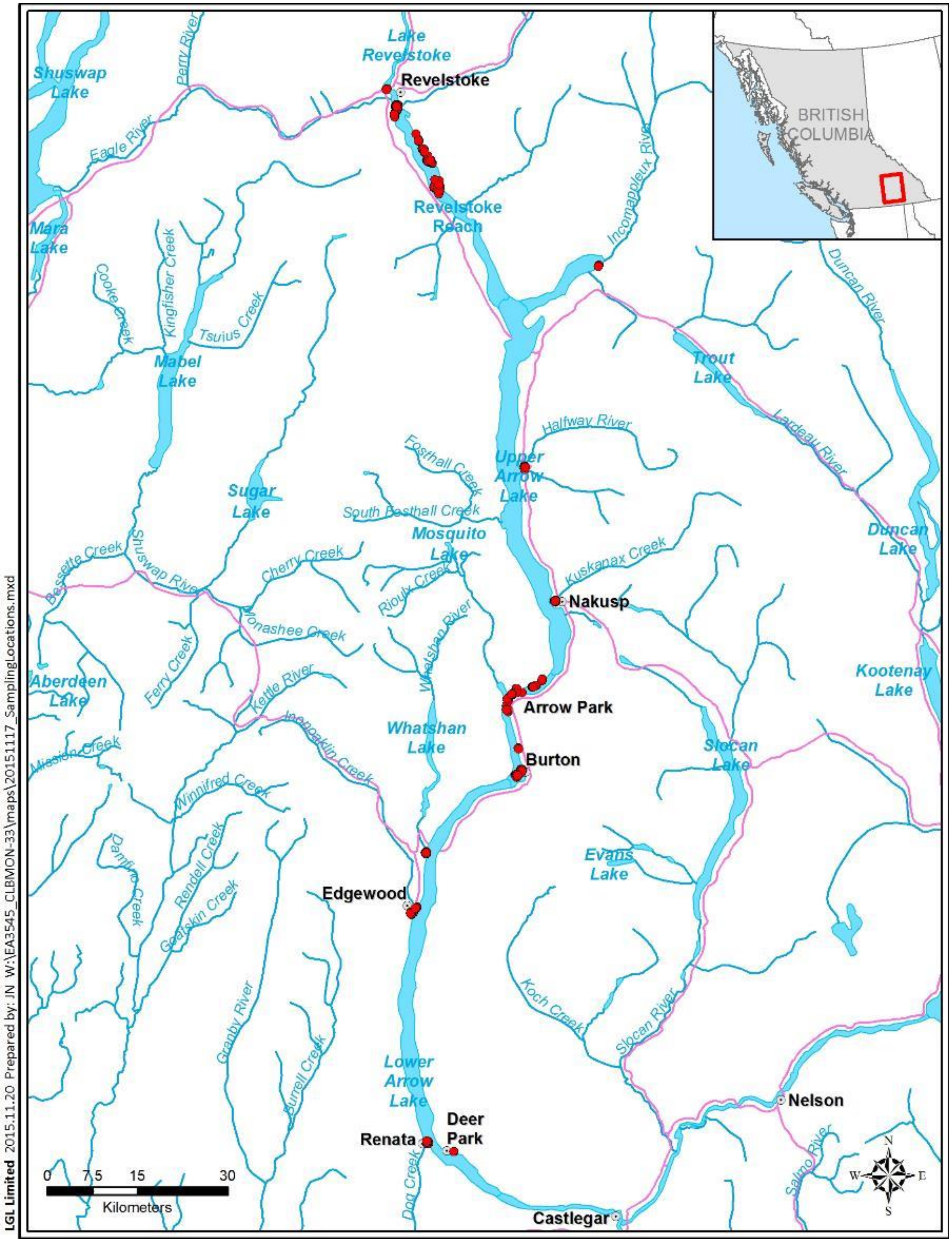

Figure 4-1: Location of the areas sampled under the CLBMON-12 project in the drawdown zone of the Arrow Lakes Reservoir, between Revelstoke Dam and Castlegar, B.C. Red dots are the 2015 monitoring locations

The present study design follows the same general approach of previous years. However, to reduce redundancies between CLBMON-12 and CLBMON-33, the primary emphasis in 2015 was on effectiveness monitoring of revegetation efforts. A number of existing vegetation plots continued to be monitored as before but these served primarily as a supplemental background reference for trends occurring within revegetation and control (i.e., treatment) plots. The specific objectives of the 2015 field sampling were: (1) to revisit previously established plots (treated, control, and existing vegetation) within all treatment elevations and community types at representative areas of the drawdown zone between Deer Park and Revelstoke; (2) to record plant composition, cover, and biomass within sample plots; (3) and to estimate revegetation survivorship (planted plugs and live stakes). The following specific questions were addressed:

1. Has the revegetation program been effective, to date, at expanding the quality (as measured by diversity and composition) and quantity (as measured by cover and biomass) of vegetation in the drawdown zone for ecological and social benefits?
2. To what extent is revegetation effectiveness influenced by soft constraint reservoir operations (i.e., hydroperiod)?

Site selection for 2015 was based on those areas treated under CLBWORKS-2. A year-by-year summary of this planting program is provided in Appendix 10.1. The sites were within one of 43 designated study areas selected by BC Hydro for long-term vegetation monitoring (Enns *et al*. 2007). A total of 22 sites, 16 of which were revegetation sites, were monitored on both sides of the reservoir between Deer Park in the south and Montana Slough, just south of Revelstoke (Figure 4-1).

Sampling was stratified geographically between the two major landscape units, Revelstoke Reach and Arrow Lakes. The specific reservoir locations visited in 2015 were (from south to north): Deer Park, Renata, Edgewood (north and south), Lower Inonoaklin, Burton (north and south), Fairhurst Creek, Arrow Park (east and west shore), Nakusp, Beaton Arm, Drimmie Creek (12 Mile), Duncan Flats (8 Mile and 9 Mile), Cartier Bay, West Revelstoke, Illecillewaet River, and Big Eddy.

Sample plots at each site (representing a combination of treated, control, and existing vegetation sites) were a subset of those previously monitored by Enns and Overholt (2013a and previous), stratified by treatment type, vegetation community type, and elevation. Sampling effort was focused on sites with a substantial concentration of established permanent plots, to reduce the time required for travelling to and accessing sites represented by just a single or a very few plots.

At the selected locations, 320 plots with a long-term field sampling history (i.e., established in 2011 or earlier) were identified as candidates for resampling. Over half (185) of these consisted of treated and control sites; the rest were existing vegetation sites. To ensure time series continuity, only treated and control plots that were previously sampled up to and including 2013 were selected for resampling. Most existing vegetation plots had been last sampled in 2013, with the exception of a small number of plots that were last sampled in 2011.

As in previous years, the current study employed the community classification system developed by Enns *et al.* (2007) and subsequently modified by Enns *et al.* (2010). The various Vegetation Community Types (VCTs) are detailed in Appendix 10.2.

4.2 Reservoir Operations

Historical daily water levels during 2004–2015 measured at the Fauquier elevation gauge within the Arrow Lakes reservoir were used to assess the influence of seasonal reservoir elevations on revegetation effectiveness.

4.3 Field Sampling

Field sampling sessions were timed to correspond generally with sampling in previous study years. Vegetation sampling occurred during two field sessions: 21–30 May and 5–9 June, when the reservoir elevation was between 432.6 and 435.3 m ASL. A crew of four workers participated in the field sampling sessions. Site access was via truck and walk-ins. Predetermined sample points were located in the field using a hand held GPS receiver (Garmin GPSMap 60CSx).

4.3.1 Existing Vegetation Plots

Existing vegetation was sampled within 10 m x 5 m (50 m^2) plots established around each predetermined plot centre (using the supplied UTM coordinates). Plots were assessed for plant species composition/cover and selected topo-edaphic characteristics. Plot data were entered onto a field data form (Appendix 10.3) following a modified version of the standards in B.C. Ministry of Environment, Lands, and Parks and B.C. Ministry of Forests (2010).

Percent cover, measured as the percentage of the ground surface covered when the crowns are projected vertically, was visually estimated and rounded as follows: <1% - traces; 1-10% - rounded to nearest 1%; 11-30% - rounded to nearest 5%; 31-100% - rounded to nearest 10%. Percent covers were considered additive due to overlapping crowns and final tallies for species and layers could exceed 100% cover. Other attributes collected at each sample location are listed in (Table 4-1).

4.3.2 Treated plots

The same data as described above for existing vegetation plots was collected for all treated (revegetation) plots. In addition, we assessed survivorship of plantings. Planting survivorship was assessed by tallying the number of live plugs and/or stakes of each planted species and, where still visible, the number of dead plugs and/or stakes. As most non-surviving plugs and stakes were no longer evident (having rotted or floated away in years previous), and could not be accurately tallied, this assessment was generally limited to a count of surviving individuals. The abundance of surviving plugs and stakes within plots/polygons was later converted to density/Ha using the known sample dimensions. We then compared these values to the initial average stocking densities previously reported for various treatment types (Keefer Ecological Services Ltd. 2011) to derive an indirect estimate of survivorship. For sedge plugs, reported average stocking density was 11,770 plugs/Ha. For cottonwood stakes, average stocking density was 1,125 stems/Ha, and for cottonwood seedlings, average stocking density was 2,944 stems/Ha (Keefer Ecological Services Ltd. 2011).

Along with survivorship, overall vigour of each planted species was also recorded, following the vigour categories presented in Table 4-1

Table 4-1: Attributes collected for plot samples using field data form

Attribute	Unit / Category
Date	
Surveyor(s)	
Plot number	
Waypoint and UTM coordinates	Easting and northing
Vegetation community type (VCT)	See Appendix 10.2 for VCT categories
Plot type	Treated, control, existing
Treatment type	Sedge plugs, cottonwood seedlings, cottonwood live stakes, willow stakes
Photo numbers	Photos taken from centre of plot facing north, east, south, west; also vertically looking down
Aspect (heat load)	Degrees, used to estimate heat load. Heat load = $(1-\cos(\theta-45))/2$, where θ = aspect.
Slope	Degrees
Soil moisture regime	Very xeric, xeric, subxeric, submesic, mesic, subhygric, hygric, subhydric, hydric
Primary water source	Precipitation, surface seep, stream sub-irrigation, stream surface flooding
General surface topography	Concave, convex, straight
Microtopography	Smooth, channeled, gullied, mounded, tussocked
Terrain texture	Boulders, cobble, gravel, fines, sand, silt, clay, mud, wood, organics
Scouring, erosion, or deposition	Qualitative evidence of scouring, erosion, or deposition – yes or no
Site disturbance	Qualitative evidence of non-operational site disturbance (ATV, wildlife, etc.) – yes or no
Species cover	Per cent cover
Total cover by stratum	Per cent cover (tree layer, shrub layer, herb layer)
Structural stage	Sparse/pioneer, herb, low shrub, tall shrub, pole/sapling, young forest, mature forest, old forest

Biomass[1]	Sample dry weight (g)
Planting survival/abundance[1]	No. live/dead
Planting vigour[1]	Categorical code: 0 (dead), 1 (poor), 2 (fair), 3 (good), (excellent)
Stake polygon location/dimension[1]	UTM coordinates of each polygon corner

[1] Treated sites only

Cottonwood plantings could be either in the form of planted seedlings or live stakes (Keefer Ecological Services Ltd. 2011). As reported by Enns *et al*. (2012), older treatments were not always distinguishable from untreated vegetation, given that treatment plants had no tags, pins, or other markings. If the plants were found in relatively uniform rows or in a grid-like pattern of planted plugs, the area was assumed to have been treated. However, in some cases it was not possible to tell if an area mapped as treated had in fact been treated (Enns *et al*. 2012).

For consistency with previous implementation years, at some locations where live stakes (cottonwood and willow) were planted in numerous or large areas, we recorded stake survivorship in two ways: first by using the 5 m x 10 m vegetation plots, as described above; and then by conducting additional stake counts over the larger area. The stake-planted areas are typically rectangular, with the long axis oriented along the 436-m to 438-m elevation band (Enns *et al*. 2012). For each staked area selected for supplemental sampling, we identified a representative rectangular area, marked the boundaries with flagging tape, recorded the corner locations with GPS, then counted the number of live and dead stakes (all species present). The sample polygons ranged in size from 200 m^2 to 1,500 m^2.

Along with plug counts, biomass samples were collected from each treated plot. Within the 10 m x 5 m plot, a 0.5 m x 0.5 m (0.25 m^2) subplot was established at a random grid location (using pairs of grid numbers blindly drawn from a bag). All aboveground herbaceous vegetation within the 0.25 m^2 subplot was clipped at ground level and placed inside a pre-weighed, labelled paper bag. Sample bags were place in the sun to dry over several days (an effective drying method given the very hot dry weather experienced in May and June), then transported to the lab for further drying and weighing.

4.3.3 2015 Fall Sampling

In 2015, the elevation of Arrow Lakes Reservoir peaked at 435.48 m, more than 4.5 m below the normal operating maximum of 440.1 m (Figure 5-1). The low annual maximum provided an unexpected opportunity (several months after completion of the regular scheduled spring surveys) to assess short-term effects of flooding versus non-flooding on plant composition, survival, growth, and reproduction.

BC Hydro requested that ONA/LGL conduct a follow-up survey in the fall of 2015 to take advantage of the unusually low water levels. The specific objective of the survey was to compare the state of late season vegetation above and below the 435.48 contour line (2015 reservoir maximum). Assessments would be both quantitative and qualitative with additional follow-up sampling to occur in spring 2016 (as part of CLBMON-33 implementation).

A comparison of conditions at sites inundated in 2015 relative to sites nearby that were not inundated allows the exploration of several questions relevant to the soft constraints operating regime, such as: (1) Does vegetation exhibit any immediate short term benefits in terms of plant diversity, vigour, height, cover, or release from competition (e.g., from reed canarygrass), etc. as a consequence of not being inundated for one growing season? (2) How does lack of inundation affect patterns of fall flowering, seed production, and seed dispersal? (3) Do different community types appear to respond differently in the absence of inundation? (4) Does a lack of inundation benefit revegetated areas?

The survey was conducted between October 2 and 7, 2015, when the elevation of Arrow Lakes Reservoir was ~429 m. Vegetation was sampled at seven locations between Revelstoke Reach and Edgewood: 8Mile, 9 Mile and 12 Mile in Revelstoke Reach; and Halfway River, East Arrow Park, Burton, and South Edgewood in Lower Arrow.

Sampling occurred as follows: a subset of the permanent plots sampled in May and June 2015 were selected based on their elevation relative to the 435.48 m summer water maximum. Plots situated above the maximum were paired, where possible, with an adjacent plot belonging to the same community and type and situated below the inundation line. Data collection followed the methods employed during the 2015 May/June session with regard to species cover estimations. In addition, average stem heights (cm), plant vigour (qualitative scale), and current reproductive status (per cent non-flowering, flowering, fruiting, dispersing) were estimated for all species recorded within each plot pairing. This process was replicated with respect to both revegetation and existing vegetation plots where possible.

To compare the two vegetation states (inundated and non-inundated) more directly, an additional series of belt transects was established running perpendicular to the elevation gradient and across the 435.48 m contour line. One half of each transect was positioned directly below the contour line, the other half directly above the line. Each transect segment ranged in length from 12 to 30 m and was subsampled using three evenly spaced 4 m x 0.5 m (2 m^2) quadrats. Transect locations were chosen during the course of sampling as representative examples of the local vegetation gradient.

At each general location, additional qualitative assessments were made by surveyors traversing selected sections of the 435.48 m contour line and using their professional expertise to visually assess inundation impacts.

4.4 Statistical Analyses

Differences in plant cover (total cover and cover by layer) and biomass, as well as in species richness, diversity (Shannon's index), and evenness, among plot types (treated, control, and existing vegetation), vegetation communities (described in Appendix 10.2), landscape units (Revelstoke Reach and Arrow Lakes), and elevation bands (434-436, 436-438, and 438-440 m ASL) were tested with a series of two-way unbalanced analyses of variance (ANOVAs). ANOVAs were tested with 9,999 permutations.

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

Regression trees (De'ath and Fabricius 2000) were used to explore the influence of various topo-edaphic variables on revegetation survivorship. The environmental variables considered were elevation band, location, vegetation community type, heat load (aspect), slope, surface topography, microtopography, water source, soil moisture, presence of erosion or deposition, disturbance type, structural stage, moss cover, and substrate texture. This approach is detailed in Appendix 10.4.

For the fall survey data, within-season differences in plant cover, height, and reproductive effort (per cent flowering or fruiting) among sites above and below the maximum line of inundation were tested using ANOVAs as above. Differences in vigour, a categorical variable, were tested using 2x2 contingency tables.

Analyses were performed in R version 3.2.2 (R Development Core Team 2015) with statistical significance set at $\alpha=0.05$.

5.0 RESULTS

5.1 Reservoir Operations

Water levels in Arrow Lakes Reservoir between 2008 and 2015 (Figure 5-1) show considerable variability in elevation across years. However, water levels typically rise quickly from approximately the beginning of May each year, and peak during mid-late July before gradually subsiding throughout the remainder of the summer and fall. The 10 to 90 percentile range indicates daily differences in water levels of up to ~8 m across years. The reservoir exceeded the normal operating maximum during July 2012. In 2015, water levels peaked on 13 June at 435.48 m, remaining at or above 435.4 m for a total of six days before receding (Figure 5-1).

The proportion of time each 1-m elevation band between 434 and 440 m was above water during each month from May to September is shown in Table 5-1. In most years, exposure time began to decrease in June each year with most of the lowest six elevation bands (434-439 m) completely inundated in July. Receding water levels after this time result in increased exposure time during August and again in September. In 2015, in contrast, all but the lowest elevations (434-435 m) were fully exposed for the entire growing season (Table 5-1).

5.2 Revegetation Survivorship

Sedge plugs: Survival rates of sedge plugs have been highly variable across sites (Figure 5-2). Live sedge densities ranged from 0 (in many locations) to 15,800/Ha (one site at Burton). The mean live density across all plots and elevations was 2441/Ha (*n*=48), implying an overall survival rate of ~21 per cent since planting (noting that planting could have occurred either in 2008, 2009, 2010, 2011, or at multiple times over this period).

In Arrow Lakes, mean live densities were highest for the mid elevation band and lowest for the high elevation band, implying a 4-7 year survival rate of ~27 and ~3 per cent, respectively (Table 5-2). However, sample size for the high elevation band (438-440 m) was small (n=2) due to an inability to distinguish natural from planted sedges in many cases (which may have resulted in an underestimate of survivorship for that elevation band), and differences among elevation bands were not statistically significant.

Sedge plugs introduced into the low elevation band in Revelstoke Reach appeared to perform slightly worse than those at similar elevation in Arrow Lakes, with an estimated 4-7 year survival rate of ~17 per cent (Table 5-2). Differences among elevation bands in Revelstoke Reach were not tested statistically due to the low sample sizes available for mid and upper elevations (where a number of plots were not assessed for sedge survival due to the difficulty of distinguishing planted from natural vegetation).

Cottonwood stakes (plots): Live cottonwood stake densities in the permanent monitoring plots were also variable (Figure 5-2), ranging from 0 (several locations) to 3600/Ha (one site at Fairhurst Creek in Lower Arrow Lakes). The mean live density across all plots and elevations was 720/Ha (*n*=30), implying an overall survival rate of ~64 per cent since planting (noting that planting could have occurred either in 2008, 2009, 2010, 2011, or at multiple times over this period).

In Arrow Lakes, mean live stake densities were higher at mid than at high elevation, with an estimated 4-7 year survival rate of 91 and 47 per cent, respectively. In Revelstoke Reach, mean densities were similar for the mid and high elevation bands, implying a 4-7 year survival rate of 49 and 61 per cent, respectively (Table 5-2). Differences among elevation bands were not statistically significant.

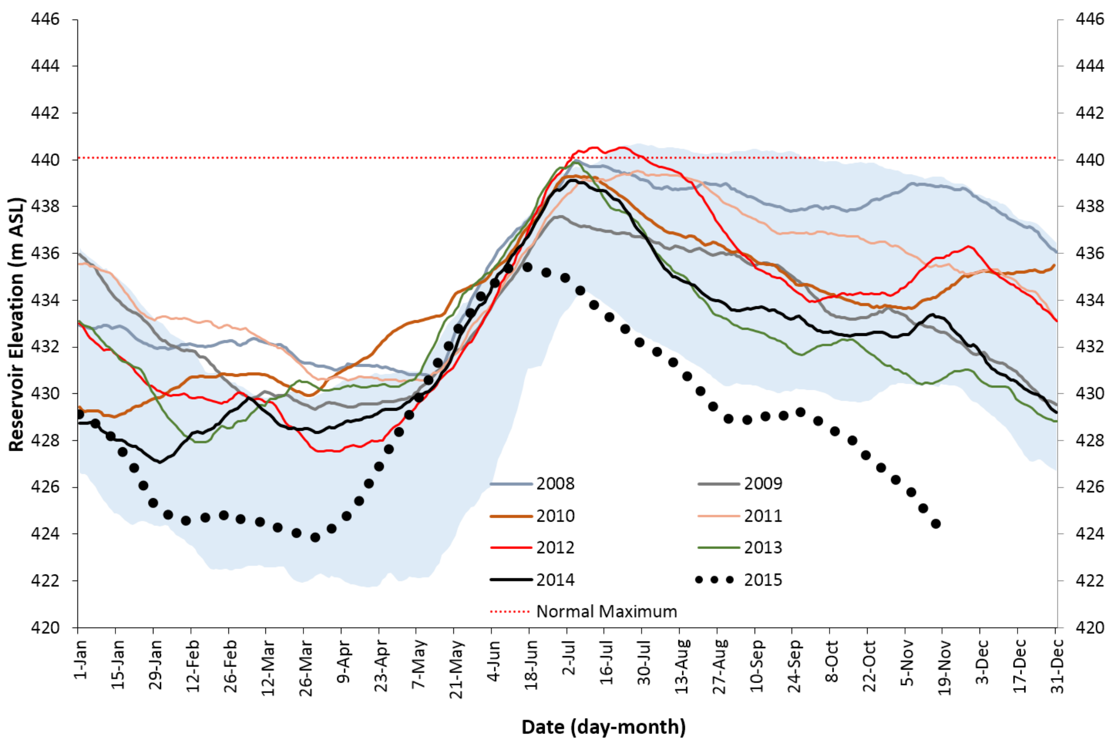

Figure 5-1: Daily water levels in Arrow Lakes Reservoir shown by year for 2008–2015. Water level data for 2015 (dotted black line) were available to 19 November only at the time of this draft report. The shaded strip in the figure illustrates the range of the daily 10th and 90th percentile of water levels across all years. The dotted red line indicates the normal maximum operating level of the reservoir (440.1 m ASL)

Table 5-1: Proportion of monthly days that each 1-m elevation band from 434–440 m ASL in Arrow Lakes Reservoir was above water for the months of May – September, 2007– 2015. Cells are colour-coded by proportion: red: < 0.1 or ~0-3 days; yellow: 0.1–0.9 or ~3-27 days; green: > 0.9 or ~28-31 days

Month	Elevation (m ASL)	2007	2008	2009	2010	2011	2012	2013	2014	2015
May	440	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	439	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	438	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	437	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	436	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	435	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	434	0.94	0.87	1.00	0.61	1.00	1.00	0.71	1.00	0.94
June	440	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	439	1.00	0.97	1.00	0.93	1.00	0.83	0.80	1.00	1.00
	438	0.67	0.73	1.00	0.73	0.90	0.70	0.63	0.77	1.00
	437	0.37	0.40	0.73	0.53	0.70	0.57	0.47	0.60	1.00
	436	0.20	0.17	0.57	0.33	0.50	0.43	0.27	0.40	1.00
	435	0.10	0.00	0.37	0.07	0.30	0.27	0.00	0.17	0.23
	434	0.00	0.00	0.13	0.00	0.13	0.13	0.00	0.03	0.00
July	440	1.00	1.00	1.00	1.00	1.00	0.10	1.00	1.00	1.00
	439	1.00	0.00	1.00	0.55	0.16	0.00	0.61	0.77	1.00
	438	0.10	0.00	1.00	0.16	0.00	0.00	0.45	0.29	1.00
	437	0.00	0.00	0.58	0.00	0.00	0.00	0.03	0.10	1.00
	436	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	435	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
	434	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68
August	440	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	439	1.00	0.94	1.00	1.00	0.32	0.45	1.00	1.00	1.00
	438	1.00	0.00	1.00	1.00	0.00	0.26	1.00	1.00	1.00
	437	0.61	0.00	1.00	0.81	0.00	0.10	1.00	1.00	1.00
	436	0.23	0.00	0.19	0.00	0.00	0.00	0.90	0.90	1.00
	435	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.68	1.00
	434	0.00	0.00	0.00	0.00	0.00	0.00	0.32	0.23	1.00
September	440	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	439	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	438	1.00	0.40	1.00	1.00	0.97	1.00	1.00	1.00	1.00
	437	1.00	0.00	1.00	1.00	0.47	1.00	1.00	1.00	1.00
	436	1.00	0.00	1.00	0.87	0.00	0.87	1.00	1.00	1.00
	435	0.90	0.00	0.23	0.27	0.00	0.47	1.00	1.00	1.00
	434	0.50	0.00	0.00	0.00	0.00	0.03	1.00	1.00	1.00

Cottonwood seedlings: Live cottonwood seedling densities were highly variable, ranging from 0 (the majority of locations, including all Arrow Lakes sites) to 3600/Ha at 9 Mile in Revelstoke Reach. The mean live density of seedlings was 400/Ha (*n*=15), yielding an overall survival rate of ~14 per cent. However, in Revelstoke Reach, seedlings introduced to the mid elevation band had an estimated survival rate of ~35 per cent (Table 5-2). Differences among elevation bands and between regions were not tested statistically due to lack of replication.

Cottonwood stakes (sample polygons): Live cottonwood stake densities in the additional sampled polygons ranged from 200 to 1500 stems/Ha (Figure 5-3). The mean live density of stakes across all polygons was 754/Ha (*n*=26), implying a 4-7 year survival rate of 67 per cent (comparable to the survival rate estimated for permanent plots, above).

Establishment success appeared to be especially good at high elevation sites in Arrow Lakes (Figure 5-3, Table 5-2). Differences among elevation bands and between regions were not tested statistically due to insufficient replication.

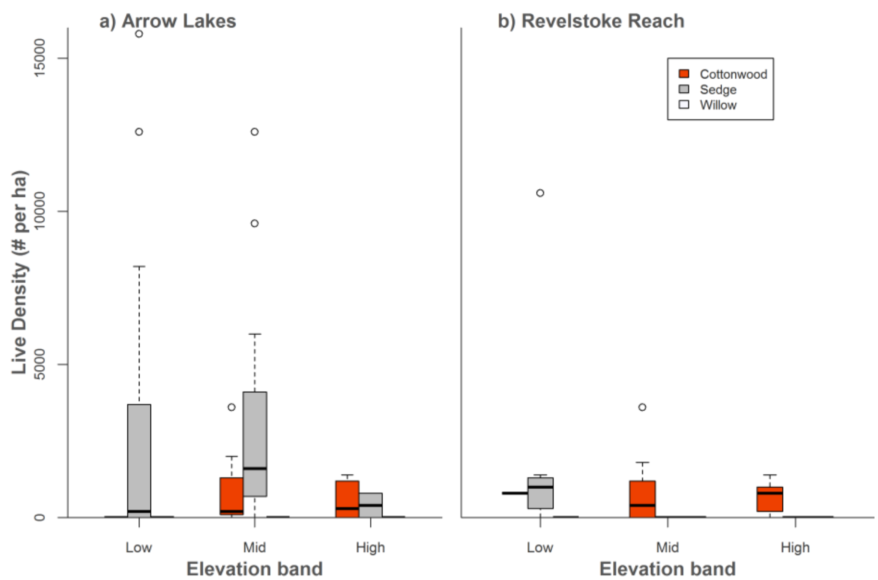

Figure 5-2: Variation in planting survival (density of live stems per Ha) among elevation bands and treatment types in a) Arrow Lakes, and b) Revelstoke Reach landscape units in 2015

Regression trees were useful in highlighting several topo-edaphic and habitat variables potentially associated with high (or low) revegetation survival rates (Figure 5-4). Densities (per Ha) of persisting sedge plugs (as a proxy for survival rates) tended to be relatively high in habitats characterized by tussocked microtopography (implying prior presence of other clumping sedges) and somewhat gravelly substrates (as opposed to fine, unanchored sand); or alternatively, on cool (northerly) aspects in terrain not overly affected by sand deposition or erosional forces (Figure 5-4). The regression tree explained a fairly large proportion of the variation in plug densities (R^2=0.48).

Soil moisture, substrate texture, and aspect (heat load) were the primary predictors of surviving cottonwood and willow stake densities (Figure 5-5). Densities tended to be relatively high on moderately moist to dry soils characterized by some silt content; on wet to dry substrates with low sand content (and presumably higher silt, clay, or loam content); or on sandier substrates combined with cool (northerly) aspects. Densities tended to be lower on moderately dry substrates with low silt content, and on sandy, southerly aspects (Figure 5-5). As with plugs, the regression tree analysis explained only some of the variation in stake densities (R^2=0.52), indicating that other factors not considered in this analysis (e.g., planting techniques, condition of stock, years since planting, surveyor error, original planting densities, reservoir operations, weather, etc.) were also likely important.

Table 5-2: Estimated 4-7 year survival rates for different treatment types (sedge plugs, cottonwood stakes, and cottonwood seedlings) based on recorded live (surviving) treatment densities within survey plots, for Arrow Lakes and Revelstoke Reach in 2015. Survival rates calculated by dividing the estimated, per Ha live densities by the reported, per Ha average stocking densities (Keefer Ecological Services Ltd. 2011)

Landscape unit	Treatment type	Elevation band (m ASL)	*n*	Live density (per Ha)	Survival rate (%)
Arrow Lakes	Sedge plugs	434-436	27	2757	23
		436-438	15	3227	27
		438-440	2	400	3
Revelstoke Reach		434-436	8	1975	17
		436-438	2	0	0
		438-440	--	--	--
Arrow Lakes	cottonwood stakes (plots)	434-436	1	0	0
		436-438	9	1022	91
		438-440	6	533	47
Revelstoke Reach		434-436	1	800	71
		436-438	4	550	49
		438-440	9	688	61
Arrow Lakes	cottonwood seedlings	434-436	6	0	0
		436-438	2	0	0
		438-440	--	--	--
Revelstoke Reach		434-436	--	--	--
		436-438	5	1040	35
		438-440	2	400	14
Arrow Lakes	cottonwood stakes (polygons)	434-436	1	600	53
		436-438	5	601	53
		438-440	4	787	70
Revelstoke Reach		434-436	--	--	--
		436-438	2	610	54
		438-440	6	401	36

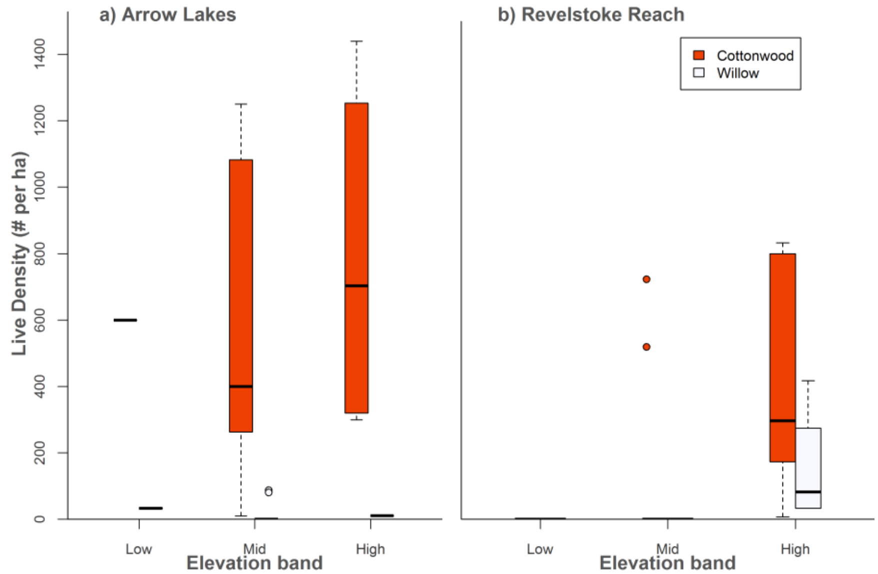

Figure 5-3: Variation in live stake densities (number per Ha) obtained from additional sample polygons in a) Arrow Lakes, and b) Revelstoke Reach landscape units in 2015. See text for details on polygon sampling. Low = 434-436 m ASL; Mid = 436-438 m ASL; High = 438-440 m ASL

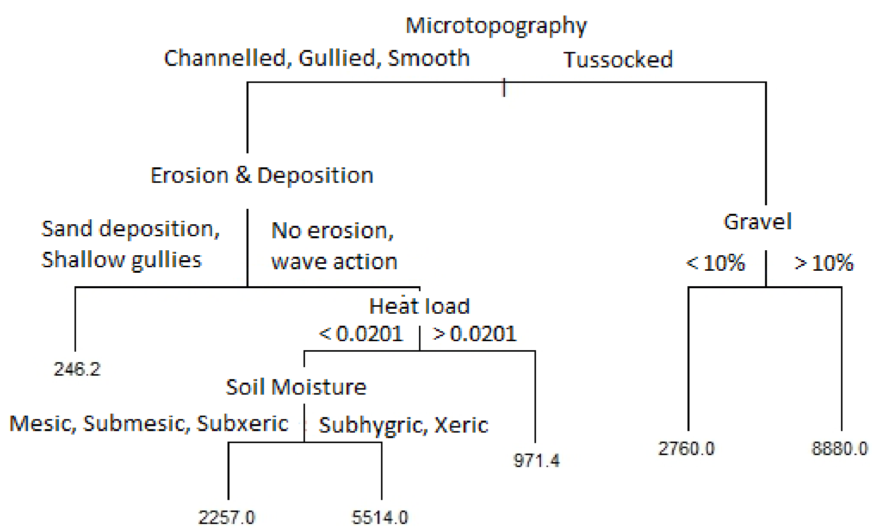

Figure 5-4: Multivariate regression tree of the surviving sedge plug densities per Ha (proxy for plug survival rates) associated with different topo-edaphic and habitat variables (surface topography, microtopography, elevation, slope, heat load, soil texture, soil moisture, water source, moss cover, evidence of erosion or deposition, and evidence of disturbance; see Table 4-1 for details). The length of the vertical lines associated with each split graphically approximates the proportion of total sum of squares explained by each split; the longer the line, the more variance the split is explaining. Numbers at the terminal points are the plug densities/Ha. Counts of surviving plugs within 50 m^2 sample plots were used to estimate the per Ha densities, which should be interpreted as relative values only

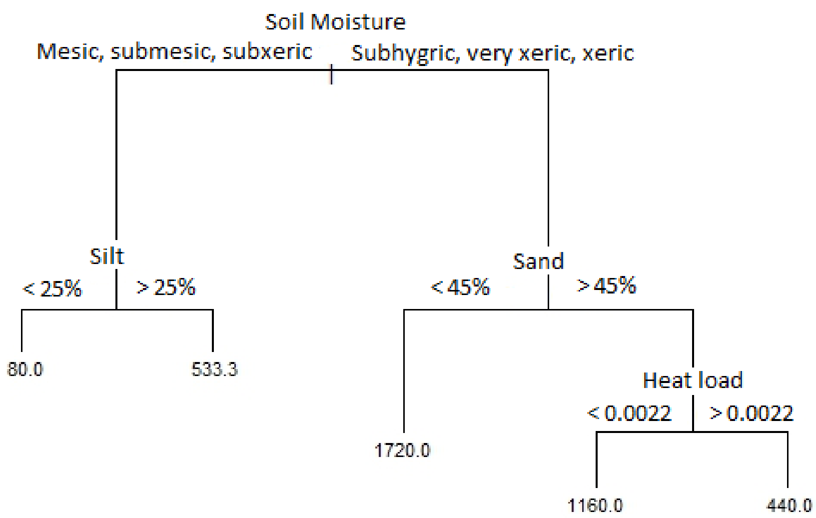

Figure 5-5: Multivariate regression tree of the surviving cottonwood and willow stake densities per Ha (proxy for plug survival rates) associated with different topo-edaphic and habitat variables (surface topography, microtopography, elevation, slope, heat load, soil texture, soil moisture, water source, moss cover, evidence of erosion or deposition, and evidence of disturbance; see Table 4-1 for details). The length of the vertical lines associated with each split graphically approximates the proportion of total sum of squares explained by each split; the longer the line, the more variance the split is explaining. Numbers at the terminal points are the plug densities/Ha. Counts of surviving plugs within 50 m^2 sample plots were used to estimate the per Ha densities, which should be interpreted as relative values only

5.3 Community Responses to Planting Treatments

5.3.1 Cover

Despite some local successes in plug and stake establishment, there was little indication that revegetation treatments have led to an overall increase in vegetation cover within treated areas at any elevation. Total vegetation cover was similar across plot types (treated, control, and existing vegetation) in the low elevation band (434-436 m), but was actually lower in treated plots at the mid (436-438 m) and high (438-440 m) elevation bands (Figure 5-6). Differences in total cover were statistically significant among elevation bands (F=3.2, p=0.042) and among types of plots (F=8.6, p=0.00036). Interactions were not significant.

There is no immediate causal explanation as to why, four or more years following treatment, treated areas should exhibit a trend toward lower covers than control areas, although a similar finding was reported by Enns and Overholt (2013). It is possible that treated and control plots were not always appropriately paired and thus some of these differences were already inherent prior to treatment application (Enns and Overholt 2013).

A similar apparent neutral to negative effect was obtained after stratifying by landscape unit: vegetation cover was similar or lower in treated than control plots, irrespective of landscape unit (Figure 5-7). In general, cover was slightly higher for all plot types in Revelstoke Reach compared to Arrow Lakes. In Revelstoke Reach, though not in Arrow Lakes, existing vegetation plots appear to have higher cover than treated or control plots (Figure 5-7). This may reflect the greater preponderance of existing dense stands of Reed canarygrass in Revelstoke Reach (Miller *et al*. 2015), which were probably less proportionately likely to be targeted for treatment applications than less vegetated areas (Keefer Ecological Services Ltd. 2011).

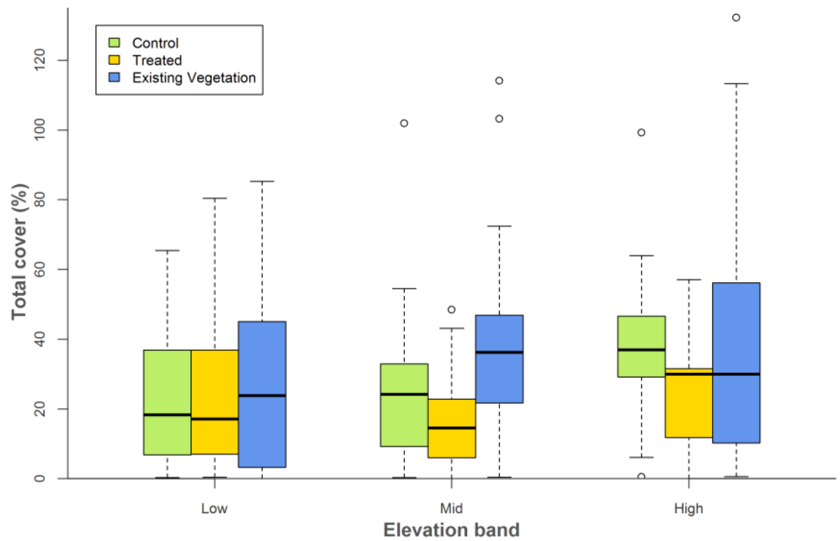

Figure 5-6: Variation in total per cent cover of vegetation in control, treated, and existing vegetation plots among the three monitored elevation bands in Arrow Lakes Reservoir. Low = 434-436 m ASL; Mid = 436-438 m ASL; High = 438-440 m ASL

Differences in cover were statistically significant between reaches (F=16, p=0.00009), and among types of plots (F=11.9, p=0.00001). Interactions were also significantly different (F=3.7, p=0.026). Cover was not statistically different among control, treated, and existing plots in Arrow Lakes (p>0.05), but was different for Revelstoke Reach (F=13.3, p=0.0001), likely because of the higher cover in existing vegetation plots.

We then considered differences in cover between pairs of treated and control plots specifically, by computing the per cent differences between treatment pairs and displaying this graphically as boxplots for different elevations and community types (Figure 5-8). There were a limited number of treated plots at all elevations where cover was higher than in their paired control, but in more cases the opposite was true. The positive difference in cover between control and treated plots appeared to increase with elevation, suggesting that control plots had increasingly more cover compared to treated plots as the elevation increased (Figure 5-8, left panel). At high elevation, the differential was generally greater for Arrow Lakes than for Revelstoke Reach.

Cover in the BE—sandy beach VCT control plots was almost always higher than in their paired treated plots at low and mid elevation, although this was not the case for the small number sampled at high elevation (Figure 5-8, right panel). Within the PC—Reed Canarygrass mesic VCT, treated plots had slightly greater cover at low

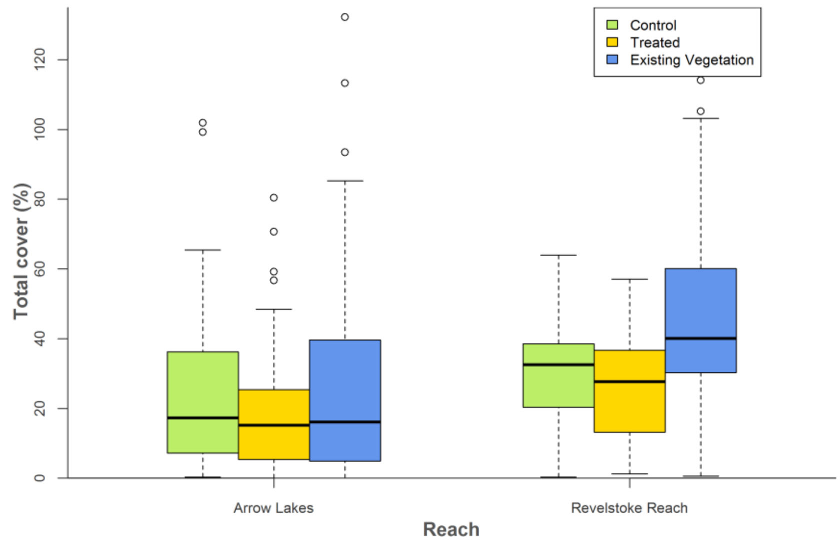

Figure 5-7: Variation in vegetation cover (%) in control, treated, and existing vegetation plots in the Arrow Lakes and Revelstoke Reach landscape units in 2015

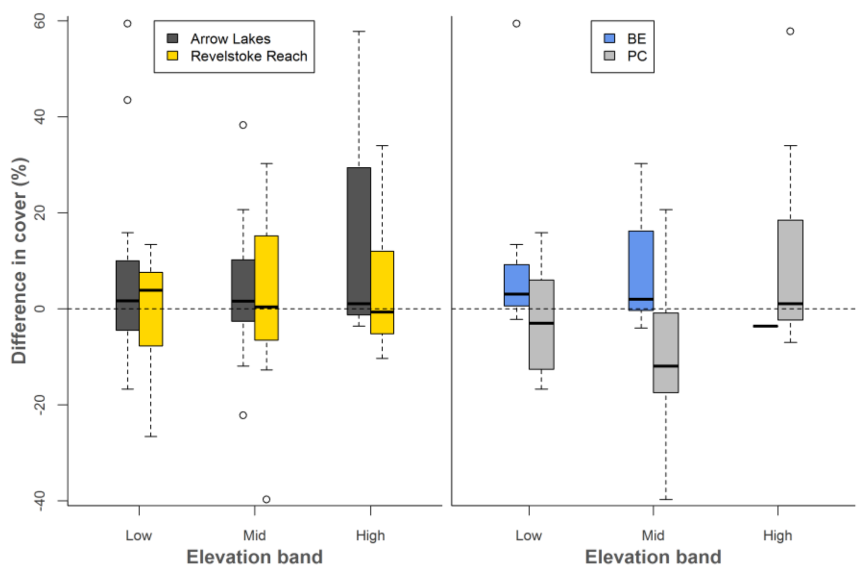

Figure 5-8: Difference in cover between control and treated plots, expressed as a positive or negative per cent value, for different elevation bands in the Arrow Lakes and Revelstoke Reach landscape units (left panel), and between the two VCTs BE—sandy beach and PC—Reed Canarygrass mesic (right panel) in 2015. Positive values indicate higher cover values for the control plots; negative values indicate higher values for the treated plots. Only BE and PC are assessed in the right pane as they were the only VCTs sampled at all three elevation bands; for the left panel, all community types were included. Low = 434-436 m ASL; Mid = 436-438 m ASL; High = 438-440 m ASL

elevation, but lower cover than their paired control plots at mid and high elevations. The relatively high vegetation cover within low elevation PC treatments may be due to past in-fill planting of sedge plugs within sparsely vegetated segments of this community type (Keefer Ecological Services Ltd. 2011).

When cover differences were stratified by vegetation layer (herb vs. shrub layers), herb cover varied significantly among plot types in Revelstoke Reach ($F=3.7$, $p=0.029$) but not in Arrow Lakes (Figure 5-9). The interaction was significant ($F=4.97$, $p=0.001$). Post-hoc, one-way ANOVAs indicated that the cover differences in Revelstoke Reach were only statistically significant at mid elevation ($F=11.6$, $p=0.0001$), where the difference appears to be due to higher cover within existing vegetation plots.

There appeared to be slightly higher shrub cover related to revegetation activities within the upper elevation band in Revelstoke Reach, but not elsewhere in the study area (Figure 5-9). Live stakes were previously reported to have survived better at high elevations (Keefer Ecological Services Ltd. 2011); this differential initial success may now be manifesting itself in the comparatively higher shrub cover seen at some upper elevation sites. However, shrub cover in treated plots remains less than that in adjacent existing vegetation plots: differences in shrub layer cover were statistically significant for control, treated, and existing plots in Revelstoke Reach ($F=7.8$, $p=0.0065$), and most of this difference was likely due to the higher cover in existing vegetation plots (Figure 5-9).

5.3.2 Biomass

Revegetation treatments do not appear to have resulted in any substantial increases to herbaceous biomass within the study area. Average biomass within plots (estimated from three biomass subsamples and excluding woody plants) was slightly greater in upper elevation plots compared to low or mid elevations, but was similar for both treated and control plots at all elevations (Figure 5-10). Differences in biomass were statistically significant among elevation bands ($F=3.4$, $p=0.038$) but not between control and treated plots.

5.3.3 Richness

Species richness was generally similar among all plot types and elevation bands, and was on average around between 7 and 10 species per plot (Figure 5-11). Richness was statistically different among control, treated, and existing plots at low elevation ($F=4.2$, $p=0.016$) but not at mid or high elevations.

In pairwise comparisons, species richness in Revelstoke Reach was higher in treated plots than in their paired control plots at low and high elevations, though not at mid elevation (Figure 5-12, left panel). The differences appear to be due largely to differences within the PC—Reed Canarygrass community type, which showed a similar trend of higher species richness in treated plots at low and high elevations (Figure 5-12, right panel).

The apparent slight positive effect of revegetation on richness at low elevations may be due in part to the introduction of sedge species (via planting of plugs) into communities where these species were not successfully establishing on their own (e.g., sparsely vegetated regions of PC—Reed Canarygrass mesic habitat). At high elevations, the slight positive effect on richness in Revelstoke Reach is likely due in part to the introduction of cottonwood and willow species to otherwise

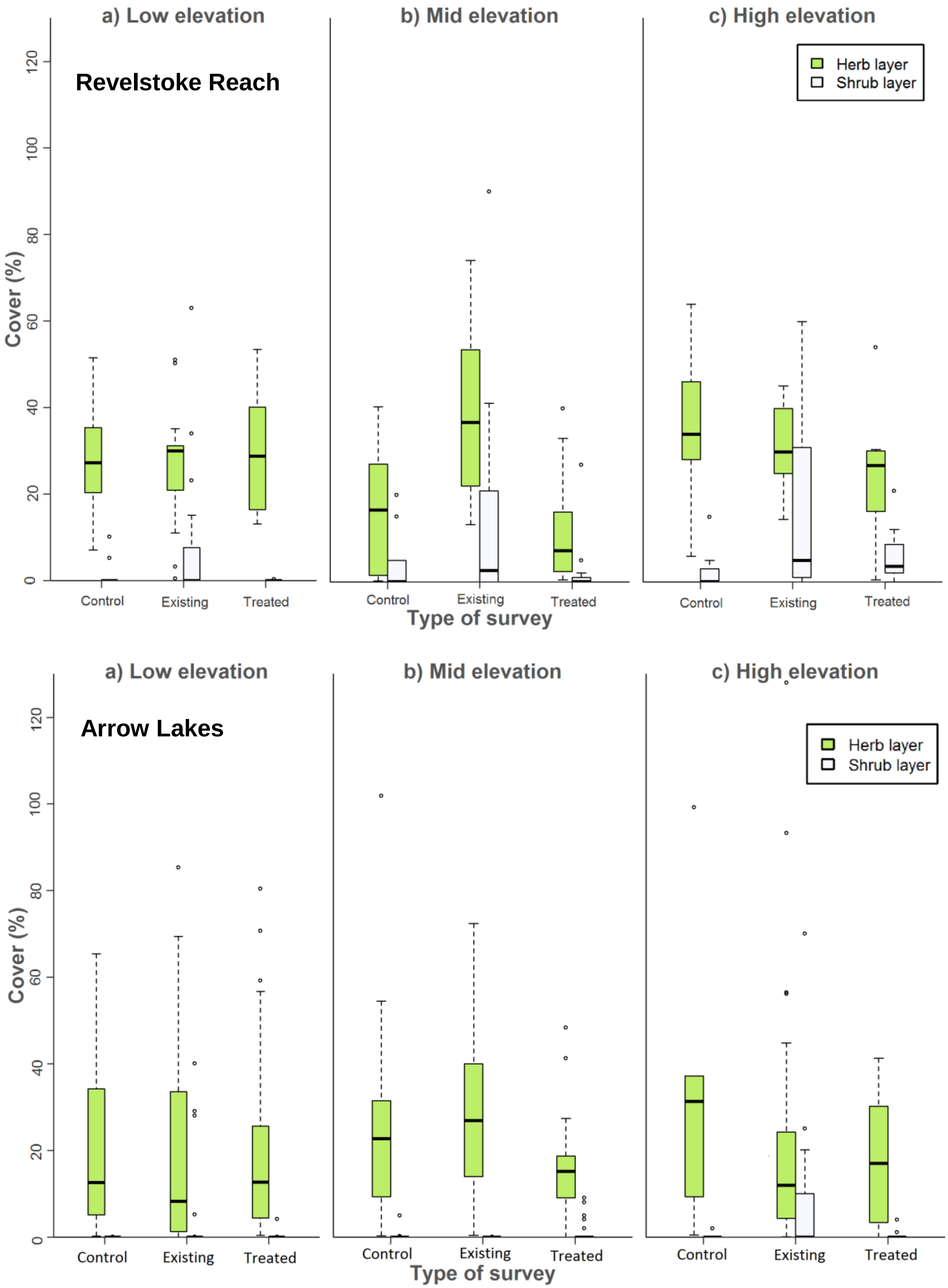

Figure 5-9: Variation in per cent cover of vegetation per layer, elevation, and type of plots in the Arrow Lakes (lower panel) and Revelstoke Reach (upper panel) landscape units in 2015. Low = 434-436 m ASL; Mid = 436-438 m ASL; High = 438-440 m ASL

depauperate reed canarygrass-dominated habitats via live staking (Keefer Ecological Services Ltd. 2011). It is possible that the presence of treatment species is acting in some areas to facilitate colonization by other species, leading to an increase in richness over time, although minor differences more likely reflect natural variation between treatment and control plots (Enns et al. 2009). To more clearly distinguish treatment from background effects, a retrospective analysis of yearly plot data should be conducted in the final implementation year to compare trajectories in species composition over time within treated and control plots.

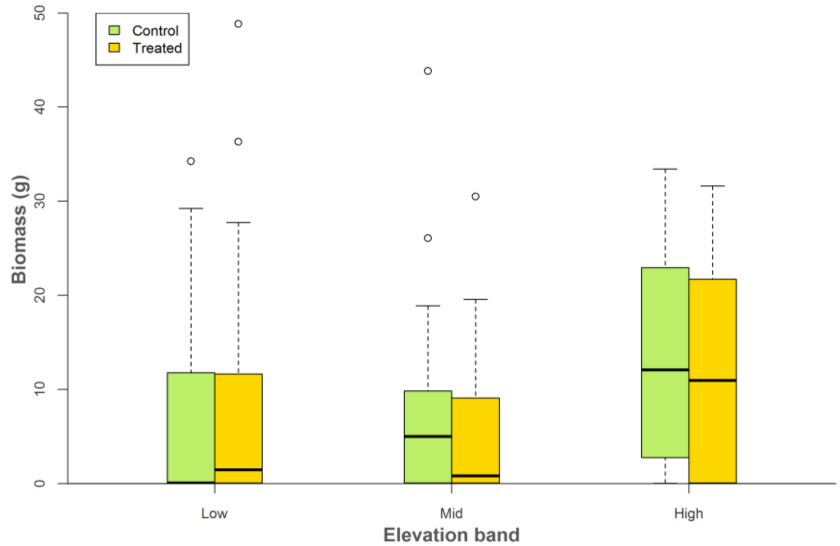

Figure 5-10: Variation in biomass (g) of herbaceous vegetation in control and treated plots among elevation bands in Arrow Lakes Reservoir in 2015. Low = 434-436 m ASL; Mid = 436-438 m ASL; High = 438-440 m ASL

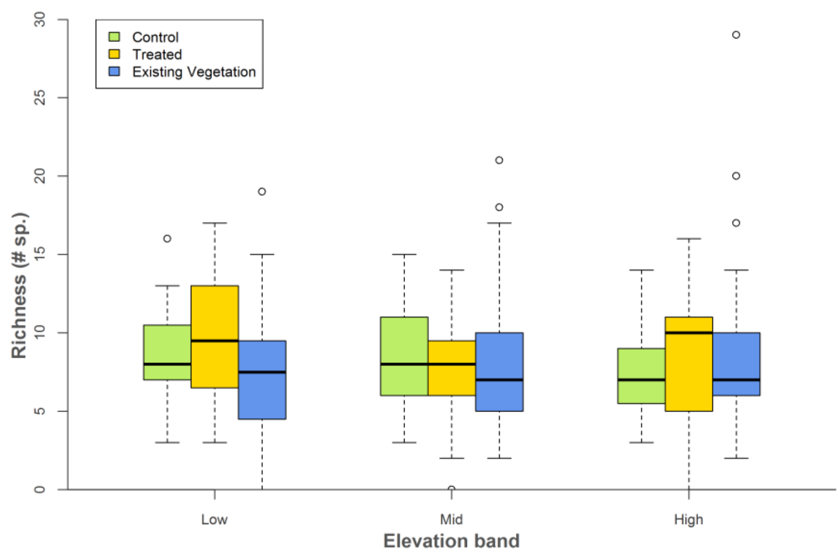

Figure 5-11: Variation in species richness (number of species) in treated, control, and existing vegetation plots among low (434-436 m), mid (436-438 m), and high (438-440 m) elevation bands in Arrow Lakes Reservoir in 2015

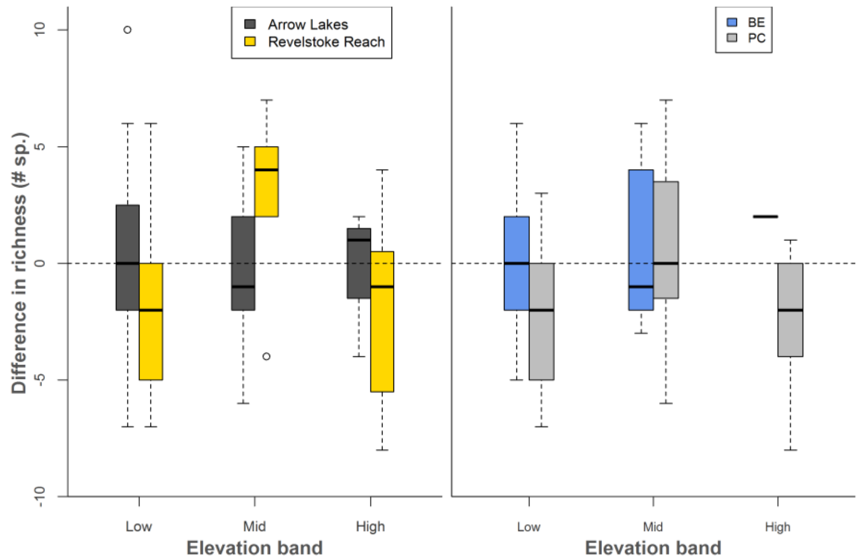

Figure 5-12: Difference in species richness (number of species) between control and treated plots, expressed as a positive or negative value, for different elevation bands in the Arrow Lakes and Revelstoke Reach landscape units (left panel), and between the two VCTs BE—sandy beach and PC—Reed Canarygrass mesic (right panel) in 2015. Positive values indicate higher cover values for control plots; negative values indicate higher values for treated plots. Only BE and PC are assessed in the right pane as they were the only VCTs sampled at all three elevation bands; for the left panel, all community types were included. Low = 434-436 m ASL; Mid = 436-438 m ASL; High = 438-440 m ASL

5.3.4 Diversity

To date, revegetation treatments appear to have had limited effect on the overall plant diversity (Shannon's H) of monitored plots; diversity was variable but was generally similar (H≈0.5) between treated and control plots (Figure 5-13). Differences in diversity were statistically significant among elevation bands (diversity tends to be higher at high elevations: F=3.2, p= 0.038) but not among the three plot types. However, treated plots were more likely to be dominated by one or a few species than control or existing vegetation plots (Appendix 10.5).

In pairwise comparisons of treated and control plots, treated plots in Arrow Lakes (though not in Revelstoke Reach) appeared to be more diverse at high elevations than their paired control plots (Figure 5-14, left panel). Comparing community types, the diversity of PC (Reed Canarygrass mesic) treated plots was usually higher than in their paired control plots at low elevation, whereas the diversity of BE (sandy beach) treated plots was actually lower than that of control plots at both low and mid elevations (Figure 5-14, right panel).

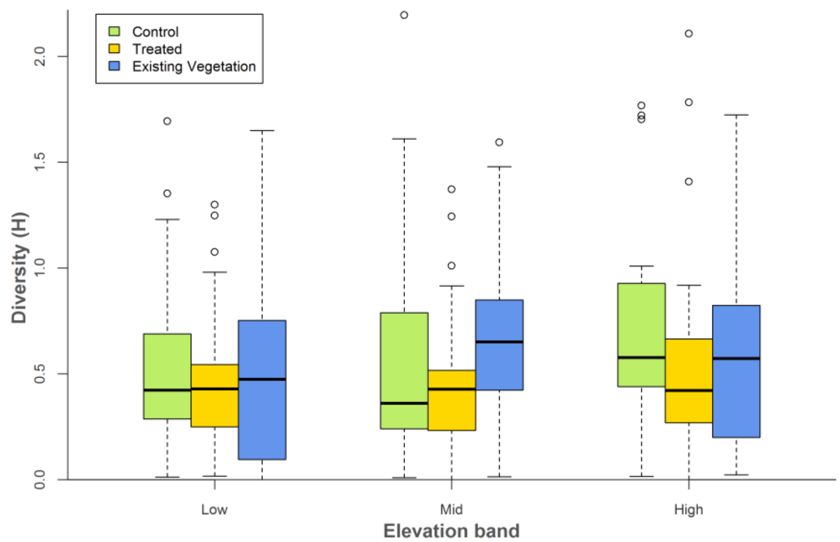

Figure 5-13: Variation in diversity (H) in control, treated, and existing vegetation plots among low (434-436 m), mid (436-438 m), and high (438-440 m) elevation bands in Arrow Lakes Reservoir in 2015. Low = 434-436 m ASL; Mid = 436-438 m ASL; High = 438-440 m ASL

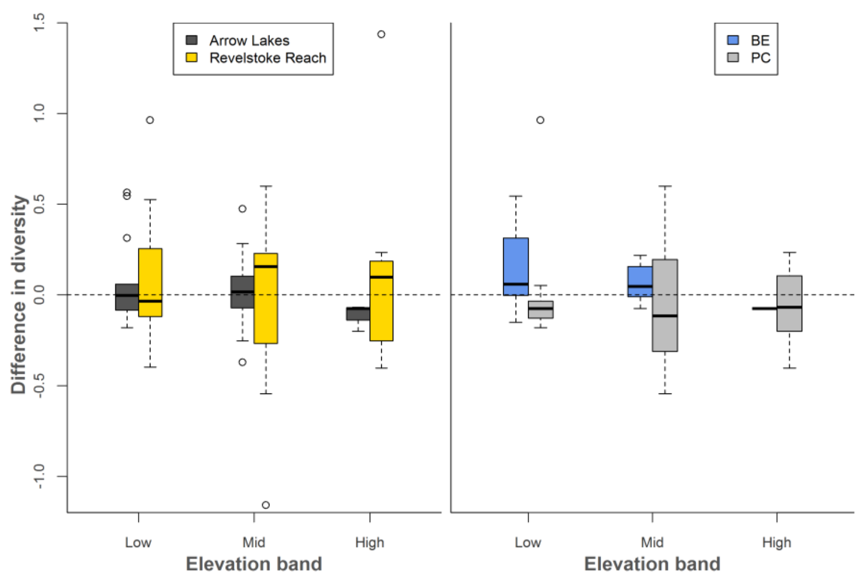

Figure 5-14: Difference in diversity (H) between control and treated plots, expressed as a positive or negative value, for different elevation bands in the Arrow Lakes and Revelstoke Reach landscape units (left panel), and between the two VCTs BE—sandy beach and PC—Reed Canarygrass mesic (right panel) in 2015. Positive values indicate higher cover values for control plots; negative values indicate higher values for treated plots. Only BE and PC are assessed in the right pane as they were the only VCTs sampled at all three elevation bands; for the left panel, all community types were included. Low = 434-436 m ASL; Mid = 436-438 m ASL; High = 438-440 m ASL

5.4 Fall Sampling

A total of 72 plots were resampled just above or below the 435.48 m contour line (maximum line of inundation) during the post-inundation October survey. In addition, 16 new transects spanning the contour line were established and sampled.

Vegetation growing above the 2015 flood line appeared, in general, to benefit from the yearlong release from inundation. Having undergone a full summer growth cycle, perennial herbs and grasses (e.g., reed canarygrass) displayed overall vigorous growth often with numerous intact (or dispersing) seed heads. Live cottonwood stakes and other deciduous plantings were still in leaf and, presumably, photosynthesizing. On some steeper slopes, we observed a distinct line of new growth demarcating the non-inundated and inundated zones (Figure 5-15, left panel).

Interestingly, at many low-elevation, sedge-dominated sites a vigorous band of vegetation was also evident just below the 2015 flood line. This band, occurring around 434-435 m, was still relatively lush and green in early October and could be visually distinguished from the non-inundated elevation band just above by its fresher-looking foliage (Figure 5-15, right panel). Within this band, a number of (mainly annual) species were re-germinating and/or undergoing a late-season flowering pulse (Figure 5-16, left panel) and several perennial graminoids such as Kellogg's sedge (Figure 5-16, right panel) were in the process of dispersing seed. Evidently, the brief (week-long) inundation did not unduly limit photosynthesis or otherwise stress the plants in this band. Furthermore, the increase in the amount of available soil moisture following inundation may have allowed some species to extend their growing season into the fall, suggesting that in some cases the short-term benefits of brief inundation may exceed or at least equal those accruing from non-inundation.

Figure 5-15: Left panel: woody debris demarcates line of maximum inundation in 2015 at Arrow Park, Arrow Lakes Reservoir, above which more advanced seasonal grass growth is visible. Right panel: a vigorous band of Kellogg's sedge just below the 2015 flood line at Burton, illustrating the possible benefits of brief inundation for some species. Blue arrows indicate inundated area; yellow areas indicate non-inundated area

Figure 5-16: Left panel: newly-germinated moss grass (*Coleanthus subtilis*) seedlings at ~435 m ASL, Burton, October 2015. In its Arrow Lakes habitat, Moss Grass (a provincially Blue-listed species) typically germinates in the spring following winter draw-down of the reservoir. This is the first reported observation of fall germination. Right panel: Kellogg's sedge following summer inundation at ~435 m ASL, Burton, October 2015

In the paired transect samples, average per cent cover of vegetation (all species combined) tended to be higher in transects below the 2015 flood line than above it (Figure 5-17). Vegetation heights, vigour, and reproductive success were similar above and below the flood line (Figure 5-17). The elevation differences in all of these traits tended to be site-specific and were not statistically significant (tests not shown). However, geographic location appeared to be an important factor in determining how vegetation responded to the absence of inundation at the local scale. Brief inundation appeared more likely to have a relative positive impact on overall cover, and a relative negative impact on plant heights and reproduction, in the more southerly sites (lower Arrow Lakes) than in Revelstoke Reach (Figure 5-17). Spatial differences in cover ($F=3.98$, $p=0.017$), height ($F=10.9$, $p=0.0004$), and reproduction ($F=3.6$, $p=0.026$) were all statistically significant, although the interactions between inundation "treatment" and location were non-significant.

We next separately assessed the impacts of non-inundation on within-year performance of two dominant drawdown zone species: reed canarygrass and Kellogg's sedge. Measured response variables for reed canarygrass did not differ significantly between inundated and non-inundated samples (Figure 5-18). Similar to the pooled vegetation, differences among sites were statistically significant with respect to cover ($F=8.6$, $p=0.0009$) and height ($F=9$, $p=0.001$).

In contrast, there were strong indications that Kellogg's sedge may have benefited from brief summer inundation; cover, height, vigour, and reproductive activity all tended to be higher in samples below the 2015 flood line (Figure 5-19). Differences were statistically significant in the case of both cover ($F=5.75$, $p=0.03$) and height ($F=12.8$, $p=0.002$).

5.5 Management Hypotheses

5.5.1 Hypothesis H_{01}: Revegetation treatments between elevation 434m and 440m support continued natural recolonization of the drawdown zone.

There is currently no strong evidence to support this hypothesis: in general, revegetation treatments appear to be having a neutral impact with respect to the natural recolonization process.

No statistically significant differences were identified between plot types with respect to total vegetation cover, diversity, or biomass. Species richness was slightly higher in treated compared to control sites at certain elevations in Revelstoke Reach, and some of this difference may be due to the introduction of new species through revegetation activities. However, while there are numerous cases of plantings persisting 4-7 years post-treatment, as yet there have been no examples observed of successful recruitment (a necessary precondition for achieving self-sustaining populations).

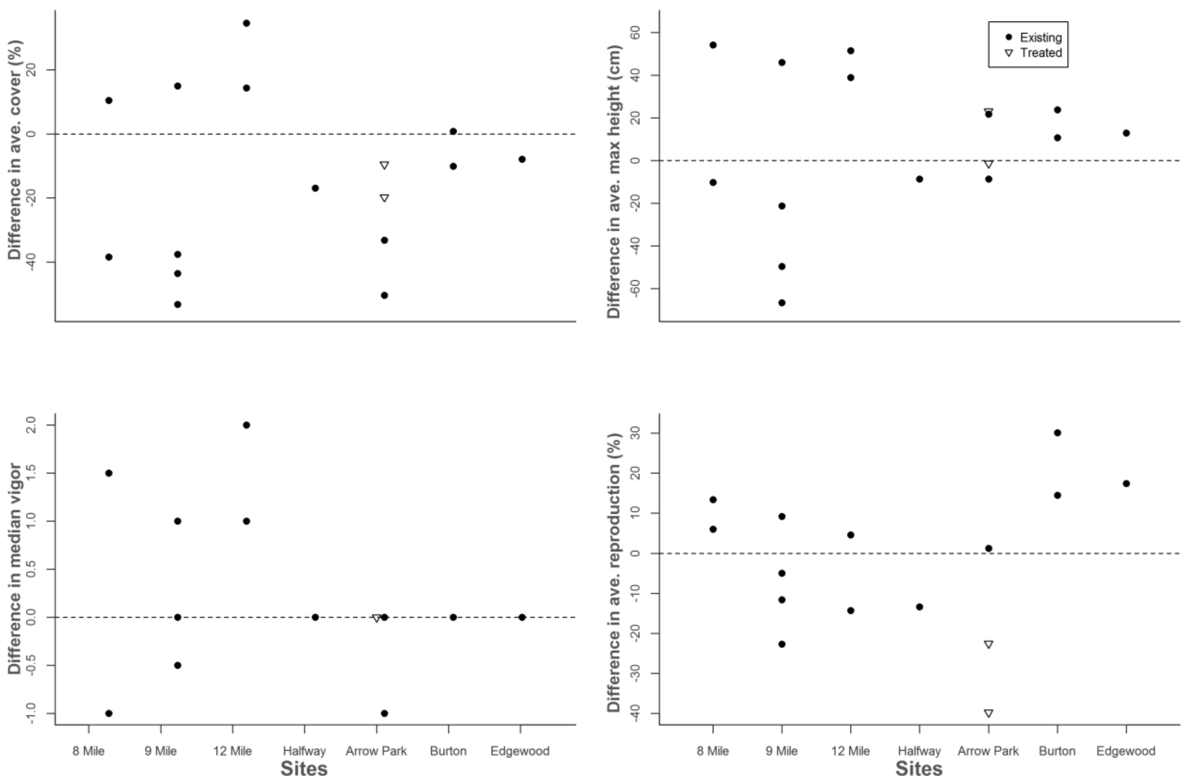

Figure 5-17: Differences in average cover, height, vigour, and reproduction (estimated as the per cent of individuals either flowering or dispersing seed) in paired transect samples of vegetation (all species) growing above and below the 2015 maximum line of inundation (435.48 m). Positive values indicate higher values for the >max transects; negative values indicate higher values for <max transects. Sites are ordered geographically from north to south

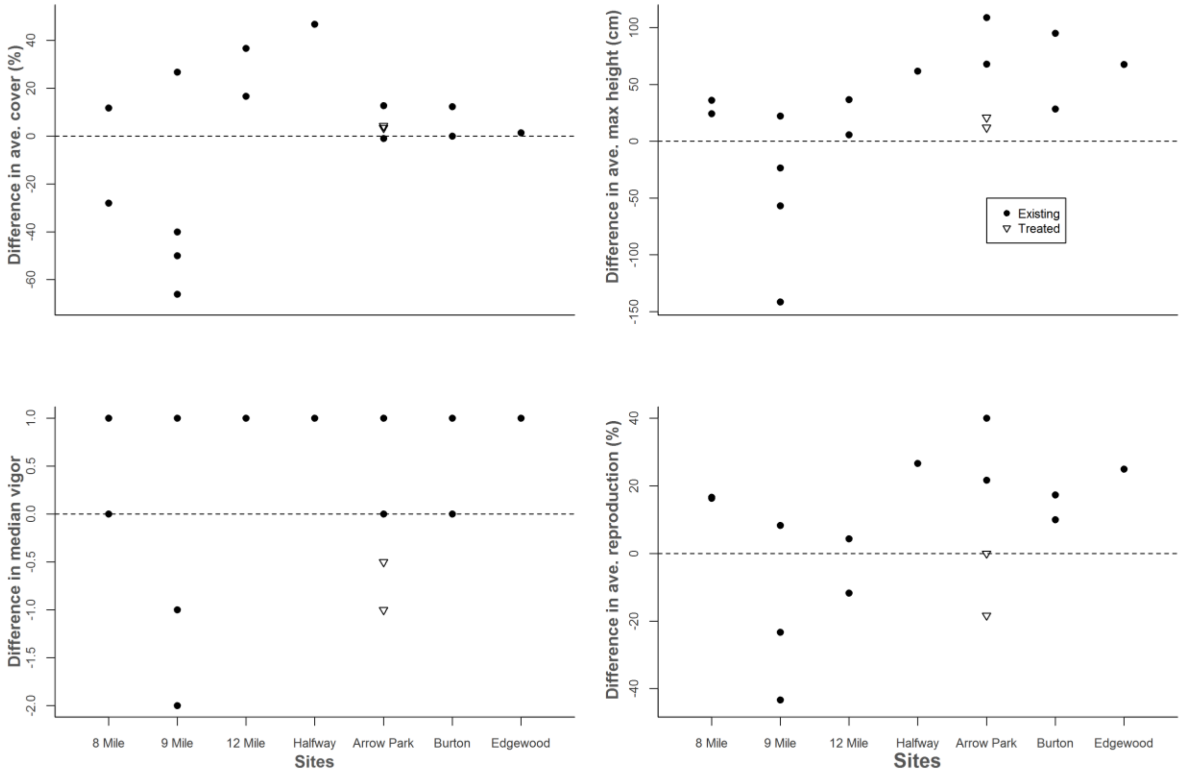

Figure 5-18: Differences for reed canarygrass in average cover, height, vigour, and reproduction (estimated as the per cent of individuals either flowering or dispersing seed) in paired transect samples below and above the 2015 maximum line of inundation (435.48 m). Positive values indicate higher values for the >max transects; negative values indicate higher values for <max transects. Sites are ordered geographically from north to south

5.5.2 Hypothesis H_{02}: Reservoir operating conditions have no significant effect on vegetation establishment in revegetated areas between elevation 434m and 440m.

This hypothesis, and its four associated sub-hypotheses (Section 2.1), cannot be directly tested statistically due both to insufficient experimental replication (both temporal and spatial) and the confounded nature of the four aspects of reservoir operations (inundation depth, duration, timing, and frequency).

However, there is indirect evidence that operating conditions have affected vegetation establishment in revegetated areas, which is that total vegetation cover, diversity, and herbaceous biomass tended to increase with elevation (i.e., with increased exposure time). Compared to higher elevations, the low elevation band is inundated earlier in the growing season and remains inundated for longer periods each year, implying a negative relationship between early/prolonged inundation and the likelihood of revegetation establishment. These elevation-specific differences generally outweighed observed differences between treated and non-treated plots at the same elevation, suggesting that reservoir operations have been more effective at structuring drawdown plant communities than have the various planting prescriptions to date.

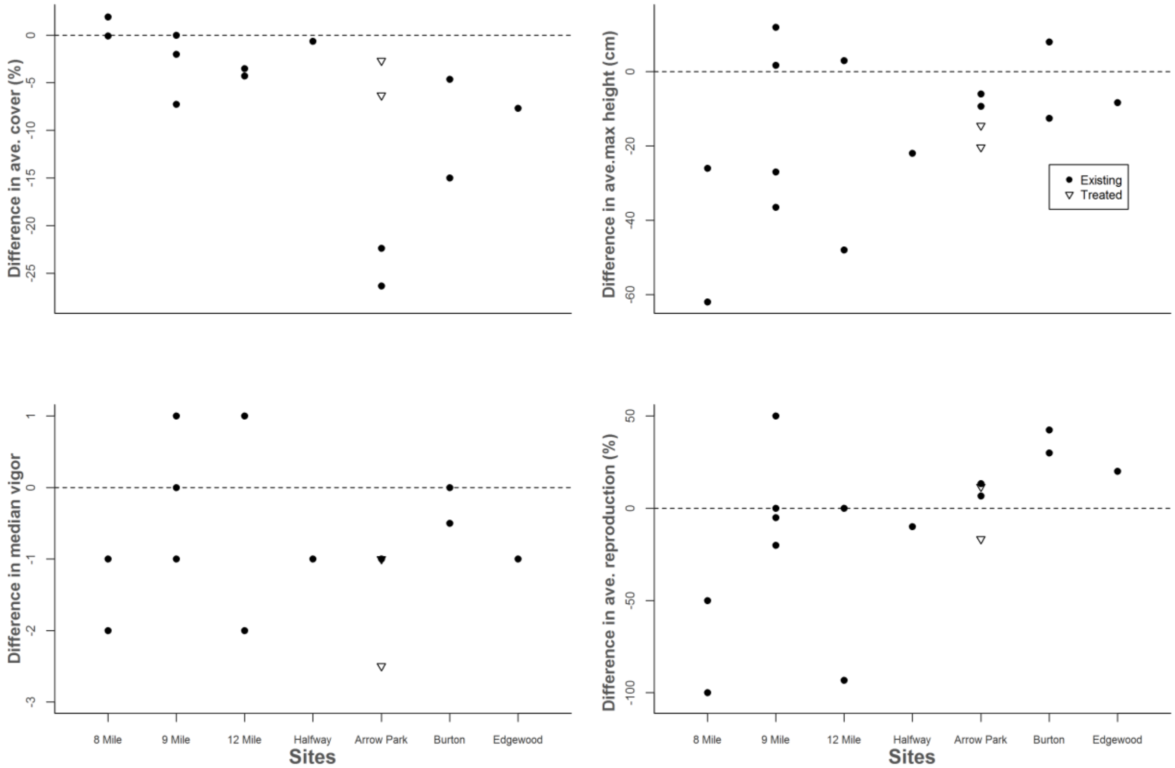

Figure 5-19: Differences for Kellogg's sedge in average cover, height, vigour, and reproduction (estimated as the per cent of individuals either flowering or dispersing seed) in paired transect samples below and above the 2015 maximum line of inundation (435.48 m). Positive values indicate higher values for the >max transects; negative values indicate higher values for <max transects. Sites are ordered geographically from north to south

6.0 DISCUSSION

The 2015 results for CLBMON-12 are discussed below in relation to the specific management questions (Section 2.0), which have been addressed to a varying degree in previous reports (Enns *et al*. 2009; Enns and Enns 2012; Enns and Overholt 2013a). The objective is not to re-summarize these earlier results, but rather to highlight any new or relevant findings from the most recent investigations.

6.1 Survival

The estimated survivorship of sedge plugs 4 to 7 years after planting was, on average, about 21 per cent, while that of cottonwood stakes was about 64 per cent.[1] Local survival rates varied greatly across locations, with numerous samples showing minimal to no survival and others indicating relatively high establishment success. Some, although not all, of this variation appeared to be tied to elevation, implying an operational effect (elevation can be regarded as a proxy for operating

[1] Note that, in most instances, the exact starting densities of plantings were unknown, which meant that mortality could not be assessed directly. Instead, survival rates had to be estimated indirectly, using the reported average planting densities as a baseline. Therefore, these survival values are best regarded as a relative rather than an absolute measure of revegetation effectiveness.

conditions because low elevations are inundated earlier, for longer periods, and to greater depth than high elevations). Thus, plantings of Kellogg's and Columbia sedge seemed to survive best at mid to low elevation in the drawdown zone (while noting that sampling of the high elevation band [436-438 m] was limited due to an inability to distinguish natural from planted vegetation in some areas), whereas cottonwood plantings tended to do best at mid to high elevation.

Such results are consistent with the expected tolerances of these taxa to extended inundation. Both Kellogg's and Columbia sedge are found naturally at all reservoir elevations between 424 m and 440 m but are generally most abundant at mid elevation (434-438 m), where they not only tolerate, but likely benefit from, intermediate levels of seasonal inundation. At lower elevations, sedges have only a brief window of opportunity during the spring months to establish and grow before being flooded for the season. At higher elevations, they are more likely to encounter soil moisture deficits in combination with increased competition from aggressive perennials such as reed canarygrass. Cottonwood, which likely copes less well with severe immersion but with deeper root systems capable of utilizing ground water sources, is much more likely to occur naturally along upper elevation bands where the annual inundation periods are briefer and shallower.

Due to the small sample sizes available for some treatment-elevation combinations, formal testing of elevational differences was not possible in all cases and these conclusions are therefore somewhat tentative. Further, because the original planting treatments were not replicated on an annual basis, it is difficult to correlate variation in their success to annual variations in the soft constraints operating regime, or to separate statistically the impacts of inundation on revegetation performance from numerous other environmental factors.

These factors include indirect operational effects such as erosive scouring, silt deposition, water energy, and floating wood debris; and non-operational effects such as off-road vehicle disturbance, pests (e.g., meadow voles and insects), planting methods (e.g., hand versus machine planting), and substrate texture (e.g., sand, silt, clay, or gravel). For example, meadow voles (sub-family *Arvicolinae*) were reported to be a significant detriment to cottonwood stake survival in Revelstoke Reach, where up to 1,284 live stakes were estimated to have been damaged or killed by girdling at ground-level (Keefer Ecological Services Ltd. 2011). Vole damage was particularly high on wet meadow sites supporting a dense cover of reed canarygrass (Keefer Ecological Services Ltd. 2011).

Live stakes planted in machine-excavated holes on coarse substrates (8 Mile, 12 Mile, and MacKay Creek) had higher initial survival rates than stakes that were hand planted on fine-textured soils (9 Mile; Keefer Ecological Services Ltd. 2011). Hand planting of stakes was only attempted at one site—a sandy spit at 9 Mile—thus it is unclear whether the relatively low survivorship here was due more to the specific planting method used or to the nature of the substrate. However, use of excavators in general for live staking purposes is thought to increase revegetation potential given their effectiveness at penetrating through the rocky substrates and matted vegetation found at many otherwise suitable but difficult-to-dig sites (Keefer Ecological Services Ltd. 2011). Mechanically tilling substrates to render them rough and loose prior to planting could also be an effective way to improve revegetation effectiveness (D. Polster, pers. comm. 2016).

Substrate texture has previously been identified as a key early predictor of establishment success, with well-anchored and stabilized substrates such as gravelly beaches and partially vegetated sites proving more amenable than highly mobile materials such as fine sand and erosive clay deposits (Keefer Ecological Services Ltd. 2011, Enns and Overholt 2013a). Our regression tree analyses identified substrate, microtopography, water energy, aspect, and soil moisture as potentially important predictors of long-term planting survival. For example, cottonwood stakes tended to perform relatively well on moderately moist to dry soils with some silt content; on substrates with low to moderate sand content; and on sandier substrates combined with cool (northerly) aspects. Surviving densities tended to be lower on substrates with low silt content, and on sandy southerly aspects. Examples of areas where cottonwood stakes have performed well include Lower Inonoaklin (high elevation gravel bar) and Edgewood South (high elevation, silt/sand/gravel grassy alluvial bench); and 8 Mile and 12 Mile (high elevation, reed canarygrass flats on [possible] old agricultural soils).

Sedge survival tended to be relatively high in those sample plots characterized by tussocked microsites (implying prior presence of other clumping graminoids) and somewhat gravelly substrates, and also in plots with a northerly aspect and minimal exposure to erosion and sedimentation. Conversely, plugs tended to do less well on south-facing or unanchored sandy sites, and had especially poor performance on sites experiencing active erosion and/or deposition. Examples of areas where sedge plugs have performed well include 12 Mile (low elevation, creek floodplain with a wet sand-gravel substrate), Burton (mid elevation, grassy flats on dry sandy soil), Fairhurst Creek (low elevation, lightly vegetated dry sand-gravel flats), and Lower Inonoaklin (low elevation, vegetated creek floodplain with wet silty-clay soil).

In summary, all drawdown zone habitats are not “created equal” with respect to their reclamation potential. Ultimately, revegetation effectiveness may be limited as much by the availability (and proper utilization) of suitable habitat areas in the drawdown zone as by the reservoir operating regime itself.

6.2 Community effects

Revegetation treatments have resulted in some local increases in species cover and richness, both via infill planting of graminoids (primarily sedges) and shrubs (primarily Black Cottonwood and willow spp.) in previously vegetated habitats, and through the introduction of these taxa into otherwise unvegetated microsites. Surviving sedge plugs (primarily those of Kellogg’s sedge) have contributed sporadically to the ground cover at various locations, while in areas such as 12 Mile (Revelstoke Reach) and Lower Inonoaklin (Arrow Lakes), planted cottonwood stakes have successfully taken root and now form small leafy stands several metres in height. These developing shrub stands may already be providing some structural values in the form of shade, as insect habitat, and as perching sites for birds.

Frequently, however, plantings have failed to establish or else have established only at low densities (typically contributing less than 1 per cent total cover in a 50 m^2 sample plot). Consequently, at the community level, the overall contributions from revegetation have not led to statistically significant differences versus untreated areas in terms of species distribution, diversity, vigour, abundance, herbaceous biomass, or cover. Going by these attributes, treated and non-treated areas remain generally indistinguishable. This may be because not enough time has passed since planting commenced (2008) for effects at this scale to become detectable. It should also be noted that this assessment is based on a “snapshot” comparison of plot conditions as recorded in 2015 (as opposed to a comparison of plot trajectories over time) and assumes that the initial, pre-treatment vegetation was similar in the case of both treated and control sites.

Consistent with these results, we found little anecdotal evidence during ground surveys that planted plugs or stakes have been able to expand their local footprint, either directly via new recruitment of juveniles into the population, or indirectly by moderating the environment in such a way as to facilitate the establishment of other species. This is especially apparent on previously unvegetated sand or cobble microsites, where the ground surface mostly remains barren and unvegetated between the planted stems.

In the case of cottonwood and willows, a lack of recruitment is not overly surprising given that the plantings are still pole-sized and may not yet be mature enough to reproduce. It could take many more years of stand development before we can determine if live staking on its own is an effective means of advancing local succession in barren areas of the drawdown zone.

In the case of sedge plugs, many of which have by now begun producing their own seed, the lack of juvenile establishment in the vicinity of established plants is more troublesome as it suggests that once the planted sedges die off, they will not be replaced by new plants (except via subsequent planting interventions). Consequently, as it stands, any benefits accruing to the vegetation community by the introduction of sedges to previously barren areas are likely to be transitory. This suggests (i) that self-sustaining revegetation of such areas is unlikely without the introduction of additional physical works (e.g., diking, windrows, mounding) designed to further ameliorate the environment in lieu of operational changes to the hydroregime; and (ii) in the absence of extra physical works or operational changes, revegetation treatments will likely need to be reapplied continuously to achieve meaningful increases in cover, abundance, or diversity.

6.3 Operations

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

(i) To facilitate development of functional riparian ecosystems, periodic, brief inundation at low elevations (i.e., 434-436 m) is likely necessary (to recharge soil moisture, protect establishing plants from summer drought, and maintain suitable growing conditions for adapted riparian species and communities).

(ii) Frequent full pool events can limit the capacity for shrub and tree establishment at upper elevations (i.e., >436 m).

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

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

In effect, the more that inundation cycles resemble natural spring/summer freshet cycles in both timing and duration, the more beneficial to revegetated communities they are likely to be. Soft constraints will be most effective at maintaining revegetated communities to the extent they are employed to limit not just the depth but also the duration of inundation during the summer and early fall growing season.

The inundation regime of 2015, which saw Arrow Lakes Reservoir peak in early June after reaching a relatively low annual maximum of 435.48 m (Figure 5-1), appeared to benefit vegetation in several respects and could provide a useful template for soft constraint operations moving forward. We predict that, if sustained over time, this inundation pattern would lead to higher cover of grass (albeit primarily non-native grass) and deciduous shrubs at mid to upper elevations, and higher sedge and annual herb cover at lower elevations. Ideally, future revegetation trials will occur in conjunction with a succession of similar annual inundation cycles to test whether these predictions also apply to revegetated areas.

7.0 SUMMARY

In this annual summary data report for CLBMON-12, we convey some of the incremental gains that have been made with respect to assessing the effectiveness of the Arrow Lakes revegetation program (CLBWORKS-2) at increasing the quantity and quality of vegetation in the drawdown zone.

Our overall conclusions are consistent with those reached following previous study years: revegetation efforts to date have met with mixed success. A portion of the stock (primarily Kellogg's sedge and black cottonwood) planted between 2008 and 2011 has survived and taken root and, in limited areas, is growing vigorously. The plantings in these areas may now be providing some ancillary ecological services such as increased erosion control, browse for waterfowl, and perching habitat for birds.

In other areas, survival of plantings has been minimal to non-existent. Establishment failures can probably be ascribed to a combination of environmental factors including prolonged inundation, infertile or unstable substrates, wave action and erosion/deposition, and soil moisture deficits. In areas where revegetated plants have taken hold, an apparent lack of new recruits suggests that revegetated populations may not be self-sustaining over the long term and may require repeated planting interventions to persist.

At the community level, revegetation activities seem to have had a neutral impact overall on associated vegetation development (as represented by such metrics as total cover, biomass, and species diversity). This could be because not enough time has elapsed since treatments were initiated for successional effects to manifest themselves (particularly in the case of developing cottonwood stands). Nevertheless, it is becoming evident that for many barren regions of the drawdown zone, additional physical modifications that are aimed at ameliorating site conditions will likely be applied in concert with revegetation prescriptions if lasting community changes are to be achieved. From an operational standpoint, opportunities also exist for advancing vegetation establishment, namely by using soft constraints to control the timing, and limit the depth and duration, of summer inundation.

The status of CLBMON-12 after Year 8 (2015) with respect to the management questions and management hypotheses is summarized below (Table 8-1).

8.0 RECOMMENDATIONS

The monitoring program in 2015, as in previous implementation years, considered only a limited sample of all sites treated under CLBWORKS-2. To help strengthen the adaptive management process moving forward, we recommend that a retrospective cataloguing and mapping of all previously treated sites be completed by 2017. This work, which should have a GIS component and which could be undertaken as an extension of CLBMON-35, would allow for a more comprehensive assessment of the various site limitations to vegetation establishment, including ones that have been touched on in this report. Having access to a comprehensive, spatially explicit database of past treatment successes and failures would also help guide managers in deciding which revegetation strategies to retain and which to discard as the restoration program moves into the next phase.

We currently lack specific information on how physicochemical factors such as groundwater levels, soil water availability, and dissolved soil and water oxygen (DO) levels vary across treatment sites and elevation bands. Without such information, it is difficult to identify potential physiological constraints to revegetation establishment (such as anoxia) or to compare these factors across different regions/elevations of the drawdown zone. As a start to obtaining baseline data on oxygen availability during different periods of the inundation cycle, it is recommended that DO dataloggers be permanently deployed within revegetation treatments at varying elevations of the drawdown zone commencing in 2016. This survey could be initiated in conjunction with the general cataloguing of biophysical site conditions at previously treated areas (see recommendation above).

Unusually low reservoir levels in 2015 allowed us to make a preliminary assessment of how drawdown zone vegetation responds to the absence of inundation. However, the full effects of this hydrological event are unlikely to become apparent until the next growing season (or later). Thus, it is recommended that the fall 2015 work described in this report be complemented by a second follow-up assessment in May and June of 2016 (i.e., the next growing season) as part of the 2016 implementation of CLBMON-33.

Table 8-1: Status of CLBMON-12 management questions after Year 8 (2015)

Management Question (MQ)	Has MQ been addressed?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where appropriate	
1. What is the quality and quantity of vegetation in revegetated areas between elevations 434 m to 440 m compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?	Partially	As of 2015, there were no statistically significant differences in vegetation quantity or quantity between treated and untreated areas.	Consider expanding the survey design to include more sample replication within and among treatments. In the final implementation year, a retrospective analysis of yearly plot data should be conducted to compare trajectories in species composition over time within treated and control plots, to more clearly distinguish treatment from background effects	The relatively short time (4 to 7 years) that has passed since the application of the revegetation prescriptions limits our ability to comment on their respective successional trajectories.
2. What are species-specific survival rates under current operating conditions (i.e. what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?	Partially	The estimated survivorship of sedge plugs 4 to 7 years after planting was, on average, about 21 per cent, while that of cottonwood stakes was about 64 per cent. Local survival rates varied greatly across locations, with numerous samples showing minimal to no survival and others indicating relatively high establishment success.	Current samples are based on repeat monitoring of permanent plots established by Enns *et al*. (2007 and subsequent). The available sample size could be increased through development of a comprehensive catalogue of survivorship at all previous treatment sites, using original stocking densities for each site where known. This would assist in identifying specific treatments that appear to be working and which could benefit from expanded testing. Some promising instances of revegetation have already been identified. Resources permitting, these high-potential treatments should be targeted for expanded testing as soon as possible under CLBWORKS-1.	Survivorship was estimated indirectly based on the number of visible live plantings at each sample plot and the average reported stocking rates for each species or treatment type. In numerous instances, planted vegetation could not be distinguished with certainty from natural vegetation. Thus, estimates are approximate and should be taken as relative indicators only.
3. What environmental conditions, including the current operating regime (i.e. timing, frequency, duration and depth of inundation), may limit or improve the restoration and expansion of vegetation communities in the drawdown zone?	Partially	Revegetation performance appears to be correlated to a range of environmental factors including inundation, infertile or unstable substrates, wave action and erosion, sedimentation, and soil moisture deficits. All aspects of the operating regime have the potential to limit or improve the restoration and	There is insufficient treatment replication in the CLBWORKS-2 revegetation program to address specific hypotheses around inundation timing, frequency, duration and depth. In order to relate revegetation performance directly to these operational components, which vary annually, the treatments themselves would need to be	Limited treatment replications (both spatially and temporally) limit our ability to directly correlate revegetation performance to different soft constraints components (i.e., timing, frequency, duration and depth of inundation), and to

Management Question (MQ)	Has MQ been addressed?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where appropriate	
		expansion of vegetation communities. Timing of inundation determines the ability of restored vegetation to set roots, grow, and reproduce within the annual cycle. Frequency of inundation can affect establishment rates, especially of woody species at upper elevations. Duration and depth of inundation determine the levels of anoxia that plants must endure and the degree of seasonal exposure to wave action, erosion, sedimentation, and woody debris.	replicated each year of the study across the full elevational gradient of the targeted portion of the drawdown zone.	separate soft constraints effects from other, non-operational effects.
4. What is the relative effectiveness of the different revegetation treatments, as applied through CLBWORKS-2, at increasing the quality and quantity of vegetation in the drawdown zone?	Partially	Cottonwood stakes have survived better, and are providing more new cover, than graminoid plugs. However, none of the treatments has yet shown to be effective at increasing the quality and quantity of associated vegetation. This may be because not enough time has elapsed since planting for beneficial effects to become evident.	It could require many more years of stand development before changes at the community level become detectable. At this stage of the study, it may be beneficial to redirect the focus of monitoring away from the assessment of community responses (which are negligible so far) and toward identification of the specific conditions or filters (both physical and methodological) acting to limit or enhance the establishment and long-term survival of individual planting treatments. Such information is needed to help guide future physical works projects in the drawdown zone. This could be accomplished through a more extensive cataloguing and survey of existing treatment areas (see comment above for MQ2).	A longer time series of data is required to address this question adequately. .
5. Does implementation of the revegetation program result in greater benefits (e.g., larger vegetated areas, more productive vegetation) than those that could be achieved through natural colonization alone?	Partially	Yes, the program has shown modest benefits beyond what would occur through natural colonization, primarily relating to the establishment of young cottonwood trees at some high elevation sites. There has been relatively little success in getting herbaceous vegetation to establish on barren sites, and	N/A	A longer time series of data is required to address this question adequately.

Management Question (MQ)	Has MQ been addressed?	Scope		Sources of Uncertainty
		Current supporting results	Suggested modifications to methods where appropriate	
		much of the gains there appear transitory (due to a lack of ongoing recruitment).		
6. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the landscape and site level in the future?	Yes	Yes, opportunities exist for modifying operations to help restoration goals. Experience with the revegetation program to date suggests that soft constraints will be most effective at maintaining revegetated communities to the extent they are employed to limit not just the depth but also the duration of inundation during the summer and early fall growing season. As noted above (MQ 3), limited treatment replications (both spatially and temporally) limit our ability to directly correlate revegetation performance to different soft constraints components (i.e., timing, frequency, duration and depth of inundation). Thus, supporting results to date are mostly observational in nature. The unusually low reservoir maximum (435 m) experienced in 2015 should eventually help to shed light on this question especially if it is replicated on a regular basis in subsequent years.	N/A	The non-experimental nature of the planting program, combined with the recent history of variable reservoir operations (also unreplicated in space and time), limits our ability to test hypotheses or to recommend specific targets around inundation timing, frequency, duration and depth. A longer time series of data, in conjunction with annually replicated planting treatments, is required to this question adequately.

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10.0 APPENDICES

10.1 Summary of CLBWORKS-2 planting treatments

Revegetation work was conducted in the drawdown zone from 2008 to 2011. In 2008, this consisted mainly of fertilization trials at Burton and Nakusp sites to evaluate the effectiveness of fertilization in facilitating sedge establishment. A total of 16,200 nursery-raised seedlings consisting of 15,800 lenticular sedge and 400 Columbia sedge plugs were planted out in the spring, and a fertilizer blend of 15-9-18-4.7S-1.6 Cu-0.3B was applied at a rate of 370 kg/hectare. These trials were largely inconclusive due to an early inundation event that prevented proper root system development in the planted plugs (Keefer *et al.* 2008).

In 2009, 272,895 nursery-raised plugs were spring-planted and 188,905 plugs were fall-planted, totalling 461,800 sedge and grass seedlings across 39.52 ha. Species planted included lenticular sedge, Columbia sedge, water sedge (*Carex aquatilis*), woolgrass (*Scirpus atrocinctus*), small-fruited bulrush (*S. microcarpus*) and bluejoint reedgrass (*Calamagrostis canadensis*). In addition, approx. 19,000 live deciduous stakes (primarily black cottonwood but including 2,188 willow and 530 red-osier dogwood [*Cornus Canadensis*] stakes) were planted in the spring over 7 ha at a density of 2,047 stems/ha. In the fall, 5,080 nursery-raised deciduous seedlings (4,180 black cottonwood and 900 chokecherry [*Prunus virginiana*]) were planted in Revelstoke Reach (Keefer Ecological Services Ltd. 2011).

In 2010, over 200,000 sedge seedlings (104,160 lenticular sedge, 84,960 Columbia sedge, and 13,920 water sedge) were planted out at an average density of 13,245 stems/ha. The highest density of plantings was at Renata (42,500 stems/ha), a uniformly open, sandy site, while the lowest density (4,033 stems/ha) was at 9 Mile, a more highly vegetated, irregular site with fewer suitable microsites available for planting. A total of 6,191 live stakes (5,551 cottonwood and 640 red-osier dogwood) and 4,320 cottonwood seedlings were planted at elevations above 438 m in areas accessible to an excavator (Keefer Ecological Services Ltd. 2011).

In 2011, a total of 266,580 sedge and grass plugs were planted during late April and early May, resulting in 19.9 ha of treated area. As in previous years, lenticular sedge was the most planted species (233,280) followed by woolgrass (16,875), bluejoint reedgrass (10,125), water sedge (5,355) and Columbia sedge (945). The average stocking density of all sites was slightly over 13,000 plugs/ha. In addition, 4,347 black cottonwood live stakes were cut and planted at 8 Mile in Revelstoke Reach (3.8 ha) and 16,680 cottonwood seedlings were planted at various sites.

Protocols for seedling propagation, live stake preparation, and out-planting generally followed those developed by Keefer (2008) and Keefer *et al.* (2009). Sedge and grass seeds were collected during the summer prior to planting. Seeds were air-dried, cleaned with an air sorter, weighed, and stored. Seeds were either propagated in the fall and the seedlings cold stored over the winter, or else grown over the winter-spring and hot-lifted for immediate, on-site planting. Planting was carried out by teams of trained tree planters.

Live cottonwood and willow stakes were harvested from locally available material in early spring of the year they were to be planted, then immediately bundled and wetted with a sprinkler system to minimize any potential damage from desiccation and handling. Following bundling, stakes were soaked for 5-10 days then transferred to a refrigerated reefer to preserve freshness. Live stakes were planted by hand or, more typically, using excavator machines. The excavator was used to dig a soil pit to a depth of 60-70 cm. After an assistant placed a live stake in the hole, the excavator operator replaced and tamped down the soil. In 2011, the planting depth was increased to 100 cm, so that between 1/3 to 1/2 of most stakes' length was belowground (Keefer Ecological Services Ltd. 2011).

10.2 Summary descriptions of Vegetation Community Types (VCTs) identified for the Arrow Lakes Reservoir (ALR). Adapted from Enns *et al.* (2007; 2012)

BB (Boulders, steep)**:** Uncommon but increasing toward the south, BB is usually derived from bouldery till and is steeply sloping. This type is usually non-vegetated to very sparsely vegetated with less than three per cent vegetation cover and is not considered vegetated at the landscape scale.

BE (Sandy beach)**:** This VCT consists of non-to sparsely vegetated sands or gravels on flat to gently undulating terrain. Typically fine-textured sands with a mixed silt content. It may occur at all elevations, and appears to be scoured by water currents. It is possible that BE is simply a frequently inundated low elevation PC types. Dust issuing from this type is a common occurrence. This vegetation type is very sparsely vegetated to non-vegetated. Annual Bluegrass, Reed Canarygrass, Pineapple Weed and Common Horsetail are some of the species that occur.

BG (Gravelly beach)**:** This sparsely-vegetated VCT is typically an alluvial or fluvial outwash plain, consisting of gravel and cobbles of various sizes, located always on gentle to flat areas of the reservoir. It may be adjacent to creeks and seepage that may provide water in the hot period of exposure in spring, summer or fall. Due to washing of fine materials over the surfaces, grit can collect between boulders, and some very drought and inundation tolerant plants occur, including willows, horsetail, Reed Canarygrass, sourweeds, and Redtop. Vegetation is almost always very sparse or absent.

CL (Cliffs and rock outcrops): Found on steep sparsely vegetated terrain at upper elevations, and derived from bedrock and colluvium, this type occurs in fewer than 10 polygons in the base map. CL has insufficient frequency of occurrence to be considered for landscape scale analysis.

CR (Cottonwood riparian)**:** This VCT mostly occurs near the 440 m ASL, but also throughout all elevations, especially in Revelstoke Reach, if the site is sheltered from scouring the soils are either remnants of, or persistent features of, well-drained alluvial fans. The CR vegetation type is often dominated by Black Cottonwood, with Trembling Aspen and occasionally very large specimens of Western Red Cedar, Douglas-fir and Western White Pine. Ponderosa pine occurs at the southern end of the Arrow Lakes portion of the reservoir, and Lodgepole Pine occurs at the northern end. There are highly variable assemblages of non-vascular and vascular plants in the CR, including horticultural species. A range of forested vegetation from wet to very dry forest types occurs, including Falsebox, Oregon-grape, Pinegrass, Trailing Bramble, bedstraws, peavines, and various mosses, liverworts, lichens. This type may be an important seed source for lower elevation sites.

IN (Industrial / residential / recreation)**:** This type occurs across all elevation bands in the DDZ. It is characterized by heavily disturbed soils and vegetation due to roads and a variety of land uses, including past settlement. Soils are variable, but are always compacted, and have weedy margins. This type is probably a major source of weed invasion into other vegetation types in the reservoir. It is dominated by a mix of drought and/or inundation tolerant opportunistic native and weedy vegetation, such as sourweed spp., Red and White Clover, Sweet Clover, knapweed spp., Cheatgrass, Pineappleweed and others.

LO (Log zone): Usually confined to high elevation, occasionally in sheltered coves and inlets, almost always at the top of the slope on convex to concave topography, dominated by logs and woody debris. LO is usually non-vegetated to very sparsely vegetated with less than three per cent vegetation cover and is not considered vegetated at the landscape scale. The LO type is not based on terrain; it is based on the presence of log debris.

LO was initially dropped as a monitored community type after 2010 due to its ephemeral nature (K. Enns, pers. comm. 2014), but was reintroduced to the study in 2014. The rationale for this inclusion was that woody debris accumulations, while not strictly a vegetation type, can have a significant influence on vegetation development (or lack thereof) within deposition zones in the upper elevation bands (Hawkes *et al.* 2013b). Furthermore, because woody debris can be picked up and dispersed to different locations with rising reservoir levels, its effects will vary over space and time, and thus serve as an important predictor of drawdown zone vegetation dynamics.

PA (Redtop upland)**:** This vegetation type occurs on raised, well drained microtopography (i.e. convex and moisture shedding) and can occur at a range of elevations including at the 433m elevation, although it is more common above 437m. It is relatively frequent, but often too small to map at the landscape level, and occurs on sloped or on well drained, sandy gravelly materials. It is physically disjunct from the CR type, which is usually flat or sloping but seldom convex. This type is usually somewhat variable, but displays a relatively high species richness compared to PC or PE, due to the presence of drought tolerant weedy species. While this type is often dominated by Reed Canarygrass, the species composition always includes at least a few species of agronomic and native grasses, including Redtop, Creeping Bentgrass, Blue Wildrye, Canada Bluegrass, Kentucky Bluegrass, and others. Various pasture and ditch weeds, such as sourweed, chickweed, Chicory, Oxen-eye Daisy also occur, in addition to somewhat dry forest-type mosses, such as Red-stemmed Feather Moss and Palm-tree Moss. Trees and shrubs usually occur.

PC (Reed Canarygrass mesic)**:** The Reed Canarygrass vegetation type is the mesic vegetation in the ALR and is both very common and widespread, occurring in all the map areas. It is relatively variable, and can be influenced by drainage, moisture regime, and slope position. Materials vary somewhat, but usually consist of gently sloping to flat anoxic, compacted sandy-silty to silty-sandy materials, often with quite coarse sand. Gravel depositional areas can have openings, which result in a few more species than the usual species composition for this VCT. The PC covers large parts of individual polygons and is dominated by Reed Canarygrass with minor amounts of Kellogg's Sedge, Common Horsetail, and Pennsylvania Bitter-cress. Reed Canarygrass can be monospecific and form very dense, mostly pure stands of 1 ha or larger in size, especially in Revelstoke Reach. This type has been heavily grazed by geese in the Arrow Lakes, and in this this condition it can be invaded by several species of sedges, grasses, cranesbill, bedstraw, and other inundation-tolerant or requiring plants.

PE (Horsetail lowland): This vegetation type occurs mainly at low to middle elevations. Physical site characteristics differ from RR sites (below) in that PE occurs in depressional topography, and water is not continuously supplied from upslope via ground water supplies, but rather mainly from reservoir water. PE can be boulder, but is always relatively compacted, non-aerated and has significantly higher silt fractions in the soil compared to its typical neighbor, the more mesic PC type. PE is less common throughout the reservoir than PC, usually occurs down-slope of PC and is less variable. Species richness is medium, dominated by Kellogg's Sedge, Purslane Speedwell, Annual Bluegrass, Reed Canarygrass, and horsetails. It can have very low covers of several inundation tolerant plants including Shortawn Foxtail, and Nodding Chickweed. It appears that annual plants occur sporadically in this type and the species composition varies both annually and seasonally.

PO (Ponds): This type occurs in backwaters, large deep depressional areas, cut-off oxbows or channels, and very rarely on flat stretches of beach. POs vary in water depth, but are usually deep enough to comprise permanent to semi-permanent features, i.e. they are not just shifting minor depressional areas caused by scouring, but possible old ponds or wetlands. They have standing brackish to slow moving water present most of the year. The areas may dry out in very dry successive years. The vegetation can be species poor and mainly consists of edge-dwelling and aquatic macrophytes. Species include Floating-leaved Pondweed, Common Spike-rush, Baltic Rush, Rocky Mountain Pond-lily, Marsh Cinquefoil, Water Smartweed, Eurasian Water-milfoil, and other semi-emergent to emergent plants.

RR: (Reed – rill): This type is always associated with continuous sources of fresh water as an underground stream or seep entering the reservoir. It is usually topographically depressional. Water may originate from open streams upslope, but may also continuously percolate through surficial materials in the DDZ. Materials usually have some fine textured and compacted component, often boulders with silts in interstitial spaces. The silts are usually also mixed with sands, and these can be cemented and embedded with fine to coarse gravels. The RR type usually has dense, but patchy cover of mixed semi-aquatic or riparian species, with barren areas. Species include rushes, reeds, and sedges, Swamp Horsetail and occasionally willows. The type can be species poor, if recent scouring has taken place.

RS: (Willow – Red Osier Dogwood – stream entry): Occurs from high to low elevation along incoming stream channels, usually gullied and undulating and almost always bouldery to gravelly with fine sand and silt deposits (i.e., mixed materials). RS is very gently sloping to moderately steeply sloped. The RS water supply is seasonal with a high flow in spring and fall freshet, and very low to completely dry during summer and winter. The effect of this water supply and its physical influence on the vegetation of RS is difficult to distinguish from the effects of the soft constraints operating regime. RS originated as minor, somewhat ephemeral, fluvial channels.

SF: (Slope failure): Usually silty sands that have slumped in response to slope failure. Buried vegetation may occur. Approximately five polygons delineated. SF has insufficient frequency of occurrence to be considered for landscape scale analysis. SF appears to be derived from very sandy till and or glaciofluvial terrace edges and escarpments.

SS (Steep sand): With the exception of the Lower Arrow Lake narrows, this VCT is not common, occurring only in small areas throughout the reservoir. It consists of steep, sandy banks, often with peeling or failing slopes. Stepped patterns may occur that correspond to the typical full pool events in the reservoir. This type consist of only a few species of plants, with very low cover, including Reed Canarygrass, Common Horsetail, and Short-awn Foxtail.

WR (Silverberry river entry): Occurs only in river entries with year-round water flow, from highest elevation locations to the lowest elevation, and is usually flat (although the sides of the river channels are included). Mainly bouldery and frequently inundated with river water. The effect of a continuous river entry water supply is dramatically greater than the influence of the soft constraints operating regime. WR is often non-vegetated to very sparsely vegetated with less than three per cent vegetation cover and is not considered vegetated at the landscape scale. WR persists as a major, active fluvial channel.

10.3 Field data form used in 2015

Project ID CLBMON-12: Arrow Lakes Reservoir Monitoring of Revegetation Efforts **Sheet No.________/________**

Date: **Surveyors:** **Plot #:** **General location:**

VCT: **Garmin #** **Wpt. #:** **UTM:**

Plot Photo # (N, E, S, W, down):

Aspect: ° **Slope:** ° **Plot type (circle one):** Treated Control Existing veg.

Gen. Surface topography: concave convex straight

Microtopraphy: smooth channelled gullied mounded tuss

Prim. Water Source:

precip. surface_seep stream_sub-irrigation stream_flood

Soil Moisture:

BIOMASS	Wet (g)	Scale used?	Dry (g)
Sample 1			
Sample 2			
Sample 3			
Total			

very_xeric xeric subxeric submesic mesic subhygric hygric subhydric hydric

Terrain texture (rank 1-3):

boulders____ cobble____ gravel____ fines____ sand ____ silt____ clay____ mud____ wood____ organics____ water_

Recent evidence of scouring, erosion, or deposition:

Evidence of non-operational site disturbance (e.g. wildlife use, ATV):

Structural Stage: sparse/pioneer herb low_shrub tall_shrub pole/sapling young_forest mature_forest old_forest

Vegetaion Cover	%	TREE LAYER (A)					Vigour Codes
Tree Layer (A)		Species	A1	A2	A3	Tot	0. dead
Shrub Layer (B)							1. poor
Herb Layer							2. fair
Seedlings (D)							3. good
Moss (E)							4. excellent

Shrub Layer (B)							
Species	B1	B2	Tot	Species	B1	B2	Tot

HERB LAYER (C)		
Species	%	Notes

PLANTING SURVIVAL

5x10m Plot

Species Live/Dead Vigour

photos:

Stake Polygon

Species Live/Dead Vigour

Polygon dimension:

UTMs:

photos:

Notes

10.4 Regression trees

Univariate regression trees were used to explore the relationships between the density of live stakes, plugs, or seedlings and a series of topo-edaphic environmental variables. Regression trees deal well with continuous or discrete variables, nonlinear relationships, complex interactions, missing values, and outliers (De'ath and Fabricius 2000), and are useful methods to explore relationships and patterns between response variable(s) of interest and a series of independent variables. A regression tree is built by partitioning the independent variables (e.g., elevation, soil moisture) into a series of boxes (the leaves) that contain the most homogeneous groups of objects (i.e. plots). Splits are created by seeking the threshold levels of independent variables that produce groups with highest homogeneity, by minimizing the sums of squares within groups (De'ath and Fabricius 2000). The length of the vertical lines associated with each split graphically approximates the proportion of total sum of squares explained by each split; the longer the line is, the more variance the split is explaining (De'ath and Fabricius 2000). The value shown at each terminal leaf corresponds to the average value of the dependent variable (here, density). The method allows computing a pseudo-R2 that corresponds to the proportion of variance explained by the tree (1-the deviance of the tree / by overall sum of squares).

The environmental variables considered were elevation band, location, vegetation community type, heat load (aspect), slope, surface topography, microtopography, water source, soil moisture, presence of erosion or deposition, disturbance type, structural stage, moss cover, and substrate texture.

10.5 Species evenness

Species evenness (J, a measure of how evenly species are distributed within plots, as indicated by their relative per cent covers), was variable but was generally higher in plots of existing and control vegetation than in treated plots (Figure 10-1) Most plots had very low evenness values, suggesting that they were dominated by a few species only.

Differences in evenness were statistically significant among elevation bands ($F=3.4$, $p= 0.036$) and among plot types ($F=3.1$, $p=0.045$). Interactions were not significant.

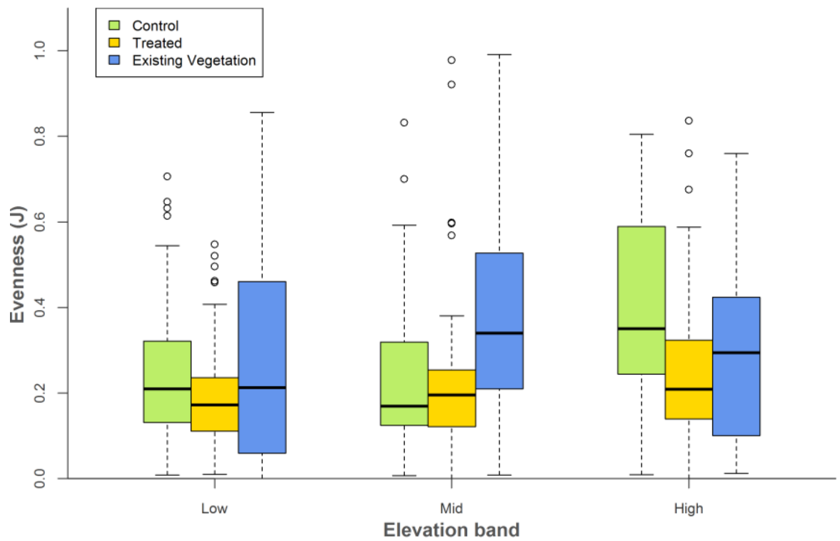

Figure 10-1: Variation in species evenness (J) in treated, control, and existing vegetation plots among low (434-436 m), mid (436-438 m), and high (438-440 m) elevation bands in Arrow Lakes Reservoir in 2015