Columbia River Project Water Use Plan

KINBASKET AND ARROW LAKES REVEGETATION MANAGEMENT PLAN

Reference: CLBMON-12

ARROW LAKES RESERVOIR MONITORING OF REVEGETATION EFFORTS AND VEGETATION COMPOSITION ANALYSIS

FINAL REPORT

Study Period: 2011

Delphinium Holdings Inc.
Castlegar, B.C.

January 2012: Revised May 22, 2012

Original Report Cover

CLBMON-12
ARROW LAKES RESERVOIR MONITORING OF REVEGETATION EFFORTS AND VEGETATION COMPOSITION ANALYSIS
2011 FINAL REPORT

Edgewood *Carex* planting

Submitted to:

BC Hydro
Water Licence Requirements
Castlegar, B.C.

by:

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Cover photo: Pre-2011 plug plantings of *Carex lenticularis* in sand at Edgewood, B.C.; Arrow Lakes Reservoir at middle elevation

EXECUTIVE SUMMARY

This is the third report in a series of ten years of documentation that describes the effect of revegetation treatments at the site level in the drawdown zone of the Arrow Lakes Reservoir. Two vegetation monitoring studies, which run during alternate years and use similar field methodologies, have been undertaken. CLBMON-33 addresses landscape-level changes in vegetation and uses aerial photography and field measurements to evaluate effects of reservoir operations on existing vegetation communities. The present study, CLBMON-12, addresses site-level changes in vegetation in response to various influences, including revegetation treatments, and uses field measurements to assess effects. This study attempts to distinguish between the effects of revegetation and the influence of reservoir operations, as well as 'background" influences, including climate, topography and parent materials.

A specific goal of this study is to assess the effectiveness of CLBWORKS-2 Arrow Lakes Reservoir Revegetation program, which was was initiated in 2007. This physical works program has the objectives of maximizing vegetation growth in the Arrow Lakes Reservoir drawdown zone, increasing plant diversity, and improving shoreline stability (BC Hydro, 2008). Initial treatments, including spring planting and fertilizing, took place in 2008. Spring and fall planting, live-staking, and re-fertilizing took place in 2009, and planting and live-staking in 2010 and 2011.

The CLBWORKS-2 revegetation program is now complete. The monitoring of CLBWORKS-2 was initiated in 2008 as an evaluation of pre-treatment baseline conditions, with two post-treatment measurements taken in 2009 and 2011 at the site level. Some of the work done for CLBMON-33 at the landscape level is applicable and can be used to show trends in the survival and condition of revegetation efforts in 2010. Therefore, a series of repeated plots showing the effects of treatments from 2008 to 2011 are evaluated in this report. In addition, an assessment of the potential effect of the additional generation from the REV 5 project at Revelstoke Dam is included in an addendum to this report.

Annual changes in vegetation from the first complete baseline of 2008 to the 2011 measurement were subtle, and depth (elevation) and duration of inundation alone did not account for a large part of the observed variation (Enns et al. 2010). The annual water levels have varied slightly each year; but two winters with exceptionally long periods of inundation have coincided with a subsequent reduction in cover and heights of vegetation. In 2008–2009, there was a long duration of high water, during which elevation bands above 348 m remained inundated. In 2010–2011, a fall to winter peak in inundation influenced the lowest elevation of the vegetation from 434 m to 436 m. Based on the results of the retrospective assessments, the pattern in inundation tended to result in some losses of vegetation cover, height and species diversity in the PE, BE, and PC vegetation community types.

Existing Vegetation

Although a measureable change in cover and heights was recorded, some of the patterns in vegetation are likely part of natural variation. The vegetation of the Arrow Lakes Reservoir has been adapting to reservoir conditions since the mid-1960's, and has developed very distinct vegetation communities with a high tolerance for reservoir conditions. Each vegetation community type has shown the same within-type trends in species composition, cover, abundance, heights, and vigour over time since 2007-2008, with clear patterns that relate to differences in elevation.

Most of the species with the highest frequency of occurence in the Arrow Lakes Reservoir drawdown zone have not changed in their dominance over time. The high-water winter of 2008-2009 did, however, influence the frequency of occurrence of dominant species. Some species declined in frequency of occurrence following a period of high water from midsummer to the following early spring (2009 measurement), but subsequently recovered in 2010 and 2011.

The low-elevation vegetation communities are somewhat negatively influenced by prolonged inundation in the midsummer to fall period. They may be reduced in cover or height. However, many of the species in the drought-tolerant vegetation community types at higher elevations apparently benefit from brief inundation if they are not scoured by too much wave activity in the winter.

Species are lost annually from communities, as shown by data from repeated plots. These are mostly opportunistic, somewhat weedy species with high natural rates of change. Introductions to the reservoir from upslope are common, and such species are often lost, whereas the drought- and inundation-tolerant species that make up the largest proportion of the vegetation communities have persisted within plots over most measurement periods.

Treated vegetation

There were no statistically significant differences between treatment and control vegetation in either 2009 or 2011. Based on a limited sample size in 2009, there was a slight increase in vegetation cover, height, richness and diversity, and distribution became more even between 2009 and 2011. The number of days of inundation and the depth of inundation (based on elevation of the plant measurement plot), and the sand, silt and gravel substrate per centages accounted for most of the variation in plant cover. Duration of inundation exceeding 100 days was found to have a negative influence on plant height.

There was no indication that vegetation treatments either increased or decreased the *total* cover of any of the existing vegetation, but treatments did add vegetation cover to individual areas in the reservoir. Vegetation heights were influenced by planting of live stakes, given thatlive stakes were usually taller than the pre-existing vegetation.

It is not certain that the vegetation cover in previously non-vegetated areas will persist over the long term. Vigour of some of the middle elevation lenticular sedge treatments was lower than that of the control vegetation, suggesting that planting may have taken place outside typical species habitats.

Treatments were “operational - that is, they were aimed at improving exposed soils and conducting infill planting on sites that had a potential to respond to treatment. It will remain to be seen in subsequent years if the treated vegetation begins to resemble the native vegetation in cover, abundance, diversity, vigour, and distribution.

It is premature to conclude that treatments have been successful. Success should be measured by evidence of long-term survival. Our assessment of benefits and costs of the treatment is qualitative, and is not based on the actual monetary cost of the treatments. The largest benefit is the increase in vegetated areas, where no vegetation previously existed. The largest “cost” or disadvantage is the potential for cottonwood stakes to introduce disease to new areas of the reservoir.

The work of CLBMON-12 was designed to address a series of 12 management questions (BC Hydro 2008; Appendix 6). Six of the management questions pertain to existing, untreated vegetation, and six management questions pertain to the effects of treatment. Table 1.1 summarizes the management questions (MQs), field data and current results. The CLBMON-33 and CLBMON-12 projects are very similar and rely on the same database and field data collection system. The management questions for both projects are very similar and could be blended without losing resolution.

Table 1. Status o f M anagement Questions for CL BMON-12, Sup porting Da ta and Results Summary. MQs 1 and 2 are combined.

Management Question	Field data	Results
	Existing Vegetation	
1 and 2. What is the cover, distribution, vigour, species diversity, abundance and biomass of existing vegetation communities in relation to elevation in the drawdown zone?	Species cover, distribution, vigour, diversity, abundance and biomass assessments.	Vegetation cover declined in low elevation communities between 2009 and 2011 in both the Arrow and Reach portions of the Arrow Lakes Reservoir. Distribution was more even at lower elevation than at high elevation between 2009 and 2011. Vigour was slightly lower across most communities and elevations in 2011 than in 2009, due to the increased number of plots in treatment areas. Species richness and diversty were higher in 2011 than in 2009, over all elevations, due to more species of existing vegetation, typically as seedlings. Abundance only measured in 2011, but was similar to cover. A large number of seedlings occur in low elevation plots, in sand dominated substrates exposed to water supplies from the reservoir. This resulted in higher abundance in low elevations than at high elevation. Biomass was measured in 2008 and 2011, and did not change much between that period of time. The highest biomass is at 438 – 440 m in the shrub and riparian forest communities where plants are taller and heavier.

3. How does the current operating regime affect the within-community quality and quantity of existing vegetation?	Species cover, abundance, biomass, diversity, distribution and height (added variable) in relation to the plot's operating regime: water level duration and depth of inundation.	Height and biomass tended to be lowest at the highest number of days of inundation. All other response measures (cover, etc.) were highly variable. Some communities, such as upland shrubs, were not inundated for long, and appeared to benefit from inundation, but not from scouring.
4. Is there a shift in community structure (species dominance) or a potential loss of existing vegetation communities that is attributable to environmental conditions, including the current operating regime?	Changes in the proportions of the dominant species in repeated plots over time. Ranked frequency of occurrence of species within communities over time. Comparisons with known ecological requirements.	Dominant species occurrence has not changed much from 2008 to 2011, although there was a measureable decline in total cover and heights following high water winters. Some annual, opportunistic species increased dramatically each year.
5. What are the species-specific survival rates under soft constraints operating regime (i.e., what are the tolerances of existing plant species to inundation?)	Species losses (individual records) from repeated plots, and comparisons with ecological data.	Losses of weedy annuals, seedlings and perennials were common, but replacement also took place. Invasions from upslope occurred and were lost. Willows declined in Revelstoke Reach at middle elevation as a result of populations expanding into low elevations, and subsequently being inundated for longer than their usual tolerance would allow.
6. What recommendations can be made to more effectively maintain existing vegetation at the site level in the future?	Comparisons of vegetation data on an annual basis with previous winter's operational data.	Allow a period of low water in late summer to early fall.
Revegetated Areas		
7. What is the quality and quantity of vegetation in revegetated areas between 434 m and 440 m compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?	Species compositions, distribution codes, vigour assessments, cover, abundance and biomass estimates in treated versus control stands.	Carex planted at and above 436 meters had lower vigour than Carex planted at low elevation. Areas where cottonwood seedlings were planted had sparser vegetation than control plots. Cottonwood live stakes did best in gravels, and had low survival below 437 meters.

8. 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)?	Comparison of species composition over time in treated plots.	Losses of planted Carex have been severe in some locations, although it is premature to attribute the losses to any particular environmental condition. The losses of cottonwood stakes are greatest below 437 meters. Mortality in cottonwood stakes is difficult to ascertain. Cottonwood stakes often appear to be dead but they can recover and sprout, often after a year or two. It is premature to judge the success of most of the treatments.
9. What environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation), may limit or improve the remediation and expansion of vegetation communities in the drawdown zone?	RDA of independent variables, including depth and duration of inundation, and all biophysical variables (slope, aspect, terrain texture, sheltering effects), accounting for the variation in existing and treated plant cover.	Existing plant cover tended to align closely with silt and clay in terrain or soil textures, and treatment vegetation tended to align closely with sands and gravels. Inundation and duration did not account for a lot of the variation in plant cover, indicating several other factors were important.
10. 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?	Cover, diversity, abundance, distribution and vigour of treated versus control vegetation. Height was an added variable.	Results are preliminary. There was no difference in any of the measured variables, except height, which was higher than control vegetation. Survival of live-stakes was poor below 437 meters.
11. 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?	Area estimates, qualitative assessment.	Results are preliminary. Some areas of vegetation have expanded to where there was previously no vegetation. Some disadvantages include increased pathogens from cottonwood stakes.
12. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the landscape and site level in the future?	Short term retrospective comparison on species survival in repeated plots (MQ8).	Results are preliminary. Recommendation from MQ 6 applies: allow a period of low water in late summer to early fall.

KEYWORDS

Arrow Lakes Reservoir, vegetation, vegetation community type, revegetation, existing vegetation, management questions, cover, height, vigour, diversity, biomass, distribution, abundance, frequency of occurrence, survival.

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1.0 INTRODUCTION

The Arrow Lakes Reservoir is located in southeastern British Columbia, between the Revelstoke dam at Revelstoke, B.C., in the north, and the Hugh Keenleyside Dam at Castlegar B.C., in the south. The Hugh Keenleyside Dam was completed on October 10th, 1968 (BC Hydro 2004[1]), and was originally intended to control the floodwaters of the Columbia River, including a drainage area of 3,650,000 hectares. In 2004, the Columbia Power Corporation completed the construction of a 185 MW power plant adjacent to the Hugh Keenleyside Dam. During the period prior to the construction of the power plant, water levels were lower than the current levels. Water levels can vary by as much as 20 metres annually, and tend to be lowest between the fall and winter months, and highest in the late spring to summer months (BC Hydro[2]). The Arrow Lakes Reservoir is 230 km long and is typically quite shallow in the northern Revelstoke Reach portion and very deep in the Arrow Lakes portion.

Riparian vegetation in the Arrow Lakes Reservoir drawdown zone extends over an elevation range of approximately 10 metres, from 430 to 440 meters (BC Hydro 2010). A review of older aerial photography indicated that some of the pre-construction vegetation has been retained throughout the history of the reservoir[3]. Although expansion of the vegetation into lower elevations may have been influenced by a fall rye (*Secale cereale)* seeding program that began in the 1990s, pre-existing vegetation occurred in the drawdown zone. Natural vegetation may have become more prominent during a series of low water years from 1990 to 1999 (BC Hydro 2010).

The Columbia River Water Use Plan Consultative Committee (WUP CC) developed a series of soft operating constraints for the Arrow Lakes Reservoir. The interests included Vegetation, Wildlife, Fish, Recreation, Culture and Heritage, Erosion control and Power Generation (BC Hydro 2010). The constraints, which related to each of the stated interests, were a series of targets with inherent flexibility and some potential conflicts. The WUP CC recognized the value of riparian and wetland vegetation for enhancing littoral productivity; providing physical, structural and biological character for wildlife habitat; protecting cultural heritage sites; and providing aesthetic benefits, including dust control (BC Hydro 2010). The WUP CC therefore supported a revegetation programfor the Arrow Lakes in which the approach consisted of repeated treatments over multiple years to facilitate the growth of vegetative cover in those areas that had good potential to become self-sustaining. The key environmental and social objective of the revegetation program was to maximize vegetation growth in the drawdown zones. The revegetation was to benefit littoral productivity and wildlife habitat, while preventing shoreline erosion and controlling dust.

[1] http://web.archive.org/web/20080221200617/http://www.bchydro.com/recreation/southern/southern1202.html Accessed February 2012.
[2] http://www.bchydro.com/community/recreation_areas/arrow_lakes_reservoir.html#Water_levels accessed February 2012.
[3] Aerial photographs of Renata (1959, 1983 and 2008, 2010); Montana Slough (1959, 1996, 2008, 2010), Beaton Bay (1996, 2008, 2010) and Cranberry Creek (1959, 1996, 2008, 2010) show retention of residual vegetation from pre-construction. BC Hydro Fish and Wildlife Compensation Program photographic collection, Nelson BC. Accessed and photographed October 2011).

To evaluate the success of the revegetation program and assess the effectiveness of the soft constraints to maintain existing vegetation and allow for expansion through the revegetation program, BC Hydro implemented two 10-year vegetation monitoring programs in the Arrow Lakes Reservoir. The programs were intended to assess the impacts of the soft constraints operating regime on existing and treated vegetation communities, as well as the long-term outcome(s) of the physical works CLBWORKS-2 Arrow Lakes Reservoir Revegetation Program. The CLBMON-12 project was initiated in 2008, to provide a site-level evaluation of the success of the CLBWORKS-2 program. Part of the evaluation included distinguishing the effects of the operating regime on non-treated vegetation from the effects of other environmental constraints. The CLBMON-33 project was initiated in 2007 to provide a landscape-level evaluation of the effects of the operating regime and environmental influences on existing vegetation of the drawdown zone. CLBMON-12 and CLBMON-33 are carried out in alternate years, with similar field measures and slightly different overall objectives. The vegetation classification developed in the mapping component of CLBMON-33 is used in the CLBMON-12 and REV 5 projects.

The revegetation project, CLBWORKS-2, was undertaken by Keefer Ecological Services Ltd (KESL) and was completed this year. Draft mapping of the treatment locations was provided annually. The current year represents the second post-treatment assessment of the revegetation of specific areas in the Arrow Lakes Reservoir. The timelines for the three projects are shown in Figure 1.

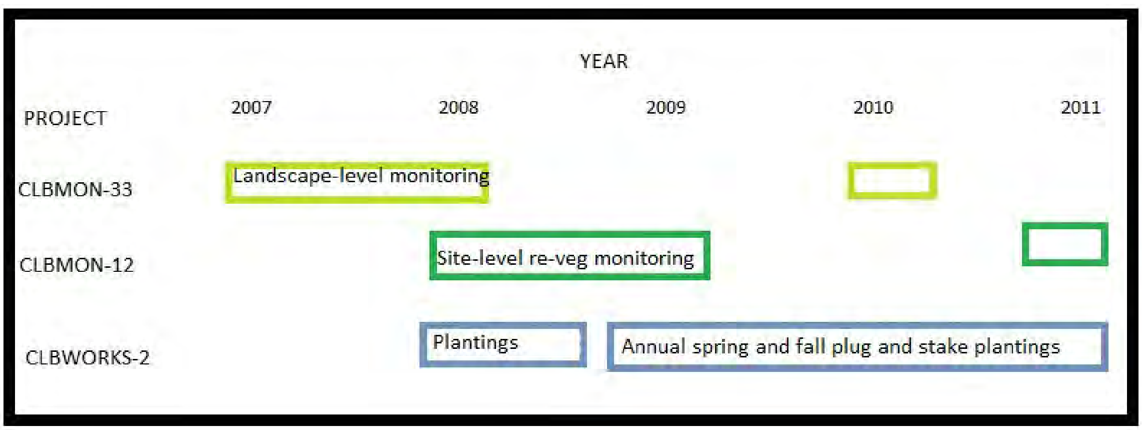

Figure 1. Timelines for CLBMON-12 and CLBMON-33 (monitoring projects) and CLBWORKS-2 (treatment project).

Planning for the revegetation treatments of CLBWORKS-2 began in 2007. Many of the initial plantings in 2008 failed due to early inundation of juvenile seedlings (BC Hydro 2010). Although monitoring plots were established in 2008, it is not clear that the plots were actually treated. During the monitoring year of 2009, CLBMON-12 plots were established in areas that were mapped as to be treated or that had already been treated in spring 2009. Fall planting and other treatments in CLBWORKS continued from 2009 through fall 2011. Some of the landscape-level plots from CLBMON-33 in 2010 were located in treatment areas, and they provided some continuity of monitoring through the 2010 monitoring year. In addition to the existing work, evaluations of the effects of REV 5 on vegetation in the drawdown zone of the Revelstoke Reach portion of the Arrow Lakes Reservoir have been ongoing during both CLBMON-12 and CLBMON-33 since

2009. As the REV 5 turbine was made operational in December 2010, the current year's evaluation is the first post-operations evaluation of field data for this project.

2.0 SCOPE, OBJECTIVES, MANAGEMENT QUESTIONS AND MANAGEMENT HYPOTHESIS

The Columbia River Water Use Planning Consultative Committee (WUP CC) recognized the value of vegetation in improving aesthetic quality, controlling dust, protecting cultural heritage sites, and enhancing wildlife habitat and littoral productivity for fish. They recognized that the most significant opportunity for accomplishing these objectives lay in restoring and expanding riparian and wetland vegetation in the reservoir drawdown zone, as this zone is the only area that can be substantially affected by changes in BC Hydro's operation of the reservoir (BC Hydro 2008).

The WUP CC supported implementation of a revegetation program that was compatible with the current operating regime to enhance and expand vegetation communities within the drawdown zone. The program was proposed as a multi-year project to facilitate long-term self-sustaining vegetation cover. The associated monitoring programs were recommended to assess selected treatment techniques, and to evaluate the effectiveness of planting and fertilization efforts over the long term. During the evaluations undertaken to define potential areas for revegetation, considerable pre-existing vegetation was found in target areas of the reservoir (BC Hydro 2008). The areas that were not vegetated, and therefore potential targets for revegetation, were designated as "problem sites", where wind or water erosion and unfavourable substrates presented challenges to vegetation establishment.

As a result of planning undertaken in 2007 and implemention from 2008 to 2011, a total of 89.15 hectares[4] were treated and mapped by KESL using a variety of ameliorative techniques (KESL 2011). The goals and objectives of CLBMON-12 are focused on the monitoring of existing and revegetated communities at the site level to document change in species composition, which the Terms of Reference define as (plant) diversity, distribution, vigour, abundance and biomass, in response to the stresses imposed by the soft constraints operating regime. The monitoring program addresses the existing uncertainties regarding the relative contribution and importance of timing, frequency, duration and depth of inundation, as well as multi-year stresses on trends in community maintenance (BC Hydro 2008).

2.1 Scope

The scope of the CLBMON-12 project is to identify and evaluate changes in vegetation communities (within the areas mapped in the CLBMON-33 project) in response to revegetation treatment, to the soft constraints operating regime and to other environmental factors.

2.2 Goals

The goals of the CLBMON-12 monitoring program (BC Hydro 2008) are to:

[4] The number of hectares treated is based on a GIS analysis of the mapped areas provided in 2012.

1) determine the species composition (i.e. distribution, diversity and vigour) of existing vegetation communities to identify species that have been surviving long-term inundation;
2) evaluate the cover, abundance and biomass of existing vegetation communities in relation to elevation in the drawdown zone;
3) monitor the response of existing vegetation communities at the local site level to the continued implementation of the soft constraints operating regime for the Arrow Lakes Reservoir and other environmental variables;
4) assess the long-term effectiveness of the revegetation program at restoring and 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; and
5) assess the costs and benefits of the recommended revegetation prescriptions applied under CLBWORKS-2 (Mid-Columbia and Arrow Lakes Reservoir Revegetation Program physical works) by monitoring the response of revegetated communities to different treatments in the drawdown zone of the reservoir.

2.3 Management Questions

The study focus of CLBMON-12 is two-fold: monitor naturally occurring vegetation change in response to the soft constraints operating regime (also a focus of CLBMON-33), and monitor the response of revegetated areas to treatments.

The management questions in relation to the objectives, and findings to date, are as follows:

2.3.1 Existing Vegetation

1. What is the species composition (i.e. distribution, diversity and vigour) of existing vegetation communities (as identified in Enns 2007, Enns et al. 2007) in relation to elevation in the drawdown zone?

2. What is the cover, abundance and biomass of existing vegetation communities (as identified by Enns et al. 2007) in relation to elevation in the drawdown zone?

3. How does the current operating regime affect the within-community quality and quantity (i.e., species cover, abundance, biomass, diversity and distribution within existing communities) of existing vegetation?

4. Is there a shift in community structure (e.g., species dominance) or a potential loss of existing vegetated communities that is attributable to environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation)?

5. What are the species-specific survival rates under the soft constraints operating regime (i.e., what are the tolerances of existing plant species to inundation)?

6. What recommendations can be made to more effectively maintain existing vegetation at the site level in the future?

2.3.2 Revegetated Areas

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

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

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

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?

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

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

2.4 Management Hypotheses

A series of management hypotheses and sub-hypotheses were proposed (BC Hydro 2008) with the option to address the management questions (Section 2.3). The management hypotheses and sub-hypotheses are included in Appendix 1, as this study will focus on the management questions. The management hypothesis and subhypothesis will be examined when sufficient data are available for quantitative testing.

3.0 STUDY AREA

The Arrow Lakes Reservoir includes the Revelstoke Reach, Beaton Arm and the Arrow Lake sections of the Columbia River drainage between Revelstoke, B.C. and the Hugh Keenleyside Dam west of Castlegar, B.C. (Figure 2). The reservoir is 230 km long. The vegetation of the drawdown zone of the Arrow Lakes Reservoir has been influenced by the timing, frequency, duration and depth of inundation of water since the construction of the Hugh Keenleyside Dam in 1968.

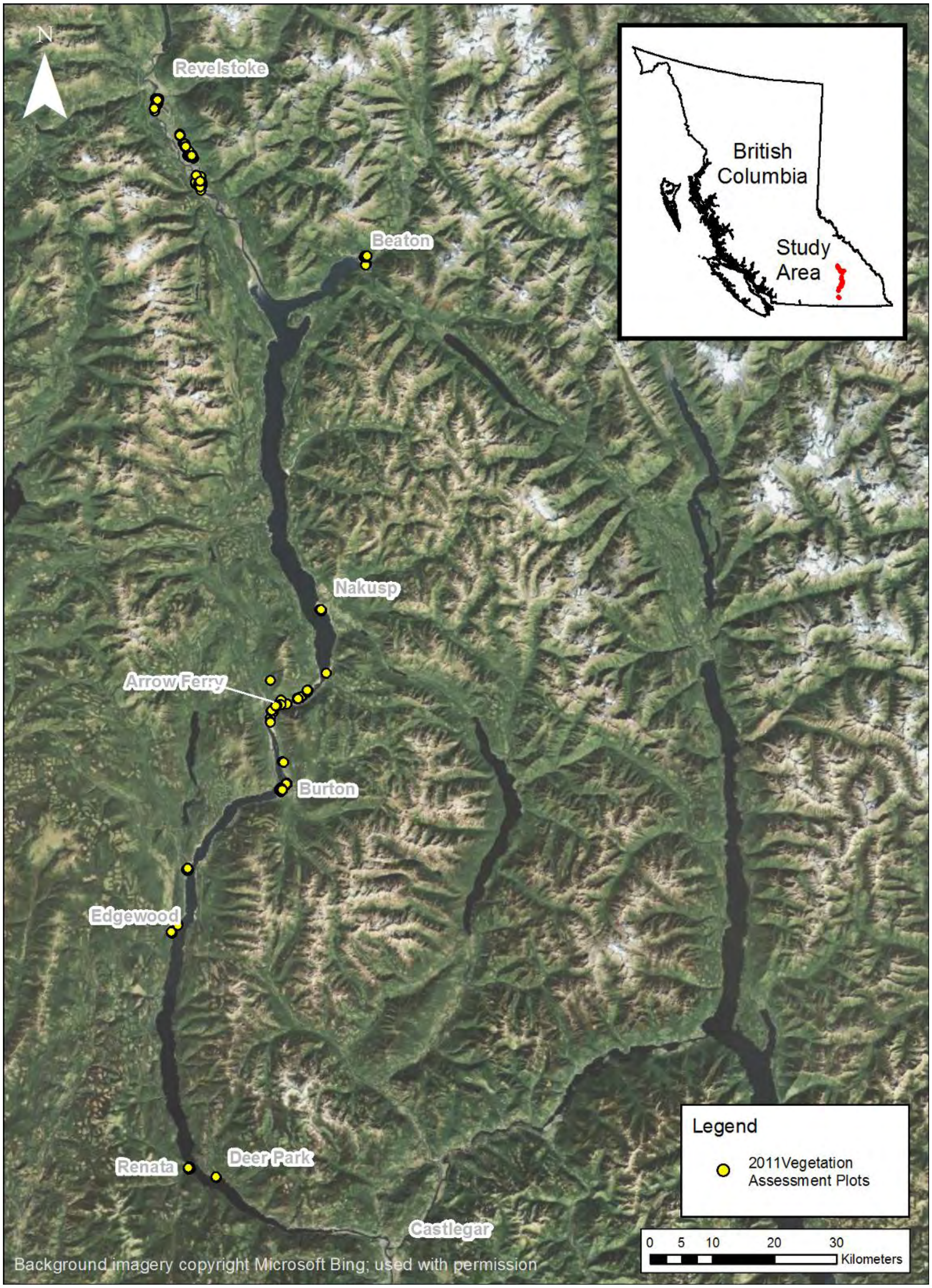

Figure 2. **General locations of field plots completed in 2011 for the CLBMON-12 project within study areas in the Arrow Lakes Reservoir. Yellow dots are the plot locations (which tend to overlap at this scale) within the Arrow Lakes Reservoir. See Folio 1 for detailed maps.**

The species assemblages identified by Enns (2007) and Enns et al. (2007) include several species from the original vegetation cover that persists in the reservoir. The revegetation efforts described in BC Hydro (2010), such as seeding repeatedly with fall rye (*Secale cereale*) and introducing reed canary grass (*Phalaris arundinacea*), have likely assisted in the stabilization of soils and vegetation communities. The cover types prior to flooding consisted of cleared and native forests, previously farmed and grazed lands, orchards, roads and other land uses. Some remnants of these land use patterns also persist in the species composition of the reservoir, e.g., numerous pasture and ditch weeds and grasses occur at low to middle elevation, and species typical of seral open forests occur at high elevation. However, a large proportion of the areas included in this study are non-vegetated to poorly vegetated. The influence of physiography, soils, geology and climate on the plant communities of the Arrow Lakes Reservoir is discussed below.

3.1 Landforms

The landforms of the study area are illustrated in Figures 3-5 below. Holland (1976) described the Columbia River trench between Revelstoke and Castlegar as lying within a large glacially carved U-shaped trough, which is relatively shallow in the Revelstoke Reach portion and considerably deeper in the Arrow portion of the Arrow Lakes Reservoir. Alluvial fans entering the reservoir at right angles create shallow sections, and some of the channels within the fans are braided and form islands. The Arrow Lakes Reservoir lies within the Columbia Mountains, and is bound by the Monashee Mountain Range on the west and the Selkirk Mountain Range on the east. Both ranges are north-trending, and are more massive and dramatic to the northeast and more subdued and rounded in the southwest (Enns et al. 2007). A mantle of deep till (glacial drift) covers the mountain sides, and is deeper in Revelstoke Reach than in the southern portions. The depth of till and colluvium over bedrock is shallower in the southern part of the Arrow Lakes portion, and the “drier” species assemblages in the drawdown zone reflect this difference (Enns et al. 2010). Several creek and river channels enter the reservoir. These entries are usually bouldery, but they appear to influence vegetation survival in the drawdown zone by supplying water at the subsurface level in quantities that do not occur in ordinary till deposits. The alluvial fans in the drawdown zone make up a large proportion of the individual study areas included in the CLBMON-12 monitoring program. For example, Deer Park, Renata, Edgewood South, Burton, Nakusp, Halfway River, Beaton North, Cranberry Creek, Montana Slough and Illecillewaet are all influenced by alluvial deposition and water supplies entering the reservoir. Figures 3 through 5 show the shallowness of the Revelstoke Reach, the steeper-sided Mid Arrow and Beaton Arm section of Arrow Lake and the thinner soils and rockier slopes of the southern portion of Arrow Lake.

Figure 3. Revelstoke Reach, looking North from the southern opening to the Reach toward Revelstoke, B.C. (from Enns et al. 2007).

Figure 4. Study a rea ph ysiography from Galena Ba y and Shel ter Ba y in the north to the alluvial fan at Nakusp (from Enns et al. 2007).

Figure 5. The lo wer section of Arrow Lake from the Narrow s to H ugh Keenleyside Dam in the southeast corner o f the image. A section of winter ima gery is patched into the summer image and show s t he pattern of sno w on the ridge s at high elevation in the S elkirk Mountains (from Enns et al. 2007).

3.2 Climate

The climate of the study area is wetter and colder in the north and drier and warmer to the south (Table 2).

Table 2. Average daily temperatures, maximum high and low temperatures and precipitation for Revelstoke, Nakusp and Castlegar. From Environmental Canada's *Climate Normals & Averages – 1971 to 2000*

Weather Station	Average Daily Temperature (°C)	Maximum high temperature (°C)	Minimum low temperature (°C)	Average precipitation (mm)	Average precipitation as snow (mm).
Revelstoke	6.9	37.2	-29.4	945.7	424.7
Nakusp	7.7	37.0	-27.8	842.0	192.1
Castlegar	8.6	37.2	-22.5	635.2	116.9

There are no climate data to illustrate where the climate becomes warmer and drier between Nakusp and Deer Park or Renata, but we suspect that the climate at Edgewood (Figure 4) is more similar to Nakusp than to Castlegar.

3.3 Biogeoclimatic Ecosystem Classification

The biogeoclimatic ecosystem classification for the study area has been under revision for several years (D. MacKillup pers.comm. 2012). The boundaries of the southernmost variants may be changed and the classification will not be made public until late in 2012. However, the following revisions to a previous table (Enns et al. 2007) describing the biogeoclimatic zones, subzones and variants was provided by Forests, Lands Natural Resources BC (D. MacKillup pers.comm. 2012). Table 3 shows the Zones, Subzones and Variants in the study area.

Table 3. Biogeoclimatic zones, subzones and variants present in the study area

Zone	Subzone	Variant(s)
Interior Cedar Hemlock	dw (dry warm)	1
Interior Cedar Hemlock	mw (moist warm)	2 & 3
Interior Cedar Hemlock	wk (wet cool)	1
Interior Cedar Hemlock	Xw	
Interior Cedar Hemlock	xw-warm	

The study area falls within the Interior Cedar Hemlock zone (ICH) and is represented by five subzones and three variants. Previously, the Interior Douglas-fir undifferentiated subzone was included in the study area, at Deer Park. Braumandl and Curran (1992) can still be used to describe the ICH subzones and variants from approximately Needles and Fauquier to the north (D. MacKillup pers comm. 2012).

3.4 Vegetation Communities

The vegetation community types (VCTs) occurring between 434 m and 440 m within the drawdown zone of the reservoir were defined in the field and were sampled repeatedly between 2007 and 2011. The VCTs are based on a combination of similar topography, parent materials (or true soils), and vegetation features (Table 4).

Table 4. Vegetation community types (VCTs) of the Arrow Lakes Reservoir CLBMON-12

Vegetation Community Type	Status
	**BE: Sandy Beach:** mostly non-vegetated to sparsely vegetated sandy areas, dominated by drought-tolerant herbaceous plants, seedlings, and grasses, and occasionally with sedges and mosses. BE occurs from 440 m to below 434 m elevation, but is most abundant below 436 m, and is gently sloping and can be undulating. It is common throughout the Arrow Lakes Reservoir, but increases in abundance to the south.
	**BG: Gravelly Beach:** very sparsely vegetated with grasses and herbaceous plants, especially drought-tolerant weeds, and occasionally small cottonwood and willows. BG occurs from 439 m to 434 m elevation, but is most abundant between 437 m and 435 m. It is often flat to gently sloping. Materials are non-soils, consisting of gravels and cobbles, but include some gritty sands which support plant life. BG is increasingly common and abundant toward the southern end of the Arrow Lakes Reservoir, and is almost non-existent in the northern portion of Revelstoke Reach.
	**PA: Redtop Upland:** dominated by shrubs and several species of grasses, with a few drought-tolerant herbs and several species of weeds. Lichens, mosses, and liverworts are very common. Stunted trees often occur, and many of these predate reservoir construction. PA is centred near the upper elevation of the drawdown zone, near 439 m, but can extend down to 434 m on very well-drained materials. The vegetation in PA seems to provide some protection from scouring. PA is very common throughout the Arrow Lakes portion of the reservoir, and is not common in Revelstoke Reach.
	**PC: Reed Canary Grass Mesic:** is comparatively species poor, and is dominated by reed canary grass (*Phalaris arundinacea*), but it can include a minor component of mint, horsetail, and agronomic species. PC occurs in all slope positions, but is centred between 435 m and 437 m elevation, and is usually flat to undulating to gently sloping. Soils are close to true soils, with some rudimentary layering, and are almost always sands with some silt and clay. PC is common and abundant throughout the reservoir, but is most common in Revelstoke Reach and becomes less common towards the south.

	**PE: Horsetail Lowland:** has a very characteristic species assemblage consisting of horsetails, rushes, reeds, and mosses. PE is centred between 433 m and 435 m elevation, but can extend upslope if moisture is available, and always occurs in concave, sloping topography. Soils are silty, often compacted, occasionally include clays and organics, and are poorly aerated. PE soils are possibly derived from organic materials or very silty glaciofluvial deposits. This type is very susceptible to scouring. PE occurs throughout the reservoir, but covers a small total area. It is almost absent from the southern end of the reservoir.
	**BB: Boulders, Steep:** Common at river entries, consisting of boulders and gravels, on steep slopes, usually with less than 3 per cent vegetation. This type increases in frequency of occurrence toward the south. Vegetation is usually very drought-tolerant and species-poor with a low biomass and often low vigour.
	**CL: Cliffs, Rock Outcrops and Steep Rocky Shores:** Very uncommon in the study areas for CLBMON-12, but very common in the reservoir; mostly steep and sparsely vegetated with extremely drought-tolerant species. Always at high elevation and influenced by upland riparian forests or other shoreline vegetation communities.
	**CR: Cottonwood Riparian Forests:** Very common and includes all seral stages of riparian foreste; highly variable, often diverse and can be close in character to the site series described in Braumandl and Curran (1992). Includes agricultural conversions of CR, such as agronomic grass-dominated pastures, fields and orchards. CR is restricted to 439 to 440 m.
	**IN: Industrial:** consists mainly of old roads, developments, and disturbed areas, very common but covers a small total area of the reservoir. Dominated by pasture and ditch weeds on the edges, and may lend some stability to materials (soils and pre-soils) from surficial scouring.

	**PO: Ponds, Standing Water:** Very uncommon; limited to a few locations in the reservoir; often in an upslope depressional area with water draining in from upslope. Dominated by flood tolerant grasses, but has some true wetland species in some locations.
	**RS: Willow Stream Entry:** Common; influenced more by streams than by the reservoir, dominated by shrubs and drought/inundation-tolerant herbs, willows, cottonwood and grasses.
	**SS: Steep Sand:** Very uncommon; steep, often failing sand banks, at various elevations; may be ephemeral, often non-vegetated or very low cover of grasses, horsetails, reeds.
	**RR: Reed Rill:** Relatively common subsurface to surface flows through the highest elevation and becoming more prominent anywhere from 438 to 434 m. RR has highly adapted vegetation consisting of inundation-tolerant plants such as horsetails, reeds, rushes, sedges and ditch weeds.
	**SF: Slope Failure:** Extremely rare vegetation type with a mix of vegetation and materials, usually characterized by peeling and slumping of sands and silts from a higher elevation in the reservoir.

Figure 6 shows a typical pattern of vegetation community types in Arrow Lakes Reservoir.

Figure 6. Typical configuration of Vegetation Community Types in Arrow Lakes Reservoir. BG = Grav elly Beach, BE = Sand y Beach , PC = Reed Canary Grass Mesic, PE = Horsetail Lo wland, SS = Steep Sand, BB = Boulders, Steep.

CLBMON-12 examines the effects of the reservoir on all of the VCTs listed in the table above; however, some VCTs are either non-vegetated (SS, BB) or heavily influenced by factors other than the reservoir, such as stream and river entries (RS). Some vegetation types, such as cliffs, ponds, and slope failures, are very uncommon; they cover less than one per cent of the study area, and have little or no representation in each of the elevation classes. The responses of plants to the water regime in communities such as these cannot be interpreted clearly. For this reason, it was agreed to focus on VCTs that are at least partly vegetated and influenced by the reservoir water behaviour. The treatments undertaken by CLBWORKS-2 took place in IN, BE, BG, PA, PC and PE types.

4.0 METHODS

4.1 Background: Existing Vegetation Community Types

The field data collected for CLBMON-12 are classified into vegetation community types based on the CLBMON-33 project in 2007. For the CLBMON-33 project, polygons were mapped at a 1:20 000 scale on aerial photographs. The polygons delineated similar groupings of physiographic features and vegetation community types within the 43 sample areas of the overall project area (Enns 2007). Each VCT has a unique combination of topographic and parent material (soil or non-soil) features together with characteristic vegetation associated with those features. The vegetation community types are described in Table 3.

Field sampling was also carried out in 2009 and 2011 to evaluate the effects of the additional REV 5 turbine on vegetation communities. This is addressed in an addendum to this report.

4.2 Background: Treated Vegetation

This year, data collected in treatment (revegetated) and untreated (control) areas were used to assess the influence of the water regime, and the effectiveness of the revegetation program in remediating and expanding the quality and quantity of vegetation in the drawdown zone. Most of the sampling in 2011 involved resurveying plots that had been established and assessed between 2007 and 2010 for either CLBMON-12 or CLBMON-33, with new plots established in treatment and control sites if there were no pre-existing plots. The new plots were required because monitoring of the treatments was last done in 2009, and two years of treatments have since been applied in the reservoir in areas where plots had not previously been established.

The choice of whether to resample a plot was based in part on whether it had been treated or made up a control site for a treatment, but also whether it had a history of monitoring, allowing the effects of the reservoir water regime to be evaluated.

As mentioned above, the VCTs with very low vegetation cover, such as bouldery beaches (BB) and steep sandy slopes (SS) were not sampled in 2011 unless they already contained an existing plot within a treatment or control area.

4.3 Field Procedures

The GPS locations and field data for previously sampled plots were recorded in the GPS (Nomad 800L with SX Blue Differential). Maps of each study area, showing the previous plot locations within sample areas, were prepared for use in the field. Treatment (revegetated) areas and designated control areas that were left untreated were also delineated on field maps. The 2011 field personnel were the same as in 2010. Field personnel reviewed safety procedures and field standardization prior to the start of field data collection.

Table 5 shows the dates of activities prior to, during and after the fieldwork for the CLBMON-12 project.

Calibration and standardization of vegetation cover estimates and height measurements were done throughout the field session. The field data collected for plots in previous years, including plant specimens, were available for reference in the field.

Table 5. Dates worked to complete CLBMON-12 in 2011.

Action Dat	e
Pre-fieldwork planning, including map preparation	April 1–May 5, 2011
Field assessment of vegetation plots in existing and treated vegetation	May 16–June 10, 2011
Field practices audit and project science meeting	June 6, 2011
Plant I.D.; review and edit field forms	June 17, 2011
Update and edit the plant species database based on unknown plant I.D.	September 27–November 5, 2011
Field data archiving; cleaning and data entry	July 2–October 15, 2011
Data analysis	October 15–December 5, 2011
Reporting	April 1–December 21, 2011

As in previous years, the location of fieldwork had to be prioritized to complete the low-elevation sites before they were inundated. Fieldwork at low elevation (434 m to 436 m) sites was completed in the first weeks of the sampling period. Middle- to high-elevation (436 m to 440 m) field sampling was completed between the last week of May and June 10, 2011.

4.1 Vegetation Sampling Methods

To ensure consistency in vegetation sampling methods, field data were collected using the same methods as in previous years (Enns et al. 2007, 2008, 2009, 2010). The methods used were adapted from methods developed by the B.C. Ministry of Forests and Range and B.C. Ministry of Environment (2010).[5]

The VCTs within polygons were sampled using 5 m x 10 m (50 m^2) vegetation plots.[6] This plot size was based on species area curves / minimal area curves (Mueller-Dombois and Ellenberg 1974, page 48). Minimal area is determined by initially recording all species that occur in a small area, then enlarging the area by increments and recording the additional species captured in the larger areas until the number of new species levels off. A curve is drawn (Mueller-Dombois and Ellenberg 1974, page 51) where number of species added for each incremental increase in area is shown on the y-axis and incremental sample area on the x-axis. This leveling off point is considered to be an adequate sample area to represent the species diversity of a vegetation community type (Mueller-Dombois and Ellenberg 1974).

An overview of the plot locations is shown in Figure 1, and detailed mapped plot locations are included in Folio 1. The number of plots sampled in 2011 is shown in Table 6a and 6b.

[5] http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh25/Lmh25_ed2_(2010).pdf

[6] In 2008 and 2009, plots consisted of three 0.5 m^2 subplots within a larger 5m X 10 m plot. A list of all species was made for each subplot and for the larger plot. In 2010, field sampling procedures were changed so that only the larger plots were sampled. This change was adopted because sampling of the smaller subplots did not add new species to the total for a site, but it did add considerably to the amount of time required to complete a plot. Also, data collected for the three subplots were amalgamated during the analysis to represent the larger plot in all of the past reports, so the use of three subplots was judged as redundant and unnecessary.

Table 6a. Number of existing vegetation plots within VCTs in the Arrow Lakes Reservoir sampled in 2011.

VCT/ elevation (m)	434 – 436	436 - 438	438 - 440	Grand Total
BE	59	25	8	92
BG	4	13	1	18
CR			10	10
IN	4	4	3	11
PA		8	11	19
PC	44	51	34	129
PE	18	3	1	22
RR	1			1
RS	2			2
SF		1	1	2
BB		2	1	3
SS	1	2		3
Grand Total	**140**	**131**	**104**	**375**

Table 6b. Number of revegetation plots sampled in 2011. Plug and Stake counts occurred in PA, PC, BE and BG community types and often crossed community type boundaries.

Treatment	Control plots	Treatment plots	Total
Cottonwood seedlings	8	8	**16**
Cottonwood stakes	26	26	**52**
Sedge plugs	41	41	**82**

The absence of plots in a given elevation band is due to vegetation communities being strongly aligned with certain elevations.

The vegetation plots were oriented in the direction of the Columbia River main stem water flow (approximately north to south) to avoid crossing over an elevation band. Each plot was 5 m x 10 m in size. Minimal sample size calculations for the Cottonwood Riparian vegetation community type indicated a larger sample was required for this type, therefore, plots in Cottonwood Riparian were 10 m x 20 m in size. The plots were temporarily marked at the corners with flagging pins, using GPS locations recorded at the time of plot establishment, and the GPS location of the centre point of the plot was also recorded using the Nomad 800L GPS. Information recorded on each plot form included the date, sample area location, control or treatment designation if applicable, name of the surveyor, vegetation community type, vegetation seasonal development and structural stages, site features, extent of scouring or wave action, parent material composition, and site disturbance types.

Plots located in naturally occurring vegetation were designated as controls for treatment plots. The control and treatment plots were not always adjacent to each other, some plots were disjunt from each other by as much as 500 meters, however they were located in the same vegetation community type, with similar topographic features, and at the same elevation. The number of the treatment plot that was paired with the control plot was also recorded.

All species observed in a plot were recorded in the species list using the B.C. provincial 7-letter codes for scientific names. If a species was unknown, it was given a field name and a specimen was collected for later identification. When time permitted, the plot forms from previous years of sampling were consulted to verify species identifications.

For each species in the plot, per cent cover, abundance class, vigour class, distribution code, and average height were recorded. Percent cover was considered to be additive due to overlapping crowns and final tallies for all species could (uncommonly) exceed 100% cover. These measurements are further described in the glossary.

Per cent cover values were estimated using the coarse fragment content–cover comparison chart (BC Ministry of Forests and Range and BC Ministry of Environment 2010) as a reference guide. Species cover estimates were recorded using values between 0.1 per cent and 100 per cent. Species with cover of < 0.1 per cent in the plot were given a value of 0.1 per cent.

Plant species abundance, vigour, and distribution codes were recorded using the procedure and codes described in B.C. Ministry of Forests and Range and B.C. Ministry of Environment (2010) (see Glossary). Notes were made in the field to describe topographic and soil conditions (i.e., soil texture, terrain texture, evidence of water energy, topographical sheltering effects, presence of grazing or other disturbance). In addition to the usual CLBMON-12 data, the average height of a species was measured, even though it is primarily a feature of the CLBMON-33 database, in order to have a consistent annual measurement of this variable. Height was determined by measuring representative plants of the species from the ground to their highest points.

Photographs of the finished plot forms were taken in the field. The vegetation in the plot and surroundings were photographed as well.

4.2 Field data collection in treatment plots

The revegetation program was carried out by Keefer Ecological Services Ltd. (KESL 2011). We attempted to assess every area that had been treated, both in 2011 and before 2011, according the interim mapping that was supplied by KESL. Treatments selected for revegetation assessments included planted sedge plugs, planted willow plugs, shrub cuttings/stakes, applied seed mixes and fertilizer treatments. In 2011, KESL planted approximately 266,580 sedge plugs and 18,680 black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), willow (*Salix* spp.), and red-osier dogwood (*Cornus stolonifera*) seedlings, as well as 4,347 live black cottonwood stakes.

We established and assessed plots within treatment areas using the same process described for existing vegetation (Section 5.2). Species cover, abundance, vigour, distribution, and average height were estimated for the pre-existing plant species, and counts of individuals of the staked or planted species were made within the plot, where they could be identified as such. Plugs or seedlings were designated as such in the database, if distinguishable. If dead individual treatment plants were present, the numbers of live and dead individuals of planted species within the plots were also counted and recorded on the plot forms. Treatment plots were paired with control plots, as described in Section 5.2.

One problem encountered during the establishement of new paired plots was that older treatments were not always distinguishable from untreated vegetation, given that treatment plants had no tags, pins, or other markings. If the plants occurred in relatively uniform rows or in a grid-like pattern of planted plugs, the area was assumed to have been treated. In several cases it was impossible to tell if an area mapped as treated had in fact been treated.

KESL used either machinery or hand planting to establish black cottonwood and willow live stakes in various places in the reservoir. We assessed stake survival in areas throughout the reservoir, using draft mapping by KESL as a guide to where stake treatments had been established. The actual method of live staking was not always clear from the baseline mapping data, but the live stakes themselves were obvious. The majority of live stakes planted were cottonwood, but willow and red-osier dogwood stakes were also observed in some treatment areas.

Two different sets of procedures were used in the live-staked areas. In some areas, we established 5 m x 10 m vegetation plots as usual, and counted the live stakes within the plots. This procedure provided good information about the diversity and condition of the vegetation, but did not adequately sample the survival of the stakes in areas that had been extensively treated. At some sites, where stakes had been planted in numerous or large areas, we sampled representative areas with the 5 m x 10 m vegetation plots and also increased the intensity of data collection on stake survival by conducting stake counts, described below. In some treated areas, we counted stakes, but did not establish vegetation plots. , because we had exceeded the number of plots required to sample the type in which stakes were planted.

The stake-planted areas were often rectangular, with the long axis along the 436-m to 438-m elevation band. We collected GPS locations around the perimeter of the stake patch to determine its area, and then surveyed the entire patch. Within larger treatment areas, we selected a representative area, mapped it to determine its size, and then surveyed it. Usually, representative areas were approximately 100 m x 50 m.

Within a survey area, the numbers of live stakes, dead stakes, and the total number of planted stakes by species were tallied and recorded on field data forms along with the assessment area identification number and the assessment area location. Dead stakes had no leaves or shoots with living buds. Stakes had to have some living leaf tissue or live buds to be classified as “live”. Because cottonwood live stakes have a Lazarus-like capability of appearing dead for long periods but eventually producing shoots, future live/dead counts may show recovery of previously “dead” plants.

The information collected at stake plot locations that did not include full vegetation plots (due to already meeting sample size requirements) was location, area, number of live and dead stems by species, and particle size of the substrate. Photographs of the stake count areas and forms were also taken. The additional numbers of stake counts was requested by BC Hydro to ensure the ability to evaluate surivival of stake planted cottonwood.

An evaluation of fertilization treatment effects was compiled by comparing the appearance of the vegetation in the two fertilized areas vs the not fertilized areas at Burton using the 2010 aerial photography.

4.3 Biomass Sampling and Estimation

Biomass is the mass or weight of all the organisms in a given population, community, trophic level, or area (Lincoln et al. 1982). For the purposes of this project, biomass was defined as the weight of all the aboveground live plant material of each species. Biomass sampling was used to estimate standing crop of vegetation within the plot. Sampling was replicated in a number of the paired treatment and control plots in order to compare standing crop between treated and control (non-treated) areas within the target VCTs.

Sampling of the biomass in plots involved clipping the aboveground live plant material of each species within a 0.5-m^2 subplot. The subplot was located within the 5 m x 10 m plot by tossing a 0.5 m x 0.5 m quadrat frame on the upslope (long axis) boundary of the plot. This general sample area was used for each biomass sample subplot because the upslope boundary was not in the way of the vegetation assessment and did not cause trampling in the assessment area or in the biomass subplot. If a frame landed in an area with no vegetation it was re-tossed so that at least some vegetation occurred in the biomass plot.[7]

The weights of all plants of each species inside the frame were first estimated, and then the plants were clipped with scissors to ground level. The plant material of each species was then placed inside a pre-weighed paper bag and weighed on a portable, battery operated, digital 0.01-g scale. Bags of clipped plant material were labelled with the plot number, species code, and fresh weight in grams and were refrigerated for future determination of dry weights and per cent dry matter. Fresh weights of each species were recorded in the “weighed” column on the plot form. After the scale was used to weigh clippings in a number of replications in the field, the surveyors conducting the biomass sampling were able to estimate fresh weights of some of the more common species with an accuracy of +/- 3 to 6 grams per species. When the weight of clipped plant material was estimated, the value was recorded in the “estimated” column on the plot form. Species that occurred in very small amounts within the biomass subplots were assigned a weight of < 1 g. Dry weights were determined in July 2010 by drying samples at 200 degrees Fahrenheit to the point of no change in weight. A dry weight correction factor was then applied to all of the samples in order to estimate the final grams per hectare estimate for each plot.

4.4 Photograp hy

Photographs were taken to record species composition and vegetation characteristics in the plot as well as the surrounding vegetation and soil characteristics. Photographs were taken while standing at the south end of the plot. A photograph of the plot itself was taken, then a series of landscape photographs were taken of each cardinal direction (east, west, and south). Significant features of the photographs were noted on the plot forms. After the plot documentation was completed, plot location flags were removed

[7] CLBMON-33 examines trends in non-vegetated substrates within VCTs, but for the purpose of investigating the effect of the reservoir operation on vegetation biomass for CLBMON-12, it was necessary to reject completely non-vegetated substrates if they occurred in the random selection of a biomass subplot.

from the corners, and a labelled wooden stake was installed at the downstream, uphill corner of the plot, if a new plot marker was required.

4.5 Field Quality Control

Field forms were reviewed and corrected daily, and were ready for data entry during each day of the fieldwork. Each completed field form was photographed on the same day the data were collected to provide backup copies of the plot data. The field data were downloaded weekly into a GIS database. Checks of the GIS data accuracy were run each week, and plots were recorded on new versions of the maps for further use in the field. Hard copies of the field data, digital photographs, and photographic backup records were stored both on and off site. An on-site inspection of the field program was conducted by BC Hydro. The results of the inspection have not been received.

4.6 Plant Identification

Many of the plants in the CLBMON-12 field study were immature when the field assessments were conducted. Collected specimens were identified daily, using standard plant field guides and taxonomic keys. Some specimens that were difficult to identify were sent to private contracting botanists for verification or identification. Names of the identified specimens were used to complete the field records and update the species list in the database. A plant collection for this project has been maintained since 2007. The species list with seven letter codes and common names is included in Appendix 2.

4.7 Data Entry, Analyses, and Interpretation

The field data were entered into a spreadsheet using the same methodology as in Enns et al. (2010). Species name codes were checked for spelling errors, and redundant names and missing data were reconciled. The corrected database has been provided to BC Hydro.

The management questions were addressed individually in the analysis by identifying the dependent and independent variables applicable to each question, and examining trends in data distributions, primarily with the use of Tukey's notched boxplots and scatterplots. Where indicated, ANOVA and canonical analysis were also used. Simple biometric tests were used to assess trends.

The plant species cover matrix included a large number of zeros and very small cover values due to the occurrence of many unique or rare species in one or two plots and to generally low cover. This is referred to as a "dust bunny" distribution,[8] and is common in vegetation species cover data (McCune and Grace 2002). To combat this potential problem[9]of non-normality, a log transformation was used specifically for examining the response of cover to the water regime. To examine the relationship between cover (= X) and days of inundation in the current year, the log transformation B_{ij} (for species i through j) used was:

[8] Dust bunnies are defined as species with very small cover values and very low frequency of occurrence in the data.

[9] The "non-normality" (issue) is not that straightforward. RDA is regression based, and uses least-squares; it therefore does NOT depend on normality. The assumption of normality is only needed if yo want to do formal testing of the individual components, as is the case for examination of the days of indundation and the influence on species cover. The assumption of normality applies to the RESIDUALS and not the individual values, so you can have a marginal distribution (i.e. looking at biomass across all the plots) that does not look normally distributed, but is acceptable as the "distribution" of predictors is odd).

$$B_{ij} = \log(X_{ij} + 0.001) - (-3)$$

where 0.001 is the lowest cover value recorded in the sample data set, and -3 is the log of the lowest cover value (McCune and Grace 2002)[10]. The species occurring in up to two plots were removed from the database for the performance of ordination, as they are too infrequent in the database and result in excess noise (McCune and Grace 2002). However, these infrequent species were retained for tabular and scatterplot data display purposes.

Non-metric multidimensional scaling was used to compare the community species composition as influenced by environmental variables, such as terrain texture class, slope, aspect, moisture and nutrient regime, and depth and duration of inundation on an annual basis (data not shown).

Tukey's notched boxplots (generated in Sygraph and Systat: Version 6.0 for Windows, 1996) were used to show the distribution of vegetation cover, abundance, distribution, vigour, height, biomass, diversity and species richness to indicate where significant relationships may benefit from further analysis through the use of ANOVA and RDA. Tukey's notched boxplots indicate data within a set of samples more completely than comparisons of means, analysis of variance tables, or use of standard errors or standard deviations. They show the characteristics of the data distribution. Notched Tukey's boxplots are also a visual method of showing statistically significant differences ($p < 0.05$) among data distributions from comparably sampled populations (Tukey 1977; Velleman and Hoaglin 1981; Wilkinson et al. 1992) (Figure 7).

The notched boxplot appears as a narrow-waisted box. The narrowed centre is the median of the set of values plotted for a variable. The hinges, or narrow ends of the box, represent the 25th and 75th percentiles of the data. The position of the hinges relative to the median provides an indication of the skewness of the values in the given data. Circles or asterisks plotted above or below the main box represent outliers.

The vertical extent of the notch in the box represents the 95 per cent confidence limits about the median value. When several of these notched boxplots are shown in the same graph, the position of the notches relative to one another shows whether the medians of the data sets are significantly different at the 95 per cent confidence level. Notches that do not overlap indicate medians that are significantly different, while notches that do overlap indicate no significant difference among the medians.

The 95 per cent confidence level of the median may occasionally exceed either one or both of the 25th and 75th percentiles (the hinges or ends of the box). The graphical result of this is a box that appears inside-out at one or both ends.

Simple notched boxplots (generated in R: Version 2.13.0, April 14,2011) were used to compare treated and control vegetation between 2009 and 2011.

[10] To log transform data containing zeros, 1 is often added to the data values because log(0) is undefined. If, however, the smallest value recorded in the dataset is more than one order of magnitude different from 1, adding 1 will distort the relationship between non-zero and zero values. The log transform used here is a generalized transformation that tends to preserve the original orders of magnitude in the dataset and also results in values of zero when the initial value was zero. See McCune and Grace (2002), page 68-69.

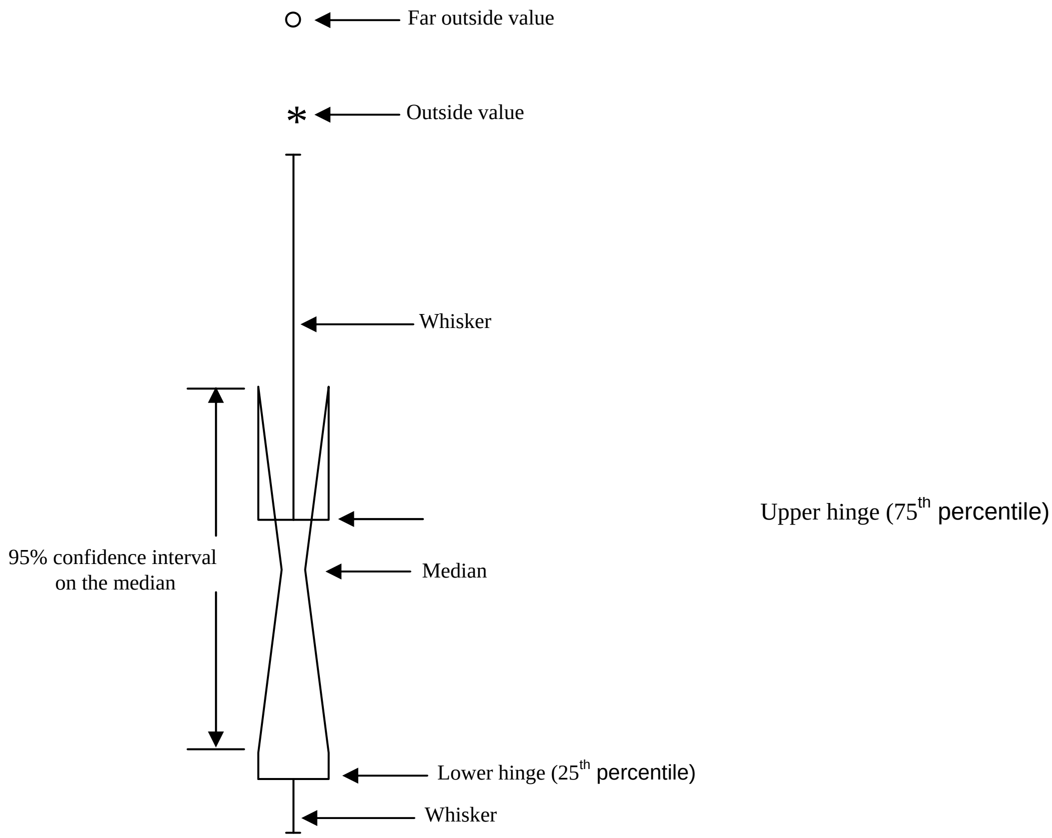

Figure 7. Illustration of a notched Tukey's boxplot. Boxplots show a statistically significant difference ($p < 0.05$) between medians from comparably sampled populations when the notches or two or more boxplots do not overlap. The narrow centre of the box represents the median point in the data set. The top and bottom of the box are the 75th and 25th percentiles, respectively, and are called the hinges. The H spread is the absolute value of the difference between the values of the two hinges. The whiskers show the range of values that fall within 1.5 H spreads of the hinges. Inner fences (not plotted) are equal to the value of the hinge ± (1.5 x Hspread). Outer fences (not plotted) are equal to the value of the hinge ± (3.0 x Hspread). Asterisks and circles show values outside the inner and outer fences of the data distribution, and are potential outliers. The notch in the box represents the 95 per cent confidence limits of the median. When the confidence limit exceeds the 75th or 25th percentile (i.e., the end of the box), the boxplot looks like it has been turned inside-out (McGill et al. 1978).

For analyses of species diversity, the Shannon-Wiener Diversity Index was calculated as follows:

$$H' = -\Sigma (p_i \ln p_i)$$

where p_i is the relative frequency or proportion of species i of the total number of occurrences of all species in each vegetation community type.

Analysis of variance and redundancy analysis (RDA) with forward selection were also used. Cover was chosen as the independent variable, because it was the most responsive and least uncertain measurement of the vegetation. Other variables, with the exception of height, were estimated /coded variables. An RDA was used to examine the relationships between cover and a number of independent variables, including ones that describe the behaviour of water in the reservoir in 2011, and the biophysical and environmental characteristics of each treatment, control, and existing vegetation site. PC-Ord (Peck 2010; McCune and Grace 2002) was used for this analysis.

The main matrix was created from cover values, with plots listed in rows and species listed in columns. Covers were non-normal, so were transformed using the following formula:

$$transcov = \log(cover + \min[cover]) - \log(\min[cover]); \quad \min(cover) = 0.001$$

Once imported into PC-ORD, plots with no cover values (i.e. no vegetation[11]) were deleted from the data set, which resulted in 298 remaining plots. Species that occurred fewer than five times in the data set were also deleted as these only add noise to the interpretation of the data (McCune and Grace, 2002). This resulted in 70 species remaining for interpretation.

The second matrix was created with the same 298 plots, with the following environmental variables (Table 7) included for each plot:

Table 7. Environmental variables (and their short form codes) included in the Redundancy Analysis.

Variable code name	Description of the variable
NATIVE	Dummy variable for existing vegetation plot type (not part of control/treatment program)
CONTROL	Control plots for control/treatment assessments
TREAT	Treatment plots for control/treatment assessments
SCOUR	Binary for whether scouring occurred in the plot
PSAND	Per cent sand/100
PSILT	Per cent silt/100
PGRAV	Per cent gravel/100
INUND	Days of inundation in the past year (May 2010 to May 2011)
ELEVM	Elevation in metres
SLOPEP	Slope per cent/100
HLI	Estimate of heat load index based on aspect = (1 – cos[aspect – 45])/2

For the purposes of testing the null hypothesis of no linear relationship (implicit in RDA) between the environmental variables (predictor matrix) and the species (response matrix), the RDA was run 998 times with randomized data. This was done by randomly shuffling the rows in one matrix relative to the other, performing the RDA on the

[11] If no vegetation is present, then a relationship with independant variables can not be ascertained.

randomized data, recording test statistics, and comparing those to the eigenvalues from the non-randomized RDA to determine the probability of a Type I error.

A table of autecological characteristics was compiled from the literature (Appendix 3) and was used to explain the difference between known ecological requirements of species with intermittent occurrence and their frequency of occurrence in the drawdown zone. The benefits and costs of the treatments were assessed qualitatively.

5.0 RESULTS

5.1 Characteristics of inundation over time

The purpose of the analysis was to test for the effects of reservoir operations on vegetation, and distinguish effects of the reservoir operations from other influences, where feasible. Vegetation in the reservoir has been influenced by operating conditions since the mid-1960s and has adapted to and been shaped by those conditions. A change in operating conditions may or may not result in a subsequent change in the vegetation. The hypotheses tests suggested in the Terms of Reference divide the variation in operating conditions into the following four components:

1. timing of inundation,
2. frequency of inundation,
3. duration of inundation, and
4. depth of inundation.

Figure 8 and 9 show the timing, frequency, duration, and depths of inundation from January 2005 to March 31, 2011. The 2005 dates is chosen as earlier conditions than those occurring in 2007 have had an influence on vegetation.

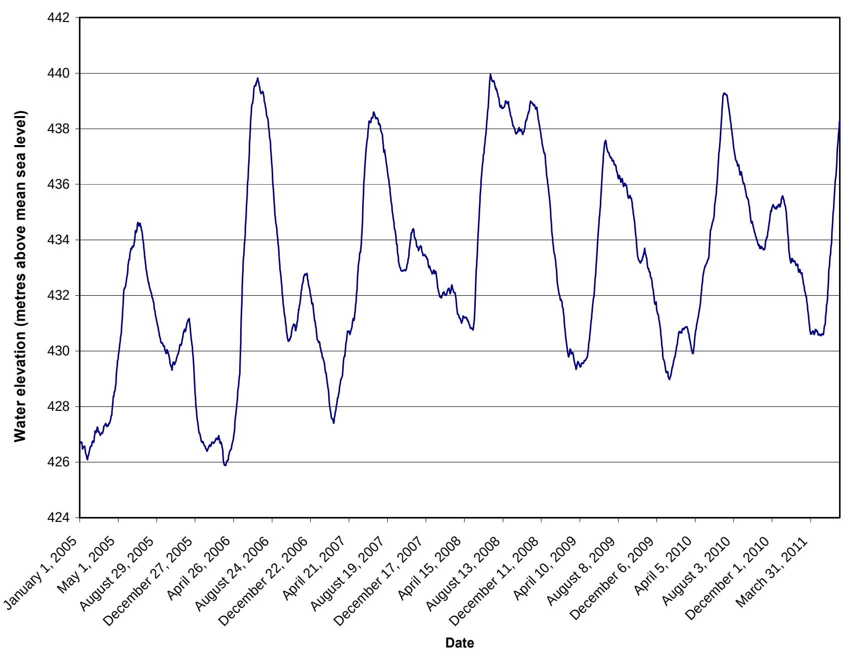

Figure 8. Water levels in the Arrow Lakes Reservoir from 2005 to 2011.

The patterns of inundation have followed a similar trend over the past six years, although there have been some year-to-year differences in water levels. In 2008, a prolonged duration of high inundation to above 438 m occurred from May to December. In most other years, a low water period had occurred during the fall. This difference in the water management regime was followed by a measurable difference in the vegetation in the spring of 2009, with reduced cover and some reduction in heights of the vegetation, especially at low elevation (Enns et al. 2010). Vegetation cover recovered the following year, and Enns et al. (2010) cautiously attributed the recovery to the return to the previous operating regime pattern of a low water period in the fall. In 2010, a second peak in water levels occurred from midsummer to fall, covering the lowest elevation vegetation at 434 to 436 m. Also, there has been a trend toward higher water levels for longer periods of time each year since 2005, but this has possibly been more subtle in its effects on vegetation. Figure 9 shows the number of days when the water level was above each of three elevation bands (434 m, 436 m, and 438 m) in each year from 2005 to 2011. Figure 9 shows that the longest durations of inundation greater than 438 m was in 2008.

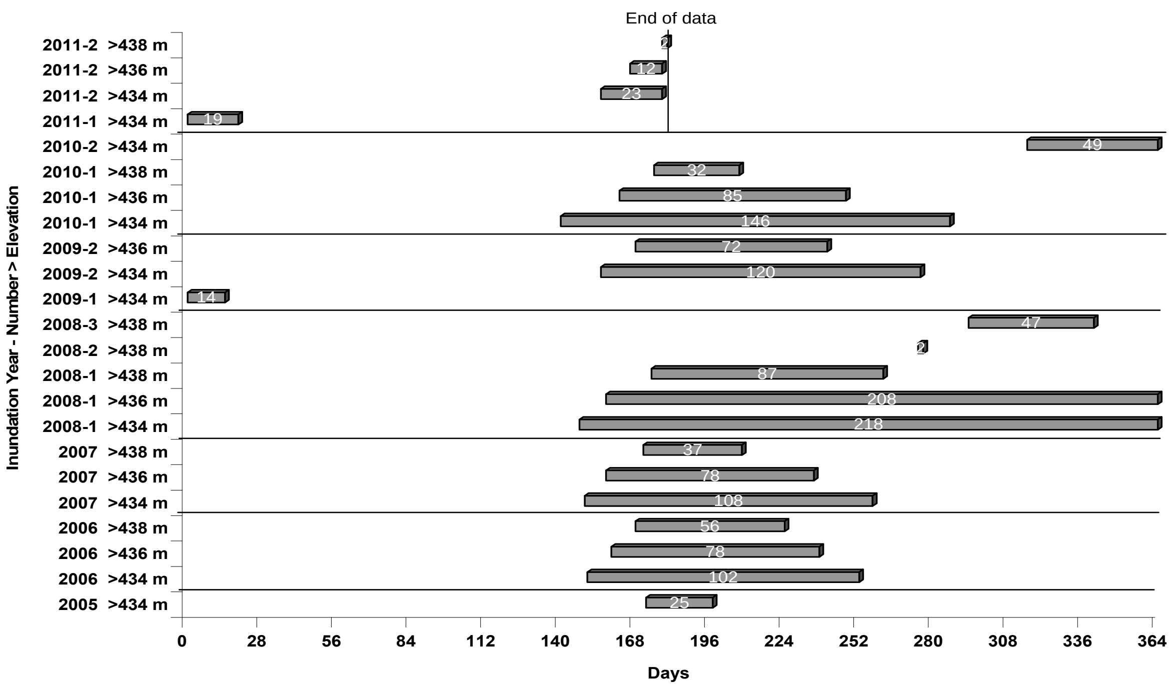

Figure 9. Number of days in which the water level in the Arrow Lakes Reservoir was above 434 m, 436 m and 438 m elevation, from 2005 to 2011.

We tested the relationship between the patterns in reservoir water cycles and vegetation with redundancy analysis, described in Section 4.7. However, both P. Legendre (pers. comm., 2009) and C. Schwarz (pers. comm., 2011) advised that it would be difficult if not impossible, and certainly not statistically valid to attribute changes in reservoir vegetation exclusively to water level changes for the following reasons:

1. Six years of measurements afford insufficient statistical power to show change over time, and it is therefore unwise to attribute vegetation change to one or more

variables (i.e., timing, frequency, duration, and depth). Trends, however, are possible to identify.

2. There is no control or reference comparison with the same vegetation and no water level fluctuation that can be used as a comparison to isolate the effects of the reservoir from the effects of other factors such as soils, climate and other disturbances.

3. The response of the vegetation to the operating regime cannot be directly observed; each year's measurement of the vegetation is assumed to be in response to the water level of the previous year.

4. Vegetation characteristics are highly variable, and data are recorded when the vegetation is at a very juvenile phase (mid-May to mid-June).

For the above reasons, this study will aim to determine *how much* of the observed variation in vegetation response can be attributed to any given independent variable, including the operating regime, rather than endeavouring to attribute any given response to changes in inundation timing, frequency, duration and depth. The results of the 2011 CLBMON-12 field study are presented below by management question.

5.2 Existing Vegetation

Two management questions were combined in the following section, and the order of the presentation of the variables differs from those stated in the MQs. A comparison between 2009 and 2011 is provided.

Management Question 1 and 2. What is the species cover, distribution, vigour, diversity, abundance and biomass of existing vegetation communities in relation to elevation in the drawdown zone?

Cover

A comparison between vegetation cover of VCTs in 2009 and 2011 is shown in Figures 10 and 11. The Arrow Lakes portion of the Arrow Lakes Reservoir (ARR) is presented separately from the Revelstoke Reach, due to climatic and floristic differences between the two portions of the reservoir (Enns, et al. 2010). A trend toward lower vegetation covers in 2011 was due to a proportion of the plots being placed in areas that served as controls for vegetation treatments, which is an introduction of bias in the study that may be rectifiable with stratification in subsequent study years. Approximately half of the existing vegetation plots represented a typical range of conditions within each VCT, away from candidate areas for treatment. The median cover of all species in each of the dominant community types in relation to elevation in the drawdown zone is shown in Figure 12, which shows that there were no differences in vegetation cover over the range in elevations between 2009 and 2011.

In 2011, there were significant differences ($p < 0.05$) between the median cover of vegetation in relation to elevation in the VCTs that occur mainly at low elevation, the BE: Sandy Beach VCT and the PE: Horsetail Lowland VCT (data not shown). The BE: Sandy Beach VCT usually had high covers of germinating seedlings at the lowest elevation. Cover of vegetation in PE, which has a clay and silt substrate, was significantly higher at the higher elevation class. The IN: Industrial VCT had a similar pattern in vegetation cover to the BE VCT.

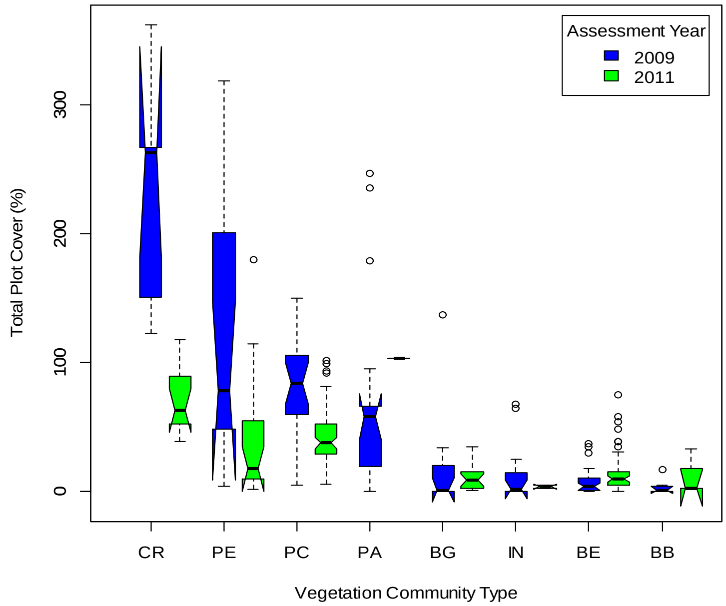

Figure 10. Total plant cover in VCTs in 2009 vs 2011 i n the Arro w Lakes portion of the ARR.

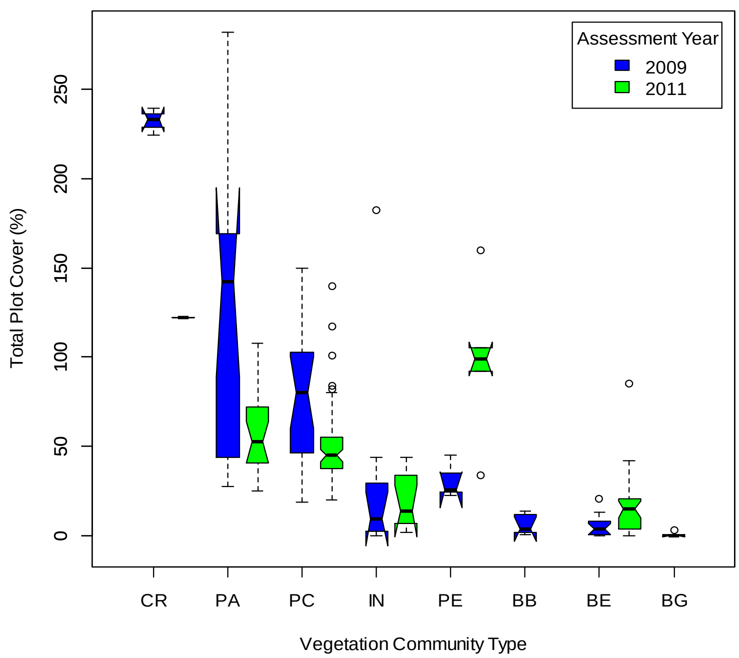

Figure 11. Total plant cover in VCTs in 2009 vs 2011 in Revelstoke Reach porti on of the ARR.

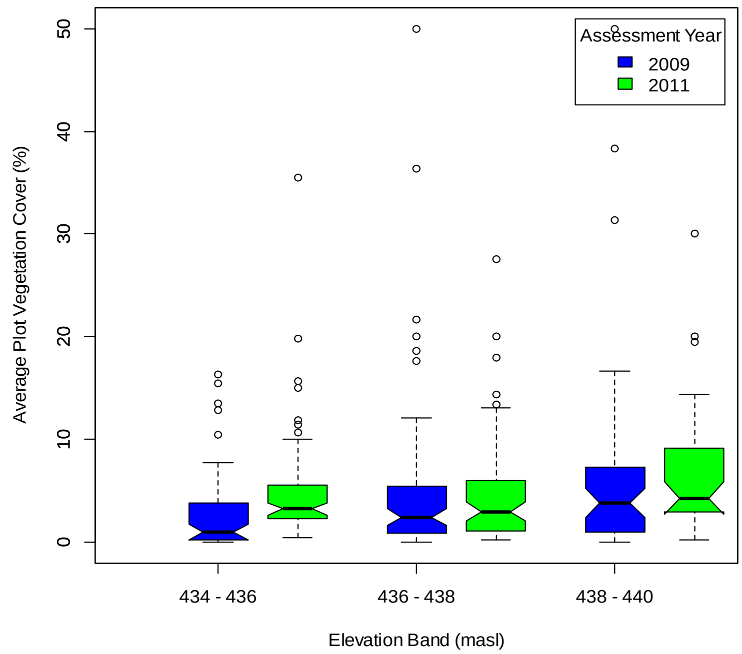

Figure 12. Average plant cover in 2009 vs 2011 in the combined Arrow Lakes and the Revelstoke Reach portion of the ARR by elevation band.

Distribution

Distribution is a measure of both abundance and response to disturbance. The distribution (i.e., spatial pattern) of species ranges from a single individual or a few scattered individuals to clumps of individuals to evenly distributed continuous distributions of individuals (Figure 13). Figure 13 is included here to assist with the interpretation of the boxplots.

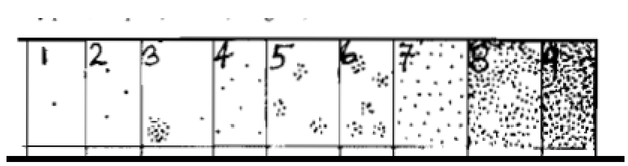

Figure 13. Distribution Classes 1 throug h 9, used in the m easurement of vegetation in the Arrow Lakes Reservoir. Adapted from Luttmerding et al. (1998).

Comparisons between vegetation distribution codes in 2009 and 2011 of VCTs in the Arrow Lakes portion of the Arrow Lakes Reservoir (ARR) are shown in Figures 14 and 15. In a similar pattern to vegetation cover, there was a trend toward lower vegetation distribution pattern codes in 2011 due to a proportion of the plots being placed in areas that served as controls for vegetation treatments. However, when sorted by elevation and combined for all vegetation community types (Figure 16), distribution codes of vegetation growing in the lowest elevation zone were higher in 2011 than in 2009.

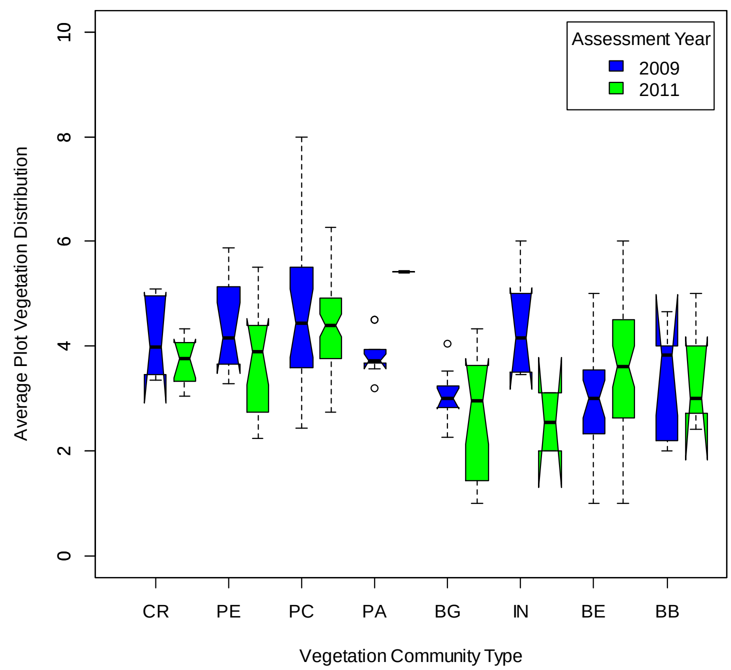

Figure 14. Average pl ot vegetation distribu tion in VCTs in 2009 vs 2011 i n the Arrow Lakes portion of the ARR (top) a nd the Re velstoke Reach portion of the ARR (bottom).

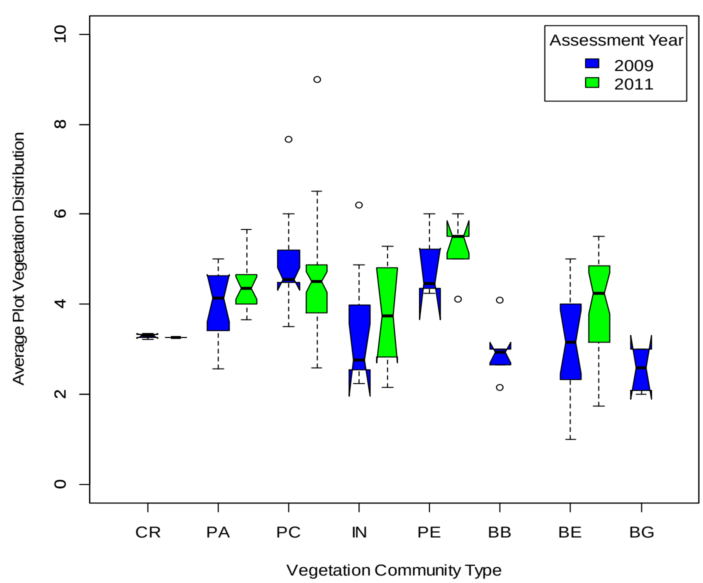

Figure 15. Average pl ot vegetation distribu tion in VCTs in 2009 vs 2011 i n the Revelstoke Reach portion of the ARR.

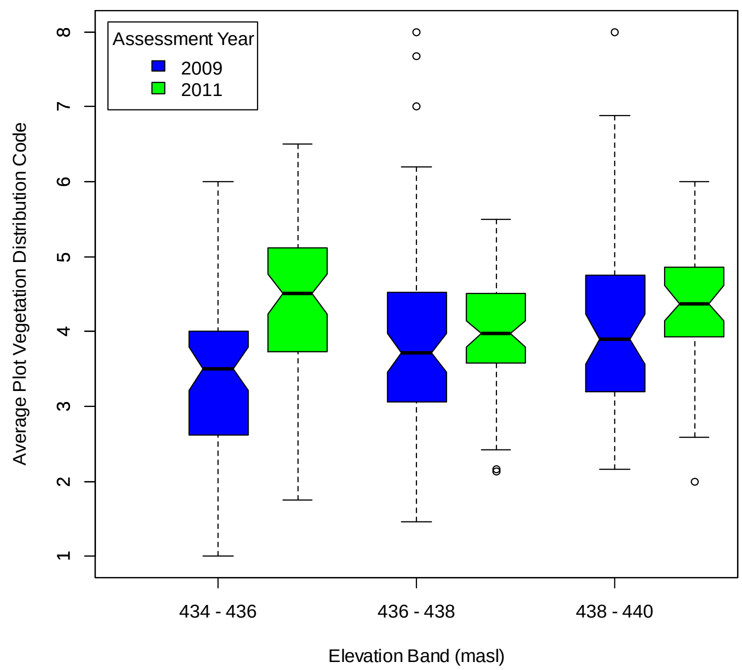

Figure 16. Average vegetation distribution codes for 2009 vs 2011 in the combined Arrow Lakes and the Revelstoke Reach portion of the ARR by elevation band.

There were no clear trends in most of the distribution values within types in relation to elevation, although the IN: Industrial vegetation community type had a wider range in distribution values at low elevation than at higher elevation, and PE: Horsetail Lowland vegetation had smaller distribution values at lower elevation.

Vigour

Species vigour ranged from dead (1) to varying degrees of necrosis, chlorosis, and symptoms of infestation or other pathology (2 and 3), to vigorous natural growth (4). Figures 17 and 18 show the range in vigour in each community type, between Arrow and Revelstoke Reach, and comparing 2009 to 2011. The vegetation in 2011 shows somewhat lower vigor than 2009 in some vegetation community types, but these differences are not statistically significant. There were no clear trends in vigour of species within VCTs in relation to elevation in the Arrow Lakes Reservoir (Figure 17) or Revelstoke Reach (Figure 18), and no patterns in vigour between elevations when 2009 is compared to 2011 (Figure 19).

There was a significant difference in vigour of vegetation in PE at low elevations (431 m and 434 m) compared to 435 m and 436 m elevation ($p < 0.05$) (Figure 20) in 2011. Although the vegetation of the PE VCT is adapted to conditions at low elevation in the reservoir, symptoms of epinasty, chlorosis, necrosis, and general poor condition were evident in plants growing at the lowest elevation of the study area in 2011.

Figures 21 through 26 compare the range in species diversity and richness in each community type in 2009 and 2011 in the Arrow and Reach portions of the Arrow Lakes

Reservoir. Some VCTs, such as Cottonwood Riparian, are restricted to certain elevation zones. In general diversity and richness were higher in 2011 than in 2009.

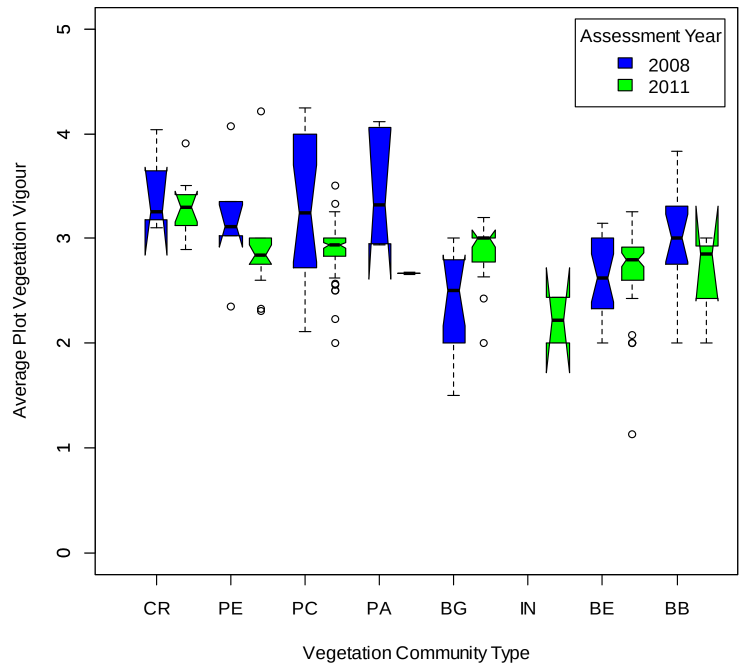

Figure 17. Average plot vegetation vigour in VCTs in 2009 vs 20 11 in the A rrow Lakes portion of the ARR (top).

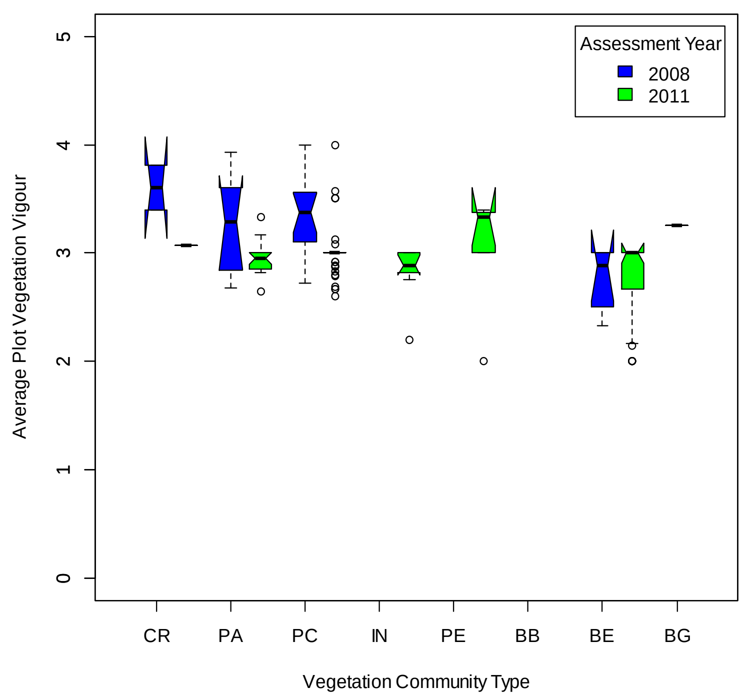

Figure 18. Average pl ot vegetation vigour in VCTs in 2009 vs 2011 in the Revelstoke Reach portion of the ARR.

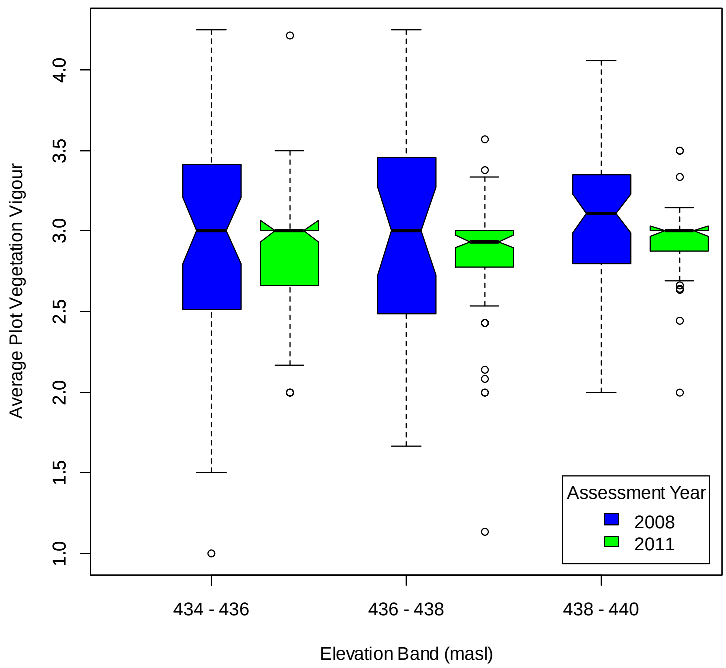

Figure 19. Average vegetation vi gour in 20 09 and 201 1 in the co mbined Arrow Lakes and the Revelstoke Reach portion of the ARR b y eleva tion band.

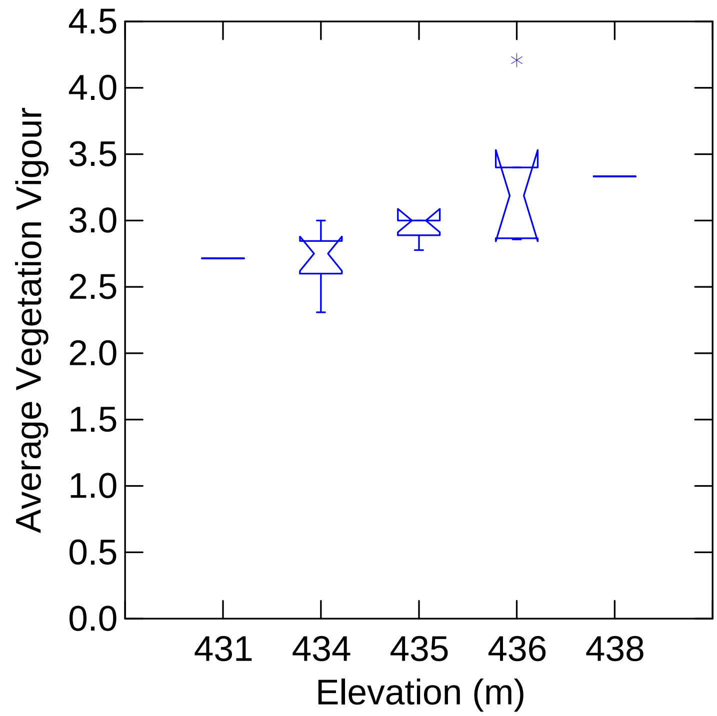

Figure 20. Vigour of a ll species in the PE: Horsetail L owland VCT in relation to elevation in the Arrow Lakes Reservoir in 2011, only. Box plot data are based on average vigour values for the plots.

Diversity and Species Richness

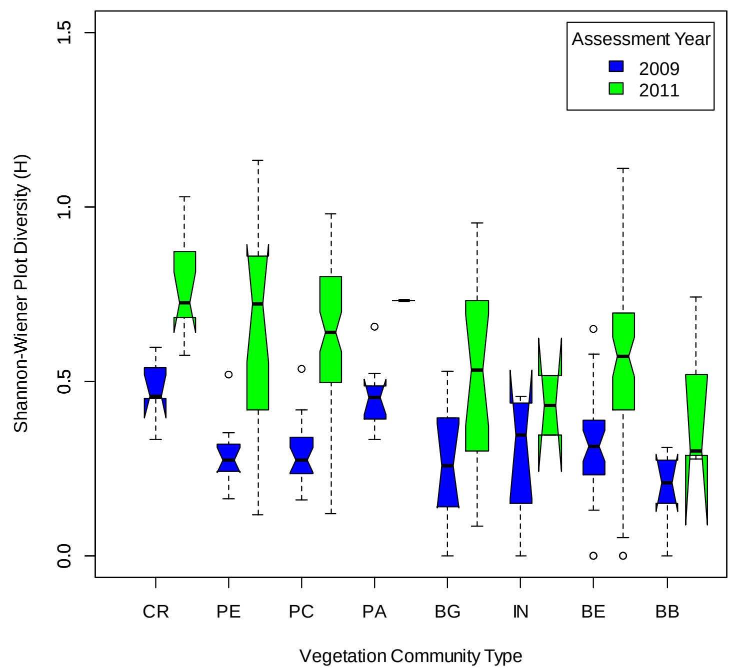

Figure 21. Shannon Wiener diversity in plots within VCTs in 2009 vs 2011 in the Arrow Lakes portion of the ARR.

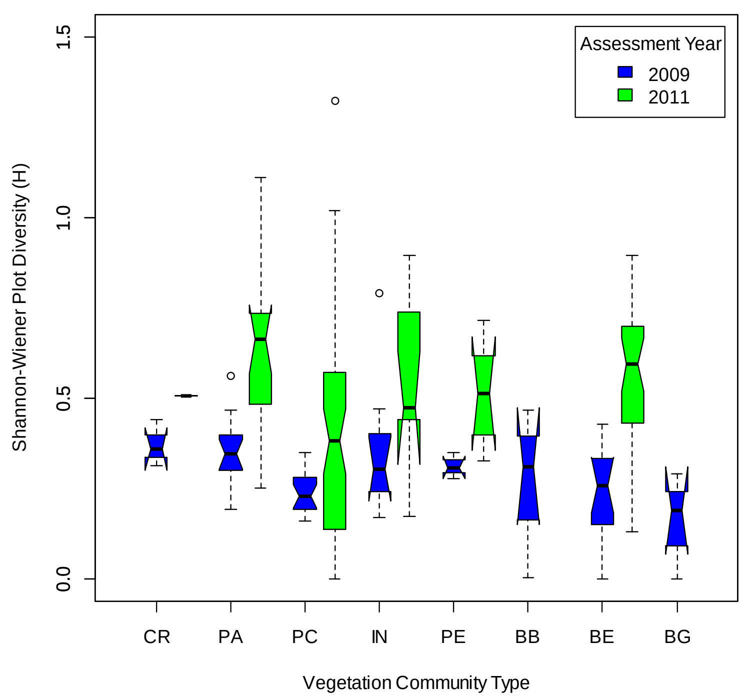

Figure 22. Shannon Wiener diversity in plots within VCTs in 2009 vs 2011 in the Revelstoke Reach portion of the ARR.

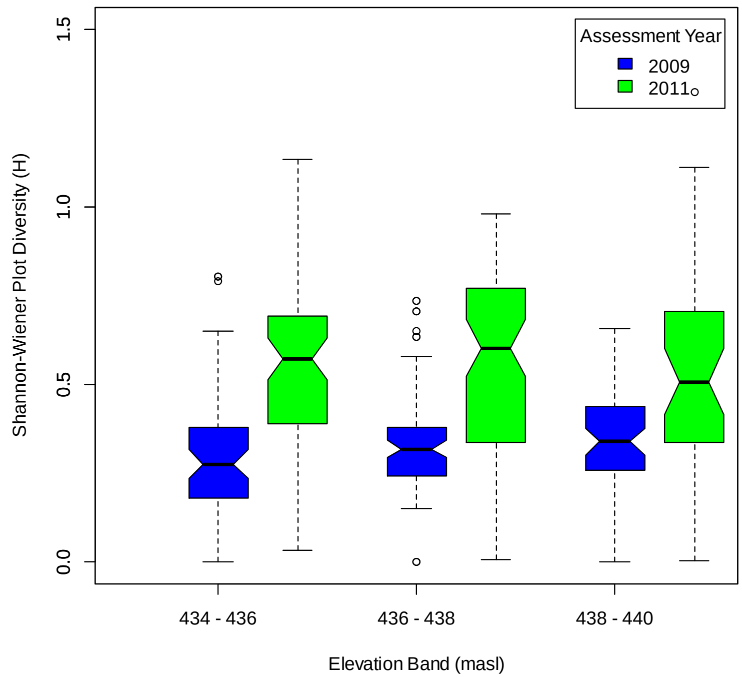

Figure 23. Shannon Wiener diversity in plots within all VCTs in 2009 vs 2011 in the Arrow Lakes and Revelstoke Reach portions of the ARR combined, by elevation zone.

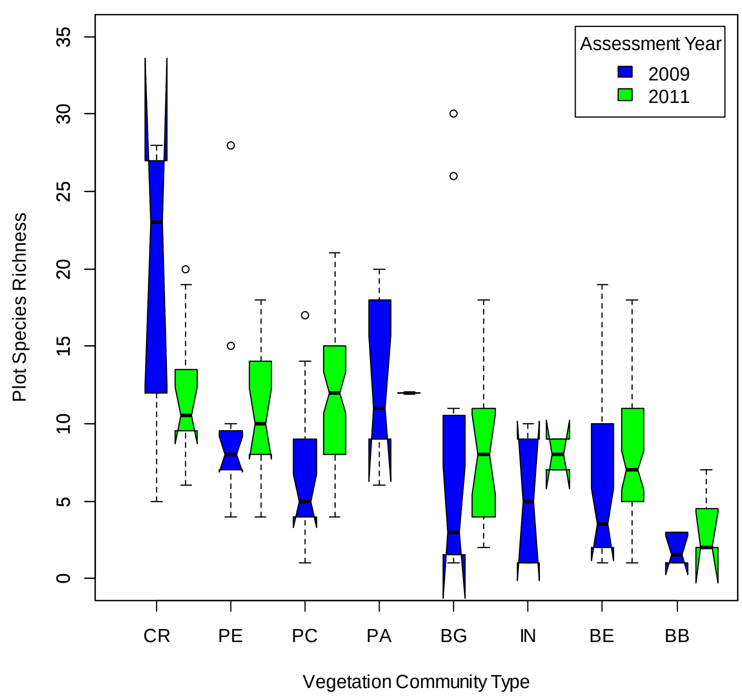

Figure 24. Species richness in plots within all VCTs in 2009 vs 2011 in the Arrow Lakes and Revelstoke Reach portions of the ARR combined over all elevations.

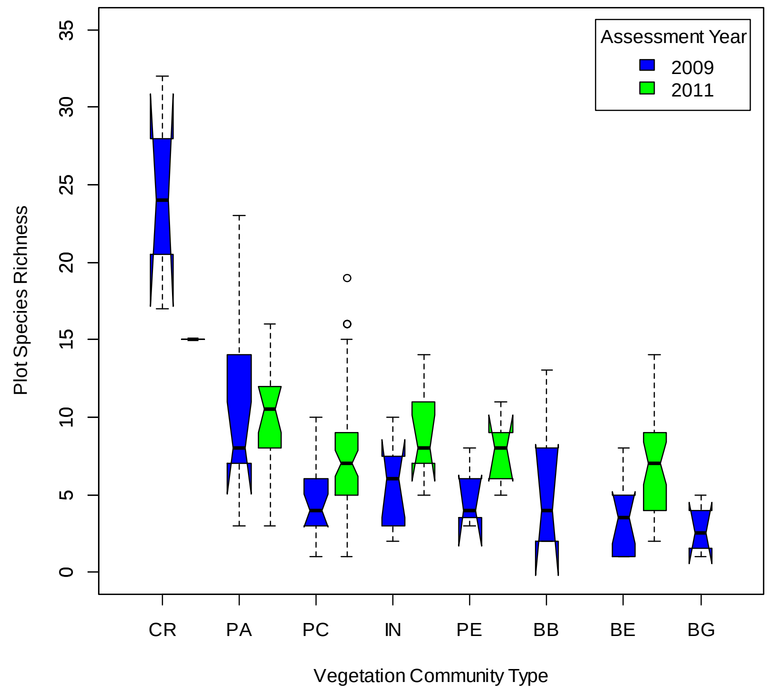

Figure 25. Species richness in plots within all VCTs in 2009 vs 2011 in the Arrow Lakes and Revelstoke Reach portions of the ARR combined, by elevation zone.

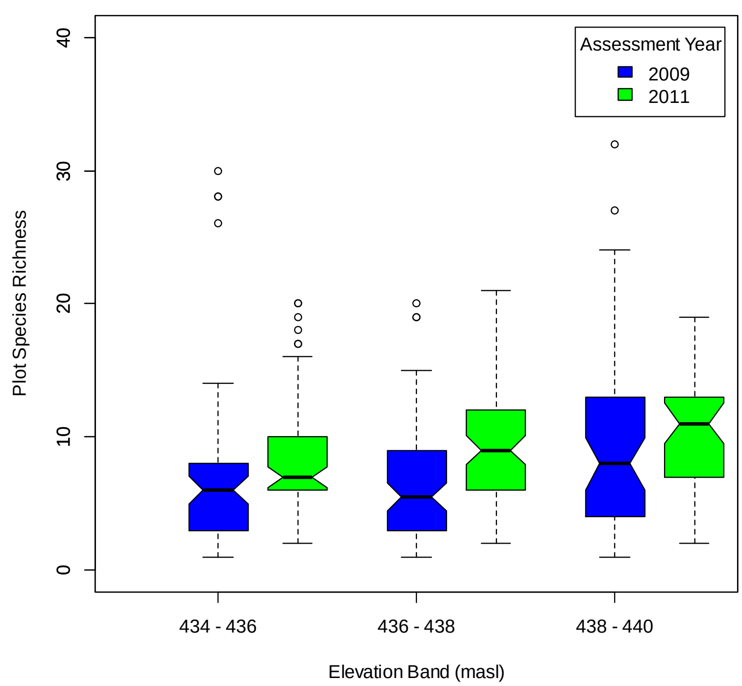

Figure 26. Species richness in plots within VCTs in 2009 vs 2011 in the Arrow Lakes and Revelstoke Reach portions of the ARR combined, by elevation zone.

Abundance

There were four classes of vegetation abundance assessed in 2011. Abundance was not assessed in 2009. Figures 27 and 28 show the range in abundance classes of the vegetation in the VCTs in the Arrow Lakes and Revelstoke Reach portions of the Arrow Lakes Reservoir, respectively. Figure 29 shows abundance in relation to elevation class in 2011.

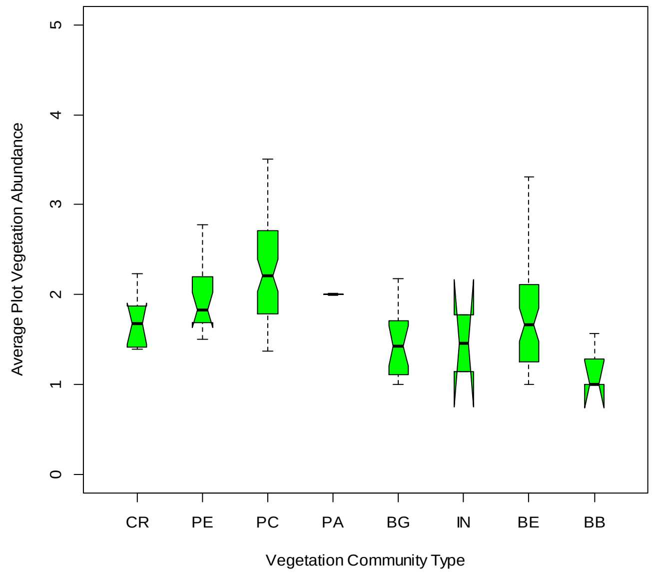

Figure 27. Average plot vegetation abundance within VCTs in 2011 in the Arrow Lakes portion of the ARR.

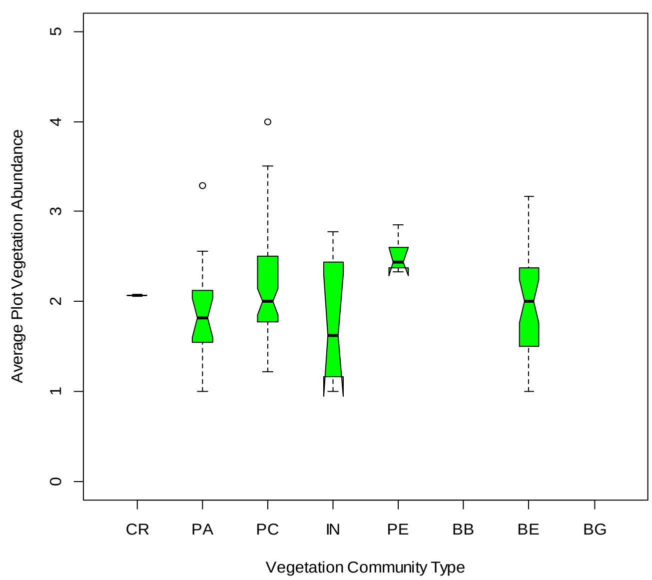

Figure 28. Average plot vegetation abundance within VCTs in 2011 in the Revelstoke Reach portion of the ARR.

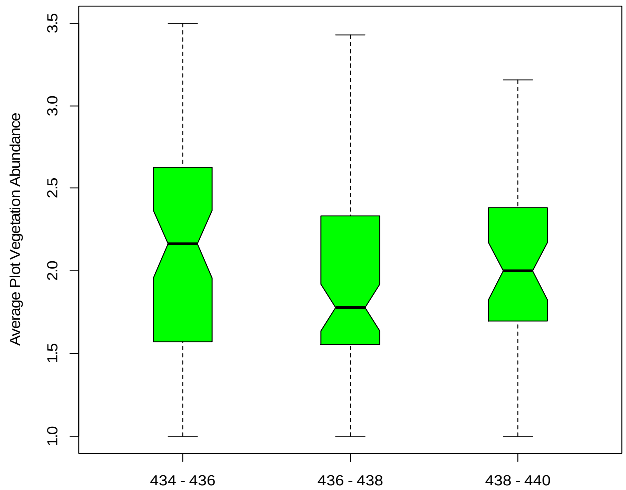

Figure 29. Average plot vegetation abundance for all combined VCTs in 2011 in the Arrow Lakes and Revelstoke Reach portion of the ARR by elevation band.

The lowest elevation had the highest species abundance. The lowest elevation bands tended to receive moisture naturally from the reservoir and from downslope drainage; therefore, seedlings tended to be more abundant at lower elevations in sandy and silty substrates, and the numbers of individual plants in low elevation plots can be copious in comparison to higher elevations. The mesic Reed Canary Grass VCT had uniform plant abundance over all three elevation classes, and the Sandy Beach VCT tended to have declining plant abundance with increasing elevation class. The main significant trend in abundance occurred in the sandy beach BE VCT (plotted showing the total range in elevation in Figure 30). The highest elevations tended to have fewer individual plants, of a larger size.

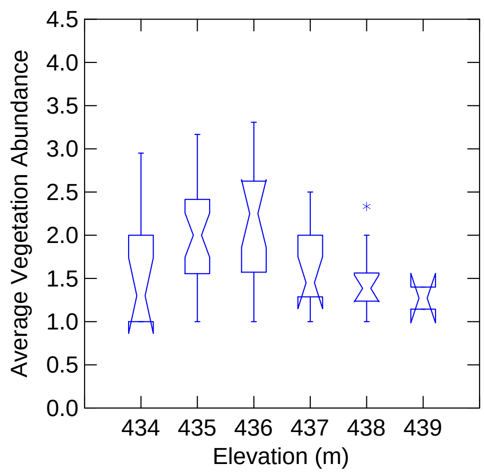

Figure 30. Abundance classes of all species in the BE: Sandy Beach VCT over a range of elevations from 434 m to 439 m in 2011.

Biomass

Data for biomass were collected in 2008 and in 2011 (Figures 31). Biomass measurements and estimates tended to follow the same pattern as the cover and abundance estimates for these VCTs. Biomass in the IN, BB, BE and BG was found to be very low and had not chang between 2008 and 2011. The PC, PE and PA VCT had higher biomass and greater variation, but also did not show much change over time. There appears to be no trend in biomass over elevation (Figure 32), but this is possibly due to combining of types, and loss of resolution.

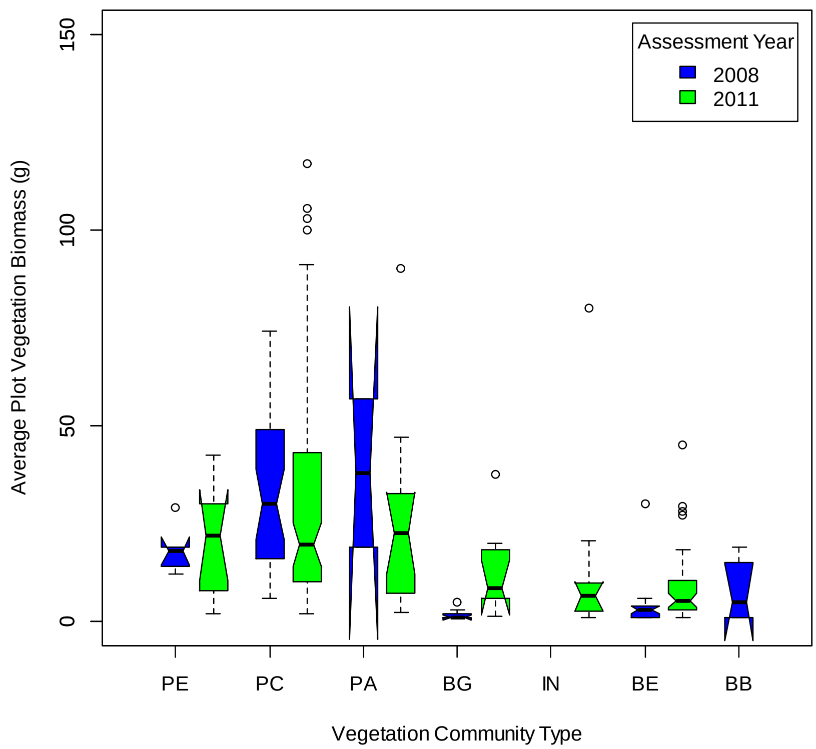

Figure 31. Biomass in plots w ithin VCTs in 2008 vs 2011 in the Arrow Lakes and Revelstoke Reach portions of the ARR combined, by elevation zone.

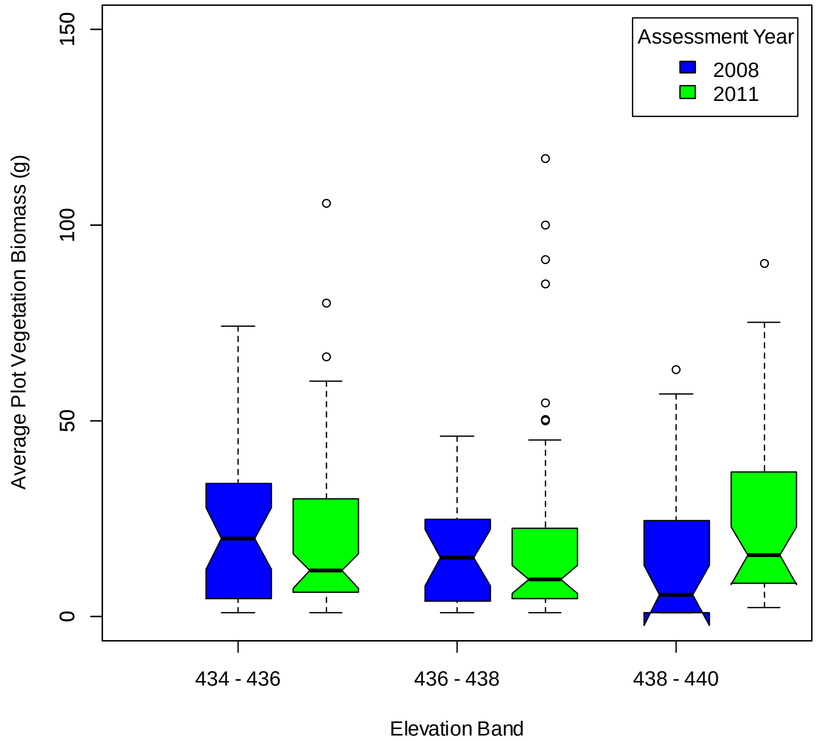

Figure 32. Biomass in plots within VCTs in 2009 vs 2011 in the Arrow Lakes and Revelstoke Reach portions of the ARR combined, by elevation zone.

Management Question 3. How does the current operating regime affect the within community quality and quantity (i.e., species cover, abundance, biomass, diversity and distribution within existing communities) of existing vegetation?

Scatterplots were used to illustrate how the current operating regime influences plant cover, abundance, biomass, diversity, distribution and height. The average values were plotted against the number of days of inundation for each plot in each of the main VCTs between June 2010 and May 2011 (Figures 33a to 35b). Some VCTs, such as PA (yellow triangles in Figure 33a), ocur only at high elevation, and are therefore inundated for a shorter overall number of days.

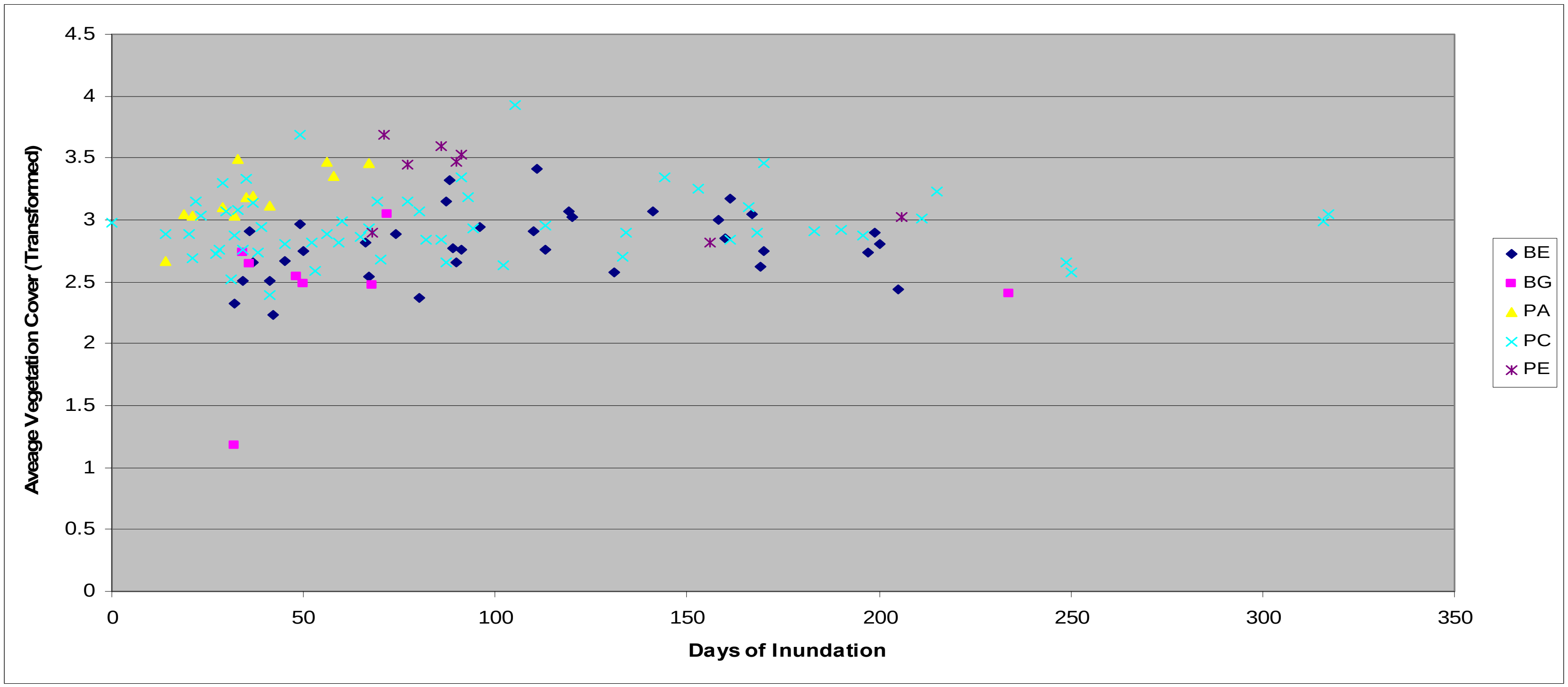

Figure 33a. Average vegetation cover of plots in the BE: Sandy Beach; BG: Gravelly Beach; PC: Reed Canary Grass Mesic; PA: Redtop Upland; and PE; Horsetail Lowland VCTs in relation to the number of days of inundation between June 2010 and May 2011 in the Arrow Lakes Reservoir.

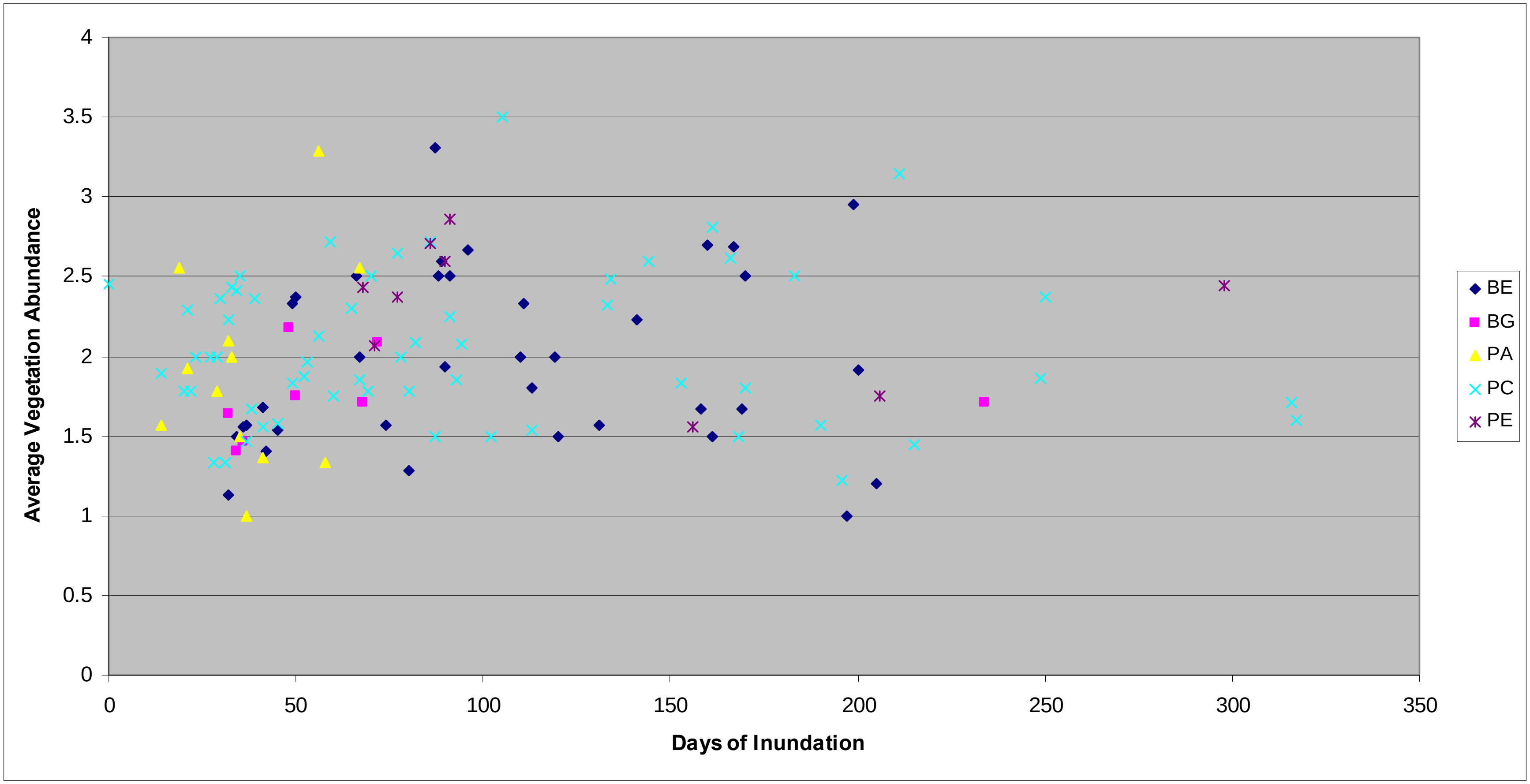

Figure 33b. Average vegetation abundance of plots in the BE: Sandy Beach; BG: Gravelly Beach; PC: Reed Can ary Grass Mesic; PA: Redtop Upland; and PE; Horse tail Lo wland VCTs in relation to the number of da ys of inundation between June 2010 and May 2011 in the Arrow Lakes Reservoir.

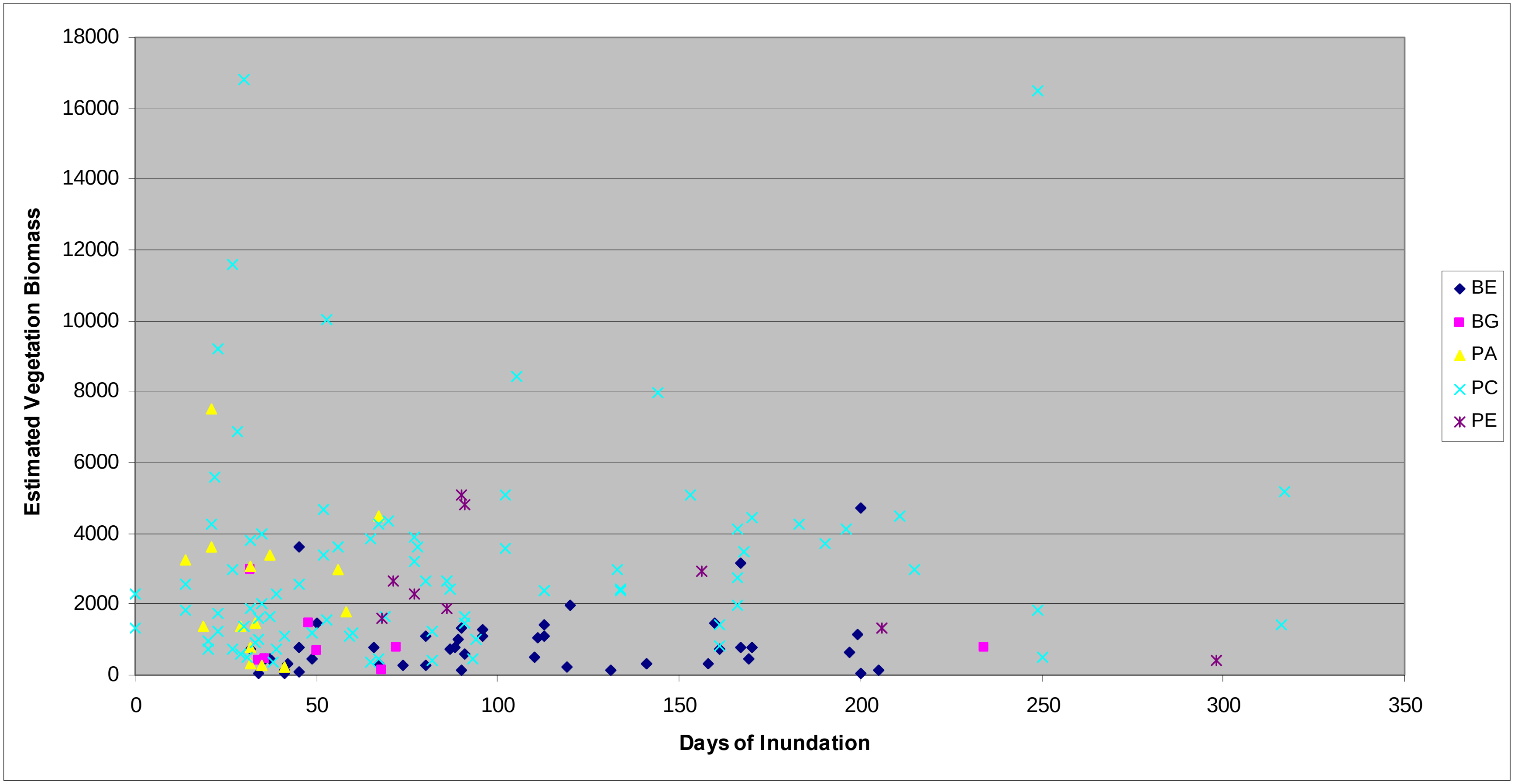

Figure 34a. Average vegetation biomass of plots in the BE ; Sandy Beach; BG; Gravelly Beach; PC; Reed Canary Grass Mesic; PA; Redtop Upland; and PE; Horsetail Lowland VCTs in relation to the number of days of inundation between June 2010 and May 2011 in the Arrow Lakes Reservoir.

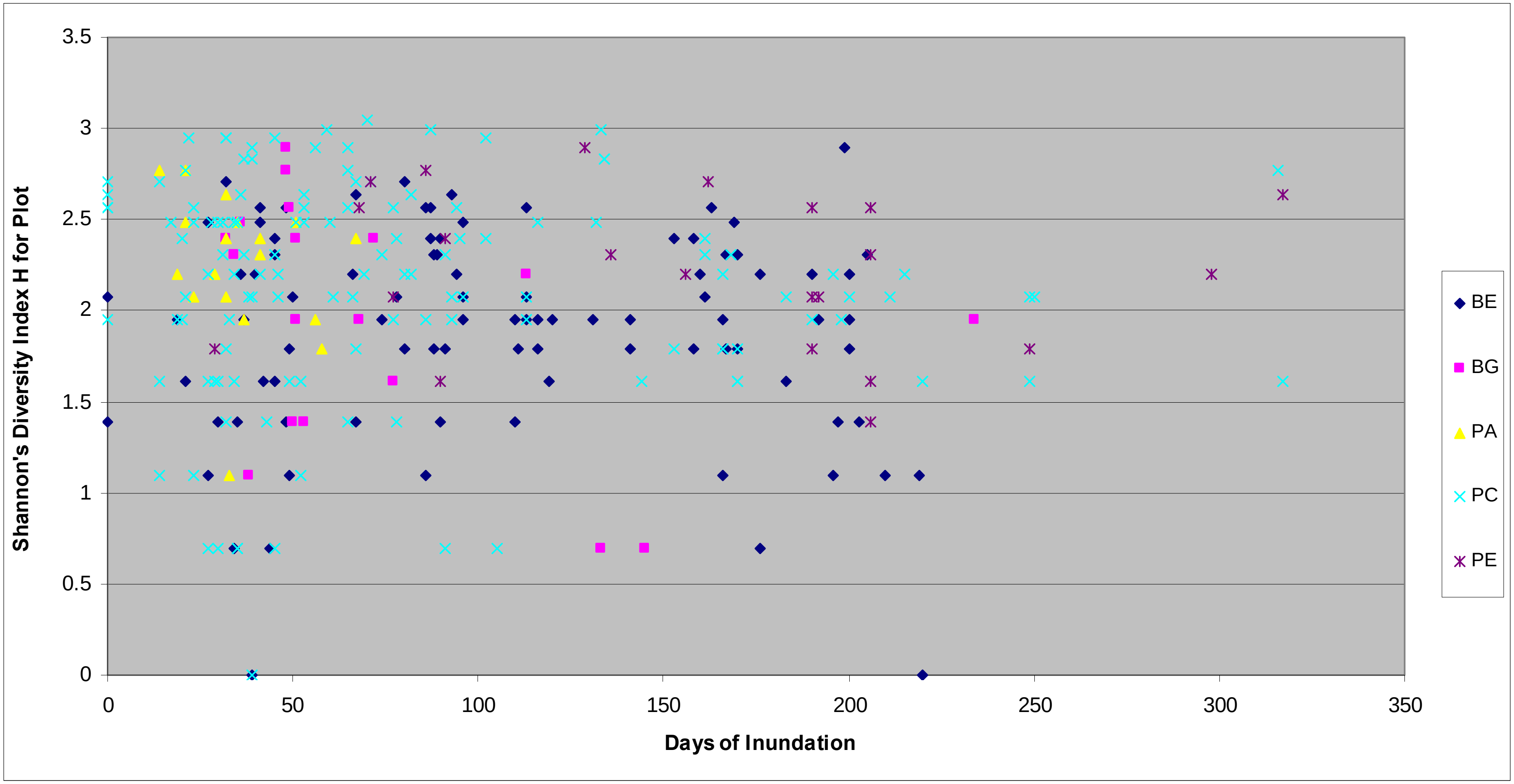

Figure 34b. Average vegetation diversity of plots in the BE; Sandy Beach; BG; Gravelly Beach; PC; Reed Canary Grass Mesic; PA; Redtop Upland; and PE; Horsetail Lowland VCTs in relation to the number of days of inundation between June 2010 and May 2011 in the Arrow Lakes Reservoir.

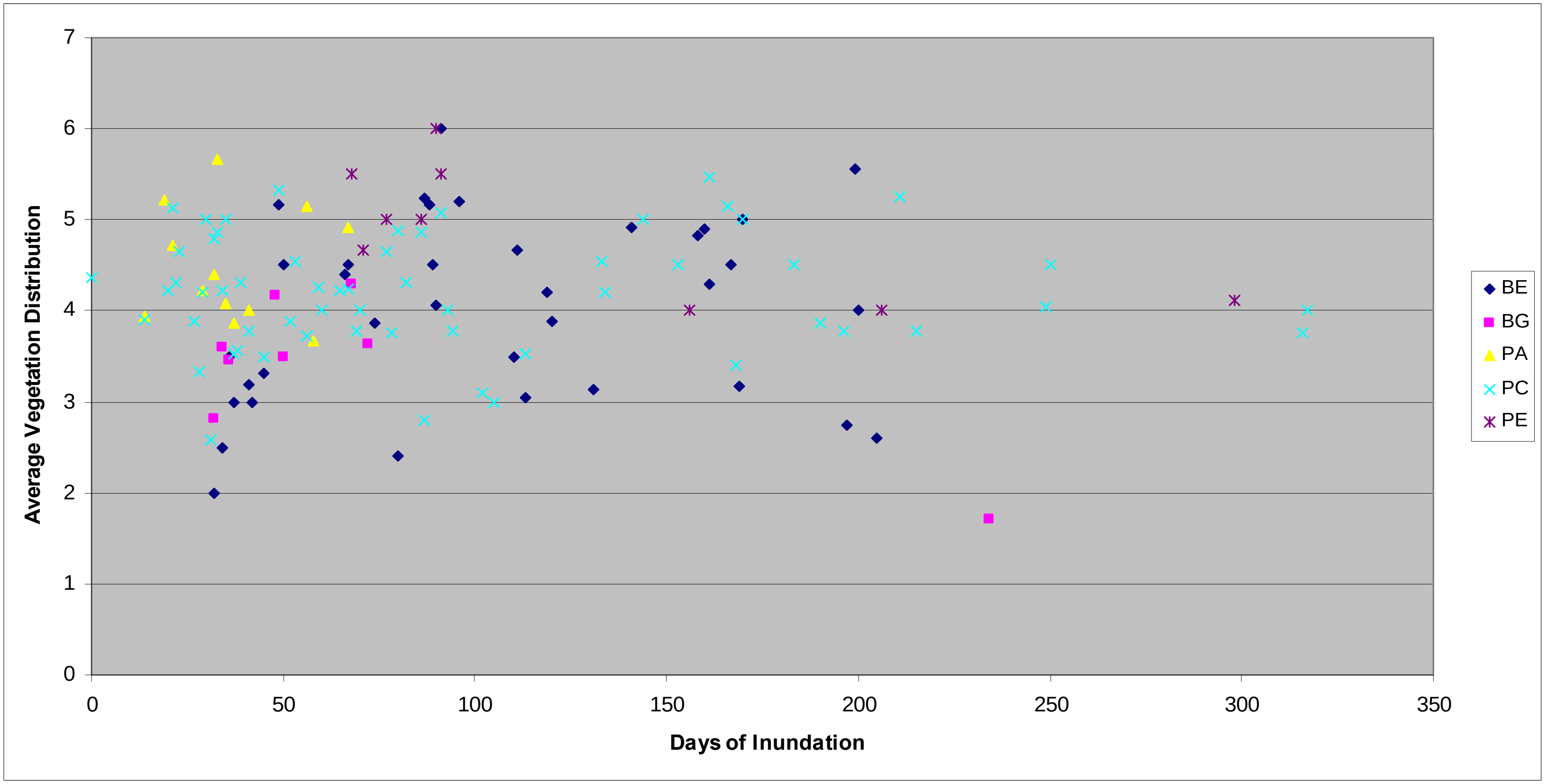

Figure 35a. Average vegetation distribution of plots in the BE: Sandy Beach; BG: Gravelly Beach; PC: Reed Canary Grass Mesic; PA: Redtop Upland; and PE: Horse tail Lowland VCTs in relation to the number of days of inundation between June 2010 and May 2011 in the Arrow Lakes Reservoir.

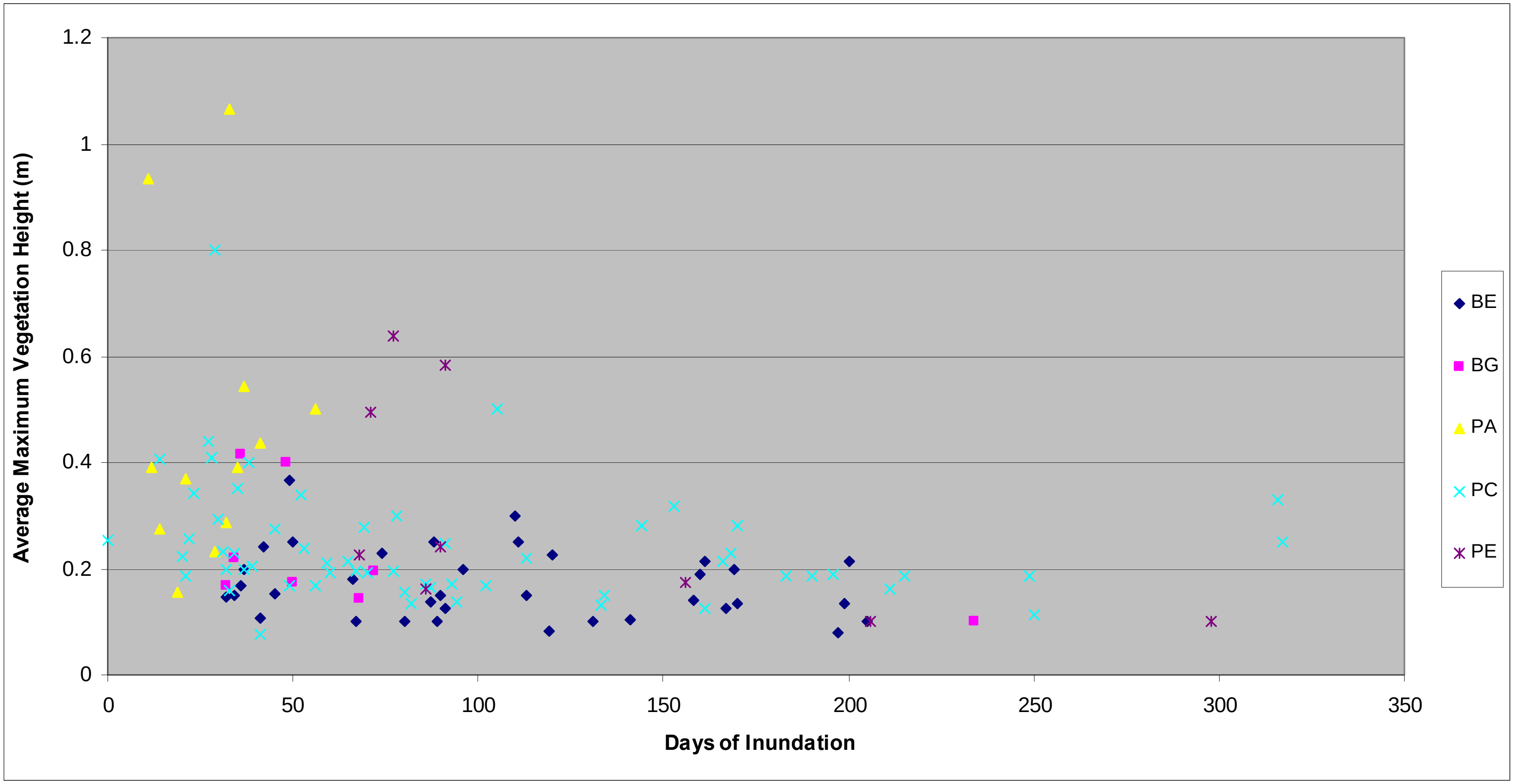

Figure 35b. Average vegetation maximum height of plots in the BE: Sandy Beach; BG: Gravelly Beach; PC: Reed Canary Grass Mesic; PA: Redtop Upland; and PE: Horsetail Lowland VCTs in relation to the number of days of inundation between June 2010 and May 2011 in the Arrow Lakes Reservoir.

With the exception of vegetation height, there were no strong relationships between the number of days of inundation and the various measures of plant characteristics. The absence of a clear response is partially due to the narrow elevation range of some of the VCTs. The PA: Redtop Upland is restricted to high elevation, for example. Also, PE tends to occur mainly at low to middle elevation. For VCTs ranging over all of the elevations in the reservoir, both high and low biomass and height development occurred during the short durations of inundation. This is an indication that factors other than inundation influence biomass and height. However, for plots in which inundation exceeded 100 days, average maximum heights tended to be lower than in plots with a shorter duration of inundation (Figure 35b). This is an indication that long duration of inundation may suppress plant heightwhich, is also noted by Blanch et al.(1999).

Management Question 4. Is there a shift in community structure (e.g., species dominance) or a potential loss of existing vegetation communities that is attributable to environmental conditions, including the current operating regime (i.e., timing, frequency, duration and depth of inundation)?

To determine if the relative proportions of species have changed over time, we identified the 18 plant species with the highest cover in 2011, and graphed the proportion of their cover in each year from 2007 to 2011 (Figure 36).

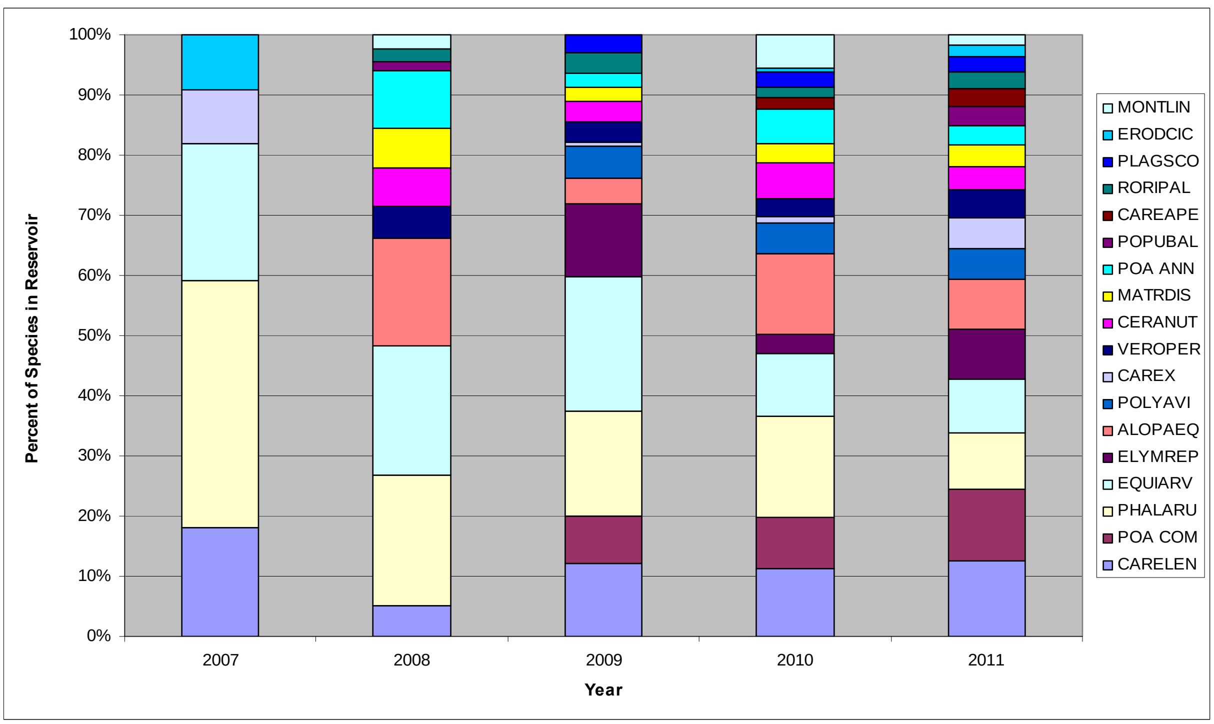

Figure 36. Percentage representation of the eighteen plant species that were most dominant in the Arrow Lakes Reservoir between 2007-2011, in relation to 2011. (In 2007 data were collected in October. The 2007 data are included here to illustrate the differences in the 2007 data versus all other years. In 2008 to 2011, data were collected in May–June). Species codes are included in Appendix 2.

The most dominant species remained relatively constant over time, and some less frequently occurring species shifted slightly in dominance. The two most commonly occurring species (lenticular sedge and reed canary grass) have not dramatically changed in their proportions. The aggressive perennial, Canada bluegrass (*Poa compressa*), has increased in the past three years, and Columbia sedge (*Carex aperta*) has also increased in the past two years. In fact, increases in species have been evident, whereas declines have been less easy to detect. A common pattern has been for a previously minor species to become more noticeably prominent over time. Species that have shown dramatic increases include common stork's bill (*Erodium cicutarium*) and hare's-foot clover (*Trifolium arvense*) in 2008 (compared to the previous year), tufted vetch (*Vicia cracca*) in 2009, and little meadow-foxtail (*Alopecurus aequalis*), which increased in 2008, declined in 2009, then steadily increased between 2009 and 2011.

To examine shifts in species dominance within vegetation community type and to identify losses of existing vegetation, we compared losses over time. The 15 species that were dominant (i.e., occurred most frequently) in 2011 were identified and their frequency of occurrence within the BE, BG, PA, PC, and PE VCTs was ranked for each year, 2007-2011 (Table 8). Those VCTs were selected because they are common throughout the reservoir and are found at a range of elevation bands, except that the PA VCT occurs at higher elevations, and the PE VCT at the lowest elevations. Thus, comparing frequency of occurrence reflects the survival over time of the most frequently occurring species in the dominant VCTs.

A review of the typical habitat requirements, tolerance for flooding, and reproductive strategies of the common plant species in the Arrow Lakes Reservoir is provided in Appendix 3. This information was obtained from the literature and was used to explain the potential for loss of existing vegetation and vegetation response to environmental conditions, including the response to the current operating regime.

Table 8. Ranked frequency of occurrence within each year of the 15 species that were dominant in 2011 in the BE, BG, PA, PC, and PE VCTs in the Arrow Lakes Reservoir; 1 is most abundant, 15 is the least abundant. Tied rankings are expressed as an average of the rank.

BE: Sandy Beach					
Species 200	**7**	**2008**	**2009**	**2010**	**2011**
lenticular sedge	3	8	3.5	3	1
Canada bluegrass	-	-	5.5	5	2
reed canary grass	1	1	2	1	3
common horsetail	2	2	1	4	4
Quackgrass	-	-	3.5	10.5	5
little meadow-foxtail	-	3	8	2	6
common knotweed	-	-	7	9	7.5
sedge sp.	-	-	-	-	7.5
purslane speedwell	-	7	11.5	12	9
nodding chickweed	-	6	11.5	6	10.5
pineapple weed	-	5	18	10.5	10.5
annual bluegrass	-	4	18	7.5	12.5
black cottonwood seedlings	-	13	-	-	12.5
Columbia sedge	-	-	-	14	14

marsh yellow cress	-	11	11.5	15	15
BG: Gravelly Beach					
Species	**2007**	**2008**	**2009**	**2010**	**2011**
reed canary grass	1	1	2.5	1	2.5
lenticular sedge	3.5	7	2.5	2	2.5
black cottonwood/ seedlings	-	9	-	-	2.5
Canada bluegrass	-	-	5.5	4	2.5
little meadow-foxtail	-	2	17	5	5
common horsetail	2	3	1	3	6
purslane speedwell	-	20	5.5	23	7
Norwegian cinquefoil	-	-	23	10	8
slender rush	-	-	-	-	9.5
nodding chickweed	-	5	40.5	6	9.5
Quackgrass	-	-	5.5	7	11
marsh yellow cress	-	12.5	23	23	12
Columbia sedge	-	-	40.5	10	14
sedge sp.	-	-	-	-	14
curled dock	-	-	-	14.5	14
PA: Redtop Upland					
Species	**2007**	**2008**	**2009**	**2010**	**2011**
reed canary grass	1	2	1	1	1
common horsetail	2	1	2	3	2
lenticular sedge	3	4.5	6	6	3
black cottonwood seedlings	37.5	4.5	-	-	4.5
Canada bluegrass	-	-	4	7	4.5
Scouler’s willow	4	3	32.5	5	6
Quackgrass	37.5	-	9	20	7
curled dock	-	30	-	-	8
Columbia sedge	-	18	8	15	9
redtop grass	10.5	-	32.5	4	10
nodding chickweed	-	-	-	62	12
Pacific willow	-	-	11.5	59	12
bluejoint reedgrass	37.5	-	-	92	12
clover sp.	-	-	-	-	17
moss sp.	-	-	-	-	14.5
PC: Reed Canary Grass Mesic					
Species	**2007**	**2008**	**2009**	**2010**	**2011**
reed canary grass	1	1	1	1	1
lenticular sedge	3	3	2	2	2
common horsetail	2	2	3	3	3
Columbia sedge	-	16.5	4	4	4
Canada bluegrass	46.5	-	8	9	5
Quackgrass	17.5	-	11	18	6
purslane speedwell	-	10	17	8	7
little meadow-foxtail	-	5	41	7	8
nodding chickweed	-	7	10	5	9
black cottonwood seedlings	25	41	-	-	10.5
thread rush	-	23.5	7	6	10.5

clover sp.	-	-	-	-	12.5
sedge sp.	-	-	-	-	12.5
slender rush	-	-	-	-	14
marsh yellow cress	-	16.5	19.5	11	15
PE: Horsetail Lowland					
Species	**2007**	**2008**	**2009**	**2010**	**2011**
common horsetail	2	6.5	3	2	1
lenticular sedge	3	2.5	1	1	2
reed canary grass	1	2.5	2	3	3
little meadowfoxtail	-	4.5	25	4	4
purslane speedwell	-	4.5	14	5	5.5
Canada bluegrass	-	-	11.5	17	5.5
marsh yellow cress	-	15	14	19	7
Scouler's willow	-	-	-	27	8.5
Columbia sedge	-	-	5.5	7	8.5
thread rush	-	15	7.5	6	12
Pennsylvanian bitter-cress	-	19	11.5	15	12
nodding chickweed	-	8	25	12	12
Scouler's popcorn flower	-	-	16.5	24	12
narrow-leaved montia	-	12	-	29	12
common knotweed	-	-	16.5	10	15

The most obvious pattern is that very similar dominant species occurred in each VCT, while some subdominant species or combinations of species were unique to a given VCT. This is very common in vegetation studies, and is why diagnostic or change-sensitive species are more often used than dominant species to show change over time[12] (Mueller-Dombois and Ellenberg 1974). Many of the dominant species, such as reed canary grass, rushes, willows, and sedges, are aggressive and disturbance-tolerant perennials, whereas others, such as marsh yellow cress (*Rorippa palustris*), the knotweeds (*Polygonum* spp.), montia (*Montia* spp.), popcorn flower (*Plagiobothrys scouleri*), and speedwell (*Veronica* spp.) are opportunistic and aggressive weeds. Some of the dominant species appear to be more aggressive under reservoir conditions than would be expected from the information found in the literature (Appendix 3). A discussion of the more common individual VCTs follows.

BE: Sandy Beach VCT has a uniformly fine to coarse sandy substrate, and occurs at all elevations in the drawdown zone and therefore presents a range of responses to variable water levels in the reservoir. In the 2011 field surveys, lenticular sedge (*Carex lenticularis)* was the most frequently occurring species in the BE VCT. Table 8 shows that this species occurred more frequently in the plots in 2011 than in previous years.

Canada bluegrass (*Poa compressa*) was ranked as the second most frequently occurring species in the BE VCT, an increase in its rank over previous years. It tolerates a range of moisture regimes and colonizes aggressively, due to having both fibrous and rhizomatous roots (Appendix 3). This species may be able to spread when the surface layer erodes and plants are carried downstream, subsequently rooting in the open sandy substrates that are common in the BE VCT.

[12] One of the first steps in community analysis and interpretation is to remove the dominant species from consideration.

In contrast to previous years, reed canary grass was not the most frequently occurring species in the BE VCT in 2011. The reason for this is not clear; we assumed that reed canary grass would maintain its dominance over the course of the study. However, the 2011 fieldwork focused on evaluating the effect of treatments, which were located in scoured areas with low vegetation cover; and it is possible that a proportion of the existing vegetation repeated plots tended to occur in similarly scoured locations. Therefore, it is not surprising that reed canary grass was less dominant in the 2011 field plots. The decline in frequency of occurrence of both reed canary grass and common horsetail (*Equisetum arvense*) from previous years may have been an artifact of treatment monitoring.

Most of the common species, such as little meadow-foxtail, purslane speedwell (*Veronica peregrina*), nodding chickweed (*Cerastium nutans*), and annual bluegrass (*Poa annua*) fluctuated in frequency of occurrence over time, while a few, such as marsh yellow cress, remained mostly unchanged in frequency of occurrence.

BG: Gravelly Beach VCT: The species composition of the BG VCT was similar to that of the BE VCT. Four ubiquitous species were common to the BE and BG: reed canary grass, lenticular sedge, black cottonwood seedlings, and Canada bluegrass. Columbia sedge increased in occurrence in both the BG and BE over time. Frequency of occurrence of leading species fluctuated to a greater extent in the BG than in the BE, perhaps because seedling germination in the BG was inhibited by the more frequent occurrence of compaction and inhospitable substrates.

PA: Redtop Upland VCT is a relatively dry, moisture shedding community, and is typically confined to higher elevations. It includes several species of shrubs. Shrubs are not always dominant in PA, but Scouler's willow and black cottonwood are the most common of the shrubs, when shrubs are dominant. This VCT has been subjected to much shorter duration and shallower depths of inundation than all of the other VCTs, with the exception of the CR: Cottonwood Riparian Forest VCT. As a result, the frequency of occurrence of the leading species has not fluctuated in the PA as much as in the BE and BG. Reed canary grass, common horsetail, and lenticular sedge have been the most frequently occurring species in this community type in most years, and have shown little variation in occurrence. Scouler's willow and black cottonwood have always been present, but only Scouler's willow has had a high enough frequency of occurrence to be recorded among the top 15 species in most measurement years. The reoccurrence of black cottonwood seedlings among the highest frequently occurring species in 2011, with a hiatus in 2009 and 2010, is similar to trends in the BE and BG, and may be linked to the high winter inundation events of 2008–2009.

PC: Reed Canary Grass Mesic VCT substrates are sandy and silty. These substrates occur over the widest range of elevations in the reservoir of all the VCTs. The PC VCT has remained dominated by reed canary grass over the duration of this study, more so than any other VCT, and rankings of the dominant species in this VCT have not changed. Changes occurred in the somewhat less common species between years, which is an indication that of all the VCTs, the species composition in the PC may be the most resistant to fluctuations in the water regime, due to the persistent nature of reed canary grass. Once established, it is not easily eradicated (Apfelbaum and Sams 1987). Black cottonwood seedlings showed a similar pattern in 2011 as in the BG and BE, with a decline following the high water winter of 2008–2009. Little meadow-foxtail and thread rush (*Juncus filifolius*) also declined following 2008–2009 but recovered in subsequent years. The presence of clover and sedge seedlings as low-ranked dominants in 2011 was a function of taking measurements in early summer when many of the high-ranked and frequently occurring plants were at the immature seedling stage. It is possible that these are continually lost and replaced each year.

PE: Horsetail Lowland VCT occurs between the low and middle elevations in the Arrow Lakes Reservoir. The soils and substrates are usually a compacted, somewhat anoxic and anaerobic mix of silts, clays, and sands with a relatively high bulk density. This VCT is the first in the reservoir to flood and the last to emerge from inundation. Very few of the most frequently occurring species in this VCT have changed over time, and the less frequently occurring species have fluctuated only slightly, indicating that the dominant plants of this VCT are well adapted to inundation. Common horsetail, lenticular sedge, and reed canary grass have not shifted in ranked frequency of occurrence over time. Little meadow-foxtail, narrow-leaved montia (*Montia linearis*), and nodding chickweed are rapidly growing annuals (Appendix 3). As in the PC, annuals may be lost and replaced each year. Little meadow-foxtail increased dramatically in 2008 compared to the previous year, declined in 2009 (similar to other declines following the high water winter of 2008–2009), then resumed its high frequency of occurrence in 2011. The above species were the main plants to show a marked decline in frequency of occurrence in the high water winter of 2008–2009. A persistent species in the PE over time is Pennsylvanian bitter-cress (*Cardamine pensylvanica*). This species is typically a ditch weed (Appendix 3), but it is common in the low elevations of the Arrow Lakes Reservoir. Many of the plant species in the PE are naturally streamside species that are well adapted to the stress of inundation. Many of the annual species that are flood tolerant use inundation as a means of dispersal for seeds and other propagules, and may persist over the current trends in the operating regime. The sporadic occurrences of some plants, such as Scouler's popcorn flower, possibly represents a recently recorded invasion into the PE. Many species records are for seedlings, however, and Scoulers popcorn flower may have not germinated in time for observances on previous years. The prevalence of invasive species in the reservoir is high in all VCTs. Generally, invasive species are not as common in the PE VCT as they are in the upper elevation VCTs.

Management Question 5. What are the species–specific survival rates under soft constraints operating regime (i.e., what are the tolerances of existing plant species to inundation)?

Table 9 shows the number of individual records of species losses from plots in each year in comparison to the subsequent year. Table 9 includes measurement errors, caused by not repeatedly measuring the same sample plots, or by slight changes in the alignment of the repeated plots. However, when plots were repeated in 2011 (with fewer new plots), the numbers of "losses" of species from the annual list declined compared to previous years.

The following description of patterns of change by plant group is based on the information summarized in Table 9, field observations, and the species autecological literature review (Appendix 3).

Trees and shrubs have established in the reservoir and most of them are observed in the same plots every year. However, individual trees and shrubs have been killed and removed at all elevations from 2008 to 2011. Two types of recruitment appear to be occurring. Some recruitment occurs from upslope in the forested riparian zone, from individual parent trees and shrubs, such as black hawthorn (*Crataegus douglasii*) and cascara (*Rhamnus purshiana*). Other recruitment occurs from floating seed and other propagule deposition from upwind or upstream (e.g., cottonwood, willow species). The loss of individual woody species from repeated plots was most common above 437 m elevation. Drought symptoms are common in invading species above 437 m, which suggests that exposure and drought caused the mortality. Inundation may also have physically removed smaller individuals.

Table 9. Numbers of species losses from plots in each year in comparison to the subsequent year (both repeated plots and new plots are included). Note: species losses are a very small proportion of the complete records for a given year.

Year-wise Comparison of "Extinctions"	Trees	Shrubs	Herbs	Grasses	Water Tolerant Plants	Ferns	Weeds	Mosses, Liverworts, Clubmosses	Lichens	Total
Number of species recorded in 2008 but not found in 2009	5	2	22	12	9	0	16	18	7	91
Number of species recorded in 2008 but not found in 2009, 2010, or 2011	1	0	14	8	4	1	9	4	2	43
Number of species recorded in 2009 but not found in 2010	5	2	15	3	2	2	12	0	1	42
Number of species recorded in 2009 but not found in 2010 or 2011	3	2	14	2	0	2	4	0	1	28
Number of species recorded in 2010 but not found in 2011	9	24	42	7	10	2	16	24	7	141
Number of species recorded in 2010 but not found in 2011	0	1	15	2	8	0	5	10	0	41

Shrubs and trees that were present at 438 m elevation and higher in 2009, but were not seen following inundation in 2010 included St. John's-wort, wild cherries, Pacific willow, and blue elderberry. These species were possibly lost due to drought because the elevation of inundation in the winter of 2009–2010 was not as high as in other years. Ponderosa pine (*Pinus ponderosa*) seedlings were also lost following the 2009 measurement, but from lower elevation sites, suggesting that inundation caused the removal of this drought-tolerant species.

One of the most dramatic losses of shrubs has been the decline of the *Salix* species complex at low-elevation sites over time, predominantly in Revelstoke Reach, but also at Halfway River and other localities in the Arrow Lakes portion of the reservoir. This was thought to be due to a combination of inundation injury to plants that invaded the low to middle elevation sites during low water years, and to gall insect infestations (Enns et al. 2009). Recovery was not seen in 2011.

Herbaceous annual a nd perennial species are less recognizable as individuals in plots than trees and shrubs. Many of the herbs and perennials recorded in the CLBMON-12 project were seedlings of the current year. Most of the losses of herbaceous species were due to annuals that failed to re-establish in repeated plots. These failures to re-establish are assumed to be due to the washing away of seedlings, seeds, roots fragments, or rhizome fragments from sites. This would be most likely if they occurred below the water line the following winter. Losses could also be attributed to drought or physical disturbance if they occurred above the water line the following winter.

A review of the losses of species from plots on a yearly basis (Appendix 4) shows that many of the herbaceous species that were lost had the following characteristics, which explain their introduction to the reservoir and subsequent loss:

- Most species with high losses are opportunistic and weedy, have high seed production, and have quite mobile seed heads - e.g., wall lettuce (*Lactuca muralis*), willowherb (*Epilobium* spp.), common groundsel (*Senecio vulgaris*), creeping spearwort (*Ranunculus flammula*).
- Many species with high losses require sand to germinate, but are not tolerant of subsequent inundation - e.g., the B.C. red-listed fern-leaved desert-parsley (*Lomatium dissectum* var. *dissectum*) and the common silverweed (*Potentilla anserine*); both are upland grassland or pasture plants. Small twistedstalk (*Streptopus streptopoides*) and western meadowrue (*Thalictrum occidentale*) are moist forest species. They may have originated from the cottonwood riparian forest adjacent to the drawdown zone, and have some inundation tolerance, but are not expected to dominate the vegetation.
- Some species or groups of species with losses, such as bedstraw (*Galium* spp.), forget-me-not (*Myosotis* spp.), and sickletop lousewort (*Pedicularis racemosa*), have physical characteristics that allow them to stick to substrates. The mature flower heads or stems with flower heads stick to the sand substrate, the seeds germinate in moist exposed sand and grow to the juvenile stage, and then they either flower and disperse seeds or fail to flower. These species can be highly mobile and losses are merely an indication of their dynamic growth strategy in the reservoir.

Grasses are prolific and abundant in the drawdown zone of the Arrow Lakes Reservoir. The loss of a grass species from one year to the next is likely an artificial loss - i.e., an error in identification. The error may have been due to the lack of maturity and associated diagnostic features at the time of sampling. Fall sampling in 2007 revealed that more than 50 species of grasses occur in the drawdown zone. An additional fall resampling of selected plots should help establish a better understanding of the survival rates of grasses in the reservoir.

The loss of reed canary grass from several locations in 2010 is an important species decline in the Arrow Lakes Reservoir. Plots in treated and control sites are sparser and more disturbed than other areas of existing vegetation in the reservoir, a consequence of the treatment regime used in CLBWORKS-2. The data show that invasion of relatively sparse reed canary grass stands by other grasses, notably quackgrass (*Elymus repens*), Canada bluegrass, and other bluegrasses has occurred in the last two years, especially in the Arrow Lakes portion of the reservoir.

Inundation-tolerant plants include several amphibious species that are well adapted to life in the reservoir. Their loss from one year to the next could be a result of the water regime exceeding or failing to meet their inundation thresholds for survival, or from the inability of field observers to recognize juveniles of the species due to the lack of flowering structures or diagnostic features of the mature plant. Some inundation-tolerant plants are mobile. For example, lenticular sedge forms relatively large floating mats and can be observed at low water, stranded on beaches at Beaton Bay and throughout the reservoir where calm water occurs, including stream inlets. Plants that are physically very small are sometimes missed in the field assessments, or easily removed by inundation. Both spring starwort (*Callitriche palustris*) and creeping spearwort are small, physically fragile, amphibious plants. They were absent from some of the plots sampled in 2009, but may have re-established downstream. Marsh cudweed (*Gnaphalium uliginosum*) is another species that seems to have consistently relocated to new sites in the reservoir every year. This changeable nature of inundation-tolerant plants makes it difficult to determine how much a change in occurrence is due to effects of the reservoir operating regime and how much is due to wily plant strategies for survival.

Many semi-emergent and emergent plant species have persisted over time, although some notable losses have occurred. Some of these losses have occurred where substrates have failed, such as where sandy slopes have peeled due to undercutting at high elevation, resulting in losses of wood horsetail (*Equisetum sylvaticum*), for example. Creek channel entries change annually due to inundation, and this has caused site-specific losses of dagger-leaf rush (*Juncus ensifolius*) and yellow monkey-flower (*Mimulus guttatus*). However, these species have often been noted to persist in other locations, just not in the plots in which records have been taken annually.

Damage from all-terrain vehicles (ATVs) can also cause losses of semi-emergent and emergent plants. ATVs destroy plant substrates and loosen plants, allowing them to be eroded by rising water. ATV damage has removed plants from plots and from outside areas near plots that have been included in photographic records annually since 2007. Burton Flats, Edgewood, Montana Slough, and 12 Mile have all incurred losses due to ATV damage. These additional causes of loss of plants make it difficult to evaluate losses due to the effects of the operating regime.

Weeds include several species of B.C. listed weeds, common wasteland weeds, roadside and ditch weeds. They were a predominant group of species in the reservoir. Some weeds declined in 2009 from the previous year, mostly at the high-elevation sites, possibly due to the high-elevation, long duration of inundation in the winter of 2008–2009. Drought-tolerant weeds have established in the highest-elevation areas and along roadsides within the IN: Industrial VCT. Old roads in the drawdown zone were likely an important source of plant propagules to the rest of the drawdown zone. A further decline in weeds occurred in 2011;however, they persisted where soils were compacted on old road edges (Enns et al. 2009, 2010).

Ferns, mosses , liverworts, hornw orts, clubmosses, a nd lichens as a group were occasionally dominant in the drawdown zone. Ferns, however, were rare in the drawdown zone of the Arrow Lakes Reservoir, and where they have occurred, they tended to be absent from repeated plots the following year. In some plots, mosses formed a very high proportion of the total plant cover, and in many cases have persisted over several years in repeated plots. Lichens, especially species of *Peltigera*, *Cladonia*, and *Cladina* were common in the 438 m to 440 m elevation band, and appeared to withstand inundation, as they have not been lost from permanent plots that were established in 2007. Several species of mosses persisted with high cover in the lowest elevation plots, and they are thought to be important in maintaining of soil stability in the drawdown zone (Odland and del Moral 2001).

Management Question 6. What recommendations can be made to more effec tively maintain existing vegetation at the site level in the future?

A indication of the influence of reservoir water levels on vegetation was that vegetation cover declined in 2009, following a winter of comparatively long duration, high-elevation inundation (August 2008 to May 2009) (Enns et al. 2010).. A slight, but significant (*p*<0.05) decline in total cover appears to have taken place again in 2011 (Figure 37).

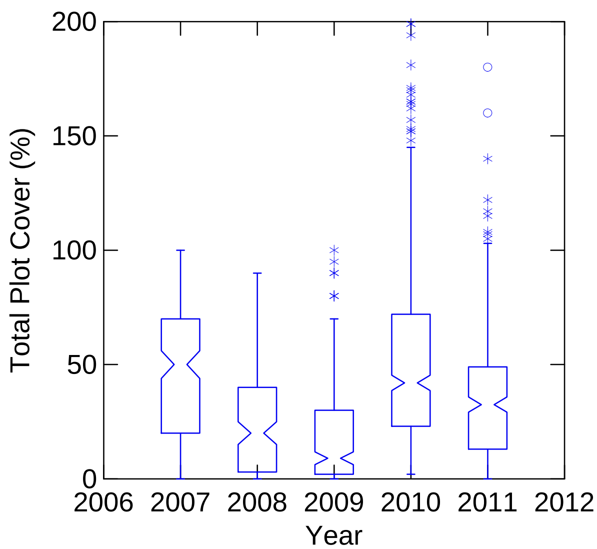

Figure 37. Total average cover o f vegetation (from all plots) ove r time in the Arrow Lakes Reservoir.

In general, winters with a long duration of high water levels, such as 2008–2009, and, to a lesser extent, 2010–2011, appear to be followed by a decline in vegetation cover. The trend in loss of cover after the high water winter of 2008–2009 appears to have reoccurred in some plots in 2011, although to a lesser degree. The winter of 2008–2009 was the only winter so far in which inundation covered plants from June to the following spring. This relationship is inferential, however. There may be other equally important annual events, such as a cold spring climate causing a decline in vegetation cover over all. To maintain vegetation in the reservoir, BC Hydro should allow for a low water period in the fall, in order to allow vegetation to mature. When vegetation is inundated over its whole growing season, unless it is an aquatic or amphibious species, it is likely to undergo a decline in total vegetation (Odland et al. 2002).

5.3 Revegetated Areas

Management Question 7. What is the quality and quantity of vegetation in revegetated areas between elevations 434 to 440 compared to untreated areas based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?

Sufficient field data were collected in 2011 to address this question in three treatments in the Arrow Lakes Reservoir; *Carex* plug planting, cottonwood seedling planting, and cottonwood stake planting. Each of the three treatments was evaluated separately over the three main elevation bands: 434 m – 436 m, 436 m – 438 m, and 438 m – 440 m. Treatments were not distributed evenly over the elevation bands. Data for the fertilizer trails was judged insufficient. According to the most recent KESL mapping available (accessed February 2012), two fertilization trials were located in co-located areas at Burton, although more areas may have been treated (KESL, 2011). The method of fertilizer application is uncertain (e.g. “side banding” was used but not defined (p. 31-32; KESL, 2011). No plots were established in the two trial areas at Burton as the mapping for fertilizer treatments was not available at the time of the field work in 2009. A single plot from 2007 was reviewed in 2011 and found to have incorrect GPS data from an older GPS. Therefore, an evaluation of fertilization treatment effects was compiled by comparing the appearance of the vegetation in the two fertilized areas vs the unfertilized areas at Burton using the 2010 aerial photography. There was found to be no difference between the cover, color expression or heights of the vegetation in the fertilized vs. non fertilized areas in the aerial photographic imagery (data not shown). Pre-treatment soil fertility data is available for comparison with post treatment data, from the CLBMON-33 project. To avoid clipping treated vegetation, we estimated biomass rather than sampling it. No trends in biomass were observed (data not shown). A comparison between 2009 and 2011, between treated vs control plots is provided below.

Carex plugs and the quality and quantity of vegetation, by elevation bands

Only limited data were available to compare the effect of treatments to controls in 2009 (14 plots). This year, at the recommendation of C. Scwartz (pers. com. 2011), Tukey’s boxplots were used to identify differences in the quality and quantity of vegetation in plots treated with *Carex* plugs versus control plots, followed by Analysis of Variance (ANOVA) where appropriate. The distributions of average species abundance, diversity (Shannon Wiener Index [H]) values, average species distribution, average vigour, average total cover, and average maximum height of vegetation in control and treated plots are shown in Figures 38 and 39. In these Figures data from Revelstoke Reach and Arrow Lakes portions of the reservoir were combined[13]. Vegetation treatments were not clipped, although biomass was estimated using the estimation methods described in Section 5.4. Therefore, there is uncertainty surrounding the biomass estimates of the treatments. In subsequent years, when treatments are more established, clipping will be done in plug planted treatments. Many planting treatments were very recent and quite small in the 2011 measurement year.

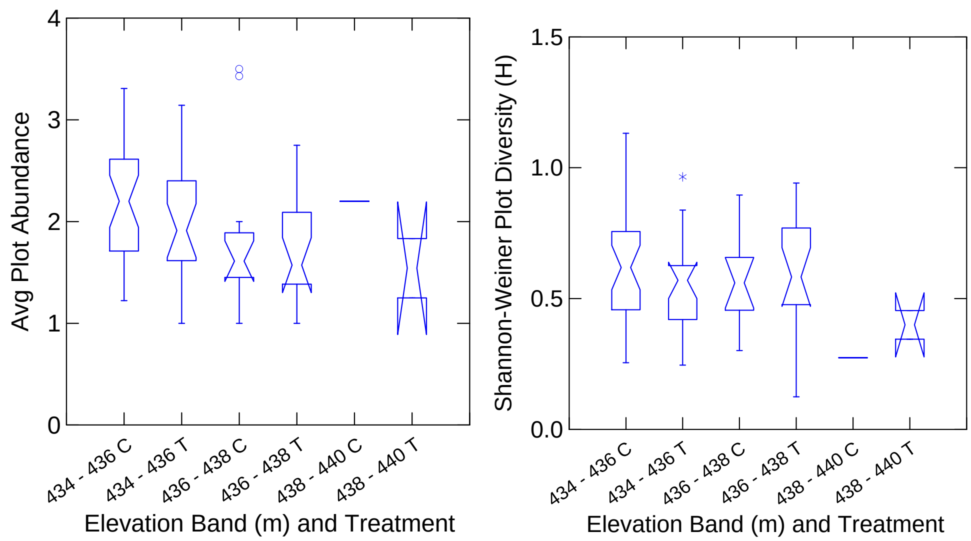

Figure 38. Abundance class of all species (left) and diversity (right) in plots treated with *Carex* plugs (T) versus control plots (C), over three elevation bands in the Arrow Lakes Reservoir. A box extending below the figure margin shows a confidence interval that extends below zero due to several very low values in the dataset. Box plot data are based on average abundance values for the plots.

There was no significant difference in species abundance between *Carex* plug treatments and controls. There was a tendency toward low species diversity in the control plots in *Carex* plug treated areas. Any higher diversity in the treated plots was not a function of treatments, as lenticular sedge and the other planted species were already present in the plots. There was no evidence that adding *Carex* or other species of plugs to the reservoir increased the diversity of existing vegetation. Several of the *Carex* plug treated plots were planted only days before the assessments and may yet fail. Monitoring the change in species diversity and abundance over time will be necessary in order to answer this Management Question.

[13] There was no evidence that the floristic differences between species compositions in existing vegetation extended to the effect of treatment; therefore, to examine treatment effects, data from the reservoir are combined.

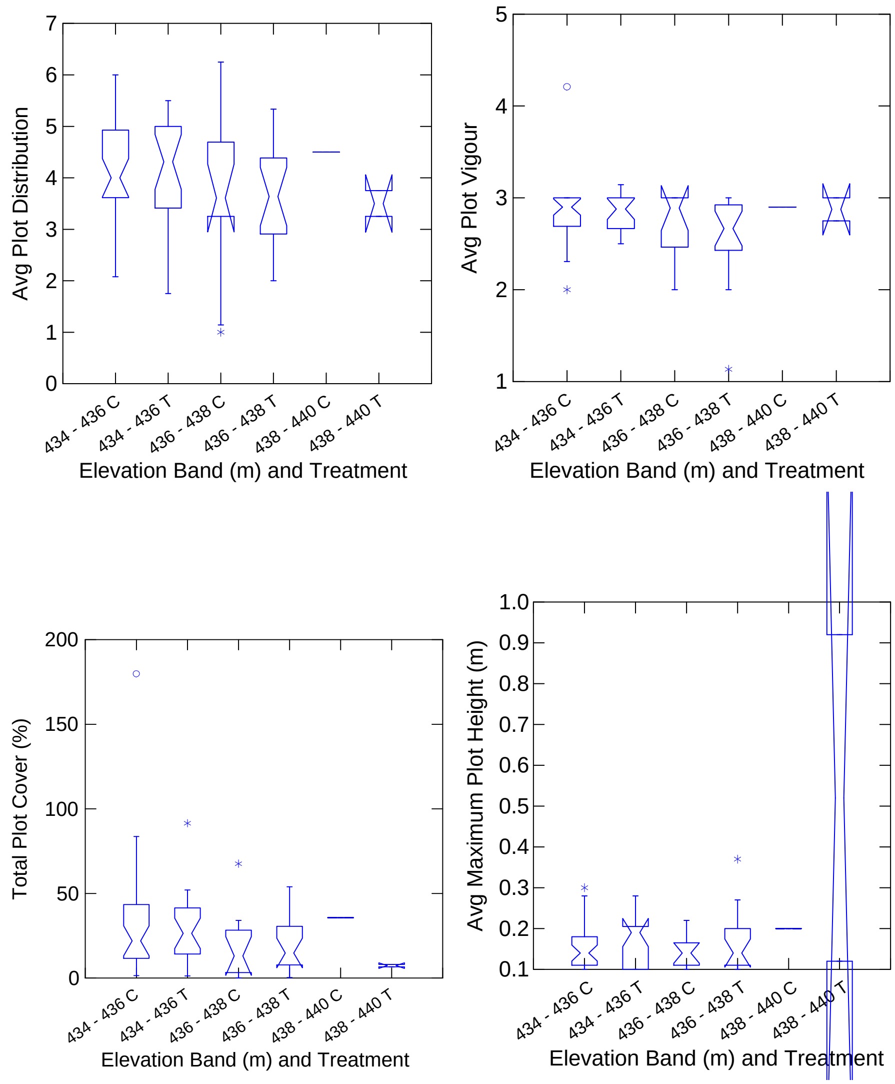

Figure 39. Plant species distribution (upper left), average plot vigour (upper right), average total cover (lower left), and average maximum height (lower right) of vegetation in control plots (C) and plots treated with *Carex* plugs (T), over three elevation bands in the Arrow Lakes Reservoir. A box extending above and below the figure margin shows a confidence interval that extends below zero and above the highest height value due to the presence of very low and very high height values in the dataset.

There was no difference between treatments and controls for the measures of plant distribution or cover. Height of the treatments in the 438 m to 440 m band was influenced by the presence of shrubs, commonly pre-existing at that elevation.

Cottonwood seedlings and the quality and quantity of vegetation, by elevation bands

The quality and quantity of vegetation in cottonwood seedling-treated stands versus controls is shown in Figures 40 and 41 (Data from Arrow Lakes and Revelstoke Reach were combined, as in Figures 38 – 39). Treatment and control pairs with insufficient numbers of replicates (fewer than five) were removed from the data set for this comparison.

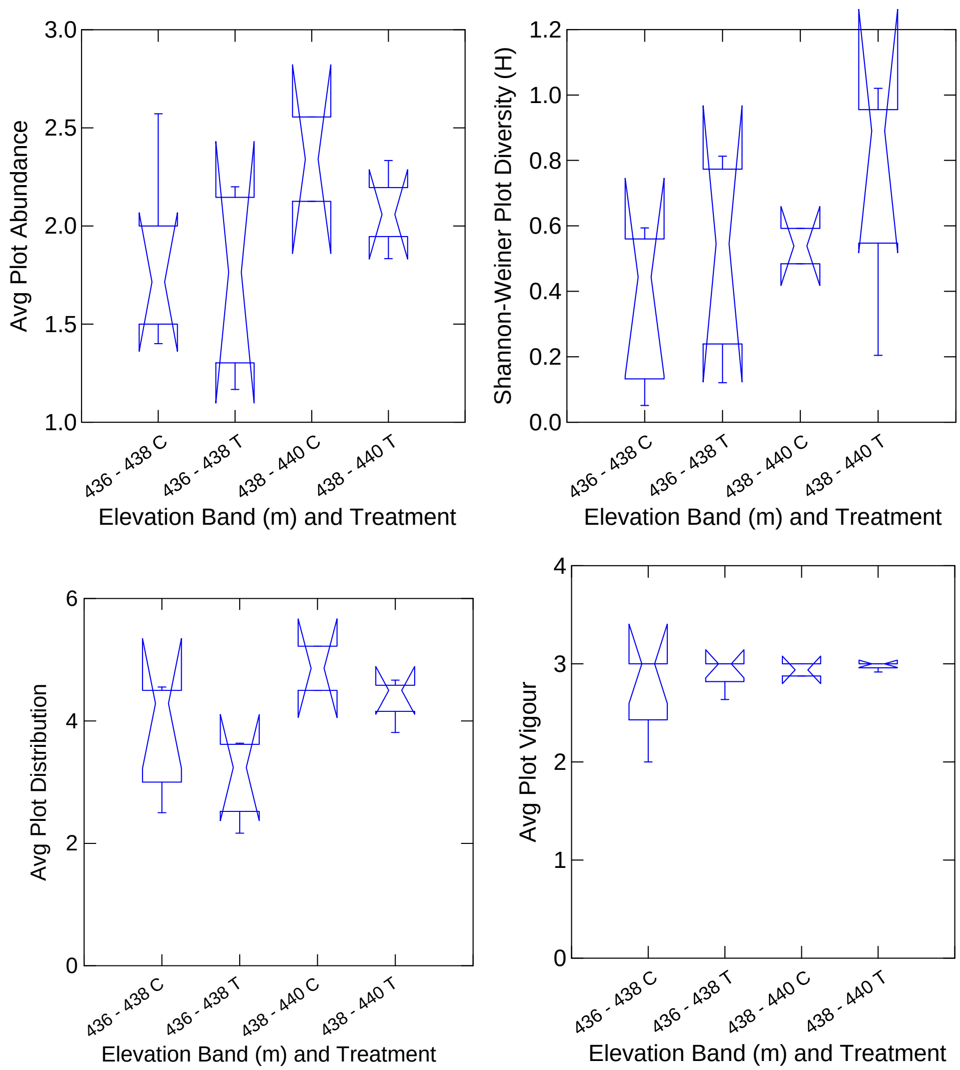

Figure 40. Abundance classes of all species (upper left), diversity (upper left), distribution (lower left), and vigour (lower right) in plots treated with cottonwood seedlings (T) versus control plots (C), over two elevation bands in the Arrow Lakes Reservoir.

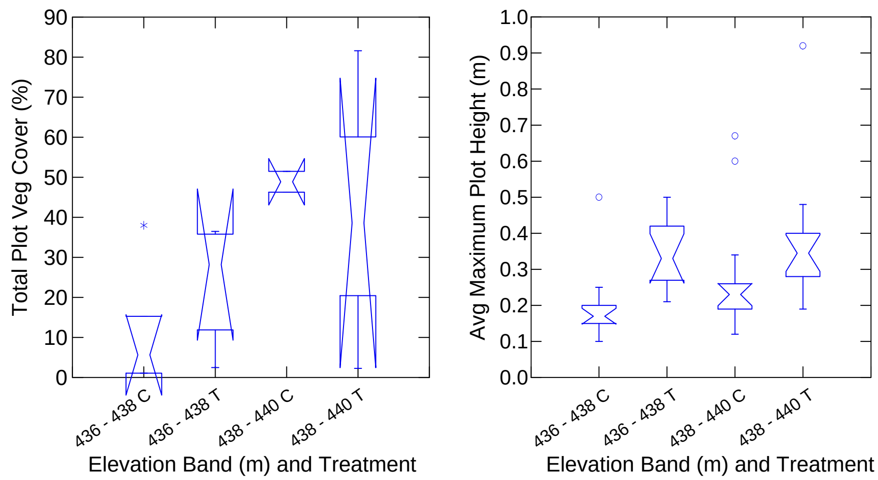

Figure 41. Treatment plant species cover (transformed) (left) and height (right) in plots treated with cottonwood seedlings (T) versus control plots (C), over two elevations bands in the Arrow Lakes Reservoir.

There was no significant difference in abundance, diversity, distribution, vigour, or cover between cottonwood seedling treatment plots and control plots over the two elevation bands (436 m–438 m and 438 m–440 m). There was a significant difference between average maximum heights of plants in treatment versus control plots ($p < 0.05$), but this is not attributed to *Carex* plugs, as they are only approximately 1 to 3 decimeters tall.

Cottonwood stakes and the quality and quantity of vegetation, by elevation bands

The quality and quantity of vegetation in stands treated with cottonwood stakes is shown in Figures 42 and 43 below, from 63 sites.

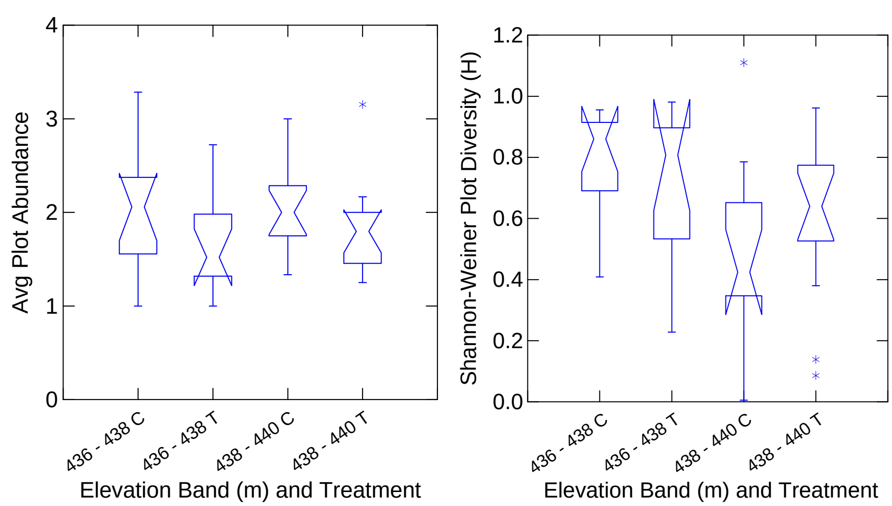

Figure 42. Plant species abundance (left) and diversity (right) in plots treated with cotton wood stakes (T) versus controls (C), over two elevation bands in the Arrow Lakes Reservoir.

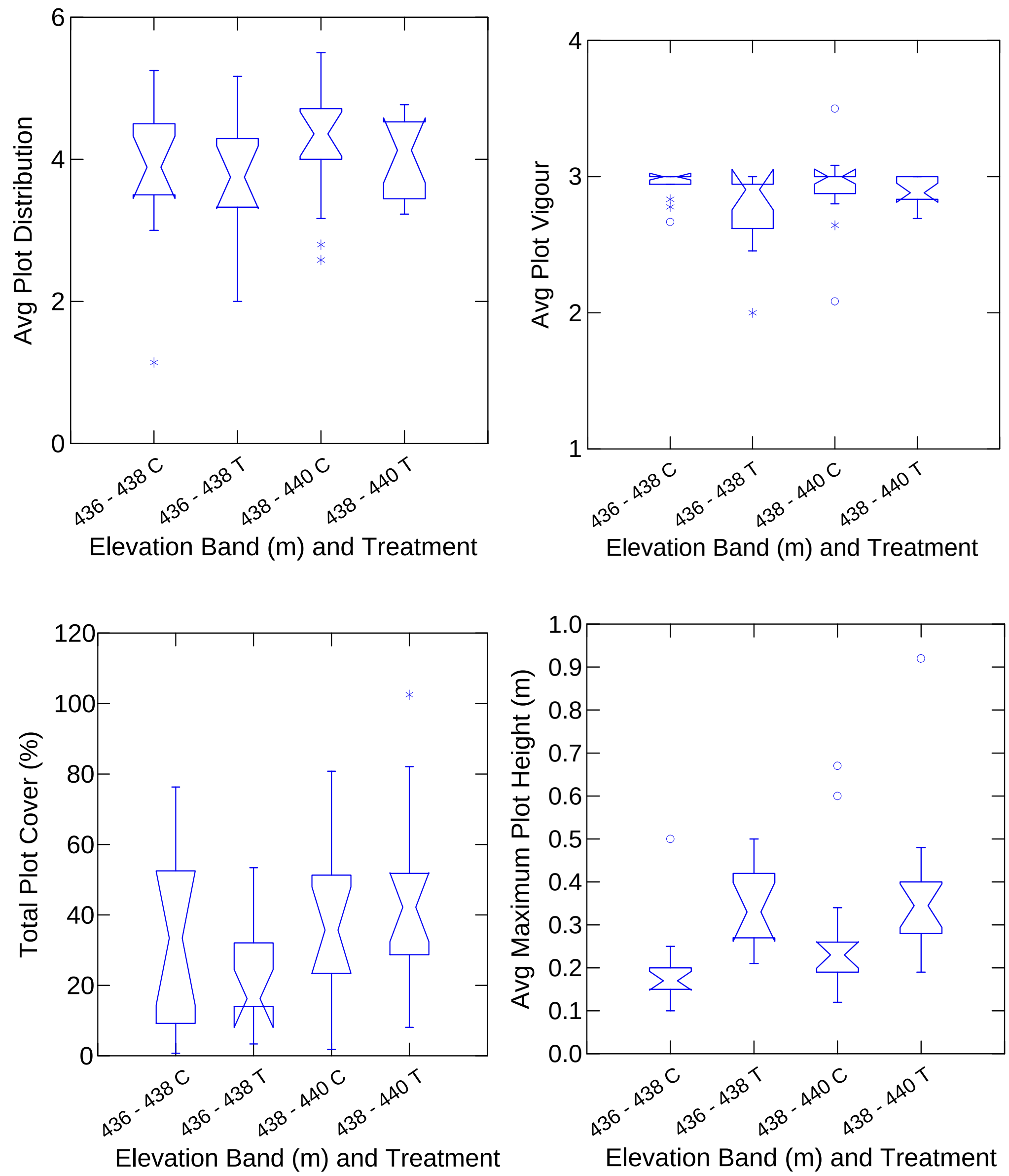

Figure 43. Plant species distribution (upper left),vigour (upper right), average plant species cover (transformed) (lower left), and height (lower right) in plots treated with cottonwood stakes (T) versus controls (C), over two elevation bands in the Arrow Lakes Reservoir.

Only heights were significantly greater in plots treated with cottonwood live stakes; none of the other variables representing quality and quantity of vegetation differed between control and treated plots.

Analyses of variance (ANOVA) were performed on these data to look for significant differences between the measurement variables. Significant results are summarized in Table 10 and the ANOVA data are presented in Appendix 5.

Table 10. Results of ANOVA for controls *vs* treatments for three treatments in the Arrow Lakes Reservoir. Only statistically significant results are shown in this table; all the ANOVA results are included in Appendix 5.

***Carex* Plug Treatments vs Controls**			
Dependent Variable	**Independent Variables**	***p* value**	**Significance**
Average vigour	Elevation band	*p* = 0.029	Average vigour poorer at 436 m – 438 m than at 434 m – 436 m
Transformed total vegetation cover	Elevation band	*p* = 0.026	Total cover at 434 m – 436 m > 436 m – 438 m; neither are significantly different from 438 m – 440 m
Vegetation height	Elevation band	*p* = 0.035	Average height significantly less at 434 m – 436 m and 436 m – 438 m than at 438 m – 440 m; 434 m – 436 m = 436 m – 438 m < 438 m – 440 m

Cottonwood Seedling Treatments vs Controls			
Dependent Variable Independ	**ent Variables**	**p value**	**Significance**
Average distribution	Elevation band	p = 0.028	Average distribution of vegetation is more sparse and patchy in treated plots at 436 m – 438 m than at either 434 m – 436 m or 438 m – 440 m

The treatment plots tended to vary slightly from control plots, for a number of reasons. Although every effort was made to pair controls with treatments in terms of elevation, vegetation species composition, materials, aspect and slope, there were some inherent differences between treated and control vegetation. Many of the treatment areas covered entire locations that were influenced by scouring, with no untreated scoured area available to place a paired control plot. Consequently, the treatment plots were often in poorer condition than the control plots. For example, plant vigour was lower in *Carex* treated plots than control plots. The differences in vigour were greater at middle elevation than at low elevation. Heights in both treatment and controls were lower at low elevation, which is consistent with other measures taken in the reservoir. There was also a tendency for existing vegetation to be sparser and more patchy in plots treated with Cottonwood seedlings. As filling in of vegetation in sparse areas is an objective of the treatment program, it is not surprising that the data should reflect this difference. The data do not show dramatic trends with respect to elevation, although vegetation is sparser in treated plots in the middle elevation band.

Management Question 8. What are the species-specific survival rates under current operating conditions (i.e., what are the tolerances of revegetated plant communities to inundation timing, frequency, duration and depth)?

Survival rates were assessed by determining if species have been lost over time from repeated plots. The longest-term repeated treatment plots were compared (Table 11; raw data are presented in Appendix 6). Fifteen plots planted with *Carex* plugs had between two and four years of data providing repeated measures from plots done repeatedly in each year, between 2008 and 2011. Very few plots have consistent annually repeated measurements. However, repeated plots were found to have either gained or lost species over time, and only one plot stayed the same. None of the plots examined both gained and lost species.

Table 11. Species losses and gains from repeatedly monitored treatment plots 2008–2011.

No. of plots with treatments and at least two annual measurements	Elevation of treatment plots, and number of plots in each elevation band	Number of plots with a loss of species over time	Number of plots with a gain in species over time	Average no. of species lost over time	Average no. of species gains over time
15	434–436 m = 8 436–438 m = 5 438–440 m = 2	5	8	2	4.5

Most species that remained in the repeated treatment plots were emergent to semi-aquatic perennials or rapidly spreading annuals, such as lenticular sedge, reed canary grass, common horsetail, little meadow-foxtail, and Canada bluegrass. These species did not change in any of the plots in which they originally occurred. Reed canary grass declined in cover in some of the treated, control, and existing vegetation plots in 2011, however. A few species that were lost from plots reappeared at a later date. Most species that were lost were relatively aggressive semi-amphibious ditch weeds, such as needle spike-rush (*Eleocharis acicularis*), purslane speedwell, nodding chickweed, small bedstraw (*Galium trifidum*), narrow-leaved montia, common knotweed (*Polygonum aviculare*), marsh yellow cress, lady's thumb (*Persicaria maculata*), and yellow clover (*Trifolium aureum*). These cannot be considered actual losses, but they do indicate dynamism in the species composition of repeated plots. The development of tolerance of plant species to drawdown zone conditions is common, but it is usually accompanied by high variation of species occurrence over time (Van der Valk and Davis 1976, Andersson et al. 2000). In future, repeated plots in treated areas can be evaluated with respect to the days of inundation of the plot, and the response of the treatment. As several of the plots included this year have actually not been inundated yet, it is not possible to present that data this year.

Management Question 9. 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 vegetated communities in the drawdown zone?

This question assumes that one or more of the vegetation response variables would show an increasing or decreasing trend in response to the treatments, and be measureable. RDA was used to determine if a linear combination of the environmental variables explained the variation found in species cover in treated, control, and existing vegetation plots (Figure 44, Table 12). Independent variables included exposure, topography, terrain texture (sand, silt, clay, gravels, and cobble percentages), aspect, latitude (representing climate), as well as elevation and days of inundation (the variables associated with the current operating regime). A total of 295 plots remained after deleting any plots that had one or zero species. Also, 65 species were retained after removing any species that occurred in fewer than six plots, in order to reduce noise.

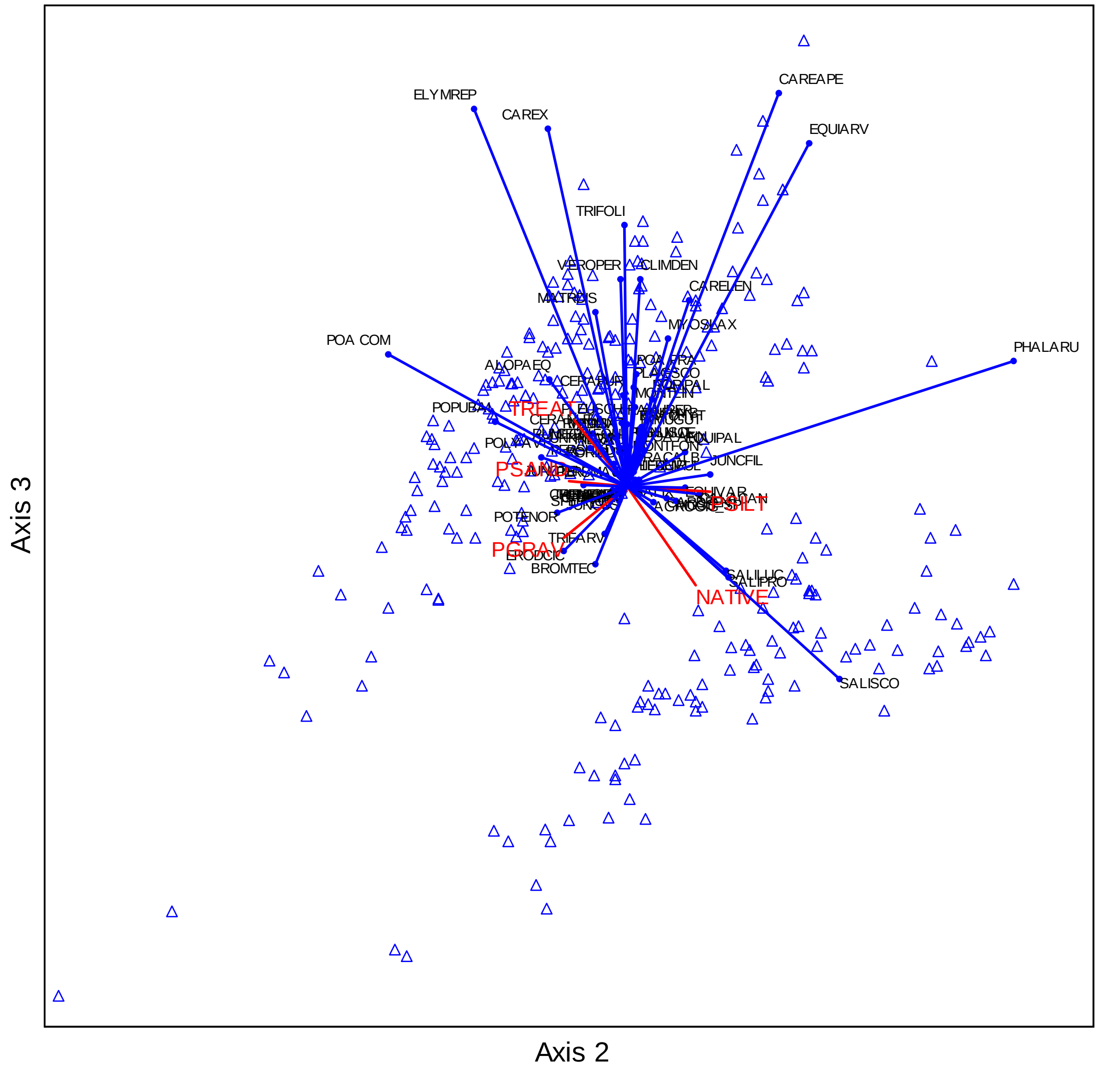

Figure 44. Redundancy anal ysis biplot: transformed species cov er and scaled environmental variables. Triangles represent the ordination scores for vegetation plots. Quali tative variables are sh own by arrow pointing in the direction in w hich the value of the enviro nmental value increases. Red lines = environmental variables, blue lines = species.

The RDA showed the importance of duration of inundation and elevation (Figures 45 and 46), and a clear separation between existing (native) vegetation and treatment/control vegetation (Figure 47 through 49).

Table 12. Summary of the variation in the main RDA matrices (Figures 44- 46).

Figure 44: Variation in main matrix) represented by the second matrix: 11 = number of canonical axes, 5.83923 = sum of all canonical eigenvalues, 46.2968 = total variance in response variables (main matrix), 0.126126 = proportion of variance in main matrix explained by predictors

Axis summary statistics:
Number of canonical axes: 3 of 11 possible
Total variance in the species data: 46.30

	Axis 1	Axis 2	Axis 3
Eigenvalue	2.080	1.543	0.844
Variance in species data			
% of variance explained	4.5	3.3	1.8
cumulative % explained	4.5	7.8	9.6
Pearson Corr., Response-Predictor*	0.638	0.619	0.467
Kendall Corr., Response-Predictor	0.482	0.429	0.333

* Correlation between sample scores for an axis derived from the response variables (main matrix) and the sample scores that are linear combinations of the predictors (second matrix)

Inter-set Correlations (Figures 45 and 46)

Variable	Axis 1	Axis 2	Axis 3
Native vegetation	-0.106	0.351	-0.344
Control vegetation	-0.092	-0.064	0.104
Treated vegetation	0.106	-0.276	0.231
Scouring	-0.060	-0.151	-0.033
Per cent sand	-0.026	-0.301	0.019
Per cent silt	-0.059	**0.424**	-0.014
Per cent gravels	0.106	-0.327	-0.176
Inundation	**-0.611**	-0.030	-0.013
Elevation	**0.475**	-0.096	-0.057
Slope per cent	0.078	0.054	0.108
HLI (Estimated heat load index).	0.070	-0.015	0.001

Existing vegetation was more closely aligned with silts, while treated and control vegetation was more closely aligned with sands and gravels. This association was commonly observed in the field, as well. There was a tendency for treatments to take place in the “poorer” soils, as an ameliorative action to enhance the vegetation cover. Cottonwood stakes were often planted in gravels and sedge plugs in sands, whereas existing native vegetation not subjected to treatments often occurred on substrates that had noticeably higher silt fractions. As in previous years, a large portion of the variation was not explained by the measurement variables (Enns, et al. 2010). An exception to this is where variation was explained due to the inclusion of dependant variables, such as hygrotope and species compositions (hygrotope is derived, in part, from species compositions). Similar to previous years, but excluding the variables derived from each other, (11) environmental variables, corresponding to the 11 canonical axes, were used in the forward selection (Table 12). In total, the 11 environmental variables explained 12 per cent of the variation in cover of the 65 species in the 295 plots. The most important three canonical axes in the RDA explained 4.5 per cent, 3.3 per cent, and 1.8 per cent of the variation in cover of species (response variables) in the plots, and the remaining eight canonical axes cumulatively explained the remaining three per cent of the variation explained by the environmental (predictor) variables. Days of inundation and elevation accounted for the highest proportion of the variation in cover, followed by substrate features; per cent sand, silt and gravels (Figures 45 and 46).

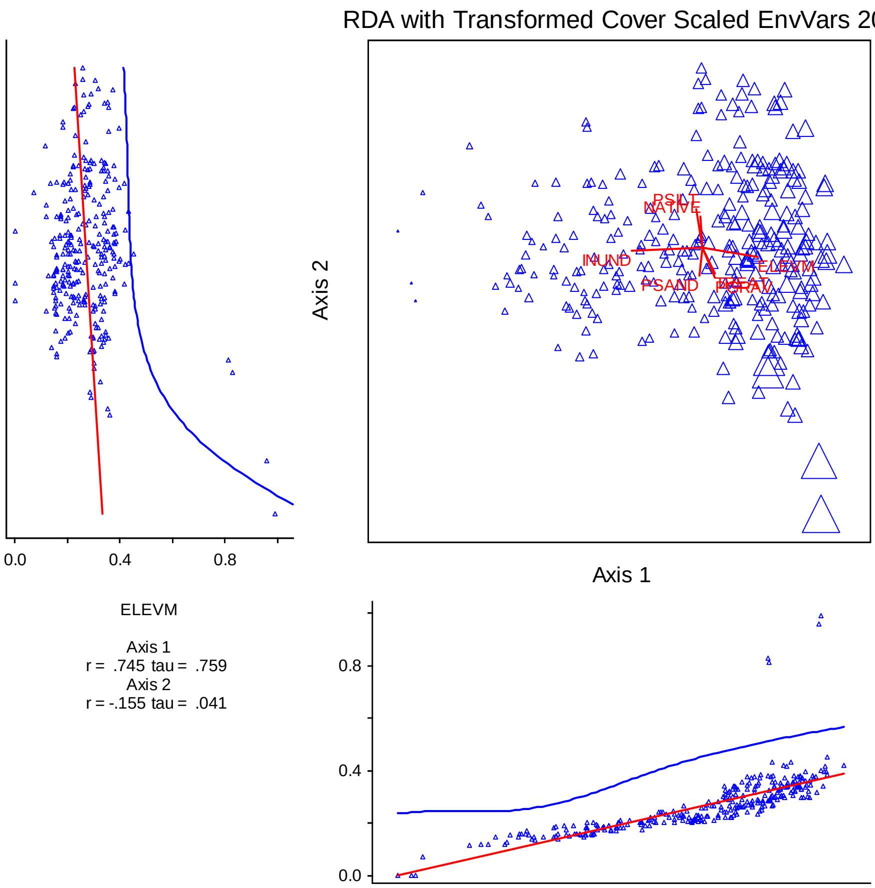

Figure 45. Redundancy anal ysis w ith transforme d cover and s caled environmental variables from 2011 field measurements and estimates from the Arrow Lakes Reservoir: Axis 1 v ersus Axis 2 sho wing a strong relationship be tween elev ation and c over of ve getation. Plots at higher elevation have higher cover (as indicated b y the size of the triangles). Elevm = plot elevation in me tres. Inund = Da ys of inundation. Psand = p er cent san d, Pgrav = Per cent g ravels, Psilt = per cent silt. Red lines = environmental variables, blue triangles = species cover values. Blue line s in margi n graphs are the 9 5% confidence limits on the regression lines.

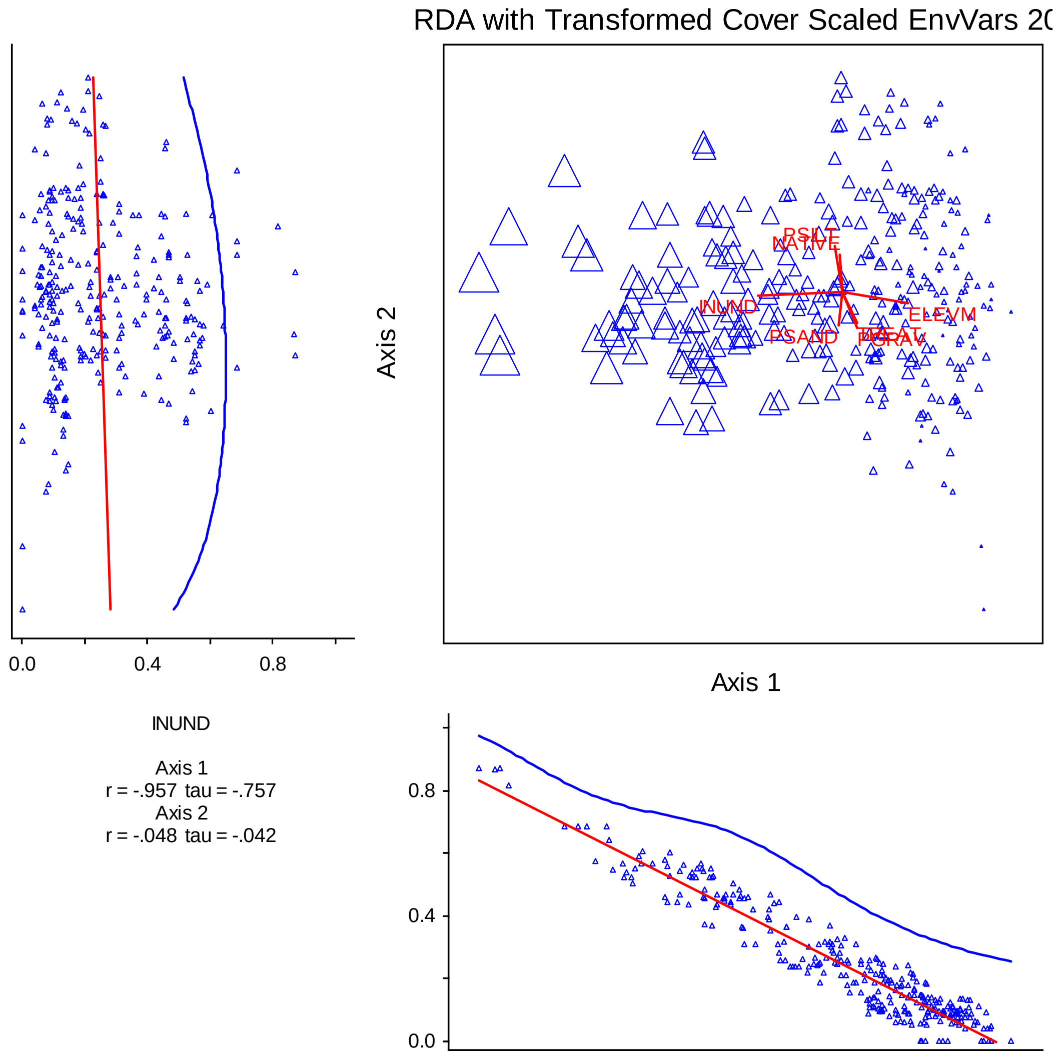

Figure 46. Redundancy anal ysis w ith transforme d cover and s caled environmental variables from 2011 field measurements and estimates from the Arrow Lakes Reservoir: Axis 1 v ersus Axis 2 sho wing a strong <u>negative</u> relationship betw een days of inundation and cov er of vegetation. Plots w ith a longer period of inundation have smaller cover (as indicated by the size of the triangles). Elevm = plot elevati on in metres. Inund = Days of inundation. Psand = per cent sand, Pgrav = Per cent g ravels, Psil t = per ce nt silt. Re d lines = environmental variables, blue triangles = specie s cover values. Blue lines in margin graphs are the 95% confidence limits on the regression lines.

Use of RDA illustrated the differences between treated, control, and existing vegetation, in response to conditions in the reservoir (Figures 47 to 49). The vegetation cover data show that when Axis 2 is plotted against Axis 3, the dissimilarity of the existing vegetation plots (those plots that represented neither control nor revegetation treatments) becomes apparent.

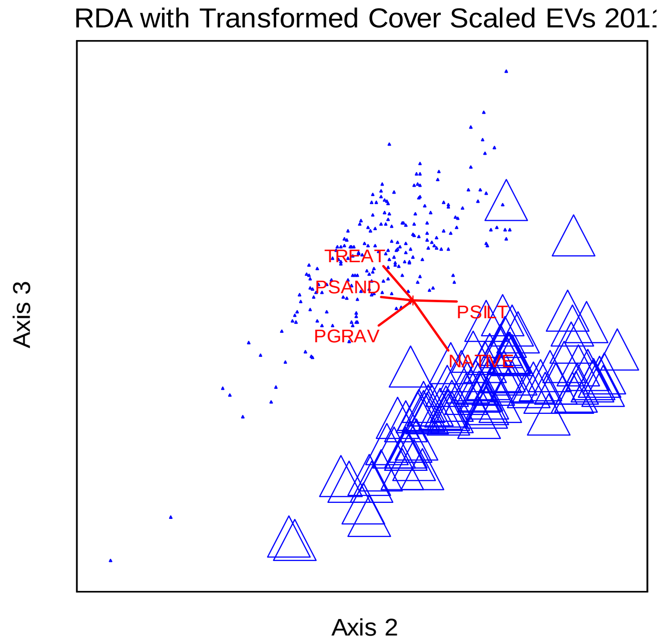

Figure 47. Redundancy analysis with transformed cover and scaled environmental variables from 2011 field measurements and estimates from the Arrow Lakes Reservoir: Axis 2 versus Axis 3 showing separation of existing (native) vegetation plots from control and treatment plots. Large triangles represent existing vegetation plot ordination scores, very small triangles are the treatment and control plot ordination scores. Psand = per cent sand, Pgrav = Per cent gravels, Psilt = per cent silt. Red lines = environmental variables, blue triangles = species cover values.

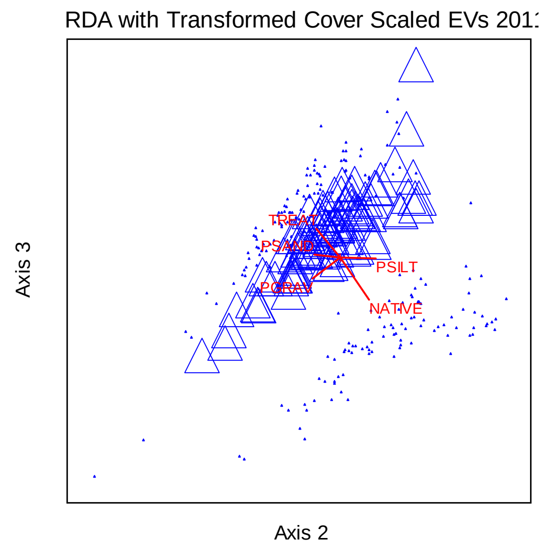

Figure 48. Redundancy analysis with transformed cover and scaled environmental variables from 2011 field measurements and estimates from the Arrow Lakes Reservoir: Axis 2 versus Axis 3 showing separation of control vegetation plots from existing (native) vegetation plots. Large triangles represent control plot ordination scores. Psand = per cent sand, Pgrav = Per cent gravels, Psilt = per cent silt. Red lines = environmental variables, blue triangles = species cover values.

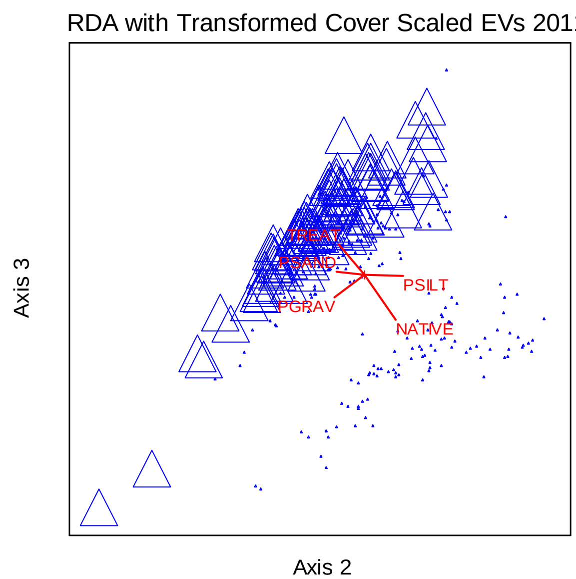

Figure 49. Redundancy analysis with transformed cover and scaled environmental variables from 2011 field measurements and estimates from the Arrow Lakes Reservoir: Axis 2 versus Axis 3 showing separation of treatment plots from existing (native) vegetation plots. Large triangles represent treatment plot ordination scores. Psand = per cent sand, Pgrav = Per cent gravels, Psilt = per cent silt. Red lines = environmental variables, blue triangles = species cover values.

In Figures 47 to 49, the control and treatment plots are grouped together, as they are most similar, and the existing vegetation plots are separated from the others. Both NATIVE and TREAT variables have fairly strong correlations to both Axis 2 and Axis 3, indicating that these designations explain a small part of the variation in total vegetation cover. The CONTROL variable is not as strongly correlated to either Axis 2 or Axis 3. The PSILT and PSAND vectors in the biplot overlays also shows that plots selected for revegetation appear to have higher proportions of sands and gravels (and lower proportions of silts), whereas the opposite is true for the native plots. The per cent gravel, sand, and silt axes show a separation between the treatments/controls and the existing vegetation. Fine-textured materials, including silt, clay, and very fine sand, were identified this year and in previous years as being important for vegetation development in the drawdown zone. They are needed to sustain a greater cover, abundance, biodiversity, or higher dispersal of individual plants for a variety of reasons. A large amount of variation remains to be explained, including aspects of the water regime that are not related to inundation and elevation alone, such as the influence of wave action, sorting of materials and non-reservoir sources of moisture. The timing of when plots are inundated is possibly also important, but this may not vary enough to result on a measurable impact to vegetation.

Management Questio n 10. Wha t is the re lative effectiveness of the diffe rent revegetation treatments, as app lied through CLBWORKS-2, at increasing the quality and quantity of vegetation in drawdown zone?

Data from paired control and treatment plots were used to compare the three revegetation treatments: *Carex* plug plantings, cottonwood seedling plantings, and cottonwood stake plantings (Figures 50 and 51).

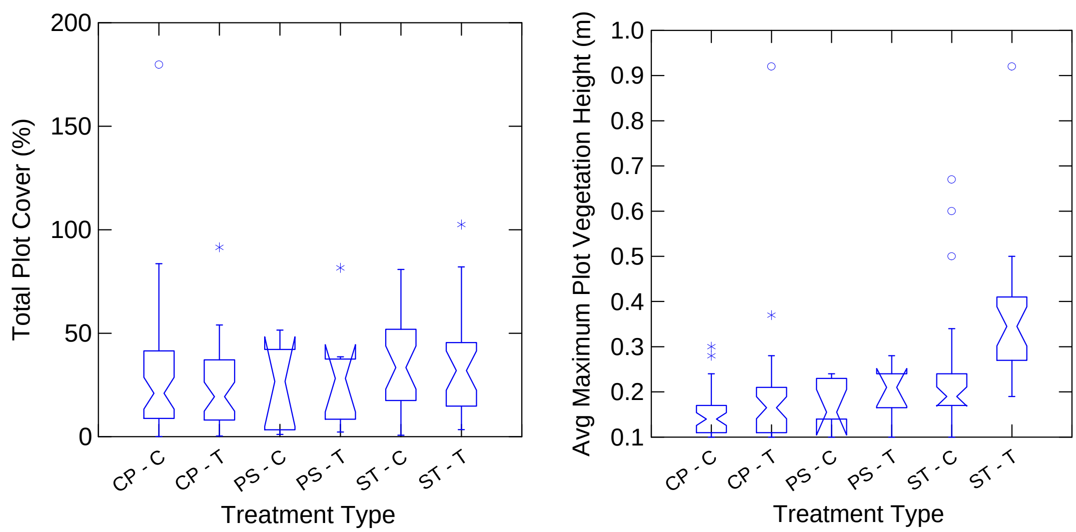

Figure 50. Tukey's boxplots of total vegetation cover (left) and average maximum vegetation height (right) in revegetation treatments versus controls: *Carex* plug control (CP-C), *Carex* plug treat ment (CP-T), cotton wood seedling c ontrol (PS-C), cottonw ood se edling treatment (PS-T), cottonwood stake control (ST-C), cottonwood stake treatment (ST-T)

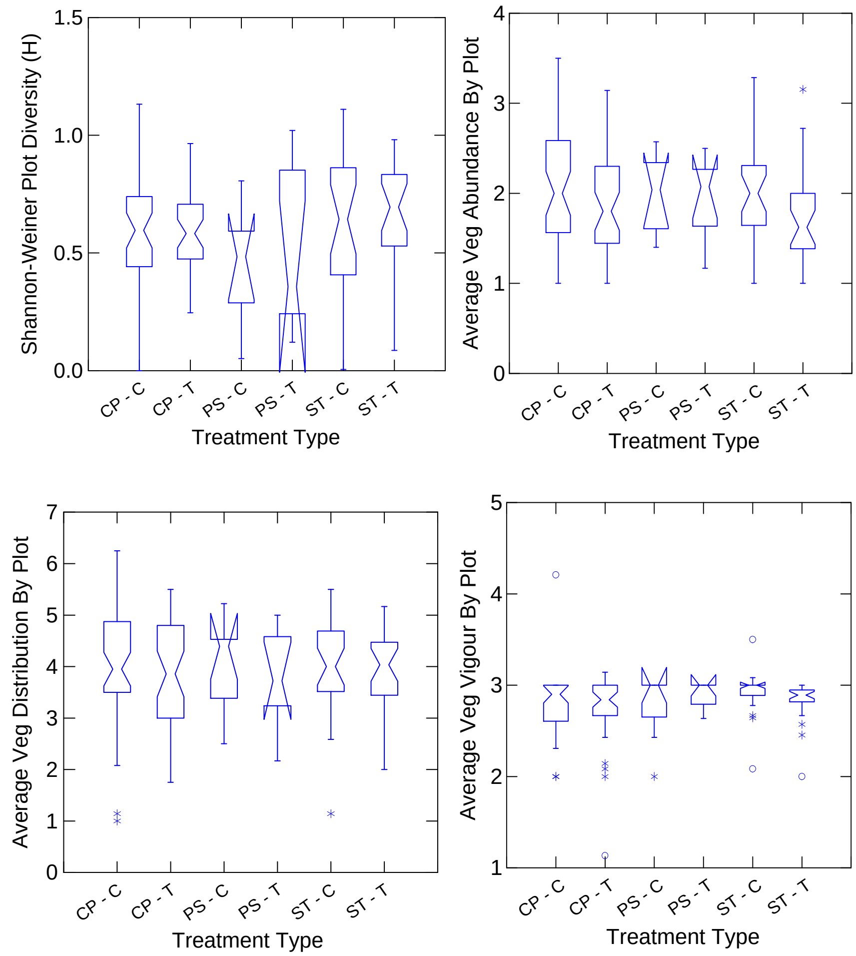

Figure 51. Tukey's b oxplots of vegetation diversit y (above left), av erage abundance (above right), average vegetation distribution (lower left), and average maximum vegetation height (lower right) in revegetation treatments versus controls: *Carex* plug co ntrol (CP-C), *Carex* plug treatment (CP-T), cottonw ood se edling control (PS-C), cottonw ood seedling treatment (PS-T), co ttonwood stake control (ST-C), cottonwood stake treatment (ST-T).

There was no significant difference in any of the measured variables between revegetation treatments and controls, except that the cottonwood stake treatment heights were significantly greater than those of the control vegetation ($p < 0.05$).

Comparisons for cover, distribution, height, species diversity and species richness in control and treated plots, in 2009 and 2011 are made in Figure 52. When compared to 2009, there is little difference between control and treated vegetation. The treated vegetation in 2009 appears to have had higher cover, distribution and species richness, than control vegetation, but this is not particularly reliable as the data shown are based on fourteen plots.

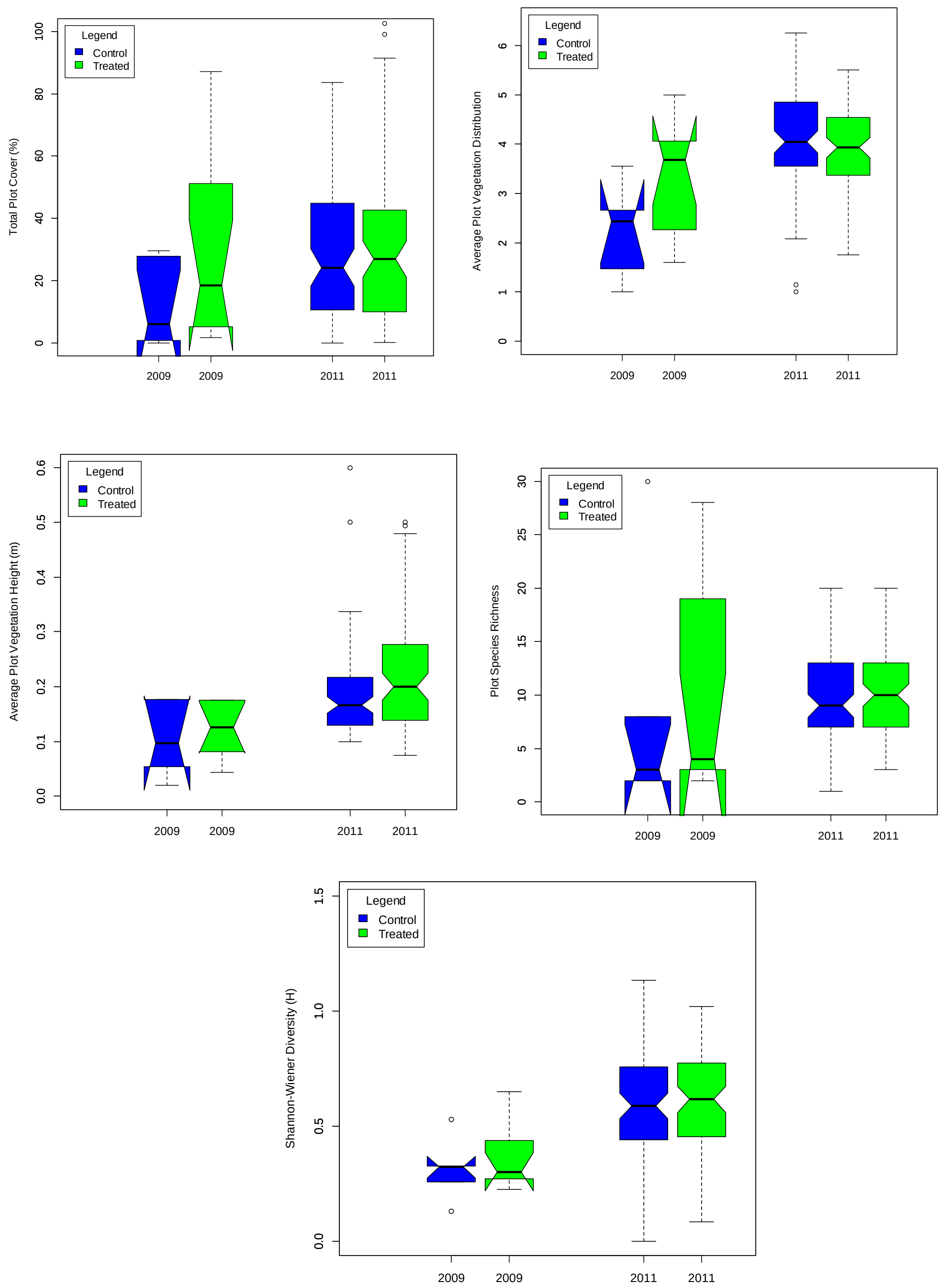

Figure 52. Tukey's boxplots of vegetation cover (above left), average vegetation distribution (above right), average height (middle left), species richness (middle right) and average diversity (bottom) in controls (blue) and treatment (green) plots in 2009 and in 2011; Arrow Lakes and Revelstoke Reach are combined due to limited data in 2009 (14 plots).

Management Question 10 assumes that the treatments would have a measurable influence on the cover, abundance, and diversity of vegetation. The boxplots in this section and in Management Question 7 show no differences in any of the measurement variables between treatments and controls, with the exception of height differences in the stake plantings. However, the treatments may result in a greater accumulation of germinants and juvenile plants in the future.

Although the question was not posed, it is perhaps more relevant at this stage to ask if plants actually survived the treatments. We evaluated the the success of planting *Carex* plugs by tallying the number of obviously[14] planted individuals in an area compared to the number of native *Carex* plants, but due to the lack of field identification markings and intermittent losses of plantings, there was a high degree of uncertainty associated with the assessments of the plug plantings. We were more certain about our assessments of cottonwood stake treatments. The percentages of live cottonwood stakes in relation to elevation and to VCT are shown in Figure 53.

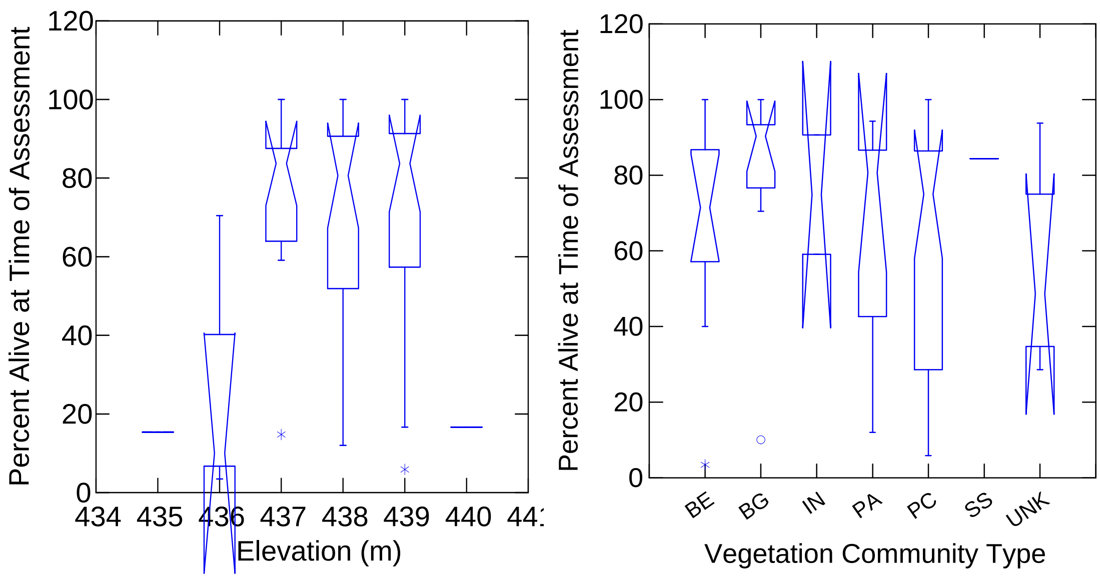

Figure 53. Percentage survival of cottonwood stakes *versus* elevation in metr es in the BE: Sandy Beach and BG: Gravelly Beach VCTs (left) and within individual VCTs acro ss all elev ations (right) in the Arrow La kes Reservoir. BE = Sand y Beach, BG = Gravelly Beach, IN = Industrial, PA = Redtop Upland, PC = Ree d Canary Grass Mesi c, SS = Steep Sand, Unk = unkno wn + areas outside the CLBMON-33 map area. A box extending belo w t he figure margin show s a confi dence interval that extends below zero.

A range of survival or condition of treatments is illustrated in Figures 51 and Figure 52.

[14] Plantings were not marked, and planted *Carex* was not always distinguishable from native *Carex*. Therefore, for a treatment to be distinguishable, the planting lines had to be evident. This was not always the case.

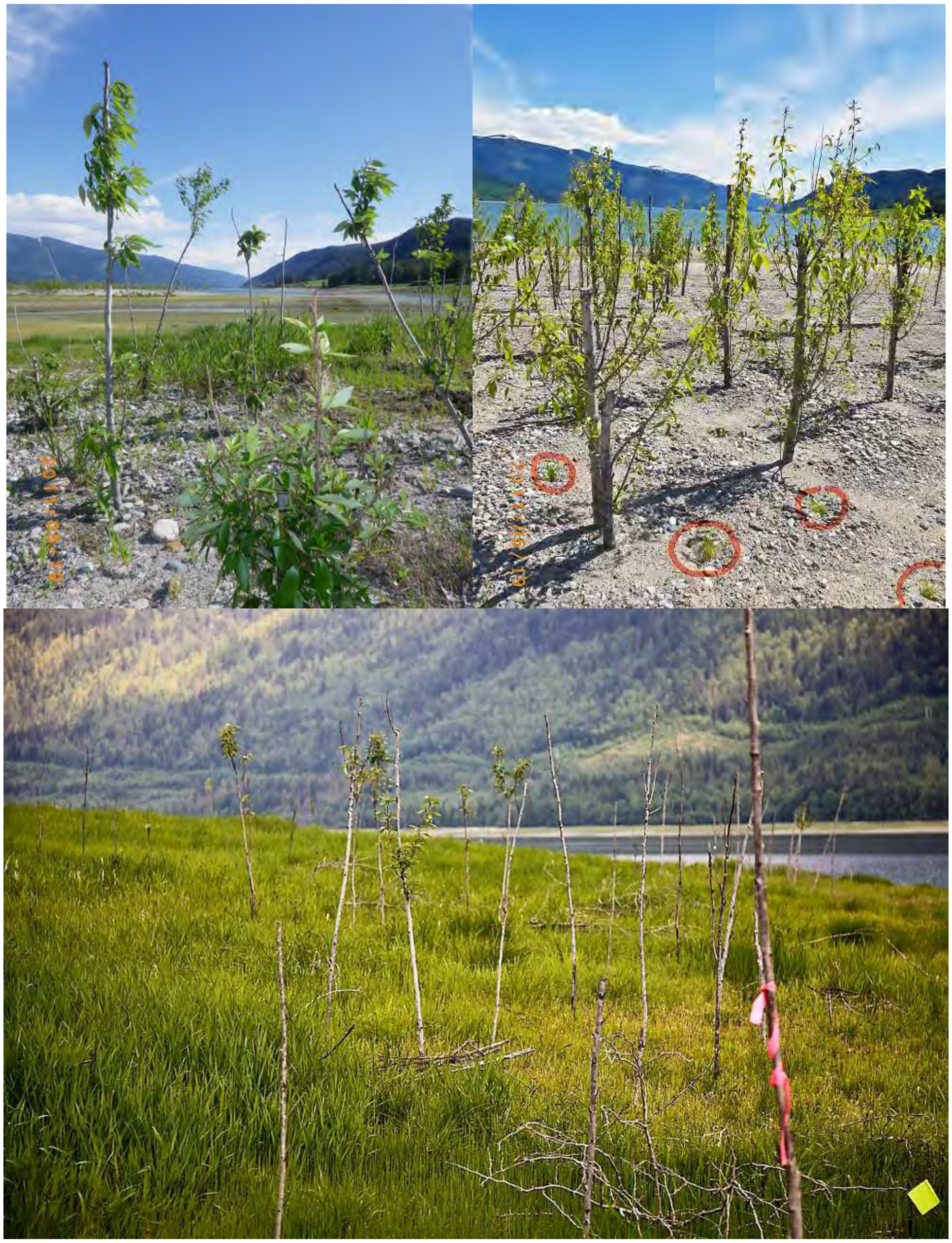

Figure 54. Two- or three-year-old cottonwood stakes with less than 10 per cent mortality but somewhat poor condition (upper left), two- or three-year-old cottonwood stakes with high relative survival and good condition, with recent *Carex* plugs circled in red (upper right), and one-year-old cottonwood stakes with poor survival and poor condition (bottom).

Figure 55. A successful 2009 *Carex* plug planting area in a non-vegetated BE: Sandy Beach VCT (above), and chlorosis in more recently planted *Carex* (below).

The highest stake survival was at 437 m, which is usually downslope from the PA: Redtop Upland and CR: Cottonwood Riparian VCTs. The 437 m elevation band is often in a moisture-receiving slope position. This location has less competition from reed canary grass than the lower elevations of the reservoir. Survival of cottonwood stakes appears to have been greatest in well drained materials at 437 m that were receiving some moisture.

A stake was judged alive if only a few leaves could be found, but this may not be a persistent condition; therefore, assessments in following years should be considered more reliable than the current data. Mortality appeared to be highest at lower elevations (<436 m) but mortality also occurred above 437 m, usually in finer textured soils with high cover of other plants that may have been outcompeting cottonwood stakes. Stake count data are included in Appendix 7.

Many of the cottonwood stake plantings were successful in that the stakes have sprouted stems and have leafed out during the past three years. Some stake plantings have formed a stand of sparse-canopied shrubs of various heights (Figure 54). Some of these occur at elevations in the reservoir where no other naturally occurring cottonwood stands exist. Previous research indicates that cottonwoods are unlikely to persist below scouring lines in the drawdown zone (Bren 1992, Bovee and Scott 2002).

Poor survival is often related to poor stock health and robustness at the time of planting (Peterson et al. 1996). For example, smaller diameter cottonwood stock tended to have higher mortality (observational data; illustrated in Figure 54). In general, vigour of cottonwood seedlings was at least 20 per cent lower than that of native vegetation. Also, chlorosis was common in the 2011 sedge plug plantings (Figure 55). These treatments may not survive as well in sands as some of the older, more robust stock from previous years (Figure 55; top versus bottom). Although many plantings in sand were successful, loss of *Carex* plugs appeared to be very high in some locations. There was no clear pattern in losses that could be related to site features. Patterns may be more recognizable with the use of aerial photographic interpretation (see below).

Management Question 11. 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?

With limited data available from 2009 (see Appendix 6), it is not possible to determine if the treatments have resulted in larger vegetated areas or more productive vegetation. Some areas, such as sites at Montana Slough, Edgewood, Inonoaklin Road and Arrow Narrows have cottonwood stakes as juvenile trees that were not present before. However, most of the data are from the current year, and the current year treatments have not had enough time to respond to conditions in the reservoir or to reach a “free-to-grow” status. In subsequent years, assessments of survival and response to treatment will be more complete as a result of this year’s efforts to install plots in treatmented areas, with comparable control plots nearby.

In general, from observations made in the field, most of the treatments are incorporated into areas with pre-existing vegetation, and therefore are not larger in area, but they do show a very small increase in cover and abundance (Figure 56).

Figure 56. A typical 2011 sedge plug planting area with existing vegetation in the background (left); clo se-up of th e *Carex* plug treatment area (right) with *Carex* plugs (circled in red).

The conditions illustrated in Figure 56 were typical of the treatment and background conditions observed in 2011 in the Arrow Lakes Reservoir. Small *Carex* plugs were sparsely planted within an already fairly sparse vegetation type. This did not add much to the baseline vegetation cover, abundance, height, or vigour. However, if the *Carex* plugs survive, they can become substantial in size. A density of 942,530 sedges planted in an area totalling 108 ha (KESL 2011) is approximately one *Carex* seedling per 1 m^2. This density of planting varies over the planting areas.

To examine the benefits and disadvantages of the treatments, we drew on a variety of information sources in addition to our own results. These included the reports of KESL, information from the literature, the comments of local residents, and our own professional experience. A summary of the estimated non-monetary benefits and disadvantages of the treatments is provided in Table 13.

Table 13. Estimated benefits and disadvantages of the CLBWORKS-2 treatments in the Arrow Lakes Reservoir in relation to the soft constraints operating regime

Benefits of treatments	Disadvantages of treatments
Provide increase in plant biomass in areas with no vegetation	Lenticular sedge is the main species used in the treatment program and is well adapted to conditions in the reservoir.
Provide forage, shade, and shelter for wildlife	Lenticular sedge encourages use by Canada Geese, which may not be preferred by local residents.
	Use of the reservoir drawdown zone by nesting birds can lead to mortality when the water levels rise during the nesting period.
Provide increased forage for fish	Some fish use of new forage areas may result in strandings.
Provide scenic views for residents	The stake plantings are viewed by some local residents as being overly uniform and unnatural, and they may block views of the water.

	Cottonwoods have been subjected to vandalism. Some vandalism has also been directed at neighbouring native plant communities, with the result being damage to sensitive pre-existing vegetation.
Provide added greenery to the reservoir	Some of the cottonwood plantings have attracted plant pathogens, or the pathogens have arrived as infected stakes. Pathogens include the cottonwood leaf beetle (*Chrysomela scripta*) and satin moth (*Leucoma salicis*) (KESL 2011). These pathogens may increase and spread to native cottonwoods and other species in the drawdown zone.
	The vigour of many of the cottonwood stakes is poor to moderate, and several stakes have died. Dead stakes are unsightly and are a vector for disease. Because they have been packed with an excavator, they may not break off or float away very readily.
Provide increased use of sites for recreation purposes by providing shade and play areas	Stakes at mid elevation present a hazard to boats during high water
Provide protection of known cultural heritage sites: when bones were found during the treatments, archaeologists were asked to attend	Unknown
Prevent soil erosion	The use of excavators and vehicles when planting disturbs the soil and causes losses of pre-existing vegetation.
Power generation	No relationship

From a biological perspective, one of the greatest advantages of the treatments is that the *Carex* and cottonwood plantings may add new species to the reservoir vegetation communities over time by helping to trap seeds, rhizomes, adventitious shoots, and other propagules. Evidence of this has not been observed yet, but some of the 2009-planted *Carex* plugs had started to expand in size and to form large, polygonal clumps by 2011.

Some of the stake plantings had grown enough to be visible in 2010 aerial photography (Figure 57).

Figure 57. A typical cottonwood stake planting from the air (2007 pre-planted condition above, 2010 post-planted condition below).

The number of stakes that survived the 2009 planting in polygon 1591 (illustrated in Figure 57) were counted using high power stereoscopy of aerial photography from 2010 (data not shown). Naturally occurring vegetation cover has not increased or decreased between 2008 and 2010 in polygon 1591, but some small clumps of vegetation and one small tree have been removed. The losses of vegetation between 2008 and 2010 may be mainly due to scouring. Image analysis is a more efficient and accurate method of evaluating the influence of scouring and wave action on treated and non-treated vegetation as the patterns of materials movement are more evident in 1: 5 000 imagery than they are in a ground inspection. For example the ridged pattern in Figure 57 is not as obvious on the ground as it is in the aerial photographs, and the overall small scale patterns can not been seen except in imagery.

Management Question 12. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the landscape and site level in the future?

It is premature to assign any changes to the operating regime to more effectively maintain revegetated communities at the landscape or site level, as there are insufficient comparisons over time. There are some indications that site factors are important for survival of cottonwood stakes, such as being located above 437 m, and having a source of moisture from upslope. We do not have enough data to evaluate the influence of variations in the operating regime on the success or failure of plantings. It may be that the same recommendations for maintaining existing vegetation apply to revegetated communities. To reiterate: to maintain vegetation in the reservoir, BC Hydro should allow for a low water period in the fall.

6.0 DISCUSSION

6.1 Existing vegetation

Management Questions 1 and 2: What is the diversity, distribution, vigour, cover, abundance and biomass of existing vegetation communities in relation to elevation in the drawdown zone?

Comparison between 2009 and 2011: Vegetation cover declined in low elevation communities between 2009 and 2011 in both the Arrow and Reach portions of the Arrow Lakes Reservoir. Distribution was more even at lower elevation than at high elevation between 2009 and 2011. Vigour was slightly lower across most communities and elevations in 2011 than in 2009. Species richness and diversty were higher in 2011 than in 2009, over all elevations. Abundance was only measured in 2011, but was highest at the low elevation sites, due to seedling germination in sand. A large number of seedlings occur in low elevation plots, in sand dominated substrates exposed to water supplies from the reservoir. Biomass was measured in 2008 and 2011, and did not change much over that period of time. The highest biomass is at 438 – 440 m in the shrub and riparian forest communities where plants are taller and heavier. These comparisons were based on fourteen plots in 2009 vs greater than 300 plots in 2011. Summaries of current conditions in response to management questions 1 and 2 are summarized in Table 14.

Table 14. Summary Table for Management Question 1 and 2: current condition

VCT	Diversity	Distribution	Vigour	Cover	Abundance	Biomass
CR	Confined to >439 and very diverse	Narrow range of distribution values from few clumps to sparse but even.	Influenced by pathogens, soils, drought, etc. Mostly moderately vigorous, no relationship with elevation.	Mostly very high cover except on edges of the VCT where it can be low in very bouldery areas or due to wave scouring.	Numbers of individuals can cover a wide range.	Not measured
PA	Highly diverse at both elevation zones, has not been dramatically impacted by fluctuation in operating regime.	Narrow range of distribution values from few clumps to sparse but even, and no relationship with elevation zone.	Mostly moderately vigorous, no relationship with elevation.	Mostly very high cover. Can be lowest at high elevation due to winter wave action.	Abundance range is higher at middle elevation than higher elevation.	Measured for non-woody species. Variable and possibly influenced by wave action.
PC	Uniform diversity, but can be reduced by wave action at	Mainly a relatively high density, clumped to uniform	Mostly moderately vigorous, no relationship with	Uniformly moderate cover values at all elevations.	Uniform abundance values with a narrowing central	Uniform across all elevations.

	high elevation, or have higher diversity if sheltered.	distribution and no relationship with elevation zone.	elevation.		tendency at the highest elevation.	
PE	Greatest range of diversity is at lowest elevation. Materials dependant (silts, clays).	Clumped distributions more common at lowest elevation, more uniform at middle elevation zone.	Some variation in vigour at low elevation, possibly related to materials, soils, moisture, anoxia, mostly moderate vigour at middle elevation.	Range of cover values at the lowest elevation, much higher covers at middle elevation, most likely due to less time under water.	Range of abundance values at the lowest elevation, much narrower range at middle elevation.	More variable and highest at low elevation. Uniform at middle elevation.
BE	Highest range of diversity at middle elevation, influenced by scouring at low elevation and waves at high elevation.	Ranges from scattered individuals to small numbers of clumps with no clear relationship to elevation zones.	Moderate vigour at high elevation, and at low elevation due to adaptation to conditions, some poorer vigour records at middle elevation due to drought in pure sands.	Over all elevations BE has very low cover values, slightly higher at the lowest elevation due to high germination rates in sand.	Abundance values are most variable at lowest elevation, and decrease with increasing elevation.	Very low biomass, slightly higher at lowest elevation.
BG	Diversity is influenced by scouring and inundation at low elevations.	Ranges from a small number of individuals to clumps of individuals between low and middle elevation zones.	Some lower vigour at low elevation, possibly due to depth and duration of inundation; moderate vigour at middle elevation.	Very low covers, with slightly higher cover at middle elevation.	Abundance increases with elevation.	Extremely low biomass, uniform across all elevations.
BB	Limited sample, most diverse at high elevation.	Limited data, range of distributions.	Limited data, moderate vigour in the highly	Limited data.	Limited data, very low abundance.	Not measured.

			drought-tolerant plants of this VCT.			
SS	Limited sample, rare VCT, variable diversity and no pattern in relation to elevation.	Mostly scattered individuals at both low and middle elevation zones.	Limited data.	Some high cover can occur in this VCT, but the data in 2011 are limited.	Limited data; low to moderate abundance and no clear pattern related to elevation.	Not measured.
IN	Most diverse at middle elevation.	Ranges from a small number of individuals to several clumps of individuals at low .elevation; mostly a few scattered individuals at middle and high elevations.	Some lower vigour at low elevation, possibly due to depth and duration of inundation, or stress from scouring. Moderate vigour at middle and high elevations.	Decreasing cover values with increasing elevation. The combination of stability from road structures and moisture can result in some high covers at low elevation.	Widest range of abundance is at low elevation. Decreasing abundance values with increasing elevation.	Highest biomass is at lowest elevation, decreases with increasing elevation. Very low biomass at high elevation, likely drought related.
RR	Limited data in 2011. Previous years indicate diversity is very high and related to subsurface streams entering above the reservoir.	Limited data, clumped pattern of distribution is most common.	Limited data. Vulnerable to ATV damage (field observation) .	Limited data.	Limited data.	Not measured.

Management Question 3. How does the current operating regime affect the within-community quality and quantity of existing vegetation?

Some vegetation communities are well adapted to the operating regime. The niche of the PE type, for example, is at low elevation, and it may require the current depth and duration of inundation to survive.

Vegetation height was almost always lower in all communities where duration and depth of inundation was at its maximum for the reservoir, with the exception of the shrubby, high-elevation PA: Redtop Upland VCT, which does not extend into low elevation, and benefits from some inundation. Vegetation cover and abundance were generally low in Arrow Lakes Reservoir vegetation communities, and did not show a dramatic or specific pattern within communities in response to the depth and duration of inundation.

In some VCTs, biomass may have declined with increasing depth and duration of inundation, but there was high variation at the shortest periods of depth and duration, possibly due to winter wave scouring and to drought.

Diversity was extremely variable and seemed to have little relationship to depth and duration of inundation.

Management Question 4. Is there a shift in community structure (species dominance) or a potential loss of existing vegetation communities that is attributable to environmental conditions, including the current operating regime?

Species dominance has not shifted for dominant species, but among the less frequently occurring species, invasive species showed some dramatic annual increases, often in sandy substrates at low and high elevation. Examples of species that fluctuated over time are the purslane speedwell, nodding chickweed, annual bluegrass and little meadow-foxtail. Most of the dominant species have remained constant in sites over time, including at low elevation where the greatest changes may be expected to occur. However, reed canary grass was not as prevalent in 2011 as in previous years. No vegetation communities have been lost, but subtle changes within communities were noted.

Management Question 5. What are the species-specific survival rates under soft constraints operating regime (i. e., what are the tolerances of existing plant species to inundation?)

Most species lost from the CLBMON-12 plots were weedy annuals and perennials that exhibited more dramatic population fluctuations than would be expected from their published autecological characteristics. Losses of germinating seedlings in sandy substrates were probably the most common type of loss. Invasions of upland plants, including trees and shrubs, into the reservoir drawdown zone, and subsequent losses over time were also common. Some losses, such as the loss of Scouler's willow at various low-elevation locations in Revelstoke Reach, appeared to be mainly inundation-related.

Management Question 6. What recommendations can be made to more effectively maintain existing vegetation at the site level in the future?

Allow a late summer to early fall low water period.

6.2 Revegetation Efforts

Management Question 7. What is the quality and quantity of vegetation in revegetated areas between 434 m and 440 m compared to untreated areas, based on an assessment of species distribution, diversity, vigour, abundance, biomass and cover?

Average vigour was poorer at middle elevation than at low elevation. As lenticular sedge is essentially a low-elevation species in Arrow Lakes Reservoir, this result may be an indication that this species should not be planted above 436 meters. Total cover and height (transformed variables) were highest at the lowest elevation, also. There were no dramatic differences between control and treatment vegetation with respect to abundance or distribution in *Carex* plug treated vegetation. Biomass was estimated, in order to not clip treated vegetation. No trends in biomass differences were observed.

Cottonwood seedling treatments were sparser and more clumped in species distribution than control areas.This was expected, given the objective to increase vegetation distribution and achieve a more uniform vegetation cover. Other than a difference in the distribution values, there were no dramatic differences between control and treatment vegetation within elevation bands. However, cover, abundance and distribution tended to be higher at higher elevation.

There was no difference between vigour of vegetation in seedling treated vs control plots. No trends in biomass differences were observed.

Cottonwood live-stake treatments had no dramatic differences between control and treatment vegetation within elevation bands, but diversity tended to be higher at middle elevation than at high elevation. Average maximum heights were significantly greater in treatments versus controls at both the middle- and high-elevation bands, an effect of the treatment. There were no dramatic differences between control and treatment vegetation in cottonwood live-stake treatments, with respect to cover, abundance distribution, vigour within or between elevation bands.

Management Question 8. 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)?

Emergent to semi-aquatic plants and rapidly spreading annuals survive the influence of longest duration and depth of flooding. Weedy species re-occur, even if they are removed periodically.

Management Question 9. 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?

The RDA showed that the number of days of inundation, elevation and per cent silts, gravels and sands accounted for some of the variation in plant cover. However, when all variables are considered, not much of the variation in plant cover in treated versus control plant communities can be attributed to any single variable. Silts and clays are common in soils of pre-existing vegetation communities and coarser textured sands and gravels are more common in the treated vegetation areas. This difference in substrate texture may influence the success of treatments over the longer term. As the treatments have not had a long enough period to survive, grow and influence other vegetation, it is premature to isolate any particular feature of the operating regime as important for restoration and expansion of treated vegetation.

Management Question 10. 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?

There was no significant difference between plant cover, diversity, abundance, distribution or vigour when treatments were compared to controls for all treatments and elevation classes combined. However, this only applies to the 2011 data. With only fourteen observations from 2009 available for comparison to 2011, it is premature to assume that treatment effects are evident or not evident in the data. However, heights of stands treated with cottonwood live-stake were significantly higher than controls. Survival of cottonwood stakes was significantly lower below 437 meters. Suvival was variable within vegetation community types, but mortality was lowest in gravels. It is premature to judge survival of the treatments as cottonwood stakes can appear to be dead, only to grow shoots or sprout new stems from roots the following year. Use of repeated aerial photography may be useful for evaluating the success of treatments.

Management Question 11. 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?

The treatments are incorporated within existing vegetation and have resulted in a very small increase in vegetation cover. New areas of small tree cover occur at Montana Slough, Edgewood, Inonoaklin Road and Arrow Narrows. These trees are not likely to have occurred in the reservoir at these locations over such a short period of time without being planted. The diversity of the reservoir has not changed, as none of the species introduced are new. Productivity may be enhanced, but low vigour of some of the plantings is a problem that requires longer term assessment. The introduction of insect and disease vectors to new locations for the Arrow Reservoir is possibly the most concerning issue.

Management Question 12. Is there an opportunity to modify operations to more effectively maintain revegetated communities at the landscape and site level in the future?

The recommendation for maintaining vegetation provided in Management Question 6, above applies: allow a late summer to early fall low water period.

If more planting is planned for Arrow Lakes Reservoir, planters should plant within the usual elevation zones for the treatment species. Workers should be trained to recognize the indicators of disease and insect pests in the treatment species, so that affected planting stock can be removed.

There was no indication that vegetation treatments either increased or decreased the total cover of any of the existing vegetation. Heights of the vegetation were influenced by planting live stakes, and some areas that were previously non-vegetated now have some vegetation cover. It is not certain this cover will persist over the long term. Vigour of some of the middle elevation lenticular sedge treatments was lower than control vegetation, indicating planting of this species should occur below 436 m.

Treatments were “operational” - that is, they were aimed at improving exposed soils and conducting infill planting in sites that had a potential to respond to treatment. It remains to be seen in subsequent years if the treated vegetation begins to resemble the existing vegetation in cover, abundance, diversity, vigour, and distribution. Detection of such changes is made more difficult by the extreme variation in vegetation that occurs naturally.

Over time, treatment areas may begin to resemble native vegetation, possibly by physically trapping new vegetation propagules as well as silts and clays, which would be incorporated into the existing sands and gravels. Such effects depend, of course, on the survival of the treatment plants. The treatment areas, which are all located in high energy or high disturbance areas, may not have the physiographic characteristics that are conducive to trapping and maintaining finer textured materials or maintaining plants. The vegetation communities of the Arrow Lakes Reservoir have been developing since the mid-1960s, and the plantations must contend with the same forces that caused the treatment areas to be depauperate.

7.0 CONCLUSIONS

The vegetation of the Arrow Lakes Reservoir has been adapting to conditions in the reservoir since the mid-1960s, and has developed distinct communities. The patterns of vegetation development are similar to other drawdown zones (Andersson et al. 2000; Merritt et al. 2000). Variations in the VCTs have been noted, but each VCT has shown the same within-type trends in species composition, cover, abundance, height, and vigour over time since 2007-2008, with clear patterns that relate to changes in elevation.

Most of the highest frequency species of the Arrow Lakes Reservoir have not changed in their dominance over time. The high-water winter of 2008-2009 influenced the frequency of occurrence of dominant species. Some species declined in frequency of occurrence following the period of high water from mid-summer to the following early spring, but subsequently recovered in 2010 and 2011.

There have been few examples of the complete extirpation of a species from the drawdown zone, and it is not possible to know for certain if the loss of a species from a known location was due to the operating regime or due to other factors, as the loss can only be detected after it has occurred. Most of the losses have taken place at the higher elevation sites, and most of these are losses of upland plants invading the reservoir.

Given the level of variation described for these main communities, it will be difficult to detect differences in vegetation that can be attributed to the effect of the operating regime versus the effect of slope, aspect, elevation, climate, wind, source of propagules, incoming water from upslope, disturbance by cows, man and geese and other variables influencing the vegetation.

Evaluating the effect of treatments in this dynamic system is relatively easy; the treatments either survive or they die, but sorting out what killed them is difficult. It may not be fair to assume that the treatments will have a measureable effect on the pre-existing community. However, it is possible to see that the characteristics of the planted species have had an effect on vegetation in many areas.

It is premature to conclude that treatments have been successful. Success should be measured by evidence of long-term survival. The current age of the treatments in the reservoir varies from two years to six months. There is evidence that some of the *Carex* plugs have failed in locations where scouring has been severe and sands are present, but the final and complete treatment mapping still needs to be applied in the field[15]. It has been difficult to determine if individual lenticular sedge plants were planted or not, because they were not marked. Completed mapping will be required as a guide to assessments in the future.

The results of the assessment of benefits and costs of the treatment are based on a qualitative assessment, and not the actual monetary cost of the treatments. The largest benefit is the increase in vegetated areas, where no vegetation previously existed. The largest "cost" or disadvantage is the potential for cottonwood stakes to introduce disease to new areas of the reservoir.

[15] Complete treatment mapping was not available during the field work in May of 2009 although draft mapping was available in subsequent years. 2010 was not a treatment monitoring year. Therefore, there are only 14 known treated plots available for comparison in 2011. In 2011 it was noted that the treatment polygons did not match the field situation in many areas. This could have resulted in several false negative assessments of the efficacy of the treatments, so we decided to not wait until final detailed treatment mapping could be obtained, but to establish plots in control and treatment areas and collect data for future comparisons.

8.0 RECOMMENDATIONS

The CLBMON-33 and CLBMON-12 projects are similar and rely on the same database and field data collection system. The management questions for both projects are similar and could be blended without losing resolution.

The monitoring of change in vegetation in response to the operating regime versus other environmental conditions could be the focus of a combined project that uses the aerial photographic data and field survey data to directly address the two projects' objectives.

At the present time the projects are separate, but in reality all of the data from all years have been used to show change in vegetation over time. The value of considering the landscape level and site level changes in vegetation does not have to be lost; the two scales of resolution can complement each other. For example, the clarity of the aerial photographic coverage can be used to show losses and gains in individual plant communities. Aerial photographic interpretation is the most accurate way to characterize and interpret the effects of scouring and the importance of terrain texture.

Stratification of the vegetation data into geographic areas is required to make better sense of the response of the existing vegetation to the operating regime.

During the final reporting, the management and reporting aspects of the Arrow Lakes Reservoir vegetation treatment program could be compared to other treatment programs (Yetka and Galatowitch 1999, Warwick and Brock 2003). Specific recommendations could be made regarding the marking of treatments in the field, accurate mapping of treatments, coordination with monitoring and other aspects of vegetation enhancement programs.

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10.0 GLOSSARY

% cover see per cent cover

abundance, or species abundance: coded data collected in each plot for each species to indicate the number of individuals. The codes are as follows: 1 – 20 plants of a species = 1, 21 – 50 plants of a species = 2, 51 – 100 plants of a species = 3, >100 plants of a species = 4.

aerial photographs pictures of the ground taken from the air

annuals plants that complete their life cycles in one growing season

amphibious: a plant that floats and can move

annuals plants that complete their life cycles in one growing season

analysis of variance (ANOVA) a statistical method and associated procedures used to test hypotheses about differences between two or more means; the technique can partition the observable variance in a particular variable into components that are attributable to different sources of variation

anaerobic: the condition consisting of the lack of oxygen in a growth medium

anastamosed: a sinuous formation in young rivers, caused by multiple channels that divide and reconnect. Formed by braided water movement and results in lenticular shaped islands.

anoxia a condition in consolidated wet soils in which plant tissues are deprived of oxygen

annual: plants that germinate, grow, flower, and set seed in a 12 month period.

anthropogenic influence by man, usually in reference to disturbance to vegetation and soils.

aspect the direction of a slope gradient

autecological characteristics a set of characteristics that plants develop in response to their environment, including tolerance and requirements for a certain moisture and nutrient regimes.

biometrics the study of measurable biological characteristics

box-plots visually display the differences between groups of data by showing the dispersion and skewness of data without making any assumptions about their underlying statistical distributions.

central tendancy: clustering of measurement data around the mean or median value.

change detection detecting differences over time in vegetation characteristics including cover, height, vigour, distribution, and composition (species richness, abundance, diversity and evenness)

chlorosis: yellow pigmentation in plant tissue due loss of chlorophyll production in response to mineral nutritional disorders or disease.

climatic regime the conditions of the climate including temperature, humidity, rainfall, snowfall and wind in a given region over a long period of time

community see vegetation community

composition see vegetation composition

cover a measure of species or vegetation abundance in a plot or polygon vegetation community type estimated in the field; see also vegetation cover

cover value see vegetation cover value

database an organized collection of data for one or more uses, typically in digital form

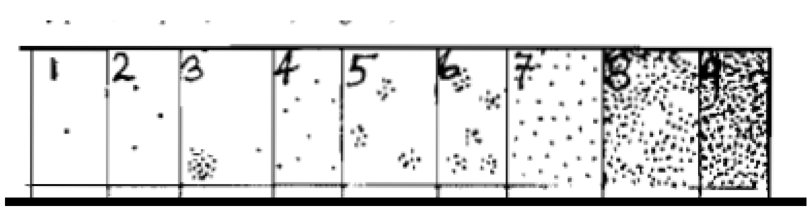
data cleaning also known as data cleansing; the act of detecting and correcting (or removing) incomplete, incorrect or inaccurate records from a record set, table, or database

data screening similar to data cleaning; the process of checking for completeness, validity and quality of input data

depauperate: a species-poor condition in a plant community.

diagnostic species: group of species used in community analysis to describe vegetation response to variation in the environment

distribution codes number codes used to represent dispersion patterns of individuals of plant species within a specified area: the distribution codes used in this study are from Luttmerding et al. 1998.



1.) single individual or small clump (< 1 per cent cover)
2.) very few individuals or small clumps (~ 1 per cent cover)
3.) one small patch occupying at least 1–5 per cent cover area

4.) scattered individuals, approximately 10 per cent cover
5.) three small patches occupying approximately 5–15 per cent cover
6.) approximately five patches or more, occupying from 15 to 40 per cent cover
7.) continuous, even distribution of individuals, variable cover
8.) continuous and dense distribution with some openings
9.) very dense uniform continuous distribution from 41 to 100 per cent cover

diversity the number of different classes (i.e., community types, genera, species) in a specified area; also see species diversity

dominance the extent to which a given species predominates in a community because of its size, abundance, frequency of occurrence or coverage. Dominants are often so frequently occurring that they do not align with or indicate any prevailing ecological gradient of interest.

drawdown zone the shoreline area along the Arrow Lakes Reservoir located between low and high water levels

dust bunny distribution: a data distribution characterized by many small amplitude measurements occurring at the right handed tail of a multidimensional space.

e-Flora an electronic atlas of the plants of British Columbia

epinasty: downward curvature or growth of a plant, due to differential growth of upper and lower surfaces, often in response to anoxic conditions

evenness see species evenness

extirpation: loss of a species from a geographic area, a local or regional extinction

fecund: prolific breeding capability in a plant; e.g. high seed production and usually some other means of dispersal besides seeding, such as fragmentation, or rhizomatous growth.

geographic information systems (GIS) a set of tools that captures, stores, analyzes, manages, and presents data that are linked to location(s); the systems digitally create and manipulate spatial areas

global positioning system: a radio navigation system that allows for determining exact locations

height see vegetation height

herbaceous: non-woody stems, often die back each year in the fall

homogeneous of the same or similar kind or nature

hygrotope the capacity of a soil to supply water for plant growth

hypotheses the plural of hypothesis

hypothesis a tentative statement that proposes an explanation for an observable phenomenon; the hypothesis can be tested by further investigation and statistical methods

incidental species the species that occur as a minor part of the vegetation composition in the study area

intrinsic an essential or inherent property of a system or thing

inundated flooded by standing or slow-moving water

inundation surface flooding by standing or slow-moving water

leading species the dominant species with the greatest abundance within a specified area

least square means the within-group means that are appropriately adjusted for the other effects in a statistical model; they estimate the marginal means for a balanced population (as opposed to the unbalanced design)

materials a soil or parent material substrate for plant growth.

median a numerical value that divides a sample, a population or a probability distribution in half when all data values are listed in order; it is the preferred measure of central tendency for a skewed distribution (in which the mean would be biased)

necrosis: brown pigmentation in plant tissue due death of tissue in response to mineral nutritional disorders or disease.

non-linearity refer to a situation or process when there is no simple proportional relation between cause and effect

normal distribution a probability distribution of a random variable which is bell-shaped, symmetrical, and single peaked and where the mean, median and mode coincide and lie at the centre of the distribution; a normal distribution is fully specified by two parameters - mean and the standard deviation

null hypothesis a type of hypothesis used in statistics that proposes that no statistical significance exists in a set of given observations; it is presumed to be true until statistical evidence nullifies it for an alternative hypothesis

orthorectification the process of correcting for errors and distortion in aerial photographic imagery; for accurate removal of image distortions, a digital elevation model and adequate GPS-derived ground control points are required

outliers observations that deviate markedly from other members of a sample in which they occur

***p*-value** in statistical significance testing, the *p*-value is the probability that the observed data or a more extreme outcome would have occurred by chance; the lower the p-value, the less likely the result is if the null hypothesis is true

parent material the underlying geological material (i.e., bedrock, glacial till, colluvium, lacustrine, fluvial deposits) in which soils develop

per cent cover the area of the foliage of a plant species projected onto the ground within a specifies area expressed as a percentage of the area

perched the location of a physiographic feature above its usual spatial distribution.

perennial: plants that germinate, grow, flower, and set seed over several years.

phenological differences the differences in the development of plants or animals related to the effects of climatic conditions on growth and life cycle stages

phenology the study of periodic plant and animal life cycle events such as flowering, breeding, and migration, in relation to climatic conditions

photogrammetic pertaining to photogrammetry which is the practice of determining the geometric properties of objects from photographic images

photo mosaics see aerial photographic mosaic

plant community see vegetation community

plant distribution codes number codes used to represent dispersion patterns of individuals of plant species within a specified area

plant species distribution the spatial arrangement or dispersion pattern of individuals of a plant species within a specified area

plant succession the replacement of one plant community by another; a site may often progress to a stable terminal community called the climax community

polygon a discrete, topographically defined unit in space and time, surrounded by a line delineating it from all other polygons; the two-dimensional shape delineated on a map or air photo can be modelled and stored within a digital database where its spatial position in the database is defined by the co-ordinates of its vertices

post-hoc comparisons comparing the results of an experiment or analysis after it has concluded for patterns that were not specified based on prior knowledge about a population

power see statistical power

power analysis a statistical method used to calculate the minimum sample size required to accept the outcome of a statistical test with a particular level of confidence

principal components analysis (PCA) a statistical method involving a mathematical procedure that transforms a number of possibly correlated variables into a smaller number of uncorrelated variables called principal components; the first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible; PCA aims at reducing a large set of variables to a small set that still contains most of the information in the large set

propagule portion of a plant including seeds or stem /leaf fragments or rhizomes that can give rise to a new plant, either genetically different or identical to the original individual plant.

random error errors in measurement that lead to measured values being inconsistent when repeated measures of a constant attribute or quantity are taken; the effect of random errors may be reduced by repetition of the measurements and averaging the results

rhizome: horizontal underground stem that can give rise to roots and new stems of a plant.

rill a narrow and shallow incision into soil or substrate layers resulting from erosion by surface runoff

riparian along the bank a river, lake or wetland

scouring the removal of soil and substrate materials by moving water and/or wave action

screening see data screening

seepage subsurface or surface groundwater discharge having less flow than a spring

Shannon index of diversity (H') a measure of species diversity that considers both the total number of species and their relative abundances (proportions) within a specified area

Shannon-Weaver diversity index (H') also known as the Shannon-Weiner diversity index; see Shannon index of diversity

shapefile a digital vector storage format for storing geometric data types (points, lines and polygons) and their associated attribute information in tables of records to specify what they represent

significance see statistical significance

skewness the degree of asymmetry about a central value of a distribution

slope see slope gradient

slope gradient the steepness of a slope

soft constraints operating regime the operating system used to allocate water of the Arrow Lakes Reservoir under competing demands where a set of soft constraints, that represent desirable conditions but not inviolable ones, are used to guide operational decisions each year to balance the objectives of different stakeholders including those concerned with recreation, fish, wildlife, vegetation, culture & heritage and erosion; the other stakeholders impose "soft" constraints on the use of water for generating hydro electricity and therefore on the operating system that manages reservoir water levels

soil/substrate texture relative proportions of the three particle sizes - sand, silt and clay in the fine fraction portion of a soil or substrate

sorting refers to the physical sifting of gravels into shapes by water movement

spatial extent the distribution of plant community cover at the polygon, site or landscape-level

species codes seven letter codes derived from the first four letters of the Genus and first three letters of the species (with exceptions where required) used to represent plant species names when collecting and analyzing vegetation data

species composition see vegetation composition

species diversity the number of different species and their relative abundances in a given area or habitat type; species diversity can be measured and quantified using an index of diversity

species evenness the degree of equitability in the distribution of individuals among a group of species; the relative abundances of species within a given area

species evenness index (J) a mathematical expression that provides a measure of species evenness or equability within a specified area

species richness the number of different species in a specified area

standing crop the total mass of vegetation within an area, expressed in kg / hectare.

statistical power the probability that a statistical test will produce a significant difference at a given significance level; the capacity of a statistical test to provide the smallest β error for the designed α error

statistical significance the statistical significance of a result is the probability that a difference (i.e., between means) in a sample occurred by pure chance and that no such difference exists in the population from which the sample was drawn

statistical significant difference in statistical testing, a difference between two test statistics is significant when the results show that the difference is too great to have occurred purely by chance (i.e., the results of the test are strong enough to prove that the null hypothesis needs to be rejected)

statistical variance the main measure of variability for a data set; variance is one of several descriptors of a population frequency distribution where it describes how far values lie from the mean

statistical variation the range of differences observed for a subject (variable) in a sample population

statistically significant see statistical significance

structure see vegetation structure

sub-hypotheses secondary hypotheses that are related to the main hypotheses of the experiment or study

substrate the surface layer of the ground where soils develop and that plants and animals may live upon; substrates can include both biotic and abiotic materials

succession see plant succession

taxonomic keys a tool used by biologists for identifying unknown organisms; keys are organized so that the user is presented with a series of choices about the characteristics of the unknown organisms; by making the correct choice at each step of the key, the user is ultimately led to the identity of a specimen

temporal of or relating to time

texture see soil/substrate texture

topo-edaphic pertaining to soil and topographic features that influence the distribution, composition and structure of plant species and communities

topography the surface shape of the land in terms of elevation, slope and orientation

Type I error: the rejection of a null hypothesis when it is true and should be accepted

undercutting: act of erosion causing removal of a subsurface soil layer

upland land lying above areas influenced by water bodies, flowing water, flooding and poor drainage

variance see statistical variance

vegetation community a group of interacting plants species inhabiting a given area; the components of each plant community are influenced by soil type, topography, climate, organisms, time and disturbance

vegetation community type the basic map unit in the reservoir drawdown zone based primarily on physiographic (terrain, soil/substrate) features and vegetation characteristics

vegetation composition includes the different plant species, their abundances and distributions within a vegetation community

vegetation cover the area of the foliage of vegetation or an individual plant species projected onto the ground within a specifies area

vegetation cover value the area of ground covered by vegetation or a plant species expressed as a percentage of the sampled area

vegetation height the height of a plant species or overall vegetation in a community type measured from the ground level to the top of the plants or canopy

vegetation structure the structure of a plant community is characterized primarily by the horizontal and vertical distributions of plant biomass, particularly foliage biomass

vigour: relative health and/or robustness of a plant species in the plot, based on the graded presentation of symptoms of deformity and or disease, poor color development, and/or necrotic tissue; using codes and estimated as follows;

dead = 1,
poor (stunting or other deformation, symptoms of disease, or chlorosis or necrosis present) = 2,
moderate (only minor chlorosis and isolated necrotic tissue present) = 3,
vigourous, completely non chlorotic, nor necrotic nor stunted = 4 (i.e., very vigourous).

wetland a site dominated by hydrophytic vegetation where soils are water-saturated for a sufficient length of time such that excess water and resulting low soil oxygen levels are principal determinants of vegetation and soil development

APPENDIX 1. HYPOTHESES AND SUB-HYPOTHESES (BC HYDRO 2008):

Existing vegetation

H_0: Changes within existing vegetation communities between elevation 434m and 440m in the drawdown zone of the Arrow Lakes Reservoir, if they occur over the monitoring period, are unrelated to the continued implementation of the soft constraints operating regime.

H_{0A}: Changes in the area occupied by specific species assemblages within existing vegetation communities, if they occur, are not related to the operating regime (timing, frequency, duration and depth of inundation).

H_{0B}: Changes in species diversity, distribution and vigour within existing vegetation communities, if they occur, are not related to the operating regime (timing, frequency, duration and depth of inundation).

H_{0C}: Changes in species productivity (cover, abundance and biomass) within existing vegetation communities, if they occur, are not related to the operating regime (timing, frequency, duration and depth of inundation).

Re-vegetated areas

H_{01}: Revegetation treatments within 434m to 436m, 436m to 438m, and 438m to 440m support continued natural re-colonization 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 to 436m, 436m to 438m, and 438m to 440m.

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

APPENDIX 2. VEGETATION SPECIES LIST FOR ALL YEARS

SPECIES	ScientificName	EnglishName
ABIELAS	Abies lasiocarpa	subalpine fir
ACER	Acer sp.	maple
ACERGLA	Acer glabrum	Douglas maple
ACHIMIL	Achillea millefolium	yarrow
ADENBIC	Adenocaulon bicolor	pathfinder
AGRISTR	Agrimonia striata	grooved agrimony
AGROCAP	Agrostis capillaris	colonial bentgrass
AGROGIG	Agrostis gigantea	redtop
AGROSCA	Agrostis scabra	hair bentgrass
AGROSTI	Agrostis sp.	bentgrass
AGROSTO	Agrostis stolonifera	creeping bentgrass
ALECSAR	Alectoria sarmentosa	common witch's hair
ALISGRA	Alisma gramineum	narrow-leaved water-plantain
ALNUINC	Alnus incana	mountain alder
ALNUS	Alnus sp.	alder
ALNUVIR	Alnus viridis	
ALOPAEQ	Alopecurus aequalis	little meadow-foxtail
ALOPGEN	Alopecurus geniculatus	water meadow-foxtail
AMARRET	Amaranthus retroflexus	rough pigweed
AMELALN	Amelanchier alnifolia	saskatoon
ANAPMAR	Anaphalis margaritacea	pearly everlasting
ANTENEG	Antennaria neglecta	field pussytoes
ANTENNA	Antennaria sp.	pussytoes
ANTERAC	Antennaria racemosa	racemose pussytoes
APERINT	Apera interrupta	interrupted apera
APOCAND	Apocynum androsaemifolium	spreading dogbane
ARALNUD	Aralia nudicaulis	wild sarsaparilla
ARCTMIN	Arctium minus	common burdock
ARCTUVA	Arctostaphylos uva-ursi	kinnikinnick
ARENARI	Arenaria sp.	sandwort
ARENSER	Arenaria serpyllifolia	thyme-leaved sandwort
ASARCAU	Asarum caudatum	wild ginger
ASPAOFF	Asparagus officinalis	garden asparagus
ASPLTRI	Asplenium trichomanes	maidenhair spleenwort
ASTER	Aster sp.	
ASTRMIS	Astragalus miser	timber milk-vetch
ATHYFIL	Athyrium filix-femina	lady fern
AULAPAL	Aulacomnium palustre	glow moss
BARBVER	Barbarea verna	early winter cress

BERTINC	Berteroa incana	hoary alyssum
BETUOCC	Betula occidentalis	water birch
BETUPAP	Betula papyrifera	paper birch
BORAGIN	Boraginaceae	
BORAGO	Borago sp.	
BOTRMUL	Botrychium multifidum	leathery grape fern
BRACALB	Brachythecium albicans	lawn moss
BRACHYT	Brachythecium sp.	ragged-moss
BRACRIV	Brachythecium rivulare	river ragged-moss
BRACSAL	Brachythecium salebrosum	golden ragged-moss
BRASCAM	Brassica campestris	field mustard
BRASHIR	Brassica hirta	white mustard
BROMCIL	Bromus ciliatus	fringed brome
BROMINE	Bromus inermis	smooth brome
BROMTEC	Bromus tectorum	cheatgrass
BROMUS	Bromus sp.	brome
BROMVUL	Bromus vulgaris	Columbia brome
BRYUM	Bryum sp.	thread-moss
CALACAN	Calamagrostis canadensis	bluejoint reedgrass
CALARUB	Calamagrostis rubescens	pinegrass
CALLGIG	Calliergon giganteum	giant water-moss
CALLPAU	Callitriche palustris	spring water-starwort
CALYMUE	Calypogeja muelleriana	
CAMPCAL	Campylium calcareum	
CAMPHIP	Campylophyllum hispidulum	
CARDNUT	Cardamine nuttallii	slender toothwort
CARDPEN	Cardamine pensylvanica	Pennsylvanian bitter-cress
CAREAPE	Carex aperta	Columbia sedge
CAREAQU	Carex aquatilis	water sedge
CAREATR	Carex athrostachya	slender-beaked sedge
CAREDIS	Carex disperma	soft-leaved sedge
CAREFOE	Carex foenea	bronze sedge
CARELEN	Carex lenticularis	lakeshore sedge
CAREMIO	Carex microptera	small-winged sedge
CAREOBT	Carex obtusata	blunt sedge
CAREPAC	Carex pachystachya	thick-headed sedge
CAREPRT	Carex praticola	meadow sedge
CAREROT	Carex rostrata	swollen beaked sedge
CARESIT	Carex sitchensis	Sitka sedge
CAREUTR	Carex utriculata	beaked sedge
CAREX	Carex sp.	sedge
CASTILL	Castilleja sp.	paintbrush
CASTMIN	Castilleja miniata	scarlet paintbrush
CASTOCC	Castilleja occidentalis	western paintbrush
CENTAUR	Centaurea sp.	

CENTBIE	Centaurea biebersteinii	spotted knapweed
CERAARV	Cerastium arvense	field chickweed
CERABEE	Cerastium beeringianum	Bering chickweed
CERAFON	Cerastium fontanum	mouse-ear chickweed
CERANUT	Cerastium nutans	nodding chickweed
CERAPUR	Ceratodon purpureus	fire-moss
CERASTI	Cerastium sp.	
CHENALB	Chenopodium album	lamb's-quarters
CHENOPO	Chenopodium sp.	
CHIMUMB	Chimaphila umbellata	prince's pine
CICHINT	Cichorium intybus	chicory
CINNLAT	Cinna latifolia	nodding wood-reed
CIRSARV	Cirsium arvense	Canada thistle
CIRSIUM	Cirsium sp.	thistle
CLADCHL	Cladonia chlorophaea	mealy pixie-cup
CLADCOR	Cladonia cornuta	
CLADFIM	Cladonia fimbriata	powdered trumpet
CLADFUR	Cladonia furcata	many-forked clad
CLADGRA	Cladonia gracilis	
CLADINA	Cladina sp.	reindeer lichens
CLADONI	Cladonia sp.	clad lichens
CLEMLIG	Clematis ligusticifolia	white clematis
CLIMACI	Climacium sp.	tree-moss
CLIMDEN	Climacium dendroides	tree-moss
CLINUNI	Clintonia uniflora	queen's cup
COLLINS	Collinsia sp.	
COLLLIN	Collomia linearis	narrow-leaved collomia
COLLPAR	Collinsia parviflora	small-flowered blue-eyed Mary
COMAPAU	Comarum palustre	marsh cinquefoil
CONYCAN	Conyza canadensis	
CORNCAN	Cornus canadensis	bunchberry
CORNSTO	Cornus stolonifera	red-osier dogwood
CORYCOR	Corylus cornuta	beaked hazelnut
CRATDOU	Crataegus douglasii	black hawthorn
CYSTFRA	Cystopteris fragilis	fragile fern
CYTISCO	Cytisus scoparius	Scotch broom
DACTGLO	Dactylis glomerata	orchard-grass
DANTHON	Danthonia sp.	oatgrass
DANTSPI	Danthonia spicata	poverty oatgrass
DAUCCAR	Daucus carota	wild carrot
DESCDAN	Deschampsia danthonioides	annual hairgrass
DESCHAM	Deschampsia sp.	hairgrass
DICRANW	Dicranoweisia sp.	thatch-moss
DICRPOL	Dicranum polysetum	wavy-leaved moss

DRABA	Draba sp.	
DREPADU	Drepanocladus aduncus	common hook-moss
DREPANO	Drepanocladus sp.	hook-moss
DRYAOCT	Dryas octopetala	white mountain-avens
ECHIVUL	Echium vulgare	viper's bugloss
ELEOACI	Eleocharis acicularis	needle spike-rush
ELEOCHA	Eleocharis sp.	
ELEOPAL	Eleocharis palustris	common spike-rush
ELEOPAR	Eleocharis parvula	small spike-rush
ELYMGLA	Elymus glaucus	blue wildrye
ELYMREP	Elymus repens	quackgrass
ELYMSIB	Elymus sibiricus	Siberian wildrye
ELYMUS	Elymus sp.	wildrye
EPILANG	Epilobium angustifolium	fireweed
EPILCIL	Epilobium ciliatum	purple-leaved willowherb
EPILGLA	Epilobium glaberrimum	smooth willowherb
EPILOBI	Epilobium sp.	willowherb
EQUIARV	Equisetum arvense	common horsetail
EQUIFLU	Equisetum fluviatile	swamp horsetail
EQUIHYE	Equisetum hyemale	scouring-rush
EQUILAE	Equisetum laevigatum	smooth scouring-rush
EQUIPAL	Equisetum palustre	marsh horsetail
EQUIPRA	Equisetum pratense	meadow horsetail
EQUISCI	Equisetum scirpoides	dwarf scouring-rush
EQUISET	Equisetum sp.	horsetail
EQUISYL	Equisetum sylvaticum	wood horsetail
EQUIVAR	Equisetum variegatum	northern scouring-rush
ERIGERO	Erigeron sp.	fleabane
ERIGPHI	Erigeron philadelphicus	Philadelphia fleabane
ERODCIC	Erodium cicutarium	common stork's-bill
EURHORE	Eurhynchium oreganum	Oregon beaked-moss
EURYCON	Eurybia conspicua	showy aster
FESTIDA	Festuca idahoensis	Idaho fescue
FESTRUB	Festuca rubra	red fescue
FESTSAX	Festuca saximontana	Rocky Mountain fescue
FESTUCA	Festuca sp.	fescue
FRAGVES	Fragaria vesca	wood strawberry
FRAGVIR	Fragaria virginiana	wild strawberry
FUNAHYG	Funaria hygrometrica	common cord-moss
GALETET	Galeopsis tetrahit	hemp-nettle
GALIBOR	Galium boreale	northern bedstraw
GALITRD	Galium trifidum	small bedstraw
GALITRF	Galium triflorum	sweet-scented bedstraw
GALIUM	Galium sp.	bedstraw
GAULOVA	Gaultheria ovatifolia	western tea-berry

GERANIU	Geranium sp.	geranium
GEUM	Geum sp.	
GEUMMAC	Geum macrophyllum	large-leaved avens
GLYCELA	Glyceria elata	tall mannagrass
GNAPULI	Gnaphalium uliginosum	marsh cudweed
GYMNDRY	Gymnocarpium dryopteris	oak fern
HACKELI	Hackelia sp.	
HERAMAX	Heracleum maximum	cow-parsnip
HIERACI	Hieracium sp.	hawkweed
HIERALI	Hieracium albiflorum	white hawkweed
HIERAUR	Hieracium aurantiacum	orange-red king devil
HIERCAE	Hieracium caespitosum	yellow king devil
HIERCYN	Hieracium cynoglossoides	hounds-tongue hawkweed
HIERGLO	Hieracium glomeratum	yellowdevil hawkweek
HIERHIR	Hierochloë hirta	common sweetgrass
HIERLAC	Hieracium lachenalii	European hawkweed
HIERMAC	Hieracium maculatum	mottled hawkweed
HIERPIO	Hieracium piloselloides	tall hawkweed
HIERPRE	Hieracium praealtum	king devil
HIERXFL	Hieracium x floribundum	kingdevil hawkweed
HOLCLAN	Holcus lanatus	common velvet-grass
HOMAAEN	Homalothecium aeneum	golden curl-moss
HOMALOH	Homalothecium sp.	curl-moss
HORDBRA	Hordeum brachyantherum	meadow barley
HYLOSPL	Hylocomium splendens	step moss
HYPEPER	Hypericum perforatum	common St. John's-wort
HYPERIC	Hypericum sp.	
HYPNLIN	Hypnum lindbergii	Lindberg's claw-moss
HYPOPHY	Hypogymnia physodes	monk's-hood
IRIS	Iris sp.	
JUNCARC	Juncus arcticus	arctic rush
JUNCART	Juncus articulatus	jointed rush
JUNCBAL	Juncus balticus	Baltic rush
JUNCBUF	Juncus bufonius	toad rush
JUNCCAN	Juncus canadensis	Canadian rush
JUNCENS	Juncus ensifolius	dagger-leaf rush
JUNCFIL	Juncus filiformis	thread rush
JUNCMER	Juncus mertensianus	Mertens' rush
JUNCPAR	Juncus parryi	Parry's rush
JUNCTEN	Juncus tenuis	slender rush
JUNCUS	Juncus sp.	rush
JUNICOM	Juniperus communis	common juniper
KOELMAC	Koeleria macrantha	junegrass
LACTTAT	Lactuca tatarica	blue lettuce
LARIOCC	Larix occidentalis	western larch

LATHOCH	Lathyrus ochroleucus	creamy peavine
LEMNTRI	Lemna trisulca	ivy-leaved duckweed
LEUCANT	Leucanthemum sp.	
LEUCVUL	Leucanthemum vulgare	oxeye daisy
LINAGEN	Linaria genistifolia	Dalmatian toadflax
LINNBOR	Linnaea borealis	twinflower
LOMADIS	Lomatium dissectum	fern-leaved desert-parsley
LONICIL	Lonicera ciliosa	western trumpet
LONIINV	Lonicera involucrata	black twinberry
LOPHINC	Lophozia incisa	ragged-leaf liverwort
LOPHOZI	Lophozia sp.	
LUPIARC	Lupinus arcticus	arctic lupine
LUPINUS	Lupinus sp.	lupine
LUPIPOY	Lupinus polyphyllus	large-leaved lupine
LUZULA	Luzula sp.	wood-rush
LUZUPAR	Luzula parviflora	small-flowered wood-rush
LYCOANN	Lycopodium annotinum	stiff club-moss
LYCODEN	Lycopodium dendroideum	ground-pine
LYSIAME	Lysichiton americanus	skunk cabbage
MAHOAQU	Mahonia aquifolium	tall Oregon-grape
MAIARAC	Maianthemum racemosum	false Solomon's-seal
MAIASTE	Maianthemum stellatum	star-flowered false Solomon's-seal
MALUS	Malus sp.	apple
MARCPOL	Marchantia polymorpha	green-tongue liverwort
MATRDIS	Matricaria discoidea	pineapple weed
MATRPER	Matricaria perforata	scentless mayweed
MEDILUP	Medicago lupulina	black medic
MEDISAT	Medicago sativa	alfalfa
MELALIN	Melampyrum lineare	cow-wheat
MELIOFF	Melilotus officinalis	yellow sweet-clover
MENTARV	Mentha arvensis	field mint
MENTHA	Mentha sp.	
MIMUGUT	Mimulus guttatus	yellow monkey-flower
MNIUM	Mnium sp.	leafy moss
MNIUSPN	Mnium spinulosum	red-mouthed leafy moss
MONTFON	Montia fontana	blinks
MONTLIN	Montia linearis	narrow-leaved montia
MYCEMUR	Mycelis muralis	wall lettuce
MYOSARV	Myosotis arvensis	field forget-me-not
MYOSASI	Myosotis asiatica	mountain forget-me-not
MYOSLAX	Myosotis laxa	small-flowered forget-me-not
MYOSOTI	Myosotis sp.	
MYOSSCO	Myosotis scorpioides	European forget-me-not
MYOSSYL	Myosotis sylvatica	wood forget-me-not

MYOSVER	Myosotis verna	spring forget-me-not
MYRISPI	Myriophyllum spicatum	Eurasian water-milfoil
NUPHLUT	Nuphar lutea	yellow pond-lily
OENOTHE	Oenothera sp.	
OPLOHOR	Oplopanax horridus	devil's club
ORTHSEC	Orthilia secunda	one-sided wintergreen
ORYZASP	Oryzopsis asperifolia	rough-leaved ricegrass
OSMOBER	Osmorhiza berteroi	mountain sweet-cicely
PANICUM	Panicum sp.	witchgrass
PARMSUL	Parmelia sulcata	waxpaper
PAXIMYR	Paxistima myrsinites	falsebox
PEDIRAC	Pedicularis racemosa	sickletop lousewort
PELTAPH	Peltigera aphthosa	freckle pelt
PELTBRI	Peltigera britannica	freckle pelt
PELTCAN	Peltigera canina	dog pelt
PELTIGE	Peltigera sp.	pelt lichens
PELTLEU	Peltigera leucophlebia	freckle plet
PELTMEM	Peltigera membranacea	greater dog pelt
PELTPOY	Peltigera polydactylon	frog pelt
PELTRUF	Peltigera rufescens	felt pelt
PERSAMP	Persicaria amphibia	water smartweed
PERSHYD	Persicaria hydropiper	marshpepper smartweed
PERSMAC	Persicaria maculata	lady's-thumb
PHACELI	Phacelia sp.	
PHACHAS	Phacelia hastata	silverleaf phacelia
PHACLIN	Phacelia linearis	thread-leaved phacelia
PHALARU	Phalaris arundinacea	reed canarygrass
PHLEPRA	Phleum pratense	common timothy
PICEENG	Picea engelmannii	Engelmann spruce
PICEGLA	Picea glauca	white spruce
PINUALB	Pinus albicaulis	whitebark pine
PINUCON	Pinus contorta	lodgepole pine
PINUMON	Pinus monticola	western white pine
PINUPON	Pinus ponderosa	ponderosa pine
PLAGSCO	Plagiobothrys scouleri	Scouler's popcornflower
PLAGUND	Plagiothecium undulatum	flat-moss
PLANLAN	Plantago lanceolata	ribwort plantain
PLANMAJ	Plantago major	common plantain
PLANTAG	Plantago sp.	
PLATGLA	Platismatia glauca	ragbag
PLATJUN	Platydictya jungermannioides	thread-like willow-moss
PLEUSCH	Pleurozium schreberi	red-stemmed feathermoss
POA	Poa sp.	bluegrass
POA ANN	Poa annua	annual bluegrass
POA COM	Poa compressa	Canada bluegrass

POA PAL	Poa palustris	fowl bluegrass
POA PRA	Poa pratensis	Kentucky bluegrass
POA SEC	Poa secunda	Sandberg's bluegrass
POACEAE	Poaceae	
POHLIA	Pohlia sp.	nodding-cap moss
POHLNUT	Pohlia nutans	nodding thread-moss
POHLWAH	Pohlia wahlenbergii	pale nodding-cap moss
POLYAVI	Polygonum aviculare	common knotweed
POLYCOM	Polytrichum commune	common haircap moss
POLYGON	Polygonum sp.	
POLYJUN	Polytrichum juniperinum	juniper haircap moss
POPUBAL2	Populus balsamifera ssp. trichocarpa	black cottonwood
POPUTRE	Populus tremuloides	trembling aspen
POTAMOG	Potamogeton sp.	pondweed
POTANAT	Potamogeton natans	floating-leaved pondweed
POTAPUS	Potamogeton pusillus	small pondweed
POTEANS	Potentilla anserina	common silverweed
POTEBIE	Potentilla biennis	biennial cinquefoil
POTEGRA	Potentilla gracilis	graceful cinquefoil
POTENOR	Potentilla norvegica	Norwegian cinquefoil
POTENTI	Potentilla sp.	
POTEREC	Potentilla recta	sulphur cinquefoil
PROSHOO	Prosartes hookeri	Hooker's fairybells
PROSTRA	Prosartes trachycarpa	rough-fruited fairybells
PRUNAVI	Prunus avium	sweet cherry
PRUNUS	Prunus sp.	cherry
PRUNVIR	Prunus virginiana	choke cherry
PRUNVUL	Prunella vulgaris	self-heal
PSEUMEN	Pseudotsuga menziesii	Douglas-fir
PSEUSPI	Pseudoroegneria spicata	bluebunch wheatgrass
PTERAQU	Pteridium aquilinum	bracken fern
PTILCRI	Ptilium crista-castrensis	knight's plume
PYROASA	Pyrola asarifolia	pink wintergreen
RACOACI	Racomitrium aciculare	black-tufted rock-moss
RACOCAN	Racomitrium canescens	grey rock-moss
RACOERI	Racomitrium ericoides	shaggy rock-moss
RACOMIT	Racomitrium sp.	rock-moss
RANUACR	Ranunculus acris	meadow buttercup
RANUFLM	Ranunculus flammula	creeping spearwort
RANUNCU	Ranunculus sp.	buttercup
RANUREP	Ranunculus repens	creeping buttercup
RANUSCE	Ranunculus sceleratus	celery-leaved buttercup
RANUUNC	Ranunculus uncinatus	little buttercup
RHAMPUR	Rhamnus purshiana	cascara

RHINMIN	Rhinanthus minor	yellow rattle
RHYTROB	Rhytidiopsis robusta	pipecleaner moss
RHYTTRI	Rhytidiadelphus triquetrus	electrified cat's-tail moss
RIBELAC	Ribes lacustre	black gooseberry
RIBES	Ribes sp.	currant or gooseberry
ROBIPSE	Robinia pseudoacacia	black locust
RORICUV	Rorippa curvisiliqua	western yellow cress
RORIPAL	Rorippa palustris	marsh yellow cress
RORIPPA	Rorippa sp.	
ROSA	Rosa sp.	rose
ROSAACI	Rosa acicularis	prickly rose
ROSAGYM	Rosa gymnocarpa	baldhip rose
ROSANUT	Rosa nutkana	Nootka rose
ROSAWOO	Rosa woodsii	prairie rose
RUBUIDA	Rubus idaeus	red raspberry
RUBUPAR	Rubus parviflorus	thimbleberry
RUBUPED	Rubus pedatus	five-leaved bramble
RUBUPUB	Rubus pubescens	dwarf red raspberry
RUMEACO	Rumex acetosa	green sorrel
RUMEACT	Rumex acetosella	sheep sorrel
RUMECRI	Rumex crispus	curled dock
RUMEOBT	Rumex obtusifolius	bitter dock
RUMESAN	Rumex sanguineus	red-veined dock
RUMEX	Rumex sp.	
SAGIPRO	Sagina procumbens	bird's-eye pearlwort
SALIBEB	Salix bebbiana	Bebb's willow
SALIDIS	Salix discolor	pussy willow
SALIGLA	Salix glauca	grey-leaved willow
SALILUC	Salix lucida	
SALILUC2	Salix lucida ssp. lasiandra	Pacific willow
SALIMEL	Salix melanopsis	dusky willow
SALIPLA	Salix planifolia	plane-leaved willow
SALIPRO	Salix prolixa	Mackenzie willow
SALISCO	Salix scouleriana	Scouler's willow
SALISIT	Salix sitchensis	Sitka willow
SALIX	Salix sp.	willow
SAMBCER	Sambucus cerulea	blue elderberry
SAMBRAC	Sambucus racemosa	
SANIMAR	Sanicula marilandica	black sanicle
SAXIFRA	Saxifraga sp.	saxifrage
SCHEARU	Schedonorus arundinaceus	tall fescue
SCIRCYP	Scirpus cyperinus	woolgrass
SCIRMIC	Scirpus microcarpus	small-flowered bulrush
SCLEANN	Scleranthus annuus	annual knawel
SENECIO	Senecio sp.	

SENEIND	Senecio indecorus	rayless mountain butterweed
SENEPAP	Senecio pauperculus	Canadian butterweed
SENEVUL	Senecio vulgaris	common groundsel
SHEPCAN	Shepherdia canadensis	soopolallie
SISYALT	Sisymbrium altissimum	tall tumble-mustard
SISYLOE	Sisymbrium loeselii	Loesel's tumble-mustard
SOLICAN	Solidago canadensis	Canada goldenrod
SOLIDAG	Solidago sp.	
SORBSCO	Sorbus scopulina	western mountain-ash
SORBSIT	Sorbus sitchensis	Sitka mountain-ash
SPERRUB	Spergularia rubra	red sand-spurry
SPIRBET	Spiraea betulifolia	birch-leaved spirea
SPIRDOU	Spiraea douglasii	hardhack
SPIRPYR	Spiraea pyramidata	pyramid spirea
SPORCRY	Sporobolus cryptandrus	sand dropseed
STELLAR	Stellaria sp.	starwort
STELMED	Stellaria media	common chickweed
STREAMP	Streptopus amplexifolius	clasping twistedstalk
STRESTR	Streptopus streptopoides	small twistedstalk
SYMPALB	Symphoricarpos albus	common snowberry
SYMPCII	Symphyotrichum ciliolatum	Lindley's aster
SYMPSPA	Symphyotrichum spathulatum	western mountain aster
SYMPSUB	Symphyotrichum subspicatum	Douglas' aster
TANAVUL	Tanacetum vulgare	common tansy
TARAOFF	Taraxacum officinale	common dandelion
TARAXAC	Taraxacum sp.	
TAXUBRE	Taxus brevifolia	western yew
THALOCC	Thalictrum occidentale	western meadowrue
THUJPLI	Thuja plicata	western redcedar
TIARTRI	Tiarella trifoliata	three-leaved foamflower
TIARTRI2	Tiarella trifoliata var. unifoliata	one-leaved foamflower
TOFICOC	Tofieldia coccinea	northern false asphodel
TOMENIT	Tomentypnum nitens	golden fuzzy fen moss
TORTULA	Tortula sp.	screw-moss
TOXIRYD	Toxicodendron rydbergii	poison ivy
TRAGDUB	Tragopogon dubius	yellow salsify
TRIAGLU	Triantha glutinosa	sticky false asphodel
TRIFARV	Trifolium arvense	hare's-foot clover
TRIFAUR	Trifolium aureum	yellow clover
TRIFDUB	Trifolium dubium	small hop-clover
TRIFHYB	Trifolium hybridum	alsike clover
TRIFOLI	Trifolium sp.	clover
TRIFPRA	Trifolium pratense	red clover
TRIFREP	Trifolium repens	white clover

TRIFVAR	Trifolium variegatum	white-tipped clover
TSUGHET	Tsuga heterophylla	western hemlock
UNKNOWN	Unknown sp.	
VACCMEM	Vaccinium membranaceum	black huckleberry
VAHLATR	Vahlodea atropurpurea	mountain hairgrass
VERBTHA	Verbascum thapsus	great mullein
VEROBEC1	Veronica beccabunga ssp. americana	American speedwell
VERONIC	Veronica sp.	speedwell
VEROOFF	Veronica officinalis	common speedwell
VEROPER	Veronica peregrina	purslane speedwell
VEROSER	Veronica serpyllifolia	thyme-leaved speedwell
VICIA	Vicia sp.	
VICIAME	Vicia americana	American vetch
VICICRA	Vicia cracca	tufted vetch
VICIHIR	Vicia hirsuta	tiny vetch
VICISAT	Vicia sativa	common vetch
VIOLA	Viola sp.	violet
VIOLCAN	Viola canadensis	Canada violet
VIOLREN	Viola renifolia	kidney-leaved violet

Mosses

Pohlia sp.
Racomitrium canescens

Brachythecium albicans
Bryum sp.
Pohlia wahlenbergii
Ceratodon purpureus

Racomitrium canescens

Calliergon giganteum
Bryum sp.

Funaria hygrometrica
Hypnum lindbergii
Climacium dendroides

Drepanocladus aduncus
Bryum sp.
Drepanocladus sp. (may be fluitans)

Calliergon giganteum
Campylium hispidulum but small amounts of Drepanocladus aduncus and Brachythecium sp.
Bryum sp.
Brachythecium albicans (with Drepanocladus aduncus)

APPENDIX 3. AUTECOLOGY OF THE COMMON PLANTS OF THE ARROW LAKES RESERVOIR

Species	Characteristics	References
Agrostis gigantea	Introduced form Europe. Perennial, tufted rhizomatous grass found on dry to mesic disturbed areas, roadsides, fields. Good at stabilizing eroding sites. Spreads by seed and rhizomes.	USDA 2011q Douglas, Meidinger and Pojar 1998-2002
Agrostis scabra	Perennial, native grass species found throughout BC. Blooms in spring and spreads by seed. Found in moist to dry meadows, rock outcrops, forest openings and clearings.	Douglas, Meidinger and Pojar 1998-2002
Agrostis stolonifera	Perennial creeping grass species introduced to BC from Europe. Found in mesic to wet conditions in field, ditches and lakesides. Bloom in mid-spring.	Douglas, Meidinger and Pojar 1998-2002
Alisma gramineum	Native perennial species found in aquatic habitats. Blooms in mid-spring. Not common in BC.	Douglas, Meidinger and Pojar 1998-2002
Alopecurus aequalis	Native, perennial grass found on disturbed sites. Favouring medium to fine textured soils on wet to mesic sites, streams, sloughs, clearings, ditches. Blooms in spring and spreads by seed.	USDA 2011u Douglas, Meidinger and Pojar 1998-2002
Alopecurus geniculatus	Non-native perennial grass found in mesic to wet openings and shores, meadows, ditches and roadsides, introduced from Eurasia. Blooming in summer. Reproduces by seed and root sprigs.	Douglas, Meidinger and Pojar 1998-2002
Apera interrupta	Annual grass species introduced from Europe. Found in dry waste areas.	Douglas, Meidinger and Pojar 1998-2002
Arenaria serpyllifolia	Introduced from Eurasia. Annual herb found in dry, disturbed areas. Common southern BC.	Douglas, Meidinger and Pojar 1998-2002
Bromus tectorum	Fast growing, annual grass species introduced from Eurasia. Considered invasive in BC. Grows quickly in spring by taking advantage of early moisture. Can germinate in autumn or spring; is a prolific seed producer. Found in dry to mesic roadsides and disturbed areas as well as meadows, grasslands, and shrub lands.	BC MoA 2002a Douglas, Meidinger and Pojar 1998-2002
Calamagrostis canadensis	Grows to nearly two meters in height, long lived perennial grass species. Spreads by seed and rhizomes. Found in moist clearings	USDA 2011e

	and disturbed areas and along ponds, streams, bogs, marshes, meadows, clearings and open forests. Tolerates only seasonal flooding. Common throughout BC.	Douglas, Meidinger and Pojar 1998-2002
Cardamine pensylvanica	Native annual or biennial herb blooming in spring. Spreads by seeds only. Common in disturbed areas including ditches, clearings and stream sides.	Douglas, Meidinger and Pojar 1998-2002
Carex aquatilis	Perennial native sedge with creeping rhizomes. Sod–forming. Common in wet areas throughout BC. Blooms in summer.	USDA 2011y Douglas, Meidinger and Pojar 1998-2002
Carex aperta	Native, perennial sedge, occurring in clumps. Spreading both by seed and by rhizomes. Common in wet areas along lakes, streams and meadows in medium and fine textured soils.	USDA 2011g Douglas, Meidinger and Pojar 1998-2002
Carex foenea	Perennial sedge of unknown origin. Common in BC in disturbed areas and forest openings.	Douglas, Meidinger and Pojar 1998-2002
Carex lenticularis	A native, perennial species that inhabits sandy beaches, marshes and wet meadows. Found in coarse and medium textures soils. Growing in a bunch. Rhizomatous.	Douglas, Meidinger and Pojar 1998-2002
Carex microptera	Perennial native sedge. Bloom in late spring. Found along lakes, swamps, bogs and moist forests and meadows.	Douglas, Meidinger and Pojar 1998-2002
Carex pachystachya	Native perennial sedge, blooms in late spring. Frequent in mesic to wet sites in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Carex praticola	Native perennial herb found throughout BC. Blooms in spring to summer. Occurs along water bodies and in moist to wet clearings.	Douglas, Meidinger and Pojar 1998-2002
Carex utriculata	Perennial native sedge with short rhizomes. Found throughout BC in riparian areas and wet meadows. Spreads by rhizomes and seeds.	Douglas, Meidinger and Pojar 1998-2002
Carex sitchensis	Native perennial sedge found throughout southern BC in wet open areas. Common in nutrient rich sites where the water table is high or above ground. Flood tolerant, shade intolerant. Rhizomatous.	Douglas, Meidinger and Pojar 1998-2002

Castilleja miniata	Native perennial species common in southern BC. Rhizomatous. Found in wet to dry open areas.	Douglas, Meidinger and Pojar 1998-2002
Cerastium fontanum	Annual or perennial species introduced from Eurasia. Found in disturbed areas. Spreads by seed and horizontal stems.	Agriculture and Agri-Food Canada 2011
Cerastium nutans	Native annual herb found in moist to wet disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Chenopodium album	Non-native annual herb. Considering invasive in BC. Generally found in mesic to dry well drained sands or gravels in disturbed areas. A prolific seed producer. Spreads by see only.	BC MoA 2002e
Collinsia parviflora	Annual native herb. Common in southern BC on sites with spring moisture and summer drought.	Douglas, Meidinger and Pojar 1998-2002
Conyza canadensis	Annual introduced herb found in disturbed areas in all soil textures.	Douglas, Meidinger and Pojar 1998-2002
Cornus stolonifera	Native perennial shrub growing up to six meters in height. Spreading by layering and seed dispersal. Found along lakes and stream and in moist forests.	Douglas, Meidinger and Pojar 1998-2002
Crataegus douglasii	Native shrub up to seven meters in height. Found in moist to mesic conditions, in openings, along creeks, lakes and gullies. Reproduces by seed and suckers after disturbance. Blooms in mid-spring.	USDA 2011d
Dactylis glomerata	Introduced from Eurasia. Perennial grass species found in disturbed areas on a variety of soil textures. Highly drought tolerant. Considered invasive. Blooms in mid-spring and spreads by seed.	USDA 2011n Douglas, Meidinger and Pojar 1998-2002
Danthonia spicata	Native perennial species common throughout BC. Found in dry soil conditions in meadows and open forests.	Douglas, Meidinger and Pojar 1998-2002
Deschampsia danthonioides	Annual tufted grass, native to BC. Inhabits vernal pools and roadsides. Common in fine and medium textured soils or saturated coarse textures.	USDA 2011a Douglas, Meidinger and Pojar 1998-2002
Equisetum fluviatile	Perennial native herb common throughout BC. Found along lakes and wet areas. Spreads vegetatively.	Douglas, Meidinger and Pojar 1998-2002

Erigeron philadelphicus	Native biennial or perennial species. Blooms in mid-spring. Found in openings throughout southern BC.	Douglas, Meidinger and Pojar 1998-2002
Eleocharis acicularis	Native perennial species found in wet areas. Can form dense groups. Spreads by seed and rhizomes. Blooms in mid-summer.	Douglas, Meidinger and Pojar 1998-2002
Elymus repens	An introduced, perennial species found on mesic to dry disturbed sites. Found to invade eroding sites quickly and may be alleopathic. Blooms throughout spring and summer. Spreads by seeds and vegetatively by roots; rhizomatous.	BC MoA 2002i Douglas, Meidinger and Pojar 1998-2002
Equisetum arvense	A native, perennial species found on in a variety of soil conditions generally associated with disturbed sites. Blooms in spring and spreads by spores, root tubers and rhizomes. Found throughout BC.	USDA 2011h
Equisetum hyemale	Native perennial species. Spreads by spores and rhizomes. Found along riverbanks, in moist clearings and forests.	Douglas, Meidinger and Pojar 1998-2002
Equisetum laevigatum	Perennial species found in dry to moist coarse soils along lakes and riverbanks. Blooms in early spring; spreads by spores and rhizomes.	Douglas, Meidinger and Pojar 1998-2002
Equisetum scirpoides	Native perennial rhizomatous species found throughout BC. Inhabits dry to wet conditions including fens, bogs, forests and swamps.	Douglas, Meidinger and Pojar 1998-2002
Equisetum variegatum	Native perennial species found along water bodies and openings. Spreads by spores	Douglas, Meidinger and Pojar 1998-2002
Equisetum palustre	Native, perennial species, spreading by rhizome. Found in wet areas and moist forests.	Douglas, Meidinger and Pojar 1998-2002
Erodium cicutarium	Non-native annual species. Found in mesic to dry disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Festuca idahoensis	Native perennial grass species. Found in disturbed areas. Has a deep root system and is drought tolerant.	USDA 2011i Douglas, Meidinger and Pojar 1998-2002
Festuca rubra	Native perennial grass species; rhizomatous and sod-forming. Common on moist to wet beaches, along streams and in dry disturbed areas. Somewhat drought tolerant.	Douglas, Meidinger and Pojar 1998-2002

Fragaria vesca	Native perennial species with rhizomes. Found in disturbed areas. Common on dry to moist sites. Spreads by seed, rhizome and runners.	Douglas, Meidinger and Pojar 1998-2002
Fragaria virginiana	Perennial, native herb spreading by runners. Common throughout BC. Found in mesic to dry open areas.	Douglas, Meidinger and Pojar 1998-2002
Galeopsis tetrahit	Annual species introduced from Eurasia. Found in mesic to wet open places. Common in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Galium trifidum	Native perennial creeping herb found throughout BC.	Douglas, Meidinger and Pojar 1998-2002
Gnaphalium palustre	Annual species found in moist vernal pools. Native to BC.	Douglas, Meidinger and Pojar 1998-2002
Hypericum perforatum	Perennial forb introduced from Eurasia. Found in coarse textured soils in disturbed areas. Spreads by seed and lateral root shoots. Prolific seed producer. Has a deep root system which enables plants to access water throughout dry periods.	BC MoA 2002g
Hieracium caespitosum	Perennial herb of European origin; considered invasive in BC. Spreads by seed, rhizomes and stolons. Found in mesic to dry disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Hierochloe hirta	Perennial grass with creeping rhizomes that spread vigourously. Common in moist meadows and forest openings. Not drought tolerant.	USDA 2011m Douglas, Meidinger and Pojar 1998-2002
Hordeum brachyantherum	Perennial, fast growing grass species native to BC. Found in all soil textures in moist soils and riparian areas. Tolerant of seasonal flooding.	USDA 2011l Douglas, Meidinger and Pojar 1998-2002
Juncus articulatus	Perennial native herb found along lakes and streams or in disturbed areas. Spreads by rhizomes, root shoots and seed. Blooms in early summer. Common in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Juncus arcticus	Perennial native herb with rhizomes. Wetland plant.	Douglas, Meidinger and Pojar 1998-2002
Juncus bufonius	Native annual herb. Common in wet open sites and disturbed	Douglas, Meidinger and Pojar

	areas of all soil textures. Blooms in spring and spreads by seeds.	1998-2002
Juncus tenuis	Perennial herb, native to BC. Found in dry to moist disturbed areas.	USAD 2011o
Juncus filiformis	Perennial herb with rhizomes. Occurring in wet to moist areas and associated with disturbance.	Douglas, Meidinger and Pojar 1998-2002
Leucanthemum vulgare	Perennial herb introduced from Europe. Prolific seed producer; also spreads vegetatively by root. Rhizomatous. Found throughout BC in disturbed areas and on nutrient-poor sites.	AIPC 2011b Douglas, Meidinger and Pojar 1998-2002
Matricaria discoidea	Annual herb introduced from elsewhere in North America. Blooms in early summer through to fall. Common all over BC in dry disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Medicago lupulina	Annual or perennial introduced species. Found in mesic to dry disturbed areas. Blooms in summer and spreads by seeds.	Douglas, Meidinger and Pojar 1998-2002
Mimulus guttatus	Native annual or perennial (from stolons). Found in open moist areas in all soil types.	Douglas, Meidinger and Pojar 1998-2002
Montia fontana	Native annual species. Found in wet meadows and shallow water.	Douglas, Meidinger and Pojar 1998-2002
Montia linearis	Native, annual species found in dry to wet openings. Common in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Myosotis arvensis	Biennial or perennial herb introduced from Europe. Common in SW BC in disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Myosotis laxa	Annual or short-lived perennial species. Found in moist to wet conditions in disturbed areas and along ponds and swamps.	Douglas, Meidinger and Pojar 1998-2002
Myosotis sylvatica	European perennial herb. Spreads by rhizomes and seeds. Occurs in disturbed mesic areas. Frequent in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Oryzopsis asperifolia	Native perennial species found in mesic to dry forests and openings. Spreads by seed.	Douglas, Meidinger and Pojar 1998-2002
Phacelia hastata	Native perennial herb with rhizomes. Found in dry forest openings and meadows.	Douglas, Meidinger and Pojar 1998-2002
Persicaria maculosa	Non-native annual herb found in dry disturbed areas. Spreads by seed.	Douglas, Meidinger and Pojar 1998-2002

Persicaria amphibia	Native perennial herb with rhizome or stolon. Occurs in shallow water, ditches and roadsides.	Douglas, Meidinger and Pojar 1998-2002
Persicaria hydropiper	Introduced from Eurasia. Annual and sometimes perennial herb. Found in moist ditches and disturbed areas in all soil textures. Reproduces by seed.	Douglas, Meidinger and Pojar 1998-2002
Phalaris arudinacea	A native species found to hybridize with an introduced species from Asia and Europe. Found in poorly drained soils, wetlands and ditches. Emerges early in spring. Perennial, rhizomatous and sod-forming. This species often forms expansive monocultures and shades out its competitors due to its height. It is flood and frost tolerant and moderately drought tolerant.	USDA 2011r Stannard and Crowder 2001 Douglas, Meidinger and Pojar 1998-2002
Phleum pratense	Perennial species introduced from Eurasia. Found in moist to wet disturbed areas. Common on fine to medium textured soils. Can tolerate only short periods of flooding; drought intolerant.	USDA 2011v Douglas, Meidinger and Pojar 1998-2002
Plagiobothrys scouleri	Native annual species. Found in moist open areas. (Dispersal is apparently by seed but the pubescent leaves when dried may stick to substrates.)	Douglas, Meidinger and Pojar 1998-2002
Plantago major	Introduced from Eurasia. Perennial species. Reproduces by seed. Blooms in late spring. Common in south west BC.	Douglas, Meidinger and Pojar 1998-2002
Poa annua	Introduced from Eurasia. Found in dry to moist disturbed areas. Blooms in spring and spreads by seed.	Douglas, Meidinger and Pojar 1998-2002
Poa compressa	A naturalized grass species introduced from Eurasia. Perennial; with both fibrous and rhizomatous roots. Blooms in spring. Found in a variety of soil textures. Has moderate moisture needs and is somewhat drought tolerant.	USDA 2011f Douglas, Meidinger and Pojar 1998-2002
Poa palustris	Native perennial species found in moist disturbed areas and in riparian ecosystems. Blooming in mid-spring; reproduces by seed.	Douglas, Meidinger and Pojar 1998-2002
Poa pratensis	Introduced from Europe; perennial, sod-forming grass. Stabilizes eroding banks. Spreading by rhizomes and seed. Found in moist to dry disturbed areas and forest openings.	USDA 2011j Douglas, Meidinger and Pojar 1998-2002

Polygonum aviculare	Annual herb; introduced from Eurasia. Found in moist to dry disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Populus balsamifera subsp. trichocarpa	Native, deciduous tree found in moist areas and on floodplains. Produces abundant seeds in spring; also sprouts from root suckers, stumps and branches. Seeds establish in recently disturbed areas, especially alluvium. Highly flood tolerant but not drought tolerant.	USDA 2011c
Potentilla norvegica	Native annual or biennial species. Found in moist to wet clearings or areas with disturbed soils.	Douglas, Meidinger and Pojar 1998-2002
Potentilla recta	Perennial forb introduced from Eurasia. Considering invasive in BC. Reproduces by seed and vegetatively by roots. Flowers in June to July. Is highly competitive and occurs on a variety of soil types in both disturbed and undisturbed areas.	BC MoA 2002h
Prunella vulgaris	Introduced from Eurasia. Perennial herb found in all soil textures in disturbed areas; mesic to dry soil moisture conditions.	Douglas, Meidinger and Pojar 1998-2002
Ranunculus acris	Perennial introduced herb, sometimes with rhizomes. Spreads by seed. Found on moist sites in disturbed areas and forest clearings.	AIPC 2011b
Ranunculus repens	Perennial introduced species. Considering invasive in BC. Found in wet disturbed areas and forest openings. Is a competitive species that has been found to deplete the soil of nutrients. Flood tolerant. Not drought tolerant.	BC MoA 2002c
Rhinanthus minor	Native annual species. Found to be hemi-parasitic on grass species.	Douglas, Meidinger and Pojar 1998-2002
Rorippa curvisiliqua	Native annual or biennial species. Blooming throughout the summer. Common in southern BC in moist open areas and waste lands.	Douglas, Meidinger and Pojar 1998-2002
Ranunculus sceleratus	Annual herb that reproduces by seed. Found in moist areas; amphibious. Common in all soil types.	Douglas, Meidinger and Pojar 1998-2002

Rorippa palustris	Native annual, biannual or perennial herb found in wet areas. Common throughout BC.	Douglas, Meidinger and Pojar 1998-2002
Rubus idaeus	Perennial native shrub with biennial stems. Common throughout BC. Found in clearings and open forests.	Douglas, Meidinger and Pojar 1998-2002
Rumex acetosa	Perennial herb introduced from Eurasia. Found in moist to mesic disturbed areas and openings.	Douglas, Meidinger and Pojar 1998-2002
Rumex acetosella	Introduced from Eurasia. A common invasive plant in disturbed areas. Spreads quickly by creeping rhizomes that produce buds. Also reproduces by seed. Can form dense colonies. Frequent in southern BC.	BC MoA 2002f
Rumex crispus	Perennial plant introduced from Eurasia; growing up to 1.5 m in height. Considering invasive in BC. Prolific seed producer but also reproduces by root fragments. Invades disturbed areas with moist to wet soil conditions. Can tolerate poor drainage.	BC MoA 2002d Douglas, Meidinger and Pojar 1998-2002
Sagina procumbens	Biennial or perennial herb found in moist to wet openings and along ponds. Frequent in southwestern BC.	Douglas, Meidinger and Pojar 1998-2002
Salix lucida	Native deciduous shrub growing up to 11 m in height. Found in clearings, along riverbanks and on floodplains. Reproduces by seeds and cuttings.	USDA 2011t
Salix prolixa	Native deciduous shrub growing up to 5 m in height. Found along stream banks in gravel and sand bars but occurring on a variety of soil types.	USDA 2011k
Salix scouleriana	Native perennial shrub common in BC. Found growing a variety of soil types. Common in seepage areas but also on drier sites. Spreads by seed. Dense thickets of this species may prevent other shade-intolerant species from establishing.	Douglas, Meidinger and Pojar 1998-2002
Spergularia rubra	Annual or short lived perennial herb, introduced to BC. Found in disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Scirpus cyperinus	Tall perennial species, introduced from other parts of North America. Found in open, wet areas; tolerates some flooding.	USDA 2011x
Spiraea douglasii	Perennial native shrub up to 2.5m high. Common throughout BC. Found in open moist forests and disturbed water receiving sites. Tolerates flooding. Reproduces by seed, cuttings and root	USDA 2011r

	segments.	
Stellaria media	Annual herb introduced from Eurasia. Prolific seed producers with seeds that can remain viable in the soil for up to 60 years. Spreads by seed and roots at nodes of stems; rhizomatous. Common in disturbed and cultivated areas. Plants are fast growing and seedlings germinate in both spring and fall.	BC MoA 2002b Douglas, Meidinger and Pojar 1998-2002
Salix bebbiana	Native shrub growing up to 10 meters in height. Found in moist conditions of all soil textures. Fast growing but short-lived. Drought tolerant. Spreading by seed, root and stem fragments.	USDA 2011b Douglas, Meidinger and Pojar 1998-2002
Salix melanopsis	Native perennial shrub growing up to four meters in height. Uncommon in BC. Found along floodplains of streams in coarse textured soils. Forms clusters by root shoots.	Douglas, Meidinger and Pojar 1998-2002
Scleranthus annuus	Annual herb species introduced from Eurasia. Not common in BC. Found in dry, disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Symphyotrichum spathulatum	Perennial herb spreading by rhizomes. Inhabits mesic open areas. Common in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Taraxacum officinale	Perennial herb of European origin. Found in a variety of soil textures in mesic to dry disturbed areas. Spreads by seed. Common in southern BC	Douglas, Meidinger and Pojar 1998-2002
Trifolium arvense	Annual species introduced from Europe. Found in disturbed areas ranging from mesic to dry soil conditions.	Douglas, Meidinger and Pojar 1998-2002
Trifolium aureum	Annual species introduced from Eurasia. Found in disturbed areas. Spreads by seed. Common in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Trifolium hybridum	Perennial species introduced from Eurasia. Found in disturbed areas. Blooms in late spring and spreads by seed. Common in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Trifolium repens	Perennial herb introduced to BC. Spreads by seed and rooting by nodes. Found in meadows, roadsides and disturbed areas. Grows well in fine and medium textured soils but also in coarse textures where water table is high.	USDA 2011w Douglas, Meidinger and Pojar 1998-2002
Vicia cracca	Perennial herb introduced from Eurasia. Associated with disturbance. Common in southern BC. Rhizomatous and trailing.	Douglas, Meidinger and Pojar 1998-2002

Veronica officinalis	Perennial herb introduced from Eurasia. Creeping plant that roots at nodes. Found in open areas. Not common in southern BC.	Douglas, Meidinger and Pojar 1998-2002
Veronica peregrine	Native, annual herb found in moist to wet disturbed areas.	Douglas, Meidinger and Pojar 1998-2002
Veronica serpyllifolia	Introduced perennial species. Spreads by rhizomes and seeds. Found in mesic to wet open or disturbed areas. Common throughout BC.	Douglas, Meidinger and Pojar 1998-2002

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APPENDIX 4. CHANGES IN SPECIES PRESENCE /ABSENCE OVER TIME, IN RELATION TO ELEVATION

Trees and shrubs (seedlings and juveniles) present in 2008 but not in 2009

water birch 436 m
twinflower 439 m
choke cherry 437 – 440 m
Douglas maple 437 m
Black cottonwood 435 – 440 m
trembling aspen 440 m
western yew 439 m

Herbs present in 2008 but not in 2009

field pussytoes; 434 m
sandwort 438 m
western paintbrush438 m
Willowherb 438 m
Fleabane 436 – 439 m
common stork's-bill 431 – 437 m
sweet-scented bedstraw 438-440 m
bedstraw 438-440 m
geranium 439 m
cow-parsnip 439 m
fern-leaved desert-parsley 436 – 437 m
wall lettuce 437 – 439 m
mountain forget-me-not 434-439 m
small-flowered forget-me-not 434-439 m
spring forget-me-not 434-439 m
sickletop lousewort 438 m
common silverweed 438 m
creeping spearwort 438 m
buttercup 436- 438 m
little buttercup 436- 438 m
saxifrage 437 m
common groundsel 436- 438 m
small twistedstalk 439 m
western meadowrue 440 m

Inundation-tolerant plants present in 2008 but not noted in 2009

thick-headed sedge 434 m
common spike-rush 434 – 436 m
meadow horsetail 434 – 436 m

dwarf scouring-rush 434 m
wood horsetail 434 - 436 m
Baltic rush 434 – 435 m
dagger-leaf rush 434 m
skunk cabbage 439 m
yellow pond-lily 439 m

Weeds present in 2008 but not seen in 2009

white mustard 436- 438 m
Knapweed 439 m
lambs quarters 436- 438 m
hounds-tongue hawkweed 439 m
Yellow devil hawkweed 439 m
European hawkweed 438 – 440 m
king devil 438 – 440 m
Margarite 436 – 437 m
black medic 438 – 439 m
Alfalfa 438 – 439 m
curled dock 438 – 439 m
tall tumble-mustard 436 – 439 m
yellow salsify 438 – 439 m

Extinctions after 2009

Trees and shrubs present in 2009 but not seen again in 2010 or 2011

St.John's-wort 438 – 439 m
Cherry 438 – 439 m
Pacific willow 438 – 439 m
Blue elderberry 438 – 439 m
Ponderosa pine 436 - 437 m
Cascara 437 m

Herbs present in 2009 but not seen again in 2010 or 2011

borage sp.1 436 – 439 m
borage sp. 2 436 – 439 m
wild carrot 437 – 439 m
draba sp. 437 – 439 m
creamy peavine 437 – 439 m
arctic lupine 437 – 439 m
cow-wheat 437 – 439 m
polygonum sp. 438 m
graceful cinquefoil 439 m
peavine sp. 437 – 439 m
common vetch 435 – 438 m
kidney-leaved violet 439 m

Inundation-tolerant plants present in 2009 but not seen again in 2010 or 2011

spring water-starwort

Weeds present in 2009 but not seen again in 2010 or 2011

common burdock 438 m
mottled hawkweed 438 m
white-tipped clover 437 m

Extinctions after 2010

Trees and shrubs present in 2010 but not present in 2011 (does not include plots in CR)

St.John's-wort 437 – 439 m
cherry 437 – 439 m
Pacific willow 437 – 439 m
blue elderberry 437 – 439 m
ponderosa pine 437 – 439 m
cascara 437 – 439 m

Herbs present in 2010 but not present in 2011 (does not include plots in CR)

pussytoes 436 m
racemose pussytoes 437 – 438 m
narrow-leaved collomia 438 m
marsh cinquefoil 434 – 436 m
white mountain-avens 436 – 438 m
purple-leaved willowherb 437 – 438 m
smooth willowherb 438 – 439 m
large-leaved lupine 438 – 439 m
European forget-me-not 437 – 439 m
cinquefoil sp. 437 – 439 m
black sanicle 437 – 439 m
groundsel sp. 434 – 437 m
rayless mountain butterweed 439 m
poison ivy 438 m
American speedwell 434 – 438 m

Inundation-tolerant plants present in 2010 but not present in 2011 (does not include plots in CR)

small spike-rush 434 – 435 m
horsetail 434 – 439 m
wood horsetail 437 m
ivy-leaved duckweed 438 m
small-flowered wood-rush 434 – 435 m

skunk cabbage 439 m
pondweed 438 m
floating-leaved pondweed 438 m
sticky false asphodel 439 m

Weeds present in 2010 but not present in 2011 (does not include plots in CR)

field mustard 435 – 438 m
Canada thistle 439 m
yellow sweet-clover 439 m
bitter dock 438 m
great mullein 439 m

APPENDIX 5. RESULTS OF THE ANALYSIS OF VARIANCE OF TREATED VEGETATION

Results of Analysis of Variance for Controls vs Treatments for Three Treatments in the Arrow Lakes Reservoir.

Carex Plug Treatments

Dependent Variable	Independent Variables	p-value	Significance
Plot diversity (H)	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Avg Plot abundance	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Avg Plot vigour	Control vs Treated	> 0.05	none
	Elevation Band	p=0.029	Average vigour poorer at 436 - 438 m than at 434 - 436 m
	Interaction Effect	> 0.05	none
Avg Plot distribution	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Transformed Total Vegetation Cover	Control vs Treated	> 0.05	none
	Elevation Band	p=0.026	Total cover greater at 434 - 436 m > 436 - 438 m; neither are significantly different from 438 - 440 m.
	Interaction Effect	> 0.05	none
Transformed Vegetation Height	Control vs Treated	> 0.05	none
	Elevation Band	p=0.035	Average height significantly less at 434 - 436 m and 436 - 438 m than at 438 - 440 m; 434 - 436 m = 436 - 438 m < 438 - 440 m;
	Interaction Effect	> 0.05	none

Cottonwood Seedling Treatments			
Dependent Variable	**Independent Variables**	**p-value**	**Significance**
Plot diversity (H)	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Avg Plot abundance	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Avg Plot vigour	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Avg Plot distribution	Control vs Treated	> 0.05	none
	Elevation Band	p=0.028	Average distribution of vegetation more sparse and patchy in treated plots at 436 - 438 m than at either 434 - 436 m or 438 - 440 m.
	Interaction Effect	> 0.05	none
Transformed Total Vegetation Cover	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Transformed Vegetation Height	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none

Cottonwood Stake Treatments			
Dependent Variable	**Independent Variables**	**p-value**	**Significance**
Plot diversity (H)	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Avg Plot abundance	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Avg Plot vigour	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Avg Plot distribution	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Transformed Total Vegetation Cover	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none
Transformed Vegetation Height	Control vs Treated	> 0.05	none
	Elevation Band	> 0.05	none
	Interaction Effect	> 0.05	none

Stake Comparisons:			
Dependent Variable	**Independent Variable**	**p-value**	**Significance**
Per cent Alive	Vegetation Community Type	> 0.05	none
Per cent Alive	Elevation	> 0.05	none

APPENDIX 6. TRENDS IN TREATED PLOT SPECIES COMPOSITIONS OVER TIME FOR REPEATED PLOTS

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	08-12-03_EM10T	434 - 436	206	ALOPAEQ	ALOPAEQ	ALOPAEQ	CARELEN
				CARELEN	CARELEN	CARELEN	EQUIARV
				CERANUT	EQUIARV	ELEOPAR	JUNCART
				EQUIARV	PHALARU	EQUIARV	TRIFOLI
				PHALARU	POA COM	JUNCART	
				POA COM		PHALARU	
						POA COM	

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	08-12-06	434 - 436	190	ALOPAEQ		ALOPAEQ	ALOPAEQ
				CARELEN		CARELEN	CARELEN
				EQUIARV		EQUIARV	EQUIARV
				JUNCUS		MONTFON	JUNCTEN
				PHALARU		PHALARU	MONTFON
							PHALARU
							POLYAVI

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	08-12-22_AE10	436 - 438	41	ALOPAEQ			ALOPAEQ
				PHALARU			CAREX
				POA ANN			CHENALB
				RORIPAL			ELYMREP

							MATRDIS
							PERSHYD
							PERSMAC
							PLAGSCO
							POA ANN
							POA COM
							POLYAVI
							RORIPAL
							VEROPER
TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	09-12-CT11	436 - 438	37		ELYMREP		CAMPHIP
					EQUIARV		CARELEN
					PLUGS		PLUGS?
							ELYMREP
							EQUIARV
							PHALARU
							POA COM
TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	33-10-AE-121	434 - 436	170			CARDPEN	CAREAPE
						CARELEN	CARELEN
						CAREAPE	EQUIARV
						CERANUT	JUNCFIL
						EQUIARV	PHALARU
						GALITRD	CARDPEN
						JUNCFIL	
						PHALARU	

						VEROPUR	

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	33-10-AE-18	434 - 436	196			ALOPAEQ	ALOPAEQ
						MONTLIN	POA COM
						POLYAVI	POLYAVI
						POA COM	

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	33-10-AE-19	< 434	219			ALOPAEQ	ALOPAEQ
						CARELEN	CARELEN
						POLYAVI	CAREX
						POLYPER	POLYAVI
						RORIPAL	

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	33-10-AE-37	434 - 436	116			CARELEN	CARELEN
						EQUIARV	CAREX
						PHALARU	ELYMREP
						POA COM	EQUIARV
							PHALARU
							POA COM

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	33-10-EM-119	436 - 438	51			ELYMREP	ALOPAEQ

						EQUIARV	CARELEN
						PHALARU	CAREX
						POA COM	EQUIARV
						TRIFAUR	JUNCTEN
							PHALARU
							POA COM
							POA PRA
							POPUBAL
							POTENOR
							VEROPER
							ELYMREP

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	33-10-EM-93B	438 - 440	31			AGROGIG	AGROGIG
						CERAPUR	CERAPUR
						POA COM	ELYMREP
						RACOCAN	PHALARU
							POA COM
							POA PRA
							POPUBAL
							RACOCAN

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG	33-10-EM-95B	434 - 436	192			LEMNTRI	ALOPAEQ
						PHALARU	CAREAPE
							CARELEN
							EQUIARV
							JUNCFIL
							PHALARU

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
CARE PLUG POPU BAL SEEDLING	33-10-KE-103	436 - 438	72			CAREAPE	CAREAPE
						CERANUT	CARELEN
						PHALARU	CERANUT
						POTENOR	ELYMREP
						TRIFAUR	PHALARU
							POA COM
							POPUBAL
							POTENOR
							TRIFAUR

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
POPU BAL SEEDLING	08-12-21_KE10	434 - 436	170	ALOPAEQ		ALOPAEQ	ALOPAEQ
				CERANUT		CARELEN	CARELEN
				MATRDIS		MATRDIS	ELYMREP
				MONTLIN		MONTLIN	MATRDIS
				PHALARU		PHALARU	PHALARU
				POA COM		POA COM	POA COM
				RORIPAL		POLYAVI	
				VEROPER			

TREAT	COPLOT	ELEVBAND	DAYS of INUNDATION	2008	2009	2010	2011
POPU BAL SEEDLING	08-12-71_EM10	436 - 438	34	ALOPAEQ		CAREAPE	CAREAPE
				CARELEN		CARELEN	CARELEN

				EQUIARV		EQUIARV	EQUIARV
				PHALARU		PHALARU	PHALARU
						POA COM	POA COM

APPENDIX 7. STAKE COUNT DATA FOR ARROW LAKES RESERVOIR ASSESSMENT OF CLBWORKS-2.

Results of Plot-based Stake Counts

Plot ID	Vegetation Type	Elevation (m)	Live Stakes	Dead Stakes	Total Stakes	Per cent Alive	Location
33-10-EM-79-T11	PC	435	2	11	13	15	Arrow Ferry South
12-11-AE-53	PC	438	4	2	6	67	Arrow Park Ferry 1
12-11-AE-50	PC	437	11	2	13	85	Arrow Park Ferry 2
12-11-EM-36	PC	438	2	5	7	29	Arrow Park Ferry North 2
12-11-EM-38	PC	437	7	4	11	64	Arrow Park Ferry North 3
12-11-EM-01	PC	439	2	10	12	17	Arrow Park South Beach
12-11-EM-42	PC	440	1	5	6	17	Burton South
12-11-AE-21	PC	439	6	2	8	75	Drimmie
12-11-AE-21	PC	439	6	2	8	75	Drimmie
12-11-AE-41	BE	438	3	3	6	50	Drimmie
12-11-AE-42	PC	439	8	0	8	100	Drimmie
12-11-AE-66	PC	439	5	0	5	100	Drimmie
12-11-EM-31	PC	439	6	0	6	100	Drimmie
12-11-AE-62	BE	437	9	5	14	64	Drimmie South
12-11-AE-33	PC	439	3	3	6	50	Duncan Mid
12-11-EM-22	BE	437	8	1	9	89	Duncan Mid
12-11-EM-23	PA	439	7	1	8	88	Duncan Mid
12-11-AE-25	PA	438	2	4	6	33	Duncan South
12-11-AE-26	PA	438	6	1	7	86	Duncan South

12-11-AE-28	IN	438	29	3	32	91	Duncan South
12-11-AE-29	IN	437	13	9	22	59	Duncan South
12-11-AE-31	PC	439	4	0	4	100	Duncan South
12-11-AE-11	BG	438	16	1	17	94	Edgewood South
12-11-AE-12	PC	438	9	7	16	56	Edgewood South
08-12-45	BG	437	2	0	2	100	Inonoaklin
12-11-AE-09	BG	438	25	2	27	93	Inonoaklin

Results of Polygon-based stake counts

Plot ID	Vegetation Type	Elevation (m)	Live Stakes	Dead Stakes	Total Stakes	Per cent Alive	Location	Count Area (sq m)
BS-STAKES-AE-01	PA	438	55	51	106	52	Burton	961
BS-STAKES-AE-02	PC	439	33	18	51	65	Burton	397
BS-STAKES-AE-03	PC	439	6	23	29	21	Burton	235
BS-STAKES-AE-04	PC	439	1	16	17	6	Burton	154
JE_MAY18	PC	439	26	22	48	54	Burton	342
KE_MAY18	PC	439	14	53	67	21	Burton	777
DC-STAKES-JE-30	BE	439	36	7	43	84	Drimmie Creek	90
DC-STAKES-JE-31	PC	439	32	4	36	89	Drimmie Creek	247
DC-STAKES-JE-32	SS	439	27	5	32	84	Drimmie Creek	288
DR-STAKES-JE-10	PC	438	13	3	16	81	Drimmie Creek	99
DR-STAKES-JE-20	PC	439	15	1	16	94	Drimmie Creek	140
DR-STAKES-JO-09	PC	439	22	3	25	88	Drimmie Creek	186
DM-STAKES-JE-11	PA	439	33	2	35	94	Duncan Flats	202
DM-STAKES-JE-12	BE	438	20	0	20	100	Duncan Flats	104
DM-STAKES-JE-13	PC	439	5	15	20	25	Duncan Flats	155
DS-STAKES-JO-10	PA	438	3	22	25	12	Duncan Flats	205
DS-STAKES-JO-11	PA	438	25	6		81	Duncan Flats	179

DS-STAKES-JO-12	PC	439	32	17	49	65	Duncan Flats	303
DS-STAKES-JO-13	PC	438	19	3	22	86	Duncan Flats	236
DS-STAKES-JO-25	PC	438	9	13	22	41	Duncan Flats	379
DS-STAKES-JO-26	PC	438	18	14	32	56	Duncan Flats	339
DS-STAKES-JO-27	PC	438	8	20	28	29	Duncan Flats	409
ES-STAKES-JO-03	PC	437	50	8	58	86	Edgewood	81
ES-STAKES-JO-04	BG	437	29	6	35	83	Edgewood	132
ES-STAKES-JO-05	BG	437	36	4	40	90	Edgewood	103
ES-STAKES-JO-06	PC	438	33	8	41	80	Edgewood	120
ES-STAKES-JO-07	BG	436	1	9	10	10	Edgewood	44
ES-STAKES-JO-08	BE	438	130	52		71	Edgewood	228
IN-STAKES-JE-01	BE	438	92	5	97	95	Needles	332
IN-STAKES-JE-02	BE	437	22	4	26	85	Needles	80
IN-STAKES-JE-03	BG	436	31	13	44	70	Needles	134
IN-STAKES-JE-04	BE	437	61	25	86	71	Needles	315
IN-STAKES-JE-05	BG	438	87	9	96	91	Needles	272
IN-STAKES-JE-06	BE	438	6	9	15	40	Needles	102
IN-STAKES-JE-07	BE	436	1	28	29	3	Needles	150
IN-STAKES-JO-01	PC	438	89	14	103	86	Needles	400
IN-STAKES-JO-02	PC	437	9	52	61	15	Needles	469