Columbia River Project Water Use Plan

Kinbasket and Arrow Lakes Revegetation Management Plan

Arrow Lakes Reservoir Inventory of Vegetation Resources

Implementation Year 4

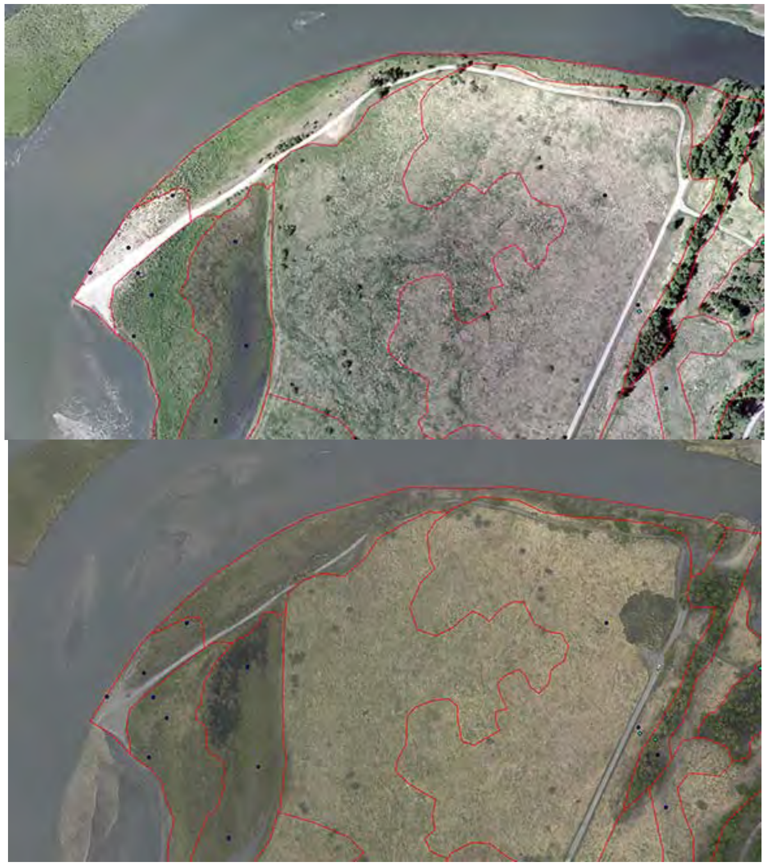
Reference: CLBMON-33

Study Period: 2012

Delphinium Holdings Inc.
Castlegar, BC

November 5, 2012

Original Report Cover



Illecillewaet, BC: 2007 above, 2012 below

CLBMON-33
ARROW LAKES RESERVOIR INVENTORY OF VEGETATION RESOURCES
2012 Draft Report

Submitted to:

BC Hydro
Water License Requirements
Castlegar, B.C.

by:

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Cover photo: Compared aerial photographic capture of Illecillewaet River entry in 2007 vs. 2012. Not colour corrected.

EXECUTIVE SUMMARY

This report for the CLBMON-33 project (Arrow Lakes Reservoir Inventory of Vegetation Resources) compares 2012 data on the spatial extent, structure and composition of vegetation in the Arrow Lakes Reservoir drawdown zone to data collected in previous years. CLBMON-33 is a long-term vegetation inventory project, based on field plots established in 2007. Subsequent field surveys of monitoring plots were carried out in 2008 and 2010, and are currently planned for alternating years until 2016. The project monitors landscape-level changes in vegetation communities between elevations 434 m and 440 m in response to the soft constraints operating regime.

We describe the fourth year of monitoring under the CLBMON-33 project, including methods, analysis, and interpretation of the fieldwork, aerial photographic capture, and mapped image data.

The field work in 2012 consisted of reassessment of plots previously established for CLBMON-33 and a companion project, CLBMON-12 (Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis). The CLBMON-33 project's focus is at the landscape scale; CLBMON-12 addresses site-level changes in existing vegetation and responses to vegetation treatments in the reservoir. Both studies use the same set of field plots to monitor change over time. In 2012, no additional plots were needed, but plots were revisited in the field to ensure continuity and accurate representation of vegetation change over time.

The 2012 aerial photographic imagery used the same digital image capture methods as in 2010. Before this, imagery was captured on film. We compared the 2012 imagery with the 2010 imagery, using the Kappa Statistics and confusion matrix. The final report for this project (due in 2016) will provide a retrospective of all the years of image capture.

There was no evidence of changes in vegetation spatial extent or structure between 2007 and 2012 at the <u>landscape level</u>. A landscape-level change is defined as a 10 per cent (decile) incremental shift in the coverage of a vegetation community type from its previous condition. Several vegetation variables are strongly influenced by environmental variables such as soil texture, and soil texture is in turn influenced by the duration of inundation in the reservoir. The drier and wetter vegetation community types showed evidence of a modest increase in vegetation height and cover at the local level. There was no evidence of changes in species richness, diversity, evenness or distribution measures over time, whereas spatial extent (cover) and structure (heights) responded to a single year shift in the soft constraints operating regime in 2008.

Table 1 is a summary of the findings in relation to the management questions and the management hypothesis for this study, as well as a summary of additional work required to answer the management questions completely.

Table 1. CLBMON-33 Status of objectives, management questions and hypothesis after Year 4 for monitoring landscape-level change in vegetation communities between 434 m and 440 m

Objective	Management Question	Management Hypothesis	Year 4 Status
Identify and spatially delineate existing riparian and wetland vegetation communities within the drawdown zone	MQ1: What are the existing riparian and wetland vegetation communities in the Arrow Lakes Reservoir drawdown zone between 434 m and 440 m?		The vegetation communities are grouped into 15 vegetation community types (VCTs) based on topography, parent materials (soils and non-soils), and vegetation.
	MQ2: Is the current distribution of vegetation communities in Revelstoke Reach representative of the remainder of the reservoir?		No, Revelstoke is not representative of the remainder of the reservoir; it is dominated by the mesic reed canary grass VCT to a greater extent than the rest of the Arrow Lakes Reservoir. The reservoir vegetation becomes more diverse toward the south, with higher proportions of the other 14 VCTs.
Measure the changes in spatial extent, structure and composition (distribution and diversity) of the communities in the drawdown zone over time.	MQ3: What are the spatial extents, structure and composition (i.e., relative distribution and diversity) of these communities within the drawdown zone between 434 m and 440 m?	H_{OA}: There is no significant difference in the spatial extent of vegetation communities within the existing vegetated zones of Arrow Lakes Reservoir. H_{OB}: There is no significant difference in the structure and composition (i.e., distribution and diversity) of vegetation communities within the existing vegetated zones of Arrow Lakes Reservoir.	There are distinct patterns in spatial extent (cover) and structure (heights) of the vegetation communities in the Arrow Lakes Reservoir, in response to wave action, erosion, etc. from normal water behavior in the reservoir as well as to changes in the soft constraints operating regime. In general, vegetation cover is low at very low elevation, although some VCTs are well adapted to the conditions at low elevation and can have high covers. Cover can also be low at high elevation, if scouring or wave action has removed vegetation and exposed the sands and gravels. In general, heights and covers tend to increase with elevation. Accordingly, both Ho_A and Ho_B have been tentatively rejected based on the data available to date. However, a final conclusion on this question cannot be made until the completion of monitoring in 2016.

Assess whether the observed changes in the communities (as above) are attributable to the soft constraints operating regime of the reservoir.	MQ4: Does the soft constraints operating regime of Arrow Lakes Reservoir maintain vegetation spatial limits, structure and composition of existing vegetation communities in the drawdown zone?	As above, with respect to H_{OA} and H_{OB}.	Several environmental factors, including the duration of inundation, account for changes in the vegetation communities. Coarse fragment contents in soils, sand:silt:clay ratios, sheltering effects and scouring or deposition of sands and silts, as well as climate differences and the temperature over the exposure period for high-elevation vegetation are all important. The maintenance of the soft constraints operating regime does not appear to have a dramatic influence on the vegetation spatial limits, structure and composition, in comparison to environmental variables.
Provide information on the effectiveness of the soft constraints operating regime at maintaining the existing spatial extent, structure and composition of existing vegetation communities.	MQ5: How do spatial limits, structure and composition of vegetation communities relate to reservoir elevation and topo-edaphic site conditions such as aspect, slope, soil moisture, etc.?	As above, with respect to H_{OA} and H_{OB}.	Environmental conditions account for substantial variation in cover and heights, and these conditions are coupled with the soft constraints operating regime. Soil texture is a fundamentally important variable, and it is strongly influenced by depth and duration of inundation. Due to the nature of river flow, silts and clays accumulate at low elevation and gravels and sands accumulate at high elevation, and these influence the vegetation. The vegetation composition (diversity, evenness and richness) was examined at the species level and has been clearly linked with moisture and nutrients. Moisture and nutrients are only indirectly linked to the soft constraints operating regime.
	MQ6: Are there operating changes that can be implemented to maintain existing vegetation communities at the landscape scale more effectively?		Yes, based on the single occurrence of a sustained high water level from the summer of 2008 to the early winter of 2009, and the subsequent decline in cover and heights of some of the vegetation in the low elevation bands of the reservoir, we recommend that water levels be allowed to decline for a period each midsummer to late fall for vegetation to recover and grow during the latter portion of the growing season. This recommendation is based on the response of vegetation to one sustained high water period.

KEYWORDS

Arrow Lakes Reservoir, landscape level, soft constraints operating regime, Vegetation Community Type, vegetation structure, vegetation composition, vegetation cover, vegetation height, vegetation diversity, vegetation distribution, vegetation evenness, species richness, aerial photographic interpretation, elevation zone, centroid elevation, climate, precipitation, temperature, sand, silt, clay, gravels, boulders, water levels, vegetation response.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

The Water Licence Requirement project (CLBMON-33 Arrow Lakes Reservoir Inventory of Vegetation Resources) was initiated in 2007. This project is a 10-year monitoring program in the Arrow Lakes Reservoir to assess the impacts of the soft constraints operating regime on existing vegetation communities in the drawdown zone between elevations 434 m and 440 m (full pool). The soft constraints operating regime was developed by a consultative committee to serve various interests. These were Vegetation, Wildlife, Fish, Recreation, Culture and Heritage, Erosion and Power Generation. Grau and Walsh (2007) described the soft constraints as follows:

> **" ...Vegetation**
>
> Maintain current level of vegetation in the drawdown zone by maintaining lower reservoir water levels during the growing season. No specific operating targets were identified to meet this general objective.
>
> If vegetation is showing signs of stress as a result of inundation during the early part of the growing season (May to July), target lower reservoir levels in the fall to allow exposure of plants during the latter part of the growing season.
>
> Preservation of current levels of vegetation at and above elevation 434 m (1424 ft) is considered a priority.
>
> **Wildlife**
>
> Ensure that inundation of nesting bird habitat by rising reservoir water levels in early summer is no worse than that which occurred on average over recent history (1984 to 1999). Match operating levels to inundation statistics for elevations 434 m (1424 ft) and above over the 1984 to 1999 period, which were used to produce the average historic performance measure score for spring/summer nesting short-eared owl habitat.
>
> Ensure that availability of migratory bird habitat in the fall is as good as or better than that which has been provided on average over recent history (1984 to 1999). Draft the reservoir quickly after full pool is reached, targeting a reservoir level of 438 m (1437 ft) or lower by August 7.
>
> **Fish**
>
> Ensure appropriate reservoir elevations for tributary access during the kokanee spawning period (late August to early November). Reservoir levels of or below 434 m (1424 ft) could cause tributary access to be restricted in some streams under certain conditions. Proposed monitoring study aimed at determining reservoir level thresholds under a range of tributary streamflow conditions below which spawner access becomes a problem.
>
> **Recreation**
>
> Target reservoir water levels between 437 m (1433 ft) and 439 m (1440 ft) from May 24 to September 30.

Flexibility to achieve lower reservoir levels of 434 m (1424 ft) during the recreation season would be acceptable with proposed construction/upgrade of boat ramps for recreation interests served by these formal access points.

Culture and Heritage

Maintain reservoir water levels at or below 436 m (1430 ft) for as long as possible.

First Nations are willing to accept water levels above this 20% of the time (or for 2.5 months) provided that it is timed in accordance with the vegetation efforts. First Nations would be willing to relax this constraint if the archaeological site protection plan is underway.

Erosion

Minimize duration of full pool events. Reservoir water levels of 439 m (1440 ft) are ideal.

Avoid sudden drawdown once full pool has been reached (particularly if high runoff has saturated the reservoir banks) to avoid slumping of the shores.

Power Generation

Optimize power values."

Each constraint set target water levels and timing of water levels to protect certain interests. Some constraints, such as those designed for the protection of fish and those designed to protect heritage and culture, are potentially in conflict. It was recognized that water levels below 434 m (1424 ft) could cause tributary access to be restricted in some streams. This is not completely compatible with protecting culture and heritage values, which require water levels to be below 436 for as long as possible. There are also similarities between some interests, however. For example, the constraints designed to protect against erosion may also protect vegetation. The final documentation for this project in 2016 will include an evaluation of how each set of constraints may influence vegetation.

1.1 Study Area

The Arrow Lakes Reservoir is situated on the Columbia River between the Revelstoke Dam at Revelstoke in the north, and the Hugh Keenleyside Dam at Castlegar, British Columbia, in the south (Figure 1).

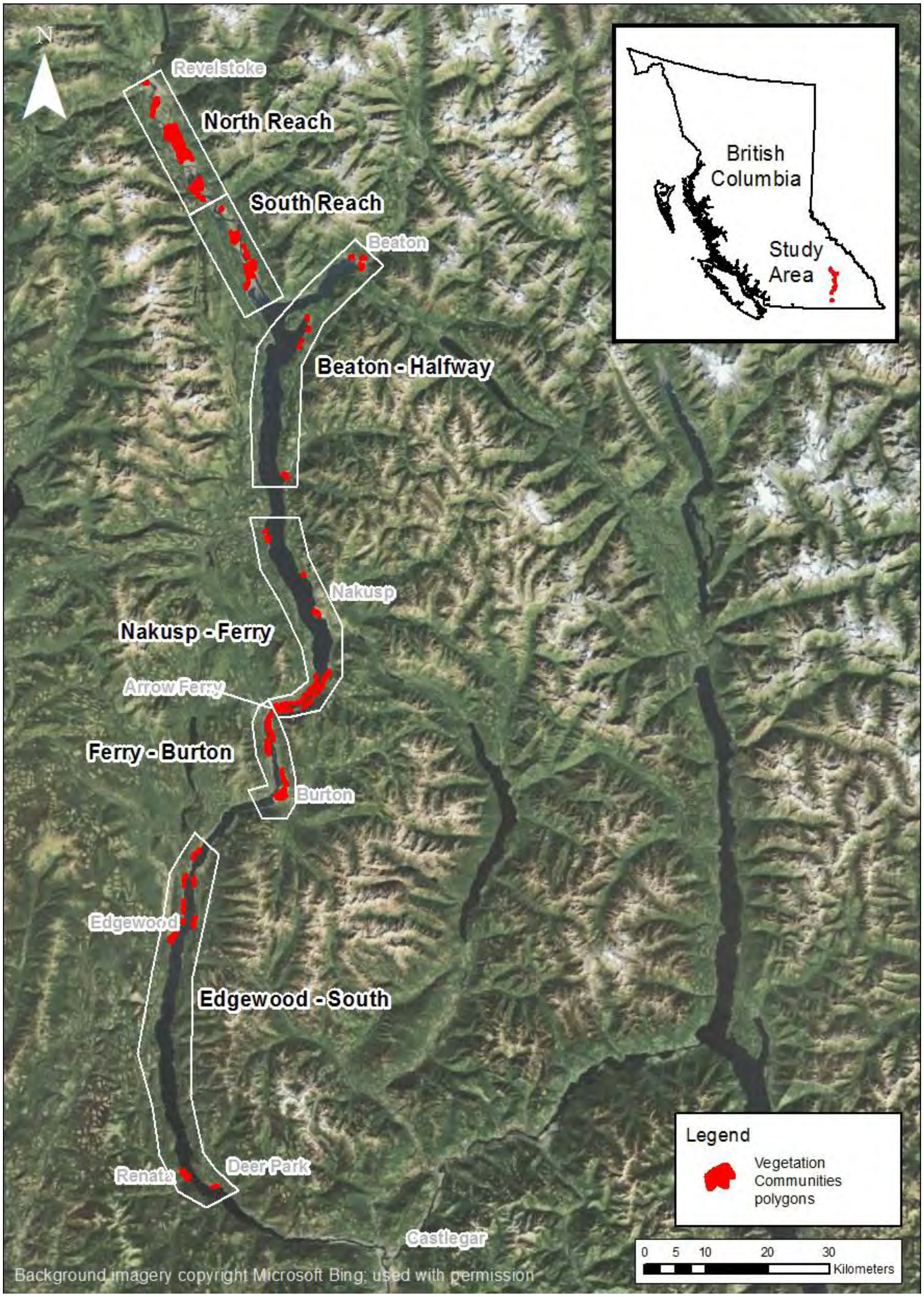


Figure 1. **Location of CLBMON-33 vegetation monitoring sites in the drawdown zone of the Arrow Lakes Reservoir, between Revelstoke and Castlegar B.C.**

1.2 Monitoring program objectives, management questions and scope.

The objectives of CLBMON-33 Arrow Lakes Reservoir Inventory of Vegetation Resources are to (BC Hydro 2007):

1. Identify and spatially delineate existing riparian and wetland vegetation communities within the drawdown zone;
2. Measure the spatial extent, structure and composition (i.e., distribution and diversity) of the communities in the drawdown zone at repeated time intervals over a 10 year period;
3. Assess whether there are changes in the spatial extent, structure and composition of the communities in the drawdown zone over the monitoring period;
4. Assess whether observed changes in the spatial extent, structure and composition are attributable to the soft constraints operating regime of the reservoir; and,
5. Provide information on the effectiveness of the soft constraints operating regime at maintaining the existing spatial extent, structure and composition of the communities in the drawdown zone at the landscape level.

   The scope of the Arrow Lakes Reservoir Inventory of Vegetation Resources project is to identify and evaluate changes in vegetation communities at the landscape level, using aerial photographic interpretation and field data collected every second year. The management questions, in relation to the objectives and findings to date, are summarized in Table 2.

Some of our management questions involve comparisons between Revelstoke Reach and the remainder of the Arrow Lakes Reservoir. Revelstoke Reach includes the areas identified as “North Reach” and “South Reach” in Figure 1. We refer to the remainder of the reservoir as the Arrow Lakes.

Table 2. Management questions, objectives relating to them, and summary of findings to date and further work required to meet the objectives

Management Question	Objectives	Summary of findings to date
What are the existing riparian and wetland vegetation communities in the Arrow Lakes Reservoir drawdown zone between 434 m and 440 m?	Objective 1 applies.	A total of 15 vegetation community types (VCTs) were identified in the field in 2007. These were sampled and mapped at a scale of approximately 1: 10,000. Polygon delineation and classification were based primarily on topography, materials (soils and non-soils) and leading plant species. The characteristics of VCTs were further defined in 2008. Low-elevation VCTs have short-statured vegetation, with tolerance for inundation. Upper-elevation VCTs are drought tolerant and have more shrubs and trees. These characteristics have not changed since 2007. All VCTs had plant species in common, but all VCTs also had diagnostic species that most likely were aligned with certain topographic or soils related features (Enns *et al.* 2007). New species have been found in individual VCTs, especially in the PA and CR, (Table 3) which are diverse, higher-elevation plant communities.
Is the current distribution of vegetation communities in Revelstoke Reach representative of conditions in the remainder of the reservoir?	Objective 1 generally applies, but CLBMON-33 does not examine vegetation outside of the designated monitoring sites. The areas included in the assessment may therefore not fully represent the proportions of types found in the entire drawdown zone (study areas are often more densely vegetated)	No, Revelstoke is not representative of the remainder of the reservoir (Enns *et al.* 2008). Revelstoke Reach has a shorter growing season, cooler summers, colder winters and less diverse soils and parent materials than the Arrow Lakes portion of the reservoir. Revelstoke Reach is dominated by the mesic reed canary grass VCT. The vegetation of the reservoir becomes more diverse toward the south, with higher proportions of the other 14 VCTs.
What are the spatial extents, structure and composition (i.e., relative distribution and diversity) of these communities within the drawdown zone between 434 m and 440 m?	Objective 2, 3 and 4 examine spatial extent (cover), structure (height) and composition (distribution and diversity) of types at the landscape scale.	Previous work indicates that the spatial extent, structure and species compositions of the VCTs tend to reflect the tolerance zones of their typical species (Enns *et al.* 2007). Species of the low elevation VCTs require and are tolerant of long periods of inundation. High-elevation VCTs have very drought tolerant species (Enns *et al.* 2007). Species invasions into adjacent elevations occur, but the invading plants are seldom seen in subsequent years, when repeated plot data are compared (Enns

		et al. 2011). A relatively small number of VCTs occur across most of the 6-metre elevation range in the reservoir and these VCTs are dominated by very tolerant, aggressive species such as reed canary grass and lenticular sedge. Spatial extent (cover) and structure (heights) of vegetation within most VCTs increase with increasing elevation. Distribution of vegetation within VCTs appears to be influenced more by potential for erosion (i.e., water energy level) and soil texture than by elevation. Diversity of the vegetation increases with elevation, but some low elevation VCTs, such as RR and PE (Table 3), can have a high diversity of plants that are specifically adapted to the conditions of frequent, prolonged inundation (PE) or continuous seepage (RR).
How do the spatial limits (cover), structure (height) and composition of vegetation communities relate to elevation and the topo-edaphic site conditions (aspect, slope and soil moisture, etc.)?	Environmental variables are assumed to influence response of the vegetation along with the soft constraints operating regime (Objective 4).	Diversity of VCTs was found to be associated with nutrient regimes and hygrotopes (Enns *et al.* 2007). Drought tolerant VCTs (and species) had higher covers and heights where soils were sandy and fine-textured (Enns *et al.* 2007), indicating soil nutrient regime and moisture availability are important for supporting vegetation in the reservoir.
Does the soft constraints operating regime of Arrow Lakes Reservoir maintain spatial limits, structure and composition of existing vegetation communities in the drawdown zone?	Objective 3 relates to this question, where maintenance of vegetation is considered over time.	There has been no significant change in cover, height or distribution of vegetation at the landscape level, but there have been some significant changes within VCTs at the local level.
What potential changes to the soft constraints operating regime could be made in order to maintain the existing vegetation communities at the landscape scale?	Objectives 4 and 5.	The annual water level patterns of the Arrow Lakes Reservoir may not have varied enough between 2007 and 2012 to show a change in vegetation. The water levels have had very similar seasonal high and low water duration. A response to a long duration high water period over the winter was noted in 2009, but was only apparent in a small proportion of the vegetation.

1.3 Program hypothesis

Monitoring was designed to address the following hypothesis and associated sub-hypotheses:

H_0: Under the soft constraints operating regime (or possibly a newly selected alternative after five years), there is no significant change in existing vegetation communities at the landscape scale.

- H_{0A}: There is no significant change in the spatial extent (cover, and number of hectares) of vegetation communities within the existing vegetated zones of Arrow Lakes Reservoir.
- H_{0B}: There is no significant change in the structure and composition (i.e., distribution and diversity) of vegetation communities within the existing vegetated zones of Arrow Lakes Reservoir.

These hypotheses link back to the management questions in the following ways: a finding of no significant change[1] in existing vegetation communities at the landscape scale would be recorded as *no significant difference* in the existing vegetation communities in comparison to the 2007, 2008 and 2010 aerial photographic data.

The vegetation community types (VCTs) occurring within the drawdown zone of the reservoir between 434 metres and 440 metres were defined in the field in 2007, and base mapping was created by delineating polygons on aerial photographic mosaics at various scales for 43 study areas in the Arrow Lakes Reservoir. The study areas were selected by BC Hydro. The VCTs were based on a combination of similar topography, soils, and vegetation features. The most common VCTs are listed in Table 3 and the less common ones in Table 4. The VCTs in Table 4 are also assumed to be affected more strongly by influences other than the soft constraints operating regime, such as incoming streams, rivers, and vehicle use. The VCTs in Table 3 have sufficient coverage at various elevations throughout the reservoir to be used in statistical analysis. The VCTs listed in Table 4 were not used in the analyses presented in this report, but a final assessment of previous plots in those VCTs is planned to show any changes over time.

[1] Defined as a change of 10 per cent or greater in vegetation cover or height.

Table 3. **VCTs thought to be mainly influenced by the Arrow Lakes Reservoir soft constraints operating regime**

BE: Sandy beach: sandy, mostly non-vegetated to sparsely vegetated with herbaceous plants, seedlings and grasses, occasionally with sedges and mosses.	
BG: Gravelly beach: sparsely vegetated mid-slope gravels with grasses and herbaceous plants, especially drought-tolerant weeds and occasionally small cottonwood and willows.	
CR: Cottonwood riparian: upland forest edge on relatively deep, occasionally bouldery soils. Includes some managed lands.	
PA: Redtop upland: gravelly to sandy upper-elevation beaches, often with remnants of former forested or farmed soils, dominated by shrubs and several species of grasses, drought-tolerant herbs, mosses, lichens and several species of weeds.	
PC: Reed canary grass mesic: silty sandy, mostly flat beaches; comparatively species=poor, and dominated by reed canary grass but can include a minor component of mint, horsetail and agronomic species.	
PE: Horsetail lowland: lowest-elevation VCT with dense, silty soils often poorly drained and receiving moisture from the reservoir, dominated by wetland species including sedges, rushes and reeds.	
RR: Reed – rill: submerged seepage tracks extending from high elevation to the reservoir edge, occasionally upwelling, and dominated by herbs, liverworts, wetland grasses, mosses, sedges, rushes and reeds.	

Table 4. VCTs in the Arrow Lakes Reservoir included in the mapping, but thought to be either less influenced by the soft constraints operating regime than by other variables, or uncommon

BB: Boulders, steep: mostly non-vegetated and steeply sloping boulders and cobble beaches.
CL: Cliffs and rock outcrops: often very steep, bedrock-dominated with cliff vegetation.
SF: Slope failure: slumps and minor slope failures dominated by silt sands. .
IN: Industrial/residential/recreational: all potential soils and parent materials; strongly influenced by recreational and industrial vehicle use.
PO: Ponds: mostly permanently flooded backwaters or collection sites.
RS: Willow stream entry: incoming stream channels, may be ephemeral.
SS: Steep sand: steep slopes dominated by sand. Usually non-vegetated.
WR: Silverberry river entry: occurs only in major river entries with year-round water flow.

The CLBMON-33 project uses mapping at the landscape level to define the vegetation communities introduced in the above tables and to examine them for change. In the mapping, these vegetation communities are expressed as deciles, i.e., 10 per cent increments of community type cover within polygons. A change in the vegetation communities at the landscape scale is therefore relatively coarse-grained. Also, a landscape-level change may not be detected at the ground level. The fieldwork complements the mapping by assessing change in cover, height, distribution, species diversity, evenness and richness over time.

1.4 Water Levels

Landscape-level analysis using aerial photographic interpretation allows us to examine changes in polygons over time in the entire study area. In 2010 few dramatic changes in vegetation cover and heights were noted (Enns *et al*. 2010). When we compared cover and heights of vegetation with reservoir water levels on an annual basis, we noted that a decline in vegetation cover and heights may have been attributable to a unique period of high water over the fall of 2008 and early winter of 2009 (Highlighted in Figure 2).

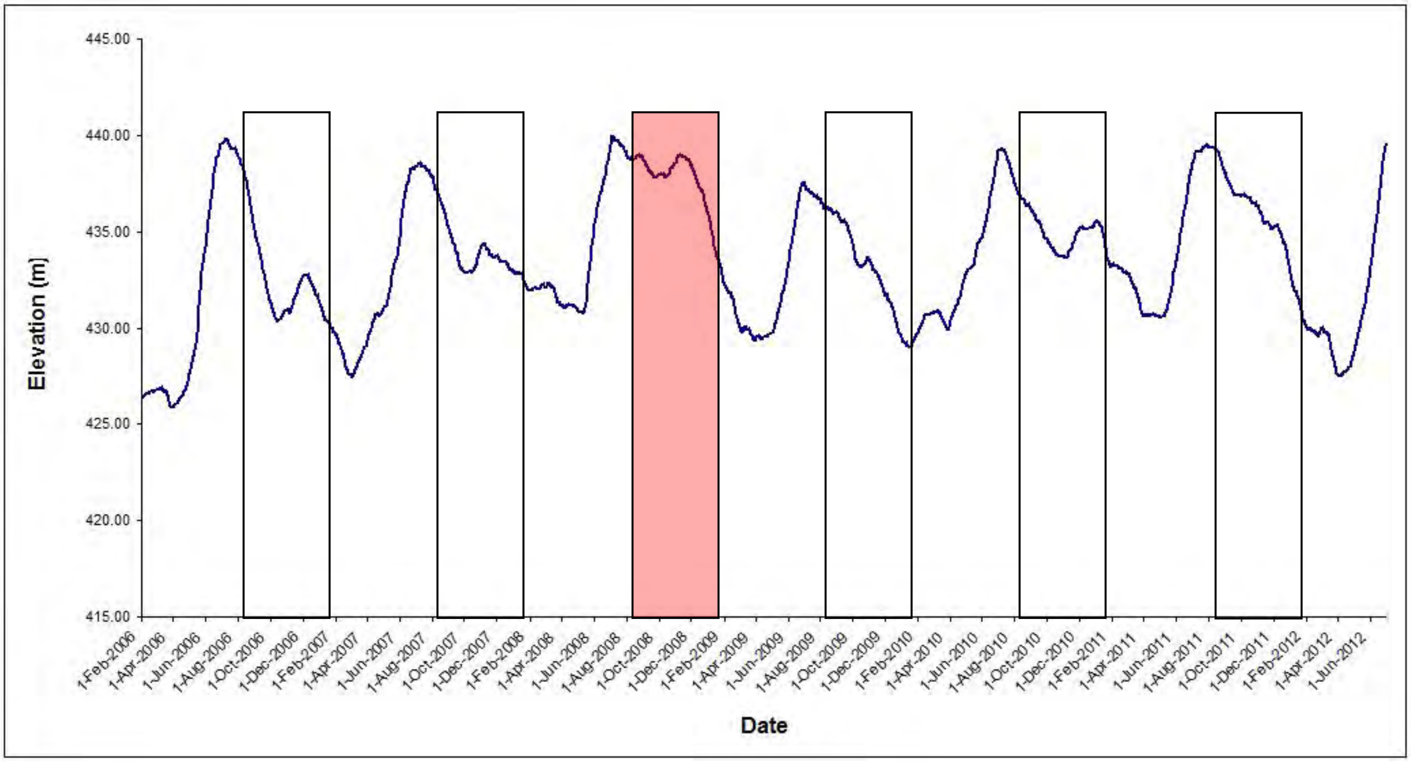


Figure 2. Water levels in the Arrow Lakes Reservoir from 2006 to 2012

In most years, the vegetation communities between 434 and 436 metres were above the water line in the spring and again during the late summer and fall. Over the average growing season, a gradual decline in water levels followed the highest water periods, which tended to occur between July and August. The inundation levels influencing this year's growing season, from June 2011 to April 2012, were similar to all other years except for 2008, when the inundation lasted from June to the following early winter. Low-elevation vegetation communities appear to be well adapted to frequent and prolonged inundation. Conversely, upper-elevation vegetation communities benefit from short-term inundation and are tolerant of drought (Enns *et al.* 2009, 2010).

2.0 METHODS

2.1 Sampling Design

The project was designed in 2007, and initial field work to define the VCTs was done in fall 2007 (Enns et al. 2007). Revisions to the study design were completed in 2008, 2009 and 2010 (Enns and Gibeau 2008; Enns and Gibeau 2009; Enns 2010). The polygons were mapped and the VCTs within each polygon were identified in 2007. Each VCT has a characteristic set of topographic and soils features together with typical vegetation for those features. Some VCTs were based on physiographic features only (Table 4). Polygon boundaries were delineated based on similarities in topography and vegetation, where patterns were more similar within the polygon lines than outside them. Each polygon could include as many as three VCTs. The study has both a landscape-level focus using repeated aerial photographic captures, with interpretation of changes over time and differences across elevations, and a field-level focus, with measurements using repeated vegetation plots to show differences over time and elevation.

The locations of field plots were selected at random in a two-stage process. Target polygons were selected from the map base using a random number generator. In the field, The stick toss method was used to identify the portion of a VCT within the target polygon to sample. Minimal sample size calculations were used to determine the plot size (a 5 by 10 metre oblong) in the field (Mueller-Dombois and Ellenberg 1974). Power analysis was used to arrive at the number of field plots within VCTs required for the analysis. Power analysis was also used to determine the number of polygons needed to accurately interpret change in the mapped vegetation.

The project uses a repeated measures sampling strategy (Enns 2010). Each year of the study, the same set of field plots are re-evaluated. Replication within types occurs over all elevations in which the vegetation type occurs. Most VCTs are centred within a range of elevations, and few of them occur at all elevations; therefore, the evaluation of how a VCT responds to water levels is influenced by niche separation and adaptation to reservoir conditions. The field measures have been taken every second year (although some of the plots are also re-measured in the CLBMON-12 project on staggered years). The inclusion of the CLBMON-12 data in the analysis has been important in evaluating the influence of water behaviour on the vegetation. The CLBMON 33 field measures coincide with the aerial photography, which has been captured every second year. However, the 2007 and 2008 aerial photographic captures differ somewhat from the 2010 and 2012 captures. In 2007 the aerial photographs were captured in early spring, whereas the field data were collected in fall. In 2008 the aerial photographic captures occurred when the reservoir was partially inundated and half the study area was under water. Field data in 2008 were complete but the aerial photographic data were only available for higher elevation portions of the reservoir. More complete imagery, timed to occur during the field data capture, was available for interpretation in 2010 and 2012. The initial analytical design included box plotted comparisons of the field measures and principal components analysis (PCA) of the vegetation measurements and environmental variables. Changes in the mapped data were evaluated using the Kappa statistic, applied to randomly selected polygons. Repeated measures ANOVA and redundancy analysis (RDA) with forward selection replaced PCA as a means of identifying which variables accounted for variation in the vegetation cover, heights and distribution codes over time (Enns, 2010).

2.2 Field Work

Plots were randomly selected for sampling in 2007 to 2009 to establish a baseline dataset, and reassessments of previously established plots began in 2008, with new plots added each year up until 2010 when the power analysis indicated the number of plots was sufficient. A total of 400 field plots (out of a potential 600) were sampled in 2012 (Table 5). All 2012 field plots had been previously assessed at least once. Plots were located within individual VCTs in the polygons and not outside polygons or across VCTs. Originally, all polygons had been selected randomly for field sampling, but in some cases, we selected specific VCTs to reassess in 2010 to increase the sample size for VCTs that had previously been undersampled. Appendix 1 shows the numbers of field plots completed in each year.

In 2012, on the advice of Dr. Schwarz (pers. comm., 2012), we aimed for an even distribution of plots among the three elevation classes (434 m to 436 m, 436 m to 438 m, and 438 m to 440 m) for each VCT. We tried to include as many of the 43 study areas as possible, but some could not be sampled because of access constraints. The field work in each location was repeated on a similar schedule as previous years in an effort to sample similar phenological stages.

Table 5. **Number of field plots sampled in each VCT within elevation bands, in Arrow Lakes Reservoir, CLBMON-33 in 2012**

VCT	Elevation Band			Total
	434-436	436-438	438-440	
Diagnostic VCTs				
BE	23	18	15	56
BG	18	20	17	55
CR	DNO	DNO	30	32
PA	DNO	23	26	47
PC	34	35	30	99
PE	23	17	DNO	40
RR	5	5	5	15
Less common VTCs				
IN	11	10	10	31
BB	3	4	3	10
CL	DNO	DNO	1	1
PO	0	1	0	1
RS	1	3	0	4
SF	1	0	0	1
SS	5	0	1	6
WR	1	0	0	1
WS	0	1	0	1
Total	125	137	138	400

DNO = VCT does not occur at this elevation

The GPS locations and field data for all plots had previously been recorded in a Nomad 800L GPS unit with SX Blue Differential. Maps of each study area showing previous plot locations were prepared and placed in a folio for use in the field. Pre-field orientation, field training, safety procedures and field standardization were completed by the field crew prior to the start of field data collection.

Calibration and standardization of vegetation cover estimates and height measurements were done on May 14, 2012, and reviewed during every week of field work. Field data, including specimens from previous years' work, were referred to in the field. A field audit by BC Hydro took place on May 29, and the field audit document was received on September 29, 2012. Table 6 shows the dates of activities in the field and after field work for the CLBMON-33 project.

Table 6. Chronology, CLBMON-33, 2012

Action	Date
Preparation for the field and documentation	February – May 2012
Aerial photographic capture (Terrasaurus Inc.)	May 16 and 17, 2012
Field assessment of vegetation plots, field truthing of the 2007 mapping, collection of data for image comparison.	May 14 – June 17, 2012
Safety and field practices audit	May 29 2012
Field data archiving, cleaning and data entry	June – July 2012
Orthorectification and aerial photograph mosaic creation (Terrasaurus)	August 24 -- 30 2012
Photo review, field data records compilation, data review, data screening, plotting for non-linearity, etc.	September 2012
Data collection from the imagery, biometrics and writing	September – October 2012

To ensure consistency, field data were collected in a similar fashion as in previous years. Once the plot boundaries were laid out, photographs were taken of the vegetation and surroundings, and all species present within plot boundaries were recorded. We referred to the previous data record for particular plots as needed. Percent cover of each plant including mosses and lichens was recorded. Covers less than 1 percent were recorded as <1 per cent (as opposed to 0.5 percent, 0.01 percent, etc.). In 2010 we assumed at the beginning of the field season that species with less than 3 percent cover could be excluded from the record. However, we found that doing so would exclude over half the species in many VCTs. Therefore, species were recorded regardless of how sparse their cover; this practice was also observed in the 2012 field survey.

Average maximum heights of each species were measured to the nearest ten centimetres for dominant individuals or clumps, for heights up to 3.5 m. We estimated heights higher than 3.5 m at 1.0-m intervals, using a 2-m measuring stick for reference and standing at a distance from the subject vegetation. The vertical projection of each species cover value was estimated using the per cent cover guide from "Describing

Ecosystems in the Field" (Luttmerding *et al.* 1990) Canopy cover was estimated separately from ground level cover, so cover estimates in plots with a canopy can exceed 100 %.

Distribution codes were used to describe dispersion of each species, also using the codes described in Luttmerding *et al.* (1990) (Figure 3).

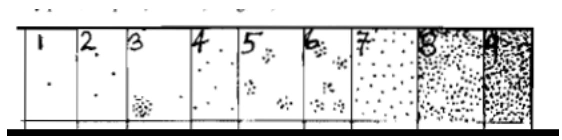


Figure 3. **Distribution codes used in the field to describe dispersion of species (taken from Luttemerding *et al.* (1990)**

Soils from the rooting layer in each plot were textured by hand in the field. Photographs of completed plot forms were then taken.

The field data were downloaded weekly into a GIS database, and photographic records were taken of each field form on the same day the data were collected.

Species identification was done daily, with reference to the plant collection for the project and use of taxonomic keys. Some species have had taxonomic name changes or splits into new species since the start of the project (e.g., the genus *Aster* is now split into various new genera; the genus *Hieraceum* has several new species; some species of *Disporum* are now in the genus *Prosartes; Smilacina* species are now placed in the genus *Mianthemum*; and some *Polygonum* species have been reclassified as *Persecaria*). In ambiguous cases, field names were used and the database corrected to match the most recent taxonomy. These data were used to complete field records in the database. Field forms were corrected daily, and prepared for data entry during field work. The species list for 2012 is provided in Appendix 2.

Most plots were resampled over time and compared using data from both CLBMON-33 and a companion project with similar field methods, CLBMON-12 (Arrow Lakes Reservoir Monitoring of Revegetation Efforts and Vegetation Composition Analysis).

VCTs with very low vegetation cover were not extensively resampled in 2012. Previously sampled low-cover VCTs with only a few small plants in them were recorded and photographed, but were not included in the comparisons over time unless they had more than three per cent cover. The same procedure was used in 2010. In the final year of work on this project, non-vegetated and very sparsely vegetated VCTs will be reassessed and compared to their baseline condition. Figure 4 shows the general locations of the field plots.

The methods used in CLBMON-33 are based on an adaptation of field and aerial photographic methods developed by Keser (1976) and Luttmerding *et al.* (1990). Aerial photography of the reservoir was captured in 2007, 2008 (incomplete due to high water), 2010 and 2012 (dates given in Section 2.3). In 2007 and 2008, the photography was film-based. In 2010 and 2012, the photography was digital. The change to digital photography resulted in higher-resolution imagery and truer colour. A total of 43 areas defined by BC Hydro were surveyed (Enns *et al*. 2007).

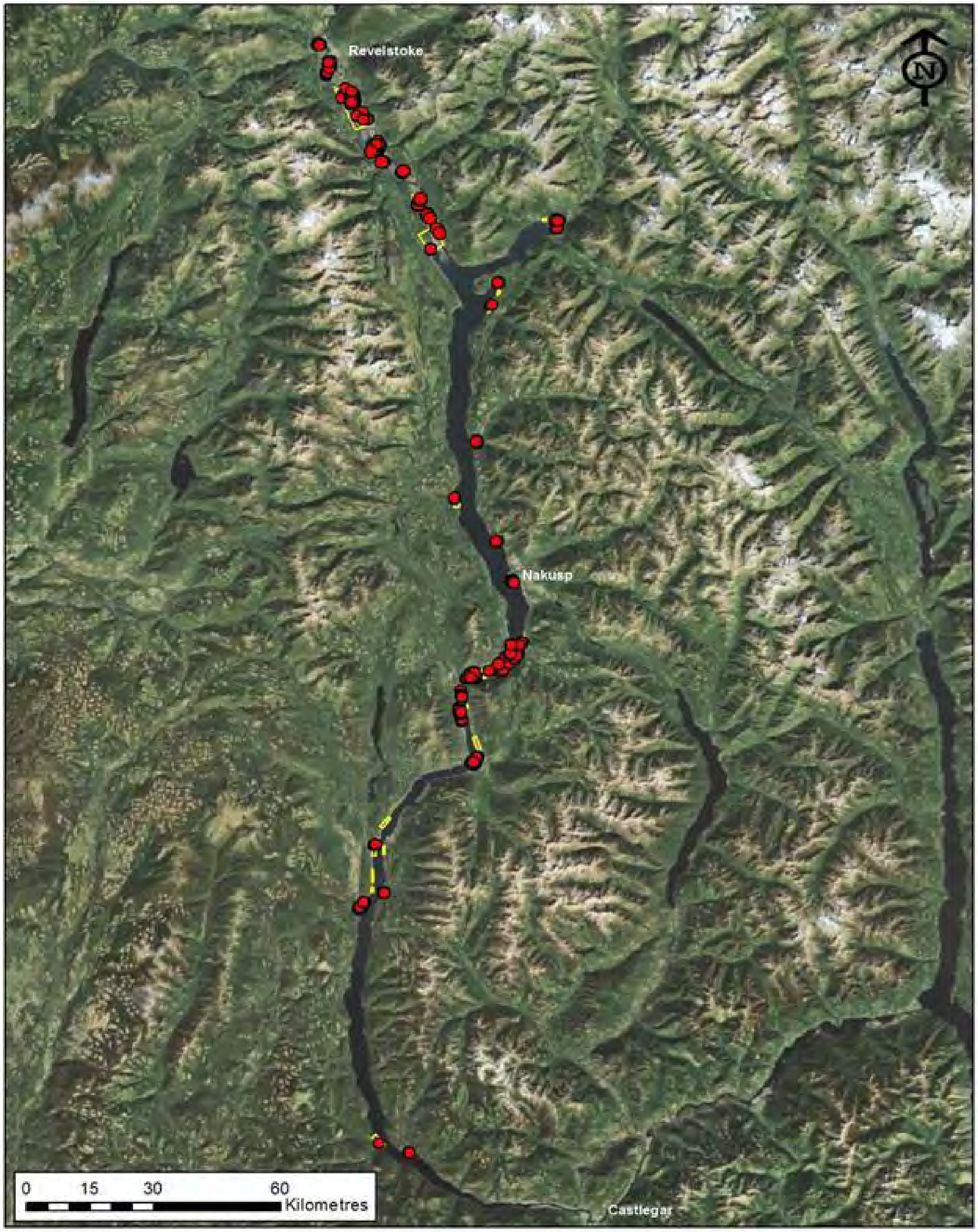


Figure 4. **General location of field plots completed in 2012 within study areas in the Arrow Lakes Reservoir for the CLBMON-33 project. Red dots are plot locations (plot locations overlap due to scale). Yellow lines identify areas sampled in previous years that were not resampled in 2012.**

Following the image capture in 2010, the photography was stitched together electronically to make mosaics for each section of the monitoring area between Deer Park and Revelstoke. The mosaics were orthorectified to fit a digital elevation model. In 2010 extensive triangulation was done to make sure the orthophoto mosaics accurately fit the topography of the reservoir. The mapping line work (delineation) and mapped classification of the VCTs had been developed and applied in 2007 and 2008, when the VCTs were identified within each polygon. In 2012, these data were overlain on the current imagery. Corrections to the past line work are underway. These include joining neighbouring polygons that were originally drawn too small or were discovered in the field to be similar. The corrections are necessary because the line work had been applied in 2007 without adequate field access to the map area.

2.3 Post-field Work

Archived soil samples collected in 2010 were textured using mesh sieves to obtain a more accurate particle size than hand texturing in the field. Comparisons were made between the hand textured samples that had also been sieved (data not shown). The particle size sieving was done following field work, in late June 2012.

Database entry was reviewed in-house prior to spreadsheet compilation. On th advice of the project statisticians, the CLBMON 33 and CLBMON 12 project databases have been merged into a single multiple year, multiple field Access database. (It is still feasible to analyze the projects separately). Data from 2012 were entered such that each species in each plot had a separate line in the database, and that line included all plot data, as well as the species cover value, maximum height, and distribution.

The database includes life form codes for species and a classification for plots with very low cover (less than three per cent).

Each field plot was assigned a climatic regime from one of four possible meteorological stations, using the weather data supplied by Environment Canada[2]. The meteorological stations were Revelstoke Reach, Nakusp, Fauquier and Castlegar.

There were three elevation bands: 434 m to 436 m, 436 m to 438 m, and 438 m to 440 m (BC Hydro 2005, Grau and Walsh 2007). Most plots were oriented with the long axis parallel to the contour lines in the mapping, and few plots overlapped between two elevation bands.

2.4 Imagery data collection and database extraction

Digital colour aerial photography of the 43 study areas, at a scale of 1:6,000, was captured using a medium format digital camera mounted with a long lens. The digital image data capture took place on May 16–17, 2012, during the CLBMON-33 field work. The same growth stage was captured as in 2010, when data capture was done on May 11–15. The water was below the minimum elevation required for data collection (434m)

2

http://climate.weatheroffice.gc.ca/advanceSearch/searchHistoricData_e.html?Prov=AB&StationID=9999&Year=2012&Month=10&Day=15&timeframe=1

and lower than it had been when the imagery was taken in 2010. The imagery was captured at a 10 cm scale during sunny to overcast conditions. The general locations of the areas of capture were based on vegetation polygon shapefiles supplied to the pilot. The imagery was triangulated using horizontal and vertical controls supplied by BC Hydro and in-flight GPS control points recorded in 2010. The mosaics were stitched together and orthorectified to fit the digital elevation model (DEM) using the 2010 control points along with some new control points obtained in 2012, especially from higher elevation areas where the existing DEM was inaccurate. The digital imagery was delivered at the end of August in RAW and 16 bit TIFF formats. The images were used directly in ArcMap software without further processing. The relationship between stationary objects in the 2007, 2010 and 2012 images was verified and colour matching was checked between the 2010 and 2012 images.

A series of overlain clips of individual polygons, selected during the power analysis in 2010, were compared between 2010 and 2012 to assess changes in vegetation over time (Figure 5). In some cases, trends over the whole photo series (2007, 2008, 2010 and 2012) were observed if the subjects were visible in 2008 and not too dark in 2007. The 2010 report (Enns *et al*. 2010) includes consideration of differences in polygons between 2007 and 2010. Some of the 2010 images could not be compared with 2012 because of poor resolution or differences in shadows and lighting between the two years of photography (2010 vs 2012). However, all vegetation types were assessed in polygons with clear and comparable resolution and colouration.

Three measures were taken during polygon review: 1.) changes in vegetation cover in deciles (by VCT), 2.) height increments by decimeter to 0.5 meter, and 3.) changes in distribution of the vegetation within the VCT using the codes illustrated in Figure 4. Each randomly located polygon was observed at various scales, ranging from 1:500 up to 1:20,000, and an attribute table was created for the individual records. Up to three VCTs can exist in a polygon. A total of 264 polygons and 2,242 VCTs were compared for changes between 2010 and 2012 (Figure 5, Table 7).

The sample size of some VCTs differed from 2010 to 2012 (Table 7) because a few VCTs were either larger or no longer present in the assessed polygons in 2012, due to vegetation growth, materials scouring or deposition of sand. Sample sizes in some other VCTs were small because these occurred infrequently in the mapped study areas. For example, PO: Ponds occurs fewer than five times in the entire study area.

Another 250 polygons were informally compared to determine if a change in vegetation cover or changes in heights of the vegetation had occurred in a pattern different from the main matrix. Observations were recorded as “yes” if there were changes and “no” if there were not (data not shown). A review of the mapped classification and line work of the vegetation was done post-field using the 2012 imagery, field data and photographs. Changes to the mapping (i.e., corrections of errors in the original classification) are in progress. These changes to mapping are not to be confused with shifts in VCT classification due to plant successional changes in response to the operating regime and other factors.

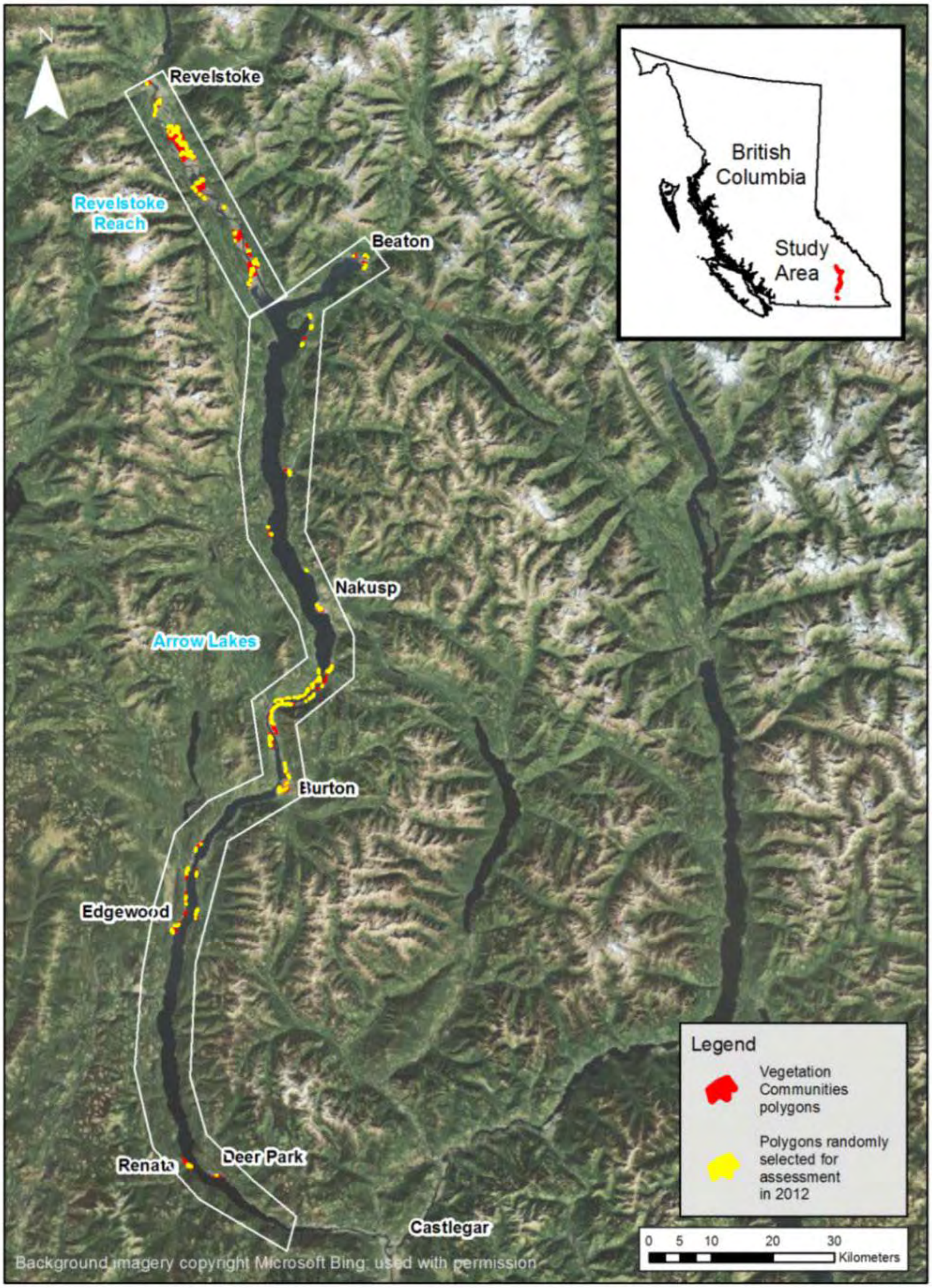


Figure 5. **Locations of the 264 polygons compared for changes in VCT features between 2010 and 2012**

Table 7. Number of VCTs compared between 2010 and 2012

Count of VCTs Compared in 2012			
TYPE	2010	2012	Grand Total
BB	19	19	38
BE	233	233	466
BG	136	136	272
CR	83	83	166
IN	62	62	124
LO	32	32	64
PA	174	176	350
PC	279	281	560
PE	102	102	204
PO	3	3	6
RR	63	63	126
RS	14	14	28
SS	3	3	6
WR	7	7	14
Grand Total	1210	1214	2424

2.5 Data Analysis

Both the map data and the field data were analyzed. The map data were examined for changes between 2010 and 2012. The field data were examined for changes between 2010 and 2012, but also between 2007 and 2012 by comparing repeated plots.

The vegetation structure and composition from the field plot data were compared using boxplots compiled in JMP (version 10.0.0, copyright SAS Inc. 2012). Boxplots show the distribution of data within a set of samples (Figure 6).

Vegetation covers and heights of selected VCTs in Revelstoke Reach were compared to the vegetation covers and heights of selected VCTs in the Arrow Lakes portion of the reservoir. We used ANOVAs to test for significant differences in average covers and heights of leading species in each VCT. Tests of the hypothesis of no differences in overall VCTs site-wise over time (from 2007 to 2012) were also done, using Repeated Measures Analysis (RMA). ANOVA post hoc comparisons done using Tukey's HSD test were used to identify differences in the mean response among VCTs by elevation band to show how vegetation has responded to the depth and duration of inundation over time. These measures are an indication of the effects of the soft constraints operating regime.

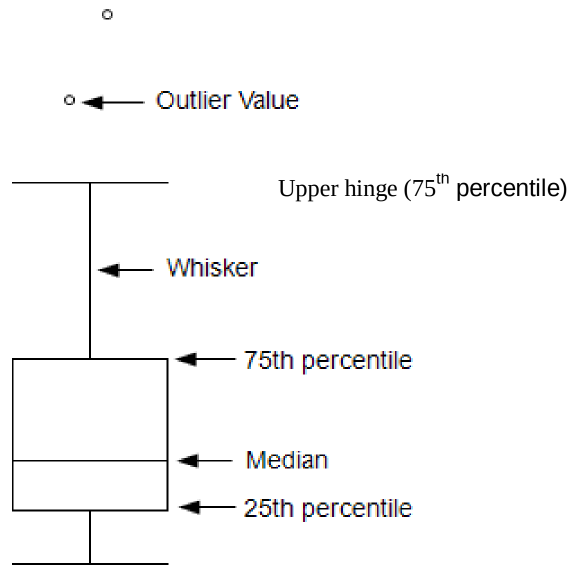


Figure 6. **Example of a boxplot. Boxplots show a compact view of a variable's distribution, including quartiles and outliers. The line at the centre of each box represents the median point in the data set. The top and bottom of the box are the 75th and 25th percentiles, respectively, and are called the hinges. Hollow circles indicate values outside the inner and outer fences of the data distribution and are potential outliers (McGill *et al*. 1978).**

Shannon-Wiener Diversity Index was calculated for landscape-level analyses of diversity:

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

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

Pielou's Evenness Index (J) was then calculated:

$$J = H'/H'_{max} = (-\Sigma\,(p_i \ln p_i))/ \ln q,$$

where q is species richness (or the total number of species in each VCT).

The H' and J indices were calculated in a similar fashion for each elevation band, based on total numbers of occurrences of all species in each elevation band and the species richness by elevation band, respectively.

In addition to the decile change data, we compiled data from the vegetation base map for use in map statistics. The map database contains polygon vegetation records, as well as environmental attributes for each sample polygon (Enns *et al.* 2007). Aerial photographic interpretation was used to compare the differences in vegetation height and cover in selected polygons between the 2010 and 2012 imagery, at the landscape scale.

A power analysis had determined the number of polygons required to detect a decile (or more) change for each leading VCT in 2010 (Omule and Enns 2010). In the 2012 dataset, the same polygons were used, but all VCTs in them were recorded in the matrix. The number of VCTs assessed was greater in 2012 than in 2010, but the polygons were not as widespread. Therefore, an additional 250 polygons were checked for changes in vegetation height and cover (data not shown).

The base map has complex polygons (each with up to three VCTs). Each polygon was assigned an individual polygon ID. The VCTs were described based on these original polygons. As in 2010, the splitting of polygons by elevation band during the comparisons proved to be prohibitively complex and error-prone. Therefore differences in VCTs by elevation (i.e., responses to the soft constraints operating regime) were examined using plot data only (see repeated measures analysis below). For each polygon, vegetation cover, height, and distribution data recorded in 2010 and 2012 were coded for comparison between years, as described below. The map analysis was based on an adaptation of the confusion matrix approach (Congalton and Mead 1983). The Kappa statistic (coarse grained analysis) was used:

$$K = \frac{P_o - P_c}{1 - P_c}$$

where P_o is the proportion of observed agreements and P_c is the proportion of agreements expected by chance (Sim and Wright 2005). Theoretically, the range of possible values of Kappa is -1 to 1. The value 1 represents perfect agreement in codes between 2010 and 2012 (i.e., no change). A value of 0 indicates agreement no better than that expected by chance. A value of -1 indicates agreement worse than that expected by chance. Negative kappa values are very rare in practice; thus, the range of K is between 0 and 1, and in most significance tests the lowest value $K = 0$ is assumed as a null hypothesis. For the purposes of this report, a null hypothesis means that there *have* been changes in vegetation cover, height or distribution codes in a VCT between 2010 and 2012. Note that the distribution codes were based on the Daubenmire cover scale for cover and half metre increments for the height variables (Mueller-Dombois and Ellenberg 1974).

The confusion matrix for each variable is square, and its rows and columns are constructed based on the codes of the variables, with the 2010 codes being the rows of the matrix and 2012 codes being the columns. The matrix cells are populated with polygon frequencies. For example, if the code in a polygon changed from a decile of 5 to a decile of 8, then it would go into the cell defined by row 5 and column 8. If there is no code change in any of the polygons, then all frequencies would line up along the diagonal of the matrix. The Kappa statistic is estimated and a test of the null hypothesis of no agreement between 2010 and 2012 codes ($K = 0$) is performed.

The analysis was done by constructing matrices from the raw map cover and height data, and calculating the simple Kappa statistic, as well as a test of no agreement at alpha = 0.05. The VCT codes for cover were used and compared between 2010 and 2012. We compared only the VCTs that occurred in the polygon dataset, and only those that were thought to be influenced primarily by the Arrow Lakes Reservoir water behaviour, and not by feeder streams and rivers, all terrain vehicles, or industrial activity. As coded data were considered coarse grained, and the image clarity from 2010 allowed a more detailed assessment of cover of vegetation within VCTs, a further analysis of change was used. This analysis was based on cover and height estimates for 2010 and 2012 of vegetation within VCTs, and used the same database as the Kappa statistic.

ANOVAs using a linear mixed-effects model (LMM) were used to test for no significant differences in cover and height between 2010 and 2012. The potential fixed effects of interest were geographic area (Arrow Lakes or Revelstoke Reach), VCT, elevation band and year (2010 and 2012). The elevation bands and the water level data, by year, are surrogates for the differences in depth, timing and duration of inundation by year in the reservoir.

The mathematical form of the fitted full LMM was:

$$y_{ijk} = \mu + VCT_i + Year_j + VCT_i \times Year_j + \rho_K + \varepsilon_{ijk} \quad [1]$$

Or:

$$y_{ijk} = \mu + Elevation_i + Year_j + Elevation_i \times Year_j + \rho_K + \varepsilon_{ijk} \quad [2]$$

where y_{ijk} represents the observation of vegetation cover or height in the *k*th polygon in the *i*th VCT or Elevation Band; μ is the overall mean of the observations; ρ_K is the random effect of the *k*th polygon and ε_{ijkm} is the random error associated with the measurement in year *j* and in the *k*th polygon.

Random effects were assumed to be independent and normally distributed with mean zero, with a unique variance component. Model [1] was for comparisons among VCTs for each elevation band and model [2] for analyses by VCT. This allowed for tests for no significant differences in changes of areas of VCTs within polygons over time.

Plots were assigned to an elevation band for ANOVA, and a more precise centroid elevation for the redundancy analysis, according to the digital elevation model (DEM) based on the location of the plot corners acquired in the field with the Nomad 800L GPS latitude.

Canonical Redundancy Data Analysis (RDA) was used to relate polygon vegetation attributes (Y, dependent variables) to environmental attributes (X, independent variables). The RDA used the centroid UTM coordinate of the plot as the elevation for the plot. RDA performs a principal components analysis on fitted values of Y, and produces canonical axes and eigenvectors. Each axis corresponds to a direction related to a linear combination of the X variables. The eigenvectors give the contributions of the X variables (and predicted Y) to the canonical axes. The eigenvectors are then used to produce RDA ordination biplots. The analyses were done separately for each geographic area, using SAS (version 9.3, 2012). The multiple yearly measurements on each plot/polygon were analyzed using RMA. The model fit similar to the above ANOVA structure where ρ_K is the effect of the kth polygon which is assumed to have a normal distribution with variance εp. This induces a compound-symmetric covariance structure on repeated measurements; i.e., measurements on the same plot are assumed to have the same correlation across any pair of years. Alternate covariance structures were explored but the compound symmetric structure was nearly always suitable and so has been used throughout.

The advantage of using the compound-symmetric covariance structure is increased power to detect changes over time compared to the unstructured covariance pattern typically assumed in ordinary repeated-measures design. As well, this covariance pattern can also deal with missing values (e.g., a polygon missing some of the yearly measurements) without having to delete the entire set of data for a polygon, which typically happens in the standard repeated measures analysis.

3.0 RESULTS

The 2012 results for CLBMON-33 are presented in relation to the management questions, and a summary is provided in Section 3.7.

3.1 Question 1. "What are the existing vegetation communities in the Arrow Lakes Reservoir drawdown zone between 434 and 440 metres?"

This management question was addressed in previous reports (Enns *et al.* 2007, Enns *et al.* 2008, Enns *et al*. 2010) by referring to the mapping and describing the existing vegetation. In 2012, as in 2010, we verified and refined the characteristics of the VCTs, and monitored changes in their heights and cover values over time.

The distribution of the VCTs with respect to elevation is shown in Figure 7. The characteristics of the VCTs were based primarily on patterns in landforms, including slope, topography, parent materials, soil textures and hydrology, but also on species composition (Enns *et al.* 2007). For example, gently sloping, sandy alluvial fans were physically different from steep exposed boulder till deposits and supported different vegetation. Boulders could have sparse but persistent, often tall weedy perennial vegetation. Sandy alluvial fans were often dominated by short, newly germinated annual species, with some drought- and inundation-tolerant perennials. Many of the VCTs shared similar dominant species, but all VCTs had a number of diagnostic or associated species assemblages typical of the VCT.

Stream and river channel confluences into the main stem of the Columbia River determined the species composition of a few VCTs (such as WR: Silverberry river entry and RS: Willow stream entry) to a greater extent than the Columbia River did. In RR: Reed-rill, small streams that have been cut off from their older beds due to the creation of the reservoir formed emergent underground streams, with species typical of freshwater seepage tracts, such as yellow monkey-flower and river ragged moss). Very old (post glacial) serpentine fluvial channels and oxbows were the origin of PO: Ponds; these had a distinct assemblage of species including the floating-leaved pondweeds. At the landscape level, however, most VCTs were distinguishable by physiography and by the colour and texture of their typical vegetation.

Seven VCTs were common throughout the reservoir. (The characteristics of these are shown in Table 3, Section 1.2). Each VCT had a typical soil moisture and nutrient regime, similar to the site series concept described in Ecosystems Working Group (1998). However, each VCT had at least one or two characteristics that were the result of periodic inundation. For example, PE: Horsetail lowland had some wetland characteristics but was compacted and anoxic. Sandy headlands and bays had characteristic sandy VCTs, such as BE: Sandy beach, and BG: Gravelly beach. Due to the shape of the deposits, these were likely sandy or gravelly textured tills before the construction of the dams. Further, the vegetation in these VCTs is continually influenced by shifting sand and deposition of silt, as well as by invasions of plant seed and vegetative propagules from upstream.

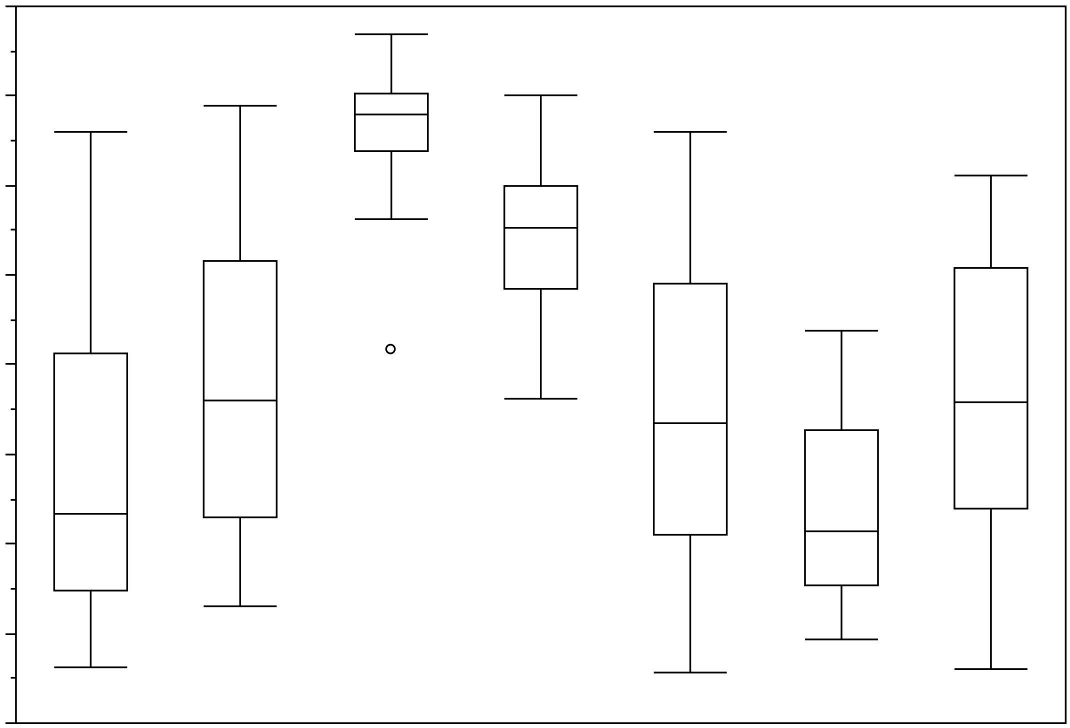


Figure 7. **Typical elevation spread of VCTs in the Arrow Lakes Reservoir. Only those VCTs with greater than three per cent cover of vegetation, sufficient sample size for meaningful comparisons (Omule and Enns 2010) and assumed to be primarily influenced by the soft constraints operating regime are shown; BE = Sandy beach, BG = Gravelly beach, CR = Cottonwood riparian, PA = Redtop upland, PC = Reed canary grass mesic, PE = Horsetail lowland, RR = Reed-rill.**

No new vegetation communities were identified in either the fieldwork or from the map analysis in 2012[3]. Variation within and among species compositions of VCTs has been described in CLBMON-12 (Enns *et al.* 2010, Enns *et al*. 2011), and no departures from the previously described mapped classification were recorded in 2012.

Some VCTs were not sampled extensively in either 2010 or 2012, other than to record changes that may have taken place since 2008 in comparison to previous data and photographs. These were VCTs that have remained almost completely non-vegetated since 2007, or have been influenced by factors other than the soft constraints operating regime. These VCTs include BB: Boulders, VCTs influenced by standing water or incoming rivers (PO: Ponds; SS: Steep sand; RS: Willow stream entry; WS: Silverberry river entry), and VCTs where industrial effects were common (IN). However, IN was sampled extensively during CLBMON-12 field work, as treatments are common in that VCT.

[3] A number of new species were found, however.

Management Question summary: Fifteen landscape-level vegetation communities in the Arrow Lakes Reservoir drawdown zone occurred between 434 and 440 metres.

- Each VCT occurred within a specific elevation range. Some were spread more broadly over elevations than others.
- Each VCT had a specific soils and vegetation character.
- No new VCTs were found in 2012.
- Seven VCTs occurred with enough frequency across the reservoir to provide a measure of response to the soft constraints operating regime. These were BE: Sandy beach, PC: Reed canary grass mesic, PA: Redtop upland, PE: Horsetail lowland, BG: Gravelly beach, RR: Reed-rill and CR: Cottonwood riparian.

3.2 3.2 Question 2. "Is the current distribution of vegetation communities in Revelstoke Reach representative of the conditions in the remainder of the reservoir?"

This question was answered in Enns *et al* 2010. The two geographic areas are not the same; Revelstoke Reach has fewer VCTs than the Arrow Lakes, due to its colder and wetter climate and finer textured soils.

3.3 3.3 Question 3. "What are the spatial extents and structure of these communities within the drawdown zone between 434 and 440 metres?"

The VCTs in the Arrow Lakes Reservoir showed distinct patterns in average maximum vegetation heights and total cover in relation to elevation. These patterns have been discussed in previous reports, and they have not changed very much since the earliest of the reports (Enns *et al.* 2007, Enns *et al*. 2008, Enns *et al.* 2009, Enns *et al.* 2010, Enns *et al.* 2011). In both the Revelstoke Reach and Arrow Lakes portions of the reservoir there was a tendency for cover to increase with elevation, but there was a lot of variation when the VCTs were combined (Figure 8).

The results of a two-factor analysis of variance for total vegetation cover and average maximum vegetation height are shown in Table 8. Significant results have a *p*-value < 0.05 and are shaded. When considering total cover by reach only, a significant difference between Revelstoke Reach and Arrow Lakes was detected. When comparing within elevation bands for the entire reservoir, total cover increased significantly with elevation. There was no significant interaction effect between elevation band and reach on the total cover. In the lowest elevation band (434 m to 436 m), there was no difference in total vegetation cover between reaches. Total cover in the middle elevation band (436 m to 438 m) was significantly higher in Revelstoke Reach than in the Arrow Lakes.

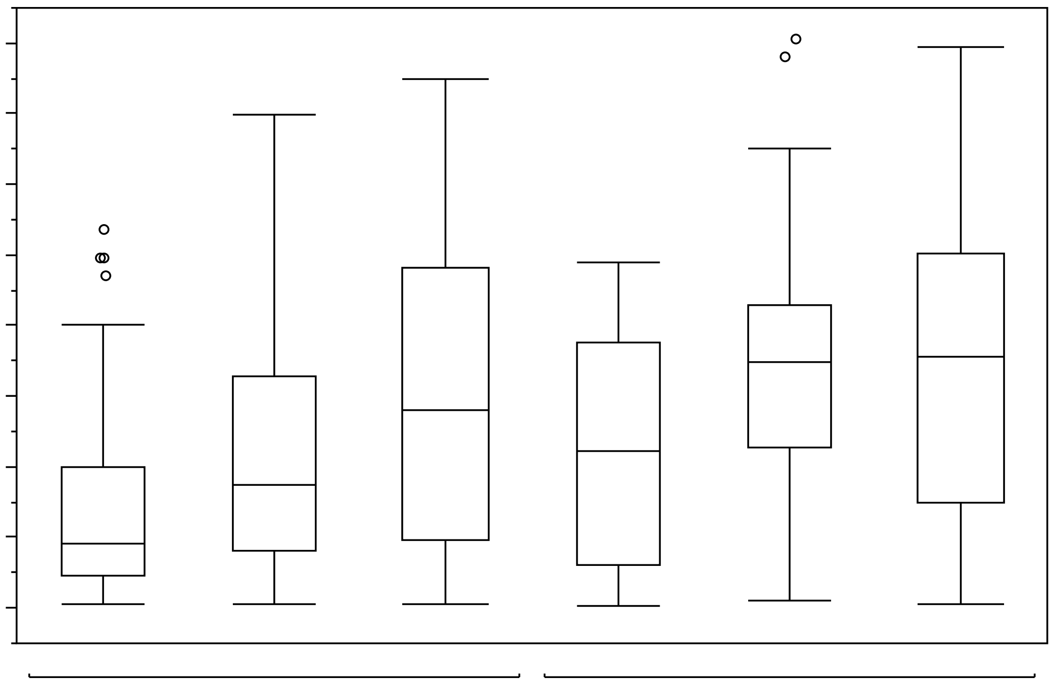


Figure 8. **Total cover of vegetation in three elevation bands (434 m to 436 m, 436 m to 438 m, and 438 m to 440 m) in the Arrow Lakes and Revelstoke Reach portions of the Arrow Lakes Reservoir, 2012**

Table 8. **ANOVA results for total vegetation cover and average maximum vegetation height by reach, elevation band, and reach x elevation band. Significant results have a p-value < 0.05 and are shaded.**

Effect Tested	**P-value**	**Result**
Total Cover by Reach	0.0001	Significant
Total Cover by Elevation Band	0.0001	Significant
Total Cover by Reach x Elevation Band	0.0910	Not Significant
Average Maximum Height by Reach	0.4586	Not Significant
Average Maximum Height by Elevation Band	0.0001	Significant
Average Maximum Height by Reach x Elevation Band	0.0105	Significant

Average maximum height by elevation band and reach is plotted in Figure 9, illustrating differences in height between elevation bands and between reaches.

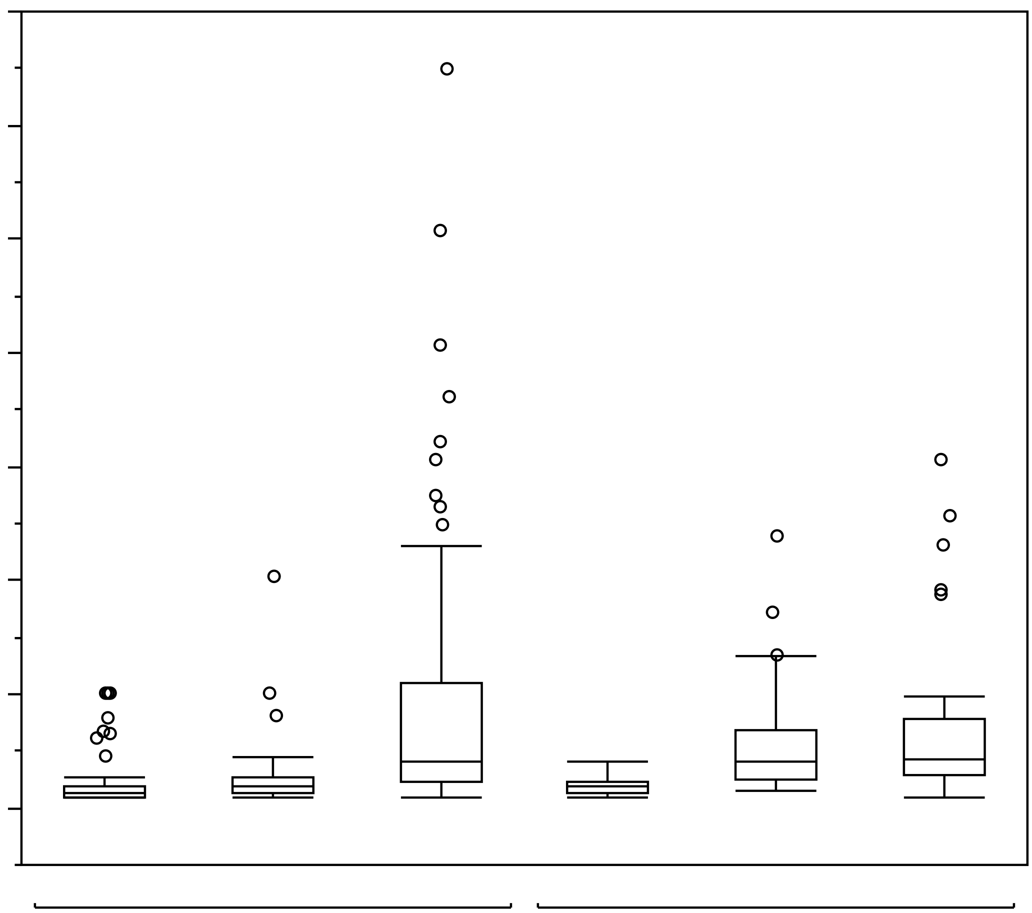


Figure 9. Total heights of vegetation in the three elevation bands (434 m to 436 m, 436 m to 438 m, and 438 m to 440 m) in the Arrow Lakes and Revelstoke Reach portions of the Arrow Lakes Reservoir, 2012

When comparing among elevation bands over the entire reservoir, average maximum vegetation heights were significantly higher with increasing elevation. There was also a significant interaction between elevation band and reach. As with previous years' observations, the VCTs confined to lower elevations, such as PE: Horsetail lowland, had lower vegetation heights than the communities confined to higher elevations, such as the tree- and shrub-dominated PA: Redtop upland and CR: Cottonwood riparian VCTs. The lower-elevation PE: Horsetail lowland VCT often had high cover of inundation-tolerant or inundation-dependent vegetation. For VCTs that extend across all elevations, heights and covers tended to increase with increasing elevation, but declined at the highest elevation if scouring from waves and log movement occurred during winter (Enns *et al.* 2009).

Management Question summary: The spatial extents (cover of types and cover of vegetation within types) and structure (heights) within the drawdown zone between 434 and 440 metres had the following statistically significant patterns:

- Total Cover by Reach: Revelstoke > Arrow;
- Total Cover by Elevation: 438 to 440 m > 436 to 438 m > 434 to 436 m;
- Average Maximum Height by Reach and Elevation: Arrow 438 to 440 m > Rev 438 to 440 m > Rev 436 to 438 m > Arrow 436 to 438 m = Arrow 434 to 436 m = Rev 434 to 436 m (ANOV results: Appendix 3).
- Total Cover did not differ significantly by Reach and Elevation Band, and Average Maximum Height did not differ significantly by Reach.

The vegetation composition within the drawdown zone between 440 and 434 m is discussed in Question 5.

3.4 Question 4. "How do the spatial limits (cover), structure (height) and composition of the vegetation communities relate to elevation and the topo-edaphic site conditions (aspect, slope and soil moisture, etc.)?"

We used RDA with forward selection to answer this question (Figures 10 and 11). Using field data from 400 plots, we examined relationships between spatial extent (total cover of vegetation in the VCT), structure (average maximum height) and the set of environmental variables described in Table 9. The values for a set of weather and water inundation variables were determined for each of the plots based on their location in the reservoir.

Environmental variables included number of days exposed, number of days inundated, and total accumulated precipitation when exposed, as measured at the nearest meteorological station. The exposure regime variables included climate data from four weather stations: Castlegar, Fauquier, Nakusp, and Revelstoke. Plots were assigned to each weather station based on proximity and the BC Forest Service Biogeoclimatic Classification (Braumandl and Curran 1992). We had identified the importance of the soils of the reservoir in retaining vegetation in 2010. Therefore, soil sieve data and coarse fragment content measurements for each plot were included in the RDA.

The redundancy analysis results were similar to those of previous years but accounted for higher variation due to the use of true elevation and more site-specific climatic and soils data. In Arrow Lakes the presence of clay and silt in soils was associated with the retention of vegetation cover. The tallest vegetation occurred at the highest elevation, in the shrub- and tree-dominated PA: Redtop upland and CR: Cottonwood riparian VCTs. Height was positively correlated with higher average annual temperatures. Similarly, the longest duration of exposure time above the water line was important in retaining cover and height in the vegetation of the Arrow Lakes portion of the reservoir.

Table 9. Environmental variables measured or estimated from the mapping for each plot used in the RDA analysis for VCTs of the Arrow Lakes Reservoir. Sand, silt, and clay texture estimates are indicative of soil nutrient and moisture regimes.

Environmental Variables	Units/ Classes
Elevation	Metres above sea level of the centroid point in the plot
Terrain texture (estimates of moisture and nutrient classes)	% boulders, gravels, sand, silt, clay
Temperature	Average air temperature in degrees Celsius during exposure
Precipitation	Accumulated precipitation during exposure
Scouring	Obvious removal of soils or materials by water action
Exposure water	Water supplies from upslope, from stream or river input to reservoir
Sheltering	Topographic shelter upstream (promontory or gravel deposit)
Exposure time	Amount of time in days that the plot was exposed and above the water line
Inundation time	Amount of time in days that the plot was inundated and below the water line
Wave action	Evidence of wave action on materials and plants in the plot.

The variables responsible for variation in vegetation were similar between the Revelstoke Reach and Arrow Lakes. Gravels, boulders, scouring, wave action, exposure to incoming streams and rivers and sandy substrates all negatively influenced height and cover in both portions of the reservoir. The RDAs accounted for 93 per cent of the variation in vegetation average cover and average maximum heights in Arrow Lakes, and 86 per cent of the variation in Revelstoke Reach. In previous RDAs (Enns, 2010) the variables slope and aspect had been consistently eliminated, and therefore were not included in this year’s analysis. As there was very little variation in slope among the VCTs, and most were between 0 and 5%, the influence of slope and aspect may not have been as important as in some other vegetation studies.

The RDAs showed that vegetation cover was negatively correlated with boulders, gravels and sand, scouring, wave action, and exposure to creek and river input from above the reservoir. All of these variables are indicative of inhospitable substrates for plants, except sand. Cover is not really linked with sand because there are several species of plants that can form very high cover of seedlings on sands if the site is sheltered and moist. However, if sites are not sheltered and moist, seedlings may germinate but they are very quickly killed.

Vegetation height increased with increasing temperature, which is related to time elapsed prior to inundation at high elevation. Sites that are exposed for longer periods of time have the advantage of being above water when the weather is warm. The low-elevation sites are covered by the second week of June, usually.

Sheltering topography and nutrient-rich soils (silts and clays) were important in retaining vegetation cover. Vegetation average maximum heights were positively correlated with a long exposure time, due to the presence of taller shrub-dominated vegetation in PA: Redtop upland and CR: Cottonwood riparian VCTs at the highest elevation (Correlation Matrices are included in Appendix 3).

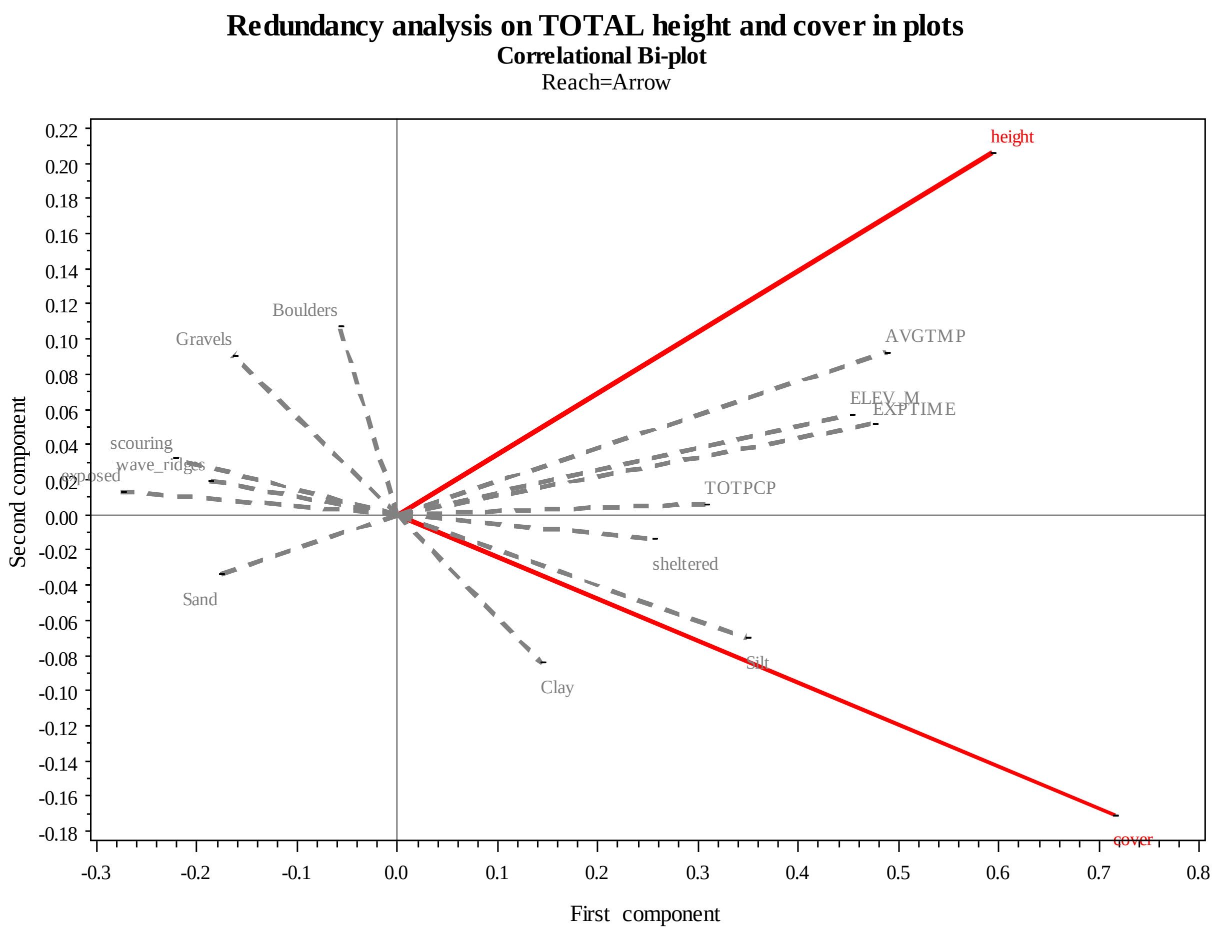


Figure 10. **RDA Biplot for the Arrow Lakes portion of the Arrow Lakes Reservoir. The red lines with the arrows are the vegetation variables (height and cover) and the dashed lines show the environmental variables. The environmental variables explained approximately 93 per cent of the variation in vegetation cover and height. AVGTEMP = average temperature over the exposure period for the plot in Celsius, ELEV = meters above sea level as a centroid measure, EXPTIME = amount of time in days the plot was exposed and above water, TOTPCP = accumulated precipitation (mm) during exposure, exposed = water supplies from upslope, sheltered = topographic sheltering from scouring or waves.**

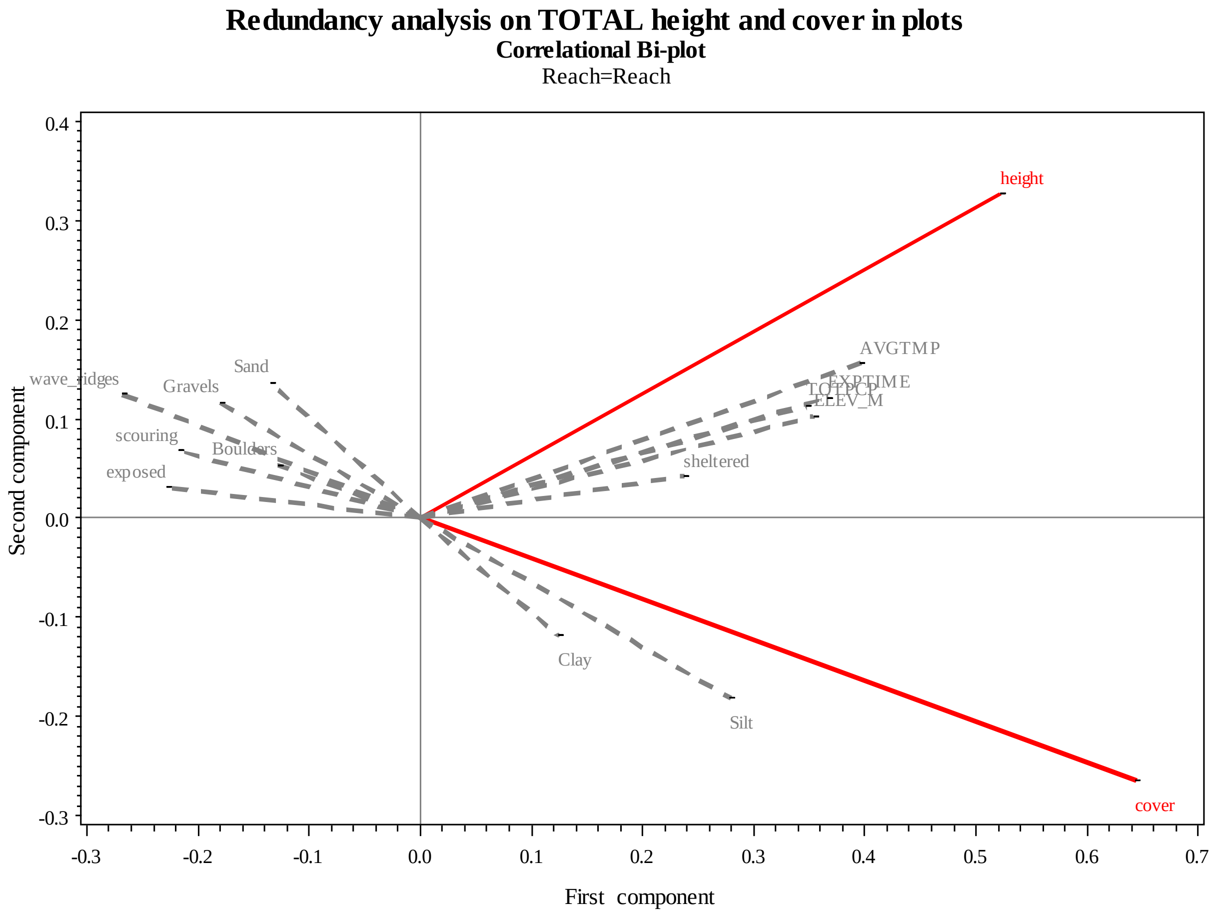


Figure 11. **RDA Biplot for the Revelstoke Reach Portion of the Arrow Lakes Reservoir. The red lines with the arrows are the vegetation variables (height and cover) and the dashed lines show the environmental variables. The environmental variables explained approximately 86 per cent of the variation in vegetation cover and height. AVGTEMP = average temperature over the exposure period for the plot in Celsius, ELEV = meters above sea level as a centroid measure, EXPTIME = amount of time in days the plot was exposed and above water, TOTPCP = accumulated precipitation (mm) during exposure, exposed = water supplies from upslope, sheltered = topographic sheltering from scouring or waves.**

Management Question summary: The spatial extents (cover of types and cover of vegetation within types), structure (heights) and composition are related to elevation and topo-edaphic site conditions in the following ways:

Arrow: 93 per cent of the variation in height and cover was explained by the environmental variables used in the RDA. Cover was negatively correlated with coarse textured materials and scouring. Height was positively associated with average annual temperature and with higher elevation, and negatively associated with sandy soils.

Revelstoke: 86 per cent of the variation in height and cover was explained by the environmental variables used in the RDA. Cover was negatively correlated with coarse textured materials and scouring. Height was positively associated with average annual temperatures, higher elevations, and shorter inundation periods.

3.5 Question 5. "Does the soft constraints operating regime of Arrow Lakes Reservoir *maintain* spatial limits, structure and composition of existing vegetation communities in the drawdown zone?"

This management question implies a consideration of change over time. To address it, we examined data from field plots collected between 2007-2012 as well as comparing the 2010 imagery and mapped data with the 2012 imagery and mapped data. Five categories of results were used:

- Review of the mapping to record changes in deciles of VCTs within polygons between 2010 and 2012 and the analysis of variance of vegetation in mapped polygons using coded data (Confusion Matrix with the K-statistic). These address differences in cover, height and distribution of the mapped data.
- Repeated measures analysis of the mapped vegetation data using ANOVA, addressing differences in average cover and average maximum heights in repeated plots over time, from 2007 to 2012.
- Comparisons of annual differences in cover and height, based on field data from 2007 through 2012, using boxplots and ANOVA.
- Annual trends in Shannon Weiner Index (H'), species evenness (J) and species richness.
- Examples of the mapping to illustrate the above findings.

The comparison of vegetation between the 2010 and 2012 mapping showed that out of a total of 264 polygons, 25 polygons had gained or lost at least 10% vegetation cover within a VCT. Ten polygons had lost a VCT. Typically, PA: Redtop upland: or PC: Reed canary grass mesic had shifted to BE: Sandy beach, based on an increased coverage of open sand in the 2012 polygon compared to the previous condition. This was mostly due to scouring and deposition of sand. In 2010, six polygons out of a sample of 398 showed a change in VCT decile coverage. None of the mapped VCTs had been removed from polygons in the aerial photographic interpretation, although both scouring and deposition were noted. The Kappa statistic was calculated to determine if a significant change in vegetation cover, height and distribution of vegetation within VCTs occurred between 2010 and 2012 (Tables 10 – 12). Locations of the polygons used in the calculation of the Kappa statistic are shown in Appendix 4.

Table 10. Confusion matrix: summary of analysis for Vegetation Cover. Analysis of SS was not possible due to insufficient data. See Tables 3 and 4 for definitions of VCTs.

VCT	N levels	N Polygons	Kappa	LowerCL	UpperCL	P value	Conclusion*
BB	6	8	0.8400	0.5620	1.0000	<.0001	Sig. Agreement
BE	11	105	0.7450	0.6550	0.8340	<.0001	Sig. Agreement
BG	10	60	0.9430	0.8810	1.0000	<.0001	Sig. Agreement
CR	10	54	0.9790	0.9380	1.0000	<.0001	Sig. Agreement
IN	5	33	0.8370	0.6630	1.0000	<.0001	Sig. Agreement
PA	11	93	0.8560	0.7760	0.9350	<.0001	Sig. Agreement
PC	11	140	0.7200	0.6400	0.8010	<.0001	Sig. Agreement
PE	10	47	0.7020	0.5560	0.8490	<.0001	Sig. Agreement
PO	3	2	0.3330	0.0250	0.6410	0.1573	No Sig. Agreement
RR	9	27	0.7670	0.5830	0.9510	<.0001	Sig. Agreement
RS	3	7	1.0000	1.0000	1.0000	0.0005	Sig. Agreement
WR	3	4	1.0000	1.0000	1.0000	0.0055	Sig. Agreement

*Significant agreement means that no significant change in VCT coding occurred between 2010 and 2012; no significant agreement means that a significant change in VCT coding occurred between 2010 and 2012.

Table 11. Confusion Matrix: summary of analysis for vegetation height. Analysis of SS and PO levels was not possible due to insufficient data. See Tables 3 and 4 for definitions of VCTs.

VCT	N levels	N Polygons	Kappa	LowerCL	UpperCL	P value	Conclusion*
BB	3	8	1.0000	1.0000	1.0000	0.0002	Sig. Agreement
BE	6	105	0.5790	0.4610	0.6970	<.0001	Sig. Agreement
BG	7	60	0.7220	0.5930	0.8510	<.0001	Sig. Agreement
CR	18	54	0.8240	0.7150	0.9330	<.0001	Sig. Agreement
IN	6	33	0.7980	0.5910	1.0000	<.0001	Sig. Agreement
PA	29	94	0.4080	0.3040	0.5110	<.0001	Sig. Agreement
PC	10	141	0.3840	0.2870	0.4800	<.0001	Sig. Agreement
PE	8	47	0.3220	0.1540	0.4900	<.0001	Sig. Agreement
RR	8	27	0.3270	0.1060	0.5480	<.0001	Sig. Agreement
RS	3	7	1.0000	1.0000	1.0000	0.0005	Sig. Agreement
WR	2	4	1.0000	1.0000	1.0000	0.0455	Sig. Agreement

*Significant agreement means that no significant change in VCT coding occurred between 2010 and 2012; no significant agreement means that a significant change in VCT coding occurred between 2010 and 2012.

The confusion matrix did not take into account elevation; it indicated only if cover, height and distribution of the vegetation within VCTs had changed between 2010 and 2012. The confusion matrix analyses showed no significant changes for any of the vegetation types in the reservoir. The significant difference in PO: Ponds that appears in Table 10 is not meaningful due to the low sample size.

Although subtle shifts in vegetation occurred, the confusion matrix indicated that gains were equal to losses at the landscape level.

Table 12. Confusion Matrix: Summary of analysis for vegetation distribution. Analysis of SS, WR, and PO VCTs was not possible due to insufficient data. See Tables 3 and 4 for definitions of VCTs.

VCT	N levels	N Polygons	Kappa	LowerCL	UpperCL	P value	Conclusion*
BB	4	8	0.8220	0.5000	1.0000	<.0001	Sig. Agreement
BE	9	104	0.7700	0.6790	0.8610	<.0001	Sig. Agreement
BG	10	60	0.7970	0.6860	0.9080	<.0001	Sig. Agreement
CR	5	54	0.9720	0.9180	1.0000	<.0001	Sig. Agreement
IN	5	33	0.5910	0.2330	0.9490	<.0001	Sig. Agreement
PA	8	95	0.8420	0.7580	0.9270	<.0001	Sig. Agreement
PC	8	141	0.7720	0.6830	0.8610	<.0001	Sig. Agreement
PE	5	47	0.7440	0.5970	0.8910	<.0001	Sig. Agreement
RR	8	27	0.8190	0.6460	0.9910	<.0001	Sig. Agreement
RS	2	7	1.0000	1.0000	1.0000	0.0082	Sig. Agreement

*Significant agreement means that no significant change in VCT coding occurred between 2010 and 2012; no significant agreement means that a significant change in VCT coding occurred between 2010 and 2012.

Repeated Measures Analysis: are vegetation cover and height maintained over time?

The previous section shows that the mapped data did not show any significant differences in VCT cover, height or distribution at the landscape scale between 2010 and 2012. However, an examination of more detailed measurements taken in the field over a longer period of time did show some significant differences. We used repeated measures Analysis of Variance to examine changes in average cover and average maximum heights of vegetation in repeated plots over the six-year duration of the CLBMON 33 study (Tables 13 and 14). The cover of the "wetter" vegetation types (PE: Horsetail lowland) showed a significant increase over time. Also, the shrub-dominated PA: Redtop upland type showed increased vegetation height and total cover over time. Similar increases over time were seen in the Revelstoke Reach and Arrow Lakes portions of the reservoir. Summary tables for the repeated measures analysis results are provided in Appendix 3.

Field data comparisons - are vegetation cover and height maintained over time?

Boxplots of individual VCTs show the changes in covers and heights of vegetation within VCTs from plots repeated between 2007 and 2012 (Figures 12 through 17). The data presented below are from the field work completed in 2012 and from Enns *et al.* (2007, 2008, 2009, 2010). These data show that covers and heights were higher in the highly variable riparian forest and shrub dominated CR: Cottonwood riparian and PA: Redtop upland VCTs in 2009 than most other years. Other than these differences over the six-year measurement period, very modest increases in average cover and average maximum heights in the wetter and more shrub-dominated VCTs have occurred since 2009.

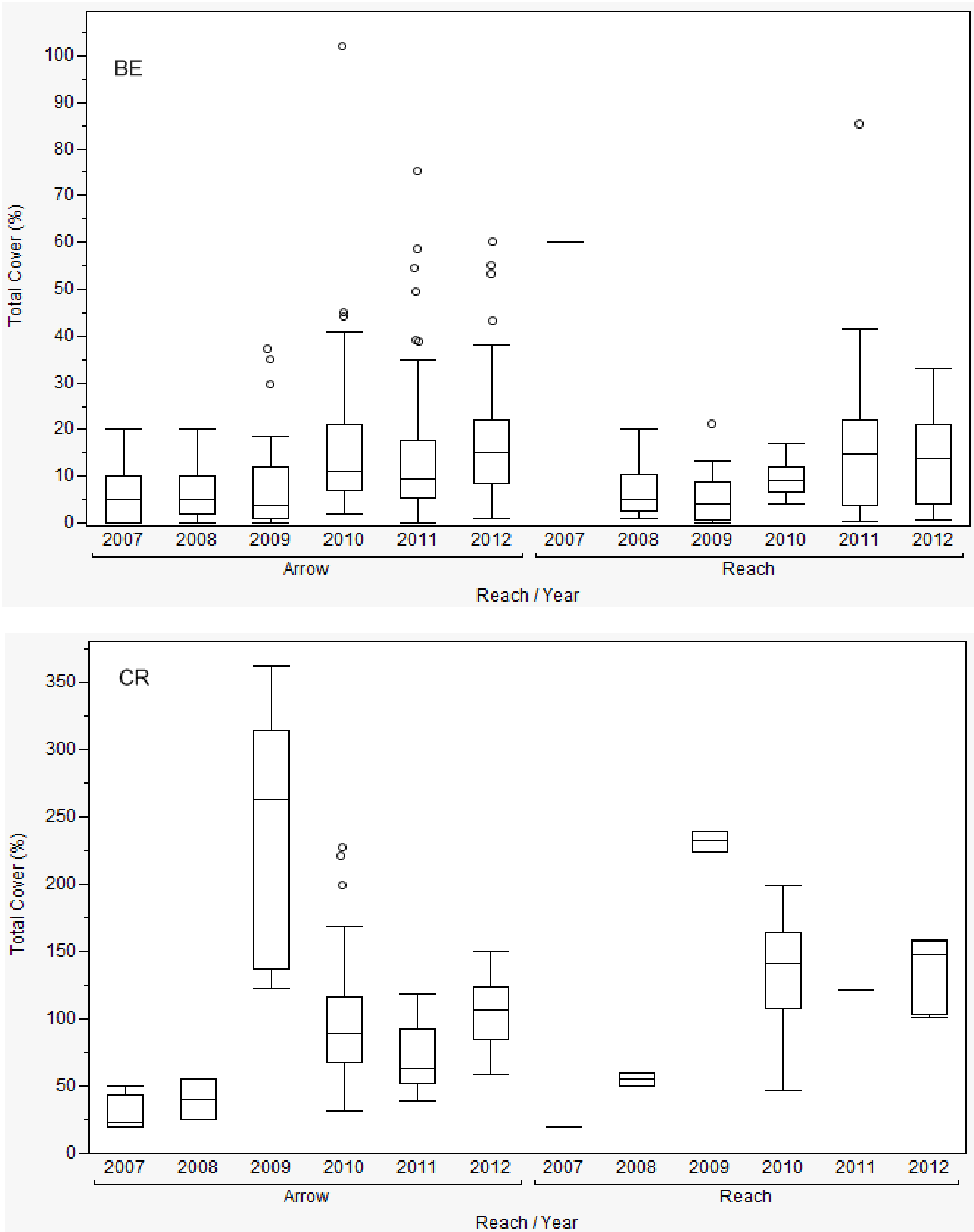
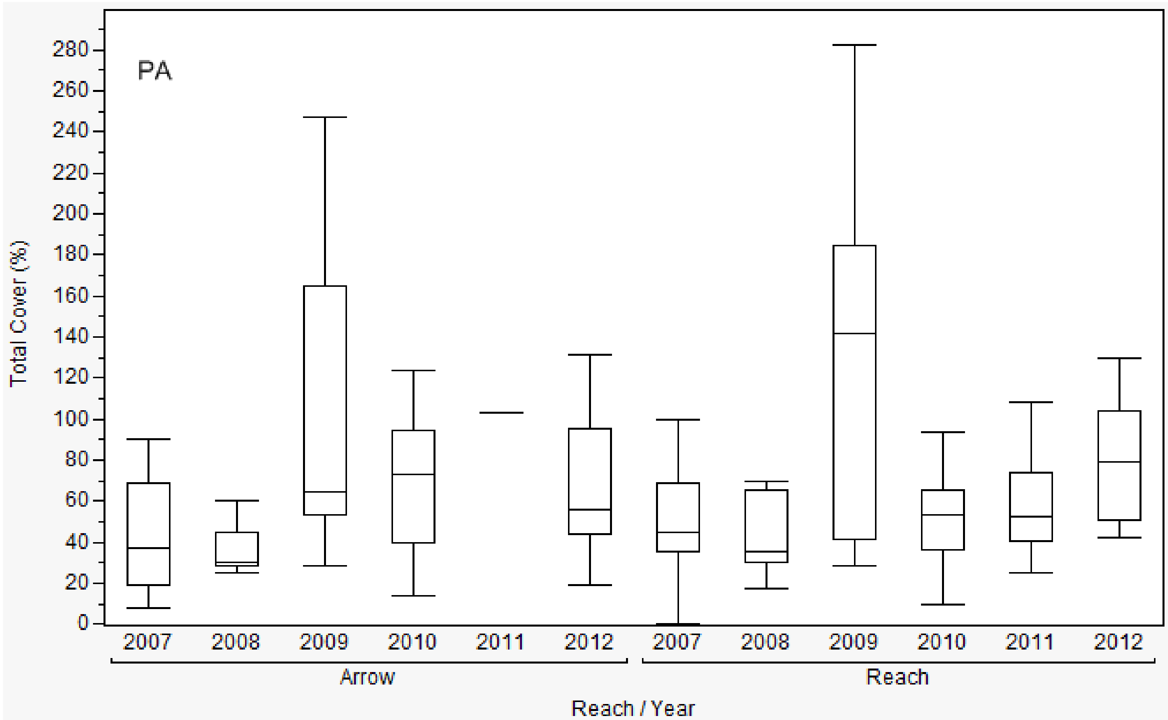


Figure 12. **Changes in total vegetation cover in BE: Sandy beach (top) and CR: Cottonwood riparian (bottom) VCTs in the Arrow Lakes Reservoir drawdown zone from 2007 to 2012. Arrow = Arrow Lakes portion of the reservoir; Reach = Revelstoke Reach portion of the reservoir. See Figure 6 for a complete description of boxplots.**



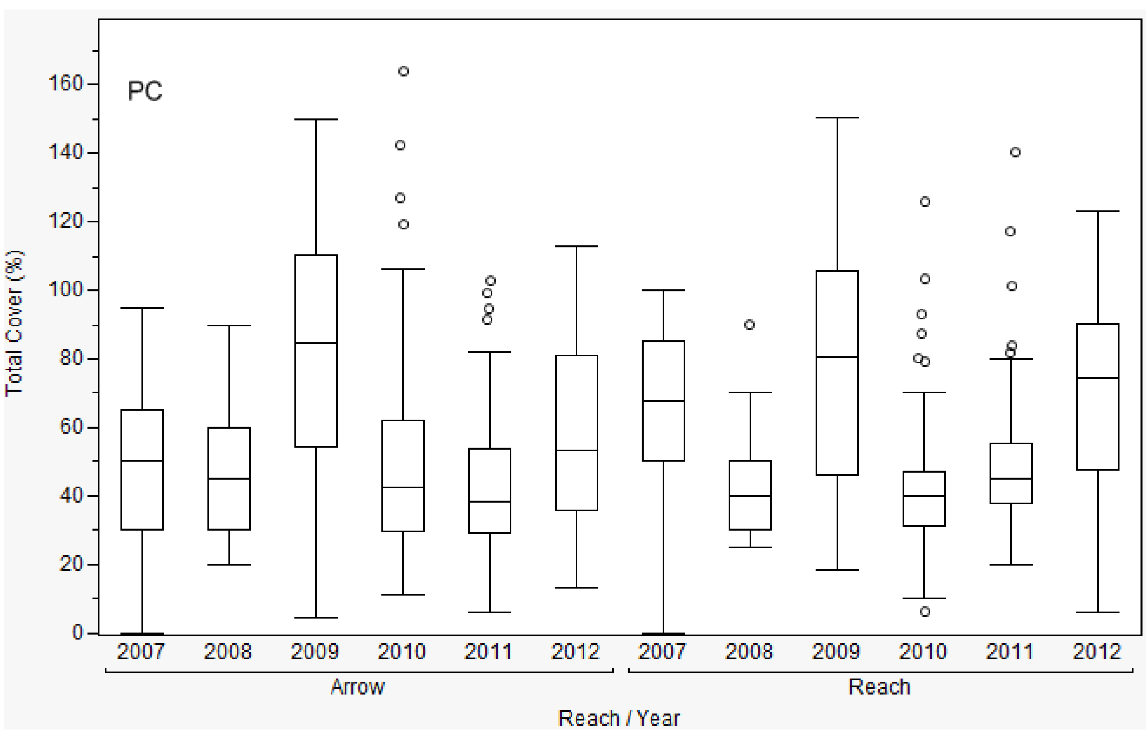
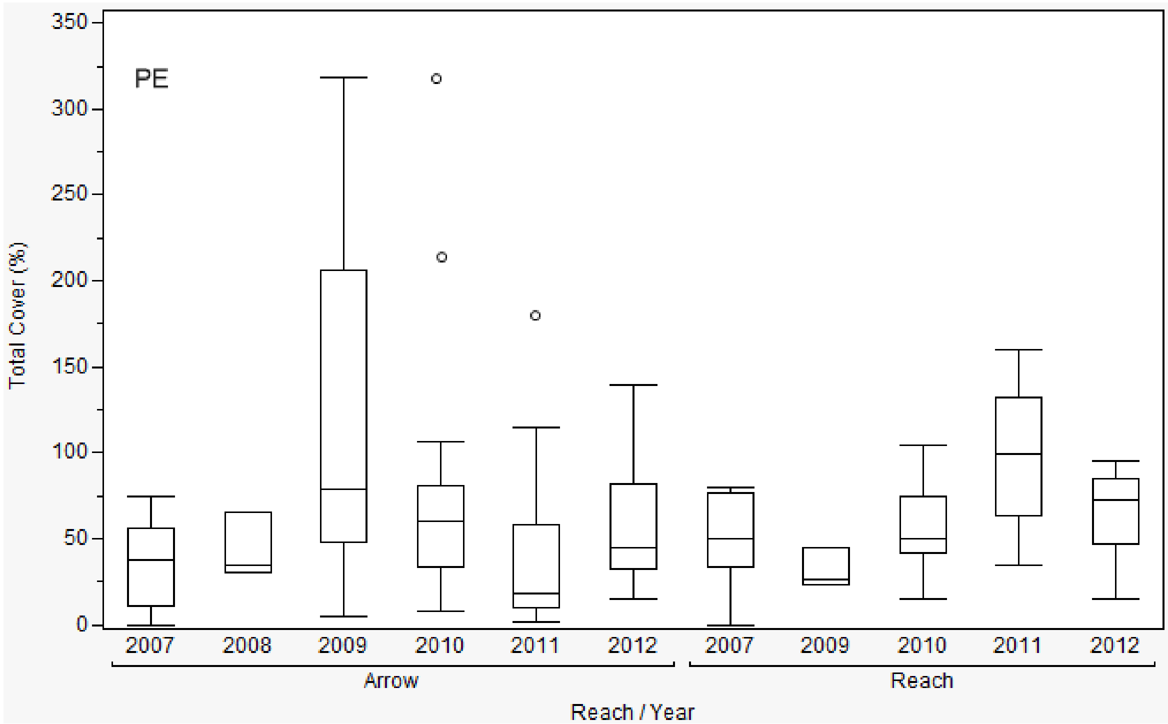


Figure 13. Changes in total vegetation cover in PA: Redtop upland (top) and PC: Reed canary grass mesic (bottom) VCTs in the Arrow Lakes Reservoir drawdown zone from2007 to 2012



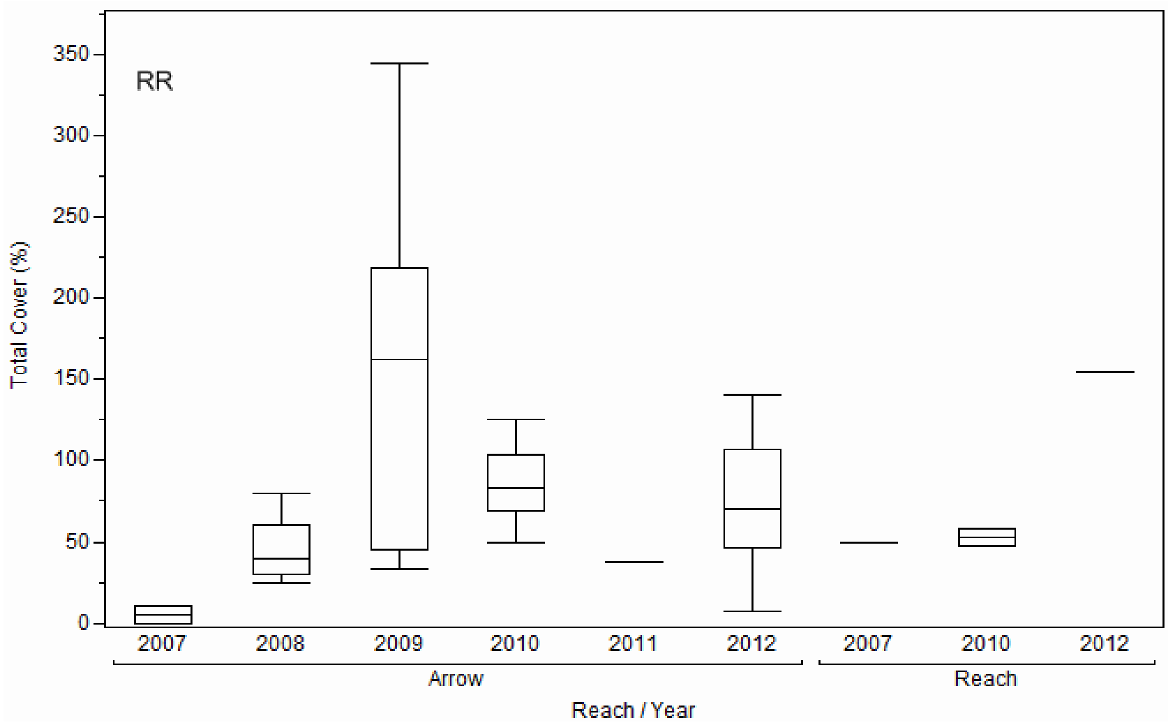
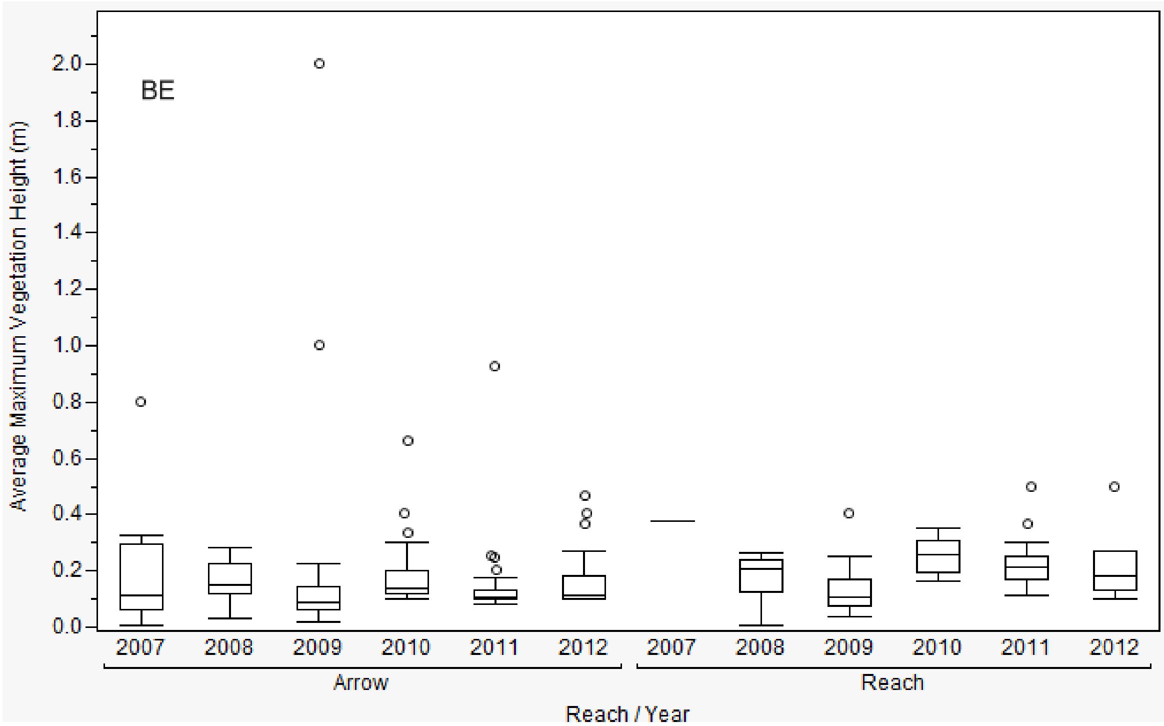


Figure 14. **Changes in total vegetation cover in PE: Horsetail lowland (top) and RR: Reed-rill (bottom) VCTs in the Arrow Lakes Reservoir drawdown zone from 2007 to 2012**



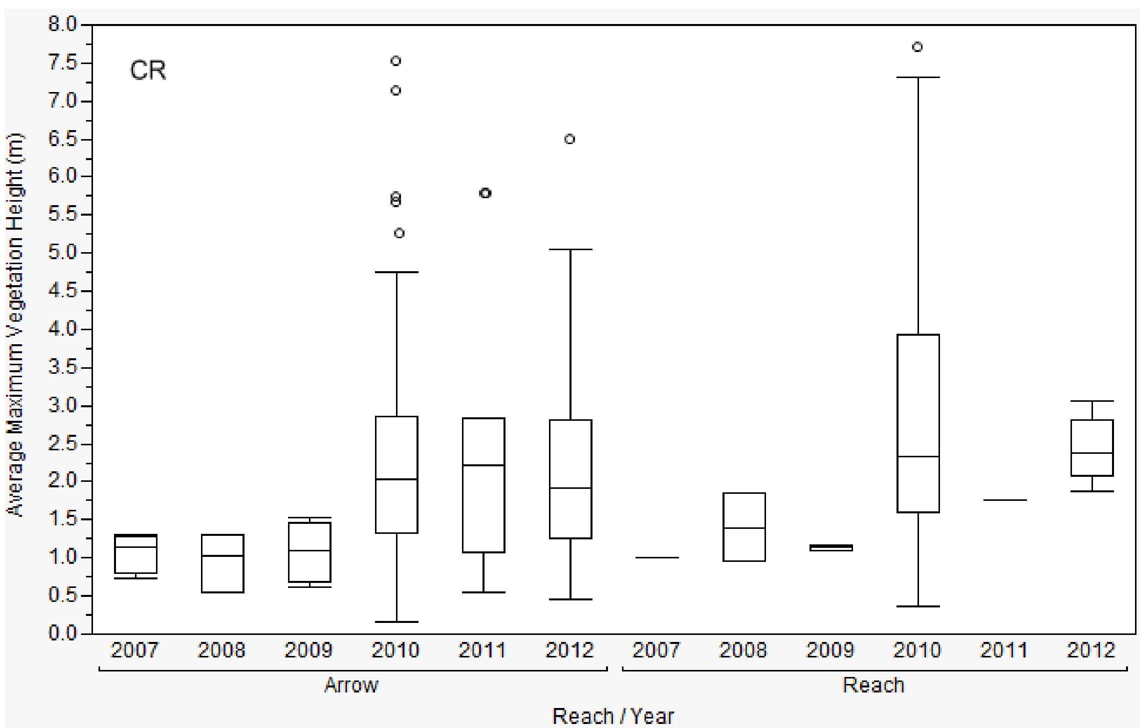


Figure 15. **Boxplot comparisons of vegetation heights in BE: Sandy beach (top) and CR: Cottonwood riparian (bottom) VCTs in the Arrow Lakes Reservoir drawdown zone in the Arrow portion and the Revelstoke Reach portion of the Arrow Lakes Reservoir between 2007 and 2012**

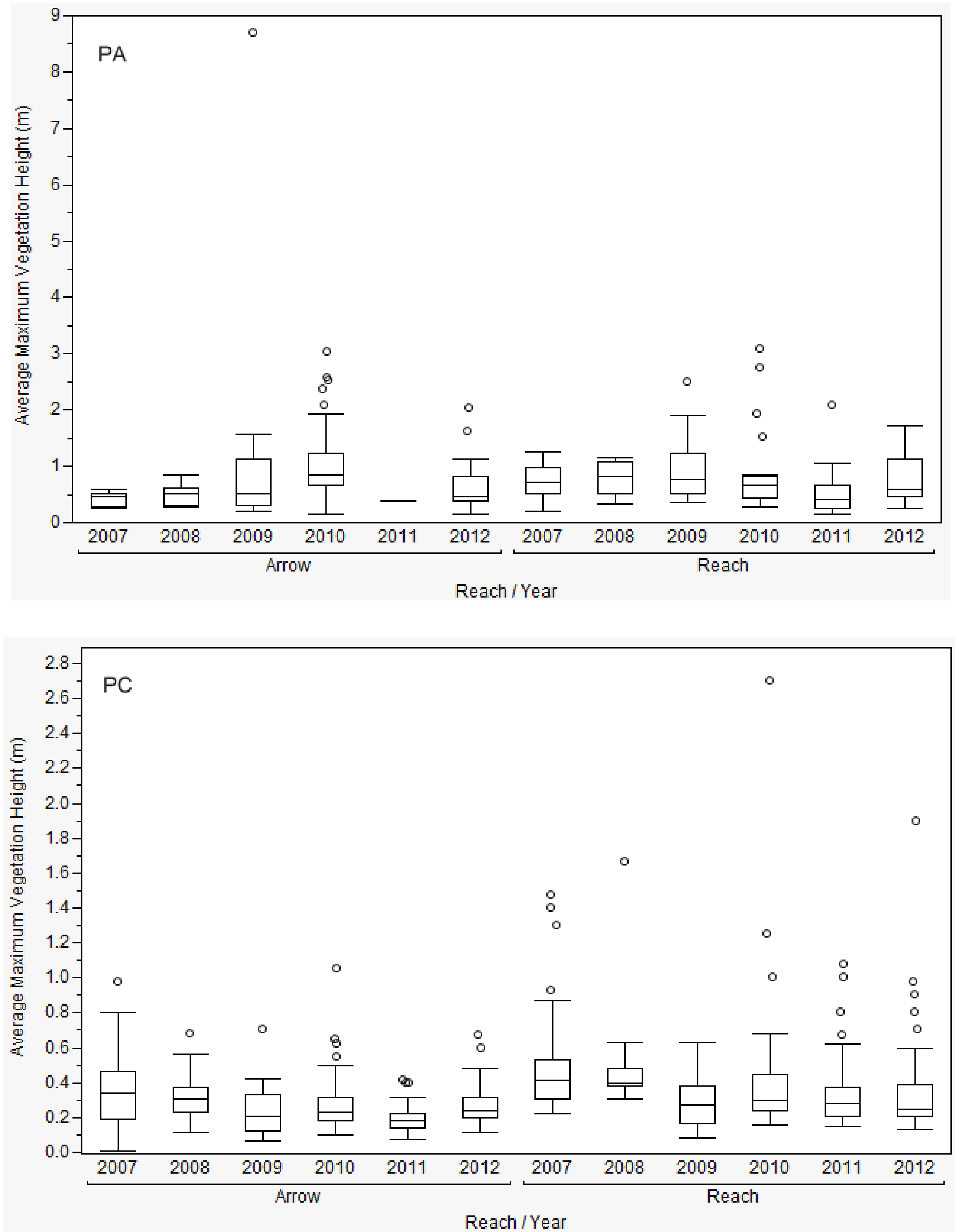
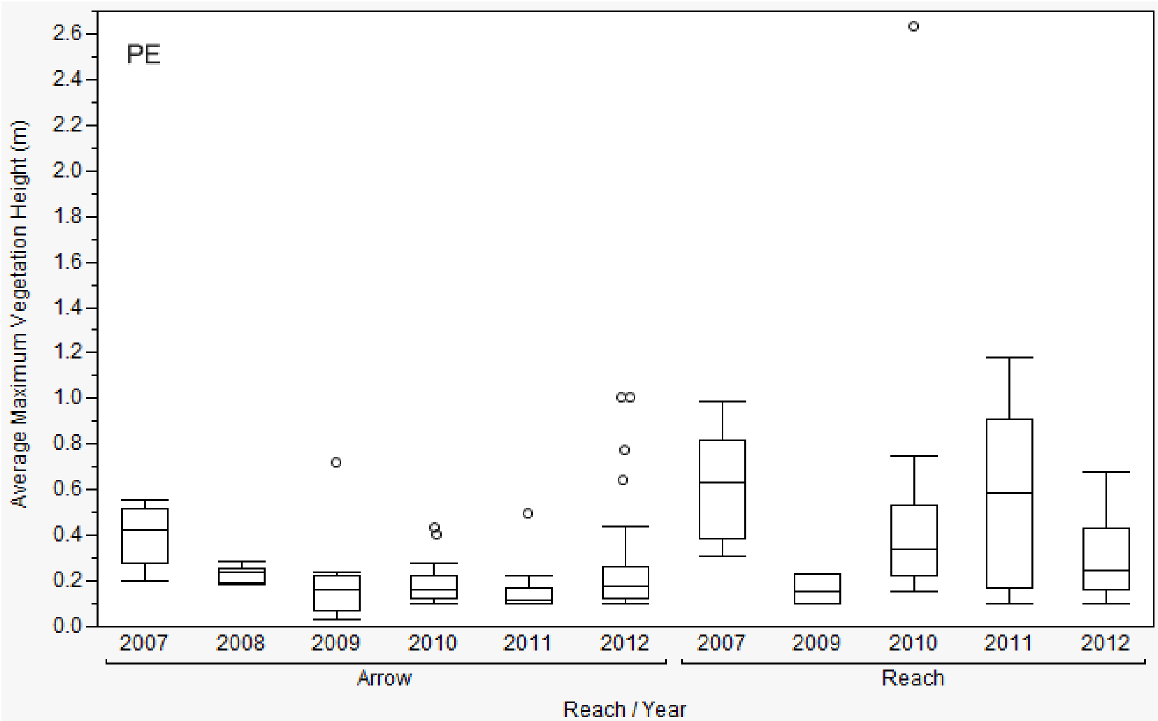


Figure 16. **Boxplot comparisons of vegetation heights in PA: Redtop upland (top) and PC: Reed canary grass mesic (bottom) VCTs in the Arrow Lakes Reservoir drawdown zone in the Arrow portion and the Revelstoke Reach portion of the Arrow Lakes Reservoir between 2007 and 2012**



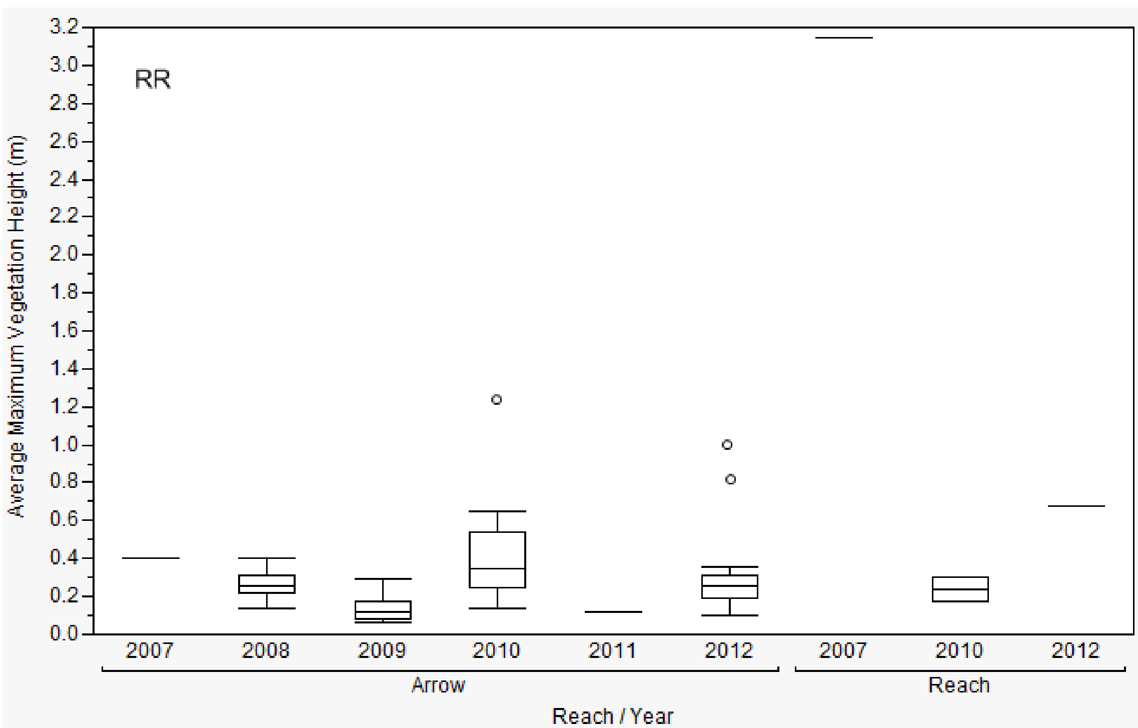


Figure 17. **Boxplot comparisons of vegetation heights in PE: Horsetail lowland (top) and RR: Reed-rill (bottom) VCTs in the Arrow Lakes Reservoir drawdown zone in the Arrow portion and the Revelstoke Reach portion of the Arrow Lakes Reservoir between 2007 and 2012**

Tables 13 and 14 provide the results of ANOVAs conducted on these field data for average cover and maximum height in selected VCTs by Reach and Year.

Table 13. ANOVA results for total vegetation cover within selected VCTs by Reach (Arrow or Revelstoke), Year (2007 to 2012), and Reach x Year interaction. Levels with significant differences in total cover are shaded. See Tables 3 and 4 for definitions of VCTs.

Type	Factor	P	Conclusion	Post hoc comparison results
BE*	Year	0.002	Significant difference	2012 > 2011 > 2010 > 2009 > 2008
BE*	Reach	0.287	No sign.diff.	
BE*	Reach x Year	0.484	No sign.diff.	
CR*	Year	0.000	Significant difference	2009 > 2010 > 2012 > 2011 > 2008
CR*	Reach	0.055	No sign.diff.	
CR*	Reach x Year	0.758	No sign.diff.	
PA	Year	0.000	Significant difference	2009 > 2012 > 2010 > 2011 > 2007 > 2008
PA**	Reach	0.937	No sign.diff.	
PA**	Reach x Year	0.093	No sign.diff.	
PC	Year	0.000	Significant difference	2009 > 2012 > 2007 > 2010 > 2011 > 2008
PC	Reach	0.163	No sign.diff.	
PC	Reach x Year	0.001	Significant difference	
PE**	Year	0.640	No sign.diff.	
PE**	Reach	0.877	No sign.diff.	
PE**	Reach x Year	0.023	Significant difference	

*Insufficient data to include 2007; Year effect had four levels: 2008, 2009, 2010, 2012.
**Insufficient data to include 2008; Year effect had four levels: 2007, 2009, 2010, 2012.

Table 14. ANOVA results for mean maximum vegetation height within selected VCTs by Reach (Arrow or Revelstoke) and Year (2007, 2008, 2009, 2010, and 2012). Levels with significant differences in mean maximum height are shaded. See Tables 3 and 4 for definitions of VCTs.

Type	Factor	P	Conclusion	Post hoc comparison results
BE	Year	0.474	No sign.diff.	
BE	Reach	0.085	No sign.diff.	
BE	Reach x Year	0.270	No sign.diff.	
CR*	Year	0.044	Significant difference	2010 > 2011=2012 > 2008=2009
CR*	Reach	0.893	No sign.diff.	
CR*	Reach x Year	0.978	No sign.diff.	
PA	Year	0.014	Significant difference	2010 > 2009 > 2012 > 2008 > 2007 > 2011
PA	Reach	0.139	No sign.diff.	
PA	Reach x Year	0.248	No sign.diff.	
PC	Year	0.000	Significant difference	2007 > 2008 > 2010 > 2012 > 2009 > 2011
PC	Reach	0.000	Significant difference	Revelstoke Reach > Arrow
PC	Reach x Year	0.748	No sign.diff.	
PE**	Year	0.069	No sign.diff.	
PE**	Reach	0.002	Significant difference	Revelstoke Reach > Arrow
PE**	Reach x Year	0.037	Significant difference	see Appendix 3

*Insufficient data to include 2007; Year effect had four levels: 2008, 2009, 2010, 2012.
**Insufficient data to include 2008; Year effect had four levels: 2007, 2009, 2010, 2012.

Is the vegetation composition (distribution, diversity, evenness and richness) maintained?

There was no significant change in the distribution of mapped VCTs between 2007 and 2012 (confusion matrix, Table 12). The additional landscape-level comparison of the aerial photography did not show a consistent pattern of change in distribution between 2007 and 2012 for 250 polygons (data not shown).

We also examined the dispersion of individual plants within VCTs. In almost all cases, mesic, mid-elevation vegetation (PC: Reed canary grass mesic) had an even distribution of plants. Vegetation in VCTs in the high- and low-elevation zones in the reservoir tended to have a clumped and/or random distribution. Although some vegetation appeared to fill in or become slightly less clumped in 2012 in comparison to 2010, scouring of materials also caused some vegetation to become more scattered with smaller clumps in 2012.

The trends in species diversity, evenness and richness over time in VCTs were examined using diversity (H') and evenness (J) indices and plots of number of species (richness) of the field data for all previous years (Figures 18 to 20). Trends in relation to elevation classes were also plotted (Figures 21 to 23).

Most VCTs showed either modest increases in species diversity, evenness and richness, or mild annual fluctuations. Species richness appeared to generally increase with time, particularly at higher elevations. In 2012 there was an average of 8.8 (SE = 0.26) species per plot, in a total of 400 plots completed during the survey (Appendix 5).

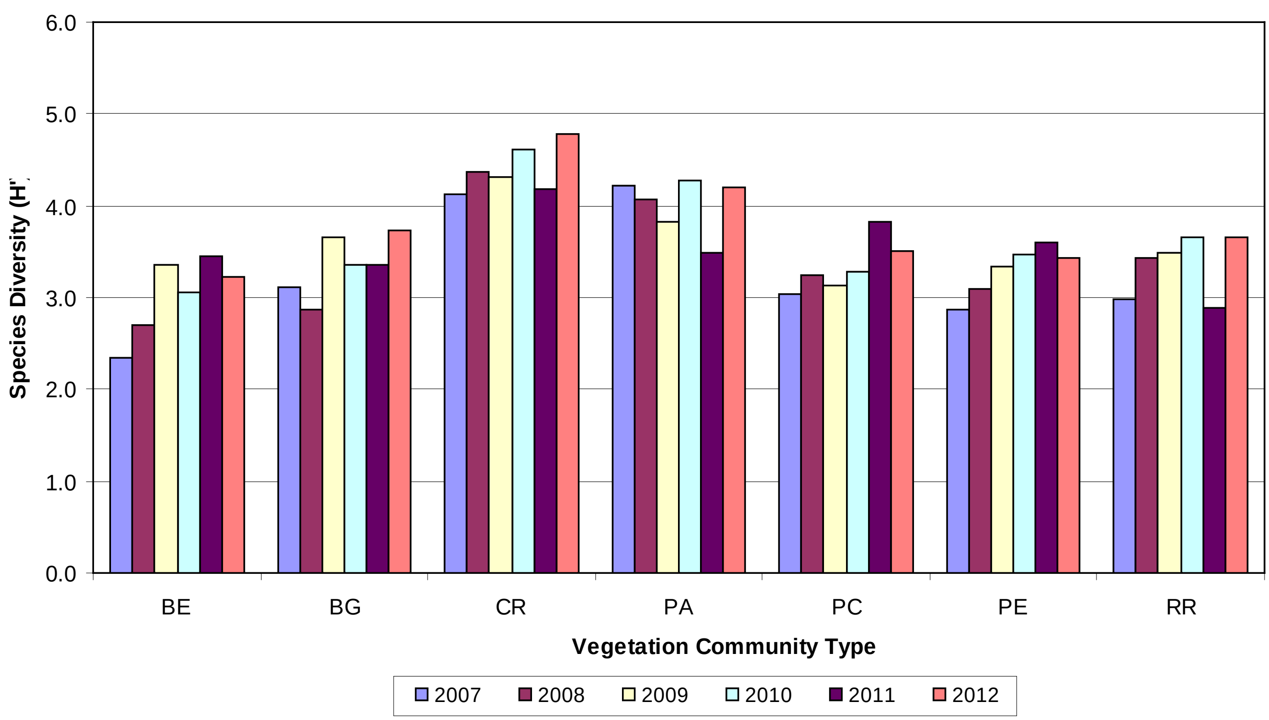


Figure 18. **Shannon-Weiner Diversity Index (H') for each VCT from 2007 to 2012 in the Arrow Lakes Reservoir drawdown zone (both geographic areas combined). See Tables 3 and 4 for definitions of VCTs.**

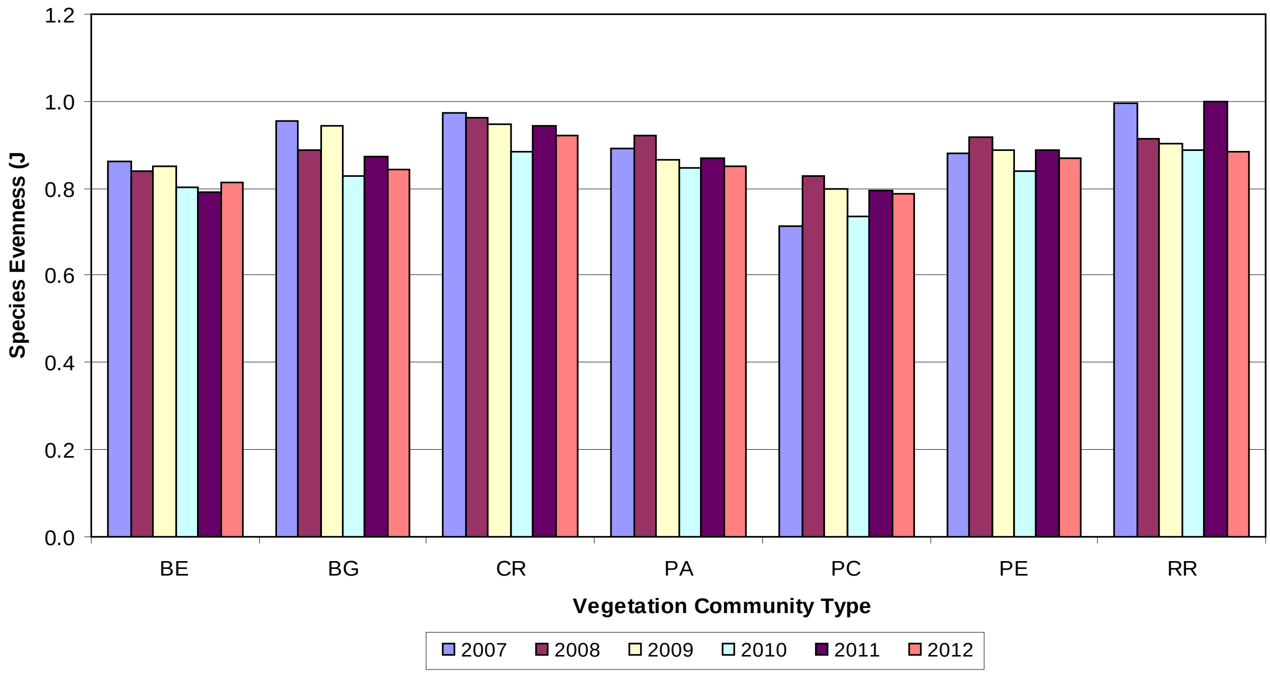


Figure 19. **Pielou's species evenness (J) for each VCT from 2007 to 2012 in the Arrow Lakes Reservoir drawdown zone (both geographic areas combined). See Tables 3 and 4 for definitions of VCTs.**

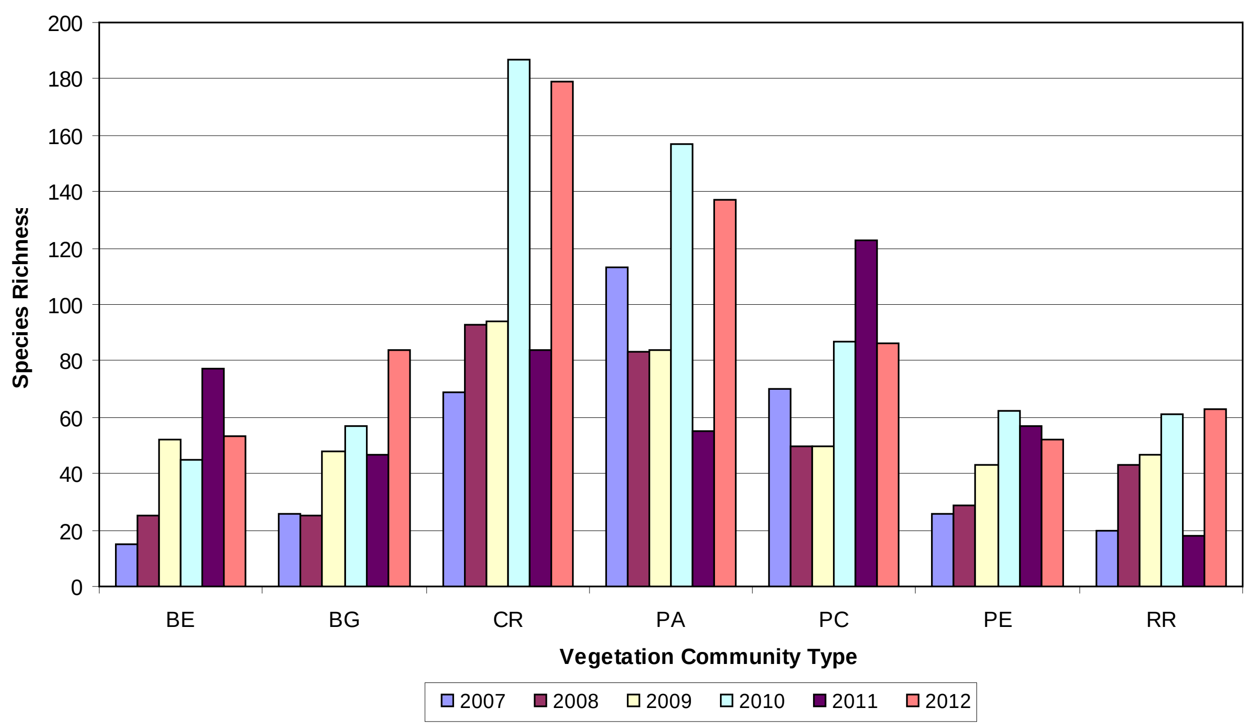


Figure 20. **Species richness for each VCT from 2007 to 2012 in the Arrow Lakes Reservoir drawdown zone (both geographic areas combined). See Tables 3 and 4 for definitions of VCTs.**

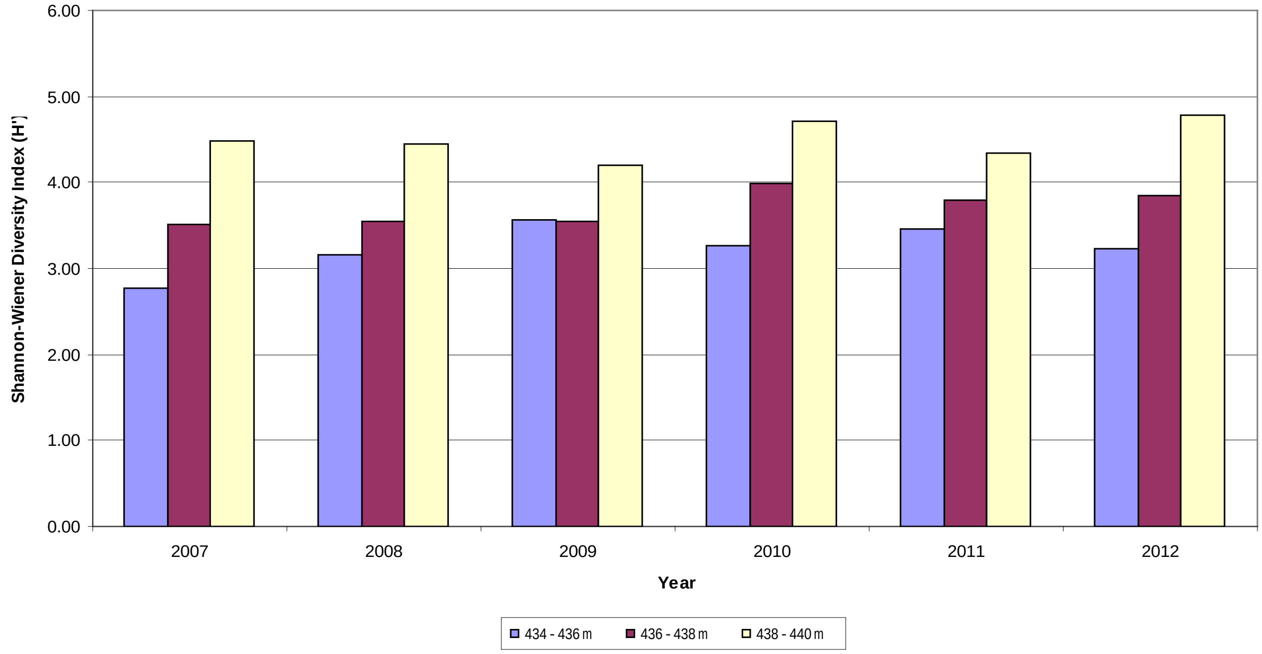


Figure 21. **Species diversity (H') for all vegetation within the three elevation bands (434 m to 436 m, 436 m to 438 m and 438 m to 440 m) from 2007 to 2012 in the Arrow Lakes Reservoir (both geographic areas combined)**

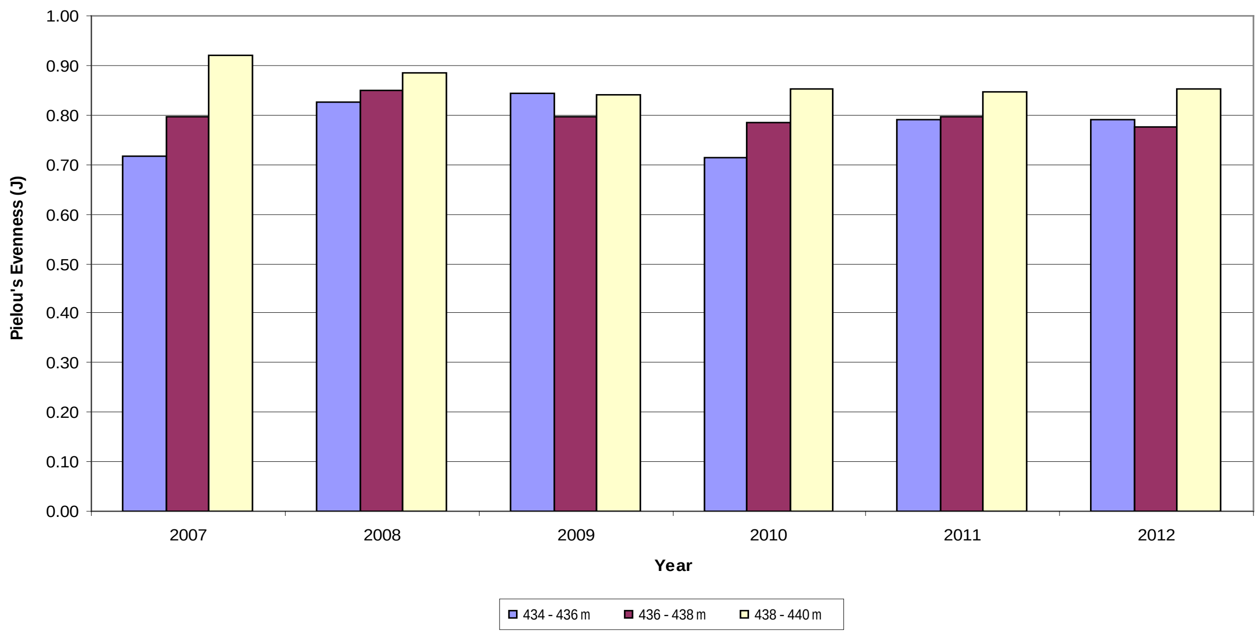


Figure 22. **Pielou's species evenness (J) for all vegetation within the three elevation bands (434 m to 436 m, 436 m to 438 m, and 438 m to 40 m) from 2007 to 2012 in the Arrow Lakes Reservoir (both geographic areas combined)**

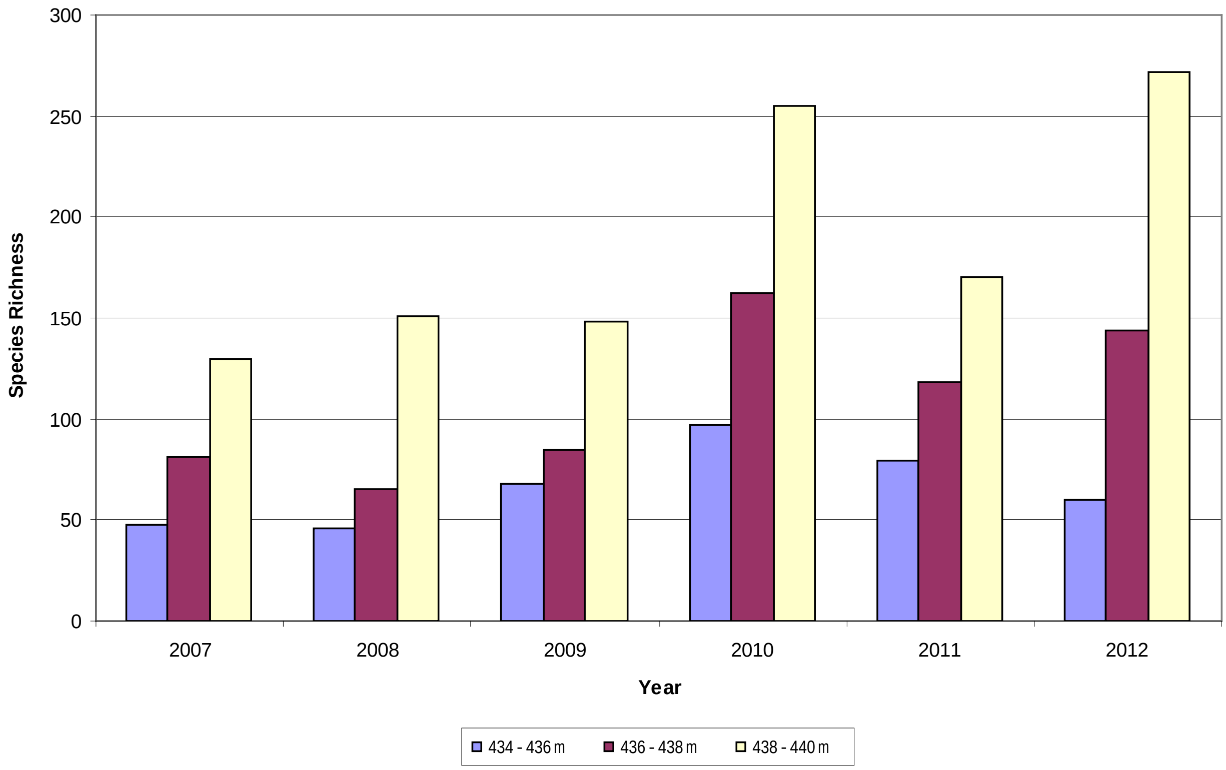


Figure 23. **Species Richness within the three elevation bands (434 m to 436 m, 436 m to 438 m, and 438 m to 440 m) from 2007 to 2012 in the Arrow Lakes Reservoir (both geographic areas combined). See Appendix 3 for the tabular values for this figure.**

Examples of changes in vegetation spatial limits (cover), from the imagery of 2007, 2010 and 2012

The aerial photographic imagery showed subtle differences in appearance between 2007 and 2012. Some of these differences resulted from the use of different media (see cover page: blue film vs. true colour digital imagery). Most true differences appeared to be due to seasonal growth in relation to annual climate (average annual temperatures and weather patterns). Comparisons in the appearance of vegetation in the same polygons, shot in 2007, 2010 and 2012 are shown in Figures 24 to 27.

Differences in colour expression between the 2007 imagery and the later imagery are consistent: the white balance of the 2007 imagery is not correct and the images have a blue tint, which can be misleading and result in a false positive assessment of the vegetation. It is possible to correct these discrepancies by using photo development software to change the white balance. The results of the image comparisons done so far indicate that although the quality of the 2007 imagery is not as good as the 2010 imagery, differences in cover and heights of the vegetation are observable with a high degree of certainty.

Figure 24. **Phenological differences in Polygon 10 between 2007 (left), 2010 (middle), and 2012 (right) in the Arrow Lakes Reservoir, from aerial photography. Note that 2007 and 2012 images are greener than 2010, indicating the small annual variation in climate and time of capture of the photographs. The 2007 photographs were taken on May 30; the 2010 photographs on May 12 – 13, and the 2012 image on May 16 - 17. The dun-coloured appearance of the middle photograph is due to standing dead reed canary grass, which is grown over by live reed canary grass in the two other photographs. Scale is approximately 1: 500.**

Figure 25. **Phenological differences in Polygon 1777 between 2007 (left), 2010 (middle) and 2012 (right) in the Arrow Lakes Reservoir, from aerial photography. Growth of reed canary grass is more advanced in the 2007 photography, and shrubs have not grown as much in 2010 as in 2007, but appear to have grown slightly by 2012. This does not constitute a decile change in the mapping, however. Scale is approximately 1: 1,500.**

Figure 26. **Example of a very subtle change in vegetation due to a combination of outdoor recreation vehicle use and phenology between 2007 (left), 2010 (middle) and 2012 (right) in Polygon 1763 in the Arrow Lakes Reservoir, from aerial photography. At middle to low elevation RR: reed-rill VCT between 2007 (left), 2010 (middle) and**

2012 (right) constitutes a decile change in the vegetation mapping for this polygon. Scale is approximately 1: 1,500.

Figure 27. Example of a change in decile cover of PE: Horsetail lowland in Polygon 1710 in the Arrow Lakes Reservoir, from aerial photography, between 2007 and 2012. A low elevation PE: Horsetail lowland VCT in 2007 (left), 2010 (middle) and 2012 (right). Changes of this magnitude were seen in fewer than six out of 398 polygons in 2010 and in 25 type comparisons in 595 types within polygons in 2012. Scale is approximately 1: 300.

Management Question summary: The vegetation of the Arrow Lakes Reservoir appears to have been maintained in most VCTs. There were some increases and declines in cover and heights in the vegetation of the more variable VCTs, especially the shrub- and tree-dominated PA: Redtop upland and CR: Cottonwood riparian VCTs. In 2010, we had attributed a decline in the vegetation to a longer inundation period in the winter of 2008 – 2009 (Enns *et al*. 2010). In 2012, when we refined our analysis by using only repeated plots with equal sample size and by using exact elevation data instead of 2-meter classes, that effect was not found. The soft constraints operating regime has only varied slightly during the years of the study, and a long-duration inundation occurred only in 2008 – 2009.

The following trends in spatial limits, structure and composition of the vegetation are apparent:

- There were no significant changes in mapped vegetation cover, heights and distribution between 2010 and 2012. Most differences were subtle fluctuations in cover due to variation in the growth stage at the time of the photographic captures. Some differences resulted from localized scouring or sand and silt deposition.
- The shrub- and tree-dominated PA: Redtop upland and CR: Cottonwood riparian VCTs were highly variable. Although local fluctuations occurred from year to year, the maintenance of the vegetation in these types was evident at the landscape level.
- Species richness, evenness and diversity fluctuated from year to year in the wettest and highest-elevation shrub-dominated plots, with modest increases in evenness, richness and diversity over time in most plots.

3.6 Question 6. "What potential changes to the soft constraints operating regime could be made in order to maintain the existing vegetation communities at the landscape scale?"

Aerial photography interpretation and deciles (10 per cent increments) of cover of vegetation within VCTs showed no significant changes in the vegetation of the Arrow Lakes Reservoir, for both comparisons (2007 vs. 2010; 2010 vs. 2012). In 2010, only six out of 398 polygons showed a decile change, and only two of these were greater than 10 per cent. In 2012, there was a slightly higher number of changes in cover when the secondary and tertiary VCTs in the polygon were compared with the previous aerial photographic coverage. It is possible that secondary and tertiary VCTs in a polygon are more susceptible to losses or more likely to increase over time than the primary vegetation type in the polygon. However, these results indicate no net change at the landscape level, despite the long duration of high water levels in 2008 - 2009.

At the field level, significant increases and declines in vegetation cover and height have occurred, but most of these could be attributed to growth stage differences and natural variation from year to year. When the data were examined using similar sample sizes and accurate elevations, the trend toward losses reported by Enns *et al.* (2010) following a high water winter in 2008 – 2009 was no longer evident.

As in previous years, plant diversity, evenness and species richness were consistently low at low elevations and increased with elevation. Prolonged inundation may reduce diversity and increase evenness at lower elevations; some plants are well adapted to inundation and can dominate the low elevation portions of the reservoir.

Management Question summary: We have recommended in the past that the soft constraints operating regime be maintained in the pattern seen between 2005 and 2008 and from 2009 to 2010, to reduce the risk of loss of vegetation cover or height in some of the VCTs of the Arrow Lakes Reservoir (Enns *et al.* 2010). This recommendation still holds, mainly because we have seen what we believe is the maintenance of natural variation and no drastic declines in the vegetation since 2007. Hence, the goal of the soft constraint for vegetation is being met.

Hypothesis test summary

Some of the results presented in this report address the management questions with statistically significant or non-significant results. Table 15 is a review of those results as they relate to the following hypothesis:

H_0: Under the soft constraints operating regime (or possibly a newly selected alternative after five years), there is no significant change in existing vegetation communities at the landscape scale.

- H_{0A}: There is no significant change in the spatial extent (cover, and number of hectares) of vegetation communities within the existing vegetated zones of Arrow Lakes Reservoir.
- H_{0B}: There is no significant change in the structure and composition (i.e., distribution and diversity) of vegetation communities within the existing vegetated zones of Arrow Lakes Reservoir.

Table 15. Summary of statistical results. See Tables 3 and 4 for definitions of VCTs.

MQ(s) Addressed	Object of Tests	Test(s) Performed	Statistical Results
MQ2: Is the current distribution of vegetation communities in Revelstoke Reach representative of the remainder of the reservoir? MQ3: What are the spatial extents, structure and composition (i.e., relative distribution and diversity) of these communities within the drawdown zone between 434 m and 440 m?	Comparing vegetation cover by reach and elevation band	ANOVA plus post hoc comparisons (See Appendix 3)	Reach: Rev > Arrow. Elevation: 438 m to 440 m > 436 m to 438 m > 434 m to 436 m.
MQ2: Is the current distribution of vegetation communities in Revelstoke Reach representative of the remainder of the reservoir?	Areal coverage by VCTs in Rev Reach vs. Arrow Lakes	Contingency table with X^2 statistic in 2010	The polygon VCT composition has not changed between 2010 and 2012. The coverage of VCTs in Revelstoke Reach was significantly different from that in the Arrow Lakes portion of the reservoir.
MQ2 MQ3	Comparing vegetation height by reach and elevation band	ANOVA plus post hoc comparisons (See Appendix 3)	Elevation: 438 m to 440 m > 436 m to 438 m > 434 m to 436 m. Reach x Elevation: Arrow 438.m to 440 m > Rev 438 m to 440 m > Rev 436 m to 438 m > Arrow 436 m to 438 m = Arrow 434 m to 436 m = Rev 434 m to 436 m.
MQ4: How do spatial limits, structure and composition of vegetation communities relate to reservoir elevation and topo-edaphic site conditions such as aspect, slope, soil moisture, etc.?	Heights and cover as they relate to environmental and topo-edaphic site conditions	RDA, aerial photographic interpretation.	As in previous years, coarse textured soils and scouring likely resulted in a reduction in heights and covers of the vegetation, and richer nutrient regimes resulted in higher covers and heights. Increased heights were correlated with longer periods of time above the water line, and warmer average annual temperatures.

MQ4 : Does the soft constraints operating regime of Arrow Lakes Reservoir maintain vegetation spatial limits, structure and composition of existing vegetation communities in the drawdown zone?	Analysis of changes in vegetation cover and height between 2012 and previous years.	Confusion matrix with K statistic. Data from interpretation of aerial photography.	Significant cover change for PO type only, but sample size for PO was very small. No significant change was found in vegetation height or cover.
MQ4	Changes in distribution of vegetation in mapped VCTs	Confusion matrix with K statistic. Data from interpretation of aerial photography	No significant changes in vegetation distribution codes were found. .
MQ4		RMA ANOVA: Arrow Lakes – change in selected VCTs by elevation band and year	Significant cover changes for BE, PA, and PC from 2010 to 2012. Significant height changes for BE, PA, PC and PE from 2010 to 2012.
MQ4		RMA ANOVA: Arrow Lakes - elevation bands compared separately for change in cover and height due to VCT and year	Significant differences in cover and height between VCTs were found for all three elevation bands. No significant difference in either cover or height between 2010 and 2012 due to year effect alone, and no significant interaction effects between year and VCT
MQ4		RMA ANOVA: Revelstoke Reach - change in selected VCTs by elevation band and year	Significant cover change for PA from 2010 to 2012. Significant height changes for PA, PC, and PE from 2010 to 2012.
MQ4		RMA ANOVA: Revelstoke Reach - Elevation Bands separately for change in cover and height due to VCT and year	Significant differences in height and cover between VCTs for all elevation bands. No significant difference in either cover or height between 2010 and 2012 due to year effect alone, and no significant interaction effects between year and VCT.

MQ4	Comparison of field data from 2007 through 2012 for changes in total vegetation cover for selected VCTs (BE, CR, PA, PC, PE)	ANOVA and post hoc comparisons	BE: (2007 excluded) Significant effect due to year, 2012 > 2011 > 2010 > 2009 > 2008. CR: (2007 excluded) Significant effect due to year, 2009 > 2010 > 2012 > 2011 > 2008. PA: Significant effect due to year, 2009 > 2012 > 2010 > 2011 > 2007 > 2008. PC: Significant effect due to year, 2009 > 2012 > 2007 > 2010 > 2011 >2008; Significant interaction effect of reach x year, indicating that reach and year levels are not independent. PE: (2008 excluded) Significant effect due to reach x year, indicating that reach and year levels are not independent.
MQ4	Comparison of field data from 2007 through 2012 for changes in average vegetation heights for selected VCTs (BE, CR, PA, PC, PE)	ANOVA and post hoc comparisons	BE: (2007 excluded) No significant differences found; CR: (2007 excluded) Significant effect due to year, 2010 > 2011 = 2012 > 2008 = 2009. PA: Significant effect due to year, 2010 > 2009 > 2012 > 2008 > 2007 > 2011; PC: Significant effect due to year; 2007 > 2008 > 2010 > 2012 > 2009 > 2011; significant effect due to reach; Rev > Arrow. PE: (2008 excluded) Significant effect due to reach, Rev > Arrow; Significant effect due to reach x year, indicating that reach and year levels are not independent
MQ4	Comparison of species diversity (H') for each VCT from field data from 2007 through 2012.	Shannon Weiner Index (H'), plotting of trends over time.	Slight increases in diversity over time in some VCTs.

MQ4	Comparisons between species evenness (J) for each VCT from field data from 2007 through 2012.	Pielou's Species evenness (J), plotting of trends over time.	Slight decrease in species evenness over time in some VCTs, also possibly due to the higher numbers of plots done in each consecutive year. No clear effect of 2008 high water scenario in the soft constraints operating regime on the evenness of plants in each VCT over time.
MQ4	Comparisons between species richness for each VCT from field data from 2007 through 2012.	Species Richness, plotting of trends over time.	Increases in species richness over time in most VCTs, which is probably due to higher numbers of plots done in progressive years. No clear effect of 2008 high water scenario in the soft constraints operating regime on the species richness of each VCT over time.
MQ5: How do spatial limits, structure and composition of vegetation communities relate to reservoir elevation and topo-edaphic site conditions such as aspect, slope, soil moisture, etc.?	Comparisons between species diversity for all vegetation within three elevation bands (434 m – 436 m, 436 m – 438 m and 438 m - 440 m) from field data from 2007 through 2012.	Shannon Weiner Index (H'), plotting of trends by elevation over time, as an indication of the effects of depth and duration of inundation.	Very little change in the patterns in species diversity x elevation band from 2007 to 2012. Species diversity by elevation: 434 m - 436 m < 436 m - 438 m < 438 m – 440 m for all years except 2009 where 434 m - 436 m = 436 m - 438 m. These are observations only and not statistically significant.
MQ5	Comparisons between species evenness for all vegetation within three elevation bands (434 m – 436 m, 436 m - 438 m and 438 m - 440 m) from field data from 2007 through 2012.	Pielou's (J), plotting of trends by elevation over time, as an indication of the effects of depth and duration of inundation.	Very little change in the patterns in species evenness x elevation band from 2008 to 2012. Species evenness increased with elevation in 2007, 2008, and 2010. In 2009 species evenness was lowest at 436 m - 438 m and approximately equal at 434 m - 436 m and 438 m - 440 m. In 2011 and 2012, evenness was equal at low and mid elevations and higher in the 438 m - 440 m elevation band.

MQ5	Comparisons between species richness for all vegetation within three elevation bands (434 m – 436 m, 436 m - 438 m and 438 m - 440 m) from field data from 2007 through 2012.	Species richness, plotting of trends by elevation over time, as an indication of the effects of depth and duration of inundation.	Species richness consistently increased with elevation for all measurement years (434 m - 436 m < 436 m - 438 m < 438 m - 440 m) with very similar patterns in species richness by elevation band for each year. Species richness was higher in the 438 m -440 m elevation band in 2010 and 2012 compared to other years, due to the inclusion (beginning in 2010) of mosses and lichens, which were abundant and common at high elevation in PA and CR.
MQ6: Are the vegetation communities in Revelstoke Reach representative of conditions in the remainder of the reservoir?	Distribution of VCTs between reaches. Comparisons of species diversity between reaches.	Shannon Diversity Index, cigarette graphs (Enns et al. 2010)	The Revelstoke Reach portion of Arrow Lakes Reservoir has fewer VCTs than the Arrow Lakes portion, and the species diversity of the VCTs in Arrow Lakes is higher than in Revelstoke Reach. This is attributable to differences in climate and parent materials. Revelstoke Reach is colder and wetter, and materials have a higher silt content than the Arrow Lakes portion.

4.0 DISCUSSION

At the landscape level, based on a sample in 264 polygons (out of approximately 2,000 polygons), 25 VCTs in individual polygons showed a change in decile cover values and ten polygons showed a change in VCT type between 2010 and 2012. Most of the changes in VCT type were from PC: Reed canary grass mesic and PA: Redtop upland to BE: Sandy beach, due to scouring and/or deposition of sand and silt. These changes in VCT deciles were not statistically significant, however. The changes to deciles of VCTs are being included in the updated mapping this year (2012). Many of the differences in the imagery are due to differences in soil moisture (usually from rising water, which is at a slightly different level in each year of photography) and growth stage and not due to actual gains or losses of vegetation.

The distribution of the vegetation communities in Revelstoke Reach has not been representative of the remainder of the reservoir. The proportions of VCTs differed between the two portions of the reservoir, and the species compositions within VCTs tended to be less diverse in the Revelstoke Reach portion than in the Arrow Lakes portion of the reservoir. The vegetation in the reservoir, ranging from Revelstoke to Deer Park, responds to a continuum from silty sandy soils and cold wet climate in the north to coarse textured soils and a warmer drier climate in the south.

Vegetation cover typically progressed from low to high with increasing elevation. Cover can be high at low elevation, in the PE: Horsetail lowland VCT, due to the dominance of a group of inundation-tolerant species, especially in sheltered topography. The plants of PE can withstand long periods of flooding, and survive well in oxygen-deficient (anoxic), compacted soils.

Vegetation was typically shorter at low elevations and increased in height with elevation. There was considerable variation in height at high elevation, due to the effects of wave action during high water.

Height development was positively correlated with temperature and precipitation, and vegetation cover and height were positively correlated with soil nutrition from silts and clays. As in previous years, coarse textured gravels and cobbles combined with scouring effects resulted in lower covers and heights of vegetation, whereas richer soil textures (silts and clays) in sheltered topography resulted in higher cover. The RDA showed that vegetation heights were influenced by the amount of time the plot location was above water, allowing for the development of shrub stages. The extended amount of time that plants are exposed to precipitation and higher temperatures at higher elevations also allows for the development of the shrubs and trees.

Changes in vegetation were examined using aerial photography and field data. Aerial comparisons (confusion matrix using coded data) between 2010 and 2012 showed no significant change in cover or heights over time. The field data from repeated plots showed that the drier, shrub- and tree-dominated VCTs (CR: Cottonwood riparian and PA: Redtop upland) showed increases in covers and heights. The repeated plots in wetter types (RR: Reed-rill and PE: Horsetail lowland) also showed significant increases in cover over time. The sand- and gravel-dominated BG: Gravelly beach, BE: Sandy beach and BB: Boulders, steep VCTs have not changed significantly over the period of repeated measures from 2007 to 2012. The mesic, reed canary grass dominated VCT (PC) has not changed significantly except in relation to elevation in Revelstoke Reach, where it has declined significantly at low elevation sites. This may be due to scouring as well as inundation.

Species richness has consistently increased with elevation over the years, except in water-requiring or water-tolerant vegetation at the lowest elevation range under study (434 m - 436 m).

Species diversity and evenness varied slightly between VCTs, and increased within VCTs with increasing elevation. These patterns have not changed since the beginning of the project.

The total number of species recorded (species richness) has increased over time in the more complex, upland shrub and forest vegetation communities. This is due to additional sampling effort in 2010, and to the additional records of lichens and mosses. Mosses can make up very high cover in some VCTs especially at low elevations, and they have been persistent over the years.

The first four management questions addressed in this report are descriptive: "What is the vegetation composed of, how is the vegetation distributed, is one part of it any different from the rest, and how is it affected by environmental variables other than the soft constraints operating regime?" The remaining two questions address whether the vegetation is maintained by the soft constraints operating regime, and what changes might be made to maintain vegetation. When addressing these questions, we are assuming that vegetation changes naturally over time, that the heights of vegetation should increase over the period of the observations, and that in the absence of the soft constraints operating regime, the effects of the environment would not be any different from the effects we observed. The evidence from this year is that where conditions are suitable for growth, modest increases in heights and covers have occurred. Some VCTs are not very suitable for vegetation growth, except for those species very tolerant of boulders or sandy soils, and these VCTs have not changed appreciably from 2007 to 2012.

5.0 CONCLUSIONS

The conclusions from this year's study are very similar to those of the 2010 study. Revelstoke Reach is not representative of the Arrow Lakes Reservoir, because it has different proportions (and fewer) VCTs than the Arrow Lakes portion of the reservoir. There are no differences in heights and covers of vegetation between the two parts of the reservoir overall, but significant differences were found between total vegetation cover by elevation band. The post-hoc comparisons of field data (Appendix 3) show that Arrow and Revelstoke Reach total covers are significantly different in the high elevation range (438 m - 440 m).

In previous years, we attributed the greater species richness and diversity in the Arrow Lakes portion of the Arrow Lakes Reservoir to higher variations in parent materials and soils in the Arrow Lakes portion than in the Revelstoke Reach portion (Enns *et al.* 2007), in particular a higher clay and silt fraction in some soils. When silts and clays are combined with some coarse textured materials, especially with topographic sheltering, the diversity of the vegetation can be very high. The higher numbers of sites sampled in 2010 and 2012 vs. 2007 and 2008 support this observation. Climatic differences are also important.

We had concluded in 2010 that a change in the main pattern of the soft constraints operating regime in 2008 – 2009 had caused a loss of cover in the lower-elevation VCTs. A more refined analysis in 2012 did not support this conclusion. The apparent relationship between duration of inundation and vegetation declines reported in 2010 may have been an artifact of natural variation and classification of data, but it is difficult to be sure because a prolonged inundation has occurred only once during the study period. This change in our understanding of the effects of inundation does not change our recommendation that the soft constraints operating regime should be maintained in the pattern seen between 2005 and 2008 and from 2009 to 2012.

H_0: Under the soft constraints operating regime (or possibly a newly selected alternative after five years), there is no significant change in existing vegetation communities at the landscape scale.

H_{0A}: There is no significant change in the spatial extent (cover and number of hectares) of vegetation communities within the existing vegetated zones of Arrow Lakes Reservoir**.** Hypothesis of no change is NOT rejected for the reservoir as a whole at a 10 per cent level. **Rejected** for some VCTs at a high resolution.

H_{0B}: There is no significant change in the structure and composition (i.e., distribution and diversity) of vegetation communities within the existing vegetated zones of Arrow Lakes Reservoir. **Rejected** for some VCTs at a high resolution with respect to structure. Hypothesis of no change NOT rejected for the reservoir as a whole at a 10 per cent level of accuracy, with respect to distribution. Data available so far suggest acceptance of the null hypothesis with respect to diversity, evenness and richness at the landscape scale.

These statements are based on six years of observation in the field, and on a comparison between two similar sets of images, over which the soft constraints operating regime was fairly constant. A large variance in the usual operating regime may show a measurable response in the vegetation.

6.0 SOURCES OF UNCERTAINTY AND POTENTIAL ERROR

The following sources of error and uncertainty apply to this study.

- Comparisons between images are always problematic, due to various observational and image quality issues. However, the clarity and detail available in the 2010 and 2012 images allowed for height and cover difference estimates.
- We attempted to include a relatively even number of samples of each VCT within the three designated elevation bands; however, some VCTs do not occur in all elevation bands. The CR type, for example, does not occur at low elevations.
- Statistical tests of samples of the populations, in this case vegetation types within a large reservoir, have high uncertainty when variation is high. The use of repeated measures of fixed but randomly located plots has helped define the relationships between environmental variables and variables related to soft constraints operating regime.

7.0 CLOSURE PLAN

A closure plan for this study is being developed. There are two years left in the project, (2014 and 2016) and plans for final analysis and reporting should be reviewed with BC Hydro. A number of actions have been put in place to ensure that the study is completed to BC Hydro's satisfaction:

- A standardized MS Access database allows for the continued use of RDA and RMA through to the conclusion of the study with the facility for additional data from the next series of field measures.
- The map changes over time will be summarized for the entire photography series.
- Repeated measures of fixed plots and sample sizes that are as close to equal as possible will be used from this point forward, and will be based on centroid elevation data for each plot, as well as the elevation classes used between 2007 and 2010. This is based on a recommendation by Dr. C. Schwarz. If time permits, the reliance on random non-repeated sampling (Enns and Gibeau 2009) will be re-examined and compared to the fixed plot sampling as an error measurement in the final year of the field work.
- The addition of more climate data and more site-specific climate variables during the days of inundation, the duration and timing of inundation will be continued and included in a 10 year retrospective examination of change in the final year of the project.

The statistical analysis will utilize the same methods of field work and analysis throughout the study, in order to be consistent. However, diversity, evenness and species richness will be examined by true elevation for plots within VCTs, and not just by elevation class. VCTs that are non-vegetated, rare, or largely affected by influences other than the soft constraints monitoring regime (BB: Boulders, steep, PO: Ponds, SF: Slope failure, SS: Steep sand, and WR: Silverberry river entry) will be re-examined in the final field assessment. In the past only annual water levels data have been examined using RDA. In the final analysis we will look for trends and significant changes in vegetation in response to water level fluctuations over the full term of the study.

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9.0 GLOSSARY

α error - the probability of rejecting a true null hypothesis in statistical testing

ß error - the probability of accepting a false null hypothesis in statistical testing

% cover - see per cent cover

a priori - in statistics, a priori knowledge is prior knowledge about a population, rather than that estimated by recent observation

adjusted-R2 - a modification of R2 that accounts for the number of explanatory (independent) variables included in multiple regression or canonical statistical analyses

aerial photographic image capture - the process of recording photographic images on film or in a digital format from the air

aerial photographic imagery - refers to a collection of aerial photographic images or pictures

aerial photographic mosaic - an aerial photograph of a large area, made by carefully fitting together aerial photographs of smaller areas so that the edges match in location, and the whole provides a continuous image of the larger area

aerial photographic interpretation - the process of studying and gathering information on aerial photographs required to identify the various natural and cultural features on the ground

aerial photography - taking photographs of the ground from the air

aerial triangulation - using the process of triangulation to correct for distortion on aerial photographic imagery; see triangulation

air photo mosaic - see aerial photographic mosaic

anoxic - lacking oxygen

ArcGIS - a group of software products used to manage, view and manipulate spatial data, create maps and perform basic spatial analysis (Produced by ESRI or Environmental Systems Research Institute).

aspect - the direction of a slope gradient or the horizontal direction to which a mountain slope faces

asymptotic - a variation in the distribution of a variable in relation to the population.

autecological - pertaining to autecology

autecology - a subfield of ecology that deals with the biological relationship between an individual species and its environment

autocorrelation - the internal correlation between members of series of observations ordered in time or space

biometrics - the study of measurable biological characteristics boxplots - 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

canonical analysis - a multivariate technique in statistics used with multiple regression models to assess the linear relationships between groups of variables in a data set

canonical correspondence analysis (CCA) - a multivariate, direct gradient analysis method that is derived from correspondence analysis but has been modified to allow environmental data to be incorporated into the analysis

chlorosis - a condition in which leaves produce insufficient chlorophyll and have a yellow appearance

central tendency - tendency for values to lie close to the median or mean.

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

colluviation - a terrain process whereby materials are developed by downslope movement

community - see vegetation community

complex polygon - a polygon that contains more than one unit or type

composition - see vegetation composition

confounding variable - an extraneous variable in a statistical model that correlates (positively or negatively) with both the dependent variable and the independent variable; a confounding variable can alter the outcome of a study by showing a false correlation between the dependent and independent variables, leading to an incorrect rejection of the null hypothesis

confusion matrix - a table that contains information about actual and predicted classes done by a classification system; the performance of such classification systems is commonly evaluated using the data in the table or matrix

concave - terrain that is bowl-shaped, receiving water

convex - terrain that is upside-down bowl-shaped, and shedding water

correspondence analysis - a statistical technique designed to analyze simple two-way and multi-way tables containing some measure of correspondence between the rows and columns; the analysis is an ordination technique that provides a graphic method for exploring the systematic relationships between categorical variables in the tables when there are incomplete a priori expectations as to the nature of those relationships -

covariance - a measure of the linear relationship between two random variables or how much the two variables change together

cover - cover estimate of vegetation in a polygon vegetation community type, see also vegetation cover (estimated in the field)

cover value - see vegetation cover value

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

data cleaning - 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

Daubenmire cover classes - classes used to group % cover value data; 1 = zero to five, 2 = five to 10, 3 = 10 to 25, 4 = 25 to 50, 4 = 50 to 75, 6 = 95 to 100.

decile - one of nine values that divide data or area into 10 equal parts or 10 per cent increments

dieback - the loss of upper crown structure in vegetation, usually seasonal, but may be pathological and often results in regrowth

degrees of freedom - the number of independent units of information in a sample used in the estimation of a parameter or calculation of a statistic

DEM - digital elevation model

dependent variables - the variables that are being measured in an experiment and that are being affected by or responding to the independent or explanatory variables

digital image analysis - see image analysis

digital image capture - the process of recording photographic images in a digital format

digital imagery - images created in a digital format that contain a fixed number of rows and columns of digital values called picture elements or pixels; each pixel in the digital image represents a brightness of a given colour

direct gradient analysis - a statistical method that examines the response of individual species or vegetation community types to gradients of environmental factors including climate, parent material, topography, other organisms and time

distribution - see plant species distribution

distribution codes - see plant distribution codes

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

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

dummy variable - a binary variable that is used to represent a given level of a categorical variable (i.e., a variable that is either present or absent); the most common choices as dummy variables are 1 and 0

edaphic - related to or caused by particular soil conditions rather than by physiographic or climatic factors

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

eigenvector - an eigenvector of a matrix is a vector such that when we multiply the matrix by the vector we get the vector back again except that it has been multiplied by a particular constant, called the eigenvalue

ephemeral - lasting only a short period of time (e.g., an ephemeral stream that only exists for a short period following precipitation or snowmelt)

error matrix - see confusion matrix

evenness - see species evenness

field truthing - see field verification

field verification - confirming the accuracy and reliability of mapping by on-the-ground field surveys and sampling

fixed effects - observed values of explanatory (independent) variables that are all treated as if they were non-random (i.e., the effects are deliberately controlled by the experimenter)

forward selection - a procedure used to select only the independent (explanatory) variables that contribute significantly to explaining the variance in dependent (response) variables within multiple regressions or canonical models

fluviation - a terrain process whereby materials are developed by water movement

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

glaciofluvial - a terrain process whereby materials are developed by a combination of glacial movement and melting glacier water movement

ground truthing - confirming the accuracy and reliability of mapping by on the ground field surveys and sampling

height - see vegetation height

herb - non-woody vascular plants including forbs and graminoids (plants with grass-like growth form including grasses, sedges, rushes and spike-rushes)

herbaceous - descriptor for plants that are classified as herbs

heterogeneity - the quality of being different in kind or nature

heterogeneous - differing in kind or type; consisting of dissimilar elements or parts

Ho - see null hypothesis

homogeneity - the quality of being similar or comparable in kind or nature

homogeneous - of the same or similar kind or nature

hygrotope - unit in a classification of soil moisture regimes

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

image analysis - the extraction of meaningful information from images including the extraction of data from aerial photography imagery using air photo interpretation methods and digital image processing techniques

image data capture - see aerial photographic image data capture

image training sites - sites selected in the field that are homogeneous, typical and representative of information classes (e.g., vegetation community types) that are used in conjunction with image processing software to develop characterizations of the spectral properties (reflectances) of each class included in an image classification scheme; the unique spectral properties of classes are used to "train" the classification decision rules used in developing the classification imagery - see aerial photographic imagery

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

independent variables - variables that are presumed to affect or explain a dependent variable; typically the variables in an experiment representing the values that are being manipulated or changing

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

Kappa (K) statistic - a statistical measure of agreement used in assessing the degree to which two or more observers, examining the same qualitative (categorical) data, agree when it comes to assigning the data to categories

kurtosis - the degree of "peakedness" of a probability distribution; a measure of whether the data are peaked or flat relative to a normal distribution

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

leading vegetation - the dominant vegetation community type with the largest spatial extent within a polygon or other specified area

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

life form codes - codes that indicate the growth form of plant species (i.e., tree, shrub, graminoid, forb, moss, lichen)

linear mixed effects ANOVA model - see linear mixed effects model (LMM)

linear mixed effects model (LMM) - a statistical model that investigates responses from a subject (dependent variable) that are thought to be the sum (linear additions) of fixed and random effects; the model shows the amounts that fixed and random factors contribute to the overall variability in the dependent variable

loam - soil containing a relatively equal mixture of sand and silt and a smaller proportion of clay (about 40-40-20% concentration respectively)

lowland - land lying below the area where water usually flows or that is influenced by flooding and poor drainage

massive catastrophic failure - structural failure in a landform or feature causing debris torrent or slide.

median - a numerical value that divides a sample, population or 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)

mesic - medium soil moisture regime where a site has neither excess soil moisture or a moisture deficit

microtopography - small scale variations in the land surface shape (i.e., hummocks and hollows) mixed effects model - a statistical model that investigates the responses from a dependent variable due to both fixed effects (factors with values that are deliberately controlled by the experimenter) and random effects (factors with values that represent a random sample of a larger population)

moisture regime - a parameter of soils that corresponds to a soil's ability to receive and retain moisture; eight classes represent the relative amounts of soil moisture available for plant growth in a biogeoclimatic subzone

monomials - a monomial is a constant (number) or a product of non-negative powers of variables

mosaic - see aerial photographic mosaic

multiple regression - a statistical method used to quantify the relationship between several independent (explanatory) variables and a dependent (response) variable

multivariate - multivariate statistics encompasses the simultaneous observation and analysis of more than one statistical variable at a time; multivariate analysis involves analyzing more than one related outcome measure per dependent variable simultaneously with adjustment for multiple confounding variables (covariates)

necrosis - premature death of cells and living tissue

non-linearity - refers to a situation or process in which there is no simple proportional relation between cause and effect

non-soil - parent materials with no soil development

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 center of the distribution; a normal distribution is fully specified by two parameters - mean and the standard deviation

normality - a property of a random variable that is distributed according to a normal distribution

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 rejects it for an alternative hypothesis

nutrient regime - a parameter of soils that indicates a soil's ability to supply major nutrients required for plant growth; five classes of soil nutrient regimes are recognized in a biogeoclimatic subzone

ocular estimates - subjective visual estimations of a value (e.g., % cover)

ordination - a statistical method in multivariate analysis that is complementary to data clustering and used mainly in exploratory data analysis; ordination orders multivariate objects so that similar objects are near each other and dissimilar objects are farther from each other and the relationships between objects (i.e., floristic and environmental gradient parameters) can be characterized numerically and/or graphically

ordination diagram - a graph used to display the relationships between multivariate objects resulting from an ordination analysis

orthogonal axes - a set of two or more mutually perpendicular axes orthophoto mosaic - see orthorectified aerial photographic mosaic

orthophotographs, orthophotos - see orthorectified photographs, photos

orthorectified photographs, photos - aerial photographs that have been corrected for distortion after image capture

orthorectified aerial photographic mosaic - an large aerial photograph created by fitting together a series of smaller air photos that have been corrected for distortion

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

orthorectified - having gone through the process of orthorectification

ORV - outdoor recreational vehicle

outliers - observations that deviate markedly from other members of the 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 silts, and fluvial sand, silt and gravel deposits) in which soil horizons form

pathogens - biological agents that cause disease to their hosts

pathology - the study and diagnosis of disease

per cent cover (% cover) - the area of the foliage of a plant species projected onto the ground within a specified area expressed as a percentage of the area

perennial plants - a plant that lives for more than two years, usually flowering each year

phenological differences - 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

photogrammetric - pertaining to photogrammetry, which is the practice of determining the geometric properties of objects from photographic images

photomosaic - see aerial photographic mosaic

physiographic features - the natural shapes, patterns and landforms of the environment that are associated with bedrock relief, glaciation, tectonic activity, volcanism, mass wasting, erosion and water movement

physiography - the systematic classification and description of the physical and geographic patterns, processes and phenomena of the natural environment

Pielou's evenness index - see species evenness index

pivot table - a data summarization tool found in data visualization programs such as spreadsheets; pivot-table tools can automatically sort, count, and total the data stored in one table or spreadsheet and create a second table (the "pivot table") that displays the summarized data pixel - a single point in a raster image; the pixel is the smallest display element of a digital image that can be controlled

pixelation - an effect caused by displaying a digital image at such a large size that individual pixels are visible to the eye

plant distribution codes - number codes used to represent dispersion patterns of individuals of a 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

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

polynomials - a polynomial is an expression of finite length constructed from variables and constants, using only the operations of addition, subtraction, multiplication, and non-negative, integer exponents

polynomial equation - any mathematical equation in which one or both sides are in the form of a polynomial; polynomial equations can be used to adequately model the complex spatial nature of an area

pooled data - data from two or more groups of data or two or more data sets that are combined for statistical analysis

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

qualitative - refers to data that are described in terms of some quality or categorization and includes virtually any information that can be captured that is not numerical in nature

quantitative - refers to data that are numeric values representing amounts that are measured

R2 (R-squared) - the coefficient of determination of multiple regression statistical analyses that measures the fraction of variance in Y (dependent or response variable) that is explained by a linear combination of the independent (explanatory) variables in X 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

redundancy analysis (RDA) - a multivariate direct gradient analysis method in which species are presumed to have linear relationships to environmental gradients -

repeated measures analysis (RMA) - a statistical method in which the same measures are collected multiple times for each subject but under different conditions

(RMA) ANOVA - a repeated measures analysis of variance that can be used to compare values for the same variable from the same sample population that has been measured at different times and/or under different conditions

replicates - Samples taken in a population, e.g., VCT polygons, or vegetation plots.

rill - an underground water supply, usually a buried stream, often comes to ground in a reservoir

riparian - along the bank of a river, lake or wetland

serpentine - bending from side to side as in the movement of a serpent, in reference to river channel shape.

Statistical Analysis System (SAS) - a comprehensive computer software system for data processing and analysis

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

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

serpentine creek or river - a moving water body with sinuous channel formation

shading effect - an artefact in a photograph where tree and shrub canopies cause shadows to appear in imagery; is both an advantage (used in interpretation of aerial photography for estimating height; provides a signature pixel colour for year-wise comparisons) and a disadvantage (obscures details)

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

shape file - 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

significant difference - see statistical significant difference

site series – classification of vegetation and soils at the local ecosystem level, based on soil nutrient and moisture regimes, and dominant and associated vegetation species.

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

slope - see slope gradient

slope gradient - the steepness of a slope

slope position - refers to the position of a site on the gradient from high elevation to low elevation

soft constraints operating regime (Grau and Walsh 2007) - 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

soil - a true soil has organic material incorporated with mineral material, and indications of development, i.e., layering over time.

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

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

species composition - see vegetation composition

species diversity - the number of different species and their relative abundances in a given area or habitat; 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 abundance with which each species is represented in an area

species evenness index (J) - a measure of species evenness or equability within a specified area

spectral data - The range in expression of colour in an image

species richness - the total number of different species in a specified area

statistical population - total of all the experimental units (i.e., polygons) in the study area

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 ß error for the designed a 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 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 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

surface expression - terrain texture, usually determined in aerial photographic interpretation, followed by field truthing

surficial changes – modification of the soil or parent material surfaces, usually caused by water, grazing, ice, downslope movement, etc.

taxa - groups of living organisms, at various levels of classification

texture - see soil/substrate texture

till - materials (rock) dropped from a retreating glacier or worked by a moving glacier

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

trained classification - a grouping of pixels, often in relation to field expression

triangulated - see triangulation

triangulation - the process of determining the location of a point by measuring angles to it from known points at either end of a fixed baseline rather than measuring distances to the point directly; the point can then be fixed as a third point of a triangle with one known side and two known angles

two-tailed statistical test - the test uses a two-tailed probability to determine significance where the null hypothesis will be rejected for values of the test statistic that are either sufficiently small or sufficiently large

upland - land lying above the area where water usually flows or that is influenced by flooding and poor drainage

UTM coordinates - x and y coordinates, called eastings and northings, respectively, that locate a point in a universal transverse Mercator (UTM) projection of the earth's surface

variance - see statistical variance

variation - see statistical variation

vectors - a quantity possessing both a magnitude and a direction

vegetation or plant 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 and disturbance

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

vegetation community type - the basic map unit in the reservoir draw down zone based primarily on physiographic (terrain, soil/substrate) features and vegetation characteristics; VCT vegetation composition - includes the different plant species, their abundances and distributions within a vegetation community

vegetation cover - the area of the foliage of a plant species projected onto the ground within a specific area

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

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

water regime - soft constraints operating regime; how water levels are managed in the reservoir

wetland - sites 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. NUMBER OF FIELD PLOTS AND MAPPED POLYGONS SAMPLED

Table A1-1. Number of field plots completed in each VCT in 2012 for CLBMON-33

VCT	Arrow Lakes				Revelstoke Reach				Grand Total
	Elevation Band				Elevation Band				
	434-436	436-438	438-440	Total	434-436	436-438	438-440	Total	
BB	2	3	3	8	1	1	0	2	10
BE	20	16	13	49	3	2	2	7	56
BG	16	19	13	48	2	1	4	7	55
CL	0	0	0	0	0	0	1	1	1
CR	0	0	26	26	0	1	5	5	31
IN	5	2	5	12	6	8	5	19	31
PA	0	5	16	21	0	16	10	26	47
PC	9	25	19	53	25	10	11	46	99
PE	19	11	0	30	4	6	0	10	40
PO*	0	0	0	0	0	1	0	1	1
RR	5	5	4	14	0	0	1	1	15
RS	1	1	0	2	0	2	0	2	4
SF	0	0	0	0	1	0	0	1	1
SS	1	0	1	2	4	0	0	4	6
WR	0	0	0	0	1	0	0	1	1
WS	0	1	0	1	0	0	0	0	1
Grand Total	78	88	100	266	47	48	39	133	400

***NOTE: PO was eliminated as a VCT in 2010 because it is ephemeral, but it may be reintroduced into the mapping if it is of sufficient cover in the map revisions of 2012**

Table A1-2. **Number of mapped polygons assessed in each VCT in 2012 for Repeated Measures Analysis**

VCT	BE	BG	CR	PA	PC	PE	RR	Total
Number of Polygons	47	37	35	25	85	25	10	264

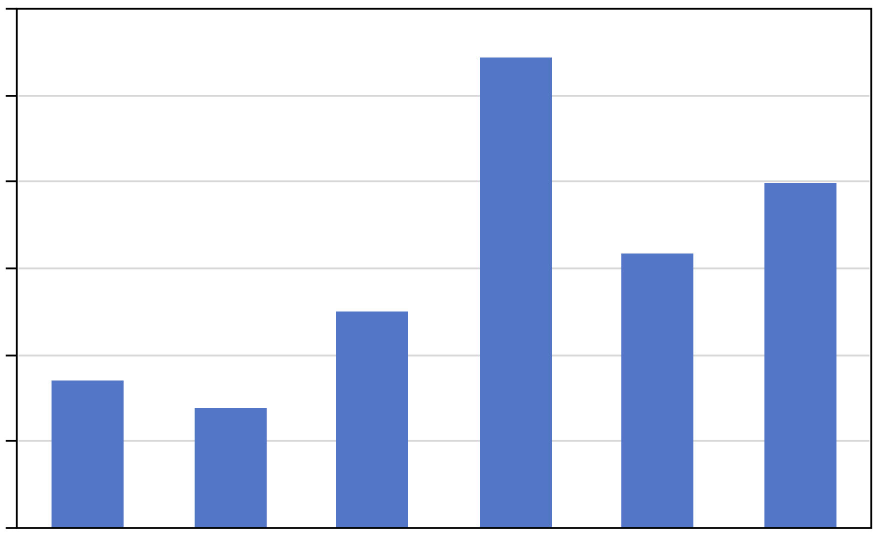


Figure A1-1. **Number of plots sampled in each field season from 2007 to 2012. N = 169 for 2007, 139 for 2008, 249 for 2009, 543 for 2010, 316 for 2011, and 399 for 2012.**

APPENDIX 2. VEGETATION SPECIES LIST FOR 2012

Species Code	Scientific Name	English Name
ACERCIR	*Acer circinatum*	vine maple
ACERGLA	*Acer glabrum*	Douglas maple
ACHIMIL	*Achillea millefolium*	yarrow
ACTARUB	*Actaea rubra*	baneberry
ADENBIC	*Adenocaulon bicolor*	pathfinder
AGROPYR	*Agropyron sp.*	wheatgrass
AGROGIG	*Agrostis gigantea*	redtop
AGROSCA	*Agrostis scabra*	hair bentgrass
ALISGRA	*Alisma gramineum*	narrow-leaved water-plantain
ALNUVIR	*Alnus viridis*	
ALOPAEQ	*Alopecurus aequalis*	little meadow-foxtail
ALOPGEN	*Alopecurus geniculatus*	water meadow-foxtail
AMELALN	*Amelanchier alnifolia*	saskatoon
ANAPMAR	*Anaphalis margaritacea*	pearly everlasting
ANTEMIC	*Antennaria microphylla*	white pussytoes
ANTENEG	*Antennaria neglecta*	field pussytoes
ANTENNA	*Antennaria sp.*	pussytoes
APOCAND	*Apocynum androsaemifolium*	spreading dogbane
ARALNUD	*Aralia nudicaulis*	wild sarsaparilla
ARCTUVA	*Arctostaphylos uva-ursi*	kinnikinnick
ARNICA	*Arnica sp.*	arnica
ARTEMIS	*Artemisia sp.*	
ASARCAU	*Asarum caudatum*	wild ginger
ASTER	*Aster sp.*	
ATHYFIL	*Athyrium filix-femina*	lady fern
AULAPAL	*Aulacomnium palustre*	glow moss
BETUOCC	*Betula occidentalis*	water birch
BETUPAP	*Betula papyrifera*	paper birch
BORAGO	*Borago sp.*	
BOTRVIR	*Botrychium virginianum*	rattlesnake fern
BRACALB	*Brachythecium albicans*	lawn moss
BRACCOL	*Brachythecium collinum*	
BRACRIV	*Brachythecium rivulare*	river ragged-moss
BRACSAL	*Brachythecium salebrosum*	golden ragged-moss
BRACHYT	*Brachythecium sp.*	ragged-moss
BROMINE	*Bromus inermis*	smooth brome
BROMTEC	*Bromus tectorum*	cheatgrass
BROMVUL	*Bromus vulgaris*	Columbia brome
CALACAN	*Calamagrostis canadensis*	bluejoint reedgrass
CALLPAL	*Calla palustris*	wild calla

CALLGIG	*Calliergon giganteum*	giant water-moss
CARDPEN	*Cardamine pensylvanica*	Pennsylvanian bitter-cress
CAREAPE	*Carex aperta*	Columbia sedge
CAREAQU	*Carex aquatilis*	water sedge
CAREFOE	*Carex foenea*	bronze sedge
CARELEN	*Carex lenticularis*	lakeshore sedge
CAREROS	*Carex rossii*	Ross' sedge
CARESIT	*Carex sitchensis*	Sitka sedge
CAREX	*Carex sp.*	sedge
CARESPE	*Carex spectabilis*	showy sedge
CAREUTR	*Carex utriculata*	beaked sedge
CASTMIN	*Castilleja miniata*	scarlet paintbrush
CASTILL	*Castilleja sp.*	paintbrush
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
CERASTI	*Cerastium sp.*	
CERAPUR	*Ceratodon purpureus*	fire-moss
CHENALB	*Chenopodium album*	lamb's-quarters
CHIMUMB	*Chimaphila umbellata*	prince's pine
CLADINA	*Cladina sp.*	reindeer lichens
CLADCAI	*Cladonia cariosa*	peg-leg soldiers
CLADCHL	*Cladonia chlorophaea*	mealy pixie-cup
CLADCOR	*Cladonia cornuta*	
CLADDEF	*Cladonia deformis*	lesser sulphur-cup
CLADECM	*Cladonia ecmocyna*	
CLADFIM	*Cladonia fimbriata*	powdered trumpet
CLADGRA	*Cladonia gracilis*	
CLADMUL	*Cladonia multiformis*	slotted cladonia
CLADONI	*Cladonia sp.*	Cladonia lichens
CLIMDEN	*Climacium dendroides*	tree-moss
CLINUNI	*Clintonia uniflora*	queen's cup
COLLPAR	*Collinsia parviflora*	small-flowered blue-eyed Mary
COLLINS	*Collinsia sp.*	
COLLLIN	*Collomia linearis*	narrow-leaved collomia
COMAPAU	*Comarum palustre*	marsh cinquefoil
CORNSTO	*Cornus stolonifera*	red-osier dogwood
CORYCOR	*Corylus cornuta*	beaked hazelnut
CRATDOU	*Crataegus douglasii*	black hawthorn
CYPRMON	*Cypripedium montanum*	mountain lady's-slipper
CYTISCO	*Cytisus scoparius*	Scotch broom
DACTGLO	*Dactylis glomerata*	orchard-grass

DANTHON	*Danthonia sp.*	oatgrass
DANTSPI	*Danthonia spicata*	poverty oatgrass
DICRFUS	*Dicranum fuscescens*	curly heron's-bill moss
DICRSCO	*Dicranum scoparium*	broom-moss
DICRANU	*Dicranum sp.*	heron's-bill moss
DREPADU	*Drepanocladus aduncus*	common hook-moss
DREPANO	*Drepanocladus sp.*	hook-moss
DRYADRU	*Dryas drummondii*	yellow mountain-avens
DRYOEXP	*Dryopteris expansa*	spiny wood fern
ELEOPAL	*Eleocharis palustris*	common spike-rush
ELEOCHA	*Eleocharis sp.*	
ELYMGLA	*Elymus glaucus*	blue wildrye
ELYMREP	*Elymus repens*	quackgrass
EPILANG	*Epilobium angustifolium*	fireweed
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
EQUIVAR	*Equisetum variegatum*	northern scouring-rush
ERIGSUB	*Erigeron subtrinervis*	triple-nerved fleabane
ERODCIC	*Erodium cicutarium*	common stork's-bill
EURYCON	*Eurybia conspicua*	showy aster
FABACEA	*Fabaceae*	
FESTOCC	*Festuca occidentalis*	western fescue
FESTSAX	*Festuca saximontana*	Rocky Mountain fescue
FESTUCA	*Festuca sp.*	fescue
FRAGARI	*Fragaria sp.*	strawberry
FRAGVES	*Fragaria vesca*	wood strawberry
FRAGVIR	*Fragaria virginiana*	wild strawberry
GALIAPA	*Galium aparine*	cleavers
GALIPAL	*Galium palustre*	marsh bedstraw
GALIUM	*Galium sp.*	bedstraw
GALITRF	*Galium triflorum*	sweet-scented bedstraw
GNAPULI	*Gnaphalium uliginosum*	marsh cudweed
GOODOBL	*Goodyera oblongifolia*	rattlesnake-plantain
GYMNDRY	*Gymnocarpium dryopteris*	oak fern
GYMNOCA	*Gymnocarpium sp.*	
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
HIERPRE	*Hieracium praealtum*	king devil
HIERACI	*Hieracium sp.*	hawkweed
HIERHIR	*Hierochloë hirta*	common sweetgrass
HORDBRA	*Hordeum brachyantherum*	meadow barley
HYLOSPL	*Hylocomium splendens*	step moss
HYPEPER	*Hypericum perforatum*	common St. John's-wort
HYPOPHY	*Hypogymnia physodes*	monk's-hood
IRIS	*Iris sp.*	
ISOTHEC	*Isothecium sp.*	
JUNCENS	*Juncus ensifolius var. montanus*	dagger-leaf rush
JUNCFIL	*Juncus filiformis*	thread rush
JUNCUS	*Juncus sp.*	rush
JUNCTEN	*Juncus tenuis*	slender rush
JUNICOM	*Juniperus communis*	common juniper
LACTCAN	*Lactuca canadensis*	Canadian wild lettuce
LARIOCC	*Larix occidentalis*	western larch
LATHYRU	*Lathyrus sp.*	peavine
LEUCVUL	*Leucanthemum vulgare*	oxeye daisy
LILICOL	*Lilium columbianum*	tiger lily
LINNBOR	*Linnaea borealis*	twinflower
LOLIPER	*Lolium perenne*	perennial ryegrass
LONIINV	*Lonicera involucrata*	black twinberry
LONIUTA	*Lonicera utahensis*	Utah honeysuckle
LUPIARC	*Lupinus arcticus*	arctic lupine
LUPIPOY	*Lupinus polyphyllus*	large-leaved lupine
LYSIAME	*Lysichiton americanus*	skunk cabbage
MADISAT	*Madia sativa*	Chilean tarweed
MAHOAQU	*Mahonia aquifolium*	tall Oregon-grape
MAIARAC	*Maianthemum racemosum*	false Solomon's-seal
MAIASTE	*Maianthemum stellatum*	star-flowered false Solomon's-seal
MARCPOL	*Marchantia polymorpha*	green-tongue liverwort
MATRDIS	*Matricaria discoidea*	pineapple weed
MEDISAT	*Medicago sativa*	alfalfa
MENTARV	*Mentha arvensis*	field mint
MENTHA	*Mentha sp.*	
MIMUGUT	*Mimulus guttatus*	yellow monkey-flower
MNIUM	*Mnium sp.*	leafy moss
MONEUNI	*Moneses uniflora*	single delight
MONTFON	*Montia fontana*	blinks
MONTLIN	*Montia linearis*	narrow-leaved montia
MONTIA	*Montia sp.*	
MYOSARV	*Myosotis arvensis*	field forget-me-not
MYOSDIS	*Myosotis discolor*	common forget-me-not

MYOSLAX	*Myosotis laxa*	small-flowered forget-me-not
MYOSSCO	*Myosotis scorpioides*	European forget-me-not
MYOSSYL	*Myosotis sylvatica*	wood forget-me-not
MYRISPI	*Myriophyllum spicatum*	Eurasian water-milfoil
ORTHSEC	*Orthilia secunda*	one-sided wintergreen
ORTHLYE	*Orthotrichum lyellii*	Lyell's bristle-moss
ORYZASP	*Oryzopsis asperifolia*	rough-leaved ricegrass
OSMODEP	*Osmorhiza depauperata*	blunt-fruited sweet-cicely
OSMOPUR	*Osmorhiza purpurea*	purple sweet-cicely
OSMORHI	*Osmorhiza sp.*	sweet-cicely
PARMSUL	*Parmelia sulcata*	waxpaper
PAXIMYR	*Paxistima myrsinites*	falsebox
PEDIBRA	*Pedicularis bracteosa*	bracted lousewort
PELTAPH	*Peltigera aphthosa*	freckle pelt
PELTCAN	*Peltigera canina*	dog pelt
PELTMEM	*Peltigera membranacea*	greater dog pelt
PELTPOY	*Peltigera polydactylon*	frog pelt
PELTRUF	*Peltigera rufescens*	felt pelt
PERSAMP	*Persicaria amphibia*	water smartweed
PERSMAC	*Persicaria maculata*	lady's-thumb
PHACHAS	*Phacelia hastata*	silverleaf phacelia
PHALARU	*Phalaris arundinacea*	reed canarygrass
PHILFON	*Philonotis fontana*	spring moss
PHLEPRA	*Phleum pratense*	common timothy
PICEGLA	*Picea glauca*	white spruce
PICEA	*Picea sp.*	spruce
PINUCON	*Pinus contorta*	lodgepole pine
PINUMON	*Pinus monticola*	western white pine
PIPECAN	*Piperia candida*	white-lip rein orchid
PLAGSCO	*Plagiobothrys scouleri*	Scouler's popcornflower
PLANLAN	*Plantago lanceolata*	ribwort plantain
PLATGLA	*Platismatia glauca*	ragbag
PLEUSCH	*Pleurozium schreberi*	red-stemmed feathermoss
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
POA	*Poa sp.*	bluegrass
POACEAE	*Poaceae*	
POHLNUT	*Pohlia nutans*	nodding thread-moss
POHLWAH	*Pohlia wahlenbergii*	pale nodding-cap moss
POLYAVI	*Polygonum aviculare*	common knotweed
POLYCOM	*Polytrichum commune*	common haircap moss

POLYJUN	*Polytrichum juniperinum*	juniper haircap moss
POLYPIL	*Polytrichum piliferum*	awned haircap moss
POPUBAL	*Populus balsamifera*	balsam poplar
POPUTRE	*Populus tremuloides*	trembling aspen
POTANAT	*Potamogeton natans*	floating-leaved pondweed
POTAMOG	*Potamogeton sp.*	pondweed
POTEANS	*Potentilla anserina*	common silverweed
POTEGRA	*Potentilla gracilis*	graceful cinquefoil
POTENOR	*Potentilla norvegica*	Norwegian cinquefoil
PROSHOO	*Prosartes hookeri*	Hooker's fairybells
PRUNVUL	*Prunella vulgaris*	self-heal
PRUNAVI	*Prunus avium*	sweet cherry
PRUNUS	*Prunus sp.*	cherry
PSEUMEN	*Pseudotsuga menziesii*	Douglas-fir
PTERAQU	*Pteridium aquilinum*	bracken fern
PTILCRI	*Ptilium crista-castrensis*	knight's plume
PYROASA	*Pyrola asarifolia*	pink wintergreen
RACOCAN	*Racomitrium canescens*	grey rock-moss
RACOERI	*Racomitrium ericoides*	shaggy rock-moss
RANUACR	*Ranunculus acris*	meadow buttercup
RANUREP	*Ranunculus repens*	creeping buttercup
RANUSCE	*Ranunculus sceleratus*	celery-leaved buttercup
RANUSCL	*Ranunculus sceleratus*	cursed buttercup
RANUNCU	*Ranunculus sp.*	buttercup
RANUUNC	*Ranunculus uncinatus*	little buttercup
RHAMPUR	*Rhamnus purshiana*	cascara
RHINMIN	*Rhinanthus minor*	yellow rattle
RHYTLOR	*Rhytidiadelphus loreus*	lanky moss
RHYTSQU	*Rhytidiadelphus squarrosus*	bent-leaf moss
RHYTTRI	*Rhytidiadelphus triquetrus*	electrified cat's-tail moss
RHYTROB	*Rhytidiopsis robusta*	pipecleaner moss
RHYTIDO	*Rhytidiopsis sp.*	
ROBIPSE	*Robinia pseudoacacia*	black locust
RORICUR	*Rorippa curvipes*	
RORIPAL	*Rorippa palustris*	marsh yellow cress
RORIPPA	*Rorippa sp.*	
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
RUMEACO	*Rumex acetosa*	green sorrel
RUMEACT	*Rumex acetosella*	sheep sorrel

RUMECRI	*Rumex crispus*	curled dock
RUMEX	*Rumex sp.*	
SAGIPRO	*Sagina procumbens*	bird's-eye pearlwort
SAGINA	*Sagina sp.*	
SALIBEB	*Salix bebbiana*	Bebb's willow
SALILUC	*Salix lucida*	
SALIPRO	*Salix prolixa*	Mackenzie willow
SALISCO	*Salix scouleriana*	Scouler's willow
SALIX	*Salix sp.*	willow
SANIUNC	*Sanionia uncinata*	sickle-moss
SCIRCYP	*Scirpus cyperinus*	woolgrass
SCIRMIC	*Scirpus microcarpus*	small-flowered bulrush
SCLEANN	*Scleranthus annuus*	annual knawel
SENEPAP	*Senecio pauperculus*	Canadian butterweed
SHEPCAN	*Shepherdia canadensis*	soopolallie
SOLICAN	*Solidago canadensis*	Canada goldenrod
SORBSCO	*Sorbus scopulina*	western mountain-ash
SORBSIT	*Sorbus sitchensis*	Sitka mountain-ash
SPERRUB	*Spergularia rubra*	red sand-spurry
SPIRBET	*Spiraea betulifolia*	birch-leaved spirea
SPIRPYR	*Spiraea pyramidata*	pyramid spirea
STERTOM	*Stereocaulon tomentosum*	eyed foam
STIPA	*Stipa sp.*	
STREAMP	*Streptopus amplexifolius*	clasping twistedstalk
STRELAN	*Streptopus lanceolatus*	
SYMPALB	*Symphoricarpos albus*	common snowberry
TARAOFF	*Taraxacum officinale*	common dandelion
TAXUBRE	*Taxus brevifolia*	western yew
THUJPLI	*Thuja plicata*	western redcedar
TIARTRI	*Tiarella trifoliata*	three-leaved foamflower
TORTRUA	*Tortula ruralis*	sidewalk moss
TRIAGLU	*Triantha glutinosa*	sticky false asphodel
TRIFARV	*Trifolium arvense*	hare's-foot clover
TRIFAUR	*Trifolium aureum*	yellow clover
TRIFHYB	*Trifolium hybridum*	alsike clover
TRIFPRA	*Trifolium pratense*	red clover
TRIFREP	*Trifolium repens*	white clover
TRIFOLI	*Trifolium sp.*	clover
TRIGMAR	*Triglochin maritima*	seaside arrow-grass
TSUGHET	*Tsuga heterophylla*	western hemlock
ULOTA	*Ulota sp.*	pincushion moss
URTIDIO	*Urtica dioica*	stinging nettle
VACCMEM	*Vaccinium membranaceum*	black huckleberry
VERBTHA	*Verbascum thapsus*	great mullein
VEROPER	*Veronica peregrina*	purslane speedwell

VERONIC	*Veronica sp.*	speedwell
VICICRA	*Vicia cracca*	tufted vetch
VIOLGLA	*Viola glabella*	stream violet
VIOLA	*Viola sp.*	violet
XANTPOL	*Xanthoria polycarpa*	pincushion orange

APPENDIX 3. ANALYSIS OF VARIANCE RESULTS FOR 2012: VEGETATION COVER AND HEIGHTS IN ARROW LAKES RESERVOIR

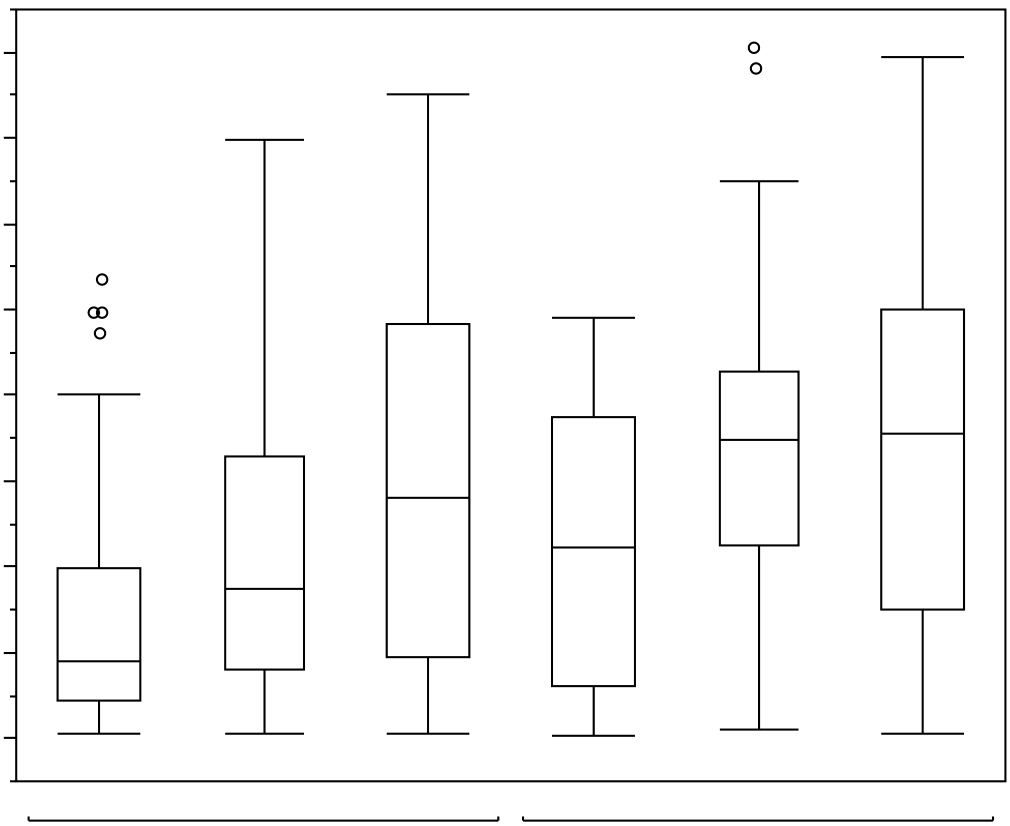
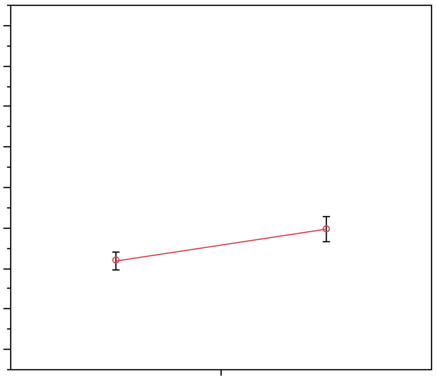


Figure A4-1. Total cover of vegetation in the three elevation bands (434 m to 436 m, 436 m to 438 m, and 438 m to 440 m) in the Arrow Lakes and Revelstoke Reach portions of the Arrow Lakes Reservoir

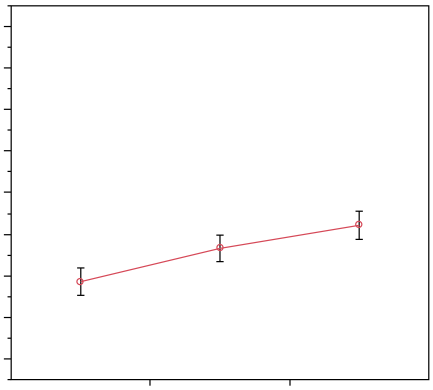
Table A4-1. Analysis of variance of total vegetation cover in Revelstoke Reach and Arrow Lakes portions of the Arrow Lakes Reservoir, within three consecutive elevation bands: 434 m to 436 m, 436 m to 438 m, and 438 m to 440 m

```
Categorical values encountered during processing are:
REACH$ (2 levels)
   Arrow, Revelstoke
ELEVBAND$ (3 levels)
   434-436, 436-438, 438-440

Dep Var: TOTCOVER   N: 399   Rsquare: 0.1356

                             Analysis of Variance

Source               Sum-of-Squares   DF     F-Ratio        P

REACH$               21643.455        1       16.5426       0.000
ELEVBAND$            42203.765        2       16.1287       0.000
REACH$*ELEVBAND$     6309.749         2        2.4113       0.091

-------------------------------------------------------------------------------
Least squares means:
                                 LS Mean        SE        N
  REACH$      =Arrow              43.686        2.243     263
  REACH$      =Revelstoke         59.429        3.154     133
-------------------------------------------------------------------------------

  ELEVBAND$   =434-436            37.174        3.356     123
  ELEVBAND$   =436-438            53.191        3.245     136
  ELEVBAND$   =438-440            64.307        3.451     138
-------------------------------------------------------------------------------

REACH$      =Arrow
  ELEVBAND$   =434-436            28.842        4.149      76
REACH$      =Arrow
  ELEVBAND$   =436-438            40.353        3.856      88
REACH$      =Arrow
  ELEVBAND$   =438-440            61.864        3.635      99
REACH$      =Revelstoke
  ELEVBAND$   =434-436            45.506        5.276      47
REACH$      =Revelstoke
  ELEVBAND$   =436-438            66.029        5.221      48
REACH$      =Revelstoke
  ELEVBAND$   =438-440            66.750        5.868      38
-------------------------------------------------------------------------------
```

Least Squares Means Plots

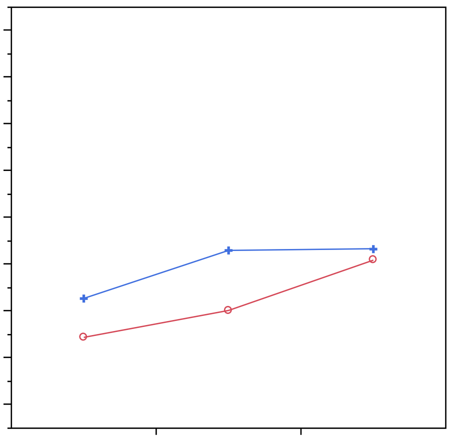


Total Cover: Revelstoke Reach > Arrow Lakes



Total Cover: 438-440 > 436-438 > 434-436

Least Squares Means indicate significant effects for both the Reach and Elevation Class Levels.



There is no evidence of a significant interaction between the Reach and Elevation Class levels.

Vegetation heights in Arrow Lakes vs. Revelstoke Reach Portions of the Arrow Lakes Reservoir

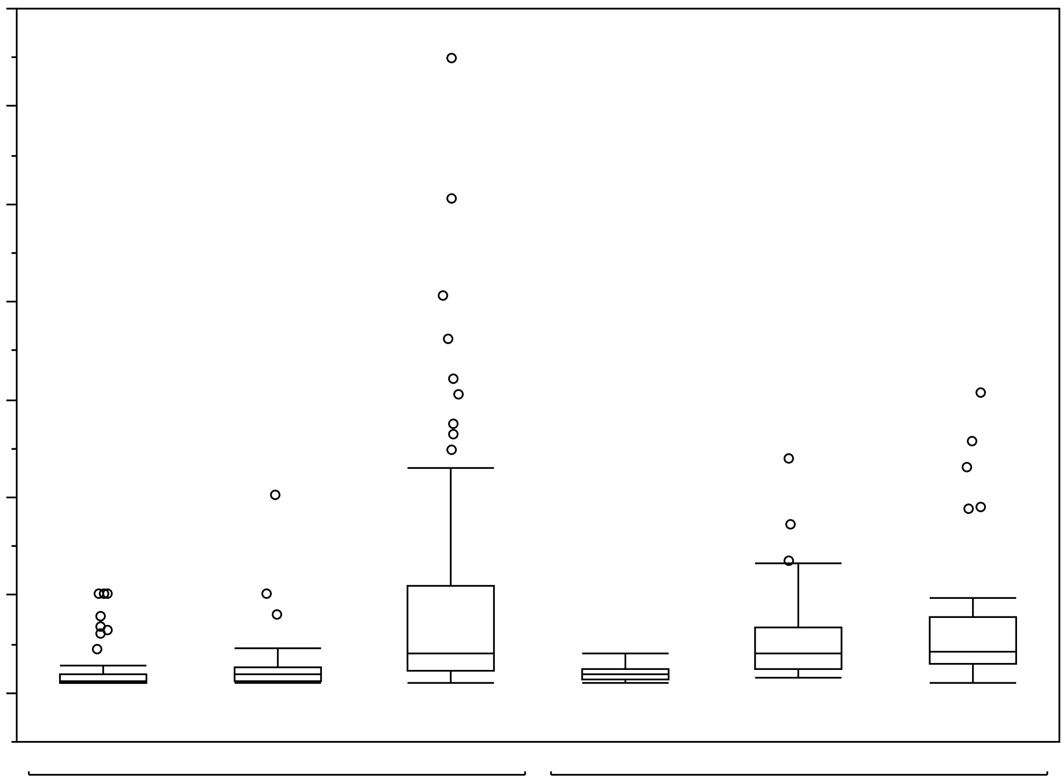
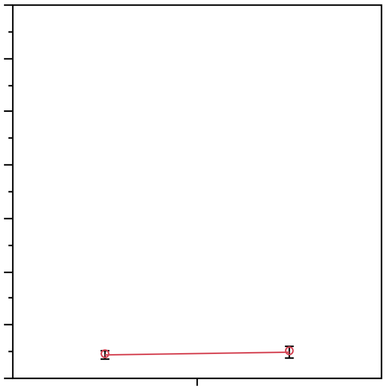


Figure A4-2. Total heights of vegetation in the three elevation bands (434 m to 436 m, 436 m to 438 m, and 438 m to 440 m) in the Arrow Lakes and Revelstoke Reach portions of the Arrow Lakes Reservoir

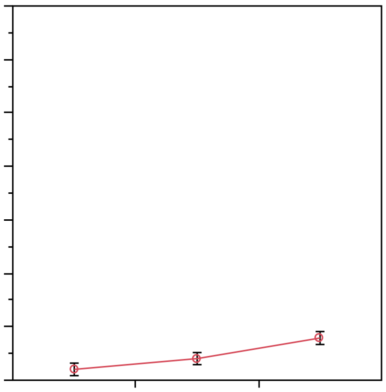
Table A4-2. Analysis of variance of total vegetation heights in Revelstoke Reach and Arrow Lakes portions of the Arrow Lakes Reservoir, within three consecutive elevation bands: 434 m to 436 m, 436 m to 438 m, and 438 m to 440 m

```
Categorical values encountered during processing are:
REACH$ (2 levels)
   Arrow, Revelstoke
ELEVBAND$ (3 levels)
   434-436, 436-438, 438-440

Dep Var: AVGMAXHT   N: 399   Rsquare: 0.1687

                             Analysis of Variance

Source             Sum-of-Squares   DF     F-Ratio       P

REACH$                      0.225    1       0.550       0.459
ELEVBAND$                  19.688    2      24.114       0.000
REACH$*ELEVBAND$            3.768    2       4.615       0.011
-------------------------------------------------------------------------------
Least squares means:
                                LS Mean           SE      N
  REACH$      =Arrow              0.440        0.040     263
  REACH$      =Revelstoke         0.491        0.056     133
-------------------------------------------------------------------------------

  ELEVBAND$   =434-436            0.202        0.060     123
  ELEVBAND$   =436-438            0.404        0.058     136
  ELEVBAND$   =438-440            0.790        0.062     138
-------------------------------------------------------------------------------

REACH$      =Arrow
  ELEVBAND$   =434-436            0.204        0.074      76
REACH$      =Arrow
  ELEVBAND$   =436-438            0.240        0.069      88
REACH$      =Arrow
  ELEVBAND$   =438-440            0.875        0.064      99
REACH$      =Revelstoke
  ELEVBAND$   =434-436            0.201        0.093      47
REACH$      =Revelstoke
  ELEVBAND$   =436-438            0.568        0.092      48
REACH$      =Revelstoke
  ELEVBAND$   =438-440            0.704        0.105      38
-------------------------------------------------------------------------------
```

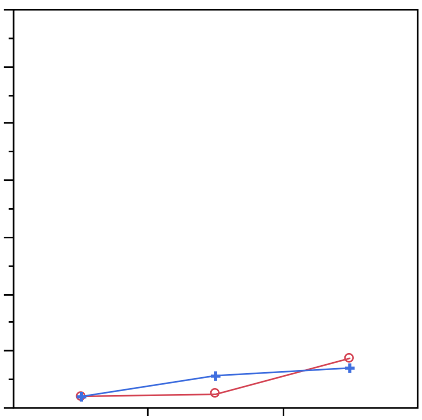
Least Squares Means Plots



Max Height: Arrow = Revelstoke Reach



Max Height: 438-440 > 436-438 > 434-436



There is a significant interaction between levels (Reach and Elevation Band)

Total vegetation cover by VCT (combined data for all plots, by VCT)

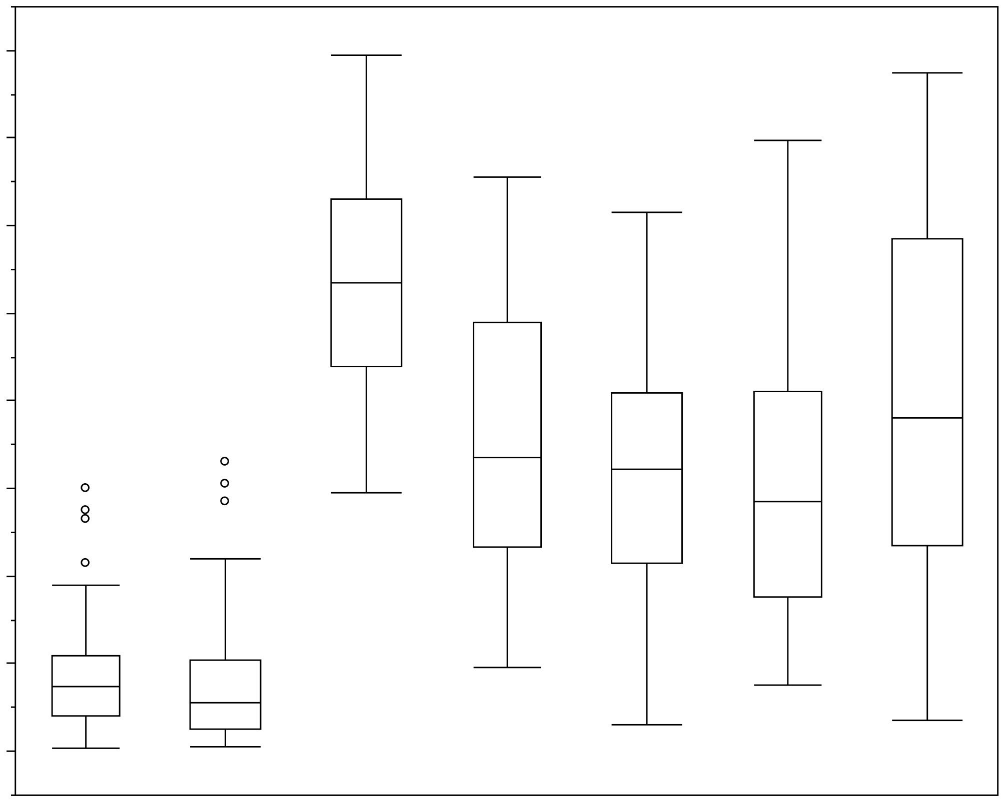


Figure A4-3. **Total cover of vegetation by VCT for all combined data in both the Arrow Lakes and Revelstoke Reach portions of the Arrow Lakes Reservoir. BE = Beach, BG = Gravelly beach, CR = Cottonwood riparian forest, PA = Redtop upland, PC = Reed canary grass mesic, PE = Horsetail lowland, RR = Reed-rill.**

Table A4-3. Analysis of variance of total vegetation cover of seven VCTs in the combined Revelstoke Reach and Arrow Lakes portions of the Arrow Lakes Reservoir

Categorical values encountered during processing are:
VCT$ (7 levels)
BE, BG, CR, PA, PC, PE, RR

Dep Var: TOTCOVER N: 343 Rsquare: 0.5509

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	P
VCT	6	277525.51	46254.3	68.6878	0.000
Error	336	226261.8	673.4		
C. Total	342	503787.31			

ANOVA indicates a significant difference between total vegetation covers in seven VCTs.

Post-hoc comparisons among VCTs

LSD Threshold Matrix
Abs(Dif)-HSD

	CR	RR	PA	PC	PE	BE	BG
CR	-19.5517	4.0551	17.9795	29.9887	30.7603	73.2717	74.7536
RR	4.0551	-28.1074	-15.3031	-3.7619	-2.3915	39.8591	41.3538
PA	17.9795	-15.3031	-15.8788	-3.5937	-3.1691	39.4865	40.9612
PC	29.9887	-3.7619	-3.5937	-10.9408	-11.0733	31.8016	33.2648
PE	30.7603	-2.3915	-3.1691	-11.0733	-17.2122	25.3888	26.8662
BE	73.2717	39.8591	39.4865	31.8016	25.3888	-14.5470	-13.0753
BG	74.7536	41.3538	40.9612	33.2648	26.8662	-13.0753	-14.6786

Positive values indicate pairs of means that are significantly different.

CR differs from all others;
RR differs from all except PA, PC, and PE;
PA differs from all except RR, PC, and PE;
PC differs from all except RR, PA, and PE;
PE differs from all except RR, PA, and PC;
BE differs from all except BG;
BG differs from all except BE.

Least Squares Means

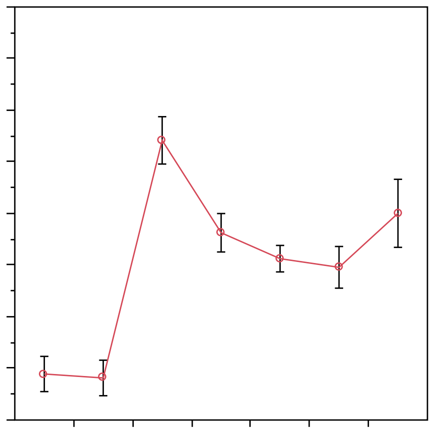


Figure A4-4. Least squares means of total cover in BE: Sandy Beach, BG: Gravelly beach, CR: Cottonwood riparian, PA: Redtop upland, PC: Reed canary grass mesic, PE: Horsetail lowland and RR: Reed rill

In Summary: CR > RR = PC = PE = RR = BE > BG

Average Maximum Vegetation Height by VCT (combined data for all plots, by VCT)

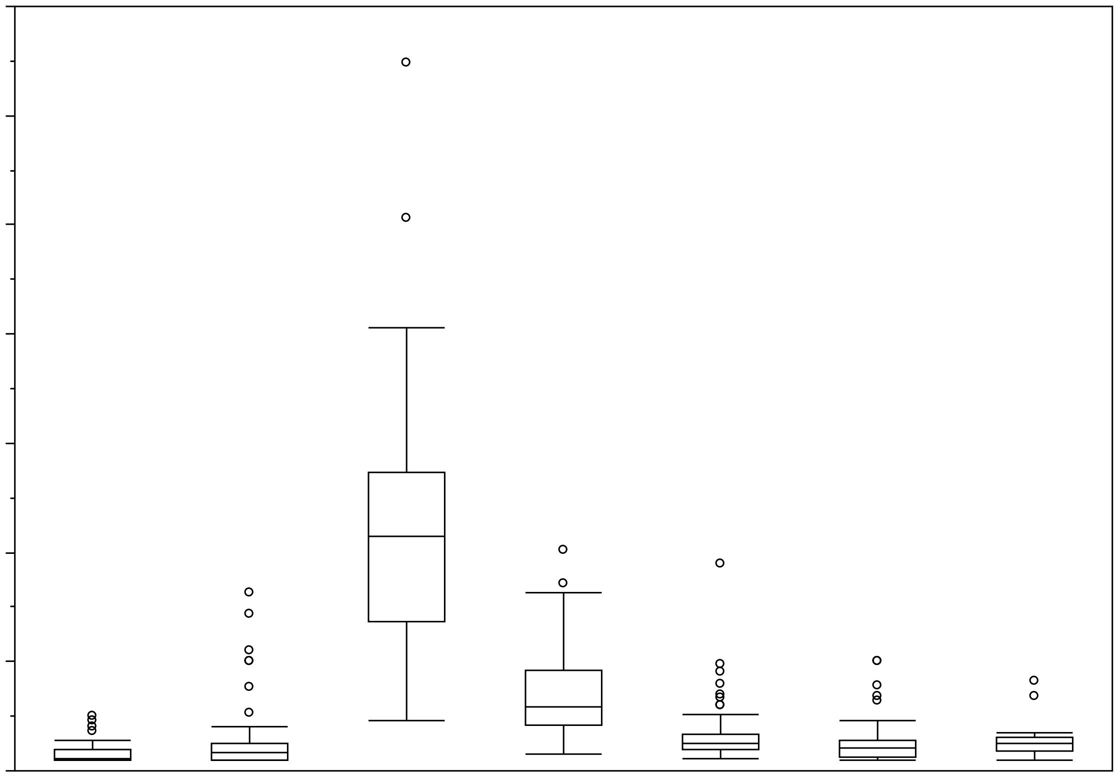


Figure A4-5. Total maximum heights of vegetation in each of the main vegetated VCTs in the Arrow Lakes Reservoir drawdown zone

Table A4-4. Analysis of variance of total vegetation heights of seven VCTs in the Arrow Lakes Reservoir

Categorical values encountered during processing are:
VCT$ (7 levels)
BE, BG, CR, PA, PC, PE, RR

Dep Var: Mean(MAX HEIGHT) N: 343 Rsquare:0.6021

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	P
VCT	6	110.775	18.463	83.463	0.000
Error	331	73.219	0.221		
C. Total	337	183.994			

- -

ANOVA indicates a significant difference between average maximum vegetation height in seven VCTs.

Post-hoc comparisons among VCTs

LSD Threshold Matrix
Abs(Dif)-HSD

	CR	PA	PC	RR	BG	PE	BE
CR	-0.354	1.192	1.643	1.500	1.636	1.625	1.764
PA	1.192	-0.288	0.169	0.011	0.157	0.144	0.285
PC	1.643	0.169	-0.199	-0.378	-0.217	-0.234	-0.089
RR	1.500	0.011	-0.378	-0.509	-0.396	-0.403	-0.268
BG	1.636	0.157	-0.217	-0.396	-0.271	-0.285	-0.143
PE	1.625	0.144	-0.234	-0.403	-0.285	-0.312	-0.172
BE	1.764	0.285	-0.089	-0.268	-0.143	-0.172	-0.269

Positive values indicate pairs of means that are significantly different.

CR differs from all others;
PA differs from all others;
PC differs from CR and PA only;
RR differs from CR and PA only;
BG differs from CR and PA only;
PE differs from CR and PA only;
BE differs from CR and PA only.

Least Squares Means

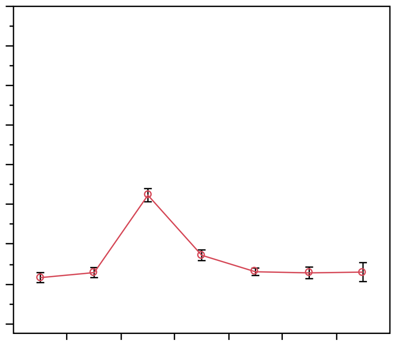


Figure A4-6. Least squares means of average vegetation height in BE: Sandy Beach, BG: Gravelly beach, CR: Cottonwood riparian, PA: Redtop upland, PC: Reed canary grass mesic, PE: Horsetail lowland and RR: Reed rill

Max Height: CR > PA > PC = RR = BG = PE = BE

ANOVA Results for Vegetation Cover in Type by Reach and Year

BE (Sandy Beach):

For BE, all data for 2007 were excluded because there was only a single measured cover value in this type in Revelstoke in 2007.

N: 280 Rsquare: 0.100

Source	DF	Sum of Squares	F Ratio	P
Year	4	3057.424	4.239	0.002
Reach	1	205.108	1.138	0.287
Year*Reach	4	625.958	0.868	0.484

Significant differences were found for Total Vegetation Cover between years, but not between Reaches. Post hoc comparison showed total cover ranked from highest to lowest: 2012 > 2011 > 2010 > 2009 > 2008. There was no interaction effect as the effects of Reach and Year were independent.

CR (Cottonwood riparian):

For CR, all data for 2007 were excluded because only a single cover value in this type was measured for Revelstoke Reach in 2007.

N: 125 Rsquare: 0.493

Source	DF	Sum of Squares	F Ratio	P
Year	4	123332.760	18.667	0.000
Reach	1	6231.150	3.773	0.055
Year*Reach	4	3101.600	0.469	0.758

A significant difference in total cover by year was indicated. Post hoc comparison showed total cover ranked from highest to lowest: 2009 > 2010 > 2012 > 2011 > 2008. There were no significant differences in total cover due to the effects of Reach or Reach x Year.

PA (Redtop upland):

For PA, all data in all years were used.

N: 201 Rsquare: 0.274

Source	DF	Sum of Squares	F Ratio	P
Year	5	82109.234	11.117	0.000
Reach	1	9.183	0.006	0.937
Year*Reach	5	14192.012	1.922	0.093

Significant differences in total cover by year were indicated. Post hoc comparison showed total cover ranked from highest to lowest: 2009 > 2012 > 2010 > 2011 > 2007 > 2008. There were no significant differences in total cover due to the effects of Reach or Reach x Year.

PC (Reed canary grass mesic):

For PC, all data in all years were used.

N: 589   Rsquare: 0.172

Source	DF	Sum of Squares	F Ratio	P
Year	5	59351.473	18.482	0.000
Reach	1	1254.490	1.953	0.163
Year*Reach	5	14246.394	4.436	0.001

Significant differences in total cover by year were indicated. Post hoc comparison showed total cover ranked from highest to lowest: 2009 > 2012 > 2007 > 2010 > 2011 > 2008. There was a significant interaction effect of Reach and Year on total cover. Post hoc comparison of interaction least square means resulted in the following ranking:

Level*					Least Sq Means
2009,Arrow	A				83.442
2009,Reach	A				79.653
2012,Reach	A	B			69.239
2007,Reach	A	B	C		65.500
2012,Arrow		B	C	D	56.653
2010,Arrow				D	50.265
2011,Reach				D	49.561
2008,Arrow		B	C	D	48.421
2007,Arrow				D	46.613
2011,Arrow				D	43.312
2008,Reach			C	D	43.125
2010,Reach				D	42.703

*Levels not connected by the same letter are significantly different.

There were no significant differences in total cover due to the effects of Reach alone.

PE (Horsetail):

For PE, all data for 2008 were excluded because of no measured cover values for this type in Revelstoke in 2008.

N: 141   Rsquare: 0.138

Source	DF	Sum of Squares	F Ratio	P
Year	4	6285.533	0.632	0.640
Reach	1	60.047	0.024	0.877
Year*Reach	4	29226.175	2.940	0.023

No Significant differences in total cover by year alone or by reach alone were indicated.

A significant differences in total cover due to the effects of Reach x Year was found.
Post hoc comparison of interaction least square means showed that total cover was greater in Arrow2009 than in Arrow 2011 and Arrow 2012. There were no other significant differences between interaction least square means.

ANOVA Results for vegetation Height in Type by Reach and Year

BE (Sandy Beach):

For BE, all data in all years were used.

N: 285 Rsquare: 0.054

Source	DF	Sum of Squares	F Ratio	P
Year	5	0.113	0.911	0.474
Reach	1	0.074	2.994	0.085
Year*Reach	5	0.160	1.286	0.270

No significant differences were found for Average Heights between Reaches or Years. There was no interaction effect as the effects of Reach and Year were independent.

CR (Cottonwood riparian):

For CR, all data for 2007 were excluded because only a single cover value in this type was measured for Revelstoke Reach in 2007.

N: 125 Rsquare: 0.093

Source	DF	Sum of Squares	F Ratio	P
Year	4	25.487	2.541	0.044
Reach	1	0.046	0.018	0.893
Year*Reach	4	1.116	0.111	0.978

Significant differences in average height by year were indicated. Post hoc comparison showed average heights ranked from highest to lowest: 2010 > 2011 = 2012 > 2008 = 2009. There were no significant differences in total cover due to the effects of Reach or Reach x Year.

PA (Redtop upland):

For PA, all data in all years were used.

N: 199 Rsquare: 0.134

Source	DF	Sum of Squares	F Ratio	P
Year	5	4.202	2.936	0.014
Reach	1	0.631	2.206	0.139
Year*Reach	5	1.921	1.342	0.248

Significant differences in average height by year were indicated. Post hoc comparison showed height ranked from highest to lowest: 2010 > 2009 > 2012 > 2008 > 2007 > 2011. There were no significant differences in total cover due to the effects of Reach or Reach x Year.

PC (Reed canary grass mesic):

For PC, all data in all years were used.

N: 585   Rsquare: 0.146

Source	DF	Sum of Squares	F Ratio	P
Year	5	1.626	7.336	0.000
Reach	1	1.384	31.225	0.000
Year*Reach	5	0.119	0.538	0.748

Significant differences in average height were found between year and between Reach levels. Post hoc comparison showed height differences between years ranked from highest to lowest: 2007 > 2008 > 2010 > 2012 > 2009 > 2011. Average heights were found to be greater in Revelstoke Reach than in Arrow. No significant differences in average height were indicated due to Reach x Year interactions.

PE (Horsetail):

For PE, all data for 2008 were excluded because of no measured height values for this type in Revelstoke in 2008.

N: 139   Rsquare: 0.228

Source	DF	Sum of Squares	F Ratio	P
Year	4	0.622	2.235	0.069
Reach	1	0.709	10.199	0.002
Year*Reach	4	0.733	2.634	0.037

Significant differences in average height by Reach and by Reach x Year were indicated. Post hoc comparison showed average heights were significantly greater in Revelstoke Reach than in Arrow Lakes. Post hoc comparison of average height by Reach x Year resulted in the following rankings:

Level*				Least Sq Means
2007,Reach	A	B		0.60858333
2011,Reach	A	B	C	0.54948333
2010,Reach	A			0.53695971
2007,Arrow	A	B	C	0.4023
2012,Reach	A	B	C	0.30038095
2012,Arrow	A	B	C	0.27358624
2009,Arrow		B	C	0.19037423
2010,Arrow			C	0.17979604
2009,Reach	A	B	C	0.1650463
2011,Arrow			C	0.14986623

*Levels not connected by the same letter are significantly different.

There were no significant differences in average vegetation height due to the effects of year alone.

Results of repeated measures analysis:

ANOVA p-values for differences in average maximum height of the vegetation by VCT, Year, and VCT x Year interaction for each elevation band and climatic regime (Nakusp, Fauquier and Castlegar meteorological stations) in the Arrow portion of the Arrow Lakes Reservoir. Significant results have a p-value < 0.05 and are indicated by shading in the cells of the table. No elevation interactions could be determined for those VCTs that do not occur over a range in elevation, such as CR. See Tables 3 and 4 for definitions of VCTs.

Reach: Arrow							
	Avg MaxHeight						
	ElevBand* Year* climate	Elev. Band	ElevBand* Year	ElevBand* climate	Year	Year* climate	climate
VCT	P-value	P-value	P-value	P-value	P-value	P-value	P-value
BE	0.9901	0.1203	0.9998	0.8857	0.5865	0.2207	0.1238
BG	0.9853	0.6558	0.886	0.9332	0.5294	0.9219	0.9519
CR	.	.	.	.	0.0009	0.0004	0.3816
PA	0.0005	0.0069	0.0025	0.0008	0.0232	0.0016	0.2664
PC	0.6224	0.1069	0.1066	0.7927	0.187	0.9701	0.9724
PE	0.363	0.8413	0.2081	0.489	0.3316	0.7922	0.512
RR	0.9787	0.7537	0.9765	0.8842	0.0341	0.692	0.3099

ANOVA p-values for differences in total cover of the vegetation by VCT, Year, and VCT x Year interaction for each elevation band and climatic regime (Nakusp, Fauquier and Castlegar meteorological stations) in the Arrow portion of the Arrow Lakes Reservoir. Significant results have a p-value < 0.05 and corresponding cells in the table are shaded. No elevation interactions could be determined for those VCTs that do not occur over a range in elevation, such as CR. See Tables 3 and 4 for definitions of VCTs.

Reach: Arrow							
	Total Cover						
	ElevBand* Year* climate	ElevBand	ElevBand* Year	ElevBand* climate	Year	Year* climate	climate
VCT	P-value	P-value	P-value	P-value	P-value	P-value	P-value
BE	0.0898	0.432	0.2527	0.5883	0.1563	0.7009	0.5011
BG	0.2944	0.6278	0.8313	0.7275	0.204	0.5778	0.7276
CR	.	.	.	.	<.0001	0.0563	0.8045
PA	0.0034	0.0187	0.02	0.207	0.0331	0.0601	0.4233
PC	0.3767	0.9718	0.6967	0.1115	0.0762	0.1037	0.0475
PE	0.1004	0.622	0.4051	0.4026	0.0004	0.0006	0.0568
RR	0.5802	0.033	0.1607	0.0313	0.0009	0.1374	0.0003

ANOVA p-values for differences in average maximum height of the vegetation by VCT, Year, and VCT x Year interaction for each elevation band in the Revelstoke Reach portion of the Arrow Lakes Reservoir. Significant results have a p-value < 0.05 and are indicated by shading in the cells of the table. No elevation interactions could be determined for those VCTs that do not occur over a range in elevation, such as CR. See Tables 3 and 4 for definitions of VCTs. No climatic interactions could be examined as there is only one climate class for Revelstoke Reach.

Reach: Revelstoke						
	AvgMaxHeight			Total Cover		
	ElevBand	ElevBand* Year	Year	ElevBand	ElevBand* Year	Year
VCT	P-value	P-value	P-value	P-value	P-value	P-value
BE	0.0712	0.207	0.0532	0.8532	0.92	0.9942
BG	0.2159	0.2025	0.2249	0.0495	0.0487	0.3386
CR	.	.	0.3376	.	.	0.0496
PA	0.3753	0.2151	0.0409	0.0177	0.0019	0.0079
PC	0.0065	0.0018	0.0237	0.9958	0.2145	<.0001
PE	<.0001	<.0001	<.0001	0.3232	0.0207	0.5805

Correlation Matrices

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in Y space

The CORR Procedure

Reach=Arrow

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Minimum**	**Maximum**	**Label**
ELEV_M	266	0	1.00000	0	-1.73335	5.42573	ELEV_M
Sand	264	0	1.00000	0	-1.40686	1.32994	Sand
Silt	266	0	1.00000	0	-0.68314	3.42712	Silt
Clay	266	0	1.00000	0	-0.46509	5.82418	Clay
Boulders	266	0	1.00000	0	-0.45233	3.71422	Boulders
Gravels	266	0	1.00000	0	-0.61717	3.63001	Gravels
AVGTMP	266	0	1.00000	0	-1.41224	2.57828	AVGTMP
TOTPCP	266	0	1.00000	0	-1.72461	2.68251	TOTPCP
sheltered	266	0	1.00000	0	-0.82521	1.20725	
exposed	266	0	1.00000	0	-1.14373	0.87105	
scouring	266	0	1.00000	0	-0.82521	1.20725	
wave_ridges	266	0	1.00000	0	-0.50375	1.97767	
EXPTIME	266	0	1.00000	0	-1.49935	1.61292	EXPTIME
Prin1	266	0	1.23727	0	-1.19552	6.48478	
Prin2	266	0	0.68495	0	-1.76598	4.59369	

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in Y space

The CORR Procedure

Reach=Arrow

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations		
	Prin1	**Prin2**
ELEV_M ELEV_M	0.51371 <.0001 266	0.11889 0.0528 266
Sand Sand	-0.20259 0.0009 264	-0.06993 0.2575 264
Silt Silt	0.39229 <.0001 266	-0.14741 0.0161 266
Clay Clay	0.16261 0.0079 266	-0.17606 0.0040 266
Boulders Boulders	-0.06528 0.2888 266	0.22115 0.0003 266
Gravels Gravels	-0.19369 0.0015 266	0.19005 0.0018 266
AVGTMP AVGTMP	0.55675 <.0001 266	0.18946 0.0019 266
TOTPCP TOTPCP	0.34677 <.0001 266	0.01647 0.7892 266
sheltered	0.29061 <.0001 266	-0.03149 0.6091 266

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in Y space

The CORR Procedure

Reach=Arrow

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations		
	Prin1	**Prin2**
exposed	-0.31430 <.0001 266	0.03098 0.6150 266
scouring	-0.25693 <.0001 266	0.06931 0.2600 266
wave_ridges	-0.21165 0.0005 266	0.03978 0.5183 266
EXPTIME EXPTIME	0.53937 <.0001 266	0.10782 0.0792 266

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in Y space

The CORR Procedure

Reach=Reach

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Minimum**	**Maximum**	**Label**
ELEV_M	266	0	1.00000	0	-1.73335	5.42573	ELEV_M
Sand	264	0	1.00000	0	-1.40686	1.32994	Sand
Silt	266	0	1.00000	0	-0.68314	3.42712	Silt
Clay	266	0	1.00000	0	-0.46509	5.82418	Clay
Boulders	266	0	1.00000	0	-0.45233	3.71422	Boulders
Gravels	266	0	1.00000	0	-0.61717	3.63001	Gravels
AVGTMP	266	0	1.00000	0	-1.41224	2.57828	AVGTMP
TOTPCP	266	0	1.00000	0	-1.72461	2.68251	TOTPCP
sheltered	266	0	1.00000	0	-0.82521	1.20725	
exposed	266	0	1.00000	0	-1.14373	0.87105	
scouring	266	0	1.00000	0	-0.82521	1.20725	
wave_ridges	266	0	1.00000	0	-0.50375	1.97767	
EXPTIME	266	0	1.00000	0	-1.49935	1.61292	EXPTIME
Prin1	266	0	1.23727	0	-1.19552	6.48478	
Prin2	266	0	0.68495	0	-1.76598	4.59369	

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in Y space

The CORR Procedure

Reach=Reach

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations		
	Prin1	**Prin2**
ELEV_M ELEV_M	0.51371 <.0001 266	0.11889 0.0528 266
Sand Sand	-0.20259 0.0009 264	-0.06993 0.2575 264
Silt Silt	0.39229 <.0001 266	-0.14741 0.0161 266
Clay Clay	0.16261 0.0079 266	-0.17606 0.0040 266
Boulders Boulders	-0.06528 0.2888 266	0.22115 0.0003 266
Gravels Gravels	-0.19369 0.0015 266	0.19005 0.0018 266
AVGTMP AVGTMP	0.55675 <.0001 266	0.18946 0.0019 266
TOTPCP TOTPCP	0.34677 <.0001 266	0.01647 0.7892 266
sheltered	0.29061 <.0001 266	-0.03149 0.6091 266

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in Y space

The CORR Procedure

Reach=Reach

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations		
	Prin1	**Prin2**
exposed	-0.27593 0.0013 133	0.06482 0.4586 133
scouring	-0.25743 0.0028 133	0.13812 0.1129 133
wave_ridges	-0.31224 0.0003 133	0.25163 0.0035 133
EXPTIME EXPTIME	0.42576 <.0001 133	0.23861 0.0057 133

Redundancy analysis on TOTAL height and cover in polygons
scaled correlations of environmental variables with site scores in Y space

Obs	Reach	Variable	Prin1	Prin2	eigenv_1	eigenv_2	total_Yvar	senv_1	senv_2
1	Arrow	ELEV_M	0.51371	0.11889	0.86104039	0.07151063	2	0.33707	0.02248
2	Arrow	Sand	-0.20259	-0.06993	0.86104039	0.07151063	2	-0.13293	-0.01322
3	Arrow	Silt	0.39229	-0.14741	0.86104039	0.07151063	2	0.25740	-0.02787
4	Arrow	Clay	0.16261	-0.17606	0.86104039	0.07151063	2	0.10669	-0.03329
5	Arrow	Boulders	-0.06528	0.22115	0.86104039	0.07151063	2	-0.04283	0.04182
6	Arrow	Gravels	-0.19369	0.19005	0.86104039	0.07151063	2	-0.12709	0.03594
7	Arrow	AVGTMP	0.55675	0.18946	0.86104039	0.07151063	2	0.36530	0.03583
8	Arrow	TOTPCP	0.34677	0.01647	0.86104039	0.07151063	2	0.22753	0.00311
9	Arrow	sheltered	0.29061	-0.03149	0.86104039	0.07151063	2	0.19068	-0.00596
10	Arrow	exposed	-0.31430	0.03098	0.86104039	0.07151063	2	-0.20622	0.00586
11	Arrow	scouring	-0.25693	0.06931	0.86104039	0.07151063	2	-0.16858	0.01311
12	Arrow	wave_ridges	-0.21165	0.03978	0.86104039	0.07151063	2	-0.13887	0.00752
13	Arrow	EXPTIME	0.53937	0.10782	0.86104039	0.07151063	2	0.35390	0.02039
14	Reach	ELEV_M	0.40955	0.20105	0.68666189	0.17693540	2	0.23997	0.05980
15	Reach	Sand	-0.15617	0.27435	0.68666189	0.17693540	2	-0.09151	0.08160
16	Reach	Silt	0.32262	-0.36429	0.68666189	0.17693540	2	0.18904	-0.10835
17	Reach	Clay	0.14381	-0.23837	0.68666189	0.17693540	2	0.08427	-0.07090
18	Reach	Boulders	-0.14782	0.10671	0.68666189	0.17693540	2	-0.08661	0.03174
19	Reach	Gravels	-0.20899	0.23351	0.68666189	0.17693540	2	-0.12245	0.06945
20	Reach	AVGTMP	0.45518	0.30721	0.68666189	0.17693540	2	0.26671	0.09137
21	Reach	TOTPCP	0.40645	0.22301	0.68666189	0.17693540	2	0.23816	0.06633
22	Reach	sheltered	0.25688	0.08655	0.68666189	0.17693540	2	0.15052	0.02574
23	Reach	exposed	-0.27593	0.06482	0.68666189	0.17693540	2	-0.16168	0.01928
24	Reach	scouring	-0.25743	0.13812	0.68666189	0.17693540	2	-0.15084	0.04108

Redundancy analysis on TOTAL height and cover in polygons
scaled correlations of environmental variables with site scores in Y space

Obs	Reach	Variable	Prin1	Prin2	eigenv_1	eigenv_2	total_Yvar	senv_1	senv_2
25	Reach	wave_ridges	-0.31224	0.25163	0.68666189	0.17693540	2	-0.18295	0.07484
26	Reach	EXPTIME	0.42576	0.23861	0.68666189	0.17693540	2	0.24947	0.07097

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in X space

The CORR Procedure

Reach=Arrow

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Minimum**	**Maximum**	**Label**
ELEV_M	266	0	1.00000	0	-1.73335	5.42573	ELEV_M
Sand	264	0	1.00000	0	-1.40686	1.32994	Sand
Silt	266	0	1.00000	0	-0.68314	3.42712	Silt
Clay	266	0	1.00000	0	-0.46509	5.82418	Clay
Boulders	266	0	1.00000	0	-0.45233	3.71422	Boulders
Gravels	266	0	1.00000	0	-0.61717	3.63001	Gravels
AVGTMP	266	0	1.00000	0	-1.41224	2.57828	AVGTMP
TOTPCP	266	0	1.00000	0	-1.72461	2.68251	TOTPCP
sheltered	266	0	1.00000	0	-0.82521	1.20725	
exposed	266	0	1.00000	0	-1.14373	0.87105	
scouring	266	0	1.00000	0	-0.82521	1.20725	
wave_ridges	266	0	1.00000	0	-0.50375	1.97767	
EXPTIME	266	0	1.00000	0	-1.49935	1.61292	EXPTIME
Prin1	264	0	1.00000	0	-1.81137	2.94912	
Prin2	264	0	1.00000	0	-3.05710	3.13064	

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in X space

The CORR Procedure

Reach=Arrow

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations		
	Prin1	**Prin2**
ELEV_M ELEV_M	0.68787 <.0001 264	0.30192 <.0001 264
Sand Sand	-0.27071 <.0001 264	-0.17964 0.0034 264
Silt Silt	0.52981 <.0001 264	-0.37038 <.0001 264
Clay Clay	0.21893 0.0003 264	-0.44600 <.0001 264
Boulders Boulders	-0.08831 0.1525 264	0.56744 <.0001 264
Gravels Gravels	-0.25011 <.0001 264	0.47916 <.0001 264
AVGTMP AVGTMP	0.74249 <.0001 264	0.48906 <.0001 264
TOTPCP TOTPCP	0.46720 <.0001 264	0.03340 0.5890 264
sheltered	0.38816 <.0001 264	-0.07210 0.2430 264

Redundancy analysis on TOTAL height and cover in polygons
correlation of X variables with site scores in X space

The CORR Procedure

Reach=Arrow

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations		
	Prin1	**Prin2**
exposed	-0.41965 <.0001 264	0.07077 0.2518 264
scouring	-0.34069 <.0001 264	0.16923 0.0058 264
wave_ridges	-0.28645 <.0001 264	0.10302 0.0948 264
EXPTIME EXPTIME	0.72248 <.0001 264	0.27317 <.0001 264

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in X space

The CORR Procedure

Reach=Arrow

Simple Statistics							
Variable	**N**	**Mean**	**Std Dev**	**Sum**	**Minimum**	**Maximum**	**Label**
ELEV_M	133	0	1.00000	0	-2.92713	1.85701	ELEV_M
Sand	131	0	1.00000	0	-1.22133	1.64134	Sand
Silt	131	0	1.00000	0	-0.99535	1.97280	Silt
Clay	131	0	1.00000	0	-0.56132	3.62861	Clay
Boulders	131	0	1.00000	0	-0.18369	8.14613	Boulders
Gravels	131	0	1.00000	0	-0.50755	3.61351	Gravels
AVGTMP	133	0	1.00000	0	-1.31986	2.52334	AVGTMP
TOTPCP	133	0	1.00000	0	-2.07444	1.60497	TOTPCP
sheltered	133	0	1.00000	0	-0.77323	1.28356	
exposed	133	0	1.00000	0	-1.13286	0.87608	
scouring	133	0	1.00000	0	-0.61848	1.60471	
wave_ridges	133	0	1.00000	0	-0.41912	2.36802	
EXPTIME	133	0	1.00000	0	-2.03488	1.85056	EXPTIME
Prin1	131	0	1.00000	0	-2.58924	2.87674	
Prin2	131	0	1.00000	0	-2.04806	2.48744	

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in X space

The CORR Procedure

Reach=Arrow

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations		
	Prin1	**Prin2**
ELEV_M ELEV_M	0.60308 <.0001 131	0.34486 <.0001 131
Sand Sand	-0.23037 0.0081 131	0.45927 <.0001 131
Silt Silt	0.47591 <.0001 131	-0.60982 <.0001 131
Clay Clay	0.21215 0.0150 131	-0.39903 <.0001 131
Boulders Boulders	-0.21806 0.0123 131	0.17864 0.0412 131
Gravels Gravels	-0.30828 0.0003 131	0.39089 <.0001 131
AVGTMP AVGTMP	0.67533 <.0001 131	0.52364 <.0001 131
TOTPCP TOTPCP	0.59206 <.0001 131	0.38081 <.0001 131
sheltered	0.40406 <.0001 131	0.14139 0.1072 131

Redundancy analysis on TOTAL height and cover in polygons correlation of X variables with site scores in X space

The CORR Procedure

Reach=Arrow

Pearson Correlation Coefficients Prob > |r| under H0: Rho=0 Number of Observations		
	Prin1	**Prin2**
exposed	-0.38975 <.0001 131	0.10342 0.2398 131
scouring	-0.37140 <.0001 131	0.22862 0.0086 131
wave_ridges	-0.45755 <.0001 131	0.41967 <.0001 131
EXPTIME EXPTIME	0.62444 <.0001 131	0.40728 <.0001 131

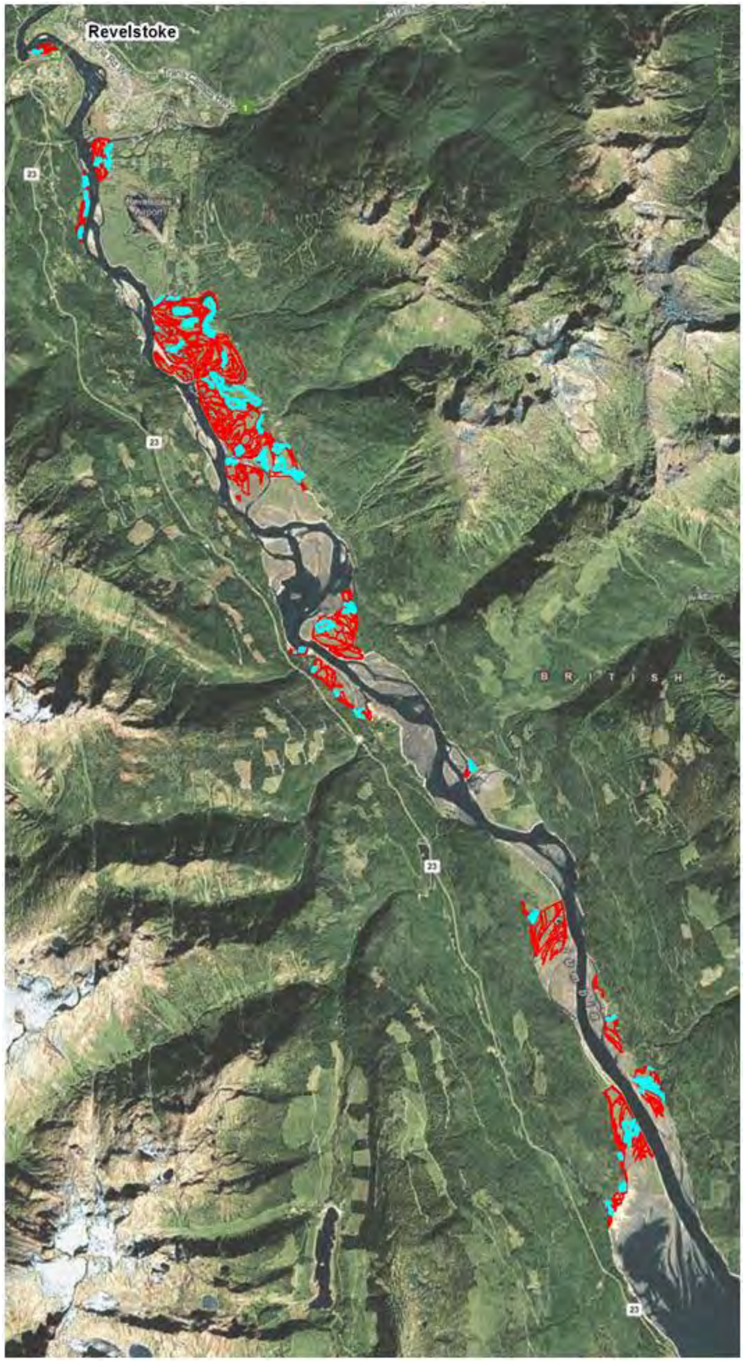
Redundancy analysis on TOTAL height and cover in polygons scaled correlations of environmental variables with site scores

Obs	Reach	Variable	Prin1	Prin2	eigenv_1	eigenv_2	total_Yvar	senv_1	senv_2
1	Arrow	ELEV_M	0.68787	0.30192	0.86104039	0.07151063	2	0.45134	0.05709
2	Arrow	Sand	-0.27071	-0.17964	0.86104039	0.07151063	2	-0.17763	-0.03397
3	Arrow	Silt	0.52981	-0.37038	0.86104039	0.07151063	2	0.34763	-0.07003
4	Arrow	Clay	0.21893	-0.44600	0.86104039	0.07151063	2	0.14365	-0.08433
5	Arrow	Boulders	-0.08831	0.56744	0.86104039	0.07151063	2	-0.05794	0.10730
6	Arrow	Gravels	-0.25011	0.47916	0.86104039	0.07151063	2	-0.16411	0.09061
7	Arrow	AVGTMP	0.74249	0.48906	0.86104039	0.07151063	2	0.48718	0.09248
8	Arrow	TOTPCP	0.46720	0.03340	0.86104039	0.07151063	2	0.30655	0.00632
9	Arrow	sheltered	0.38816	-0.07210	0.86104039	0.07151063	2	0.25469	-0.01363
10	Arrow	exposed	-0.41965	0.07077	0.86104039	0.07151063	2	-0.27535	0.01338
11	Arrow	scouring	-0.34069	0.16923	0.86104039	0.07151063	2	-0.22354	0.03200
12	Arrow	wave_ridges	-0.28645	0.10302	0.86104039	0.07151063	2	-0.18795	0.01948
13	Arrow	EXPTIME	0.72248	0.27317	0.86104039	0.07151063	2	0.47405	0.05165
14	Reach	ELEV_M	0.60308	0.34486	0.68666189	0.17693540	2	0.35337	0.10257
15	Reach	Sand	-0.23037	0.45927	0.68666189	0.17693540	2	-0.13498	0.13660
16	Reach	Silt	0.47591	-0.60982	0.68666189	0.17693540	2	0.27886	-0.18138
17	Reach	Clay	0.21215	-0.39903	0.68666189	0.17693540	2	0.12431	-0.11869
18	Reach	Boulders	-0.21806	0.17864	0.68666189	0.17693540	2	-0.12777	0.05313
19	Reach	Gravels	-0.30828	0.39089	0.68666189	0.17693540	2	-0.18064	0.11626
20	Reach	AVGTMP	0.67533	0.52364	0.68666189	0.17693540	2	0.39571	0.15575
21	Reach	TOTPCP	0.59206	0.38081	0.68666189	0.17693540	2	0.34691	0.11327
22	Reach	sheltered	0.40406	0.14139	0.68666189	0.17693540	2	0.23675	0.04205
23	Reach	exposed	-0.38975	0.10342	0.68666189	0.17693540	2	-0.22837	0.03076
24	Reach	scouring	-0.37140	0.22862	0.68666189	0.17693540	2	-0.21762	0.06800

Redundancy analysis on TOTAL height and cover in polygons
scaled correlations of environmental variables with site scores

Obs	Reach	Variable	Prin1	Prin2	eigenv_1	eigenv_2	total_Yvar	senv_1	senv_2
25	Reach	wave_ridges	-0.45755	0.41967	0.68666189	0.17693540	2	-0.26810	0.12482
26	Reach	EXPTIME	0.62444	0.40728	0.68666189	0.17693540	2	0.36589	0.12114

APPENDIX 4. LOCATIONS OF POLYGONS INCLUDED IN THE KAPPA STATISTIC AND THE REPEATED MEASURES ANALYSIS.



Cyan-coloured areas represent polygons chosen for analysis

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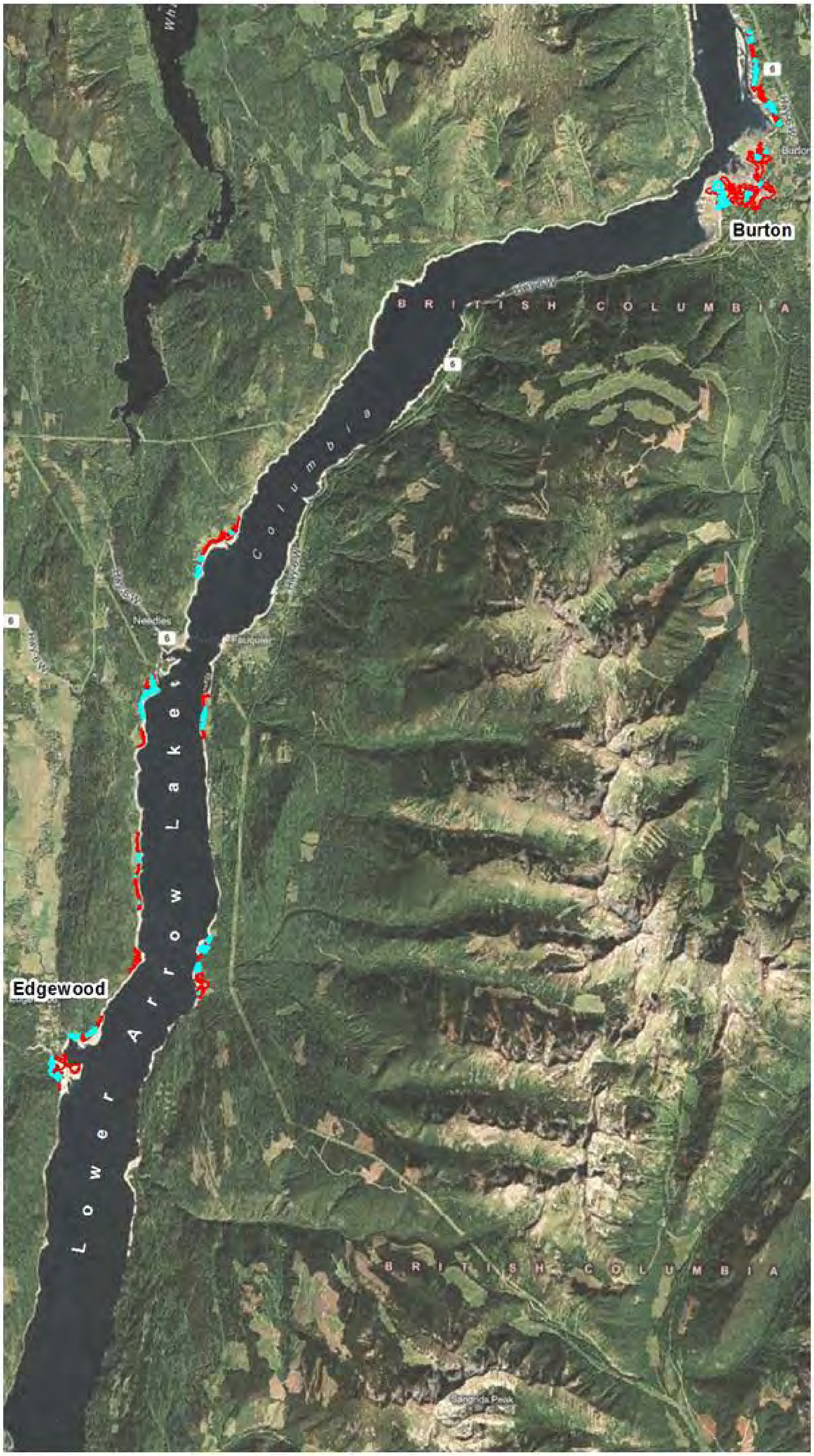
Cyan-coloured areas represent polygons chosen for analysis



Cyan-coloured areas represent polygons chosen for analysis

Cyan-coloured areas represent polygons chosen for analysis

APPENDIX 5. TABLES OF SPECIES RICHNESS, SPECIES EVENNESS, AND SPECIES DIVERSITY.

Table A5-1. Shannon-Weiner Diversity Index (H') for each VCT from 2007 to 2012, in the Arrow Lakes Reservoir (both geographic areas combined)

Vegetation Community	Shannon-Weiner Diversity Index (H')					
	2007	2008	2009	2010	2011	2012
BE	2.34	2.70	3.36	3.05	3.44	3.22
BG	3.12	2.86	3.65	3.35	3.36	3.73
CR	4.13	4.36	4.31	4.62	4.19	4.79
PA	4.21	4.07	3.83	4.27	3.49	4.19
PC	3.03	3.24	3.13	3.29	3.83	3.50
PE	2.87	3.09	3.34	3.47	3.59	3.43
RR	2.98	3.44	3.48	3.65	2.89	3.67

Table A5-2. Pielou's species evenness (J) measures for dominant and co-dominant species of each VCT in the Arrow Lakes Reservoir (both geographic areas combined) from 2007 to 2012

Vegetation Community	Pielou's Evenness (J)					
	2007	2008	2009	2010	2011	2012
BE	0.86	0.84	0.85	0.80	0.79	0.81
BG	0.96	0.89	0.94	0.83	0.87	0.84
CR	0.97	0.96	0.95	0.88	0.95	0.92
PA	0.89	0.92	0.87	0.85	0.87	0.85
PC	0.71	0.83	0.80	0.74	0.80	0.79
PE	0.88	0.92	0.89	0.84	0.89	0.87
RR	0.99	0.91	0.90	0.89	1.00	0.88

Table A5-3. Species richness measures for dominant and co-dominant species of each VCT in the Arrow Lakes Reservoir (both geographic areas combined) from 2007 to 2012

Vegetation Community	Species Richness					
	2007	2008	2009	2010	2011	2012
BE	15	25	52	45	77	53
BG	26	25	48	57	47	84
CR	69	93	94	187	84	179
PA	113	83	84	157	55	137
PC	70	50	50	87	123	86
PE	26	29	43	62	57	52
RR	20	43	47	61	18	63

Table A5-4. Shannon-Weiner Diversity Index (H') for each elevation band from 2007 to 2012 in the Arrow Lakes Reservoir (both geographic areas combined)

Elevation Band	Shannon-Wiener Diversity Index (H')					
	2007	2008	2009	2010	2011	2012
434-436	2.77	3.16	3.56	3.27	3.46	3.23
436-438	3.51	3.54	3.54	3.99	3.80	3.85
438-440	4.48	4.44	4.20	4.72	4.35	4.77

Table A5-6. Pielou's species evenness (J) measures for all vegetation within the three elevation bands (434 m - 436 m, 436 m - 438 m and 438m - 440 m) from 2007 to 2012 in the Arrow Lakes Reservoir (both geographic areas combined)

Elevation Band	Pielou's Evenness (J)					
	2007	2008	2009	2010	2011	2012
434-436	0.72	0.83	0.84	0.71	0.79	0.79
436-438	0.80	0.85	0.80	0.78	0.80	0.77
438-440	0.92	0.89	0.84	0.85	0.85	0.85

Table A5-6. Species richness by elevation band from 2007 to 2012 in the Arrow Lakes Reservoir (both geographic areas combined)

Elevation Band	Species Richness					
	2007	2008	2009	2010	2011	2012
434-436	48	46	68	97	79	60
436-438	81	65	85	162	118	144
438-440	130	151	148	255	170	272