Bridge River Project Water Use Plan

Downton Reservoir Riparian Vegetation Monitoring Project

Implementation Year 1

Reference: BRGMON-5

Study Period: 2013

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Executive Summary

BRGMON-5 is aimed at developing and implementing a vegetation monitoring program at the west end of the Downton Reservoir drawdown zone, in a 170 ha area known as the Western Fan. The monitoring program was intended to assess the spatial distribution, composition and productivity of the vegetation communities in the Western Fan. The monitoring program was implemented with the objective of establishing baseline data in 2013, to be compared to the vegetation communities that will be observed in ten years.

Between May and July 2013, an inventory plan was developed, and a database was amassed to describe the 170 ha Western Fan. The region was classified and inventoried using a combination of aerial photo interpretation, GIS mapping, terrain class stratification, ground truthing, permanent vegetation monitoring plot establishment, and permanent photo point monitoring.

Using GIS and orthophotography from 2005 and 2013, vegetation communities were stratified spatially by terrain classes and elevations at a 1:5,000 scale. Terrain classes for the Western Fan area were defined as mudflats, fluvial bars, alluvial fans, steep colluvium, and above free crest (above full pool) terrain. The elevations of 737m, 745m, 748m and 749.8m were identified as significant contours that were bordering vegetation community transitions throughout the low grade mudflat and fluvial bar zones. On the steeper alluvial fan zones, three elevation bands were used to stratify the vegetation communities into mid, upper and fringe zones, and each was sampled at 741m, 747m, and 749m, respectively. Ten terrain types were identified based on terrain class, elevation, and vegetation community; nine were sampled in 2013. Steep colluvium sites were not surveyed due to low representation in the Western Fan Area. Forty-five permanent transects were randomly located throughout the Western Fan, with a minimum of four and a maximum of seven transects placed within each of the nine terrain/elevation types sampled. Four 1X1m quadrats and two permanent photo points were established along each transect to form the foundation for future monitoring at the site level, and provide a reproducible framework for collecting detailed site and species data throughout the project.

The Western Fan is comprised of 45 per cent mudflats, 17 per cent fluvial bars, 15.5 per cent alluvial fans, 16 per cent steep colluvium, and 5.83 per cent above free crest terrain. Common horsetail (*Equisetum arvense*) is the most ubiquitous species found throughout the Western Fan area, in all terrain classes. A general trend was observed of increasing vegetation complexity and composition from the low elevation mudflats in the east, to the upper elevation above free crest polygons in the west. The transition region tended to be in the middle, between the herbaceous upper mudflats to the expanding shrub stands in the fringe mudflats. There was also a general trend in observable biomass increasing with elevation, from very low in the low elevation mudflats and alluvial fan mid drawdown, to high in the upper mudflats, fringe and above free crest areas. Wildlife sign was reflective of the vegetation communities, with geese being the dominant presence in the central and eastern end of the flat areas, where short annuals and horsetails dominated. Moose, hare and beaver were more evident to the west in the more developed vegetation.

Physical changes in the Western Fan were observable during a spatial analysis of the aerial photography between 2005 and 2013. The Western Fan area is a dynamic river floodplain as well as a reservoir. Land is being eroded from the mudflats, and recruited by fluvial bars. The rate of erosion, particularly on the north side of the Western Fan, appears to be greater than the rate of deposition, and consequently, vegetation is being lost. However, woody vegetation is expanding in the Fringe flat areas, shifting available habitat types from herbaceous to woody shrub stands. The vegetation survey and analysis of aerial photography were inconclusive in determining how much of the observed erosion patterns and shifts in vegetation are attributable to the management of the reservoir water levels, and how much is due to natural successional and erosion processes.

It is challenging to directly attribute any observed shifts in vegetation to management of the reservoir water levels given the numerous confounding variables (e.g. climate, naturally dynamic nature of the reservoir, etc.), the limited statistical power, and the lack of a replicated reservoir where the water regime could be manipulated in isolation of any other variables. However, the sampling design should allow assessing whether or not any changes in vegetation occurred over the 10 years of the study, and how likely those changes can be attributed to the implementation of the N2-2P alternative. The use of techniques such as partial regression analysis and variance partitioning might also increase our understanding of the respective influences of the new water regime, and any other spatial or temporal confounding variables. Also, an analysis and spatial mapping of terrain/elevation and vegetation types from historical aerial photography (if available) would be useful to contextualize the 2013 aerial imagery, and increase the power of the statistical tests to detect significant differences in vegetation characteristics over time.

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1.0 Introduction

This report has been prepared to meet the objectives of the Bridge Seton Water Use Plan monitoring program, Downton Reservoir Riparian Vegetation Monitoring Study (BRGMON-5). The goal of this report is to describe the characteristics of the current species composition, spatial distribution, and biomass productivity of the vegetation throughout the Western Fan area of Downton Reservoir (Figure 1).

The objectives of the BRGMON5 monitoring study as outlined in the TOR (B.C. Hydro, 2012) are to assess the following management questions:

- Will the implementation of the N2-2P alternative[1] have a negative, neutral or positive impact on the quality and quantity (species composition, biological productivity, spatial area) of the riparian area of the Upper Bridge River and the immediately adjacent drawdown zone of Downton Reservoir?
- Has there been a negative impact on riparian vegetation and the overall quality of the habitat for wildlife in the area? What activities could be undertaken to preserve this critical habitat area?

The primary and sub-hypothesis being addressed by BRGMON-5 Monitoring Program are:

H1: Implementation of the chosen alternative will not result in an alteration of the critical wildlife areas located on the Upper Bridge River Fan and the adjacent areas in the drawdown zone of Downton Reservoir.

> H1a: There is no significant change in the spatial extent of the vegetated area on the fan or in the adjacent drawdown zone.
>
> H1b: There is no significant change in the species composition of the plant community in the vegetated area on the fan or in the adjacent drawdown zone.

[1] Items included in the N2-2P alternative operating regime: (1) Water release from Carpenter Lake to the lower Bridge River will be 1.5-15 m 3 ·s -1 varied by month of the year; (2) Targets for the water surface elevation of reservoirs are defined but the elevation may go below a minimum elevation to provide minimum flows in downstream rivers; (3) Targets are set for ramping rates at the Terzaghi Dam that controls outflow from Carpenter Lake to the lower Bridge River and controls water surface elevation in Carpenter Lake. Ramping rate is the rate of change in flow during a lowering of water releases; (4) Partial (6+ hours) or blanket (24 hours) daily shutdowns are required for Seton Generating Station during smolt out-migration between April 20 and May 20; and, (5) Targets are set for flows in the Seton River to protect migrating salmon.

H1c There is no significant change in the relative productivity of the plant community in the vegetated area of the fan or in the adjacent drawdown zone.

The Western Fan area of Downton reservoir, and in particular the Grizzly flats, were identified as key areas to be protected by the 2003 Consultative Committee Report for BC Hydro Water Use Plan for the Bridge Seton Systems. This area is characterized by a river delta and reservoir inundation zone, from the western inflow of the Upper Bridge River into the reservoir-dominated mudflats to the east. The terrestrial study area totaled 170 ha. Much of the study area is located within the 992 hectare Bridge Delta Provincial Park. This area represents a remnant glacial-fed, broad river valley that forms into a braided stream complex surrounded by Douglas-fir forests and riparian cottonwood stands. Because of the high value of this area, it was classified as a class A park in 2010 (BC Parks, 2012), meaning it is under crown obligation to protect and preserve the natural environment for public use.

BASELINE Conditions – new sub-section –Environmental Setting?
The Downton Reservoir watershed is 998 km² and is part of the Bridge River Watershed drainage. Downton Reservoir covers 23.3km² at full pool (BC Hydro, 2011 Bridge River Power Development Water Use Plan). The resulting shoreline is approximately 60 km in length, and the water levels fluctuate in elevation by 42.14 m (707.67-749.81 m). The March 30th 2011 Water Control Act order sections 87 and 88 limit water level management of Downton Reservoir to a drawdown minimum of 710 m, unless dictated by lower flows in the Middle Bridge River.

The study area lies at the transition between the Coast and Mountains and the Southern Interior Mountains Eco-provinces (Demarchi, 2011). The majority of the Downton Reservoir area falls into the Interior Douglas-fir dry cold (IDFdc) Biogeoclimatic zone, which shifts to the drier Interior Douglas-fir very dry zone (IDFvd) to the East (Meidinger and Pojar 1991). At the Western most end in the Bridge River fan zone there is a minor influx of Montane Spruce moist warm (MSmw) zone. The IDF biogeoclimatic zone average annual rainfall is between 300-700mm and the average temperature between 1.6-9.5°C (Hope *et al.* 1991*).*

The Bridge River Forest Service road parallels the south shore of Downton Reservoir, often within several hundred meters of the full pool line. A significant amount of the upland forest along the southern side of the reservoir has been logged within the past 20 years. An independent power production facility is being constructed at Jamie Creek, located at 16km along the Bridge River Forest Service Road. There is limited access to the North Shore of Downton Reservoir from the Eastern end, where some logging has taken place. On the north side of Downton Reservoir, and at the mid to west end, the land remains relatively undisturbed from anthropogenic activities, with no road building or logging. The area of study has been recognized as an important food source for grizzly bears in late spring between May and June (Robertson, Bennett and Page, 1998).

2.0 Methods

2.1 Air Photo Interpretation and GIS

Aerial photography for BRGMON-5 encompasses the entire Downton Reservoir drawdown zone and several hundred meters into the surrounding upland forests Historical orthophotography flown in 2005was obtained from St'at'imc Government Services to assist with field work planning and vegetation polygon mapping of the study area. BC Hydro's photogrammetry department was enlisted to produce current aerial photography, orthophotography and digital elevation data for Downton Reservoir, with a focus on the Western Fan area. The data was captured on June 6th 2013 and the resulting imagery was received early September for use in post-field work.

Digital Terrain Mapping and contours were also generated for the Western Fan area. Half meter contour lines were generated for the Western fan study areas. The area covered was from the 753.0 m contour (3 m above full pool), and down, for the entire Western Fan area. Data was provided in two different formats: 1) Esri Shape files, and 2) MicroStation dgn files.

Polygon stratification and orthophoto mapping was conducted at a scale of 1:5,000 down to 1:2,000. Polygons were drawn around areas of similar terrain class, and a shapefile layer was created in Arc Map 10 software. Terrain classes were established based on landforms resulting from hydrological and geomorphological processes. Terrain classes were further stratified by elevation, using 2005 digital elevation data provided by BC Hydro. Observed shifts in vegetation patterns were interpreted from orthophotography for the mudflat terrain classes at elevations 749.8m (full pool), 747m, 745m and 737m.

2.2 Field Methods

Random points were generated within stratified sampling locations using a GIS random point generator (Beyer, H.L. 2012). These random points were located in the field using SXBlue2 GNSS GPS for sub meter accuracy. The suitability of the randomly generated sampling locations was assessed in the field, and in some cases, points were eliminated due to physical constraints, such as a landing too close to steep edges, or in some cases the actual site being eroded away. In these cases, a secondary or tertiary point was used. When the sampling location was deemed adequate, 12 inch spike nails with two inch washers on the heads were installed in the ground to mark transect points of origin (see Appendix 3). At each point of origin, a random azimuth was chosen, and a meter tape laid out for 40m. Quadrats of 1X1m were placed 10m apart along the transect beginning at the 40m mark. Quadrat placement was alternated along left and right sides of the transect. To ensure enough replication for statistical analysis, the goal was to establish five permanent transects per terrain class, with four 1X1m quadrats surveyed per transect.

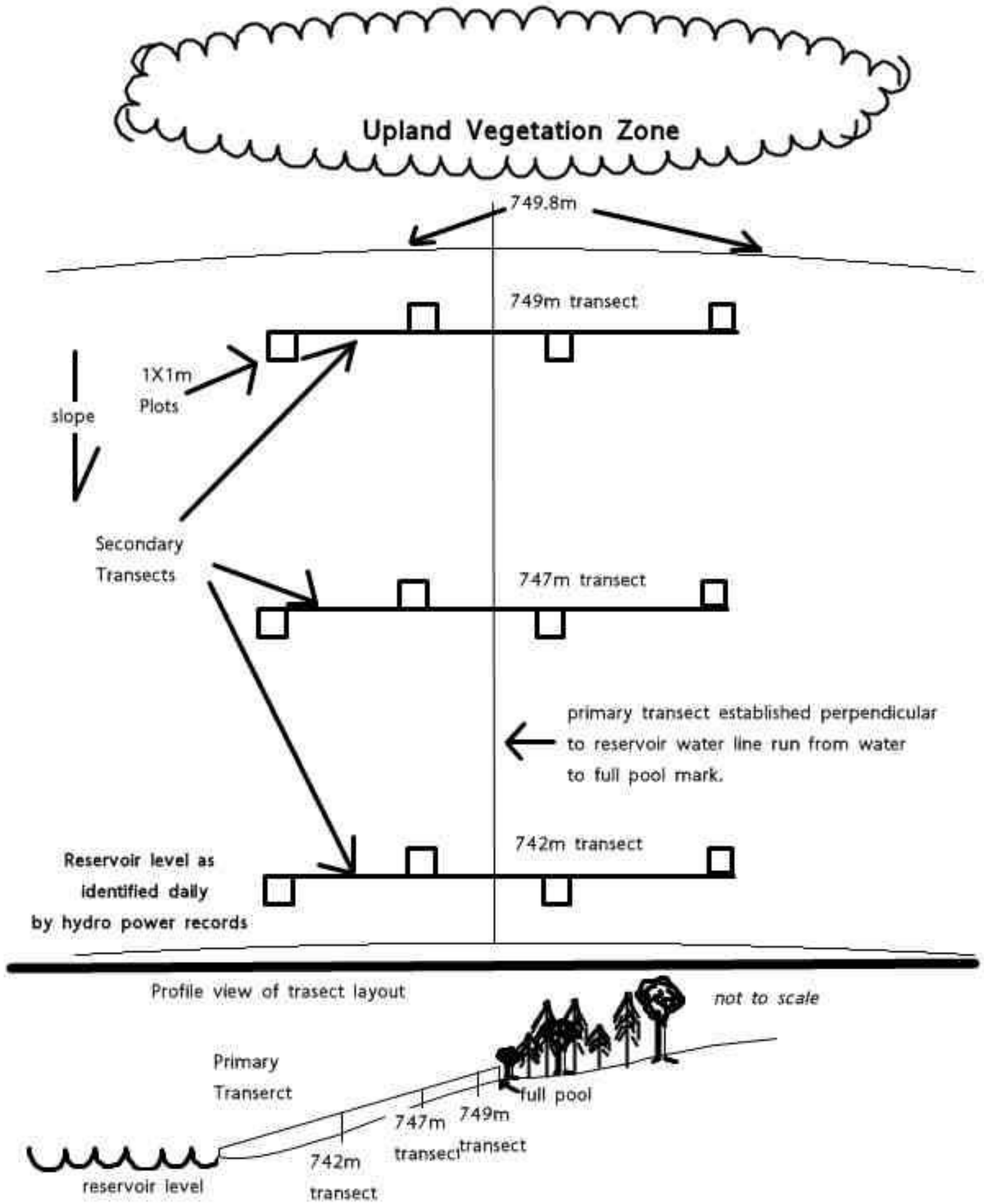
Within each quadrat, plot site data were collected, including date, transect number, terrain class, substrate cover, soil texture, coarse fragment type, drainage, growing season water source, wildlife sign, and wildlife species. The vegetation found in the quadrat was also identified to species, when possible (in some cases, only identification to genius was possible). Data recorded for each species of vegetation included percent cover, distribution, density, vigor, utilization, and generative and vegetative phenology. Data codes were based on the codes found in Field Manual for Describing Terrestrial Ecosystems 2nd edition LMH-25, (BC Ministry of Forests and Range and BC Environment, 2010). Data were entered digitally in the field using FLINT S series F4 hand held devices running EZytag CE software. Hand written back-up copies of the data were also collected. Collected data were uploaded and converted to GIS shapefile data using EZytag Viewer software. Layers were checked for completeness and quality in Arc Map 10, and in Microsoft Excel. Data were edited as needed in the office, and cross referenced with hand written data. Samples of species were collected, and a herbarium was compiled to verify identification. The Illustrated flora of BC, XID digital software, and E-Flora BC were all used to guide identification of unknown species.

Most of the Western Fan area was accessible by vehicle access along the Bridge River forest service road, followed by hiking down to the reservoir. Chest waders enabled access to sites in the central portion of the fan area, and a small inflatable row boat was utilized to access sites on the North side.

During preliminary field observations, three uniquely vegetated elevation bands were identified at several alluvial fan sites. Consequently, sampling methodology was modified to capture the variation in elevation on the fans. The width of the bands characterized by those indicator species were measured, and the results were used to establish three widths for the three elevation bands.

The lowest sampling band on the alluvial fans was determined to be between 739 m and 744 m, and the transect elevation was chosen at 742 m. The next sampling contour was chosen at 747 m to represent the Upper Drawdown zone, located between 744 m and 748 m. The final sampling contour was set at 749 m to represent the fringe of the drawdown zone, between 748 m and 749.8 m. Due to the curvature of the shoreline and the related high probability of crossing elevation bands as horizontal distance increased from a point of commencement, primary transects formed the center points of perpendicularly run secondary transects at each of the three selected elevation (Figure 2). At each primary transect, a permanent pin was established to run a transect line perpendicular to the water line, and parallel to the direction of slope on the fan. Once the primary transect was established down to the water line, the secondary transect center line points of origin were established at the three selected elevations. Secondary transect points of origin were located using a clinometer and measuring tapes, and by referencing the previous day's reservoir pool levels (as posted by BC Hydro Power records) as an benchmark for establishing elevations in the field. From the center point, the secondary transects were stretched for 15 m in opposite directions perpendicular to the primary line. As for the other terrain classes, four 1X1m quadrats were spaced 10m apart along these transects. Quadrat placement was alternated above and below the transects in a further attempt to confine sampling within a narrow elevation band. Permanent pins were installed at the center point of each secondary transect on the alluvial fans, and one main pin was set at the full pool mark along the initial primary transect.

Upland vegetation was also sampled above the alluvial fans, using one 10mX10m quadrat to represent the forest stand characteristics. Upland communities were sampled by running 10m along the azimuth of the primary transect into the upland vegetation. This point was established as the center pin for laying out a 10X10m plot. FS1333 Site Visit Form (BC Ministry of Forests and Range and BC Environment, 2010) was used to gather descriptive ecosystem data for the upland forest ecosystems. This data is not reported on in this document.



Upland Vegetation Zone
749.8m
749m transect
1X1m
Plots
slope
Secondary
Transects
747m transect
primary transect established perpendicular
to reservoir water line run from water
to full pool mark.
742m transect
Reservoir level as
identified daily
by hydro power records
Profile view of trasect layout
not to scale
Primary
Transerct
full pool
747m
749m
transect
transect
742m
transect
reservoir level

2.3 Photo Monitoring and Biomass

Two photo monitoring points were established for each transect to provide a visual record of change. A one meter tall by 0.10 m wide photo board was set 10m away from the camera, and directly along the transect. The camera was set up on a tripod right over the pin, and one meter high. Two photos were taken with a Canon Power Shot D20 camera 5.0-2.5mm- 1:3.9-4.8 lens. Photo frames were centered on the top to the meter board; a photo was captured at the widest zoom, and a close-up shot was taken.

For the mudflats and fluvial bar transects, the camera was set up at each end of the transect line. On the alluvial fans, the camera was set up over the secondary transect center point of origin, and remained the same for the two photos. Photos were taken in opposite directions along the secondary transect, with the meter board being 10 m away. Photos were also taken of each 1X1m quadrat. Quadrat photos were taken with camera held from above.

Photo point images were analyzed to produce two values: biomass , and vertical percent cover of vegetation on the meter board. A height value for vegetation was estimated from each photo point image based on the meter board, and these values were averaged per transect and terrain class. The amount of vegetation obscuring the meter board was estimated for each photo, and a percent cover value for vertical growth of vegetation was estimated (out of 100 percent as in Figure 3). This percent cover value, along with average height and average percent cover, was utilized as a representation of biomass for each transect. The average per cent cover of vegetation for the 1mx1m plots along each transect was also used to together indicate the heatlh of biomass for each transect.

Figure 3. UMF 02 b presented as an example of utilizing the photo image to estimate vegetation cover of meter board. In this case (UMF 02 b), cover was estimated at 49 % of the 1mX 0.1m board. Lower black line marks the 0.5 meter line.

2.4 Data Analysis

2.4.1 General description of vegetation

Data from the four quadrats sampled per transects were averaged to avoid pseudoreplication (Hurlbert 1984). Four community descriptors (total cover, richness, diversity and evenness of vegetation) were first used to describe the vegetation in the Western Fan zone. Total cover was computed by adding up the cover of all species and taxa in a transect, including unknowns and vegetation from all layers. Similar to other studies conducted in the Carpenter (BRGMON-2, Scholz and Gibeau 2014) and Kinbasket reservoirs (e.g. CLBMON-9, Hawkes et al. 2013, Fenneman and Hawkes 2012; CLBMON-10, Hawkes et al. 2012, 2010), only taxa identified to species (thus excluding taxa identified to genera or unknowns) were used to compute species richness, diversity and evenness. One exception was made for species of genera *Salix*; given the difficulty of identifying individuals to species at the early stage of the vegetation when it was sampled, all *Salix* were grouped under a common taxum.

Species richness was the total number of species sampled in transects, while diversity was computed with Shannon's index, and corresponds to a measure of species composition that combines both the number of species and their relative abundance (Legendre and Legendre 2012):

$H = -\Sigma (p_i \log p_i)$, where p_i is the relative proportion of species *i* in the transect.

Diversity increases along with the number of species recorded in transects, based on their relative abundance. Evenness (Pielou 1966) was computed to determine how the species were distributed within each transect, e.g. if one or a few species were dominating the plots, or if all the species recorded were distributed fairly equally in the transects. It corresponds to:

$J = H/Hmax = (-\Sigma (p_i \log p_i)) / \log q$, where q is the species richness, and H the diversity.

If the species are evenly distributed in a transect, J will tend towards a value of 1, and if one or a few species are dominating the vegetation, the value of J will tend towards 0 (Legendre and Legendre 2012). The combination of diversity and evenness measures gives an indication about the degree of interspecific competition; if the two indices show high values, transects are diverse and with species evenly distributed (low interspecific competition). Conversely, if diversity is high but evenness is low, it suggests that one or a few species are dominating the transects, and therefore that interspecific competition is high (Legendre and Legendre 1998, 2012).

Trends were described among terrain classes, elevation bands, and location in the Western Fan using boxplots. Boxplots display the variation, dispersion and skewness of groups of data without making any assumptions about their underlying statistical distributions (Massart et al. 2005). The median is represented by a horizontal line in the box, which is drawn to show the interquartile range (25 per cent to 75 per cent of the ranked data, Sokal and Rohlf 1995). Data with low dispersion (i.e. mostly found around the median) will be indicated by a small box, while data widely dispersed will be shown by a long box. The largest and smallest observations will be represented by whiskers drawn from the top and bottom of the box, respectively, within 1.5 interquartile range of its extremities. Outliers are shown by open circles. In this case, the boxes represent the variation in total cover, richness, diversity, and evenness observed among transects for any combination of terrain classes, elevation bands, and locations assessed. Interpretation of the boxplots is only an indication of general tendencies in the data, given the relatively small sample size for some of the combinations of terrain classes, elevation bands, and locations. Differences in cover, richness, diversity or evenness were not statistically tested also because of the small sample size, and lack of replication among categories of factors.

2.4.2 Classification of vegetation communities

Different methods were used to try classifying transects into groups reflecting common physical (environmental) characteristics, or common vegetation species communities. The goal was to create an in-depth description of the vegetation and environmental characteristics of the Western Fan zone in 2013, in order to facilitate the comparison in 10 years. The approach is similar to that taken for another BC Hydro long-term vegetation monitoring project in the Kinbasket Reservoir (CLBMON-10, Hawkes *et al.* 2007).

The point of performing clustering analyses is to explore which transects were similar to one another and which ones were different, and based on common characteristics such as substrate or soil texture, for example (please see Table 1 for more example of variables used to describe characteristics) (Legendre and Legendre 2012). Ultimately, associations between characteristics will be used to assess how vegetation communities change over time (or not). Given the complexity of the ecosystem studied, the clustering performed here involved multiple variables considered at once, and was therefore conducted in a multidimensional space (Legendre and Legendre 2012). Different coefficients and different methods will consider the various variables differently (e.g. by giving different weight to rare and abundant species), and may therefore yield different clusters of sites. It is important to try various methods and discuss, at least qualitatively, the convergence in the different results obtained. The various methods used, along with their justifications and interest, are described below.

The first method used was the Kendall W Coefficient of concordance (Legendre 2005). The analysis assesses if the species are distributed independently of one another across the Western Fan, or if they are significantly associated into specific groups of species. Association of species is thus described as a group of species that are significantly found together (Legendre 2005). If such groups of species are found, one can then assess to which environmental variables they are associated.

First, the cover data was transformed using the Hellinger distance, to make them suitable for ordinations and other techniques requiring Euclidian distances (Legendre and Gallagher 2001). Then, an overall test of independence of all species was conducted. Since it was significant, the analysis proceeded with grouping the species with K-Means partitioning, and testing with permutations, within each group, the contribution of each species to the group (Legendre 2005). The probabilities of the tests were adjusted for multiple testing (correction of Holm, 100,000 permutations) to preserve an approximately correct experiment-wise error rate (Legendre 2005). The results of the groupings and tests were plotted on a principal component analysis (PCA) to illustrate the relationship among species, to try identifying if a significant group of species were found in specific groups of transects, and to which environmental variables they were associated (see below for the interpretation of a PCA diagram).

Next, a series of clustering analyses were performed to assess further if, and how, the transects would group together based on their environmental characteristics or species composition. The various coefficients and clustering techniques consider differently in their computation the various characteristics of the data, and thus may highlight different particularities of the data. First, a series of environmental variables were compiled and used to assess the similarity among transects (Table 1). The similarity coefficient used was that of Gower (S15), since it deals well with qualitative and quantitative variables (Legendre and Legendre 2012). The qualitative variables were coded as binary variables (Legendre and Legendre 2012). The quantitative variables were standardized prior to computing the similarities, since data had different units and dimensions (Legendre and Legendre 2012). Their mean was divided by two standard deviations to make them comparable with the qualitative binary variables (Gelman 2008).

Table 1. Environmental and physical variables included in the clustering analysis.

Variables	Units	Categories	Symbol
Substrate	%	Organic matter	organic
	%	Woody debris	wood
	%	Rock	rock
	%	Mineral Soil	Msoil
Vegetation	%	total cover	Cover
	--	Diversity	Diversity
Soil texture	--	Loam/Sand	Loam/Sand
	--	Sand	Sand
	--	Silt	Silt
	--	Silt/loam	Silt/loam
Drainage	--	Imperfectly/Poorly	Imperf/poorly. drained
	--	Moderately/Well	modwell.drained
	--	Rapidly	rapidly.drained
	--	Well	well.drained
Geomorphic type	--	Fluvial	Fluvial
	--	Lacustrine	Lacustrine
	--	Colluvium/Wave actions	Coll/wave
Microtopography	--	Channelled, incised water tracks	Channelled
	--	Mounded with mineral materials	Mounded
	--	Smooth, surface relatively flat	Smooth
	--	ribbed (raised ridges)/tussock (forming graminoids)/undulating	Rib/Tussock/ Undulating
Source of water during growing season	--	Sub-irrigation and flooding	Sub/Flood
	--	Precipitation	Precip

Clusters of transects based on their similarities were then produced by weighted arithmetic average clustering (WPGMA), which was chosen because it corrects for distortions that may occur if groups formed are of unequal size (Legendre and Legendre 1998), and given that the sampling was not random or systematic (Legendre and Legendre 2012). The method produces dendrograms that can be analyzed to find the clusters of transects. The groups of transects were subsequently superposed to a PCA diagram to show the variation in the environmental variables, and to try identifying which environmental variables influenced the grouping.

A similar procedure was used with species composition data, to assess whether or not the groups of transects formed based on species composition would be similar to those formed based on environmental characteristics. Species that appeared in at least three transects were kept for that analysis. The similarity coefficient used was the Hellinger distance coupled with the Euclidian distance, since it avoids the problem of the double-zeros, and gives more weight to differences in abundant species rather than differences in rare species in computing the similarity among transects, when objects are of unequal importance (Legendre and Legendre 2012). That is considered better for immature communities where the less abundant species are less likely to be adequately sampled (Legendre and Legendre 2012). The similarities were again used with a WPGMA, and results of the dendrograms superposed on a PCA diagram to help in identifying clusters, and variables responsible for the groupings.

PCA diagrams can be interpreted as follows. The type of scaling gives indication about how to interpret the angles among vectors (variables), and the distances between objects (transects) in the diagram (Legendre and Legendre 2012). Scaling was of Type 1 for all the PCAs done except for the Kendall analysis; it means that the positions of the transects (in blue) were approximations of their similarity – the closer two transects are in the diagram, the more similar they are in terms of their species composition or environmental characteristics (depending on the variables involved and the similarity coefficients used). The scaling was of Type 2 for the Kendall analyses, which means that angles between vectors (in black, representing species abundance or environmental variables) reflect their correlations – the closer two vectors were, the more correlated the variables (Legendre and Legendre 2012). Vectors pointing in totally opposite directions suggest that the variables are inversely correlated. Vectors at right angle suggest that the variables are orthogonal (i.e. not correlated at all). The projection of a transect at right angle on vectors of variables reflects their correlation. The contribution of the variables to the axis is carried by the standardized coefficients that give the weights of the variables in the formation of the site scores (that are plotted). These coefficients are usually not shown but they can be visually approximated by the length of the vectors representing the variables: the longer one vector is along a given axis, the more it contributes to this axis. Variables clustered at the middle of the ordination are considered not to be contributing much to the ordination. Units of the ordination axis are meaningless and usually omitted.

Finally, the Gower and Hellinger-Euclidian distances were used to compute a principal coordinate analysis (PCoA), in order to further assess which transects formed clusters, and based on what characteristics. The elevation, terrain class, and location of each transect were coded and included in the PCoA diagram to try identifying better if they influenced the grouping. The Euclidian distances in the ordination diagram approximates the similarity among transects; the closest two transects were located in the figure, the more similar they were in terms of species composition or environmental variables.

Results of the clustering analyses are represented with dendrograms, ordination diagrams, and summary tables. All analyses were performed in the R language (version 3.0.2).

2.4.3 Reservoir Water Levels

Reservoir water levels were summarized in a series of figures and tables to show their variation across elevation bands and years. Average daily water levels were provided by BC Hydro for each year.

Duration, timing, and depth of inundation were graphically assessed, and are discussed. The vegetation growing season was considered to span from April 1 until September 30, and elevations sampled ranged from 730 to above 750m.

Duration of inundation was calculated as the proportion of the growing season for which each given elevation band was above the current reservoir water levels. It was computed as a ratio between the number of days that the elevation band was above water levels and the total number of days in the growing season (n=183). Timing corresponded to the date on each year at which a given elevation band was first inundated. Depth of inundation was also dependent on the elevation band, and was computed as the average of all the water that covered a given elevation band in the Western Fan.

3.0 Results

3.1 Air photo Analysis

The reservoir water levels were at 723.46m above sea level (ASL) at the time of the air photo flight on June 6, 2013. The 2005 aerial photography, on which the 2013 preliminary GIS mapping work was based, was flown when reservoir water levels were at approximately 740m. Air photo image plates were captured for the entire drawdown and surrounding area of Downton Reservoir. Based on the aerial imagery, ten orthophoto Tiff files 4200X6000 pixels, with horizontal and vertical resolutions of 96 dpi's, were produced.

Orthophoto interpretation and analysis produced 63 polygons mapped between 1:2,000 and 1:5000 on Arc Map 10 software. Based on the 2013 orthophotos, polygons were refined from 63 to 87 over the 170 ha study area (Figure 4, Figure 5, Figure 6). The 87 polygons were stratified into five broad hydro-geomorphological terrain types: alluvial fan, mudflat, fluvial bar, steep colluvium, and above free crest. These categories were further stratified by elevation bands to produce four categories for the flats (low, mid, upper and fringe) and three categories for the alluvial fans (mid, upper, fringe), for a total of ten stratified terrain classes (Table 2).

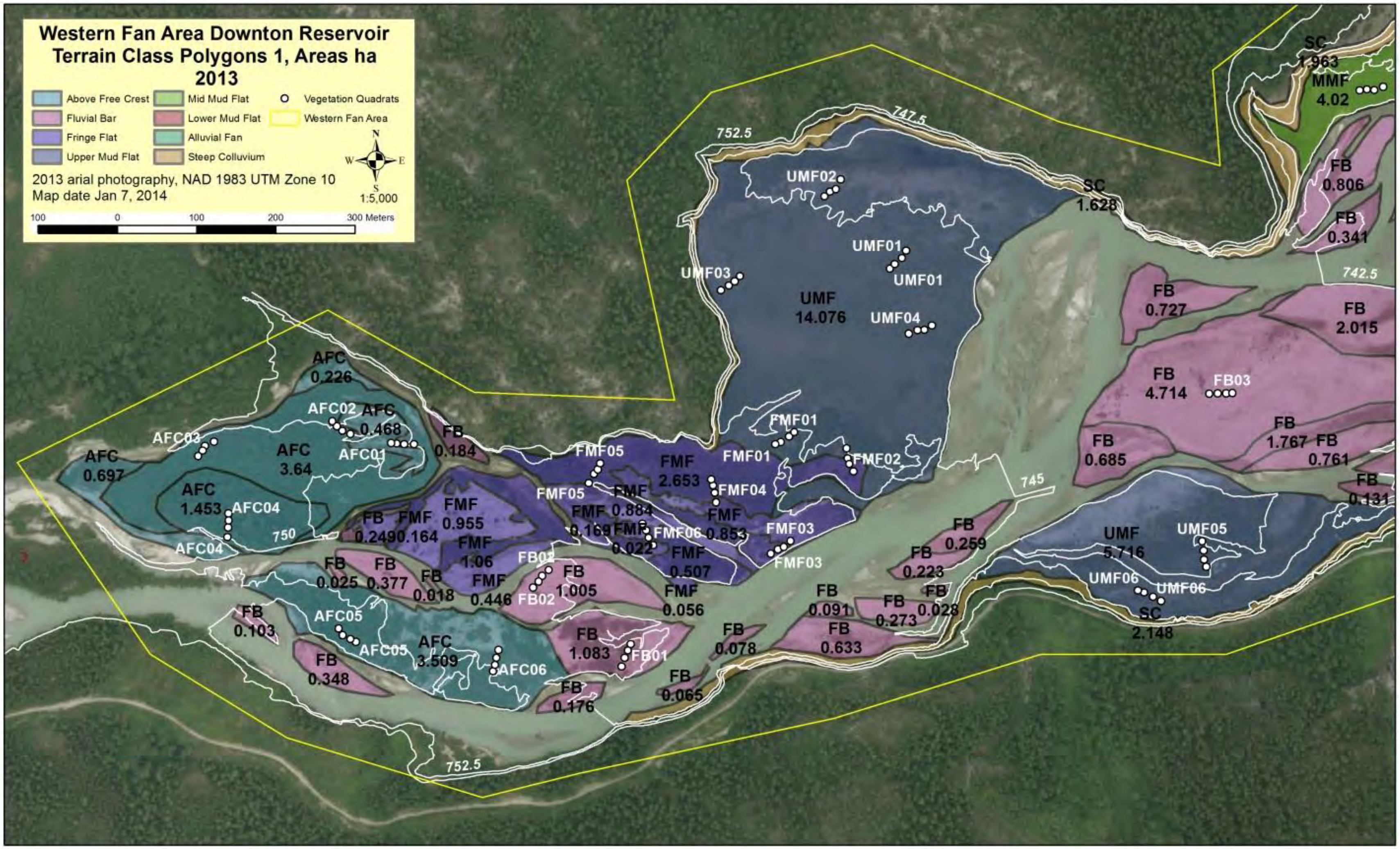


Figure 4. West end of the Western Fan area in Downton Reservoir, terrain/elevation polygon stratification, and areas in hectares, based on the 2013 orthophotography and digital elevation data.

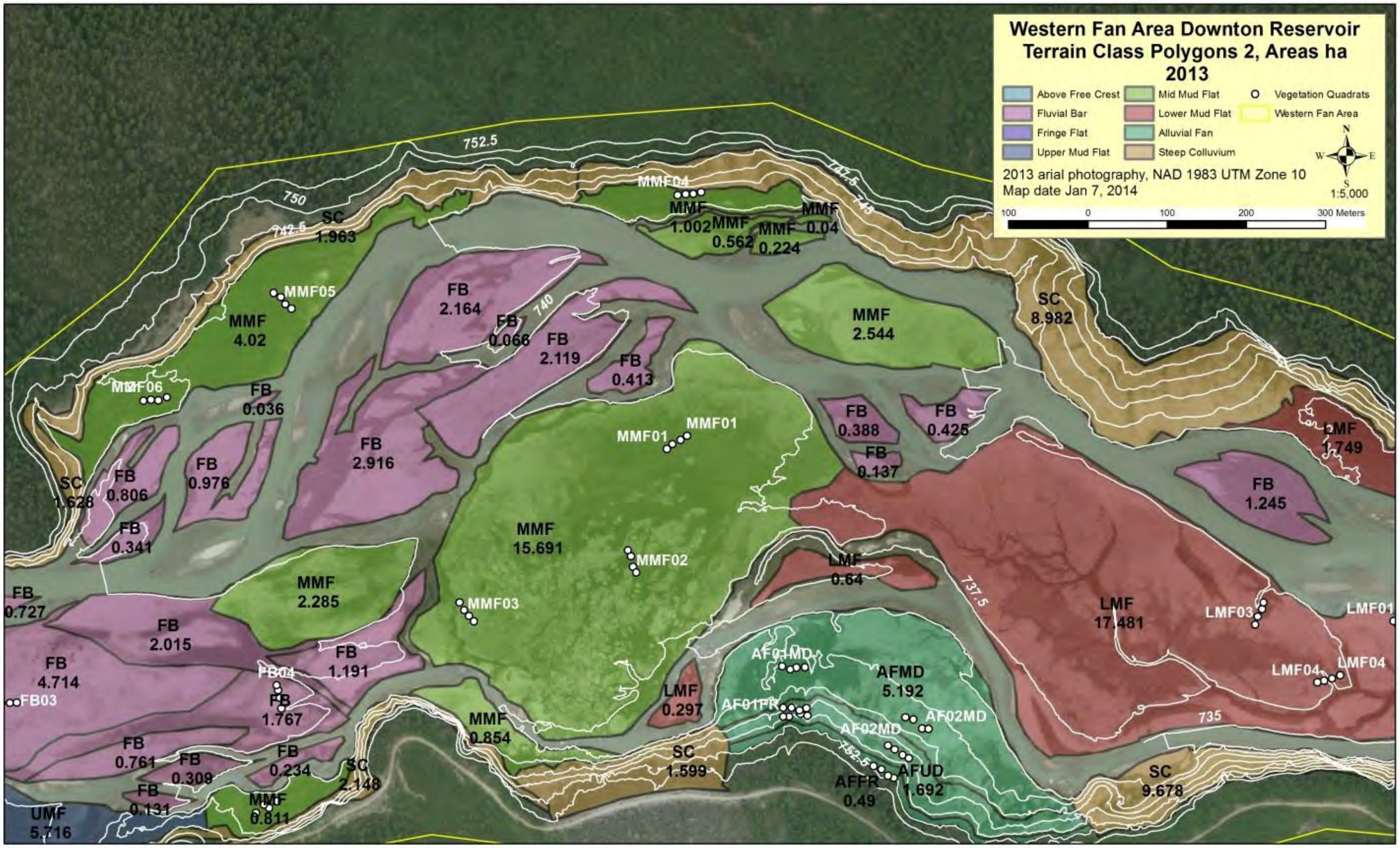


Figure 5. Central area of the Western Fan in Downton Reservoir, terrain/elevation class polygon stratification, with area in hectares, based on the 2013 orthophotography and digital elevation data.

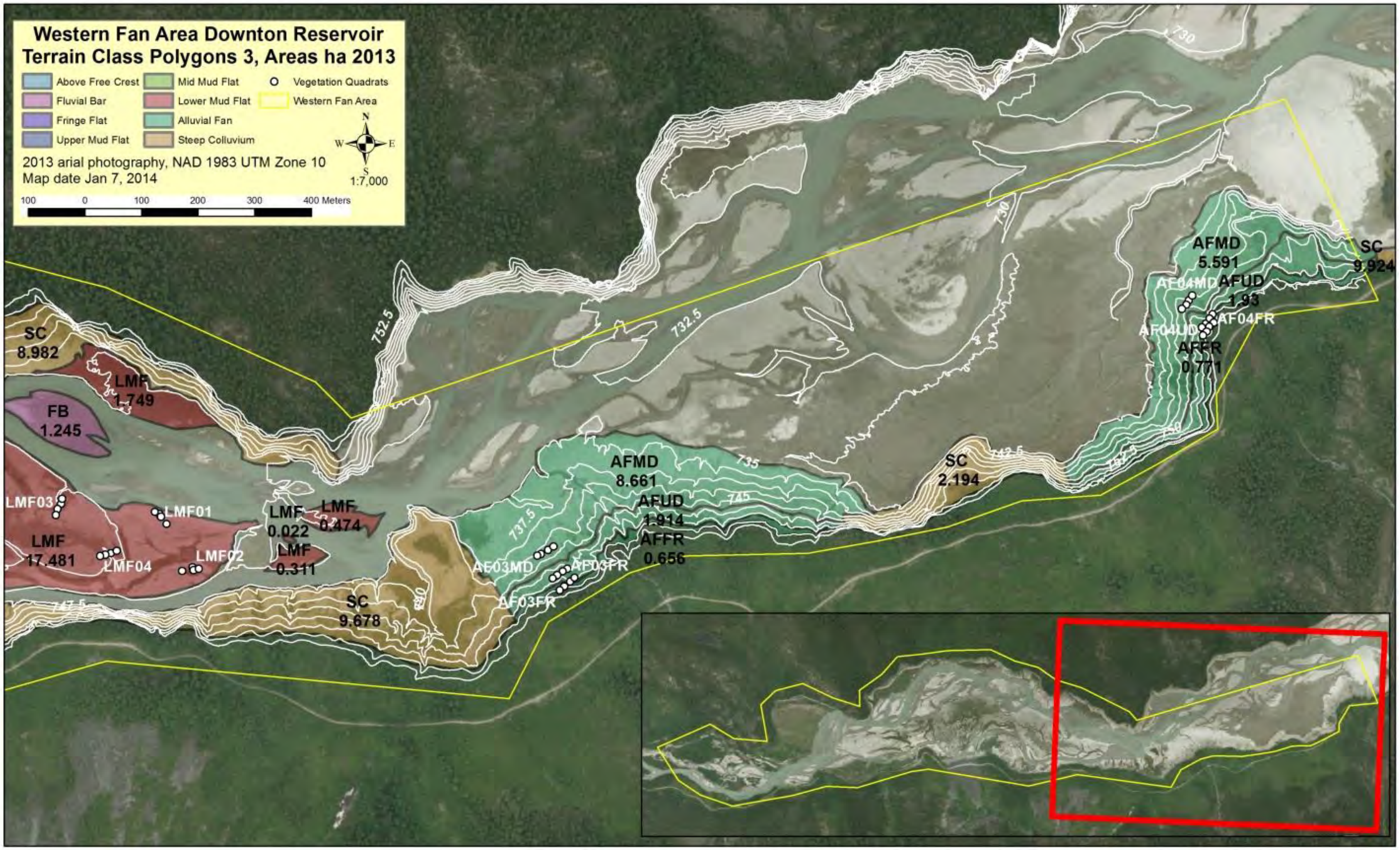

Western Fan Area Downton Reservoir
Terrain Class Polygons 3, Areas ha 2013
Above Free Crest
Fluvial Bar
Fringe Flat
Upper Mud Flat
Mid Mud Flat
Lower Mud Flat
Alluvial Fan
Steep Colluvium
Vegetation Quadrats
Western Fan Area
2013 arial photography, NAD 1983 UTM Zone 10
Map date Jan 7, 2014
1:7,000
100 0 100 200 300 400 Meters
SC 8.982
LMF 1.749
FB 1.245
LMF03
LMF01
LMF 17.481
LMF04
LMF02
LMF 0.022
LMF 0.474
LMF 0.311
SC 9.678
AFMD 8.661
AFUD 1.914
AFFR 0.656
AF03MD
AF03FR
SC 2.194
AFMD 5.591
AFUD 1.93
AF04MD
AF04UD
AF04FR
AFFR 0.771
SC 9.924
752.5
732.5
730
747.5

Figure 6. East end of the Western Fan area in Downton Reservoir, terrain/elevation polygon stratification, and areas in hectares, based on the 2013 orthophotography and digital elevation data.

Table 2. Terrain/elevation polygons for the Western Fan of Downton Reservoir in 2013.

Terrain class	Elevation	Area ha	Number polygons	%	# transects
Alluvial Fan Mid	741m	19.444	3	11.34	4
Alluvial Fan Upper	747m	5.536	3	3.23	4
Alluvial Fan Fringe	749m	1.917	3	1.12	4
Above Free Crest	>749.8m	9.993	6	5.83	6
Fluvial Bar	739-750m	29.78	41	17.37	4
Lower Mud Flat	<737.4m	20.97	7	12.23	4
Mid Mud Flat	737.4-744.6	28.03	10	16.35	7
Upper Mud Flat	744.6-747.9	19.79	2	11.54	6
Fringe Mud Flat	>747.9<749.8m	7.77	11	4.53	6
Steep Colluvium	739-750m	28.19	7	16.44	0
Total		171.43	93	100.00	45

3.2 Description of polygon types

Characteristics of all polygon types are summarized based on observations from the aerial photography interpretation, and with details and photos from the field work. More detailed characteristics of the vegetation sampled in the field (including composition and productivity), as well as results of the statistical analyses aimed at characterizing the vegetation communities, are presented in the next section.

). Six transects were established within above free crest, upper mudflat, and fringe mudflat polygons. An extra transect was set in the mid mudflat zone due to the large area and the wide distribution of this terrain type across the north, south and central regions of the Western Fan. Alluvial fans, lower mudflats and fluvial bar zones were each sampled with four transects. The lower mudflats were limited to four transects based on the small area available for study at the time of the survey, because of rising water levels. Fluvial bars were sampled with four transects due to time constraints, access issues, and because of the limited amount of vegetation cover observed on these sites. Alluvial fans were limited to four transects due to time constraints. Steep colluvium was not sampled on the ground due to time constraints, and logistical issues related to the steepness of the terrain.

3.2.1 Mudflats

Four categories of mudflats were identified below full pool in the Western Fan, based on the elevation at which they were found. These zones were typically sediment deposition areas of low gradient terrain (below 5 percent grade). Mudflats comprised thirty-two polygons and occupied an area of 47.7 per cent (81.28 ha) of the Western Fan. The mudflats spanned an elevation gradient from full pool (749.8 m) in the west, down to 735 m in the east of the Western Fan. In general, an increase in elevation of the mudflats occurred from east to west, with the lower mudflats in the east, mid mudflats in the center, and the upper and fringe mudflats in the west.

3.2.1.1 Lower Mudflats

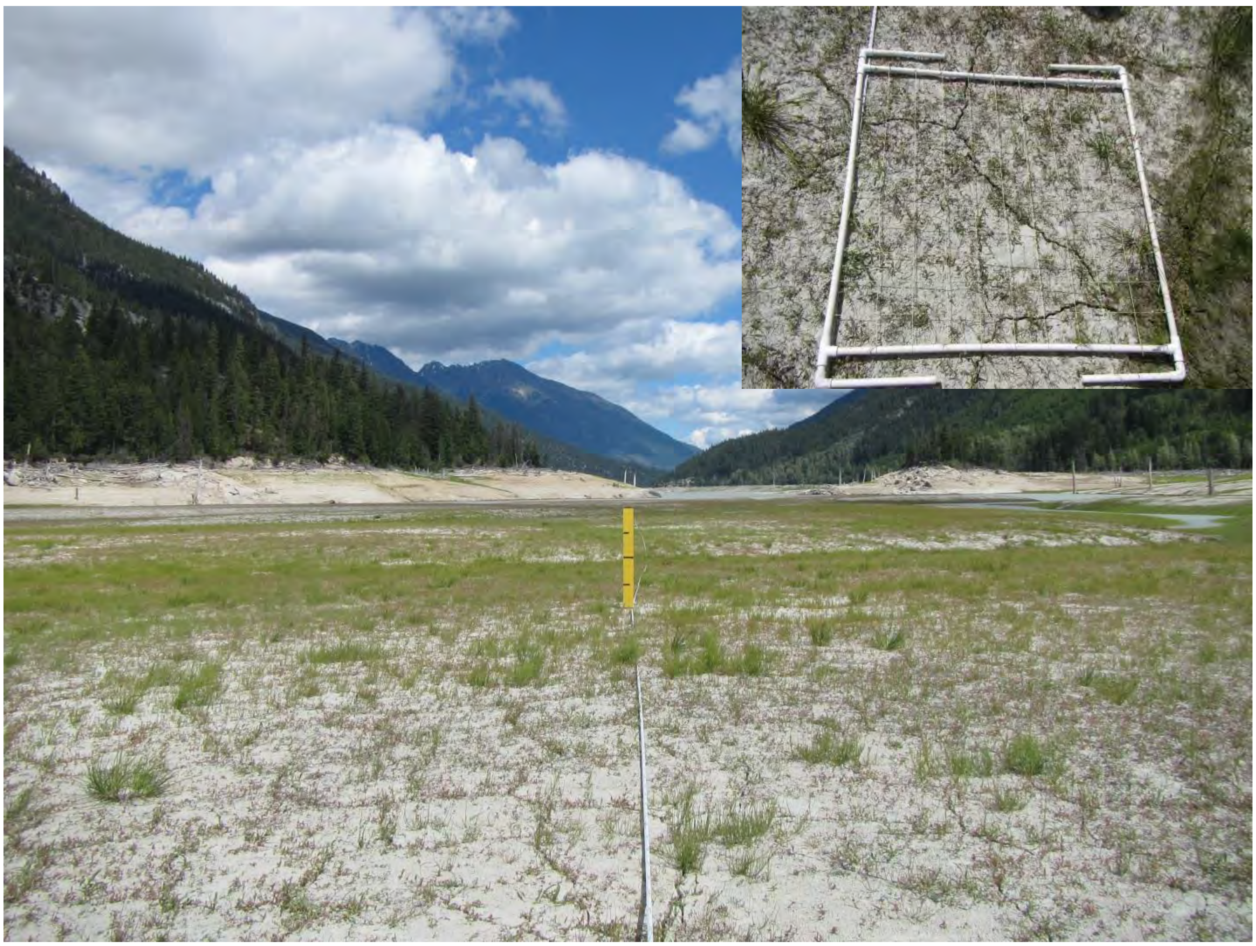


Figure 7. LMF04 Transect West end, inset photo quadrat LMF04 veg plot4.

Lower mudflats (LMF) were sampled below 737m elevation at four transect locations; rising water levels prevented sampling a fifth transect. The low mudflats were active deposition or settling zones, with frequent inundation from the reservoir. That is reflected in the substrates being 100 percent mineral soil, and almost all soils being silty. Common horsetail (*Equisetum arvense*), and annual vegetation fast to grow and mature, characterized the vegetation cover in the low mudflats. Vegetation growth and cover was in general low (Figure 7). Wildlife signs were observed, with extensive evidence of Canada goose (*Branta canadensis*) browse and droppings.

3.2.1.2 Mid Mudflats

Seven transects sampled the mid mudflats (MMF) terrain/elevation types, from 737m to 745m. Mid mudflats were the largest (at 28.03ha) of the mudflat areas spanning the south, central and north sides of the Western Fan. MMF polygons were characterized by lacustrine silt deposits from the seasonal inundation of the reservoir. Soils were primarily silts with some sand deposits where the mud flats experienced fluvial influence from the Upper Bridge River. Substrate cover was varied and reflected the age of the geomorphological feature, with geologically younger central areas having predominantly mineral soil deposits and the older north and south side polygons having organic matter as the predominant cover.

Figure 8. Mule deer (3 point buck) crossing fluvial bars between mid mudflat polygons. Inset picture muskrat gathering sedges and rushes from eroding chunk of mid mudflat near transect MMF04.

Wildlife signs in the mid mudflats included Canada goose, and mule deer (*Odocoileus hemionus)* tracks and browse. Mule deer were observed on two occasions (Figure 8). Gray wolf (*Canis lupus*) tracks were also seen, in addition to three juvenile wolves observed by the survey crew, on the north shore. Important wetlands were noted in the mid mudflats to the north and east end of the Western Fan. These areas were very wet, with hundreds of pacific tree frogs (*Pseudacris regilla*) observed among the vegetation. Finally, a muskrat (*Ondatra zibethicus*) was observed gathering *Carex* and *Equisetum* stems from a chunk of earth that was eroding into the river, near transect MMF04 (Figure 8).

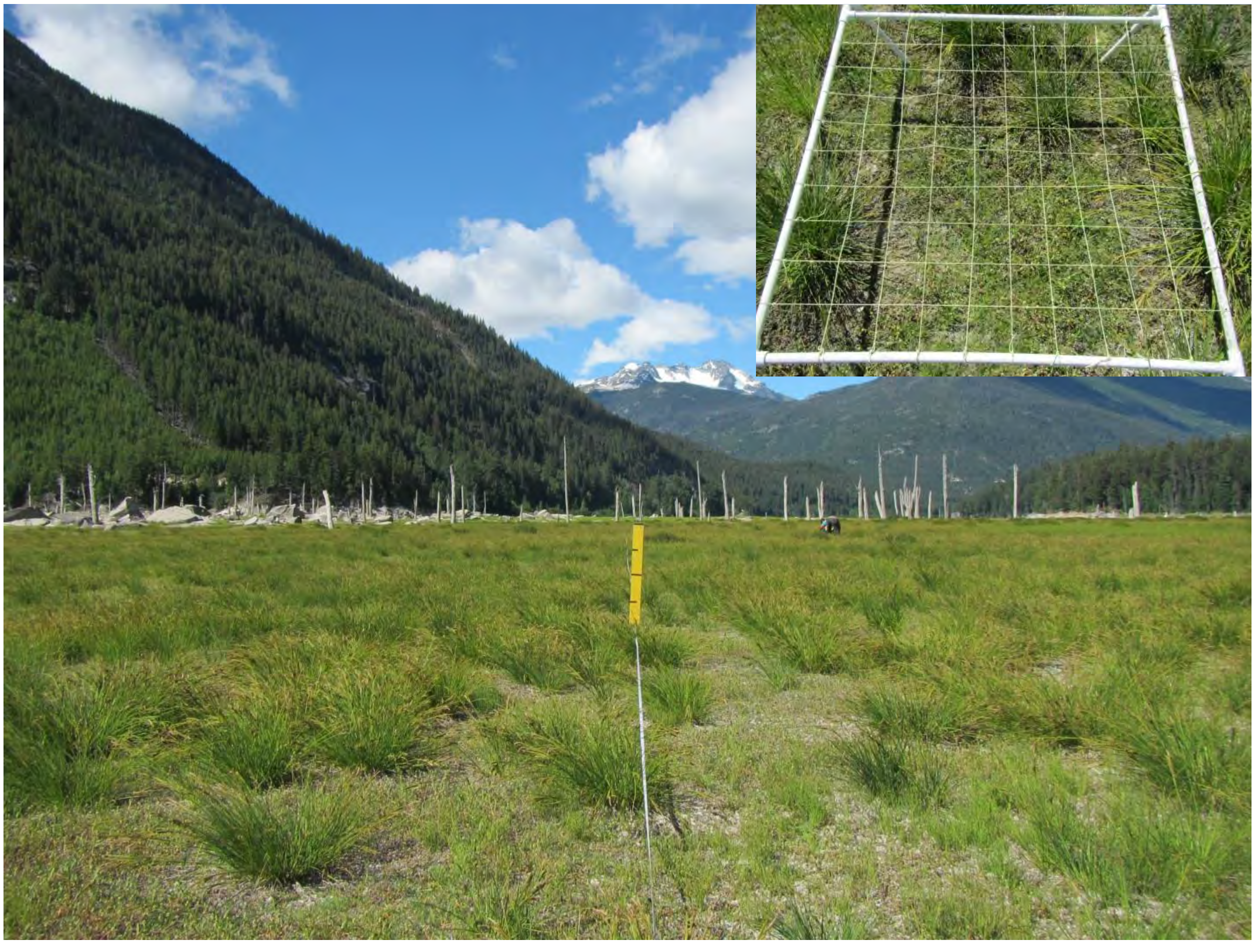


Figure 9. Mid Mudflat 01 inset photo quadrat 04, note the CARLEN (*Carex lenticularis ssp. lipocarpa*) tufts.

Vegetation in the mid mudflat transects varied in composition with dominant recurring cover of perennial native herbaceous species including lakeshore sedge (*Carex lenticularis*), common horsetail, and swamp horsetail (*Equisetum laevigatum*) (Figure 9).

3.2.1.3 Upper Mudflats

There were two mudflat polygons designated as upper mudflat (UMF) types, lying between 745 m and 748 m elevation; one was located on the north, and one on the south side of the Western Fan. Upper mudflats were characterized by lacustrine silt deposits with predominantly organic matter covering the substrates. Wildlife species tracks observed included mule deer, Canada goose, and multiple occurrences of moose (*Alces alces)*. Beaver (*Castor Canadensis*) and snowshoe hare (*Lepus americanus*) browse was also observed on willows (*Salix* sp.) in the south side polygon. UMF vegetation was characterized by the appearance and dominance of bluejoint grass (*Calamagrostis canadensis*), and an increase in the occurrence of willow species (Figure 10).

Figure 10. UMF01 transect with dominance of bluejoint grass (*Calamagrostis canadensis*).

The north side UMF polygon corresponds to a relatively large proportion of the Western Fan and is considered very significant grizzly bear (*Ursus arctos horribilus*) habitat. Protecting grizzly flats was indicated as an important management target in the 2003 Consultative Committee Report for the Bridge Seton Water Use Plan (Compass Resource Management and BC Hydro, 2003). No direct observations of bears (*Arctos* sp.) were made in the Western Fan during the project in 2013. However, one set of grizzly bear footprints were observed on the south side of the fan, and further west in the above free crest zone where there were stark sets of footprints and well-worn wildlife trails. It is likely that grizzly bears utilize the mudflat habitat areas in the early spring (Robertson *et al*.1998), and the bears were likely utilizing higher elevation terrain by the time of the surveys in July 2013.

Using 2005 imagery, spatial mapping of the large UMF polygon on the north side of the delta totaled 16.02 ha (Figure 11); however, by 2013, the same area had been reduced to 14.08 ha. The 1.94 ha (12%) reduction in area has occurred along the southern edge of the polygon, which has been, and continues to be, eroded (Figure 12). Large cohesive chunks of earth were also observed being eroded on the north side of eastern MMF polygons.

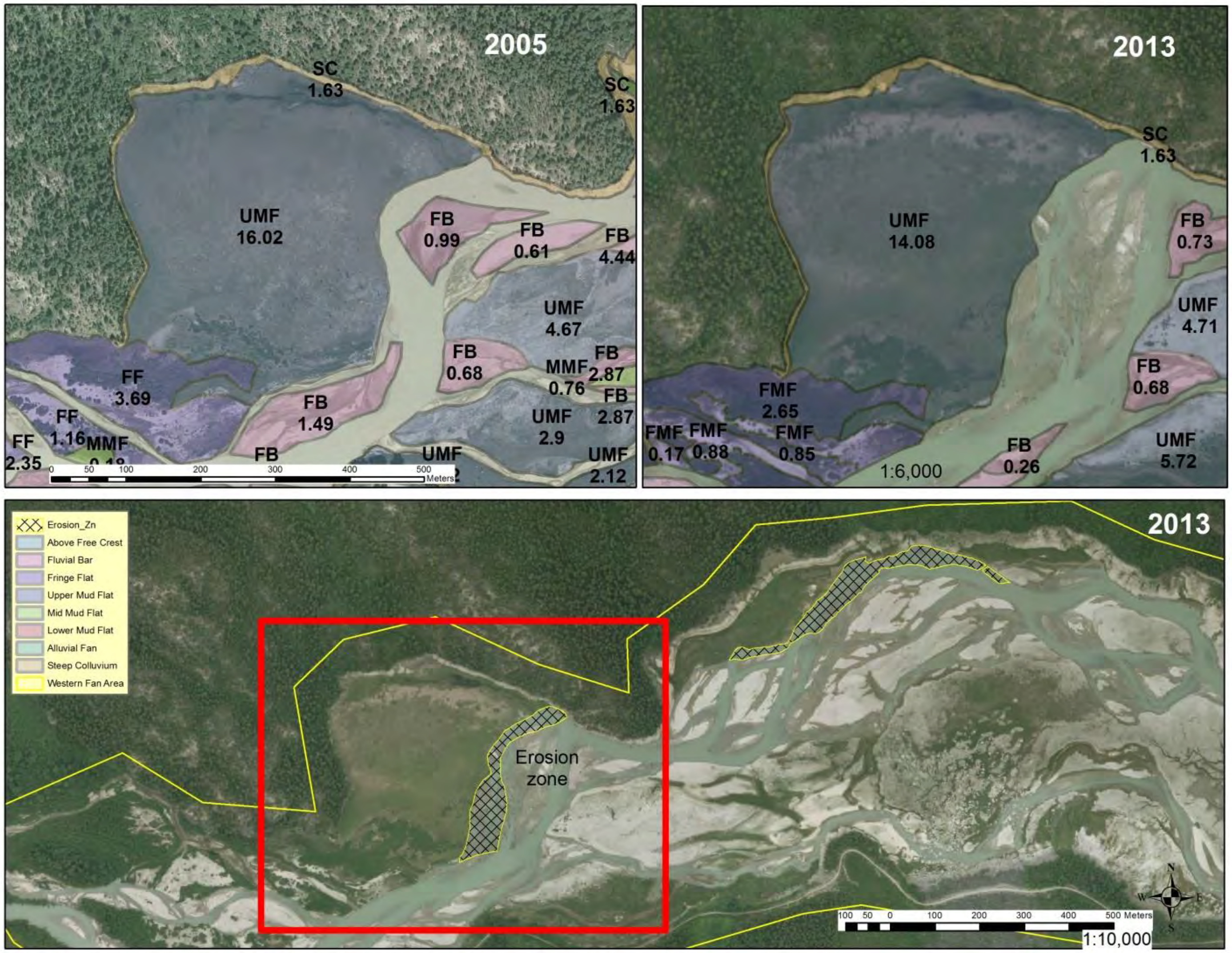


Figure 11 Map series highlighting the change in area of the large Upper Mudflat polygon on the north side of Western Fan in the Downton Reservoir, between the 2005 and 2013 aerial orthophotography.

Figure 12. Eroding southern edge of large UMF polygon on north side of western fan in the Downton Reservoir, in 2013. The inset photo is from just south of transect MMF04, where large chunks of land are also being eroded.

3.2.1.4 Fringe Mudflats

Fringe mudlats (FMF) totaled 7.77 ha in area, and were made up of 11 polygons. The FMF polygons were clustered to the north and west end of the Western Fan (Figure 4). This terrain class was characterized by a complex mosaic of successional stages of vegetation, ranging from tall shrubby thickets of willow, to open grass, herb dominated areas with minimally vegetated, more recently fluvial-washed sandy patches (Figure 13). The soils were relatively well drained with a mix of sandy soils in the south edge of the polygon, and silt in the north. Substrates of the FMF polygons were mixed, with mineral soil being dominant in the open areas, and organic debris dominant in the more stable shrubby vegetation zones. Deer tracks and browse were observed at each of the six transects in the FMF zone. Moose browse was also noted on willows along transect FMF02.

Figure 13 FMF03 East patchy mosaic with horsetail grass openings among willow thickets (inset).

3.2.2 Above Free Crest

Above free crest (AFC) polygons formed 5.87% of the Western Fan area, and were made up of six polygon units. AFC transects were located up to two meters above the full pool elevation of 749.8m. Predominant vegetation cover in each of the AFC polygons varied in composition from drier open patches, to thick shrubby areas, and well developed young forest stands dominated by mature cottonwood (*Populus balsamifera*) trees (Figure 14). Substrate cover was predominantly organic matter; soils were sandy and well drained. The greatest amount of evidence of large mammal presence in the Western Fan was noted in the north-east of the AFC zone (Figure 15). Wildlife sign was extensive in this area, with numerous well-worn trails on the east side of the region, that included wolf, grizzly bear, snowshoe hare, mule deer, and moose tracks. Evidence of recent beaver activity was noted in the deciduous forest and shrub stands. Deciduous tree and shrub species, including cottonwood trees, mountain alder (*Alnus incana*), willow, and red-osier dogwood (*Cornus stolonifera*), were the dominant vegetation throughout the AFC polygons.

Figure 14. Above Free Crest (AFC 04) young cottonwood stand, structurally complex habitat.

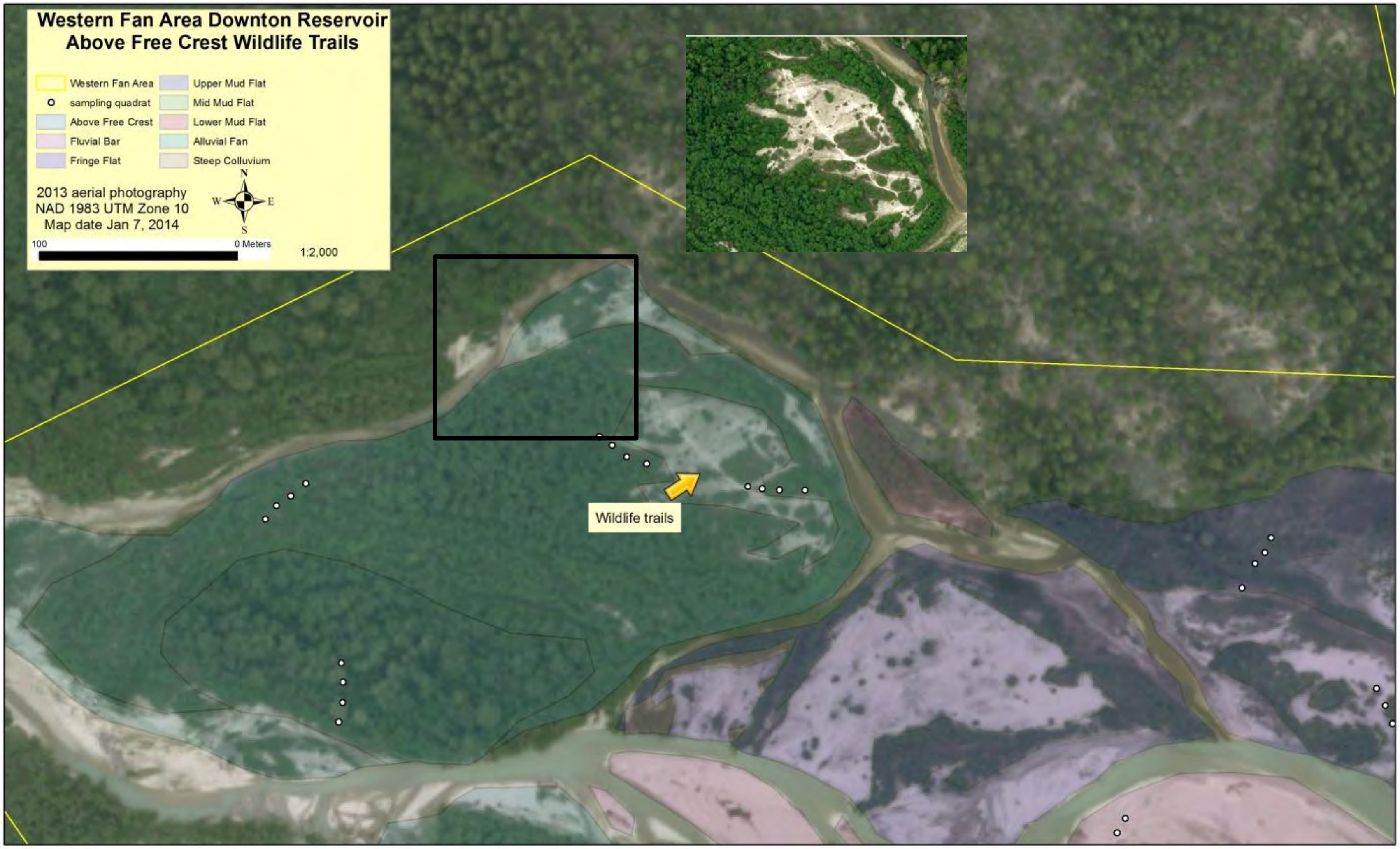


Figure 15. Above free Crest wildlife trails.

3.2.3 Fluvial Bars

Fluvial bars (FB) made up the greatest number of polygons, with a total of 41; most of these polygons were relatively small, with an average area of 0.75ha (Figure 4, Figure 5, Figure 6)). FB polygons tended to be high energy sites with recent fluvial activity, including river scouring and deposition. Due to the high mobility of the FB substrates, vegetation cover tended to be quite low. The larger FB polygons were selected to provide more stable sites for the set-up of the long-term monitoring transects. Those larger polygons were in the center and west end of the Western Fan area (Figure 4). Substrates were predominantly mineral soil and rock; soil texture was sandy.

Mule deer tracks and pellets were noted at three of the four transects. Snowshoe hare pellets were observed at one transect. Vegetation consisted of a mix of sparse herb layer with scattered incursions of low shrubs. The polygon vegetation successional development appeared to be between the FMF and the MMF polygons with vegetation from both terrain types being found (Figure 16).

Figure 16. Patches of willows amid sparse herbaceous vegetation, largely *Equisetum arvense*, in fluvial bars (FB 03). Inset is FB04, quadrat 2.

3.2.4 Alluvial Fans

Three alluvial fan (AF) polygons occurred in the Western Fan of Downton Reservoir (Figure 6). All three fans were on the south side of the reservoir. Four permanent primary transects sites were randomly selected and established across the three alluvial fans. Field observations indicated that there was a marked occurrence of three types of vegetation as elevation increased. The low elevation band was characterized by common horsetail, the upper elevation band by bluejoint grass, and the drawdown fringe band by woody vegetation such as cottonwood and willow species.

3.2.4.1 Mid alluvial fans

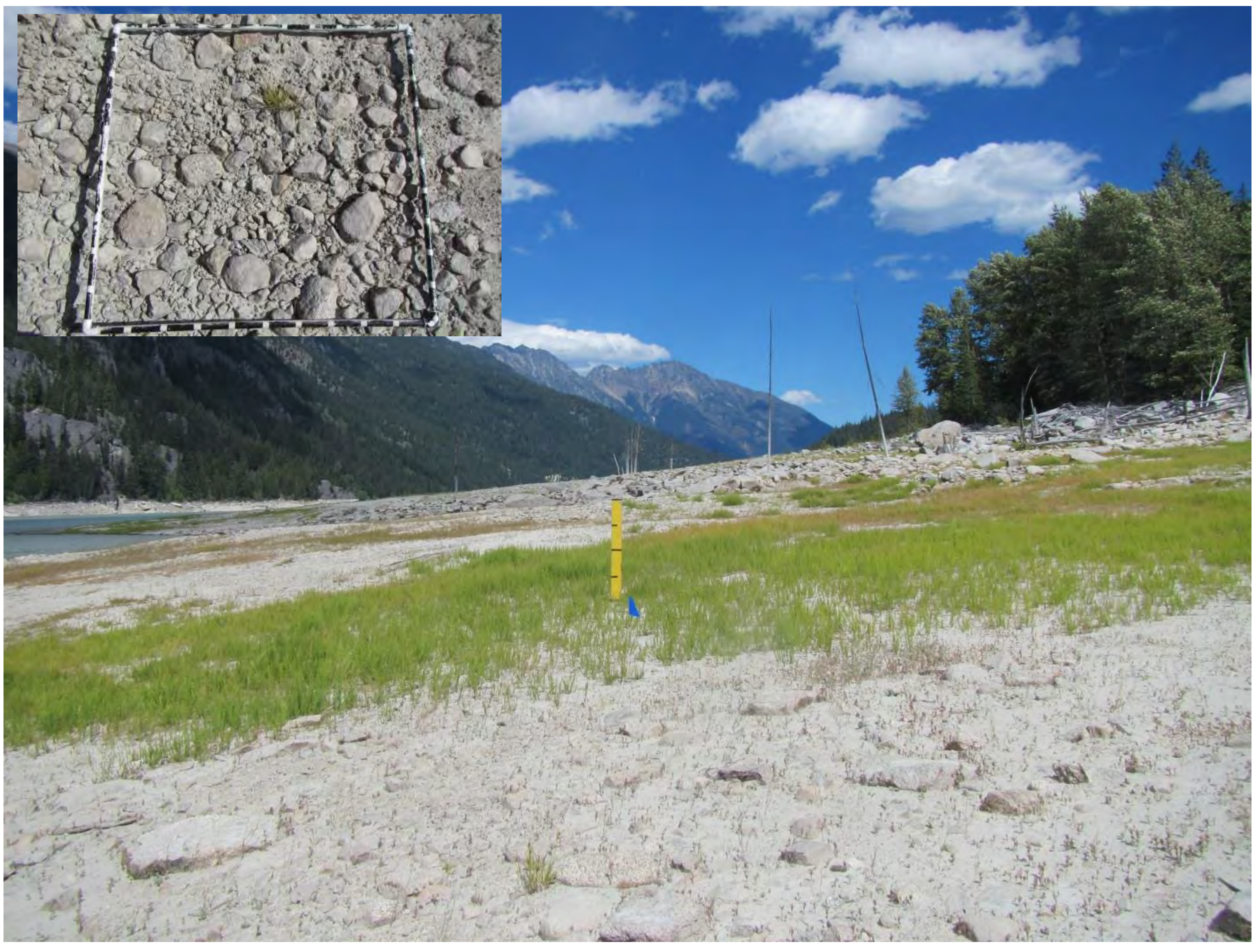


Figure 17. Mid-elevation alluvial fan (AFmd03) looking east. Horsetails are dominant with minor cover in annual plants. Inset photo is quadrat 04 with coarser soils.

The mid alluvial fans (AFmd) polygons covered the greatest amount of area of all the alluvial fans in the eastern end of the Western Fan (Figure 6). The AFmd polygon encompassed five vertical meters of elevation (739 m-744 m). Substrate cover was primarily mineral soil, and the soils were largely silts to silt loams. Wildlife sign was limited to Canada goose browse noted at two of the four AFmd transects. The bulk of the vegetation cover in the AFmd polygons was meadow horsetail and lakeshore sedge*Carex lenticularis ssp. lipocarpa*, with a small amount of annual herb species (Figure 17).

3.2.4.2 Upper Alluvial fan

Figure 18. Upper alluvial fan (AFud03); note driftwood in foreground, and line of *Calamagrostis canadensis* on the right hand side of the image.

The upper alluvial fan (AFud) totaled 5.5 ha of the Western Fan in Downton reservoir (Figure 6). Substrate cover at this elevation was mixed, with a high percentage of coarse fragments, mineral soil, some organics, and an incursion of large driftwood in some quadrats (Figure 18). One transect had water running through quadrats from a small tributary stream. Soils of the AFud were often coarse and sandy. Mule deer tracks were noted at two of the four transects. Vegetation was similar to the middle elevation zone, with the addition of the bluejoint grass. There were rare occurrences of woody vegetation into the AFud zone including black twinberry (*Lonicera involucrata*), and red osier dogwood cottonwood and willow species (*sp.*).

3.2.4.3 Fringe Alluvial Fan

Figure 19 Fringe alluvial fan (AFfr04), lots of driftwood with canopy cover from the upland foreshore. Inset photo is AFfr04 quadrat 3.

The narrow elevation band covered by the fringe alluvial fan (AFfr) corresponded to the smallest area of the Western Fan (just under 2 ha or 1.12%). This type was characterized by very high coarse woody debris substrate cover, and the increase in woody vegetation as a dominant form of vegetation cover (

Figure 19 Fringe alluvial fan (AFfr04), lots of driftwood with canopy cover from the upland foreshore. Inset photo is AFfr04 quadrat 3.

). Soils in the AFfr zone varied in texture from sands to silts. Mule deer browse and tracks were noted at two transects, and moose browse was observed along one transect. Dominant woody species include cottonwoods and willows as well as red-Osier dogwood, black twinberry, paper birch (*Betula papyfera*), Douglas maple (*Acer macrophyllum*), mountain alder (*Alnus incana*) and Sitka mountain ash (*Sorbus sitchensis*).

3.2.5 Steep Colluvium

Figure 20. Steep colluvium around the Western Fan of Downton Reservoir; high water mark is indicated by white staining on shore and bedrock.

The steep colluvium (SC) polygons made up 16.44% (28.19 ha) of the Western Fan. The steep (>30 per cent) sloping shoreline zones were characterized by rock, boulders and bedrock substrates, with limited vegetation growth (Figure 20). These zones were mapped as polygons with GIS but due to time constraints, they were not sampled for vegetation in the field.

3.3 Statistical Analysis of Field Data

Forty-five permanent monitoring transects were installed throughout the Western Fan of Downton Reservoir between May and July 2013 (Table 3, Figure 21

Table 3. Number of transects in each combination of terrain class, elevation, longitude and latitude.

Factors	Categories	Number of transects
Terrain classes	Bar	4
	Fan	12
	Mudflats	23
	Above Free Crest	6
Elevation	Low	4
	Middle	15
	Upper	10
	Fringe	10
	Above Free Crest	6
Location: latitude	North	17
	Central	13
	South	15
Location: longitude	West	8
	Central	13
	East	24

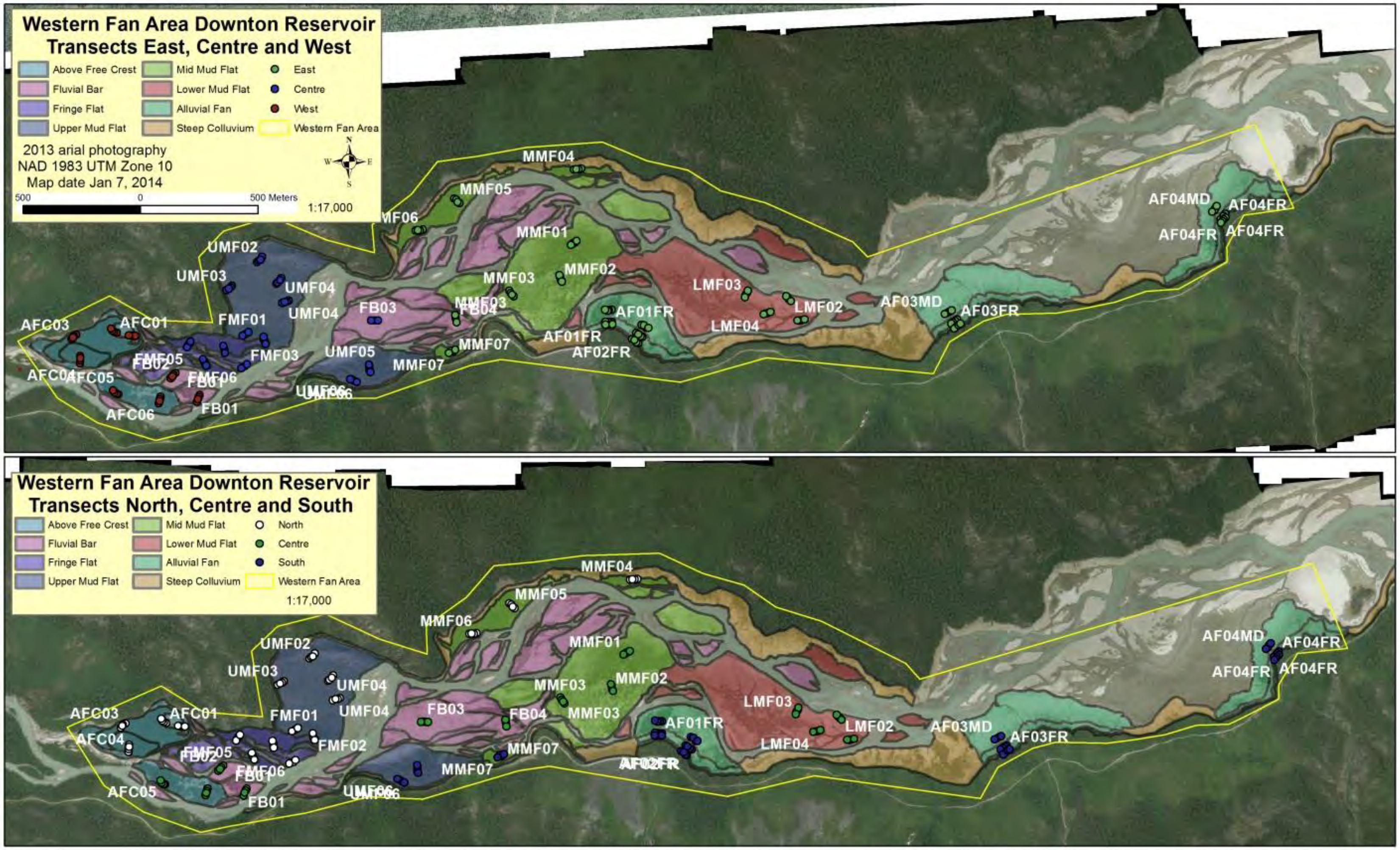


Figure 21. Location of the transects sampled in the Western Fan area of Downton Reservoir in 2013.

3.3.1 General description of vegetation

A minimum of 72 species of vegetation was sampled over the 45 transects (Appendix 1. List of species sampled in 2013
). Common horsetail was sampled in all transects but one (,, most of the other species sampled were rare; 31 species (42%) were sampled in less than two transects (Table 4). Bluejoint grass, lakeshore sedge(*Carex lenticularis ssp. lipocarpa*,), and Lady's thumb (*Persicaria maculosa*) were seen in about half of the transects. Moss was also frequent (found in 28 out of 45 transects).

Table 4. List of species sampled in the Downton reservoir in 2013, in order of frequency of occurrence in transects (n=45 transects). Acronyms are explained in Appendix 1. List of species sampled in 2013

.

Species	Frequency
EQUIARV	44
MOSS	28
CALACAN	25
CARELEN	24
SALIX	23
PERSMAC	21
POAPALU	18
COLLLIN, MATRDIS	15
POLYFOW	14
POPUBAL	13
ALNUINC	12
SAGIPRO	11
EPILCIL, EQUIHYE, EQUIPAL, PLAGSCO	10
GALITRD	9
CAREAQU, CHENALB	8
CORNSTO, ELYMGLA, FILAARV, RANUPEN	7
EPILANG, EPILLEP, EQUILAE	6
LONIINV	5
ARCTUVA, ELYMTRA, EQUIVAR, TARAOFF	4
EPILBRA, EPILLAT, GALITRI, LICHEN, LOTUDEN, ORTHSEC, PLANDIL, PYROASC, RUBUIDE, SCOLFES, STELCRI	3
ACHIMIL, ALNUCRI, AMELALN, ANAPMAR, PICEENG, RIBELAC, SPIRDOU	2
ABIELAS, ACERGLA, AMSISPE, ARABHOE, BETUPAP, CASTMIN, CORNCAN, CREPOCC, HEIRACI, HERALAN, LACTMUR, MENTDIS, OPLOHOR, OZMOCHIL, PINUCON, PINUMON, POAPRAT, POLYAQU, RORIPAL, SOLISPA, SORBSCO, STELLON	1

3.3.2 Exotic species

Of the 72 species of vegetation observed during this study, 7 (9.5 per cent) were exotic, and 63 (87.5 per cent) were native to the Western Fan. The most common exotic species was lady's thumb , a dominant annual species found colonizing throughout the mudflat polygons. Pineapple weed (*Matricaria discoidea*) was also fairly common in the mudflats, but its origin as exotic or native is questionable according to BC Conservation Data Centre. Of the exotic species found in the Western Fan none were provincial noxious weeds nor were any recognized as a regional noxious species or on the regional priority species lists, according to the Lillooet Regional Invasive Species Society and the province of British Colunbia's noxious weed lists (Cranston and Ralph. 1996). One concern would be to establish conclusive identification of the unknown hawkweed (*Heiracium sp.)* species to make sure that the species in question are not the exotic hawkweeds.

None of the vegetation species identified during the vegetation inventory in 2013 were listed as rare or species of concern on the BC Conservation Data Center Species and Ecosystems Explorer.

3.3.3 Variation in vegetation cover

The total cover of vegetation varied greatly among terrain classes and elevation bands (Figure 22). Above free crest (AFC) transects, located above the drawdown zone of the reservoir, had higher cover of vegetation. Above Free Crest polygons also had more complex layers of vegetation (tree, shrub, and herb layers), explaining why cover of vegetation in some transects totaled above 100 per cent. Fluvial bars, sampled at middle elevation, had generally low cover of vegetation (median of 20%, maximum cover of 52%). Alluvial fans and mudflats spanned all elevation bands, and showed a wider range of vegetation cover. Transects located at middle elevation in fans had a wider range of vegetation cover than in the upper elevation band or in the fringe, including few transects with very high covers (>100 per cent). Vegetation cover in mudflats was markedly lower at low elevation, but similar for the middle, upper or fringe elevation bands.

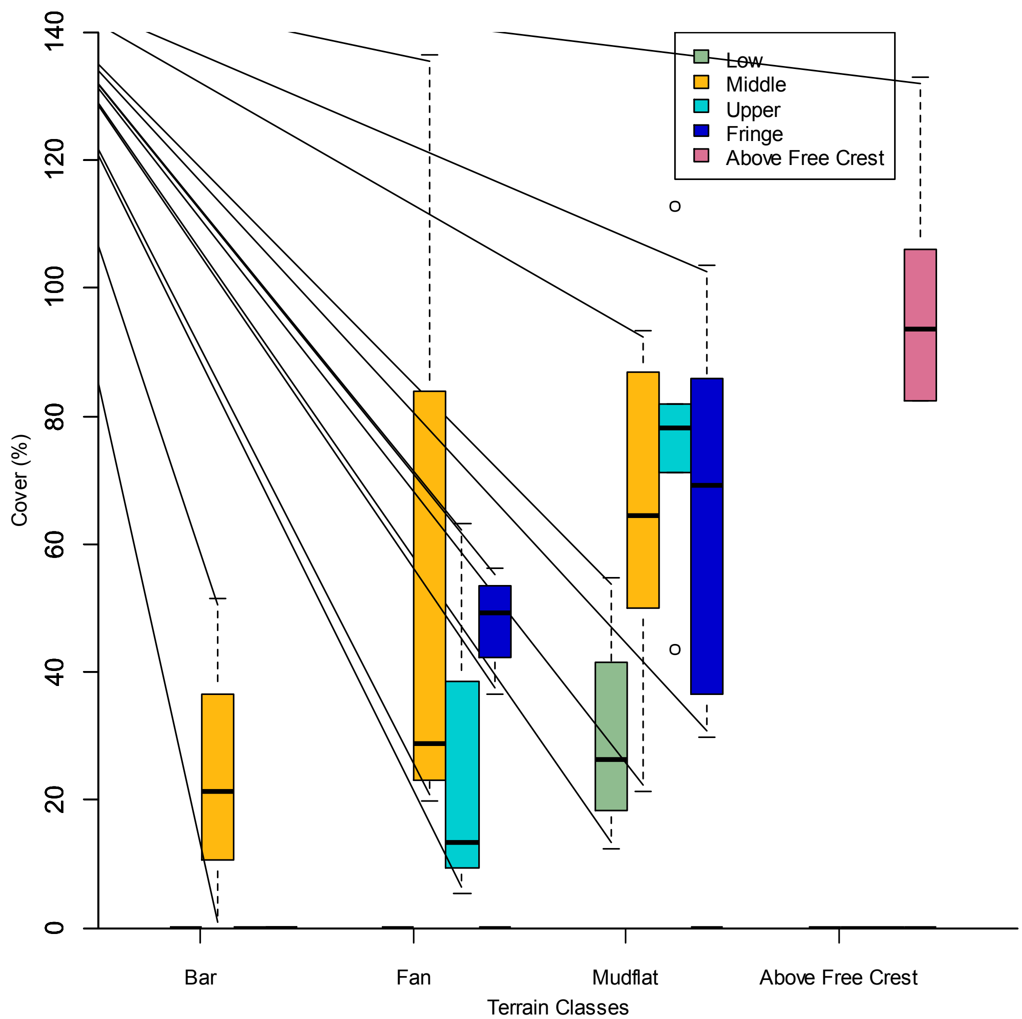


Figure 22. Variation in vegetation cover (%) in the different terrain classes and elevation bands in the Western Fan in 2013.

Only transects above free crest and mudflats were sampled in the north side of the Western Fan, and alluvial fans and mid mudflats were sampled in the southern portion of the study area (Figure 23a). Vegetation cover was slightly greater in the mudflats in the south compared to the north of the Western Fan, while the mudflats located in the center of the Western Fan had the lowest cover overall. Cover of vegetation in transects above the free crest was similar between north and central areas of the Western Fan. However, all terrain classes considered, cover of vegetation was generally higher in the north of the Western Fan than in its center or south at middle, upper, and fringe elevation bands (Figure 23b).

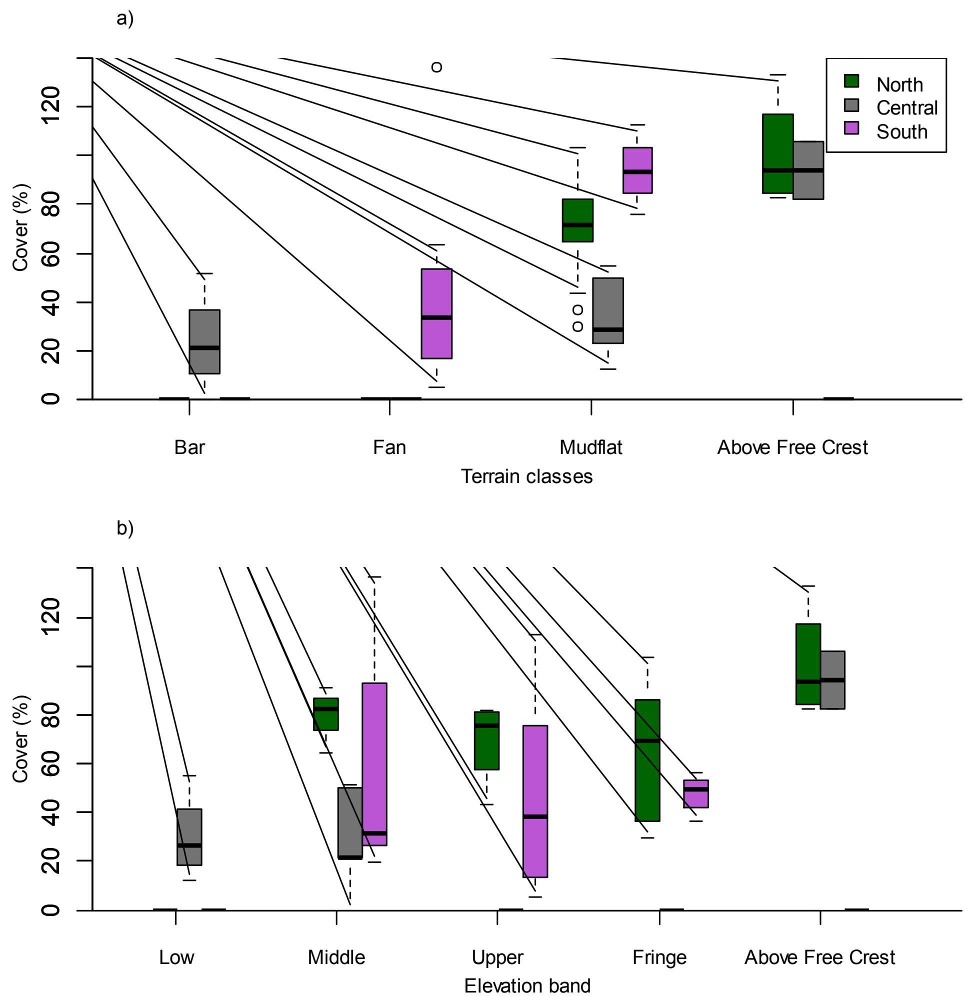


Figure 23. Variation in vegetation cover (%) between the north and the south of the reservoir, across a) terrain classes, and b) elevation bands.

Figure 24 summarizes, with many details, the variation in cover among the various transects, as per location, terrain classes, and elevation bands. In summary, only mudflats were sampled at low elevation and in the eastern side of the Western Fan; the transects above free crest were sampled only in the western side of the Western Fan (in the river delta); mudflats had generally higher cover of vegetation than fans, independently of their elevations or locations; sampling in the eastern side of the Western Fan happened mostly at low and middle elevation, while sampling in the central and western areas was mostly at upper and fringe elevations, or above free crest; and finally, all fluvial bars were sampled at middle elevation and had low cover (Figure 24).

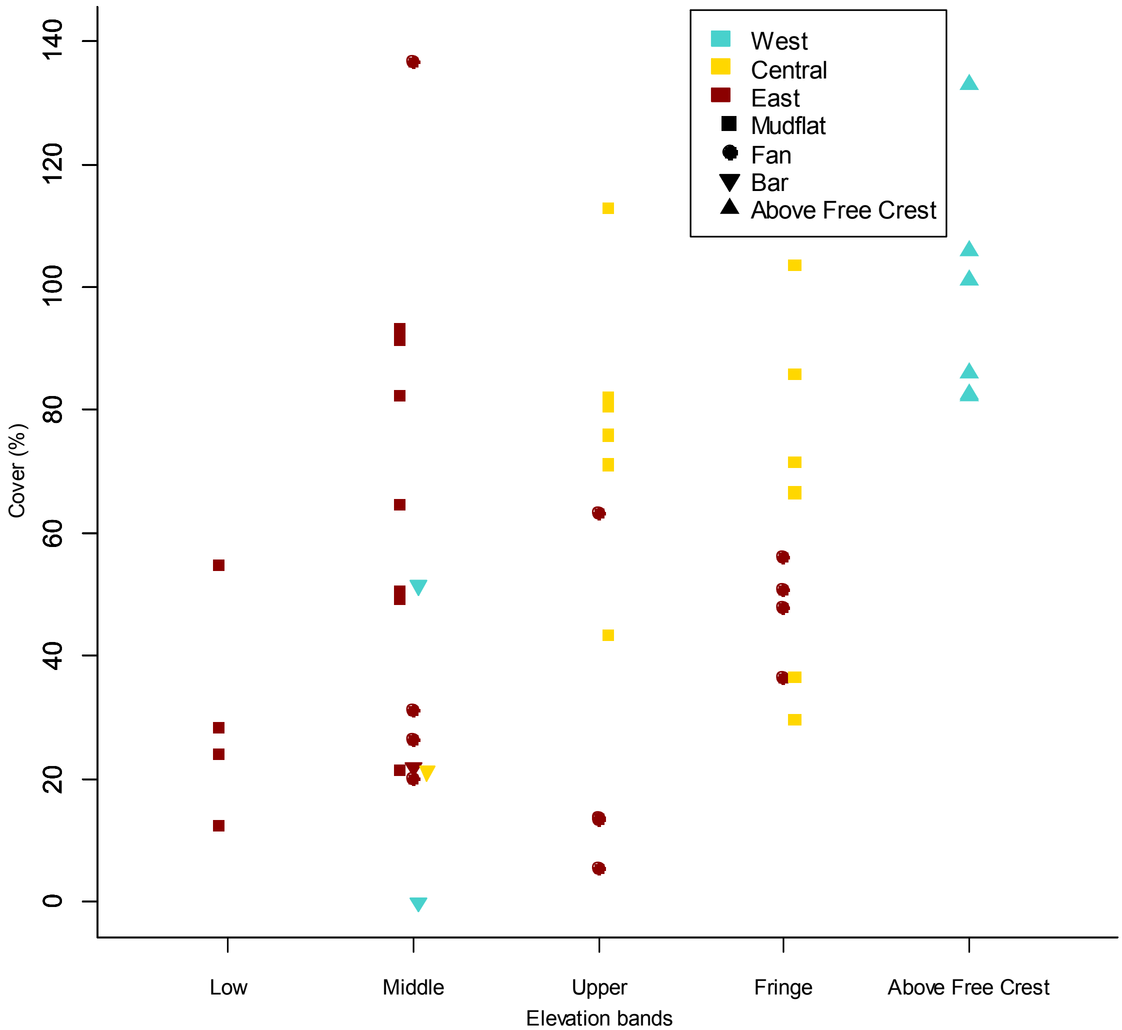


Figure 24. Variation in cover of vegetation (%) over elevation bands, terrain classes (symbols), and areas of the Western Fan Zone (colors).

3.3.4 Variation in species richness

Species richness varied between 5 and 15 species on average per transect, in all terrain classes and at all elevations (Figure 25). The mudflats at the fringe had the most variation in species richness, followed by the transects above free crest. The fluvial bars (all at mid elevations) and the low mudflats had the lowest richness.

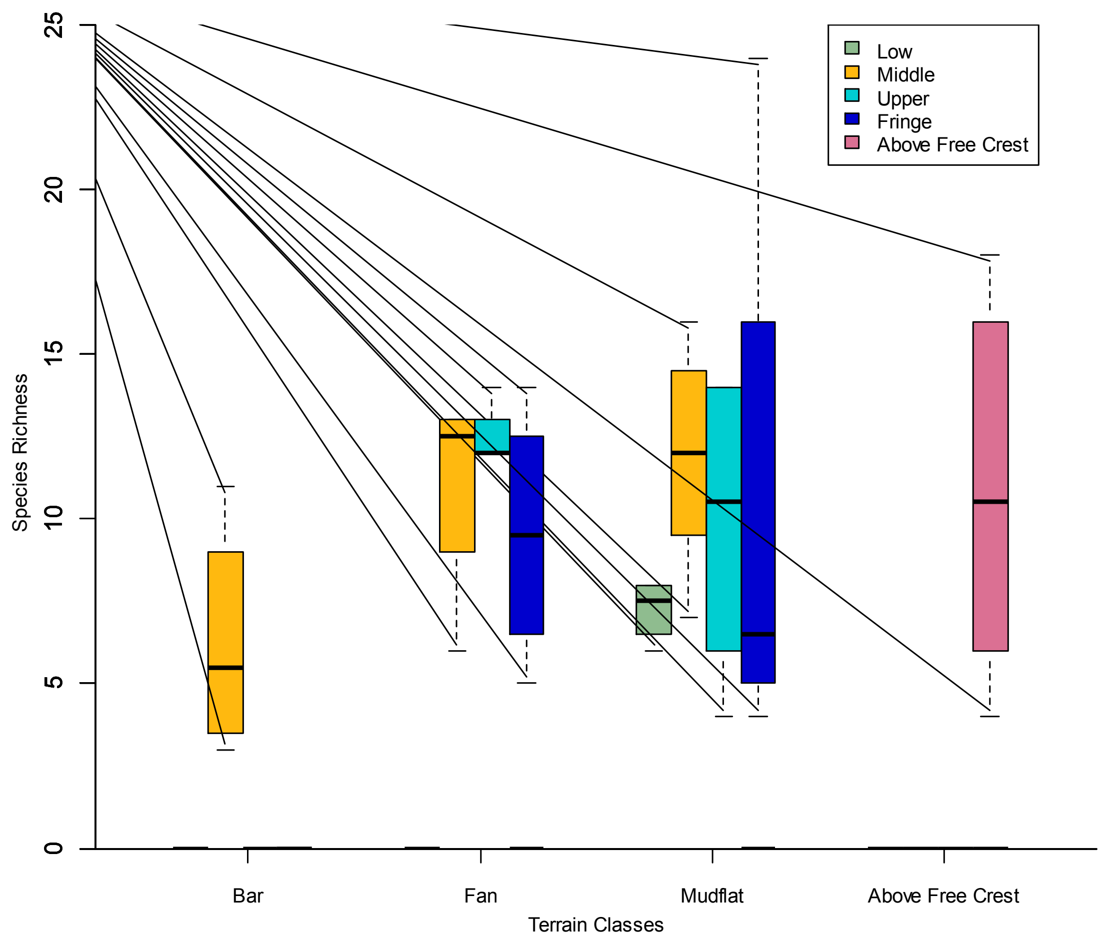


Figure 25. Variation in vegetation species richness in the different terrain classes, and at various elevations in 2013.

Mudflats in the north of the Western Fan had higher species richness than mudflats in the center or south; the transects above free crest in the north had, on average, similar species richness than in the center, but showed more variation among transects (Figure 26a). Species richness in the alluvial fans in the south of the Western Fan was higher than in the mudflats of the same region. Species richness was also higher in the north than in the center or south of the Western Fan at middle and upper elevations, but slightly lower on average at the fringe (Figure 26b).

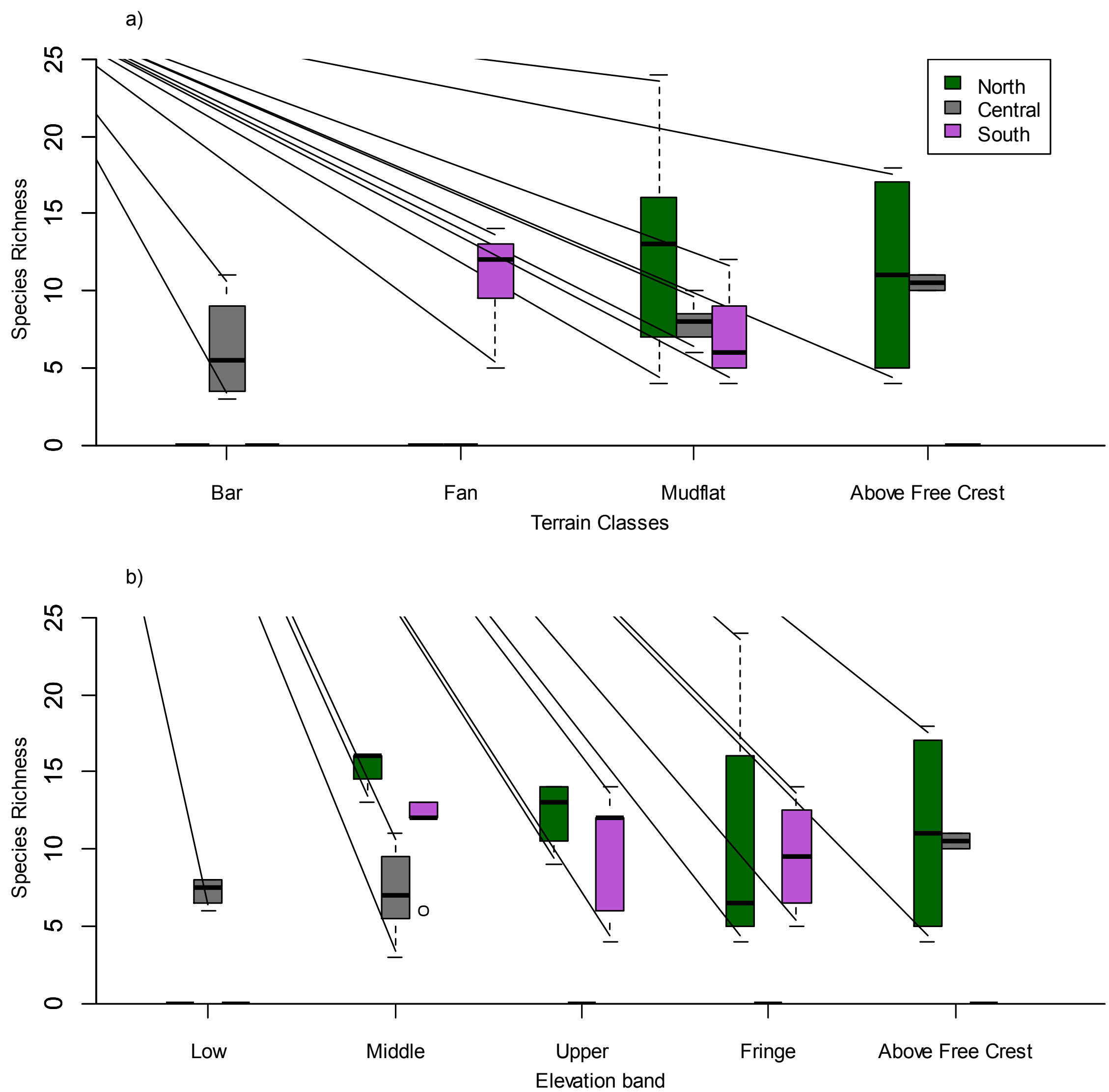


Figure 26. Variation in vegetation species richness between the north and the south of the reservoir, across a) terrain classes, and b) elevation bands.

Species richness was highest in two mudflats sampled at the fringe in the central area of the Western Fan, and lowest at middle elevations in fluvial bars in the central and west areas (Figure 27). Species richness in the transects sampled above free crest varied greatly, and was not higher, on average, than for other terrain classes. Species richness was generally similar between the center and east areas of the Western Fan.

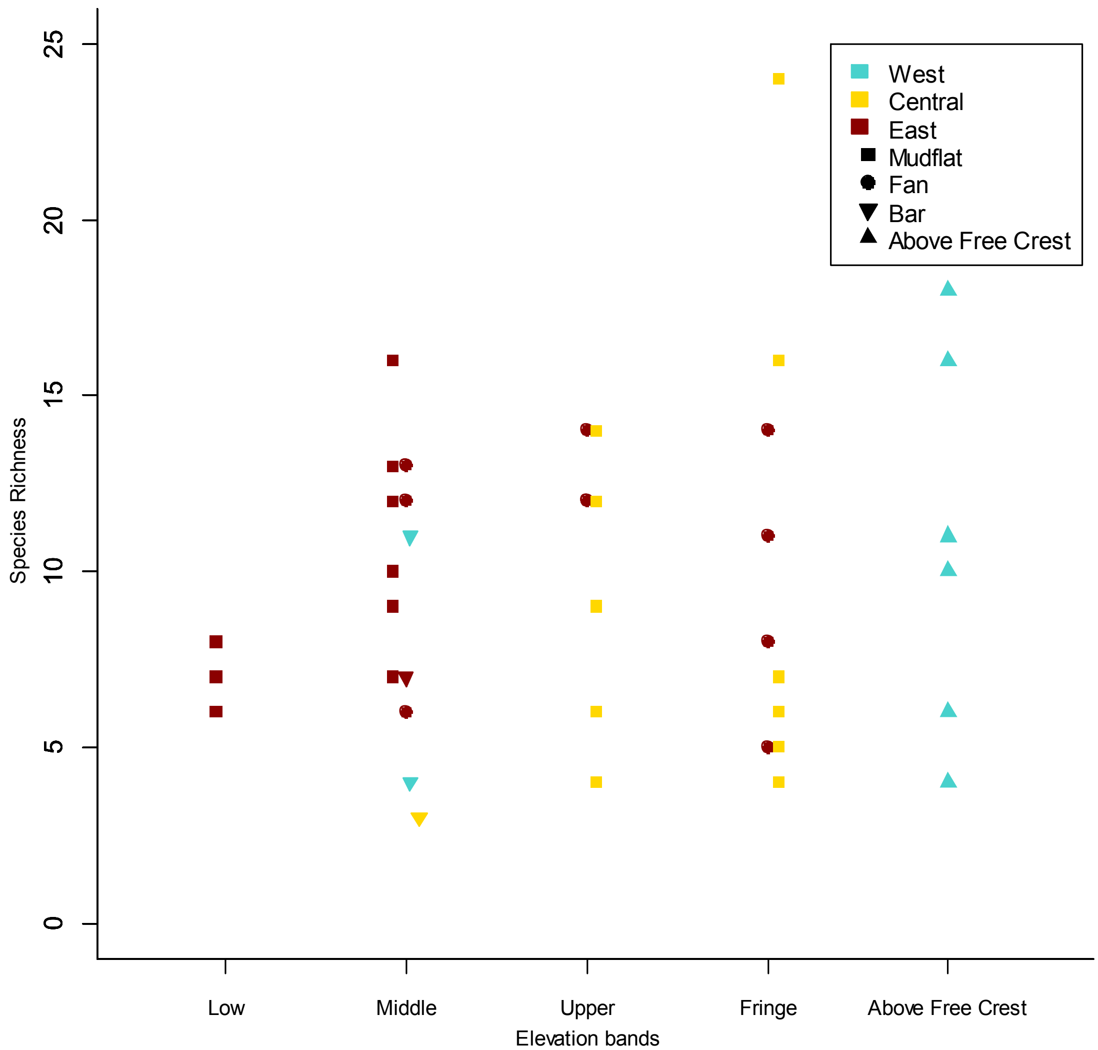


Figure 27. Variation in vegetation species richness over elevation bands, landscape features (symbols), and areas of the reservoir (colors).

3.3.5 Variation in vegetation diversity

Species diversity was variable among transects (Figure 28). It was slightly less diverse at upper elevation in the fans, while it was generally more diverse at middle and upper elevations in mudflats, and markedly less diverse at low elevations.

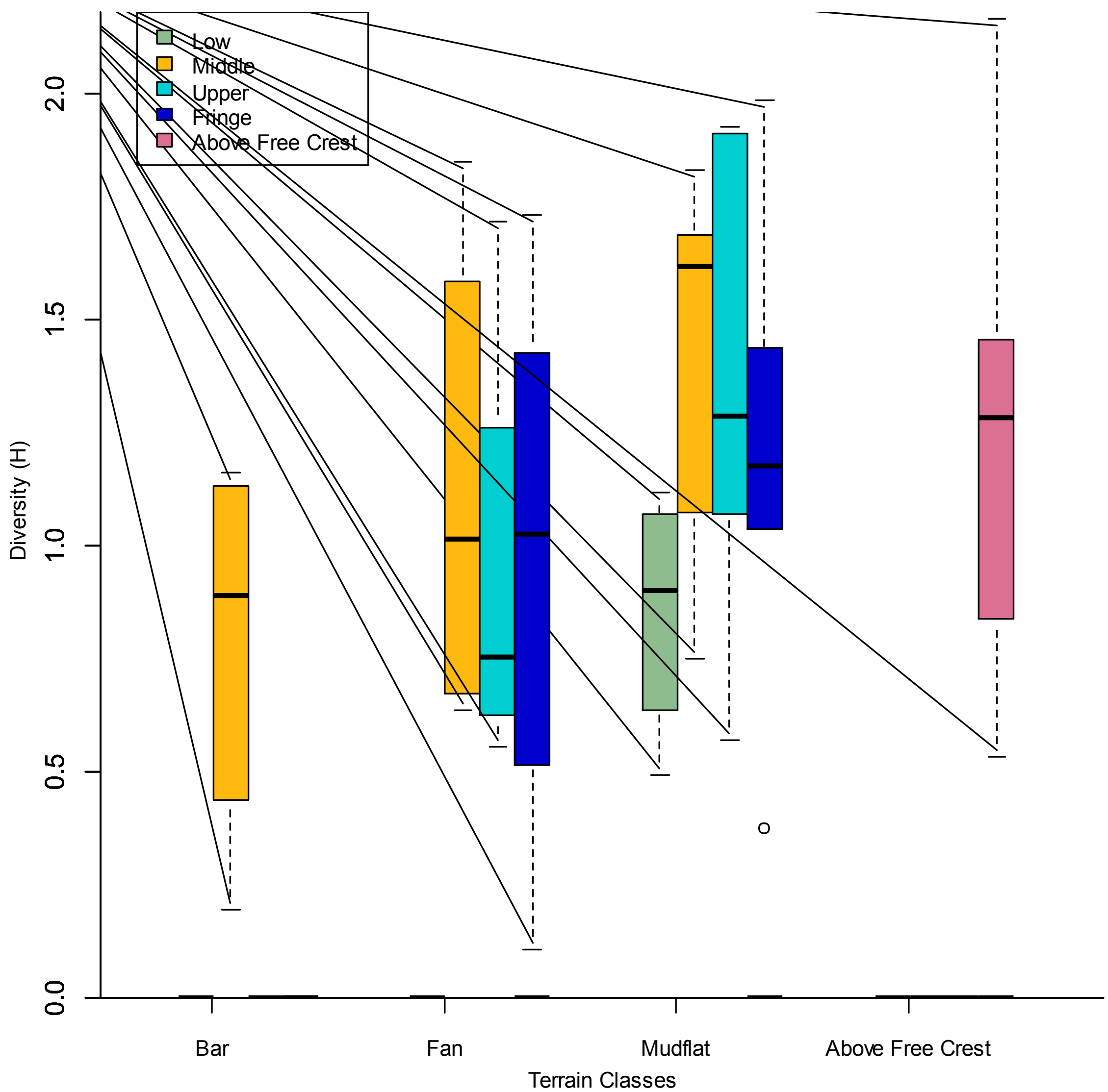


Figure 28. Variation in diversity of vegetation (Shannon index) in the different terrain classes, and at various elevations in 2013.

Diversity of vegetation was lower in the mudflats in the central areas of the Western Fan, and slightly higher in the south than in the north (Figure 29a). The transects sampled above free crest had slightly higher diversity in the central areas than in the north of the Western Fan. However, the diversity of vegetation was generally higher in the north than in the center or south at middle, upper and fringe elevations (Figure 29b).

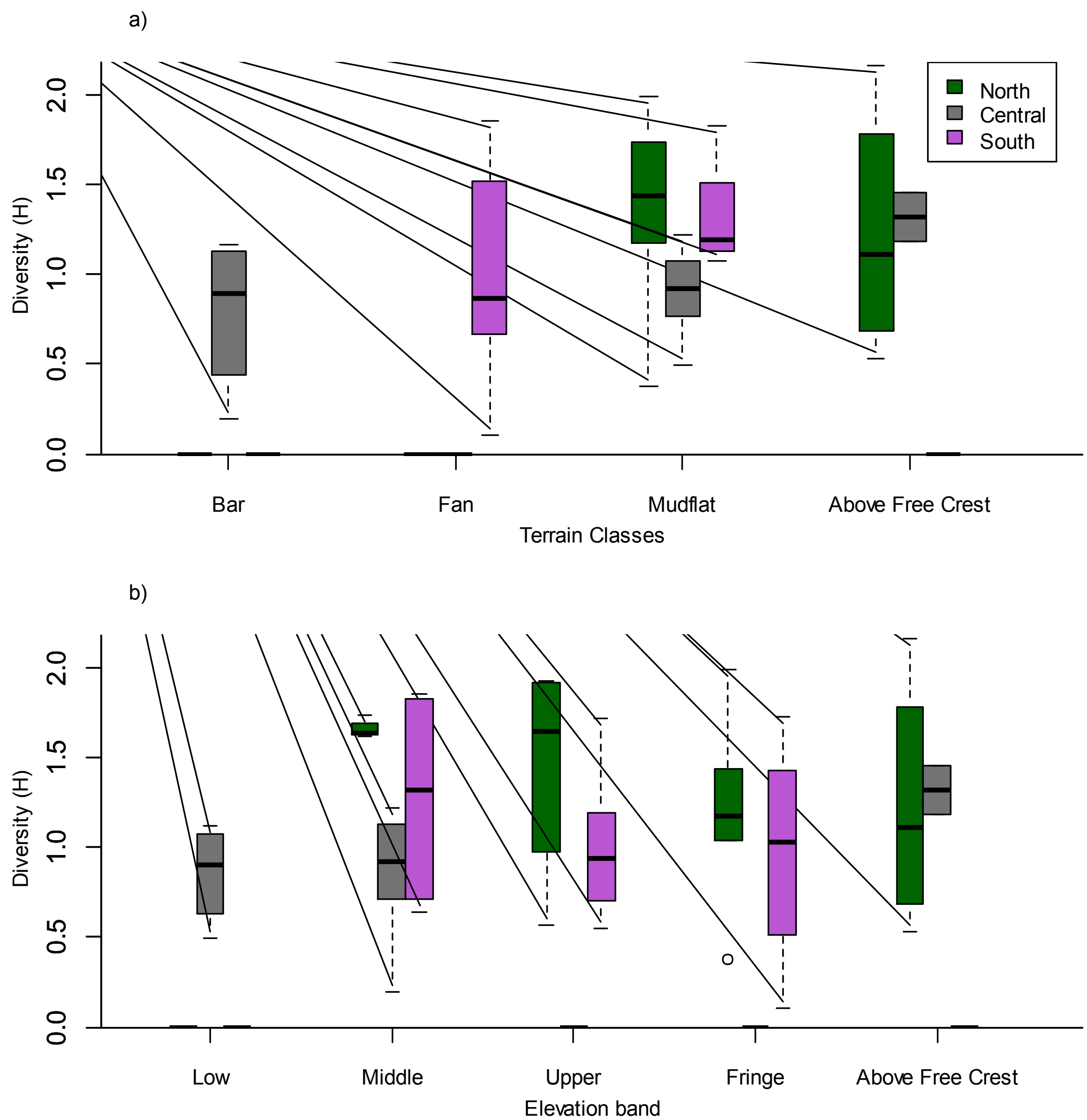


Figure 29. Variation in diversity of vegetation (Shannon index) between the north and the south of the reservoir, across a) terrain classes, and b) elevation bands.

Species diversity was highest in one transect sampled above free crest in the west side of the Western Fan, and in one central mudflat (Figure 30). One fluvial bar in the east area had the lowest diversity, along with an alluvial fan in the East. The diversity varied greatly among transects of the same terrain classes within elevation bands; mudflats still generally had higher diversity of vegetation than alluvial fans.

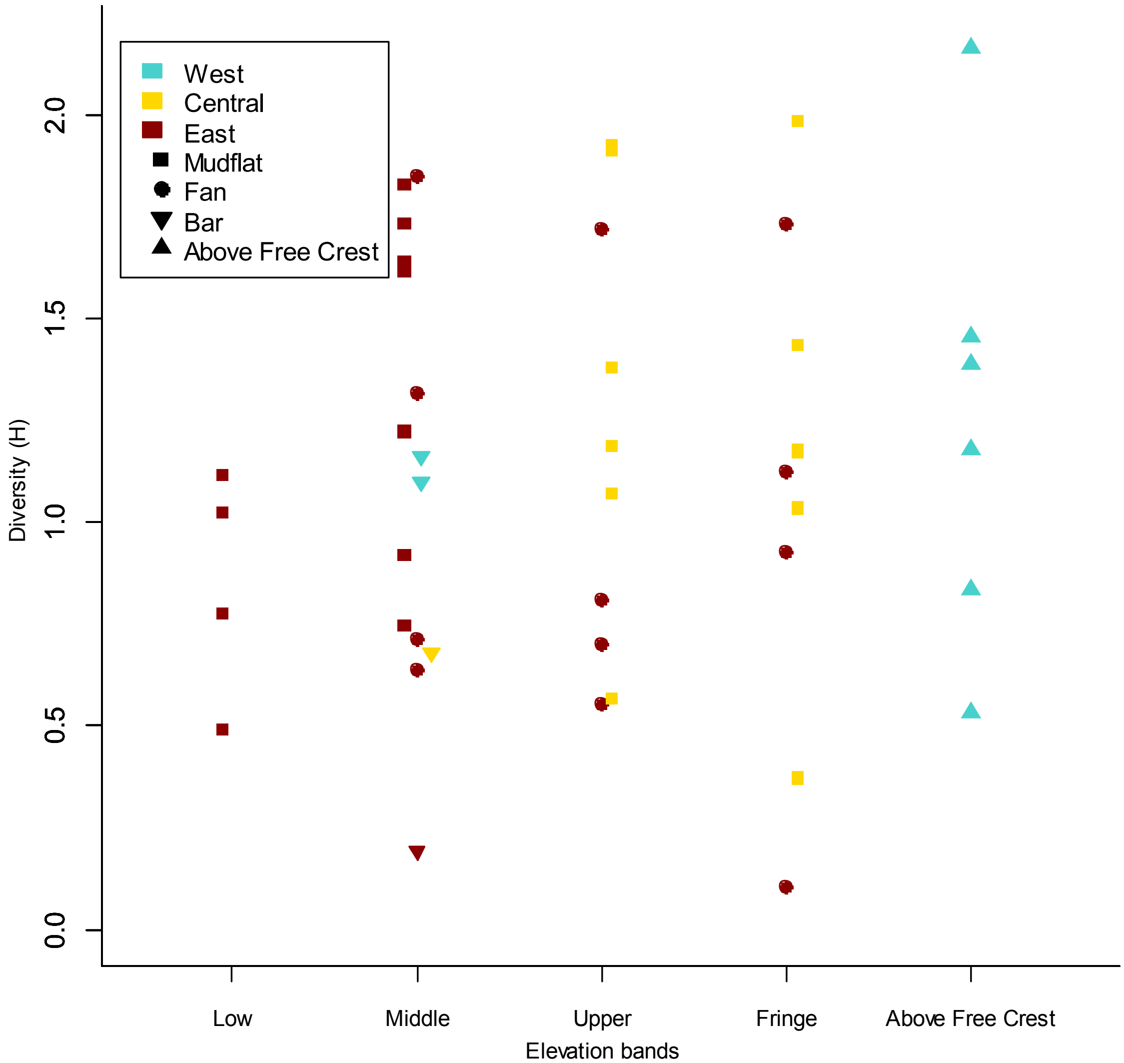


Figure 30. Variation in diversity of vegetation (Shannon index) over elevation bands, terrain classes (symbols), and areas of the reservoir (colors).

3.3.6 Variation in evenness of vegetation

The variation in evenness of vegetation was very wide in fluvial bars, while it was not as great for the other terrain classes (Figure 31). Vegetation was slightly less even at upper elevation in alluvial fans, while it was maximal at upper elevation in mudflats.

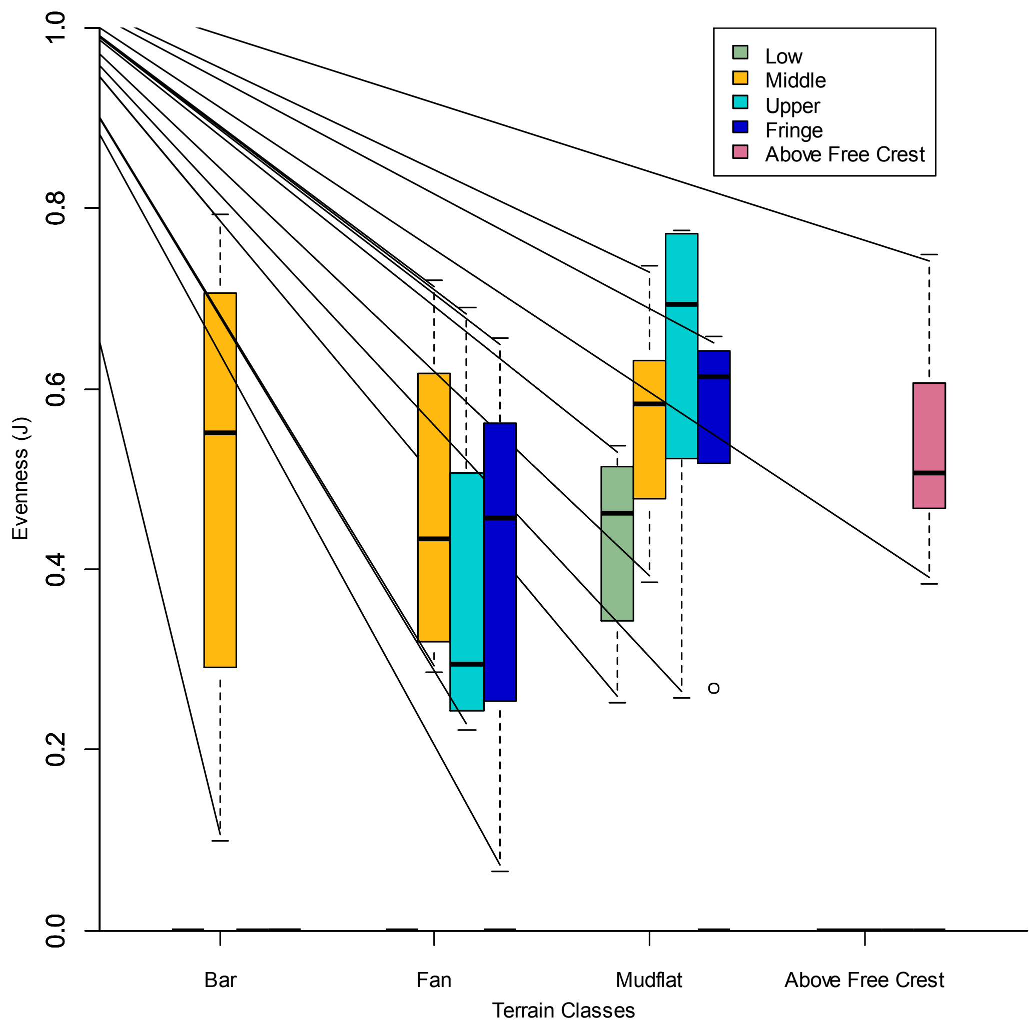


Figure 31. Variation in evenness (J) of vegetation in the different terrain classes, and at various elevations in 2013.

Evenness of vegetation was markedly higher in mudflats in the south of the Western Fan, and lower in mudflats in the central areas, and in transects sampled above free crest in the north (Figure 32a). Evenness was highest at middle, upper and fringe elevation bands in the north of the delta; it appears lower at the fringe in the south than in the north of the Western Fan (Figure 32b).

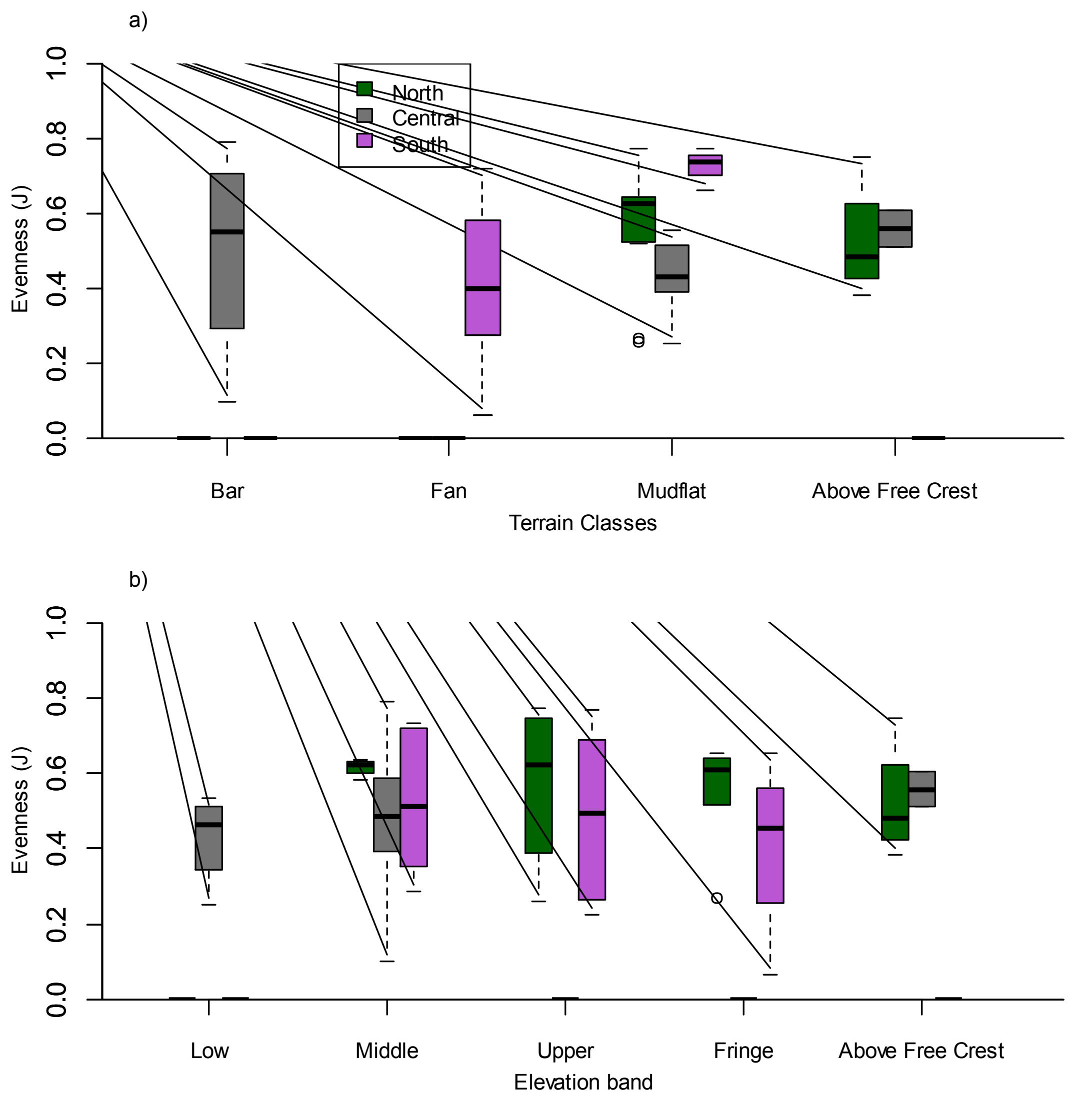


Figure 32. Variation in evenness (J) of vegetation between the north and the south of the reservoir, across a) terrain classes, and b) elevation bands.

Vegetation was the most even in one transect located in a fluvial bar in the west side of the Western Fan at middle elevation (Figure 33); it corresponds to a transect that had 3 species evenly distributed, and very low covers. The two lowest values of evenness were found in fluvial bars at middle elevation and in a fan at the fringe, in the eastern areas of the reservoir; these transects had limited number of dominant species.

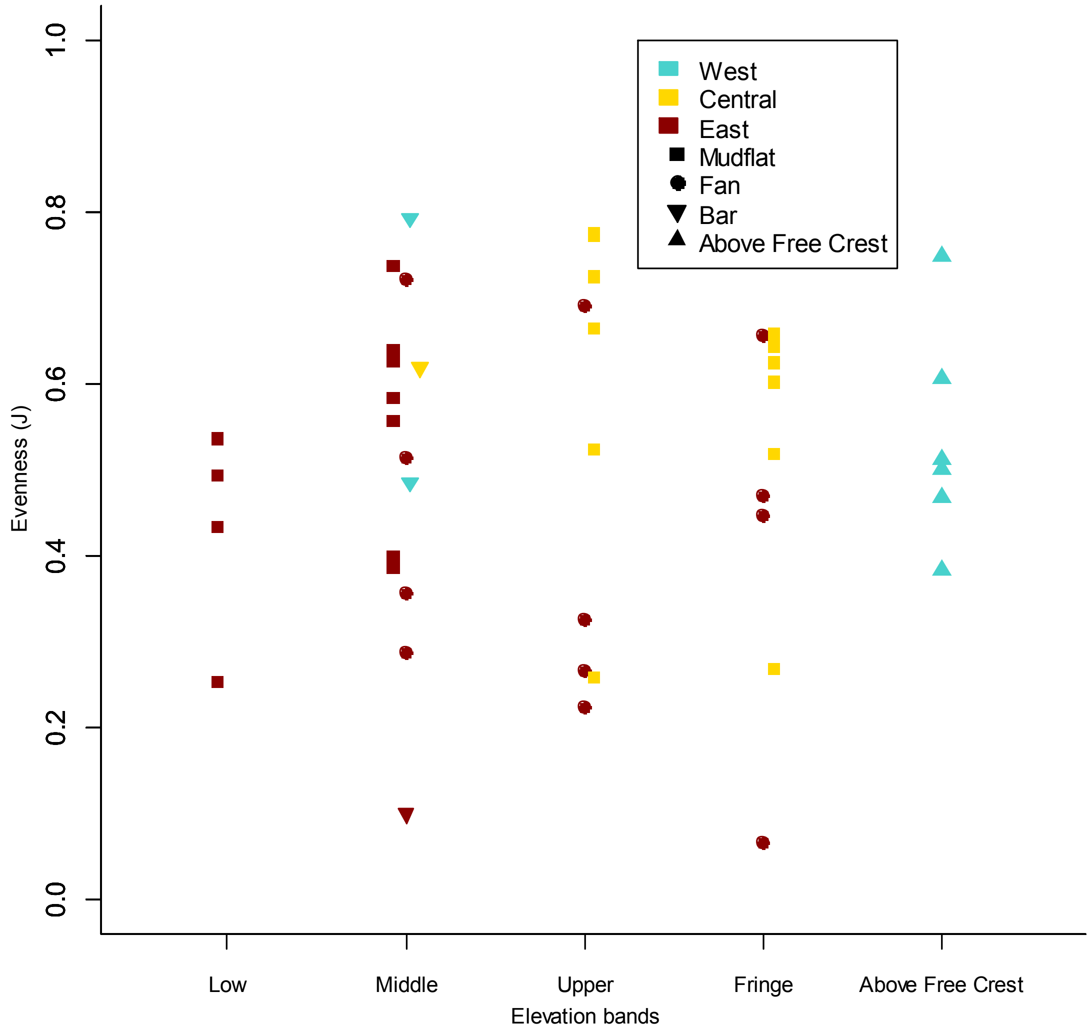


Figure 33. Variation in evenness (J) of vegetation over elevation bands, terrain classes (symbols), and areas of the reservoir (colors).

3.3.7 Classification of vegetation communities

3.3.7.1 Species association with Kendall W coefficient of concordance

A total of 46 species and taxa of vegetation were included in the Kendall W concordance analysis (those that were present in at least three transects).

The overall test of concordance was significant (W=0.036 p=0.002), suggesting that at least some species among those 46 included were significantly found together. The K-means analyses suggested that species were partitioned along two main groups. Each group had significant associations of species (Group 1: W = 0.21, p=0.001; Group 2: W = 0.14, p=0.0001). Eleven species were significantly associated to each other in Group 1 (mountain alder (*Alnus incana*), kinnickinnick (*Arctostaphylos ura-ursi*), blue wildrye (*Elymus glaucus*), slender wheat-grass (*Elymus trachycaulus*), fireweed (*Epilobium angustifolium*), scouring rush (*Equisetum hyemale*), northern scouring rush (*Equisetum variegatum*), black cottonwood (*Populus balsamiera*), willow (*Salix sp.*), spangle top (*Scolochloa festucacea*), and dandelion (*Taraxacum officinale*)), and nine species were significantly associated in Group 2 (Lakeshore sedge (*Carex lenticularis ssp. lipocarpa*), narrow-leafed Collomia (*Collomia linearis*), tall willowherb (*Epilobium brachycarpum*), purple-leafed willowherb (*Epilobium ciliatum*), field filago (*Filago arvensis*), small bedstraw (*Galium trifidum*), pineapple weed (*Matricaria discoidea*), lady's thumb (*Persicaria maculosa*), and Scouler's popcornflower (*Plagiobothrys scouleri*)).

Results of the analysis were superposed on a PCA diagram to show the relationships among the significant species in each group (Figure 34). A fringe transect (FMF05) and a transect sampled above free crest (AFC06) appear to have a high cover of dandelion, fireweed, scouring rush, slender wheat-grass, kinnickinnick, and spangle top. A group of other transects lead by FB01 and AFC03 had a high cover of willow, mountain alder, and blue wildrye. A series of transects in mudflats appear to have a high cover of field filago, tall willowherb, pineapple weed, small bedstraw, bluejoint grass, and narrow-leafed Collomia. Species in Group 1 were made of more perennial tree and shrub species, and appear more associated with later succession, high elevation transects, and transects sampled above the free crest. Species in Group 2 were more often early successional annual species, except for lakeshore sedge a perennial sedge species, and were more often associated with lower transects and mudflats lower down in the drawdown zone, that are subjected to longer periods of inundation.

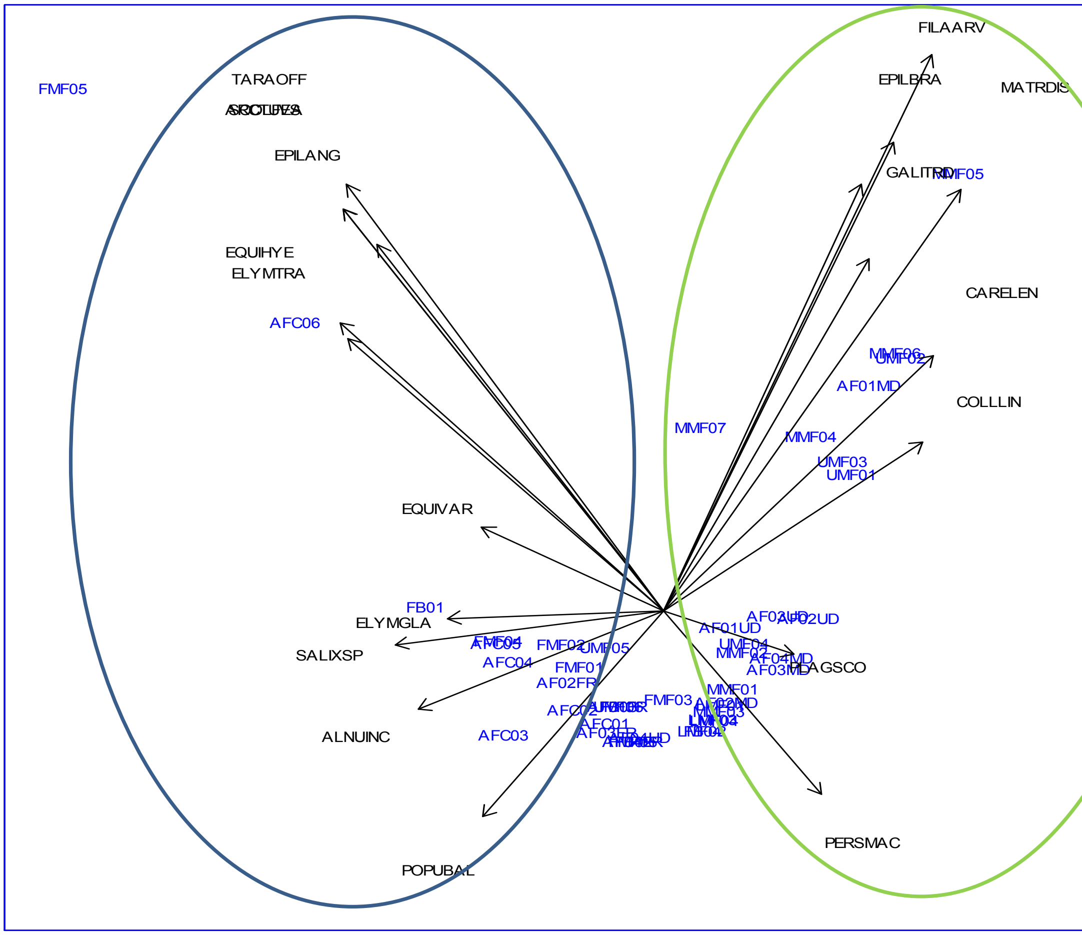


Figure 34. PCA diagram showing relationships between concordant species over the 45 transects sampled in the Western Fan in 2013. Axis 1 explains 22% of the variation in species cover, and axis 2, 14%. The blue ellipse encompasses the species belonging to Group 1 as defined by the Kendall W analysis, and the green ellipse surrounds species that belong to Group 2. Species acronyms can be found in Appendix 1. List of species sampled in 2013

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3.3.7.2 Clustering based on species composition

The second step in the classification of vegetation communities was to perform clustering based on the species composition at each transect. It is somewhat similar to the Kendall concordance analysis, except that it groups transects instead of species. The same 46 species used in the Kendall analysis (those sampled in at least three transects) were included to assess the similarity of transects. The results of the clustering analysis with similarities computed on species composition and WPGMA, PCA, and PCoA suggest the presence of five groups of transects (Figure 35, Figure 36,

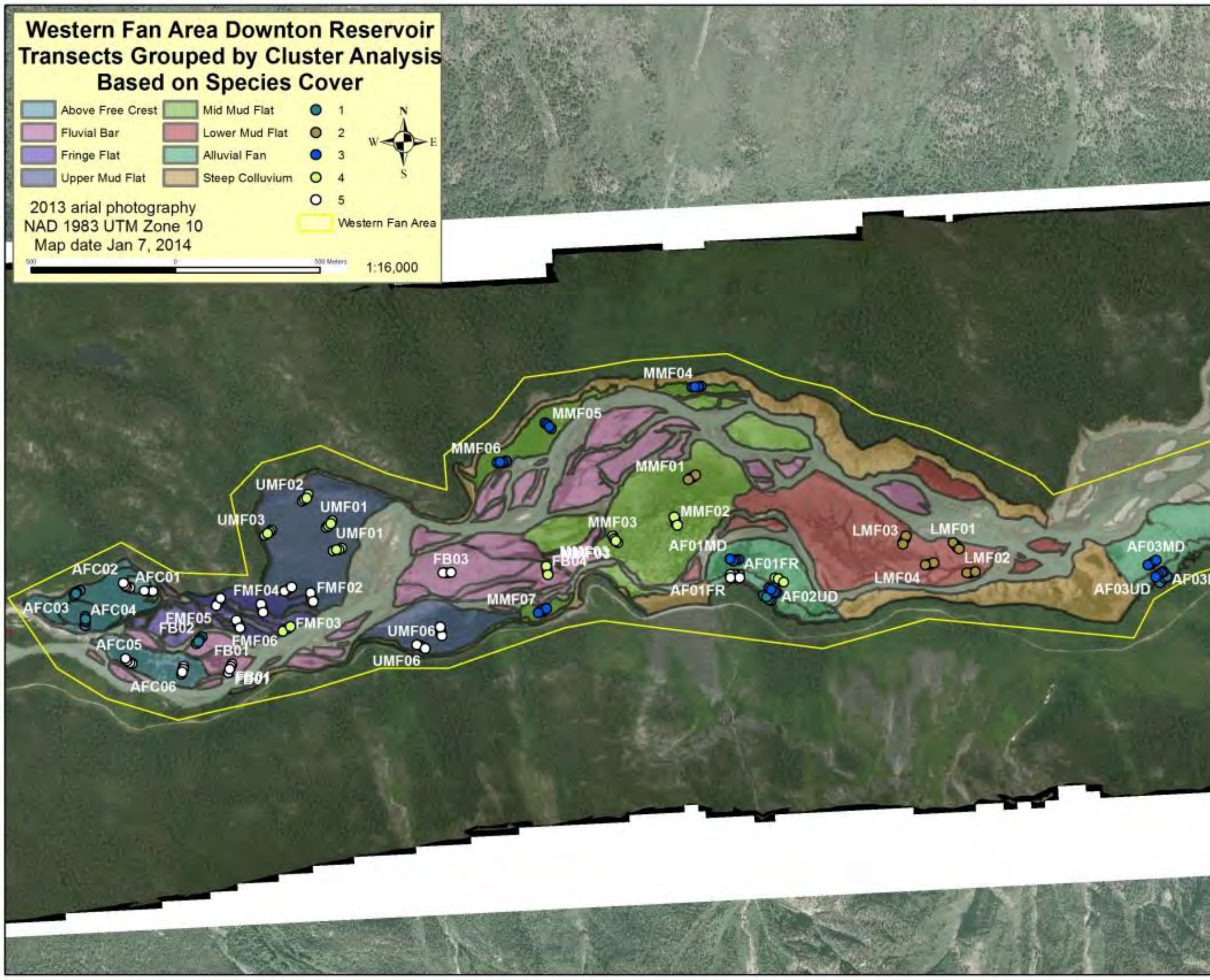

Figure 37).

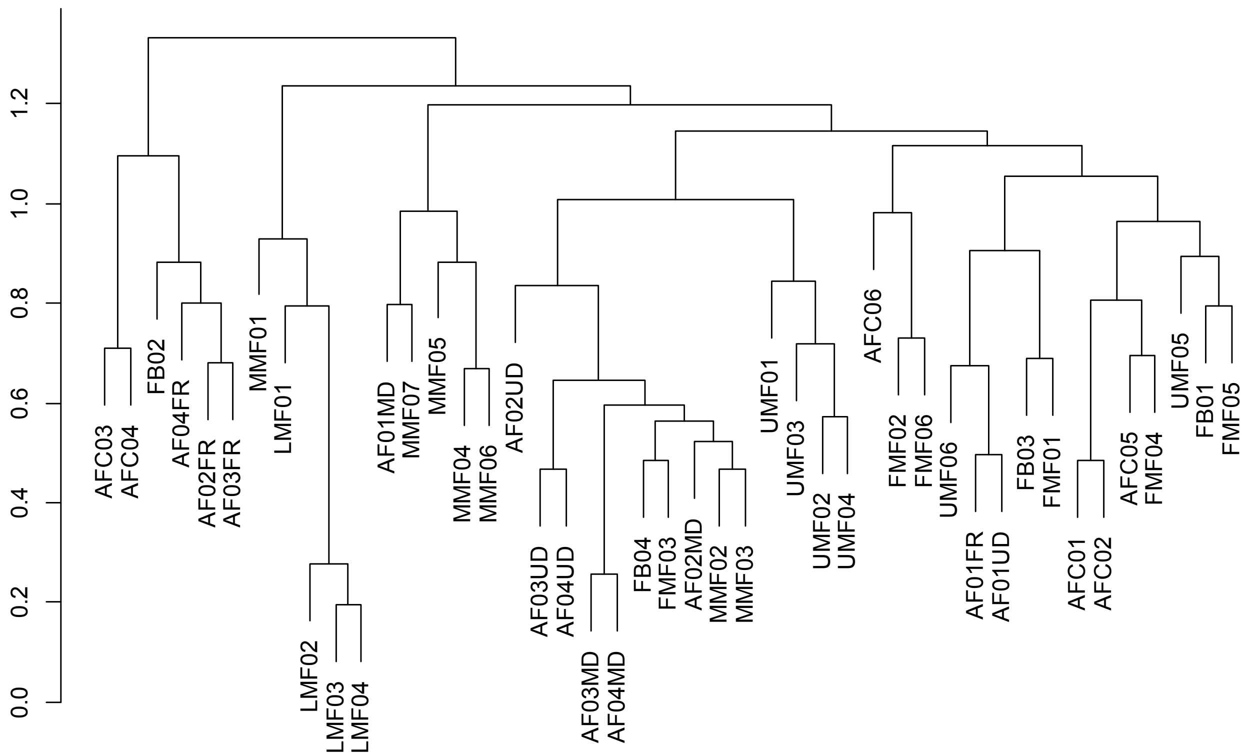

Figure 35. Dendrogram showing groups of transects formed by WPGMA hierarchical clustering applied after computing similarities among transects with a Hellinger-Euclidian distance coefficient, and based on species covers. AF=Alluvial Fan, AFC= Abover Free Crest, FB=Fluvial Bar, LMF=Low Mud Flat, MMF=Mid Mud Flat, UMF=Upper Mud Flat, FMF=Fringe Mud Flat.

The five groups seem segregated along a gradient of elevation, and terrain classes. Transects in Groups 1 and 5 had a high cover of treed species, and were alluvial fans and transects above free crest. Transects in Groups 2, 3 and 4 were at lower elevations, often mudflats, and had more herbaceous, moisture loving, vegetation.

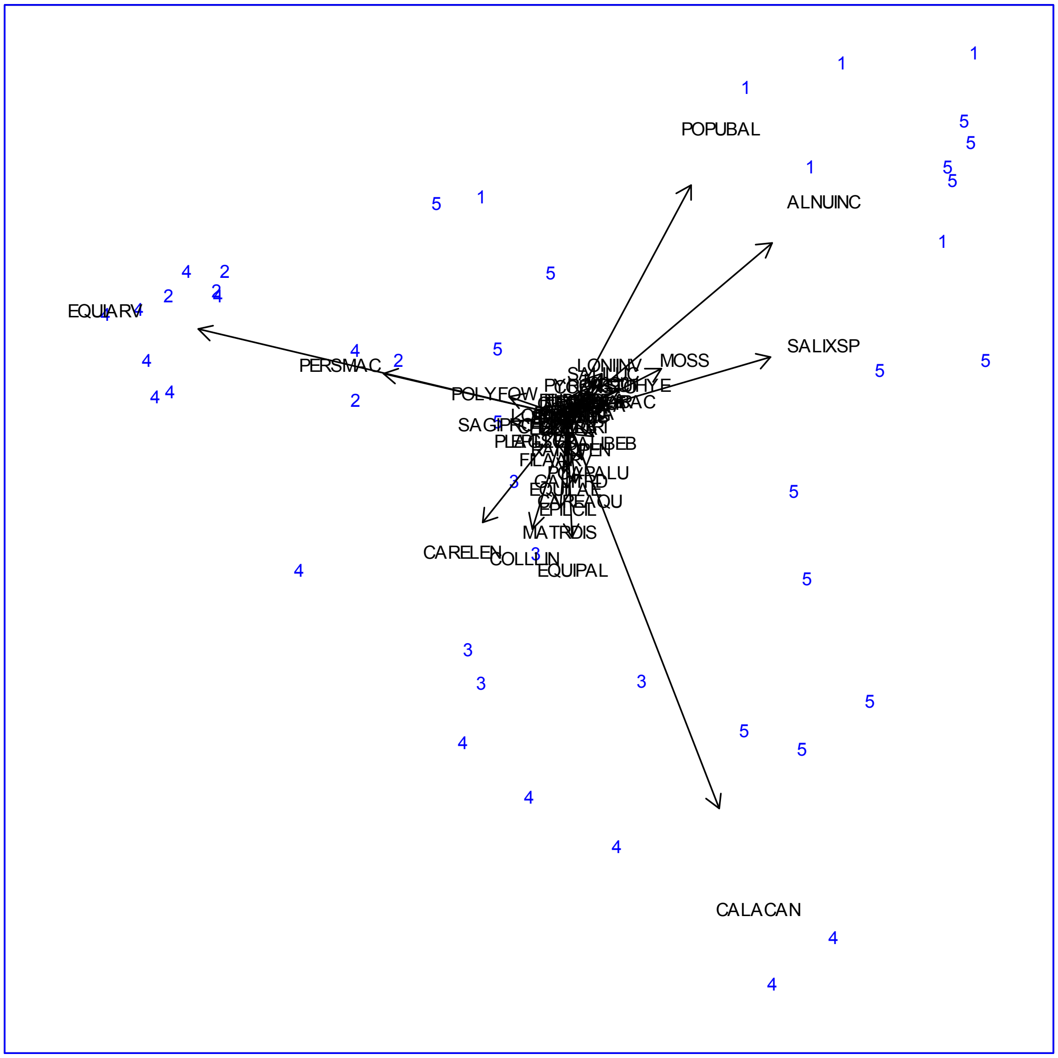

Figure 36. PCA diagram showing variation in environmental variables among transects sampled in the Western Fan in 2013. Axis 1 explains 21% of the variation in species cover, and axis 2, 15%. Numbers refer to groups of transects as formed by the clustering analysis (Hellinger-Euclidian distance coefficient and WPGMA; see Table 5 for the names of transects per group).

Results of the groupings are summarized in (Table 5. Characteristics of each group of transects based on species covers, issued from the hierarchical clustering analysis (Hellinger-Euclidian distance, WPGMA, PCA, and PCoA)Table 5).

Table 5. Characteristics of each group of transects based on species covers, issued from the hierarchical clustering analysis (Hellinger-Euclidian distance, WPGMA, PCA, and PCoA)

Group	Transects	Species	Elevation	Terrain classes	Location in the river delta
1	AFC03-04, FB02, AFO4FR, AF02FR, AF03FR	POPUBAL, ALNUINC	fringe and above free crest	fans and above free crest	throughout
2	MMF01, LMF01-04	EQUIARV	mostly lower	mudflats	throughout
3	AF01MD, MMF04-07	CARELEN, COLLLIN	middle	mudflats	throughout
4	AF02UD, AF03UD, AF04UD, AF03MD, AF04MD, FB04, FMF03, AF02MD, MMF02-03, UMF01-04	CALACAN, EQUIARV	Middle to upper	mudflats and fans	South, East
5	FMF01-02, AF01FR, AF01UD, FB03, AFC01-02, AFC05-06, FMF04-06, UMF05-06, FB01	ALNUINC, SALIX, CALACAN	mostly fringe and above free crest	above free crests and fans	West, otherwise throughout

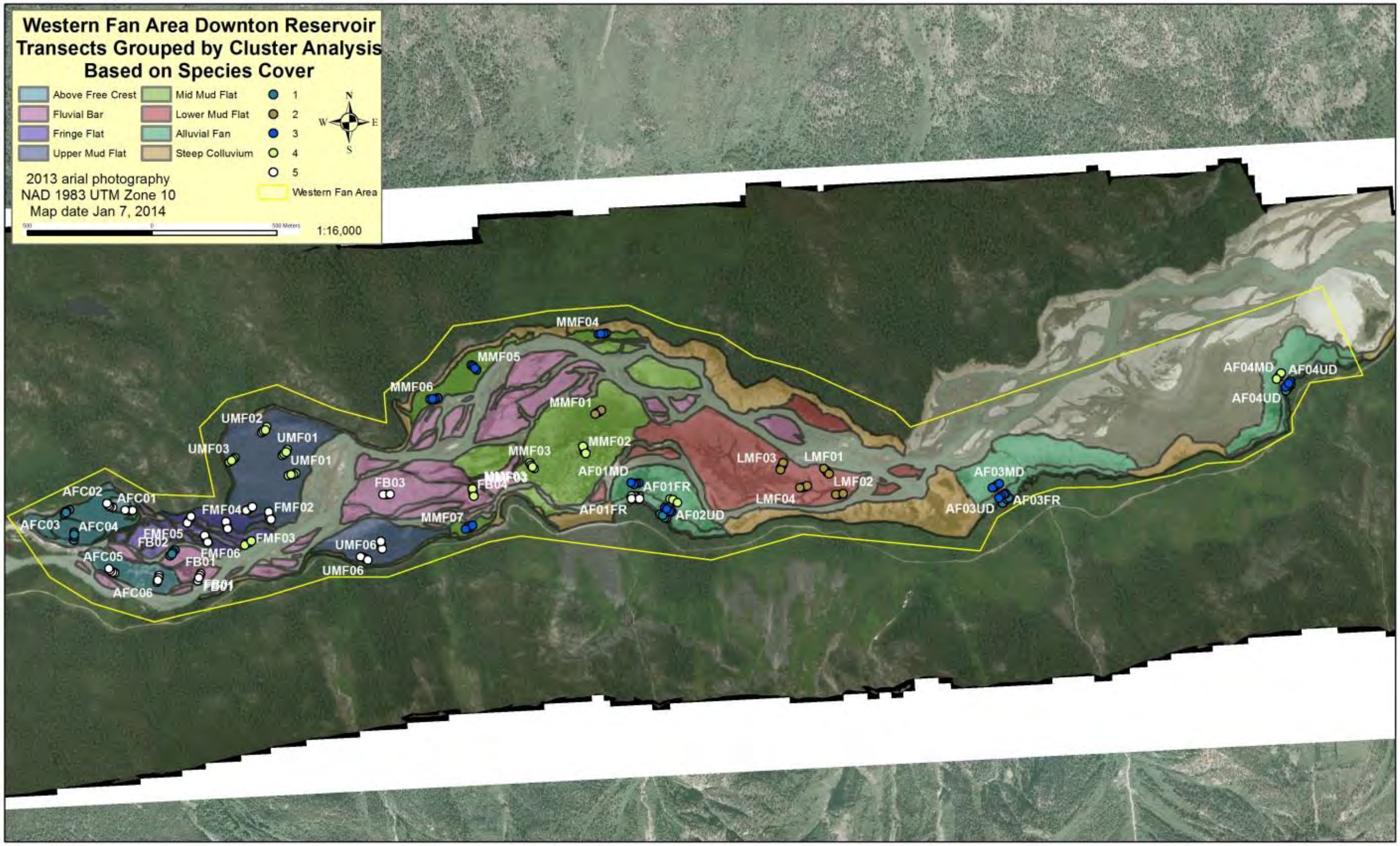

Figure 37 Map showing the groups of transects based on cluster analysis with vegetation species cover (Table 5).

3.3.7.3 Clustering based on environmental variables

A similar exercise as performed in Section 3.3.7.2 was repeated, but using environmental variables to group transects (Table 1), instead of species composition. The 23 environmental variables presented in Table 1 were combined to compute the similarity of transects based on their environmental characteristics. This time, the results of the similarities computed on environmental variables with WPGMA, PCA, and PCoA suggest the presence of four main groups of transects (Figure 38, Figure 39, Figure 40). Table 6 summarizes the characteristics of each group based on their environmental characteristics.

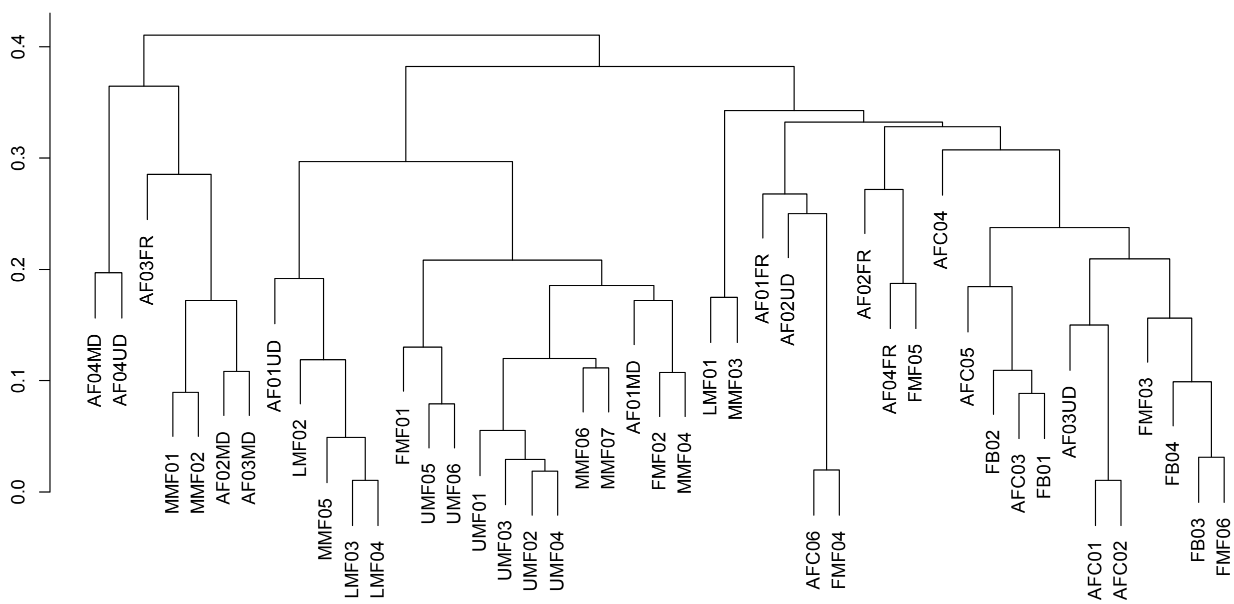

Figure 38. Dendrogram showing the groups of transects formed by WPGMA hierarchical clustering applied after computing similarities among transects with a Gower distance coefficient, and based on environmental variables. . AF=Alluvial Fan, AFC= Abover Free Crest, FB=Fluvial Bar, LMF=Low Mud Flat, MMF=Mid Mud Flat, UMF=Upper Mud Flat, FMF=Fringe Mud Flat.

Group 1 was specific to one elevation band (middle elevation), in one area of the Western Fan (the south-east), while Group 4 ranged from upper and fringe elevations, species rich transects dominated by tree and shrub species, to sandy/rocky, rapidly draining transects. Groups 2 and 3 were mostly comprised of mudflats, with either high cover of mineral soils, or smooth topography and diverse vegetation. The four groups segregated fairly well geographically in the Western Fan zone (Figure 40).

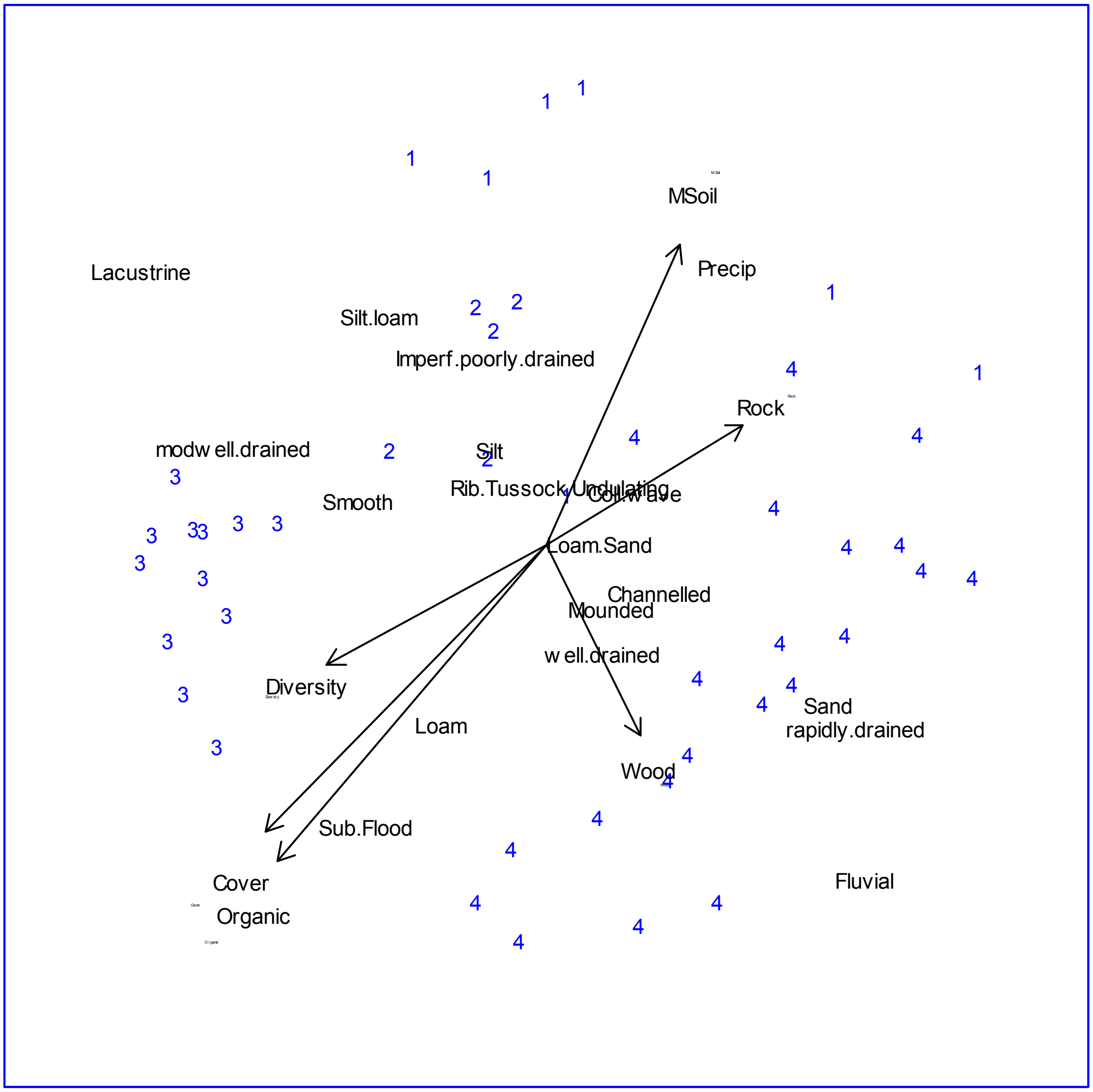

Figure 39. PCA diagram showing the variation in environmental variables among transects sampled in the Western Fan in 2013. Axis 1 explains 22% of the variation in environmental variables, and axis 2, 15%. Numbers refer to groups of transects as formed by the clustering analysis based on environmental variables (Gower coefficient and WPGMA; see Table 6 for the names of transects per group).

Table 6. Summary of the of each group of transects based on their environmental characteristics, as well as the top five most abundant species in each group (frequency of occurrence, and total cover).

Group	Transects	Environmental characteristics	Elevation	Terrain classes	Location in the river delta	Top 5 most abundant species (frequency)	Top 5 most abundant species (cover)
1	AF04MD, AF04UD, AF03FR, MMF01-02, AF02MD, AF03MD	Silt and loam, imperfectly/poorly drained, precipitation fed, lacustrine geomorphology	middle	Fans and mudflats	South, East	EQUIARV, CARELEN, PERSMAC, POLYFOW, SAGIPRO	EQUIARV, SAGIPRO, CARELEN, POPUBAL, PERSMAC
2	AF01UD, LMF02, MMF05, LMF03, LMF04	(Silt and loam, imperfectly/poorly drained, precipitation fed, lacustrine), high cover of Mineral soil	All	mostly mudflats	Throughout	CARELEN, EQUIARV, MOSS, PERSMAC, MATRDIS	PERSMAC, EQUIARV, MOSS, CALACAN, EQUILAW
3	FMF01-02, UMF01-06, MMF06-07, AF01MD, MMF04	Moderately well drained, smooth topography, diverse vegetation, high cover of vegetation, high cover of organic matter	All	mostly mudflats	Throughout	CALACAN, EQUIARV, CARELEN, MOSS, CAREAQU	CALACAN, CARELEN, EQUIARV, MOSS, EQUIPAL
4	LMF01, MMF03, AF01FR, AF02UD, FMF03-06, AF02FR, AF04FR,FB01-04, AF03UD, AFC01-06	high cover of vegetation and organic matter, sub-irrigation and flooding sources of water, loam, fluvial geomorphology, sand/rapidly drained, rock substrate	Upper, fringe and above free crest	All	has the only sites in the West, otherwise located throughout	EQUIARV, MOSS, SALIX, POPUBAL, ALNUINC	ALNUINC, EQUIARV, POPUBAL, SALIX, MOSS

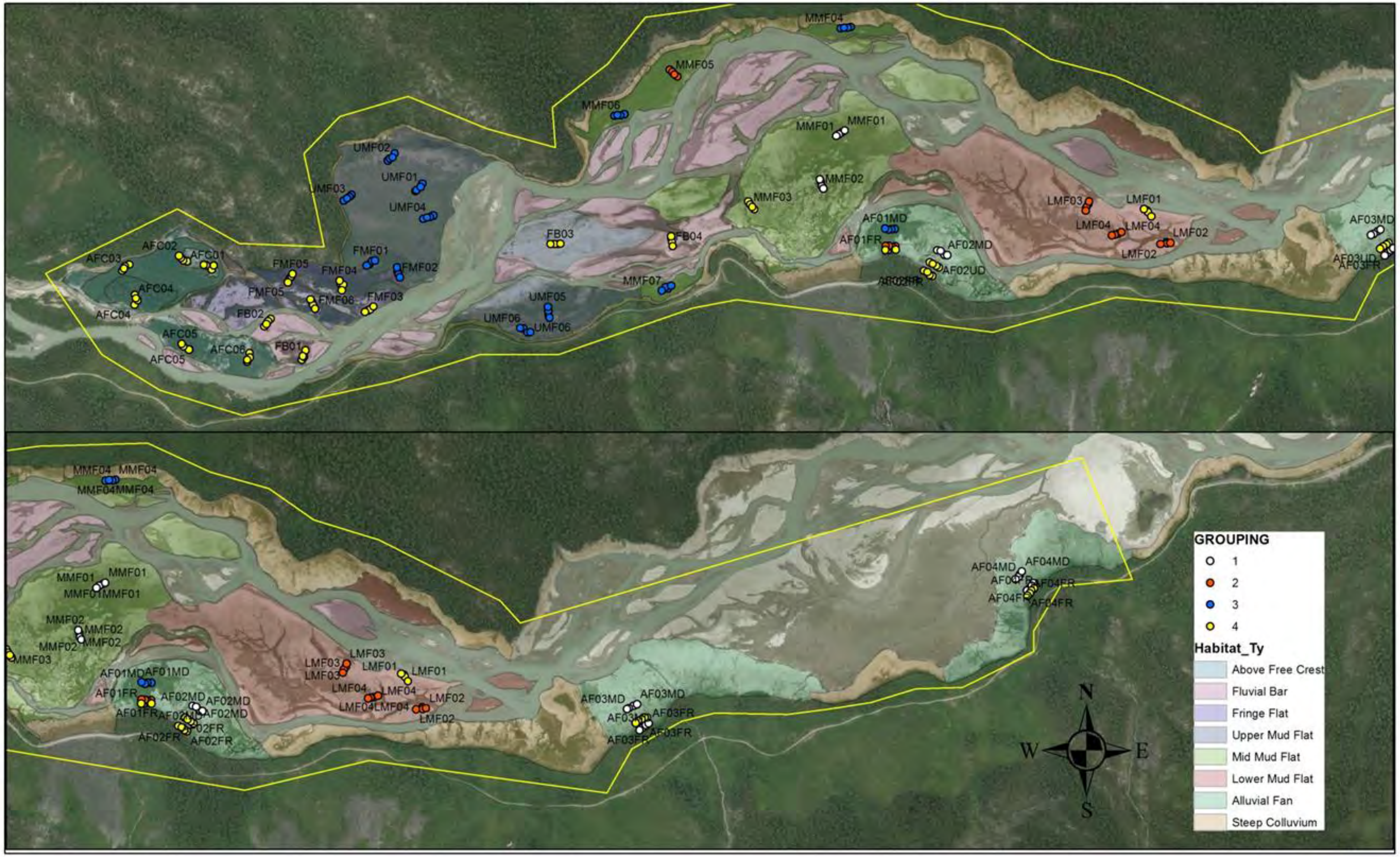

Figure 40. Location of the four groups of transects in the Western Fan, based on the clustering analysis with environmental variables; 1 = Poor imperfectly drained, 2 = poor imperfectly drained; 3 = moderately well drained, 4 = rapidly drained. (Table 6).

3.3.8 Biomass

Most of the Western Fan lies within BC parks jurisdiction, and a request to Parks for permission to clip biomass samples was denied. Biomass productivity was therefore inferred through a combination of average percent cover data for each transect, estimated vegetation height, and estimated horizontal cover of the 1mX0.10m photo point meter board (Figure 41

Figure 41, Appendix 4 Permanent monitoring transect pin locations).

Table 7. Summary of per cent covers by transect, and vegetation height and cover based on photo point monitoring (Appendix 5). . AF=Alluvial Fan, AFC= Abover Free Crest, FB=Fluvial Bar, LMF=Low Mud Flat, MMF=Mid Mud Flat, UMF=Upper Mud Flat, FMF=Fringe Mud Flat.

Transect Names	Avg. % Cover	Vegetation	Vegetation	Avg ht	% metre board covered
LMF01	12.390	0.02	0.02	0.02	2
LMF02	24.145	0.02	0.02	0.02	2
LMF03	54.768	0.1	0.08	0.09	5
LMF04	28.395	0.05	0.05	0.05	4
MMF01	49.388	0.24	0.27	0.255	10
MMF02	50.515	0.35	0.22	0.285	18
MMF03	21.385	0.1	0.26	0.18	15
MMF04	91.393	0.5	0.51	0.505	30
MMF05	82.395	0.35	0.6	0.475	23
MMF06	64.525	0.48	0.51	0.495	37

Transect Names	Avg. % Cover	Vegetation ht. a m	Vegetation ht. b m	Avg ht	% metre board covered
MMF07	93.258	0.75	0.75	0.75	75
UMF01	82.018	0.8	0.8	0.8	45
UMF02	80.523	0.8	0.65	0.725	55
UMF03	43.393	0.7	0.7	0.7	45
UMF04	71.135	1.3	1.3	1.3	100
UMF05	75.883	1.4	1.2	1.3	65
UMF06	112.755	1.7	2	1.85	95
FMF01	66.630	0.45	0.5	0.475	40
FMF02	103.503	1.1	1	1.05	55
FMF03	36.505	2	0.15	1.075	10
FMF04	85.893	1.1	2.5	1.8	70
FMF05	71.525	0.35	0.5	0.425	35
FMF06	29.755	0.23	0.15	0.19	12
FB01	51.508	2	2	2	70
FB02	0.008	0	0	0	0
FB03	21.258	0.1	0.09	0.095	7
FB04	21.400	0.18	0.15	0.165	10
AFC01	101.138	2	2.5	2.25	50
AFC02	82.503	3	3	3	70
AFC03	86.145	3	3	3	60
AFC04	132.893	10	10	10	72
AFC05	106.003	10	10	10	75
AFC06	82.378	2	2	2	50
AF01FR	56.133	2	2	2	85

Transect Names	Avg. % Cover	Vegetation	Vegetation	Avg ht	% metre board covered
AF01MD	136.508	0.45	0.37	0.41	32
AF01UD	63.270	0.7	0.75	0.725	80
AF02FR	36.518	2.5	1.5	2	45
AF02MD	26.385	0.22	0.2	0.21	18
AF02UD	13.270	0.75	0.77	0.76	10
AF03FR	50.773	2	1.5	1.75	50
AF03MD	31.140	0.15	0.1	0.125	5
AF03UD	5.305	0.9	1.1	1	52
AF04FR	47.758	2	10	6	40
AF04MD	19.905	0.13	0.15	0.14	10
AF04UD	13.650	0	0	0	0

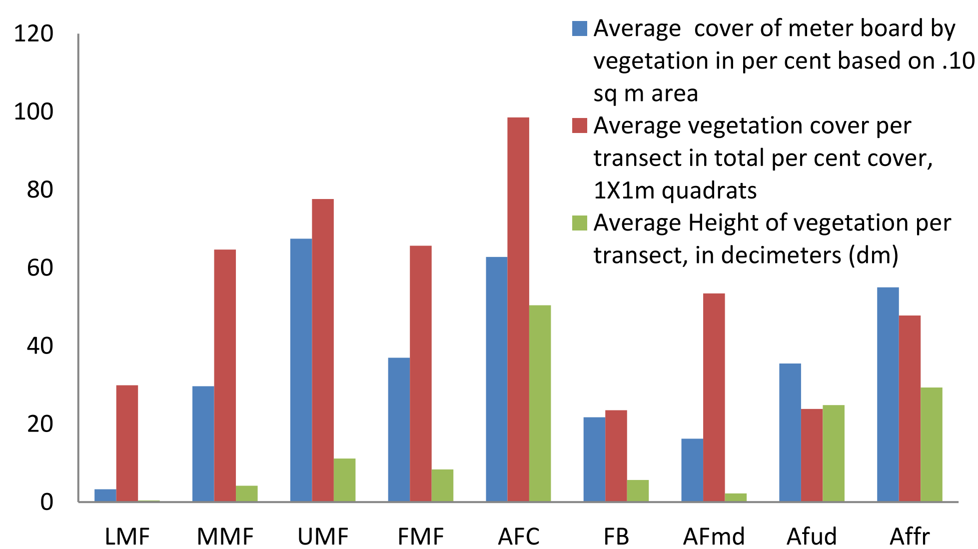

Figure 41. Variation in the estimated biomass height of vegetation by terrain/elevation class Y axis values represent per cent or decimeters as indicated in legend

Individual quadrat photos were also used to compare to the values estimated from the photos. High per cent cover of vegetation in the meter board, in conjunction with high vegetation cover per quadrat, and vegetation height approaching 20 dm, was interpreted to indicate a proxy measure of substantial herbaceous biomass. Vegetation height over 20dm indicated presence of shrub or tree, and do not necessarily reflect higher biomass of the ground level vegetation. The upper mudflat terrain class (UMF) had the greatest amount of herbaceous biomass in the Western Fan (meter board cover averaging about 70 per cent, quadrat cover averaging about 80 per cent, and average height of vegetation around one meter;

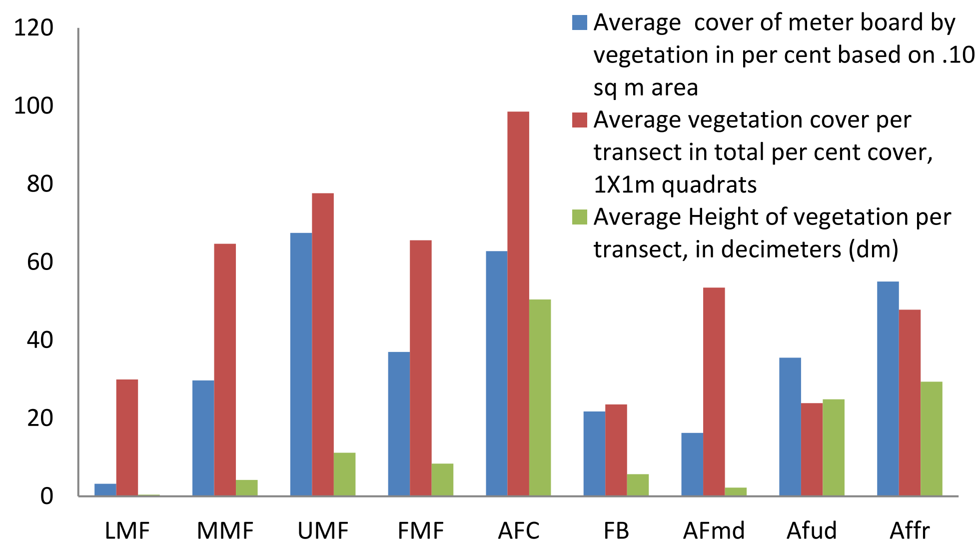

Figure 41). In contrast, the lower mudflats (LMF) had low biomass, with an average meter board cover of 5 per cent, average quadrat cover of 30 per cent, and height of vegetation about 0.1m. Biomass productivity was low in fluvial bars (FB) and mid alluvial fans (AFmd). The above free crest (AFC), and the fringe alluvial fan (AFfr) polygons also showed relatively high biomass productivity.

3.3.9 Variation in reservoir water levels

The biggest variations in water levels in the reservoir occurred in 1987 (Figure 42). Water levels were very low from the middle of April to the end of May in 1986, 1987, and 1996, while the highest water levels were in 1991, and 1998. The variations in water levels in the last 10 years were within the average of the last 28 years (Figure 43). The water levels in 2011 and 2012 were higher than average from January until early May, when they tipped below average until the middle of July. The water levels in 2013 were higher than the average since 2000 from the early April until the end of October.

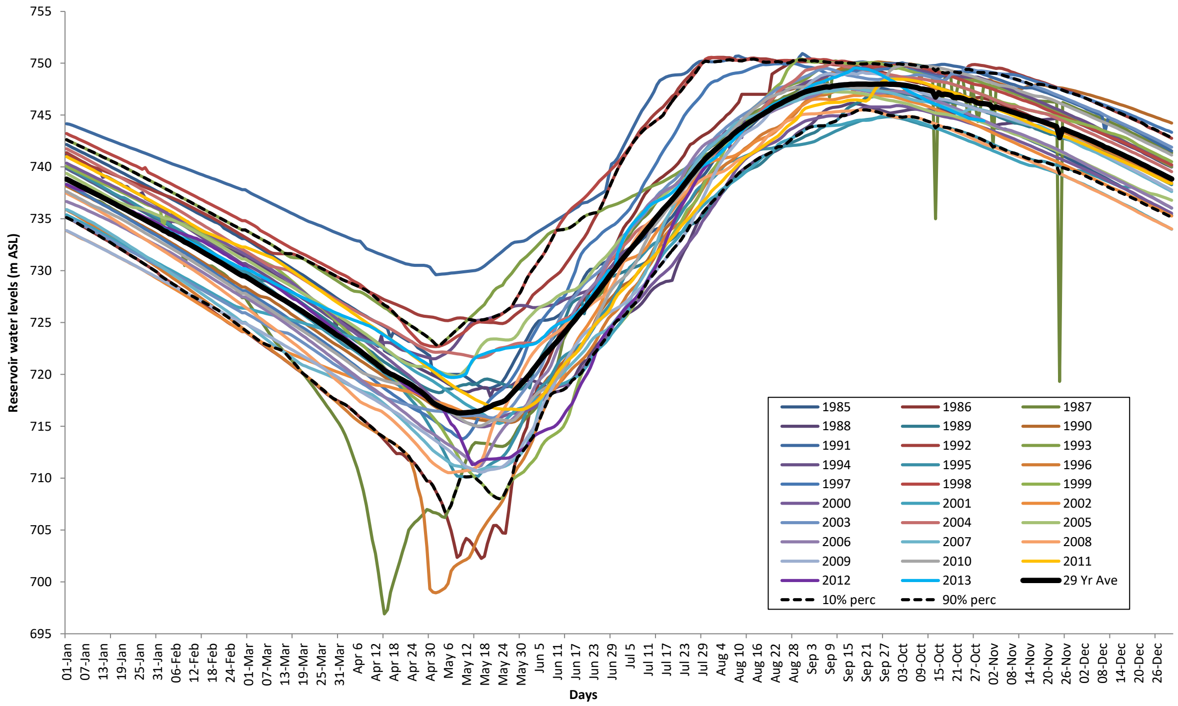

Figure 42. Variation in water levels in Downton Reservoir from 1985 to 2013.

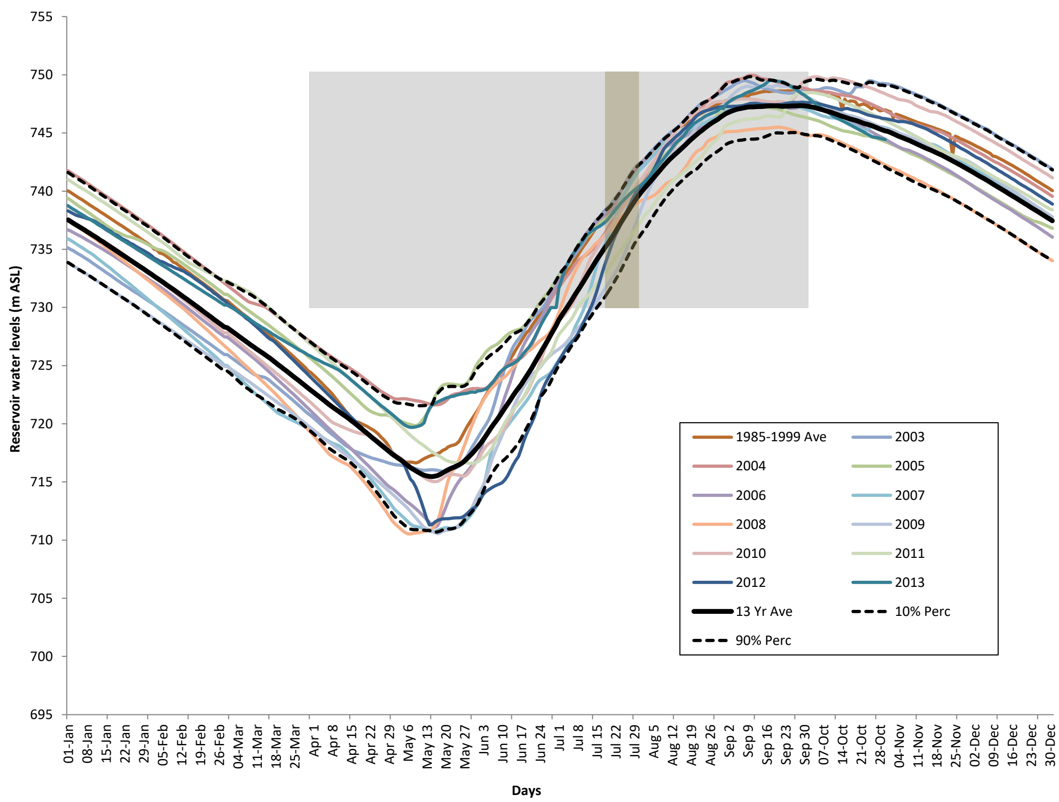

Figure 43. Variation in water levels in Downton Reservoir from 2003 to 2012. The pale shaded area represents the length of the vegetation growing season (April 1 – September 30), and the range of elevations at which sampling occurred in 2013. The darker shaded area corresponds to the period at which field sampling occurred in 2013.

The proportion of the growing season for which habitat was available for colonization and growth of terrestrial vegetation varied according to the elevation band and the year's hydrograph (Table 8). The proportion of time habitat was available was similar among years for all elevations; e.g. the low elevation band (<737m) was above the reservoir water levels from 58% (102 days) (in 2006) to 66% (116 days) (in 2009 and 2011) of the time each year, while the habitats at the fringe of the reservoir were available from 93 to 100% in the last five years.

In the last five years, the proportion of time each elevation band was above the reservoir water levels was highest in 2011 for the upper and fringe elevations (83 and 96%, respectively). Reservoir water levels did not reach elevations higher than 749m since 2004 (and only very briefly then).

Table 8. Proportion of the growing season (April 1 to September 30) for which each elevation band was above reservoir water levels, from 2003 to 2013. The shaded band are the upper limits of each elevation band as sampled in the field (low:< 737, middle: 737-745m, upper: 745-747, fringe: 747-750, above full crest: >750).

Elevation band (m ASL)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
730	46	48	45	48	55	50	57	52	54	56	48
731	48	49	47	48	56	51	58	54	56	57	50
732	49	50	49	50	57	52	60	54	57	58	50
733	50	52	50	51	57	53	61	55	60	59	51
734	52	54	52	52	58	55	63	56	61	60	52
735	54	57	54	54	58	56	63	57	63	60	54
736	56	58	55	55	60	58	64	59	64	61	55
737	**57**	**60**	**58**	**57**	**61**	**61**	**66**	**61**	**66**	**62**	**58**
738	58	62	60	60	62	63	66	62	68	63	61
739	61	63	62	62	62	66	67	63	69	64	62
740	62	65	65	63	63	70	68	65	71	66	65
741	64	67	67	64	65	73	69	67	73	68	68
742	66	69	69	65	67	75	71	68	76	69	69
743	68	72	71	68	69	77	72	70	79	70	72
744	70	74	74	72	70	80	75	72	81	72	73
745	**72**	**75**	**76**	**77**	**75**	**84**	**77**	**73**	**83**	**74**	**75**
746	75	77	80	80	80	100	79	75	86	77	78
747	**78**	**79**	**89**	**86**	**84**	**100**	**82**	**79**	**96**	**80**	**83**
748	81	81	100	100	100	100	85	97	97	100	85
749	94	85	100	100	100	100	93	99	100	100	93
750	**100**	**99**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

The timing of inundation also varied based on the elevation band and year's hydrograph (Table 9). Each elevation band was inundated considerably later in 2011 than in 2010, 2012 or 2013, and the low elevation band was under water at least a week earlier in 2013 than in the three previous years. The timing of inundation for the upper and fringe elevation bands was comparable for 2010, 2012 and 2013, while the reservoir reached full pool only in 2009 and 2013.

Table 9. Days at which each elevation band was inundated in 2013, and the three previous years (2010-2012). The shaded band are the upper limits of each elevation band as sampled in the field in 2013 (low:< 737, middle: 737-745m, upper: 745-747, fringe: 747-750, above full crest: >750).

Elevation band (m ASL)	2010	2011	2012	2013
730	05-Jul	08-Jul	13-Jul	28-Jun
731	08-Jul	12-Jul	15-Jul	01-Jul
732	09-Jul	15-Jul	16-Jul	02-Jul
733	11-Jul	19-Jul	18-Jul	03-Jul
734	13-Jul	22-Jul	19-Jul	05-Jul
735	15-Jul	25-Jul	20-Jul	08-Jul
736	18-Jul	28-Jul	22-Jul	11-Jul
737	21-Jul	31-Jul	24-Jul	16-Jul
738	24-Jul	03-Aug	26-Jul	21-Jul
739	26-jl	06-Aug	28-Jul	24-Jul
740	29-Jul	09-Aug	30-Jul	29-Jul
741	01-Aug	13-Aug	03-Aug	03-Aug
742	04-Aug	18-Aug	06-Aug	06-Aug
743	07-Aug	23-Aug	08-Aug	10-Aug
744	10-Aug	27-Aug	11-Aug	13-Aug
745	13-Aug	31-Aug	15-Aug	18-Aug
746	17-Aug	05-Sep	20-Aug	22-Aug
747	23-Aug	23-Sep	26-Aug	30-Aug
748	26-Sep	26-Sep	--	04-Sep
749	29-Sep	--	--	Sep 14-Sep 25
750	--	--	--	--

Comparatively, the depth of water above each elevation band also varied per elevation band and year (Table 10, Figure 44). Average depth of water was lower in 2011 than in the 10 previous years, up to the upper limit of the upper elevation band (746 m). Average depth of water over each elevation band was the highest for the recent years in 2009. Vegetation at the fringe of the reservoir faced little depth of water, ranging on average from none to 2.1 m (in 2004).

Table 10. Average depth of water (m) above each given elevation band over 11 years, during the growing season (April 1 to September 30). The shaded band are the upper limits of each elevation band as sampled in the field (low:< 737, middle: 737-745m, upper: 745-747, fringe: 747-750, above full crest: >750).

Elevation band (m ASL)	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
730	13.2	12.9	11.8	12.6	13.7	11	13.4	13.3	11.1	13.7	12.9
731	12.6	12.2	11.2	11.7	12.9	10.2	12.9	12.8	10.6	13	12.3
732	11.9	11.6	10.5	11.1	12.2	9.3	12.4	11.9	10	12.2	11.4
733	11.2	11	9.9	10.3	11.3	8.5	11.8	11.2	9.5	11.5	10.5
734	10.6	10.3	9.3	9.6	10.5	7.8	11.3	10.5	8.9	10.6	9.8
735	10	10.1	8.5	8.9	9.6	7.1	10.4	9.7	8.3	9.8	9.1
736	9.4	9.5	7.8	8.2	8.9	6.4	9.7	9.1	7.6	9	8.4
737	8.6	8.8	7.3	7.5	8.1	5.9	9	8.4	7	8.3	7.9
738	7.9	8.2	6.5	6.9	7.3	5.2	8.2	7.8	6.3	7.5	7.4
739	7.3	7.5	6	6.3	6.4	4.5	7.4	7	5.6	6.7	6.8
740	6.6	6.9	5.4	5.5	5.6	4.1	6.6	6.3	4.9	5.9	6.2
741	6	6.2	4.7	4.6	4.8	3.5	5.9	5.6	4.2	5.3	5.7
742	5.3	5.6	3.9	3.8	4	2.8	5.2	4.9	3.7	4.6	5
743	4.5	5.1	3.2	3.1	3.3	1.9	4.3	4.1	3.1	3.7	4.4
744	3.8	4.5	2.5	2.5	2.5	1.1	3.9	3.3	2.4	2.9	3.6
745	3.1	3.7	1.7	1.8	1.8	0.3	3.1	2.5	1.6	2.1	2.9
746	2.4	2.9	0.9	1.1	1.1	--	2.3	1.6	0.8	1.3	2.2
747	1.6	2.1	0.2	0.4	0.3	--	1.6	0.8	1	0.4	1.6
748	0.8	1.3	--	--	--	--	0.8	0.8	0.4	--	0.8
749	0.3	0.5	--	--	--	--	0	0.4	--	--	0.3
750	--	--	--	--	--	--	--	--	--	--	--

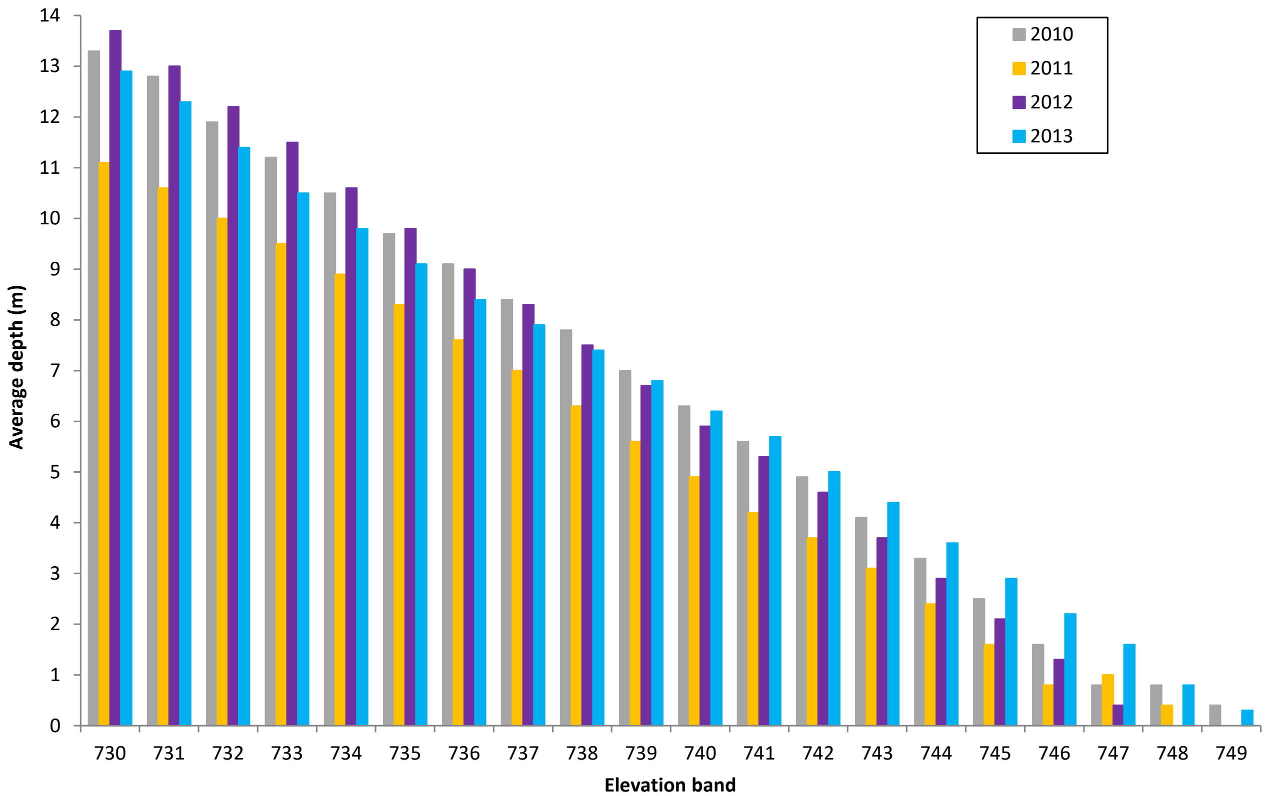

Figure 44. Average depth (m) at each elevation band from 2010 to 2013, during the growing season (April 1 to September 30).

4.0 Discussion

The general objective of the BRGMON-5 project in 2013 was to develop and implement a vegetation monitoring program at the west end of Downton Reservoir, in a drawdown zone known as the Western Fan. The monitoring program was intended to map the spatial distribution, species composition, and biomass productivity of the vegetation in the Western Fan. The sampling is to be repeated in 10 years, to compare the vegetation to the baseline dataset collected in 2013.

More specifically, the objectives of the study are to assess the following management questions:

- Will the implementation of the N2-2P alternative have a negative, neutral or positive impact on the quality and quantity (species composition, biological productivity, spatial area) of the riparian area of the Upper Bridge River and the immediately adjacent drawdown zone of Downton Reservoir?
- Has there been a negative impact on riparian vegetation and the overall quality of the habitat for wildlife in the area? What activities could be undertaken to preserve this critical habitat area?

The spatial distribution of vegetation was mapped using GIS and aerial orthophotography from the 2005 imagery, and adjusted to the 2013 imagery when it became available. The area was separated into polygon types, and further divided based on elevation. The dividing elevations of 737m, 745m, 748m were chosen based on a subjective review of the orthophotography of the Western Fan, and the observation that there was an apparent shift in vegetation cover between those elevation bands. Permanent plots were established and sampled within the selected elevation/polygon types, and will be sampled again in 10 years.

One of the most striking differences visible on the imagery over the past eight years is the amount of land that has been eroded from the north side of the Western fan (Figure 45) this is a notable shift in the spatial distribution of the vegetation communities of the western fan area. Erosion is a natural process in river systems, with balanced erosion and deposition of sediments as rivers meander across flood plains (Leopold 1960). Deltas form at the upstream end of reservoirs as river water slows and the sediment particles settle and aggrade (Thornton K. et al, 1990). The west end of Downton reservoir is a depositional area. Erosion can be related to shifts in the flow and sediment transport in rivers. Through comparing imagery from 2005 to the 2013 images using ArcMap GIS an area of land measuring 4.5 hectares has eroded away from the north side of the Western Fan. This could be significant when considering the objective expressed by the Bridge Seton Consultative Committee (2003) to protect the grizzly flats. Based on the 2013 field data, the north side of the Western fan showed more diverse vegetation communities, with a greater relative degree of species evenness, indicating a diverse and stable ecology (Isbell *et al.* 2011). The importance of this northern habitat is further indicated by the high observed incidence of wildlife signs and sightings during the field surveys.

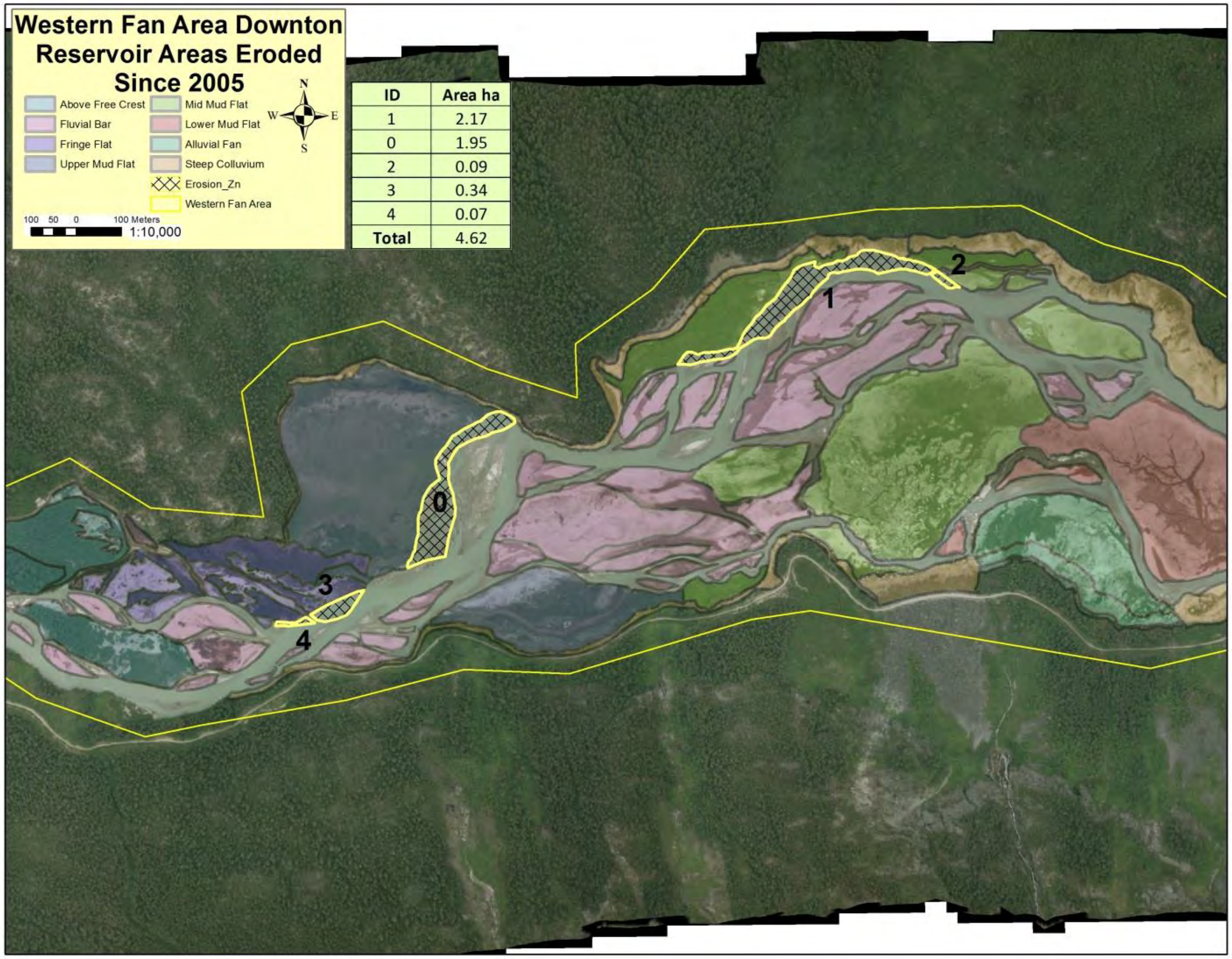

Figure 45. Western Fan zones where erosion was extensive and active, on the north side of Downton reservoir.

A tally of differences in land area between 2005 and 2013 indicated an overall decrease in land in the Western Fan of over 18 ha, or 10 per cent. The LMF and AF classes were eliminated from this comparison as these areas were largely under water when the 2005 imagery was captured, making an accurate assessment of area impossible. Overall, there were large decreases in land areas in the MMF and the UMF polygons between 2005 and 2013 (Table 11). There were increases in areas in the above free crest, the fluvial bar, and the fringe mudflat polygons. There appears to be a shift in area from mudflats to fluvial bars. Increases in areas of alluvial fan and lower mudflat classes are attributable to the greater amount of area inundated when the 2005 images were captured. Spatial mapping in the final year of the 10 year program will shed more light on the erosion and deposition trends in the Western Fan.

Table 11. Variation in area of land per terrain class between 2005 and 2013.

Terrain Class	Code	2013 area ha	2005 area ha	2013-2005
Above Free Crest	AFC	9.993	8.725	1.268
Alluvial fan total	AF	26.897	16.58	10.317
Fluvial Bar	FB	29.784	21.806	7.978
Fringe Flat	FMF	9.532	7.9537	1.5783
Lower Mud Flat	LMF	20.974	14.12	6.854
Mid Mud Flat	MMF	28.033	49.876	-21.843
Steep Colluvium	SC	28.192	27.858	0.334
Upper Mud Flat	UMF	18.018	25.709	-7.691
Total				-1.2047

On the other hand, spatial mapping of the above free crest (AFC) and the fringe mudflat (FMF) polygons did show some degree of vegetation expansion between 2005 and 2013, mainly in the form of woody plant growth (

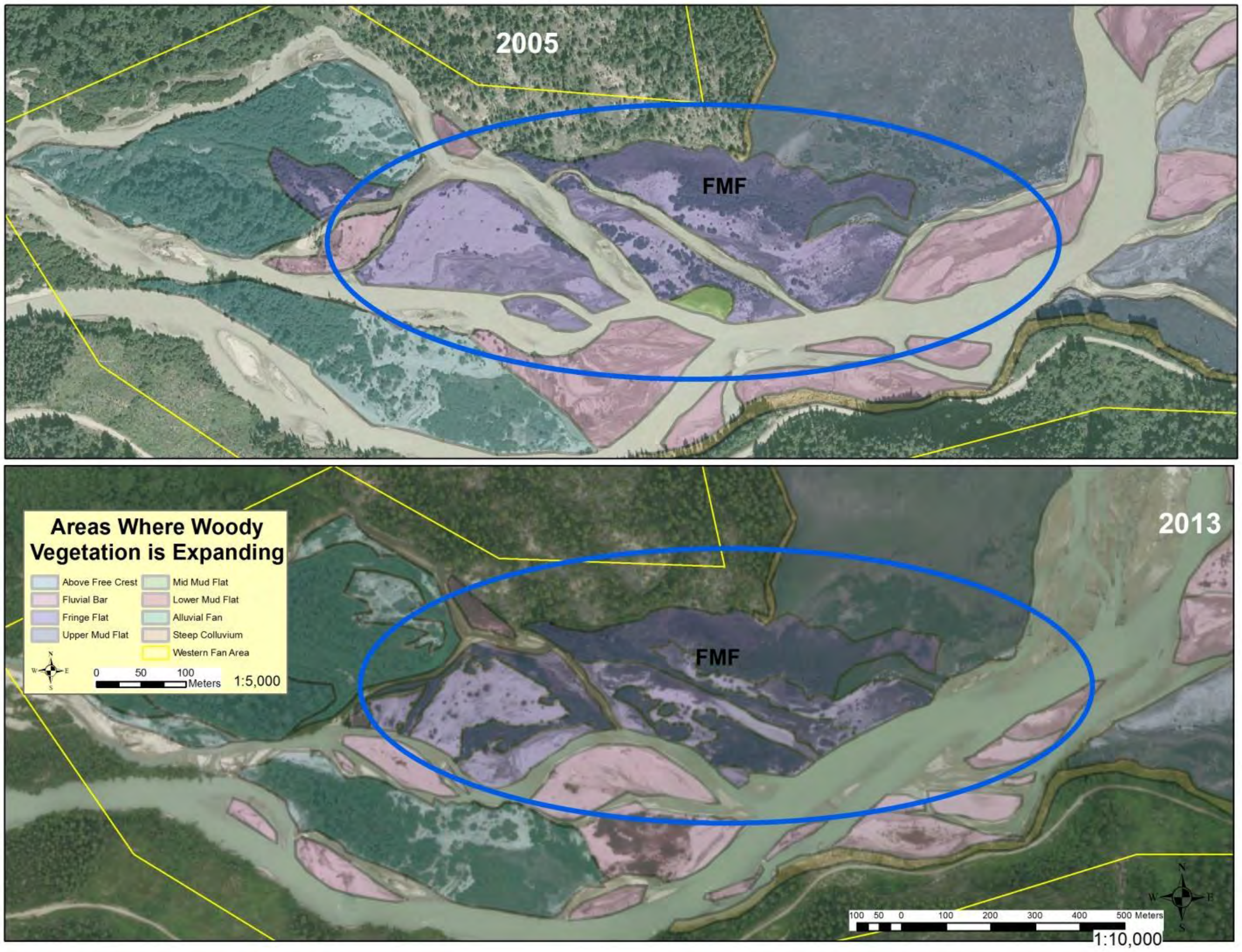

Figure 46Figure 46).
The willow stands that form a mosaic in the fringe mudflat polygons consolidated into vast shrub stands in the above free crest polygons. The FMF polygons are areas where fluvial bars are stabilizing as vegetation is establishing, and succession is occurring with a shift from herbaceous vegetation to tall shrub-dominated communities. This shift in vegetation community should be re-assessed at the end of the project to see if the trend continued. The comparative analysis of aerial photography could also be cross-referenced with the FMF transect and photo point data.

Also worth noting, the fringe band in the alluvial fans was characterized by woody vegetation and was heavily influenced by high amounts of driftwood. The fringe was a zone of relatively high vegetation productivity in the form of woody plants. The presence of the driftwood, and the abrasion caused when reservoir is at full pool, likely limits vegetation establishment and growth, favoring vegetative reproduction.

There was a general trend of increasing vegetation complexity and composition from the low elevation mudflats in the east, to the upper elevation above free crest polygons in the west. The transition region tended to be in the middle, between the herbaceous upper mudflats to the expanding shrub stands in the fringe mudflats. Wildlife sign was reflective of the vegetation communities, with geese being the dominant presence in the central and eastern end of the mudflat areas, where short annuals and horsetails dominated. Moose, hare and beaver were more evident to the west.

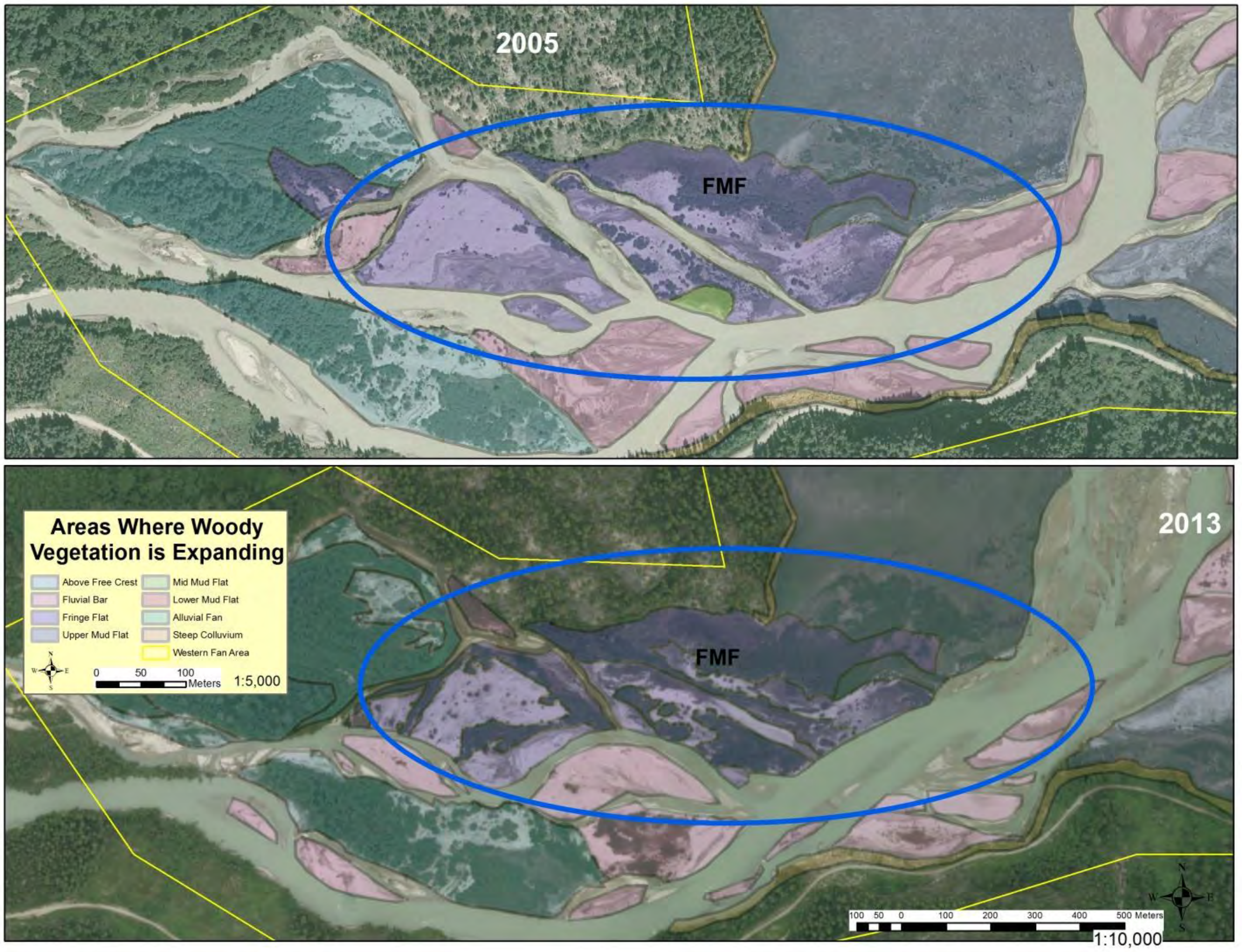

Figure 46. Areas of shrub expansion in fringe mudflat polygons.

Animal signs were observed throughout the Western Fan. For example, signs of Mule deer were observed across most of the Western Fan except for the lower mudflat polygons (Figure 47). This may be because of the exposure, poor escape routes, lack of vegetation, and soft substrates of these zones. Evidence of moose presence was concentrated in the upper mudflats, with some evidence in the north and south mid mudflat areas. Evidence of grizzly bear was only observed at one transect with tracks on a wildlife trail in the above free crest polygon (Figure 48). As mentioned, it is likely the grizzly bears were at higher elevations by the time of the 2013 survey.

In the eastern end of the Western Fan, Canada geese were present throughout parts of the lower mudflat and the north shore mid mudflat polygons, with extensive goose browse trampling and droppings (Figure 48). In the western end of the fan area, there was evidence of beaver and snowshoe hare browse. Juvenile Pacific tree frogs were recorded on the north shore mid mudflats. This mid mudflat area was a natural marsh fed with water coming down the adjacent mountainside. The high amount of surface moisture in this area was providing amphibian spawning grounds, resulting in the high observed numbers of juvenile frogs that had completed metamorphosis. This unique area was however one of the sites experiencing extensive erosion.

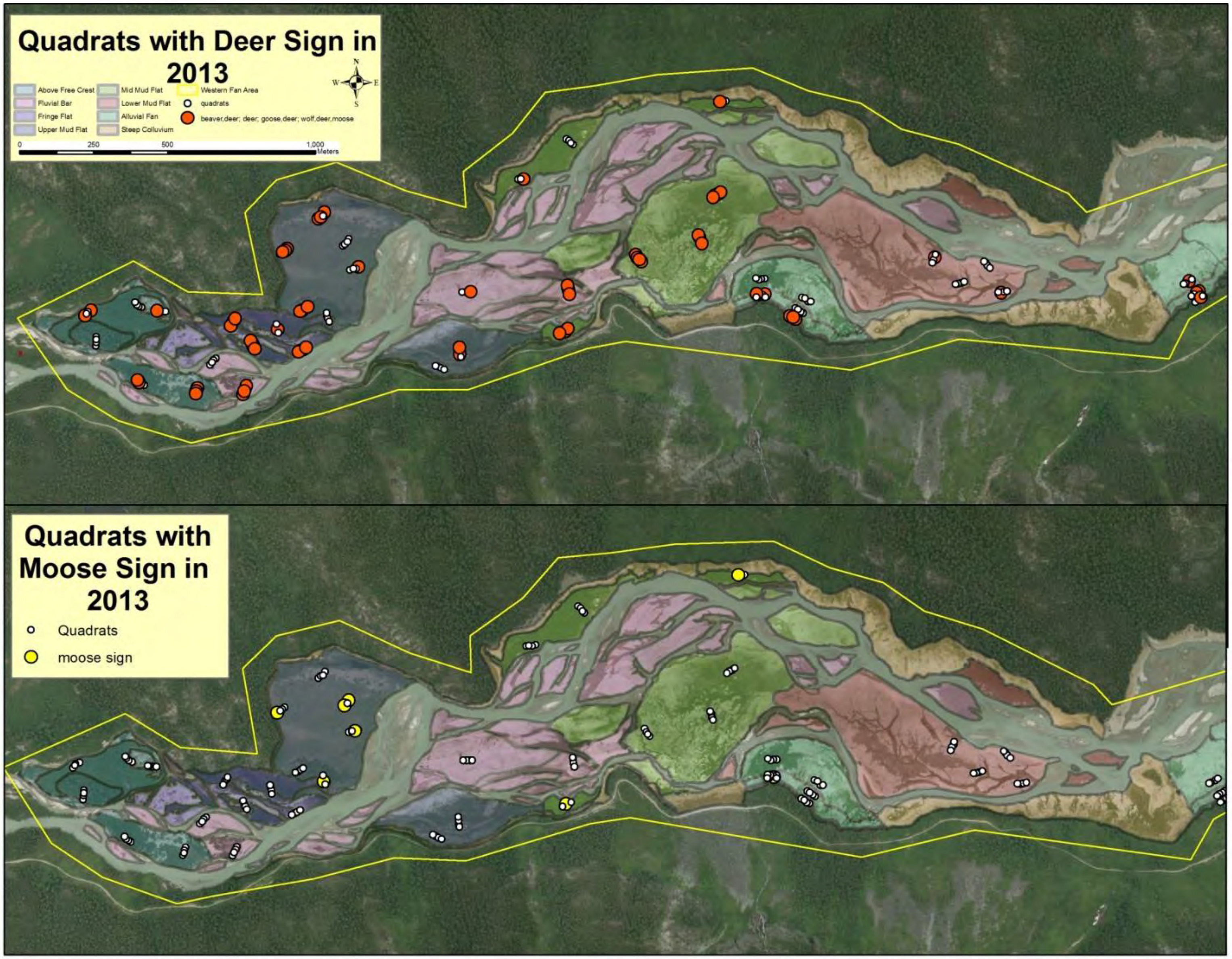

Figure 47 Mule deer and Moose sign observation.

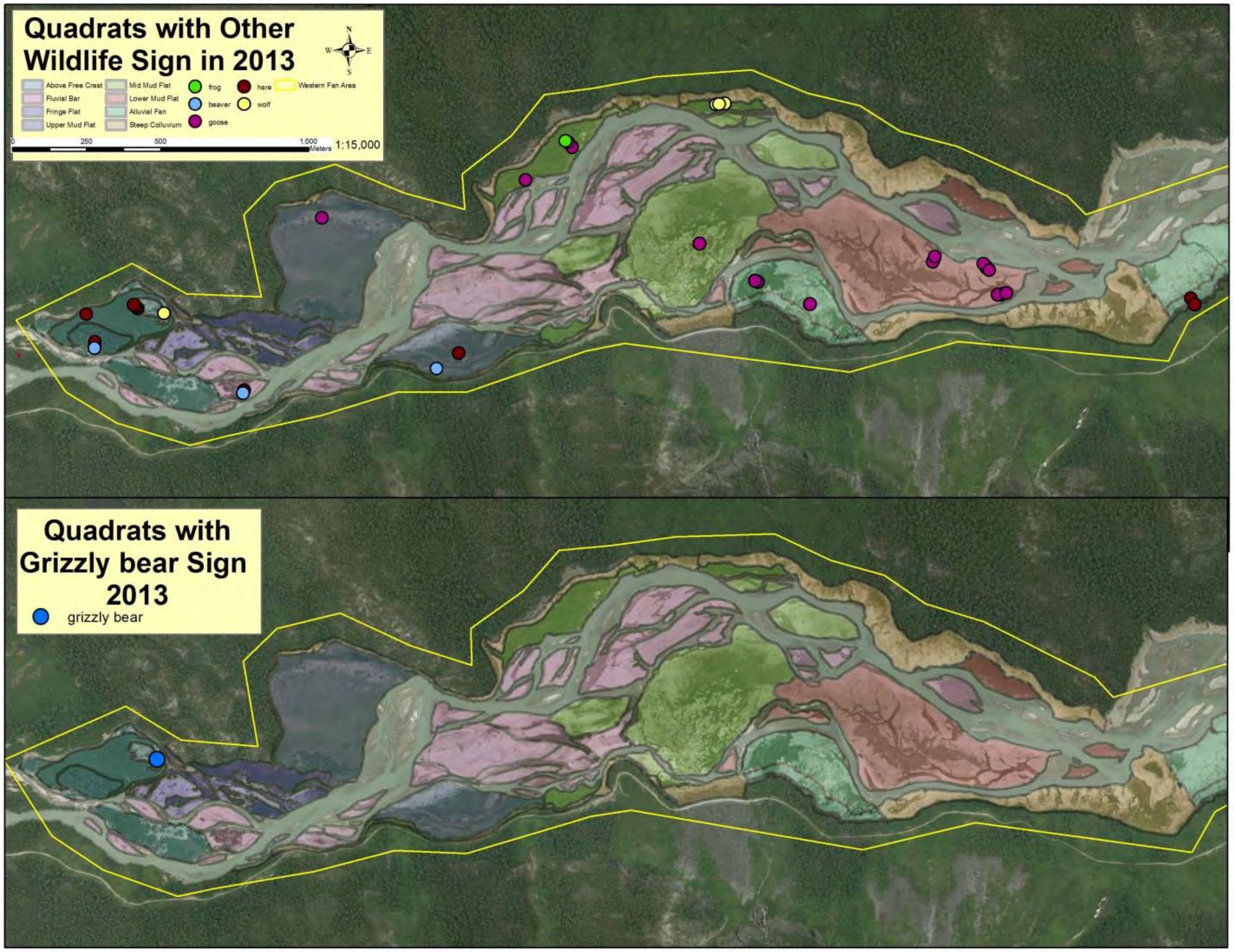

Figure 48. Other wildlife signs observed during the 2013 field survey.

The following observations from the statistical analysis can be summarized:

- It would have been expected that the fringe and upper elevations would have noticeably more cover than middle elevations. The only clear difference in cover within the Western Fan was that the lower mudflats had low cover and the above free crest transects had very high cover. The species that occupied these polygons generally shifted from east to west in species dominance, from horsetails to sedges, grasses, shrubs, and deciduous trees (Figure 49).

- Alluvial fans increased in biomass from lower elevations up through the fringe, with dominant species shifting from horsetails to sedges, and grasses to woody vegetation.

- There is not a big difference (1 to 2 weeks) in the proportion of the growing season available to vegetation between middle and upper elevations (see Table 8), and both are inundated late in the growing season (see Table 9).

Figure 49. Shift in the dominant vegetation in 2013, and increases in structural complexity and successional stage, from east to west, and as elevation increases

LMF	Horsetails Annuals	**MMF**	Sedges, horsetails, Annuals	**UMF**	Bluejoint grass, Willows	**FMF**	Willows	**AFC**	Willows, Cottonwood

Successional stage

Elevation

- Generally, there was a lower cover of vegetation in the central region of the Western Fan compared to the north or south: the center or island lands may have reduced cover due to being more recently formed depositional features, or they may be subjected to more surface disturbance in the form of erosion and deposition during Upper Bridge River freshet and then during reservoir full pool.

- Fluvial bars had generally low cover of vegetation, low richness and were only sampled at middle elevations. They had very variable species diversity and evenness likely due to the patchy vegetation coverage Related to microtopography and variable effects of deposition and erosion with variable river flows and reservoir flooding.

- Alluvial fans and mudflats showed a wide range of vegetation cover. Vegetation cover, richness, and diversity in mudflats were markedly lower at low elevation; mudflats had generally higher cover and diversity of vegetation than fans, independently of their elevations or locations.

- The mudflats at the fringe had the most variation in species richness, followed by the transects sampled above the free crest. This would be a reflection of the mosaicked appearance of the fringe mudflats and the above free crest polygons, where there were herbaceous patches among shrub and deciduous forest stands.

- Species richness was higher in the north than in the center or south of the Western Fan at middle and upper elevations, but slightly lower on average at the fringe. This could be a reflection of the exclusion effect that the dense shrub stands had on herbaceous vegetation cover.

  Diversity and evenness of vegetation was generally higher in the north than in the center or south at middle, upper and fringe (especially for evenness) elevations. Vegetation was slightly less even at upper elevation in alluvial fans, while it was maximal at upper elevation in mudflats. This fact may have more to do with the difference in substrate conditions and aspect in the alluvial fan zones. Mud flats had finer soils, level aspect and the fans coarse soils and moderate slopes.
- 2011 was a year with lower water levels; higher proportion of available habitat to grow, later flooding, and less water covering each elevation band. Conditions in 2012 were comparable to the average in previous years.Statistical limitations

The long-term monitoring program is observational in nature, as it is impossible to manipulate directly (and with replication) the independent variables that are, and will be, influencing the vegetation communities of the reservoir. The confrontation of observational findings to hypotheses may still allow inferential testing as long as hypotheses, sampling design and statistical analyses are adequately developed and interpreted.

The challenge lies in having statistical analyses robust and powerful enough to detect effects of the water operating regime and other environmental/spatial variables on the vegetation communities, over time. Robust tests are able to tolerate departure from the requirements of the tests (Scherrer 1984), which is important considering how little natural un-manipulated data usually complies with statistical assumptions. When needed, several methods to transform data to meet the requirements of test were considered before conducting tests. Also, tests by permutations were employed to reduce impacts of non-normal data distributions and spatial autocorrelation on the conclusions of the tests (Legendre and Legendre 1998, Borcard *et al.* 2011).

The power of a statistical test is defined as its capacity to provide the smallest β error for a given α error (Scherrer 1984). The probability of accepting a false null hypothesis corresponds to β error, while α error is the probability of rejecting a true null hypothesis (Sokal and Rohlf 1995). The potential consequence of a low power is that the null hypothesis of no-effects (H0) would not be rejected because the sampling size was small and/or the effect was weak (weaker than the random components), not because H0 was true (which represents a type II error). Given the complexity of the ecosystem studied and the fact that the sampling size is limited to 45 transects and two periods of sampling (10 years apart), it may be that no conclusions can be reached in 10 years as far as effect of the changes in water regimes on the vegetation communities. However, the interpretation of results is easier when H0 is rejected, and given the expected changes in water regime over the coming 10 years, we are confident that the current design will at least allow the detection of general trends in vegetation, and indicate potential impacts from the changes in water regime.

Other assumptions include the fact that differences in climate over time will not be confounded with effects from the water operating regime. It is also assumed that sampling will not alter the structure of the vegetation, that all variables of interest will be included in the models, and that no effects observed on dependent variables will be attributed to the wrong independent variables, i.e. that the effects of confounding variables will be acknowledged and controlled for, as much as possible.

5.0 Conclusion and Recommendations

The 170 ha Western Fan is a dynamic, diverse and ecologically important region of Downton Reservoir. Its unique habitat values have been recognized provincially, and the region has been protected as a class A park. The Western Fan is the terminus of the free flowing Upper Bridge River, and the beginning of the Downton Reservoir drawdown zone. To monitor changes and shifts in vegetation over the next ten years, 45 permanent monitoring transects and 90 photo monitoring points were established across nine terrain/elevation types in July 2013. The dataset gathered provides a baseline of the vegetation in the Western Fan, exploring relationships between elevation, species composition, and biomass productivity. Repeating the sampling in the permanent transects in 10 years will provide a comparison and reference to assess impacts and shifts in vegetation communities, distribution and biomass productivity across the Western Fan of Downton Reservoir.

The following recommendations can be made:

- Utilize historical ortho-corrected photography to identify terrain polygon areas for all sampled terrain classes before the implementation of the N2-2P alternative (Pre-2000), to provide a historical benchmark for monitoring change in the spatial distribution of the vegetation communities associated with the terrain around the Western Fan of Downton Reservoir.

- Monitor and compare the area of shrub habitat in the Western Fan to assess direction of vegetation pattern shifts.

- Consider adding an additional year of field monitoring within the 10 year project (ideally mid-way, year 5) to provide an additional data set and perspective on annual operations and vegetation community patterns.

- The Western Fan area of Downton Reservoir is a dynamic fluvial zone with erosion and deposition causing shifts in the location and size of vegetated zones. Since 2005 there has been a reduction in the area of the largest of the grizzly flats. It is recommended that the scope of BRGMON 5 be expanded to include the opinion of a fluvial geomorphologist regarding the stability of the mud flats found in the Western Fan Area of Downton reservoir

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Appendix 1. List of species sampled in 2013

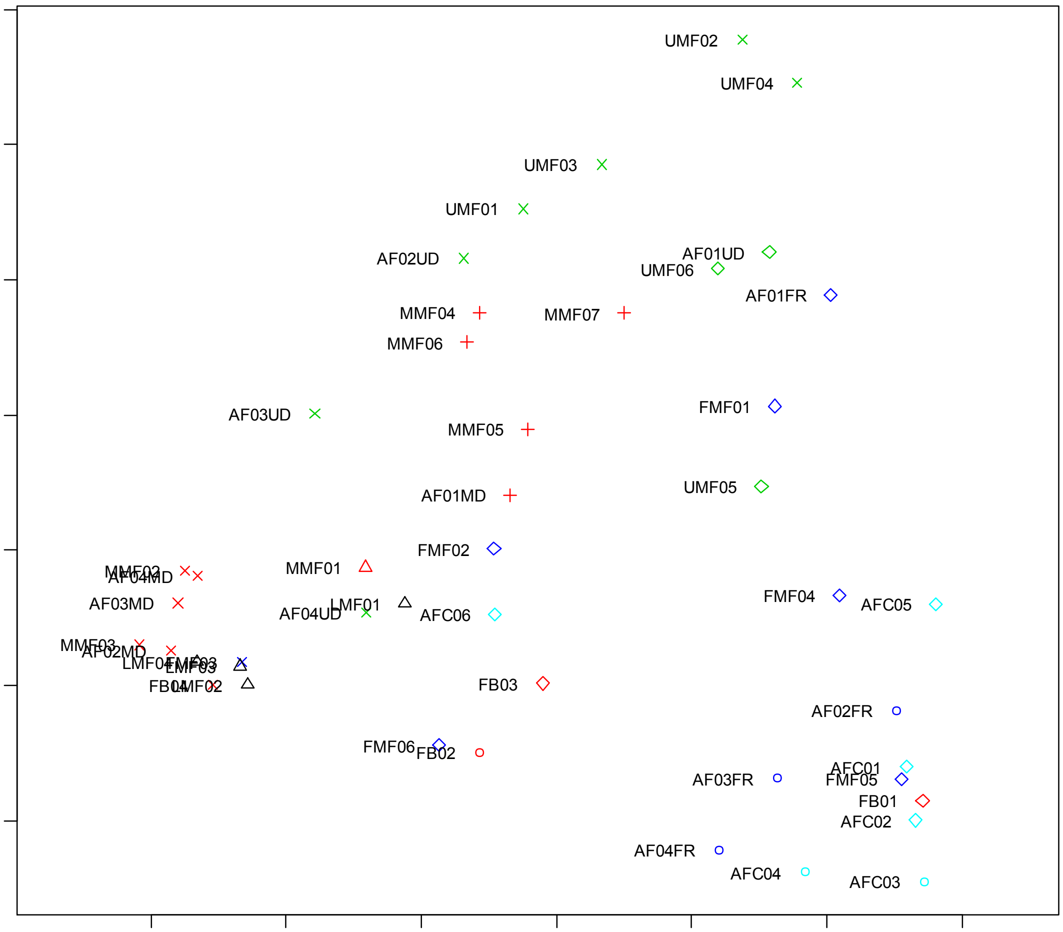
Table A1. List of species sampled in 2013, with acronyms, full common and scientific names, origins, whether they are annual/perennial and plant family

Species	Common Name	Scientific Name	Perennial/ Annual	Origin	Family
ABIELAS	subalpine fir	*Abies lasciocarpa*	perennial	native	Pinaceae
ACERGLA	Douglas maple	*Acer glabrum*	perennial	native	Aceraceae
ACHIMIL	yarrow	*Achillea millifolium*	perennial	native	Asteraceae
ALNUCRI	green alder	*Alnus crispus*	perennial	native	Betulaceae
ALNUINC	mountain alder	*Alnus incana*	perennial	native	Betulaceae
AMELALN	Saskatoon berry	*Amelanchier alnifolia*	perennial	native	Rosaceae
AMSISPE	fiddleneck, common	*Amsinckia spectrabilis*	annual	native	Boraginaceae
ANAPMAR	pearly everlasting	*Anaphalis margaritacea*	perennial	native	Asteraceae
ARABHOE	Holboell's rock cress	*Arabis holboellii*	annual	native	Brassicaceae
ARCTUVA	kinnickinnick	*Arctostaphylos uva-ursi*	perennial	native	Ericaceae
BETUPAP	paper birch	*Betula papyrifera*	perennial	native	Betulaceae
CALACAN	bluejoint grass	*Calamagrostis canadensis*	perennial	native	Poaceae
CAREAQU	water sedge	*Carex aquatilis*	perennial	native	Cyperaceae
CARELEN	Lakeshore sedge	*Carex lenticularis ssp. lipocarpa*	perennial	native	Cyperaceae
CASTMIN	Indian paint brush	*Castilleja miniata*	perennial	native	Scrophulariaceae
CHENALB	lamb's quarters	*Chenopodium album*	annual	exotic	Chenopodiaceae
COLLLIN	narrow-leafed Collomia	*Collomia linearis*	annual	native	Polemoniaceae
CORNCAN	creeping dogwood	*Cornus canadensis*	perennial	native	Cornaceae
CORNSTO	red-osier dogwood	*Cornus stolonifera*	perennial	native	Rosaceae
CREPOCC	western hawksbeard	*Crepis occidentalis*	perennial	native	Asteraceae
ELYMGLA	blue wildrye	*Elymus glaucus*	perennial	native	Poaceae
ELYMTRA	slender wheat-grass	*Elymus trachycaulus*	perennial	native	Poaceae
EPILANG	fireweed	*Epilobium angustifolium*	perennial	native	Onagraceae
EPILBRA	tall willowherb	*Epilobium brachycarpum*	annual	native	Onagraceae
EPILCIL	purple-leafed willowherb	*Epilobium ciliatum*	perennial	native	Onagraceae
EPILLAT	broad-leaved willowherb	*Epilobium latifolium*	perennial	native	Onagraceae
EPILLEP	narrow leafed willowherb	*Epilobium leptophyllum*	perennial	native	Onagraceae
EQUIARV	common horsetail	*Equisetum arvense*	perennial	native	Equisetaceae
EQUIHYE	scouring rush	*Equisetum hyemale*	perennial	native	Equisetaceae
EQUILAE	smooth scouring rush	*Equisetum laevigatum*	perennial	native	Equisetaceae
EQUIPAL	common horsetail	*Equisetum palustre*	perennial	native	Equisetaceae
EQUIVAR	northern scouring rush	*Equisetum variegatum*	perennial	native	Equisetaceae
FILAARV	field filago	*Filago arvensis*	annual	exotic	Asteraceae

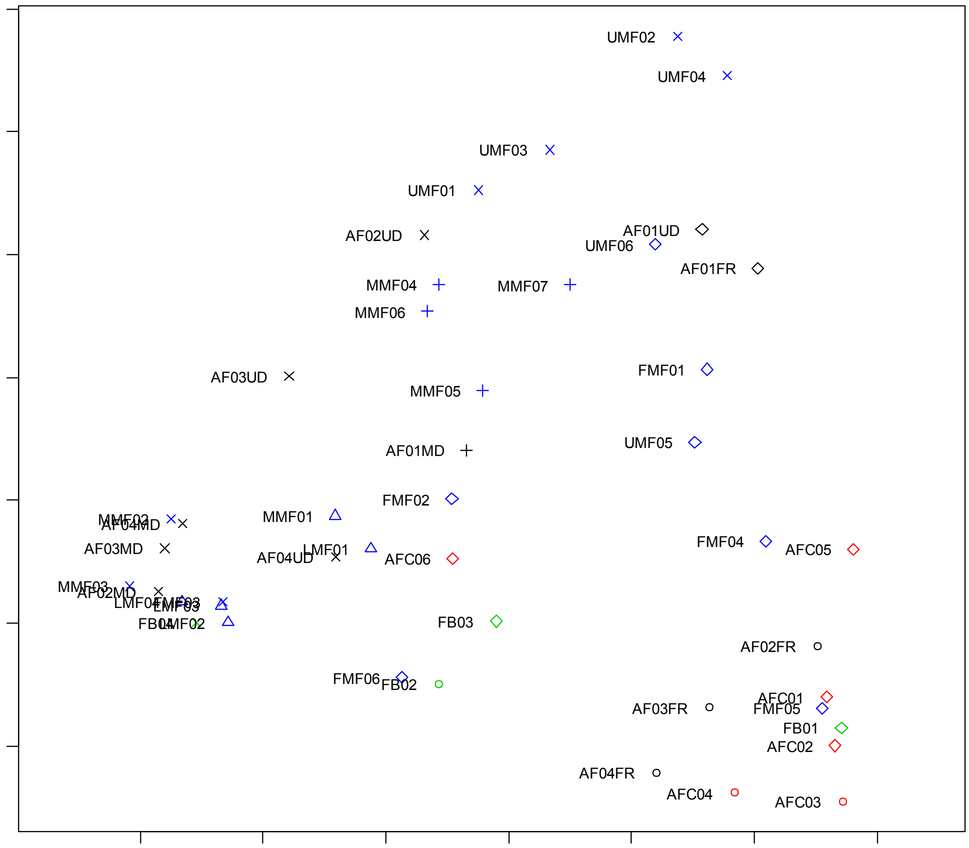
Species	Common Name	Scientific Name	Perennial/ Annual	Origin	Family
GALITRD	small bedstraw	*Galium trifidum*	perennial	native	Rubiaceae
GALITRI	bedstraw, Sweet scented	*Galium triflorum*	perennial	native	Rubiaceae
HEIRACI	hawkweed sp	*Hieracium sp*	perennial	both	Asteraceae
HERALAN	cow parsnip	*Heracleum lanatum*	perennial	native	Apiaceae
LACTMUR	wall lettuce	*Lactuca muralis*	biennial	exotic	Asteraceae
LONIINV	black twinberry	*Lonicera involucrata*	perennial	native	Caprifoliaceae
LOTUDEN	meadow birds-foot trefoil	*Lotus denticulatus*	annual	native	Fabaceae
MATRDIS	pineapple weed	*Matricaria discoidea*	annual	exotic	Asteraceae
MENTDIS	small flowered evening star	*Mentzelia albicaulis*	annual	native	Loasaceae
OPLOHOR	Devil's club	*Oplopanax horridus*	perennial	native	Araliaceae
ORTHSEC	one-sided wintergreen	*Orthilia secunda*	perennial	native	Pyrolaceae
OZMOCHIL	sweet cicily	*Osmorhiza chilensis*	perennial	native	Apiaceae
PERSMAC	lady's thumb	*Persicaria maculosa*	annual	exotic	Polygonaceae
PICEENC	Engelman spruce hybrid	*Picea engelmannii*	perennial	native	Pinaceae
PINUCON	lodgepole pine	*Pinus contorta*	perennial	native	Pinaceae
PINUMON	western white pine	*Pinus monticola*	perennial	native	Pinaceae
PLAGSCO	Scouler's popcornflower	*Plagiobothrys scouleri*	annual	native	Boraginaceae
PLANDIL	white rein orchid	*Platanthera dilatata*	perennial	native	Orchidaceae
POAPALU	fowl bluegrass	*Poa palustris*	perennial	native	Poaceae
POAPRAT	Kentucky bluegrass	*Poa pratensis*	perennial	exotic	Poaceae
POLYAQU	water smartweed	*Persicaria amphibia*	perennial	native	Polygonaceae
POLYFOW	Fowler's knotweed	*Polygonum fowleri*	annual	native	Polygonaceae
POPUBAL	black cottonwood	*Populus balsamifera ssp. trichocarpa*	perennial	native	Salicaceae
PYROASC	pink wintergreen	*Pyrola asarifolia*	perennial	native	Pyrolaceae
RANUPEN	Pennsylvania buttercup	*Ranunculus pensylvanicus*	annual	native	Ranunculaceae
RIBELAC	black gooseberry	*Ribes lacustre*	perennial	native	Grossulariaceae
RORIPAL	marsh yellow cress	*Rorippa palustris*	a/b/slp*	native	Brassicaceae
RUBUIDE	red raspberry	*Rubus ideaus*	perennial	native	Rosaceae
SAGIPRO	birdseye pearlwort	*Sagina procumbens*	perennial	unkn	Caryophyllaceae
SALIBAC	Barclay's willow	*Salix barclayi*	perennial	native	Salicaceae
SALIBEB	Bebb's willow	*Salix bebbiana*	perennial	native	Salicaceae
SALILUC	Pacific willow	*Salix lucida ssp. Lasiandra*	perennial	native	Salicaceae
SCOLFES	spangle top	*Scolochloa festucacea*	perennial	native	Poaceae
SOLISPA	spikelike goldenrod	*Solidago spathulatum*	perennial	native	Asteraceae
SORBSCO	western mountain ash	*Sorbus scopulina*	perennial	native	Rosaceae

Species	Common Name	Scientific Name	Perennial/ Annual	Origin	Family
SPIRDOU	hardhack	*Spiraea douglasii*	perennial	native	Rosaceae
STELCRI	crisp starwort	*Stellaria crispa*	perennial	native	Caryophyllaceae
STELLON	long leaf starwort	*Stellaria longifolia*	perennial	native	Caryophyllaceae
TARAOFF	dandelion	*Taraxacum officinale*	perennial	exotic	Asteraceae

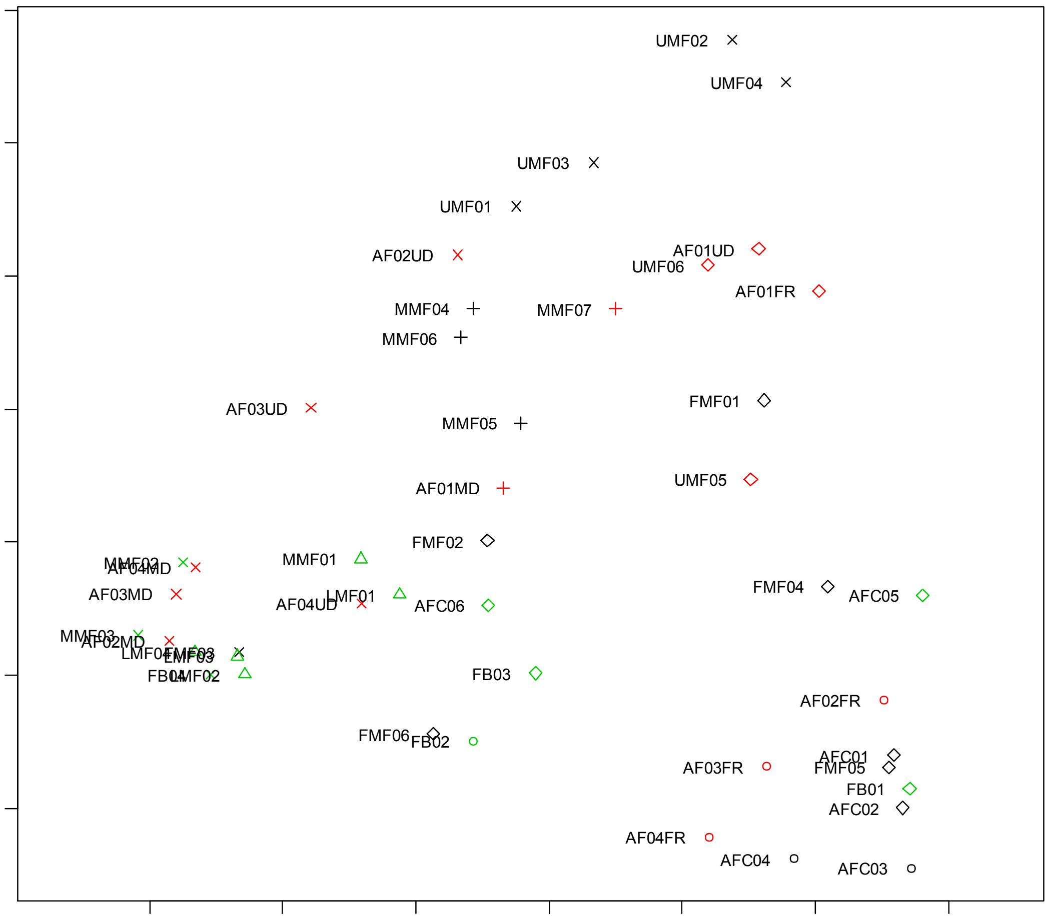
Appendix 2. PCoA diagrams of similarities among transects based on species composition (D17, Hellinger-Euclidian distance) and WPGMA, with categories from the four factors (elevation, location North-South, East-West, and terrain classes) overlaid to assess if any of them would influence clustering.



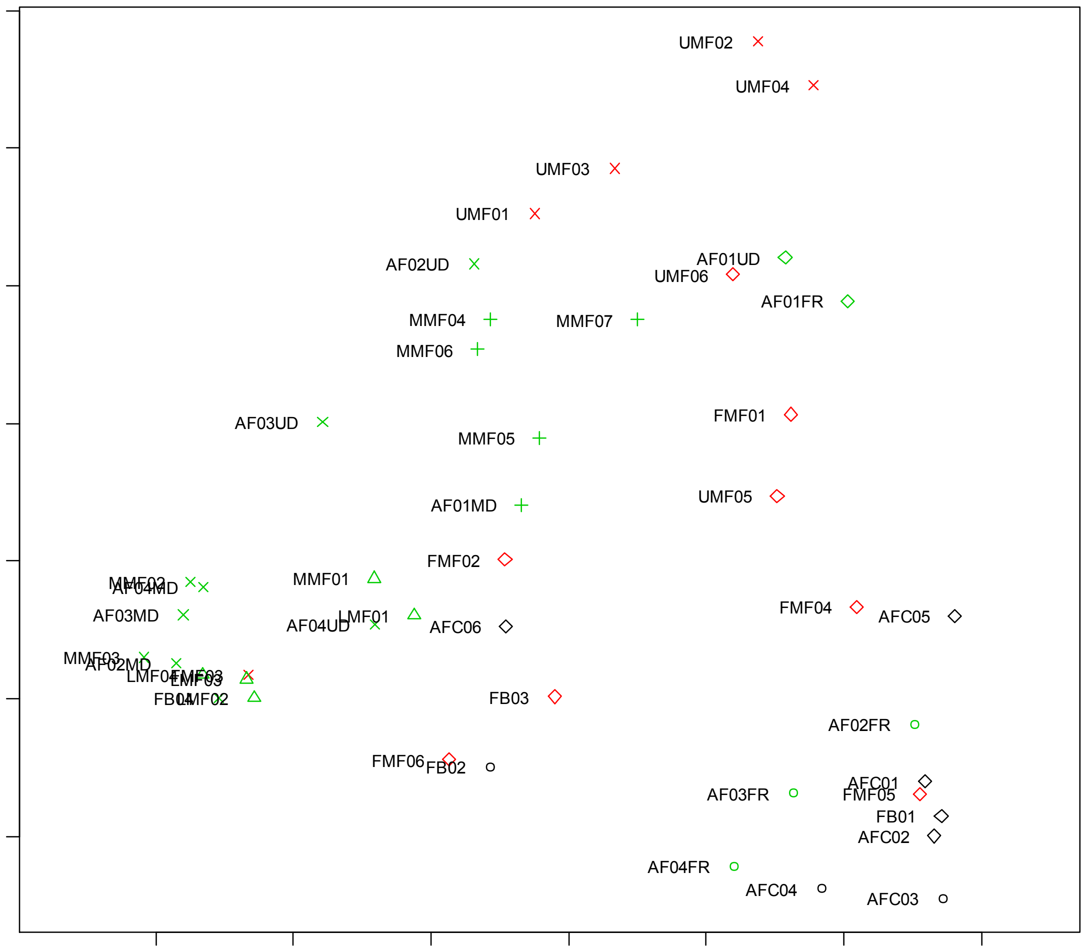
A2.1. PCoA diagram showing similarities among transects sampled in the Western Fan zone in 2013, based on their species composition, and in relation with elevation bands (Hellinger-Euclidian distance). Axis 1 explains 21% of the variation in species cover, and axis 2, 15%. Symbols are: °: Group 1, Δ: Group 2, +: Group 3, χ: Group 4, diamond: Group 5. Colors code for elevation bands: black: low, red: middle, green: upper, blue: fringe, turquoise: above free crest.



A2.2 PCoA diagram showing similarities among transects sampled in the Western Fan zone based on their species composition, and in relation with terrain classes (Hellinger-Euclidian distance) in 2013. Axis 1 explains 36% of the variation in species cover, and axis 2, 24%. Symbols are: °: Group 1, Δ: Group 2, +: Group 3, χ: Group 4, diamond: Group 5. Colors code for elevation bands: black: alluvial fans, red: above free crest, green: fluvial bar, blue: mudflats.

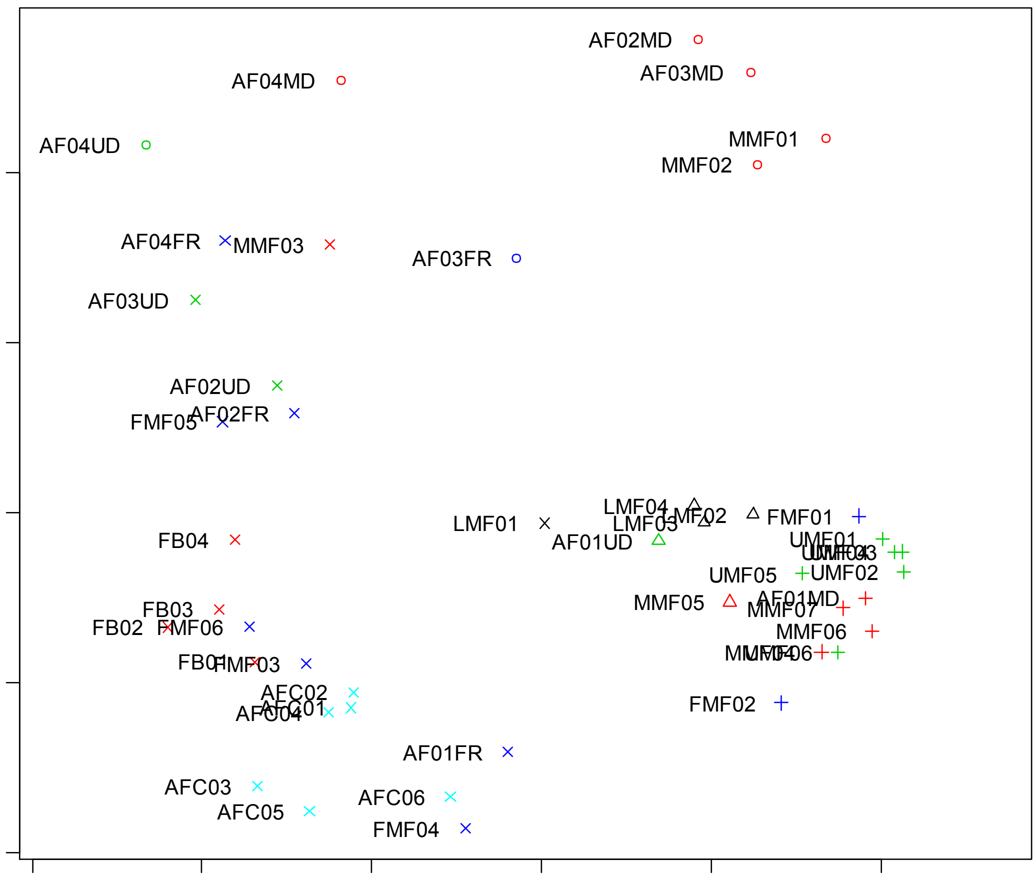


A2.3 PCoA diagram showing similarities among transects sampled in the Western Fan zone based on their species composition, and in relation with their latitudinal location (Hellinger-Euclidian distance) in 2013. Axis 1 explains 36% of the variation in species cover, and axis 2, 24%. Symbols are: °: Group 1, Δ: Group 2, +: Group 3, χ: Group 4, diamond: Group 5. Colors code for elevation bands: black: North, green: Central red: South.

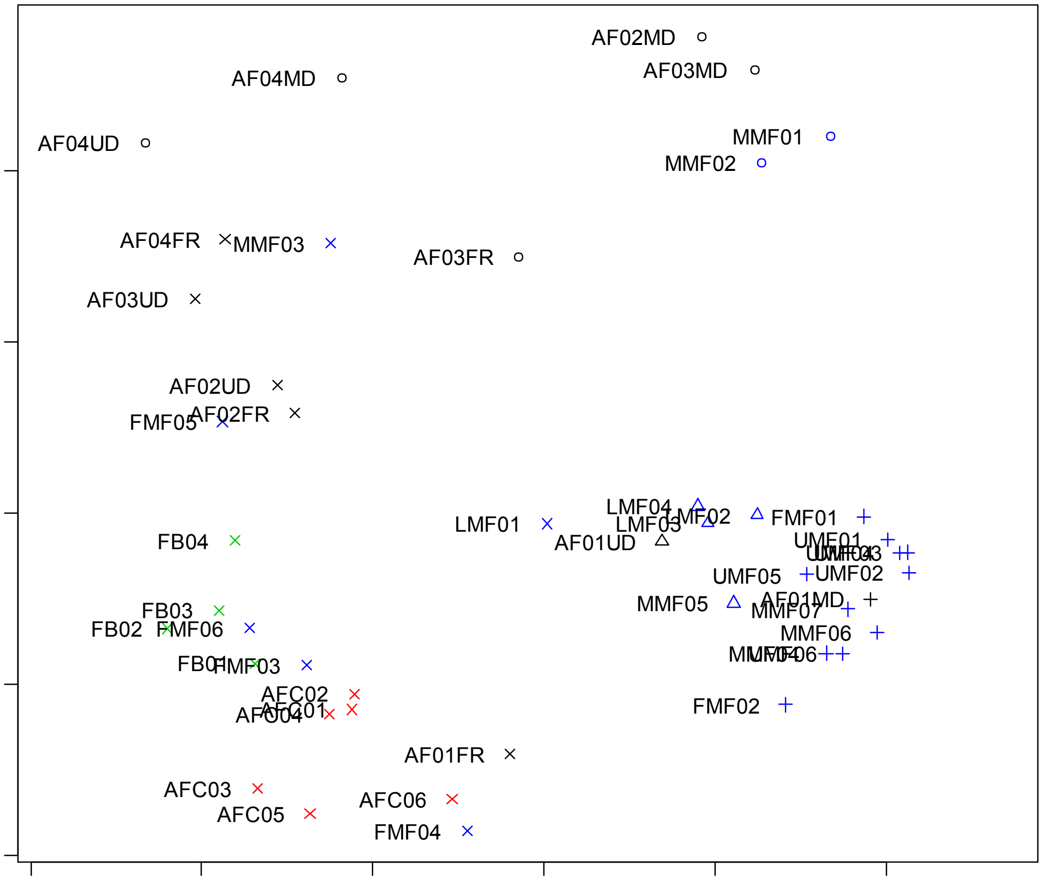


A2.4 PCoA diagram showing similarities among transects sampled in the Western Fan zone based on their species composition, and in relation with their longitudinal location (Hellinger-Euclidian distance) in 2013. Axis 1 explains 36% of the variation in species cover, and axis 2, 24%. Symbols are: °: Group 1, Δ: Group 2, +: Group 3, χ: Group 4, diamond: Group 5. Colors code for elevation bands: black: West, red: Central, green: East.

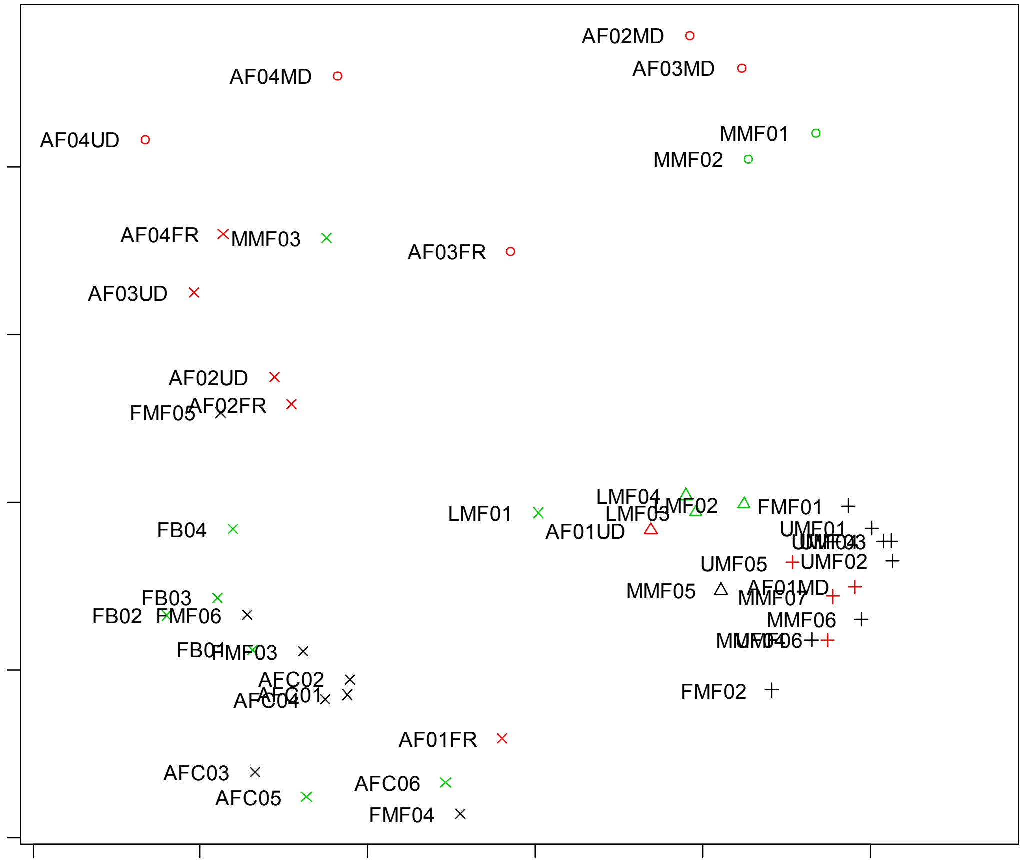
Appendix 3. PCoA diagrams of similarities among transects based on environmental characteristics (Gower coefficients and WPGMA), with categories from the four factors overlaid to assess if any of them would influence clustering.



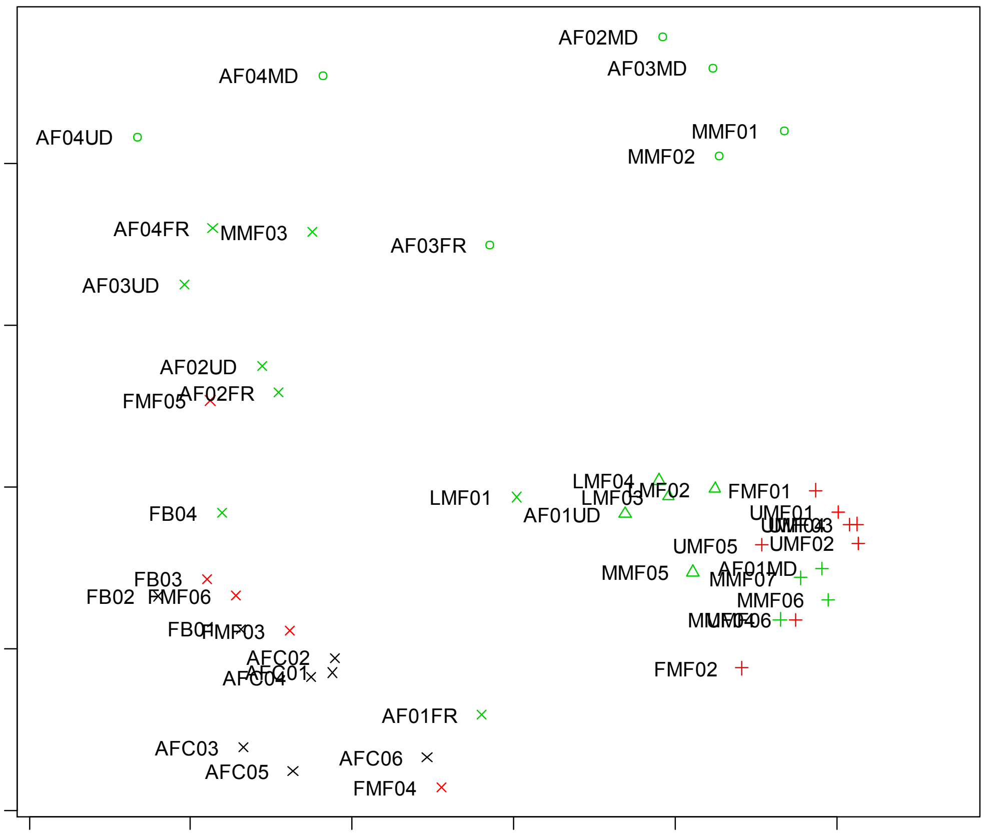
A3.1. PCoA diagram showing similarities among transects sampled in the Western Fan zone in 2013, based on their environmental characteristics, and in relation with elevation bands (Hellinger-Euclidian distance). Axis 1 explains 36% of the variation in species cover, and axis 2, 24%. Symbols are: °: Group 1, Δ: Group 2, +: Group 3, χ: Group 4. Colors code for elevation bands: black: low, red: middle, green: upper, blue: fringe, turquoise: above free crest.



A3.2 PCoA diagram showing similarities among transects sampled in the Western Fan zone in 2013, based on their species characteristics, and in relation with terrain classes (Hellinger-Euclidian distance). Axis 1 explains 36% of the variation in species cover, and axis 2, 24%. Symbols are: °: Group 1, Δ: Group 2, +: Group 3, χ: Group 4. Colors code for elevation bands: black: alluvial fans, red: above free crest, green: fluvial bar, blue: mudflats.



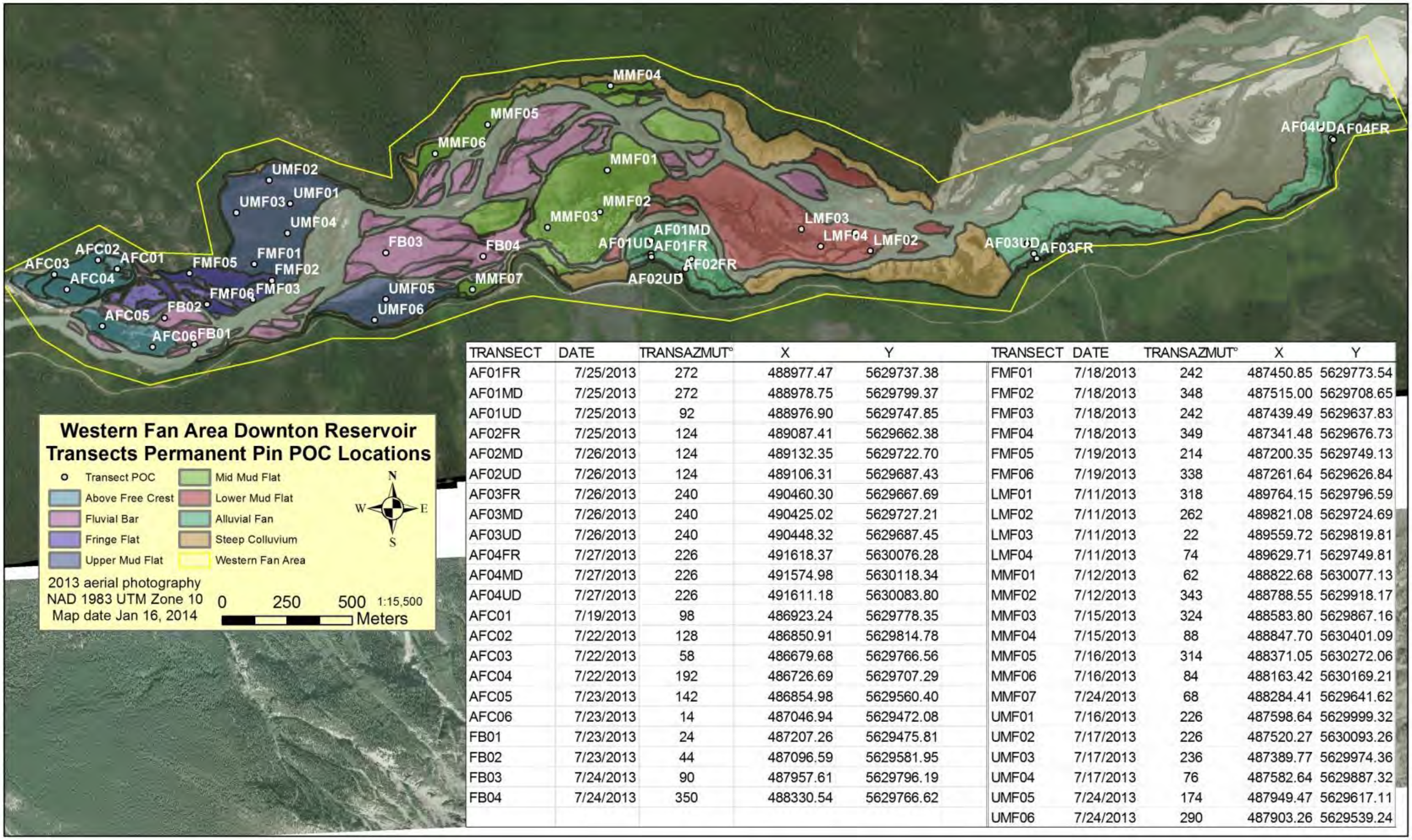
A3.3 PCoA diagram showing similarities among transects sampled in the Western Fan zone) in 2013, based on their species characteristics, and in relation with their latitudinal location (Hellinger-Euclidian distance. Axis 1 explains 36% of the variation in species cover, and axis 2, 24%. Symbols are: °: Group 1, Δ: Group 2, +: Group 3, χ: Group 4. Colors code for elevation bands: green: North, black: Central, red: South.



A3.4 PCoA diagram showing similarities among transects sampled in the Western Fan zone in 2013, based on their species characteristics, and in relation with their longitudinal location (Hellinger-Euclidian distance). Axis 1 explains 36% of the variation in species cover, and axis 2, 24%. Symbols are: °: Group 1, Δ: Group 2, +: Group 3, χ: Group 4. Colors code for elevation bands: black: West, red: Central, green: East.

Appendix 4 Permanent monitoring transect pin locations

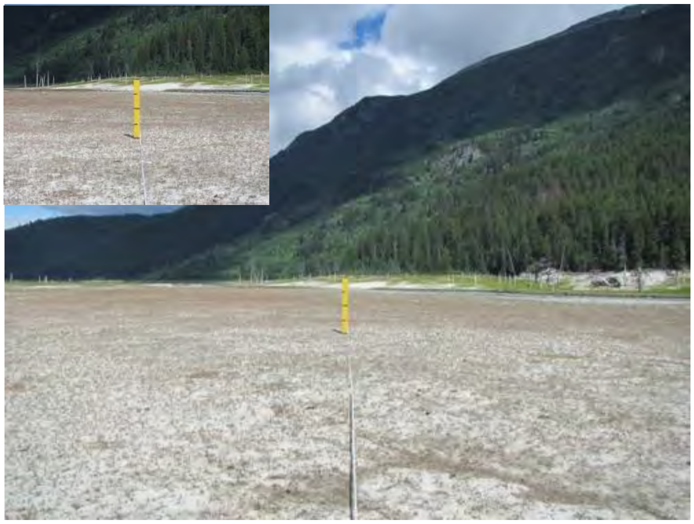
TRANSECT	DATE	TRANSAZMUT°	X	Y
AF01FR	7/25/2013	272	488977.47	5629737.38
AF01MD	7/25/2013	272	488978.75	5629799.37
AF01UD	7/25/2013	92	488976.90	5629747.85
AF02FR	7/25/2013	124	489087.41	5629662.38
AF02MD	7/26/2013	124	489132.35	5629722.70
AF02UD	7/26/2013	124	489106.31	5629687.43
AF03FR	7/26/2013	240	490460.30	5629667.69
AF03MD	7/26/2013	240	490425.02	5629727.21
AF03UD	7/26/2013	240	490448.32	5629687.45
AF04FR	7/27/2013	226	491618.37	5630076.28
AF04MD	7/27/2013	226	491574.98	5630118.34
AF04UD	7/27/2013	226	491611.18	5630083.80
AFC01	7/19/2013	98	486923.24	5629778.35
AFC02	7/22/2013	128	486850.91	5629814.78
AFC03	7/22/2013	58	486679.68	5629766.56
AFC04	7/22/2013	192	486726.69	5629707.29
AFC05	7/23/2013	142	486854.98	5629560.40
AFC06	7/23/2013	14	487046.94	5629472.08
FB01	7/23/2013	24	487207.26	5629475.81
FB02	7/23/2013	44	487096.59	5629581.95
FB03	7/24/2013	90	487957.61	5629796.19
FB04	7/24/2013	350	488330.54	5629766.62
FMF01	7/18/2013	242	487450.85	5629773.54
FMF02	7/18/2013	348	487515.00	5629708.65
FMF03	7/18/2013	242	487439.49	5629637.83
FMF04	7/18/2013	349	487341.48	5629676.73
FMF05	7/19/2013	214	487200.35	5629749.13
FMF06	7/19/2013	338	487261.64	5629626.84
LMF01	7/11/2013	318	489764.15	5629796.59
LMF02	7/11/2013	262	489821.08	5629724.69
LMF03	7/11/2013	22	489559.72	5629819.81
LMF04	7/11/2013	74	489629.71	5629749.81
MMF01	7/12/2013	62	488822.68	5630077.13
MMF02	7/12/2013	343	488788.55	5629918.17
MMF03	7/15/2013	324	488583.80	5629867.16
MMF04	7/15/2013	88	488847.70	5630401.09



TRANSECT	DATE	TRANSAZMUT°	X	Y
AF01FR	7/25/2013	272	488977.47	5629737.38
AF01MD	7/25/2013	272	488978.75	5629799.37
AF01UD	7/25/2013	92	488976.90	5629747.85
AF02FR	7/25/2013	124	489087.41	5629662.38
AF02MD	7/26/2013	124	489132.35	5629722.70
AF02UD	7/26/2013	124	489106.31	5629687.43
AF03FR	7/26/2013	240	490460.30	5629667.69
AF03MD	7/26/2013	240	490425.02	5629727.21
AF03UD	7/26/2013	240	490448.32	5629687.45
AF04FR	7/27/2013	226	491618.37	5630076.28
AF04MD	7/27/2013	226	491574.98	5630118.34
AF04UD	7/27/2013	226	491611.18	5630083.80
AFC01	7/19/2013	98	486923.24	5629778.35
AFC02	7/22/2013	128	486850.91	5629814.78
AFC03	7/22/2013	58	486679.68	5629766.56
AFC04	7/22/2013	192	486726.69	5629707.29
AFC05	7/23/2013	142	486854.98	5629560.40
AFC06	7/23/2013	14	487046.94	5629472.08
FB01	7/23/2013	24	487207.26	5629475.81
FB02	7/23/2013	44	487096.59	5629581.95
FB03	7/24/2013	90	487957.61	5629796.19
FB04	7/24/2013	350	488330.54	5629766.62

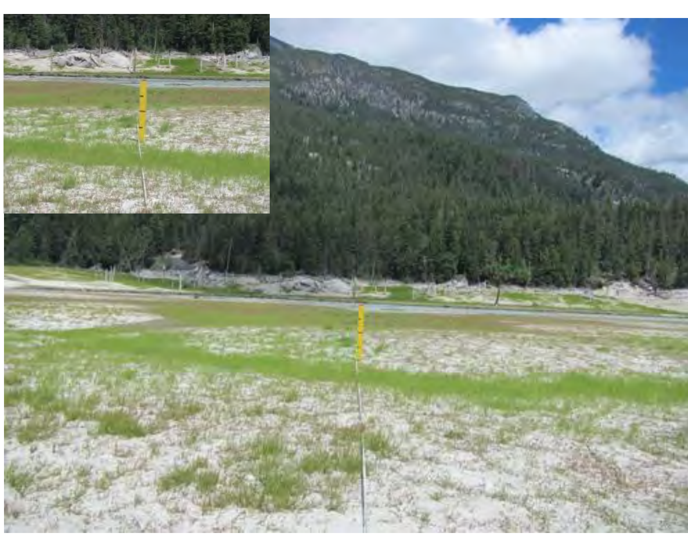
TRANSECT	DATE	TRANSAZMUT°	X	Y
FMF01	7/18/2013	242	487450.85	5629773.54
FMF02	7/18/2013	348	487515.00	5629708.65
FMF03	7/18/2013	242	487439.49	5629637.83
FMF04	7/18/2013	349	487341.48	5629676.73
FMF05	7/19/2013	214	487200.35	5629749.13
FMF06	7/19/2013	338	487261.64	5629626.84
LMF01	7/11/2013	318	489764.15	5629796.59
LMF02	7/11/2013	262	489821.08	5629724.69
LMF03	7/11/2013	22	489559.72	5629819.81
LMF04	7/11/2013	74	489629.71	5629749.81
MMF01	7/12/2013	62	488822.68	5630077.13
MMF02	7/12/2013	343	488788.55	5629918.17
MMF03	7/15/2013	324	488583.80	5629867.16
MMF04	7/15/2013	88	488847.70	5630401.09
MMF05	7/16/2013	314	488371.05	5630272.06
MMF06	7/16/2013	84	488163.42	5630169.21
MMF07	7/24/2013	68	488284.41	5629641.62
UMF01	7/16/2013	226	487598.64	5629999.32
UMF02	7/17/2013	226	487520.27	5630093.26
UMF03	7/17/2013	236	487389.77	5629974.36
UMF04	7/17/2013	76	487582.64	5629887.32
UMF05	7/24/2013	174	487949.47	5629617.11
UMF06	7/24/2013	290	487903.26	5629539.24

Appendix 5. Permanent Photo Points

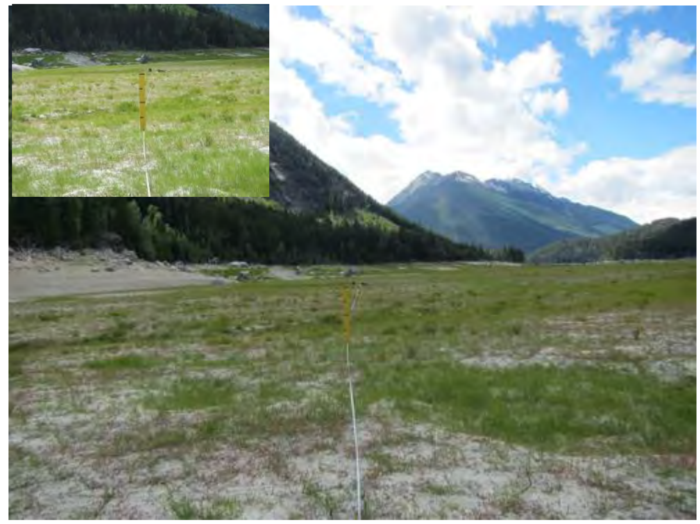



LMF01 a bearing 318°, b bearing 138°

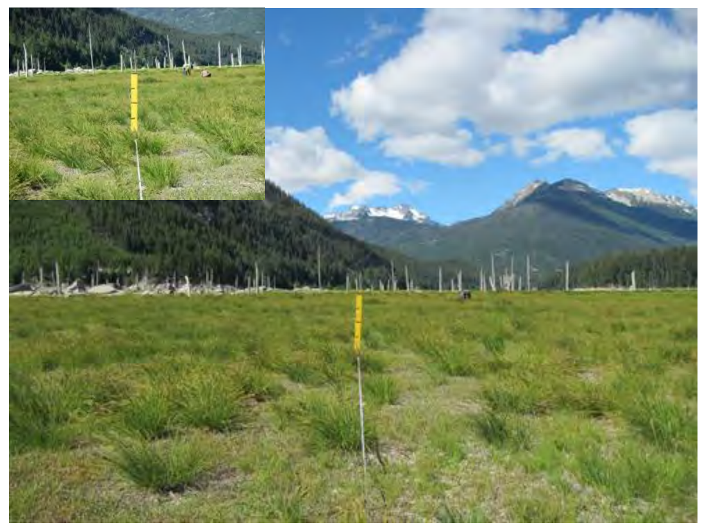

LMF02 a bearing 262°, b bearing 82°




LMF03 a bearing 22°, b bearing 202°



LMF04 a bearing 74°, b bearing 254°

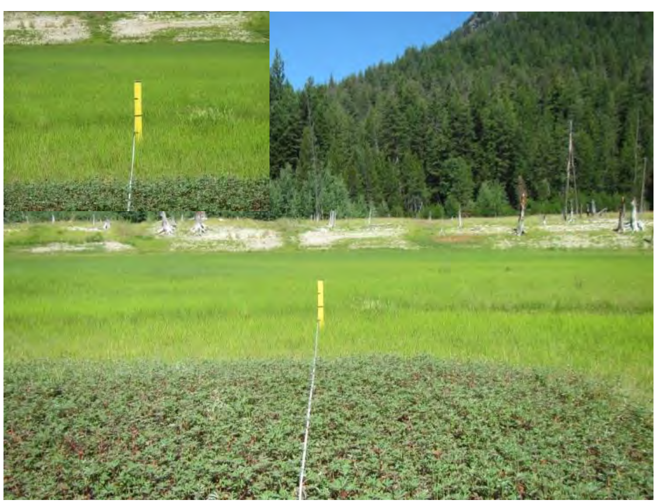


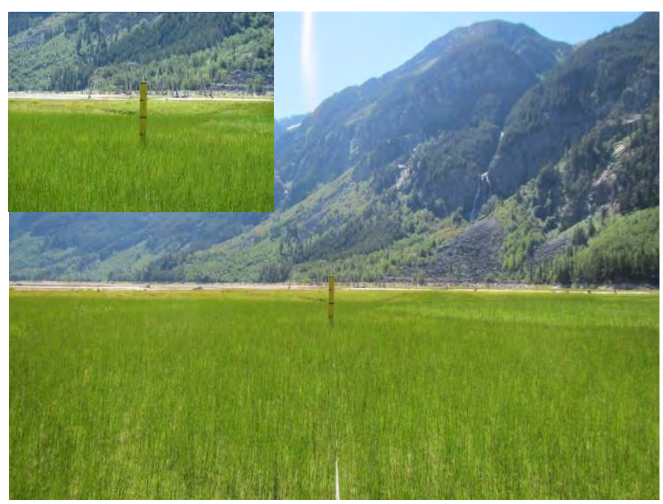
MMF01 a bearing 62°, b bearing 242°

MMF02 a bearing 343°, b bearing 163°

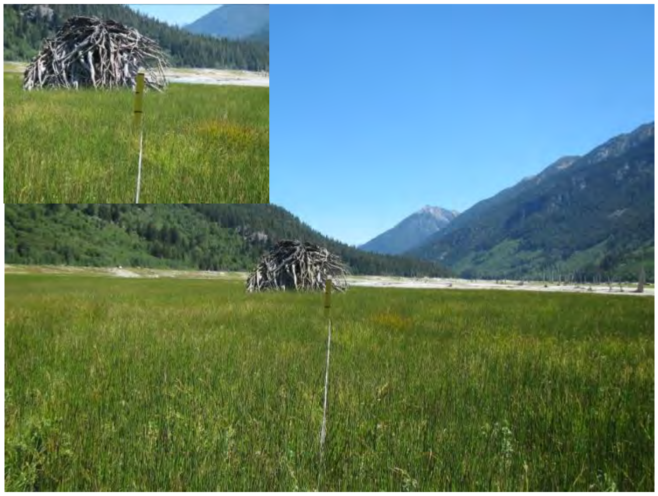
MMF 03 a bearing 324°, b bearing 144°

MMF 04 a bearing 88°, and b bearing 268°





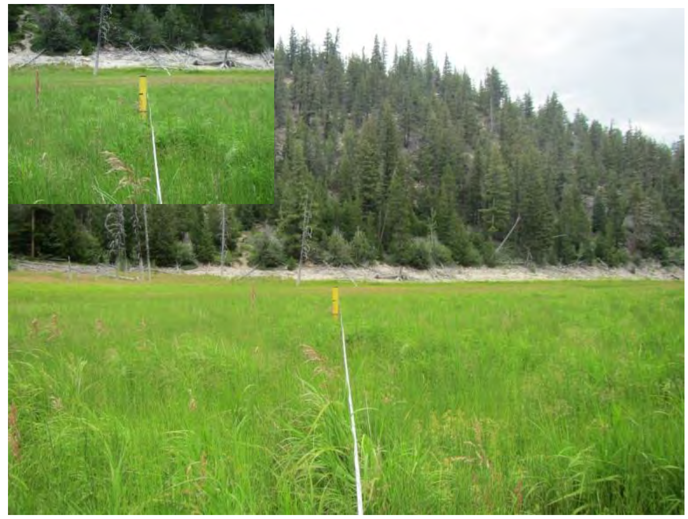
MMF05 a bearing 314° and b bearing 124°




MMF 06 a bearing 84°, b bearing 264°

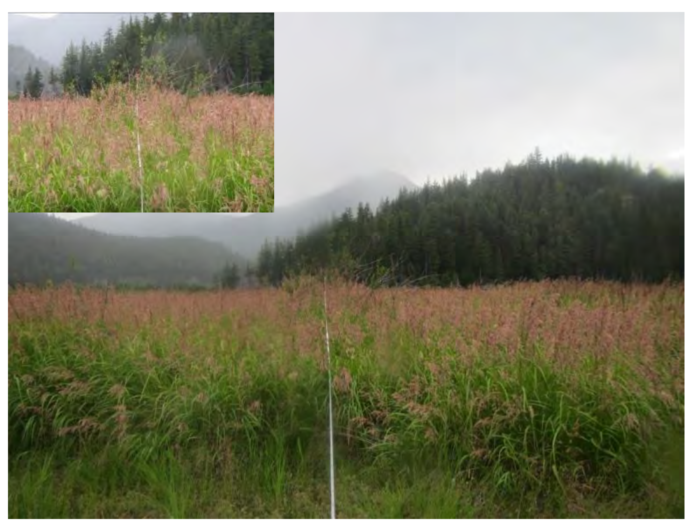

MMF 07 a bearing 70°, b bearing 250°


UMF 01 a bearing 226°, b bearing 46°

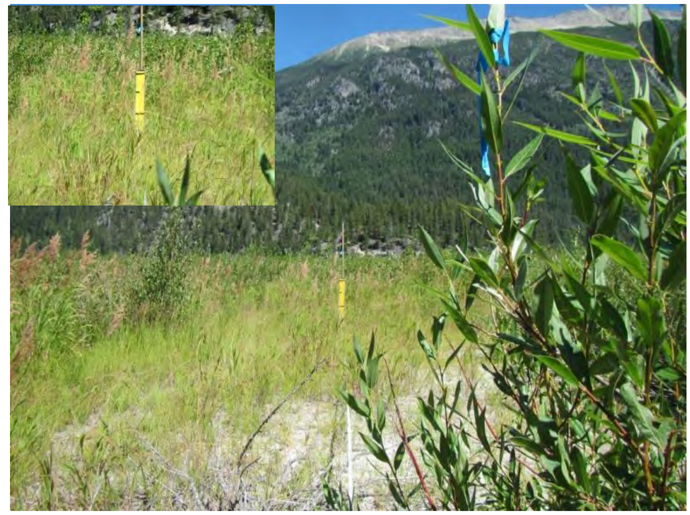



UMF02 a bearing 226°, b bearing 46°


UMF 03 a bearing 236°, b bearing 56°

UMF 04 bearing 76°, b bearing 256°

UMF 05 a bearing 174° , b bearing 354°


UMF 06 a bearing 290°, b bearing 110°


FMF 01 a bearing 134°, b bearing 62°

FMF 02 a bearing 348°, b bearing 189°

FMF03, a bearing 242, and b bearing 62°

FMF04 a bearing 349°, b bearing 169°


FMF05 a bearing 214°, b bearing 114°


FMF 06 a bearing 26°, b bearing 158°

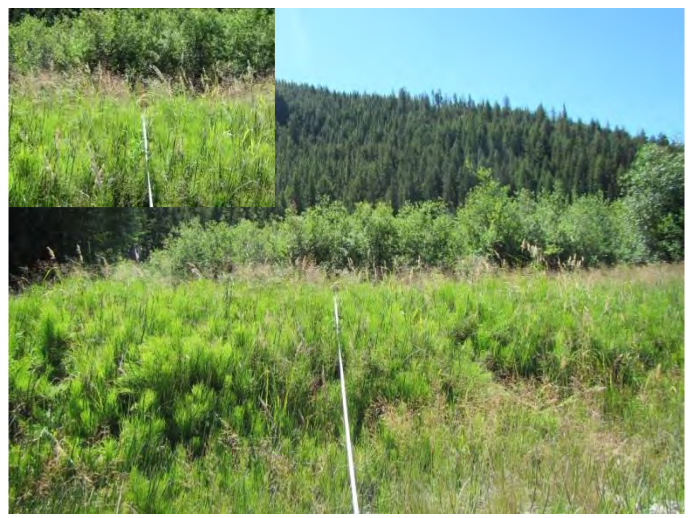

AFC01 a bearing 98°, b bearing 278°


AFC 02 a bearing 128°, b bearing 308°


AFC03 a bearing 58°, b bearing 238°


AFC04 a bearing 198°, b bearing 18°


AFC 05 a bearing 142°, b bearing 322°

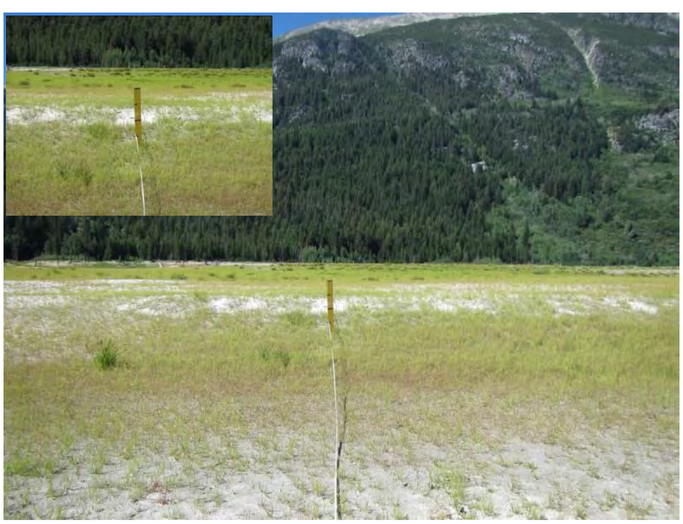



AFC06 a bearing 14°, b bearing 194 °


FB 01 a bearing 24°, b bearing 204°


FB02 a bearing 44°, b bearing 224°


FB03 a bearing 90°, b bearing 270°




FB 04 a bearing 350°, b bearing 170°


AFmd01 a bearing 272°, b bearing 92°


AFmd02 a bearing 124°, b bearing 304°


AFmd03 a bearing 240°, b bearing 60°

AFmd04 a bearing 226°, b bearing 46°

AFud01 a bearing 240°, b bearing 60°

AFud02 a bearing 124°, b bearing 304°

AFmd04 a bearing 226°, b bearing 46°

AFud01 a bearing 240°, b bearing 60°

AFud02 a bearing 124°, b bearing 304°


AFfr02 a bearing 124°, b bearing 304°


AFfr03 a bearing 240°, b bearing 60°


AFfr04 a bearing 226°, b bearing 46°