# BRGMON-11 Bridge-Seton Water Use Plan Lower

## Bridge River Riparian Vegetation Monitoring and Riverine Bird Monitoring

**Implementation Year 1**

**Reference: BRGMON-11**

**Study Period: May 06 to Oct 24, 2013**


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## Executive Summary

The Lower Bridge River has been dammed for over half a century. Up until 2000, flows down the river were limited to sporadic spill events. In August of 2000, a trial flow release was initiated to allow an annual average flow of 3 cms down the Lower Bridge River. The 3 cms flow release was in place for 10 years. In 2011, the annual flow release was doubled to an average of 6 cms. The 6 cms release was to be implemented for a 10 year period, at the end of which a decision on what flow regime to implement as a long term management strategy was to be decided upon. The BRGMON-11 study is intended to provide information to guide the final flow release decision, based on impacts of the flow regime on the Lower Bridge River riparian vegetation and riverine bird populations.

Riverine bird studies have been conducted on the Lower Bridge River since the pre-flow release era through the Water Use Planning Process, and the independent study is attached to this report. The study area for the riparian vegetation assessment overlaps the area of focus for the riverine bird study, and corresponds to the section of the Lower Bridge River that is most affected by the various flow regimes. In particular, Reach 4 was completely dry before the experimental flow releases were established in 2000.

In order to capture a variety of geomorphic features in our sampling, we stratified the Lower Bridge River into terrain classes, and mapped the study area by vegetation structural stages. Alluvial fans, fluvial, fluvial mid bars, and three types of colluvium sites were studied. Aerial photography was flown on September 2, 2013 to provide high resolution ortho-imagery of the study area. Small scale GIS mapping was carried out, stratifying 125 hectares of the study area into 194 vegetation polygons. Finally, during the late summer and early fall of 2013, 30 permanent transects were established at 15 locations along Reaches 3 and 4 of the Lower Bridge River. It is expected that impacts on vegetation from the shift in flow regimes will be most prevalent immediately above and below the bankfull width of the river. The bankfull width was readily discernable in the field, and corresponded to where the permanent markers for the transect pins were installed.

Most of the Lower Bridge River is steep colluvium with some alluvial fans and fluvial bars. At least 111 taxa of vegetation were recorded in 2013, the most common and frequent species being riparian deciduous tree and shrub species such as paper birch (*Betula papyrifera*), black cottonwood (*Populus balsamifera ssp. trichocarpa*), mountain alder (*Alnus incana*), and willow species (Salix sp.), as well as upland species such as Douglas-fir (*Pseudotsuga menziesii*) and Saskatoon berry (*Amelancier alnifolia*). Only eight annual species of vegetation were recorded in the surveys, and they were mostly weedy exotic species. Perennial plant recruitment was fairly low along the Lower Bridge River, with seedlings of deciduous species limited to few records in the plots around bankfull width, and records of Douglas-fir in the upland plots. Most of the seedling recruitment was in the fluvial and alluvial fan terrain. Colluvium is the dominant terrain class throughout the study area but it had only one record of seedling recruitment. The biomass in the plots above bankfull width was higher than in the plots below bankfull width, particularly in the alluvial fans where there was the greatest amount of herbaceous biomass overall.

There has been evidences of erosion and loss of vegetation along the bankfull edges of the fluvial and alluvial fan terrain, particularly at the Hell Creek fan; but there might also be gains in the riparian vegetation community higher up slope over time with the higher flow regime. If the current flow regime does not continue for 10 years (as originally planned) and changes in 2015,

there will be limited information and statistical power to infer with any certainty that any changes in riparian vegetation are attributable to the shift in flow regime. From a vegetation perspective, it is therefore recommended that the current flow regime continues for the full 10 years. This recommendation is also applicable to the riverine bird component of the study that has an additional four years to study the community at the 6 cms flow regime. It is currently difficult to identify areas where restoration techniques could be carried out to improve the recruitment and development of black cottonwood along the Lower Bridge River. If the regime is maintained at the current 6 cms flow, restoration work on vegetation could be carried out around the Eagle Pond area, located approximately 1.5 km east of Terzaghi dam. The Hell Creek fan is another site with a fair amount of weedy vegetation, where restoration techniques and revegetation could assist with moving this fan towards a cottonwood stand.

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## *1.0 Introduction*

The Lower Bridge River was first dammed in 1947 by the Mission dam, creating the Carpenter Reservoir. Mission dam was enlarged in 1960 and became the Terzaghi dam. It diverts waters through Mission mountain to the Bridge Power generation facilities on Seton Lake (BC Hydro, 2003). Pre-dam flows on the Lower Bridge River were estimated at 101 cms, with an average high water flow of 473 cms; the record high was made in June 1948 at 900 cms (Hall *et al.* 2009). After the construction of Terzaghi dam, the first section of the Lower Bridge River downstream of the dam was typically dry, apart from occasional spillover events, between 1948 through to 2000 (Hall *et al.* 2009). In 1998, BC Hydro and the Federal Department of Fisheries and Oceans (DFO) signed an interim agreement to provide a minimum average annual flow of 3 cms to the Lower Bridge River. That annual flow release started on the 1st of August 2000.

An adaptive management approach to the Lower Bridge River Flow regime was adopted, with the intent of testing a range of average annual flows over a period of time. Initially, four separate flows were to be tested for four years each, beginning with 3 cms, followed by declines to 1 cms, and subsequent increases to 6 cms, and 9 cms (BC Hydro, 2003). After the four years at 3 cms, it was decided to forgo the decline to a level of 1 cms, and the 3 cms level was maintained for a period of 10 years. In May of 2011, the average annual flow was shifted to 6 cms, and will remain at this level until 2015 (BC Hydro, 2011). In 2015, all the information gathered through various monitoring reports will be considered by BC Hydro. In partnership with the Comptroller of Water Rights, provincial and federal fisheries agencies, and the St'at'imc, a decision will then be made for the implementation of a long-term flow release strategy on May 1 2015 (BC Hydro, 2011). The recommended flow release is intended to simulate a naturalized hydrograph, and will be between 3 cms and 6 cms by order of the water Comptroller.

The increase in flow release may have an influence on the riparian vegetation along the Lower Bridge River, with subsequent impacts on wildlife use of the system. The monitoring program BRGMON-11 project intends to document the impacts of changes in flow releases on the riparian vegetation and habitat of the Lower Bridge River. The monitoring program will provide the opportunity to document if, and how, the riparian community is affected by the changes in flow, and will specifically focus on the spatial extent and species composition of vegetation, the relative recruitment of plant species, and the overall relative productivity (biomass) of the riparian community.

This report summarizes the work undertaken on the Lower Bridge River during the late summer/early fall of 2013. The main objective in 2013 was to establish a baseline describing the current conditions along the river, and characteristics of the vegetation in the riparian zone, in order to allow a monitoring of changes over time. Characteristics of the vegetation in 2013 will be compared to the characteristics of the vegetation in 2022 to assess the impacts on the vegetation of changes in the flow releases at the Terzaghi dam.

### *1.1 Study Area*

The Bridge River is divided into three sections by two BC Hydro dams. The Upper Bridge River is in a free flowing section beginning approximately 22 km south-west of La Joie Dam, and is fed by the Bridge Glacier approximately 30 km to the east. La Joie Dam, West of the town of Goldbridge, divides the Upper Bridge River from the Middle Bridge River, and forms Downton Reservoir. The regulated Middle Bridge River flows for approximately 3 km past the town of Goldbridge, before reaching the Carpenter Reservoir. Carpenter Reservoir stretches for approximately 70 km, and is formed by Terzaghi Dam in the East. The Lower Bridge River flows for approximately 39 km, from Terzaghi Dam through the steep canyon slopes of the Bridger River Valley, to its confluence with the Fraser River. The Bridge River enters the Fraser River about 6 km north of the Town of Lillooet at a location that is a very significant to St'at'imc peoples as traditional salmon fishing and drying site.

The Lower Bridge River is further stratified into four reaches based on two tributaries and the historic dry river bed from the influence of Terzaghi Dam (Hall *et al.* 2009). Reach 1 extends 16 km from the Fraser River to Camoo Creek, while Reach 2 extends 8 km from Camoo Creek to the confluence of the Yalakom River. Reach 3 stretches approximately 11 km from the Yalakom River confluence up to Mission Creek, and finally, Reach 4 runs the final 4 km from Mission Creek to Terzaghi Dam (Figure 1). The fifteen kilometers of Reaches 3 and 4 were the target area for sampling the composition, distribution, and biomass of vegetation under BRGMON-11.

The Lower Bridge River is in the Ponderosa Pine very dry hot biogeoclimatic zone (PPxh2) for much of Reaches 1 and 2, with Interior Douglas-fir dry cold (IDFdc) on the north facing slopes of the canyon, and very dry cold on the upper south facing slopes (IDFxc) (Meidinger and Pojar 1991). Reaches 3 and 4 are within the Interior Douglas fir Dry cold (IDFdc) zone.

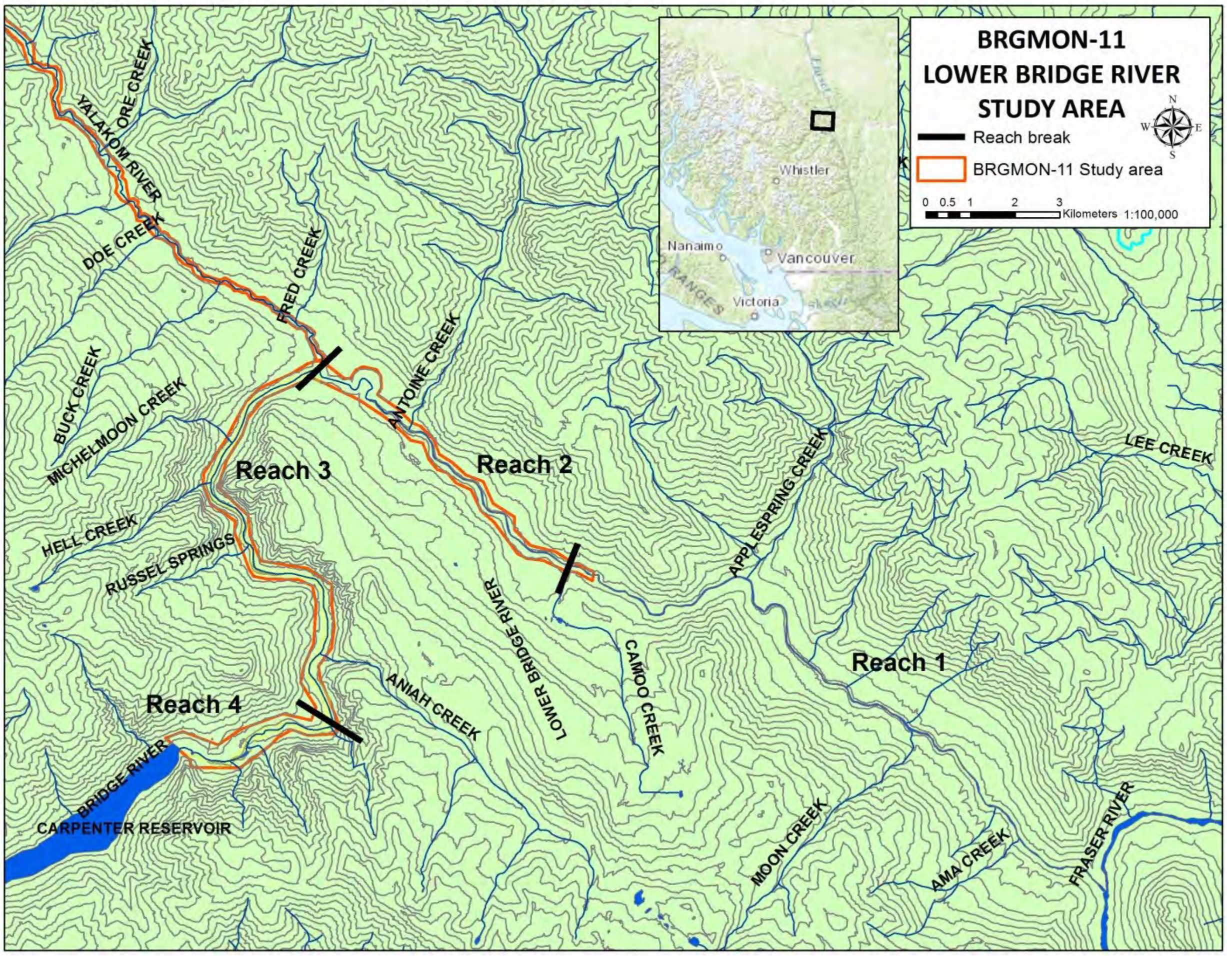


**Figure 1.** **The Lower Bridge River, a section of the Bridge River between Carpenter Reservoir and the Fraser River, in South-Western British Columbia.**

### *1.2 Goals and hypotheses*

The objectives of the BRGMON-11 monitoring program are to document, over time, the impacts of alternate flow regimes from Terzaghi Dam on the composition and productivity of riparian vegetation, and the subsequent population and usage response of Riverine Birds in the Lower Bridge River. The question relating to the riverine birds is dealt with in a separate report (see the attached 'Riverine Bird Response to Habitat Restoration on the Lower Bridge River: 2013 Report', Heinrich and Walton 2013)

The overarching null hypothesis addressed is: there is no relationship between the magnitude of instream flow release and riparian vegetation along the Lower Bridge River.

The sub-hypotheses included in the terms of reference for this Water Use Project were:

$H_1$: The population increase of riverine birds in the Lower Bridge River corridor is directly related to the instream flow release from Terzaghi Dam.

$H_2$: The species composition of the riparian vegetation community in the Lower Bridge River corridor is related to the instream flow release from Terzaghi Dam

$H_3$: The relative productivity (biomass) of the riparian vegetation in the Lower Bridge River corridor is related to the instream flow release from Terzaghi Dam.

$H_4$: The abundance of annual plant species in the Lower Bridge River corridor is related to the instream flow release from Terzaghi Dam.

$H_5$: The relative rate of recruitment of perennial plant species and especially woody plants in the Lower Bridge River corridor is directly related to the instream flow release from Terzaghi Dam.

$H_6$: The rate of growth of perennial plant species in the Lower Bridge River corridor is directly related to the instream flow release from Terzaghi Dam.

The focus of this report is to address Hypothesis $H_2$ through $H_5$. As mentioned, hypothesis $H_1$ is addressed in a separate report (Heinrich and Walton 2013). Hypothesis $H_6$ will be addressed through a separate study using dendrochronology to interpret growth in cottonwood (*Populus balsamifera ssp. trichocarpa*) prior to the annual flow release, and during the 3 cms and the 6 cms flow regimes. The dendrochronology work will be carried out in 2016.

# 2.0 Methods

## *2.1 Air photo interpretation*

Aerial photography of the Lower Bridge River was captured on Sept 2, 2013. Resulting digital air photos and high resolution orthophotography (15cm_pixel) were developed by the Photogrammetry Department of BC Hydro, and received for use in Feb 2014. The aerial photography was captured from Camoo Creek on the lower Bridge River, up to Terzaghi Dam. Imagery of the Yalakom River was also captured, from the confluence with the Bridge River to approximately 13 km upstream (Figure 2). The capture of the air photography was timed with the river being at low levels to sample as much of the river bank as possible; discharge was at 3.06 cms on that day. The aerial photography provides baseline data that will allow mapping the vegetation zones along the Lower Bridge River and the Yalakom River, and monitoring the small scale vegetation change through the course of the project. The imagery of Yalakom River provides a reference with a system where river flows are not controlled, which will allow comparing characteristics of vegetation between a regulated and non-regulated system over time. The imagery will also assist with planning by identifying sites where it will be possible to sample perennial plants to assess the variation in growth rates (in relation to hypothesis $H_{6)}$.

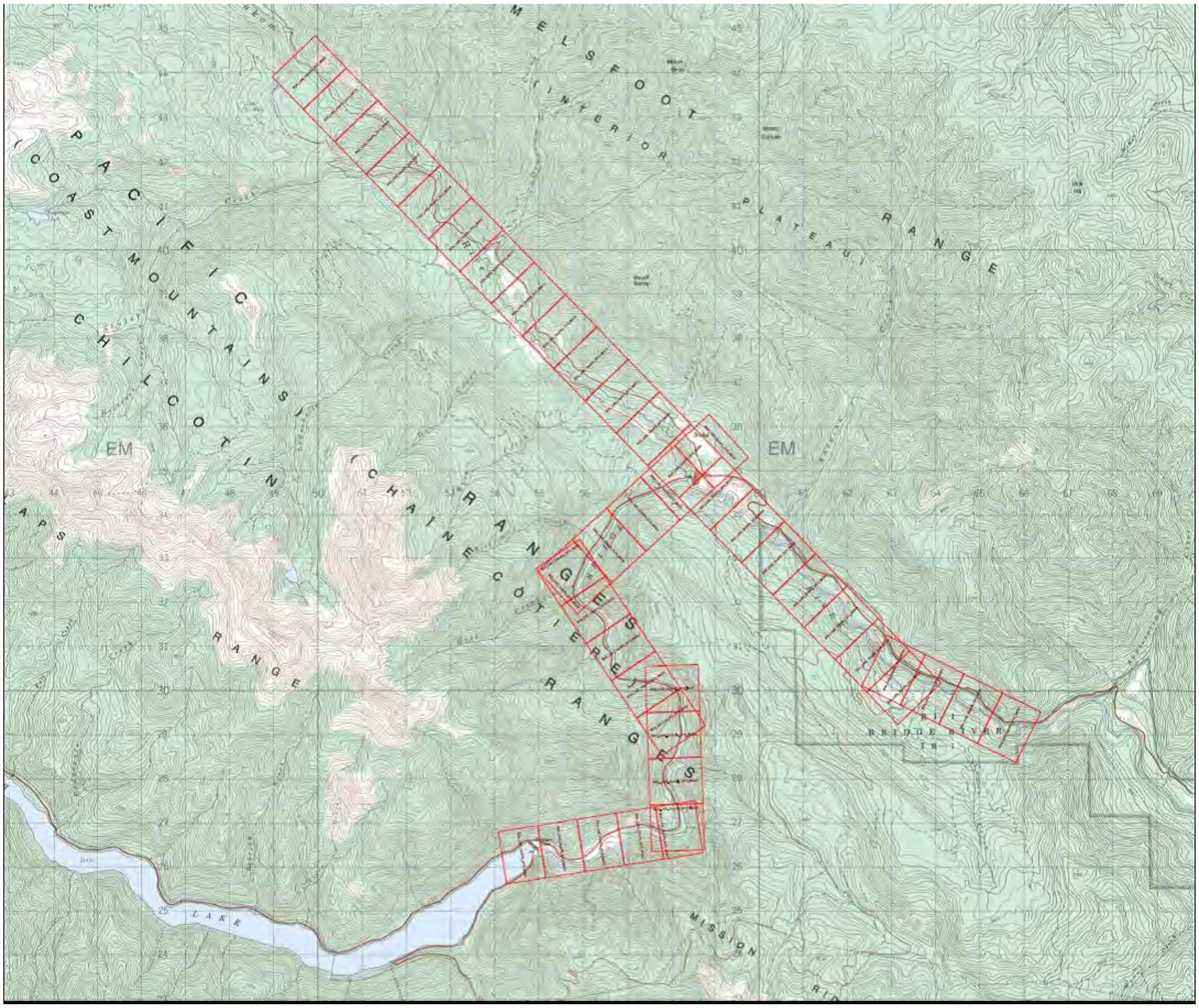


**Figure 2.** **Capture locations of the aerial photography of the Lower Bridge River and Yalakom Valley (Sept 02, 2013).**

Since the post processing of the 2013 flight data was not available until Feb 2014, the planning and initial mapping of the Lower Bridge River was carried out using 1m_pixel ortho-imagery from 2005 in ArcMap10 Geographic Information System (GIS). In August, 1m_pixel ortho-imagery from the June 2013 flight for similar monitoring programs on the Downton and Carpenter reservoirs (BRGMON-2 and BRGMON-5) was provided for the Lower Bridge River. Spatial mapping was initially carried out at a 1:3000 scale using 1_m_pixel imagery, and further refined in February 2014 when 15 cm_pixel imagery from the September 2013 flight was received, allowing mapping down to a 1:1000 scale. Digital elevation data was also available from the Sept 2013 flight.

Polygon delineation was carried out by interpreting geomorphology, and inferring vegetation successional stage. Terrain classes and successional stages were based on the site description of Describing Terrestrial Ecosystems in the Field LMH-25 (BC Ministry of Environment and Ministry of Forests, 2010). Terrain classification was stratified into alluvial fans, colluvium, bedrock, fluvial, and anthropogenic zones. Fluvial sites were further divided into side bars directly connected to the upland, and mid bars that were islands in the river. Structural stage classification is listed in Table 1.

**Table 1. Description of the structural stages of vegetation along the Lower Bridge River, as used for the delineation of polygons in 2013.**

| Structural stages | Description |
|---|---|
| Sparse | <10% vegetation cover |
| Herb | forbs and grasses dominated |
| Shrub Herb | forbs and shrub mix |
| Low Shrub | shrubs < 2m dominated |
| Tall Shrub | shrubs >2 m dominated |
| Young Forest Conifer | forest 30-80 years |
| Young Forest Broadleaf | forest 30-80 years |
| Mature Forest Broadleaf | forest 80-140 years |

The mapping of the riparian ecosystems along the Lower Bridge River was carried out from the Terzaghi Dam in the West, to the Yalakom River confluence to the north-west (Reach 3 and 4, Figure 1). The riparian ecosystem that was considered for mapping ranged from the edge of the water, upslope; the upslope extent of the polygons was drawn to more or less within 30-50 m of the river depending on the site.

## *2.2 Field Methods*

The area targeted to sample the composition, distribution, and biomass of vegetation along the Lower Bridge River was the same area as the one targeted by the aerial photography (i.e. Reaches 3 and 4). It also is the region of study for the riverine bird monitoring component of BRGMON-11 (Heinrich and Walton 2013).

The mapping done in the GIS was used to identify potential sampling areas, based on terrain classes and structural stages. The list of potential polygons chosen for sampling was randomly produced using Geospatial Modeling environment and ArcMap 10. Terrain classes were further selected for sampling based on their abundance in the study area, as well as accessibility and uniqueness on the landscape. A random point generator was used to produce potential sampling locations within polygons (Beyer, H.L. 2012). Field maps with the random point locations were generated in Arc Map10, and points were located in the field using a SXBlue2 GNSS GPS for sub meter accuracy. The precipitous nature of the Lower Bridge River Canyon in the sections sampled impeded GPS reception, and required the occasional use of maps, compass and tape measures to locate random sampling locations.

Fifteen polygons were selected to install thirty permanent monitoring transects recording vegetation characteristics along the Lower Bridge River. Identifying the high water mark levels (5 cms and 16 cms marks), or bankfull widths, for the two annual average flow regimes under study (3 cms and 6 cms, respectively) was important for referencing and monitoring vegetation change along the Lower Bridge River over time. It is predicted that the most direct impacts to vegetation, including erosion and deposition forces, will occur around the new high water mark. Identification of the bankfull width on many streams can often be inferred through a change in substrate as well as vegetation (Leopold, 1994). Below bankfull width, any vegetation is subject to disturbance from river flows, including erosion and deposition forces.

The high water discharge for the 10-year 3 cms regime was just over the flow release of 5 cms (Hall *et al.* 2009). Currently, under the 6 cms flow regime, the bankfull width is approximately 16 cms. By determining in the field the 5 cms and the 16 cms flow elevations, we could identify and sample areas that were above bankfull width under the 3 cms flows, but under high water with the 16 cms flow. It was anticipated that the three years of higher flows under the current 6 cms flow regime would have potentially obscured evidence of the 10-year high water marks formed by 5 cms flow, so it was decided to mark the water level in the field when the flow release was at 5 cms.

For ten days in August 2013, the water flow release for the Lower Bridge River was at 5.16 cms. On August 27$^{th}$ 2013, the 15 sites were selected along the Lower Bridge River, and the edge of the water (therefore at 5 cms) was marked with a metal pin. The intention was to establish our permanent monitoring transects at or near these markers, where we would be able to transfer the pin levels onto the sampling transect, and therefore identify and sample areas knowing their relationship to the bankfull widths at the annual 3 cms and 6 cms. The sites chosen for sampling represented a combination of terrain classes and structural stages (Table 2). No transects were located in the bedrock and anthropogenic terrain classes because of the lack of vegetation in those zones.

**Table 2. Number of transects sampled in each combination of terrain class and structural stage of vegetation.**

| Terrain Class | Structural stage | Number of Transects |
|---|---|---|
| Fluvial mid bar | mixed | 6 |
| Fluvial | tall shrub | 2 |
| Alluvial fan | mixed | 8 |
| Colluvium | Sparse | 4 |
| Colluvium | tall shrub | 8 |
| Colluvium | mature forest | 2 |
| Total | | 30 |

**Figure 3. Example of a high water mark on a boulder along the Lower Bridge River in 2013, for the flow regime of 6 cms.**

Two transects were sampled at each site. The point of commencement (POC) for the first transect was set at the 16 cms high water mark along the river bank. The 16 cms mark was identified with evidence of high water, including erosion marks, vegetation disturbance, and staining on boulders (Figure 3). Once the initial point was established at the bankfull mark, the azimuth was determined in order to run the transect at a 90° angle to water flow. A distance of 10 m was measured with a tape to determine the location of the second transect. The POC for the second transect was positioned at the 16 cms high water mark (10 m upstream of the initial transect); transects were run parallel to each other. A ¼ inch diameter rebar stake was used to permanently mark the transects at the POC (16 cms mark) for repeat monitoring. A reference object (most often a tree or boulder) was identified (and recorded by a GPS) as a feature to help relocate the transects in the future. The distance and azimuth from the reference feature to the starting pin location was also recorded for each transect.

All transects ran up to a vertical elevation of six meters above the POCs at the 16 cms watermark. That distance was chosen as a cutoff as it is the distance at which vegetation characteristics quickly shift from riparian communities to dry upland communities, in the steep canyon and coarse substrates that characterize much of the Lower Bridge River valley. Along each transect, rectangular plots were used to sample the vegetation. Two sizes of plots were used to represent adequately the riparian vegetation: 1m x 2m plots were used to sample at various locations above and below the 16cms bankfull mark, and 2m x 5m plots were used to sample the upland communities. Plots were oriented parallel to the transect if there was at least 2 m between the 16 cms pin and the water's edge, and perpendicular to the transect if the distance to the water was <1m. During sampling, the Lower Bridge River discharge was at 3 cms; in steeper terrain, the number of plots below the bankfull width pin was limited to one plot, while in flatter terrain, several plots could be laid below the bankfull pin and the 5 cms marks, as well as between the 5 cms and the edge of the water. All plots were oriented depending on the width of each band, whether it was the elevation zones around the bankfull marks, or the width of the upland vegetation bands crossed by the transects. Perpendicular plot placement was used when sampling within narrow elevation or vegetation bands, and parallel placement where bands were wide enough to accommodate the plots. Plots were centered within the widths of the bands being sampled. If there was any vegetation growing mid-stream, and if it was in line with the transect, the in-stream bars received additional sampling plots below bankfull pin. The distance between each elevation and vegetation band relative to the transect POC pin was recorded, along with the slope of the terrain and the elevation gain. Chest waders were worn to enable access to mid-stream fluvial bars, and to cross the river to access transects on the right bank of the river.

**Table 3. List of transects, number and type of associated plots (*upland plots were 5X2 m and BBF/ABF plots were 1X2 m). Their location can be found in Appendix 1.**

| Transect | Fluvial bar | BBF 3-5cms | BBF16- | ABF16+ | *Upland | TOTAL |
|---|---|---|---|---|---|---|
| FMB01A | 0 | 2 | 2 | 2 | 1 | 7 |
| FMB01B | 0 | 1 | 2 | 2 | 1 | 6 |
| FMB02A | 1 | 2 | 4 | 4 | 3 | 14 |
| FMB02B | 0 | 2 | 4 | 4 | 3 | 13 |
| FMB03A | 0 | 2 | 2 | 2 | 1 | 7 |
| FMB03B | 0 | 1 | 2 | 2 | 1 | 6 |
| FTS01A | 1 | 1 | 2 | 1 | 4 | 9 |
| FTS01B | 0 | 2 | 2 | 1 | 4 | 9 |
| AF01A | 0 | 0 | 1 | 1 | 2 | 4 |
| AF01B | 0 | 0 | 1 | 1 | 2 | 4 |
| AF02A | 0 | 1 | 1 | 1 | 4 | 7 |
| AF02B | 0 | 1 | 1 | 1 | 4 | 7 |
| AF03A | 0 | 0 | 1 | 1 | 2 | 4 |
| AF03B | 0 | 0 | 1 | 1 | 3 | 5 |
| AF04A | 0 | 0 | 1 | 1 | 3 | 5 |
| Af04B | 0 | 1 | 1 | 1 | 3 | 6 |
| CMF01A | 0 | 1 | 1 | 1 | 3 | 6 |
| CMF01B | 0 | 0 | 1 | 1 | 3 | 5 |
| CS01A | 0 | 0 | 1 | 1 | 2 | 4 |
| CS01B | 0 | 0 | 1 | 1 | 2 | 4 |
| CS02A | 0 | 1 | 1 | 1 | 2 | 5 |
| CS02B | 1 | 0 | 1 | 1 | 2 | 5 |
| CTS01A | 1 | 0 | 1 | 1 | 2 | 5 |
| CTS01B | 1 | 0 | 1 | 1 | 2 | 5 |
| CTS02A | 1 | 0 | 1 | 1 | 3 | 6 |
| CTS02B | 0 | 1 | 1 | 1 | 3 | 6 |
| CTS03A | 2 | 1 | 1 | 1 | 1 | 6 |
| CTS03B | 0 | 1 | 1 | 1 | 1 | 4 |
| CTS04A | 0 | 1 | 1 | 1 | 3 | 6 |
| CTS04B | 0 | 1 | 1 | 1 | 3 | 6 |
| TOTAL | 8 | 23 | 42 | 40 | 73 | 186 |

The number of plots per transect was dictated by the shape of the terrain and the site conditions (Table 3). Fluvial mid bars tended to be the more complex transects, with FMB02 having 14 plots. In that case, the shape of the topography meant that the transect crossed the 16 cms mark at four separate locations, and therefore it had three upland sites and one mid bar to sample. In contrast, the Colluvium Sparse (CS) transects tended to be the more simple ones; they had four plots, one plot above and below the 16cms pin, and two upland plots.

For each plot, data was gathered to describe the plot size, orientation, start and end distance along the transect, slope, substrate cover, soil texture, coarse fragment shape, terrain texture codes, geomorphology, drainage, micro topography, wildlife sign, wildlife species, and growing season water source. The relative elevation (V) of the transect and vegetation bands were determined in the field using slope distance (sd) and angle ($\propto$), following the following formula: V =sd X Sin ($\propto$). In addition to site descriptors, a full list of vegetation was recorded in each plot as outlined in Describing Terrestrial Ecosystems in the Field LMH 25 (BC Ministry of the Environment and Ministry of Forests, 2010). Species of vegetation, as well as the layer of vegetation to which they belong, were noted, as well as percent cover, density, distribution, vigor, utilization by wildlife, and phenology of the generative and vegetative phases of growth. In addition, a densitometer reading was taken at each transect pin location to provide an estimate of canopy cover for each transect.

### *2.3 Photo monitoring*

A photo monitoring point was established for each transect to provide a visual record of change through time. A one meter tall by 0.10 m wide photo board was set at the 16 cms transect POC pin, and oriented towards the river. A tripod and camera were set up directly opposite to the meter board on the opposite bank of the river. The camera was optimally set at one meter high but any variation in lens height was recorded. At least two photos were taken from the photopoint to capture the vegetation surrounding the transect POC, and the surrounding forest canopy (Figure 4). Hand held photos were also taken, from a standing position, of each rectangular vegetation sampling plot (Figure 5). Photos were taken with a Canon Power Shot D20 camera with a 5.0-2.5mm- 1:3.9-4.8 lens.

**Figure 4. Example of a photo monitoring the forest canopy surrounding a transect.**

**Figure 5. Example of hand-held photograph taken of vegetation sampling plots in the Lower Bridge River in 2013. The left image shows a 1x2 m plot, while the image on the right shows a 2x5 m upland plot.**

### 2.4 Biomass productivity

Over a three day period (October 15-17), biomass samples were collected at each transect along the Lower Bridge River. Two 1X1m quadrats were located 3m off the transects to avoid clipping areas that will be monitored again in the final year of the project; one was placed directly above the 16 cms line, and the second one was placed directly below the 16 cms line. Clipped vegetation was placed into durable plastic bags for transport to field vehicle, and then transferred to paper bags for transport to drying room. Biomass was clipped to ground level using scissors, and only herbaceous vegetation was clipped (Figure 6). Quadrats with dense and evenly distributed vegetation were reduced to a size of 1X0.5m to make clipping more manageable; these half plot values were doubled before analysis to harmonize data. Clipped vegetation was dried in paper bags for several weeks until moisture content stabilized at less than 10% and drying in a dehydrator for 24hrs did not change the weight of a sample. Clippings were then weighed to the gram.

**Figure 6. Example of a biomass quadrat before (left) and after (right) the clipping of vegetation.**

### 2.5 Analyses of vegetation characteristics

Four community descriptors (total cover, richness, diversity and evenness of vegetation) were first used to describe the overall vegetation characteristics along the Lower Bridge River in 2013. Total cover was computed by adding up the cover of all species and taxa in a plot, including unknowns and vegetation from all layers. 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 plots, 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 plot.

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

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

If the species are evenly distributed in the plot, 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, plots 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 plots, and therefore that interspecific competition is high (Legendre and Legendre 1998, 2012).

Trends were described among terrain classes and locations of the plots along transects, using graphs and boxplots (when possible). 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, that 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 and location assessed. All plots were included in the boxplots, even though they were of two sizes, to give a general idea of the variation in the system; small and large plots were used separately when any formal statistical tests were done to account for the potential differences in variance due to sizes.

Variation in biomass across terrain classes and locations along transects was also displayed with a boxplot, and differences were statistically tested with unbalanced two-ways analysis of variance (ANOVA), tested with 9999 permutations.

After the overall tendencies in the characteristics of vegetation were assessed, the composition of vegetation was explored in each layer separately, in order to see if different species would occur at the different layers, or if different layers would characterize different terrain classes, or locations along the transects. A combination of figures and boxplots were used to assess variations in total cover for each layer; again, plots of both sizes were included since no formal statistical testing was performed.

The Kendall W analysis of concordance was used to see if given species would be characteristic of locations along the transects (around the bankfull width, or upland locations), or terrain classes. The Kendall W analysis assesses if the species are distributed independently of one another along the Lower Bridge River, 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). That analysis was performed separately for the small (BBF/ABF) plots and the upland plots, given their differences in sizes.

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 plots.

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 (plots) in the diagram (Legendre and Legendre 2012). Scaling was of Type 2 for all the PCAs done, which means that angles between vectors (in black, representing species abundance) 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 plot 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.

Variations in abundance of annual, exotic, and perennial species were assessed with a series of figures and boxplots. PCAs were also performed to assess specifically juveniles of which perennial species were associated with the various terrain classes and plot locations.

The variations in flows in the Lower Bridge River from 2000 to 2013 were represented with a figure.

All analyses were performed in the R language (version 3.0.2).

# 3.0 Results

## 3.1 Air photo interpretation

The initial GIS mapping was carried out using 1m_pixel resolution ortho-imagery, allowing photo interpretation down to approximately 1:3000. These polygons were adjusted with the high resolution 12cm-pixel ortho-imagery which allowed mapping down to 1:1000 (Figure 7). This mapping at relatively fine scale was deemed necessary, as the Lower Bridge River valley is very steep and narrow, and the resultant riparian vegetation forms relatively thin bands that quickly shift to upland habitat (maps of all transects appear in Appendix 1: Locations of transects and plots.).

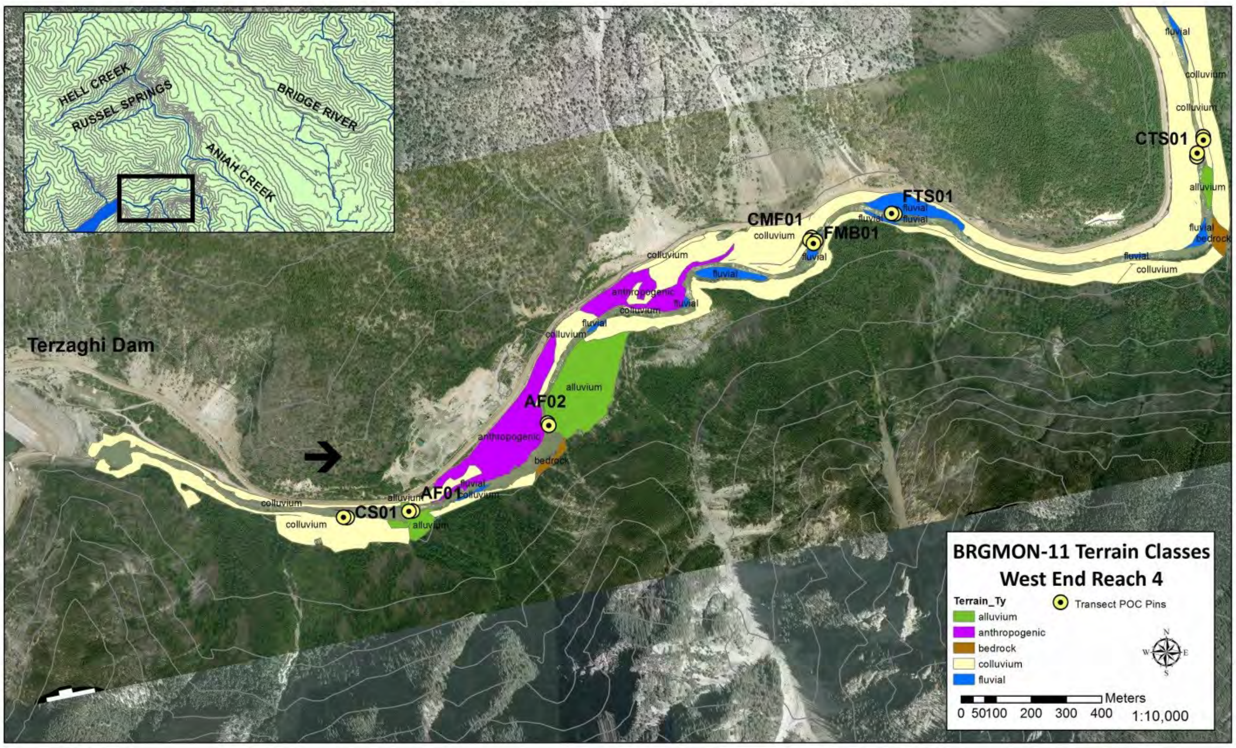


**Figure 7. Classification of the terrain classes in the west end of the Lower Bridge River (Reach 4).**

The Lower Bridge River valley is made of very steep and actively eroding slopes that rise above 30° quickly from the edge of the water. A total of 125 hectares of the riparian and upland communities in Reaches 3 and 4 of the Lower Bridge River was mapped into the five broad terrain classes (fluvial, colluvium, alluvial fans, bedrock and anthropogenic zones; Figure 8) producing 86 polygons. The terrain was primarily colluvium in its geomorphology, and the colluvium terrain class made up 78 per cent of the area (Figure 8). Bedrock covered little with four polygons, making up just over a hectare of the total area mapped. Thirty-eight fluvial polygons were divided into mid bars and river bank sites. Fluvial mid bars composed only 2.6 hectares of the total section of river mapped, and the fluvial river banks made up an additional 7.3 hectares.

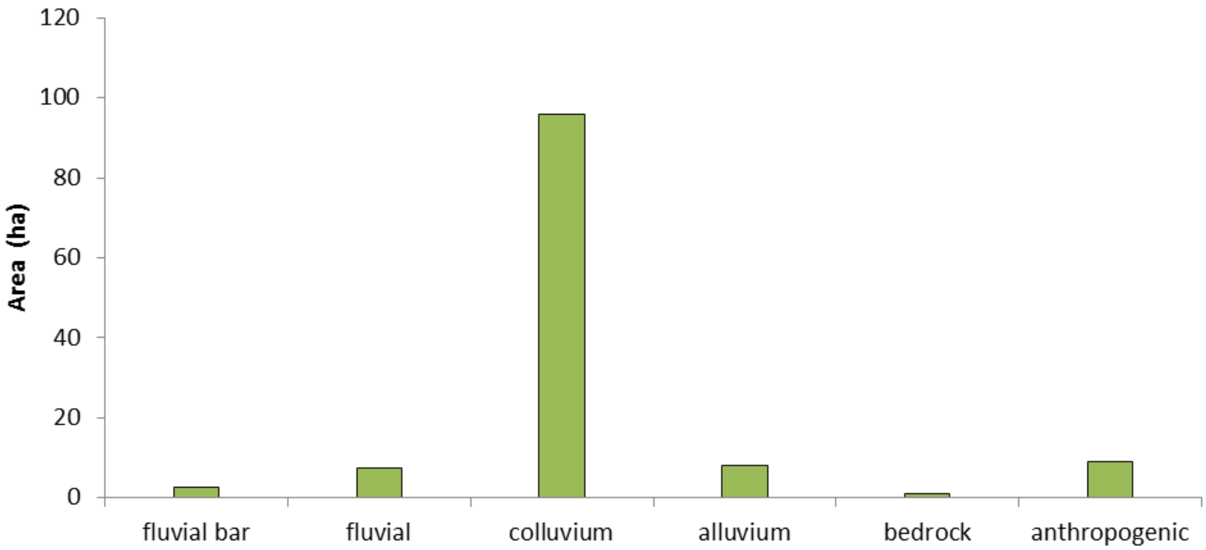


**Figure 8. Area (in hectares) covered by the various terrain classes in the mapped areas of Reaches 3 and 4 in the Lower Bridge River (2013).**

There are, at least, four perennial creeks that feed into the Lower Bridge River over the two reaches mapped (Michelmoon Creek, Hell Creek, Aniah Creek, and Russel Springs). In addition, there are at least five ephemeral creeks that have created alluvial fans by moving materials downstream with their respective flows. Hell Creek is the largest fan, and is located approximately 3.8 km upstream of the confluence with the Yalakom River. The Hell Creek fan was the recent site of a major flow event, and the comparison of the 2005 and 2013 aerial photography highlighted a recent deposition of substrate materials (Figure 9). In total, nine polygons of alluvial fan were identified, covering eight hectares of the mapped area. One large polygon (east of AF02) made up almost half of the total area in alluvium fans (3.6 ha), while five polygons were very small and totaled less than a $10^{th}$ of a hectare.

Finally, seven anthropogenically modified polygons were identified in the study area. The impacts were largely related to past and current mining activities, as well as instream and off channel habitat construction, and highway road side modification. Modified sites totaled just over nine hectares. Several small mining sites were observed throughout the study area, but many were too small to qualify as polygons.

The polygons were further stratified by structural stage of the vegetation communities. Based on air photo interpretation, a total of 194 polygons were identified. Sparsely vegetated zones were the dominant cover type in the study area, and accounted for 52 hectares (41 per cent) of the mapped areas (

Figure 10). Young conifer forest was the second largest type identified, and covered 33.27 ha (26 per cent) of the study area. The conifer forest was dominated by young Douglas-fir (*Pseudotsuga menziesii*), and covered the more upland slopes along the river banks.

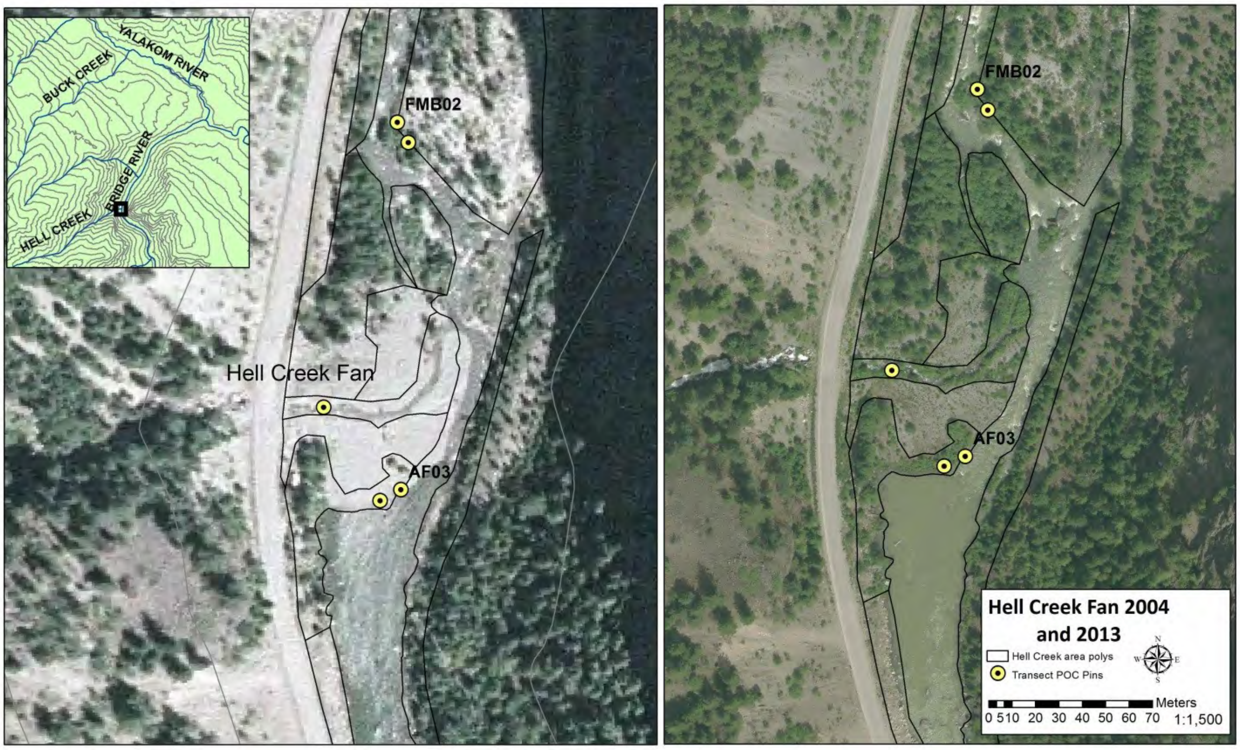


**Figure 9. Imagery of the Hell Creek fan; in 2004 on the left, and in 2013 on the right.**

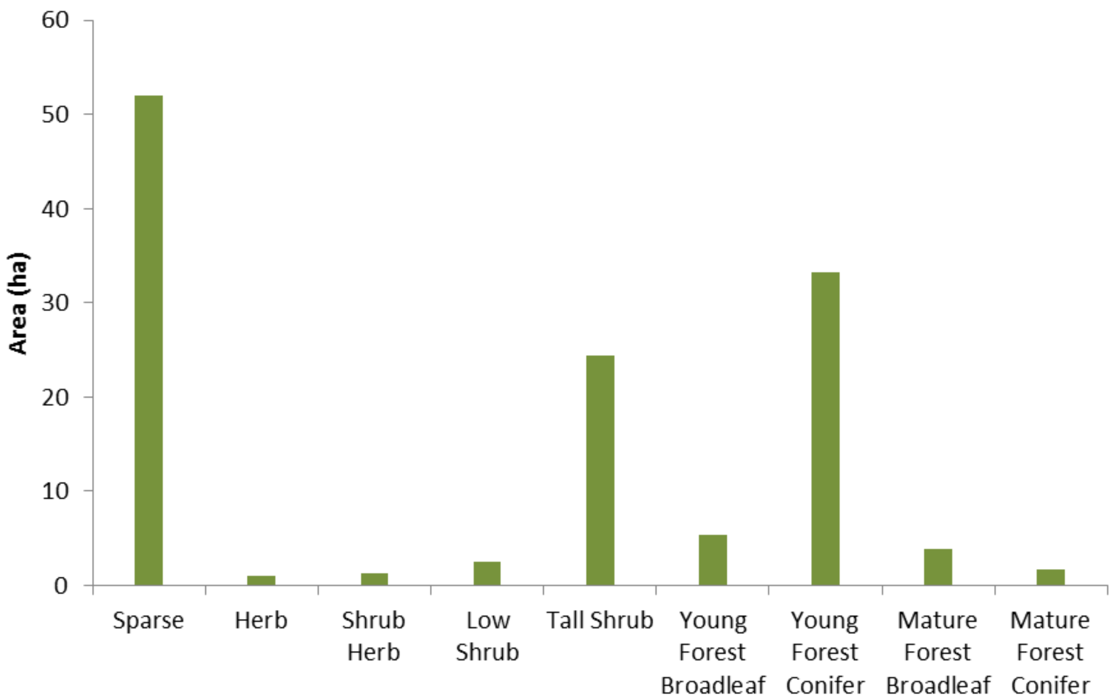


**Figure 10. Area (in hectares) covered by the various structural stages of vegetation in the mapped areas of Reaches 3 and 4 in the Lower Bridge River (2013).**

The tall shrub structural stage was also well represented in the study area, totaling 24.5 hectares (19.5 per cent; Figure 11). It was the most common riparian area as it tended to line the edges of the river throughout most of Reaches 3 and 4. The tall shrubs were a combination of alder species (*Alnus sp*.), birch (*Betula papyrifera*), willow species (*Salix sp*.), and black cottonwood trees (*Populus sp*.).

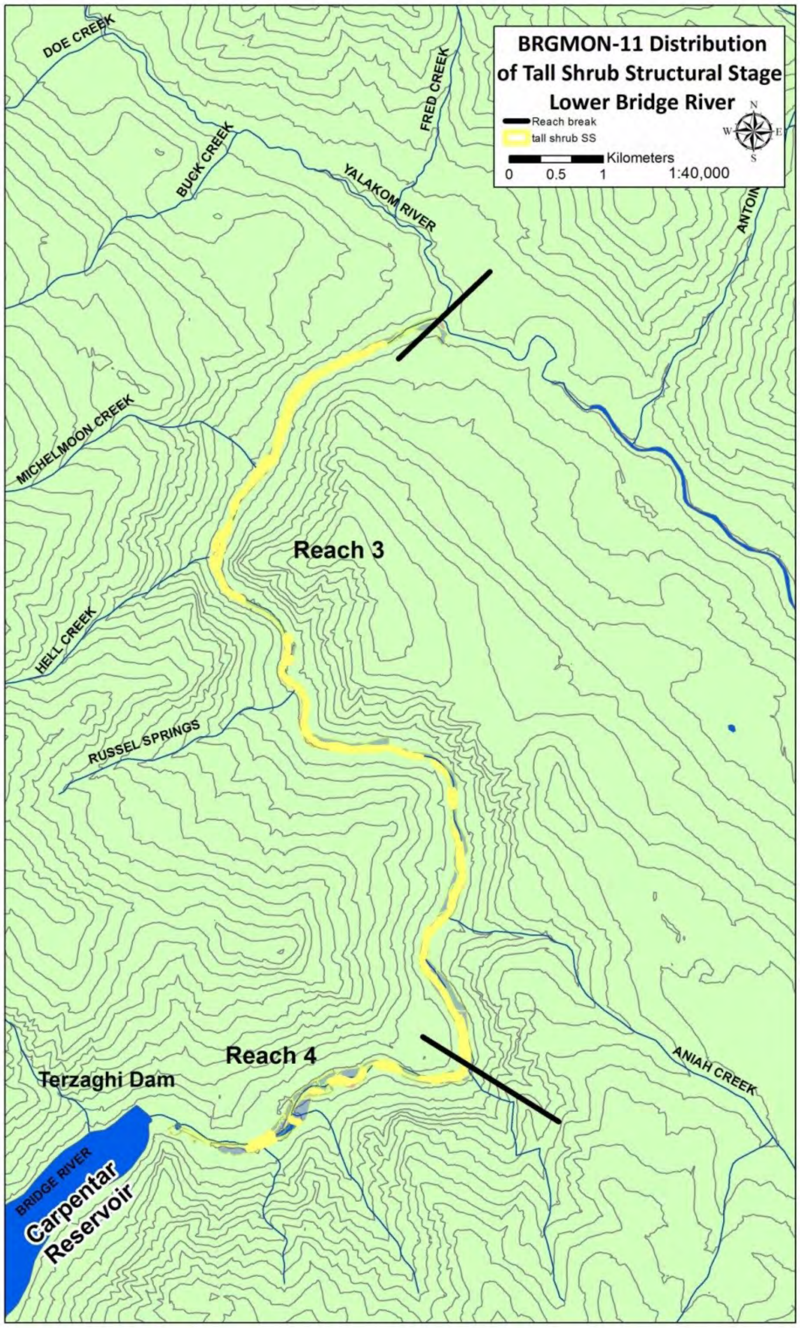


**Figure 11.** **Distribution of the areas covered by the Tall Shrub structural stage on the Lower Bridge River (2013).**

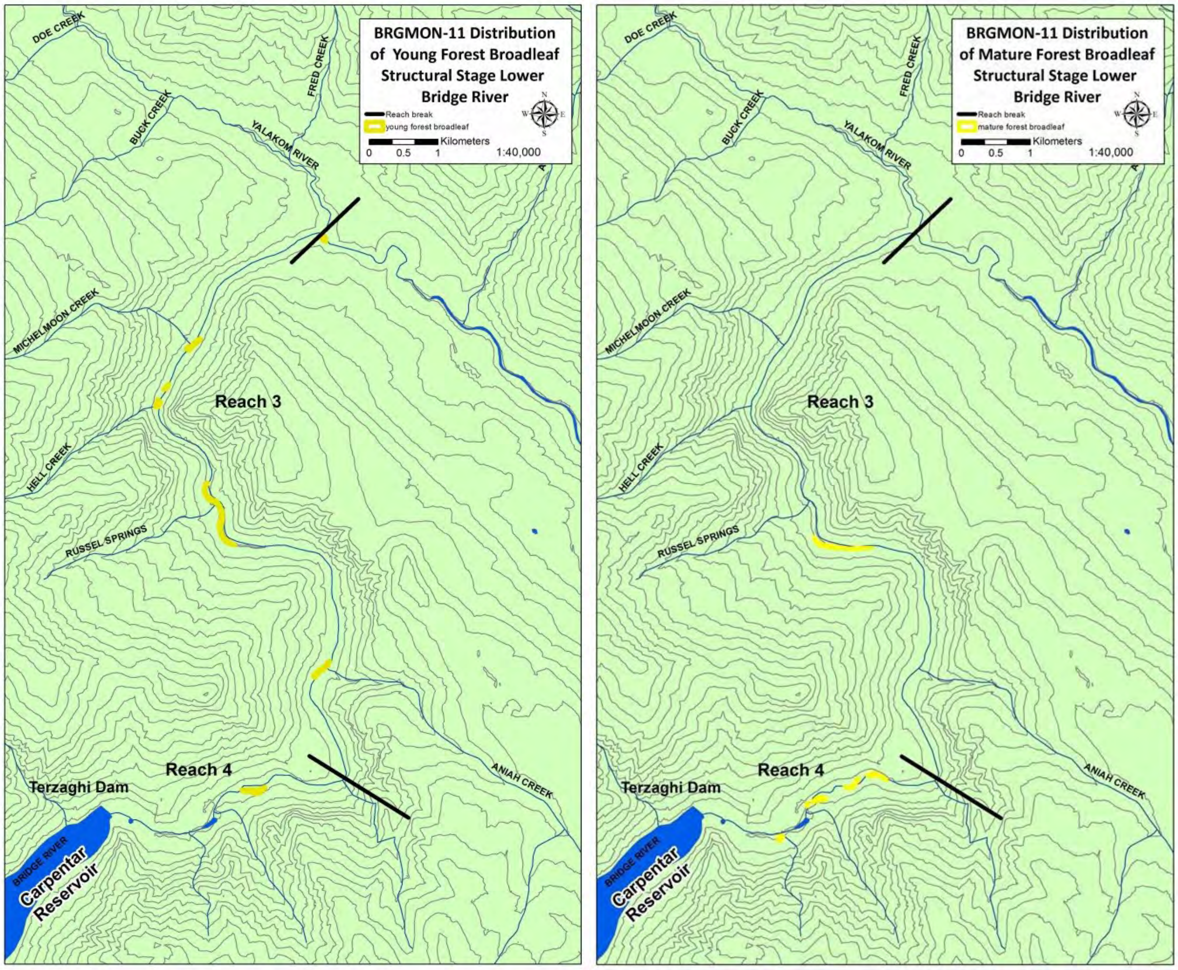


**Figure 12.** **Distribution of two structural stages in 2013 in the Lower Bridge River: Young forest broadleaf of the left and Mature forest broadleaf on the right.**

Young forest broadleaf made up approximately 5.5 ha (4.3%) of the terrain in Reaches 3 and 4 of the Lower Bridge River. The young forest broadleaf polygons tended to be associated with tributary creeks flowing into the Lower Bridge River (Figure 12). Mature forest broadleaf covered 3.8 ha (3%) of the study region (Figure 12). Mature cottonwood trees defined these stands, with the broadest area being south of Russel Springs, where there was a narrow forested band between highway 40 and the Lower Bridge River. Finally, low shrub made up 2.5 ha of the study area, with an additional 1.3 ha of shrub herb, and just under a hectare of herb.

This broad scale classification presents a spatial distribution of the structural stages throughout the Lower Bridge River. In general, there was a change in structural stage as one moved away from the river, with the edges of the river being dominated by deciduous trees, shrubs, herbs, and grasses, while the trend upslope was towards conifer species and a sparser understory. The permanent transects typically sampled more than one structural stage as the transects ran from the edge of the river to the upland communities.

## 3.2 Field Results

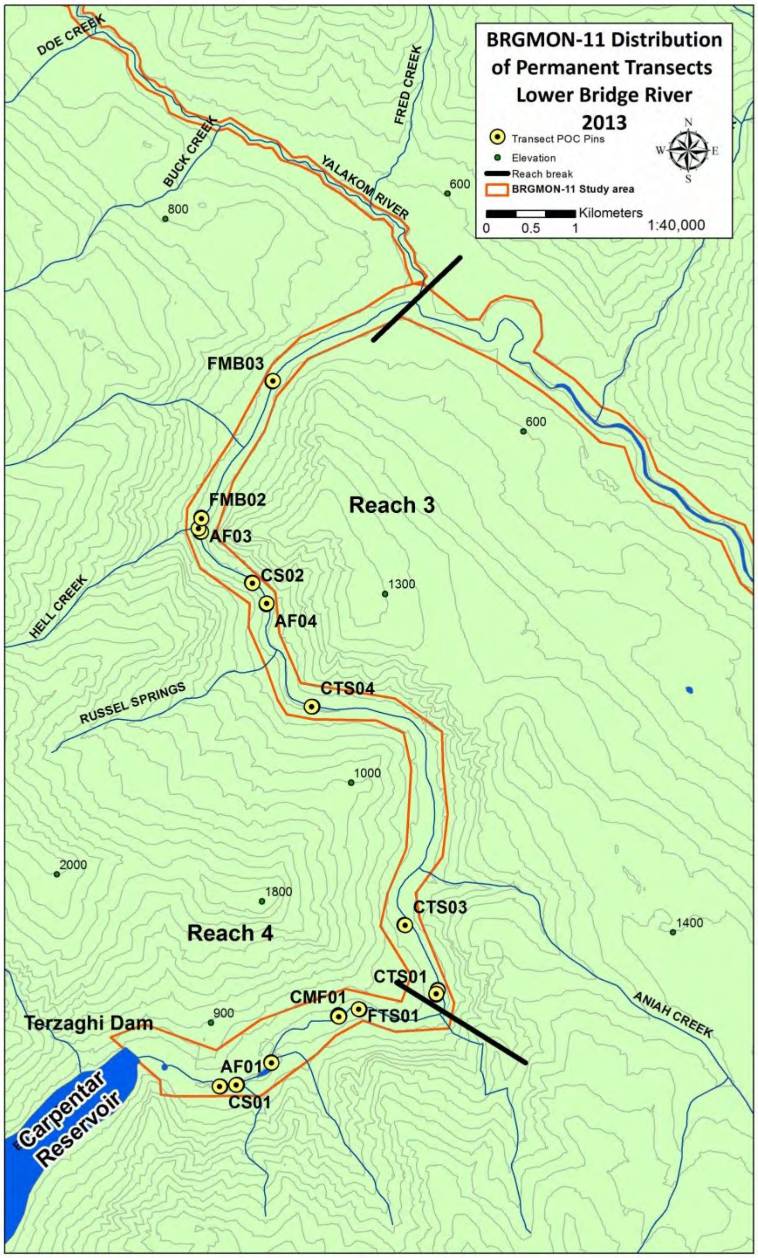


**Figure 13. Locations of the permanent transect along Reaches 3 and 4 of the Lower Bridge River.**

Thirty transects were established throughout Reaches 3 and 4 of the Lower Bridge River in 2013 (Figure 13). A total of 186 plots were sampled in those transects; 110 of these were the small vegetation plots (1m x 2m) centered around the 16 cms bankfull width mark, and 76 were the bigger upland plots (2m x 5m), targeting the more developed and complex vegetation higher up the slope of the river banks (Table 4). Fluvial sites had the longest transects, with an average of eight plots per transect. The majority (75%) of the plots along the fluvial transects were 1X2 m plots. The topography of the fluvial bars created the need to sample a higher number of small plots in the fluvial transects. The river flows on both sides of the fluvial bars at least during bankfull periods, which creates multiple above bankfull (ABF) and below bankfull (BBF) 16 cms sampling sites.

The alluvium sites were sampled with an average of five plots per transect (Table 4), 55 per cent of which were upland plots. That majority of upland plots was the result of the moderate slopes of the fans, which provided for a gradual shift in vegetation communities as slope increased. Colluvium plots were also sampled with an average of five plots per transect, although the transect length was, on average, much shorter than that of the alluvium and fluvial transects. The colluvium transects had 55 per cent of the plots that were smaller plots located around the 16 cms high water mark; less plots were required in the upland area since the slope was steeper slopes in the colluvium terrain.

**Table 4. Summary of the characteristics of the transects sampled in each terrain class in 2013.**

| Terrain class | Transect length (ave, m) | Number of transects | Number of plots | | | Average # plots per transect |
|---|---|---|---|---|---|---|
| | | | Small (1X2m) | Large (2X5m) | Total | |
| Fluvial | 43.63 | 8 | 53 | 18 | 71 | 9 |
| Alluvium | 33.63 | 8 | 19 | 23 | 42 | 5 |
| colluvium | 22.8 | 14 | 41 | 32 | 73 | 5 |
| Total | -- | 30 | 113 | 73 | 186 | -- |

All but eight of the 186 plots had either fragmental or skeletal soils. The extremely coarse nature of the soils contributes to the sharp shift in vegetation community as distance from the river increases, and water becomes a growth limiting factor. Unless there are alternate sources of groundwater, the upslope community is dry Douglas-fir forest. Although many of the most common species in the study were riparian deciduous trees and shrubs, dry upland species (like Douglas-fir and Saskatoon berry) were also very frequent occurrences.

### 3.2.1 Wildlife

Salmon were running in the Lower Bridge River while field work was being carried out in 2013. It was a pink salmon (*Oncorhynchus gorbuscha*) run year, and live and dead salmon were readily observable throughout the study area. Two black bears *(Ursus americanus)* were observed on two separate occasions during the survey; one sighting was of a large adult feeding on salmon carcasses, and the other one was a yearling traversing the right river bank. Many evidences of bear presence were also observed in the form of feces, tracks, and partially eaten salmon. Next to salmon, beaver (*Castor canadensis*) browse and cutting were by far the most common indication of wildlife activity along the study area, and several lodges were observed (Figure 14). A total of 71 plots (38 per cent) had evidence of beaver browse either in, or surrounding the plot.

**Figure 14. Beaver lodges like this one were some of the evidences of wildlife presence observed during the surveys along the Lower Bridge River in 2013.**

Four coyotes (*Canis latrans*) were also observed travelling down the right bank of the Lower Bridge River during the study (Figure 15). Finally, tracks and feces of mule deer (*Odocoileus hemionus*) were observed at six transects.

**Figure 15. Coyotes moving down the Lower Bridge River valley during field surveys in 2013.**

## 3.2.2 Photo Monitoring

All the photo monitoring images from the study are included in the Appendix 3: Photopoint monitoring. It is anticipated that photo points will provide complementary information to field plots and aerial photo interpretation, since they provide another scale at which to assess impacts to vegetation. For example, photos taken at one alluvial fan (AF01) captured dead Douglas-fir saplings in the above bankfull width plots (Figure 16). Also, in several instances, mid bar vegetation was so thick that it obscured much of the meter board (Figure 17). It was decided to avoid cutting the vegetation in those cases, in order to see if the meter board will become more visible over time, or if vegetation cover gets thicker.

**Figure 16.** **Example of a transect in an alluvial fan (AF01A), where at least six Douglas-fir saplings have died within the bankfull width zone.**

**Figure 17.** **Example of a case when the vegetation (Alnus sp) obscured the photo board (fluvial mid bar transect). Note salmon in the river in the foreground.**

### 3.2.3 Biomass productivity

There was more biomass of vegetation sampled in the quadrats clipped above bankfull width, especially in the alluvial fans (Figure 18). The biomass was higher in the plots below bankfull width only in the fluvial terrain. Differences in biomass were statistically significant among terrain classes ($F=7.9$, $p=0.002$), but not among quadrats above and below bankfull width ($p > 0.05$).

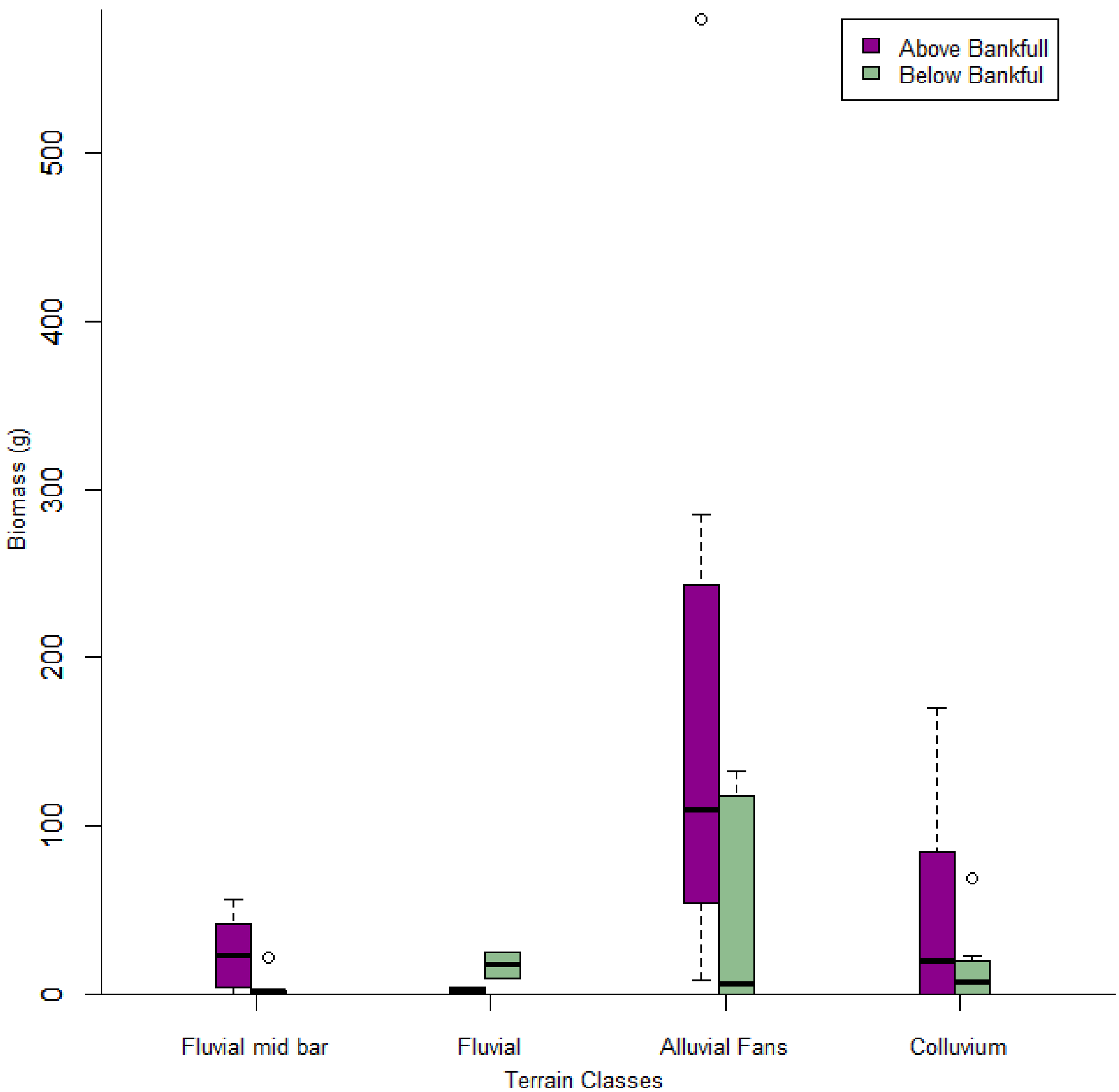


**Figure 18.** **Variation in biomass (g) of vegetation in each terrain class, and above and below the bankfull width, in the Bridge River in 2013.**

### *3.3 Analyses of vegetation characteristics*

#### 3.3.1 Overall description

To explore how the characteristics of vegetation varied based on terrain classes, and location along the transect, all layers of vegetation were considered together at first (Figure 19). For all terrain classes, the highest cover of vegetation was in the upland plots. Cover of vegetation was similar in the below and above bankfull width plots in the fluvial, fluvial mid bars, and colluvium transects, but was smaller below bankfull width in the alluvial fans.

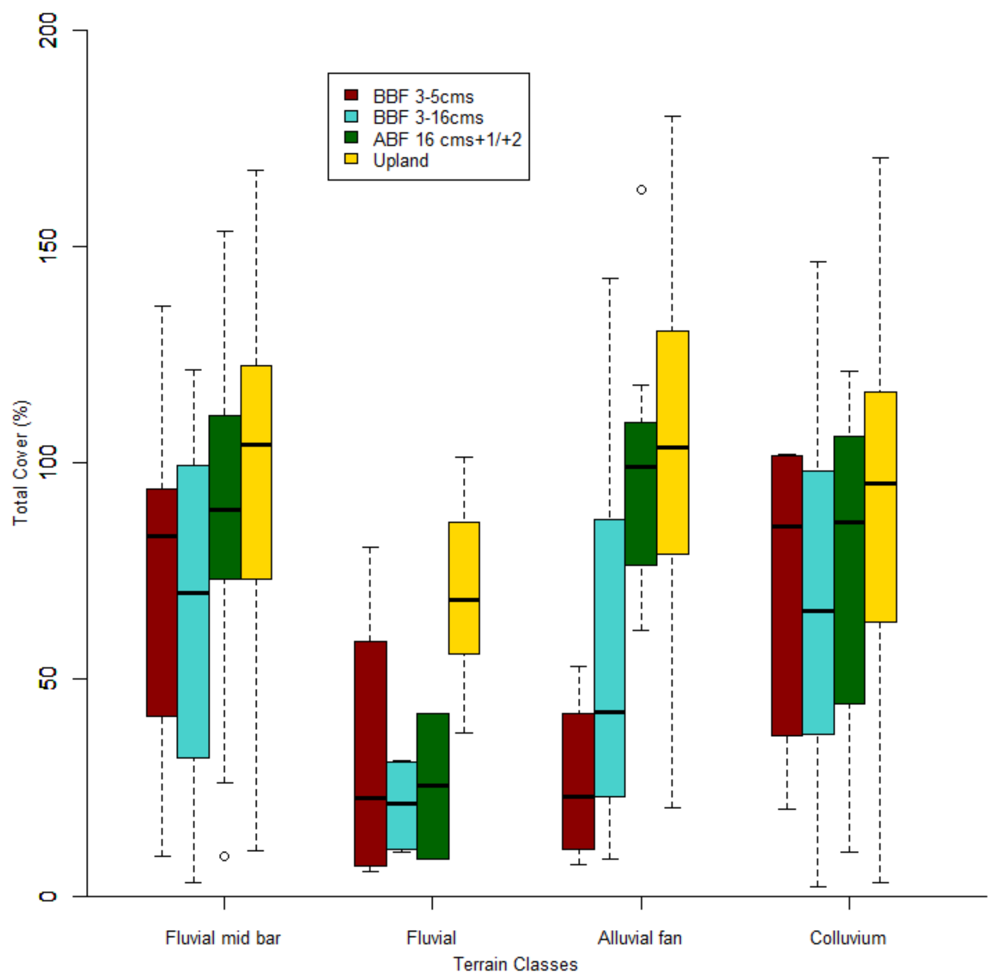


**Figure 19. Variation in cover of vegetation of all layers (%) in the various terrain classes along the Bridge River in 2013.**

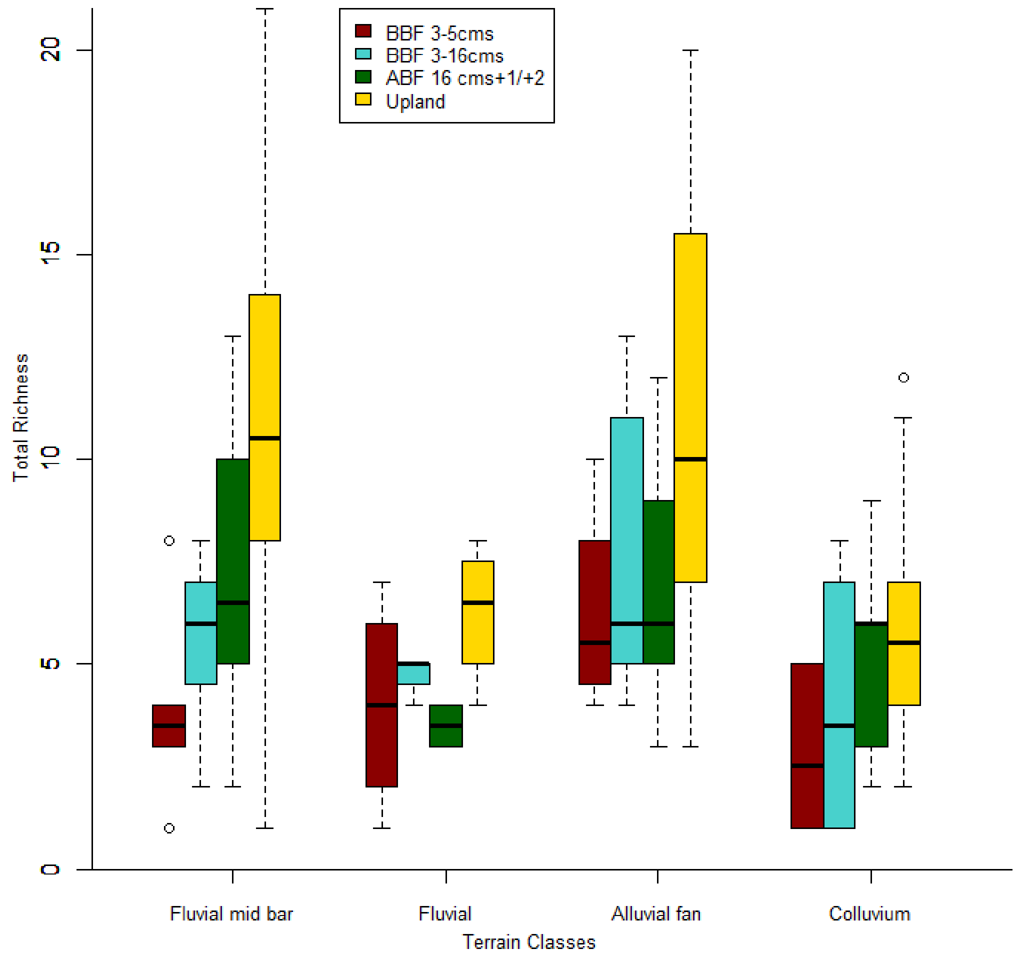


**Figure 20. Variation in richness of vegetation of all layers (# of taxa) in the various terrain classes along the Bridge River in 2013.**

Richness of vegetation was also higher in the upland plots for all terrain classes (Figure 20), which is not surprising given their more complex vegetation, and their distance from water. The richness of vegetation was especially low in the fluvial mid bars below the bankfull width, and in the fluvial transects above the bankfull width. Richness was generally lower in all locations in the colluvium transects.

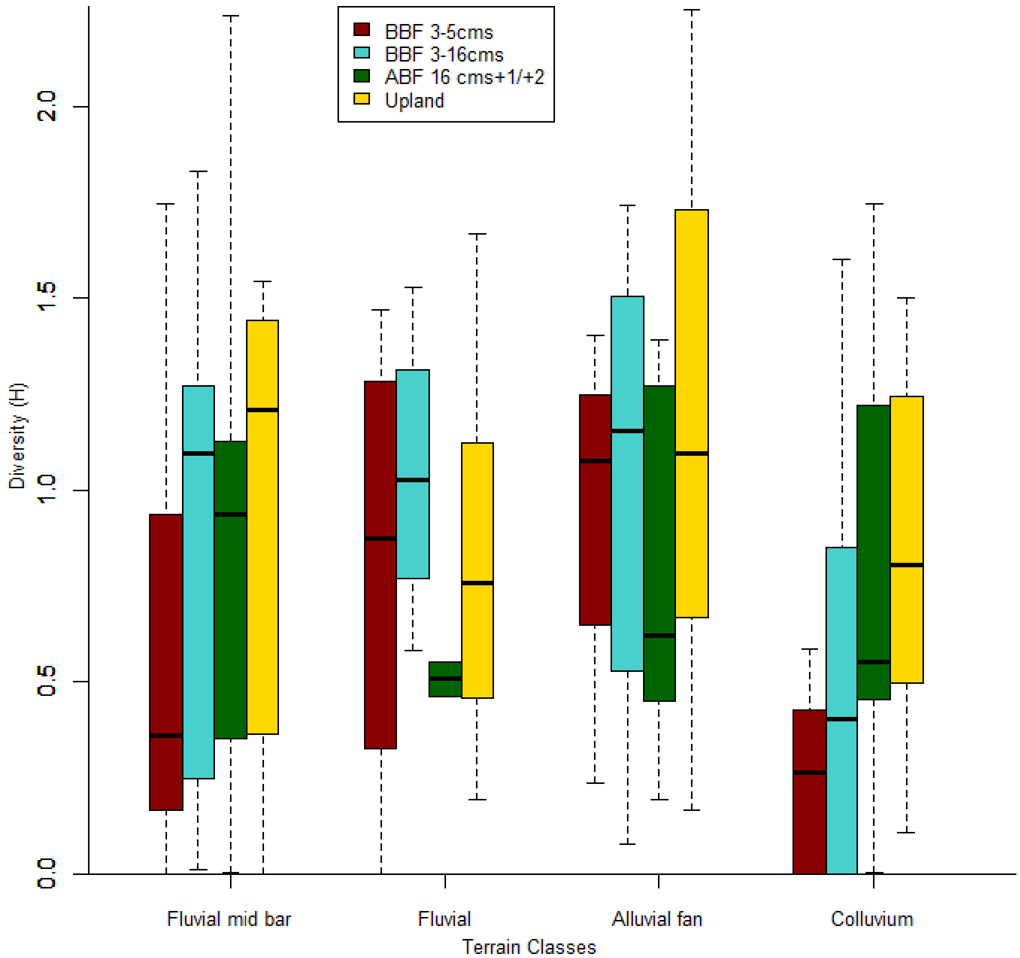


**Figure 21.** **Variation in diversity of vegetation of all layers (H) in the various terrain classes along the Bridge River in 2013.**

Diversity of vegetation was also lower in the plots above the bankfull width in the fluvial transects, and in the plots below the bankfull width at 3-5cms in the colluvium (Figure 21). Diversity was quite variable in the plots of the fluvial mid bars, and not higher in the upland plots, contrary to what was the case for cover and richness.

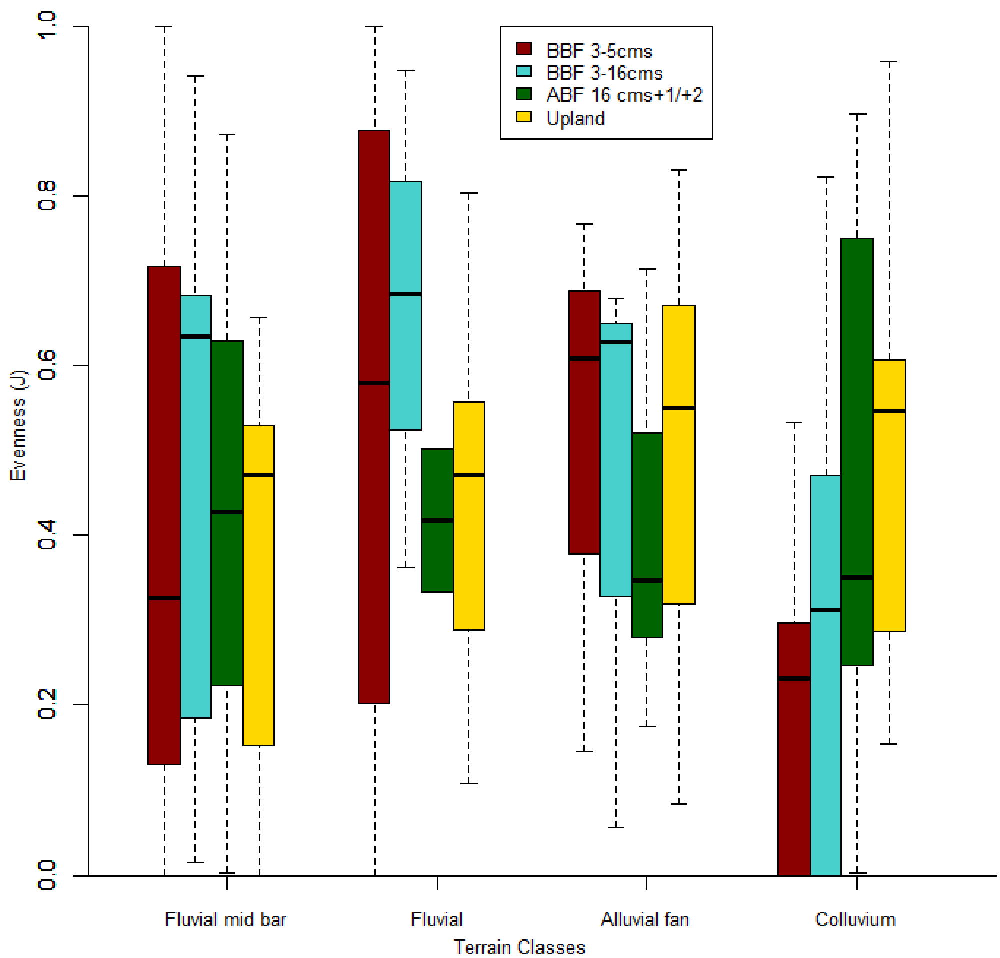


**Figure 22.** **Variation in evenness of vegetation of all layers (J) in the various terrain classes along the Bridge River in 2013.**

Evenness of vegetation was also very variable among plots in the fluvial mid bars, indicating that some plots were dominated by some species, while others had vegetation more evenly distributed (Figure 22). Evenness of vegetation was lower in plots above the bankfull width and upland plots in fluvial transects, while it increased with distance from the edge of water in the colluvium but was rather stable in the alluvial fans.

### 3.3.2 Composition of vegetation by layers

Mature trees of only two species were sampled, and only in the alluvial fans and the colluviums. They were noted mostly in the upland plots, although some mature trees were also seen above and below the bankfull width in some colluviums (Figure 23). Seven of the mature trees were black cottonwood (*Populus balsamifera*, POPUBAL), and five of them were Douglas-fir (PSEUMEN). Overall, a limited number of plots had mature trees (12 plots out of 186).

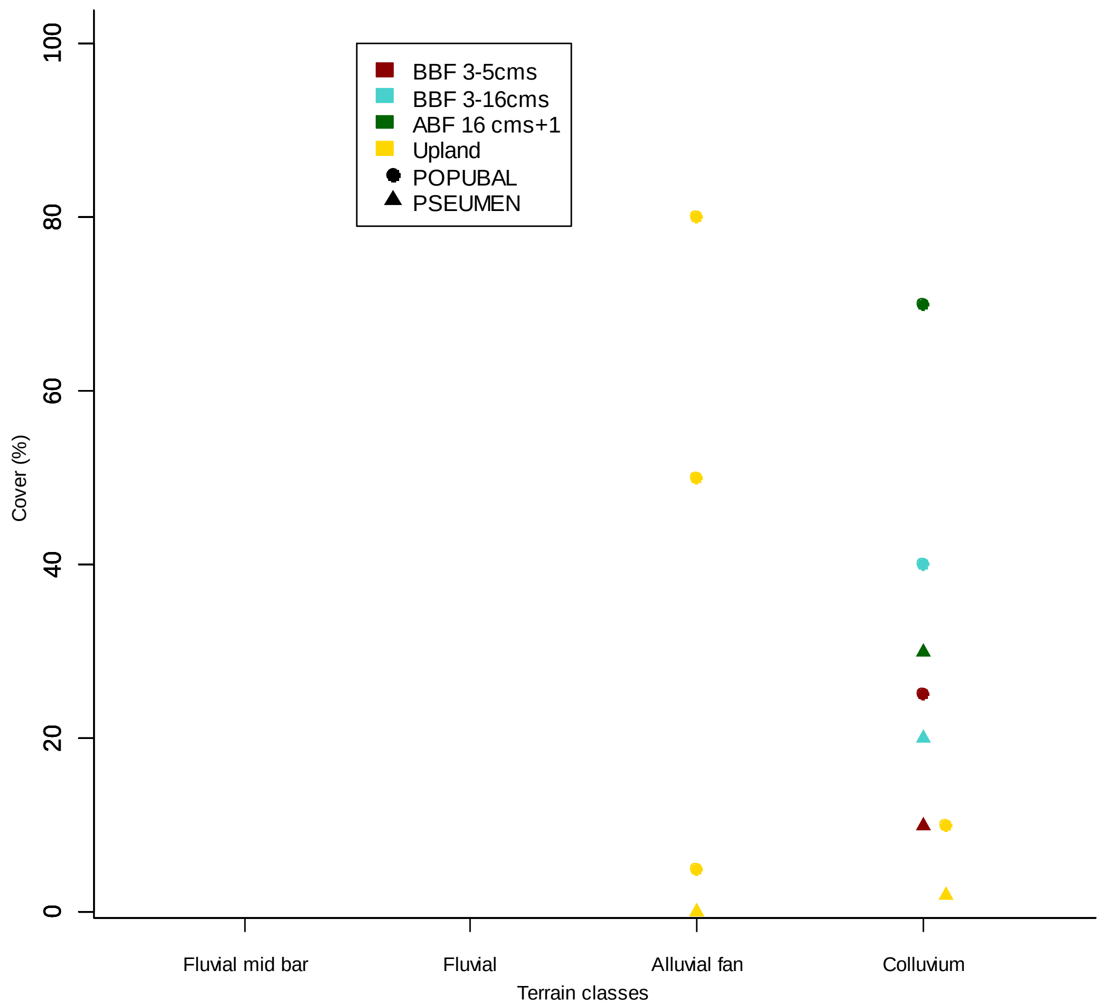


**Figure 23. Variation in cover of mature trees (%, A1 layer) in the various terrain classes along the Lower Bridge River in 2013. Colors represent the location of the plots in the upland, and above (ABF) and below the bankfull width (BBF), while symbols represent the tree species (POPUBAL or PSEUMEN).**

There were more trees of the layers A2-A3 in the upland plots of all terrain classes than closer to the bankfull width mark (Figure 24). Trees appeared below the bankfull width mostly in the fluvial mid bars, while, apart from trees in the upland plots, the fluvial plots and the alluvial fans had only one occurrence of black cottonwood above the bankfull width and below the bankfull width (respectively). Only two occurrences of western redcedar (*Thuja plicata*, THUJPLI) were noted, one in the upland zone of fluvial transect, and one in a plot above bankfull width in a colluvium. Fluvial mid bars had high cover (> 70%) of paper birch (*Betula papyrifera*, BETUPAP) and black cottonwood in plots above and below bankfull width, while black cottonwood and Douglas-fir were the species with the highest covers in the alluvial fans and colluvium.

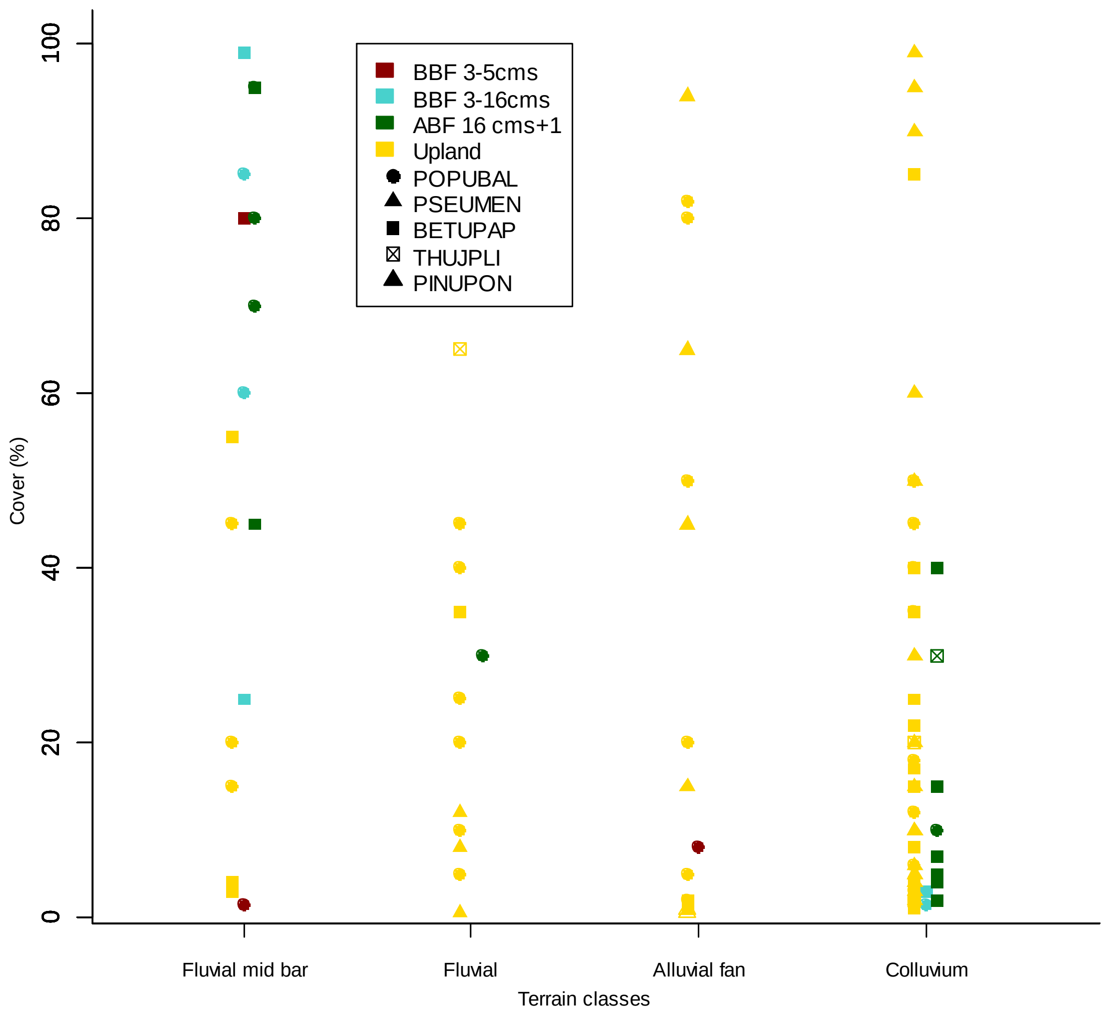


**Figure 24.** **Variation in cover of trees (%, A2-A3 layers) in the various terrain classes along the Bridge River in 2013. Colors represent the location of the plots in the upland, and above (ABF) and below the bankfull width (BBF), while symbols represent the tree species (POPUBAL, PSEUMEN, BETUPAP, THUJPLI, PINUPON).**

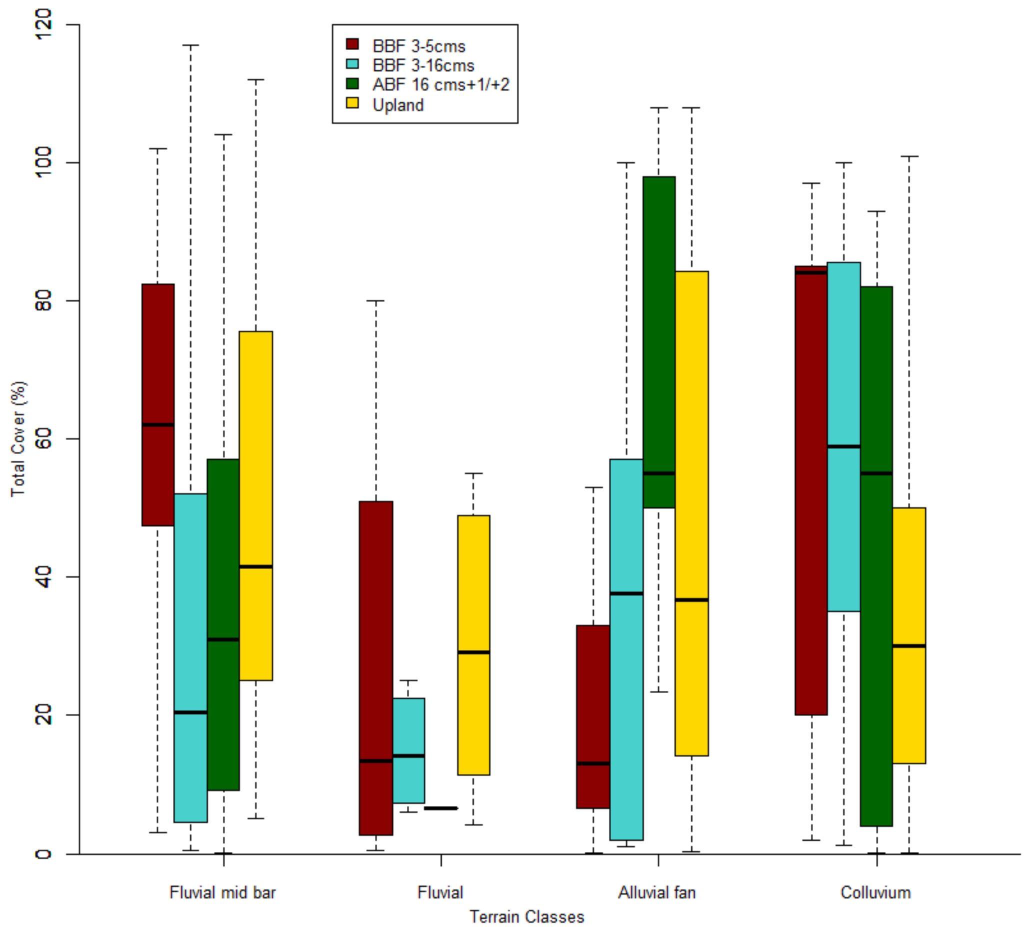


**Figure 25. Variation in cover of vegetation in the B layer (%, B1 and B2) in the various terrain classes along the Bridge River in 2013.**

A total of 24 species composed the B layer, of which ACERGLA, ALNUCRI, ALNUINC, AMELALN, BETUPAP, CORNSTO, POPUBAL, PSEUMEN, RUBUIDA, SALIX, SHEPCAN, and THUJPLI were the most abundant taxa (see Appendix 2 for the species codes). The cover of vegetation in the B layer (B1 and B2 combined) varied greatly among plots, terrain classes, and location (Figure 25). Vegetation in the B layer was generally lower in the fluvial terrain, while it was highest, generally, in the plots above the bankfull width in the alluvial fans. Surprisingly, cover in the B layer was also high in plots below bankfull width in fluvial mid bars, compared to the other locations in that terrain. Colluvium also had lower cover of vegetation of the B layer in the upland plots compared to the other plots location in that terrain; that terrain however had high cover, generally, in the A2-A3 layers (Figure 24).

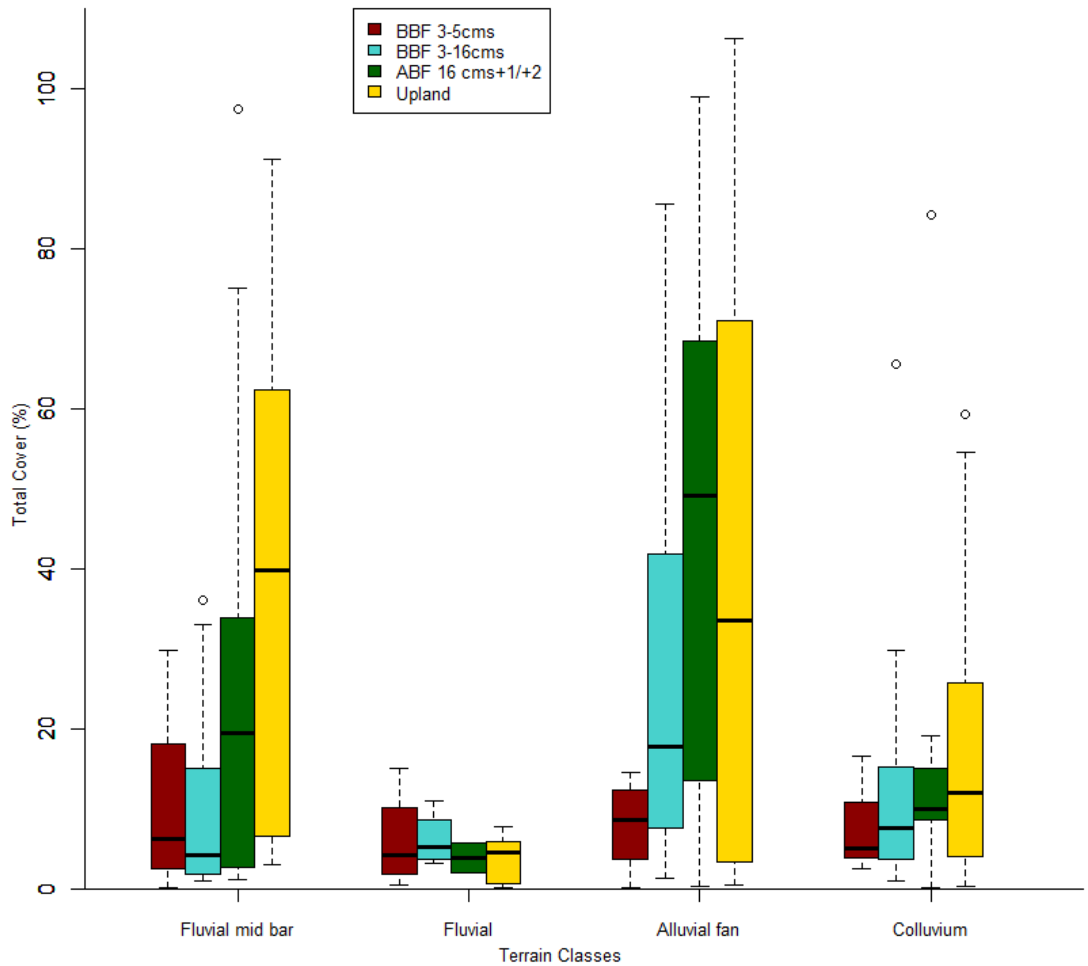


**Figure 26.** **Variation in cover of vegetation in the herb and grass layer (%) in the various terrain classes along the Bridge River in 2013.**

The cover of vegetation in the herb and grass layer was very low in the fluvial plots, low in the colluvium terrain, and low in the plots below the bankfull width in the fluvial mid bars (Figure 26). The plots above the bankfull width in the alluvial fans had generally the highest cover of herbs and grass, while the upland plots in the fluvial mid bars and the alluvial fans varied greatly (between ~1% to over 80%).

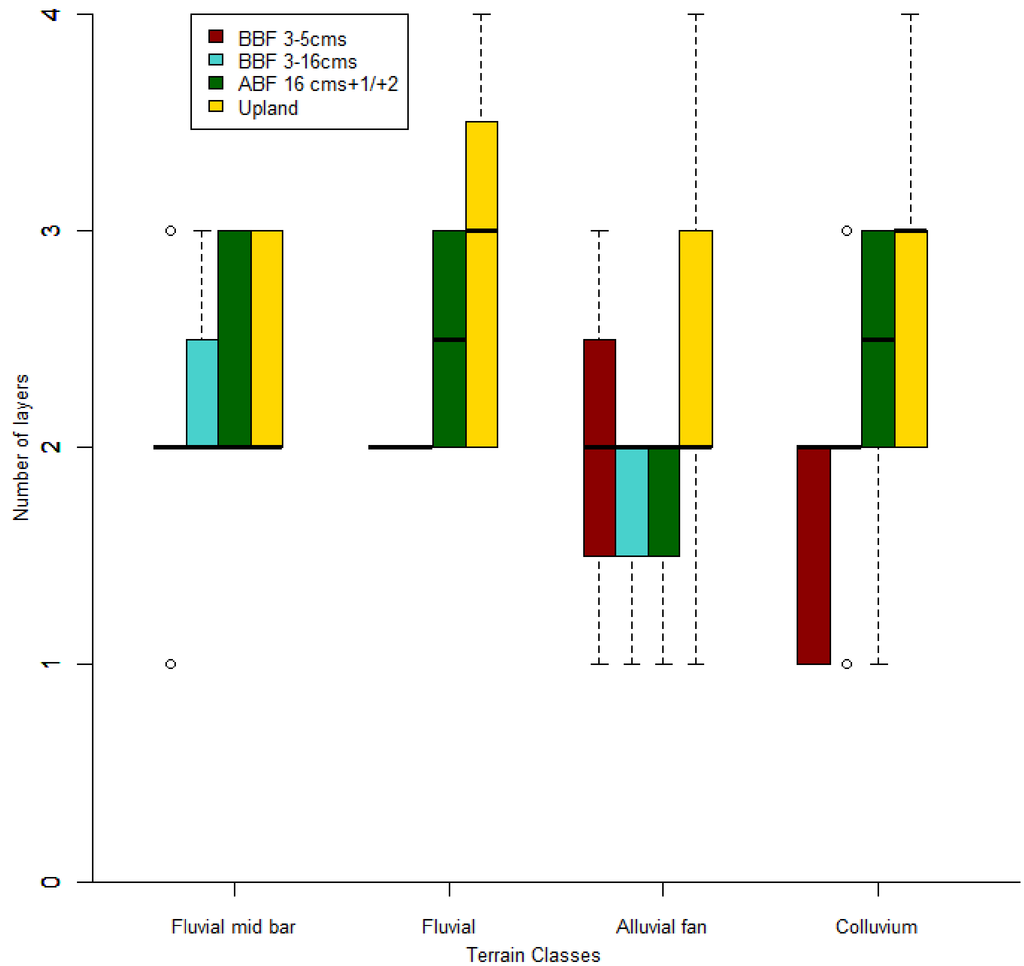


**Figure 27.** **Number of vegetation layers per plot in the various terrain classes and locations along the Bridge River, in 2013.**

Most plots had between two and three layers of vegetation (Figure 27); in the fluvial mid bars, fluvial, and alluvial fans, vegetation was mostly of the herb/grass and B layers. In the colluvium plots however, they was more presence of vegetation at the A2-A3 layers. The only times there was vegetation of the four layers were in the upland plots of fluvial, alluvial, and colluvium terrain. Plots below the bankfull width had generally less layers of vegetation.

### 3.3.3 Variation in species composition

There was a minimum of 111 taxa of vegetation sampled along the Lower Bridge River in 2013 (minimum since some individuals were identified only to genius, and therefore could be of different species). The majority of species (58 species, 52% of total) were sampled in less than 2% of the plots, while two taxa were seen in more than half of the plots (paper birch, sampled in 54% of the plots, and moss, present in 68% of the plots; Table 5).

**Table 5. Frequency (in numbers and per cent) of the various species and taxa in the plots sampled in 2013 along the Lower Bridge River (n=186 plots). See Appendix 2 for the full species names.**

| Species/ taxa | Frequency (#) | Frequency (%) |
|---|---|---|
| Moss | 126 | 68 |
| BETUPAP | 100 | 54 |
| PSEUMEN | 83 | 45 |
| POPUBAL | 80 | 43 |
| POA COM | 79 | 42 |
| ALNUINC | 45 | 24 |
| POA PAL | 43 | 23 |
| LACTMUR | 40 | 22 |
| AMELALN, SALIX | 38 | 20 |
| ACHIMIL | 37 | 20 |
| ELYMGLA | 35 | 19 |
| ELYMTRA | 32 | 17 |
| ARTEMIC | 29 | 16 |
| ACERGLA, TARAOFF | 27 | 15 |
| ALNUCRI | 25 | 13 |
| EPILCIL | 24 | 13 |
| AGROGIG, EQUIARV, Lichens | 21 | 11 |
| CENTDIF, RUBUIDA | 19 | 10 |
| LACTSER, RORIPAL, THUJPLI | 18 | 10 |
| CIRSARV | 16 | 9 |
| MELIALB | 14 | 8 |
| DACTGLO, RUMECRI, VERBTHA | 13 | 7 |
| DRYADRU, PENSFRU, SHEPCAN, TRAGDUB | 12 | 6 |
| CORNSTO | 11 | 6 |
| EPILANG | 10 | 5 |
| ARCTLAP, CICUDOU, MEDISAT | 9 | 5 |
| CIRSVUL, PHELPRA, ROSAACI | 8 | 4 |
| SPIRBET | 7 | 4 |
| EQUILAE, FESTUCA, FRAGVIR | 6 | 3 |
| FESTOCC, GOODOBL, LINAVUL, PHACHAS, SOLISPA, TRIFOLI | 4 | 2 |
| AGROCRI, ARABHOE, BROMTEC, CARDOLI, CHENALB, CHIMUMB, CREPATR, HIERUMB, JUNICOM, LINAGEN, LYGOJUN, PINUPON, POPUTRE, PRUNPEN, RIBELAC, RUBUPAR | 3 | 1.6 |
| ANTENA, BROMINE, CALACAN, GALITRI, HEUCCYL, PLANMAJ, SYMPALB | 2 | 1.1 |
| ABIELAS, ANENMUL, AQUIFOR, ARCTUVA, ARTELUD, ASTER, BROMCIL, CENTBIE, EPILOBIUM, EQUIPAL, ERIGER, GAILARI, HEIRACI, HEIRGRA, HOLODIC, LEUCVUL, MEDILUP, ORTHSEC, PERSMAC, PHILLEW, PICEGLA, PINUCON, POA PRA, POLEPUL, PROSTRA, PSEUSPI, PYROASA, RANUAQU, SALILAS, SELAWAL, SOLICAN, TANAVUL, TRIFPRA, VEROAME, VIOLGLA | 1 | 0.5 |

A total of 43 species and taxa of vegetation were included in the Kendall W concordance analysis when only the plots right above and below the bankfull width were included (those that were present in at least three transects).

The overall test of concordance was significant (W=0.04 p=0.0001), suggesting that at least some species among those 43 were significantly found together. The K-means analyses suggested that species were partitioned along two main groups. Each group further had significant associations of species (Group 1: W = 0.203, p=0.0001; Group 2: W = 0.057, p=0.0001). Eight species (AGROGIG, CHENALB, CIRSARV, EQUIARV, MEDISAT, PHELPRA, RORIPAL, and RUMECRI) were significantly associated to each other in Group 1, and seven species (ACHIMIL, ARTEMIC, CENTDIFF, EPILCIL, LACTMUR, MELIALB, and POA PAL) were significantly associated in Group 2 (Figure 28).

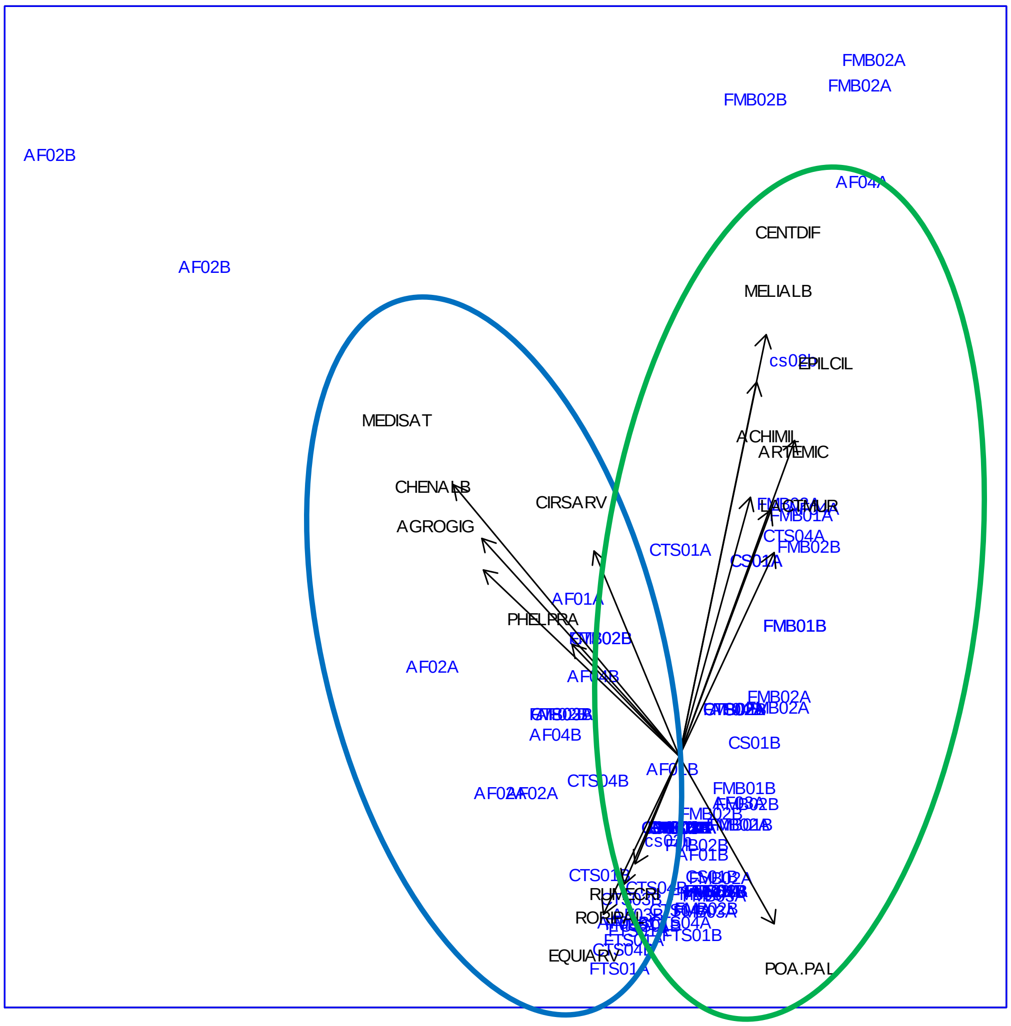


**Figure 28.** **PCA diagram showing relationships between the 15 concordant species over the 110 plots above and below the bankfull width along the Lower Bridge River in 2013. Axis 1 explains 14% of the variation in species cover, and axis 2, 11.5%. The blue ellipse encompasses the species belonging 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 2. Plots are labelled with the terrain classes to which they belonged; AF stands for alluvial fans, FMB for fluvial mid bars, CTS and CS for colluvium, and FTS for fluvial transects.**

Each group was more closely associated to some plots. For example, the AF02B BBF 3-5cms and BBF 5-16cms plots were driving much of the variation in Group 1, along with most of the other plots located in the alluvial fans. Some species in Group 1 (EQUIARV, RORIPAL, and RUMECRI) were found with higher covers in most of the colluvium plots, while most of the species of Group 2 seem characteristics of the fluvial mid bars. The location above (ABF) or below (BBF) the bankfull width did not seem to influence the composition in species (Figure 29).

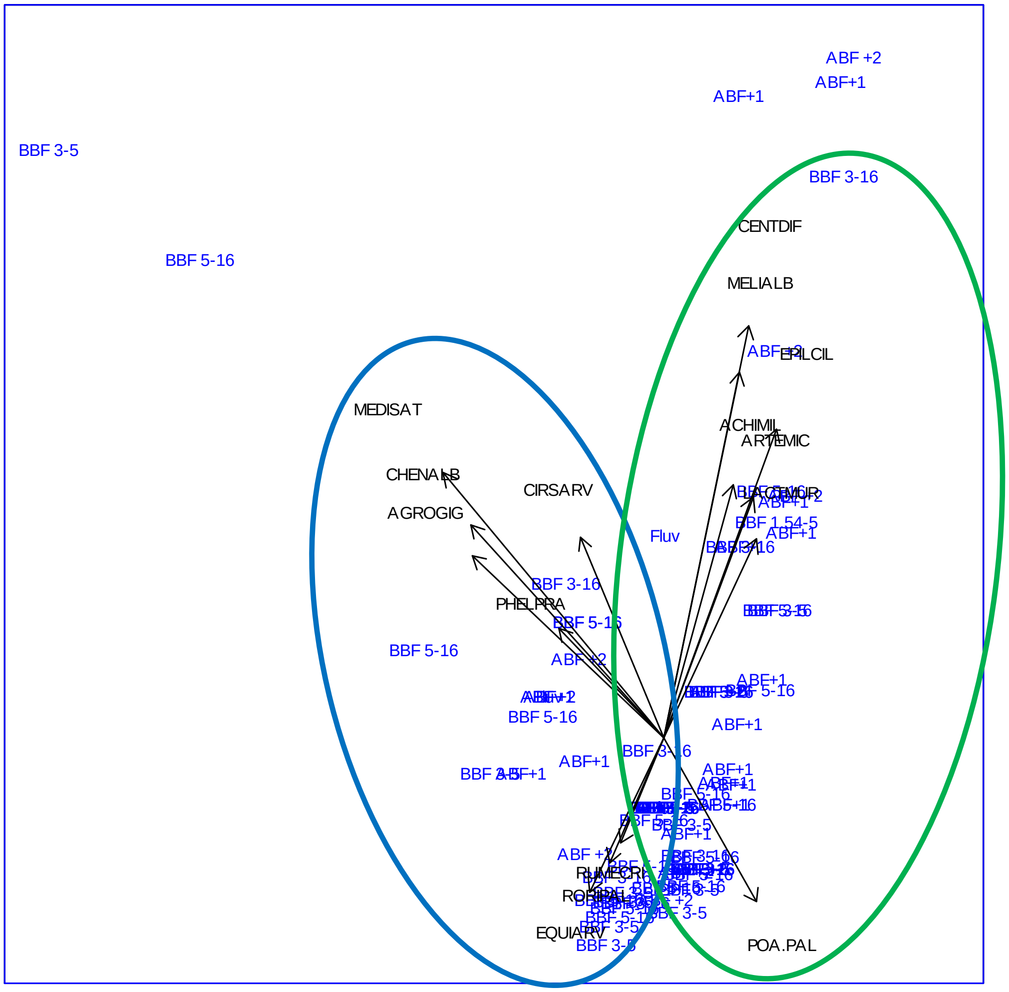


**Figure 29.** **PCA diagram showing relationships between the 15 concordant species over the 110 plots above and below the bankfull width along the Lower Bridge River in 2013. Axis 1 explains 14% of the variation in species cover, and axis 2, 11.5%. The blue ellipse encompasses the species belonging 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 2. Plots are labelled by their location above (ABF) and below (BBF) the bankfull width.**

Different species were found to be significant when the plots included were higher up from the edge of the water, i.e. using the upland plots. This time, a total of 54 species and taxa were included in the analysis; again those were the ones seen in at least three plots. The overall test of concordance was significant (W=0.057 p=0.0001), suggesting that at least some species among those 54 were significantly found together. The K-means analyses suggested that species were again partitioned along two main groups. Each group further had significant associations of species (Group 1: W = 0.304, p=0.0001; Group 2: W = 0.048, p=0.0001). All 14 species belonging to Group 1 were found to be significantly associated to each other (ACHIMIL, ARABHOE, ARTEMIC, BROMTEC, CENTDIFF, DRYADRU, ELYMTRA, LACTSER, LINAVUL, LYGOJUN, MELIALB, TARAOFF, TRAGDUB, and VERBTHA), while four species were significantly associated in Group 2 (EPILCIL, POA COM, POA PAL, and RIBELAC).

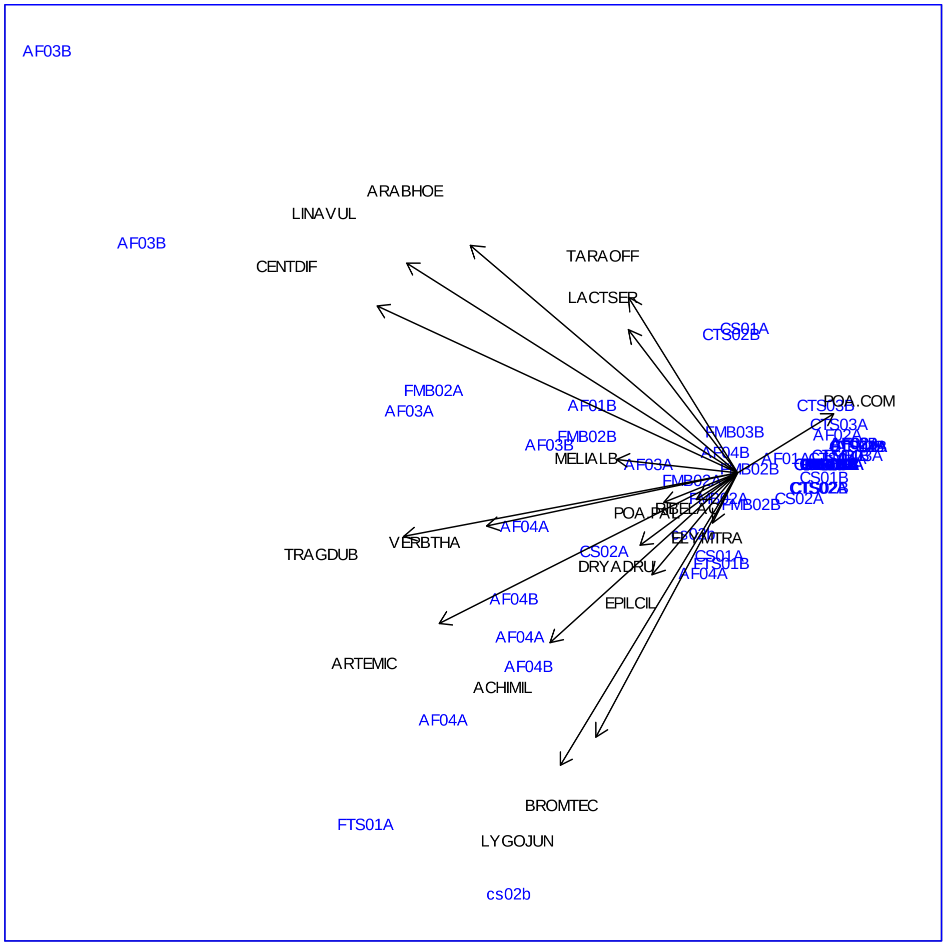


**Figure 30.** **PCA diagram showing relationships between the 18 concordant species over the 76 plots located upland along the Lower Bridge River in 2013. Axis 1 explains 15% of the variation in species cover, and axis 2, 10%. Species acronyms can be found in Appendix 2. Plots are labelled with the terrain classes to which they belonged; AF stands for alluvial fans, FMB for fluvial mid bars, CTS and CS for colluvium, and FTS for fluvial transects.**

The species in Group 1 seemed again to be associated mostly to the alluvial fans and they were mostly exotic species, while species in Group 2 were not clearly associated with any terrain class, except maybe for POA COM that seemed to be found mostly in colluvium plots (Figure 30).

The species from Group 1 in the ABF/BBF plots were not found to be concordant when the upland plots were considered, while the species in Group 2 in the ABF/BBF plots were all found within the groupings of the upland plots. Species of Group 1 in the ABF/BBF plots were almost all exotic and annual species, more likely to support inundation, or colonize shortly after water levels have receded.

### 3.3.4 Variation in abundance of annual plant species

Among all the vegetation sampled along the Lower Bridge River in 2013, only eight species were annuals: ARABHOL, BROMTEC, CARDOLI, CHENALB, MEDILUP, MELIALB, PERSMAC, and RORIPAL (see Appendix 2 for the species codes). They overall had limited cover, with the maximum cover recorded being 16 per cent (Figure 31). Annual species were mostly abundant in the plots sampled below the bankfull width at 3-5 cms, and had limited cover above the bankfull width or in the upland plots.

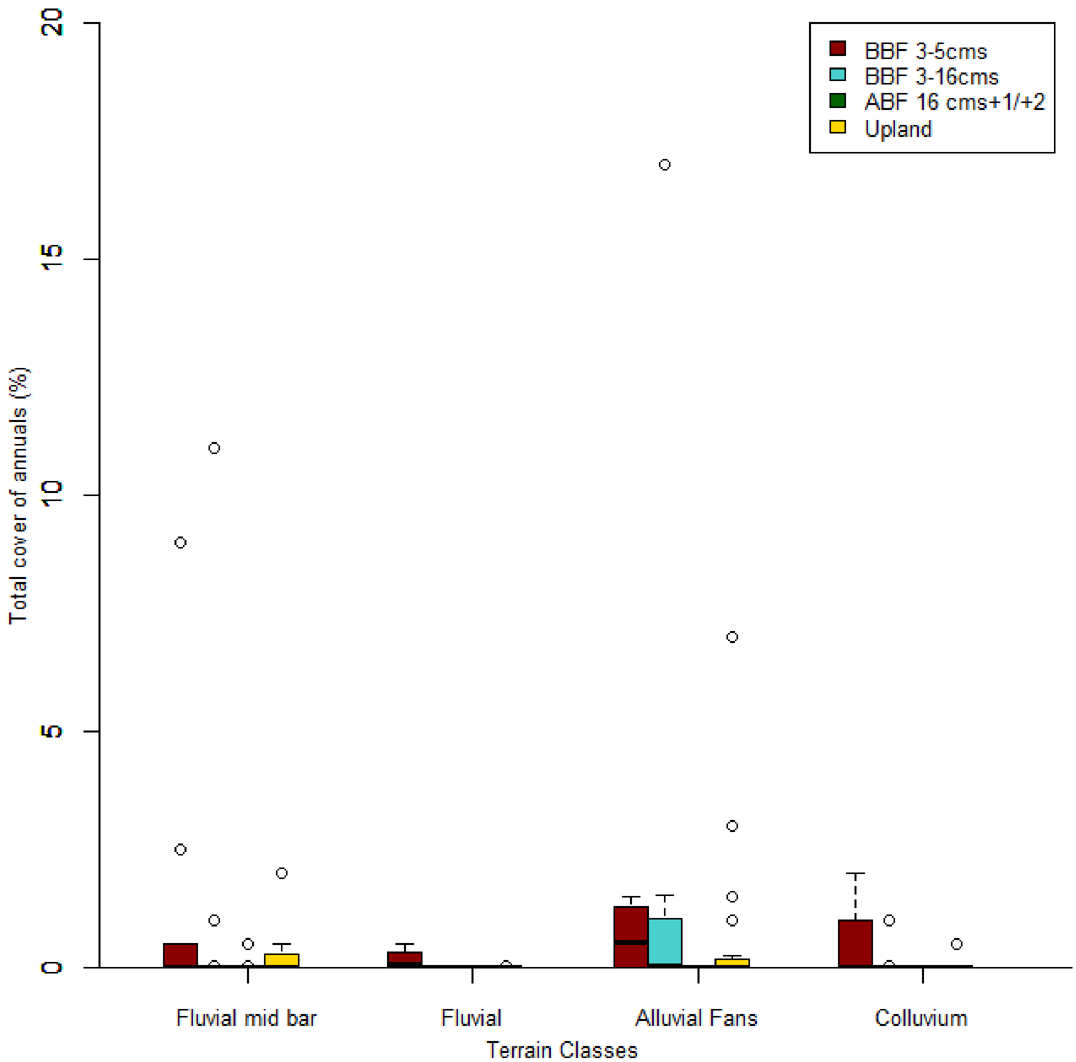


**Figure 31.** **Variation in the total cover (all vegetation layers combined) of annual plant species in the transects sampled along the Lower Bridge River in 2013, according to terrain classes and location of the plots along the transects.**

The cover of exotic species was more important, especially in the alluvial fans, where it was high in the plots above the bankfull width (Figure 32). The most common exotic species were Canada bluegrass (*Poa compressa*) and wall lettuce (*Lactuca muralis*).

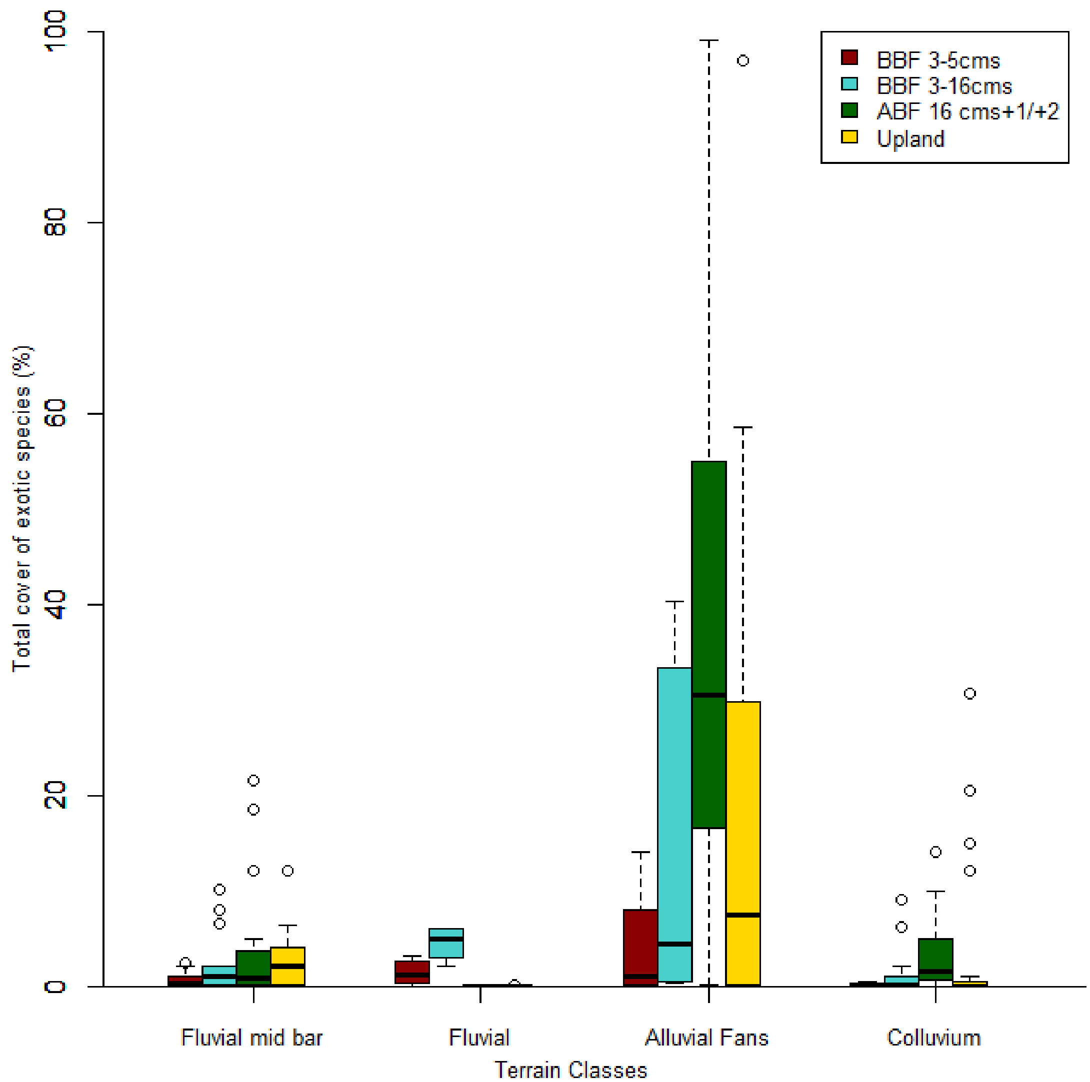


**Figure 32.** **Variation in the total cover (all vegetation layers combined) of exotic species in the transects sampled along the Lower Bridge River in 2013, according to terrain classes and location of the plots along the transects.**

### 3.3.5 Variation in recruitment of perennial species

Occurrences of seedlings of tree and shrubs in the herb/grass layer were infrequent along the Lower Bridge River in 2013. 23 of the 186 plots had tree seedlings in the herb layer; 17 of the plots were upland plots, five were above bankfull width, and one was below bankfull width (Table 6). The occurrences around the 16 cms bankfull width were in four fluvial transects, and two alluvial fans. The seedling species around the 16 cms included birch, cottonwood, alder as well as Douglas-fir.

**Table 6. Summary of the perennial tree species found along the Lower Bridge River in 2013.**

| Species | BBF and ABF plots | Upland plots | Alluvial fans | Fluvial terrain | Colluvium |
|---|---|---|---|---|---|
| Douglas- fir | 2 | 11 | 7 | 5 | 1 |
| Cottonwood | 2 | -- | -- | 2 | -- |
| Mountain alder | 1 | 1 | 1 | 1 | -- |
| Paper birch | 1 | 3 | 1 | 2 | -- |
| Western red cedar | -- | 2 | 2 | -- | -- |
| | 6 | 17 | 11 | 10 | 1 |

Nine species whose mature growth is in the B1 layer (>2m tall) were recorded as seedlings in the B2 layer. Birch, cottonwood, and Douglas-fir were the most commonly occurring species. Of the 96 occurrences of juvenile species in the B2 layer recorded in the plots around the bankfull width, 27per cent were birch, 21 per cent were cottonwood, 14.5 per cent were Douglas-fir, and 28 per cent were willows (Table 7). Nine juvenile species were recorded as being dead in the plots around the bankfull width, and five of them were Douglas-fir saplings, and three were cottonwoods. There was also one dead alder that was recorded. 81 juvenile species were recorded in fluvial plots, 65 in alluvium and 42 in colluvium plots.

**Table 7. Summary of the occurrences of juvenile trees and shrubs recorded in the B2 layer along the Lower Bridge River in 2013.**

| Species | Number of occurrences of saplings in… | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | BBF and ABF plots | Dead | Upland plots | Dead | Fluvial terrain | Dead | Alluvial fans | Dead | Colluvium | Dead |
| Alder | 7 | 1 | 7 | 0 | 7 | 0 | 10 | 0 | 5 | 1 |
| Birch | 26 | 0 | 12 | 0 | 14 | 0 | 15 | 0 | 6 | 0 |
| Cottonwood | 20 | 3 | 16 | 0 | 26 | 1 | 8 | 0 | 5 | 2 |
| Engelmann's spruce | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Ponderosa pine | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| trembling aspen | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| Douglas-fir | 14 | 5 | 34 | 1 | 16 | 6 | 10 | 1 | 19 | 1 |
| Western red cedar | 0 | 0 | 9 | 0 | 1 | 0 | 8 | 0 | 0 | 0 |
| Pin Cherry | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 |
| Willow species | 27 | 0 | 4 | 0 | 17 | 0 | 12 | 0 | 2 | 0 |
| Total | 96 | 9 | 87 | 1 | 81 | 7 | 65 | 1 | 42 | 4 |

The cover of tree species in the B and herb/grass layers was very variable among plots, in the colluvium transects especially (Figure 33). It was low in the plots below the bankfull width in the alluvial fans, and in the BBF 3-16 cms in the fluvial mid bars and fluvial transects. Tree species had similar cover in the BBF 3-5 cms and upland plots in the fluvial mid bars, fluvial transects, and colluvium. The tree species included were ACERGLA, ALNUCRI, BETUPAP, POPUBAL, PICEGLA, POPUTRE, PINUPON, PRUNPEN, PSEUMEN, SALIX, THUJPLI (see Appendix 2 for the species codes).

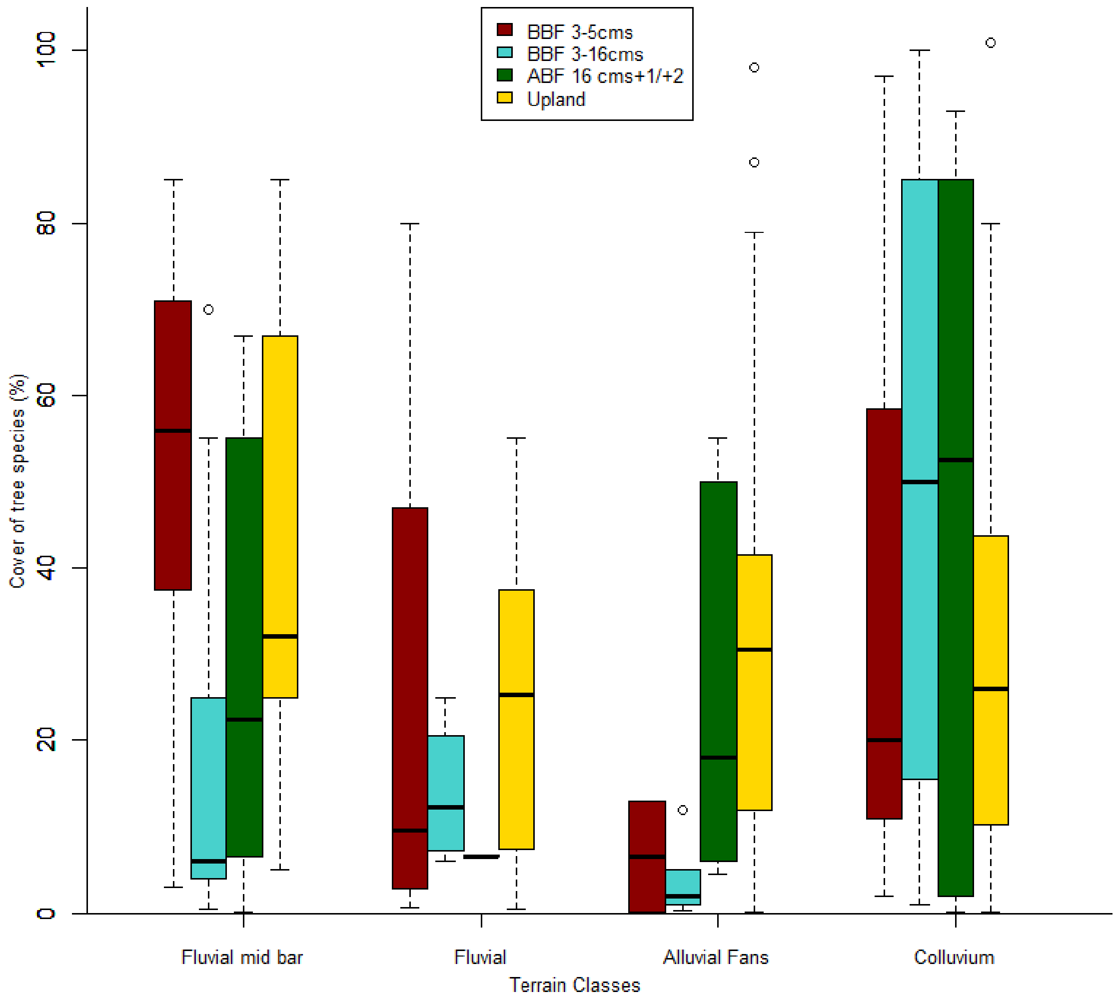


**Figure 33.** **Variation in the cover of tree species (%) in the B and herb/grass layers, over the various terrain classes, and at the different locations along the transects in the Lower Bridge River, in 2013.**

Western redcedar (THUJPLI), white spruce (PICEGLA, *Picea glauca*), and Douglas-fir were more abundant in upland located in alluvial fans, as well as one transect in colluvium, and one transect in the fluvial mid bars (Figure 34 and Figure 35). In contrast, Douglas maple (ACERGLA, *Acer glabrum*) and trembling aspen (POPUTRE, *Populus tremuloides*) appeared generally more abundant in the colluviums (above bankfull width and upland plots), as did Sitka alder (ALNUCRI, *Alnus crispa*). Finally, willow species (SALIX) and black cottonwood seemed more abundance in the plots centered around the bankfull width in the fluvial mid bars and fluvial transects.

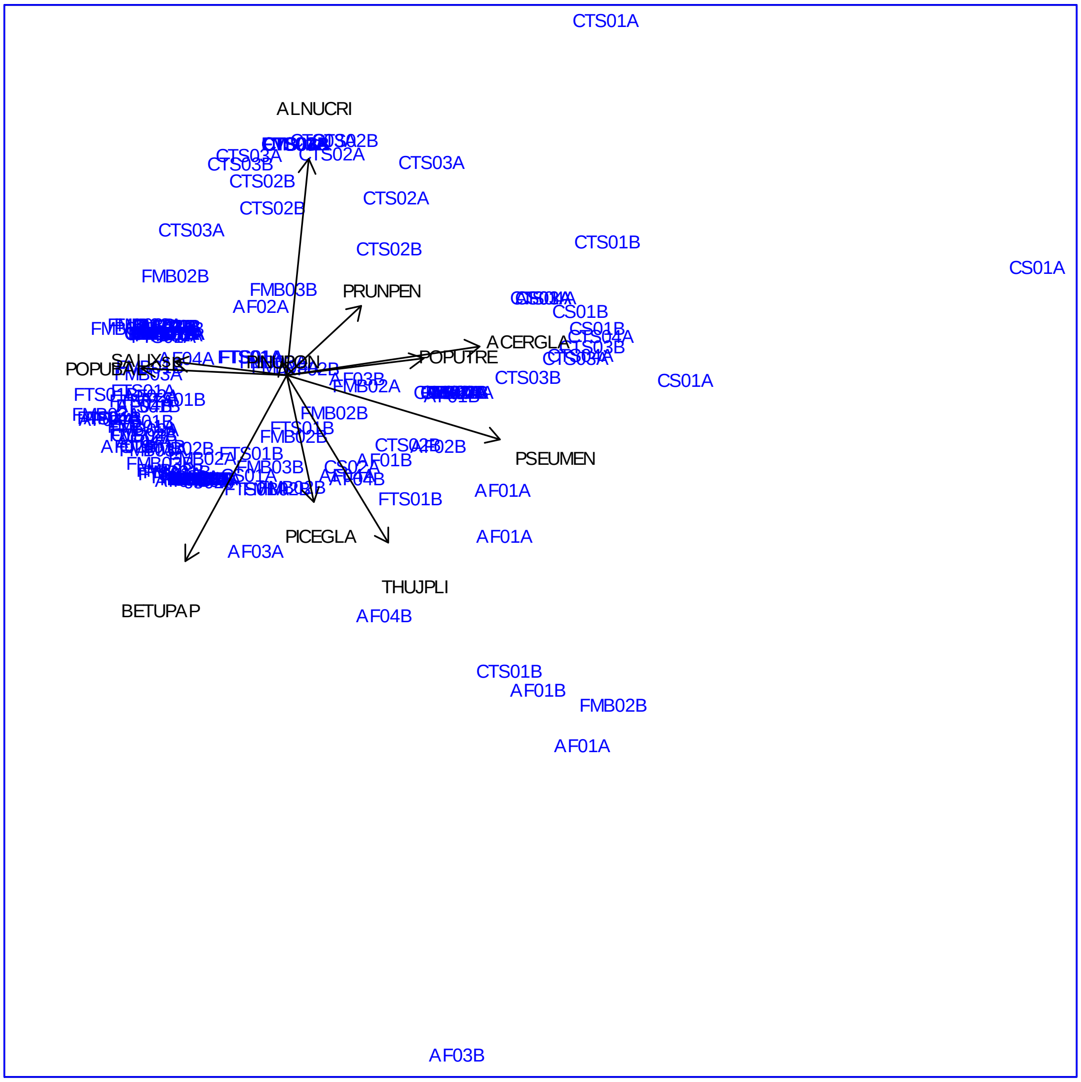


**Figure 34.** **PCA diagram showing relationships among the 11 tree species sampled in the B and herb/grass layers along the Lower Bridge River in 2013. Axis 1 explains 15% of the variation in species cover, and axis 2, 13%. Species acronyms can be found in Appendix 2. Plots are labelled with the terrain classes to which they belonged; AF stands for alluvial fans, FMB for fluvial mid bars, CTS and CS for colluvium, and FTS for fluvial transects.**

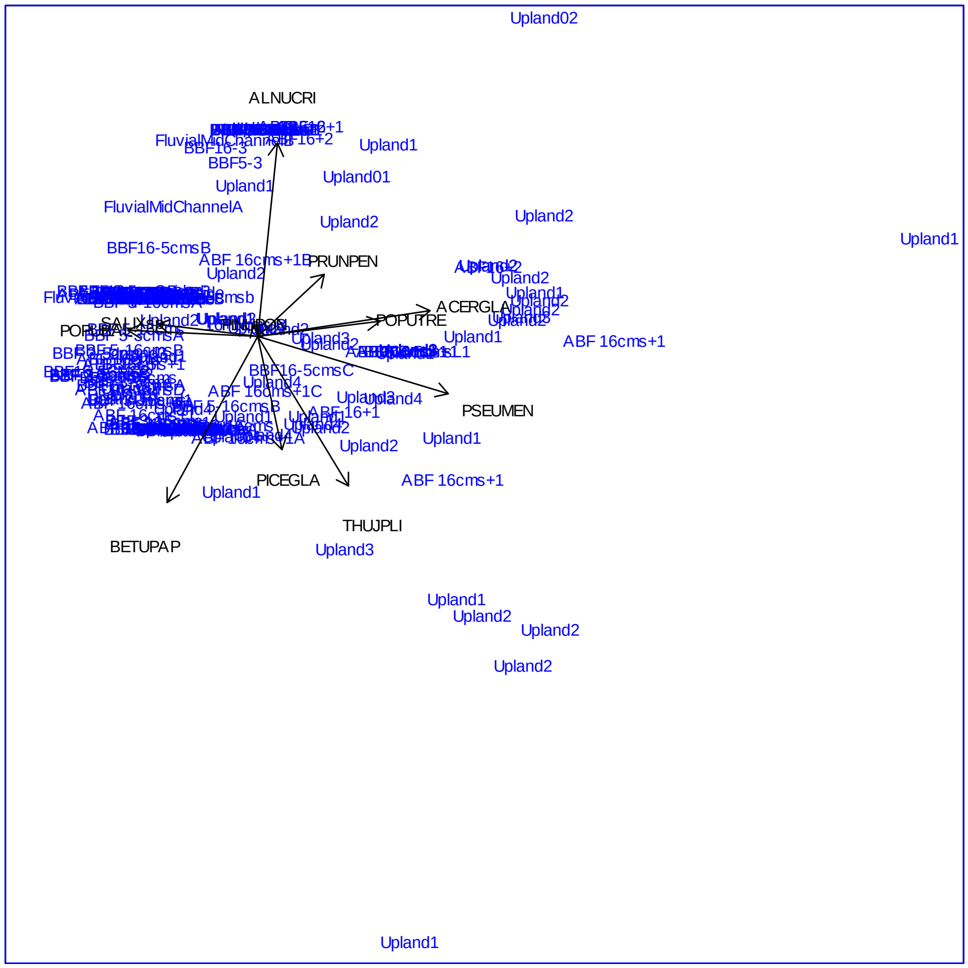


**Figure 35.** **PCA diagram showing relationships among the 11 tree species sampled in the B and herb/grass layers along the Lower Bridge River in 2013. Axis 1 explains 15% of the variation in species cover, and axis 2, 13%. Species acronyms can be found in Appendix 2. Plots are labelled with the locations to which they belonged; BBF stands for below bankfull width, while ABF stands for above bankfull width.**

### *3.4 Variation in flows of the Lower Bridge River*

As noted in the introduction, the flows were maintained around 3 cms in Reaches 3 and 4 from 2000 until August 2011 (Figure 36). In August 2011, flows were increased to 6 cms, bringing the bankfull width up to 16 cms (from a bankfull width of 5 cms when the annual flow regime was at 3 cms). Under the 6 cms flow regime, the river stays at its bankfull width through much of June and July, when flows are ramped down by 12 cms over the period of a month. Our vegetation sampling began with the water flow at 3 cms, and ended when the river was at 1.54 cms.

The greatest horizontal change in area was at one fluvial transect (AF02), where the area under inundation increased by four meters with the change in flow regime. Anecdotally, the greater area of flooding was observed on the left bank of the river at Eagle Pond (opposite bank to AF02), where the new flow regime caused the waters to cover a horizontal area over 30 m.

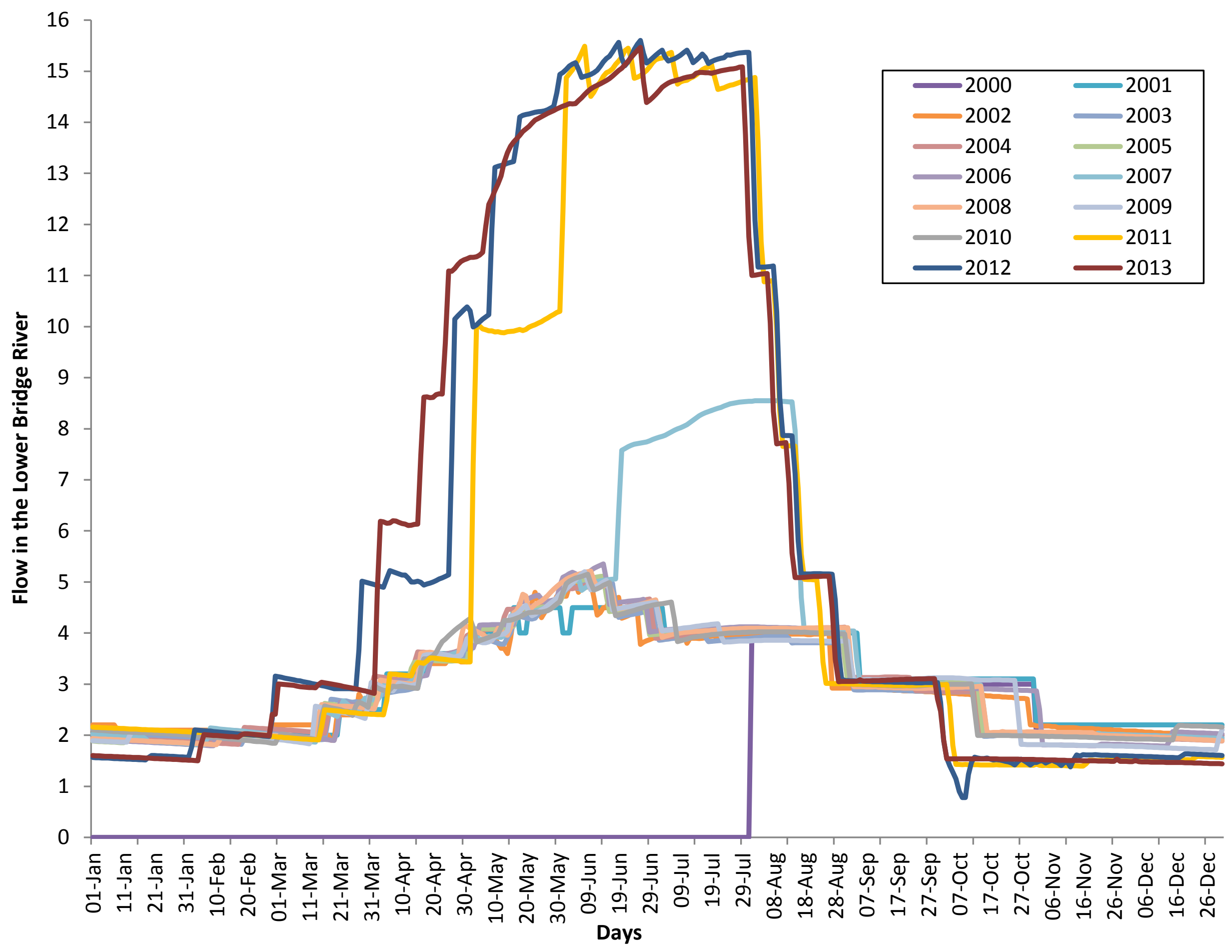


**Figure 36.** **Variation in flows in the Lower Bridge River from 2000 to 2013, outside of the Terzaghi dam.**

# 4.0 Discussion

## 4.1 H3: Biomass productivity in relation to flow regime

Hypothesis $H_3$ assesses biomass productivity in relation to the various flow regimes that the Lower Bridge River experienced, and will experience, over time. The biomass data associated to historical flows is lacking, therefore impeding our ability to properly address this question at this point in time. 2013 marked the third year at an average annual discharge of 6 cms for the Lower Bridge River, but the historic flows through the system were 100 times higher than that. The narrow geology of the Lower Bridge River canyon would have created severe scouring events when the pre-dam, free flowing river was at its bankfull flows, and the sites sampled for biomass in 2013 would have been perpetually under water with the historic flows. Given that the historic high waters even reached 473 cms at times, there would have been very limited areas in the Reaches 3 and 4 of the Lower Bridge River that would have had the topography to support riparian vegetation communities. The majority of the complex riparian vegetation communities along the Bridger River system would have been throughout the wide valley bottoms currently occupied by Carpenter and Downton Reservoirs (Wood G.A., 1949).

We targeted the herbaceous layer of vegetation for sampling, and decided to place the 1mX1m clip quadrats above and below the 16 cms bankfull width zone to monitor for shifts in vegetation growth. These samples allow for a general assessment of changes in herbaceous vegetation biomass for the study area as a whole, or based on the terrain class stratification. The samples have been analyzed separately in 2013 to compare biomass productivity above and below bankfull width. It was anticipated that there would be more biomass production above the bankfull width than below, due to the flooding and erosion caused by high water events.

The 2013 biomass sampling was conducted after three years of high water at 16 cms, and we are likely sampling within the transition period in vegetation production brought on by the new flow regime, with no pre-change data to serve as a baseline. It is likely that any current shift in vegetation community will continue throughout the course of the 6 cms flow regime. A 10 year trial period would create a clearer distinction at the bankfull width, 5 years may be enough time to assess changes but the current plan is to assess information for a decision on the flow regime in spring of 2015 (BC Hydro, 2011). Given this short time frame, it would be important to sample vegetation biomass again in the fall of 2014 to increase the power to detect changes in biomass over time, and across the different flow regimes in the future. Even then, the two years of biomass sampling will likely provide limited insight to inform a decision on flow release levels in 2015, but would at least constitute a baseline to which compare effects of future flow regimes.

Based on the data collected in 2013, it was found that the biomass of the herbaceous layer was greater above bankfull width, than below. The only exception to that observation was the fluvial terrain where the biomass in the below bankfull width samples was higher than the biomass in the samples above bankfull width. That may be caused by the low gradient and very coarse boulder substrate in the fluvial terrain (Figure 37). The vegetation growth at these sites was heterogeneous and patchy, rather than forming a linear transition like for the vegetation associated with higher and steeper slopes, or finer soils.

**Figure 37. Example of biomass quadrats in the Lower Bridge River in 2013. The picture on the left shows a quadrat on a BBF 5cms-16cms transect located in a fluvial area, while the picture on the right shows the quadrat on the same transect, but above the bankfull width (ABF 16cms+1), Note the very coarse fragmental soils that limit herbaceous growth.**

Higher biomass in the samples above bankfull width in the alluvial fan was to be expected, as the alluvial fans in general had better growing conditions for the herbaceous layer, with relatively fine soil, low slopes, and additional ground water from upslope sources (Figure 39). There seemed to be a retreat in the vegetation taking place upslope in the alluvial fans. However, not having the pre-6 cms data makes it difficult to confirm this was due to the shift in flow regime, but it suggests these would be places to watch for an upslope shift in herbaceous vegetation in future years. The same shift in biomass upslope was not as visible in the other terrain classes, but it might be that their steeper slopes made it challenging to detect, or that the broader bankfull width in alluvial fans encouraged more vegetation growth and biomass production overall.

## *4.2 H2: Vegetation composition in relation to flow regime*

Deciduous shrub and tree species were the dominant component of the vegetation along the Lower Bridge River in 2013 (especially Douglas-fir, black cottonwood, paper birch, willow, and mountain alder). Most of these tree species are characteristic of moist sites, and limited to growing where there is moisture (Parish *et al.,* 1996).

On the other hand, Douglas-fir is an upland species suited to drier conditions, and less tolerant of saturated soils (Parish *et al*., 1996). The intolerance of Douglas-fir to flooding may explain the observations of dead fir saplings throughout the study area (Figure 38). Lower flows likely encouraged encroachment of firs down to the edge of water, and higher flood waters subsequently caused their mortality.


**Figure 38. Examples of dead Douglas-fir saplings observed along the Lower Bridge River study area in 2013. Both of these sites were on alluvial fans.**

Deciduous stands of birch and cottonwood were dominant at the edges of the river in the fluvial mid bar terrain, and to a lesser degree, in fluvial and colluvium areas. The proportion of deciduous species could be compared at the end of the study to determine if there is any change in their importance along the river. The dominance of cottonwoods on the alluvial fans should also be closely monitored, since cottonwoods could become more competitive under higher flow regimes than the currently dominant Douglas-firs.

Black cottonwood habitats are recognized as rare and very important habitats on the landscape of the Southern Interior of BC (Ministry of Environment Lands and Parks, 1997). Riparian ecosystems are important to instream and terrestrial species, and there are several rare species that depend on cottonwood habitats in the Southern Interior of BC, including Western Screech owl (*Megascops kennicottii macfarlanei*) and Lewis' woodpecker (*Melanerpes lewis).*

**Figure 39 Example of an alluvial fan rich in dense herbaceous vegetation around the bankfull width (AF02 transect A).**

Shrub layer cover was highest in the colluvium transects around the bankfull width. This is likely due to the narrow band of tall shrub dominated by mountain alder and birch that lines the river banks throughout much of its course. The fact that the cover of the shrub layer is highest below bankfull width in the colluvium terrain, and decreased through to the above bankfull width, provides an occasion to monitor and see if there is any increase or decrease in cover following changes in flow regimes in the future. This tall shrub zone is significant because of its extent throughout Reaches 3 and 4 of the Lower Bridge River. The relatively high below bankfull width cover of shrubs in the fluvial mid bar terrain is also a characteristic to watch over time, as these shrubs are experiencing the most direct impacts of higher water flows, with longer and higher inundation periods. It would be interesting to carry out additional vegetation inventories along the free running Yalakom River and on the Reach 2 of the Lower Bridge River (downstream of the confluence with the Yalakom river), to determine if alder and birch are as significant a component of the B1 and A3 layers as they are in Reaches 3 and 4 of the Lower Bridge River. Alternatively, species more associated with water dispersal (e.g. cottonwoods and willows) may be more prevalent in those sections.

Cover in the herbaceous layer was relatively low throughout the study area with none of the plot cover averages over 50 per cent. Alluvial fans were the most densely vegetated in herbs and grass species (Figure 39). Upland sites in the fluvial mid bars had also relatively high cover in herbs and grasses, but this was due to moss and several large patches of mountain avens (*Dryas drummondi*). Colluvium sites had low cover in herbs and grasses due to the steep slopes, coarse soils, and disturbance from downslope movement of substrate. Herbs and grass covers were also low in the fluvial sites, likely because of the coarse substrates and high disturbance from flooding.

**Figure 40. Example of recent erosion of the deciduous riparian edge along the Lower Bridge River (2013).**

We have stratified sampling sites to monitor the variety of habitats that occupy the Lower Bridge River, if there is a shift in vegetation due to the change in flow regimes. Fluvial mid bars are relatively new features to the fluvial geomorphology of the Lower Bridge River, as pre-dam instream features would have been fewer, and more prone to disturbance from extreme flood events at historic flows. The colonized fluvial bars are likely a result of the dam eliminating major disturbance events and stabilizing flows. Erosion of the edges of fluvial bars was observed (Figure 40), and is expected to continue with the 6 cms flow regime directly reducing the physical areas along river edges. It will be interesting to see if this is associated with an increase in area colonized by riparian deciduous species on the upslope side of the fluvial bars.

### *4.3 H4: Abundance of annual species in relation to flow regime*

There were not a lot of annual plant species sampled in 2013. Of the eight species detected, six were weedy exotics, and two were native species. Six of the species were relatively rare occurrences, while two species were more common. The native marsh yellow cress (*Rorippa palustris*) was the most abundant species, and was detected in 18 plots (all but one being below bankfull width plots). White sweet clover (*Melilotus alba*) was the second most frequently occurring annual species, occurring in 15 plots (ten were upland sites, and only one was below bankfull width). These two relatively common annuals were also two of the more common annual species in the Carpenter Reservoir riparian vegetation study (BRGMON-2, Scholz and Gibeau, 2014).

It may useful to include biennial species into hypothesis $H_4$ as these are all exotic species, including some invasive species of concern. The biennial list includes provincially noxious weed species diffuse and spotted knapweed (*Centaurea diffusa* and *C. biebersteinii*), found in 20 plots, and regional noxious weed great burdock (*Arctium lappa*), found in seven plots, six of which were around the 16 cms bankfull width. Prickly lettuce (*Lactuca serriola*) was found in 18 plots, 11 of which were plots around the bankfull width. Bull thistle (*Cirsium vulgare*) was found in six bankfull width plots and one upland plot. Other biennials found primarily in upland plots were yellow salsify (*Tragopogon dubius*), and great mullein (*Verbascum thapsus*). Knapweed and burdock are known to have negative impacts on the ecosystem (Ralph, 2007). These species should be closely monitored throughout the study to assess for shifts in importance that may be related to flow regime changes.

### *4.4 H5: Rate of recruitment of perennial plant species in relation to flow regime*

Juvenile and seedlings of tree and shrub species were a relatively minor component of the vegetation along the Lower Bridge River in 2013. Deciduous tree seedlings occurrences were limited to four plots. Most of the seedlings recorded were in upland plots, and there was no recruitment of seedlings in plots around the bankfull width in colluvium terrain. Douglas-fir seedlings were the most frequent seedlings found, and were largely recorded in upland plots. The frequent occurrences of bare soil provide several opportunities of seedling beds for Douglas-fir, but the riparian species are more dependent on moisture than bare soil for recruitment. Cottonwoods seedling distribution is associated with natural spring flooding events. The short viability (1 to 2 weeks) of cottonwood seeds makes their dispersal and survival success closely connected to flooding timing. Ideally, flooding followed by a slow drop in the riparian water table is required for successful seedling establishment; a water table drop of 5 cms/day or less would apparently be required to support seedling establishment (Rood and Mahoney, 2000). Consequently, the current hydrograph for the Lower Bridge River does not provide adequate conditions to support cottonwood and willow seedling establishment.

Fresh deposits of sands, silts, gravel, and, in particular, deep alluvial deposits, provide appropriate cottonwood seed beds along the shores and floodplains of rivers (Borman and Larson, 2002). The increase in annual flow regime of the Lower Bridge River has marginally increased the area of flooding along the Lower Bridge River; however the steep grades along Reaches 3 and 4 do not provide many areas that are suitable for seedling recruitment. Dams are known to alter the sediment inputs into river systems for kilometers below the dam structures (Church, 1995). Terzaghi dam settles out many of the fines, sands and gravels that would have otherwise been transported down the river on an annual basis, particularly in Reach 4. Without the input of these materials, the potential for new seedling beds for cottonwoods are limited.

Several small alluvial fans in the study area were relatively recent deposits of alluvium, e.g. AF04 was a relatively fresh deposit of alluvium from an event that occurred in 2004 (R. Walton and R. Heinrich personal communication). Juvenile recruitment along the fringes of these features was high. Regulated flows should limit the area suitable for seedling recruitment and germination at these sites, as the moisture supply and seed inputs from the high waters are limited to the low fringe of the fan inundated. Also, the fresh, unconsolidated alluvium deposits on these recruitment sites are highly erodible because of the high waters. It is expected that the 6 cms flows will erode the fan edges back, but the higher flows might also create seedling and recruitment potential higher up on the fans. The lack of upland flooding limits the seedling recruitment to more dry-land vegetation species such as Douglas-fir.

## 5.0 Conclusion and Recommendations

In 2013, the main objective of the riparian vegetation monitoring program (BRGMON-11) was to gather baseline data on vegetation characteristics along Reaches 3 and 4 of the Lower Bridge River. No pre-flow release vegetation surveys were available to address the species composition, spatial distribution, and biomass productivity of vegetation along the Lower Bridge River. The fact that this survey was conducted three years into the 6 cms flow regime means the survey occurred as the vegetation is likely still transitioning and adjusting to the new flows. Higher bankfull widths along the river mean a greater amount of flooded terrain, and longer inundation periods for low lying areas. Higher flood levels also mean more erosion along the edges of the river, and in theory, more deposition of sediments in some floodplain areas. We have seen examples of erosion taking place along the bankfull edges of the fluvial and alluvial fan terrain, particularly at the Hell Creek fan. There was little evidence of new sediment recruitment and deposition at any of the transects sampled in 2013 along the Lower Bridge River. Another sign of a transition being in process was the number of dead Douglas-fir saplings observed in the study area. It is obvious that there are some losses of vegetation along the bankfull margins, but there may also be gains in the riparian vegetation community higher up slope.

Without the information from before the flow releases, it is difficult to say at this point what the changes in flow regimes induced in the riparian vegetation community along the Lower Bridge River. If the current flow regime does not continue for 10 years (as originally planned) and changes in 2015, there will be limited information to infer with any certainty that any changes in riparian vegetation are attributable to the shift in flow regime. From a vegetation perspective, it is therefore recommended that the current flow regime continues for the full 10 years. This recommendation is also applicable to the riverine bird component of the study that has an additional four years to study the community at the 6 cms flow regime. These additional years are needed to reduce the year to year variability in riverine bird populations, and to better test the hypothesis that variations in riverine bird populations are related to flow release (Heinrich and Walton, 2013).

There was not a great amount of herbaceous productivity, except in the alluvial fan terrain. There was a significant difference in biomass productivity above and below bankfull width, and this difference may become more pronounced by the end of the study period. Annuals were a minor component of the vegetation inventory in 2013, but that might be different in the future with more years at this higher flow regime. We recommend that $H_4$ be extended to include biennials species and perennial noxious weeds.

The lack of seedling recruitment could be an impetus to carry our restoration assessment of the Lower Bridge River. It is currently difficult to identify areas where restoration techniques could be carried out to improve the recruitment and development of black cottonwood along the Lower Bridge River. If the regime is to remain at the current 6 cms flow, restoration work on vegetation could be carried out around the Eagle Pond area, located approximately 1.5 km east of Terzaghi dam. Given the higher flooding at this site under the current flow regime, the high vehicle access, and high cover of exotic weed species, this site is a prime candidate for restoration in order to assist with the development of a healthy riparian vegetation community. The Hell Creek fan is another site with a fair amount of weedy vegetation, where restoration techniques and revegetation could assist with pushing this fan towards a cottonwood stand.

## 6.0 References

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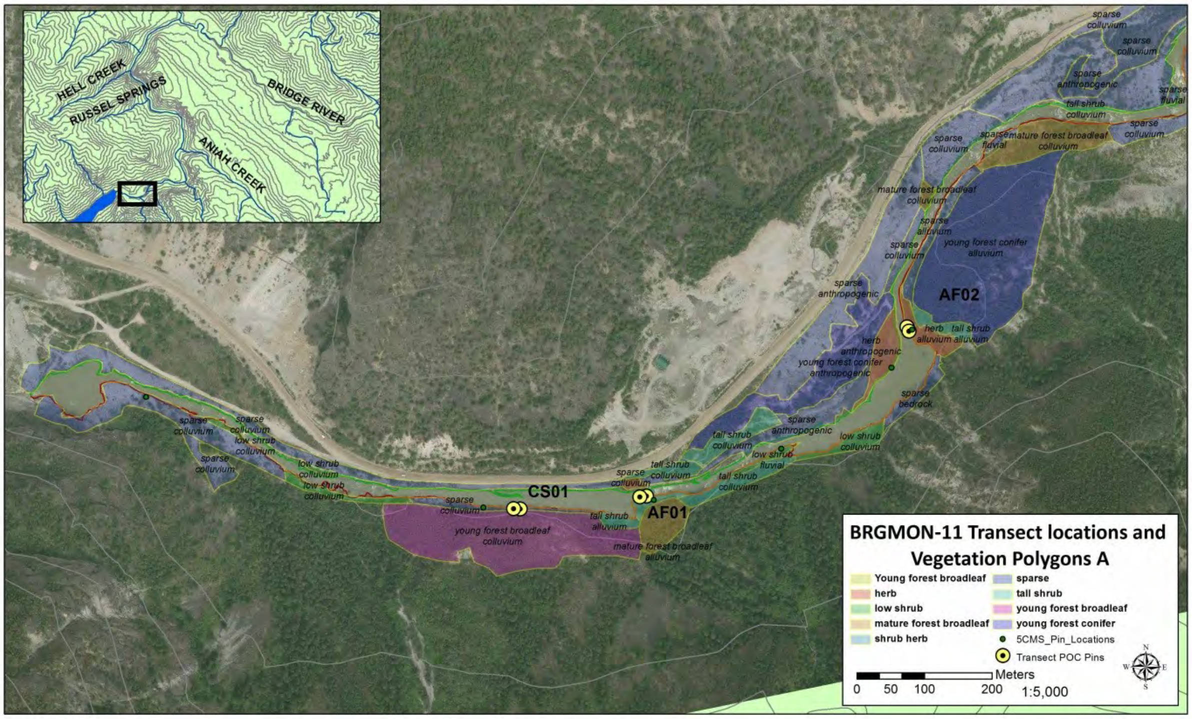
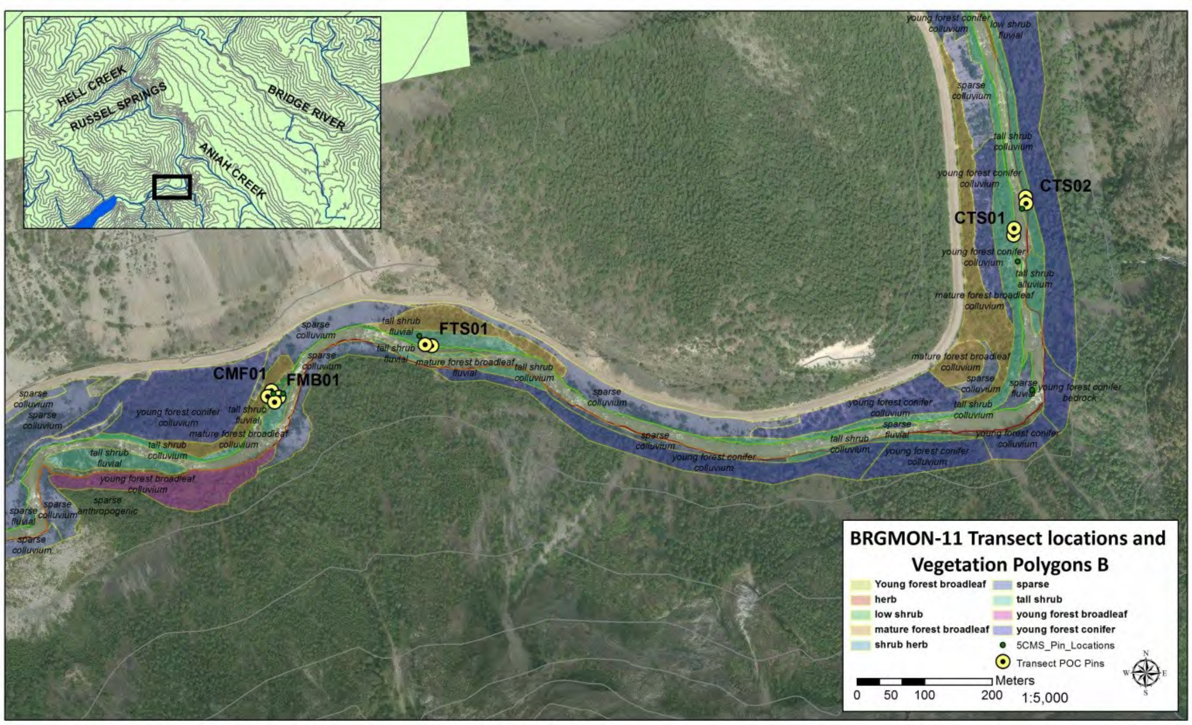
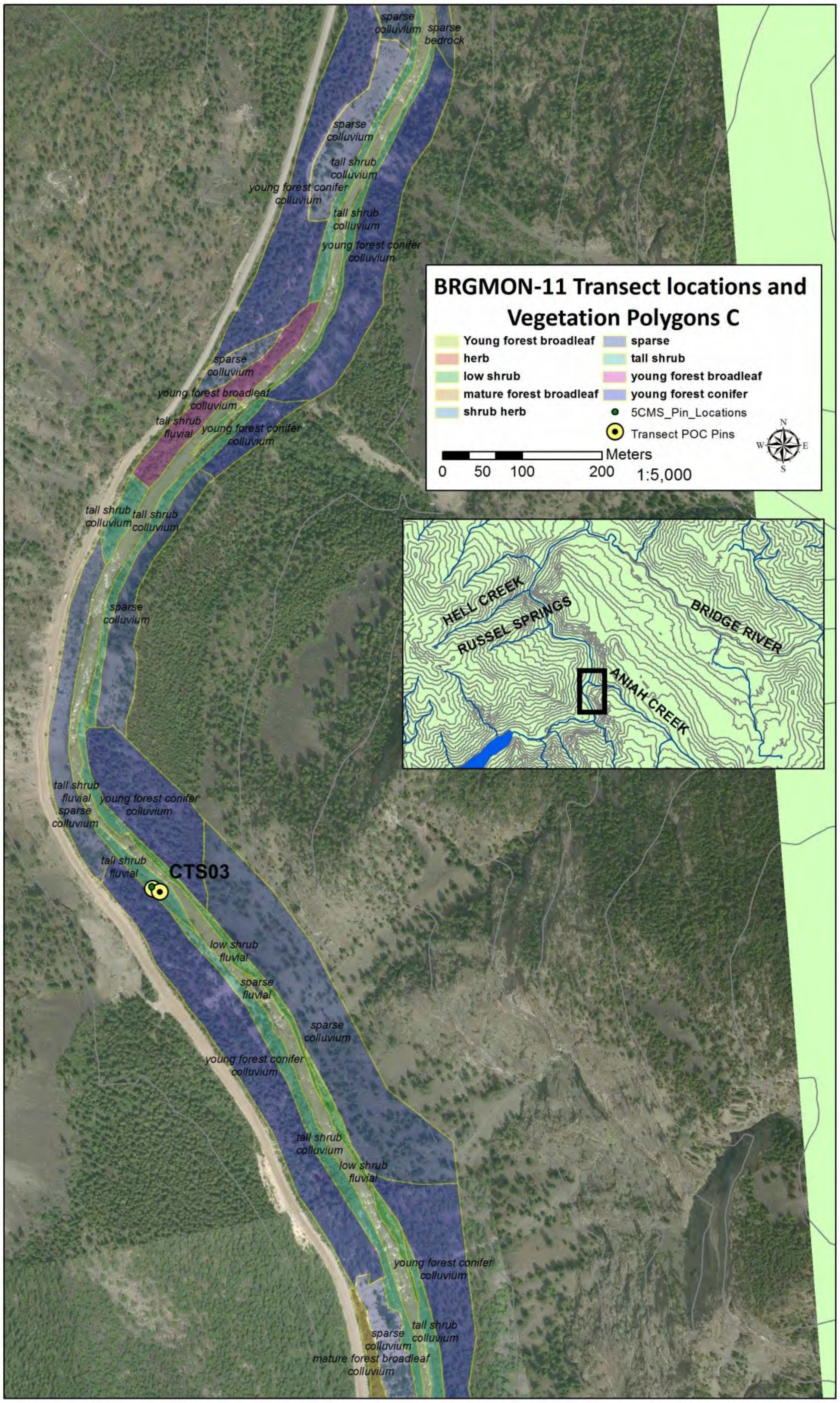
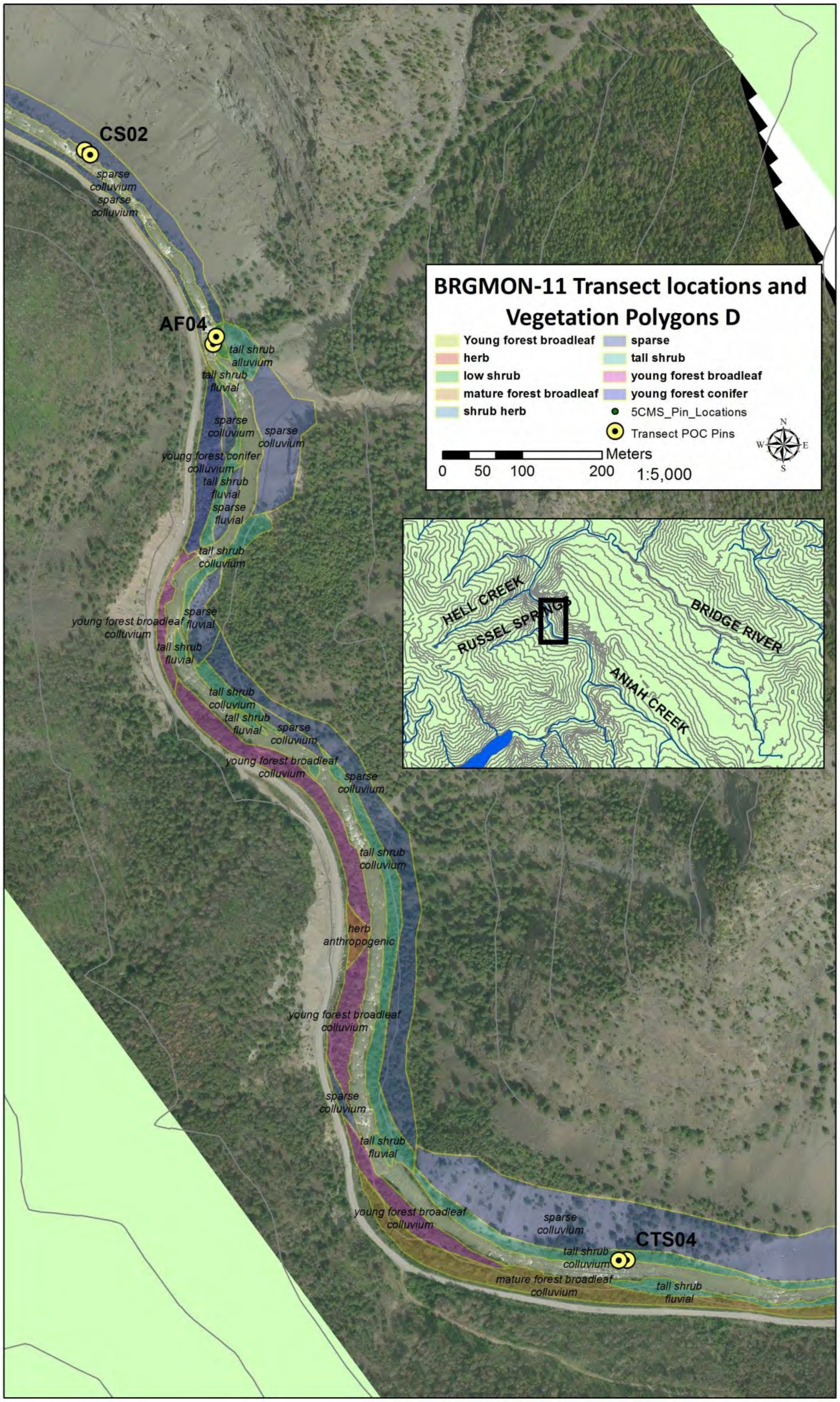
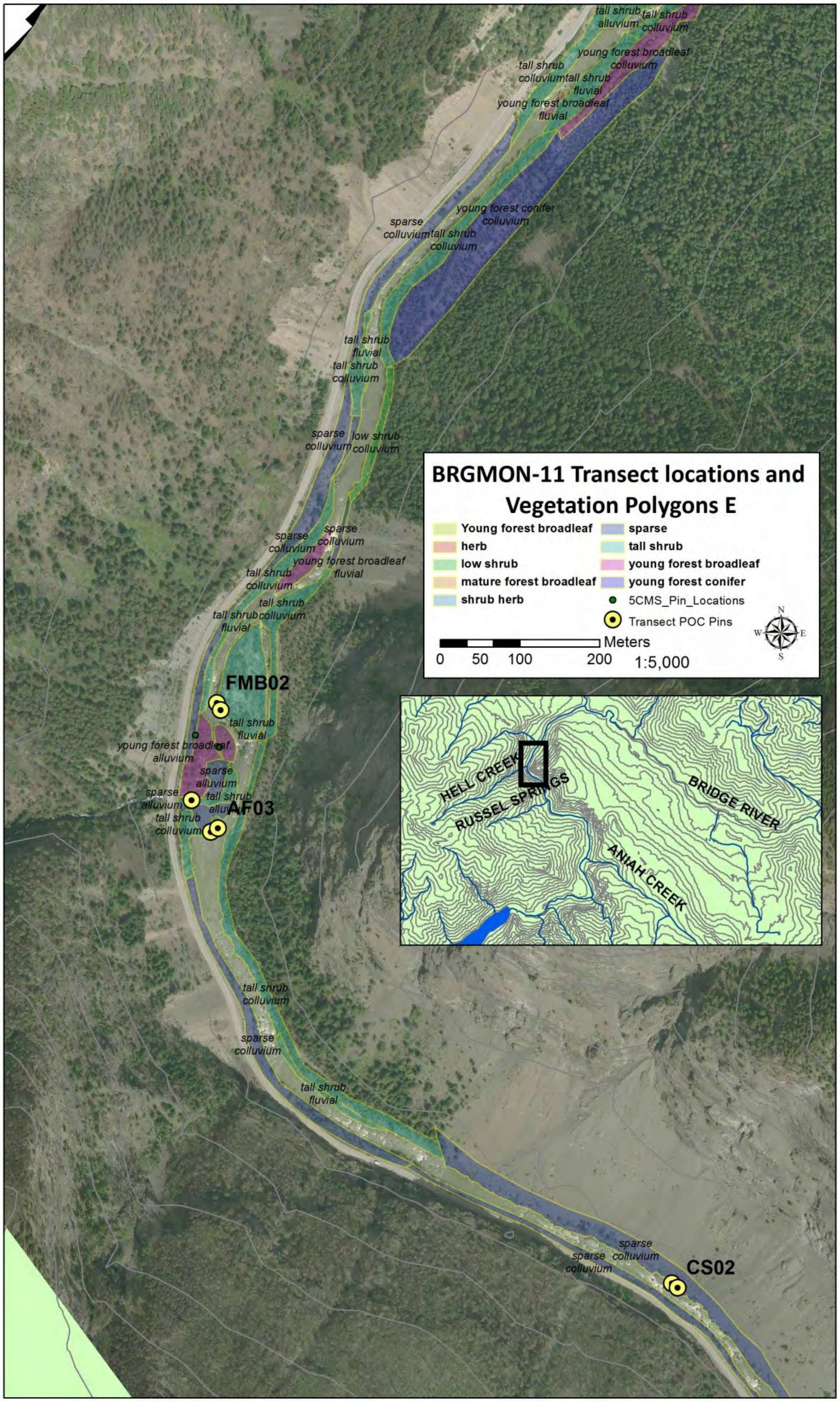
## Appendix 1: Locations of transects and plots.




BRGMON-11 Transect locations and Vegetation Polygons C
Young forest broadleaf
herb
low shrub
mature forest broadleaf
shrub herb
sparse
tall shrub
young forest broadleaf
young forest conifer
5CMS_Pin_Locations
Transect POC Pins
Meters
0 50 100 200
1:5,000
HELL CREEK
RUSSEL SPRINGS
BRIDGE RIVER
YALAKOM RIVER
CTS03
sparse colluvium
sparse bedrock
tall shrub colluvium
young forest conifer colluvium
young forest broadleaf colluvium
tall shrub fluvial
low shrub fluvial
sparse fluvial
mature forest broadleaf colluvium


BRGMON-11 Transect locations and Vegetation Polygons D
Young forest broadleaf
herb
low shrub
mature forest broadleaf
shrub herb
sparse
tall shrub
young forest broadleaf
young forest conifer
5CMS_Pin_Locations
Transect POC Pins
0 50 100 200 Meters
1:5,000
HELL CREEK
RUSSEL SPRINGS
BRIDGE RIVER
ANIAH CREEK
CS02
AF04
CTS04
sparse colluvium
tall shrub alluvium
tall shrub fluvial
young forest conifer colluvium
sparse fluvial
tall shrub colluvium
young forest broadleaf colluvium
herb anthropogenic
mature forest broadleaf colluvium


BRGMON-11 Transect locations and Vegetation Polygons E
Young forest broadleaf
herb
low shrub
mature forest broadleaf
shrub herb
sparse
tall shrub
young forest broadleaf
young forest conifer
5CMS_Pin_Locations
Transect POC Pins
Meters
0 50 100 200
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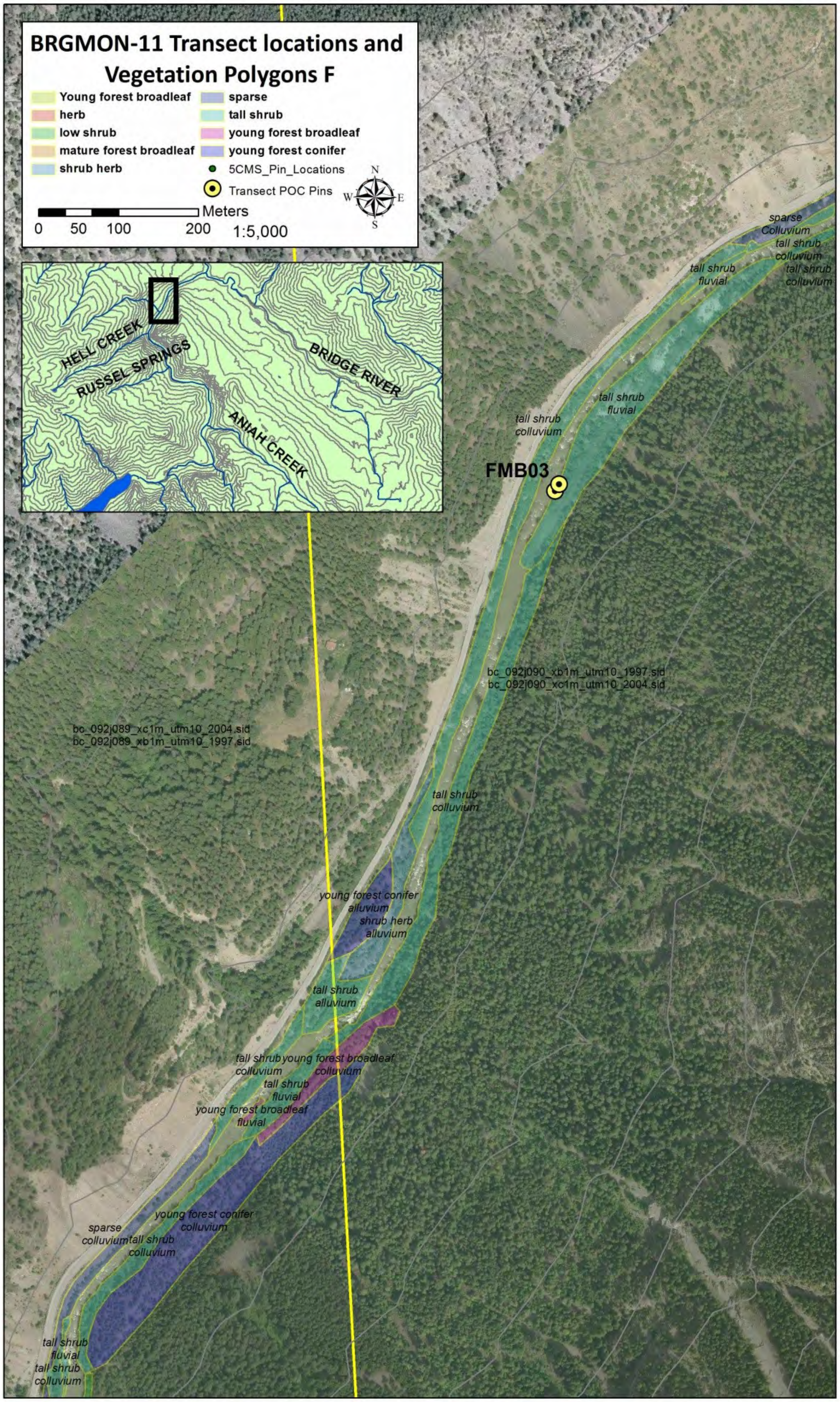
N
W
E
S
FMB02
AF03
CS02
HELL CREEK
RUSSEL SPRINGS
BRIDGE RIVER
ANIAH CREEK
tall shrub alluvium
tall shrub colluvium
young forest broadleaf colluvium
tall shrub fluvial
young forest broadleaf fluvial
young forest conifer colluvium
sparse colluvium
low shrub colluvium
young forest broadleaf alluvium
sparse alluvium


BRGMON-11 Transect locations and Vegetation Polygons F
Young forest broadleaf
herb
low shrub
mature forest broadleaf
shrub herb
sparse
tall shrub
young forest broadleaf
young forest conifer
5CMS_Pin_Locations
Transect POC Pins
Meters
0 50 100 200
1:5,000
N
S
W
E
HELL CREEK
RUSSEL SPRINGS
BRIDGE RIVER
ANIAH CREEK
FMB03
sparse Colluvium
tall shrub colluvium
tall shrub fluvial
tall shrub colluvium
tall shrub fluvial
tall shrub colluvium
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tall shrub colluvium
young forest conifer alluvium
shrub herb alluvium
tall shrub alluvium
tall shrub colluvium
young forest broadleaf colluvium
tall shrub fluvial
young forest broadleaf fluvial
young forest conifer colluvium
sparse colluvium
tall shrub colluvium
tall shrub fluvial
tall shrub colluvium

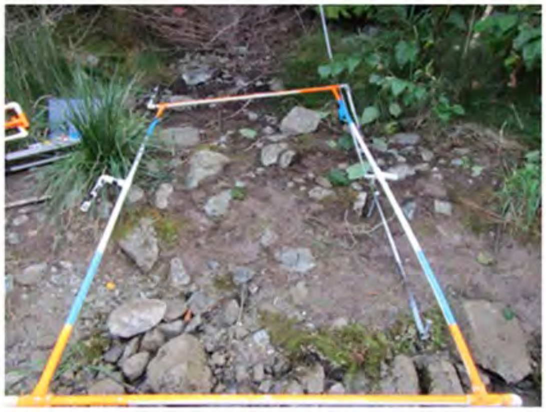
## Appendix 2: List of species

| Species | Common Name | Scientific Name | family | Perennial annual | Origin |
|---|---|---|---|---|---|
| **ABIELAS** | subalpine fir | *Abies lasiocarpa* | Pinaceae | perennial | native |
| **ACERGLA** | Douglas maple | *Acer glabrum* | Aceraceae | perennial | native |
| **ACHIMIL** | yarrow | *Achillea millifolium* | Asteraceae | perennial | native |
| **AGROCRI** | crested wheatgrass | *Agropyron cristatum* | Poaceae | perennial | exotic |
| **AGROGIG** | redtop | *Agrostis gigantea* | Poaceae | perennial | exotic |
| **ALNUCRI** | Sitka alder | *Alnus crispa* | Betulaceae | perennial | native |
| **ALNUINC** | mountain alder | *Alnus incana* | Betulaceae | perennial | native |
| **AMELALN** | Saskatoon | *Amelanchier alnifolia* | Rosaceae | perennial | native |
| **ANENMUL** | cut-leaved anemone | *Anemone multifida* | Ranunculaceae | perennial | native |
| **ANTENNAsp** | pussytoes | *Antennaria* ssp. | Asteraceae | perennial | native |
| **AQUIFOR** | red columbine | *Aquilegia formosa* | Ranunculaceae | perennial | native |
| **ARABHOL** | Holboell's rock cress | *Arabis holboellii* | Brassicaceae | annual | native |
| **ARCTLAP** | great burdock | *Arctium lappa* | Asteraceae | biennial | exotic |
| **ARCTUVA** | kinnikinnick | *Arctostaphylos uva-ursi* | Ericaceae | perennial | native |
| **ARTELUD** | western mugwort | *Artemisia ludoviciana* | Asteraceae | perennial | native |
| **ARTEMIC** | Michaux's mugwort | *Artemisia michauxiana* | Asteraceae | perennial | native |
| **ASTERsp** | aster species | *Aster* ssp. | Asteraceae | perennial | n/a |
| **BETUPAP** | paper birch | *Betula papyrifera* | Betulaceae | perennial | native |
| **BROMCIL** | fringed brome | *Bromus ciliatus* | Poaceae | perennial | native |
| **BROMINE** | smooth brome | *Bromus inermis* ssp. *Inermis* | Poaceae | perennial | exotic |
| **BROMTEC** | cheat grass | *Bromus tectorum* | Poaceae | annual | exotic |
| **CALACAN** | bluejoint grass | *Calamagrostis canadensis* | Poaceae | perennial | native |
| **CARDOLI** | little western bitter-cress | *Cardamine oligosperma* | Brassicaceae | annual | exotic |
| **CENTBIE** | spotted knapweed | *Centaurea biebersteinii* | Asteraceae | biennial | exotic |
| **CENTDIF** | diffuse knapweed | *Centaurea diffuse* | Asteraceae | biennial | exotic |
| **CHENALB** | lamb's quarters | *Chenopodium album* | Chenopodiaceae | annual | exotic |
| **CHIMUMB** | prince's-pine | *Chimaphila umbellata* | Pyrolaceae | perennial | native |
| **CICUDOU** | Douglas's water-hemlock | *Cicuta douglasii* | Apiaceae | perennial | native |
| **CIRSARV** | Canada thistle | *Cirsium arvense* | Asteraceae | perennial | exotic |
| **CIRSVUL** | bull thistle | *Cirsium vulgare* | Asteraceae | biennial | exotic |
| **CORNSTO** | red-osier dogwood | *Cornus stolonifera* | Rosaceae | perennial | native |
| **CREPATR** | slender hawksbeard | *Crepis atribarba originalis* | Asteraceae | perennial | native |
| **DACTGLO** | orchard grass | *Dactylis glomerata* | Poaceae | perennial | exotic |
| **DRYADRU** | yellow mountain-avens | *Dryas drummondii* | Rosaceae | perennial | native |
| **ELYMGLA** | blue wildrye | *Elymus glaucus* | Poaceae | perennial | native |
| **ELYMTRA** | slender wheat-grass | *Elymus trachycaulus* | Poaceae | perennial | native |
| **EPILANG** | fireweed | *Epilobium angustifolium* | Onagraceae | perennial | native |
| **EPILCIL** | purple-leafed willowherb | *Epilobium ciliatum* | Onagraceae | perennial | native |
| **EPILOBIsp** | willowherb species | *Epilobium* ssp. | Onagraceae | perennial | na |
| **EQUIARV** | common horsetail | *Equisetum arvense* | Equisetaceae | perennial | native |
| **EQUILAE** | smooth scouring rush | *Equisetum laevigatum* | Equisetaceae | perennial | native |
| **EQUIPAL** | swamp horsetail | *Equisetum palustre* | Equisetaceae | perennial | native |
| **ERIGEROsp** | daisy species | *Erigeron* ssp. | Asteraceae | perennial | n/a |
| **FESTOCC** | Western fescue | *Festuca occidentalis* | Poaceae | perennial | native |
| **FESTUCAsp** | fescue species | *Festuca* ssp. | Poaceae | perennial | native |
| **FRAGVIR** | wild strawberry | *Fragaria virginiana* | Rosaceae | perennial | native |
| **GAILARI** | brown-eyed Susan | *Gaillardia aristata* | Asteraceae | perennial | native |
| **GALITRI** | sweet-scented bedstraw | *Galium triflorum* | Rubiaceae | perennial | native |
| **GOODOBL** | rattlesnake-plantain | *Goodyera oblongifolia* | Orchidaceae | perennial | native |
| **HEUCCYL** | round-leaved alumroot | *Heuchera cylindrica* | Saxifragaceae | perennial | native |
| **HIERACIsp** | hawkweed | *Hieracium* | Asteraceae | perennial | n/a |
| **HIERGRA** | slender hawkweed | *Hieracium gracile* | Asteraceae | perennial | native |

| Species | Common Name | Scientific Name | family | Perennial annual | Origin |
|---|---|---|---|---|---|
| **HIERUMB** | narrow-leaved hawkweed | *Hieracium umbellatum* | Asteraceae | perennial | native |
| **HOLODIS** | oceanspray | *Holodiscus discolor* | Rosaceae | perennial | native |
| **JUNICOM** | common juniper | *Juniperus communis* | Cupressaceae | perennial | native |
| **LACTMUR** | wall lettuce | *Lactuca muralis* | Asteraceae | biennial | exotic |
| **LACTSER** | prickly lettuce | *Lactuca serriola* | Asteraceae | biennial | exotic |
| **LEUCVUL** | oxeye daisy | *Leucanthemum vulgare* | Asteraceae | perennial | exotic |
| **LICHEN** | lichen | n/a | n/a | perennial | n/a |
| **LINAGEN** | dalmatian toadflax | *Linaria genistifolia* | Scrophulariaceae | perennial | exotic |
| **LINAVUL** | common toadflax | *Linaria vulgaris* | Scrophulariaceae | perennial | exotic |
| **LYGOJUN** | rushlike skeleton-plant | *Lygodesmia juncea* | Asteraceae | perennial | native |
| **MEDILUP** | black medick | *Medicago lupulina* | Fabaceae | annual | exotic |
| **MEDISAT** | alfalfa | *Medicago sativa* | Fabaceae | perennial | exotic |
| **MELIALB** | white sweet clover | *Melilotus alba* | Fabaceae | annual | exotic |
| **MOSS** | moss | n/a | n/a | perennial | n/a |
| **ORTHSEC** | one-sided wintergreen | *Orthilia secunda* | Pyrolaceae | perennial | native |
| **PENSFRU** | shrubby penstemon | *Penstemon fruticosus* | Scrophulariaceae | perennial | native |
| **PERSMAC** | lady's thumb | *Persicaria maculosa* | Polygonaceae | annual | exotic |
| **PHACHAS** | silverleaf phacelia | *Phacelia hastata* | hydrophyllaceae | perennial | native |
| **PHILLEW** | mock-orange | *Philadelphus lewisii* | Hydrangeaceae | perennial | native |
| **PHLEPRA** | common Timothy | *Phleum pratense* | Poaceae | perennial | exotic |
| **PICEGLA** | white spruce | *Picea glauca* | Pinaceae | perennial | native |
| **PINUCON** | lodgepole pine | *Pinus contorta* | Pinaceae | perennial | native |
| **PINUPON** | ponderosa pine | *Pinus ponderosa* | Pinaceae | perennial | native |
| **PLANMAJ** | common plantain | *Plantago major* | Plantaginaceae | perennial | exotic |
| **POA COM** | Canada bluegrass | *Poa compressa* | Poaceae | perennial | exotic |
| **POA PAL** | fowl bluegrass | *Poa palustris* | Poaceae | perennial | native |
| **POA PRA** | Kentucky bluegrass | *Poa pratensis* | Poaceae | perennial | exotic |
| **POLEPUL** | Jacob's ladder | *Polemonium pulcherrimum* | Polemoniaceae | perennial | native |
| **POPUBAL** | black cottonwood | *Populus balsamifera* ssp. *trichocarpa* | Salicaceae | perennial | native |
| **POPUTRE** | trembling aspen | *Populus tremuloides* | Salicaceae | perennial | native |
| **PROSTRA** | rough-fruited fairybells | *Prosartes trachycarpa* | Liliaceae | perennial | native |
| **PRUNPEN** | pin cherry | *Prunus pensylvanica* | Rosaceae | perennial | native |
| **PSEUMEN** | Douglas-fir | *Pseudotsuga menziesii* | Pinaceae | perennial | native |
| **PSEUSPI** | bluebunch wheatgrass | *Pseudoroegneria spicata* | Poaceae | perennial | native |
| **PYROASA** | pink wintergreen | *Pyrola asarifolia* | Pyrolaceae | perennial | native |
| **RANUAQU** | white water-buttercup | *Ranunculus aquatilis* var. *aquatilis* | Ranunculaceae | perennial | native |
| **RIBELAC** | black gooseberry | *Ribes lacustre* | Grossulariaceae | perennial | native |
| **RORIPAL** | marsh yellow-cress | *Rorippa palustris* | Brassicaceae | annual/perennial | native |
| **ROSAACI** | prickly rose | *Rosa acicularis* | Rosaceae | perennial | native |
| **RUBUIDA** | red raspberry | *Rubus idaeus* | Rosaceae | perennial | native |
| **RUBUPAR** | thimbleberry | *Rubus parviflorus* | Rosaceae | perennial | native |
| **RUMECRI** | curly dock | *Rumex crispus* | Polygonaceae | perennial | exotic |
| **SALILAS** | Pacific willow | *Salix lasiandra* | Salicaceae | perennial | native |
| **SALIXSP** | willow species | *Salix* ssp. | Salicaceae | perennial | native |
| **SELAWAL** | Wallace's selaginella | *Selaginella wallacei* | Selaginellaceae | perennial | native |
| **SHEPCAN** | soapberry | *Sheperdia canadensis* | Elaeagnaceae | perennial | native |
| **SOLICAN** | Canada goldenrod | *Solidago canadensis* | Asteraceae | perennial | native |
| **SOLISPA** | spikelike goldenrod | *Solidago spathulatum* | Asteraceae | perennial | native |
| **SPIRBET** | birch-leaved spirea | *Spiraea betulifolia* | Rosaceae | perennial | native |
| **SYMPALB** | snowberry | *Symphoricarpos albus* | Caprifoliaceae | perennial | native |
| **TANAVUL** | common tansy | *Tanacetum vulgare* | Asteraceae | perennial | exotic |
| **TARAOFF** | dandelion | *Taraxacum officinale* | Asteraceae | perennial | exotic |
| **THUJPLI** | Western redcedar | *Thuja plicata* | Cupressaceae | perennial | native |
| **TRAGDUB** | yellow salsify | *Tragopogon dubius* | Asteraceae | biennial | exotic |
| **TRIFOLI** | clover species | *Trifolium* ssp. | Fabaceae | perennial | exotic |
| **TRIFPRA** | red clover | *Trifolium pratense* | Fabaceae | biennial | exotic |
| **VERBTHA** | great mullein | *Verbascum thapsus* | Scrophulariaceae | biennial | exotic |
| **VEROAME** | American brooklime | *Veronica beccabunga* | Scrophulariaceae | perennial | native |
| **VIOLGLA** | stream violet | *Viola glabella* | Violaceae | perennial | native |

## Appendix 3: Photopoint monitoring

**Transect AF01A**



BBF 3-16cms, transect AF01A. Start –0.35 m, end 1.65 m.

ABF 16cms+1, transect AF01A, front photo. Start 1.65 m, end 3.75 m.

ABF 16cms+1, transect AF01A, side photo. Start 1.65 m, end 3.75 m.

Upland1, transect AF01A. Start 3.75 m, end 8.5 m.

**Transect AF01A**

Upland2, transect AF01A. Start 25.7 m, end 31.5 m.

Upland2, transect AF01A, canopy photo. Start 25.7 m, end 31.5 m.

## Transect AF03A

Transect AF03A Site Photo. Camera height 1.3 m, bearing 133°, distance 16.4 m to board at bank full mark.

Transect AF03A Site Photo, zoomed. Camera height 1.3 m, bearing 133°, distance 16.4 m to board at bank full mark.

BBF 3-16, transect AF03A. Start 0 m, end —1.0 m.

BBF 3-16, transect AF03A, canopy photo. Start 0 m, end —1.0 m.

ABF 16cms+1, transect AF03A. Start 0 m, end 2 m.

ABF 16cms+1, transect AF03A, canopy photo. Start 0 m, end 2 m.

**Transect AF03A**

Upland1, transect AF03A. Start 2.23 m, end 7.23 m.

Upland2, transect AF03A. Start 23.93 m, end 25.93 m.

Upland2, transect AF03A, canopy photo. Start 29.93 m, end 25.93 m.

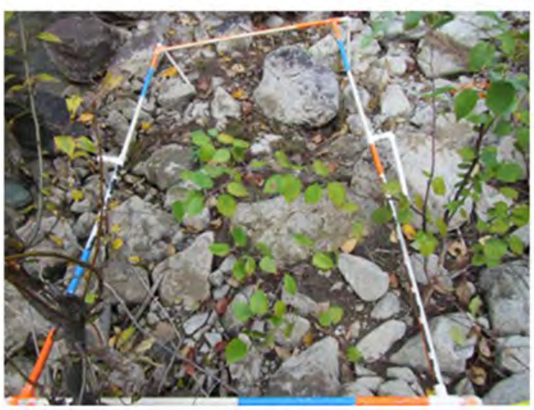
**Transect FMB01A**

Transect FMB01A Site Photo. Camera height 1.5 m, bearing 131°, distance 16.5 m to mark.

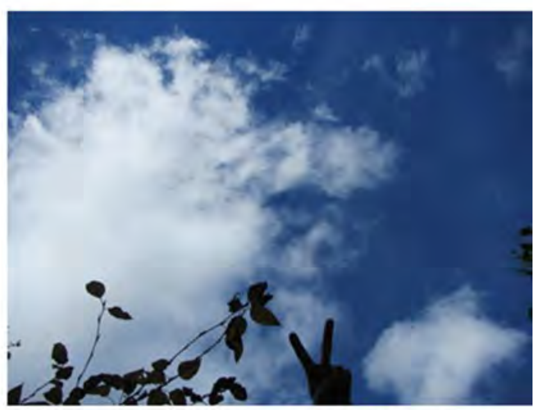
Transect FMB01A Site Photo, zoomed. Camera height 1.5 m, bearing 131°, distance 16.5 m to mark.

BBF 5-16cms, transect FMB01A. Start 0 m, end −1 m.

BBF 5-16cms, transect FMB01A, canopy picture. Start 0 m, end −1 m.



BBF 5-3, transect FMB01A. Start −1 m, end −2 m.



BBF 5-3, transect FMB01A, canopy picture. Start −1 m, end −2 m.

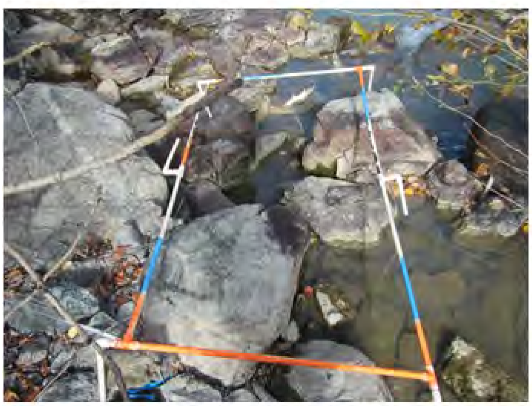
**Transcect FMB01A**

Upland1, transect FMB01A. Start 5.85 m, end 7.85 m.

Upland1, transect FMB01A, canopy picture. Start 5.85 m, end 7.85 m.

ABF 16 cms+1, transect FMB01A. Start 0 m, end 1 m.

ABF 16 cms+1, transect FMB01A, canopy picture. Start 0 m, end 1 m.



BBF 3-16cms, transect FMB01A. Start 13.7 m, end 14.7 m.

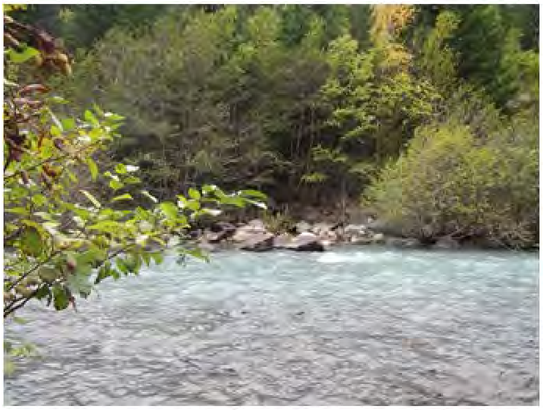
BBF 3-16cms, transect FMB01A, canopy picture. Start 13.7 m, end 14.7 m.

## Transect FMB01A

BBF 3-5cms, transect FMB01A. Start 15.1 m, end 17.1 m.

BBF 3-5cms, transect FMB01A, canopy picture. Start 15.1 m, end 17.1 m.

**Transect CTS01A**



Transect CTS01A Site Photo. Camera height 1.5 m, bearing 274°, distance 22.5 m.

Transect CTS01A. Site Photo, zoomed. Camera height 1.5 m, bearing 274°, distance 22.5 m.

FluvialBarMid, transect CTS01A. Start –4.1 m, end –6.1 m.

BBF 16-3cms, transect CTS01A. Start 0 m, end –1 m.

BBF 16+1, transect CTS01A. Start 0 m, end 1 m.

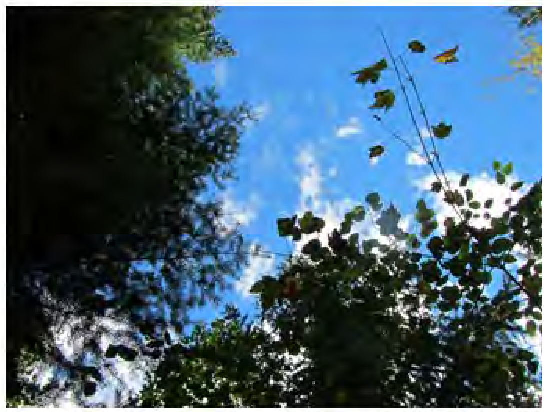
BBF 16+1, transect CTS01A, canopy picture. Start 0 m, end 1 m.

**Transect CTS01A**

Upper01, transect CTS01A. Start 0.73 m, end 6.45 m.

Upper01, transect CTS01A, canopy picture. Start 0.73 m, end 6.45 m.

Upper02, transect CTS01A. Start 7.15 m, end 12.15 m.



Upper02, transect CTS01A, canopy picture. Start 7.15 m, end 12.15 m.

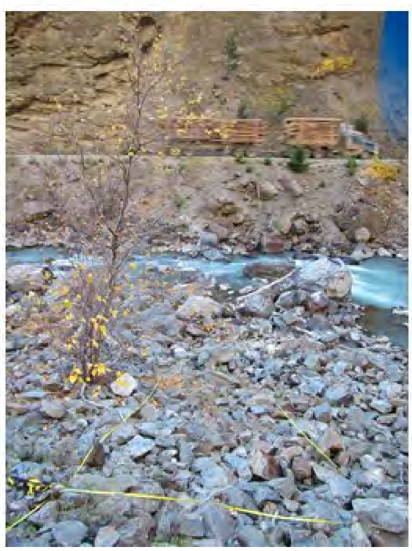
**Transect CS02B**

Transect CS02B Site Photo. Camera height 1.2 m, bearing 48°, distance 20.4 m.

Transect CS02B Site Photo, zoomed. Camera height 1.2 m, bearing 48°, distance 20.4 m.

BBF 3-5cms, transect CS02B. Start −5.65 m, end −4.65 m.

BBF 16-5cms, transect CS02B. Start −2 m, end 0 m.



Upland2, transect CS02B. Start 10 m, end 15 m.

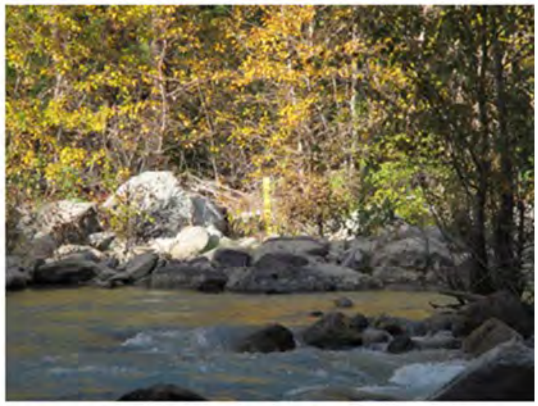
**Transect CS02B**

ABF 16cms+1, transect CS02B. Start 0 m, end 2 m.

Upland1, transect CS02B. Start 3 m, end 5 m.

**Transect FTS01A**

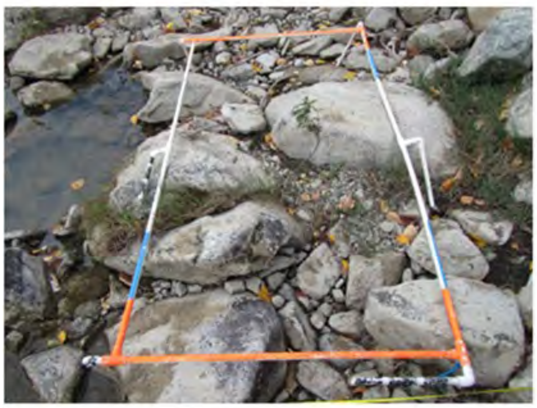
Transect FTS01A Site Photo. Camera height 1 m, bearing 200°, distance 33.9 m.



Transect FTS01A Site Photo, zoomed. Camera height 1 m, bearing 200°, distance 33.9 m.

BBF 3-5cms mid bar, transect FTS01A. Start –17 m, end –15 m.

BBF 3-5cms mid bar, transect FTS01A, canopy picture. Start –17 m, end –15 m.

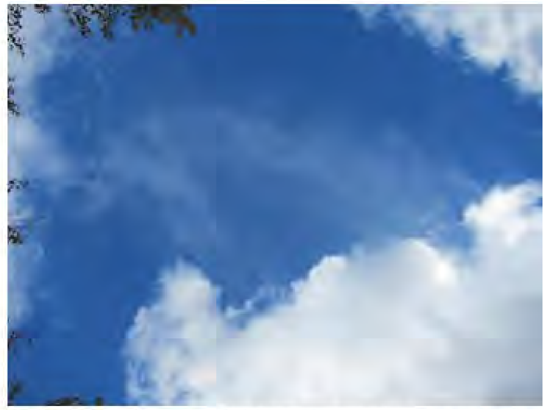


BBF 3-5cms, transect FTS01A. Start –4.59 m, end –5.59 m.

BBF 3-5cms, transect FTS01A, canopy picture. Start –4.59 m, end –5.59 m.

**Transect FTS01A**

BBF 5-16cmsA, transect FTS01A. Start −2.3 m, end −4.3 m.



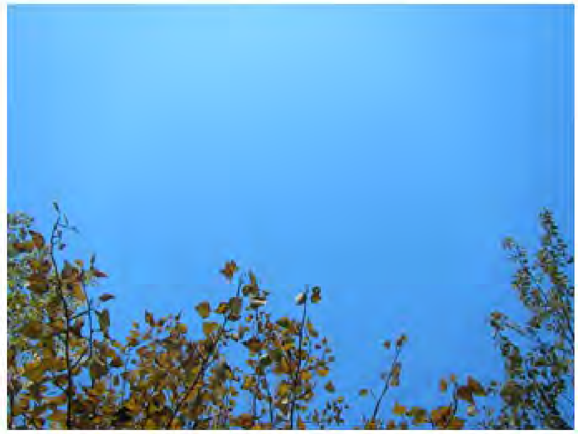
BBF 5-16cmsA, transect FTS01A, canopy picture. Start −2.3 m, end −4.3 m.

ABF 16cms+1, transect FTS01A. Start 0 m, end 1 m.

ABF 16cms+1, transect FTS01A, canopy picture. Start 0 m, end 1 m.

**Transect FTS01A**

Upland1, transect FTS01A. Start 0.75 m, end 2.75 m.



Upland1, transect FTS01A, canopy picture. Start 0.75 m, end 2.75 m.

Upland2, transect FTS01A. Start 9.5 m, end 14.5 m.

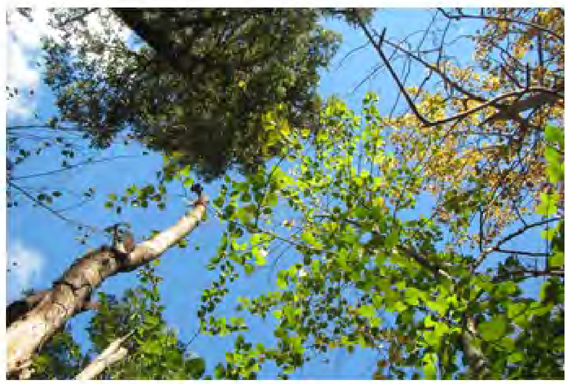
Upland2, transect FTS01A, canopy picture. Start 9.5 m, end 14.5 m.

## Transect FTS01A


Upland3, transect FTS01A. Start 22 m, end 27 m.


Upland3, transect FTS01A, canopy picture. Start 22 m, end 27 m.


Upland4, transect FTS01A. Start 32.4 m, end 37.4 m.


Upland4, transect FTS01A, canopy picture. Start 32.4 m, end 37.4 m.

**Transect CMF01A**


BBF 3-5cms, transect CMF01A. Start 0 m, end –2 m.

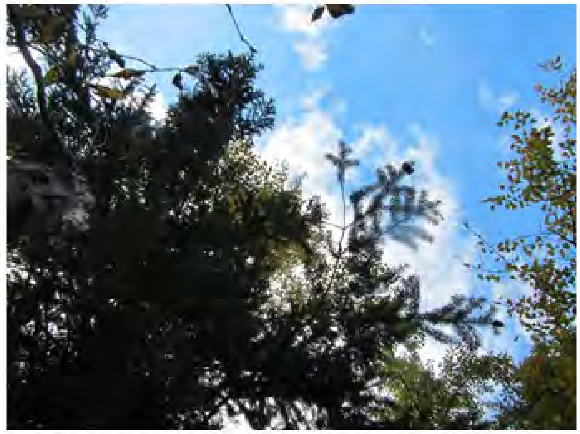

BBF 3-5cms, transect CMF01A, canopy picture. Start 0 m, end –2 m.


BBF 3-16cms, transect CMF01A. Start 0 m, end –1 m.


BBF 3-16cms, transect CMF01A, canopy picture. Start 0 m, end –1 m.

**Transect CMF01A**


ABF 16cms+1, transect CMF01A. Start 0 m, end 1 m.


ABF 16cms+1, transect CMF01A, canopy picture. Start 0 m, end 1 m.


Upland1, transect CMF01A. Start 1 m, end 3 m.


Upland1, transect CMF01A, canopy picture. Start 1 m, end 3 m.

**Transect CMF01A**

Upland2, transect CMF01A. Start 4.05 m, end 9.05 m.

Upland2, transect CMF01A, canopy picture. Start 4.05 m, end 9.05 m.