Duncan Dam Project Water Use Plan

Duncan Watershed Riparian and Cottonwood Monitoring

Implementation Year 7

Reference: DDMMON#8-1

Lower Duncan River Riparian Cottonwood Monitoring
Annual Report

Study Period: April 2016 – January 2017

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DDMMON#8-1 Lower Duncan River Riparian Cottonwood Monitoring Year 7 Annual Report (2016)

Final

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Cover photo

Lower Duncan River, Segment 3, Transect line 11 on mid-channel bar, looking towards the point of commencement (POC) which is on the point bar behind the mid-channel bar. Photo © Mary Louise Polzin, VAST Resource Solutions Inc.

EXECUTIVE SUMMARY

A ten-year riparian vegetation monitoring program was initiated along the lower Duncan River in 2009 as part of the Duncan Dam Project Water Use Plan (WUP). This study is intended to evaluate the impacts of the flow regime Alternative S73 (Alt S73) on black cottonwoods (*Populus trichocarpa* Torr. & Gray) and other vegetation. The Alt S73 flow regime criteria were:

- Sufficient time between the spring freshet recession and late summer/fall dam releases to allow seedlings to establish;
- Short intervals for late summer through winter high flows (<3 weeks); and
- Lower winter flows relative to spring freshet flows.

The study provides site-specific results to guide river flow regulation and better understand the relationships between flow regime, physical environmental conditions, and riparian vegetation. This report describes study Year 7 of the monitoring project that includes the lower Duncan River and the adjacent free-flowing lower Lardeau River as a comparative reference reach.

The floodplain zones, riparian vegetation, and black cottonwood (referred to as cottonwood in the Executive Summary) recruitment are being assessed in order to address two integral management questions and their associated hypotheses (see following table):

1) Are there changes in cottonwood recruitment or riparian vegetation communities?

2) What are the drivers of cottonwood success since Alt S73 was implemented?

The performance assessment of Alt S73 on the lower Duncan River riparian community will combine all years of the study and the 2016 results extend that data set.

The lower Duncan reach had significantly higher densities of cottonwood seedlings than the Lardeau reach ($P = 0.004$). Patterns in 2016 were consistent with patterns from prior sampling years but the lower August stage allowed seedling establishment at lower elevations along the Duncan, often within or very close to the active channel. Survival was consistent with past years with the Duncan and the Lardeau reaches having similar first year survival rates and the Lardeau having higher second and third year survival. Cottonwood phenology in 2016 revealed cottonwood seed release commencing in June, ideally following the declining discharge along the free-flowing Lardeau River.

The results from 2016 are consistent with previous years' data, suggesting that the river flow regime is the primary influence on cottonwood seedling establishment and survival along the Duncan River. The flow regime determines inundation timing and duration as well as sediment erosion and deposition. These have major impacts on cottonwood establishment and recruitment success. Colonization requirements are linked to elevational position with reference to stream stage pattern, geomorphic context, sediment substrate, longitudinal position (upstream-downstream), influence from tributary inflows, lake level and channel morphology. Influences from these multiple environmental factors were supported in the 2016 data.

Preliminary comparisons suggest that cottonwood recruitment may have actually been greater during pre-Alt73 flows in 1987 through 2007 than during the current Alt S73 flow regime. However, this is a provisional finding and more rigorous statistical analyses will follow in 2018.

Keywords – black cottonwoods, Duncan River, Lardeau River, river flow regime, seedling recruitment

DDMMON#8-1 Status of Objectives, Management Questions and Hypotheses after monitoring Year 7. Hypotheses testing was not part of year 7 analyses.

Objectives	Management Questions	Management Hypotheses	Year 7 (2016) Status
1) To assess the performance of Alt S73 on the lower Duncan River riparian community and specifically black cottonwoods, through comparisons of field-based performance measures.	1) Will the implementation of Alt S73 result in neutral, positive, or negative changes for black cottonwoods and riparian habitat diversity along the lower Duncan River as compared to past-regulated regimes?	H_{01}: There is no change in black cottonwood establishment or survival resulting from the implementation of Alt S73.	The 2016 results showed that seedling establishment, survival and recruitment continue to display variability. Tree core samples were collected to assess Pre-Alt S73 survival rates so H_{01} and Management Question 1 can be further investigated in 2018.
2) To quantify the relationships between abiotic influences and biological responses based on analyses of field data.	2) What are the key drivers of black cottonwood recruitment success along the lower Duncan River floodplain? How are these drivers influenced by river regulation?	H_{02}: Black cottonwood establishment and survival along the lower Duncan River are not affected by the river flow regime.	Cottonwood establishment and survival are linked to water inundation duration, river stage during the growth season, sediment erosion and deposition, establishment elevation, and the growth season weather. These factors, except weather, are influenced by river regulation. The past 7 years results show strong trends indicating that river flow regime does influence establishment and survival along the Duncan River. Rigorous hypothesis testing will follow in 2018.
3) To utilize the derived relationships in conceptual models for predicting the long-term response of black cottonwood and other riparian plant communities to a variety of flow regimes		H_{03}: The river flow regime is the primary driver of black cottonwood establishment and survival along the lower Duncan River.	The analyses from Year 7 along the lower Duncan River continue to indicate that the river flow regime is a primary driver of black cottonwood establishment and survival along the lower Duncan River. Deliberate hypothesis testing will also occur in 2018.

ACKNOWLEDGEMENTS

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1 INTRODUCTION

1.1 Overview

Located in southeastern British Columbia, the Duncan River is the major river that flows into the north end of Kootenay Lake. The Duncan River was first dammed in 1967, as the first of four major dams built on rivers in the upper reaches of the Columbia River Basin, following the 1964 Columbia River Treaty between Canada and the United States. These dams and reservoirs were built to provide flood control and hydroelectric power generation. The Duncan Dam installation resulted in extensive flooding of the full 25 km length of Duncan Lake and its adjacent wetlands along with river segments. This flooding created a reservoir that reaches approximately 45 km in length. The Duncan Dam has no hydroelectric power station, thereby increasing its operational flexibility. Water is released downstream from the dam to be stored in Kootenay Lake and subsequent reservoirs with passage through an extensive sequence of hydroelectric turbines of downstream dams along the Kootenay and Columbia Rivers.

In 2001 BC Hydro, the owner and operator of the Duncan Dam, initiated a Water Use Planning (WUP) process to consider alternate river regulation regimes. Following hydrologic modeling and a multi-stakeholder consultative process, the flow scenario Alternative (Alt) S73 was selected for implementation. The aim of Alt S73 was to balance the flood control and hydropower objectives with environmental benefits for fish in the Duncan and Lardeau Rivers and Kootenay Lake, and for reproduction of black cottonwood, *Populus trichocarpa*. The resulting flow regime includes peak flows of ~400 m^3/s from May 16 to July 31, with declining flows to ~250 m^3/s from August through September, and then further decline to 73 m^3/s for October. The flows then gradually increase to mid-May peak for the new Alt S73 targets. In 2009 it was projected that the Alt S73 would result in a narrow seedling survivable 'safe site zone' and some successful recruitment in any given year when:

- The free-flowing spring freshet peak is higher than 300 m^3/s; and
- Winter dam release flows are significantly lower than this for several subsequent years, or alternatively infrequently with a duration less than three weeks.

Minimal recruitment was expected when the spring freshet peak was less than 250 m^3/s, a late summer peak greater than the spring freshet peak occurs, or the fall and winter high flows were above 250 m^3/s for more than four weeks. The actual annual flow regime is being monitored during this ten year study relative to effects on black cottonwood recruitment.

The black cottonwoods provide the foundation for the floodplain forests and associated wildlife habitat along the lower Duncan and Lardeau rivers as well as along Kootenay Lake. Past research has demonstrated strong links between black cottonwood recruitment and river flows, especially below dams (Polzin 1998, Polzin and Rood 2000). Studies by Naiman et al. (2005) have also revealed the links between cottonwoods, wildlife habitat and overall ecosystem function. Accordingly, black cottonwood was identified by the WUP as the indicator species for monitoring the effects of Alt S73 on riparian biological diversity along the lower Duncan River.

The operation regime was implemented in 2008 and VAST Resource Solutions Inc. (VAST) (formerly Interior Reforestation Company Ltd.) have been investigating the environmental responses along the lower Duncan River and along the adjacent free-flowing Lardeau River as a reference for comparison, since 2009. A more detailed description of the background to this project is provided in the initial Year 1 report (Polzin et al. 2010). This riparian black cottonwood monitoring program was designated as DDMMON#8-1 (BC Hydro 2009).

Two key management questions were developed by BC Hydro (2009) to help address uncertainty associated with black cottonwood hydrograph performance measures:

1) Will the implementation of Alt S73 result in neutral, positive, or negative changes for black cottonwood and riparian habitat diversity along the lower Duncan River, as compared to past-regulated regimes?
2) What are the key factors enabling successful black cottonwood recruitment along the lower Duncan River floodplain, and how are these influenced by river regulation?

Declines in cottonwood populations downstream from dams along other river systems have been documented (see Rood and Mahoney 1990, Polzin and Rood 2000, Merritt and Cooper 2000). However, the lower Duncan River differs from most other studied dammed systems for three main reasons:

First, 50 to 60 per cent of the flow below the Duncan Dam comes from the free-flowing Lardeau River and two smaller tributaries, Hamill and Copper Creeks. The input from the Lardeau River and the creeks results in substantial sediment and woody debris inputs below the dam. In contrast, most other dammed systems experience a 'silt shadow', or zone of sediment depletion, and the loss of large woody debris downstream of the dam. This results in a deficiency of sediment and woody debris downstream from almost all other dams (Williams and Wolman 1984, Dunne 1988, Debano and Schmidt 1990, Rood and Mahoney 1995, Polzin 1998).

Second, the Duncan Dam has reduced spring peak flow release into the Lower Duncan River since the completion of the Duncan Dam and Alt S73 did not change this. The reduced spring peak freshet cannot effectively transport the sediment and woody debris entering the Lower Duncan River system from the free-flowing tributaries (i.e. Lardeau River) as it did before the dam was installed. This has resulted in extensive large woody debris deposition along the lower Duncan River as well as aggradation from the net sediment deposition.

Third, the lower Duncan River is situated in a humid, mountainous region, which results in extensive groundwater inflows from the adjacent mountain uplands. Consequently the alluvial groundwater in the floodplain zone is recharged by upland groundwater, rather than being more dependent upon infiltration from river flow, as is the case in prairie semi-arid ecoregions.

The data collected during DDMMON#8-1 monitoring project will thus characterize the unusual hydrogeomorphic conditions along the lower Duncan River and the subsequent influences on black cottonwood recruitment and the broader influence on the riparian woodlands.

1.2 Objectives

The objectives of the DDMMON#8-1 monitoring program are designed to be achieved over a 10-year study period (BC Hydro 2009). They are:

- To assess the performance of Alt S73 on the lower Duncan River riparian community and specifically black cottonwood through comparison of field-based performance measures;
- To quantify the relationships between abiotic influences (e.g., river hydrology or groundwater hydrology), and biological responses (i.e., black cottonwood recruitment), based on analyses of field data; and
- To utilize the above-derived relationships in conceptual models for predicting the long-term response of black cottonwoods and other riparian plant communities to a variety of flow regimes.

To meet the objectives and address the management questions, BC Hydro (2009) has identified three hypotheses:

Hypothesis 1

H$_{01}$: There is no change in black cottonwood establishment or survival resulting from the implementation of Alt S73; versus

H$_{A1}$: The implementation of Alt S73 results in either (a) a positive or (b) a negative influence on black cottonwood establishment or survival.

Hypothesis 2

H$_{02}$: Black cottonwood establishment and survival along the lower Duncan River are not affected by the river flow regime; versus

H$_{A2}$: Black cottonwood establishment and survival along the lower Duncan River are affected by the river flow regime.

Hypothesis 3

H$_{03}$: The river flow regime is the primary driver of black cottonwood establishment and survival along the lower Duncan River; versus

H$_{A3}$: The river flow regime is not the primary driver of black cottonwood establishment and survival along the lower Duncan River.

Guided by the above long-term objectives and hypotheses, the primary objectives in study Year 7 were to:

- Collect black cottonwood seedling data for 2014, 2015, and 2016 to add to the previous data sets (2009 – 2015); and
- Collect black cottonwood tree core samples within 100 m^2 plots within the recruitment band for black cottonwood trees established from 1987 to 2007 for pre-Alt S73 recruitment data.

The black cottonwood seedling establishment and recruitment analyses at the transect level for study Year 7 were analyzed relative to the key management questions. Data in previous years have shown that the Duncan River flow regime affects black cottonwood establishment and survival. Study Year 7 is a summary reporting year with comparisons of the 2014, 2015, and 2016 seedling data. Data from study Year 7 will add to the collective data sets for statistical testing of the three Hypotheses in 2018, to assess the effect of Alt S73.

Additional data collection and analyses of tree cores were used to investigate black cottonwood recruitment over two decades for the pre-Alt S73 interval from 1987 to 2007. This will supply pre-Alt S73 data to enable further testing of hypothesis 1 (H$_{01}$) in 2018.

2 METHODS

2.1 Study Area

The lower Duncan River is located in the Columbia Mountains region in southeastern British Columbia. It flows south out of the 45 km-long Duncan Reservoir (includes the former Duncan Lake which was 15 km long), which was impounded by the Duncan Dam in 1967. Approximately 300 m downstream from the Dam, the lower Duncan River is joined by the free-flowing Lardeau River, and the combined rivers continue south for approximately 11 km to Kootenay Lake where a broad delta is formed (Figure 2-1). Midway along in Segment 4, the lower Duncan River channel is joined by three free-flowing tributaries: Meadow, Hamill and Cooper creeks. Meadow Creek includes an artificial channel producing a low gradient stream, contributing only small amounts of sediment and woody debris during spring high water. At their confluence, the Duncan River sometimes flows into Meadow Creek creating a back-water effect. This backup of water into Meadow Creek channel has been documented to occur past the second meander point bar upstream of the confluence since 2009, and earlier by Miles (2002). In contrast to Meadow Creek, Hamill and Cooper Creeks are high gradient streams that contribute substantial sediment and large woody debris to the lower Duncan River.

The Lardeau River was selected as the reference reach because of its proximity to the lower Duncan River and similar channel reaches compared to the Duncan River (Polzin et al. 2010 and 2015 has further information about the similarities and differences between the lower Duncan River and the Lardeau River reference reach). The Lardeau River flows out of a nearly parallel watershed with a higher gradient and lower discharge volume compared to the Duncan River. The Lardeau River study reach starts approximately 3 km upstream of the confluence with the lower Duncan River and extends upstream for approximately 11 km (Figure 2-2).

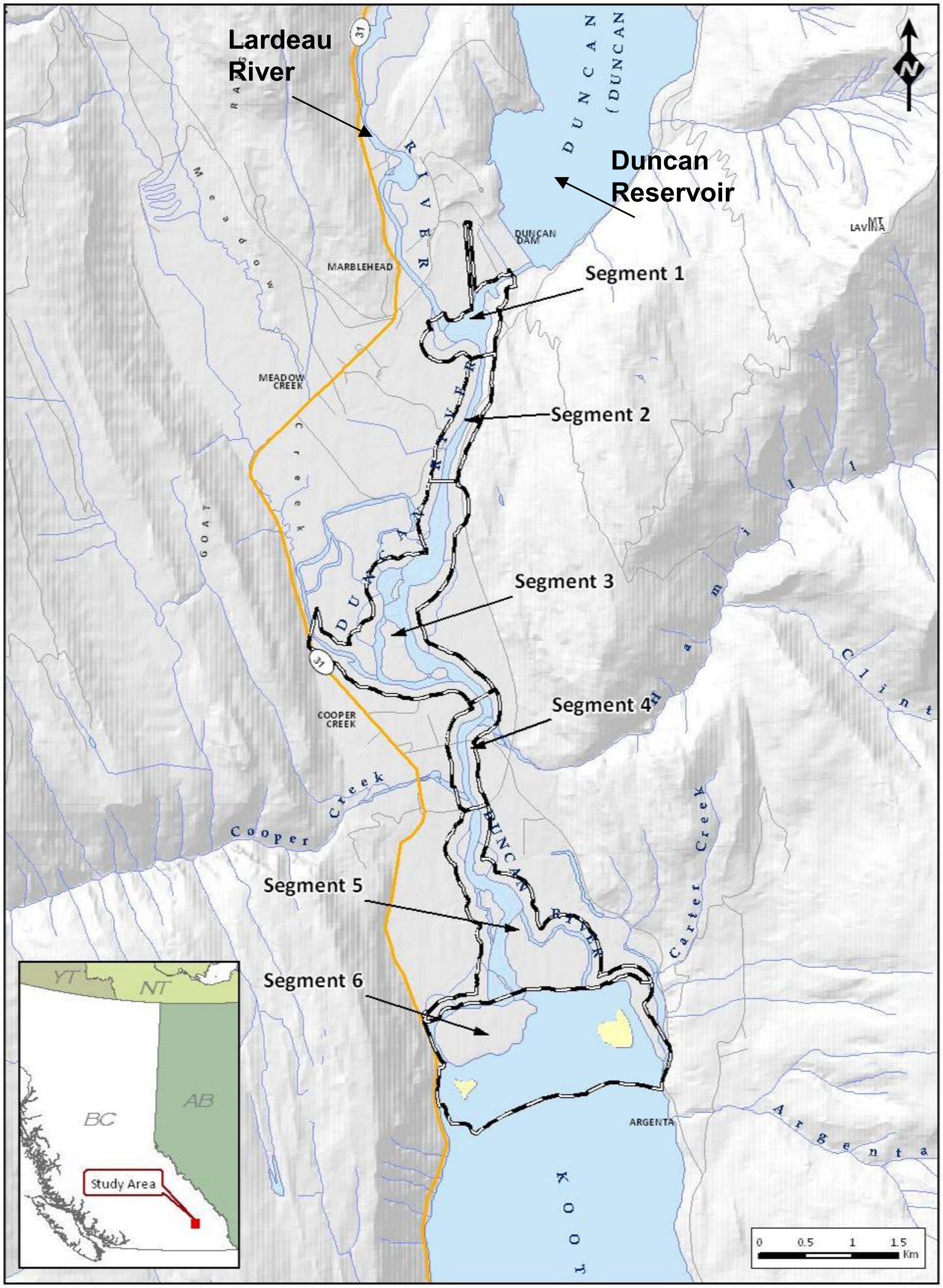


Figure 2-1: Study area for the lower Duncan River with stratification of the river study segments.

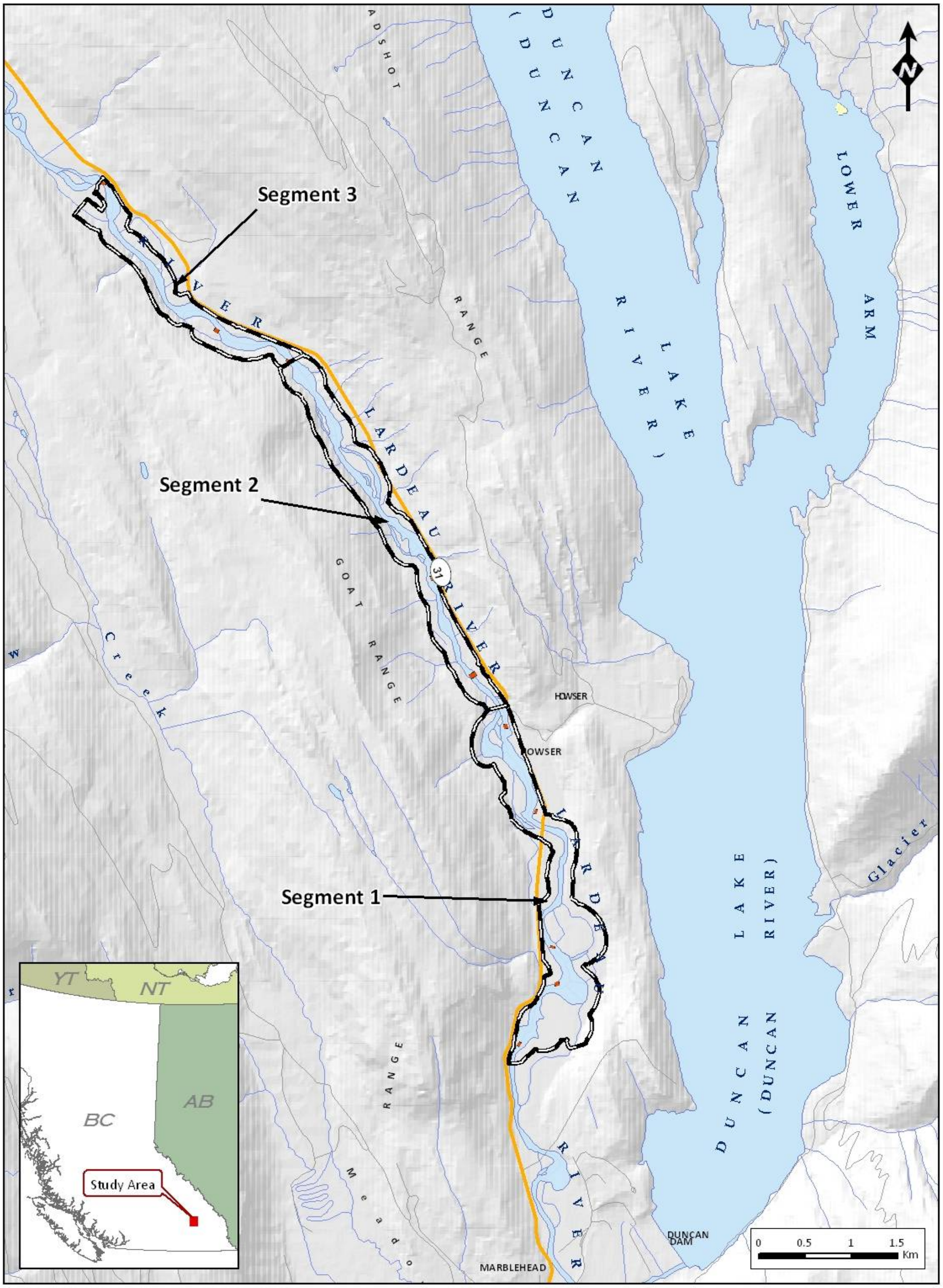


Figure 2-2: **Study area for the Lardeau River with stratification of the river study segments.**

2.2 Sampling Design

Study Year 7 (2016) of this project utilized the study design from Year 1 (2009) (see Polzin et al. 2010) with the modifications implemented in study Year 3 (2012), (Polzin and Rood 2013). In brief, the sampling design included the following tasks and collection of the following data for 2016:

- Collect seedling information from 2016 black cottonwood germinants and previously measured seedlings from 2014 and 2015;
- Collect transect-specific stages at locations with gradually sloping point bars;
- Download hydrometric records from Water Survey of Canada stations 08NH118, and request data for station 08NH007 for hydrometric analyses;
- Download precipitation and temperature records (Duncan Lake Dam station at Meadow Creek station 1142574) for weather analyses; and
- Describe black cottonwood phenology, timing of development.

The Duncan Reach was stratified into six segments and the Lardeau Reach into three, based on channel morphology (Polzin et al. 2010). Each segment was sampled using randomly selected transect lines for the Duncan Reach (Figure 2-4) and Lardeau Reach (Figure 2-5; see Polzin et al. 2010 for details). All potential recruitment meander point bars and mid-channel bars in each segment had transect lines laid out perpendicular to the river, every 10 m (the length of a tree quadrat) and numbered sequentially using GIS. Then using a random number generator, ("randombetween" where 1 is the bottom, and the number of transect lines for the segment is the top number, example 30), random number(s) were generated per segment. The number associated with each selected transect line had GPS coordinates and were used to locate the position in the field. The resulting transect lines had tag numbers attached to a tree for the point-of-commencement (POC) and the bearing for the line recorded. The established POC's and end-of-transect (EOT's) had their locations recorded based on a Trimble precision GPS used in the field (see Polzin et al. 2010 for detailed description). The UTM coordinates are located in Appendix 4.

The Duncan Reach segments had the following number of permanent transect lines established.

- Duncan Segment 1 (D1) has three transect lines – one transect line in the splash zone of the dam and two transect lines on the meander lobe back channel – influenced by Duncan River similar to delta zone.
- D2 has a moderately entrenched straight channel pattern (Leopold and Wolman 1957, Schumm 1981) with very limited opportunities for black cottonwood recruitment. This segment is monitored through periodic float trips to observe any recruitment sites that might develop during the study period. It was floated in 2009, 2013, 2015, and 2016 with no new development of potential recruitment sites. It is also monitored with the orthophoto analysis that is completed every three years.
- D3 has ten transect lines on a wide floodplain with a meandering channel pattern (Leopold and Wolman 1957, Schumm 1981).
- D4 has three transect lines along an entrenched, relatively straight channel pattern, and is influenced by Hamill and Cooper creeks.
- D5 has six transect lines and is more constrained than D3 with a meandering channel pattern (lower sinuosity) (Leopold and Wolman 1957, Schumm 1981).

- D6 has four transect lines in the delta zone that is influenced by Kootenay Lake and the Duncan River outflow.

The Lardeau Reach segments had the following number of permanent transect lines established.

- Lardeau Segment 1 (L1) has four transect lines. This involves the widest floodplain with a meandering channel.
- L2 has three transect lines along a very constrained to slightly meandering channel.
- L3 has three transect lines along a river reach that is intermediate between L1 and L2 for the extent of constraint versus meandering.

The sampling designed (set up in 2009) incorporated the basic concept of a hydrogeomorphic framework, where the relationships between riparian vegetation, elevation and substrate conditions, as well as river flow, stage patterns and groundwater patterns can be analyzed and modelled. We implemented a composite study design within this framework, which included both temporal and spatial comparisons, as employed by Braatne et al. (2008). The use of a surveyed (elevational profile) belt transect lines allowed for the collection of riparian plant occurrence along three spatial dimensions (Cartesian coordinated x, y, z) (Figure 2-3). The x-axis represents the longitudinal axis, the position along the upstream-to-downstream corridor of a river. The y-axis represents the distance away from the river edge. The banks rise up from the river and this elevational rise provides the third spatial dimension, the z-axis. Long-term monitoring to analyze responses to human alterations, such as changes in river flow regime requires a study system that facilitates repetitive observations relative to the three spatial dimensions which adds the fourth dimension, temporal (time) comparisons.

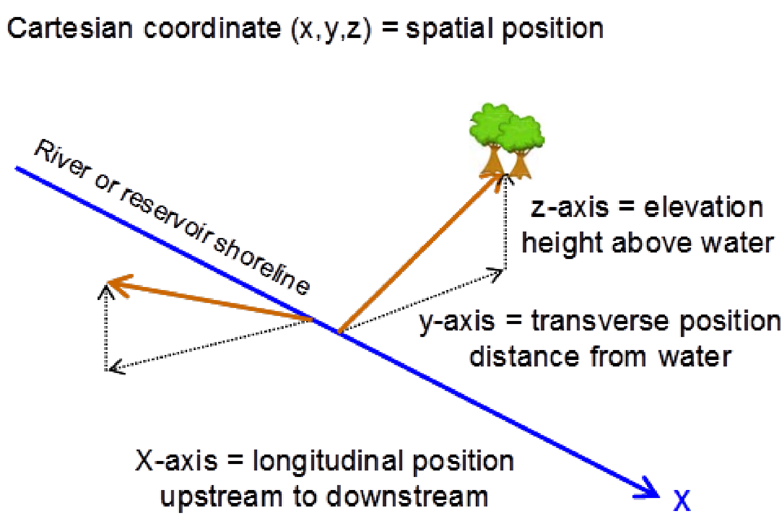


Figure 2-3: Riparian plant occurrence along three spatial dimensions.

The 2016 black cottonwood germinants densities, heights, and positions along the transect line (for elevation) were recorded when they occurred along the transect line. Seedling data were recorded within 1 m^2 quadrats along the downstream side of the transect lines. The previous seedlings from 2014 to 2016 were tracked for survival densities and heights, resulting in three age classes being recorded each year. Quadrats that had seedlings recorded in the previous two years were revisited and any new locations where germinates occurred were also inventoried.

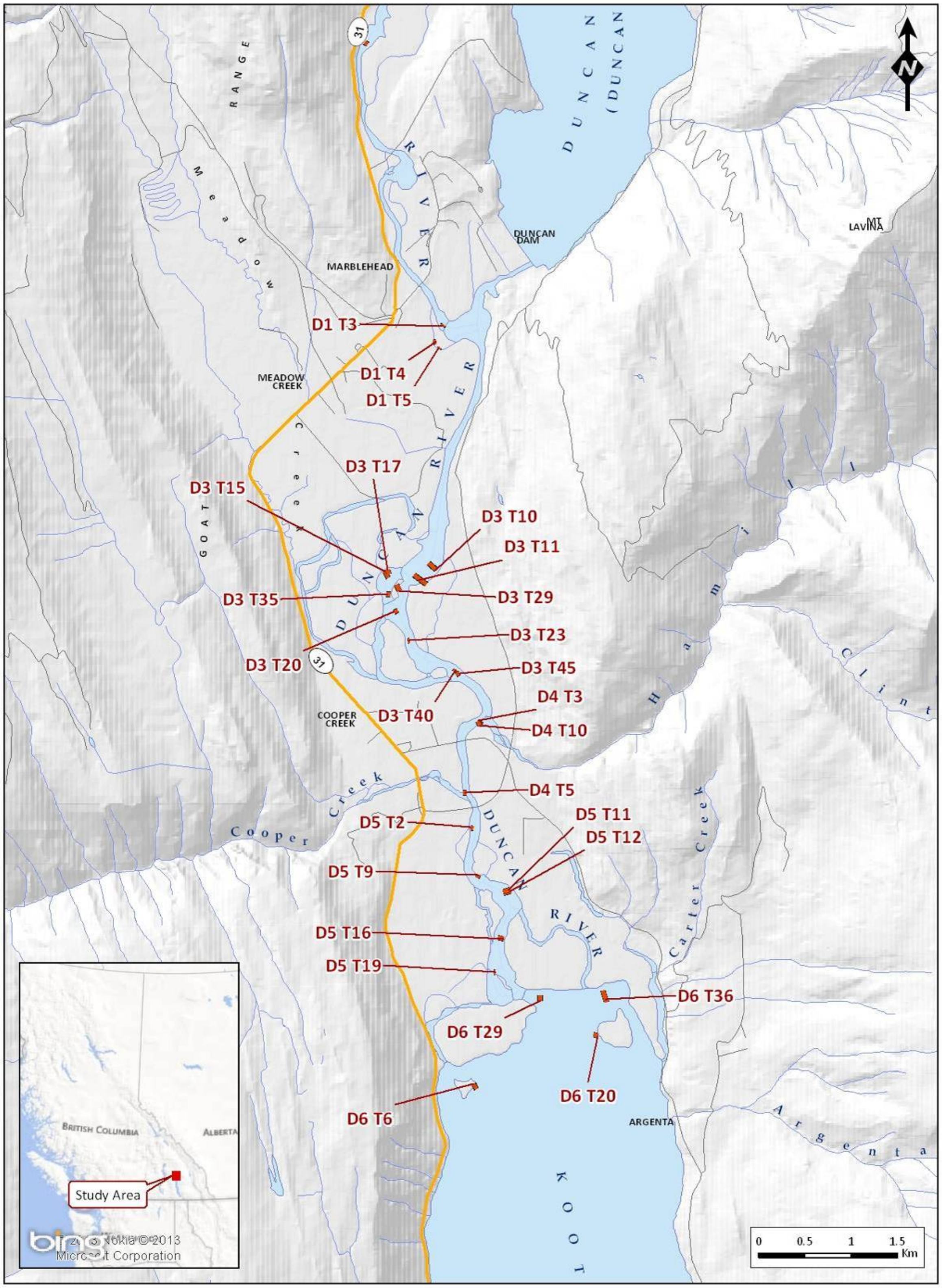


Figure 2-4: **Lower Duncan River study transects in 2016. Segments are indicated by the number following D (Duncan), and transect numbers are indicated after the T (transect).**

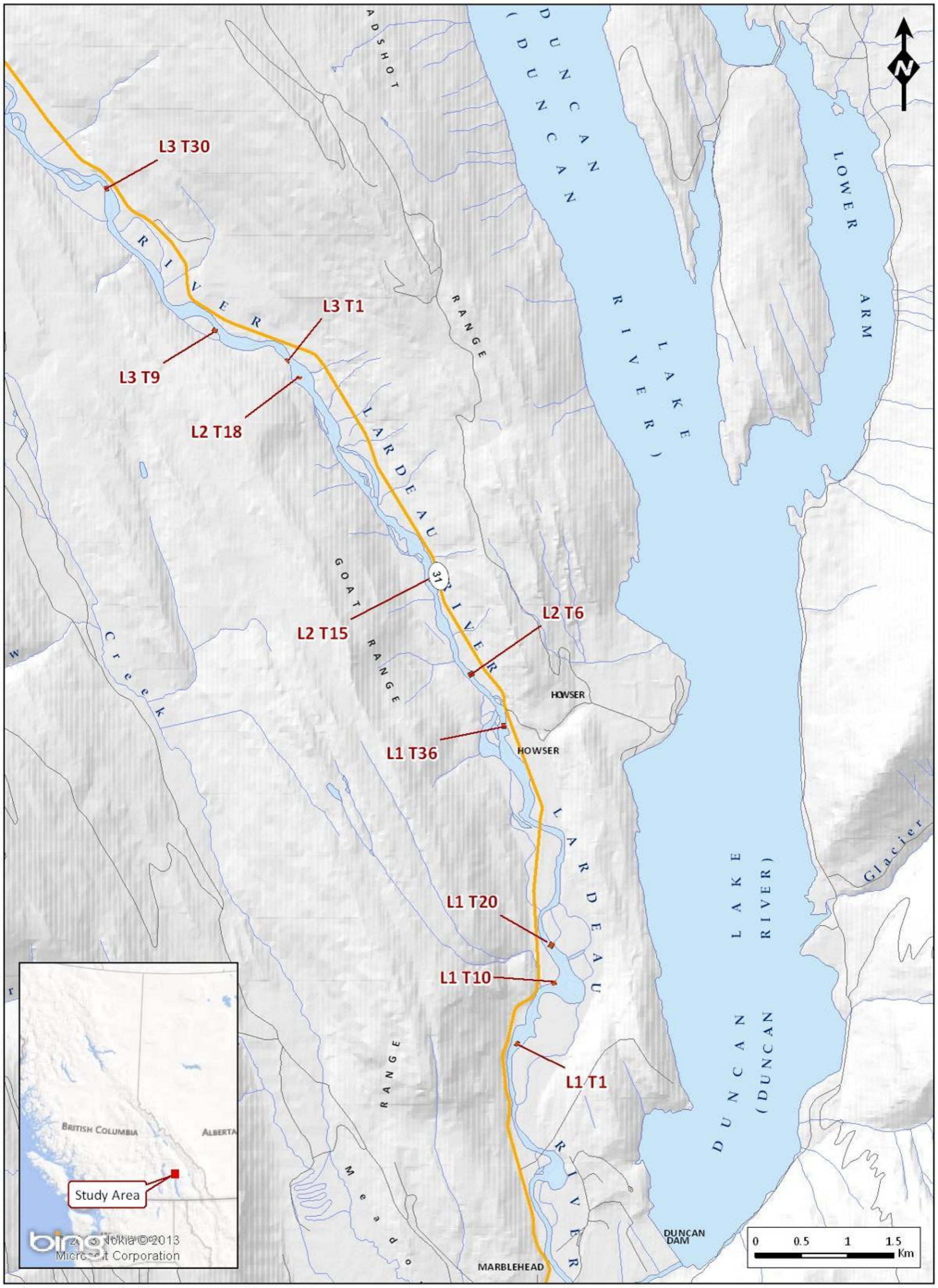


Figure 2-5: Lardeau River study transects in 2016. Segments are indicated by the number following L (Lardeau), and transect numbers are indicated after the T (transect).

All transect lines were surveyed in 2009 and resurveyed in April/May of 2013. New transect lines were established to replace transect lines that no longer met requirements or were removed following the extended flood of 2012. Duncan River Segment 4 (D4) transect lines are located along the Duncan River, but are also influenced by the Hamill Creek (two transect lines) and Cooper Creek (one transect line) outflows. Both of these creeks experienced large flash flood events triggered by an extreme rain event resulting in considerable erosion and deposition. Therefore, the three transect lines were resurveyed in spring of 2014 to record the extent of change that occurred from the high water event (Polzin et al. 2015).

2.3 Pre-Alt S73 Sampling Design

This sampling design builds on the randomly selected transect line locations for the vegetation and seedling monitoring as previously described. The existing sampling design is based on segments, with the transect lines representing replicates within each segment. The pre-Alt S73 tree recruitment sampling design will establish ‘Sites’ within each segment, based on meander lobe morphology and the size based on the area occupied by pre-Alt S73 black cottonwood trees within the 20 year pre-Alt S73 interval, which was the 1987 to 2007 time period. Plots were randomly selected within each site and 100 m^2 plots were used so previously collected data within 100 m^2 plots by Herbison (2003) could be used for the power analysis. The 2008 to current polygon was also delineated for the newly established “Sites” for the study seedling results for hypothesis testing.

We performed an *a priori* power analysis to determine if our sampling design was sufficient to avoid Type II errors in our pre-Alt S73 monitoring along the lower Duncan Rivers. Sample size calculations were used for determining how many sampling plots were required along the entire lower Duncan reach to achieve a desired power of 0.9.

Power analyses require the following information:

- Definitions of the population and sampling unit;
- Standard deviation;
- Mean;
- Effect size (minimum deviation from the null hypothesis that will be detected);
- A measure of expected variation; and
- Either the desired power (if calculating sample size), or the sample size (if calculating the power of a study).

Previous data collected by Herbison (2003) was used for the sample size power analysis for calculating the standard deviation and arithmetic mean. The data was collected within 100 m^2 plots in 2002. The sampling data used were the number of black cottonwood trees cored within a 100 m^2 plot, which were within the 20 year bracket defined for the pre-Alt S73 analyses. Plots with no trees occurring within the 20 year bracket were not used. Pre-field analysis used tree core counts previously collected (Herbison 2003) for plots located within the “Sites” designated for analysis along the lower Duncan River.

The power analysis was conducted using the following equation (Zuuring 1996) to ensure that the sample size captured by this design was sufficiently large to allow for detection of change within the 20 year bracket recruitment zone, for comparison to the 10 year bracket of black cottonwood recruitment post-Alt S73.

Equation 1: $$\mathbf{n = (A^2 / \mathit{t}^2\, cv^2 + 1/N)^{-1}}$$

Where: n = sample size (number of plots)

t = critical values of the t distribution with an alpha set at 0.05 ($t_{(\alpha = 0.05)}$) from statistical tables = 2.069 (for a df = 23 plots utilized for this pre-field assessment). This value is used as a proxy for effect size.

cv = coefficient of variation =13.85 ([standard deviation/arithmetic mean]*100)

A = allowable Type II error percentage set at 10 per cent = 90 per cent power. This value is used as a proxy for desired power.

N = population size

When population size is unknown, N is arbitrarily set at infinity, reducing the 1/N expression to effectively zero, thus:

$$\mathbf{n = \mathit{t}^2 cv^2 / A^2}$$

Statistical methods using analysis of variance (such as this one) are designed to deal with continuous dependent variables. Count data was therefore adapted by using data transformation – square root of the count plus 1 – for sampling size calculation. Pre-field data collection occurred within 100 m^2 plots for the Duncan River (all sites combined); therefore, results represent how many 100 m^2 plots are required for 90 per cent power for the Lower Duncan River.

Lower Duncan River - $n= 2.069^2(13.85)^2/10^2$

$n = 8.2$ plots = 8 plots for power of 90%

A sample size estimate of 8 plots was needed for 90 per cent power, for the lower Duncan River. Post-field actual number of plots was a total of 42 plots.

Building on the original sampling design for transects, Sites were assigned and delineated within segments as:

Segment 1 – Two sites were delineated and completed during the May field survey.

- Site 1: includes Transect 3 area with the associated point bar for seedling establishment and recruitment surveys (2008 – 2017) and the area behind the transect line point of commencement (POC) that includes the past recruitment zone for 1987 to 2007. Actual boundaries for the pre-Alt S73 were delineated from 2015 air photos, field-verified and adjusted if required once core sample results were obtained post field work. Completed in May.
- Site 2: included Transects 4 and 5 areas with the same criteria described above for delineation of the site back boundary and all sites within the study. Completed in May.

Segment 3 – Four sites were delineated:

- Site 3: included Transect 10 area (May);
- Site 4: included Transect 11 area (May and mid-channel bar in August);
- Site 5: included Transects 15 and 17 areas (August);
- Site 6: included Transects 29 and 35 areas not competed because of access problems; and

- Sites 7, 8 and 9: are not part of this design but will be used in 2018 for seedling recruitment per hectare, so included here as place holders so it does not complicate naming convention later.

Segment 4 – Two sites were delineated:

- Site 10: included Transects 3 and 10 areas (May); and
- Site 11: included Transect 5 area (May).

Segment 5 – Four sites were delineated:

- Site 12: included Transect 2 area (May);
- Site 13: included Transect 9 area (May);
- Site 14: not part of this sampling (place holder) but has Transects 11 and 12;
- Site 15: included Transect 16 area (October); and
- Site 16: included Transect 19 area (October).

Segment 6 had two sites delineated that had a possibility of having recruitment within the time bracket of interest. The majority of the cover since 1987 has been willow recruitment in the transect line areas already established. However, sites were delineated for each transect line location where black cottonwood trees were identified in the process (from enlarged air photos of the site and field survey of the delineated area) that were not sampled previously, beyond the recruitment age of interest, or were sampled during the October seedling monitoring in 2016. It includes:

- Site 17, included Transect 29 area (October);
- Site 18, included Transect 36 area (October);
- Site 19, included Transect 20 area (no black cottonwoods in delineated area) and
- Site 20, not part of this sampling (place holder) but has Transect 6.

Site 20 is along the lake so it was not included in the analysis and only older trees greater than 70 years since recruitment were near the possible area of delineation.

The delineated sites were split into two age brackets: 1987 to 2007 for the pre-Alt S73, and 2008 to 2017 for the Alt S73 flow regime recruitment data. The size of each area within a site was used to calculate the number of seedlings per hectare and the number of seedlings per Site. Table 2-1 has the area in square metres, as well as hectares, for each site, each age bracket and the total Site area in hectares.

Plot locations within each site for the 1987-2007 age bracket involved random selection from a grid pattern of dots of 10 m X 10 m for the location of each 100 m^2 plot with the dot representing the plot center. Two to four plots were randomly selected depending on the size of the site. Each dot in the grid pattern was numbered sequentially and a random number generator was used to randomly select the location of the plots. The numbers of dots were used to define the random number generator, i.e. 1 to 50, or 1 to 36, etc. The order of locations was recorded with additional plots selected in case the area was determined not to be within the appropriate age bracket when the field work was undertaken.

Table 2-1: Tree core sampling site areas for the 1987 to 2007 and 2008 to 2017 age brackets and total site area (provisional data).

Segment	Site#	1987-2007 Area (m^2)	1987-2007 Area (ha)	2008-2017 Area (m^2)	2008-2017 Area (ha)	Total Site Area (ha)
1	1	2,619.4	0.26	2,080.05	0.21	0.47
	2	6,272.9	0.63	4,244.45	0.42	1.05
3	3	8,972.3	0.90	9,413.78	0.94	1.84
	4	10,628.0	1.06	10,358.35	1.04	2.10
	5	7,022.8	0.70	13,130.64	1.31	2.02
4	10	4,307.4	0.43	6,392.66	0.64	1.07
	11	4,571.5	0.46	4,030.91	0.40	0.86
5	12	5,693.8	0.57	4,244.9	0.42	0.99
	13	1,226.6	0.12	1,012.8	0.10	0.22
	15	4,831.8	0.48	4,732.95	0.47	0.96
	16	5,879.2	0.59	487.76	0.05	0.64
6	17	7,525.5	0.75	8,045.47	0.80	1.56
	18	9,390.5	0.94	19,968.14	2.00	2.94

There were 13 sites with a total of 42 plots completed in 2016, which substantially surpassed the required 8 plots for the 90 per cent power and the 33 plots required for the 95 per cent power.

Preliminary data structure for analysis consisted of the two age brackets for pre-post-Alt S73 flow regime. The 1987 to 2007 age bracket can be split again into two ten year periods, one from 1987 to 1996 and a second from 1997 to 2007. This was not done for preliminary analysis, but will be useful in the full analysis in 2018 for comparing the Alt S73 to the previous 10 year bracket and to track changes between the two 10 year age bracket recruitment levels. Trees with corresponding ages can be grouped by the two brackets as well as all together for the twenty year bracket. The Alt S73 (2008 to 2018) bracket will have additional seedling recruitment data added in 2017 and 2018. This may change mean recruitment slightly compared to this provisional data, which ends with seedling established in 2014 and survived to the fall of 2016 thereby being considered recruitment seedlings.

2.4 Seasonal Weather

Daily precipitation and temperature data were downloaded from Environment Canada's website for the Duncan Lake Dam station at Meadow Creek, climate ID: 1142574. The web site location was changed in 2016[1].

Precipitation and temperature data were provided for years 2014, 2015 and 2016, from January to December (only tracking changes over a three year period). At the time of analyses and report writing, weather data from weather station 1142574 for 2016 ended

11 http://climate.weather.gc.ca/climate_data/daily_data_e.html?timeframe=2&hlyRange=%7C&dlyRange=1963-03-01%7C2016-07-20&mlyRange=1963-01-01%7C2007-02-01&StationID=1115&Prov=BC&urlExtension=_e.html&searchType=stnProv&optLimit=yearRange&StartYear=1840&EndYear=2016&selRowPerPage=25&Line=439&lstProvince=BC&Day=18&Year=2016&Month=8

December 14th as of December 19, 2016. Historical averages for precipitation were also downloaded. The Canadian Climate Averages were updated from the above web site with their calculation set at 1981 to 2010.

2.5 Hydrology

The 2016 river discharge (*Q*) and stage data were downloaded from Environment Canada's Water Survey website[2] for the lower Duncan hydrometric station. The Lardeau River provisional discharge data were provided by special request from Environment Canada's water office. Hydrometric data were collected from the following stations:

1) Station 08NH118: located on the lower Duncan River, below the dam and below the confluence of Lardeau River (downstream (d/s) station), the 2016 data are provisional; and
2) Station 08NH007: located on the Lardeau River at Marblehead located approximately 700 m upstream of the confluence with the lower Duncan River, the 2016 data are provisional.

Base stages were identified in 2009 for both the Duncan and Lardeau rivers (Polzin et al. 2010). The Duncan River base stage of 1.52 m was selected as it was the typical stage for late September into early October, before the Duncan Dam was constructed. The Lardeau River base stage of 0.843 m was used as the typical stage for the same time period.

2.6 Black cottonwood Phenology

The seasonal timing of developmental and reproductive events was documented for black cottonwood phenology, consistent with previous year's data collection. Close-up observations of representative trees were used to track dates of catkin and leaf emergence. Visual observations from fixed vantage points overlooking the lower Duncan-Lardeau River floodplain were used to rate seed release events as Low, Medium, or High based on the visible airborne seed densities and the number of hours duration. Observation sites and geographic coverage were similar to previous years. No differences in timing and apparent quantity of seed release were noted between the two reaches, so only one data set is reported representing both reaches.

2.7 Field Visits

Three field visits occurred in 2016: May 2 to May 4; August 8 to August 12; and October 3 to October 6. The May 2016 field visit was scheduled to occur before spring high water, allowing easy access to sites with shallow or no wading based on the previous years of data. However, discharged volumes started to rise April 1 and peaked May 19, at 359 m^3/s. During field days in May discharge was over 300 m^3/s, resulting in leaving the field early without completing four sites that required wading. Eight sites were completed during the first field visit.

The August visit, and first black cottonwood recruitment monitoring for 2016, occurred when discharges for the Duncan River were between 188.6 m^3/s to 204.8 m^3/s. The Lardeau River discharge was 48.2 m^3/s for the August 11 sampling day. One of the tree core sites that was partially completed in May was completed in August plus an additional site was completed for tree core sampling data during the August field work.

[2] http://wateroffice.ec.gc.ca/report/report_e.html?type=realTime&stn=08NH118&prm1=47&prm2=-1

The October field visit occurred during low flows to assess the establishment and survival of the seedlings during the 2016 growing season, and the condition of seedlings from the two prior years. The discharge was between 97.9 m^3/s and 100.0 m^3/s for the October 3 to October 7 field monitoring interval along the Duncan River, and 23.7 m^3/s and 26.5 m^3/s for the Lardeau River for October 5 and 6 (respectively) monitoring period. Four additional sites were completed for the tree core data collection.

2.8 Seedling Establishment and Recruitment

Belt transects were randomly located within pre-stratified river reach segments and pre-identified recruitment areas. These transects allowed for tracking of the 2014 and 2015 seedlings, and for the assessments anywhere along the transect line where new 2016 seedlings germinated (as described in the Study Design Section 2.2). Black cottonwood seedling densities, heights (averages from 10 seedling heights within a 1 m^2 quadrat), and positions along the transect line were collected for 2014, 2015 and 2016 seedlings.

Data for black cottonwood establishment for 2016 germinants, and for continuing 2015 and 2014 seedling survival and recruitment (2014), were collected during the August and October field visits. The field data collected were tied to distances along the surveyed transect lines. This provided surveyed elevation points from 2013 for the Lardeau and most of the Duncan reaches and from 2014 elevational data for transects in D4. The link to transect distances will facilitate comparisons over time, by enabling assessment of sediment deposition and erosion, as well as revealing changes in vegetation patterns, including black cottonwood colonization and survival.

The 2016 seedling sampling methods followed the methods described in Polzin et al. (2014). By following seedlings for a three-year period, we are able to assess establishment levels, survival through three growing seasons, and recruitment levels achieved for each year of establishment (1st, 2nd, and 3rd year survival). We use the term ‘recruitment’ to represent the successful contribution to the floodplain forest population (Rood et al. 2007). Recruitment is the result of two sequential but somewhat independent processes of establishment (or colonization) and survival:

Recruitment = Establishment (colonization) + Survival

The seedlings established in 2014 (that survived to the October 2016 field sampling) were considered successful recruits. Therefore, the 2014 seedlings will shift to be part of the vegetation monitoring design, utilizing cover by species to assess growth and cover expansion during 2018 riparian vegetation monitoring.

Photos taken during the 2016 field season are documented in Appendix 1, and contact sheets of photos are located in Appendix 2. Original digital images are supplied on a video disc (DVD) with the final report.

2.9 Transect-Specific Stage/Discharge Relationships

The position of the water’s edge along each transect was determined at each visit to permit site-specific stage-discharge rating curves. This information will be utilized in the advancement of the conceptual models as well as for determining stages at transect lines during a specific discharge of interest during analyses of years, as needed. Transect and quadrat positions are subsequently expressed relative to the transect elevation of the river at a base flow of 57.8 m^3/s (1.52 m stage at Duncan station 08NH118) for the Duncan River as described in Polzin et al. (2010). The Lardeau River base flow of 11.1 m^3/s (0.843 m at Lardeau station 08NH007) was used for transect elevation for the Lardeau River.

2.10 Data Analyses

Data analyses focused on addressing the second key management question that relates to the relationship between river flow pattern and black cottonwood seedling establishment and recruitment. These analyses involved comparisons between seedling establishment and recruitment across the 2014, 2015, and 2016 data sets. With-in and between comparisons were completed for representative reaches along the lower Duncan River and the free-flowing Lardeau River (reference reach details in Polzin et al. 2010 and 2015).

Hypotheses testing will be completed in 2018 with full analyses of what has occurred over the nine years of monitoring (2011 was cancelled). The tenth year (2019) will collect one more field season data point and re-run the statistical model developed in the previous year to determine if any of the key results change in regards to the management questions. For the annual report, data analyses are limited to data summaries without any hypothesis testing.

Statistical analyses were conducted using SigmaPlot 12.5 (Systat Software. Inc. San Jose California USA) and all tests were interpreted with an alpha criterion of 0.05. Descriptive statistics were used for general data distribution. Data transformation was unable to provide normal distributions for seedling density data (for germinants) when comparing previous years and between reaches; therefore, non-parametric tests were used when needed. Tests included: Kruskal-Wallis One Way Analysis of Variance on Ranks (Kruskal-Wallis) for the Duncan and Lardeau rivers germinant densities across 2016, 2015, and 2014. A pairwise multiple comparison procedure using Tukey's test was used to isolate the group or groups that differed from the others. Tukey's test was selected as it is a more conservative test than the Student-Newman-Keuls test. When the treatment group sizes were unequal the Dunn's test was used. Uneven sample sizes occur when comparing the Duncan (27 transects) reach to the Lardeau (10 transects) reach.

Paired data was used for comparing the same transect lines between years. When quadrats had seedlings one year but were bare in the previous or subsequent year, a 0 was entered in the spreadsheet. If no seedlings occurred at a meter mark in any of the three years the cell was left blank. This gave the 0 meaning; therefore, it was included when doing analyses for paired data between years.

The Kruskal-Wallis test was used for survival comparisons as the data failed the normality test between the Duncan and Lardeau reaches for 2016, 2015, and 2014 survival percentages. Dunn's Method was used on all pairwise multiple comparison procedures when unequal data occurred. The t-test was used for analysis comparison between reaches for average survival rates, as the data were normally distributed. Paired t-Test or Wilcoxon signed-rank test were used on non-parametric data. Statistical outputs related to results are provided in Appendix 3.

3 RESULTS

3.1 Weather

The mean temperature for April in 2016 (10.2 °C) was higher than in all previous sampling years and higher than the average temperature for the month (7.2 °C) (Figure 3-1) (Government of Canada[3]). The mean temperature for the summer months (June-August) were highest in 2015 compared to other sampling years, even though 2014 had high July

[3] http://climate.weather.gc.ca/climate_normals/index_e.html

and August temperatures, but the low June temperatures reduced the average below the 2015 average (Figure 3-1). Mean temperatures for the 2016 summer months were lower than 2009, and 2012 to 2015, but were similar to averages for the station (1142574).

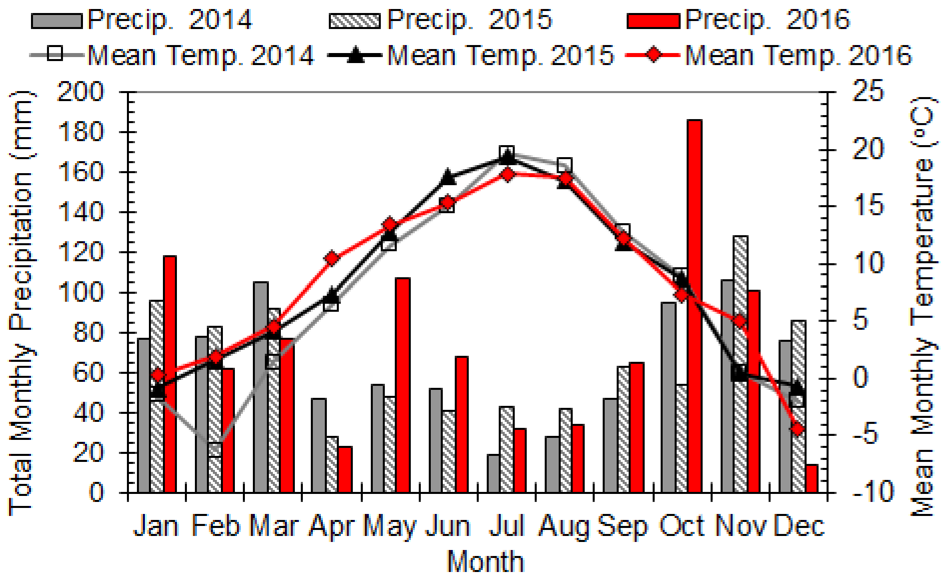


Figure 3-1: Duncan Lake Dam weather station at Meadow Creek monthly mean temperature and monthly total precipitation for 2014, 2015, and 2016.

The total precipitation for the 2016 summer months was similar to 2015 (Table 3-1). However, June 2016 experienced higher precipitation than 2014 and 2015, and May 2016 experienced much higher rainfall compared to the month of May in 2014 and 2015.

Table 3-1: Average precipitation and temperatures and total precipitation for the summer months of June, July, and August from 2008 to 2016.

Average	2008	2009	2010	2012	2013	2014	2015	2016
Precipitation (mm)	65.9	45.0	41.6	74.4	68.1	33.1	42.1	44.5
Total Precipitation	197.8	134.9	124.7	223.1	204.4	99.3	126.3	133.6
Temperature (ºC)	16.5	17.3	16.2	17.0	17.5	17.8	18.1	16.9

The total monthly precipitation for 2016 compared to 2015 showed a lot of variability (Figure 3-2). The most notable difference in monthly precipitation was for May 2016 (107.0 mm), which was 54.3 mm above the average. Precipitation was average for June, but well below average for July and August. Past the growing season influence, October precipitation was worth noting as it was 186.4 mm compared to the historical average of 66.2 mm.

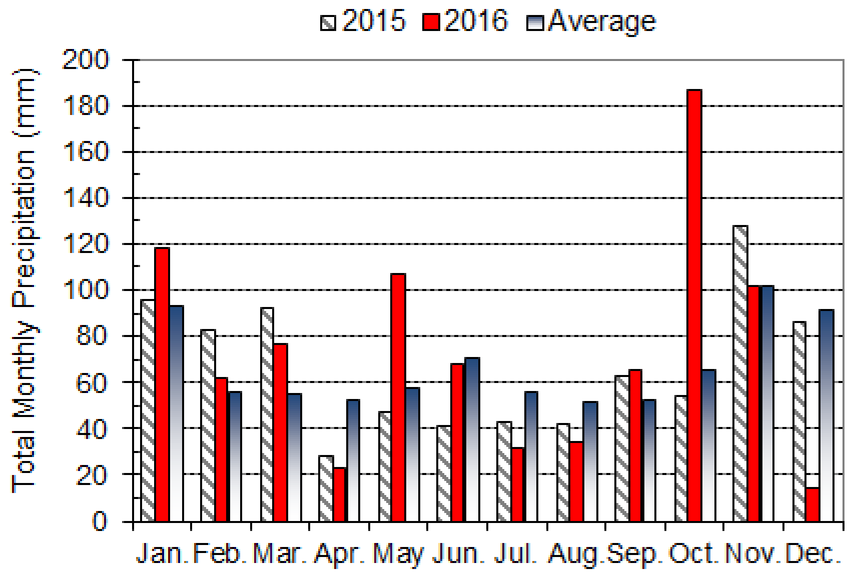


Figure 3-2: Total precipitation (mm) for 2015 and 2016 recorded at Duncan Lake Dam weather station. Total precipitation for the month of May was 107.0 mm.

Both the Duncan and Lardeau rivers are snow-melt dominated systems. As such, seasonal snow pack levels play a role in the extent of freshet flooding. However, variations in weather determine snow melt rates and control flood probability. The Snow Water Equivalent (SWE) for 2014, 2015, and 2016 were obtained from the Duncan Lake watershed station 2D07A (archive manual snow survey data), which is at 662 m elevation at the Marble Head Weather station. When 2016 was compared to 2014, 2015, and the Normal (average but 'Normal' is used at the web site for the data) (1981 to 2010 from 2D07A station), SWE was below the Normal for February and March, and below 2013 and 2014 levels. The snowpack was gone in April, with no snow pack at this low elevation site in 2015 either and 1 mm in 2013 (Figure 3-3). The valley bottom snow pack was gone by April so it did not influence freshet that occurred in early May.

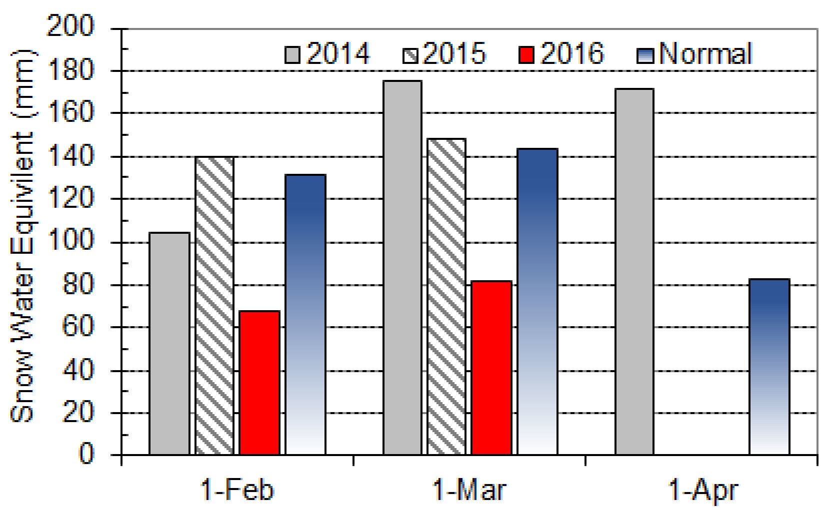


Figure 3-3: Snow water equivalent totals for the months February to April at the station 2D07A Duncan Lake No. 2 at Marble Head weather station for 2014 to 2016.

The snow pack at higher elevations influence the extent of freshet flooding more than the valley bottom snow pack. For the Duncan Lake drainage, East Creek is the established station and is actively monitored. East Creek station 2D08P is at 2,004 m elevation and had snow pack levels similar to the Normal levels for the area up to May 1, 2016. The snow pack drops below Normal by May 15 and continues to drop until there is almost no SWE (4) by June 15, 2016 (Figure 3-4). June 1, 2016 SWE was 53 per cent of Normal and by June 15 it had dropped to 1 per cent of Normal.

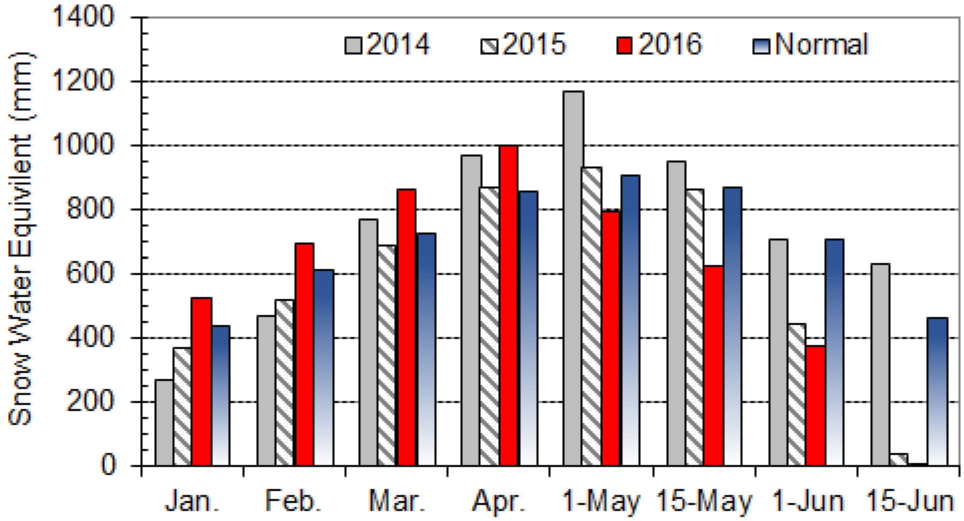


Figure 3-4: Snow water equivalent (mm) data for East Creek station 2D08P, elevation 2004 m, for 2014, 2015, 2016, and the Normal levels (1981 – 2010) for the station.

3.2 Hydrology

3.2.1 Duncan River

Past historic flow patterns consists of three years of data prior to the completion of the Duncan Dam; therefore, no historic flow pattern is presented. We show the average for those three years, but this is a limited representation of past historic flows.

Mean monthly discharges from 2009 to 2016 (2009 and 2010 were combined and 2013 and 2014 were combined as these provided similar patterns as demonstrated in Polzin et al. 2014), are shown in Figure 3-5. The sampling year of 2012 was an exception with the regular Alt S73 flow regime pre-empted by high snowmelt and rainfall in the Duncan Basin (see Polzin and Rood 2013). The past sampling year, 2016, had lower flows for January and February with increasing discharge in April, above all previous year volume. May's average discharge was similar to 2012 flows but the peak flow occurred earlier in May compared to the 2012 peak flow (Figure 3-6). The 2016 May peak flow was the earliest peak flow for the year compared to flows since 2009 when the study started. Discharge then receded to similar flows that occurred in 2009 and 2010 through June to October (Figure 3-5). The 2016 hydrograph closely follows the proposed new Alt S73 flow regime criteria.

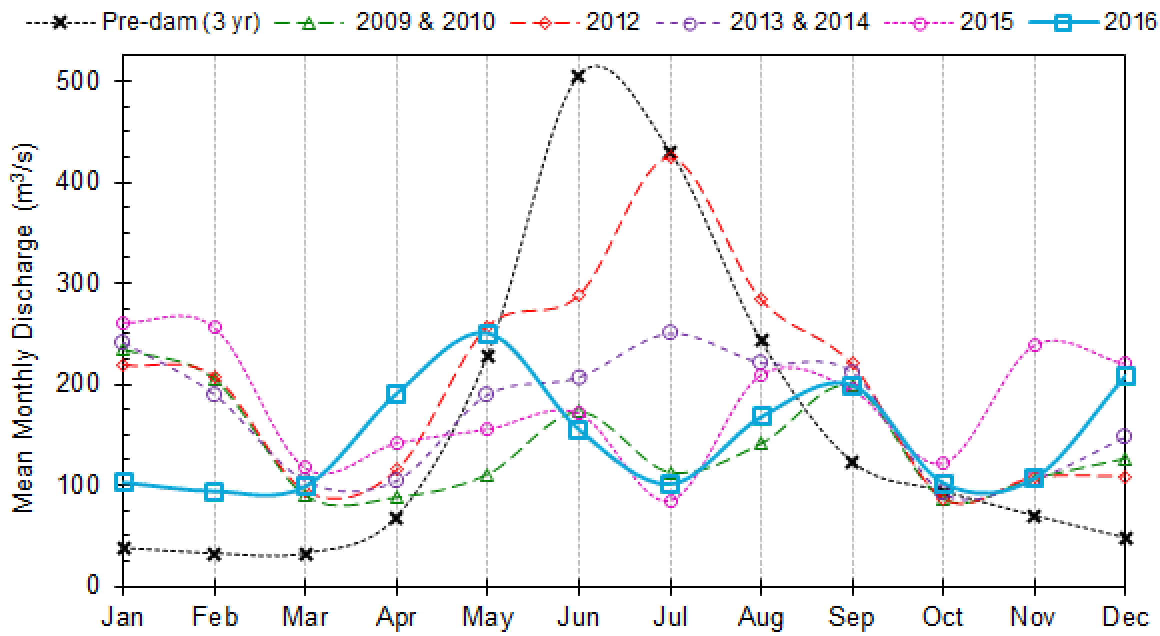


Figure 3-5: Mean monthly hydrographs for the lower Duncan River for sampling years 2009 and 2010 averaged, 2012, 2013 and 2014 averaged, 2015, 2016 (provisional) and pre-dam (3 years of data) discharges plotted with smoothed lines.

The daily mean flow data shows the variation that occurs during the year which is smoothed out by monthly means. The 2016 flow data showed the earliest peak flow that occurred in May for the study period (Figure 3-5). Two maximum peaks with similar intensities occurred May 8 (320 m^3/s) and May 18 (322 m^3/s). The May peak occurred over an extended period from late April through most of May (Figure 3-6). The flow declined through June and was similar to the 2009 and 2010 flows for the summer months into the fall months. Fall flows continued to be similar to previous years, excluding 2015, through November and is estimated to be similar to discharge from 2009 to 2014 for December. Flows were greatly reduced through January and February, which was not similar to any of the previous flows for these months.

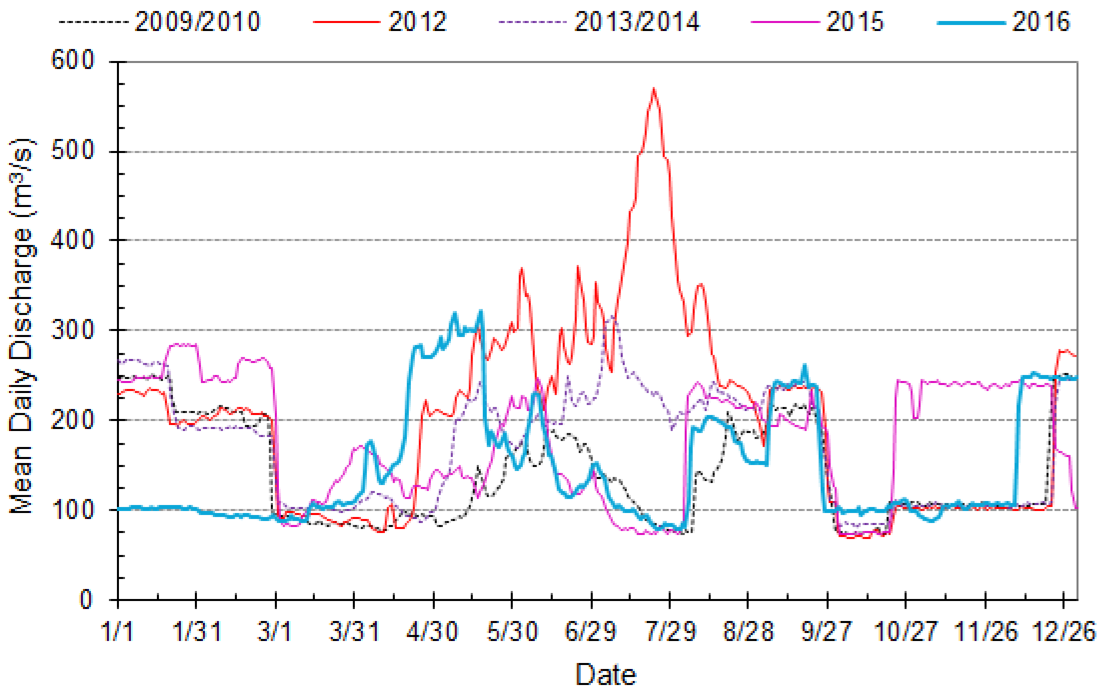


Figure 3-6: **Mean daily discharge (m^3/s) for 2009 and 2010 (averaged), 2012, 2013 and 2014 (averaged), 2015, and 2016 (provisional) for the lower Duncan River at Station 08NH118.**

3.2.2 Lardeau River

In 2016, the Lardeau River experienced an average spring freshet flow with a peak discharge of 206 m^3/s that was below the 2-year recurrence peak (Q_{max2} = 269.2 m^3/s). However, it was a month earlier than in the past sampling years. The mean monthly discharges for 2016 were higher in April and May compared to previous sampling years with the peak flow occurring May 8 (Figure 3-7). The 2016 discharge decline was similar to the 2009 and 2010 declines through the summer. October mean discharge increased slightly compared to past years with November mean the highest since 2009, with flows returning to average flows for the study period for December. The 2016 discharge record is provisional.

There were 70 years of flow records for the Lardeau River records starting in 1917, with a period of missing records from 1920 through 1945. Flow records from two hydrometric sites were coordinated by regression analysis for the period of overlap for the missing years of 1997 through 2002 (Q_{max} at 08NH007 = Q_{max} at 08NH118 x 0.37, R^2 = 0.96, linear regression forced through origin). Recurrence analysis indicated that the 2016 spring freshet along the Lardeau River was below the 1-in-2 year flood event (Q_{max2}) see Polzin and Rood (2013) for detailed log Pearson Type III analysis.

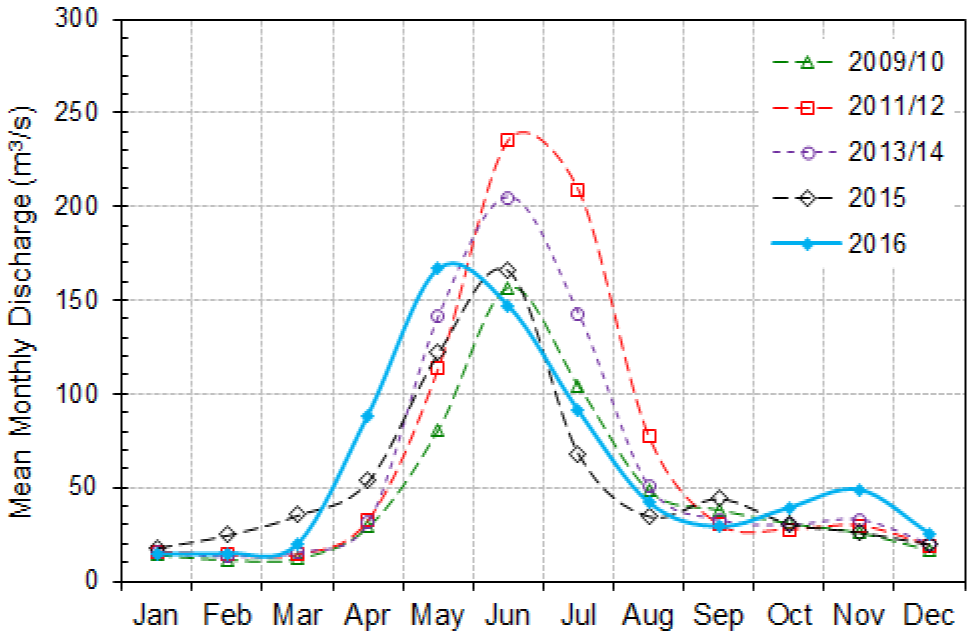


Figure 3-7: Mean monthly discharge (m^3/s) for the Lardeau River for 2016, and averages for years 2009/2010, 2011/2012, 2013/2014 (very similar flows for the paired years see Appendix 3), 2015 and 2016 (provisional).

The 2016 peak flow occurred on May 8 (206 m^3/s), which was the earliest it has occurred in the recorded history (from 1917) for the Lardeau River. Historically, 73.1 per cent of annual peaks have occurred within June, May peak flows occur 14.9 per cent of the time. During the research years of this project, spring freshet usually occurred mid to late June. In 2016 the peak flow was a month earlier than 2015 (Table 3-2). The historical data had two mid-May spring peaks, one in 1949 (May 16) and one in 1987 (May 12), the remaining 8 peaks occurred May 21 to 29 with the 26 as the median date.

Table 3-2: Peak spring freshet discharge for the Lardeau River from 2009 to 2016 with log Pearson Type III flood return periods and predicted discharge levels.

				Log Pearson Type III		
Year	**Month and Day**	**Peak Discharge**		**Return Period**	**Prediction (m^3/s)**	**Std. Dev.**
2009	June 17	201 m^3/s		**10**	349	12
2010	June 29	183 m^3/s		**5**	319	9
2011	June 23	297 m^3/s	**Q_{max3}**	**3**	294	8
2012	July 1	314 m^3/s	**Q_{max5}**	**2**	269	7
2013	June 20	269 m^3/s	**Q_{max2}**			
2014	June 25	243 m^3/s				
2015	June 9	245 m^3/s				
2016	May 8	206 m^3/s				

3.3 Black cottonwood Phenology

In 2016 we recorded dates of catkin and flower emergence, leaf emergence, seed development, and senescence, in addition to seed release events, consistent with the

2009 sampling. In 2016 most stages of development occurred earlier than in previous years (Table 3-3). This was attributed to an early spring and a warm April (Figure 3-1).

Table 3-3: Black cottonwood phenology for 2016 with 2015 and 2014 phenology for comparison, along the Duncan and Lardeau rivers (same times for both rivers.

Occurrence / Stage	2014	2015	2016
Gradual emergence of male (1st) and female (2nd) inflorescences.	April 1 – April 30	Rapid growth Apr. 1+	Mar 20 to 30 male, Mar 25-Apr 8 female
Flowers developed, pollination	End of April,	April 12 - 19	April 8-15
Abscission of male catkins	Early May	April 20-30	April 10- 15
Leaf emergence	End of April to mid-May	April 10- 30	End of April
Seed pods developing	May to mid-June	Green by May 25	Green by May 1
Seed release begins	June 19 through July	June 7 to July 16	May 30 to Jun 20
Leaf senescence	Late Sep. through Oct	Late Sep. through Oct.	Early Sep., through Sep.

The first seed release event was May 30 and the last was observed in the middle of June. Most releases noted in 2016 were low to moderate. There was a notably steady, prolonged period of all-day low to moderate seed releases from June 2 through June 7 during a period of hot, calm, windless weather following a cooler period. No late seed releases were observed (Table 3-4).

Table 3-4: Black cottonwood seed dispersal event details for the lower Duncan and lower Lardeau region of British Columbia.
Event T_{max} = average max temperature for the event and time period.

Event	Date	Seed Abundance	T_{max} (°C)	Rain (mm)	Event T_{max}	Prior and Post Rain Events Time Periods
1	May 30	Low	20.5	0.0	**20.5**	Rained May 26 to 29th total 31.0 mm, T_{max} for rain period – 16.8 °C.
2	Jun. 2 Jun. 3 Jun. 4 Jun. 5 Jun. 6 Jun. 7	Moderate Moderate Moderate Moderate Moderate Low	21.0 26.0 29.0 32.5 31.5 32.5	4.6 0 0 0 0 0	**26.0**	Rained 7.2 mm from May 31 to Jun. 2.
3	Jun. 15	Low	17.0	1.0	**17.0**	Rained June 8 to 15th, total of 40.8 mm. No rain Jun. 16th & 17th.
4	Jun. 20	Very Low	24.0	0.0	**24.0**	Rained 6.6 mm Jun. 18th and 1.2 mm Jun. 21st.

3.4 Black Cottonwood Establishment and Recruitment along the Lower Duncan and Lardeau Rivers

3.4.1 Seedling Abundance

Duncan River

During the August field visit the discharge rate began increasing on August 5, with discharge at 191 m^3/s by August 8, and stayed at similar discharge during the field work to August 11 (199 m^3/s). The increase in stage from an average of 82 m^3/s to the average of 192 m^3/s resulted in some germinates and seedlings to be inundated during sampling. Seedlings that survived the inundation were recorded during fall monitoring.

Following the 2016 field inventories, a total of 473 sampling quadrats along the lower Duncan River had black cottonwood seedlings, established in 2014 to 2016 but mainly in 2016. This was lower than 2014, and higher than in 2013 and 2015, but there was no significant difference between 2016 and 2013 to 2015 levels (Table 3-5).

The total number of germinants (12,802) were lower than previous sampling years (2009 to 2015), except 2012, and lower than the average. However, there was no significant difference between total numbers of 2016 germinates and 2013 to 2015 total number of germinates. The average number of germinates is 20,100 excluding 2009 (unknown number of willow seedling counted on some lines) and 2012 (almost zero establishment from extreme high water levels during seed release) as they were years with anomalies and/or possible sampling errors on some lines. There was variation between total germinate densities between 2015 and 2016 for individual transect lines (Table 3-5).

Table 3-5: Comparisons of 2013, 2014, 2015, and 2016 numbers of quadrats with seedlings and the total density per transect of germinants for the corresponding year, along the Duncan River (Dun. Seg. = Duncan Segment, Tran = Transect, Quad = Quadrats, # Germ = total density of Germinants (2016 seedlings) per transect).

Dun. Seg.	Tran #	2013		2014		2015		2016	
		# Quad	# Germ	# Quad	# Germ	# Quad	# Germ	# Quad	# Germ
D1	T3	21	857	9	2,786	13	8,026	20	1,315
	T4	0	0	0	0	0	0	2	7
	T5	0	0	0	0	0	0	0	0
D3	T10	0	0	1	2	0	0	0	0
	T11	54	2,084	67	4,604	9	2	25	2,871
	T15	17	1,075	41	1,639	21	507	36	1,251
	T17*	14	851	26	651	24	660	23	569
	T29*	28	1,267	35	1,551	7	38	19	242
	T35*	11	1,221	21	982	14	201	31	1,147
	T20	13	609	12	400	12	160	0	0
	T23	0	0	0	0	0	0	0	0
	T40*	2	6	8	250	12	183	21	476
	T45*	17	370	20	465	27	4,347	38	934
D4	T3	64	3,003	62	3,273	51	951	39	260
	T10*	35	813	42	1,027	45	493	47	227
	T5	0	0	0	0	0	0	0	0
D5	T2	11	90	9	88	7	59	9	113
	T9	5	571	13	156	9	184	14	329
	T11	22	787	21	740	18	5,893	17	139
	T12	4	8	31	1,395	38	4,006	39	995
	T16	13	260	18	574	4	170	0	0
	T19	3	206	7	268	6	76	3	61
D6	T6	0	0	5	696	0	0	1	4
	T20*	0	0	13	83	0	0	3	13
	T29	0	0	19	231	20	1,092	28	1,210
	T36	0	0	60	758	65	979	58	639
Totals		**334**	**14,078**	**540**	**22,619**	**402**	**28,027**	**473**	**12,802**

Note: * indicates new transect lines established in 2013.

Lardeau River

There was an increase in the total number of Lardeau River quadrats with seedlings in 2016 (131), as compared to 2015 and 2013, and similar to 2014, but lower than in 2010 (145 quadrats) (Table 3-6). There was no significant difference across the total numbers of quadrats for years 2013 to 2016. There was a total of 1,607 germinants (2016 seedlings) along transect lines in 2016. This was a slight increase compared to 2015 and lower than in 2014 or 2013. The average number of germinants (2009 to 2016) for the Lardeau Reach was 4,118. Number of germinates varied by transect line compared to previous years, but there was no significant difference between total number of germinates compared to 2013 to 2015).

Table 3-6: Comparisons of 2013, 2014, 2015 and 2016 numbers of quadrats with seedlings and the total density per transect line of germinants for the corresponding year, along the Lardeau River (Lard. Seg. = Leadeau Segment, Tran = Transect, Quad = Quadrats, # Germ = total density of Germinants (2016 seedlings) per transect line).

Lard. Seg.	Tran #	2013		2014		2015		2016	
		# Quad	# Germ	# Quad	# Germ	# Quad	# Germ	# Quad	# Germ
L1	T1	13	523	8	238	12	95	14	124
	T10	20	3,895	20	575	21	292	23	249
	T20	19	415	43	1,823	36	339	42	918
	T36	17	687	14	670	10	61	9	50
L2	T6	15	31	11	312	7	313	16	143
	T15	1	1	4	173	1	0	0	0
	T18*	13	122	19	648	0	0	8	24
L3	T1	1	1	5	200	0	0	8	35
	T9	3	7	6	179	0	0	2	5
	T30*	0	0	0	0	0	0	9	59
Totals		**102**	**5,682**	**130**	**4,818**	**87**	**1,100**	**131**	**1,607**

Note: * indicates new transect lines established in 2013.

3.4.2 Seedling densities and survival

Duncan River

The total amount of germinants per transect lines did not show any significant difference, but there was significant differences when individual plot data was paired for counts at each metre mark germinants occurred ($P<0.001$, $H = 128.7$, Appendix 3). Box plot comparisons between densities for 2013, 2014, and 2015 illustrate the magnitude of differences for the Duncan Reach across years (Figure 3-8 and Figure 3-9)[4]. To isolate which years differences occurred it was found that 2014 was significantly higher than 2015 and 2016 ($P<0.05$ Appendix 3) densities but there was no significant difference between 2015 and 2016. When densities for each year were compared, the mean for 2015 is above the box where 25 to 75 per cent of the data occurs. This result indicates the magnitude of the skew is from outliers.

The 2016 seedling densities for the Duncan reach were significantly higher ($P = 0.004$, $H = 8.4$) compared to the 2016 seedling densities for the Lardeau reach. This is consistent with previous years' data (except for 2012 flood year), as the Duncan reach has 27 transects and a wider floodplain compared to the reference Lardeau reach (10 transects). When the Duncan reach has densities lower than the Lardeau reach, something other than precipitation and temperature has impacted the Duncan reach, such as the extended flood stage impact of 2012 along the lower Duncan River.

[4] For box plots, the lower boundary of the box indicates the 25th percentile, the black line within the box marks the median, the red line marks the mean and the upper boundary indicates the 75th percentile. Whiskers above and below the box indicate the 90th and 10th percentiles. Outliers are indicated with an open circle.

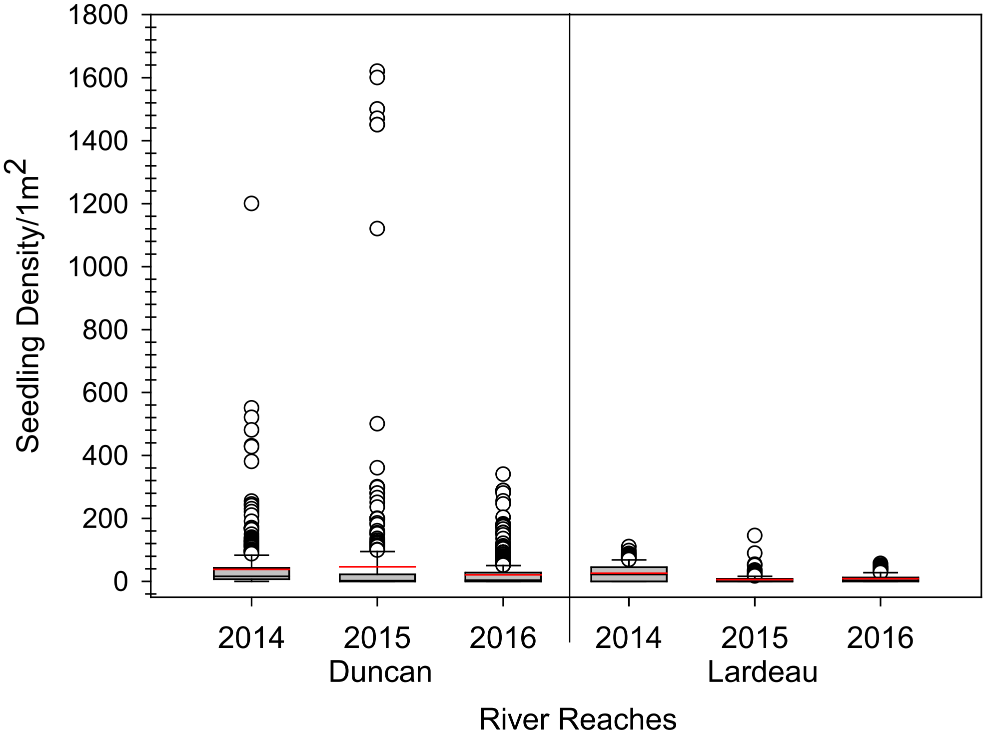


Figure 3-8: **The 2014, 2015, and 2016 black cottonwood germinant densities**

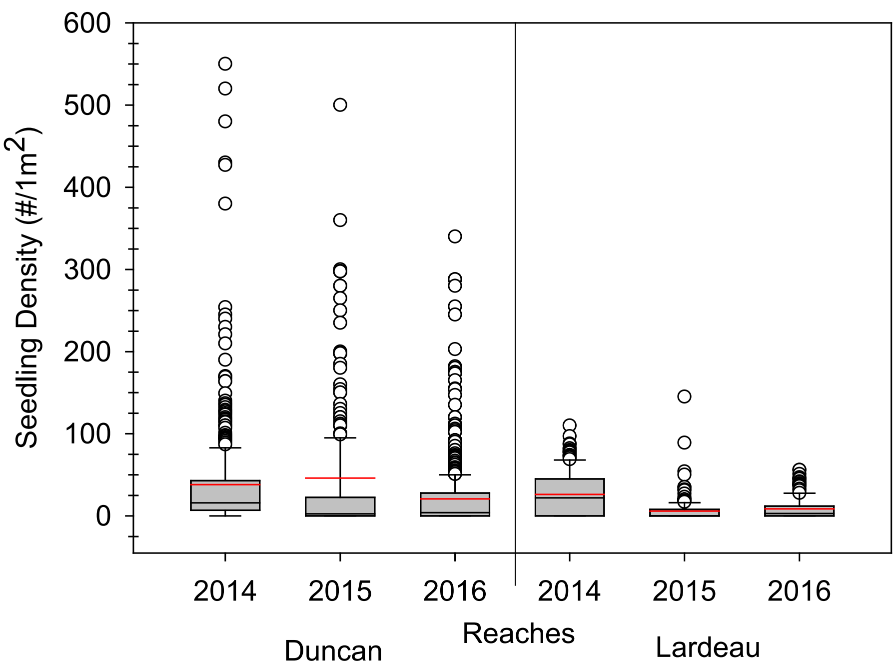


Figure 3-9: **The 2014, 2015, and 2016 black cottonwood germinant densities for the Duncan reach. Extreme outliers were scaled off graph for the Duncan reach (see Figure 3-8).**

Figure 3-10 illustrates where the differences for germinant densities occurred per segment for the three years. Duncan Segment 1 (D1) had a significant difference (P = 0.025, H =

7.4) between years with 2016 being greater than 2014 and 2015 which is not easily detected by looking at the graph. Despite the high-density counts in some quadrats in 2014 and 2015, the median for those years were 0 and 18 (respectively) while 2016 median was 45 (Figure 3-11). Duncan Segment 3 (D3) had a significant difference in the median values between years (P = <0.001, H = 86.9).

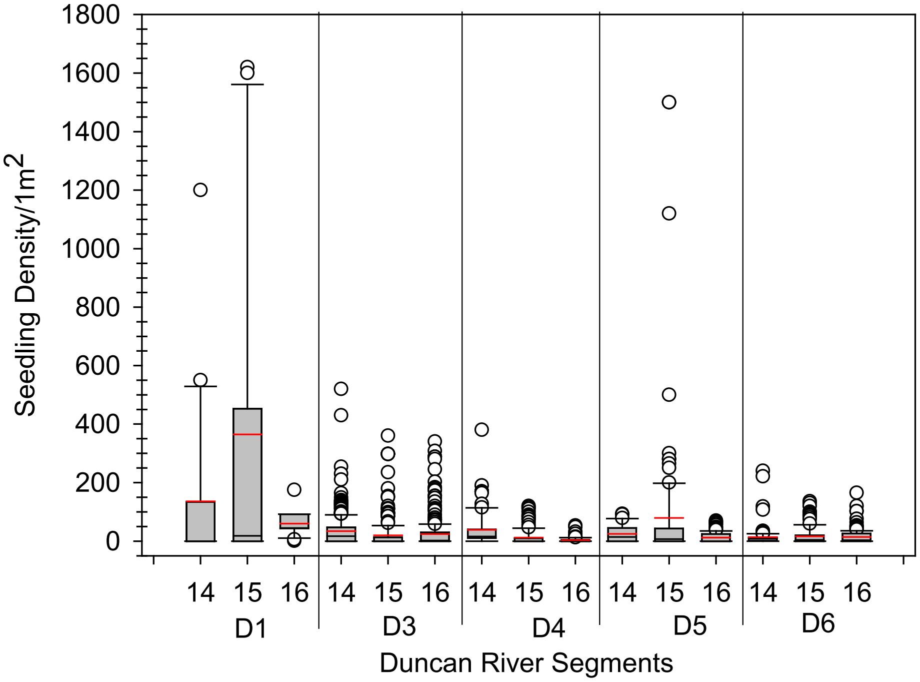


Figure 3-10: Germinant densities for 2014, 2015, and 2016 for each segment along the lower Duncan (D) River.

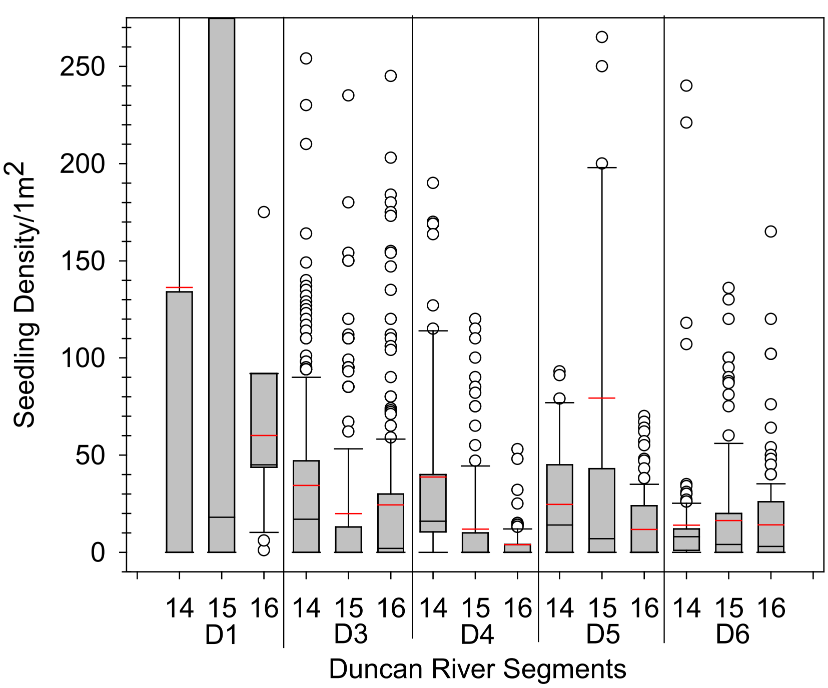


Figure 3-11: Figure 3-10 scaled down to 275 seedlings/m^2 on the Y axis so that medians (black lines) can be seen for the segments.

Duncan Segment 4 (D4) had a significant difference between years (P=<0.001 H = 105.9), with most of the difference occurring from 2014 vs 2015 and 2016. D5 was similar to D4 with a significant difference in medians between years (P=<0.001, H = 20.7). D6 differs from the rest of the segments with no significant differences between years (P = 0.106. H = 4.5). Median values for each reach is presented in Table 3-7 for reference and complete statistical information in Appendix 3.

Table 3-7: The median values for combined transect lines for each segment along the lower Duncan Reach.

Segments	2014 median	2015 median	2016 median
Duncan 1	0	18	45
Duncan 3	17	0	2
Duncan 4	16	0	0
Duncan 5	14	7	0
Duncan 6	8	4	3

Lardeau River

The Lardeau River also had significantly different median values for germinant densities in 2016, compared to 2014 and 2015 for paired data along transect lines measured within quadrats (P = <0.001 Appendix 3) (Figure 3-12). Comparison of raw data counts shows that 2015 was a very low establishment year on a natural river system compared to 2014, but similar to 2016.

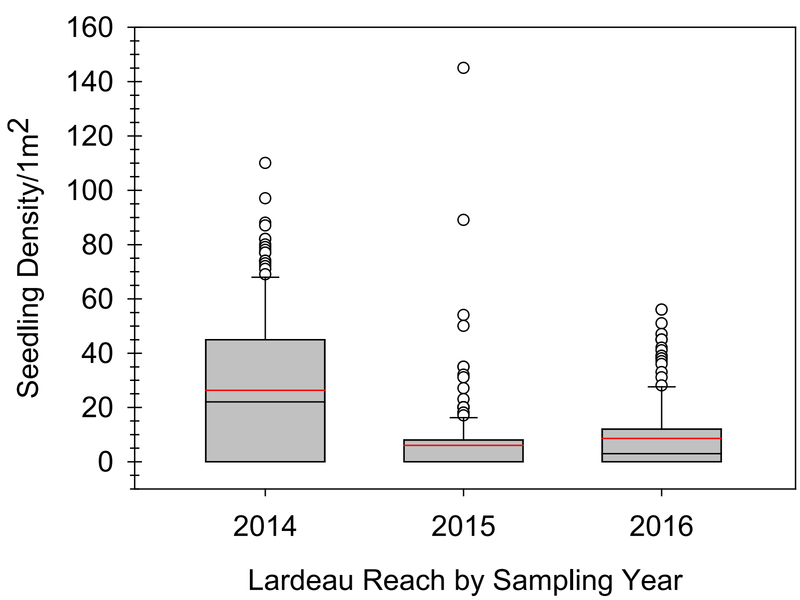


Figure 3-12: The 2014, 2015, and 2016 black cottonwood germinant densities along the Lardeau Reach with the Y axis scaled for data.

Comparisons between segments show that Lardeau Segment 1 (L1) had median values greater than would be expected by chance across 2014 to 2016 years (P <0.01, H = 37.6; Appendix 3). The significant differences occurred between 2014 vs 2015 and 2016, and no significant difference between 2015 and 2016 (Figure 3-13). This result was similar with L2 being significantly different across years (P = <0.01, H = 34.8), but no statistical difference between 2015 and 2016 results. L3 had slightly different results compared to L1 and L2 results in that the same quadrats had higher densities in 2014 but the actual median was lower than in 2016 (Figure 3-13). L3 had a significant differences across years for the segment (P = <0.01, H = 21.0) with 2015 vs 2014 and 2016 significant (P <0.05) and no significant difference between 2014 vs 2016.

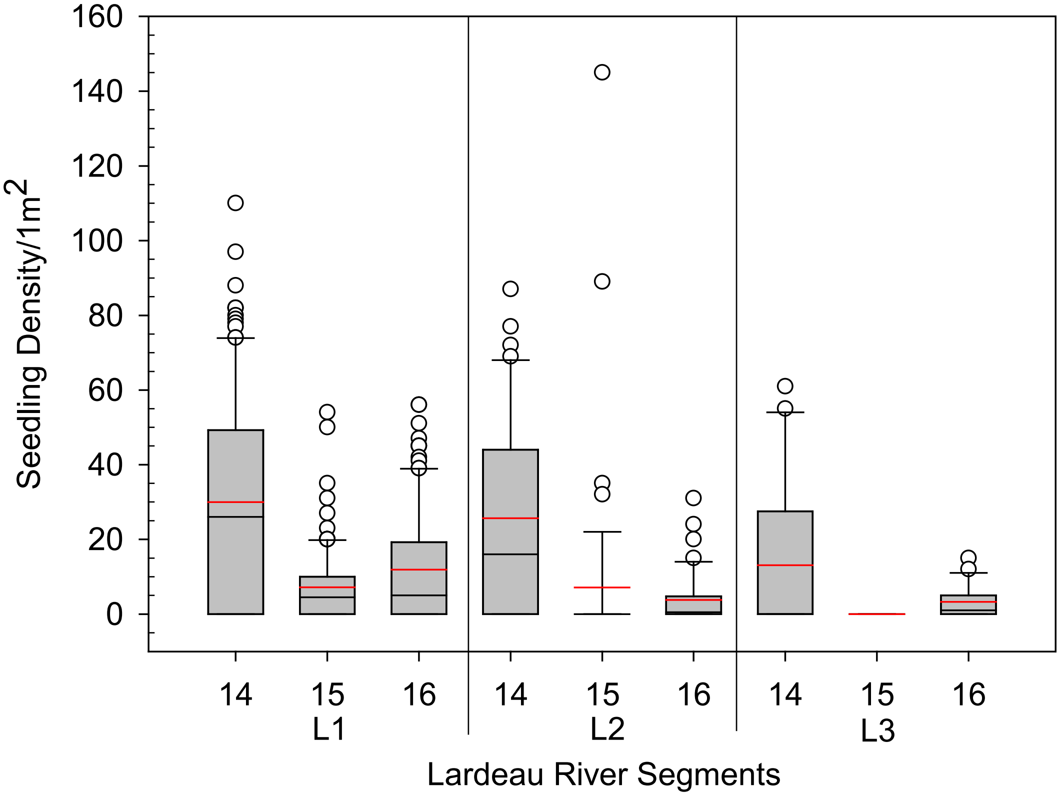


Figure 3-13: Germinants densities for 2014, 2015, and 2016 for each segment along the Lardeau (L) River.

3.4.3 Seedlings, establishment to recruitment of 2014 seedlings

In 2016, seedlings were monitored that had established in 2014, 2015, and 2016. Substantial decreases in seedling density by the end of the first growing season are typical for black cottonwood survival through the first season (Bradley and Smith 1986, Polzin 1998, Rood et al. 2007). The average survival rates for seedlings in their third growing season are usually the highest (Polzin and Rood 2013). The surviving seedlings established in 2014 are considered recruited by the fall of 2016.

The first year survival rates for the 2016 seedlings (germinants) were significantly higher for the Duncan compared to the Lardeau reaches, with 40 per cent and 29.5 per cent respectively (Figure 3-14; P=<0.01, H=12.42; full statistical information in Appendix 3). The 2015 and 2014 survival rates (2nd and 3rd year survival) were lower for the Duncan compared to the Lardeau rates. However, there was no significant difference for the third year survival rates between the Duncan and the Lardeau reaches (P = 0.2, *t* = -1.38), but significant difference in the second year survival rates (P = 0.006 and H = 7.59).

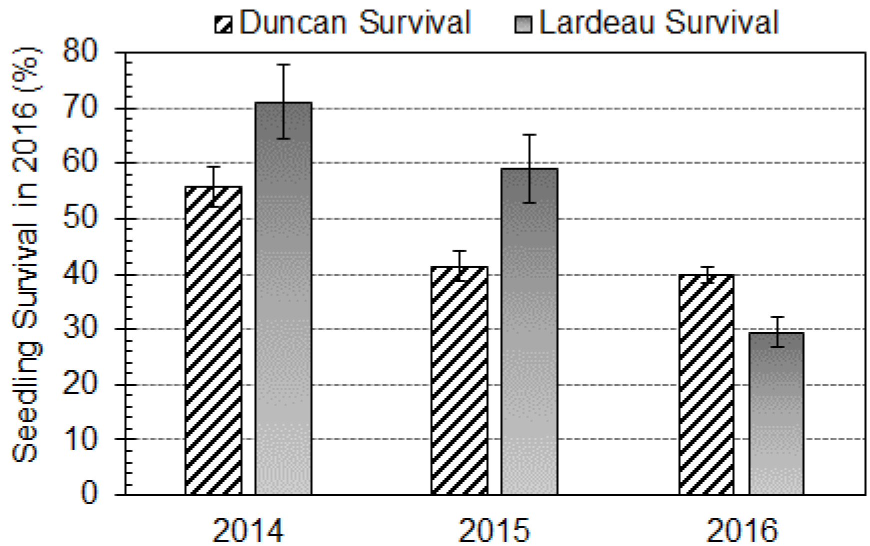


Figure 3-14: Mean (± s.e.) survival percentages for 2014 (3rd year survival), 2015 (2nd year survival), and 2016 (1st year survival), 2014, 2015, and 2016 seedlings monitored in 2016.

Average survival rates (seedlings monitored since 2009 to 2015) were similar between the two reaches for 1st year survival, but the second and third year average survival rates are lower for the Duncan Reach (Table 3-8). The Duncan and the Lardeau reaches had increased germinant survival compared to the average for each reach. Both the second and third year survival rates were similar to the averages for both reaches. Average survival rates from 2009 to 2015 data had no significant differences between the two reaches for 1st, 2nd, and 3rd year average survival rates (Appendix 3).

Table 3-8: Comparison of the 2016 established seedling for the 1st, 2nd, and 3rd year survival and the average seedling survival (2009 to 2015) for the Duncan and Lardeau rivers

Survival Year for the 2016 Monitoring Year	**Duncan Reach recorded in 2016**		**Lardeau Reach recorded in 2016**	
	Average % Survival	Seedling % Survival	Average % Survival	Seedling % Survival
1st Year Survival established 2016	23.2	39.9	23.8	29.5
2nd Year Survival established 2015	43.4	41.4	60.4	60.2
3rd Year Survival established 2014	51.1	55.6	77.2	71.0

There were no significant differences between average survival rates between the Duncan and Lardeau reaches (Appendix 3). However, the difference may be biologically significant as related to the overall impact of a Dam flow regime system for the second and third year survival rates. The survival rates following the Pre-Alt S73 flow regime are unknown and this impedes conclusions about the new Alt S73 flow regime. The comparison shows that the average Duncan River recruitment (3rd year survival) and second year survival were below the averages of the free flowing Lardeau River by approximately 20 per cent, while both reaches experienced the same weather and similar seed release densities.

3.5 Investigation of Black Cottonwood Recruitment in the Pre-Alt S73 Interval

Additional sampling was undertaken in the fall of 2016 to investigate prospective black cottonwood recruitment in the interval that preceded the implementation of the Alt S73 flow regime. This involved sampling of increment cores and stem discs and age counts from the annual terminal bud scars. This provided indirect results and can complement the direct observations of black cottonwood recruitment with the ongoing field study and relate to the assessment of management question 1 and testing of H_{01} hypothesis, relating to the impacts of Alt S73 on black cottonwood recruitment.

For this sampling:

- 13 Sites were investigated; involving;
- 42 plots; and
- 192 trees.

Of these:

- 61 were seedling origin (31.8 per cent); and
- 131 were clonal origin, through adventitious root suckers, and a few were unknown relative to ontogeny (68.2 per cent).

Within the 20 year bracket (1987 to 2007):

- 46 were seedling origin (26.6 per cent);
- 127 were clonal origin (73.4 per cent); and
- Of the 127 clones, 11 were established between the years 1987-1996, 27 were established between the years 1997-2007 and 89 were established from 2008 to 2016.

This conclusion that about three-quarters were clonal is slightly higher than the prior determination by Herbison (2003), also with core data, of 63 per cent clonal recruitment for an overlapping time interval of 1986 to 2002.

- Increment cores were extracted from 90 of the 192 trees, and for the smaller sapling, ages were determined through counts of the stem bud scars.
- 1 cored tree had severe heart rot that challenged aging, which was estimated by comparison with intervals from intact tree cores at the site. This tree estimated age was 32 years.

Averages were calculated for plots, stems per hectare and stems per bracket area (Table 3-9). These provisional results suggest lower recruitment following Alt-S73, when compared to the prior 20 years with a prior flow regime.

Column headings in Table 3-9 clarification.

- Column 1 is the average of all trees sampled within plots (100 m^2 area) within the 1987 to 2007 bracket (1987) area.
- Column 2 is the average number of seedling origin trees within plots that are $\leq$ 29 years of age within the 1987 bracket area.
- Column 3 has the data from column 2 with the number of seedling origin trees calculated as number per hectare.
- Column 4 has the same data from column 2 but the number of trees was calculated as number per the 1987 delineated area at the site (bracket area). Each Site had the area delineated which was then split into two bracket areas, 1987-2007 and 2008-2017 (2008). Area for each Site and each age bracket (1987 and 2008) can be found in Table 2-1 (Methods Section).

- Columns 5 and 6 are the number of seedling origin trees within 2008 age bracket calculated per hectare and per bracket area.

Table 3-9: Tree core results within delineated Sites within the 1987 and 2007 age brackets. The average of all trees are shown in column 1 that occurred within plots (100 m^2). Trees that were older than bracket and of clonal origin were removed for columns 3, 4, and 5. The 2008 bracket (shading) is seedlings monitored 2009 to 2016 recruitment trees (right columns).

		Averages by Plots, Sites, and Segments					
		# of all trees	Number of trees from seedling origin (no clones)				
River Seg.	Site #	in the 1987-2007 bracket per plot area (100 m^2)	trees in the 1987-2008 bracket ≤ 29 yr/100 m^2	trees in the 1987-2008 bracket (#/ha)	trees in the 1987-2007 bracket (#/1987 area)	trees in the 2008-2017 bracket (#/ha)	trees in the 2008-2017 bracket (#/2008 area)
1	1	3.00	0.00	0.00	0.00	2.50	0.52
	2	2.00	0.00	0.00	0.00	0.00	0.00
3	3	13.00	1.67	166.67	149.54	0.00	0.00
	4	14.00	0.60	60.00	63.77	0.10	0.10
	5	2.75	1.25	125.00	87.79	0.40	0.52
4	10	1.67	0.33	33.33	14.36	1.50	0.96
	11	0.00	0.00	0.00	0.00	1.70	0.69
5	12	9.67	7.67	766.67	436.52	0.20	0.08
	13	3.00	1.67	166.67	20.44	3.70	0.37
	15	0.25	0.00	0.00	0.00	3.60	1.70
	16	3.00	0.50	50.00	29.40	3.70	0.18
6	17	1.67	1.33	133.33	100.34	1.90	1.53
	18	0.00	0.00	0.00	0.00	0.40	0.80
Overall		**4.15**	**1.16**	**115.51**	**69.40**	**1.52**	**0.57**

4 DISCUSSION

Naturally flowing rivers are dynamic, with seasonal flow patterns and internal variations, including flood events that provide physical disturbances of the river bed, banks, and adjacent floodplains. River flooding provides essential occasional disturbance that underlies the episodic rejuvenation of riparian woodland resulting in arcuate bands of single age cohorts (Hughes 1990, Stromberg et al. 1991, Friedman et al. 1996, Friedman and Lee 2002). Prior study results consistently reveal that section *Aigeiros* cottonwoods *Populus deltoids* Marsh, *P. fremontii* Watson and *P. nigra* L. require floods for population replenishment through seedling colonization. (Rood and Mahoney 1995, Scott et al. 1996, Cordes et al. 1997, Shafroth et al. 1998, Cooper et al. 1999, Guilloy-Froget et al. 2002). Episodic rejuvenation occurs when suitable conditions (flood events large enough to create new recruitment zones) are created on intervals of five to ten years or longer (Bradley and Smith 1986, Baker 1990, Stromberg et al. 1991, and 1993, Hughes 1994, Johnson 1994).

Conversely, the role of flood events for reproduction of section *Tacamahaca* cottonwoods is less well understood (Baker 1990, Polzin and Rood 2000, Fierke and Kauffman 2005). This taxonomic group of ‘balsam poplars’ includes narrowleaf cottonwood, *P. angustifolia* James, balsam poplar, *P. balsamifera* L., and black cottonwood, *P. trichocarpa* Torr. & Gray, species that have greater reliance on clonal reproduction and other ecophysiological differences from the section *Aigeiros* cottonwoods (Farrar 1995, Gom and Rood 1999, Rood et al. 2003).

The Duncan and Lardeau rivers occur within humid reaches where patch recruitment of black cottonwood occurs. Patch recruitment is documented along the Elk River for black cottonwood within a humid reach (Polzin and Rood 2006). Patch recruitment consists of patches of relatively even-aged cottonwoods (1 to 5 year-aged cottonwoods Polzin 1998 and 2006) in contrast to arcuate banding of single age cohorts. In the humid reach of the free-flowing Elk River, water was less limiting and geomorphic disturbance was the more vital component of the flood event for successful recruitment.

This study is focussed on the long-term investigation of the riparian vegetation and black cottonwood recruitment trends in response to Alt S73. This report summarizes the 2016 results and compares these observations with previous year patterns.

4.1 Black cottonwood monitoring summary 2016

The black cottonwood phenological developmental stages occurred earlier in 2016 than in 2015, and the previous study years. Similarly, overall earlier development was observed in herbaceous plants and earlier leaf emergence was observed for other woody species in 2016. There was a pattern of seed release following rain events in 2016 in the Lardeau-Duncan black cottonwoods, which has been previously observed since 2009 (Polzin et al. 2015). Herbison et al. (2015) concluded that rain may promote seed release from black cottonwoods in this humid, temperate-climate mountain ecoregion. There was no August seed release in 2016. The main seed release event started June 2 and continued through to June 7. Seed release ended 26 days earlier in 2016 (June 20) compared to 2015, which also had no August seed release.

The earlier than average seed release corresponded well to the earlier than average time for spring freshet high water on the free flowing Lardeau River. This was very interesting as it confirmed a hypothesis put forward by Dr. Polzin in 2003 at the University of Montana as a possible response of riparian cottonwood trees on a snowmelt system to climate change. Climate change predictions for the mountains of the Pacific Northwest is earlier snow pack melt, followed by earlier precipitation falling as rain instead of snow, which combined would result in earlier freshets (Schnorbus et al. 2011, Hamlet et al. 2013). The 2016 freshet was the earliest on record for the free flowing Lardeau River. Germinant establishment levels were similar to the 2015 levels which had similar seed release levels to 2016. Earlier freshets may become more common as climate change progresses.

Along with the earlier leaf emergence recorded in the spring of 2016, earlier senescence also occurred for both reaches. Keenan and Richardson (2015) found that earlier budburst brought on by early warm spring weather is correlated to earlier leaf senescence in the same trees across the entire eastern United States. Fu et al. (2014) showed similar results for two trees species from various locations in Europe. This is not to suggest this one data point represents support for the studies carried out in other areas with extensive data, but it is interesting that the same correlation was recorded along the Duncan and the Lardeau reaches of this study and observed in the East Kootenay, lower Kootenay River area.

Germinant densities were similar to 2015 densities along the Duncan reach. However, they were significantly lower than 2014 densities and lower than previous years during the study, excluding 2012 flood year. Most of the difference was attributed to natural succession. As recruitment zones become vegetated and increase in elevation they transition out of the recruitment zone. Cottonwood recruitment sites are moist, barren sites with full sunlight exposure (Bradley 1982, Scott et al. 1996, Braatne et al. 1996). Cottonwood seedlings have been well documented as shade-intolerant, but very tolerant of flooding and requiring moist sites and shallow ground water through the growing season (Brink 1954, Hosner 1958, Bradley 1982, Fenner et al. 1984 and 1985, Bradley and Smith 1986, Braatne et al. 1992, Mahoney and Rood 1992 and 1993, Braatne et al. 1996, Scott et al. 1997). In a long term study it is not surprising that some of the former high establishment rate transects experienced reduced establishment levels as the recruitment zone becomes colonized by cottonwood, willow, grasses, and forb species. The same zones increased in elevation with deposition from periodic flooding of the recruitment zones and/or some recruitment zones were scoured away.

Survival of germinants of the first growing season along the Duncan reach was 40 per cent, well above the average of 23 per cent. This was attributed to the lower August flows which allowed greater survival of seedlings especially ones established at low elevation locations along transects. The free flowing Lardeau reach also had higher than average survival of 30 per cent, compared to the average of 24 per cent. This suggests that the weather and a natural stage decline through the growing season resulted in 6 per cent increase over the average survival rate. The 17 per cent increase along the flow regulated Duncan reach suggests that some of the increase in survival may be contributed to by the regulated flows of the Duncan reach. However, the increase occurred at low elevation locations which may be scoured or buried in deposition in the following year. The increase in the first year season survival does not imply that there will be increased survival in recruitment of 2016 seedlings by 2018.

Both the Duncan and the Lardeau reaches had second and third year survival rates similar to the average survival rates for each reach. The summer of 2016 precipitation during the growing season was similar to 2014 and 2015. Additionally, similar survival rates compared to the average survival rates suggest that there was no net impact to increase or decrease survival in the second and third year seedlings due to weather.

The slight decrease (2 per cent) in the second year survival rate compared to the average was attributed to natural variation in data. The small variation in the third year survival rates is hard to attribute to any particular driver as the Duncan had a slight increase compared to the average and the Lardeau had a slightly larger decrease. It may be that the controlled flow of the Duncan River contributed to the increase because the 2014 seedlings were established with high flows during the growing season resulting in colonization of higher elevation points than in most of the previous years, followed by high August flows in 2015. These two events probably resulted in deep root establishment so that the lower August flows in 2016 had connectivity through groundwater levels to support the 2014 seedlings in 2016. The Lardeau reach, with natural flows, had a larger decrease in the third year survival rates. This suggests that some of the increase for the Duncan reach was offset by the controlled flow levels, compared to the decrease experienced by the reference reach. With no significant difference and similar weather patterns the difference is attributed to natural annual variation.

The Duncan reach average survival rates for 2nd and 3rd year seedlings were lower than the average rates along the Lardeau reach. The difference in the 2nd and 3rd year survival rates between the two reaches show that the Duncan Dam, and resulting controlled discharge rates, do impact survival rates. The degree that the new Alt S73 regime impacts survival compared to pre-Alt S73 rates will be determined in 2018 utilizing the recruitment data for the pre-Alt S73 compared to the 3rd year survival densities, which has been classified as recruitment for the Alt S73 regime.

The 1st year average survival rates were similar between reaches, showing the ability of black cottonwood seedlings to establish where ever moisture levels are sufficient and the area is bare or relatively bare. However, the ability to survive to the end of the third growing season requires a broader range more specific requirements (Polzin and Rood 2006. These factors were identified in Polzin et al. (2010) and data has been collected for these factors since 2009 (Year 1) monitoring started. This data will be used in the 2018 hypothesis testing and analysis.

4.2 Pre-Alt S73 seedling recruitment

The information gathered through the tree core sampling within established Sites and randomly placed 100 m^2 plots will allow for exploration of recent past events pre-Alt S73. Preliminary analysis for stems/ha and stems/site area indicates a decrease in black cottonwood recruitment occurring since the initiation of Alt S73. However, there are still two recruitment years to gather data before completing comprehensive analyses. This is also summary data, and not put into context of available recruitment area per each segment.

5 CONCLUSIONS

The data collection for DDMMON#8-1 study Year 7 data extended from May to October 2016. The purpose of study Year 7 was to investigate the effects of the implementation of the Alt S73 flow regime on black cottonwood establishment and recruitment with respect to the following attributes:

- The extent of black cottonwood seedling establishment; and
- The level of black cottonwood seedling survival and recruitment; and
- Collect pre-Alt S73 recruitment data through the use of tree core data for a 20 year bracket from 1987 to 2007 utilizing “Sites” and plot data collection.

The results in this report document black cottonwood establishment and recruitment since 2014 along the lower Duncan River and along the reference reach, the Lardeau River.

Establishment densities for 2016 germinants were above average for both the Duncan and Lardeau reaches. Second season survival rates were average for both reaches. Recruitment survival of the third growing season were slightly above for the Duncan average and slightly below the Lardeau average.

The relationship between abiotic influences and the biological responses by black cottonwood seedling, supported key factors identified in previous years, which affected black cottonwood establishment and survival along the lower Duncan River during this monitoring period which included:

1. Lower August stage allowed seedling establishment at lower elevations. Most of the lower elevation areas were close to or within the active channel.
2. Seedling establishment elevation is a factor that determines the extent affected by inundation. Additionally, for seedlings established on lower recruitment zones, the probability of burial by deposition or scour is increased which is correlated with river stage patterns.
3. Water availability for seedlings is very important during the summer months. In previous years an artificially high river stage resulting in high groundwater level during the growing season along the Duncan reach moderated the influence from drought. In 2016 there was no summer drought condition. Both the Duncan and the Lardeau reaches had increased first year seedling survival compared to their average. Second and third year survival rates compared to each reach average were similar for both reaches.

The lower Duncan River peak discharge occurred in May, with the lowest discharge during February. This is with the assumption that December discharge will not spike to a level greater than the May peak discharge of 322 m^3/s. This is the first year of the seven year study period where the peak discharge occurred in the spring, and at the same time as the free flowing Lardeau peak discharge occurred. Usually the peak discharge occurs in January for the flow attenuated Duncan River.

The Lardeau River did not experience a Q_{max2} (a 1-in-2 year peak) peak flow, but did experience the earliest freshet on record (70 years) that occurred May 8th. Early seed release corresponded to the earlier freshet suggesting that climate change may not impact seedling establishment as much as some climate change prediction models may suggest.

Results from comparative analyses for 2014, 2015, and 2016 indicated that sediment deposition and erosion, inundation duration and timing, discharge, and establishment elevation are key factors for assessing the performance of Alt S73 on black cottonwoods along the lower Duncan River. The findings in 2016 support the previous results of key factors and drivers affecting black cottonwood recruitment. Continued monitoring of annual black cottonwood recruitment, and the 2018 monitoring of riparian vegetation and communities over the next two years, will be important to complete the decade interval analyses in 2018 with 2019 as confirmation data collection year. The results of the 2018 analyses will then be used to assess the three hypotheses, and subsequently to address the objectives and the two key management questions outlined in Section 1 (taken from the BC Hydro TOR 2009).

In conclusion, the study Year 7 results largely extended and confirmed the patterns observed in previous years. The consistency of black cottonwood seedling recruitment distributions supports a deterministic pattern, whereby establishment and survival follow from particular physical conditions and seasonal timing.

6 RECOMMENDATIONS

6.1 Transect Line Resurveying

We recommend resurveys of all transect lines in 2018, to assess the changes to transect profiles through sediment deposition and erosion that has occurred since 2012/2014. Resurveys of the recruitment zone is needed as this is the zone of interest for calculating seedling safe zones and the amount of deposition/erosion occurring in the recruitment zone affecting survival. This will update partial information on the transect line elevations and will contribute stage/discharge specific data for these lines as well as the profiles for seedling establishment elevations, thus contributing further to the foundational data required for the study objectives. It will also be helpful to derive a more accurate relationship for use in the conceptual model for predicting the long-term response of black cottonwood recruitment to a variety of flow regimes. The field work should occur in late April or early May depending on spring weather conditions, before leaf out so surveying is not limited by foliage cover.

6.2 Air Photo Acquisition

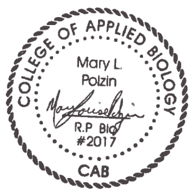
We recommend that the flight-time for the 2018 air photo acquisition be switched from autumn back to spring. Mid-May is recommended so that foliage is on the deciduous trees and shrubs or an appropriate date determined from spring timing in 2018. This will allow for photos to be available for the August field monitoring for navigating the rivers to avoid new log jams. It will also provide additional time for air photo analysis and reporting.

7 CLOSURE

VAST Resource Solutions Inc., trusts that this report satisfied your present requirements. Should you have any comments, please contact us at your convenience.

Vast Resource Solutions Inc.,

Prepared by:



March 31 2017

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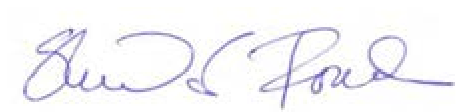

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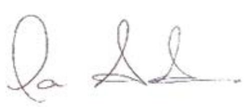

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Appendix 1: Lower Duncan and Lardeau Rivers Photo Documentation

Date: August 2016			**Environmental Crew:** MLP, AS, JS, CC
Location: Duncan River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
8-Aug	IMG_0185	15:36	**D1T3** at 21 m looking at plot
8-Aug	IMG_0187	16:08	At EOT
8-Aug	IMG_0186	15:38	At 2 m looking at POC
8-Aug	IMG_0189	16:21	**D1T4** at EOT
8-Aug	IMG_0190	16:22	At POC
8-Aug	DSCN4595	14:14	**D3T10** at EOT looking at POC
8-Aug	DSCN4596	14:14	At EOT looking across the river
8-Aug	DSCN4597	14:16	At 2 m looking at EOT
8-Aug	DSCN4598	14:17	At 2 m looking at POC
8-Aug	DSCN4599	14:23	At 50.4 m looking at clones on the downstream side - 2016 growth
8-Aug	DSCN4600	14:24	At EOT looking downstream
8-Aug	DSCN4601	14:25	At EOT looking upstream
8-Aug	DSCN4602	14:26	At 34 m looking downstream
8-Aug	DSCN4603	14:26	At 34 m looking upstream
8-Aug	DSCN4604	14:26	At 34 m looking down the line (at the EOT)
8-Aug	DSCN4605	14:26	At 34 m looking up the line (at the POC)
8-Aug	DSCN4606	14:51	**D3T11** at 57.3 m looking at POC
8-Aug	DSCN4607	14:52	At 57.3 m looking at EOT
8-Aug	DSCN4608	14:53	At 57.3 m looking downstream
8-Aug	DSCN4609	14:53	At 57.3 m looking upstream
8-Aug	DSCN4610	15:43	At EOT looking at POC
8-Aug	DSCN4611	15:43	At EOT looking upstream
8-Aug	DSCN4612	15:44	At EOT looking downstream
8-Aug	DSCN4613	15:44	At EOT looking across river
8-Aug	DSCN4614	15:49	At 141 m looking at 2016 seedlings
8-Aug	DSCN4615	15:49	At 141 m looking at seedling band
8-Aug	DSCN4616	15:50	At 141 m looking upstream
8-Aug	DSCN4617	15:55	Upstream of line about 200 m looking at older cottonwood seedlings at upstream end of of mid-channel bar
8-Aug	DSCN4618	15:58	Upstream of line about 200 m looking at older cottonwood seedlings at upstream end of of mid-channel bar
8-Aug	DSCN4619	15:58	Upstream of line about 200 m looking at older cottonwood seedlings at upstream end of of mid-channel bar
8-Aug	DSCN4620	15:58	Upstream of line about 200 m looking at older cottonwood seedlings at upstream end of of mid-channel bar
9-Aug	DSCN4633	10:49	**D3T15** at EOT looking at POC
9-Aug	DSCN4634	10:50	At EOT looking across the side channel
9-Aug	DSCN4635	10:50	At EOT looking upstream
9-Aug	DSCN4636	10:50	At EOT looking downstream
9-Aug	DSCN4637	11:11	At 71.3 m looking at 2016 seedlings - cottonwoods and willows
9-Aug	DSCN4638	11:12	At 60 m looking at POC
9-Aug	DSCN4639	11:13	At 60 m looking at EOT
9-Aug	DSCN4640	11:13	At 60 m looking downstream
9-Aug	DSCN4641	11:13	At 60 m looking upstream
9-Aug	DSCN4642	11:17	At 17 m looking at POC (standing in old channel)
9-Aug	DSCN4643	11:18	At 17 m looking at EOT
9-Aug	DSCN4644	11:18	At 17 m looking upstream
9-Aug	DSCN4621	9:24	**D3T17** at 5 m looking at EOT
9-Aug	DSCN4622	9:25	At EOT looking at POC
9-Aug	DSCN4623	9:27	At EOT looking across the side channel
9-Aug	DSCN4624	9:27	At EOT looking downstream
9-Aug	DSCN4625	9:27	At EOT looking upstream
9-Aug	DSCN4626	9:37	Looking upstream of line at band of 2016 seedlings
9-Aug	DSCN4627	9:37	About 200 m upstream of line looking at 2016 seedling band of willows and cottonwoods
9-Aug	DSCN4628	9:41	About 200 m upstream of line looking at 2016 seedling band of willows and cottonwoods

Date	Image #	Time	Description
9-Aug	DSCN4629	9:44	At 21 m looking at POC
9-Aug	DSCN4630	9:45	At 21 m looking at EOT
9-Aug	DSCN4631	9:47	At 21 m looking upstream
9-Aug	DSCN4632	9:48	At 21 m looking downstream
9-Aug	DSCN4657	13:35	**D3T29** at 10 m looking at EOT
9-Aug	DSCN4658	13:38	At 10 m looking upstream
9-Aug	DSCN4659	13:38	At 10 m looking downstream
9-Aug	DSCN4660	13:55	At EOT looking at POC
9-Aug	DSCN4661	13:55	At EOT looking across side stream
9-Aug	DSCN4662	13:55	At EOT looking downstream
9-Aug	DSCN4663	13:55	At EOT looking upstream
9-Aug	DSCN4664	13:59	At 53 m looking upstream
9-Aug	DSCN4665	13:59	AT 53 m looking downstream
9-Aug	DSCN4666	13:59	At 53 m looking at POC
9-Aug	DSCN4667	14:02	At POC looking at EOT
9-Aug	DSCN4668	14:02	At 5 m looking at POC
9-Aug	DSCN4645	12:10	**D3T35** at 5 m looking at EOT
9-Aug	DSCN4646	12:11	At 5 m looking at POC
9-Aug	DSCN4647	12:11	At 5 m looking downstream
9-Aug	DSCN4648	12:11	At 5 m looking upstream
9-Aug	DSCN4649	13:01	At 28.5 m looking at seedlings in plot quade
9-Aug	DSCN4650	13:02	At 24 m looking at POC
9-Aug	DSCN4651	13:02	At 24 m looking at EOT
9-Aug	DSCN4652	13:02	At 24 m looking upstream
9-Aug	DSCN4653	13:03	At 24 m looking downstream
9-Aug	DSCN4654	13:05	At EOT looking at POC
9-Aug	DSCN4655	13:06	At EOT looking across side channel
9-Aug	DSCN4656	13:06	At EOT looking downstream
9-Aug	DSCN4682	16:30	**D3T40** at EOT looking at POC
9-Aug	DSCN4683	16:30	At EOT looking across the river
9-Aug	DSCN4684	16:30	At EOT looking upstream
9-Aug	DSCN4685	16:30	At EOT looking downstream
9-Aug	DSCN4686	16:33	At 18 m looking at POC
9-Aug	DSCN4687	16:33	At 18 m looking downstream
9-Aug	DSCN4688	16:33	At 18 m looking upstream
9-Aug	DSCN4689	16:34	At 12 m looking at seedling plot
9-Aug	DSCN4669	15:05	**D3T45** at 7 m looking at EOT
9-Aug	DSCN4670	15:06	At 19 m looking at POC
9-Aug	DSCN4671	15:06	At 19 m looking upstream at side channel covered with willows and cottonwoods
9-Aug	DSCN4672	15:07	At 19 m looking downstream at side channel
9-Aug	DSCN4673	15:54	At EOT looking upstream
9-Aug	DSCN4674	15:54	At EOT looking downstream
9-Aug	DSCN4675	15:54	At EOT looking at POC
9-Aug	DSCN4676	15:54	At EOT looking across river - use to be main channel
9-Aug	DSCN4677	15:57	At 40 m looking at POC
9-Aug	DSCN4678	15:57	At 40 m looking upstream
9-Aug	DSCN4680	15:58	At 40 m looking downstream
9-Aug	DSCN4681	16:00	At 11 m looking at mainly willow seedlings
9-Aug	IMG_0191	8:23	**D4T3** at EOT looking upstream
9-Aug	IMG_0192	8:23	At EOT looking downstream
9-Aug	IMG_0193	8:23	At EOT looking at POC
9-Aug	IMG_0194	9:33	At 29 m looking at plot
9-Aug	IMG_0195	9:33	At 24m looking at 332 baring
9-Aug	IMG_0196	11:06	Midway looking at POC

Date	Image #	Time	Description
9-Aug	IMG_0197	11:06	Midway looking upstream
9-Aug	IMG_0198	11:06	Midway looking downstream
9-Aug	IMG_0206	14:08	**D4T5** at 9 m looking upstream
9-Aug	IMG_0209	14:09	At 9 m looking downstream
9-Aug	IMG_0207	14:08	At 9 m looking down line
9-Aug	IMG_0208	14:08	At 9 m looking downstream at sand bar
9-Aug	IMG_0210	14:09	At 9 m looking at plot
9-Aug	IMG_0199	12:36	**D4T10** at 11 m looking upstream
9-Aug	IMG_0200	12:36	At 11 m downstream
9-Aug	IMG_0202	12:36	At 23 m looking at plot
9-Aug	IMG_0203	12:37	At EOT looking upstream
9-Aug	IMG_0204	12:37	At EOT looking downstream
9-Aug	IMG_0205	12:37	At EOT looking at POC
9-Aug	IMG_0211	16:09	**D5T2** at EOT looking downstream
9-Aug	IMG_0212	16:09	At EOT looking upstream
9-Aug	IMG_0214	16:09	At EOT looking at POC
9-Aug	IMG_0215	16:09	At 19 m looking at plot
9-Aug	IMG_0216	16:09	At 17 m looking at plot
9-Aug	IMG_0217	16:10	At POC looking at EOT
10-Aug	IMG_0218	9:35	**D5T9** at EOT looking upstream
10-Aug	IMG_0219	9:35	At EOT looking downstream
10-Aug	IMG_0220	9:35	At EOT looking down line
10-Aug	IMG_0222	9:35	At EOT looking at POC
10-Aug	IMG_0221	9:35	At 27 m looking at plot
10-Aug	IMG_0226	9:36	At 16 m looking at plot
10-Aug	IMG_0223	9:36	At 17 m looking upstream
10-Aug	IMG_0224	9:36	At 17 m looking downstream
10-Aug	IMG_0227	9:37	At midpoint looking at POC
10-Aug	IMG_0229	9:38	At POC looking at EOT
10-Aug	IMG_0228	9:37	Looking at rebar
10-Aug	DSCN4690	7:51	**D5T11** at 36 m looking at POC
10-Aug	DSCN4691	7:51	At 36 m looking downstream at side channel
10-Aug	DSCN4692	7:51	At 36 m looking upstream at side channel
10-Aug	DSCN4693	8:00	At 40 m looking at EOT
10-Aug	DSCN4694	8:10	At 51 m looking at POC
10-Aug	DSCN4695	8:10	At 51 m looking downstream
10-Aug	DSCN4696	8:11	At 47 m looking at POC at a section of knapweed
10-Aug	DSCN4697	8:32	At 63 m looking at EOT
10-Aug	DSCN4698	8:32	At 63 m looking upstream
10-Aug	DSCN4699	8:33	At 66 m looking at EOT and across the river
10-Aug	DSCN4700	8:34	At EOT looking downstream
10-Aug	DSCN4701	8:34	At EOT looking at POC
10-Aug	DSCN4702	8:42	**D5T12** at 46 m looking at POC
10-Aug	DSCN4703	8:43	At 46 m looking at EOT
10-Aug	DSCN4704	8:43	At 46 m looking downstream of side channel that meets up the main channel
10-Aug	DSCN4705	8:43	At 46 m looking upstream
10-Aug	DSCN4706	9:47	At EOT looking at POC
10-Aug	DSCN4707	9:47	At EOT looking across the river
10-Aug	DSCN4708	9:48	At EOT looking downstream
10-Aug	DSCN4709	9:48	At EOT looking upstream
10-Aug	DSCN4710	9:49	At 60 m looking at seedling frame
10-Aug	DSCN4711	9:50	At 60 m looking upstream
10-Aug	DSCN4712	9:51	At 60 m looking downstream

Date	Image #	Time	Description
10-Aug	DSCN4713	9:51	At 60 m looking at EOT
10-Aug	DSCN4714	10:12	**D5T16** at EOT looking across the river
10-Aug	DSCN4715	10:12	At EOT looking downstream
10-Aug	DSCN4716	10:12	At EOT looking upstream
10-Aug	DSCN4717	10:13	At 50 m upstream of the line facing downstream
10-Aug	DSCN4718	10:14	Off the line downstream 30 m, facing the line
10-Aug	DSCN4719	10:15	Off the line downstream, facing 10 m piezo
10-Aug	DSCN4720	10:37	**D5T19** at POC looking at EOT
10-Aug	DSCN4721	10:37	At POC looking at rebar and tag tree
10-Aug	DSCN4722	10:39	At EOT looking across the river
10-Aug	DSCN4723	10:39	At EOT looking upstream
10-Aug	DSCN4724	10:39	At EOT looking downstream
10-Aug	DSCN4757	15:52	**D6T6** at 6 m looking at POC
10-Aug	DSCN4758	15:52	At 6 m looking at EOT
10-Aug	DSCN4759	15:52	At 6 m looking to the right of the line
10-Aug	DSCN4760	15:52	At 6 m looking to the left of the line
10-Aug	DSCN4761	15:57	At 24 m looking at POC
10-Aug	DSCN4762	15:57	At 24 m looking at EOT
10-Aug	DSCN4763	15:57	At 24 m looking to the right of the line
10-Aug	DSCN4764	15:57	At 24 m looking to the left of the line
10-Aug	DSCN4765	15:58	At 37 m looking at EOT
10-Aug	DSCN4766	15:59	At 37 m looking at POC
10-Aug	DSCN4767	15:59	At 37 m looking to the right of the line
10-Aug	DSCN4768	15:59	At 37 m looking to the left of the line
10-Aug	DSCN4749	14:58	**D6T20** at EOT looking across the river
10-Aug	DSCN4750	14:59	At EOT looking at POC
10-Aug	DSCN4751	14:59	At EOT looking downstream
10-Aug	DSCN4752	14:59	At EOT looking upstream
10-Aug	DSCN4753	15:01	At 16 m looking upstream
10-Aug	DSCN4754	15:02	At 16 m looking at POC
10-Aug	DSCN4755	15:02	At 16 m looking downstream
10-Aug	DSCN4756	15:04	At EOT looking at EOT
10-Aug	DSCN4725	11:09	**D6T29** at 36 m looking at POC
10-Aug	DSCN4726	11:09	At 36 m looking at EOT
10-Aug	DSCN4727	11:09	At 36 m looking downstream
10-Aug	DSCN4728	11:09	At 36 m looking upstream
10-Aug	DSCN4729	11:52	At EOT looking at POC
10-Aug	DSCN4730	11:52	At EOT looking across the river
10-Aug	DSCN4731	11:52	At EOT looking downstream
10-Aug	DSCN4732	11:53	At EOT looking upstream
10-Aug	DSCN4733	11:56	At 49 m looking downstream
10-Aug	DSCN4734	11:56	At 49 m looking upstream
10-Aug	DSCN4735	11:57	Off line at 50 m looking at depression with seedlings
10-Aug	DSCN4736	11:57	Off line at 50 m looking at depression with seedlings
10-Aug	DSCN4740	12:46	**D6T36** at 27 m looking at POC
10-Aug	DSCN4739	12:46	At 27 m looking at EOT
10-Aug	DSCN4741	13:54	At EOT looking across the river
10-Aug	DSCN4742	13:55	At EOT looking downstream
10-Aug	DSCN4743	13:55	At EOT looking upstream
10-Aug	DSCN4744	13:56	At EOT looking at POC
10-Aug	DSCN4745	13:57	Upstream of line looking at willow band 45 - 70 m
10-Aug	DSCN4746	14:00	Upstream of transect looking between 45 - 18 m
10-Aug	DSCN4747	14:00	At 34 m looking upstream at band of willows
10-Aug	DSCN4748	14:03	At 90 m looking at small band of 2016 cottonwoods

Date: October 2016			**Environmental Crew:** MLP, AS, BH, KM
Location: Duncan River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
3-Oct	IMG_0305	14:04	**D1T3** at POC looking at EOT
3-Oct	IMG_0306	14:05	At EOT looking at POC
3-Oct	IMG_0307	14:06	At EOT looking upstream
3-Oct	IMG_0308	14:06	At EOT looking downstream
3-Oct	IMG_0309	14:06	At EOT looking across stream
3-Oct	IMG_0310	14:07	At 14 m looking upstream
3-Oct	IMG_0311	14:07	At 14 m looking downstream
3-Oct	IMG_0312	14:08	At 14 m looking at POC
3-Oct	IMG_0313	14:08	At 14 m looking at EOT
3-Oct	IMG_0314	14:10	Looking at a plot at 19 m
3-Oct	IMG_0315	14:35	Looking at a plot at 9 m
3-Oct	IMG_0287	13:16	**D1T4** at POC looking at EOT
3-Oct	IMG_0288	13:18	At EOT looking at POC
3-Oct	IMG_0289	13:20	At EOT looking upstream
3-Oct	IMG_0290	13:20	At EOT looking downstream
3-Oct	IMG_0291	13:20	At Eot looking across stream
3-Oct	IMG_0292	13:23	At 19.5 m looking upstream
3-Oct	IMG_0293	13:23	At 19.5 m looking dowstream
3-Oct	IMG_0294	13:24	At 19.5 m looking at POC
3-Oct	IMG_0295	13:24	At 19.5 m looking at EOT
3-Oct	IMG_0296	13:42	**D1T5** at POC looking at EOT
3-Oct	IMG_0297	13:43	At EOT looking at POC
3-Oct	IMG_0298	13:43	At EOT looking upstream
3-Oct	IMG_0299	13:43	At EOT looking downstream
3-Oct	IMG_0300	13:43	At EOT looking across the stream
3-Oct	IMG_0301	13:44	At 11 m looking upstream
3-Oct	IMG_0302	13:45	At 11 m looking downstream
3-Oct	IMG_0303	13:45	At 11 m looking at POC
3-Oct	IMG_0304	13:45	At 11 m looking at EOT
3-Oct	DSCN4957	13:28	**D3T11** at 57.3 m looking at POC
3-Oct	DSCN4958	13:28	At 57.3 m looking at EOT
3-Oct	DSCN4959	13:28	At 57.3 m looking downstream
3-Oct	DSCN4960	13:29	At 57.3 m looking upstream
3-Oct	DSCN4961	14:00	At EOT looking at POC
3-Oct	DSCN4962	14:00	At EOT looking across river
3-Oct	DSCN4963	14:00	At EOT looking upstream
3-Oct	DSCN4964	14:00	At EOT looking downstream
3-Oct	DSCN4965	14:02	At 79 m looking at 2016 seedlings
3-Oct	DSCN4966	14:03	At 79 m looking downstream at band
3-Oct	DSCN4967	14:03	At 79 m looking upstream at band
3-Oct	DSCN4968	14:04	At 79 m looking at POC
3-Oct	DSCN4981	15:04	**D3T15** at 24 m looking at POC
3-Oct	DSCN4982	15:04	At 24 m looking downstream
3-Oct	DSCN4983	15:05	At 24 m looking upstream
3-Oct	DSCN4984	15:08	At 51 m looking at POC
3-Oct	DSCN4985	15:08	At 51 m looking at EOT
3-Oct	DSCN4986	15:08	At 51 m looking upstream
3-Oct	DSCN4987	15:09	At 51 m looking downstream
3-Oct	DSCN4988	15:10	At 72 m looking at EOT
3-Oct	DSCN4989	15:11	At 72 m looking at POC
3-Oct	DSCN4990	15:11	At 72 m looking downstream
3-Oct	DSCN4991	15:11	At 72 m looking upstream

Date	Image #	Time	Description
3-Oct	DSCN4992	15:40	Looking at two grizzly bears
3-Oct	DSCN4993	15:40	Looking at two grizzly bears
3-Oct	DSCN4994	15:42	Looking at two grizzly bears
3-Oct	DSCN4995	15:42	Looking at two grizzly bears
3-Oct	DSCN4969	14:18	**D3T17** at 8 m looking at POC
3-Oct	DSCN4970	14:19	At 8 m looking at EOT
3-Oct	DSCN4971	14:19	At 8 m looking downstream
3-Oct	DSCN4972	14:19	At 8 m looking upstream
3-Oct	DSCN4973	14:21	At EOT looking across channel
3-Oct	DSCN4974	14:22	At EOT looking at POC
3-Oct	DSCN4975	14:22	At EOT looking downstream
3-Oct	DSCN4976	14:22	At EOT looking upstream
3-Oct	DSCN4977	14:23	At 43 m looking at POC
3-Oct	DSCN4978	14:23	At 43 m looking at EOT
3-Oct	DSCN4979	14:23	At 43 m looking downstream
3-Oct	DSCN4980	14:23	At 43 m looking upstream
4-Oct	DSCN5011	11:00	**D3T20** at the area but no access and no recruitment zone from 2015
4-Oct	DSCN4996	9:53	**D3T29** at EOT looking at POC
4-Oct	DSCN4997	9:54	At EOT looking across back channel
4-Oct	DSCN4998	9:54	At EOT looking upstream
4-Oct	DSCN4999	9:54	At EOT looking downstream
4-Oct	DSCN5000	9:57	At 57 m looking at EOT
4-Oct	DSCN5001	9:57	At 57 m looking at POC
4-Oct	DSCN5002	9:57	At 57 m looking downstream
4-Oct	DSCN5003	9:57	At 57 m looking upstream
4-Oct	DSCN5004	10:42	**D3T35** at 26 m looking at 2016 seedlings
4-Oct	DSCN5005	10:48	At 54 m looking at EOT
4-Oct	DSCN5006	10:49	At 54 m looking at POC
4-Oct	DSCN5007	10:50	At 54 m looking upstream
4-Oct	DSCN5008	10:50	At 54 m looking downstream
4-Oct	DSCN5009	10:50	At 28 m looking upstream at seedling band
4-Oct	DSCN5010	10:51	At 28 m looking downstream
4-Oct	DSCN5019	13:11	**D3T40** at 11 m looking at POC
4-Oct	DSCN5020	13:11	At 11 m looking at EOT
4-Oct	DSCN5021	13:12	At 11 m looking upstream
4-Oct	DSCN5022	13:12	At 11 m looking downstream
4-Oct	DSCN5023	13:37	At 25 m looking at EOT
4-Oct	DSCN5024	13:37	At 25 m looking at POC
4-Oct	DSCN5025	13:37	At 25 m looking upstream
4-Oct	DSCN5026	13:37	At 25 m looking downstream
4-Oct	DSCN5027	13:40	Looking at kokanee upstream of D3T40
4-Oct	DSCN5028	13:40	Looking at kokanee upstream of D3T40
4-Oct	DSCN5029	13:41	Looking at kokanee upstream of D3T40
4-Oct	DSCN5030	13:41	Looking at kokanee upstream of D3T40
4-Oct	DSCN5031	13:41	Looking at kokanee upstream of D3T40
4-Oct	DSCN5032	13:42	Looking at kokanee upstream of D3T40
4-Oct	DSCN5012	12:59	**D3T45** at 43 m looking at EOT
4-Oct	DSCN5013	12:59	At 43 m looking at POC
4-Oct	DSCN5014	12:59	At 43 m looking upstream
4-Oct	DSCN5015	12:59	At 43 m looking downstream
4-Oct	DSCN5016	13:01	At 27 m looking at POC
4-Oct	DSCN5017	13:01	At 27 m looking at EOT
4-Oct	DSCN5018	13:01	At 27 m looking downstream

Date	Image #	Time	Description
4-Oct	IMG_0335	10:47	**D4T3** at POC looking at EOT
4-Oct	IMG_0336	10:50	At EOT looking at POC
4-Oct	IMG_0337	10:53	At EOT looking upstream
4-Oct	IMG_0338	10:53	At EOT looking downstream
4-Oct	IMG_0339	10:53	At EOT looking across stream
4-Oct	IMG_0340	10:55	At 47 m looking upstream
4-Oct	IMG_0341	10:55	At 47 m looking downstream
4-Oct	IMG_0342	10:55	At 47 m looking at POC
4-Oct	IMG_0343	10:55	At 47 m looking at EOT
4-Oct	IMG_0344	**13:17**	**D4T10** at POC looking at EOT
4-Oct	IMG_0345	13:19	At EOT looking at POC
4-Oct	IMG_0346	13:19	At EOT looking upstream
4-Oct	IMG_0347	13:20	At EOT looking downstream
4-Oct	IMG_0348	13:20	At EOT looking across stream
4-Oct	IMG_0349	13:20	At 45 m looking upstream
4-Oct	IMG_0350	13:21	At 45 m looking downstream
4-Oct	IMG_0351	13:21	At 45 m looking at POC
4-Oct	IMG_0352	13:21	At 45 m looking at EOT
3-Oct	IMG_0316	16:06	**D5T2** at POC looking at EOT
3-Oct	IMG_0317	16:10	At EOT looking at POC
3-Oct	IMG_0318	16:10	At EOT looking upstream
3-Oct	IMG_0319	16:10	At EOT looking downstream
3-Oct	IMG_0320	16:11	At EOT looking across the stream
3-Oct	IMG_0321	16:11	At 16 m looking upstream
3-Oct	IMG_0322	16:11	At 16 m looking downstream
3-Oct	IMG_0323	16:12	At 16 m looking at POC
3-Oct	IMG_0324	16:12	At 16 m looking at EOT
3-Oct	IMG_0325	16:28	Looking at a cottonwood covered in mud
3-Oct	IMG_0326	16:28	Looking at a cottonwood in the river bed
4-Oct	IMG_0327	9:15	**D5T9** at POC looking at EOT
4-Oct	IMG_0328	9:17	At EOT looking at POC
4-Oct	IMG_0329	9:17	At EOT looking upstream
4-Oct	IMG_0330	9:17	At EOT looking downstream
4-Oct	IMG_0334	9:19	At EOT looking across stream
4-Oct	IMG_0331	9:18	At 18 m looking upstream
4-Oct	IMG_0332	9:18	At 18 m looking downstream
4-Oct	IMG_0333	9:19	At 18 m looking at POC
4-Oct	IMG_0334	9:19	At 18 m looking at EOT
5-Oct	DSCN5033	9:18	**D5T11** at 72 m looking at EOT
5-Oct	DSCN5034	9:18	At 72 m looking at POC
5-Oct	DSCN5035	9:18	At 72 m looking upstream
5-Oct	DSCN5036	9:21	At EOT looking downstream
5-Oct	DSCN5037	9:23	At 42 m looking downstream
5-Oct	DSCN5038	9:24	At 34 m looking at POC
5-Oct	DSCN5039	9:25	At 34 m looking downstream
5-Oct	DSCN5040	9:25	At 34 m looking upstream
5-Oct	DSCN5041	9:33	**D5T12** at 49 m looking at POC
5-Oct	DSCN5042	9:33	At 49 m looking at EOT
5-Oct	DSCN5043	9:34	At 49 m looking upstream
5-Oct	DSCN5044	9:34	At 49 m looking downstream
5-Oct	DSCN5045	9:36	At 29 m looking at POC
5-Oct	DSCN5046	9:36	At 29 m looking at EOT
5-Oct	DSCN5047	9:36	At 29 m looking upstream
5-Oct	DSCN5048	9:36	At 29 m looking downstream

Date	Image #	Time	Description
5-Oct	DSCN5049	10:35	At 80 m looking at EOT
5-Oct	DSCN5050	10:35	At 80 m looking at POC
5-Oct	DSCN5051	10:35	At 80 m looking upstream
5-Oct	DSCN5052	10:35	At 80 m looking downstream
5-Oct	DSCN5053	11:02	**D5T19** at 9 m looking downstream
5-Oct	DSCN5054	11:02	At 9 m looking at EOT
5-Oct	DSCN5055	11:02	At 9 m looking upstream
5-Oct	DSCN5056	11:33	**D6T29** at 31 m looking at POC
5-Oct	DSCN5057	11:33	At 31 m looking at EOT
5-Oct	DSCN5058	11:33	At 31 m looking upstream
5-Oct	DSCN5059	11:33	At 31 m looking downstream
5-Oct	DSCN5060	11:34	At 50 m looking at EOT
5-Oct	DSCN5061	11:34	At 50 m looking at POC
5-Oct	DSCN5062	11:34	At 50 m looking downstream
5-Oct	DSCN5063	11:34	At 50 m looking upstream
5-Oct	DSCN5064	14:33	**D6T36** at 38 m looking at POC
5-Oct	DSCN5065	14:34	At 38 m looking at EOT
5-Oct	DSCN5066	14:34	At 38 m looking upstream
5-Oct	DSCN5067	14:34	At 38 m looking downstream
5-Oct	DSCN5068	14:39	At 79 m looking at POC
5-Oct	DSCN5069	14:39	At 79 m looking at EOT
5-Oct	DSCN5070	14:39	At 79 m looking upstream
5-Oct	DSCN5071	14:39	At 79 m looking downstream

Date: August 2016			**Environmental Crew:** MLP, AS, JS, CC
Location: Lardeau River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
11-Aug	IMG_0257	9:13	**L1T1** at EOT looking upstream
11-Aug	IMG_0258	9:13	At EOT looking downstream
11-Aug	IMG_0259	9:14	At EOT looking down line
11-Aug	IMG_0260	9:14	At EOT looking up line
11-Aug	IMG_0261	9:14	At 26 m looking upstream
11-Aug	IMG_0262	9:14	At 26 m looking downstream
11-Aug	IMG_0263	9:14	At 26 m looking at EOT
11-Aug	IMG_0265	9:15	At 18 m looking at plot
11-Aug	IMG_0266	9:16	At 16 m looking at plot
11-Aug	IMG_0264	9:15	At 16 m looking at POC
11-Aug	IMG_0268	9:17	At POC looking at EOT
10-Aug	IMG_0230	12:49	**L1T10** at EOT looking upstream
10-Aug	IMG_0231	12:49	At EOT looking downstream
10-Aug	IMG_0232	12:49	At EOT looking across
10-Aug	IMG_0237	12:51	At 34 m looking at plot
10-Aug	IMG_0238	12:52	At 40 m looking at plot
10-Aug	IMG_0233	12:49	At EOT looking at POC
10-Aug	IMG_0234	12:50	At middle looking downstream
10-Aug	IMG_0235	12:50	At middle looking upstream
10-Aug	IMG_0244	15:32	**L1T20** at POC looking at a tree
10-Aug	IMG_0245	15:33	At 11 m looking at plot
10-Aug	IMG_0246	15:33	At 11 m looking down line
10-Aug	IMG_0247	15:34	At 11 m looking to EOT
10-Aug	IMG_0248	15:34	At 30 m looking upstream
10-Aug	IMG_0249	15:34	At 30 m looking downstream
10-Aug	IMG_0250	15:34	At 30 m looking up line
10-Aug	IMG_0255	15:36	At EOT looking up line
10-Aug	IMG_0251	15:35	At EOT looking down line
10-Aug	IMG_0253	15:35	At EOT looking upstream
10-Aug	IMG_0252	15:35	At EOT looking downstream
10-Aug	IMG_0254	15:36	At 58 m looking at plot
10-Aug	IMG_0256	15:37	At 48 m looking at plot
11-Aug	DSCN4816	12:03	**L1T36** at 11 m looking at POC
11-Aug	DSCN4817	12:03	At 11 m looking at EOT
11-Aug	DSCN4818	12:03	At 11 m looking upstream
11-Aug	DSCN4819	12:03	At 11 m looking downstream
11-Aug	DSCN4820	12:07	At 20 m looking at EOT
11-Aug	DSCN4821	12:07	At 20 m looking at POC
11-Aug	DSCN4822	12:07	At 20 m looking upstream
11-Aug	DSCN4823	12:07	At 20 m looking downstream
11-Aug	DSCN4824	12:18	At 21 m looking at 2014 and 2015 seedlings on a log, 2016 seedlings just outside
11-Aug	DSCN4825	12:23	At EOT looking at POC
11-Aug	DSCN4826	12:23	At EOT looking upstream
11-Aug	DSCN4827	12:23	At EOT looking downstream
11-Aug	IMG_0270	10:31	**L2T6** at EOT looking upstream
11-Aug	IMG_0269	10:31	At EOT looking downstream
11-Aug	IMG_0271	10:31	At EOT looking down line
11-Aug	IMG_0272	10:31	At EOT looking at POC
11-Aug	IMG_0274	10:33	At the middle looking upstream
11-Aug	IMG_0275	10:33	At the middle looking downstream
11-Aug	IMG_0276	10:34	At the middle looking down line
11-Aug	IMG_0277	10:34	At the middle looking up line

Date	Image #	Time	Description
11-Aug	IMG_0273	10:32	Looking at a plot
11-Aug	IMG_0278	10:34	Looking at a plot
11-Aug	IMG_0279	10:37	Looking at POC tree
11-Aug	IMG_0280	10:37	At POC looking at EOT
11-Aug	IMG_0281	11:14	**L2T15** at POC looking at tree
11-Aug	IMG_0282	11:14	At POC looking at EOT
11-Aug	IMG_0283	11:15	At EOT looking upstream
11-Aug	IMG_0284	11:15	At EOT looking downstream
11-Aug	IMG_0285	11:15	At EOT looking down
11-Aug	IMG_0286	11:16	At EOT looking at POC
11-Aug	DSCN4805	10:36	**L2T18** at POC looking at EOT
11-Aug	DSCN4806	10:38	At 13 m looking at POC
11-Aug	DSCN4807	10:38	At 13 m looking at EOT
11-Aug	DSCN4808	10:38	At 13 m looking upstream
11-Aug	DSCN4809	10:38	At 13 m looking downstream
11-Aug	DSCN4810	10:39	At EOT looking at POC
11-Aug	DSCN4811	10:40	At EOT looking across the river
11-Aug	DSCN4812	10:40	At EOT looking upstream
11-Aug	DSCN4813	10:40	At EOT looking downstream
11-Aug	DSCN4814	10:58	At 16 m downstream looking upstream at cottonwood and willow recruitment
11-Aug	DSCN4815	11:01	At 19 m looking downstream about 40 m at a band
11-Aug	DSCN4793	9:52	**L3T1** at 19 m looking at POC
11-Aug	DSCN4794	9:52	At 19 m looking at EOT
11-Aug	DSCN4795	9:52	At 19 m looking upstream
11-Aug	DSCN4796	9:52	At 19 m looking downstream
11-Aug	DSCN4797	9:53	At EOT looking across the river
11-Aug	DSCN4798	9:53	At EOT looking at POC
11-Aug	DSCN4799	9:53	At EOT looking upstream
11-Aug	DSCN4800	9:53	At EOT looking downstream
11-Aug	DSCN4801	9:55	At 26 m looking at recruitment upstream of line
11-Aug	DSCN4802	9:56	At 26 m looking at recruitment downstream of line
11-Aug	DSCN4803	10:06	At 23.5 m looking at 2015 and 2016 seedlings
11-Aug	DSCN4804	10:06	At 26.5 looking at older recruitment in seed frame
11-Aug	DSCN4781	9:06	**L3T9** at 13 m looking at POC
11-Aug	DSCN4782	9:06	At 13 m looking at EOT
11-Aug	DSCN4783	9:09	At 45 m looking at POC (almost on EOT)
11-Aug	DSCN4784	9:09	At 45 m looking at EOT
11-Aug	DSCN4785	9:10	At 45 m looking upstream
11-Aug	DSCN4786	9:10	At 45 m looking downstream
11-Aug	DSCN4787	9:12	At 22 m looking at EOT
11-Aug	DSCN4788	9:12	At 22 m looking at POC
11-Aug	DSCN4789	9:13	At 22 m looking upstream
11-Aug	DSCN4790	9:19	At 42 m looking past recruitment on line
11-Aug	DSCN4791	9:19	Looking at the upstream end of the point bar
11-Aug	DSCN4792	9:22	Looking downstream of line at branch and root sucker
11-Aug	DSCN4769	8:15	**L3T30** at 7 m looking at EOT
11-Aug	DSCN4770	8:17	At 21 m looking at POC
11-Aug	DSCN4771	8:17	At 21 m looking at EOT
11-Aug	DSCN4772	8:17	At 21 m looking upstream
11-Aug	DSCN4773	8:17	At 21 m looking downstream
11-Aug	DSCN4774	8:18	At 36 m looking at EOT
11-Aug	DSCN4775	8:19	At 36 m looking at POC
11-Aug	DSCN4776	8:19	At 36 m looking upstream
11-Aug	DSCN4777	8:19	At 36 m looking downstream
11-Aug	DSCN4778	8:21	At 16.5 m looking at seedling plot - 2014 and 2015 seedlings
11-Aug	DSCN4779	8:33	Downstream of line looking at seedling
11-Aug	DSCN4780	8:34	Downstream of line looking at different seedlings

Date: October 2016			**Environmental Crew:** MLP, AS, BH, KM
Location: Lardeau River			**Project Leader:** Mary Louise Polzin
Date	**Image #**	**Time**	**Description**
5-Oct	IMG_0373	15:27	**L1T1** at POC looking at EOT
5-Oct	IMG_0374	15:27	At EOT looking at POC
5-Oct	IMG_0375	15:28	At EOT looking upstream
5-Oct	IMG_0376	15:28	At EOT looking downstream
5-Oct	IMG_0377	15:28	At EOT looking across stream
5-Oct	IMG_0378	15:28	At 19.6 m looking upstream
5-Oct	IMG_0379	15:29	At 19.6 m looking downstream
5-Oct	IMG_0380	15:29	At 19.6 m looking at POC
5-Oct	IMG_0381	15:29	At 19.6 m looking at EOT
5-Oct	IMG_0362	12:20	**L1T10** at POC looking at EOT
5-Oct	IMG_0363	12:34	At EOT looking at POC
5-Oct	IMG_0364	12:34	At EOT looking upstream
5-Oct	IMG_0365	12:34	At EOT looking downstream
5-Oct	IMG_0366	12:34	At EOT looking across stream
5-Oct	IMG_0367	12:35	At 25 m looking upstream
5-Oct	IMG_0368	12:35	At 25 m looking downstream
5-Oct	IMG_0369	12:35	At 25 m looking at POC
5-Oct	IMG_0370	12:35	At 25 m looking at EOT
5-Oct	IMG_0371	12:35	At sandbar downstream looking at cottonwoods and willows
5-Oct	IMG_0372	12:36	At sandbar downstream looking at cottonwoods and willows
5-Oct	IMG_0353	9:19	**L1T20** at POC looking at EOT
5-Oct	IMG_0354	9:21	At EOT looking at POC
5-Oct	IMG_0355	9:21	At EOT looking upstream
5-Oct	IMG_0356	9:21	At EOT looking downstream
5-Oct	IMG_0357	9:21	At EOT looking across stream
5-Oct	IMG_0358	9:22	At 30.4 m looking upstream
5-Oct	IMG_0359	9:22	At 30.4 m looking downstream
5-Oct	IMG_0360	9:22	At 30.4 m looking at POC
5-Oct	IMG_0361	9:22	At 30.4 m looking at EOT
6-Oct	DSCN5092	12:18	**L1T36** at 15 m looking at POC
6-Oct	DSCN5093	12:18	At 15 m looking at EOT
6-Oct	DSCN5094	12:18	At 15 m looking upstream
6-Oct	DSCN5095	12:18	At 15 m looking downstream
6-Oct	DSCN5096	12:18	Looking at vegetation on the roots of a fallen tree
6-Oct	IMG_0382	15:29	**L2T6** at POC looking at EOT
6-Oct	IMG_0383	15:29	At EOT looking at POC
6-Oct	IMG_0384	9:16	At EOT looking upstream
6-Oct	IMG_0385	9:25	At EOT looking downstream
6-Oct	IMG_0386	9:25	At EOT looking across stream
6-Oct	IMG_0387	9:25	At 29.4 m looking upstream
6-Oct	IMG_0388	9:25	At 29.4 m looking downstream
6-Oct	IMG_0389	9:25	At 29.4 m looking at POC
6-Oct	IMG_0390	9:26	At 29.4 m looking at EOT
6-Oct	DSCN5088	11:08	**L2T18** at 15 m looking at POC
6-Oct	DSCN5089	11:08	At 15 m looking at EOT
6-Oct	DSCN5090	11:08	At 15 m looking upstream
6-Oct	DSCN5091	11:09	At 15 m looking downstream
6-Oct	DSCN5084	10:38	**L3T1** at 25 m looking at EOT
6-Oct	DSCN5085	10:38	At 25 m looking at POC
6-Oct	DSCN5086	10:38	At 25 m looking upstream
6-Oct	DSCN5087	10:38	At 25 m looking downstream

Date	Image #	Time	Description
6-Oct	DSCN5080	9:52	**L3T9** at 41 m looking at EOT
6-Oct	DSCN5081	9:52	At 41 m looking at POC
6-Oct	DSCN5082	9:53	At 41 m looking upstream
6-Oct	DSCN5083	9:53	At 41 m looking downstream
6-Oct	DSCN5072	8:54	**L3T30** at 20 m looking at POC
6-Oct	DSCN5073	8:54	At 20 m looking at EOT
6-Oct	DSCN5074	8:54	At 20 m looking upstream
6-Oct	DSCN5075	8:54	At 20 m looking downstream
6-Oct	DSCN5076	9:05	At 38 m looking at EOT
6-Oct	DSCN5077	9:06	At 38 m looking upstream
6-Oct	DSCN5078	9:06	At 38 m looking downstream
6-Oct	DSCN5079	9:06	At 38 m looking at POC

Appendix 2: Duncan and Lardeau rivers contact sheets

Duncan River August 2016, Segment 1, Transect 3 and 4

IMG_0185

IMG_0186

IMG_0187

IMG_0189

IMG_0190

Duncan River August 2016, Segment 3, Transect 10

DSCN4595

DSCN4596

DSCN4597

DSCN4598

DSCN4599

DSCN4600

DSCN4601

DSCN4602

DSCN4603

DSCN4604

DSCN4605

Duncan River August 2016, Segment 3, Transect 11


DSCN4606


DSCN4607


DSCN4608


DSCN4609


DSCN4610


DSCN4611


DSCN4612


DSCN4613


DSCN4614


DSCN4615


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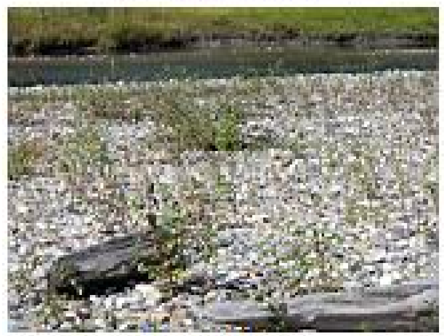
DSCN4617


DSCN4618


DSCN4619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Duncan River August 2016, Segment 3, Transect 15


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DSCN4634


DSCN4635


DSCN4636


DSCN4637


DSCN4638


DSCN4639


DSCN4640


DSCN4641


DSCN4642


DSCN4643


DSCN4644

Duncan River August 2016, Segment 3, Transect 17

DSCN4621

DSCN4622

DSCN4623

DSCN4624

DSCN4625

DSCN4626

DSCN4627

DSCN4628

DSCN4629

DSCN4630

DSCN4631

DSCN4632

Duncan River August 2016, Segment 3, Transect 29

DSCN4657

DSCN4658

DSCN4659

DSCN4660

DSCN4661

DSCN4662

DSCN4663

DSCN4664

DSCN4665

DSCN4666

DSCN4667

DSCN4668

Duncan River August 2016, Segment 3, Transect 35

DSCN4645

DSCN4646

DSCN4647

DSCN4648

DSCN4649

DSCN4650

DSCN4651

DSCN4652

DSCN4653

DSCN4654

DSCN4655

DSCN4656

Duncan River August 2016, Segment 3, Transect 40

DSCN4682

DSCN4683

DSCN4684

DSCN4685

DSCN4686

DSCN4687

DSCN4688

DSCN4689

Duncan River August 2016, Segment 3, Transect 45


DSCN4669


DSCN4670


DSCN4671


DSCN4672


DSCN4673


DSCN4674


DSCN4675


DSCN4676


DSCN4677


DSCN4678


DSCN4680


DSCN4681

Duncan River August 2016, Segment 4, Transect 3

IMG_0191

IMG_0192

IMG_0193

IMG_0194

IMG_0195

IMG_0196

IMG_0197

IMG_0198

Duncan River August 2016, Segment 4, Transect 5

IMG_0206

IMG_0207

IMG_0208

IMG_0209

IMG_0210

Duncan River August 2016, Segment 4, Transect 10

IMG_0199

IMG_0200

IMG_0202

IMG_0203

IMG_0204

IMG_0205

Duncan River August 2016, Segment 5, Transect 2

IMG_0211

IMG_0212

IMG_0214

IMG_0215

IMG_0216

IMG_0217

Duncan River August 2016, Segment 5, Transect 9

IMG_0218

IMG_0219

IMG_0220

IMG_0221

IMG_0222

IMG_0223

IMG_0224

IMG_0226

IMG_0227

IMG_0228

IMG_0229

Duncan River August 2016, Segment 5, Transect 11

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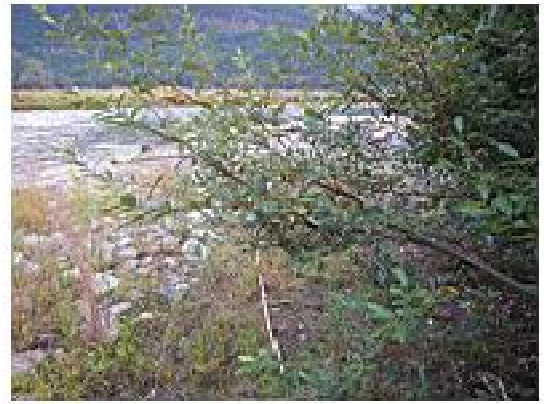
DSCN4696



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DSCN4700

DSCN4701

Duncan River August 2016, Segment 5, Transect 12


DSCN4702


DSCN4703


DSCN4704


DSCN4705


DSCN4706


DSCN4707


DSCN4708


DSCN4709


DSCN4710


DSCN4711


DSCN4712


DSCN4713

Duncan River August 2016, Segment 5, Transect 16

DSCN4714

DSCN4715

DSCN4716

DSCN4717

DSCN4718

DSCN4719

Duncan River August 2016, Segment 5, Transect 19

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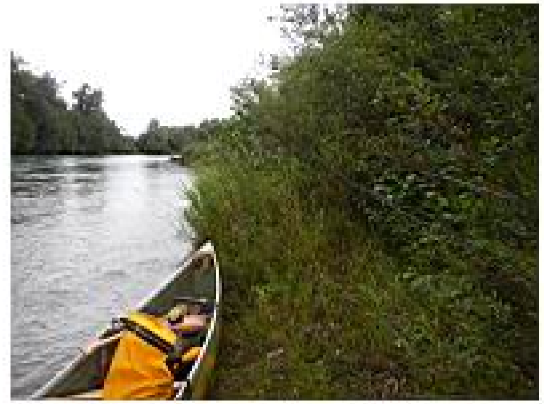
DSCN4721

DSCN4722



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Duncan River August 2016, Segment 6, Transect 6

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DSCN4759

DSCN4760

DSCN4761

DSCN4762

DSCN4763

DSCN4764

DSCN4765

DSCN4766

DSCN4767

DSCN4768

Duncan River August 2016, Segment 6, Transect 20

DSCN4749

DSCN4750

DSCN4751

DSCN4752

DSCN4753

DSCN4754

DSCN4755

DSCN4756

Duncan River August 2016, Segment 6, Transect 29

DSCN4725

DSCN4726

DSCN4727

DSCN4728

DSCN4729

DSCN4730

DSCN4731

DSCN4732

DSCN4733

DSCN4734

DSCN4735

DSCN4736

Duncan River August 2016, Segment 6, Transect 36

DSCN4739

DSCN4740

DSCN4741

DSCN4742

DSCN4743

DSCN4744

DSCN4745

DSCN4746

DSCN4747

DSCN4748

Lardeau River August 2016, Segment 1, Transect 1

IMG_0257

IMG_0258

IMG_0259

IMG_0260

IMG_0261

IMG_0262

IMG_0263

IMG_0264

IMG_0265

IMG_0266

IMG_0268

Lardeau River August 2016, Segment 1, Transect 10

IMG_0230

IMG_0231

IMG_0232

IMG_0233

IMG_0234

IMG_0235

IMG_0237

IMG_0238

Lardeau River August 2016, Segment 1, Transect 20


IMG_0244


IMG_0245


IMG_0246


IMG_0247


IMG_0248


IMG_0249


IMG_0250


IMG_0251


IMG_0252


IMG_0253


IMG_0254


IMG_0255


IMG_0256

Lardeau River August 2016, Segment 1, Transect 36

DSCN4816

DSCN4817

DSCN4818

DSCN4819

DSCN4820

DSCN4821

DSCN4822

DSCN4823

DSCN4824

DSCN4825

DSCN4826

DSCN4827

Lardeau River August 2016, Segment 2, Transect 6

IMG_0269

IMG_0270

IMG_0271

IMG_0272

IMG_0273

IMG_0274

IMG_0275

IMG_0276

IMG_0277

IMG_0278

IMG_0279

IMG_0280

Lardeau River August 2016, Segment 2, Transect 15

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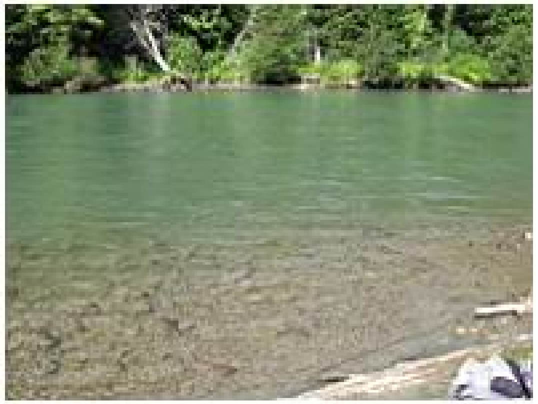
IMG_0282

IMG_0283

IMG_0284



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IMG_0286

Lardeau River August 2016, Segment 2, Transect 18

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DSCN4809

DSCN4810

DSCN4811

DSCN4812

DSCN4813

DSCN4814

DSCN4815

Lardeau River August 2016, Segment 3, Transect 1

DSCN4793

DSCN4794

DSCN4795

DSCN4796

DSCN4797

DSCN4798

DSCN4799

DSCN4800

DSCN4801

DSCN4802

DSCN4803

DSCN4804

Lardeau River August 2016, Segment 3, Transect 9

DSCN4781

DSCN4782

DSCN4783

DSCN4784

DSCN4785

DSCN4786

DSCN4787

DSCN4788

DSCN4789

DSCN4790

DSCN4791

DSCN4792

Lardeau River August 2016, Segment 3, Transect 30

DSCN4769

DSCN4770

DSCN4771

DSCN4772

DSCN4773

DSCN4774

DSCN4775

DSCN4776

DSCN4777

DSCN4778

DSCN4779

DSCN4780

Duncan River October 2016, Segment 1, Transect 3

IMG_0305

IMG_0306

IMG_0307

IMG_0308

IMG_0309

IMG_0310

IMG_0311

IMG_0312

IMG_0313

IMG_0314

IMG_0315

Duncan River October 2016, Segment 1, Transect 4


IMG_0287


IMG_0288


IMG_0289


IMG_0290


IMG_0291


IMG_0292


IMG_0293


IMG_0294


IMG_0295

Duncan River October 2016, Segment 1, Transect 5


IMG_0296


IMG_0297


IMG_0298


IMG_0299


IMG_0300


IMG_0301


IMG_0302


IMG_0303


IMG_0304

Duncan River October 2016, Segment 3, Transect 11


DSCN4957


DSCN4958


DSCN4959


DSCN4960


DSCN4961


DSCN4962


DSCN4963


DSCN4964


DSCN4965

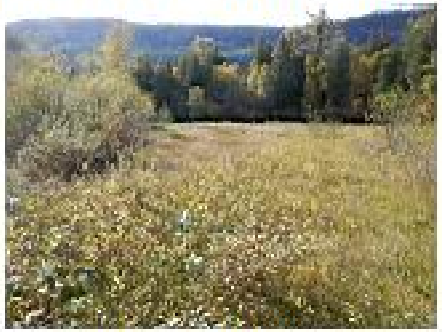

DSCN4966


DSCN4967


DSCN4968

Duncan River October 2016, Segment 3, Transect 15


DSCN4981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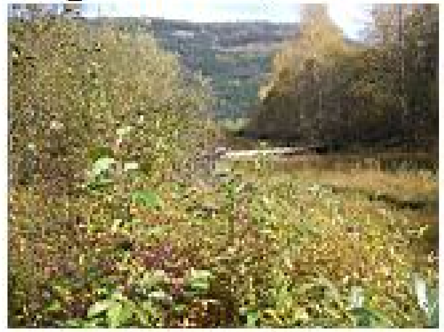
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DSCN4984


DSCN4985


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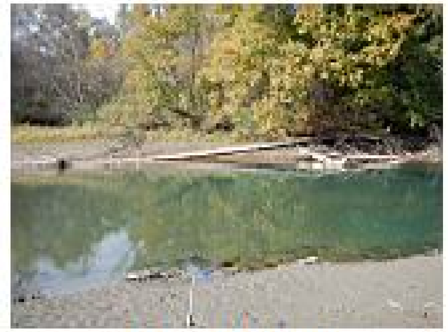
DSCN4987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DSCN4989


DSCN4990


DSCN4991


DSCN4992


DSCN4993


DSCN4994


DSCN4995

Duncan River October 2016, Segment 3, Transect 17


DSCN4969


DSCN4970


DSCN4971


DSCN4972


DSCN4973


DSCN4974


DSCN4975


DSCN4976


DSCN4977


DSCN4978


DSCN4979


DSCN4980

Duncan River October 2016, Segment 3, Transect 20 and 29

DSCN4996

DSCN4997

DSCN4998

DSCN4999

DSCN5000

DSCN5001

DSCN5002

DSCN5003

DSCN5011

Duncan River October 2016, Segment 3, Transect 35

DSCN5004

DSCN5005

DSCN5006

DSCN5007

DSCN5008

DSCN5009

DSCN5010

Duncan River October 2016, Segment 3, Transect 40

DSCN5019

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DSCN5021

DSCN5022

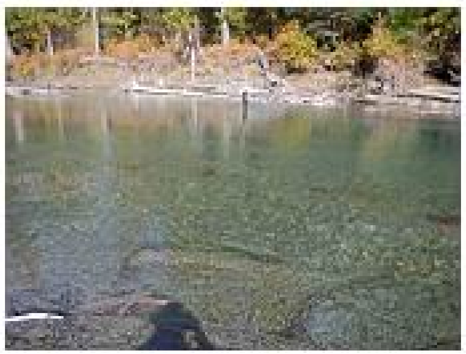
DSCN5023

DSCN5024

DSCN5025

DSCN5026

DSCN5027



DSCN5028

DSCN5029

DSCN5030

Duncan River October 2016, Segment 3, Transect 45

DSCN5012

DSCN5013

DSCN5014

DSCN5015

DSCN5016

DSCN5017

DSCN5018

Duncan River October 2016, Segment 4, Transect 3


IMG_0335


IMG_0336


IMG_0337


IMG_0338


IMG_0339


IMG_0340


IMG_0341


IMG_0342


IMG_0343

Duncan River October 2016, Segment 4, Transect 10

IMG_0344

IMG_0345

IMG_0346

IMG_0347

IMG_0348

IMG_0349

IMG_0350

IMG_0351

IMG_0352

Duncan River October 2016, Segment 5, Transect 2

IMG_0316

IMG_0317

IMG_0318

IMG_0319

IMG_0320

IMG_0321

IMG_0322

IMG_0323

IMG_0324

IMG_0325

IMG_0326

Duncan River October 2016, Segment 5, Transect 9

IMG_0327

IMG_0328

IMG_0329

IMG_0330

IMG_0331

IMG_0332

IMG_0333

IMG_0334

Duncan River October 2016, Segment 5, Transect 11

DSCN5033

DSCN5034

DSCN5035

DSCN5036

DSCN5037

DSCN5038

DSCN5039

DSCN5040

Duncan River October 2016, Segment 5, Transect 12

DSCN5041

DSCN5042

DSCN5043

DSCN5044

DSCN5045

DSCN5046

DSCN5047

DSCN5048

DSCN5049

DSCN5050

DSCN5051

DSCN5052

Duncan River October 2016, Segment 5, Transect 19

DSCN5053

DSCN5054

DSCN5055

Duncan River October 2016, Segment 6, Transect 29

DSCN5056

DSCN5057

DSCN5058

DSCN5059

DSCN5060

DSCN5061

DSCN5062

DSCN5063

Duncan River October 2016, Segment 6, Transect 36


DSCN5064


DSCN5065


DSCN5066


DSCN5067


DSCN5068


DSCN5069


DSCN5070


DSCN5071

Lardeau River October 2016, Segment 1, Transect 1

IMG_0373

IMG_0375

IMG_0376

IMG_0377

IMG_0378

IMG_0379

IMG_0380

IMG_0381

Lardeau River October 2016, Segment 1, Transect 10

IMG_0362

IMG_0363

IMG_0364

IMG_0365

IMG_0366

IMG_0367

IMG_0368

IMG_0369

IMG_0370

IMG_0371

IMG_0372

Lardeau River October 2016, Segment 1, Transect 20

IMG_0353

IMG_0354

IMG_0355

IMG_0356

IMG_0357

IMG_0358

IMG_0359

IMG_0360

IMG_0361

Lardeau River Oct. 2016, Seg. 1, Tran. 36 & Seg. 2, Tran. 6

DSCN5092

DSCN5093

DSCN5094

DSCN5095

DSCN5096

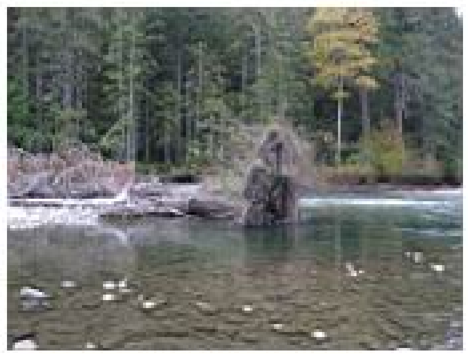
IMG_0382

IMG_0384

IMG_0385

IMG_0386

IMG_0387



IMG_0388

IMG_0390

Lardeau River Oct. 2016, Seg. 2, Tran. 18 & Seg. 3, Tran. 1 & 9

L2_DSCN5088

L2_DSCN5089

L2_DSCN5090

L2_DSCN5091

L3T1_DSCN5084

L3T1_DSCN5085

L3T1_DSCN5086

L3T1_DSCN5087

L3T9_DSCN5080

L3T9_DSCN5081

L3T9_DSCN5082

L3T9_DSCN5083

Lardeau River October 2016, Segment 3, Transect 30

DSCN5072

DSCN5073

DSCN5074

DSCN5075

DSCN5076

DSCN5077

DSCN5078

DSCN5079

Appendix 3: Statistical Analysis Details

Descriptive Statistics for Duncan and Lardeau seedlings

Duncan Reach

Column	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
D_Seed_14_Paired	709	0	32.785	71.118	2.671	5.244
D_Seed_15_Paired	709	0	39.530	162.916	6.118	12.012
D_Seed_16_Paired	709	0	17.797	39.657	1.489	2.924

Column	Range	Max	Min	Median	25%	75%
D_Seed_14_Paired	1200.000	1200.000	0.000	14.000	0.500	37.000
D_Seed_15_Paired	1620.000	1620.000	0.000	0.000	0.000	18.000
D_Seed_16_Paired	340.000	340.000	0.000	2.000	0.000	23.500

Column	Skewness	Kurtosis	K-S Dist.	K-S Prob.	SWilk W	SWilk Prob
D_Seed_14_Paired	8.615	114.110	0.322	<0.001	0.408	<0.001
D_Seed_15_Paired	7.906	67.446	0.404	<0.001	0.230	<0.001
D_Seed_16_Paired	4.453	24.811	0.327	<0.001	0.484	<0.001

Column	Sum	Sum of Squares
D_Seed_14_Paired	23244.825	4342962.871
D_Seed_15_Paired	28026.500	19899372.250
D_Seed_16_Paired	12618.000	1338020.000

Lardeau Reach

Column	Size	Missing	Mean	Std Dev	Std. Error	C.I. of Mean
L_Seed_14_Paired	183	0	26.273	27.273	2.016	3.978
L_Seed_15_Paired	183	0	6.011	14.950	1.105	2.180
L_Seed_16_Paired	183	0	8.568	12.832	0.949	1.872

Column	Range	Max	Min	Median	25%	75%
L_Seed_14_Paired	110.000	110.000	0.000	22.000	0.000	45.000
L_Seed_15_Paired	145.000	145.000	0.000	0.000	0.000	8.000
L_Seed_16_Paired	56.000	56.000	0.000	3.000	0.000	12.000

Column	Skewness	Kurtosis	K-S Dist.	K-S Prob.	SWilk W	SWilk Prob
L_Seed_14_Paired	0.723	-0.494	0.203	<0.001	0.865	<0.001
L_Seed_15_Paired	5.899	46.136	0.344	<0.001	0.424	<0.001
L_Seed_16_Paired	1.920	3.087	0.252	<0.001	0.706	<0.001

Column	Sum	Sum of Squares
L_Seed_14_Paired	4808.000	261692.000
L_Seed_15_Paired	1100.000	47288.000
L_Seed_16_Paired	1568.000	43402.000

Duncan River Seedling densities

One Way Analysis of Variance

Normality Test (Shapiro-Wilk) Failed (P < 0.050)

Test execution ended by user request, ANOVA on Ranks begun

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
D_Seed_14_Paired	709	0	14.000	0.500	37.000
D_Seed_15_Paired	709	0	0.000	0.000	18.000
D_Seed_16_Paired	709	0	2.000	0.000	23.500

H = 128.693 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

To isolate the group or groups that differ from the others use a multiple comparison procedure.
All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
D_Seed_14_Pai vs D_Seed_15_Pai	230598.000	14.101	Yes
D_Seed_14_Pai vs D_Seed_16_Pai	204414.000	12.500	Yes
D_Seed_16_Pai vs D_Seed_15_Pai	26184.000	1.601	No

Note: The multiple comparisons on ranks do not include an adjustment for ties (applies to all tests below).

Kruskal-Wallis One Way Analysis of Variance on Ranks

Normality Test (Shapiro-Wilk) Failed (P < 0.050)

Group	N	Missing	Median	25%	75%
D_1_14	22	0	0.000	0.000	134.000
D_1_15	22	0	18.000	0.000	452.500
D_1_16	22	0	45.000	43.750	92.000

H = 7.404 with 2 degrees of freedom. (P = 0.025)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.025)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
D_1_16 vs D_1_14	335.000	3.721	Yes
D_1_16 vs D_1_15	154.000	1.710	No
D_1_15 vs D_1_14	181.000	2.010	No

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
D_3_14	307	0	17.000	0.000	47.000
D_3_15	307	0	0.000	0.000	13.000
D_3_16	307	0	2.000	0.000	30.000

H = 86.885 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
D_3_14 vs D_3_15	57788.500	12.398	Yes
D_3_14 vs D_3_16	36380.000	7.805	Yes
D_3_16 vs D_3_15	21408.500	4.593	Yes

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
D_4_14	121	0	16.000	10.500	40.000
D_4_15	121	0	0.000	0.000	10.000
D_4_16	121	0	0.000	0.000	4.000

H = 105.942 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
D_4_14 vs D_4_16	14279.000	12.371	Yes
D_4_14 vs D_4_15	13585.000	11.769	Yes
D_4_15 vs D_4_16	694.000	0.601	No

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
D_5_14	131	0	14.000	0.000	45.000
D_5_15	131	0	7.000	0.000	43.000
D_5_16	131	0	0.000	0.000	24.000

H = 20.743 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
D_5_14 vs D_5_16	7851.000	6.039	Yes
D_5_14 vs D_5_15	2157.000	1.659	No
D_5_15 vs D_5_16	5694.000	4.380	Yes

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
D_6_14	127	0	8.000	1.000	12.000
D_6_15	127	0	4.000	0.000	20.000
D_6_16	127	0	3.000	0.000	26.000

H = 4.484 with 2 degrees of freedom. (P = 0.106)

The differences in the median values among the treatment groups are not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.106).

Testing for difference between the Duncan and Lardeau Reaches for seedling abundance in 2016

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
D_2016_den	419	0	14.000	4.000	35.000
L_2016_den	113	0	8.000	4.000	20.000

H = 8.434 with 1 degrees of freedom. (P = 0.004)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.004)

To isolate the group or groups that differ from the others use a multiple comparison procedure.

All Pairwise Multiple Comparison Procedures (Dunn's Method):

Comparison	Diff of Ranks	Q	P<0.05
D_2016_den vs L_2016_den	47.271	2.901	Yes

Mann-Whitney Rank Sum Test Wednesday, February 22, 2017, 4:02:04 PM

Data source: Data 1 in Dun_Lard_Seedl_Den_'13 to 16analysis.JNB

Group	N	Missing	Median	25%	75%
D_Seed_16	709	0	2.000	0.000	23.500
L_Seed_16	183	0	3.000	0.000	12.000

Mann-Whitney U Statistic= 64613.500

T = 81449.500 n(small)= 183 n(big)= 709 (P = 0.930)

The difference in the median values between the two groups is not great enough to exclude the possibility that the difference is due to random sampling variability; there is not a statistically significant difference (P = 0.930)

Lardeau River germinants density analysis

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
L_Seed_14_Paired	183	0	22.000	0.000	45.000
L_Seed_15_Paired	183	0	0.000	0.000	8.000

L_Seed_16_Paired	183	0	3.000	0.000	12.000

H = 65.722 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
L_Seed_14_Pai vs L_Seed_15_Pai	23362.500	10.887	Yes
L_Seed_14_Pai vs L_Seed_16_Pai	14244.000	6.638	Yes
L_Seed_16_Pai vs L_Seed_15_Pai	9118.500	4.249	Yes

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
L1 2014	110	0	26.000	0.000	49.250
L1 2015	110	0	4.500	0.000	10.000
L1 2016	110	0	5.000	0.000	19.250

H = 37.587 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
L1 2014 vs L1 2015	8241.500	8.236	Yes
L1 2014 vs L1 2016	5980.000	5.976	Yes
L1 2016 vs L1 2015	2261.500	2.260	No

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
L2 2014	44	0	16.000	0.000	44.000
L2 2015	44	0	0.000	0.000	0.000
L2 2016	44	0	0.500	0.000	4.750

H = 34.783 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
L2 2014 vs L2 2015	1916.500	7.554	Yes
L2 2014 vs L2 2016	1145.000	4.513	Yes
L2 2016 vs L2 2015	771.500	3.041	No

Kruskal-Wallis One Way Analysis of Variance on Ranks

Group	N	Missing	Median	25%	75%
L3 2014	29	0	0.000	0.000	27.500

L3 2015	29	0	0.000	0.000	0.000
L3 2016	29	0	1.000	0.000	5.000

H = 21.039 with 2 degrees of freedom. (P = <0.001)

The differences in the median values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = <0.001)

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparison	Diff of Ranks	q	P<0.05
L3 2016 vs L3 2015	696.500	5.120	Yes
L3 2016 vs L3 2014	131.500	0.967	No
L3 2014 vs L3 2015	565.000	4.154	Yes

Duncan vs Lardeau Seedling Survival

t-test

Group Name	N	Missing	Mean	Std Dev	SEM
D_Ave_1st_yr	6	0	23.186	11.148	4.551
L_Ave_1st_yr	6	0	23.809	9.747	3.979

Difference -0.623

t = -0.103 with 10 degrees of freedom.

95 percent two-tailed confidence interval for difference of means: -14.093 to 12.847

Two-tailed P-value = 0.920

The difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability. There is not a statistically significant difference between the input groups (P = 0.920).

One-tailed P-value = 0.460

The sample mean of group L_Ave_1st_yr does not exceed the sample mean of the group D_Ave_1st_yr by an amount great enough to exclude the possibility that the difference is due to random sampling variability. The hypothesis that the population mean of group D_Ave_1st_yr is greater than or equal to the population mean of group L_Ave_1st_yr cannot be rejected. (P = 0.460).

t-test

Group Name	N	Missing	Mean	Std Dev	SEM
D_Ave_2nd_yr	6	0	43.385	29.978	12.239
L_Ave_2nd_yr	6	0	60.360	7.552	3.083

Difference -16.975

t = -1.345 with 10 degrees of freedom.

95 percent two-tailed confidence interval for difference of means: -45.096 to 11.146

Two-tailed P-value = 0.208

The difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability. There is not a statistically significant difference between the input groups (P = 0.208).

One-tailed P-value = 0.104

The sample mean of group L_Ave_2nd_yr does not exceed the sample mean of the group D_Ave_2nd_yr by an amount great enough to exclude the possibility that the difference is due to random sampling variability. The hypothesis that the population mean of group D_Ave_2nd_yr is greater than or equal to the population mean of group L_Ave_2nd_yr cannot be rejected. (P = 0.104).

t-test

Group Name	**N**	**Missing**	**Mean**	**Std Dev**	**SEM**
D_Ave_3rd_yr	5	0	51.134	40.546	18.133
L_Ave_3rd_yr	5	0	77.232	11.824	5.288

Difference -26.099

t = -1.382 with 8 degrees of freedom.

95 percent two-tailed confidence interval for difference of means: -69.654 to 17.457

Two-tailed P-value = 0.204

The difference in the mean values of the two groups is not great enough to reject the possibility that the difference is due to random sampling variability. There is not a statistically significant difference between the input groups (P = 0.204).

One-tailed P-value = 0.102

The sample mean of group L_Ave_3rd_yr does not exceed the sample mean of the group D_Ave_3rd_yr by an amount great enough to exclude the possibility that the difference is due to random sampling variability. The hypothesis that the population mean of group D_Ave_3rd_yr is greater than or equal to the population mean of group L_Ave_3rd_yr cannot be rejected. (P = 0.102).

Appendix 4: POC UTM Coordinates for the Duncan and Lardeau reaches

OBJECTID	TRANSECT_ID	TYPE	UTM_ZONE	UTM_N	UTM_E	LOCATION	GNSS_Heigh	Vert_Prec	Horz_Prec	Std_Dev
1	D3 T10	P.O.C.	11	5,563,098	502,915	D3T10 POC	544.1	1.0	1.3	0.14
2	D3 T11	P.O.C.	11	5,562,967	502,761	d3t11 poc	543.1	1.0	1.2	0.15
3	D3 T15	P.O.C.	11	5,562,941	502,483	d3t15 poc	543.1	0.8	1.0	0.11
4	D3 T17	P.O.C.	11	5,562,976	502,492	d3t17 poc shr cot	540.9	0.8	1.1	0.05
5	D1 T3	P.O.C.	11	5,565,650	503,065	d1t3 poc	549.5	0.9	1.1	0.73
6	D1 T4	P.O.C.	11	5,565,490	502,999	d1t4 poc cottenwood	548.0	0.9	1.2	0.22
7	D1 T5	P.O.C.	11	5,565,423	503,032	d1t5 poc alder	546.9	1.0	1.2	0.05
8	D3 T29	P.O.C.	11	5,562,795	502,596	d3t29 poc spruce	542.2	0.8	1.1	0.02
9	D3 T35	P.O.C.	11	5,562,758	502,506	d3t35 poc Willow	541.2	0.8	1.1	0.06
10	D3 T20	P.O.C.	11	5,562,587	502,582	d3t20 poc alder	542.4	1.8	2.3	0.49
11	D3 T23	P.O.C.	11	5,562,253	502,686	d3t23 poc downtree	541.1	0.9	1.1	0.06
12	D3 T45	P.O.C.	11	5,561,894	503,209	d3t45 poc Willow	539.4	0.9	1.1	0.04
13	D3 T40	P.O.C.	11	5,561,926	503,195	d3t40 poc flat top 31	540.4	0.9	1.1	0.10
14	D5 T11	P.O.C.	11	5,559,550	503,718	d5t11 poc birch	534.7	1.1	1.2	0.07
15	D5 T12	P.O.C.	11	5,559,531	503,726	d5t12 poc	536.4	1.0	1.1	0.22
16	D5 T16	P.O.C.	11	5,559,040	503,726	d5t16 poc	533.9	1.2	1.2	0.73
17	D5 T19	P.O.C.	11	5,558,679	503,638	d5t19 poc cot down beaver	535.9	1.0	1.2	0.09
18	D6 T29	P.O.C.	11	5,558,373	504,120	d6t29 poc alder	534.9	1.1	1.3	0.31
19	D6 T36	P.O.C.	11	5,558,360	504,841	d6t36 poc Willow	534.0	0.8	1.0	0.02
20	D6 T20	P.O.C.	11	5,557,994	504,746	d6t20 new poc	533.2	0.9	1.1	0.07
21	D6 T6	P.O.C.	11	5,557,477	503,399	d6t6 poc alder	533.7	0.8	1.1	0.09
23	L1 T20	P.O.C.	11	5,569,740	502,598	L1T20 poc birch	557.2	1.1	1.2	0.07
24	L1 T10	P.O.C.	11	5,569,377	502,644	L1T10 poc cot	559.3	1.5	2.1	2.09
25	L1 T1	P.O.C.	11	5,568,715	502,230	L1T1 poc alder	554.3	1.5	1.2	0.37
26	D4 T3	P.O.C.	11	5,561,351	503,484	D4T3 poc 6 m bearing 330	542.4	1.3	1.6	2.44
27	D4 T10	P.O.C.	11	5,561,344	503,470	D4T10 poc cot 1 m infront	541.4	1.6	2.0	2.97
28	D4 T5	P.O.C.	11	5,560,622	503,286	D4T5 poc alder	540.7	1.0	1.2	0.29
29	D5 T2	P.O.C.	11	5,560,236	503,370	D5T2 poc cot	541.0	1.0	1.2	0.12
30	D5 T9	P.O.C.	11	5,559,732	503,460	D5T9 poc aspen	539.0	1.0	1.2	0.76
32	L3 T30	P.O.C.	11	5,577,918	497,775	l3t30 poc	579.0	4.5	2.3	1.05
33	L3 T9	P.O.C.	11	5,576,381	498,953	L3t9 poc cot	584.6	1.1	1.3	0.41
35	L3 T1	P.O.C.	11	5,576,065	499,739	L3T1 poc 2m u/str of cot	581.5	1.3	1.6	0.39
36	L2 T18	P.O.C.	11	5,575,906	499,883	L2T18 poc fir tr	579.7	1.0	1.2	0.15
37	L2 T15	P.O.C.	11	5,573,724	501,317	L2T15 poc cottenwood	573.4	1.1	1.1	0.61
38	L2 T6	P.O.C.	11	5,572,702	501,774	L2T6 poc cot	568.4	1.1	1.3	0.37
39	L1 T36	P.O.C.	11	5,572,128	502,074	L1T36 poc fir	567.7	1.0	1.2	0.23
40	D3 T10	E.O.T.	11	5,563,023	502,994	D3T10 EOT 110.8 m	540.4	0.9	1.1	0.03

OBJECTID	TRANSECT_ID	TYPE	UTM_ZONE	UTM_N	UTM_E	LOCATION	GNSS_Heigh	Vert_Prec	Horz_Prec	Std_Dev
41	D3 T11	E.O.T.	11	5,562,870	502,890	d3t11 eot river edge	541.2	1.3	1.7	0.08
42	D3 T15	E.O.T.	11	5,563,006	502,444	d3t15 eot 77.35mBackChEdg	540.0	0.8	1.0	0.04
43	D3 T17	E.O.T.	11	5,563,023	502,471	d3t17 eot backCh riveredg	539.4	0.8	1.1	0.20
44	D1 T3	E.O.T.	11	5,565,670	503,082	d1t3 eot river edge	545.2	0.8	1.1	0.21
45	D1 T4	E.O.T.	11	5,565,479	502,963	d1t4 eot 37.9m backchan	545.6	1.0	1.2	0.09
46	D1 T5	E.O.T.	11	5,565,406	503,025	d1t5 eot 20.2m backch	547.6	1.9	1.3	0.23
47	D3 T29	E.O.T.	11	5,562,869	502,565	d3t29 eot 80.7m R edge	540.8	0.8	1.1	0.10
48	D3 T35	E.O.T.	11	5,562,762	502,455	d3t35 eot 53.3 m	540.0	0.8	1.1	0.28
49	D3 T20	E.O.T.	11	5,562,568	502,545	d3t20 eot 42.9m	540.3	0.8	1.0	0.22
50	D3 T23	E.O.T.	11	5,562,263	502,707	d3t23 eot 25 m	540.9	0.8	1.1	0.13
51	D3 T45	E.O.T.	11	5,561,911	503,250	d3t45 eot 46.5 m	538.2	0.8	1.1	0.19
52	D3 T40	E.O.T.	11	5,561,949	503,214	d3t40 eot 30.25m	538.9	0.8	1.1	0.06
53	D5 T11	E.O.T.	11	5,559,576	503,788	d5t11 eot 76 m	534.6	0.9	1.1	0.28
54	D5 T12	E.O.T.	11	5,559,559	503,803	d5t12 eot 82.4 m on log	535.3	0.8	1.1	0.05
55	D5 T16	E.O.T.	11	5,559,048	503,692	d5t16 eot 1 Wedge	532.8	0.8	1.1	0.05
56	D5 T16	E.O.T.	11	5,559,053	503,678	d5t16 eot Wedge iland 2	533.2	0.8	1.1	0.06
57	D5 T16	E.O.T.	11	5,559,057	503,659	d5t16 eot MainChan 69.5	533.5	0.9	1.2	0.07
58	D5 T19	E.O.T.	11	5,558,681	503,622	d5t19 eot 15.7 m	534.7	0.9	1.1	0.12
59	D6 T29	E.O.T.	11	5,558,435	504,119	d6t29 eot 65.6 m	533.4	0.8	1.1	0.07
60	D6 T36	E.O.T.	11	5,558,488	504,798	d6t36 eot 134 m about	533.2	0.8	1.0	0.04
61	D6 T20	E.O.T.	11	5,558,005	504,694	d6t20 eot 53.6 m	532.2	1.0	1.1	0.22
62	D6 T6	E.O.T.	11	5,557,421	503,431	d6t6 eot 66.5 lake bottom	531.7	0.8	1.0	0.07
65	L1 T20	E.O.T.	11	5,569,794	502,629	L1T20 eot 67 m	557.1	1.0	1.1	0.06
66	L1 T10	E.O.T.	11	5,569,331	502,651	L1T10 eot	555.1	0.8	1.1	0.14
67	L1 T1	E.O.T.	11	5,568,692	502,259	L1T1 eot 38.6 m	552.0	1.0	1.1	0.11
68	D4 T3	E.O.T.	11	5,561,399	503,454	D4T3 eot	539.2	0.8	1.1	0.14
69	D4 T10	E.O.T.	11	5,561,389	503,446	D4T10 eot	538.7	0.8	1.1	0.03
70	D4 T5	E.O.T.	11	5,560,619	503,328	D4T5 eot 42 m	538.5	0.8	1.0	0.12
71	D5 T2	E.O.T.	11	5,560,228	503,399	D5T2 eot	537.7	0.8	1.0	0.20
72	D5 T9	E.O.T.	11	5,559,702	503,443	D5T9 eot 35 m	536.9	0.8	1.1	0.12
73	L3 T30	E.O.T.	11	5,577,936	497,813	l3t30 eot	592.2	1.0	1.1	0.17
74	L3 T9	E.O.T.	11	5,576,418	498,982	L3t9 eot 47.5 m	582.5	0.8	1.1	0.10
75	L3 T1	E.O.T.	11	5,576,081	499,766	L3t1 eot 32.6 m	579.0	0.9	1.1	0.19
76	L2 T18	E.O.T.	11	5,575,874	499,876	L2T18 eot 33.6 m	578.3	0.9	1.0	0.16
77	L2 T15	E.O.T.	11	5,573,715	501,285	L2T15 correct eot	569.9	0.8	1.1	0.10
78	L2 T6	E.O.T.	11	5,572,672	501,722	L2T6 eot 60.7 m	567.5	0.8	1.0	0.17
80	L1 T36	E.O.T.	11	5,572,135	502,121		565.7	3.5	1.6	1.36