SHEEP FLATS ECOSYSYEM REST0RATION PROJECT

Prepared for

Habitat Conservation Trust Foundation
(Project 5-304)

Forest Enhancement Society of BC

B.C. Parks – Thompson-Cariboo

Prepared by

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Acknowledgements

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Due to the necessity to schedule work with regard to favourable weather conditions to access the site while avoiding extreme wildfire danger and the potential presence of California Bighorn Sheep, scheduling flexibility was required with respect to the availability of field personnel. Logistical support for the project was received from Fred Lamash of the Cariboo Fire Center, John Liscomb from Stswecem'c Xgat'tem Development Limited Partnership (SXDLP), Kendra Rolston from Unlimited Medical Services and Tom Hughes, Area Supervisor for BC Parks.

Helicopter pilots, Paige Goodlife in 2019 and 2020 and Jeff Cleveland in 2019, with Interior Helicopters Limited skillfully and efficiently provided access for personnel and equipment to the project site. First aid attendants from Unlimited Medical Services, Frank Sellars in 2019 and 2020 and Trevor Billy in 2019, were on site and prepared to provide first aid. The hard-working slashing crews from SXDLP in 2019 comprised of crew leader Michael Boston, Andrew Boston, Dennis Sargent, Walter Rosette, Felix Boston, Jimmie Rosette, James Rosette, Timothy Rosette and Sheldon Harry and in 2020 crew leader Darwin Louie, Kory Billy, Derrick Bob, Robert Kalelest, Buddy Sampson, Timothy Rosette, Gary Harry, James Rosette, and Fred Louie. Friends of Churn Creek Protected Area Society dedicated volunteers included Jim Young, Glen Davidson, Peter Opie and Kristi Iverson. Field support was also received from Jillian Wheatley of MFLNRORD, in 2019. Dispatchers from the Cariboo Fire Center kindly provided safety check-in services for the helicopter and crew.

Ordell Steen, Peter Opie and Glen Davidson reviewed an earlier draft of this report.

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Cover photograph is of a California Bighorn Sheep ram approaching the west end of Sheep Flats in October 2018.

Executive Summary

Sheep Flats is located within Churn Creek Protected Area and falls within the range of the migratory Red Mountain/Wycott-Sheep Flats Herd of the Churn Creek/Camelsfoot Range sub-population. This herd migrates along Churn Creek between its winter and summer ranges and the Sheep Flats area is a critical section of the route where sheep historically concentrated before moving up or down the valley. In the late 1990's herds within this sub-population experienced major population declines with little observed recovery to date. Recent population surveys suggest there may be as few as eight ewes remaining in the Red Mountain/Wycott-Sheep Flats Herd.

The recent recovery plan for the Churn Creek/Camelsfoot Range Big Horn Sheep recommends that stalking cover for predators be removed to increase survival of the sub-population. One of the principal contributors to stalking cover is tree encroachment onto grasslands. Recent prescribed burns by BC Parks targeting encroachment have had limited success, in part because low intensity burning alone will not necessarily remove tree encroachment more than 2.0 m tall. To ensure encroachment is removed as stalking cover for predators, prescribed burns should be preceded by slashing treatments.

The principal objective of this project was to reduce stalking cover for predators of California Bighorn Sheep on Sheep Flats. This objective was met through treating 47 hectares of encroachment and ingrowth by removing small diameter (<15.0 cm dbh) Douglas-fir stems and by delimbing lower branches from the remaining larger stems. Stem densities within plots located along transects in the taller and denser areas of encroachment and ingrowth, of the treatment area, were reduced from 1513 stems per hectare pre-treatment to 85 stems per hectare post-treatment. Similarly, horizontal cover was reduced from an estimated 41 to 7 percent at a sight distance of 10 meters and from 66 to 16 percent at a sight distance of 20 meters.

This project focused on felling encroachment and ingrowth. It is anticipated that Sheep Flats, including the areas of felled stems, will be prescribed burned by BC Parks in the near future, separate from this project.

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Introduction

Churn Creek Protected Area is one of the most important grassland/dry forest conservation areas within British Columbia. It was established to conserve a range of grassland and dry forest ecosystems including important California Bighorn Sheep and Mule Deer populations. The area is unique in that it includes unbroken representation of lower (BGxh), middle (BGxw), and upper (IDF) elevation grasslands.

Grasslands and open forests at mid and higher elevations within the protected area are disappearing due to tree encroachment onto grasslands and ingrowth of open forests. In order to maintain quality wildlife habitat within this important wildlife area, open grasslands and dry open forests need to be restored and maintained.

The Sheep Flats area lies within the migratory route of the Red Mountain/Wycott-Sheep Flats Herd of the Churn Creek/Camelsfoot Range California Bighorn Sheep sub-population. These sheep migrate along Churn Creek between winter and summer ranges (Sugden 1961, Freemen and Dielman 2006). In the late 1990's herds within this sub-population experienced major population declines with little observed recovery to date. Recent late summer aerial surveys observed a total of 44 sheep in 2018, 53 sheep in 2019 and 39 sheep in 2020 within the two migratory herds (Patrick Dielman, pers. comm. 2020).

Wilson (2015) prepared a recovery plan for the Churn Creek/Camelsfoot Range and Junction sub-populations of California Bighorn Sheep and recommended several management actions, including improving forage conditions and reducing predator stalking cover on or adjacent to sheep seasonal ranges and migration corridors.

Figure 1. Glen Davidson holding California Bighorn Sheep ram skull found adjacent to encroachment on Sheep Flats.

Recent efforts by BC Parks to remove grassland encroachment within the Protected Area by burning without manual pre-treatment have had limited success because stems > 2 m tall cannot be reliably removed by burning alone (Steen 2012). Stand-level pre-burn manual treatments are needed to ensure stalking cover is reduced.

The key objective of this project was to manually cut encroachment which provided stalking cover for predators of migratory California Bighorn Sheep that utilize Sheep Flats. Removal of these stems should also enhance grassland forage. Prescribed burning of felled stems, not part of this proposed project, is expected to be undertaken separately by BC Parks staff.

Project Area

The Sheep Flats project area is within the western portion of Churn Creek Protected Area, approximately 80 kilometers south of Williams Lake and 27 kilometers west of Dog Creek. Sheep Flats falls within the Interior Douglas Fir Very Dry Mild (IDFxm) biogeoclimatic subzone (Steen and Coupe 1997) and is located at approximately 1000 meters above sea level. Slopes are gentle and warm (southeast to south) with the terrace of glaciofluvial origin consisting of deep, medium-textured soils with an eolian veneer cap (Sinclair et al. 1999). Open, mature Douglas-fir forests surround the flat with steeper escape terrain consisting of rocky bluffs above and steep eroded banks below the terrace leading directly into Churn Creek. Sheep lambing areas are also present on cliffs to the north and west of Sheep Flats. The project area is also valuable winter and spring range for Mule Deer.

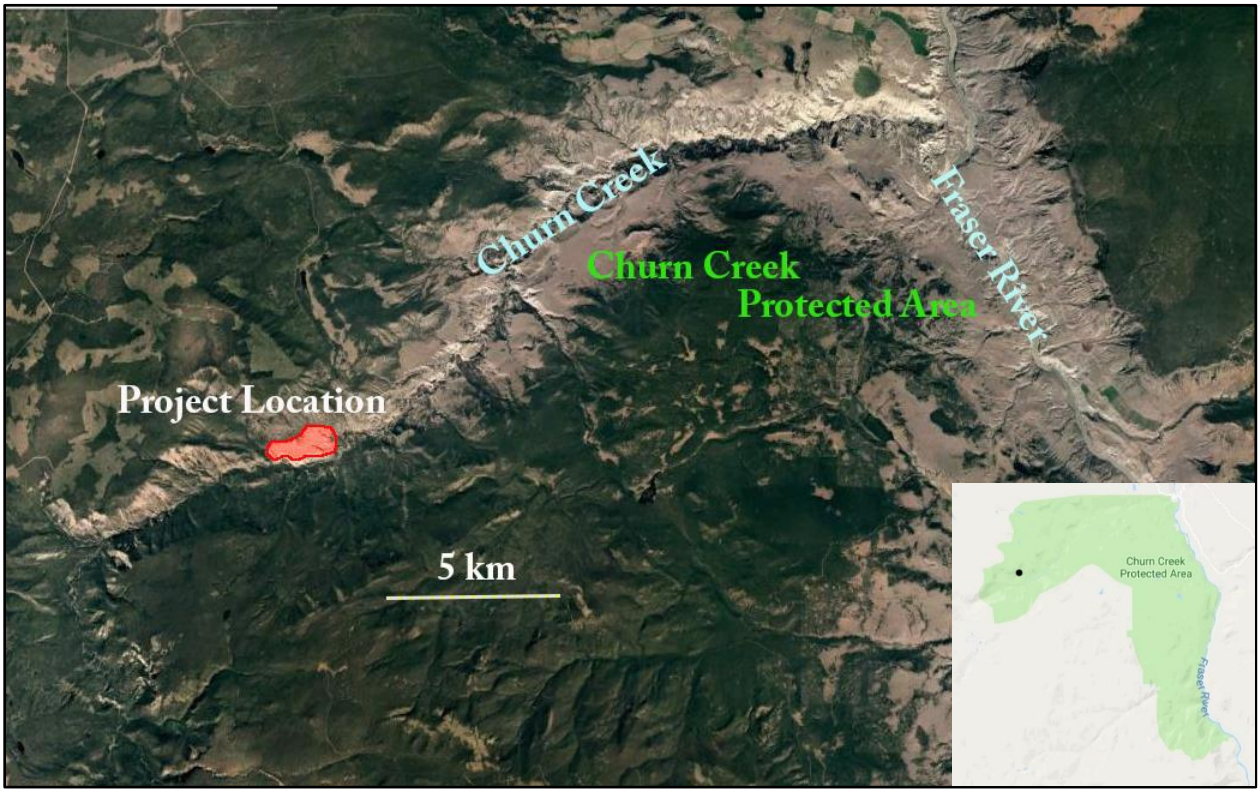

Figure 2. Project location in relation to Churn Creek Protected Area.

Sheep Flats is approximately 80 hectares in size of which approximately 47 hectares were identified for treatment for this project. The terrace was classified as Grassland Benchmark in 2001 as part of the Cariboo Chilcotin Grassland Strategy and is dominated by the bluebunch wheatgrass – prairie sagewort - junegrass grassland association. Grassland condition is predominately near or at reference or Potential Natural Condition (PNC). Some grasslands have lower than typical vegetation cover as there is active erosion from above that is deposited on the upper portions of the terrace. The level portion of the terrace has little encroachment while

tree encroachment was converting the grassland to forest along the lower slope terrain on the north and west boundaries of the flat near the forest edge. Some ingrowth was present within the band of Douglas-fir forest located on the upper portions of the terrace along the north boundary of the flat.

Figure 3. Eroding banks below Sheep Flats showing glaciofluvial deposits with aeolian veneer and Churn Creek below.

The majority of Sheep Flats was pre-empted in 1921 with the creation of DL 1230 Lillooet District. Due to the value of the area as California Bighorn Sheep habitat, in 1976 the land reverted back to the Province for conservation purposes and was later incorporated into Churn Creek Protected Area when it was established in 1995. There has been no authorized grazing of the terrace by cattle for several decades.

There is no vehicle access to Sheep Flats and the site was reached on foot from a trailhead near Goose Lakes during the project planning phase in 2018. In 2019 the site was reached by helicopter during the treatment phase of the project and on foot in October for additional post-treatment sampling. In 2020 the site was accessed by helicopter to complete planned slashing and sampling.

Methods

Treatment to Remove Encroachment and Ingrowth

All cutting was conducted by a Stswecemc Xgat'tem Development Limited Partnership (SXDLP) crew under contract to the Friends of Churn Creek Protected Area Society (FCCPAS). The contracted crew was given cutting specifications and distinct portions of the project area were prioritized for cutting. FCCPAS volunteers monitored progress and undertook quality assurance to ensure the crew was meeting specifications. Adjustments were made when necessary. The contract crew worked for five days in June and July 2019 with 9 persons for four of the days and eight persons in the crew for the last day. At the completion of the fifth day, 41 hectares of the 43 hectares of encroachment identified for treatment were successfully treated. In 2020 the slashing crew worked for two days in August with 9 persons in the crew the first day and 8 persons the second day. The crew treated two additional hectares of encroachment and four hectares of ingrowth for a total of 47 hectares treated over the two years.

Douglas-fir encroachment and ingrowth stems were hand felled using a combination of brush saws and chain saws. Generally, personnel with brush saws felled stems with a basal (ground level) diameter of less than about 10 cm. Individuals using chain saws, generally felled the larger stems with a diameter at breast height (dbh) of up to 15.0 cm. The largest felled stems had a basal diameter of about 20 cm. Most stems with a dbh > 15.0 cm were left standing but lower branches were limbed up to shoulder height.

Following treatment in 2019, a band of heavy slash loading was present at the west end of Sheep Flats. To ensure that the slash was not an impediment to wildlife movement, FCCPAS volunteers cleared a swath of slash along two obvious game trails passing through the area.

Figure 4. James Rosette operating a brush saw to fell layer 4 size encroachment on Sheep Flats. Trees were considered in good condition with 100% live crown.

Establishing Monitoring Point Locations

A preliminary map was prepared from interpretations of Google Earth outlining the key areas of detected encroachment and forest ingrowth. As imagery was relatively old (from 2004) the project area was visually checked during initial reconnaissance walks resulting in more recent areas of encroachment being identified, and the overall area for treatment expanded and a final map prepared. The treatment area was sub-divided into five units to allow for prioritization of cutting by the slashing crew.

In 2018, three transects (1, 3 & 4) containing a total of 16 plots were established through the main bands of encroachment within units bordering the north east, west and north edges of Sheep Flats, respectively. Due to the relatively small size of Unit 2, located on the south side of Sheep Flats, no transect or plots were established in that polygon. In 2020 one additional transect with three plots was established within Unit 5, a stand of Douglas-fir containing ingrowth north of Transect 4. Plots were systematically spaced 100 meters apart along each transect (Figure 5). Plot 3.2 was located near the edge of the treatment area and was only partially treated.

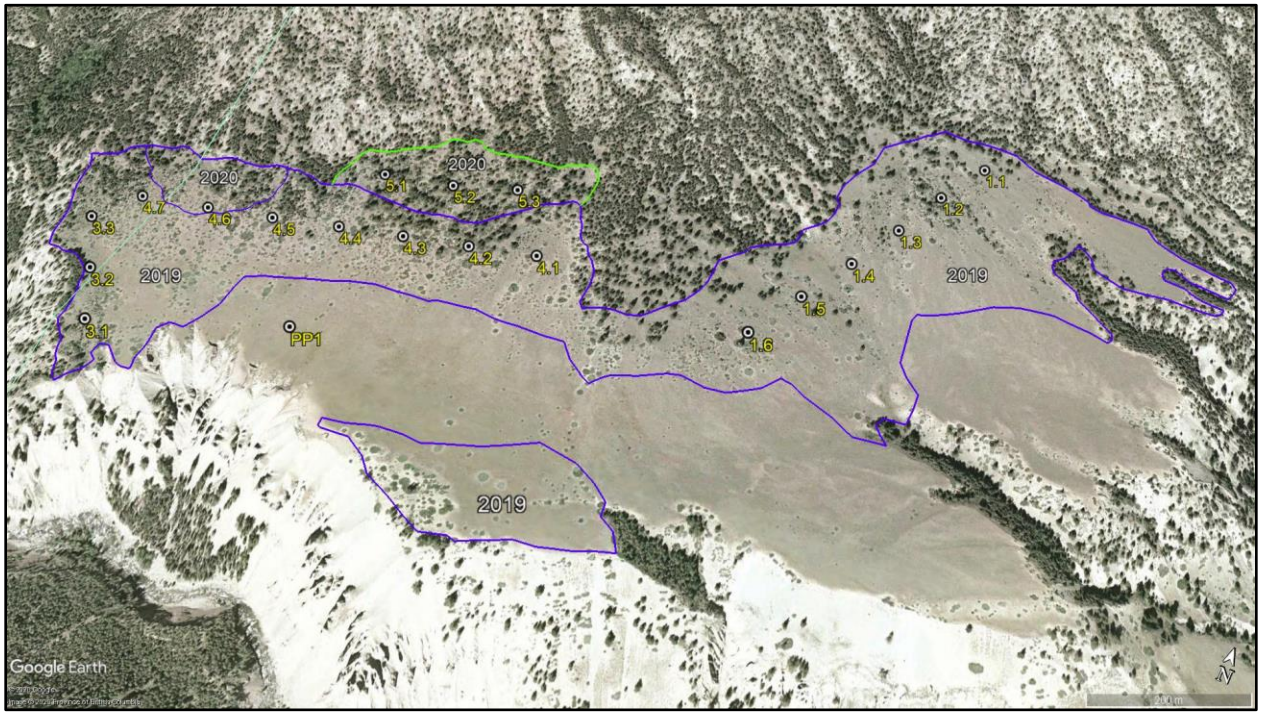

Figure 5. Map showing treated encroachment outlined in heavy blue, treated ingrowth outlined in heavy green and location of vegetation monitoring plots by transect and plot number and lone photo point (PP1). Thin line represents boundary between 2019 (south side) and 2020 slashing (north side).

Transect locations were selected based on areas of encroachment identified from 2004 Google Earth imagery. Field reconnaissance identified additional patches of more open encroachment resulting in the treatment area being expanded towards the central portion of Sheep Flats. This

resulted in plots only being representative of the taller and more densely encroached portion of the total area identified for treatment. As no transects or plots were established in the areas of more recent, open encroachment it should be noted that the sampling is not representative of the entire treatment area.

Sample points were used to monitor vegetation, encroachment/ingrowth tree characteristics and photo points and to obtain estimates of horizontal cover along each of the transects. Each sample point center was permanently marked by pushing a ten-inch common nail spike with a two-inch fender washer into the ground. The spike head and washer were painted blue and GPS coordinates of the 19 monitoring points recorded (Table 1) to assist future relocation.

The project was originally planned to be completed during the summer of 2018 while sheep were on their summer range at higher elevation. However, numerous wildfires in 2018 resulted in limited availability of slashing crews and helicopters and the project was extended into 2019. Following field work in 2019, we were able to secure a major funding contribution from BC Parks which allowed the project to be extended an additional year and the remaining identified encroachment/ingrowth on Sheep Flats to be treated in 2020.

Table 1. GPS locations and site characteristics of monitoring plots at Sheep Flats.

Plot Locations and Site Characteristics						
Transect/Plot	**UTM Coordinates (U10)**		**Elevation**	**Slope**	**Slope**	**Slope**
	East	**North**	**(m)**	**Aspect**	**Grade (%)**	**Position**
1.1	531729	5699392	1002	SE	12	Lower
1.2	531681	5699305	999	SE	10	Lower
1.3	531639	5699217	991	SE	11	Lower
1.4	531593	5699130	983	S	9	Lower
1.5	531546	5699040	981	SE	10	Lower
1.6	531500	5698947	981	SE	10	Lower
3.1	530679	5698623	991	S	7	Lower/Toe
3.2	530622	5698701	999	SE	10	Lower/Toe
3.3	530560	5698780	1011	SE	5	Lower
4.1	531185	5698956	1002	S	10	Lower
4.2	531088	5698937	1002	S	15	Lower
4.3	530991	5698921	1002	S	10	Lower
4.4	530895	5698904	1002	S	10	Lower
4.5	530795	5698884	1003	S	9	Lower
4.6	530698	5698864	1006	S	8	Lower
4.7	530601	5698842	1014	S	12	Lower
5.1	530905	5699018	1018	S	10	Lower
5.2	531010	5699036	1015	S	12	Lower
5.3	531105	5699059	1019	S	11	Lower
Photo Point	530936	5698718	987	S	0	Level

Shrub and Herbaceous Vegetation Characteristics

Shrub, herb, moss, and lichen species abundance was assessed at each monitoring point within encroachment along Transects 1, 3 and 4 in 5.64 m radius (100 m^2 area) permanent plots centered on the monitoring points. Abundance was assessed by visual estimates of percent ground cover in July 2019 just prior to treatment. The following information was recorded at each of the 16 plots:

- percent ground cover of each shrub, forb, and graminoid species present in the plot;
- percent ground cover of two moss species groups ("feather mosses" (including *Pleurozium* sp, *Hylocomium* sp, *Rhytidiadelphus* sp) and other mosses) and three lichen species groups (*Cladonia* spp., *Peltigera* spp. and other lichen species)
- percent ground cover of plant litter;
- percent of plot with bare mineral soil.

Mean percent cover of each species prior to treatment was calculated for each of the three transects using data from each transect plot and then data from all three transects were combined.

Tree Characteristics

Tree encroachment or ingrowth located at each monitoring point was described with a combination of a fixed radius and a variable radius plot. Fixed radius plots (5.64 m radius plots centered on each sample point) were used to sample all tree species stems < 17.5 cm dbh, including young seedlings. Larger trees (≥ 17.5 cm dbh) were sampled in variable radius plots, also centered on the sample points, using a basal area factor (BAF) 4 prism. In the fixed radius plot, the center of the tree bole at 30 cm height was the point for judging whether the tree was in or out of the plot.

In both the fixed and variable radius plots, the following information was recorded for each tree stem within the plot:

- stem number
- species
- diameter (cm) at breast height (dbh)
- diameter (cm) at 30 cm height
- height (m)
- tree condition (good, fair, poor, morbid, dead)
- percent live crown (percent of total stem height with live branches)

Trees were grouped into five size classes or layers defined for the purposes of this project:

- Layer 1 - stems ≥ 17.5 cm dbh.
- Layer 2 - stems 12.5 – < 17.5 cm dbh
- Layer 3 - stems 7.5 – < 12.5 cm dbh
- Layer 4 - stems > 1.3 m tall and < 7.5 cm dbh
- Layer 5 - stems < 1.3 m tall

Any, none, or all of these size layers may be present.

Tree condition was documented in four classes for live trees and one class for dead trees:

- good – all upper stem branches are fully leafed (have full complement of needles) with dark green, long needles;
- fair – several upper stem branches are not fully leafed or many needles are light or yellow-green or stunted, tree vigor obviously reduced;
- poor – many to most upper branches with reduced complement of needles or all needles light to yellow-green;
- moribund – live needles on only 1 – few branches, tree appears near death.
- dead – no live needles on any tree branch.

Percent live crown of a tree was estimated as the percent of the total stem length, from the ground to the top leader, that has live branches.

Plots at all 16 monitoring points within the encroached area were measured in June or July of 2018, prior to treatment, and again in July 2019 (except for Plot 4.6) immediately following tree cutting/felling. Plot establishment and pre- and post-treatment measurements for the three plots within the ingrowth area occurred in August 2020, along with post-treatment sampling of Plot 4.6 which was only partially treated in 2019.

Following treatment, any stumps from cut trees having live basal branches remaining within monitoring plots were documented. Tree encroachment age estimates were obtained from tree stems in the vicinity of Transect 1 by counting tree rings from a sample of stumps of freshly cut trees and measuring the stump diameter.

Tree stand data were summarized by tree size class for each monitoring point and then averaged across the four transects and then pooled. Pre- and post-treatment data for each monitoring point and transect were summarized and compared for tree stem density (stems/ha) to document success in meeting treatment objectives.

Horizontal Cover Estimates

Horizontal visibility measures were obtained at 10 and 20 meters utilizing the staff-ball method of estimating horizontal cover (Collins and Becker 2001). A dimensionless-point target, represented by the intersection of the upper arc of a 9 cm tennis ball and the right side of a half inch diameter vertical staff on which the ball was mounted one meter above ground was observed from 10 points systematically distributed (36 degrees apart) in a circle. The target point and observer height of one meter was chosen to approximate eye level of California Bighorn Sheep and large predators. The point target was observed at a radius of 10 and 20 meters at a height of one meter around the target, which was located at the center of the 19 monitoring plots. Each circle of observations was treated as a single observation with the percent of locations around the target from which the target was obscured by vegetation indicating the percent of horizontal cover. Estimates of horizontal cover were obtained for all 16 encroachment monitoring points in June or July of 2018, prior to treatment, and again in July

2019, immediately following tree cutting/felling. As only a portion of Plot 4.6 was slashed in 2019, post-treatment cover data from that plot along with pre- and post-treatment data for the three ingrowth plots in Transect 5 was obtained in 2020.

Photographic Record

The 19 monitoring point locations also served as photo points with both pre-treatment (2018 for 16 plots and 2020 for three plots) and post-treatment (2019 for 15 plots and 2020 for four plots) photographs taken from each plot center. Four photographs were taken at each point, one in each of the four cardinal directions. One additional monitoring point was established solely for use as a photo point in the west-central area of Sheep Flats to provide overview photographs of the treated area. At this point photographs were taken at 28, 120, 260 and 310 degrees azimuth.

Results

Shrub and Herbaceous Vegetation Characteristics

Pre-treatment vegetation along Transects 1, 3 and 4 was dominated by encroaching Douglas-fir (*Pseudotsuga menziesii*) together with creeping juniper (*Juniperus horizontalis*), bluebunch wheatgrass (Pseudoroegneria spicata), and the ground surface was mostly covered by litter, clad lichens (*Cladonia* spp.), and rusty steppe-moss (*Syntrichia ruralis*) (Figure 6; Appendix 1). Cover of bare mineral soil was variable and quite high in some areas where there are frequent depositions of eroded material from the steep slopes above Sheep Flats.

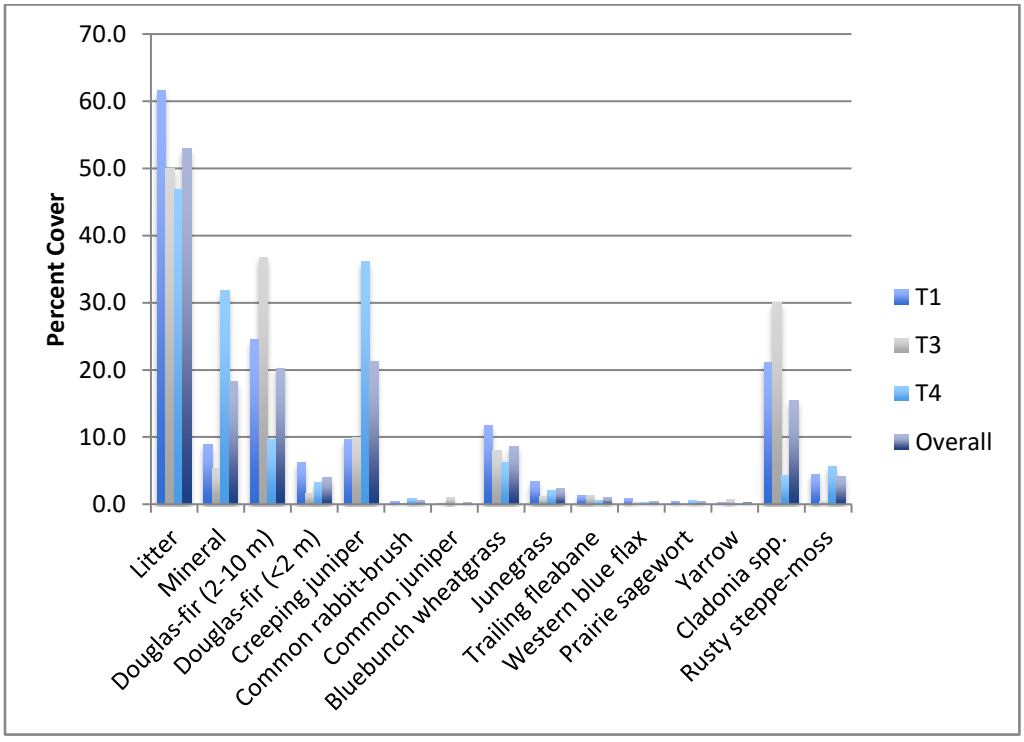

Figure 6. Mean cover of litter, mineral soil, and dominant vegetation species.

Tree Characteristics

Pre-treatment mean densities and size of trees in plots from each transect are summarized in Table 2. All stems recorded in plots were live Douglas-fir with virtually all stems considered in good condition and almost all had 100% live crowns. Pre-treatment tree characteristics by plot are summarized in Appendix 2.

Stem densities in the six plots along Transect 1 varied from 0 to 5600 stems per hectare and averaged 2001 stems per hectare. This transect had the most diverse stand structure, with a high density of trees in layer 4, a moderate density of trees in layer 3 and layer 5 and a low density of trees in layer 2.

Stem densities along the three plots of Transect 3 were the highest, varying from 2300 to 4600 stems per hectare and averaged 3167 stems per hectare. This transect had a high density of trees in layer 4 and a moderate density of stems in layer 3 and layer 5. No layer 1 or layer 2 stems occurred in any plots.

Stem densities along the seven plots of Transect 4 were the lowest, varying from 0 to 1400 stems per hectare and averaged 671 stems per hectare. This transect had a moderate density of layer 4 and 5 trees, a low density of layer 2 and 3 trees and no layer 1 trees located in any plots.

Table 2. Pre-treatment (2018 for Transect 1, 3 & 4 & 2020 for Transect 5) Douglas-fir stand characteristics as an average by transect and all plots combined at Sheep Flats.

Transect	Tree Size Layer	Stems/ha	Std. Dev.	Diameter (cm)		Height (m)
				1.3 m	0.3 m	
1	1	1	3	83.5	91.9	19.4
	2	83	117	13.5	16.7	6.8
	3	233	216	9.7	12.5	5.5
	4	1233	1698	2.8	4.7	2.7
	5	430	268	-	2.0	1.0
3	1	0	0	-	-	-
	2	0	0	-	-	-
	3	167	379	9.7	12.5	5.0
	4	2033	1137	3.0	4.7	2.9
	5	867	666	-	1.9	1.1
4	1	0	0	-	-	-
	2	14	38	15.0	19.3	7.2
	3	14	38	9.1	14.2	6.0
	4	414	372	2.5	5.2	2.3
	5	229	138	-	1.5	0.7
5	1	13	12	51.6	53.8	15.4
	2	0	0	-	-	-
	3	167	58	9.7	13.3	4.9
	4	300	173	2.2	4.9	2.3
	5	367	58	-	1.4	0.8
Combined	1	2	6	53.9	56.5	15.7
	2	31	75	13.7	17.1	6.9
	3	147	204	9.7	12.2	5.2
	4	910	1170	2.8	4.7	2.7
	5	421	457	-	1.8	1.0

Stem densities along the three plots of Transect 5 were similar to Transect 4 with the exception of a greater number of stems in layer 1. Plot densities varied from 714 to 1000 stems per hectare and averaging 846 stems per hectare. This transect had a moderate density of layer 3, 4 and 5 trees, no layer 2 trees located in any plots and an average of 13 stems per hectare in layer 1.

Overall stem density averaged 1513 stems per hectare pre-treatment with 88% of recorded stems under 7.5 cm dbh. Only 6 stems were observed in layer 2 with none recorded over 15.0 cm dbh. Only three layer 1 trees occurred within the plots.

A small number of freshly cut stumps, clustered along Transect 1, were sampled and tree age and diameter estimates obtained. Based on this non-random and biased sample, age estimates from tree rings suggested that most removed encroachment and ingrowth was likely less than 40 years old at stump height (Figure 7).

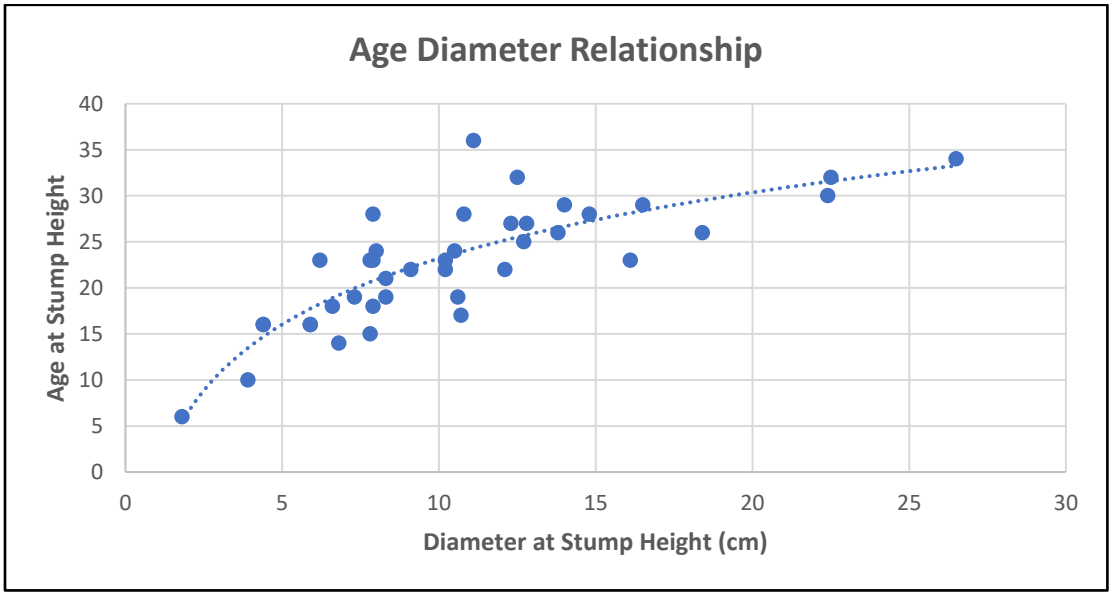

Figure 7. Age to diameter relationship of Douglas-fir encroachment felled at Sheep Flats.

Immediately post-treatment overall stem density averaged 85 stems per hectare with all layer 3 size trees removed from plots by the slashing crew (Table 3; Appendix 3). Only one layer 4 tree remained within plots. One layer 2 tree, which was over 15.0 cm dbh, and three layer 1 trees were also within plots. There was an average of 73 layer 5 stems per hectare remaining in plots and these trees averaged 0.5 meters in height. Freshly cut stumps with live basal branches averaged 111 per hectare.

Table 3. First year post-treatment (2019 for Transect 1, 3 & 4 and 2020 for Transect 5) Douglas-fir stand characteristics as an average by transect and all plots combined at Sheep Flats.

Transect	Tree Size Layer	Stems/ha	Diameter (cm)		Height (m)
			1.3 m	0.3 m	
1	1	1	83.5	91.9	19.4
	2	0	-	-	-
	3	0	-	-	-
	4	17	0.5	3.0	1.6
	5	83	-	1.1	0.5
3	1	0	-	-	-
	2	0	-	-	-
	3	0	-	-	-
	4	0	-	-	-
	5	0	-	-	-
4	1	0	-	-	-
	2	14	16.5	20.2	7.6
	3	0	-	-	-
	4	0	-	-	-
	5	71	-	0.4	0.4
5	1	13	51.6	53.8	15.4
	2	0	-	-	-
	3	0	-	-	-
	4	0	-	-	-
	5	133	-	0.6	0.5
Combined	1	2	53.9	56.5	15.7
	2	5	16.5	20.2	7.6
	3	0	-	-	-
	4	5	0.5	3.0	1.6
	5	73	-	0.6	0.5

Horizontal Cover Estimates

Pre-treatment estimates of horizontal cover varied by transect and sight distance (Table 4; Appendix 4) with the estimate of horizontal cover increasing by over 60% at a sight distance of 20 meters compared to 10 meters. At a sight distance of 10 meters there was a correlation between the density of Douglas-fir encroachment and ingrowth at Sheep Flats and estimates of horizontal cover (Figure 8).

Post-treatment estimates of horizontal cover were greatly reduced following slashing in 2019 and 2020 (Table 4; Appendix 4). The majority of remaining horizontal cover at Sheep Flats was the result of fresh slash loading depth being greater than one meter in height.

Table 4. Pre- and Post-treatment horizontal percent cover estimates from 10- and 20-meter radius plots by transect and all plots combined at Sheep Flats.

Transect	Pre-treatment		Post-treatment	
	10 m. Radius	20 m. Radius	10 m. Radius	20 m. Radius
1	38	60	12	22
3	57	97	0	10
4	21	36	2	5
5	33	53	7	17
Combined Mean	41	66	7	16

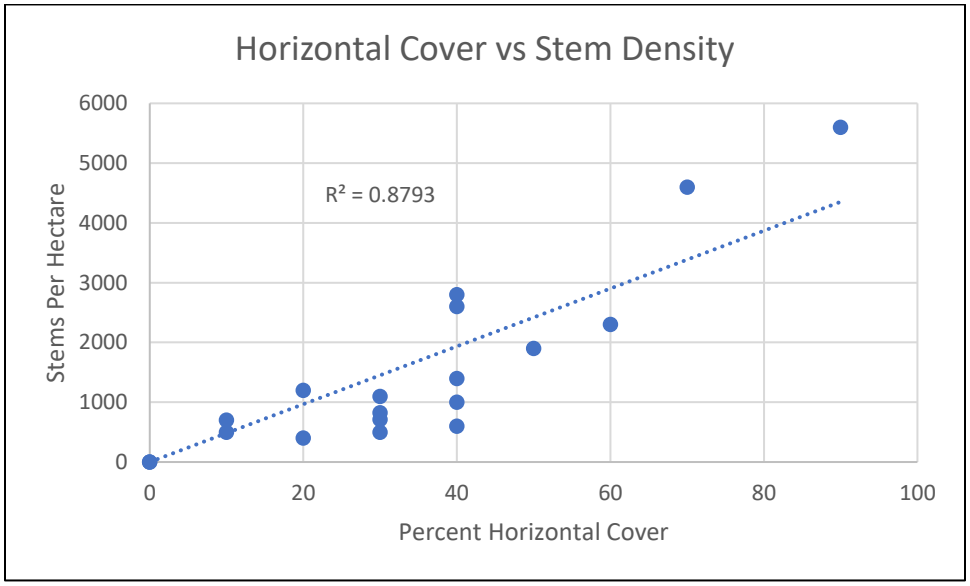

Figure 8. Correlation between estimates of horizontal cover at a sightability distance of 10 meters and tree density estimates within Douglas-fir encroachment and ingrowth at Sheep Flats.

Discussion

Treatment Prescription

The need for treatment of forest encroachment of grassland and forest ingrowth is widespread within the Cariboo-Chilcotin with numerous relevant guidelines developed to aid in ecosystem restoration projects. When developing the prescriptions for this project, the guiding principles outlined in several relevant documents were reviewed and considered including Best Management Practices (Cariboo-Chilcotin Grassland Strategy Working Group 2001, 2007), guidelines for restoring Mule Deer habitat (Dawson and Armleder 2000), the Churn Creek migration corridor restoration plan (Blackwell & Associates, 2006), regional grassland restoration recommendations (Steele et. al. 2007) and the BC Parks Tree Removal Policy. Encroachment stand attributes and FCCPAS experience with past restoration projects were also considered when developing the final treatment prescriptions for removing encroachment from the project area.

The prescription utilized at Sheep Flats essentially removed all layer 3 stems and all layer 2 stems less than 15 centimeters dbh and the vast majority of layer 4 and 5 stems. With the exception of Transect 3, layer 2 stems greater than 15 centimeters dbh and layer 1 stems appeared to be under represented in sampling plots. Horizontal cover estimates post-treatment were influenced by slash loading with some areas of slash exceeding one meter in depth. The horizontal cover estimates will likely be reduced over time as slash settles from snow press. Examples of pre-and post-treatment stand characteristics and slash loading for each transect are shown in Figures 9 through Figure 16.

Figures 9 and 10. Representative example of encroachment along Transect 1. View south from Plot 1.6 pre-treatment (2018) and post-treatment (2019).

Figures 11 and 12. Representative example of encroachment along Transect 3. View south from Plot 3.3 pre-treatment (2018) and post-treatment (2019).

Figures 13 and 14. Representative example of encroachment along Transect 4. View west from Plot 4.3 pre-treatment (2018) and post-treatment (2019).

Figures 15 and 16. Representative example of ingrowth along Transect 5. View east from Plot 5.2 pre-treatment (2020) and post-treatment (2020).

Treatment Productivity

In 2019 the SXDLP slashing crew worked a total of 44 person days with days usually 12 hours long except for one day when the crew only worked 11 and one-half hours. Due to daily driving time from Dog Creek and helicopter shuttle times the slashing crew was on site just over seven hours each day. The crew treated 41 hectares of encroachment of varying density over the five days or just under one hectare per person day. In 2020, the slashing crew worked a total of 17 person days with days 12 hours long. With several days of High fire hazard immediately prior to field work in 2020, Wildfire Regulations called for the early shut down of operations (by 1:00 pm) followed by a two-hour fire watch, resulting in the crew working on site for less than six hours both days. The crew treated six hectares of encroachment and ingrowth which averaged about 1000 stems per hectare or about one-third of a hectare per person day. Both years, the helicopter was based out of Williams Lake with daily flying time averaging just under three hours per day.

Project Costs

The total direct costs of this project were $51,817.41 of which HCTF/FESBC contributed $36,500.00 and BC Parks provided $15,317.41. These funds generate a per hectare treatment cost of approximately $1,100.00 for the project. Of the total direct costs $30,354.85 or 58.6% was directed to contracts to SXDLP for the slashing crew and first aid support. $19,117.41 or 36.9% was associated with helicopter transportation costs of which BC Parks funded $15,317.41 of the costs. Expenses totaled $1,345.31 or 2.6% and included materials, supplies and vehicle mileage costs for FCCPAS volunteers. Administration and overhead costs totaled $999.84 or 1.9%. FCCPAS in-kind contributions were valued at an additional $17,500.00.

Future Monitoring

In the past, fires were a frequent and widespread natural disturbance agent in the region (Blackwell et. al. 2001, Harvey et. al. 2017). Although essentially all layer 3 stems were removed from the treatment area a few of the shorter layer 5 and a very small number of layer 4 stems were overlooked by the slashing crew. Some of the cut stumps had live limbs remaining on them immediately following treatment, although it is unclear what proportion of these stems will survive. The basal branches of many trees were growing along the ground, with some buried in the duff layer, which made removal difficult. Prescribed burning of the site will reduce the risk of the shorter remaining live stems persisting longer term and the need for any additional manual treatment of the site.

The Friends of Churn Creek Protected Area Society anticipates monitoring the vegetation/ horizontal cover plots following treatment of the project area with a prescribed burn as Sheep Flats will be incorporated into BC Parks ongoing burning program for Churn Creek Protected Area. For vegetation, the principal interest is in documenting any changes to the shrub and herbaceous layers and occurrence of invasive species following tree removal and prescribed burning. For horizontal cover estimates, the interest is in observing if there are any further reductions in horizontal cover following burning.

Recommendations

This project successfully treated 47 hectares of encroachment and ingrowth from an isolated area within Churn Creek Protected Area. Similar and smaller areas of encroachment and forest ingrowth exist within the Protected Area along the migration route of California Bighorn Sheep that summer at Red Mountain and winter within the Protected Area. We recommend that BC Park and local wildlife managers review the success of this project and consider the value of undertaking similar projects within the Protected Area to aid in the recovery of the Red Mountain/Wycott-Sheep Flats herd of California Bighorn Sheep.

Literature Cited

BC Parks. 2000. Churn Creek Protected Area Management Plan. BC Ministry of Environment Lands and Parks, Victoria, B.C.

Blackwell, B., F. Steele, R. Gray, K. Iverson, K. Mackenzie. 2001. Fire management plan, Churn Creek Protected Area. Unpublished report submitted to BC Parks, Cariboo District, Williams Lake, BC.

Blackwell and Associates. 2006. Churn Creek Bighorn Sheep migration corridor restoration plan. Prepared for: BC Ministry of Environment, Williams Lake, B.C.

Cariboo-Chilcotin Grassland Strategy Working Group. 2001. Cariboo-Chilcotin Grassland Strategy – Forest Encroachment onto Grasslands and Establishment of a Grassland Benchmark Area. Unpublished Report submitted to the Cariboo Mid-coast Interagency Management Committee, Williams Lake, B.C.

Cariboo-Chilcotin Grassland Strategy Working Group. 2007. Best Management Practice Guidelines for Harvesting Treatments on CCLUP Grassland Benchmark Sites. Unpublished Report submitted Cariboo Managers Committee., Williams Lake, B.C.

Collins, W. B. and E. F. Becker. 2001. Estimation of Horizontal Cover. Journal of Range Management. 54(1), pp. 67-70.

Dawson, R. and H. Armleder. 2000. Structural Definitions for Management of Mule Deer Winter Range Habitat in the Interior Douglas-fir Zone. Cariboo Forest Region Research Section Extension Note. Extension Note #25A.

Harvey, J. E., D. J. Smith and T. T. Veblen. 2017. Mixed-severity fire history at a forest-grassland ecotone in west central British Columbia, Canada. Ecological Applications, 0(0), 2017, pp. 1-15.

Freeman, N. L. and P. Dielman. 2006. Fraser River West, Churn Creek/Camelsfoot Range and Junction California Bighorn Sheep Population monitoring and Radio Telemetry Project, Cariboo Region, 1995-2005. BC Ministry of Environment, Cariboo Region, B.C.

Sinclair, B. A., Lowrey, U., McKay, R., Burns, G. and Ketcheson, M. V. 1999. Bioterrain and Ecosystem Mapping Project Report, Churn Creek Terrestrial Ecosystem Mapping for Mapsheets 92O 028, 92O 029, 92O 038, 92O 039, 92O 048 & 92O 049. JMJ Holdings Inc., Nelson, B.C.

Steele, F. M., K. L. MacKenzie, O. A. Steen, B. A. Blackwell, A. Needoba and R.W. Gray. 2007. Cariboo-Chilcotin Grassland Restoration Plan: Grassland Benchmark. Unpublished Report Submitted to the Cariboo-Chilcotin Grassland Strategy Committee. B. A. Blackwell and Associated Ltd. Report available at: http://sernbc.ca/sern_library.html

Steen, O. A. 2012. An Assessment of First Year Vegetation Effects of a 2012 Prescribed Burn in the Onion Lake Area, Churn Creek Protected Area. Unpublished Report Submitted to BC Parks, Williams Lake, B.C. Friends of Churn Creek Protected Area Society, Williams Lake, B.C. Report available at: http://www.friendsofchurn.ca/resources.html

Sugden, L.G. 1961. The California Big Horn in British Columbia with Particular Reference to the Churn Creek Herd. British Columbia Department of Recreation and Conservation.

Wilson, S. F. 2015. Recovery plan for the California Bighorn Sheep (*Ovis canadensis californiana*) of the Churn Creek-Camelsfoot Range and Junction sub-populations. Prepared for: Habitat Conservation Trust Foundation, Victoria, B.C.

Appendices

Appendix 1: Pre-treatment Percent Cover of Vegetation.

Layer/ Species	Transect/Plot															
	1.1	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**3.1**	**3.2**	**3.3**	**4.1**	**4.2**	**4.3**	**4.4**	**4.5**	**4.6**	**4.7**
Litter	60	85	45	45	70	65	65	45	40	50	45	65	45	60	35	28
Mineral	0.5	1	5	15	12	20	4	2	10	35	35	20	30	30	35	38
B-1 (Tall Shrub Layer – woody plants 2- 10 meters tall)																
Pseu men	25	65	22	0	15	20	35	40	35	10	22	15	0.5	3	2	15
B-2 (Low shrub layer – woody plants less than 2 meters tall except low (< 15 cm) woody plants)																
Eric nau			2	0.2		0.2		0.1	0.2	0.5	0.2	2		0.2	0.2	3
Juni com		1					2	1								
Juni hor	0.2	5	0.2	0.5	12	40	20	5	5	35	7	65	35	60	33	18
Pseu men	1	7	2		15	12	1	2	2	2	3	10		2	0.5	5
C-G (Herb Layer – grasses)																
Achn nel								0.1								
Care coc		0.1						0.1								0.2
Care ros								0.1			0.2	0.2		0.2		0.1
Fest sax			0.1					0.1								
Koel mac	4	0.2	4	10	1	1	2	1	0.5	4	2	1	0.2	1	3	3
Pseu spi	15	3	15	18	12	7	10	7	7	7	12	2	8	5	5	5
C-F (Herb Layer – forbs)																
Achi mil	0.5	0.2		0.2	0.2		0.5	1	0.5		0.2					0.2
Alli cer	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1		0.1	0.1		0.2	0.1
Andr sep	0.1						0.1	0.1								
Anem mul					0.1											
Ante dim							0.1		0.1							
Ante mic	0.2						0.1	0.1							0.1	
Ante par	0.2	0.2		1	0.5	0.2	0.1	0.2	0.2		0.2			0.2	0.1	0.5
Arab hol	0.1		0.1			0.1	0.1									0.1
Arab is											0.1					
Arte cam			0.1			0.2					0.2					0.2
Arte fri	0.2		0.2	2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.2	2	0.5	0.2	0.2
Astr agr	0.5														0.2	
Astr mis		0.1														
Cham ere												0.1				
Cirs hoo	0.1															
Coma umb	0.2		0.2		0.2	0.2		0.2		0.2	0.2					0.2
Erig com															0.1	
Erig fla	2	0.2	5	0.2	0.5	0.2	1	1	2	0.5	0.5	0.1	0.2	0.2	0.2	2
Erig spe								0.2								
Eris imu			0.1	0.1		0.1			0.1							
Frag vir		0.2			0.2			0.2								
Gali bor								0.2			0.2					
Lepi den													0.1			
Linu per	0.5		0.5	3	0.5	0.2	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Layer/ Species	Transect/Plot															
	1.1	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**3.1**	**3.2**	**3.3**	**4.1**	**4.2**	**4.3**	**4.4**	**4.5**	**4.6**	**4.7**
Lith inc					0.1											
Lith rud	0.1															
Loma mac	0.2	0.1			0.1	0.1			0.1					0.1		0.1
Medi sat							0.1	0.1								
Opun fra	0.1	0.1	0.1	0.2	0.1	0.2	0.2		0.2	0.2		0.2	0.5	0.2	0.2	0.2
Orob fas				0.1											0.1	
Pote hip					0.2			0.2	0.1			0.2				
Pote pen		0.1	0.2	0.1	0.1	0.1	0.2	0.2	0.2			0.2	0.2	0.2	0.2	0.2
Sile dru									0.1			0.1		0.1		
Soli spa															0.1	
Tara off	0.2		0.5		0.1	0.1	0.1	0.1	0.1						0.1	0.1
Trag dub	0.1		0.1		0.1		0.2	0.1	0.1							
C-M/L (Moss, Lichen, Liverwort and Seedling Layer)																
Brac alb																0.2
Bryu m		0.2						0.2								
Calo pla															0.1	
Clad oni	35	5	45	35	5	2	20	35	35	0.5	2	0.2	10	2	5	10
Dipl mus			1	2			1		0.2							0.2
Drep unc		0.2					1		0.2							
Pelt did					0.2				0.1							
Pelt lep				0.2				0.1								
Pelt ruf		0.2					0.2									
Phys mus								0.2		0.1		0.2	0.2		0.2	0.2
Pleu sch							0.2									
Psor a										0.1					0.2	
Synt rur	5	10			5	7	0.2	0.5	0.5	5	12	2	5	5	5	5
Xant wyo													0.2			

Appendix 2: Pre-treatment (2018 & 2020) Stand Characteristics. All stems were live Douglas-fir.

Transect/ Plot	Tree Size (dbh)	Stems/ha.	Diameter (m)		Height (m)	Tree Condition	% Live Crown
			1.3 (m)	0.3 (m)			
1.1	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	100	13.3	17.8	6.5	G	100
	7.5 - < 12.5	300	9.4	12.7	5.0	G	100
	0 - < 7.5	800	3.2	3.6	2.8	G	100
	< 1.3m tall	0	-	-	-	-	-
	Total	1200					
1.2	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	600	9.3	11.6	5.5	G	100
	0 - < 7.5	4600	3.4	5.0	3.0	G	88
	< 1.3m tall	400	-	1.7	0.9	F	72
	Total	5600					
1.3	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	100	13.8	17.0	6.3	G	100
	7.5 - < 12.5	100	11.1	15.4	5.7	G	100
	0 - < 7.5	200	1.4	3.9	2.0	G	100
	< 1.3m tall	100	-	1.5	1.0	G	100
	Total	500					
1.4	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
1.5	≥ 17.5	7	83.5	91.9	19.4	G	50
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	100	11.0	14.8	6.5	G	100
	0 - < 7.5	1100	1.6	4.3	2.0	G	100
	< 1.3m tall	1600	-	2.1	1.0	G	100
	Total	2807					
1.6	≥ 17.5	-	-	-	-	-	-
	12.5 - < 17.5	300	13.5	16.2	7.1	G	100
	7.5 - < 12.5	300	10.1	12.2	5.6	G	100
	0 - < 7.5	700	1.0	4.4	1.8	G	100
	< 1.3m tall	600	-	2.2	0.9	G	100
	Total	1900					

Transect/ Plot	Tree Size (dbh)	Stems/ha.	Diameter (m)		Height (m)	Tree Condition	% Live Crown
			1.3 (m)	0.3 (m)			
3.1	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	2300	3.9	5.4	3.6	G	100
	< 1.3m tall	300	-	2.0	0.9	G	100
	Total	2600					
3.2	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	100	8.2	11.0	4.5	G	100
	0 - < 7.5	2900	2.5	4.2	2.4	G	100
	< 1.3m tall	1600	-	2.0	1.1	G	100
	Total	4600					
3.3	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	700	9.9	12.7	5.1	G	100
	0 - < 7.5	900	2.1	4.3	2.4	G	100
	< 1.3m tall	700	-	1.6	1.1	G	100
	Total	2300					
4.1	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	200	1.5	3.5	1.8	G	100
	< 1.3m tall	300	-	0.8	0.4	G	100
	Total	500					
4.2	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	1100	3.2	6.2	2.6	G	100
	< 1.3m tall	300	-	2.8	1.2	G	100
	Total	1400					
4.3	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	100	15.0	19.3	7.2	G	100
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	400	1.6	4.9	2.1	G	100
	< 1.3m tall	100	-	0.5	0.4	G	100
	Total	600					

Transect/ Plot	Tree Size (dbh)	Stems/ha.	Diameter (m)		Height (m)	Tree Condition	% Live Crown
			1.3 (m)	0.3 (m)			
4.4	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
4.5	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	300	2.2	5.0	2.2	G	100
	< 1.3m tall	400	-	1.4	0.6	G	100
	Total	700					
4.6	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	200	2.8	5.2	2.5	G	100
	< 1.3m tall	200	-	1.2	0.6	G	100
	Total	400					
4.7	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	100	9.1	14.2	6.0	G	100
	0 - < 7.5	700	2.1	4.4	2.1	G	100
	< 1.3m tall	300	-	1.7	0.6	G	100
	Total	1100					
5.1	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	200	9.2	12.5	5.1	G	100
	0 - < 7.5	400	2.0	4.1	2.4	G	100
	< 1.3m tall	400	-	1.9	1.1	G	100
	Total	1000					
5.2	≥ 17.5	23	46.5	57.3	14.8	G	95
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	100	7.6	10.2	3.1	G	100
	0 - < 7.5	400	2.0	5.2	2.0	G	100
	< 1.3m tall	300	-	0.5	0.5	G	100
	Total	823					

Transect/ Plot	Tree Size (dbh)	Stems/ha.	Diameter (m)		Height (m)	Tree Condition	% Live Crown
			1.3 (m)	0.3 (m)			
5.3	≥ 17.5	14	60.1	64.5	16.4	G	95
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	200	11.2	15.6	5.6	G	100
	0 - < 7.5	100	3.9	6.7	3.1	G	100
	< 1.3m tall	400	-	1.6	0.8	G	100
	Total	714					

Appendix 3: Post-treatment (2019 & 2020) Stand Characteristics. All stems were live Douglas-fir.

Transect/ Plot	Tree Size (dbh)	Stems/ha.	Diameter (m)		Height (m)	Tree Condition	% Live Crown
			1.3 (m)	0.3 (m)			
1.1	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
1.2	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	100	0.0	0.0	0.2	G	100
	Total	0					
1.3	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
1.4	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
1.5	≥ 17.5	7	83.5	91.9	19.4	G	50
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	200	-	0.4	0.4	G	100
	Total	207					
1.6	≥ 17.5	0					
	12.5 - < 17.5	0					
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	100	0.5	3.0	1.6	G	100
	< 1.3m tall	200	0.0	1.5	0.9	G	100
	Total	300					

Transect/ Plot	Tree Size (dbh)	Stems/ha.	Diameter (m)		Height (m)	Tree Condition	% Live Crown
			1.3 (m)	0.3 (m)			
3.1	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
3.2	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
3.3	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
4.1	≥ 17.5		-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	100	-	-	0.3	G	100
	Total	100					
4.2	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	200	-	-	0.3	G	100
	Total	200					
4.3	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	100	16.5	20.2	7.6	G	80
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	100					

Transect/ Plot	Tree Size (dbh)	Stems/ha.	Diameter (m)		Height (m)	Tree Condition	% Live Crown
			1.3 (m)	0.3 (m)			
4.4	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
4.5	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
4.6	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	0	-	-	-	-	-
	Total	0					
4.7	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	200	-	1.0	0.5	G	100
	Total	200					
5.1	≥ 17.5	0	-	-	-	-	-
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	100	-	0.5	0.6	G	100
	Total	100					
5.2	≥ 17.5	200	46.5	47.3	14.8	G	95
	12.5 - < 17.5	0	-				
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	23	-	0.2	0.4	G	100
	Total	223					

Transect/ Plot	Tree Size (dbh)	Stems/ha.	Diameter (m)		Height (m)	Tree Condition	% Live Crown
			1.3 (m)	0.3 (m)			
5.3	≥ 17.5	14	60.1	64.5	16.4	G	95
	12.5 - < 17.5	0	-	-	-	-	-
	7.5 - < 12.5	0	-	-	-	-	-
	0 - < 7.5	0	-	-	-	-	-
	< 1.3m tall	100	-	1.0	0.7	G	100
	Total	114					

Appendix 4: Pre- and post-treatment horizontal percent cover estimates from ten- and twenty-meter radius plots.

Transect/Plot	Pre-treatment (2018 & 2020)		Post-treatment (2019 & 2020)	
	10 m Radius	20 m Radius	10 m Radius	20 m Radius
1.1	20	80	20	40
1.2	90	100	10	10
1.3	30	40	10	20
1.4	0	0	0	0
1.5	40	70	0	0
1.6	50	70	30	60
3.1	40	100	0	0
3.2	70	90	0	10
3.3	60	100	0	20
4.1	10	10	0	0
4.2	40	60	0	0
4.3	40	50	0	10
4.4	0	0	0	0
4.5	10	30	0	20
4.6	20	20	0	0
4.7	30	80	10	0
5.1	40	50	0	10
5.2	30	30	10	20
5.3	30	80	10	20