

**NOXIOUS WEED MONITORING  
AND CONTROL ON  
ROCKY MOUNTAIN BIGHORN SHEEP  
WINTER RANGE  
AT WIGWAM FLATS**

**prepared for:**

**British Columbia  
Ministry of Environment  
Kootenay Region**

**by:**

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**December, 2009**

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## Executive Summary

Rocky Mountain bighorn sheep are blue listed (vulnerable) within BC primarily due to predators, disease and habitat loss from conifer ingrowth. To improve the quality of bighorn sheep winter range an intensive noxious weed control and monitoring program has been implemented at Wigwam Flats. The Nature Conservancy of Canada secured funding through the Columbia Basin Fish and Wildlife Compensation Fund (CBFWCF) and the Habitat Conservation Trust Fund (HCTF). In-kind support has been received from Tembec Industries Inc., the ministries of Environment and Forestry, TransCanada Pipelines, BC Hydro, and CJ Holdings. Spotted knapweed is the target species.

The objectives of the monitoring component of the project are:

- Assess knapweed-infested sites at Wigwam Flats and select sites for future monitoring,
- Install monitoring plots on these sites,
- Document pre-treatment vegetation species composition,
- Document post-treatment vegetation species composition, and
- Compare the results and determine the efficacy of herbicide treatment.

A reconnaissance survey of the area was conducted, and pre-treatment vegetation monitoring was undertaken at Wigwam Flats between June 26 and 28, 2002. All sites were located adjacent to the TransCanada Pipelines right-of-way. Aspect at Wigwam #1 was predominantly 200°. Slopes here ranged from 0 to 20°. Aspect at Wigwam #2 and #3 ranged between 205 and 245°. Slopes at these sites were generally 10 to 20°, but ranged up to 30° at Wigwam #2. Elevation was between 1010 and 1050 m.

The three sites had similar pre-treatment plant communities. Grass cover ranged between 24 and 30% with bluebunch wheatgrass, Idaho fescue, pinegrass, Canada bluegrass, Kentucky bluegrass, western needlegrass and Columbia needlegrass as the dominant species. Forb cover was between 31 and 39%. Spotted knapweed was the leading forb species at all sites. Spotted knapweed cover was 8 to 10%, while St. John's-wort cover was >5% at Wigwam #1 and #2, and >1% at Wigwam #3. Other weed species, such as goatsbeard, sulphur cinquefoil, chickweed and dandelion, are generally <1% cover. Shrub cover varied between 4 and 10% among sites. The leading species were snowberry, prickly rose and saskatoon.

In 2009, grass cover was between 1 and 3% lower than in 2002. Although there has been some annual variation in the ranking, bluebunch wheatgrass, Idaho fescue, Columbia needlegrass, pinegrass, and Canada bluegrass are still the leading grass species. Forb cover in 2009 was between 7 and 29% lower at all sites than it was in 2002, principally due to reductions in spotted knapweed cover. Shrub cover was slightly lower at all sites. Substrate cover differed at Wigwam #1 as litter was lower and bryophytes and bare soil were higher. In contrast, litter was higher, while rock and bryophytes were lower at Wigwam #2. Substrate cover was largely unchanged at Wigwam #3 between 2002 and 2009.

Herbicide treatment has significantly reduced spotted knapweed cover from between 8 and 10% in 2002 to about 1 to 3% in 2009. Target species misses ranged between 8 and 10% in 2009 and between 2 and 26% over the course of the trial. St. John's-wort cover increased between 2002 and 2009 at Wigwam #2 and #3.

The herbicide treatment has not significantly altered the composition of the plant community at any site by removing non-target species. Non-target species hits on native and domestic forbs was estimated at between 6 and 10% in 2009, and 2 and 24% among years. No significant impact was recorded on balsamroot and alfalfa cover between 2002 and 2009. Herbicide treatment had little effect on total shrub cover although there has been variation in the cover of some species.

Significant increases were measured for bluebunch wheatgrass at Wigwam #2 in 2004, 2005 and 2006, and for prairie Junegrass at Wigwam #3 in 2009. There have been no other increases in bunchgrass cover.

Changes in cover for other species between 2002 and the post-treatment years have been less consistent so may be affected by other factors such as precipitation, grazing or browsing. Herbicide treatment and the monitoring program should continue for three to five years to fully validate the success of the herbicide treatment.

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## 1.0 Introduction

### 1.1 Issue

Rocky Mountain bighorn sheep are blue listed (vulnerable) within BC primarily due to predators, disease and loss of habitat from conifer ingrowth. When weedy species increase on bighorn sheep winter range other species decline, thereby reducing available winter forage. Reduced weed cover on bighorn sheep winter ranges will increase the value of these ranges for bighorn sheep, and will increase forage production potential. A noxious weed management plan has been written (Fraser et al. 2001) for the Mt. Broadwood – Wigwam Flats area and an intensive noxious weed control program has been implemented. The Nature Conservancy of Canada and the BC Ministry of Environment (MOE) have secured funding for noxious weed control through the Columbia Basin Fish and Wildlife Compensation Fund (CBFWCF) and the Habitat Conservation Trust Fund (HCTF). In-kind support has been received from Tembec Industries Inc., the ministries of Environment and Forestry, TransCanada Pipelines, BC Hydro, and CJ Holdings. Spotted knapweed is the primary target species.

The objective of this project is to implement recommendations derived from a research project embarked upon by the East Kootenay Wildlife Association (1997-2001) that examined the ability of winter ranges to support bighorn sheep populations (Jalkotzy et al. in press). Results indicated "*Spotted knapweed is a concern at Bull River, and throughout much of the grassland and shrubland of Mt. Broadwood, as well as disturbed areas in the Columbia Lake study area. Tyser and Key (1988 cited in Rice et al. 1997) and Tyser (1992 cited in Rice et al. 1997) found that as spotted knapweed increases on a site, other species decline. In Montana, spotted knapweed invasions reduced available winter forage for elk by 50 to 90% (Duncan 1997 cited in Asher 2000). Accordingly, Hakim (1975 cited in Bedunah 1992) found that elk used knapweed sites much less than bunchgrass communities. Knapweed can increase exponentially, beginning slowly, then doubling and redoubling (Kummerow 1992). In B.C., over 40,000 hectares (100,000 acres) are infested by knapweed, reducing forage potential by up to 90 per cent (Anon. 1998).*"

Spotted knapweed was not identified in bighorn sheep diets at Wigwam Flats in the above-mentioned study. However, it has been identified as a major component of California bighorn sheep winter diet at other locations in British Columbia. Seed heads are available above the snow, and over-wintering basal rosettes became available when the snow recedes (Miller 1990 cited in Carey 1995). However, despite spotted knapweed's higher nutritive value, Olson and Wallander (2001) found it was not grazed more than Idaho fescue. Sheep rumen microbial populations are negatively affected when a sheep's diet contains 70% or more spotted knapweed, especially when parts with higher cnicin concentrations are consumed (e.g., mature leaves, flower heads) (Olson and Kelsey 1997).

The HCTF has funded noxious weed control on bighorn sheep winter ranges from 1992-96, and in 2002-06 through the Rocky Mountain Bighorn Sheep project. The ministries of Forests and Agriculture, Food and Fisheries provided weed control in the intervening time. Due to funding constraints, the emphasis of their weed control activities has been directed toward the most serious infestations within Range Units, which often do not encompass critical sheep winter ranges. In addition, current weed control efforts are

typically applied along motorized access routes, and areas of infestation away from roads are ignored (Jalkotzy et al. in press). To be effective, weed control must target all seed sources, not just those that are easily accessible.

## **2.0 Project Objectives**

The MOE and other stakeholders are attempting to improve the condition of grass/shrub communities by reducing the spread and concentration of noxious weed species. An intensive noxious weed control and monitoring program was initiated on critical bighorn sheep winter range at Wigwam Flats. This program operates cooperatively with the Ministry of Forests, Regional District of the East Kootenay (RDEK), Tembec Industries Inc., TransCanada Pipelines, BC Hydro and the Nature Conservancy of Canada.

Specifically, the objectives of the vegetation monitoring component of the project are:

- Assess knapweed infested sites at Wigwam Flats and select sites for future monitoring activities,
- Install vegetation monitoring plots on these sites,
- Document pre-treatment vegetation species composition in 2002,
- Document post-treatment vegetation species composition in all years, and
- Compare the results and determine the efficacy of herbicide treatment.

## **3.0 Description of the Study Area**

The study area is located at Wigwam Flats, east of the Elk River and north of the confluence of the Elk and Wigwam rivers, and is found within Management Unit 4-02 (Figure 1). Wigwam Flats is bisected by the TransCanada Pipelines right-of-way (ROW). Aspect is generally south to southwest. The study area is gently to moderately sloping, and slopes of 0 to 20° are most common, although 30° slopes can be found. Elevation ranges between 1010 and 1050 m.

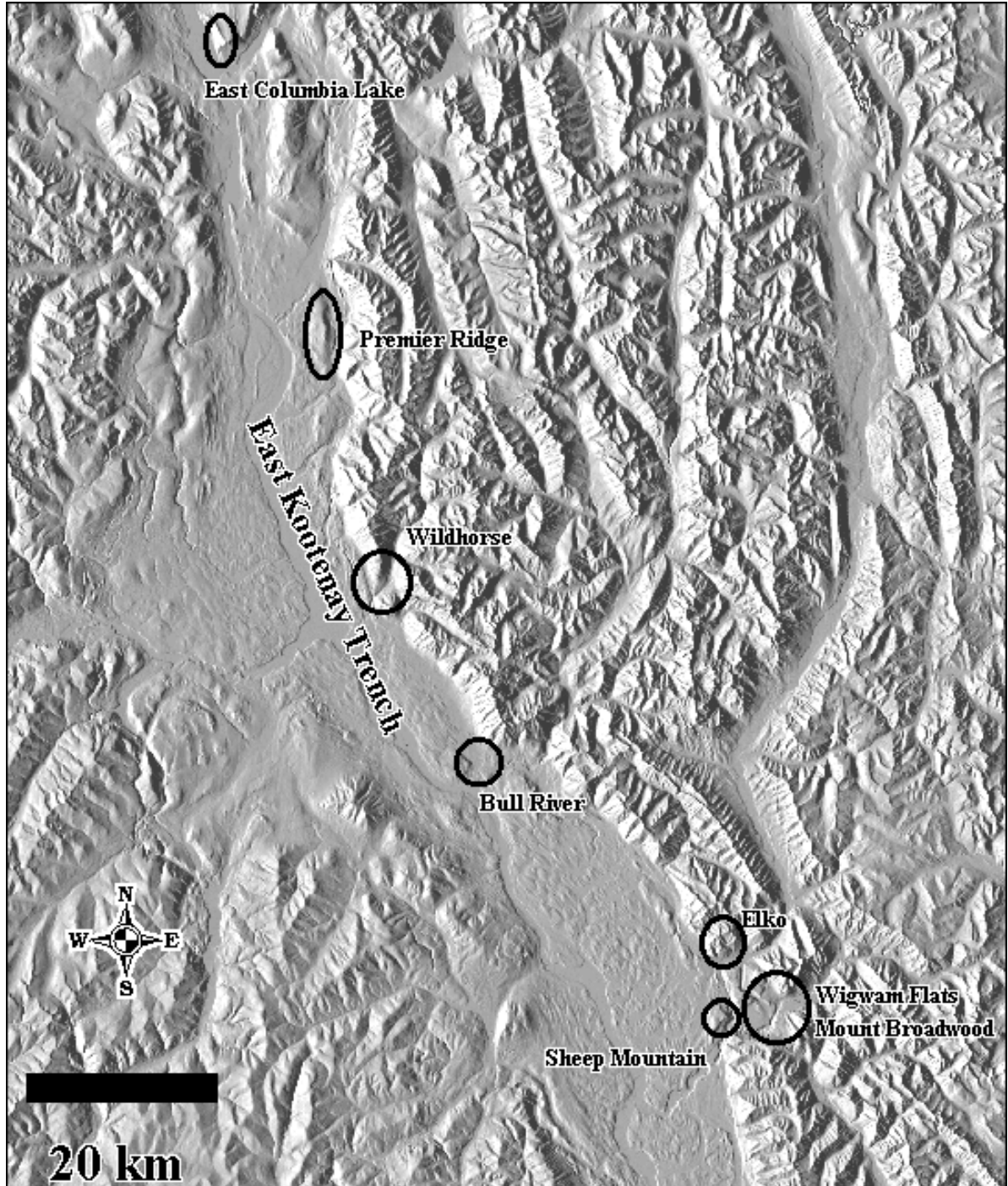
### **3.1 Landforms and Soils**

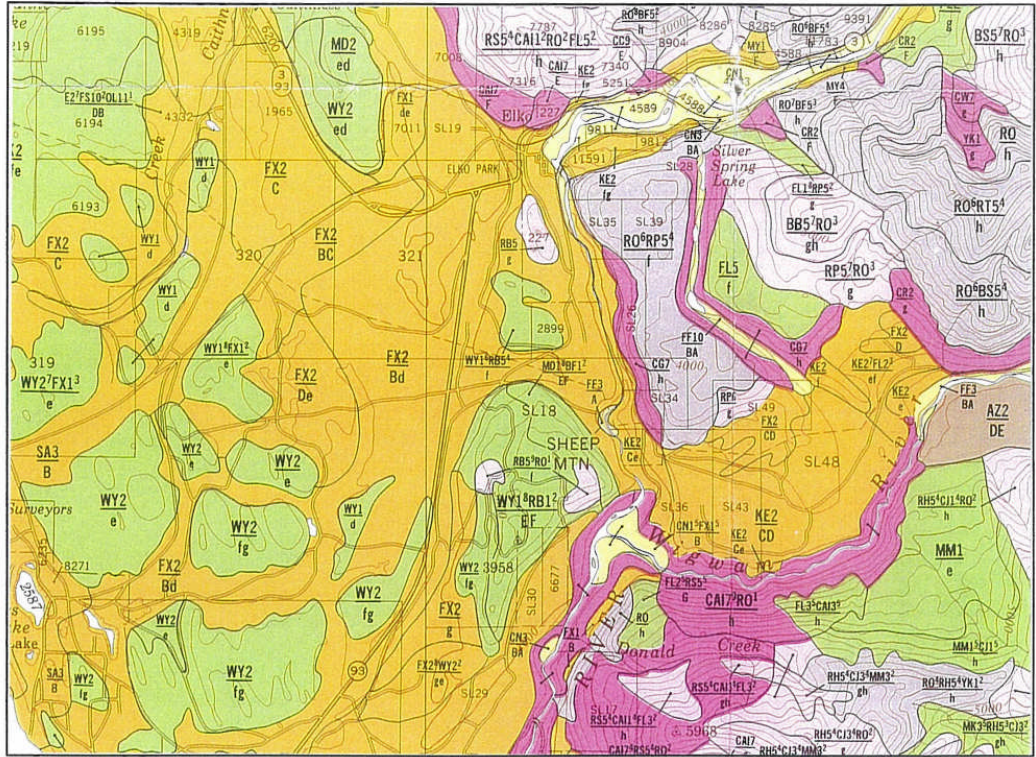
The study area lies within the Rocky Mountain Trench physiographic region (Holland 1976). Topography is defined by glaciofluvial and colluvial processes (Lacelle 1990). Overlying loess (windborne) deposits are common.

The Keeney soil association predominates in the study area (Figure 2). These soils have developed in silty or sandy fluvial or aeolian veneers overlying gravelly glaciofluvial outwash plains, terraces and fans. Texture in the upper soil horizon varies from very gravelly loam to very gravelly loamy sand, while coarse fragments comprise up to 80% of the subsoil and consist mainly of rounded gravels and cobbles. The soil association phase mapped for this area (KE2) is an Orthic Eutric Brunisol, but soils that have developed under grassland vegetation are Orthic Dark Brown Chernozems.

Round Prairie (RP5) soils are found associated with rock outcrops (RO) to the north of the pipeline ROW. These soils overlie bedrock and are commonly < 50 cm thick. Round Prairie soils are classified as Orthic Dystric Brunisols.

Figure 1. Bighorn sheep winter ranges in the East Kootenay region of southeastern BC (from Jalkotzy et al. in press).





Symbol	Soil Assoc.	Parent Material	Texture	Drainage	Soil	Vegetation Zone	Description
KE2	Keeney	glaciofluvial	fsl/gsl	w	Orthic Eutric Brunisol, Orthic Dark Brown Chemozem	IDF sub-zones	Limestone- derived terraces and fans
RP5	Round Prairie	colluvium	gsl	r	Orthic Dystric Brunisol	IDF sub-zones	Stony, acidic soils; steep slopes

Figure 2. Soils at Wigwam Flats (1:100,000) (Lacelle 1990).

### **3.2 Vegetation**

The study area is contained within the Interior Douglas-fir (IDF) biogeoclimatic zone (Braumandl and Curran 1992). The most common sub-zone is the “Kootenay Dry, Mild Interior Douglas-fir Variant” (IDFdm2). Douglas-fir<sup>1</sup> is the dominant tree species, however, ponderosa pine, western larch, trembling aspen and lodgepole pine are also present (Appendix 1).

Common shrubs within the area include bitterbrush, snowberry, rose, saskatoon, common juniper, bearberry, chokecherry, soopolallie, and willow species (Appendix 1). Grass and grasslike species that are present throughout the study area include bluebunch wheatgrass, needle-and-thread, prairie Junegrass, Kentucky bluegrass, Canada bluegrass, rough fescue, Idaho fescue, western needlegrass, Columbia needlegrass, Richardson’s needlegrass and pinegrass.

Hairy goldaster, western yarrow, shaggy fleabane, compound fleabane, balsamroot, asters, pussytoes and twinflower are common forbs. Weedy forbs common to the site include spotted knapweed, houndstongue, St. John’s-wort, goatsbeard, common mullein, yellow hawkweed and dandelion.

### **3.3 Wildlife and Cattle**

Lands which have very high (Class 1, 1W, and 2W) and moderate to high capability (Class 3) to support ungulates occur in the area (Canada Land Inventory 1976). Bighorn sheep, elk, mule deer and white-tailed deer use the study area for migration routes and winter/spring range. There has been no cattle grazing since at least 1987 when the area was declared a wildlife management area.

## **4.0 Methods**

### **4.1 Weed Control**

In 2002 to 2006, areas of concern were sprayed with the herbicide Transline\* (active ingredient is clopyralid) from a motor vehicle if accessible, or by backpack sprayer. Particular attention was paid to controlling noxious weeds on slopes with no road access. Transline\* is selective for knapweed, Canada thistle, scentless chamomile, and ox-eye daisy. It does not affect grass, forbs or shrubs. At 300 g of clopyralid, cover of knapweed is reduced from 85% coverage to less than 4% (Dow AgroScience 1998). Transline\* is more selective, and cost effective than other herbicides such as Tordon\*. Herbicide is considered an effective method of noxious weed removal at Wigwam Flats (A. Skinner, Ministry of Forests, pers. comm.). A “Weed Treatment Record” was completed for each site, including areas patrolled, areas treated, amount of herbicide used, and the methods of application.

A combination of reconnaissance and intensive surveys was performed to locate monitoring sites and determine the pre-treatment plant communities.

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<sup>1</sup> Plant species names follow Hitchcock and Cronquist (1973).



## **4.2 Stratification**

The Wigwam Flats area was first stratified into polygons by topography and forest cover class. Areas of Open Range (OR - 0-10% canopy cover), Open Forest (OF - 11-40% canopy cover) and Closed Forest (CF - >40% canopy cover) were marked on 1:20,000 colour aerial photographs. Forest canopy closure classes follow Inventory Branch classes (BC Ministry of Forests 1997). Initial polygon boundaries were refined by examination of 1:20,000 forest cover maps and 1:100,000 soils maps (Lacelle 1990).

## **4.3 Field Vegetation Assessment - Reconnaissance Survey**

Following the initial stratification, a reconnaissance level survey, which consisted of site visits for all OR and lightly stocked OF polygons, was completed. The plant community composition was determined by ocular estimate of percent foliar cover for each vegetation layer; trees, shrubs, forbs and grass. Total cryptogam cover and estimates of percent litter, bare soil and rock were also recorded. Weed species and other plants, such as indicator species and poisonous plants, were noted when observed during the reconnaissance survey.

Slope, aspect, elevation and landform type were recorded. Forest canopy and the shrub and herbaceous layers were described. The overstory is composed of veteran and dominant trees. The regeneration layer consists of all trees up to 3 m in height. The remaining trees comprise the understory. Range condition (Dyksterhuis 1949) is used to describe the seral stage of the herbaceous and shrub plant community's response to past grazing disturbance. Excellent range condition represents ecological "climax" while poor condition corresponds to the lowest seral stage.

Polygons were evaluated in order to choose sites with similar slope, aspect, landform, soils and vegetation cover. The range reconnaissance level survey was undertaken between June 12 and 26, 2002.

## **4.4 Field Vegetation Assessment - Intensive Survey**

Three sites were chosen and an intensive survey was completed at each (Figure 3). Five permanent 60 m transects were established at each site and the pre-treatment plant community was evaluated using the following methodology (see Appendix 2).

Herbaceous vegetation was sampled in 20 cm X 50 cm Daubenmire frames, which were randomly located along the transects such that 50 plots were read per site (Daubenmire 1959). These plots were nested within 1 m X 2 m plots. Tree and shrub cover was determined in these larger plots according to cover classes listed in Appendix 2. Transect ends were permanently marked with painted 12 cm rebar stakes, aluminium tags, and flagging tape. A tie-point consisting of a 7 cm X 10 cm aluminium tag was located on a prominent, nearby tree. Plot name, number and bearing and distance to the baseline were recorded on this tag. Global Positioning System (GPS) coordinates were determined for each sampling location. Summarized data are appended (Appendix 3, 4, 5).

Plant species cover and frequency are described in text and tables. Permanent photopoints were established at each intensive sampling location. Photos are located in Appendix 6.



#### **4.5 Post-treatment Vegetation Sampling and Weed Control**

All vegetation transects were re-sampled after herbicide application to determine the composition of the plant community following treatment, and to determine effects on target and non-target species. Target species hits, target species misses, and non-target hits were calculated as below:

$$\text{Target species hits (\%)} = \frac{\text{\# plots with spotted knapweed showing treatment effects}}{\text{Total \# of plots sampled}} \times 100$$

Beginning in 2005 spotted knapweed plants were counted in a 2 m wide band on either side of each transect. The presence or absence of treatment effect was noted and application efficiency was calculated as a percentage.

#### **4.6 Data Analysis**

Spearman's rank correlation procedure is used to compare the composition of the pre- and post-treatment plant communities and determine the efficacy of the treatment (Zar 1984). Paired t-tests are used to compare pre- and post-treatment cover values of the key plant species (eg. spotted knapweed, bluebunch wheatgrass and Idaho fescue).

### **5.0 Results and Discussion**

The sites are located in an area with high weed infestations adjacent to the TransCanada Pipelines ROW. Wigwam #1 is located on the south side, while Wigwam #2 and #3 are found on the north side. Wigwam #1 is located on the crown of a small hill, so small variations in aspect and slope were encountered. Wigwam #2 and #3 are located mid-slope. Wigwam #1 and #3 were treated with a sprayer-mounted ATV and backpack sprayers, while Wigwam #2 was treated with backpack sprayers. Post-treatment sampling took place between July 16 and 22 in 2009.

#### **5.1 Aspect, Slope and Elevation**

Aspect at Wigwam #1 varied from 135 to 315°, although the predominant aspect of the site is 200°. Slopes here were from 0 to 20°. Aspect at Wigwam #2 and #3 ranged between 205 and 245°. Slopes at these sites were generally 10 to 20°, but are as steep as 30° at Wigwam #2. Elevation ranged between 1010 and 1050 m among sites.

#### **5.2 Plant Communities – Pre-Treatment**

The three sites had similar pre-treatment plant communities. Grass cover ranged between 24 and 30% with bluebunch wheatgrass, Idaho fescue, pinegrass, Canada and Kentucky bluegrass, western and Columbia needlegrass as the dominant species (Table 1, 2, 3).

Forb cover was higher than grass cover at all sites and ranged between 31 and 39% (Table 1, 2, 3). Spotted knapweed was the leading forb species. Other forb species that commonly contributed more than 1% to canopy cover were St. John's-wort, monarda, desert parsley, leafy aster, western yarrow, death camas, spreading dogbane, balsamroot, wild strawberry and spiny phlox.



**Table 1. Cover and frequency of plant species at Wigwam Flats #1 in 2002 and 2009.**

Species	2002		2009	
	Cover	Frequency	Cover	Frequency
		%		%
<b>Grass and Grasslike</b>				
Idaho fescue	13.9	74.0	14.1	74.0
Canada bluegrass	5.3	54.0	3.5	46.0
Pinegrass	3.6	18.0	2.8	32.0
Bluebunch wheatgrass	3.5	16.0	2.0	18.0
Prairie Junegrass	2.0	28.0	1.2	24.0
Kentucky bluegrass	1.0	10.0	0.3	2.0
Northwest sedge	0.3	2.0	0.0	0.0
Columbia needlegrass	0.1	4.0	0.7	8.0
Alkali bluegrass	0.1	2.0	0.0	0.0
Cheatgrass	0.0	0.0	0.3	2.0
Sandberg's bluegrass	0.0	0.0	0.3	10.0
Western needlegrass	0.0	0.0	1.3	20.0
<b>Total Grass and Grasslike</b>	<b>29.8</b>		<b>26.3</b>	
<b>Forbs</b>				
Spotted knapweed	9.0	36.0	1.2	18.0
St. John's-wort	5.5	50.0	3.0	38.0
Desert parsley	3.6	34.0	3.6	32.0
Leafy aster	2.3	20.0	0.2	6.0
Balsamroot	2.1	6.0	1.2	8.0
Western yarrow	2.0	28.0	0.1	2.0
Alfalfa	1.7	10.0	0.8	10.0
Death camas	1.2	16.0	0.0	0.0
Timber milkvetch	1.1	14.0	0.0	0.0
Chickweed	0.9	24.0	0.3	12.0
Orange arnica	0.9	14.0	0.0	0.0
Spiny phlox	0.8	12.0	1.1	12.0
Baker's mariposa lily	0.7	18.0	0.0	0.0
Upland larkspur	0.7	8.0	0.0	0.0
Fairy candelabra	0.6	22.0	0.3	10.0
Goatsbeard	0.6	4.0	0.0	0.0
Dandelion	0.5	8.0	0.1	4.0
Rosy pussytoes	0.5	8.0	0.0	0.0
Wild strawberry	0.5	8.0	0.0	0.0
Hairy goldaster	0.4	4.0	0.0	0.0
Spreading dogbane	0.4	4.0	2.0	16.0
Yellow sweet-clover	0.4	4.0	0.1	2.0
Common red paintbrush	0.3	2.0	0.0	0.0
Showy aster	0.3	2.0	0.1	2.0
Early blue violet	0.2	8.0	0.1	2.0
Nine-leafed lomatium	0.2	6.0	0.0	0.0
Prairie groundsel	0.2	6.0	0.0	0.0

**Table 1 (cont'd).**

Species	2002		2009	
	Cover	Frequency	Cover	Frequency
<b>Forbs (cont'd)</b>		%		%
Sulphur cinquefoil	0.2	8.0	0.0	0.0
Hoelboel's rockcress	0.1	2.0	0.0	0.0
Lance-leaved stonecrop	0.1	4.0	0.0	0.0
Pacific anemone	0.1	2.0	0.1	2.0
Yellow hawkweed	0.1	2.0	0.0	0.0
Dune goldenrod	0.0	0.0	0.4	6.0
Nodding onion	0.0	0.0	0.2	8.0
Purple owl-clover	0.0	0.0	0.1	4.0
Slender hawksbeard	0.0	0.0	0.4	6.0
Tiny penstemon	0.0	0.0	0.1	2.0
Field peppergrass	0.0	0.0	0.1	2.0
Monarda	0.0	0.0	0.3	2.0
Norway cinquefoil	0.0	0.0	0.1	2.0
Scouler's hawkweed	0.0	0.0	0.1	4.0
<b>Total Forbs</b>	<b>38.2</b>		<b>15.4</b>	
<b>Shrubs</b>				
Snowberry	4.4	50.0	2.5	38.0
Saskatoon	1.2	16.0	1.1	12.0
Willow species	1.2	8.0	0.8	2.0
Prickly rose	0.5	18.0	1.4	24.0
Low oregongrape	0.3	12.0	0.6	14.0
Birch-leafed spirea	0.2	6.0	0.2	6.0
Chokecherry	0.0	0.0	0.1	2.0
Soopolallie	0.0	0.0	0.1	4.0
Squaw currant	0.0	0.0	0.1	2.0
<b>Total Shrubs</b>	<b>7.8</b>		<b>6.6</b>	
<b>Trees</b>				
Trembling aspen	0.1	4.0	0.1	2.0
Douglas-fir regen	0.0	0.0	0.1	2.0
<b>Total Trees</b>	<b>0.1</b>		<b>0.1</b>	
<b>Substrate</b>				
Litter	61.5	100.0	38.0	100.0
Bryophytes	27.3	88.0	42.8	90.0
Soil	2.4	48.0	13.0	66.0
Rock	2.0	18.0	2.8	30.0
Litter >2cm	0.7	6.0	0.3	2.0
Sheep feces	0.5	8.0	0.6	14.0
Elk feces	0.4	16.0	0.8	22.0
Deer feces	0.1	2.0	0.0	0.0

**Table 2. Cover and frequency of plant species at Wigwam Flats #2 in 2002 and 2009.**

Species	2002		2009	
	Cover	Frequency	Cover	Frequency
		%		%
<b>Grass and Grasslike</b>				
Bluebunch wheatgrass	4.6	36.0	4.9	56.0
Canada bluegrass	6.8	50.0	7.5	56.0
Pinegrass	4.0	34.0	1.0	18.0
Columbia needlegrass	2.5	18.0	4.3	42.0
Cheatgrass	1.6	22.0	1.0	12.0
Prairie Junegrass	1.1	14.0	0.4	6.0
Kentucky bluegrass	1.1	14.0	0.4	6.0
Bromegrass species	1.0	10.0	0.5	8.0
Western needlegrass	0.7	6.0	1.5	28.0
Idaho fescue	0.6	4.0	0.2	6.0
Timothy	0.3	2.0	2.0	20.0
Slender wheatgrass	0.1	2.0	0.0	0.0
<b>Total Grass and Grasslike</b>	<b>24.4</b>		<b>23.5</b>	
<b>Forbs</b>				
Spotted knapweed	10.4	60.0	2.5	18.0
Monarda	6.3	40.0	6.7	42.0
St. John's-wort	6.1	36.0	9.4	68.0
Spreading dogbane	3.4	26.0	2.9	26.0
Alfalfa	1.9	6.0	1.3	12.0
Balsamroot	1.6	6.0	0.0	0.0
Wild strawberry	1.0	8.0	0.0	0.0
Western yarrow	0.9	16.0	0.0	0.0
Little-podded false flax	0.9	26.0	0.0	0.0
Stoneseed	0.7	6.0	1.2	8.0
Leafy aster	0.6	12.0	0.3	2.0
Fairy candelabra	0.5	8.0	0.0	0.0
Sulphur cinquefoil	0.5	8.0	1.6	14.0
Goatsbeard	0.4	6.0	0.0	0.0
Yellow rattle	0.4	4.0	0.0	0.0
Rosy pussytoes	0.3	2.0	0.0	0.0
Chickweed	0.4	14.0	0.3	12.0
Hairy goldaster	0.3	2.0	0.0	0.0
Yellow sweet-clover	0.3	12.0	1.9	16.0
Timber milkvetch	0.2	6.0	0.0	0.0
Upland larkspur	0.2	6.0	0.0	0.0
Showy aster	0.1	2.0	0.0	0.0
Common harebell	0.1	2.0	0.0	0.0
False flax	0.1	2.0	0.0	0.0
Tiny penstemon	0.1	2.0	0.0	0.0
Common mullein	0.1	2.0	0.0	0.0
Death camas	0.1	2.0	0.0	0.0

**Table 2 (cont'd).**

Species	2002		2009	
	Cover	Frequency	Cover	Frequency
<b>Forbs (cont'd)</b>		%		%
Scouler's hawkweed	0.0	0.0	0.4	4.0
Pale comandra	0.0	0.0	0.3	2.0
Golden clover	0.0	0.0	0.1	4.0
Filago	0.0	0.0	0.1	2.0
Field peppergrass	0.0	0.0	0.1	2.0
Nodding onion	0.0	0.0	0.1	2.0
<b>Total Forbs</b>	<b>37.9</b>		<b>28.8</b>	
<b>Shrubs</b>				
Prickly rose	3.9	40.0	1.9	36.0
Snowberry	3.0	50.0	2.7	40.0
Saskatoon	1.3	20.0	2.8	32.0
Low oregongrape	0.6	22.0	0.5	20.0
Birch-leaved spirea	0.4	16.0	0.3	10.0
Squaw currant	0.4	4.0	0.0	0.0
Common juniper	0.3	2.0	0.3	2.0
Willow species	0.3	2.0	0.0	0.0
Chokecherry	0.1	2.0	0.3	12.0
Prairie rose	0.0	0.0	0.6	14.0
<b>Total Shrubs</b>	<b>10.3</b>		<b>9.4</b>	
<b>Substrate</b>				
Litter	39.1	100.0	51.3	100.0
Rock	33.5	94.0	30.9	96.0
Bryophytes	6.4	78.0	4.3	48.0
Soil	6.3	64.0	6.2	60.0
Elk feces	0.6	4.0	0.0	0.0
Sheep feces	0.6	14.0	0.3	12.0
Deer feces	0.0	0.0	0.0	0.0

**Table 3. Cover and frequency of plant species at Wigwam Flats #3 in 2002 and 2009.**

Species	2002		2009	
	Cover %	Frequency	Cover %	Frequency
<b>Grass and Grasslike</b>				
Bluebunch wheatgrass	12.2	52.0	11.5	62.0
Canada bluegrass	8.5	82.0	4.3	60.0
Prairie Junegrass	1.8	30.0	4.6	46.0
Columbia needlegrass	1.0	8.0	1.9	14.0
Western needlegrass	0.8	10.0	2.6	24.0
Cheatgrass	0.5	8.0	0.6	22.0
Pinegrass	0.4	4.0	0.3	2.0
Kentucky bluegrass	0.1	2.0	0.0	0.0
Sandberg's bluegrass	0.0	0.0	0.0	0.0
Bromegrass species	0.0	0.0	0.1	2.0
<b>Total Grass and Grasslike</b>	<b>25.3</b>		<b>25.7</b>	
<b>Forbs</b>				
Spotted knapweed	8.1	52.0	1.1	12.0
Alfalfa	6.1	20.0	7.7	44.0
Monarda	2.9	20.0	2.5	20.0
Spreading dogbane	2.2	18.0	1.2	16.0
Fairy candelabra	1.4	36.0	0.3	10.0
Spiny phlox	1.4	26.0	0.3	12.0
St. John's-wort	1.3	10.0	5.1	44.0
Western yarrow	1.2	18.0	0.3	2.0
Goatsbeard	0.9	6.0	1.3	32.0
Timber milkvetch	0.8	2.0	0.0	0.0
Chickweed	0.9	34.0	0.2	8.0
Balsamroot	0.7	6.0	0.3	2.0
Wild strawberry	0.7	6.0	0.0	0.0
Little-podded false flax	0.4	16.0	0.0	0.0
Yellow hawkweed	0.4	4.0	0.0	0.0
Stoneseed	0.3	2.0	0.6	4.0
Yellow sweet-clover	0.2	8.0	0.0	0.0
Mariposa lily	0.2	6.0	0.0	0.0
Thompson's paintbrush	0.2	6.0	0.1	2.0
Hairy goldaster	0.1	4.0	0.5	8.0
Upland larkspur	0.1	4.0	0.2	8.0
Desert parsley	0.1	4.0	0.5	10.0
Rosy pussytoes	0.1	2.0	0.0	0.0
Leafy aster	0.1	2.0	0.0	0.0
Common harebell	0.1	2.0	0.1	4.0
Long-leaf fleabane	0.1	2.0	0.0	0.0
Nodding onion	0.0	0.0	0.4	16.0
Silky phacelia	0.0	0.0	0.2	8.0
Field peppergrass	0.0	0.0	0.7	18.0

**Table 3 (cont'd).**

Species	2002		2009	
	Cover	Frequency	Cover	Frequency
<b>Forbs (cont'd)</b>		%		%
Dune goldenrod	0.0	0.0	0.1	2.0
Sulphur cinquefoil	0.0	0.0	0.1	2.0
Fern species	0.0	0.0	0.1	2.0
Death camas	0.0	0.0	0.1	2.0
<b>Total Forbs</b>	<b>31.0</b>		<b>23.5</b>	
<b>Shrubs</b>				
Chokecherry	1.7	12.0	0.2	6.0
Prickly rose	1.3	22.0	0.5	10.0
Saskatoon	0.9	14.0	1.1	12.0
Snowberry	0.2	8.0	0.1	2.0
Low oregongrape	0.1	4.0	0.0	0.0
Soopolallie	0.1	2.0	0.3	2.0
Birch-leaved spirea	0.1	2.0	0.0	0.0
Willow species	0.0	0.0	0.3	2.0
Ceanothus	0.0	0.0	0.0	0.0
<b>Total Shrubs</b>	<b>4.4</b>		<b>2.4</b>	
<b>Trees</b>				
Douglas-fir regen	0.1	4.0	0.0	0.0
<b>Total Trees</b>	<b>0.1</b>		<b>0.0</b>	
<b>Substrate</b>				
Litter	38.1	98.0	39.3	100.0
Bryophytes	33.7	94.0	29.7	94.0
Rock	15.6	84.0	10.8	76.0
Soil	5.9	60.0	5.5	54.0
Elk feces	1.0	10.0	0.5	10.0
Sheep feces	0.1	4.0	0.6	14.0
Litter >2cm	0.0	0.0	0.3	2.0
Deer feces	0.0	0.0	0.1	2.0

Introduced domestic species such as alfalfa and yellow sweet-clover were found on all sites. Alfalfa contributed as much as 6% cover at Wigwam #3, while yellow sweet-clover was less than 1% cover.

Trees were poorly represented at the Wigwam Flats monitoring sites, but shrub cover was an important component, varying between 4 and 10% (Table 1, 2, 3). Leading species were snowberry, prickly rose and saskatoon, but other species such as chokecherry, low oregongrape, willow, common juniper and birch-leafed spirea were common.

Wigwam #2 and #3 had similar substrate composition with litter cover slightly less than 40%, and bare soil approximately 6%. Bryophyte cover was more than 33% at Wigwam #3, while rock was approximately 15%. In contrast, rock was nearly 34% cover at Wigwam #2, while bryophytes were less than 7%. Wigwam #1 differed slightly from the other sites by having nearly double the amount of litter, nearly 30% bryophyte cover, and bare soil and rock that were each less than 3% cover. Deer, elk and sheep feces combined, generally accounted for 1 to 2% cover at each site.

The most likely BEC zones for the monitoring area are IDFdm2 – series 01 and 03.

### **5.3 Weed Species – Pre-treatment**

Weedy species, in particular spotted knapweed and St. John's-wort, are dominant in the plant communities at Wigwam Flats (Table 1, 2, 3). Spotted knapweed ranged from approximately 8 to 10% cover among sites, while cover of St. John's-wort was more than 5% at Wigwam #1 and #2, and more than 1% at Wigwam #3. Other species of concern, such as goatsbeard, sulphur cinquefoil, chickweed and dandelion, are common, but generally contributed less than 1% cover.

### **5.4 Range Condition**

Wigwam Flats has had a long history of grazing. This is evident from the range condition found at the three sites (McLean and Marchand 1968). Although decreasers such as Idaho fescue and bluebunch wheatgrass are the leading species at two of the sites, increaser species such as Canada bluegrass, Kentucky bluegrass, western needlegrass and Columbia needlegrass are collectively more abundant (Table 1, 2, 3). Cheatgrass is commonly found in the area, as well as some introduced annual brome grasses, but these species are not predominant in the plant community at any site.

The prevalence of increaser forb species such as balsamroot, western yarrow, rosy pussytoes, spreading dogbane and monarda is further evidence of past grazing disturbance in these plant communities (McLean and Marchand 1968). Based on the percentages of decreasers and increasers in the plant community, and without considering the invasive weedy species, Wigwam #1 and #3 are rated as fair condition sites, while Wigwam #2 is a poor condition site.

### **5.5 Plant Communities – Post-treatment**

In 2009, grass cover ranged between 25 and 30% at the three sites, similar or slightly lower than in 2002 (Table 1, 2, 3). Although there has been some annual variation in the ranking, bluebunch wheatgrass, Idaho fescue, Columbia needlegrass, pinegrass, and Canada bluegrass are still the leading grass species. The Spearman's rank correlation statistic reveals that the plant communities are similar ( $P < 0.05$ ) among years (Table 4).

Forb cover in 2009 was between 7 and 23% lower at all sites than it was in 2002 (Table 1, 2, 3). The principle reason is the reduction in spotted knapweed cover. Monarda, spreading dogbane, desert parsley, and balsamroot are leading native forbs, and alfalfa is the most common domestic forb. The Spearman's rank correlation statistic indicates these plant communities are similar between 2002 and 2009. The herbicide treatment has not significantly altered the composition of the plant community by removing non-target species (Table 4).

At all sites shrub cover was slightly lower in 2009 than in 2002 (Table 1, 2, 3). Herbicide treatment has had little effect on total shrub cover although there has been variation in the cover of some species.

Some changes in substrate cover have occurred between 2002 and 2009 (Table 1, 2, 3). At Wigwam #1 litter was nearly 24% lower, while bryophytes and bare soil were nearly 16 and 11% higher, respectively. This follows a trend that was found in the data in 2006. It is unlikely that this trend is a result of the herbicide treatment. More probably this is a result of foraging, as the frequency of elk, deer and sheep feces was higher in 2009 than in 2002.

In contrast, at Wigwam #2 litter was nearly 12% higher in 2009 than in 2002, while rock and bryophytes were about 4 and 2% lower, respectively (Table 1, 2, 3). Bare soil was similar between years. Sheep use was about the same in 2009 as in 2002, but neither deer nor elk feces were recorded at Wigwam #2 in 2009. Differences are most likely due the differences in foraging behaviour.

Substrate cover was only slightly changed at Wigwam #3 (Table 1, 2, 3). Although litter and bare soil cover were similar between years, bryophyte and rock cover were both lower. The frequency of elk feces was similar between years, but in 2009 sheep feces was higher and deer feces were recorded, whereas they were absent in 2002.

It is doubtful that the herbicide treatment has impacted substrate cover. Grazing effects and annual variability in precipitation are most likely responsible for variations in substrate cover among years.

### **5.6 Target and Non-target Species – Post-treatment**

In 2009, spotted knapweed cover ranged between 1 and 3% among sites at Wigwam Flats (Table 1, 2, 3). Frequency data show that in 2002 between 36 and 60% of the plots contained spotted knapweed plants (Table 1, 2, 3). By 2009 the range has been decreased to 12 to 18%. Variation in cover among years is likely evidence of a substantial amount of spotted knapweed seed remaining in the soil seed bank.



**Table 4. Spearman's rank correlation at Wigwam Flats, 2002 to 2009.**

	<b>Wigwam1-2002</b>	<b>Wigwam2-2002</b>	<b>Wigwam3-2002</b>
<b>Wigwam1-2003</b>	0.545 *		
<b>Wigwam2-2003</b>		0.753 *	
<b>Wigwam3-2003</b>			0.639 *

	<b>Wigwam1-2002</b>	<b>Wigwam2-2002</b>	<b>Wigwam3-2002</b>
<b>Wigwam1-2004</b>	0.531 *		
<b>Wigwam2-2004</b>		0.454*	
<b>Wigwam3-2004</b>			0.458 *

	<b>Wigwam1-2002</b>	<b>Wigwam2-2002</b>	<b>Wigwam3-2002</b>
<b>Wigwam1-2005</b>	0.455 *		
<b>Wigwam2-2005</b>		0.391 *	
<b>Wigwam3-2005</b>			0.407 *

	<b>Wigwam1-2002</b>	<b>Wigwam2-2002</b>	<b>Wigwam3-2002</b>
<b>Wigwam1-2006</b>	0.421*		
<b>Wigwam2-2006</b>		0.542*	
<b>Wigwam3-2006</b>			0.560*

	<b>Wigwam1-2002</b>	<b>Wigwam2-2002</b>	<b>Wigwam3-2002</b>
<b>Wigwam1-2009</b>	0.983 *		
<b>Wigwam2-2009</b>		0.981 *	
<b>Wigwam3-2009</b>			0.967 *

<sup>1</sup> The Spearman's rank correlation statistic is calculated by comparing pre-treatment (2002) and post-treatment (2003, 2004, 2005, 2006, 2009) plant communities.

\* Indicates plant communities that are statistically similar (P<0.05).

Although herbicide treatment has resulted in reductions in spotted knapweed cover at all sites, missed areas, and areas where control was not adequate, point to the need to re-apply herbicide to these infestations over a number of years. While treatment effects on spotted knapweed have been notable, site effects have varied. Target species hits ranged between 2 and 8% in 2009, and between 0 and 12% among years (Table 5).

Target species misses ranged between 8 and 10% in 2009 (Table 5). During the course of the trial target misses have varied between 2 and 26%.

Determining herbicide effects on non-target species is an important aspect of this monitoring program. Leaf-cupping, stem-twisting and yellowing are the most common signs of herbicide effect. In 2009 non-target hits ranged between 6 and 10%. Herbicide effect was noted on balsamroot, slender hawksbeard, alfalfa, yellow sweet-clover, filago and goatsbeard (Table 5). Over the course of the trial non-target hits have ranged between 2 and 24%.

Non-target species hits and the affected species have varied somewhat during the course of the trial (Table 5). In 2006 non-target hits ranged between 8 and 10%, with herbicide effects noted on alfalfa, long-leaf fleabane, white sweet-clover, leafy aster and goatsbeard. In 2005, herbicide effects were noted on alfalfa, goatsbeard, stoneseed and yellow sweet-clover and non-target species hits were estimated at between 2 and 24%. In 2004, non-target treatment effects were only noted on balsamroot and alfalfa, and non-target hits were in the range of 6 to 10%. In 2003 non-target species hits were between 2 to 10%, and herbicide effects were noted on five native forbs and two domestic forbs.

Field observations of herbicide application efficiency reveal that in 2009 spotted knapweed plants adjacent to, but not on the transects, were observed at 32, 78 and 98 locations at Wigwam #1, #2 and #3, respectively (Table 6). This information is complemented by observations of spotted knapweed in 31 to 57 locations in 2005, and between 41 and 104 locations in 2006. Herbicide efficiency in the 2009 field observations was 50, 79 and 59% at Wigwam #1, #2 and #3, respectively. In contrast, in 2005 and 2006 efficiency ranged from lows of 26 and 34% at Wigwam #1 to highs of 70 and 74% at Wigwam #3.

### **5.7 Herbicide Effects on Key Species**

Herbicide treatment has significantly ( $P < 0.05$ ) reduced spotted knapweed cover at all sites, in all years, except in 2003 at Wigwam #2 (Table 7, 8, 9). Pre-treatment cover varied between 8 and 10% among sites in 2002. Treatment has been the most successful at Wigwam #1 and #3 where spotted knapweed cover has not exceeded 2% since the initiation of the herbicide treatment, and was less than 1% in several years. Treatment success has been more variable at Wigwam #2 where cover has fluctuated from less than 1% to nearly 8% (Table 7, 8, 9). This has largely resulted from application problems as target species misses have been between 8 and 26% at Wigwam #2 (Table 5). Much of Wigwam #2 is too steep and rocky for machine application so the remainder of the site has been treated with backpack sprayers.

**Table 5. Herbicide effects at Wigwam Flats, 2003 to 2009.**

<b>2003 Site</b>	<b>Non-Target Hits (%)</b>	<b>Non-Target Species</b>	<b>Target Hits (%)</b>	<b>Target Misses (%)</b>	<b>Target Species</b>
Wigwam#1	10	Showy aster Leafy aster Balsamroot Dune goldenrod Spreading dogbane	0	2	Spotted knapweed
Wigwam#2	10	Alfalfa Balsamroot White sweet-clover	10	26	Spotted knapweed
Wigwam#3	2	Alfalfa	0	8	Spotted knapweed

<b>2004 Site</b>	<b>Non-Target Hits (%)</b>	<b>Non-Target Species</b>	<b>Target Hits (%)</b>	<b>Target Misses (%)</b>	<b>Target Species</b>
Wigwam#1	10	Alfalfa	4	12	Spotted knapweed
Wigwam#2	8	Alfalfa Balsamroot	2	8	Spotted knapweed
Wigwam#3	6	Alfalfa	2	6	Spotted knapweed

<b>2005 Site</b>	<b>Non-Target Hits (%)</b>	<b>Non-Target Species</b>	<b>Target Hits (%)</b>	<b>Target Misses (%)</b>	<b>Target Species</b>
Wigwam#1	24	Alfalfa Goatsbeard Stoneseed	4	2	Spotted knapweed
Wigwam#2	2	Alfalfa Yellow sweet-clover	2	8	Spotted knapweed
Wigwam#3	22	Alfalfa Goatsbeard	2	12	Spotted knapweed

<b>2006 Site</b>	<b>Non-Target Hits (%)</b>	<b>Non-Target Species</b>	<b>Target Hits (%)</b>	<b>Target Misses (%)</b>	<b>Target Species</b>
Wigwam#1	8	Alfalfa Long-leaf fleabane	4	6	Spotted knapweed
Wigwam#2	8	Alfalfa White sweet-clover Leafy aster	12	16	Spotted knapweed
Wigwam#3	16	Alfalfa Long-leaf fleabane Goatsbeard	2	18	Spotted knapweed

<b>2009 Site</b>	<b>Non-Target Hits (%)</b>	<b>Non-Target Species</b>	<b>Target Hits (%)</b>	<b>Target Misses (%)</b>	<b>Target Species</b>
Wigwam#1	10	Balsamroot Slender hawksbeard	4	8	Spotted knapweed
Wigwam#2	6	Alfalfa Yellow sweet-clover Filago	8	10	Spotted knapweed
Wigwam#3	10	Alfalfa Goatsbeard	2	10	Spotted knapweed

<sup>1</sup> Non-target hits indicate herbicide effects (eg. stem-twisting, leaf-cupping and yellowing) were noted on non-target species.

<sup>2</sup> Target hits indicate herbicide effects were noted on spotted knapweed survivors.

<sup>3</sup> Target misses indicate herbicide effects were not noted on spotted knapweed survivors.

**Table 6. Herbicide application efficiency at Wigwam Flats between 2005 and 2009.**

Year	Wigwam #1				Wigwam #2				Wigwam #3			
	Hit	No-hit	Total	Efficiency (%)	Hit	No-hit	Total	Efficiency (%)	Hit	No-hit	Total	Efficiency (%)
2005	8	23	31	26	12	26	38	32	40	17	57	70
2006	14	27	41	34	73	31	104	70	40	14	54	74
2009	16	16	32	50	59	19	78	76	58	40	98	59

**Table 7. Cover (%) of key species at Wigwam Flats #1 pre- and post-treatment.**

Species	2002	2003	T statistic	T critical	Probability	Significance <sup>1</sup>
Bluebunch wheatgrass	3.5	3.6	-0.048	1.677	0.481	NS
Idaho fescue	13.9	14.5	-0.243	1.677	0.405	NS
Prairie Junegrass	2.0	2.0	0.000	1.677	0.500	NS
Balsamroot	2.1	0.3	0.998	1.677	0.162	NS
Spotted knapweed	9.0	0.1	4.120	1.677	7.279 x 10 <sup>-5</sup>	P<0.05
Alfalfa	1.7	3.3	-0.689	1.677	0.247	NS
Saskatoon	1.2	1.1	0.830	1.677	0.467	NS
Prickly rose	0.5	1.1	-1.424	1.677	0.080	NS
Snowberry	4.4	3.0	1.085	1.677	0.142	NS

Species	2002	2004	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	3.5	3.6	-0.480	1.677	0.481	NS
Idaho fescue	13.9	10.1	1.727	1.677	0.0453	P<0.05
Prairie Junegrass	2.0	1.7	0.340	1.677	0.368	NS
Balsamroot	2.1	0.3	0.998	1.677	0.162	NS
Spotted knapweed	9.0	1.6	3.418	1.677	0.001	P<0.05
Alfalfa	1.7	3.8	-0.983	1.677	0.165	NS
Saskatoon	1.2	1.3	-0.264	1.677	0.400	NS
Prickly rose	0.5	0.9	0.976	1.677	0.167	NS
Snowberry	4.4	1.4	2.672	1.677	0.005	P<0.05

Species	2002	2005	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	3.5	1.1	1.490	1.677	0.071	NS
Idaho fescue	13.9	13.4	0.168	1.677	0.434	NS
Prairie Junegrass	2.0	1.9	0.109	1.677	0.46	NS
Balsamroot	2.1	0.6	0.813	1.677	0.210	NS
Spotted knapweed	9.0	0.6	3.721	1.677	0.001	P<0.05
Alfalfa	1.7	2.7	-0.567	1.677	0.287	NS
Saskatoon	1.2	0.8	1.044	1.677	0.151	NS
Prickly rose	0.5	1.1	-1.158	1.677	0.126	NS
Snowberry	4.4	0.9	3.276	1.677	0.001	P<0.05

Species	2002	2006	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	3.5	2.8	0.376	1.677	0.356	NS
Idaho fescue	13.9	12.3	0.647	1.677	0.260	NS
Prairie Junegrass	2.0	0.3	2.589	1.677	0.006	P<0.05
Balsamroot	2.1	0.6	0.837	1.677	0.203	NS
Spotted knapweed	9.0	0.3	4.038	1.677	9.45 x 10 <sup>-5</sup>	P<0.05
Alfalfa	1.7	3.3	-0.732	1.677	0.234	NS
Saskatoon	1.2	1.2	0.000	1.677	0.000	NS
Prickly rose	0.5	1.6	-1.141	1.677	0.093	NS
Snowberry	4.4	2.7	1.494	1.677	0.071	NS

Species	2002	2009	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	3.5	2.0	0.935	1.677	0.177	NS
Idaho fescue	13.9	14.1	-0.101	1.677	0.460	NS
Prairie Junegrass	2.0	1.2	1.198	1.677	0.118	NS
Balsamroot	2.1	1.2	0.480	1.677	0.317	NS
Spotted knapweed	9.0	1.2	3.587	1.677	3.9 x 10 <sup>-4</sup>	P<0.05
St. John's-wort	5.5	3.0	1.646	1.677	0.053	NS
Alfalfa	1.7	0.8	0.695	1.677	0.245	NS
Saskatoon	1.2	1.2	1.1	1.677	0.413	NS
Prickly rose	0.5	1.4	-1.846	1.677	0.035	P<0.05
Snowberry	4.4	2.5	1.613	1.677	0.057	NS

<sup>1</sup> Indicates comparisons that are statistically different (P<0.05) between years.

**Table 8. Cover (%) of key species at Wigwam Flats #2 pre- and post-treatment.**

Species	2002	2003	T statistic	T critical	Probability	Significance <sup>1</sup>
Bluebunch wheatgrass	4.6	7.8	-1.353	1.677	0.091	NS
Idaho fescue	0.6	0.6	0.105	1.677	0.458	NS
Prairie Junegrass	1.1	1.7	0.777	1.677	0.221	NS
Balsamroot	1.6	1.8	-0.099	1.677	0.461	NS
Spotted knapweed	10.4	7.9	1.023	1.677	0.155	NS
Alfalfa	1.9	5.5	-1.454	1.677	0.076	NS
Saskatoon	1.3	3.0	-1.513	1.677	0.068	NS
Prickly rose	3.9	3.6	0.191	1.677	0.424	NS
Snowberry	3.0	2.4	0.486	1.677	0.315	NS

Species	2002	2004	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	4.6	13.6	-3.063	1.677	0.002	P<0.05
Idaho fescue	0.6	0.9	-0.574	1.677	0.284	NS
Prairie Junegrass	1.1	0.5	1.066	1.677	0.146	NS
Balsamroot	1.6	0.1	1.426	1.677	0.080	NS
Spotted knapweed	10.4	0.8	5.299	1.677	1.38 x 10 <sup>-6</sup>	P<0.05
Alfalfa	1.9	2.9	-0.549	1.677	0.293	NS
Saskatoon	1.3	3.7	-1.989	1.677	0.026	P<0.05
Prickly rose	3.9	3.4	0.322	1.677	0.374	NS
Snowberry	3.0	2.2	0.743	1.677	0.230	NS

Species	2002	2005	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	4.6	12.8	-3.116	1.677	0.002	P<0.05
Idaho fescue	0.6	0.6	0.000	1.677	0.500	NS
Prairie Junegrass	1.1	0.4	1.744	1.677	0.044	P<0.05
Balsamroot	1.6	0.0	1.477	1.677	0.073	NS
Spotted knapweed	10.4	1.5	4.764	1.677	8.7 x 10 <sup>-6</sup>	P<0.05
Alfalfa	1.9	2.8	-0.475	1.677	0.318	NS
Saskatoon	1.3	2.2	-1.019	1.677	0.156	NS
Prickly rose	3.9	2.4	1.035	1.677	0.158	NS
Snowberry	3.0	2.8	0.129	1.677	0.449	NS

Species	2002	2006	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	4.6	9.3	-2.130	1.677	0.019	P<0.05
Idaho fescue	0.6	0.9	-0.573	1.677	0.284	NS
Prairie Junegrass	1.1	0.3	1.596	1.677	0.058	NS
Balsamroot	1.6	1.4	1.088	1.677	0.141	NS
Spotted knapweed	10.4	3.7	3.462	1.677	5.6 x 10 <sup>-4</sup>	P<0.05
Alfalfa	1.9	1.9	0.000	1.677	0.000	NS
Saskatoon	1.3	2.0	-0.709	1.677	0.241	NS
Prickly rose	3.9	5.8	-0.899	1.677	0.186	NS
Snowberry	3.0	6.2	-1.855	1.677	0.035	P<0.05

Species	2002	2009	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	4.6	7.5	-1.611	1.677	0.057	NS
Idaho fescue	0.6	0.2	1.137	1.677	0.131	NS
Prairie Junegrass	1.1	0.4	1.206	1.677	0.117	NS
Balsamroot	1.6	ND		1.677		
Spotted knapweed	10.4	2.5	3.973	1.677	1.2 x 10 <sup>-4</sup>	P<0.05
St. John's-wort	6.1	9.4	-1.364	1.677	0.089	NS
Alfalfa	1.9	1.3	0.397	1.677	0.347	NS
Saskatoon	1.3	2.8	-1.609	1.677	0.057	NS
Prickly rose	3.9	1.9	1.482	1.677	0.072	NS
Snowberry	3.0	2.7	0.186	1.677	0.427	NS

<sup>1</sup> Indicates comparisons that are statistically different (P<0.05) between years.

**Table 9. Cover (%) of key species at Wigwam Flats #3 pre- and post-treatment.**

Species	2002	2003	T statistic	T critical	Probability	Significance <sup>1</sup>
Bluebunch wheatgrass	12.2	10.5	0.618	1.677	0.270	NS
Idaho fescue	N/A	N/A	N/A	1.677	N/A	N/A
Prairie Junegrass	1.8	3.0	-1.185	1.677	0.121	NS
Balsamroot	0.7	0.3	0.667	1.677	0.254	NS
Spotted knapweed	8.1	0.5	5.255	1.677	1.6 X10 <sup>-6</sup>	P<0.05
Alfalfa	6.1	6.0	0.037	1.677	0.485	NS
Saskatoon	0.9	1.4	0.662	1.677	0.256	NS
Prickly rose	1.3	0.4	1.905	1.677	0.031	P<0.05
Snowberry	0.2	0.1	1.767	1.677	0.042	P<0.05

Species	2002	2004	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	12.2	8.2	1.439	1.677	0.078	NS
Idaho fescue	N/A	N/A	N/A	1.677	N/A	N/A
Prairie Junegrass	1.8	1.0	1.043	1.677	0.151	NS
Balsamroot	0.7	0.0	1.542	1.677	0.065	NS
Spotted knapweed	8.1	0.7	4.928	1.677	5.0 x 10 <sup>-6</sup>	P<0.05
Alfalfa	6.1	9.1	-1.133	1.677	0.131	NS
Saskatoon	0.9	1.8	-0.970	1.677	0.168	NS
Prickly rose	1.3	0.7	1.726	1.677	0.045	P<0.05
Snowberry	0.2	0.1	1.353	1.677	0.091	NS

Species	2002	2005	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	12.2	15.1	-0.975	1.677	0.167	NS
Idaho fescue	N/A	N/A	N/A	1.677	N/A	N/A
Prairie Junegrass	1.8	2.3	-0.534	1.677	0.298	NS
Balsamroot	0.7	0.0	1.542	1.677	0.065	NS
Spotted knapweed	8.1	1.4	4.229	1.677	5.1 x 10 <sup>-5</sup>	P<0.05
Alfalfa	6.1	9.4	-1.219	1.677	0.114	NS
Saskatoon	0.9	1.6	-0.859	1.677	0.197	NS
Prickly rose	1.3	0.4	2.483	1.677	0.008	P<0.05
Snowberry	0.2	0.1	0.814	1.677	0.210	NS

Species	2002	2006	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	12.2	9.1	0.122	1.677	0.134	NS
Idaho fescue	N/A	N/A	N/A	1.677	N/A	N/A
Prairie Junegrass	1.8	2.3	-0.590	1.677	0.279	NS
Balsamroot	0.7	0.4	0.568	1.677	0.286	NS
Spotted knapweed	8.1	1.5	3.964	1.677	1.2 x 10 <sup>-4</sup>	P<0.05
Alfalfa	6.1	9.2	-1.142	1.677	0.130	NS
Saskatoon	0.9	2.2	-1.471	1.677	0.083	NS
Prickly rose	1.3	1.7	-0.444	1.677	0.330	NS
Snowberry	0.2	0.4	-1.137	1.677	0.131	NS

Species	2002	2009	T statistic	T critical	Probability	Significance
Bluebunch wheatgrass	12.2	11.5	0.217	1.677	0.415	NS
Idaho fescue	N/A			1.677		
Prairie Junegrass	1.8	4.6	-2.363	1.677	0.011	P<0.05
Balsamroot	0.7	0.3	0.667	1.677	0.254	NS
Spotted knapweed	8.1	1.1	5.197	1.677	2.0 x 10 <sup>-6</sup>	P<0.05
St. John's-wort	1.3	5.1	-2.992	1.677	0.002	P<0.05
Alfalfa	6.1	7.7	-0.620	1.677	0.269	NS
Saskatoon	0.9	1.1	-0.393	1.677	0.348	NS
Prickly rose	1.3	0.5	1.966	1.677	0.027	P<0.05
Snowberry	0.2	0.1	1.353	1.677	0.091	NS

<sup>1</sup> Indicates comparisons that are statistically different (P<0.05) between years.

Spotted knapweed frequency has decreased from between 36 and 60% in 2002, to a range of 10 to 28% in 2006 (Table 1, 2, 3). These data indicate the importance of repeated treatments on heavily infested sites, particularly when the herbicide has limited residual effect. Sheley et al. (2000) concluded that spotted knapweed re-establishes itself from the soil seedbank, rather than regrowth from mature plants. Working in Montana, these authors found clopyralid plus 2, 4-D provided 100 and 50% control, one and three years, respectively, after treatment.

Other weed species remain dominant in the plant communities at Wigwam Flats. There is a potential for weed species that are not affected by the herbicide treatment to fill the niche remaining after the herbicide treatment has reduced spotted knapweed cover. Significant ( $P < 0.05$ ) increases in cover were noted for St. John's-wort at Wigwam #2 and #3 between 2002 and 2009 (Table 8, 9).

An objective of the project has been improvement in the quality of the plant community for ungulate winter range by increasing the bunchgrass component. However, significant ( $P < 0.05$ ) increases were only calculated for prairie Junegrass at Wigwam #3 in 2009 (Table 9).

Bunchgrass cover has been variable over the course of the trial. Bluebunch wheatgrass cover was significantly ( $P < 0.05$ ) higher at Wigwam #2 between 2002 and all years except 2003 and 2009 (Table 8). As bluebunch wheatgrass cover at Wigwam #2 has more than two times higher in most years since 2002 this likely represents a positive treatment response. There have been no significant ( $P > 0.05$ ) differences in bluebunch wheatgrass cover at Wigwam #1 and #3 between 2002 and any other monitoring year (Table 7, 9).

A significant decrease ( $P < 0.05$ ) was noted in Idaho fescue cover at Wigwam #1 between 2002 and 2004 (Table 7). However, Idaho fescue cover at Wigwam #1 has been similar among 2002 and the other monitoring years. It is poorly represented at Wigwam #2 and has not been recorded at Wigwam #3 in any year (Table 8, 9).

Prairie Junegrass cover has been more variable over the course of the trial. Significant decreases in prairie Junegrass cover were noted at Wigwam #1 and #2 between 2002 and 2003 (Table 7, 8), at Wigwam #2 in 2005, and at Wigwam #1 in 2006. This is in contrast to significant increases at Wigwam #3 between 2002 and 2009.

Herbicide treatment effects were likely not responsible for variations in bunchgrass cover (Table 5). The more probable explanation is spring forage use or fluctuations in precipitation among years. Field observations noted increased use on Idaho fescue at Wigwam #1 in 2004, particularly in the vicinity of transects 4 and 5.

While increased cover of bunchgrass species is a principal objective of the weed control program at Wigwam Flats, further monitoring is required to determine if these species have fully responded to reduced spotted knapweed competition. Sheley and Jacobs (1997) found the highest grass biomass three years after picloram application in a bluebunch wheatgrass-Idaho fescue habitat type in Montana.



Saskatoon, prickly rose and snowberry were also evaluated for treatment effects (Table 7, 8, 9). In 2009, significant ( $P < 0.05$ ) changes in cover were noted for prickly rose at Wigwam #1 and at Wigwam #3. However, as cover increased at Wigwam #1 and decreased at Wigwam #3, it is unlikely that these changes resulted from the herbicide treatment.

Shrub cover has been variable in other years also. Snowberry cover was significantly ( $P < 0.05$ ) lower at Wigwam #1 in 2004 and 2005, and at Wigwam #3 in 2003, than in 2002. Prickly rose cover was significantly ( $P < 0.05$ ) lower at Wigwam #3 in 2003, 2004 and 2005. As pre- and post-treatment cover of all species is low, these changes may be due to browsing or another type of disturbance other than herbicide effect. Conversely, at Wigwam #2, saskatoon and snowberry cover were higher ( $P < 0.05$ ) in 2004, and 2006, respectively. Further monitoring is required.

Overall, results from the study appear to confirm claims that Transline\* is not harmful to non-target species when applied at proper rates. No significant ( $P > 0.05$ ) impact was recorded on cover of the non-target forbs, balsamroot and alfalfa in 2003 to 2009 (Table 7, 8, 9). However, visible herbicide effects in the form of leaf-cupping, stem-twisting and yellowing were reported for both species (Table 5). It may be that balsamroot and alfalfa are sensitive to the increased application rates resulting from spray overlaps.

The outcome of the herbicide treatment may have been affected by other factors as well. Precipitation has likely influenced the composition of the plant community over the course of the trial. Grass cover was highest at all sites in 2005 when growing season precipitation was 175% of the long-term average (Table 10). Forb cover was also highest in 2005 of all the post-treatment years. Precipitation was also higher than the long-term average in 2002, 2004 and 2006. In contrast, growing season precipitation was 82% of the long-term normal in 2003.

In 2009 precipitation was 121% of the long-term average during the growing season, but it was below average in April and May (Table 10). This likely affected plant community cover, especially bunchgrasses, in 2009.

Grazing effects have also likely varied during the trial. While forage use data has not been collected, deer, elk and sheep feces cover is used as an indicator of the presence of grazing animals. These data reveal that use of these sites has fluctuated among years (Appendix 3, 4, 5). Annual variations in site conditions point to the importance of monitoring over successive years.

**Table 10. Precipitation at the Cranbrook Airport between 2002 and 2009.**

<b>Month</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>Long-Term Average</b>
January	1.63	2.88	2.40	2.51	5.32	2.84	2.64	0.84	2.51
February	4.24	1.34	0.96	0.44	1.64	3.17	1.46	1.70	2.16
March	1.70	2.82	1.06	2.44	1.51	2.08	1.34	4.92	2.11
April	2.64	3.77	2.28	0.58	4.36	0.97	1.12	2.51	2.84
May	12.83	3.68	3.62	4.86	2.28	6.70	3.42	1.92	4.57
June	3.30	3.39	4.26	19.00	5.62	6.08	3.62	5.24	5.08
July	3.38	0.38	4.38	1.54	4.50	1.84	2.96	5.38	3.40
August	1.14	1.54	6.75	6.28	2.16	1.02	2.86	6.42	2.92
September	4.39	4.86	6.37	6.54	3.68	1.20	1.80	1.26	3.07
October	0.28	1.92	3.01	2.78	4.96	1.28	1.74	5.98	1.83
November	1.04	3.22	1.34	3.78	9.68	2.46	1.54	1.26	3.61
December	5.41	2.44	2.89	2.30	3.60	5.86	4.96	1.74	3.00
<b>Total</b>	<b>41.98</b>	<b>32.24</b>	<b>39.32</b>	<b>53.05</b>	<b>49.31</b>	<b>35.50</b>	<b>29.46</b>	<b>39.17</b>	<b>37.11</b>
<b>Long-term Average (%)</b>	<b>113</b>	<b>87</b>	<b>106</b>	<b>143</b>	<b>133</b>	<b>96</b>	<b>79</b>	<b>106</b>	<b>100</b>
<b>Growing Season (Apr-Oct)</b>	<b>27.96</b>	<b>19.54</b>	<b>30.67</b>	<b>41.58</b>	<b>27.56</b>	<b>19.09</b>	<b>17.52</b>	<b>28.71</b>	<b>23.71</b>
<b>Long-term Average (%)</b>	<b>118</b>	<b>82</b>	<b>129</b>	<b>175</b>	<b>116</b>	<b>81</b>	<b>74</b>	<b>121</b>	<b>100</b>

Note: December, 2009 totals up to December 22 only.

## 6.0 Recommendations

The high level of weed invasion at the monitoring sites at Wigwam Flats continues to be a concern, especially considering their value as winter/spring range. Herbicide treatment should continue as it is the only short-term option available to assist native vegetation in out-competing weed species, and to check weed encroachment into other important winter/spring range areas. An important component of this project is to eliminate seed formation. As Transline\* has no residual effect the spotted knapweed content of the soil seed bank will be an important factor in determining the duration of the program.

Transline\* has been shown to be an effective treatment agent in controlling populations of spotted knapweed in native range plant communities. Negative impacts on non-target grasses, forbs and shrubs appear to be minimal. Positive effects on bluebunch wheatgrass populations at Wigwam #2 and prairie Junegrass at Wigwam #3 indicate the forage production objectives of this project are attainable. However significant changes in the plant community, and therefore the quality of these sites as ungulate winter range, may require a longer time-frame to materialize.

The lack of effective control at Wigwam #2 in 2003, non-target hits, and herbicide misses on all sites in all years point to other problems. Application problems are responsible for the poor performance of the herbicide at Wigwam #2 in 2003 and likely for the leaf-cupping, stem-twisting, and yellowing noted at all sites. Wigwam #2 is the steepest of the three sites, necessitating application by backpack sprayer. Some coordination difficulties led to sections of Wigwam #2 being missed by the applicators in 2003. Wigwam #1 and #3 were mainly sprayed by ATV-mounted boom sprayer, but some areas at the edges of the sites were too steep for the ATV, so were sprayed by the backpack crew. It is likely that some overlap occurred and this was responsible for non-target species damage. It should be re-stated that herbicide effect was confined to some distortion of the plant's growing habit, and there were no significant ( $P>0.05$ ) reductions in cover (Table 7, 8, 9).

During the course of the trial the best control has been attained at Wigwam #1 and #3. However, in 2009 herbicide efficiency was highest at Wigwam #2, so this indicates that backpack application can provide good results. The lower efficiencies at Wigwam #1 and #3 are likely due to the herbicide treatment only being applied as spot spraying. Efficiency actually increased at Wigwam #1 in 2009, compared to 2005 and 2006. However, at Wigwam #3 efficiency decreased in 2009 as compared to 2005 and 2006, mainly as a result of spotted knapweed rosettes being missed while spot spraying.

The principal objective of this program, reducing spotted knapweed populations, has been reached. The critical question is whether this level of control is sustainable without repeated herbicide application. If seed production has been curtailed, and the soil seed bank has been depleted sufficiently, then biocontrol agents should be able to maintain spotted knapweed populations in the order of 1 to 2%. Although spotted knapweed cover has been reduced by as much as eight-fold among sites between 2002 and 2009, frequency has only been reduced by between 50 and 75%. It is recommended that the treatment program continue for an additional three to five years.

The adjacent ROW is likely the most important source of re-infestation. The ROW has received herbicide treatment with Transline herbicide, but field observations confirm that spotted knapweed populations persist. A trial should be initiated on the ROW that compares the effectiveness of a clopyralid-based herbicide with that of a picloram-based formulation, which has a soil residual effect. Alternative treatments, such as fertilizer and seeding treatments should be investigated in conjunction with the herbicide treatment.

Specific recommendations for the noxious weed control and monitoring program at Wigwam Flats in 2010 are:

- Re-apply herbicide at all sites before spotted knapweed flowers
- Continue the monitoring program whether herbicide is re-applied or not
- Re-sample sites in late June/early July using the same methodology
- Re-photograph photopoints
- Apply statistical procedures described above to determine if differences between pre- and post-treatment plant communities are significant ( $P < 0.05$ ) and ongoing
- Initiate a trial with herbicide and alternative treatments on the adjacent ROW

No other management recommendations are included at this time.

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## **8.0 Appendices**

## Appendix 1. Plant Species. <sup>1</sup>

Latin Name	Common Name
<i>Achillea millefolium</i> ,ACMI, 2	Western yarrow
<i>Agoseris glauca</i> ,AGGL, 2	Smooth agoseris
<i>Agropyron spicatum</i> ,AGSP, 1	Bluebunch wheatgrass
<i>Agropyron trachycaulum</i> ,AGTR, 1	Slender wheatgrass
<i>Allium cernuum</i> ,ALCE, 2	Nodding onion
<i>Amelanchier alnifolia</i> ,AMAL, 3	Saskatoon
<i>Anthemis arvensis</i> ,ANAR, 2	Scentless chamomile
<i>Antennaria microphylla</i> ,ANMI, 2	Rosy pussytoes
<i>Anemone multifida</i> ,ANMU, 2	Pacific anemone
<i>Androsace septentrionalis</i> ,ANSE, 2	Fairy candelabra
<i>Apocynum androsaemifolium</i> ,APAN, 2	Spreading dogbane
<i>Arnica fulgens</i> ,ARFU, 2	Orange arnica
<i>Arabis holboellii</i> ,ARHO, 2	Holboell's rockcress
<i>Arctostaphylos uva-ursi</i> ,ARUV, 3	Bearberry
<i>Aster conspicuous</i> ,ASCO, 2	Showy aster
<i>Aster foliaceus</i> ,ASFO, 2	Leafy aster
<i>Astragalus miser</i> ,ASMI, 2	Timber milkvetch
<i>Balsamorhiza sagittata</i> ,BASA, 2	Balsamroot
<i>Berberis repens</i> ,BERE, 3	Low oregongrape
<i>Bromus</i> spp.,BRSP, 1	Brome grass species
<i>Bromus tectorum</i> ,BRTE, 1	Cheatgrass
<i>Calochortus apiculatus</i> ,CAAP, 2	Baker's mariposa lily
<i>Carex concinnoidea</i> ,CADO, 1	Northwest sedge
<i>Calochortus macrocarpum</i> ,CAMA, 2	Mariposa lily
<i>Camelina microcarpa</i> ,CAMI, 2	Little-podded false flax
<i>Castilleja miniata</i> ,CAMN, 2	Common paintbrush
<i>Campanula rotundifolia</i> ,CARO, 2	Common harebell
<i>Calamagrostis rubescens</i> ,CARU, 1	Pinegrass
<i>Castilleja thompsonii</i> ,CATH, 2	Thompson's paintbrush
<i>Cerastium arvense</i> ,CEAR, 2	Chickweed
<i>Centaurea maculosa</i> ,CEMA, 2	Spotted knapweed
<i>Chrysanthemum leucanthemum</i> ,CHLE, 2	Ox-eye daisy
<i>Chrysopsis villosa</i> ,CHVI, 2	Hairy goldaster
<i>Cirsium arvense</i> ,CIAR, 2	Canada thistle
<i>Crepis atrabarba</i> ,CRAT, 2	Slender hawkbeard
<i>Cynoglossum officinale</i> ,CYOF, 2	Houndstongue
<i>Delphinium nuttallianum</i> ,DENU, 2	Upland larkspur

<sup>1</sup> Plant species list includes IDFdm2 species listed in text and tables.



## Appendix 1. Plant Species (cont'd).

Latin Name	Common Name
Erigeron compositus,ERCO, 2	Compound fleabane
Erigeron corymbosus,ERCR, 2	Long-leafed daisy
Erigeron pumilis,ERPU, 2	Shaggy fleabane
Festuca idahoensis,FEID, 1	Idaho fescue
Festuca scabrella,FESC, 1	Rough fescue
Fragaria virginiana,FRVI, 2	Wild strawberry
Hieracium pratense,HIPR, 2	Yellow hawkweed
Hypericum perforatum,HYPE, 2	St. John's-wort
Juniper communis, JUCO, 3	Common juniper
Koeleria cristata,KOCR, 1	Prairie junegrass
Larix occidentalis,LAOC, 4	Western larch
Linnaea borealis,LIBO, 2	Twinflower
Linum perenne,LIPE, 2	False flax
Lithospermum ruderae,LIRU, 2	Stoneseed
Lomatium macrocarpum,LOMA, 2	Desert parsley
Lomatium triternatum,LOTR, 2	Nine-leafed lomatium
Melilotus alba,MEAL, 2	White sweet-clover
Medicago lupulina,MELU, 2	Black medic
Medicago sativa,MESA, 2	Alfalfa
Melilotus officianalis,MEOF, 2	Yellow sweet-clover
Monarda fistulosa,MOFI, 2	Wild bergamo
Orthocarpus luteus,ORLU, 2	Yellow owl-clover
Orthocarpus tenuifolia,ORTE, 2	Purple owl-clover
Penstemon confertus, PECO, 2	Tiny penstemon
Phleum pratense,PHPR, 1	Timothy
Phlox rigida,PHRI, 2	Spiny phlox
Phacelia sericeus,PHSE, 2	Silky phacelia
Pinus contorta,PICO, 3	Lodgepole pine
Pinus ponderosa,PIPO, 3	Ponderosa pine
Poa compressa,POCO, 1	Canada bluegrass
Poa junctifolia, POJU, 1	Alkali bluegrass
Poa pratensis,POPR, 1	Kentucky bluegrass
Potentilla recta,PORE, 2	Sulphur cinquefoil
Poa sandbergii,POSA, 1	Sandberg's bluegrass
Populus tremuloides,POTR, 3	Trembling aspen
Prunus virginiana,PRVI, 3	Chokecherry
Pseudotsuga menziesii,PSME, 3	Douglas-fir
Purshia tridentata,PUTR, 3	Bitterbrush
Ribes cereum,RISP, 3	Squaw currant

## Appendix 1. Plant Species (cont'd).

Latin Name	Common Name
Rhianthus minor,RHMI, 2	Yellow rattle
Rosa acicularis,ROAC, 3	Prickly rose
Salix spp.,SASP, 3	Willow species
Senecio canus,SECA, 2	Prairie groundsel
Sedum lanceolatum,SELA, 2	Lance-leafed stonecrop
Shepherdia canadensis,SHCA, 3	Soopolallie
Solidago spathulata,SOSP, 2	Dune goldenrod
Spirea betulifolia,SPBE, 3	Birch-leafed spirea
Stipa columbiana,STCL, 1	Columbia needlegrass
Stipa comata,STCO, 1	Needle-and-thread
Stipa occidentalis,STOC, 1	Western needlegrass
Stipa richardsonii,STRI, 1	Richardson's needlegrass
Symphoricarpus albus,SYAL, 3	Snowberry
Taraxacum officinale,TAOF, 2	Dandelion
Tragopogon pratense,TRPR, 2	Goatsbeard
Verbascum thapsis,VETH, 2	Common mullein
Viola adunca,VIAD, 2	Early blue violet
Zygadenus venenosus,ZYVE, 2	Death camas

## Appendix 2. Intensive Survey Methodology.

<b>Intensive Survey Plot</b>	<b>Airphoto</b>	<b>Elevation (m)</b>	<b>Slope (°)</b>	<b>Aspect (°)</b>	<b>Soil Association</b>
Wigwam #1	BCC00075-103	1030	0-20	200	Keeney
Wigwam #2	BCC00075-103	1020-1050	20-30	245	Keeney
Wigwam #3	BCC00075-103	1035-1050	5-20	205	Keeney

### Daubenmire Cover Classes

1 = 0 to 5%; 2 = 6 to 25%; 3 = 26 to 50%; 4 = 51 to 75%; 5 = 76 to 95%; 6 = 96 to 100%

### Photopoints

A permanent photo-point was marked with a 7 cm X 11 cm metal tag at T3+30m.

Five photos were taken from this point;

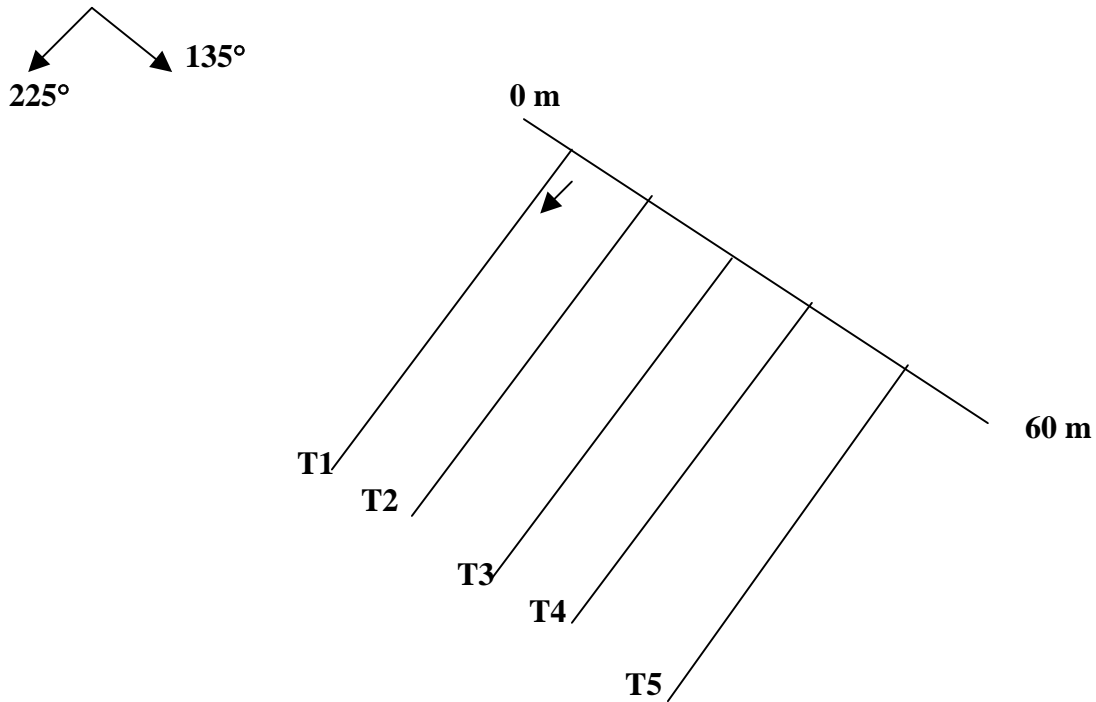
- 1) 90 degrees at T3+30m
- 2) oblique at T3+25m
- 3) 0 degrees at T3+25m
- 4) oblique at T3+35m
- 5) 0 degrees at T3+35m

**Appendix 2. (cont'd)**

**Sampling Layout – Wigwam #1**

Transect	Dist from 0										
		Plot 1	2	3	4	5	6	7	8	9	10
1	7m	4	8	13	23	28	35	42	51	57	60
2	19	3	6	12	16	24	26	31	43	58	60
3	30	3	9	12	17	23	38	40	47	53	58
4	37	1	5	7	15	24	33	36	39	44	60
5	52	2	5	11	18	27	34	46	55	58	59

**Wigwam #1**



**Sample:** North to south, east side of transect.

**Tie Point:** Located S of the pipeline right-of-way. Painted rock.

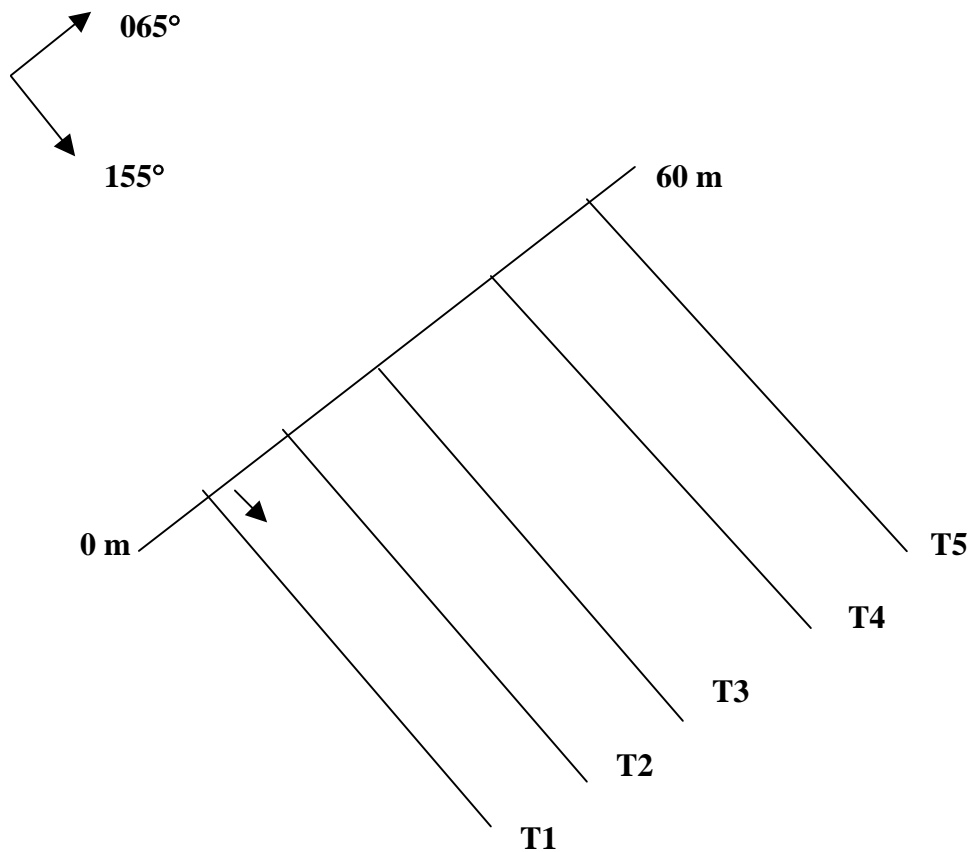
**TP to T0 Baseline-** 225°/6 m - from TP to T2+0 m.

Appendix 2. (cont'd)

Sampling Layout – Wigwam #2

Transect	Dist from 0										
	Plot	1	2	3	4	5	6	7	8	9	10
1	7m	4	8	13	23	28	35	42	51	57	60
2	19	3	6	12	16	24	26	31	43	58	60
3	30	3	9	12	17	23	38	40	47	53	58
4	37	1	5	7	15	24	33	36	39	44	60
5	52	2	5	11	18	27	34	46	55	58	59

Wigwam #2



**Sample:** North to south, east side of transect.

**Tie Point:** 70 cm dbh Py beside right-of way – tagged and flagged.

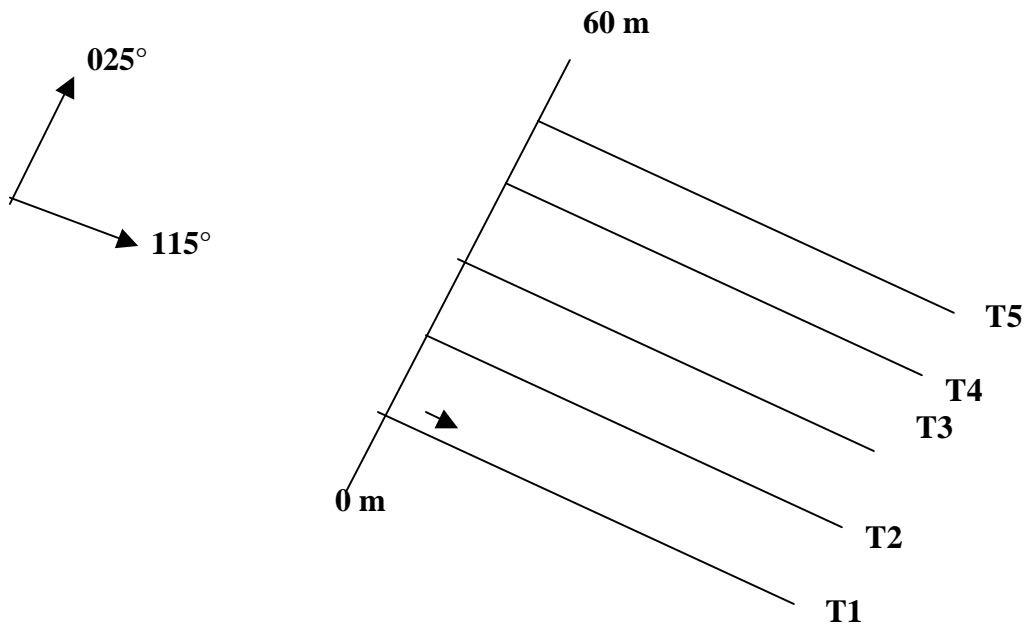
**TP to T0 Baseline:** 320°/10 m from TP to T1 + 60 m.

Appendix 2. (cont'd)

Sampling Layout – Wigwam #3

Transect	Dist from 0										
	Plot	1	2	3	4	5	6	7	8	9	10
1	7m	4	8	13	23	28	35	42	51	57	60
2	19	3	6	12	16	24	26	31	43	58	60
3	30	3	9	12	17	23	38	40	47	53	58
4	37	1	5	7	15	24	33	36	39	44	60
5	52	2	5	11	18	27	34	46	55	58	59

Wigwam #3



**Sample:** North to south, east side of transect.

**Tie Point:** Located to N of pipeline right-of-way.

**TP to T0 Baseline-** 010°/70 m - from painted rock on S side of right-of-way (same TP as Wigwam #1) to T1 + 0 m.

**Appendix 2. (cont'd)**

**Wigwam Flats – UTM Co-ordinates**

<b>Site</b>	<b>Shot</b>	<b>El (m)</b>	<b>Easting</b>	<b>Northing</b>
Wigwam #1	Tie-point	1042	0639603	5457826
	Baseline – M0	1038	0639578	5457831
	T1 – M0	1039	0639584	5457826
	T2 – M0	1039	0639593	5457817
	T3 – M0	1039	0639602	5457810
	T4 – M0	1039	0639608	5457806
	T5 – M0	1036	0639619	5457795
	Baseline – M60	1033	0639625	5457790
	T5 – M60	1041	0639580	5457750
	T4 – M60	1039	0639570	5457760
	T3 – M60	1039	0639565	5457765
	T2 – M60	1037	0639556	5457772
	T1 – M60	1034	0639547	5457779
Wigwam #2	Tie-point	1025	0639444	5458008
	Baseline - M0	1019	0639402	5458062
	T1 – M0	1023	0639407	5458066
	T2 – M0	1027	0639416	5458072
	T3 - M0	1032	0639425	5458076
	T4 – M0	1035	0639431	5458079
	T5 – M0	1042	0639443	5458085
	Baseline – M60	1045	0639449	5458088
	T5 – M60	1045	0639473	5458033
	T4 – M60	1037	0639461	5458027
	T3 – M60	1034	0639456	5458024
	T2 – M60	1030	0639446	5458020
	T1 – M60	1025	0639436	5458014
Wigwam #3	Tie-point	1042	0639603	5457826
	Baseline – M0	1041	0639611	5457890
	T1 – M0	1044	0639613	5457896
	T2 – M0	1046	0639618	5457907
	T3 – M0	1049	0639621	5457917
	T4 – M0	1050	0639624	5457924
	T5 – M0	1055	0639629	5457938
	Baseline – M60	1053	0639632	5457945
	T5 – M60	1054	0639685	5457918
	T4 – M60	1049	0639679	5457905
	T3 – M60	1047	0639678	5457898
	T2 – M60	1044	0639674	5457888
	T1 – M60	1041	0639669	5457878

### Appendix 3. Cover and frequency of plant species at Wigwam Flats #1, 2002 to 2009.

Species	2002		2003		2004		2005		2006		2009	
	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency
<b>Grass and Grasslike</b>												
Idaho fescue	13.9	74.0	14.5	70.0	10.1	70.0	13.4	68.0	12.3	76.0	14.1	74.0
Canada bluegrass	5.3	54.0	9.1	54.0	4.6	54.0	6.4	50.0	6.9	58.0	3.5	46.0
Pinegrass	3.6	18.0	6.4	26.0	3.1	24.0	5.5	26.0	2.8	24.0	2.8	32.0
Bluebunch wheatgrass	3.5	16.0	3.6	18.0	3.5	30.0	1.1	14.0	2.8	16.0	2.0	18.0
Prairie Junegrass	2.0	28.0	2.0	28.0	1.7	26.0	1.9	24.0	0.3	12.0	1.2	24.0
Kentucky bluegrass	1.0	10.0	0.5	8.0	1.1	12.0	1.2	8.0	0.4	6.0	0.3	2.0
Northwest sedge	0.3	2.0	0.4	4.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
Columbia needlegrass	0.1	4.0	0.1	4.0	0.4	4.0	0.4	6.0	0.9	6.0	0.7	8.0
Alkali bluegrass	0.1	2.0	0.2	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cheatgrass	0.0	0.0	0.0	0.0	1.2	8.0	0.1	4.0	0.1	2.0	0.3	2.0
Rough fescue	0.0	0.0	0.0	0.0	0.3	2.0	0.0	0.0	0.0	0.0	0.3	10.0
Timothy	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Western needlegrass	0.0	0.0	0.0	0.0	0.1	2.0	0.3	2.0	0.6	4.0	0.0	0.0
Sandberg's bluegrass	0.0	0.0	0.0	0.0	0.5	10.0	0.5	8.0	0.5	10.0	1.3	20.0
<b>Total Grass and Grasslike</b>	<b>29.8</b>		<b>36.5</b>		<b>26.3</b>		<b>30.6</b>		<b>27.6</b>		<b>26.3</b>	
<b>Forbs</b>												
Spotted knapweed	9.0	36.0	0.1	2.0	1.6	14.0	0.6	4.0	0.3	10.0	1.2	18.0
St. John's-wort	5.5	50.0	3.0	38.0	4.3	42.0	5.8	54.0	2.7	38.0	3.0	38.0
Desert parsley	3.6	34.0	2.3	32.0	3.2	36.0	3.6	32.0	1.7	26.0	3.6	32.0
Leafy aster	2.3	20.0	1.0	10.0	0.4	6.0	0.5	10.0	0.5	8.0	0.2	6.0
Balsamroot	2.1	6.0	0.3	2.0	0.3	2.0	0.6	4.0	0.6	4.0	1.2	8.0
Western yarrow	2.0	28.0	0.6	14.0	1.0	18.0	0.5	8.0	1.0	18.0	0.1	2.0
Alfalfa	1.7	10.0	3.3	14.0	3.8	18.0	2.7	18.0	3.3	16.0	0.8	10.0
Death camas	1.2	16.0	0.6	4.0	0.6	12.0	0.5	8.0	0.2	6.0	0.0	0.0
Timber milkvetch	1.1	14.0	0.1	2.0	0.1	4.0	0.1	2.0	0.0	0.0	0.0	0.0



Appendix 3 (cont'd). Species	2002		2003		2004		2005		2006		2009	
	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
	%	%	%	%	%	%	%	%	%	%	%	%
Orange arnica	0.9	14.0	0.4	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chickweed	0.9	24.0	1.7	36.0	0.7	16.0	0.0	0.0	0.9	36.0	0.3	12.0
Spiny phlox	0.8	12.0	1.7	16.0	1.6	14.0	1.1	14.0	0.8	10.0	1.1	12.0
Baker's mariposa lily	0.7	18.0	0.9	16.0	0.6	12.0	0.2	6.0	0.5	18.0	0.0	0.0
Upland larkspur	0.7	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Goatsbeard	0.6	4.0	0.1	2.0	0.4	4.0	0.1	4.0	0.0	0.0	0.0	0.0
Fairy candelabra	0.6	22.0	0.2	6.0	1.3	22.0	1.9	34.0	1.1	22.0	0.3	10.0
Rosy pussytoes	0.5	8.0	0.1	4.0	0.2	6.0	0.1	2.0	0.1	4.0	0.0	0.0
Wild strawberry	0.5	8.0	0.1	2.0	0.0	0.0	0.6	4.0	0.1	2.0	0.0	0.0
Dandelion	0.5	8.0	0.1	4.0	0.0	0.0	0.1	2.0	0.5	10.0	0.1	4.0
Spreading dogbane	0.4	4.0	1.1	12.0	3.0	20.0	3.2	28.0	1.9	16.0	2.0	16.0
Hairy goldaster	0.4	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow sweet-clover	0.4	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
Showy aster	0.3	2.0	0.2	6.0	0.1	2.0	0.6	4.0	0.4	6.0	0.1	2.0
Common red paintbrush	0.3	2.0	0.2	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulphur cinquefoil	0.2	8.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
Early blue violet	0.2	8.0	0.3	12.0	0.2	8.0	0.3	10.0	0.1	2.0	0.1	2.0
Nine-leafed lomatium	0.2	6.0	0.1	4.0	0.1	4.0	0.0	0.0	0.1	4.0	0.0	0.0
Prairie groundsel	0.2	6.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
Lance-leaved stonecrop	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.0	0.0	0.0
Pacific anemone	0.1	2.0	0.1	2.0	0.0	0.0	0.0	0.0	0.1	2.0	0.1	2.0
Holboell's rockcress	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow hawkweed	0.1	2.0	0.2	8.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0
Smooth agoseris	0.0	0.0	0.5	8.0	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow rattle	0.0	0.0	0.5	8.0	0.0	0.0	1.3	12.0	1.3	10.0	0.0	0.0
Tiny penstemon	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.8	2.0	0.0	0.0
Dune goldenrod	0.0	0.0	0.1	2.0	0.3	12.0	0.0	0.0	0.4	4.0	0.4	6.0
Purple owl-clover	0.0	0.0	0.1	4.0	0.5	8.0	0.1	2.0	0.2	8.0	0.1	4.0

Appendix 3 (cont'd). Species	2002		2003		2004		2005		2006		2009	
	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
	%	%	%	%	%	%	%	%	%	%	%	%
Monarda	0.0	0.0	0.1	2.0	0.0	0.0	0.1	2.0	0.0	0.0	0.3	2.0
Silky phacelia	0.0	0.0	0.1	2.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow owl-clover	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black medic	0.0	0.0	0.0	0.0	0.5	10.0	0.0	0.0	0.2	6.0	0.0	0.0
Common harebell	0.0	0.0	0.0	0.0	0.5	18.0	0.5	18.0	0.1	4.0	0.0	0.0
Slender hawksbeard	0.0	0.0	0.0	0.0	0.4	6.0	0.4	6.0	0.1	2.0	0.4	6.0
Nodding onion	0.0	0.0	0.0	0.0	0.1	4.0	0.1	2.0	0.2	6.0	0.2	8.0
Northern bedstraw	0.0	0.0	0.0	0.0	0.1	4.0	0.0	0.0	0.2	8.0	0.0	0.0
Alumroot	0.0	0.0	0.0	0.0	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Little-podded false flax	0.0	0.0	0.0	0.0	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Shaggy fleabane	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Golden clover	0.0	0.0	0.0	0.0	0.0	0.0	4.0	14.0	0.0	0.0	0.0	0.0
Heart-leaved arnica	0.0	0.0	0.0	0.0	0.0	0.0	0.4	14.0	0.0	0.0	0.0	0.0
Mariposa lily	0.0	0.0	0.0	0.0	0.0	0.0	0.2	6.0	0.1	2.0	0.0	0.0
Stoneseed	0.0	0.0	0.0	0.0	0.0	0.0	0.4	6.0	0.1	4.0	0.0	0.0
Long-leaf fleabane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	6.0	0.0	0.0
Tiny penstemon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
Field peppergrass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
Norway cinquefoil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
Scouler's hawkweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.0
<b>Total Forbs</b>	<b>38.2</b>		<b>19.6</b>		<b>25.7</b>		<b>29.9</b>		<b>20.0</b>		<b>15.4</b>	

Appendix 3 (cont'd).	2002		2003		2004		2005		2006		2009	
Species	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
	%	%	%	%	%	%	%	%	%	%	%	%
<b>Shrubs</b>												
Snowberry	4.4	50.0	3.0	32.0	1.4	36.0	0.9	24.0	2.7	40.0	2.5	38.0
Willow species	1.2	8.0	0.3	2.0	0.3	2.0	1.3	2.0	0.8	2.0	0.8	2.0
Saskatoon	1.2	16.0	1.1	14.0	1.3	14.0	0.8	12.0	1.2	16.0	1.1	12.0
Prickly rose	0.5	18.0	1.1	24.0	0.9	16.0	1.1	12.0	1.6	16.0	1.4	24.0
Low oregongrape	0.3	12.0	0.6	14.0	0.5	10.0	0.4	6.0	0.7	16.0	0.6	14.0
Birch-leafed spirea	0.2	6.0	0.2	6.0	0.2	6.0	0.0	0.0	0.2	8.0	0.2	6.0
Soopolallie	0.0	0.0	0.3	2.0	0.3	2.0	0.1	2.0	0.3	2.0	0.1	4.0
Chokecherry	0.0	0.0	0.0	0.0	0.0	0.0	0.4	4.0	0.1	2.0	0.1	2.0
Squaw currant	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0	0.1	2.0	0.1	2.0
Grouseberry	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
<b>Total Shrubs</b>	<b>7.8</b>		<b>6.6</b>		<b>4.9</b>		<b>5.1</b>		<b>7.5</b>		<b>6.6</b>	
<b>Trees</b>												
Trembling aspen	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.0	0.1	2.0
Douglas-fir regen	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.1	2.0	0.1	2.0
<b>Total Trees</b>	<b>0.1</b>		<b>0.0</b>		<b>0.0</b>		<b>0.1</b>		<b>0.9</b>		<b>0.1</b>	
<b>Substrate</b>												
Litter	61.5	100.0	57.8	100.0	55.0	100.0	45.5	100.0	51.4	100.0	38.0	100.0
Bryophytes	27.3	88.0	31.1	86.0	22.5	88.0	34.4	96.0	33.1	92.0	42.8	90.0
Soil	2.4	48.0	2.6	42.0	6.7	74.0	3.6	38.0	2.8	44.0	13.0	66.0
Rock	2.0	18.0	2.4	24.0	2.1	14.0	1.9	26.0	2.2	26.0	2.8	30.0
Litter >2cm	0.7	6.0	0.4	4.0	0.7	8.0	1.1	12.0	0.7	8.0	0.3	2.0
Sheep feces	0.5	8.0	0.0	0.0	0.6	14.0	0.3	12.0	0.6	12.0	0.6	14.0
Elk feces	0.4	16.0	0.3	10.0	0.9	8.0	1.2	18.0	0.5	8.0	0.8	22.0
Deer feces	0.1	2.0	0.4	6.0	0.4	4.0	0.1	2.0	0.0	0.0	0.0	0.0

#### Appendix 4. Cover and frequency of plant species at Wigwam Flats #2, 2002 to 2009.

Species	2002		2003		2004		2005		2006		2009	
	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency
<b>Grass and Grasslike</b>												
Canada bluegrass	6.8	50.0	7.3	62.0	6.0	50.0	9.4	64.0	6.2	56.0	7.5	56.0
Bluebunch wheatgrass	4.6	36.0	7.8	42.0	13.6	54.0	12.8	54.0	9.3	52.0	4.9	56.0
Pinegrass	4.0	34.0	4.5	36.0	3.3	26.0	2.4	24.0	1.3	10.0	1.0	18.0
Columbia needlegrass	2.5	18.0	2.6	44.0	2.8	22.0	6.1	42.0	2.5	28.0	4.3	42.0
Cheatgrass	1.6	22.0	0.4	14.0	0.5	8.0	0.9	24.0	0.2	8.0	1.0	12.0
Prairie Junegrass	1.1	14.0	1.7	16.0	0.5	8.0	0.4	4.0	0.3	10.0	0.4	6.0
Kentucky bluegrass	1.1	14.0	3.3	26.0	1.2	16.0	2.1	14.0	3.1	20.0	0.4	6.0
Bromegrass species	1.0	10.0	0.6	14.0	2.0	30.0	1.2	20.0	1.8	40.0	0.5	8.0
Western needlegrass	0.7	6.0	0.1	4.0	3.0	20.0	2.6	34.0	1.7	26.0	1.5	28.0
Idaho fescue	0.6	4.0	0.6	12.0	0.9	6.0	0.6	4.0	0.9	6.0	0.2	6.0
Timothy	0.3	2.0	0.8	12.0	1.4	14.0	1.9	16.0	1.8	20.0	2.0	20.0
Slender wheatgrass	0.1	2.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
Northwest sedge	0.0	0.0	0.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<b>Total Grass and Grasslike</b>	<b>24.2</b>		<b>29.8</b>		<b>34.9</b>		<b>40.2</b>		<b>28.7</b>		<b>23.5</b>	
<b>Forbs</b>												
Spotted knapweed	10.4	60.0	7.9	44.0	0.8	10.0	1.5	10.0	3.7	28.0	2.5	18.0
Monarda	6.3	40.0	4.0	26.0	3.5	30.0	3.4	26.0	3.3	32.0	6.7	42.0
St. John's-wort	6.1	36.0	4.3	40.0	8.0	50.0	13.3	54.0	10.2	68.0	9.4	68.0
Spreading dogbane	3.4	26.0	2.9	20.0	4.6	28.0	2.7	28.0	3.4	26.0	2.9	26.0
Alfalfa	1.9	6.0	5.5	18.0	2.9	12.0	2.8	16.0	1.9	6.0	1.3	12.0
Balsamroot	1.6	6.0	1.8	4.0	0.1	2.0	0.0	0.0	0.4	4.0	0.0	0.0
Wild strawberry	1.0	8.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Western yarrow	0.9	16.0	0.1	4.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0
Little-podded false flax	0.9	26.0	0.3	10.0	0.5	10.0	0.0	0.0	0.0	0.0	0.0	0.0
Stoneseed	0.7	6.0	0.4	6.0	0.3	2.0	0.4	4.0	0.5	10.0	1.2	8.0

Appendix 4 (cont'd). Species	2002		2003		2004		2005		2006		2009	
	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
	%	%	%	%	%	%	%	%	%	%	%	%
Leafy aster	0.6	12.0	0.4	6.0	0.0	0.0	0.3	2.0	0.1	2.0	0.3	2.0
Fairy candelabra	0.5	8.0	0.0	0.0	0.2	8.0	0.3	10.0	0.0	0.0	0.0	0.0
Sulphur cinquefoil	0.5	8.0	0.8	12.0	1.4	6.0	1.8	14.0	0.5	10.0	1.6	14.0
Goatsbeard	0.4	6.0	0.0	0.0	0.1	2.0	0.1	4.0	0.0	0.0	0.0	0.0
Yellow rattle	0.4	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Rosy pussytoes	0.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chickweed	0.4	14.0	0.7	16.0	0.6	12.0	0.2	6.0	0.3	10.0	0.3	12.0
Hairy goldaster	0.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow sweet-clover	0.3	12.0	0.2	6.0	0.0	0.0	3.2	0.0	0.3	2.0	1.9	16.0
Timber milkvetch	0.2	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0
Upland larkspur	0.2	6.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Showy aster	0.1	2.0	0.0	0.0	0.4	6.0	0.0	0.0	0.0	0.0	0.0	0.0
Common harebell	0.1	2.0	0.3	10.0	0.0	0.0	0.1	4.0	0.2	8.0	0.0	0.0
False flax	0.1	2.0	0.1	2.0	0.0	0.0	0.2	6.0	0.1	2.0	0.0	0.0
Tiny penstemon	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common mullien	0.1	2.0	0.1	2.0	1.9	8.0	1.9	8.0	1.3	12.0	0.0	0.0
Death camas	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
White sweet-clover	0.0	0.0	0.3	2.0	0.0	0.0	0.0	0.0	0.4	6.0	0.0	0.0
Black medic	0.0	0.0	0.1	4.0	0.1	4.0	0.4	4.0	0.0	0.0	0.0	0.0
Field peppergrass	0.0	0.0	0.0	0.0	1.0	18.0	0.2	6.0	0.3	2.0	0.1	2.0
Silky phacelia	0.0	0.0	0.0	0.0	0.4	6.0	0.0	0.0	0.1	4.0	0.0	0.0
Nodding onion	0.0	0.0	0.0	0.0	0.1	4.0	0.1	4.0	0.1	2.0	0.1	2.0
Spiny phlox	0.0	0.0	0.0	0.0	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Baker's mariposa lily	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.0	0.0	0.0	0.0	0.0
Early blue violet	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
Filago	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.1	2.0
Golden clover	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0	0.0	0.0	0.1	4.0
Northern bedstraw	0.0	0.0	0.0	0.0	0.0	0.0	0.2	8.0	0.0	0.0	0.0	0.0

Appendix 4 (cont'd). Species	2002		2003		2004		2005		2006		2009	
	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
	%	%	%	%	%	%	%	%	%	%	%	%
Pacific anemone	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
Long-leaf fleabane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	18.0	0.0	0.0
Dune goldenrod	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0	0.0	0.0
Scouler's hawkweed	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	4.0
Pale comandra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0
<b>Total Forbs</b>	<b>37.0</b>		<b>29.8</b>		<b>26.7</b>		<b>33.2</b>		<b>27.8</b>		<b>28.8</b>	
<b>Shrubs</b>												
Prickly rose	3.9	40.0	3.6	34.0	3.4	48.0	2.5	40.0	5.8	46.0	1.9	36.0
Snowberry	3.0	50.0	2.4	36.0	2.2	36.0	2.8	34.0	6.2	62.0	2.7	40.0
Saskatoon	1.3	20.0	3.0	32.0	3.7	30.0	2.2	26.0	2.0	22.0	2.8	32.0
Low oregongrape	0.6	22.0	0.4	16.0	0.4	14.0	0.6	14.0	0.5	18.0	0.5	20.0
Birch-leafed spirea	0.4	16.0	0.5	20.0	0.3	10.0	0.3	10.0	0.2	8.0	0.3	10.0
Squaw currant	0.4	4.0	0.6	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common juniper	0.3	2.0	0.1	2.0	0.3	2.0	0.8	2.0	0.3	2.0	0.3	2.0
Willow species	0.3	2.0	0.1	2.0	0.1	2.0	0.0	0.0	0.4	4.0	0.0	0.0
Chokecherry	0.1	2.0	0.2	8.0	0.0	0.0	0.1	2.0	0.2	8.0	0.3	12.0
Mock-orange	0.0	0.0	0.0	0.0	0.1	2.0	0.3	2.0	0.0	0.0	0.0	0.0
Ceanothus	0.0	0.0	0.0	0.0	0.0	0.0	0.1	4.0	0.1	2.0	0.0	0.0
Prairie rose	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	14.0
<b>Total Shrubs</b>	<b>10.1</b>		<b>10.7</b>		<b>10.3</b>		<b>9.5</b>		<b>15.5</b>		<b>9.4</b>	

Appendix 4 (cont'd). Species	2002		2003		2004		2005		2006		2009	
	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency	Cover %	Frequency
<b>Substrate</b>												
Litter	39.1	100.0	43.1	98.0	37.8	100.0	43.9	100.0	45.3	100.0	51.3	100.0
Rock	33.5	94.0	27.6	88.0	28.1	98.0	26.1	90.0	29.5	96.0	30.9	96.0
Bryophytes	6.4	78.0	13.6	70.0	8.9	64.0	10.0	82.0	6.2	64.0	4.3	48.0
Soil	6.3	64.0	6.4	78.0	10.4	80.0	5.7	74.0	7.6	54.0	6.2	60.0
Elk feces	0.6	4.0	0.5	10.0	0.6	14.0	0.1	4.0	0.0	0.0	0.0	0.0
Sheep feces	0.6	14.0	0.4	14.0	1.5	20.0	0.6	12.0	0.2	6.0	0.3	12.0
Litter > 2cm	0.0	0.0	0.1	2.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
Deer feces	0.0	0.0	0.0	0.0	0.4	6.0	0.1	2.0	0.1	2.0	0.0	0.0

### Appendix 5. Cover and frequency of plant species at Wigwam Flats #3, 2002 to 2009.

Species	2002		2003		2004		2005		2006		2009	
	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
	%		%		%		%		%		%	
<b>Grass and Grasslike</b>												
Bluebunch wheatgrass	12.2	52.0	10.5	52.0	8.2	56.0	15.1	60.0	9.1	56.0	11.5	62.0
Canada bluegrass	8.5	82.0	9.7	72.0	4.4	54.0	7.0	54.0	7.9	70.0	4.3	60.0
Prairie Junegrass	1.8	30.0	3.0	30.0	1.0	20.0	2.3	30.0	2.3	32.0	4.6	46.0
Columbia needlegrass	1.0	8.0	1.0	12.0	2.3	20.0	5.4	24.0	2.5	18.0	1.9	14.0
Western needlegrass	0.8	10.0	0.6	10.0	2.0	12.0	2.4	26.0	2.9	26.0	2.6	24.0
Cheatgrass	0.5	8.0	1.1	12.0	1.9	24.0	1.0	20.0	1.7	28.0	0.6	22.0
Pinegrass	0.4	4.0	0.0	0.0	0.4	4.0	0.0	0.0	0.0	0.0	0.3	2.0
Kentucky bluegrass	0.1	2.0	1.9	24.0	0.1	4.0	1.0	20.0	0.1	2.0	0.0	0.0
Bromegrass species	0.0	0.0	0.8	4.0	0.1	2.0	0.0	0.0	0.0	0.0	0.1	2.0
Alkali bluegrass	0.0	0.0	0.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northwest sedge	0.0	0.0	0.1	4.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Sandberg's bluegrass	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0
<b>Total Grass and Grasslike</b>	<b>25.3</b>		<b>28.9</b>		<b>20.2</b>		<b>34.0</b>		<b>26.5</b>		<b>25.7</b>	
<b>Forbs</b>												
Spotted knapweed	8.1	52.0	0.5	8.0	0.7	8.0	1.4	14.0	1.5	18.0	1.1	12.0
Alfalfa	6.1	20.0	6.0	24.0	9.1	44.0	9.4	40.0	9.2	40.0	7.7	44.0
Monarda	2.9	20.0	2.2	18.0	2.7	26.0	5.4	22.0	2.2	18.0	2.5	20.0
Spreading dogbane	2.2	18.0	2.5	18.0	2.1	24.0	1.5	18.0	3.4	20.0	1.2	16.0
Fairy candelabra	1.4	36.0	0.2	6.0	0.7	6.0	1.6	32.0	0.7	28.0	0.3	10.0
Spiny phlox	1.4	26.0	1.1	22.0	1.0	18.0	0.3	10.0	1.3	22.0	0.3	12.0
St. John's-wort	1.3	10.0	1.0	18.0	0.5	8.0	1.2	18.0	1.7	26.0	5.1	44.0
Western yarrow	1.2	18.0	0.1	4.0	0.0	0.0	0.0	0.0	0.1	2.0	0.3	2.0
Goatsbeard	0.9	6.0	0.2	6.0	1.1	12.0	2.3	22.0	0.4	6.0	1.3	32.0
Timber milkvetch	0.8	2.0	0.0	0.0	0.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Chickweed	0.9	34.0	1.2	38.0	0.5	10.0	0.3	10.0	0.5	18.0	0.2	8.0



Appendix 5 (cont'd). Species	2002		2003		2004		2005		2006		2009	
	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
	%	%	%	%	%	%	%	%	%	%	%	%
Balsamroot	0.7	6.0	0.3	2.0	0.0	0.0	0.0	0.0	0.4	4.0	0.3	2.0
Wild strawberry	0.7	6.0	0.1	4.0	0.0	0.0	0.1	2.0	0.1	4.0	0.0	0.0
Little-podded false flax	0.4	16.0	0.4	16.0	1.1	16.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow hawkweed	0.4	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stoneseed	0.3	2.0	0.1	2.0	0.1	2.0	0.4	6.0	0.6	4.0	0.6	4.0
Yellow sweet-clover	0.2	8.0	0.0	0.0	0.0	0.0	2.1	14.0	0.0	0.0	0.0	0.0
Mariposa lily	0.2	6.0	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Thompson's paintbrush	0.2	6.0	0.1	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.1	2.0
Hairy goldaster	0.1	4.0	0.4	4.0	0.1	2.0	0.3	2.0	0.4	4.0	0.5	8.0
Upland larkspur	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	8.0
Desert parsley	0.1	4.0	0.7	6.0	0.3	2.0	0.6	4.0	0.9	6.0	0.5	10.0
Rosy pussytoes	0.1	2.0	0.1	4.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Leafy aster	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Common harebell	0.1	2.0	0.2	6.0	0.8	10.0	0.1	2.0	1.0	10.0	0.1	4.0
Long-leaf fleabane	0.1	2.0	0.0	0.0	0.0	0.0	0.8	12.0	1.3	12.0	0.0	0.0
False flax	0.0	0.0	0.4	6.0	0.0	0.0	0.1	4.0	0.0	0.0	0.0	0.0
Nodding onion	0.0	0.0	0.2	6.0	0.4	14.0	0.4	14.0	0.1	2.0	0.4	16.0
Silky phacelia	0.0	0.0	0.1	4.0	1.2	28.0	0.9	6.0	0.3	10.0	0.2	8.0
Smooth agoseris	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Black medic	0.0	0.0	0.1	2.0	0.1	4.0	0.1	4.0	0.1	2.0	0.0	0.0
Early blue violet	0.0	0.0	0.1	2.0	0.1	2.0	0.1	4.0	0.0	0.0	0.0	0.0
Bastard toadflax	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Field peppergrass	0.0	0.0	0.0	0.0	1.5	20.0	0.8	20.0	0.3	12.0	0.7	18.0
Filago	0.0	0.0	0.0	0.0	0.1	2.0	0.1	2.0	0.0	0.0	0.0	0.0
Stickseed	0.0	0.0	0.0	0.0	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Yellow rattle	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
White sweet-clover	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0
Dune goldenrod	0.0	0.0	0.0	0.0	0.0	0.0	0.2	6.0	0.1	2.0	0.1	2.0

Appendix 5 (cont'd). Species	2002		2003		2004		2005		2006		2009	
	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency	Cover	Frequency
	%	%	%	%	%	%	%	%	%	%	%	%
Golden clover	0.0	0.0	0.0	0.0	0.0	0.0	0.3	2.0	0.0	0.0	0.0	0.0
Dandelion	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0
Common mullien	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0
Baker's mariposa lily	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	6.0	0.0	0.0
Holboell's rockcress	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0	0.0	0.0
Sulphur cinquefoil	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
Fern species	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
Death camas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
<b>Total Forbs</b>	<b>31.0</b>		<b>17.7</b>		<b>24.2</b>		<b>30.2</b>		<b>26.3</b>		<b>23.5</b>	
<b>Shrubs</b>												
Chokecherry	1.7	12.0	0.7	6.0	0.4	6.0	0.7	6.0	0.4	6.0	0.2	6.0
Prickly rose	1.3	22.0	0.4	16.0	0.7	16.0	0.4	6.0	1.7	20.0	0.5	10.0
Saskatoon	0.9	14.0	1.4	8.0	1.8	14.0	1.6	14.0	2.2	18.0	1.1	12.0
Snowberry	0.2	8.0	0.1	2.0	0.1	2.0	0.1	4.0	0.4	14.0	0.1	2.0
Low oregongrape	0.1	4.0	0.0	0.0	0.1	2.0	0.0	0.0	0.0	0.0	0.0	0.0
Soopolallie	0.1	2.0	0.5	8.0	0.3	2.0	0.3	2.0	0.1	2.0	0.3	2.0
Birch-leaved spirea	0.1	2.0	0.2	6.0	0.1	2.0	0.0	0.0	0.1	2.0	0.0	0.0
Willow species	0.0	0.0	1.3	2.0	0.1	2.0	1.3	2.0	1.1	4.0	0.3	2.0
Ceanothus	0.0	0.0	0.0	0.0	0.1	2.0	0.1	2.0	0.4	4.0	0.0	0.0
<b>Total Shrubs</b>	<b>4.4</b>		<b>4.4</b>		<b>3.4</b>		<b>4.3</b>		<b>6.1</b>		<b>2.4</b>	
<b>Trees</b>												
Douglas-fir regen	0.1	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<b>Total Trees</b>	<b>0.1</b>		<b>0.0</b>		<b>0.0</b>		<b>0.0</b>		<b>0.0</b>		<b>0.0</b>	

<b>Appendix 5 (cont'd).</b>	<b>2002</b>		<b>2003</b>		<b>2004</b>		<b>2005</b>		<b>2006</b>		<b>2009</b>	
<b>Species</b>	<b>Cover</b>	<b>Frequency</b>	<b>Cover</b>	<b>Frequency</b>	<b>Cover</b>	<b>Frequency</b>	<b>Cover</b>	<b>Frequency</b>	<b>Cover</b>	<b>Frequency</b>	<b>Cover</b>	<b>Frequency</b>
	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>	<b>%</b>
<b>Substrate</b>												
Litter	38.1	98.0	37.7	100.0	37.0	98.0	48.3	100.0	37.9	100.0	39.3	100.0
Bryophytes	33.7	94.0	34.6	92.0	28.8	88.0	21.2	88.0	34.5	100.0	29.7	94.0
Rock	15.6	84.0	12.3	74.0	19.8	78.0	11.7	84.0	15.7	80.0	10.8	76.0
Soil	5.9	60.0	7.0	38.0	3.3	52.0	5.7	16.0	5.2	54.0	5.5	54.0
Elk feces	1.0	10.0	0.6	14.0	0.6	12.0	0.2	6.0	0.4	6.0	0.5	10.0
Sheep feces	0.1	4.0	0.6	4.0	0.1	4.0	0.0	0.0	0.3	12.0	0.6	14.0
Deer feces	0.0	0.0	0.4	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.0
Litter >2cm	0.0	0.0	0.4	4.0	0.7	6.0	0.4	4.0	0.8	4.0	0.3	2.0

**Appendix 6. Intensive Survey Photopoints.**



**Wigwam #1 – Plot photo - 210° - from Tiepoint**



**Wigwam #1 - T3+30 m - Photopoint**





**Wigwam #1 - T3+30 m - T3+25 m - 045° at 45°**



**Wigwam #1 - T3+30 m - T3+25 m - 045° at 00°**





**Wigwam #1 - T3+30 m - T3+35 m - 225° at 45°**



**Wigwam #1 - T3+30 m - T3+35 m - 225° at 00°**





**Wigwam #2 – Plot photo - 285° - from T5 + 60 m – Elko mill in background**



**Wigwam #2 - T3+30 m - Photopoint**





**Wigwam #2 - T3+30 m - T3+25 m - 335° at 45°**



**Wigwam #2 - T3+30 m - T3+25 m - 335° at 00°**





**Wigwam #2 - T3+30 m - T3+35 m - 155° at 45°**



**Wigwam #2 - T3+30 m - T3+35 m - 155° at 00°**





**Wigwam #3 – Plot photo - 030° - at plot center from Tie-point**



**Wigwam #3 – T3+30 m – Photopoint**





**Wigwam #3 - T3+30 m - T3+25 m - 295° at 45°**



**Wigwam #3 - T3+30 m - T3+25 m - 295° at 00°**





**Wigwam #3 - T3+30 m - T3+35 m - 115° at 45°**



**Wigwam #3 - T3+30 m - T3+35 m - 115° at 00°**