Restoration Plan 2007

Desert Society

Restoration Program

1 Mandate

The mandate of the Osoyoos Desert Centre Restoration Program is to use restoration as a tool for enhancing habitat, encouraging stewardship, and conducting scientific research in the antelope-brush ecosystem of the south Okanagan Valley.

2 Overview

2.1 Project Location and Boundaries

This project is located at the Osoyoos Desert Centre Site, Osoyoos B.C. The Osoyoos Desert Centre is operated by the non-profit Osoyoos Desert Society, and is the site of a boardwalk on which visitors receive interpretive tours of the local ecology. The Osoyoos Desert Society's mission is

> "To protect and restore the antelope-brush ecosystem in the South Okanagan, BC, thereby ensuring species survival through habitat conservation and through education; and, to generate public knowledge, respect, and active concern for fragile and endangered habitats throughout Canada and worldwide."

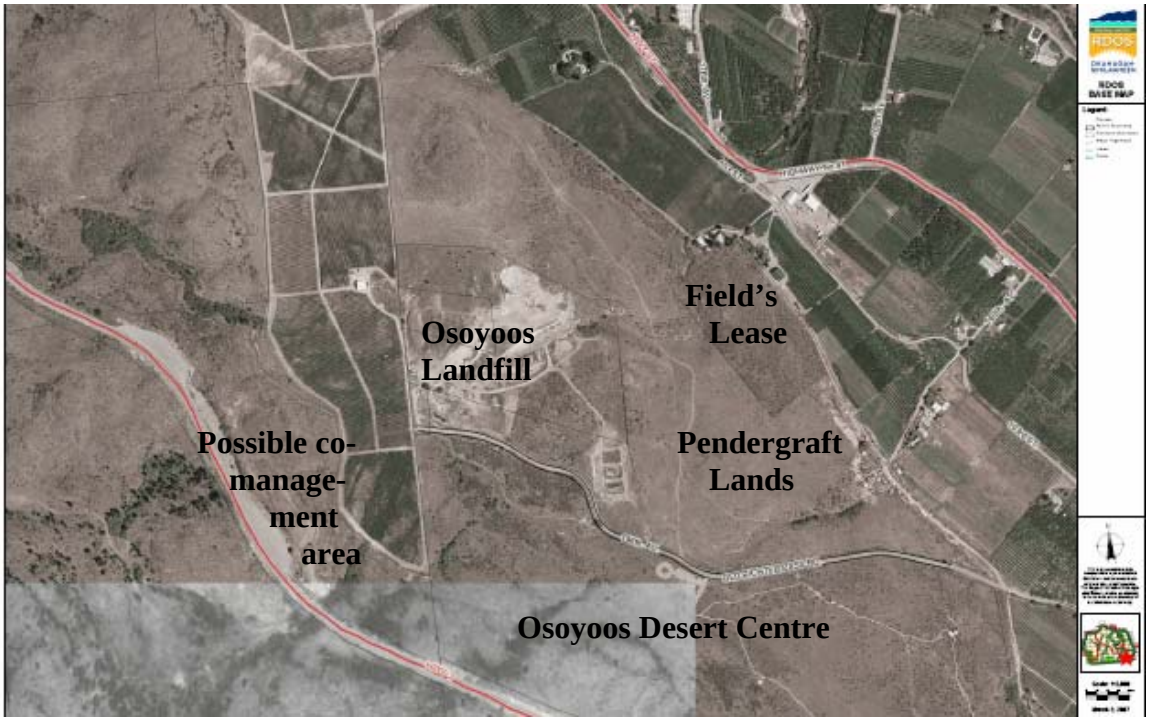
The Osoyoos Desert Centre site is approximately 50 hectares in size, and is referred to as the unsubdivided portion of lot DL 2450s SDYD. The Osoyoos Desert Centre site is located three kilometers north of Osoyoos, on the west side of the valley. The Osoyoos Desert Centre is bordered by the Osoyoos Landfill to the north, 146th Avenue to the east, vineyards and a quarry to the south, and highway 3 to the west. There is one area, discussed below, which directly connects the Osoyoos Desert Centre site to larger natural areas to the north. Map 1 shows the location of the Osoyoos Desert Centre and other relevant areas.

Three other sites are of importance in this report. The first are the 'Pendergraft lands', directly across the road from the Osoyoos Desert Centre. This area is currently grazed

and is owned by the town of Osoyoos, though the Osoyoos Desert Society has obtained permission to conduct research on the Pendergraft lands on a short-term (5-10 years) basis.

Field's Lease ecological reserve, created to preserve the rare antelope-brush ecosystem, measures 4.5 hectares and is located just north of the Pendergraft lands. This reserve abuts on a power line and private orchards to the south-east, and is suffering from edge effects and misuse along that border (personal observation). Field's Lease ecological reserve was given a rating of 3.5, with 3 meaning "Moderate Ecological Integrity: the reserve really needs to be restored through efforts such as…" and 4 meaning "High Ecological Integrity: the reserve is in good condition but can be improved through increased management intervention" (Friends of Ecological Reserves 2006: 37). This reserve may serve as a reference site and a future site of restoration.

Finally, a tract of un-developed Crown Land to the north-west, could be managed in conjunction with the Osoyoos Desert Society site, if protection for the site could be obtained. This area connects the Osoyoos Desert Centre site with large natural areas between highways 3 and 97, south of the town of Osoyoos.



Map 1. Location of Osoyoos Desert Centre site and other areas of interest.

2.2 Ownership Status

The Osoyoos Desert Centre site is Crown Land, and is currently licensed to the Osoyoos Desert Society on a 10-year basis (expires on April 28, 2008) by the Regional District of Osoyoos. The Osoyoos Desert Society is attempting to change this to a lease situation when the current license expires.

2.3 Ecology of the Project Site

The Osoyoos Desert Centre site is located in the BGxhl (Bunchgrass very hot/dry) biogeoclimatic zone, and contains five habitat types as described by Atwood (1996). These are: Antelope-Brush (*Purshia* tridentate) Shrub-steppe; Great Basin Sage (*Artemisia tridentate*) Shrub-steppe; Bunchgrass Grassland; Riparian; Rock Outcrop. Atwood conducted a site assessment of the site in 1996; much of the habitat information below comes from the 1996 assessment.

Some major changes have occurred on the Osoyoos Desert Centre site since 1996, including the construction of a 1.5 kilometre boardwalk, the addition of three interpretive centre buildings, and most significantly, the removal of cattle from the site. The response of the shrub-steppe communities to the removal of cattle was documented over a five year period directly following cattle removal (Atwood and Scudder 2003). Atwood and Scudder found that herb and native grass cover increased significantly after the removal of cattle, while non-native species decreased in cover by 71 to 77 percent. In the 5 year period of the study (1998-2002), the dominant weed species changed from diffuse knapweed (*Centaurea diffusa*) to crested wheatgrass (*Agropyron cristatum*), a perennial bunchgrass seeded by the former lessee.

2.3.1 Antelope-Brush Shrub-steppe

About 20% of the Osoyoos Desert Centre Site contains antelope-brush habitat (Atwood 1996). This habitat is generally found on sandy-loam or loamy sand-textured soils in the project site, though antelope-brush shrub-steppe on the west edge of the site contains more silt and clay (Atwood 1996). The antelope-brush shrub-steppe section of the Osoyoos Desert Centre site has an average shrub cover of 39% (dominant shrubs are antelope brush and great basin sage), a perennial native grass cover of 20% (dominant grasses are sand dropseed [*Sporobolus cryptandrus]* and needle-and-thread grass [*Stipa comata*]), a native forb cover of 11% (dominant forbs are snow buckwheat [*eriogonum niveum*], arrow-leaf balsam root [*Balsamorhiza sagittata*], brittle prickly-pear cactus [*Opuntia fragilis*], Indian wheat [*Plantago patagonica*], and yarrow [*Achillea millefolium*]), a micriobiotic crust cover of 25% (dominant species is rusty steppe moss [*Torula ruralis*]), and a non-native species cover of 57% (dominant species are cheatgrass [*Bromus tectorum*], diffuse knapweed, spotted knapweed [*Centaurea maculosa*], sweet white clover [*Melilotus alba*] and Japanese brome [*Bromus japonicus*]) (Atwood 1996).

A survey of three 10 by 10 meter plots located in the antelope-brush shrub steppe areas in spring of 2007 showed few significant changes in the dominant vegetation. Non-native species cover was much lower (18.5 %) in 2007 than 1996, though cover of invasives would have been greater if the 2007 survey were carried out in late summer after the often annual and biennial non-natives had grown. Cheatgrass is by far the most dominant invasive species on site.

2.3.2 Great Basin Sage Shrub-steppe

The northern section of the Osoyoos Desert Centre site contains most of the Great Basin sage shrub-steppe, which makes up about 20% of the total site. Soil texture for this habitat type ranged from clay to silty loam (Atwood 1996). The Great Basin sage shrub-steppe component has a shrub cover of 31% (dominant shrubs are the Great Basin sage, common rabbitbrush [*Chrysothamnus nauseosus*] and green rabbitbrush [*Chrysothamnus viscidiflorus*]), a perennial native grass cover of 33% (dominant grasses are needle-and-thread grass, and sand dropseed), a native forb cover of 12% (dominant forbs are Indian wheat, pale comandra [*Comandra umbellatum*], long-leaved phlox [*Phlox lonifolia*], and yarrow), a microbiotic crust cover of 11% (dominant species are rusty steppe moss, fire moss [*Ceratodon purpureus*], and lichen species [*Cladonia* spp.]), and a non-native species cover of 42% (dominant species are cheatgrass, Japanese brome, and sweet white clover) (Atwood 1996).

A 2007 site survey of Sagebrush shrub-steppe at the Desert Centre site (see section 2.3.1 for methods) showed some changes in this habitat type from 1996 to 2007. Sand dropseed was not found in the grass layer (though this could be due to limited sampling), and another species, sandberg's bluegrass (*Poa secunda*) was found in low amounts in two of the three plots. Non-native species made up 22% of cover, as opposed to 42% in 1996, though as mentioned in the previous section, this is partly due to the time of year when sampling occurred. One non-native grass, perennial ryegrass (*Lolium perenne*), had a cover of 20% in one of the plots, but is not found throughout most of the site.

2.3.3 Bunchgrass Grassland

Grassland habitat is located on flat areas of the Osoyoos Desert Centre site, and covers about 51% of the site (Atwood 1996). The soil texture is generally loamy sand, and a there is a large percentage (16%) of bare ground associated with the grassland sites (Atwood 1996). The bunchgrass grassland found at the Osoyoos Desert Centre site has an average shrub cover of 7% (dominant shrubs are antelope brush, common rabbitbrush, Great Basin sage, and silver sage [*Artemisia cana*]), a perennial native grass cover of 18% (dominant grasses are sand dropseed, and needle-and-thread grass), a native forb cover of 19% (dominant forbs are brittle prickly-pear cactus, Indian wheat, snow buckwheat, and golden aster [*Heterotheca villosa*]), a microbiotic crust cover of 16% (dominant species are rusty steppe moss, fire moss, and foliose and fruticose lichens [*Peltigera didactyla* and *P. rufescens*, and *Cladonia* spp., respectively]), and a non-indigenous species cover of 51% (dominant species are diffuse knapweed, cheatgrass, crested wheatgrass, sweet white clover, spotted knapweed, Japanese brome, Kentucky bluegrass [*Poa pratensis*], quackgrass [*Agropyron repens*], toadflax [*Linaria genistifolia*], hound's tongue [*Cynoglossum officinale*], and asparagus [*Asparagus officinalis*]) (Atwood 1996).

A survey of three grassland plots was carried out in 2007 (see section 2.3.1 for methods) and found a few changes in species composition between 1996 and 2007. In the native bunchgrasses, sand dropseed had an average cover of 1%, while Sandberg's bluegrass had a cover of 3.7%. Needle and thread grass is still a dominant grass with over 10%

cover. Non-native species had a cover of 27% in 2007, dominated by crested wheatgrass and cheatgrass.

2.3.4 Riparian

Six percent of plots surveyed by Atwood (1996) contained deciduous trees and shrubs that were growing in depressions and run-off areas. These riparian areas were on soils with a texture ranging from clay to silty clay loam. The riparian areas of the Osoyoos Desert Centre site contain a few sporadic shrubs (dominant shrubs are Saskatoon [*Amelanchier alnifolia*], mock orange [*Philadelphus lewisii*], poison ivy [*Rhus radicans*], Great Basin sage, and antelope brush), a perennial native grass cover of 15% (dominant grasses are sand dropseed and needle-and-thread grass), a native forb cover of 2% (dominant forbs are lemonweed [*Lithospermum ruderale*], showy milkweed [*Asclepias speciosa*], shaggy daisy [*Erigeron pumilus*], parsnip-flowered buckwheat [*Eriogonum heracloises*] and yarrow), a microbiotic crust cover of 8% (dominant species are rusty steppe moss, golden curls moss [*Homalothecium aeneum*], and shaggy yellow sand moss [*Racomitrium ericoides*]), and a non-native species cover of 40% (dominant species are Japanese brome, cheatgrass, diffuse knapweed, and sweet white clover) (Atwood 1996).

2.3.5 Rock Outcrop

Two percent of plots surveyed by Atwood (1996) contained rock outcrop habitat, which contain very shallow soils of a silty clay loam texture. The rock outcrop sites contain a shrub cover of 12% (dominant shrubs are Great Basin sage, Saskatoon, and prickly phlox, and antelope brush), a perennial native grass cover of 35% (dominant species are bluebunch wheatgrass and sandberg bluegrass [*Poa secunda*]), a native forb cover of 79% (dominant forbs are compact selaginella [*Selaginella densa*], low pussytoes [*Antennaria dimorpha*], thread-leaved daisy [*Erigeron filifolius*], snow and parsnip-flowered buckwheat, round-leaved alumroot [*Heuchera cylindrica*], and bitterroot [*Lewisia redeviva*]), a microbiotic crust cover of 2% (dominant species are rusty steppe moss, a foliose lichen [*Peltigera rufescens*], and a fruticose lichen [*Cladonia spp.*]), and a non-native species cover of 9% (dominated by cheatgrass, Japanese brome, and diffuse knapweed) (Atwood 1996).

2.4 Ecology of the South Okanagan

2.4.1 Ecological Communities

There are many different ecosystem types and plant communities found in the south Okanagan, and that is one of the reasons that there is high biological diversity and a high number of rare or endangered species found in the area. Riparian forests could once be found covering much of the valley bottoms, containing tree species such as black cottonwood (*Populus balsamifera* ssp. *trichocarpa P. trichocarpa*), trembling aspen (*Populus tremuloides*), and mountain alder (*Alnus incana* ssp. *tenufolia*) (BC MoE 2001). Many wildlife species rely on riparian areas for their survival and for various life stages, but unfortunately less than four percent of this habitat type remains (BC MoE 2001).

As one moves up from the valley bottom, dryer grasslands and shrub-steppe replace the riparian areas. The shrub-steppe is made up of antelope-brush-dominated and sagebrush-

dominated ecosystems, and the antelope brush ecosystem is of special concern to this restoration project and to the south Okanagan in general. Less than forty percent of the antelope-brush ecosystem remains in the Okanagan, and many red or blue-listed species are associated with the antelope brush ecosystem and grassland/shrub-steppe ecosystems in general (BCMoE 2001). The red or blue-listed species, or species of special concern, associated with the ecosystems of the South Okanagan are listed in table 1.

Above the grassland and shrub-steppe ecosystems of the Okanagan can be found low elevation forests containing open stands of ponderosa pine (*Pinus ponderosa*) and interior douglas fir (*Pseudotsuga menziesii* var *glauca*), followed by wetern larch (*Larix lyallii*) forests at higher elevations, and engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) on high plateaus (BC Moe 2001).

Finally, rugged cliffs, ridges, and talus slopes represent another habitat type in the Okanagan. Many wildlife species need this rugged habitat, such as the gopher snake, pallid bat, canyon wren, and California bighorn sheep (BC MoE 2001).

Table 1. Management priority vertebrate species in the South Okanagan (from Bonnemaison 2006).

	Species
Birds **total 14**	Brewer's Sparrow
	Lark Sparrow
	Grasshopper Sparrow
	Prairie Falcon
	Burrowing Owl
	Common Poorwill
	Turkey Vulture
	Long-eared Owl
	Long-billed Curlew
	Western Bluebird
	Sharp-tailed Grouse
	Ferruginous Hawk
	Golden Eagle
	Sage Grouse
Mammals **total 10**	Western Harvest Mouse
	Spotted Bat
	Nuttal's Cottontail
	Fringed Myotis
	Western Small-footed Myotis
	Pallid Bat
	Badger
	Great Basin Pocket Mouse
	Bighorn Sheep
	White-tailed Jackrabbit
Reptiles **total 6**	Western Rattlesnake
	Short-horned Lizard
	Painted Turtle
	Rubber Boa
	Western Yellow-bellied Racer
	Gopher Snake
Amphibians **total 3**	Western Skink
	Tiger Salamander
	Great Basin Spade-foot Toad

2.4.2 Causes of Degradation and Habitat Loss

2.4.2.1 Development

Development for housing, roads, agriculture, and other uses have greatly reduced natural ecosystems in the south Okanagan, particularly in the valley bottoms (BC MoE 2001). Some ecological communities, such as the antelope-brush – needle-and-thread grass community, have been reduced to less than 40% of their historical extent, and are continually being threatened with even greater habitat loss (Dyer and Lea 2003). Riparian ecosystems have been very affected by development and by the channelization of the Okanagan River, and only 15% of these ecosystems remain (BC MoE 2001).

2.4.2.2 Habitat Fragmentation

With so few natural areas remaining in the valley bottoms, habitat fragmentation is a serious problem for the wildlife of the area. Wetlands and ponds are often separated by other habitat types by roads, fields, orchards, or development, making it very difficult for species that need multiple habitat types (for example the spadefoot toad must migrate from pond to grassland and back throughout its life) (BC MoE 2001). Natural areas containing similar ecosystems are also segregated, making it difficult or impossible for populations to inter-breed or to colonize new habitat. Species richness as well as the genetic diversity within species decreases with a decrease in habitat patch size (Duerksen et. al. 1997) and this reduction in patch size due to fragmentation contributes to the long list of threatened or endangered species in the south Okanagan.

Fragmentation reduces the quality of the natural areas within the fragments through an increase in edge effects. Invasion by exotic species, wind and temperature fluctuations, changes in nutrient cycling, and altered inter-species relationships within edges can all contribute to a negative impact on native species remaining in the habitat patch (Debinski and Holt 2000).

2.4.2.3 Invasive Species

A report (Wooten and Morrison 1995) written for the Interior Columbia River Basin (of which the Okanagan would be part if the U.S. / Canada border did not separate the two) lists the ways in which non-native species affect natural ecosystems. These are: displacement of native species through competition; changes in ecosystem processes such as nutrient cycling, erosion, and evapotranspiration; reduced or eliminated habitat for native species; and disrupted food webs. Wooten and Morrison (1995) also discuss specific examples of the effects of invasive species, such as:

- the “displacement of native plant diversity resulted following entry of *Centaurea maculosa* (spotted knapweed)” (from Tyser and Key 1988).
- “increased surface runoff and sediment yield occurred in areas infested with *Centaurea maculosa*” (from Lacey et. al. 1989).
- “displacement of native bunchgrasses by *Bromus tectorum* following fire” (from Melgoza et. al. 1990).
- “changes in uptake and cycling of soil nutrients have resulted from elimination of cryptobiotic crusts, which accompany species changes resulting from soil disturbance” (from Bolton et. al. 1993; Anderson et. al. 1982; Kleiner and Harper 1972);

2.4.2.4 Over-Grazing

The native species of the south Okanagan are ill-equipped to withstand heavy grazing (Daubenmire1970). Grazing by cattle has decreased the density of native bunchgrasses (Daubenmire 1970), has largely destroyed the cryptobiotic crust (Cannings and Durance 1998), and has driven the spread of non-native species such as cheatgrass (Daubenmire 1970).

2.4.3 Species of Special Concern

2.4.3.1 Cryptobiotic Crust

The cryptobiotic crust is a soil crust composed of microscopic organisms including mosses, lichens, cyanobacteria, green algae, and fungi, and are an essential component of many dryland ecosystems, including those found in the south Okanagan (Wuerthner n.d.). The cryptobiotic crust can be thought of as a keystone species, meaning that the health of the entire ecosystem relies on the health of the crust layer. Damage to the cryptobiotic crust can lead to problems such as "increased soil erosion, diminished water-holding capacity of the soil, (…) less favorable nutrient flows, (…) greater vulnerability to invasion by exotic plants", more frequent and damaging fires, and cooler soil temperatures (Wuerthner n.d.: 199). Native vascular plant species which have adapted to growing with the cryptobiotic crust layer often have methods of self-burial, while non-native plants are more likely to germinate on bare soil; ecosystems with intact cryptobiotic crusts are better able to maintain self-producing native plant populations and to ward off invasive species spread (Wuerthner n.d.).

2.4.3.2 Vesicular Arbuscular Mycorrhizae

Mycorrhizae "is a mutualistic symbiosis between plant and fungus localized in (the) root", which increases the water and nutrient uptake of the host plant (Wicklow-Howard 1994). Little is known about the specific species of fungi found in different ecosystems, but it is clear that different regions will host different fungal associations, and some fungi may be specific to a host plant (Wicklow-Howard 1994). One example is the species *Glomus gerdemannii*, which appears to be specific to *Purshia tridentate* and a few other shrubs (Wicklo-Howard 1994).

Vesicular-arbuscular mycorrhizae (VAM) are likely a significant component of South Okanagan shrub-steppe ecosystems. Reeves et. al. (1979) found that 99% of plant cover in an un-disturbed mid-elevation sage community was mycorrhizal, while only one percent of plant cover growing on an old roadbed in the same area was mycorrhizal. Many native plants in the antelope-brush ecosystem are associated with VAM, as shown in Table 2; very few plant families are non-mycotrophic and many of the native shrubs of the Great Basin are obligate mycotrophs (Wicklow-Howard 1994), while a majority of the invasive species in Canada are non-mycotrophic (Mulligan 1965).

Cheatgrass (*Bromus tectorum*) is mycorrhizal, but the addition of VAM inoculum has been shown to increase competition from native shrubs on cheatgrass (Pendleton et. el. 2003). Furthermore, though cheatgrass is able to associate with VAM, it can survive independently of VAM (Wicklow-Howard 1994).

One method of restoring VAM is to inoculate plants or sites with VAM, which was found to increase the cover of bluebunch wheatgrass at the Osoyoos Desert Centre site (Atwood 2003). Another is to create native plant islands with shrubs and bunchgrasses that serve as capture points for precipitation, VAM, and fungal spores (Allen 1988).

Table 2. Mycorrhizal status of selected plants found at project site. Sourced from Reeves et. al. 1979; Howard 2003.

Eriogonum spp.	Y	*Bromus tectorum* (non-native)	Y
Artemisia frigida	Y	*Chenopodium album* (non-native)	N
Chrysothamnus nauseosus	Y	*Salsola kali* (non-native)	N
Crysothamnus viscidiflorus	Y	*Kochia scoparia* (non-native)	N
Erigeron spp.	Y	*Sisymbrium altissimum* (non-native)	N
Purshia tridentate	Y		
Artemisia tridentata	Y		
Stipa comata	Y		

2.5 Site History

The Osoyoos Desert Centre site was grazed by cattle for approximately three weeks per year during the spring. In 1998, about forty head of cattle were removed when the Osoyoos Desert Society assumed the License to Occupy (Atwood and Scudder 2003).

Experimental ecological restoration was conducted on the Osoyoos Desert Centre site from 1998 to 2002, aimed at the recruitment of native bunchgrasses and management of invasive species (Atwood and Scudder 2003). A hayseed experiment was conducted where seed heads and plant stalks of the native species red three-awn, needle-and-thread grass, sand dropseed, and bluebunch wheatgrass were distributed over 100 meter squared plots. This (re)introduced a low cover of bluebunch wheatgrass to all plots, and in the sandier plots, needle-and-thread grass had a cover of 9.0% plus or minus 5.51% where it had not been found before the hayseeding (Atwood and Scudder 2003).

Another experiment conducted at the Osoyoos Desert Centre site involved broadcast seeding a seed mix of red-three-awn, needle-and-thread grass, sand dropseed, bluebunch wheatgrass, and the agronomic annual ryegrass (*Lolium multiflorum*) (Atwood and Scudder 2003). The mix was combined evenly between the five species, and was seeded at the rates of 28 kg/ha (1027 seeds/m2) and 41 kg/ha (1504 seeds/m2) on plots that had either been tilled, or stripped of vegetation but not tilled. In both cases shrubs remained in the plots. The seeding rate did not make a significant difference in the cover of seeded species, but native grass cover was much higher in the plots that had been left un-tilled. Of the native species seeded, sand dropseed was able to germinate and grow in all of the plots, while red-three-awn did best in the sandier plots and needle-and-thread grass did well in plots with a higher silt content. Bluebunch wheatgrass did not grow in any of the plots.

The third active restoration experiment conducted at the Osoyoos Desert Centre site between 1998 and 2002 was the addition of vesicular arbuscular mycorrhizae (VAM) to plots seeded with the above-mentioned bunchgrass mix (Atwood and Scudder 2003). The addition of VAM increased the cover of bluebunch wheatgrass significantly but did not affect other native species or the overall cover of the broadcast seed mix.

The methods of invasive-species control tested in 1998 to 2002 were solarization, manual, and chemical control (Atwood and Scudder 2003). Solarization altered the invasive species composition of the site somewhat, but was not found to be an effective method of weed control. Though both manual and chemical control were effective in reducing the cover of diffuse knapweed (*Centaurea diffusa*) in the short term, the cover of diffuse knapweed decreased dramatically with the removal of cattle from the site, and by 2001 no difference was apparent between areas that had or had not been treated.

2.6 Need for Restoration

Invasive species make up a large component of the plant cover of the Osoyoos Desert Centre site. The provincially listed noxious weeds found at the site are diffuse and spotted knapweed, dalmation toadflax (*Linaria dalmatica*), hounds tongue (*Cynoglossum officinale*), and puncturevine (*Tribulus terrestris*). Most dalmation toadflax plants at the Osoyoos Desert Centre site are being controlled by bio-control agents, and should be left on-site. A weed-control plan for the site should include methods of reducing cover of noxious weed species.

Some non-native species that are not considered noxious are playing a large role in degrading the plant communities found at the Osoyoos Desert centre site. One species which was very abundant in 2006 (personal observation), is tall tumble mustard (*Sisymbrium altissimum*), a species that tends to do well in wetter years (Howard 2003). Tumble mustard is commonly found in highly-disturbed sagebrush steppe communities, but is not invasive in intact ecosystems (Howard 2003). It is generally the successional predecessor to cheatgrass in these ecosystems (Howard 2003). Because tumble mustard is an early seral species, active control against it is not recommended; the best management practices for tumble mustard are to avoid soil disturbance and enhance natural successional processes on the site (Howard 2003). Another species present at the Osoyoos Desert Centre is the non-native tree Siberian elm (*Ulmus pumila*) which is encroaching on moister sites. One large, mother tree is present and should be left on site as it provides habitat value, but the removal of all seedlings is recommended.

Cheatgrass and Japanese brome (*Bromus japonicus*) are the largest threat to the health of the natural communities of the Osoyoos Desert Centre site. Unlike tumble mustard, cheatgrass (and perhaps Japanese brome also) is able to form its own climax community, to the exclusion of more desirable native species (Daubenmire 1970).
According to Daubenmire (1970) “there is no concrete evidence that *Bromus tectorum* ever relinquishes an area to indigenes, once it is established.” One of the ways in which it is able to exclude native plants is by using all available soil moisture, thus making it impossible for native species to re-colonize infested areas (Daubenmire 1970). A major component of restoration at the Osoyoos Desert Society should be the study of methods of allowing natural ecosystems to ‘break through’ the cheatgrass climax and progress towards historical climax communities. Establishing a dense cover of perennial bunchgrasses is one recommended method of reducing cheatgrass method, and sand dropseed is one species that may be able to compete successfully with cheatgrass (Link, Mast, and Hill n.d.).

The third non-native species of special concern at the Osoyoos Desert Centre site is crested wheatgrass (*Agropyron cristatum*). Crested wheatgrass was planted at the site by a previous lessee (the first crested wheatgrass seeding occurred about 80 years ago, but it has since been re-seeded as late as the mid 1980s) and has never relinquished its hold. Crested wheatgrass has an early growth pattern which allows it to out-compete native vegetation, and forms 'wolf plants' – woody stems that, when un-grazed, are even more able to compete for moisture and nutrients (Saskatchewan Watershed Authority n.d.). Crested wheatgrass that is allowed to go to seed is able to spread to un-disturbed ecosystems, especially in dry years (Saskatchewan Watershed Authority n.d.). Most management strategies involve grazing, mowing, or burning the crested wheatgrass while it is in an elongation stage, ideally to 5cm in height or less (Saskatchewan Watershed Authority n.d.) Spot application of a weed killer such as glyphosate can be effective if maintained over several years, and applied to plants 8-15 cm. tall (Saskatchewan Watershed Authority n.d.).

Cryptobiotic crust cover is an important factor in the health of shrub-steppe ecosystems in the south Okanagan, and the cryptobiotic crust is in poor condition at the Osoyoos Desert Centre site. The tilling and planting of crested wheatgrass, and trampling by cattle in years prior to the establishment of the Osoyoos Desert Centre, are likely the largest contributors to the fragmentation and low percent cover of the cryptobiotic crust. There are many reasons to prioritize restoration of the cryptobiotic crust, but one particularly compelling one is that an intact crust may effectively keep cheatgrass and other weed seeds from germinating (Wuerthner n.d.). One method of restoring cryptobiotic crusts that has shown success locally is to salvage crust from development sites and spray a slurry of crust and water onto the target site. In the Vaseux-Bighorn National Wildlife Area, this method resulted in a 92% increase in cryptobiotic crust cover over areas that were not inoculated (Atwood 2000).

Another factor pointing towards the need for restoration at the Osoyoos Desert Centre site is the lack of native plant recruitment. Lynn Atwood (1996) found that few grasses and forbs, and no shrubs were germinating and establishing themselves under the current ecological regime. This likely is due to lack of soil moisture, nutrients, and litter, caused by invasive species that dominate the site such as cheatgrass (Atwood 1996).

2.7 Landscape Restrictions

2.7.1 Habitat Connectivity

The Osoyoos Desert Centre site (and all natural areas in the Okanagan lowlands) suffers from fragmentation. The site is nearly surrounded on all four sides by a road, highway, vineyard, and landfill. Nevertheless, the site is used by transient wildlife such as coyotes (*Canis latrans*), mule deer (*Odocoileus hemionus*), possibly black bears (*Ursus americanus*), and American badger (*Taxidea taxus*). The above species spend most of their time in the mountains to the west of the site, and cross the highway to access the Osoyoos Desert Centre site. Other species found at the Osoyoos Desert Centre site which may need to access habitat beyond the site's boundaries include the Great Basin

spadefoot toad (*Spea intermontana*) (access to other ponds), Great Basin gopher snake (*Pituophis catenifer deserticola*) (access to hibernacula), Nuttall's cottontail (*Sylvilagus nuttallii*), and many bird species such as the western meadowlark (*Sturnella neglecta*), mountain bluebird (*Sialia currucoides*), and lark sparrow (*Chondestes grammacus*). Many invertebrate species, such as the agile ground mantid (*Litaneutria minor*), robber fly species (*Megaphorus spp.*), and behr's hairstreak butterfly (*Satyrium behrii*), are found at the Osoyoos Desert Centre site and may require outside habitat for their survival.

Some options exist for improving the connectivity of the Osoyoos Desert Centre site, and these include protecting and managing neighboring natural areas, particularly the area shown as the 'possible co-management area' on map 2. The higher-elevation habitat to the west of the Osoyoos Desert Centre site and the Pendergraft lands are being used by wildlife in conjunction with the project site, but it is currently necessary for wildlife to cross 146th Ave. or highway 3. Underpasses could be created to facilitate the movement of wildlife from one habitat fragment to another, though this would require a large amount of funding, compliance with appropriate government bodies, and detailed understanding of the requirements of species that would be using the underpasses.

One further option for increasing habitat connectivity of the Osoyoos Desert Centre site is to restore a section of land connecting the site to a strip of natural vegetation running north-south from the Osoyoos Desert Centre to highway 3. This habitat strip is located on a steep slope connecting upper and lower benches, which is the reason it has been left intact. Though it is not a pristine environment (it suffers from edge effect, invasive species, erosion, and in some cases serves as a local dumping grounds) (personal observation), it may serve as a corridor linking the Osoyoos Desert Centre site to other intact antelope-brush shrub-steppe such as the Osoyoos Airport lands and the natural areas surrounding the Osoyoos Golf and Country Club. One action that must be taken before this corridor is actively pursued is the protection of the ecologically intact sections of the Osoyoos Airport lands (the lower, eastern end).

Map 2. Possible enhancements of the habitat connectivity of the Osoyoos Desert Centre site. Note the wildlife corridor (mid-right) linking the site with natural areas to the south, and the underpasses providing linkage to the mountains and Pendergraft lands.

2.7.2 Invasive Species Spread

The Osoyoos Desert Centre site is a relatively small habitat patch, and is vulnerable to invasive species spread from its edges. Roads, agricultural areas, and other disturbed areas (such as a landfill) are prone to containing large populations of weedy species, and seeds of these species may enter the Desert Centre Site by various means, including being transported by the wind, wildlife, humans, and water. Consequently, weed management will be an ongoing activity at the Osoyoos Desert Centre, with weed pulls occurring yearly.

2.7.3 Altered Fire Regime

Fire was an important driver of the pre-settlement landscape in the South Okanagan. Low-intensity fires would have created a mosaic of successional stages in shrub-steppe ecosystems (Knick 1999). The question of whether to re-introduce fire to ecosystems of the lower South Okanagan valley is a complex one, as the level of habitat fragmentation in the valley is so severe that it is difficult to re-create the mosaic-pattern of burns. Small reserves can be negatively affected by fire (Lea 1996); when a small reserve burns completely, there is nowhere for wildlife to go while the reserve recovers. Invasive species, particularly cheatgrass, are able to negatively alter the way that fire affects a landscape (Updike, Loft, and Hall 1990), but Krannitz and Mottihaw (2003) found that fire on an antelope-brush needle-and-thread grass stand had the effect of removing cheatgrass for two years, creating a window for native grass establishment.

An important reason to consider re-introducing fire to the landscape is to prevent tree encroachment into shrub-steppe and grassland ecosystems. Confier density has increased in unburned areas of the south Okanagan (Turner and Krannitz 2001), and it is clear that this process is occurring at the Osoyoos Desert Centre site. The west edge of the site, bordering highway three, is riddled with young Douglas fir and ponderosa pine trees.

Conducting a controlled burn at the Osoyoos Desert Centre site would be a worthwhile experiment. Timing, intensity, and weather conditions are some of the factors that need to be examined in more detail before concrete plans are written. Native and invasive species response to the burn would be evaluated, and other variables that would be interesting to monitor include response of selected wildlife species, and seed bank remaining after the fire. This project would be best conducted in conjunction with another organization, as it would be quite costly.

2.8 Goals

2.8.1 Describe Reference Ecosystem

Because there are no pristine natural areas remaining in the south Okanagan valley, the reference ecosystem must be re-created from various sites and historical accounts. The table below lists the climax species for each ecosystem type according to a variety of sources.

Table 3. Dominant species and cover in reference ecosystems.

Ecosystem Type	Dominant Species	% cover	Associated Species	% cover	Source
Antelope-Brush needle-and-thread grass,	Antelope-brush Bluebunch wheatgrass Compact selaginella (*Selaginella densa*) Red three-awn Sandberg's bluegrass (*Poa secunda*) Needle-and thread grass	24-33 22-99 85-99	Sand dropseed Three-leaved sedge (*Carex spp.*) Cheatgrass		Lea, Maxwell, and Swanson 1998; percentages from Daubenmire 1970 (stand 128)
Antelope-Brush needle-and-thread grass,	Antelope-brush Cryptobiotic crust Needle-and thread grass	16 70 18	Bare soil Litter Big sagebrush Sand dropseed Cheatgrass	2 12 3 3 5	Line intercept in east section of Osoyoos Golf and Country Club (Mar.

					2007)
Big-Sagebrush needle-and-thread grass	Big sagebrush Needle-and-thread grass Bluebunch wheatgrass Cryptobiotic crust	11-25 80-99	Rabbitbrush (*Chrysothamnus nauseosus.*) Threetip sagebrush (*Artemisia tipartita*) Antelope brush Sandberg's bluegrass Sand dropseed Brittle prickly pear (*Opuntia fragilis*) Cheatgrass	29-99	L ea, Maxwell, and Swanson 1998; percentages from Daubenmire 1970 (stand 128)
Saskatoon mock-orange talus (corresponds with 'riparian areas' in this report)	Mock orange (*Philadelphus lewisii*) Saskatoon (*Amelanchier alnifolia*) Big sagebrush Sumac (*Rhus glabra*)		Cheatgrass Poison Ivy (*Toxicodendron rydbergii*) Bluebunch wheatgrass White Clematis (*Clematis ligusticifolia*)		L ea, Maxwell, and Swanson 1998
Big sage-Bluebunch wheatgrass on loamy soil.	Big sagebrush Bluebunch wheatgrass Cryptobiotic crust	30 28 16	Bare ground Cheatgrass Litter Antelope brush	11 <1 13 2	Line intercept in southeast section of Desert Centre site. (Mar. 2007)

In general, sources (Daubenmire 1970; Lea, Maxwell, and Swanson 1998; line intercepts in reference ecosystems for this report) agree that the major distinguishing features of intact shrub-steppe ecosystems are a shrub cover ranging from 11 to 33 percent, a perennial bunchgrass cover of 18 to 100 percent, and an intact cryptobiotic crust layer covering the spaces between shrub and grasses. The most dramatic changes from historical to present day conditions have taken place in the bunchgrass cover (bluebunch wheatgrass has been replaced by needle-and-thread grass or sand dropseed, and all bunchgrasses have been replaced by weedy annuals such as cheatgrass), and in the cryptobiotic crust cover (crust is now absent or fragmented, contains only early-successional species).

Species that are not dominant components of Okanagan shrub-steppe ecosystems are not as well studied, but a long list of species that were or are still present in these ecosystems

includes the sagebrush mariposa lily (*Calochortus macrocarpus*), arrow-leaf balsam (*Balsamorhiza sagittata*), junegrass (*Koeleria* cristata), snow buckwheat (*Eriogonum niveum*), brittle prickly-pear cactus, and bublet prairie star (*Lithophragma glabrum*) (Daubenmire 1970). In big sagebrush – needle-and-thread grass and antelope-brush needle-and-thread grass ecosystems, Daubenmire (1970) found perennial forb cover to be between 2 and 36 percent, and 4m² plots to contain between 5 and 22 native species.

2.8.2 Ecological Goals

General targets set out by Atwood (1996) for the Osoyoos Desert Centre site are still effective. These are:

- Reduce the weedy species component
- Increase the cover and recruitment rate of native grasses and forbs
- Replace areas of early successional species with climax species
- Maximize species diversity within each habitat type.

This phase of the Osoyoos Desert Centre restoration plan will focus on the first two targets, "reduce the weedy species component", and "increase the cover and recruitment rate of native grasses and forbs". Future efforts could be directed at the last two targets as set out by Atwood.

Table 4. Ecological goals.

Target	Objective	Specific Goal	Time Frame
Reduce the weedy species component	Control of noxious weeds by hand-pulling	Eliminate noxious weeds from site systematically –break up site into manageable blocks.	First block cleared of listed noxious weeds by 2008. Further blocks cleared when possible. Maintenance of cleared areas is priority.
	Weeding and re-planting of high-visibility locations	Enhance aesthetic appeal of site: remove all large weeds	ongoing
	Weed and plant plots	Non-native cover of 25% pre-treatment levels	2 years after weeding
	Cryptobiotic crust study	Cryptobiotic crust cover of 20 % greater than pre-treatment cover	By 5 years after application
Increase the cover and recruitment rate of native grasses and forbs	Seed mix study	Native species cover 30%; 60%	2 years after treatment for 30%; 5 years for 60%
	Weed and plant plots	Native species cover 30%; 60%	2 years after treatment for 30%; 5 years for 60%

Replace areas of early successional species with climax species: Future target
Maximize species diversity within each habitat type: Future target

2.8.3 Social Goals

An important component of ecological restoration is the sense of stewardship that it can foster within the community. In a quickly-developing area such as the Okanagan, building stewardship and caring for the landscape is especially important, and may be an effective method of promoting habitat conservation. Furthermore, educating the public about the importance and ecology of local and endangered ecosystems is central to the Osoyoos Desert Society's mandate. Involvement of the public should be an important component of the Osoyoos Desert Centre restoration plan, which can take place through the following objectives:

- Discussion of restoration during boardwalk tours
- Native plant salvaging
- Restoration open-houses
- Weed pulls or native plantings
- Workshops
- Native plant landscaping information and selling native plants and seeds

Table 5. Social goals.

Objectives	Action Needed	Specific Goals	Timeframe
Discussion of restoration during boardwalk tours	Teach restoration tour to Desert Centre tour guides	All guides knowledgeable on restoration issues	Spring/early summer each year
Native plant salvaging	Gain support from town, developers. Build salvager group	All town of Osoyoos development on natural habitat salvaged, all new developers have access to salvaging information.	2009
Restoration open houses	Plan for, advertise, and hold open houses	At least one open house per year.	Spring 2007, ongoing
Weed pulls/native plantings	Determine weeding/planting schedules. Build volunteers database.	At least two weed pulls/plantings per year, with 5 or more volunteers.	Begin 2007, ongoing
Workshops	Organize, advertise, and hold workshops	At least two restoration-related workshops per year.	Begin 2007, ongoing
Native plant landscaping information and selling native plants	Create native plant landscaping booklet, make collected seeds available for purchase	Create booklet, obtain funding for printing. Make seeds for at	Booklet ready for spring 2008. Seeds by

and seeds	in small amounts, start native plants.	least 5 species available. Grow out 100 plants for sale each year.	spring 2009 or earlier. Begin spring 2007.

2.8.4 Research Goals

Because restoration as a practice is still in its infancy, and very little is known about the success of restoration efforts in the Okanagan, integrating scientific research into restoration projects is necessary. Some components of the restoration plan do not involve rigorous scientific study, but will be recorded, monitored, and assessed. These components include the collection of seed and propagation, pulling noxious weeds from the entire site, and weeding and planting plots. Two rigorous scientific studies are planned for the Osoyoos Desert Society in this restoration plan:

- Seeding mix
- Cryptobiotic crust restoration

Another important consideration is the curation of data and the dissemination of research findings.

Table 6. Scientific research and data management.

Research Topic	Research Question	Study Method	Time Frame
Seed mix	Is there a native seed mix that can be used to establish a high percentage of cover, before invasive species are able to colonize the area?	Three seed mixes will be sown onto 6.5 m² plots at a rate of 1200 PLS, with ten replicates of each mix and control plots. Plots will be tilled twice in the spring 2007, and weeded in the fall immediately before sowing. Seeds will be hand-broadcasted over the plots and raked in evenly. As well, one 16m² plot will be seeded with each individual species used in the mixes, at the same rate. Monitoring will occur in late Aug and will survey plant counts and cover of all species in plots.	Spring 2007 – fall 2007: Seed collection and processing. Test seed for PLS Till plots spring, Weed fall 2007. Seed plots 2007. Monitoring: Late Aug. 2008, 2009, 2010, 2011.
Cryptobiotic crust	What is the best	All non-native species	Lay out plots

restoration	method of applying cryptobiotic crust that has been salvaged?	will be hand-weeded out of plots. Plots will receive one of two treatments: cryptbiotic crust slurry, or planting the same size of crust in fragments. Each of three treatments (fragment/slurry/control) will be randomly replicated ten times, located in area of 1998 solarization experiment. Each plot will have a one meter buffer on each side.	summer 2007 Salvage crust and replant ASAP Fall 2007 Monitoring each fall for 5 years or more
Data Management and Curation		Data collected from the study will be entered into a spreadsheet, and metadata will be created.	Metadata creation: Spring/summer 2007 Data entry: shortly after monitoring, yearly
Dissemination of findings		A two-year report will be written outlining methods and results to date, and a 6-year report will be written after final monitoring. This will be posted on the Desert Society website, circulated to interested individuals and organizations, and attempts will be made to publish it in journals and other publications.	2009 for interim report, 2013 for 6-year report. Ongoing postings to website, Osoyoos Desert Society newsletter, etc.

2.9 Project Duration

This restoration plan outlines yearly restoration activities to be undertaken at the Osoyoos Desert Centre site, as well as a four and a six-year study. Most of the above targets and experiments are to be initiated in the next one to two years, but monitoring is scheduled for three to five years following the experiments, at a minimum. Some tasks, such as the social goals and noxious weed control, are to be kept up on an ongoing basis. An evaluation of the restoration plan will be performed yearly to determine the effectiveness and feasibility of: hand-weeding noxious weeds; hand-weeding high-visibility areas;

weed and plant plots; native plant salvaging; open houses; workshops; and landscaping information/ seed sales. The restoration plan for the Osoyoos Desert Centre may be amended as deemed necessary through examination of the yearly evaluation. See appendix one for yearly evaluation forms.

The two scientific experiments (cryptobiotic crust restoration and seed mix experiment) will be evaluated after the three or five year monitoring period, and reports will be written sharing the results. The results of the study may present opportunities for further study. An updated version of this plan should be created at the end of the current study periods, and should outline future research and restoration to be carried out at the Osoyoos Desert Centre site.

Table 7. Ideas for future research and restoration.

Research topic	Opportunities for further study/actions
Cryptobiotic crust	Monitoring for crust effect on weed or native plant establishment. Test crust application/planting under various soil preparations (not weeded, tilled, etc)
Seed mix	Test establishment of preferred seed mix using different rates, different times of sowing, different soil types or site conditions. Apply seed mix to other areas, such as highway strips.
Replacement of early-seral communities with late-seral	Test combinations of seeding and planting to achieve desired species mix.
Maximize species diversity within each habitat type	Determine suitable species for re-introducing in various habitats, and study the best method (seeding/planting) of doing so. Determine barriers to natural biodiversity of site.
Enhance habitat connectivity of site	Secure rights and protection to lands acting as corridors, and restore them as necessary.
Controlled burning as a restoration tool	Conduct a controlled burn and monitor the effects.

3 Pre-Planning

3.1 Restoration Objectives

3.1.1 Objective 1: Control of noxious weeds by hand-pulling

- Divide Osoyoos Desert Centre site into easily-managed sections. Prioritize areas with minimal weed cover or high visibility.
- Assemble list of interested volunteers.

- Instruct volunteers on species to pull: knapweed, hound's toung, (*Cynoglossum officinale*), puncturevine (*Tribulus terrestris*), and Russian thistle (*Salsola kali*)
- Organize date, location of pulls, and alert volunteers.
- Assemble work gloves, garbage bags, sunscreen, drinks, snacks.
- Keep records: Which blocks completed, number of bags of weeds per block, number of volunteer hours, photos.

3.1.2 Objective 2: Weeding and re-planting of high-visibility locations

- Organize date, location of pulls, and alert volunteers.
- Instruct volunteers on which species to pull (these should be all non-native species).
- Assemble native plants – grown or salvaged
- Assemble resources, same as objective 1 plus shovels and watering cans if planting.
- Keep records: same as objective 1 plus number and species of plants planted.

3.1.3 Objective 3: Weed and plant plots

- Create 3m by 2m plot near boardwalk in areas with high-weed cover.
- Remove all weeds from plot.
- Plant 4 native plants per square m. (can be any species)
- Monitoring: photos (before and after), species cover before and after.

3.1.4 Objective 4: Cryptobiotic crust study

- Locate a source of intact crust that will be developed.
- Create 30 one m^2 plots with a one meter buffer on all sides of each plot.
- Randomly assign treatments to each plot. Treatments are ten each of: cryptobiotic crust slurry, cryptobiotic crust fragments, or no crust.
- Weed all non-native vegetation from plots.
- Survey species (including cryptobiotic crust moss and lichen species), litter, bare ground, cover of each plot. Survey soil texture of each site.
- Assess cover of macroscopic component, by morphological groups, or species if possible, in salvage site cryptobiotic crust. Use m^2 quadrats, and use pages 8 to 9 in Peterson 2001 for identification of morphological groups, and Parish, Coupe and Lloyd (1996) for species of moss, lichen, and liverworts.
- Collect 20 cryptobiotic crust fragments that measure 5 cm in height and a surface of 25cm by 25cm, and store on separate trays in a shaded location.
- Break crust fragments into four more-or-less same sized pieces and plant fragments of cryptobiotic crust (crust slightly above soil level) in appropriate plots. Water with same amount of water used in slurry.
- Place one crust fragment in a large container and add one gallon of water. Using a blunt pole, mash contents. Spread evenly over appropriate plots.

- Water control plots evenly with one gallon of water.
- Monitoring: percent cover of visible crust species/morphological groups, native and non-native species.

3.1.5 Obective 5: Seed mix study

- Collect and clean seed. Table 8 estimates the total weight of seed needed based on an average Pure Live Seed rate of 50% of total weight.

Table 8. Seed amounts needed for seed mix study.

Species	Weight in clean seed needed (g)
Sand dropseed	26.6
Pasture sage	19.6
Yarrow	25.3
Needle-and-thread grass	712.5
Red three-awn	600
Junegrass (*Koeleria macrantha*)	45
Sandberg's bluegrass	81.7
Wooly plantain	46.8
Brown-eyed susan	468.9
Golden aster (replacement if junegrass and/or sandberg's bluegrass is not available	2.94 to replace one species at 20% of mix 3.43 to replace 2 species

- Have seed tested for PLS rate.
- Lay out plots in spring 2007, transplant native species in plots to another location and till. The study will be carried out in the degraded area behind (north) the display trailer at the Osoyoos Desert Centre site. Seed mix plots will be randomly assigned to two 2-plot by 10-plot grids, separated by a 1m walkway, with each plot measuring 2.5m by 2.5 m (total grid size is 10 m by 25 m.) Individual species plots will measure 2m by 8m and will be created in the same area as the seed mix plots.
- In late Oct 2007, re-weed/till all plots. Seed mixed and single-species plots (Pasture sage may need to be seeded separately depending on ripening date)
- Monitor plant count and cover per species in late August 2008 to (and including) 2011.

Mix 1	%	Mix 2	%	Mix 3	%
sand dropseed	50	sand dropseed	30	sand dropseed	30
pasture sage	10	pasture sage	10	pasture sage	10
yarrow	40	needle-and-thread grass	20	yarrow	20
				wooly plantain	10
		red-three-awn	20	brown-eyed susan	10
		junegrass	20	sandberg's bluegrass	20

Table 9. Species and seed rates (%) to be used in three seed mixes. Forb species chosen were recommended in Atwood (2000).

3.1.6 Objective 6: Native landscaping info. and sale of plants and seeds

- Grow out a variety of native plants throughout the year, and make available for sale at Osoyoos Desert Centre and other events.
- Compile auto-ecological information about target species, and keep good records of propagation and seed collection/extraction methods.
- Harvest native seeds as they become available. Clean and store properly.
- Test viability of seed by sprouting in wet paper towel (may have to stratify first).
- Package native seeds for individual sale.
- Create a native plant propagation booklet (available for purchase or printed with grant money).

3.1.7 Objective 7: Native Plant Salvaging

- Establish program with cooperation fro RDOS
- Obtain equipment: shovels, gloves, pots.
- Create waiver, have each volunteer fill it out, and store safely.
- Organize salvaging events.

3.1.8 Objectives 8 – 10: Other social objectives

- Tour instruction, open houses, and workshops will be planned on an ongoing basis.

3.1.9 Assess Resource Needs and Budget

Table 10. Resource needs and costs.

Objective	Task	Resources Needed	Cost
1 and 2: Control of noxious weeds by hand pulling/ high visibility area weeding	weeding	Gloves (8 pairs) Garbage Bags Sunscreen Snacks/Drinks 3 shovels (we have)	72.00 5.97 12.00 36.00 0.
3:Weed and plant pots	Grow out plugs of native grasses, Grow nursery beds of bluebunch	8 Plug trays (we have) Potting mix Greenhouse (we have) Heater (we have) Watering can (we have) Sprinkler (we have)	0 $25/bale 0 0 0 0

	wheatgrass	Pots (we have) Sand (for red 3 awn)	0 2.99
	Mark out plots	Surveyor's tape (purchased below) Stakes (4 per plot) Compass (we have) Sledgehammer	0 10.99 0 25.99
	Weed	Garbage bags (same bags as weed pulls) Gloves (same pairs as weed pull) Shovel (we have)	5.97 0 0
	Plant plugs	Shovel (we have) Watering cans, 2 (we have 1)	0 4.99
4: Cryptobiotic crust study	Mark out plots	Surveyor's tape (purchased below) Stakes (120) Compass (we have)	0 32.97 0
	weed	Shovel Garbage bags (purchased above)	0 0
	Collect crust and apply	Shovel Trays -40 (we have) Large bucket 'pestle' (blunt lumber) 1 gallon jug Watering can	0 0 0 0 0 0
5: Seed mix study	Mark out plots	Surveyor's tape Stakes (102) Compass sledgehammer	49.99 21.98 0 0
	Weed	Shovel Garbage bags	 11.94
	Seed-related	(see table 8 for seed amounts) PLS tests for 9 spp Scale to 1/100 th g. Sand rake	 1440.00 50.00 2.99 29.99
6: Native landscaping info and sale of plants and seeds			
7: Native plant salvaging	Salvage and transportation	Shovels: 10 Gloves: 10 pairs Pots and trays Snacks and drinks Trailer?	
	Storage	Shade cloth and clips Posts 6	23.00

	Re-plant	Shovels 4 Watering cans 2	
8-10: Other social objectives	To be determined on an individual basis		

4 Works Cited

Allen, E. (1988). Some trajectories of succession in Wyoming sagebrush grasslands: Implications for restoration. *In* Allen, E. *The Reconstruction of Arid Lands*. Westview Press, Colorado, U.S.A.

Anderson, D., K., Harper, and R. Holmgren. (1982). Factors influencing development of cryptogamic soil crusts in Utah deserts. J. Range Mgt. 35: 180-185.

Atwood, L. (1996). Site Assessment of Unsubdivided Portion of DL 2450s SDYD: Proposed Area for the Osoyoos Desert Centre. Unpublished report. Prepared for Dr. G. Scudder, U.B.C. Dept. of Zoology.

Atwood, L. (2000). Monitoring restoration of the Vaseux-Bighorn National Wildlife Area following pipeline construction. *In* Proceedings, Biology and Management of Species and Habitats at Risk. Kamloops, B.C. <http://wlapwww.gov.bc.ca/wld/documents/so10atwood1.pdf>. Retrieved 03/01/2007.

Atwood, L. and G. Scudder. (2003). Experimental ecological restoration in the south-Okanagan shrub-steppe. *In* Proceedings, Ecosystem at Risk: Antelope-Brush Restoration Conference. Osoyoos, B.C. <http://www.serbc.info/resources/file_repository/2003%20Proceedings%20v3web.pdf>. Retrieved 03/01/2007.

B.C. MoE. (2001). Habitat Atlas for Wildlife at Risk: South Okanagan and Lower Similkameen. Govt. of B.C. <http://wlapwww.gov.bc.ca/sir/fwh/wld/atlas/introduction/intro_index.html>. Retrieved 03/01/2007.

Bolton, H. Jr., J. Smith, and S. Link. (1993). Soil microbial biomass and activity of a disturbed and undisturbed shrub-steppe ecosystem. Soil Biol. Biochem. 25: 545-552.

Bonnemaison, T. (2006). Replanting more than divots: ecological restoration at golf course in the South Okanagan, British Columbia. ER 390 final report, University of Victoria.

Cannings, R., and E. Durance. (1998). Human use of natural resources in the South Okanagan and Lower Similkameen valleys. *In*, Smith, I.M., and G.G.E. Scudder, eds. Assessment of species diversity in the Montane Cordillera Ecozone. Burlington: Ecological Monitoring and Assessment Network, 1998.

Daubenmire, R. (1970). Steppe Vegetation of Washington. Technical Bulletin 62, Experimental Station. Washington State University, Pullman, Washington.

Debinski, D. and R. Holt. A survey and overview of habitat fragmentation experiments. Cons. Biol. 14(2): 342-355.

Duerksen, C., D. Elliott, N. Hobbs, E. Johnson, and J. Miller. (1997). *Habitat Protection Planning: Where the Wild Things Are*. American Planning Association Publications Office. Illinoise, U.S.A.

Dyer, O., and T. Lea. (2003). Status and importance of the antelope-brush – needle-and-thread grass plant community in the south Okanagan valley, British Columbia. *In* Proceedings, Ecosystem at Risk: Antelope-Brush Restoration Conference. Osoyoos, B.C. <http://www.serbc.info/resources/file_repository/2003%20Proceedings%20v3 web.pdf>. Retrieved 03/01/2007.

Friends of Ecological Reserves (2006). State of British Columbia's ecological reserves: Report for 2005. Victoria, B.C. < http://www.ecoreserves.bc.ca/newsissues _files/State%20of%20Ecological%20Reserves%202005%20final.pdf>. Retrieved 03/03/2007.

Howard, J. (2003). Sisymbrium altissimum. *In*: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). <http://www.fs.fed. us/database/feis/ >. Retrieved 03/01/2007.

Kleiner, E. and K. Harper. (1972). Environment and community organization in grasslands of Canyonlands National Park. Ecology 53: 299-309.

Knick, S. (1999). Requiem for a sagebrush ecosystem?. Northwest Science 73: 1: 53-83.

Krannitz, P., and J. Mottishaw. (2003). Fire effects and antelope-brush: fire not as detrimental as might be expected. Pp 36-42 *In* Proceedings, Ecosystem at Risk: Antelope-Brush Restoration Conference. Osoyoos, B.C. <http://www.serbc.info /resources/file_repository/2003%20Proceedings%20v3 web.pdf>. Retrieved 03/01/2007.

Lacey, J., C. Marlow, and J. Lane. 1989. Influence of spotted knapweed (*Centaurea maculosa*) on surface runoff and sediment yield. Weed Technology 3: 627-631.

Lea, T. (1996). The antelope-brush ecosystem: Endangered in the Okanagan Valley. Cordillera, summer: 22-27.

Lea, T., R. Maxwell, and A. Swanson. (1998). Biophysical habitat units of the South Okanagan study area. B.C. MoELP. <http://srmapps.gov.bc.ca/appsdata/acat /documents/documents/r1846/tem_0019_el01_1099947054937_3071863aace54bb4 a4f5f75dccc0d27b.pdf>. Retrieved 10/03/2007.

Link, S., W. Mast, and R. Hill. (no date). Chapter 11: Shrub-steppe restoration. Washington State University. < http://www.tricity.wsu.edu/shrub_steppe/sage9-052.pdf>. Retrieved 05/03/2007.

Melgoza, g., R. Nowak, and R. Tausch. (1990). Soil water exploitation after fire: competition between *Bromus tectorum* (cheatgrass) and two native species. Oecologia 83: 7-13.

Mulligan, G. (1965). Recent colonization by herbaceous plants in Canada. *In* H. Baker and G. Stebbins (Eds.). *The Genetics of Colonizing Species*. P. 127-143. Academics Press, New York.

Parish, R., R. Coupe, and D. Lloyd. Eds. (1996). Plants of Southern Interior British Columbia. Lone Pine Publishing, Canada.

Pendleton, R., B. Pendleton, J. Johansen, and L. St. Clair. (2003). Soil microorganisms affect survival and growth of shrubs in competition with cheatgrass. *In* Proceedings,

ESA Annual Meeting. <http://abstracts.co.allenpress.com/pweb/esa2003/document/?ID=25770>. Retrieved 03/01/2007.
Peterson, P. Ed. (2001). Biological soil crusts: ecology and management. U.S. Dept. of the Interior. Technical reference 1730-2.
Reeves, F., D. Wagner, T. Moorman, and J. Kiel. (1979). The role of endomycorrhizae in revegetation practices in the semi-arid west: I. A comparison of incidence of mycorrhizae in severely disturbed VS natural environments. Amer. J. Bot. 66(1): 6-13.
Saskatchewan Watershed Authority. (no date). Managing crested wheatgrass in native grassland. < http://www.swa.ca/Publications/documents%5CManagingCrestedWheatgrassInNativeGrassland.pdf>. Retrieved 03/01/2007.
Turner, S., and P. Krannitz. (2001). Conifer density increases in semi-desert habitats of British Columbia in the absence of fire. Northwest Science 75:2: 176-182.
Tyser, R., and C. Key. (1988). Spotted knapweed in natural area fescue grasslands: an ecological assessment. Northwest Sci. 62: 151-159.
Updike, D., E. Loft, and F. Hall. (1990). Wildfires on big sagebrush/antelopebitterbrush range in northeastern California: implications for deer populations. Pp 41-46 *In* E. McArthur, E. Romney, S. Smith, and P. Tueller (eds). Proceedings--symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management. U.S. Forest Service General Technical Report INT-GTR-276. Intermountain Forest and Range Experiment Station, Ogden, Utah.
Wicklow-Howard, M. (1994). Vesicular-arbuscular mycorrhizae from sagebrush steppe habitat in western Idaho and parts of eastern and central Oregon. Un-published report prepared for Eastside Ecosystem Management Project. <http://www.icbemp.gov/science/wicklow1.pdf>. Retrieved 03/01/2007.
Wooten, G., and P. Morrison. (1995). Biological invasions of alien plants in the Interior Columbia River Basin. From, Key Elements for Ecological Planning: Management Principles, Recommendations, and Guidelines for Federal Lands East of the Cascade Crest in Oregon and Washington. Cara Nelson (Ed.). Columbia River Bioregion Campaign, WA, U.S.A.
Wuerthner, G. (no date). The soil's living surface: Biological crusts. National Public Lands Grazing Campaign. < http://www.publiclandsranching.org/htmlres/PDF/wr_SOIL_SURFACE.pdf>. Retrieved 03/01/2007.

5 Appendix 1: seed collection

Table 11. Seed collection dates and methods.

Species	Time of collection	Method of collection	Cleaning	Storage
Sand dropseed		Sprinkle or strip seeds into a container	Pass through a very fine seive	
Pasture sage	Early Oct to - early Jan.	Seed (achene) easily hand stripped from plant inflorescences	Hand cleaned using rub board and hand screens; then placed in seed	No information on storage is available, but *A tridentate* needs a period of dry

			blower to remove fine inert materials	storage after ripening so keep in paper envelope in refrigerator until spring. No long-term.
Yarrow	July-Sept	Cut whole flower heads when seed has dried, and place in paper bag. Allow to dry indoors at least one week before cleaning.	In paper bags, shake seeds loose, or crush with rolling pin. Sieve seeds through screening to separate seed from chafe.	Low humidity and moderate temperatures: seed is viable 5 years when properly stored.
Needle and thread grass	Mid August	Collect by hand and hang to dry in cloth bag		
Red three awn	Mid to August	Collect by hand and hang to dry in cloth bag		
Sandberg's bluegrass				
Junegrass				
Brown-eyed susan	Aug- Sept	Cut or strip seed heads into cloth bags and hang to dry.	Thresh dried seed heads to release seeds. De-beard seeds to prevent seed movement after sowing	No information available. Try cold storage in sealed containers at 3-5^0 C.
Wooly plantain	Late June-July	Strip seeds by hand, or cut seed heads, and hang to dry	Thresh seed heads to release seeds.	

6 Appendix 2: yearly evaluation

Year:			
Target	**Goals met for the year?**	**Continue target next year?**	**Improvements to be made:**

hand-weeding noxious weeds			
hand-weeding high-visibility areas			
weed and plant plots			
native plant salvaging			
open houses			
Workshops			
Landscaping information/seed sales			