WILDLIFE MITIGATION BURN MONITORING PROGRAM AT TECK COAL LIMITED – FORDING RIVER OPERATIONS

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ABSTRACT

In 1997, Fording River Operations (FRO) implemented a prescribed–burn program with the objective of mitigating the effects of ungulate habitat loss due to mine expansion. Fording River personnel, in consultation with the British Columbia Ministry of Water, Land and Air Protection, identified six mitigation burn areas totaling 460.0 hectares (ha) of habitat improvement. The objective of the mitigation burns was to increase wildlife habitat suitability and to provide winter habitat for elk and moose. Each of the treatment areas was subjected to a similar prescribed burn.

A monitoring program was established in 1998 to evaluate the results of the prescribed burns in terms of forest cover, forage production, and wildlife utilization. The effects of the prescribed burn treatments on forest cover were evaluated with pre-burn and post-burn aerial photographs. A total of 36 transects were located in paired burned and unburned habitats. Vegetation, wildlife use, and standing crop production (production clip) data were collected at each transect. The monitoring program operated from 1998 to 2007.

In general, the prescribed mitigation burns were successful. Although variable between treatment areas and years, standing crop production measurements showed consistently that forage production and, consequently, Animal Unit Months (AUMs) were greater within the burn treatment areas compared with non-burned areas. The increased cover of palatable grasses and forbs was particularly beneficial for the enhancement of elk winter range. Canopy reduction ranged from 10% to 60% within the off-site burned areas. The prescribed burns also altered species dominance and stand structure. Signs of habitat use (i.e., evidence of browsing/grazing and pellet groups) indicated that elk and mule deer continued to use the burned sites preferentially during the monitoring period.

Key Words: coal mine, mitigation burn, monitoring, wildlife

INTRODUCTION

In 1996, Teck Coal Limited – Fording River Operations (Teck) projected that the expansion of mining activities in the Henretta Valley would disturb 131.0 ha of Class 2 and Class 3 elk winter range and Class 3 moose winter range on the south slopes of Henretta Ridge (Fording Coal Limited 1996). To compensate for this habitat loss, a prescribed burn mitigation program was implemented.

Fording River Operations (FRO) personnel, in consultation with government regulators, identified seven potential mitigation burn areas totaling 460.0 ha. A total of 127.6 ha were identified for mitigation burning, of which, 87.1 ha were burned. The purpose of the mitigation burns was to offset the impacts to wildlife caused by mining activities through increasing the wildlife habitat suitability of on-site (within mining lease) and off-site (outside mining lease) mitigation areas. The objective of the mitigation burns for the Turn Creek (A2), Henretta Ridge (A3), and Turnbull South (A4) areas was to provide winter habitat for 5.5 elk per year, while the objective for the Lookout Draw (B1), Lookout Bowl (B2), and Britt Creek (B3) areas was to provide winter habitat for 1.5 moose and 4.0 elk per year.

The vegetation within the study area is part of the Engelmann Spruce – Subalpine Fir dry cool (ESSFdk1) and Engelmann Spruce – Subalpine Fir dry cool woodland (ESSFdkw) biogeoclimatic subzones. The mitigation areas that were burned were described by four physiognomic classifications: (1) grass/shrubland, (2) deciduous (aspen) forest, (3) open coniferous forest, and (4) closed coniferous forest.

Vegetation Response to Prescribed Burn

Many species benefit from fire-induced habitat alterations (Agee 1993). In fact, game animals prefer to graze on recently burned areas (Sachro 2003). The reasons for this preferential grazing are numerous, and it is for these reasons that Teck selected prescribed burns as part of their program to mitigate the habitat losses created by the Henretta Ridge mine expansion.

Monitoring Objectives

The objective of the monitoring program was to evaluate the results of the prescribed burn in terms of a reduction in forest cover and increase in forage production and wildlife utilization.

METHODOLOGY

The monitoring methodology followed, for the most part, the Procedures for Environmental Monitoring in Range and Wildlife Habitat Management (Habitat Monitoring Committee 1996).

For each of the mitigation enhancement sites (i.e., Turn Creek [A2], Henretta Ridge [A3], South Turnbull [A4], Lookout Draw [B1], Lookout Bowl [B2], and Britt Creek [B3]), six macroplots / transects were established: three within the treatment areas and three in adjacent "control" areas. The use of treatment and control plots enabled habitat monitoring or trend analysis and facilitated the assessment of the habitat enhancement project by directly comparing treated and untreated vegetation stands.

The monitoring program had a sampling frequency of once every two years for a period of six years and then a single monitoring "event" after a subsequent period of five years (Bartos et al. 1994). Monitoring began in the year following the burns at these sites.

Description of the monitoring program methods is separated into five sections in order to clarify understanding of the methodology and reporting procedures: (1) site description, (2) vegetation survey, (3) species composition, (4) herbaceous forage production, and (5) pellet group counts.

Site Description

Site information such as sample system and reference point descriptions, biophysical descriptions, macroplot / microplot descriptions, and herbaceous forage production were recorded. 'Signs' or indirect evidence of wildlife presence was part of the general site descriptions as well. Evidence of wildlife utilization included indirect 'sign' observations (e.g., sounds, home site, browse utilization, territorial markings, and excavations).

Vegetation Survey

The vegetation surveys were designed to document species composition and percent cover and were conducted using the quadrat-transect sampling methodology described in the Procedures for Environmental Monitoring in Range and Wildlife Habitat Management (Habitat Monitoring Committee 1996). Vegetation was sampled within 15 microplots placed randomly along eighteen permanently marked 30 m transects. At each microplot location, a 20 cm x 50 cm microplot was used for grasses and forbs. Two 10 m x 10 m plots were located at the end of each transect to estimate low shrub cover. A single 20 m x 2 m macroplot was located at the center of each transect to estimate the canopy coverage of trees and tall shrubs (stems > 2.5 m). The canopy coverage method of Daubenmire (1959) was used for the microplot sampling. Sampling was conducted between July 25th and August 10th each year.

Plant specimens were identified to species. Differences in dominant and understory vegetation between the control (non-burned vegetation) and treatments (prescribed burn) were analyzed using the Multi-Response Permutation Procedure (MRPP) and Indicator Species Analysis (McCune and Mefford 2006).

Species Composition

Species percent cover data was used to calculate diversity measures within the controls and treatments. Three measures of diversity (species richness, diversity, and evenness) were calculated.

Herbaceous Forage Production

The efficacy of the prescribed burn enhancement project was determined, in large measure, by increases in forage available to the target ungulates. Therefore, herbaceous forage production was measured for the control and treatment sites, and the results compared. Herbage production and forage use levels are determined typically by harvesting vegetation from within a range cage exclosure and from non-exclosure at each transect (Bonham 1989). In the monitoring program, 36 forage production exclosures (three pairs per treatment/control per area) were located in the spring of 1998. The exclosures prevent herbivore grazing from an area of approximately 1.0 m^2.

The forage production assessments were done as the vegetation and site assessments were being completed. At each transect, a representative 50 cm x 100 cm rectangular quadrat or sampling unit was clipped to a height of 2 cm. Another clip was made within the exclosure cage. Litter was removed and bagged prior to clipping. The clipping material was separated into shrubs (< 2.5 m), grasses (and grass-like vegetation), and forbs and placed into labeled bags for drying. Only the current year's growth of shrubs was clipped (Bonham 1989).

Herbage production clips (samples) were weighed, oven-dried, and re-weighed to the nearest 0.1 gm. Production (kg/ha) was calculated from raw data (grams/0.5 m^2) using a conversion factor (x 20). Animal Units (AUs) were calculated using the formula described by Gayton (1993).

The equation uses the total amount of forage production on the enhanced (prescribed burn) site and divides it by the amount one animal is capable of consuming during a specified time period. The result of the calculation is the maximum number of animals that the habitat is capable of supporting during the specified time period in the long-term.

The focus of the treatment/control forage comparisons was to assess the magnitude of increase in forage production as well as the areal increase in the palatable forage-producing habitat over time.

Pellet Group Surveys

Ungulate fecal pellet group surveys were conducted at each plot site using Method 4 (Luttmerding et al. 1990). Method 4 involves the establishment of a 50 m long by 1 m wide transect that is divided into five contiguous 10 m segments. All pellet groups present within the segments were removed from the segments following each observation to enable comparisons between years (Lancia et al. 1994). The results of the pellet group counts were used to test the relative differences in elk and moose activities between treatment and control areas.

The pellet group data was used to estimate the abundance of elk or moose (Neff 1968). The defecation rate for moose was assumed to be 13 times per day, and the defecation rate for elk was assumed to be 11 times per day (Harestad and Bunnell 1984). The deposition period was 150 days / year (Demarchi 1995) and the size of the plot was 50 m^2.

Present use (as calculated from pellet group counts) and capability (as calculated by forage production) was reported.

RESULTS AND DISCUSSION

The following text describes the results of the 2007 assessments. Monitoring of the on-site (A) and off-site (B) prescribed-burn mitigation areas was combined in 2007.

Typically, the burn/control areas were located on moderately steep to steep, warm slopes. The mesoslope positions range from lower to upper slope positions. The ecological moisture regime of the sites varied

between submesic and mesic while the ecological nutrient regime was generally mesotrophic. The predominant structural stages for the vegetation were low shrub and/or young forest.

Prescribed Burn Evaluation

Each of the mitigation burn areas was subjected to a similar prescribed burn although the burn intensity could only be inferred indirectly. Overall success was determined by evaluation of before and after aerial photographs. Assessment was also undertaken on the ground using the criteria developed by Ryan and Noste (1985).

Approximately 20% of the vegetation within the Turn Creek (A2) area was burned. Burning in this area caused a 15% reduction in crown canopy within the coniferous stands (CF) and a 25% reduction in the open coniferous (OF) forest stands. Overall, 35% of the Henretta East (A3) target area was burned. Burning resulted in a 55% reduction in crown canopy in both the aspen and open grassland (G) and shrubland (S) stands and a 10% reduction in the mixed conifer/aspen (M) stands. Approximately 15% of the vegetation was burned within the Turnbull South (A4) area. Within this area, burning caused a 20% reduction in crown canopy within the coniferous stands (CF) and a 45% reduction in both the open coniferous (OF) and trembling aspen (A) forest stands. Approximately 50% of the North Greenhills (B1) area was burned. Burning resulted in a 60% reduction in crown canopy in both the aspen (A) and open grassland/shrubland (G) stands and a 10% reduction in the mixed coniferous (M) stands. In the North Greenhills (B2) area, approximately 30% of the vegetation was burned. Burning in this area caused a 20% reduction in crown canopy within the closed coniferous stands (CF) and a 35% reduction in both the open coniferous (OF) and aspen (A) forest stands. Approximately 50% of the vegetation was burned within the Britt Creek (B3) area. Within this area, burning caused a 30% reduction in crown canopy within the closed coniferous stands (CF) and a 60% reduction in both the open coniferous (OF) and aspen (A) forest stands.

Vegetation Monitoring

A total of 122 plant species were recorded within the on-site unburned/burn monitoring areas and 126 plant species were recorded within the off-site unburned/burn monitoring areas during the monitoring period. Ordination of the transects based on floristics revealed that the samples were paired consistently and that the site conditions were comparable. Analyses during the monitoring period illustrated that the three dominant environmental parameters controlling vegetation within the study area are slope, ecological moisture regime and treatment (i.e., unburned or burned).

Mean species richness R increased at each of the on-site and off-site burned areas while species richness (R) of the unburned mitigation controls remained relatively constant. Between-year diversity, as determined with the Shannon's (H'), varied slightly within mitigation burn areas during the monitoring period. Comparisons of diversity between the burn treatment and the unburned control reveal slight changes in species proportional abundance between 1998 and 2007. The evenness statistic (J) represents the extent to which all species in a community are equally abundant. This statistic varied slightly at each site between 1998 and 2007. Comparisons of the burn treatment and control revealed variable responses

between 1998 and 2007 with no distinct trend or pattern. In general, changes in evenness were slight.

Mean total cover increased at all sites between 1998 and 2005 but declined slightly in 2007. The productive capacity of the sites and structural stages appeared to reach its maximum in 2005. The decline may be due to lower precipitation values in 2007. Mean total cover for both the unburned controls and burned treatments increased during the monitoring period. At the end of the monitoring program, the difference in cover between the unburned controls and burned treatments ranged from approximately 2.7% for the on-site mitigation areas to 4.8% for off-site areas. During the recording period, the Britt Creek (B3) site consistently had the highest mean cover of forage species. This result was interpreted to indicate that the prescribed burn, although effective at all sites, was most effective at the B3 site.

Shrub cover increased between 1998 and 2005 but declined slightly in 2007. During the monitoring period, shrub cover was consistently highest at the burned treatment off-site mitigation sites. In 2007, the difference in shrub cover between unburned controls and burned treatments was greatest for the on-site mitigation areas. The treatment – control differences range from 2.2% for the off-site areas to 6.6% for the on-site areas in 2007.

Forb cover increased consistently between 1998 and 2005 but declined slightly in 2007. In 2007, treatment – control differences ranged from an average of 12.2% for the on-site areas to an average of 10.7% for the off-site areas.

Graminoid cover increased consistently between 1998 and 2005 but decreased slightly in 2007. In 2007, the treatment – control differences (i.e., mean difference in graminioid cover values between paired control and burned treatments) ranged from 3.2% for the off-site areas to 10.1% for the on-site areas.

Species Change

Individual species response to prescribed burning was variable at each of the mitigation burn and control areas during the monitoring period. Initially, the percent cover of woody species such as trembling aspen (*Populus tremuloides*), prickly rose (*Rosa acicularis*), saskatoon (*Amelanchier alnifolia*), soapberry (*Shepherdia canadensis*), Scouler's willow (*Salix scouleriana*), and western thimbleberry (*Rubus parviflorus*) decreased significantly due to the prescribed burn. However, re-sprouting of these and other shrubs was vigorous. Re-sprouting following the burns was most prominent in Scouler's willow, prickly rose, thimbleberry, trembling aspen, and birch-leaved spirea (*Spirea betulifolia*). Extensive growth of showy aster (*Aster conspicuus*) was observed at most of the sites.

Mortality of lodgepole pine (*Pinus contorta* var. *latifolia*) and Douglas fir (*Pseudotsuga menziesii* var. *glauca*) trees, saplings, and seedlings was high in the early stages following prescribed burning, but tree mortality was not recorded at either the on-site or off-site areas after 2000. Lodgepole pine and Douglas fir seedlings are common now within all of the burned open and closed coniferous forest treatment areas.

Indicator species analysis was undertaken to assess species response to fire over the monitoring period to date. Sticky geranium (*Geranium viscossimum*), star-flowered Solomon's seal (*Smilacina stellata*), and

golden ragged moss (*Brachythecium salebrosum*) were negatively correlated with fire and have a strong affinity for undisturbed forested sites. Fireweed (*Epilobium angustifolium*), western meadow rue (*Thalictrum occidentale*), showy aster, birch leaf spirea and western thimbleberry all respond favorably to prescribed fire.

The 2007 vegetation data were analyzed to examine changes in species composition and species dominance. Species turnover, for the most part, was small within sites and treatments after 2000. However, where changes have occurred, the changes reflect the recovery of the vegetation following prescribed fire. The differences between the unburned controls and burned treatments reflect the replacement of late seral tree- or shrub-dominated stands with young seral forb-dominated stands.

A multi-response permutation procedure analysis (MRPP) was applied to the vegetation data. The results of the on-site ($T = -3.15$, δ observed = 1.25, δ expected = 1.29, $p = 0.03$) and off site analyses ($T = -3.01$, δ observed = 20.98, δ expected = 22.34, $p = 0.01$) conducted in 2007 indicated that there was a statistical difference in species composition between the burn treatments and the unburned controls.

Pair-wise percent similarity comparisons revealed the efficacy of the prescribed burns in altering vegetation structure and species dominance at each of the burn areas. The paired transects with the greatest dissimilarity or lowest percentages are those in which the fire effectively decreased tree and shrub cover. In response to burning, the burned areas typically had a much higher forb cover and a lower stature shrub layer.

Forage Species Composition and Diversity

The effectiveness of wildlife habitat mitigation burns is determined by the degree to which stand structure (i.e., crown closure) is altered. As well, a change in plant species composition towards an increase in palatable forage species cover and above ground biomass is desirable.

To evaluate the efficacy of the burns at each site, between-treatment comparisons of forage cover were made from transect species lists. The shrub species most commonly browsed were saskatoon, Douglas maple, trembling aspen, soapberry and Scouler's willow. The forbs most commonly grazed were fireweed, showy aster, Idaho fescue, and interior bluegrass. Typically, browsing was greater within the burn treatments in comparison to the unburned controls.

The number of browsed forb species also varied between sites and years during the monitoring period. In general, the number of browsed species was greater within the on-site mitigation areas (both burned and control treatments) in comparison to the off-site areas; the number of browsed species was greater within the burn treatments in comparison to the unburned controls.

Forage Production

Research indicates generally that burning produces positive results for elk and mule deer. During the first 5 years to 10 years following stand-replacement fires, grass and forb biomass generally increases. Often,

grass and forb biomass decreases the first season after fire but increases in the second and third growing seasons to above pre-fire levels. Typically, grass species recover more slowly than forbs (Bartos et al., 1994).

Standing crop data were collected within each of the areas. The measurement units are reported in kg/ha/yr. Total standing crop varied between sites during the monitoring program. Total production numbers were comparable between on-site and off-site mitigation areas. Production was greatest within the burn treatments in both the on-site and off-site mitigation areas.

Mean shrub standing crop production increased at all mitigation sites between 1998 and 2005 but declined in 2007. The B1 and B3 mitigation sites consistently had the greatest shrub standing crop production. Shrub standing crop was consistently higher in the burn treatments in comparison to the unburned controls.

Mean forb standing crop production also varied over the monitoring period but forb standing crop production was consistently higher within the burned treatments in comparison to the unburned controls.

Mean graminoid standing crop production varied over the monitoring period. At some sites, graminoid standing crop production declined consistently while at others, production increased and then declined. Graminoid standing crop production consistently was higher within the burned treatments in comparison to the unburned controls throughout the monitoring period.

Wildlife Habitat Use

The following text describes the wildlife habitat use associated with each of the monitoring transects.

The number of AUMs and, therefore, the carrying capacity for ungulates exceeded the projected targets in each year. In 2007, the increases for burn versus control treatments ranged from 1.0 AUM for the B3 mitigation area to 6.3 AUM for the A3 and A4 mitigation areas.

Wildlife use of the mitigation areas also was variable, but signs and direct observations of several species were recorded in the mitigation areas consistently throughout the monitoring period. For example, numerous signs (i.e., pellet groups, trails, rubs and signs of browsing) were recorded for elk, mule deer, and moose.

Evidence of browsing of trembling aspen, saskatoon shrubs and prickly rose was common throughout the grassland, shrubland, and open conifer forest mitigation areas both on-site and off-site. Browsing of Douglas maple, soapberry, western thimbleberry and Scouler's willow was common within both the on-site and off-site open, mixed and closed forest mitigation burn areas. Showy aster and heart-leaved arnica were the prominent forbs utilized while Idaho fescue was the most commonly grazed graminoid.

Grizzly bear diggings and scats are typically associated with the unburned and burned grasslands, shrublands and mixed deciduous/coniferous forest. The majority of the diggings, scats and browsing signs were recorded in the off-site mitigation areas.

Pellet Group Surveys

Pellet group surveys were conducted at each transect location within the on-site and off-site mitigation areas. The number of elk pellet groups recorded at each location varied annually through the duration of the monitoring program. With the exception of 1999, more elk pellet groups were observed in the burn treatments as compared to the unburned controls. The number of moose pellet groups varied but again the number of moose pellet groups in the burn treatments was typically higher than in the unburned control.

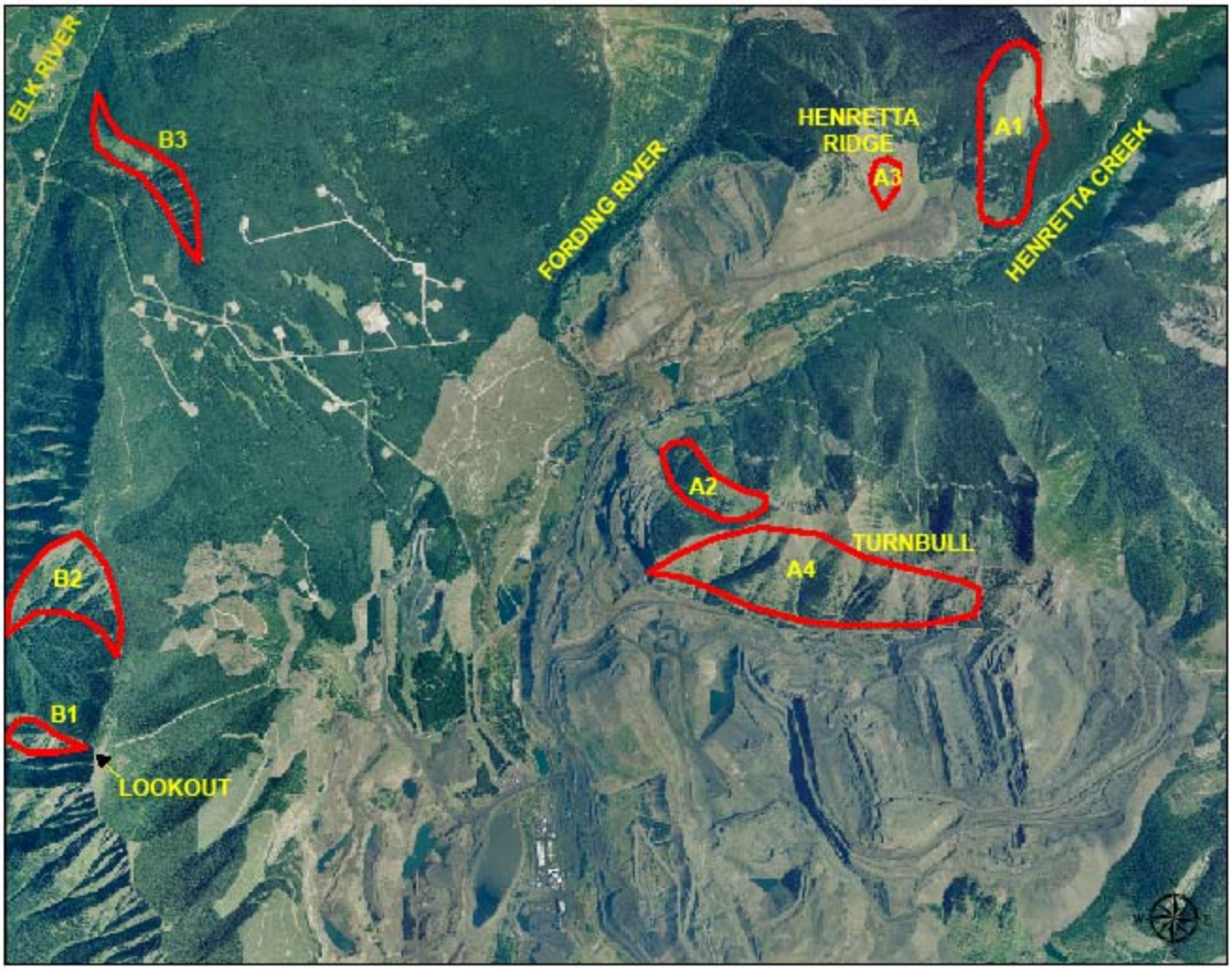
At the completion of the monitoring program in 2007, based on pellet group data and calculations, the A2 site had 0.5 elk, the A3 site had 0.4 elk, and the A4 site had 3.1 elk. The B1 site had 5.0 elk, the B2 site had 22.9 elk, and the B3 site had 1.1 moose.

SUMMARY AND CONCLUSION

Teck – FRO implemented a prescribed–burn program in 1997 with the intention of mitigating the effects of habitat loss in the Henretta Ridge mining development. The objective of the mitigation burns for the on-site Turn Creek (A2), Henretta East (A3), and Turnbull South (A4) areas was to increase the wildlife habitat suitability and to provide winter habitat for 5.5 elk per year while the objective of the mitigation burns for the off-site Lookout Draw (B1), Lookout Bowl (B2), and Britt Creek (B3) areas was to provide winter habitat for 1.5 moose and 4.0 elk per year. The target was to provide potential winter habitat suitability for 258.6 elk and 15.9 moose per year, which was a targeted increase in habitat for 9.5 elk per year and 1.5 moose per year.

Based on the results of the final monitoring event (10 years since burning), the mitigation burns were very successful. The capability of the enhanced areas, as determined by standing crop production measurements, indicated that overall forage production was higher. The wildlife habitat suitability for both the on-site and off-site mitigation areas has increased and provided an increase in capacity for 16.1 elk and 1.0 moose in 2007.

The prescribed burns have accomplished other important objectives. First, canopy closure was reduced in the areas where previously it was extensive. Second, plant species dominance was altered. The change in species dominance resulted in a greater abundance of herbaceous species and, therefore, potential forage. Third, physical stand structure has changed. The tall shrubs present prior to the burn now produce forage within reach of the ungulates.


ELK RIVER
B3
FORDING RIVER
HENRETTA
RIDGE
A3
A1
HENRETTA CREEK
A2
TURNBULL
A4
B2
B1
LOOKOUT

LITERATURE CITED

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Washington D.C. 493 pp.

Bartos, D.L., Brown, J.K. and G.D. Booth 1994. Twelve years biomass response in aspen communities following fire. Journal of Range Management, 47, 1, 79-83.

Bonham, C.D. 1989. Measurements for Terrestrial Vegetation. John Wiley and Sons, New York. 338 pp.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science, 33, 1, 43-64.

Demarchi, D.A. 1995. Wildlife Mitigation Monitoring for Eagle Mountain /South Spoil and Henretta Dragline Mining. Report No. 1. Prepared for Fording Coal Limited Fording River Operations by Demarchi Bros. Bioresearch, Cranbrook. 71 pp.

Gayton, D. 1993. Carrying Capacity: A Useful Tool for Range and Habitat Management. Information Bulletin No. 1. East Kootenay Trench Agriculture Wildlife Committee, Cranbrook. 4 pp.

Habitat Monitoring Committee. 1996. Procedures for Environmental Monitoring in Range and Wildlife Habitat Management. Version 5.0. British Columbia Ministry of Environment, Lands and Parks and British Columbia Ministry of Forests. Victoria. 225 pp.

Harestad, A.S. and F.L. Bunnell. 1984. Persistence and visibility of black-tailed deer pellets. Proceedings of a Seminar on Ungulate Pellet Group Sampling and Data Analysis Techniques. (L.A. Stordeur, Editor). Wildlife Habitat Research, British Columbia Ministry of Forests, Victoria. pp. 98-105.

Lancia, R.A., J.D. Nichols and K.H. Pollock. 1994. Estimating the number of animals in wildlife populations. Research and Management Techniques for Wildlife and Habitats. (T.A. Bookhout, Editor). The Wildlife Society, Bethesda. pp. 215-274.

Luttmerding, H.A., D.A. Demarchi, E.C. Lea, D.V. Meidinger and T. Vold. 1990. Describing Ecosystems in the Field. MOE Manual 11. Province of British Columbia, Ministry of Environment, Victoria. 213 pp.

McCune, B. and M.J. Mefford. 2006. PC-ORD. Multivariate Analysis of Ecological Data, Version 5.0. User's Guide. MjM Software Design, Gleneden Beach. 237 pp.

Neff, D.J. 1968. The pellet-group count technique for big game trend, census and distribution: a review. Journal of Wildlife Management, 32, 3, 597-614.

Ryan, K.C. and N.V. Noste. 1985. Evaluating prescribed fires. Proceedings – Symposium and Workshop on Wilderness Fire. November 15th – 18th, 1983, Missoula, Montana. General Technical Report INT-182. United States Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden. pp. 230-238.

Sachro, L. 2003. The Effects of Prescribed Burning on Elk Forage Habitat Suitability in the Central eastern Slopes of Alberta. Master's Degree Project, Faculty of Environmental Design, University of Calgary, Calgary. 260 pp.