Armells Creek Prescribed Fire Demonstration Project
JFSP 01C-3-1-02
Final Report

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**Project Synopsis:** A hazardous fuel reduction project planned for Dry Armells Creek within the Missouri Breaks National Monument, Montana was modified to test the effects of prescribed fire on various ecological processes within the dry, prairie savanna forest types common to the lower Missouri River and Yellowstone River corridors. Because of the focus on improvement of riparian and upland ecological processes through prescribed fire the action plan was modified to facilitate comparisons between burned and unburned drainages. Rather than burning the watershed in one continuous block the area was divided into 6 nearly equal units containing similar dry forest, sagebrush grassland and riparian community types. Baseline or pre-burn information on shallow groundwater level, forest canopy cover, tree density, herbaceous community composition and wildlife security and thermal cover was collected over a 9 month period in 2001 prior to implementation of the prescribed fire. The overall goal of the controlled burn was to apply fire to at least 75% of the total watershed area to reduce hazardous fuels. In addition to reducing the volume of downed timber and standing dead trees, the burn plan was designed to further limit catastrophic wildfire by eliminating 75% of the Rocky Mountain juniper and Ponderosa pine saplings (dbh<0.08m, <3m height) in the understory of the forested communities. Four subwatersheds ranging in size from 63ha to 96ha were burned under prescription over a period of 10 days in late May and early June 2002. Immediate post-burn inventories indicated a 93% reduction in Ponderosa pine and Rocky Mountain Juniper <3m tall with associated 21-33% mortality of larger trees.

Sixty days following the prescribed burn grass and sedge cover in the burned watersheds had recovered to levels similar to those recorded prior to the burn in 2001. By August 2002 shallow groundwater levels in two of the four burned drainages were higher than those in the unburned drainages. Security cover for mule deer and elk was reduced nearly 50% in some areas of each treated drainage by the prescribed fire but thermal cover changed little due to the marginal loss of large trees. In spite of the reduction in security cover, one year after the prescribed fire no significant difference (P=0.91) existed in mule deer use of non-burned, moderately burned or heavily burned areas. There was more bare ground, less litter and fewer woody species in burned than unburned areas (P<0.05) in 2003. Shallow groundwater levels in two burn units were significantly greater (P<0.05) than the unburned units throughout 2003. However, there was no difference in groundwater levels within the other two burn units and the unburned drainages. Upland herbaceous species had recovered to levels at or slightly above unburned species cover in the first year following the fire. In spite of higher groundwater levels in half of the burned drainages riparian herbaceous cover was similar to that recorded in unburned drainages in August 2003.

Three years after the prescribed burn (August of 2005) herbaceous canopy cover in upland communities was significantly higher (P=0.09) in burned drainages while canopy cover in burned riparian areas remained unchanged. Most importantly canopy cover in the unburned drainages did not undergo significant changes between 2001 and 2005. Forb and graminoid canopy cover in upland communities increased significantly (P=0.01) following the fire while there was a significant reduction in shrub canopy cover (P=0.03). In contrast, there was no change in forb, graminoid or shrub canopy cover.
from 2001 to 2005 in riparian areas of both burned and unburned drainages. However, riparian species dominance changed significantly (P<0.10) in burned drainages. For example, baltic rush and field sedge were more abundant in burned drainages in 2006 than what had been recorded in 2001. Even though forb and graminoid cover increased in the uplands there was little change in the overall availability of species preferred by mule deer from 2002 to 2005. Shallow groundwater levels in all but one of the burn units were significantly higher (P=0.01) in 2005 than levels recorded in 2002. Importantly, groundwater levels where highly correlated with the reduction in overall tree canopy (P=0.01, Radj =0.97) following the prescribed burn. Even though small Ponderosa pine and Rocky Mountain juniper numbers increased following the 2002 burn the numbers were not significantly greater (P=0.54) in 2005. Changes in drainage way width-depth ratios between 2001 and 2005 were used as surrogate erosion measures. Four years after the prescribed burn channel floors in the burned drainages were largely unchanged from 2001. A similar pattern was recorded in the unburned drainages between 2001 and 2005.

The initial goal of reducing small tree density with minimal impact to larger trees was reached and has been maintained over the four years since the prescribed burn. Efforts to reduce hazardous fuels in terms of small trees and shrubs produced a corresponding increase in groundwater levels. Elevated groundwater promoted increased dominance of riparian/wetland indicator species in burned drainages. Comparison of pre-burn channel width/depth ratios with those four years after the fire indicated that erosion/deposition rates had been equivalent in burned and unburned areas. Even though upland herbaceous cover increased following the prescribed burn the anticipated improvement in preferred wildlife forages was not recorded. However, equivalent use of burned and unburned areas by mule deer suggests minimal or no negative affects to local big game habitat use. Earlier monitoring results indicate a substantial linkage between conifer canopy cover in uplands and groundwater recharge of adjacent riparian areas. This suggests the need for watershed level management changes to achieve improvement in riparian form and function. Short term improvements in upland herbaceous cover and diversity coupled with enhanced riparian function suggest that fire may be integral to the rehabilitation and maintenance of dry, prairie savanna ecosystems.
Project Description: As part of the Judith-Valley-Phillips Resource Management Plan (USDI 1994) the watersheds administered by the Lewistown Field Office of the Bureau of Land Management were prioritized for implementation of specific land use plans. Because of the number of noted deficiencies, the Armells Creek watershed was given a high priority for immediate implementation of the finalized land use plan. In a subsequent environmental assessment of the watershed (USDI 2000) BLM managers identified several areas of concern; riparian and upland standards were not being met and decadent sagebrush stands were not meeting the needs of dependent wildlife species. The action plan proposed to improve the ecological function of upland and riparian areas within the Armells Creek watershed through a series of prescribed fires followed by implementation of a variety of livestock management guidelines. In the proposed action plan 75% of the forest, shrub and rangeland communities were to be burned to “reduce the fuel loading in the area; reduce the pine and juniper encroachment; provide additional forage to improve livestock distribution; and increase and improve quality of mule deer and elk forage.” Even though two earlier prescribed fires in the Armells drainage had appeared successful in accomplishing big game and other wildlife habitat improvement goals, the scanty information from scientific studies and long-term prescribed fire demonstrations in prairie savanna environments provided few criteria for designing successful prescribed fires for the dry forest types of the lower Missouri River and Yellowstone River corridors.

During burn plan formulation the Lewistown BLM resources staff invited input from range scientists assigned to the Montana Agricultural Experiment Station to develop a fire-response monitoring strategy that would evaluate the outcome of the Dry Armells prescribed fire and create a data base for planning prescribed fires in other parts of the watershed. Even though assessment of the effectiveness of prescribed fire for achieving improvements in wildlife habitat and riparian function was the primary monitoring goal, it became apparent that with a few adjustments to the burn plan a more detailed evaluation of the effects of fire on riparian ecosystem function as well as forest and rangeland recovery could be achieved. For example, earlier research conducted by the Montana Agricultural Experiment Station (Law et al. 2000) indicated that monitoring shallow groundwater levels in riparian areas could address some of the questions about riparian function in drainages some distance from the main stem of the Missouri River. The fire effects monitoring protocol was expanded to include shallow (1-2m deep) groundwater wells and the burn plan was modified to apply the burn treatment to individual drainages rather than the entire subwatershed. Four of six drainages identified for monitoring during field surveys in 2001 were selected for fire application with the remaining drainages left unburned. Monitoring information from the unburned drainages would be used to assess short term climate affects on plant communities and shallow groundwater levels in the Dry Armells subwatershed. Establishment of specific burn units would provide a framework for statistical comparison of differences in vegetation and groundwater attributes between burned and unburned areas within the subwatershed. The redesigned burn plan coupled with annual monitoring would provide an opportunity to 1) address the monitoring outcomes discussed in the EA, 2) demonstrate the use of prescribed fire to reach non-fuel load resource objectives in the Missouri Breaks, 3) quantify the effects of conifer encroachment on riparian recovery
potential and 4) document the effects of fire on the conifer, browse and upland components of a prairie savanna community.

Armells Creek Demonstration Project Objectives

The primary goal of this project was to document the short-term and long-term response of Missouri River Breaks forest, upland and riparian plant communities and wildlife habitat to prescribed fire. This was accomplished through the following objectives.

Objective 1. – Document the immediate affect (2002-2004) of the planned fire prescription through the measurement of:

a) conifer mortality and the associated change in conifer canopy cover,
b) the survival of key big game browse species,
c) monthly fluctuations in shallow groundwater levels,
d) the proportion of the target communities actually burned (air photos),
e) soil erosion/deposition in burned areas reflected by changes in draw cross-sectional area, and
f) breeding bird population composition.

Objective 2. – Document the long term (2005 and 2009) effects of prescribed fire on a Missouri Breaks ecosystem by:

a) comparing the density (stems/acre) and productivity of important wildlife browse species between burned and unburned areas,
b) comparing the level or degree of stand structural diversity (size and height classes) within conifer stands between burned and unburned areas,
c) comparing plant species diversity within unburned forest understory, range and riparian communities with that in burned areas,
d) comparing breeding bird species counts in 2005 and 2008 to those made in 2002 (pre-burn),
e) comparing shallow groundwater levels in unburned riparian areas to those that have been burned.

f) comparing the level of conifer regeneration in burn areas to that in unburned areas.

Objective 3. – Develop technical guides for private landowners and conservation groups on prescribed burning of conifers in a prairie savanna environment.

a) Results submitted for publication in peer reviewed scientific and technical journals (2004, 2006 and 2009)
b) User guides (Extension bulletins) criteria and recommendations for private landowners and state and Federal land managers (2004 and 2009)
Objective 4. – Provide “hands-on” training for Federal, state land managers, extension agents and private landowners.

a) 2005 – tour of treatment sites for state and Federal wildlife/resource management personnel, conservation organizations, livestock organizations, conservation districts and general public; fact sheets and brochures developed in 2004 under objective 3 will be distributed to tour participants.

b) 2009 - development of prescribed fire management guide for use by agency personnel, conservation groups and private landowners; several different levels of publication will be produced to meet specific stakeholder needs, conduct workshops and tours as requested; training workshops for “re-entry” fire management to maintain desired plant community and habitat structure.

**Project Area Description:** The Missouri River Breaks occur within a 10-50km wide by 300 km long belt of rugged landscape along the Missouri River in central Montana (Fig. 1). Elevations range from 554m to 1,354m and erosion is the primary geomorphic process (Nesser et al. 1997). Mean annual air temperatures in this area range from -0.6°C to 14°C and 20 to 30% of the mean annual precipitation occurs as snow (Nesser et al. 1997). While long term climate records at nearby Roy, Montana indicate 350mm of precipitation falls within the Breaks environment during most years the area has received less than 80% of the expected amount since 1997 (Western Regional Climate Center 2006). Ponderosa pine (*Pinus ponderosa* P.&C. Lawson) and a prostrate growth form of Rocky Mountain Juniper (*Juniperus scopulorum* Sarg.) dominate drainage ways among the highly dissected uplands. Typical forest understory for the Ponderosa Pine/Bluebunch wheatgrass habitat type (Pfister et al. 1977) occupying much of the Missouri River Breaks is Rocky Mountain juniper, bluebunch wheatgrass (*Pseudoroegneria spicata* A. Love), prairie sandreed (*Calamovilfa longifolia* Scribn.), elk sedge (*Carex garberi* Fern) and chokecherry (*Prunus virginiana* L.). Non-forested communities are dominated by Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young), rubber rabbitbrush (*Chrysothamnus nauseosus* (Pallas ex Pursh) Nesom & Baird ssp. *nauseosus*), and silver sagebrush (*Artemisia cana* Pursh) intermixed with western wheatgrass (*Pascopyrum smithii* A. Love), and bluebunch wheatgrass (USDI 2000).

An initial survey of fire-scarred trees within the the 768 ha Dry Armells watershed (-109.0724, 47.3808, WGS84) indicated that the last major wildfire had occurred sometime between 1930 and 1937. The pre-treatment evaluation, in 2001, of upland conditions revealed forest stands that often contained Ponderosa pine tree densities (trees > 1.5 m tall) as high as 2,200/ha (average density = 1,276 trees/ha). There was virtually no understory vegetation, and when present, consisted primarily of ponderosa pine saplings. These saplings (trees < 1.5 m tall) were found in excess of 17,000 trees/ha (average density = 8,233 trees/ha). The initial survey of the riparian areas also revealed the absence of defined stream channels and surface flow. Transitional
zones between the forested uplands and riparian areas were almost non-existent with Ponderosa pine and various shrubs such as Wyoming big sagebrush, rubber rabbit brush and Rocky Mountain juniper creating a sharp edge along the graminoid dominated riparian areas. The three most abundant herbaceous species recorded in the Dry Armells riparian areas in 2001 were redtop bentgrass (*Agrostis gigantea* Roth), Baltic rush (*Juncus balticus* Willd.) and Kentucky bluegrass (*Poa pratensis* L.).

Forest and grassland soils in the study watershed fall within the *Dilts* soil series which developed from soft, acidic shales of Cretaceous origin (Veseth and Montagne 1980). Soils formed from these shales tend to be clayey to silty clay loams and are excessively well drained because of low permeability and rapid runoff. *Dilts* soils often have rooting depths less than 0.5m. Riparian area soils represent those of the *Marvan* series (Veseth and Montagne 1980). These soils developed in deep, clayey alluvium on level to moderately sloping landforms adjacent to shale uplands. While these soils are well drained they have very slow permeability and a high shrink-swell potential. *Marvan* soils have very slow runoff and an effective rooting depth of 1.5 m.
**Study Approach:** The burn prescription targeted hazardous fuel loads with an anticipated loss of 70% of pine saplings and understory shrubs and no more than 20% reduction in the mature pine canopy. Application was carried out over 10 days in late May and early June 2002. Fire lines were constructed around 4 drainages within the watershed (Fig. 2) and these units were burned individually with a combination of hand and helicopter ignition. Fire crews successfully maintained fire lines around the drainages designated for protection (unburned). However, because of high soil and vegetation moisture levels the riparian areas did not burn like the surrounding uplands.

Because groundwater recharge is a formative process (Jewett et al. 2004), wells were placed in the bottom of drainages in a 3 (wide) by 5 (deep) matrix, totaling 15 wells per burn/control unit (Fig. 3). Each well was set to a depth of 2 m based on results reported by Law et al (2000). Depth to groundwater, within each well, was monitored monthly for 3 months prior to the prescribed burns. Since then, depth to groundwater has been measured monthly from April to November each year.

Cumulative changes in drainage way cross-section were monitored at each line of shallow groundwater monitoring wells. The outer-most well of each line was set at the riparian-upland boundary which corresponds to the approximate location of the greenline on active stream channels. A tape was attached to the top of one well stretched across the channel to the other boundary well (Fig. 3) and leveled. Elevation of the tape on each well was then recorded for subsequent measurements. The distance from the stretched tape to the channel floor was measured at 0.5m intervals across the entire channel width with a stadia rod. Measurements where rounded to the nearest 0.01m and summarized as width-depth ratios using width between the two wells and maximum channel depth. Channel cross-sections were measured annually in August.

To monitor riparian plant community composition and vegetative cover response to both prescribed fire and potential changes in groundwater, permanent vegetation transects were systematically placed at well rows 1, 3, and 5 in each unit. Transects were run across the drainage (3 riparian transects) and 50 m into the uplands on both sides of the drainage (6 forested transects). Species, by percent cover, was recorded using a Daubenmire (1968) frame (0.12 m²) located at 10 m intervals along each transect. Species diversity was monitored by recording the number of plant species within a 2m X 50m belt overlying the permanent vegetation transects. Initially average percent cover, by species, was categorized in two groups per treatment; riparian species and upland species. Species cover was also ranked individually from most abundant to least abundant for all riparian and upland transects.

Big game thermal/security monitoring transects were randomly located in 6 unburned, 6 moderately burned and 6 heavily burned patches across the Dry Armells watershed. Measures of visual obstruction (security cover) were made at random intervals along each 50m transect following the method described by Griffith and Youtie (1988) and Nudds (1977). Thermal cover (mature canopy) was measured with a densitometer at 5m intervals along each transect (10 observations per transect). Cover measurements were categorized as unburned (0 loss of small trees and mature canopy),
moderately burned (80-93% loss of small trees, <30% loss of mature canopy) and heavily burned (100% loss of small trees and >30% mature canopy loss).

Comparison of wildlife cover, ground water and vegetation changes between burned and unburned treatments and the relationship between changes in tree density and groundwater levels were analyzed with ANOV, REGRESS, PAIRED T and FREIDMAN F models (McClave et. al 1997) using drainage as replicates (n=6). However, comparison of tree and shrub density before and after the burn required use of individual vegetation transects as replicates (n=36) to gain enough sensitivity to make statistical comparisons. An alpha of 0.10 was used as the criteria for significance in all statistical tests. Mean separation was performed with the least significant difference test (Steel and Torrie 1960).

Fig. 2. The location and approximate size of unburned and prescribed burn units in the Dry Arnells Creek watershed, Fergus Triangle quadrant. Burns were carried out in late May and early June, 2002.
Fig. 3. Basic layout of groundwater wells and vegetation transects used to monitor changes in groundwater, riparian and upland vegetation communities in the Fergus Triangle watershed. This design was used in all six drainages.

**Results:** Application and management of the prescribed burn from 21 May 2002 to 7 June 2002 achieved a 93% reduction of small trees (0.1m to 3m tall) with a corresponding loss of 21-33% of the mature tree canopy. Both levels exceeded the burn plan targets of 75% reduction of smaller trees and a 20% or less loss of mature canopy.

**Immediate Impact (60-120 days after the fire)**

Post fire monitoring in August 2002 indicated that upland graminoid (grasses and sedge species) canopy cover was similar to levels recorded prior to the prescribed burn in 2001. Shallow groundwater response was mixed with 2 drainages showing no change in groundwater elevation and 2 exhibiting raising levels throughout the summer and early fall. However, differences between burned and unburned drainages were not significant (P>0.10).

Thermal and security cover immediately after the fire varied considerably across the watershed. Even though heavily burned areas had the lowest levels of thermal and security cover (Table 1) the range in cover in unburned, heavily burned and moderately burned areas meant differences were not significant (P<0.10).
Table 1. Mule deer and elk cover attributes in burned and unburned drainages of the Dry Armells watershed sixty days after a prescribed burn in May 2002.

<table>
<thead>
<tr>
<th>Burn Class</th>
<th>Security Cover</th>
<th>Thermal Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (%)</td>
<td>Range (%)</td>
</tr>
<tr>
<td>Unburned</td>
<td>48.7</td>
<td>42-60</td>
</tr>
<tr>
<td>moderately</td>
<td>39.9</td>
<td>30-48</td>
</tr>
<tr>
<td>Heavily</td>
<td>22.9</td>
<td>16-28</td>
</tr>
</tbody>
</table>

Comparison of channel width/depth ratios collected before the prescribed burn (Table 2) indicated that unburned drainages were significantly wider than those in the burned drainages (P<0.10). However, immediately following the prescribed burn in 2002 differences were no longer significant. This suggests minimal sediment delivery to or erosion of channels during the year of the fire.

Table 2. Width/depth ratios calculated from cross-sectional transects in burned and unburned drainages of the Dry Armells Creek watershed. Values in the same column with different letters are significantly different at P<0.10).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>2001</th>
<th>2002</th>
<th>2003</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>unburned</td>
<td>36.0a</td>
<td>37.5</td>
<td>34.7</td>
<td>40.4a</td>
</tr>
<tr>
<td>burned</td>
<td>22.9b</td>
<td>23.6</td>
<td>23.2</td>
<td>21.6b</td>
</tr>
</tbody>
</table>

One Year Later

In 2003 the graminoid and forb composition of vegetative communities in burned and unburned drainages did not differ significantly (P>0.10). Not surprisingly the shrub component of forest and shrub/grassland communities in burned drainages was significantly lower (P<0.10) following the prescribed fire (Fig. 4). Relatively minor differences in riparian vegetative community composition between burned and unburned drainages were noted in 2003 (Fig. 4). It is worthwhile to note that none of the riparian areas burned during the prescribed fire.
Security cover for mule deer and elk changed enough from 2002 to 2003 to record a significant difference between burn intensities within burned portions of the watershed. One year after the prescribed fire heavily burned areas had significantly less cover (P<0.10) than the unburned areas (Table 3). Moderately burned and unburned areas had similar levels of security cover in 2003. Even with the loss of some mature canopy in areas of the watershed overall thermal cover was not different between the various burn classes.

### Table 3. Mule deer and elk cover attributes in burned and unburned drainages of the Dry Armells watershed one year after a prescribed burn in May 2002. Values with different letters are significantly different at P<0.10.

<table>
<thead>
<tr>
<th>Burn Class</th>
<th>Security Cover</th>
<th>Thermal Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (%)</td>
<td>Mean (%)</td>
</tr>
<tr>
<td>Unburned</td>
<td>45a</td>
<td>77a</td>
</tr>
<tr>
<td>moderately</td>
<td>32b</td>
<td>68a</td>
</tr>
<tr>
<td>Heavily</td>
<td>21b</td>
<td>58a</td>
</tr>
</tbody>
</table>

Fig. 4. Vegetative community composition one year after a prescribed fire in the Dry Armells Creek watershed. Bars with different letters are different at P <0.10.
Even after the 2002/2003 snow pack had melted differences in channel width/depth ratios between burned and unburned drainages remained relatively unchanged from 2002 to 2003 (Table 2). However, changes that did occur varied across the watershed to the point that differences between burned and unburned drainages were not significant. Unlike channel shape shallow groundwater levels exhibited significant (P<0.10) differences between burned and unburned drainages in 2003 (Fig. 5). One year after the prescribed fire had removed small trees and shrubs from the forest understory in burn units 3 and 4 groundwater filled almost the entire well depth in each drainage (1-1.5m deep). These levels were significantly higher (P<0.10) than those recorded in the other burn units and the drainages that had not been burned.

![2003 Groundwater Levels](image)

Fig. 5. Shallow groundwater levels recorded in burned and unburned drainages of Dry Armells Creek from April to November 2003.
Summarization of biomass harvested from 30 randomly located grazing cages indicated little difference between unburned and burned drainages (Fig. 6). As with the other parameters variable response among the drainages produced no significant differences between burned and unburned drainages. Nonetheless, these results suggest minimal negative impact to herbaceous species productivity from the prescribed fire. This relationship was noteworthy because annual precipitation was about 70% of average from 2000 to 2003 (Fig. 7).

Fig. 6. Biomass production in burned and unburned drainages of the Dry Armells Creek watershed.
2005 Results

Three years after the prescribed fire herbaceous ground cover in forested and shrub/grassland communities was much higher (P<0.10) in burned drainages than those that had not been burned (Fig. 8). Graminoid cover (grasses and sedges) was significantly greater (P<0.10) in burned drainages in 2005 than the cover measured prior to the prescribed burn in 2001 (Fig. 8a). Importantly graminoid cover increases in the unburned drainages was not different from the amount measured in 2001. The forb component of the vegetative communities in burned drainages had also increased above levels (P<0.10) recorded in the same areas in 2001 (Fig. 8b). As with grass and sedge species the forb component of the unburned drainages did not exhibit an increase over the three year period. There was, however, a significant decrease (P<0.10) in shrub cover throughout the Dry Armells Creek watershed between 2001 and 2005 (Fig. 8c). Review of differences in shrub cover between 2001 (pre-burn) and 2002 (post burn) indicate that all of the change in shrub cover in the burned drainages occurred immediately following the fire while the change in shrub cover in the unburned drainages occurred over a three year period (Fig. 8c).
Average Grass Cover (Uplands)

(a)

2001 Burn Units vs 2002 Burn Units P=0.034
2001 Burn Units vs 2005 Burn Units P=0.008
2005 Burn Units vs 2005 Burn Units P=0.036

Control Units = No Significant Differences Found Between Years

Average Forb Cover (Uplands)

(b)

2001 Burn Units vs 2002 Burn Units P=0.005
2001 Burn Units vs 2005 Burn Units P=0.008
2002 Burn Units vs 2005 Burn Units P=0.052

Control Units = No Significant Differences Found Between Years
Fig. 8. Recorded changes in herbaceous and woody canopy cover in burned and unburned drainages of the Dry Armells Creek watershed between 2001 and 2005. 2002 values represent cover levels immediately following the prescribed fire.

Unlike the uplands cover changes in riparian communities between 2001 and 2005 were not significant (P>0.10) for any of the life form classes. The lack of change in riparian cover reinforces the idea that the lack of disturbance from fire reduced opportunities for species entry into riparian communities. Conifer species recruitment was marginal in the first 3 years following the prescribed fire (Fig. 9). While there was some recruitment following the prescribed fire the level of increase from 2002 to 2005 was too low in any of the burned drainages to be considered significant (P>0.10).

The pattern of increasing groundwater levels recorded in burned drainages in 2002 and 2003 continued through 2005 (Fig. 10). By 2004 and 2005 cattle grazing was permitted in the upper unburned control and burn units 1 and 2 with little apparent change in the overall pattern. While groundwater levels in burn units 3 and 4 remained significantly higher (P<0.10) than levels recorded in the unburned controls, groundwater in burn unit 1 began increasing after 2003 and stayed higher than the unburned controls through 2005. Stepwise multiple regression of various vegetation attributes and groundwater levels revealed a highly significant relationship between groundwater level and burned/unburned status (adjusted Rsq = 0.97, P=0.01). The overall reduction in small trees was noted as the stepwise “best alternative” at P=0.02.
Average Tree Density (1.5m and shorter)

Control Units = No significant differences found

- 2001 Burn Units vs 2002 Burn Units P=0.07
- 2001 Burn Units vs 2005 Burn Units P=0.08
- 2002 Burn Units vs 2005 Burn Units P=0.54

Fig. 9. Conifer recruitment in burned and unburned drainages of Dry Armells Creek watershed following the 2002 prescribed fire.

Fig. 10. Shallow groundwater levels recorded over four years in burned and unburned drainages of the Dry Armells Creek watershed.

The limited response of groundwater in burn units 1 and 2 compared to the immediate and dramatic increases in units 3 and 4 might be explained by tree...
canopy coverage prior to the prescribed fire (Fig. 11). Forest canopy cover was significantly higher (P<0.10) in the control units and burn units 3 and 4 than what was recorded in units 1 and 2 in 2001. It is possible, then, that tree canopy cover was not high enough in units 1 and 2 to have affected groundwater recharge within those drainages. Taken in combination with the significant relationship noted between the reduction in small trees and increased groundwater levels it is clear that a tree canopy/density threshold for groundwater response to fire may exist.

![Pre-burn Ponderosa Pine Canopy Cover](image)

Fig. 11. Ponderosa pine canopy cover measured in six drainages of the Dry Armells Creek watershed prior to a prescribed fire in 2002. Bars with different letters are significantly different at P<0.10.

Even though there was no apparent response in the overall riparian vegetative cover from the elevated groundwater there were significant changes in the dominance or rank of individual species within the riparian community of burned drainages. Comparison of 2001 ranked means for the three most common species within the Dry Armells riparian areas indicated that redtop bent (*Agrostis gigantea*) was more abundant in the drainages that were to be burned than in those to be left unburned. There was, however, no difference in the abundance of Baltic rush (*Juncus balticus*) and clustered sedge (*Carex praegracilis*) between burned and unburned drainages prior to the prescribed fire (Table 4). Three years after the prescribed fire both Baltic rush and clustered sedge had become more abundant (P<0.10) in the riparian areas of burned drainages than the levels recorded in the unburned drainages. While not significantly
different redtop bent increased slightly in burned drainages while remaining virtually unchanged in the riparian areas of unburned areas. The abundance of Baltic rush in unburned drainages did not change from 2001 to 2005. Thus, the shift to greater abundance for species listed as wetland indicators (USFWS 2003) in burned drainages suggests improved riparian function resulting from elevated groundwater.

Table 4. Changes in ranked cover means for the three most common riparian species in drainages of the Dry Armells watershed. Values in the same row with different letters are significantly different at P<0.10.

<table>
<thead>
<tr>
<th>Year</th>
<th>2001</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species</td>
<td>Burned</td>
<td>Unburned</td>
</tr>
<tr>
<td>Agrostis gigantea</td>
<td>21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9.7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Carex praegracilis</td>
<td>3.4</td>
<td>13.5</td>
</tr>
<tr>
<td>Juncus balticus</td>
<td>3.7</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Biomass production by forage species was estimated from clipped plots in 2005. Production potential determined from caged plots was not significantly different (P>0.10) between burned and unburned units (Fig. 12). Even though total biomass production wasn’t different between burned and unburned drainages, comparison of grazed plot biomass revealed low use in upland areas of burned drainages, moderate use in grazed riparian zones of burned drainages and heavy use of the upper unburned drainage (Table 5). Upland utilization levels were well below published guidelines (50% or less) and riparian use was acceptable (personal communication, V. Shea, Lewistown, BLM).

Table 5. Recorded utilization of herbaceous forages (%) by cattle and big game in upland and riparian communities of the Dry Armells Creek watershed in 2005. Cattle did not graze burn units 3 and 4 in 2005.

<table>
<thead>
<tr>
<th>Location</th>
<th>Unburned Lower</th>
<th>Unburned Upper</th>
<th>Burn Unit 1</th>
<th>Burn Unit 2</th>
<th>Burn Unit 3</th>
<th>Burn Unit 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uplands</td>
<td>7</td>
<td>25</td>
<td>0</td>
<td>12</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>riparian</td>
<td>26</td>
<td>95</td>
<td>55</td>
<td>54</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Fig. 12. 2005 Biomass production by livestock and big game preferred herbaceous species in the Dry Armells Creek watershed.

The significant increase in herbaceous cover recorded in burned areas suggested improved forage conditions for mule deer and elk in 2005. While the cover of mule deer preferred forages like western wheatgrass (*Pascopyrum smithii*), various sedges (*Carex* spp) and yellow blossom sweetclover (*Melilotus officinale*) increased significantly (P<0.10) from 2001 to 2005 the same pattern was noted in the unburned drainages (Fig. 13). While the increases noted in the burned areas were of a greater magnitude than those in the unburned drainages the low number of replicates (drainages) limited statistical inferences.
Fig. 13. Recorded increases in a representative group of herbaceous species found in the diets of mule deer using the Dry Armells Creek watershed (Wood 2004). WWGUN = western wheatgrass cover in unburned drainages, WWGBU = western wheatgrass cover in burned drainages; CARUN = sedge cover in unburned drainages, CARBU = sedge cover in burned drainages; MELUN = yellow blossom sweetclover cover in unburned drainages and MELBU = yellow blossom sweetclover cover un burned drainages.

Channel cross-sectional morphology in burned and unburned drainages changed very little over the three years following the prescribed fire (P>0.10). Even though there appeared to be a trend towards deeper, narrower channels in the burned drainages over time (Table 2) the changes between 2001 and 2006 within individual drainages were not significant. Essentially the prescribed fire did not appear to create conditions within the watershed that led to either accelerated erosion in the uplands or substantial sediment accumulation in the drainages.
Conclusion:

Management Outcomes

The 2002 prescribed fire in the Dry Armells watershed reached a number of the resource objectives the BLM planners had anticipated. Ponderosa pine and Rocky mountain juniper densities were decreased and the reduction has remained in effect for the past 3 years. This slowed conifer encroachment into riparian, grass and shrub communities within the watershed. The reduction in tree canopy cover in the uplands adjacent to riparian areas led to an immediate increase in shallow groundwater levels within two of the treated drainages. Groundwater levels in those drainages remained higher than levels in the unburned drainages throughout the first three years following the burn. The most rapid response in groundwater occurred in drainages with tree canopy cover greater than 20% while drainages with less canopy cover may take a number of years to experience similar increases. Elevated groundwater levels appear to have initiated some of the improvement in riparian function targeted by resource managers in the watershed plan.

Even though there was not a corresponding change in biomass productivity or general vegetative cover in the riparian zones following the prescribed fire the increased abundance of wetland indicator species like Baltic rush and clustered sedge demonstrated improved riparian function following reduction of Ponderosa pine and Rocky Mountain juniper canopy in the adjoining uplands. Upland herbaceous species responded quickly and positively to the prescribed fire. The increased ground cover in the uplands appeared to hold erosion in check during the first few years after the fire and increased livestock distribution sufficiently to limit grazing impacts to acceptable levels. Improved livestock distribution was one of the primary goals for the prescribed fire in the Dry Armells watershed. Unlike improvements in livestock management the anticipated enhancement of wildlife habitat was not realized.

The 2002 prescribed fire significantly reduced the canopy cover of Rocky Mountain juniper in the watershed. This was of concern to state wildlife biologists because mule deer use Rocky Mountain juniper heavily during severe winters (Mackie 1970). However, in the Dry Armells Creek watershed the majority of juniper loss occurred within stands of Ponderosa pine rather than in the open meadows interspersed among the forested drainages. BLM fire crews successfully held fire to forested drainages and side hills (Fig. 14) preventing loss of shrub and grass communities within the watershed. This left some juniper and the more highly preferred Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) (Mackie 1998) growing outside of forested sites unburned and available for mule deer use. Additionally, cover of herbaceous species preferred by deer increased within both unburned and burned areas in the years following the fire. A second concern with the prescribed fire was the loss of security or hiding cover for mule deer and elk in a largely prairie environment (Fig. 14). Security cover was significantly reduced in heavily burned areas but deer use of unburned grass and shrub communities adjacent to these areas was not different from levels recorded in the unburned drainages (Wood 2004). It must be emphasized that the
highly dissected landform characteristic of the Missouri and Yellowstone river breaks may dampen the loss of tree security cover. In regions with less diverse topography tree loss may preclude deer use of shrub communities for the first years following a prescribed fire. Taken in combination the wildlife habitat monitoring data suggests that even if the goal of improved wildlife habitat was not obtained negative impacts to mule deer use of the Dry Armells watershed were minimal.

Fig. 14. Mosaic of burned and unburned vegetative communities in the Dry Armells Creek watershed following the 2002 prescribed fire. Rocky Mountain juniper intermixed with the sagebrush communities was left unburned (Mark Phillipi photograph).

A late spring/early summer prescribed fire contained within heavily wooded drainages of the Missouri River Breaks accomplished several resource management goals in addition to the reduction of hazardous fuel conditions. Cessation of conifer encroachment, increased herbaceous cover on sites that had been invaded by conifers and the minimal impact to big game habitat by the prescribed fire met many of the resource management goals developed in the watershed plan. Most important, however, was the evidence that riparian function could be enhanced by managing tree canopy within the watershed. The fundamental importance of this relationship is highlighted by the fact
that positive changes in the riparian vegetation community were accomplished while cattle were grazing BLM lands.

Reducing or eliminating livestock grazing to rehabilitate western riparian areas has been the primary focus of Federal and state natural resource agency planners since publication of the earliest Rangeland Health Standards (USDI 1997). As recently as September 2005 the Draft Environmental Impact Statement for the Upper Missouri River Breaks National Monument only recognized irrigation withdrawals, dam regulation and hot season livestock grazing as the driving causes for impaired riparian function along the river and its tributaries (USDI 2005). Based on the information generated through the Dry Armells Demonstration Project which lies along the Monument’s southern boundary it is very possible that the proposed plans for rehabilitating the Monument’s riparian areas will have limited success. Failure to address the impact of conifer encroachment on the shallow groundwater that maintains riparian processes in the network of tributaries discharging into the river and connected streams will marginalize improvements that might have been gained through amended grazing practices. Successful riparian rehabilitation will require conifer canopy reduction in upland portions of the various watersheds followed by changes in season of livestock use.

Ecological Implications

Results of the monitoring effort in the uplands were not surprising; many of the plant species and communities appear to be able to recover quickly following fire. What is noteworthy is the recognition of an apparent linkage between conifer canopy cover in the uplands and riparian processes.

It is unclear whether the dry forest communities found intermixed with sagebrush and grasslands in the upper Missouri River corridor and along the lower Yellowstone River burned at relatively frequent intervals but it is clear from historic photographs that conifers have invaded into sagebrush and riparian communities since the beginning of the 20th century. The long term effect of encroachment is generally thought to be loss of livestock forage and elevated vulnerability to catastrophic wildfire but one of the outcomes of the Dry Armells Creek Demonstration project is evidence that conifer encroachment may disrupt processes important to the functioning and sustainability of riparian ecosystems. Over utilization of grass and shrub communities in the Missouri River Breaks by livestock during the early 20th century coupled with an aggressive, long term fire suppression policy fostered invasion of rangeland communities by unpalatable and drought tolerant conifers. Once pine and juniper canopy cover in the former range sites exceeded 20% groundwater flow to riparian areas was probably reduced and riparian function would have been compromised. Declining groundwater recharge reduced the resiliency of riparian vegetation to livestock use and riparian ecological condition continued to spiral downward.

Another outcome of the demonstration project was indirect evidence of the role channel erosion and deposition may play in fostering riparian vegetation succession. Tributaries to Dry Armells Creek have broad, flat bottoms with no defined channel (Fig.
15) but many of them can be categorized as wetlands because of the presence of indicator species like Baltic rush, clustered sedge and prairie cordgrass (*Spartina pectinata*). Indication of groundwater recovery after the 2002 fire suggested a change in riparian

Fig. 15. A riparian area typical of many of the tributaries to Dry Armells Creek. Note the lack of a defined channel (Mark Phillipi photograph).

vegetation would soon follow. While changes in the abundance or dominance of riparian species were noted three years after the fire the overall composition of the community remained the same. In short, elevated groundwater levels did not appear to foster riparian vegetation succession. This might be explained by both the lack of open niches for the establishment of new species and the lack of a delivery mechanism for plant propagules. Without channel flow to scour out areas or create silt and sand bars there would be very few microsites available for new plant establishment. The lack of channel flow would also slow the rate at which new species could migrate into the riparian area. Thus, without a major erosion event or consumption of riparian vegetation during wildlife there is a very low likelihood for the introduction and establishment of new riparian species in the Missouri River Breaks. Because the Dry Armells Creek prescribed fire was carried out in late spring/early summer none of the riparian areas in the drainages burned (please see the cover for an example). Naturally occurring wildfires probably did reduce canopy cover and litter in riparian areas which then exposed microsites for colonization. The
question then arises as to the interaction between late summer or fall burns and subsequent rates of erosion and deposition in the tributaries.

The results from the Dry Armells Demonstration coincide with the reported outcomes from water yield studies, e.g. Grace et al. (2003) and emerging recognition of the affects of vegetation change on the hydrologic cycle (Wilcox and Thurow 2006 and Huxman et al. 2005). The Dry Armells Creek project is also in agreement with findings of a 2002 National Research Council report that land management practices can seriously alter riparian processes. This body of information supports the efforts by BLM resource managers to include prescribed fire in management plans for improving ecological conditions in the dry prairie savanna woodlands of the Upper Missouri River and Lower Yellowstone River corridors.
**Literature Cited:**


