Draft Final Soils Assessment for US Sheep Experiment Station Grazing Program

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Introduction

This report will discuss the effects on soils of continuing operations of the US Sheep Experiment Station (USSES) administered by the Agricultural Research Station (ARS) outside Dubois, Idaho. The purpose of this Environmental Assessment, and specifically this report, is to ascertain whether continued operations would lead to degradation of soils resources beyond current conditions, and if the current conditions are in violation of appropriate laws and regulations. Fieldwork was performed during June and July 2008, and August 2009 to evaluate the current conditions on the ground.

The project area is the collective land of the ARS, USSES, totaling 47,340 acres. This includes the old ranch land Humphrey, Henninger, and Headquarters (30,125 acres) and the summer grazing area in the Centennial Mountains (17,215 acres), which are approximately 25 miles due west of Yellowstone National Park.

Currently, the USSES grazes on average 3,000 mature sheep on their landbase. Part of their mission is to monitor reproductive efficiency with the ultimate goal of increasing production in the context of environmental factors. Sheep numbers are kept below the carrying capacity of the USSES properties. Sheep are held at the headquarters facilities for most of the year, staged in the various pastures, and then graze the summer range for one to two months depending on weather conditions.

Methodology

Each of the ARS parcels was transected during two separate field visits in 2008 (July 8 through July 12, and August 28 through September 2). Periodic observations of ground cover, surface condition, geology, and, where applicable, stream channel stability and trend were noted. Surface condition used soil indicators from the R4 soil quality monitoring protocol (USDA 2003). An ancillary overview assessment was performed in August 2009.

A classification of soil condition and cover with ratings 1 through 4 was devised to catalogue observations. These classifications were quantified to portray general conditions and spatial trends.

- Condition class 1 indicated ground that has severe soil disturbance and in a hydrologically impaired state. Soil conditions follow USDA Forest Service (2003) indications for long-term impairments to soil productivity with sparse ground cover, evidence of severe compaction (surface ponding), displacement, or erosion (rills, soil pedestals).
- Condition class 2 would be ground that also had evidence of soil disturbance with marginal hydrologic functionality, and little or no sign of recent sheet wash, surface erosion. Soil ground cover and understory vegetation are adequate to resist erosion.
- Condition class 3 indicates conditions with one-time impairment, but recovery to full hydrologic function.
- Condition class 4 has minimal sign of impairment with complete soil and hydrologic function.

Range surveys performed in 2009 by TEAMS range staff were also correlated with results from Keith Klements (1997) to gage soil conditions and long-term trend for soil productivity. Ancillary information was gathered through discussion with USSES staff in addition to Natural Resource Conservation Service (NRCS) soil scientist Bill Hiett (Idaho Falls, ID) and Justin Urroti (Dillon, MT) along with historical assessments obtained from the USSES staff. Soils information is still being developed for the USSES though preliminary mapping concepts from the Clark county survey, and 1990s data collection (1991) was used. This information helped verify the appropriate range sites chosen from which to evaluate range condition. Ultimately, the professional knowledge of the USSES staff, NRCS staff, and BLM were invaluable for evaluating current conditions and trends.

Affected Environment

The USSES lands comprise low and highland areas along the northeastern edge of the Snake River Plain. The highlands serve as summer range and are located within the Centennial Mountains to the northeast of the USSES. The lowlands are lava-dominated sage plains where the sheep are grazed fall through spring.

The Centennials belong to the Rocky Mountain province and consist of folded and thrusted sedimentary rocks covered with basalt and tertiary sediments. Vegetation ranges from mixed conifer to alpine meadow. The USSES has two summer pastures:

- West Summer - Includes “Odell”, which is west of O’dell Creek, and to the east.
- East Summer– Tom Creek

The lowlands are gently sloping lava flow benchlands made up of Quaternary aged lava flows over rhyolite tuffs. These lava flows have interfingered alluvial deposits from Centennial mountains in addition to sediment from aeolian and lake deposits (Stevenson 1993 unpublished report, Link 2008). The USSES original Headquarters and the acquired old ranch Henninger are located on these lowlands with sage steppe as the dominant plant community. Another old ranch, Humphrey, borders these lowlands on the western footslope of the Centennial Mountains near Monida pass and is predominantly sagebrush.

This volcanic plain increases in elevation to the northeast and generates a strong moisture gradient from Headquarters to Henninger. Annual precipitation is in the range of 8-12 inches near the southwest corner of Headquarters and increases to 17-22 inches in the upper portion of Henninger due to the orographic lift of the Centennial mountains (Hiett 2009 personal communication). The Centennials proper reach over 40 inches of precipitation annually primarily as snow (NRCS 1991; Prism Model, USDA Forest Service 2009).

The moisture and temperature gradients drive vegetation and soil development, though parent material is also a constraining factor. For the lowlands, the cold temperatures and arid conditions make for slow soil development, in part due to the relatively recent lava flow-rock. The inherent parent material properties of the lava and interbedded alluvium together are factors in the formation of both coarse-loamy and fine-loamy soil textures. Soil formation factors in this area lead to predominantly well drained conditions and may be limiting to plant available water. Cold conditions also limit vegetation to cold adaptive species, especially in areas over 6,200 feet elevation. This is a breakpoint whereby soils are classified cryic; temperatures average no more 46 degrees F annually thereby nominally shortening the extent of the growing season and subsequent use and management of these soils. Headquarters and Henninger edge to cryic conditions, however, the summer pastures with gentle slopes and northern aspects in the Centennials and foothill Humphrey sites have these more extreme cold air influences (Hiett 2009, personal communication).

For Headquarters and Henninger, the degree of soil development on the lava flows is a strong indicator for productivity. Lava ridges have very poor productivity compared to adjacent swales that have accumulated sediment and water runoff from the exposed rock. The basalt exposures also known as pressure ridges have lithic soils less than 20 inches deep with bare mafic lava rock on the surface. Range production varies from 250 to 800 pounds per acre on the pressure ridges (NRCS 1991). In contrast, soil development and productivity are accentuated by the microtopography of the lava flows where swales continue to trap alluvial and aeolian sediment. Old alluvium and aeolian deposition from nearby mountain glaciers and Pleistocene-aged Lake Terreton, once located at the foot of the Centennials, provides fine sediment for much of the soil profile (Stevenson 1993, Hiett 2009 personal communication). Production ranges from 1200 to 1600 pounds per acre within these swales based on range site information (SCS 1981, NRCS 1991).

The productivity contrasts on the lava plain are highlighted by the vegetation. The lava pressure ridges support sparse sub-shrub communities compared to adjacent communities where grasses key into deeper, more productive soils. The generalized vegetation includes: three-tip sage (*Artemesia tripartita*) as the dominant vegetation; with needle and thread (*Hesperostipa comata*), bluebunch wheatgrass (*Psuedoroegenaria spicata*), prairie junegrass (*Koeleria macrantha*), and sandberg poa (*Poa secunda*) typical grasses. Cheatgrass (*Bromus tectorum*) tends to occupy these less fertile areas in occasional small, less than half-acre clumps.

Soils deepen dramatically to greater than 60 inches in the swale bottoms with topsoil organics and subsurface clay accumulation increasing water holding capacity and cation exchange capacity, both productive attributes that support native and pasture grasses. The swale indicator species are basin big sagebrush (*Artemesia tridentate spp. tridentata*) and basin wildrye (*Leymus cinereus*).

Soils on the lava plain can also vary according to the type of lava flow; the rough surface aa lava breaks to coarse rock that allows for deeper development and catches aeolian sediments while the smooth pahoehoe lava formed a viscous surface that is prone to wind scour. Soils on both Henninger and Headquarters parcels are found on Pahoehoe and aa lava.

Across the lava plain, the shift in moisture to the NE increases the potential productivity with subsequent increase of fescue grasses (*Festuca spp.)* closer to the Centennial Mountains. Rainfall increases to 16-22 inches creating an even-tempered growing environment with most of the carbonates in soil leached to a lower depth below the effective rooting area. The loss of carbonates is marked by increases in mountain big sagebrush (*Artemesia tridentata ssp. vaseyana*) and Idaho fescue (*Festuca idahoensis*) (Ecosite B13-05, B13-39, NRCS (In review)). This increase in moisture is most evident in the Henninger pasture where the lava pressure ridges support aspen (*Populus tremuloides*) instead of sage. The plantings of crested wheatgrass in the southwest corner of Headquarters correlate to the low productive conditions from high carbonates and very low precipitation. These areas represent an altered plant community from the historic vegetation (Ecosite B11b-R011BY010ID, NRCS (In review)).

Henninger soils have greater depth than Headquarters soils because of alluvial deposits and underlying glacial outwash derived from the Centennial Mountains. This alluvium creates planar surfaces with dry meadow conditions that support hay fields. Silver sage (*Artemesia ludoviciana*) and mules-ears (*Wyenthia amplexicaulis*) are the prominent indicators of these semi-wet meadows along with associated vegetation species: death camas (*Zigadenus venenosus*), sedge (*Carex spp.*), and pasture grasses (Kentucky bluegrass (*Poa pratensis*) and timothy (*Phleum pratense*)). These soils have profound thick mollic epipedons and clay subsoils with good productive capacity (R013XY039ID, NRCS (in review)). Adjacent footslopes have moderately steep slopes and inceptic soils on pitchstone obsidian residuum/colluvial footslopes (R013XY005ID, NRCS (in review)). Range production is upwards of 1,800 pounds per acre for hillocks and benchlands compared to 1,400 pounds per acre on alluvial flats for average years.

Soils at Humphrey vary highly due to the minor slump terrain. Ridge soils are lithic and skeletal with poor site quality. Back slope concavities are prone to form from the unconsolidated nature of the parent material; old alluvium gravels and cobbles from the Beaverhead formation. These “slips” form catchments that have deep soils below. Across a hillslope, soil depth varies from moderately deep to deep with dark topsoils. Productivity varies accordingly with the soils below catchment areas supporting robust grassland species. Mountain sage is the dominant component along with Idaho fescue and mountain brome.

The summer range soils have strong aspect and slope location controls on productivity and vegetation. Moderately-deep loamy soils occur on ridgetops and hillslopes that support rich forb and short grass communities with production in the realm of 1,000-1,200 pounds per acre on windswept ridges and 2,000-2,400 pounds per acre on thick soils on protected shallow slopes. Topsoils have a high proportion of organics from the forb and grassland vegetation. Conifer thickets on sideslopes and within protected aspects shift forest floors to forest herb and conifer litter with production less than 200 pounds per acre.

Shifts in geology to limestone or shales can lead to shallow less productive soils. Within the limestone and shales, steep armored gravel slopes support sparse shrubs and clumped conifers. Tom's Creek is a good example of where a contact exists between sedimentary and volcanic rocks in the upper watershed. The western portion of the watershed has steep graveled slopes with sparse snowberry (*Symphorocarpos spp.*) and conifer clumps on shales and limestone, compared to the forb- and grass-rich eastern portion of the watershed on mafic volcanic material.

Summer Pastures

The vegetation and soil associations of the summer range are unique given the persistent tall forb communities and a high proportion of forbs within grasslands (ARS 2008a). Annual and perennial forbs are typically associated with degraded conditions where forb increases are accompanied by a lack of groundcover (Pyke et al. 2002). However, ongoing studies on the USSES suggest that the high presence of forbs here may be unique to these highlands. Past evaluations vary on the interpretation of conditions with initial estimates showing degraded conditions from the 1950s until the late 1970s, despite a steady grazing rate of 1,000 to 3,000 sheep (ARS 2008a). More recently, interpretations shifted to good to excellent ratings and research focused on the prevalence and persistence of these vegetative conditions even within grazing exclosures (2008a).

The persistence of the tall forb communities and high expression of forbs may also be an artifact of pre-settlement grazing disturbance from the late 1800s and early 1900s, and/or from turn of the century wildfire. The Great Burn proposed wilderness along the Montana and Idaho border has similar forb dominated communities. In particular, there are very tall, mainly monocultural stands of coneflower (*Rudbeckia spp.*) with large expanses of bare soil. This community could be a relic from the 1910 wildfire. Sampled communities in the USSES summer pastures include an abundance of sticky purple geranium (*Geranium viscosissimum*), sunflower (*Heliomeris multiflora*), lambstongue groundsel (*Senecio integerrimus*), and cinquefoil (*Potentilla gracilis*).

The current vegetation could be considered an altered potential. The rich forb-land communities appear stable (see VanHorn-Ecret 1986, Klements 1997) and are not following traditional concepts for grassland regrowth with perhaps a strong interconnection to the soil biota community. Plants can affect soils nutrient status by forming a positive feedback relationship (Hobbie 1992, Burke et al. 1998) as demonstrated in California Mediterranean grasslands and Colorado steppe (Vinton and Burke 1995). Moreover, the pertinent implication is the risk for ongoing erosion and sedimentation into creeks.

Current assessments found bare soil mainly along steep ridges and where thin soils occur, particularly in protected concavities. Bare soil is partially a function of the very active slips from the complex topography and protected snow patches. Extensive faulting and bedrock orientation have created unstable conditions that inhibit deep soil development. This is particularly evident in the upper Tom's Creek watershed where shale slopes have shallow soils. Bare soils are also evident on historical grazing sites, typically bedding areas. These erosion features do not connect to drainage bottoms.

Roads, including a 4-wheeled drive jeep trail and the closed mine access road, account for most of the soil condition class 1 and 2 in Big Mountain, Odell, and East summer pastures — about 30 percent of total measured sites, but only a minor fraction of the total summer pasture areas. Some water crossings have low ground cover (less than 50 percent) and minor rilling. Bedding areas have cover between 60 and 95 percent and a minor degree of compaction, though sites are often thin soil over bedrock as they are on ridge tops.

Tilling effects from rodents are pervasive, nearly 100 percent of slump slopes, particularly those with noted convex top surface and well drained. These sites are predominately broad leaf, forbs, and total live ground cover is about 60 percent, plus or minus a few percent.

The imprint of disturbance appears to vary in the summer pastures. Forbs and grasses respond quickly post disturbance as long as excessive soil erosion does not occur. In extreme areas where topsoils are lost from historic grazing and fire disturbance, recolonization is slow and depends on the slope shape. Upper concave slopes are prone to soil erosion and limit soil redevelopment, while the lower catchments provide deposition zones. These conditions seem tied to geologic contacts with shale and alluvial deposits such as the Beaverhead formation.

The northside ridge opposite of Tom Creek is a good example of slope shape condition on erosion. A quarter acre area on the ridges shows chronic signs of sheetwash. Past grazing and continued use by ungulates aggravate the erosion upslope. Old erosion gullies likely from historical fire still are apparent below although vegetated. The downslope position shows active accretion of soil materials with vegetation responding.

Similar recovery trends are found in a 90-year tracking of range conditions in the subalpine ecosystem of the Wallowa Mountains in northeastern Oregon (Johnson 2003). Soil erosion stopped after the grazing pressure was reduced from historic highs in the 1950s. Recolonization in high meadows was strong as long as soils were somewhat intact. The exception was thin soils in an erosive slope position. These areas hold a steady state where vegetation remained sparse and sheet wash common.

Again, Tom’s Creek provided good context for soil potential. The area likely burned towards the early portion of the 1900s based on feedback from USSES staff. The current state shows no erosion beyond dry ravel of the slope gravels and cobble. Slopes are well armored. These slopes support subshrub and sparse grass with occasional clumps of conifer. This slope shows possibly an altered potential from the fire and historical grazing use with lower water storage available than adjacent thick mantled slopes.

Headquarters Area

The flatland of Henninger, Humphrey and Headquarters are dominated by sagebrush vegetation. Headquarters is a primary wintering facility and has a more intensive use history than the other flatland areas. In addition, these are historic ranch facilities and thus have long term grazing effects. Grassland surrogates include rough fescue and Idaho fescue, more abundant in the upper basin allotments of Henninger and Humphrey. Invasive weeds are present, though targeted by select grazing and localized herbicide use.

Prescribed burning on the USSES has occurred on Headquarters since 1936, the purpose of which is to restore and improve the range. During the past 30 years, roughly 5,400 acres have burned by prescription, and 13,867 acres from wildfire (see range report). Prescribed burn occurs on approximately 200-acre units and averages 670 acres per year. Since 1990, prescribed burning efforts have used experimental designs to identify differences in impacts between fall and spring burning. The USSES is planning a 30-year fire-return interval, within the 25-40 year natural interval based on the ecological site references for historic range condition (NRCS (in review)).

The Henninger ranch was acquired from private owners in the 1940s. Flood irrigation does occur from midsummer to early fall each year. Farming does not occur, although, once in the past 30 years, a pasture has been plowed and re-seeded (ARS 2008b).

Headquarters

The results of the summer 2008 survey found about 10 percent of 127 data points are soil condition class 1 or 2 showing substantial soil disturbance. Half of these points (and all with soil class condition rating of 1) are trails or roads; the remainder are small depressions that hold surface water or remain moist due to clayey deposits, and are trampled by livestock. Compaction and ponding of surface water are the most apparent disturbance.

Henninger

About one-half of the data points are soil condition class 1 or 2 due to compaction or soil loss. All of these points are on flat irrigated fields (points 2, 9 and 10) that have desert-like pavement, gravel surface, are highly compacted, and support little plant life other than arrowroot (*Maranta arundinacea*). Cover ranges between 70 and 95 percent in these areas. There is little slope to farmed fields and it is possible that soil loss is due to wind erosion.

Humphrey

Disturbed areas are due to natural slumping in weakly cemented inter-bedded sand and silt stone. Bedding areas have a high degree of cover, though they are compacted. The Beaver Creek floodplain/valley bottom has lush grass cover; as do all the smaller tributary valleys that support only ephemeral or disconnected flow in small incised, and loamy bank channels. The ephemeral drainage that connects with Beaver Creek ,which has abundant willow growth, showed bank trampling from sheep watering along a quarter mile of the stream. The sedge meadow drainages had no observed bank disturbance.

Environmental Consequences by Alternatives

Methodology

Professional judgment, insight from the NRCS, and referenced literature were used to evaluate the potential effects.

Spatial and Temporal Context for the Effects Analysis

The spatial boundaries for soils direct, indirect and cumulative effects are the USSES properties since soil processes are largely in-place. The spatial boundary is the USSES lands Headquarters, Henninger, Humphrey and the summer pastures. The BL M and FS allotments are not considered since these are not under ARS ownership.

Effects occurring within ten years are considered short term. While long term impacts are typically greater than 30 years. Short-term impacts are considered recoverable, with regrowth established and no excavation of topsoil. For long-term impacts, vegetation is slow to re-establish, and soil is partially removed.

Alternative 1 - Proposed Action (No New Federal Action)

Direct and Indirect Effects

The proposed action would continue sheep grazing and associated activities. The current soil conditions appear functional at all USSES ownerships. Bare soils are in the expected range for all areas sampled and soil erosion sign is rare. From a soil physical standpoint, all areas are functional and do not show overt signs of degradation.

Other effects considered are the impacts of grazing-related actions such as fence building and road-grading (see Proposed Future USSES Projects for Ground Disturbance in project file). Indirect activities considered are range stewardship activities such as prescribed burning and treatment of noxious weeds. The latter is done through a combination of targeted grazing by sheep and use of herbicides (appendix A).

Grazing effects

Using vegetation as an indicator of soil health, the current vegetation composition for Humphrey and the summer pastures appears stable, showing no signs of degrading range condition. Reports on trend for the summer pastures by Klements (1997) and VanHorn-Ecret (1986) show the composition of vegetation within exclosures installed in the 1960s does not differ substantially from the composition outside exclosures. Humphrey has a strong presence of desirable native range species and approaches the expected sagebrush community type based on the NRCS range sites (SCS 1981). These conditions should persist given the long history of the USSES and consistent grazing numbers. The low utilization of 6 percent at Headquarters and 14 percent at Humphrey; along with the varied staging of the animals throughout the year; has resulted in the conditions observed. At Henninger, grazing use observations and higher utilization (24percent) compared to the other properties, indicate a downward trend (see Range Report, 2009), possibly related to the altered hydrology regime from historic downcutting of Dry Creek and irrigation diversion.

Localized areas of soil disturbance associated with sheep driveways and bedding would continue to occur, though the vegetation appears robust enough to recover seasonally and no chronic erosion is occurring.

Headquarters

Soil physical function would continue at Headquarters with vegetation composition aligning with expected diversity and species representation (NRCS 1991, (in review)) on the shallow and moderately deep soils. Bottomlands have more divergent species mixes with a higher abundance of pasture grasses in addition to 10-15 percent of the property planted with crested wheatgrass (*Agropyron cristaetum*) to improve forage. The productive swales have an influx of exotic pasture grasses due to the richer soil fertility here. In these arid environments, higher productivity sites have a propensity for supporting exotic species (Lejuene and Seastedt 2001, Bashkin et al. 2003). Vegetation composition would persist in the Headquarters areas, although crested wheatgrass could expand.

The presence of exotic grasses such as the planted paddocks of crested wheatgrass and pasture grasses impacts the soil biotic community (Wardle et al. 2004, Wolfe and Klironomos 2005), but does not lower productivity per se. Expansion of the perennial grasses would have less impact than expansion of cheatgrass (*Bromus tectorum*) (Norton et al. 2007). Predominance of cheatgrass changes the moisture regime in soil with finer root structure and different litter quality, ultimately shifting the fertility regime to favor itself and out of line with competing native species adaptations (Belnap and Phillips 2001, Thorpe and Callaway 2005, Norton et al. 2007). Currently, cheatgrass is relatively sparse across the range. The presence of the exotic perennial grasses would most likely show changes in arbuscular mycorrhizal assemblages (Wardle et al. 2004) but not impact resources such as nutrients and water (Norton et al. 2007).

Henninger

Henninger shows degradation on the sage flats where conditions have departed from the expected community (see USSES Range Report. 2009; NRCS (in review)). Species composition is stable with pasture grasses and grazing increaser forb species, but lacks native grass species. The current condition shows a downward trend, although no overt erosion sign was observed. Historical grazing at the site along with evidence of dewatering from entrenched drainages suggests a shift in the water table. This site also has irrigation, both at the site and from adjacent land users. The upland sage community has likely expanded into bottomland areas though the extent is uncertain.

Henninger uplands show fair conditions with plant species diverging from the historic community. The exotic perennial grass smooth brome (*Bromus inermus*) is common indicating past seeding and thus may interfere with recolonization of native grass species. Observations found that upland rocky areas where conifers and aspen predominate are closer to the expected plant assemblage. That said, this area gets higher sheep use at 24 percent utilization than all other ownerships of USSES (see Table 1). The forested upland areas are stable; soil erosion is sparse at the site.

Humphrey

Continued sheep grazing at Humphrey would not substantially change soil resources from existing conditions. This area has moderate use at 13 percent (Table 1, page 10) and the vegetation is close to the expected range for this area. Overall, vegetation is robust, diverse and soil erosion not evident outside the bare slope zones from small landslip. These bare slope areas are considered a natural feature and continue to feed water into deep mineral soils in adjacent swales below. Soil development is a century to millennium process. The very dark accumulated organics in these swales compared to much shallower adjacent hillslope soils suggest that these slips are a natural ongoing process.

Riparian soil impacts are mixed at Humphrey. Sedge meadow soils appear intact with minimal impacts for the north tributary of Beaver creek on Humphrey. Willow sedge soils along a quarter mile of southern Beaver Creek tributary will continue to experience season impacts from sheep watering. Canada thistle and upland species along the banks here show historical grazing use at the site. Given the long history and steady grazing numbers, the conditions would likely stay the same with continued livestock grazing.

Summer Pasture

The summer pastures show abundant productive capacity given the higher precipitation regime and vegetation state. Current vegetative assemblages suggest a stable vegetation community. Keith Klement found no outstanding differences for vegetation inside and outside exclosures during his 1990s sampling (1997). Sampling during summer 2009 showed vegetation within expected ranges for the sites compared to the soil surveys in the 1990s (see USSES Range Report. 2009; NRCS 1991). Given the similar management regime to the 1990s, the existing range and soil conditions would continue.

Bared soils from annual operations were observed, but do not show chronic erosion sign. Soil disturbance from sheep drives is temporary and groundcover restored with regrowth. Past evidence of bare soils and degraded conditions is referenced (Klement 1997) and reported for Tom’s Creek in the middle 1980s (Montagne 1988). Bare soils are isolated and related to sheep bedding on ridges, past impacts from combination of old wildfire and/or historic grazing practices (Klement 1997), and natural bare slopes related to snow patches on protected aspects. Sheep bedding areas are typically scattered and less than one quarter acre each. The chronic erosion patch observed is one-quarter acre and continues to sheet wash. This area is not grazed. The snow slopes are steep un-vegetated slopes and therefore experience only transient use by sheep.

Sheep impacts on the nutrient regime are most prevalent at bedding sites. A recent study by Leytem and Seefedt (2008) for sites on the USSES summer range highlights the changes. The bedding sites have reduced vegetation and this translates to lower organic carbon and long-term nitrogen (total N). The input of sheep feces offsets the lack of vegetation somewhat with spikes of ammonium (NH_4-N) and soluble phosphorus (P), although overall the bedding areas experience a net loss of nutrient potential (Leytem and Seefedt ,2008). The impact of these conditions can influence the vegetation at these bedding areas although specifics were not given in the study. More opportunistic vegetation is associated with these spikes (Vinton and Burke 1994) with exact characterizations dependant on grazing history and ecological context (Milchunas and Laurenroth 1993, Biondini et al. 1998).

Nutrient impacts from sheep grazing outside of the main congregation areas such as bedding areas are not expected. Areas outside of the bedding areas have strong vegetation production and thus shifts in nutrients from urine and manure input would not occur. The dispersal of sheep and low grazing capacity diminishes the impacts.

Overall the summer pastures have likely improved from the 1980s with rest rotation instituted, elimination of one band of sheep (1,000 animals), and continued emphasis on herding for light, even use by sheep. Adaptive management principles emphasize even usage by the sheepherders and avoidance of low productivity sites. The poor conditions cited by Montagne (1988) at Tom’s Creek were initially monitored for grazing effects, and later closed to grazing altogether due to low forage and snow displacing the monitoring exclosure fencing (Jacobson, 2009, personal communication).

Table 1. Percent utilization with the existing proposed action (Alt 1) versus the no grazing alternatives.

Properties	AUM Available	Existing Alt1	Alternatives with varying degrees of no grazing			
			Alt2	Alt3	Alt4	Alt5
ARS total	**48,667**	**6.8**	**-**	**5.9**	**7**	**4**
Headquarters	28,353	5.6	-	9.1	5.6	3.9
Humphrey	4,476	13.5	-	-	13.5	9.4
Henninger	1,914	23.8	-	15.5	24.6	16.6
Summer East (Toms Cr.)	4,043	3.8	-	-	-	2.7
Summer West (Odell Cr./Big Mt.)	9,881	5.1	-	-	7.2	3.5
Leased total (DOE, USDA-FS, DOI-BLM)	**26,087**	**5.8**	**0.6**	**3.9**	**5.5**	**1.4**
Mud Lake	560	28.6	28.2	28.2	28.6	29.6
Snakey-Kelly	1,756	24	-	19.2	24	-
East Beaver	17,887	1.2	-	-	1.2	0.8
Meyers Creek	3,076	2.3	-	-	-	1.6
Bernice	2,808	23.2	-	18.5	23.2	-

Invasive plants

The containment of invasive plants advances soil productivity by limiting the expansion of weeds capable of changing soil properties. The containment and eradication strategies poses risk for adverse effects from select grazing and herbicide use. Select grazing can result in overgrazing of non-target species if grazers are mismanaged. The most common herbicides used, Curtail (2,4 D), Krovar (Bromacil and Diuron), and Roundup (Glyphosate) have minimal adverse effects on soil biota, but do vary in leaching and runoff potential. Krovar has particularly high risk for offsite transport to groundwater and runoff.

Select sheep grazing and herbicide spraying are used to contain the spread of invasive plants. The main species targeted are leafy spurge (*Euphorbia esula*), spotted knapweed (*Centaurea stroebe*), and cheatgrass (*Bromus tectorum*). Minor infestations are noted for hoary cress (*Cardaria draba*), lambsquarters (*Chenopodium album*), kochia (*Bassia scoparia*) and thistle (*Cirsium spp.*). Handspraying targets roadsides, feedlots and corrals, and near building structures. Broadcast spraying is done with a four-wheeler or tractor- in small pastures and large feedlots. Aerial application is not used. Roughly, 50 acres are sprayed annually (Table 2, page 12).

The ecological and thus soil related implication is notable for leafy spurge, spotted knapweed, and cheatgrass. These plants are pervasive in arid rangelands. The success of these species may be due in part to positive feedbacks they create in the soils as self sustenance in addition to lack of predators such as soil pathogens (Thorpe and Callaway 2005, Wolf and Klironomos 2005). Cheatgrass changes soil structure and can influence nutrient content and timing (Hawkes et al. 2006, Norton et al. 2007). Spotted knapweed may “mine” phosphorus unavailable to other species (Thorpe et al. 2006) in addition to altering nutrient cycles with its root exudates (Thorpe and Callaway 2005).

Select grazing by sheep is documented as effective for control and eradication of leafy spurge and spotted knapweed (Olson and Lacey 1994, Tu et al. 2003). Select grazing for leafy spurge has reportedly resulted in up to 90 percent eradication (Olson and Lacey 1994), while spotted knapweed control is mixed, probably due to the bittering agent in leaves cnicin (Whitney and Olson 2006). It would make sense that select grazing would benefit soils by moving plant community structure further toward native composition.

Herbicide treatment on the USSES lands is outlined below. The main herbicide used is Curtail which is a mix of 2,4 D and clopyralid. Roadsides and fence lines at Headquarters are the main targets for control of weed infestations with an average annual treatment of 45 acres. Secondarily, Krovar – a composition of Bromacil and Diuron – is applied to the two acres of headquarters feedlots. A recent pasture reseeding at Humphrey used Roundup (Glyphosate) for 12 acres. Other herbicides with some prior use at the USSES, though not used regularly, include Arsenal (impazapyr), Tordon (picloram) and Garlon (triclopyr).

Herbicide application indirectly benefits soil function by containing the spread of noxious weeds, particularly those that alter soil nutrient regimes. Most of the spraying focuses on weed containment and eradication along travelways and high disturbance areas such as the feedlots. Adverse impacts on soil organisms overall is not expected given the low toxicity listed by Tu et al. (2003) and using application rates within label restrictions. Decomposition of all listed herbicides is primarily by soil microbe metabolism.

However, certain suites of microbes are sensitive to Tordon (picloram), Arsenal (imazapyr) and Garlon (tryclopyr). Tordon has some toxicity to certain fungi at high application rates and is known to affect the nitrification portion of the N mineralization cycle (SERA 2003a). Garlon is toxic to some soil bacteria at low and high doses (2004). Arsenal has slight effect on soil microbes at high doses (SERA 2004).

Table 2. Herbicide general use, types and location

Herbicide	Active ingredients	Area	Frequency	Acres	Notes
Curtail	2,4 D (39%) and Clorpyralid (5%)	Headquarters roadsides +/- 5 m	Annual	35	Leaches, esp sandy soils and shallow water tables
Curtail	2,4 D (39%) and Clorpyralid (5%)	Humphrey roadsides (+/- 5 m) and fencelines (+/- 2 m)	Annual	10	Leaches, esp sandy soils and shallow water tables
Krovar	40% Bromacil (40%) and Diuron (40%)	Headquarters feedlots	Annual	2	leaches readily, long half life in soil
Roundup	Glyphosate (48%)	Humphrey pasture reseeding	One time	12	Strong sorption to soil

Herbicides are typically used on disturbed areas such as roads and feedlots. These areas are characteristically compact and barren and may increase herbicide residence time. Soil processes are key to the breakdown of herbicides, so impaired conditions can lead to longer residency. Krovar and Tordon have relatively long residence times in soils, with soil half lives in the order of a year or more (Extronet 1993, SERA 2003a); while Roundup and Garlon have short residency times in soil, at 47 days (SERA 2003b) and 30 days (SERA 2004) respectively. It should be noted that these half lives are averages and vary depending on the amount of moisture available, organic matter and warmth for soil processing (Bollag and Liu 1990).

Krovar, Tordon, and Curtail have moderate to high leaching potential and can contaminate groundwater if used near shallow aquifers (Extronet 1993, Dow 2008, Dupont 2008). Herbicide buffers are recommended to ensure adequate protection (see Protocols, Appendix A: Integrated Pest Management). Roundup has a very strong affinity to soils and thus has the least potential for affecting groundwater. Once absorbed by soils the herbicide is degraded by soil microbes and is unavailable to plants.

Prescribed Burning

Short-term adverse impacts to soils from severe burning are not expected from either fall or spring burning, nor are offsite erosion given the low seasonal rainfall. Prescribed burning is expected to increase mineral forms of N and P in the short term (1-2 years) with long term effects uncertain. Soil biota and productivity would be adversely affected with expansion of cheatgrass.

Prescribed fire generally increases mineralization cycles in the short-term (Fisher and Binkley 2000, Erickson and White 2008) with long-term consequences depending on the vegetation and soil biotic conditions (Hart et al. 2005). Plant available nitrogen and phosphorus increases for the first (one) year, while increases in sagebrush systems of up to four years for nitrate are reported (Rau et al. 2007). Mackenzie et al. (2006) have found elevated nitrate in nearby forested systems for up to 60 years. The effects are highly dependent on biological substrate and precipitation since mineralization is a soil biotic process (Hart et al. 2005, Rau 2007).

Cheatgrass is of particular concern with regards to changes to the soil nutrient regime and the risk of more frequent flashy fires (D’Antonio and Vitousek 1992, Norton et al. 2007). These sagebrush regimes appear sensitive to the increased fire frequency associated with cheatgrass expansion (NRCS (in review), Zouhar et al. 2008). Cheatgrass invasion is thought to occur during high moisture years and may actually decline in drought (Zouhar 2008). ARS personnel have not observed cheatgrass expansion in the mountain big sagebrush vegetation types where they are burning.

Alternatives 2-5

Direct and Indirect Effects

Areas of current and historical sheep use would continue in the current vegetative state for both lowland Headquarters, Henninger, Humphrey and the highland summer ranges in the Centennials. Discontinuation of grazing would allow for more leaf litter available for organic accumulation into soils. The no grazing alternatives would not result in detectible changes on the soils resource for Headquarters, Humphrey, and east summer pastures since the projected use is near or less than the current 10 percent (Table 1). Soil conditions may improve at Henninger for alternative 2 since use would be discontinued compared to the current 24 percent. Alternative 3 would extend grazing through summer months on Headquarters, but the effect is uncertain since utilization continues at less than 10 percent. Alternative 4 could have some lower recovery potential at west summer range without a rest rotation system.

Conceptually, where grazing is discontinued on lowlands, plant and soil associations would persist since the arid conditions lend to slow recovery potential. Long-term studies on sheep grazing during the mid 20th century show varied potential for recovery based on current soil potential and vegetation composition (Michunas and Laurenroth 1993, Johnson 2003). State and transition models developed for rangeland integrate these ideas and use indicator species and surface soil conditions to judge not only current condition, but also recovery or trajectory of the plant community (NRCS (in review)). Compacted staging areas for animals would stay compacted for the long term given arid conditions and the relatively infertile environment. In contrast, uplands with species compositions closer to the historic climax communities and with hydrologic regimes intact would have greater regrowth potential. For the USSES properties on the lava plains, Henninger has the highest potential for regrowth with no grazing given the favorable climatic conditions.

The absence of sheep grazing would no doubt improve litter accumulation and retention of biomass. This cover would add mulch and further protection to soils. Plant composition changes would be difficult to detect after resting given the resilience of the current communities and the closeness to the expected natural habitat for the northern reaches of Headquarters and especially Humphrey, using the NRCS ecological site logic. Again, the differences may be subtle given the current low uses on these lands.

No grazing would improve footslope and dry meadow sites at Henninger for alternative 2. Henninger serves as a staging area and has utilization of 24 percent (Table 1). Henninger has higher moisture, deep soils, and lacks the calcareous upper soil layer that can limit plant production. Improvement would be most notable on the footslope sage sites. The predominant species mix of pasture grasses in the lowlands would persist and therefore a higher-level plant community state is not expected, though production could improve. In addition, the altered hydrology from irrigation and deeper entrenchment of Dry Creek has less potential to support historic dry meadow plant species.

Humphrey pasture has strong semblance to the expected native vegetative community, and, therefore, may show minute improvements except in the willow riparian area. Floodplain soils along this tributary of Beaver Creek would show improvement over the current condition if grazing was terminated since soils have good functional attributes, albeit with some Canada thistle and upland shrubs. Compaction is rare and the current vegetation suggests good soil through-flow. Given these conditions, recovery potential is high. The collapsed banks would stabilize allowing improved movement of soil moisture outward. In addition, mesic vegetation species adjacent to the stream could establish without sheep grazing facilitating vegetation and soils recovery.

Alternative 4 would condense grazing to the west summer pasture only for the summer and likely not utilize the rest rotation system. Alternatives 2 and 3 eliminate grazing for both alternatives. Alternative 5 decreases grazing proportionally about 2/3 of current levels. No differences would be detected in the short term for alternatives 2-5. Alternative 4 could potentially generate worse seasonal range conditions with concentrated use in the west range with more incidental soil damage from trampling and bedding.

Invasive Plants

Eliminating grazing and active management in alternatives 2-5 has uncertain impacts for invasive weeds and thus soils productivity. Eliminating selective sheep grazing and loss of active management could further expand existing invasives. On the other hand, reduced sheep numbers and associated inputs of fecal matter and disturbance along with less travel use of road ways decreases opportunities for invasive plants and, thus, impacts to soil productivity.

Herbicide use would decline by 10 acres annually with elimination of the Humphrey range in alternatives 2 and 3 and cease altogether except for the two acres at the USSES main facility (Table 1). No changes in soil productivity are anticipated with this reduction in use since the sprayed areas are primarily disturbed sites. The tradeoffs are similar to those for the elimination of selective grazing.

Prescribed Burning

Alternatives 3-5 would have similar impacts from prescribed burning to alternative 1, since these alternatives retain Headquarters as primary range. The assumption is the elimination of sheep grazing at Headquarters would eliminate the burning program. For Alternative 2, eliminating the burning program reduces the opportunity to maintain the natural 25-40-year fire cycle,

Summary of Direct and Indirect Effects

Table 3 displays a comparison of direct/indirect soils effects by alternative.

Table 3. Summary of soil effects

Soil Effects	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Grazing					
Headquarters	Stable	Slight improvement with added leaf litter	Stable		
Henninger	Downward trend from decreased plant vigor, litter production	Improvement on lowland and footslopes with higher litter, less disturbance	Downward trend	Downward trend	Slight improvement with less grazing use
Humphrey	Stable	Improvement in Beaver Creek riparian soils	Improvement in Beaver Creek riparian soils	Stable	Stable
Summer Range	Stable	Slight improvement with added leaf litter	Slight improvement with added leaf litter	Risk for downward trend in summer west from no rest-rotation	Slight improvement with added leaf litter
Other Activities					
Invasive Plants	Decreases risk of invasion, possible offsite leaching of krovar	Uncertain: eliminates grazing weed dispersal, decreases active control	Decreases risk of invasion, possible offsite leaching of krovar		
Prescribed burning	Mimics fire cycle, increases cheatgrass spread risk	Tradeoff: Lowers cheat grass risk and active burning program	Mimics fire cycle, increases cheatgrass spread risk		

Cumulative Effects

Adverse cumulative effects are not expected for any of the alternatives. Effects from the mine at Odell, wildfire and prescribed burning are not degrading soil productivity.

The additive effects of past grazing are considered more in detail within the context of the current plant community and soil condition (see Affected Environment and Direct Effects sections). Over the last 86 years, grazing management appears relatively consistent with possibly upward trends in the last twenty years from reduced grazing and rest rotation in the uplands along with evolving grazing practices.

Rehabilitation has occurred on the road to Blair Lake and to the Odell mine, returning hydrologic function; soil impairments from soil removal will continue at the mine site (see USSES Hydrology Report, 2009) while the road to Blair lake has mixed revegetation success. Observations in summer 2009 found some sign of continued offroad vehicle use. The forb-dominated vegetation was responding well due to the mollic soils. Ruts were still visible in some areas with continued erosion between water bars. Reclamation at this area will depend on successfully halting motorized travel. Adverse effects are limited to the road area and thus isolated.

Historic wildfire continues to affect the ongoing soil productivity on USSES lands for the summer range. Wildfire sign from the early 1900s is visible in the east summer pasture with old erosion gullies still visible at the north side of Tom’s Creek divide. This is indicative of the low production for the dolomite and shale geology on steep slopes. Elsewhere, old wildfire sign is not visible and soil/vegetation is robust. Recent fire on the Meyer’s Creek allotment shows quick recovery.

Prescribed fire is limited to the Headquarters range where ongoing efforts continue. Roughly 19,000 acres have burned since 1936. About 70 percent of this is from wildfire, though a more active burning program has been in place over the past 10 years; with prescribed burning averaging 600 acres per year. The USSES would like to increase to 900 acres per year to approximate a natural 30-year fire-return interval (NRCS (in review)). Positive effects occur where fire is returned to the system through nutrient influx. Adverse effects occur where cheatgrass increases.

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