Determining rangeland suitability for cattle grazing based on distance-to-water, terrain, and barriers-to-movement attributes

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ABSTRACT

There are methods developed for determining the suitability of rangelands for cattle grazing based on slope and distance-to-water. Current methods do not account for the distance cattle must travel around steep terrain (barriers-to-movement) to reach water. Failure to adjust grazing suitability for terrain issues and travel distances to water can result in rangeland degradation.

The project goal was to develop a grazing suitability model and test it for the Lander Field Office of the Bureau of Land Management (BLM) in Wyoming. The primary objective was to develop a GIS Model that creates a systematic process to calculate areas suitable for grazing using slope and distance-to-water that accounts for terrain barriers. This project compared GIS-based calculations with previous hand-generated suitability calculations to check their validity. Finally, the project documented the methodology and data used for calculations. This would allow for modification of the model to local conditions and the addition of supplementary attributes.

This project tested the model on nine pastures having three different terrain types within the Lander Field Office. The model uses elevation data to calculate slope and determine terrain-based movement barriers. The water source layer is a combination of streams, wetlands, and water well locations. The BLM provided the pasture boundary layer.

The importance of the barriers-to-movement modification increases as steepness of the terrain increases. The accuracy of the model improves with complete water well or stock pond data, which requires local knowledge. The terrain classification categories can be changed based on knowledge of cattle use within a pasture. The model can reflect seasonal and long-term changes in water availability by adjusting the water source layer. The model can adjust predicted forage production in combination with the NRCS Grazing Land Spatial Analysis Tool and the USDA Soil Data Viewer. In addition, the model can be used to evaluate the need and location of additional water sources and fencing. An important use of this model is to predict areas of grazing use intensity, which would aid in establishing rangeland monitoring.

The barriers-to-movement layer has a limited effect on total number of suitable areas. The barriers-to-movement does represent the areas suitable for cattle grazing. The model depends on the knowledge of range specialists to accurately create and modify the water source layers.

INTRODUCTION

A commonly argued issue between biologists and range specialists is the deterioration of wildlife and fisheries habitat caused by overgrazing along streams and riparian areas. There is a need to determine grazing suitability to limit land degradation caused by cattle staying in one place for long periods. Determining suitability leads to determining the appropriate number of cattle and the timing of grazing.

This capstone project developed a methodology that uses ESRI's Geographic Information System (GIS) software package to determine rangeland grazing suitability for cattle. I based this work on two existing methods developed by Holechek (1988) and Guenther et al. (2000) to determine cattle grazing suitability and estimate rangeland use by cattle, and I analyzed additional suitability criteria.

The Bureau of Land Management (BLM) in Wyoming is in the process of updating Resource Management Plans (RMP) for all of its Field Offices. The RMP is the planning document that guides land management decisions on public lands administered by the BLM. Livestock grazing is a major use of public rangelands throughout the west. Due to the variability in types of grazing land, the number of animals each grazing allotment can support must be determined. The identification of rangelands suitable for cattle grazing occurs during the RMP revision process. Areas far from water with steep slopes are usually unsuitable for cattle grazing. Due to the effort it takes to account for terrain conditions, the majority of lands are typically deemed suitable for cattle grazing (BLM 1986). Failure to adjust grazing for terrain issues and travel distances to water can result in rangeland degradation, as grazing will occur only on suitable areas of the allotment.

There are limited opportunities outside the RMP revision process to evaluate lands available for grazing (BLM 1997, 2005). Generally, re-evaluations are performed if grazing permits are voluntarily relinquished or if the grazing allotment does not meet Rangeland Health Standards and cannot achieve the standards under any level of livestock management (BLM 1997, 2005). Seldom are grazing allotments voluntarily relinquished, so it is important to re-evaluate the grazing suitability during the RMP revision process.

A major objective of grazing management is to achieve uniform livestock use across rangelands. Cattle tend to congregate on flat areas, such as stream bottoms, riparian zones, and ridge tops in rough terrain as they avoid grazing in areas having steeper slopes (Holechek et al. 1999). These steeper areas should not be included when determining the acres available for grazing. In areas with diverse topography, cattle will over-utilize the level areas adjacent to water sources (Pinchak 1991). Grazing concentrated on the easily accessed sites having flat terrain near water sources leads to overgrazing and land degradation, resulting in an eventual decline in rangeland health, even though the forage supply is adequate over the entire pasture.

The BLM Land Use Planning Handbook (BLM 2005) identifies the following factors for consideration when determining availability of land for livestock grazing:

other uses for the land;

terrain characteristics;

soil, vegetation, and watershed characteristics;

presence of undesirable vegetation, including significant invasive weed infestations;

and presence of other resources that may require special management or protection, such as special status species, special recreation management areas or Areas of Critical Environmental Concern.

Because cattle grazing is a predominate use of public lands and can affect other uses of the lands, determining the appropriate number of cattle an area can support is important in order to balance resource allocations.

Methods for adjusting grazing suitability for terrain (slope) and distance-to-water are developed. Holechek (1988) describes one method to adjust the grazing capacity of a pasture for slope and water distribution. Omitted from grazing are areas with slopes greater than 60 percent, which receive little to no use by cattle (Holechek 1988). Areas having slope greater than 10 percent receive a reduced level of grazing. In addition, several studies have shown that cattle seldom use areas greater than 3.2 km (2 miles) from water (Valentine 1947; Holechek et. al 1998). Adjustments for percent slope reduction used by Holechek (1988) are summarized in Table 1. Holechek (1988) also developed an adjustment for reducing grazing capacity considering distance-to-water, summarized in Table 2.

Table 1. Percent reduction in grazing capacity based on percent slope. (Holechek et al. 1998)

Percent Slope	**Percent Reduction in Grazing Capacity**
0 - 10	None
11 - 30	30
31 - 60	60
Over 60	100 (ungrazable)

Table 2. Percent reduction in grazing capacity based on distance-to-water. (Holechek et al. 1998)

Distance-to-Water Miles	**Distance-to-Water** Kilometers	**Percent Reduction in Grazing Capacity**
0 - 1	0 - 1.6	None
1 - 2	1.6 - 3.2	50
2	Over 3.2	100 (ungrazable)

The second grazing adjustment method also predicts suitability of an area for cattle grazing based on slope and distance-to-water. Guenther et al. (2000) developed an "Expected Use Model" using the IDIRIS GIS/Analysis system (The IDIRIS Project, Clark University, Worcester, MA.) that combined slope and distance-to-water to predict expected levels of forage utilization. Factors dealing with terrain and water currently have digital data sources that make it possible to use this method. The model requires three map layers: slope as derived from a digital elevation model, a manually digitized map identifying water sources, and a layer delineating pasture boundaries. The expected use maps developed by Guenther et al. (2000)

categorized the expected forage use into five classes, similar to the four categories in Holechek (1988). The expected use classes developed are:

Incidental use areas: Areas expected to receive 0-5% use,

Slight use areas: Areas expected to receive 5-20% use,

Light use areas: Areas expected to receive 20-40% use,

Moderate use areas: Areas expected to receive 40-60% use, and

Concentrated areas: Areas expected to exceed 60% use.

Areas of incidental use are underutilized and thus are considered unsuitable for grazing. Summarized in Table 3 and Table 4 are adjustments developed Guenther et al. (2000) for slope and distance-to-water respectively.

Table 3. Percent suitable for cattle grazing using percent slope (Guenther et al. 2000).

Percent Slope	**Percent Suitability Grazing Capacity**
0 – 6	100%
> 6 to 60	> 0 to < 100%[1]
Greater 60	0%

[1]Intermediate slopes are given intermediate values with a slope of 30% considered 50% suitable (50% reduction)

Table 4. Percent suitable for cattle grazing using distance-to-water (Guenther et al. 2000)

Miles	Kilometers	Percent Suitability Grazing Capacity
0 - 0.14	0 - 0.29	100%
> 0.14 – 2	0.29 – 3.2	> 0 to < 100%[1]
2	Over 3.2	0%

[1]Intermediate distances are given intermediate values with a distance of 1 mile (1.6 km) considered 50% suitable (50% reduction)

Guenther el al. (2000) combined the suitability for slope and distance-to-water to create a total grazing suitability or expected use map. The computer model allows for an infinite number of values between 0 and 100%. Comparison of the values derived using both methods is shown in Table 5. The percent suitable concept by Guenther et al. (2000) is the inverse of the percent reduction developed by Holechek (1988).

Table 5. Comparison of percent reduction and percent suitable categories.

Use Type	**Percent Suitable** (Guenther et al. 2000)	**Percent Reduction** (Holechek et al. 1998)
Incidental	0 - 5	95 - 100
Slight	5 - 35	65 - 95
Light	35 - 70	30 - 65
Moderate	70 - < 100	> 0 - 30
Concentrated	100	0

In summary, Holechek (1988) developed his method during the infancy of GIS and divided the slope and distance-to-water into four major categories to allow for easier calculations. Most of the current grazing suitability calculations used Holechek's methodology with paper maps before

GIS was available to most land management agencies. Guenther et al. (2000) expanded the method using a continuous gradient of grazing suitability, instead of discrete categories, and incorporated GIS technology.

There is a desire on the part of rangeland managers to develop a systematic computer-based methodology to determine grazing suitability (J. Kelly, BLM LFO Field Manager, personal communication, June 2005). Most federal and state agencies have limited to no access to the IDRISI GIS/Analysis software needed to run the Expected-Use Model developed by Guenther et al. (2000), however, most government agencies currently have access to ESRI's ArcGIS software (C. Breckinridge, BLM LFO GIS Specialist, personal communication, June 2006). There is a need to develop an integrated GIS method to complete the necessary steps for any method.

GOALS / OBJECTIVES

The goal of this capstone project was to develop and test a model using ESRI's ArcGIS Model Builder Tools to determine the grazing suitability of rangeland in the Lander Field Office (LFO) of the BLM.

Objective: Develop a GIS methodology using ESRI Model Builder Tools to create a systematic process to calculate areas suitable for cattle grazing, using slope and distance-to-water around slope barriers for selected pastures with various terrain types.

Objective: Compare the GIS based analysis with and without the barrier layer to previous (paper map) calculations of suitable acres. Verify the derived calculations are reasonable and validate the modifications with local range specialists.

Objective: Develop a summary to explain the methodology and data required for the grazing suitability model.

METHODS

The project area was limited to nine pastures within the LFO planning area that have a diversity of topography. The areas tested were the Sweetwater Canyon and Lewiston Lakes pastures of the Silver Creek Allotment, the North, East, West, and Upper Rock Creek pastures of the Rim Pasture Allotment, the East and West pastures of the Shoshoni Road Allotment, and the Haybarn Hill Allotment (Figure 1). The Sweetwater Canyon and Lewiston Lakes pastures have steep sided canyons, Rim Pasture Allotment pastures have foothill terrain, and Shoshoni Road pastures and Haybarn Hill Allotment have relatively flat terrain. Table 6 lists basic terrain characteristics for the test pastures.

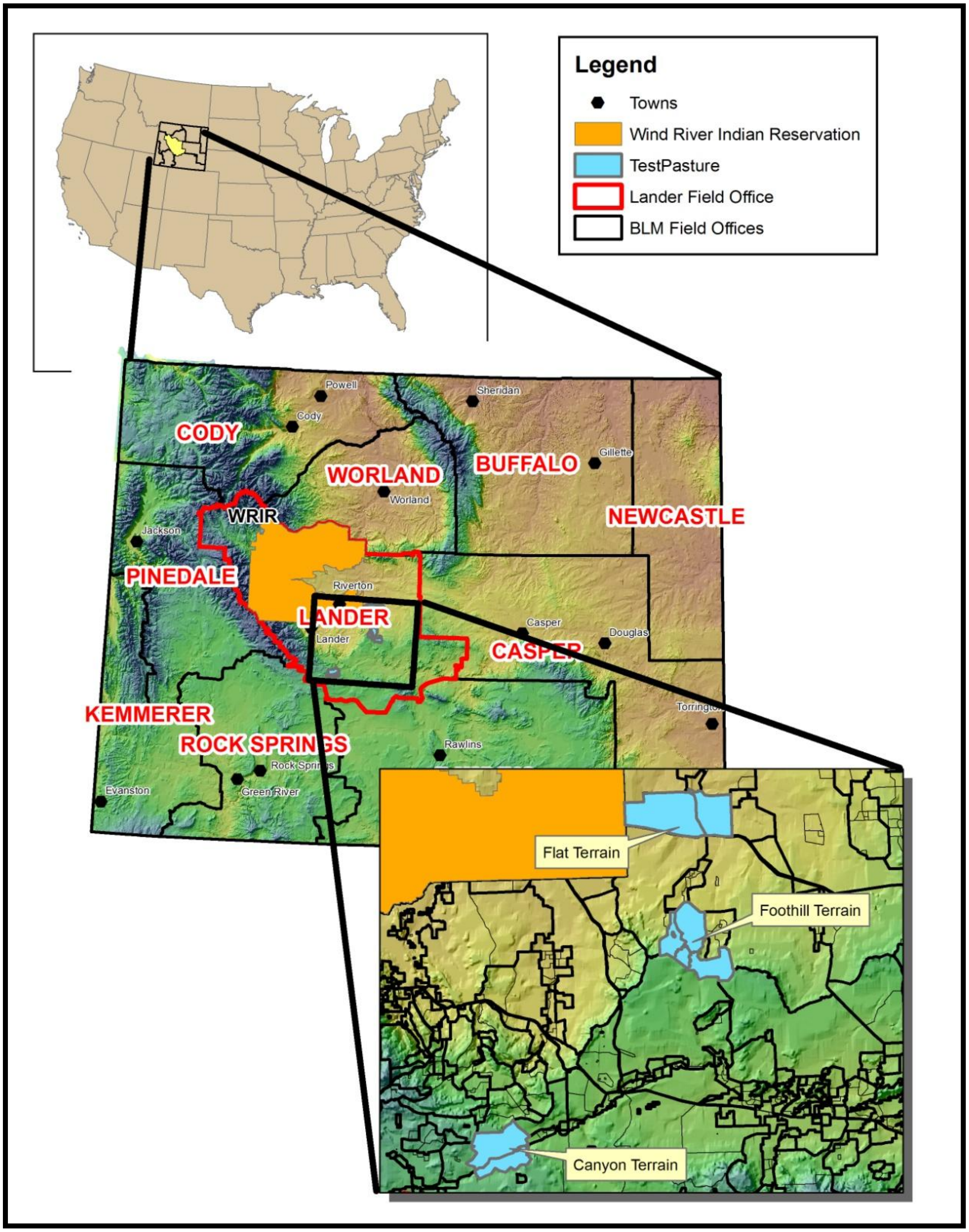

Figure 1. The study area is highlighted in yellow (top map). The Lander Field Office, study area, is outlined in red with selected towns and the Wyoming BLM Field Offices labeled (middle map). The test pastures are shown in blue (bottom map).

Table 6. Summary of the elevation characteristics in meters (m) and feet (ft) and the sizes of the nine test pastures in hectares (ha) and acres (ac).

Pasture	Max. Elevation	Min. Elevation	Elevation Difference	Size
FLAT TERRAIN				
West Shoshoni Road	1691 m 5548 ft	1568 m 5144 ft	123 m 404 ft	5232 ha 12,926 ac
East Shoshoni Road	1672 m 5486 ft	1599 m 5246 ft	73 m 240 ft	3807 ha 9408 ac
Haybarn Hill	1697 m 5568 ft	1579 m 5180 ft	118 m 388 ft	4804 ha 11,872 ac
FOOTHILL TERRAIN				
East Rim	2222 m 7290 ft	1874 m 6148 ft	348 m 1142 ft	3308 ha 8174 ac
West Rim	2176 m 7139 ft	1760 m 5774 ft	416 m 1365 ft	2028 ha 5011 ac
North Rim	2133 m 6998 ft	1734 m 5689 ft	399 m 1309 ft	3829 ha 9461 ac
Upper Rock Creek	2228 m 7309 ft	1962 m 6437 ft	266 m 872 ft	785 ha 1939 ac
CANYON TERRAIN				
Sweetwater Canyon	2319 m 7608 ft	2045 m 6709 ft	274 m 899 ft	2583 ha 6382 ac
Lewiston Lakes	2325 m 7628 ft	2056 m 6745 ft	269 m 883 ft	5178 ha 12,795 ac

The LFO planning area is located in central Wyoming (Figure 1) and encompasses 6.6 million acres. Of these 6.6 million acres, approximately 2.5 million (35 percent) are public lands managed by BLM. In the middle of the LFO planning area is the Wind River Indian Reservation, which comprises 2 million acres. There are approximately 700,000 acres of privately owned lands and 300,000 acres of Wyoming state lands (BLM 1986) in the planning area.

The LFO planning area has a semi-arid climate with a diverse topography. The Wind River Mountains block the moist air currents from the Pacific Coast, causing most of the moisture to fall on the western slope of the mountains and less on the eastern slopes where the LFO is located. This has resulted in the high desert, semi-arid rangelands that cover most of the LFO. These rangelands have a limited number of natural water sources, with many being only available on a seasonal basis.

The initial step for this project was to acquire data from various public sources and check it for accuracy. I removed extraneous features outside the LFO to expedite the data analyses. The Wyoming Geographic Information Science Center is the spatial data clearinghouse for the State of Wyoming and stores some of the base GIS data used for this project. A summary of the data used is in Table 7. The software needed to complete this project was ESRI's ArcMap software with the Spatial Analyst Extension (ESRI 2006).

Table 7. Data used for range suitability model.

Spatial Data	Data Sources
Grazing allotment and pasture boundaries	Available from LFO BLM, and http://www.blm.gov/wy/st/en/resources/public_room/gis/datagis/office/allot/lander.html
BLM Lander Field Office boundary	Available from LFO BLM and ftp://piney.wygisc.uwyo.edu/data/boundary/blm_districts.zip
Fences for Southwest Wyoming	Spatial Data and Visualization Center, 200102, Fences of Southwest Wyoming, 1990-1992: University of Wyoming Spatial Data and Visualization Center, Laramie, WY
Digital Elevation Data	USGS Seamless Data Site, downloaded 1/3 degree (10 meter) National Elevation Data (NED) http://seamless.usgs.gov/website/seamless/viewer.php
Stream Layers	USGS (1:24,000 scale) flow lines. National Hydrography Dataset (NHD), http://nhdgeo.usgs.gov/viewer.htm
National Wetland Inventory (NWI)	Available from LFO BLM and http://wetlandsfws.er.usgs.gov/imf/imf.jsp?site=NWI_CONUS
Permitted water wells	Wyoming State Engineers' Office, buffered by 10 meters and converted to polylines ftp://seoftp.wyo.gov/geolibrary_data/SEO_wells08.zip

The conceptual diagram (Figure 2) summarizes the steps used for this range suitability model. Combining allotment boundary and fence maps created the pasture boundaries, and each pasture boundary was then saved as a separate layer. The models used the pasture boundary as an analysis mask to eliminate the time consuming process of clipping the data each time the models ran. The models summarized the classifications using the 10-meter cell size of the original digital elevation data.

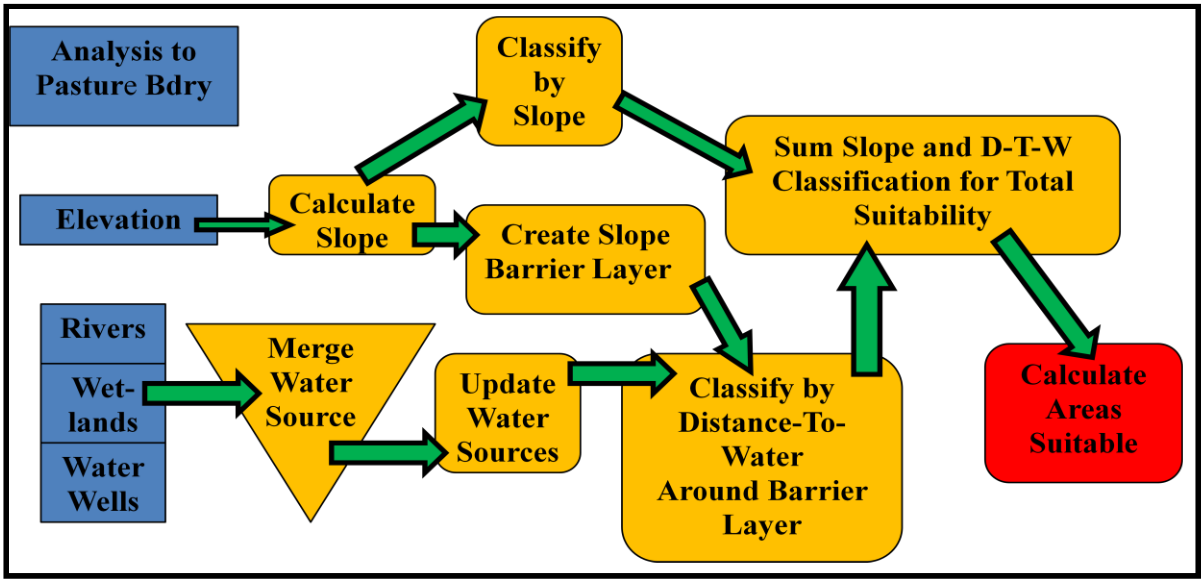

Figure 2. Conceptual diagram of steps used to determine suitable areas for grazing. The blue boxes are model inputs and the red box is the final output.

A model created the percent slope layer from the 1/3-degree (10 meter) National Elevation Data (NED). The percent slope layer covered an area larger than the individual pasture and once created, the models used this layer multiple times. This sped up the process and saved disk storage space without the need to store the derived percent slope layers each time the model was ran.

The classification of the percent slope layer created the slope-reduction categories using 10 percent slope groupings following Holechek et al. (1998) and Guenther et al. (2000) as presented in Table 8. The selection of areas with slopes greater than 60% and 45% created the terrain boundary layer treated as Barriers-To-Movement (B-T-M).

Table 8. The percent slope and distance-to-water with the corresponding percent reduction and percent suitable by 10 percent categories.

Percent Slope	**Distance-to-Water (m)**	**Percent Reduction Categories**	**Percent Suitable Categories**
0 - 6	0 - 290	0	100
6 - 12	290 - 613	10	90
12 - 18	613 - 937	20	80
18 - 24	937 - 1260	30	70
24 - 30	1260 - 1583	40	60
30 - 36	1583 - 1907	50	50
36 - 42	1907 - 2230	60	40
42 - 48	2230 - 2553	70	30
48 - 54	2553 - 2887	80	20
54 - 60	2877 - 3200	90	10
60 - 300	3200 - 14000	100	0

Three water source sub-models were prepared to create a seasonal water source layer by selecting water sources by type, seasonality, and beneficial use. Seasonal water models were developed for late spring (May 1- May 30), early summer (June 1- July 15), and late summer (July 15 - September 15). The dates of seasonal adjustments were for the specific areas analyzed. All water source sub-models selected permitted water wells for stock use. The late spring model selected all National Hydrography Dataset (NHD) streams and all wetlands. The early summer model selected named NHD streams that are not intermittent, and selected National Wetland Inventory (NWI) areas that were emergent and plaustrine. The late summer model selected named perennial streams and emergent wetland areas. The sub-models merged the water sources into one layer. The models allowed for modifications of the water source layer at this step. The method allowed for checking the layer for accuracy and modification, based on local knowledge of the pasture. If needed, the additional water sources were mapped as linear features to complete the water source layer.

Three range suitability models (60% slope B-T-M, 45% slope B-T-M, and No B-T-M) determined the shortest distance to seasonal water around the various B-T-M layers. The cost distance analysis tool calculated the least accumulative distance from each cell to the nearest water source around the B-T-M (cost) layer. The range suitability models then classified the distance-to-water into 10 percent reduction categories following Holechek et al. (1998) and Guenther et al. (2000) as presented in Table 8. At this point, both the distance-to-water and slope-reduction categories were calculated.

The three range suitability models summed the slope-reduction categories and the distance-to-water categories to calculate the final reduction categories. It is important to stress that the final reduction in grazing suitability is both cumulative and additive. For example, a 10 percent reduction for slope added to a 30 percent reduction for distance-to-water would result in a total reduction of 40 percent. A 40 percent reduction is considered 60 percent suitable. (J. L. Holechek, Professor of Range Science New Mexico State University, personal communication, January 2009). The model reclassified areas with a combined reduction greater than 100 percent to 100 percent, areas could not have a reduction greater than 100 percent.

The final steps mapped the areas suitable for grazing and calculated the acres suitable by 10 percent suitability categories. Lastly, summing the areas suitable for grazing determined the total acres suitable.

Shown in Figure 3 is the range suitability model for the 60% slope B-T-M as represented in the ESRI Model Builder Tool. The inputs are grazing pasture boundary, percent slope, and water sources calculated in separate sub-models. The final output is the acres suitable summarized by 10 percent suitability categories.

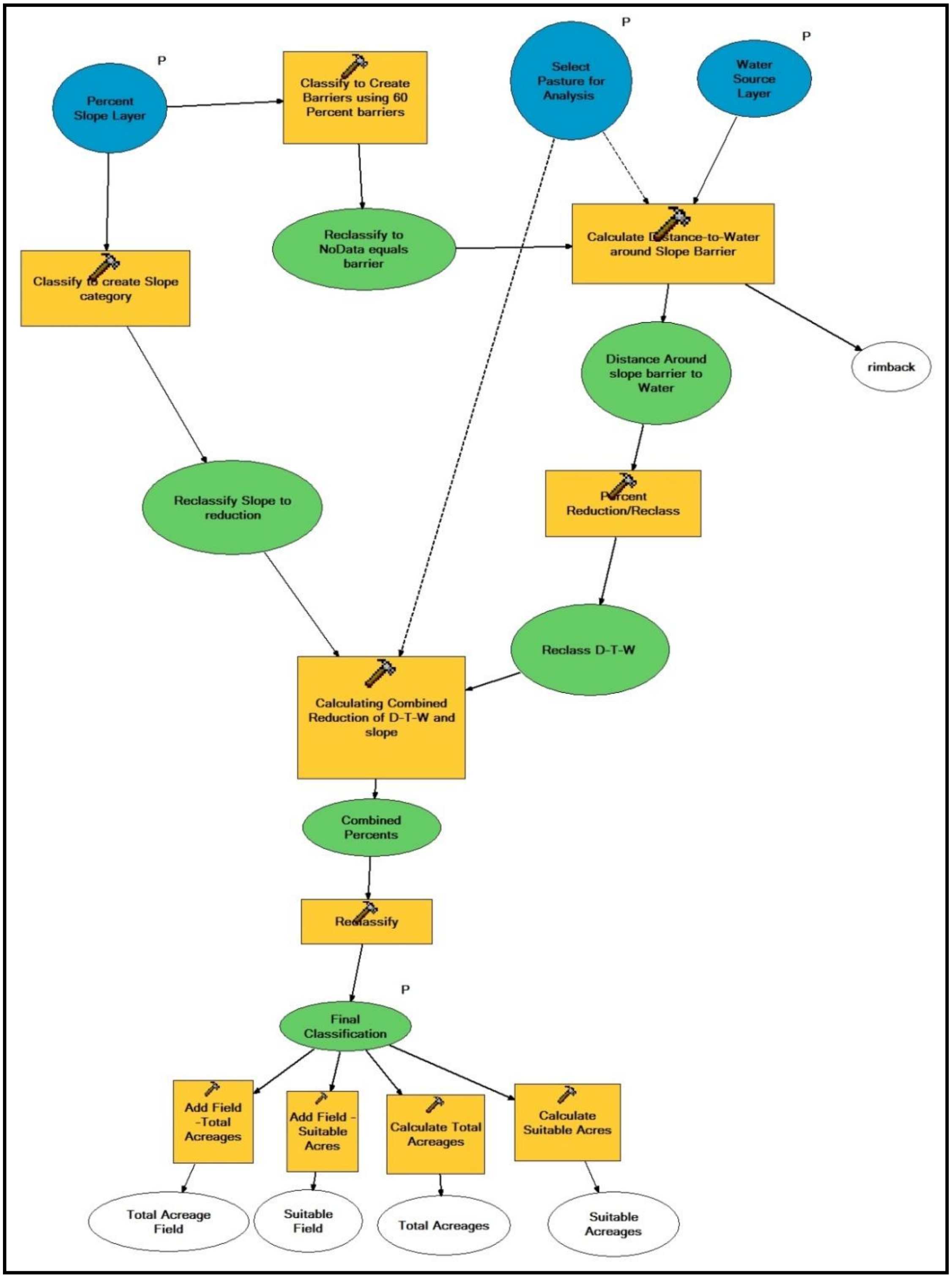

Figure 3. Steps used to determine suitable areas for grazing with inputs of the pasture boundary, percent slope, and water sources.

RESULTS

I measured the distance around the B-T-M layers to water sources and compared these distances to the GIS calculated distances using the cost distance analysis tool. These two distance measurements were within 10 meters of each other, which was the same as the 10-meter cell size of the original elevation data.

The GIS derived calculations are reasonable compared to the previous manual calculations of total acres suitable for grazing. The suitable acres calculated by the model was consistently smaller than previous calculations, but were well within expected values (BLM LFO personnel, personal communication, January 2009). The LFO range specialists, wildlife biologists, and soil scientist reviewed the model to determine the validity of the slope-barrier modifications. Suitable acre calculations were reasonable when the water source layer was accurate. I modified the water source layer based on the LFO range specialist's knowledge of the pasture, which improved the results.

Based on discussions (BLM LFO personnel, personal communication, January 2009), I changed the method to have separate steps (sub-models) derive the percent slope and seasonal water source layers. Once created, the models used the percent slope layer multiple times to analyze adjoining pastures. These sub-models allowed for the creation of a basic water source layer, based on the seasonal availability of water, which I modified using based on specific knowledge of the pasture.

I created three range suitability models for 60% slope B-T-M, 45% slope B-T-M, and No B-T-M. The inputs for the range suitability models are the grazing pasture boundary, percent slope, and seasonal water source layer. The output of these models was the final classification of suitability acreages summarized in 10 percent reduction categories.

A summary of the final calculations of suitable acres for the nine test pastures using the early summer water layer and the three B-T-M range suitability models are shown in Table 9. The B-T-M layer affected areas of four pastures, three in the foothill terrain and one in the canyon terrain. The outcome was a 0 to 4 percent change in total suitability, not considered significant. The model calculates the shortest distance to the nearest water source, so it is sometimes closer to another water source then going around the barrier to reach the original water source.

Table 9. Summary of the acres suitable for grazing by No B-T-M, 60% Slope B-T-M and 45% Slope B-T-M range suitability models using early summer water sources.

PASTURE	Pasture Size	No Slope Barrier	Percent Suitable	60% Slope Barrier	Percent Suitable	45% Slope Barrier	Percent Suitable
FLAT TERRAIN							
West Shoshoni Road	12,928 ac / 5232 ha	7654 ac / 3097 ha	59	7663 ac / 3101 ha	59	7654 ac / 3097 ha	59
East Shoshoni Road	9408 ac / 3807 ha	5508 ac / 2229 ha	59	5509 ac / 2230 ha	59	5508 ac / 2229 ha	59
Haybarn Hill	11,872 ac / 4804 ha	8159 ac / 3302 ha	69	8167 ac / 3305 ha	69	8159 ac / 3302 ha	69
FOOTHILL TERRAIN							
East Rim	8174 ac / 3308 ha	5300 ac / 2145 ha	65	5308 ac / 2148 ha	65	5281 ac / 2137 ha	65
West Rim	5011 ac / 2028 ha	2634 ac / 1066 ha	53	2611 ac / 1057 ha	52	2497 ac / 1011 ha	50
North Rim	9461 ac / 3829 ha	4896 ac /1981 ha	52	4902 ac / 1984 ha	52	4864 ac / 1968 ha	51
Upper Rock Creek	1939 ac / 785 ha	1063 ac / 430 ha	55	1063 ac / 430 ha	55	1049 ac / 424 ha	54
CANYON TERRAIN							
Sweetwater Canyon	6382 ac / 2583 ha	3847 ac / 1557 ha	60	3796 ac/ 1536 ha	59	3550 ac / 1437 ha	56
Lewiston Lakes	12,795 ac / 5178 ha	9492 ac / 3841 ha	74	9501 ac / 3845 ha	74	9439 ac / 3820 ha	74

While the total acres stayed similar using the different B-T-M range suitability models, the range suitability pattern differed. The Sweetwater Canyon (Figure 4) and West Rim pastures (Figure 5) show this change in pattern. The 100 percent suitable areas along the river in the center of map (inset map) are absent in the 45 percent terrain barrier for Sweetwater Canyon pasture (Figure 4). There was an increase in suitable areas in the north part of the West Rim pasture (outlined in white), which is balanced with a decrease in the suitable areas in the west central section of the pasture. The terrain barriers had limited effects on the total acres suitable, but did affect the suitability pattern.

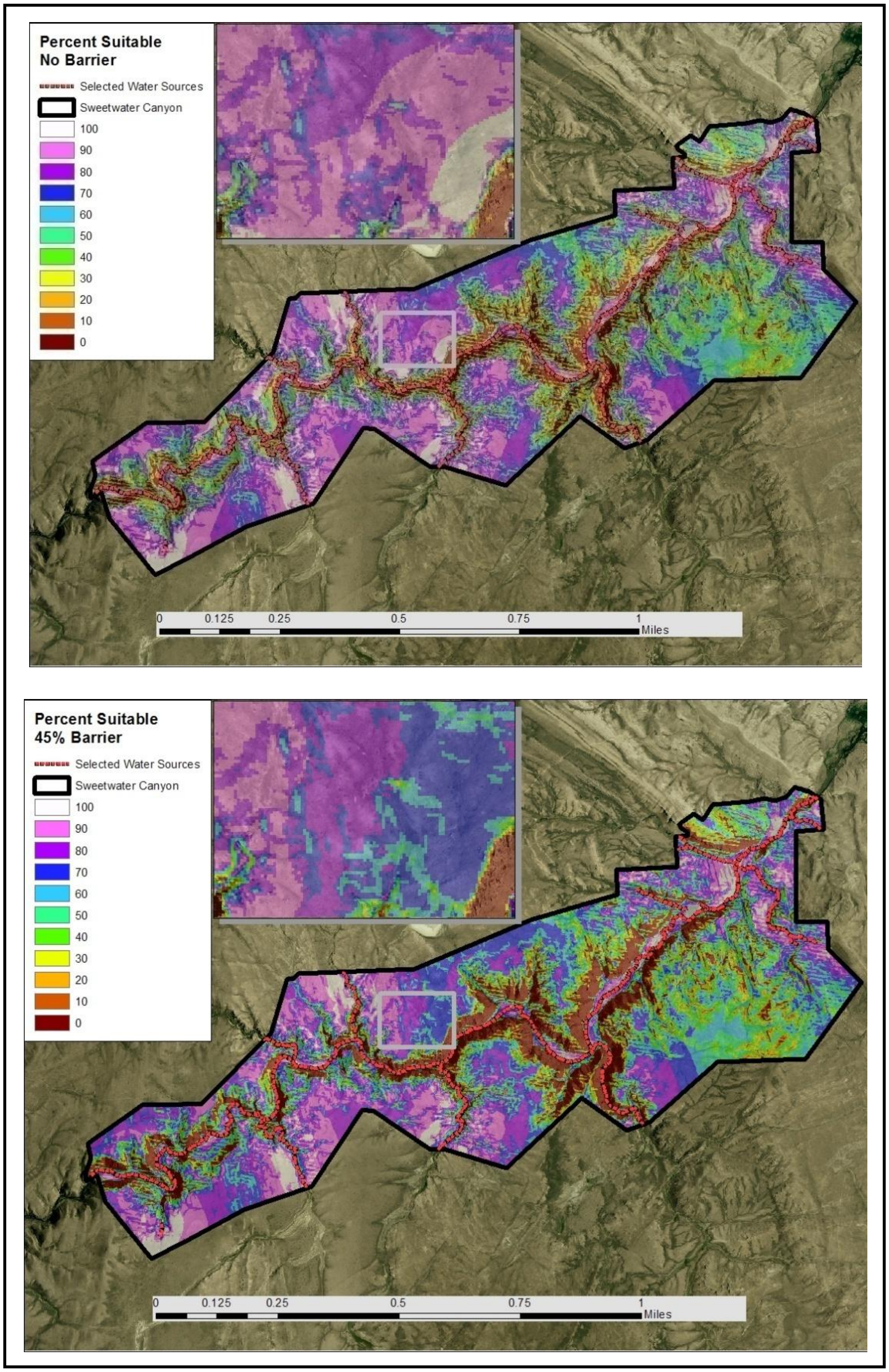

Figure 4. Comparison of range suitability for the Sweetwater Canyon pasture for No B-T-M (top) and 45% slope B-T-M (bottom) range suitability models using early summer water sources.

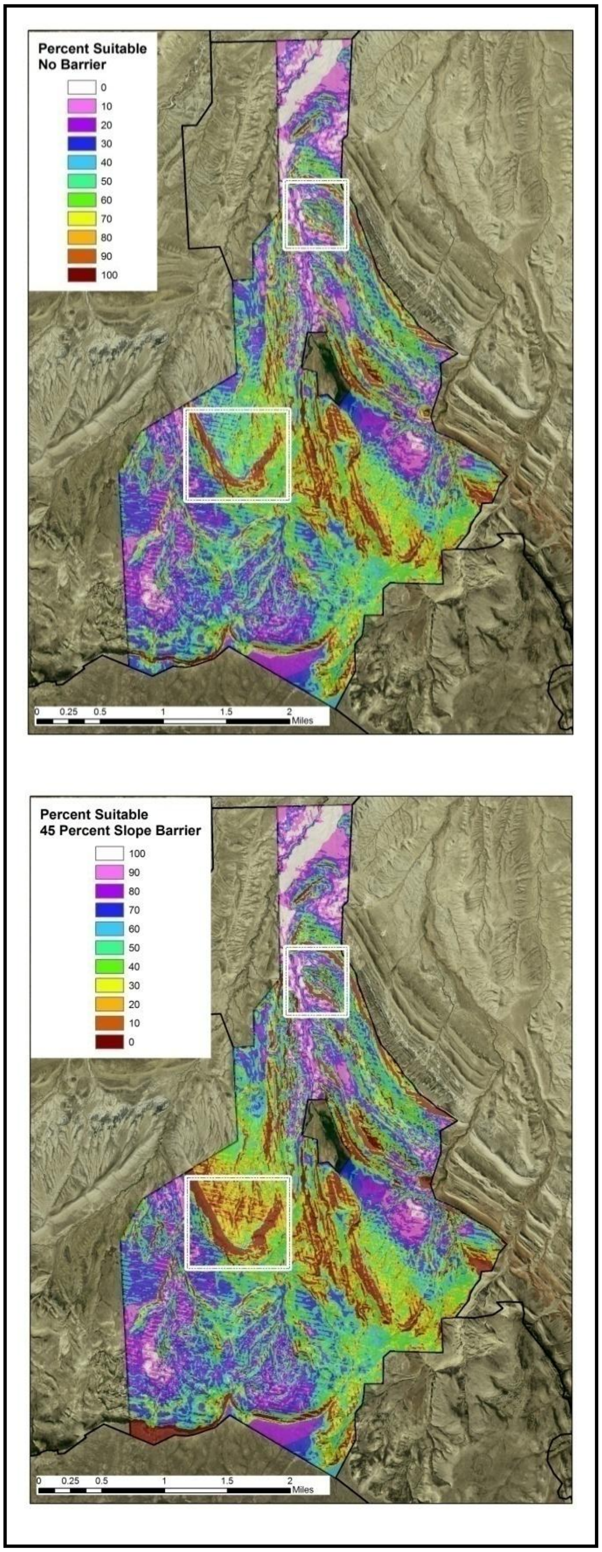

Figure 5. Comparisons of the suitability for the West Rim pasture for No B-T-M (top) and 45 percent slope B-T-M (bottom) range suitability models using early summer water sources.

A summary of the analysis of the three different seasonal water source sub-models on acres suitable for grazing are shown in Table 10. This evaluated the utility of the water source sub-models. The range specialists (BLM LFO personnel, personal communication, February 2009) reported the late-spring model over-estimated suitable acres because it selected nearly all water sources. Although range specialists reported water in all areas represented at least once during the last few years, they had not seen water at all locations at the same time in the spring. The early and late summer water source models still over-estimated water availability, but suitable acres were reasonable using early and later summer water sources (BLM LFO personnel, personal communication, February 2009).

Table 10. Summary of the acres suitable for grazing using seasonal water sources selection sub-models. This analysis was completed using the 60 percent range suitability model.

PASTURE	Pasture Size	Late Spring	Percent Suitable	Early Summer	Percent Suitable	Late Summer	Percent Suitable
FLAT TERRAIN							
West Shoshoni Road	12,928 ac / 5232 ha	11,598 ac / 4694 ha	90	7662 ac / 3101 ha	59	6744 ac / 2729 ha	52
East Shoshoni Road	9408 ac / 3807 ha	8071 ac / 3266 ha	86	5509 ac / 2229 ha	59	4931 ac / 1996 ha	52
Haybarn Hill	11,872 ac / 4804 ha	10,679 ac / 4322 ha	90	8167 ac / 3305 ha	69	6920 ac / 2800 ha	58
FOOTHILL TERRAIN							
East Rim	8174 ac / 3308 ha	6179 ac / 2501 ha	76	5307 ac / 2148 ha	65	5190 ac / 2100 ha	65
West Rim	5011 ac / 2028 ha	3210 ac / 1299 ha	64	2611 ac / 1057 ha	52	2309 ac / 934 ha	46
North Rim	9461 ac / 3829 ha	7458 ac /3018 ha	79	4902 ac / 1984 ha	52	4902 ac / 1984 ha	52
Upper Rock Creek	1939 ac / 785 ha	1296 ac / 524 ha	67	1063 ac / 430 ha	55	1063 ac / 430ha	55
CANYON TERRAIN							
Sweetwater Canyon	6382 ac / 2583 ha	4003 ac / 1620 ha	63	3796 ac/ 1536 ha	59	3767 ac / 1524 ha	59
Lewiston Lakes	12,795 ac / 5178 ha	10,901 ac / 4411 ha	85	9501 ac / 3845 ha	74	9070 ac / 3671 ha	71

The East Shoshoni Road pasture (Figure 6) and North Rim pasture (Figure 7) are representative of the effects that the separate water source models had on the pattern of areas suitable for grazing. By the end of the grazing season, the East Shoshoni Road pasture had over 6000 less acres suitable for grazing. The North Rim pasture had a large change in suitable areas from late spring to early summer (4144 acres), but no change from early summer to late summer. This was due to the limited number of spring water sources in this pasture.

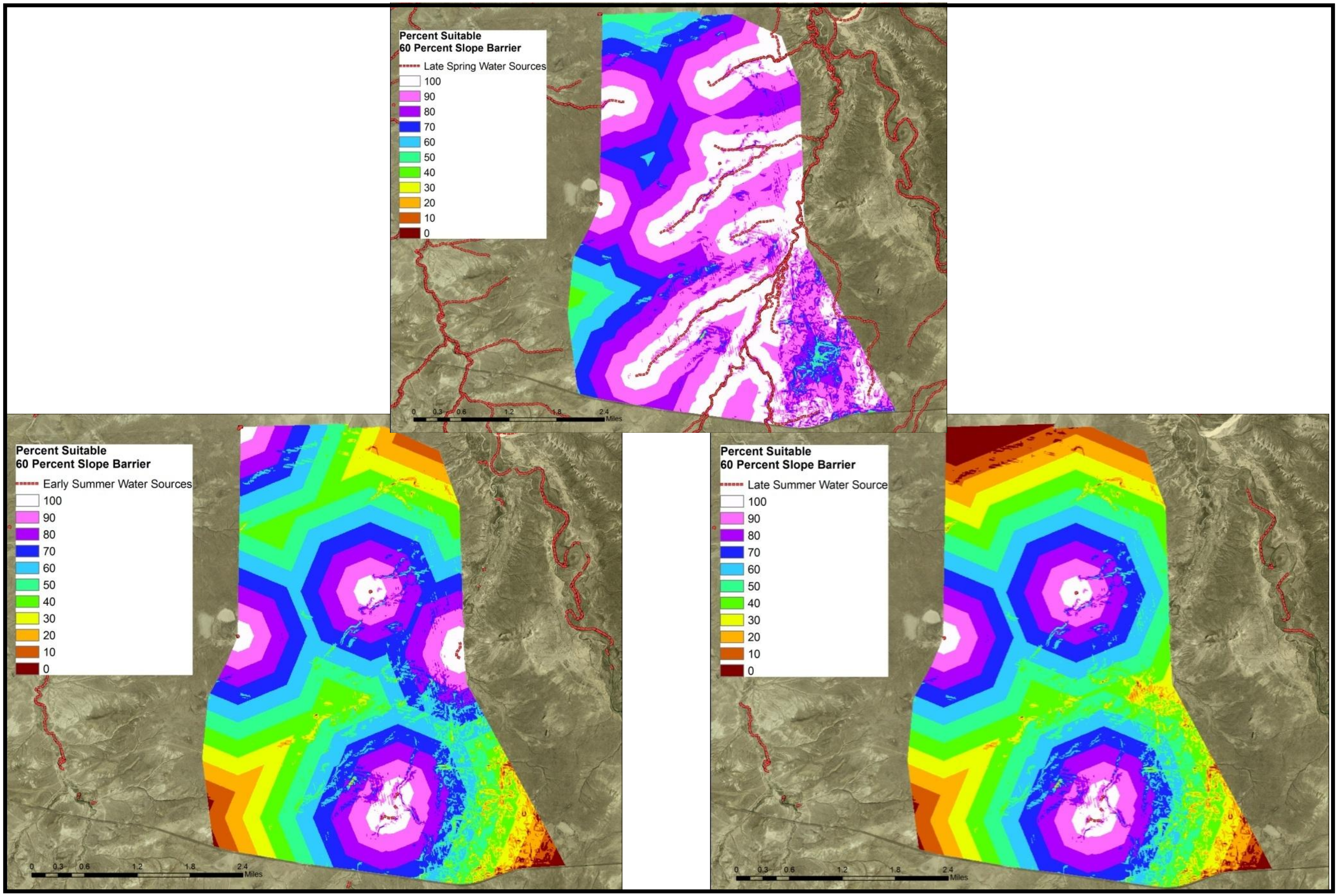

Figure 6. Maps of the grazing suitability for the East Shoshoni Road pasture for late spring (top), early summer (left), and late summer (right) water sources using the 60% slope B-T-M range suitability model.

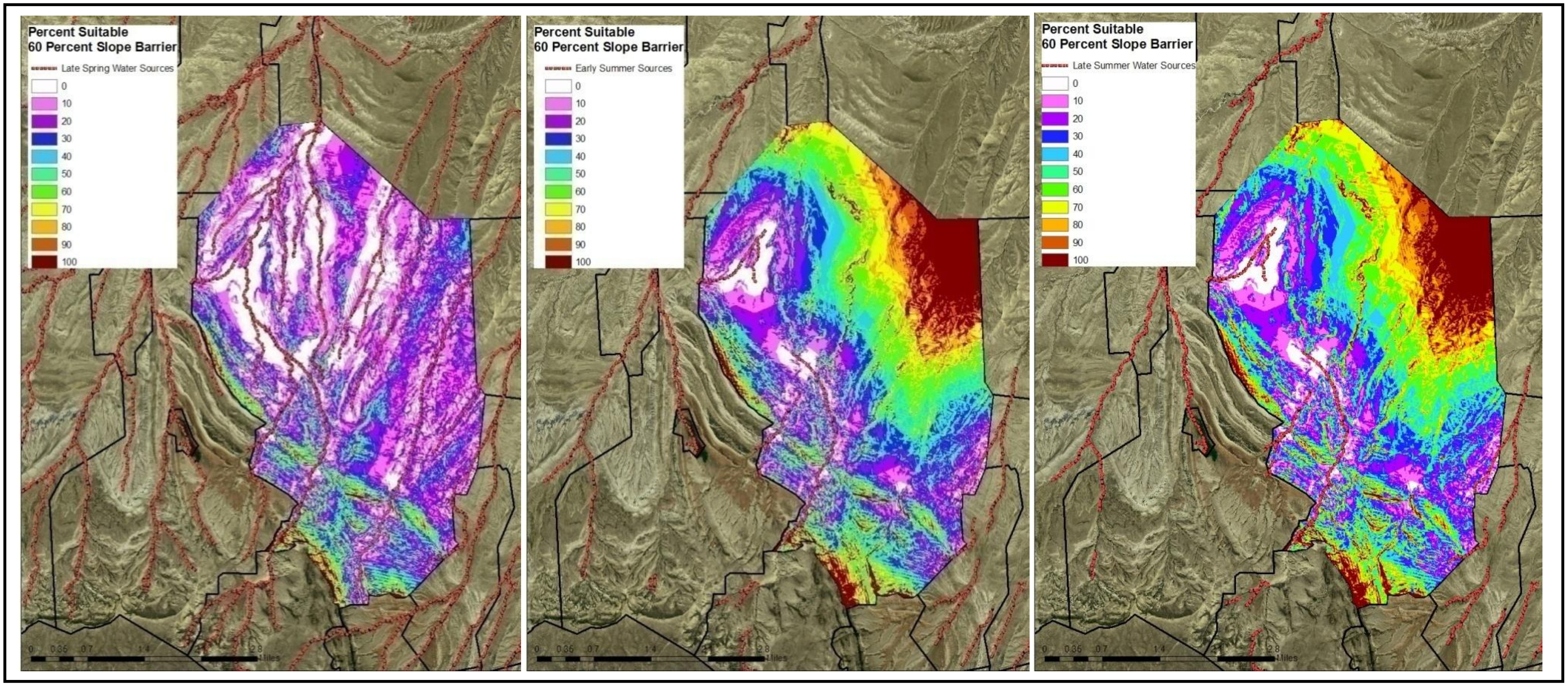

Figure 7. Maps of the grazing suitability of the North Rim pasture for late spring (left), early summer (middle), and late summer (right) seasonal water availability using the 60% B-T-M range suitability model.

ESRI's model documentation tools accomplished the final objective of summarizing the data needs and model methodology. The model documentation tools explained the individual steps in the sub-models, provided usage tips, and summarized the purpose of the sub-models. The documentation tools provided contact information, explanation of the parameters used for models and use constraints of these models. The completion of this report further explains and discusses applications of these models.

DISCUSSION

I presented results of a trial project for the Sweetwater Canyon pasture to the BLM LFO range specialists in 2005 (BLM LFO personnel, personal communication, June 2005). They expressed concerns with the current methods of calculating range suitability, as these methods did not address other criteria they felt should be considered. One concern focused on when the water source (river) was inside steep-sided canyons (S. Fluer, BLM LFO Range Specialist, personal communication, June 2005). Both models, Holechek et al. (1998) and Guenther et al. (2000), assume cattle can move directly across the steep slopes to reach suitable grazing areas. In reality, cattle may have to travel more than 1/4 mile to exit the canyon to reach suitable grazing areas. Areas above the steep-sided canyon should have a reduced grazing suitability due to the actual distance cattle must travel to water. A second concern presented was that models do not account for soil and bedrock features that limit vegetation production (G. Bautz, BLM LFO Soil Scientist, personal communication, June 2005). Including areas not capable of producing vegetation would over-estimate the availability of forage. It was felt that both terrain barriers and soil suitability should also be considered when determining rangeland suitability.

The trial project used both Holechek et al. (1998) and Guenther et al. (2000) methods and calculated the distance-to-water by using GIS to create a buffer around water sources. Both methods used a straight line distance to calculate the distance-to-water and did not account for the additional distance around the terrain barriers. These methods used slope categories in their range suitability methods. This project created a B-T-M layer using the slope greater than 60 and 45 percent respectively and calculated the additional distance around terrain barriers to obtain the distance-to water.

I presented the range suitability analyses of the nine test pastures using the new GIS model to the LFO personnel for review (BLM LFO personnel, personal communication, January 2009). There was agreement that the methodology accurately accounted for increased distance around terrain barriers. The results were reasonable when water sources were predominantly perennial streams in the canyon areas. The results for the flat terrain pastures were incorrect due to the absence of two water wells and a stock pond in the water source layer, and over-estimating water availability due to using a named intermittent stream. I modified the water source layer by adding water wells and a stock pond, deleted part of the intermittent stream, and ran the model again. The local range specialist (BLM LFO personnel, personal communication, January 2009) confirmed the results as reasonable with the modified water source layer. This demonstration reinforced the advantage of models that would systematically recalculate rangeland suitability when improved (corrected) water source data or pasture boundary data becomes available.

If needed, the range specialist can modify the results of the three sub-models that created the base layer for seasonal water sources. The three seasonal water source models often over-estimated water availability. Reviewers did not perceive this to be a major flaw of the water source selection process, since it was easier to have the range specialist delete features than it was to add water sources. The BLM has a list of range improvements, including water development projects, which could be used to update the water source layer. This data was not complete at the time of this project.

The documentation tools with ESRI Model Builder were effective to document the data and methods used during the development of this method. There is a need to develop a detailed guide to assist new users in operating this tool in the future.

I noted there were gaps in the GIS modeled B-T-M layer that allowed cattle movement through the perceived terrain barrier that requires further field investigation. These gaps could be due to the accuracy or errors in the 10-meter elevation data. A 10-meter buffer around the terrain barriers would close most gaps.

One use of this range suitability model is to determine optimal placement of additional water sources to increase cattle distribution. Expected grazing suitability maps will identify areas over two miles from water and classified as 100 percent unsuitable for grazing. The placement of new water sources in these previous “unsuitable” areas could increase acres available for grazing.

Another use of the model is determining the impact of dividing a pasture or grazing allotment with cross fencing. Dividing a pasture without accounting for water availability and terrain could concentrate cattle in heavily used areas, resulting in deterioration of grazing lands. Splitting a pasture with fencing could isolate cattle away from adequate water sources, making some areas unsuitable for grazing.

It is recommended (Guenther et al. 2000; Holechek et al. 2000) that livestock grazing use be monitored in areas of moderate use. This model predicts what level of grazing use a particular area might receive and could assist cattle ranchers and BLM personnel in selecting areas for grazing monitoring. Knowing the expected use of an area would improve the interpretation of the monitoring data. Presented are examples of expected use maps for the East Shoshoni Road (Figure 8) and Sweetwater Canyon (Figure 9) pastures. The East Shoshoni Road pasture has a large percentage of the pasture in moderate use (green) areas, while the Sweetwater Canyon pasture has a small percentage of the pasture in moderate use areas.

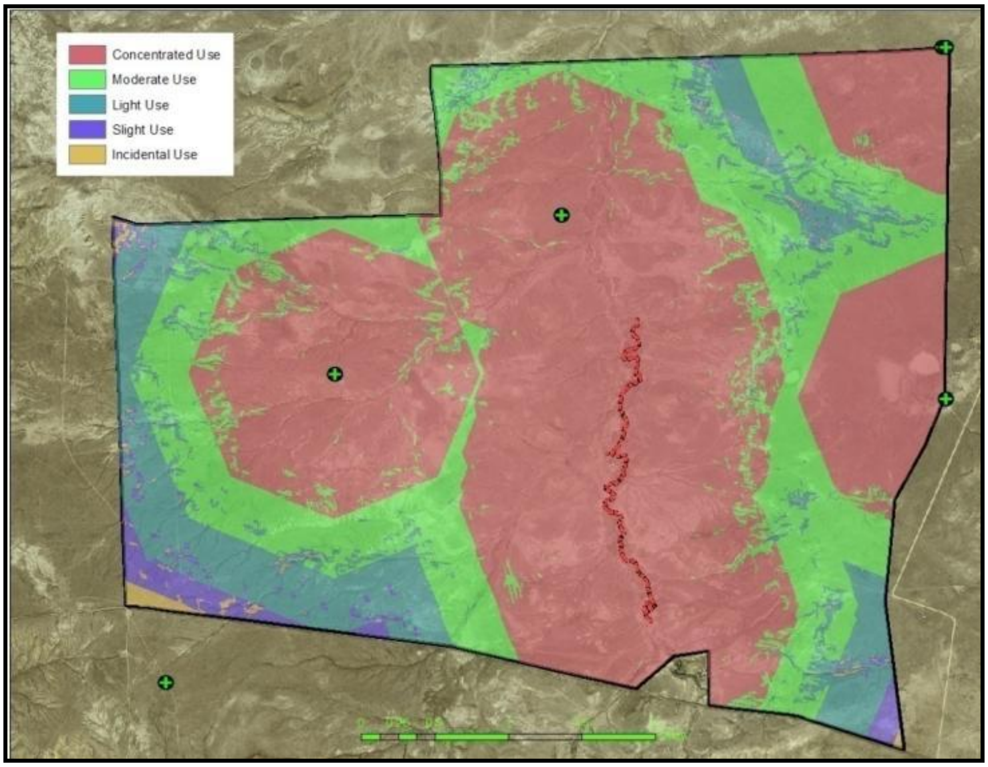

Figure 8. Expected use map for the East Shoshoni Road pasture using 60% slope B-T-M range suitability and late summer water source model.

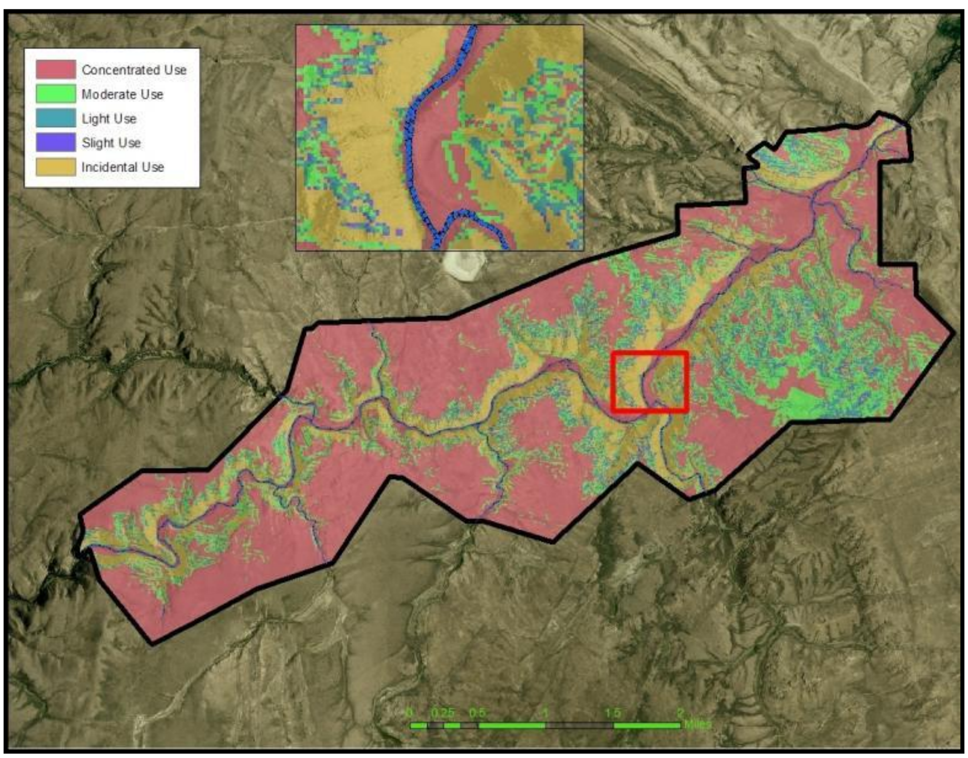

Figure 9. Expected use map for the Sweetwater Canyon pasture using 60% slope B-T-M range suitability and late summer water source model.

The model could be used in conjunction with the Natural Resources Conservation Service (NRCS) Soil Data Viewer (NRCS 2007b), which summarizes range production by pasture in pounds of forage produced per acre for favorable, normal, and unfavorable years. Suitable acres calculated by this model multiplied by the pounds of forage produced per acre will determine a range of animal unit months (AUMs) available for grazing. The ability to calculate available AUMs has been the most requested upgrade of this model. It would be worthwhile to investigate the possibility of integrating this method with the NRCS Soil Data Viewer, but elevation data and water sources layer are currently not part of the Soil Data Viewer basic dataset (NRCS 2007b).

The NRCS has developed the Grazing Land Spatial Analysis Tool, which is a stand-alone decision support tool utilized to inventory both grazing resources and animal use (domestic and wild) (NRCS 2007). This tool balances forage supply in relationship to animal demand. The tool depends on inventory data and analysis of grazing lands to balance supply and demand. Limited knowledge of its existence (Wyoming Game and Fish Dept. Aquatic Habitat Biologists, personal communication, January 2009) and the need for multiple pastures inventory sites that are often not available has limited the use of this tool. The tool does not integrate streams as linear features, slope of the pasture, or travel distances around barriers to water. Water sources (i.e., springs and streams) must be hand digitized as a series of points, which is a time consuming process and often not completed. Models created for this project can be integrated into this decision support tool.

During project development other factors were identified that could improve the model. The most commonly mentioned factor was the addition of a vegetation layer (K. Spence, Wyoming

Game and Fish Dept. Habitat Biologist, personal communication, June 2008). While vegetation maps are available in digital format, the resolution is currently too coarse to be usable for this project. There are on-going efforts to map vegetation communities due to concerns related to greater sage-grouse habitat in Wyoming. The model could be expanded to include vegetation attributes once mapping efforts are completed.

Another factor mentioned for inclusion in evaluating grazing suitability is the significant invasive weed infestations in the LFO. Fremont County Weed & Pest District is developing a comprehensive map of weed infestations for both private and public lands in the LFO. The LFO encompasses other Weed & Pest Districts in neighboring counties that do not have a comprehensive map at this time. Using a weed layer in this model is currently not possible due to the lack of complete data, but could be included in the future.

This model can factor in conflicting land uses that affect grazing such as mines, oil/gas fields, and roads that are significant impacts. There is currently no agreement on methods to adjust grazing suitability to account for these impacts. For example, is the impact of roads on grazing suitability the road surface or does it could include the barrow areas adjacent to the road, which might double the width of the road footprint? With little agreement on how to adjust grazing suitability for a seemingly straightforward example for roads, getting agreement on methods to adjust grazing suitability due larger impacts such as oil/gas fields and mines, will be difficult.

CONCLUSIONS

These models introduce a level of complexity when the B-T-M layers are included that has a limited effect on the total suitable acres for cattle grazing. With the barriers added, the models more accurately represent the distribution of rangeland suitability.

The success of the range suitability models depends on the knowledge of range specialists to accurately create and modify the water source layers. Water availability is an important issue due to the seasonal nature of water throughout the western United States. There are no consistent records of the seasonal availability of water, making it difficult to automate the water source selection process. Range specialists often know the water sources for the pastures they manage. The range specialists could add and delete water sources, as needed, if provided with a basic water source layer. It is “easier” to delete water sources than to add new water sources.

The GIS-modeled suitable acres for grazing were reasonable when compared to current hand generated suitability calculations. The LFO rangeland specialists determined the validity of the modifications of the range suitability models. I modified the model based on input from the local experts to have sub-models to create percent slope and water source layers. The experts determined that this model was faster than using paper map methodology.

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