APPENDIX E

FINE-FILTER CONSERVATION ELEMENT DESCRIPTIONS AND ANALYSES

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APPENDIX E-1

GRIZZLY BEAR CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NUMBER

1.0 INTRODUCTION

The grizzly bear (*Ursus arctos horribilis*) was selected as a conservation element (CE) for the Middle Rockies ecoregion by the Assessment Management Team (AMT) because it is a regionally significant species sensitive to landscape-level change due to low population density, low fecundity, susceptibility to management actions due to human interactions, and other traits that lower ecological resilience (Carroll et al 2001). Grizzly bears in this ecoregion occur primarily in the Greater Yellowstone Ecosystem (GYE), although occurrences in the Northern Continental Divide Ecosystem (NCDE) overlap with Middle Rockies boundaries. The GYE population has been studied intensively for several decades, and the literature from this effort includes the best current understanding of the species in the Middle Rockies ecoregion. Much of the grizzly bear Rapid Ecoregional Assessment (REA) modeling will be based on the work of the Interagency Grizzly Bear Study Team (IGBST) in the GYE (Schwartz et al. 2006; see also IGBST annual reports, e.g., Schwartz et al 2010).

A variety of the management questions (MQs) apply to this assemblage. Many of the MQs can be summarized into two primary questions: 1) where are the important areas for this species? and 2) what is happening to these areas? The central focus of these two MQs is to document the current status of grizzly bear at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future change agent (CA) threats.

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2.0 CONSERVATION ELEMENT DESCRIPTION

Historically, grizzly bears occurred in a variety of forested and open habitat types from Alaska to Mexico and from the Pacific coast to near the Mississippi River. Following development of ranching, mining, farming, and timber extraction in western North America in the 19^{th} and 20^{th} centuries, grizzly bears were eliminated from 98 percent of their historic range (Mattson et al. 1995). The Middle Rockies ecoregion includes two separate grizzly bear populations: portions of the NCDE population in Montana, and the entire GYE population in Wyoming/Montana/Idaho. The following focuses on results of studies of the GYE population, which differs in some respects from the NCDE population; differences in the analysis of the two populations are described in Section 5.0, Change Agent Analysis.

The life cycle of grizzly bears in the GYE is characterized by the following phases: over-winter denning, den emergence (early spring), estrus (corresponding to the mating season), early hyperphagia (indicated by an escalation in feeding activity), and late hyperphagia (continued high levels of feeding activity) (Mattson et al. 2003). With the exception of the denning period, grizzly bears' habitat use and movements are dictated by availability of seasonal food resources. Grizzly bears are opportunistic omnivores throughout their range. In the GYE, ungulate carrion is a significant food source in late winter/early spring (Green et al. 1997; Mattson 1997); graminoids and forbs dominate from May through the summer months (Mattson et al. 1991a); and whitebark pine seeds are most important in late summer/early autumn (Mattson et al. 1991a). Grizzly bears in the GYE also exploit army cutworm moth aggregations and spawning Yellowstone cutthroat trout when available (Mattson et al. 1991a,b; French et al. 1994; Reinhart and Mattson 1990; Haroldson et al. 2005).

Consistent with a very broad diet, grizzly bears are habitat generalists. Depending on availability of seasonal food resources, grizzly bears may be present in meadows, riparian zones, mixed shrub fields, closed and open forest stands, sidehill parks, alpine talus slopes, among other habitats. Grizzly bears do not migrate, but they do exhibit elevation movements from spring to fall, following seasonal food availability (LeFranc et al. 1987). Grizzly bears generally occur at lower elevations in spring, after emerging from their winter dens, and move to higher elevations in mid-summer and winter.

In general, the availability of key food resources affects grizzly bear survival and productivity; however, human-caused mortality appears to be the primary limitation on populations in the GYE (Harris et al. 2006; Haroldson et al. 2006). Most documented grizzly bear mortality in the GYE has resulted from conflicts with humans (Schwartz et al. 2006) involving bears' attempts to use anthropogenic foods and/or bears' use of lower elevation areas for foraging during years of poor whitebark pinecone production (Mattson et al. 1992; Blanchard and Knight 1995; Mattson 1997). Bear-human interactions were inversely correlated to the abundance of naturally-occurring bear foods, although livestock depredations were independent of the availability of bear foods (Gunther et al. 2004). Grizzly bear survival has been correlated with home range location (i.e., inside Yellowstone National Park [YNP], inside the surrounding Recovery Zone [RZ], or outside the RZ). Survival of grizzly bears outside the RZ is lower than inside the YNP or the RZ, with most mortality on or near private lands (Haroldson et al. 2006)

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3.0 CONSERVATION ELEMENT DISTRIBUTION MAPPING

To answer the MQs regarding the location and status of this species across the ecoregion, a variety of existing data layers representing important habitat for the species were used. The goal was to obtain data to determine the current distribution and status of this species throughout the ecoregion for critical periods.

Table E-1-1 lists the types of data and data sources that were proposed for use in the REA as part of the pre-assessment data identification effort in Task 2. Data layers were obtained to determine the current distribution and modeled suitable habitat of this species in the ecoregion for critical periods in its life cycle (winter denning habitat, spring foraging habitat, summer foraging habitat, etc.). Suitable grizzly bear habitat models were acquired from Gap Analysis Program (GAP) and NatureServe for portions of the ecoregion. Other data important for this species include state (Maxent) known occurrences from natural heritage programs, and recent management plans from the U.S. Forest Service (USFS), National Park Service (NPS), and U.S. Fish and Wildlife Service (USFWS). However, Natural Heritage Program occurrence data were deteremined to be a data gap and there has been no Maxent modeling completed. There is also Western Governors' Association (WGA) Wildlife Council Crucial Habitat Assessment Tool (CHAT) underway that will generate models and datasets for the ecoregion; however, no data were available for this REA.

Table E-1-1. Data Sources for CE Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Modeled Suitable Habitat	GAP Habitat Models	U.S. Geological Survey (USGS)	Raster (30-m)	Acquired	No[2]
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No[2]
	GYE Range	USFWS, USGS	Polygon	Acquired	Yes
	NCDE Range	USFWS, USGS	Polygon	Acquired	Yes
Denning Areas		USFS, NPS, USGS, USFWS	Point	Require Data	No[1]
Occurrences	State Natural Heritage Databases	Natural Heritage Programs – ID, MT, WY	Point	Data Gap	No[1]
Habitat	Bison Winter Range	USFWS (GYE only)	Polygon	Acquired	Yes
	Elk Winter Ranges	Rocky Mountain Elk Foundation (RMEF)	Polygon	Acquired	Yes
	Yellowstone Cutthroat Trout	StreamNet (MT only)	Polyline	Acquired	Yes
Areas with Potential for Restoration of Habitat or Habitat Connectivity	Management Plan Areas	NPS, USGS, USFWS	Polygon	Same as Range	Yes
	Grizzly Bear Distribution Areas and RZs	USFS Region 1	Polygon	Acquired	Yes

[1] Data gap
[2] More representative data was selected for use

It was determined that data from the USFWS recovery and occupied habitat layer would be used for the grizzly bear distribution map. Figure E-1-1 presents the distribution map for the grizzly bear that will be used to conduct the CA analyses.

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4.0 CONCEPTUAL MODELS

The current and potential future threat analyses were based on CE-specific ecological conceptual models, selected Key Ecological Attributes (KEAs) likely to be impacted by CAs, and the availability of data.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model (Figure E-1-2) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that affect the status of the population at each stage of the life cycle.

The model identifies the relationship between the grizzly bear and the ecological mechanisms that affect the species' future distribution through CAs. The key life stages are identified in the model as green boxes. Following Unnasch et al. (2009), three broad headings or categories of ecological attributes (EAs) (size, condition, and landscape context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat, and context refers to the landscape-scale spatial structure of the habitat. At the landscape level, the KEAs under the condition category were the most challenging to spatially represent; they depended on the data available.

4.2 SYSTEM-LEVEL CONCEPTUAL MODEL

The system-level conceptual model for the grizzly bear (Figure E-1-3) depicts the interactions of primary habitat functions at the landscape level and at the stand level with CAs based on known or hypothesized ecological relationships. The grizzly bear in the GYE is a "conservation-reliant species," (e.g., a species that is at risk from threats so persistent that it requires continuous management to maintain population levels) (Scott et al. 2005). As noted in the species description, grizzly bears require seasonal food resources, denning habitat, and security in an area of sufficient size for survival. Much suitable habitat may be unoccupied in part because conflicts with human use of habitats lead to management actions that remove bears in these areas (Interagency Conservation Strategy Team 2007).

The system-level conceptual model depicts the most important functions of grizzly bear habitat (seasonal food resources and security from sources of mortality and disturbance) and the effects of CAs. Many of the system-level attributes that cannot be represented geospatially in this REA, either because data are not available or because data are at a scale that is unsuitable for use in the REA, are labeled on Figure E-1-3.

Three CAs were identified for the grizzly bear analysis; development, climate change, and insect/disease outbreaks. Climate change and insect/disease outbreaks are closely related and are treated together as a CA in the following discussion. Available literature does not indicate that wildland fire or invasives are significant CAs for grizzly bear in this ecoregion.

4.2.1 Development

Direct mortality due to interactions with humans is the primary threat to the grizzly bear; several studies have demonstrated spatial relationships involving hazards affecting grizzly bear survival (Johnson et al. 2004; Haroldson et al. 2006; Schwartz et al. 2010). Schwartz et al. (2010) found that the most important predictors of survival were the amount of secure habitat within a bear's home range and road densities outside of secure habitat. On private lands, the number of homes per section and the roads associated with those developments were the best predictors of grizzly bear survival. Development in the region surrounding the GYE consists of large-lot, rural subdivisions accompanied by increased road density and human access to remote areas.

Figure E-1-3 shows management actions that lead to direct take or disturbance. Conflicts with hunters, livestock growers, and backcountry recreationalists lead to management actions that generally result in the death of the targeted bear(s). Mortality-related effects reduce population density and the potential for dispersal to other suitable habitats. Disturbance of grizzly bears due to backcountry recreation is a stressor that may result in abandonment of dens and home ranges, and avoidance of suitable habitat. Thus, the disturbance may result in decreases in survival and reproductive success of bears.

Suitable habitat outside of the designated grizzly bear RZ has been identified in Idaho, Wyoming, and Montana for the grizzly bear, within which the population will be allowed to recolonize. The model also shows land cover conversion for exurban development, transportation infrastructure, and energy development, among other CAs.

4.2.2 Climate Change/Insect Outbreak and Disease

Grizzly bear responses to climate change are primarily associated with impacts on food resources. These impacts include changes in hydrology affecting cutthroat trout, vegetation cover type changes (Ashton 2010), and the incidence and severity of insect and disease outbreaks affecting whitebark pine. Mountain pine beetle (MPB) and white pine blister rust (WPBR) outbreaks as CAs affect grizzly bears indirectly through whitebark pine seed abundance. Climate change affects grizzly bear populations indirectly through impacts on availability of food sources and interactions with humans. Changes in food availability cause bears to move into areas where they are more likely to interact with humans. In the GYE, the bear mortality rates are two to three times higher during years of low whitebark pine production (Mattson and Reinhart 1997), in part because the bears are forced to forage for other foods such as ungulates and root crops at lower elevations, where they come into contact with humans. This effect may be exacerbated under future climate change in areas outside of the RZ, where agencies have less control over availability of anthropogenic food resources. Effects of reduced whitebark pine seed availability also include reduced fecundity and reduced survival.

4.3 CHANGE AGENTS PROPOSED FOR ANALYSIS

Although numerous attributes and indicators affecting this species were initially identified in the early phases of this REA, not all are included in this analysis. Development-related CAs, including urban/exurban development, agriculture, and road density, are included in the analysis. Wildland fire is not a significant CA for the grizzly bear in the Middle Rockies ecoregion and, therefore, no analyses for this CA were conducted. The climate change and invasive species CAs were evaluated qualitatively because the direct effect indicators were determined to be data gaps or because it was impractical to model at the ecoregional scale because appropriate geospatial data were not available. If possible, surrogate indicators that are available or are better suited to geospatial analysis were used. The specific indicators that could not be modeled are identified with an asterisk on Figure E-1-3. Further information on the data gaps for these indicators are discussed in the respective CA analyses contained in Appendix C.

5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the grizzly bear was conducted for the Middle Rockies ecoregion using the 12-digit Hydrologic Unit Codes (HUCs) as the analysis unit. Based on the ecological process and system level models, KEAs were identified for the current status and future threat analyses, with a specific emphasis on the ability to measure impacts using existing geospatial data. Development was the only CA used for the current status analysis. The CAs evaluated for future threats include development and climate change.

The scale of the analysis for this REA is at the 6th level HUC . The CA analysis included the evaluation of indicators and metric values for only those watersheds where the distribution of the CE was indicated based on the selected distribution layer. An overall current status layer was created by combining the 6th level HUC watershed ratings for each KEA. Future threat analysis was conducted by comparing the CE distribution layer with future CA threat geographic information system (GIS) output layers.

5.1 CURRENT STATUS OF THE GRIZZLY BEAR

5.1.1 Key Ecological Attribute Selection

Table E-1-2 identifies the original KEAs that were proposed in Task 3 and which of these were used in the final current status analysis. Following Rolling Review Team (RRT) guidance, some KEAs were revised to be specific to conditions experienced by two grizzly bear populations in the ecoregion (GYE and NCDE populations). Not all of the KEAs proposed were used, based on the rationale provided in Table E-1-2, and some were revised based on RRT guidance. Some KEAs were used in the analysis because they are important for establishing current condition of the CE, but are not directly related to CAs. For example, the ungulate (elk, bison) availability KEA is not related to a CA in this analysis, but it was mapped to show the location of prey/carrion availability.

Table E-1-2. Key Ecological Attributes Retained or Excluded

Category	Attribute	Explanation
1. Size	Large blocks of suitable habitat	Retained to show the availability of suitable habitat of sufficient size for adult female home range.
2. Condition	Whitebark pine seed availability	Retained and modified to show occurrence of whitebark pine.
	Ungulate (elk, bison) availability	Retained to show occurrence of these prey species.
	Yellowstone cutthroat trout	Retained to show occurrence of this prey species.
3. Landscape Context	Distance to human disturbance/interaction	Retained to show distance to high- and low-use human features; roads information analyzed in road density KEA.
	Road density	Added to show affects of roads.
	Land management designation	Retained to show habitat security and re-titled Designated Protected Areas.
	Proportion of developed area	Excluded because analysis was similar to distance to human disturbance/interaction KEA.

Table E-1-3 identifies the KEAs, indicators, and metrics that were used to evaluate the current status of this CE across the ecoregion (as illustrated on Figure E-1-3). Several indicators were used to assess the current status of this CE, including size of suitable habitat, habitat condition, and landscape context (distance to human features, road density, designated protected areas).

Table E-1-3. Grizzly Bear Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric: Poor =3	Metric: Fair = 2	Metric: Good = 1	Data Source	Citation
Size	Suitable Habitat Blocks	Natural land cover types (square kilometer [km^2])	<150	150-250	>250	GAP	**GYE population**: Merrill et al. 1999; Merrill & Mattson 2003; Mattson et al. 2003 **NCDE population:** Servheen 1983; Merrill et al. 1999; Waller & Mace 1997; Mace and Waller 1996; Montana Field Guide (associations with ecological systems)
Condition	Seasonal Food resources	Whitebark pine (WBP) seed availability	WBP not present	WBP present, not dominant	WBP dominant	LANDFIRE	**GYE population**: Mattson 1997; Mattson et al. 1991b; Felicetti et al. 2003; Haroldson & Podruzny 2010 **NCDE population**: Mace & Jonkel 1983
		Ungulate (elk, bison) availability	**GYE population:** Good = Within elk or bison winter range Fair = Outside elk or bison winter range **NCDE population:** Good = Within elk winter range Fair = Outside elk winter range			RMEF USFWS	**GYE population:** Green et al. 1997; Mattson 1991; Mattson 1997 **NCDE population:** Mace & Jonkel 1983
		GYE only: Yellowstone cutthroat trout Distance from stream (kilometer [km])	>2	0.5-2	<0.5	National Hydrography Dataset (NHD), Streamnet	Reinhart & Mattson 1990; Mattson & Reinhart 1995; Haroldson et al. 2005; Schwartz et al. 2010
Landscape Context	Mortality/ Disturbance Risk	Distance to high-use features (km)	<5	5-10	>10	Human Footprint GAP ICLUS	Mattson & Knight 1991a; Gunther et al. 2004; Schwartz et al. 2010
		Distance to low-use features (km)	<1	1-5	>5		
		Road Density (km/km^2) Highways, secondary roads, all other roads &	>1.0	0.5-1	<0.5	Human Footprint TIGER	Mattson & Knight 1991a; Schwartz et al. 2010; Merrill et al. 1999; Mace et al. 1996
		Designated protected areas (GYE population)	Outside of GYE RZ	Within designated GYE RZ	Within YNP	PAD-US, Other databases (e.g., Rivers.gov)	Haroldson et al. 2006; AMT recommendations
		Designated protected areas (NCDE population)	Outside of designated protected area or study area	na	Within designated protected area or study area including BLM ACEC		

a = binary metric
ACEC = Area of Critical Environmental Concern, BLM = Bureau of Land Management
PAD-US = Protected Areas Database of the United States, ICLUS = Integrated Climate and Land-Use Scenarios
TIGER = Topologically Integrated Geographic Encoding and Referencing

The metrics used to identify attribute quality were based on available scientific literature and reports, coupled with subject matter expert opinion and professional judgment in association with data-driven metrics. Most of the rating scales for the proposed metrics are based on professional judgment based on review of the literature. Some of the sources for indicators and metrics include: Carroll et al. 2001; Johnson et al. 2004; Mace et al. 1996; Schwartz et al. 2006; Schwartz et al. 2010; and Apps et al. 2007. A review of the KEAs and CA analysis for this CE was conducted through the establishment of a CE RRT comprised of Bureau of Land Maanagement (BLM) wildlife biologists, other Federal agency biologists, and state level experts. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics as well as to ascertain the accuracy of each step of the modeling process.

5.1.1.1 Suitable Habitat Blocks

Grizzly bears occupy a wide range of habitat types in the Middle Rockies; for this analysis, the GAP land cover types listed in Table E-1-4 were considered suitable habitat based on information on habitat associations in the Montana Field Guide (Montana Natural Heritage Program and Montana Fish, Wildlife and Parks 2012).

A vegetation data layer provided information pertaining to the foraging, breeding, and dispersal requirements of the species. Prey species and other food resources are also closely associated with the natural vegetation systems included in this layer. GAP landcover data were extracted as indicated in Table E-1-4. The sizes of suitable habitat blocks were then calculated and scored according to the metrics in Table E-1-3 based on the home range sizes of adult female grizzly bears in the GYE as reported in the literature and refined by RRT. Figure E-1-4 presents the results of the suitable habitat block size by HUC for the grizzly bear.

Table E-1-4. GAP Level 3 Codes and Descriptions Extracted for the Grizzly Bear Suitable Habitat Layer in the Middle Rockies Ecoregion

GAP Level 3	Level 3 Description
3503	Rocky Mountain Alpine Bedrock and Scree
4111	Rocky Mountain Aspen Forest and Woodland
4147	Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland
4154	Western Great Plains Wooded Draw and Ravine
4324	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
4524	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
4525	Northern Rocky Mountain Subalpine Woodland and Parkland
4526	Rocky Mountain Foothill Limber Pine-Juniper Woodland
4527	Rocky Mountain Lodgepole Pine Forest
4529	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
4531	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
4543	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
4544	Rocky Mountain Poor-Site Lodgepole Pine Forest
4609	Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
4611	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
5103	Rocky Mountain Alpine Dwarf-Shrubland
5307	Inter-Mountain Basins Big Sagebrush Steppe
5308	Inter-Mountain Basins Montane Sagebrush Steppe
5805	Northwestern Great Plains Shrubland

Table E-1-4. GAP Level 3 Codes and Descriptions Extracted for the Grizzly Bear Suitable Habitat Layer in the Middle Rockies Ecoregion (Continued)

GAP Level 3	Level 3 Description
5808	Northern Rocky Mountain Montane-Foothill Deciduous Shrubland
5812	Northern Rocky Mountain Subalpine Deciduous Shrubland
7102	Rocky Mountain Alpine Fell-Field
7203	Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland
7204	Northern Rocky Mountain Subalpine-Upper Montane Grassland
7205	Rocky Mountain Subalpine-Montane Mesic Meadow
7306	Northwestern Great Plains Mixedgrass Prairie
8107	Harvested forest-shrub regeneration
9227	North American Arid West Emergent Marsh
9304	Northern Rocky Mountain Conifer Swamp
9503	Rocky Mountain Subalpine-Montane Fen
9606	Rocky Mountain Alpine-Montane Wet Meadow
9704	Northern Rocky Mountain Wooded Vernal Pool
9824	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
9825	Rocky Mountain Lower Montane Riparian Woodland and Shrubland
9826	Northwestern Great Plains Floodplain
9832	Rocky Mountain Subalpine-Montane Riparian Woodland
9837	Rocky Mountain Subalpine-Montane Riparian Shrubland
9847	Northwestern Great Plains Riparian
9848	Western Great Plains Riparian Woodland and Shrubland

5.1.1.2 Ungulate (Elk, Bison) Availability

Ungulate (Elk, Bison) availability was selected as an indicator because elk and bison are important prey for the GYE grizzly bear population, particularly during early spring months when carcasses or winter-killed animals are available for grizzly bears as they emerge from their winter dens.

This KEA uses elk or bison winter range as a surrogate indicator for availability of this food resource. Use of ungulate carrion has been documented, but has been less well studied, in the NCDE grizzly bear population. Since elk are available in this portion of the grizzly bear occupied habitat, elk winter range was included in the analysis. Bison winter range from the USFWS, and elk winter range from the Rocky Mountain Elk Foundation were overlaid. The resulting layer was summarized at the watershed level. This KEA was scored as good if the HUC was located within winter range of elk and/or bison, and scored as fair if the HUC was outside elk and/or bison winter range. Figure E-1-6 presents ungulate availability for the grizzly bear.

5.1.1.3 Yellowstone Cutthroat Trout Availability

This indicator was selected because spawning yellowstone cutthroat trout are an important seasonally-available food resource for GYE grizzly bears in the vicinity of Yellowstone Lake and its tributaries. Although most use of Yellowstone cutthroat trout has been documented in close proximity to the lake, it was assumed that spawning fish may be available to grizzly bears elsewhere in the fish's range.

Geospatial data on spawning streams for this species were not available, so presence of Yellowstone cutthroat trout in streams was used as a surrogate for availability to grizzly bear. Use of other trout species has not been well documented in the Middle Rockies. Therefore, the analysis of this KEA was confined to the extent of Yellowstone cutthroat trout in occupied habitat of the GYE grizzly bear population. Streams with Yellowstone cutthroat trout were buffered to a distance of 2 kilometers (km) and the results were classified according to the KEA table, and were displayed as the majority of values per watershed.

The metrics for scoring this KEA (Table E-1-3) are based on review of literature reporting bear predation on cutthroat trout and on professional judgment. HUCs that are in close proximity (within 0.5 km) to Yellowstone cutthroat trout streams were scored as good, while HUCs further away received lower scores. Figure E-1-7 presents Yellowstone cutthroat trout availability for the grizzly bear.

5.1.1.4 Distance to Human Disturbance/Interaction

This KEA was used as an indicator to assess potential impacts from human disturbance and interaction on the risk of mortality of grizzly bears. Distance to sources of human disturbance or interaction with grizzly bears was used as a surrogate indicator of the risk of mortality for grizzly bears due to management actions resulting from interactions or proximity to human activities.

For this KEA, the analysis categorized high use and low-use human features, as indicated in Table E-1-3. High-use in this analysis means that there is the likelihood of a high level of human activity at a site, in contrast to low-use, which is intended to cover human activities where there may be a “footprint” of human development but where actual presence of humans is less frequent or consistent than in high-use areas. Two separate layers were created for high-use and low-use features. The high-use features included housing density and energy development. These features were buffered and assigned values according to the KEA table. Low-use features included grazing and agricultural land use. These features were buffered and assigned values according to the KEA table. The two layers were overlaid and the results are displayed at the watershed level.

Scoring for this KEA was categorized separately for high-use and low-use human features, as indicated in the table; the metrics are based on literature review. Figure E-1-8 presents distance to human disturbance/interaction for both the low and high-use areas.

5.1.1.5 Road Density

This KEA was used as an indicator to assess potential impacts from road density on the risk of mortality of grizzly bears. Road density was established as a separate KEA from other human development features because it has been reported and modeled in the literature separately, as indicated in Table E-1-3. However, like the Distance to human disturbance/interaction KEA, proximity to areas with high road densities may lead to lethal management actions.

Linear density analysis was run on Topographically Integrated Geographic Encoding and Referencing (TIGER) roads, which determined the total length of roads per square kilometer (km^2). Results were classified according to the KEA table and are displayed at the watershed level. Scoring for this KEA was adapted from research results and models for both grizzly bear populations in the ecoregion, as listed in Table E-1-3. Figure E-1-9 presents road density for the grizzly bear.

5.1.1.6 Designated Protected Areas

This KEA was included in the analysis to identify HUCs that lie within YNP, the surrounding designated RZ, or outside the RZ. Mortality of grizzly bears (primarily due to management actions following conflicts with humans) is higher outside the YNP or the RZ. Much of the land outside of the park and RZ is privately owned, and most grizzly bear mortality occurs in these areas.

Scoring for this KEA in the GYE is based on a HUC’s location in one of these three zones, as indicated in Table E-1-3. For the NCDE population, the metric involves location of HUCs within designated protected areas or study areas managed by federal or state agencies (Table E-1-3). Figure E-1-10 presents designated protected areas for the grizzly bear.

5.1.2 Current Status of Habitat for the Grizzly Bear

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of grizzly bear habitat for each 6th level HUC across the ecoregion. Individual threats can identify areas of potential risk to grizzly bear populations, but the aggregated analysis can provide important information with relation to areas where grizzly bears might encounter multiple threats.

In order to provide information on the overall current status for each CE, each of the KEA indicator ratings were assigned a score (1=good, 2=fair, 3=poor) and averaged. In some cases, KEAs were weighted before averaging based on RRT decisions. The overall current status was determined only for the HUCs that intersect with the CE distribution layer. A final overall rating (good, fair, or poor) for each HUC was determined using the natural breaks method. Using this method, the data distribution were explicitly considered for determining the class breaks. The results of the current status for the ecoregion is presented on Figure E-1-11.

The modeled suitable habitat blocks (Figure E-1-4) that were rated as good based on GAP land cover type and size, match USFWS consistently-occupied habitat in the GYE rather closely (Figure E-1-1). Relatively small numbers of watersheds were scored as poor or not suitable landcover. Modeled suitable habitat blocks that scored good in the NCDE encompass about half of the area reported as consistently-occupied habitat by USFWS (Figure E-1-1). Large areas of modeled suitable habitat blocks occur in Idaho outside of the mapped consistently-occupied habitat. Whitebark pine seed is a significant food resource in the GYE; analysis of the whitebark pine distribution layer showed that this species is present in most watersheds, but dominant in relatively few (Figure E-1-5). Ungulate winter range was found to be present in most of the GYE and the NCDE (Figure E-1-6), providing a food resource for bears of both populations. The Distance to Human Disturbance/Interaction indicator (Figure E-1-8) scored good in portions of both occupied habitat areas, fair in much of YNP, and poor in most of the NCDE occupied habitat area and peripheral areas of the GYE occupied habitat area. The Designated Protected Areas KEA map (Figure E-1-10) shows HUCs within YNP, the GYE RZ, and other areas that are occupied by grizzly bears but do not receive the protections that are in place in the YNP and RZ.

A 5-year review of the status of grizzly bear populations in the GYE and the NCDE indicates that both populations have been increasing (4-7 percent annually and 3 percent annually, respectively) (USFWS 2011). Despite human-caused mortalities, GYE and NCDE grizzly bear populations appear to be expanding their ranges. However, issues related to adequacy of regulatory mechanisms to protect these populations from excessive human-caused mortalities and the potential impacts from the loss of whitebark pine remain (Appendix E-8).

A summary of the overall current status ratings based on the CE distribution is provided in Table E-1-5. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor (Figure E-1-12). The results of the current status assessment indicate that nearly 72 percent of the 6th level HUC watersheds that intersect the grizzly bear distribution received an overall fair or poor rating.

Table E-1-5. Summary of Current Status Ratings for the Grizzly Bear

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	7,966	27.9
Fair	12,487	43.7
Poor	8,144	28.5

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

The grizzly bear system-level model (Figure E-1-3) was used to create a series of intermediate layers that are primarily based on the geospatial data that was available on the future projections for the development CA and climate change CA.

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than to a specific time period) for some of these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their affect on grizzly populations.

5.2.1 Development Change Agent

Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069). Future spatial data for development was limited to potential energy development area, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1. The climate CA layer was created through the results of the 2025 and 2060 U.S. Geological Survey (USGS) climate change models. These models show areas that may be negatively and positively affected by climate change. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis is provided in Appendix C-5.

A comparison of the consistently-occupied habitat for grizzly bears (Figure E-1-1) with the future potential urban growth (Figure C-1-8) shows some areas of potential risk, primarily in the vicinity of Jackson, Wyoming, and along highways in western Wyoming. Relative to the size of occupied habitat, the areas of overlap are small; however, given the small population size and low population growth rate of grizzly bears, any areas of potential human-grizzly bear interaction are a concern because these interactions often lead to removal of the bears from the population. As modeled in this analysis, some risk of urban growth is anticipated adjacent to grizzly bear-occupied habitat elsewhere in Wyoming (e.g., along Highway 14). In addition, major urban growth is anticipated in the vicinity of Bozeman, and Missoula, and southward along Highway 93, in areas that are not far from occupied habitat. Urban/exurban growth accompanied by increased recreational use of nearby wildlands may be expected to continue the problem of managing human-grizzly bear interactions outside of protected areas in the future. Future expansion of agricultural use shows limited overlap with grizzly bear-occupied habitat (Figure E-1-1). Grizzly bear habitat appears to be at risk in the GYE on the east front of the Absaroka Range from potential wind energy development (Figure C-1-7). If developed in occupied grizzly bear habitat, wind energy facilities could possibly lead to human-grizzly bear interactions, with adverse results for the bear population.

5.2.2 Climate Change Future Threats

The climate CA layer was created from the results of the 1980-1999 baseline and 2050-2069 predicted future climate models with the intention of displaying areas that may be negatively and positively affected by future climate change, as described in detail in Appendix C-5. Temperature change modeling in various periods during the year shows increases of up to 7 degrees Celsius (°C) in some of the higher elevation areas such as the Teton Range, the Wyoming Range, and the Wind River Range. If this happens, increases in summer temperatures will significantly increase water stress in plants and provide more flammable fuels for wildfires. The main concern related to climate change for grizzly bears in the Middle Rockies ecoregion lies in the indirect effects on vegetation communities that support their animal prey and plant food resources. Range shifts in plant food resources due to climate change will affect the distribution of seasonal foraging areas for grizzly bears in complex ways that cannot be readily assessed in this analysis. Effects of climate change on whitebark pine, an important component of the grizzly bear's diet in the GYE, are described in Appendix E-8 five-needle pine CE. Whitebark pines are currently subject to widespread outbreaks of MPB and WPBR. Increased water stress on whitebark pine is likely to increase the trees' susceptibility to MPB outbreaks, exacerbating the outbreak and reducing an important seasonal food resource for GYE grizzly bears.

The NatureServe Climate Change Vulnerability Index (NSCCVI) tool was utilized to assess grizzly bear vulnerability to the effects of climate change. Using annual raster datasets from NatureServe to perform climate change calculations in ArcGIS (through the Predicted Temperature 2040-2069 [Fahrenheit (F)] and the Predicted Hamon ratio of actual evapotranspiration to potential evapotranspiration [AET : PET] Moisture Metric 2040-2069 datasets), the NSCCVI calculator was applied and produced an Index score of Not Vulnerable/Presumed Stable**.** The NSCCVI tool indicated that available evidence does not suggest that abundance and/or range extent of this species within the geographical area assessed will change (increase/decrease) substantially by 2050. The assessment rating was largely based on a majority of neutral scores calculated when assessing factors that influence vulnerability, such as: distribution to barriers, dispersal and movements, sensitivity to temperature and moisture changes (historical thermal/hydrological niche), and reliance on interspecific interactions to generate habitat.

6.0 MANAGEMENT QUESTIONS

The relevant MQs for the grizzly bear CE include those defined as part of the Landscape Species/Species Richness category. The overall MQ was: Where are the key habitat types (seasonal, refuges, corridors/connectivity, migration routes, concentrations of regionally significant species, etc.) for landscape species, keystone species, regionally significant species, and regionally significant suites of species? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQ and the distribution map for the CE. Several examples of how the REA can be used to answer MQs (as noted in Appendix A) are provided below; these examples demonstrate the functionality of the REA and provide an opportunity to discuss data gaps that were identified during the REA.

6.1 WHERE ARE AREAS THAT HAVE POTENTIAL FOR RESTORING REGIONALLY SIGNIFICANT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR REGIONALLY SIGNIFICANT SPECIES?

The map of suitable habitat blocks (Figure E-1-4) and the currently occupied habitat map (Figure E-1-1) could be used to identify suitable, currently unoccupied habitat. The map of overall score for habitat quality (Figure E-1-11), in conjunction with local information on site-specific land use and other conditions, could be used to identify areas with greatest restoration potential.

6.2 WHERE ARE THE KEY HABITAT TYPES (SEASONAL REFUGES, CORRIDORS/CONNECTIVITY, MIGRATION ROUTES, CONCENTRATIONS OF REGIONALLY SIGNIFICANT SPECIES)?

Key habitat types within the occupied habitat for each grizzly bear population can be predicted from the maps of suitable habitat and the maps of overall habitat quality. It is currently understood that there is very little connectivity between the two grizzly bear populations in the Middle Rockies, in part because of existing human development located between the two occupied habitat areas. Habitat quality was not modeled in this intervening area in this analysis.

6.3 WHERE ARE CURRENT REGIONALLY SIGNIFICANT LANDSCAPE/KEYSTONE SPECIES AND THEIR HABITATS, INCLUDING SEASONAL HABITAT AND MOVEMENT CORRIDORS, AT GREATEST RISK FROM CHANGE AGENTS, INCLUDING CLIMATE CHANGE (CONNECTIVITY, SMALL POPULATION SIZE)?

The full range of maps and analyses for grizzly bears can be used to answer this complex MQ with respect to current and future development. The models created in this REA were designed to address the effects of development CAs on grizzly bears with spatial output for current conditions. Future development CA threats were described and mapped in the development CA appendix (Appendix C-1) and were qualitatively discussed with reference to grizzly bears in previous sections of this appendix. Similarly, climate change was discussed qualitatively in this appendix.

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APPENDIX E-1

FIGURES

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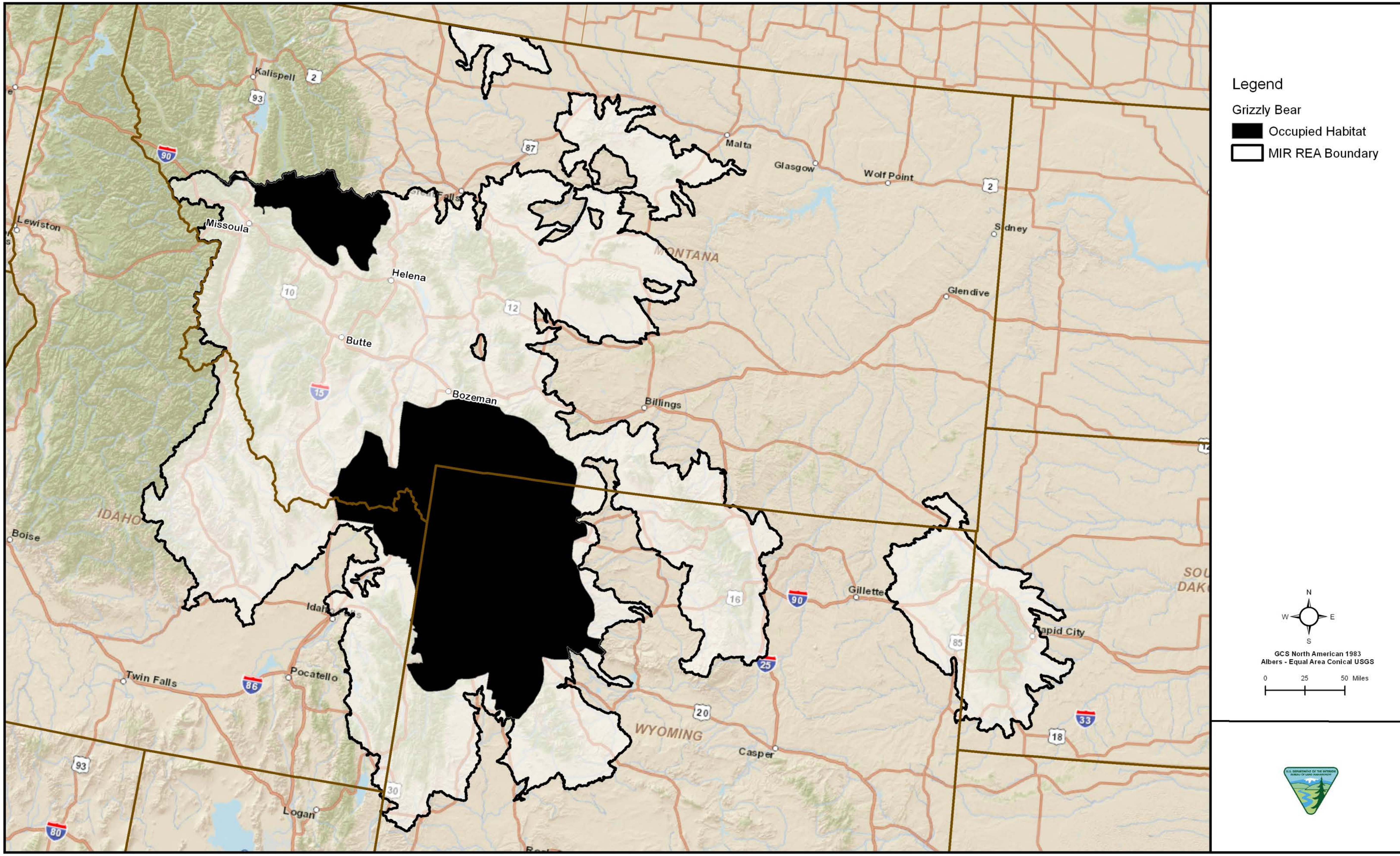

Figure E-1-1. Grizzly Bear Consistently Occupied Habitat Map

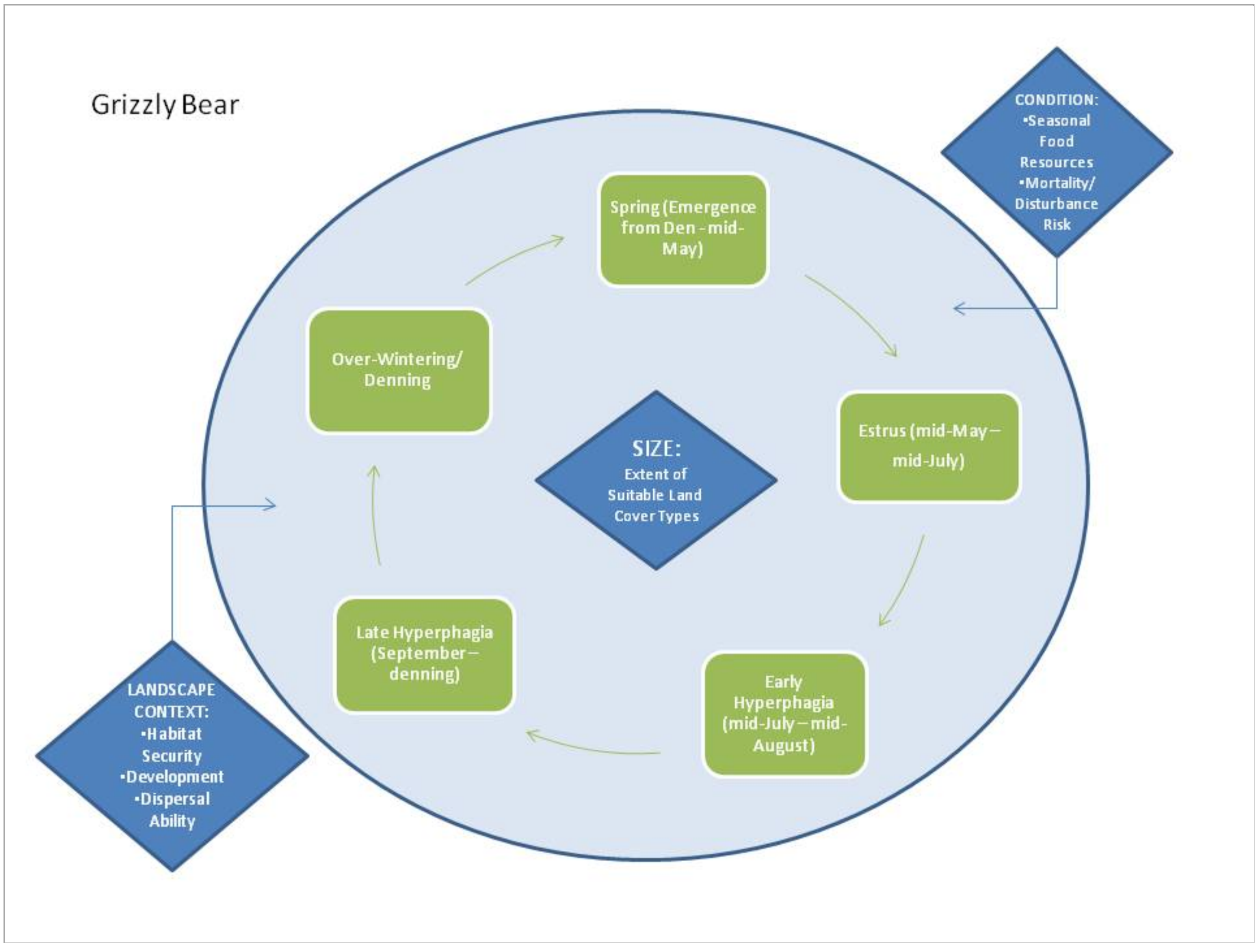

Figure E-1-2. Grizzly Bear Ecological Process Model

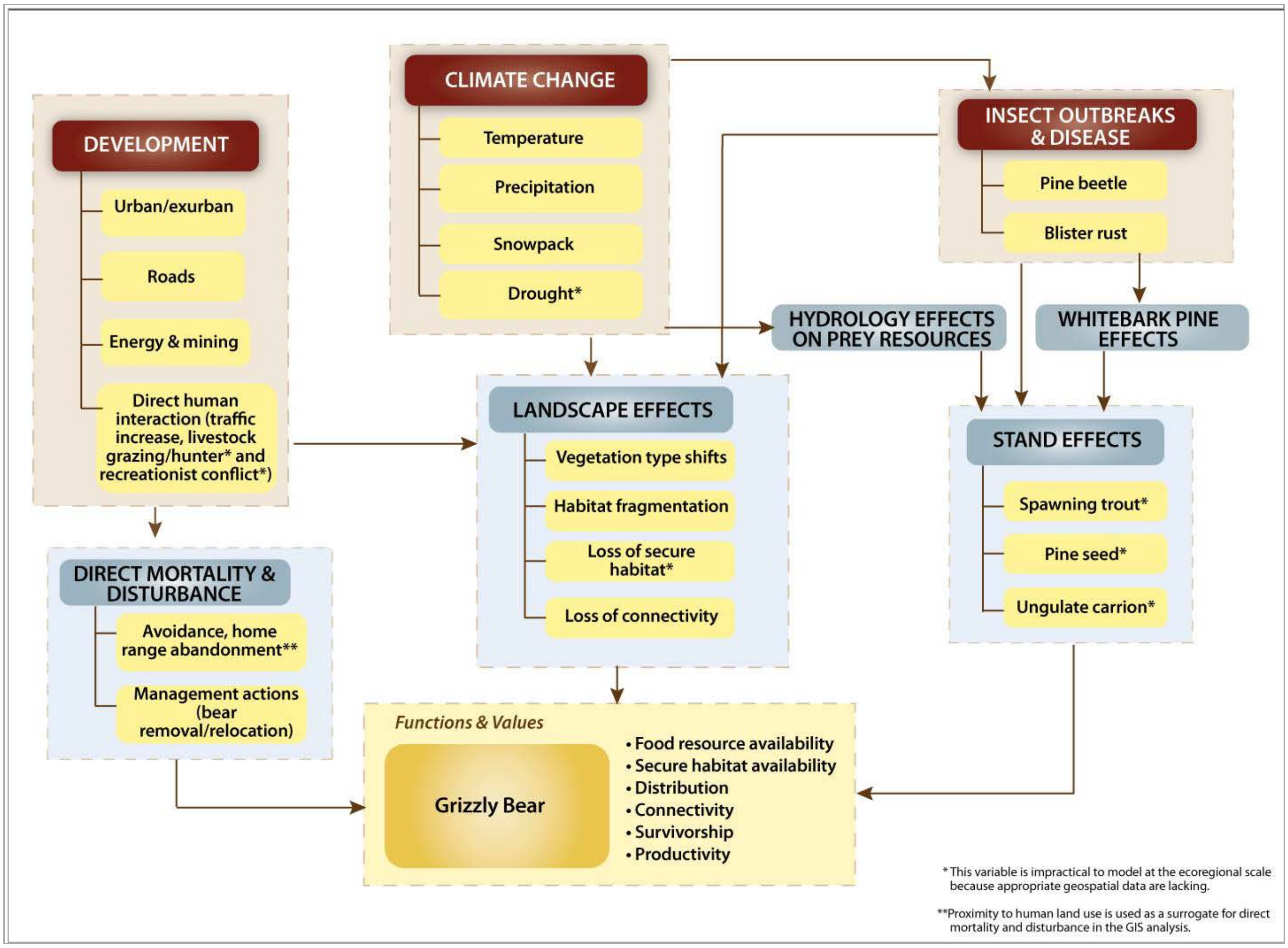

Figure E-1-3. Grizzly Bear System-Level Conceptual Model

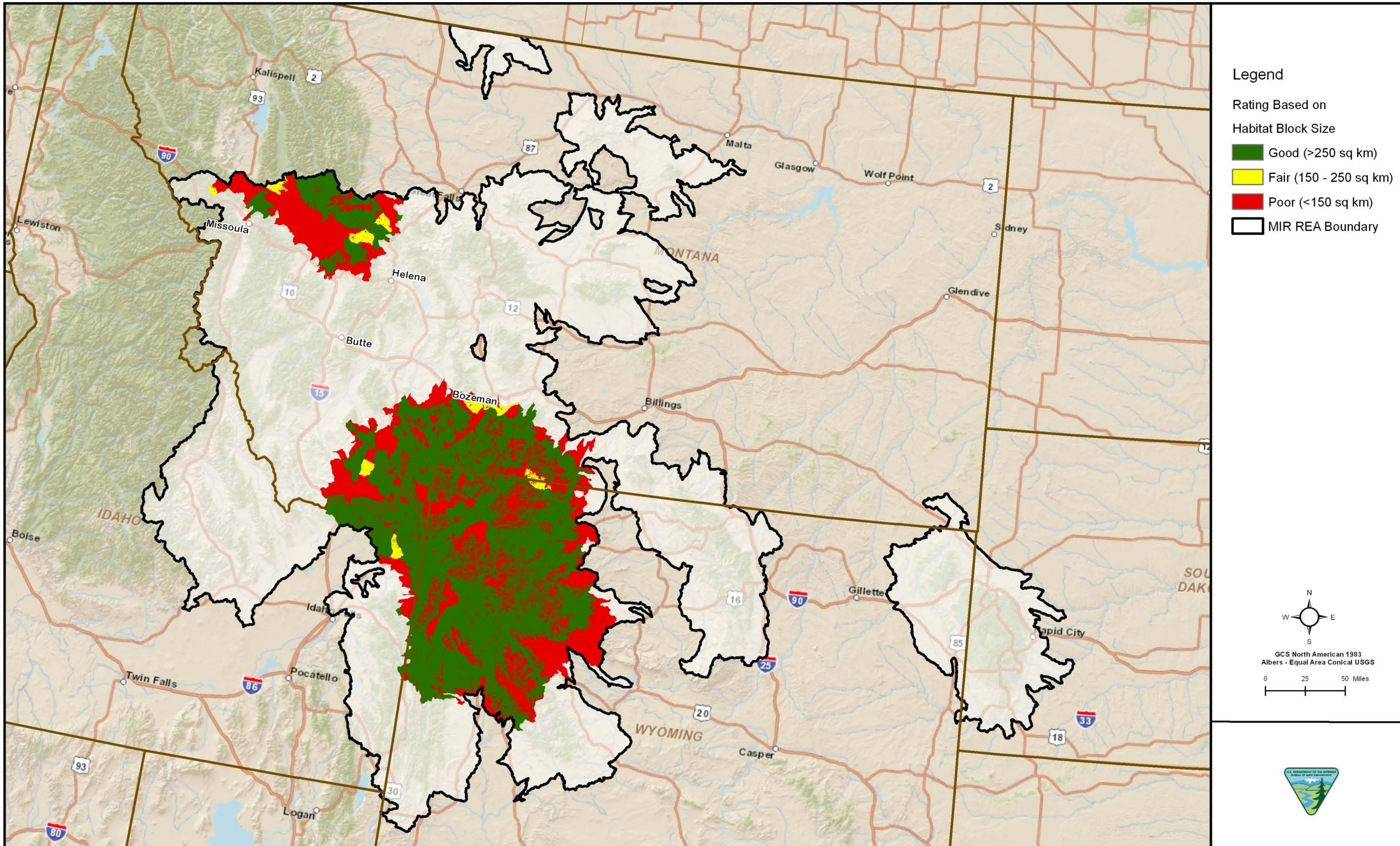

Figure E-1-4. Suitable Landcover Blocks for Grizzly Bear

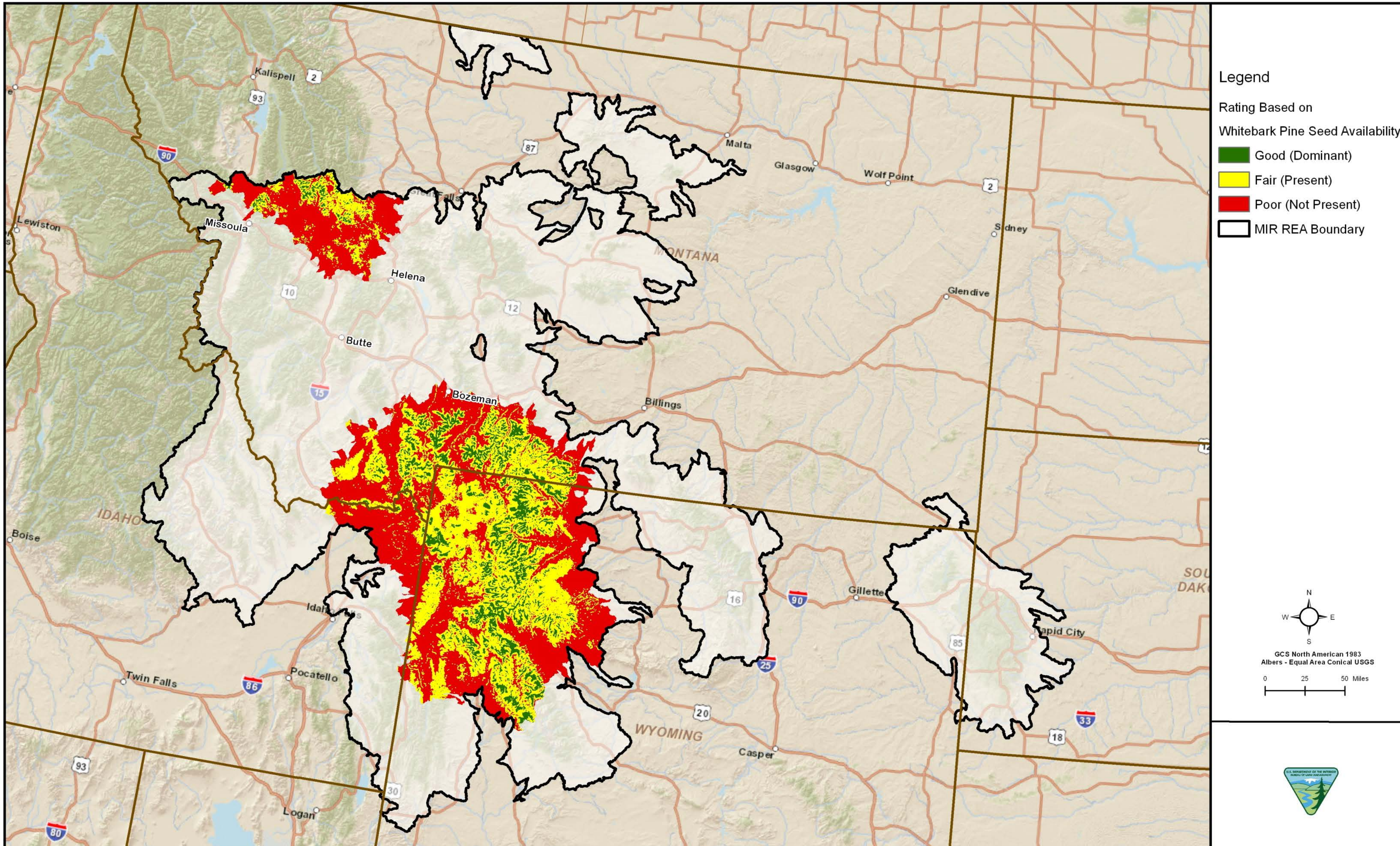

Figure E-1-5. Whitebark Pine Cover/Seed Availability

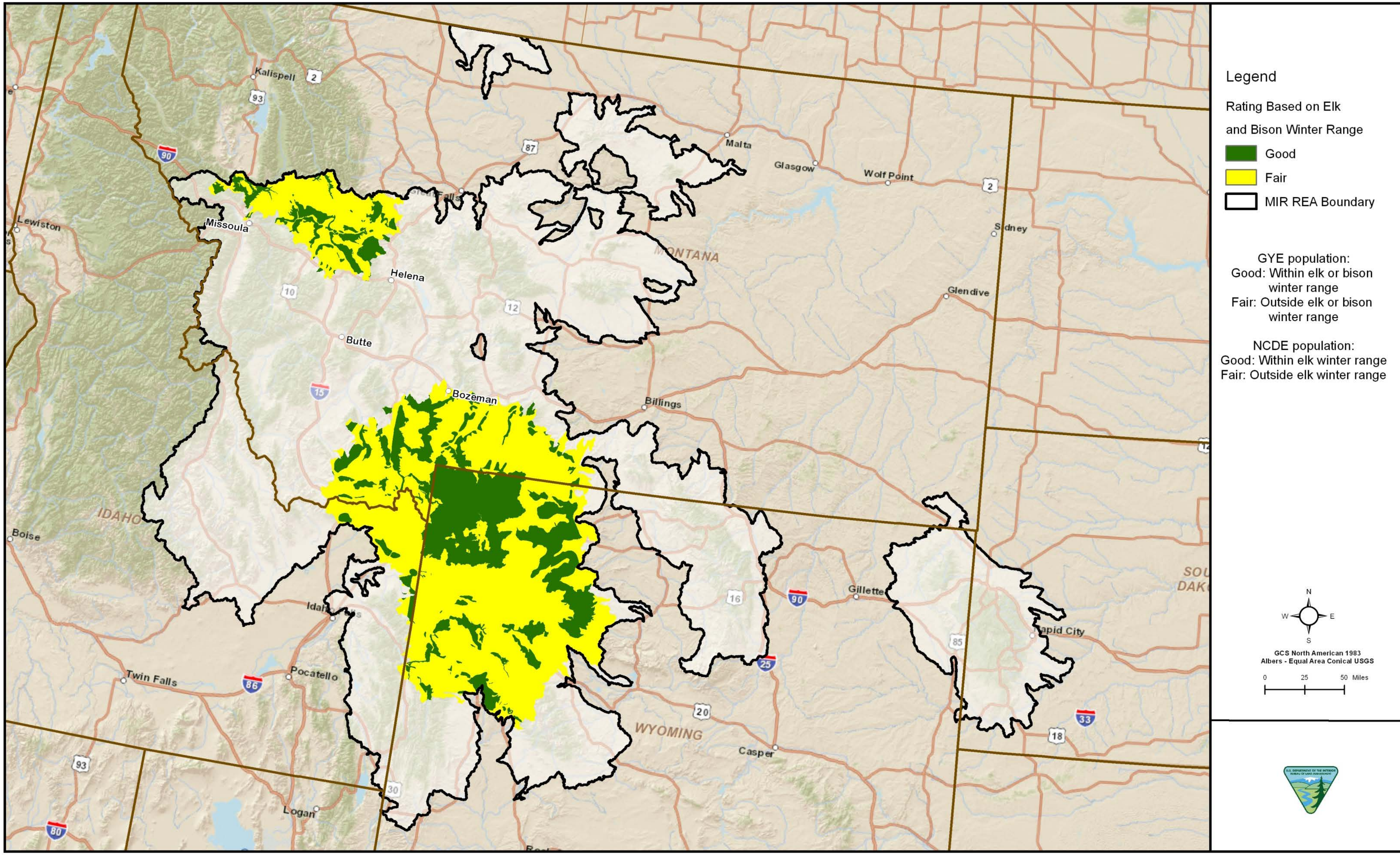

Figure E-1-6. Ungulate Availability (Elk/Bison)

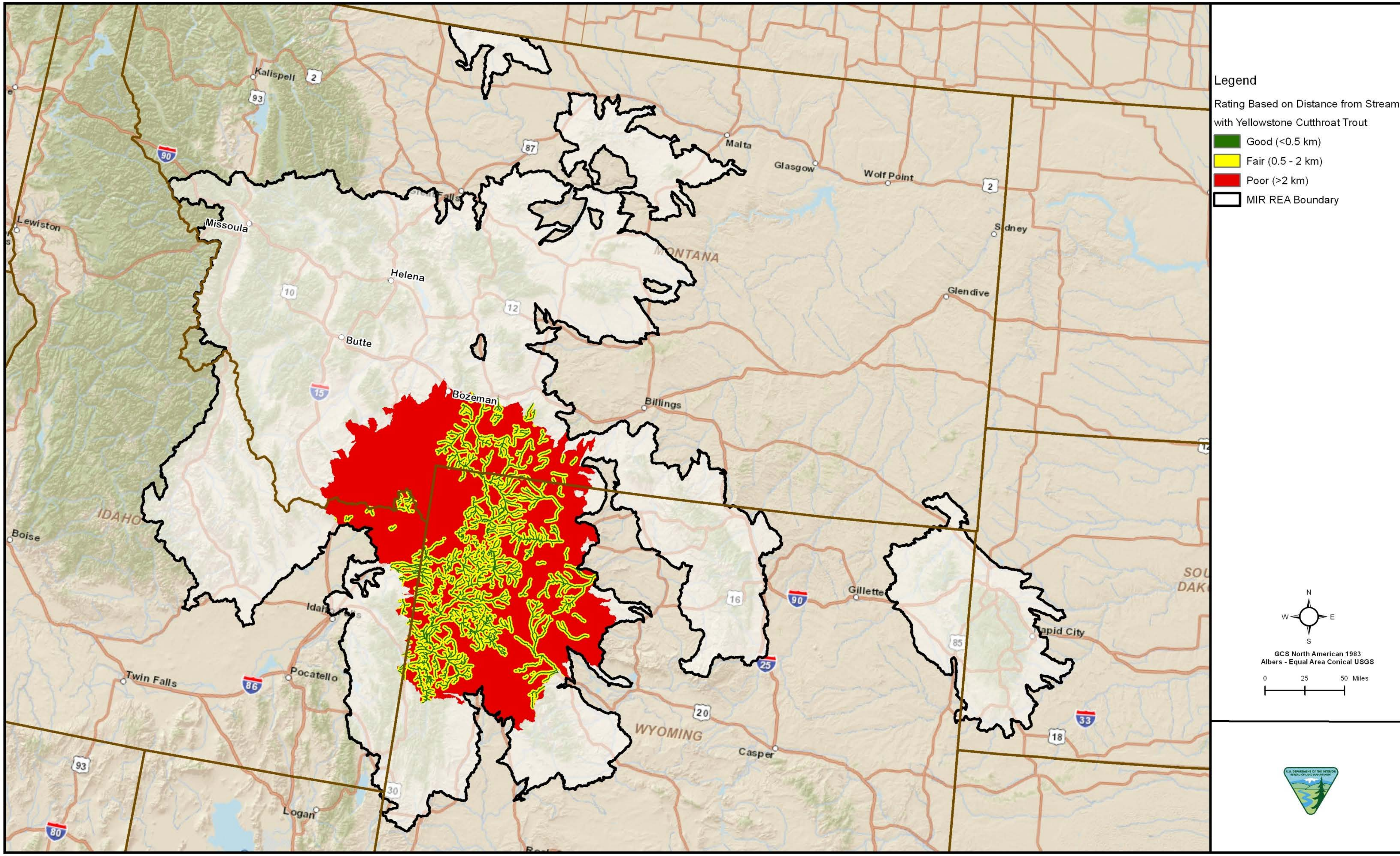

Figure E-1-7. Yellowstone Cutthroat Trout Availability

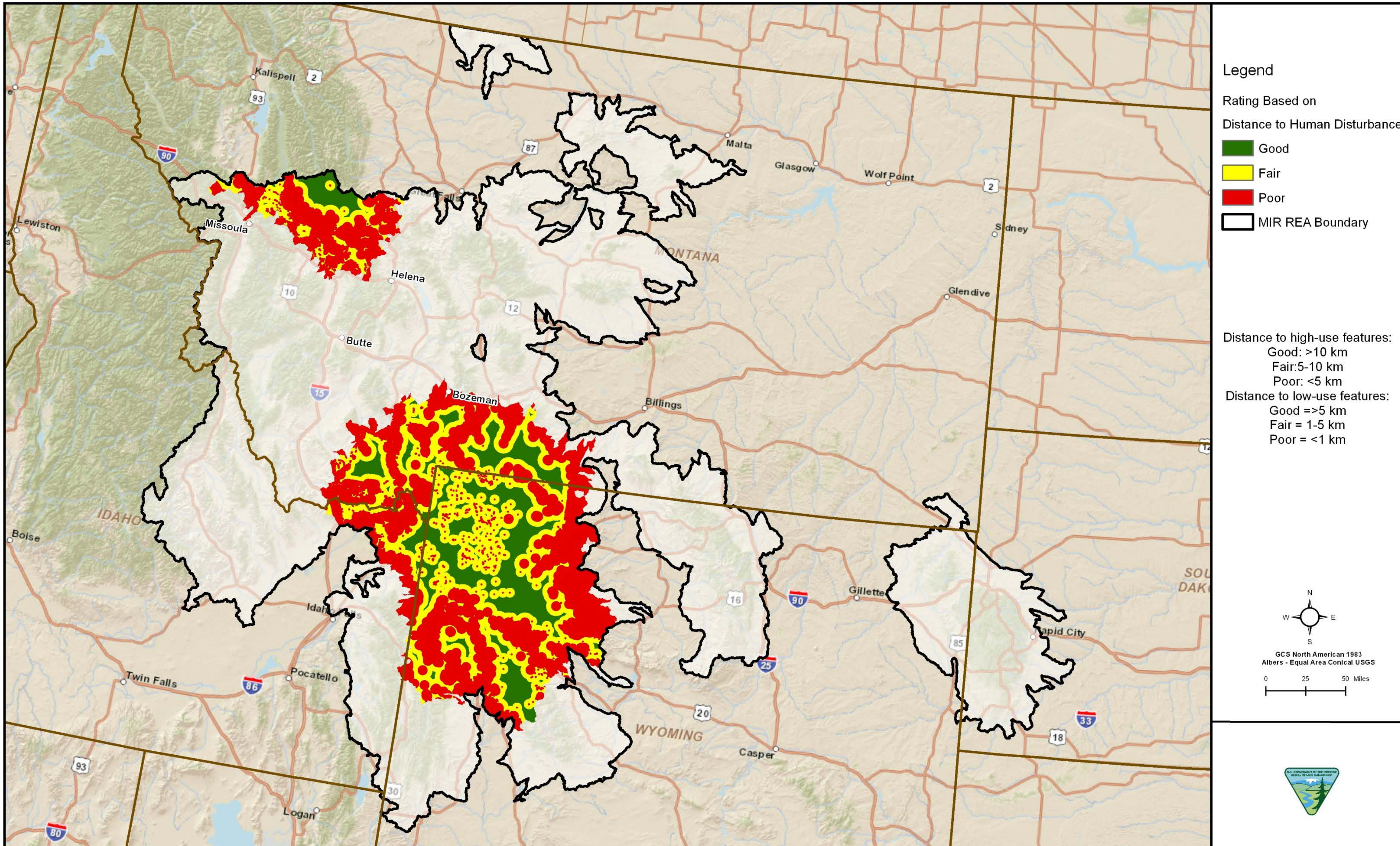

Figure E-1-8. Distance to Human Disturbance/Interaction

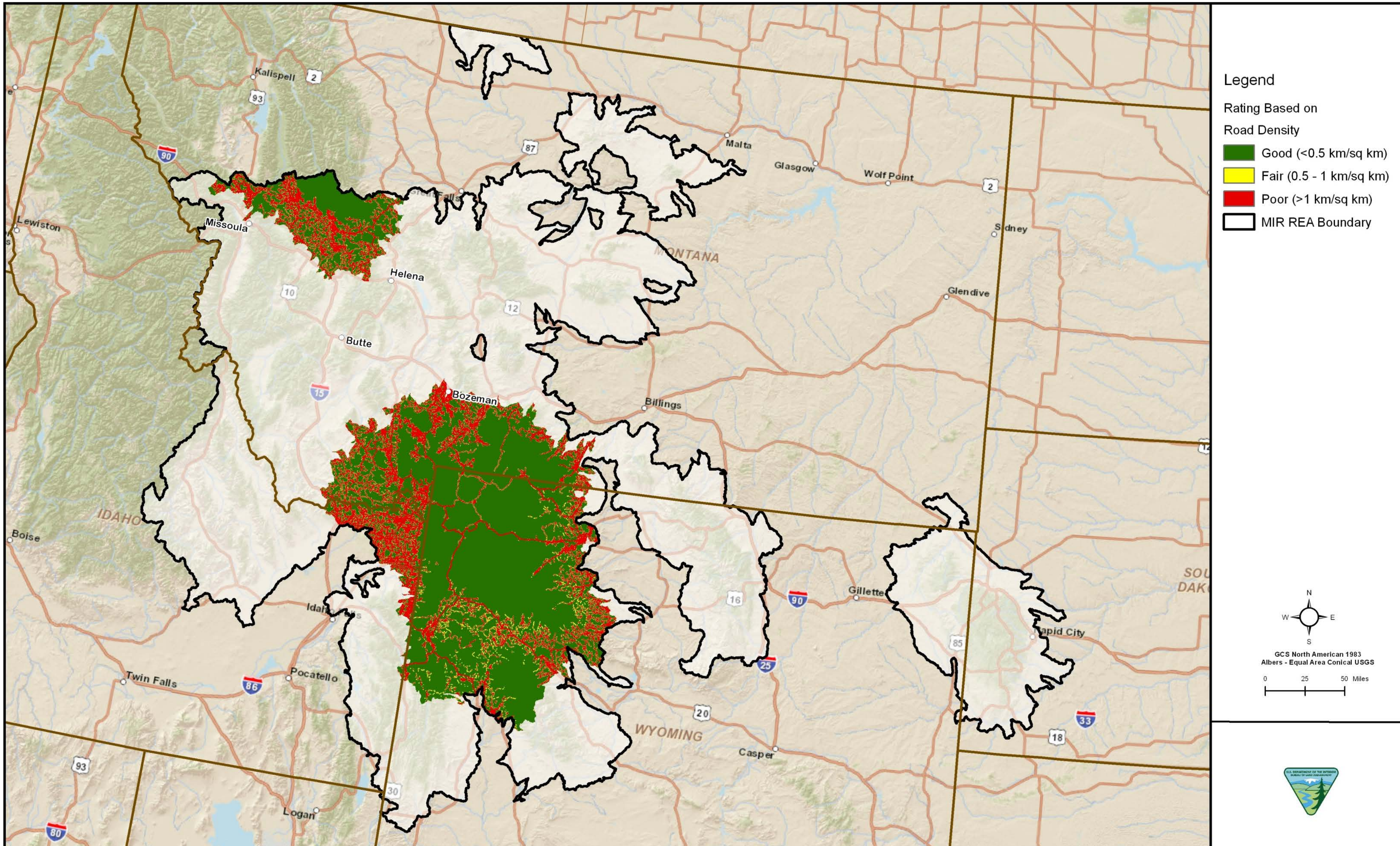

Figure E-1-9. Road Density

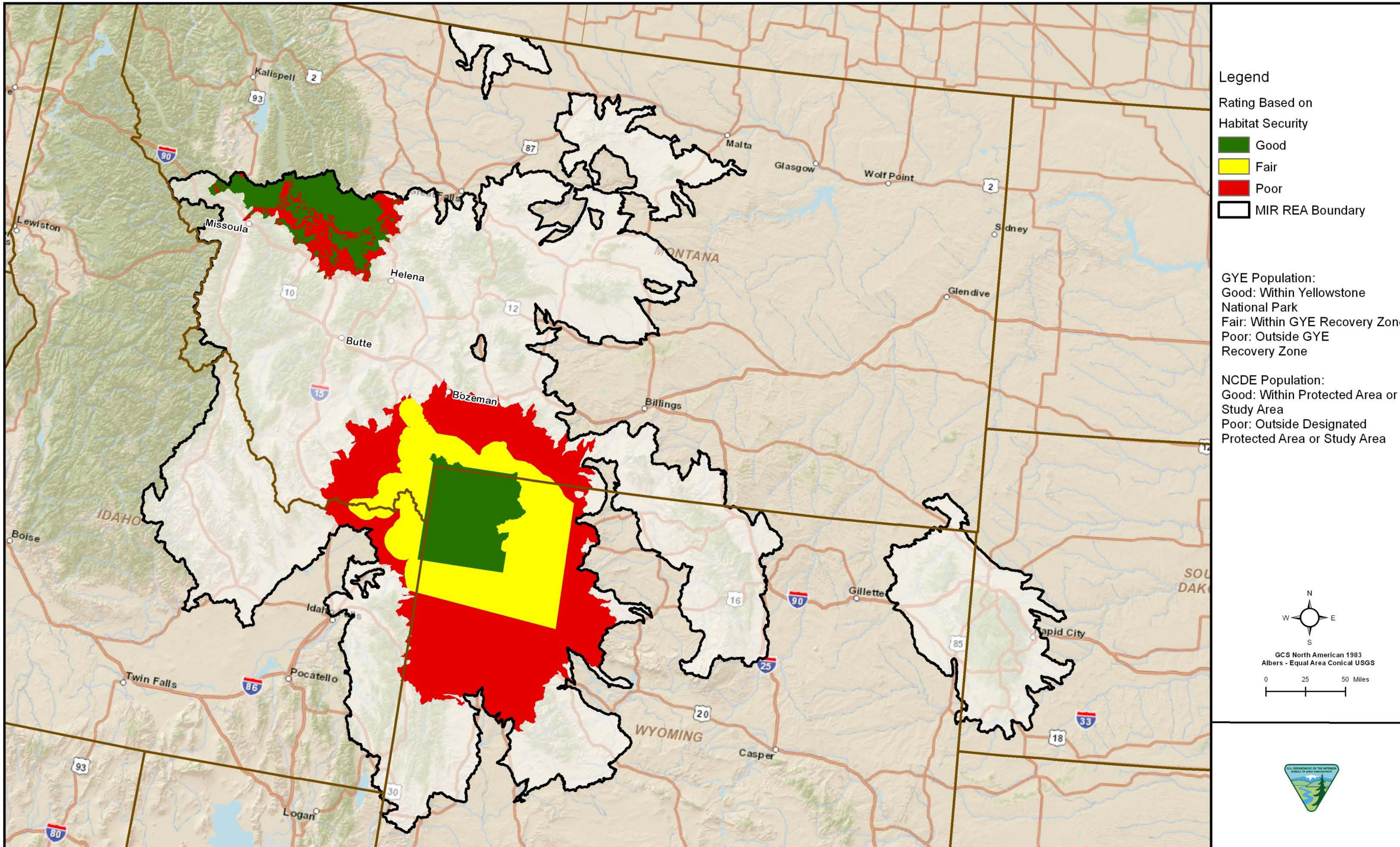

Figure E-1-10. Designated Protected Areas

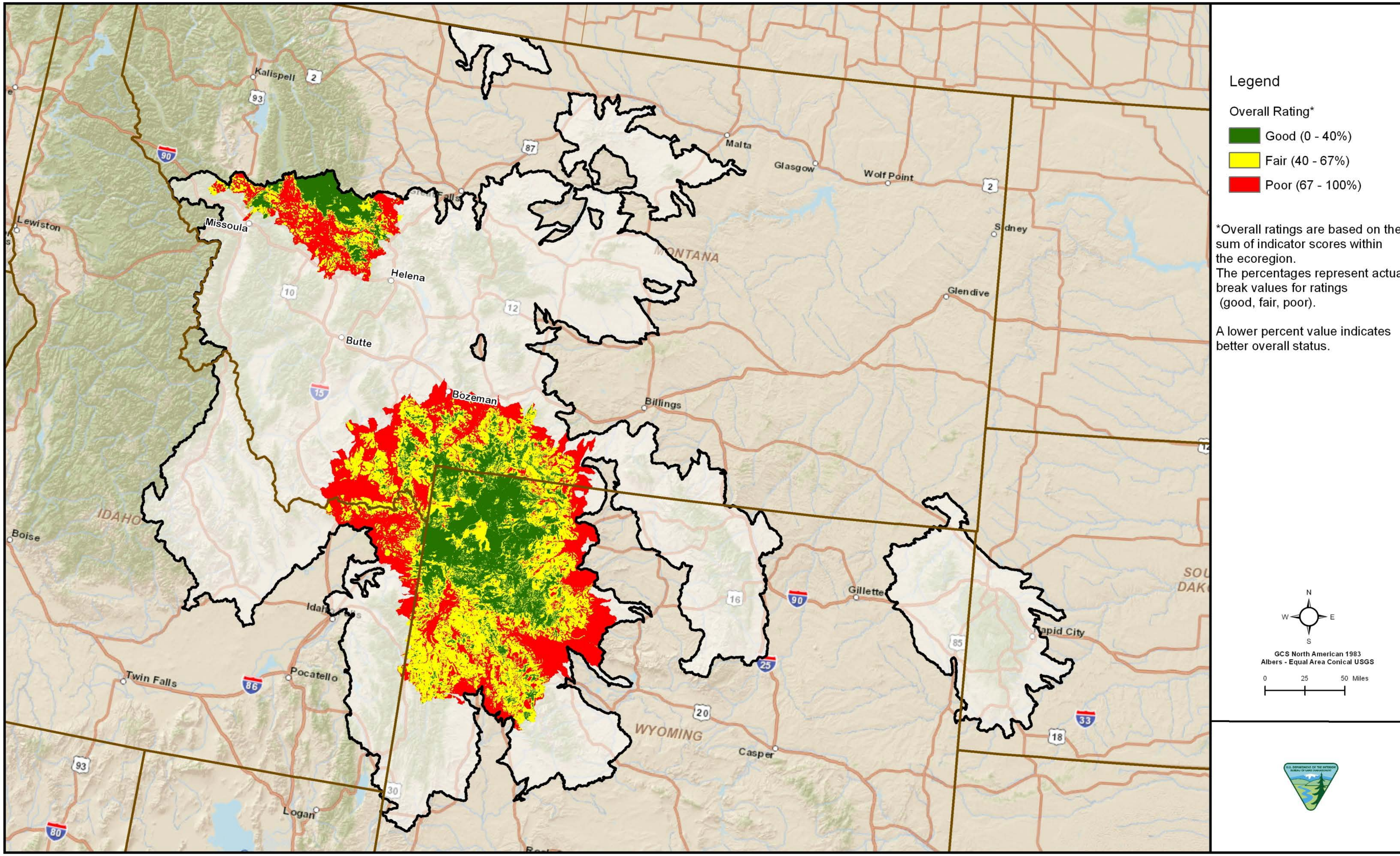

Figure E-1-11. Current Status of Grizzly Bear Habitat in the Middle Rockies

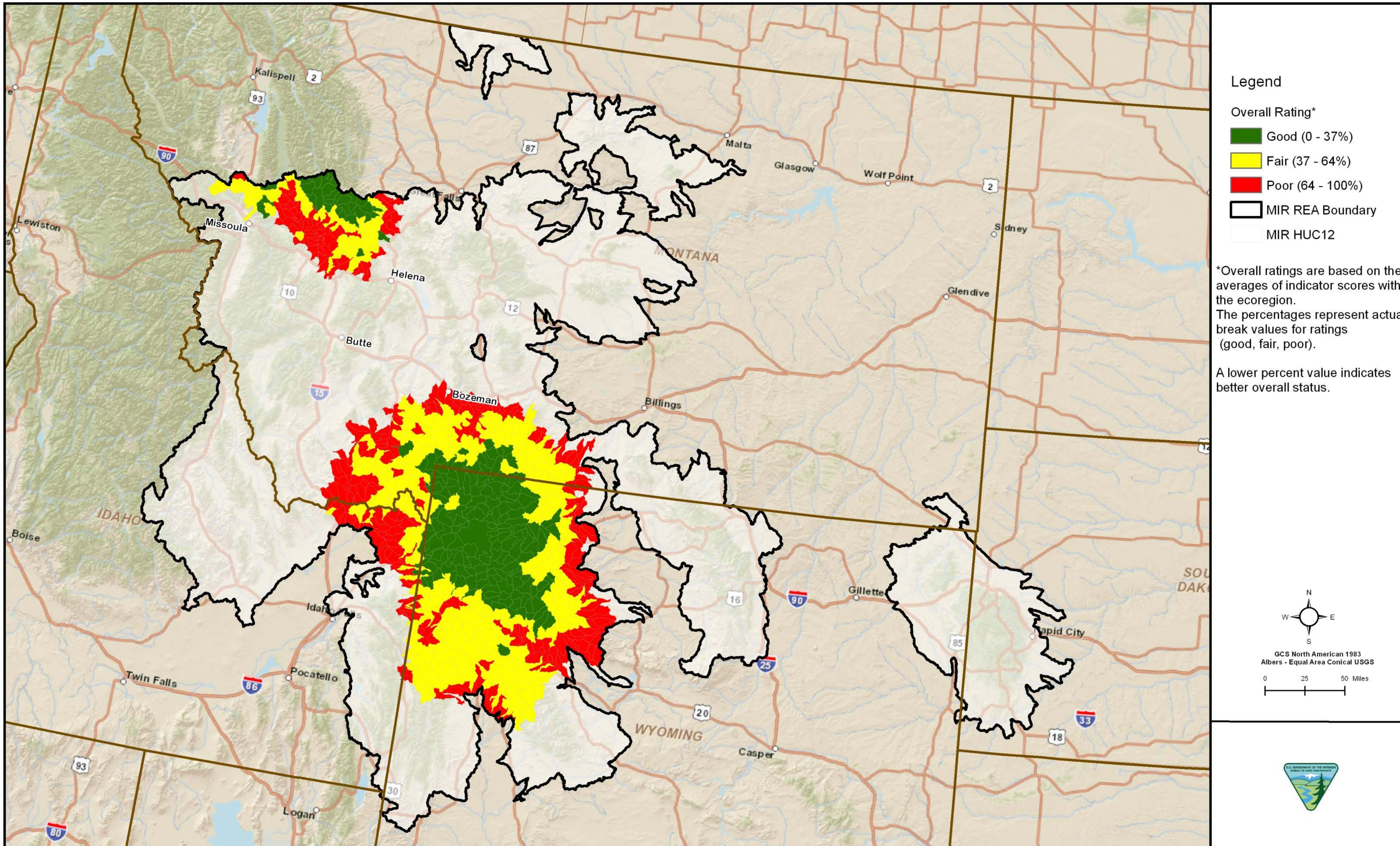

Figure E-1-12. Current Status of Grizzly Bear Habitat in the Middle Rockies by 6th Level HUC

APPENDIX E-2

GREATER SAGE-GROUSE CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NUMBER

1.0 INTRODUCTION

The greater sage-grouse (GRSG) (*Centrocercus urophasianus*) is considered an umbrella species for sagebrush-associated vertebrates (Rowland et al. 2006). Indirect effects of sagebrush habitat loss, fragmentation, and degradation are thought to have caused the extirpation of the GRSG from approximately 50 percent of its original range (Connelly and Braun 1997; Connelly et al. 2004; Schroeder et al. 2004), leading to its declaration as a candidate species for listing under the Endangered Species Act (ESA).

Management questions (MQs) pertaining to this ecoregion were identified in Task 1 and can be summarized into two primary questions: 1) where are the important areas for this conservation element (CE)? and 2) what is happening to these areas? The central focus of these two MQs is to document the current status of selected CEs at the ecoregion scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future change agent (CA) threats.

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2.0 CONSERVATION ELEMENT DESCRIPTION

GRSG are true sagebrush obligates that rely on large, intact blocks of sagebrush as habitat and food year-round. Generally, sagebrush habitats provide critical winter range for GRSG. However, depending on the time of year and where they are in their life cycle, GRSG move to different areas to survive. Sagebrush/grassland habitats also provide critical breeding range for GRSG. Meadows, riparian areas, alfalfa fields, and other moist areas provide important summer range, but GRSG will use a variety of habitats at that time of year. GRSG populations decline when sagebrush/grassland habitat is altered or fragmented by reducing or eliminating sagebrush canopy cover seeded to introduced grass species, converted to agriculture dominated by annual grasses (e.g., cheatgrass), or altered in any way that results in significant reduction of the native grass/forb understory (Idaho Department of Fish and Game 1997).

Sagebrush and understory grasses and forb cover are key components of GRSG nesting and early brood-rearing habitat. Most GRSG nests occur under sagebrush. If sagebrush is eliminated from a large area, that area will not support GRSG populations because nesting success and/or juvenile survival will also be reduced (Idaho Department of Fish and Game 1997).

Insects are a key component of GRSG brood habitat. A high-protein diet of insects is necessary for all young upland game birds during the first month of life. The best early (June to mid-July) GRSG brood habitat includes native grasses and forbs as well as a 15 to 25 percent canopy coverage of sagebrush. Late summer (mid-July to September) brood range consists of a variety of habitats including agricultural fields, meadows and riparian areas adjacent to big sagebrush communities. In years of above-average summer precipitation, late summer brood range may overlap early summer brood range. During winter, GRSG feed almost exclusively on sagebrush leaves and buds. If adequate sagebrush is available for winter food and cover, GRSG are seldom impacted by severe winter weather. Loss of sagebrush on grouse winter ranges can, however, severely reduce GRSG numbers (Idaho Department of Fish and Game 1997).

GRSG were recently designated by the U.S. Fish and Wildlife Service (USFWS) as a candidate species under the ESA (U.S. Department of the Interior 2010). The USFWS determined protection under the ESA was warranted; however, listing the GRSG was precluded by the need to address other listings of higher priority.

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3.0 CONSERVATION ELEMENT DISTRIBUTION MODELING

To answer the MQs regarding the location of this species across the ecoregion, a variety of existing data layers representing important habitat for the species were used. The goal was to obtain data to determine the current distribution and status of this species throughout the ecoregion. The GRSG is found in all states within the ecoregion.

Because of its long history as a valuable upland game species, unexpected population declines in recent years, and recent addition to the federal ESA candidate list, there is an abundance of information available regarding the GRSG via various data sources such as Sagemap and eBird, as well as data provided from the Bureau of Land Management (BLM) on range and buffered lek locations (Table E-2-1). Because there has been so much focus on answering the "where" MQs related to GRSG distribution across the west, there are many different GRSG distribution maps available, including those that include priority habitats, lek locations, and occupied habitats. Montana Fish, Wildlife, and Parks previously attempted to create a Maxent model of this species distribution with limited success.

Table E-2-1. Data Sources for Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in Rapid Ecoregional Assessment (REA)
Modeled Suitable Habitat	Gap Analysis Program (GAP) Habitat Models	U.S. Geological Survey (USGS)	Raster (30-m)	Acquired	No[3]
	Habitat Model (BpS)	NatureServe	Polygon	Acquired	Yes[2]
	Current and Historic Range	Washington Fish and Wildlife	Polygon (1:2 million)	Acquired	No[1]
	State-Derived Models	MT, WY, ND, SD State Agencies	Raster		
	Western Governors' Association (WGA) Decision Support System (DSS) Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[1]
Occurrences	State Natural Heritage Databases	MT, WY, ND, SD, Heritage Programs and Fish and Game	Point	GRSG data not acquired	No[1]
	Breeding Bird Survey	USGS	Polygon	Acquired	Yes
	eBird	Avian Knowledge Network, Partners in Flight	Point	Acquired	No[3]
Areas with Potential for Restoration of Habitat or Habitat Connectivity	Management Plan Areas	U.S. Forest Service (USFS), National Park Service (NPS), BLM, USFWS	Polygon	Not Available	No[1]
Location of Core Areas	Core GRSG	BLM	Polygon	Acquired	Yes
Location of Leks, Nesting, Brood-Rearing, and Winter Habitat	BLM 2006 Compilation of States	BLM; MT, WY, ND, SD, Fish and Game Agencies	Point 1:24k	Acquired	No[1]
Habitat Connectivity	WGA DSS Data	WGA	Polygon	Future Dataset	No[1]

[1] Data gap
[2] Scale is inappropriate
[3] More representative data were selected for use.

As a result of the variety of distribution maps available, the BLM determined that new distribution maps for GRSG for this Rapid Ecoregional Assessment (REA) would not be necessary. The BLM recommended using a combination of the existing breeding bird density (BBD) (Doherty et al. 2010) and GRSG range maps, as developed by Schroeder (2004), because these maps cross land ownerships and provide coarse-scale information about where most of the GRSG are located.

The BBD map uses maximum count of male GRSG on actual leks to develop GRSG breeding density circles for 11 states across the west (Doherty et al. 2010). This map displays GRSG breeding densities in 25, 50, 75 and 100 percent buffer circles around existing leks. More specifically, in order to identify a given proportion of the population (e.g., 25 percent) within the smallest area, the BBD map highlights those areas with the greatest lek density and highest male counts. The rolling review team (RRT) recommended only using the 75 percent (8.5 kilometer [km] radius) breeding circles from this dataset. This was based on the fact that most birds nest within certain distances of leks and, therefore, the BBD map provides a way to evaluate breeding and nesting seasonal habitats. Because of the sensitivity of these data, the center point of each buffered lek location was not provided and the buffered lek circles were dissolved into one polygon for the analysis.

The GRSG range map, as developed by Schroeder (2004) and updated by BLM in 2006 (hereinafter referred to as the Schroeder range map), shows the current and historic distribution of potential habitat, or range. These data were initially researched and compiled by Dr. Michael A. Schroeder of the Washington State Department of Fish and Wildlife. The combination of these maps were used because it was determined to be the best representation of all seasonal habitat usage for this species and because these maps represent the areas of management concern that are relevant at the scale of this REA. Figure E-2-1 presents the combination of the BBD and the Schroeder range map that was used for this analysis. Although this map is not intended to portray actual distribution of GRSG, it will be referred to as the REA GRSG distribution layer. As illustrated on this map, the majority of the Schroeder range overlaps the 75 percent buffered leks.

4.0 CONCEPTUAL MODELS

The 75 percent current BBD map and the Schroeder range map data layers formed the starting point of the CA analysis across the ecoregion, to understand how this species will react to the potential future impact of CAs. The current status and potential future threat analyses were based on CE-specific ecological conceptual models, selected environmental variables (Key Ecological Attributes [KEAs]) likely to be impacted by CAs, and the availability of data. CAs initially considered in this analysis included development, climate change, invasive species, wildfire, and disease.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model (Figure E-2-2) was developed to identify and link the key life cycle processes to ecological attributes (EAs) that have the greatest potential to affect GRSG habitat throughout the ecoregion. As noted in the species description, this species requires large, intact blocks of sagebrush for all phases of its life history.

The key processes are identified in the model as green boxes. Following Unnasch et al. (2009), three broad headings or categories of EAs (size, condition, and context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat, and context refers to the spatial structure of the habitat. At the landscape level, the EAs under the condition category were the most challenging to spatially represent and will primarily depend on the data available.

4.2 SYSTEM-LEVEL MODEL

The system-level conceptual model (Figure E-2-3) illustrates the interactions between the CAs and the primary habitat functions of this species. The CAs for this CE are development, climate change, invasive species, wildfire, and disease, which are identified across the top of the figure in red. The availability, suitability, and connectivity of sagebrush communities are the primary factors affecting GRSG populations.

4.2.1 Development

Development, infrastructure (roads, pipelines, transmission lines), oil and gas exploration, and wind farms in proximity to GRSG leks and winter habitat can significantly impact GRSG populations (Doherty et al. 2008; Holloran 2005; Kaiser 2006; Naugle et al. 2006; Aldridge and Boyce 2007; Harju et al. 2010). Abandonment of GRSG leks in response to power lines has been documented (Ellis 1987; Hall and Haney 1997; Braun 1998), presumably due to an increase in the number of nesting raptors and ravens offered new or alternative nesting structures (Gilmer and Wiehe 1977; Steenhof et al. 1993). Collision of GRSG with fences and transmission lines during flight has been documented (Beck et al. 2006).

Potential impacts of gas and oil development to GRSG include physical habitat loss, habitat fragmentation, spread of exotic plants, increased predation probabilities, and greater anthropogenic activity and noise resulting in displacement of individuals through avoidance behavior (Connelly et al. 2004). GRSG leks within 0.4 km of coalbed methane (CBM) wells in northern Wyoming had fewer males per lek and lower annual rates of population growth compared to leks situated >0.4 km from a CBM well (Braun et al. 2002).

Conversion of sagebrush to pasture, cropland, or irrigated hayfields has been widely recognized as a dominant factor in the decline of GRSG populations. On the landscape scale, reducing the land cover of sage brush communities below 25 percent of a 30-km radius (i.e., the mean home range size) has been suggested as a strong predictor of GRSG extirpations (Aldridge et al. 2008), and losses have been observed when the proportion fell below 65 percent.

Urban development results in direct loss of sagebrush ecosystem acreage, and the human disturbance associated with these developments makes even more acreage non-functional. Selection of town sites is based on a variety of factors including easy access, presence of water, presence of building materials, a relatively high degree of security and safety, etc. Some residences and subdivisions (i.e., ranch/farmsteads and ranchettes) are far removed from actual incorporated towns, but have the same type of impact on the ecosystem on a smaller scale. This trend in habitat loss is continuing at an ever-expanding rate as the human population grows (Wyoming Interagency Vegetation Committee 2002). Some investigators have estimated that as much as 3-5 percent of this ecosystem may have already been negatively impacted by town and urban development (Braun 1998).

4.2.2 Climate Change

Climate change effects are expressed primarily as a range of suitable temperature and precipitation (Wisdom et al 2011) and the frequency and duration of drought (Aldridge et al. 2008). Evers (2010) suggests that under projected climate change in the Great Basin, cooler and moister sagebrush communities (i.e., nesting and brood-rearing habitat) would decrease substantially. The synergistic effects of climate change have the potential to adversely impact GRSG habitat throughout this ecoregion. Increasing temperatures within in the region may lead to fragmentation and habitat loss. Modeling efforts suggest that the geographic range of big sagebrush (*Artemesia tridentata*) will contract significantly and move northward and upward in elevation (Shafer et al. 2001; Miller et al. Undated).

Climate change will facilitate the incursion of invasive plants and the associated changes in fire regime, which currently pose significant threats to GRSG and the sagebrush ecosystem (USFWS 2011). When sagebrush covered much of the western United States, fire helped to recycle nutrients and suppress woody invasion. However, the recent pattern of more frequent fires eventually results in vegetation shifts from sagebrush to grassland vegetation systems. Grassland systems are more vulnerable to invasive species, which also cause compounding problems for sagebrush.

Also, because many crops at northern latitudes are currently temperature limited, warmer seasonal temperatures associated with climate change may lead to greater conversion of native shrub-steppe to tilled agriculture in the near term (Motha and Baier 2005; Stubbs 2007).

4.2.3 Invasive Species

Invasive species occurrences and fire history are often linked and have been estimated to contribute to an increase in juniper and pinyon woodlands (Miller and Tausch 2001), which are avoided by GRSG. In Wyoming big sage communities, invasion of annual grasses or weeds (e.g., cheat grass, medusahead) is the greatest threat because these fuels increase the fire frequency from > 100 years to < 10 years (Whisenant 1990). Tree establishment within sagebrush communities generally decreases forb availability due to moisture depletion (Bates et al. 2000).

Increases in the spread of non-native species such as cheatgrass, Japanese brome, and knapweed (*Centaurea spp.*) are also adversely impacting sagebrush-steppe habitat (Quigley and Arbelbide 1997). The increased fire frequency in areas with cheatgrass affects the ability of sagebrush to reestablish between fire events. Exotic plants also are opportunists, and, when present, quickly increase to establish and colonize areas that have experienced soil-surface disturbance or areas that lack plant cover. Construction activities from mines, wells, roads, and other surface disturbance activities provide avenues for the establishment of non-native plants that degrade sagebrush ecosystems (Wyoming Interagency Vegetation Committee 2002).

A data gap exists with regard to invasive species due to the lack of large-scale comprehensive geospatial datasets covering the ecoregion and the inability to identify suitable surrogates.

4.2.4 Wildfire

Wildfire reduces habitat quality and quantity for GRSG (Connelly and Braun 1997; Connelly et al. 2000a; Nelle et al. 2000; Fischer et al. 1996). Moderate fire return intervals (FRIs) and low intensity fires are necessary to maintain the mixed composition of sagebrush communities for lekking, nesting, and brood rearing. The predominant impacts of wildfire are expected to occur at the vegetation community level, as sage-brush sites shift from one state to another with changes in disturbance regimes.

4.2.5 Disease

Naugle et al. (2004) reported the first West Nile virus (WNV) case in GRSG in northeast Wyoming, resulting in a 25 percent decline in survival of four populations (Naugle et al. 2004). Walker (2007) showed that GRSG chick and adult survival was significantly lower due to WNV and resulted in declining male and female lek attendance. A highly efficient vector of WNV in North America is the mosquito (*Culex tarsalis*), (Hayes et al. 2005; Turell et al. 2005), which is thought to increase due to water development and well ponds associated with oil and gas exploration.

4.3 CHANGE AGENTS PROPOSED FOR ANALYSIS

Although numerous attributes and indicators affecting this species were initially identified in early phases of this REA, not all are included in this analysis. Analysis for wildfire, invasive species, and disease CAs were not included for this CE because the direct effect indicators were determined to be data gaps or because they were impractical to model at the ecoregional scale because appropriate geospatial data were not available. The specific indicators that could not be modeled are identified with an asterisk on Figure E-2-3. Further information on the data gaps for these indicators is discussed in the respective CA analysis contained in Appendix C. Analysis for the development and climate change CAs are included for this CE.

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5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the GRSG was conducted for the ecoregion using the 12-digit Hydrologic Unit Codes (HUCs) as the analysis unit. Based on the ecological process and system-level models, KEAs were identified for the current status and future threat analyses, with a specific emphasis on the ability to measure impacts using existing geospatial data.

Since the scale of the analysis is at the HUC 12, a layer of 6th level HUCs was extracted for the ecoregion. A geographic information system (GIS) process was iterated through the KEA indicators and determined the metric values associated with each watershed. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. The final layers were created by combining the HUC 12 watersheds (with ranked KEAs) with the final suitable habitat layer and the habitat layer from the current status CA layer.

The CAs evaluated for current status include development and wildfire. The CAs evaluated for future threats include development and climate change.

5.1 CURRENT STATUS OF THE GREATER SAGE-GROUSE

5.1.1 Key Ecological Attribute Selection

Table E-2-2 identifies the original KEAs that were proposed in Task 3 and which of these were used in the final current status analysis. Not all of the KEAs proposed were used, based on the rationale provided. Other KEAs were used, but are not directly related to CAs. For example, one of the primary problems with the CA analysis was that the 75 percent buffered lek circles were used as part of the initial distribution maps. The center of each of the circles was not provided, and the circles were all dissolved together into one polygon. Many of the initial KEAs used the center point of the breeding circle as what could be referred to as the actual lek location. Because the distribution data were formatted in this manner, many of the metrics for the KEAs had to be modified. Subsequent to the initial analysis, the RRT recommended combining the Schroeder range map with the BBD map as an additional distribution layer for the analysis.

Table E-2-2. Key Ecological Attributes Retained or Excluded for the Greater Sage-Grouse

Category	Attribute	Explanation
1. Size	Percent cover of sagebrush in buffered lek and Schroeder range area	Retained to show the amount of sagebrush within each lek circle and throughout the Schroeder range.
	Percent of cropland in buffered lek and Schroeder range area	Retained to show the potential impact of agriculture to GRSG habitat.
	Sagebrush patch size	Retained to show core habitat fragmentation.
2. Condition	Cover type	Retained to show the relative quality of the cover types around habitat.
	Vegetation Condition Class (VCC)	This KEA was excluded because of the uncertainty associated with the use of VCC in shrub and grassland systems.
3. Context	Edge density, ratio of edge to interior	This KEA was excluded because the analysis was too large to complete at an ecoregional scale.
	Patch density (No. of patches per 101,704 hectare [ha])	This KEA was excluded because the analysis was too large to complete at an ecoregional scale.
	Oil and gas well density (within 11.3 square miles)	This KEA was excluded because the next KEA listed below completes the same analysis with a smaller, more-conservative assessment.
	Oil and gas well density (1 square mile)	Retained to show the oil and gas well density relative to the spatial location of buffered leks (smaller moving window).
	Road density	Retained to show the density of roads relative to buffered leks and GRSG range.
	Distance to highways	Retained to show the proximity of major highways relative to buffered lek locations and GRSG range.

Table E-2-2. Key Ecological Attributes Retained or Excluded for the Greater Sage-Grouse (Continued)

Category	Attributes	Explanation
3. Context	Presence of power lines	This KEA was excluded because this KEA was combined with the next KEA listed below.
	Distance to towers and power lines	Retained to show the proximity of power lines and towers to buffered leks and GRSG range.
	Percent of combined breeding circle and range area in agriculture	Included as part of percent of cropland in buffered lek area and GRSG range.
	Human density	Retained to show the proximity of populated areas.
	Annual precipitation	Excluded because precipitation is an indirect indicator for GRSG relative to habitat condition. Also, data not adequate scale for analysis.

Table E-2-3 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion. For each of the KEAs listed in Table E-2-2, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Several indicators were used to assess the current status for this CE. This table was limited to size, condition, and landscape context based on spatially available attributes and key factors affecting GRSG in this ecoregion. For this CE, metrics used were equally weighted when evaluating the overall current status of the CE.

Table E-2-3. Greater Sage-Grouse Key Ecological Attributes, Indicators, and Metrics

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Lek Quality	Sagebrush density (% Cover of sagebrush)	<20%	20%-65%	>65%	GAP/National Land Cover Data (NLCD)	Aldridge et al. 2008
		Cropland Proximity	>65%	20%-65%	<20%	GAP/NLCD	Aldridge et al. 2008
	Core Habitat Patch Size	Patch Size (ha)	<500	500-4,000	>4,000	GAP/NLCD	Wisdom et al. 2011
Condition	Quality Community Composition Landscape Structure Habitat Condition	Cover Type	Cultivated fields (e.g., alfalfa, wheat, crested wheatgrass); Woodlands; Other landcover types (water, human land use	Scrub-willow; Sagebrush savannas with trees	Small sagebrush (e.g., low, black); forb-rich mosaics of low and tall sagebrush Riparian meadows; Large, woody, tall sagebrush (e.g., big, silver, and three-tip) trees	GAP/NLCD	Crawford et al. 2004
Landscape Context	Connectivity Habitat Condition	Oil and gas well pad density (quantity per square mile)	>7	1 – 7	<1	Oil & Gas Wells	Naugle et al. 2006
		Road density (km/square kilometers [km^2])	>0.112	0.087-0.112	<0.087	Linear Features	Wisdom et al. 2011
		Distance to highway (km)	<5	5-8	>8	Linear Features	Wisdom et al. 2011
		Distance to towers and power lines (km)	<8.5	8.5-21	>21	Tower layer file	Hall and Haney 1997; Wisdom et al. 2011
		Human density (persons/km^2)	>31	4 – 31	<4	Topologically Integrated Geographic Encoding and Referencing (TIGER), Core Areas & Census	Wisdom et al. 2011

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. The evaluation of the indicators and metrics used was carried out through the establishment of a GRSG RRT comprised of BLM wildlife biologists and state-level GRSG experts. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics, as well as to ascertain the accuracy of each step of the modeling process.

Similar efforts developing ecological attribute tables have been provided by Oliver 2006, the Uinta Basin Adaptive Resource Management Local Working Group (UBARM, 2006), and O'Brien 2007. Definitions for rankings of indicators were adapted from UBARM (2006) as follows:

- Poor: Allowing the indicator to remain in this condition for an extended period will make restoration or prevention of extirpation of GRSG practically impossible (e.g., it will be too complicated, costly, and/or uncertain to reverse the alteration).
- Fair: The indicator lies outside of its range of acceptable variation and requires human intervention for maintenance. If unchecked, GRSG will be vulnerable to serious degradation.
- Good: The indicator is functioning within its range of variation, although it may require some human intervention for maintenance.

Each of the analyses described below were completed for the entire ecoregion and not just on the distribution layer (BBD and Schroeder range). Upon completion of each analysis, the combination of the distribution layer (BBD and Schroeder range) was dropped onto the completed analysis as a mask for display of the analysis. Completing each analysis in this manner allowed every pixel to retain its original value from the original analysis. All of the CA layers for this CE are presented showing the attributes by pixel because it was the only way to show the level of detail necessary for interpretation at the ecoregional scale.

5.1.1.1 Sagebrush Density

This KEA was designed to show the amount or density of sagebrush across the REA GRSG distribution map through the evaluation of the amount of habitat classified as sagebrush. Because each of the buffered lek circles had an 8.5 km radius, a moving window analysis with a window radius of 8.5 km was completed on all Gap Analysis Program (GAP) vegetation data labeled as sagebrush in the ecoregion. The moving window analysis was then extracted to the REA GRSG distribution map and, if greater than 65 percent of the moving window contained sagebrush, it was rated as good. The pixels within the REA GRSG distribution map extent were assigned values between 1 and 3 (Table E-2-3) based on the percent cover within the moving window analysis area. The sagebrush density layer, based on percent sagebrush cover, is presented on Figure E-2-4.

5.1.1.2 Cropland Proximity

This KEA was included to identify the amount of cropland across the REA GRSG distribution map. Land use cover data from GAP was used to identify cropland. A moving window analysis was completed for this analysis with the same moving window size as the previous KEA. If less than 20 percent of the REA GRSG distribution map area contained pixels that were labeled as cropland, the pixels were rated as good. The pixels of the REA GRSG distribution map were assigned a value between 1 and 3 (Table E-2-3) based on the percent cropland within each area. The percent cropland is presented on Figure E-2-5.

5.1.1.3 Sagebrush Patch Size

This KEA was included to assess habitat fragmentation by identifying the larger patches of sagebrush relative across the REA GRSG distribution map. This analysis was initially completed for the entire ecoregion and all of the GAP vegetation types classified as any type of sagebrush were reclassified into one layer for this analysis. A GIS tool was used to group contiguous 30-m pixels. This tool assigns each pixel group unique values, and a value is then assigned to the pixels based on the size of the group that they are located in. The REA GRSG distribution layer was then dropped over the previously assigned pixels to show the patches assigned as good, fair, or poor. While it is recognized that sagebrush areas are naturally patchy, this indicator identifies those larger blocks of sagebrush that are naturally patchy. The sagebrush patch size layers are presented on Figure E-2-6.

5.1.1.4 Cover Type

The quality and composition of cover types is important for all GRSG lifecycles. This KEA was included to attempt to classify the quality and community composition of the cover types across the REA GRSG distribution map. The GAP vegetation layers were used to complete this analysis. The vegetation layers were reclassified into three classes. The class rated as good contains small sagebrush with a mosaic of low and tall sagebrush, riparian meadows, and large, woody, tall sagebrush (e.g. big, silver, and three-tip). The class rated as fair contains scrub-willow, sagebrush savannahs with minor tree encroachment. The class rated as poor contains cultivated fields and woodlands. Each pixel was assigned values between 1 and 3 based on the definitions listed above. The REA GRSG distribution map was then dropped over the cover type analysis as a mask to display the cover types of the REA GRSG distribution map labeled as good, fair, and poor. The cover type layers are presented on Figure E-2-7.

5.1.1.5 Oil and Gas Well Density

Oil and gas wells have the potential to negatively affect GRSG and associated habitat. This KEA was developed to analyze the potential impact of energy development on GRSG. Use of this indicator was based on the assumption that increased levels of oil and gas development near known GRSG leks and range could influence breeding and other behaviors. The metric values for this indicator were based on Holloran (2005), and evaluated GRSG leks relative to natural gas wells in western Wyoming. He categorized each lek based on the total number of producing wells within 3.1 miles of the lek. His research used fewer than five wells as the control (minimal gas field-related disturbance), leks with 5-15 wells as lightly impacted, and leks with more than 15 wells as heavily impacted.

The analysis completed for this REA used a moving window to identify the density of oil and gas wells relative to the REA GRSG distribution map. The moving window was 1 square mile in size. Pixels were assigned values between 1 and 3 (Table E-2-3) based on the number of oil or gas wells within the 1 square mile moving window, and the REA GRSG distribution map was then dropped over the analysis to display areas on the distribution map as good, fair, or poor relative to their proximity to oil and gas wells. Figure E-2-8 presents the results of the oil and gas well pad density analysis.

5.1.1.6 Road Density

KEAs defined to assess landscape context evaluate the quality of the landscape immediately surrounding an ecological system in order to provide an assessment of the potential threats to the habitat of the GRSG. Both improved and unimproved roads compact soil and vegetation, increasing surface runoff. Road rights of way are often inroads for exotic species colonization points, and unimproved roads contribute to wind and water-borne sedimentation.

Roadway data were extracted from selected geographic and cartographic information from the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) database. For this REA, the criterion used was the All Roads County-based shapefile (U.S. Census Bureau 2012).

The analyses used a 1-km^2 moving window to show the density of roads relative to the REA GRSG distribution map areas. Pixels were assigned values between 1 and 3 (Table E-2-3) based on the road density (km/km^2), using values described in Wisdom et al. 2011. Figure E-2-9 presents the road density evaluation.

5.1.1.7 Distance to Highways

A second indicator was used to assess potential anthropogenic impacts from roadways. This KEA assesses the distance to highways relative to REA GRSG distribution areas. For this analysis, pixels were assigned values of 1, 2, or 3 (Table E-2-3) based on their distance (km) from highways. The REA GRSG distribution map was then dropped over these pixels to display the good, fair, and poor values across the REA GRSG distribution map. Figure E-2-10 presents the distance to highways data layer.

5.1.1.8 Distance to Towers and Power lines

The presence of towers and power line infrastructure is considered in this assessment as an indicator associated with decreased lek success, higher mortality, and poor landscape structure (fragmentation). For example, abandonment may increase if leks are repeatedly disturbed by raptors perching on power lines near leks (Ellis 1984), or by noise and human activity associated with energy development during the breeding season. Additionally, deaths resulting from collisions with power lines were an important source of mortality for sage-grouse in southeastern Idaho (Beck et al. 2006). Three potential factors associated with towers could decrease GRSG numbers or lek use: 1) raptors, especially immature golden eagles, hunt more efficiently from perches such as towers and may harass or take adult grouse near or on leks; 2) common ravens (*Corvus corax*) may use the towers as perches and nest sites, and prey on eggs and young of GRSG near leks; and 3) GRSG may respond to towers as potential raptor perch sites and thus abandon, or decrease their use of, a lek from which towers can be seen (Rowland 2004).

Wisdom (2011) found different tolerance distances between transmission lines and cellular towers. He indicated that this difference could be due to the fact that cellular towers are associated with more intense human development and are concentrated along major highways and within and near larger towns.

Transmission line data were obtained for major utility lines within this ecoregion. These transmission lines are generally greater than 115 kilovolts (kV) and tie major power plants to the electrical grid. Minor transmission line (e.g., neighborhood electrical lines, etc.) data were not available for use in this analysis.

The values for this indicator were derived from two different studies based on distances of leks from power lines and cellular towers. Hall and Haney (1997) found that leks located less than 3 km from utility lines had declining population trends; Wisdom et al. (2011) found GRSG populations within 12 km of cellular towers were extirpated, while areas greater than 21 km from cellular towers were occupied. The concern with the towers and power lines in both of these studies was related to raptor predation on leks, collisions, electromagnetic radiation, and associations with human developments. Because the center of each of the lek circles was not provided, it was necessary to calculate the radius of each buffered lek circle; this turned out to be 8.5 km. Therefore, in order to cover both of the referenced studies, the metric of less than 8.5 km was used for the poor category. The metric for the good category was greater than 21 km, based on the Wisdom et al. (2011) study; the metric for the fair category was a combination of both studies and was established at 8.5 to 21 km. The raster layer that was used for this KEA included a combination of cellular towers and wind turbine towers combined with the power line layer. Figure E-2-11 presents the distance to towers and power lines evaluation.

5.1.1.9 Human Density

Human population growth is an indicator of landscape context and is used as a surrogate indictor for the potential impacts associated with increased human access. Human land use, including tillage agriculture, historic grazing management, urban and exurban development, roads and power line infrastructure, and even recreation, have contributed both individually and cumulatively to lower numbers of sage-grouse across the range (Knick et al. 2011).

Housing data for the spatial locations was used in order to estimate number of people per square mile. The number of houses was used per location and then multiplied by 2.58, representing the national average people per household number. Pixels were then assigned values of 1, 2, or 3 (Table E-2-3) based on the human population density analysis. The REA GRSG distribution map was then dropped over the pixels to display the good, fair, and poor ratings for the human density analysis. Figure E-2-12 presents the human density data layer.

5.1.2 Current Status of Habitat for the Greater Sage-Grouse

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of the GRSG habitat for each HUC across this ecoregion. A method of aggregating scores was used to summarize overall threats with regard to GRSG habitat quality. Individual indicators can identify areas of potential risk to GRSG populations, but aggregated scores can provide important information with relation to areas where this species might encounter multiple indicators.

In order to create a current status layer, an overall score for each pixel across the ecoregion was calculated by summing the values of each pixel from each analysis. For this CE, the metrics were equally weighted when evaluating the overall current status. Each watershed has the potential to receive a maximum score of 27 points (i.e., 9 indicators assessed, each having the potential for a maximum score of 3). The summed scores were then divided by a factor of 9 to yield a value between 1 and 3. This final overall score was then ranked as poor, fair or good based on the natural breaks method, which seeks to reduce the variance within classes while maximizing the variance between classes. The overall current status layer for GRSG is presented on Figure E-2-13. The result of the overall analysis is also presented based on HUC 12 and is displayed on Figure E-2-14.

The current status analysis indicates that there are some existing concerns associated with a few areas of the ecoregion (Figure E-2-14). The size attributes indicate that several areas are threatened by lower patch sizes (Figure E-2-6) and a low percentage of sagebrush (Figure E-2-4), particularly in the southern part of the ecoregion. The anthropogenic features that contribute most to the ecoregion as a whole are the distances from highways (Figure E-2-10) and power infrastructure (Figure E-2-11).

A summary of the current status ratings based on the CE distribution is provided in Table E-2-4. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that nearly 73 percent of the 6th level HUC watersheds that intersect the GRSG distribution received an overall fair or poor rating.

Table E-2-4. Summary of Current Status Ratings for the Greater Sage Grouse

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	13,904	27.1
Fair	23,321	45.4
Poor	14,122	27.5

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

The system-level model (Figure E-2-3) was used to create a series of intermediate layers that are primarily based on the geospatial data that was available on the future projections for the development CA and climate change CAs. Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069).

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period, rather than a specific time period, for some of these attributes. However, because of the limits placed on these data outputs it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their affect on GRSG populations.

5.2.1 Development Change Agent

Future spatial data for development was limited to potential energy development area, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1.

Future agricultural growth is most likely to threaten GRSG populations in the northeastern areas of the ecoregion (Figure C-1-1). Future agricultural growth is most likely to threaten GRSG populations in the northeastern areas of the ecoregion (Figure C-1-1). The GRSG habitat in the southwestern portion of the ecoregion south of Pinedale, Wyoming, does appear to be at high risk from future fossil fuel development (Figure C-1-7). Because future energy development is already occurring in the area, the BLM should consider more detailed step-down analysis for this area. Although the future expansion of agriculture and the future development of energy resources pose a risk to GRSG habitats, urban/exurban growth poses a low overall risk to GRSG habitats (Figure C-1-5).

5.2.2 Climate Change Future Threats

The climate CA layer will be created through the results of the 2025 and 2060 U.S. Geological Survey (USGS) climate change models. These models should document areas that may be negatively and positively affected by climate change. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis are provided in Appendix C-5.

The results of the climate change modeling conducted for this REA indicate that most of the ecoregion could experience a temperature increase of between 1.9 to 2.4^{0}C (Figure C-5-8). For this species, the predicted temperature changes in summer appear most relevant (Figure C-5-11). Increases will significantly increase evapotranspiration rates and reduce the water content of dead vegetation and litter. Both conditions will likely increase water stress in plants and provide more flammable materials for wildfires.

The modeled changes in precipitation in the ecoregion indicate that the western and northern mountain ranges could experience a modest increase in annual precipitation; the Wind River Range, the Owl Creek Mountains, and the Bighorn Range will experience a modest decrease in precipitation; and the basins will remain relatively unchanged (Figure C-5-1). The only notable seasonal difference for the basins of the ecoregion would be in the September to October period, in which the effect of less precipitation in the Lost River Range, the Lemhi Range, and the Beaverhead Mountains of Idaho will be relatively greater as will the effect in the basins lying between those ranges (Figure C-5-5).

The dependence of the species on sagebrush through all seasonal periods has been well documented. The presence of early-greening forbs (broad-leafed flowering plants) improves hen nutrition during this pre-laying season, which increases nest initiation, hatching success, and chick survival. Tall, dense, residual grass (previous year's growth) in nesting habitat improves hatching success. During the summer months, as forbs and other food plants mature and dry out, GRSG seek areas still supporting green vegetation. Sagebrush stands closely associated with riparian areas provide important security cover, and are used during loafing and roosting periods. During the fall, forbs and insects decrease in availability, so the amount of sagebrush in the diet increases. Fall habitats are those used during migration to winter areas, the timing of which depends on temperatures and snow depth. During the winter, the primary requirement of GRSG is sagebrush exposed above the snow. Winter habitat may be limited in deep snow areas (Cagney et. al 2010).

The NSCCVI tool was utilized to assess GRSG vulnerability to the effects of climate change. Using annual raster datasets from NatureServe to perform climate change calculations in ArcGIS (through the Predicted Temperature 2040-2069 [Fahrenheit (F)] and the Predicted Hamon ratio of actual evapotranspiration to potential evapotranspiration [AET : PET] Moisture Metric 2040-2069 datasets), the NSCCVI calculator was applied and produced an index score of moderately vulnerable. The NSCCVI tool indicated that available evidence suggests the abundance and/or range extent of this species within the geographical area assessed is likely to decrease by 2050. The assessment rating was largely based on a majority of neutral and somewhat increased vulnerability scores calculated when assessing factors that influence vulnerability, such as, distribution to relative barriers, dispersal and movements, reliance on interspecific interactions, and genetic factors.

6.0 MANAGEMENT QUESTIONS

The relevant MQs for the GRSG would include those defined as part of the Landscape Species/Species Richness category. The overall MQ was: Where are the key habitat types (seasonal, refuges, corridors/connectivity, migration routes, concentrations of regionally significant species, etc.) for landscape species, keystone species, regionally significant species, and regionally significant suites of species? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the distribution map for the CE. Specific MQ examples for the REA were developed in Task 1 and are presented in Appendix A. Several of these MQs are discussed below to demonstrate the functionality of the REA and to provide an opportunity to discuss significant data gaps that were identified during the REA.

6.1 WHERE ARE AREAS THAT HAVE POTENTIAL FOR RESTORING REGIONALLY SIGNIFICANT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR REGIONALLY SIGNIFICANT SPECIES?

The BBD maps (Figure E-2-1) were developed by the BLM using count data at leks to delineate high abundance population centers that contain 25, 50, 75, and 100 percent of the known breeding population. The Schroeder range and BBD maps also indicate the habitat necessary to sustain the species year round. Several KEAs were selected to evaluate suitable habitat size and conditions of existing breeding areas within the ecoregion. The size attributes indicate that several existing leks have low patch size (Figure E-2-6) and a low percentage of sagebrush (Figure E-2-4), particularly in the southern part of the ecoregion. The overall combined assessment of the current habitat conditions for the CE by BBD and Schroeder range is presented on Figure E-2-14 and can be used to identify potential areas for restoration.

6.2 WHERE ARE CURRENT REGIONALLY SIGNIFICANT LANDSCAPE/KEYSTONE SPECIES AND THEIR HABITATS, INCLUDING SEASONAL HABITAT AND MOVEMENT CORRIDORS, AT GREATEST RISK FROM CHANGE AGENTS, INCLUDING CLIMATE CHANGE (CONNECTIVITY, SMALL POPULATION SIZE)?

The results of the climate change modeling conducted for this REA indicate that most of the ecoregion could experience a temperature increase of 1.9 to 2.4^{0}C. For this species, the predicted temperature changes in the ecoregion during the summer appear most significant (Figure C-5-11). Temperature increases will significantly increase evapotranspiration rates and reduce the water content of dead vegetation and litter. Both conditions will likely increase water stress in plants and provide more flammable materials for wildfires.

The modeled changes in precipitation indicate that basin areas of the ecoregion will remain relatively unchanged (Figure C-5-1). The only notable seasonal difference for the basins of the ecoregion would be in the September to October period, where the effect of less precipitation in the Lost River Range, the Lemhi Range, and the Beaverhead Mountains of Idaho will be relatively greater, as will the effect in the basins lying between those ranges (Figure C-5-5).

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APPENDIX E-2

FIGURES

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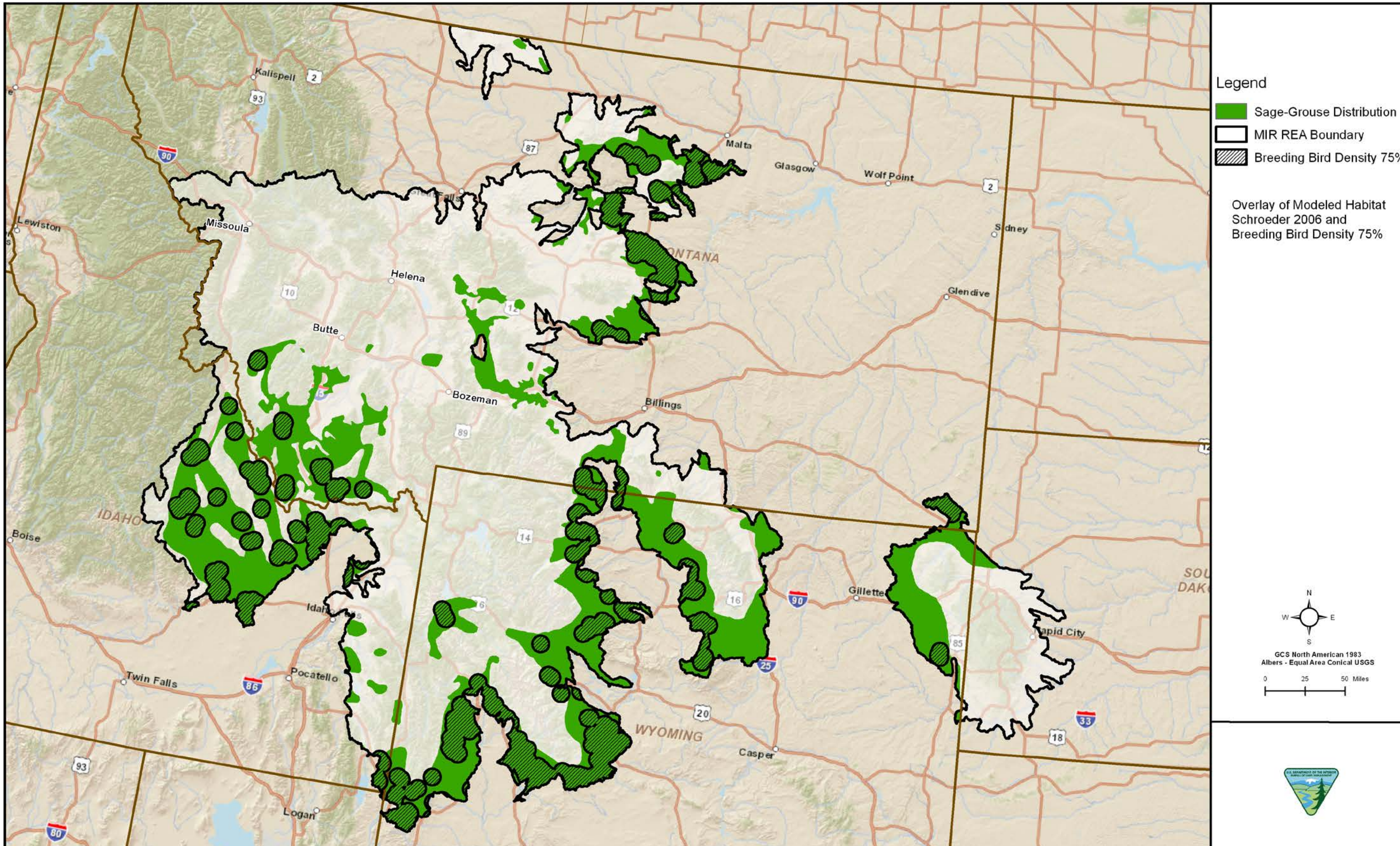


Figure E-2-1. Greater Sage-Grouse Distribution

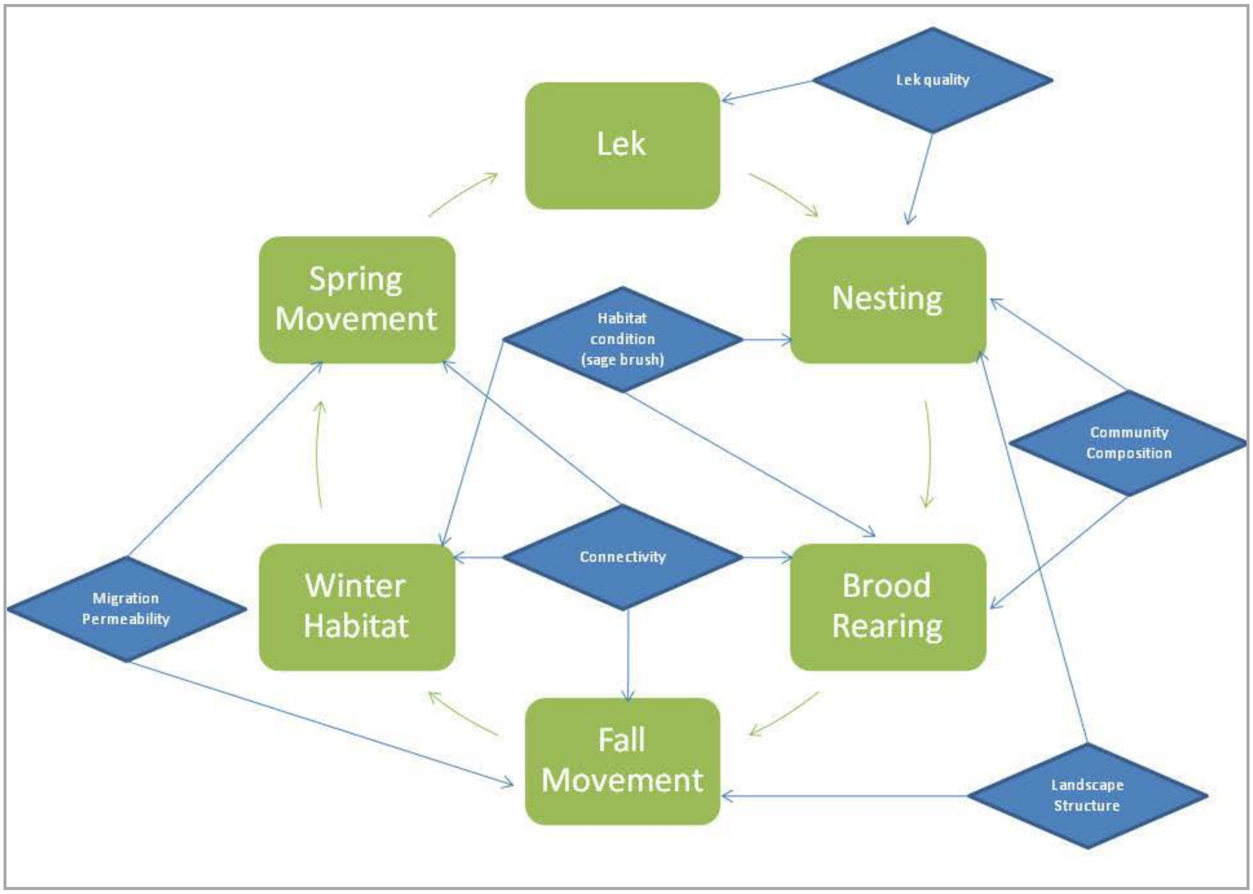


Figure E-2-2. Greater Sage-Grouse Ecological Process Model

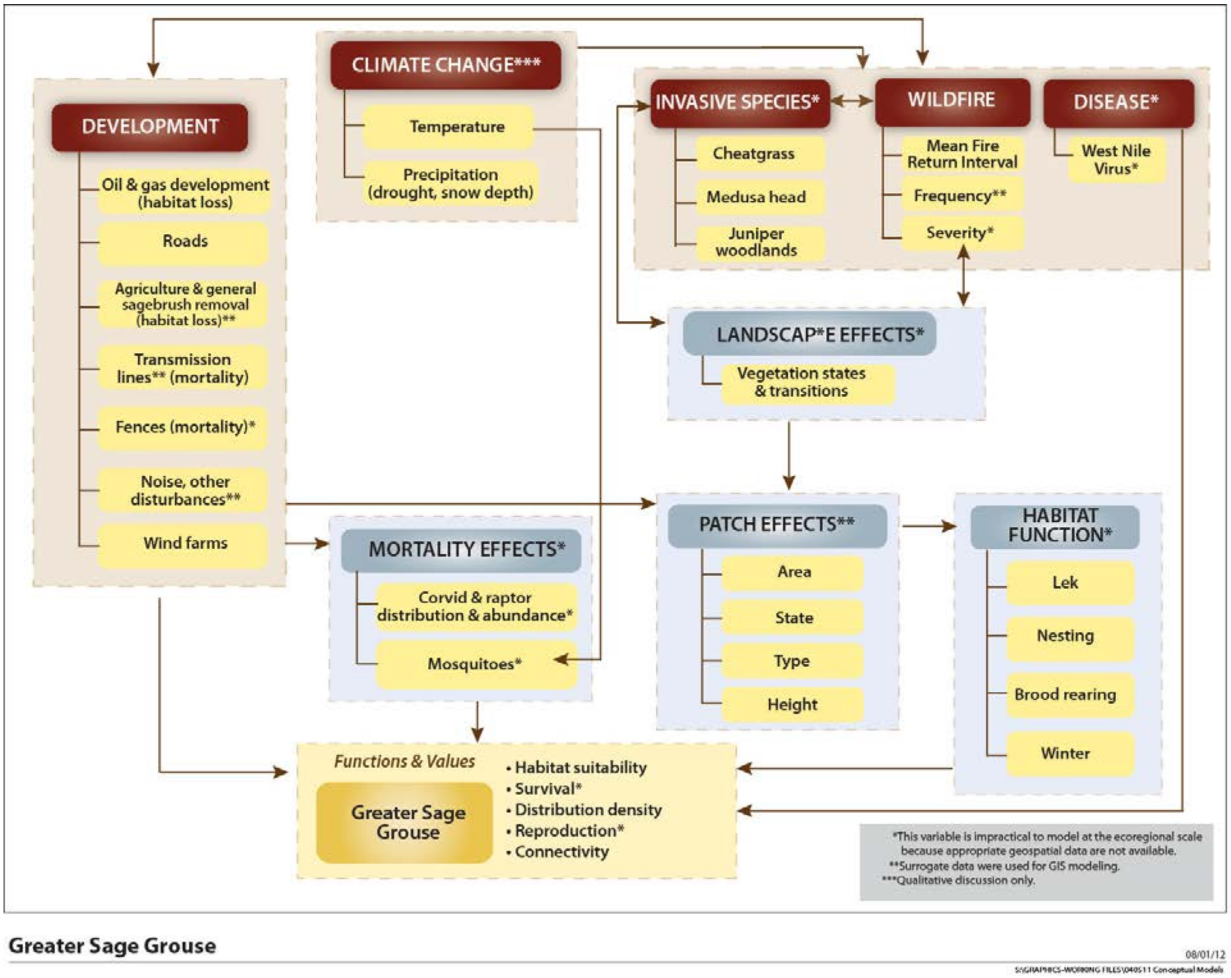


Figure E-2-3. Greater Sage-Grouse System-Level Conceptual Model

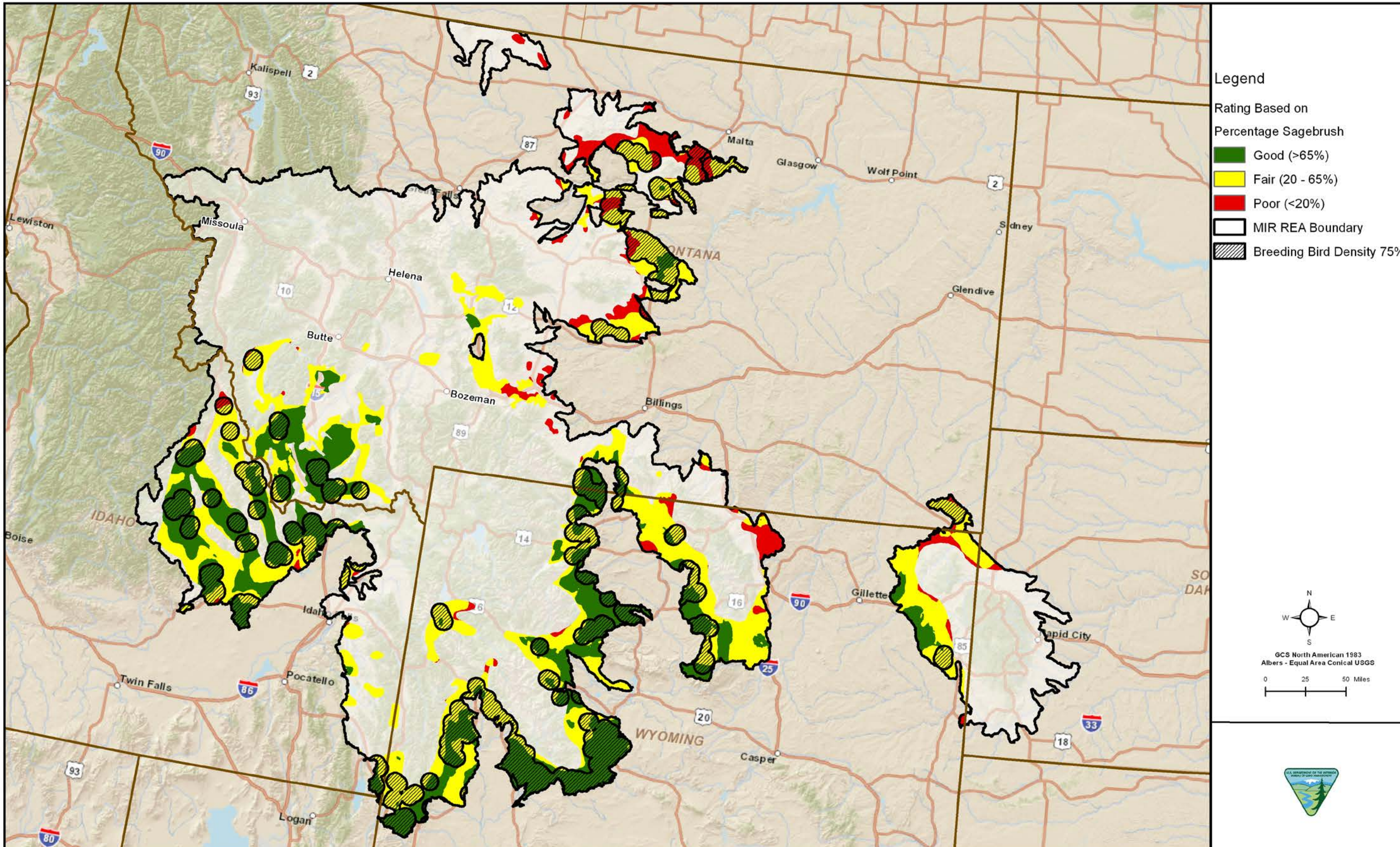
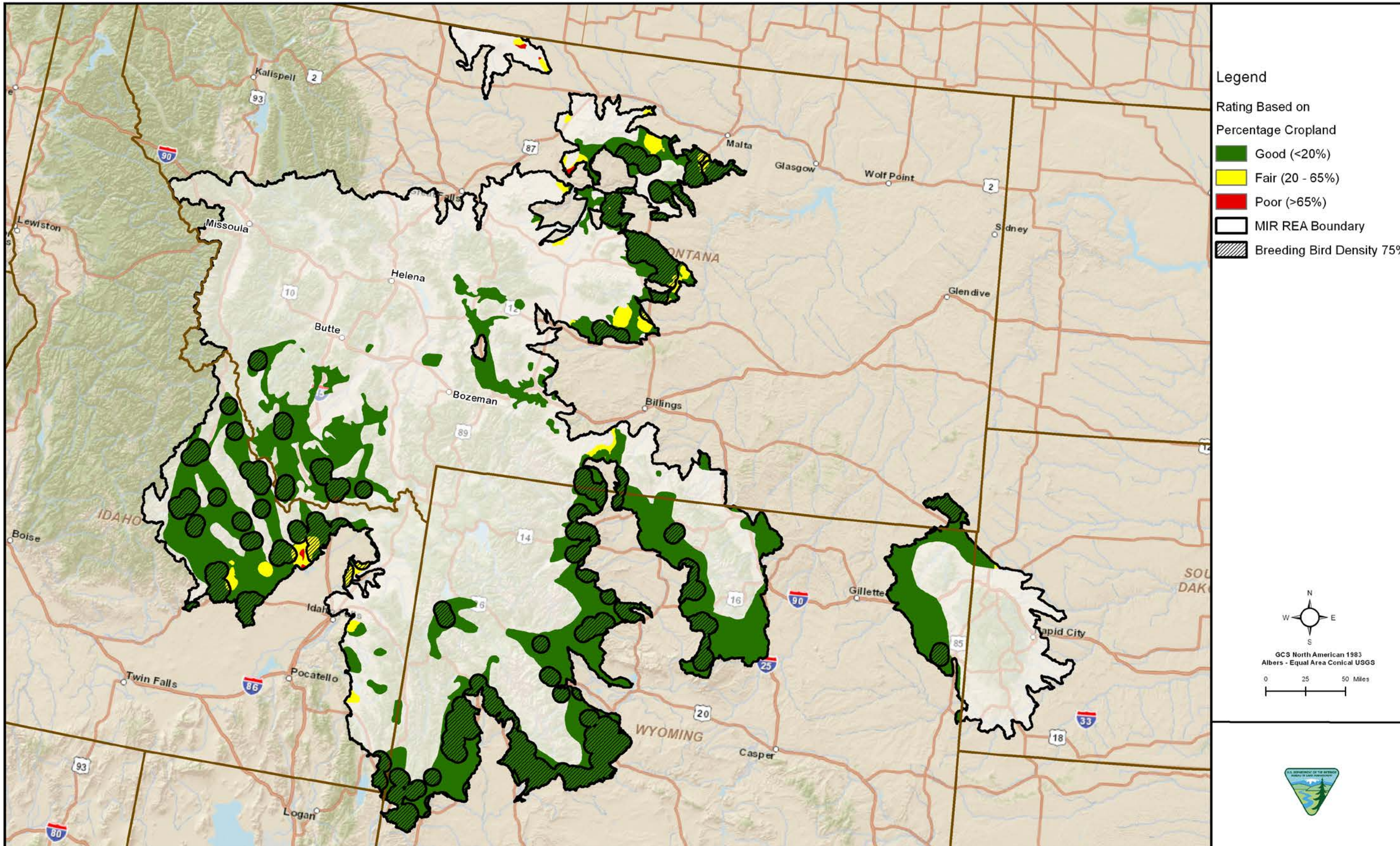


Figure E-2-4. Greater Sage-Grouse Percent Sagebrush



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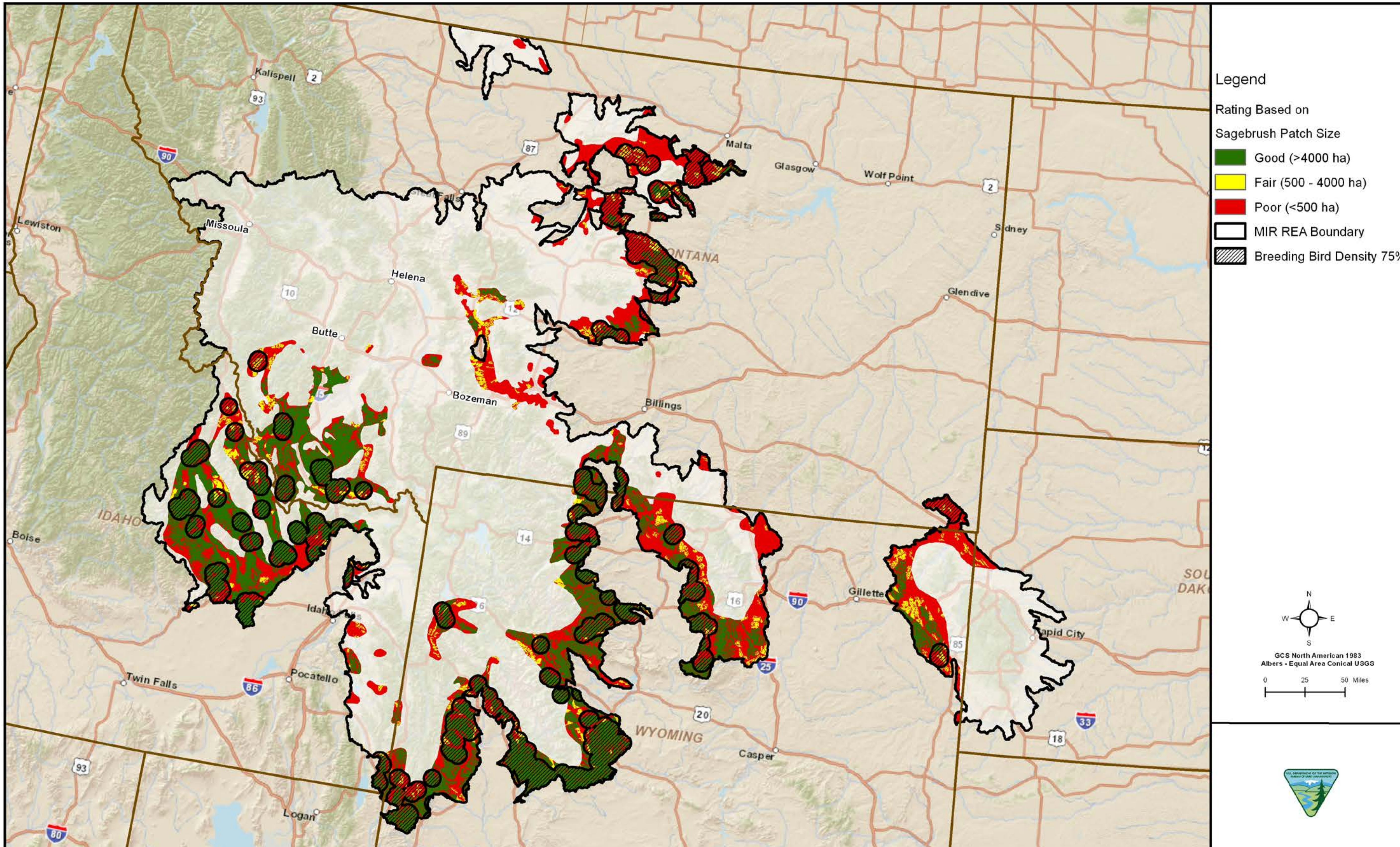

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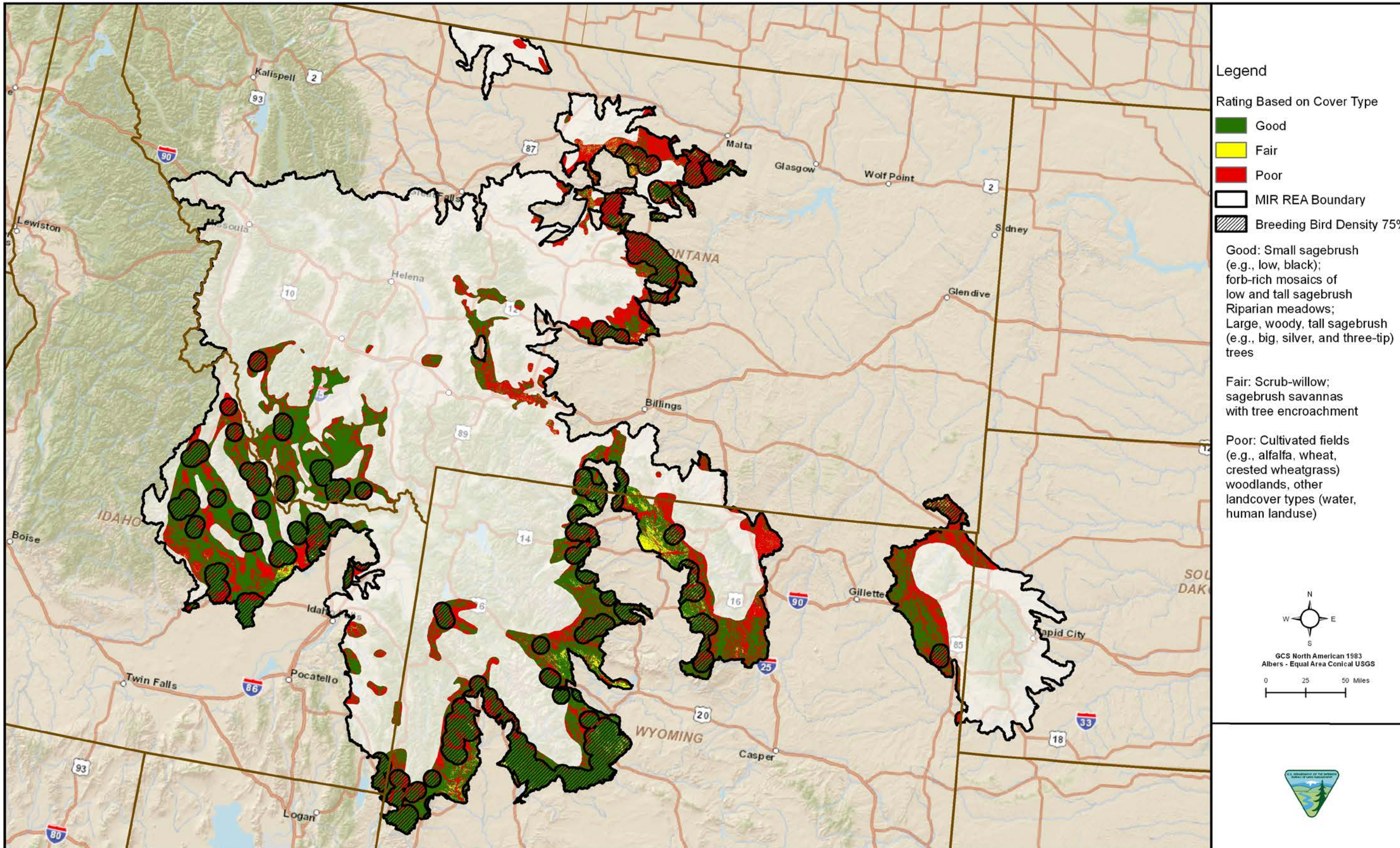

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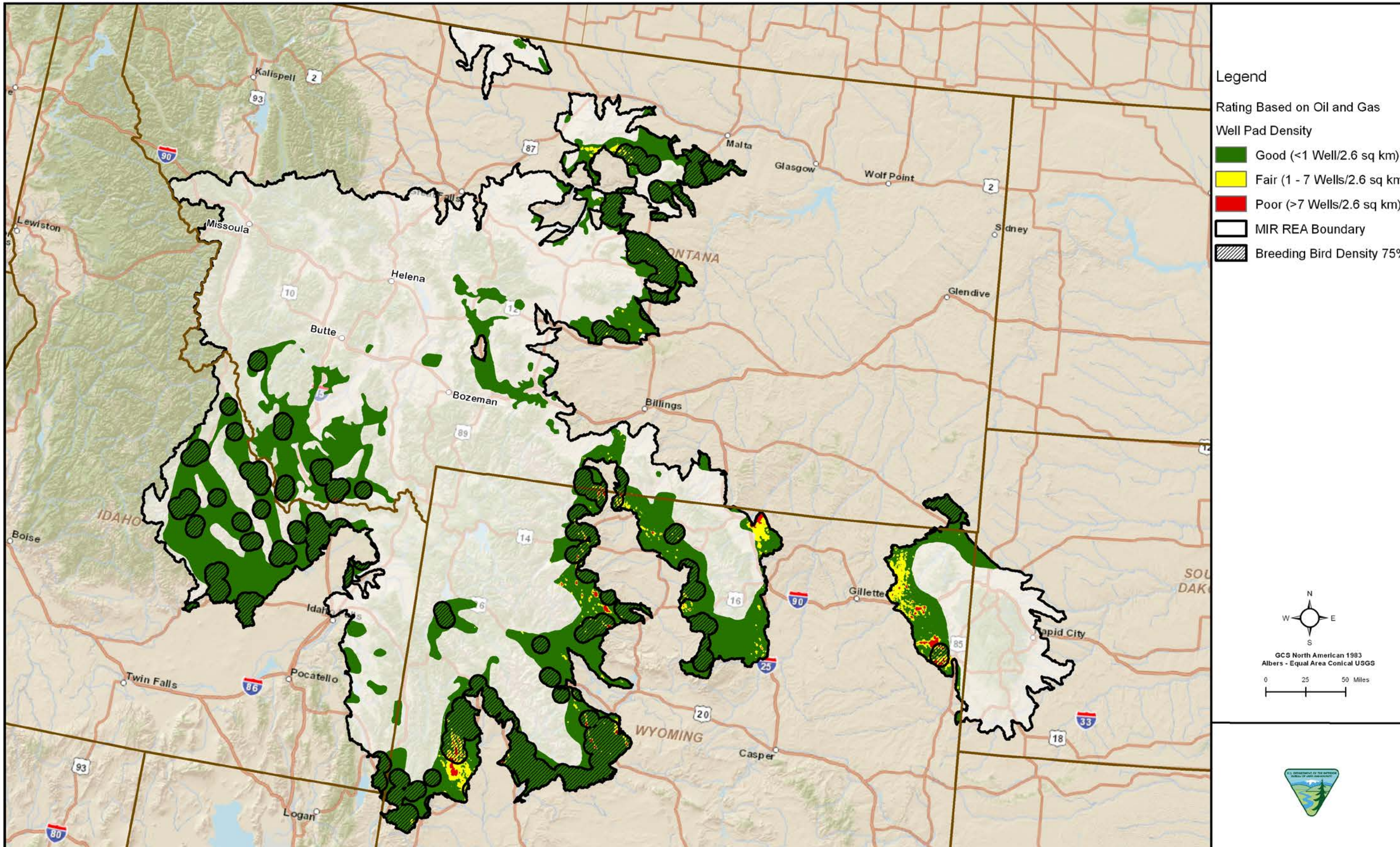

Figure E-2-8. Greater Sage-Grouse Oil and Gas Well Density 1 Square Mile

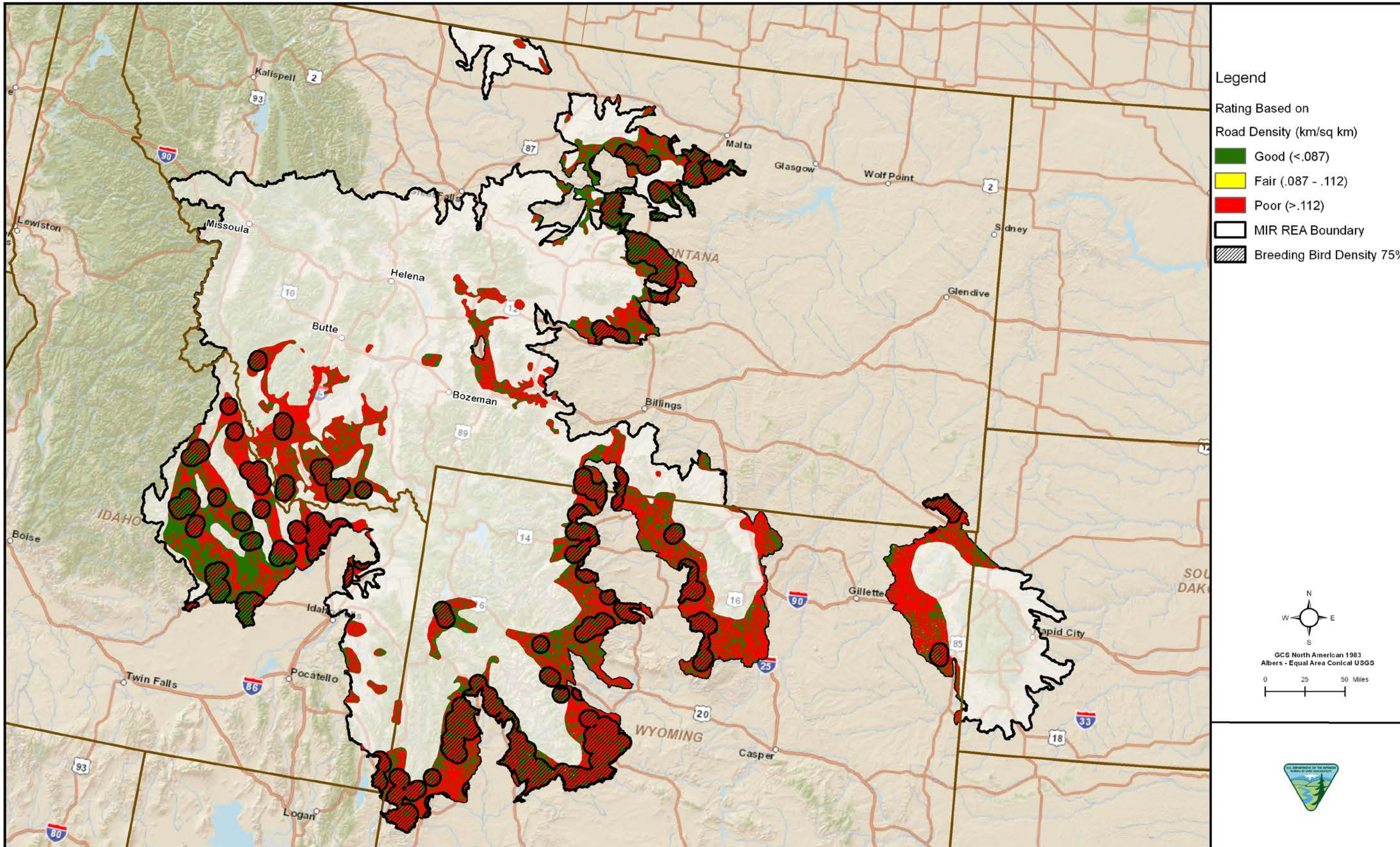

Figure E-2-9. Greater Sage-Grouse Road Density

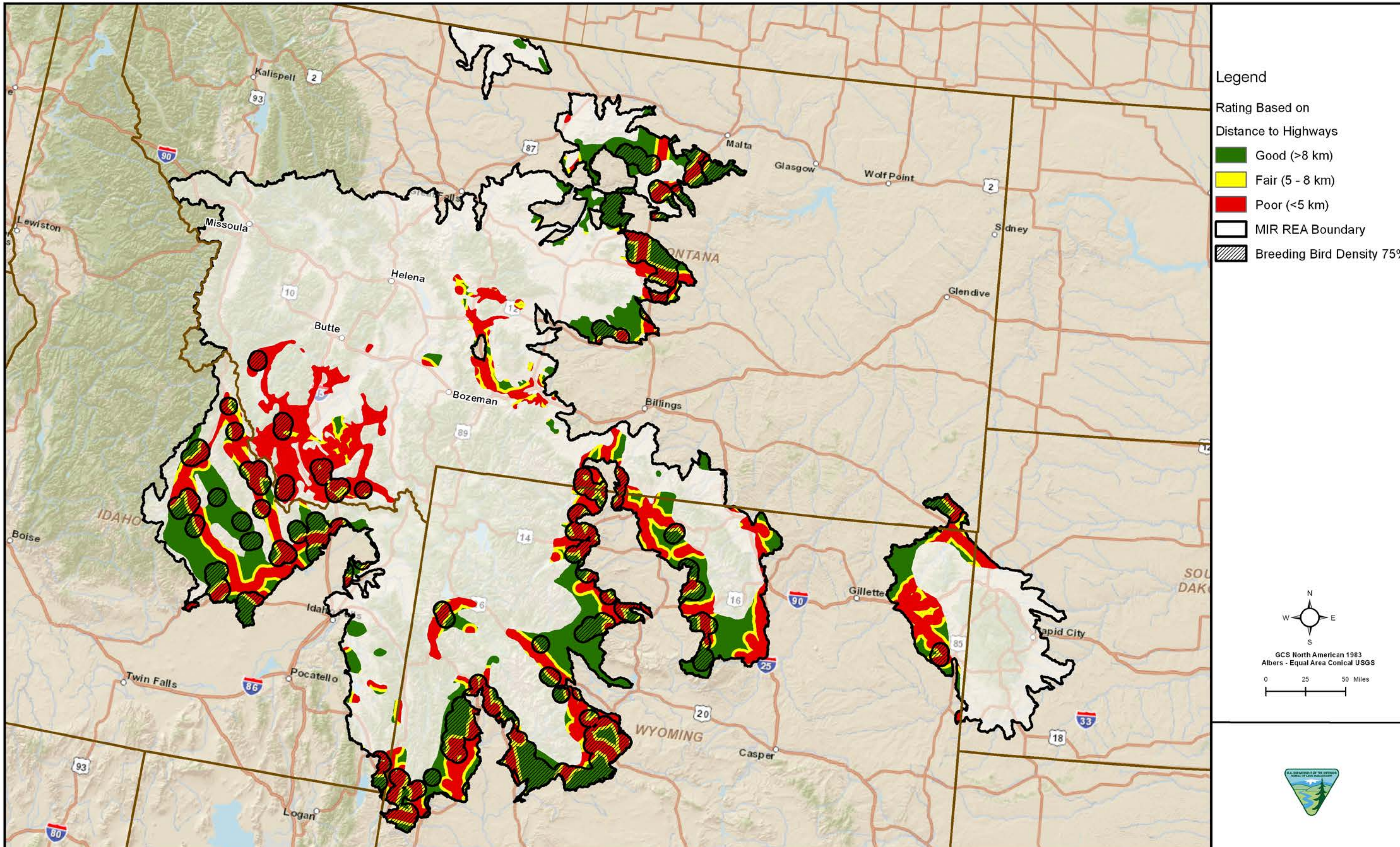

Figure E-2-10. Greater Sage-Grouse Distance to Highways

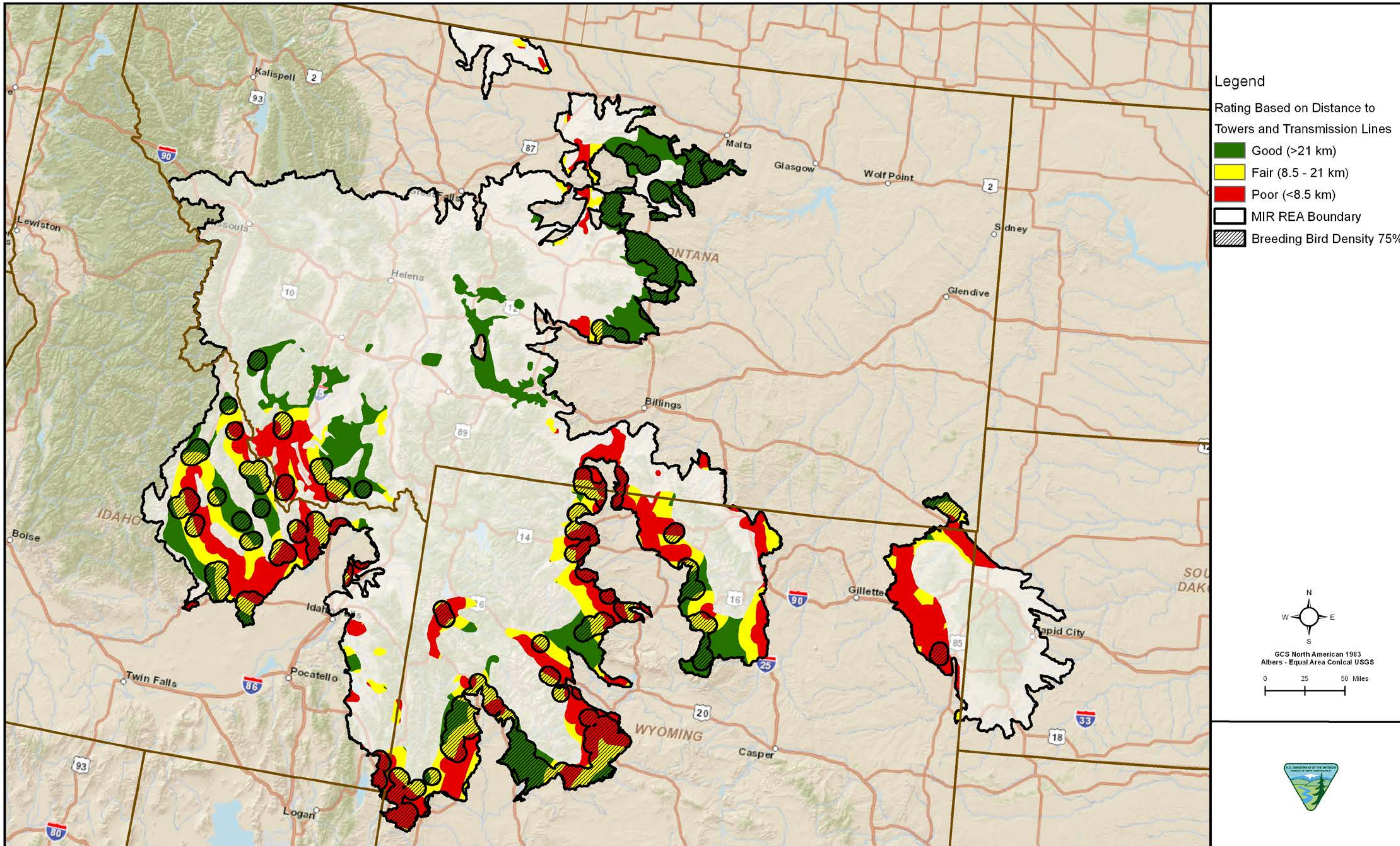

Figure E-2-11. Greater Sage-Grouse Distance to Towers and Transmission Lines

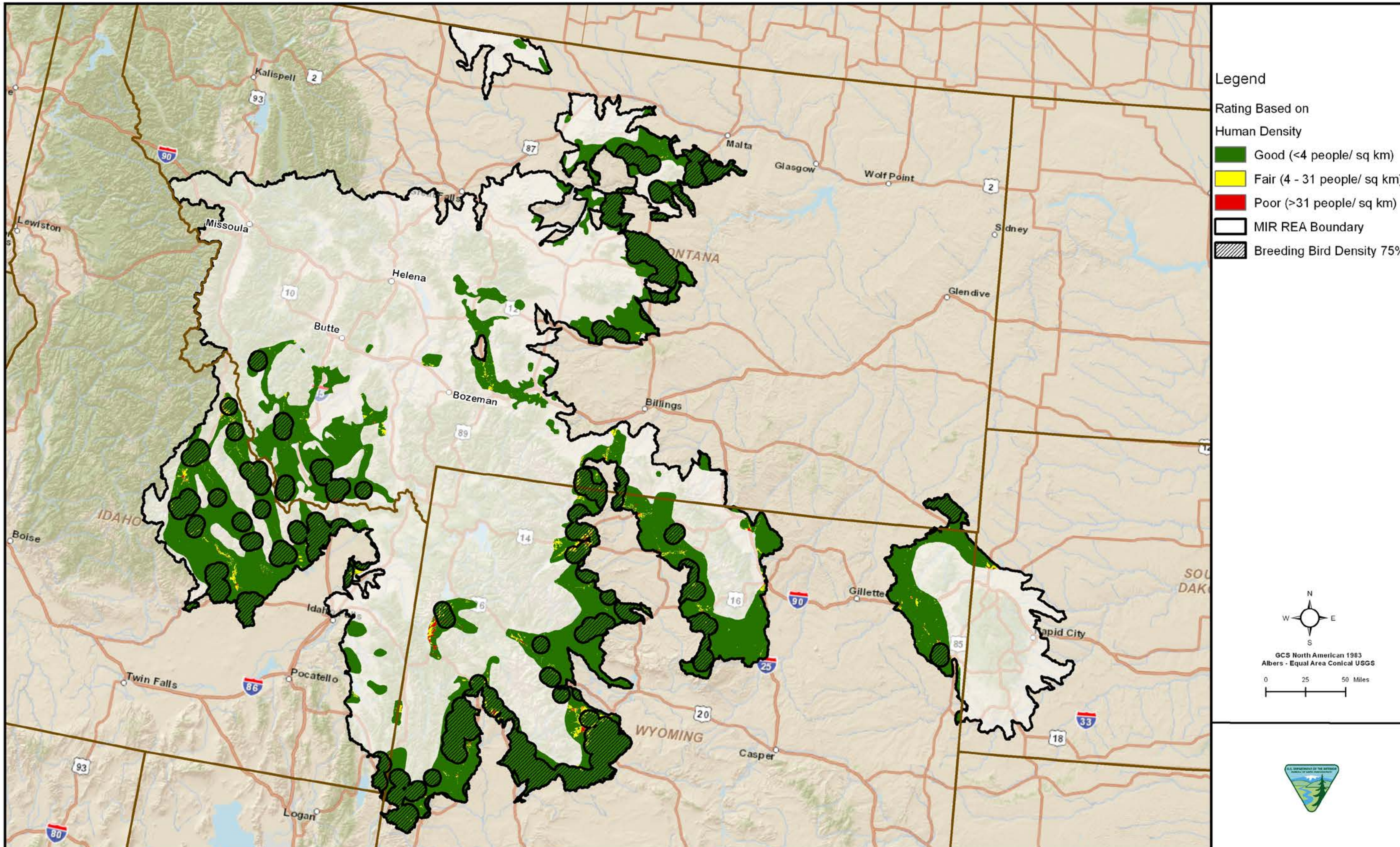

Figure E-2-12. Greater Sage-Grouse Human Density

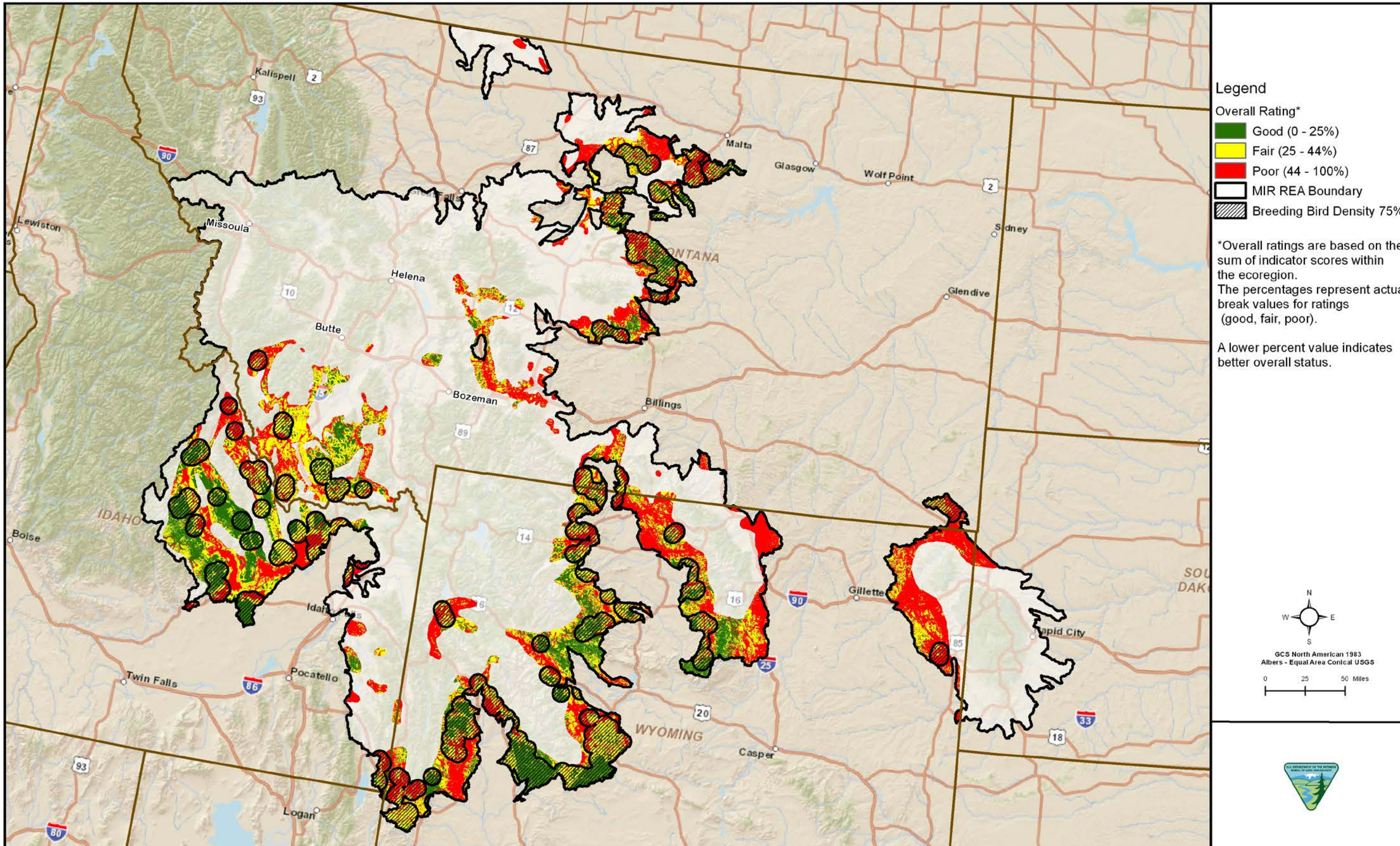

Figure E-2-13. Greater Sage-Grouse Figure Overlay

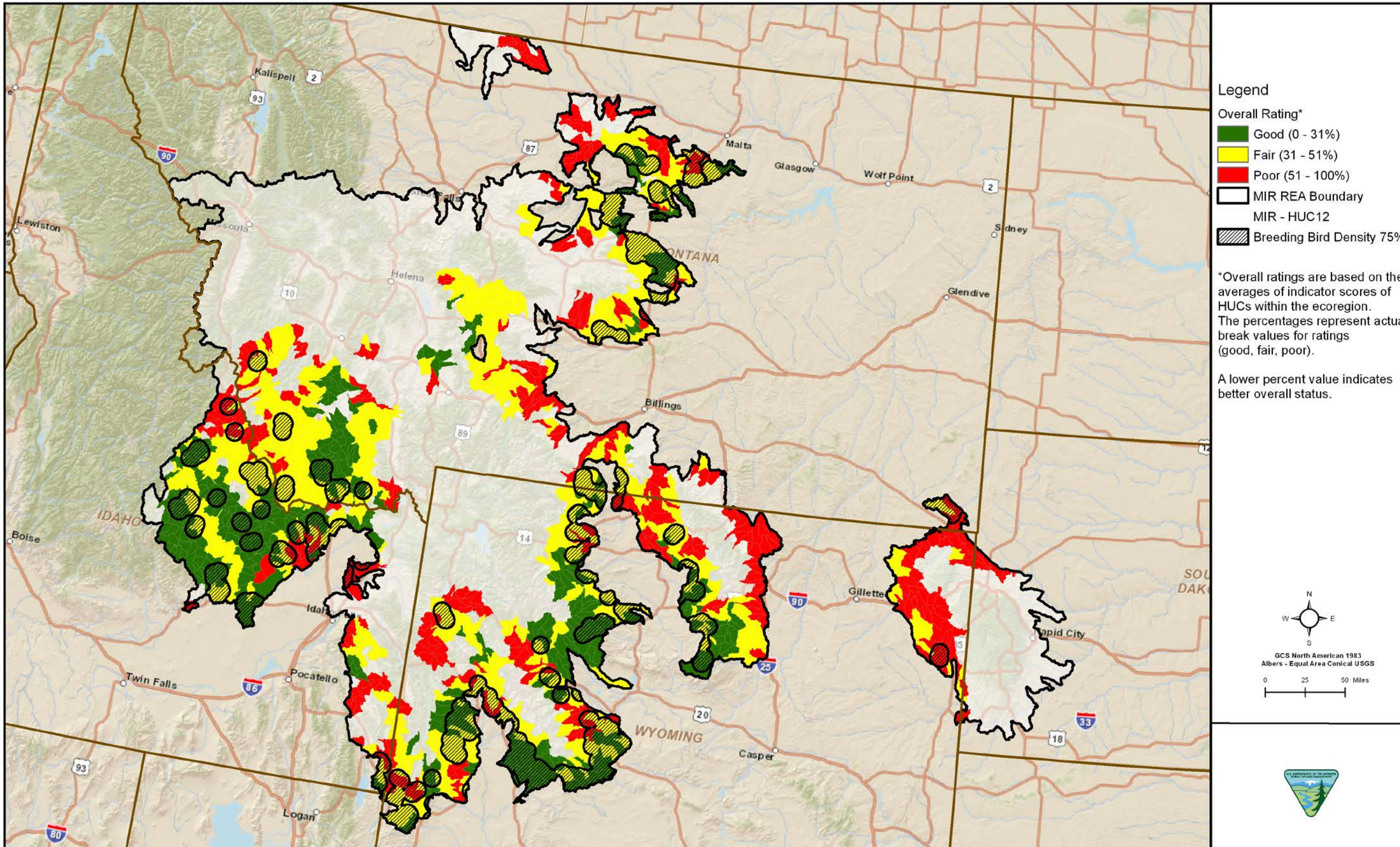

Figure E-2-14. Greater Sage-Grouse Overall Current Status

APPENDIX E-3

GOLDEN EAGLE CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

The golden eagle (*Aquila chrysaetos*) occurs year-round in the Middle Rockies (Kochert et al. 2002). Its status in the ecoregion likely reflects the status of the species on a larger scale, due in part to the dispersal of immature and non-breeding adults from outside the region to and throughout the Middle Rockies. In the western United States, the population of golden eagles has been conservatively estimated to be approximately 27,392 individuals. Despite this relatively high estimate, the population of golden eagles in the western United States is believed to be declining (Good et al. 2004). Due to management concerns and potential declining numbers, the golden eagle was defined as a species of concern for this Rapid Ecoregional Assessment (REA).

A variety of the management questions (MQs) apply to this conservation element (CE). Many of the MQs can be summarized into two primary questions: 1) where are the important areas for this assemblage? and 2) what is happening to those areas? The central focus of these two MQs is to document the current status of the golden eagle at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current and potential future change agent (CA) threats.

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2.0 CONSERVATION ELEMENT DESCRIPTION

The golden eagle is one of the widest ranging raptor species in the world, occupying the majority of the Northern Hemisphere. Despite its broad range, the species is declining throughout the world due to habitat loss. Although a generalist, specific habitat requirements must be met for the golden eagle to thrive. In the western United States, the golden eagle occupies habitat at elevations ranging from 4,000-10,000 feet (ft), with occasional nesting occurrences above 10,000 ft (Good et al. 2004). The species generally nests on cliff faces with varying aspect and height, but the golden eagle will also nest in trees along riparian corridors, occasionally on man-made structures (e.g. telephone poles), or on the ground. In one area in northeastern Wyoming, 86 percent of golden eagle nests were located in trees. Where tree nesting occurs, eagles generally select locations in the upper third of large trees on the edge of riparian areas that are associated with open grassland vegetation. Tree nesting has been documented in both deciduous and coniferous trees (Menkens and Anderson 1987).

Golden eagles are habitat generalists and as such are likened to vegetation communities through prey populations. The communities associated with the species are primarily limited in this ecoregion to open grassland and sagebrush steppe habitat. Golden eagles are considered generalist predators but rely mostly on mammals, particularly rabbits and ground squirrels (Kochert et al. 2002), with prairie dogs also recorded as locally important (Mollhagen et al. 1972).

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3.0 CONSERVATION ELEMENT DISTRIBUTION MODELING

The Maxent modeling program was used to determine the distribution of the golden eagle in the ecoregion. This model uses various geospatial environmental variables (i.e. climate variables, elevation, vegetation layer, etc.) and species occurrence data to determine the distribution of a species within a given area. The Maxent model layer was required for use in the assessment as a boundary to limit the output to those areas where golden eagles were currently nesting.

3.1 DATA IDENTIFICATION

Table E-3-1 lists the types of data and data sources that were proposed for use in the REA as part of the pre-assessment data identification effort. Suitable habitat models, point occurrence data, nest sites, and sensitive habitat data were proposed for use in defining distribution of the golden eagle in this ecoregion.

An evaluation of the available data was conducted to determine which data would be used for the Maxent modeling. State-derived distribution models for the golden eagle were not available for all states within the ecoregion. There is also a Western Governors' Association (WGA) Wildlife Council Crucial Habitat Assessment Tool (CHAT) underway that could generate models and datasets for the ecoregion; however, no data were currently available. In some cases, data were acquired but it was determined that other data were more representative for use in the REA (e.g. Christmas Bird Count, Breeding Bird Surveys).

The Bureau of Land Management (BLM) determined that nest site location data were the preferential data type to be assessed in the distribution model. Nest site point location data were obtained from each state for use in a Maxent distribution model. Data attributes varied widely from nest data to mortality data (i.e. road kills), and were inconsistent both on an interstate and intrastate basis. In several cases states only provided nest location data with no further attributes associated with the data. Additionally, the data varied greatly in accuracy with some data providing an estimate of the spatial quality of the data collection method. This attribute information was used to further remove data that appeared to show poor spatial accuracy. The initial datasets provided by the state agencies reflected a variety of spatial attributes, so some data culling and aggregation was required to create a uniform dataset.

Table E-3-1. Data Sources for CE Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Used in REA
Modeled Suitable Habitat	Gap Analysis Program (GAP) Habitat Models	U.S. Geological Survey (USGS)	Raster (30m)	Acquired	No[3]
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No[3]
	State-Derived Models	ID, MT, WY, SD State Agencies	Raster	Not Acquired	No[3]
	WGA Decision Support System (DSS) Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[1]
Point Occurrences	State Natural Heritage Databases	Natural Heritage Programs – ID, MT, WY, SD	Point	Acquired	No[2]
	eBird	Avian Knowledge Network	Point	Acquired	No[3]
	Breeding Bird Survey	USGS	Polygon	Acquired	No[3]
	Christmas Bird Count	Audubon	Point	Acquired	No[3]
Sensitive Areas	Audubon Important Bird Areas	Audubon	Polygon	Acquired	No[2]
	Bird Conservation Areas	Partners in Flight	Polygon	Not Acquired	No[2]
Nest Sites	Nests and Roosting Areas	BLM, ID, MT, WY, SD State Fish and Game Agencies	Point	Acquired	Yes

[1] Data gap
[2] Scale is inappropriate
[3] More representative data available for use

3.2 DISTRIBUTION MAPPING METHODS

Maxent modeling consists of using presence-only species occurrence data and a series of environmental raster layers (soil, temperature, elevation, etc.) to attempt to determine modeled habitat. During a model run, the species occurrence data are compared to the individual values within the environmental raster layers to evaluate the commonality among observations (training the model). Once these commonalities are established it can expand beyond locations of occurrences to find suitable locations based on the commonalities between data. The Maxent model output is a value between 0-1; the higher the number the higher the modeled area suitability. Maxent also allows for testing of the model to validate the accuracy of the predictions based on occurrence data and also provides various validation measures. Because Maxent is a standalone tool, geographic information system (GIS) process models will be used to extract, project and format the data into required formats for the model inputs and also convert them back to a GIS format for additional processing.

The intent of the REA modeling effort was to identify modeled habitat of breeding golden eagles within the ecoregion. Since Maxent uses species occurrence data, the Rolling Review Team (RRT) determined that the nest location data should be limited to 1990 to the present to be consistent with timeframes used by other CEs being modeled with Maxent. This substantially limited our data, but increased the likelihood of capturing active or recently-active nest site locations. Furthermore, because of the potential for multiple counting of a given nest site within the Maxent model, duplicate records (based on spatial coordinates) were removed from the occurrence (nesting) dataset. The total number of observations for golden eagle nests in the ecoregion was 238. Figure E-3-1 shows individual state contribution of occurrences to the Maxent model.

The raster output from the Maxent model provides cell values that provide information regarding the probability of modeled habitat. Several iterations of the model were run to determine the best fit for golden eagles. The main Maxent parameter that was modified was regularization. This parameter helps push the analysis out to areas without occurrence data so that the model is not over-trained on areas with closely clustered occurrence data. Montana Fish, Wildlife, and Parks had previously carried out numerous Maxent modeling efforts and were able to assist in the determination of the Maxent output format that best described presence/absence raster data for the golden eagle. The resulting Maxent output consists of data values ranked 0-1. The higher the value, the higher the suitability based on the environmental layers used.

The Maxent modeling software generates output files that describe what environmental variables contributed the most to generating the output model. Table E-3-2 contains the sixteen environmental variables used in the Maxent model with their contribution listed in the 'Percent Relative Contribution' column. The golden eagle Maxent model had rugosity, Parameter-elevation Regressions on Independent Slopes Model (PRISM) max temperature, and slope environmental layers as the highest contributors. Because most golden eagle nesting occurs on rocky outcrops and cliffs, these environmental variables in the Middle Rockies ecoregion are potentially of higher importance as temperature, slope and precipitation are good indicators of snowfall, which is an important factor affecting golden eagle nest site distribution. Reviewing what layers contribute the most and least may allow the Maxent model to be fine tuned by removing low contributing environmental layers but for the purposes of the REA this was not done.

The next step was to separate the Maxent output into groups that best describe various thresholds between low, moderate and optimal suitability. Through the advice of Montana Fish, Wildlife, and Parks and the BLM National Operations Center (NOC) Wildlife Habitat Spatial Analysis Lab, two possible methods were proposed for determining thresholds.

The first method was based on modeling done by Montana Fish, Wildlife and Parks that utilized a method that used validation generated by the Maxent model to determine where the model passed different thresholds. This method, based on work by Hirzel (Hirzel et al. 2006), focused on the location at which the predicted over expected frequency (P/E) ratio vs. logistic value crosses 1 (where the model started to perform better than random selection). This threshold became the moderate suitability threshold. The optimal threshold was determined by analyzing the P/E vs. logistic value curve for the location at which the increase in P/E is greater than the increase in logistic value. To help in determining these values, the BLM NOC Wildlife Habitat Spatial Analysis Lab wrote an ‘R’ script that was used to analyze the background predictions generated by Maxent. The R script generated a portable document format (PDF) output detailing the moderate and optimal thresholds (Figure E-3-2). The lowest suitability threshold was determined by calculating the 5 percent test omission rate. The test omission rate is another validation comma-separated file created by the Maxent software.

Table E-3-2. Maxent Environmental Variables for Golden Eagle

Environmental Variable	Maxent Variable Code	Percent Relative Contribution	Percent Permutation Importance
Rugosity	vrm_mr_90	22.9	6.2
PRISM Temperature (max)	prsmmaxt90	22.1	47
Slope	slope_mir_90m	12.3	0.2
PRISM Precipitation	prsm_pres90	11.6	8.4
STATSGO Soils	soil_mir_90	11.2	0.6
Elevation	ned_mir_90	5.9	17.2
Aspect (N/S)	aspns_mir_90	3.3	3.6
Solar Radiation (Summer Solstice)	sri_ss_mr_90	2.7	7.1
GAP Vegetation	gap_mir_90	2.5	0.8
LANDFIRE Vegetation	evt_mr_90	2.3	0.4
Solar Radiation (Equinox)	sri_eq_mr_90	1.8	7
Aspect (E/W)	aspew_mir_90	0.6	0.8
PRISM Temperature (min)	prsmmint90	0.3	0.6
Distance to Water	edw_mir_90	0.2	0
Solar Radiation (Winter Solstice)	sri_ws_mr_90	0.2	0
Geology	geol_mir_90	0.1	0

The second method was based on Maxent modeling by the Wyoming Natural Diversity Database (WYNDD). The low and optimal suitability thresholds were calculated from the sample prediction comma separated file generated by the Maxent modeling. The thresholds were calculated by ranking the logistic prediction of the samples used to train the model using the 5th percentile (low suitability) and 50th percentile (optimal suitability). Since this method uses actual training data, the thresholds are based on real data, and everything below the 5th percentile will be classified as unsuitable. The moderate threshold was the ‘Maximum training sensitivity plus specificity’ calculated by the Maxent software.

Based on two methods of determining thresholds, the modeling team (Science Applications International Corporation [SAIC]; BLM NOC Wildlife Habitat Spatial Analysis Lab; and Montana Fish, Wildlife, and Parks) determined the WYNDD thresholds (Figure E-3-3) to be the most appropriate break in the values for the golden eagle distribution model. The WYNDD model provided an output based on very low probability, low probability, moderate probability, and optimal probability of distribution. This model insured that all breeding eagles were included in the data layer. Table E-3-3 lists the thresholds for the golden eagle for both methods

Table E-3-3. Maxent Thresholds Calculated for Golden Eagle

Method	Measurement	Threshold	Value
MT / Hirzel	Test Omission Rate (0.05)	Low	0.002
MT / Hirzel	P/E =1 (R Script)	Moderate	0.079
MT / Hirzel	Δ P/E Ratio > Δ Logistic Value (R Script)	Optimal	0.705
WYNDD	5% Training Value	Low	0.01
WYNDD	Max. Training Sen. + Spec.	Moderate	0.073
WYNDD	50% Training Value	Optimal	0.31

To establish a modeled habitat map, the Maxent model output requires a binary display of what is modeled habitat and what areas did not result in a Maxent output. The RRT decided that combining the low, moderate, and optimal thresholds would be the best representation of golden eagle modeled habitat. These three thresholds were combined because it was the most inclusive. The Maxent output was then reclassified to show two classes, modeled and not potentially modeled habitat, as shown in Figure E-3-4.

The Maxent output distribution model (Figure E-3-4) was overlain with the nest site location points to visually inspect the relative accuracy of the model. Knowledge of the species natural history and the nest location data was used to infer the initial quality of the modeled output. The RRT, consisting of state and BLM specialists, reviewed the accuracy of the model based on their experience, regional knowledge, and the validation output generated by Maxent, such as area under the curve (AUC). Threat analysis outputs were correlated to reporting units that spatially contained distribution data.

4.0 CONCEPTUAL MODELS

The current status and potential future threat analyses were based on CE-specific ecological conceptual models, selected environmental variables (key ecological attributes [KEAs]) likely to be impacted by CAs, and the availability of data. CAs considered in this CE analysis include development and climate change.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model (Figure E-3-5) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that have the greatest potential to affect golden eagle habitat throughout the ecoregion.

The key processes are identified in the model as the green boxes and following Unnasch et al. (2009), three broad headings or categories of ecological attributes (EAs) (size, condition and context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat and context refers to the spatial structure of the habitat. At the landscape level, the EAs under the condition category will be the most challenging to spatially represent and will primarily depend on the data available to represent this category.

4.2 SYSTEM-LEVEL MODEL

The system-level conceptual model (Figure E-3-6) illustrates the interactions between the CAs and the primary habitat functions of this species. The three primary CAs for this CE are development, climate change, and wildfire which are identified across the top of the figure in red. The important factors (or “drivers”) affecting the abundance and distribution of golden eagle populations include those that impact territorial occupancy, productivity, and survivorship.

Although numerous attributes and indicators affecting this species were initially identified in an early phase of this REA, not all were included in this analysis. For some of the CAs, it was determined that either the attribute or indicator was not suitable for a landscape level analysis or data were not available to support the analysis. The specific indicators that could not be modeled are identified with an asterisk in Figure E-3-6. Further information on the data gaps for these indicators is discussed in the respective CA of Appendix C.

4.2.1 Development

The effect of human disturbance on golden eagle nesting remains largely understudied. The primary anthropogenic features likely affecting golden eagle populations are roads, wind turbines, transmission lines, and energy production and exploration activities (gas, oil, coal).

Roads play an important and complex role in the life history of golden eagles. Areas containing higher road densities are avoided as nest site locations by golden eagles (Steenhof et al. 1993). Roads not only increase mortality through collision with vehicles, but are often spatially associated with transmission lines, further increasing the likelihood of mortality. However, transmission lines offer suitable hunting perches and nest site locations.

The impacts of industrial development on golden eagles have not all been well documented, although power lines and wind turbines represent known sources of increased mortality (e.g., Anderson and Estep 1988, LaRoe et al. 1995, Harness and Wilson 2001). Wind turbines and transmission lines do not necessarily affect distribution of the species but are likely to increase mortality through electrocution and collision, thereby affecting habitat suitability (Delong 2004). Research in North America from the early 1960s to 1995 showed, in particular, that electrocution by power lines was the second greatest cause of mortality among golden eagles (LaRoe et al. 1995). Of 1,428 electrocuted raptors documented from 1986 to 1996 throughout the western United States, 748 (52 percent) were golden eagles. Electrocution is a serious factor affecting mortality in golden eagles. Sub-adult eagles occupy marginal habitat consisting of higher transmission line densities in areas that adult eagles tend to avoid (Delong 2004).

Although collisions with wind turbines are relatively high in some areas, attributing distance between wind turbines and golden eagle habitat is a difficult correlation to consider. In the Altamont Pass Wind Resource Area in California, a search for bird carcasses from 1998 to 2002 led to estimates of 67 golden eagles killed annually by the 5,400 wind turbines installed in that area (Smallwood and Thelander 2008). Hunt et al. (1997) assigned relatively arbitrary (<20 km for sub-adults; <30 km for adults) values to distance and found no significant difference at the scale used in the analysis. For the purpose of this REA, it seems prudent to use a more conservative approach in determining appropriate distance analysis between wind turbines and golden eagle habitat.

In areas experiencing oil and gas development, golden eagles may nest in close proximity to wells and compressors. To date, no research has been conducted to determine whether noise levels from compressors influences re-occupancy of nests or nesting success. Research on the influence of weapons testing noise on bald eagles in Maryland did not suggest any impact on nest success and productivity (Brown et al. 1999). Coal mining activities have been known to affect breeding populations of golden eagles (Platt 1984). Nests monitored at a coal mine site in Wyoming resulted in nesting failure for two eagle nests immediately adjacent to mining activities (Platt 1984; Delong 2004). Research on noise impacts on bald eagles in Arizona suggests that noise around nest sites is less important than other forms of human disturbance (Grubb and King 1991). However, no research has specifically investigated the impact of continuous noise on patterns of nest territory re-occupancy in golden or bald eagles. Although oil and gas activities were considered prior to analysis, the RRT determined that the potential effect from oil and gas development was probably minimal, as suggested by previous research (Grubb and King 1991). This dataset was eliminated from the analysis.

Agricultural activities also greatly affect golden eagle distribution (Marzluff et al. 1997; Beecham and Kocher 1975; Smith and Murphy 1973; McGahan 1968). As predators, eagle habitat is closely related to prey species. The primary prey species of the golden eagle inhabit predominately natural areas of shrubsteppe and grassland vegetation. Agricultural activities in these areas severely limit habitat use by golden eagles, as prey species habitat quality. Golden eagles are less likely to occupy grassland and sagebrush habitat fragmented by cropland (Delong 2004). A summary of golden eagles studies by Delong (2004) stated that in areas where agricultural land was available as habitat, eagles were sometimes present but not prevalent. Conversion of golden eagle habitat to agriculture will reduce the prey base for eagles and thus reduce the value of those areas as golden eagle habitat. Marginal habitat is occasionally used by breeding individuals if nest site locations are available and suitable alternative prey sources exist (Martzluff et al. 1997).

Hydrological features, such as rivers and streams, often influence the nest locations of raptor species (e.g. peregrine falcons). Golden eagles, however, do not appear to be limited in their distribution by this feature. Although distance to hydrological features has been considered in golden eagle studies, no correlation has been drawn between the two. It is likely that hydrology for other raptors species is closely associated with prey, rather than a direct requirement of a raptor. This has been intentionally omitted from the golden eagle model.

4.2.2 Climate Change

Climate change is one of the substantial potential threats that could affect golden eagle populations over time. Although there is a paucity of information on golden eagles and climate change in the Middle Rockies, numerous studies from outside the region address some key relationships among prey abundance and climate, as well as the impacts on golden eagle nesting and brood-rearing that likely apply throughout most of the species' distribution.

For golden eagles nesting at high elevations, the effect of temperature change on reproduction is important in determining nesting success. Near the Middle Rockies, in southwestern Idaho, Steenhof et al. (1997) investigated the joint influence of climate and jackrabbit abundance on nesting success of the golden eagle based on 23 years of data and observed that climate variables and jackrabbit abundance were found to often interact in their effects on the productivity of golden eagles. In that same study, jackrabbit abundance was positively correlated with the proportion of golden eagle pairs that laid eggs, the proportion of pairs that were successful, and mean brood size at fledging. Facka et al. (2010) reported the collapse of black-tailed prairie dog populations in the Chihuahuan Desert in relation to a drought. In southwestern Idaho, Smith and Johnson (1985) found reproductive success in the Townsend ground squirrel to be related to the availability of a fresh growth of grasses and ultimately to the amount of rainfall in the preceding fall and early winter. Jackrabbits also experience cyclical increases and decreases in abundance; however, these cyclical patterns are more complex and, in one study (Lightfoot et al. 2010), did not appear related to rainfall.

Steenhof et al. (2007) reported that winter severity negatively influenced the number of golden eagles that laid eggs the following spring, and that the number of hot days during the brood-rearing season negatively influenced both the percentage of pairs that successfully fledged young and mean brood size at fledging. The amount of snowfall present at nest sites dictates the ability of breeding eagles to rear young. Breeding pairs occupying nest sites in areas that receive annual snowfall greater than 500 centimeters (cm) do not reproduce, presumably because of remnant snow cover at nest sites (Delong 2004). In years of heavy snowfall (>500 cm) successful reproduction is substantially diminished.

4.2.3 Wildfire

Throughout the ecoregion, fire is an important factor in affecting vegetation communities and prey populations. Although fire plays a part in short-term effects on breeding populations, there is no correlation between fire and long-term effects on golden eagles. Increased temperature, leading to wildfires and destruction of natural habitat, is a substantial detrimental effect of climate change. Despite the potential negative effects associated with wildfire, positive effects to the golden eagle are also associated with wildfire. Fire has the potential to eliminate forested habitats and create clearings that golden eagles can use as alternative habitat, similar to habitat currently occupied by the species in its natural range in California and the eastern United States. Generalist species such as the golden eagle are readily adaptable, and despite the potential negative short term effects on the breeding population, it is likely that the species would reoccupy historical home ranges once the habitat has recovered (Kochert et al. 1999).

4.3 CHANGE AGENTS PROPOSED FOR ANALYSIS

Although numerous attributes and indicators affecting this species were initially identified in early phases of this REA, not all are included in this analysis. Analysis for the wildfire and invasive species CAs were not included for this CE because the direct effect indicators were determined to be data gaps, or because they were impractical to model at the ecoregional scale because appropriate geospatial data were not available. Climate change was analyzed using a qualitative approach, due to the scale of the climate change data. If possible, surrogate indicators that are available or better suited to geospatial analysis were used. The specific indicators that could not be modeled are identified with an asterisk in Figure E-3-6. Further information on the data gaps for these indicators is discussed in the respective CA analyses contained in Appendix C.

Analysis for the development and climate change CAs are included for this CE.

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5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the golden eagle was conducted for this ecoregion using the 6th level Hydrologic Unit Code (HUC) as the analysis unit. Based on the ecological process and system level models, KEAs were identified for the current status and future threat analyses, with a specific emphasis on the ability to measure impacts using existing geospatial data. Development and wildfire were evaluated as current status CAs for the golden eagle. The CAs evaluated for future threats include development and climate change.

Because the scale of the analysis is at the 6th level HUC, this layer was extracted for the ecoregion. GIS processes were iterated through the KEA indicators and determined the metric values associated with the 6th level watershed for some of the attributes. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the 6th level HUC layer. The intermediate CA layers were then combined to form a single layer outlining the current status or future threat status for each HUC.

5.1 CURRENT STATUS OF THE GOLDEN EAGLE

Table E-3-4 identifies the original KEAs that were proposed in Task 3 and identifies which of those were used in the final current status analysis. Not all of the KEAs proposed were used based on the rationale provided. Other KEAs were used but are not directly related CAs. For example, the KEA initially selected to assess the wildfire CAs were the fire regime and vegetation condition class (VCC) provided by the U.S. Geological Survey (USGS) (LANDFIRE 2010). Upon evaluation of the condition classes, the RRT did not agree that the attribute was a good indicator of golden eagle habitat. For this reason, the potential impacts of wildfire on golden eagle habitat could not be evaluated as part of the REA

Table E-3-4. Key Ecological Attributes Retained or Excluded

Category	Attribute	Explanation
1. Size	Extent of Suitable Habitat Patches	Retained to show the large patches of shrubsteppe and grassland habitat.
2. Condition	Wildland Fire Return Interval (FRI)	Excluded per RRT comments. This is not a good indicator of habitat quality for the golden eagle.
	Nesting Location Quality – Annual Snowfall	Excluded per RRT comments. Snowfall is more of an indicator of distribution than an indicator of a CA. Closely related to climate change.
3. Context	Connectivity	Excluded per RRT comments. Connectivity pertains more to migratory populations than to nesting populations.
	Road Density	Retained to show the anthropogenic impacts.
	Distance to Anthropogenic Features	Retained to show the potential effect of transmission lines on golden eagle mortality.
	Distance to Mining Activities	Excluded per RRT comments. Mining activity is not perceived to be a major CA to golden eagles.

Table E-3-5 identifies the KEAs, indicators and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion (as illustrated in Figure E-3-6). Several indicators were used to create a series of intermediate layers that are primarily based on the development CA and the geospatial data that was available.

Table E-3-5. Golden Eagle Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation	Weight
			Poor = 3	Fair = 2	Good = 1			
Size	Foraging Habitat	Extent of Suitable Habitat (% of HUC [a])	0- 46 [a]	47 - 77 [a]	78 - 100 [a]	GAP	Marzluff et al. 1997; Beecham and Kocher 1975; Smith and Murphy 1973; McGahan 1968	0.700
Landscape Context	Landscape Structure	Road Density (roads/km^2)	>10	5 - 9	<5	Linear Feature	Steenhof et al. 1993 & Professional Judgment	0.075
		Distance to Transmission Lines (km)	<1	1 - 5	>5	Transmission Line Locations/ BLM	Delong 2004; Professional Judgment	0.075
		Distance to Wind Turbines (km)	<10	10 – 16	> 16	Wind Turbine Towers	Hunt et al. 1998; USFWS Eagle Conservation Plan Guidelines	0.150

[a] Based on Natural Breaks for the GAP vegetation range in this ecoregion

5.1.1 Key Ecological Attribute Data Analysis for Current Status

For each of the KEAs listed in Table E-3-5, a discussion of the indicator, metric, metric rank and value, data source(s), and references is provided. Four indicators were used to assess the current status for the golden eagle. This table was limited to size and landscape context based on spatially available attributes and key factors affecting golden eagles in this ecoregion.

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. This process was carried out through the establishment of a golden eagle RRT comprised of BLM wildlife biologists and state-level golden eagle experts. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics, as well as to ascertain the accuracy of each step of the modeling process. Weights were attributed to each metric in order to provide an overall score for all metrics combined, based on the reporting unit.

5.1.1.1 Foraging Habitat

Vegetation is one of the key features that most substantially affects the distribution of the golden eagle. A vegetation data layer provides information pertaining to the breeding and feeding requirements for the species, nesting habitat, and prey species availability. Prey species (e.g. blacktailed jackrabbit, ground squirrel, etc.) are closely associated with open vegetation communities (i.e. grasslands and shrubsteppe). Vegetation data are also useful in identifying eagle nesting locations. Although eagle nests are closely associated with rocky cliffs, in the Middle Rockies the species also nests in riparian systems that border open grassland vegetation.

Foraging habitat was selected as a key indicator of prey availability for golden eagles. Reliable prey distribution data were not available; therefore, golden eagle habitat was used as a surrogate. The data source for the foraging habitat data layer was the 2001 Level 2 GAP landcover data. The GAP Level 2 data attribute extraction was part of an iterative process that aided in determining the best combination of Level 2 data that reflected actual habitat use by golden eagles and their prey. These attributes were determined through literature reviews and biological knowledge of the species. Some attributes (i.e. conifer-dominated forest and woodland) were included in this layer despite their lack of direct use by golden eagles in foraging activity because they where noted to be an important habitat resource for golden eagles in certain areas, specifically with regard to nesting (Baglien 1975, Seibert et al. 1976). In areas where conifers are adjacent to shrubland or grassland habitat, golden eagles use these areas as nesting and foraging habitat (Seibert et al. 1976). Table E-3-6 provides the Level 2 raster attributes that were extracted for this analysis.

Table E-3-6 GAP Level 2 Codes and Descriptions Extracted for the Golden Eagle Foraging Habitat Layer

Level 2 Code	Level 2 Description
32	Cliff, canyon and talus
33	Bluff and badland
45	Conifer dominated forest and woodland (xeric-mesic)
46	Conifer dominated forest and woodland (mesic-wet)
51	Alpine and avalanche chute shrubland
52	Scrub shrubland
53	Steppe
57	Sagebrush dominated shrubland
58	Deciduous dominated shrubland
71	Alpine grassland
72	Montane grassland
73	Lowland grassland and prairie (xeric-mesic)

The extent of suitable habitat was analyzed in relation to individual HUC units. The 12-digit HUC was used as the CE reporting unit for all species, and in the case of the golden eagle, it was also used as the analysis unit. This was the result of a lack of consistent information with regard to home range size in relation to the golden eagle. Past research has shown that home range sizes for breeding golden eagles range from 1.9 km^2 to as high as 92 km^2 (DeLong 2004). This indicator required a method for defining the metric values. The reporting unit (percentage of habitat in the HUC) was used as the determinant boundary, and the data derived from the reporting unit was used to determine the importance of habitat size within the 12-digit HUC. The Natural Breaks (Jenks) method of determining break points for low (46 percent), medium (77 percent), and high (100 percent) percentages per HUC using the spatial statistics created in ArcGIS was used to determine these metrics. Foraging habitat was assigned the highest weight (70 percent) based on its relative importance to breeding and foraging golden eagles (Table E-3-5). Figure E-3-7 shows the foraging habitat ranking by HUC.

5.1.1.2 Roads Density

The effect of roads within golden eagle habitat acts in a complex relationship with regard to foraging and mortality. Despite the potential for increased foraging habitat along roadways, the RRT attributed roads to high mortality rates based on the mortalities commonly associated with traffic collision and illegal shooting. Additionally, areas of greater road densities indicate greater human activity and are therefore a probable indication of lower nesting suitability.

Road density models were created in ArcGIS based on the number of roads per square kilometer. TIGER data for all road types were used to create this layer, which was then clipped to this ecoregion boundary. The limitations of the TIGER data are discussed in Appendix C-1. The variation in road attributes among states precluded an efficient method of selecting roads by size and/or type.

The roadway density (number of roadways per km2) within the HUC was calculated, and relative rank as good, fair, or poor (as noted in Table E-3-5) was assigned. The metrics used for this indicator were derived from Steenhof et al. 1993 and professional judgment. If the road density was less than 5 roads per km^2, then the HUC was ranked as good and received a metric score of 1. If the road density was between 6 and 9 per km^2, then a rating of fair with a metric score of 2 was assigned. If the road density was 10 or greater per km^2, then a rating of poor with a metric score of 3 was assigned. Road density was assigned one of the lowest weight ratings (7.5 percent). The RRT determined that although road densities have a negative impact on golden eagles, some positive associations can also be attributed to this key attribute.

The road density analysis was reported in relation to individual HUC units (Figure E-3-8). The 12-digit HUC was used as the analysis unit and reporting unit for this metric.

5.1.1.3 Distance to Transmission Lines

Transmission lines play a role similar to roads in the life history of the golden eagle in the western United States. They are important to the species as a foraging perch in areas with few trees, yet they are responsible for high mortality rates through electrocution (Boeker and Nickerson 1975, DeLong 2004). Electrocution is a serious factor affecting mortality in golden eagles, but it has less of an effect on species distribution. Sub-adult eagles occupy marginal habitat consisting of higher transmission line densities in areas that adult eagles tend to avoid (Delong 2004). Therefore, distance to transmission lines is considered in this assessment as an indicator associated with higher mortality and poor landscape structure.

Transmission line data were obtained for major utility lines within this ecoregion. These transmission lines are generally greater than 115 kilovolts (kV) and tie major power plants to the electrical grid. Minor transmission line (e.g. neighborhood electrical lines, etc.) data were not available for use in this analysis.

Transmission line information with regard to the assigning of metrics was difficult to obtain. Therefore, after review of the literature, the RRT experts determined an appropriate distance to transmission lines for use in this metric. The Euclidean distance tool in ArcGIS was used to derive the distance calculations for this attribute and its associated metrics. Distance in km to transmission lines within the HUC was calculated, and relative rank as good, fair, or poor (as noted in Table E-3-5) was assigned. Transmission line density was assigned one of the lowest weight ratings (7.5 percent). The RRT determined that the impact of this attribute on the golden eagle was similar in many aspects to the road density analysis and should therefore be assigned a similar weight.

The transmission line analysis was reported in relation to individual HUC units. The 12-digit HUC was used as the analysis unit for this metric. This was the result of a lack of available information with regard to the effect of transmission line distance to golden eagle nesting habitat. The output from this analysis is shown on Figure E-3-9.

5.1.1.4 Distance to Wind Turbines

Wind turbines are an important factor affecting golden eagle mortality (Hunt et al. 1995, Hunt 2002) and therefore can be used to define the integrity of the landscape structure for this CE. The U.S. Fish and Wildlife Service (USFWS) and its partners have developed a “Draft Eagle Conservation Plan Guidance” (USFWS 2011) that outlines the current relationship between golden eagle mortality and wind turbine prevalence. The guidance document provided the basis for the metrics for this indicator.

The USFWS provided a compiled dataset for wind turbine locations and test towers throughout the United States. These data were clipped to this ecoregion, and point occurrence data were limited to wind turbines for use in this analysis. Distance in miles to wind turbines within the HUC was calculated, and relative rank as good, fair, or poor (as noted in Table E-3-5) was assigned. The wind turbine KEA was assigned a weight of 15 percent because of the high rate of mortality for golden eagles inhabiting areas currently occupied by wind turbines, but the indicator was not given a greater weight overall because wind turbine locations are currently limited to smaller areas within the ecoregion. As wind turbines increase throughout golden eagle habitat, they will likely have a substantially greater effect on the overall population of golden eagles. Figure E-3-10 presents the results of this model.

5.1.2 Current Status of Habitat

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of golden eagle habitat of each 12-digit HUC across this ecoregion. A method of aggregating scores was used to summarize overall current status with regard to golden eagle habitat quality. Individual CAs can identify areas of potential risk to golden eagle populations, but aggregated scores can provide important information with relation to areas where golden eagles might encounter multiple CAs.

In order to create a current status data layer, an overall score for each HUC unit was calculated. Based on each KEA rating of good, fair, or poor, an HUC quality rank score was subsequently assigned to the KEA. If the KEA rating was good, then the HUC quality rank score of 1 was assigned (Table E-3-7). In some cases, the KEA was assigned a varying weighting factor based on varying levels of importance of each KEA (as noted in Table E-3-5). The HUC quality rank score was then multiplied by the weighting factor for the KEA, and the total score was averaged (Table E-3-8).

Table E-3-7. Hydrologic Unit Code Quality Ranking Scores

HUC Quality	Rank
Good	1
Fair	2
Poor	3

Table E-3-8. Example of the Weighted Method of Scoring for 12-Digit Hydrologic Unit Code

Threat	HUC Quality Rank	Weight	Score
Foraging Habitat	3	0.700	2.1
Roads	2	0.075	0.15
Transmission Lines	1	0.075	0.075
Wind Turbines	2	0.150	0.3
Overall Threat Score (Averaged)			0.656

The overall threat score for each HUC was assigned a current habitat quality rating of good, fair, or poor, based on the natural breaks method. A higher overall threat score would result in a rating of poor for the HUC, indicating that there are existing threats to the eagle habitat based on the KEA metrics.

The results of the current status analysis for the ecoregion are presented on Figure E-3-11. The current overall status of the golden eagle is fairly stable across its entire distribution range, with a slight decline in population in the western United States (USFWS 2011). In this ecoregion, substantial habitat currently exists to sustain good populations of breeding golden eagles. Figure E-3-7 indicates that the majority of the ecoregion maintains suitable habitat for golden eagles, with only small areas within northeastern Idaho and west-central Montana indicating potential habitat loss. The effect of roads on golden eagles in this ecoregion is minimal, generally localized around larger population centers, and does not pose a current substantial threat to populations across the ecoregion (Figure E-3-8). Transmission lines exist throughout large portions of this ecoregion, and Figure E-3-9 shows a substantial extent of the ecoregion as fair with regard to these lines. However, because the transmission lines themselves are relatively small (spatially) in relation to the ecoregion, it is likely that the effect from transmission lines on breeding populations of golden eagles will have less of an effect than that which is displayed on this figure. Only a small portion of the ecoregion exists in areas where proximity to transmission lines is a substantial threat. The threat of wind turbines in this ecoregion is a concern for localized golden eagle populations (Figure E-3-10). Wind turbine threats represent a substantial portion of this ecoregion and are a current threat to the golden eagle population in western Montana, northeastern Idaho, eastern Wyoming, and western South Dakota. The overall current status of the golden eagle in this ecoregion in the context of this assessment is good to fair

(Figure E-3-11). It is important to note that the locations receiving the lowest scores in this assessment are those areas in close proximity to urban areas. The majority of this ecoregion (with the exception of very high elevation areas) is inhabited by golden eagles and provides suitable habitat for the species.

A summary of the current status ratings based on the CE distribution is provided in Table E-3-9. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that nearly 65 percent of the 6th level HUC watersheds that intersect the distribution layer for the golden eagle received a good rating. Only a 6.7 percent of the total land area in use by the golden eagle within ecoregion received a poor rating.

Table E-3-9. Summary of Current Status Ratings for the Golden Eagle

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	69,198	65.2
Fair	29,808	28.1
Poor	7,056	6.7

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 FUTURE THREAT ANALYSIS

The system-level model (Figure E-3-6) was used to create a series of intermediate layers that are primarily based on the geospatial data that were available on the future projections for the development CA and climate change CA. Future threats were evaluated for development for a short-term time horizon (5-10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069).

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than to a specific time period) for these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their effect on golden eagle populations.

5.2.1 Development Change Agent

Future spatial data for development were limited to the future potential for energy development, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1. KEAs used to define future threats from development are presented in Appendix C-1.

5.2.1.1 Agricultural Growth

Agricultural activities are detrimental to golden eagle distribution, and, as human populations increase, it is expected that the demands of a larger human population will require additional agriculture.

Because no future agricultural models exist for use within this ecoregion, a model was created using surrogate data to derive potential agricultural areas. STATSGO data were used to determine potential agricultural soil types. The appropriate soil types for use in this classification are types 1 through 4, which are shown on Figure C-1-1 in Appendix C-1. No specific future time period was considered in this analysis (e.g., 2025 or 2060). This analysis considered the maximum potential for future agricultural areas within this ecoregion.

Figure C-1-1 shows the results of the analysis, indicating potential habitat loss due to potential future agricultural land development. In this ecoregion, only a small portion of the areas occupied by golden eagles will potentially be affected by future increases agricultural activity. There is potential for small changes in the distribution of breeding golden eagles in some areas, but overall, the population is likely to remain unaffected.

5.2.1.2 Future Growth of Urban Areas

Urban growth affects golden eagle habitat with impacts similar to those of agricultural activities. In this ecoregion, a small portion of the area that is inhabited by golden eagles is currently in close proximity to urban/suburban populations. Urban growth, as noted by increasing population trends, impacts a variety of species; the golden eagle may be susceptible to habitat loss in near-term and long-term temporal periods.

The Integrated Climate and Land Use Scenarios (ICLUS) model is a universally accepted model, created by the U.S. Environmental Protection Agency (USEPA) for use in future climate change modeling, that provides spatial data that can be used to determine the future extent of urban areas for various time periods. The model uses U.S. Census data to predict urban growth. The ICLUS future urban extent for the year 2060 was used in this analysis.. The ICLUS urban area footprint for 2060 was used to assess its association with golden eagle distribution areas. Figure C-1-8 shows the results of the analysis.

Golden eagle habitat areas in this ecoregion are mainly affected by urban growth in the major urban centers (e.g. Rapid City, South Dakota; Bozeman, Helena, and Missoula, Montana; Idaho Falls, Idaho; etc.). However, these areas are minimal in size with regard to the distribution extent of the golden eagle and are unlikely to greatly affect the population of the golden eagle in this ecoregion. The possible exception to this would be localized populations within the immediate vicinity of these urban centers.

5.2.1.3 Oil Production Potential

Oil production potential was not characterized in this analysis as a current threat to golden eagles. Although oil production activities were considered prior to analysis, the RRT determined that the potential effect from current oil well locations was minimal, as suggested by previous research (Grubb and King 1991). Other CAs associated with disturbance to golden eagles (e.g. road proximity, transmission lines, etc.) were assessed in the current analysis, but unavailable for assessment in the future analysis.

This future analysis characterized the future potential for oil production rather than oil well locations (Figure C-1-4). These larger oil production extents can be used to qualitatively assess the potential effect of future oil production activities. Although these areas are based on oil density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential oil production areas on golden eagle populations.

Most of the golden eagle populations in the ecoregion will likely remain unaffected by oil production. The majority of potential oil production is limited to Wyoming in the northern portion of the Green River Basin, a small portion of the Wind River Basin, a small portion of the Tongue/Powder River Basin, and a small portion of the Cheyenne/Belle Fourche River Basin. There is potential for some risk to golden eagle populations from this CA in Wyoming, but the overall distribution of the species is expected to remain unaffected by oil production.

It is important to note that the Energy Policy and Conservation Act (EPCA) oil and gas data used in this assessment are based on the maximum potential for oil and gas reserves within this ecoregion. As a result, these data are likely over represented in these figures, and care should be taken in assessing the effects of oil and gas production within the constraints of this analysis.

5.2.1.4 Natural Gas Production Potential

Natural gas production potential was not characterized in this analysis as a current threat to golden eagles. Although gas production activities were considered prior to analysis, the RRT determined that the potential effect from current gas well locations was minimal, as suggested by previous research (Grubb and King 1991). Other CAs associated with disturbance to golden eagles (e.g. road proximity, transmission lines, etc.) were assessed in the current analysis, but were unavailable for assessment in the future analysis.

The future analysis characterized potential gas production areas rather than gas well locations (Figure C-1-3). These larger gas production extents could be used to qualitatively assess the potential risk to habitat from future potential gas production activities. Although the future potential for natural gas production is based on gas density data, the application of these data to future potential well site activity is unknown. Therefore, a carefully considered approach should be taken when assessing the effect of potential gas production areas on golden eagle populations.

Most of the golden eagle populations in the ecoregion will likely remain unaffected by gas production. Future potential natural gas development is limited to Wyoming in the northern portion of the Green River Basin. There is potential risk from this CA for some golden eagle populations in Wyoming, but the overall distribution of the species is expected to remain unaffected by gas production.

5.2.1.5 Solar Energy Potential

The effect of solar photovoltaic arrays on golden eagles is similar in function to the effects of any anthropogenic disturbance. Future solar energy development is not likely to directly affect the golden eagle through higher mortality rates, but it could be responsible for displacing prey habitat or suitable nesting habitat. The USFWS considers any anthropogenic disturbance as a potential threat to golden eagles (USFWS 2011), and treats all renewable energy resources as a similar threat to the species. Because spatial distribution of a solar array is the key factor affecting golden eagles, a reliable assessment from the available National Renewable Energy Laboratory (NREL) model (Figure C-1-6) is difficult and can only be generalized for the purposes of this analysis.

The slope and elevation associated with this ecoregion are likely to eliminate substantial areas from future solar energy development. Similarly, golden eagles utilize the more rugged areas of the ecoregion as habitat. This increases the potential for limited interactions within the ecoregion. However, in areas where foothills and less-rugged mountainous terrain exist, there is potential for habitat displacement. The most likely areas for potential effect from solar energy in this ecoregion are the foothills and areas surrounding the Absaroka Range, the Wind River Range, the Bighorn Mountains in Wyoming, the Black Hills in South Dakota, and the ranges surrounding the Snake River Plain in Idaho.

5.2.1.6 Wind Turbine Potential

The USFWS wind turbine data contained attribute information for current and future wind turbine locations. However, the future turbine locations dataset was very limited in number, because most turbines will presumably be erected in the very near future. Therefore, an alternative dataset was used to determine the potential areas for wind turbine development over a long-term period. The future potential for a wind turbine development layer was based on the availability of suitable wind speeds.

Data characterized by the NREL was used to create a potential future wind turbine development data layer. A full description of the methods and processes implemented to create this data layer and its corresponding scoring system can be found in Appendix C-1.

The potential threats to golden eagle habitat based on future wind energy development are presented in Figure C-1-7. Higher elevations within this ecoregion are more susceptible to the threat of wind turbine development due to the higher wind speed levels within these areas. However, limited accessibility to these higher elevations may limit the range of future wind energy development to lower-elevation mountainous regions. Throughout the ecoregion, many of these areas are inhabited by nesting golden eagles. There is substantial potential for a negative effect on golden eagles as a result of the potential wind energy development in these areas. Although this assessment is primarily qualitative, the spatial distribution of the golden eagle and mid-level elevation potential wind turbine development overlap is apparent. There is potential for a substantial negative effect on golden eagle populations within this ecoregion if wind energy development increases in these areas.

5.2.1.7 Overall Development Change Agent Future Threats

The future overall score was compiled by averaging the values associated with each of the two energy types: renewable and fossil fuels. Future potential agriculture and urban areas were characterized as binary functions, and further assessment of these attributes based on the values associated with each was not possible in this analysis.

A future potential fossil fuel energy development layer was created to address the MQs associated with future fossil fuels production. This layer was created by averaging the EPCA oil data layer with the EPCA gas data layer (Figure C-1-2).

Most of the golden eagle populations in the ecoregion will likely remain unaffected by fossil fuels development in this ecoregion. The majority of future potential for fossil fuels development is limited to Wyoming in the northern portion of the Green River Basin, a small portion of the Wind River Basin, and a small portion of the Tongue/Powder River Basin. There is potential for some effect on golden eagle populations in Wyoming, but the overall distribution of the species is expected to remain unaffected by fossil fuel development.

A future renewable energy development layer was created to address the MQs associated with future renewable energy development. This layer was created by averaging the NREL wind speed data layer with the NREL solar energy data layer (Figure C-1-5).

This output layer gives equal weigting to potential wind and solar energy development areas, and could therefore mischaracterize the effects of each. Unlike oil and gas, wind and solar energy are not necessarily closely associated with one another spatially. Photovoltaic solar arrays threaten the species by their effect on habitat availability. Solar arrays are diverse in scope and size, and it is therefore difficult to create a clear correlation between habitat loss and solar energy production. The potential substantial effect of wind turbines on the mortality of golden eagles is directly correlated. In areas in which wind turbine production overlaps golden eagle distributions, substantial mortality can be attributed to wind turbines (Hunt et al. 1995; Hunt 2002). As a result, it might be beneficial for managers to consider wind and solar energy development as separate entities when determining the effects of renewable resources on golden eagles.

Because of the intricacies involved in the assessment of renewable energy production with regard to golden eagle populations, a limited approach must be taken in this analysis. A large portion of the Middle Rockies golden eagle habitat is rated at moderate risk for renewable energy development. In most of the assessments for golden eagle, areas that were considered high risk were primarily described as having a potential negative effect. These areas are limited to the southeastern portions of the Middle Rockies ecoregion. However, because of the large area represented as moderate risk, it is important to consider these areas as having the potential for a considerable long-term effect on golden eagle populations in areas in which renewable energy development occurs.

5.2.2 Climate Change Future Threats

5.2.2.1 Ecoregion Climate Change Analysis

From a climate change perspective, the relationship between temperature, precipitation, and prey species of the golden eagle is the factor that most affects the species distribution, and to some extent, nesting success. Based on the analysis conducted for the ecoregion (as presented in Appendix C-5), there are potential climate change conditions that could dramatically affect localized populations of golden eagles, especially at high elevations within the ecoregion.

The golden eagle predominately preys on a variety of small mammals, but throughout most of its western range, the black-tailed jackrabbit is its prey base. A constant overall increase in temperature is expected across the golden eagle range within the Middle Rockies (1.9 degrees Celsius [°C]-2.4°C). Temperature increases over time resulting from climate change will most likely result in increases in wildfire potential, which will directly affect golden eagle prey availability. Across this ecoregion, annual precipitation is predicted to be highly variable around the 2060 timeframe. Most of the region is expected to experience a mild increase (25-75 millimeter [mm]) in annual precipitation, or no annual change in precipitation. Several small pockets of increased annual dry periods are expected to occur in the Bighorn Mountains (decrease to 93 mm) and the Great Divide Basin (decrease to 74 mm) in Wyoming. Pockets of increased annual precipitation (76-99 mm) are also expected in major river bottoms such as the Yellowstone and Missouri Rivers. Bronson and Tiemeier (1959) found substantial shifts in populations of black-tailed jackrabbits in areas of decreased precipitation. Jackrabbits used habitat that was located along the periphery of river and stream drainages. Populations increased dramatically in these areas and even reached carrying capacity in some locations.

Golden eagles could potentially adapt in various ways to climate change. A very likely scenario would be a shift in nesting periods. As snowfall decreases in April and milder spring periods occur more regularly, it is likely that golden eagles will begin to nest earlier, especially in mountainous regions where snowfall is expected to decrease. A geographical response from golden eagle populations is also possible on a macro and micro level. The entire breeding population of golden eagles could potentially shift northward, increasing the overall population in Canada and Alaska. More likely, there will be a substantial micro-population shift. Golden eagles maintain numerous nest sites within a breeding season home range (Beecham and Kochert 1975). It is possible that golden eagles will simply increase the number of nest sites within these home ranges to take advantage of microclimates within current home ranges. Eagles might simply nest at higher elevations or move to areas near hydrological features where temperatures are lower.

Climate change presents many different issues relating to golden eagle foraging and nesting. However, it remains difficult to draw conclusions from the data presented in this REA. Climate change models are highly variable and often difficult to predict. In this case, the resolution of the spatial data is an important factor to consider. Additionally, the golden eagle is a highly mobile species that is uninhibited by most man-made and geographical features. Like all raptor species, golden eagles are highly adaptable and often able to compensate for climatic variation.

5.2.2.2 NSCCVI

The NatureServe Climate Change Vulnerability Index (NSCCVI) tool was utilized to assess golden eagle vulnerability to the effects of climate change. Using annual raster datasets from NatureServe to perform climate change calculations in ArcGIS (through the Predicted Temperature 2040-2069 [Fahrenheit (F)] and the Predicted Hamon ratio of actual evapotranspiration to potential evapotranspiration [AET : PET] Moisture Metric 2040-2069 datasets), the NSCCVI calculator was applied and produced an index score of not vulnerable/increase likely. The NSCCVI tool indicated that available evidence suggests the abundance and/or range extent of this species within the geographical area assessed is likely to increase by 2050. The assessment rating was largely based on a majority of neutral and somewhat decreased vulnerability scores calculated when assessing factors that influence vulnerability, such as dispersal and movements, sensitivity to changes in historical thermal niche, dependence on ice or snow-cover habitats, reliance on interspecific interactions to generate habitat, and dietary.

6.0 MANAGEMENT QUESTIONS

The relevant MQs for the golden eagle include those defined as part of the Landscape Species/Species Richness category. The overall MQ was: Where are the key habitat types (seasonal, refuges, corridors/connectivity, migration routes, concentrations of regionally significant species, etc.) for landscape species, keystone species, regionally significant species, and regionally significant suites of species? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQ and the distribution map for the CE. Specific MQs examples for the REA were developed in Task 1 and are presented in Appendix A. Several of these MQs are discussed below to demonstrate the functionality of the REA and to provide an opportunity to discuss significant data gaps that were identified during this REA.

6.1 WHERE ARE THE HABITATS THAT SUPPORT BREEDING GOLDEN EAGLES?

The response to this MQ was required to perform all additional analyses and data comparisons for the golden eagle. The Maxent habitat model is presented on Figure E-3-4. Although there are potential limitations to the quality of this model, all efforts were made to accurately describe the distribution of breeding golden eagles within the ecoregion.

6.2 WHERE ARE THE KEY HABITAT AREAS THAT SUPPORT REGIONALLY SIGNIFICANT CONCENTRATIONS OF GOLDEN EAGLES?

The Maxent distribution model was able to determine the overall distribution of the golden eagle within the ecoregion. This model created a probability range of potential golden eagle distribution areas that ranged from 0-1. In this analysis, the output value was limited to areas that provided potential for golden eagle distribution; however, it could easily be reclassified to create revised thresholds for areas likely to contain large populations, based purely on the environmental variables associated with the Maxent model. Similarly, the analysis used to create the current status of golden eagles by 12-digit HUC provides this result. Figure E-3-11, which portrays the current overall score, specifically answers this MQ by scoring HUCs within golden eagle distribution areas.

6.3 WHERE ARE THE AREAS THAT HAVE POTENTIAL FOR RESTORING GOLDEN EAGLE HABITAT OR HABITAT CONNECTIVITY, CURRENTLY AND IN THE FUTURE?

Several of the figures present data layers that could be used to answer this MQ. Habitat quality is identified both as a sum and individually across the ecoregion. These attributes can be analyzed by managers at the 12-digit HUC level to determine areas that are preferential for restoring golden eagle habitat based on their proximity to good quality habitat.

6.4 WHERE ARE REGIONALLY SIGNIFICANT GOLDEN EAGLE HABITAT AREAS AT GREATEST RISK FROM CHANGE AGENTS, INCLUDING CLIMATE CHANGE (CONNECTIVITY, SMALL POPULATION SIZE), DISTURBANCE, OR DEVELOPMENT?

The full range of figures and analyses in the golden eagle section of this REA can be used to answer this complex MQ. The models created throughout this process were created to directly address the effects of CAs on the golden eagle. All of the CAs were addressed spatially and described in detail in this section, and all of the CAs were spatially attributed to the distribution of the golden eagle. Climate change was addressed separately because of data issues, but the spatial relationship between climate change and golden eagle distribution was described in detail.

6.5 WHERE ARE AREAS OF EXISTING, PLANNED, AND POTENTIAL FUTURE DEVELOPMENT, INCLUDING ROADS (BASED ON EXISTING WILDLAND-URBAN INTERFACE LITERATURE, INCLUDING THEOBALD AND OTHERS)?

The effect of CAs on future populations of golden eagles was limited by data availability, but in most cases, surrogate data were available for use in this analysis. Therefore, although the data were limited in quality, assumptions could still be made to address this MQ. The future CA figures in Appendix C provide a spatial display of the effects of these future CAs on areas in which golden eagles occur.

6.6 WHICH CORE CONSERVATION ELEMENTS ARE THREATENED BY SOD-BUSTING, ENERGY DEVELOPMENT, GRAVEL MINING, FRAGMENTATION, LOSS OF CONNECTIVITY, AND OTHER DEVELOPMENT PRESSURES?

This MQ was addressed in the future CA analysis. The results of the analysis indicate that agricultural activity, urban growth, and wind turbines could have a potential negative effect on future golden eagle populations in some areas.

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APPENDIX E-3

FIGURES

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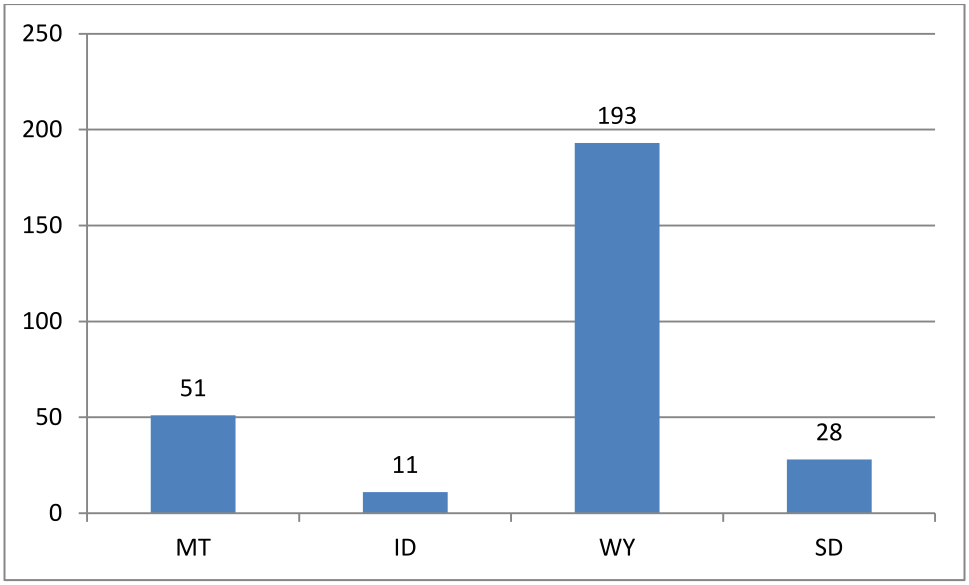

Figure E-3-1. Golden Eagle Nest Observations Used in Maxent Habitat Model

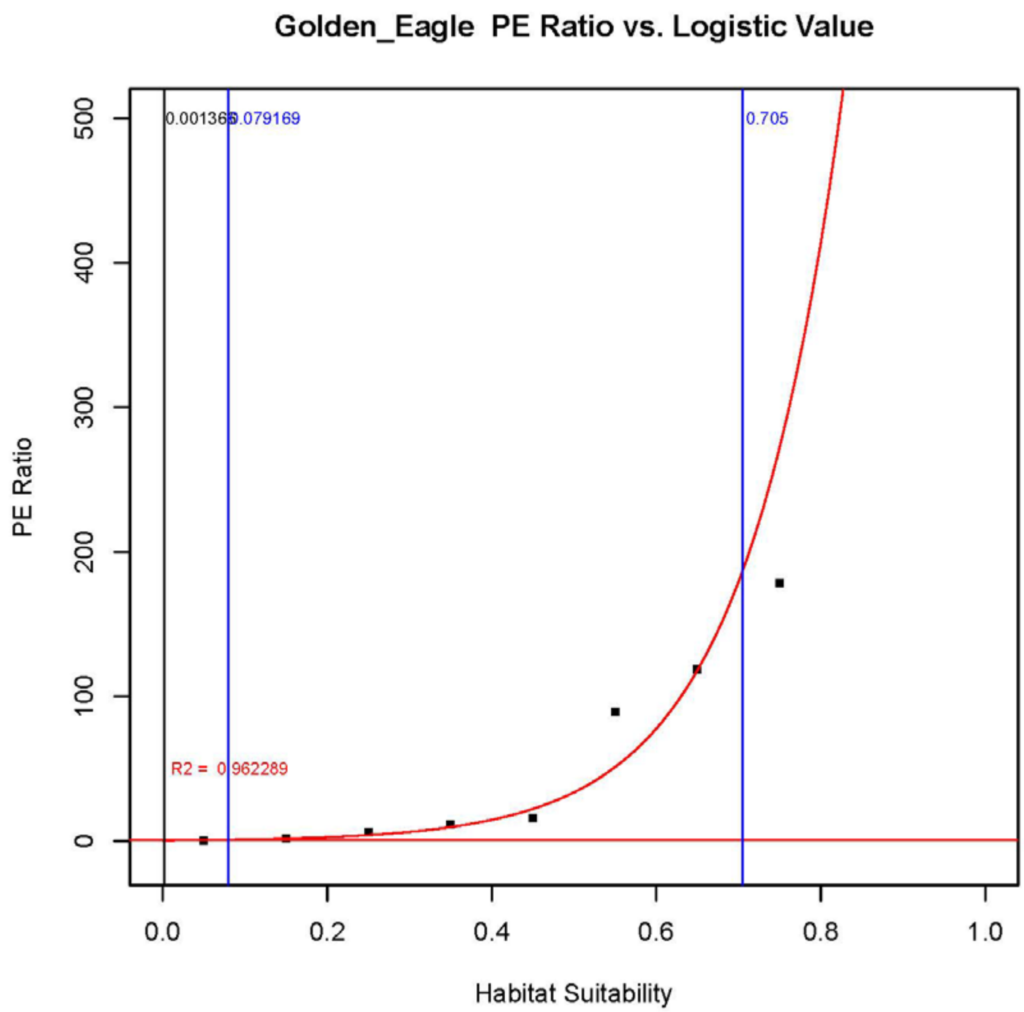

Figure E-3-2. R-Script Output for the Maxent Habitat Model for Golden Eagle

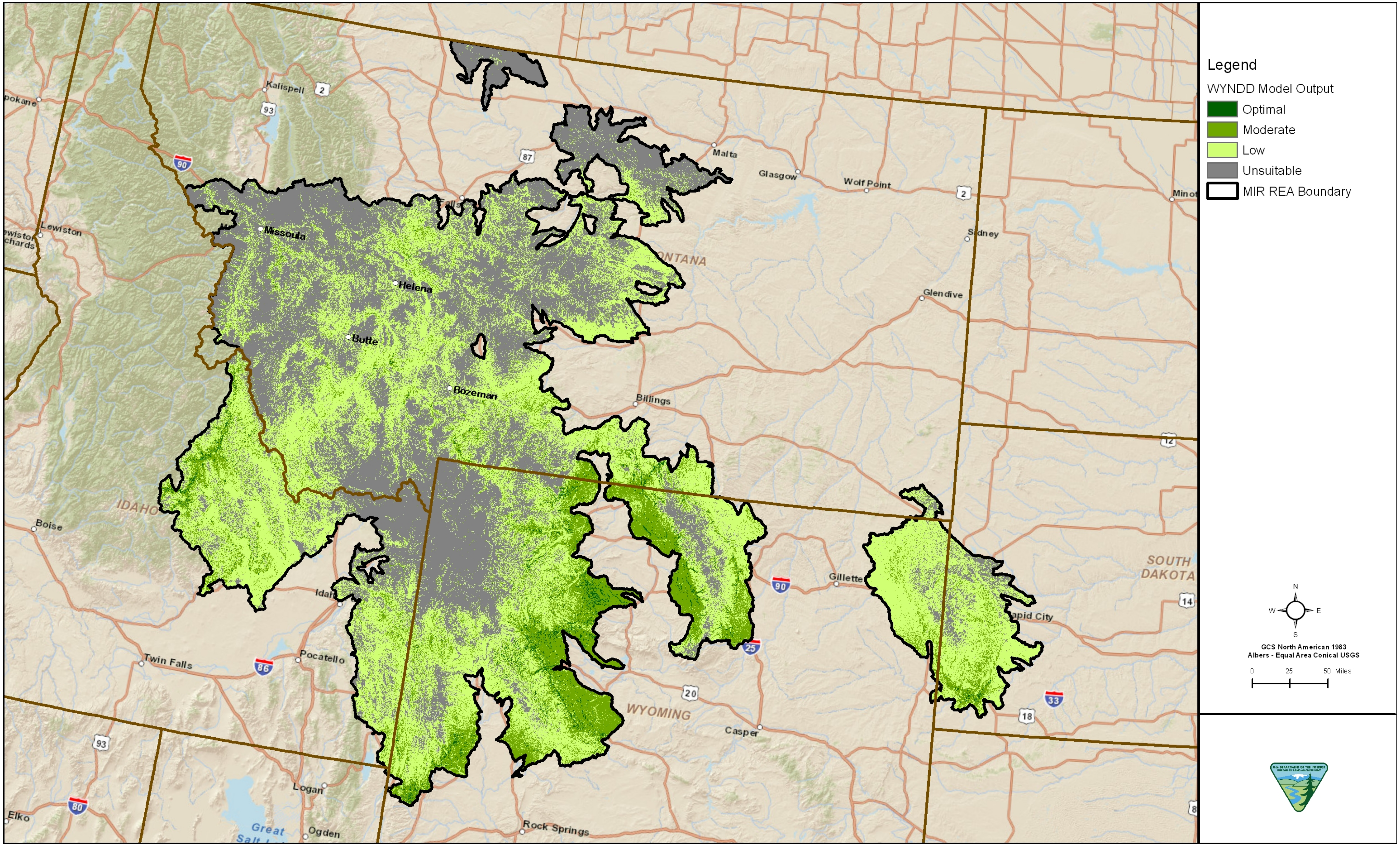

Figure E-3-3. WYNDD Habitat Model for the Golden Eagle

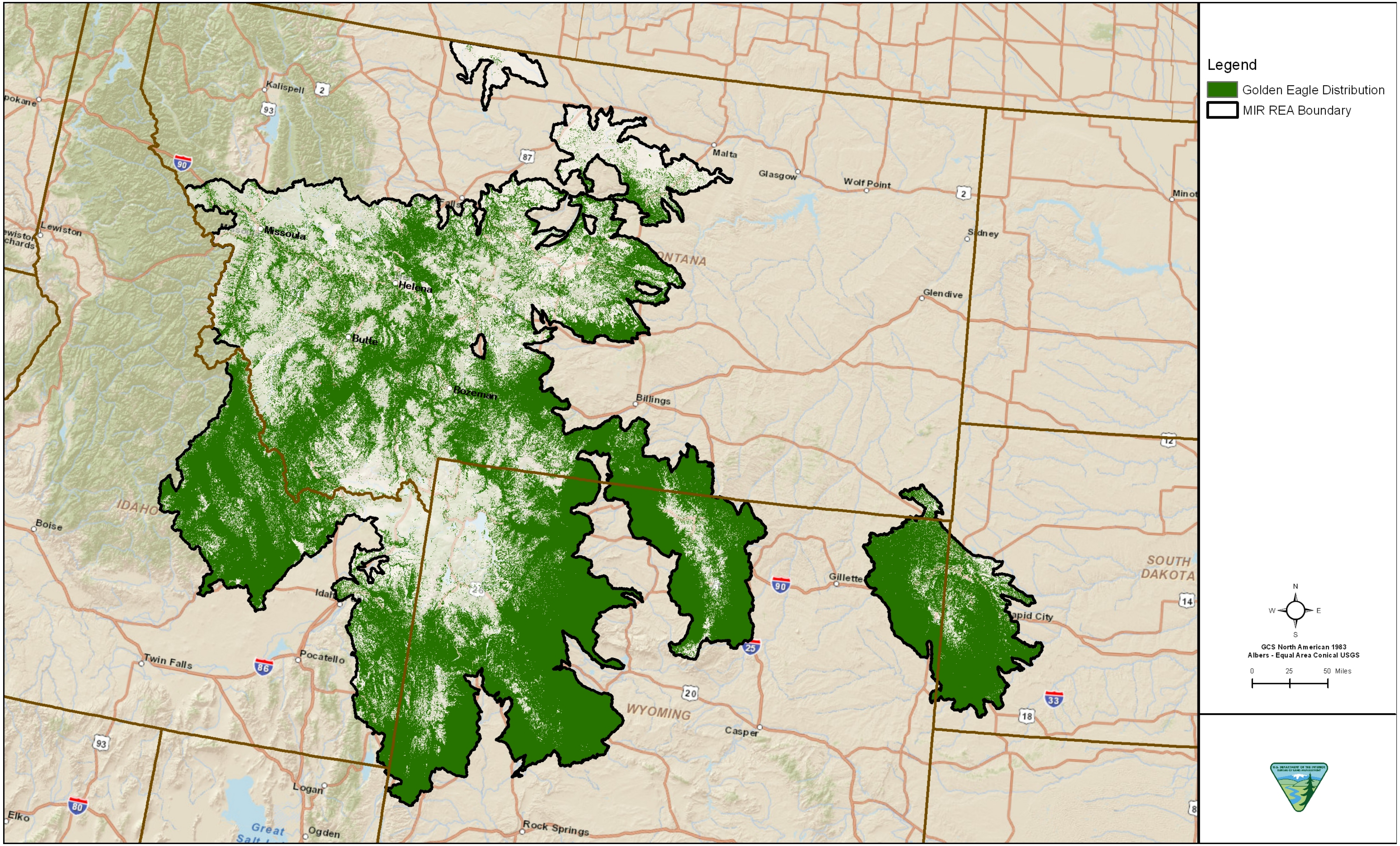

Figure E-3-4. Maxent Habitat Model for the Golden Eagle

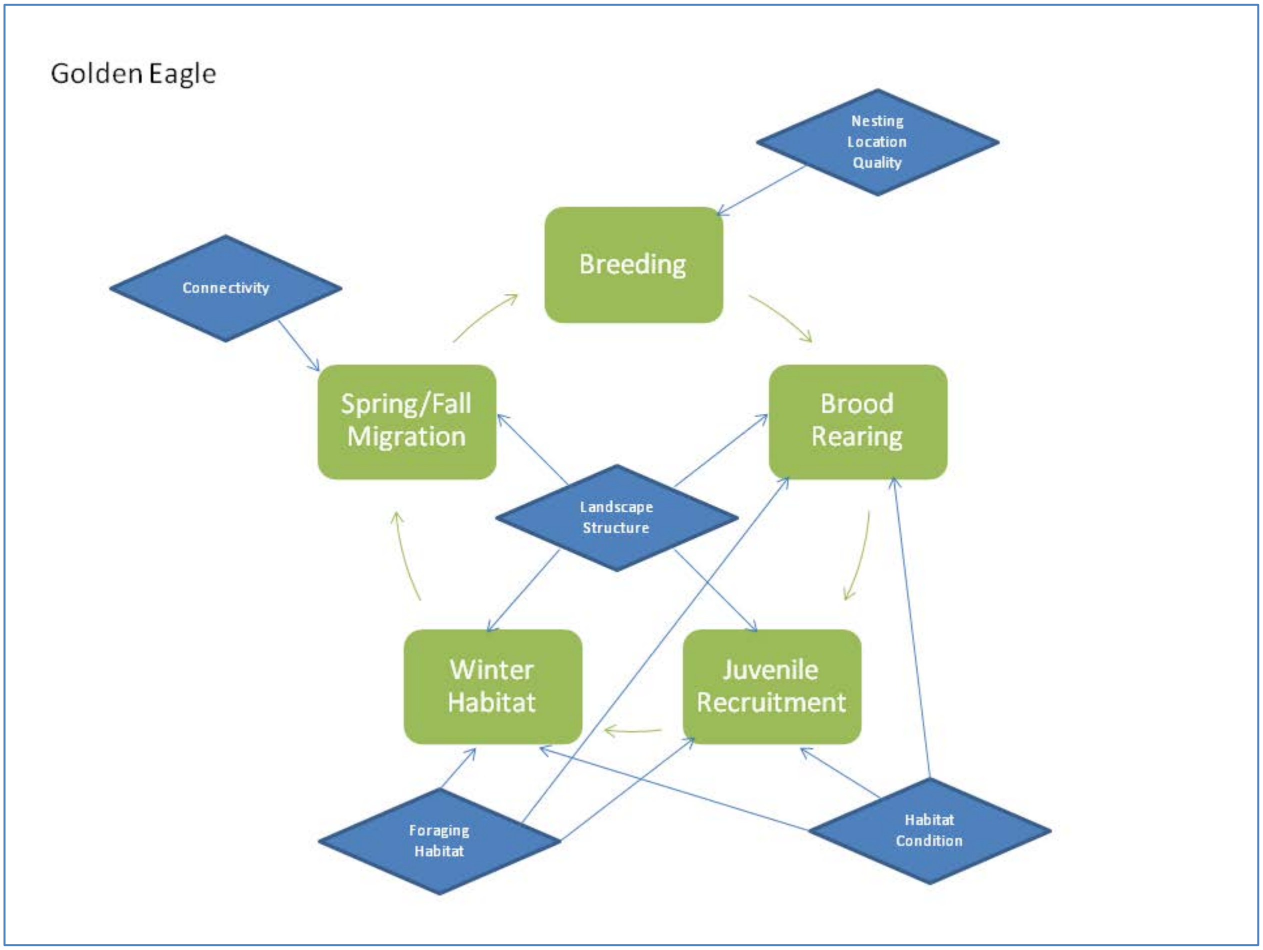

Figure E-3-5. Ecological Process Model for the Golden Eagle

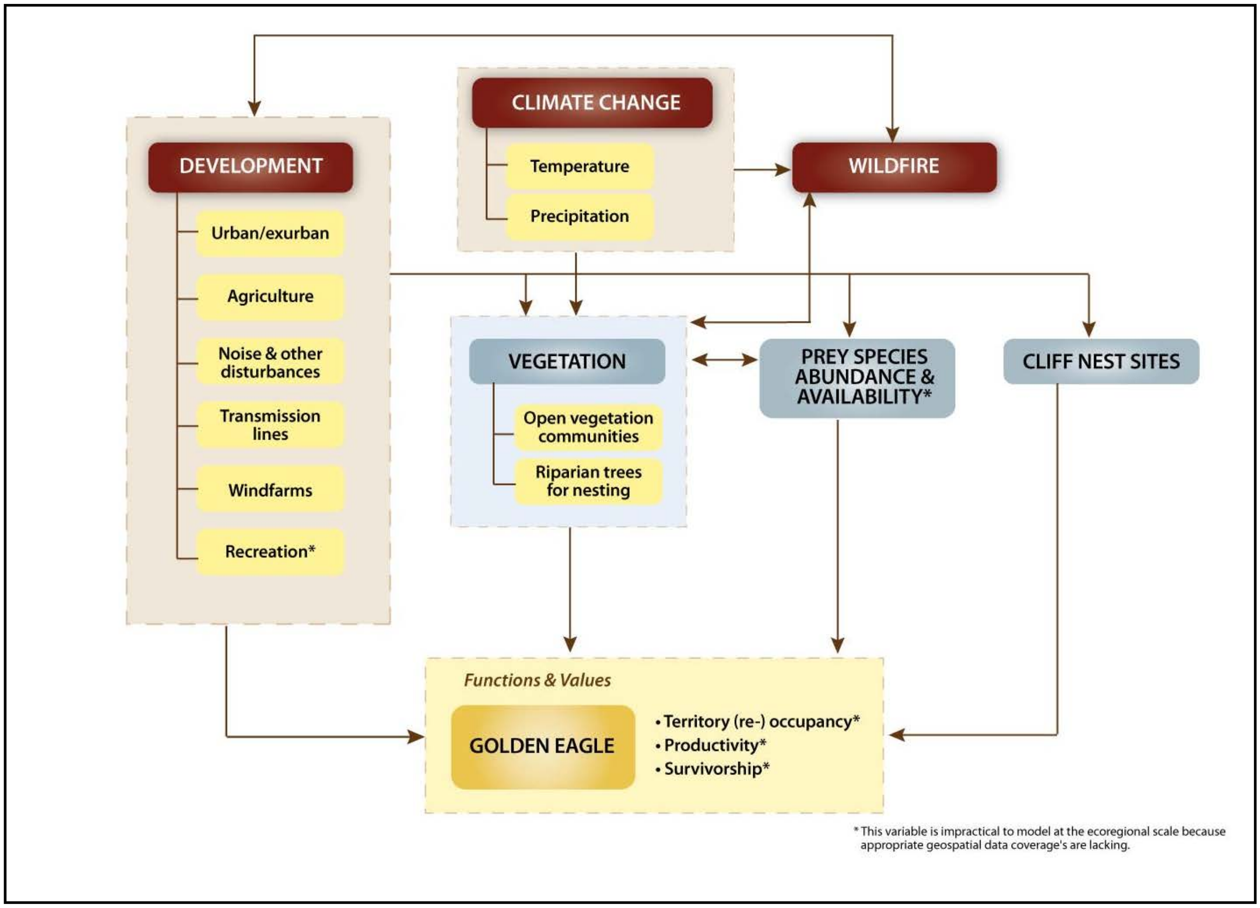

Figure E-3-6. System-Level Model for the Golden Eagle

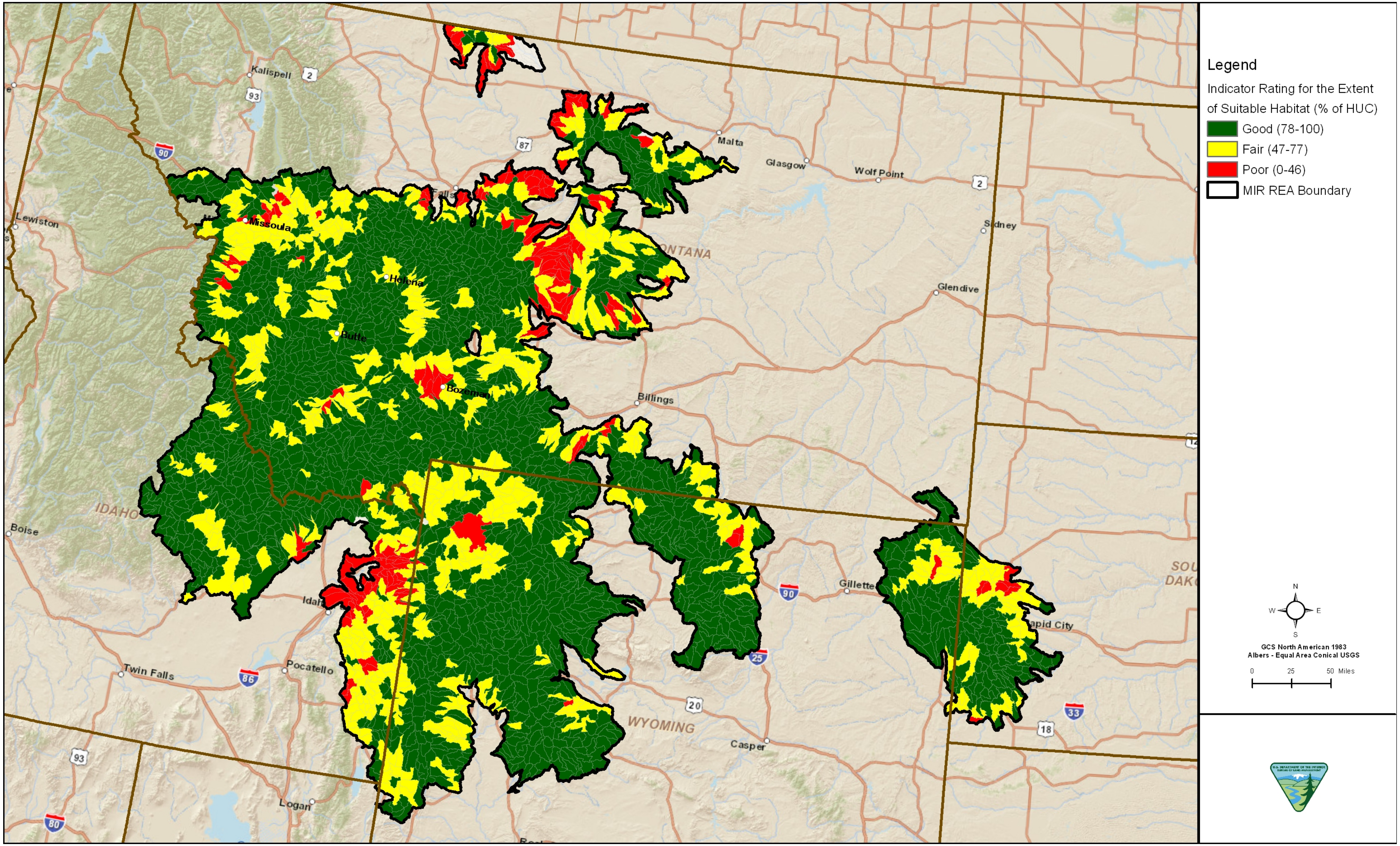

Figure E-3-7. Golden Eagle Foraging Habitat

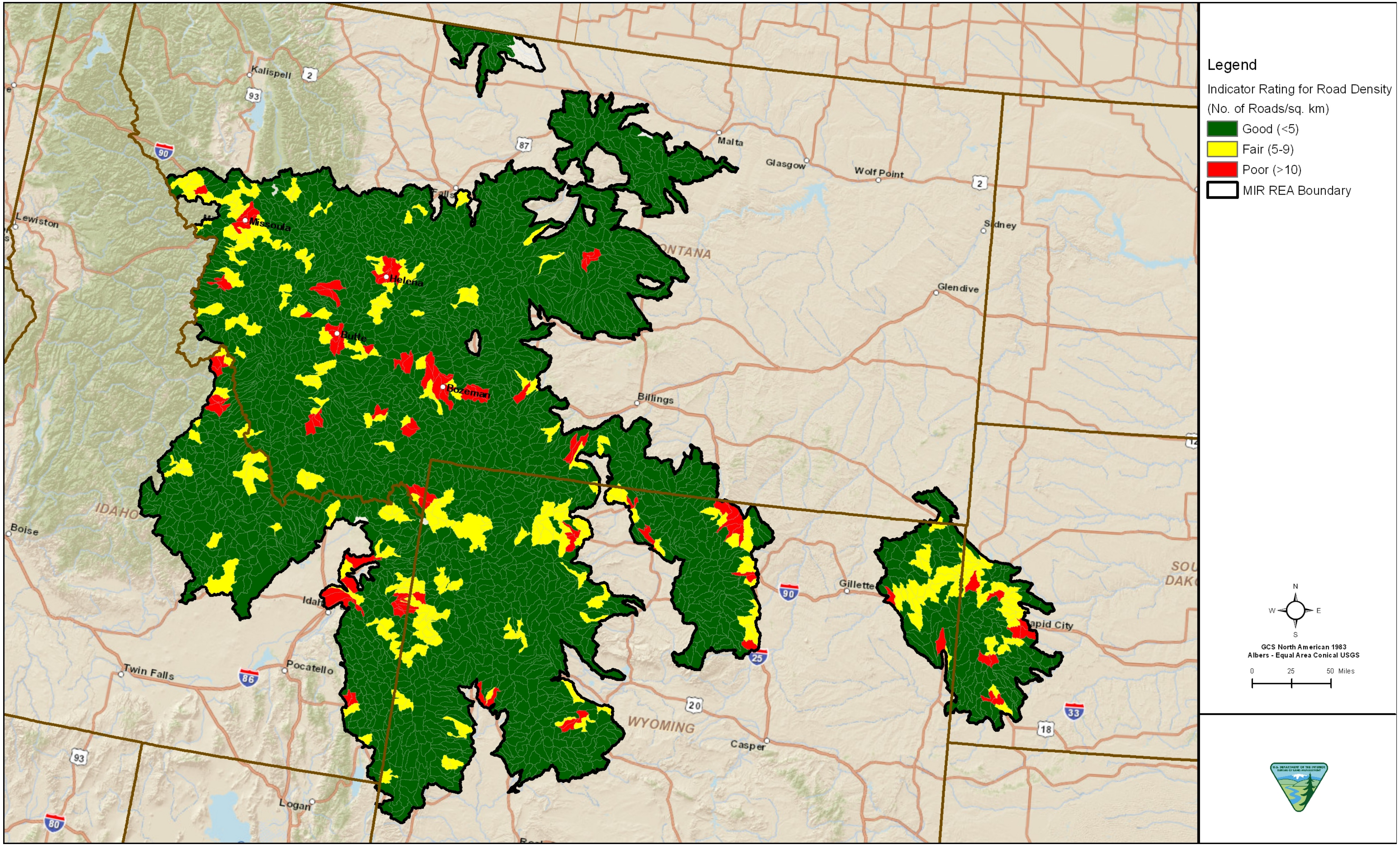

Figure E-3-8. Road Density

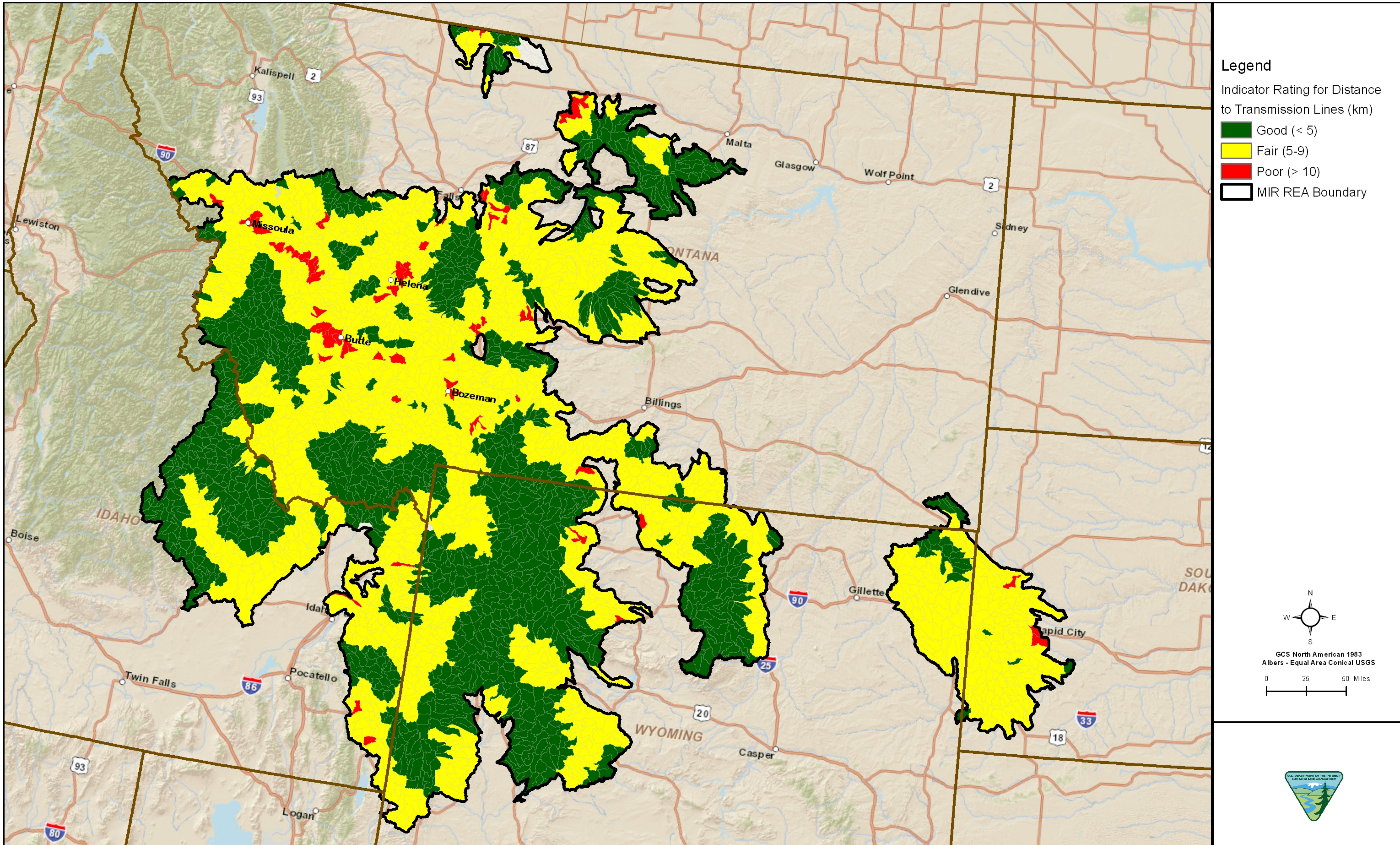

Figure E-3-9. Transmission Line Proximity

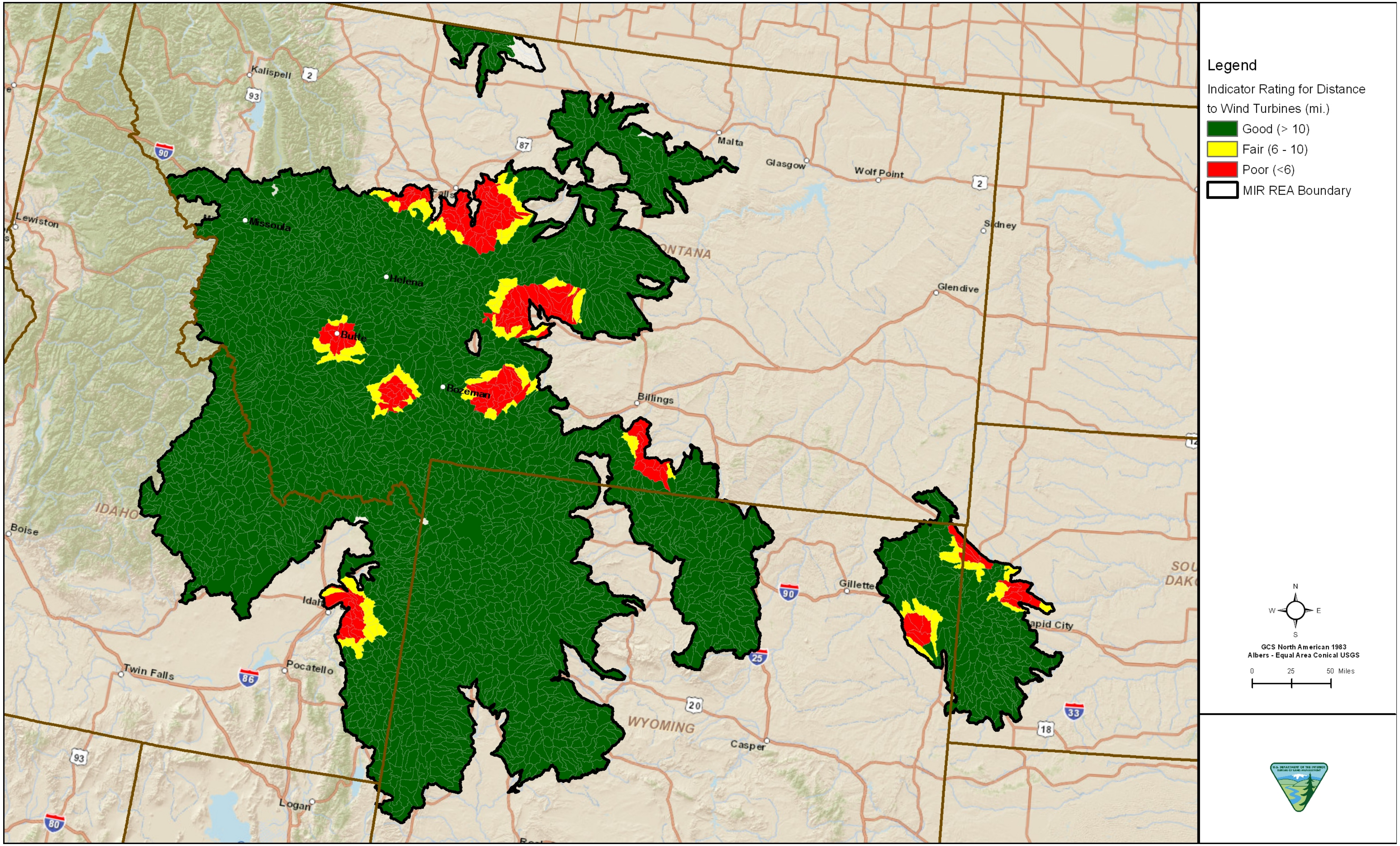

Figure E-3-10. Wind Turbine Proximity

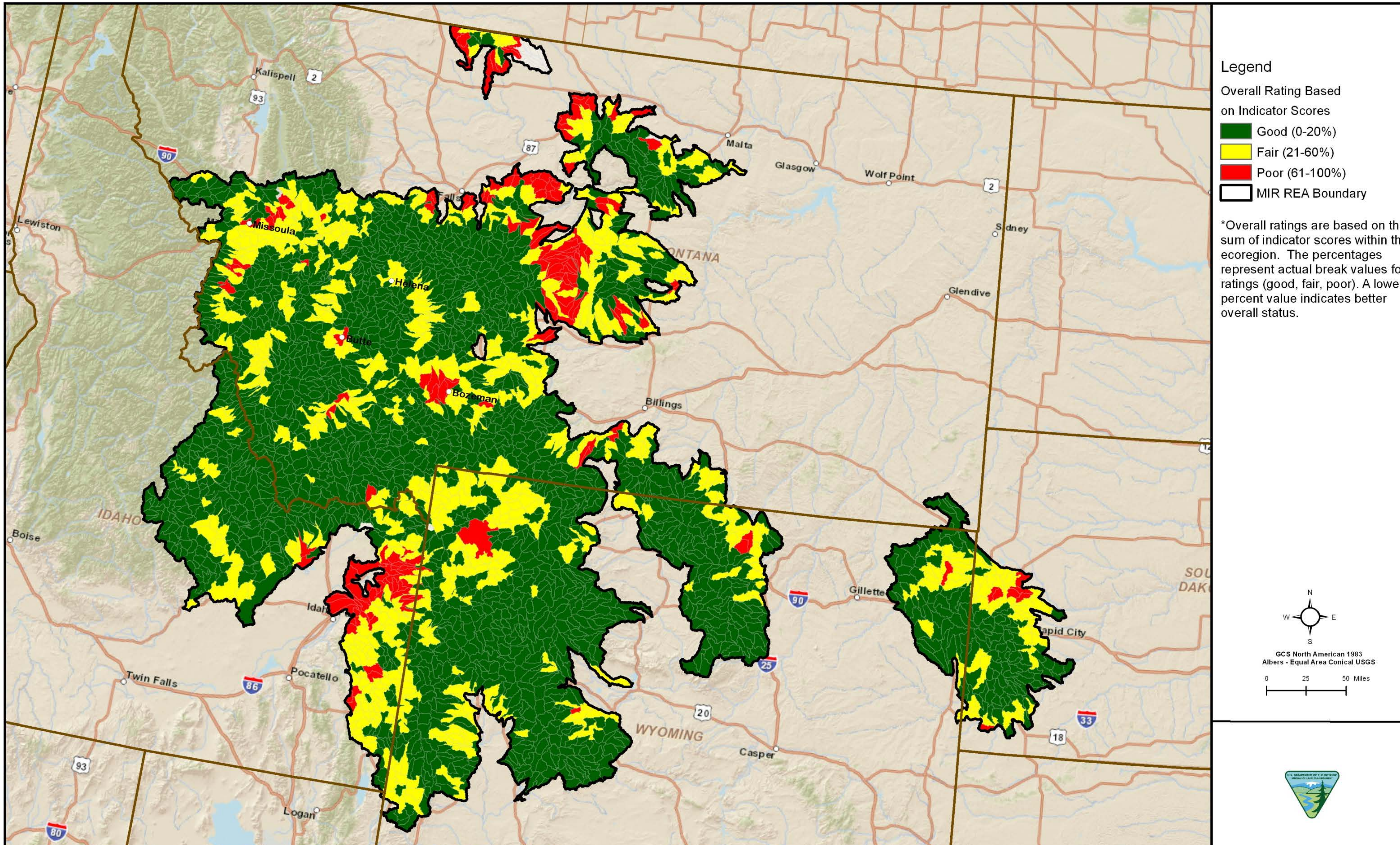

Figure E-3-11. Overall Current Status for the Golden Eage Analysis

APPENDIX E-4

BIG GAME ASSEMBLAGE CONSERVATION ELEMENT ANALYSIS FOR THE MIDDLE ROCKIES ECOREGION

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF ATTACHMENTS

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1.0 INTRODUCTION

The Middle Rockies ecoregion is home to some of the largest populations of ungulates in the nation. The focal species selected to represent the big game assemblage include the elk (*Cervus canadensis*), mule deer (*Odocoileus hemionus*), bighorn sheep (*Ovis canadensis*), and pronghorn (*Antilocapra americana*). Due to the topographic relief variability of the ecoregion, most ungulates exhibit seasonal shifts among seasonal habitats. However, habitats delineated for this big game assemblage comprise a composite of habitats for several species and encompass a greater diversity of habitats than what would be used by any one of the four species. For this reason, the bighorn sheep is defined as a single-species fine-filter conservation element (CE) and is presented in Appendix E-5. Additionally, due to a lack of adequate geospatial data to define the distribution of the pronghorn, the Bureau of Land Management (BLM) decided that this species would be dropped from the assemblage; no change agent (CA) analyses were conducted for the pronghorn. Therefore, the species that represent the big game assemblage are the mule deer and elk.

Management questions (MQs) pertaining to the big game assemblage in the ecoregion were identified in Task 1 and can be summarized as: 1) where are important habitat areas for the species? and 2) how will their condition and suitability for the species change in the future? The central focus of these two MQs is to document the current status of selected CEs at the ecoregional scale and to evaluate how this status may change over a future time period. The first step is to identify suitable habitat for the CE within the ecoregion. Then, these areas are assessed relative to current status and potential future CA threats.

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2.0 CONSERVATION ELEMENT DESCRIPTION

2.1 MULE DEER

The mule deer (*Odocoileus hemionus*) is restricted to western North America with a range that extends from southern Alaska, through Canada, into the entire western half of the United States, and to the highlands of central Mexico. Over such a large area, mule deer are capable of living in unusually different types of environments. The species is numerous, widespread, and found in a habitat range that includes alpine meadow, mixed forest, arid plains, and open prairie. The mule deer is primarily a deer of open forests and broken brush lands.

Mule deer will migrate as much as 80 miles between summer and winter ranges. In winter, mule deer prefer lowland riparian ecosystems that provide thermal and protective cover and will concentrate in these areas. However, in summer the mule deer tend to roam widely and may concentrate around water sources where green vegetation is most abundant. Adult females have a mean home range of 0.3 to 1.2 square miles, while adult males have a mean home range from 1.2 to 4 square miles, but may be as large as 30 square miles (NRCS 2006).

Survival of mule deer is directly linked to the quality of food plants and the ability of the deer to reach it, particularly in areas of heavy snow cover concentrations. Mule deer can tolerate snow depths of 18 to 24 inches, but lower levels are sought in order to conserve energy (NRCS 2006). Poor winter range conditions and severe winter weather in the form of deep snow and cold temperatures can result in high mortality, especially among the old and young (Northwest Power and Conservation Council 2004). Nutritional status also affects a deer's vulnerability to predation, as well as its ability to compete for food and survive when severe weather persists for extended periods. The primary cause for winter starvation is habitat in poor conditions often exacerbated by too many deer and other herbivores competing for the same forage (Wyoming Game and Fish 2011).

2.2 ELK

Elk (*Cervus canadensis*) occur in many parts of western North America; where they are sympatric, elk and mule deer occupy many of the same habitats, but the species tend to segregate by habitat features within areas of distribution overlap. Recent studies in Oregon suggested mule deer avoided areas used by elk. Elk selected more gentle slopes, westerly aspects, and areas farther from roads, whereas mule deer selected steeper slopes, easterly aspects, and areas closer to roads (Johnson et al. 2000). Elk populations have increased in western North America during the past few decades, whereas populations of mule deer generally have declined concurrent with increased abundance of elk (Lindzey et al. 1997; Keegan and Wakeling 2003). Elk are known for their migration and seasonal habitat use, including distinct parturition areas, summer and rutting season ranges, and traditional winter range. Thermal cover under a canopy may be a behaviorally important element of winter habitat for elk, primarily in spring when elk seek shade to avoid excessive thermal loads. The parturition period of elk occurs from May 15 to June 30. Most elk are on crucial winter range from December 1 to April 30.

2.3 PRONGHORN

The pronghorn (*Antilocapra americana*) is commonly associated with grasslands and sagebrush communities of western North America, Habitats with short vegetation and relatively flat terrain help the pronghorn evade predators. The pronghorn generally prefers areas with vegetation averaging about 15 inches or less in height and avoid taller vegetation areas. The vast majority of pronghorn populations depend on the large, woody sagebrush species as a preferred food (Wyoming Interagency Vegetation Committee 2002). Studies also indicate that areas with an intermixing of ridges and drainages provide a greater diversity of vegetation which may provide foraging benefits to the antelope (Wyoming Game and Fish Department 2002). In northern climates, deep snows frequently preclude the use of less nutritious dried forb and grass forage in winter, and it is here the available, highly nutritious sagebrush species permit the continued survival of the pronghorn and provide for its maximum productivity (Sundstrom et al. 1973).

In Wyoming, home ranges tend to be relatively small (1 to 2 square miles) in the summer if water and food are adequate and as large as four to six square miles in winter although fall and spring migration have been reported to exceed 250 miles. Snow depth strongly influences the pronghorn's choice of winter range. At snow depths exceeding seven inches, antelope seek areas with topographic diversity (windswept ridge, south-facing slopes) where snow depths are reduced (Wyoming Game and Fish Department 2002).

Pronghorn mate during a September breeding season and give birth in late May or early June. The vegetative structure of sagebrush often provides crucially needed cover for fawns in the spring and early summer (O'Gara and Yoakum 1992).

3.0 CONSERVATION ELEMENT DISTRIBUTION MODELING

To answer the MQs regarding the location and status of this CE across the ecoregion, a variety of existing data layers representing important habitat for the focal species were evaluated for use. The goal was to obtain data to determine the current distribution and status of each species throughout the ecoregion for critical periods (migration, winter and parturition habitats).

3.1 DATA IDENTIFICATION

Table E-4-1 lists the types of data and data sources for the mule deer that were proposed for use in the Rapid Ecoregional Assessment (REA) as part of the pre-assessment data identification effort in Task 2. The most important datasets for mule deer are the locations of crucial and severe winter range, parturition areas, and travel and migration corridors.

Since this species is considered to be common, occurrences are not recorded by natural heritage programs. Suitable mule deer habitat models were acquired from Gap Analysis Program (GAP) and NatureServe. Habitat data for this species was also acquired from Utah State University. In addition, the Western Governors' Association (WGA) Wildlife Council Crucial Habitat Assessment Tool (CHAT) is being used to generate models and datasets for the ecoregion; however, no data are currently available.

Mule deer migration routes are described by agency publications, internal knowledge of land managers, and conservation organizations (Western Association of Fish and Wildlife Agencies [WAFWA], Mule Deer Foundation). The mule deer Working Group (2005) has mapped the entire range of mule deer in North America and has identified two types of winter range: 1) winter range (defined as the part of the overall range where 90 percent of the individuals are located during the average five winters out of ten from the first heavy snowfall to spring green-up, or during a site-specific period of winter) and 2) "severe winter range" (areas within the winter range where 90 percent of the individuals are located when annual snow pack is at its maximum and/or temperatures are at a minimum in the two worst winters out of ten). In addition to identifying and mapping distribution, habitat classification factors that limited habitat quality for mule deer were also identified.

The Assessment Management Team (AMT) decided that only the winter range would be used to assess CA impacts as part of the REA. The AMT has recommended using the WAFWA mule deer ranges to develop distribution layers.

Table E-4-1. Data Sources for Mule Deer Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Modeled Suitable Habitat	GAP Habitat Models	U.S. Geological Survey (USGS)	Raster (30-m)	Acquired	No[2]
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No[2]
	WAFWA Mule Deer Ranges	WAFWA	Polygon	Pending	Yes
	WGA DSS Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[1]
	Mule Deer Habitat	Utah State University	Polygon (1:250k)	Acquired	No[2]
Crucial and Severe Winter Ranges	Crucial and Winter Range	ID, MT, WY, SD State Fish and Game		WAFWA	No[2]
Travel Corridors	Travel Corridors	ID, MT, WY, SD State Fish and Game		Pending Data Sharing Agreement (DSA)	Yes
Migration Corridors	Migration Corridors	WGA; ID, MT, WY, SD State Fish and Game		Pending DSA	Yes

[1] Data gap
[2] Better data are available

3.2 DISTRIBUTION MAPPING METHODS

The WAFWA mule deer winter range data were used to create a range map for this species. The mapped data appears to be combinations of detailed mapping and coarse management boundaries (Figure E-4-1). After review by the RRT, the WAFWA mule deer range data were found to have too many inconsistencies of mapping scale; therefore, the habitat patch layer for mule deer was developed using the Habitat Core Area (HCA) tool developed by the Washington Wildlife Habitat Connectivity Working Group (WHCWG 2010). The methods for developing estimates of core habitat for individual species in the absence of quality range data developed and applied by the Washington Connected Landscapes Project were reviewed with respect to mule deer and applied with slight adjustments to reflect conditions within the Middle Rocky ecoregion. Some regions were mapped at fine scale, providing very detailed delineations of range habitat, while other areas reflected management boundaries mapped at a coarse level.

The HCA model uses attributes representative of the focal species and on the distribution of natural conditions. Using the HCA toolset developed by WHCWG, large, contiguous areas that have retained high levels of naturalness (i.e., core areas characterized by a relatively light human footprint) were identified. The HCAs are aggregations of habitat grid cells that are connected to one another by species-specific home range movement radius. These aggregations must typically meet a minimum size requirement that would be needed to support multiple individuals. To implement the HCA tool, two datasets were required: (1) a habitat raster and (2) a resistance raster. The habitat raster can be derived from range data (if available) and mapped consistently at an appropriate scale. In the absence of range data, a habitat identification model can be derived from the resistance raster. For mule deer, the HCAs were developed by using a combination of a prior knowledge and a habitat identification model.

A binary habitat raster was developed where a grid cell was either classed as 'habitat' (assigned a value of '1') or non-habitat (assigned a value of '0'). The WHCWG developed a habitat grid by using a resistance grid developed for mule deer and assigning all resistance values of 3 or less as 'habitat'. All values greater than 3 were assigned a 'non-habitat' value (i.e., 0). For this application, a threshold resistance value of '5' was used to delineate between 'habitat' and 'non-habitat'.

The habitat resistance raster for mule deer was developed by using five variables to assess resistence: landcover, elevation, slope, housing density, and presence of transportation corridors. Each dataset was reclassified into meaningful metric categories and assigned resistance values based on those applied and reported by the WHCWG statewide project report (Table E-4-2). The landcover dataset was reclassified to general vegetation classes (see Attachment A). Various scenarios were applied and compared to WAFWA winter range data. BLM wildlife ecologists further examined the patch distributions to assess whether the outputs were reasonable and adjusted accordingly. This analysis adjusted resistance parameters set within the WHCWG analysis. The resistance raster output from scenario 2, as presented in Table E-4-2, was used to develop the habitat binary raster. The proportion of habitat within a circular moving window of a size representative of the mule deer's home range radius is calculated. For this analysis, a home radius of 2,000 meters (m) was used. The outcome of this step generates a surface that identifies the areas where habitat is most concentrated.

The HCA tool deletes the grid cells in areas where habitat is sparse. Habitat grid cells are removed from the habitat binary raster if the proportion of the habitat within the home range radius is less than 0.89. This prevents habitat concentrations from forming in areas where habitat is not concentrated to the level that would be considered core habitat. Only grid cells meeting the minimum average habitat value of home range were evaluated. The threshold habitat value was set to 0.75. Grid cells meeting the minimum average habitat value of home range were then compared to the 0.75 threshold and, if greater, were then classified as core habitat. Remaining habitat grid cells were joined together if they were within a home range distance. Habitat areas were expanded outward (from the remaining habitat grid cells after step 4) up to a total cost-weighted distance equal to the species home range movement radius (2,000 m). This effectively joins nearby habitat grid cells together if the intervening landscape supports movements within the home-range connectivity.

Table E-4-2. Variables Used for Habitat Resistance Model for the Mule Deer

Spatial Data Layers	Data Source	Factors Used	Initial (WHCWG)	Scenario 2
Landcover/land use	GAP	Agriculture	5	2
		Urban/developed	100	100
		Water	20	20
		Sparsely vegetated	5	5
		Alpine	0	0
		Riparian	0	0
		Wetland	1	1
		Grass-dominated	2	2
		Shrub-dominated	2	2
		Dry forest	0	0
		Wet forest	0	0
Elevation	USGS National Elevation Dataset (NED)	0-250 m	0	0
		>250-500 m	0	0
		>500-750 m	0	0
		>750-1,000 m	0	0
		>1,000-1,500 m	0	0
		>1,500-2,000 m	1	2
		>2,000-2,500 m	2	5
		>2,500-3,300 m	25	25
		>3,300 m	25	25
Slope	USGS NED	0-20 degrees	0	0
		>20-40 degrees	0	0
		>40 degrees	30	30
Acres/Dwelling Unit (ac/du)	Housing Density 2000, Natural Resource Ecology Lab, Colorado State University, 2008	>80 ac/du	0	0
		>40 to <80 ac/du	0	0
		>20 to <40 ac/du	1	1
		>10 to <20 ac/du	2	2
		<10 ac/du	10	10
Transportation Freeway	Topologically Integrated Geographic Encoding and Referencing (TIGER) Line Roads Census 2000	>500-1,000 m	0	0
		>0-500 m	0	0
		centerline	200	200
Transportation Secondary Highway	TIGER Line Roads Census 2000	>500-1,000 m	0	0
		>0-500 m	0	0
		centerline	20	20
Transportation Local Road	TIGER Line Roads Census 2000	>500-1,000 m	0	0
		>0-500 m	0	0
		centerline	2	2

The WHCWG statewide application of the HCA tool removed habitat core areas smaller than a threshold that was meaningful to the mule deer range. This analysis of patch size sought to examine a range of habitat patches, thus a low threshold was established (100 hectare [ha]). This process was reapplied to develop a secondary patch size layer that was used within the connectivity analysis to develop connectivity corridors between large, significant habitat patches. This secondary patch size layer used a threshold of 100 square kilometers (km^2) to limit habitat patches to large core areas.

Figure E-4-2 presents the winter range distribution map for mule deer that was used to conduct the CA analyses.

3.2.1 Elk Distribution

Table E-4-3 lists the types of data and data sources for the elk that were proposed for use in the REA as part of the pre-assessment data identification effort in Task 2. The most important datasets for elk include the locations of crucial and severe winter range, parturition areas, travel corridors, and migration corridors. Because Elk are actively managed in this ecoregion, it was anticipated that several types of datasets could be identified. Habitat models were acquired from GAP and NatureServe for portions of the ecoregion (Table E-4-3). In addition, the Western Governors' Association (WGA) Wildlife Council Crucial Habitat Assessment Tool (CHAT) is being used to generate models and datasets for the ecoregion; however, no data are currently available.

Table E-4-3. Data Sources for Elk Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Modeled Suitable Habitat	GAP Habitat Models	USGS	Raster (30-m)	Acquired	No[2]
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No[2]
	Rocky Mountain Elk Foundation (RMEF) Elk Ranges	RMEF	Polygon	Acquired	Yes
	WGA Decision Support System (DSS) Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[1]
Crucial and Severe Winter Ranges	Crucial and Winter Range	ID, MT, WY, ND, SD State Fish and Game Agencies		Using RMEF	No[2]
Parturition Areas	Parturition Areas	State Fish and Game Agencies		Data Gap	No[1]
Travel Corridors	Travel Corridors	WGA; ID, MT, WY, ND, SD, State Fish and Game Agencies		Data Gap	No[1]
Migration Corridors	Migration Corridors	WGA; ID, MT, WY, ND, SD State Fish and Game Agencies		Data Gap	No[1]

[1] Data gap
[2] More representative data were selected for use.

Because of the use of the WAFWA dataset for the mule deer, the AMT has recommended using the WAFWA elk winter ranges dataset to develop distribution layers. The WAFWA elk range dataset was reviewed and found suitable for analysis at the ecoregional scale. The WAFWA winter, winter crucial and yearlong range mapped elk habitat were combined to represent the winter range for elk in the Middle Rockies. Figure E-4-3 presents the winter range distribution map for elk, which was used to conduct the CA analyses.

3.2.2 Pronghorn Distribution

Table E-4-4 lists the types of data and data sources for the pronghorn that were proposed for use in the REA as part of the pre-assessment data identification effort in Task 2. This species has been recorded in Montana, Wyoming, and South Dakota. The most important datasets required for pronghorn are their travel corridors and migration corridors. The only data located for this species was the GAP and NatureServe habitat models. The AMT recommended relying on state fish and game agencies as the best sources of data for this species. As noted in Table E-4-4, although there were localized datasets and some multi-state migration corridor datasets, no comprehensive ecoregion-wide data could be acquired that was uniform enough for the entire ecoregion. As a result of a lack of adequate geospatial data to define the distribution of the pronghorn, the BLM decided that this species would be dropped from the assemblage and therefore no CA analyses were conducted for the pronghorn.

Table E-4-4. Data Sources for the Pronghorn Conservation Element Distribution Mapping

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Modeled Suitable Habitat	GAP Habitat Models	USGS	Raster (30-m)	Acquired	No[2]
	NatureServe Habitat Model	NatureServe	Polygon	Acquired	No[2]
	State Derived Models	ID, MT, WY, ND, SD, NE State Fish and Game Agencies	Raster	Require Data	No[1]
	WGA DSS Models	WGA Pilot Crucial Habitat	Raster	Future Dataset	No[1]
Crucial and Severe Winter Ranges	Crucial and Winter Range	ID, MT, WY, ND, SD, NE State Fish and Game Agencies		Require Data	No[1]
Travel Corridors	Travel Corridors	ID, MT, WY, ND, SD State Fish and Game		Pending DSA	Yes
Migration Corridors	Migration Corridors	WGA; ID, MT, WY, ND, SD State Fish and Game		Pending DSA	Yes

1 Data gap
2 More representative data were selected for use.

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4.0 CONCEPTUAL MODELS

The current and potential future threat analyses were based on CE-specific ecological conceptual models, selected environmental variables (Key Ecological Attributes [KEAs]) likely to be impacted by CAs, and the availability of data.

4.1 ECOLOGICAL PROCESS MODEL

The ecological process model for the big game assemblage (Figure E-4-4) was developed to identify and link the key life cycle processes to specific ecological factors, or KEAs, that have the greatest potential to affect mule deer and elk habitat throughout the ecoregion. As noted in the species description, winter ranges within the ecoregion are critical habitat for the mule deer and elk. Forage quality and accessibility is a key factor in winter survival and parturition.

The key processes are identified in the model as green boxes and following Unnasch et al. (2009), three broad headings or categories of ecological attributes (EAs) (size, condition, and context) are identified in the model as blue diamonds. Size refers to attributes related to habitat or patch size, condition refers to the condition of the habitat, and context refers to the spatial structure of the habitat. At the landscape level, the EAs under the condition category will be the most challenging to spatially represent and will primarily depend on the data available to represent this category.

4.2 SYSTEM-LEVEL MODEL

The system-level conceptual model (Figure E-4-5) illustrates the interactions between the CAs and the primary habitat functions of this species. The primary CAs for this CE are development, climate change, invasive species, wildfire, and insect outbreak and disease, which are identified across the top of Figure E-4-5 in red. The important factors (or “drivers”) affecting the abundance and distribution of mule deer populations include those that impact survival, reproduction, distribution, density, and metapopulation structure.

4.2.1 Development

The specific types of development that may impact the important winter habitat for the mule deer include roads, oil & gas exploration and development, mining, urban/exurban expansion, recreation, and renewable energy development. Roads are widely recognized by the scientific community as having a range of direct, indirect, and cumulative effects on wildlife and their habitats (Trombulak and Frissell 2000; Gucinski et al. 2001; Gaines et al. 2003; Wisdom et al. 2004a; Wisdom et al. 2004b; New Mexico Department of Game and Fish 2005). Elk are most sensitive to human disturbance, much of which is associated with energy development, subdivisions, and roads. Direct impacts of roads and associated traffic on elk have been summarized (Rowland et al. 2004) and generally involve strong avoidance of roads. Lyon (1979) suggested that road densities above 1 mile of road per square miles, reduced habitat effectiveness by 25 percent. At road densities of 2 miles of road per square miles, effective habitat decreased by 50 percent, and at road densities of 6 miles of road per square miles, elk use of suitable habitat declined by 75 percent. Wisdom et al. (2004b) found that elk responded with flight in 65 percent of all cases when a human disturbance was at close range (under 500 m); beyond 500 m, the probability of flight declined for hiking and horseback riding, but remained high for ATV and mountain biking until distance increased to 1,500 m (Wisdom, et al. 2004a). Creel et al. (2002) reported that fecal glucocorticoid levels (a measure of stress) responded to snowmobile activity and were higher for snowmobiles than for wheeled vehicles in Yellowstone National Park. Coe et al. (2011) developed resource selection functions (RSFs) to estimate and predict spatial distributions and resource use by elk in Oregon in which distance to traffic, slope, and percent forest cover figured prominently. A commonly used minimum patch size for security habitat is 250 contiguous acres or more than 0.5 miles from an open road (Christensen et al. 1993, Leege 1984). Physiological stresses occur when energy expenditures by an animal are increased due to alarm and/or avoidance movements. These are generally attributed to interactions with humans and/or activities associated with human presence (traffic, noise, pets, etc.). Added consequences from human presence include, but are not limited to, mortality and injury due to vehicle collisions, illegal hunting, and harassment from a variety of increasing recreational activities (WAFWA 2010).

Mule deer and elk are occasionally perceived as a problem to agricultural crops, especially alfalfa and haystacks during fall and winter. Efforts to fence or haze deer and elk from these agricultural areas may result in increased energy expenditure and loss of body condition of deer and elk in winter. Conflicts on agricultural lands are often resolved by issuing kill permits and conducting depredation hunts. Thus, agricultural areas within traditional migration and or wintering areas are considered a risk factor to elk and mule deer and may even be a sink habitat.

4.2.2 Climate Change

The primary impact of climatic conditions on big game species and their habitat is through the effects of the moisture and temperature regime on forage resources (i.e., productivity, species composition, and nutrient content are affected by drought, late frosts, etc), and snow depth on winter ranges and migration corridors. Mule deer are less affected by severe cold weather than by high levels of snow cover, which restrict access to forage. Gilbert et al. (1970) stated that snow depth over 18 inches precluded use of winter range by deer, but energy costs of locomotion for mule deer increase significantly at 10 inches (25 centimeters [cm]), regardless of the density of snow (Parker et al. 1984). Lower snowfall is projected to occur in much of western North America as a result of climate change, which may reduce the importance of traditional winter ranges for mule deer.

Climate change is thought to negatively affect abundance and distribution of mule deer in hotter and drier ecoregions; in ecoregions where extreme winters presently limit these populations in some years, short-term effects on abundance and distribution may be positive, but long-term effects are uncertain.

Rapid changes in climate have been documented to have adverse effects on bighorn sheep. Epps et al. (2004) investigated how climate change affected bighorn sheep in southern California and concluded that increased temperature and decreased precipitation in the late 1900s was an important factor in bighorn sheep population extirpations in California. These findings could also apply to understanding the direction and role of climate change on mule deer or elk in more xeric areas.

4.2.3 Invasive Species

Habitat fragmentation creates landscapes made of altered habitats or developed areas fundamentally different from those shaped by natural disturbances that species have adapted to over evolutionary time (Noss and Cooperrider 1994). These changes very likely manifest themselves as changes in vegetative composition, often to weedy and invasive species. This, in turn, changes the type and quality of the food base, as well as the structure of the habitat. Increased ‘edge effect’ between developed and undeveloped areas often results in reduced forage quality and security cover, potentially increasing susceptibility to predation (WAFWA 2010).

In addition, some invasive species (especially *Bromus* spp.) can alter fire regimes and thus affect entire landscapes and their communities. The increase of severe droughts associated with global warming will exacerbate cheat grass growth and the spread of other harmful invasive species, thereby converting sagebrush steppe into exotic annual grassland with less forage value. Furthermore, cheat grass and other invasive plants increase the frequency and intensity of wildfires, thereby leaving sagebrush habitat with little chance of recovering (National Wildlife Foundation 2012).

4.2.4 Wildfire

Wildfire threats to big game are generally related to short-term loss of forage. Depending on fire severity and the size and timing of fires, big game species may need to migrate out of affected areas. However, within one to several vegetation periods, forage conditions are generally improved over pre-fire conditions and these effects may last for several years, depending on the vegetation community. Vegetation transitions across ecological thresholds following wildfires are often associated with loss of important habitat resources and functions for wildlife, such as foraging areas, parturition areas, or winter ranges. Thus, vegetation state and fire regime conditions are an important indicator of habitat stability for big game.

4.2.5 Insect Outbreak and Disease

MPB outbreaks have the potential to remove forest cover in large expanses of the Middle Rockies. Loss of forest canopy is generally thought to benefit big game species due to increased herbaceous forage yields and foraging opportunities. However, cover is an important aspect of elk habitat use during hot spring and summer days and during the hunting season; loss of forest cover may increase daily movement distances between foraging and cover areas.

Chronic wasting disease (CWD) is a prion disease that affects North American cervids. The known natural hosts of CWD are mule deer, white-tailed deer (*Odocoileus virginianus*), elk, and moose (*Alces alces*). CWD was first identified as a fatal wasting syndrome in captive mule deer in Colorado in the late 1960s and in the wild in 1981. By the mid-1990s, CWD had been diagnosed among free-ranging deer and elk in a contiguous area in northeastern Colorado and southeastern Wyoming, where the disease is now endemic. In recent years, CWD has been found in areas outside of this disease-endemic zone, including areas east of the Mississippi River. The geographic range of diseased animals currently includes 15 U.S. states and two Canadian provinces and is likely to continue to grow. Surveillance studies of hunter-harvested animals indicate the overall prevalence of the disease in northeastern Colorado and southeastern Wyoming from 1996 to 1999 was estimated to be approximately 5 percent in mule deer, 2 percent in white-tailed deer, and less than 1 percent in elk.

4.3 CHANGE AGENTS PROPOSED FOR ANALYSIS

Although numerous attributes and indicators affecting this species were initially identified in the early phases of this REA, not all are included in this analysis. The specific indicators that could not be modeled are identified with an asterisk on Figure E-4-5. Analyses for the invasive species CA and insect outbreak and disease CA are not included for this CE because the direct effect indicators were determined to be data gaps or because it was impractical to model at the ecoregional scale as appropriate geospatial data were not available. Further information on the data gaps for indicators are discussed in the respective CA analyses contained in Appendix C.

Analyses for the development, wildfire, and climate change CAs are included for this CE.

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5.0 CHANGE AGENT ANALYSIS

A current status and future threat assessment for the big game assemblage was conducted for the Middle Rockies ecoregion using the 12-digit Hydrologic Unit Codes (HUCs) as the analysis unit. Based on the ecological process and system-level models, KEAs were identified for the current status and future threat analyses, with a specific emphasis on the ability to measure impacts using existing geospatial data. The CAs evaluated for current status include development and wildfire. The CAs evaluated for future threats include development and climate change.

Since the scale of the analysis is at the HUC 12, a layer of 6th level HUCs was extracted for the ecoregion. A geographic information system (GIS) process was iterated through the KEA indicators and determined the metric values associated with some watersheds. In other instances, sufficient published data indicated cut-off points for these values. These values were added as an attribute to the HUC 12 layer. Since the primary reporting units for final mapping outputs is at a minimum of the 6th level watershed (HUC 12) for the CEs, the values from the final output maps need to be added as an attribute to the HUC 12 watersheds. In some cases, zonal statistics will be calculated to determine a value associated with each watershed. The final layers will be created by combining the HUC 12 watersheds (with ranked KEAs) with the final suitable habitat layer and the habitat layer from the current status CA layer. The GIS process model can then be rerun changing necessary inputs for other CA analyses.

5.1 CURRENT STATUS OF MULE DEER

5.1.1 Key Ecological Attribute Selection

Table E-4-5 identifies the original KEAs that were proposed in Task 3 and which of these were used in the final current status analysis. Not all of the KEAs proposed were used, based on the rationale provided. Other KEAs were used but are not directly related CAs. For example, the KEA related to corridor width is an important aspect of the quality and utility of habitat available to species such as mule deer. However, this indicator was excluded from the analysis because of the focus upon winter range habitat. Experts concluded that mule deer typically navigate corridors during their migration between winter and summer ranges and, since summer range habitat had been excluded, there would be little movement of mule deer between the winter range habitats during the winter season.

Table E-4-5. Key Ecological Attributes Retained or Excluded for the Mule Deer

Category	Attribute	Explanation
Size	Patch Size (Availability of contiguous, large native habitat patches)	Retained to show the large patches of grassland habitat.
	Corridor Width	Excluded from the analysis because of the focus upon winter range habitat.
Condition	LANDFIRE Vegetation Condition Class (VCC)	Excluded because it was observed that the dataset classified grassland communities as having a high departure from original conditions that was not agreed upon by regional experts.
Context	Habitat Heterogeneity (Patch Density - no./100 ha)	
	Distance to roads	Retained to evaluate anthropogenic impacts.
	Development (minimum distance from well pads)	Retained to evaluate anthropogenic impacts.
	Permeability (mean annual snow depth)	Excluded because dataset was not suitable for assessing the barriers to movement (melting, compaction, sublimation) presented to mule deer herds by snow depth. No other dataset was available.

The KEAs proposed to evaluate wildfire were excluded because the Rolling Review Team (RRT) disagreed with information from the Fire Regime Vegetation Condition Class (VCC) data regarding the condition of the grassland communities within the ecoregion. Therefore, the potential risks of wildfire on this CE were not assessed for this REA.

Climate change conditions were also not evaluated because the KEA selected (mean annual snow depth) was not suitable for assessing the barriers to mule deer movement (melting, compaction, sublimation). A qualitative discussion regarding impacts of climate change on this CE is presented in Section 5-4-2.

Table E-4-6 identifies the KEAs, indicators, and metrics that were used to evaluate the CAs and pathways affecting this CE across the ecoregion, as illustrated on Figure E-4-5. Several indicators were used to assess the current status for this assemblage. Size and landscape context (e.g., heterogeneity, distance to roads, fragmentation) attribute layers were developed.

Table E-4-6. Mule Deer Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Connectivity & Context Cover Landscape Structure Escape	Patch Size (Availability of contiguous, large native habitat patches)	<300 ha	300-500 ha	>500 ha	GAP National Land Cover Data (NLCD)	Best Judgment
Landscape Context	Connectivity & Context	Habitat Heterogeneity (Patch Density - no./100 ha)	<0.3 or >0.55	0.3-0.4	0.40-0.55	GAP NLCD	Kie et al. 2002
	Landscape Structure	Distance to roads	<300 m	300-1,000 m	>1,000 m	TIGER Linear features	Poor 2010
		Development (minimum distance from well pads)	<300 m	300-1,000 m	>1,000 m	Oil and gas wells	Sawyer et al. 2006

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. This process was carried out through the establishment of a CE RRT comprised of BLM wildlife biologists and state-level experts. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics, as well as to ascertain the accuracy of each step of the modeling process. Metrics used were equally weighted when evaluating the overall current status of this CE species.

5.1.1.1 Patch Size

Patch size was selected as an indicator of spatial distribution (home-range), which has been related to a variety of factors including body size, trophic level, sex and age, reproductive status, seasonal availability of forage and water, and intra- and inter-specific competition. Home-range size in mule deer correlate with a variety of landscape metrics and, therefore, may play a role in determining population densities (Kie et al. 2002).

Using the HCA toolset developed by WHCWG (2010), large, contiguous areas that have retained high levels of naturalness (i.e., core areas characterized by a relatively light human footprint) were identified. Using the patch layer outputs for the mule deer, the layer output (low threshold) was reclassified based on the patch acreage ranges established for this indicator and were assigned associated values between 1 and 3 (Table E-4-6). This layer was converted to raster with assigned values. Zonal statistics were applied against the layer using the HUC 12 watershed GIS layer to determine an overall summary score for the patches contained within each watershed. The habitat patch size by HUC is presented on Figure E-4-6.

5.1.1.2 Habitat heterogeneity (Patch Density)

Spatial heterogeneity is a structural feature of landscapes that can be defined as the complexity and variability in the habitat of the species. Large mammalian herbivores require temporally and spatially diverse habitat elements (such as food and cover), and these mammals can have significant effects on vegetation composition and basic ecosystem processes (such as nutrient cycling), thereby acting as keystone species (Kie et al. 2002).

Habitat heterogeneity was assessed by using the core habitat developed for the patch size analysis. This dataset was evaluated by applying the following patch density equation to assess the level of habitat heterogeneity:

$$PD = \frac{N}{A}$$

where PD = Patch Density, N = number of unique patches, and A = unit area (100 ha).

The patch layer had the roads layer removed from it to develop a more realistic representation of the landscape. Each patch contained within the ‘core habitat’ GIS layer was then attributed with a unique identifier. The core habitat was then intersected with the HUC 12 watershed boundary layer. This process allowed each patch to be assigned with an HUC 12 identifier. The associated GIS attribute table was imported to excel, and pivot tables were developed based upon the HUC 12 identifier. The data were summarized by performing a count of unique patch identifiers and of the total area of patches per watershed. The patch density was then calculated. Each patch density value was then graded. The resulting summary table was then rejoined to the HUC 12 watershed GIS dataset. The patch density values were scored based on the metric values presented in Table E-4-6. The patch density layer output is presented on Figure E-4-7.

5.1.1.3 Distance to Roads

Roads limit connectivity through the creation of physical barriers (such as right-of-way fences), increased mortality due to collisions, and behavioral alienation (avoidance of roads or high traffic volumes) (WHCWG 2010). This KEA was used as an indicator to assess potential impacts from development.

Road features were identified using Topologically Integrated Geographic Encoding and Referencing (TIGER) line data; features mapped as freeways, secondary roads, and local roads were extracted. Summary zonal statistics were applied to the graded data to generate a rating for each watershed included within the HUC 12 watershed boundary dataset. A proximity analysis was performed, and then scores were assigned based on the metric values presented in Table E-4-6. The distance to roads layer output is presented on Figure E-4-8.

5.1.1.4 Distance to Development

Development was characterized as the minimum distance from well pads at which mule deer are most likely to occur over 3 years of progressive oil and gas development. This KEA was used as an indicator to assess potential impacts from oil and gas development.

Well point data were compiled into one dataset from all applicable states. Summary zonal statistics were applied to the graded data to generate a rating for each watershed included within the HUC 12 watershed boundary dataset. A proximity analysis was performed and then scores were assigned based on the metric values presented in Table E-4-6. The distance to development layer output is presented on Figure E-4-9.

5.1.2 Current Status of Mule Deer Habitat

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of mule deer habitat for each HUC across the ecoregion. In order to create a current status layer, an overall score for each HUC unit was calculated. To generate overall scores for each watershed, all scored criteria were additively combined. Each watershed has the potential of receiving a maximum score of 12 points (i.e., 4 indicators assessed, each having a grading system of 1 to 3). The summed scores were then divided by a factor of 12 to yield a value between 0 and 1. This final overall score was then ranked as Poor, Fair, or Good based on the natural breaks methods, which seeks to reduce the variance within classes while maximizing the variance between classes. The overall current status layer for the mule deer is presented on Figure E-4-10.

The patch size evaluation (Figure E-4-6) indicates that habitat size is good (>500 ha) over most of the winter range in the Middle Rockies; however, the patch density is fair to poor (Figure E-4-7). Much of the habitat is characterized as fair (300-1000 m) relative to distance from roads (Figure E-4-8). Current impacts associated with oil and gas development are not significant, as the distance to most existing well development is rated as good (>1000 m) throughout the ecoregion (Figure E-4-9).

A summary of the current status ratings based on the mule deer distribution is provided in Table E-4-7. The CE distribution layer was used to calculate the total number of square miles of the CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that nearly 40 percent of the 6th level HUC watersheds that intersect the mule deer distribution received a good rating. The majority of the land (54.5 percent) in use by the mule deer is rated as fair while only 6.3 percent was rated as poor.

Table E-4-7. Summary of Current Status Ratings for the Mule Deer

Overall Rating by 6th Level HUC	Total Square Miles[a]	Percentage of Total Square Miles[a, b]
Good	39,779	39.2
Fair	55,287	54.5
Poor	6,388	6.3

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.2 CURRENT STATUS OF ELK

5.2.1 Key Ecological Attribute Selection

Table E-4-8 identifies the original KEAs for elk that were proposed in Task 3, and which of these were used in the final current status analysis. Not all of the KEAs proposed were used, based on the rationale provided. Other KEAs were used but are not directly related to CAs. For example, the KEA related to corridor width is an important aspect of the quality and utility of habitat available to species such as mule deer. However, this indicator was excluded from the analysis because of the focus upon winter range habitat. Experts concluded that mule deer typically navigate corridors during their migration between winter and summer ranges and, since summer range habitat had been excluded, there would be little movement of mule deer between the winter range habitats during the winter season.

Table E-4-8. Key Ecological Attributes Retained or Excluded for Elk

Category	Attribute	Explanation
Size	Patch Size (contiguous)	Retained to show the large patches of elk habitat.
	Patch size of Forested Habitat (>75% canopy cover)	Retained to show patches of forested elk habitat.
	Patch shape	Eliminated because a method of assessing metric values was not available.
Condition	VCC	Excluded because it was observed that the dataset classified grassland communities as having a high departure from original conditions that was not agreed upon by regional experts.
Context	Road density Forested Cover	Retained to show where the colonies occur relative to protected lands.
	Road density Non-forested Cover	Retained to show the proportion of the HUC in agricultural lands.
	Distance from open road	Excluded because road data did not have information on this condition.
	Development distance (oil and gas, residential, etc)	Retained to show the fragmentation.
	Snow depth	Excluded because dataset was not suitable for assessing the barriers to movement (melting, compaction, sublimation) presented to elk herds by snow depth. No other dataset was available.

Several CAs initially proposed for analysis were not based on available data. The KEAs proposed to evaluate wildfire were excluded because the RRT disagreed with information from the VCC data regarding the condition of the grassland communities within the ecoregion. Climate change conditions were also not evaluated because the KEA selected (mean annual snow depth) was not suitable for assessing the barriers to mule deer movement (melting, compaction, sublimation). A qualitative discussion regarding impacts of climate change on this CE is presented in Section 5-4-2.

Table E-4-9 identifies the KEAs, indicators, and metrics that were used to evaluate the CA and pathways affecting this CE across the ecoregion (as illustrated on Figure E-4-5). Several indicators were used to assess the current status for this assemblage. Size and landscape condition (e.g., patch size distribution, patch shape, habitat connectivity, fragmentation) of the applicable elk habitat output was incorporated into a GIS overlay.

Table E-4-9. Elk Key Ecological Attributes, Indicators, and Metrics for Current Status Assessment for the Middle Rockies Ecoregion

Category	Ecological Attribute	Indicator / Unit of Measure	Metric			Data Source	Citation
			Poor = 3	Fair = 2	Good = 1		
Size	Connectivity & Context Cover Landscape Structure Escape	Patch Size (contiguous)	<250 ac	250-400 ac	>400 ac	WAFWA	Christensen et al. 1993
		Patch size of Forested Habitat (>75% canopy cover)	<250 acres	na	>250 acres	GAP LANDFIRE WAFWA	Hillis et al. (1991)
Landscape Context	Connectivity & Context/ Landscape Structure	Road density- Forested Cover (mi/mi^2)	>2	1-2	<1	Linear Feature/ GAP/NLCD	Lyon 1983
		Road density Non-Forested Cover (mi/mi^2)	>1	na	<1	Linear Feature/ GAP/NLCD	Lyon 1979
		Development to distance; Oil and gas, residential (m)	<500 m	500-1,000 m	>1000 m	Oil & Gas Human Footprint	

na = no metric value

In most cases, the metrics used to identify attribute quality were based on available publications, coupled with expert analysis and professional judgment in association with data-driven metrics. This process was carried out through the establishment of a CE RRT comprised of BLM wildlife biologists and state-level experts. The RRT met periodically to contribute information and to analyze input attributes and outputs that were derived from various forms of spatial analyses in GIS. This process enabled the RRT to determine the efficacy of attributes, indicators, and metrics, as well as to ascertain the accuracy of each step of the modeling process. Metrics used were equally weighted when evaluating the overall current status of elk winter habitat.

5.2.1.1 Patch Size

Patch size was selected as an indicator of spatial distribution (home-range), which has been related to a variety of factors including body size, trophic level, sex and age, reproductive status, season availability of forage and water, and intra- and inter-specific competition. Home-range size in elk correlate with a variety of landscape metrics and, therefore, may play a role in determining population densities (Kie et.al. 2002).

The winter range for elk in the Middle Rockies was used to assess patch size. The habitat patch layer was reclassified based on the patch acreage ranges and metric values between 1 and 3, as noted in Table E-4-8. This layer was converted to raster with assigned values. Zonal statistics were applied against the layer using the HUC 12 watershed GIS layer to determine an overall summary score for the patches contained within each watershed. The patch size layer output is presented on Figure E-4-11.

5.2.1.2 Patch Size- Forested Habitat

To assess the forested portions of the elk patch habitat, three datasets were utilized: the GAP landcover dataset, LANDFIRE canopy cover density dataset, and WAFWA elk winter range habitat. The GAP dataset was used to isolate forested regions defined as Level 1 Forest and Woodland Systems. The NLCD Canopy Cover dataset was then used to delineate portions of forest with a 75% or greater canopy cover which also fell within the mapped WAFWA elk winter range habitat. Data were converted to shapefile format in order to calculate acreage per patch. The acreage values were then assigned scores as presented in Table E-4-8. Zonal statistics were applied to the raster output and summarized on a watershed basis using HUC 12 identifiers. The patch size of forested habitat layer is presented on Figure E-4-12.

5.2.1.3 Road Density Within Forested Cover

Roads limit connectivity through the creation of physical barriers (such as right-of-way fences), increased mortalities due to collisions, and behavioral alienation (avoidance of roads or high-traffic volumes (WHCWG 2010). This KEA was used as an indicator to assess potential impacts from development, particularly within forested habitat.

A line density analysis was applied to the TIGER line dataset using a one-square-mile moving window with a 30-m raster cell output within elk patch habitat. The line density output was then constrained to forested habitat regions, which were extracted from the GAP landcover dataset using areas categorized as GAP Level 1 forest and woodland systems. The density values were then assigned scores, as presented in Table E-4-8. Zonal statistics were applied to the raster output and summarized on a watershed basis using HUC 12 identifiers. The road density within forested cover layer is presented on Figure E-4-13.

5.2.1.4 Road Density Within Non-forested Cover

This KEA was used as an indicator to assess potential impacts from development and in particular within non-forested elk habitat.

A line density analysis was applied to the TIGER line dataset using a one square mile moving window with a 30-m raster cell output. The line density output was then constrained to non-forested habitat regions, which were extracted from the GAP landcover dataset using areas categorized as other GAP Level 1 vegetation systems, (except for: forest and woodland systems, developed, mining, agriculture, open water, beach/shore and sand, cliff/canyon and talus, bluff/badlands, other sparse and baren, harvest forest, and disturbed). The resulting density values were then assigned scores, as presented in Table E-4-8. Zonal statistics were applied to the raster output and summarized on a watershed basis using HUC 12 identifiers. The road density within non-forested cover layer is presented on Figure E-4-13.

5.2.1.5 Distance to Development

Development was characterized as the minimum distance from oil and gas development and urban areas. Well point data were compiled into one dataset from all applicable states. Urban areas were extracted from the GAP landcover dataset by isolating pixels that represented residential cover types. Distance from the well pad/urban area was assessed for 3 distance zones, as noted in Table E-4-8. Proximity analyses were applied to both development datasets. Outputs were combined and then graded based on the criteria presented in Table E-4-8. Summary zonal statistics were applied to the graded data to generate a rating for each watershed included within the HUC 12 watershed boundary dataset. The distance to development layer is presented on Figure E-4-15.

5.2.2 Current Status of Elk Habitat

The individual KEA analyses provide the basis for the compilation of an overarching data layer that defines the current status of elk habitat for each HUC across this ecoregion. In order to create a current status layer, an overall score for each HUC unit was calculated. To generate overall scores for each watershed, all scored criteria were additively combined. Each watershed has the potential of receiving a maximum score of 15 points (i.e., 5 indicators assessed, each having a grading system of 1 to 3). The summed scores were then divided by a factor of 15 to yield a value between 0 and 1. This final overall score was then ranked as poor, fair or good based on the natural breaks method, which seeks to reduce the variance within classes while maximizing the variance between classes. The overall current status layer for elk is presented on Figure E-4-16.

The habitat patch size (Figure E-4-11) indicates that habitat size is good (>400 acres) within most of the winter range. However, most of the areas are not forested (Figure E-4-12). Additionally, much of the existing forested cover is threatened by high road density (Figure E-4-13). Except for small, scattered areas of the ecoregion, elk winter range does not appear to be at risk from current development (Figure E-4-15).

A summary of the current status ratings based on the elk distribution is provided in Table E-4-10. The CE distribution layer was used to calculate the total number of square miles of CE habitat and a percentage of the total number of square miles per HUC that were rated as good, fair, or poor. The results of the current status assessment indicate that approximately 38.2 percent of the 6th level HUC watersheds that intersect the distribution layer for the elk were rated as good. Approximately 40.3% of the land in use by the elk within the ecoregion was rated as fair, while 21.5 percent was found to be rated as poor.

Table E-4-10. Summary of Current Status Ratings for Elk

Overall Rating by 6th Level HUC	Total Square Miles [a]	Percentage of Total Square Miles[a, b]
Good	29,385	38.2
Fair	30,991	40.3
Poor	16,548	21.5

[a] These values include only the area of HUCs that intersect with the CE distribution layer.
[b] Values rounded to one decimal place.

5.3 FUTURE THREAT ANALYSIS FOR THE MULE DEER

The system-level model (Figure E-4-4) was used to create a series of intermediate layers, which are primarily based on the geospatial data that were available on the future projections for the development and climate change CAs. Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069).

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than a specific time period) for some of these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their affect on big game populations.

5.3.1 Development Change Agent

Future spatial data for development was limited to potential energy development area, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1.

Future agricultural development (Figure C-1-1) activities are considered limited for most of the ecoregion. Risks associated with urban growth are considered low (Figure C-1-8). Areas of high future risk to the mule deer are from energy development, most notably in the southern portion of the ecoregion. The potential high risk of solar energy can be considered more widespread within the southern and eastern portions of the ecoregion (Figure C-1-6).

5.3.2 Climate Change

The climate CA layer was created through the results of the 2025 and 2060 U.S. Geological Survey (USGS) climate change models. These models should document areas that may be negatively and positively affected by climate change. Climate change was modeled based on a 15-kilometer (km) grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis are provided in Appendix C-5.

With temperature increases expected across North America, lower snowfall is projected to occur in the ecoregion. Changes in traditional summer/winter ranges may lead to a short-term positive effect on the abundance and distribution of mule deer in this ecoregion. Increases in populations or ranges of mule deer within the region will depend on forage availability and quality, with a likely increase in competition for available resources.

The NSCCVI tool was utilized to assess mule deer vulnerability to the effects of climate change. Using annual raster datasets from NatureServe to perform climate change calculations in ArcGIS (through the Predicted Temperature 2040-2069 (F) and the Predicted Hamon AET : PET Moisture Metric 2040-2069 datasets), the NSCCVI calculator was applied and produced an Index score of Not Vulnerable/Increase likely. The NSCCVI tool indicated that available evidence suggests the abundance and/or range extent of this species within the geographical area assessed is likely to increase by 2050. The assessment rating was largely based on a majority of neutral and somewhat decreased vulnerability scores calculated when assessing factors that influence vulnerability, such as dispersal and movements, sensitivity to temperature and moisture changes (historical thermal/hydrological niche), dependence on ice or snow-cover habitats, reliance on interspecific interactions to generate habitat, and dietary versatility.

5.4 FUTURE THREAT ANALYSIS FOR THE ELK

The system-level model for the big game assemblage (Figure E-4-5) was used to create a series of intermediate layers, which are primarily based on the geospatial data that were available on the future projections for the development and climate change CAs. Future threats were evaluated for development for a short-term time horizon (5 to 10 years) and for climate change for a long-term time horizon (50-year; 2050 to 2069).

Because of the inherent inaccuracies of the temporal scale of the future data, it is only possible to infer information pertaining to a subjective future period (rather than a specific time period) for some of these attributes. However, because of the limits placed on these data outputs, it is fair to assume that this model predicts the overall future potential for these attributes within this ecoregion. It is an upper limit of potential growth and should therefore be carefully applied to future estimates of their affect on elk populations.

5.4.1 Development Change Agent

Future spatial data for development was limited to potential energy development area, modeled urban growth, and potential agricultural development, as discussed in the development CA analysis presented in Appendix C-1.

Potential risk due to agricultural development (Figure C-1-1) activities is considered low for most of the ecoregion, except for the eastern portion of this ecoregion (near Rapid City). The current distribution of elk is widespread; therefore, even minor increases in agricultural development may affect elk habitat. Threats associated with urban growth are similar to those indicated for agricultural development (Figure C-1-8). Areas of high risk to elk habitat from energy development are most notable in the southwestern corner of Montana, where large habitat patches occur (Figure E-4-15). The potential for solar energy can be considered a more widespread risk within the southern and eastern portions of the ecoregion (Figure C-1-6), as well as areas where large elk habitat patches occur.

5.4.2 Climate Change

The climate CA layer was created through the results of the 2025 and 2060 USGS climate change models. These models should document areas that may be negatively and positively affected by climate change. Climate change was modeled based on a 15-km grid created for regional analysis. This analysis included a comparison of current climate patterns to future modeled climate patterns and resulted in the delta (change) output figures. Further details regarding the climate change analysis is provided in Appendix C-5.

With temperature increases expected across North America, lower snowfall is also projected to occur in the ecoregion, changes in traditional summer/winter ranges of the elk and may lead to a short-term positive effect on the abundance and distribution of this species in this ecoregion. Increases in populations or ranges will depend on forage availability and quality with a likely increase competition for available resources.

The NSCCVI tool was utilized to assess elk vulnerability to the effects of climate change. Using annual raster datasets from NatureServe to perform climate change calculations in ArcGIS (through the Predicted Temperature 2040-2069 (F) and the Predicted Hamon AET : PET Moisture Metric 2040-2069 datasets), the NSCCVI calculator was applied and produced an Index score of Not Vulnerable/Increase likely. The NSCCVI tool indicated that available evidence suggests the abundance and/or range extent of this species within the geographical area assessed is likely to increase by 2050. The assessment rating was largely based on a majority of neutral and somewhat decreased vulnerability scores calculated when assessing factors that influence vulnerability such as; distribution to barriers, dispersal and movements, sensitivity to temperature and moisture changes (historical thermal/hydrological niche), dependence on ice or snow-cover habitats, reliance on interspecific interactions to generate habitat, and dietary versatility.

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6.0 MANAGEMENT QUESTIONS

The relevant MQs for the big game assemblage would include those defined as part of the Landscape Species/Species Richness category. The overall MQ was: Where are the key habitat types (seasonal, refuges, corridors/connectivity, migration routes, concentrations of regionally significant species, etc.) for landscape species, keystone species, regionally significant species, and regionally significant suites of species? This MQ was considered in implementing the GIS analyses. Emphasis was placed on the spatial relationship of attributes mentioned in the MQs and the distribution map for the CE. Several examples of how the REA can be used to answer MQs (as noted in Appendix A) are provided below; these examples demonstrate the functionality of the REA and to provide an opportunity to discuss data gaps that were identified during the REA.

6.1 WHERE ARE AREAS THAT HAVE POTENTIAL FOR RESTORING REGIONALLY SIGNIFICANT SPECIES HABITAT OR HABITAT CONNECTIVITY FOR REGIONALLY SIGNIFICANT SPECIES?

The habitat patch size assessment (Figures E-4-1 and E-4-11) may be used to identify general areas where habitat patch size is rated as good and that would likely continue to support these species through conservation efforts.

6.2 WHERE ARE THE KEY HABITAT TYPES (SEASONAL REFUGES, CORRIDORS/CONNECTIVITY, MIGRATION ROUTES, CONCENTRATIONS OF REGIONALLY SIGNIFICANT SPECIES)?

The RRT determined that this REA would focus upon winter range habitat. Experts concluded that mule deer and elk typically navigate corridors during their migration between winter and summer ranges and, since summer range habitat had been excluded, there would be little movement of the species between the winter range habitats during the winter season. Additionally, occurrence data for the species was not available across the ecoregion to assess concentration centers.

6.3 WHERE ARE CURRENT REGIONALLY SIGNIFICANT LANDSCAPE/KEYSTONE SPECIES AND THEIR HABITATS, INCLUDING SEASONAL HABITAT AND MOVEMENT CORRIDORS, AT GREATEST RISK FROM CHANGE AGENTS, INCLUDING CLIMATE CHANGE (CONNECTIVITY, SMALL POPULATION SIZE)?

The habitat patch size (Figure E-4-11) indicates that habitat size is good (>400 acres) within most of the winter range. However, most of the areas are not forested (Figure E-4-12). Additionally, much of that forested cover is threatened by high road density (Figure E-4-13). Within the elk winter range, current development is not significant issue except for small but scattered areas of the ecoregion (Figure E-4-15). The primary future threats to the mule deer are from energy development, most notably in the southern portion of the ecoregion. The potential growth of solar energy can be considered a more widespread threat within the southern and eastern portions of the ecoregion (Figure C-1-6).

Within the elk winter range, current development is not a significant issue except for small but scattered areas of the ecoregion (Figure E-4-15). The future threats to elk habitat from energy development are most notable in the southwest corner of Montana, where large habitat patches occur. The potential growth of solar energy can be considered a more widespread threat within the southern and eastern portions of the ecoregion (Figure C-1-6) and in areas where large habitat patches for the elk occur.

6.4 WHERE ARE THE CRUCIAL WINTER AND/OR PARTURITION AREAS FOR BIG GAME SPECIES AT RISK FROM LONG-TERM HABITAT CONVERSION OR FRAGMENTATION?

The overall status figures (Figures E-4-10 and E-4-16) can be used to evaluate the areas within the ecoregion that are at risk from habitat conversion or fragmentation based on development activities.

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APPENDIX E-4

FIGURES

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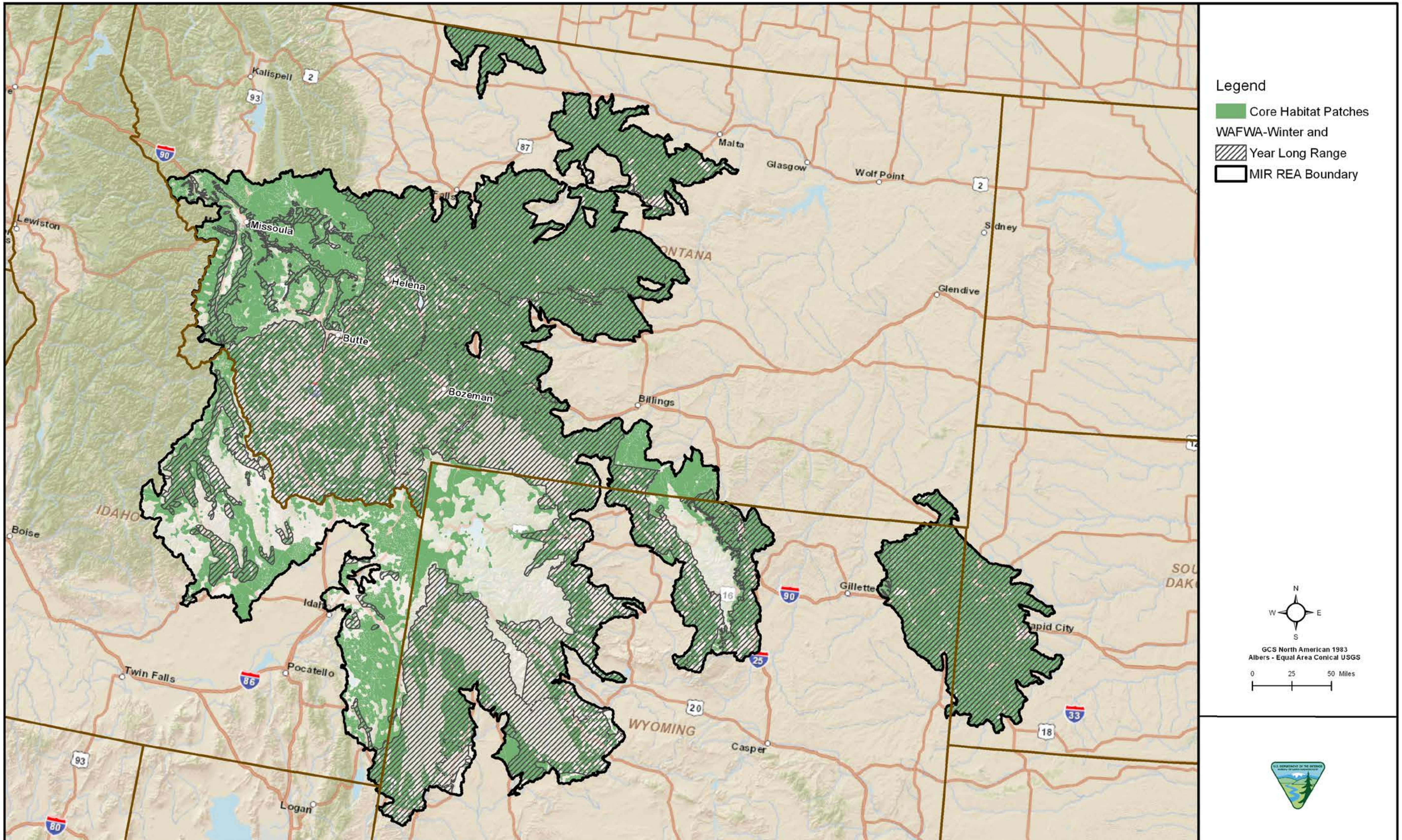

Figure E-4-1. WAFWA Mule Deer Range versus Habitat Core Area (HCA) Model for Mule Deer in Middle Rockies

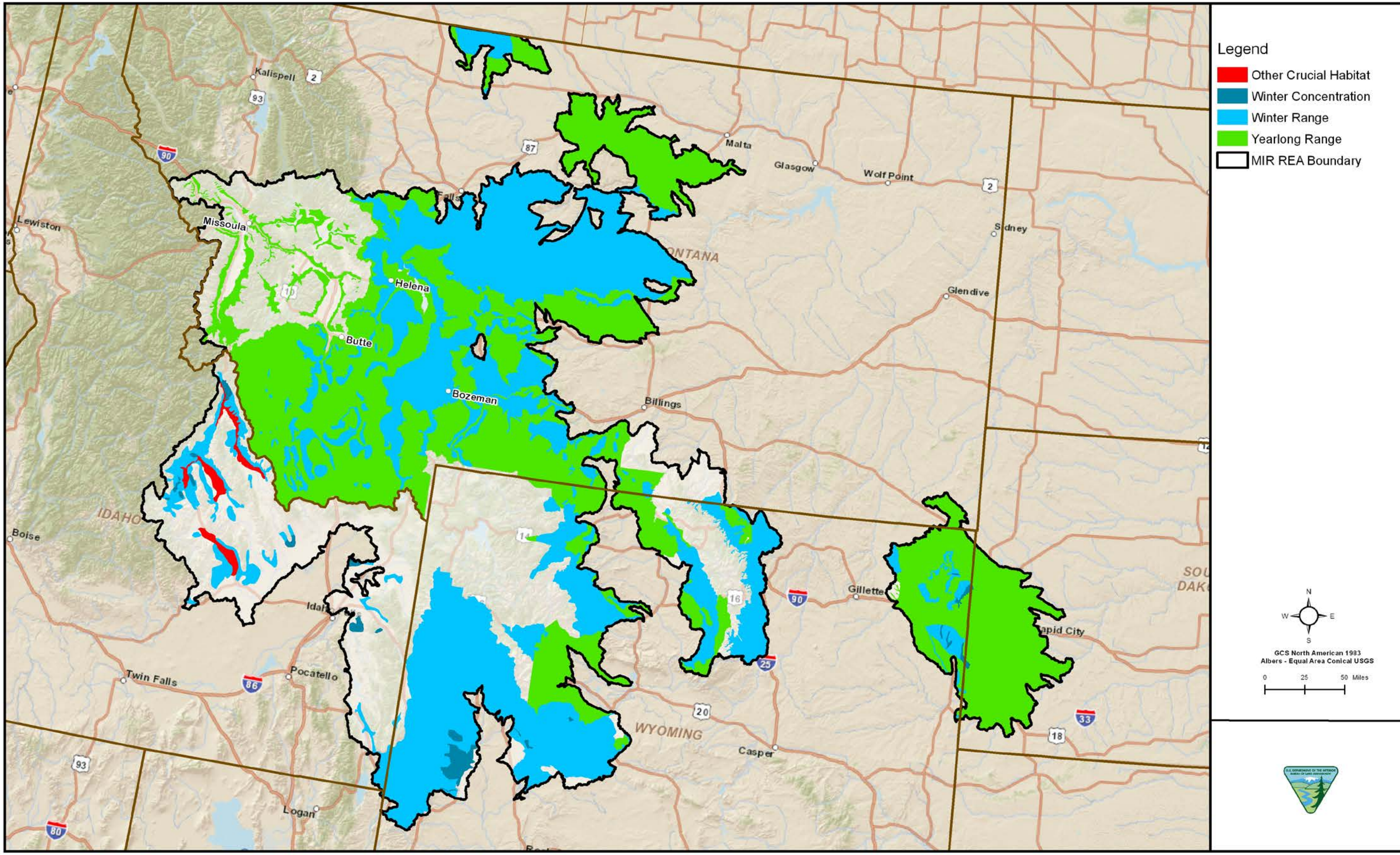

Figure E-4-2. Winter Range Distribution for the Mule Deer

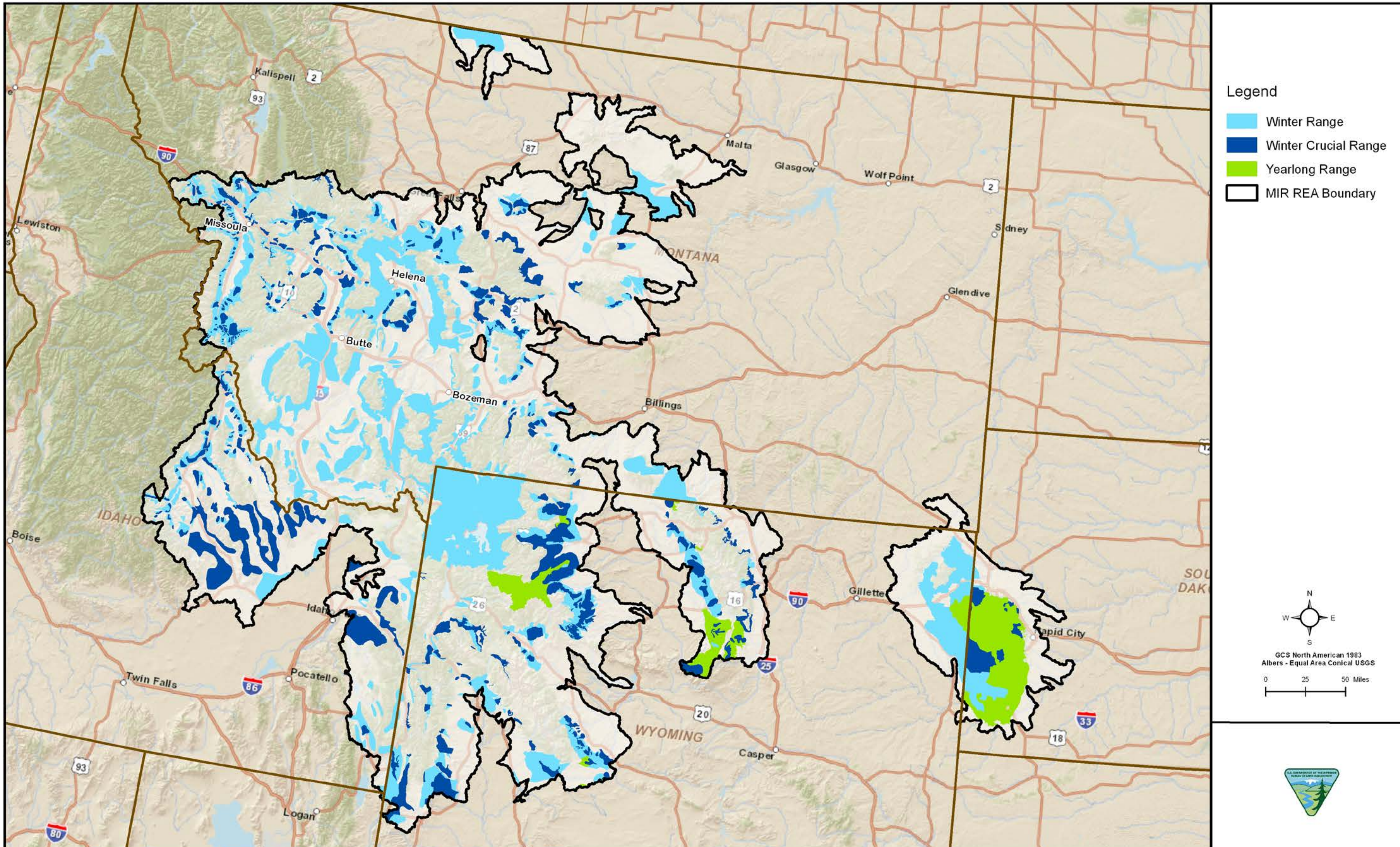

Figure E-4-3. Winter Range Distribution for the Elk

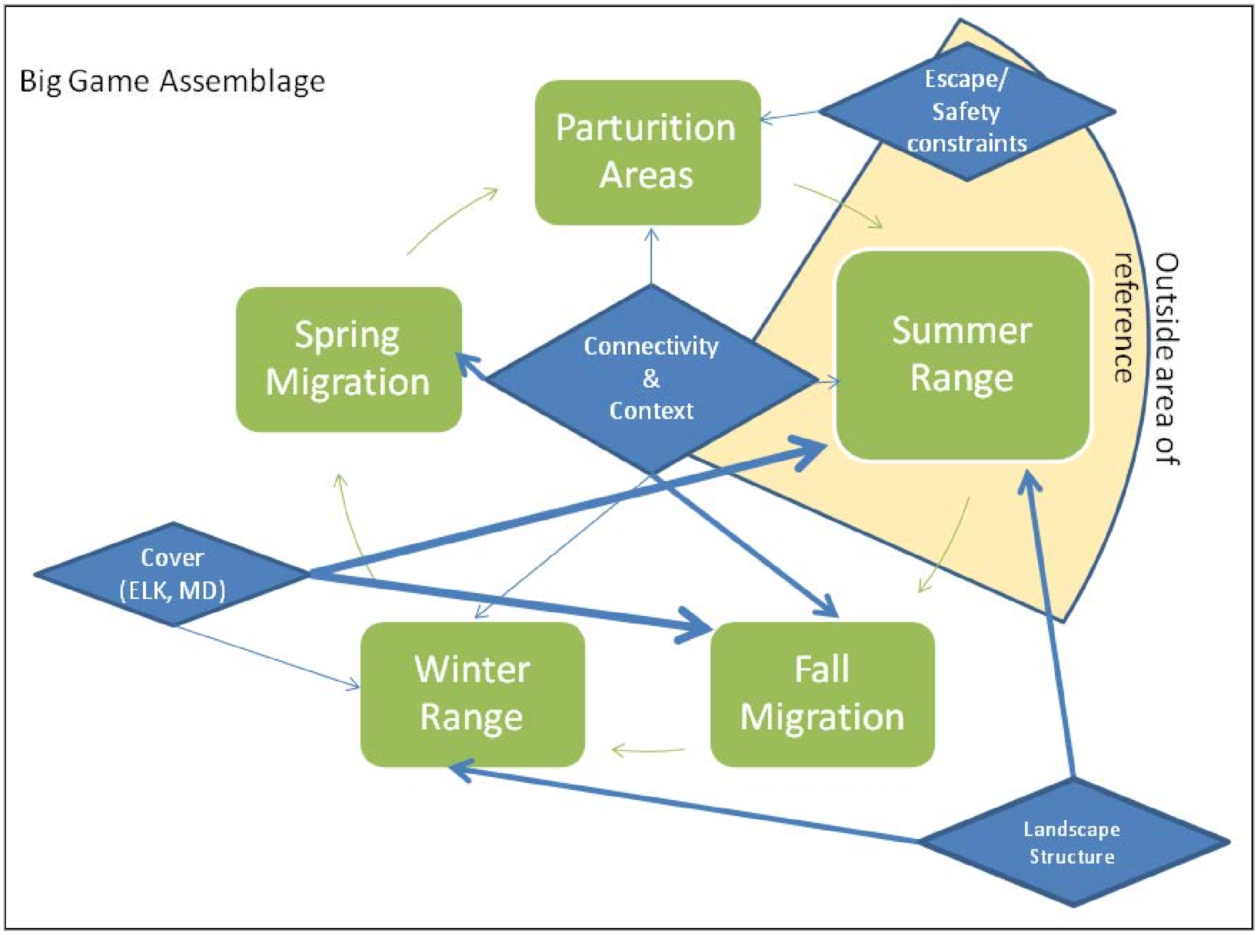

Figure E-4-4. Big Game Assemblage Ecological Process Model

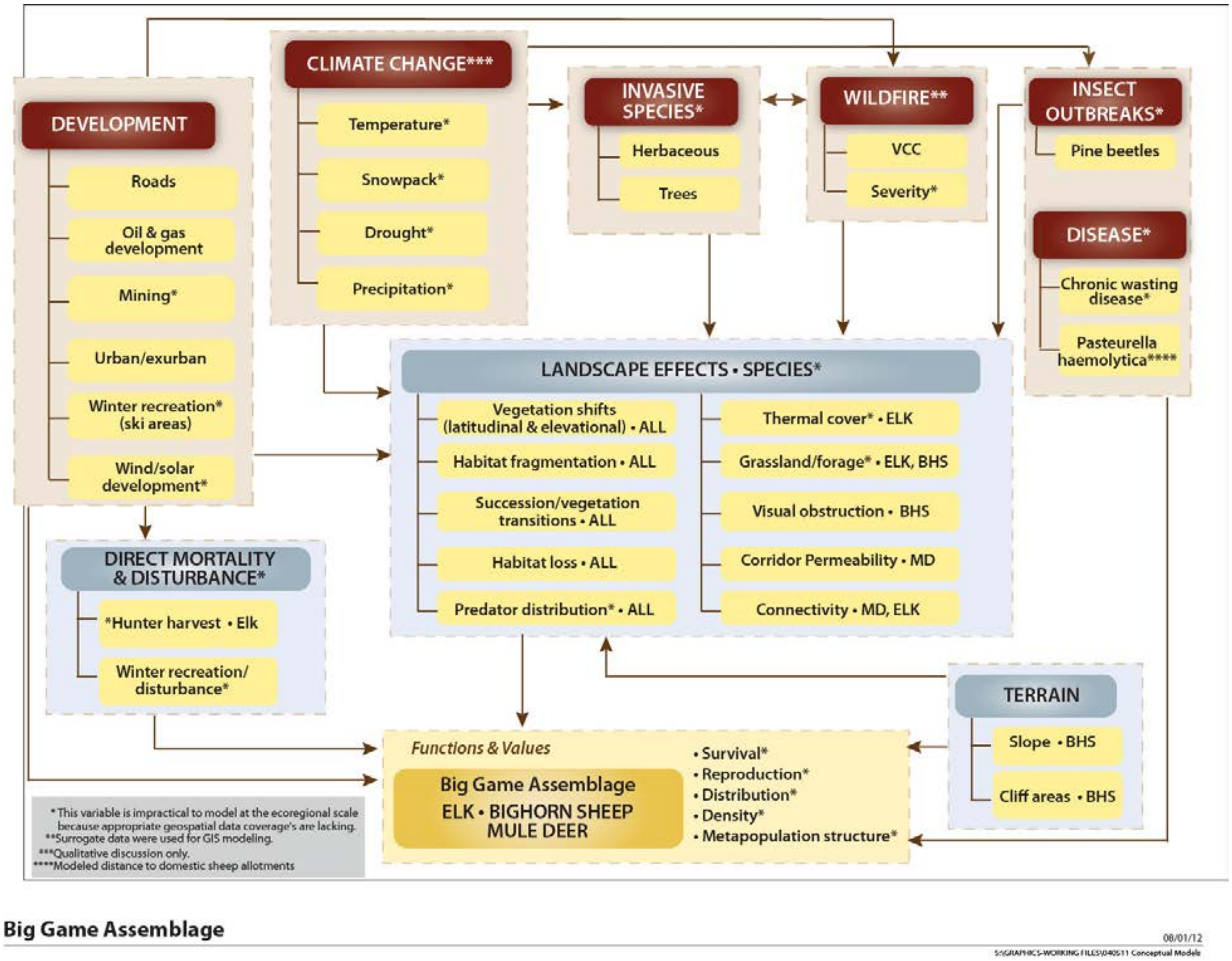

Figure E-4-5. Big Game Assemblage System-Level Model

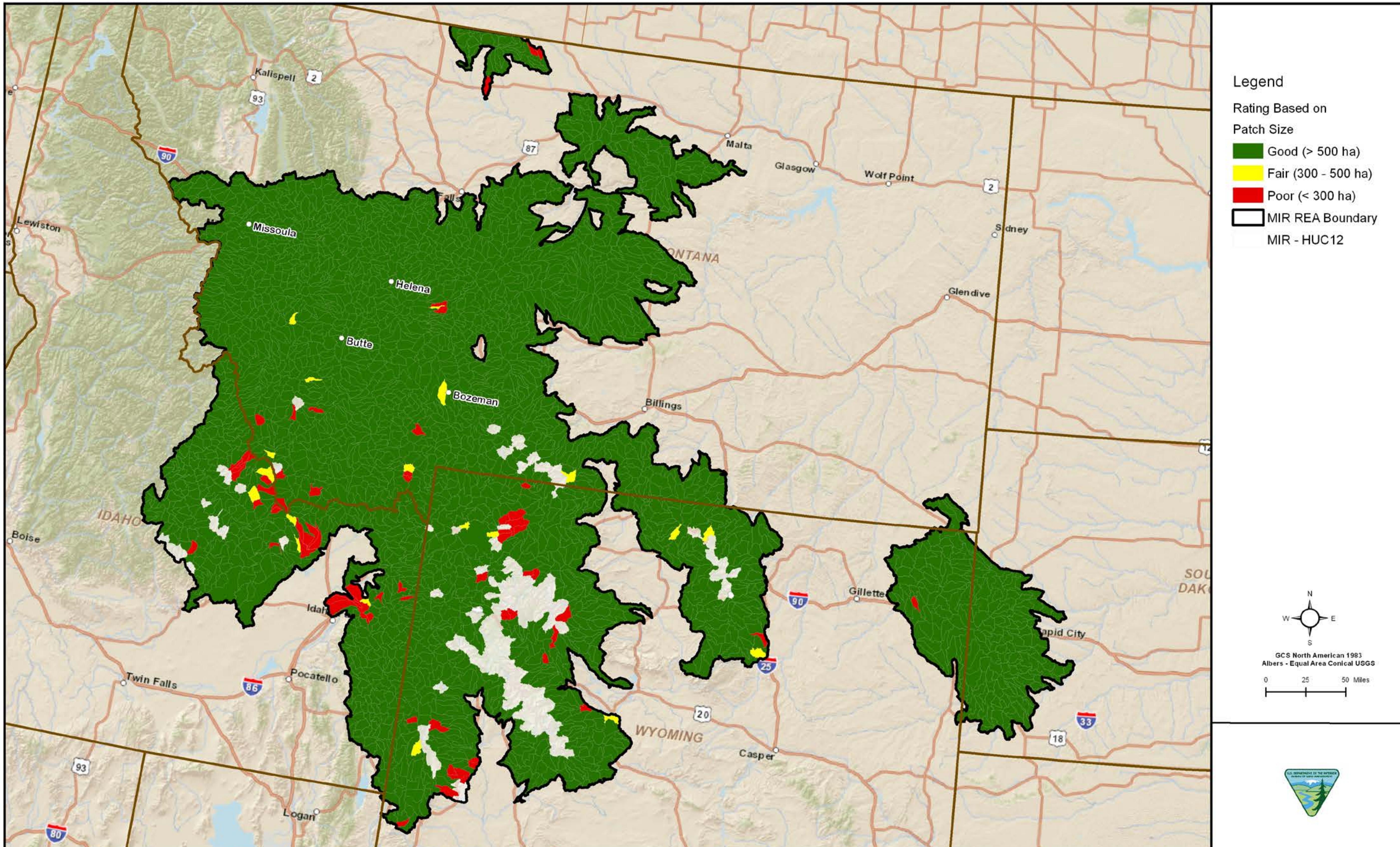

Figure E-4-6. Core Habitat Patch Size Model for Mule Deer

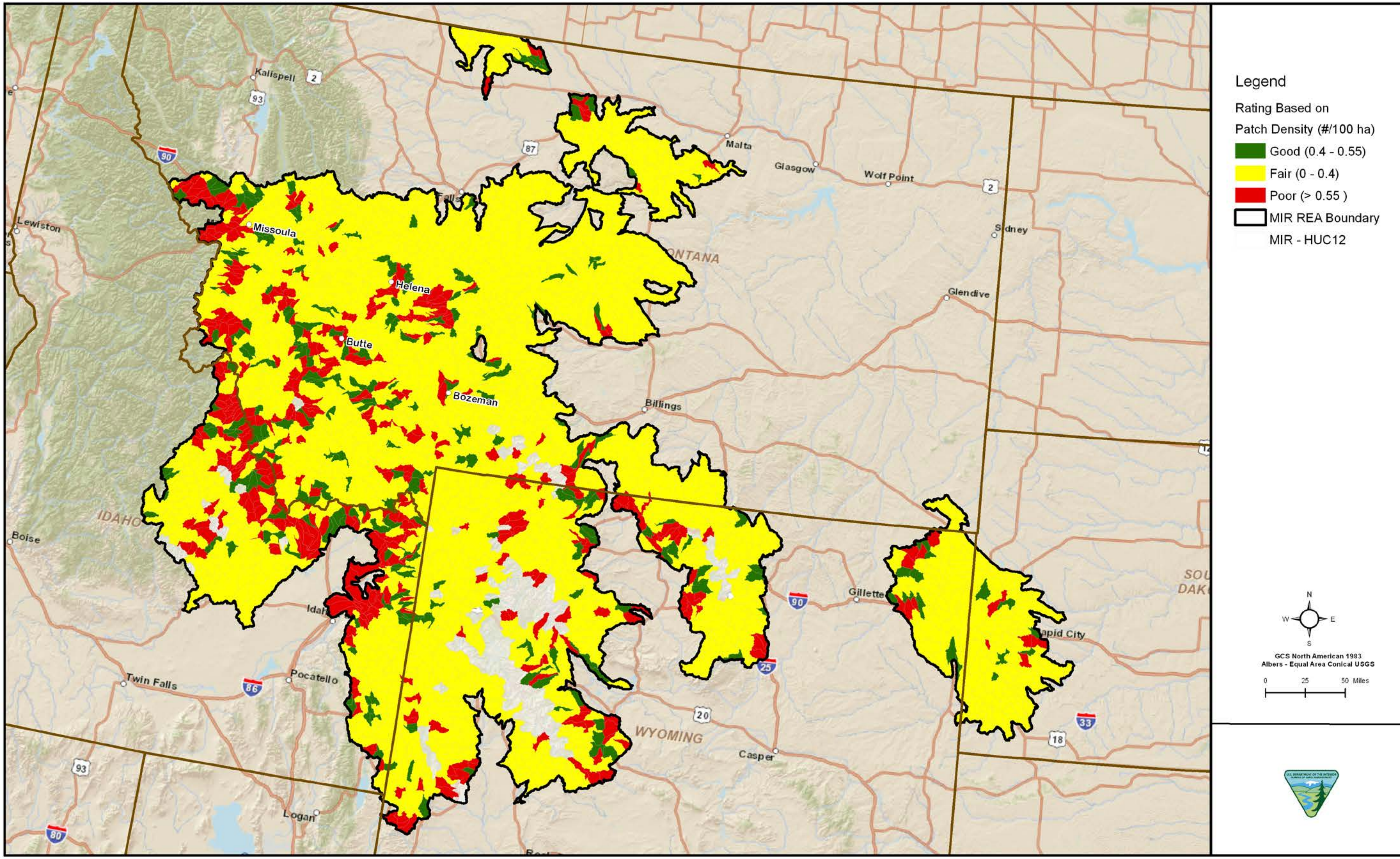

Figure E-4-7. Habitat Heterogeneity (Patch Density per 100 hectares) per Hydrologic Unit Code

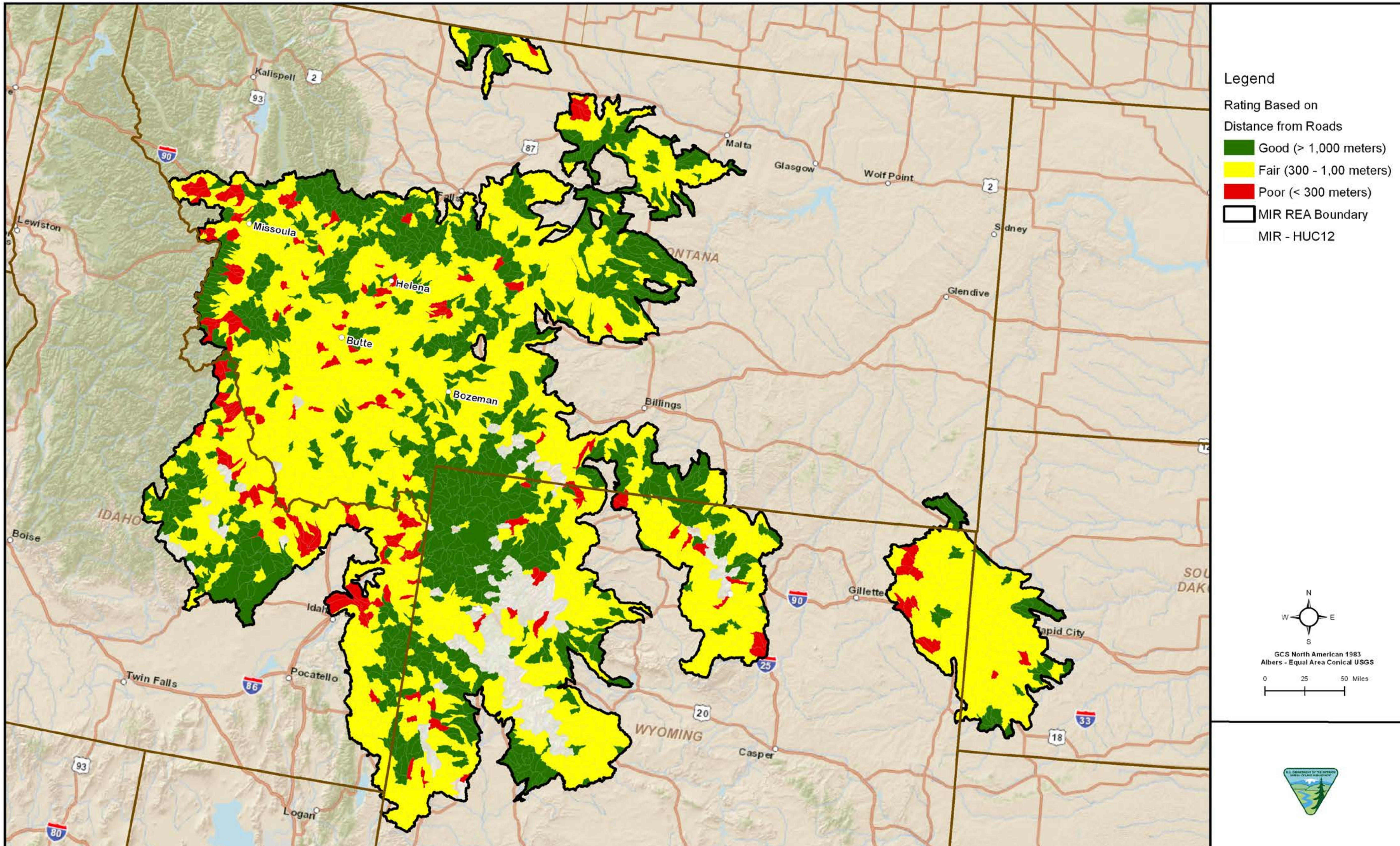

Figure E-4-8. Distance to Roads by Hydrologic Unit Code

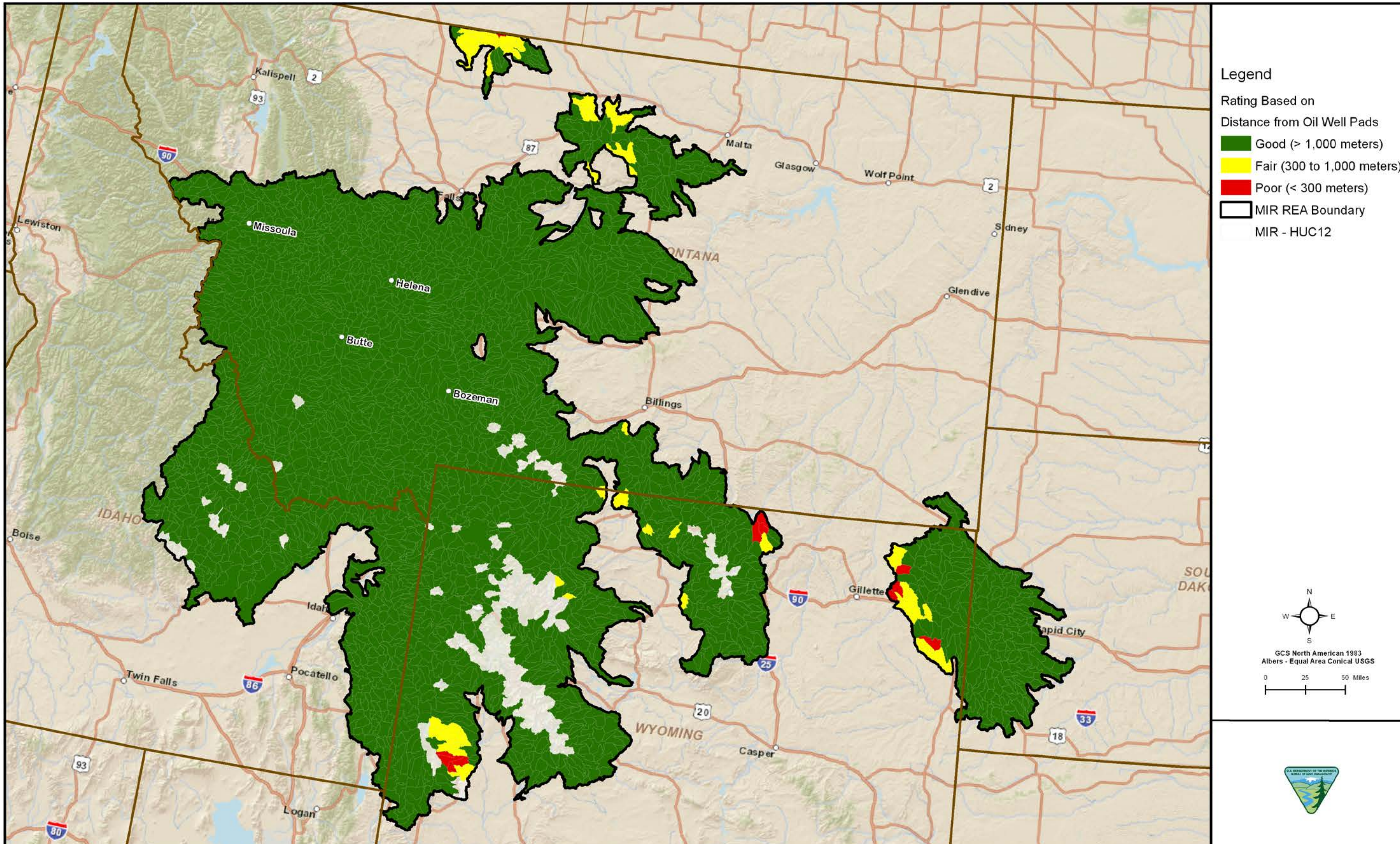

Figure E-4-9. Distance to Oil and Gas Development by Hydrologic Unit Code

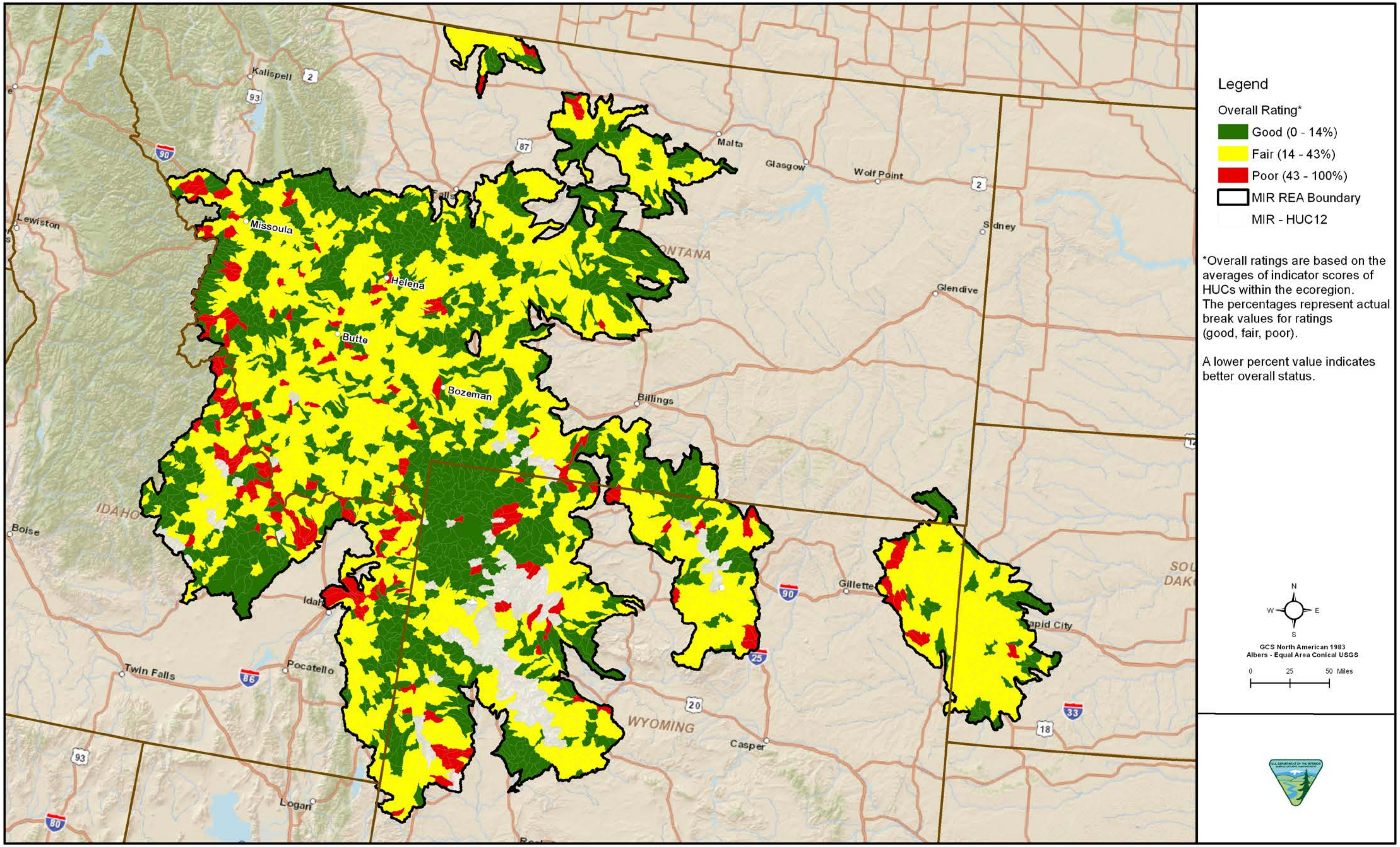

Figure E-4-10. Current Status of the Mule Deer based on Hydrologic Unit Code within the Middle Rockies Ecoregion

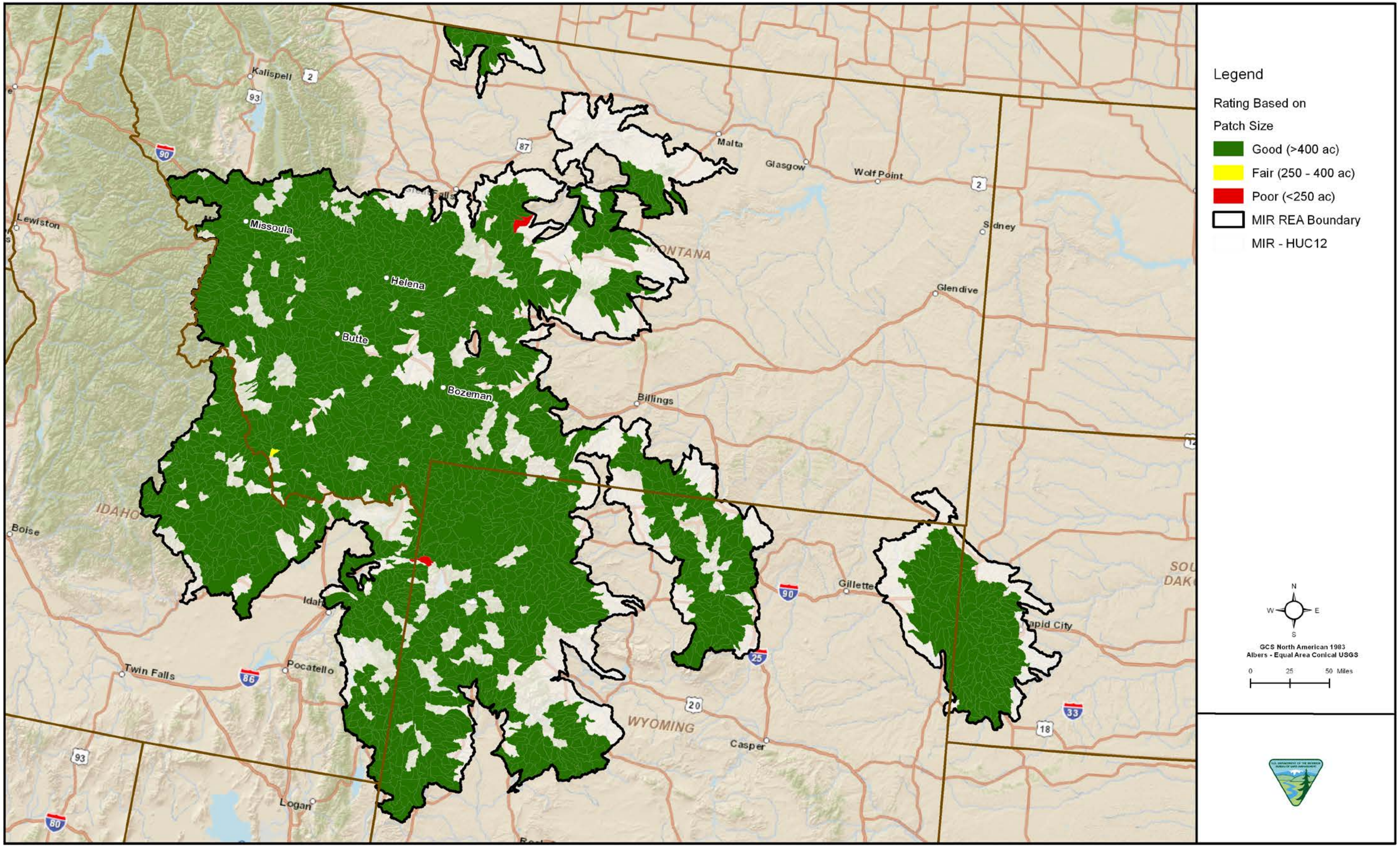

Figure E-4-11. Core Habitat Patch Size Model for Elk

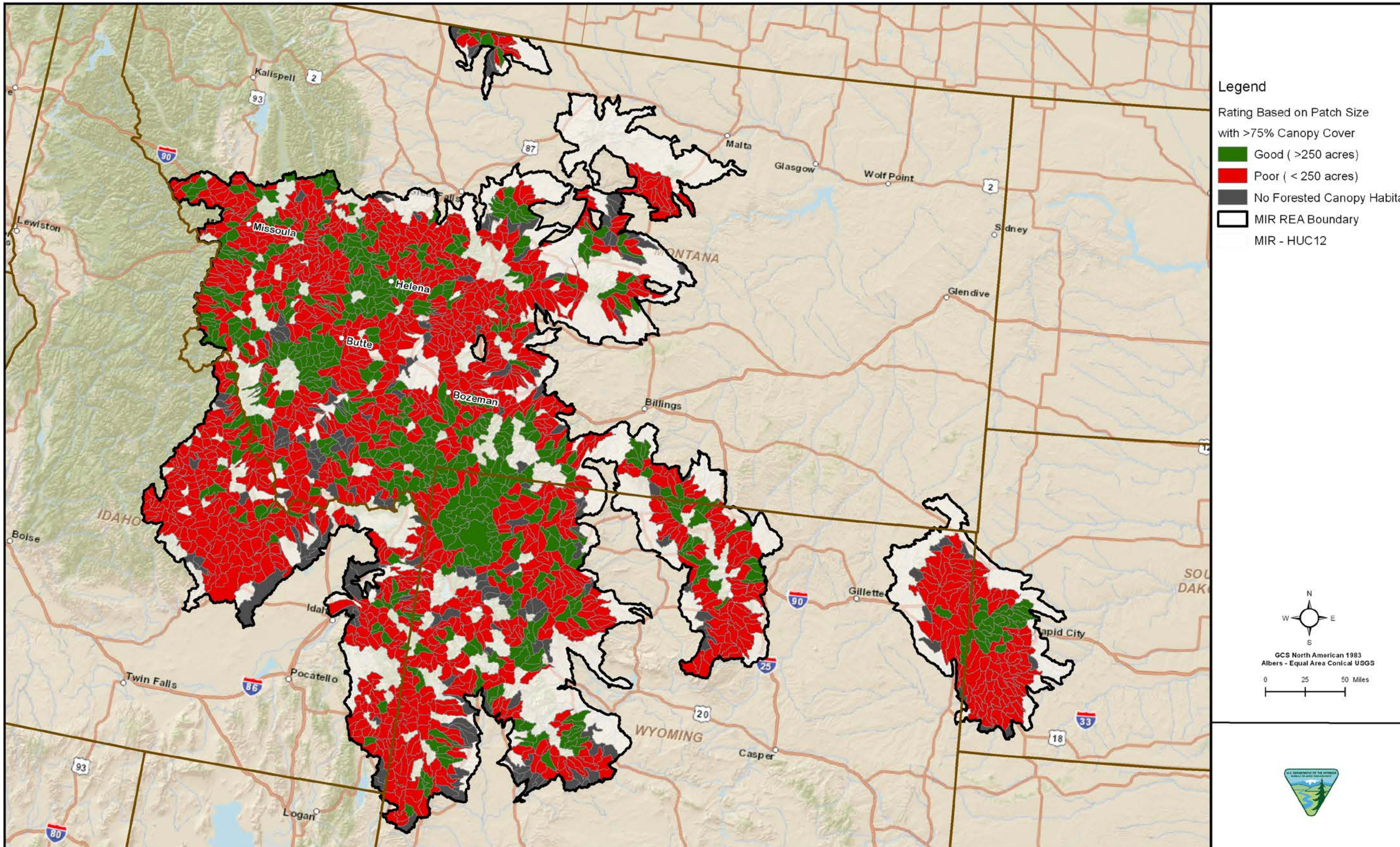

Figure E-4-12. Patch Size of Forested Habitat for Elk Winter Range

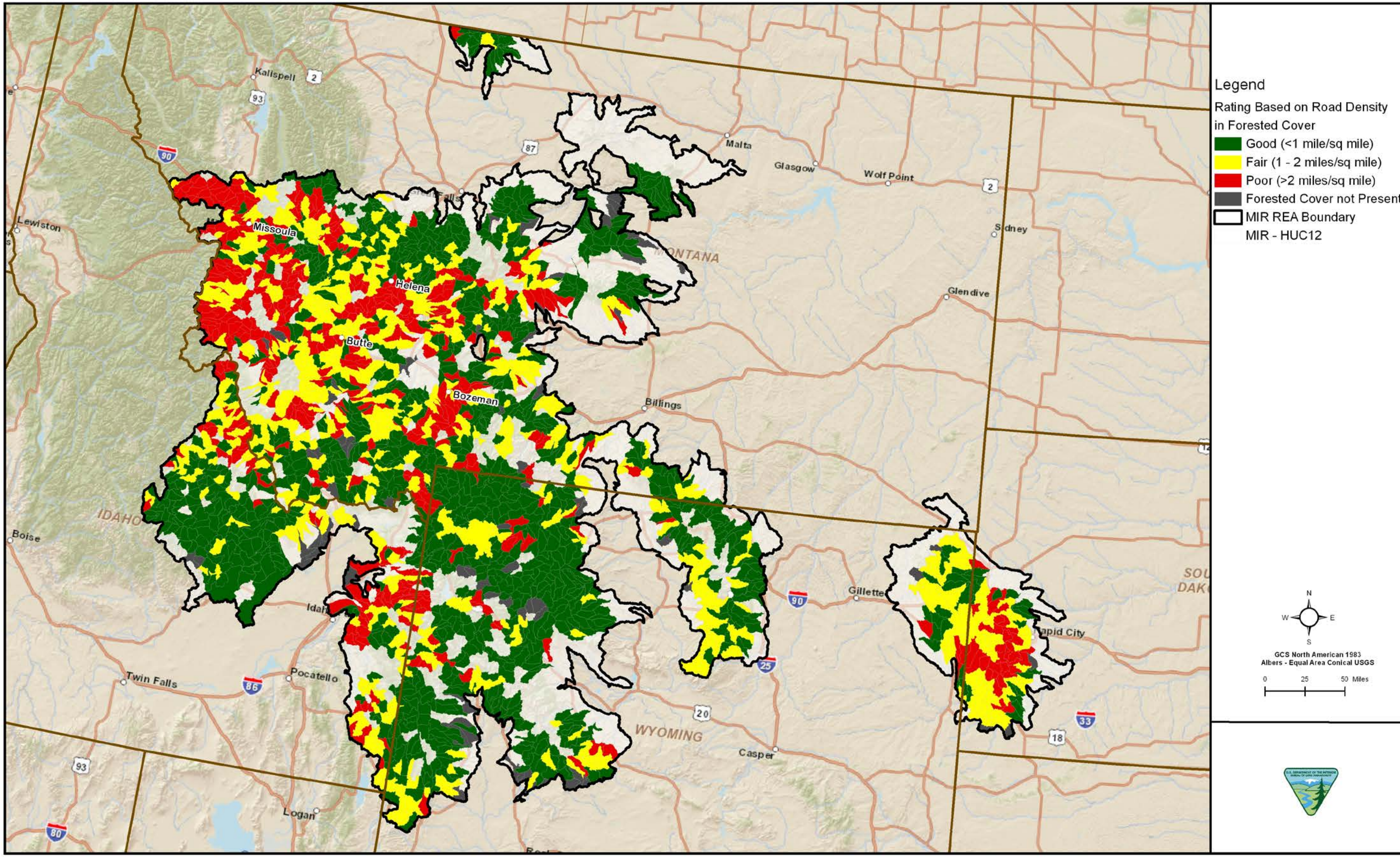

Figure E-4-13. Road Density within Forested Habitat for Elk Winter Range

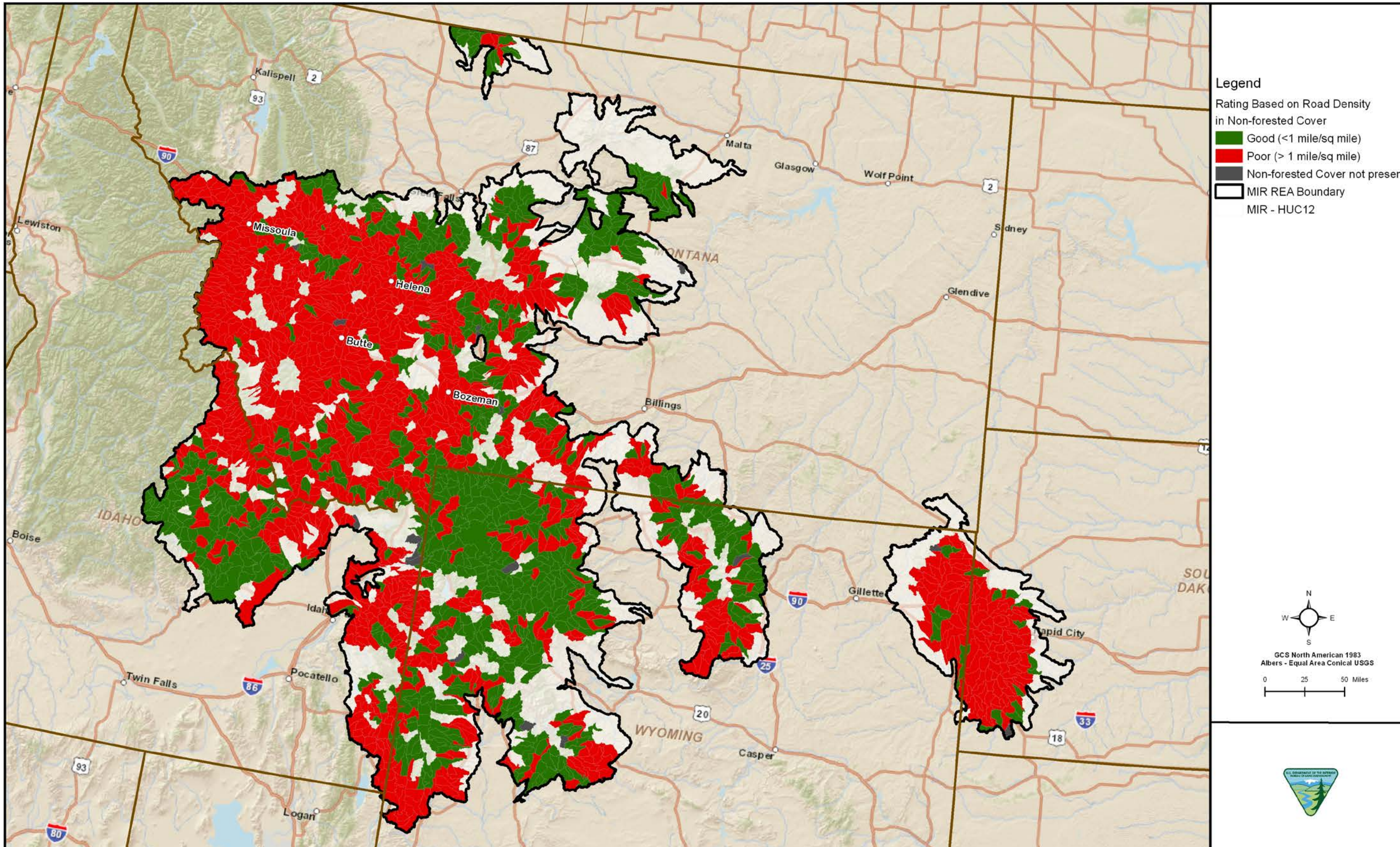

Figure E-4-14. Road Density within Non-Forested Habitat for Elk Winter Range

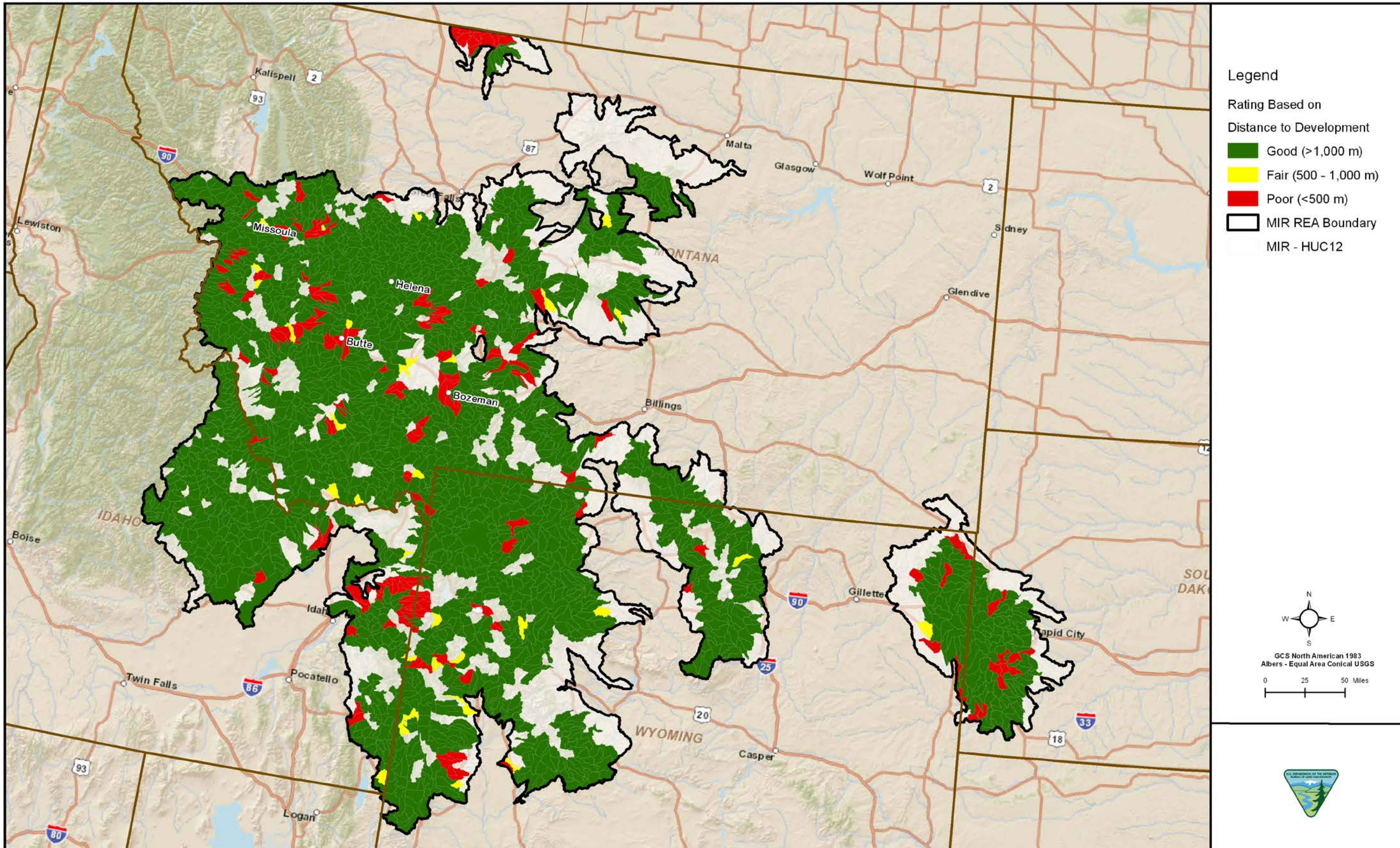

Figure E-4-15. Distance to Development (Oil and Gas/Residential) by Hydrologic Unit Code

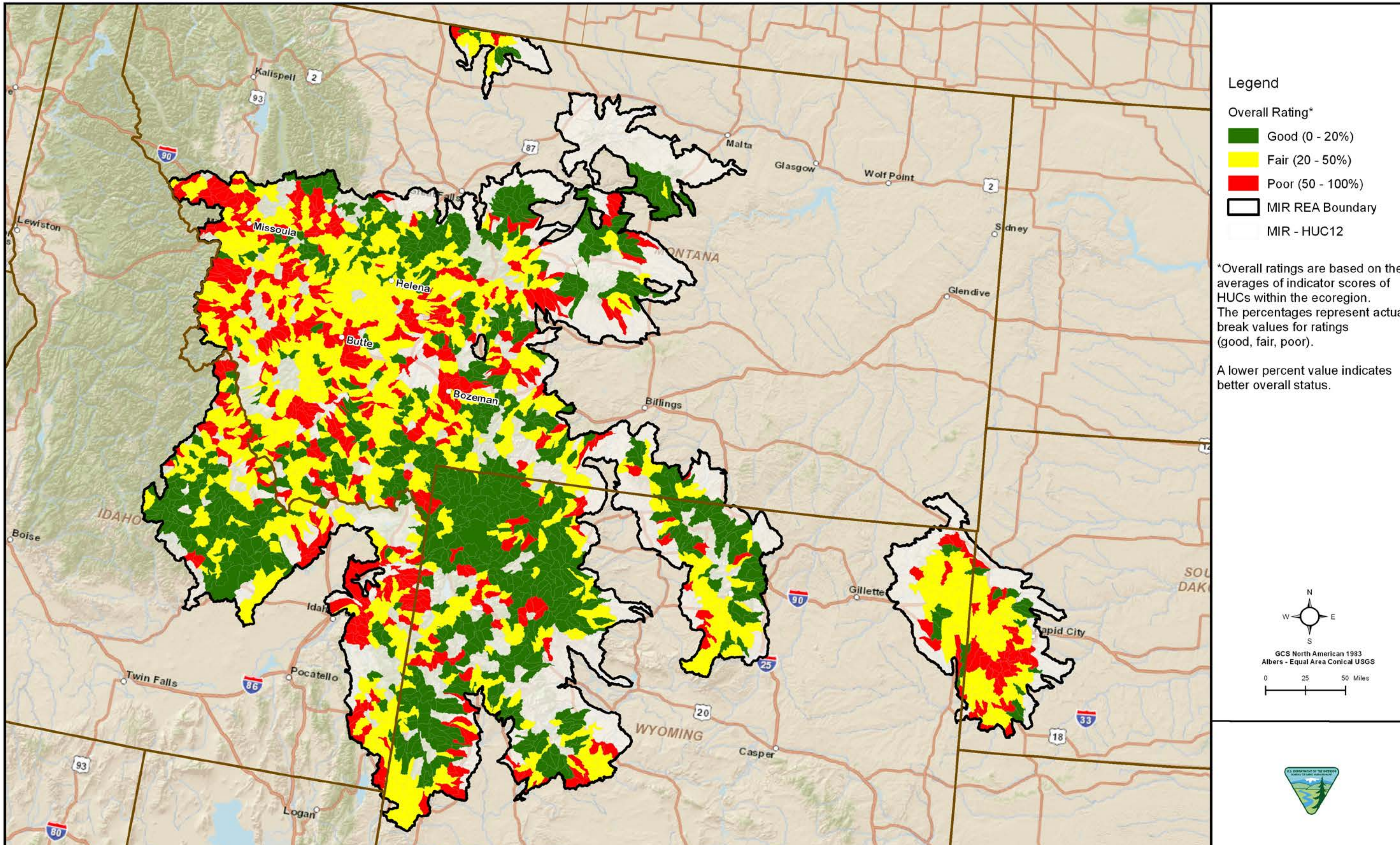

Figure E-4-16. Current Status of the Elk based on Hydrologic Unit Code within the Middle Rockies Ecoregion

ATTACHMENT A

CURRENT STATUS CHANGE AGENT ANALYSIS FOR THE MULE DEER GAP ANALYSIS PROGRAM LANDCOVER CLASSES RECLASSIFIED TO WHCWG CLASSES

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GAP LANDCOVER CLASSES RECLASSIFIED TO WHCWG CLASSES

Agriculture	Cultivated Cropland
	Pasture/Hay
Alpine	North American Alpine Ice Field
	Rocky Mountain Alpine Bedrock and Scree
	Rocky Mountain Alpine Dwarf-Shrubland
	Rocky Mountain Alpine Fell-Field
	Rocky Mountain Dry Tundra
Dry Forest	Harvested forest-tree regeneration
	Inter-Mountain Basins Aspen-Mixed Conifer Forest and Woodland
	Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
	Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
	Northern Rocky Mountain Subalpine Woodland and Parkland
	Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna
	Rocky Mountain Aspen Forest and Woodland
	Rocky Mountain Bigtooth Maple Ravine Woodland
	Rocky Mountain Foothill Limber Pine-Juniper Woodland
	Rocky Mountain Lodgepole Pine Forest
	Rocky Mountain Poor-Site Lodgepole Pine Forest
	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
	Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland
	Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodland
	Southern Rocky Mountain Ponderosa Pine Woodland
	Western Great Plains Dry Bur Oak Forest and Woodland
	Western Great Plains Wooded Draw and Ravine
Grass-dominated	Columbia Basin Foothill and Canyon Dry Grassland
	Harvested forest-grass/herbaceous regeneration
	Inter-Mountain Basins Semi-Desert Grassland
	Introduced Upland Vegetation - Annual Grassland
	Introduced Upland Vegetation-Perennial Grassland and Forbland
	Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland
	Northern Rocky Mountain Subalpine-Upper Montane Grassland
	Northwestern Great Plains Mixedgrass Prairie
	Recently burned forest
	Recently burned grassland
	Rocky Mountain Subalpine-Montane Mesic Meadow
	Southern Rocky Mountain Montane-Subalpine Grassland
	Western Great Plains Sand Prairie
	Western Great Plains Shortgrass Prairie
	Western Great Plains Tallgrass Prairie

GAP LANDCOVER CLASSES RECLASSIFIED TO WHCWG CLASSES (Continued)

Riparian	Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland
	Inter-Mountain Basins Greasewood Flat
	Introduced Riparian and Wetland Vegetation
	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
	Northwestern Great Plains Floodplain
	Northwestern Great Plains Riparian
	Rocky Mountain Lower Montane Riparian Woodland and Shrubland
	Rocky Mountain Subalpine-Montane Riparian Shrubland
	Rocky Mountain Subalpine-Montane Riparian Woodland
	Western Great Plains Floodplain
	Western Great Plains Floodplain Systems
	Western Great Plains Riparian Woodland and Shrubland
Shrub-Dominated	Columbia Plateau Low Sagebrush Steppe
	Columbia Plateau Steppe and Grassland
	Columbia Plateau Western Juniper Woodland and Savanna
	Great Basin Xeric Mixed Sagebrush Shrubland
	Harvested forest-shrub regeneration
	Inter-Mountain Basins Big Sagebrush Shrubland
	Inter-Mountain Basins Big Sagebrush Steppe
	Inter-Mountain Basins Curl-leaf Mountain Mahogany Woodland and Shrubland
	Inter-Mountain Basins Juniper Savanna
	Inter-Mountain Basins Mat Saltbush Shrubland
	Inter-Mountain Basins Mixed Salt Desert Scrub
	Inter-Mountain Basins Montane Sagebrush Steppe
	Inter-Mountain Basins Semi-Desert Shrub Steppe
	Introduced Upland Vegetation - Shrub
	Northern Rocky Mountain Foothill Conifer Wooded Steppe
	Northern Rocky Mountain Montane-Foothill Deciduous Shrubland
	Northern Rocky Mountain Subalpine Deciduous Shrubland
	Northwestern Great Plains Shrubland
	Rocky Mountain Lower Montane-Foothill Shrubland
	Western Great Plains Sandhill Steppe
	Wyoming Basins Dwarf Sagebrush Shrubland and Steppe

GAP LANDCOVER CLASSES RECLASSIFIED TO WHCWG CLASSES (Continued)

Sparsely Vegetated	Columbia Plateau Ash and Tuff Badland
	Disturbed, Non-specific
	Geysers and Hot Springs
	Inter-Mountain Basins Active and Stabilized Dune
	Inter-Mountain Basins Cliff and Canyon
	Inter-Mountain Basins Shale Badland
	Inter-Mountain Basins Volcanic Rock and Cinder Land
	Rocky Mountain Cliff, Canyon and Massive Bedrock
	Southwestern Great Plains Canyon
	Western Great Plains Badland
	Western Great Plains Cliff and Outcrop
Urban/Developed	Developed, High Intensity
	Developed, Low Intensity
	Developed, Medium Intensity
	Developed, Open Space
	Quarries, Mines, Gravel Pits and Oil Wells
Water	Open Water (Fresh)
Wet Forest	Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
	Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland
Wetland	Columbia Plateau Vernal Pool
	Eastern Great Plains Wet Meadow, Prairie, and Marsh
	Great Plains Prairie Pothole
	Inter-Mountain Basins Alkaline Closed Depression
	North American Arid West Emergent Marsh
	Northern Rocky Mountain Conifer Swamp
	Northern Rocky Mountain Wooded Vernal Pool
	Rocky Mountain Alpine-Montane Wet Meadow
	Rocky Mountain Subalpine-Montane Fen
	Western Great Plains Closed Depression Wetland
	Western Great Plains Depressional Wetland Systems
	Western Great Plains Open Freshwater Depression Wetland
	Western Great Plains Saline Depression Wetland

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