APPENDIX C-3

INVASIVE SPECIES CHANGE AGENT ANALYSIS FOR THE NORTHWESTERN PLAINS ECOREGION

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1.0 INTRODUCTION

The Bureau of Land Management (BLM) has recognized invasive species as one of the primary change agents (CAs) for this REA. The BLM implements multiple strategies in combating invasive species. These include BLM's Partners Against Weeds (PAW) Plan, the Department of the Interior's Invasive Plant Management Plan, and the National Invasive Species Management Plan. Also, as part of its implementation of the National Fire Plan, the BLM acts to reduce invasive weeds that function as fire fuels and works with partners to enhance native plant restoration.

MQs developed for this REA focus on invasive plants. Plant pests and diseases are analyzed as a separate CA (see Appendix C-4). A variety of MQs apply to this CA which are summarized into one primary MQ: ***Where will the conservation elements (CEs) be affected through changes in the spatial distribution and abundance of invasive, (undesired) non-native species?***

As part of the pre-assessment, a wide variety of invasive species were originally evaluated for inclusion into the REA. These included terrestrial invasive plant and animal species and aquatic plant and invertebrate species. The terrestrial invasive plant species included a variety of invasive weed species including medusahead, yellow starthistle, leafy spurge, knapweed, Russian olive, tamarisk and many others. The aquatic plant species included didymo and Eurasian watermilfoil. The terrestrial vertebrates included European starlings. The aqutic invertebrates and fish included the quagga mussel, Asian clam, Zebra mussel, New Zealand mudsnail, and northern pike.

Although some localized data exists for some of these species, no comprehensive national or ecoregion-wide data sources were identified for any of the targeted invasive species groups. Due to the lack of data and existing ecoregion-wide models, this data gap was addressed by focusing on terrestrial plant invasives through the use of bioclimatic modeling to predict the potential distribution of ten plant species (Table C-3-2). A number of bioclimatic factors were used to develop graphical representations of potential areas where species are most likely to be present or invade natural habitats based on the combination of optimal conditions. The results of the analysis are summarized using graphical output of the bioclimatic models as data drivers.

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2.0 CHANGE AGENT DESCRIPTION

Invasive species are most commonly defined as a non-native plant, animal or other organism that dominates the encountered ecosystem and impairs its function and structure (Sutherst 2000). Invasive species are those organisms that are not part of (exotic), or are a minor component of (native) the original plant community or communities that have the potential to become a dominant or co-dominant species on a site if their future establishment and growth is not actively controlled by management interventions (BLM 2008). Invasive species displace or damage native fauna and flora, often posing serious threats to local biodiversity and causing adverse environmental, economic or public health effects. The lack of a natural competitor in this new ecosystem allows invasive species to be successful and resistant enough to survive in a foreign environment (Sutherst 2000). Invasive species generally include invasive wildlife; invasive aquatic species; invasive plants; plant pests and diseases (including pathogens and microorganisms) and insects. The term invasive species as applied in this REA includes those species that are also classified as exotic or noxious under state or federal law. Species that become dominant for only one to several years (e.g. short-term response to drought or wildfire) are not considered invasives (BLM 2008) and therefore not included as part of this CA.

Common traits of invasive species include fast growth, rapid reproduction, high dispersal ability, and tolerance of a wide range of environmental conditions. The expansion of terrestrial invasives is strongly associated with anthropogenic activity with disturbance of native habitat through development of roads, pipelines and transmission lines, and other activities being one of the primary drivers. When disturbances such as exploration and production (E&P), oil and gas wells, forest fire, or clearing for agriculture occurs, invasive species can spread faster and out-compete native species for resources. But in stable ecosystems, equilibrium exists in the use of available resources and the population growth of individual species, and therefore, the less likely invasives will disrupt the natural community. Several species, such as cheatgrass, knapweeds, Canada thistle, whitetop, and leafy spurge, have the potential to cause serious ecological effects in terrestrial environments because of their ability to quickly invade, establish, and reproduce. In addition, woody, invasive non-native species such as Russian-olive and tamarisk have spread through riparian areas and continue to threaten habitat loss of riparian cottonwood forests throughout the Northwestern Plains ecoregion. Energy development throughout the ecoregion is primarily associated with sagebrush ecosystems. Linear access such as rights of way (ROWs) and roads provide effective vectors and preferred habitat for invasive species.

Several of the other CAs influence the introduction or spread of invasive species. It has been well documented in the literature that ROW construction associated with energy development and transportation and communication systems enhance the spread of invasive species through not only disturbance of native vegetation and soils but also through the introduction of invasive seeds on vehicles or in seed sources brought in to revegetate bare soil. In addition, wildfire and climate change have also been documented to enhance the spread of invasive species. Wildfire has the potential to reduce or eliminate native vegetation creating favorable conditions for invasive species. Energy development throughout the ecoregion is primarily associated with sagebrush ecosystems.

The direct effects of invasive species may lead to biologically significant decreases in native plant species populations, alterations to plant and animal communities or ecological processes that native species and other desirable plants and animals and humans depend on for survival (NISC 2006). Invasive plants contributed to increases in fire frequency and intensity; reduced water resources, forest growth, and timber; and negatively affected native species and their habitats throughout the United States (USFS 2010). Damaging impacts of invasive infestations may include diminished ecosystem productivity, decreased carrying capacity for wildlife and livestock, lowered recreational value, increased soil erosion, decreased water quality, and loss of native species. As native vegetation becomes displaced, further alterations in natural ecosystem processes occur including changes in fire frequency and nutrient cycling. The impacts of invasive species can be further exacerbated by increasing atmospheric CO_2 concentrations and climate change (USFS 2012).

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3.0 METHODS, MODELS, AND TOOLS

One of the primary goals of the REA was to identify areas of the ecoregion where invasives are known to occur and also identify areas where they could potentially occur in the future in order to assess their relative threat to the CEs defined for the ecoregion.

3.1 DATA IDENTIFICATION

A variety of state and federal agencies collect data and information related to invasive species (Table C-3-1). The invasive species team reviewed the National Invasive Species Management System (NISMS), various sources of state and county invasive species data and made telephone calls to multiple county noxious weed coordinators in multiple states across the ecoregion. In addition, multiple herbariums were contacted to attempt to locate data that could be used to develop ecoregion-wide maps of the ten most important invasive species in this ecoregion. Species-specific data sources for plant species such as leafy spurge, knapweed, cheatgrass, Russian-olive, and tamarisk were identified, but much of the data were limited in scale, quality, and number of occurrences, or not georeferenced. After a substantial amount of research, it was determined that consistent ecoregion-wide invasive species data were not available to create an ecoregional map.

An evaluation of the available aquatic invasives data were also conducted for use in this REA. New Zealand mudsnail (*Potamopyrgus antipodarum*) distribution data are available from the USGS as part of the Non-indigenous Aquatic Species (NAS) database but data are limited in geographical extent. Montana State University has carried out extensive research on this invasive species, but data maintained by the university are limited in comparison to the USGS dataset. Possible sources of information regarding didymo (*Didymosphenia geminata*), (USGS National Water-Quality Assessment Program and USEPA Environmental Monitoring and Assessment Program) were considered, but limited data availability and spatial distribution precluded the use of didymo as an invasive species for this analysis. Zebra mussel (*Dreissena polymorpha*), which occurs across the region, was also considered during the data identification and acquisition process and were included in the non-native aquatic invasive species dataset. Because much of the aquatic invasive data were limited in coverage across the ecoregion, further evaluation of aquatic invasive species as part of this CA was not considered.

Table C-3-1. Data Sources for Invasive Species Change Agent

Data Needs	Dataset Name	Source Agency	Type/Scale	Status	Use in REA
Terrestrial Invasives	Infestation Location	NISIMS	Polygon	Acquired	No[1]
	Survey Area	NISIMS	Polygon	Acquired	No[1]
	Treatment Boundaries	NISIMS	Polygon	Acquired	No[1]
	Weed Management Areas	NISIMS	Polygon	Acquired	No[1]
Aquatic Invasives	Non-native Aquatic Invasives	USGS	Point	Acquired	No[1]
	New Zealand Mudsnail Distribution	USGS	Point	Acquired	No[1]
	Didymo Distribution	USGS	Point	Acquired	No[1]
	Non-indigenous Aquatic Species (IMS Website)	USGS	Point	Require Data	No[1]

[1] Data gap; limited data availability or usability.

3.2 CHANGE AGENT MODEL

Because of the lack of invasives species data across the ecoregion, the RRT suggested a bioclimatic approach be used for the terrestrial invasive plant CA analysis. The ten species selected for the bioclimatic model are presented in Table C-3-2 and were determined based on the species most commonly reported among the states represented in the ecoregion (Attachment A). The bioclimatic modeling effort was intended to show where (on the ground) there is a high likelihood of occurrence of the terrestrial invasive plant species based on preferred environmental attributes of the species and a high likelihood of effects (on the ground) to conservation elements in the future, attributable to the future presence of these terrestrial invasive plant species.

Table C-3-2. Invasive Species Selected for Change Agent Analysis

Common Name	Scientific Name	# of States Reporting An Occurrence	ND	WY	NE	SD	MT
Russian knapweed	*Acroptilon repens*	4	X	X		X	X
Hoary Cress	*Cardaria draba*	3		X		X	X
Diffuse knapweed	*Centaurea diffusa*	4	X	X		X	X
Spotted Knapweed	*Centaurea stoebe*	4	X	X		X	X
Canada thistle	*Cirsium arvense*	4	X	X		X	X
Leafy spurge	*Euphorbia esula*	4	X	X		X	X
Dalmatian toadflax	*Linaria dalmatica*	4	X	X		X	X
Yellow toadflax	*Linaria vulgaris*	4	X	X		X	X
Houndstounge	Cynoglossum officinale	4		X		X	X
Saltcedar (Tamarisk)	*Tamarix aphylla, T. chinensis, T. gallica, T. parviflora, T. ramosissima*	4	X	X		X	X

3.2.1 Bioclimatic Factors

Five bioclimatic factors (vegetation, elevation, soil factors, precipitation, and temperature) were defined to graphically represent the affinities of the ten most common terrestrial invasive species throughout the ecoregion (Velman 2012). The bioclimatic factors were used as surrogate indicators along with the presence of roadways due to the lack of actual presence/absence data on these species in the region. A description of these factors, data sources and scoring for each factor is presented below. The bioclimatic data presented in Table 3-3 were obtained from the literature sources contained in the U.S. Forest Service (USFS) Fire Effects Information System (FEIS) (Velman 2012). The bioclimatic data output layers are presented by species and attribute on Figures C-3-1 through C-3-49.

3.2.1.1 Vegetation (Land Classification)

Land classification was selected as an attribute to indicate the preferred vegetation habitat commonly associated with the specific invasive species in the ecoregion. Several Level 3 GAP vegetation systems were identified based on the literature search conducted by Velman (2012) for each of the species as noted in Table C-3-3. Using this information, the land cover classes defined for the Northwestern Plains ecoregion were used to delineate specific vegetation community affinities. The land cover definitions for the Northwestern Plains were taken from the Northwest and North Central Gap Analysis Program (GAP) and the Regional GAP (ReGAP) Program. Level 3 formations are identified using a detailed level of classification that contains region-specific ecological systems names. An example of a Level 3 formation is the Northern Rocky Mountain Ponderosa Pine Woodland and Savanna Southern Rocky formation.

The Level 3 vegetation systems were mapped at the 90 m pixel level using the GAP and ReGAP data. The presence of the Level 3 vegetation system identified for the species was given a value of 1 in calculating the associated affinity. Areas of the ecoregion where the specific vegetation system was not found were given a value of “0”.

3.2.1.2 Roadways

The presence of roadways throughout the ecoregion was selected as an indicator because invasives have the ability to survive on disturbed sites and roads are known as a common vector. The land adjacent to roadways tends to be ideal habitat for invasive plants because of its high level of disturbance and abundant sunlight (NHDOT 2008). Roadways serve as effective dispersal mechanisms for invasives, however not all invasive plants distributions are defined by the presence of roads.

Roadway data used for this CA analysis were extracted from the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) database. The TIGER database contains geographic linear, areal, and point features such as streets, railroads, rivers, lakes, and landmarks (airports, schools, etc.). Geographic entity boundaries from the TIGER database are represented in the files, as well as the polygons that make up the legal and statistical geographic areas for which the Census Bureau tabulates data. The TIGER database also contains attribute information about these features, such as names, the type of feature, address ranges for most streets, the geographic relationship to other features, and other related information. TIGER/Line®Shapefiles are available to the public and are designed for use with geographic information system (GIS) software. The most recent version is the 2006 Second Edition TIGER/Line® Files (U.S. Census Bureau 2012).

Linear road features and attributes are available in the following layers: Primary Roads Nation-based Shapefile, Primary and Secondary Roads State-based Shapefile, and All Roads County-based Shapefile. For this REA, the All Roads County-based Shapefile was used. The content of the All Roads shapefile includes primary roads, secondary roads, local neighborhood roads, rural roads, city streets, vehicular trails (4WD), ramps, service drives, walkways, stairways, alleys, and private roads. The All Roads shapefile contains all linear street features with “S” (Street) type MTFCCs in the TIGER database. The shapefiles are provided at a County geographic extent and in linear elemental feature geometry (U.S. Census Bureau 2012).

The areas at a 90-m scale with roads were given an indicator value of 1 and areas without roads were given a value of “0”. Because the same roads GIS layer was used for all of the invasive species figures, only one map of roads was produced for this document (Figure C-3A-1).

3.2.1.3 Elevation

The altitude or elevation of the land influences plant growth and development primarily through temperature and precipitation effects. The 90-meter resolution U.S. Geological Survey (USGS) National Elevation Dataset (NED) was used to provide data on elevations for the ecoregion. All elevation values are in meters and are referenced to the North American Vertical Datum of 1988 (NAVD 88).

The areas located within the specific elevations defined in Table C-3-3 for each species were given an indicator value of 1 in defining the elevations where each invasive species has been documented to occur. All other elevations were given a value of “0”. It should be noted, due to the large size of an ecoregion, conditions could vary latitude. This analysis does not take this into consideration.

3.2.1.4 Soil Characteristics

Plant growth and distribution is determined by several bioclimatic conditions. Physical and chemical properties having the most pronounced effects on plant growth include soil type and soil pH. Specific soil properties identified by Velman (2012) for the CA analysis are identified in Table C-3-3 .

Soil data were provided from the Natural Resources Conservation Service (NRCS) State Soil Geographic (STATSGO) dataset published in 2006. STATSGO consists of a broad-based inventory of soils and non-soil areas that occur in a repeatable pattern on the landscape and that can be cartographically shown at the scale mapped. The map data were collected in 1- by 2-degree topographic quadrangle units and merged into a seamless national dataset which are available in state/territory or national extents. The soil map units are linked to attributes in the tabular data, which give the proportionate extent of the component soils and their properties (NRCS 2012).

The soil areas meeting the specific soil properties as defined in Table C-3-3 for each species were given an indicator value of 1 while all other areas were given a value of “0”.

3.2.1.5 Temperature and Precipitation

Temperature and precipitation play key roles in determining the distribution of plants throughout the ecoregion. Elevation also has a profound impact on climate, where both temperature and precipitation can change dramatically from the top to bottom of a mountain, or west or east of a mountain range. Shifting species habitats can also result from natural climate fluctuations and geographical species migration. Changes in weather and climate can also have both individual and cumulative effects on ecosystems that can further facilitate the expansion and abundance of invasive plant species (Tausch 2008).

The datasets used to provide precipitation and temperature data were created using the Parameter-elevation Regressions on Independent Slopes Model (PRISM) climate mapping system. PRISM uses point measurements of precipitation, temperature, and other climatic factors to produce continuous, digital grid estimates of monthly, yearly, and event-based climatic parameters (PRISM Climate Group 2010).

Datasets were queried based on the specific temperature and precipitation ranges defined in Table C-3-3. The areas meeting the specific climate conditions for a specific species were given an indicator value of 1 while all other areas were given a value of “0”.

Table C-3-3. Surrogate Indicators for Invasive Species Occurrence[a]

Symbol	Invasive Species Common name	Invasive Species Scientific name	REGAP Level 2/Level 3 Classifications	Tiger Roads	National Elevation Data (meters)	STATSGO Soil Factors	PRISM Annual Precipitation Minimum and Maximum [b] (mm)	PRISM Mean Summer Temperature Minimum and Maximum [b] (°C)
ACRE3	Russian Knapweed	*Acroptilon repens*	• Grassland • Riparian • Agriculture	Presence	711 – 2835	pH > 7 and Clay > 40%	184 – 306	16.1 – 26.75
CADR	Hoary Cress	*Cardaria draba*	• Lowland Grassland/Prairie (xeric-mesic) • Deciduous shrubland • Sagebrush dominated shrubland • Scrub shrubland • Agriculture • Recently disturbed or modified	Presence	0 – 2400	pH > 7	450 - 1250	11.25 -21.25
CEDI3	Diffuse Knapweed	*Centaurea diffusa*	• Lowland Grassland/Prairie (xeric-mesic) • Northern Rocky Mountain Ponderosa Pine Woodland and Savanna • Southern Rocky Mountain Ponderosa Pine Woodland • Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna	Presence	0 – 2134	Sand 35-45% Silt 35-45% Clay 15-25% OR Sand> 60%	305-432	Not available [a]
CEST8	Spotted Knapweed	*Centaurea stoebe*	• Lowland Grassland/Prairie (xeric-mesic) • Northern Rocky Mountain Ponderosa Pine Woodland and Savanna Southern Rocky Mountain Ponderosa Pine Woodland • Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna	Presence	610 – 2743	Sand > 60%	310 – 1015	Not available [a]
CIAR4	Canada thistle	*Cirsium arvense*	• Recently disturbed or modified • Riparian • Forested	Presence	0 – 2500	Sand >= 60%	229 to 1269	Not available [a]
CYOF	Houndstongue	*Cynoglossum officinale*	• Lowland Grassland/Prairie (xeric-mesic) • Deciduous shrubland • Sagebrush dominated shrubland • Forest and woodland systems • Recently disturbed or modified • Floodplain and riparian • Northern Rocky Mountain Ponderosa Pine Woodland and Savanna • Southern Rocky Mountain Ponderosa Pine Woodland • Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna	Presence	1480 – 3000	Not available [a]	268 - 448	22
EUES	Leafy spurge	*Euphorbia esula*	• Lowland Grassland/Prairie (xeric-mesic) • Deciduous shrubland • Sagebrush dominated shrubland • Recently disturbed or modified • Floodplain and Riparian	Presence	1402 – 3000	Sand 35-45% Silt 35-45% Clay 15-25% OR Sand> 60%	180 – 630	Not available [a]

Table C-3-3. Surrogate Indicators for Invasive Species Occurrence[a] (Continued)

Symbol	Invasive Species Common name	Invasive Species Scientific name	REGAP Level 2/Level 3 Classifications	Tiger Roads	National Elevation Data (meters)	STATSGO Soil Factors	PRISM Annual Precipitation Minimum and Maximum [b] (mm)	PRISM Mean Summer Temperature Minimum and Maximum [b] (°C)
LIDA	Dalmation Toadflax	*Linaria dalmatica*	• Lowland Grassland/Prairie (xeric-mesic) • Deciduous shrubland • Sagebrush dominated shrubland • Recently disturbed or modified • Floodplain and riparian • Northern Rocky Mountain Ponderosa Pine Woodland and Savanna • Southern Rocky Mountain Ponderosa Pine Woodland • Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna	Presence	1600 – 2500	Sand 35-45% Silt 35-45% Clay 15-25% OR Sand> 60%	Not available [a]	Not available [a]
LIVU3	Yellow Toadflax	*Linaria vulgaris*	• Lowland Grassland/Prairie (xeric-mesic) • Northern Rocky Mountain Ponderosa Pine Woodland and Savanna • Southern Rocky Mountain Ponderosa Pine Woodland • Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna • Agriculture	Presence	2000 – 2800	Sand 35-45% Silt 35-45% Clay 15-25% OR Sand> 60%	Not available [a]	Not available [a]
TARA	Tamarisk (Saltcedar)	*Tamarix sp.*	• Floodplain and Riparian	Presence	Not available [a]	Electricity conductivity > 4 (Moderately Saline)	285 – 375 [c]	21.2 – 31

[a] Attributes values for each species was provided by BLM based on literature search of key environmental characteristics (Velman 2012). If data were not provided or available, factor was not included in the analysis.
[b] The minimum value is -25% of provided value and the maximum value is +25% of the provided value.
[c] Precipitation was not used as a bioclimatic factor in the overall current conditions based on Rolling Review Team (RRT) input.

4.0 ANALYSIS OF INVASIVE SPECIES ON ECOREGION CONDITIONS

A GIS-based multi-criteria evaluation (MCE) model was incorporated with spatial analyst tools built within ArcGIS. The MCE approach utilizes decision-making rules to combine the information from several criteria in the form of geospatial layers. The geospatial layers for each of the five bioclimatic factors were aggregated to produce a single figure using the weighted sum tool in GIS (equally weighted for this analysis) to depict the areas of the ecoregion where the bioclimatic factors selected for each invasive species overlapped. These figures are intended to represent the current conditions of this CA for the ecoregion. Future threats were not evaluated for this CA based on the data gaps associated with the invasive species data.

4.1 DATA LIMITATIONS

The results of the bioclimatic analysis are influenced by the resolution of the predictor data (bioclimatic factors) as well as the values assigned as thresholds from the literature. The native data are 30 x 30m pixel Landsat data. Though 30-m data are considered fine scale, there is variability within the cell. Even though a single value (attribute) is assigned to that cell it likely includes (reflects) native vegetation, invasive vegetation, bare ground, litter, etc. In other words, just because a pixel returns a result for a vegetation classification doesn't mean that every square foot within that pixel contains only that vegetation type. For the analysis the 30 x 30-m data were converted to 90 x 90m pixel using the nearest neighbor methodology. This is a more coarse analysis unit, but it was determined appropriate for a landscape scale analysis encompassing approximately 236,249 square miles, this was appropriate.

The precipitation and temperature data from PRISM has a spatial resolution of approximately 3 x 4 km but 800 m x 800 m data has been made available for the REA. Currently, only monthly and annual minimum, maximum, and mean temperatures, monthly and annual mean diurnal temperature range and monthly and annual mean total precipitation are available as outputs from PRISM. The fine scale patterns in environmental variables will not be represented accurately by coarse 800-m predictor data. Further, the response of each species may not be precisely defined, with respect to each predictor.

For analysis purposes these data had to be resampled to the 90-m resolution using the nearest neighbor methodology. This was necessary able to sum the bioclimatic factors used in the analysis. This does not increase the accuracy of the PRISM data.

In addition, attempting to apply quantitative values for elevation, temperature and precipitation across a particular species distribution in an area with a semi-arid climate might not be completely accurate. Sometimes, physiological details of species abilities are known and can be related to environmental data and therefore reasonably modeled. Upon review of all of the figures in this appendix, it must be recognized that there is a mixture of data quality, general ability, and similar specifications on the target species. The discussion of this CA on ecoregional conditions is presented with these limitations in mind.

4.2 RESULTS BY SPECIES

A set of figures were developed for each invasive species, based on the bioclimatic factors identified in Table C-3-3. The geospatial layers for each of the five bioclimatic factors were aggregated by an additive overlay analysis to produce a single overall figure to depict the areas of the ecoregion where the bioclimatic factors selected for each invasive species overlapped. The higher output values indicate the higher number of bioclimatic factors in a 90-m cell.

4.2.1 Russian Knapweed

The GIS output figures for Russian knapweed are presented on Figures C-3-1 through C-3-6. This species is associated with grasslands, agricultural lands, and riparian habitats and is therefore considered a threat throughout most of the ecoregion (Figure C-3-1). However, the other bioclimatic data described for this species indicate that the habitats most at threat occur in the northwestern portions of the ecoregion (Figure C-3-6).

4.2.2 Hoary Cress

Hoary cress is defined as an invasive primarily to shrublands, grasslands, and agricultural areas (Table C-3-3). The GIS output figures for hoary cress are presented on Figures C-3-7 through C-3-12. Most of the bioclimatic conditions which favor this species occur throughout the region. The primary limiting factor would be annual precipitation (Figure C-3-10). As a result, the habitats within the southeastern portions of the region are at greatest risk from hoary cress (Figure C-3-12).

4.2.3 Diffuse Knapweed

Diffuse knapweed is identified as a woodland and grassland invasive (Table C-3-3). The GIS output figures for diffuse knapweed are presented on Figures C-3-13 through C-3-17. Most of the bioclimatic conditions which favor this species occur throughout the region. Annual precipitation limits the extent of diffuse knapweed in the southeastern portion of the ecoregion (Figure C-3-16). Grassland and woodland habitats throughout the region, but primarily in the central areas, are at risk from diffuse knapweed (Figure C-3-17).

4.2.4 Spotted Knapweed

Spotted knapweed is identified as a woodland and grassland invasive (Table C-3-3). The GIS output figures for spotted knapweed are presented on Figures C-3-18 through C-3-22. Spotted knapweed prefers sandy soil (Table C-3-3) and therefore the soil along with the GAP vegetation areas define the central areas of the ecoregion at greatest risk due to invasive of spotted knapweed (Figure C-3-22).

4.2.5 Canada thistle

The GIS output figures for Canada thistle are presented on Figures C-3-23 through C-3-27. Canada thistle is typically associated with recently disturbed habitats in forested and riparian areas (Table C-3-3). The elevations where this species has been documented are wide ranging. This species' preference for sandy soils may limit its distribution throughout the ecoregion (Figure C-3-25 and Figure C-3-27).

4.2.6 Houndstongue

This species is identified as occurring in many different types of habitat within the ecoregion including shrubland, grassland, forest, and riparian habitats. The GIS output figures for houndstongue are presented on Figures C-3-28 through C-3-32. The elevation at which this species is documented to occur (Figure C-3-29) as well as the mean summer temperature (Figure C-3-31) indicates that the highest impact from houndstongue may be areas located along the north, west, and eastern boundaries of the ecoregion (Figure C-3-32).

4.2.7 Leafy spurge

This species is identified from shrubland, grasslands, disturbed, and riparian habitats. The GIS output figures for leafy spurge are presented on Figures C-3-33 through C-3-37. Soil factors and annual precipitation data (Figures C-3-35 and C-3-36) for this species indicates wide-spread potential for invasion within the ecoregion. The elevation at which this species is documented to occur (Figure C-3-34) indicates that the greatest risk is associated with habitats located along west boundary of the ecoregion (Figure C-3-37).

4.2.8 Dalmation toadflax

This species is identified as occurring in many different types of habitat within the ecoregion including shrubland, grassland, woodlands, and riparian habitats. The GIS output figures for dalmation toadflax are presented on Figures C-3-38 through C-3-41. The elevation at which this species is documented to occur (Figure C-3-39) indicates that the highest impact from Dalmation toadflax may be areas located along the western boundary of the ecoregion (Figure C-3-41).

4.2.9 Yellow Toadflax

This species is identified in grasslands, woodlands, and agricultural habitats. The GIS output figures for yellow toadflax are presented on Figures C-3-42 through C-3-45. The combined bioclimatic factors show that the potential risks from yellow toadflax as invasives are likely areas located along the northwestern and eastern boundaries of the ecoregion (Figure C-3-45).

4.2.10 Tamarisk (Saltcedar)

Tamarisk is an invasive species associated with riparian habitats. The GIS output figures for tamarisk are presented on Figures C-3-46 through C-3-49. The bioclimatic factors identified for this species did not distinguish particular riparian habitat within the ecoregion as being more at risk than another. Overall, all riparian habitats in this ecoregion are considered at risk from this species (Figure C-3-49).

4.3 SUMMARY OF BIOCLIMATIC EVALUATION

Overall, this was a difficult and challenging CA to evaluate based on the significant lack ecoregion-wide invasive species data. The resulting effort to identify current CA conditions within the ecoregion using bioclimatic approach was problematic. For many of the selected species (e.g. diffuse knapweed, Canada thistle), the range of values for the specific bioclimatic values taken from the literature was often too great and therefore, encompassed most of the ecoregion. Additionally, it was difficult to evaluate the impacts of this CA on the coarse-filter CEs since many of the invasives selected where documented to occur in several ecosystems. Instead of a species approach to evaluating this CA, an ecosystem approach utilizing bioclimatic factors of a few, highly aggressive, species may improve the analysis. However, attempting to evaluate this CA using bioclimatic factors only may still prove difficult to answer the MQs for this CA. The USFWS (2009) notes that researchers have attempted to identify general site attributes and conditions that make some ecological communities more susceptible to invasion than others (Stohlgren et al. 2002; Endress et al. 2006); however, these studies depend on accompanying invasive species point occurrence data to develop predictor models.

Future studies that provide point occurrence data along with bioclimatic factors could be used with spatial models to estimate the actual and potential distribution of non-native species richness, cover, and the probability of occurrence. These models could also provide an indication of how environmental variables contribute to these distributions, and can also be useful for directing control and assessing impact to natural resource assets and management objectives (Barnett et al. 2006).

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5.0 MANAGEMENT QUESTIONS

Although some of the original MQs were specific to the CAs, all of these are addressed in the specific CE packages contained in Appendices D and E. The individual KEA maps and the resulting overall current status output contained in these appendices answer all of the MQs specific to CAs.

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APPENDIX C-3

FIGURES

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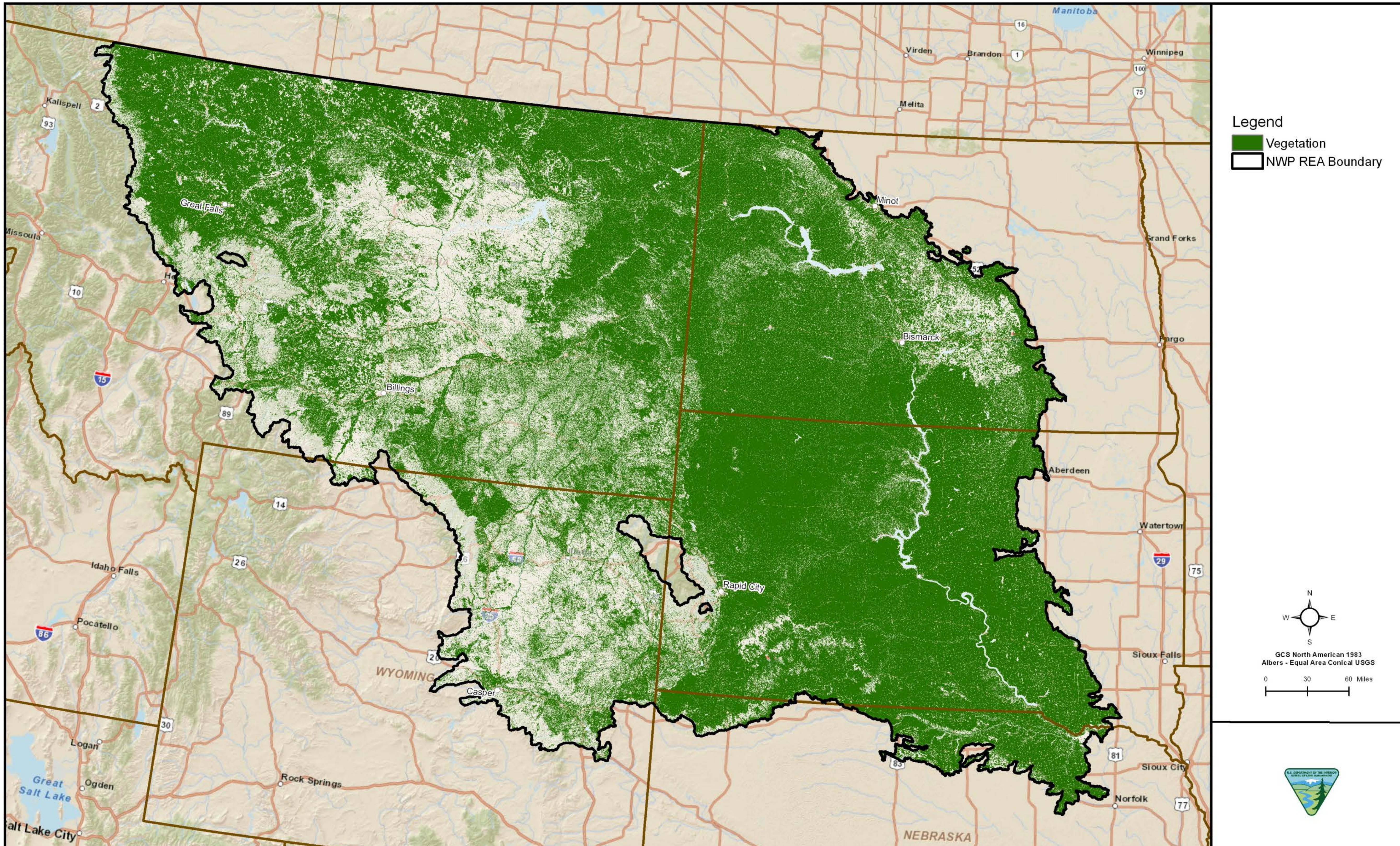

Figure C-3-1. Russian Knapweed REGAP Level 2 /Level 3 Classifications

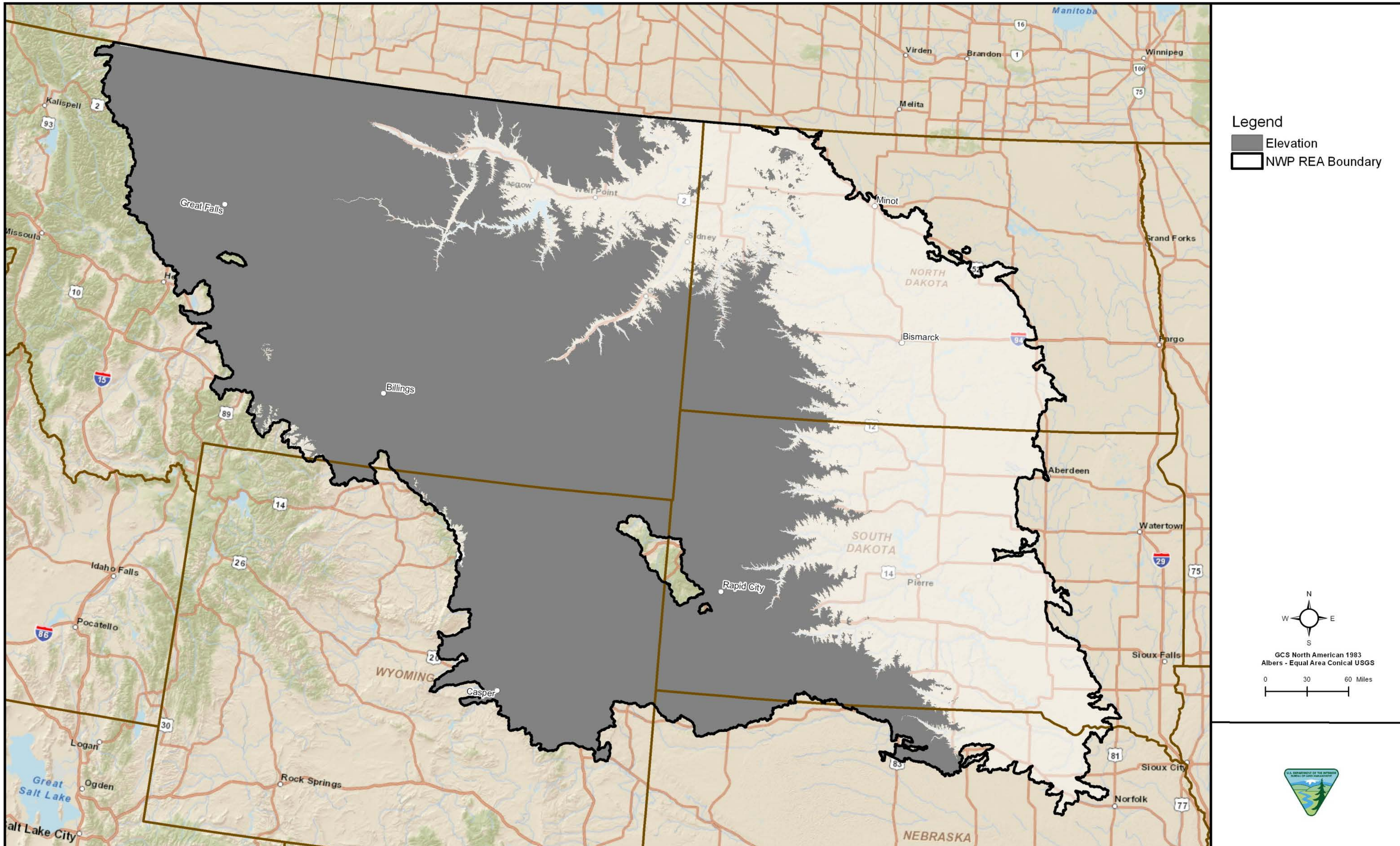

Figure C-3-2. Russian Knapweed Elevation

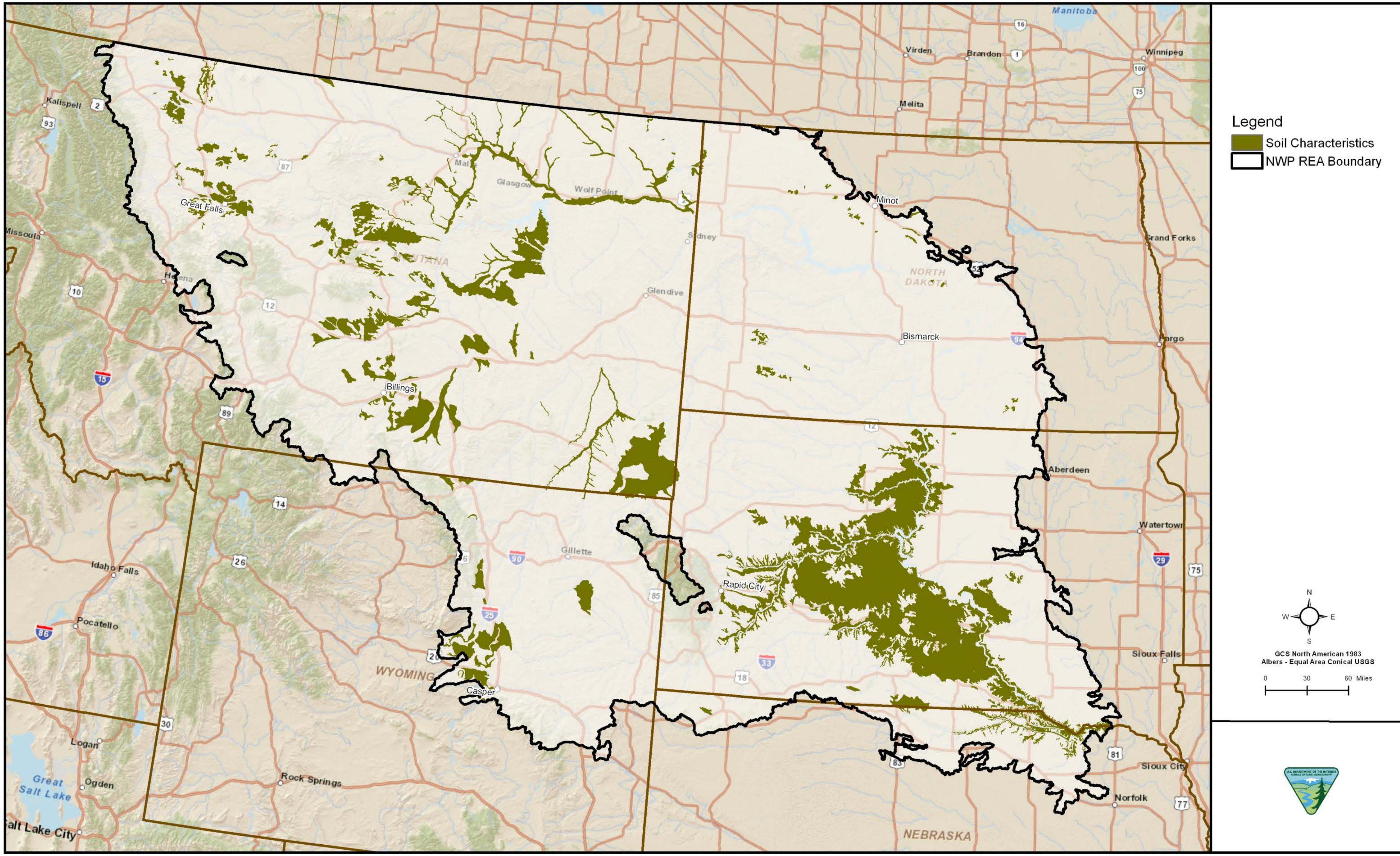

Figure C-3-3. Russian Knapweed Soil Factors

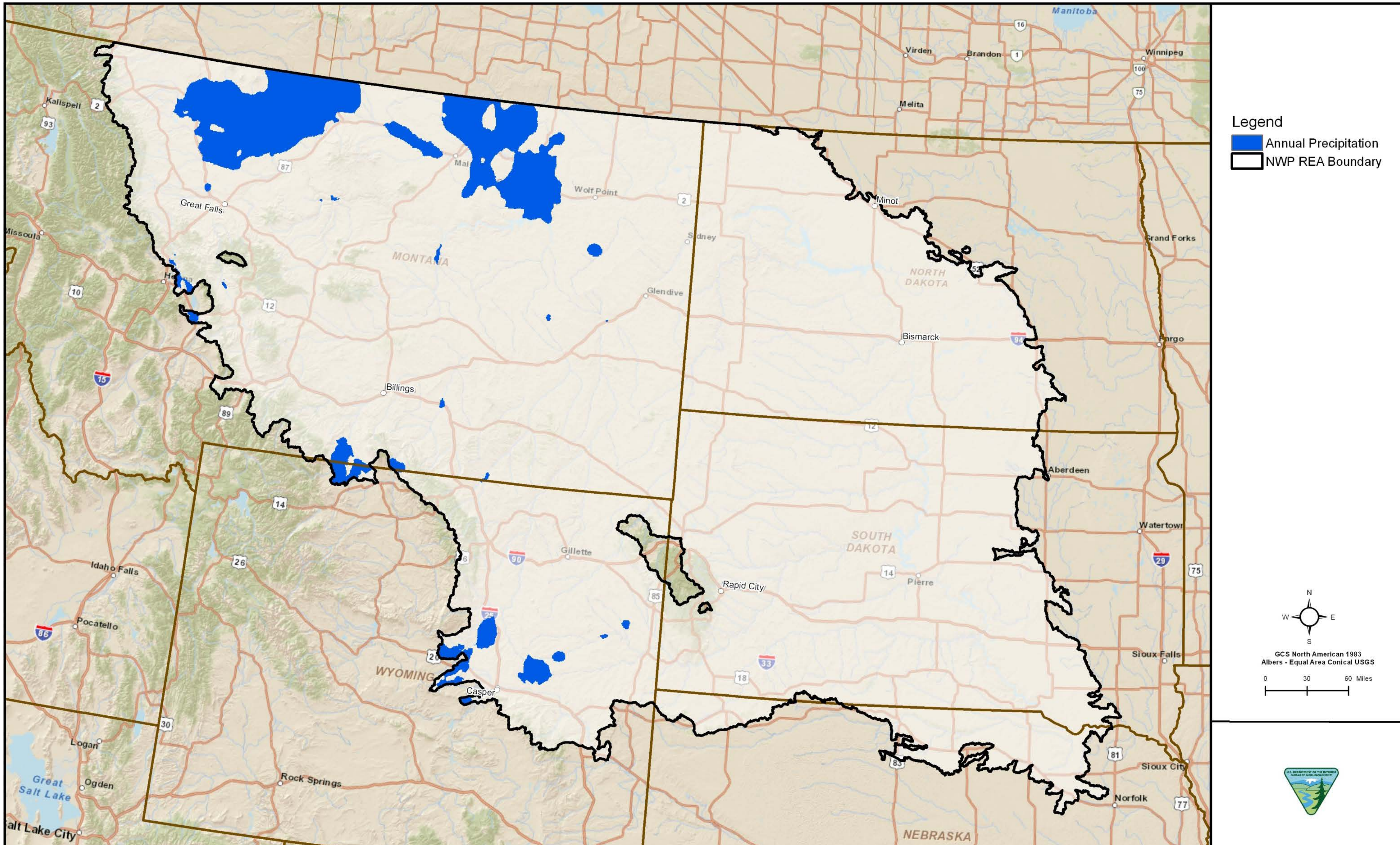

Figure C-3-4. Russian Knapweed Annual Precipitation

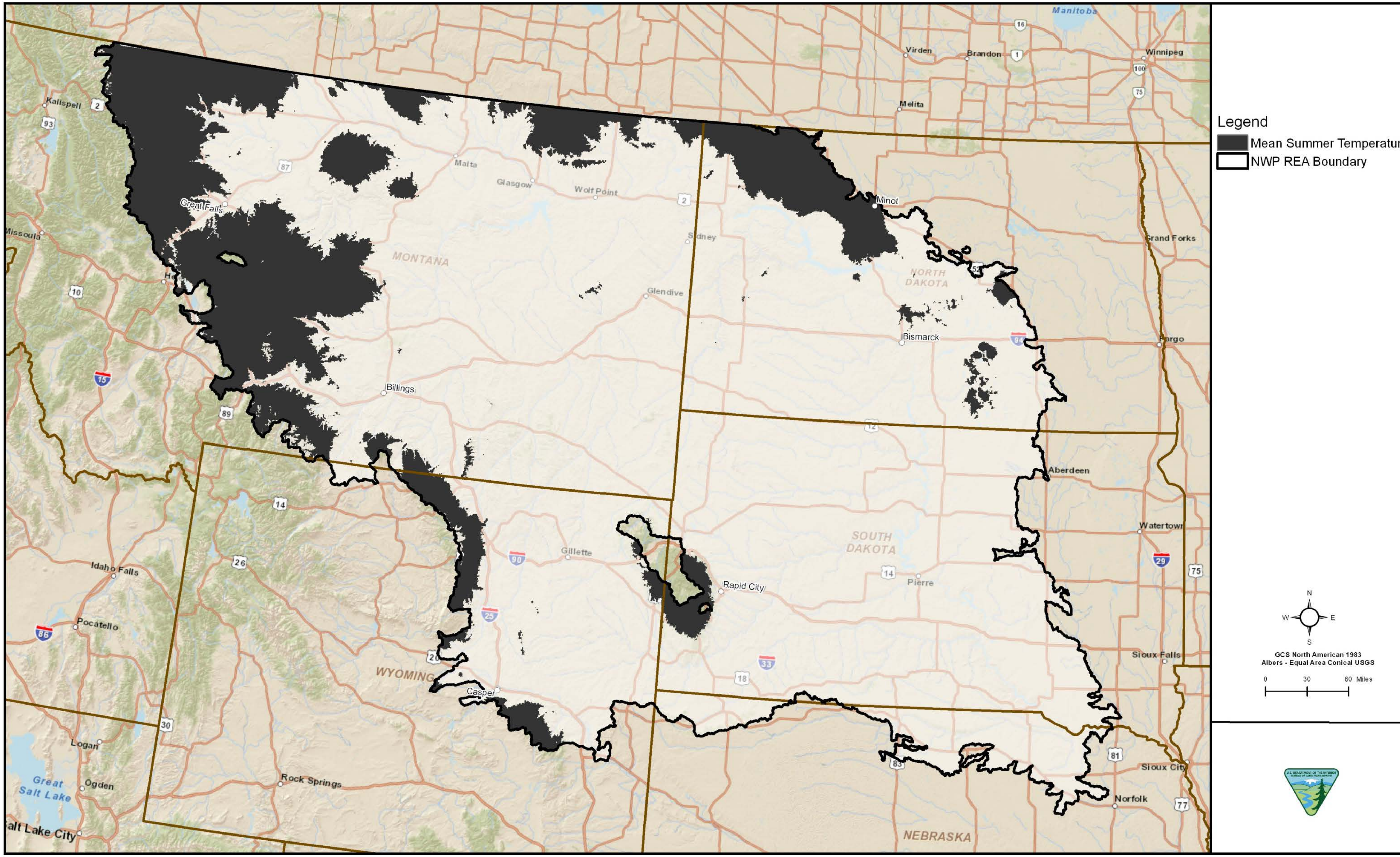

Figure C-3-5. Russian Knapweed Mean Summer Temperature

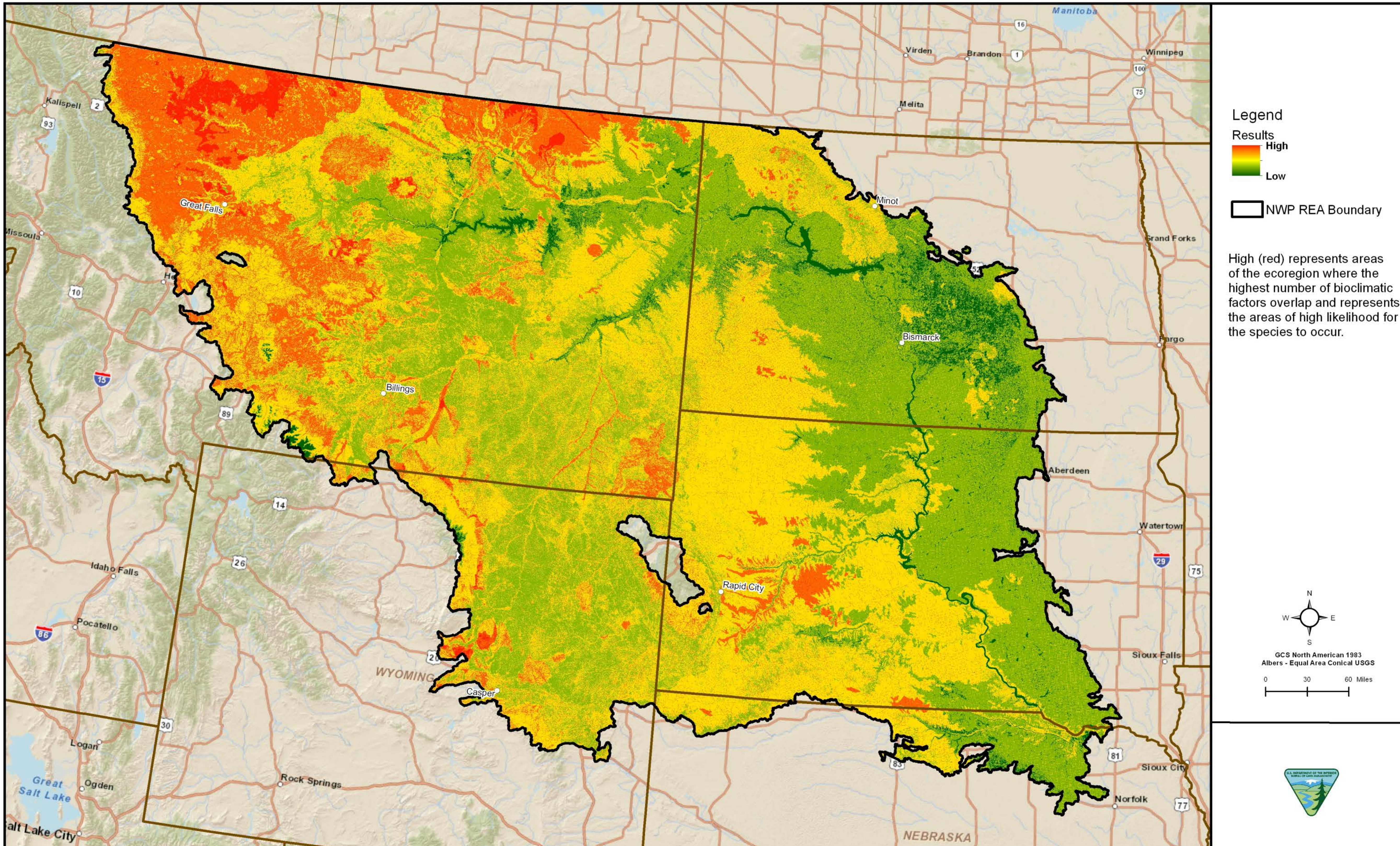

Figure C-3-6. Russian Knapweed Combined Bioclimatic Factors

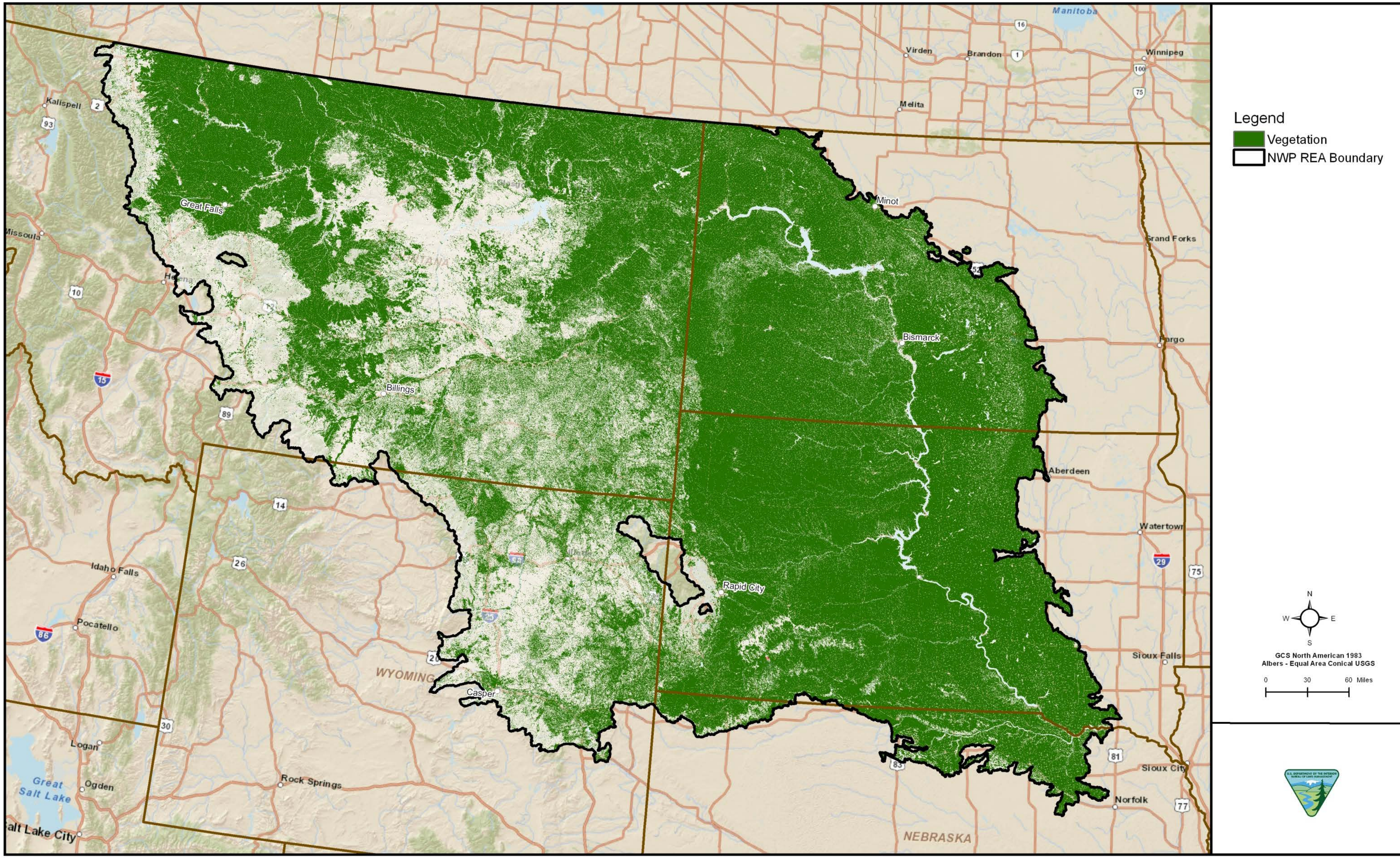

Figure C-3-7. Hoary Cress REGAP Level 2 /Level 3 Classifications

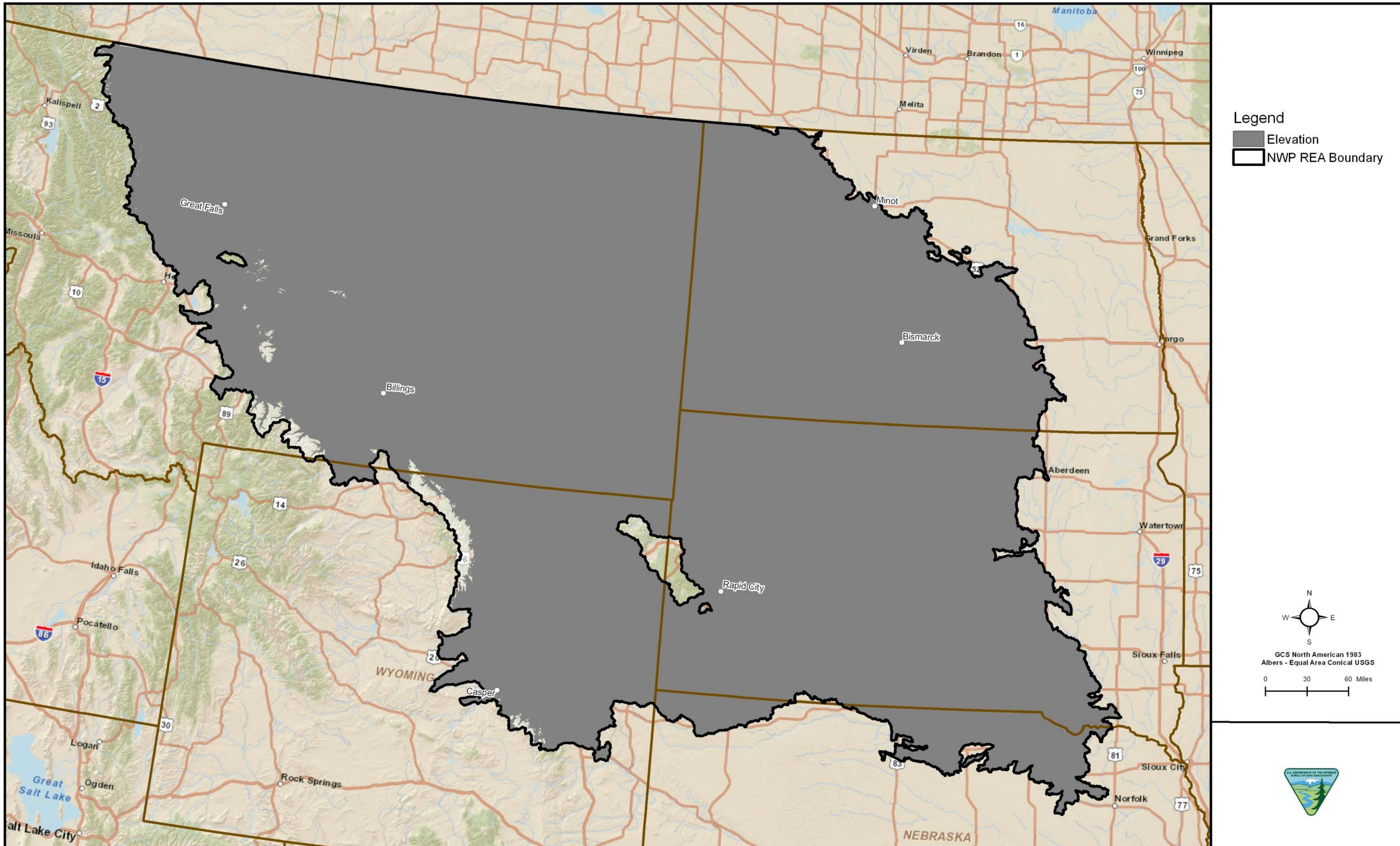

Figure C-3-8. Hoary Cress Elevation

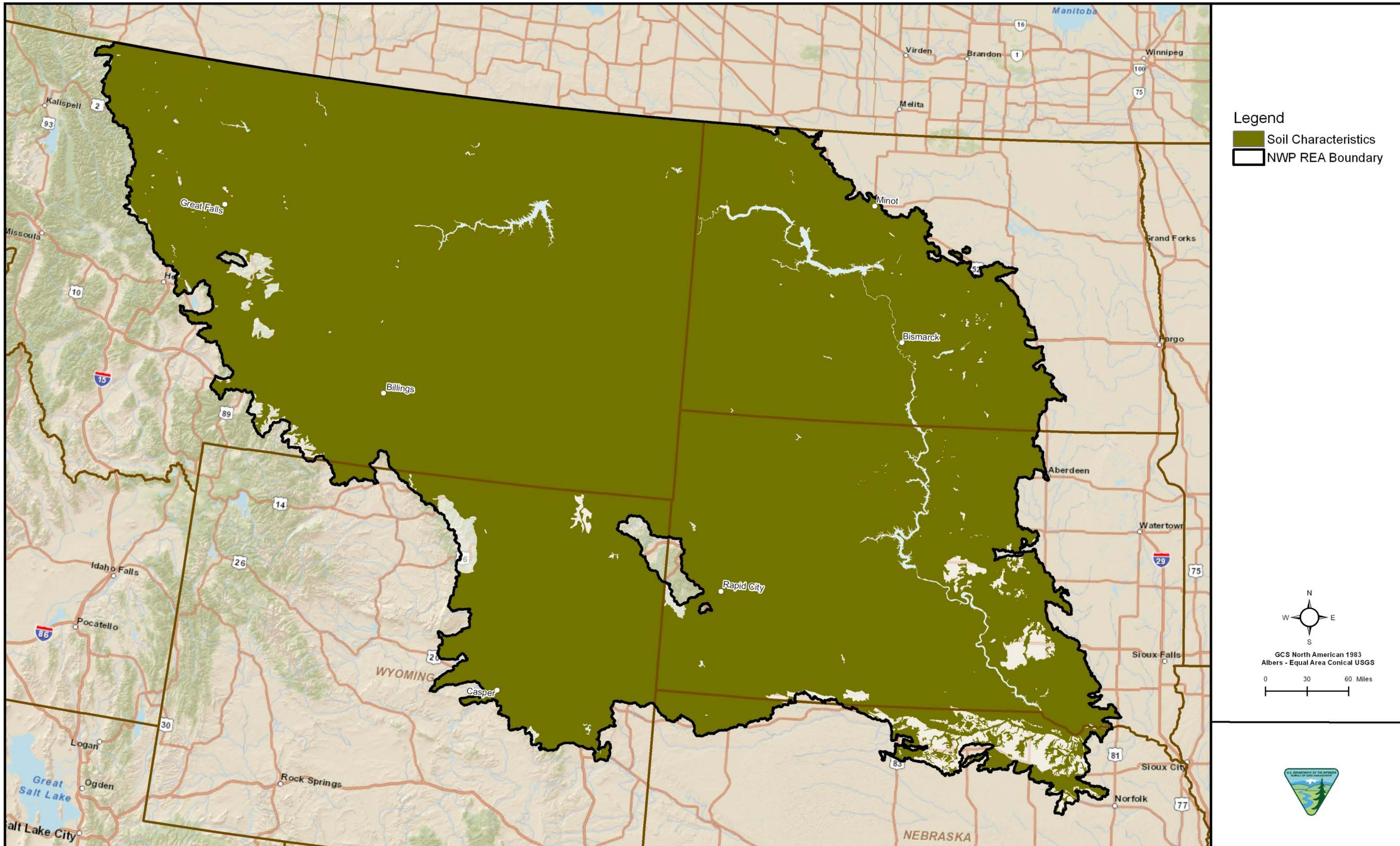

Figure C-3-9. Hoary Cress Soil Factors

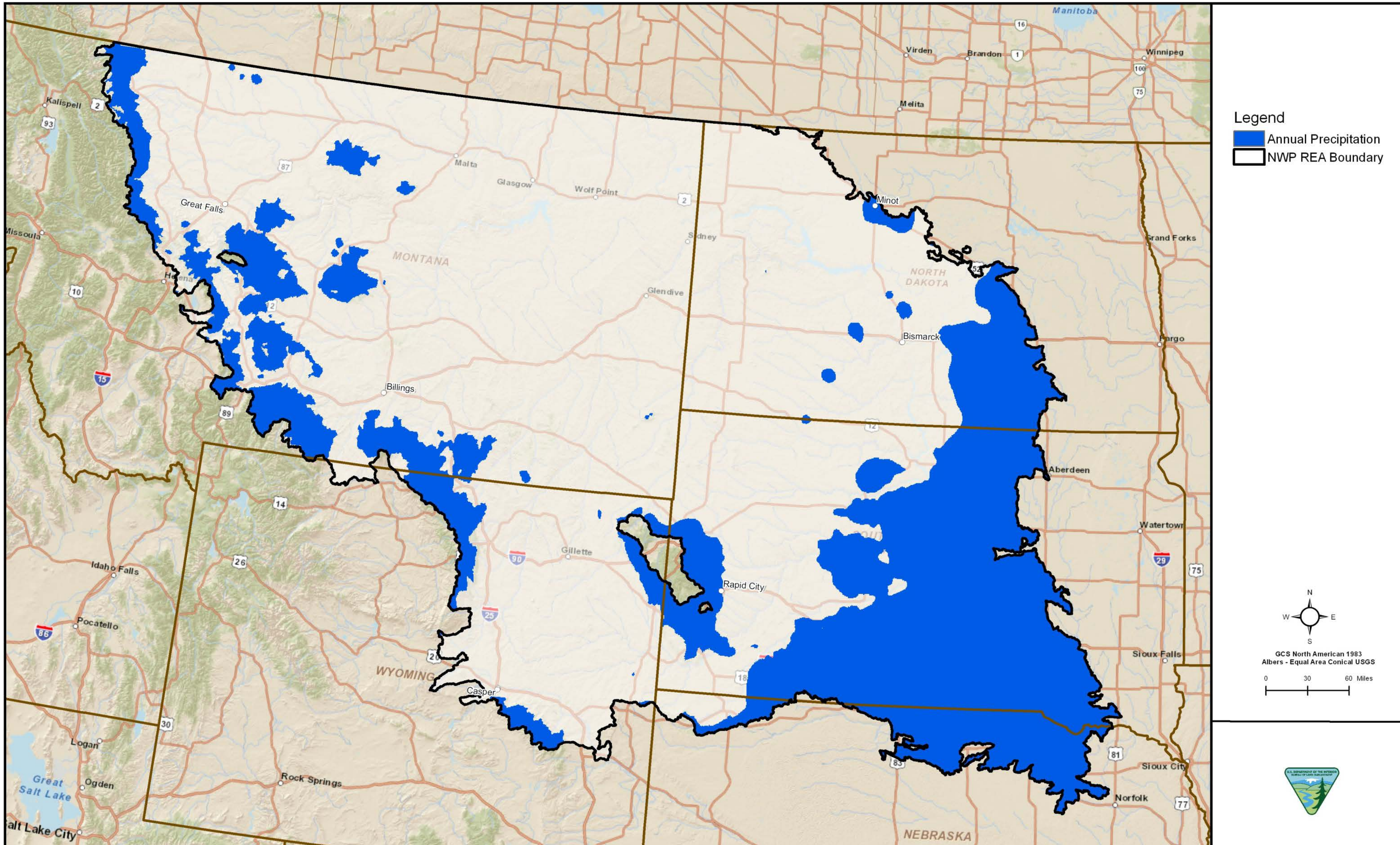

Figure C-3-10. Hoary Cress Annual Precipitation

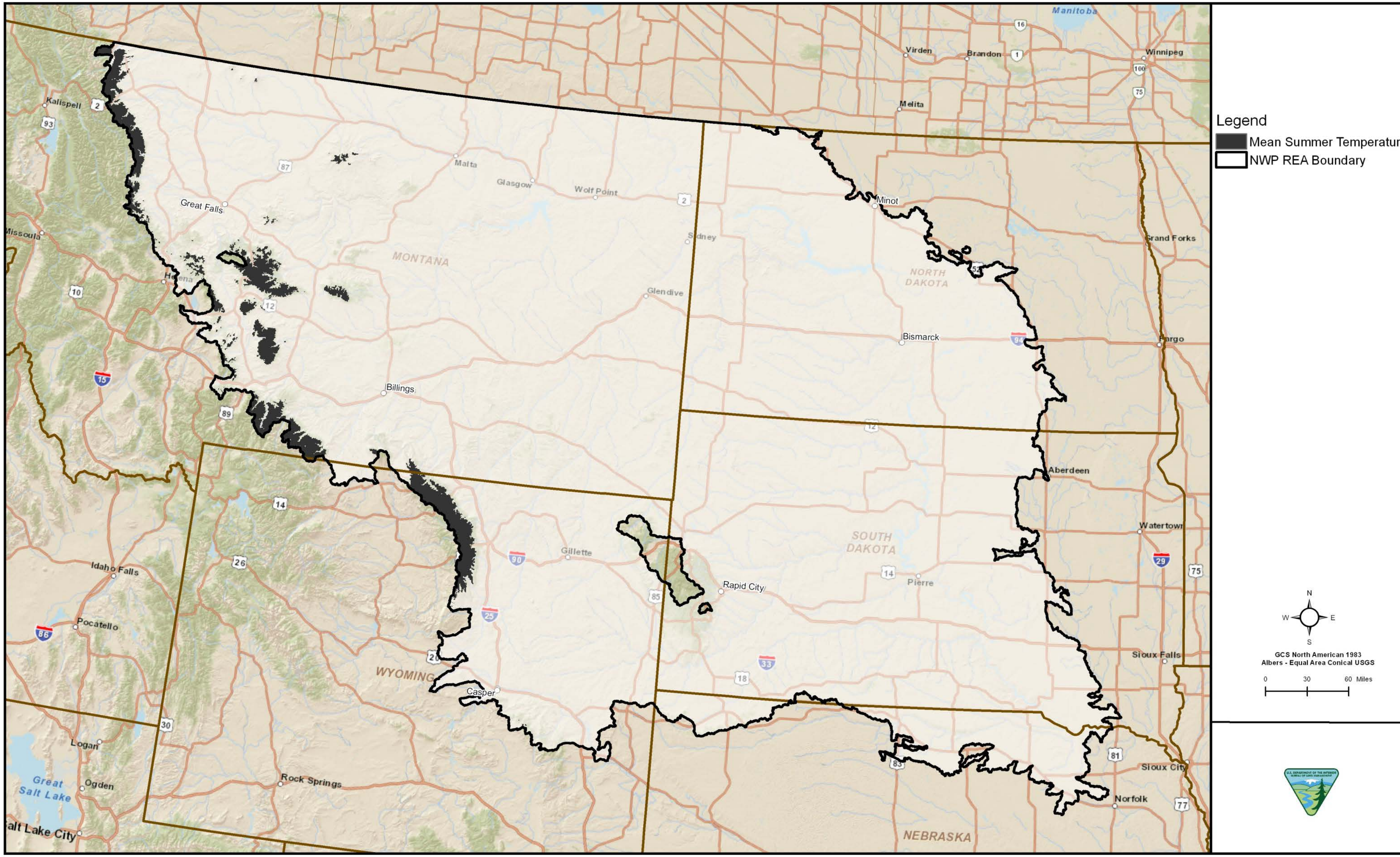

Figure C-3-11. Hoary Cress Mean Summer Temperature

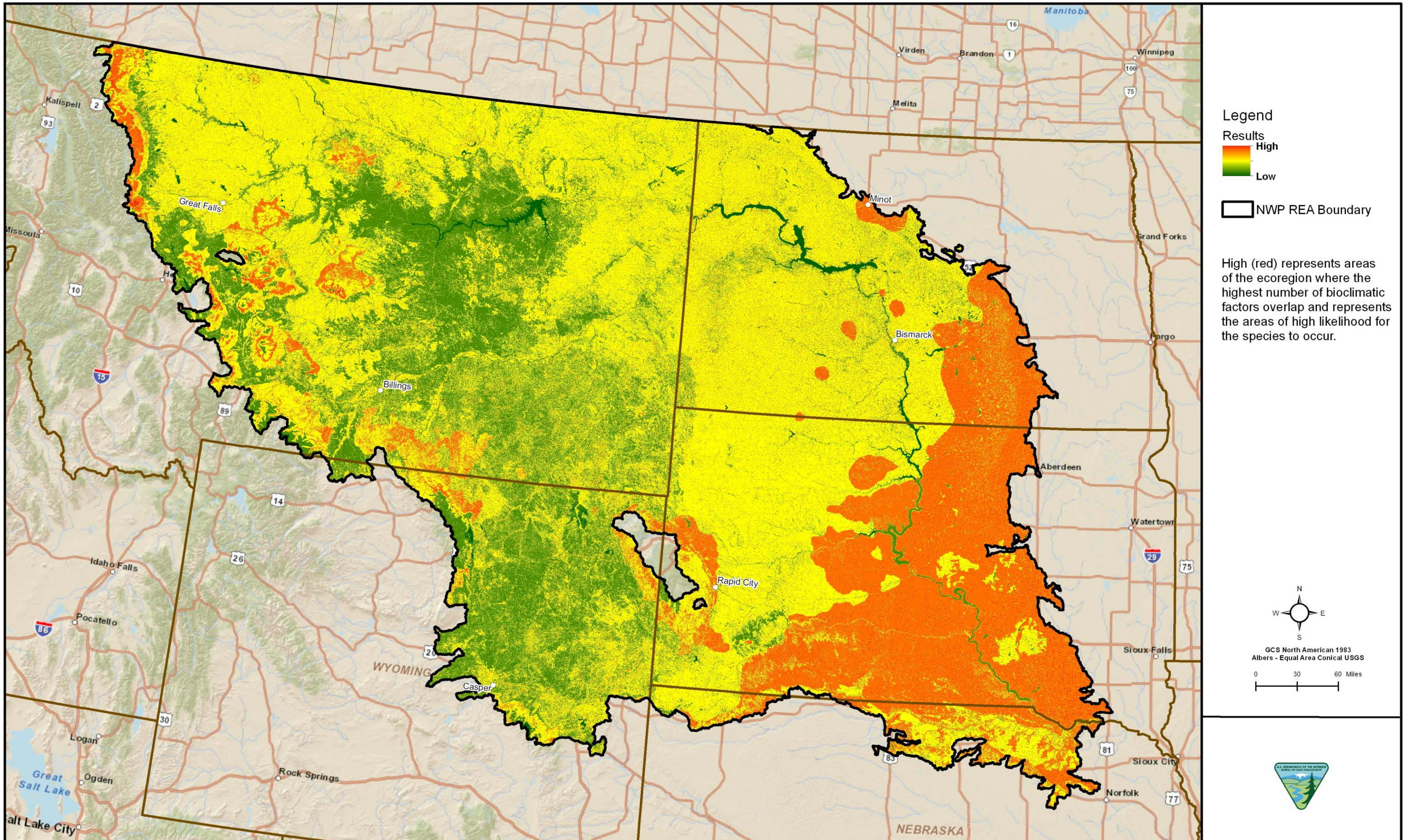

Figure C-3-12. Hoary Cress Combined Bioclimatic Factors

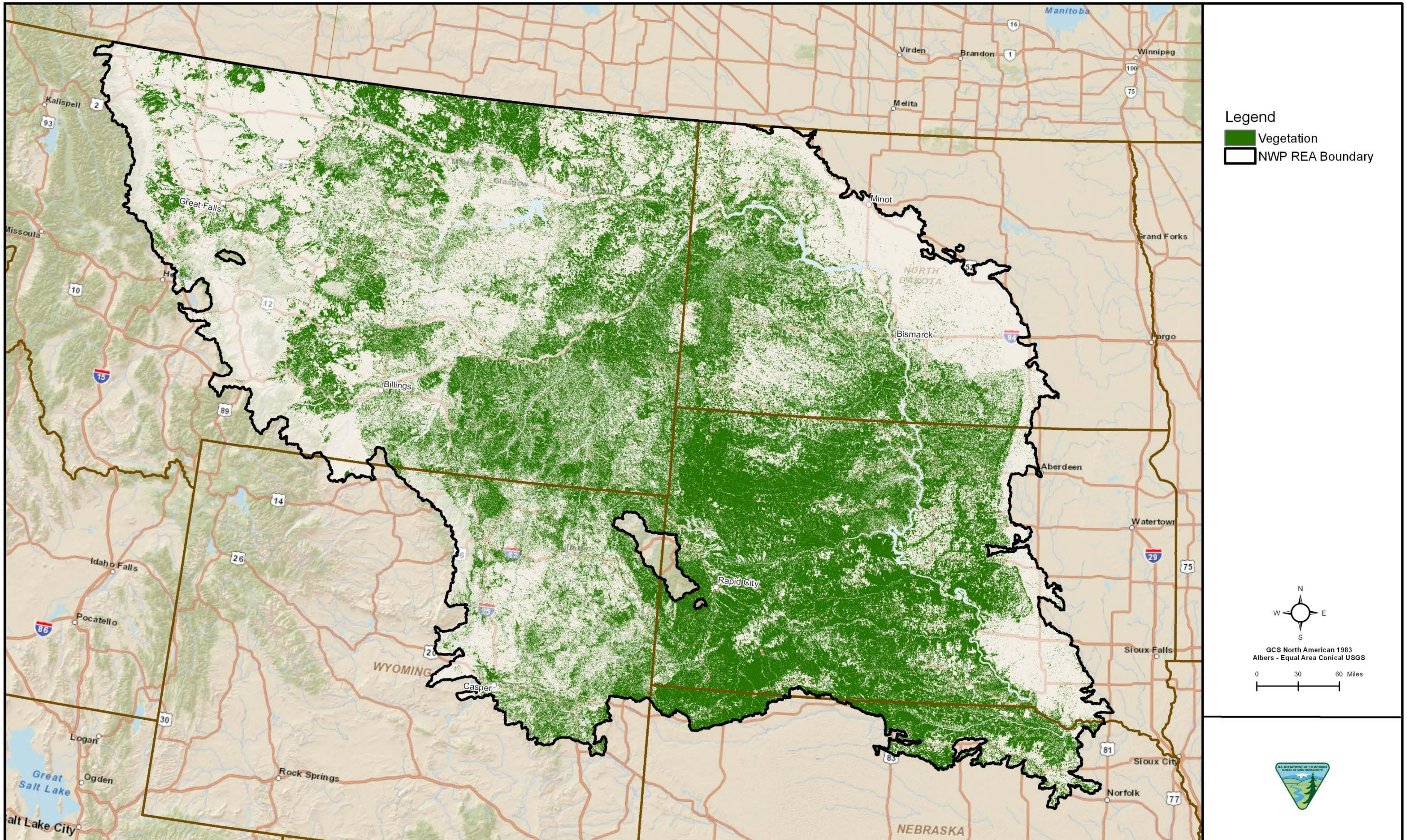

Figure C-3-13. Diffuse Knapweed REGAP Level 2/Level 3 Classifications

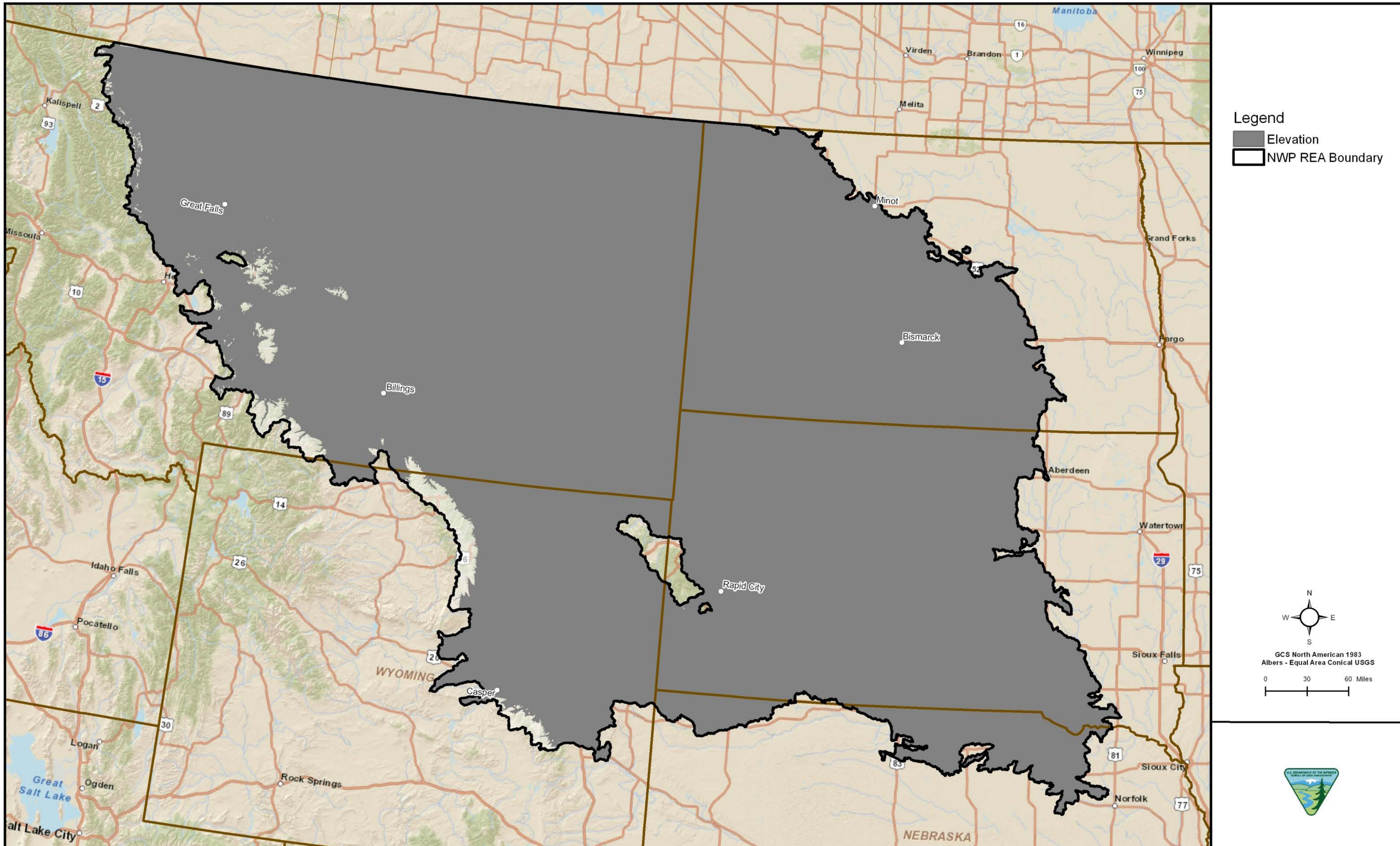

Figure C-3-14. Diffuse Knapweed Elevation

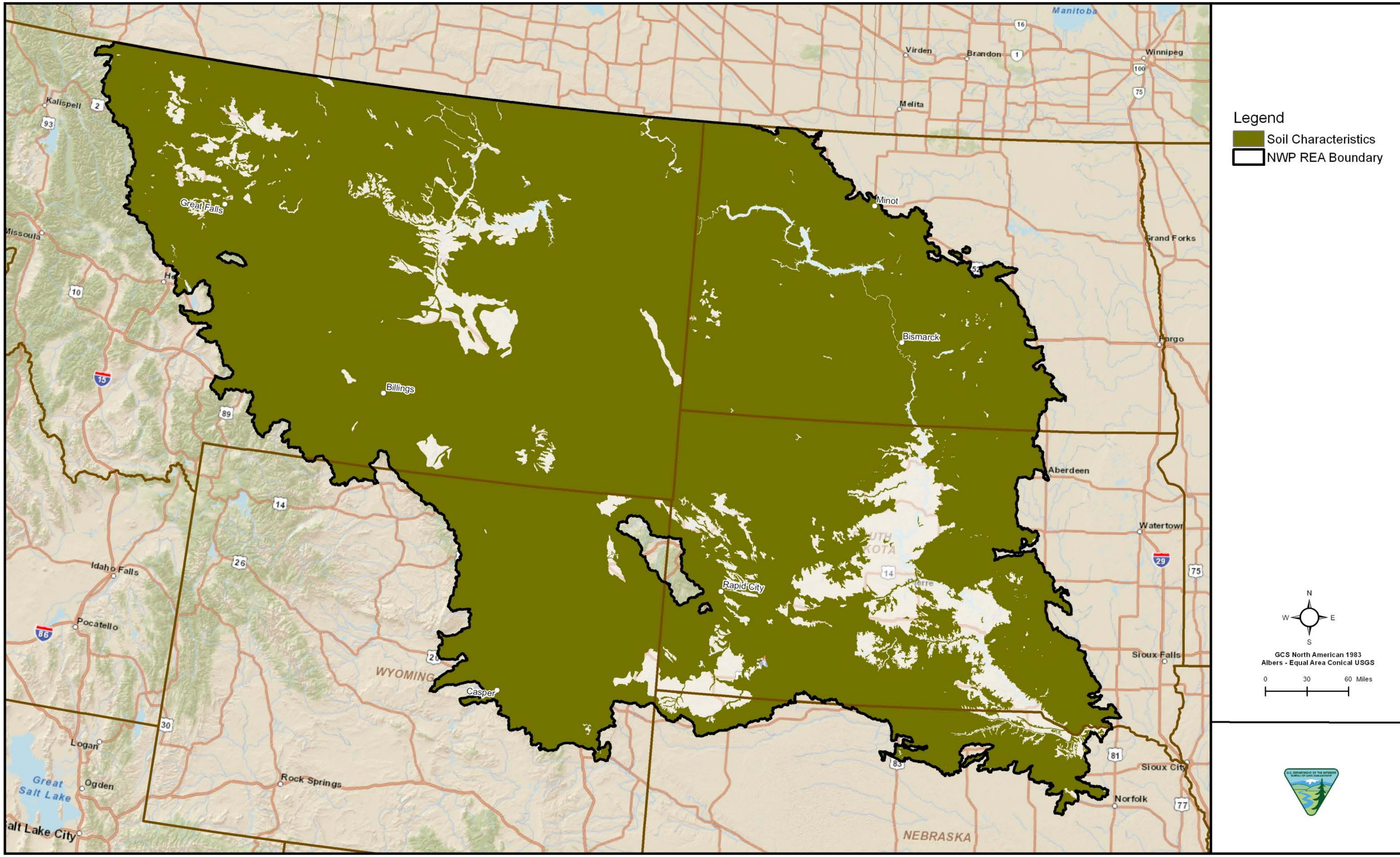

Figure C-3-15. Diffuse Knapweed Soil Factors

Figure C-3-16. Diffuse Knapweed Annual Precipitation

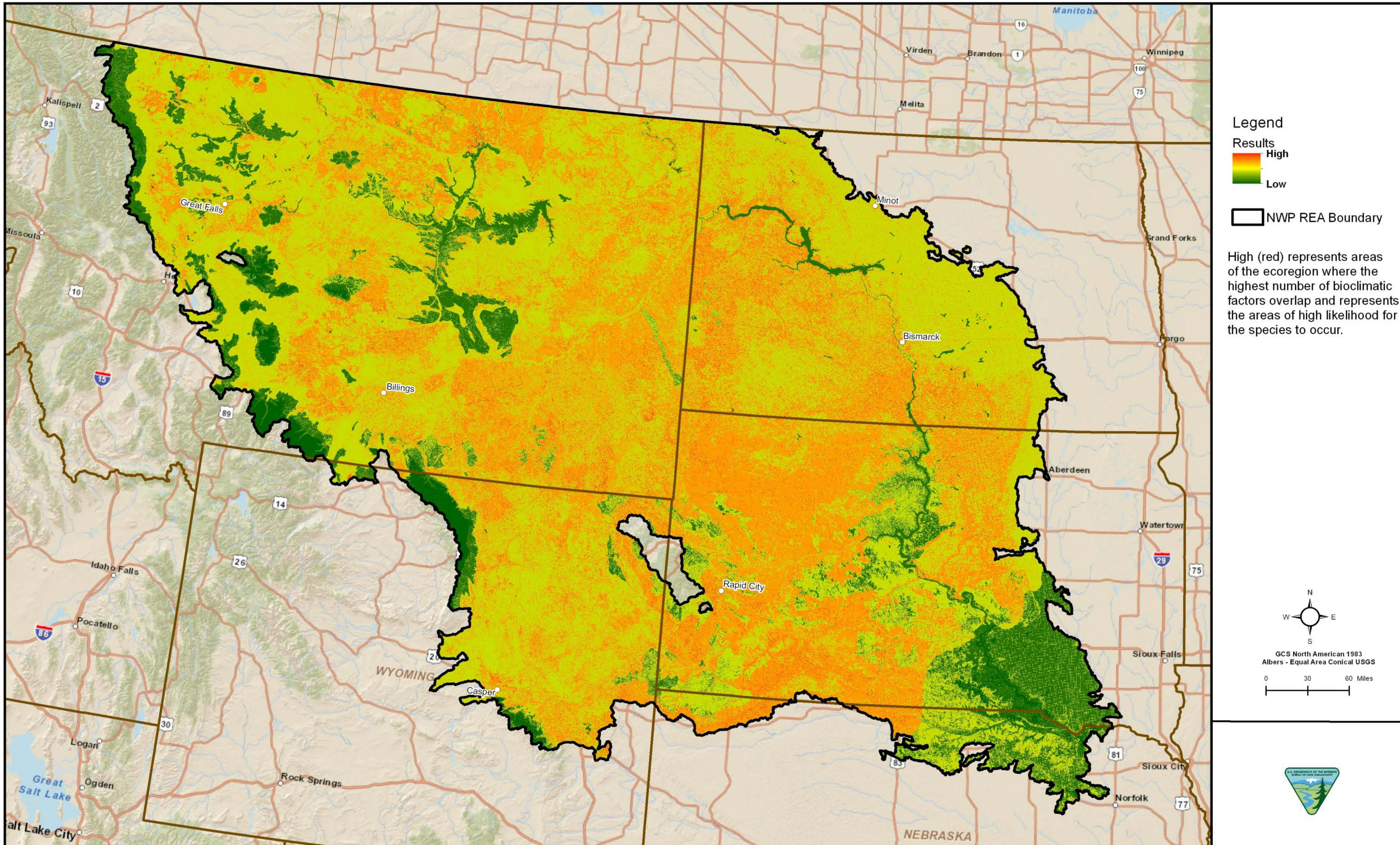

Figure C-3-17. Diffuse Knapweed Combined Bioclimatic Factors

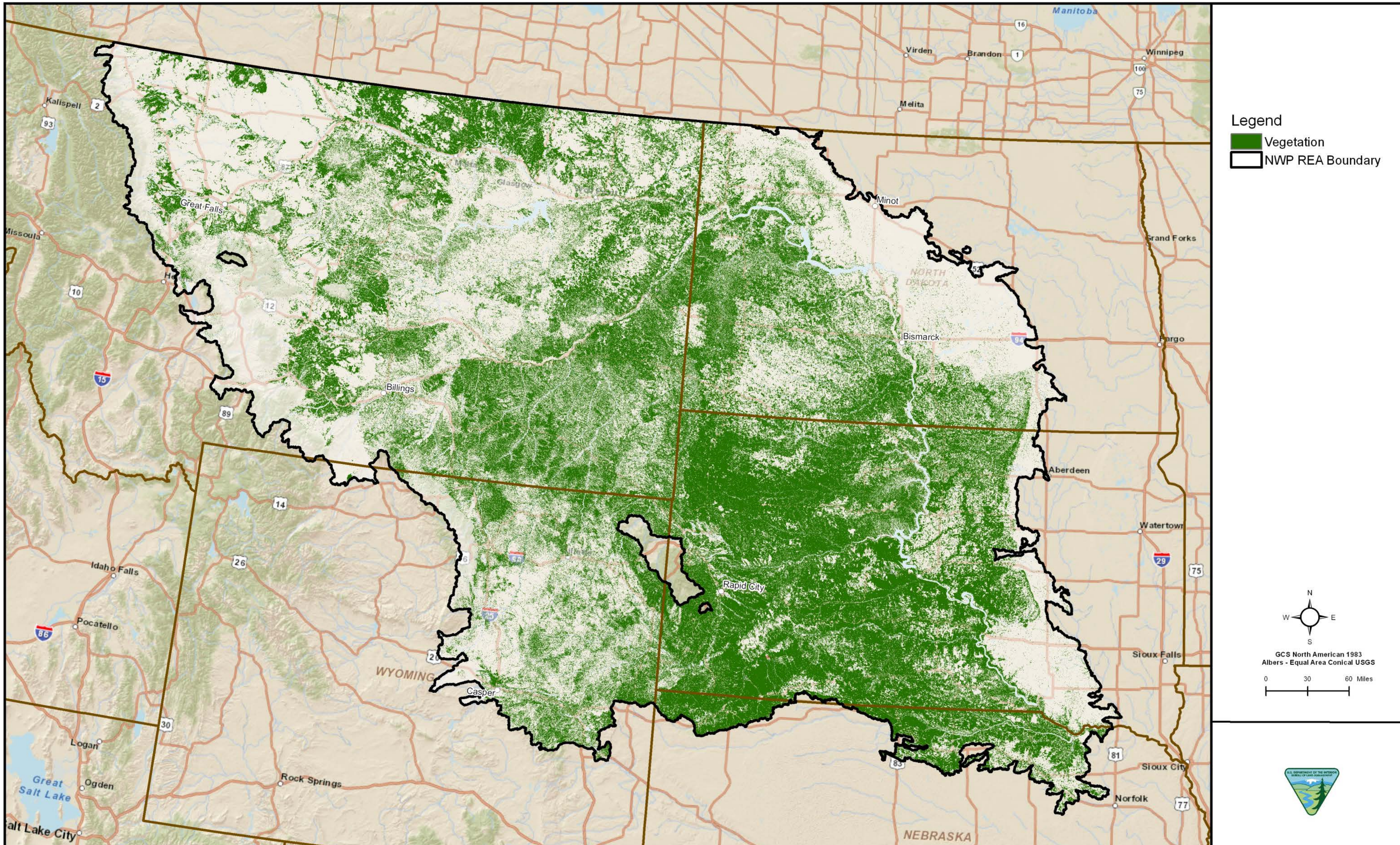

Figure C-3-18. Spotted Knapweed REGAP Level 2/Level 3 Classifications

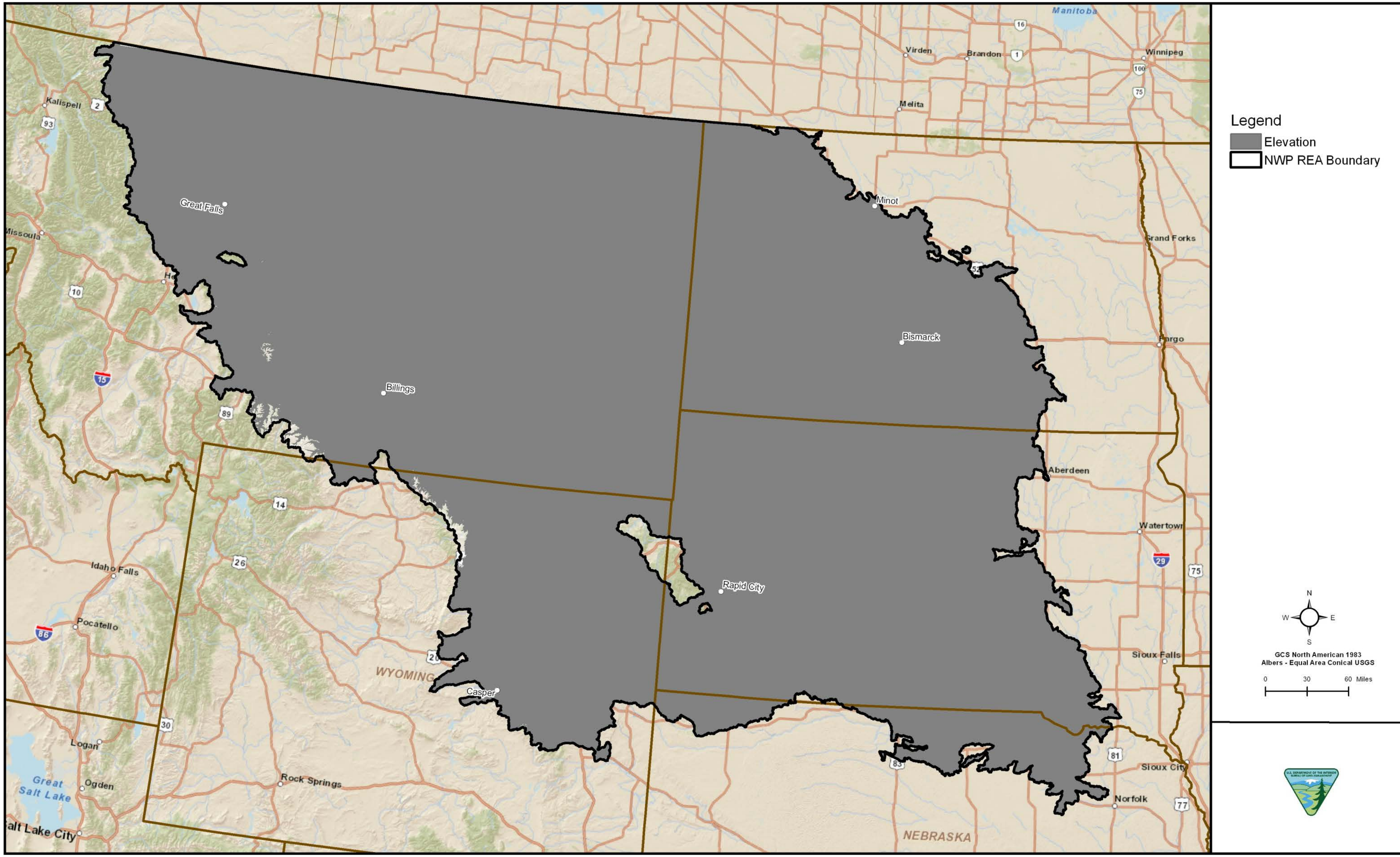

Figure C-3-19. Spotted Knapweed Elevation

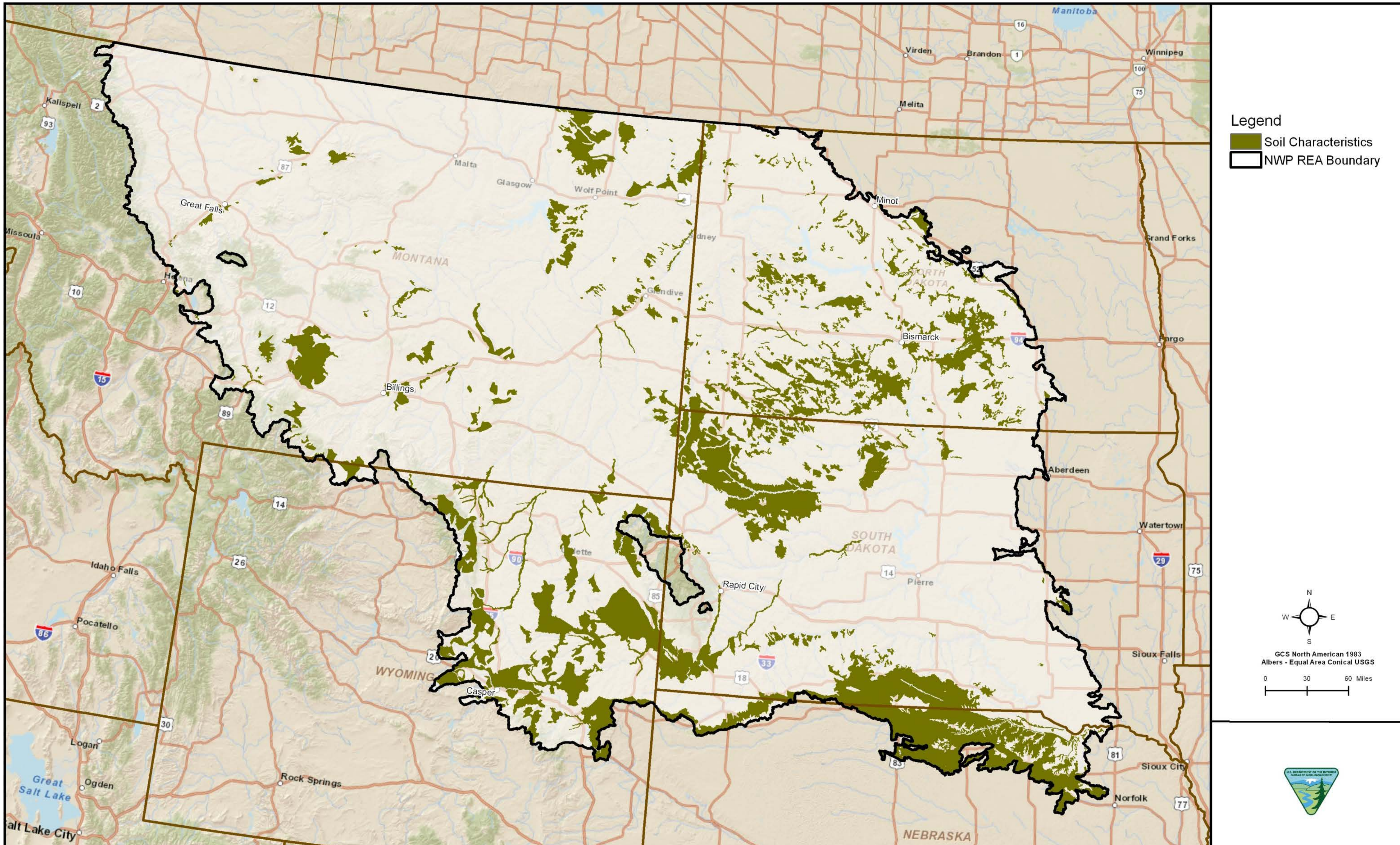

Figure C-3-20. Spotted Knapweed Soil Factors

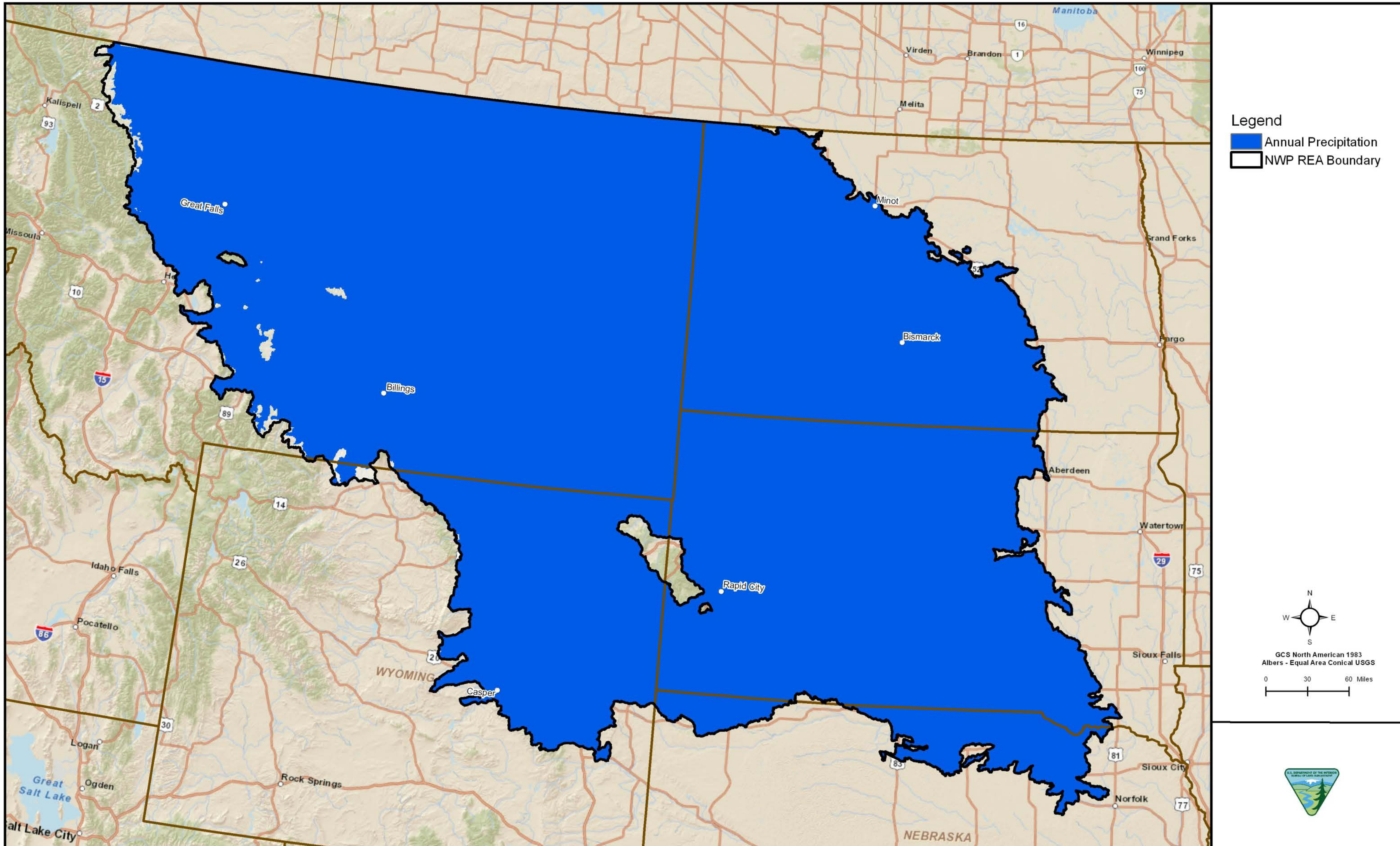

Figure C-3-21. Spotted Knapweed Annual Precipitation

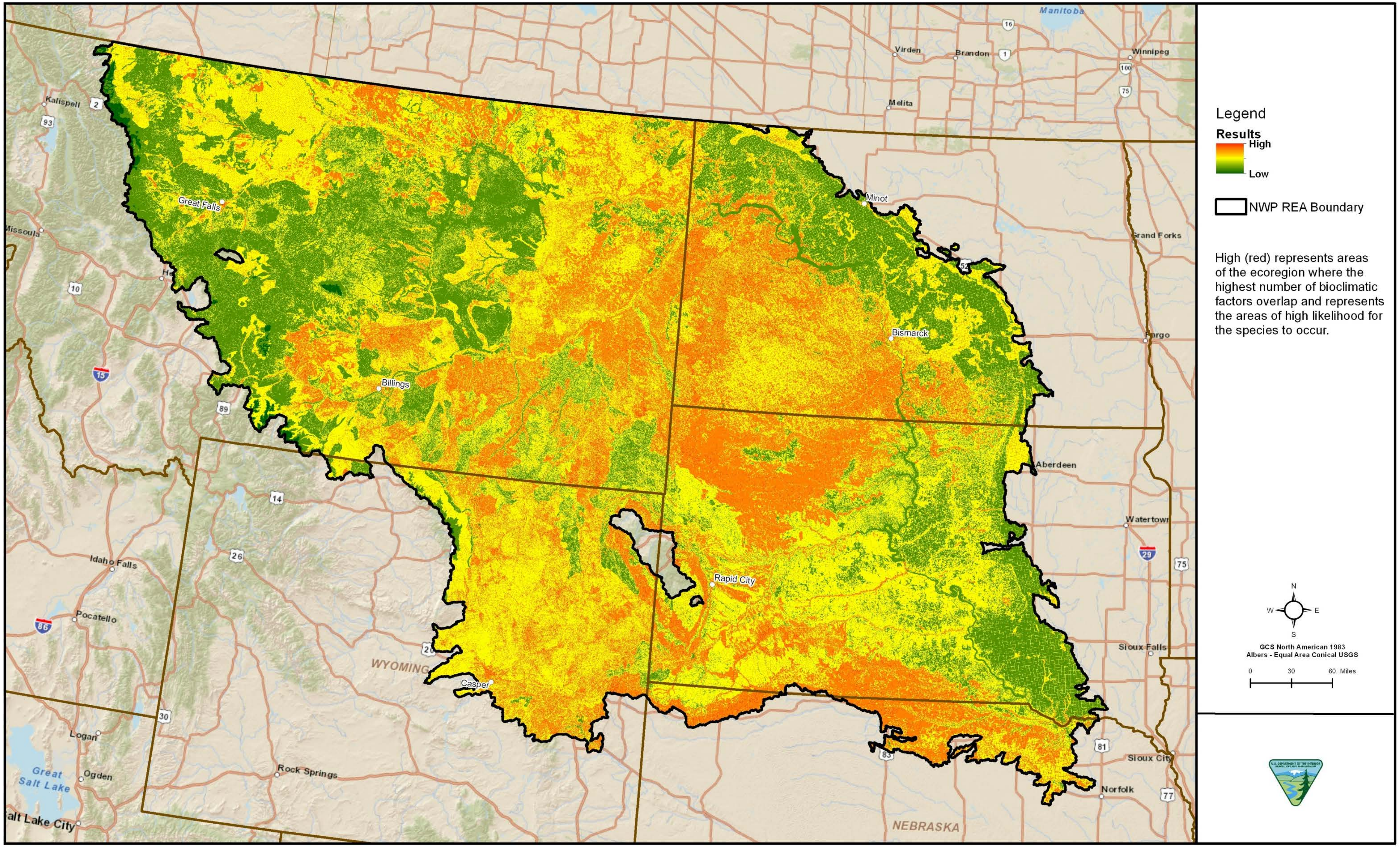

Figure C-3-22. Spotted Knapweed Combined Bioclimatic Factors

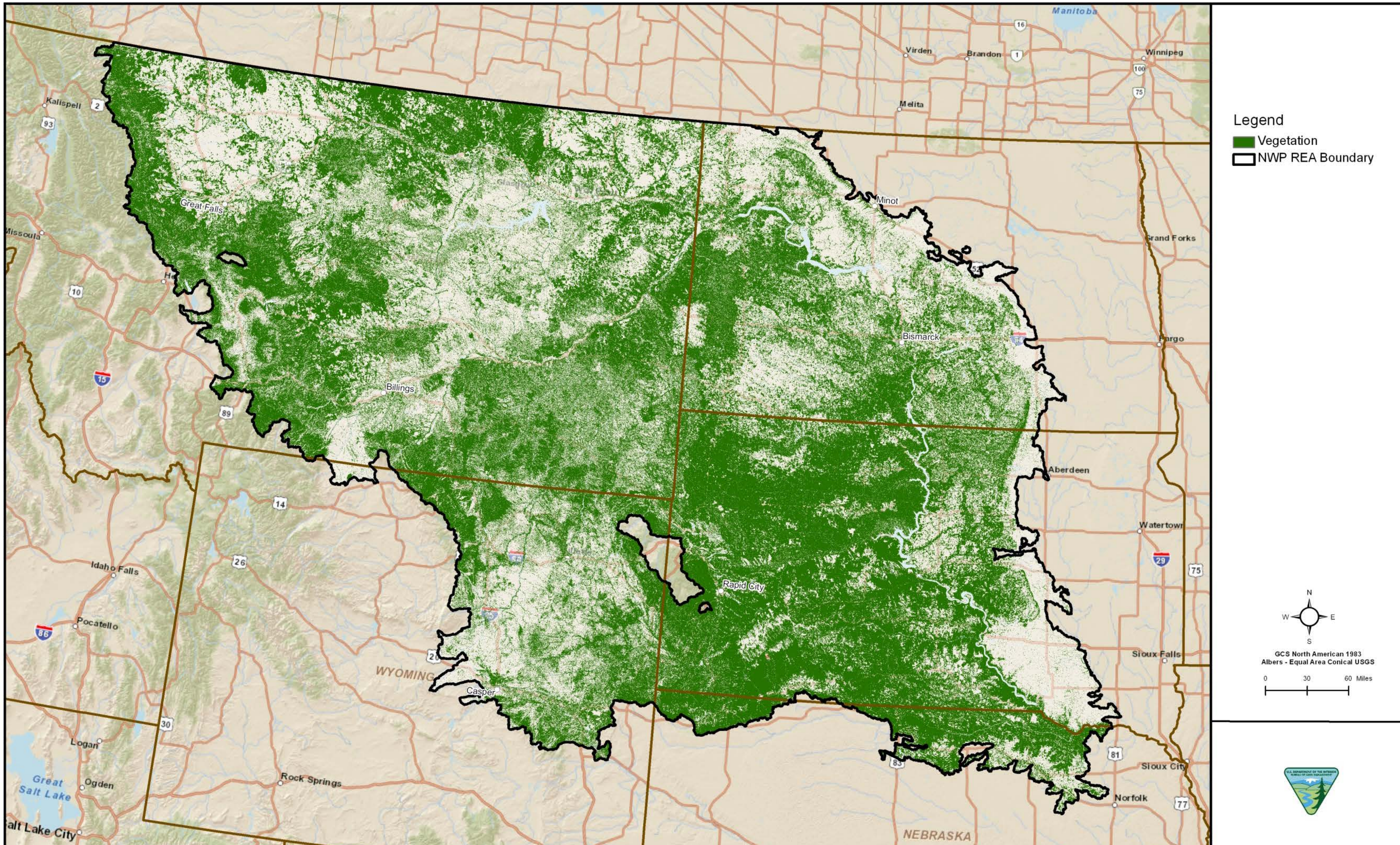

Figure C-3-23. Canada Thistle REGAP Level 2/Level 3 Classifications

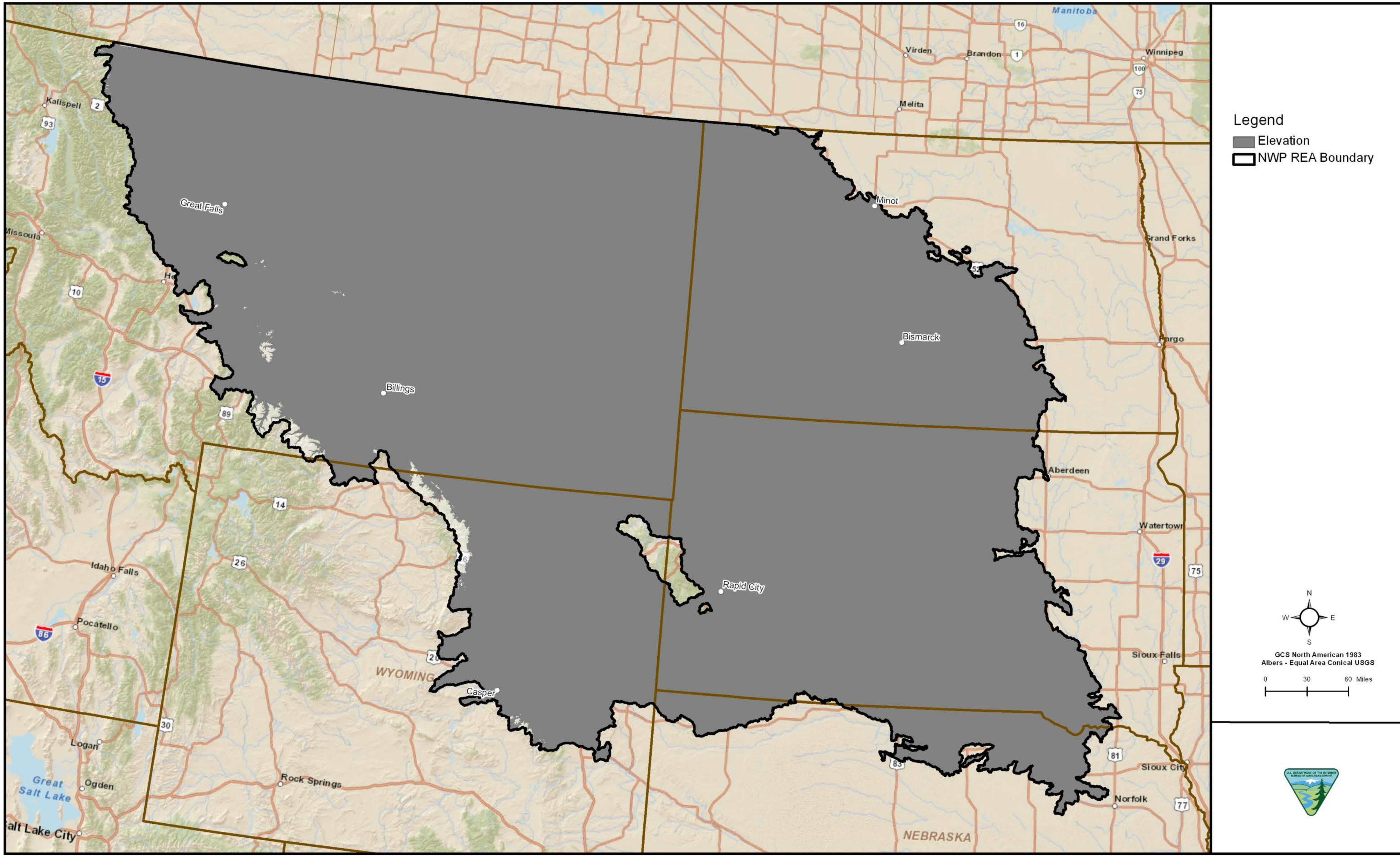

Figure C-3-24. Canada Thistle Elevation

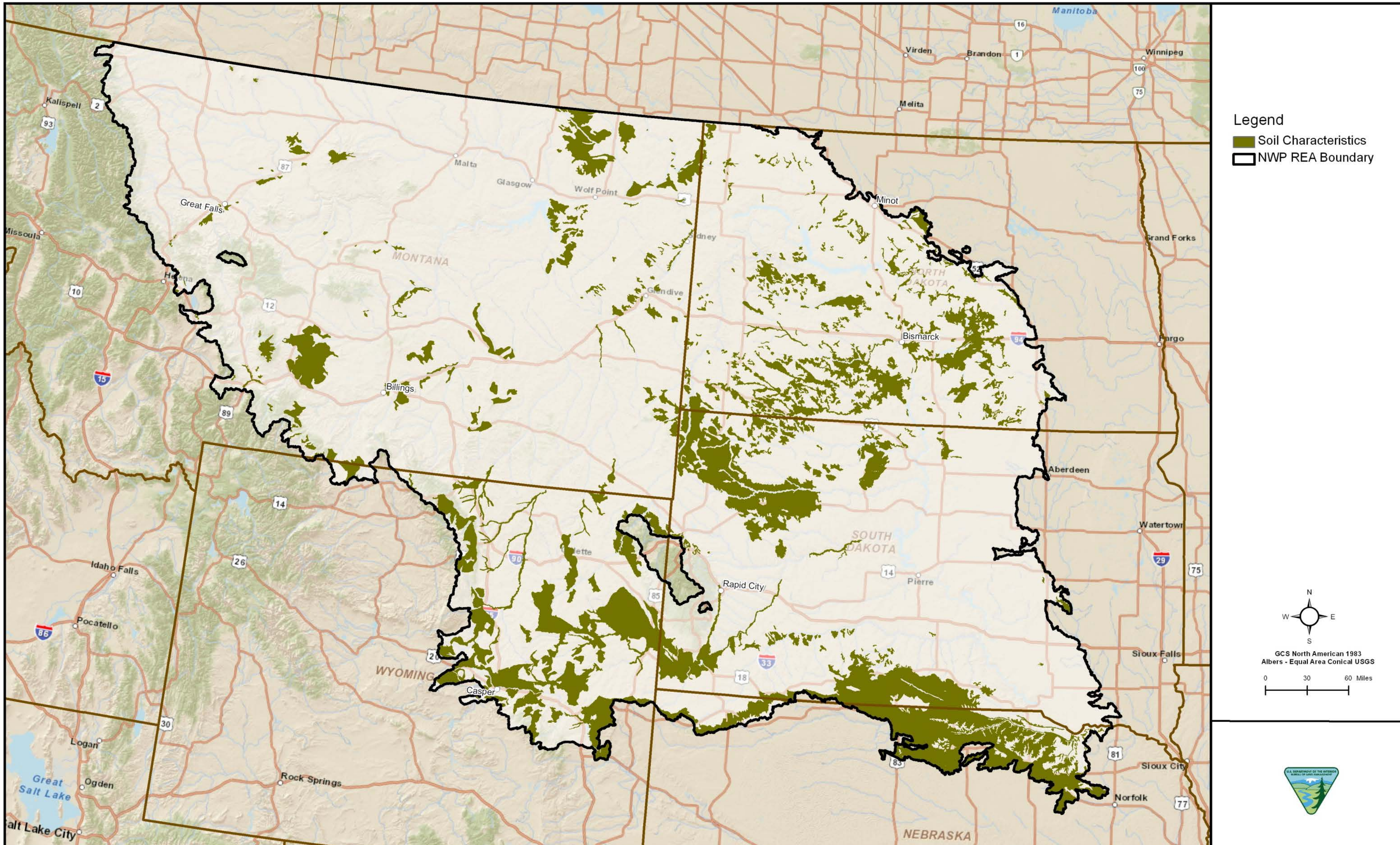

Figure C-3-25. Canada Thistle Soil Factors

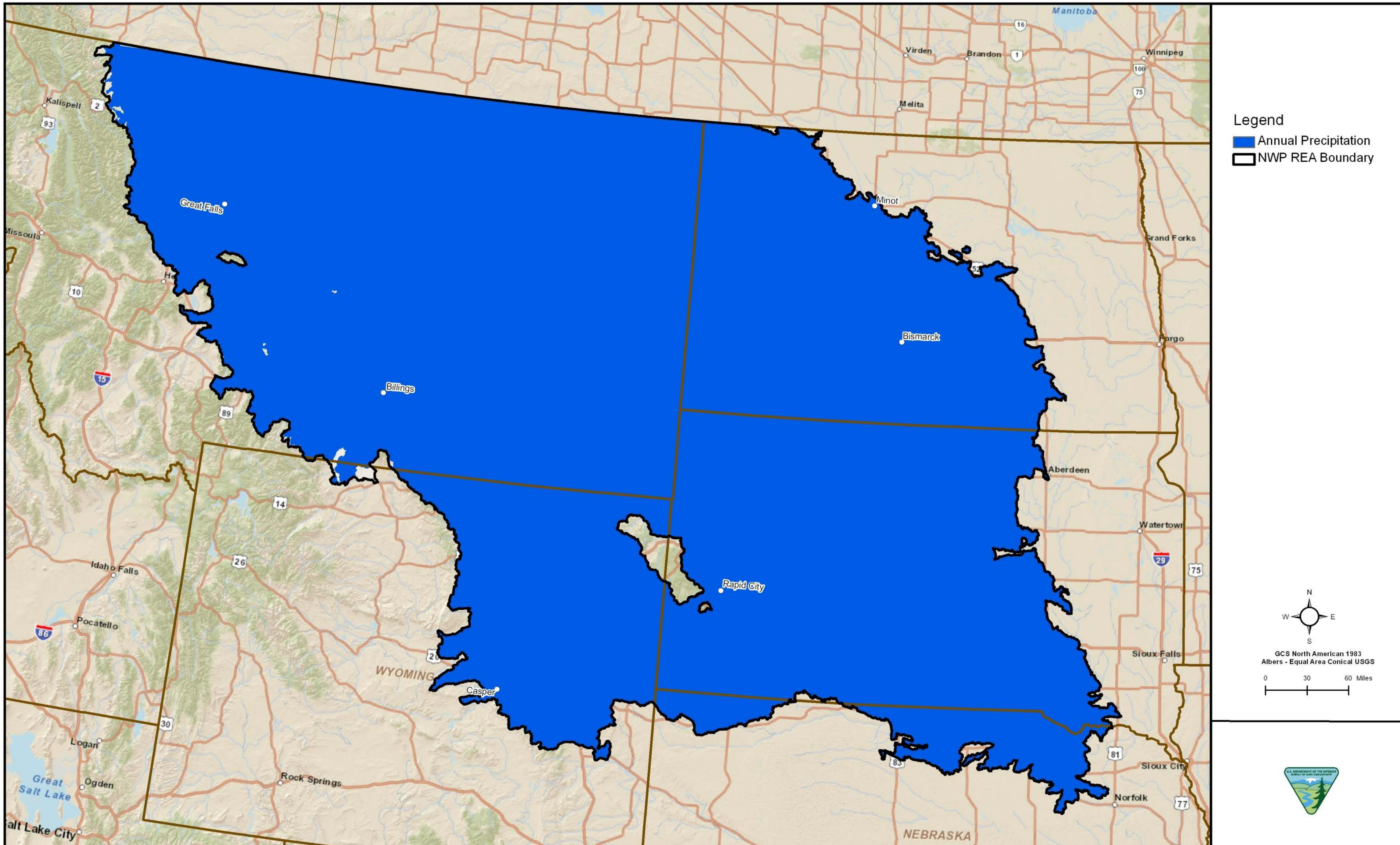

Figure C-3-26. Canada Thistle Annual Precipitation

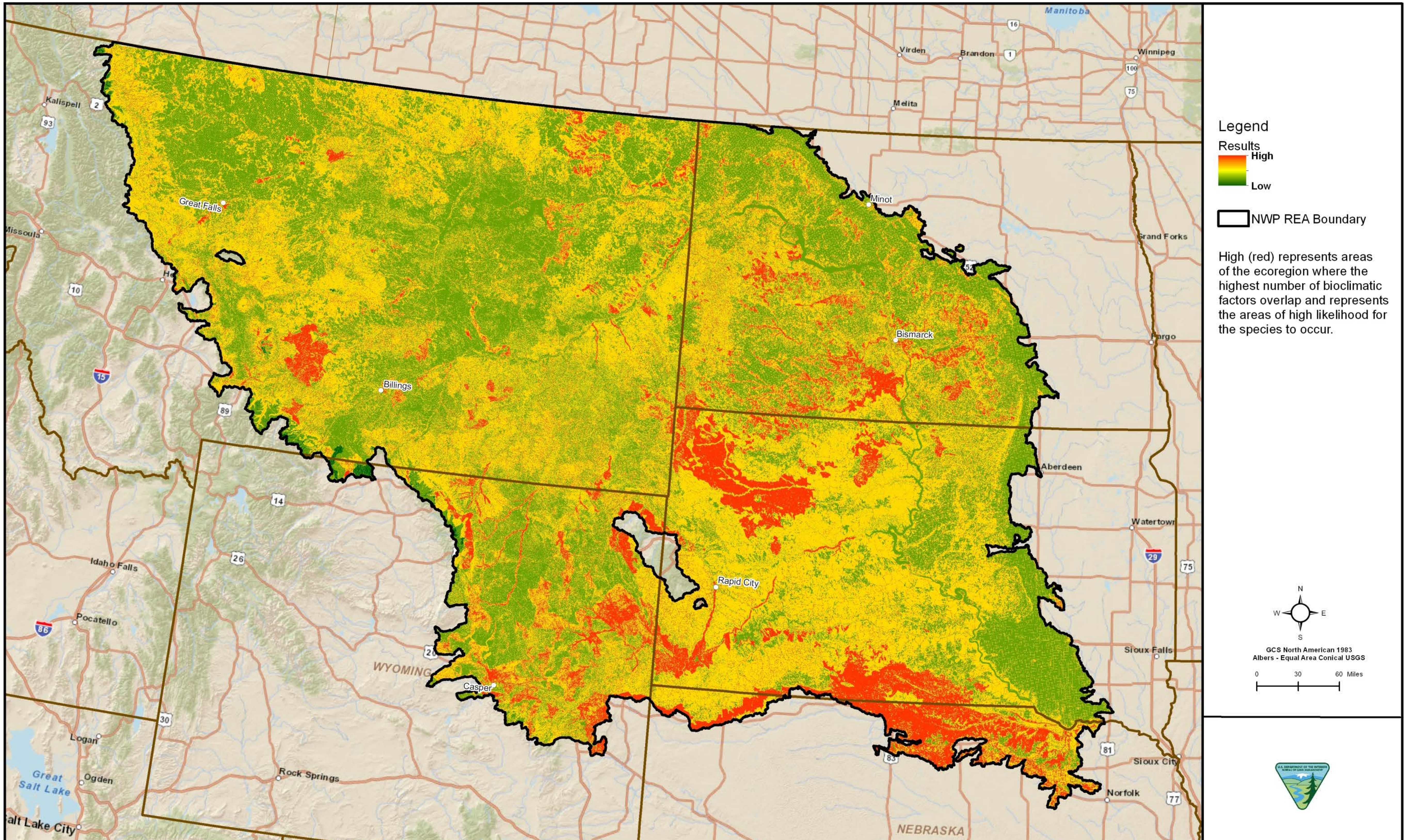

Figure C-3-27. Canada Thistle Combined Bioclimatic Factors

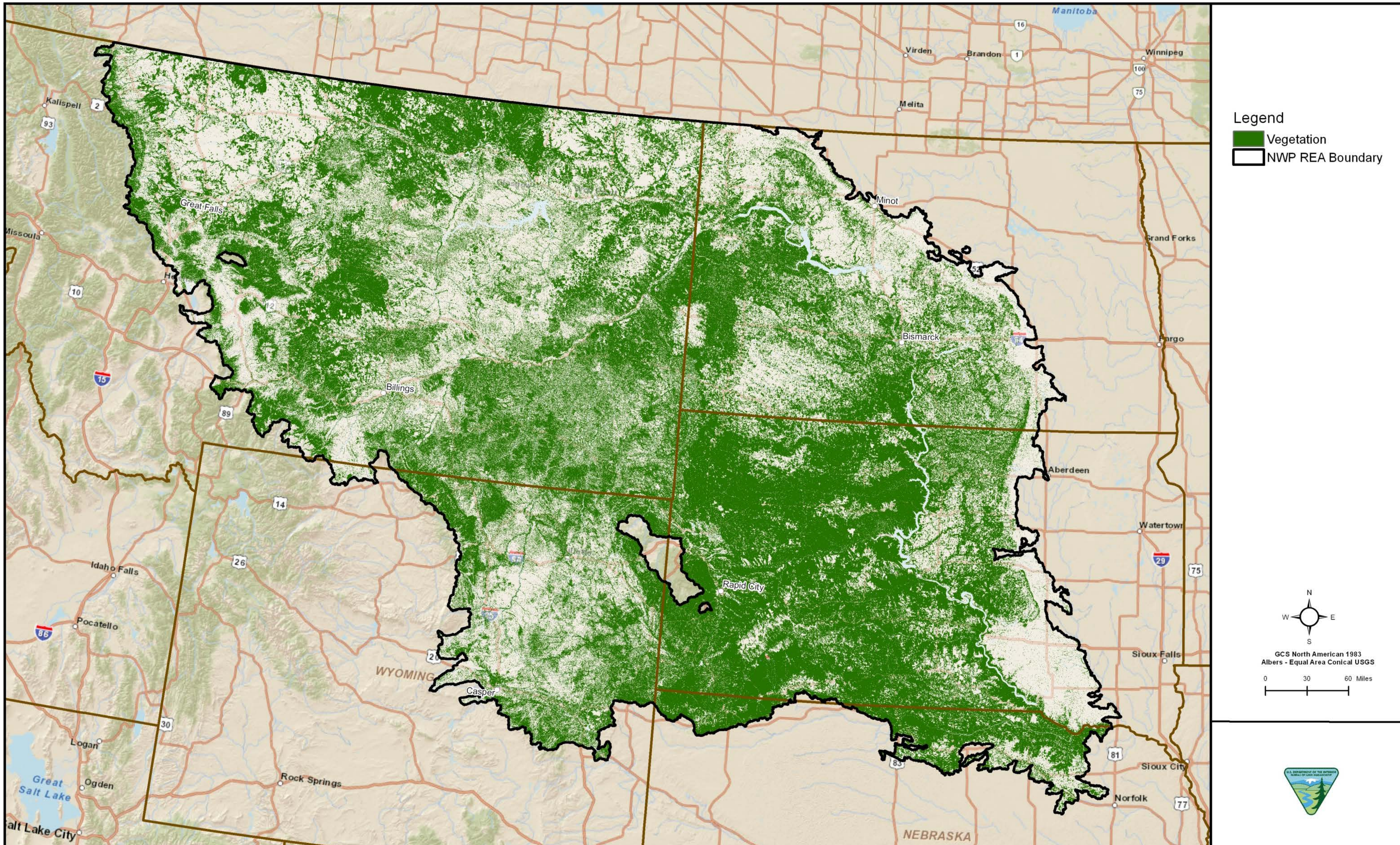

Figure C-3-28. Houndstongue REGAP Level 2/Level 3 Classifications

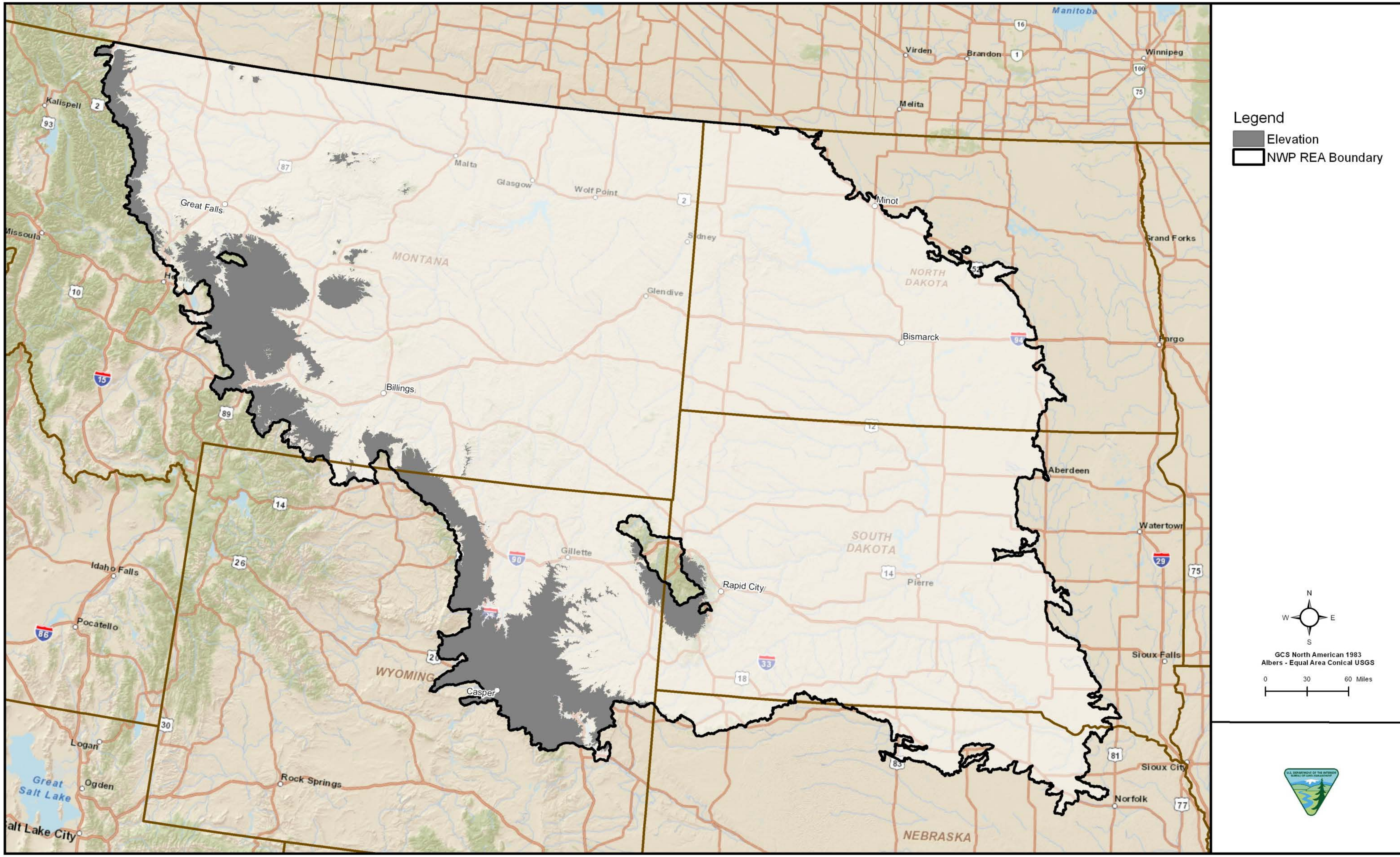

Figure C-3-29. Houndstongue Elevation

Figure C-3-30. Houndstongue Annual Precipitation

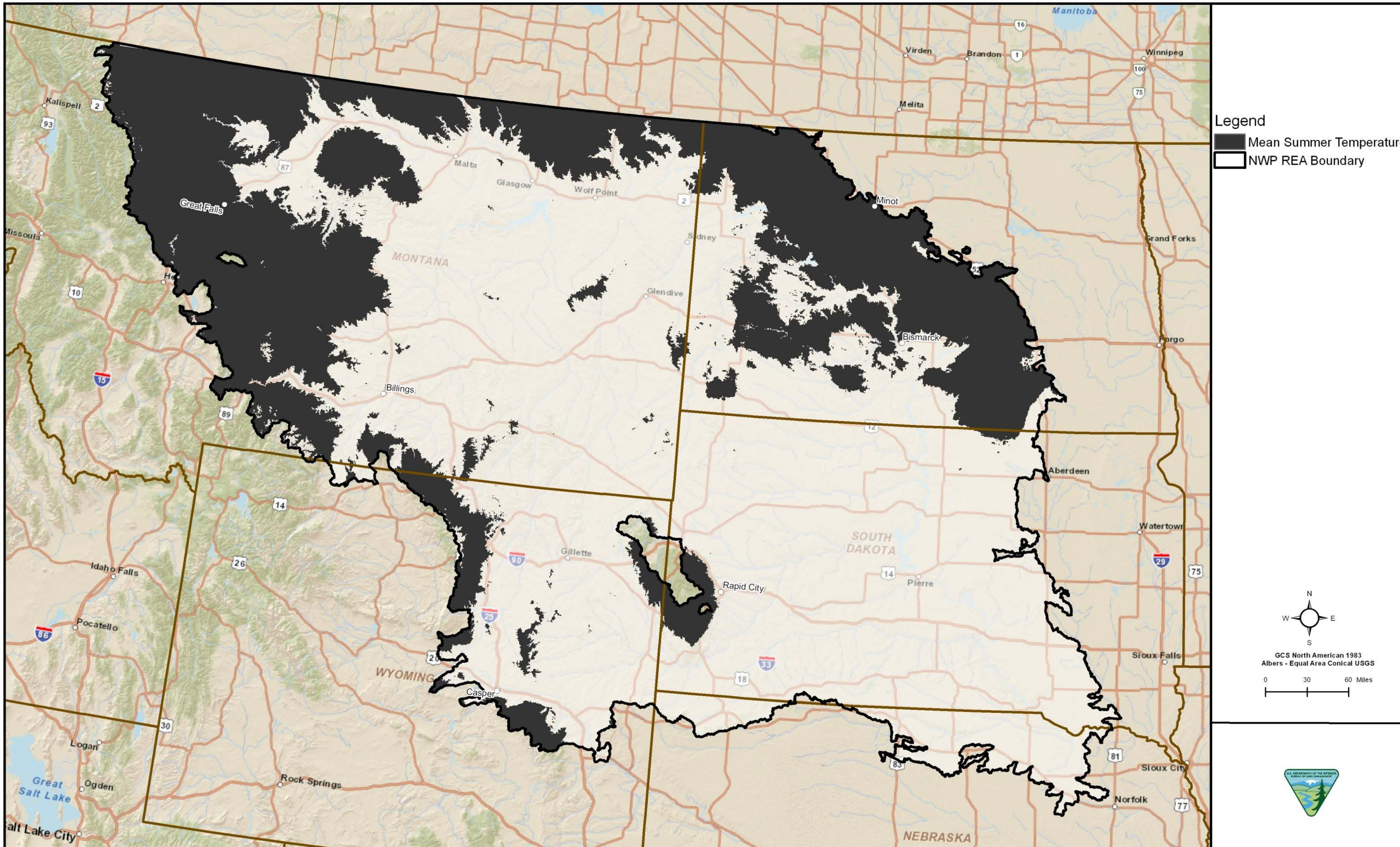

Figure C-3-31. Houndstongue Mean Summer Temperature

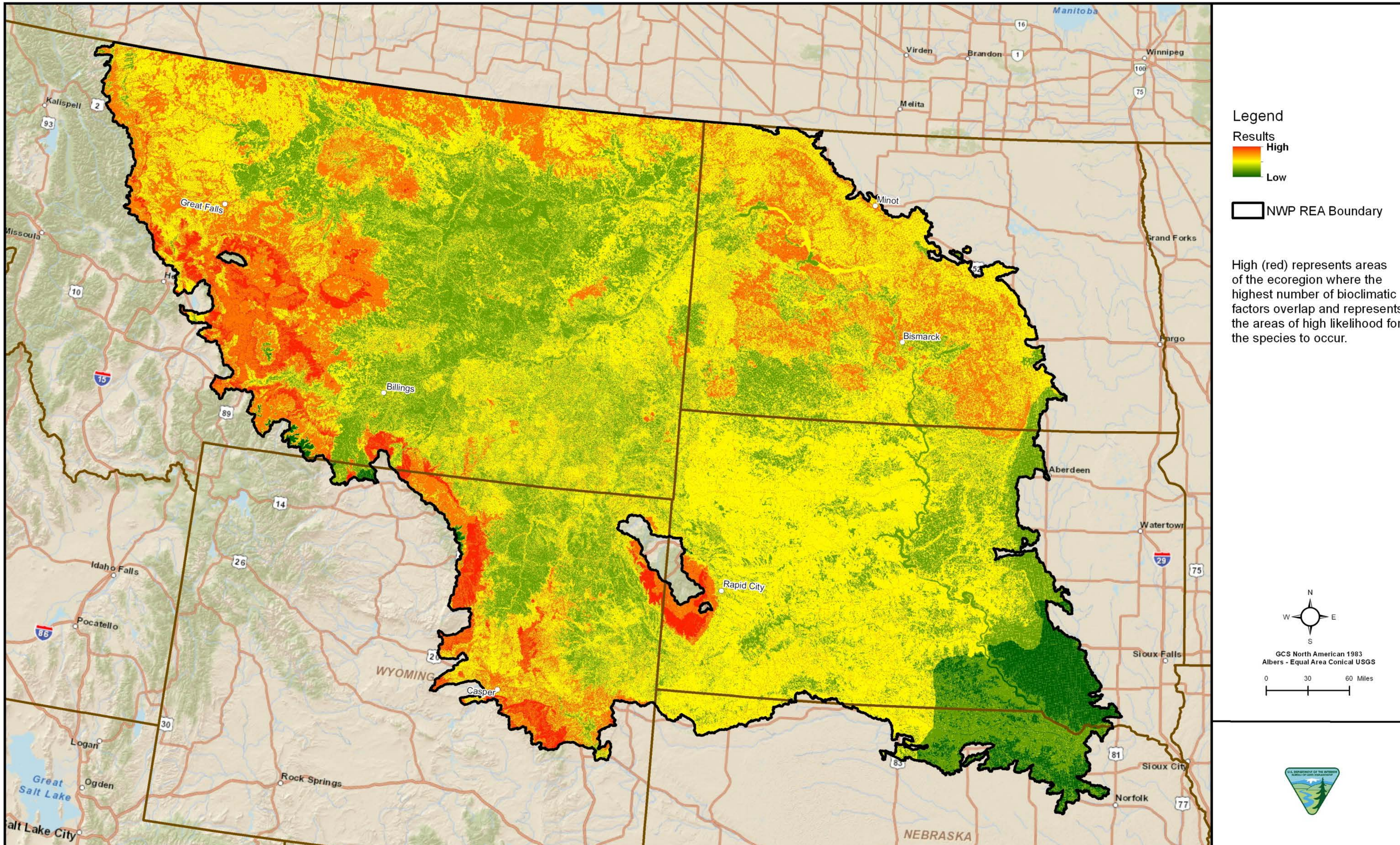

Figure C-3-32. Houndstongue Combined Bioclimatic Factors

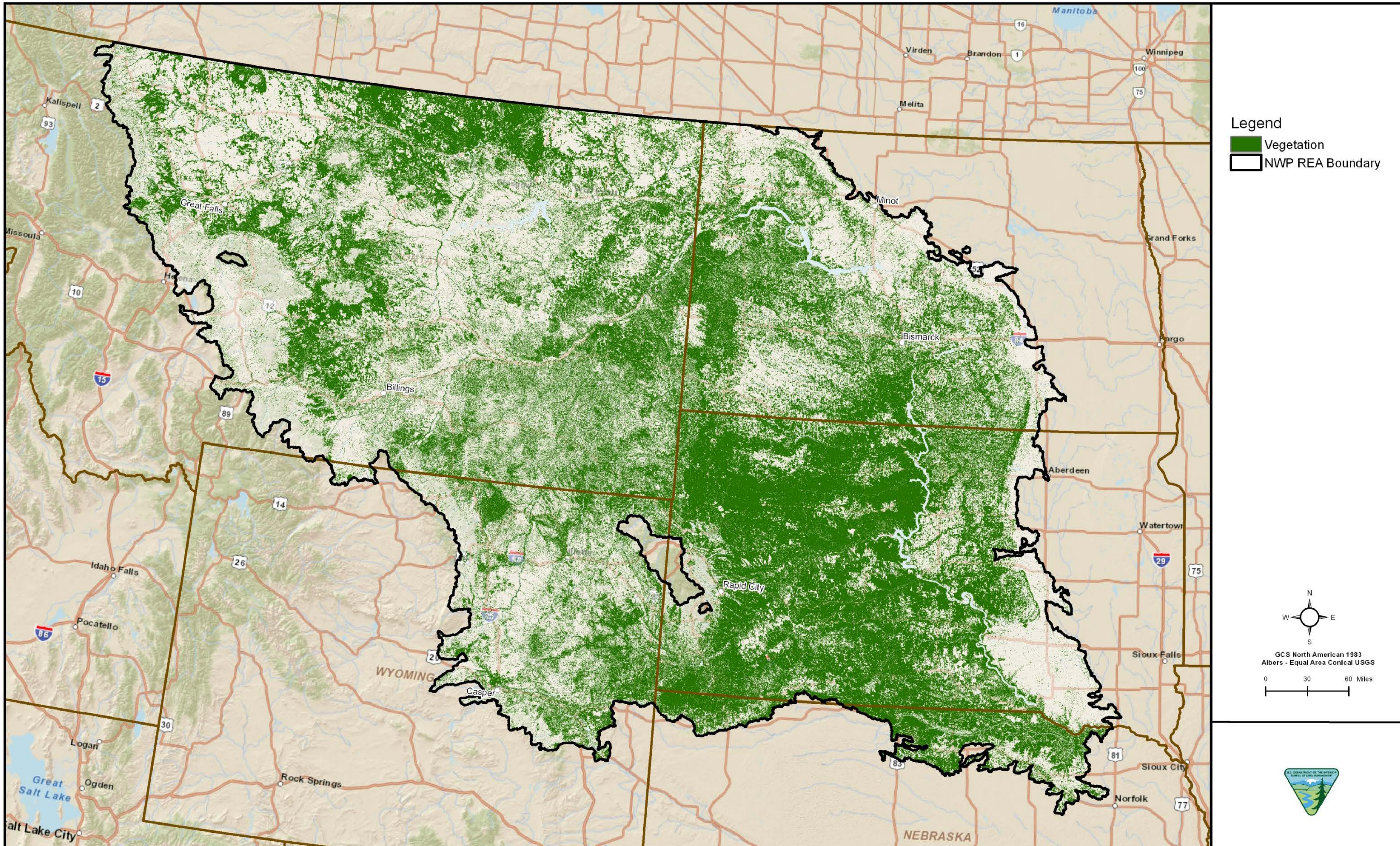

Figure C-3-33. Leafy Spurge REGAP Level 2/Level 3 Classifications

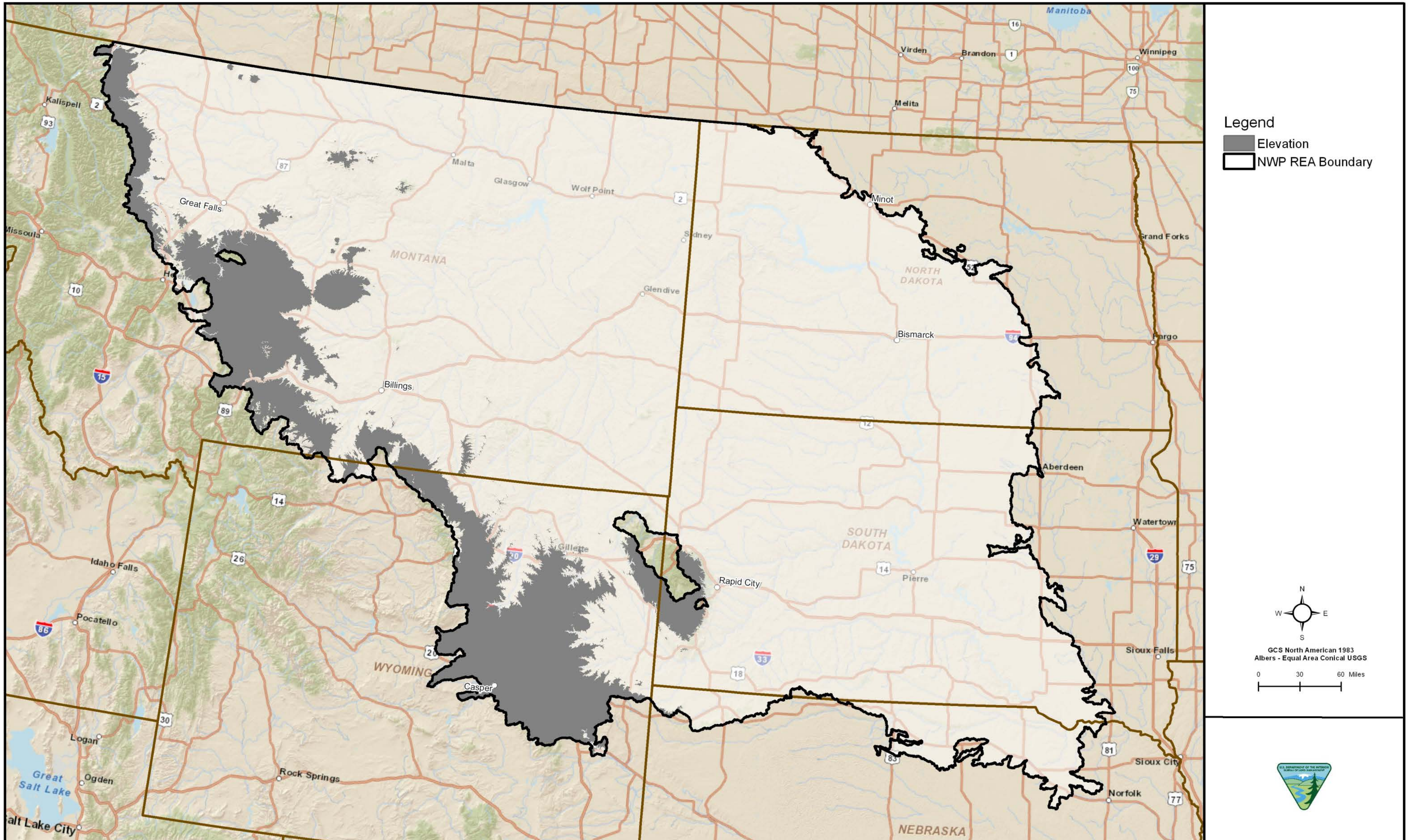

Figure C-3-34. Leafy Spurge Elevation

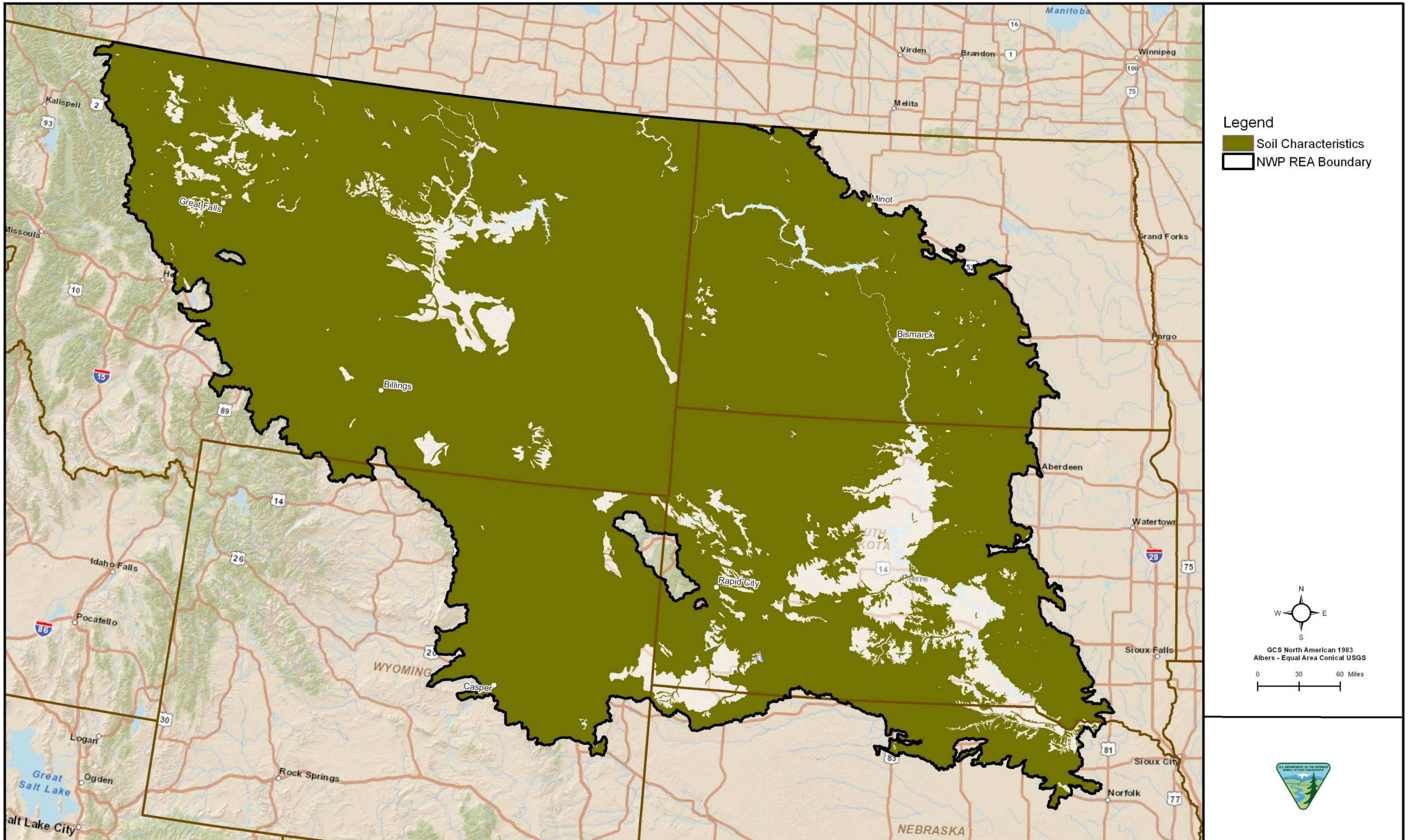

Figure C-3-35. Leafy Spurge Soil Factors

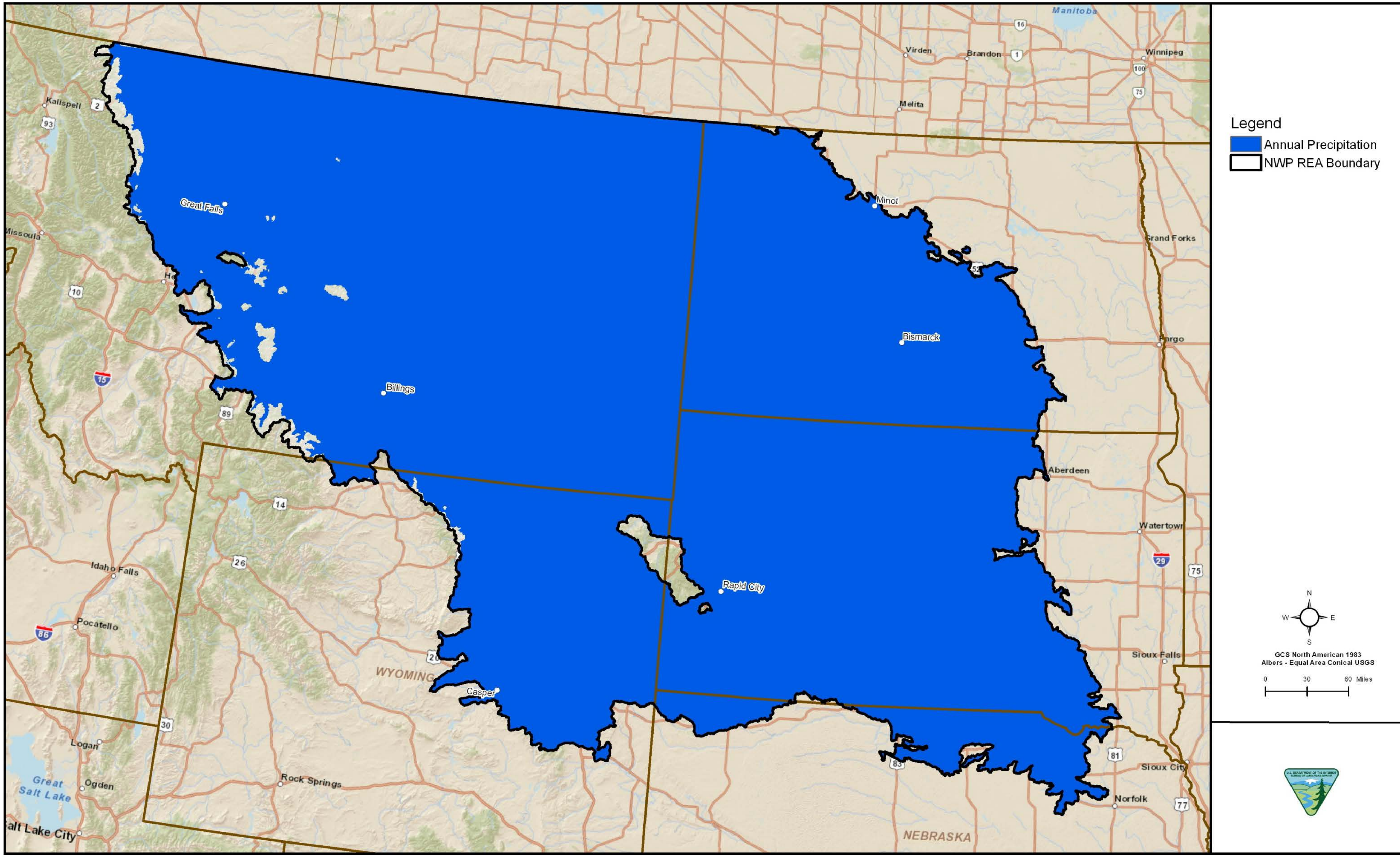

Figure C-3-36. Leafy Spurge Annual Precipitation

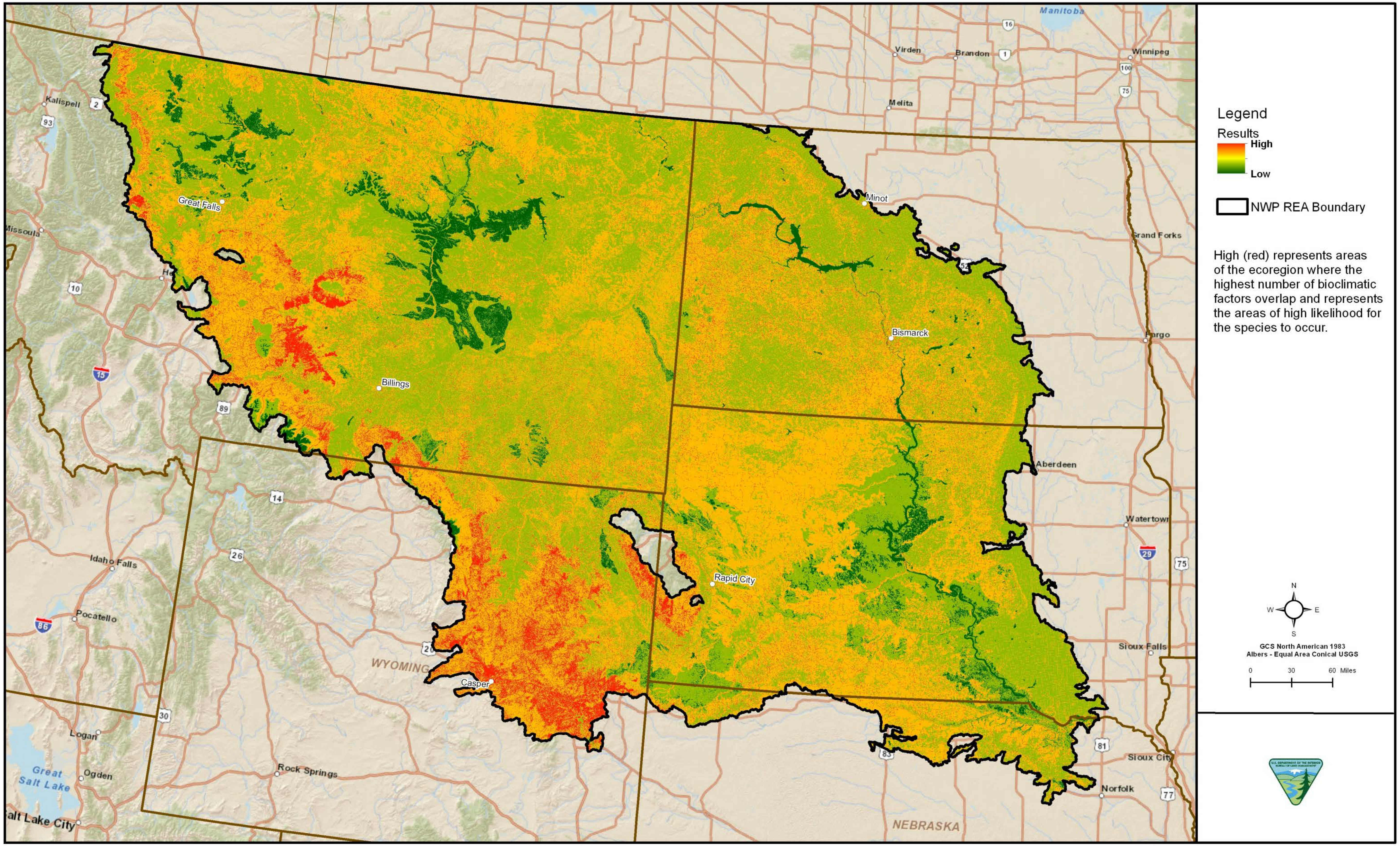

Figure C-3-37. Leafy Spurge Combined Bioclimatic Factors

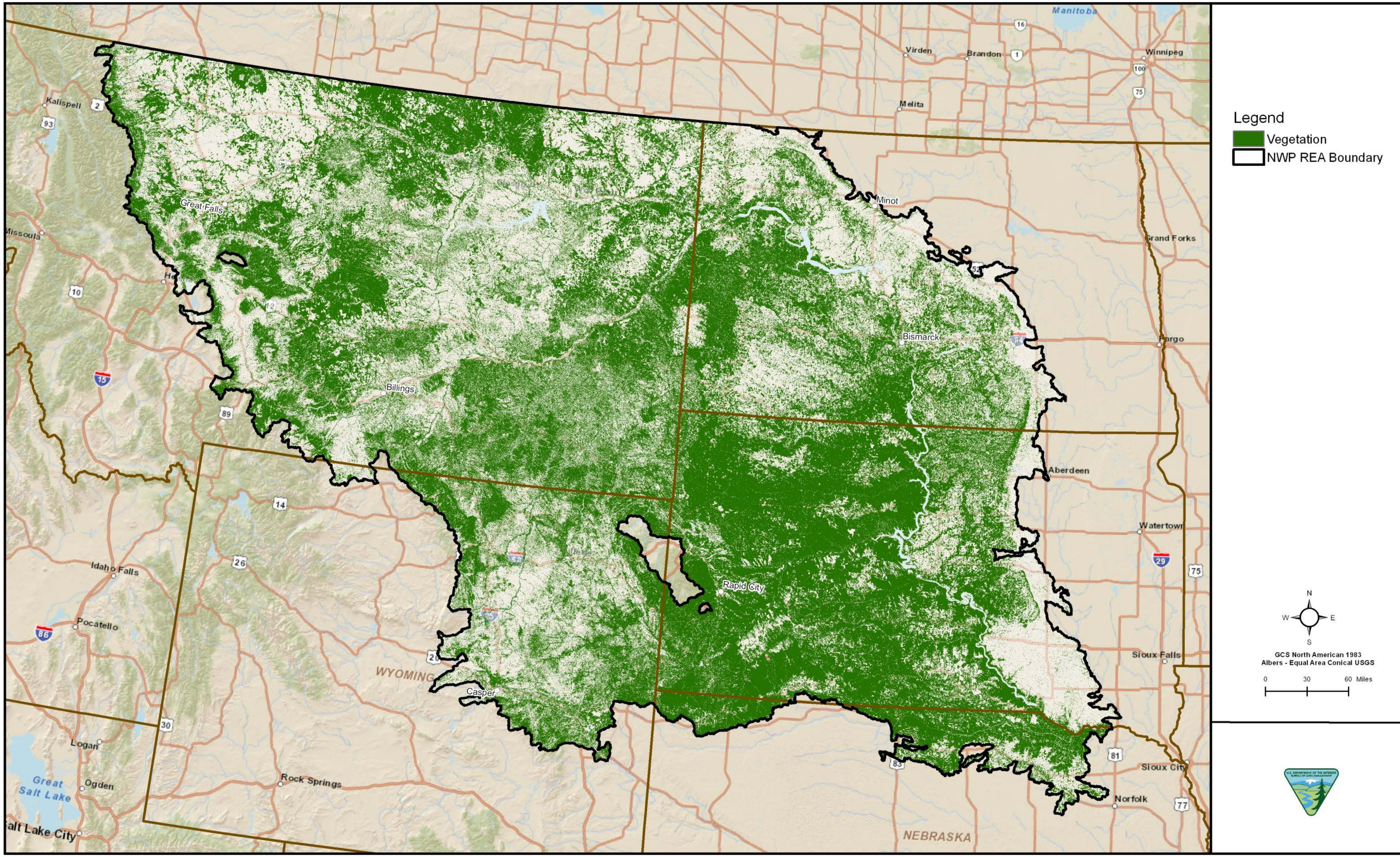

Figure C-3-38. Dalmatian Toadflax REGAP Level 2/Level 3 Classifications

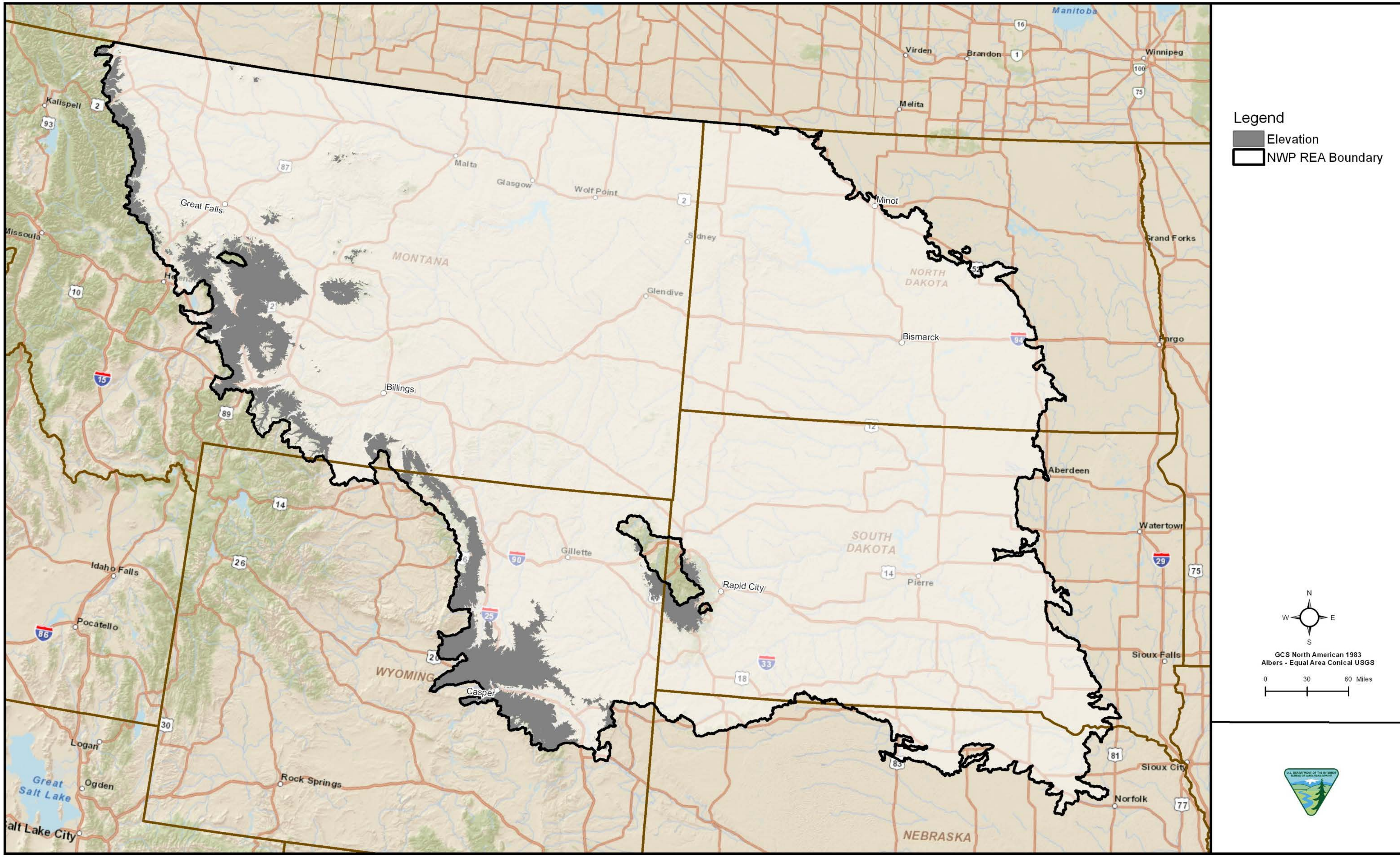

Figure C-3-39. Dalmatian Toadflax Elevation

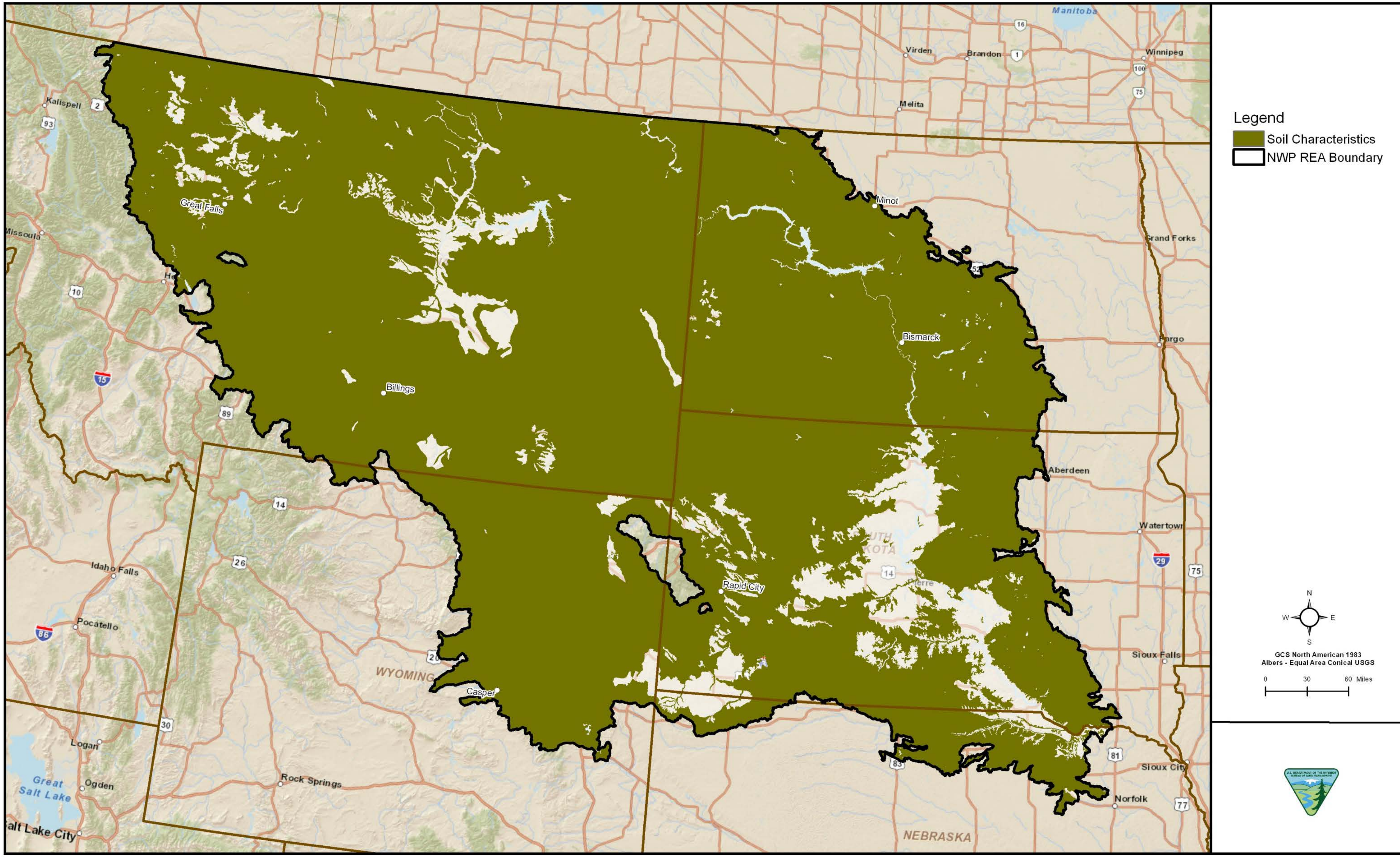

Figure C-3-40. Dalmatian Toadflax Soil Factors

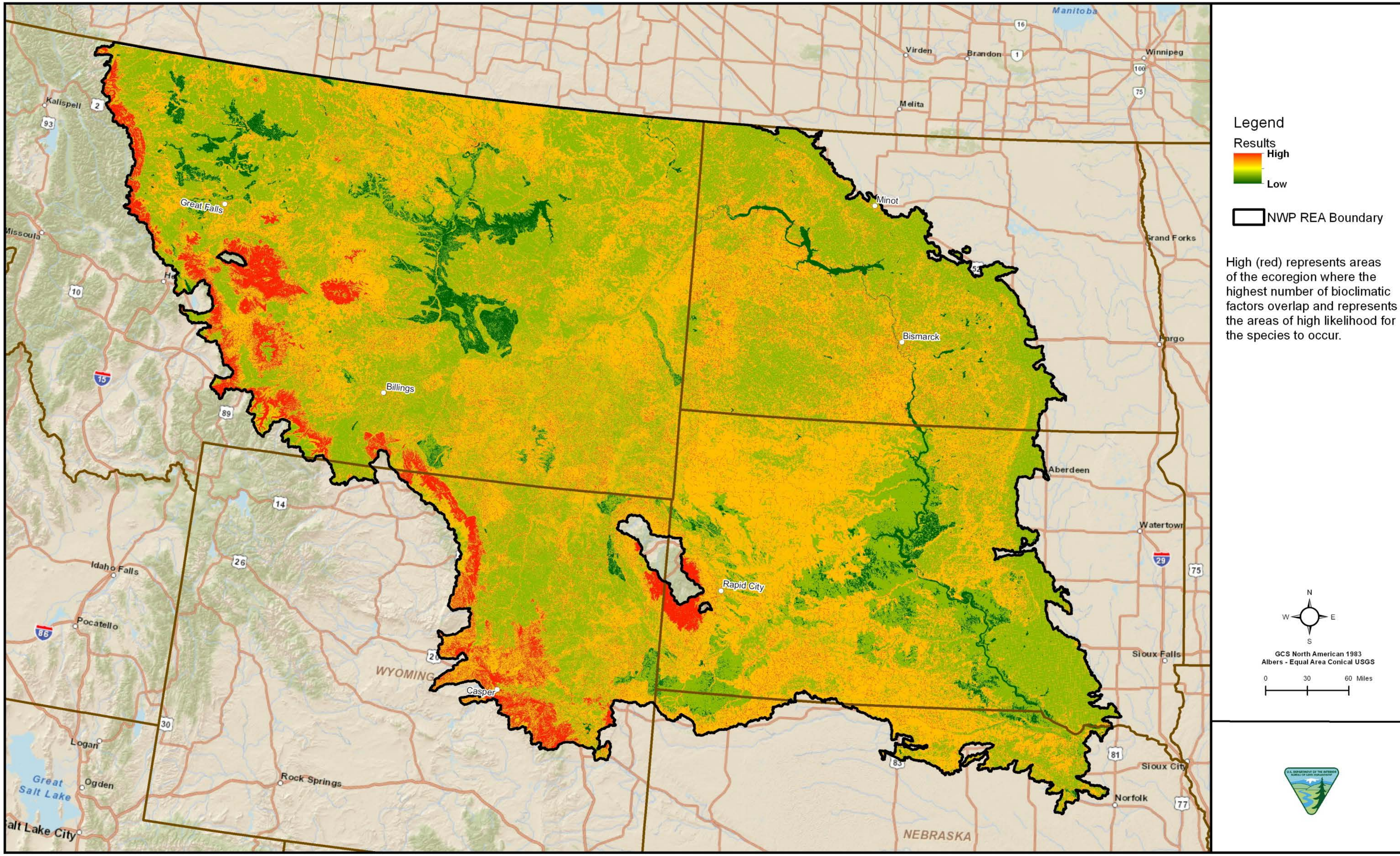

Figure C-3-41. Dalmatian Toadflax Combined Bioclimatic Factors

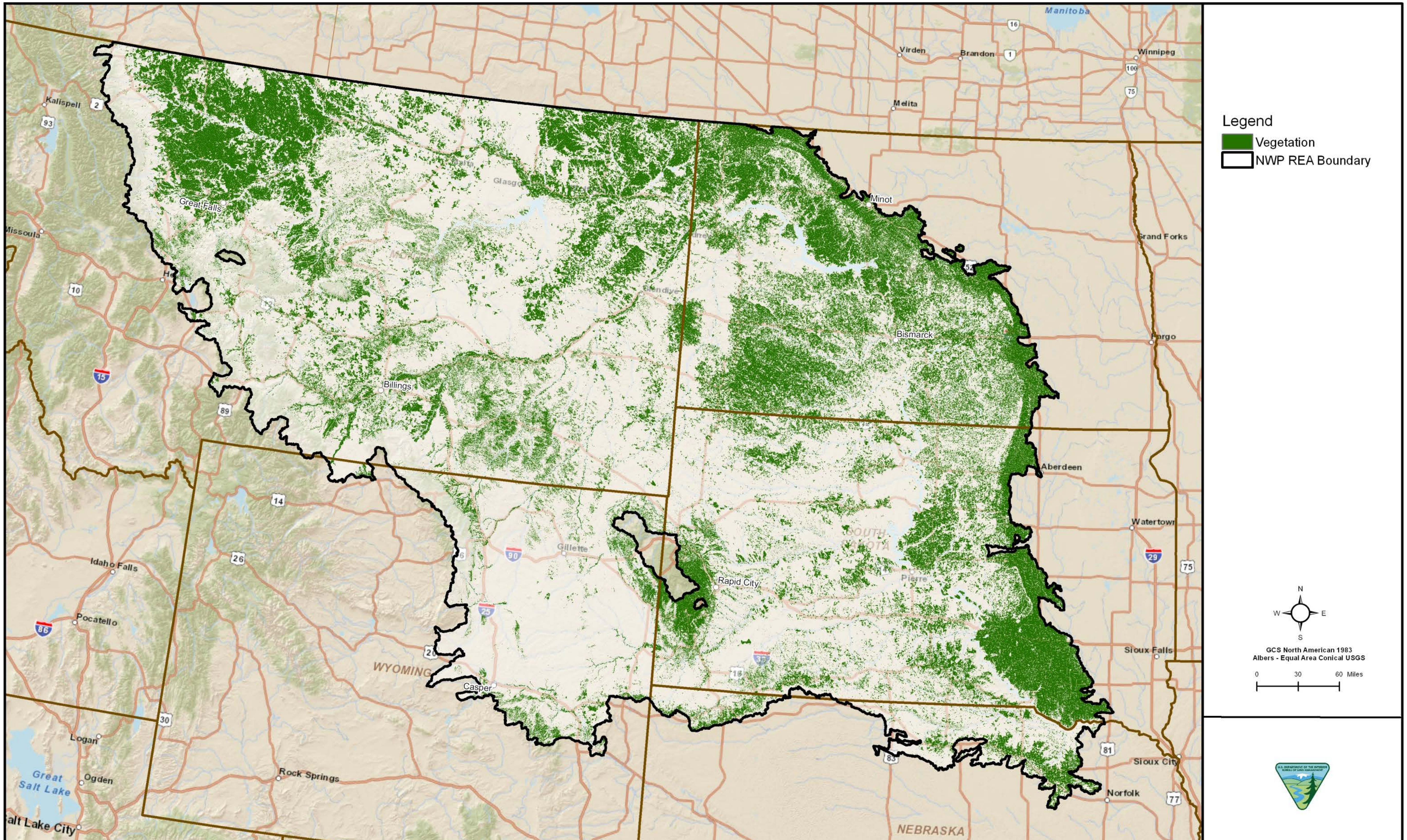

Figure C-3-42. Yellow Toadflax REGAP Level 2/Level 3 Classifications

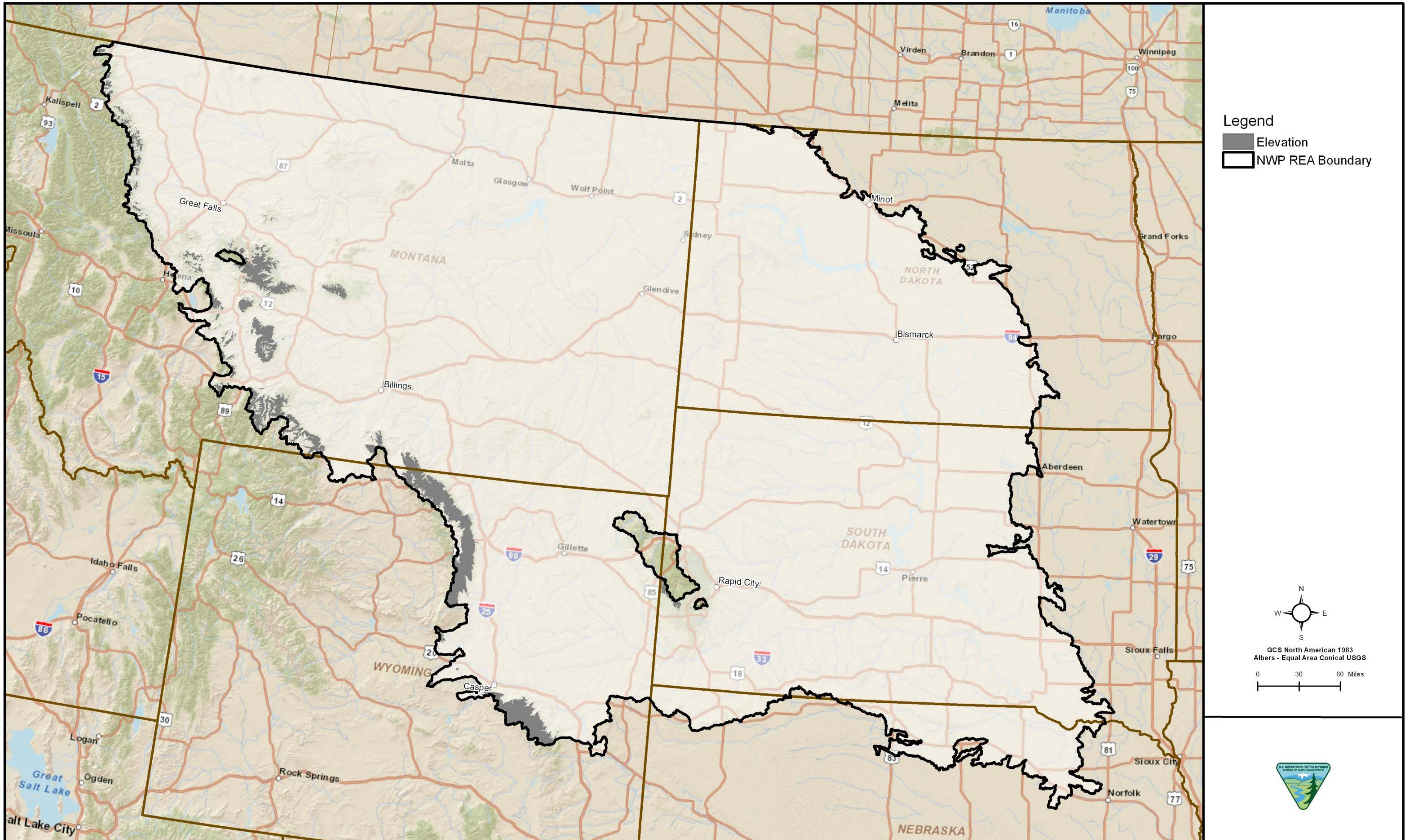

Figure C-3-43. Yellow Toadflax Elevation

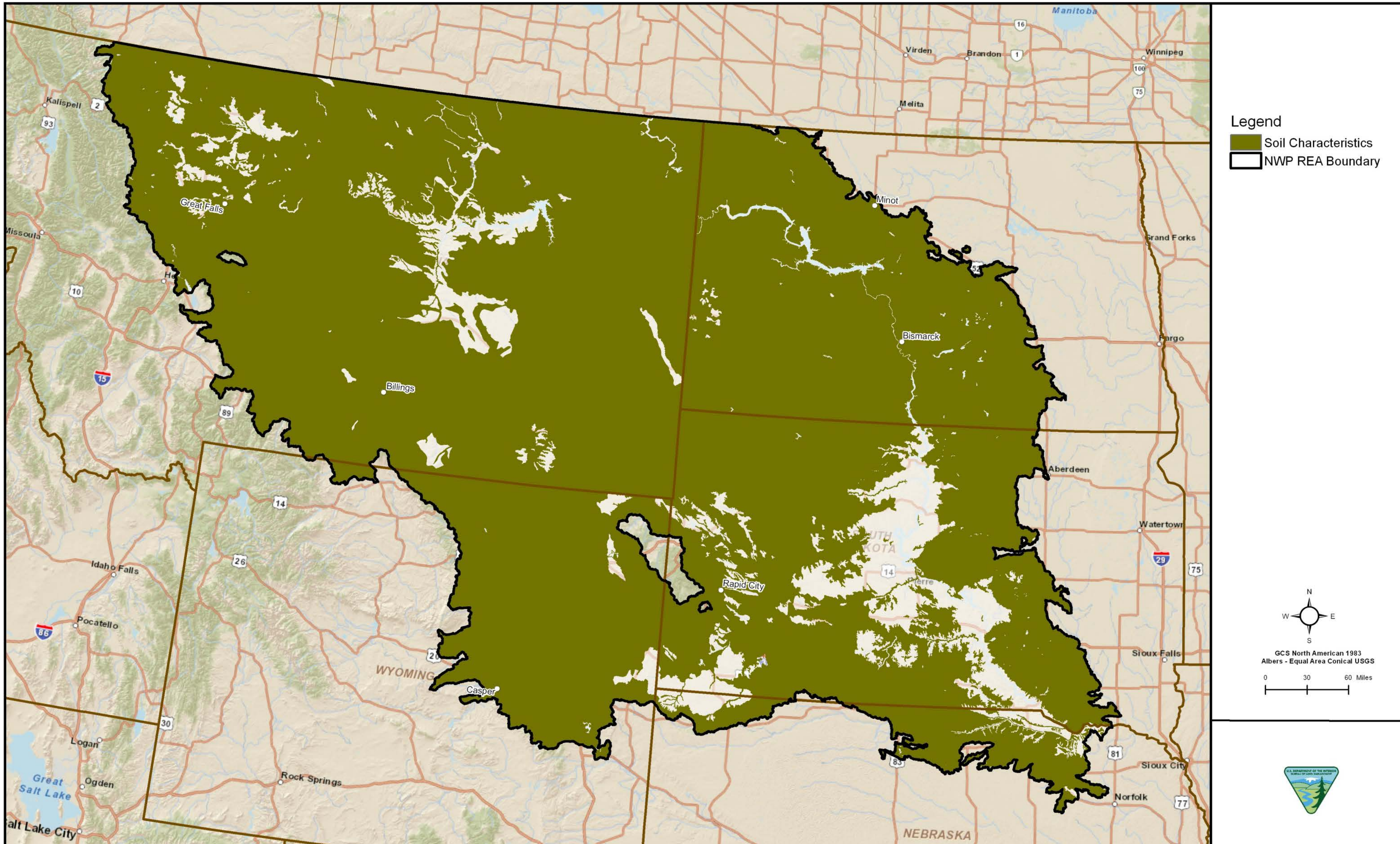

Figure C-3-44. Yellow Toadflax Soil Factors

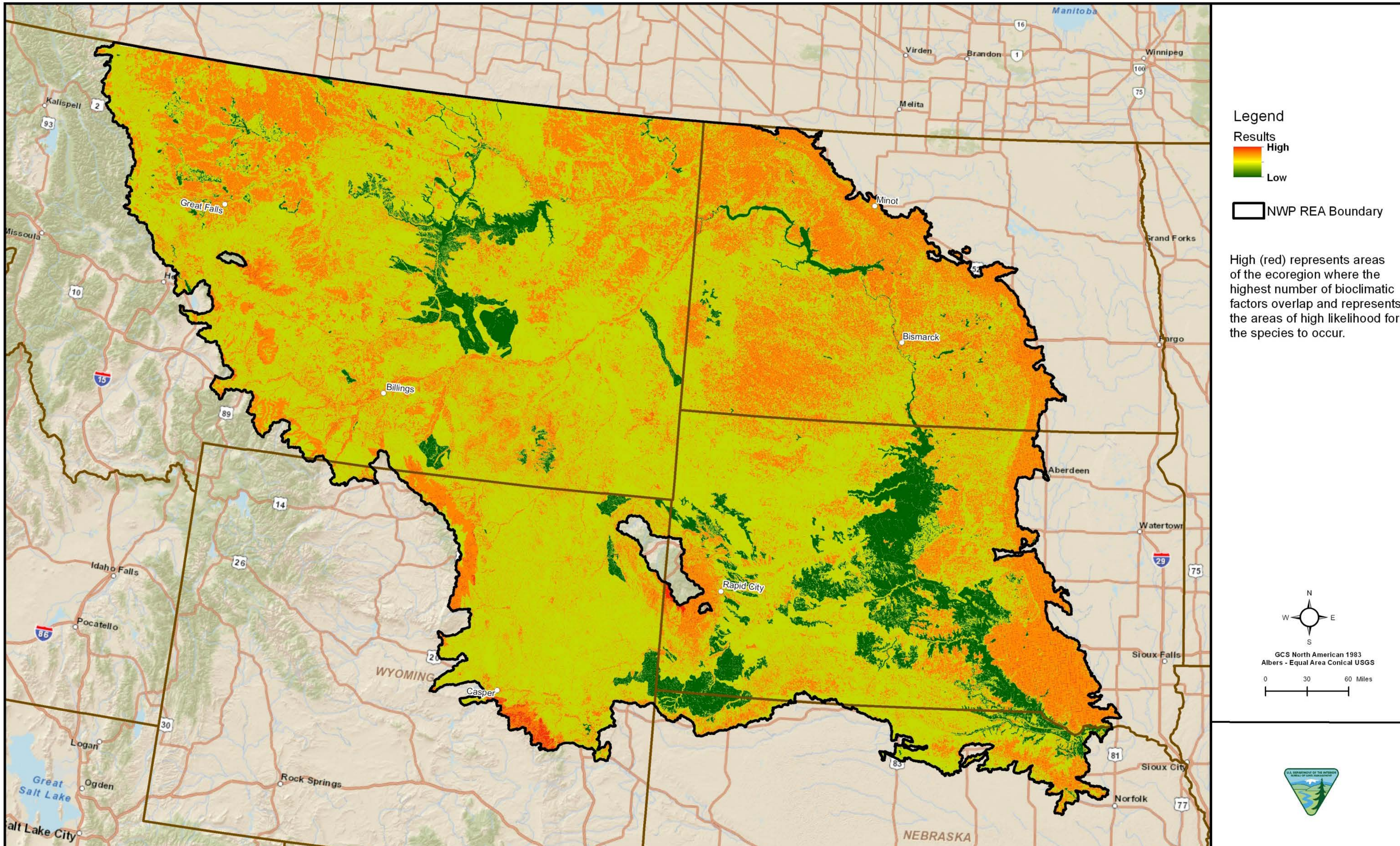

Figure C-3-45. Yellow Toadflax Combined Bioclimatic Factors

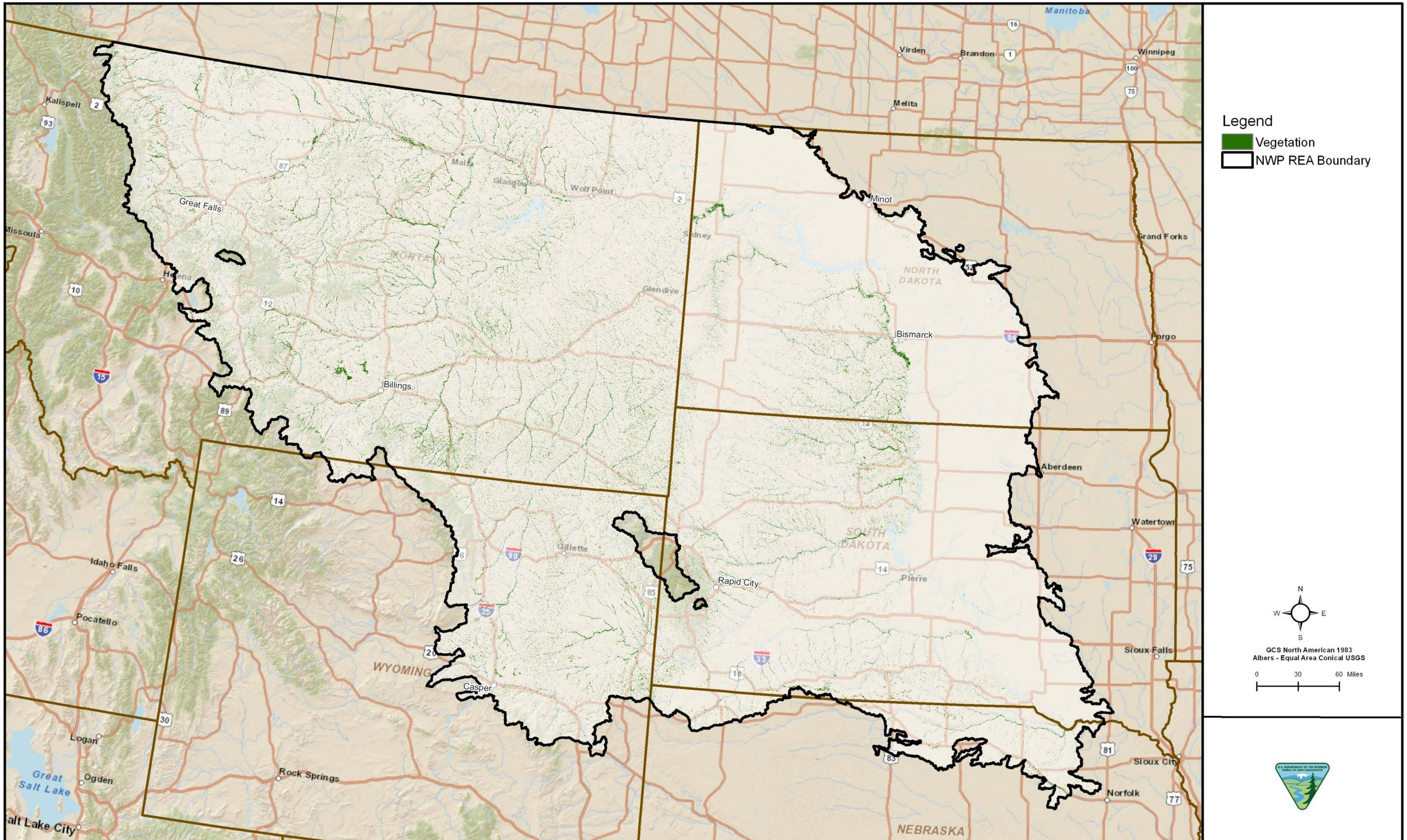

Figure C-3-46. Tamarisk (Saltcedar) REGAP Level 2/Level 3 Classifications

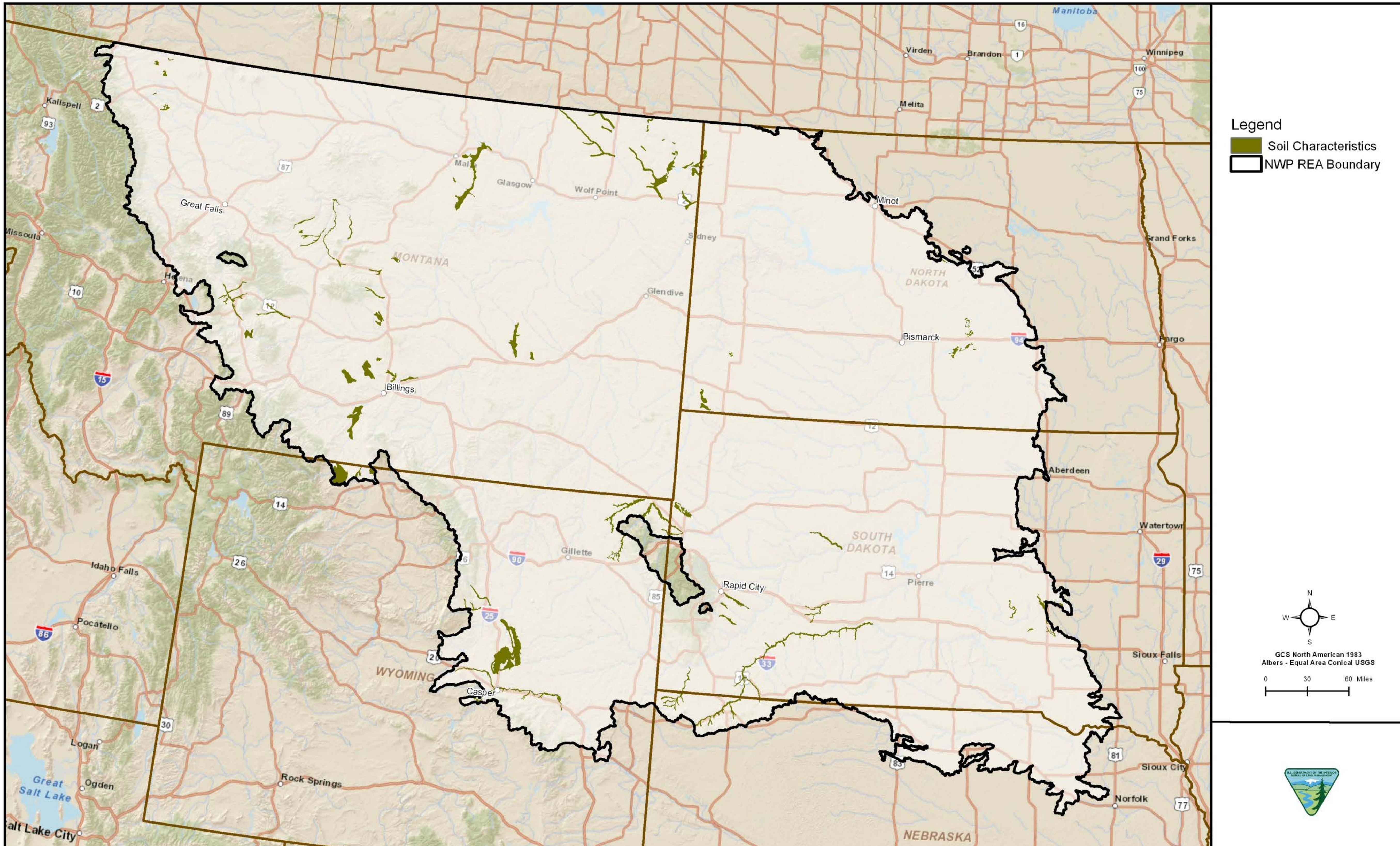

Figure C-3-47. Tamarisk (Saltcedar) Conductivity

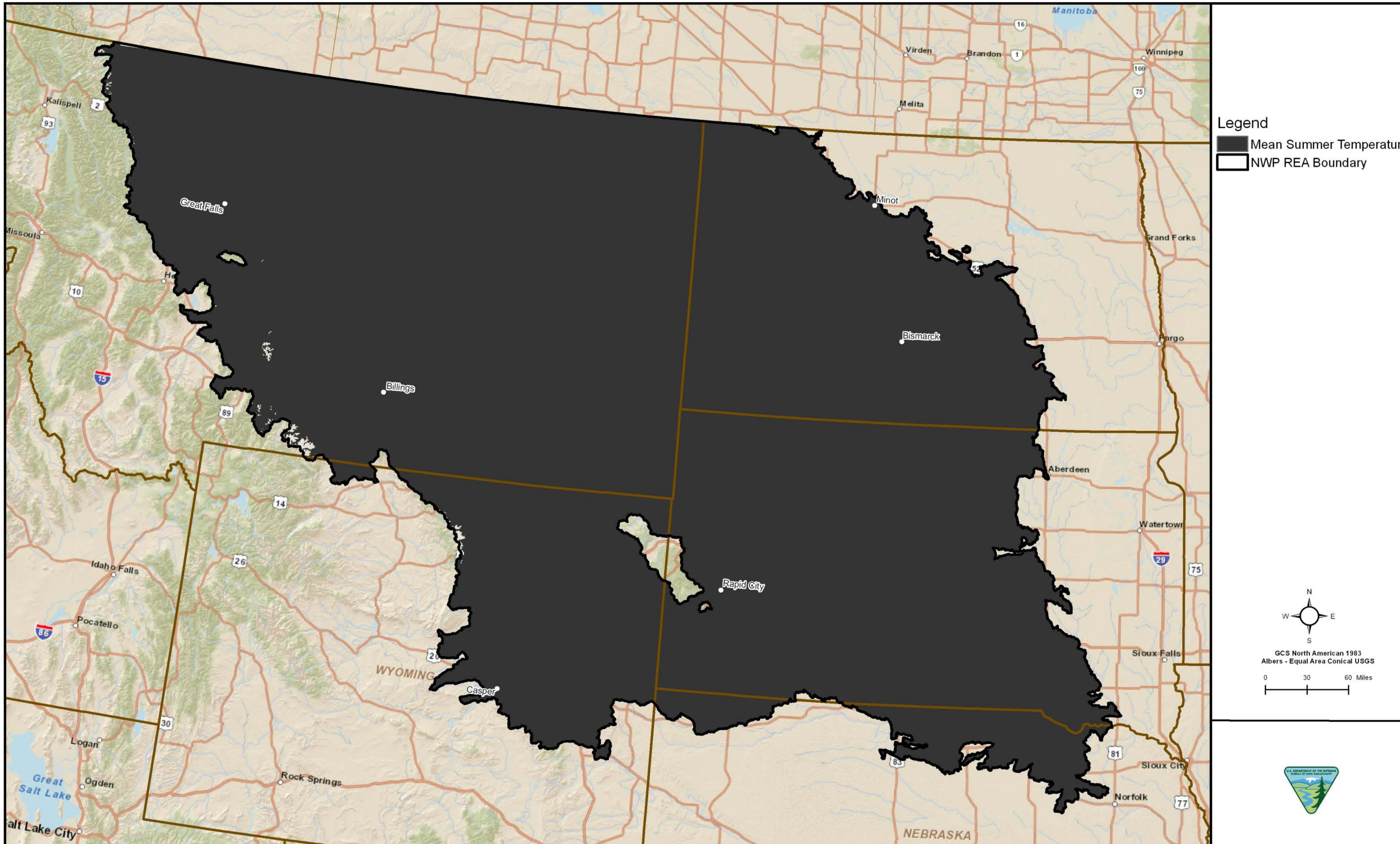

Figure C-3-48. Tamarisk (Saltcedar) Mean Summer Temperature

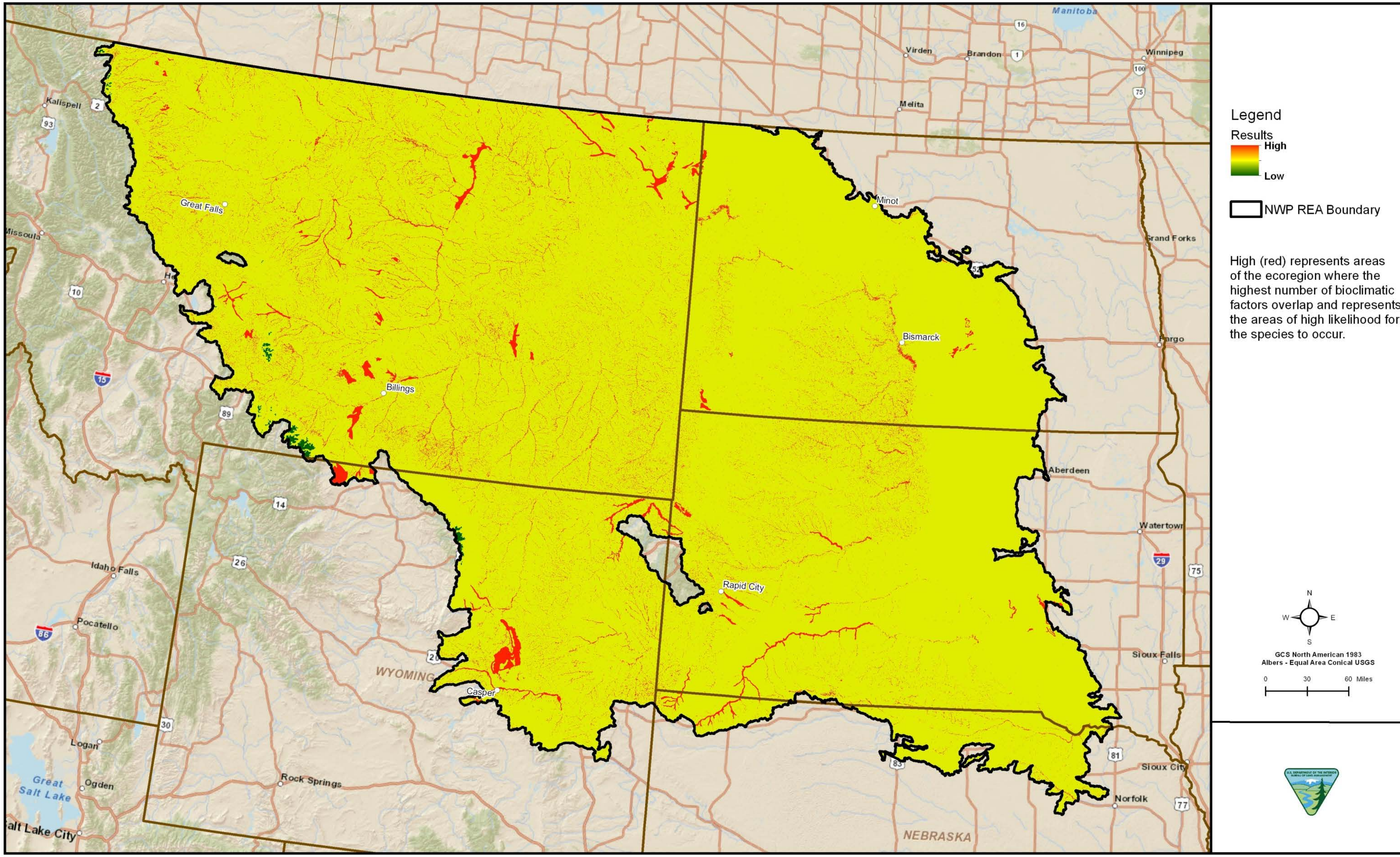

Figure C-3-49. Tamarisk (Saltcedar) Combined Bioclimatic Factors

ATTACHMENT A

LIST OF INVASIVE TERRESTRIAL PLANT SPECIES REPORTED BY STATE

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LIST OF INVASIVE PLANT SPECIES REPORTED BY STATE AGENCY PROGRAMS COMMON TO STATES WITHIN THE ECOREGION[a]

Symbol	Common Name	Scientific Name	WY	SD	MT	NE	ND	Number of States
CEDI3	**Diffuse knapweed**	***Centaurea diffusa***	**X**	**X**	**X**	**X**	**X**	**5**
CEST8	**Spotted Knapweed**	***Centaurea stoebe***	**X**	**X**	**X**	**X**	**X**	**5**
CIAR4	**Canada thistle**	***Cirsium arvense***	**X**	**X**	**X**	**X**	**X**	**5**
EUES	**Leafy spurge**	***Euphorbia esula***	**X**	**X**	**X**	**X**	**X**	**5**
TARA	**Saltcedar (Tamarisk)**	***Tamarix aphylla, T. chinensis, T. gallica, T. parviflora, T. ramosissima***	**X**	**X**	**X**	**X**	**X**	**5**
ACRE3	**Russian knapweed**	***Acroptilon repens***	**X**	**X**	**X**		**X**	**4**
CYOF	**Houndstongue**	***Cynoglossum officinale***	**X**	**X**	**X**			**3**
LIDA	**Dalmatian toadflax**	***Linaria dalmatica***	**X**	**X**	**X**		**X**	**4**
LIVU3	**Yellow toadflax**	***Linaria vulgaris***	**X**	**X**	**X**		**X**	**4**
CADR	**Hoary cress (whitetop)**	***Cardaria draba***	**X**	**X**	**X**			**3**
CARDU	Plumeless thistle	*Carduus acanthoides*	X	X		X		3
COAR4	Field bindweed	*Convolvulus arvensis*	X	X	X			3
CANU4	Musk thistle	*Carduus nutans*	X	X		X	X	4
HYPE	Common St. Johnswort (St. John'swort)	*Hypericum perforatum*	X	X	X			3
LYSA2	Purple loosestrife	*Lythrum salicaria*	X	X	X	X	X	5
TAVU	Common Tansy	*Tanacetum vulgare*	X	X	X			3
ARMI2	Common burdock	*Arctium minus*	X	X				2
ARAB3	Absinth wormwood (Absinthium)	*Artemisia absinthium*		X			X	2
ISTI	Dyer's woad	*Isatis tinctoria*	X		X			2
LELA2	perennial pepperweed	*Lepidium latifolium*	X		X			2
LEVU	oxeye daisy	*Leucanthemum vulgare*	X		X			2
ONAC	Scotch thistle	*Onopordum acanthium*	X	X				2
PHAU7	Common Reed (Phragmites)	*Phragmites australis*		X		X		2

LIST OF INVASIVE PLANT SPECIES REPORTED BY STATE AGENCY PROGRAMS COMMON TO STATES WITHIN THE ECOREGION[a] (Continued)

Symbol	Common Name	Scientific Name	WY	SD	MT	NE	ND	Number of States
SOAR2	perennial sowthistle	*Sonchus arvensis*	X	X				2
ELRE4	Quackgrass	*Agropyron repens*	X					1
BEIN2	Hoary alyssum (hoary false madwort)	*Berteroa incana*			X			1
BRTE	Cheatgrass	*Bromus tectorum*			X			1
BUUM	Flowering rush	*Butomus umbellatus*			X			1
CESO3	Yellow Starthistle	*Centaurea solstitialis*			X			1
CHJU	Rush skeletonweed (Hogbite)	*Chondrilla juncea*			X			1
CIIN	Chicory	*Cichorium intybus*		X				1
CIVU	Bull thistle	*Cirsium vulgare*		X				1
COMA2	Poison hemlock	*Conium maculatum*		X				1
CYSC4	Scotch broom	*Cytisus scoparius*			X			1
ECVU	Blueweed (Common Vipersbugloss; Vipers Bugloss)	*Echium vulgare*			X			1
ELAN	Russian olive	*Elaeagnus angustifolia*	X					1
AMTO3	Skeletonleaf bursage (skeletonleaf bur ragweed)	*Franseria discolor (Ambrosia tomentosa)*	X					1
HIAU	Orange hawkweed	*Hieracium aurantiacum*			X			1
HICA10	Meadow hawkweed complex	*Hieracium spp.*			X			1
HYVE3	Hydrilla (waterthyme)	*Hydrilla verticillata*			X			1
HYNI	Black henbane	*Hyoscyamus niger*		X				1
IRPS	Yellow Flag Iris	*Iris psudocorus*			X			1
MYSP2	Eurasian watermilfoil	*Myriophyllum spicatum*			X			1
POCU6	Japanese Knotweed	*Polygonum cuspidatum*			X			1
POSA4	Giant knotweed	*Polygonum sachalinense*		X				1

LIST OF INVASIVE PLANT SPECIES REPORTED BY STATE AGENCY PROGRAMS COMMON TO STATES WITHIN THE ECOREGION[a] (Continued)

Symbol	Common Name	Scientific Name	WY	SD	MT	NE	ND	Number of States
POCR3	Curlyleaf pondweed	*Potamogeton crispus*			X			1
PORE5	Sulfur cinquefoil	*Potentilla recta*			X			1
RAAC3	Tall buttercup	*Ranunculus acris*			X			1
SEJA	Tansy Ragwort	*Senecio jacobaea*			X			1
TRTE	Puncturevine	*Tribulus terrestris*		X				1
VETH	Common Mullein	*Verbascum thapsus*		X				1
AECY	Jointed Goatgrass	*Aegilpos cylindrica*						0 [b]
ANAR16	Small Bugloss	*Anchusa arvensis*						0 [b]
AZIP	Feathered Mosquitofern	*Azolla pinnata*						0 [b]
BRAL4	White Bryony	*Bryonia alba*						0 [b]
CACA	Fanwort (Carolina fanwort)	*Cabomba caroliniana*						0 [b]
CEDE5	Meadow Knapweed	*Centaurea debeauxii*						0 [b]
CETR8	Squarrose Knapweed	*Centaurea triumfetti*						0 [b]
CRVU2	Common Crupina	*Crupina vulgaris*						0 [b]
EGDE	Brazilian Elodea (Brazilian waterweed)	*Egeria densa*						0 [b]
HEMA17	Giant Hogweed	*Heracleum mantegazzianum*						0 [b]
HICA10	Yellow Hawkweed (meadow hawkweed)	*Hieracium caespitosum*						0 [b]
HIGL3	Yellow Devil Hawkweed (queen-devil hawkweed)	*Hieracium glomeratum*						0 [b]
HIPI2	Tall Hawkweed	*Hieracium piloselloides*						0 [b]
HYMO6	Common/Europea n Frogbit	*Hydrocharis morsus-ranae*						0 [b]
IMGL	Policeman's Helmet (ornamental jewelweed)	*Impatiens glandulifera*						0 [b]
MIVE3	Milium (spring milletgrass)	*Milium vernale*						0 [b]

LIST OF INVASIVE PLANT SPECIES REPORTED BY STATE AGENCY PROGRAMS COMMON TO STATES WITHIN THE ECOREGION[a] (Continued)

Symbol	Common Name	Scientific Name	WY	SD	MT	NE	ND	Number of States
MYAQ2	Parrotfeather Milfoil (Parrot Feather Watermilfoil)	*Myriophyllum aquaticum*						0 [b]
MYHE2	Variable-Leaf-Milfoil	*Myriophyllum heterophyllum*						0 [b]
NAST3	Matgrass	*Nardus stricta*						0 [b]
NYPE	Yellow Floating Heart	*Nymphoides peltata*						0 [b]
POBO10	Bohemian Knotweed	*Polygonum bohemicum*						0 [b]
SAAE	Mediterranean Sage	*Salvia aethiopis*						0 [b]
SAMO5	Giant Salvinia (kariba-weed)	*Salvinia molesta*						0 [b]
SORO	Buffalobur (Buffalobur Nightshade)	*Solanum rostratum*						0 [b]
SOHA	Johnsongrass	*Sorghum halepense*						0 [b]
TRNA	Water Chestnut	*Trapa natans*						0 [b]
ZYFA	Syrian Beancaper	*Zygophyllum fabago*						0 [b]

[a] This list is data obtained by BLM as reported by Velman (2012). Species shown in **bold** were selected for CA analysis based on the total number of states reporting a species occurrence.
[b] Evaluated but no reported occurrence for the states in this ecoregion.

ATTACHMENT A

FIGURE

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LIST OF ATTACHMENT A FIGURES

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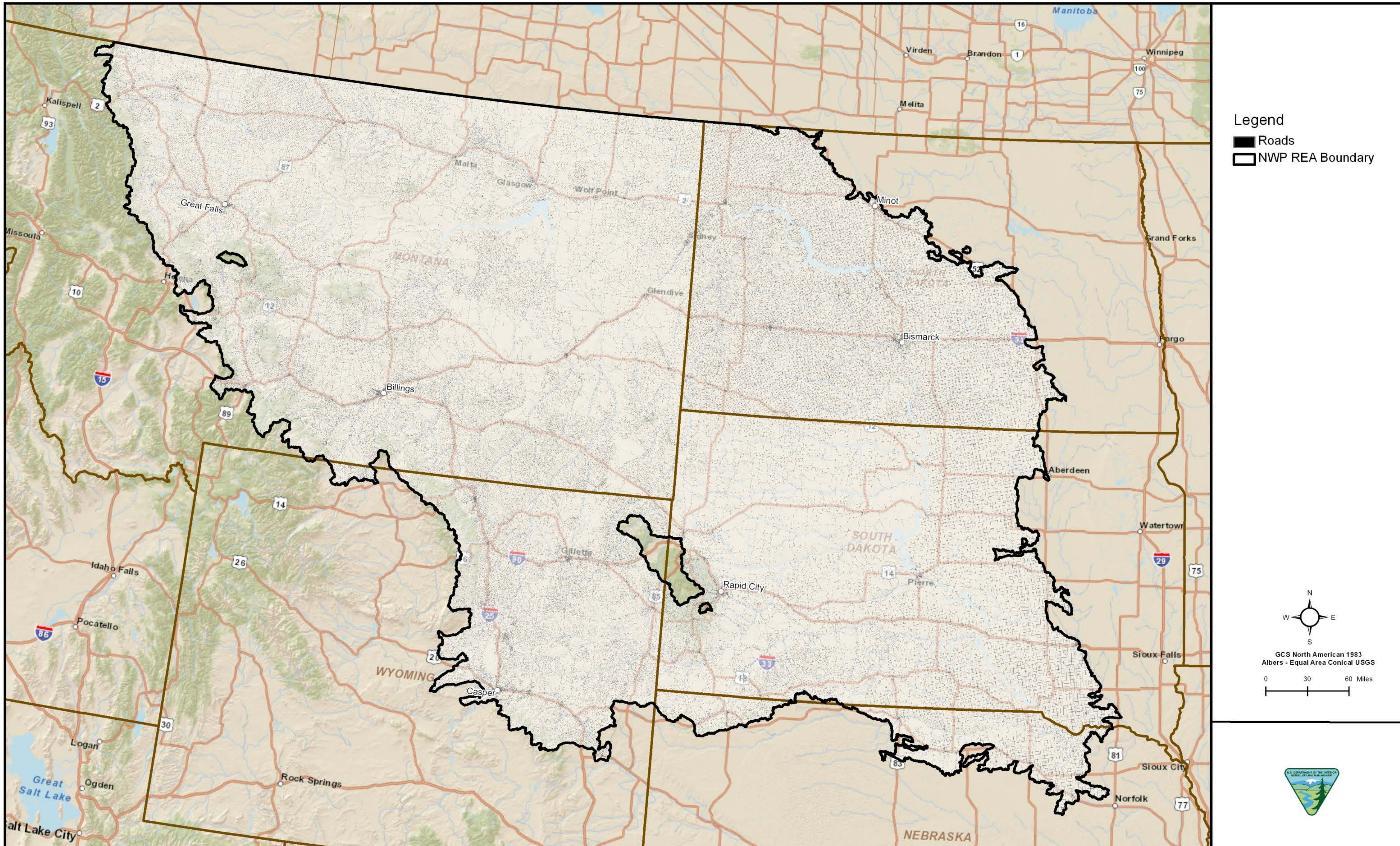

Figure C-3-A1. Invasive Species Roads Layer

APPENDIX C-4

INSECT OUTBREAK AND DISEASE CHANGE AGENT ANALYSIS FOR THE NORTHWESTERN PLAINS ECOREGION

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1.0 INTRODUCTION

Plant pests and diseases (including pathogens and microorganism) are classified as invasive species. Invasives are defined as non-native species whose uncontrolled or unintended spread outside its native range does or is likely to cause economic or environmental harm or harm to human, animal, or plant health (NISC 2006). The emerald ash borer and White Pine Blister Rust (WPBR) have the potential to spread through portions of the ecoregion, causing severe ecological damage to woodland and forest ecosystems. The animal diseases such as sylvatic plague, canine distemper, chronic wasting disease, and West Nile virus (WNV) have had, and continue to have, the potential to exert severe effects on populations of species such as prairie dogs, black-footed ferrets, important game ungulates, swift fox, and a wide variety of birds, including Greater sage-grouse.

Because of the lack of consistent scale, comprehensive datasets for the disease component of this change agent (CA), insect outbreaks were the only component of this CA analyzed and described below.

MQs developed for this CA focus on damaging insect outbreaks and disease and what habitats and species have the potential to be most severely affected by these infestations. The primary MQ is: ***Where will regionally significant values be affected through changes in the spatial distribution and abundance of invasive, (undesired) non-native species?***

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2.0 CHANGE AGENT DESCRIPTION

Insect outbreaks on susceptible hosts on are generally controlled by climatic conditions and the effects on plant morphology, especially water stress. Drought increases pathogen and insect survival and growth through elevated plant nutrient levels, especially nitrogen; lowered plant defenses and a more suitable physical environment (Rhoades 1983; 1985; Mattson and Haak 1987). Important insects and diseases in the Northwestern Plains ecoregion affect forest and grassland communities. Forested portions of the ecoregion are primarily affected by the mountain pine beetle (MPB) (*Dendroctonus ponderosae*), a native to western North America. Periodic outbreaks of MPB can cause the loss of millions of trees. MPBs develop in pines, particularly ponderosa, lodgepole, and limber pine (bristlecone and pinyon pine are less frequently attacked). Although grasslands are prone to insect outbreaks, it is recognized that at a landscape scale, these data may not be available or applicable.

2.1 INSECT OUTBREAKS

2.1.1 Mountain Pine Beetle

The MPB is one of over 1,400 species of bark beetles distributed in over 90 genera. Their habitat is the nutrient and sugar carrying phloem tissue immediately under the bark of host trees where the beetles excavate galleries, introduce pathogenic fungi and bacteria, and lay their eggs (Raffa et al. 2008). When the larvae hatch they continue to feed on the phloem and construct galleries that end in a pupal chamber from which brood adults will emerge. Less than one percent of the bark beetle species experience population outbreaks and only a few of those species, concentrated in three genera, generally kill their tree host species. Even within those few tree-killing species, population densities generally remain in a low endemic state so only a few trees are killed within stands. When infrequent eruptive outbreaks occur, a large percentage of larger trees within stands are killed. During early stages of an outbreak, attacks are limited largely to trees under stress from drought, injury, poor site conditions, fire damage, overcrowding, root disease or old age. However, as beetle populations increase, MPB attacks may involve most large trees in the outbreak area and thus can kill even healthy trees due to the overwhelming attack.

Historically, outbreaks tended to build and then subside rapidly due to complex interactions between MPB biology, host tree vulnerability (function of biology, stand age structure, stand structural heterogeneity, and stand connectivity), MPB predators and competitors, and climate (primarily temperature) (Raffa et al. 2008). MPB occurs in endemic and epidemic proportions depending on stand structure, host susceptibility, climate and environmental interactions.

MPB interacts with other CAs such as wildfire regime, WPBR, and climate change in complex ways that overlap with other MQs.

2.1.2 Ecological Considerations for the Mountain Pine Beetle

The conceptual model for MPB is based on what is known about its biology and how it interacts with the species of the Five-Needle Pine assemblage. Because of its complex interactions with other CAs its ecological and ecosystem-level interactions are shown in the Five-Needle Pine assemblage models.

Generally, MPB occurs endemically at low population densities primarily in low elevation primary-host lodgepole-ponderosa pine forests, less so in mid-elevation non-host spruce-fir forests, and only infrequently in high elevation rare-host whitebark-limber pine forests. This elevational separation is not absolute and lodgepole-whitebark pine mixed forests are also common (Logan and Powell 2001). Little information is available regarding its effects on lower treeline limber pine woodland. Historically, eruptive outbreaks have occurred infrequently in all three forest/woodland types in response to short term climatic variation but this pattern appears to be changing to more protracted outbreaks and an increasing frequency and novel impacts in high elevation whitebark pine forests and woodlands in response to GCC driven temperature changes (Logan et al. 2010; Raffa et al. 2010). Lower treeline limber pine woodlands are an exception to this pattern as the frequency of outbreaks at lower elevations is expected to decrease with GCC driven temperature changes (Littell et al. 2010).

The altitudinal or topographic driven historical reduced frequency of MPB outbreaks on whitebark pine has been explained through the use of models that incorporate temperature controls on MPB larval spring or early summer survivorship and MPB adult population size and the distribution of living host trees (Powell and Bentz 2009; Bentz et al. 2010; Logan and Powell 2009). In low elevation lodgepole-ponderosa pine forests the critical factors that are correlated with a high risk of a MPB eruptive outbreak are a dense population of adult MPB and host susceptibility. Temperature determines the rate of development of the various life stages of MPB and hence the timing of the various life stages and there is an evolutionary tradeoff between early emergence to maximize the period for egg laying, and later emergence to avoid mortality due to cold spring or early summer temperatures. Additionally, because attacks by MPB on its primary hosts are only successful if there is a coordinated mass attack on individual trees, synchronous maturation of the adult beetles is also critical to its success. This synchronization is controlled by the higher temperature threshold requirement of the forth larval stage (instar) (Benz et al. 2008). So both timing and synchrony are critical and controlled directly by the temperature of its habitat which is the phloem of the host tree (Logan and Powell 2001; Powell and Logan 2005; Powell and Benz 2009). MPB life cycle synchrony is optimal when the cycle is completed in a single year (univoltine) as is the typical case at lower elevations, less optimal when cooler temperatures slow the cycle to one to two years per generation (fractional voltinism) as is common in mid-elevation forests, and even less optimal at the coolest high elevation whitebark pine forests where the life cycle requires at least two years to complete (semivoltism) (Logan and Powell 2001; Logan and Powell 2009).

Host tree vulnerability in low elevation primary-host lodgepole-ponderosa pine forests is a function of biology as these pine species have evolved pitch and toxic chemical defense mechanisms. Tree stress level which can reduce the defensive response (water, nutrient, root infections, etc.), the density of host trees, and a homogeneous age structure dominated by larger trees that are more preferable hosts to MPB. Neither limber pine nor whitebark pine have significant defenses against MPB (Raffa et al. 2008) so the complex ecological relationships among the species are reduced to temperature controls on MPB and dispersal distance from lodgepole-ponderosa pine forests (Logan and Powell 2009; Logan et al. 2010).

High elevation whitebark pine forests and woodlands have historically been infrequently impacted by eruptive outbreaks (1930s and 1970s) only when winter temperatures were warm enough to allow all life stages to overwinter and when there is sufficient summer thermal energy to maintain univoltine life cycles (Logan and Powell 2009; Logan et al. 2010). Temperature changes due to global climate change has likely changed this historic pattern (Logan and Powell 2009; Logan et al. 2010). While initially creating less optimal temperatures, when the temperature increases beyond approximately 2°C, a threshold is reached where univoltine life cycles become stable in high elevation whitebark pine forests and woodlands (Logan et al. 2001; Logan and Powell 2009).

Management actions to reduce the impact of MPB on five-needle pines are very limited and may include:

- Protection of five-needle pine in areas that are more resistant to climate change and integrate the protection with the WPBR resistance breeding program described under that CA.
- Maintain a heterogeneous structure in the forests and woodlands.

2.1.3 Spruce Budworm

The western spruce budworm (*Choristoneura occidentalis*) is the most widely distributed and destructive defoliator of coniferous forests in western North America. It is one of nearly a dozen Choristoneura species, subspecies, or forms, with a complexity of variation among populations found throughout much of the United States and Canada. It occurs in the Rocky Mountains from Arizona and New Mexico northward into Colorado, Utah, Wyoming, Montana, and Idaho; in the Pacific Northwest in Oregon and Washington; and in British Columbia and Alberta, Canada. The most common host-tree species of the western spruce budworm are Douglas-fir, grand fir, white fir, subalpine fir, blue spruce, Engelmann spruce, white spruce, and western larch. Larvae also feed occasionally on Pacific silver fir, mountain hemlock, western hemlock, lodgepole pine, ponderosa pine, western white pine, limber pine, and whitebark pine. Some of these tree species are also hosts of other closely related species of Choristoneura whose populations sometimes occur simultaneously with the western spruce budworm (Fellin and Dewey 1982).

Budworm larvae mine or tunnel into year-old needles, closed buds, or newly developing vegetative or reproductive buds. As new shoots flush, larvae spin loose webs among the needles and feed on new foliage. As shoots continue to elongate and needles develop, adjacent shoots are often webbed together by the larvae and appear twisted or stunted. New foliage, the preferred food, is usually entirely consumed or destroyed before larvae will feed on older needles. As larvae mature, the webbed branch tips on which they have fed begin to turn reddish brown. In addition to foliage, budworm larvae feed heavily on staminate flowers and developing cones of host trees. The resultant decline in seed production has a serious impact in seed orchards, seed production areas, and forest sites that are difficult to regenerate naturally. Unlike some cone and seed insects, budworm larvae do not always restrict their feeding to a single cone. Often, second-or third-stage larvae feed on newly developing conelets that soon shrivel up, dry out, and fall from the tree. As these cones dry out and become unsuitable for food, larvae continue feeding on other cones or on foliage. In some Douglas-fir stands, nearly all cones may be damaged or destroyed by feeding larvae, especially when larval population densities are high and cone crops are light (Fellin and Dewey 1982).

Topkilling of some host trees, as a result of persistent heavy defoliation precludes cone production for many years, even when budworm populations subside. Host trees are usually less than 5 feet tall and 1 to 2 inches in diameter. These young trees are especially vulnerable when growing beneath mature trees, since larvae disperse from the overstory and feed on the small trees below. Coniferous seedlings have relatively few needles and shoots and can be seriously deformed or killed by only a few larvae. In stands of Douglas-fir, true firs, and spruce, after 3 or more years of sustained larval feeding, many trees are almost entirely defoliated, and diameter and height growths are sharply reduced. Some trees are top-killed, which often results in stem deformity, multiple leaders, or the death of the entire tree. The greatest impact from budworm defoliation in mature stands is reduced growth, although repeated defoliation sometimes results in top-killing. In some mature stands, trees severely defoliated by the western spruce budworm may be predisposed to one or more species of tree-killing bark beetles, mainly the Douglas-fir beetle (*Dendroctonus pseudotsugae*) and the fir engraver beetle (*Scolylus ventralis*) (Fellin and Dewey 1982).

2.1.4 Other Beetle Species

Other beetle species that were evaluated for analysis included the Douglas-fir beetle, spruce beetle (*Dendroctonus rufipenni*), and pine engraver beetle (*Ips pini*). Members of the genus Dendroctonus are by far the most destructive group of bark beetles in the North America. All species breed under the bark of the trunk of living or dying trees or in fresh stumps or logs of various conifers. Some species attack only felled, weak, or dying trees, whereas others attack and kill apparently healthy trees, especially during epidemics (Furniss and Carolin 1977).

2.1.4.1 Douglas-Fir Beetle

The Douglas-fir beetle infests and kills Douglas-fir throughout most of its range in the western United States, British Columbia and Mexico. Occasionally, western larch trees are infested when growing among Douglas-fir attacks. Douglas-fir beetles normally kill small groups of trees, but during outbreaks 100 tree groups are not uncommon. At low or endemic levels, the beetle infests scattered trees, including windfalls and trees injured by fire, defoliation, or root disease. Where these susceptible trees are abundant, they can become infested and killed, and then beetle populations can build up rapidly and spread to adjacent green, standing trees. Damage is greatest in dense stands of mature Douglas-fir (Schmitz and Gibson 1996).

An indication of infestation is a reddish orange frass expelled from bark crevices by invading beetles. Distinctive egg galleries are constructed by the female beetle which bore through the bark and tunnel upward in the phloem. The females lay groups of eggs along the galleries as construction progresses. The eggs hatch, and the newly hatched larvae mine outward from the egg gallery. These mines are visible on the inner surface of the phloem and increase in width as the larvae molt and grow. Douglas-fir beetle egg galleries are usually denser and the brood survival higher in the middle portion of the infested stem. Generally, Douglas-fir beetle attacks are denser, and success rate higher, in down trees than standing ones. A more evident sign of attack is the clear resin exuding from entrance holes on the stem at the upper limit of infestation (Schmitz and Gibson 1996).

Several months after a tree is successfully infested, its foliage becomes discolored; needles turn yellow, then sorrel, and finally reddish brown. Although some trees may become discolored as early as August, generally the trees remain green until the following June. The time of year that this discoloration becomes visible varies with locality, intensity of infestation, elevation, and seasonal weather. Needles begin to fall from infested trees the year following the attack but becomes more noticeable the second year after infestation (Schmitz and Gibson 1996).

2.1.4.2 Spruce Beetle

The spruce beetle (*Dendroctonus rufipennis)* is the most significant natural mortality agent of mature spruce. Spruce beetle outbreaks cause extensive tree mortality and modify stand structure by reducing the average tree diameter, height, and stand density. Residual trees are often slow-growing small and intermediate-sized trees which eventually become dominant. The spruce beetle infests all species of spruce within its geographical range (Holsten et al. 1999). In the West, white spruce, Sitka spruce, and Englemann spruce are principal hosts.

On standing trees, the first sign of spruce beetle infestation is the reddish-brown boring dust. Normally this beetle is present in small numbers in weakened or windthrown trees, large pieces of slash, and fresh stumps. Sporadic outbreaks have killed extensive stands of spruce in Alaska, western Canada, Colorado, Montana, and Utah. Such outbreaks commonly develop in windthrown timber. During, epidemics, trees of all ages and diameters, except reproduction, are attacked, preference being shown for trees of larger diameter.

The life cycle and habits of the spruce beetle differ widely in various portions of its vast range. Two years are required to complete a generation, from attack to attack, in the main body of Engelmann spruce stands. At high elevations 3 years may be required, and in coastal forests a 1-year life cycle is normal. In the Rocky Mountains, the principal flight, attack, and egg laying takes place when hibernated adults emerge after the snow disappears late in June and in July. Some of the parent beetles reemerge and establish another brood. Eggs hatch and larvae develop during the summer. The progeny pass the winter as half- to nearly full-grown larvae and complete development to adults by the following August. The new adults emerge and migrate to the basal trunk and root collar of the host tree from August to October; there they bore beneath the bark and hibernate until the ensuing June and July. Overwintering stages consist primarily of hibernating adults of the previous seasonal attacks and half- to three-fourths-grown larvae of the current seasonal attacks. Spruce beetle populations are kept at low levels most of the time by a combination of natural control factors. During outbreaks the beetle outruns its natural controls, often for years, until much of the mature forest is killed. Woodpeckers are important predators in the Rocky Mountains. The start of an outbreak is difficult to detect, because the foliage does not fade until a year after attack, and it turns pale green only before dropping. There are no pitch tubes. First-year attacks can be detected only by the presence of brown boring dust around the base of trees.

2.1.4.3 Pine Engraver Beetle

The pine engraver beetle is one of the most common and widely distributed bark beetles in North America. It occurs from southern Appalachia north to Maine and Quebec, westward across the northern United States and Canada, into the interior of Alaska, throughout the Pacific Coast States and the Rocky Mountain region, to northern Mexico. In the western United States, the insect is a significant and frequent pest of ponderosa pine. In some localities it is also an important killer of lodgepole and Jeffrey. In rare instances, it may infest pinyon, Coulter, limber, sugar, western white, southwestern white pines, and probably most other pine species occurring within its range (Kegley et al. 1997).

Indication of infestation (attack) of the pine engraver beetle is reddish-orange boring dust which appears in small mounds on the surface of logs or logging slash at points of beetle entry. Attacks are initiated by male beetles that bore through the outer bark into bark (phloem) and excavate a nuptial chamber several times the beetle's size. Pheromone attractants released by the male attract one to seven females, though typically two or three. After mating, each female constructs a tunnel or “egg gallery” in the phloem layer, slightly scoring the wood surface in the process. During gallery construction, the boring dust is pushed to the outside, clearing the nuptial chamber and egg galleries. Additional males are also attracted to the vicinity of the initial attack. The attractant pheromone promotes an aggregation of beetles or “mass attack.” A female lays eggs along the sides of the egg gallery, eggs hatch within 4 to 14 days, and larvae mine laterally from the egg gallery. Larvae feed for 2-4 weeks and then excavate an oval cell at the end of their tunnels where pupation occurs. New adults begin to appear about 12 days after pupation. When mature, new adults bore through the bark and emerge to make new attacks. During late summer, large numbers of beetles may infest living trees during "feeding" attacks. During this time, they mine extensive mazelike galleries under the bark without producing brood. Occasionally these feeding attacks result in tree mortality. Adults overwinter under the bark of infested trees and slash or in duff and litter on the forest floor. As overwintering beetles become active, they infest fresh slash or trees damaged by wind or snow (Kegley et al. 1997).

In most years, the pine engraver is not an aggressive tree killer, even though large populations commonly infest logging slash, windthrown trees, or trees broken by wind or snow. When populations are low, the beetle may kill or top-kill widely scattered single trees or small groups usually numbering less than ten. Often these trees have been previously damaged by wind, snow, fire, or lightning. In outbreak years they may kill groups of 50 to more than 500 trees, especially in unthinned young stands. Saplings and pole-sized trees averaging 5-8 inches in diameter are most commonly attacked. Larger trees are often top-killed with the lower bole uninfested or colonized by other species of bark beetles or wood borers. Foliage of infested standing trees usually begins fading within a few months of attack. The rate of fading depends on tree species and weather. Some infested trees may fade by late summer or early fall during the same year they are attacked, while others may not fade until the following spring (Kegley et al. 1997).

2.1.5 Grasshoppers

Of the 400 species of grasshoppers in the Western United States, only about 25 are known to regularly reach economically damaging densities (Hewitt and Onsager 1983). Grasshopper populations in the intermountain sagebrush-bunchgrass range of Idaho and shortgrass prairies in eastern Colorado are generally limited by food supply (Fielding and Brusven 1996; Carter et al. 1998). Periodic outbreaks are related to above-normal precipitation years with above-normal forage production. However, in semi-arid grasslands, as in the Northwestern Plains, grasshopper outbreaks are generally associated with drought conditions (Capinera and Horton 1989) or heavy grazing intensity (Onsager 1996). Many rangeland species of grasshoppers are favored by vegetation with an open canopy and numerous patches of bare ground.

2.2 DISEASE

Although it is recognized that disease plays an important role in the ecology of the Northwestern Plains ecoregion, adequate data might not be available to illustrate the real impact of disease on the ecoregion. If data are not available, it was noted as such, and appropriate assumptions were made for this CA.

2.2.1 West Nile Virus

First observed in New York in 1999, the WNV has rapidly spread west across North America, reaching the west coast in 2004 (Centers for Disease Control and Prevention 2011). Most affected by this virus were American crow (*Corvus brachyrhynchos*) populations (Caffrey et al. 2005). Naugle et al. (2004)

reported the first WNV case in GSG in northeast Wyoming, resulting in a 25 percent decline in survival of four populations (Naugle et al. 2004). Walker (2007) showed that Greater Sage-Grouse chick and adult survival was significantly lower due to WNV and resulted 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.

2.2.2 Sylvatic Plague

Sylvatic Plague *(Yersinia pestis)* is a non-native, lethal bacterial disease that entered the United States around 1900 and became established in San Francisco in 1900 (Link 1955). From there it spread throughout the United States and has become a major source of mortality for rodent species, especially prairie dogs. Sylvatic plague is the major threat to the black-tailed prairie dog (BTPD) assemblage. Mortality rates associated with sylvatic plague outbreaks in prairie dog colonies can exceed 90 percent and cause local extinctions Cully and Williams 2001). Stapp et al. (2004) demonstrate a link between plague-caused extinctions of colonies attributed to plague and climatic fluctuations associated with El Niño southern oscillation events that promote the growth of flea vector and rodent host populations. The probability of extinction of colonies is thought to be influenced by the size and fate of adjacent colonies, but spatial isolation may not reduce the vulnerability of colonies to plague (Stapp et al. 2004). Sylvatic plague has a keystone function within the grassland biome by affecting prairie dogs and indirectly a host of other species, such as black-footed ferrets (*Mustela nigripes*), burrowing owls *(Athene cunicularia)*, ferruginous hawks *(Buteo regalis)* and mountain plovers *(Charadrius montanus)*.

2.2.3 Chronic Wasting Disease

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, elk, and moose. 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 (Figure C-4-7). 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 <1 percent in elk.

3.0 ANALYTICAL METHODS

3.1 INSECT INFESTATION

Insect infestation was analyzed using the aerial detection survey (ADS) from by the U.S. Forest Service. Survey (USFS) data on the health of affected forest areas is collected across state, private and Federal lands, assigned standardized forest damage codes, and recorded and maintained by the Forest Heath Technology Enterprise Team (FHTET).

ADS, also known as aerial sketchmapping, is a remote sensing technique of observing forest change events from an aircraft and documenting them manually onto a map. The surveys are conducted by an observer in a small high-wing aircraft, typically flying at altitude of approximately 1,000 - 1,500 feet above ground level. Aircraft fly in either a grid pattern over relatively flat terrain or following the contours of the terrain in mountainous or deeply dissected landscapes.

To identify insect and disease activity, the observer looks for characteristic signatures to distinguish the tree species and the type of damage that has occurred. Characteristics that observers use to determine the host tree species include: the shape of the tree's crown, slope position, elevation and aspect. Variation in the color of the tree's foliage indicates the presence and type of insect or disease activity. For example, bark beetle activity causes tree mortality which results in foliage color fading from green to a species specific yellow, red or straw color. In contrast, defoliators remove some of the foliage, resulting in discoloration such as a gray, red, or yellow tinge. During the survey, all of the observed damages are recorded in a digital format which is compiled for use in the production of maps and summary statistics. When unknown signatures are observed, ground checks are conducted to verify the host and damage causing agent (Johnson 2012).

Surveys were recorded using a digital sketchmap system. The digital sketchmap system incorporates a GPS unit that provides the observer with realtime position locations over a base map. The map base will often be of the 1:100,000 scale topographic or satellite image variety. For more intensive "special" surveys, using 1:24,000 scale maps is common. The mapped areas (polygons) are drawn on the touchscreen and directly entered into a national geographic information system (GIS) database using common standards that are required for Forest Health Monitoring reporting efforts (Johnson 2012). Polygons are coded to identify the damage agent, damage type, and other attributes. Reporting the number of dead trees or dead trees per acre is required for areas with mortality. In large areas where mortality is widely scattered, other attributes may be used to capture the pattern of damage, but are not required. In all cases, mortality may be continuous or discontinuous; therefore, acres are reported as acres "with" mortality.

ADS vector data from 1994 to 2010 was merged and clipped to the Northwestern Plains ecoregion. Three insects were identified for analysis; MPB, spruce budworm, and an "other beetles" category which included Douglas-fir beetle, Douglas-fir engraver beetle, pine engraver beetle, and spruce beetle. Each beetle dataset was then converted to raster for spatial analysis.

3.2 ANALYSIS OUTPUT

The ADS data were overlayed with the insect host evergreen forest to determine the magnitude of infestation. Insect infestation was calculated based on forested ecosystem analyzed at a 30-m pixel unit by determining the percent infestation on evergreen forested patches. Magnitude of infestation was defined based on percent infestation on evergreen patches and identified by rating as shown in Table C-4-1 through Table C-4-3. An evergreen forested patch was simply an individual pixel or group of pixels defined as evergreen by the landcover data. Each pixel was given a score based on the current status rating. Jenks natural breaks classes were identified and are based on natural groupings inherent in the data.

Figures C-4-1 through C-4-7 present the current status of the insect outbreaks in the ecoregion. Areas in red represent higher current risk because the percent infestation was greater than of the total area. Areas in green represent a lower current risk based on a percent infestation.

Table C-4-1. Magnitude of MPB Infestation Ranking

Percent (%) Infestation	Rating	Score
0 to 18	Good	1
>18 to 52	Fair	2
>52	Poor	3

Table C-4-2. Magnitude of Western Spruce Budworm Infestation Ranking

Percent (%) Infestation	Rating	Score
0 to 17	Good	1
>17 to 63	Fair	2
>63	Poor	3

Table C-4-3. Magnitude of "Other Beetle"[a] Infestation Ranking

Percent (%) Infestation	Rating	Score
0 to 7	Good	1
>7 to 46	Fair	2
>46	Poor	3

[a] Douglas-fir beetle, Douglas-fir engraver beetle, pine engraver beetle, and spruce beetle.

4.0 RESULTS

Figures C-4-1 through C-4-6 present the current status of the insect outbreaks based on ADS in the Northwestern Plains ecoregion. Areas in red represent higher current risk because the percent infestation of the total area. Areas in yellow represent a percent infestation of fair and areas in green represent a lower current risk based on a percent infestation.

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5.0 MANAGEMENT QUESTIONS

Although some of the original MQs were specific to the CAs, all of these are addressed in the specific CE packages contained in Appendices D and E. The individual KEA maps and the resulting overall current status output contained in these appendices answer all of the MQs specific to this CA.

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APPENDIX C-4

FIGURES

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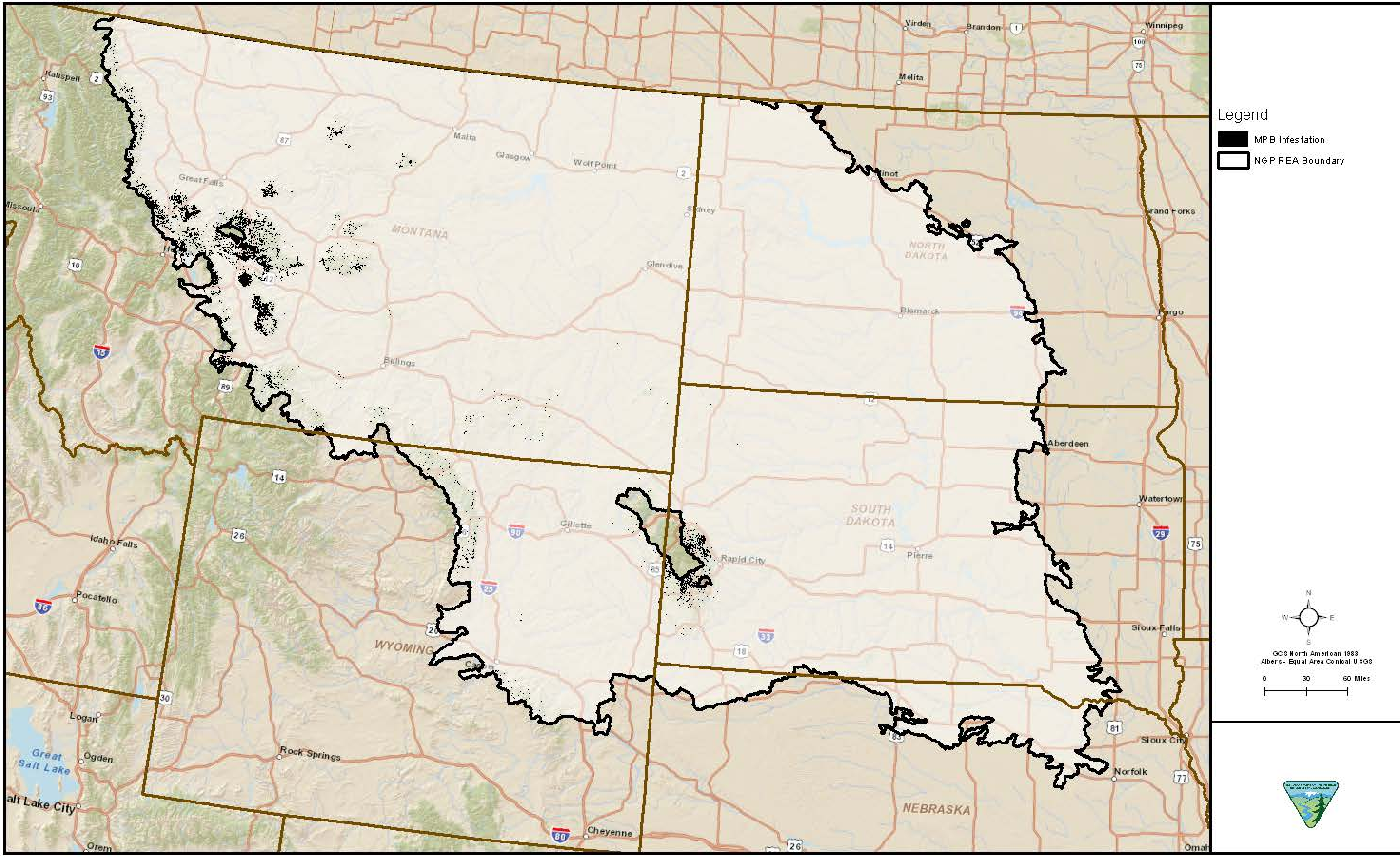

Figure C-4-1. Mountain Pine Beetle Infestation

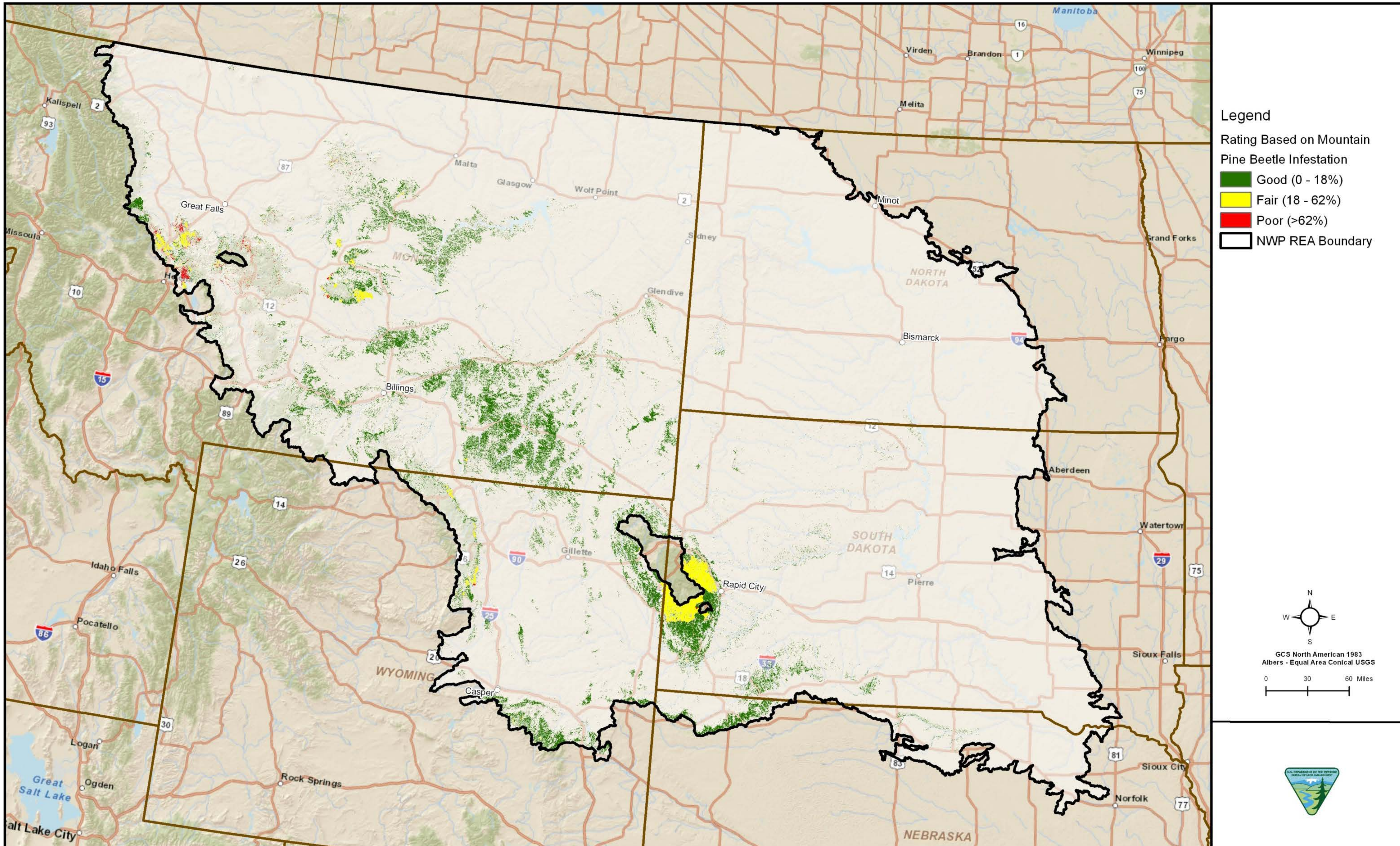

Figure C-4-2. Mountain Pine Beetle Infestation Scores

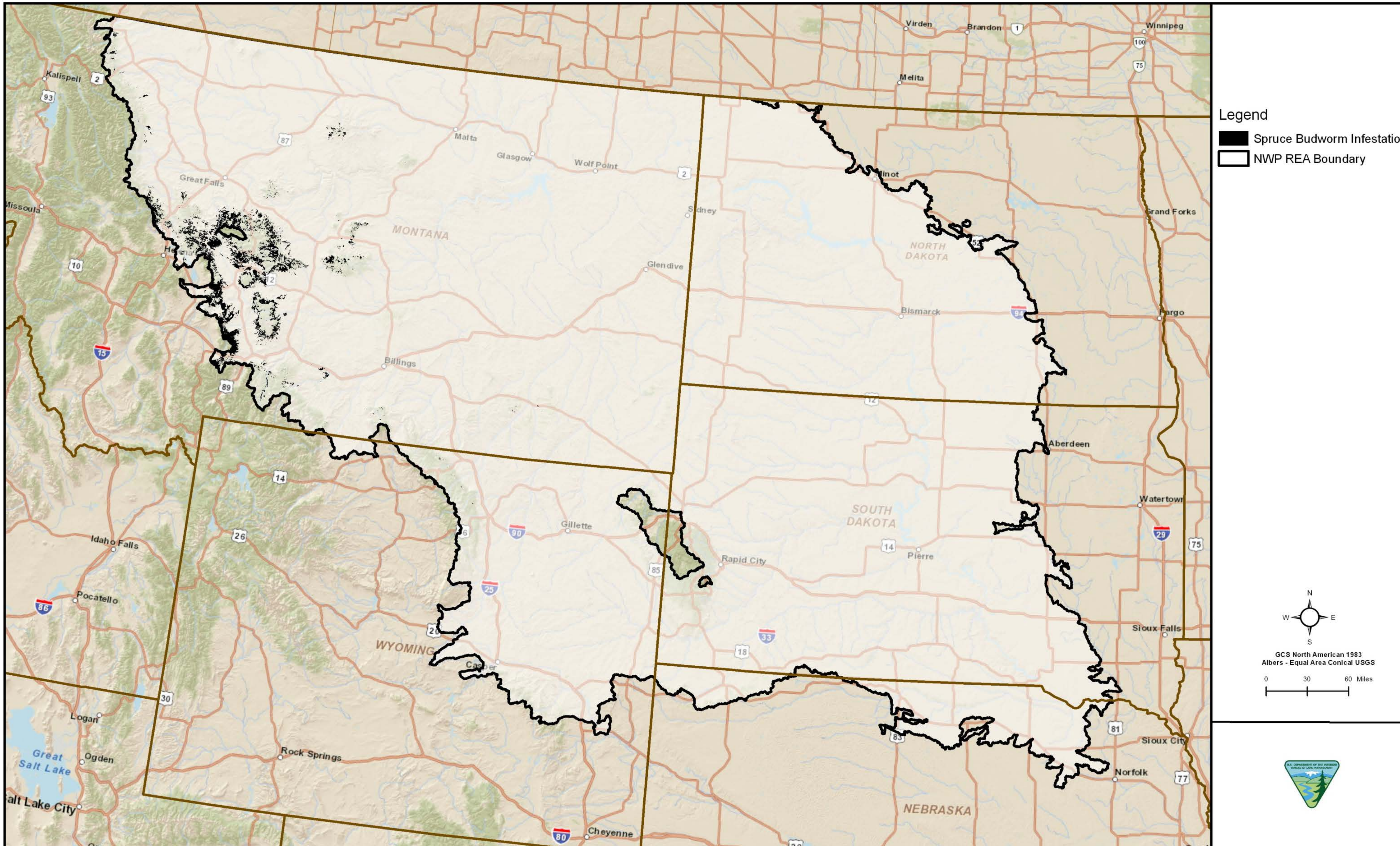

Figure C-4-3. Western Spruce Budworm Infestation

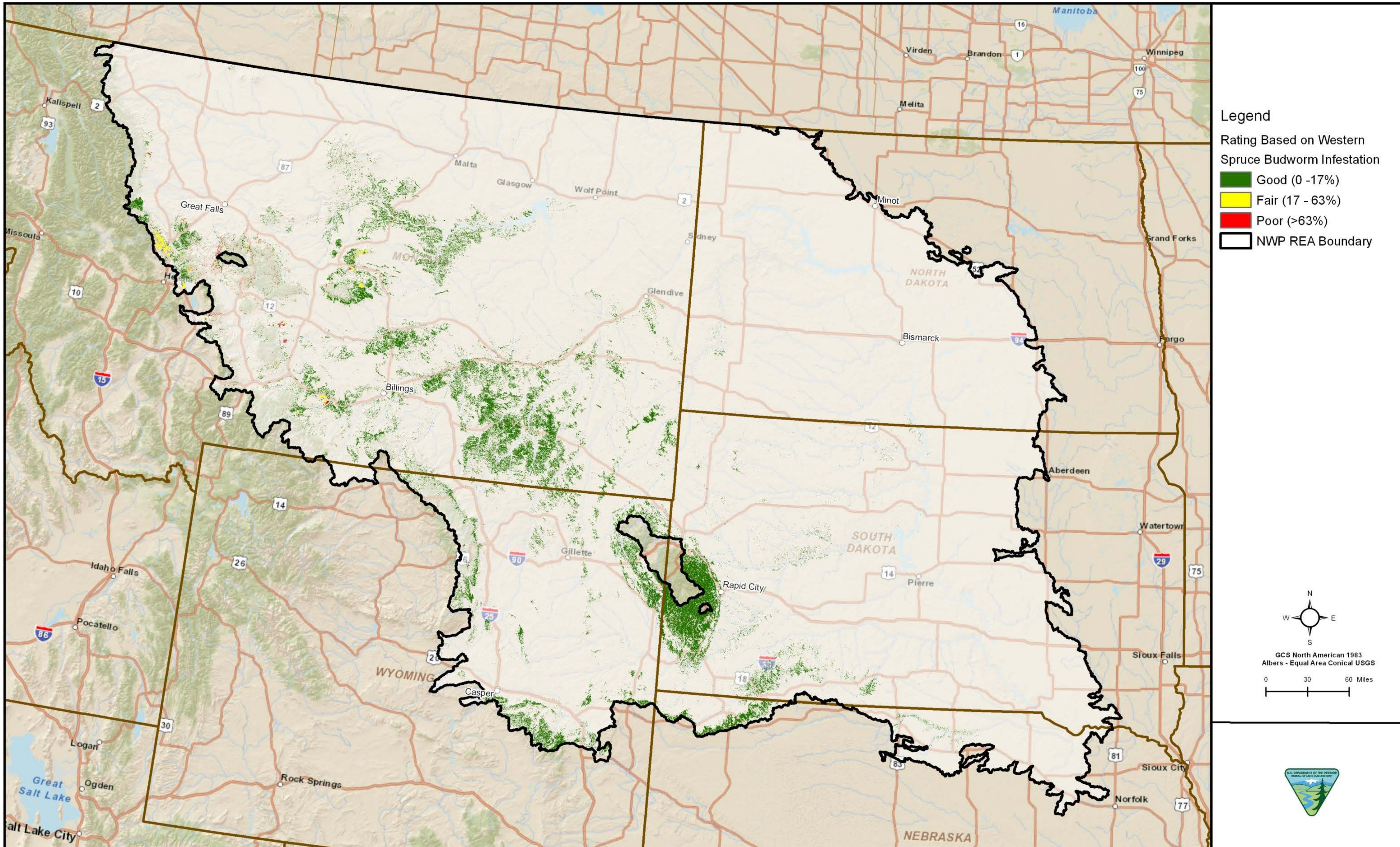

Figure C-4-4. Western Spruce Budworm Infestation Scores

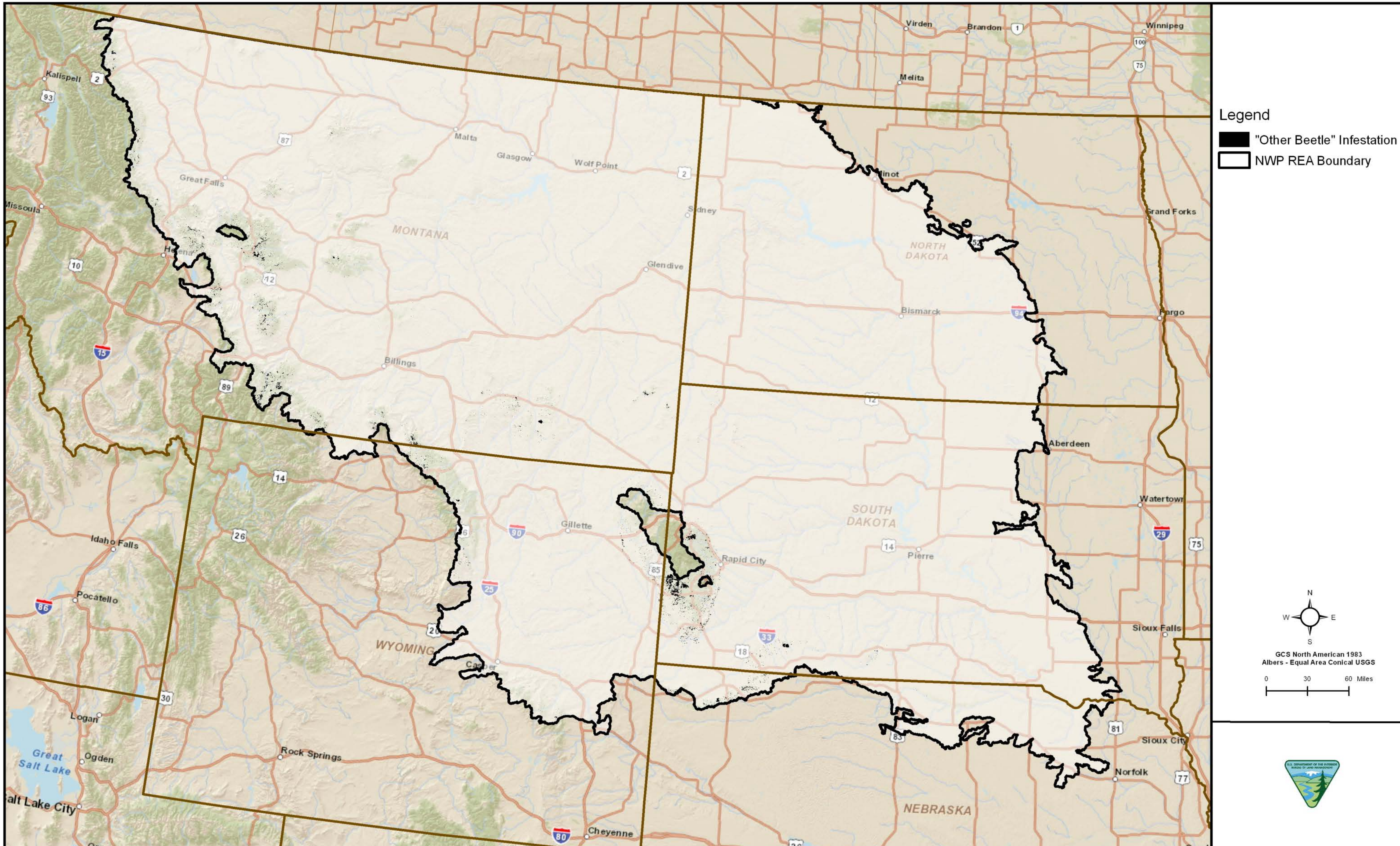

Figure C-4-5. Other Beetle Infestation

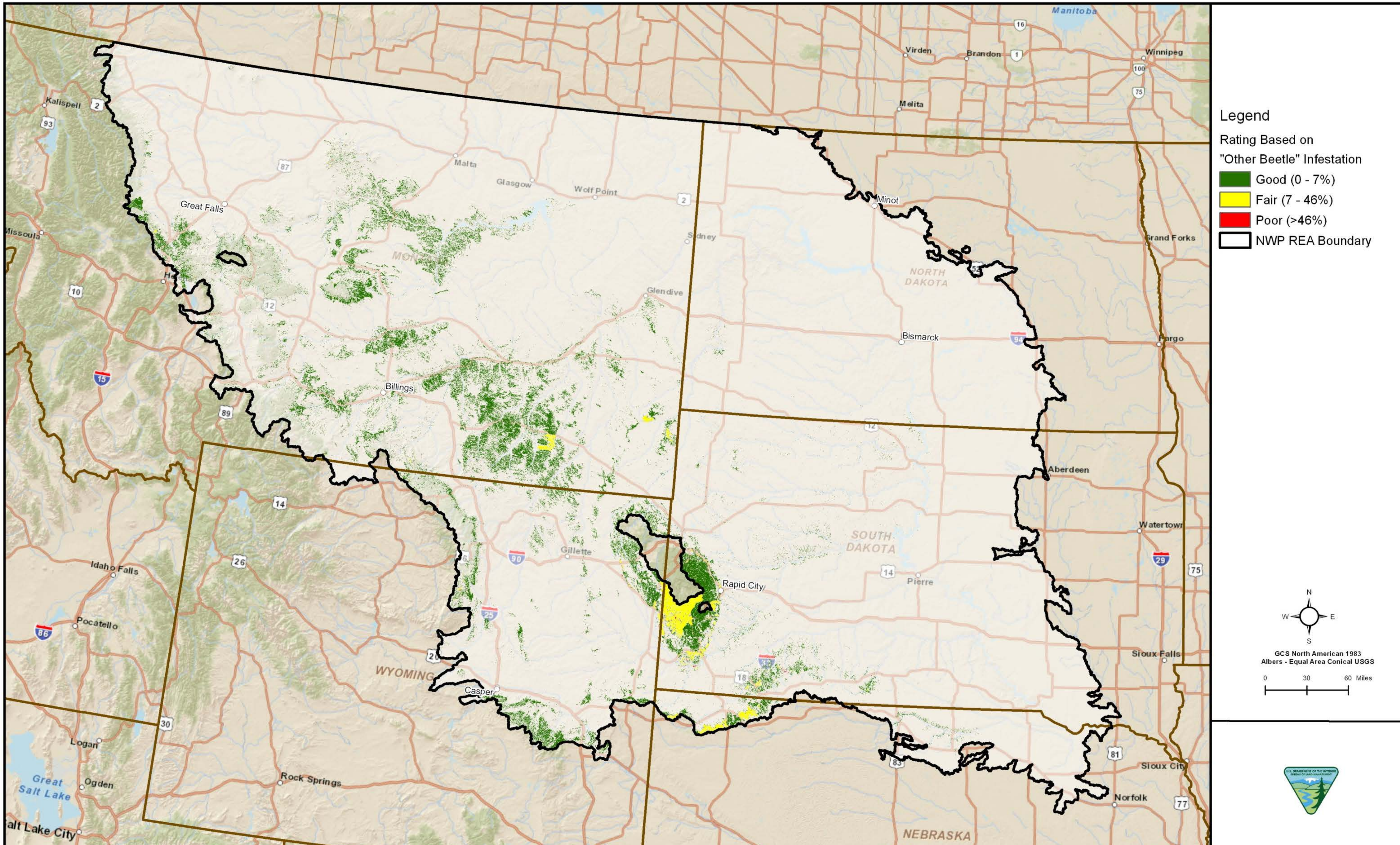

Figure C-4-6. Other Beetle Infestation Scores

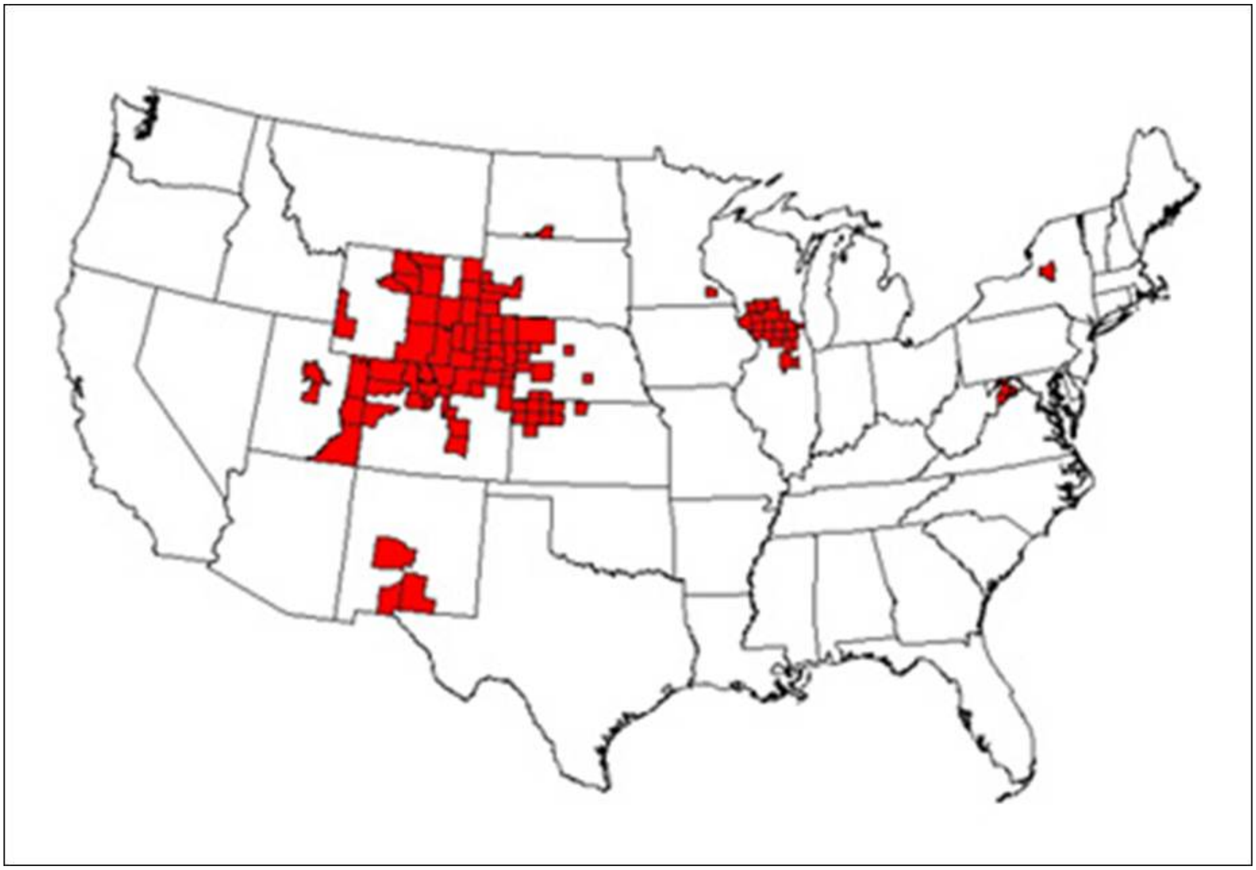

Figure C-4-7.   Chronic Wasting Disease

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Data Request Method

Rapid Ecoregional Assessments (REAs)—National Operations Center, CO

Individual REA data layers and some other products are still available but are no longer being published.

If you would like to obtain more information, including data and model zip files* (containing Esri ModelBuilder files for ArcGIS 10.x and relevant Python scripts), please email **BLM_OC_REA_Data_Portal_Feedback_Team@blm.gov**.
*Note that a few models require software that BLM does not provide such as R, Maxent, and TauDEM.

Models associated with individual REAs may require data links to be updated to function properly. REA reports, technical appendices, and model overviews (for some REAs) contain detailed information to determine what products are available and what datasets are necessary to run a certain model.

Please include the report name and any specific data information that you can provide with your request.

Other BLM data can be found on the Geospatial Business Platform Hub (https://gbp-blm-egis.hub.arcgis.com).