Final Memo 3-C

Northern Basin and Range and Snake River Plain Ecoregion Rapid Ecoregional Assessment

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Rapid Ecoregional Assessment

FINAL MEMORANDUM 3-c

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Acronyms

AMT	Assessment Management Team
AUM	Animal Unit Months
BBD	Breeding Bird Density
BLM	Bureau of Land Management
CA	Change Agent
CE	Conservation Element
COH	Currently Occupied Habitat
EPA	Environmental Protection Agency
EVT	Existing Vegetation Type
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
FRCC	Fire Regime Condition Class
GCM	Global Climate Model
GFDL	Geophysical Fluid Dynamic Laboratory
GSG	Greater Sage-Grouse
HCA	Habitat Core Area
HMA	Herd Management Area
HUC	Hydrologic Unit Code
ICLUS	Integrated Climate and Land Use Scenarios
KEA	Key Ecological Attribute
km	kilometer
MCE	Multi Criteria Evaluation
MQs	Management Question
NAD	North American Dataset
NBR	Northern Basin and Range and Snake River Ecoregions
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NDOW	Nevada Department of Wildlife
NED	National Elevation Dataset
NHD	National Hydrographic Dataset
NHP	Natural Heritage Program
NISIMS	National Invasive Species Information Management System
NLCD	National Land Cover Dataset

NWI	National Wetlands Inventory
PADS	Protected Areas Database
PGH	Preliminary General Habitat
PPH	Preliminary Priority Habitat
PRISM	Parameter-elevation Regressions on Independent Slopes Model
REA	Rapid Ecoregional Assessment
SERGoM	Spatially Explicit Regional Growth Model
SOW	Statement of Work
SDA	Specially Designated Area
TIGER	Topologically Integrated Geographic Encoding and Referencing
USFS	US Forest Service
USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
VCC	Vegetation Condition Class
WAFWA	Western Association of Fish and Wildlife Agencies
WGA	Western Governors Association
WLC	Weighted Linear Combination
WWHCWG	Washington Wildlife Habitat Connectivity Working Group

1 Introduction

The Assessment Management Team (AMT) is comprised of resource specialists from Bureau of Land Management (BLM) and other state, federal, and stakeholder scientists and planners. The US Geologic Survey (USGS) provides scientific peer review for the REA.

Phase 1, Task 3 includes the development of GIS process models, modeling methods and analysis tools that will be used to answer the management question. At the AMT Workshop # 3, the AMT asked to be able to see examples of final products based on the GIS process models included in this memo. Seeing examples would allow the AMT to visualize the analysis methodology, analysis units (4 kilometer [km] grid, Hydrologic Unit Code [HUC] 10 and HUC 12 watersheds) and make recommendations on fine tuning approaches to modeling conservations elements (CEs) and change agents (CAs).

This memo contains:

- GIS process models and resulting outputs for three example CEs, greater sage-grouse (GSG), mule deer and three types of sagebrush (low sagebrush, mountain big sagebrush and Wyoming / Basin big sagebrush).
- A GIS process model for evaluating the potential livestock grazing intensity gradient across grazing allotments is introduced. The intent is that the AMT can help develop the model and necessary attributes (distances to buffer water features, slopes, etc) based on member experiences.
- A GIS process model for invasive species is also presented based on those used in other ecoregions to bypass data gaps in invasive species data. The model uses two example species of Canada thistle and Russian knapweed which are prevalent in the ecoregion. Key ecological attributes (KEAs) for GSG and mule deer are displayed with the GIS process models and resulting output maps using two analysis units (4 km grid and HUC 12 watershed).
- Terrestrial Ecological Intactness (EI) is also modeled for the ecoregion using the Montana / Washington state Ecological Intactness methodology. A couple of EI KEAs for the terrestrial EI are also modeled with the resulting output at a HUC 10 watershed analysis unit. It is expected that EI will be adopted from the Western Governors Association (WGA) methodology currently being evaluated and reviewed. Since the WGA is a separate entity and having different timeframes, the EI approach could be a fall back plan.

This memo builds on previous memos (Defining Management Questions (MQs), CEs and CAs and Developing Conceptual Models for CEs) to form the foundation of the Draft REA Work Plan (memo #4). It is expected that the Draft Work Plan will be a very detailed plan as to how each management question will be answered and CE or CA modeled. Since data collection has been moved to Phase 2 of the REA, it is difficult to visualize data challenges that will be encountered in executing the Draft Work Plan.

1.1 The REA Process

The BLM is currently evaluating a wide variety of environmental challenges to western ecosystems. These challenges transcend land ownership and administrative jurisdictions, and necessitate a landscape-scale approach to evaluation of these ecosystems. The Rapid Ecological Assessment (REA) process is the BLM's first step toward a broader initiative to systematically develop and incorporate landscape-scale information into the evaluation and eventual management of public land resources.

REAs encompass an ecoregion to more fully understand ecological conditions and trends; natural and human influences; and opportunities for resource conservation, restoration, and development. They seek to identify important resource values and patterns of environmental change that may not be evident when managing smaller, local land areas. REAs describe and map areas of high ecological value. REAs then gauge the potential of these values to be affected by environmental change agents (CAs). REAs are called "rapid" assessments because they synthesize existing information, rather than conduct research or collect new data, and are generally completed within 18 months.

REAs are organized into various phases, with specific tasks in each phase (Table 1.1-1). Phase I is the pre-assessment, and includes four tasks including finalization of the management questions (MQs), CAs, and Conservation Elements (CEs) that the REA will attempt to answer. In a departure from the order of tasks in previous REA efforts, Phase I, Task 2 includes development of conceptual models to understand the process framework of the CEs. Geo-processing models, work-flows, and applied data tools will be developed under Phase I, Task 3. The final task under Phase I will include the preparation of the REA Work Plan (Task 4).

Table 1.1-1. REA Phases and Tasks

Phase	Task #	Product
I. Pre-assessment	1	Refine MQs (Completed)
	2	Identify, Evaluate, and Recommend Conceptual Models (Completed)
	3	**Identify, Evaluate, and Recommend Geoprocessing Models, Methods, and Tools (Subject of this memo)**
	4	Prepare REA work plan
II. Assessment	1	Compile and Generate Source Datasets
	2	Conduct analyses and generate findings
	3	Prepare REA report, maps, and supporting documents

Phase II is the assessment, and includes an analysis of the data relative to the identified CAs and CEs, documentation of the results, and culminates in the REA document, which will guide BLM and other land managers in developing and prioritizing planning and management strategies.

1.2 Document Contents and Organization

Based on the feedback received from the AMT at the 3rd workshop, the AMT wanted to see examples of the GIS process model and threat analysis for a couple example conservation elements. This would allow the AMT to see samples of the process models, threat analysis and output maps for each of the conservation elements. The AMT also wanted to compare and review analysis units of both a 4 km grid and the HUC 12 watershed.

This memo presents the GIS process model for creating two fine filter CEs (GSG and mule deer) and one coarse filter CE (sagebrush). Each of these conservation elements will have a GIS process model for merging data from different data sources. Change Agents will focus on climate change, development, invasive species and wildland fire. Since grazing will be included as a change agent, a proposed model will be created based on comments received from the AMT. A threat analysis based on key ecological attributes (KEAs) for the two fine filter species (GSG and mule deer) shows examples of individual KEA's along with a cumulative threat analysis. Finally ecological intactness (EI) is discussed comparing two possible approaches, one being the WGA approach and the other based on Washington and Montana State's approaches to EI.

Memo #3 will be used along with the first two memos to create memo #4, the draft REA work plan. It is expected that the draft REA work plan will document in detail how each management question will be answered, the expected data sources and how each conservation element and change agent will be modeled. Since the data acquisition task is later in Phase 2 Task 1, it is expected that some conservation elements may be dropped or management questions changed to reflect what data are available and attainable within the timeframe of the REA. These decisions will be made in collaboration with the AMT.

2 Modeling Conservation Elements

2.1 Introduction

The modeling of conservation elements details the approach being recommended to take existing data and alter it to match the needs to the REA. This can be as simple as clipping an existing spatial layer to an ecoregion or as complex as using an inductive model such as Maxent (Phillips et al. 2006) which defines the extent of suitable habitat based on species occurrence data. Certain species that may not have region wide datasets may rely on other modeling approaches such as Maxent to create a modeled suitable habitat across the ecoregion. Maxent is a presence only data model using species observation and a series of environmental layers to try to predict the species suitable habitat. It is expected that occurrence data will be provided from each state's Natural Heritage Programs or Fish and Wildlife agencies to populate the models. Since many of the conservation elements (CEs) will be modeled using existing established datasets such as Western Association of Fish and Wildlife Agencies (WAFWA) for Bighorn sheep or mule deer, simple GIS process models will document the altering of the spatial layers for the Rapid Ecological Assessment (REA) (see Table 2.1-1). If needed, newer state data may be used to alter existing WAFWA data layers with approval of the Assessment Management Team (AMT).

Table 2.1-1. Each of the Conservation Elements and the Expected Modeling Approach and Data Sources

Fine Filter Conservation Element	Expected Modeling Approach (Data Source)
Greater Sage-grouse	GIS Process Model (State's Preliminary Priority Habitat)
Bighorn Sheep	GIS Process Model (WAFWA 2011)
Mule Deer	GIS Process Model (WAFWA 2004, Nevada Department of Wildlife 2009)
Pronghorn	GIS Process Model (State Fish & Game Data?)
Golden Eagle	Maxent (State NHP, State Fish & Game)
Bald Eagle	Maxent (State NHP, State Fish & Game)
Spotted Frog	Maxent (State NHP, State Fish & Game)
Pygmy Rabbit	Maxent (State NHP, State Fish & Game)
Bats	Maxent (State NHP, State Fish & Game)?
Bull Trout	GIS Process Model (Streamnet, USFWS)
Coldwater Fish Assemblage	GIS Process Model (Streamnet, USFS)
White Sturgeon	GIS Process Model (Streamnet)
Coarse Filter Conservation Element	**Expected Modeling Approach (Data Source)**
Terrestrial Coarse Filter Conservation Element	
Sagebrush-steppe	GIS Process Model (NW REGAP, SW REGAP, LANDFIRE [CA only])
Salt Desert Shrub	GIS Process Model (NW REGAP, SW REGAP, LANDFIRE [CA only])
Western and Utah Juniper	GIS Process Model (NW REGAP, SW REGAP, LANDFIRE [CA only])
Aspen	GIS Process Model (NW REGAP, SW REGAP, LANDFIRE [CA only])
Other Conifers	GIS Process Model (NW REGAP, SW REGAP, LANDFIRE [CA only])
Aquatic and other Coarse Filter Conservation Elements	
Perennial Steams	GIS Process Model (NHD)
Vulnerable Soils	GIS Process Model (STATSGO Soils)
Cottonwood Galleries	GIS Process Model (NW REGAP, SW REGAP, LANDFIRE [CA only])
Riparian Habitats	GIS Process Model (NW REGAP, SW REGAP, LANDFIRE [CA only], NHD)
Springs and Seeps	GIS Process Model (NHD)
Wetlands	GIS Process Model (National WI Wetlands)
Open Water Habitat	GIS Process Model (NHD)
Groundwater	TBD
Specially Designated Areas (SDAs)	GIS Process Model (Protected Areas Database [USGS])
Wild Horse and Burro Herd Management Area	GIS Process Model (BLM)

2.1.1 GIS Process Modeling

Every conservation element will have a GIS process model to document how each spatial layer was created. This serves two purposes: first being a transparent way to show all of the processes that were done to derive the final layer; and secondly a way to quickly repeat the process if a data layer is updated or the process needs to be altered. GIS process models will be created and delivered using ESRI's Modelbuilder as a required deliverable in the statement of work. This module of ArcGIS allows users to graphically depict the workflow of their analysis and save the workflow in individual models within toolboxes that are sharable with other users. One of the deliverables of later tasks is to deliver Modelbuilder models and toolboxes for each conservation element. This information will be used by the BLM National Operation Center's GIS team to QA/QC the data layers being used in the REA.

GIS process models in Modelbuilder consist of boxes (representing spatial operations) and ovals (input or output datasets) linked by flow arrows representing input layers, spatial operations on the layers and output layers (see Figure 2.1.1-1). In this example, the GIS process is as follows.

1. Vegetation condition class (VCC) layer (raster) has attributes extracted from the raster,
2. Zonal statistics as a table is then run on the extracted layer using the HUC 12 watershed boundaries within the ecoregion as the zones within which to generate statistics. The statistical operator that will be calculated in each zone will be the Majority (most common value in zone) since VCC data is ordinal (1,2,3, etc.) and not continuous.
3. The resulting table will be then joined to the HUC 12 watersheds
4. The final step will be to calculate a field in the HUC 12 watershed to populate the Majority value from the table.

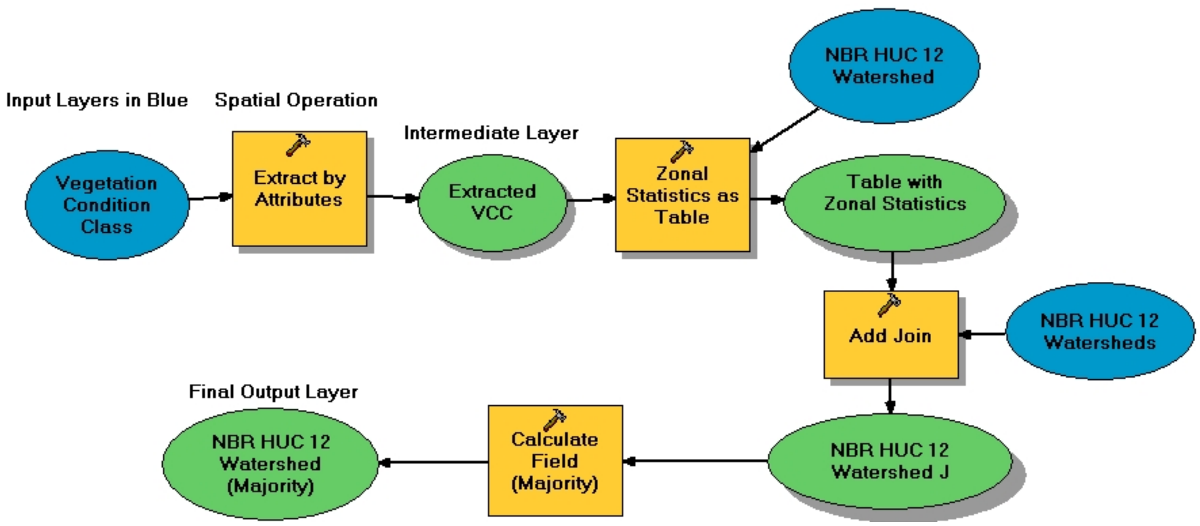


Figure 2.1.1-1 Sample GIS Process Model in ESRI's Modelbuilder

2.1.2 Maxent Modeling

Maxent modeling consists of using presence-only species occurrence data and a series of environmental raster layers (Soil, Temperature, Elevation, etc) to try to determine suitable habitat. During a model run, the species occurrence data is 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 output is a value between 0-1, with the higher the number the higher the habitat suitability. Maxent also allows for testing the model to validate the accuracy of the predictions based on occurrence data and also provides various validation measures. Figure 2.1.2-1 shows an example of the process of creating a modeled suitable habitat using Maxent for Pygmy Rabbit. Since Maxent is a standalone tool, GIS process models will be used to extract, project and format the data into required formats for the model inputs.

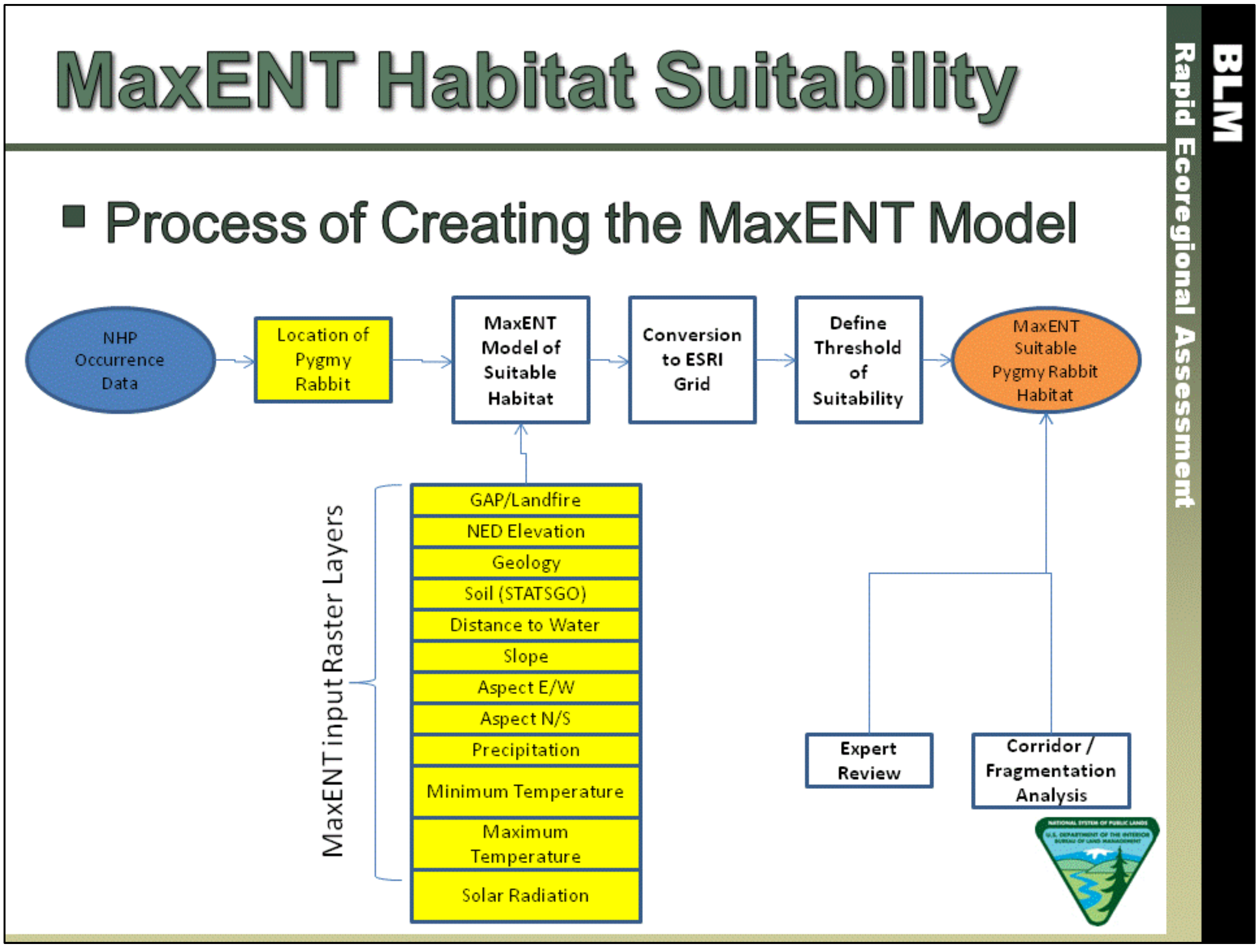


Figure 2.1.2-1 Process Flow for Running Maxent model

2.1.3 Data Sources

The data sources will vary based on the CEs and what data the AMT decides to use to model its location. CEs such as greater sage-grouse (GSG) could have several possible different sources showing its distribution such as State Preliminary Priority Habitat (PPH), Breeding Bird Density (BBD) (Doherty et al. 2010) and the Currently Occupied Habitat (COH) done by Bruce Durtsche (2008) and updated by the BLM Spatial Lab. The AMT decided during AMT workshop #3 to use the State's PPH data as it is available for each state, recent or being updated and matches boundaries used by each state.

One of the main data sources for big game will be the Western Association of Fish and Wildlife Agencies (WAFWA). This collection of state data will be used for mule deer and bighorn sheep (at least). Nevada Department of Wildlife (NDOW) provided updated mule deer data from 2009 that would be used instead of the existing WAFWA data for Nevada. The merging of the data will be documented in a GIS process model in section 2.2.2.

Maxent data will rely on occurrence data from the state's Natural Heritage or Fish and Wildlife agencies. The observation data collected will be filtered by date to remove older occurrence data that may be spatially inaccurate or not represent the current condition of the area. The date used for deciding what data to use in the model will be decided with guidance from the AMT.

The fisheries data will come from a variety of sources such as Streamnet, the Bull Trout Five Year Plan (USFWS) and the Yellowstone cutthroat trout Range Wide Assessment (USFS). Since Streamnet doesn't cover Nevada (except for the Bull Trout in the Jarbidge Area), California or Utah, other state data may be needed to cover the full range of the species across the ecoregion.

2.2 Fine Filter Model Examples

This section will provide two examples of GIS process models for two fine-filter CEs, GSG and mule deer. These examples were chosen because they are landscape species and the data was readily available or already obtained.

2.2.1 Greater Sage-Grouse

2.2.1.1 Data Sources

The primary data source for Greater sage-grouse (GSG) will be each state's PPH data. This was downloaded from a BLM website provided by the National Operation Center which is collecting the PPH data as part of a larger GSG initiative. As each state has recently reviewed or in the process of reviewing the PPH data, it is expected that most of these layers will need to be updated during the REA timeframe. The GIS process model makes this a fairly simple task as long as each state keeps their attributes fairly similar so new datasets can be easily swapped out.

2.2.1.2 GIS Process Model

An example of the GIS process model for GSG can be viewed in Figure 2.2.1.2-1. Oregon, California, Idaho and Utah all provided their PPH data in shapefile format. The PPH data was extracted from the shapefiles (some states included other habitats such as Preliminary General Habitat (PGH) in the same layer) based on the attributes and the data was projected to the REA common project (Albers NAD 1983) and clipped (limited to the spatial extent) to the ecoregion. Nevada's PPH data was provided as a raster (grid of cells) so it was converted to polygons and PPH was extracted by attributes. The data once clipped and projected was unioned (merged) to form one dataset, dissolved (to remove coincident boundaries such as state lines) and converted back to a raster for use in modeling KEAs and Change Agent (CAs) threat analysis.

2.2.1.3 Greater Sage-grouse Distribution in the Ecoregion

The final map showing the distribution of GSG PPH data for the NBR (Northern Basin and Range and Snake River Plain) ecoregion can be viewed in figure 2.2.1.3-1. Since this is a collection of data from multiple states, different methodologies have gone into defining the PPH. Reviewing Oregon's PPH, it appears to be based on buffered leks (similar to the Breeding Bird Density) with circular pattern showing. Nevada has a large section on the border with Idaho that was listed as 'Areas to be Completed'. Overall most PPH data seems to match relatively well across state lines. As a comparison, Currently Occupied Habitat is shown in Figure 2.2.1.3-2 and the Breeding Bird Density Map (25, 50 and 75% populations) are shown in figure 2.2.1.3-3.

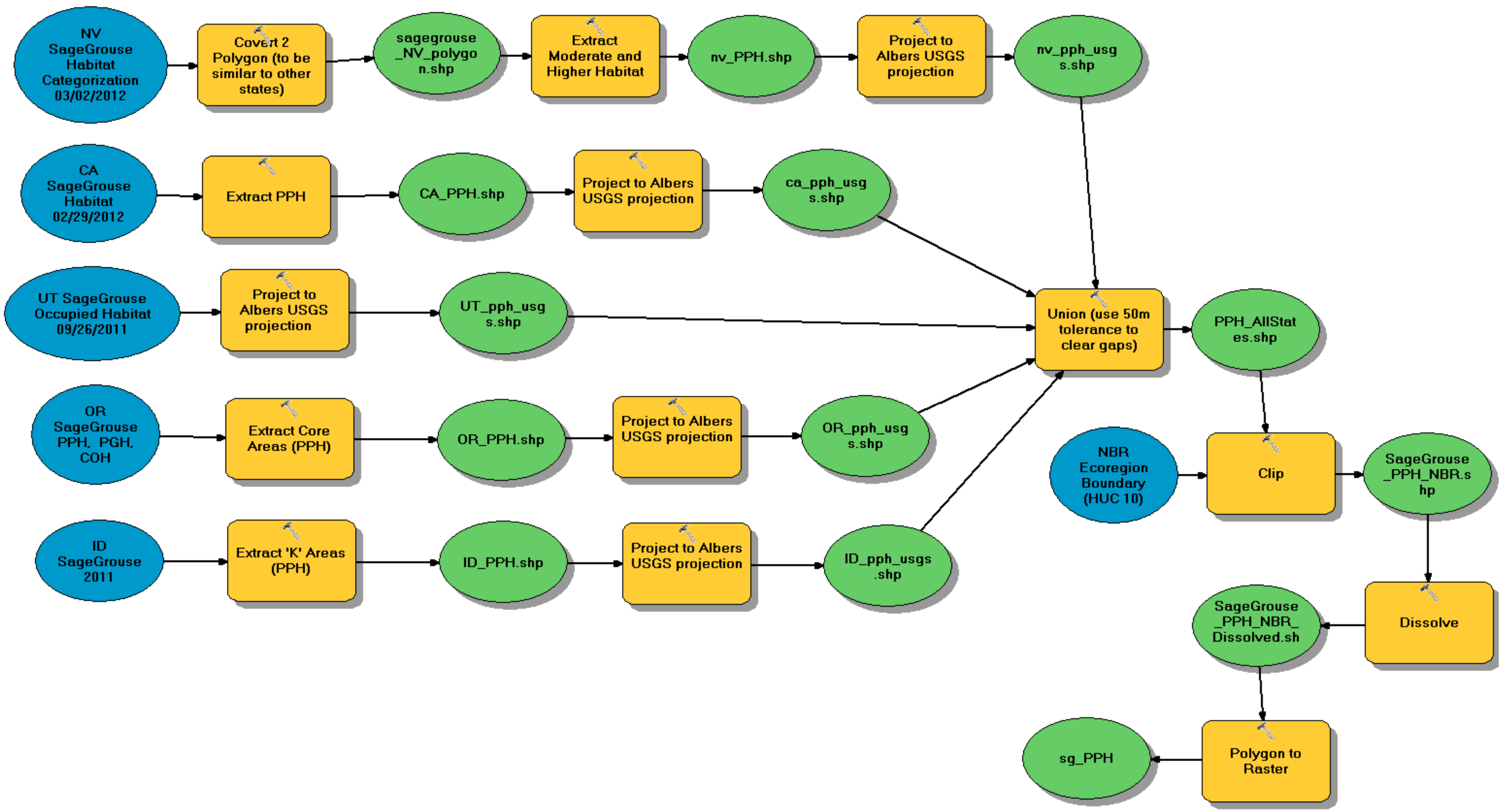


Figure 2.2.1.3-1. Process Model for Greater Sage-grouse

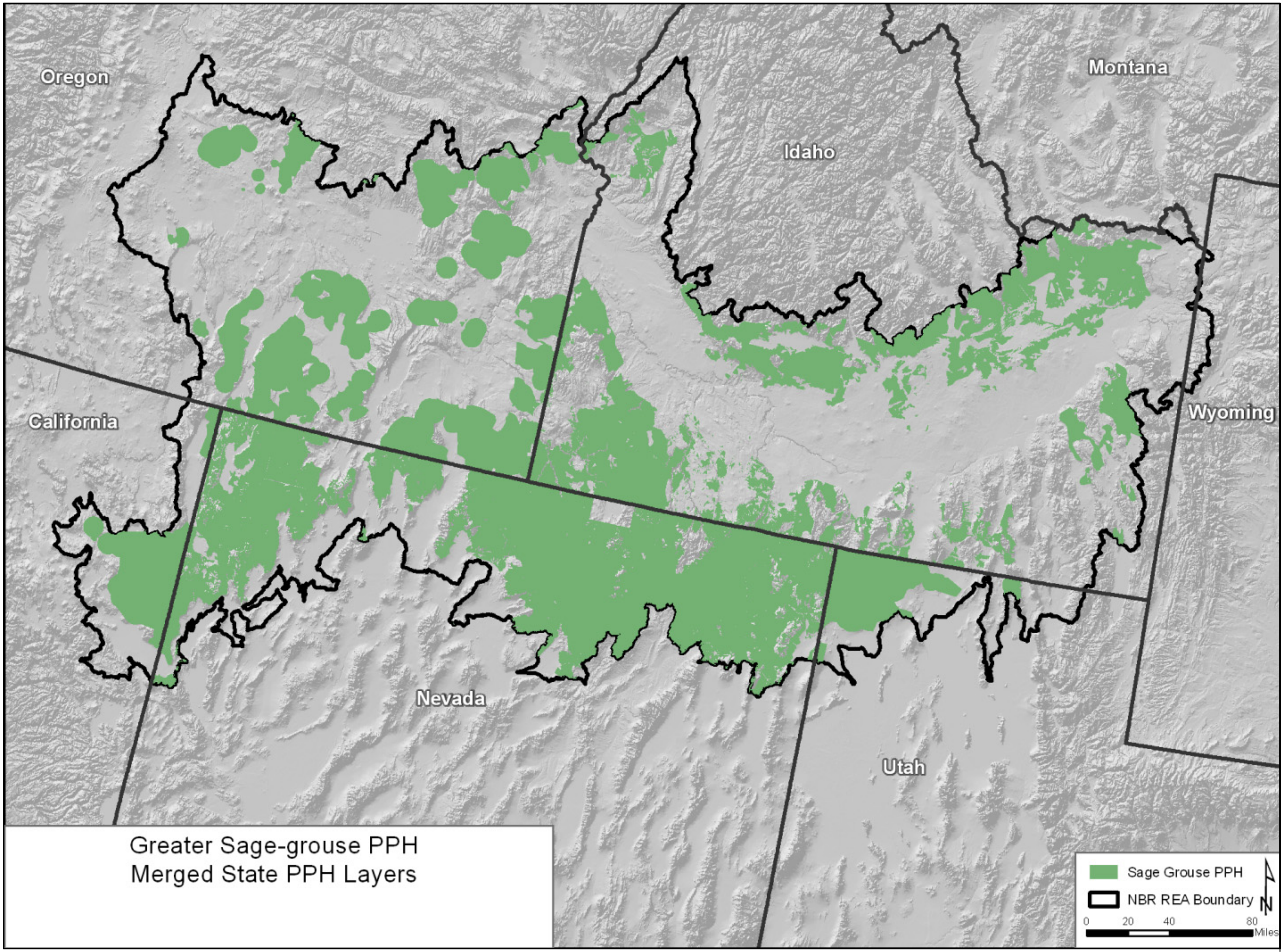


Figure 2.2.1.3-1 Greater Sage-grouse Distribution in the NBR Ecoregion using PPH data

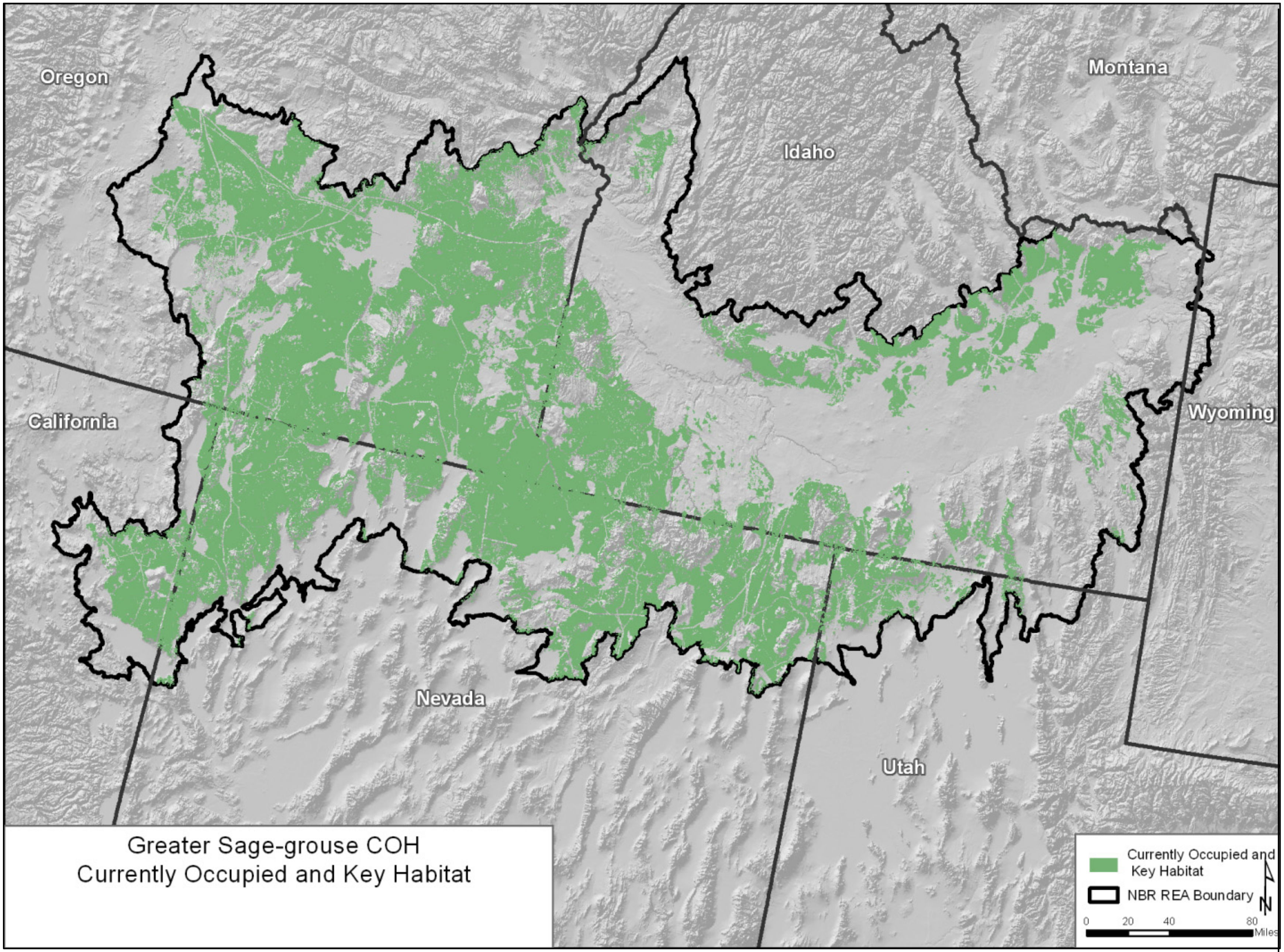


Figure 2.2.1.3-2 Greater Sage-grouse Distribution in the NBR Ecoregion using COH data

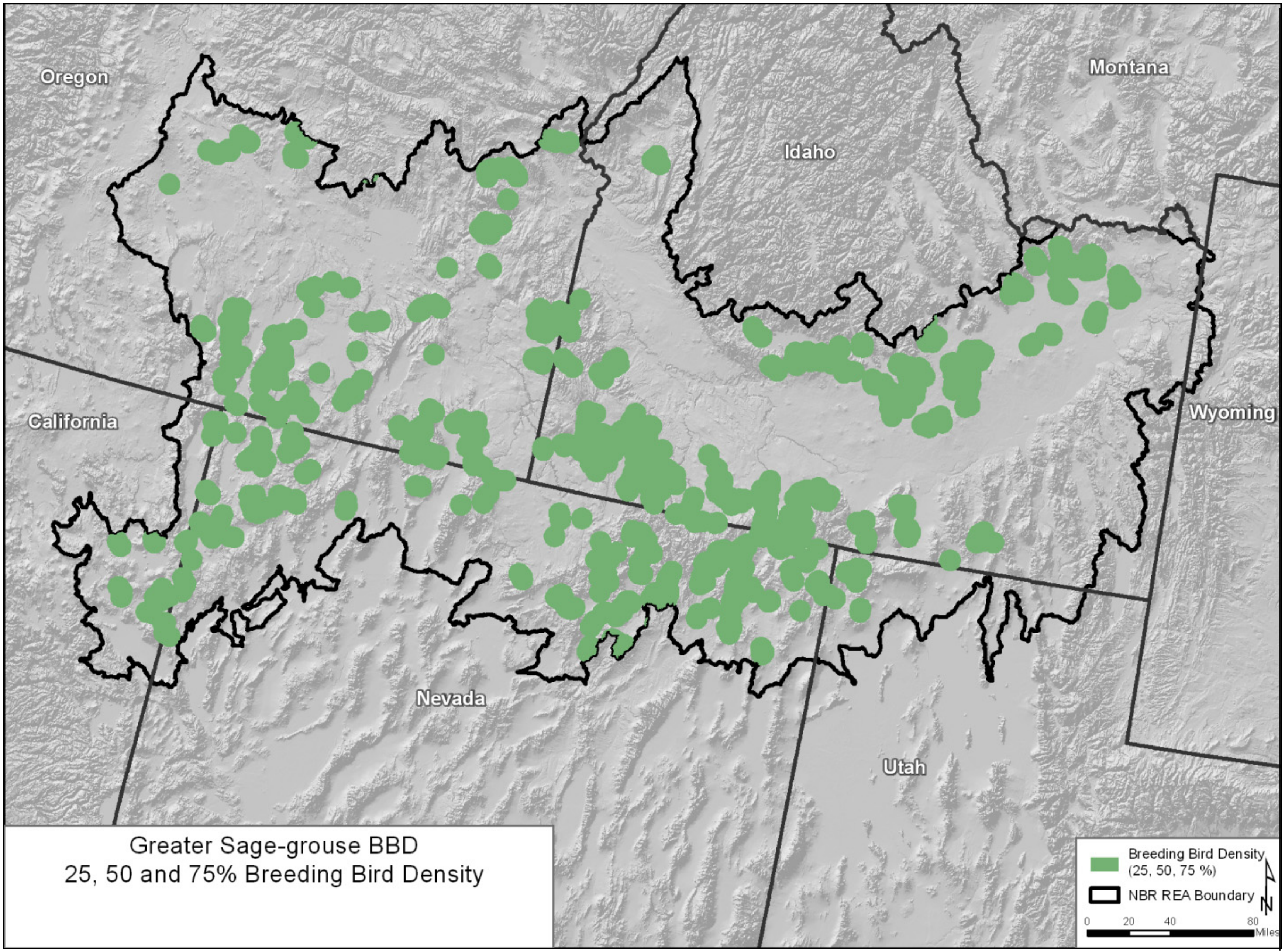


Figure 2.2.1.3-3 Greater Sage-grouse Distribution in the NBR Ecoregion using BBD data

2.2.2 Mule Deer

2.2.2.1 Data Sources

The two primary data sources for the mule deer were the WAFWA data and NDOW. Nevada had expressed interest in using their more recent mule deer data rather than the older WAFWA layer. After receiving the NDOW 2009 data layer it was merged with the WAFWA layer. Since this memo is not fully analyzing the CE, other states may want to have their mule deer data updated in a similar fashion based on the results and recommendations by the AMT.

2.2.2.2 GIS Process Model

WAFWA Mule Deer

The GIS process model for mule deer took several steps to convert, clip, and merge the two datasets. Figure 2.2.2.2-1 shows the initial processing on the WAFWA dataset to pull the data from its ArcINFO coverage and into one dataset. The process also erases Nevada's mule deer data from the WAFWA merged dataset so that NDOW data can be merged in a later step.

NDOW Mule Deer

Figure 2.2.2.2-2 shows the processing done on the NDOW mule deer layer so that it can be joined to the WAFWA layer built in the previous step.

Mule Deer Resistance Layer

The WAFWA mule deer layer covers most of the entire ecoregion. The Washington Wildlife Habitat Connectivity Working Group (WWHCWG) created some tools and methodology for delineating core habitat areas and then erasing areas of habitat resistance such as high elevation areas, urban areas, etc. Since the AMT wants to use State based spatial data for mule deer, creating and delineating new habitat based on a different methodology (National Land Cover Dataset or LANDFIRE) such as used by WWHCWG wasn't appropriate. An alternate approach being proposed is to use the resistance methodology to erase areas of the WAFWA mule deer data that are in areas that are known to be unsuitable or unfavorable to mule deer. Figure 2.2.2.2-3 shows the creation of a resistance layer that can be used to erase habitat for mule deer adopted from the WWHCWG. The resistance values used in the GIS process model are urban areas, open water, elevation over 2500m, slopes greater than 40 degrees, housing density of less than 10 acres per housing unit and primary and secondary TIGER roads.

Assembling Final Mule Deer Layer

Figure 2.2.2.2-4 shows the final assembling of the mule deer layer with the subtraction of the resistance layer.

2.2.2.3 Mule Deer Distribution in the Ecoregion

Mule Deer Distribution (WAFWA)

Figure 2.2.2.3-1 shows the initial WAFWA layer that was used as an input for the GIS process model described in Figure 2.2.2.2-1.

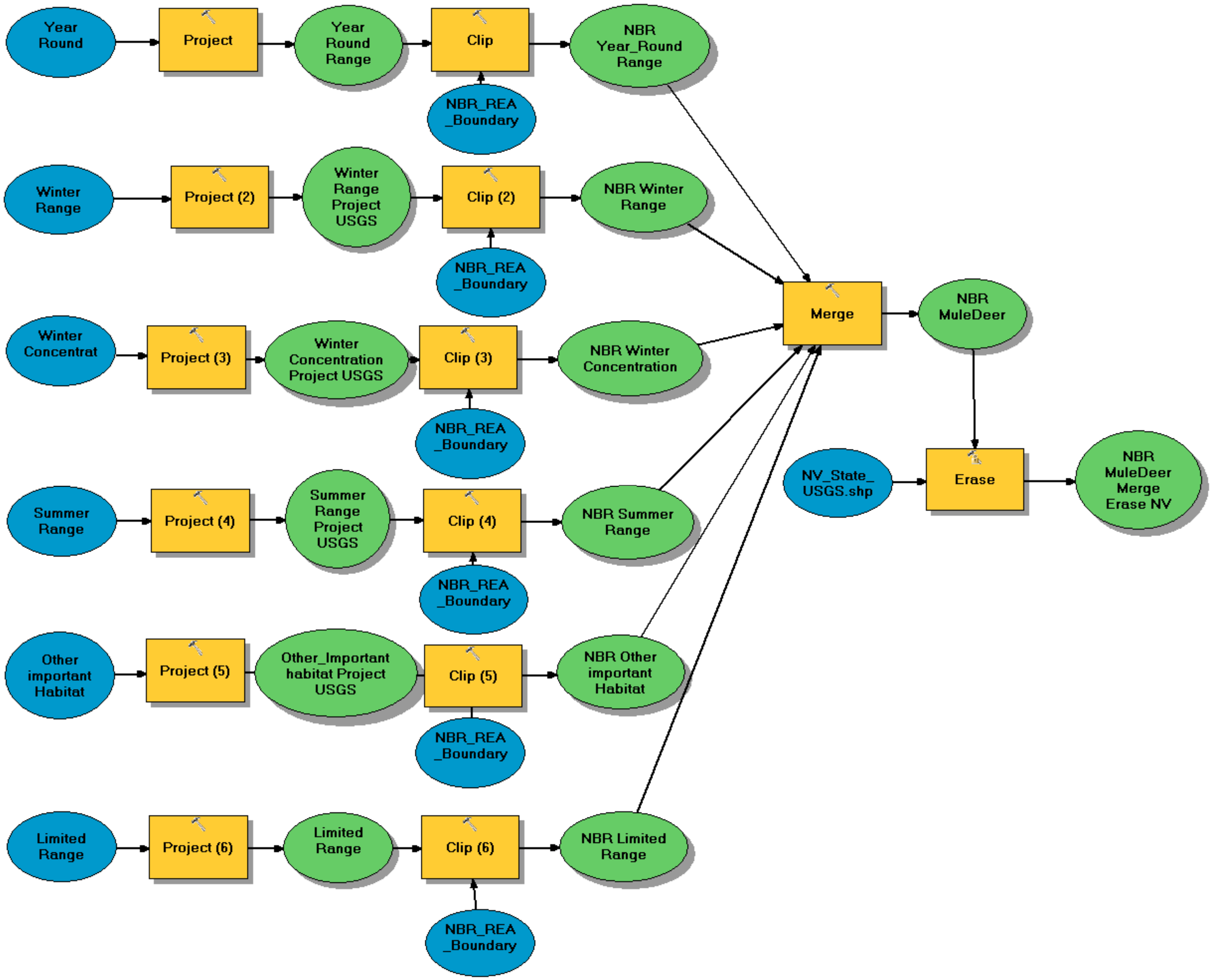


Figure 2.2.2.2-1 GIS Process Model for merging WAFWA Mule Deer

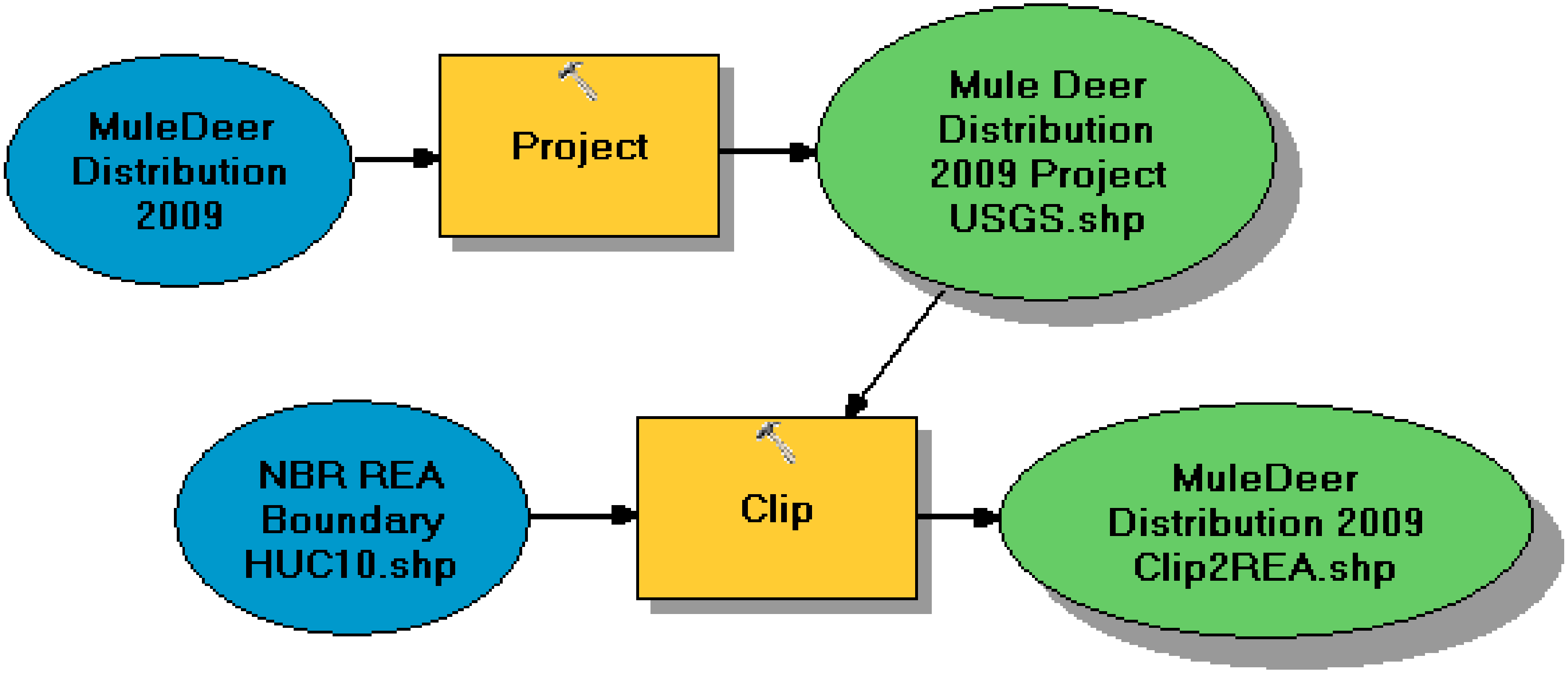


Figure 2.2.2.2-2 GIS Process Model for Preparing NDOW Mule Deer Layer

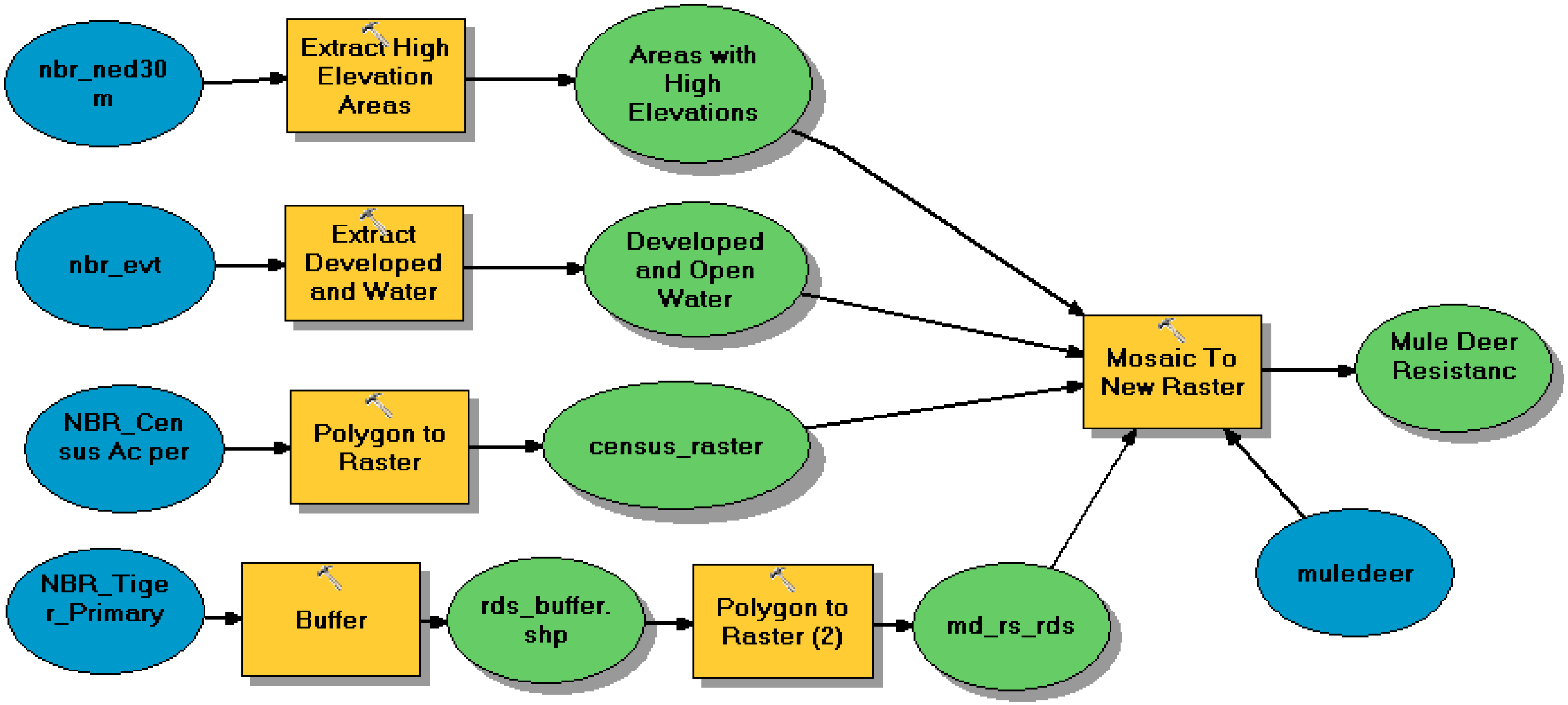


Figure 2.2.2.2-3 GIS Process Model for Creating a Resistance Layer

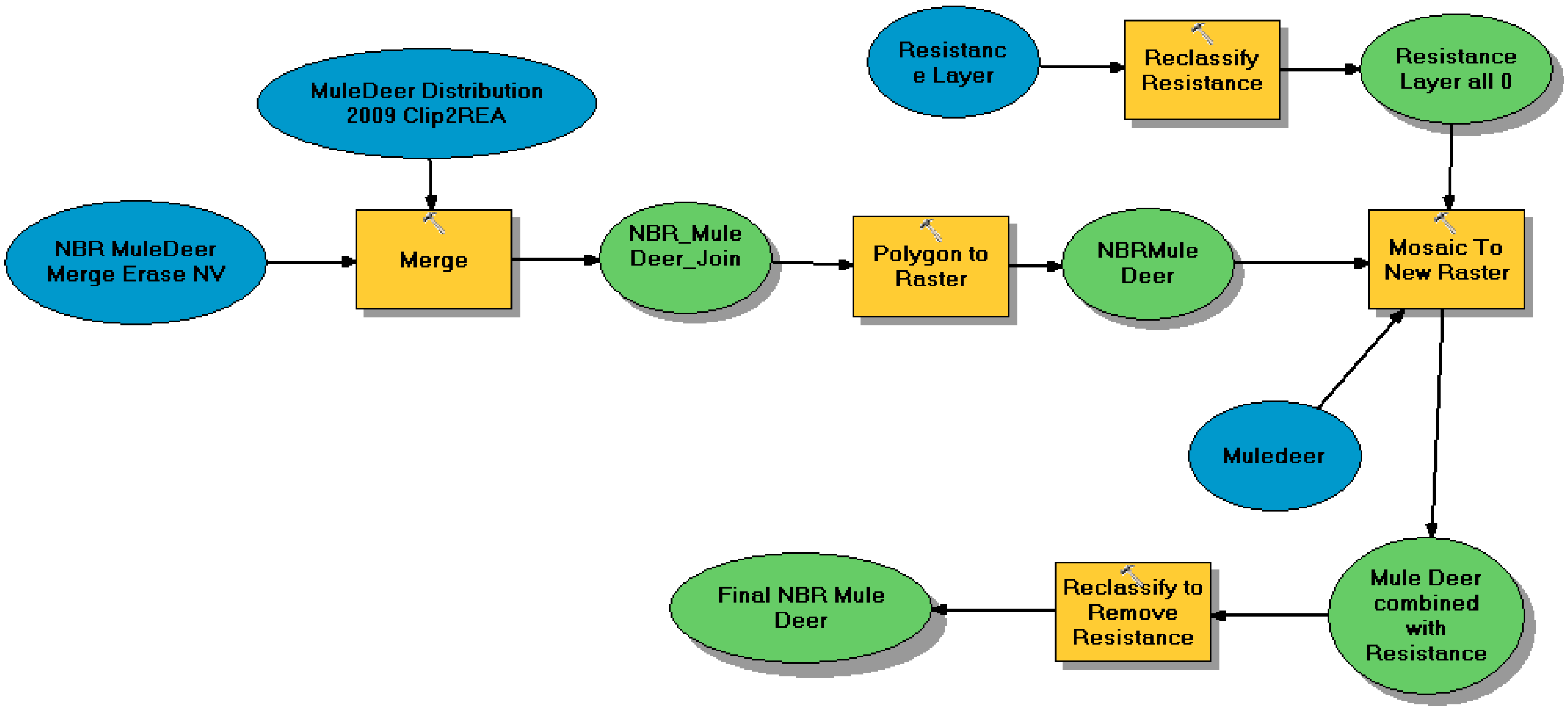


Figure 2.2.2.2-4 GIS Process Model for Assembling Final Mule Deer Layer

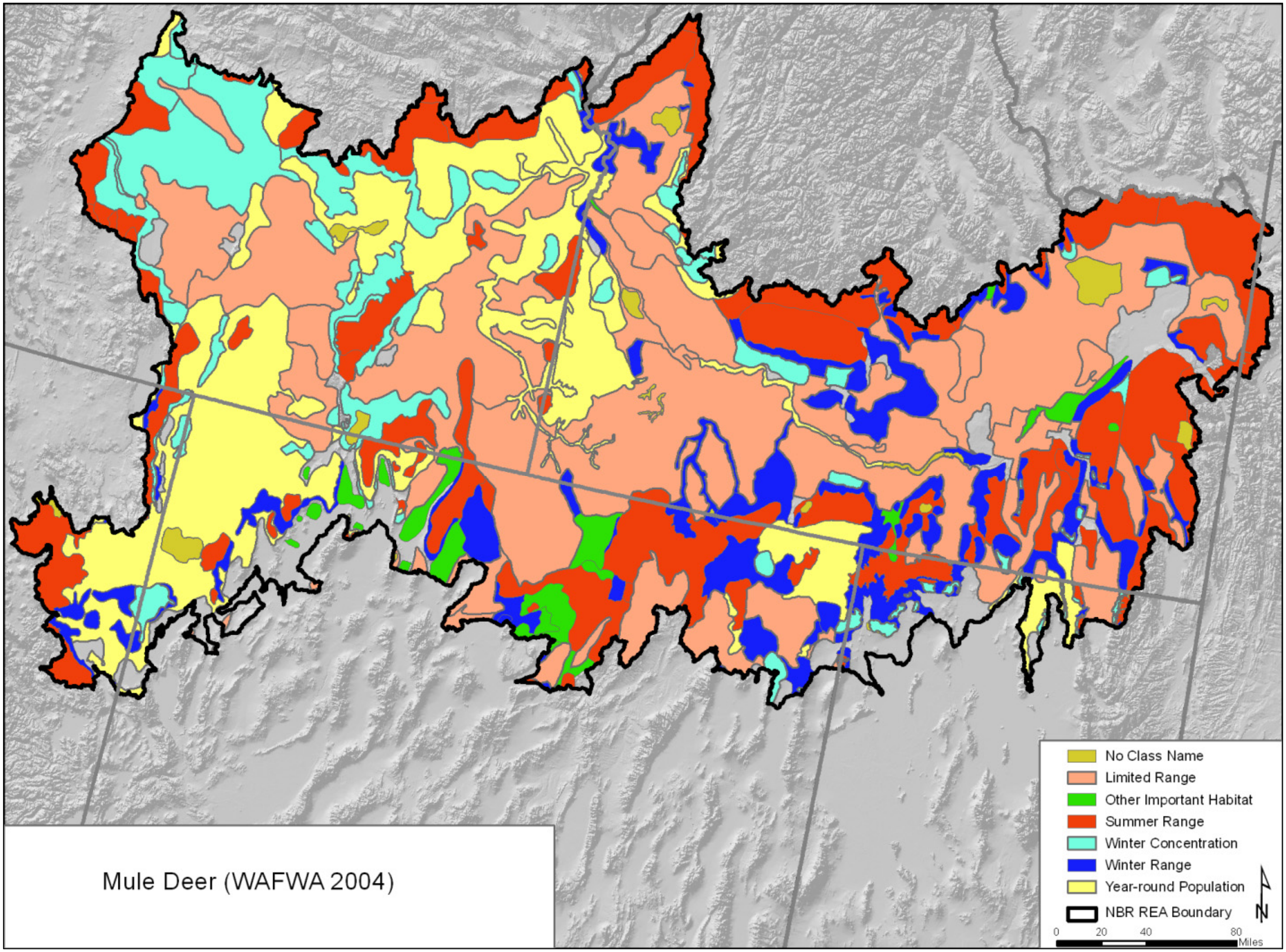


Figure 2.2.2.3-1 Mule Deer Distribution (WAFWA 2004)

Mule Deer NDOW

Figure 2.2.2.3-2 shows the NDOW 2009 mule deer layer clipped to the NBR ecoregion. This layer was merged with the WAFWA layer to allow the use of the updated NDOW data for the Nevada part of the ecoregion.

Mule Deer Resistance Layer

Figure 2.2.2.3-3 shows the resistance mule deer layer that will be subtracted from the merged WAFWA and NDOW mule deer layer in Figure 2.2.2.3-2. The areas of resistance will erase some of the areas or break them into pieces such as being fragmented by primary roads.

Final Ecoregion Mule Deer Layer

Figure 2.2.2.3-4 shows the final output layer for Mule Deer for the Northern Basin and Range and Snake River Plain (NBR) ecoregion. The WAFWA and NDOW layers have been merged and the resistance layer has been erased. Examining the final data layer there appear to be some differences in habitat classifications between WAFWA and NDOW that appear as edge effects along the Nevada border with its neighboring states. Some of these differences could be mitigated by cross walking or homogenizing some of the classifications such as Winter Concentration and Winter Critical. Other categories could be removed such as the no class name (no attributes given for the habitat), Agricultural or Other Important Habitat.

2.3 Coarse Filters Model Example

The AMT thought it would be useful to also show an example of a coarse filter vegetation CE. The example below is Sagebrush. The AMT wanted sagebrush to be expanded to focus on three different species of sagebrush that are predominant in the area, low sagebrush, Wyoming / Basin big sagebrush and mountain big sagebrush.

2.3.1 Sagebrush

2.3.1.1 Extracting Three Types of Sage Brush

To keep consistent with the Central Basin and Range, the AMT recommended using Northwest REGAP and Southwest REGAP as the primary data source for Sagebrush. Since California is not included in either of those mapping efforts, LANDFIRE was used for that portion of the ecoregion. The three types of sagebrush being focused on are mountain big sagebrush, low sagebrush and Wyoming / Basin big sagebrush. Wyoming and Basin big sagebrush were grouped together because they are commonly mapped together in the ReGAP and LANDFIRE sine they have similar spectral signatures. Basin big sagebrush occurs in deep, well-drained soils in lower elevation portions of the sagebrush belt, Wyoming big sagebrush occurs on shallower, more xeric soils in a similar elevational range. Precipitation is roughly 10-14 inches for both types. Compared to mountain big sagebrush, which grows at higher elevation sites with more precipitation, both Wyoming and Basin big sagebrush are slow to recover from fire and highly susceptible to cheatgrass invasion.

2.3.1.2 GIS Process Model

A GIS process model was created to extract the three different types of sagebrush from the three different data sources (NW REGAP, SW REGAP and LANDFIRE). Since the NBR ecoregion slightly extends into Wyoming and also touches the Montana border, these states were included as well in the NW REGAP. Figure 2.3.1.2-1 shows the GIS process model for extracting, projecting and merging the datasets. The reclassify step extracts from the data layer vegetation codes that distinguish between the three types of sagebrush. The individual pieces are then overlaid to show distribution for each individual state.

2.3.1.3 Sagebrush Distribution in the Ecoregion

The final map product for the three types of sagebrush is shown in Figure 2.3.1.3-1. The distribution appears to follow elevation fairly well with the mountain sagebrush in the higher elevation areas and most of the ecoregion containing Wyoming /Basin big sagebrush.

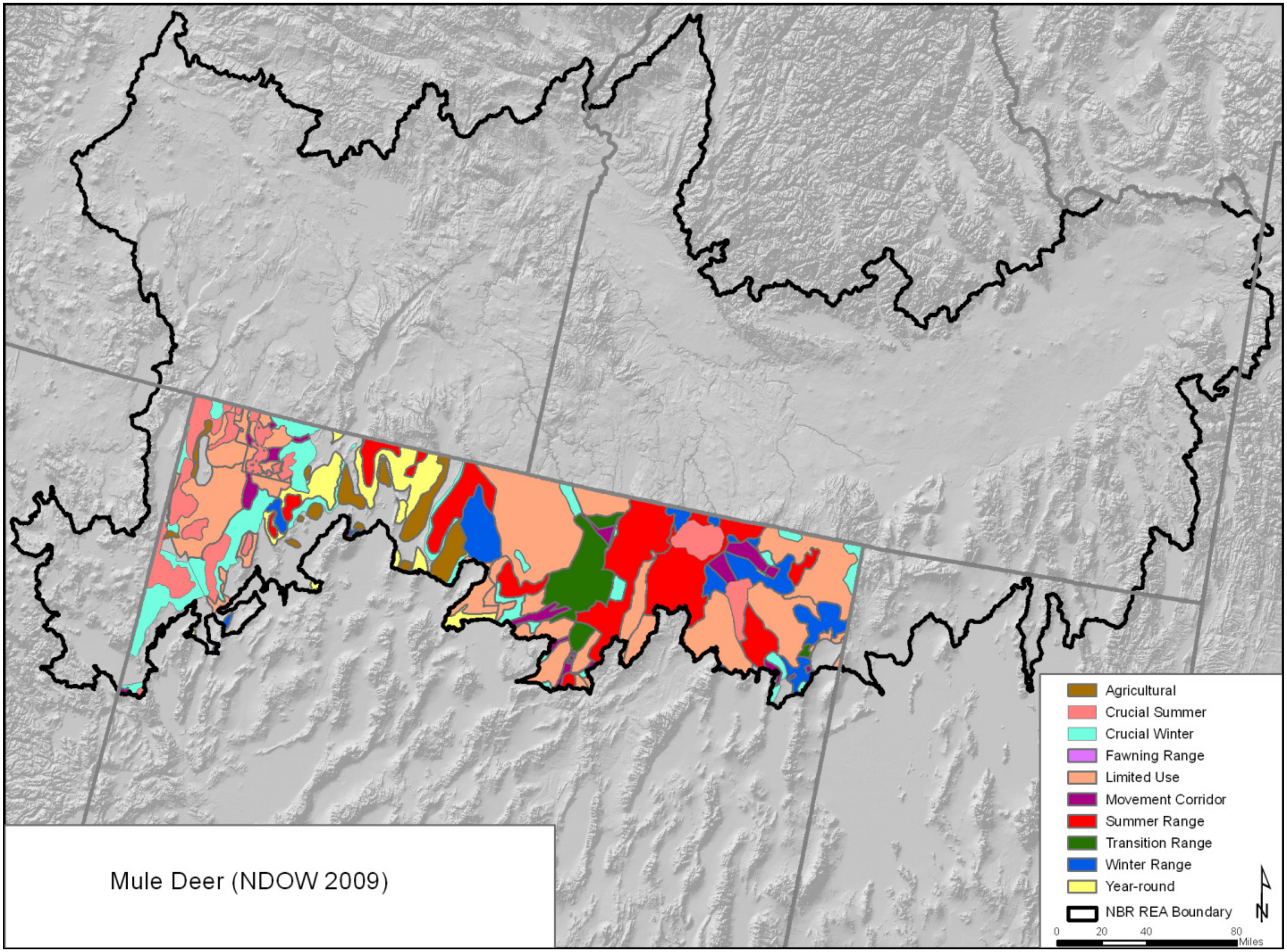


Figure 2.2.2.3-2 Mule Deer Distribution NDOW 2009 Clipped to Ecoregion

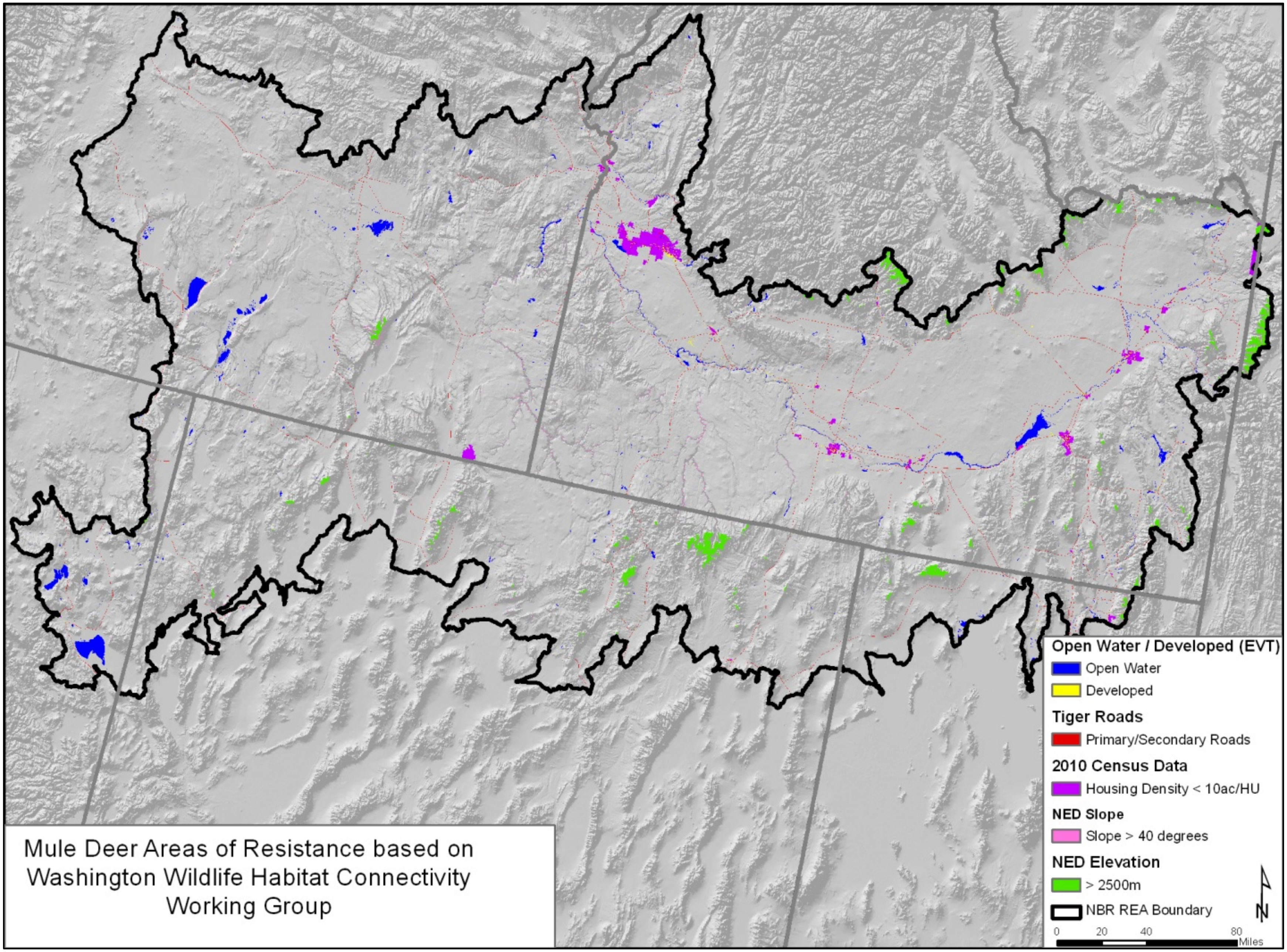


Figure 2.2.2.3-3 Mule Deer Resistance Layer

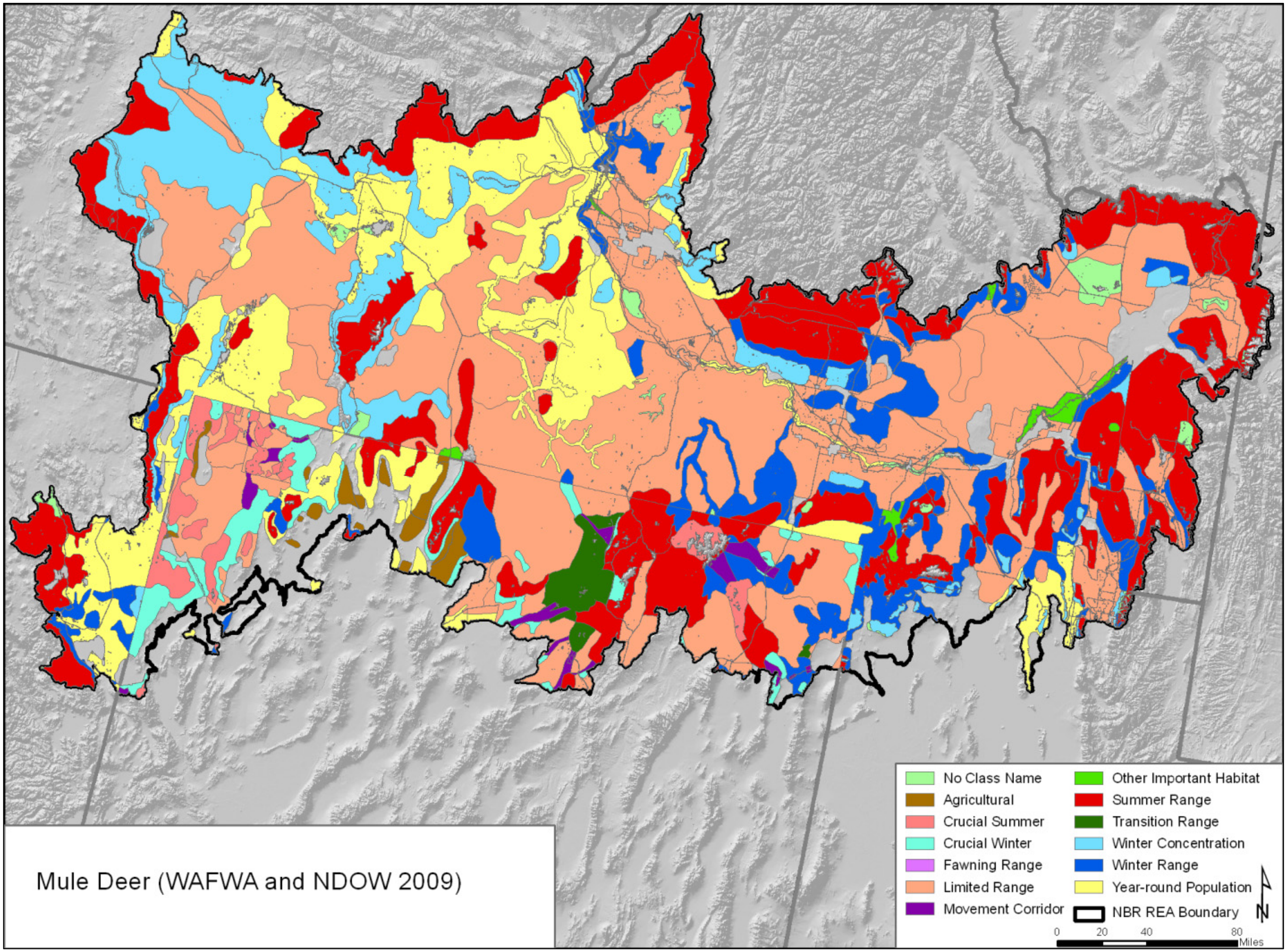


Figure 2.2.2.3-4 Final NBR Mule Deer Layer

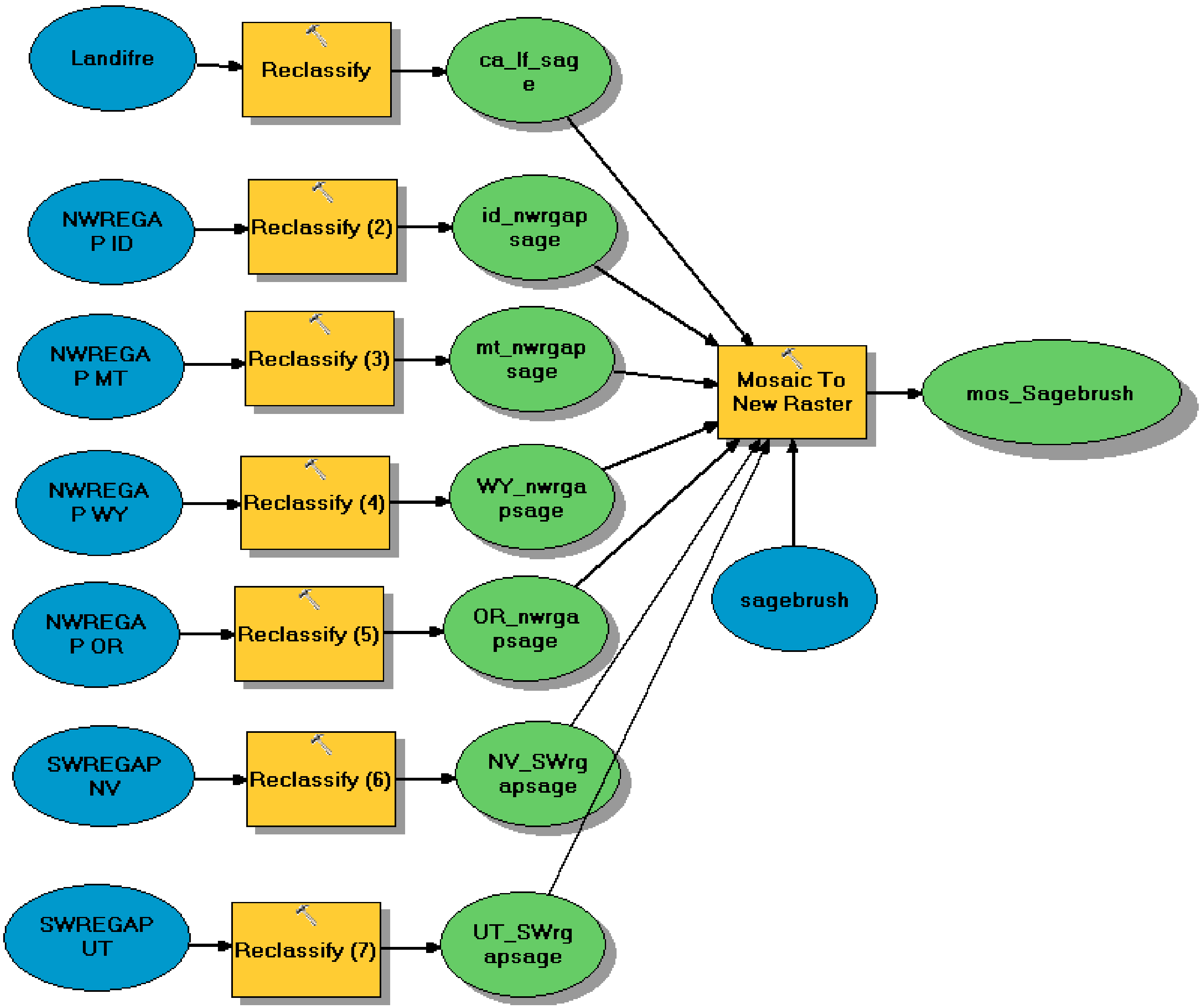


Figure 2.3.1.2-1 GIS Process Model for Extracting the Three Species of Sagebrush

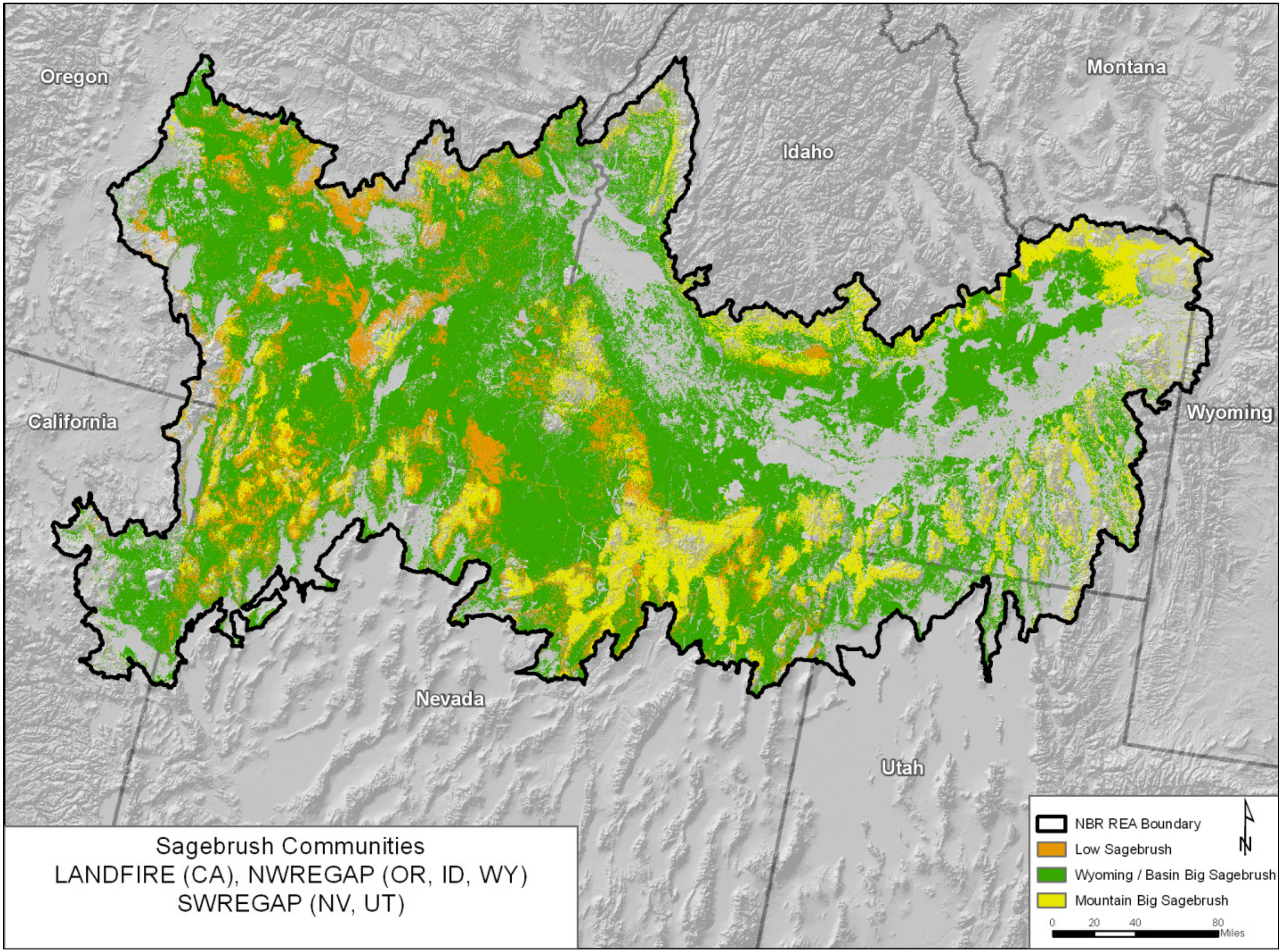


Figure 2.3.1.3-1. Final Map Product for the Three Types of Sagebrush

3 Modeling Change Agents

3.1 Introduction

Change Agents (CAs) are natural or anthropogenic disturbances that influence the current and future status of CEs. The initial CAs for this ecoregion were outlined by the Assessment Management Team (AMT) in the Statement of Work (SOW). The Rapid Ecological Assessment (REA) process focuses on regionally significant CAs that operate and impact on large scales and not on a site-by-site basis. The following is the list of CAs that will be included in the REA:

Change Agents
Climate Change
Development
Urban and Exurban, Transportation and Energy (including Renewables)
Agricultural and Mineral Extraction
Recreation and Military Expansion
Rangeland Treatments and Grazing
Major Hydrologic Alterations
Invasive Species (Terrestrial and Aquatic)
Wildland Fire

3.2 Climate

3.2.1 Introduction

The goal for the REA is to have an understanding of how predicted changes in climate may affect Management Questions (MQs) region-wide and for managers to be able to determine how some characteristic of the climate at a particular location contributes to determining appropriate management actions and whether a CE can exist there now and in the future. It is understood that there will be a number of factors other than climate that contribute to the current or future distribution of CEs. Therefore, a method of assessing the small number of important characteristics of current and future climate at that location is necessary to relate that information to other ecological factors that control the distribution of the species or community (Fagre et al. 2009, Littell et al. 2010). In most cases, it is not known how or even if the various climatic characteristics and ecological characteristics at a specific site are important to the distribution of the CE so what is required are tools to help managers make a first educated guess that is understood to be only approximate and would be refined in the future with additional data.

Models, whether physical, statistical, mathematical, computer simulations, or various combinations of those different model types are designed, constructed, and intelligently used to help answer "what if" questions where the desired objective is inaccessible because it is distant in time and/or space or because there are a large number of objects that have some desired expected characteristic (mean, median, etc) with a desired range of variation around the expected characteristic. Individual models produce outputs that can either be a single value (deterministic: i.e. you give it one set of inputs and when run it, you always get the same result), a range of values (probabilistic: i.e. you give it exactly the same inputs each time you run it but the model may produce different results each time). Probabilistic models are designed to generate variable output, or some form of unpredictable output (extreme or chaotic events: i.e. you give the model one set of inputs, run it, and get very different results each time). Combinations of the various types of models as sub-models of a larger model or combining them as a chain of models can also significantly affect the result.

Two classes of predictive climate models are required for the REA:

- coarse scale spatial resolution Global Climate Model (GCM) output converted into fine scale spatial resolution for temperature or precipitation using the Parameter-elevation Regressions on Independent Slopes Model (PRISM), and;
- coarse scale spatial resolution GCM output converted into medium scale spatial resolution for a number of climatic variables using the USGS Regional Climate Model (RegCM) for the region of the REA.

3.2.2 Current Climate Models

PRISM is a model that uses historical data from weather stations and follows a coordinated set of rules, decisions, and calculations that are typically used by climatologists to create a climate map. Using a weighted linear regression for each station it interpolates the data across the landscape using the grid square size set in the analysis. The weight is the sum of the weights specified for distance, elevation, cluster, vertical layer, topographic facet, coastal proximity, and effective terrain (Daly and Johnson 2008). PRISM's spatial resolution is approximately 4x4 km but 800x800 m data is available for the specific timeframe of 1971 – 2000. Currently only monthly and annual minimum, maximum, and mean temperature, monthly and annual mean diurnal temperature range, and monthly and annual mean total precipitation are available outputs from PRISM. The NCEP model predicts and extrapolates a range of climatic variables but at a medium spatial scale resolution of 32 x 32 km resolution and its data are generally downscaled (discussed later) for incorporation into regional climate models (RCMs).

3.2.3 Future Climate Models

There are approximately 50 GCMs that are well documented but three are required for use in the REA (ECAMS5, GMA2, and Geophysical Fluid Dynamic Laboratory [GFDL] CM2.0). All GCMs divide the earth into four compartments: atmosphere, terrestrial, sea ice, and oceans but differ in how much complexity they simulate those four compartments (e.g. the atmosphere can be 6,000 to 15,000 grid squares in extent on the earth's surface and 12 to 56 layers deep), how sensitive they are to the drivers of climate, and how sensitive they are to anthropogenic changes (Ray 2008, Mote and Salathé Jr. 2010, Ray et al. 2010). While any level of anthropogenic changes could be simulated in the models, most models have been run for three CO_2 emission scenarios over a 100 year time period (B1=low CO_2 emissions, A1B=medium CO_2 emissions, and A2=high CO_2 emissions which is also known as "business as usual") so that they can be compared against those standards. The REA requires the use of the A2 scenario. Regardless of the emission scenario, the output of the models is similar until the mid-century evaluation point required for the REA when they begin to diverge (Ray 2008, Mote and Salathé Jr. 2010, Ray et al. 2010). After mid-century the differences in climate predictions arise partially due to different CO_2 emissions levels but most of the differences are due to differences in the models themselves (Ray 2008, Mote and Salathé Jr. 2010, Ray et al. 2010). Unless there is a particular need to use a single model, the next choice is how many models to run, how to select which models to run, and how to use the model output from multiple models (statistical or ensemble techniques) and there are no hard and fast rules (Mote and Salathé Jr. 2010). For the REA there is the option of using the individual results or a simple average of results of the three GCMs as incorporated into PRISM and RegCM, which is described below. GCMs provide useful predictions of temperature changes (at a particular altitude above the influences of the earth's surface) but not very useful predictions in precipitation changes (because of interactions with the earth's surface) so GCM temperature predictions are used in more spatially localized models (downscaled - which is discussed later). The output of the GCMs produces averages and variability that mimic, in a general way, large-scale climatic events such as the El Nino/La Nina pattern. The temporal resolution of GCMs is generally three-month seasons and their spatial resolution is approximately a 120x120 km grid square (Ray et al. 2010). RegCM was developed by the National Center for Atmospheric Research (NCAR) in the late 1980s (Elguindi et al. 2010). RegCM is characterized as a dynamic downscaled regional climate model. It is dynamic because it is composed of a number of mathematical equations representing physical factors that act on climate near the surface of the earth where local effects such as mountain ranges can exert influence on climate. This explicit influence of surface topography and other factors is in contrast to GCMs that use similar equations but look at broad-scale atmospheric and oceanic circulation patterns at an altitude that is generally above the influence of surface features such as mountain ranges.

In addition to the CO_2 scenario there are a number of other conditions and parameters that must be set in RegCM, PRISM (Daly and Johnson 1998), and NCEP (Messinger et al. 2006; Saha et al. 2010) and those choices will have a significant effect on model output. Perhaps the most important parameter is the land surface and vegetation classification or Common Land Model that uses any of 25 USGS vegetation categories which do not necessarily correspond in classification or extent to the vegetation CEs. The result of the model's vegetation requirement is that the model may not accurately depict changes in a species true habitat.

3.3 Development

The objective of assessing effects of development-related CAs is to identify areas in which CEs are currently affected by CAs and areas in which CEs are at risk from CAs in the future. Table 3.3-1 summarizes the data categories related to human development as a CA that we depict in models for fine-filter CEs.

3.3.1 Future Development Scenarios

One of the models available for predicting future growth scenarios is the Integrated Climate and Land Use Scenarios (ICLUS). The spatial allocation model used within ICLUS is the Spatially Explicit Regional Growth Model (SERGoM) developed by Theobald (2005). Unlike the majority of land use change models focusing on urban growth, SERGoM uses and models a full continuum of housing density, from urban to rural. This allows a more comprehensive examination of growth patterns, since exurban/low-density development has become more prevalent in the past decades and is an important aspect of possible future growth scenarios (EPA 2010). Figure 3.3.1-1 shows the Toolbox developed for use in ArcGIS.

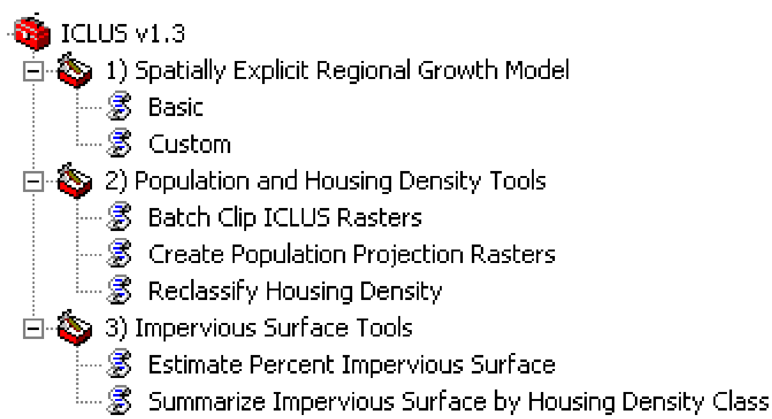


Figure 3.3.1-1. Toolbox for ICLUS (EPA 2010)

Table 3.3-1. Human Development Change Agents

Change Agent Category	Change Agent	Effect Pathways	Interactions with other CAs	Affected CEs
• Urban development • Exurban residential • Industrial development	• Dwellings, commercial and industrial facilities and associated land clearing)	• Habitat loss: Land cover conversion from native ecological systems to human-dominated ecological systems • Habitat degradation: Fragmentation of suitable habitats, spread of invasive species, increased ignition sources, contaminant, nutrient, and sediment runoff into aquatic systems. • Behavioral/avoidance effects on wildlife species due to increased human access into native ecosystems • Population effects on wildlife species due to increased risk of mortality, disruption of reproductive cycles	• Transportation and transmission line/corridors • Fire • Invasive species	• Many coarse filter CEs: Increasingly foothills and lower montane ecological systems • Many fine filter CEs
• Transportation	• Roads, railroads, two track roads	• Habitat loss: Land cover conversion from native ecological systems to transportation corridors and development sites. • Habitat degradation: Fragmentation of suitable habitats, spread of invasive plant seed vectors, increased ignition sources, contaminant and sediment runoff into aquatic systems, increased mass wasting, channelized or constrained stream flow. • Behavioral/avoidance effects on wildlife species due to increased human access into native ecosystems for fire suppression, energy site access, and recreation. • Population effects: Increased risk of mortality for wildlife species	• Urbanization (growth-induced expansion of transportation infrastructure) • Fire	• Greater sage-grouse • Mule Deer • Golden eagle • Coldwater fish assemblage • Many coarse-filters
• Transmission lines/ corridors	• Electric transmission; water, gas pipelines and associated land clearing	• Habitat loss: Land cover conversion from native ecological systems to transmission corridors. • Habitat degradation: Habitat fragmentation, increased human access into native ecosystems for infrastructure construction and maintenance. • Population effects: Increased risk of mortality for wildlife species: collision, electrocution, and increased predation	• Urbanization (growth-induced expansion of infrastructure) • Fire	• Golden eagle • Greater sage-grouse • Many coarse-filters
• Energy development	• Existing and leased oil and gas extraction sites and facilities • Existing and leased renewable energy sites and facilities (wind, solar, geothermal)	• Habitat loss: Land cover conversion from native ecological systems to transmission corridors. • Habitat degradation: Habitat fragmentation and loss of connectivity, increased human access into native ecosystems for energy development, corridors for invasive species, ignition sources, groundwater extraction, discharge of pollutants into aquatic systems. • Population effects: Increased risk of mortality for wildlife species due to collisions with infrastructure, behavioral/avoidance due to increased human access into native ecosystems, disruption of reproductive cycles.	• Transportation • Transmission lines/corridors • Fire	• Many coarse-filter CEs and fine-filter CEs (pronghorn, mule deer, Greater sage-grouse, Golden eagle)

Table 3.3-1. Human Development Change Agents

Change Agent Category	Change Agent	Effect Pathways	Interactions with other CAs	Affected CEs
• Agriculture	• Cropland, pastures, orchards • Surface water diversion (irrigation withdrawals) • Water quality effects • Rangeland Improvements	• Habitat loss: Land cover conversion from native ecological systems to agricultural systems • Habitat degradation: Runoff conveying nutrient, sediment and contaminant loads	• Invasive species	• Many coarse filter CEs • Fine filter CEs: • Greater sage-grouse and coldwater fish
• Mineral extraction	• Buildings, other structures, and associated land clearing	• Habitat loss: Land cover conversion from native ecological systems to human-dominated ecological systems • Habitat degradation: Fragmentation of suitable habitats spread of invasive species, increased ignition sources, contaminant, nutrient, and sediment runoff into aquatic systems. • Population effects: Increased risk of mortality for wildlife species, behavioral/avoidance due to increased human access into native ecosystems, disruption of reproductive cycles.	• Transportation	• Many coarse-filter CEs and fine-filter CEs
• Major Hydrologic alterations	• Groundwater extraction, wells(municipal and industrial uses) • Surface water diversion (municipal, industrial or mining uses) • Flood control, dams and reservoirs, weirs, channelization, levees	• Habitat loss and degradation: Loss of wetlands and riparian ecological systems extent and suitability due to reduced water table and surface water flows. • Habitat degradation for aquatic biota due to hydrograph (flow and depth) changes resulting from impoundments and channelization. • Population effects: Barriers to migration for aquatic biota, genetic isolation	• Agriculture, • Urban/industrial development • Energy development (water withdrawals and discharge of pollutants) • Mineral Extraction (water withdrawals and discharge of pollutants) • Fire regime (decreased fuel moisture) • Climate change	• Many coarse-filter CEs and fine-filter CEs

The SERGoM model's ability to allocate a full continuum of housing density from urban to rural allows a more comprehensive examination of growth patterns, since exurban/low-density development generally has a footprint 10 times as large as urban areas and is growing at a faster rate than urban areas (Theobald 2005). In addition, SERGoM forecasts housing development by establishing a relationship between neighboring housing density, population growth rates, and transportation infrastructure (Theobald 2005). SERGoM also incorporates a detailed layer of developable/un-developable areas that incorporates public protected lands as well as private protected lands (e.g., through conservation easements). Finally, population forecasts are a principal driver of SERGoM; in the model, population growth is converted to housing units, which are spatially allocated in response to the spatial pattern of previous growth and transportation infrastructure (EPA 2010). Figure 3.3.1-2 shows the SERGoM data inputs and modeling process.

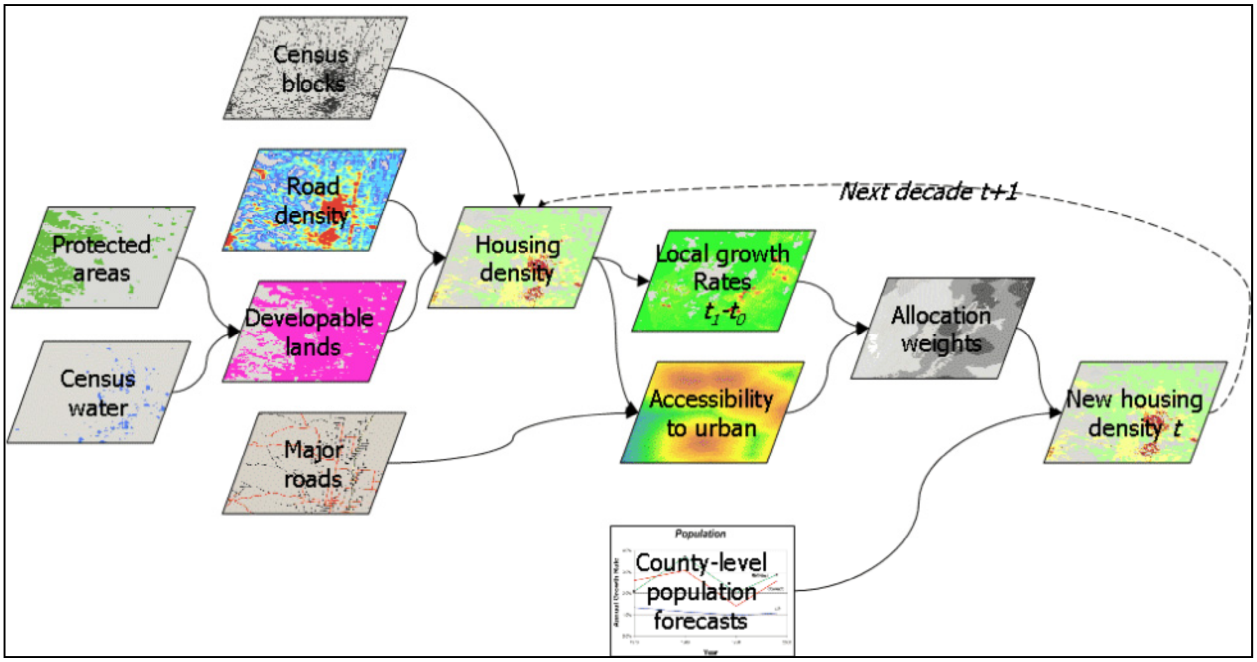


Figure 3.3.1-2. SERGoM data inputs and modeling process

3.4 Grazing

3.4.1 Introduction

The USGS has probably the most up to date and spatially accurate dataset for grazing in the ecoregion based on their work published on OFR 2011-1263 (Veblen *et al.* 2011). The USGS did a lot of data mining with the BLM national office along with state and field offices to gather the data and topological clean up to remove overlaps and gaps. At the AMT meeting held on March 15th 2012, grazing was discussed along with the challenges in trying to create a model with a limited amount of data. It was decided that modeling efforts would focus on areas within a grazing intensity and vegetation resiliency.

3.4.2 GIS Process for Analyzing Grazing Intensity and Vegetation Resiliency

The main data sources discussed for including in the model were:

Grazing Allotments (BLM)

Grazing Allotments spatial data is available showing locations of allotments. The spatial data usually doesn't contain Animal Unit Month (AUM), number of livestock, or type of livestock. That information is available currently in report format from the BLM's Rangeland Administration System. BLM also provided a Sheep and Goat grazing allotments dataset for use in comparing overlap with Bighorn sheep range. Figure 3.4.2-1 shows the location of grazing allotments with the NBR ecoregion.

Slope

Slope is calculated from the National Elevation Dataset (NED). Areas with high slope may be more prone to erosion, less vegetated and less suitable for livestock to traverse.

Water Sources

A requirement for a grazing allotment is a source of water. This source can be a natural spring or seep, lake, pond, reservoir, well, or water can be trucked or piped in. Since all animals need water, areas around water sources may experience additional grazing pressure, erosion and other effects. On an ecoregion scale, it may be difficult to locate the water source for every allotment. Data sources for water would be NHD for springs and seeps wells, lakes, ponds and other open water. Figure 3.4.2-2 shows the NHD spring seeps and wells within the ecoregion. Based on information from the AMT, some allotments have extensive water pipes to move water around an allotment which probably wouldn't be available as a spatial dataset.

Roads

Roads could be used to truck water into allotments so proximity to roads could be an indicator for a water source. Since not all grazing allotments require water to be trucked in, roads should carry less weighting as compared to other items in the model. Roads could also be erased if they are within a certain distance (1km for example) from a known water source so that they aren't included. The primary source of road spatial data is TIGER 2010 roads layer.

Soils

The primary source of soils data is the Natural Resource Conservation Service STATSGO spatial layer. It contains some attributes such as the K value that measures soils ability to be affected by water erosion and the Wind Erosion Group which identifies soils susceptible to wind erosion.

GIS Process Model

Figure 3.4.2-3 shows an example of a GIS process model to determine areas that may have higher grazing intensity or lower vegetation resiliency. This model assumes that areas around water sources may be more intensively grazed. It also includes components such as slope, soil erosion and proximity to roads. The model takes five components and extracts areas for each that, when combined, could model areas at higher grazing intensity and lower vegetation resiliency. Some features such as water sources and roads could be buffered to show multiple classes to model the distance livestock will travel from a water source. Areas with the potential for soil erosion will be overlaid to determine areas near the water sources also contain erodible soils. At AMT Workshop 4, it was agreed that there wasn't enough scientific information for determining accurate distance from water, slope thresholds or accurate data on water sources (water piped in) to run the model in Figure 3.4.2-3. Since the ecoregion is so large and grazing allotments vary in size, terrain and condition, using this model to make general predictions was deemed inappropriate.

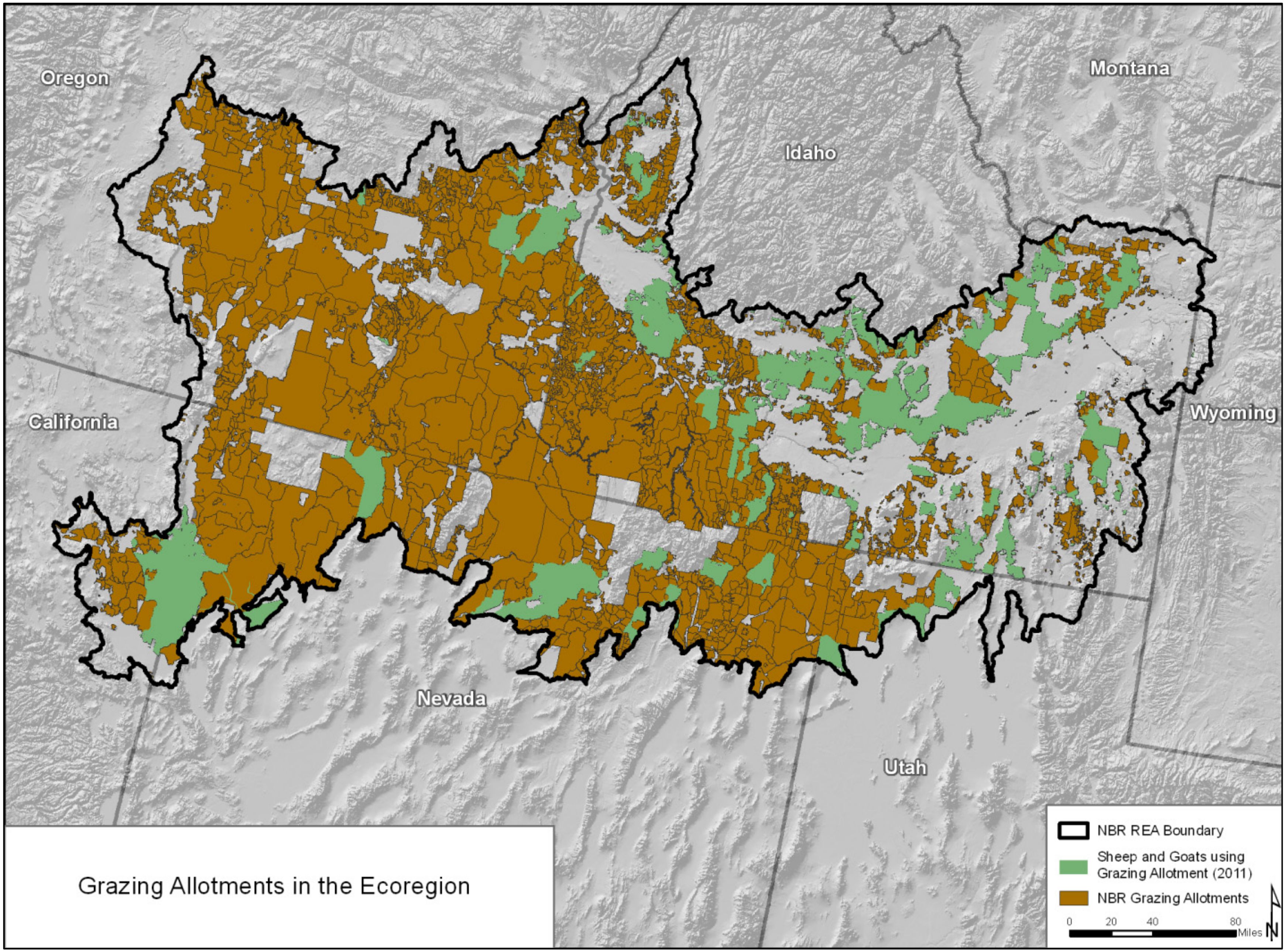


Figure 3.4.2-1 Location of Grazing Allotments within the NBR Ecoregion

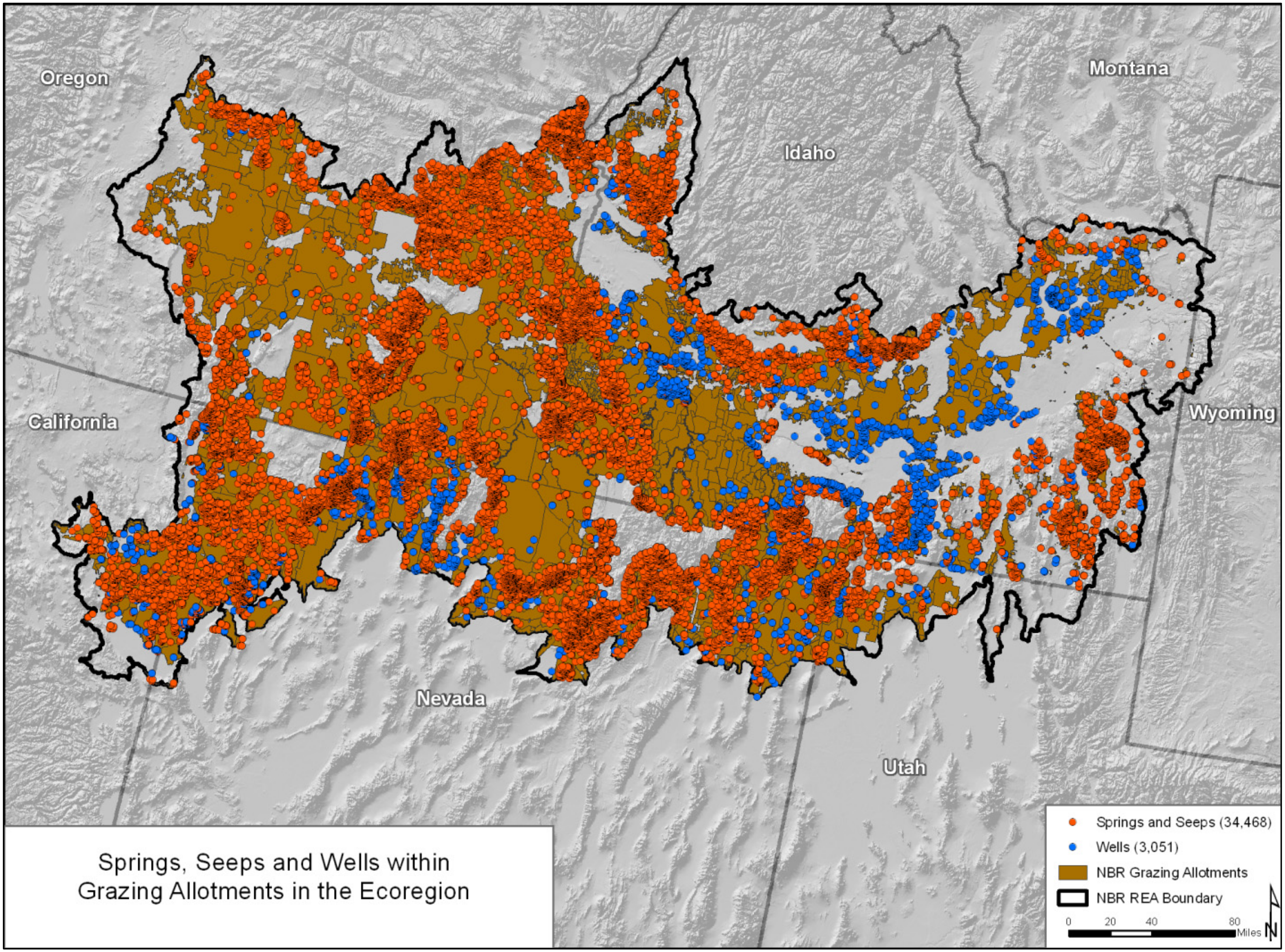


Figure 3.4.2-2 Locations of Springs, Seeps and Wells within Grazing Allotments in the NBR Ecoregion

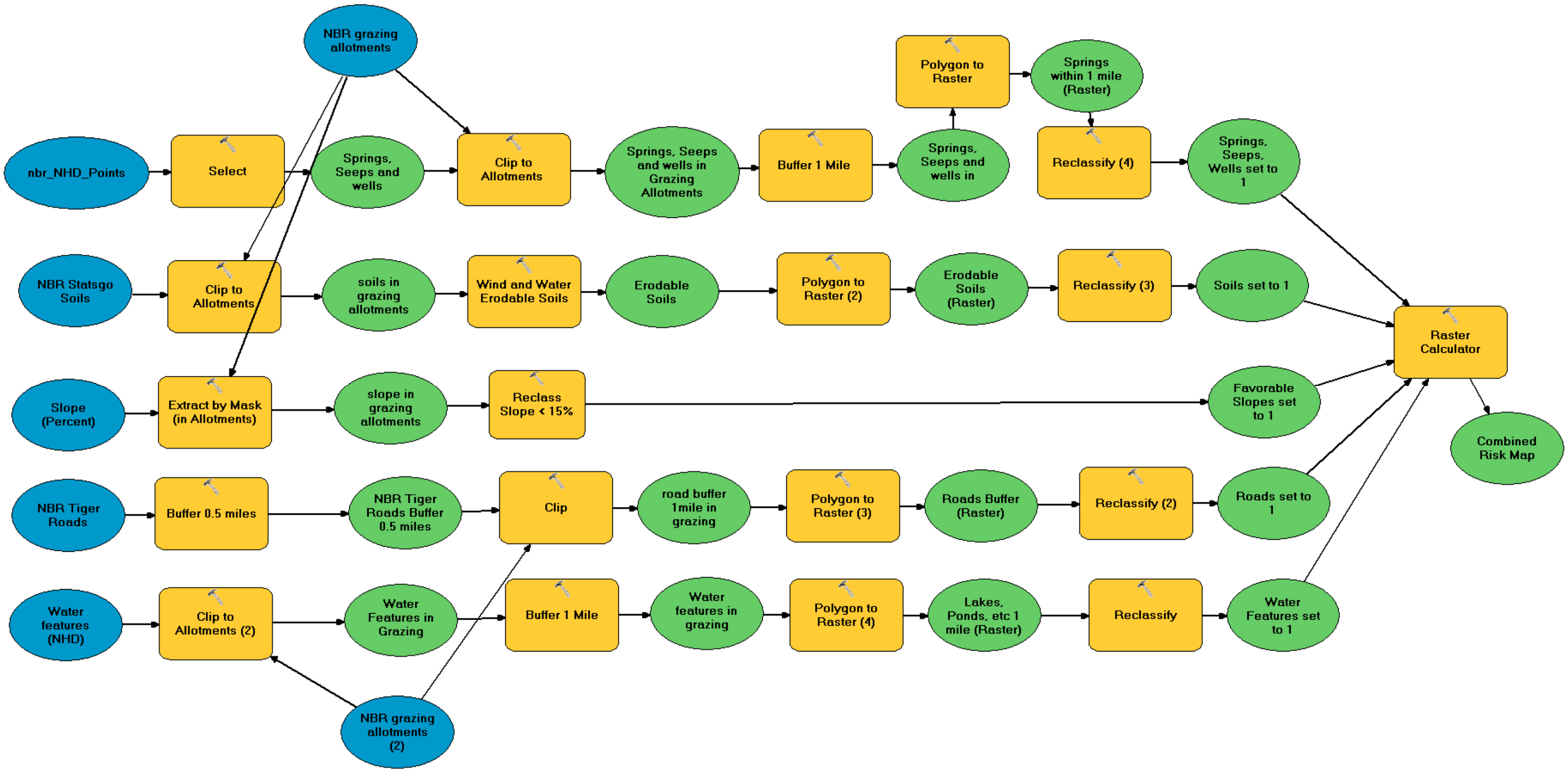


Figure 3.4.2-3 Proposed GIS Process Model for Grazing Intensity and Vegetation Resiliency (but not used in the REA due to data availability on mechanically provided water sources and distance / slope gradients to use on an ecoregion wide basis)

3.5 Invasive Species

3.5.1 Introduction

Invasive species modeling for a large ecoregion has proven to be challenging mostly due to variability in data across the many states and field offices comprising the ecoregion. In the Northern Great Plains and Middle Rockies ecoregions, the AMT suggested using plant characteristics to attempt to define the risk of invasive species. The following is a similar approach for the NBR ecoregion for the AMT to review that uses elevation, precipitation, soil affinities, roads and vegetation.

3.5.2 Data Sources

The main data source BLM uses for tracking invasive species is National Invasive Species Information Management System (NISIMS). The invasive species occurrences currently within NISIMS can be viewed in Figure 3.5.2-1. The data distribution is fairly well populated for some locations and species but lacking in some regions such as Oregon. Figure 3.5.2-2 is a graph showing the abundance of species observations (minimum 100 occurrences).

3.5.3 Modeling Invasive Species

The GIS process model in Figure 3.5.3-3 shows the method for creating the five layers that will be overlaid to determine the overall risk for a specific invasive species. The model consists of:

- extracting favorable soils from the STATSGO soils,
- buffering TIGER roads,
- extracting favorable elevation tolerance,
- extracting favorable precipitation tolerance,
- extracting favorable vegetation.

The resulting layers are added together to look for areas with increased risk. In Middle Rockies and Northwestern Plains ecoregion, values for elevation and precipitation were given from the AMT's invasive species specialist. Since there were some samples within the ecoregion for the two example invasive species within this memo, Canada thistle and Russian knapweed, elevation and precipitation were extracted using the occurrences within the ecoregion. The precipitation and elevation values were extracted using the Values to Points spatial operation. The resulting values were next exported to Excel for a statistics summary and histogram. When the full range of elevation and precipitation values were used as favorable most of the entire ecoregion was included. To try to remove some of the outliers in the range, the mean plus and minus two standard deviations was used to cover 95% of the sample range. The precipitation mean after subtracting two standard deviations was lower than the actual lowest precipitation value for the ecoregion so only one standard deviation was subtracted.

3.5.4 Example Model Results

The results of the model for Canada thistle and Russian knapweed are shown here. These examples of modeling these invasive species are meant to show concepts and process and will require feedback and guidance from the AMT to find an approach suitable for this ecoregion. Figures 3.5.4.1-1 through Figure 3.5.4.2-7 present the results of the invasive species modeling for Canada thistle while Russian knapweed modeling results are displayed in Figures 3.5.4.2-1 through 3.5.4.2-7

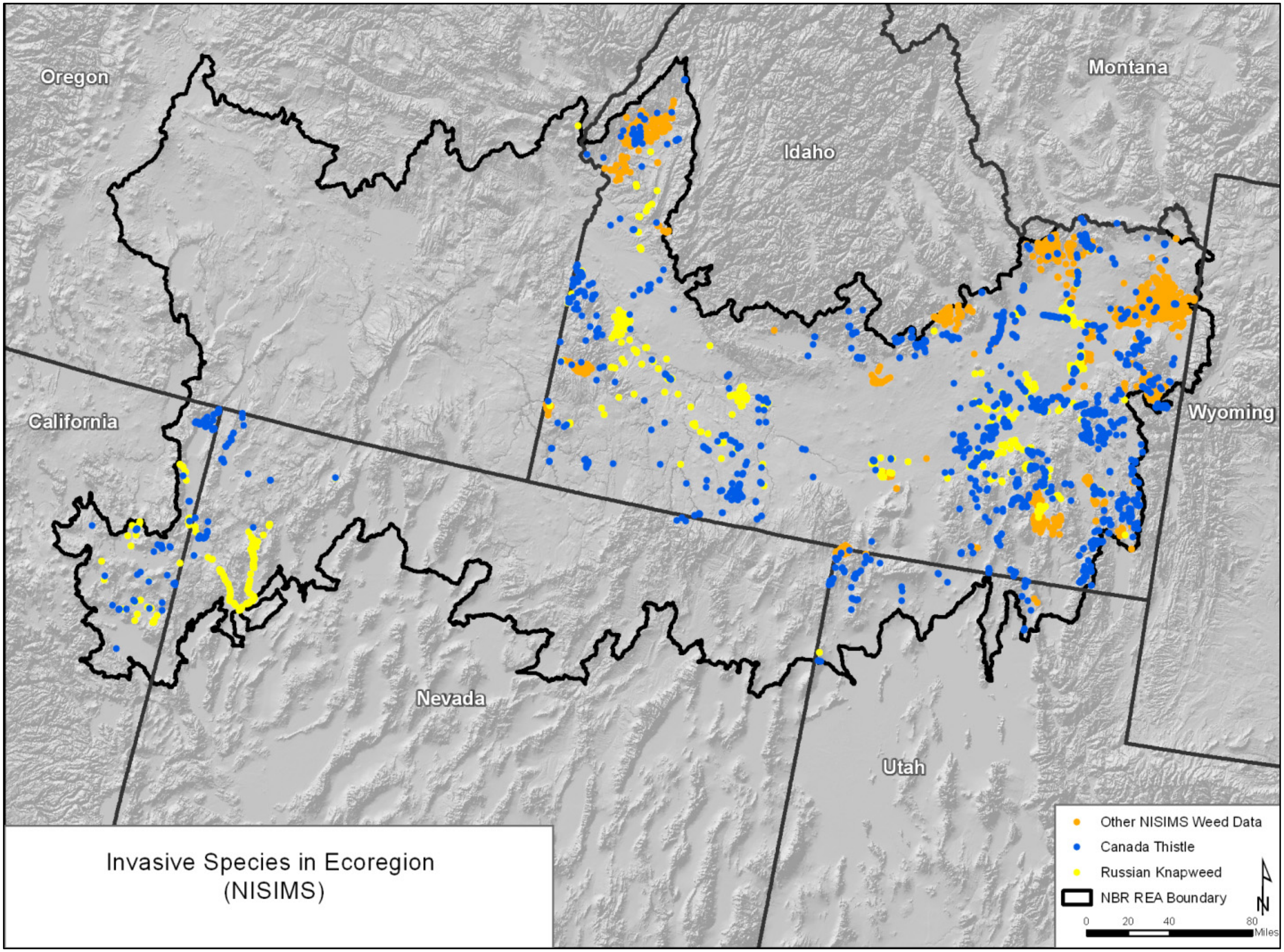


Figure 3.5.2-1 Invasive Species within the Ecoregion (NISIMS)

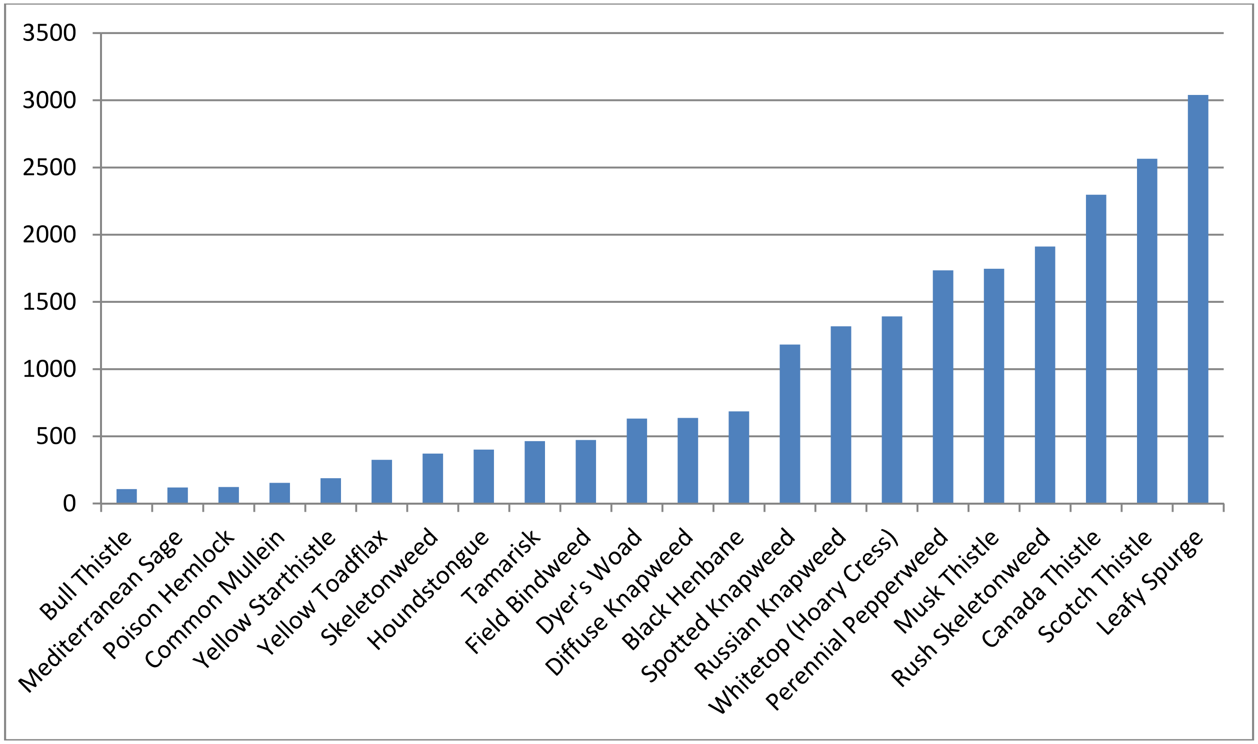


Figure 3.5.2-2 Invasive Species Occurrences in NBR Ecoregion within NISIMS (min 100 occurrences)

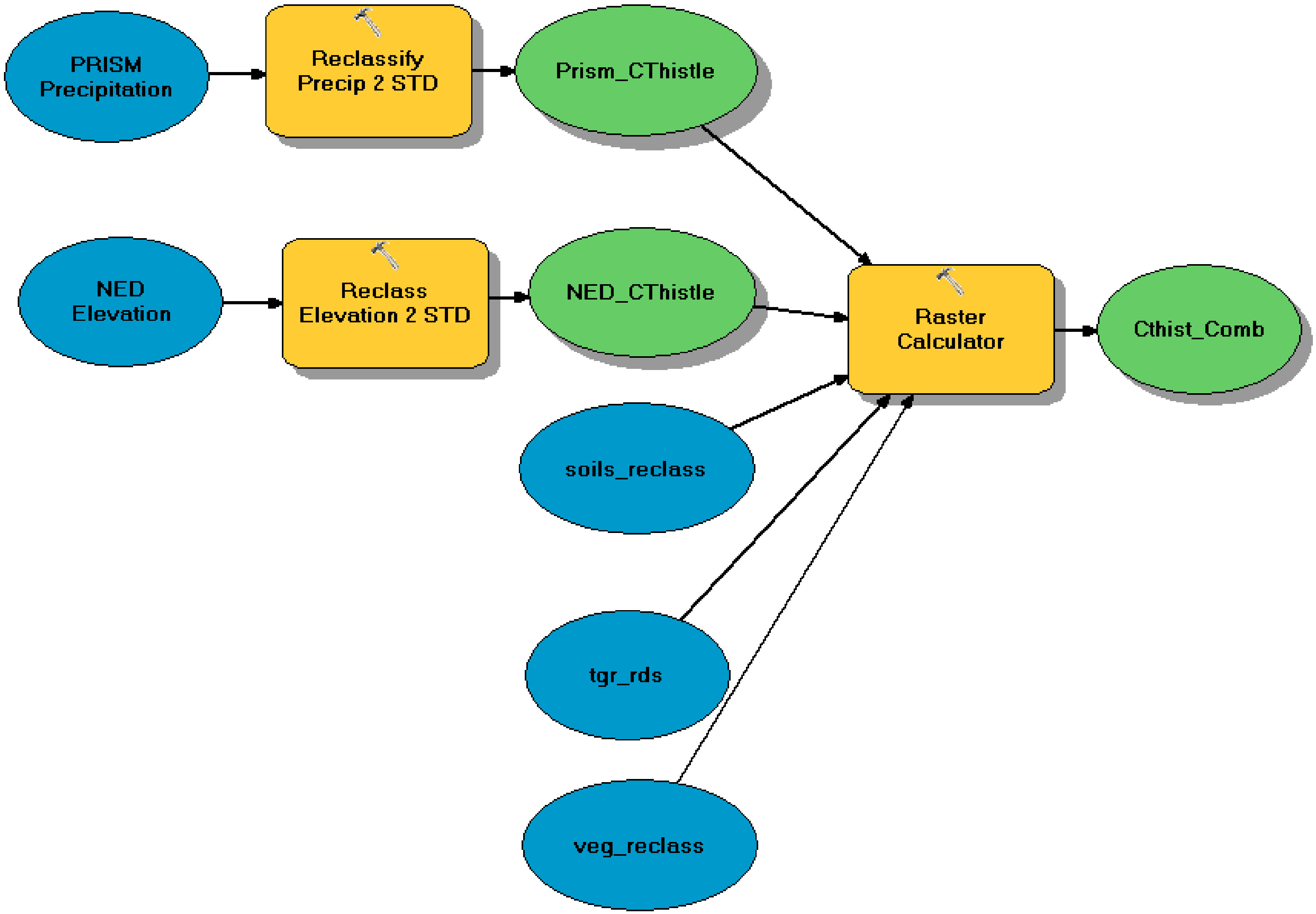
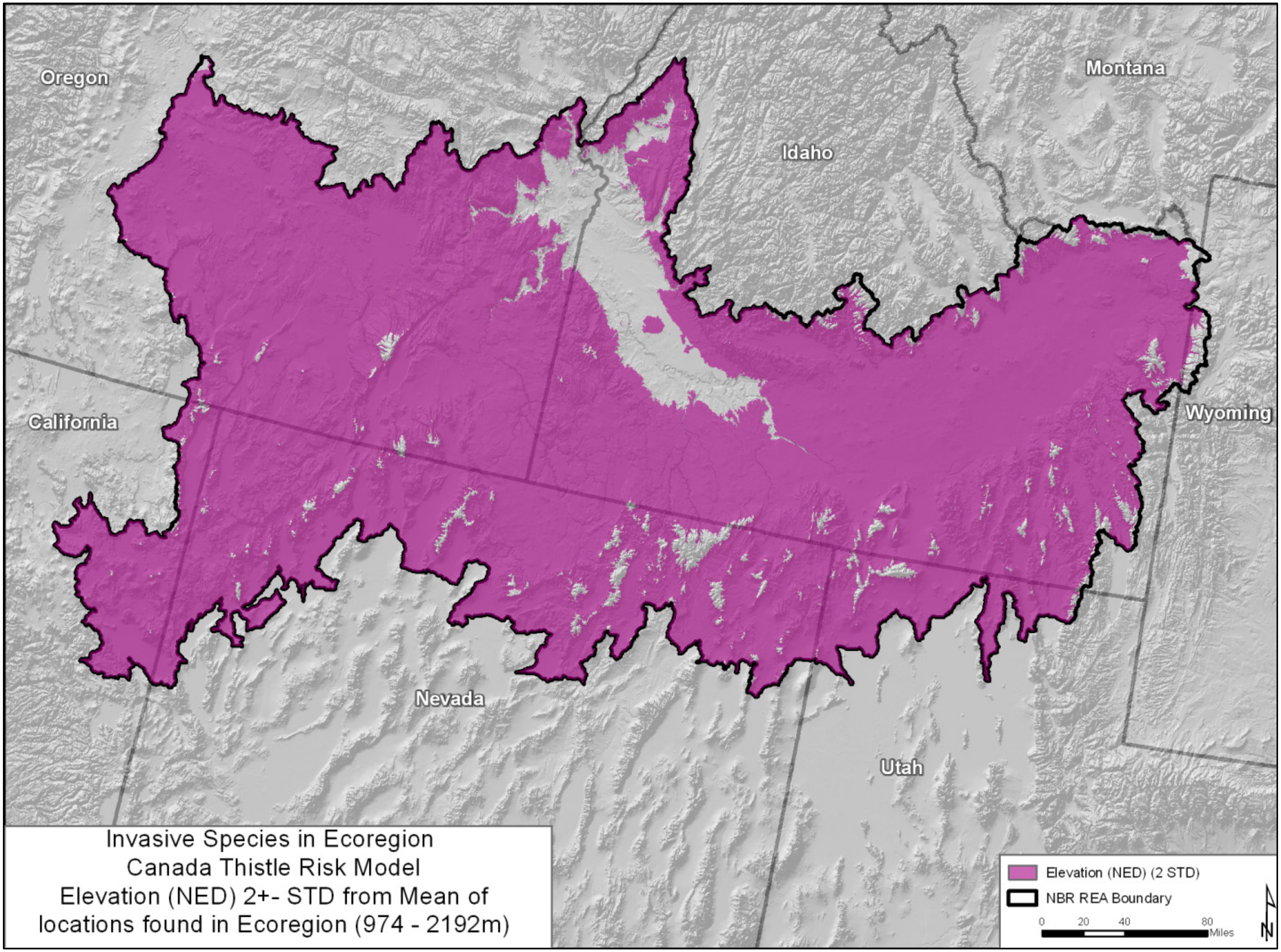


Figure 3.5.3-3 GIS Process Model for Canada thistle Risk



3.5.4.1-1 Canada thistle Favorable Elevation Tolerance in Ecoregion

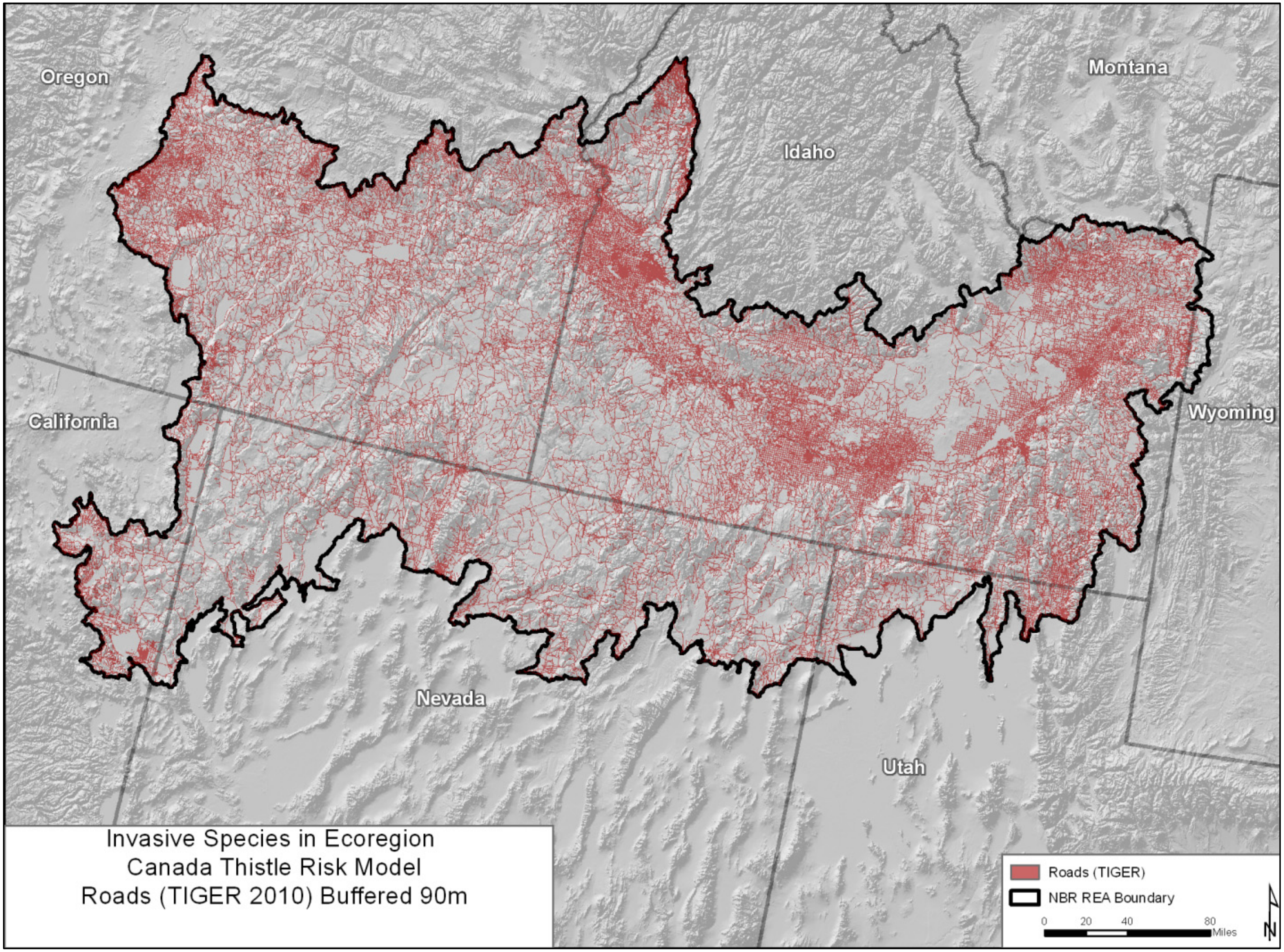


Figure 3.5.4.1-2 Canada thistle Road Risk in Ecoregion

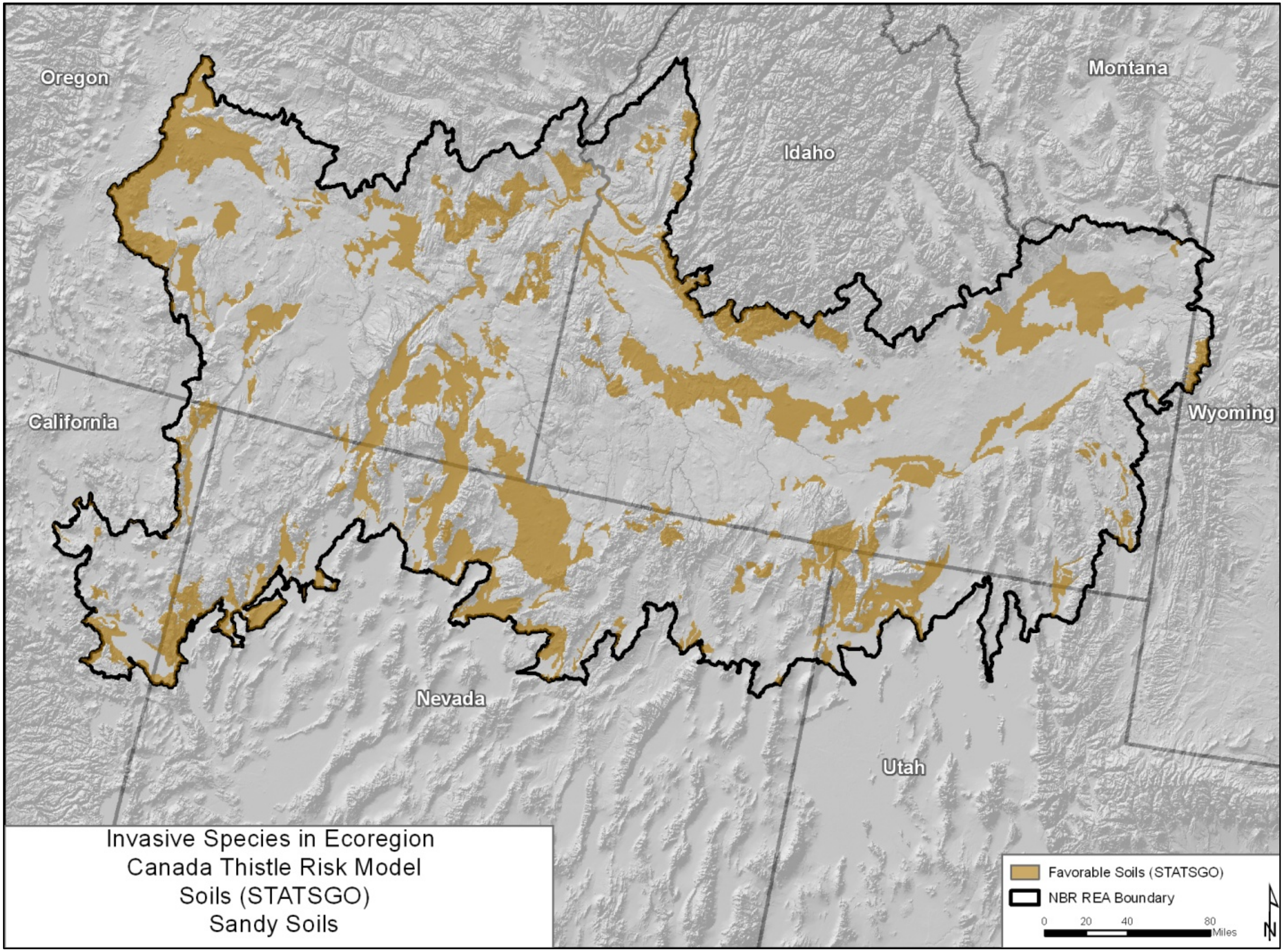


Figure 3.5.4.1-3 Canada thistle Favorable Soils in Ecoregion

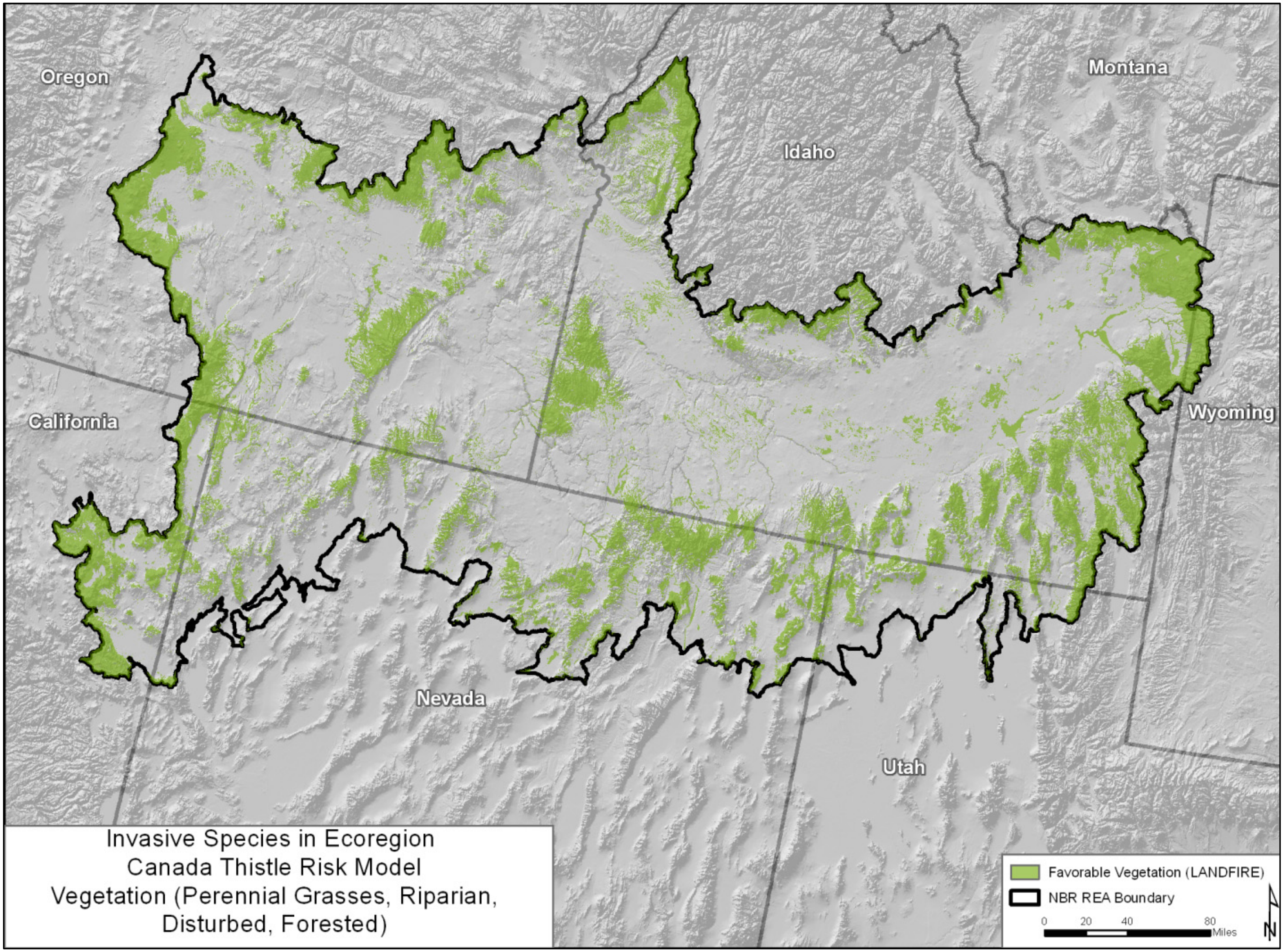


Figure 3.5.4.1-4 Canada thistle Favorable Vegetation in Ecoregion

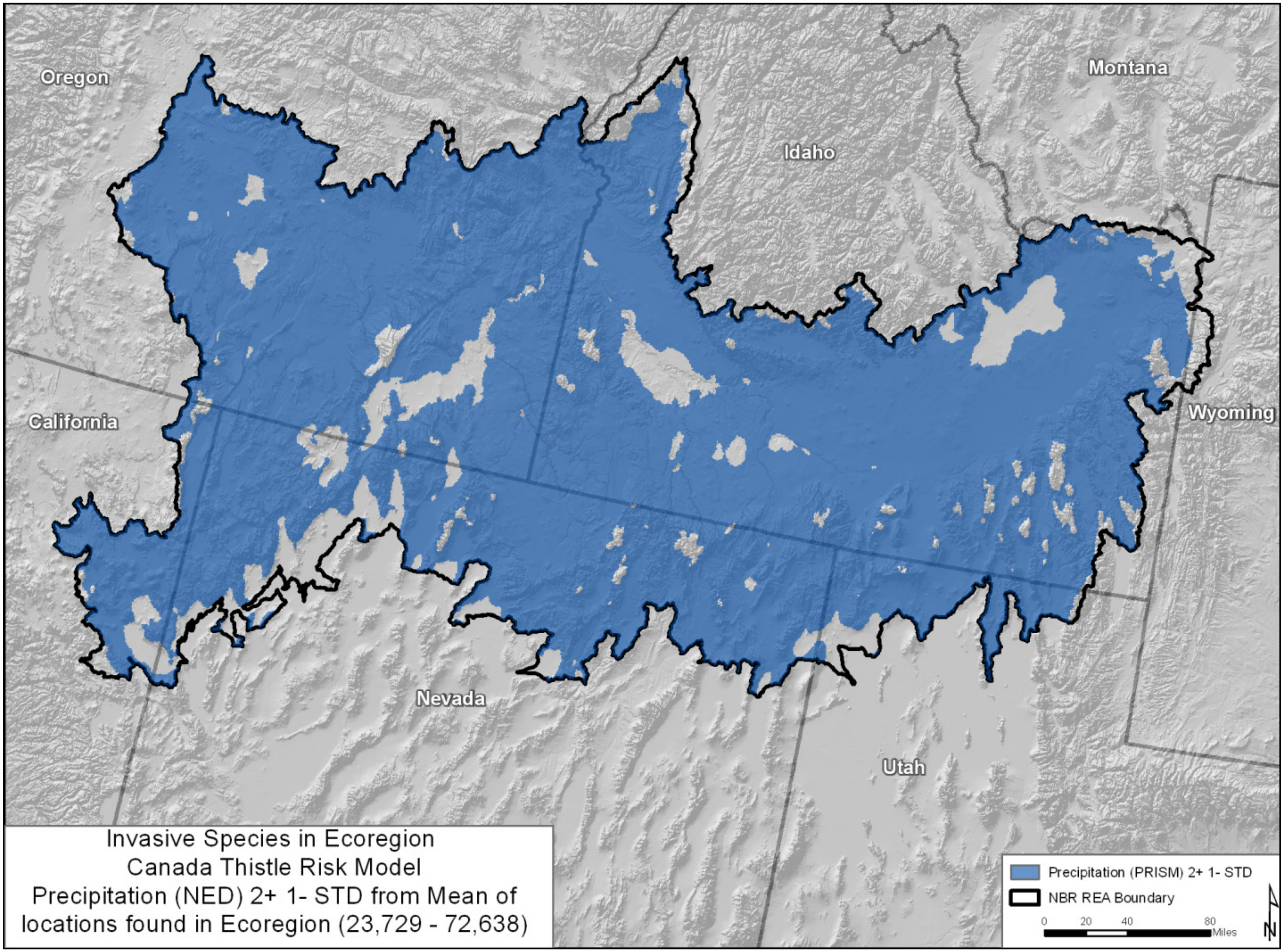


Figure 3.5.4.1-5 Canada thistle Favorable Precipitation Tolerance in Ecoregion

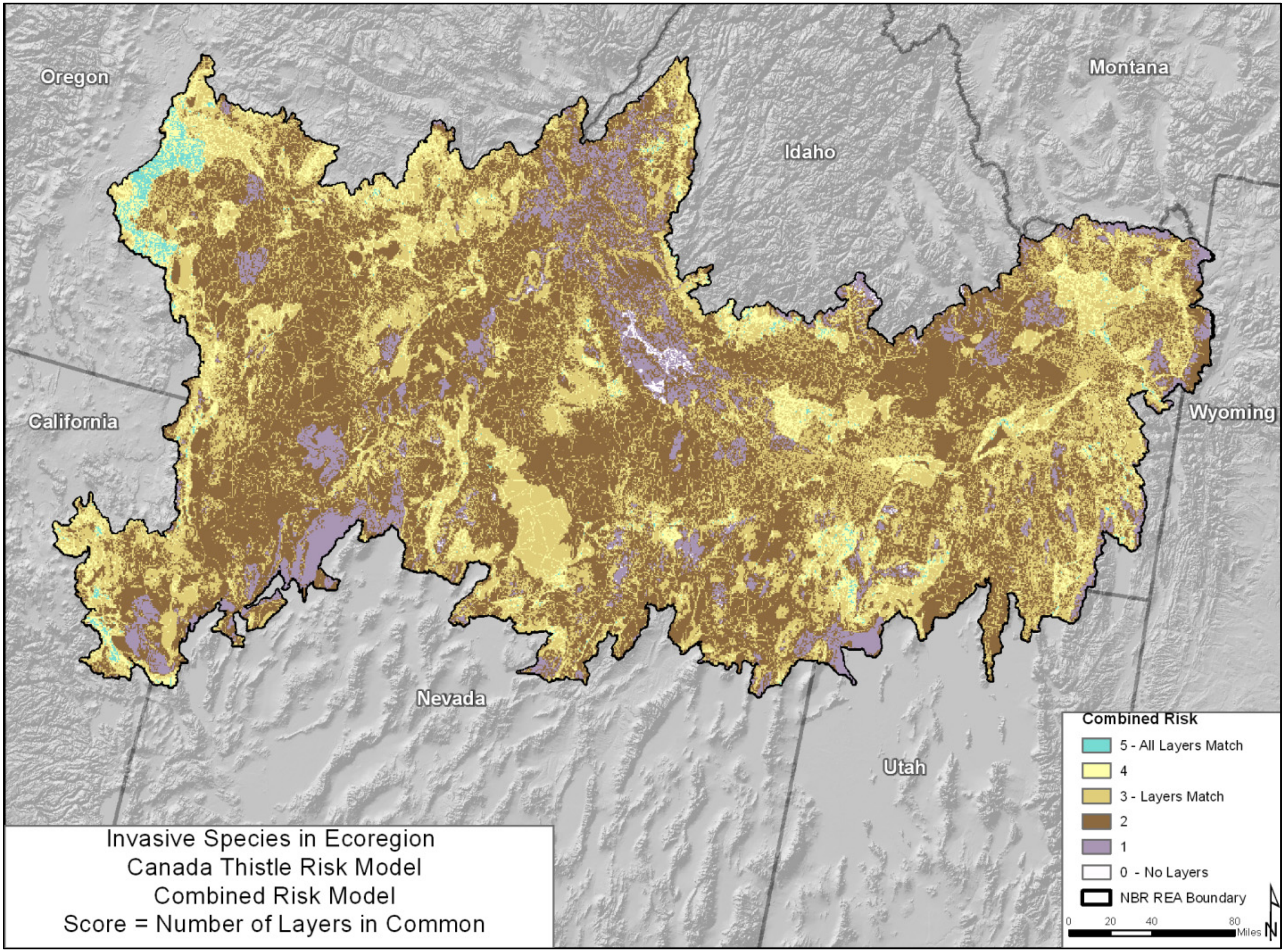


Figure 3.5.4.1-6 Canada thistle Combined Risk in Ecoregion

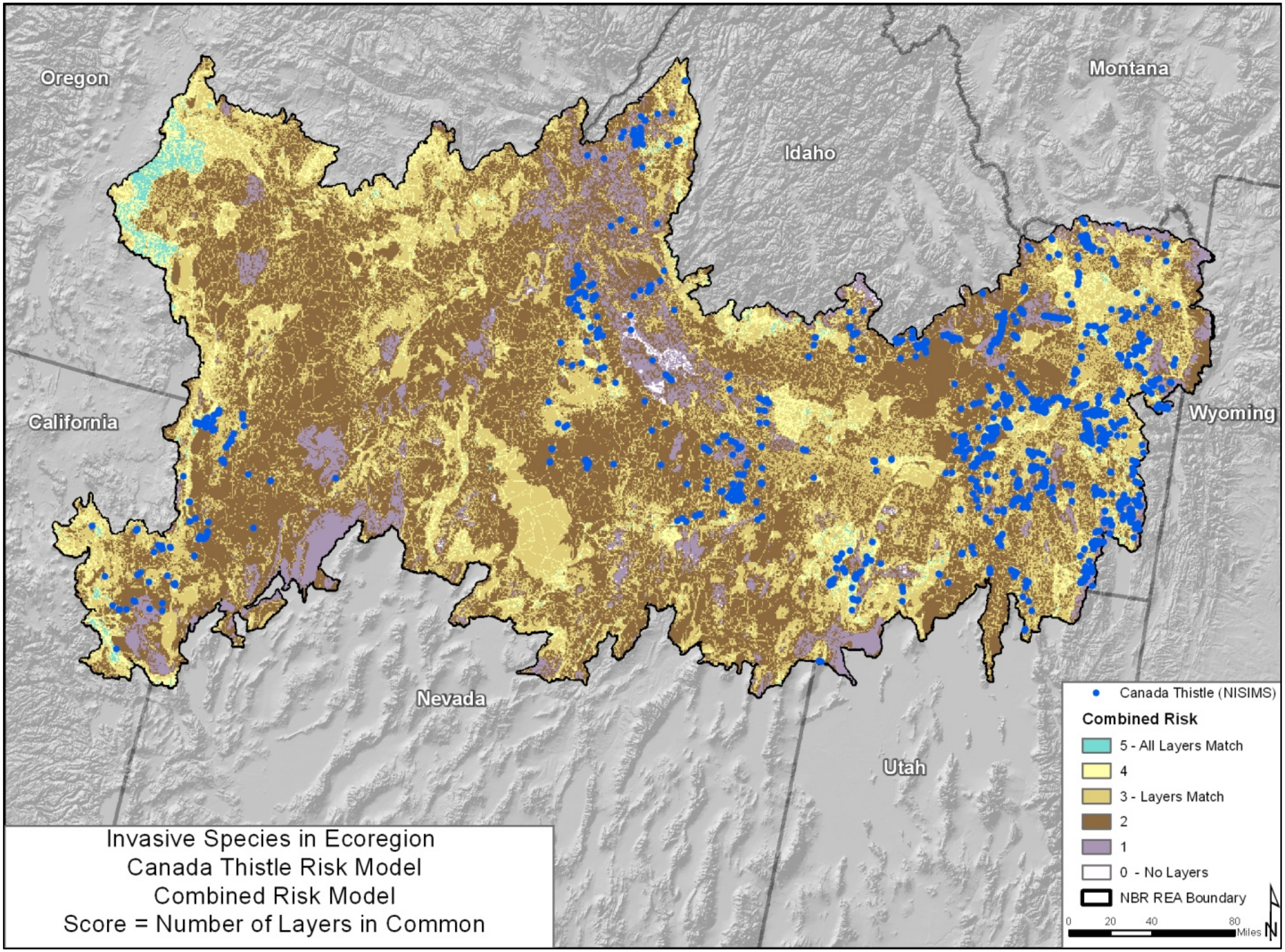


Figure 3.5.4.1-7 Canada thistle Combined Risk with Occurrences within Ecoregion

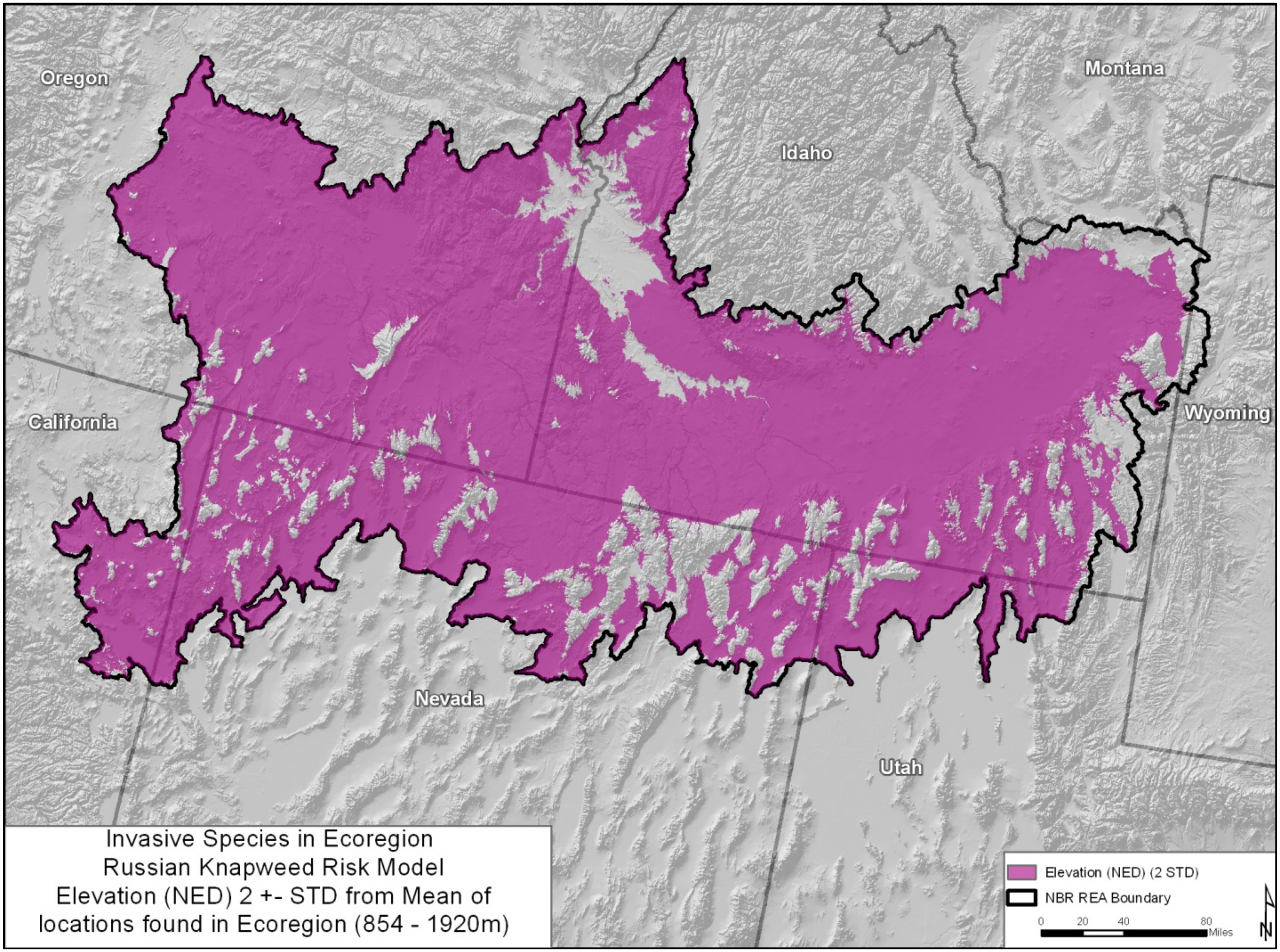


Figure 3.5.4.2-1 Russian knapweed Favorable Elevation Tolerance in Ecoregion

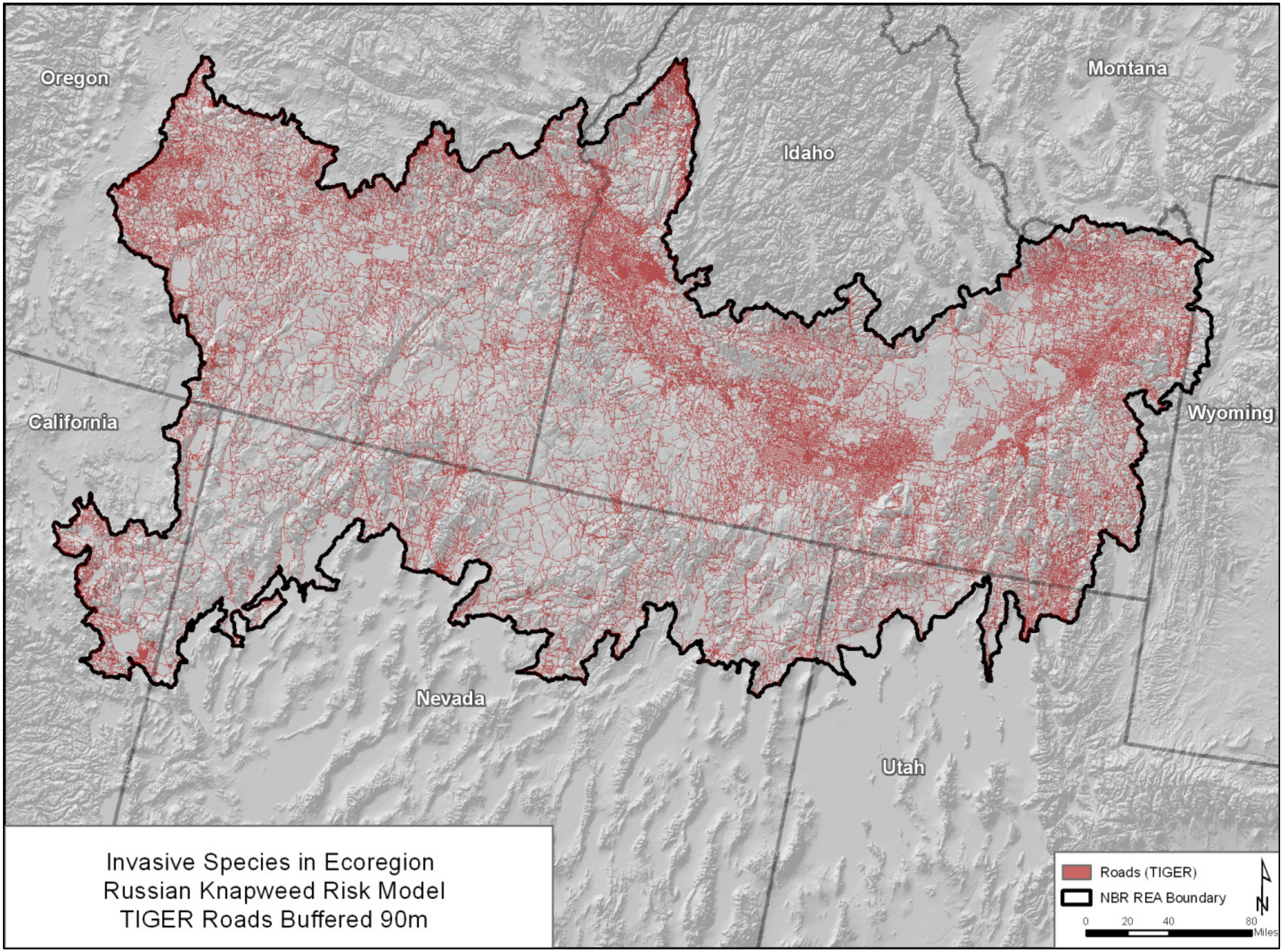


Figure 3.5.4.2-2 Russian knapweed Road Risk in Ecoregion

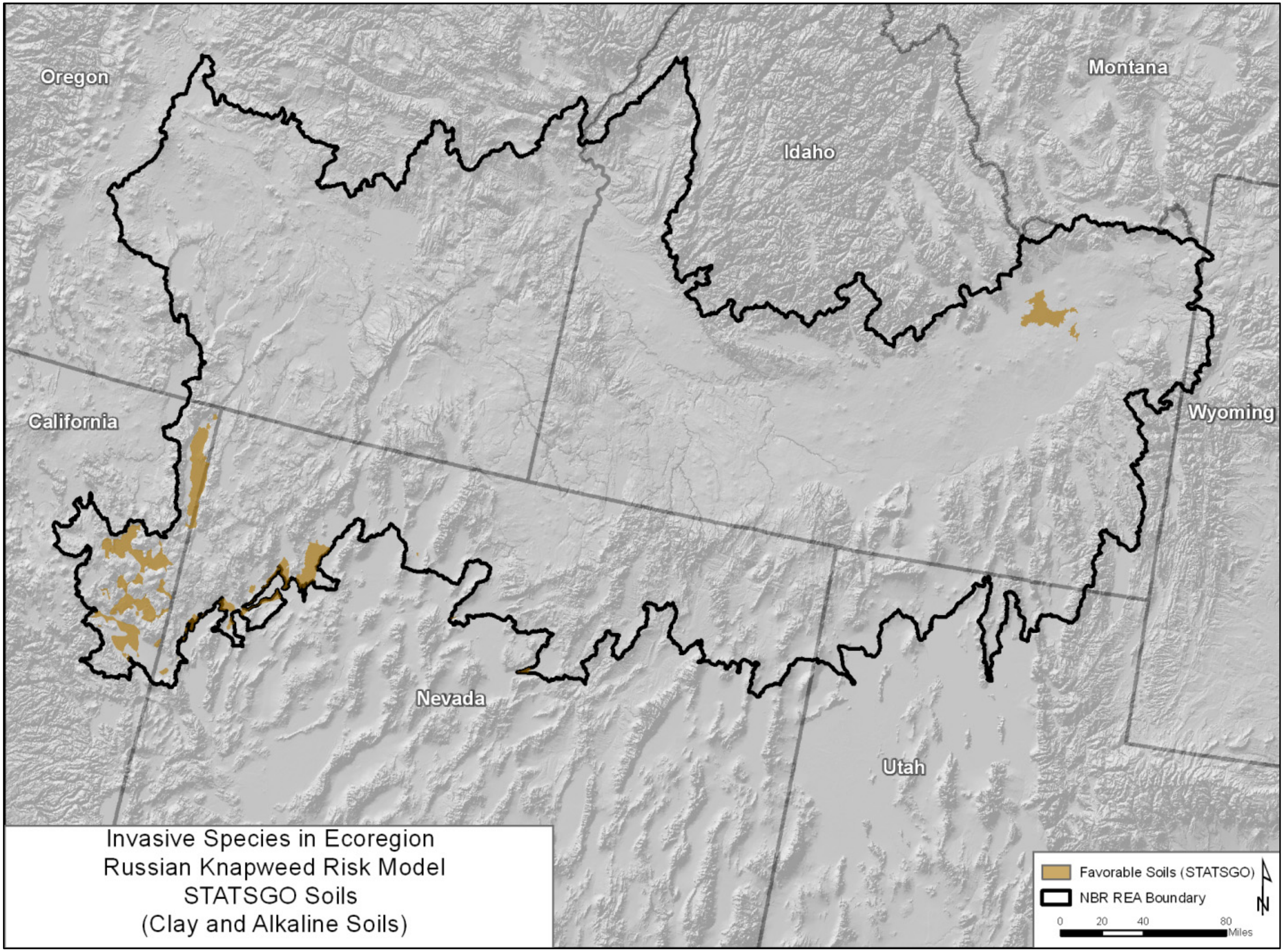


Figure 3.5.4.2-3 Russian knapweed Favorable Soils in Ecoregion

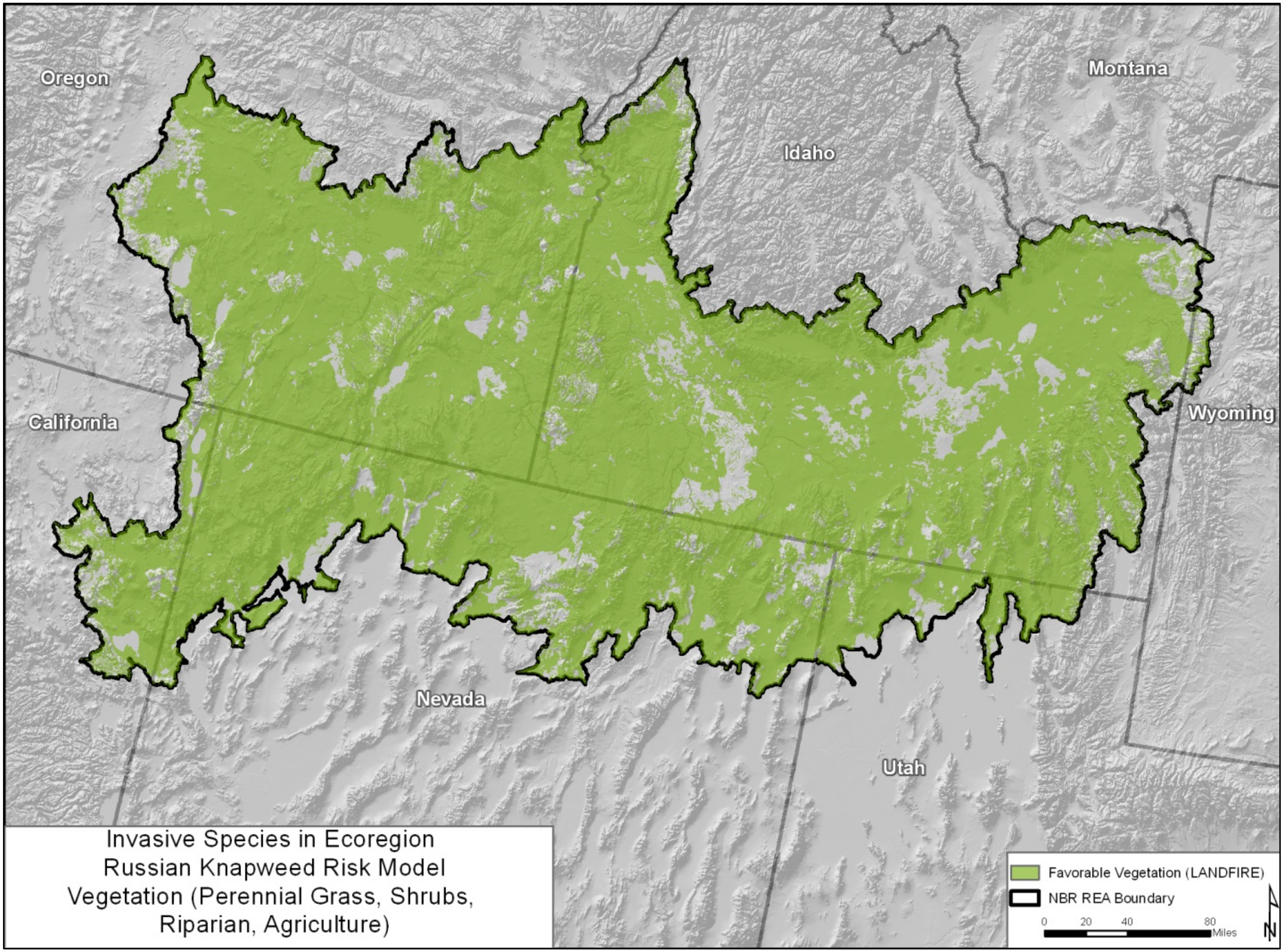


Figure 3.5.4.2-4 Russian knapweed Favorable Vegetation in Ecoregion

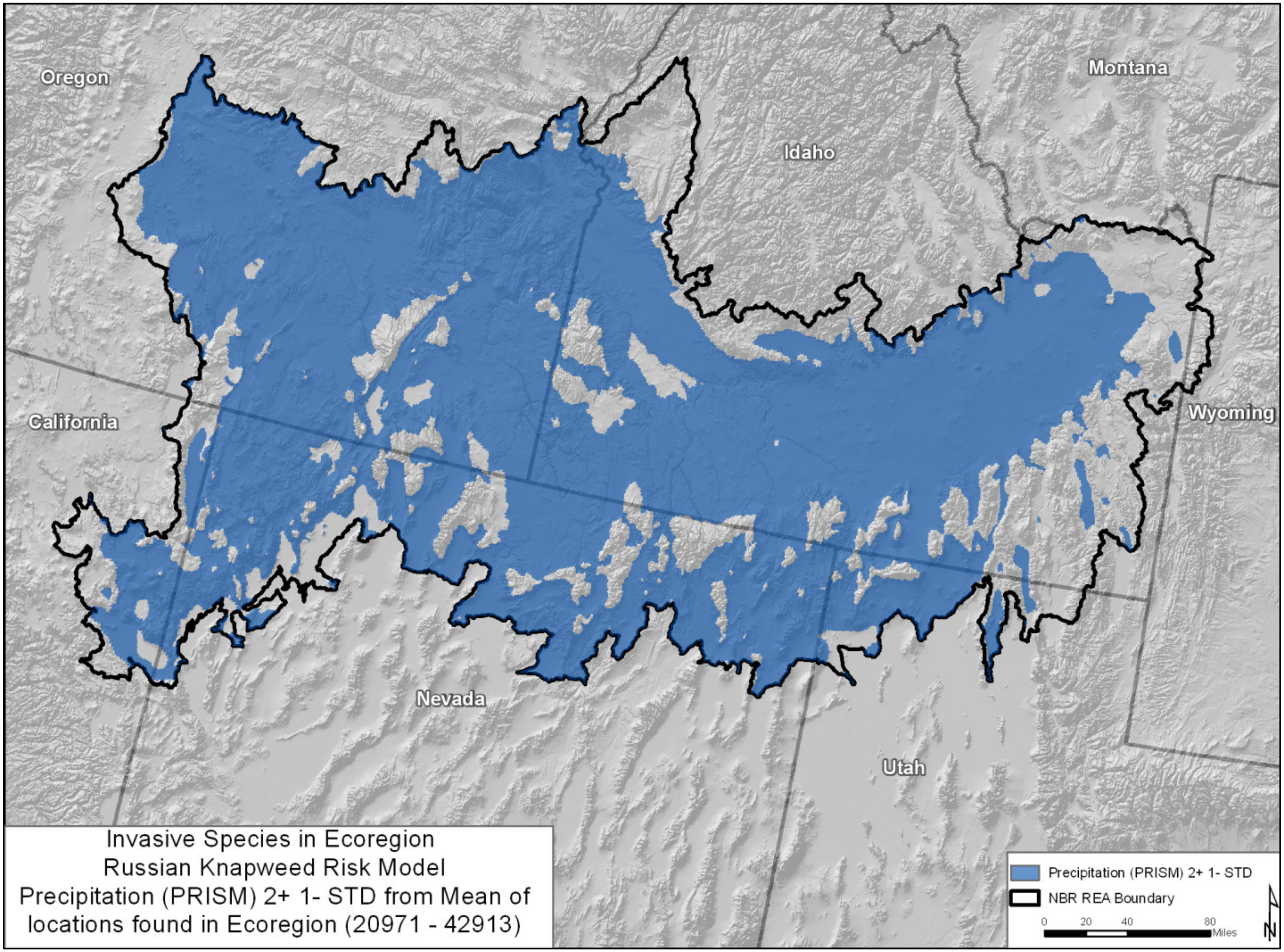


Figure 3.5.4.2-5 Russian knapweed Favorable Precipitation Tolerance in Ecoregion

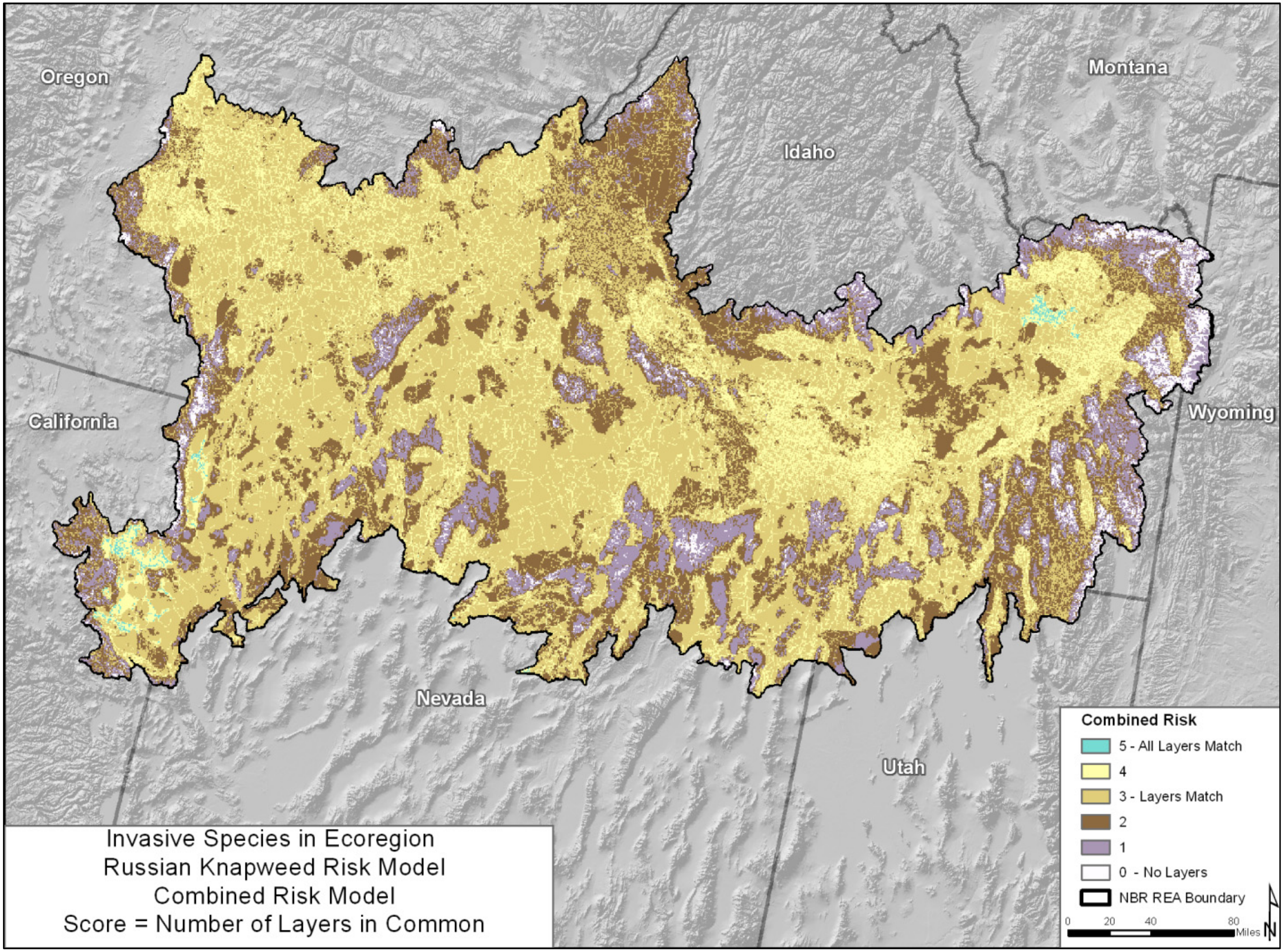


Figure 3.5.4.2-6 Russian knapweed Combined Risk in Ecoregion

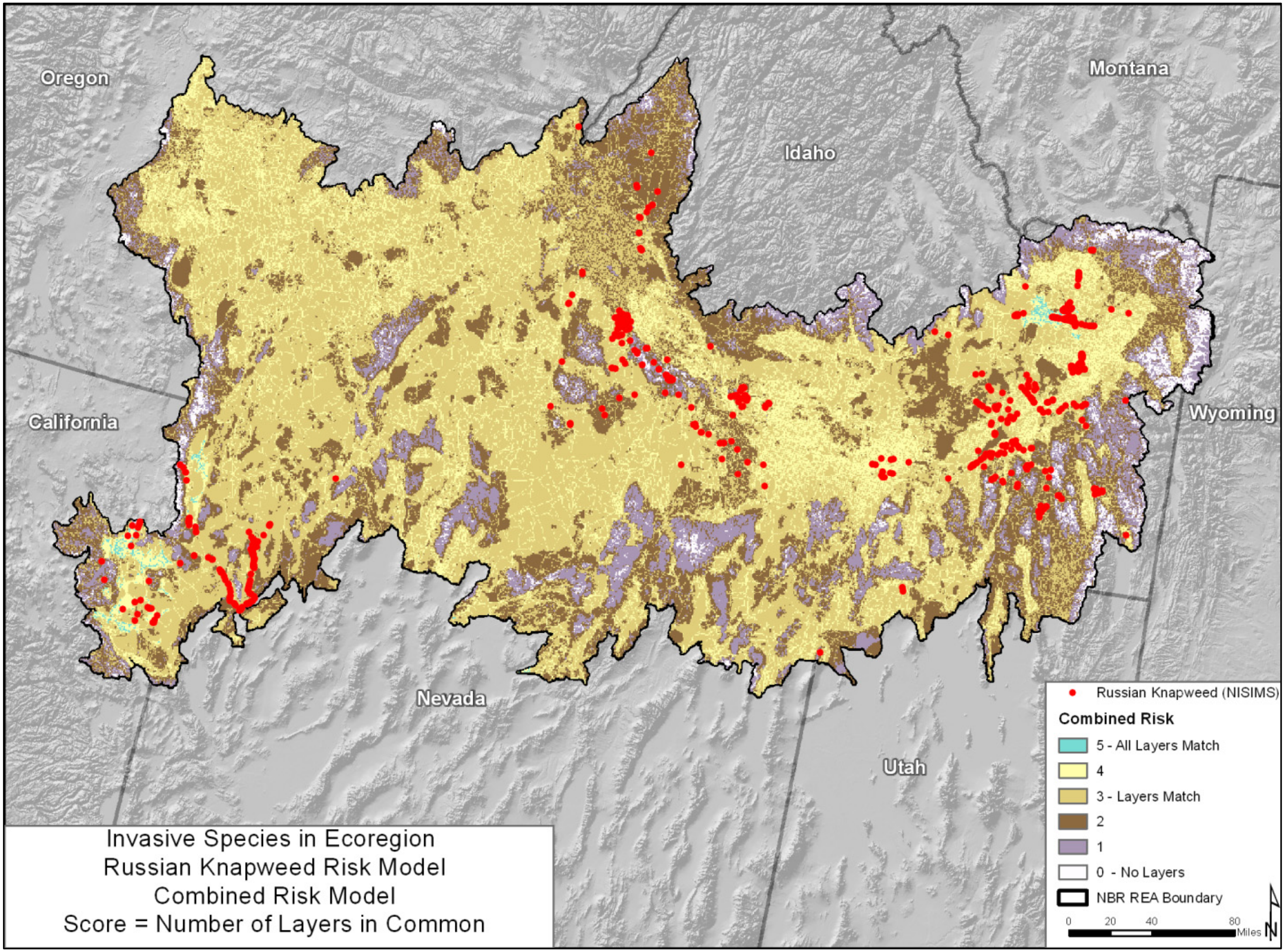


Figure 3.5.4.2-7 Russian knapweed Combined Risk with Occurrences in the Ecoregion

3.6 Wildland Fire

3.6.1 Introduction

Fire is a key ecological process in western ecosystems (Baker 2009, Pyne 1992). Fire influences virtually all other ecosystem processes (Agee 1993, Dale *et al.* 2001), such as landscape patterns and species diversity (Swetnam and Betancourt 1997, Haire and McGarigal 2009), nutrient cycling, hydrology and erosion (Agee 1993), air quality (Sampson *et al.* 2000), plant ecology (Miller 2000) and the maintenance of wildlife habitats and biodiversity (Noss and Cooperrider 1994). Fire is strongly influenced by weather and climate, but also may in return affect climate feedbacks (Houghton and Hackler 2000, Westerling *et al.* 2006). Climate change and fire interactions include increased area burned (Flannigan *et al.* 2005), variability and frequency of extreme fire weather (Flannigan and Wotton 2001) and length of fire seasons (Wotton and Flannigan 1993).

3.6.2 Fire Regime Condition Class

A fire regime condition class (FRCC, Barrett *et al.* 2010) characterizes the degree of departure from the historical fire regime, mostly due to human intervention in natural fire regimes. This departure results in changes to one (or more) of the following ecological components: (a) vegetation characteristics (species composition, structural stages, stand age, canopy closure, and mosaic pattern), (b) fuel composition, (c) fire frequency, severity, and pattern, and (d) other associated disturbances (e.g. insect and disease mortality, grazing, and drought). Low departure is considered to be within the natural (historical) range of variability, while moderate and high departures are outside of that range. Characteristic vegetation and fuel conditions are considered to be those that occurred within the natural (historical) fire regime. Uncharacteristic conditions include invasive weeds, insects, diseases, selectively harvested forest composition and structure, or repeated annual grazing (Barrett *et al.* 2010).

Since LANDFIRE characterizes conditions with respect to departure from "simulated" historical reference conditions, the resulting succession classes (SCLASS), FRCC and departure (DEP) are dependent on the accuracy of the modeled results. It is important to recognize that the LANDFIRE maps were designed to support fire and landscape management planning, but were not designed to develop detailed species-driven EI assessments. LANDFIRE generally does not explicitly describe uncharacteristic vegetation conditions and may not be appropriate at the finer scale required to model fire effects on individual CEs, which may be sensitive to vegetation condition, especially where non-equilibrium conditions prevail. Furthermore, LANDFIRE provides coarse-scale reference condition for vegetation communities through its Biophysical Settings module. It is also important to note that there is still considerable scientific debate over historic fire regimes (see Baker 2009).

3.6.3 Data Sources

3.6.3.1 Existing and Historical Fire Perimeters

Having both historical and current fire perimeters is important in being able to update modeled output based on recent fire activity that has occurred or to determine fire frequency. GeoMac (an inter agency collaboration) provides web mapping and spatial data downloading of recent and historic fire perimeters to fulfill this need. GeoMac contains fire perimeter information from 2000 to present. Monitoring Trends in Burn Severity (MTBS) is another source of data that tracks the fire perimeters but also the burn intensity. This dataset has wildland fires from 1984-2010 currently available for download.

3.6.4 Modeling Wildland Fire

Modeling wildland fire will mostly involve acquiring the most recent data from the sources above to show locations of fires and intensity. MTBS burn intensity data is stored in yearly datasets so data may need to be mosaiced to show the full burn intensity for all fires in the ecoregion.

A recommendation by the AMT was to try to link wildland fires by spatial adjacency to allow two adjacent fires to be considered one larger fire. Once a full GIS analysis begins on wildland fire, guidance from the AMT will be sought to determine what distance and temporal threshold to consider combining fires.

4 Threat Modeling

4.1 Introduction

4.1.1 Threat Analysis

One of the major difficulties of the Rapid Ecological Assessment (REA) process is to develop the framework to investigate the conservation elements (CEs) and change agents (CAs) to attempt the answer the management questions (MQs) finalized in Memo 1-c. The REA process lends itself using GIS as tool for both visualization of what is on the landscape, but also to aid in investigating an area for preservation and restoration of the resources. A decision support model is a GIS-based method for combining spatial data and expert knowledge framework to aid in the evaluation of the landscape for the CEs. Decision support models give managers the power of GIS support and a methodology in the decision making process.

The overall approach SAIC recommends using is a GIS-based Multi Criteria Evaluation (MCE) model. This approach has been well documented in land use planning, landscape ecosystem analysis, and regional and urban planning.

MCE is a method to combine the information from several criteria to form a single index or map (Voogd 1983 and Carver 1991). Each criterion can be multiplied by a weight and then summed to arrive at a final suitability map. The most common MCE technique is the weighted linear combination (WLC). Using the WLC, weights are applied to each factor and then summed for a final suitability score (Eastman *et al.*1995 and Eastman 1997).

$$S=\sum w_i x_i$$

Where S=Suitability

W_i= Weight of criterion i

X_i=Score of criterion i

The MCE approach can be easily implemented with the ArcGIS platform using ModelBuilder. ModelBuilder allows the users to change and add parameters, change data and data processes within ArcGIS. In addition it allows the user to add weights to the criteria to be evaluated.

4.1.2 Key Ecological Attributes

The next step in the process of modeling threats to the CEs is to extract from the conceptual models created in memo 2, the key ecological attributes (KEAs) of the systems that can be measured or categorized and spatially represented. "A key ecological attribute of a focal ecological resource is a characteristic of the resource's biology, ecology, or physical environment that is so critical to the resource's persistence, in the face of both natural and human-caused disturbance, that its alteration beyond some critical range of variation will lead to the degradation or loss of the resource…." (Unnasch *et al.* 2009). For some species, the KEAs are well known from historical and recent research. For others, KEAs may depend on the geographic location of the CE. In general, however, KEAs of a resource include "critical biological and ecological processes and characteristics of the environment that : (a) limit the regional or local spatial distribution of the resource; (b) exert pivotal causal influence on other characteristics; (c) drive temporal variation in the resource's structure, composition, and distribution; (d) contribute significantly to the ability of the resource to resist change in the face of environmental disturbances or to recover following a disturbance; or (e) determine the sensitivity of the resource to human impacts." (Unnasch 2009).

In this section, we describe their use in formulating data inputs into GIS process models. Unnasch *et al.* (2009) recommended that three factors be considered when selecting attributes:

- "**Size** refers to attributes related to the numerical size and/or geographic extent of the focal ecological resource" (conservation element in this REA). An example would be the area within which a particular ecological system occurs.
- "**Condition** refers to attributes related to biological composition, reproduction and health, and succession; critical ecological processes affecting biological structure, composition and interactions; and physical environmental features within the geographic scope of the focal ecological resource". Examples include species composition and variation, patch and succession dynamics in ecological systems, and…disturbance regimes….
- "**Landscape Context** refers to both the spatial structure (spatial patterning and connectivity) of the landscape…and to critical processes and environmental features that affect the focal ecological resource from beyond its immediate geographic scope. Examples of the former include attributes of fragmentation, patchiness, and proximity or connectivity among habitats. Examples of the latter include…regional or larger-scale disturbances."

Indicators are specific characteristics of the KEAs that can be individual measured, categorized, or expressed as a frequency (Unnasch *et al.* 2009). Indicators should be:

- Easily measured in a reliable, repeatable, and accurate fashion.
- Unambiguously associated with ecological attributes.
- Sensitive to CAs or other stressors at relevant spatial and temporal scales.
- Comprehensive and complementary.
- Scientifically defensible and interpretable in common language.

Indicators in this REA will be developed primarily based on remotely sensed information, some of which has been previously field-calibrated. The CE KEA table also suggests appropriate metrics for each indicator and the type of rating scale that would be used for each indicator (e.g., presence/absence, or ranking within an appropriate range of variability for the attribute in question). Indicators will be the subject of geospatial modeling applications depicted in the GIS process models for each example CE described in Section 2.2 (greater sage-grouse [GSG] and mule deer). Thus, the information in the KEA tables links conceptual models completed in memo #2 of the effects of CAs on CEs with the data manipulation steps depicted in the GIS process models.

4.2 Analysis Units

Analysis units are areas that are used to roll up average, majority, minimum or maximum values to a defined zone or geographic area. Since many of the resulting GIS process models will be making use of raster data at a 30m or 90m pixel size, using the larger analysis unit allows for a statistical value to be given to the geographic area. At the scale that people will be using the maps, an individual pixel will be too small to distinguish the color or the relative abundance. There are several proposed analysis units in this memo from both the statement of work as well as recommendations from the Assessment

Management Team (AMT). Examples of the KEA and threat analysis will be shown in Section 4.4 showing analysis at both the 4 km grid and HUC 12 unit. Section 5 will show examples of ecological integrity at the HUC 10 analysis unit.

4.2.1 HUC 10 Watershed

The HUC 10 watershed was listed in the statement of work as the proposed analysis unit for ecological integrity. There are 490 HUC 10 watersheds in the Northern Basin and Range and Snake River Plain (NBR) ecoregion that range in size from 26,900 acres to the largest being 321,700 acres.

4.2.2 HUC 12 Watershed

The HUC 12 watershed was listed in the statement of work as the proposed analysis unit for conservation elements in the statement of work. There are 2,666 HUC 12 watersheds in the NBR ecoregion that range from 7,000 ac to 230,700 acres.

4.2.3 4 km grid

Based on recommendations from the AMT, a 4 km grid is also being used as an analysis unit. This is being done to both maintain consistency with Central Basin and Range as well as provide a smaller unit that will remove any bias associated with using a watershed as an analysis unit. It was observed in previous REAs that the watershed didn't match with how Nevada and other BLM state offices manage their lands. A consistent 4 km grid was deemed a better approach to match Nevada's basin and range land management style. The 4 km grid across the NBR ecoregion consists of 17,154 individual tiles. Section 4.4 will show examples of the visual display of using such a fine grid.

4.2.4 1km grid

A 1km grid was brought up on one of the AMT conference calls. This concept was examined but appears to be too fine scaled for the mapping products and scale of the figures. There are 261,645 individual 1km tiles spanning the NBR ecoregion.

4.3 Key Ecological Attributes for Example CEs

Based on recommendations by the AMT to see preliminary output of data as early in the REA process as possible, there will be two conservation elements (CE) focused on. These two CEs will be GSG (Table 4.3.1-1) and mule deer (Table 4.3.1-1). These fine filter conservation elements were chosen because of their regional importance and ability to acquire data since data collection is occurring in a future task. The list of KEAs are a subset of the final KEA list that will be created for each CE. The KEAs were selected based on data availability (since data collection is a later task) and intended to show examples of outputs and not a full analysis of the CE.

4.3.1 Greater Sage-grouse Example (limited to what data we currently have)

Table 4.3.1-1 Selected KEAs for Greater sage-grouse

Ecological Attribute	Indicator	Metric	Data Source	Citation
Landscape Context				
Connectivity/ Habitat Condition	Wind energy projects	>21 km from lek center and outside core area = good 12-21 km from lek center or within core area = fair <12 km from lek center = poor	Wind Energy Turbines (FAA)	Wisdom et al. 2011
	Road density (km/km2)	<0.087 = good 0.087 – 0.112 = fair >0.112 = poor	Tiger 2010	Wisdom et al 2011
	Distance to highway	>8 km from lek center and outside core area = good 5-8 km from lek center or within core area = fair <5 km from lek center = poor	Tiger 2010	Wisdom et al. 2011
	Distance to cell towers	>21 km from lek center and outside core area = good 12-21 km from lek center or within core area = fair <12 km from lek center = poor	Tower Structures (FCC)	Wisdom et al. 2011
	Distance to electric transmission lines	>15 km from lek center and outside core area = good 6-15 km from lek center or within core area = fair <6 km from lek center = poor	Global Energy	Wisdom et al 2011
	% of combined leks and core area in agriculture	<9% = good 9-25% = fair >25% = poor	LANDFIRE	Wisdom et al. 2011

4.3.2 Mule Deer Example (limited to what data we currently have)

Table 4.3.2-1 Selected KEAs for Mule Deer

Ecological Attribute	Indicator	Metric	Data Source	Citation
Condition				
Habitat Condition	Vegetation Condition Class	1=good 2=fair 3=poor	LANDFIRE	LANDFIRE
Landscape Context				
	Distance to Roads	1000m =good 300-1000m = fair < 300m = poor	TIGER 2010	Rost and Bailey 1978

4.4 Threat Analysis GIS Process Models

The GIS process models used to create the distribution or suitable habitat for these two fine filter CEs was documented in section 2.2. The resulting layer will be used as an extent layer to limit the analysis to areas of suitable habitat. This is done so that areas with high threats to the CE such as urban areas aren't highlighted rather keeping the focus on threats within the CE's suitable habitat or range. If there was a CE that the AMT wanted to review for the whole ecoregion, modifying the GIS process model could be easily done.

4.4.1 Greater sage-grouse Example Model and Map Output (HUC 12 and 4 km)

GSG was analyzed mostly for anthropogenic or development threats within the Preliminary Priority Habitat (PPH) area. There is one GIS process model for each KEA listed below containing the analysis for both analysis units (4 km grid and the HUC 12 watershed). The final analysis will be displayed on a map for each analysis unit.

4.4.1.1 Distance to Highways

The main data source for the distance to highways was the most recent 2010 TIGER Roads layer. Primary and Secondary roads will only used in the analysis since the KEA is defined as Highways. To analyze this KEA, Figure 4.4.1.1-1 shows the GIS process model that takes the Highways layer and runs a Euclidean distance spatial operation on it to determine the distance to each cell from a primary road. Some spatial operations, such as Euclidean Distance, were done before the GIS process model starts to save processing time from rerunning analysis. Using the output of the distance operation it then clips it to the GSG PPH and zonal statistics is run on the layer to calculate the average distance in the analysis unit. Figure 4.4.1.1-2 shows the final map with the results binned to the KEA's metrics. Figure 4.4.1.1-3 displays the Distance to Highways using the HUC 12 analysis unit and Figure 4.4.1.1-4 the 4 km grid. Comparing the two analysis units for this KEA shows the difference in the influence of the larger watershed unit. There are a larger number of yellow watersheds (representing fair conditions) where roads might snake though several watersheds, increasing the average distance to highway for both. The 4 km grid is much more precise and the output is similar to the Figure 4.4.1.1-2 (Raw Distance Binned) only more coarse.

4.4.1.2 Road Density

Road density is still a work in progress. The metrics used from Wisdom et al. 2011 seem to use a dataset that is much less detailed than the TIGER 2010 dataset. The resulting maps show that the majority of the GSG PPH is poor. The Wisdom article may have been using the TIGER 2000 roads layer or using a subset of roads. There is no map in the article to view as Wisdom was extracting metrics for various anthropogenic features. If this KEA is used in future analysis runs, the metric values may need to be altered or the road layer changed to match the metric. Figure 4.4.1.2-1 shows the GIS process model for creating the analysis at the HUC 12 and 4 km grid units. The kernel density spatial operation to 1km was done in a separate process since it takes hours to run. Figure 4.4.1.2-2 shows the road density throughout the GSG PPH area. Figure 4.4.1.2-3 displays the Road Density at a HUC 12 analysis unit and Figure 4.4.1.2-4 shows the 4 km Grid.

4.4.1.3 Distance to Wind Energy Towers

This KEA's metrics was the same as Distance to Communication Towers. The data source for this data was from the Federal Aeronautical Administration (FAA) and processed by the US Fish and Wildlife Service (USFWS) to convert it into a spatial product. The tower data contains both proposed and existing tower locations. The GIS process (Figure 4.4.1.3-1) begins with a Euclidean distance to the closest wind tower. That distance is clipped to the GSG PPH data and analyzed for the average distance within each HUC 12 or 4 km grid cell. The resulting map (Figure 4.4.1.3-2) shows the distance binned to the three metrics. The wind energy towers are fairly fragmented across the PPH area. Some patches in the northern part of the Oregon section of the ecoregion are almost exclusively in the poor category. Nevada appears to have some of the largest patches of PPH without wind energy towers. Figure 4.4.1.3-3 and Figure 4.4.1.3-4 display that average distance using the HUC 12 and 4 km Grid analysis units. The HUC 12 map seems to accentuate the areas effected due to their larger analysis units while the 4 km Grid looks very similar to the raw distance map (Figure 4.4.1.3-2).

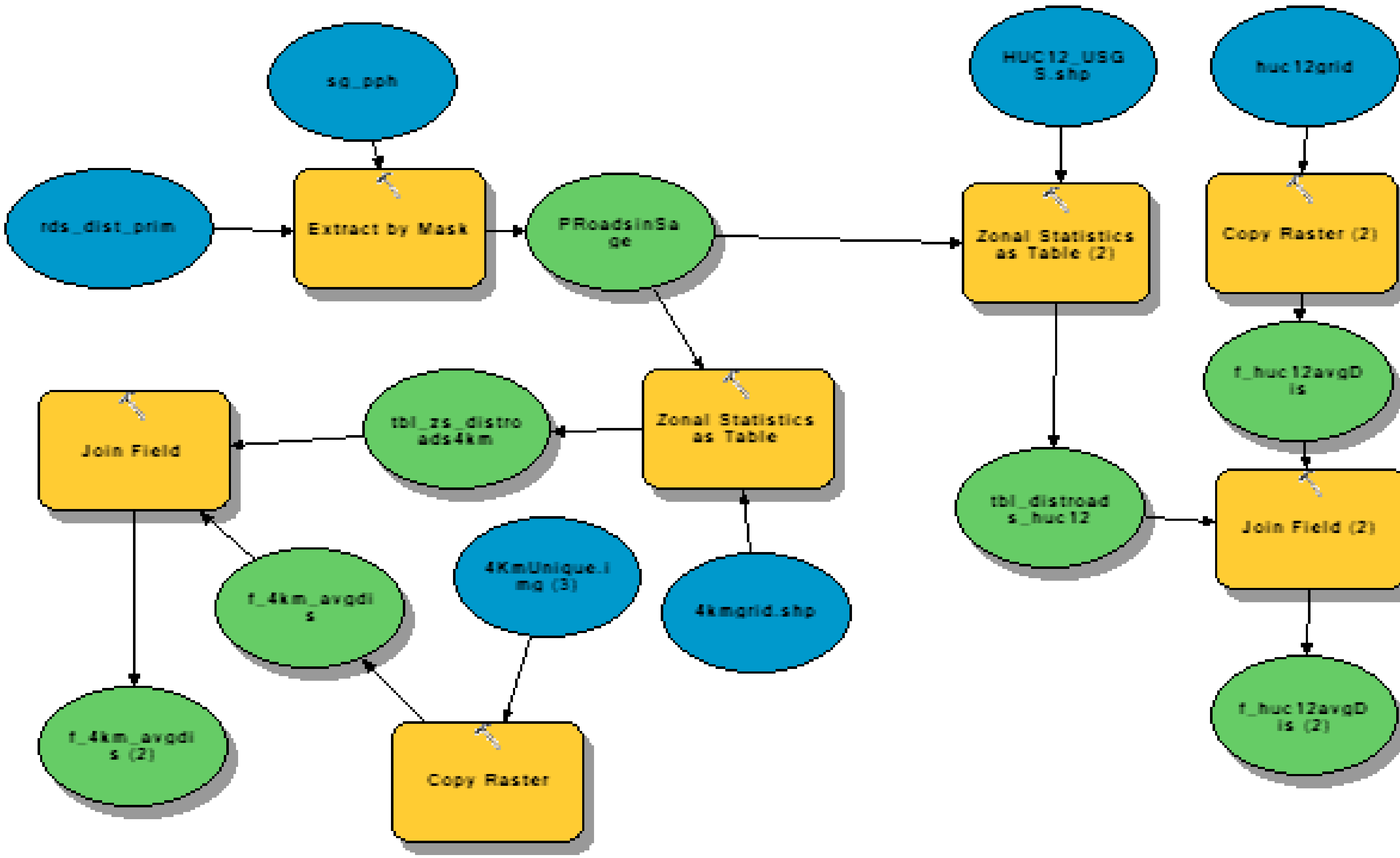


Figure 4.4.1.1-1 GIS Process Model for Distance to Highway KEA for Greater sage-grouse

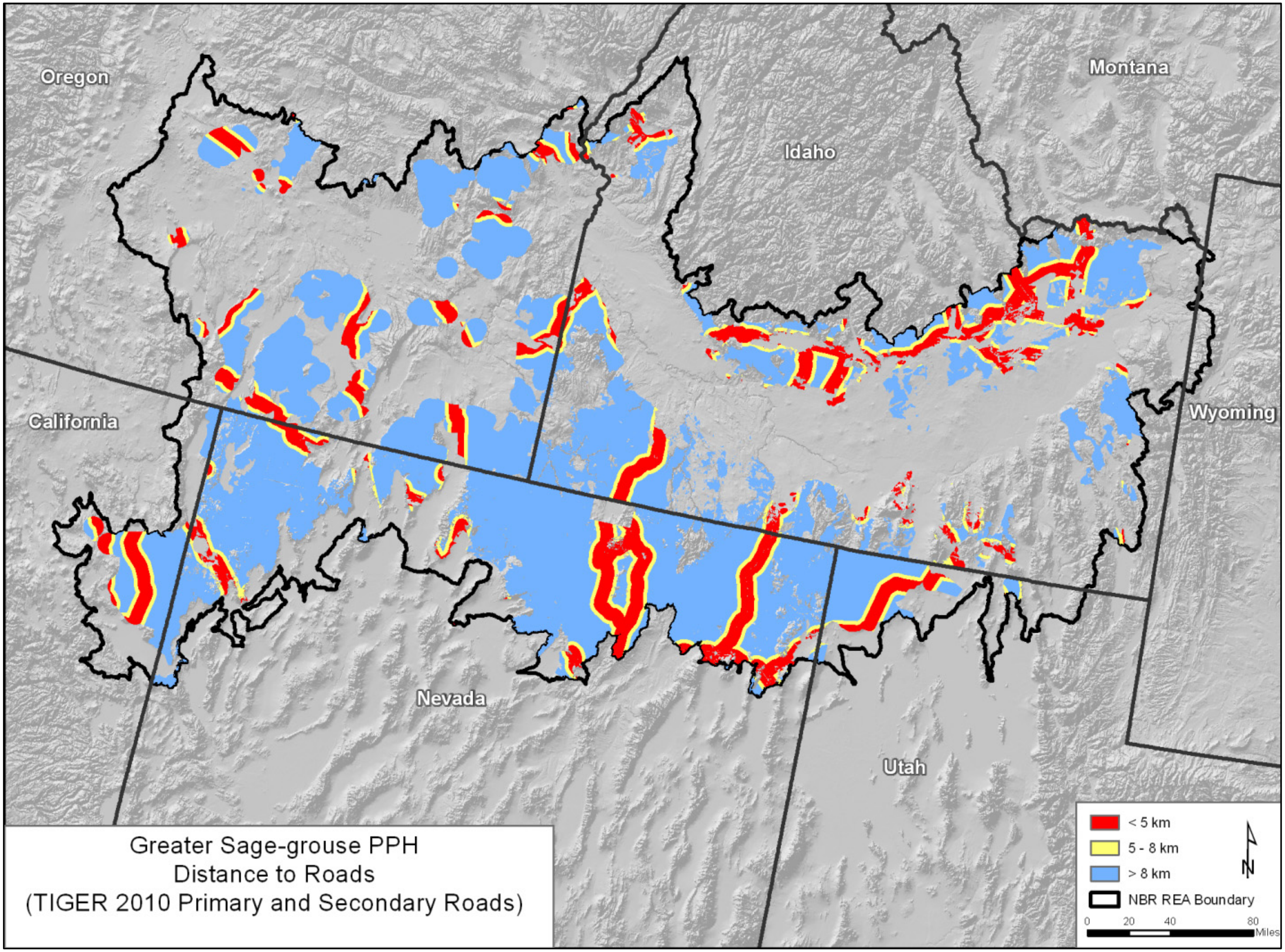


Figure 4.4.1.1-2 Distance to Highways within Greater sage-grouse PPH areas

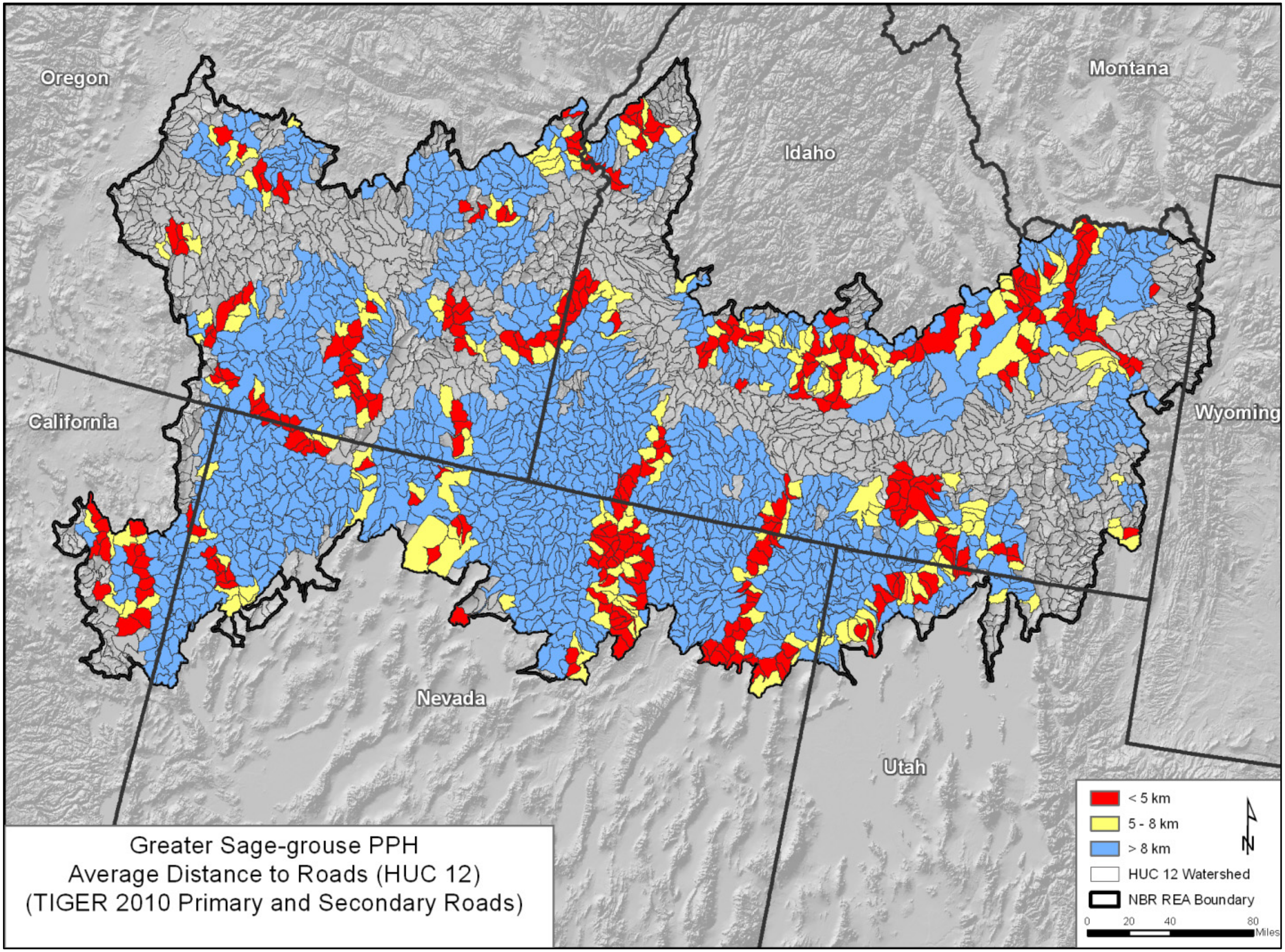


Figure 4.4.1.1-3 Distance to Highways within Greater sage-grouse PPH areas (HUC 12)

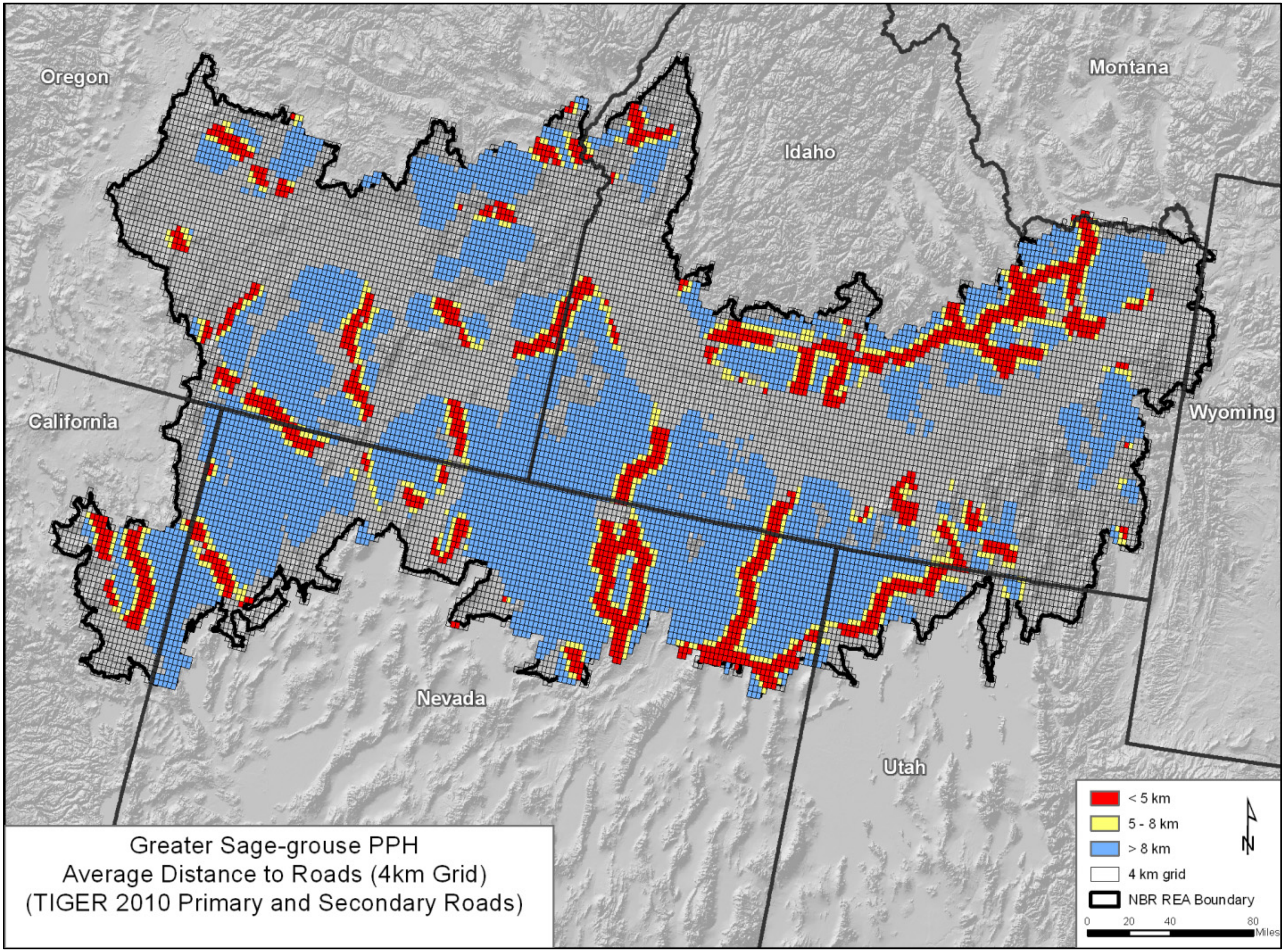


Figure 4.4.1.1-2 Distance to Highways within Greater sage-grouse PPH areas (4 km Grid)

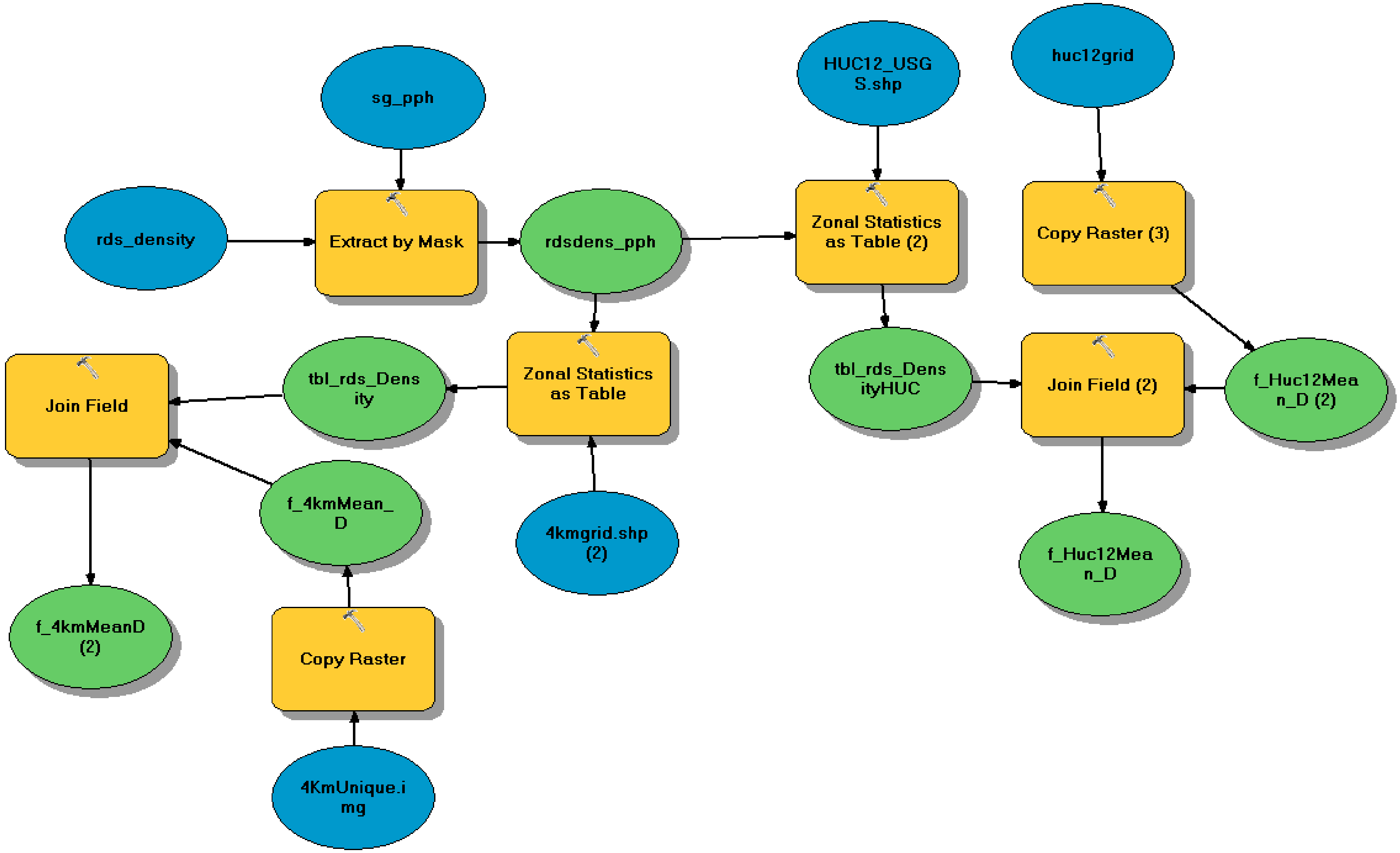


Figure 4.4.1.2-1 GIS Process Model for Road Density KEA for Greater sage-grouse

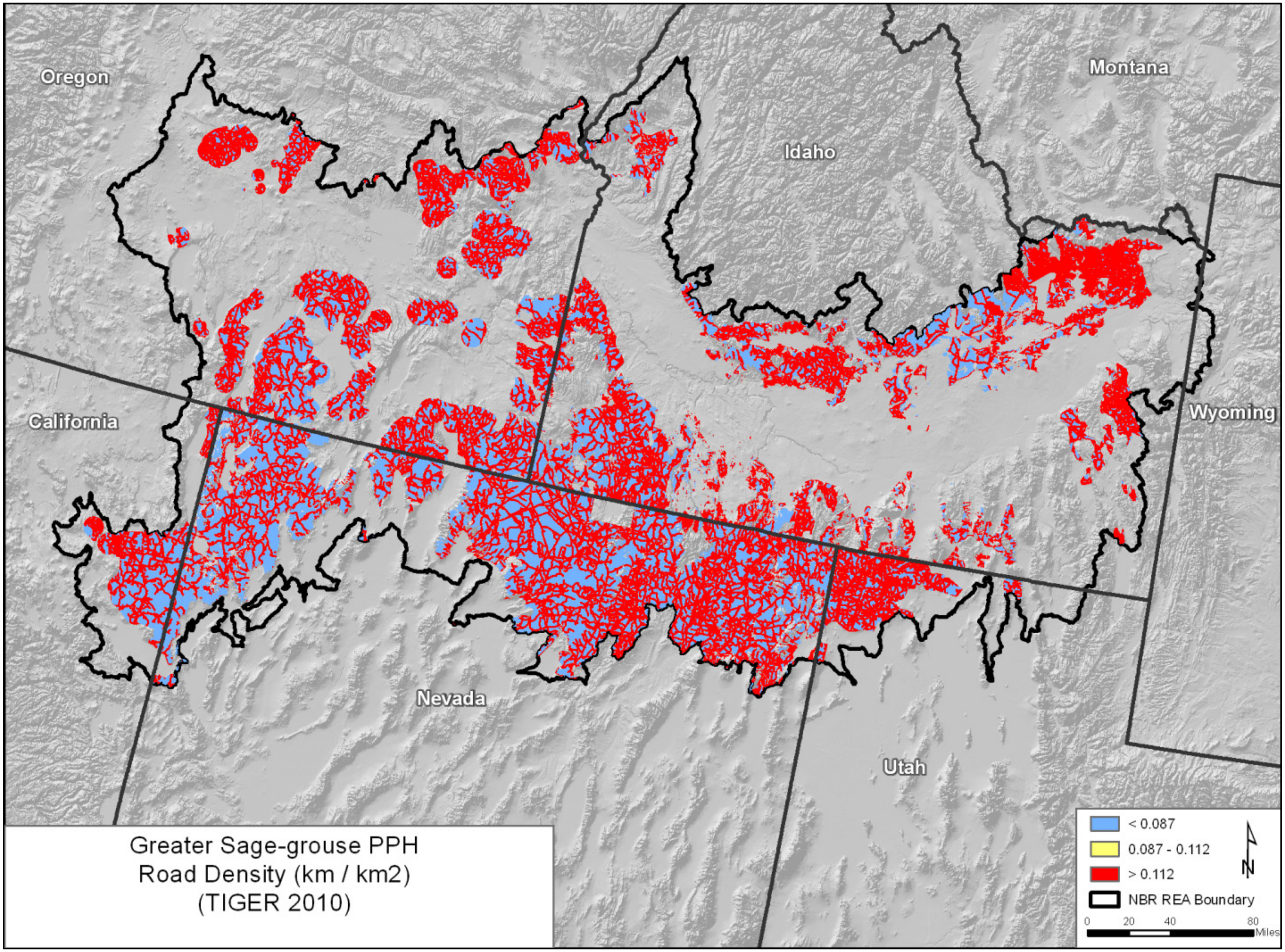


Figure 4.4.1.2-2 Road Density within Greater sage-grouse PPH areas

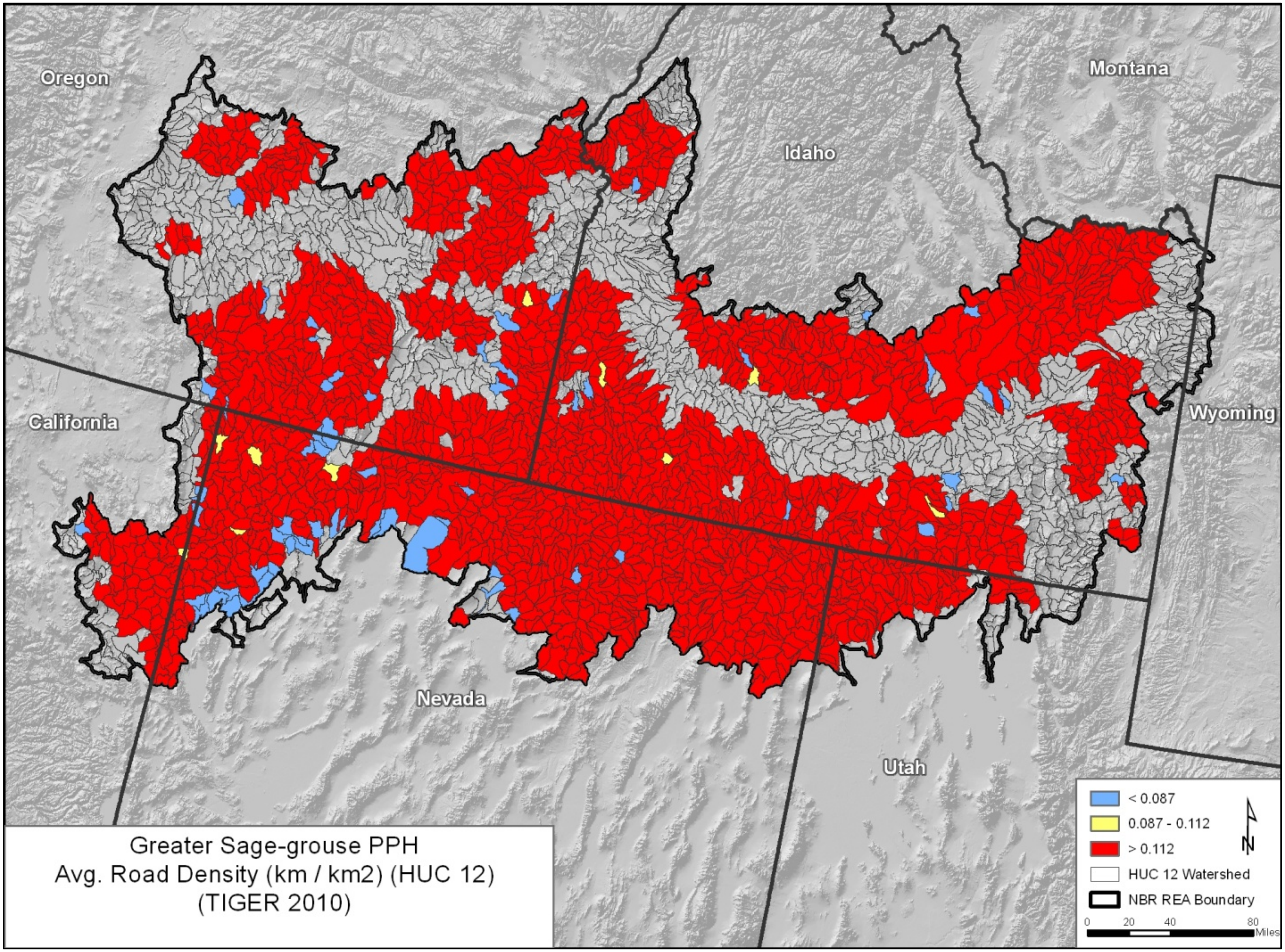


Figure 4.4.1.2-3 Road Density within Greater sage-grouse PPH areas (HUC 12)

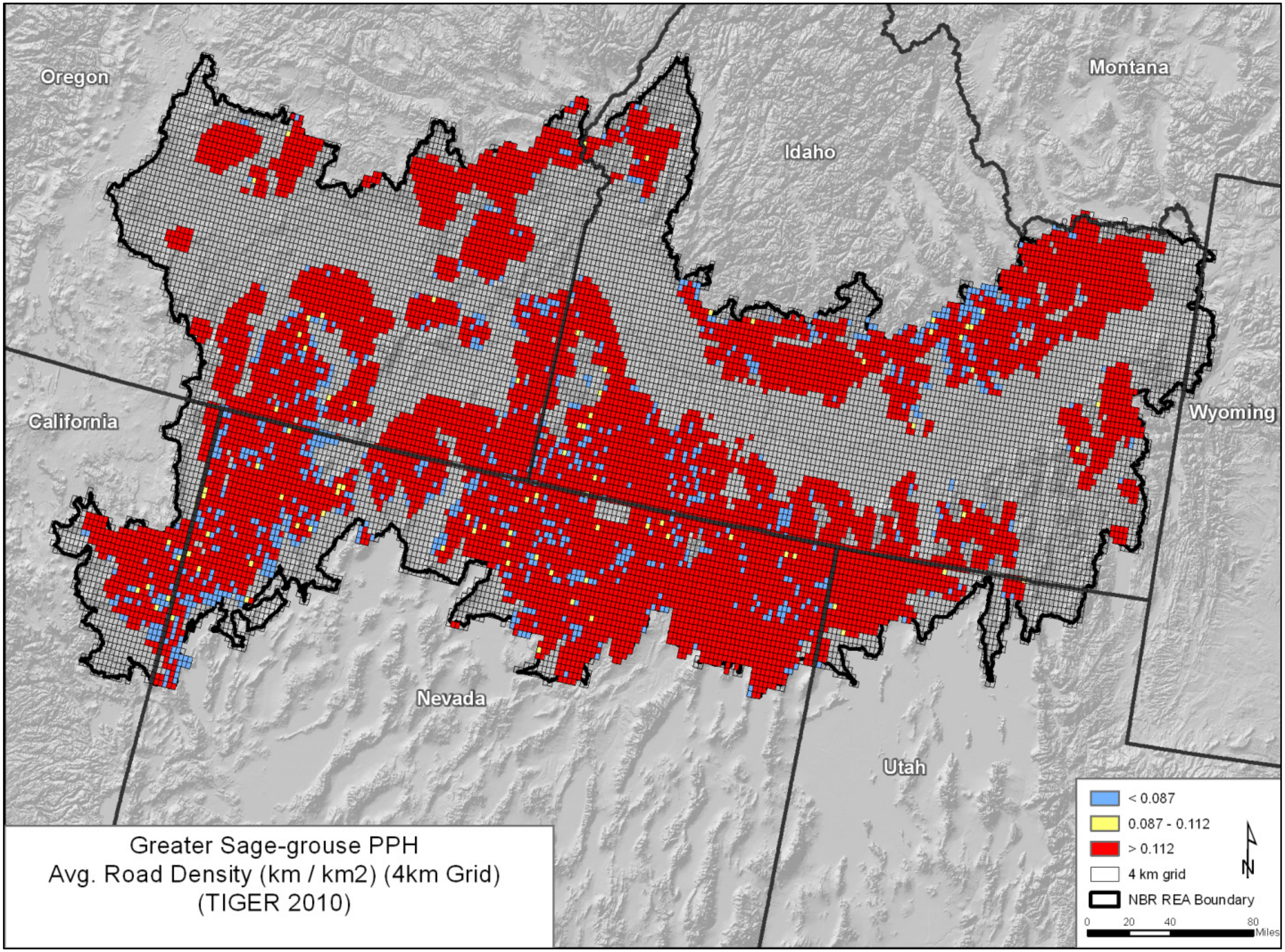


Figure 4.4.1.2-4 Road Density within Greater sage-grouse PPH areas (4 km Grid)

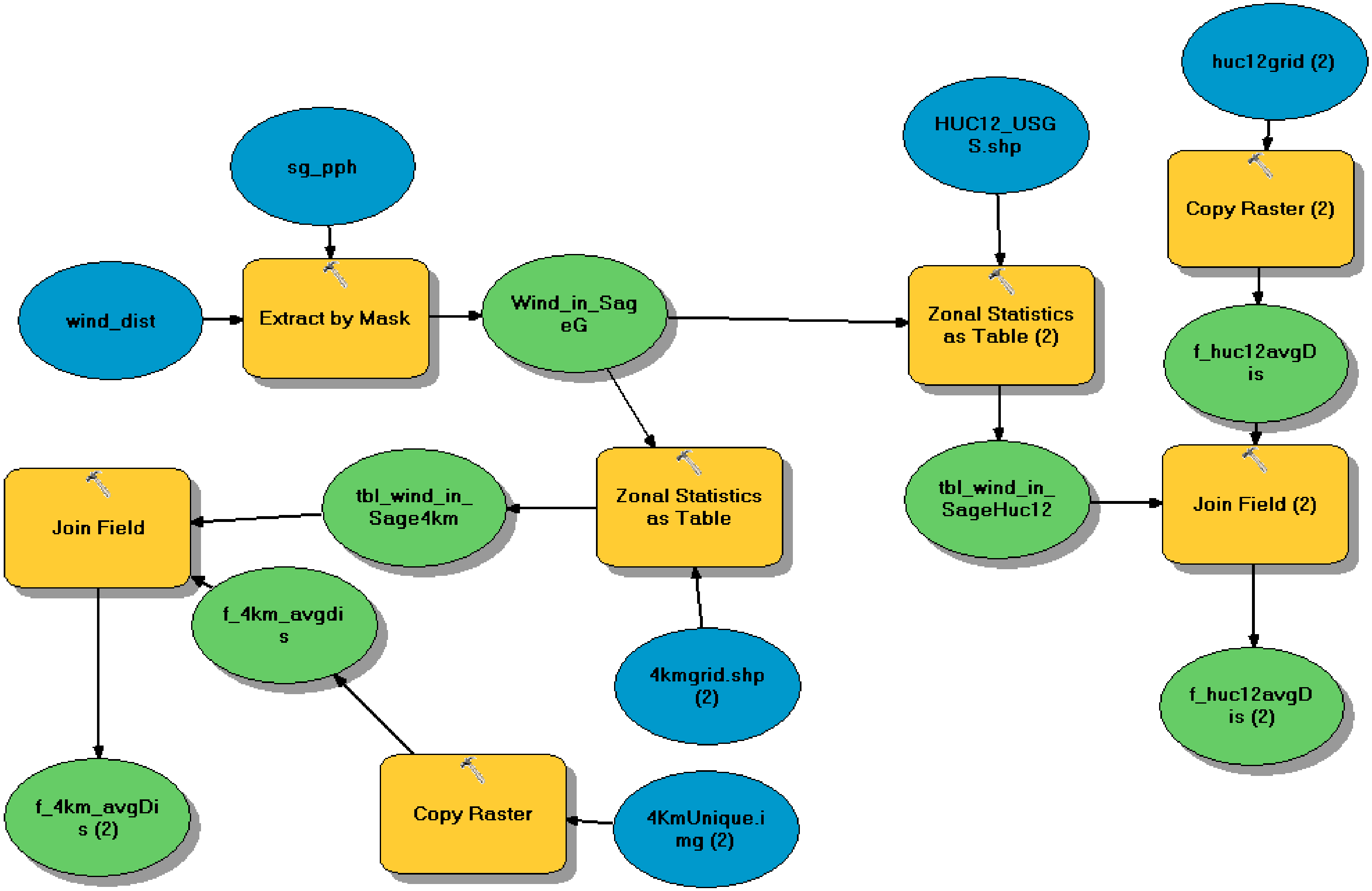


Figure 4.4.1.3-1 GIS Process Model for Distance from Wind Energy Towers KEA for Greater sage-grouse

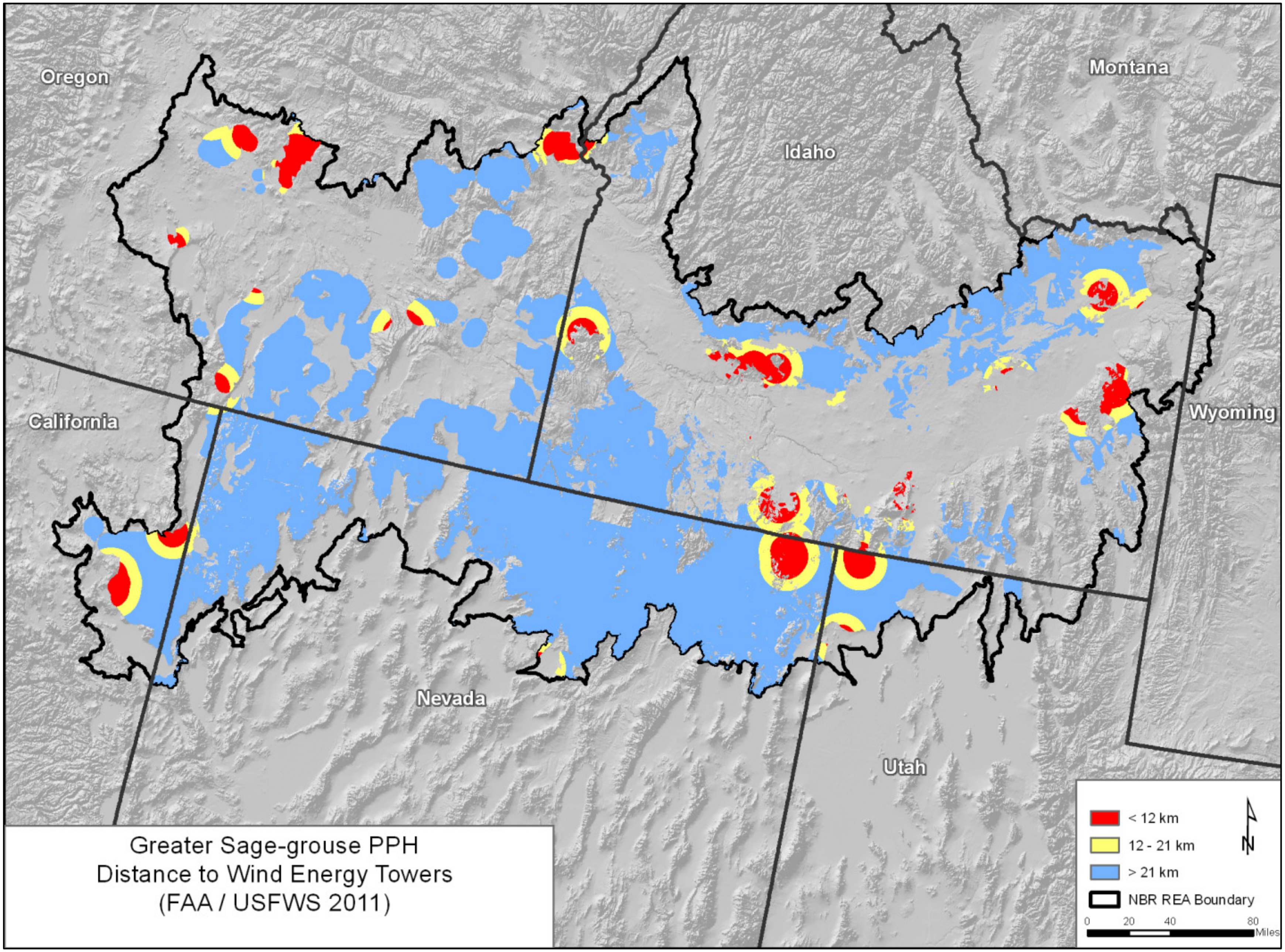


Figure 4.4.1.3-2 Distance to Wind Energy Towers within Greater sage-grouse PPH area

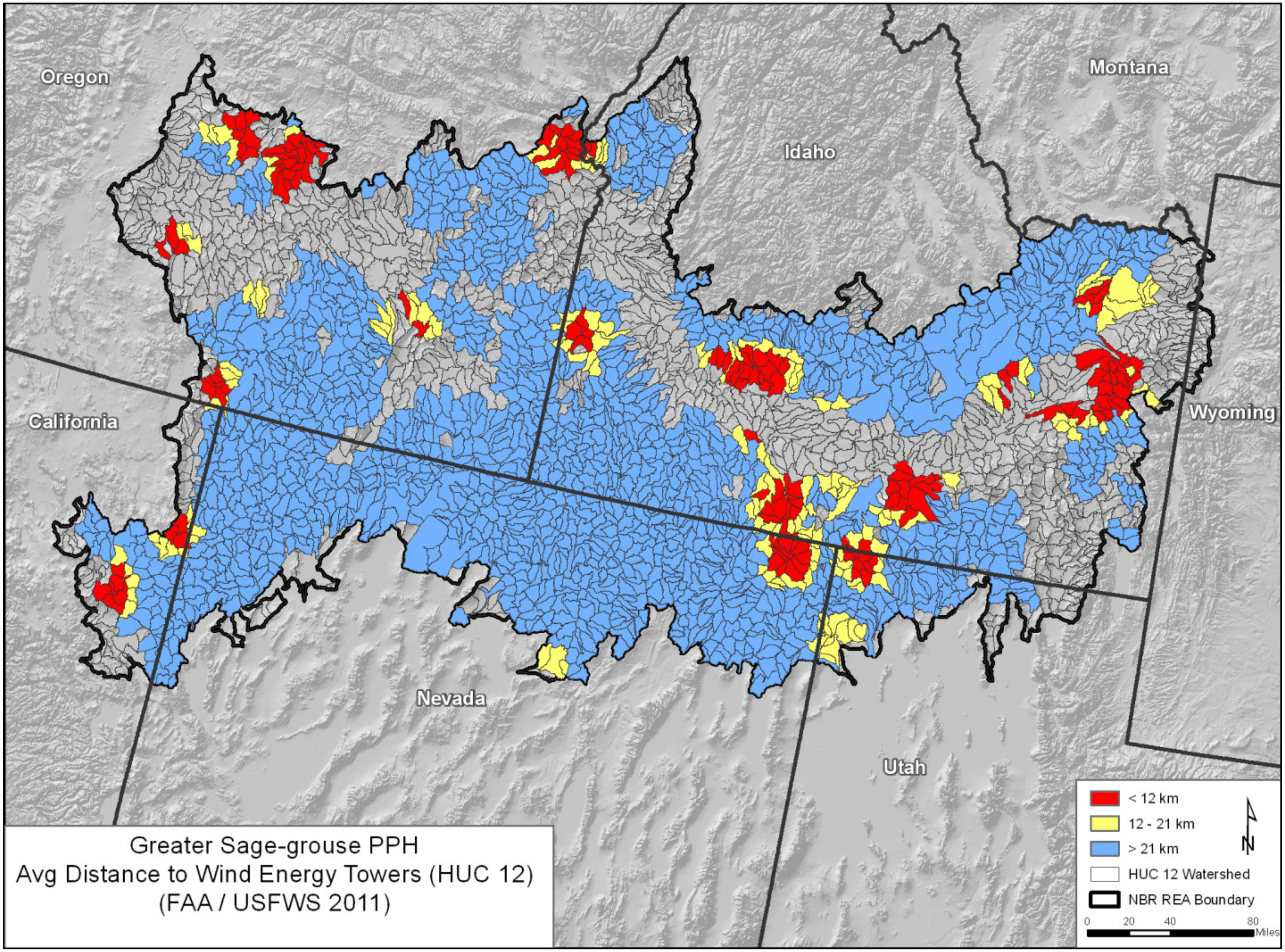


Figure 4.4.1.3-3 Distance to Wind Energy Towers within Greater sage-grouse PPH area (HUC 12)

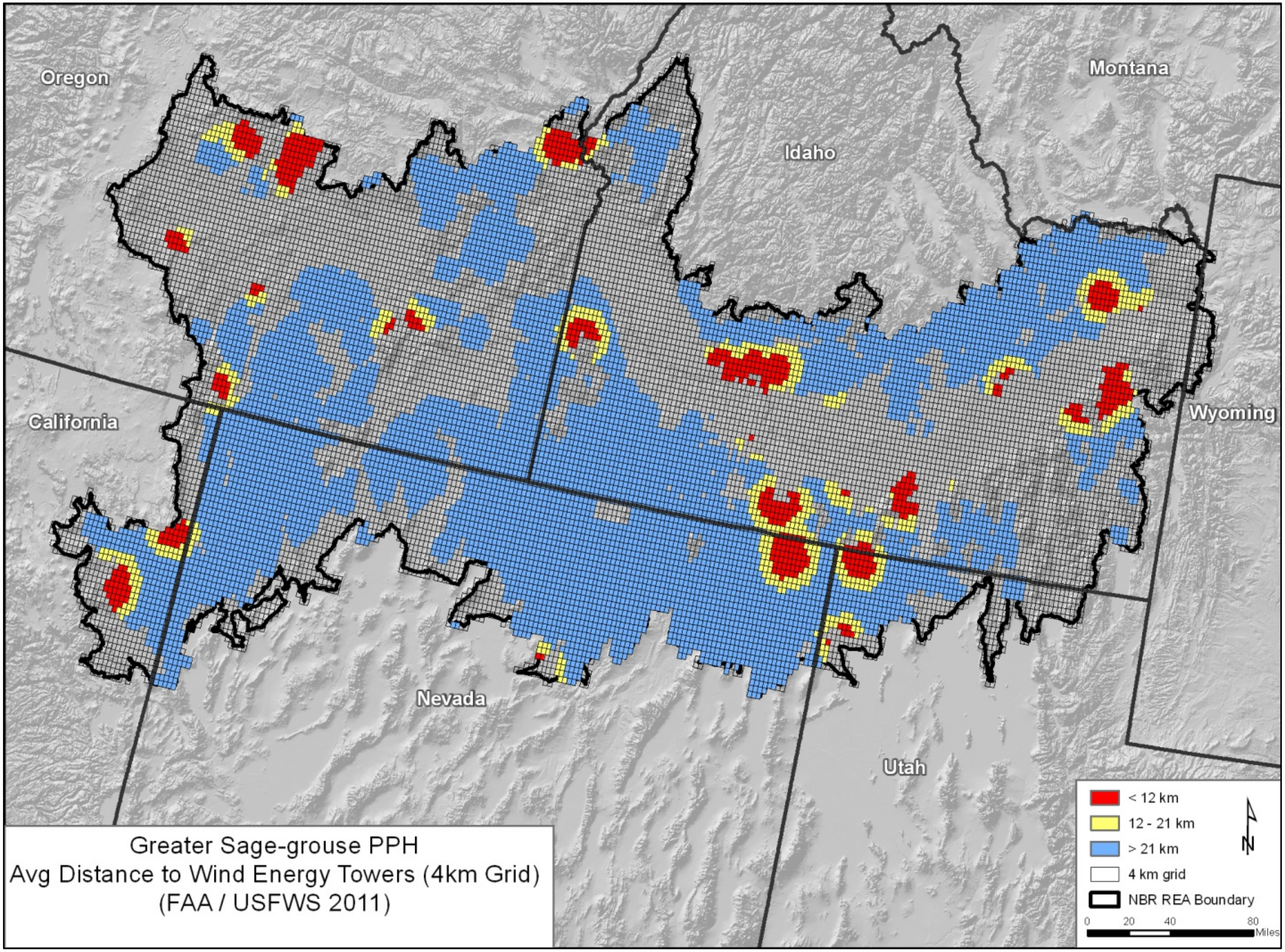


Figure 4.4.1.3-4 Distance to Wind Energy Towers within Greater sage-grouse PPH area

4.4.1.4 Distance to Communication Towers

The distance to communication towers is similar to the analysis in the previous KEA, Distance to Wind Energy. The data that was used in this analysis was collected from the Federal Communications Commission (FCC) and contains cell towers, am/fm stations, TV, etc. The GIS process (Figure 4.4.1.4-1) is similar with a Euclidean distance done on the towers and then only distances with the GSG PPH area are extracted and analyzed. The resulting map showing the distances binned by the metrics for this KEA can be viewed in Figure 4.4.1.4-2. Using the metrics for this KEA from Wisdom et al. 2011, most of the region is in the poor category with the exception being northern and northwestern Nevada with some large contiguous blocks in the good metric (blue). Figure 4.4.1.4-3 displays the average distance within each HUC 12 watershed while Figure 4.4.1.4-4 shows the average based on the 4 km grid.

4.4.1.5 Distance to Transmission Lines

The distance to transmission lines KEA uses data collected by Global Energy and was dated 2005. This might a little out of date but it was provided by BLM so it might be the best dataset for ecoregion wide coverage. The GIS process model (Figure 4.4.1.4-1) starts with a Euclidean distance to the nearest transmission line and is then clipped to the GSG PPH area. Figure 4.4.1.4-2 show the resulting map of the distances binned to the KEA metrics. Since transmission lines are linear this creates corridors through the PPH areas. It appears that north eastern Idaho has some PPH area that seems to fall mostly in the poor metric Wisdom et al. 2011 uses. Figure 4.4.1.4-3 displays the average distance by HUC 12 watershed and Figure 4.4.1.4-4 show the average for the 4 km grid.

4.4.1.6 % of PPH area in Agriculture

There appears to a fairly low amount of agriculture in the GSG PPH area within the ecoregion. The data source used for the agricultural areas was LANDFIRE Existing Vegetation Type (EVT). The GIS process (Figure 4.4.1.6-1) used for the analysis was to extract the agricultural areas from LANDFIRE then to clip the agricultural areas to the PPH area. As seen in Figure 4.4.1.6-2 there are a few clusters of agriculture that stand out in red in California, Nevada and Idaho. Oregon doesn't seem to have any clustering of agriculture in the PPH area. Figure 4.4.1.6-3 displays the percentage of the HUC 12 watershed with agriculture and Figure 4.4.1.6-4 show the percent for each 4 km grid cell. Using the metrics for this KEA, there weren't any HUC 12 watersheds that fell into the poor category (> 27%). The 4 km grid did have some cells that fell into the poor category.

4.4.1.7 Combined Greater Sage-grouse Threat Map

The results of the each of the KEA are combined to generate a threat map highlighting areas where multiple threats overlap each other. Viewing the PPH area in this fashion would allow land managers to determine areas that might be suitable for remediation or areas that should be protected by limiting new threats where possible. The GIS process (Figure 4.4.1.7-1) used to overlay the threats reclassifies each of the threats into the good (3), fair (2) and poor (1) metrics used. The resulting five threat layers are then divided by 15 to derive a value between 0.33 and 1. An area with good in all the threats would score a perfect 1.0 (3*5/15). An area with poor in all the threats would score 0.33 (1*5/15). A weighting system could also be used for the analysis if certain KEAs were considered more significant than others. The KEAs used for combined threats for the GSG will be the distance to road, distance to wind energy, distance to communication towers, distance to transmission lines and percent agriculture. Road density will be left out in this example since its metrics were classifying most of the PPH as high (see section 4.4.1.2 for description of difficulties encountered with this KEA and dataset). The map of the overlaid threats can be viewed in Figure 4.4.1.7-2 showing the compounding of threats in the PPH. Jenks natural breaks (a way of splitting data by natural groupings) were used to classify the data, 0.66 was classified as poor, greater than 0.86 was good. The GIS process for processing the data to the HUC 12 and 4 km grid analysis units can viewed in Figure 4.4.1.7-3. Figure 4.4.1.7-4 displays the combined threat at the HUC 12 analysis unit while Figure 4.4.1.7-5 shows the 4 km grid. Jenks 'natural breaks' were again used to divide the results into three classes with the resulting values being very close to the same between the two figures.

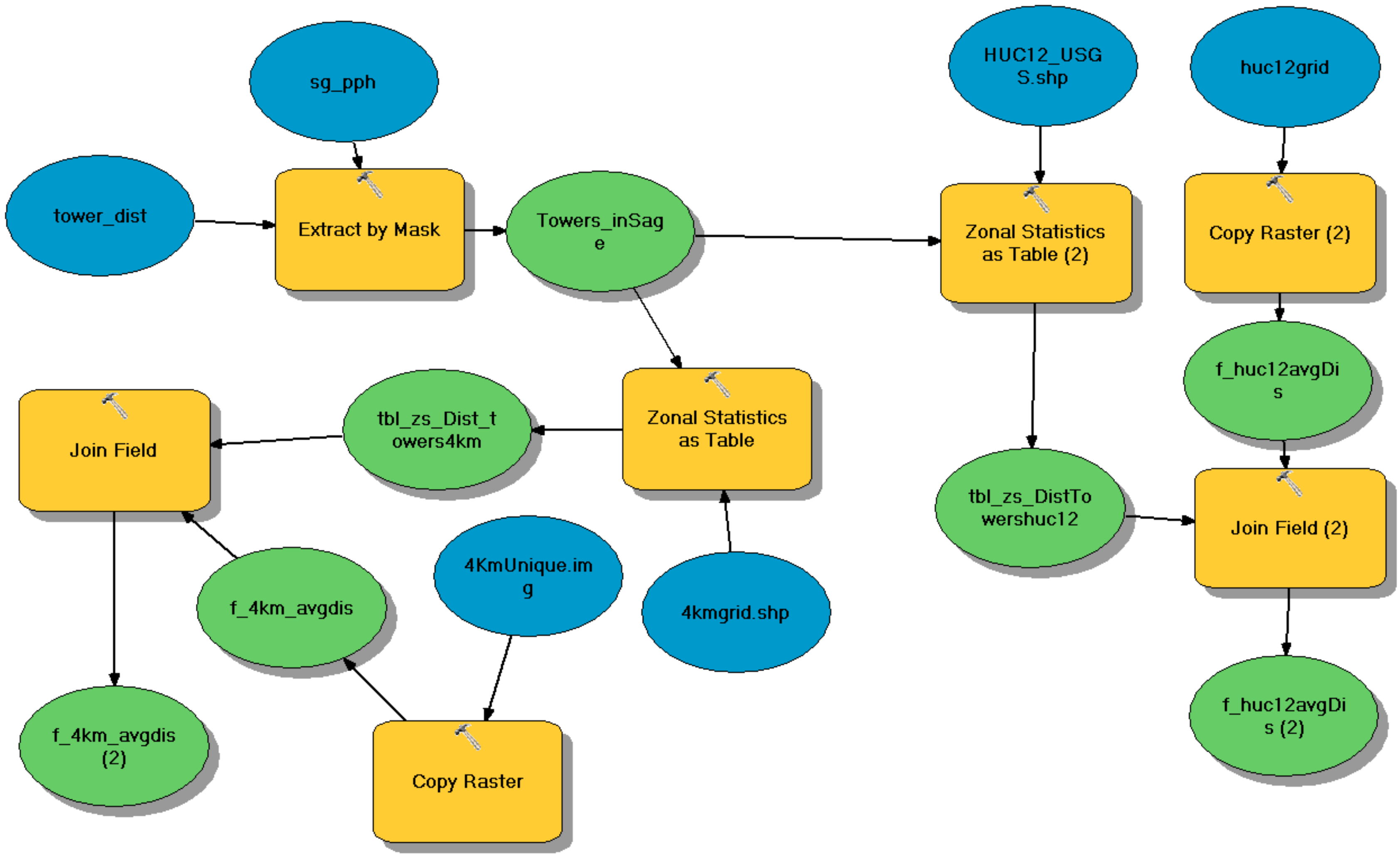


Figure 4.4.1.4-1 GIS Process Model for Distance from Communication Towers KEA for Greater sage-grouse

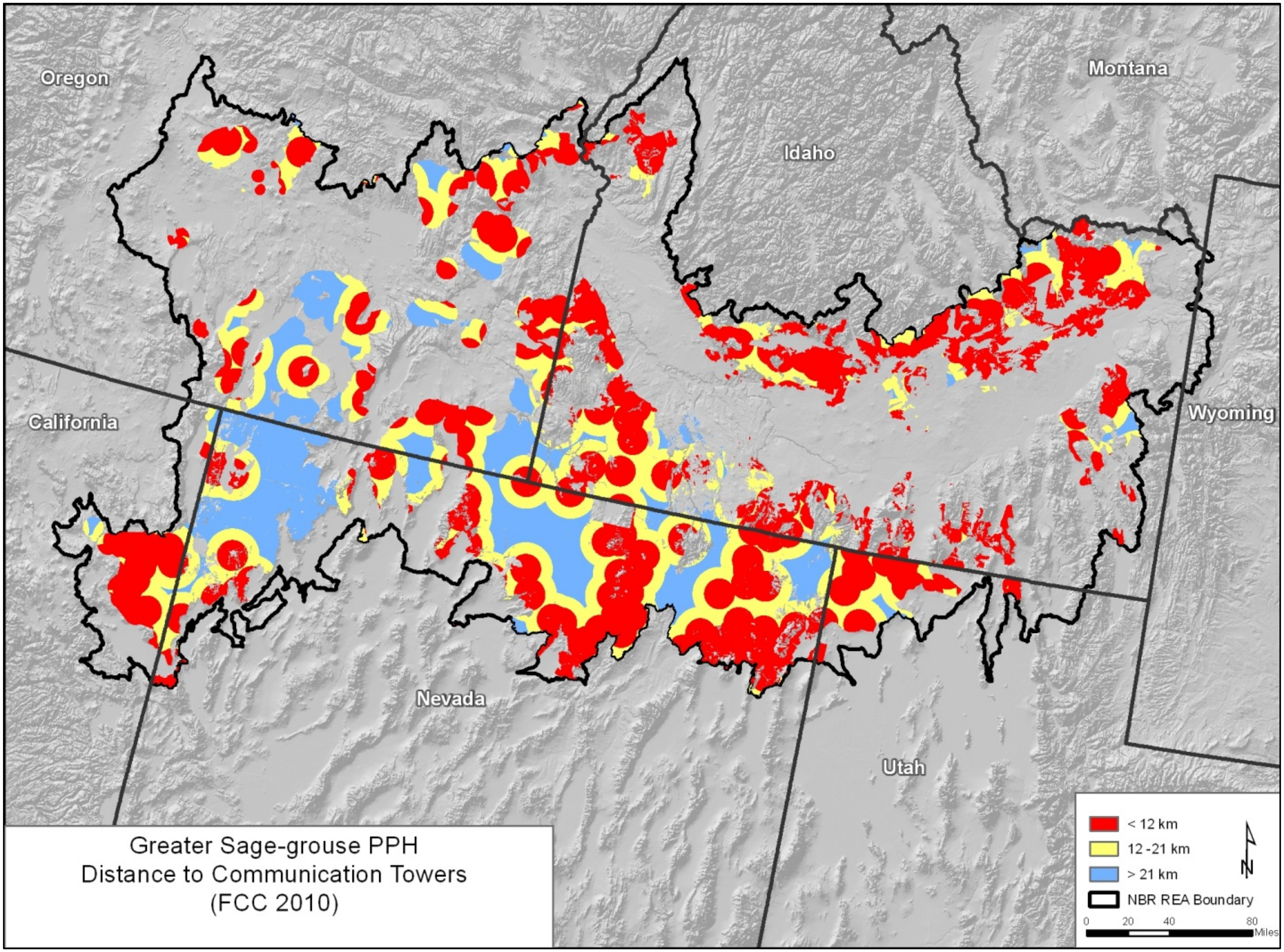


Figure 4.4.1.4-2 Distance to Communication Towers within Greater sage-grouse PPH area

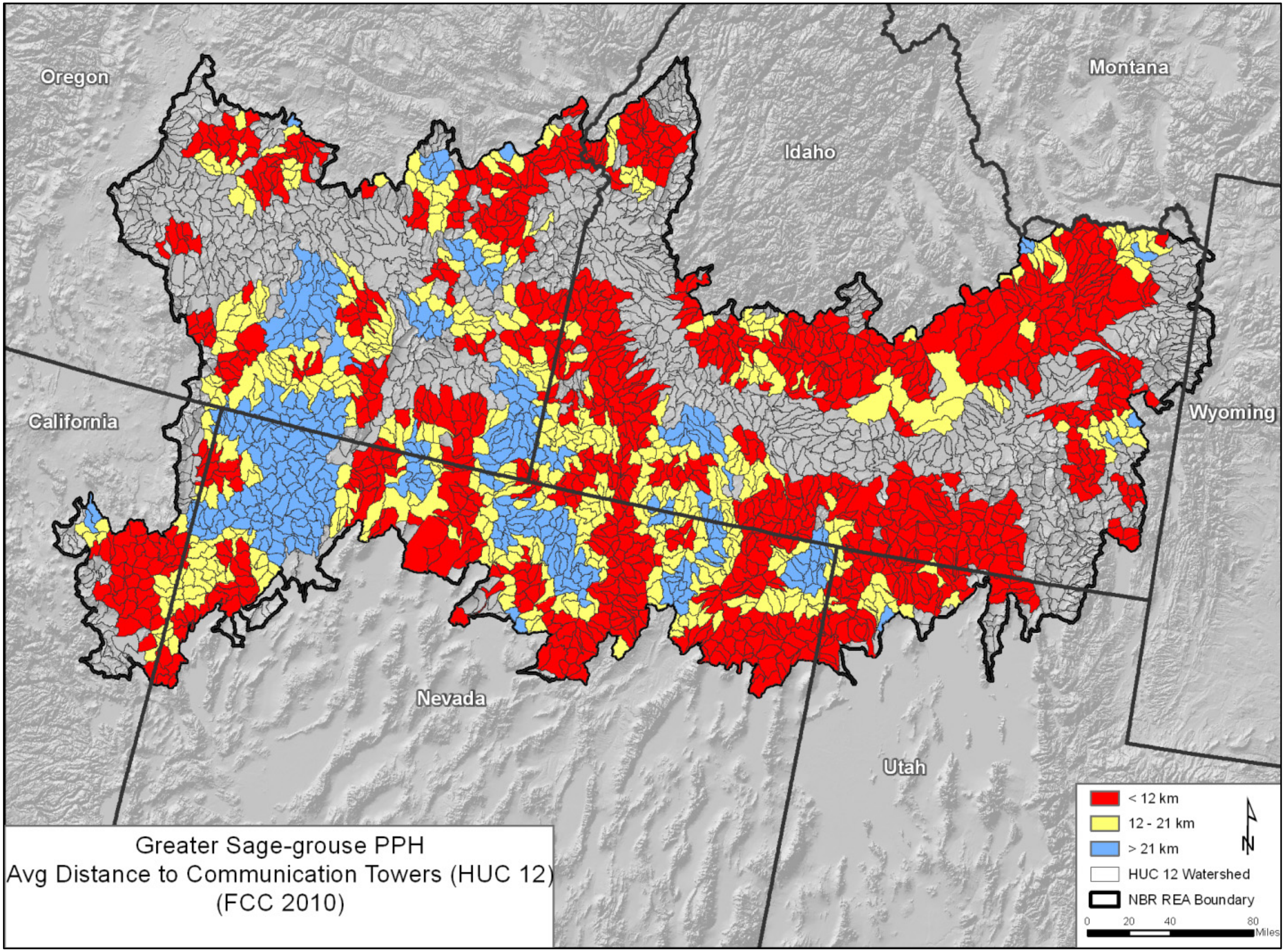


Figure 4.4.1.4-3 Distance to Communication Towers within Greater sage-grouse PPH area (HUC 12)

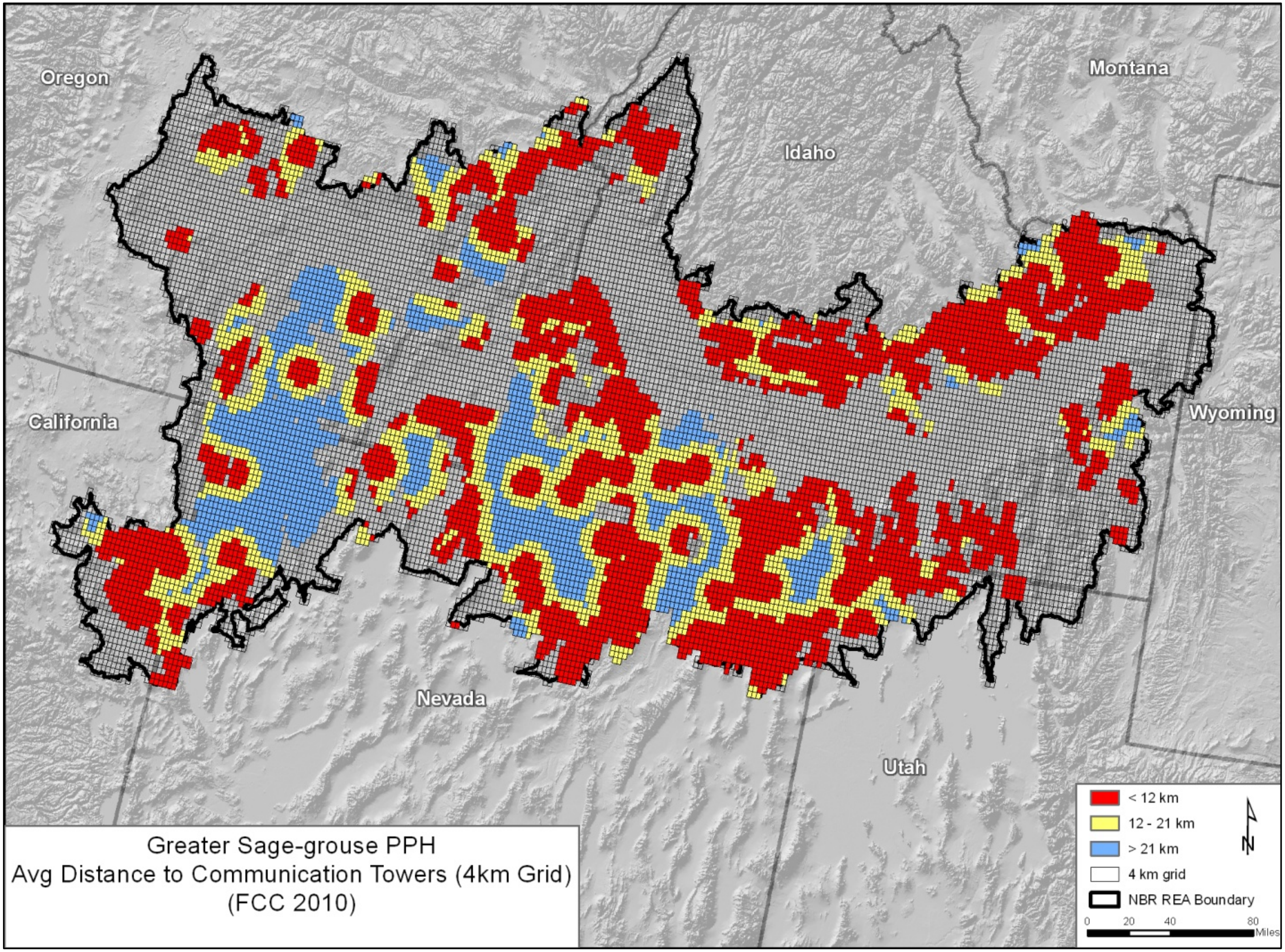


Figure 4.4.1.4-4 Distance to Communication Towers within Greater sage-grouse PPH area (4 km Grid)

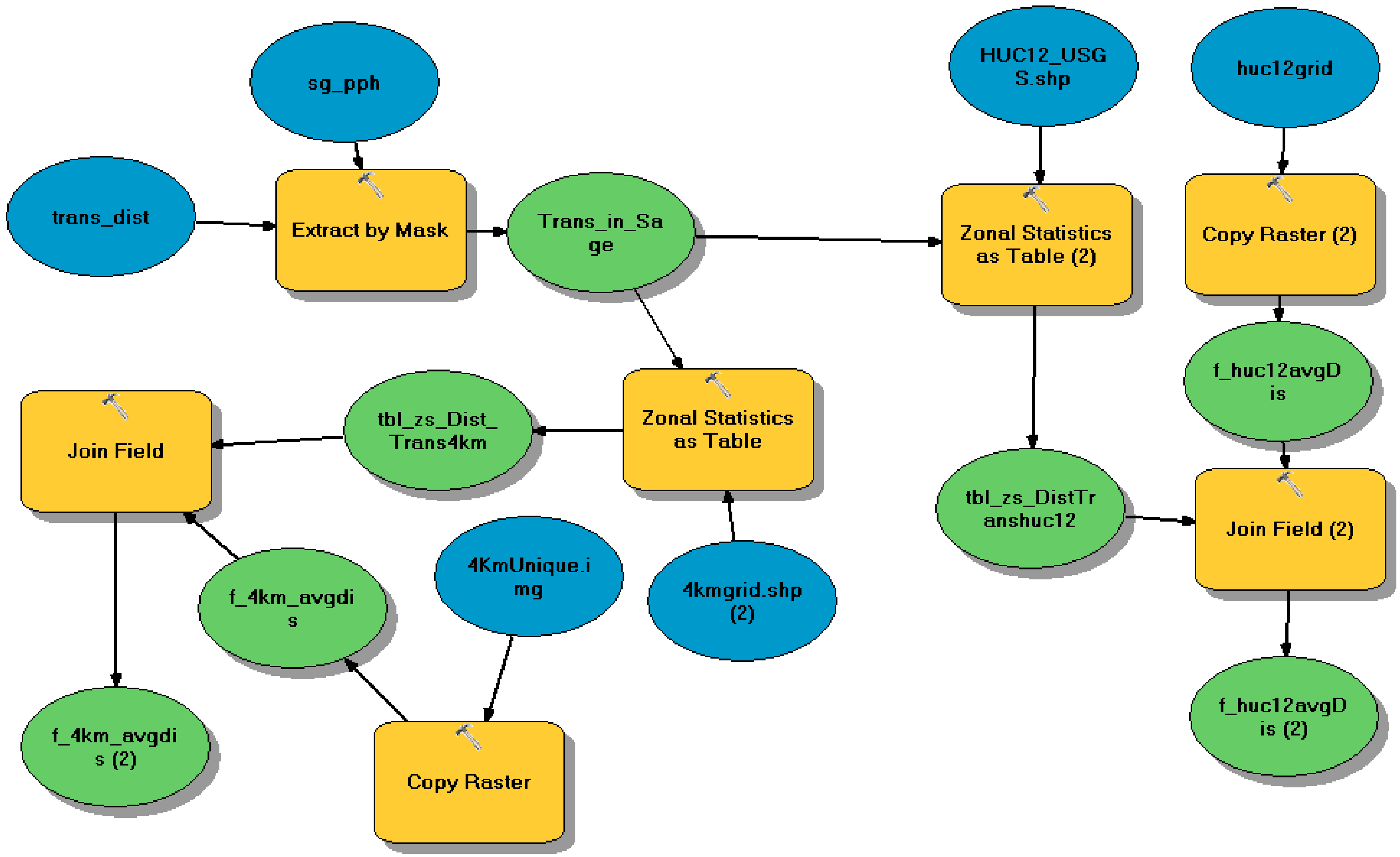


Figure 4.4.1.5-1 GIS Process Model for Distance from Transmission Lines KEA for Greater sage-grouse

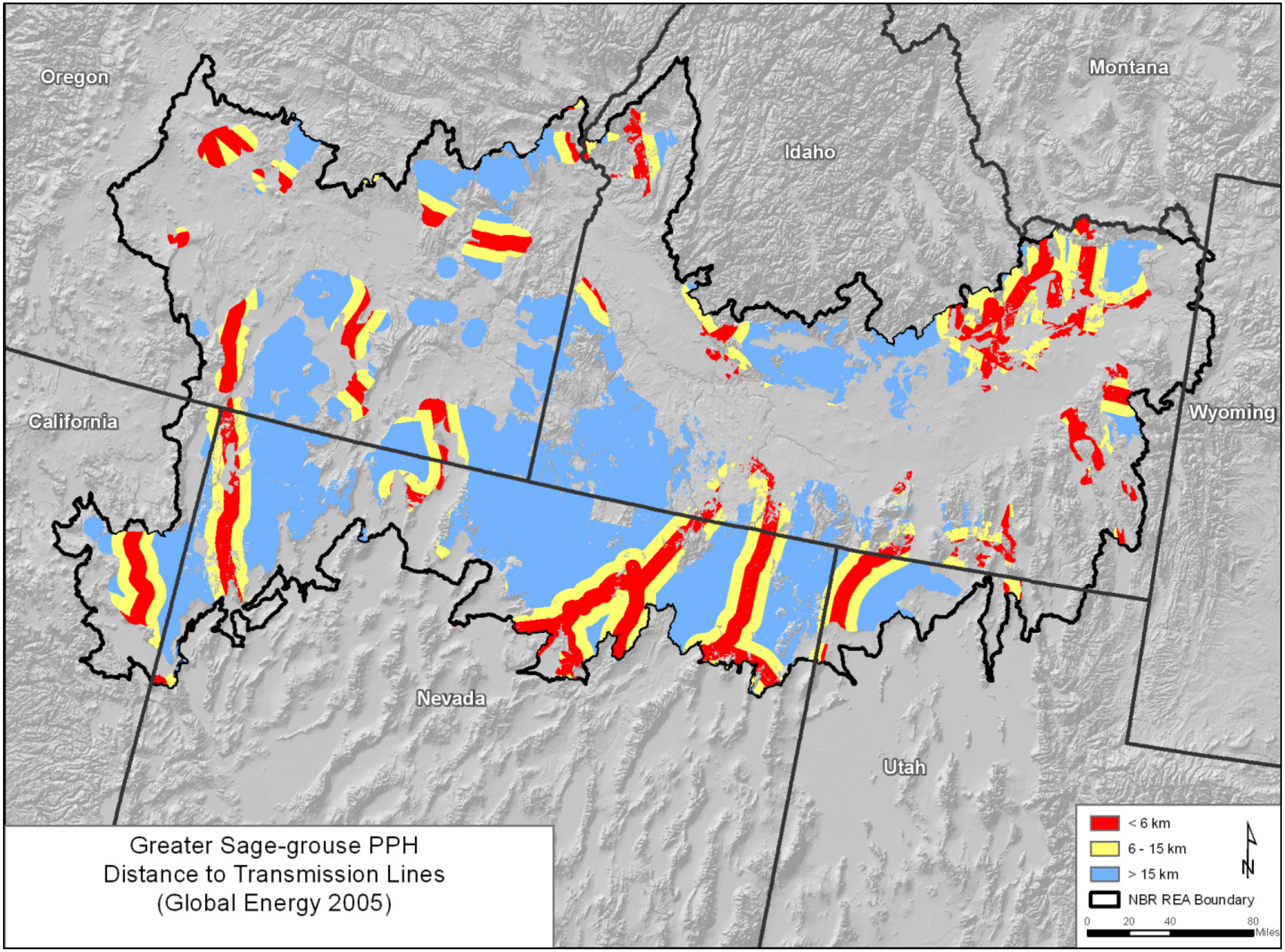


Figure 4.4.1.5-2 Distance to Transmission Lines within Greater sage-grouse PPH area

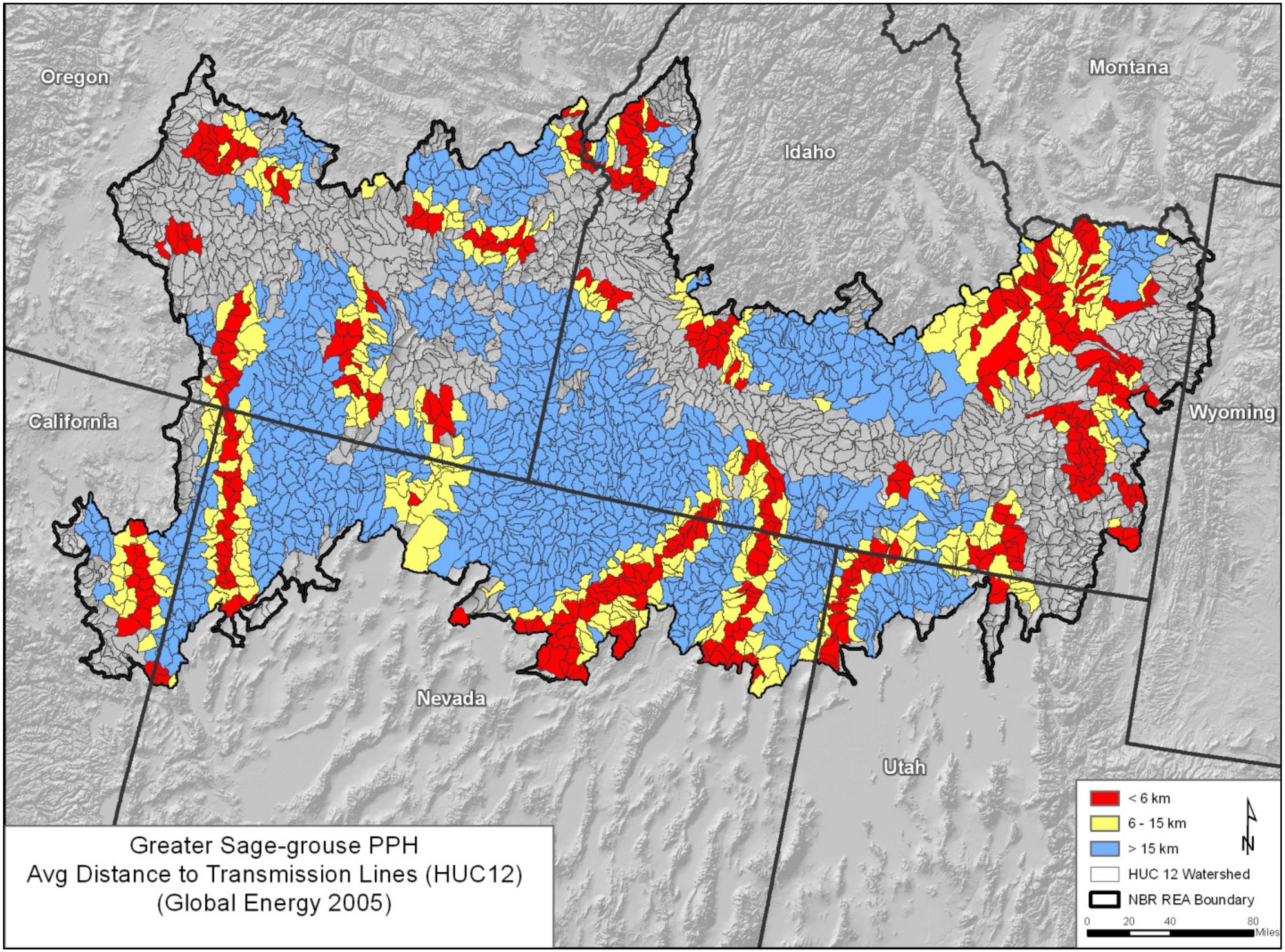


Figure 4.4.1.5-3 Average Distance to Transmission Lines within Greater sage-grouse PPH area (HUC 12)

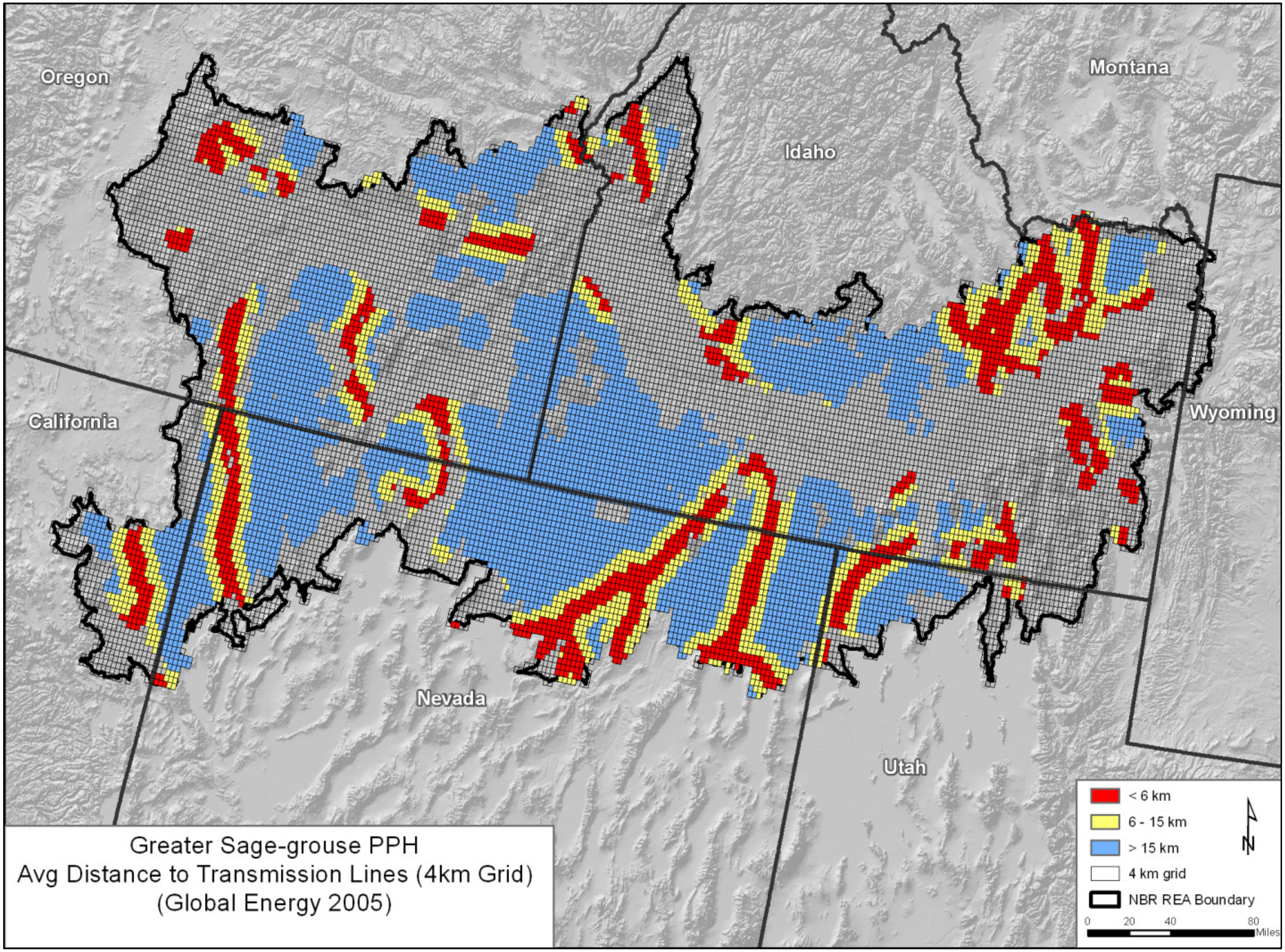


Figure 4.4.1.5-4 Average Distance to Transmission Lines within Greater sage-grouse PPH area (4 km Grid)

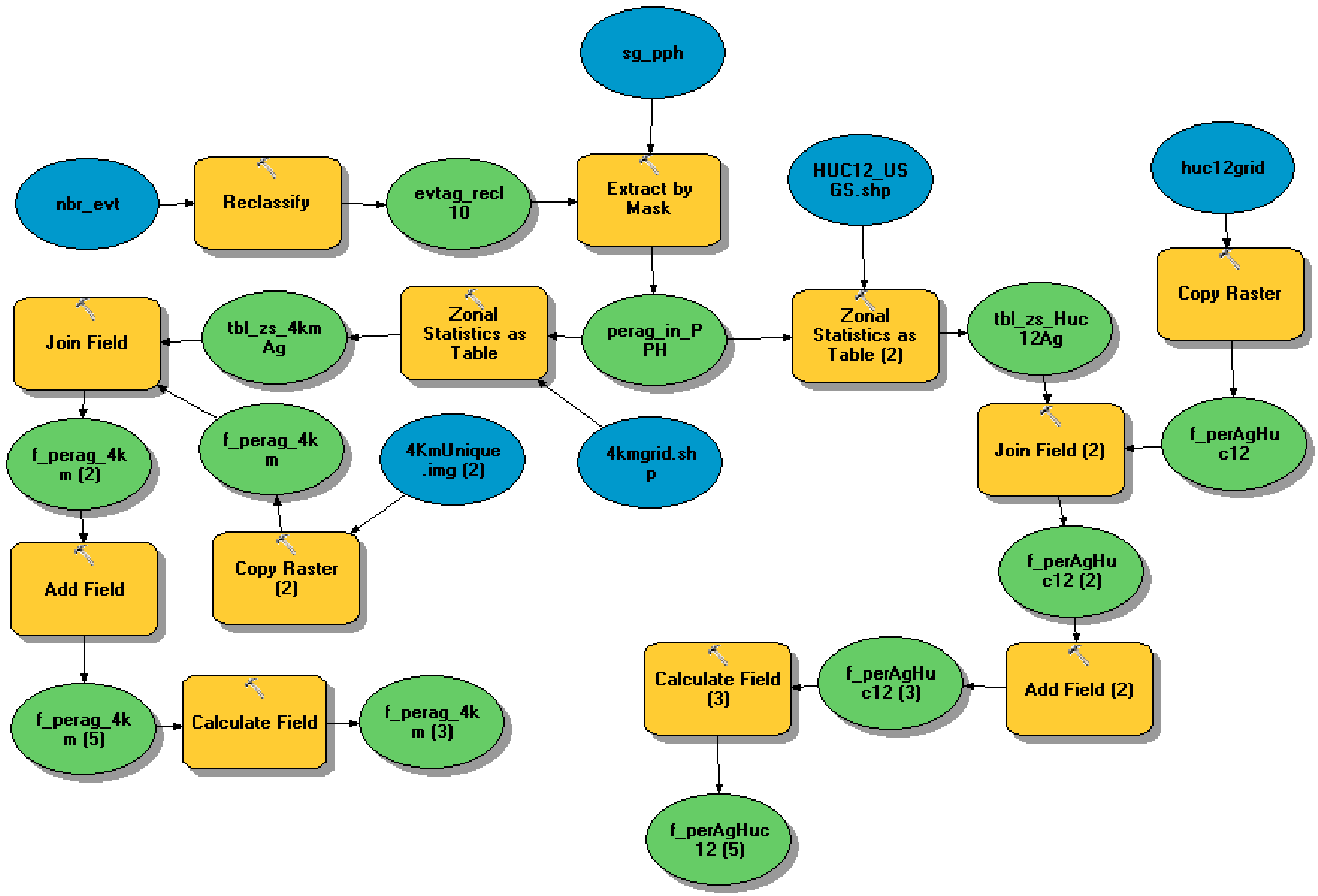


Figure 4.4.1.6-1 GIS Process Model for Percent of Agriculture KEA for Greater sage-grouse

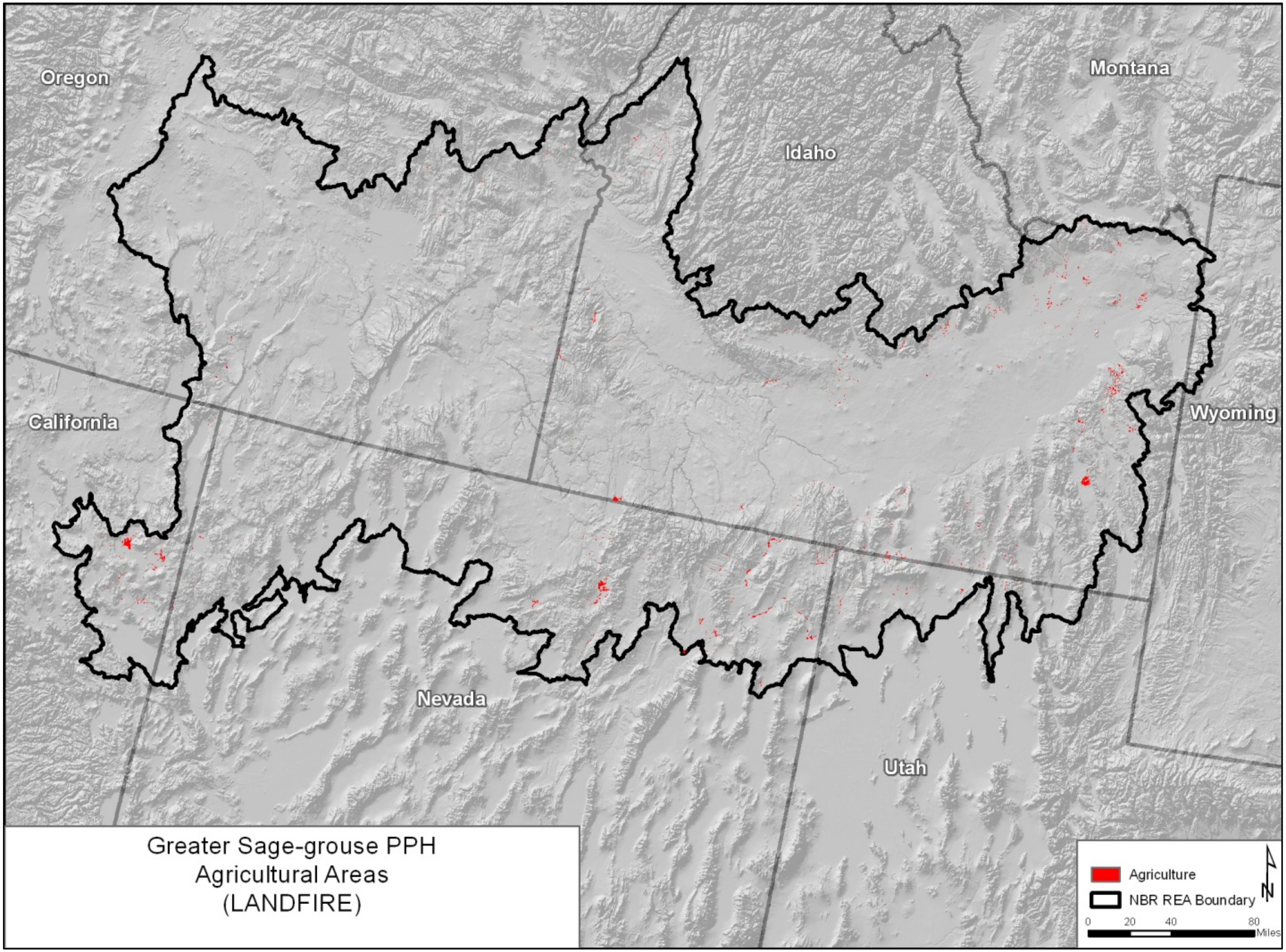


Figure 4.4.1.6-2 Agricultural Areas within Greater sage-grouse PPH

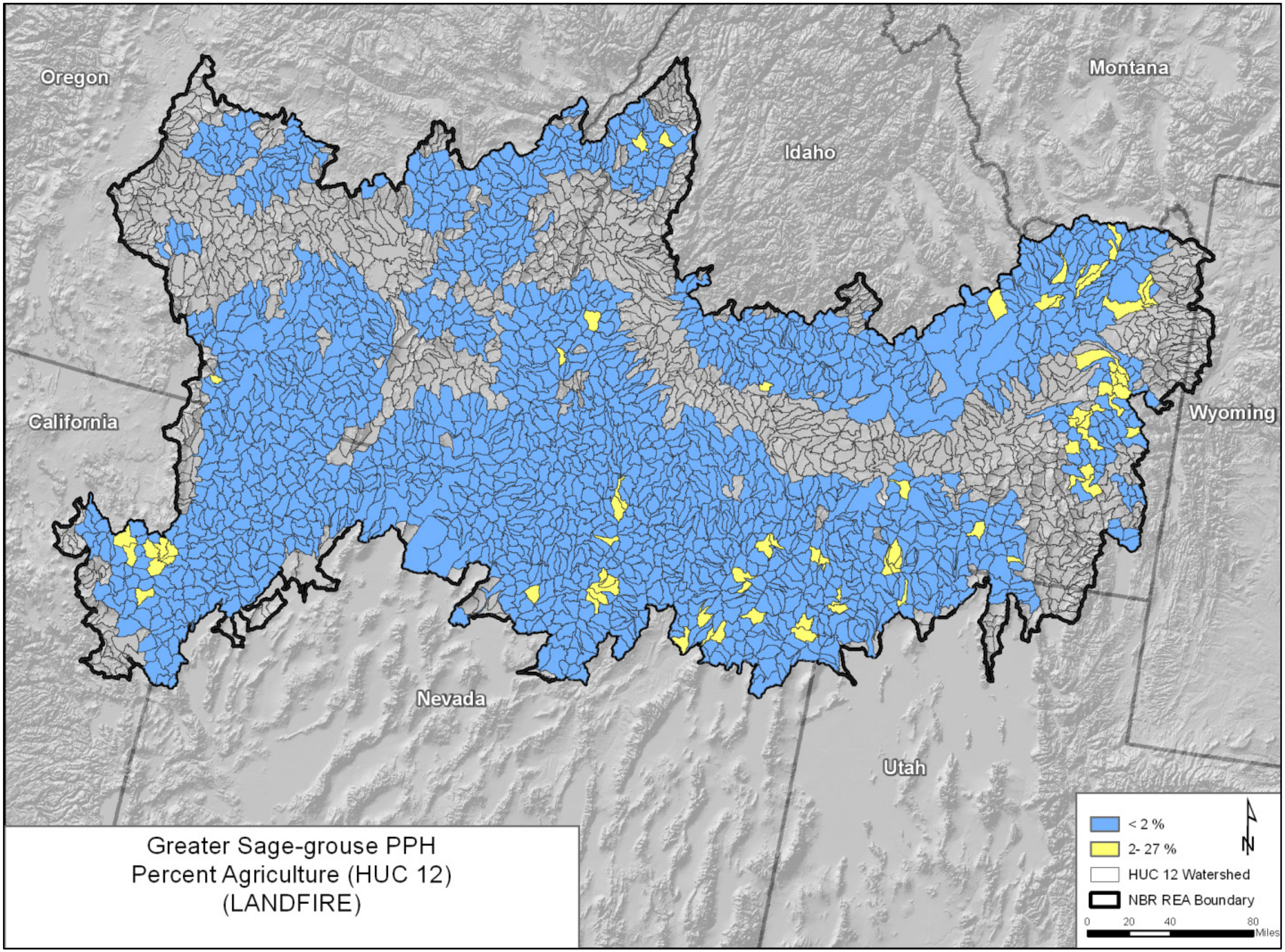


Figure 4.4.1.6-3 Percent Agricultural within Greater sage-grouse PPH (HUC 12)

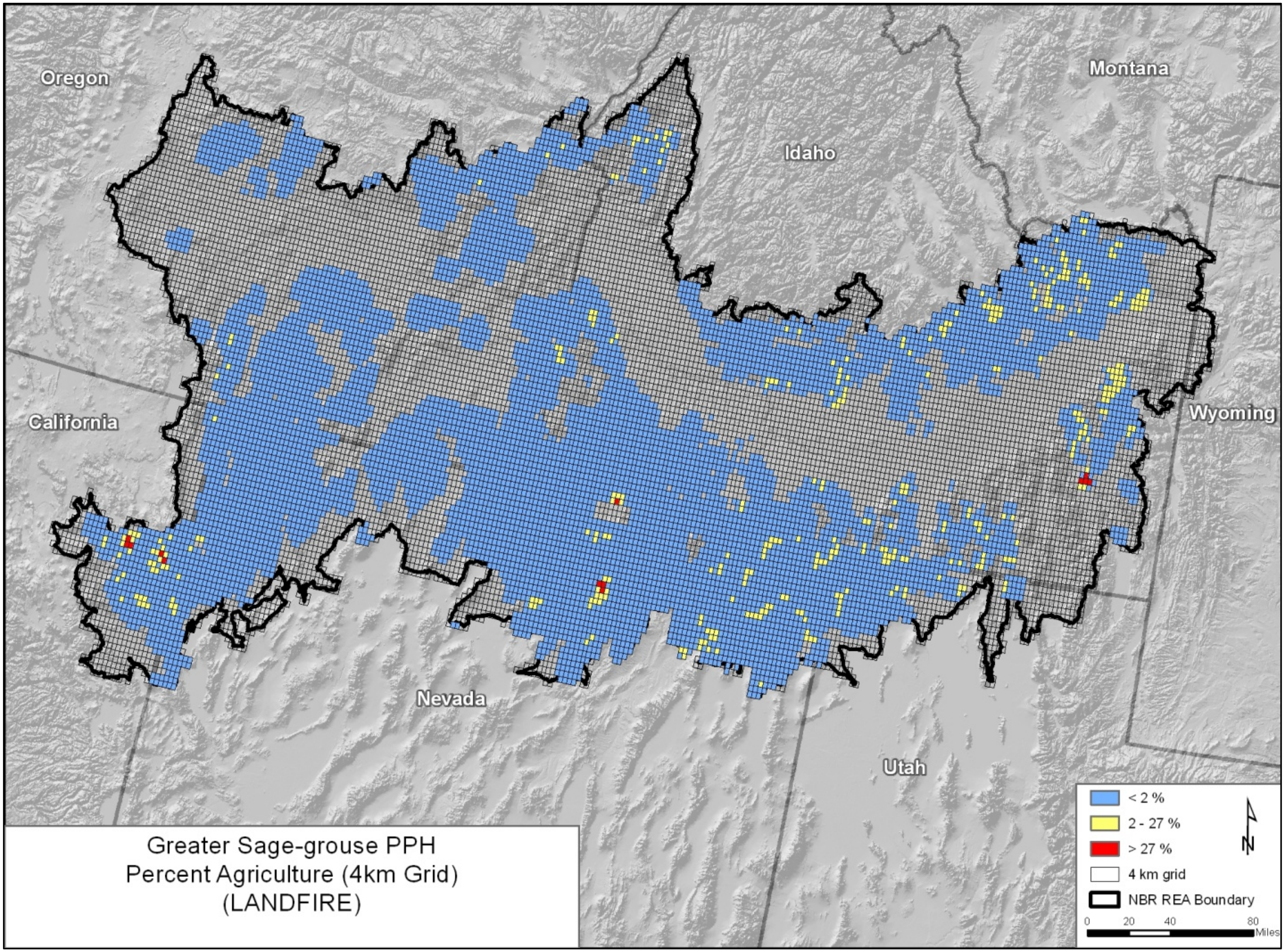


Figure 4.4.1.6-4 Percent Agricultural within Greater sage-grouse PPH (4 km Grid)

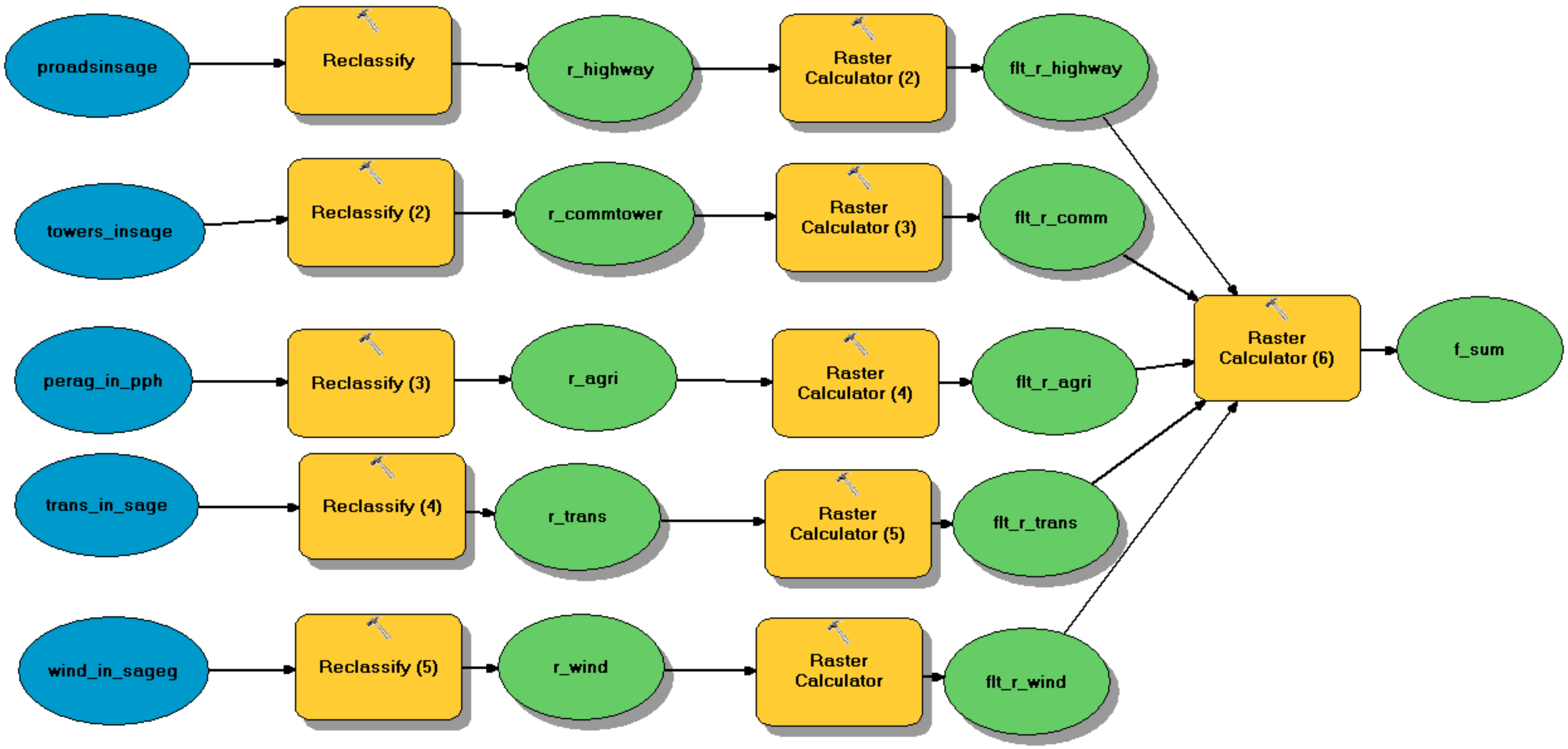


Figure 4.4.1.7-1 GIS Process Model for Combining Threats for Greater sage-grouse

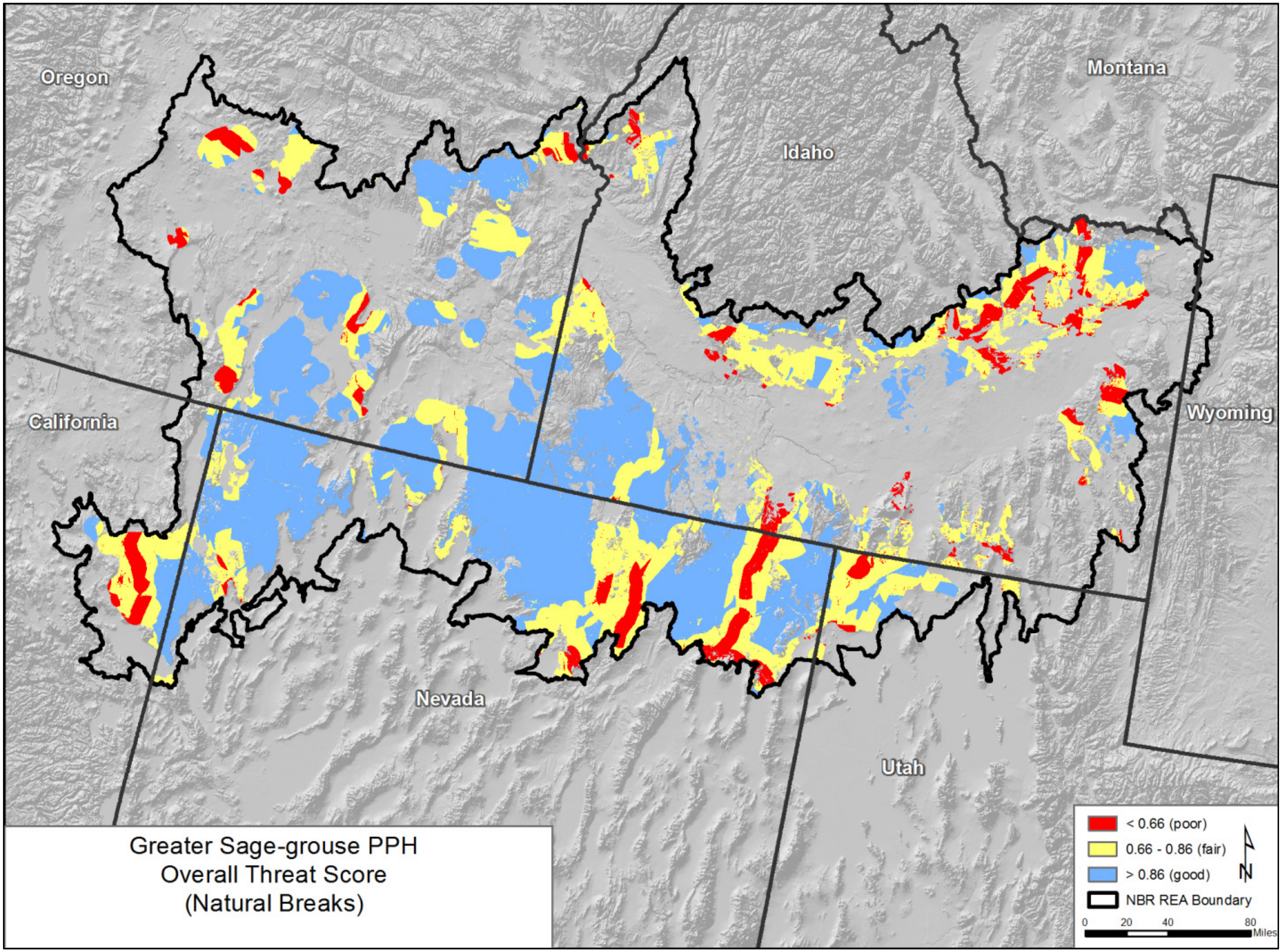


Figure 4.4.1.7-2 Combined Threats for Greater sage-grouse PPH

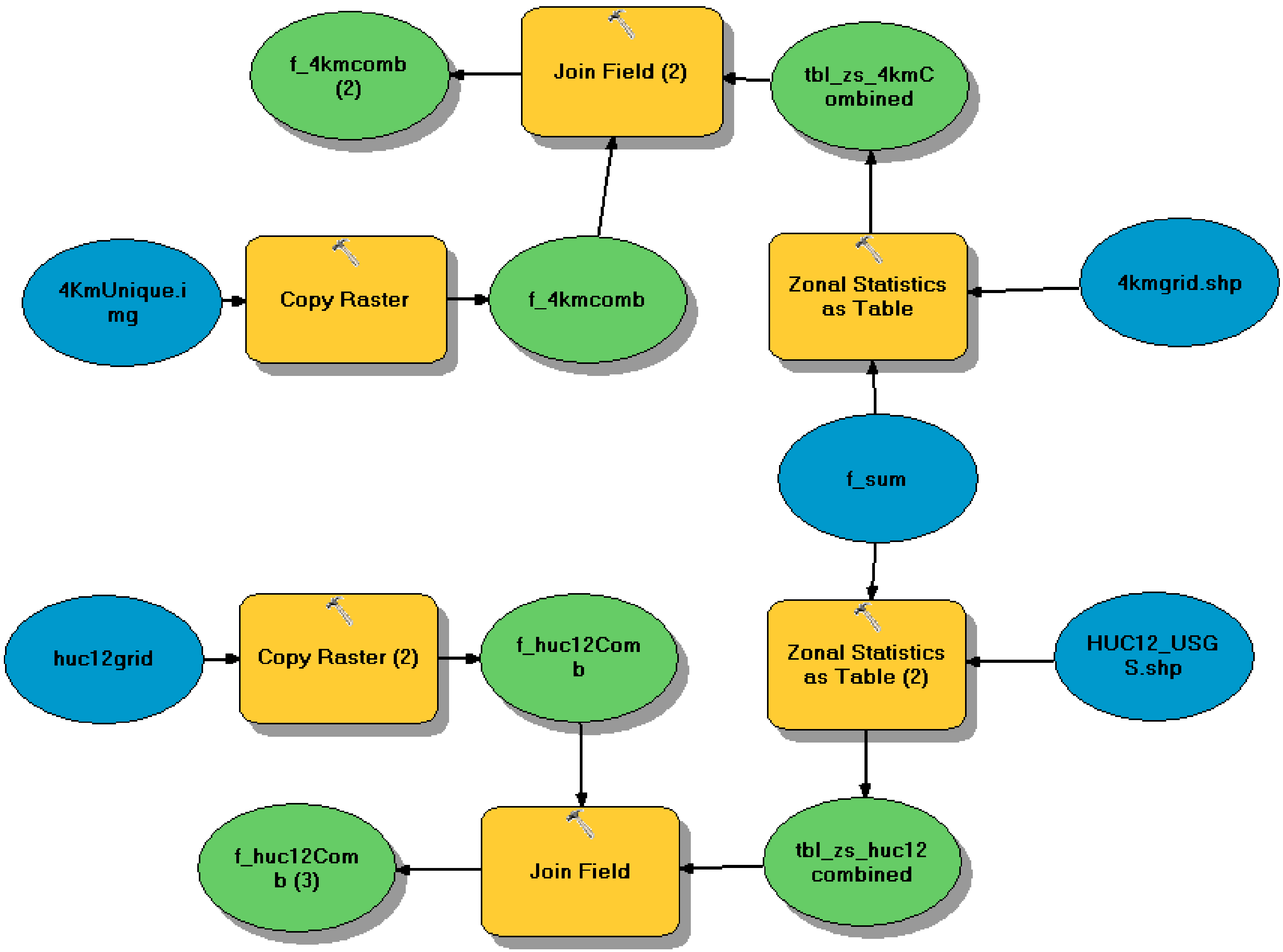


Figure 4.4.1.7-3 GIS Process Model for Analyzing Threats for Greater sage-grouse by Analysis Units

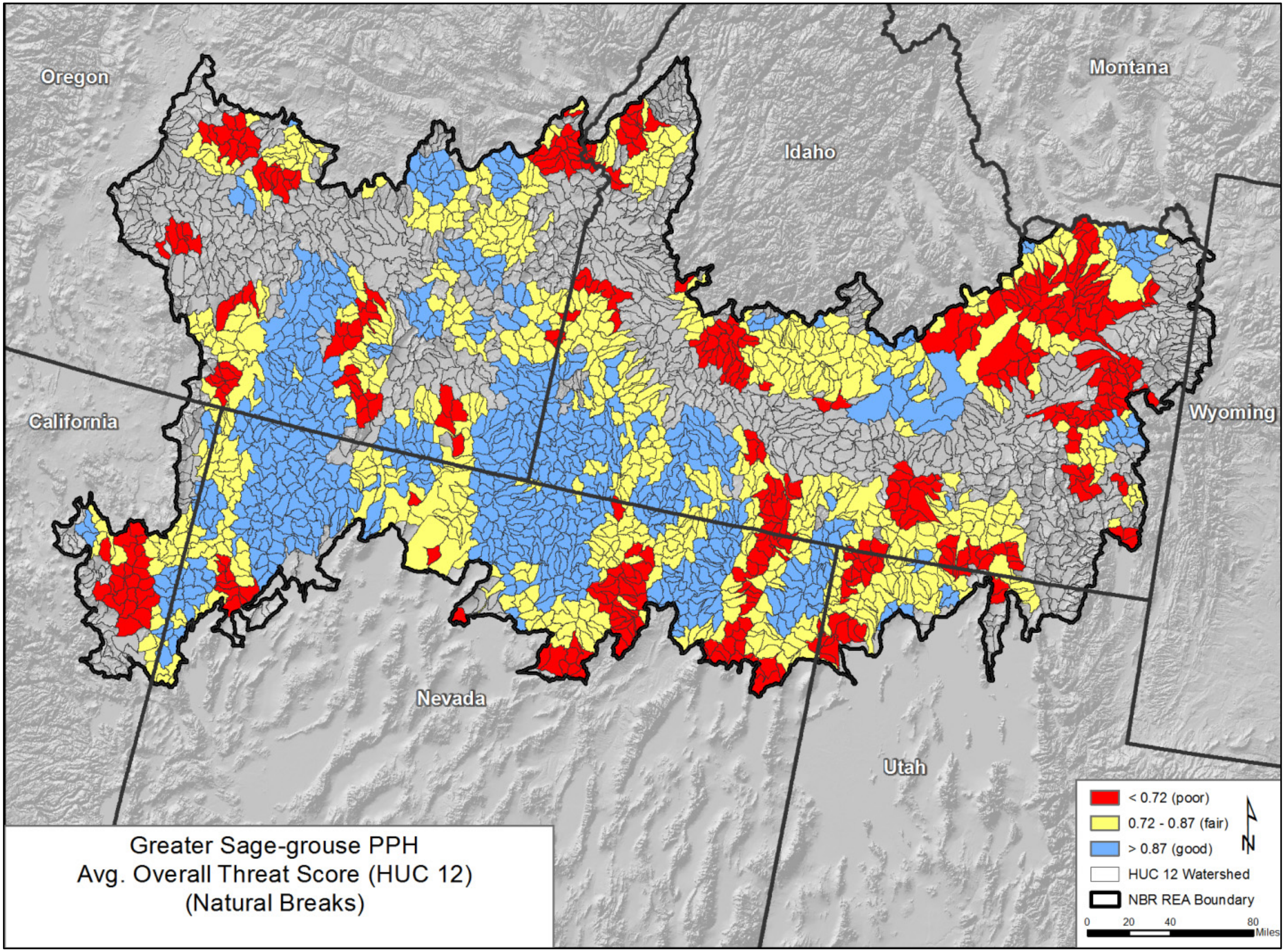


Figure 4.4.1.7-4 Combined Threats within Greater sage-grouse PPH (HUC 12)

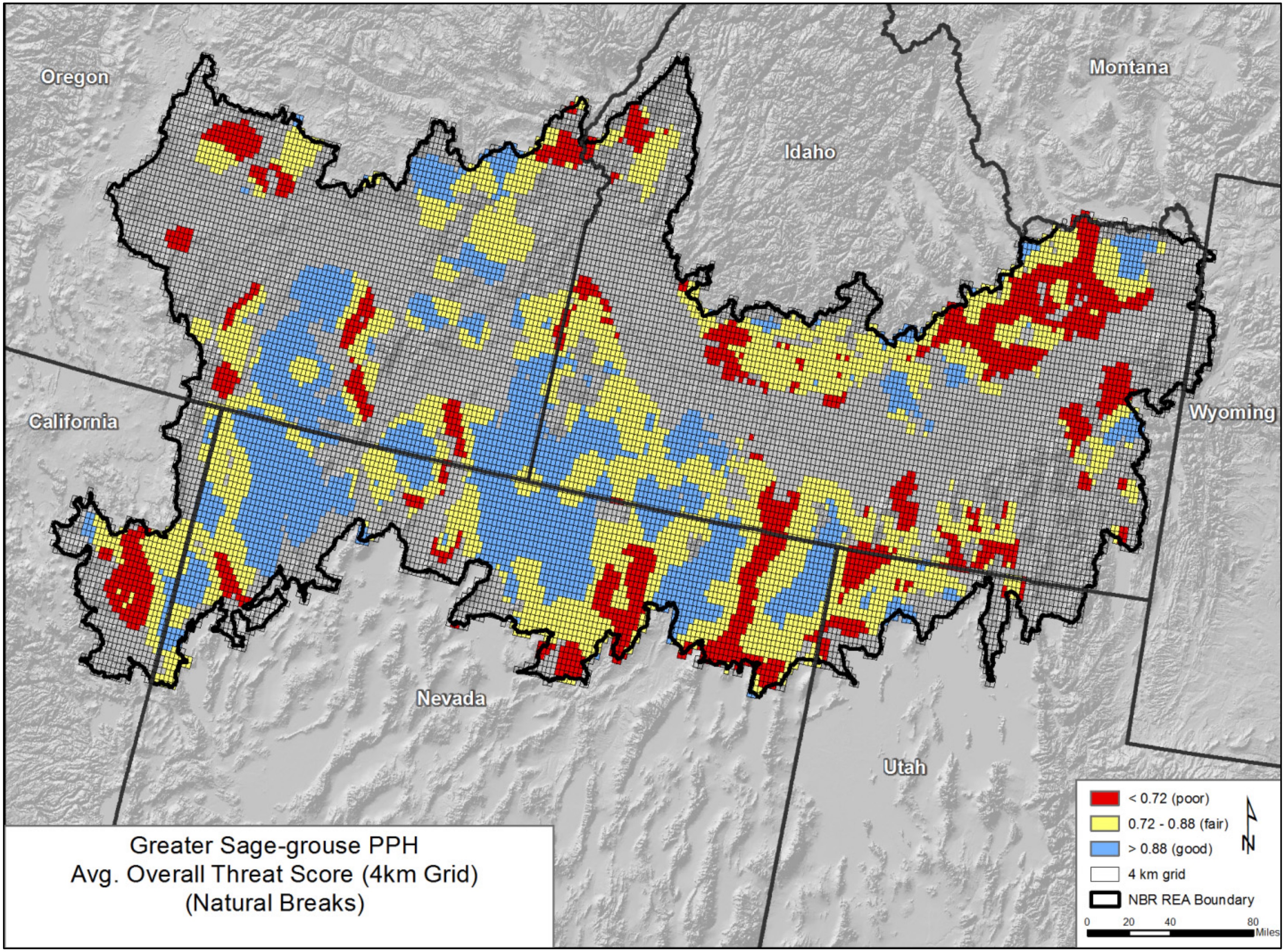


Figure 4.4.1.7-5 Combined Threats within Greater sage-grouse PPH (4 km Grid)

4.4.2 Mule Deer Example Model and Map Output (HUC 12 and 4 km)

Mule deer was the second CE chosen to give examples of KEA analysis since data was available for both its distribution and some of its KEA criteria. Since WAFWA and NDOW state data are being used, some of the KEAs that were developed for other ecoregions weren't applicable such as patch size or corridor width. In the Middle Rockies REA, mule deer habitat was classified using an approach developed by the Washington Wildlife Habitat Connectivity Working Group (WWHCWG). Their Habitat Core Area (HCA) toolkit generated suitable habitat based on known sources of resistance such as elevation or urbanization. The WAFWA and NDOW data consists of large polygons that cover most of the ecoregion in seasonal mule deer ranges. There are only two example KEAs for mule deer to be displayed in this memo. Since there are only two KEAs, a combined threat analysis didn't seem useful and is not presented.

4.4.2.1 Fire Regime/Vegetation Condition Class (FRCC/VCC)

The vegetation condition class (VCC) is a dataset from LANDFIRE that shows the departure from normal vegetation regimes. The main data attributes for VCC are low vegetation departure (1), moderate vegetation departure (2) and high vegetation departure. There are also additional classes for water, agriculture, open water, etc. The GIS process model (Figure 4.4.2.1-1) for this KEA starts with extracting the VCC attributes from the LANDFIRE VCC and clipping it to the mule deer habitat. Figure 4.4.2.1-2 shows the VCC within the NBR ecoregion. Several areas in the ecoregion have a high vegetation departure, especially the border between Central Basin and Range and the Northern Basin and Range. To determine a value for the analysis unit, the majority statistical parameter is used to calculate the most common VCC value within the analysis unit. Figure 4.4.2.1-3 shows the results for the HUC 12 watershed and Figure 4.4.2.1-4 displays the results for the 4 km grid.

4.4.2.2 Distance to Roads

The data source for distance to roads KEA for mule deer is the 2010 TIGER roads. The GIS process for this KEA (Figure 4.4.2.2-1) starts with calculating the Euclidean distance from all the TIGER roads. The resulting layer is then clipped to the mule deer habitat. Figure 4.4.2.2-2 displays the distance to roads binned into three different categories based on the metrics in the KEA table. The TIGER 2010 roads layer is very dense with roads resulting in very little blue (good metric). There are some roadless areas within the ecoregion mostly near the Craters of the Moon Nation Monument in Idaho. The densest areas within the ecoregion appear to be along the I-84 interstate corridor and agricultural areas of the Snake River Plain running from Boise to Burley. Figure 4.4.2.2-3 displays the analysis unit results for the HUC 12 watershed, Figure 4.4.2.2-4 shows the results using a 4 km grid.

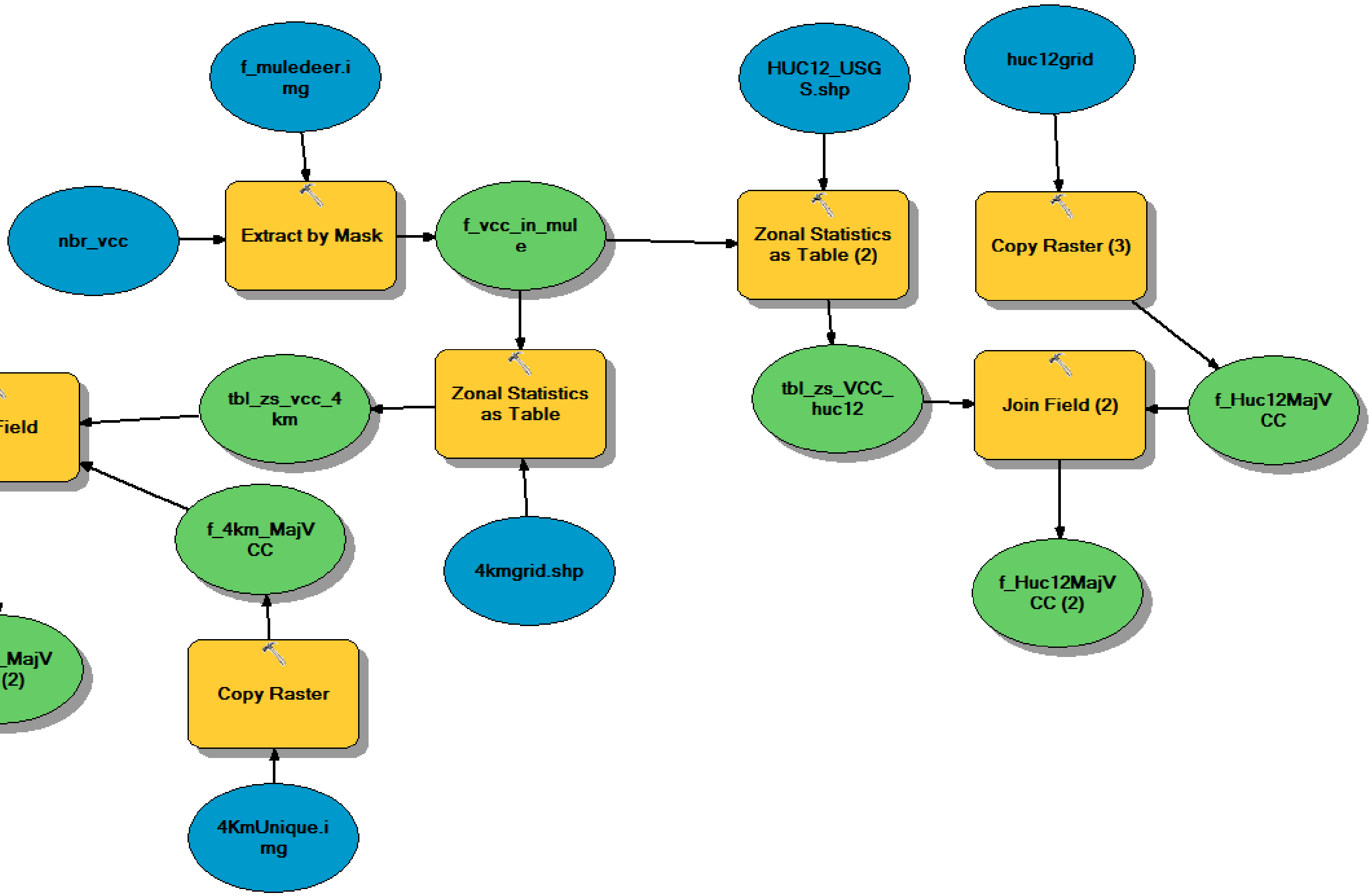


Figure 4.4.2.1-1 GIS Process Model for Analyzing Vegetation Condition Class KEA for Mule Deer

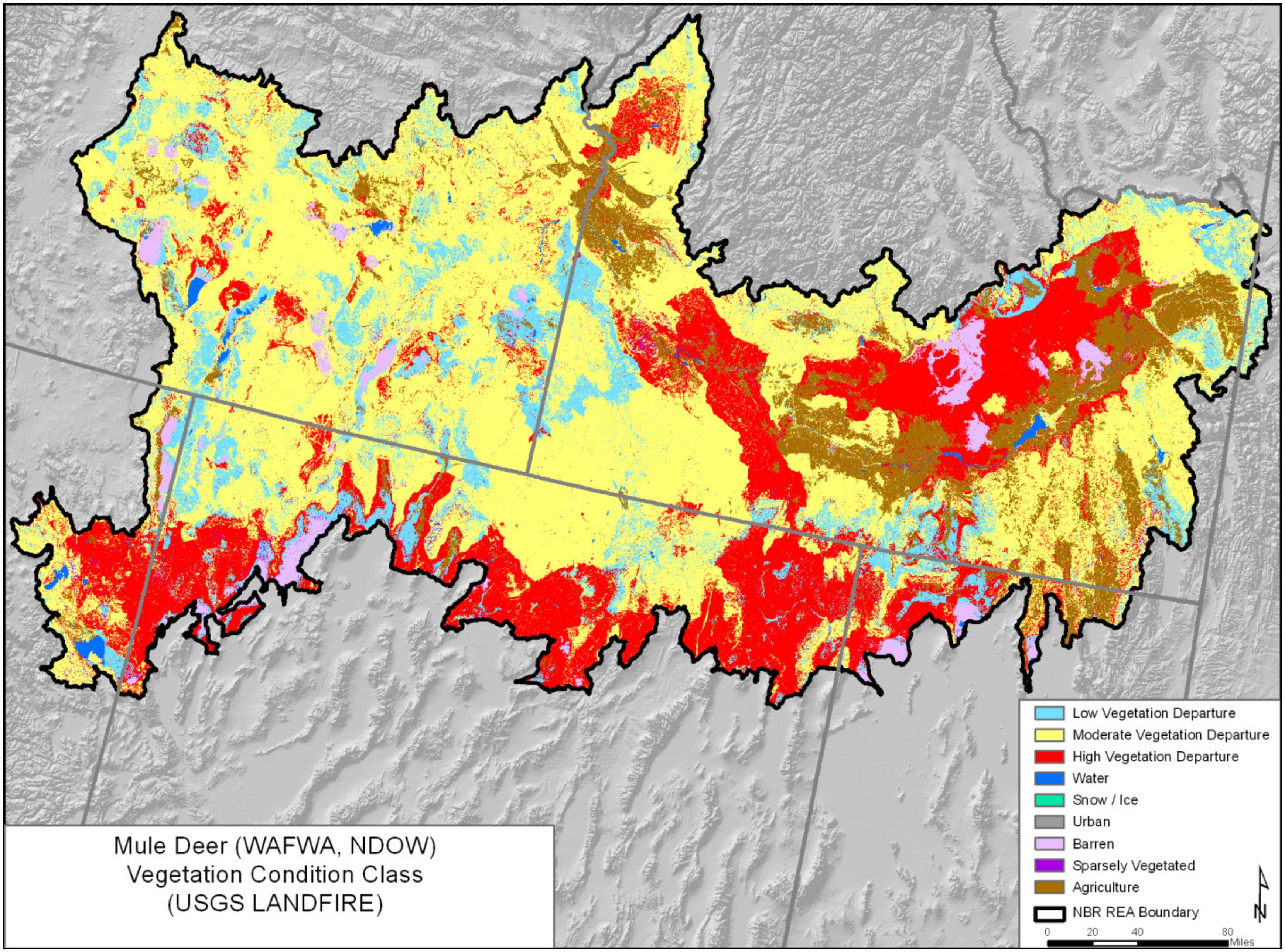


Figure 4.4.2.1-2 Vegetation Condition Class within Mule Deer Habitat

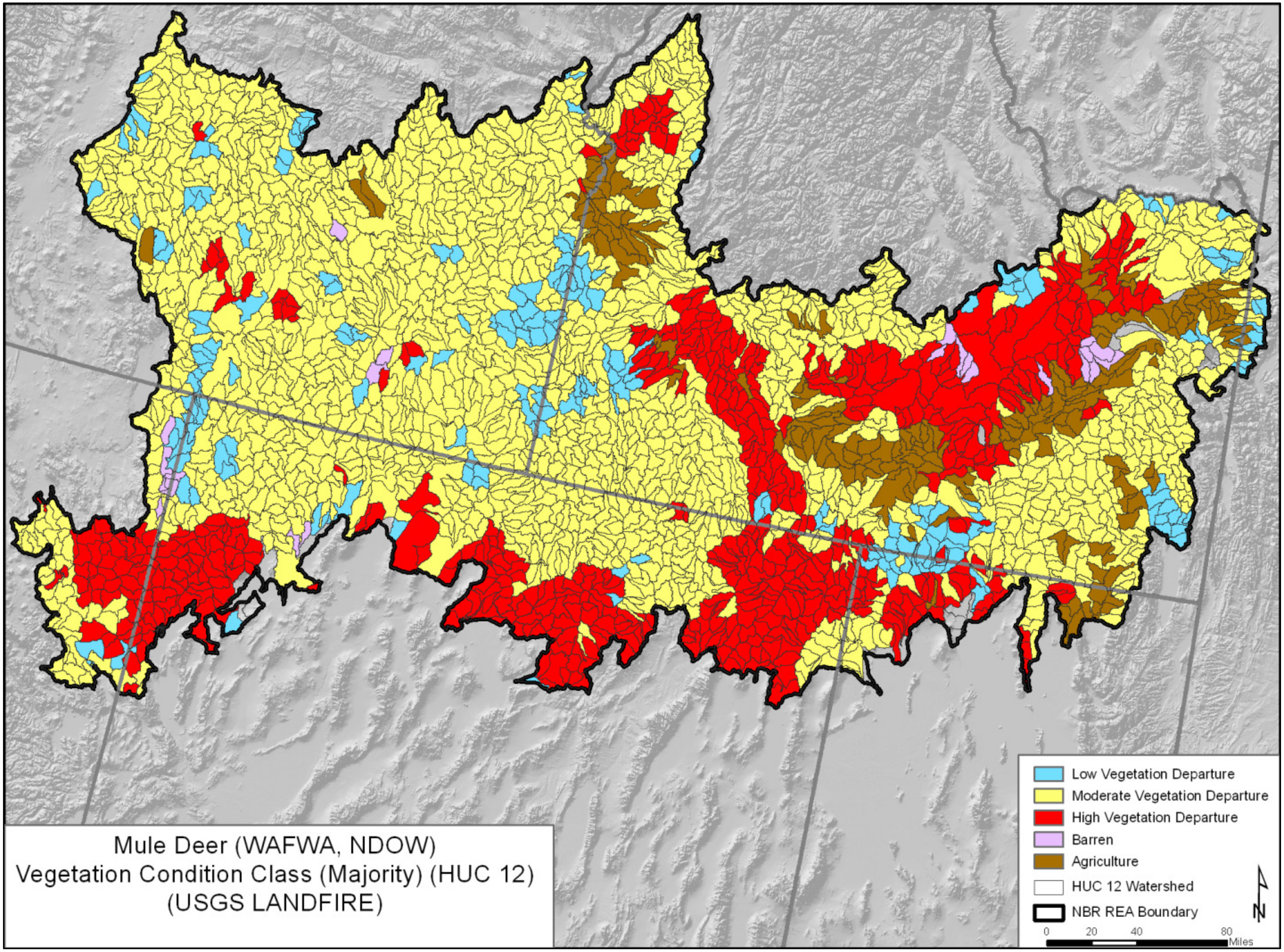


Figure 4.4.2.1-3 Majority Vegetation Condition Class within Mule Deer Habitat (HUC 12)

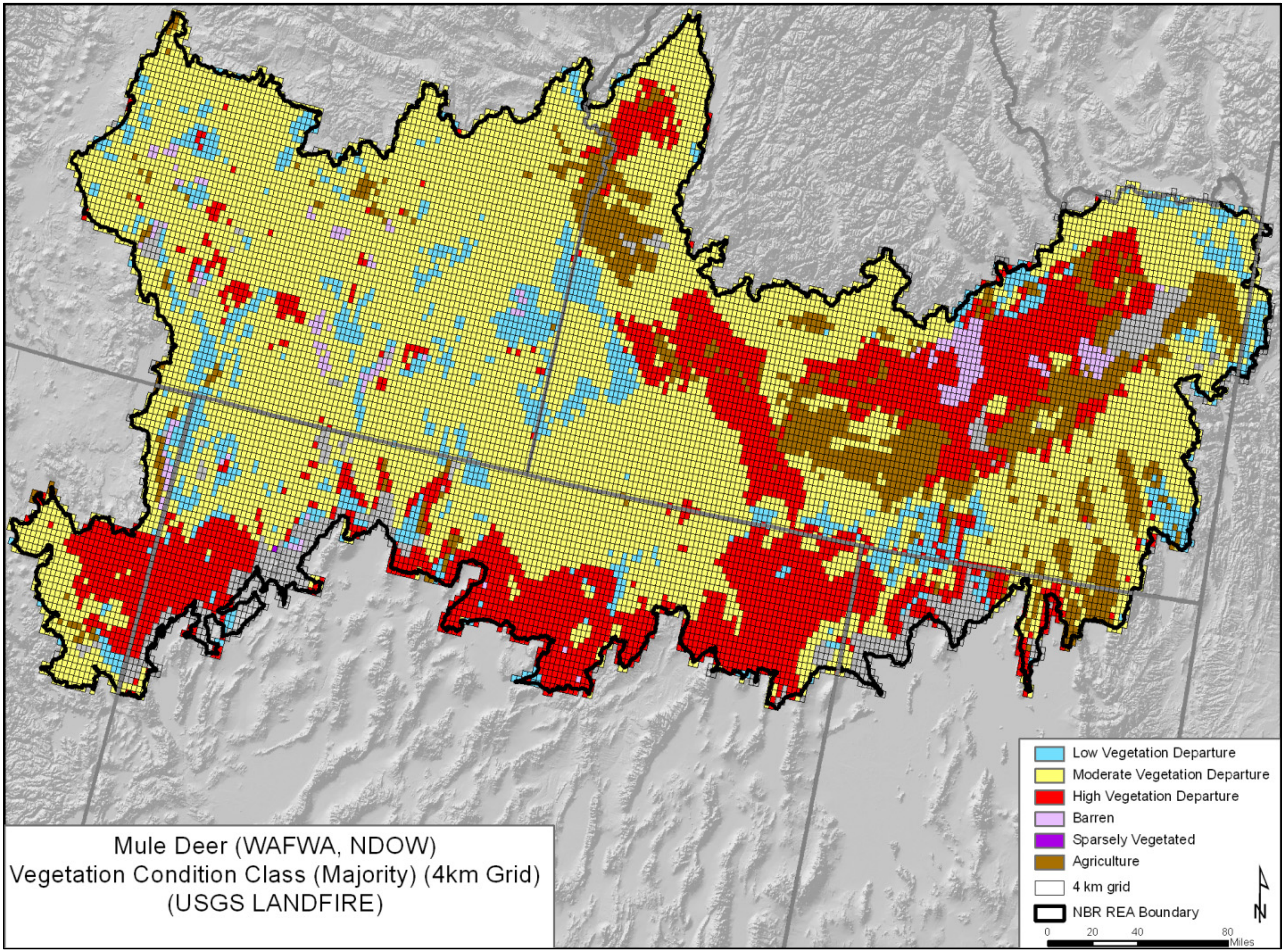


Figure 4.4.2.1-4 Majority Vegetation Condition Class within Mule Deer Habitat (4 km Grid)

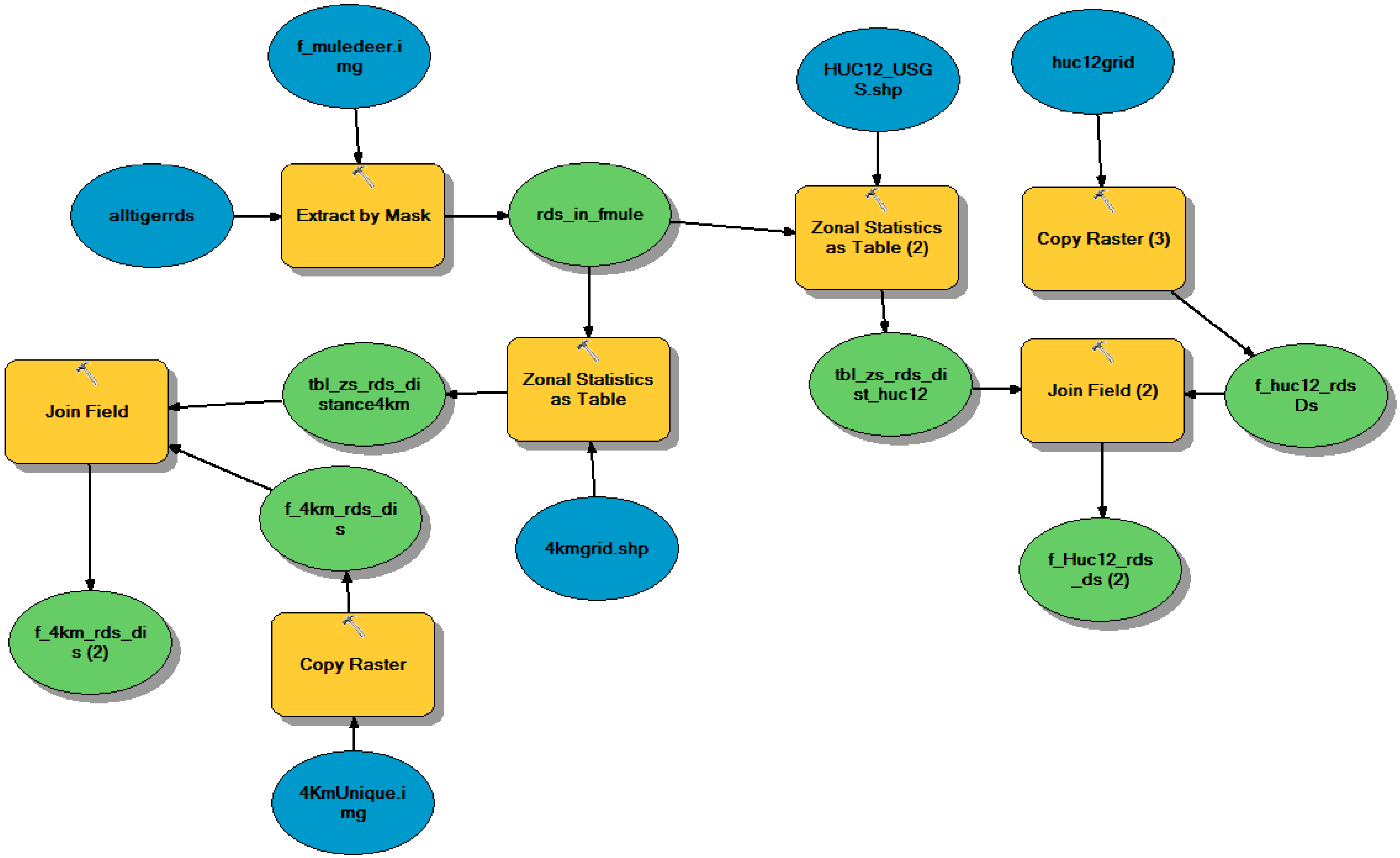


Figure 4.4.2.2-1 GIS Process Model Distance to Roads KEA for Mule Deer

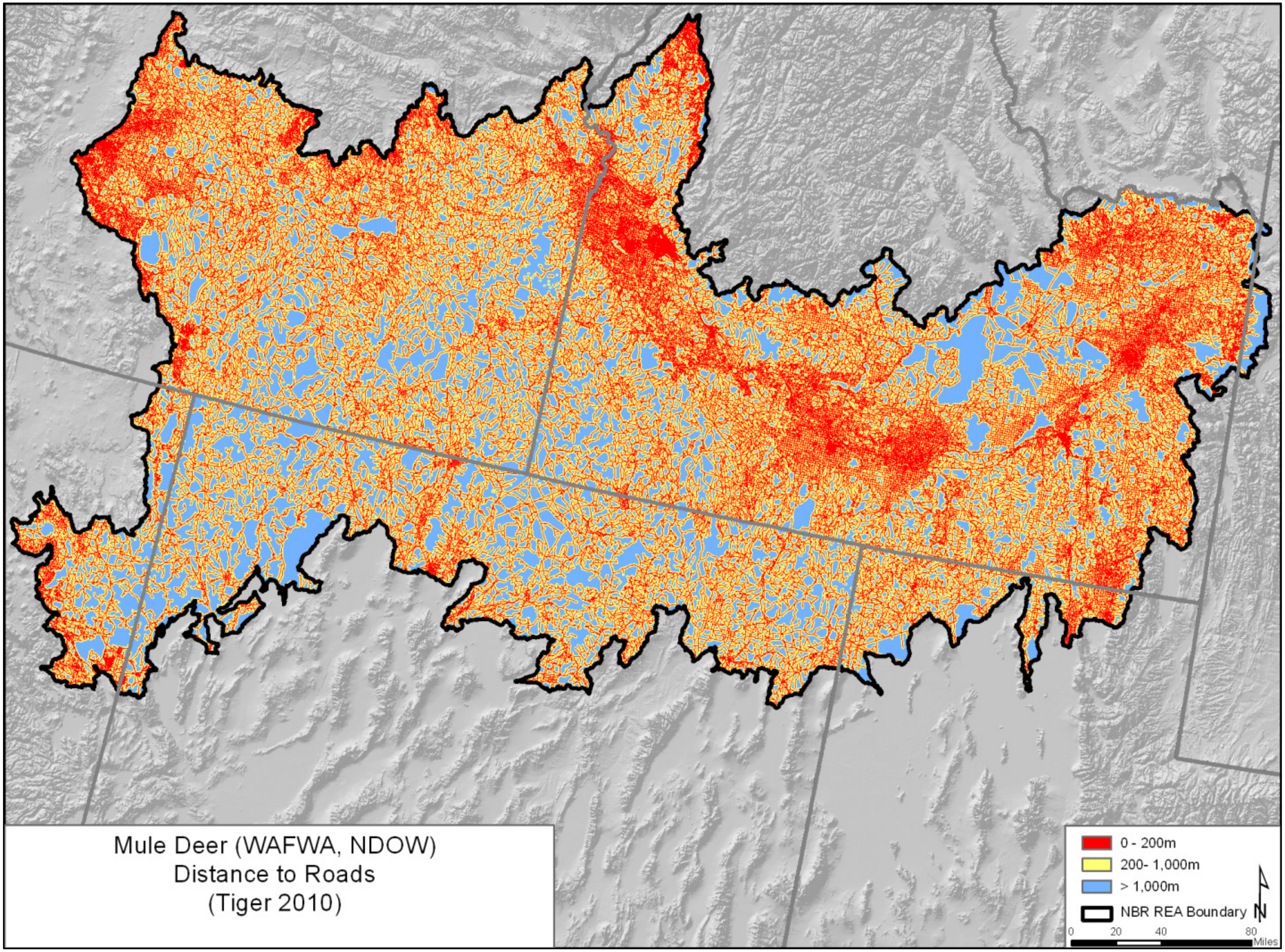


Figure 4.4.2.2-2 Distance to Roads within Mule Deer Habitat

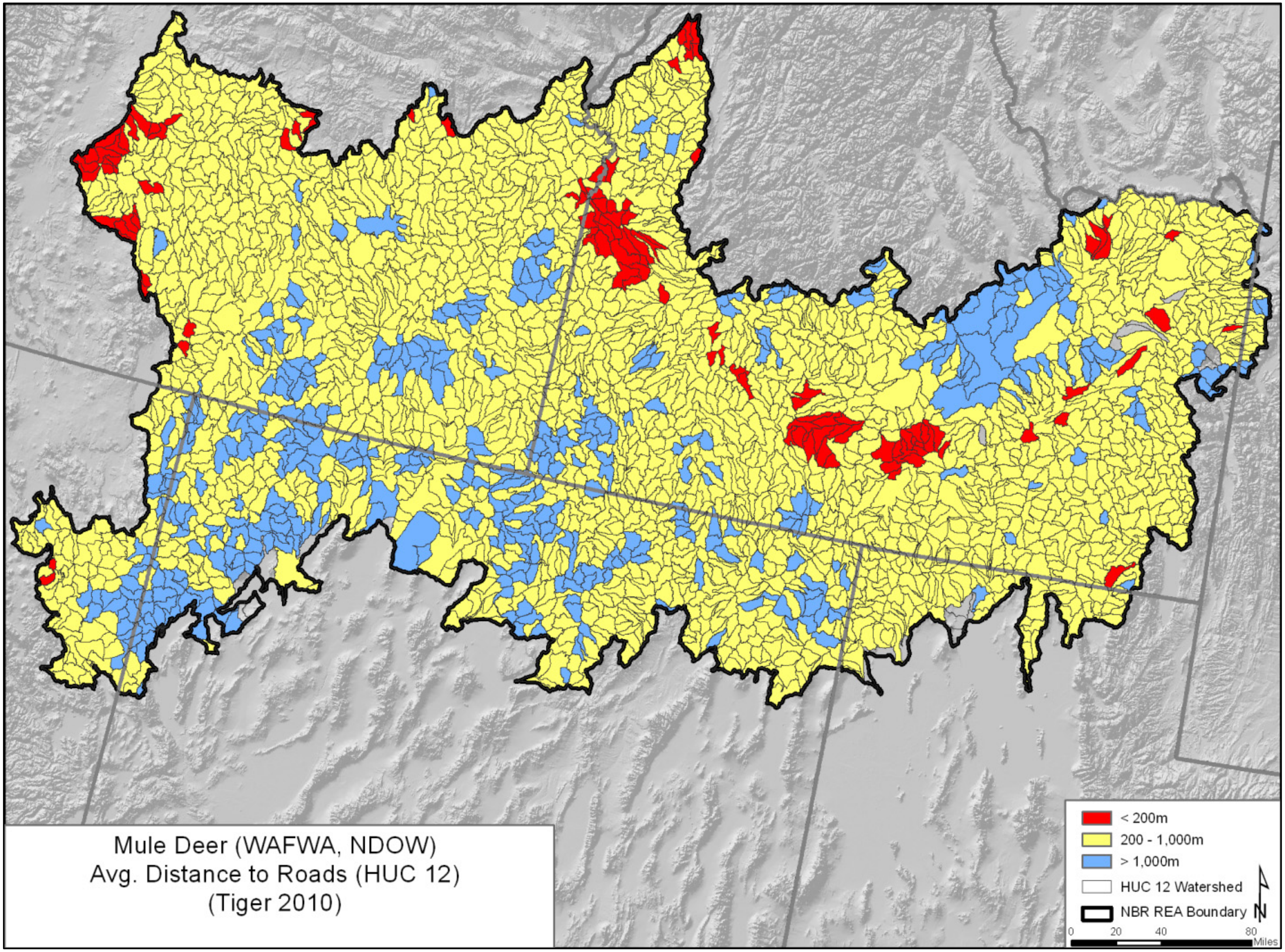


Figure 4.4.2.2-3 Average Distance to Roads within Mule Deer Habitat (HUC 12)

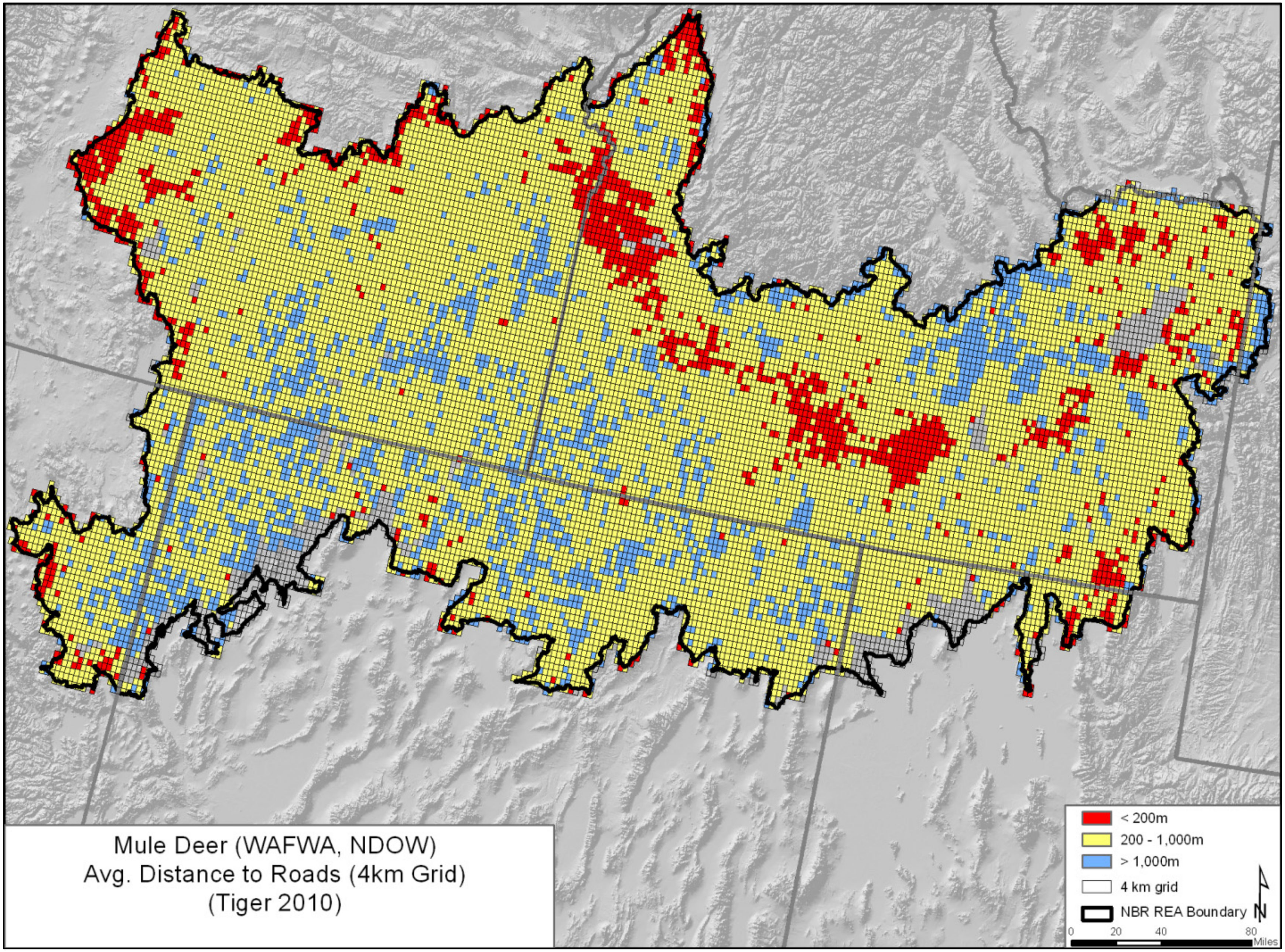


Figure 4.4.2.2-3 Average Distance to Roads within Mule Deer Habitat (4 km Grid)

5 Ecological Intactness

5.1 Introduction

Recent applications of ecological intactness (EI) directly trace their origins to the site specific concept of an Index of Biological Integrity that have been used in riparian studies (Faber-Langendoen et al. 2008, Faber-Langendoen et al. 2009, Roccio 2007, Tiner 2004). Those early site specific assessments were subsequently modified into less field time intensive rapid assessments and ultimately to assessments that use only existing data sources and take a landscape level approach instead of a site level approach.

EI is defined in the statement of work (SOW) as: "The ability of ecological systems to support and maintain a community of organisms that have the species composition, diversity, and functional organization comparable to those of natural habitats within the ecoregion range (or area)." In this definition, "functional organization" refers to the dominant ecological characteristics and processes that "occur within their natural (or acceptable) ranges of variation and can withstand and recover from most perturbations" (Parrish et al. 2003).

5.1.1 Western Governors' Association Initiative

The Western Governors Association (WGA) is currently finalizing a methodology for determining ecological integrity across the western region for both terrestrial and aquatic ecological integrity. Using WGA's approach (once finalized) may provide the best results as it will be a common approach that can be used by present and future Rapid Ecological Assessments (REAs).

5.1.2 Montana and Washington State Modeling

The following is an example of determining ecological integrity that is based off the approaches used by Washington State and Montana State. The two approaches (aquatic and terrestrial) are similar and starting with what is natural vegetation or riparian areas and removing what has been altered by humans. What is left is scored using metrics defined in the Ecological Attribute tables (Table 5.1.2.1-1).

The terrestrial habitat modeling for EI will focus on use of land cover data sets National Land Cover Dataset (NLCD) to extract relevant information regarding large intact natural vegetation within each 5th level watershed (HUC 10). This factor is important in determining the EI score for each watershed and will be used to account for the departure of each watershed from its natural state. The approach generally follows the Washington Wildlife Connectivity Study that was also adopted by Montana. The goal is to find the "best of what's left" of the remaining landscape. The methodology also uses spatial tools to identify small fragmented patches that are more susceptible to conversion to development or agriculture uses. The following steps (1-10) outline the spatial analytical approach that will be used in this REA analysis to model the natural areas within the ecoregion:

1. Begin with an appropriate land cover (NLCD or LANDFIRE) for the ecoregion.
2. Remove agricultural areas and other non-natural habitat.
3. Remove additional anthropogenic impacts (buffered road areas, energy production areas, superfund sites, mines, urban areas and other features associated with anthropogenic effects).
4. Remove sites with less or dispersed development infrastructure that significantly impacts natural areas within them including wind development areas, coal mines, etc.

5. Overlay the removed areas on the raster grid map and expand them by one cell.

6. For any overlapping 100 meter grid cells, buffer an additional 100 meter area for potential impact of vehicles, structures, etc, and inaccurate data layers.

7. Remove the grid cells that fall within the buffered areas to show how roads, etc are removed.

8. Using grid cells of the appropriate size, conduct a moving window analysis on surrounding areas by using the appropriate sized moving window.

9. Select all areas within the moving window that contain native habitat cell information above an appropriate percent threshold.

10. Calculate acreage for all intact, connected natural areas within the ecoregion boundary. Intact natural areas of an appropriate minimum size will be identified as the best available natural habitat areas within the ecoregion. (This step will not be used to model the natural areas, but is used in the EI scoring approach and additionally to identify ecoregion-wide areas of importance).

The next step of the terrestrial EI will be to apply a set of surrogate variables for KEAs to the selected natural areas in order to obtain a score or relative ranking of the natural areas located throughout the ecoregion. Due to the scale of the REA and the timeframe associated with completion of the REA, the KEAs will be based completely on readily available and processed imagery and on existing GIS data. The attributes and indicators associated with EI can be categorized by size, landscape context, and condition. The KEAs for the terrestrial EI and potential scores for metrics are located in Table 5.1.2-1.

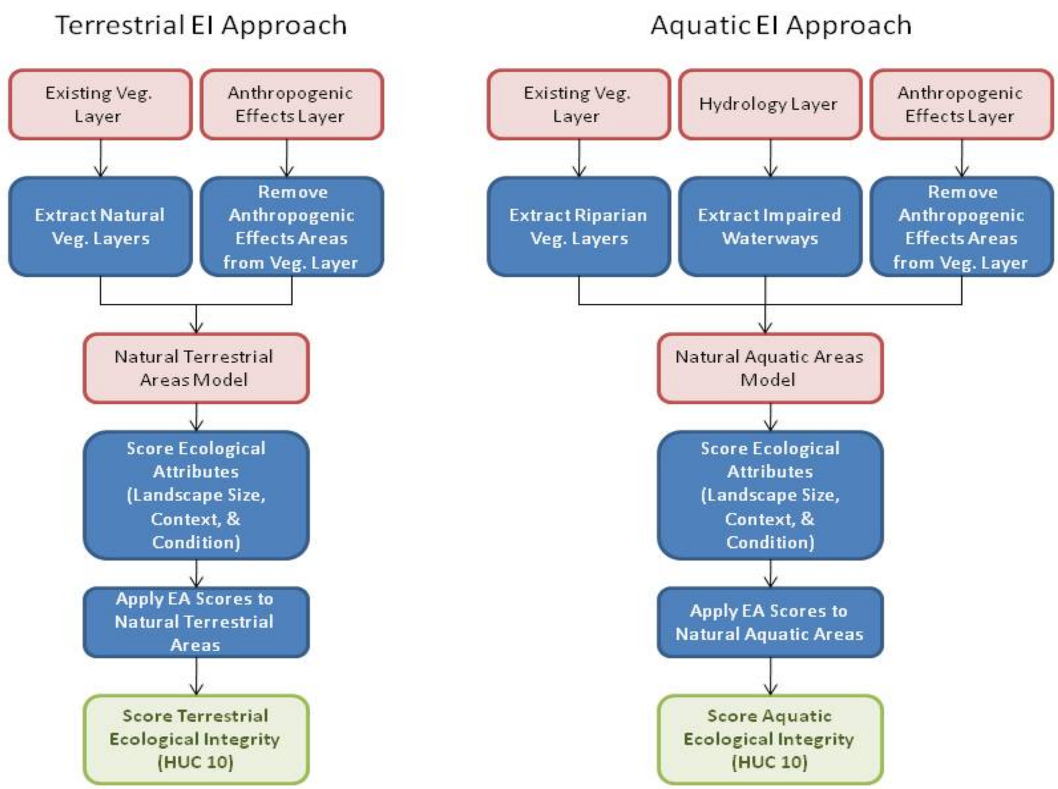


Table 5.1.2.1-1 Example Key Ecological Attributes for Terrestrial Ecological Intactness

Ecological Attribute	Indicator	Metric	Data Source	Citation
Size				
Naturalness	Proportion of Natural Vegetation Remaining (Size as % of HUC)[1]	90% = good 81-89% = fair 0%-80% = poor	LANDFIRE / NLCD	MT and WA State EI Analysis
Absolute Size	Extent of Natural Vegetation (acres)	>10,000 ac = good 5,000-9,999 ac = fair <5,000 ac = poor	LANDFIRE / NLCD	MT and WA State EI Analysis
Condition				
Habitat Condition	FRCC	FRCC 1 = good FRCC 2 = fair FRCC 3 = poor	LANDFIRE	Landfire; Direction from AMT
	Vegetation Structure	Varies by Coarse-Filter Analysis (see Coarse-Filter Analysis)	LANDFIRE	MT and WA State EI Analysis
	Protected Areas (Degree of Habitat Protection; Wildlife Areas, National Parks, State Parks, etc.)	High Degree of Protection = good Moderate Degree of Protection = fair Low Degree of Protection = poor	PADS	Best Professional Judgment
Landscape Context				
Connectivity	Intact Areas (Intact areas with continuous corridors)	Circuitscape Analysis	LANDFIRE / NLCD	MT and WA State EI Analysis
	Riparian/Wetlands	>50 % of HUC 10 = good 10 to 49% of HUC 10 = fair 0 to 9% of HUC 10 = poor	LANDFIRE, NHD, NWI	Best Professional Judgment

Notes:

[1] Metrics are applied after deducting agricultural and other anthropogenic altered areas from the total land cover of the region as described in 5.1.2.1 steps 2-7.

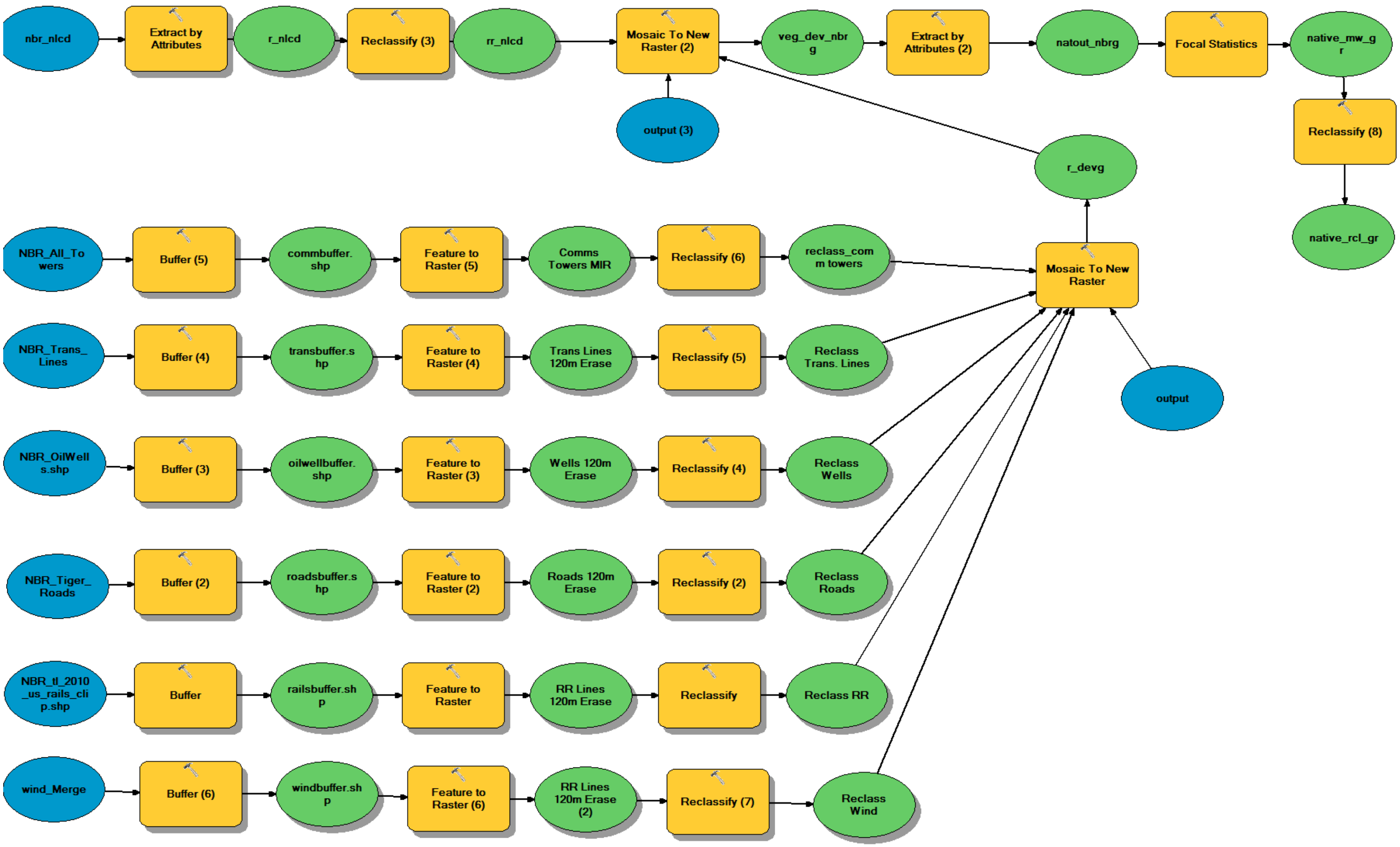


Figure 5.1.2-1 GIS Process Model for Determining Ecologically Intact Areas

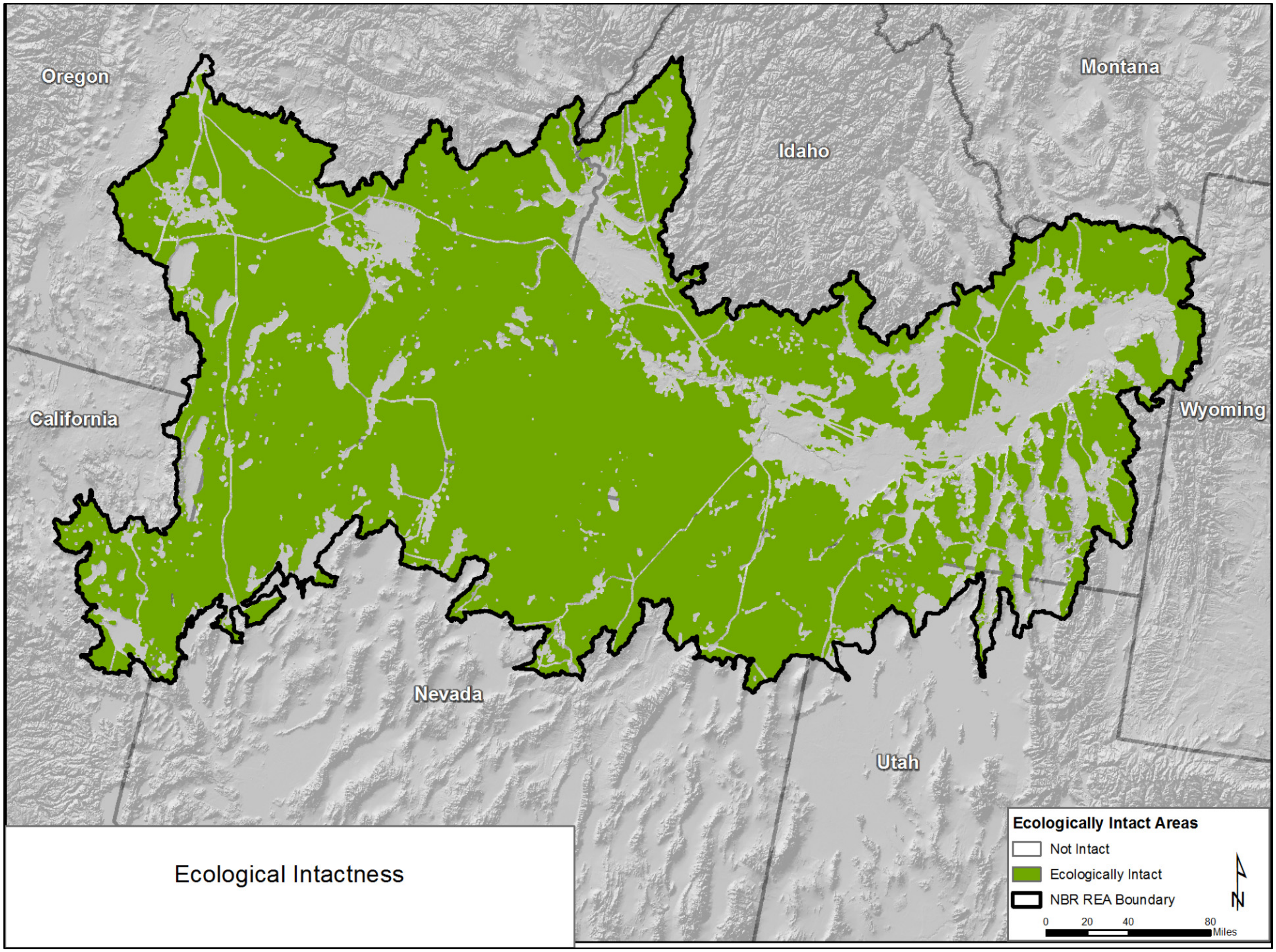


Figure 5.1.2-2 Ecologically Intact Areas within the NBR Ecoregion

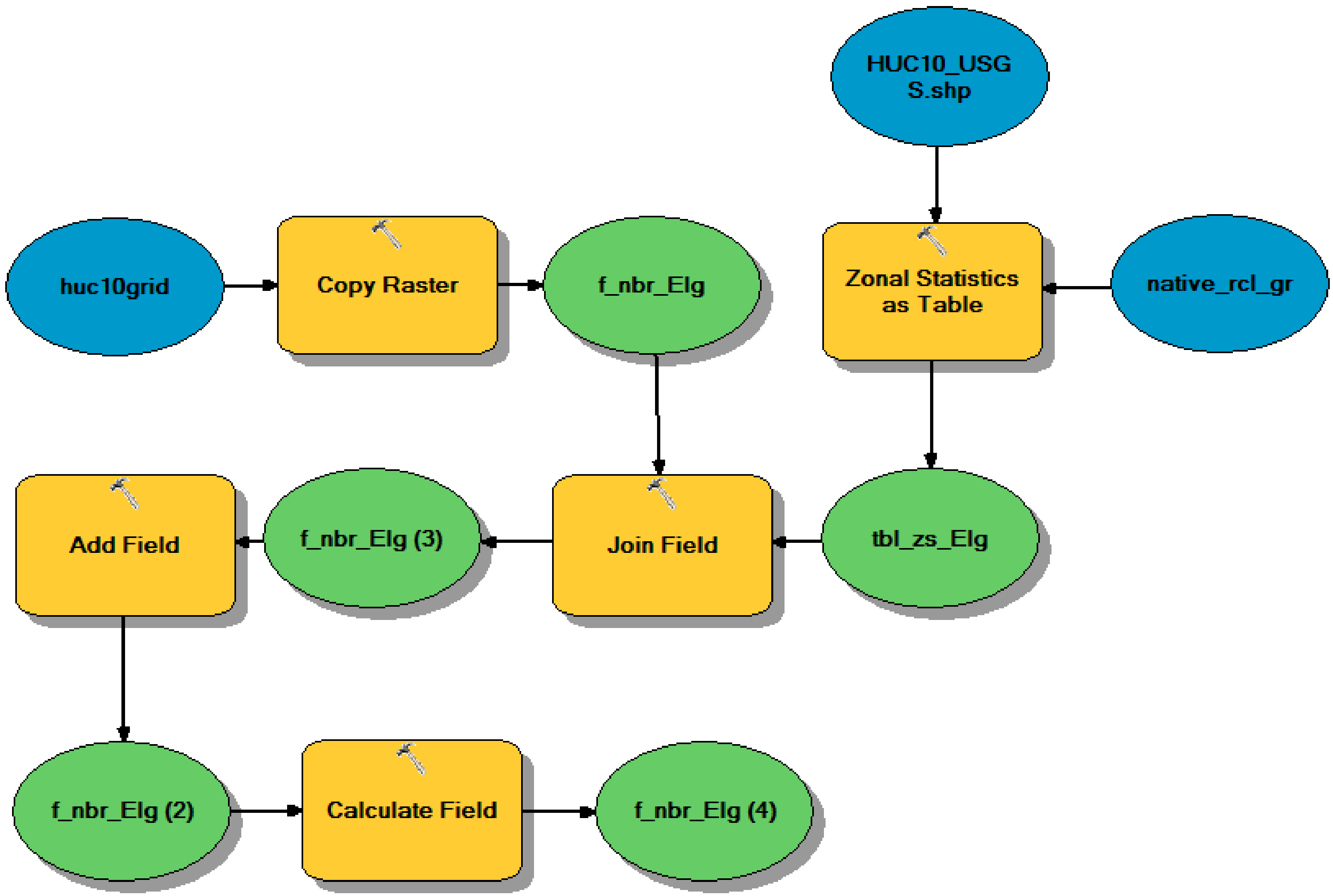


Figure 5.1.2-3 GIS Process Model for Determining Percent of Ecologically Intact Areas by Analysis Units

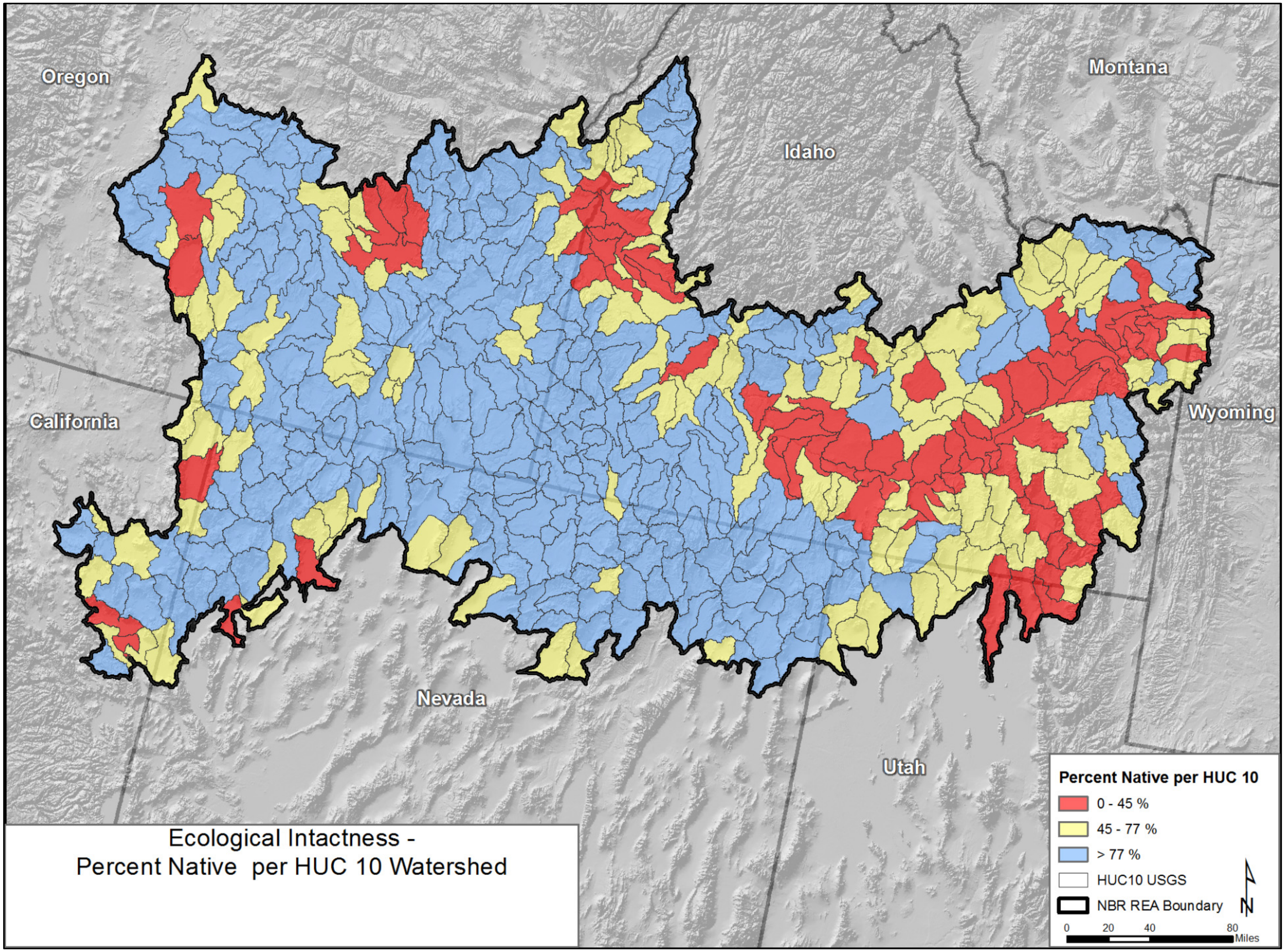


Figure 5.1.2-4 Percent Native (Ecologically Intact Areas) by HUC 10 Watershed

5.1.3 Aquatic Ecological Intactness Analysis Approach

The aquatic EI will focus predominantly on the hydrology data layers (National Hydrography Dataset [NHD] and National Wetlands Inventory [NWI]). Land cover data layers will also provide relevant information in determining EI scores for aquatic ecosystems in areas where riparian and wetland vegetation is important in determining aquatic EI. The format and steps used in the in the aquatic analysis will be similar to those used for the terrestrial analysis with modifications required because of the spatial heterogeneity of the hydrology layer. Note that in contrast to the aquatic GIS data which generally is linear in spatial extent, the terrestrial GIS data are more extensive and cover greater portions of each HUC 10 unit than the aquatic data, requiring a simpler analysis.

1. Begin with an appropriate land cover (NLCD or LANDFIRE) for the ecoregion.
2. Remove all non-aquatic land cover areas.
3. Remove additional anthropogenic impacts (buffered road areas, buffered agricultural areas, energy production areas, superfund sites, mines, urban areas and other features associated with anthropogenic effects).
4. Add the NHD (hydrology) layer for the ecoregion.
5. Remove impaired waterways.
6. Add NWI data layer. Exclude all non-natural wetland areas.
7. Overlay the combined riparian, NHD, and NWI layer on the raster grid map and expand them by one cell.
8. For any overlapping 100 meter grid cells, buffer an additional 100 meter area for potential impact of cars, structures, etc, and inaccurate data layers.
9. Remove all of those grid cells with the buffers to show areas adjacent to roads, etc are removed.
10. Using grid cells of the appropriate size, conduct a moving window analysis on surrounding areas by using the appropriate sized moving window.
11. Select all areas within the moving window that contain native habitat cell information above an appropriate percent threshold.

Upon completion of the spatial analysis listed above, Circuitscape or another analogous program will be used to conduct a least cost path analysis for the purposes of determining connectivity of the selected natural areas across the landscape. The third step to completion of aquatic EI will be to apply a set of surrogate variables for KEAs to the selected natural areas in order to obtain a score or relative ranking of the natural areas located throughout the ecoregion. Due to the scale of the REA and the timeframe associated with completion of the REA, the KEAs will be based on readily available and processed imagery and on existing GIS data. The attributes and indicators associated with EI can be categorized by size, landscape context, and condition. The KEAs for the aquatic EI and potential scores for metrics are located in Table 5.1.3-1.

Table 5.1.3-1. Example Aquatic Ecological Intactness Key Ecological Attributes

Ecological Attribute	Indicator	Metric	Data Source	Citation
Land Cover	Urban (Buffer distance in meters)	>2000m = good 1000-1999m = fair 0-999m = poor	LANDFIRE	MT / WA State EI Analysis
	Crop Agriculture (Buffer distance in meters)	>500m = good 300-499m = fair 0-299m = poor	LANDFIRE	MT / WA State EI Analysis
Anthropogenic Disturbance	4-wheel Drive Roads (Buffer distance in meters)	>200m = good 100-199m = fair 0-99m = poor	TIGER 2010	MT / WA State EI Analysis
	Local Roads, City Streets (Buffer distance in meters)	>300m = good 100-299m = fair 0-99m = poor	TIGER 2010	MT / WA State EI Analysis
	Highways (Buffer distance in meters)	>500m = good 200-499m = fair 0-199m = poor	TIGER 2010	MT / WA State EI Analysis
	Mines (Buffer distance in meters)	>500m = good 200-499m = fair 0-199m = poor	Mines	MT / WA State EI Analysis
	Oil or Gas Wells (Buffer distance in meters)	>500m = good 200-499m = fair 0-199m = poor	Oil & Gas Wells	MT / WA State EI Analysis
Hydrology	Artificial Source (Buffer distance in meters)	>200m = good 100-199m = fair 0-99m = poor	NHD	MT / WA State EI Analysis
	303d listed water (Buffer distance in meters)	>500m = good 300-499m = fair 0-299m = poor	NHD/303d	MT / WA State EI Analysis

Source: Vance, L. 2009. Assessing Wetland Condition with GIS: A Landscape Integrity Model for Montana.

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Appendix A

Management Questions

Appendix A. Management Questions for the NBR

Table A. Management Questions for the NBR

MQ #	MQ Group	Final Management Question
		Questions Related to Conservation Elements (CEs)
1	Species	What is the current distribution of potential habitat for each species CE?
2	Species	Where are current locations of species CEs that are potentially affected by existing CAs (and thus potentially at risk)?
3	Species	What is the current distribution of suitable habitat, including seasonal habitat and movement corridors, for each landscape species and species assemblage CE?
4	Species	Where are existing CAs potentially affecting this current habitat and/or movement corridors, for landscape species and species assemblage CEs?
5	Species	Where are species CEs whose current locations or suitable habitats overlap with the potential future distribution of CAs (other than climate change)?
6	Species	Given current and anticipated future locations of CAs, which habitat areas remain as opportunities for habitat enhancement/ restoration?
7	Species	Where are potential areas to restore connectivity for landscape species and species assemblage CEs, based on current locations of CAs?
8	Species	Where will landscape species and species assemblage CEs experience climate outside their current climate envelope?
9	Native Plant Communities	Where are intact (i.e., minimally disturbed by human activities) CE vegetative communities located?
10	Native Plant Communities	Where are the likeliest current locations for high-integrity examples of each major terrestrial ecological system?
11	Native Plant Communities	Where are existing and potential future CAs (aside from climate change) likeliest to affect current communities?
12	Native Plant Communities	Where will current locations of these communities experience significant deviations from normal climate variation?
13	Terrestrial Sites of High Biodiversity	Where are sites identified as having high biodiversity characteristics? Which designated sites are protected?
14	Terrestrial Sites of High Biodiversity	Where will CAs (aside from climate change) potentially affect sites of high biodiversity?
15	Terrestrial Sites of High Biodiversity	Where will locations of these high biodiversity sites experience significant deviations from normal climate variation?
16	Aquatic Sites of High Biodiversity	What has been the general level of survey effort (ecoregion-wide, not site-specific) for spring snails and other species of concern?
17	Aquatic Sites of High Biodiversity	Where are areas representing unique aquatic lineages or assemblages or other areas of high aquatic biodiversity (considering both local [alpha] and regional [beta or gamma] diversity)?
18	Aquatic Sites of High Biodiversity	Where will these aquatic high biodiversity sites (as defined in MQ 17) be potentially affected by CAs (aside from climate change)?
19	Aquatic Sites of High Biodiversity	Where will current locations of these aquatic high biodiversity sites (as defined in MQ 17) experience significant deviations from normal climate variation?
20	Specially Designated Areas of Ecological Value	Where are specially designated areas of ecological or cultural value?
21	Wild Horse and Burro Management Areas	Where are the current wild horse and burro Herd Management Areas (HMAs)?
22	Wild Horse and Burro Management Areas	Where will CAs (excluding climate change) overlap HMAs, under each time scenario?
23	Wild Horse and Burro Management Areas	Which HMAs will experience climate outside their current climate envelope?
24	Grazing	Where are the current livestock grazing allotments?
25	Grazing	Where will CAs (excluding climate change) overlap grazing allotments under each time scenario?

Table A. Management Questions for the NBR

MQ #	MQ Group	Final Management Question
Questions Related to CEs (continued)		
26	Grazing	Which grazing allotments will experience climate change outside their current climate envelope?
27	Vulnerable Soils	Where are vulnerable (e.g., erodible, slickspot) soil types within the ecoregion?
28	Vulnerable Soils	Where will vulnerable soil types overlap with CAs (aside from climate change) under each time scenario?
29	Vulnerable Soils	Where will current vulnerable soil types experience significant deviations from normal climate variation?
30	Surface and Subsurface Water Availability	Where are current natural and man-made surface water resources, and which are perennial ephemeral, etc?
31	Surface and Subsurface Water Availability	What is the natural variation of monthly discharge and monthly base flow for streams and rivers?
32	Surface and Subsurface Water Availability	Where are the likely recharge areas within a HUC?
33	Surface and Subsurface Water Availability	Where will the recharge areas (relating to aquatic CEs) identified in MQ 32 potentially be affected by CAs?
34	Aquatic Ecological Function and Structure	What is the condition (ecological integrity) of aquatic CEs?
Questions Related to Change Agents (CAs)		
35	Fire History	What is the frequency, size, and distribution of wildfire on the landscape?
36	Fire Potential	What areas now have (high, medium, low) potential for fire based on fuels composition (e.g., invasive plants)?
37	Fire Potential	Where are areas that in the future will have high potential for fire?
38	Invasive Species	What is the current distribution of invasive species included as CAs?
39	Invasive Species	What areas are significantly affected by invasive species?
40	Invasive Species	Focusing on the distributions of terrestrial and aquatic CEs that are significantly affected by invasive species, which areas have restoration potential?
41	Invasive Species	Given current patterns of occurrence and expansion of the invasive species included as CAs, what is the potential future distribution of these invasive species?
42	Development	Where are current locations of development CAs?
43	Development	Where are areas of planned or potential development CAs?
44	Development	Where do development CAs cause significant loss of ecological integrity?
45	Development	Where do current locations of CEs overlap with development CAs?
46	Recreation	Where are areas with significant recreational use?
47	Recreation	Where have designated recreation areas, such as for off-highway vehicle (OHV) use, affected CEs and invasive species?
48	Recreation	Where are other areas of likely high OHV use [as determined by modeling] that may affect CEs and invasive species?
49	Oil, Gas, and Mining Development	Where are the current locations of oil, gas, and mineral extraction?
50	Oil, Gas, and Mining Development	Where will locations of oil, gas, and mineral extraction potentially exist by 2025?
51	Oil, Gas, and Mining Development	Where are the areas of potential future locations of Oil, Gas, and Mining (including gypsum) development (locatable, salable, and fluid and solid leasable minerals)?
52	Oil, Gas, and Mining Development	Where do locations of current CEs overlap with areas of potential future locations of non-renewable energy development?
53	Renewable Energy Development	Where are the current locations of renewable energy development (solar, wind, geothermal, transmission)?

Table A. Management Questions for the NBR

MQ #	MQ Group	Final Management Question
		Questions Related to CAs (continued)
54	Renewable Energy Development	Where are the areas identified by the National Renewable Energy Laboratory (NREL) as potential locations for renewable energy development?
55	Renewable Energy Development	Where are the areas of low renewable and non-renewable energy development that could potentially mitigate impacts to CEs from potential energy development?
56	Renewable Energy Development	Where do current locations of CEs overlap with areas of potential future locations of renewable energy development (MQ 65)?
57	Renewable Energy Development	Where will locations of renewable energy [development] potentially exist by 2025?
58	Groundwater Extraction and Transportation	Where will CAs potentially impact groundwater-dependent aquatic CEs?
59	Groundwater Extraction and Transportation	What is the present distribution of municipal and agricultural water use of groundwater resources in relation to the distribution of aquatic CEs?
60	Groundwater Extraction and Transportation	Where are the aquatic CEs showing degraded ecological integrity from existing groundwater extraction?
61	Surface Water Consumption and Diversion	Where are artificial water bodies including evaporation ponds, etc.?
62	Surface Water Consumption and Diversion	Where are the areas of potential future change in surface water consumption and diversion?
63	Surface Water Consumption and Diversion	Where are the CEs showing degraded ecological integrity from existing surface water diversion?
64	Climate Change: Terrestrial Resource Issues	Where will changes in climate be greatest relative to normal climate variability?
65	Climate Change: Terrestrial Resource Issues	Given anticipated climate shifts and the direction shifts in climate envelopes for CEs, where are potential areas of significant change in extent such as ecotones?
66	Climate Change: Terrestrial Resource Issues	Where are vegetation CEs that will experience significant deviations from normal climate variation?
67	Climate Change: Terrestrial Resource Issues	Where are wildlife CE habitats that will experience significant deviations from normal climate variation?
68	Climate Change: Aquatic Resource Issues	Where will aquatic CEs experience significant deviations from historic climate variation that potentially could affect the hydrologic and temperature regimes of these aquatic CEs?
69	Military Constrained Areas	Where are areas of planned expansion for military use?
70	Atmospheric Deposition	Where are areas affected by atmospheric deposition of pollutants, as represented specifically by nitrogen deposition, acid deposition, and mercury deposition?
71	Livestock Grazing	Where is structure of vegetation CEs affected by livestock grazing?
72	Livestock Grazing	Where can livestock grazing be used to reduce wildfire risk in areas with herbaceous fuel loads and proximity to high-probability ignition locations (roads, train tracks, lightning etc.)
73	Livestock Grazing	Where will livestock grazing have the potential to increase fire from vegetation cover type conversion (high, medium, low)?
74	Livestock Grazing	Where are areas in the landscape with various (low, medium, high) levels of resilience to livestock grazing (based upon ecological site and existing vegetation)?
75	Livestock Grazing	Where has the landscape been modified for purposes of livestock grazing and management (sagebrush elimination, fences, plantings, water sources, etc)?

Table A. Management Questions for the NBR

MQ #	MQ Group	Final Management Question
Questions Related to CAs (continued)		
76	Livestock Grazing	What areas of the landscape are low density vs. high density livestock grazed (streams, water developments, corrals, steep slopes, etc)?
77	Livestock Grazing	Where are areas best suited to potential livestock cattle and sheep grazing based on environmental factors (such as slope, aspect, water availability, wild ungulate grazing)?
78	Livestock Grazing	Where do grazing areas have the highest potential to increase invasive and/or noxious species occurrences?