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# Suitability Analysis of Grizzly Bear Habitat and Food Sources in the Greater Yellowstone Ecosystem

On March 22, 2007 the U.S. Fish and Wildlife Service removed the Grizzly Bear from the endangered species list; this removed the Grizzly bear from federal oversight and control and returned management back to the states. On September 22, 2009 a federal judge ordered the U.S. Fish and Wildlife Service to relist the Grizzly Bear as an endangered species, restoring federal protections and management. In his judgment U.S. District Judge Donald Malloy listed the major reasons for relisting is the lack of consideration by the U.S. Fish and Wildlife Service for scientific findings of low birth weights and numbers, decreasing food supply and sources, and human intrusion reducing viable habitats.
I will look at the restricted area of the Greater Yellowstone ecosystem and analyze the factors that Judge Malloy cited in his decision; specifically the three primary food sources of the Grizzly Bear, the Whitebark Pine, Cutthroat Trout, and the Army Cutworm Moth. I will also look at the spatial extent of these food sources and see determine the potential level of anthropogenic interference.

## **Determination of Requirements**

Before beginning this project I need to decide the specifics of what items are going to be considered and analyzed. The following is a listing of items;

1. Definition and outline of the GYE.
2. Food factors
    a. Whitebark Pine – Need a raster or shape file with delineated areas of Whitebark Pine trees

    b. Cutthroat trout – need shape or raster files showing where there is an abundance of Cutthroat.
    c. Army Cutworm moth – need a raster or shape file showing favored areas for the moth.
3. Digital Elevation Model – to develop a hillshade layer and an aspect layer if it is needed
4. Soil or land cover – a raster to define various ground covers as needed
5. Tree canopy – a raster to find the Whitebark Pine and other tree covers or forested areas as needed.
6. Hydrographic
    a. Rivers and streams – shape file
    b. Lakes – shape file
7. Wildlife Management Areas – there are current areas specified as Grizzly Bear Management areas
8. Wildlife ranges
    a. Elk
    b. Bison
    c. Wolf
9. Anthropogenic Features
    a. Roads
    b. Buildings – cities – towns
    c. Hiking trails and camp grounds
    d. Resources
        i. Mines
        ii. Pits
        iii. Power generation
        iv. Hydrothermal
        v. Coal
        vi. Minerals

There will most likely be more data I will need that I will have to define as I proceed. I am intentionally not factoring in fie effects, while fire is important to Whitebark pine viability and has a direct effect on streams environments and the cutthroat trout. I felt that this was so extensive an issue in that it has not just a spatial element but a very significant time element that it would add too much time to this project. The analysis of the effects of fire on forest populations, habitat and the effects on trout populations over time is research ideally suited for GIS as sequences and changes over time could be portrayed and amounts of change over time could be calculated.

## Data Acquisition

There are several locations that may have relevant data;

- National Atlas
- USGS Seamless Server
- U.S. National Park Service
- Geospatial One Stop
- U.S. Forest Service
- U.S. Fish and Wildlife Service
- U.S. Census Bureau TIGER files
- U.S. Department of Agriculture
- Bureau of Land Management
- USGS National Biological Information Infrastructure (NBII)
- Wyoming Geographic Information Service Center (WyGISC)
- Inside Idaho – Interactive Numeric & Spatial Information Data Engine
- Idaho Department of Lands
- Idaho State University's GIS Center
- Montana Geographic Information Clearinghouse
- Montana GIS Portal
- Montana State University Geographic Information and Analysis Center (GIAC) and Digital Atlas of the Greater Yellowstone Area
- Big Sky Institute at Montana State University
- Greater Yellowstone Coordinating Committee

- Greater Yellowstone Coalition
- Goddard Space Flight Center – Global Change Master Directory

There are several difficulties with most of the above sources. The USGS Seamless Server has been down 5 times for a day or more over the last 4 weeks, many other US agencies tie their GIS portals into the Seamless Server so when it goes down the Agriculture, Fish and Wildlife, BLM and others are also down. Several of these internet resources have just disappeared in the last few months. The Greater Yellowstone Coalition and Greater Yellowstone Coordinating Committee no longer host GIS data on its web sites; the Montana State University's GIS center and Atlas of Greater Yellowstone no longer exist. The Big Sky Institute's GIS web page is no longer available via their web page, it still exists but you can only access it via an old NBII link or if you find the link via Google and go directly to the page, even then several of their data links are dead.

Problems common to many of these sources are; even if they do have GIS data available then their web interfaces are slow, clunky and confusing. Data tends to be quite old; much of the data I was able to find was older then 2004. Inconsistency of data, especially in projections and in metadata, in one case I downloaded three files from the Montana GIS portal and each file had a different projection and the one raster would never re-project properly. Metadata was mostly nonexistent; many times it was impossible to determine the quality or veracity of the data.

## Constructing the GIS Database

### Choosing the GIS Data to Use

The first thing I need to define was just exactly what is and what the boundaries of the GYE are. I found three differing definitions of the GYE; the first (Figure 1) is based on political and administrative boundaries as defined by the National Park and U.S. Forestry Services. This is apparent by the cubic north-south and east-west orientation of the boundaries.

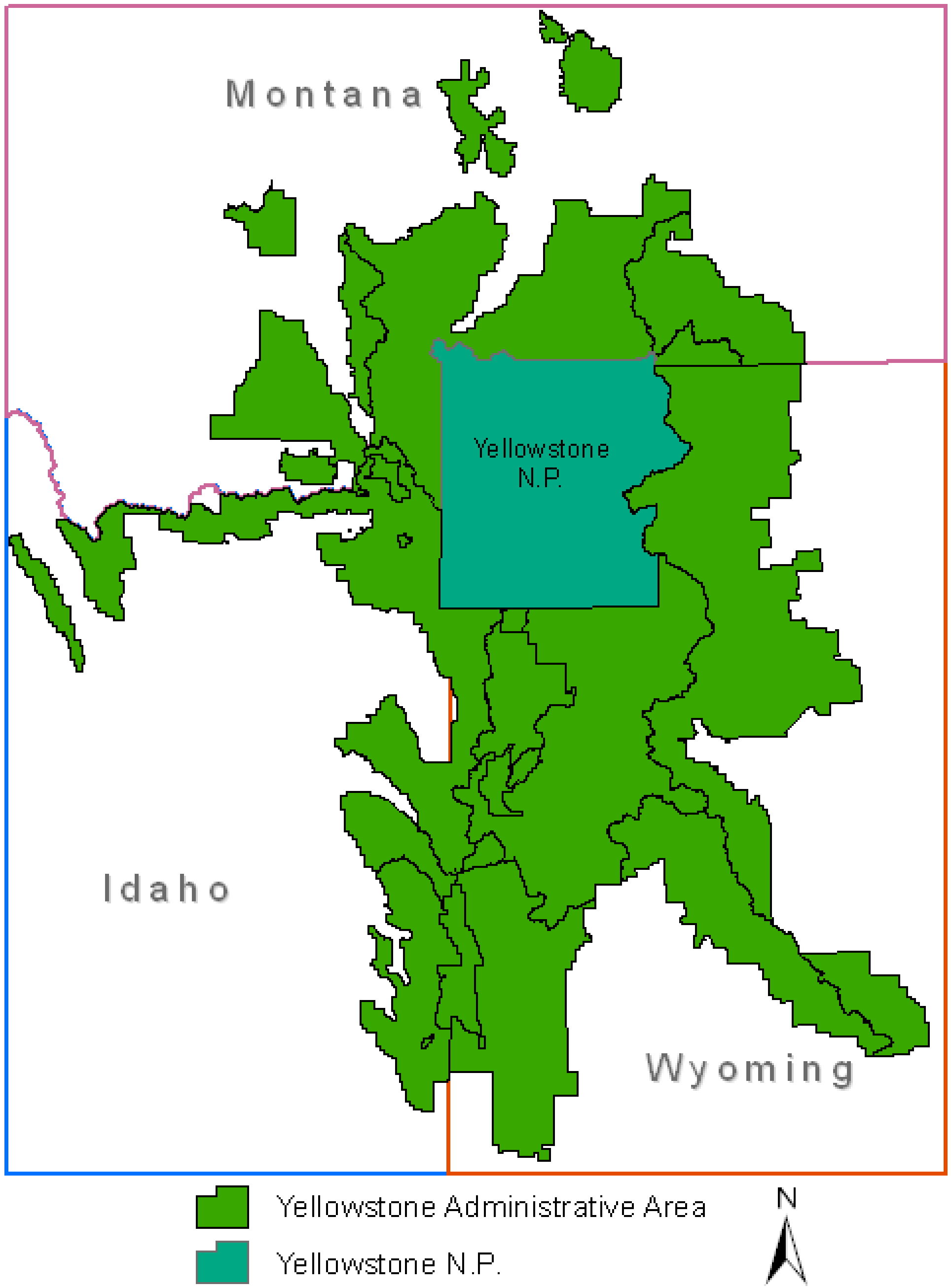


**Figure 1: GYA Administrative based boundaries**

The second was a definition I found no information on nor was there any associated metadata. I acquired it from the Big Sky Institute at Montana State University; it seems to be delineated both by political and geographic boundaries as you can see in Figure 2.

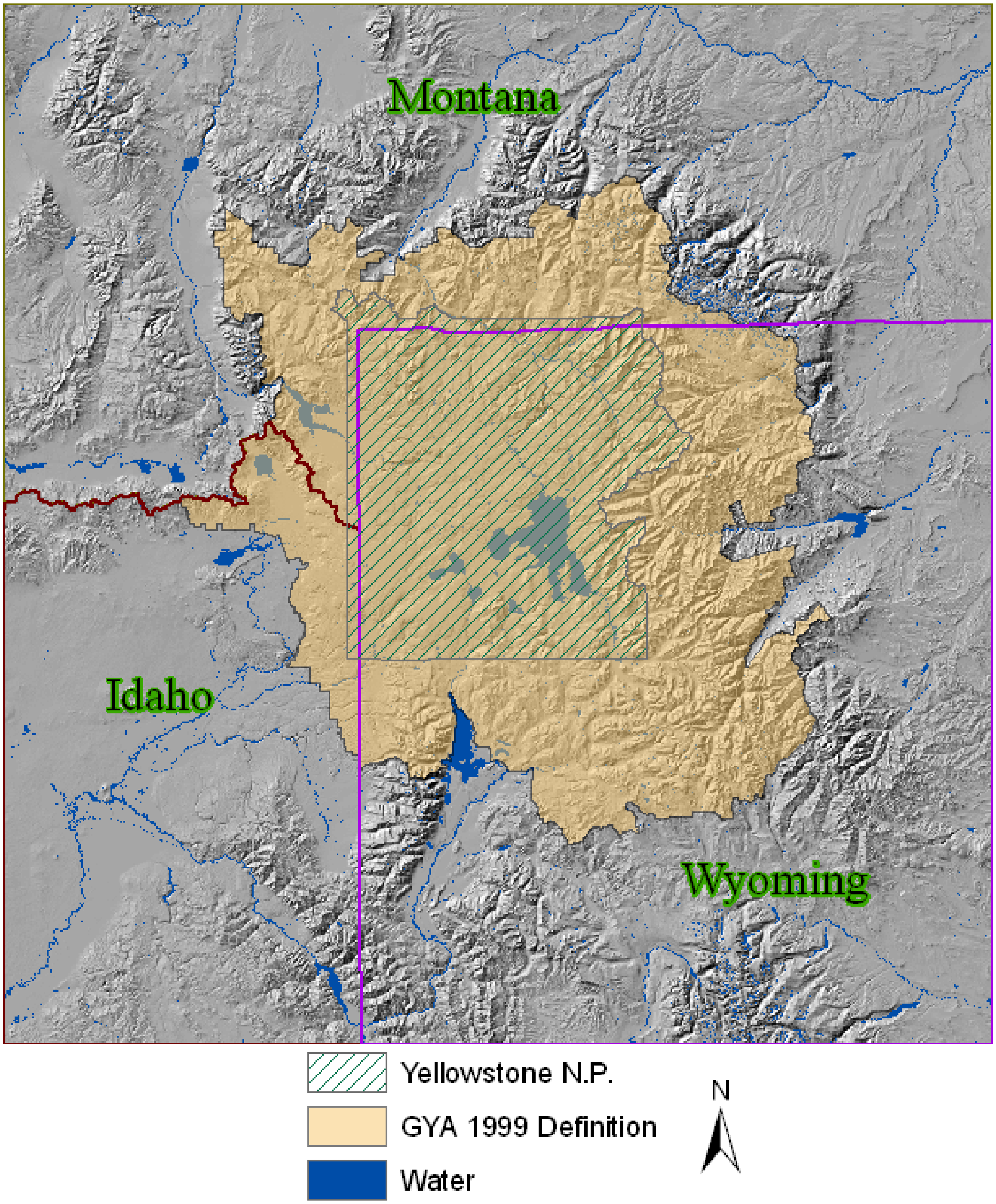



**Figure 2: GYA defined by both political and geographic boundaries**

The third definition was from Noss (2001) the GIS data and report was found on the Greater Yellowstone Coalitions web site, yet it is no longer there. The report itself can still be found on the Conservation Planning Institutes web site. Noss defined the GYE using geographic, biome and ecosystem factors considering water, food, habitat and other factors as shown in Figure 3.

This is the definition I chose to use as it seemed to be the most contiguous and well thought out boundary.

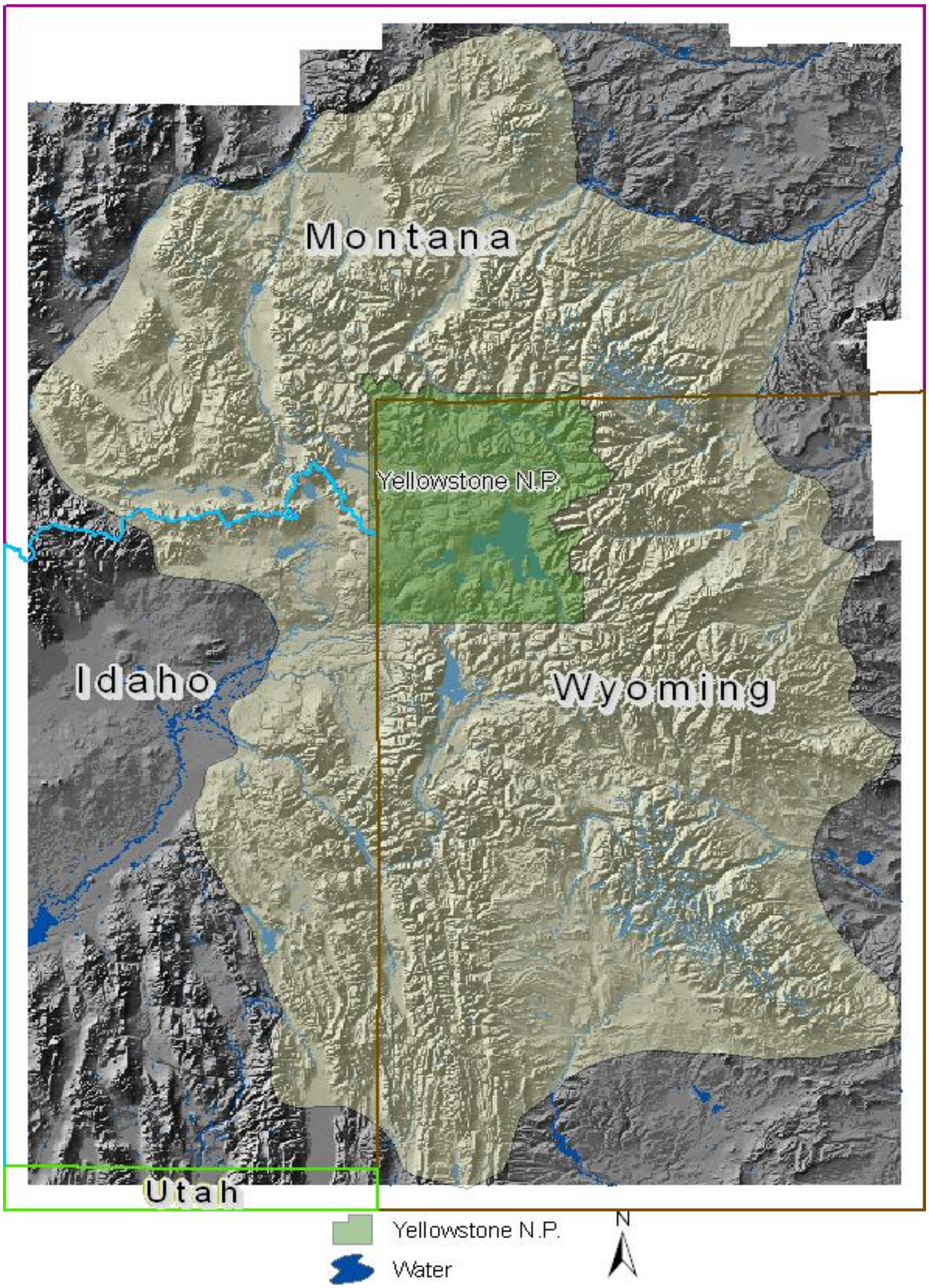



**Figure 3: GYA per Noss (2001)**

In the above cases I needed to re-project the boundaries as they were all in different projections then in Figures 2 and 3 I had to build a hillshade raster from a DEM to determine if there was a geographic correlation and I also added in water bodies for a reference point.

My next task was to find where stands of Whitebark Pine were located.  I initially started with USGS Land Use-Land Cover (LULC) rasters, the most recent 2001 files have definitions built into the raster but the 16 generalized classifications were too broad and not useful (Figure 4).  In 2001 the USGS begin reclassifying LULC files and renamed those to National Land Cover Database (NCLD) files, there is now a broader classification scheme but it still didn't have specifically a Whitebark Pine class (Figure 5).


**Figure 4: LULC Classifications**


**Figure 5: 2001 NCLD Classes**

I then looked at the USGS Tree Canopy rasters which provided me with 127 classes but the attributes do not define the classes.  What is provided are Red, Green, and Blue (RGB) index numbers (Figure 6), with these if you know the composite RGB numbers for the target canopy then you can use the RGB numbers to match your targets RGB numbers. Its doubtful if it's possible to get exact RGB matches that is where classification is useful, you are able to define ranges of RGB values and group them together. The assumption is that all of the RGB values in the raster that fall within the defined class range are the target item. But this may not be a valid assumption and can only be confirmed by ground truthing. Unfortunately I have been unable to find RGB values for the Whitebark Pine so the USGS NCLD Tree Canopy rasters are not going to be useful.

Attributes of canopy3_011007.img

| OID | Value | Count | Red | Green | Blue | Opacity |
|---|---|---|---|---|---|---|
| 0 | 0 | 380357026 | 0.827451 | 0.827451 | 0.827451 | 1 |
| 1 | 1 | 188669 | 0.819608 | 0.819608 | 0.819608 | 1 |
| 2 | 2 | 200610 | 0.807843 | 0.819608 | 0.807843 | 1 |
| 3 | 3 | 234808 | 0.8 | 0.807843 | 0.8 | 1 |
| 4 | 4 | 275593 | 0.788235 | 0.807843 | 0.788235 | 1 |
| 5 | 5 | 322095 | 0.776471 | 0.8 | 0.776471 | 1 |
| 6 | 6 | 622411 | 0.776471 | 0.8 | 0.776471 | 1 |
| 7 | 7 | 659424 | 0.756863 | 0.8 | 0.756863 | 1 |
| 8 | 8 | 694176 | 0.756863 | 0.788235 | 0.756863 | 1 |
| 9 | 9 | 707092 | 0.74902 | 0.788235 | 0.74902 | 1 |
| 10 | 10 | 734857 | 0.737255 | 0.776471 | 0.737255 | 1 |
| 11 | 11 | 1133293 | 0.729412 | 0.776471 | 0.729412 | 1 |
| 12 | 12 | 1133580 | 0.729412 | 0.756863 | 0.729412 | 1 |
| 13 | 13 | 1133564 | 0.717647 | 0.756863 | 0.717647 | 1 |
| 14 | 14 | 1141201 | 0.709804 | 0.756863 | 0.709804 | 1 |
| 15 | 15 | 1152965 | 0.698039 | 0.756863 | 0.698039 | 1 |
| 16 | 16 | 1170756 | 0.686275 | 0.756863 | 0.686275 | 1 |
| 17 | 17 | 1192967 | 0.686275 | 0.74902 | 0.686275 | 1 |
| 18 | 18 | 1220382 | 0.678431 | 0.74902 | 0.678431 | 1 |
| 19 | 19 | 1256425 | 0.666667 | 0.737255 | 0.666667 | 1 |
| 20 | 20 | 1299842 | 0.658824 | 0.737255 | 0.658824 | 1 |
| 21 | 21 | 1372348 | 0.647059 | 0.729412 | 0.647059 | 1 |
| 22 | 22 | 1410125 | 0.639216 | 0.729412 | 0.639216 | 1 |
| 23 | 23 | 1445426 | 0.639216 | 0.729412 | 0.639216 | 1 |
| 24 | 24 | 1476199 | 0.627451 | 0.717647 | 0.627451 | 1 |
| 25 | 25 | 1512833 | 0.619608 | 0.717647 | 0.619608 | 1 |
| 26 | 26 | 1547596 | 0.607843 | 0.709804 | 0.607843 | 1 |
| 27 | 27 | 1581860 | 0.6 | 0.709804 | 0.6 | 1 |
| 28 | 28 | 1615736 | 0.588235 | 0.698039 | 0.588235 | 1 |

Record: 1 Show: All Selected Records (0 out of 128 Selected) Options

**Figure 6: NCLD Tree Canopy raster with Read, Green and Blue values.**

I was fortunate to find a USGS GAP Analysis raster for the Northwestern US. There is 200 defined classes built into this raster and provides a tremendous level of detail (Appendix Figure A). Unfortunately of the 200 classifications none are for Whitebark Pine. I was able to find a GAP Analysis raster at Idaho State University's GIS center what was reclassified specifically for the Whitebark Pine, in fact the creators of the raster had gone as far as ground truthing portions of the raster to confirm that it represented actual Whitebark Pine locations. It is fortunate that this raster covers over 99% of the Noss GYA defined area, only a small portion at the top of the area is not covered with this raster (Figure 7). While the class definitions were not built into the raster file (Figure 8) there was a spreadsheet (Figure 9) and a text file (Figure 10) with the Value-to-Definition conversion. The spreadsheet had special formatting and wasn't in a simple columnar formatting but I was able to read the text file into Excel as a delimited file and save it (Figure 11). I was then able to join the raster and table to provide definitions (Figures 12). The definitions associated with this raster has a specific attribute number defined for Whitebark Pine but in the spreadsheet that accompanied the raster, that was not used for classification, has a second classification for a mixed Alpine Fir/Lodgepole/Whitebark/Spruce/Subalpine forest. It is possible that there is enough of a Whitebark Pine population in these mixed forests to attract Grizzly Bear but I am making an assumption that predominant Whitebark Pine woodlands will draw in more bear then the mixed woodlands. So I will add the mixed woodlands in to my analysis but it will be ranked low.

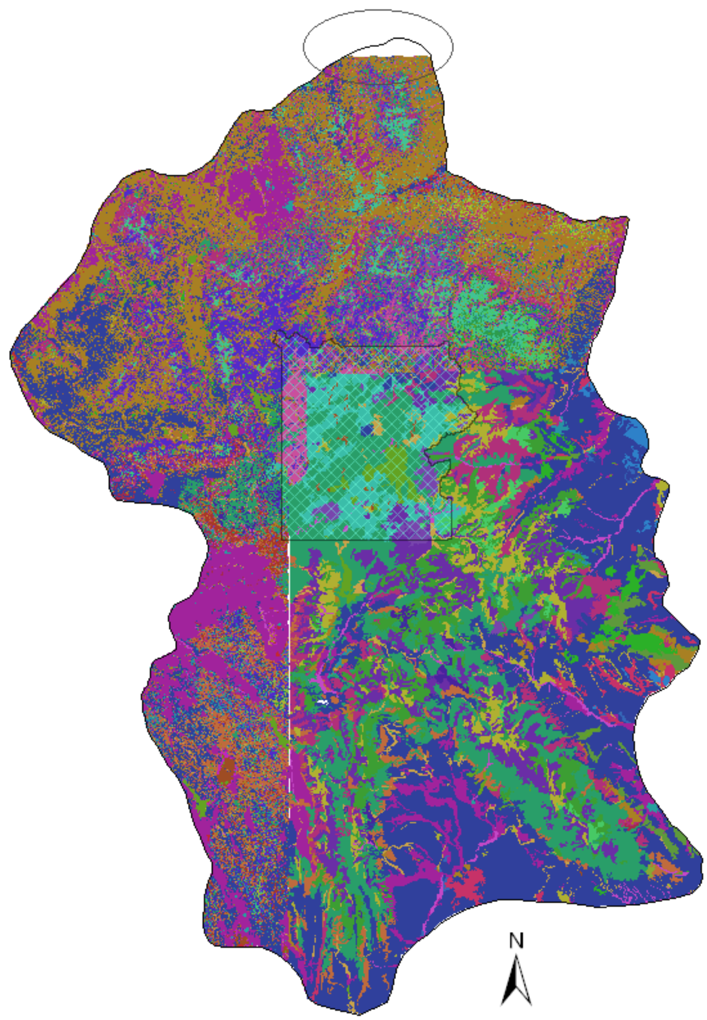



**Figure 7: Missing Canopy Type raster coverage**

With this raster I will be able to extract 3 features, water, Whitebark Pine stands, and low density Whitebark Pine stands as seen in Figures 13, 14 and 15 respectively. Looking at the Whitebark

Attributes of Noss_veg

| Rowid | VALUE * | COUNT |
|---|---|---|
| 0 | 101 | 1167550 |
| 1 | 102 | 6104059 |
| 2 | 103 | 225964 |
| 3 | 105 | 109136 |
| 4 | 106 | 14434233 |
| 5 | 202 | 1540945 |
| 6 | 203 | 1036987 |
| 7 | 204 | 373151 |
| 8 | 205 | 26174845 |
| 9 | 207 | 137689 |
| 10 | 208 | 61588 |
| 11 | 209 | 13189 |
| 12 | 210 | 146018 |
| 13 | 211 | 83394 |
| 14 | 212 | 884914 |
| 15 | 213 | 2302 |
| 16 | 301 | 3964938 |
| 17 | 303 | 2875 |
| 18 | 305 | 652514 |
| 19 | 306 | 981678 |
| 20 | 307 | 234 |
| 21 | 308 | 1016627 |
| 22 | 309 | 5270137 |
| 23 | 310 | 8069 |
| 24 | 311 | 589928 |
| 25 | 313 | 4406089 |
| 26 | 314 | 1788287 |
| 27 | 316 | 6982973 |
| 28 | 318 | 131999 |

Record: 1 Show: All Selected Records (0 out of 52 Selected) Options

**Figure 8: Attributes for Tree Canopy raster**

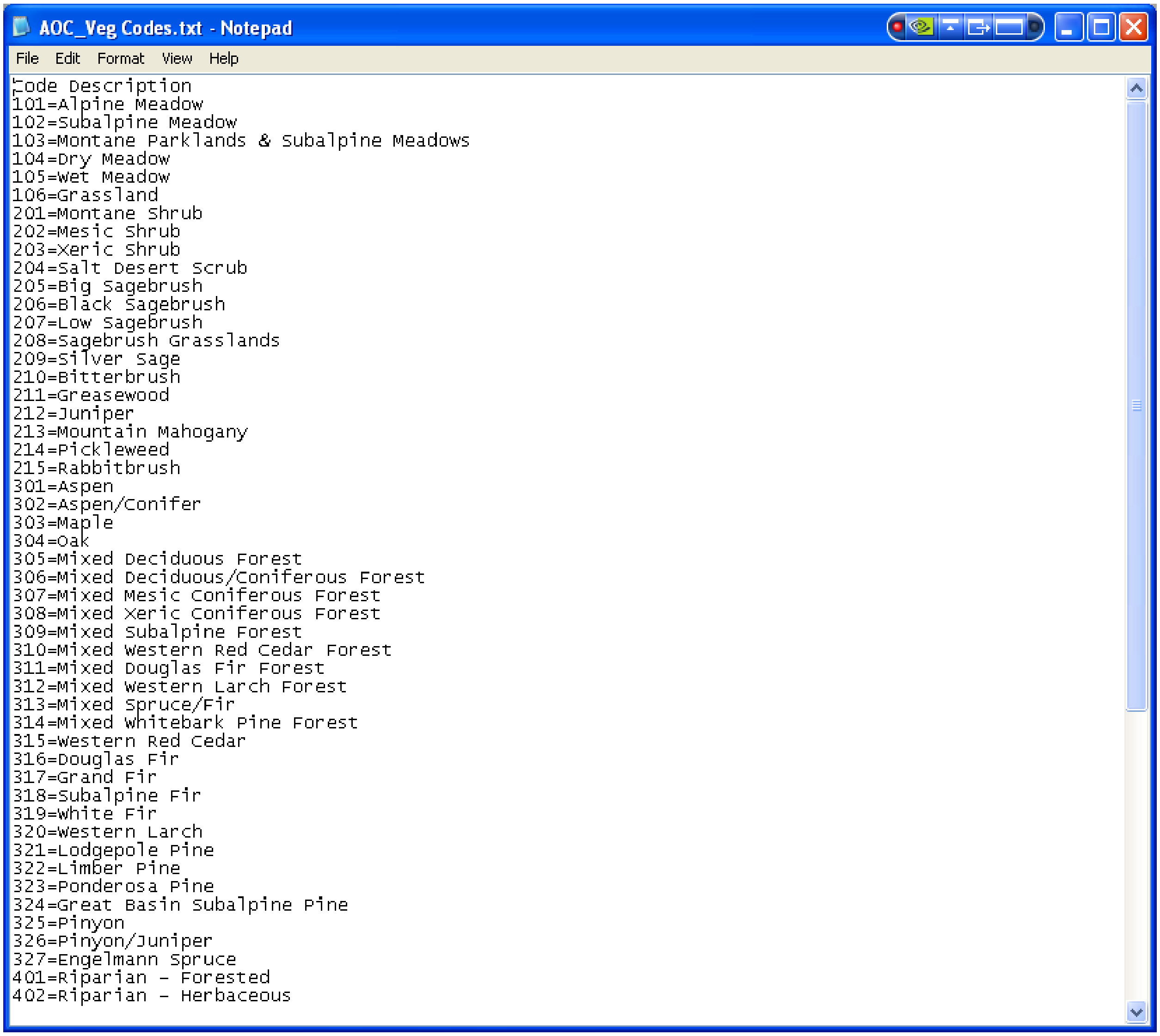
in Figures 13 and 14 causes me to have some suspicion of the veracity of the data. The perfect north-south and east-west breaks in ground cover is highly suspicious.

I will also need data on Cutthroat trout populations and locations. I was able to find a shape file that is the result of field counts of Cutthroat, reports from fisherman, and historical records compiled by Yellowstone Cutthroat Trout Interagency Conservation Team in 2003. They generated site data which was combined with stream shape files from the National Hydrographic Dataset (Figure 16). Because they were able to do extensive ground truthing they were able to give a population, quality and genetic profile ranking to sections of various streams throughout the GYA. From this data set I am extracting out streams or sections of streams that have what they class as “abundant” healthy Cutthroat populations (Figure 17). While Grizzly Bear may be drawn to streams with lesser populations I am fielding an assumption that the larger and healthier the Cutthroat population the more it will draw bear.

| | | | | |
|---|---|---|---|---|
| 100 Series - Meadow/Grassland | | 500 Series - Unvegetated/Bare Lands | | |
| 200 Series - Shrubs/Shrublands | | 600 Series - Human impacted lands | | |
| 300 Series - Forested Lands | | 700 Series - Burned Lands | | |
| 400 Series - Riparian/Wetlands | | | | |
| | | | | |
| | | | | |
| **Our Code** | **Our Description** | **Their Code** | **Their Description** | **State** |
| 101 | Alpine Meadow | 90 | Alpine Herbaceous | S_ID |
| 101 | Alpine Meadow | 8100 | AlpineMeadows | N_ID |
| 101 | Alpine Meadow | 8100 | AlpineMeadows | MT |
| 101 | Alpine Meadow | 82001 | Meadow tundra | WY |
| 101 | Alpine Meadow | 52 | Alpine | NV |
| 102 | Subalpine Meadow | 98 | Tall Forb Montane | S_ID |
| 102 | Subalpine Meadow | 82002 | Subalpine meadow | WY |
| 103 | Montane Parklands & Subalpine Meadows | 3104 | Montane Parklands & Subalpine Meadows | N_ID |
| 103 | Montane Parklands & Subalpine Meadows | 3180 | Montane Parklands & Subalpine Meadows | MT |
| 104 | Dry Meadow | 94 | Dry Meadow | S_ID |
| 104 | Dry Meadow | 18 | DRY MEADOW | UT |
| 105 | Wet Meadow | 99 | Wet Meadow | S_ID |
| 105 | Wet Meadow | 19 | WET MEADOW | UT |
| 106 | Grassland | 91 | Annual Grass/Forb | S_ID |
| 106 | Grassland | 95 | Perennial Grass | S_ID |
| 106 | Grassland | 97 | Perennial Grass Montane | S_ID |
| 106 | Grassland | 96 | Perennial Grass Slope | S_ID |
| 106 | Grassland | 3101 | Foothills Grasslands | N_ID |
| 106 | Grassland | 3150 | Low / Moderate Cover Grasslands | MT |
| 106 | Grassland | 3170 | Moderate / High Cover Grasslands | MT |
| 106 | Grassland | 3130 | Very Low Cover Grasslands | MT |
| 106 | Grassland | 31003 | Great Basin foothills grassland | WY |
| 106 | Grassland | 31001 | Mixed grass prairie | WY |
| 106 | Grassland | 33 | DESERT GRASSLAND | UT |
| 106 | Grassland | 16 | GRASSLAND | UT |
| 106 | Grassland | 54 | Grassland | NV |
| 201 | Montane Shrub | 81 | Montane Shrub | S_ID |

**Figure 9: More detailed GAP classifications**

The Army Cutworm moth is typically found in the GYE in southward facing talus slopes at or above the tree line. Making the assumption that the tree line in the GYE was around 9000 feet and that a “southward facing” aspect would run from 112 degrees ESE to 247 degrees WSW throughout the spring through fall months. I then took the DEM I generated for the GYE and removed everything from 0 to 9000 feet creating a new raster that has elevations from 9000 feet and up (Figure 18). I then took a land cover raster extracted all the talus, gravel and rock classes from the raster leaving a raster with just rocky areas (Figure 19). I then used this new raster as a



AOC_Veg Codes.txt - Notepad

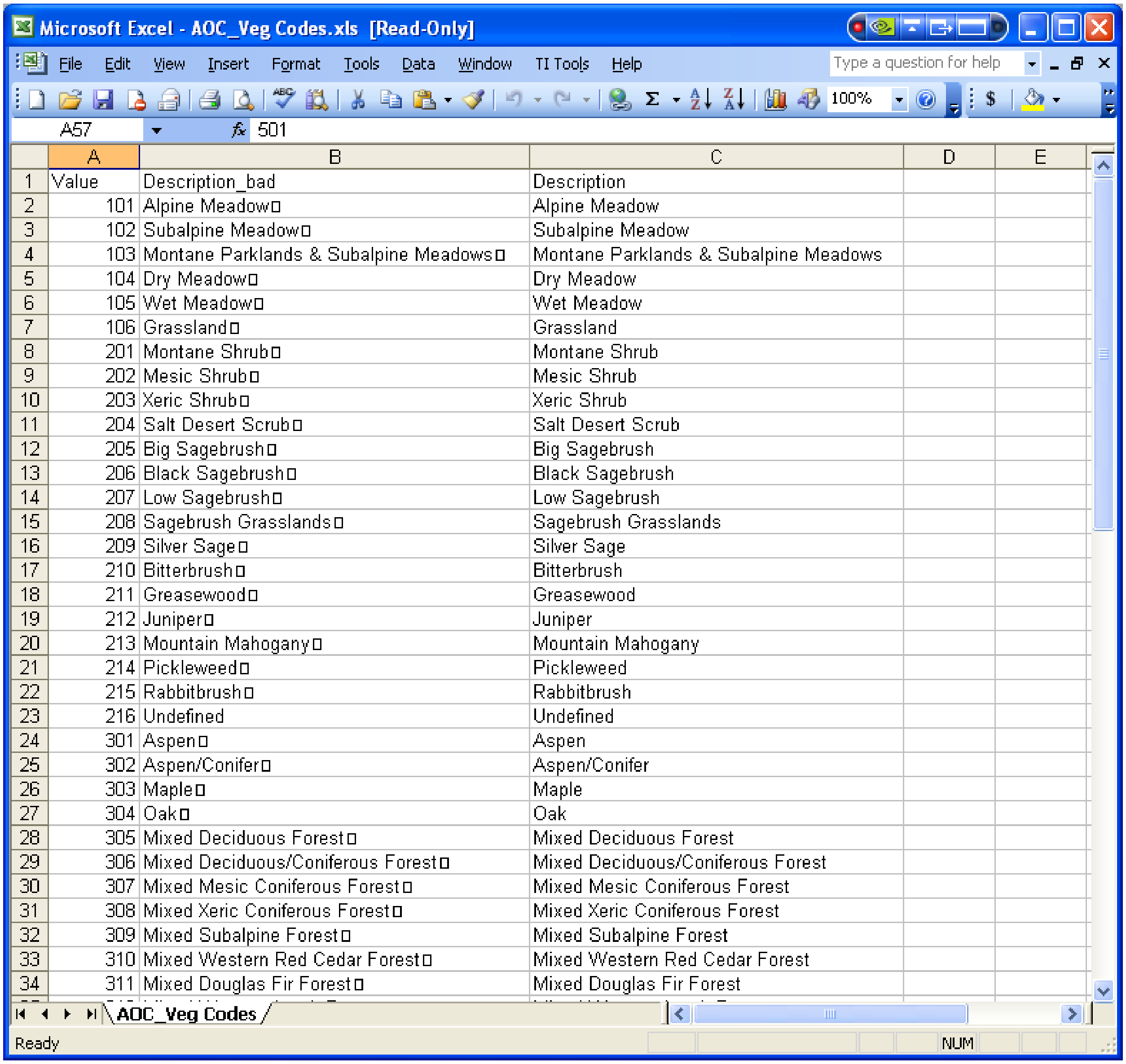
File Edit Format View Help

```
Code Description
101=Alpine Meadow
102=Subalpine Meadow
103=Montane Parklands & Subalpine Meadows
104=Dry Meadow
105=Wet Meadow
106=Grassland
201=Montane Shrub
202=Mesic Shrub
203=Xeric Shrub
204=Salt Desert Scrub
205=Big Sagebrush
206=Black Sagebrush
207=Low Sagebrush
208=Sagebrush Grasslands
209=Silver Sage
210=Bitterbrush
211=Greasewood
212=Juniper
213=Mountain Mahogany
214=Pickleweed
215=Rabbitbrush
301=Aspen
302=Aspen/Conifer
303=Maple
304=Oak
305=Mixed Deciduous Forest
306=Mixed Deciduous/Coniferous Forest
307=Mixed Mesic Coniferous Forest
308=Mixed Xeric Coniferous Forest
309=Mixed Subalpine Forest
310=Mixed Western Red Cedar Forest
311=Mixed Douglas Fir Forest
312=Mixed Western Larch Forest
313=Mixed Spruce/Fir
314=Mixed Whitebark Pine Forest
315=Western Red Cedar
316=Douglas Fir
317=Grand Fir
318=Subalpine Fir
319=White Fir
320=Western Larch
321=Lodgepole Pine
322=Limber Pine
323=Ponderosa Pine
324=Great Basin Subalpine Pine
325=Pinyon
326=Pinyon/Juniper
327=Engelmann Spruce
401=Riparian - Forested
402=Riparian - Herbaceous
```

**Figure 10: GAP classifications that were converted from text to a spreadsheet**

mask and extracted from the new 9000 foot+ raster all the locations in the GYE over 9000 feet that consist of loose talus or scree slopes (Figure 20). At this point I created a TIN out of the raster of rocky areas over 9000 foot. I then ran the new elevation TIN through the TIN aspect tool using a defined table creating a three aspect TIN from 0-120 degrees, from 120-240 degrees and from 240-360 degrees (Figure 21). The resultant TIN has aspect codes that define their aspect, with the definition table I used the only aspect I want is aspect code 2. The rest of the aspect entries I will delete from the TIN; this is an extremely time intensive task, it can take several hours. Because TINs create a performance drain on screen refreshes I converted the final

TIN to a raster representing southward facing rocky surfaces above 9000 feet, ideal habitat for the Army Cutworm moth (Figure 22).




| | A | B | C | D | E |
|---|---|---|---|---|---|
| 1 | Value | Description_bad | Description | | |
| 2 | 101 | Alpine Meadow□ | Alpine Meadow | | |
| 3 | 102 | Subalpine Meadow□ | Subalpine Meadow | | |
| 4 | 103 | Montane Parklands & Subalpine Meadows□ | Montane Parklands & Subalpine Meadows | | |
| 5 | 104 | Dry Meadow□ | Dry Meadow | | |
| 6 | 105 | Wet Meadow□ | Wet Meadow | | |
| 7 | 106 | Grassland□ | Grassland | | |
| 8 | 201 | Montane Shrub□ | Montane Shrub | | |
| 9 | 202 | Mesic Shrub□ | Mesic Shrub | | |
| 10 | 203 | Xeric Shrub□ | Xeric Shrub | | |
| 11 | 204 | Salt Desert Scrub□ | Salt Desert Scrub | | |
| 12 | 205 | Big Sagebrush□ | Big Sagebrush | | |
| 13 | 206 | Black Sagebrush□ | Black Sagebrush | | |
| 14 | 207 | Low Sagebrush□ | Low Sagebrush | | |
| 15 | 208 | Sagebrush Grasslands□ | Sagebrush Grasslands | | |
| 16 | 209 | Silver Sage□ | Silver Sage | | |
| 17 | 210 | Bitterbrush□ | Bitterbrush | | |
| 18 | 211 | Greasewood□ | Greasewood | | |
| 19 | 212 | Juniper□ | Juniper | | |
| 20 | 213 | Mountain Mahogany□ | Mountain Mahogany | | |
| 21 | 214 | Pickleweed□ | Pickleweed | | |
| 22 | 215 | Rabbitbrush□ | Rabbitbrush | | |
| 23 | 216 | Undefined | Undefined | | |
| 24 | 301 | Aspen□ | Aspen | | |
| 25 | 302 | Aspen/Conifer□ | Aspen/Conifer | | |
| 26 | 303 | Maple□ | Maple | | |
| 27 | 304 | Oak□ | Oak | | |
| 28 | 305 | Mixed Deciduous Forest□ | Mixed Deciduous Forest | | |
| 29 | 306 | Mixed Deciduous/Coniferous Forest□ | Mixed Deciduous/Coniferous Forest | | |
| 30 | 307 | Mixed Mesic Coniferous Forest□ | Mixed Mesic Coniferous Forest | | |
| 31 | 308 | Mixed Xeric Coniferous Forest□ | Mixed Xeric Coniferous Forest | | |
| 32 | 309 | Mixed Subalpine Forest□ | Mixed Subalpine Forest | | |
| 33 | 310 | Mixed Western Red Cedar Forest□ | Mixed Western Red Cedar Forest | | |
| 34 | 311 | Mixed Douglas Fir Forest□ | Mixed Douglas Fir Forest | | |

**Figure 11: Spreadsheet created from the text file in Figure 10 and use to join a table giving descriptions.**

I decided to also include a fourth food source, carrion.  In general Grizzly Bears are not hunters they are opportunists and will always feed on a downed bison or elk.  So I included winter ranges for both bison and elk in the GYE, the assumption is that more wolf kills, weather related deaths and natural deaths happen in the winter and that in the winter both elk and bison herd up so any deaths will happen in the more concentrated area of their winter range (Figure 23).

Attributes of Noss_veg

| noss_veg.vat:Rowi | noss_veg.vat:VALUE | noss_veg.vat:COU | 'AOC_Veg Codes$'.Val | 'AOC_Veg Codes$'.Description |
|---|---|---|---|---|
| 0 | 101 | 1167550 | 101 | Alpine Meadow |
| 1 | 102 | 6104059 | 102 | Subalpine Meadow |
| 2 | 103 | 225964 | 103 | Montane Parklands & Subalpine Meadow |
| 3 | 105 | 109136 | 105 | Wet Meadow |
| 4 | 106 | 14434233 | 106 | Grassland |
| 5 | 202 | 1540945 | 202 | Mesic Shrub |
| 6 | 203 | 1036987 | 203 | Xeric Shrub |
| 7 | 204 | 373151 | 204 | Salt Desert Scrub |
| 8 | 205 | 26174845 | 205 | Big Sagebrush |
| 9 | 207 | 137689 | 207 | Low Sagebrush |
| 10 | 208 | 61588 | 208 | Sagebrush Grasslands |

Record: 0 Show: All Selected Records (0 out of 52 Selected) Options

**Figure 12: Final joined table from Figure 8 giving class codes and descriptions**

The next item to account for is the human effects; adding major roadways and cities and urban areas to the maps (Figure 24), hiking trails and camping areas (Figure 25). Lastly let's look at commercial entities like mines, geothermal, coal and others (Figure 26).

## Data Analysis

It is time to start putting the various features together to determine if there is a viable habitat for Grizzly Bear in the GYA. One of the general problems with graphical GIS analysis is of scale of detail. With an area as large as the GYA it is hard on a letter sized sheet of paper to show the level of detail that is sometimes needed.

Starting with food supplies; adding all the food sources together and look for conjunction (Figure 27). First analysis shows that food sources are spatially varied, to the east and northeast of Lake Yellowstone there is a confluence of all food sources. This is also where specific bear management areas have been designated. It seems though that most of the prime Cutthroat trout streams are to the southeast and southwest, prime Army Cutworm moth areas are to the east and southeast with some to the northeast. Prime Whitebark Pine stands tend to the north part of the GYA, mostly to the northeast with some to the northwest. Bison and Elk winter ranges tend to northeast and north of Lake Yellowstone. Roughly it seems that there is good contiguous habitat in a roughly crescent shaped 144 km arc that follows the spine of the mountains to the east and northeast of Lake Yellowstone (Figure 28).

Now to lay over the human factors and see how these affect Grizzly Bear habitat quality and connectivity. Starting off with low impact intrusions such as trails and camp sites it clear that there is already significant intrusion into prime Grizzly Bear habitat (Figure 29). Laying on roads in the GYA, buildings significant fragmentation is becoming apparent (Figure 30). The map is beginning to be come cluttered so in Figure 31 I zoomed in to the area I marked as possible quality habitat to better show the fragmentation by roads and human habitation. In Figure 32 I removed all the campsites and trails to lower clutter and added on the GYA cities with population ratings. Figure 33 takes the same map as Figure 32 and adds on mineral and energy resources and commercial, residential and tourist developments.

I would like to use ArcGIS to perform a pattern analysis, to look for the gaps where each of the food sources exists yet there is no interference from anthropogenic factors. Determine where food and cover is and people aren't. I'm sure it's possible but I have yet to figure out how. Part of the problem is the inability to perform complex queries between rasters and vectors. So I just used the Mark I Eyeball and looked for the gaps. Not surprisingly my initial estimate of prime habitat was approximately 14,104 $km^2$ while the final analysis after all factors are accounted for is approximately 18,000$km^2$, almost 20% more area then the first estimate(Figure 34). While these numbers are still just estimates they do provide an educated and informed guidepost to make decisions and to point out areas that need further research and more refinement of data. Three aspects of this analysis that would have been interesting and potentially helpful would have been the addition of time, how has the GYA and human influences changed over time but this would have required a significant amount more data and analysis with much of the data requiring digitizing by hand; the effects of fire and fire over time on habitat in the GYA, and the locations and numbers of Grizzly Bear dens over time in the GYA.

In the end GIS analysis relies in three things; availability of relevant data, the quality of the data, but mostly on the judgment and interpretation of the data by the users. As in this analysis of Grizzly Bear habitat, after all the data was represented it still required me to manually make an initial estimate and a final estimate and input that by hand. GIS systems provide an excellent tool to use in making a decision but in the end the decision still requires human input, analysis and decision making.

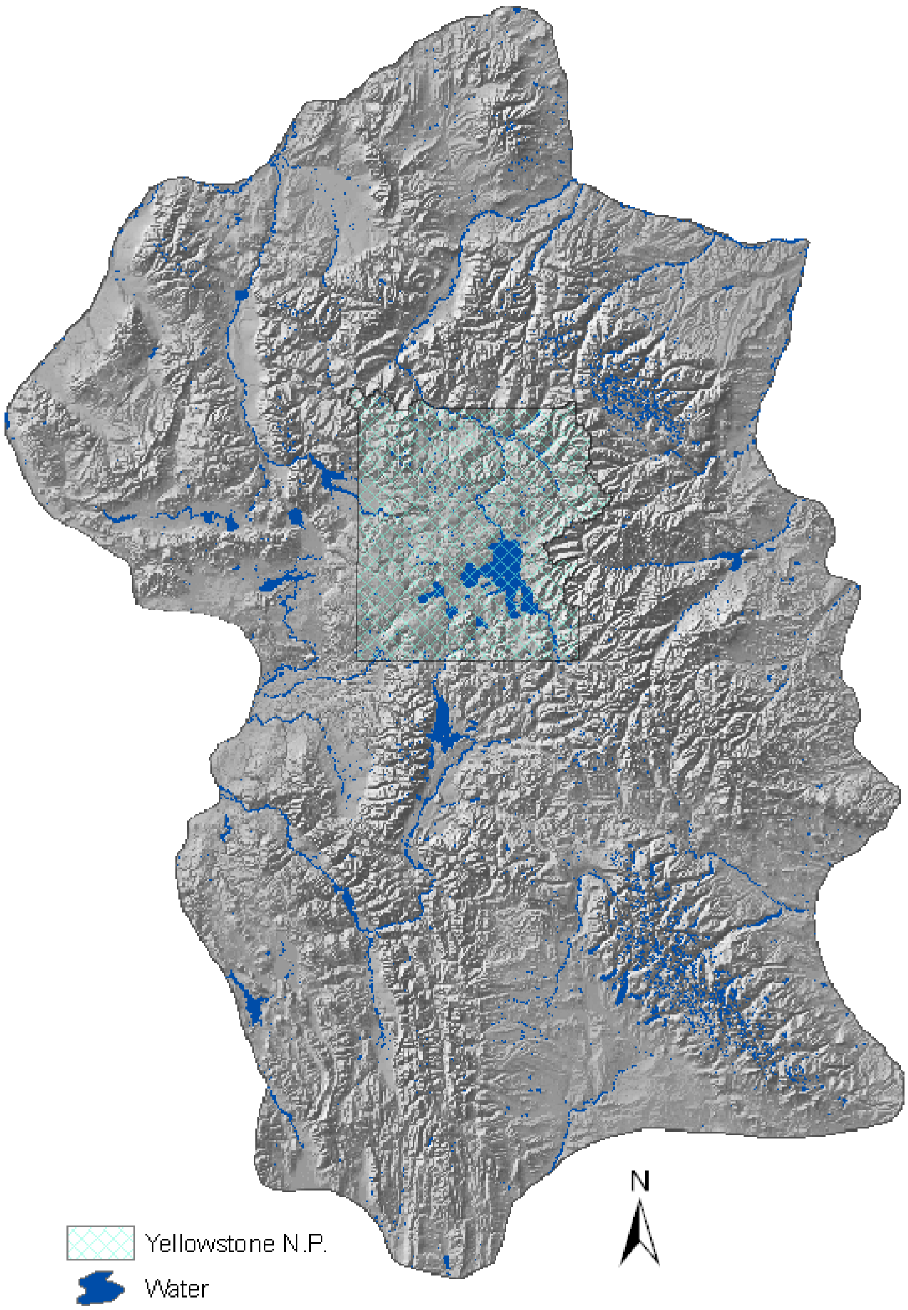



**Figure 13: Water bodies in the GYA**

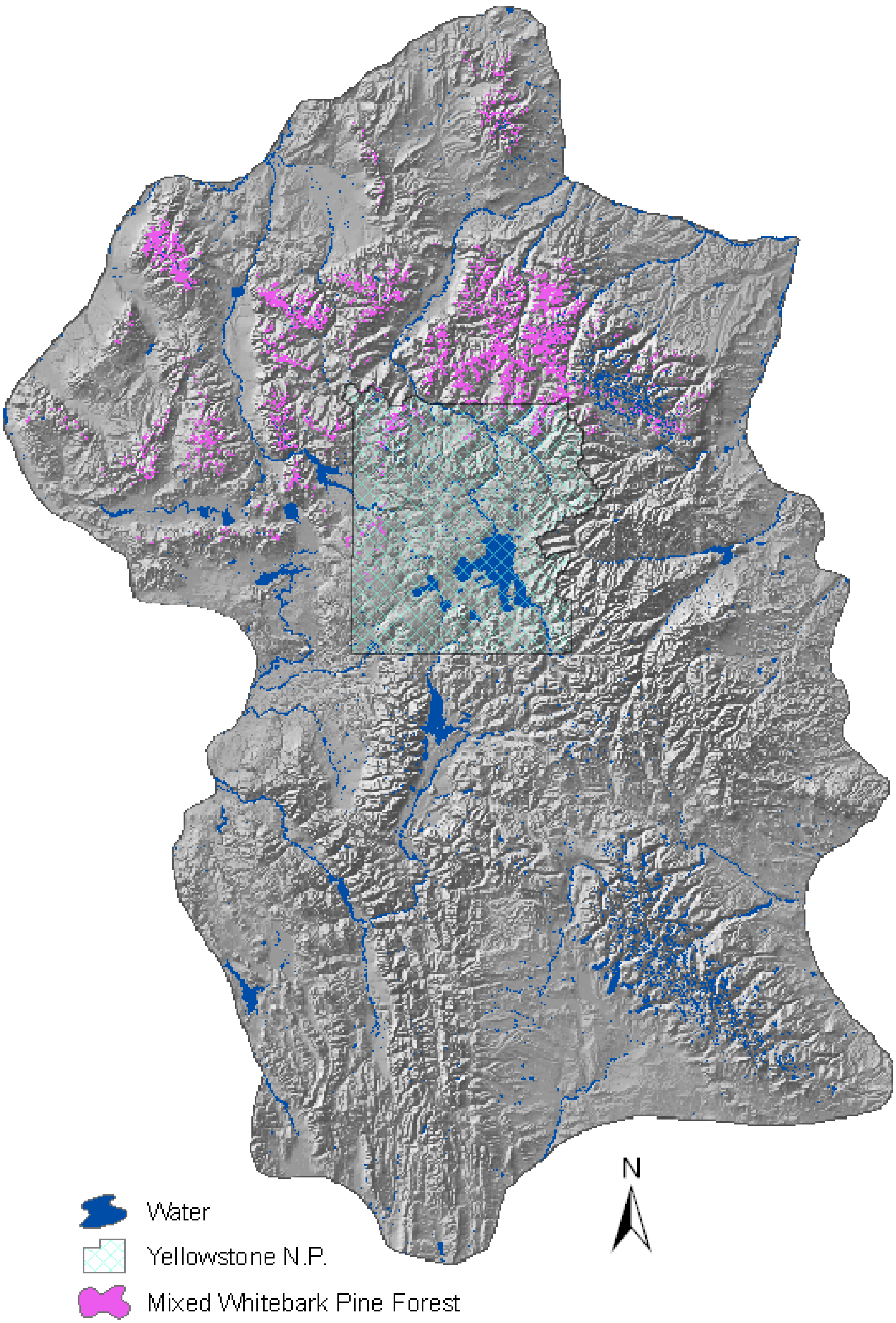



**Figure 14: Prime stands of Whitebark Pine**

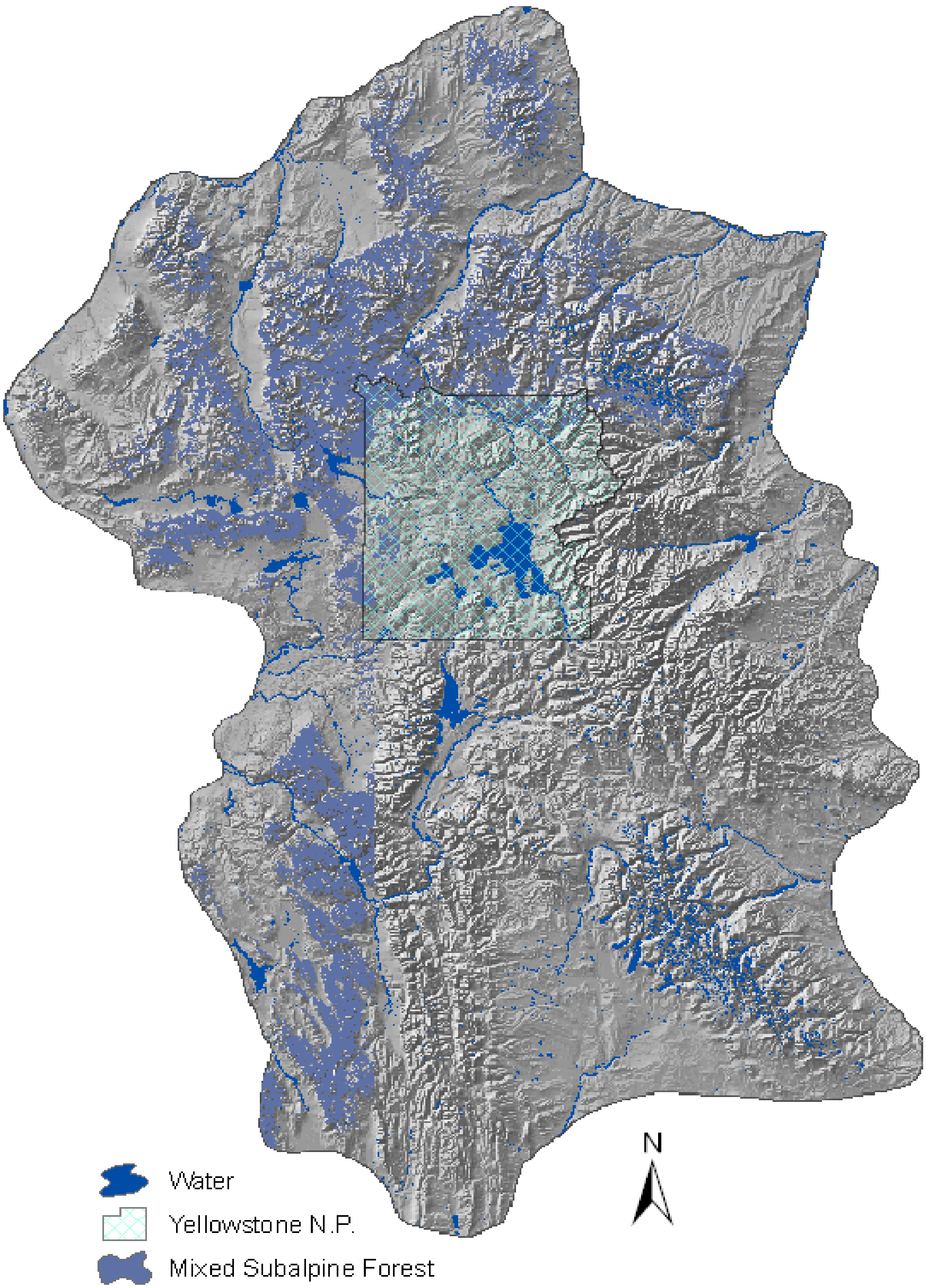



**Figure 15: Mixed stands of Whitebark Pine and other trees**

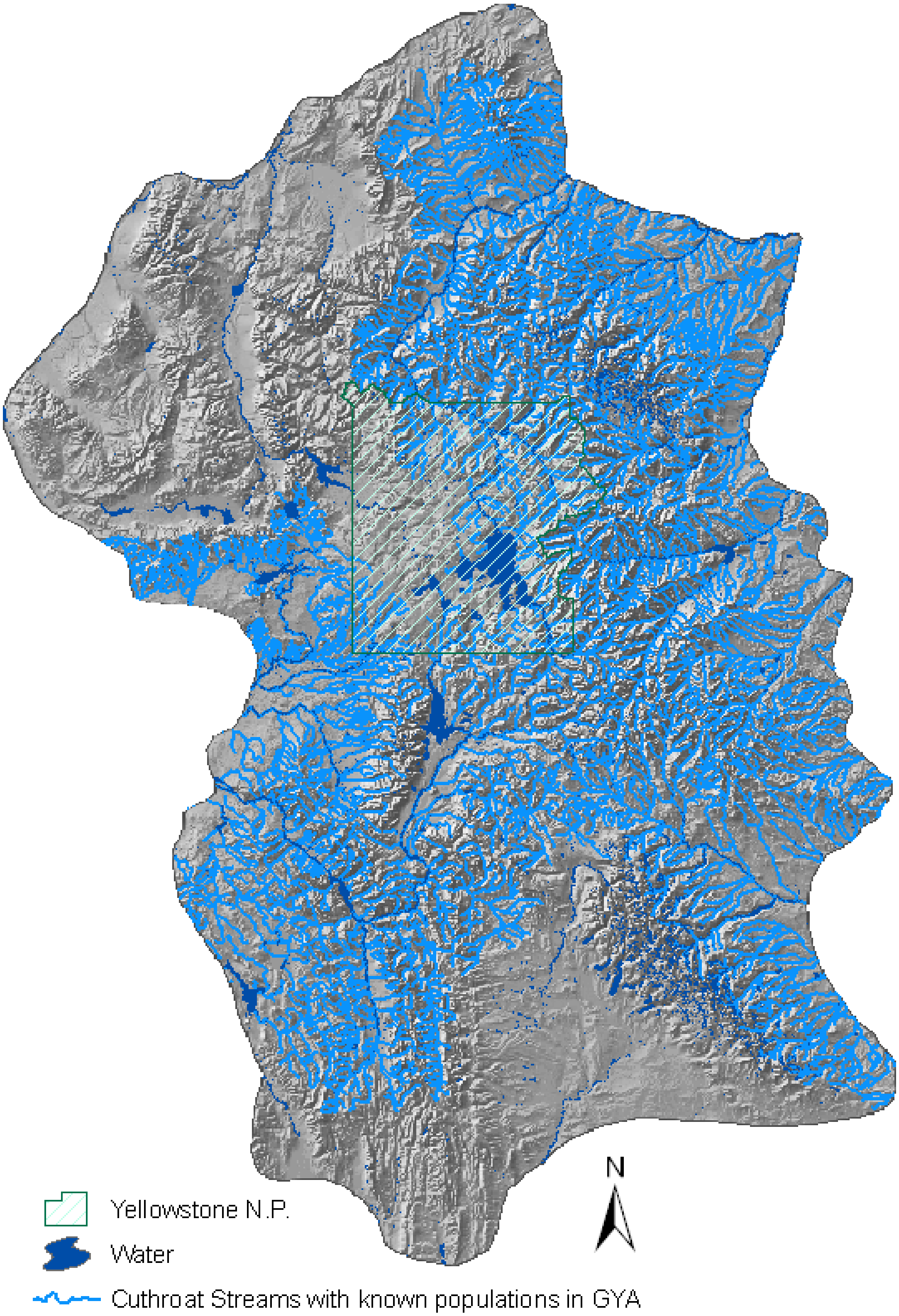



**Figure 16: Streams with known Cutthroat trout populations**

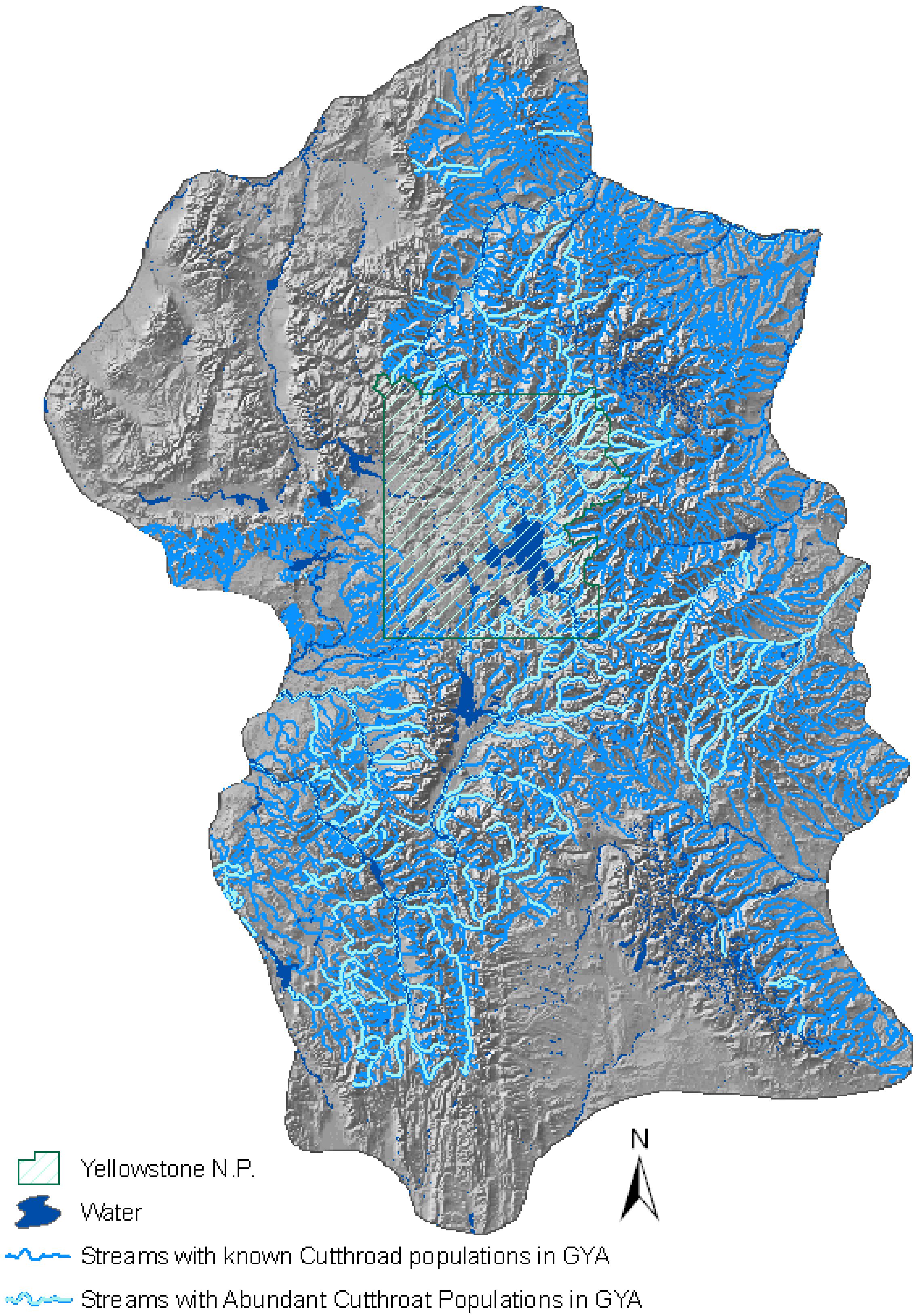



**Figure 17: Streams with abundant Cutthroat populations**

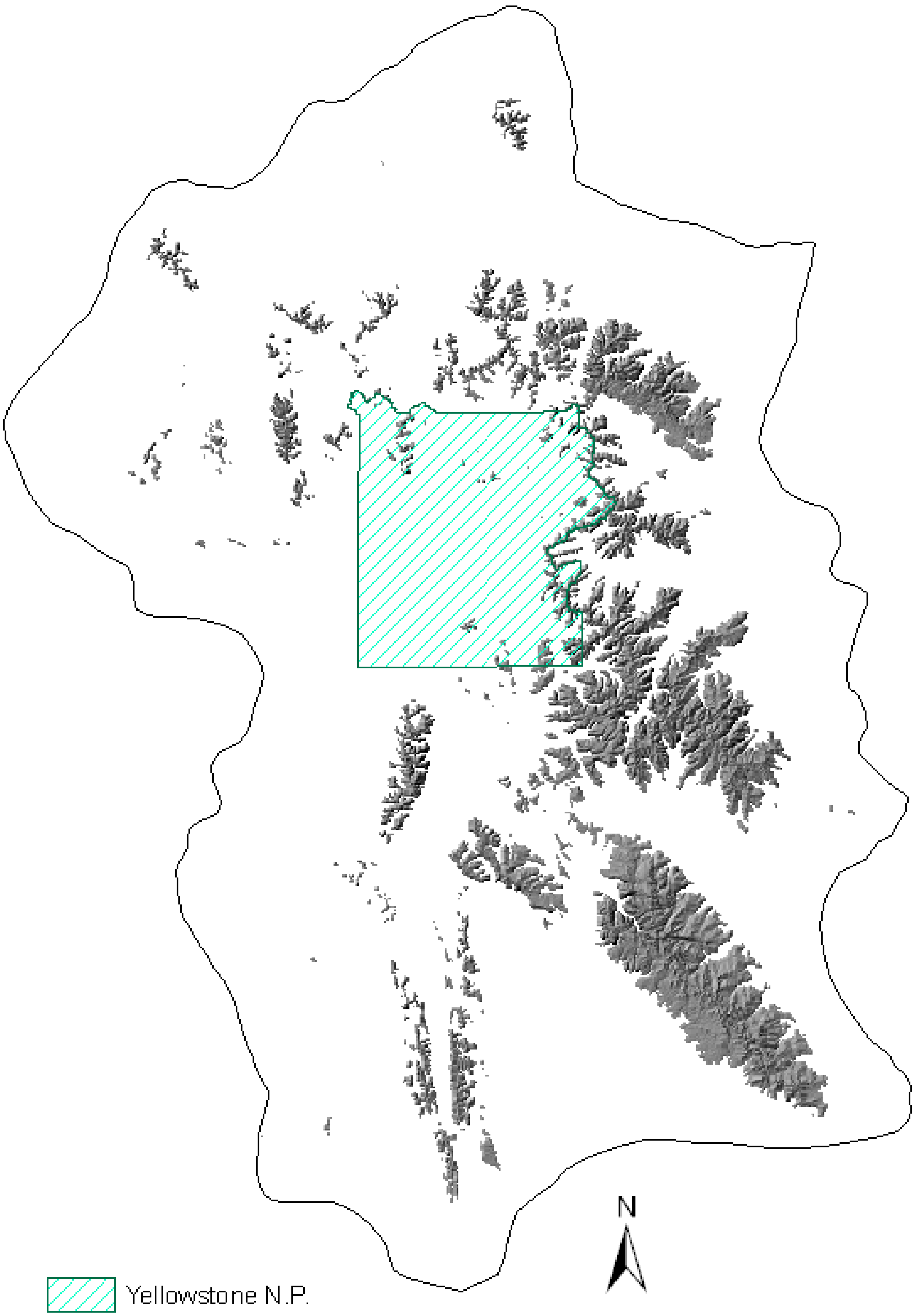



**Figure 18: Areas over 9000 ft in the GYA**

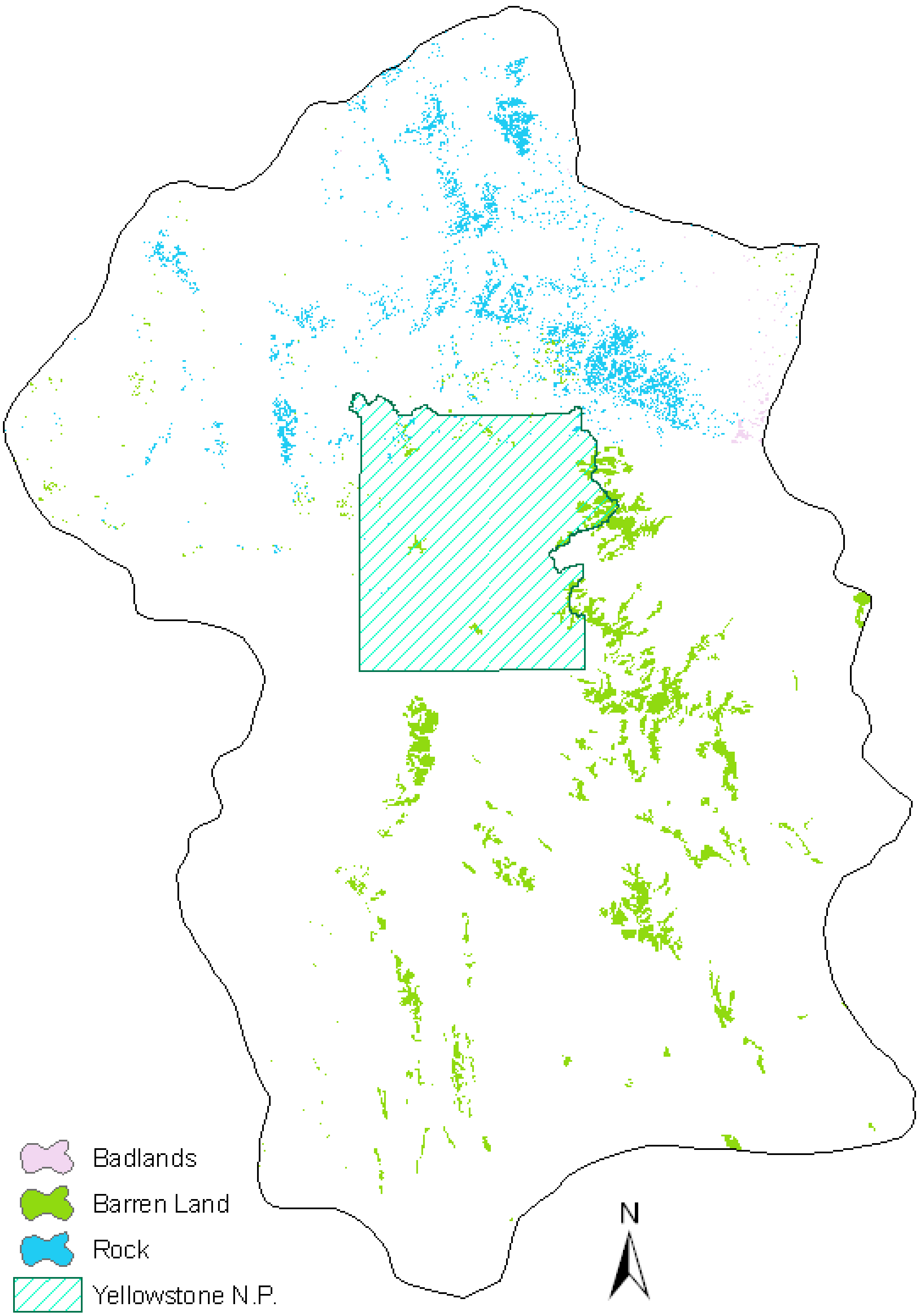



**Figure 19: Areas of rock, talus, scree, etc.**

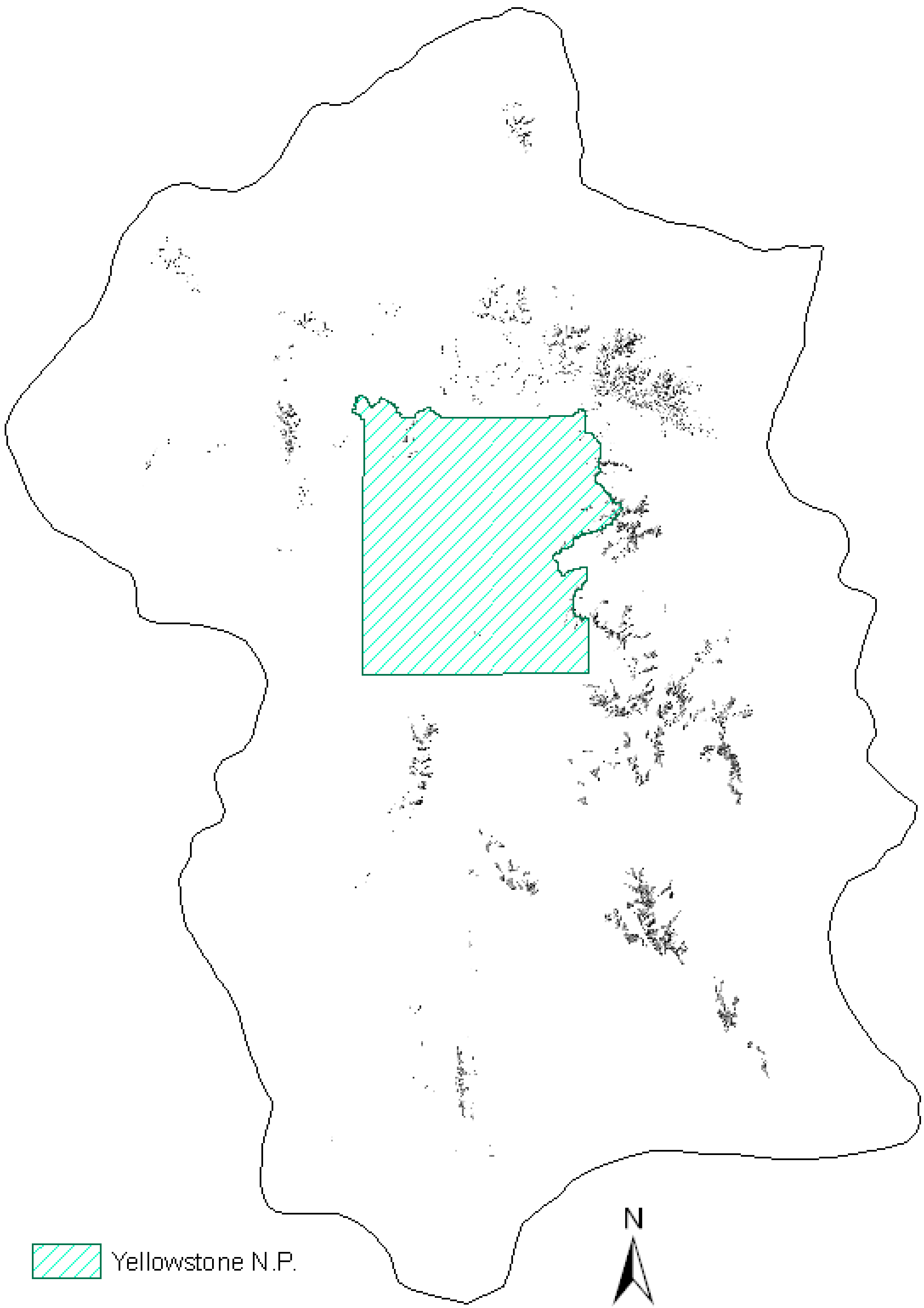



**Figure 20: Barren rock, scree and talus over 900ft**

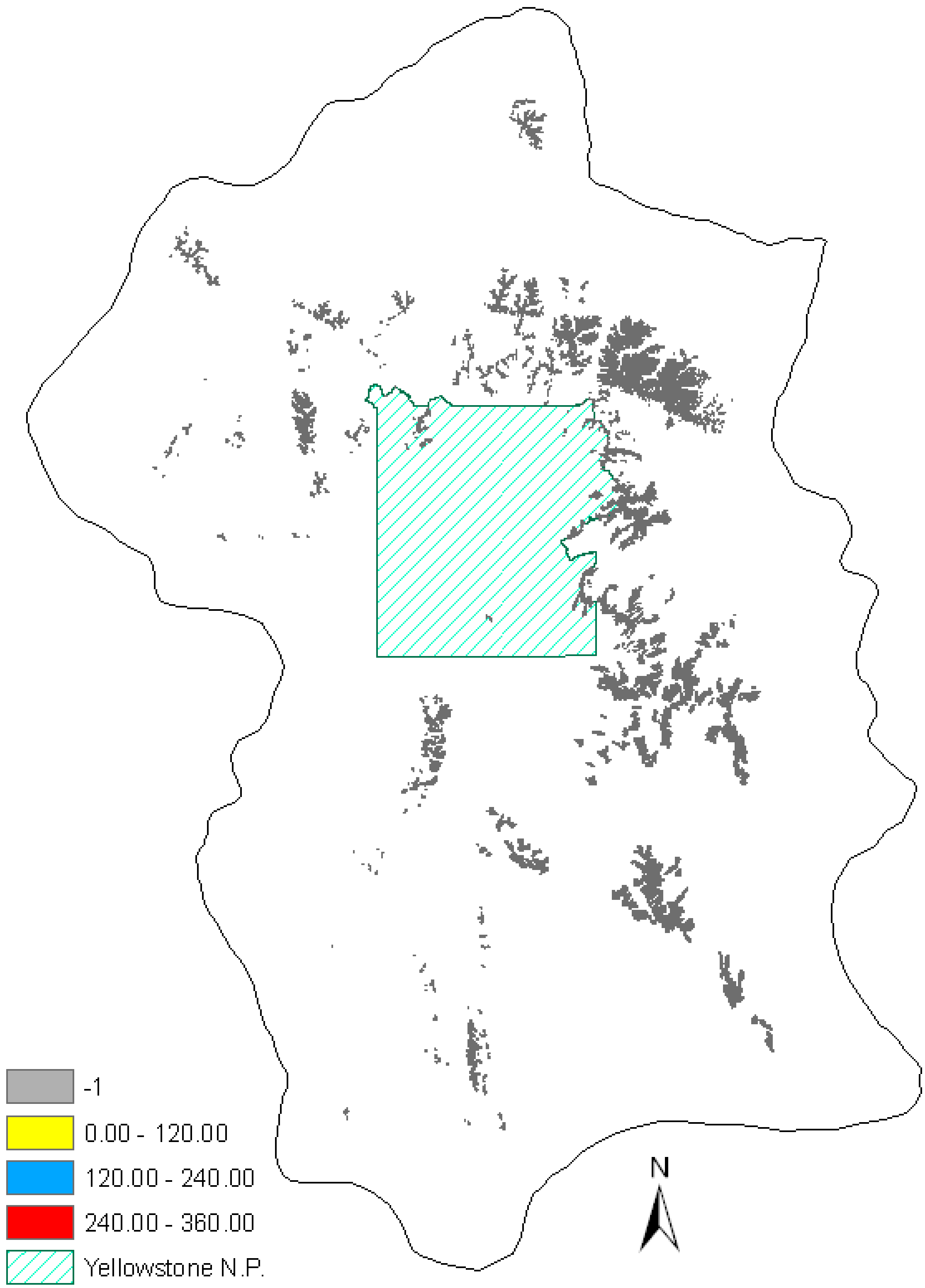



**Figure 21: TIN Aspect, showing the three aspect directions and no aspect surfaces**

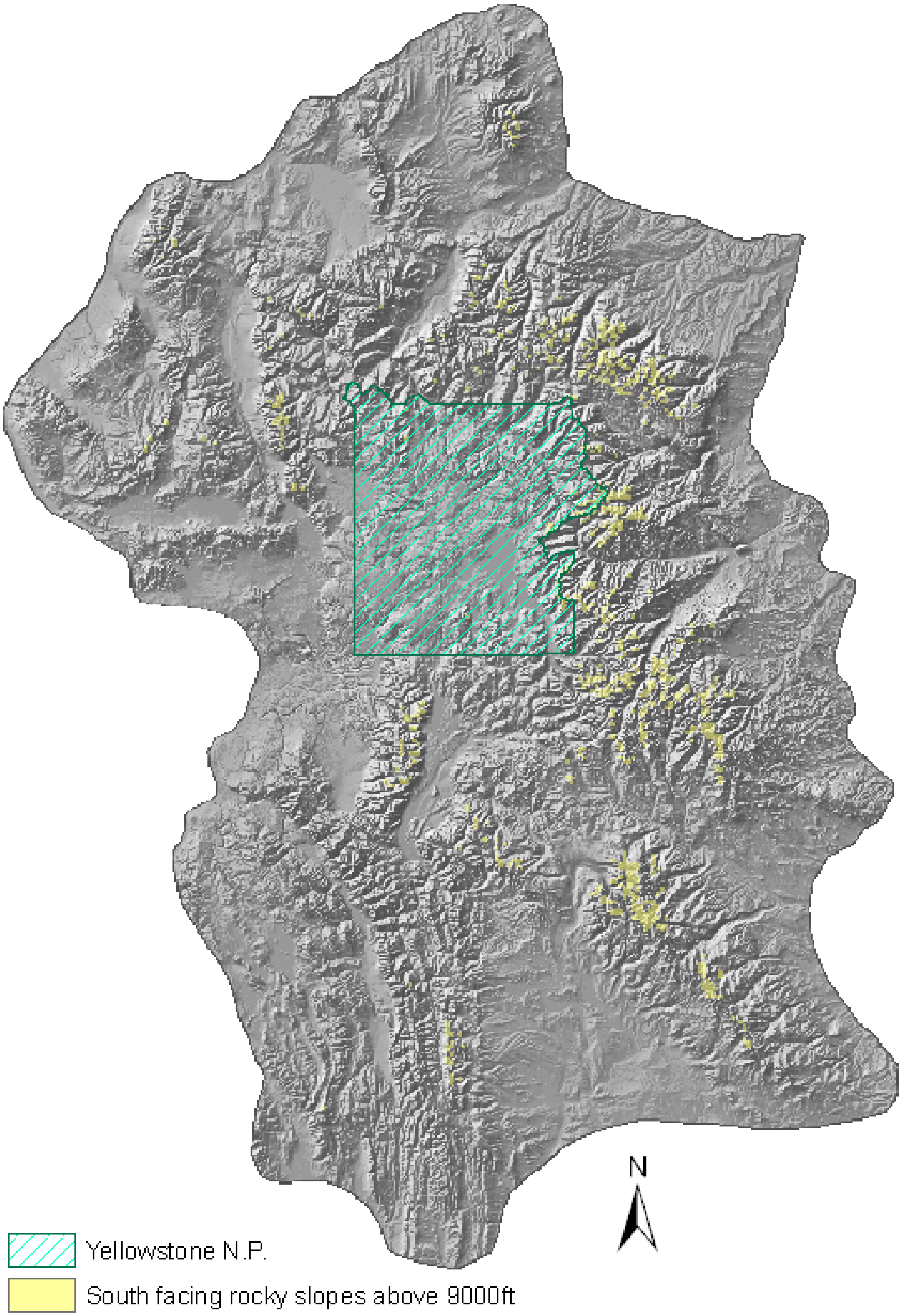



**Figure 22: Final raster displaying hypothetical areas ideal for the Army Cutworm moth**

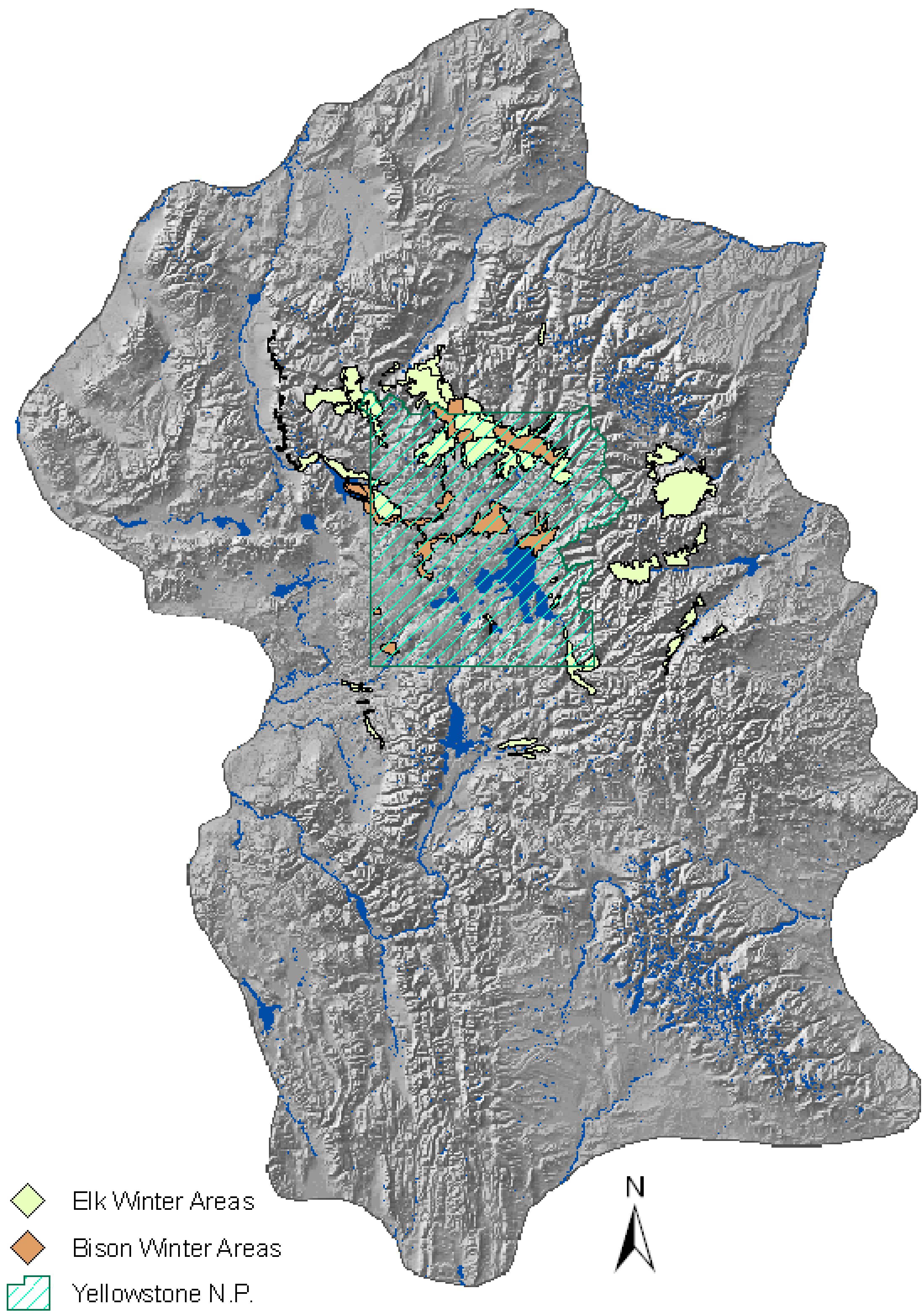



**Figure 23: GYA Bison and Elk wintering areas**

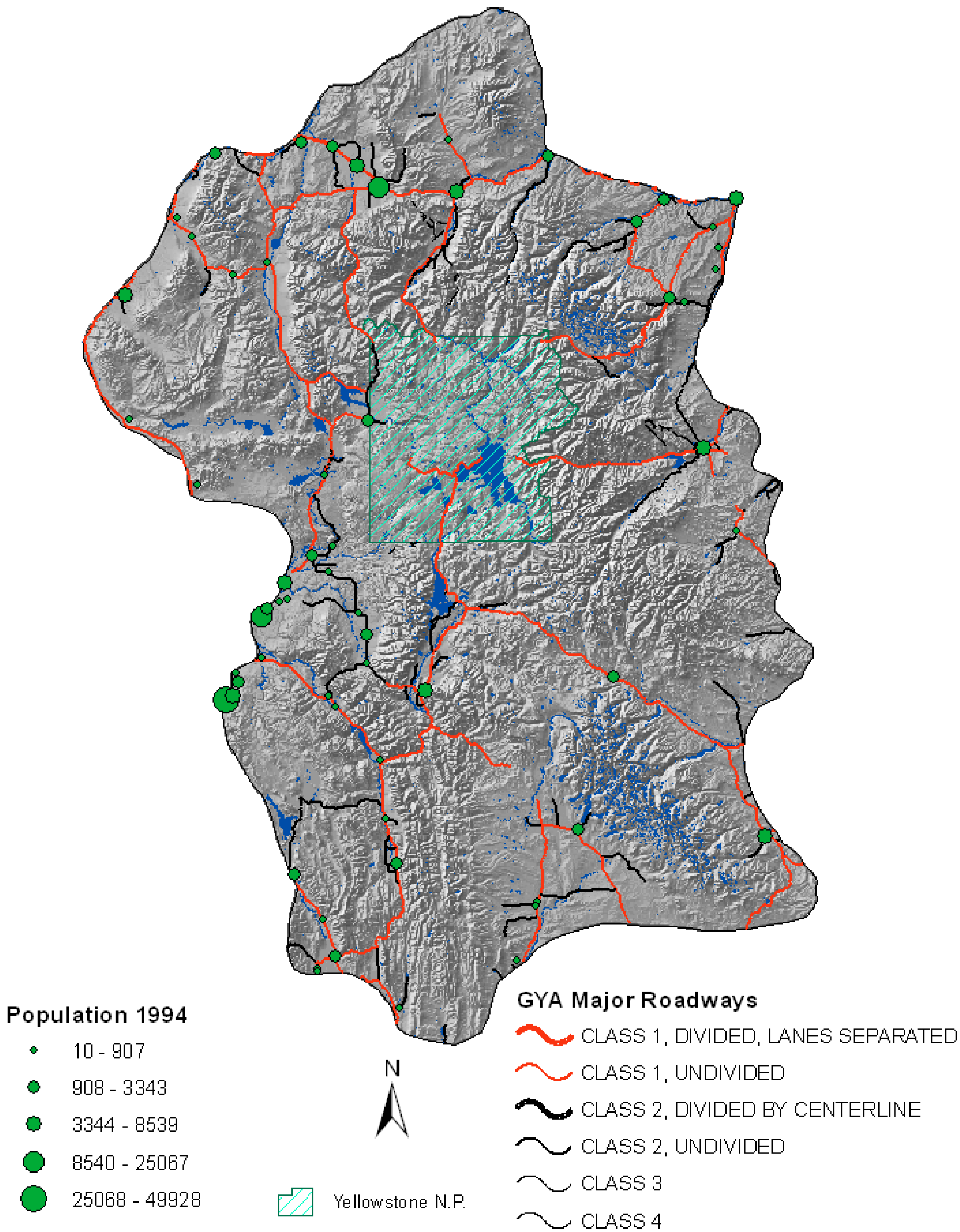



**Figure 24: GYA Roads and cities with 1994 populations**

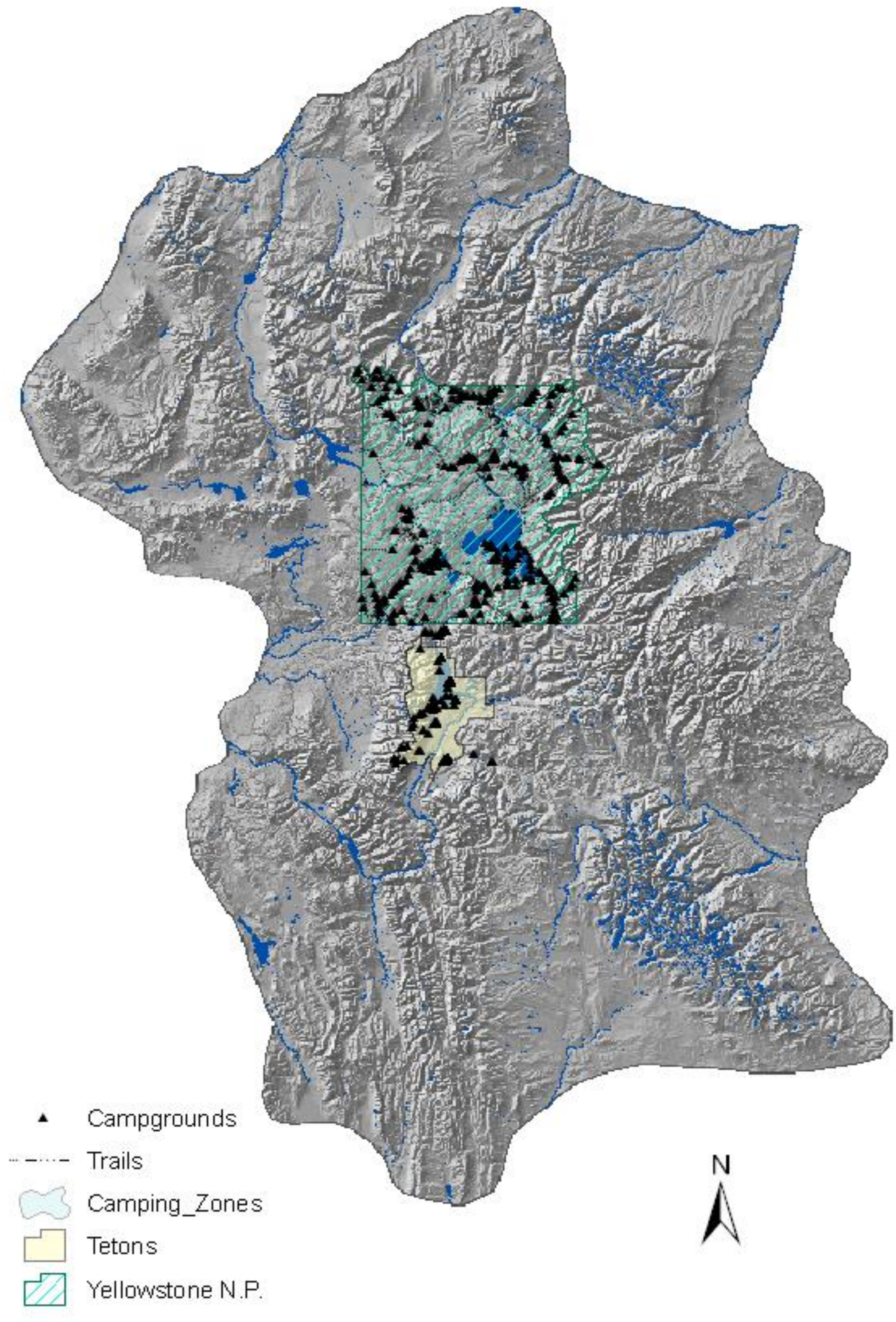



**Figure 25: Public camp sites and trails**

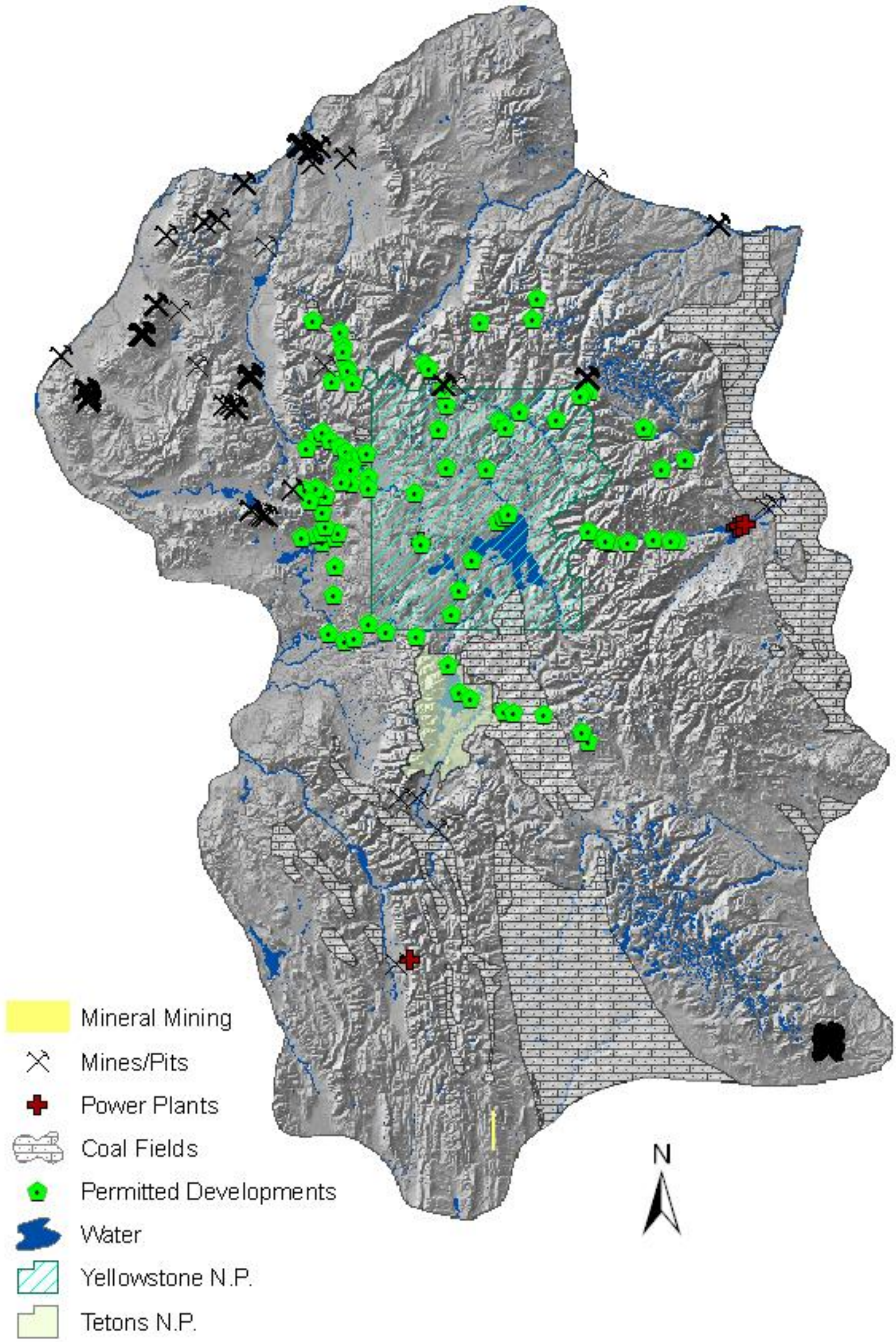



**Figure 26: Commercial land uses in the GYA**

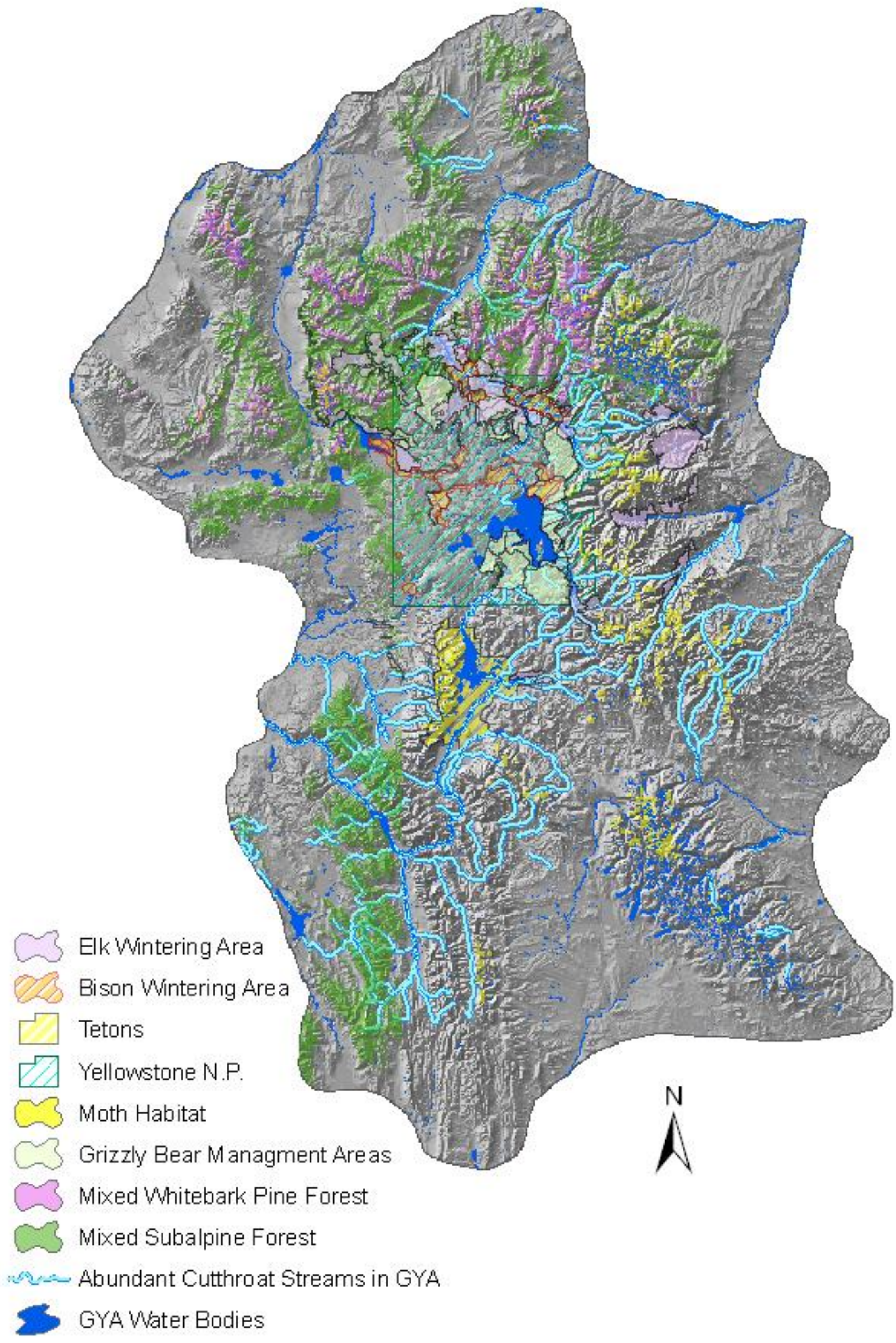



**Figure 27: Analysis of food sources**

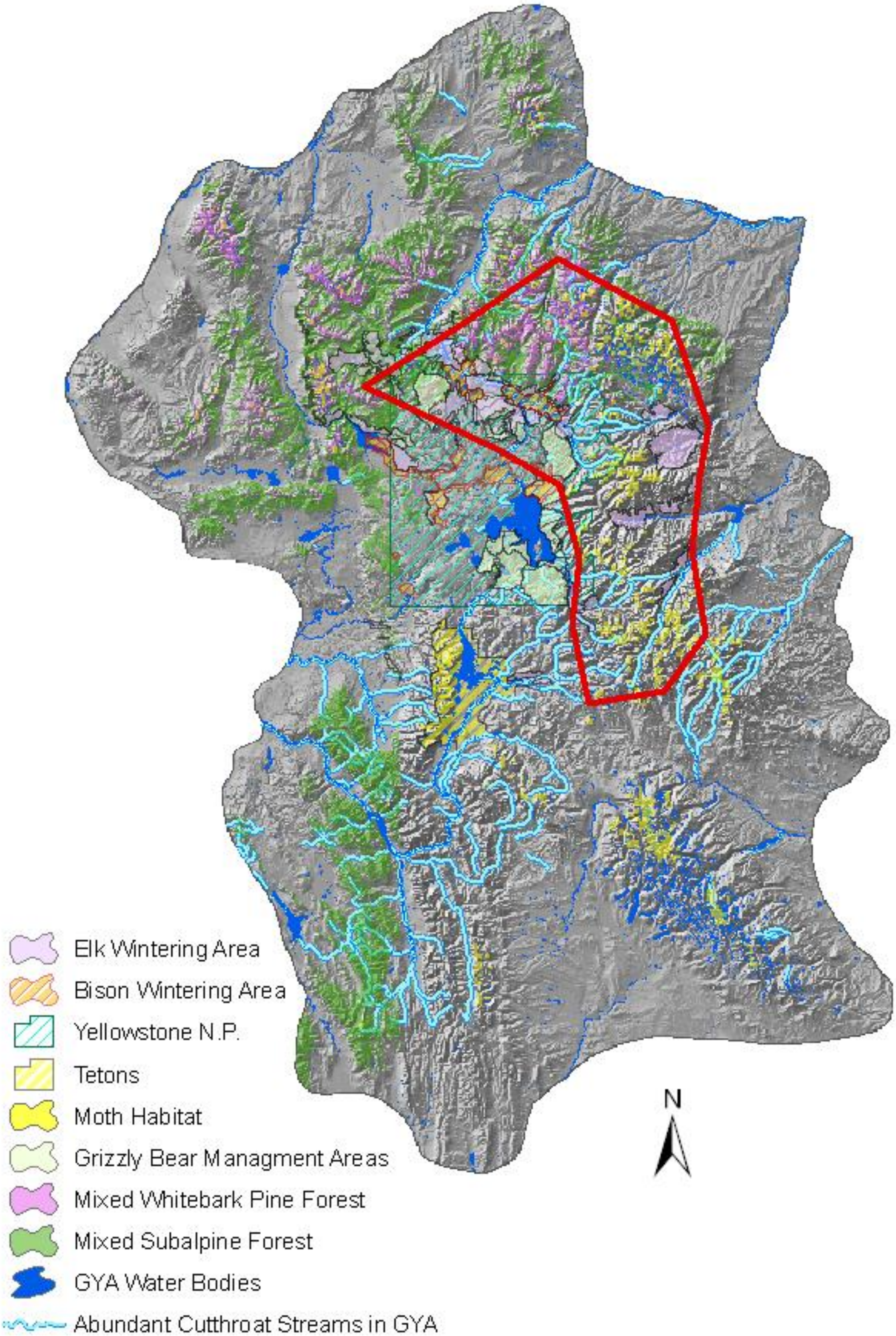



**Figure 28: First estimate of prime habitat**

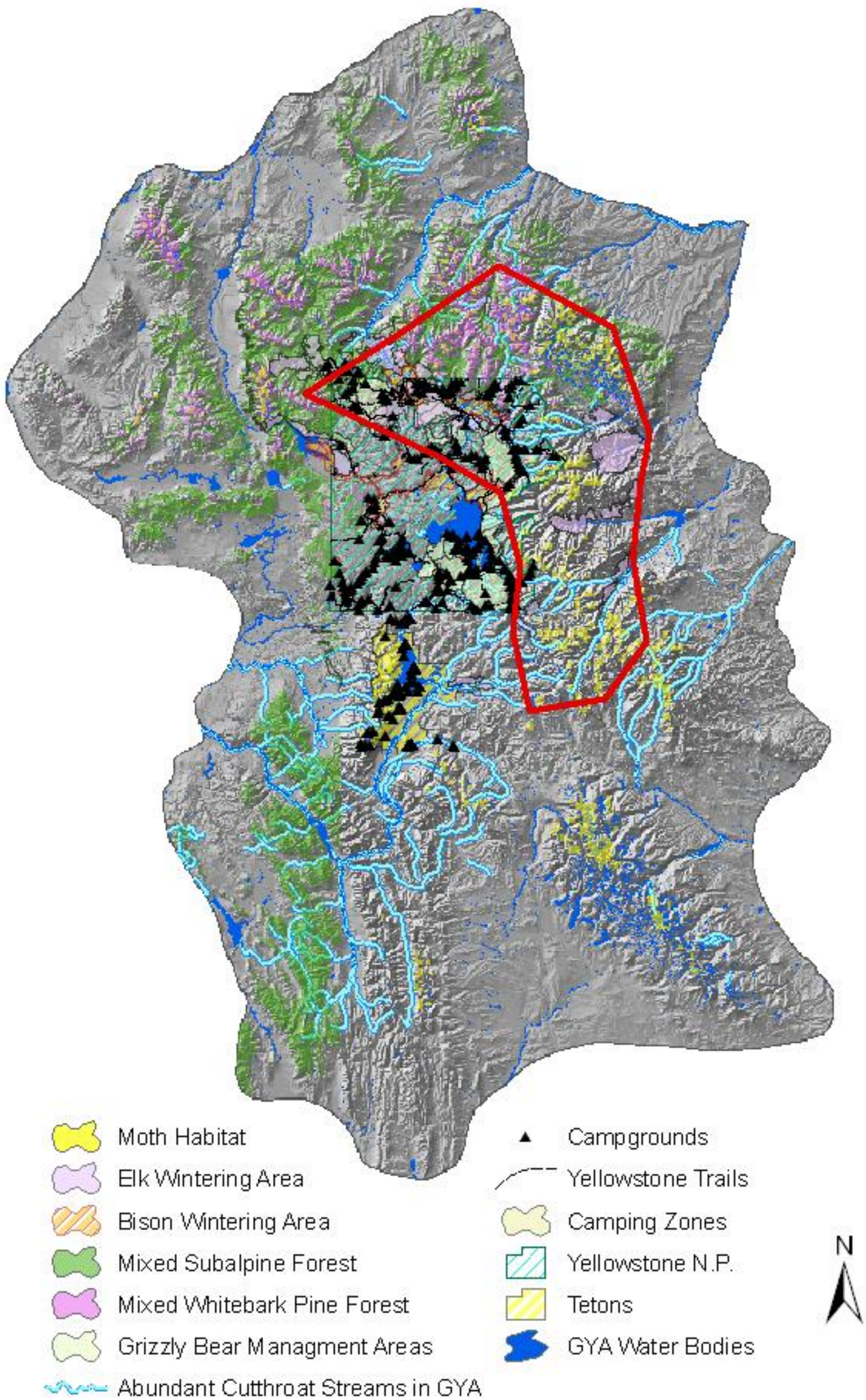



**Figure 29: Beginnings of encroachment**

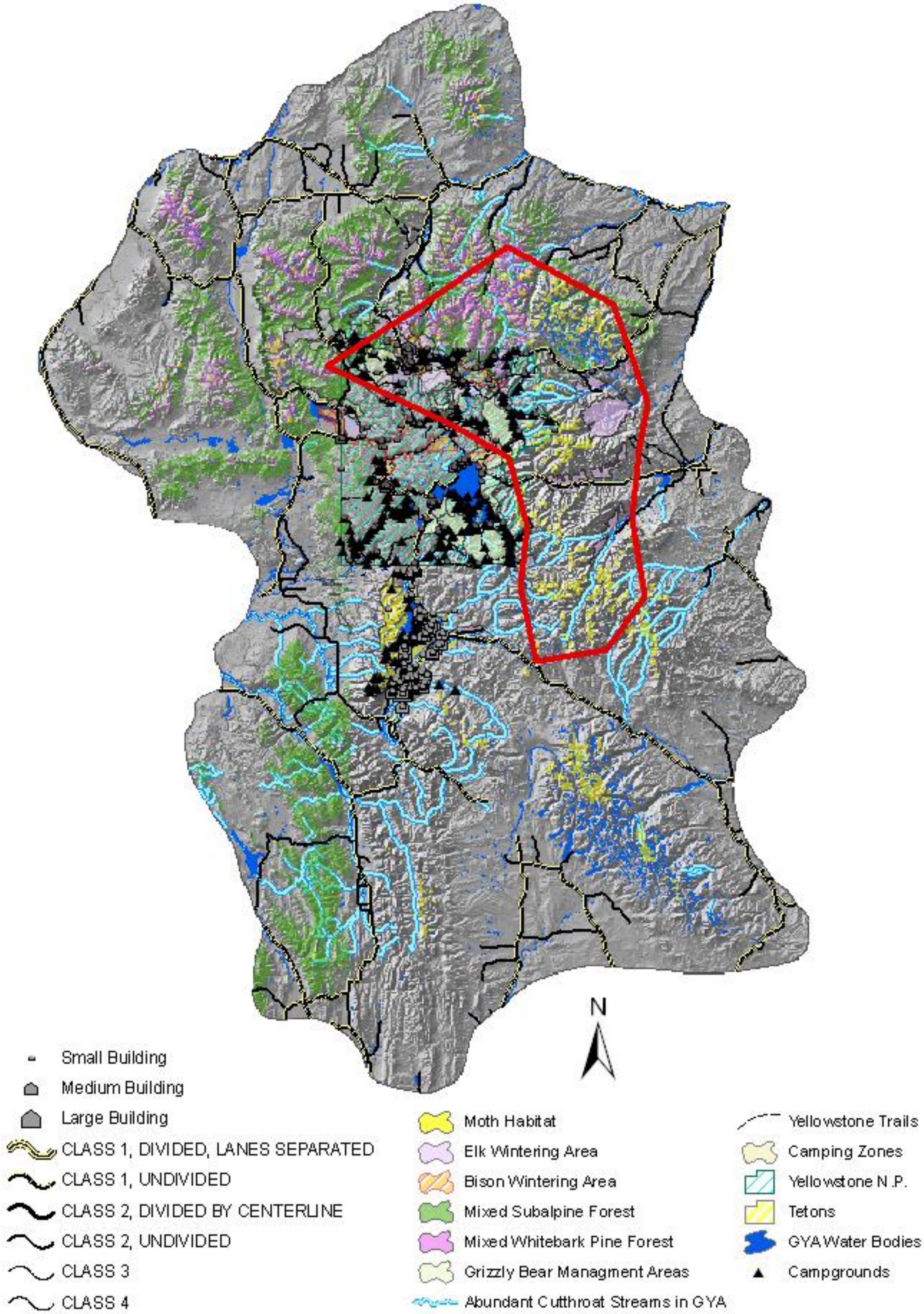



**Figure 30: Extensive habitat fragmentation**

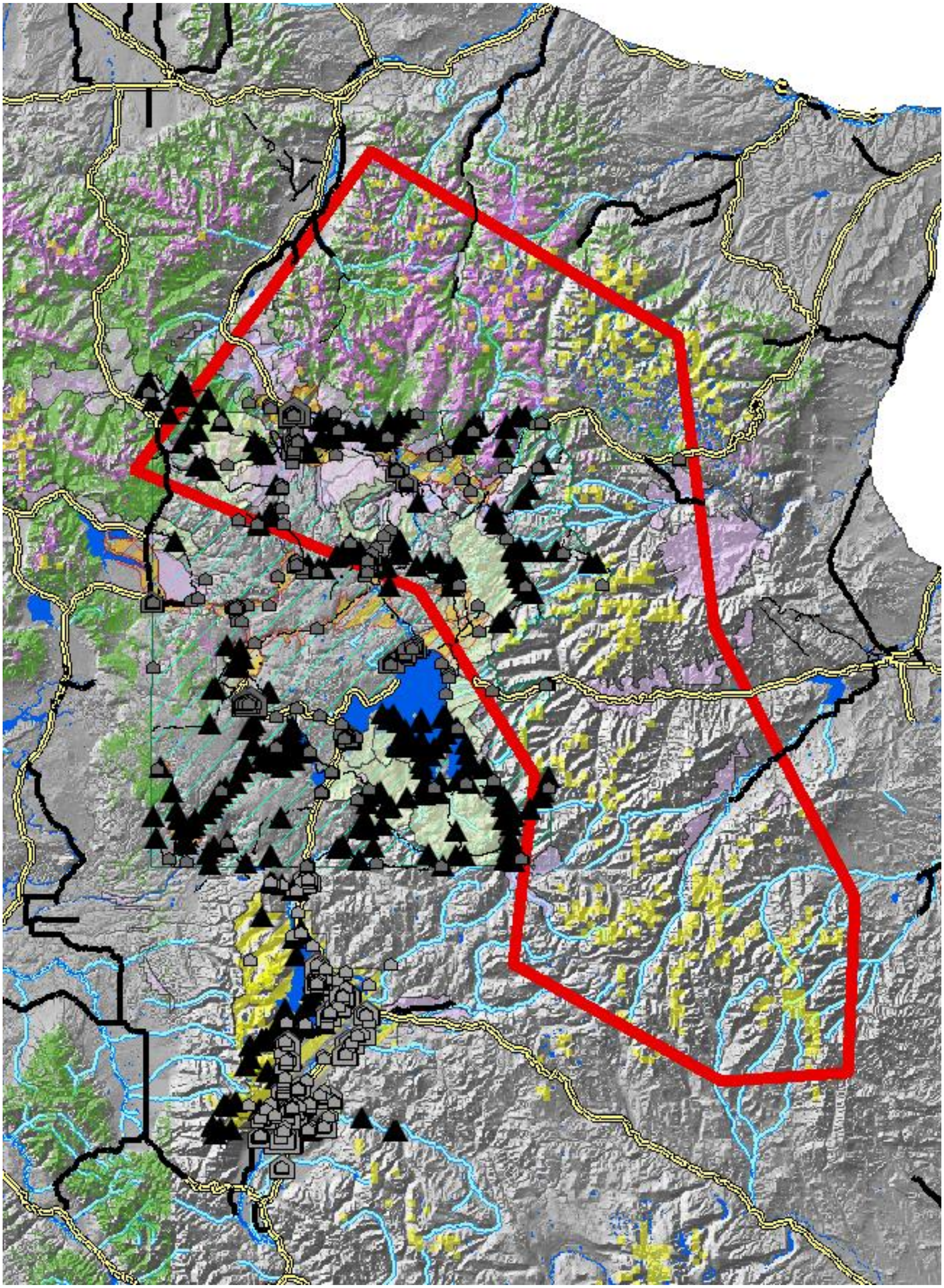


**Figure 31: A closer look at encroachment and fragmentation of prime habitat**

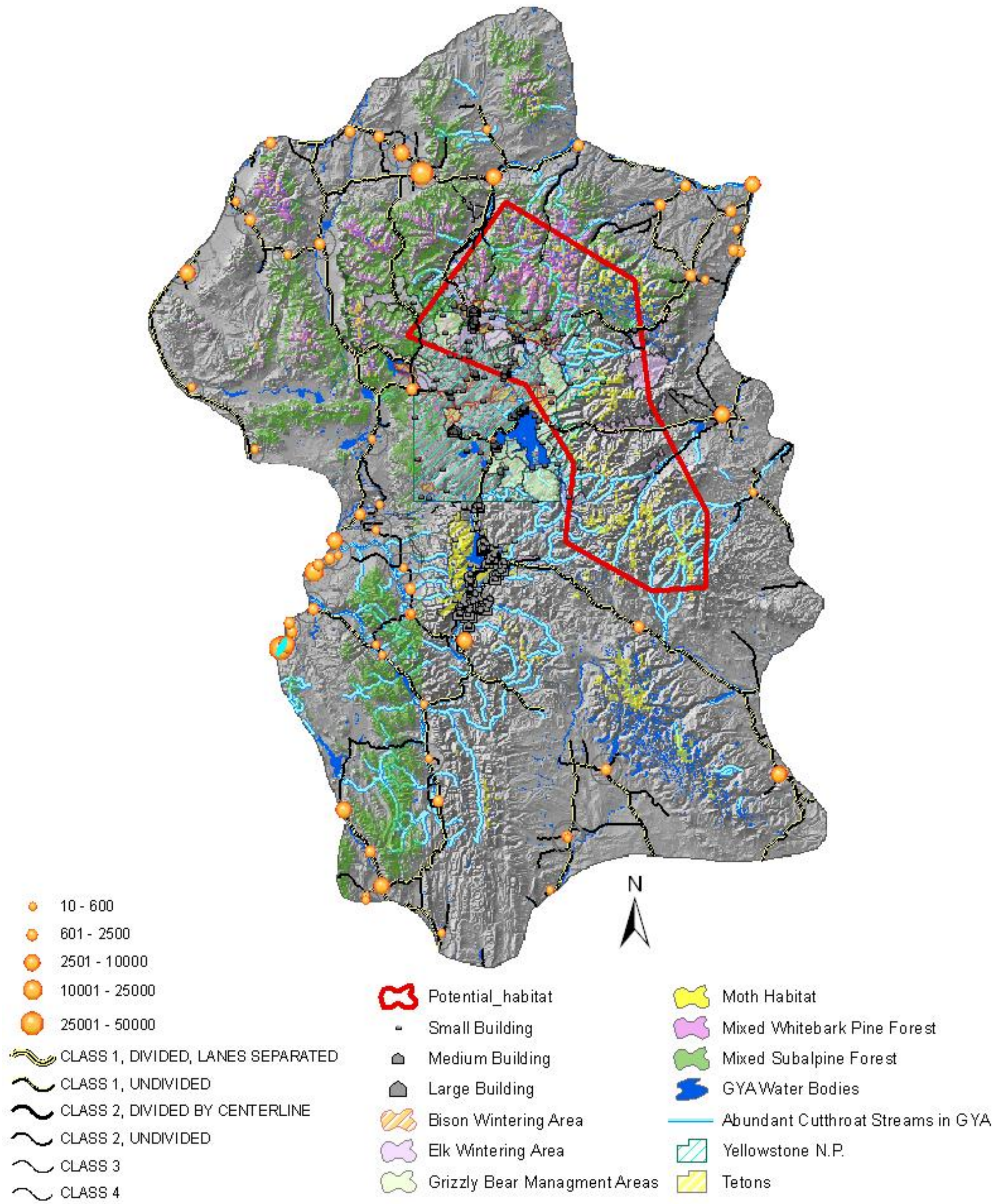



**Figure 32: Cities and populations**

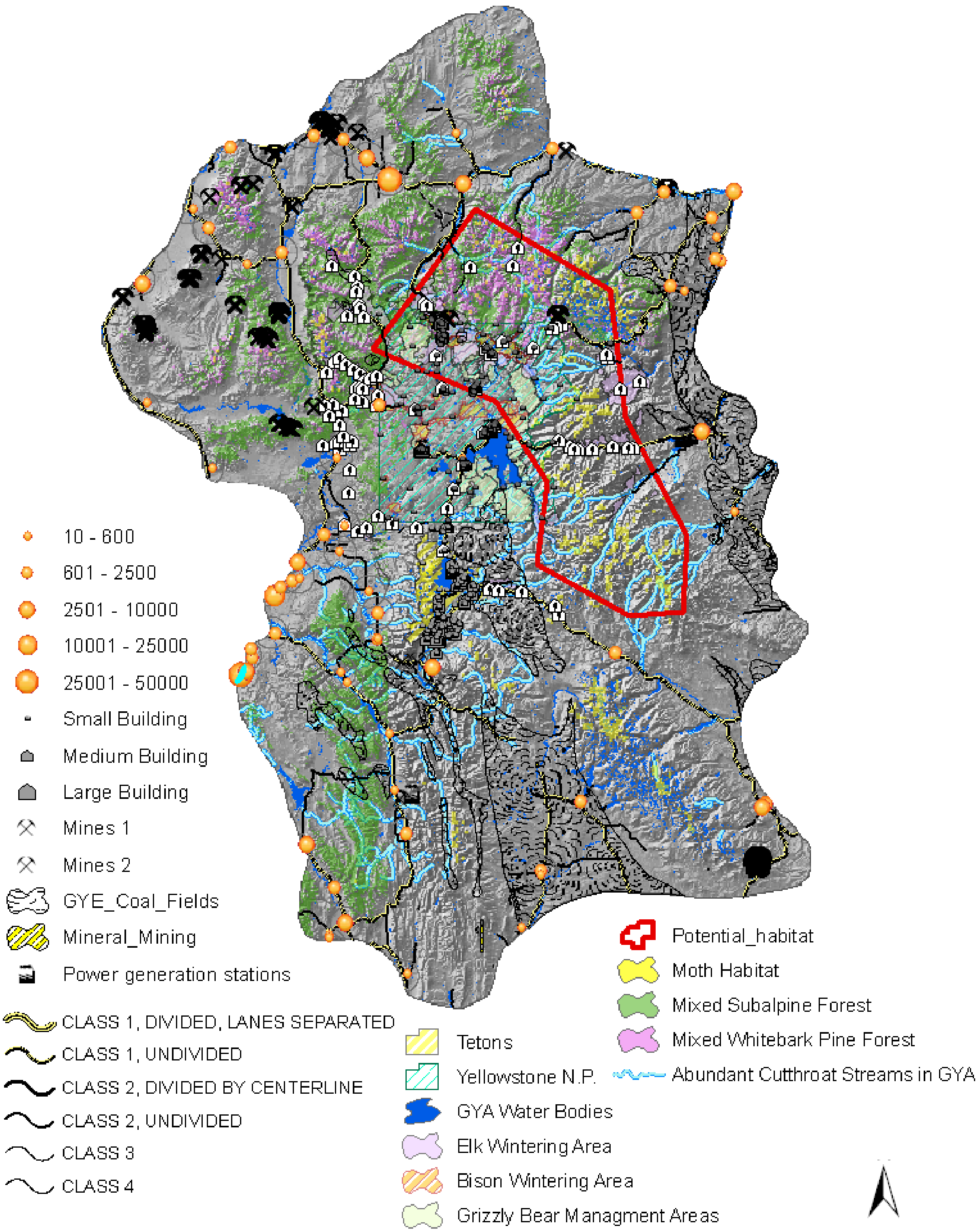



**Figure 33: Human effects vs. Grizzly Bear habitat**

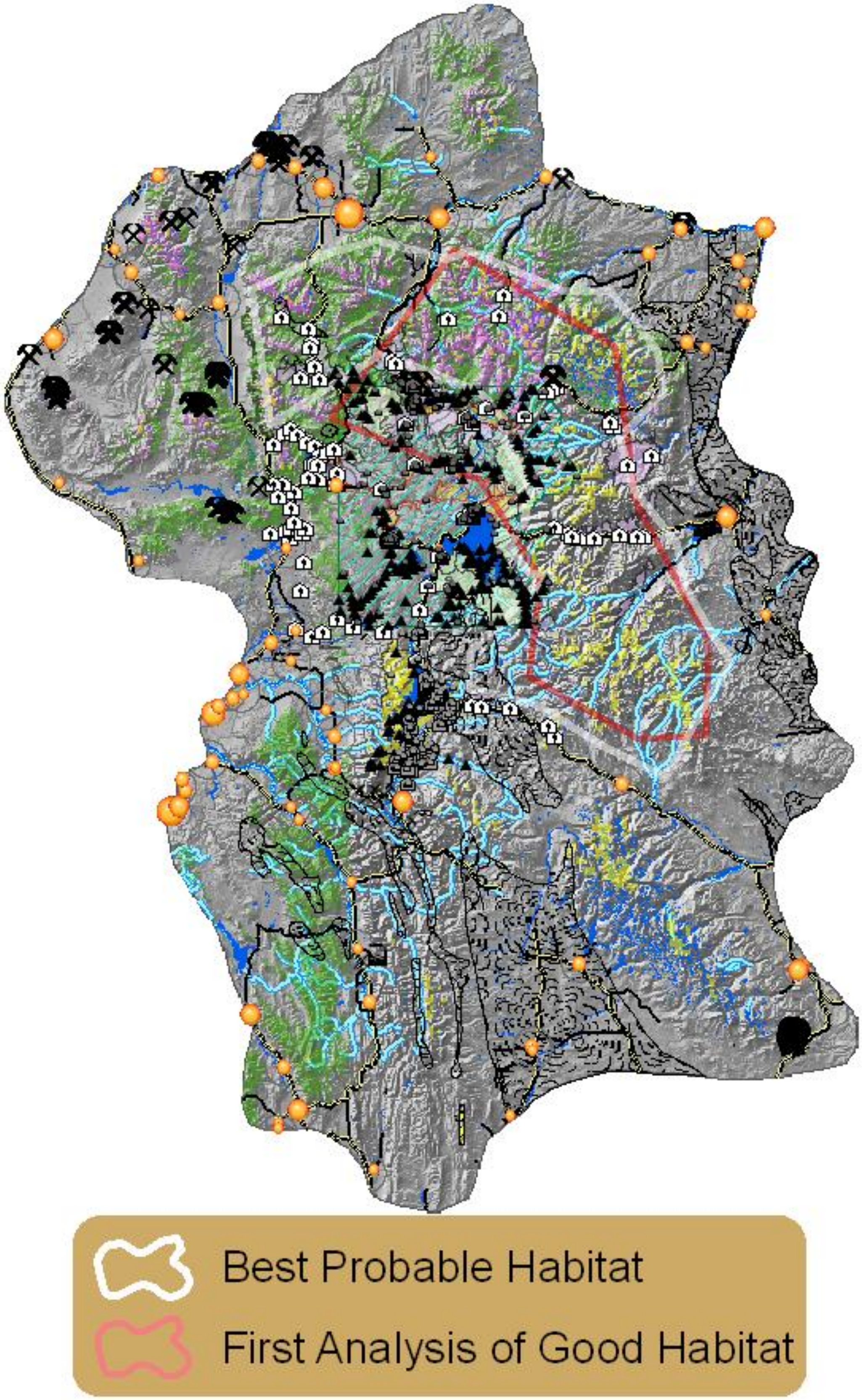



**Figure 34: Initial best habitat guess and final analysis**

# Appendix

## Figures

- Northwestern Great Plains - Black Hills Ponderosa Pine Woodland and Savanna
- California Coastal Closed-Cone Conifer Forest and Woodland
- California Coastal Redwood Forest
- California Lower Montane Blue Oak-Foothill Pine Woodland and Savanna
- California Mesic Serpentine Grassland
- California Montane Jefferey Pine Woodland
- California Montane Woodland and Chaparral
- California Northern Coastal Grassland
- California Xeric Serpentine Chaparral
- Columbia Basin Foothill and Canyon Dry Grassland
- Columbia Basin Foothill Riparian Woodland and Shrubland
- Columbia Basin Palouse Prairie
- Columbia Plateau Low Sagebrush Steppe
- Columbia Plateau Scabland Shrubland
- Columbia Plateau Silver Sagebrush Seasonally Flooded Shrub-Steppe
- Columbia Plateau Steppe and Grassland
- Columbia Plateau Vernal Pool
- Columbia Plateau Western Juniper Woodland and Savanna
- Coulmbia Plateau Ash and Tuff Badland
- CRP
- Cultivated Cropland
- Developed, High Intensity
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, Open Space
- East Cascades Mesic Montane Mixed-Conifer Forest and Woodland
- East Cascades Oak-Ponderosa Pine Forest and Woodland
- Geysers and Hotsprings

**Figure A: GAP Classifications**

- Klamath-Siskiyou Cliff and Outcrop
- Klamath-Siskiyou Lower Montane Serpentine Mixed Conifer Woodland
- Klamath-Siskiyou Upper Montane Serpentine Mixed Conifer Woodland
- Klamath-Siskiyou Xeromorphic Serpentine Savanna and Chaparral
- Mediterranean California Alpine Bedrock and Scree
- Mediterranean California Alpine Dry Tundra
- Mediterranean California Alpine Fell-Field
- Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland
- Mediterranean California Foothill and Lower Montane Riparian Woodland
- Mediterranean California Lower Montane Balck Oak-Conifer Forest and Woodland
- Mediterranean California Mesic Mixed Conifer Forest and Woodland
- Mediterranean California Mesic Serpentine Woodland and Chaparral
- Mediterranean California Mixed Evergreen Forest
- Mediterranean California Mixed Oak Woodland
- Mediterranean California Northern Coastal Dune
- Mediterranean California Red Fir Forest
- Mediterranean California Serpentine Barrens
- Mediterranean California Serpentine Fen
- Mediterranean California Serpentine Foothill and Lower Montane Riparian Woodland and Seep
- Mediterranean California Subalpine Meadow
- Mediterranean California Subalpine Woodland
- Mediterranean California Subalpine-Montane Fen
- Middle Rocky Mountain Montane Douglas-fir Forest and Woodland
- No Data
- Non-specific Disturbed
- North American Alpine Ice Field
- North American Arid West Emergent Marsh
- North Pacific Alpine and Subalpine Bedrock and Scree
- North Pacific Alpine and Subalpine Dry Grassland
- North Pacific Avalanche Chute Shrubland
- North Pacific Bog and Fen
- North Pacific Broadleaf Landslide Forest and Shrubland
- North Pacific Coastal Cliff and Bluff
- North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow
- North Pacific Dry Douglas-fir (Madrone) Forest
- North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest

North Pacific Hypermaritime Shrub and Herbaceous Headland
North Pacific Hypermaritime Sitka Spruce Forest
North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest
North Pacific Intertidal Freshwater Wetland
North Pacific Lowland Mixed Hardwood-Conifer Forest and Woodland
North Pacific Lowland Riparian Forest and Shrubland
North Pacific Maritime Coastal Sand Dune and Strand
North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
North Pacific Maritime Eelgrass Bed
North Pacific Maritime Mesic Subalpine Parkland
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
North Pacific Mesic Western Hemlock-Silver Fir Forest
North Pacific Montane Grassland
North Pacific Montane Massive Bedrock, Cliff and Talus
North Pacific Montane Riparian Woodland and Shrubland
North Pacific Montane Shrubland
North Pacific Mountain Hemlock Forest
North Pacific Oak Woodland
North Pacific Serpentine Barren
North Pacific Shrub Swamp
North Pacific Volcanic Rock and Cinder Land
North Pacific Wooded Volcanic Flowage
Northern and Central California Dry-Mesic Chaparral
Northern California Claypan Vernal Pool
Northern California Coastal Scrub
Northern California Mesic Subalpine Woodland
Northern Rock Mountain Avalanche Chute Shrubland
Northern Rocky Mountain Conifer Swamp
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
Northern Rocky Mountain Foothill Conifer Wooded Steppe
Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland
Northern Rocky Mountain Lower Montane, Foothill and Valley Grassland
Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
Northern Rocky Mountain Montane-Foothill Deciduous Shrubland
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna
Northern Rocky Mountain Subalpine Deciduous Shrubland
Northern Rocky Mountain Subalpine Woodland and Parkland

Northwestern Great Plains Floodplain
Northwestern Great Plains Mixedgrass Prairie
Northwestern Great Plains Riparian
Northwestern Great Plains Shrubland
Open Water
Pasture/Hay
Quarries, Mines and Gravel Pits
Recently burned forest
Recently burned grassland
Recently burned shrubland
Rocky Mountain Alpine Bedrock and Scree
Rocky Mountain Alpine Dwarf-Shrubland
Rocky Mountain Alpine Fell-Field
Rocky Mountain Alpine Tundra/Fell-field/Dwarf-shrub Map Unit
Rocky Mountain Alpine Turf
Rocky Mountain Alpine-Montane Wet Meadow
Rocky Mountain Aspen Forest and Woodland
Rocky Mountain Bigtooth Maple Ravine
Rocky Mountain Cliff, Canyon and Massive Bedrock
Rocky Mountain Foothill Limber Pine-Juniper Woodland
Rocky Mountain Lodgepole Pine Forest
Rocky Mountain Lower Montane Riparian Woodland and Shrubland
Rocky Mountain Lower Montane-Foothill Shrubland
Rocky Mountain Poor Site Lodgepole Pine Forest and Woodland
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland
Rocky Mountain Subalpine-Montane Limber-Bristlecone Pine Woodland
Rocky Mountain Subalpine-Montane Mesic Meadow
Rocky Mountain Subalpine-Montane Riparian Shrubland
Rocky Mountain Subalpine-Montane Riparian Woodland
Rocky Mountain Supalpine-Montane Fen
Ruderal Upland- Old Field
Sierra Nevada Cliff and Canyon
Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland
Sierran-Intermontane Desert Western White Pine-White Fir Woodland
Southern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest and Woodlanc
Southern Rocky Mountain Mesic Montane Mixed Conifer Forest and Woodland

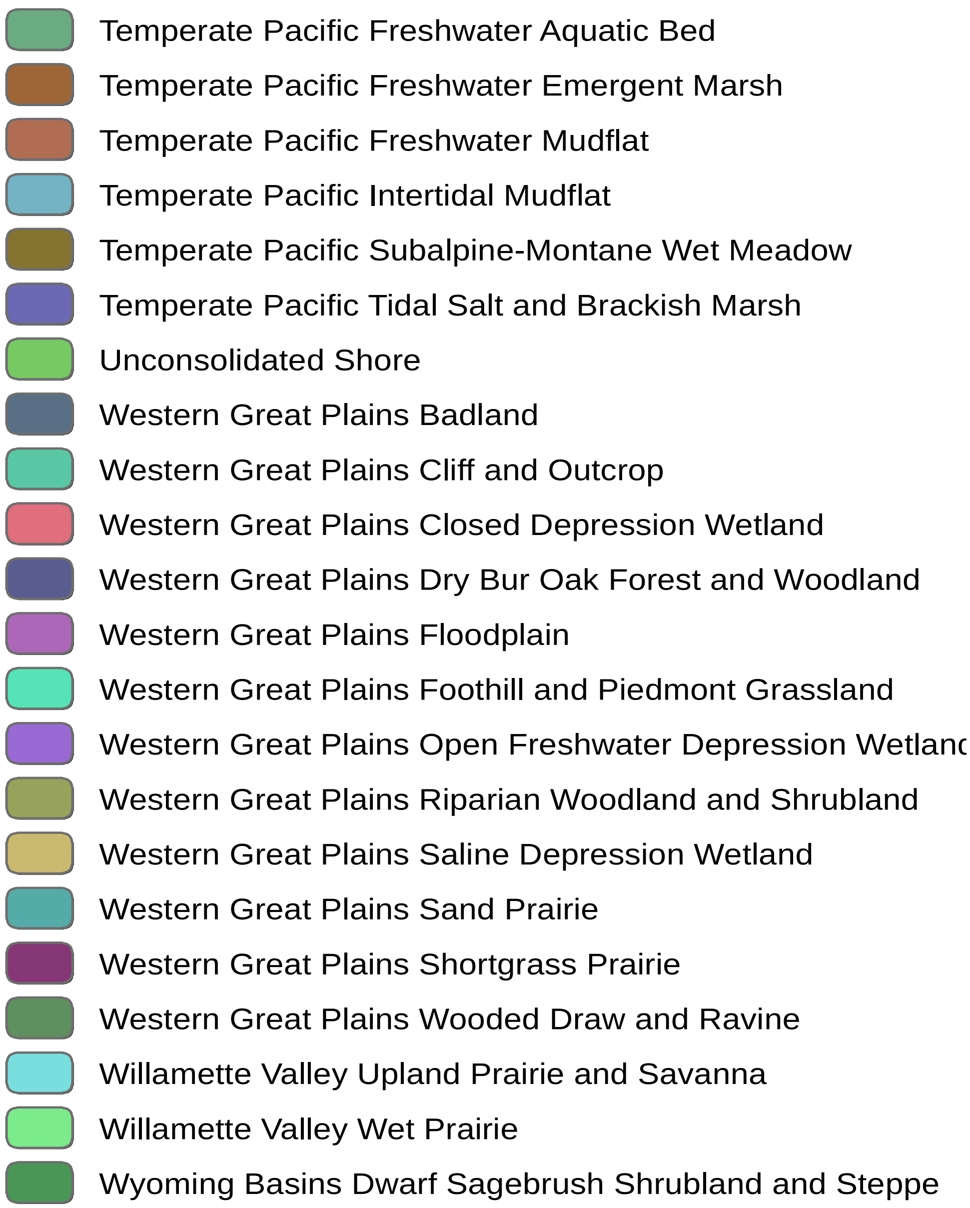



**Figure A: GAP Classifications**