Fen Mapping for the Rio Grande National Forest

Colorado Natural Heritage Program

April 2016

CNHP's mission is to preserve the natural diversity of life by contributing the essential scientific foundation that leads to lasting conservation of Colorado's biological wealth.

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EXECUTIVE SUMMARY

The Rio Grande National Forest (RGNF) covers nearly two million acres within the Rio Grande Headwaters River Basin in south central Colorado. The diverse geography of the RGNF created an equally diverse set of wetlands that provide important ecological services to both RGNF and lands downstream. Organic soil wetlands known as fens are an irreplaceable resource that the U.S. Forest Service has determined should be managed for conservation and restoration. Fens are defined as groundwater-fed wetlands with organic soils that typically support sedges and low stature shrubs. In the arid west, organic soil formation can take thousands of years. Long-term maintenance of fens requires maintenance of both the hydrology and the plant communities that enable fen formation.

In 2012, the U.S. Forest Service released a new planning rule to guide all National Forests through the process of updating their Land Management Plans (also known as Forest Plans). The RGNF is the first National Forest in Colorado to revise its Forest Plan under the current guiding policy. A component of the new planning rule is that each National Forest must conduct an assessment of important biological resources within its boundaries. Through the biological assessment, biologists at the RGNF identified a need to better understand the distribution and extent of fen wetlands under their management. To this end, U.S. Forest Service contracted Colorado State University and the Colorado Natural Heritage Program (CNHP) to map all potential fens within the RGNF.

Potential fens in the RGNF were identified from digital aerial photography and topographic maps. Each potential fen polygon was hand-drawn in ArcGIS based on the best estimation of fen boundaries and attributed with a confidence value of 1 (low confidence), 3 (possible fen) or 5 (likely fen). The final map contained 6,408 potential fen locations (all confidence levels), covering 16,644 acres or 0.85% of the total land area. This total included 2,532 ***likely fens***, 2,374 ***possible fens***, and 1,502 ***low confidence fens.*** The average fen polygon was just 2.60 acres, but the largest polygon was over 200 acres.

Fen distribution was analyzed by elevation, bedrock geology, ecoregion, and watershed. The vast majority of mapped potential fens occurred between 10,000 to 12,000 feet, spanning both the upper subalpine and lower alpine zones. This elevation range contained 80% of all potential fen locations and 89% of likely fen locations. Three watersheds in particular have very high numbers of likely fens. Elk Creek had 170 likely fens, Headwaters of Alamosa River had 157 likely fens, and Ute Creek had 142 likely fens. All of the watersheds with more than 50 likely fens were on the western border of the Rio Grande National Forest, in the highest elevation regions.

The Rio Grande National Forest contains a rich resource of fen wetlands. This report and associated dataset provide the RGNF with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing RGNF biological assessment required by the 2012 Forest Planning Rule, but can also be used for individual management actions, such as planning for timber sales, grazing allotments, and trail maintenance. Wherever possible, the Forest should avoid direct disturbance to the fens mapped through this project, and should also strive to protect the watersheds surrounding high concentrations of fens, thereby protecting their water sources.

Acknowledgments

The authors at Colorado Natural Heritage Program (CNHP) would like to acknowledge the U.S. Forest Service for their financial support of this project. Special thanks goes to Randy Ghormley, Wildlife, Fisheries & Rare Plant Program Manager for the Rio Grande National Forest, for recognizing the importance of fen wetlands within the Rio Grande National Forest. Thanks also to U.S. Forest Service Region 2 Botanist, Tyler Johnson, for supporting this project.

Thanks to Jacob Mohrmann with Colorado Mountain College for sharing the location of known fens sites he and others at CMC have visited on the RGNF. Those data were very helpful in refining our search image for fens in Saguache County.

We also thank colleagues at CNHP who have worked on previous projects mapping and surveying fen wetlands in the field, specifically Erick Carlson, Denise Culver, Laurie Gilligan, Peggy Lyon, and Dee Malone. Thanks to Lexine Long, CNHP Wetland Ecologist, for conducting a random review of mapped fens for consistency in our application of confidence ratings. Special thanks David Cooper, Rod Chimner, and Brad Johnson, each of whom has shared with us their great knowledge of fens over the years.

Finally, we would like to thank Mary Olivas and Carmen Morales with Colorado State University for logistical support and grant administration.

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1.0 INTRODUCTION

The Rio Grande National Forest (RGNF) covers nearly two million acres within the Rio Grande Headwaters River Basin in south central Colorado and spans a broad elevation range from 7,536 to 14,332 ft. The diverse geography of the RGNF creates a template for an equally diverse set of wetlands. Heavy snowfall in the mountains percolates through shallow mountain soils and creates extensive areas of wet meadows, riparian shrublands, and organic soil wetlands known as fens. These wetland habitats provide important ecological services to both RGNF and lands downstream (Mitsch & Gosselink 2007; Millennium Ecosystem Assessment 2005). Wetlands act as natural filters, helping to protect water quality by retaining sediments and removing excess. Wetlands help to regulate local and regional hydrology by stabilizing base flow, attenuating floods, and replenishing belowground aquifers. Wetlands also support habitat for numerous plant and animals species that depend on aquatic habitats for some portion of their life cycle (Redelfs 1980 as cited in McKinstry et al. 2004).

Organic soil wetlands known as fens are an irreplaceable resource. The Rocky Mountain Region (R2) of the U.S. Forest Service considers fens a sensitive plant habitat that should be managed for conservation and restoration (USFS 2011). Fens are defined as groundwater-fed wetlands with organic soils that typically support sedges and low stature shrubs (Mitch & Gosselink 2007). The strict definition of an organic soil (peat) is one with 40 cm (16 in) or more of organic soil material in the upper 80 cm (31 in) of the soil profile (Soil Survey Staff 2014). Accumulation of organic material to this depth requires constant soil saturation and cold temperatures, which create anaerobic conditions that slow the decomposition of organic matter. By storing organic matter deep in their soils, fens act as a carbon sink. In the arid west, peat accumulation occurs very slowly; estimates are 20 cm (8 in) per 1,000 years in Colorado (Chimner 2000; Chimner and Cooper 2002). Long-term maintenance of fens requires maintenance of both the hydrology and the plant communities that enable fen formation.

In 2012, the U.S Forest Service released a new planning rule that will guide all National Forests through the process of updating their Land Management Plans (also known as Forest Plans).[1] The RGNF is the first National Forest in Colorado to revise its Forest Plan under the current guiding policy. A component of the new planning rule is that each National Forest must conduct an assessment of important biological resources within its boundaries. Through the process of conducting the biological assessment, biologists at the RGNF identified a need to better understand the distribution and extent of fen wetlands under their management. To this end, U.S. Forest Service contracted Colorado State University and the Colorado Natural Heritage Program (CNHP) to map all potential fens within the RGNF. This project builds upon CNHP's previous projects mapping fens on the White River National Forest (Malone et al. 2011) and assessing the general condition of wetlands across the RGNF (Lemly 2012).

[1] For more information on the 2012 Forest Planning Rule, visit the following website: http://www.fs.usda.gov/main/planningrule/home.

2.0 Study Area

2.1 Geography

The fen mapping study area was the entire Rio Grande National Forest (RGNF), located within the Rio Grande Headwaters River Basin (HUC 6: 130100) in south central Colorado, on the north side of the Colorado/New Mexico border (Figure 1). The Forest is located on the eastern flank of the Continental Divide, which forms the Forest's western border. Much of the RGNF is located in the high San Juan Mountains, which contain the headwaters of the Rio Grande River. However, the RGNF extends beyond the mountain peaks into the foothill zone above the San Luis Valley. In addition to the San Juan Mountains, the RGNF also includes the long thin line of the Sangre de Cristo Mountains to the east, which rise abruptly from the valley below. Elevation in the study area ranges from 7,536 ft. (2,297 m) to 14,337 ft. (4,370 m) and the mean elevation is 10,436 ft. (3,181 m). The floodplains of the major rivers are the lowest elevation areas.

Two major rivers flow through the RGNF study area: the Rio Grande and the Conejos Rivers, along with numerous tributaries (Figure 2). The Rio Grande River starts at the farthest western edge of the study area and is joined by the South Fork as it spills out from the Forest onto the San Luis Valley. The Conejos River flows out of the southern portion of the study area and joins the Rio Grande beyond the Forest's border.

The RGNF includes portions of Hindsdale, Mineral, Saguache, Rio Grande and Conejos counties, as well as the eastern edge of Alamosa County. The only sizeable municipalities surrounded by the study area are Creede and South Fork. Bonanza in the north, Del Norte to the west, and Crestone in the east all sit just outside of the study area. Larger towns of the San Luis Valley, such as Monte Vista and Alamosa, are located on the valley floor beyond the Forest (Figure 1).

2.2 Ecoregions

The mapping study area falls within two Omernik Level III Ecoregions (Figure 3). The majority of the Forest is located within the Southern Rockies Level III Ecoregion. Only a sliver of the Forest includes the Arizona/New Mexico Plateau Level III Ecoregion (Omernik 1987[2]).

Level IV Ecoregions further divide the landscape into finer units based on vegetation, topography and geology (Figure 3; Table 1). The majority (56%) of the study area falls within the 21g Volcanic Subalpine Forest Level 4 ecoregion. The next most common ecoregions are the 21a Alpine Zone (18% of study area) and 21h Volcanic Mid-Elevation Forests (11% of the study area).

[2] For more information on Omernik/EPA Ecoregions and to download GIS shapefiles, visit the following website: https://archive.epa.gov/wed/ecoregions/web/html/level_iii_iv-2.html.

2.3 Geology

The most common type of geology in the fen mapping study area is metamorphic or igneous bedrock (of either mafic or silicic composition), which together cover 80% of the study area (Figure 4). The next most common geology is quaternary alluvium along the floodplains of major rivers and streams (10% of study area). Sandstone (9% of study area) is found in the southern study area and in part of the Sangre de Cristo Mountains.

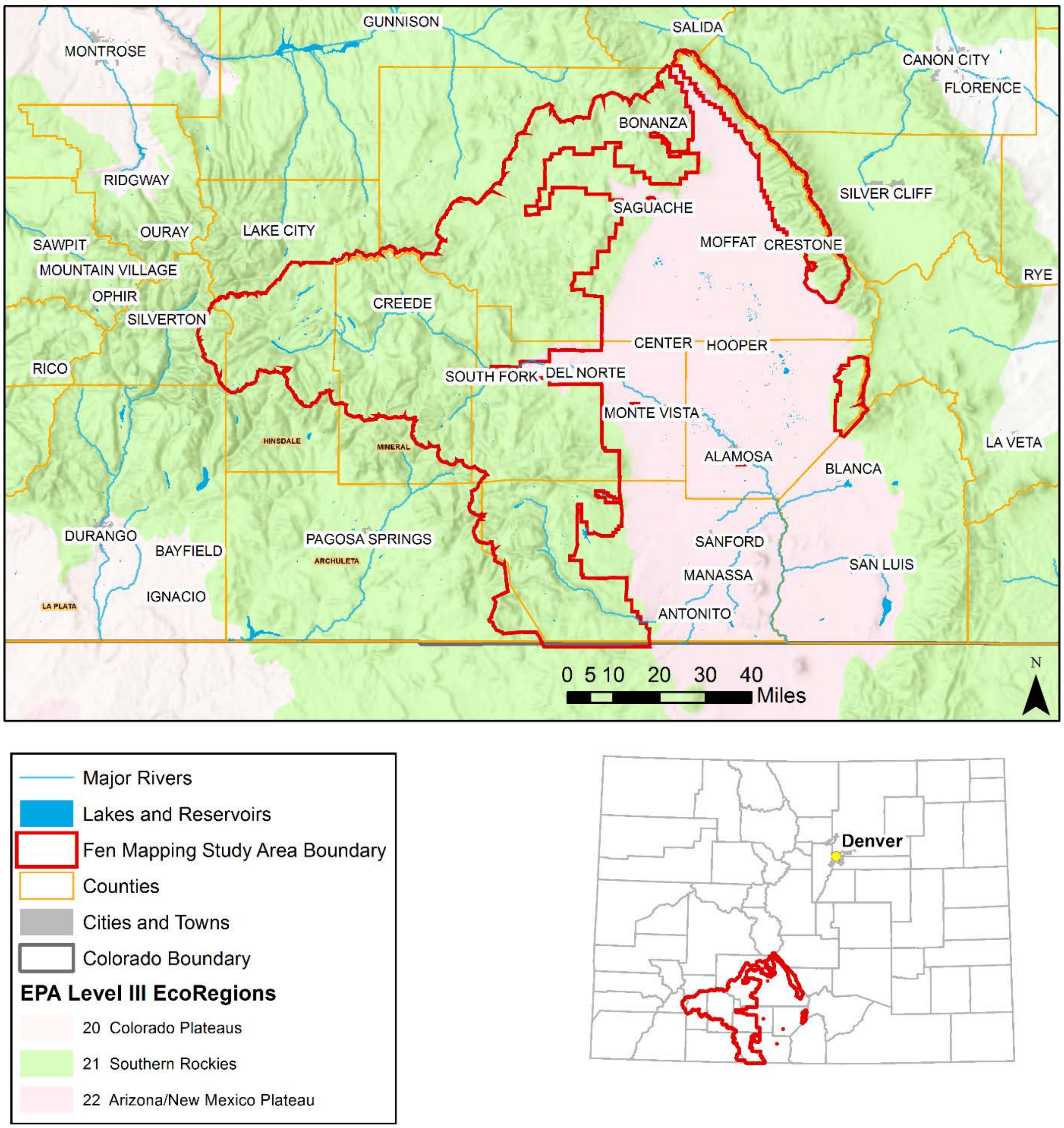

Figure 1. Location of the Rio Grande National Forest (fen mapping study area) within the state of Colorado.

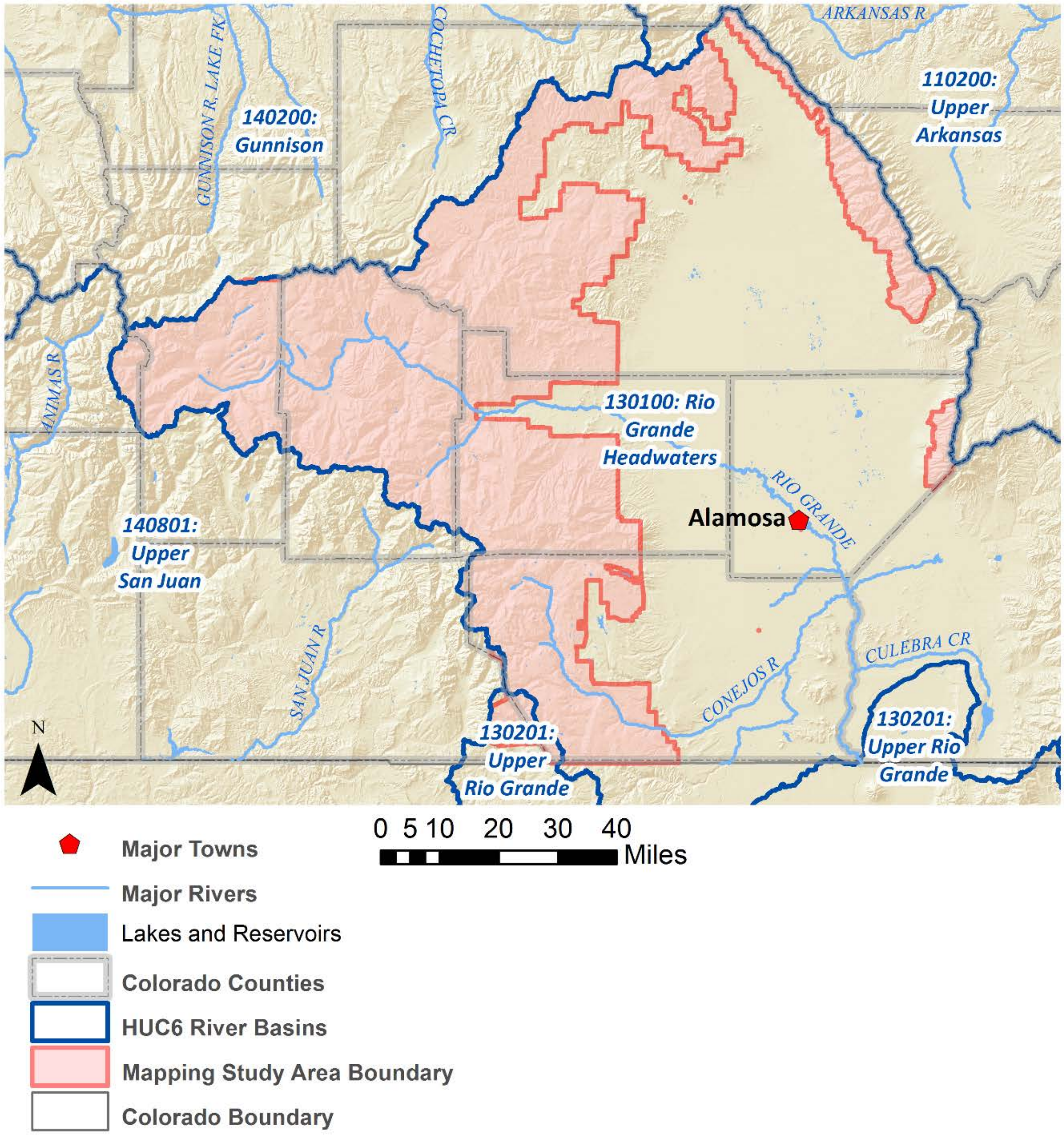

Figure 2. HUC6 river basins, major waterways, and counties in the fen mapping study area.

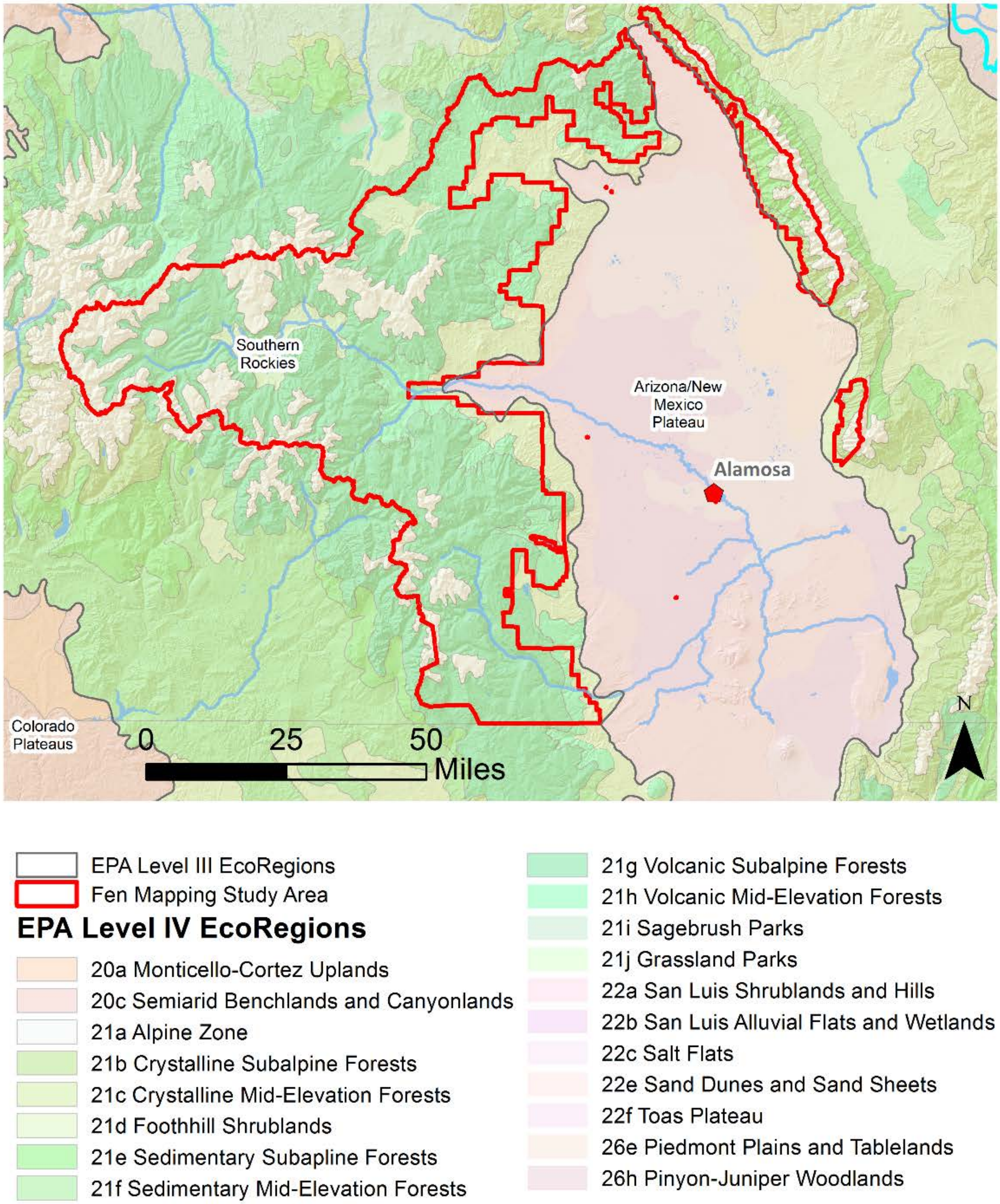

Figure 3. Level III and IV Ecoregions of the fen mapping study area.

Table 1. Descriptions of Level IV Ecoregions within the fen mapping study area.

NAME	***DESCRIPTION***
21a: Alpine Zone	The **Alpine Zone** occurs on mountain tops above treeline, beginning at about 10,500 to 11,000 feet. It includes alpine meadows as well as steep, exposed rock and glaciated peaks. Annual precipitation ranges from about 35 to greater than 70 inches, falling mostly as snow. Vegetation includes low shrubs, cushion plants, and wildflowers and sedges in wet meadows. The forest-tundra interface is sparsely colonized by stunted, deformed Englemann spruce, subalpine fir, and limber pine (krummholz vegetation). Rocky Mountain bristlecone pines are also found here, some of the oldest recorded trees in North America. Land use, limited by difficult access, is mostly wildlife habitat and recreation. Ecoregion 21a is snow-free only 8 to 10 weeks annually. Snow cover is a major source of water for lower, more arid ecoregions.
21b: Crystalline Subalpine Forests	The **Crystalline Subalpine Forests** ecoregion occupies a narrow elevational band on the steep, forested slopes of the mountains, becoming more extensive on the north-facing slopes. The elevation range of the region is 8,500 to 12,000 feet, just below the Alpine Zone (21a). The lower elevation limit is higher in the south, starting at 9,000 to 9,500 feet. The dense forests are dominated by Englemann spruce and subalpine fir; aspen and pockets of lodgepole pine locally dominate some areas. Subalpine meadows also occur. Forest blowdown, insect outbreaks, fire, and avalanches affect the vegetation mosaic. Soils are weathered from a variety of crystalline and metamorphic materials, such as gneiss, schist, and granite, as well as some areas of igneous intrusive rocks. Recreation, logging, mining, and wildlife habitat are the major land uses. Grazing is limited by climatic conditions, lack of forage, and lingering snowpack.
21c: Crystalline Mid-Elevation Forests	The **Crystalline Mid-Elevation Forests** are found mostly in the 7,000 to 9,000 feet elevation range on crystalline and metamorphic substrates. Most of the region occurs in the eastern half of the Southern Rockies (21). Natural vegetation includes aspen, ponderosa pine, Douglas-fir, and areas of lodgepole pine and limber pine. A diverse understory of shrubs, grasses, and wildflowers occurs. The variety of food sources supports a diversity of bird and mammal species. Forest stands have become denser in many areas due to decades of fire suppression. Land use includes wildlife habitat, livestock grazing, logging, mineral extraction, and recreation, with increasing residential subdivisions.
21d: Foothill Shrublands	The **Foothill Shrublands** ecoregion is a transition from the higher elevation forests to the drier and lower Great Plains (Ecoregions 25, 26) to the east and to the Colorado Plateaus (20) to the west. This semiarid region has rolling to irregular terrain of hills, ridges, and footslopes, with elevations generally 6,000 to 8,500 feet. Sagebrush and mountain mahogany shrubland, pinyon-juniper woodland, and scattered oak shrublands occur. Other common low shrubs include serviceberry and skunkbush sumac. Interspersed are some grasslands of blue grama, Junegrass, and western wheatgrass. Land use is mainly livestock grazing and some irrigated hayland adjacent to perennial streams.
21e: Sedimentary Subalpine Forests	The **Sedimentary Subalpine Forests** ecoregion occupies much of the western half of the Southern Rockies, on sandstone, siltstone, shale, and limestone substrates. The elevation limits of this region are similar to the crystalline (21b) and volcanic (21g) subalpine forests. Stream water quality, water availability, and aquatic biota are affected in places by carbonate substrates that are soluble and nutrient rich. Soils are generally finer-textured than those found on crystalline or metamorphic substrates of Ecoregion 21b, and are also more alkaline where derived from carbonate-rich substrates. Subalpine forests dominated by Englemann spruce and subalpine fir are typical, often interspersed with aspen groves or mountain meadows. Some Douglas-fir forests are at lower elevations.

NAME	***DESCRIPTION***
21f: Sedimentary Mid-Elevation Forests	The **Sedimentary Mid-Elevation Forests** ecoregion occurs in the western and southern portions of the Southern Rockies, at elevations generally below Ecoregion 21e. The elevation limits and vegetation of this region are similar to the crystalline (21c) and volcanic (21h) mid-elevation forests; however, a larger area of Gambel oak woodlands and forest is found in this region. Carbonate substrates in some areas affect water quality, hydrology, and biota. Soils are generally finer-textured than those found on crystalline and metamorphic substrates such as those in Ecoregion 21c.
21g: Volcanic Subalpine Forests	The steep, mountainous **Volcanic Subalpine Forests** ecoregion is composed of volcanic and igneous rocks, predominately andesitic with areas of basalt. The region is found mainly in the San Juan Mountains, which have the most rugged terrain and the harshest winters in the Southern Rockies of Colorado. Smaller areas are found in the West Elk Mountains, Grand Mesa, Flat Tops, and in the Front Range. The area is highly mineralized, and gold, silver, lead, and copper have been mined. Relatively young geologically, the mountains are among the highest and most rugged of North America and still contain some large areas of intact habitat. Englemann spruce, subalpine fir, and aspen forests support a variety of wildlife.
21h: Volcanic Mid-Elevation Forests	The **Volcanic Mid-Elevation Forests** ecoregion occurs at elevations of 7,000 to 9,000 feet and is composed of igneous rocks of andesite and basalt. The majority of the region is found in the San Juan Mountains, the West Elk Mountains, and in a small area of the Front Range. Forests of ponderosa pine, Douglas-fir, and aspen occur. Land use includes wildlife habitat, livestock grazing, logging, recreation, and mineral extraction of silver and gold.
21j: Grassland Parks	The **Grassland Parks** ecoregion also consists of high intermontane valleys similar in elevation to the drier Sagebrush Parks (21i); however, water availability is greater in 21j and the region supports grasslands rather than the sagebrush shrubland and steppe found in 21i. Grasslands with bunchgrasses are dominant, and include Arizona fescue, Idaho fescue, mountain muhly, bluebunch wheatgrass, needle-and-thread, Junegrass, and slender wheatgrass. Springs and wetlands may occur. Some subalpine/montane fens are found where groundwater seepage has persistently reached the surface and supported peatland development. There are only a few trees or shrubs, and if present, they are widely scattered and mature.

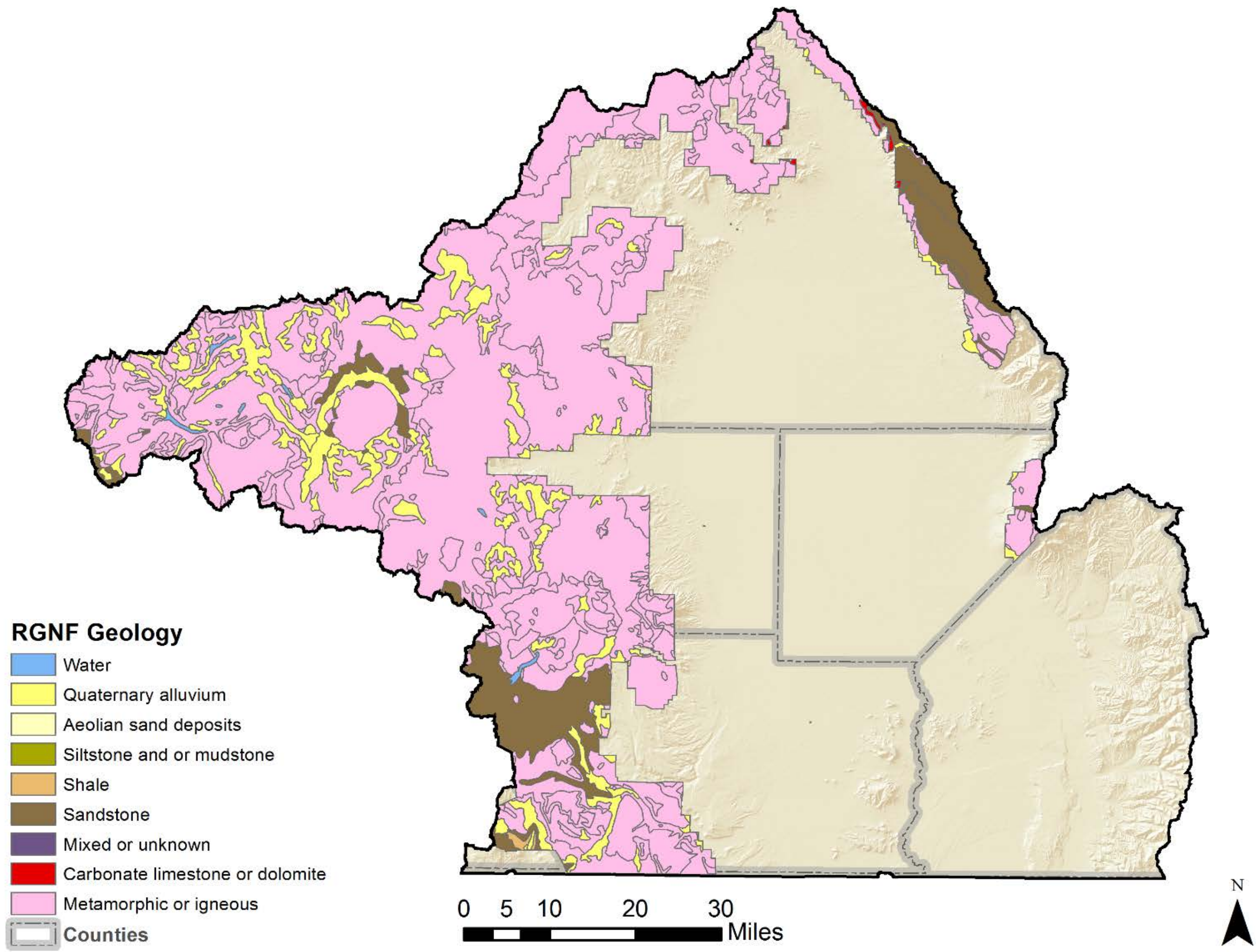

Figure 4. Geology within the fen mapping study area.

3.0 Fen Mapping Methods

Potential fens in the RGNF were identified by analyzing digital aerial photography and topographic maps. True color National Agricultural Imagery Program (NAIP) from 2005, 2009 and 2011 were used in conjunction with color-infrared imagery from 2015. High (but variable) resolution ESRI World Imagery was also used.

To focus the initial search, all wetland polygons mapped by the National Wetland Inventory (NWI) program in the 1970s and early 80s with a “B” (saturated) hydrologic regime were isolated from the full NWI dataset and examined.[3] Wetlands mapped as “Palustrine Emergent Saturated” (PEMB) and “Palustrine Scrub-Shrub Saturated” (PSSB) were specifically targeted, as they are the best indication of fen formation, and every PEMB and PSSB polygon in the study area was checked. However, photo-interpreters were not limited to the original NWI polygons and also mapped any fens they observed outside of B regime NWI polygons (Figure 5).

Potential fen polygons were hand-drawn in ArcGIS 10.2 based on the best estimation of fen boundaries. In most cases, this did not match the exact boundaries of the original NWI polygons because the resolution of current imagery is far higher than was available in the 1980s. The fen polygons were often a portion of the NWI polygon or were drawn with different, but overlapping boundaries. This will provide RGNF the most accurate and precise representation of fens in the Forest, as opposed to estimates based on the NWI polygons themselves. Each potential fen polygon was attributed with a confidence value of 1, 3 or 5 (Table 2). In addition to the confidence rating, any justifications of the rating or interesting observations were noted. Potential iron fens, beaver influence and springs were noted where observed.

Table 2. Description of potential fen confidence levels.

Confidence	*Description*
5	***Likely fen.*** Strong photo signature of fen vegetation, fen hydrology, and good landscape position.
3	***Possible fen.*** Some fen indicators present (vegetation signature, topographic position, ponding or visibly saturated substrate), but not all indicators present. Some may be weak or missing.
1	***Low confidence fen.*** At least one fen indicator present, but weak.

[3] For more information about the National Wetland Inventory and the coding system, please visit: http://www.fws.gov/wetlands/

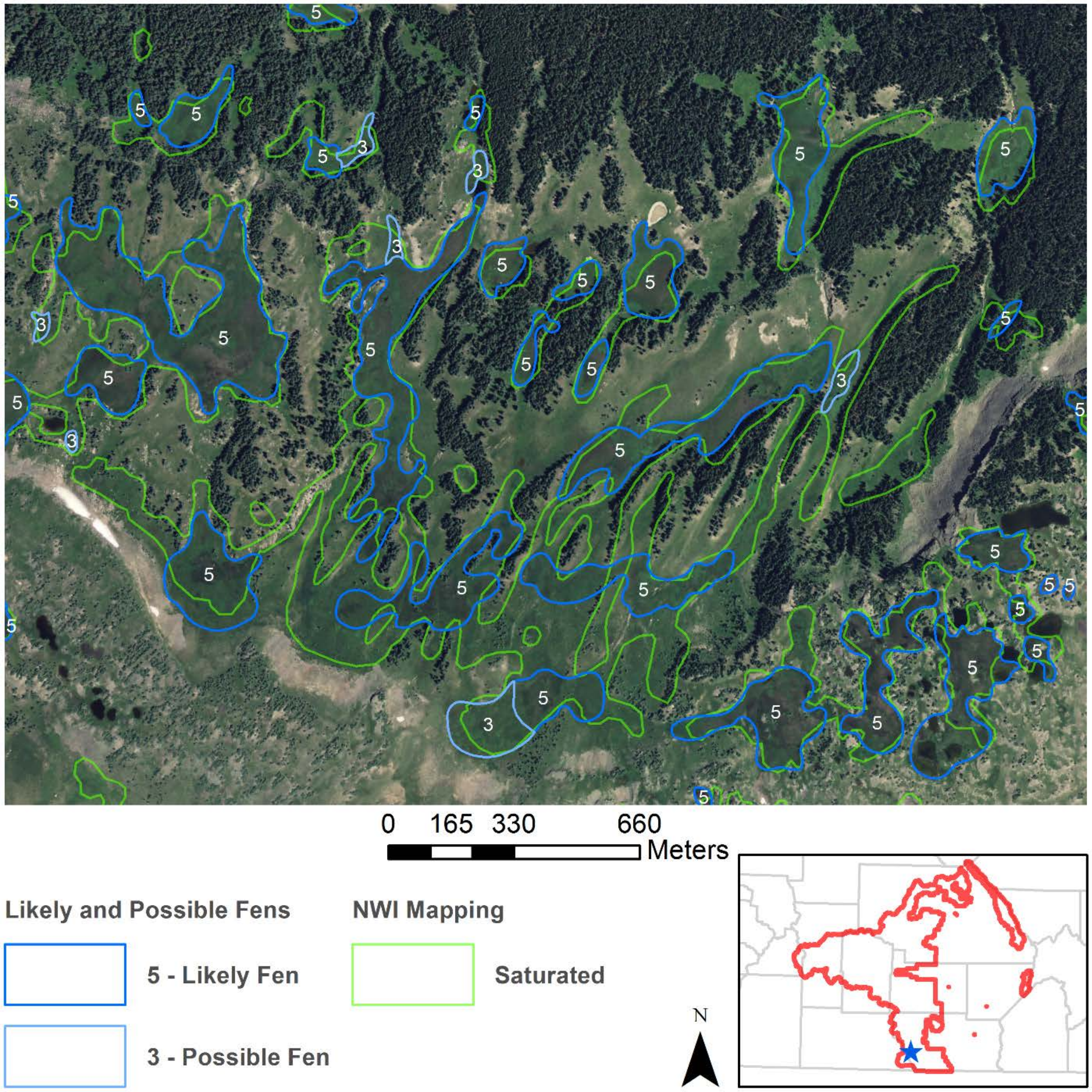

Figure 5. Example of potential fen mapping (blue) over NWI polygons with a saturated regime (green). Note areas of overlap and areas where the fen mapping is either more extensive or more restricted than the NWI saturated polygons.

4.0 Results

4.1 Potential Fen Mapping Acreage

Original NWI mapping for the RGNF contained 33,327 acres with a "B" (saturated) hydrologic regime, including 23,863 acres of herbaceous wetlands (PEMB and PEMBb), 9,459 aces of shrub wetlands (PSSB and PSSBb), and just 7 acres of forested wetlands (PFOB) (Table 3). These polygons were the starting point for potential fen mapping. After examining each polygon with a saturated hydrologic regime, and the landscape surrounding them, fen polygons were drawn covering 35% of those acres (11,578 acres), while 65% of the acres were determined to not be potential fens (21,749 acres). In addition to the area within NWI polygons, 5,067 acres not mapped as saturated by NWI were mapped as potential fens.

Saturated herbaceous polygons were more likely to be mapped as potential fens (40% overall), while saturated shrub polygons were less likely fens (23% overall). This was probably because many shrub polygons mapped with the saturated regime in NWI are along streams and are more influenced by overbank flows and beaver than by groundwater discharge. The "b" modifier within NWI coding should refer to sites with beaver influence, but it was not used frequently in the 1980s NWI mapping, though many acres of wetlands are influenced by beaver.

Table 3. Acres mapped by NWI as saturated and the overlap with mapped potential fens.

NWI Code	*Not Mapped as Fen*	*Mapped as Fen, by Confidence*			*Total Mapped as Fen*	*Grand Total by NWI Code*
		1	*3*	*5*		
PEMB	14,385	1,454	2,177	5,792	9,423	23,808
PEMBb	36	7	10	3	19	55
PSSB	7,164	505	925	675	2,105	9,269
PSSBb	159	6	24	--	30	189
PFOB	6	--	--	1	1	7
Total NWI Acres	**21,749**	**1,972**	**3,135**	**6,471**	**11,578**	**33,327**
No NWI Code	--	1,273	1,702	2,092	5,067	5,067
Grand Total	**21,749**	**3,245**	**4,837**	**8,563**	**16,664**	**38,394**

The final map of potential fens contained 6,408 potential fen locations (all confidence levels), covering 16,644 acres or 0.85% of the total land area (Table 4; Figures 6 and 7). This total included 2,532 ***likely fens*** (confidence level = 5), 2,374 ***possible fens***, and 1,502 ***low confidence fens.***

While the count of likely fens was similar to the count of possible fens, on average the likely fens were considerabley larger (3.38 acres vs. 2.04 acres), resulting in 8,563 acres of likely fens, 4,837 acres of possible fens, and 3,245 acres of low confidence fens (Table 4). The size of individual potential fens ranged from over 200 acres to 0.10 acres. The two largest mapped fens are shown in Figures 7 and 8.

Table 4. Potential fen counts and acreage, by confidence levels.

Confidence	*Count*	*Acres*	*Average size (acres)*
5 – Likely Fen	2,532	8,563	3.38
3 – Possible Fen	2,374	4,837	2.04
1 – Low Confidence Fen	1,502	3,245	2.16
TOTAL	**6,408**	**16,644**	2.60

The following sections break down the fen mapping by elevation range, bedrock geology, ecoregion and HUC12 watershed. The last section summarizes observations made by the fen mappers during the mapping process, including potential iron fens.

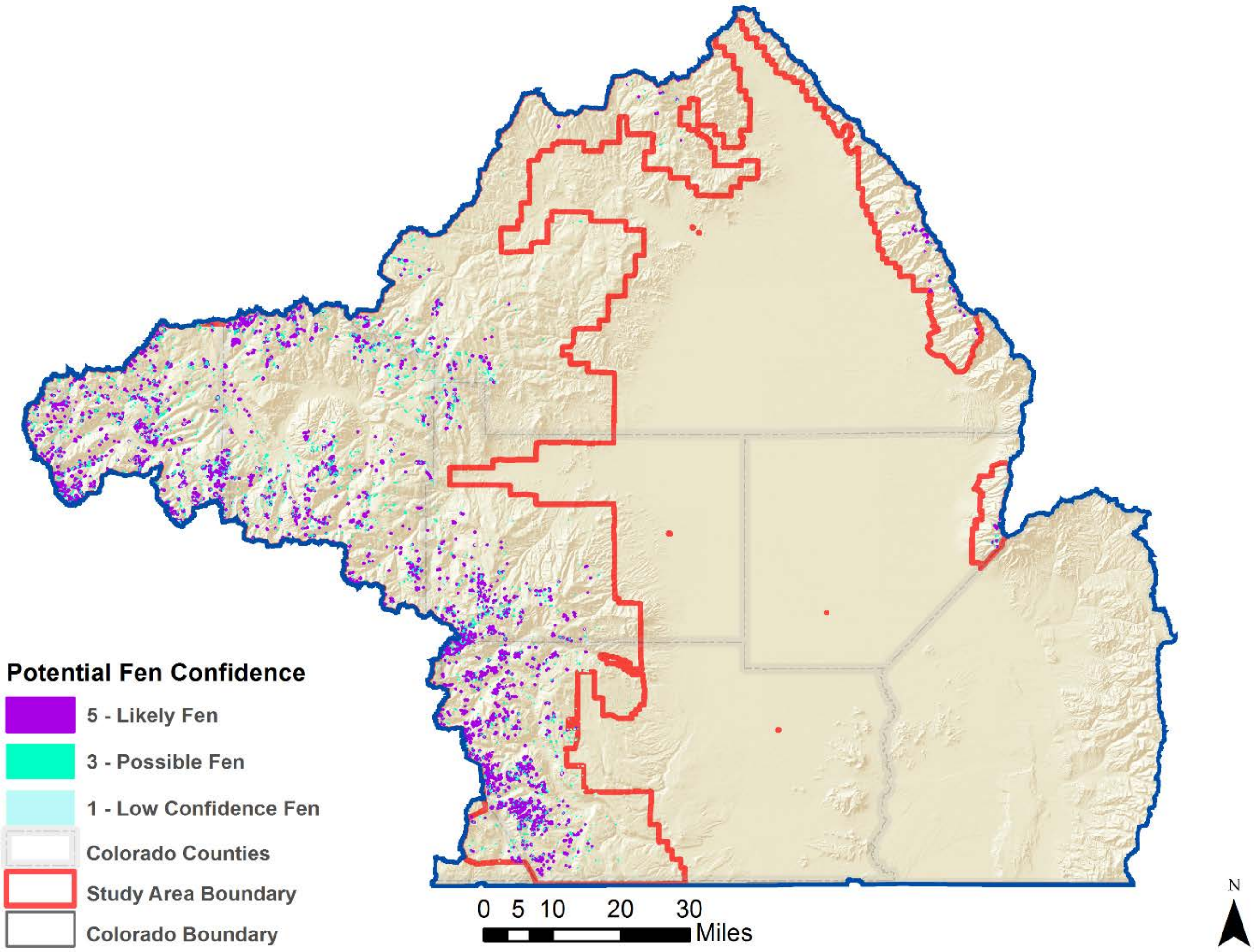

Figure 6. All potential fens within the fen mapping study area.

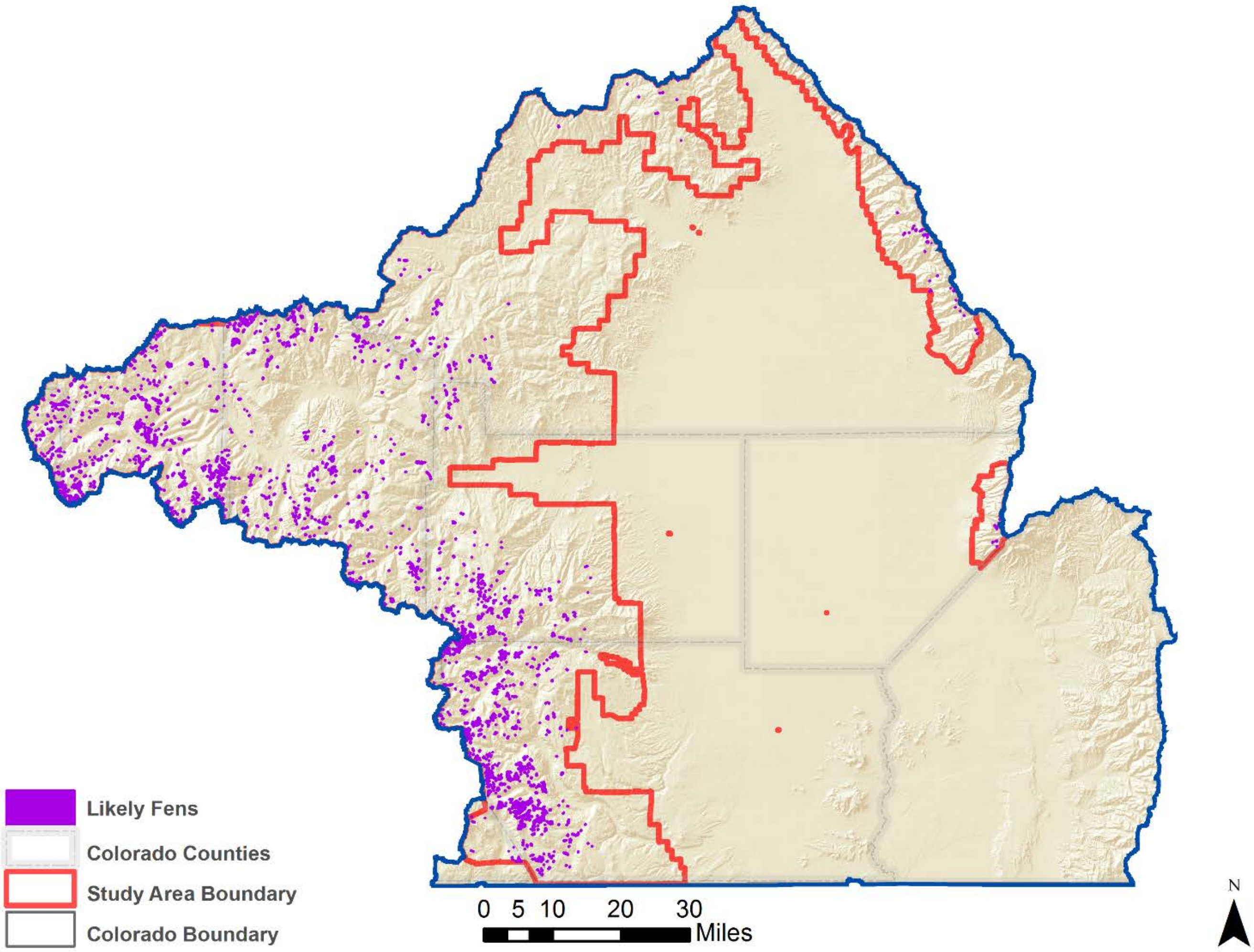

Figure 7. Likely fens (confidence rating = 5) within the fen mapping study area.

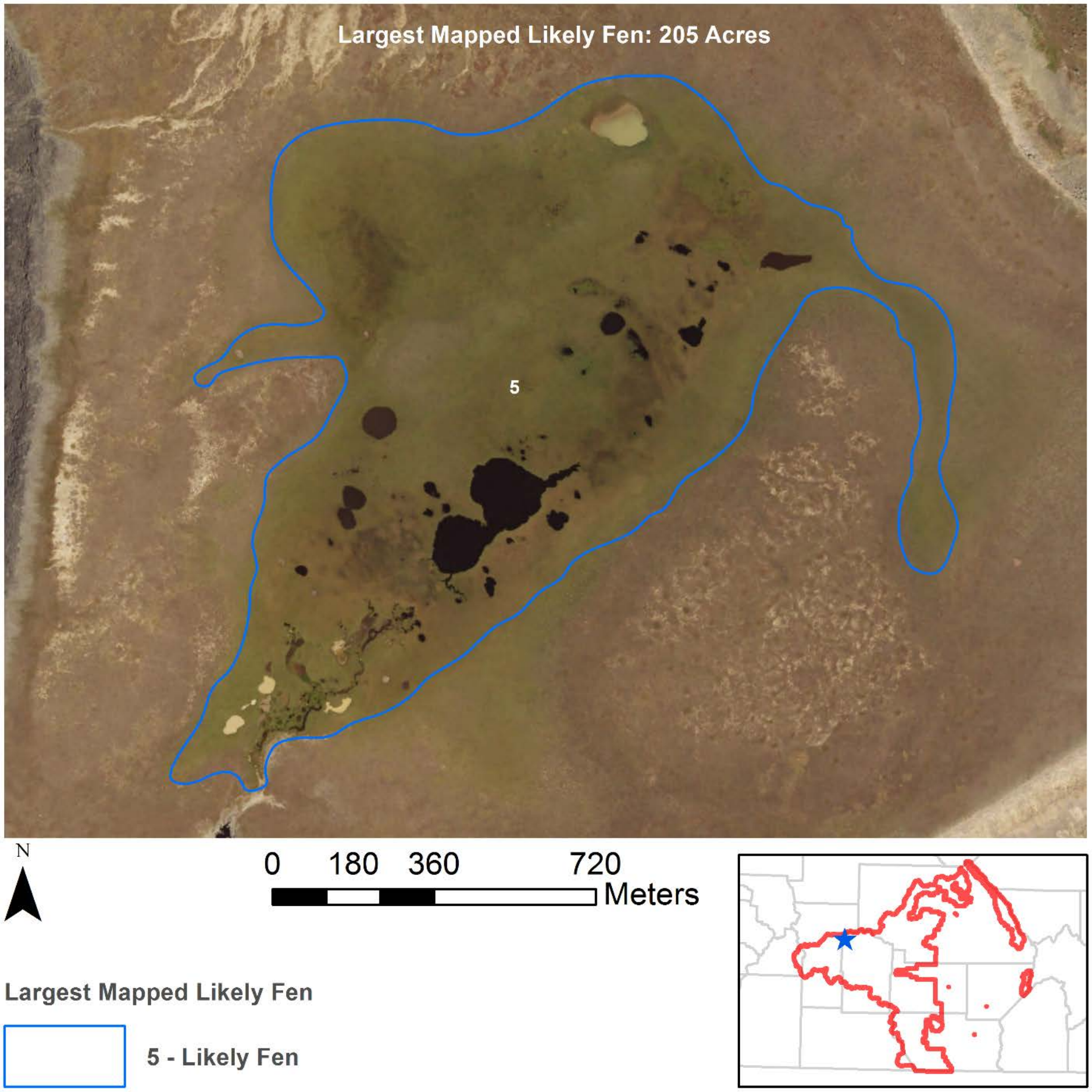

Figure 8. Largest mapped likely fen, 205 acres within one polygon. This fen is located on Snow Mesa within Mineral County.

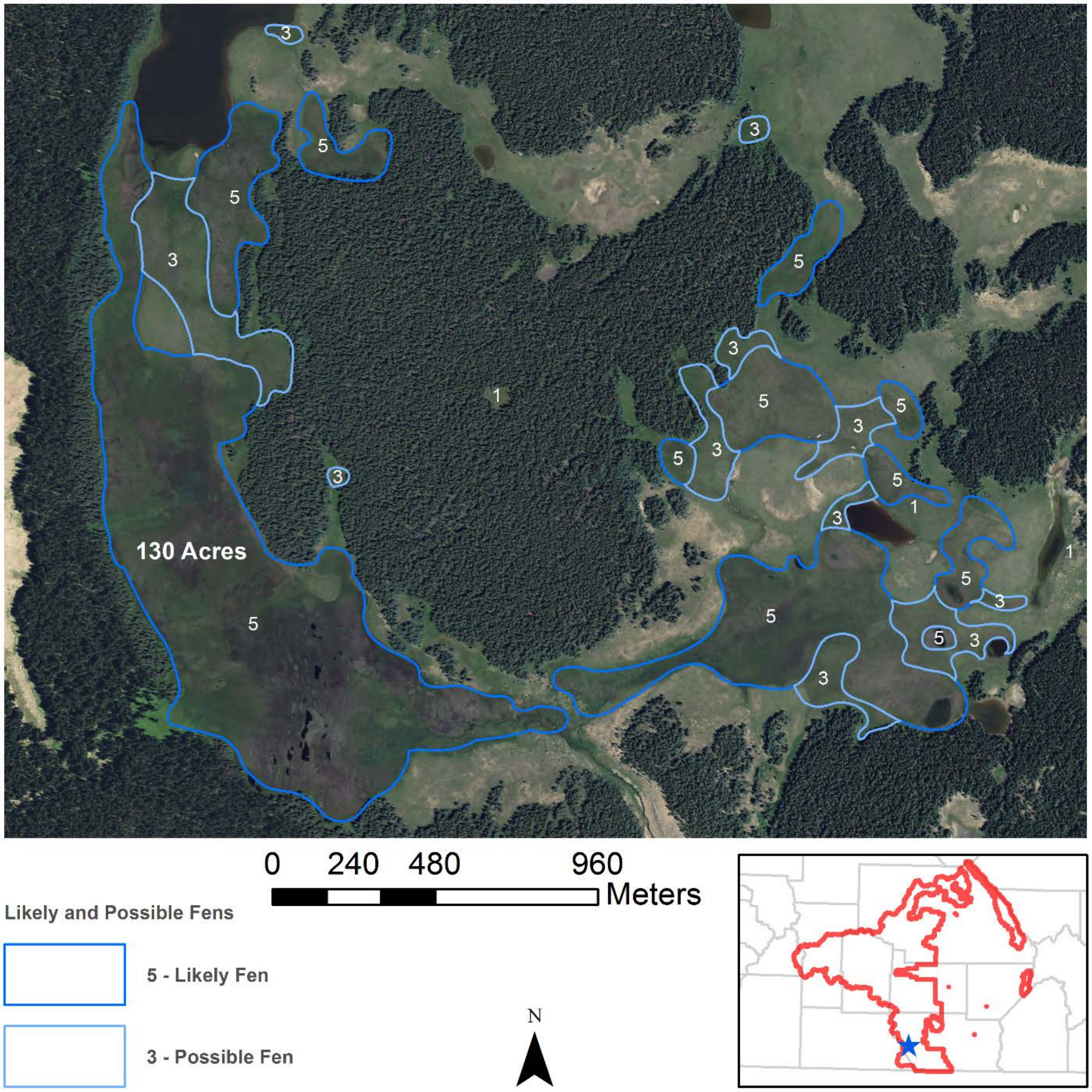

Figure 9. Second largest mapped likely fen, 130 acres within one polygon (to the left) among a complex of likely and possible fens. This complex is in an area called Victoria Lake in Conejos County.

4.2 Mapped Potential Fens by Elevation

Elevation is an important factor in the location of fens. Fen formation occurs where there is sufficient groundwater discharge to maintain permanent saturations. This is most often at higher elevations, closer to the zone of where slow melting snowpack can percolate into subsurface groundwater. Of all potential fens, 2,895 polygons (8,214 acres) were mapped between 11,000 and 12,000 feet, which represents 45% of potential fen locations and 50% of potential fen acres (Table 5; Figure 11). Of the 2,532 total likely fens mapped, 1,417 polygons (56%) and 5,148 acres (60%) were located between 11,000 and 12,000 feet (Table 4; Figures 10 and 12). This is clearly the zone of maximum fen formation for the RGNF.

The elevation band of 10,000 to 11,000 feet was the next most numerous in terms of potential and likely fens. There were 2,273 mapped potential fens (5,438 acres) in that elevation range, which represent 35% of potential fen locations and 33% of potential fen acres. In addition, there were 840 likely fens (2,493 acres) mapped in that elevation range, which represent 33% of likely fen locations and 29% of likely fen acres. These two elevation bands combined (10,000 to 12,000 feet) contain 80% of potential fen locations and 89% of likely fen locations.

Table 5. Potential and likely fens by elevation within the fen mapping study area.

Elevation Range (ft)	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
< 9,000	206	522	24	100
> 9,000 – 10,000	896	2,059	196	612
> 10,000 – 11,000	2,273	5,468	840	2,493
> 11,000 – 12,000	2,895	8,214	1,417	5,148
> 12,000	138	384	55	209
Total	**6,408**	**16,444**	**2,532**	**8,562**

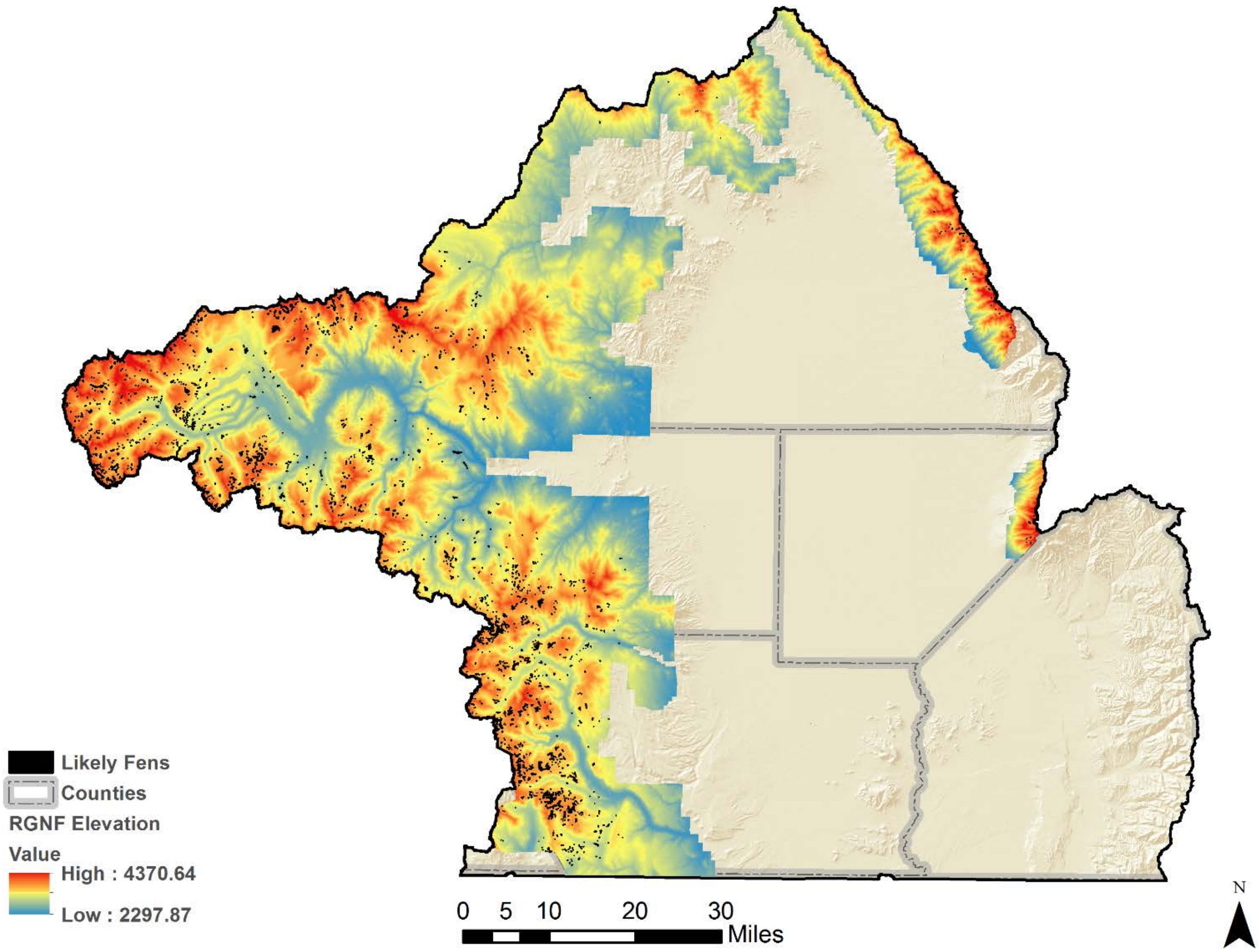

Figure 10. Likely fens (confidence rating = 5) and elevation within the fen mapping study area.

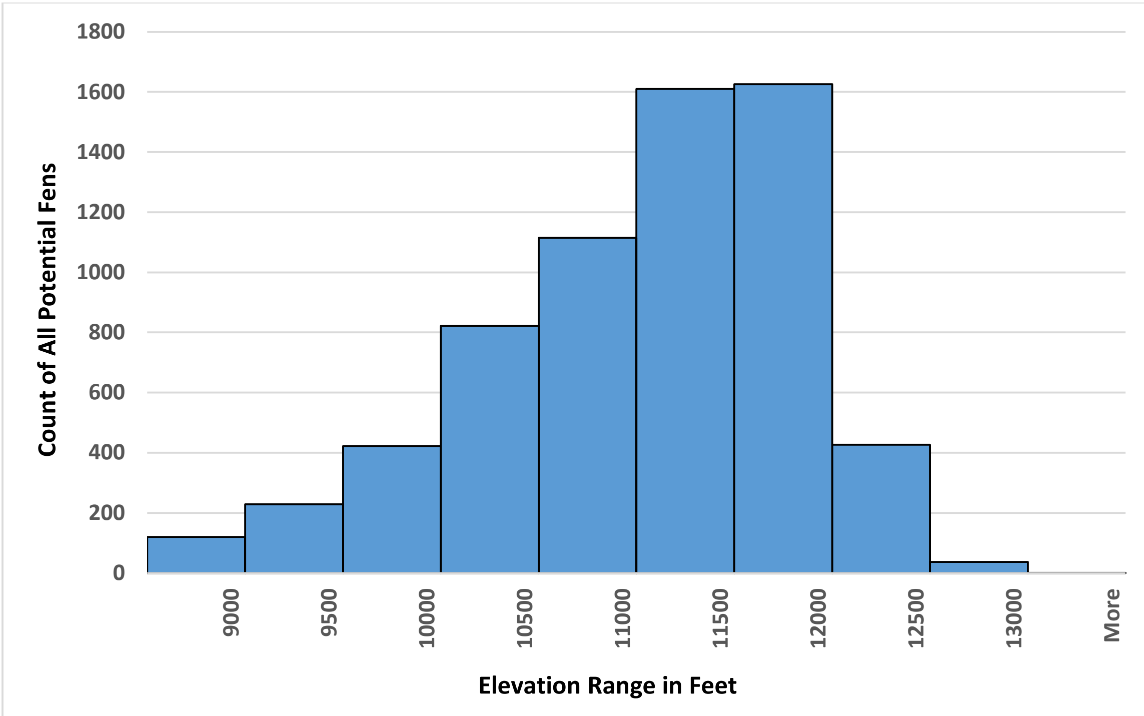

Figure 11. Histogram of all potential fens by elevation within the fen mapping study area.

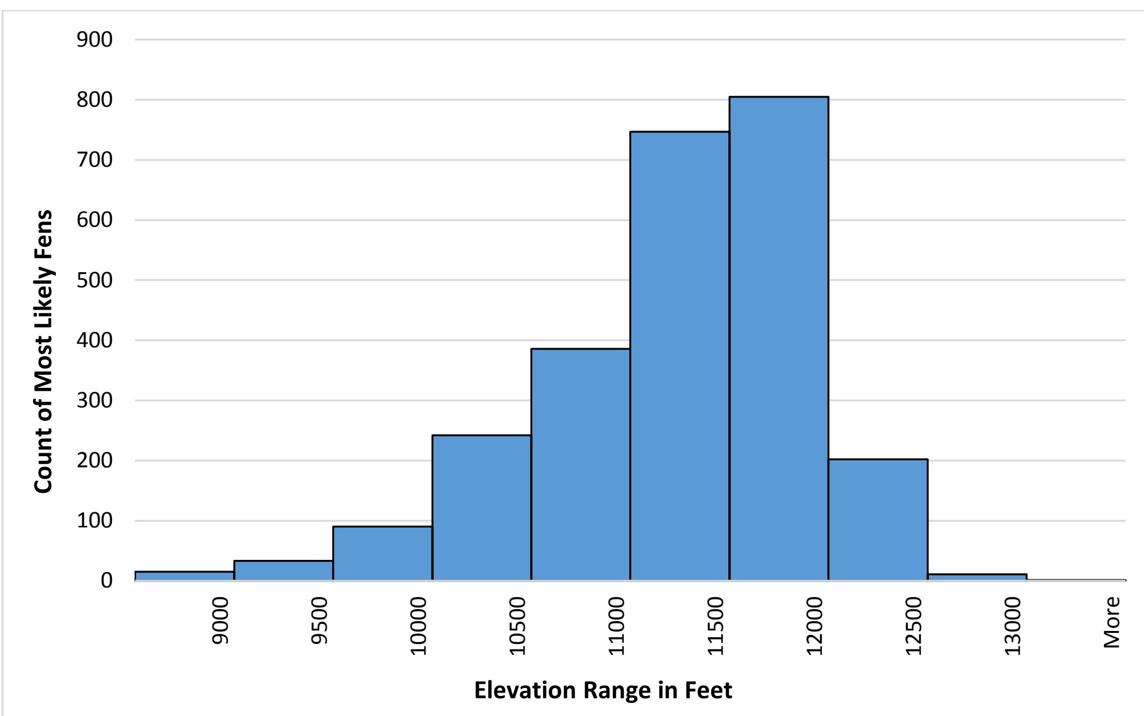

Figure 12. Histogram of the most likely fens by elevation within the fen mapping study area.

4.3 Mapped Potential Fens by Geology

Bedrock geology can exert a strong influence on species composition within fens (Chimner et al. 2010; Lemly & Cooper 2011). The most common geologic substrate for both potential and likely fens was metamorphic or igneous bedrock with dominantly silicic composition, which had 4,151 mapped potential fens (11,088 acres) and 1,558 likely fens (5,583 acres) (Table 6). This represents 65% of potential fen locations and 62% of likely fen locations. These figures are not surprising, as this is also the dominant geologic substrate within the Forest, covering 76% of the Forest area. More specific geologic information, such as the presence of outcrops of iron pyrite, would indicate the potential for iron fen formation (Cooper et al. 2002)

The next most common substrate containing potential or likely fens was quaternary age older alluvium, which had 1,054 mapped potential fens (2,785 acres) and 349 mapped likely fens (1,214 acres). While alluvium represents the dominant substrate in only 10% of the Forest, 16% of all potential fens and 14% of likely fens occurred in these areas. Alluvium typically occurs within the floodplains of rivers and other low-lying areas that can accumulate alluvial material over long periods of time. Fens often form at the edges of floodplain valleys, where there is a distinct break in slope.

Sandstone bedrock covers 9% of the RGNF and a proportional 10% of all potential fens (1,284 locations) and 14% of likely fens (347 locations) occurred in these areas. Sedimentary bedrocks can contain a higher concentration of calcium and magnesium ions and groundwater fens formed on these substrates may support a distinct suite of plants, though the most calcium rich fens are often found associated with limestone or dolomite and not sandstone (Cooper 1996; Johnson & Steingraeber 2002). While present in the Rio Grande National Forest in small amounts, no potential or likely fens were mapped on carbonate dominated formations of either limestone or dolomites, siltstone, or unconsolidated Aeolian sand deposits.

Table 6. Potential and likely fens by geologic substrate within the fen mapping study area

Geology	Acres of Geologic Substrate Within RGFN[1]	# of All Potential Fens	All Potential Fen Acres	# of Likely Fens	Likely Fen Acres
Metamorphic or igneous with dominantly silicic composition	1,479,355	4,151	11,088	1,558	5,583
Quaternary age younger alluvium	186,756	1,054	2,785	349	1,214
Sandstone	173,162	647	1,284	347	875
Metamorphic or igneous with dominantly mafic composition	82,456	498	1,288	270	808
Water	5,666	15	103	5	78
Quaternary age older alluvium	3,936	39	92	3	3
Shale	2,277	4	5	---	---
		6,408	**16,644**	**2,532**	**8,562**

[1] Acres of geologic substrate shown are only for those substrates where fens were mapped. The total acreage is not shown because it does not equal the total acreage of the RGNF.

4.4 Mapped Potential Fens by Level IV Ecoregion

Level IV Ecoregion combines elevation, geology, and dominant vegetation. This analysis provides similar conclusions to those presented above, but offers a slightly different context. Volcanic subalpine forests cover just over half of the RGNF (56%), and this ecoregion contains 3,786 mapped potential fens (9,274 acres) and 1,429 likely fens (4,518 acres) (Table 7). This represents 59% of potential fen locations and 56% of likely fen locations.

The alpine zone, which covers only 18% of the Forest, contains 2,346 mapped potential fens (6,670 acres) and 1,062 likely fens (3,883 acres). This represents 37% of potential fen locations and 42% of likely fen locations, proportionally more than the area this zone represents in the Forest. A large share of fens occur just above and below treeline, crossing into the low alpine zone.

Table 7. Potential and likely fens by Level IV Ecoregion within the fen mapping study area.

Level 4 Ecoregion	*Acres within RGNF[1]*	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Alpine Zone	342,706	2,346	6,670	1,062	3,883
Volcanic Subalpine Forests	1,047,307	3,786	9,274	1,429	4,518
Crystalline Subalpine Forests	40,149	6	14	1	12
Sedimentary Subalpine Forests	30,329	5	4	2	2
Volcanic Mid-Elevation Forests and Shrublands	209,302	93	185	16	87
Grassland Parks	50,982	154	486	21	61
Foothills and Shrublands	98,173	18	11	1	<1
		6,408	**16,644**	**2,532**	**8,562**

[1] Acres of Level IV Ecoregions shown are only for those ecoregions where fens were mapped. The total acreage is not shown because it does not equal the total acreage of the RGNF.

4.5 Mapped Potential Fens by Watershed

An analysis of likely fens in HUC 12 watersheds revealed interesting patterns. Three watersheds in particular had very high numbers of likely fens (Figure 13). Elk Creek (HUC12: 130100050402) had 170 likely fens, which covered 2.43% of the landscape in this watershed. Headwaters of Alamosa River (HUC12: 130100020302) had 157 likely fens, covering 1.90% of the landscape. Ute Creek (HUC12: 130100010105) had 142 likely fens, representing 1.68% of the landscape. All of the watersheds with more than 50 likely fens were on the western border of the Rio Grande National Forest, in the highest elevation regions.

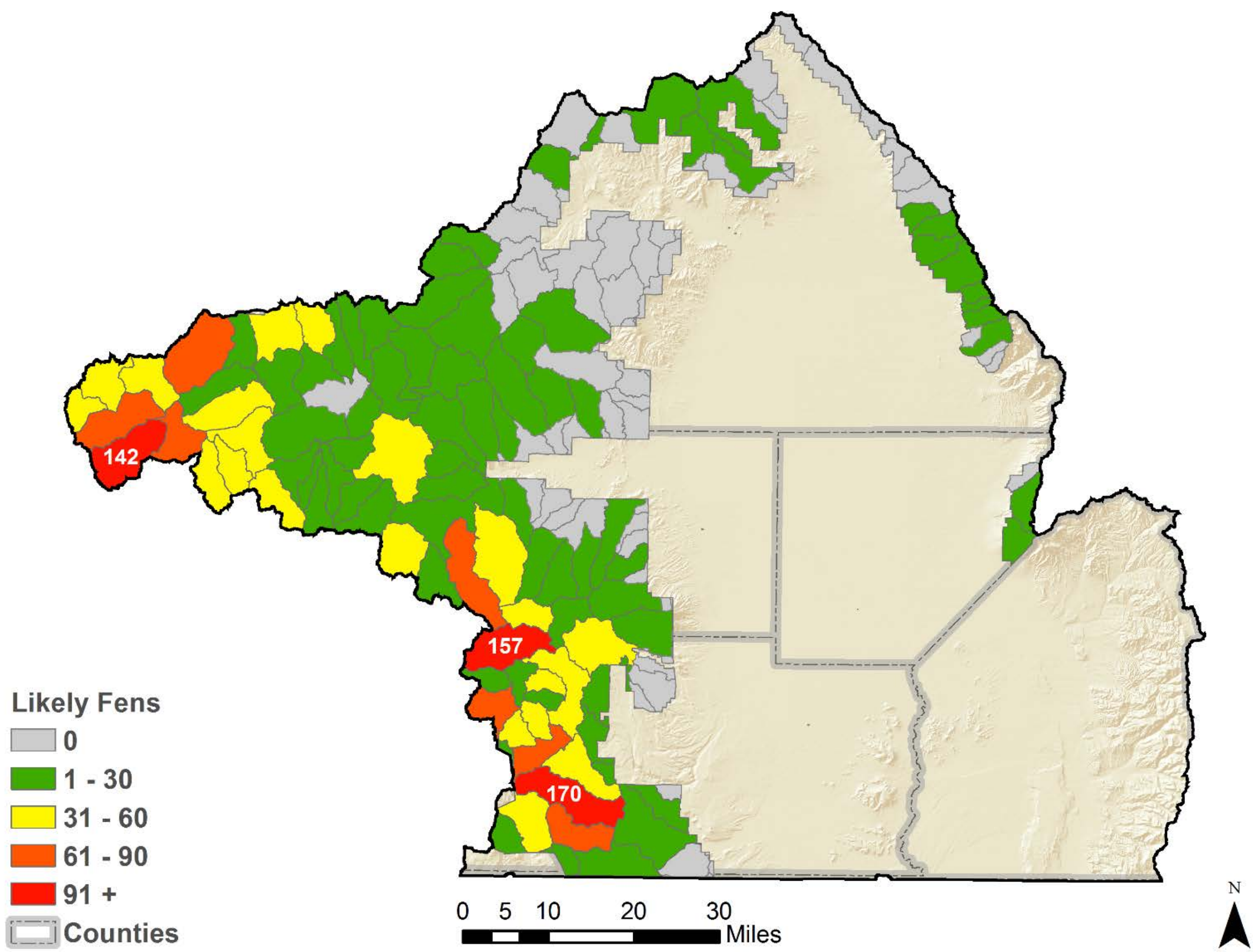

Figure 13. Likely fens by HUC12 watershed within the fen mapping study area, note the high number of likely fens in Elk Creek, Headwaters of the Alamosa River and Ute Creek.

4.6 Mapped Potential Fens with Distinctive Characteristics

Several characteristics related to fens were noted by photo-interpreters when observed throughout the fen mapping process (Table 8), though this was not an original objective of the project and was not consistently applied. Of particular interest was identifying markers for potential iron fens, a rare type of fen that occurs near iron pyrite outcrops (Cooper et al. 2002). Iron fens are notable because of their highly acidic groundwater (as low as 4.0) and their potential to support rare *Sphagnum* moss species. Within the RNGF, few potential fens were observed to have the characteristics of iron fens. However, a cluster of potential fens with some visible iron were noted near Platoro in Conejos County, just south of the Conejos River (Figure 14).

Springs and fens are both important components of groundwater-dependent ecosystems (GDEs) and are of particular interest to the U.S. Forest Service (USDA 2012). Springs were noted when observed on either the topographic map or aerial imagery. However, this was not a comprehensive investigation of springs or even springs within fens. Nine potential fens were observed in proximity to springs.

Beaver influence is a potentially confounding variable in fen mapping because longstanding beaver complexes can cause persistent saturation that looks very similar to fen vegetation signatures. Beavers also build dams in fens, so areas influenced by beavers cannot be excluded from the mapping. Forty potential fens (185 acres) and seven likely fens (43 acres) showed some evidence of beaver influence.

Table 8. Potential and likely fens with distinctive characteristics within the fen mapping study area.

Observation	*# of Potential Fens*	*Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Beaver Influence	40	185	7	43
Possible Iron Fen	9	19	4	14
Spring	9	6	---	---
Total	**116**	**397**	**18**	**85**

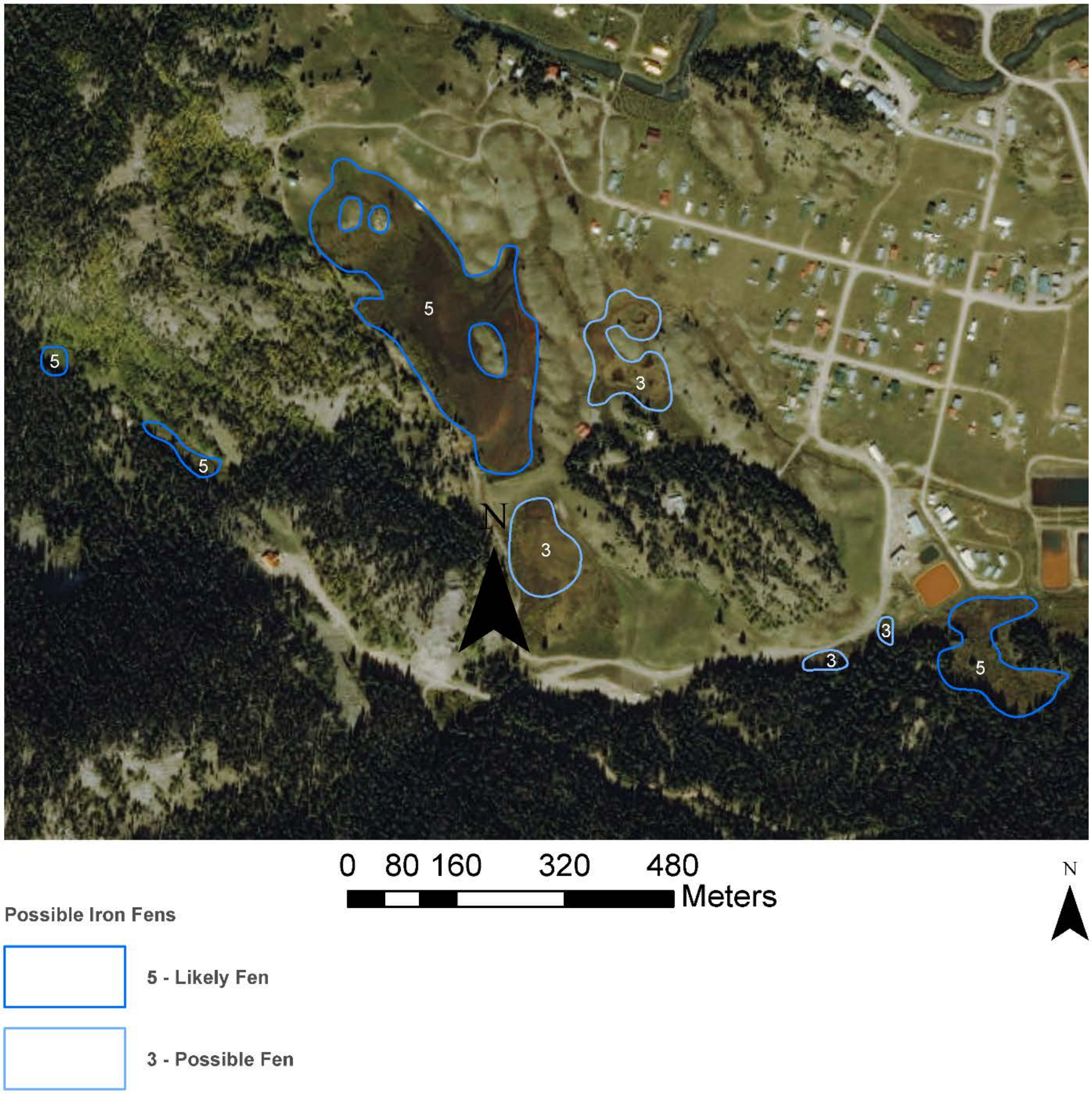

Figure 14. Possible iron fens near the town of Platoro.

5.0 DISCUSSION

The Rio Grande National Forest contains a rich resource of fen wetlands, covering up to 16,644 acres across its jurisdiction. While that represents only 0.85% of the entire landscape, these fen wetlands are an irreplaceable resource for the Forest and the citizens of Colorado. Fens throughout the Southern Rockies support numerous rare plant species that are often disjunct from their main populations (Cooper 1996; Cooper et al. 2002; Johnson & Stiengraeber 2003; Lemly et al. 2007). Within Colorado, 29 plant species considered rare in our state (S1 and S2 as tracked by the Colorado Natural Heritage Program)[4] can be found in fen wetlands (Appendix B). Along with habitat for rare plant species, fens also play a pivotal role in regional hydrologic processes. By slowly releasing groundwater, they help maintain stream flows throughout the growing season. With a predicted warmer future climate, in which snow pack may be less and spring melt may occur sooner (CNHP 2015), maintaining groundwater storage high in the mountains is imperative. Intact fens also sequester carbon in their deep organic soils, however, disturbing fen hydrology can lead to rapid decomposition of peat and associated carbon emissions (Chimner 2000).

Analysis of the potential fen data showed clear patterns in fen distribution within the RGNF. There was a strong elevation gradient, with 80% of potential fens falling between 10,000 and 12,000 feet, spanning both the subalpine and alpine zones. This is very similar to patterns found in the San Juan Mountains on the western side of the Continental Divide (Chimner et al 2010). High snowfall and slow snowmelt at these elevations allows for ample groundwater discharge for fen wetlands. There were also clear hotspots for fens in the RGNF, including Elk Creek, the Headwaters of Alamos River, and Ute Creek. These areas should be actively conserved.

Previous studies of wetland condition in the RGNF, while not targeted at fens, found that high elevation wetlands were generally in excellent to good condition (Lemly 2012; Lemly & Gilligan 2011). However, human stressors were observed in some sites, including grazing, logging of the surrounding forest, and erosion. These previous efforts included limited fens sites, and few other studies have targeted fens on the RGNF. Researchers and students at Colorado Mountains College have recently begun surveying fen wetlands on the RGNF in Saguache County (J. Mohrmann, *personal communication)*. These efforts and other field studies of RGNF fens should be continued. Field-based studies of fens in other areas of Colorado have consistently found rare plant species within fens (Johnson & Stiengraeber 2003; Chimner et al. 2010; Malone et al 2011). Of the 29 state rare plants found in fens across the state, only two are known to occur in the RGNF (Appendix B). This is likely due to a lack of field studies, not a lack of plant diversity in RGNF fens.

In total, 6,408 potential fens were mapped throughout the RGNF, of which 2,532 were most likely to be fens. The number and acreage of mapped potential fens is less than for saturated polygons mapped by the National Wetland Inventory. While NWI polygons were an excellent starting point for identifying fens, this project showed that delineating new polygons specifically for fens

[4] More information about the CNHP ranking system can be found online at: http://www.cnhp.colostate.edu/about/heritage.asp.

produced a more accurate and precise accounting of fen number and acreage. We see this as a model for future fen mapping efforts in the state and for the U.S. Forest Service.

This report and associated dataset provide the RGNF with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing RGNF biological assessment required by the 2012 Forest Planning Rule, but can also be used to establish buffers around fens for individual management actions, such as timber sales, grazing allotments, and trail maintenance. In addition, the RGNF may want to pay special attention to fens mapped within the perimeter of the major burn areas, like the West Fork Fire complex, where erosion and excess runoff could alter fen hydrology. Wherever possible, the Forest should avoid direct disturbance to the fens mapped through this project, and should also strive to protect the watersheds surrounding high concentrations of fens, thereby protecting their water sources.

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APPENDIX A: LIKELY FENS BY HUC12 WATERSHED, SORTED BY FEN DENSITY

HUC 12 Code	*HUC 12 Name*	*Watershed Acres*	*Likely Fen Count*	*Likely Fen Acres*	*Fen Density (Fen Acres/ Watershed Acres)*
130100050402	Elk Creek	27,574	170	670	2.43%
130100050108	Outlet South Fork Conejos River	12,182	82	288	2.37%
130100010203	Spring Creek	18,829	40	442	2.35%
130100010304	Texas Creek-Rio Grande	17,174	55	348	2.02%
130100020302	Headwaters Alamosa River	24,185	157	460	1.90%
130100050101	North Fork Conejos River	12,778	89	227	1.78%
130100020301	Wrightman Fork	10,235	46	174	1.70%
130100010105	Ute Creek	25,564	142	430	1.68%
130100050201	Headwaters Rio de Los Pinos	16,356	82	271	1.66%
130100010302	Little Squaw Creek	11,333	40	182	1.60%
130100050107	Hansen Creek	7,415	33	115	1.55%
130100050103	Platoro Resvervoir-Conejos River	6,695	25	85	1.27%
130100010301	Squaw Creek	13,920	48	164	1.18%
130100010106	Rio Grande Reservoir	15,398	60	168	1.09%
130100011001	Lime Creek	9,816	22	107	1.09%
130100050106	Headwaters South Fork Conejos River	7,346	31	78	1.06%
130100050401	Rough Creek-Conejos River	17,891	48	188	1.05%
130100010102	Pole Creek	14,934	44	156	1.05%
130100010101	Headwaters Rio Grande	8,721	36	86	0.98%
130100010401	Headwaters Trout Creek	14,798	42	143	0.97%
130100010204	South Clear Creek	14,993	25	136	0.91%
130100010602	Outlet Miners Creek	10,596	16	90	0.85%
130100011103	Park Creek	26,149	87	219	0.84%
130100050104	Lake Fork	6,221	35	52	0.84%
130100010201	Continental Reservoir-North Clear Creek	32,208	65	262	0.81%
130100010303	Spring Creek	20,726	54	145	0.70%
130100020101	East Fork Pinos Creek	13,711	21	95	0.69%
130100010503	Ivy Creek-Red Mountain Creek	9,566	30	64	0.67%

HUC 12 Code	HUC 12 Name	Watershed Acres	Likely Fen Count	Likely Fen Acres	Fen Density (Fen Acres/ Watershed Acres)
130100010601	Headwaters Miners Creek	12,279	37	79	0.64%
130100050102	Adams Fork Conejos River	6,721	21	43	0.64%
130100010202	North Clear Creek	10,962	11	70	0.64%
130100010902	Fisher Creek	10,249	20	64	0.62%
130100010104	Bear Creek-Rio Grande	22,635	62	138	0.61%
130100010802	West Bellows Creek-Bellows Creek	18,188	21	100	0.55%
130100010502	Middle Creek	5,087	14	28	0.55%
130100050105	Saddle Creek	4,742	8	26	0.55%
130100010702	West Willow Creek-Willow Creek	12,413	14	66	0.53%
130100011104	Beaver Creek	32,355	53	165	0.51%
130100050109	Trail Creek-Conejos River	21,187	38	108	0.51%
130100011106	Outlet South Fork Rio Grande	30,585	27	150	0.49%
130100011102	Headwaters South Fork Rio Grande	18,449	33	84	0.45%
130100010402	Outlet Trout Creek	10,947	21	50	0.45%
130100010903	Leopard Creek-Goose Creek	35,436	33	156	0.44%
130100010901	Headwaters Goose Creek	14,877	21	65	0.44%
130100011007	Elk Creek	10,436	8	46	0.44%
130100040501	Headwaters La Garita Creek	14,435	17	61	0.43%
130100011301	Alder Creek	19,647	14	79	0.40%
130201020201	Headwaters Rio Chama	19,597	53	76	0.39%
130100010103	Lost Trail Creek	16,053	32	62	0.39%
130100010501	Headwaters Red Mountain Creek	10,718	12	39	0.37%
130100011101	Pass Creek	14,061	16	47	0.34%
130100040103	South Fork Saguache Creek	28,723	30	88	0.31%
130100020102	West Fork Pinos Creek	15,314	29	46	0.30%
130100011003	Shallow Creek	11,346	8	33	0.29%
130100040105	Middle Fork Saguache Creek	24,549	20	66	0.27%
130100010701	Whited Creek-East Willow Creek	13,320	5	34	0.25%
130100020304	French Creek-Alamosa River	23,150	31	54	0.23%
130201020203	Wolf Creek	18,005	24	41	0.23%
130100020401	Jarosa Creek	14,987	9	34	0.23%
130100011202	Headwaters Embargo Creek	25,291	8	57	0.23%

HUC 12 Code	HUC 12 Name	Watershed Acres	Likely Fen Count	Likely Fen Acres	Fen Density (Fen Acres/ Watershed Acres)
130100010801	East Bellows Creek	18,015	11	40	0.22%
140801010601	East Fork Navajo River	13,215	17	26	0.19%
130100040101	North Fork Saguache Creek	13,613	6	26	0.19%
130100020303	Jasper Creek-Alamosa River	11,283	10	19	0.17%
130100011008	Blue Creek-Rio Grande	22,828	3	40	0.17%
130100010205	Outlet Clear Creek	17,382	11	25	0.15%
130100020201	Headwaters Rock Creek	21,026	10	30	0.14%
130100020103	Bennett Creek	10,529	7	15	0.14%
130100011002	Seepage Creek-Rio Grande	28,318	13	32	0.11%
130100011105	Trout Creek	14,214	2	14	0.10%
130100011201	Baughman Creek	15,567	2	15	0.09%
130100011302	Bear Creek	9,535	2	8	0.09%
130100030403	Rito Alto Creek	13,604	13	10	0.07%
130201020205	Rio Chamita-Rio Chama	29,045	9	17	0.06%
130100030701	South Zapata Creek	10,809	5	6	0.06%
130100050403	Fox Creek	21,164	4	14	0.06%
130100011004	Deep Creek	9,943	3	6	0.06%
130100050203	Toltec Creek-Rio de Los Pinos	32,769	7	12	0.04%
130100030404	San Isabel Creek	26,984	6	11	0.04%
130100020704	North Fork Raton Creek	13,255	3	5	0.04%
130100011006	Farmers Creek-Rio Grande	20,061	2	8	0.04%
130100030405	Crestone Creek	24,257	6	8	0.03%
130201020202	Archuleta Creek	9,133	3	3	0.03%
130100030501	Deadman Creek	11,122	2	3	0.03%
130100030408	Willow Creek-San Luis Creek	73,950	4	14	0.02%
130100030407	Cottonwood Creek	14,185	3	3	0.02%
130100030402	Wild Cherry Creek	11,935	1	3	0.02%
130100040302	Antelope Creek-Sheep Creek	26,891	1	6	0.02%
130100030102	Cottonwood Creek-Kerber Creek	39,851	7	4	0.01%
130100020402	Headwaters La Jara Creek	25,978	2	2	0.01%
130100040102	Horse Canyon	11,193	2	2	0.01%
130100050405	Sheep Creek-Conejos River	28,581	2	2	0.01%

HUC 12 Code	HUC 12 Name	Watershed Acres	Likely Fen Count	Likely Fen Acres	Fen Density (Fen Acres/ Watershed Acres)
140801010203	Wolf Creek	13,038	2	1	0.01%
130100040402	South Fork Carnero Creek	28,202	1	3	0.01%
130100030703	130100030703	112,411	6	4	0.00%
130100040306	Middle Creek	34,115	2	1	0.00%
130100040701	Ford Creek	15,891	2	1	0.00%
130100011303	Willow Creek	11,450	1	1	0.00%
130100011305	Old Woman Creek	13,830	1	0	0.00%
130100020204	Headwaters Cat Creek	19,138	1	0	0.00%
130100020701	San Fransisco Creek	21,582	1	1	0.00%
130100030101	Little Kerber Creek	13,498	1	0	0.00%
130100030406	Spanish Creek	9,827	1	0	0.00%
140801011102	Flint Creek-Los Pinos River	24,949	1	0	0.00%

APPENDIX B: RARE PLANT SPECIES THAT OCCUR IN FENS

Scientific Name	*Common Name*	*G Rank*[1]	*S Rank*	*USFS Sensitive*	*Known to occur in RGNF*[2]
Carex capitata ssp. *arctogena*	Capitate sedge	G5T4?	S1	--	--
Carex diandra	Lesser panicled sedge	G5	S1	Yes	--
Carex lasiocarpa	Woollyfruit sedge	G5	S1	---	--
Carex limosa	Mud sedge	G5	S2	--	Yes
Carex livida	Livid sedge	G5	S1	Yes	--
Carex retrorsa	Knot-sheath sedge	G5	S1	--	--
Carex sartwellii	Sartwell's sedge	G5G4	S1	--	--
Carex scirpodidea ssp. *scirpodidea*	Northern singlespike sedge	G5T5	S2	--	--
Carex tenuiflora	Spareseflower sedge	G5	S1	--	--
Carex viridula	Little green sedge	G5	S1	--	--
Drosera anglica	English sundew	G5	S1	Yes	--
Drosera rotundifolia	Roundleaf sundew	G5	S2	Yes	--
Eriophorum chamissonis (syn. *E. altaicum* var. *neogaeum*)	Chamisso's cottongrass	G5	S1	Yes	Yes
Eriophorum gracile	Slender cottongrass	G5	S1	Yes	--
Hypoxis hirsuta	Common goldstar	G5	S1	--	--
Juncus filiformis	Thread rush	G5	S2	--	--
Juncus vaseyi	Vasey's rush	G5?	S1	--	--
Kobresia simpliciuscula	Simple bog sedge	G5	S2	Yes	--
Lomatogonium rotatum	Marsh felwort	G5	S2	--	--
Muhlenbergia glomerata	Spiked muhly	G5	S2	--	--
Packera debilis	Weak groundsel	G4	S1	--	--
Primula egaliksensis	Greenland primrose	G4	S2	Yes	--
Ptilagrostis porteri	Porter's false needlegrass	G2	S2	Yes	--
Rhynchospora alba	White beaksedge	G5	S1	--	--
Rubus arcticus ssp. *acaulis*	Dwarf raspberry	G5T5	S1	Yes	--
Salix candida	Sageleaf willow	G5	S2	Yes	--
Salix myrtillifolia	Blueberry willow	G5	S1	Yes	--
Sisyrinchium pallidum	Pale blue-eyed grass	G3	S2	--	--
Trichophorum pumilum	Rolland's bulrush	G5	S2	--	--

[1] More information about the CNHP ranking system can be found online at: http://www.cnhp.colostate.edu/about/heritage.asp.

[2] Based on element occurrence records in the CNHP database. Herbarium records or data held by the U.S. Forest Service may include additional species known to occur in the RGNF. It is highly likely that more species could occur within the RGNF.