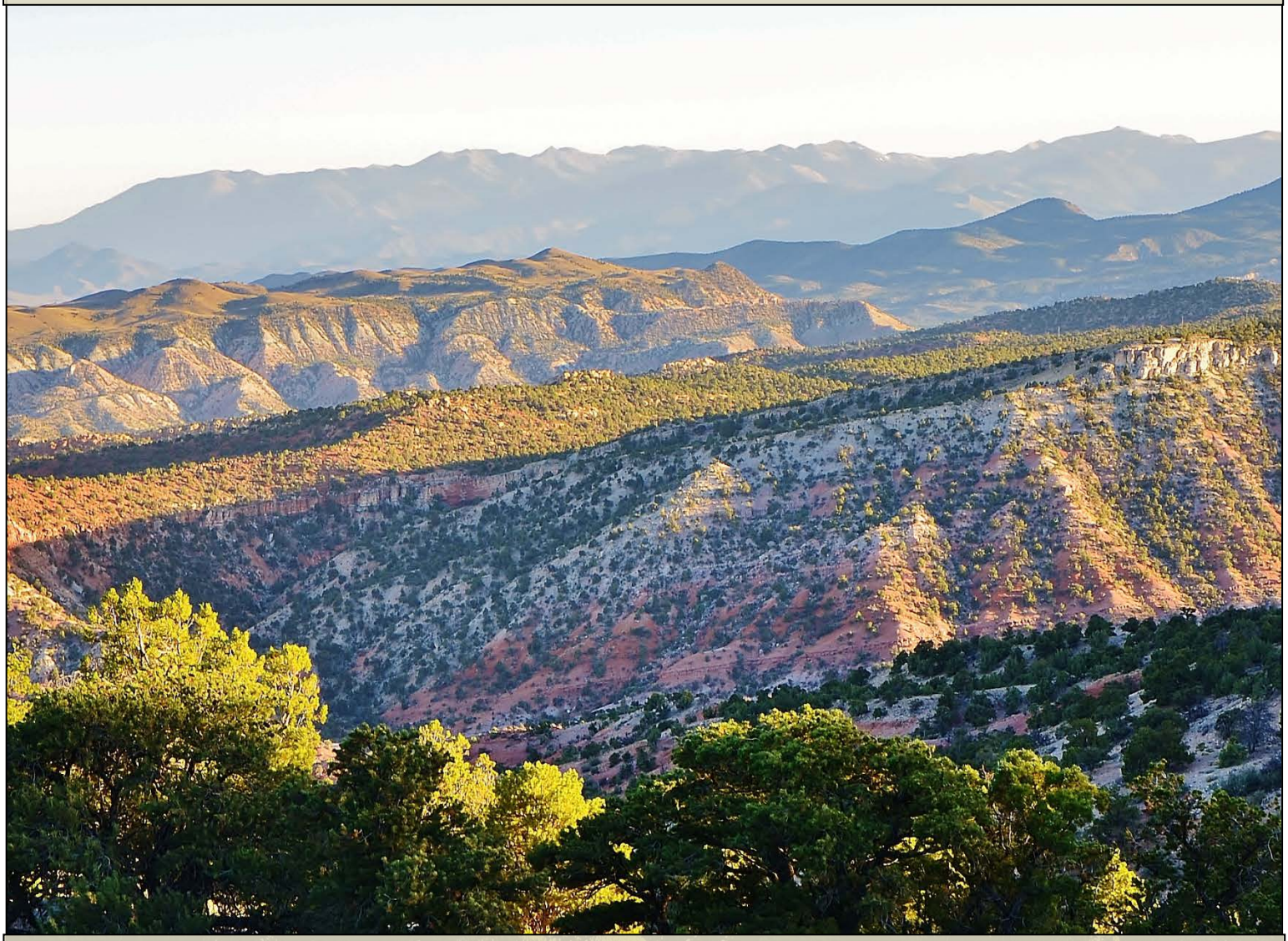
Fen Mapping for the Fishlake National Forest



January 2020

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.

Colorado Natural Heritage Program
Warner College of Natural Resources
Colorado State University
1475 Campus Delivery
Fort Collins, CO 80523

Report Prepared for:

Fishlake National Forest
115 East 900 North
Richfield, UT 84701

Recommended Citation:
Smith, G. and J. Lemly. 2020. Fen Mapping for the Fishlake National Forest.
Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Front Cover Photo:

By On^ste82 – accessed via Wikimedia commons,
Photo title: Fishlake National Forest

Fen Mapping for the Fishlake National Forest

Gabrielle Smith and Joanna Lemly
Colorado Natural Heritage Program
Warner College of Natural Resources
Colorado State University
Fort Collins, Colorado 80523

January 2020

Page intentionally left blank.

EXECUTIVE SUMMARY

The Fishlake National Forest covers 1.5 million acres spread across four units in south central Utah. Wetlands within the Fishlake National Forest provide important ecological services to both the Forest 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). 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 Fishlake National Forest 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 Fishlake National Forest.

Potential fens in the Fishlake National Forest 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 2,323 potential fen locations (all confidence levels), covering 4,892 acres or less than 1% of the total land area. This total included 199 ***likely fens***, 604 ***possible fens***, and 1,520 ***low confidence fens.*** The average fen polygon was 2.14 acres, but individual fen polygons ranged from 204 acres to less than an acre.

Fen distribution was analyzed by elevation, geology, Land Type Association Subsection, and watershed. The majority of mapped potential fens occurred between 8,000 to 11,000 feet. This elevation range contained 68% of all potential fen locations and 83% of likely fen locations. Three watersheds in particular have higher numbers of likely fens: Headwaters of Boulder Creek watershed contains 34 likely fens, and Rock Spring Draw and Upper Pleasant Creek watersheds both contain 26 likely fens.

This report and associated dataset provides the Fishlake National Forest with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing Fishlake National Forest 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 to John Proctor, Regional Botanist for U.S. Forest Service Region 4, for supporting this project.

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, Lexine Long, Peggy Lyon, Dee Malone, Sarah Marshall, and Kristin Schroder. 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 Tracey Trujillo and Carmen Morales with Colorado State University for logistical support and grant administration.

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

1.0 INTRODUCTION

The Fishlake National Forest covers over 1.46 million acres in south central Utah and spans a broad elevation range from 4,741 to 12,154 ft. Several types of wetlands occur within the Fishlake National Forest. Snowfall in the mountains percolates through shallow mountain soils and creates wet meadows, riparian shrublands, and organic soil wetlands known as fens. These wetland habitats provide important ecological services to both Fishlake National Forest 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 nutrients. 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. 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] A component of the new planning rule is that each National Forest must conduct an assessment of important biological resources within its boundaries. In advance of the biological assessment, biologists at the Fishlake National Forest 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 Fishlake National Forest. This project builds upon CNHP's previous projects mapping fens on the White River National Forest (Malone et al. 2011), Rio Grande National Forest (Smith et al. 2016), Ashley National Forest (Smith & Lemly 2017a), Manti-La Sal National Forest (Smith & Lemly 2017b), Salmon-Challis National Forest (Smith et al. 2017), Bridger-Teton National Forest (Smith & Lemly 2018a), Dixie National Forest (Smith & Lemly 2018b) and Humboldt-Toiyabe National Forest (Smith & Lemly 2019).

[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 Fishlake National Forest, which is administered as five discontinuous units located in central Utah (Figure 1). Fishlake National Forest borders Manti-La Sal National Forest to the north and Dixie National Forest to the south. The Forest also shares a border with Capitol Reef National Park to the southeast. Fishlake National Forest includes portions of nine counties in Utah. The counties with the largest share of National Forest land are Sevier, Millard, Piute, Beaver, and Wayne counties. The largest municipalities near the study area are Richfield, Delta, Gunnison and Beaver. Elevation in the study area ranges from 4,741 ft. (1,445 m) to 12,154 ft. (3,705 m) and the mean elevation is 8,241 ft. (2,512 m).

Fishlake National Forest contains land in two different HUC6 basins (Figure 2). The largest amount of Forest land occurs in the Escalante Desert–Sevier Lake basin (HUC6: 160300) and the remaining southeastern portion of the Forest occurs in the Upper Colorado–Dirty Devil basin (HUC6:140700). In the Escalante Desert–Sevier Lake basin, the Sevier River originates in southern Utah, west of Bryce Canyon National Park. The river flows north through an agricultural valley located between the Fillmore and Richfield Ranger Districts of Fishlake National Forest. At the north end of the Fillmore Ranger District in the Canyon Mountains, the Sevier River takes a turn to the south and empties into the terminal Sevier Lake. Before the river turns south, upstream of the Sevier Bridge Reservoir, the Sevier River merges with the San Pitch River that flows in from the north.

In the Upper Colorado–Dirty Devil basin, the Fremont River flows southeast from the Johnson Valley Reservoir through the Thousand Lake Mountains, also collecting water from the Aquarius Plateau from the south. Muddy Creek collects water from the Wasatach Plateau and flows southeast, eventually merging with the Fremont River to form the Dirty Devil River. Both the Aquarius Plateau and the Thousand Lake Mountains have numerous ponds, lakes and small depressional wetlands.

2.2 Land Type Associations

The U.S. Forest Service has developed Land Type Associations for each National Forest to describe the major geomorphic landforms within the Forest (USDA 2019). The Land Type Association subsections referenced in this report were in draft form at the time of analysis (version date October 2018). The final version of the LTA dataset may be different than what is described in this report.

There are 205 unique Land Type Associations in Fishlake and 12 subsections. The most common Land Type Association subsection in the Fishlake National Forest is the Pahvant Range (21% of study area) (Figure 3). The next most common Land Type Association subsections are the Tushar Mountains (17%), Fish Lake Plateau (15%) and Aquarius Plateau (14%).

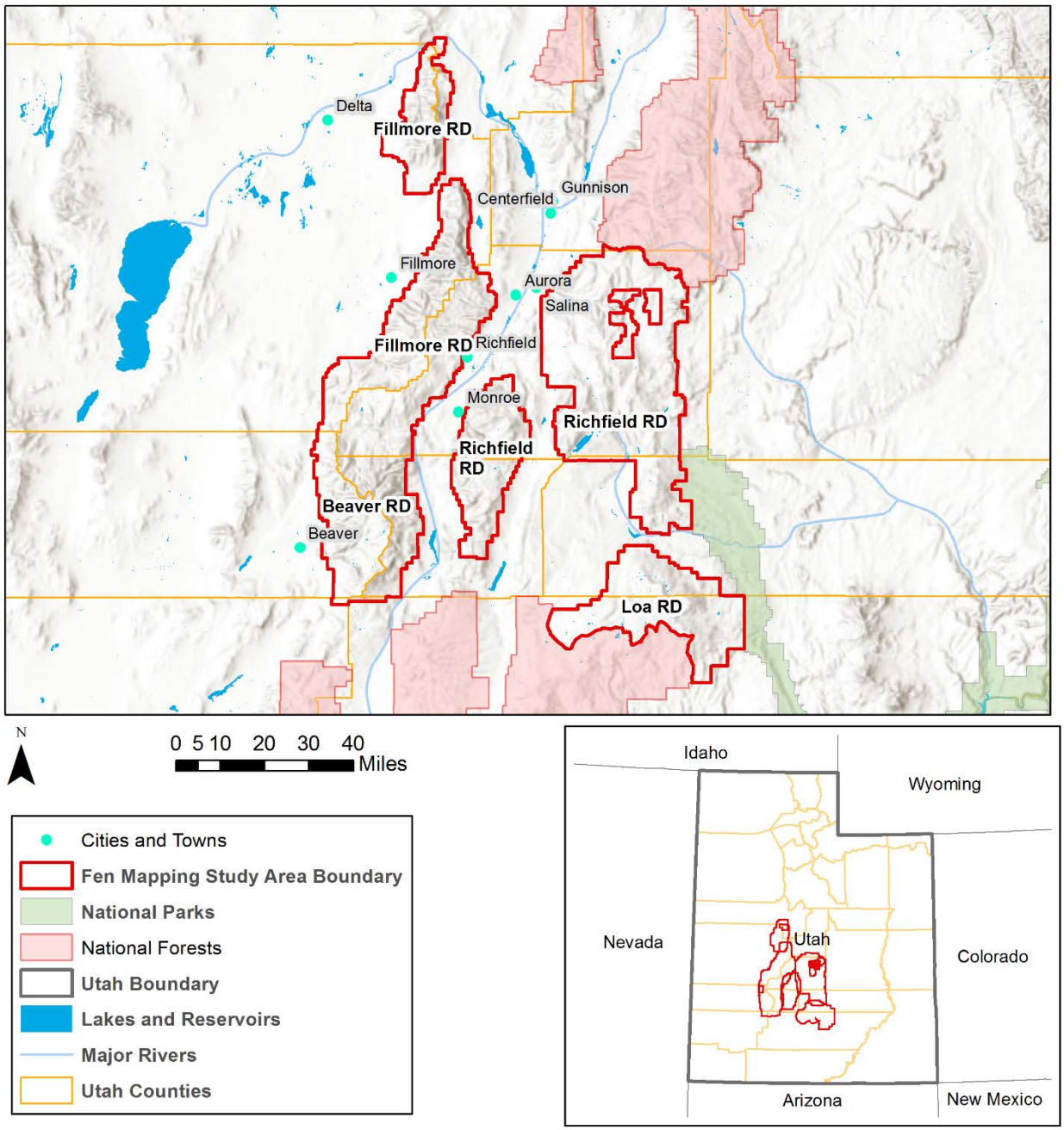


Figure 1. Location of the Fishlake National Forest (fen mapping study area) within Utah.

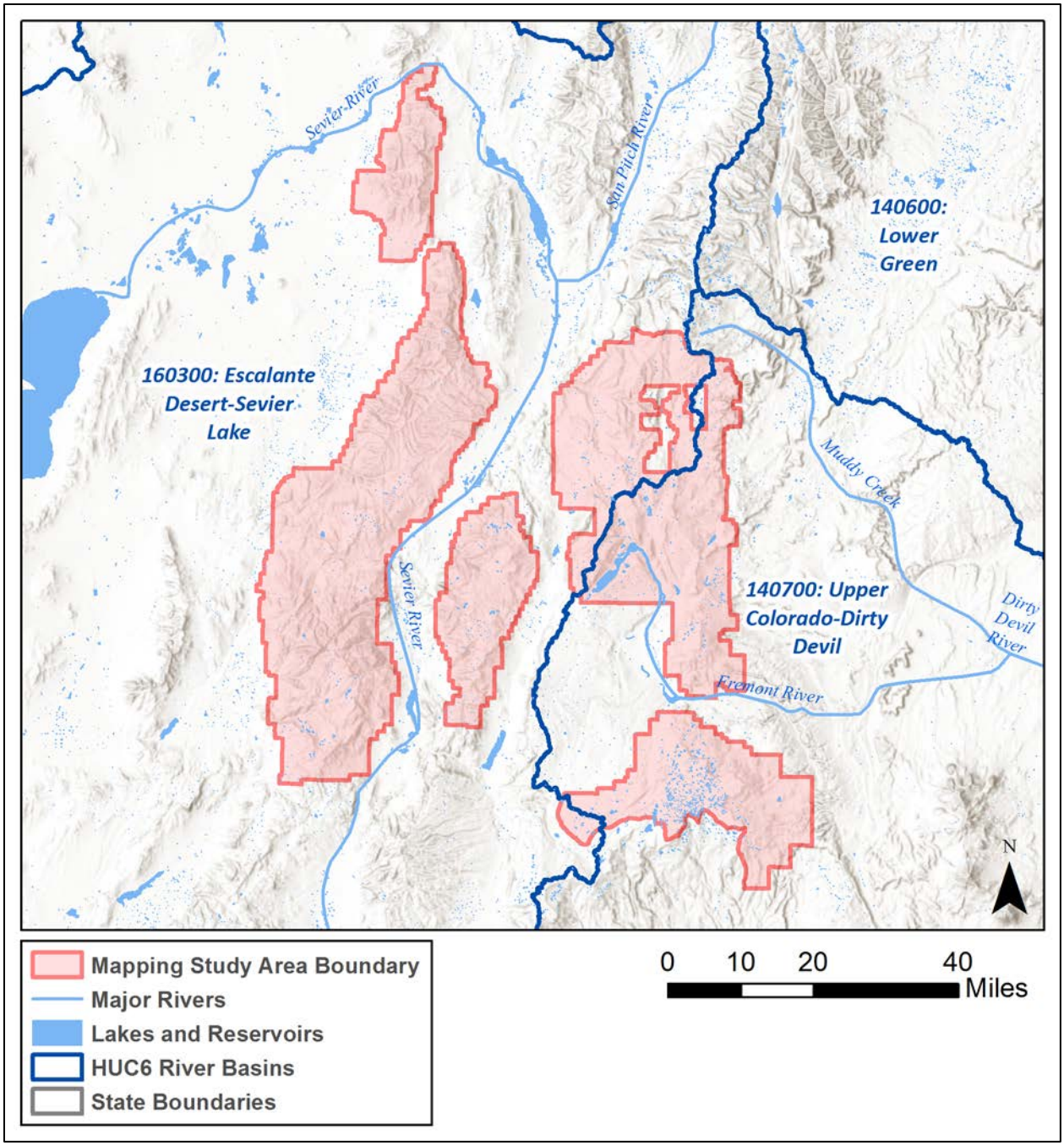


Figure 2. HUC6 river basins and major waterways in the fen mapping study area.

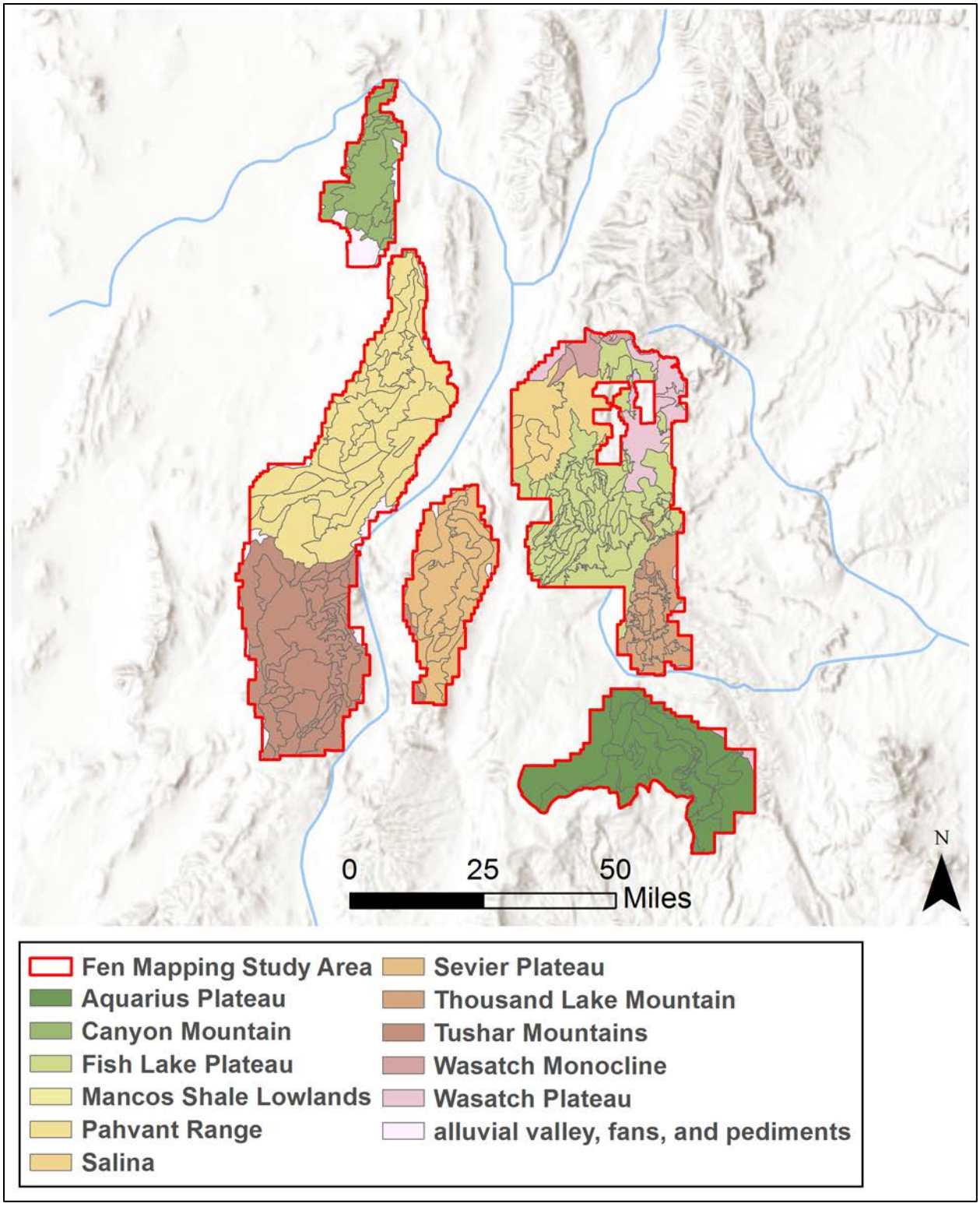


Figure 3. Land Type Association Subsections of the fen mapping study area.

2.3 Geology

Based on geologic mapping created by the Southwest ReGap (2004), the most common geology in the fen mapping study area is metamorphic or igneous, dominantly silicic, which covers 41% of the study area (Figure 4). The next most common geology is quaternary alluvium (20% of study area). Sandstone (19%) and shale (9%) are also common.

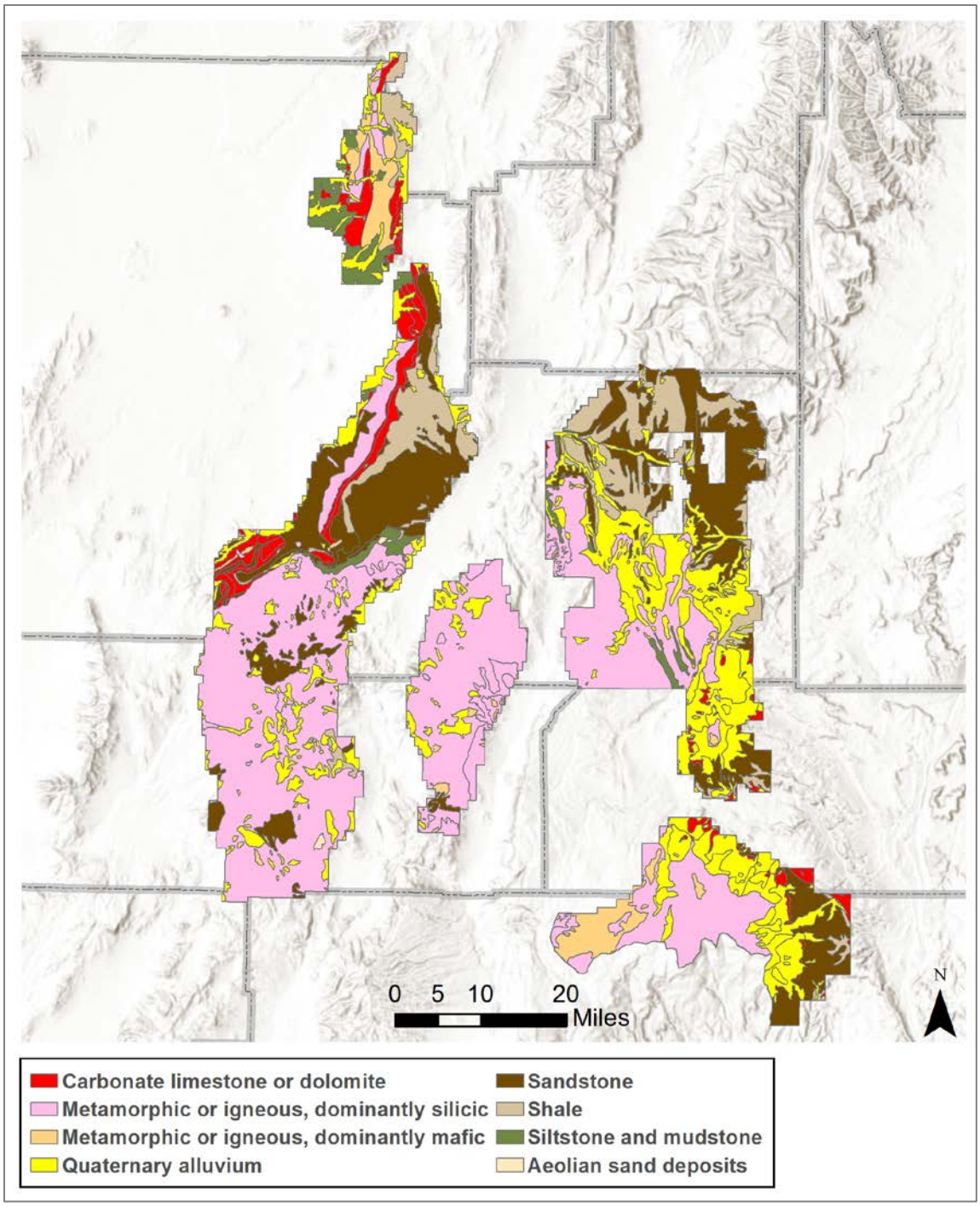


Figure 4. Geology within the fen mapping study area.

3.0 Fen Mapping Methods

Potential fens in the Fishlake National Forest were identified by analyzing digital aerial photography and topographic maps. True color aerial photography taken by the National Agricultural Imagery Program (NAIP) in 2018, 2014, 2011, and 2009 were used in conjunction with color-infrared imagery from 2016. High (but variable) resolution World Imagery from Environmental Systems Research Institute (ESRI) was also used. To focus the initial search, where possible, all wetland polygons mapped by the U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) program in the 1970s and early 80s with a "B" (seasonally saturated) hydrologic regime were isolated from the full NWI dataset and examined.[2] Wetlands mapped as Palustrine Emergent Saturated (PEMB) and Palustrine Scrub-Shrub Saturated (PSSB) were specifically targeted, as they can be 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.

Potential fen polygons were hand-drawn in ArcGIS 10.4 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 Fishlake National Forest 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 1). In addition to the confidence rating, any justifications of the rating or interesting observations were noted, including impoundments, beaver influence, floating mats and springs.

Table 1. Description of potential fen confidence levels.

Confidence	*Description*
5	***Likely fen.*** Strong photo signature of fen vegetation, fen hydrology, and good landscape position. All likely fens should contain peat of 40cm or more throughout the entire area of the mapped feature.
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. Possible fens may or may not have the required peat depth of 40cm, but may have patchy or thin peat throughout.
1	***Low confidence fen.*** At least one fen indicator present, but weak. Low confidence fens are consistently saturated areas that do not show peat signatures in the aerial photography, but may contain fen or peat.

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

4.0 RESULTS

4.1 Potential Fen Mapping Acreage

The final map of potential fens contained 2,323 potential fen locations (all confidence levels), covering 4,982 acres or 0.3% of the total land area (Table 2; Figures 5 and 6). This total included 199 likely ***fens*** (confidence level = 5), 604 ***possible fens***, and 1,520 ***low confidence fens.*** On average the likely fens much were larger in size than the possible and low confidence fens (5.83 acres vs. 1.85 or 1.78 acres), resulting in 1,161 acres of likely fens, 1,117 acres of possible fens, and 2,703 acres of low confidence fens. The size of individual potential fens ranged from over 204 acres to 0.2 acres. The two largest mapped likely fens are both adjacent to Fish Lake (Figures 7 and 8). Figure 9 displays a large high elevation (11,000 feet) fen complex in the Boulder Meadows area of the Aquarius Plateau.

Table 2. Potential fen counts and acreage, by confidence levels.

Confidence	*Count*	*Acres*	*Average size (acres)*
5 – Likely Fen	199	1,161	5.83
3 – Possible Fen	604	1,117	1.85
1 – Low Confidence Fen	1,520	2,703	1.78
TOTAL	**2,323**	**4,982**	**2.14**

Original NWI mapping for the Fishlake National Forest contained 1,632 acres with a "B" (seasonally saturated) hydrologic regime, including 1,483 acres of herbaceous wetlands (PEMB) and 149 acres of shrub wetlands (PSSB) and one acre of forested wetland (PFOB). These polygons were the starting point for potential fen mapping. However, photo-interpreted NWI data are not available for about half of Fishlake National Forest. In these areas, the available data are from a model developed by NWI that does not include most vegetated wetlands, like fens. This lack of comprehensive NWI data limits the meaningfulness of a comparison between NWI mapping and fen mapping.

After examining each polygon with a saturated hydrologic regime and the landscape surrounding them, fen polygons were drawn covering 59% of those acres (962 acres), while the remaining 31% were determined to not be potential fens. Polygons mapped as saturated herbaceous in NWI made up a greater share of the potential fens (95% of the fen/NWI overlap) than polygons mapped as saturated shrubs (5%). Finally, 4,020 acres not mapped as saturated by NWI were mapped as potential fens.

The sections that follow (4.2 through 4.5) break down the fen mapping by elevation range, geology, Land Type Association, and HUC12 watershed. The last section summarizes observations made by the fen mappers during the mapping process, including potential floating mat fens.

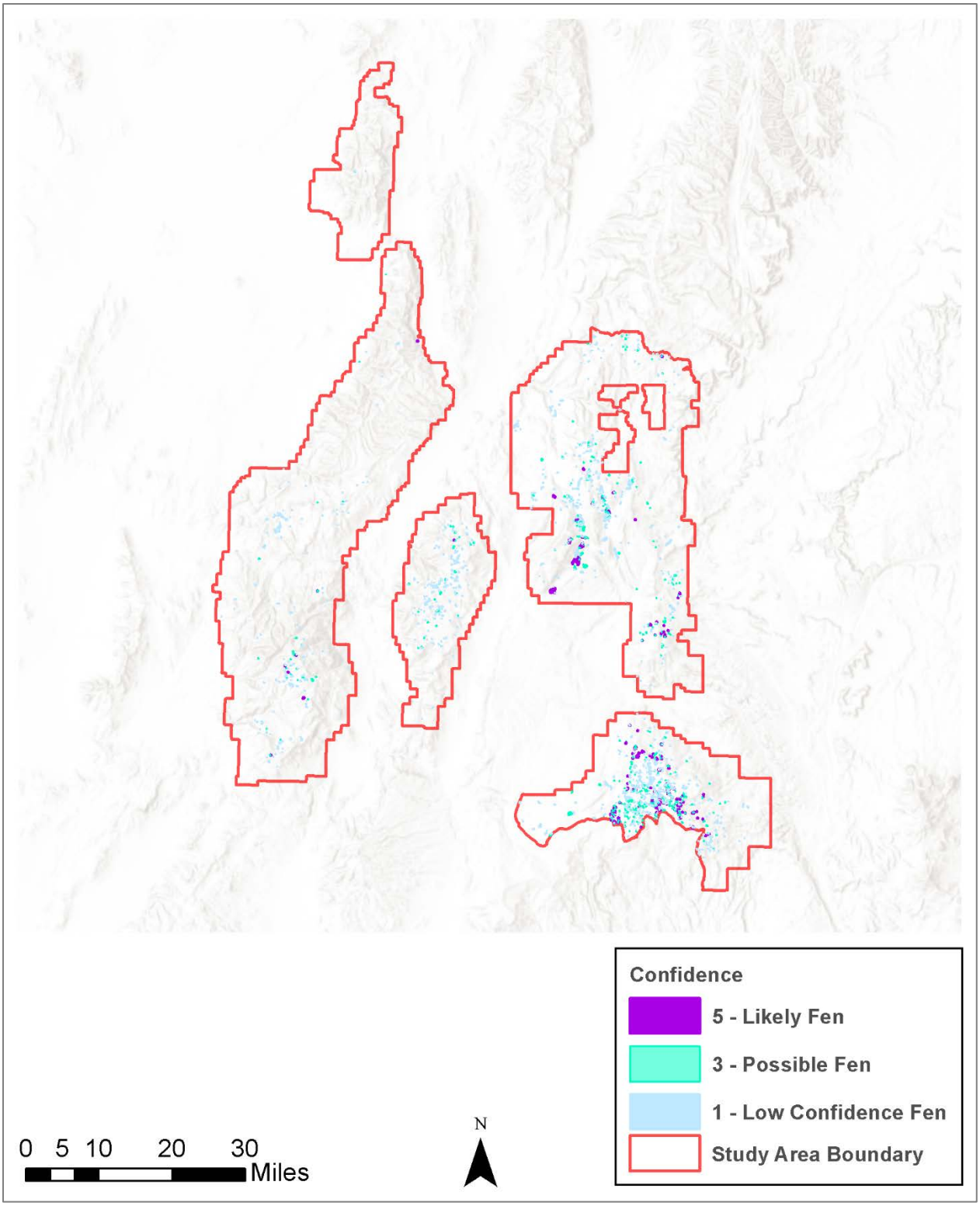


Figure 5. All potential fens within the fen mapping study area.

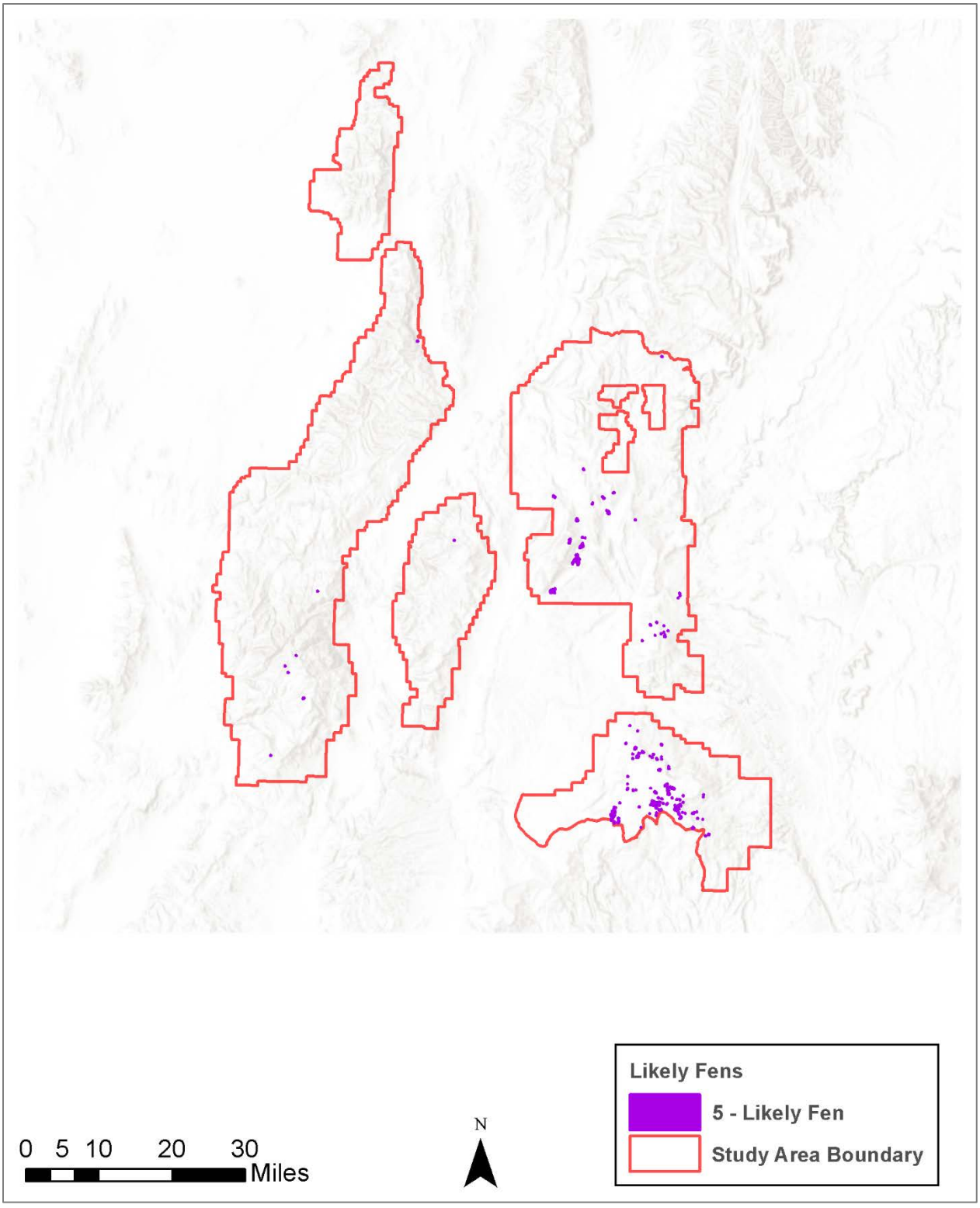


Figure 6. Likely fens (confidence rating = 5) within the fen mapping study area.

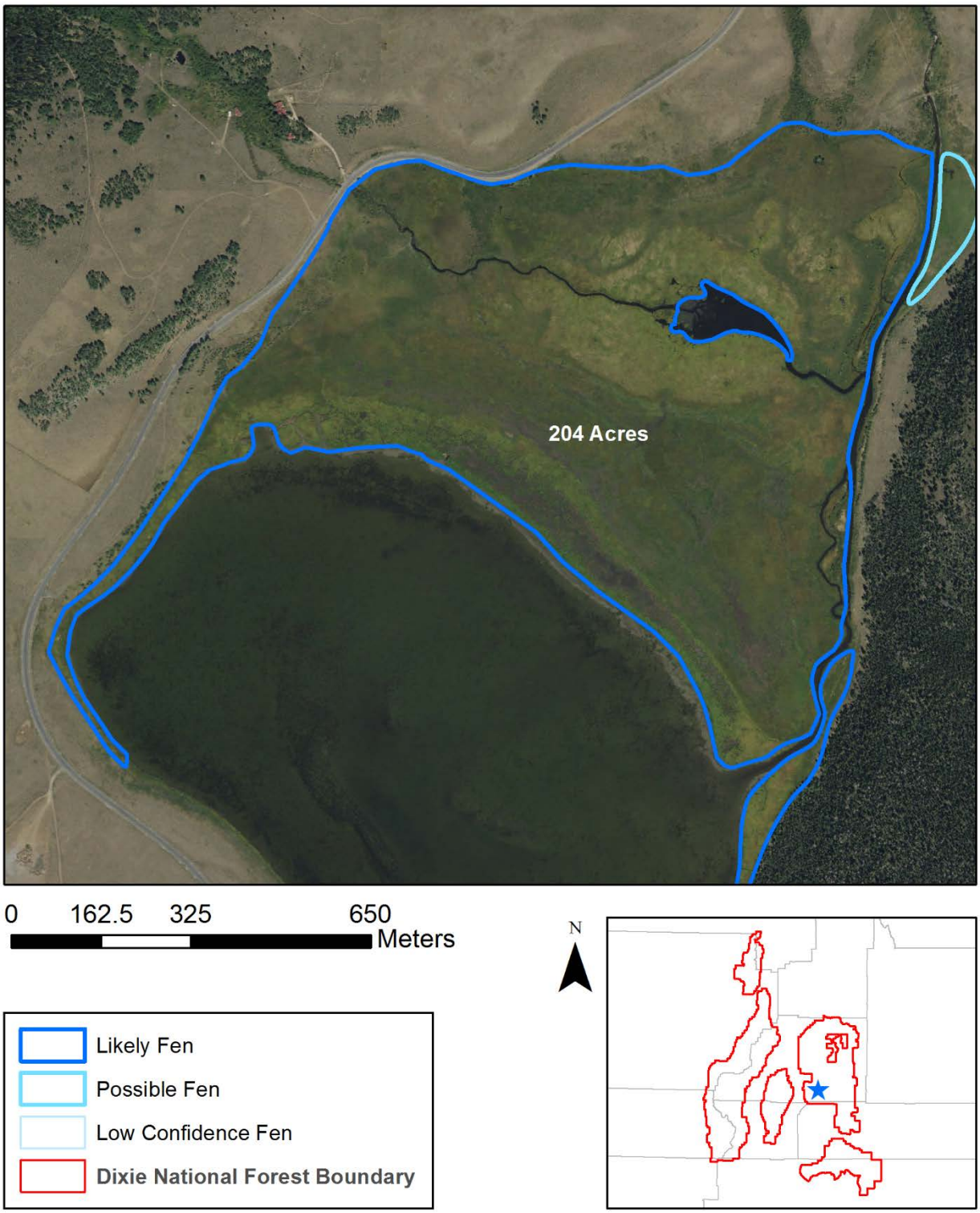


Figure 7. Largest mapped likely fen, 204 acres within one polygon. This fen is located adjacent to Widgeon Bay, at the north end of Fish Lake.

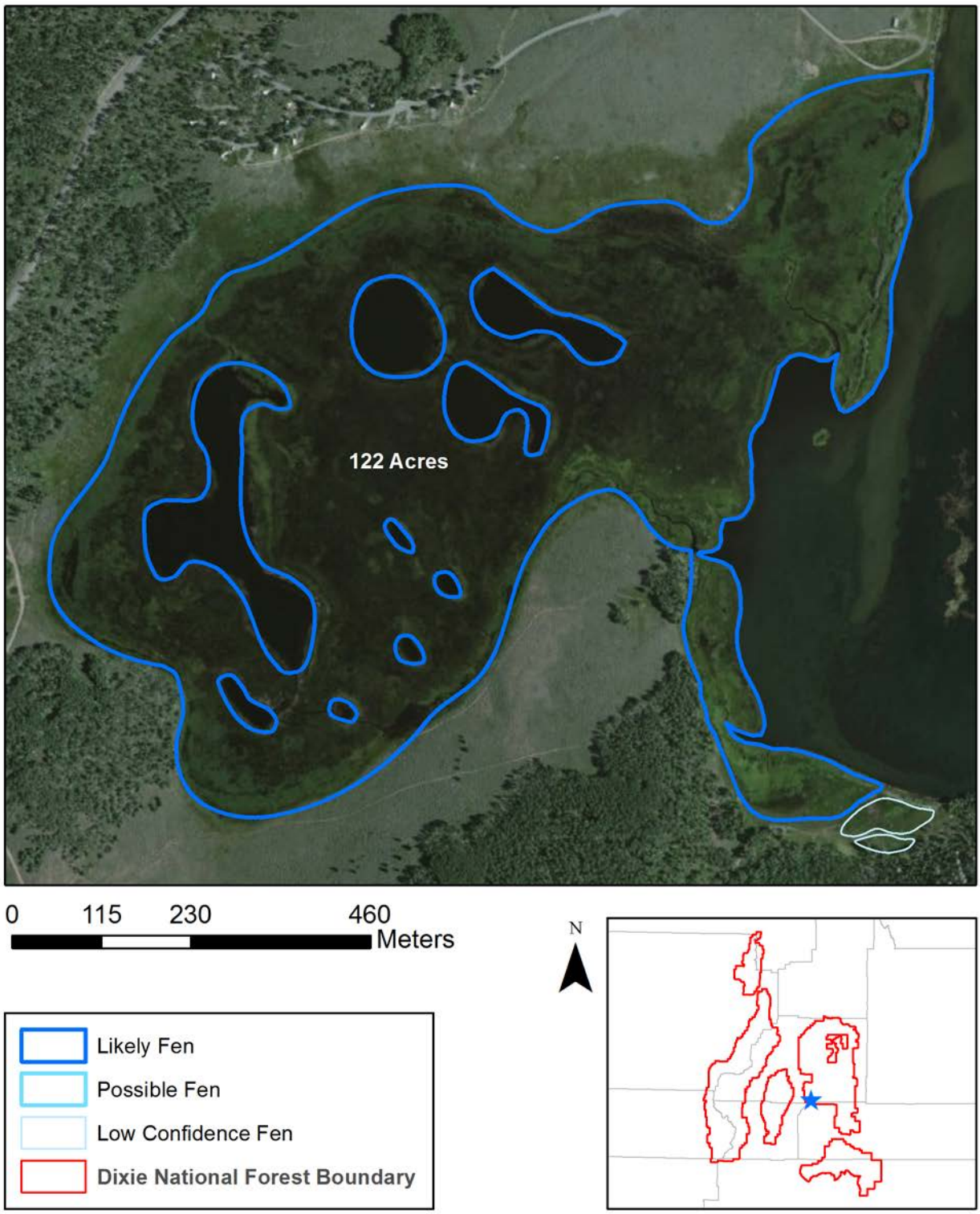


Figure 8. Second largest mapped likely fen, 122 acres within one polygon. This fen is located along the southwest bank of Mallard Bay in Fish Lake.

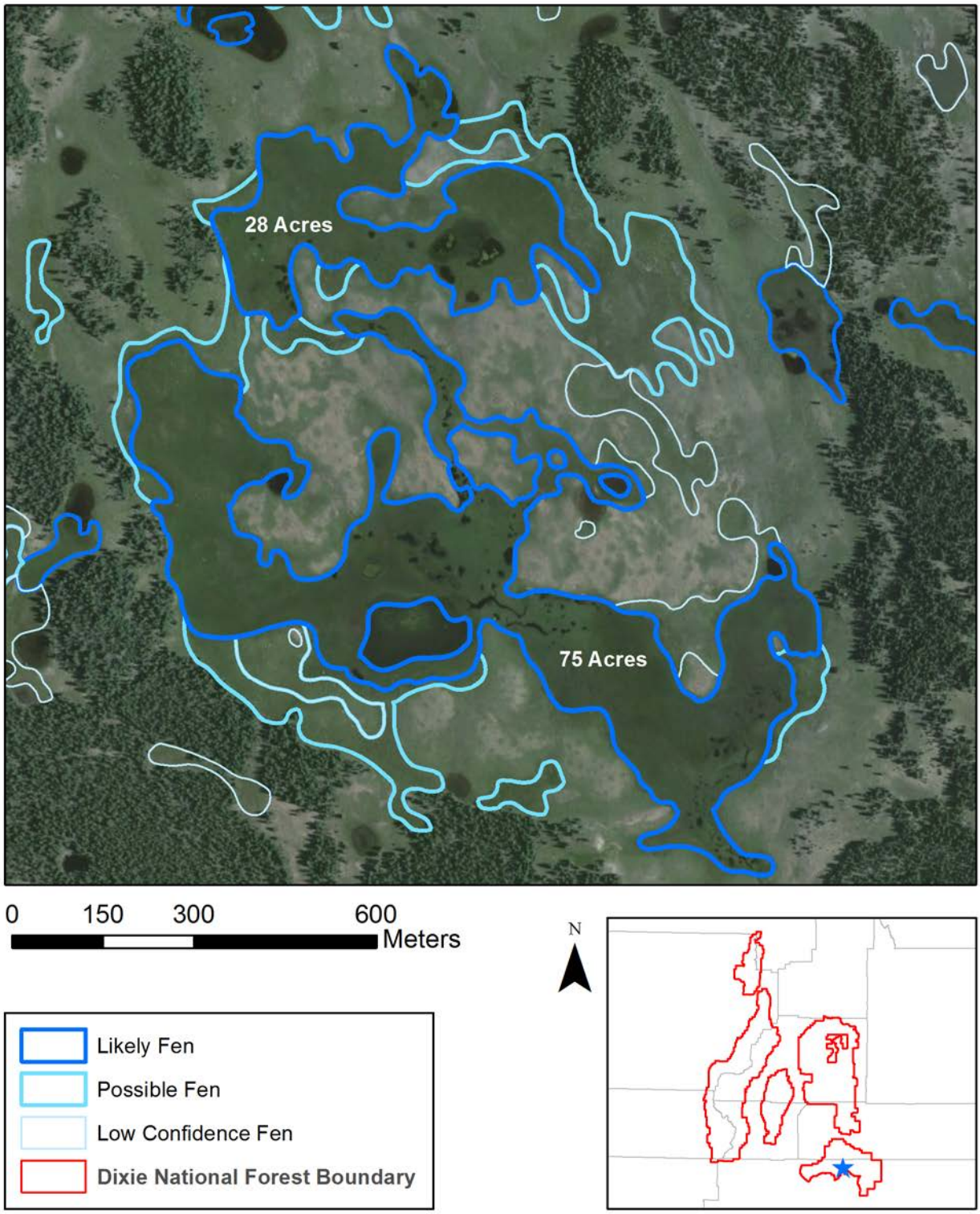


Figure 9: Large fen complex located in the Boulder Meadows area of the Aquarius Plateau.

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. Springs are also an important water source for fens in more arid regions and can occur across a wider elevation range.

Of all potential fens, 612 polygons (1,117 acres) were mapped between 10,000 and 11,000 feet, which represents 26% of potential fen locations and 22% of potential fen acres (Table 3; Figure 10). Of the 199 total likely fens mapped, 122 polygons (61%) and 266 acres (43%) were located between 10,000 and 11,000 feet (Table 3; Figures 11 and 12). The elevation band of 8,000 to 9,000 feet also has high acreages of mapped likely fens: nine likely fens represent 434 acres (37%), which suggests that the zones of maximum fen formation for the Fishlake National Forest are 8,000 to 9,000 feet and 10,000 to 11,000 feet.

The elevation bands of 9,000 to 10,000 feet also contain many potential and likely fens. Between 9,000 to 10,000 feet, there were 665 mapped potential fens (1,701 acres), which represent 29% of potential fen locations and 34% of potential fen acres. In addition, there were 35 likely fens (73 acres), which represent 18% of likely fen locations and 6% of likely fen acres.

These three elevation bands combined (8,000 to 11,000 feet) contain 68% of potential fen locations (79% of acres) and 83% of likely fen locations (87% of acres).

Table 3. 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*
< 8,000	220	447	3	6
> 8,000 – 9,000	299	1,112	9	434
> 9,000 – 10,000	665	1,701	35	73
> 10,000 – 11,000	612	1,117	122	498
> 11,000	527	604	27	150
Total	**2,323**	**4,982**	**199**	**1,161**

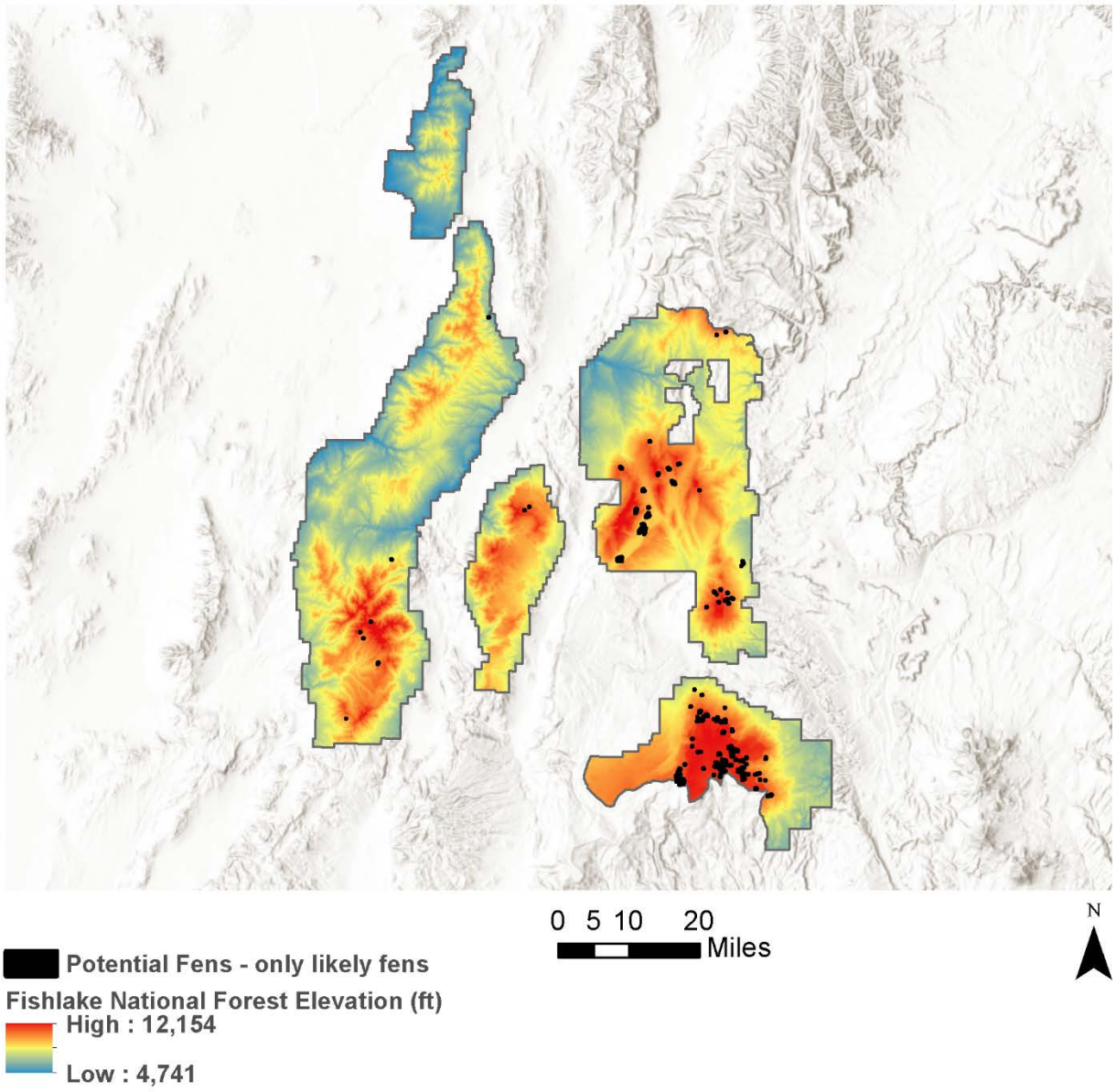


Figure 10: Likely fens (confidence rating = 5) and elevation within the fen mapping study area.

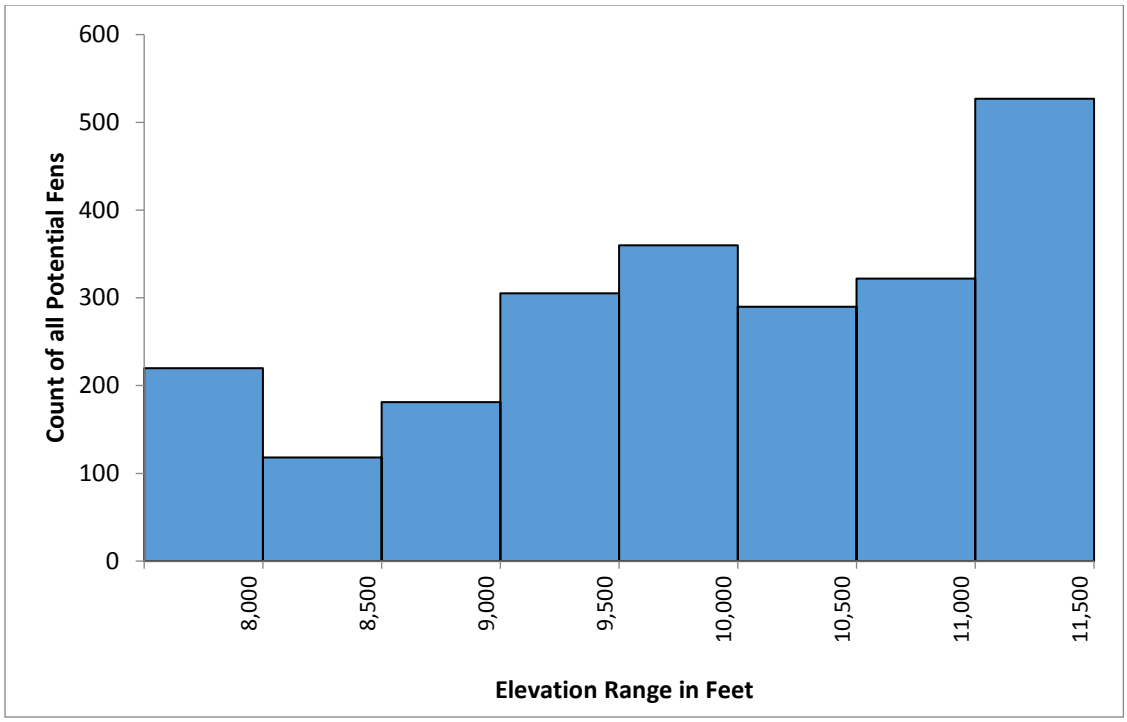


Figure 11. Histogram of all potential fens by elevation within the fen mapping study area.

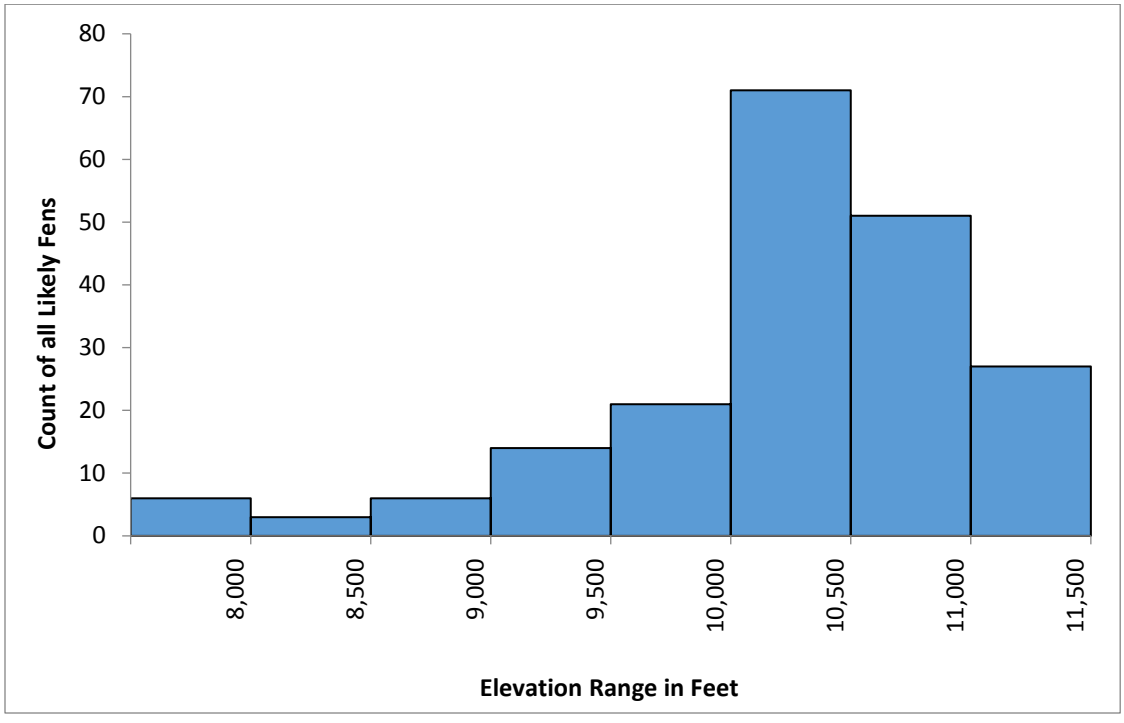


Figure 12. Histogram of the most likely fens by elevation within the fen mapping study area.

4.3 Mapped Potential Fens by Geology

The most common geologic substrate under potential fens in Fishlake National Forest was metamorphic or igneous units with dominantly silicic composition, which underlie 1,293 mapped potential fens (2,665 acres). The most common geologic substrates under likely fens were metamorphic or igneous units with a dominantly silicic composition, which underlie 95 mapped likely fens (593 acres), and quaternary age younger alluvium, which underlies 100 mapped likely fens (565 acres) (Table 4). While quaternary age younger alluvium is the geology underlying only 24% of the Forest, 35% of all potential fens and 50% of likely fens occurred in these areas. Alluvium typically occurs at the toe of slopes as alluvial fans or within the floodplains of rivers and other low-lying areas that can accumulate alluvial material over time. Similarly, fens often form at the toe of slopes or the edges of floodplain valleys where there is a distinct break in slope, locations that are likely to contain alluvium.

Table 4. Potential and likely fens by geologic substrate within the fen mapping study area

Geology	*Acres of Geologic Substrate Within HTNF*[1]	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Metamorphic or igneous units with a dominantly silicic composition all ages	726,305	1,293	2,665	95	593
Quaternary age younger alluvium and surficial deposits	355,493	802	1,998	100	565
Shale dominated formations of all ages	164,842	93	113	1	1
Sandstone dominated formations of all ages	333,175	89	109	2	2
Metamorphic or igneous units with dominantly mafic composition all ages	62,905	28	79		
Carbonate dominated formations either limestone or dolomites of all ages	82,643	9	5	1	<1
Siltstone and or mudstone dominated formations of all ages	46,916	6	9	--	--
Quaternary age older alluvium and surficial deposits	14,185	3	5	--	--
		2,323	**4,982**	**199**	**1,161**

[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 Fishlake National Forest.

4.4 Mapped Potential Fens by Land Type Association

Land Type Associations (LTA) combine location, geology, and dominant vegetation and are defined by each Forest. The LTA subsection Aquarius Plateau covers 17% of the Fishlake National Forest but this LTA contains 48% of potential fens (1,106) and 69% likely fen locations (131) in Fishlake National Forest. LTA subsection Fish Lake Plateau covers 18% of the Forest and contains 19% of potential fens (346), 17% of likely fens (33), and 42% of likely fen acres (490). The Thousand Lake Mountain subsection covers only 6% of the Forest yet it contains 161 mapped potential fens (122 acres) and 22 likely fens (18 acres) (Table 5).

Table 5. Potential and likely fens by Land Type Association within the fen mapping study area.

Land Type Association Subsection Name	*Acres within Fishlake National Forest*[1]	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Aquarius Plateau	249,890	1,106	1,935	131	633
Fish Lake Plateau	263,942	436	1,809	33	490
Sevier Plateau	167,084	216	502	2	2
Tushar Mountains	298,252	169	224	6	14
Thousand Lake Mountain	86,049	161	122	22	18
Pahvant Range	369,493	93	165	2	3
Salina	100,227	54	171	--	--
Wasatch Plateau	74,844	38	28	3	2
Wasatch Monocline	22,198	35	23	--	--
Canyon Mountain	96,065	10	2	--	--
alluvial valley, fans, and pediments	54,311	5	2	--	--
		2,323	**4,982**	**199**	**1,161**

[1] Acres of Land Type Associations 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 Fishlake National Forest.

4.5 Mapped Potential Fens by Watershed

An analysis of likely fens in HUC12 watersheds revealed interesting patterns. Three watersheds in particular had significant numbers of likely fens (Figure 13). Headwaters Boulder Creek (HUC12: 140700050206) had 34 likely fens, which covered 0.55% of the landscape in this watershed. Rock Spring Draw (HUC12: 140700030207) had 26 likely fens, covering 0.23% of the landscape. Upper Pleasant Creek (HUC12: 140700030401) also had 26 likely fens, representing 0.25% of the landscape. One additional watershed stands out with a high likely fen acreage: Fish Lake (HUC12: 140700030102) had 4 likely fens representing 2.03% of the basin.

See Appendix A for the full HUC12 watershed and likely fens table.

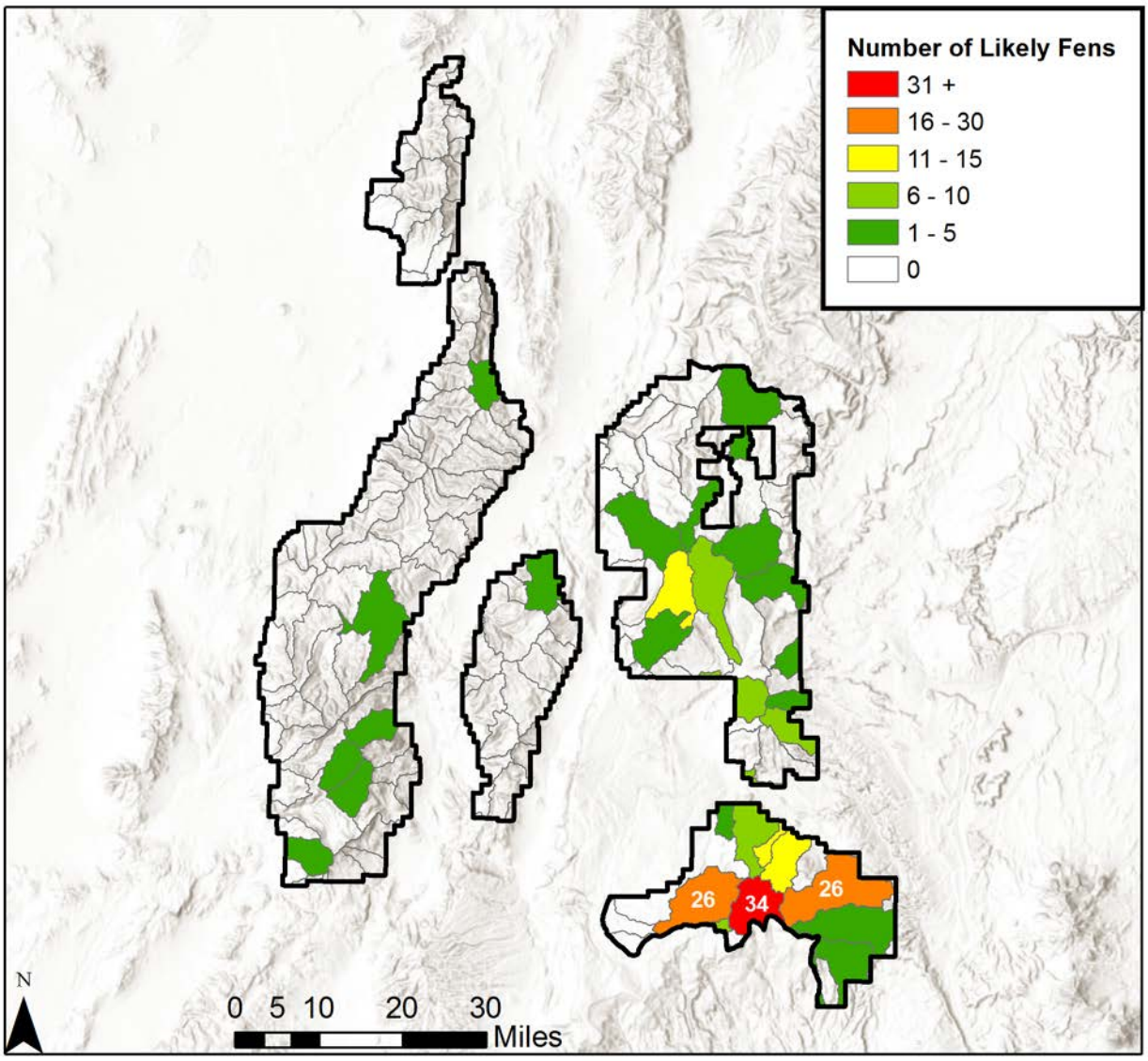


Figure 13. Likely fens by HUC12 watershed within the fen mapping study area.

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 6), though this was not an original objective of the project and was not consistently applied.

Of particular interest was identifying markers for potential floating mat fens, a rare type of fen that may occur in Fishlake National Forest (Kate Dwire, *personal communications*). Sixty potential fens (125 acres) and eighteen likely fens (87 acres) were identified as potential floating mat fens. See Figure 14 for a large likely fen that shows floating mat characteristics located on the Aquarius Plateau.

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. Two hundred potential fens and five likely 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. Thirty-four potential fens (230 acres) showed some evidence of beaver influence.

Table 6. 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*
Spring	200	330	5	9
Possible Floating Mat	60	125	18	87
Beaver Influence	34	230	--	--
Total	**293**	**685**	**23**	**96**

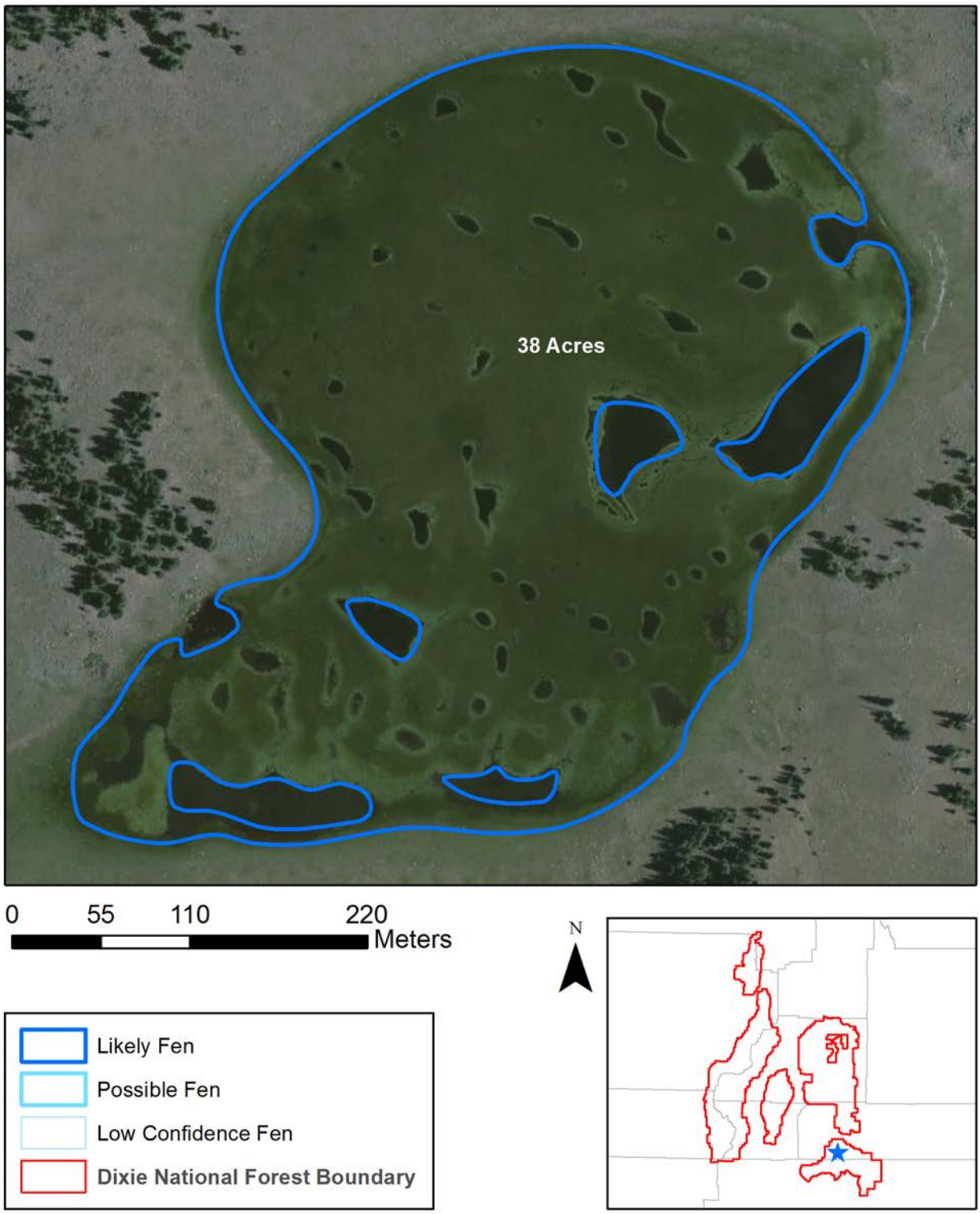


Figure 14. Possible floating mat fen located in Grass Lake, on the Aquarius Plateau.

5.0 Discussion

The Fishlake National Forest contains a relatively small number of potential fen wetlands, covering up to 4,982 acres across its jurisdiction. Some of the landforms in Dixie National Forest are not conducive to fen formation, with the notable exceptions of landforms on the Aquarius and Fish Lake Plateaus. While the potential fen resource represents only a very small portion of the entire landscape, these fen wetlands are an irreplaceable resource for the Forest and the citizens of Utah. Fens throughout the West 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). 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, 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).

In total, 2,323 potential fens were mapped throughout the Dixie National Forest, of which 199 were most likely to be fens. Analysis of the potential fen data showed clear patterns in fen distribution within the Dixie National Forest. There was a strong elevation gradient, with 83% of likely fens falling between 8,000 and 11,000 feet. 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 Fishlake National Forest, particularly the Headwaters of Boulder Creek, which was also identified as a fen hotspot in the adjacent Dixie National Forest (Smith and Lemly 2018b). The Rock Spring Draw, Upper Pleasant Creek and Fish Lake watersheds all contain high numbers of likely fen locations or acres. These areas should be actively conserved.

Previous studies of wetland condition in other high elevation forests have found that high elevation wetlands were generally in excellent to good condition (Lemly 2012). Human stressors were observed in some fen wetlands while mapping fens on the Dixie National Forest, such as impoundments or excavated ponds, and those observations were captured in the “Notes” field of the GIS dataset accompanying this report. However most potential fens in Fishlake National Forest showed little sign of human disturbance, particularly at higher elevations.

This report and associated dataset provide the Fishlake National Forest with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing Fishlake National Forest 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. 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.

6.0 LITERATURE CITED

Chimner, R. A. (2000) Carbon dynamics of Southern Rocky Mountain fens. Carbon dynamics of Southern Rocky Mountain fens, Ph.D. Dissertation, Colorado State University, Ft. Collins, CO.

Chimner, R.A. and D.J. Cooper. (2002) Modeling carbon accumulation in Rocky Mountain fens. Wetlands 22: 100-110.

Chimner, R.A., J.M. Lemly, and D.J. Cooper. (2010) Mountain fen distribution, types, and restoration priorities, San Juan Mountains, Colorado, USA. *Wetlands,* **30:** 763–771.

Cooper, D.J. (1996) Water and soil chemistry, floristics, and phytosociology of the extreme rich High Creek Fen, in South Park, Colorado, USA. *Canadian Journal of Botany*, **74**, 1801-1811.

Johnson, J.B. and Steingraeber, D.A. (2003) The vegetation and ecological gradients of calcareous mires in the South Park Valley, Colorado. *Canadian Journal of Botany*, **81**, 201-219.

Lemly, J. (2012) Assessment of Wetland Condition on the Rio Grande National Forest. Colorado Natural Heritage Program, Fort Collins, CO.

Lemly, J.M. and D.J. Cooper. (2011) Multiscale factors control community and species distribution in mountain peatlands. *Botany,* **89:** 689–713.

Lemly, J.M., R.E. Andrus, and D.J. Cooper (2007) *Sphagnum lindbergii* Schimp. in Lindb. and other new records of *Sphagnum* in geothermal fens, Yellowstone National Park, Wyoming, USA. *Evansia*, **24:** 31–33.

Malone, D., E. Carlson, G. Smith, D. Culver, and J. Lemly. (2011) Wetland Mapping and Fen Survey in the White River National Forest. Colorado Natural Heritage Program, Fort Collins, CO.

McKinstry, M.C., W.A. Hubert and S.H. Anderson (eds.) (2004) *Wetland and Riparian Areas of the Intermountain West: Ecology and Management.* University of Texas Press, Austin, TX.

Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-Being: Biodiversity Synthesis*. Island Press, 2005.

Mitsch, W. J., and Gosselink, J. G. (2007). *Wetlands, Fourth Edition.* Louisiana State University, Baton Rouge, LA.

Redlefs, A.E. (1980) Wetland values and losses in the United States. M.S. thesis. Oklahoma State University, Stillwater, OK.

Smith, G. J. Lemly, P. Smith, and B. Kuhn. (2016) Fen Mapping for the Rio Grande National Forest. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Smith, G. J. Lemly, and K. Schroder. (2017) Fen Mapping for the Salmon-Challis National Forest. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Smith, G. and J. Lemly. (2017a) Fen Mapping for the Ashley National Forest. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Smith, G. and J. Lemly. (2017b) Fen Mapping for the Manti-La Sal National Forest. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Smith, G. and J. Lemly. (2018a) Fen Mapping for the Bridger-Teton National Forest. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Smith, G. and J. Lemly. (2018b) Fen Mapping for the Dixie National Forest. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Smith, G. and J. Lemly. (2019) Fen Mapping for the Humboldt-Toiyabe National Forest. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

Soil Survey Staff. (2014) *Keys to Soil Taxonomy, Twelfth Edition.* USDA Natural Resources Conservation Service, Washington, DC.

U.S. Department of Agriculture (USDA) (2012) Groundwater-Dependent Ecosystems: Level 1 Inventory Field Guide. *Gen. Tech. Report WO-86a.* USDA Forest Service, Washington, DC.

U.S. Department of Agriculture (USDA) (2019) HT LTA Development. *GTAC-10xxxx-Brief 1.* USDA Forest Service, Geospatial Technology and Applications Center, Salt Lake City, UT.

U.S. Geological Survey (USGS) (2004) *1:500,000 Scale Geology for the Southwestern U.S.* RS/GIS Laboratory, College of Natural Resources, Utah State University, Salt Lake City, UT.

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)
140700050206	Headwaters Boulder Creek	33998	34	187	0.55%
140700030207	Rock Spring Draw	30393	26	71	0.23%
140700030401	Upper Pleasant Creek	40815	26	102	0.25%
140700030103	Sevenmile Creek	19428	13	87	0.45%
140700030302	Fish Creek	18697	12	96	0.51%
140700030305	Donkey Creek-Fremont River	22192	11	16	0.07%
140700030308	Upper Deep Creek	22729	10	7	0.03%
140700030101	U M Creek	28043	9	17	0.06%
140700030301	Boulder Creek-Fremont River	33623	8	95	0.28%
140700050105	Upper Pine Creek	33051	7	38	0.11%
140700030106	Reese Creek-Fremont River	25751	6	7	0.03%
140700020504	Temple Wash	33544	5	4	0.01%
140700030102	Fish Lake	18251	4	370	2.03%
160300030402	Skumpah Creek-Salina Creek	37295	3	2	0.00%
140700020101	Clear Creek-Meadow Draw Creek	24933	3	2	0.01%
140700030406	Oak Creek	37345	3	2	0.01%
160300070201	Merchant Creek	11872	2	3	0.02%
160300030308	Water Creek	34236	2	2	0.00%
160300030505	Headwaters Lost Creek	25811	2	9	0.03%
160300050101	Pharo Creek-Ivie Creek	14596	2	3	0.02%
140700050401	Upper the Gulch	33355	2	12	0.04%
160300070202	Three Creeks	12559	1	7	0.06%
160300070205	Big Twist Creek-South Creek	13909	1	1	0.01%
160300030105	Outlet Clear Creek	30591	1	2	0.01%
160300030205	Pine Creek	14568	1	1	0.00%
160300030403	Niotche Creek	13153	1	4	0.03%
140700050207	Deer Creek	30767	1	13	0.04%

140700030209	Lower Pine Creek	19489	1	2	0.01%
140700030307	Polk Creek	18765	1	0	0.00%
140700020501	Last Chance Creek	22078	1	2	0.01%