Fen Mapping for the Manti-La Sal National Forest

April 2017

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

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EXECUTIVE SUMMARY

The Manti-La Sal National Forest (MLSNF) covers 1.4 million acres in four discontinuous units within central and southeast Utah. Wetlands within the MLSNF 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 MLSNF 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 MLSNF.

Potential fens in the MLSNF 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 1,118 potential fen locations (all confidence levels), covering 1,544 acres or 0.1% of the total land area. This total included 30 ***likely fens***, 336 ***possible fens***, and 752 ***low confidence fens.*** The average fen polygon was just 1.38 acres, but the largest likely fen polygon was over 32 acres.

Fen distribution was analyzed by elevation, bedrock geology, Land Type Association, and watershed. The vast majority of mapped potential fens occurred between 8,000 to 10,000 feet. This elevation range contained 73% of all potential fen locations and 70% of likely fen locations. The majority of likely fen locations and acres occurred in the Wasatch Plateau Northern Fault Valley Land Type Association. Likely fens were concentrated in four particular watersheds: Left Fork of Huntington Creek had 7 likely fens, Lowry Water had 6 likely fens, Indian Creek had 6 likely fens and Ferron-Reservoir-Ferron Creek had 5 likely fens. All of the watersheds with likely fens were in the Ferron-Price Ranger District.

This report and associated dataset provide the MLSNF with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing MLSNF 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. Thanks to, John Proctor, Regional Botanist for U.S. Forest Service Region 4, for supporting this project. Special thanks also to Forest Service botanist Nathan Dulfon for providing potential fen locations in Manti La Sal National Forest based on rare plant observations that were invaluable in this mapping effort.

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 Sarah Marshall, CNHP Wetland Ecologist, for conducting a review of mapped fens. 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.

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1.0 INTRODUCTION

The Manti-La Sal National Forest (MLSNF) covers nearly 1.4 million acres in four discontinuous units within central and southeast Utah. The Forest spans a broad elevation range from 5,279 ft. to 12,706 ft. and is dominated by sedimentary bedrock geology. Several types of wetlands occur within MLSNF. Snowfall in the mountains percolates through shallow mountain soils and creates wet meadows, riparian shrublands, and a limited area of organic soil wetlands known as fens. All wetland habitats provide important ecological services to both MLSNF 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. 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. Through the process of conducting the biological assessment, biologists at the MLSNF 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 MLSNF. This project builds upon CNHP's previous projects mapping fens on the White River National Forest (Malone et al. 2011) and the Rio Grande National Forest (Smith et al 2016).

[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 Manti-La Sal National Forest (MLSNF), which is administered as four discontinuous units in central and southeast Utah (Figure 1). The largest unit includes the Ferron-Price Ranger Districts, located on portions of the Wasatch Plateau and Monocline south of Provo. The smallest unit, the Sanpete Ranger District, is located west of Ferron-Price, separated by the San Pitch River valley. The Moab Ranger District contains the La Sal Mountains east of Moab. A small portion of this district extends into Colorado. The Monticello Ranger District is the farthest south and contains the Abajo Mountains and a portion of the Gunnison Plateau. Arches and Canyonlands National Park are both located in the middle of the four MLSNF units.

The MLSNF includes portions of the following Utah Counties: Juab, Utah, Sanpete, Carbon, Emery, Sevier, Grand and San Juan, as well as small portions of Montrose and Mesa Counties in Colorado. The largest municipalities near the study area are Provo, Ferron, Price, Ephraim, Moab and Monticello, all in Utah. Elevation in the study area ranges from 5,279 ft. (1,609 m) to 12,706 ft. (3873 m) and the mean elevation is 10,436 ft. (3,181 m).

The MLSNF straddles six different HUC6 river basins: the Jordan River Basin, which drains north to Great Salt Lake; the Escalante Desert-Sevier Lake Basin, which drains west and terminates in Sevier Lake; and the Lower Green, Upper Colorado-Delores, Upper Colorado-Dirty Devil, and Lower San Juan Basins, which are all part of the Colorado River system (Figure 2). Two major rivers have headwaters in MLSNF: Muddy Creek, which eventually becomes the Dirty Devil River, flows southeast out of the Ferron-Price Ranger District towards the Colorado River. The San Pitch River flows southwest out of the Ferron-Price towards the Sevier River.

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. The MLSNF LTA system is still in draft form and contains 118 LTAs, grouped into 45 LTA groups. Those groups are generally nested in subsections, which are displayed in Figure 3. The most common LTA subsection in the study area is the Wasatch Plateau, which makes up 44% of the study area, all in the Ferron-Price Ranger Districts. The next most common is the Elk-Ridge-Cottonwood Creek Canyons LTA subsection, which is 14% of the study area located in the Monticello Ranger District. The La Sal Mountains Borderlands and the Wasatch Monocline both comprise 9% of the MLSNF, and the Abajo Mountains cover 8%. The LTA maps and tables in this report are based on a draft LTA dataset, dated March 8, 2017.

2.3 Geology

The most common type of geology in the fen mapping study area is sandstone, which covers 43% of the study area followed by shale (37%) (Figure 4). The next most common geology is quaternary alluvium along the floodplains of major rivers and streams (9%). Carbonate limestone or dolomite together cover 9% of study area, primarily found in the far western portion of the study area.

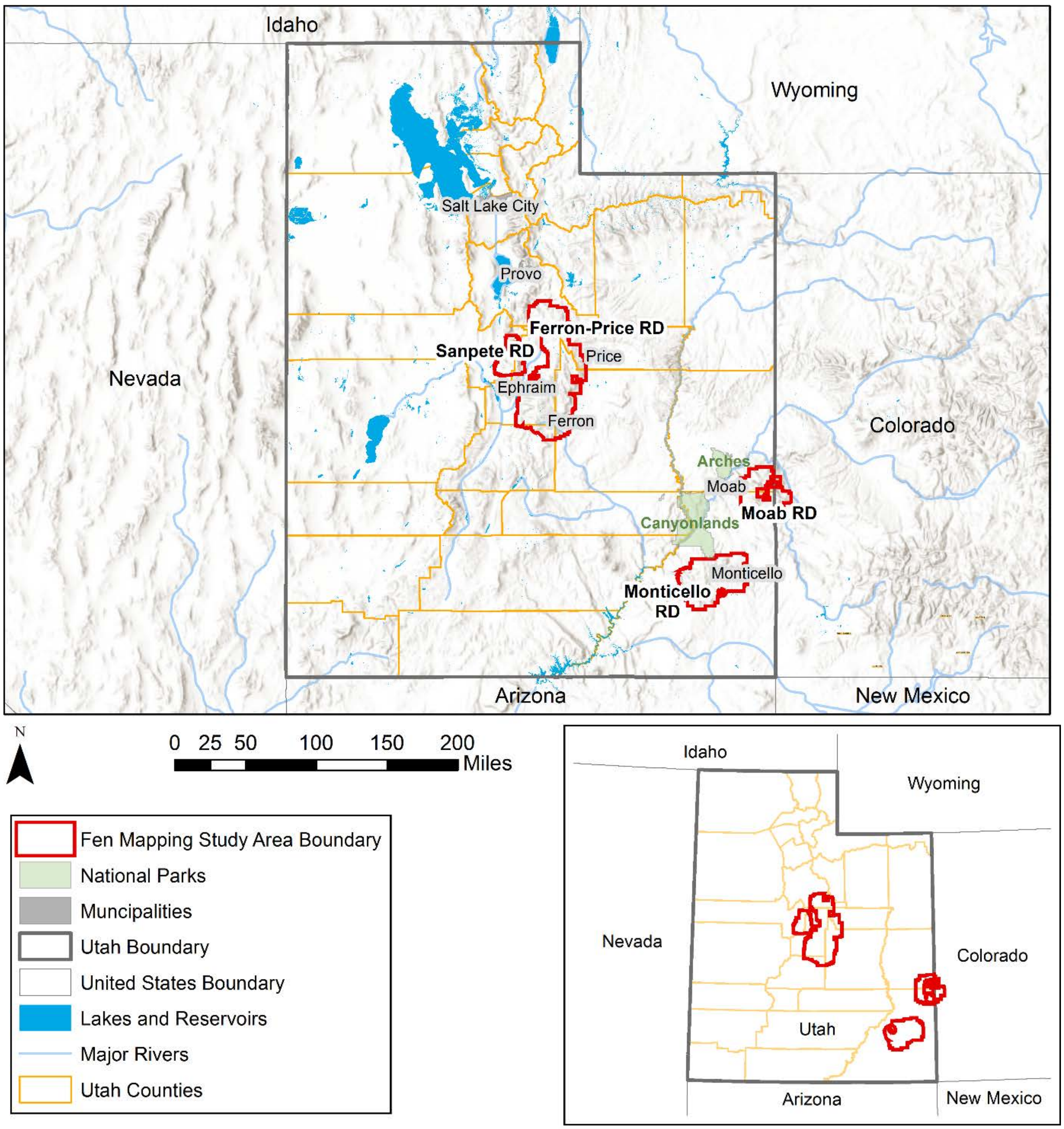

Figure 1. Location of the Manti-La Sal National Forest (fen mapping study area) within the state of Utah.

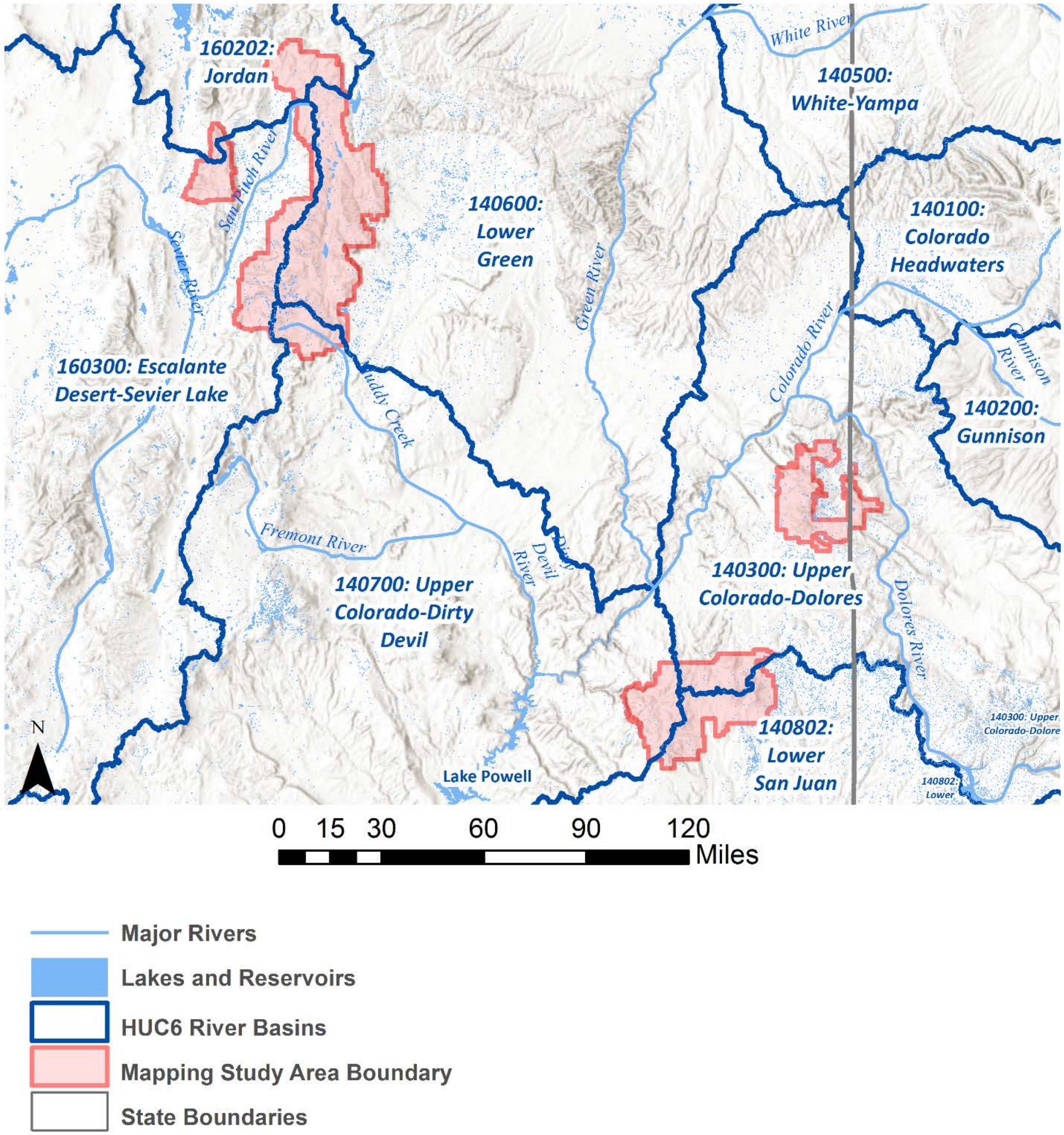

Figure 2. HUC6 river basins and major waterways in the fen mapping study area.

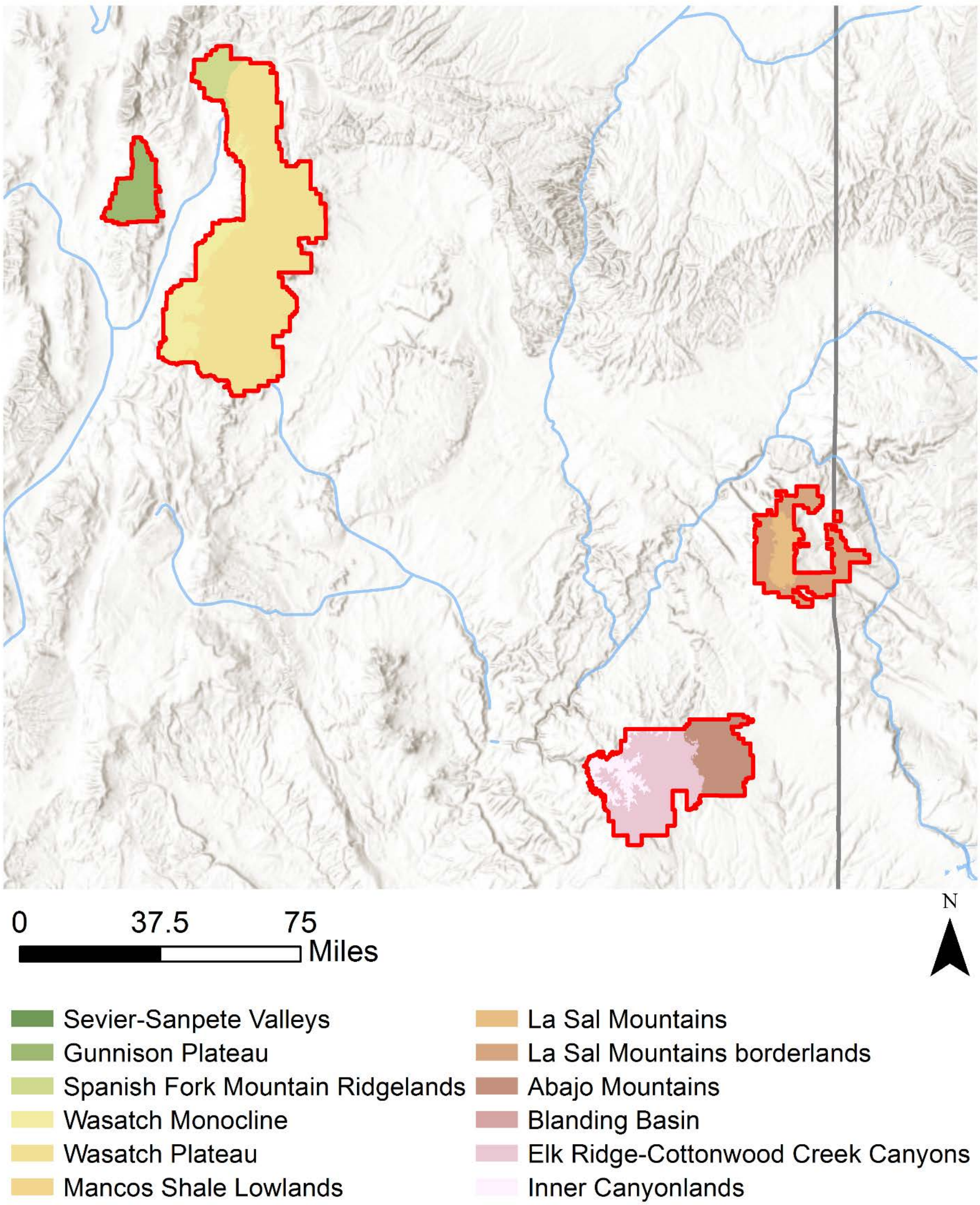

Figure 3. Land Type Associations of the fen mapping study area, symbolized by subsection Name.

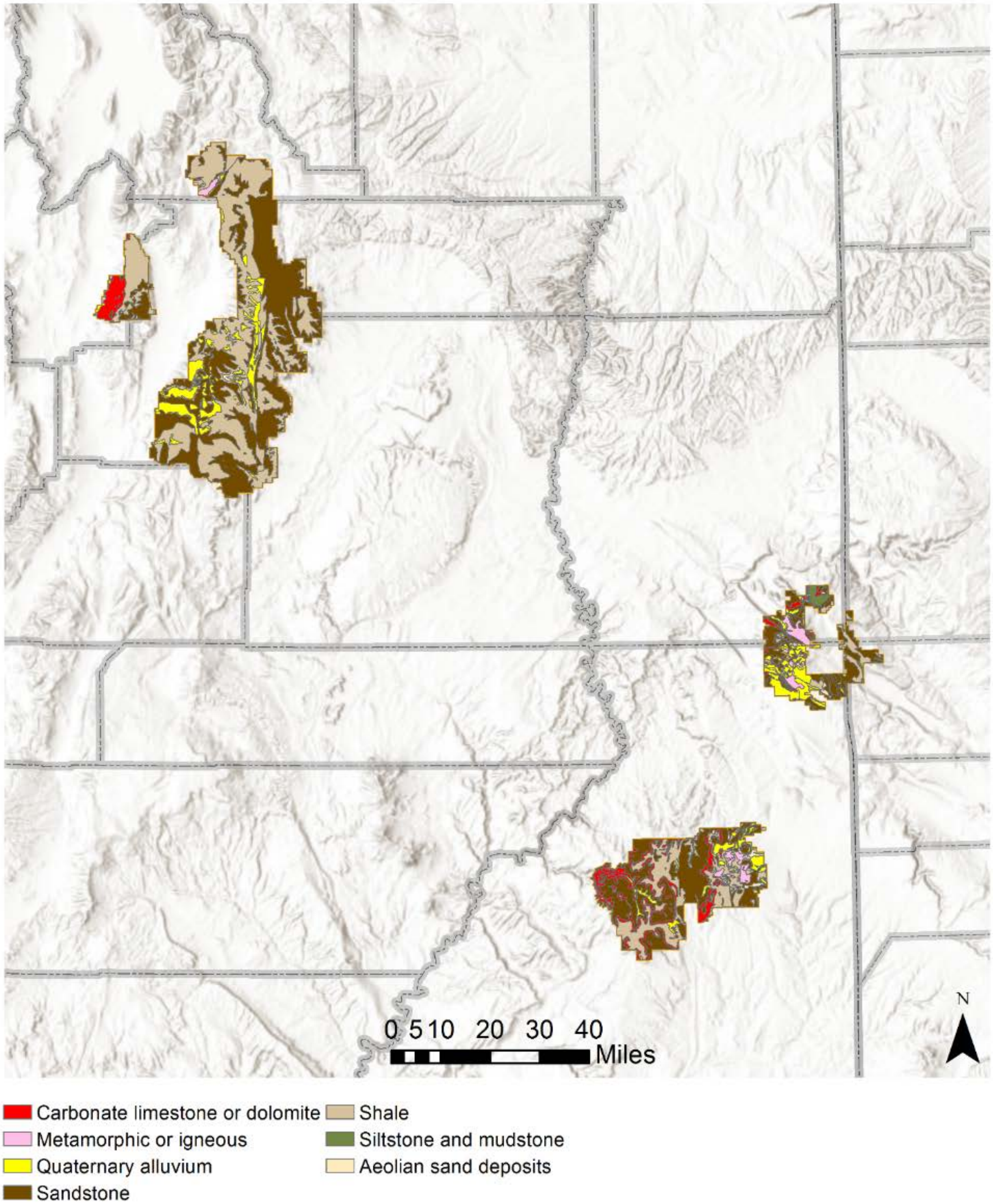

Figure 4. Geology within the fen mapping study area.

3.0 Fen Mapping Methods

Potential fens in the MLSNF were identified by analyzing digital aerial photography and topographic maps. True color aerial photography taken by the National Agricultural Imagery Program (NAIP) in 2005, 2009 and 2011 were used in conjunction with color-infrared imagery from 2014. High (but variable) resolution World Imagery from Environmental Systems Research Institute (ESRI) was also used. To focus the initial search, 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" (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 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 10.3 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 MLSNF 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.
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.

In addition to the fen mapping described above, the Forest Service will also receive an enhanced version of the 1980s original NWI mapping with a "Fen Potential" attribute. This attribute will highlight NWI polygons that contain or have significant overlaps with Likely or Possible fen mapping polygons (Figures 5, 6 and 7)

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

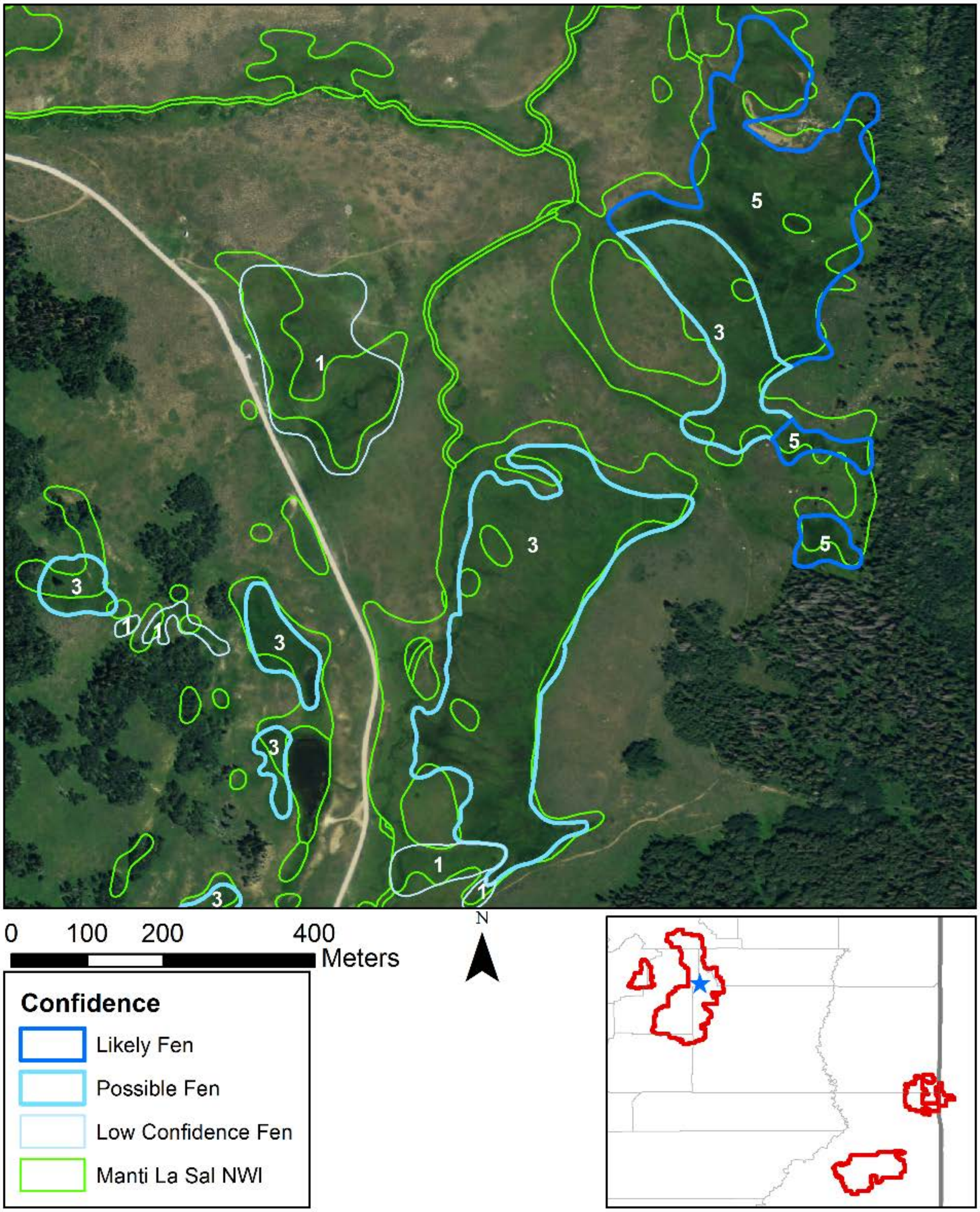

Figure 5. Example of potential fen mapping (blue) over NWI polygons (green). Note areas of overlap and areas where the fen mapping is either more extensive or more restricted than the NWI saturated polygons.

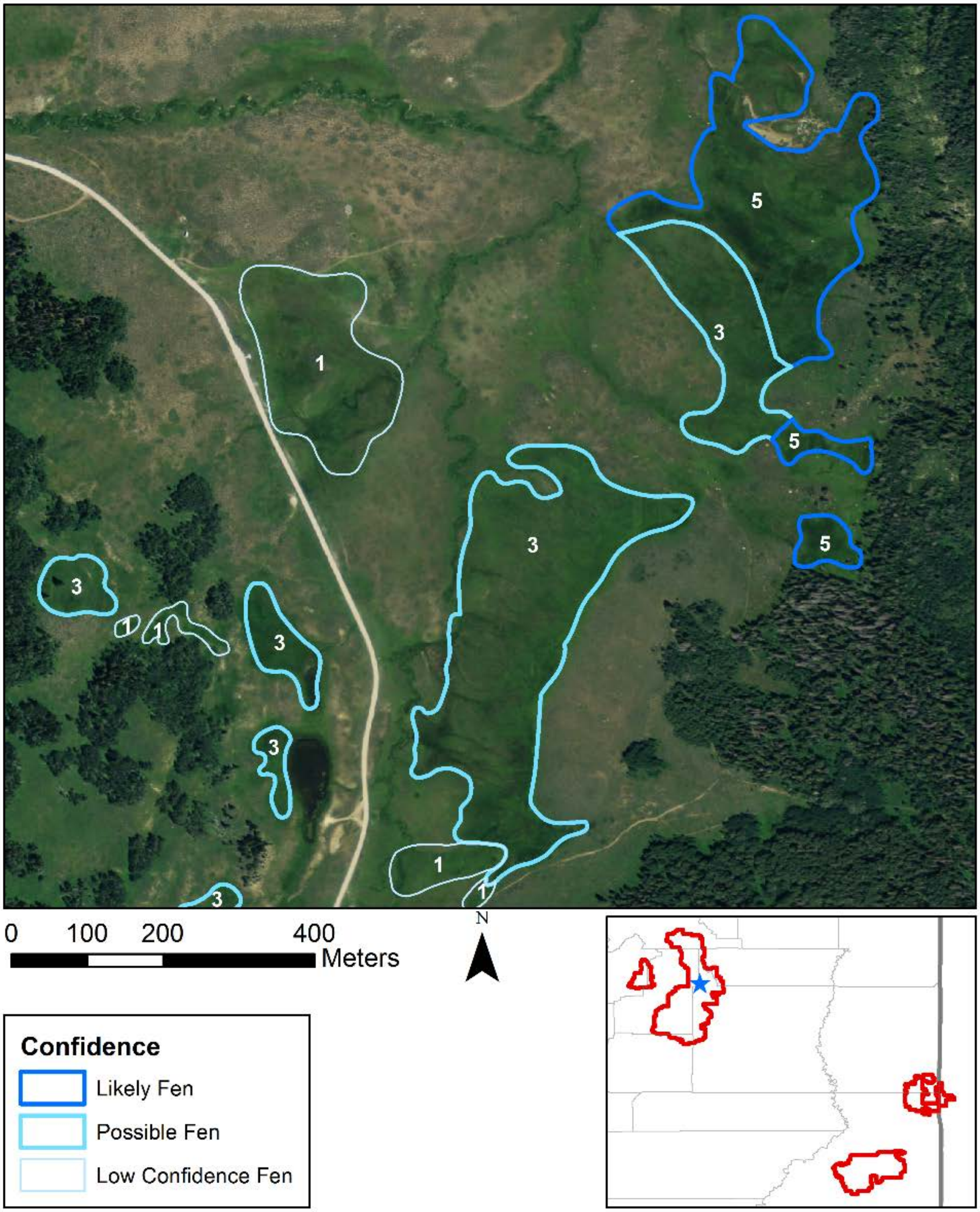

Figure 6. An example of potential fen mapping on Manti-La Sal National Forest.

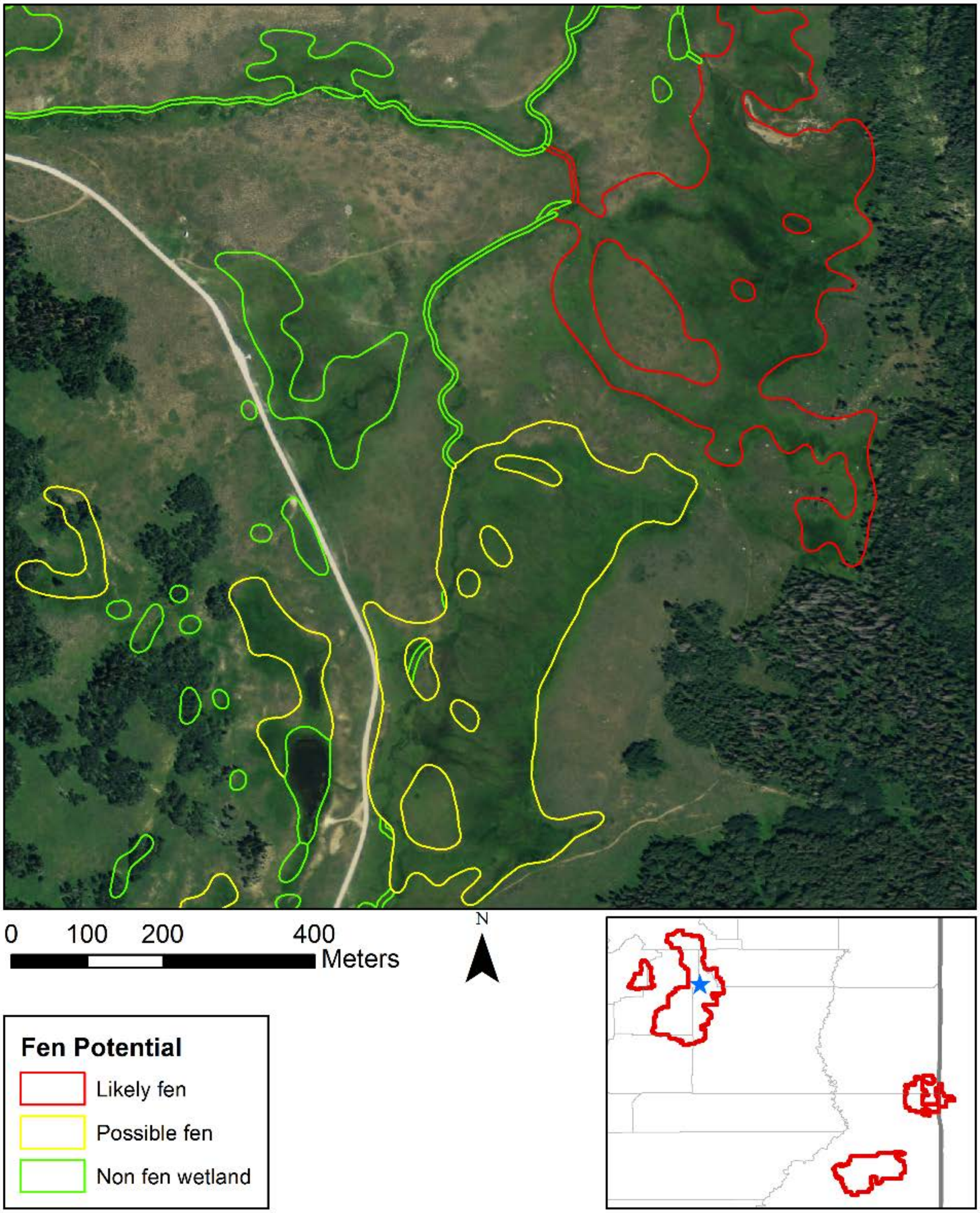

Figure 7. Example area of "Fen Potential" attribution of original 1970s/80s NWI data.

4.0 RESULTS

4.1 Potential Fen Mapping Acreage

The final map of potential fens contained 1,118 potential fen locations (all confidence levels), covering 1,544 acres or 0.1% of the total land area (Table 2; Figures 8 and 9). This total included 30 ***likely fens*** (confidence level = 5), 336 ***possible fens***, and 752 ***low confidence fens.*** While the count of likely fens was much less than the count of possible fens, on average the likely fens were considerably larger (5.26 acres vs. 2.38 acres), resulting in 158 acres of likely fens, 800 acres of possible fens, and 586 acres of low confidence fens. The size of individual potential fens ranged from 194 acres to 0.10 acres.

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

Confidence	*Count*	*Acres*	*Average size (acres)*
5 – Likely Fen	30	158	5.26
3 – Possible Fen	336	800	2.38
1 – Low Confidence Fen	752	586	0.78
TOTAL	**1,118**	**1,544**	**1.38**

Original NWI mapping for the MLSNF contained 3,066 acres with a "B" (saturated) hydrologic regime, including 2,507 acres of herbaceous wetlands (PEMB and PEMBb) and 559 acres of shrub wetlands (PSSB and PSSBb) (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 38% of those acres (1,154 acres), while the remaining 62% were determined to not be potential fens. In addition to the area within NWI polygons, 390 acres not mapped as saturated by NWI were mapped as potential fens.

Polygons mapped as saturated herbaceous in NWI made up a far greater share of the potential fens (85% of the fen/NWI overlap) than polygons mapped as saturated shrubs (15%). This ratio was relatively similar to the ratio of all saturated herbaceus vs. shrub acres in NWI and indicates that the fens in MLSNF are far more likely to be herbaceus dominated. However, this should be confirmed in the field, as many fen shrubs are short statured and may have been missed by NWI.

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*		
PEM1B	1,499	294	550	117	960	2,459
PEM1Bb	30	13	5	--	18	48
PSSB	259	59	20	23	102	361
PSSBb	125	36	37	--	74	198
Total NWI Acres	**1,913**	**402**	**612**	**140**	**1,154**	**3,066**
Other or No NWI Code	--	184	188	18	390	390
Grand Total	**1,913**	**586**	**800**	**158**	**1,544**	**3,457**

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.

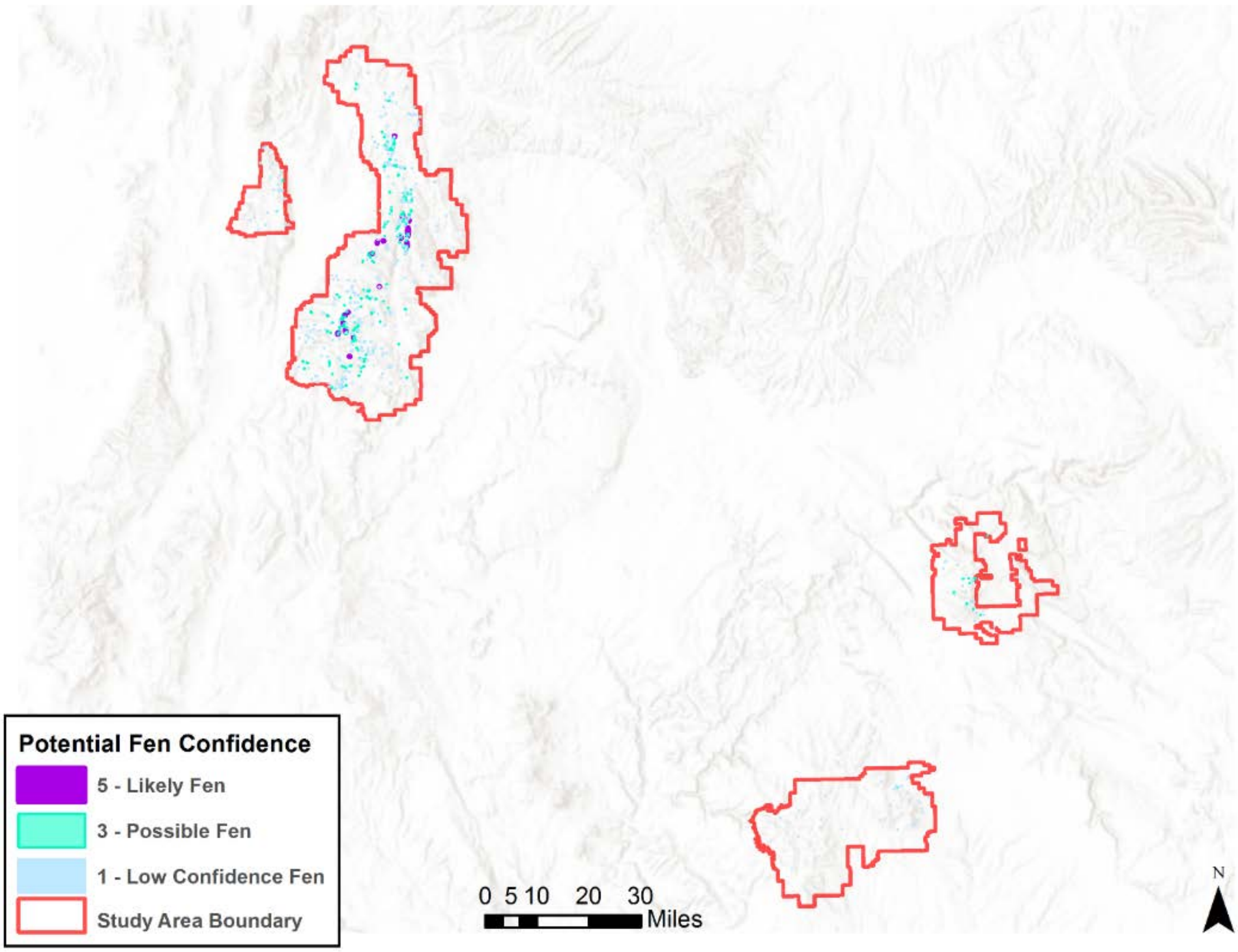

Figure 8. All potential fens within the fen mapping study area.

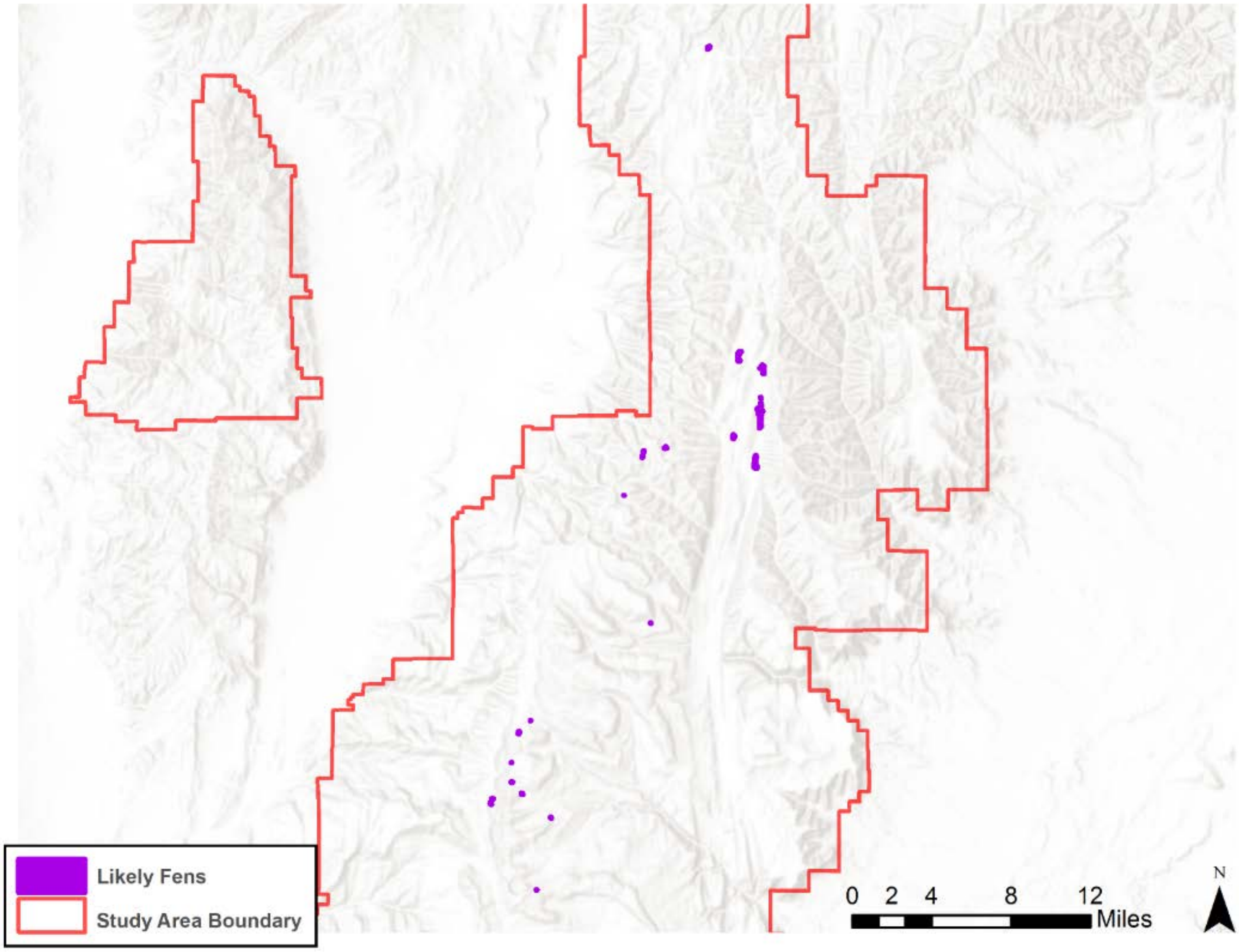

Figure 9. Likely fens (confidence rating = 5) within the fen mapping study area.

Likely fen area exaggerated for map visibility.

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, 502 polygons (1,104 acres) were mapped between 8,000 to 9,000 feet, which represents 45% of potential fen locations and 72% of potential fen acres (Table 4; Figure 11). Of the 30 total likely fens mapped, 12 polygons (40%) and 98 acres (62%) were located between 8,000 to 9,000 feet (Table 4; Figures 10 and 12). This is likely the zone of maximum fen formation for the MLSNF.

The elevation band of 9,000 to 10,000 feet was the next most numerous in terms of potential and likely fen acreage. There were 310 mapped potential fens (293 acres) in that elevation range, which represent 28% of potential fen locations and 19% of potential fen acres. In addition, there were 9 likely fens (44 acres) mapped in that elevation range, which represent 30% of likely fen locations and 28% of likely fen acres. These two elevation bands combined (8,000 to 10,000) contain 73% of potential fen locations and 70% of likely fen locations.

Table 4. 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*
< 6,000	1	< 1	0	0
> 6,000 – 7,000	43	8	0	0
> 7,000 – 8,000	86	42	0	0
> 8,000 – 9,000	502	1,104	12	98
> 9,000 – 10,000	310	293	9	44
> 10,000	176	97	9	16
Total	**1,118**	**1,544**	**30**	**158**

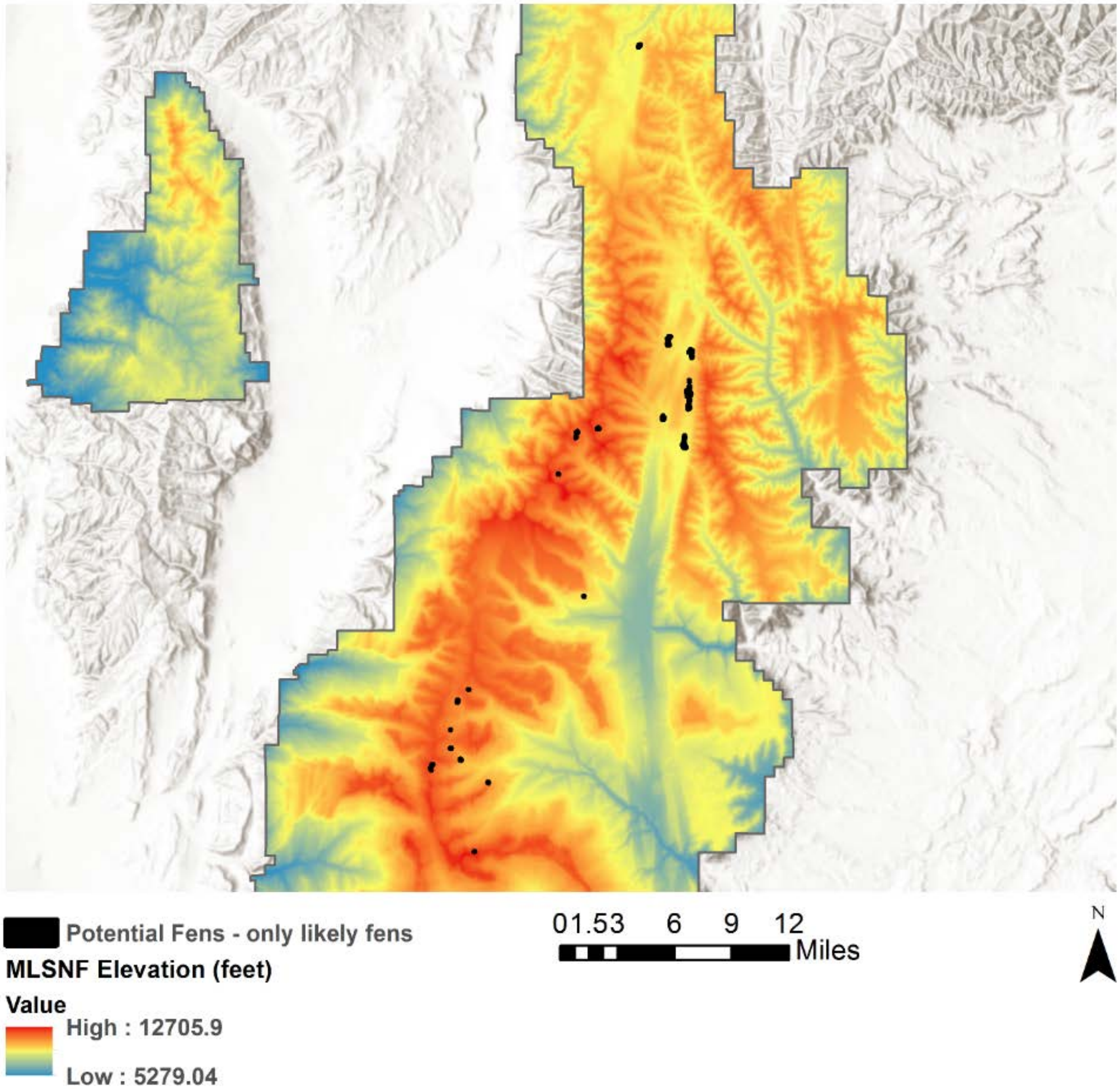

Figure 10. Likely fens (confidence rating = 5) and elevation within the fen mapping study area. Likely fen area exaggerated to visually highlight the locations.

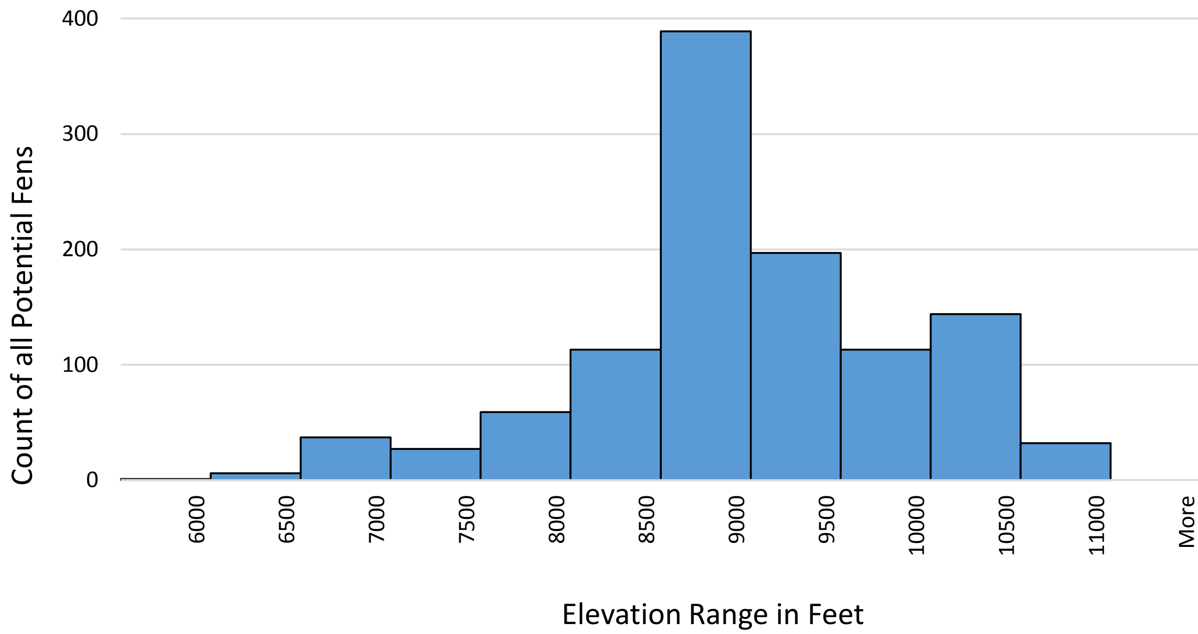

Figure 11. Histogram of all potential fens by elevation within the fen mapping study area.

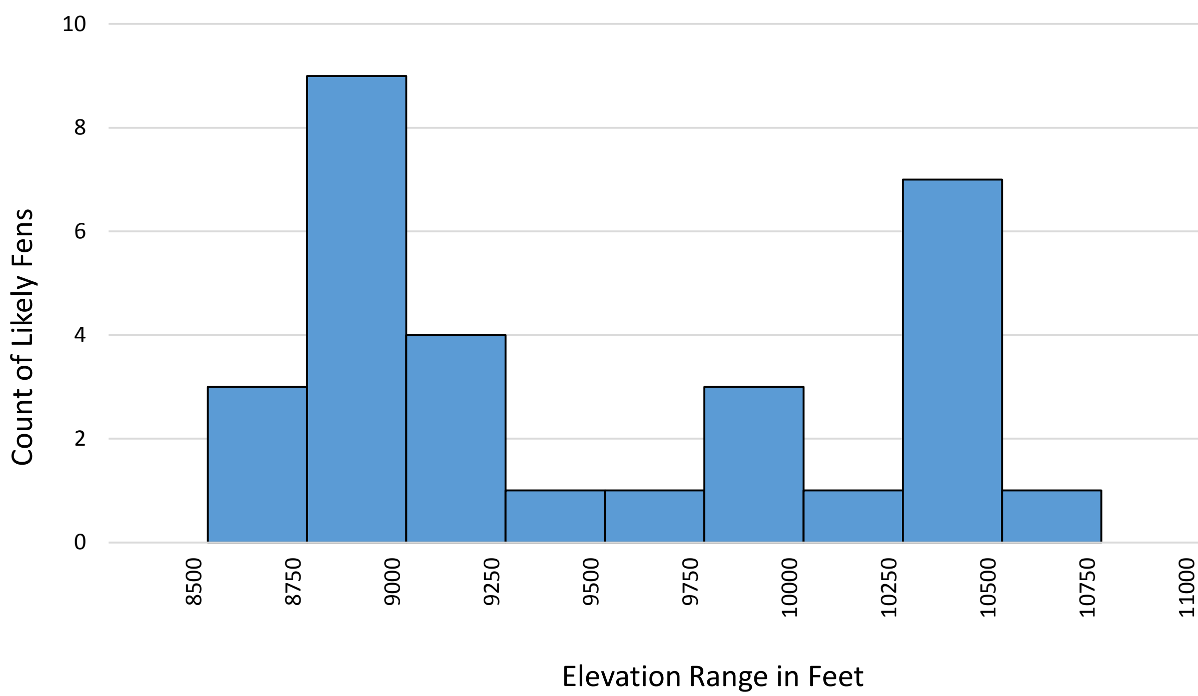

Figure 12. Histogram of the most likely fens by elevation within the fen mapping study area.

4.3 Mapped Potential Fens by Geology

The most common geologic substrate under potential fens was shale, which had 502 mapped potential fens (598 acres) (Table 5). This represents 44% of potential fen locations. The most common geologic substrate for likely fens was quaternary age younger alluvium, which had 12 mapped likely fens (66 acres) and 292 potential fens (585 acres). This represents 40% of likely fen locations. Sandstone bedrock, which covers 48% of the MLSNF, underlies only 26% of all potential fens (291 locations) and 30% of likely fens (9 locations). While present in the Manti-La Sal National Forest in small amounts, no likely fens were mapped on carbonate dominated formations of either limestone or dolomites, metamorphic or igneous formations, quaternary age older alluvium or unconsolidated Aeolian sand deposits.

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

Geology	Acres of Geologic Substrate Within MLSNF[1]	# of All Potential Fens	All Potential Fen Acres	# of Likely Fens	Likely Fen Acres
Shale	524,047	502	598	9	65
Quaternary age younger alluvium	120,660	292	585	12	66
Sandstone	610,582	291	344	9	31
Carbonate dominated limestone or dolomite	89,421	10	1	--	--
Unconsolidated Aeolian sand	8,638	8	11	---	---
Metamorphic or igneous	30,954	7	2	--	--
Quaternary age older alluvium	22,786	7	3	--	--
		1,118	**1,543**	**30**	**158**

[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 MLSNF.

4.4 Mapped Potential Fens by Land Type Association

Land Type Associations in MLSNF combine location and geomorphology. The LTAs for MLSNF are still in draft form, but an analysis of fens by LTA is provided for continuity with other Forest planning documents that tie to LTAs.

The Wasatch Plateau (WP) Western Mountains and Basins covers 16% of the MLSNF and this LTA contained 250 mapped potential fens (165 acres) and 10 likely fens (21 acres) (Table 6). This represents 22% of potential fen locations and 33% of likely fen locations.

The WP Northern Fault Valleys, which covers only 2% of the Forest, contained 241 mapped potential fens (928 acres) and 15 likely fens (131 acres). This represents another 22% of potential fen locations and 50% of likely fen locations. Proportional to the area this zone represents in the Forest, this LTA contained a large share of potential and likely fens.

Table 6. Potential and likely fens by Land Type Association within the fen mapping study area.

Land Type Association Groups	*Acres within MLSNF[1]*	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
WP Western Mountains & Basins	208,694	250	165	10	21
WP Northern Fault Valleys	29,368	241	928	15	131
WP Western Mountain Mid-Mountain Benches	40,925	170	167	3	5
WP Western Mountain Plateau Top	41,911	65	36	2	<1
WP Western Mountain SE Lower Slopes	47,993	58	25	--	--
WP Eastern Mountains Upper Canyon Slopes	75,013	43	102	--	--
SP Central Plateau	23,811	36	5	--	--
WP Eastern Mountains Lower Canyon Slopes	79,022	32	8	--	--
WP Western Front Lower Canyon Slopes	29,410	27	13	--	--
LSM Mid-Slopes and Passes	23,485	20	20	--	--
LSM Lower Slope Alluvial Fans and Moraines	15,109	16	8	--	--
MC higher elevation mesas	103,226	15	7	--	--
WP Western Front Flat Iron Ridges	31,929	13	14	--	--
A landslides terrain	5,632	13	7	--	--
WP Southern Fault Valleys	38,155	10	12	--	--
SP Western Front Mountains	12,156	10	2	--	--
A alluvial fans and plains	54,553	9	3	--	--
MC canyon slopes	69,837	9	1	--	--
LSMB eastern moraines and slopes	7,199	7	3	--	--

WP Thistle Highlands North Eastern Slopes	16,596	7	1	--	--
WP Thistle Highlands Western Slopes	29,010	7	1	--	--
MC canyon bottomlands	5,830	6	1	--	--
SP Conglomerate Cliffs	17,030	6	1	--	--
LSMB southern alluvial fans	15,105	6	1	--	--
SP North Eastern Canyons	10,807	6	<1	--	--
LSMB upper till covered mesas	4,558	5	1	--	--
LSMB southern graben valleys	2,534	3	3	--	--
LSMB lower sandstone and till covered mesas	28,314	3	1	--	--
LSMB eastern Ponderosa pine covered mesas	33,671	3	<1		
SP Eastern Front Benches and Cliffs	2,897	3	<1	--	--
A igneous mountains	29,557	2	1	--	--
WP Southern Tablelands	34,443	2	1	--	--
A Shay Mountain	8,369	2	<1	--	--
LSMB rocky canyons	13,091	2	<1	--	--
WP Northern Slope	17,968	2	<1	--	--
SP Western Front Lower Slopes	9,640	2	<1	--	--
LSMB dissected mesas	9,959	2	<1	--	--
LSM Peaks	8,900	1	1	--	--
MC lower mesas	34,703	1	<1	--	--
A Shay Mountain colluvial slopes and fans	11,640	1	<1	--	--
MC mid elevation mesas	45,076	1	<1	--	--
		1,118	**1,544**	**30**	**158**

[1] Acres of Land Type Associations shown are only for those LTAs where fens were mapped. The total acreage is not shown because it does not equal the total acreage of the MLSNF.

4.5 Mapped Potential Fens by Watershed

An analysis of likely fens in HUC 12 watersheds revealed interesting patterns. Four watersheds in particular had higher numbers of likely fens (Figure 13). Left Fork Huntington Creek (HUC12: 140600090101) had 7 likely fens, which covered 0.09% of the landscape in this watershed. Lowry Water (HUC12: 140600090202), Indian Creek (HUC12: 140600090201) and Ferron Reservoir-Ferron Creek (HUC12: 140600090302) all had 6 likely fens. All of the watersheds with more than 5 likely fens were in the Ferron-Price Ranger district. See Appendix A for the full HUC12 watershed and likely fens table.

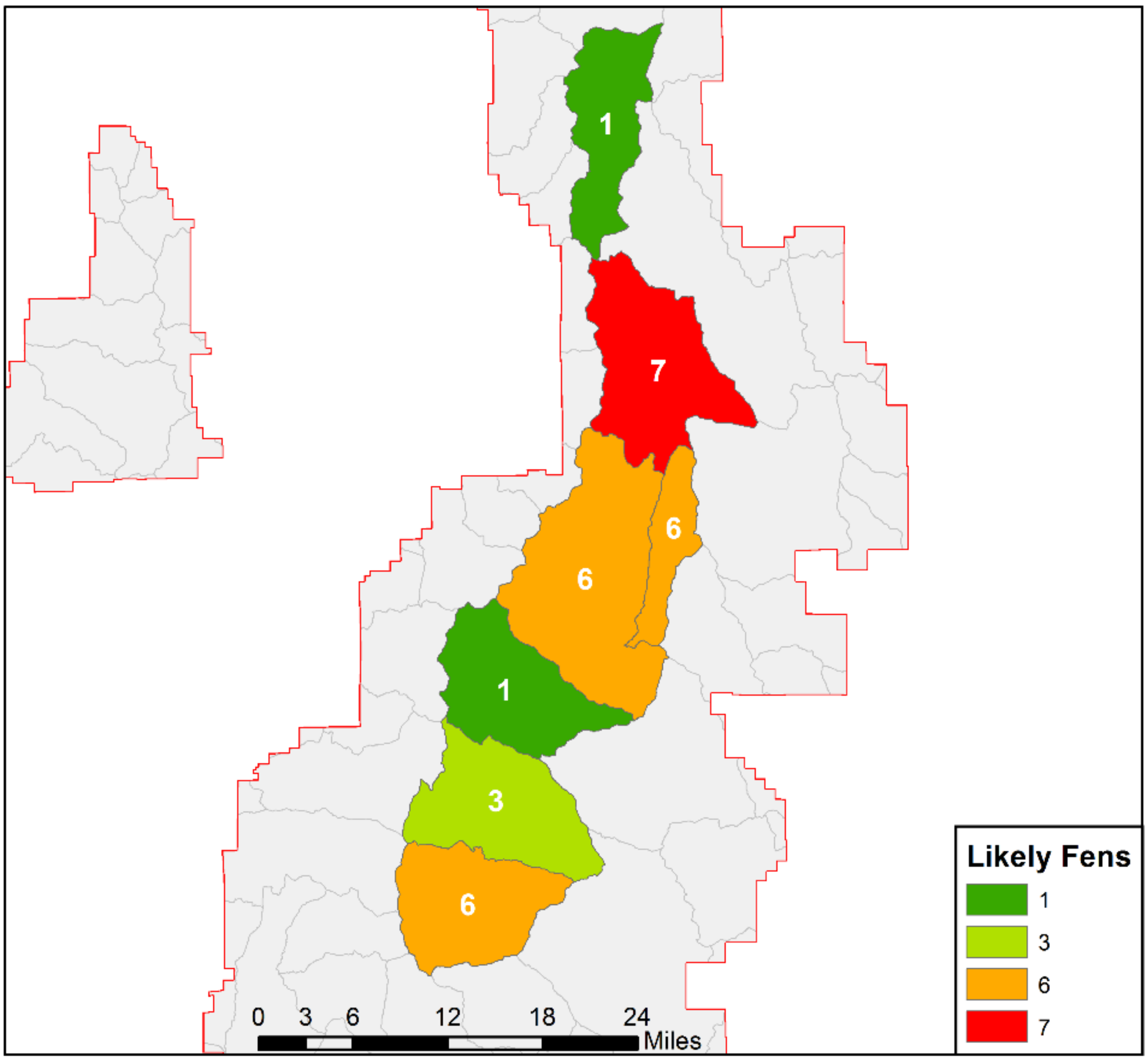

Figure 13. Likely fens by HUC12 watershed within the fen mapping study area.

4.6 Notable Mapped Potential Fens

Several characteristics related to fens were noted by photo-interpreters when observed throughout the fen mapping process (Table 7). 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 and eighty-one potential fens were observed in proximity to springs including two likely fens. This is not an exhaustive examination of springs, but does indicate their connection to fen formation.

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. Fifty-four potential fens (162 acres) showed some evidence of beaver influence.

Table 7. 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	54	162	--	--
Spring	281	80	2	7
Total	**335**	**242**	**18**	**7**

The two largest likely fens (Figures 14 and 15) are both located in Upper Joe's Valley. In this valley and the neighboring Scad Valley, the west side of East Mountain creates a steep slope and groundwater flows generally west into the valleys, creating springs and potentially fens. Of 158 acres of likely fens mapped, 107 of those acres occur in the Upper Joe's Valley/ Scad Valley area. This is clearly an important area for fen resources on the MLSNF.

There is, however, one other location that may be worth ground truthing: a likely fen identified in Sanpete County, near Skyline Drive and the headwaters of the Lake Fork of Ferron Creek (Figure 16). This likely fen is identified in the Notes attribute field of the dataset as a very good fen candidate, it is the most likely fen outside of the Scad Valley/Upper Joe's Valley area.

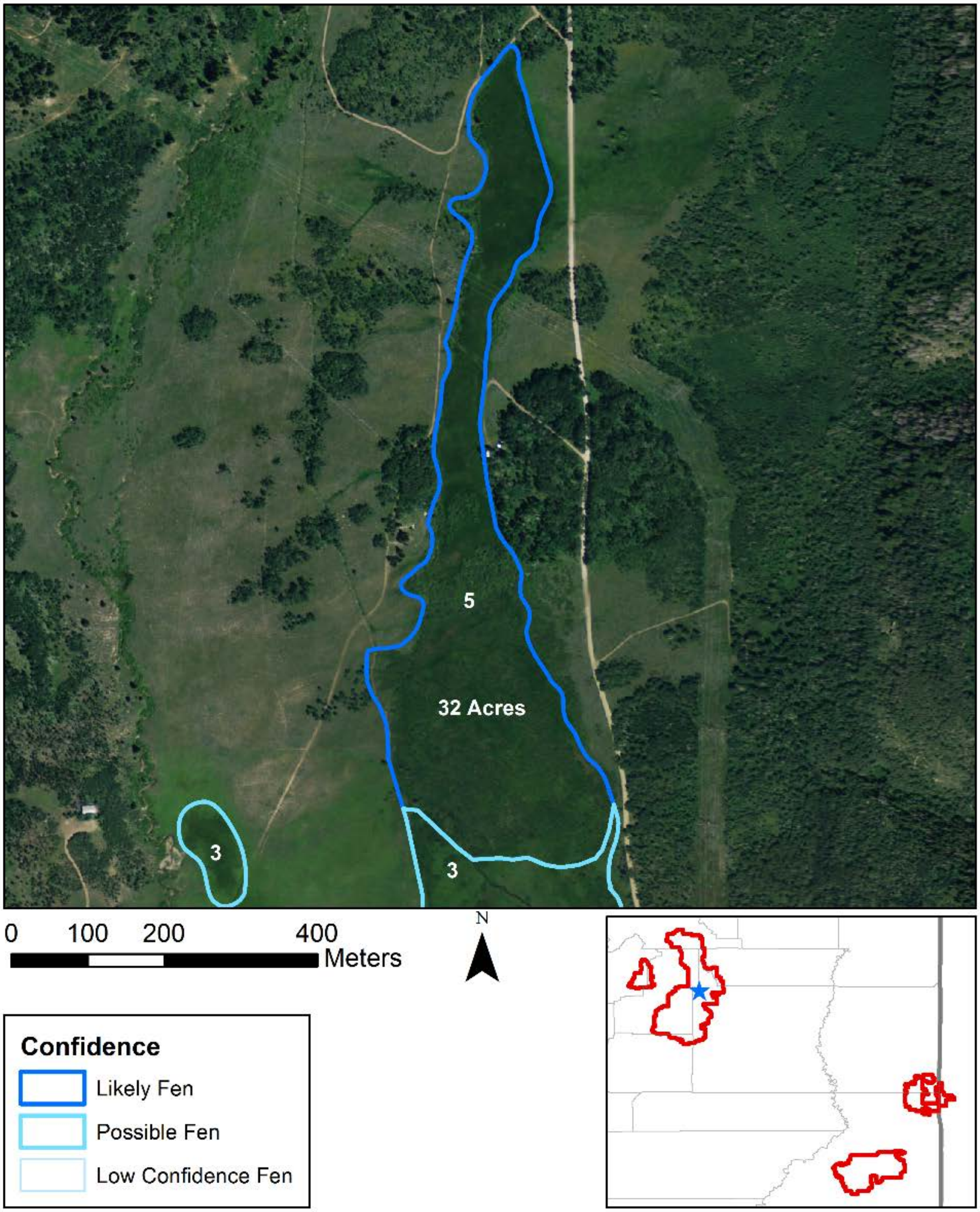

Figure 14. Largest mapped likely fen, 32 acres within one polygon. This fen is located Upper Joe's Valley within Emery County.

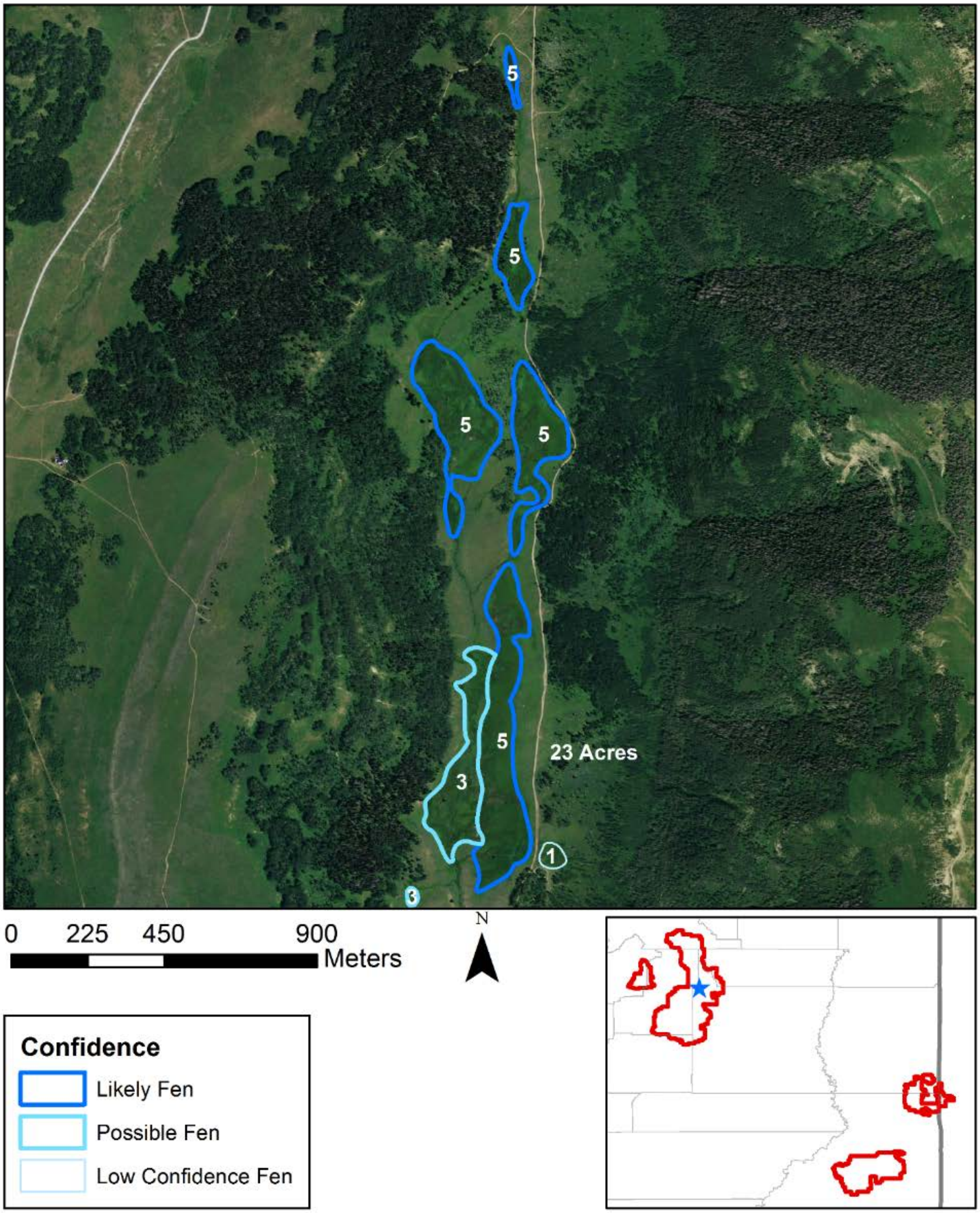

Figure 15. Second largest mapped likely fen, 23 acres within one polygon among a series of likely and possible fens. This fen is in Upper Joe's Valley just east of Bald Ridge, and is the start of Indian Creek.

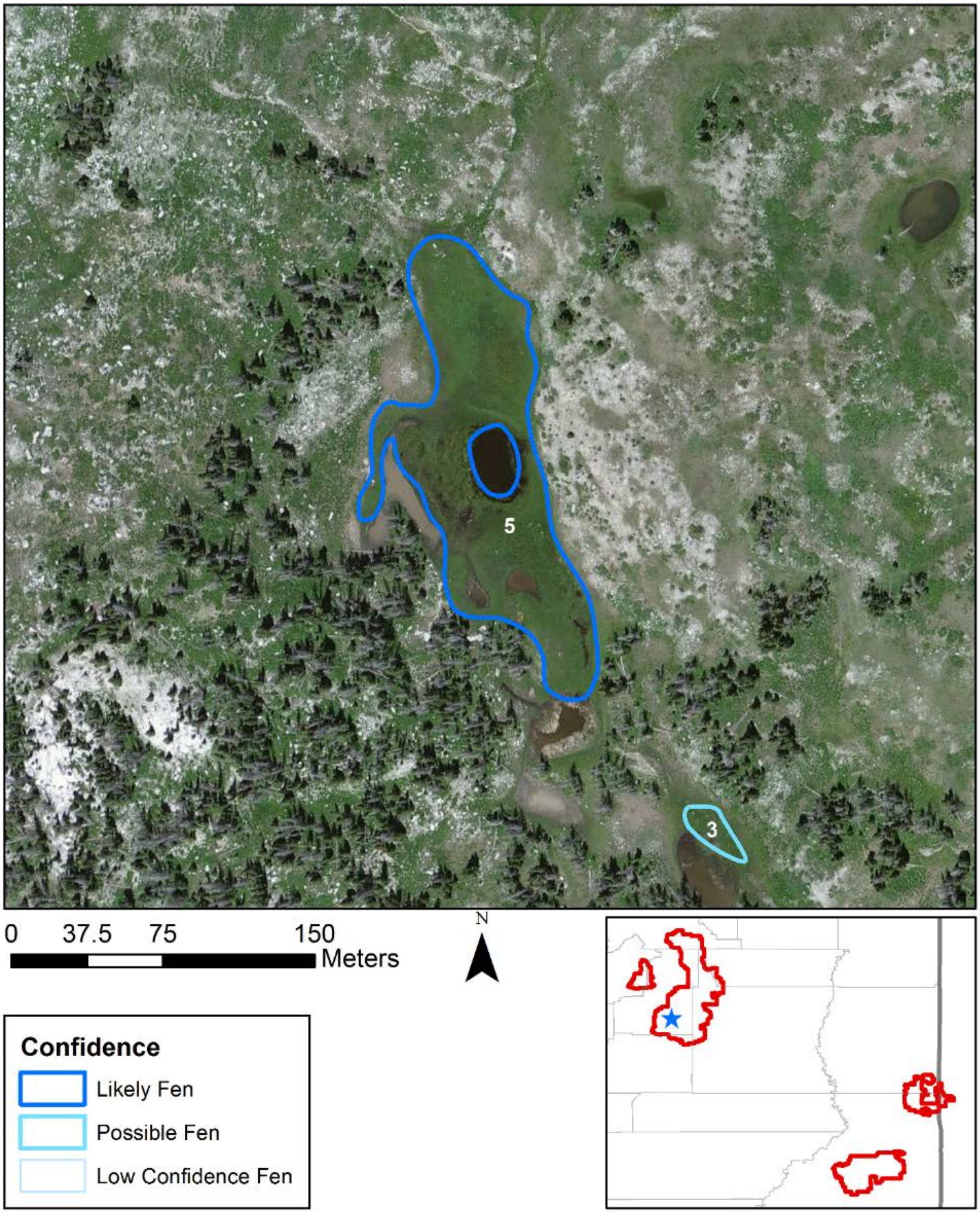

Figure 16. Likely fen identified in Sanpete County, at the headwaters of the Lake Fork of Ferron Creek.

5.0 DISCUSSION

The Manti-La Sal National Forest contains a relatively small number of potential fen wetlands, covering up to 1,544 acres across its jurisdiction. Most of the landforms in MLSNF are not conducive to fen formation, with the exception of the areas along the Wasatch fault where groundwater seeps out the valley sides. 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 Rocky Mountains 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).

Analysis of the potential fen data showed some interesting patterns in fen distribution within the MLSNF. Unlike other National Forests where CNHP has mapped fens, the elevation range containing the majority of likely fen acres (98 acres) was < 9,000 feet, which is lower than most zones of fen formation. This is likely because of the unusual fen formation potential of the of the Wasatch fault. The Land Type Association analysis support this theme, with 131 likely fen acres (83% of likely fen acres) occurring on the Wasatch Plateau Northern Fault Valleys LTA. Four HUC12 Basins stand out as likely fen hotspots in MLSNF: Left Fork of Hunting Creek, Lowry Water, Indian Creek and Ferron Reservoir-Ferron Creek. These areas should be actively conserved. Human stressors were observed in some of these sites, including off road vehicle trails, foot trails, ditches and canals. Limiting the impacts of these activities would be beneficial to MLSNF fens.

Bedrock geology can exert a strong influence on species composition within fens (Chimner et al. 2010; Lemly & Cooper 2011). The MLSNF is dominated by sedimentary geologic formations and quaternary alluvium. Because much of the surrounding subsurface geology is sedimentary, it is reasonable to assume that even the alluvium in MLSNF is sedimentary in origin. Groundwater flowing through sedimentary bedrocks can contain a high concentration of calcium and magnesium ions and groundwater fens formed on these substrates may support a distinct suite of plants. The most calcium rich fens are often found associated with limestone or dolomite (Cooper 1996; Johnson & Steingraeber 2003). Given the variety of sedimentary formations with the MLSNF, it is possible that fens in the Forest may be rich or extreme rich fens with uncommon plant species.

In total, 1,118 potential fens were mapped throughout the MLSNF, of which only 30 were most likely to be fens. The number and acreage of mapped potential fens is much 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 produced a more accurate and precise accounting of fen number and acreage. The NWI data in

MLSNF is not as representative of the wetland resource of the Forest as it could be, and MLSNF stands out as a good candidate for updating NWI data using more modern methods and imagery in the future.

This report and associated dataset provide the MLSNF with a critical tool for conservation planning at both a local and Forest-wide scale. Hopefully these 30 likely fen locations can serve as good starting point for field based verification and biological assessment. These data will be useful for the ongoing MLSNF 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.

Cooper, D.J., R.E. Andrus, and C.D. Arp. (2002) *Sphagnum balticum* in a southern Rocky Mountain iron fen. *Madroño*, **49**, 186-188.

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.

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.

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
140600090201	Indian Creek	9,970	6	89
140600090101	Left Fork Huntington Creek	30,537	7	27
140600090302	Ferron Reservoir-Ferron Creek	24,173	6	12
140600090202	Lowry Water	43,907	6	18
140600070201	Gooseberry Creek	19,816	1	6
140600090301	Big Bear Creek	26,934	3	5
140600090203	Seely Creek	24,050	1	<1

Only watershed containing potential fens are shown.