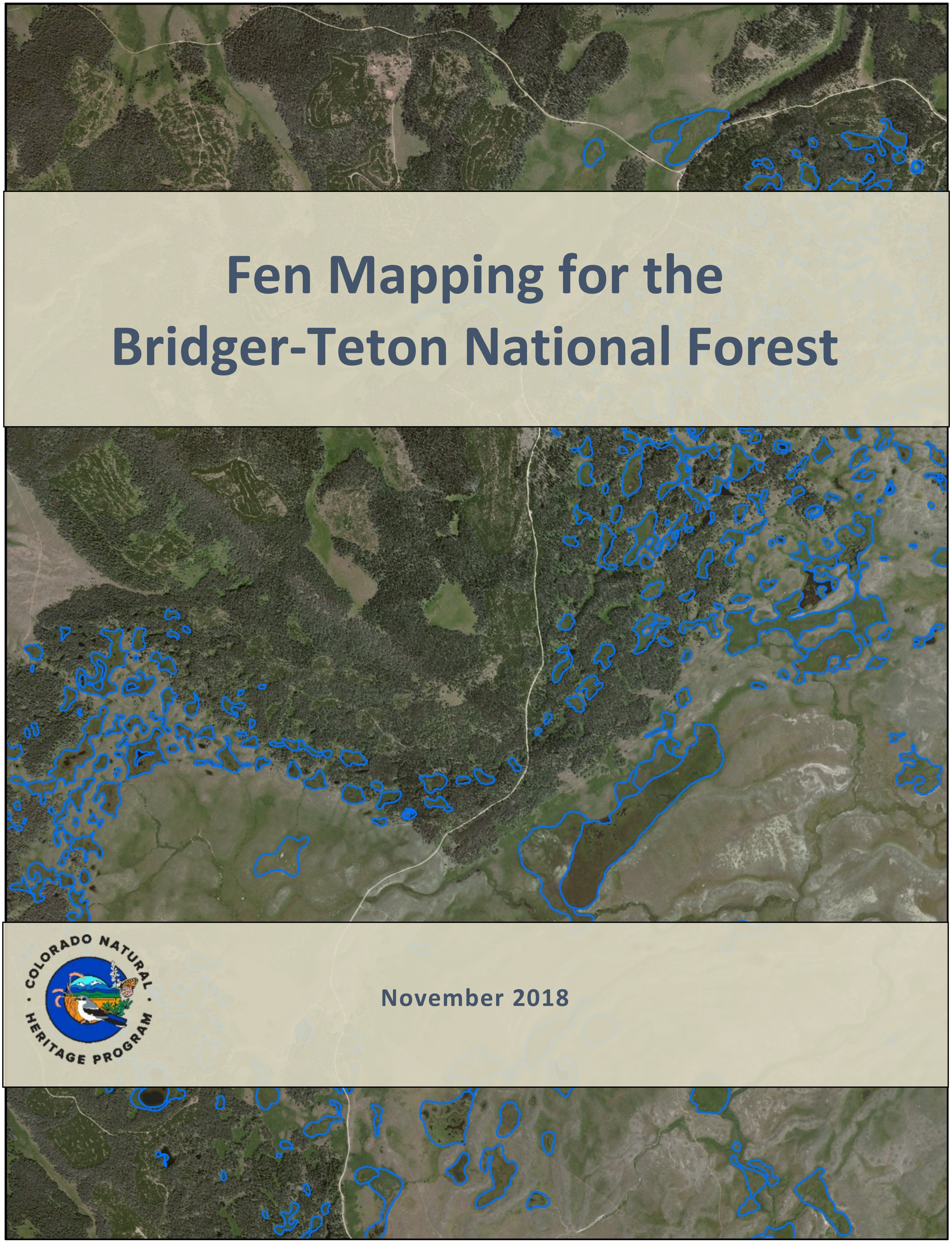

Fen Mapping for the Bridger-Teton National Forest

COLORADO NATURAL HERITAGE PROGRAM

November 2018

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:

Bridger-Teton National Forest
340 N. Cache
Jackson, WY 83001

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

Fen Mapping for the Bridger-Teton National Forest

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

November 2018

Page intentionally left blank.

EXECUTIVE SUMMARY

The Bridger-Teton National Forest (BTNF) covers 3.4 million acres within the Upper Green and Snake Headwaters River Basins in northwest Wyoming. The diverse geography of the BTNF creates an equally diverse set of wetlands that provide important ecological services to both BTNF 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 BTNF 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 BTNF.

Potential fens in the BTNF 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 9,503 potential fen locations (all confidence levels), covering 13,708 acres or 0.4% of the total land area. This total included 2,966 ***likely fens***, 2,863 ***possible fens***, and 3,674 ***low confidence fens.*** The average fen polygon was just 1.44 acres, but the largest polygon was over 80 acres.

Fen distribution was analyzed by elevation, surficial geology, and watershed. The vast majority of mapped potential fens occurred between 8,000 to 11,000 feet. This elevation range contained 89% of all potential fen locations and 94% of likely fen locations. Four watersheds in particular have very high numbers of likely fens. North Fork of Silver Creek had 302 likely fens, Upper Boulder Creek had 290 likely fens, Upper Pole Creek had 231 likely fens, and Washakie Creek-East Fork River had 208 likely fens.

The Bridger-Teton National Forest contains a rich resource of fen wetlands. This report and associated dataset provides the BTNF with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing BTNF 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 (USFS) for their financial support of this project. Special thanks to John Proctor, Regional Botanist for USFS Region 4, for supporting this project. Thanks also to Kate Dwire of the USFS Rocky Mountain Research Station for continually advocating for research on fens on USFS-managed lands. Thanks to Rose Lehman, Botanist at Caribou-Targhee National Forest and Martina Keil, Botanist/Range Management Specialist, and Bonnie Heidel, Botanist with the Wyoming Natural Diversity Database, for providing insight into the ecology of the BTNF and for visiting a handful of early mapped polygons.

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, and Dee Malone. These folks helped set the stage for our current work. Thanks to Kristin Schroder, CNHP Wetland Ecology Research Associate, for assisting with mapping in a few watersheds on the Forests. Thanks to Sarah Marshall, CNHP Wetland Ecologist, for reviewing mapped fens for consistency in our application of confidence ratings. And special thanks to researchers 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 Bridger-Teton National Forest (BTNF) covers 3.4 million acres within the Upper Green, Snake Headwaters and Upper Yellowstone River Basins in northwest Wyoming and spans a broad elevation range from 5,630 to 13,804 ft. The diverse geography of the BTNF 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 BTNF 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 BTNF 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 BTNF. 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), and the Salmon Challis National Forest (Smith et al. 2017).

[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 Bridger-Teton National Forest (BTNF), which is located in northwest Wyoming along the state's western border (Figure 1). The BTNF includes portions of Sublette, Teton, Lincoln, Park and Fremont counties. Jackson, Wyoming is the largest municipality near Bridger-Teton National Forest, smaller towns of Alpine, Thayne, Afton, Pinedale are also located near the Forest. BTNF spans several mountain ranges, including the Wind River, Snake River and Teton Ranges, as well as Gannett Peak, the highest mountain in Wyoming. Elevation in the study area ranges from 5,630 ft. (1,716 m) to 13,804 ft. (4,207 m), and the mean elevation the study area is 8,700 ft. (2,652 m).

The BTNF is primarily located within two river basins: the Snake Headwaters (HUC6: 170401) and the Upper Green (HUC6: 140401). Portions of the Forest also extend into the Upper Yellowstone (HUC6: 100700), the North Platte (HUC6: 101800), and the Upper Bear (HUC6:160101) basins (Figure 2). The Green River flows south out of the study area. Tributaries to the Snake River also originate in the Forest.

2.2 Land Type Associations

The U.S. Forest Service is currently developing Land Type Associations for Bridger-Teton National Forest to describe the major geomorphic landforms within the Forest. The map presented in Figure 3 is in a draft state with no LTA names or descriptions yet applied.

2.3 Geology

Bedrock geology of the Forest is highly complex, with 77 individual bedrock geology units (Figure 4; Table 1). The most common bedrock geology units within the Forest are of Quaternary age and include glacial deposits (11% of the land area), landslide deposits (6%), and alluvium and colluvium (5.5%). Common older units include members of the Tertiary-aged Absaroka Volcanic Super group (8.6% combined), Jurassic and Triassic-aged sedimentary layers (13.7%), Paleozoic-aged limestones (7.4%), and Precambrian granites and gneiss (13.4%).

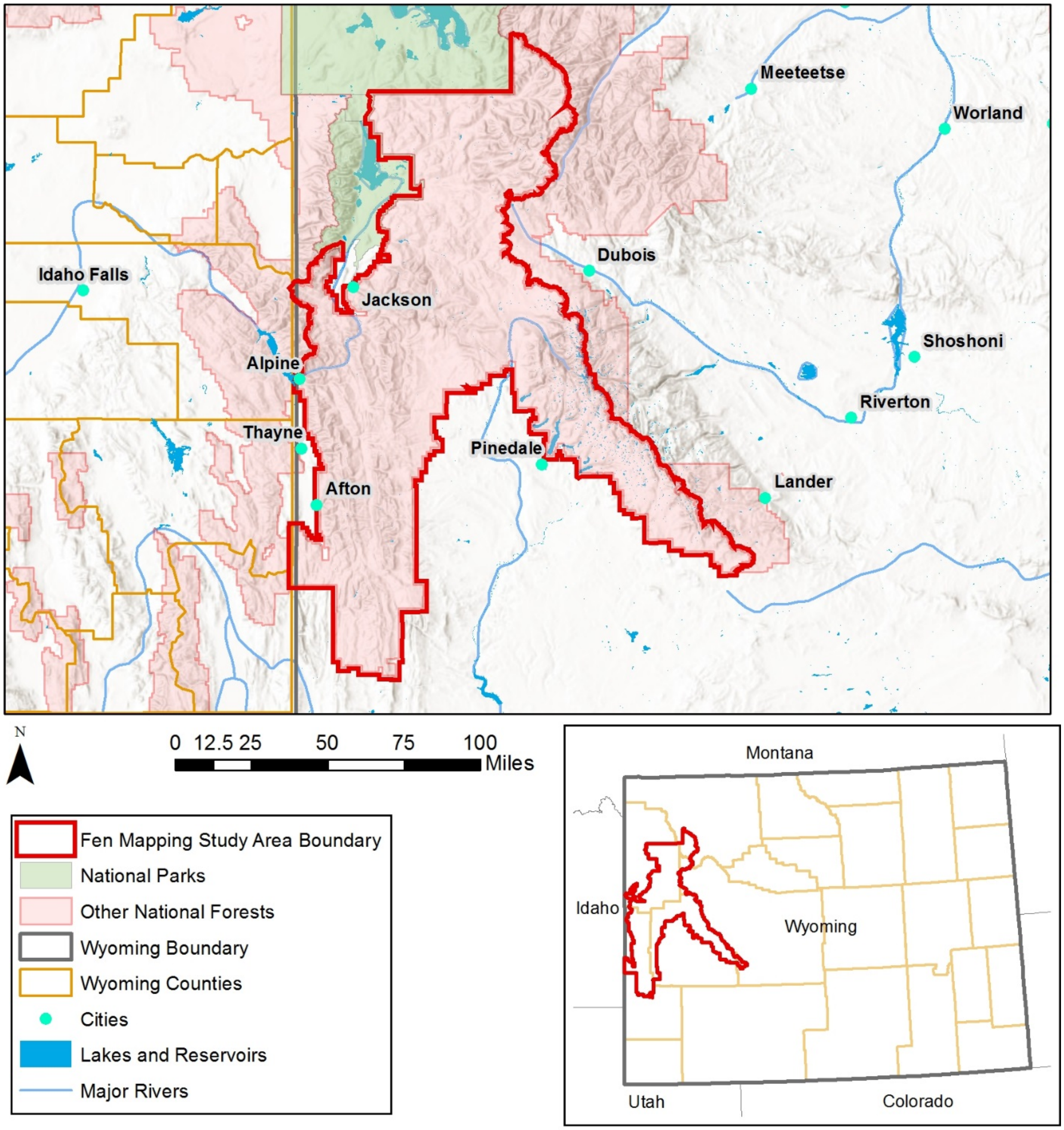

Figure 1. Location of the Bridger-Teton National Forest (fen mapping study area) within the state of Wyoming.

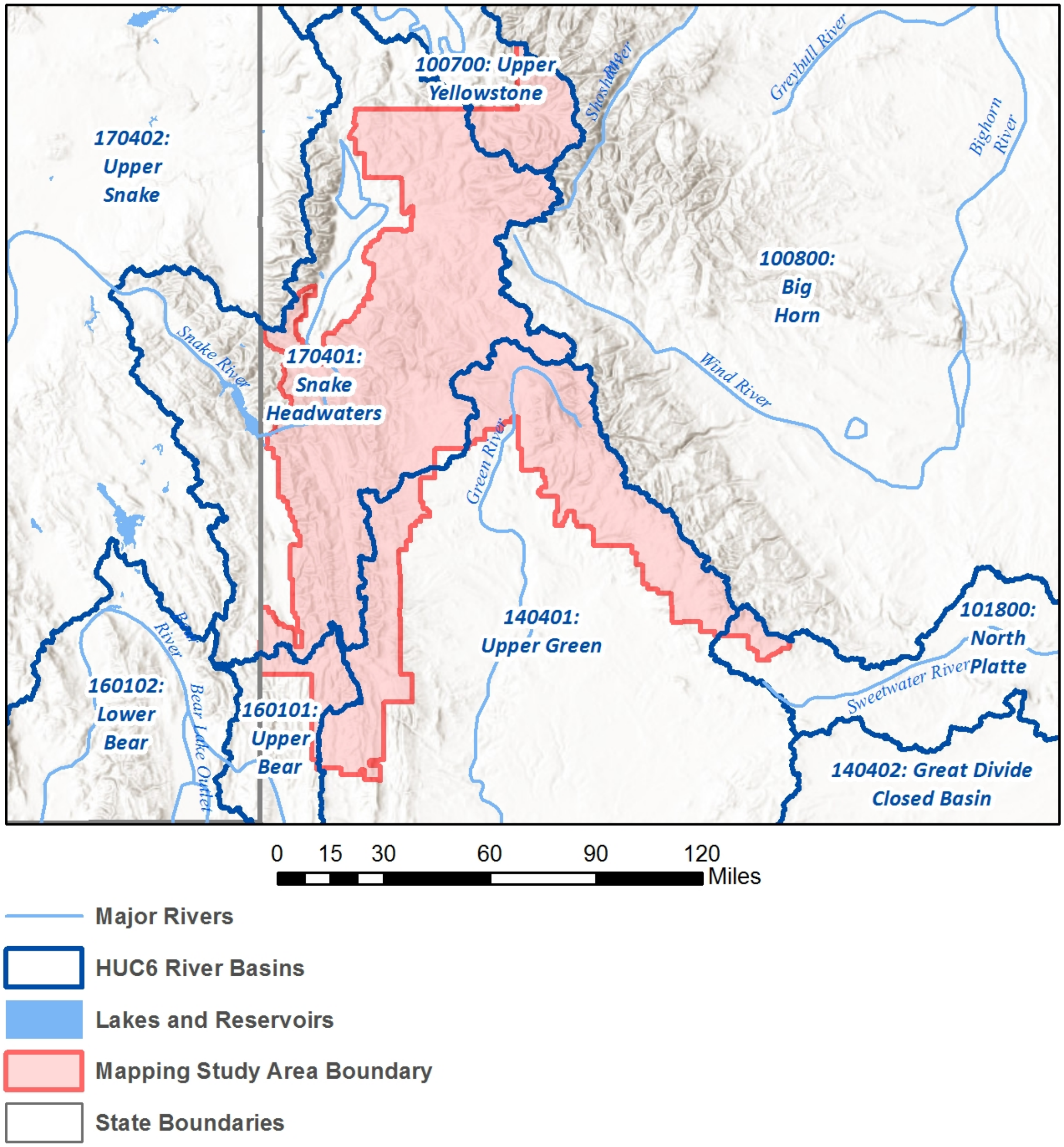

Figure 2. HUC6 river basins and major waterways in the fen mapping study area.

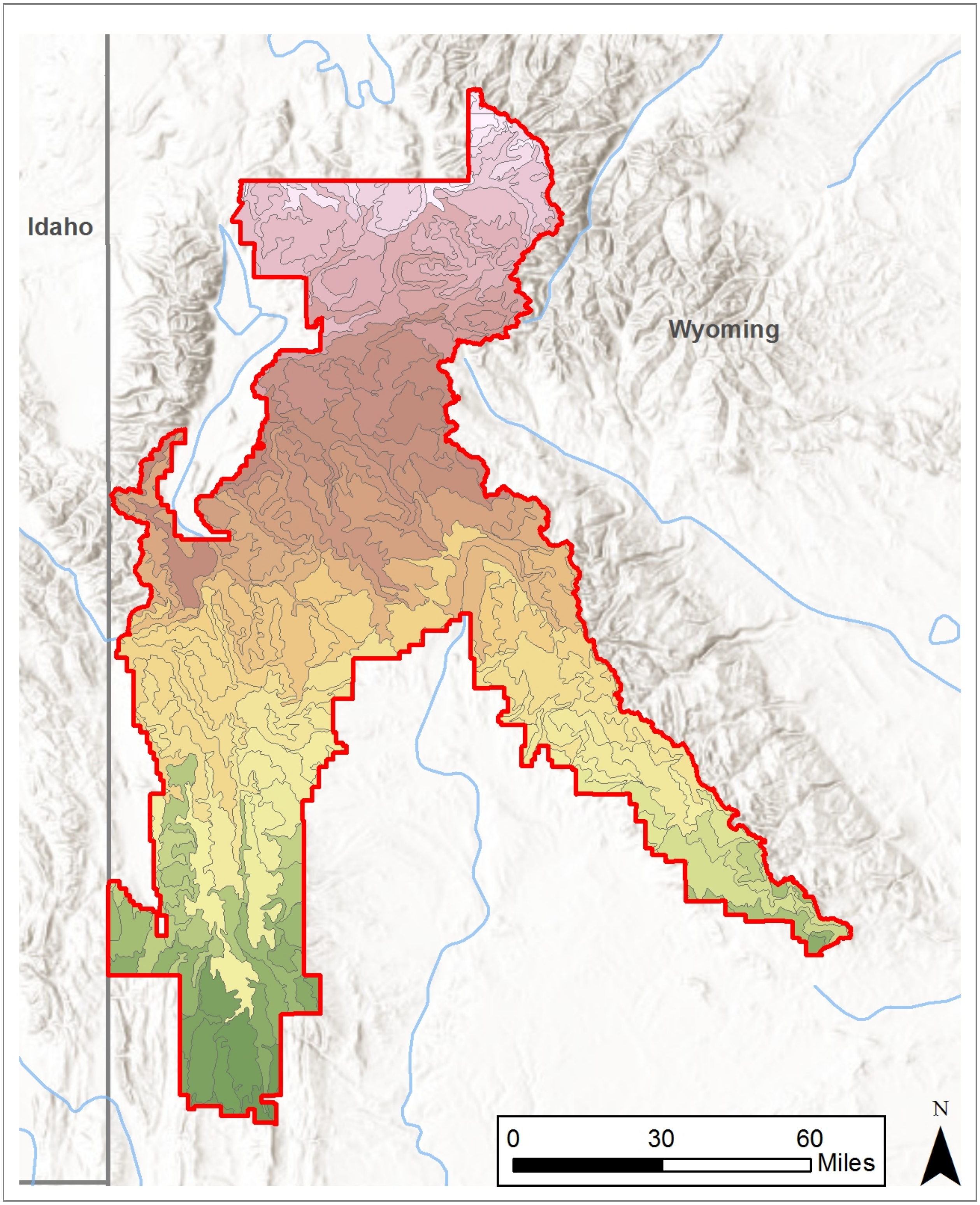

Figure 3. Draft Land Type Association (LTA) polygons of the fen mapping study area. Map is symbolized by polygon Unique ID, not by any characteristic or grouping. Once the LTA development is complete, polygons will be grouped by similar characteristics.

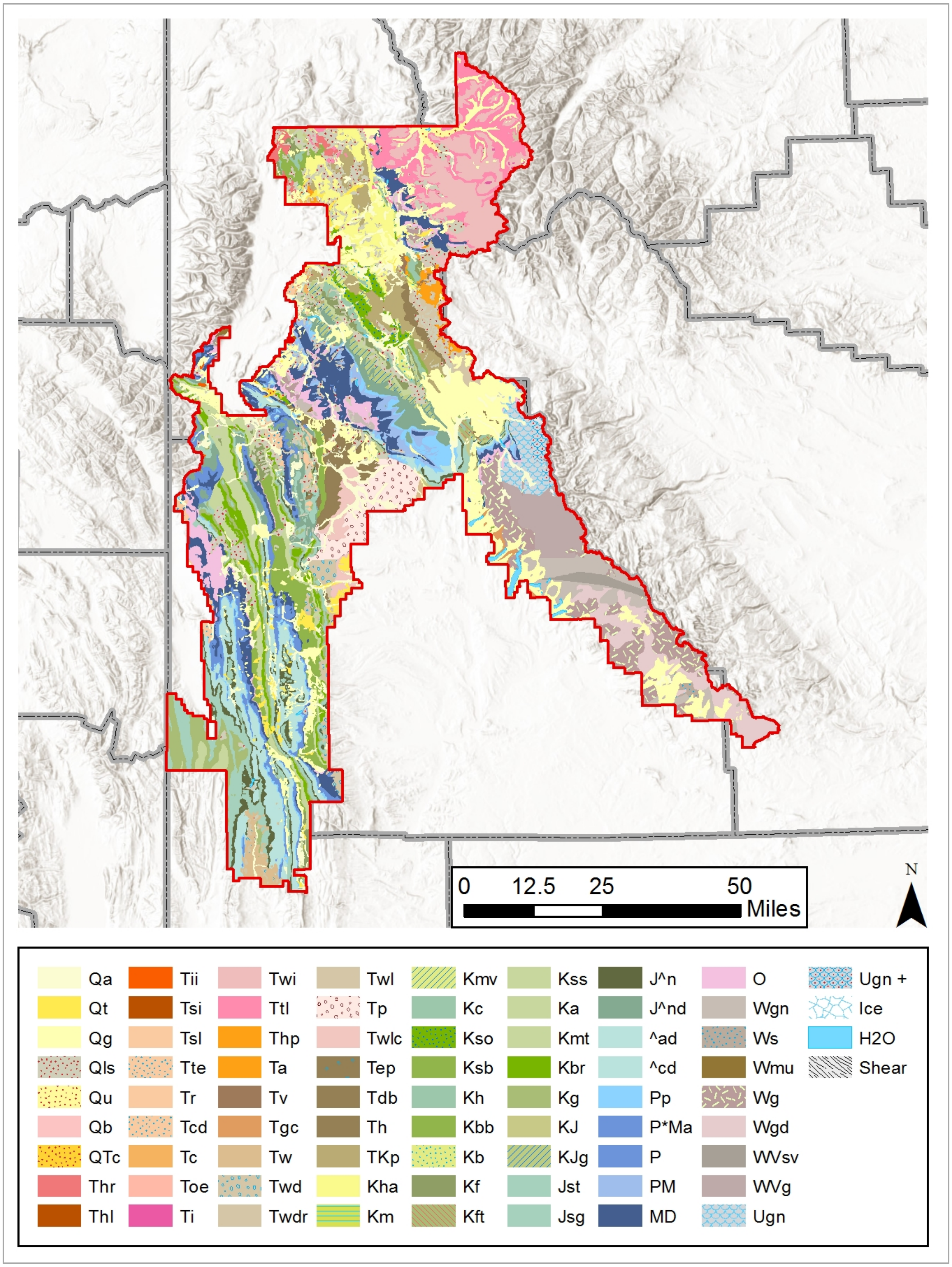

Figure 4. Bedrock geology within the fen mapping study area.

Table 1. Description of bedrock geology units within the fen mapping study area.

Geologic Period or Era	*Map Symbol*	*Map Unit name*	*Acres within BTNF*	*Percent of BTNF*
n/a	ice	Ice	2,295	0.1%
	water	Water	13,730	0.4%
Quaternary	Qa	Alluvium and colluvium	191,925	5.5%
	Qt	Gravel, pediment, and fan deposits	38,087	1.1%
	Qg	Glacial deposits	381,716	11.0%
	Qls	Landslide deposits	207,752	6.0%
	Qu	Undivided surficial deposits	9,235	0.3%
	Qb	Basalt flows and intrusive igneous rocks	525	0.0%
	QTc	Conglomerate (fn 1)	1,796	0.1%
Tertiary	Thr	Huckleberry Ridge Tuff of Yellowstone Group	11,454	0.3%
	Thl	Heart Lake Conglomerate	147	0.0%
	Tii	Intrusive and extrusive igneous rocks	966	0.0%
	Tsi	Shooting Iron Formation	342	0.0%
	Tsl	Salt Lake Formation	51	0.0%
	Tte	Teewinot Formation	12,593	0.4%
	Tr	Red conglomerate on top of Hoback and Wyoming Ranges	5,227	0.2%
	Tcd	Camp Davis Formation	5,303	0.2%
	Tc	Colter Formation	2,614	0.1%
	Toe	Oligocene and/or upper and middle Eocene rocks	240	0.0%
	Ti	Intrusive igneous rocks	1,101	0.0%
	Twi	Absaroka Volcanic Supergroup: Thorofare Creek Group - Wiggins Formation	148,729	4.3%
	Ttl	Absaroka Volcanic Supergroup: Thorofare Creek Group - Two Ocean and Langford Formations; may include Trout Peak Trachyandesite of Sunlight Group	128,800	3.7%
	Thp	Absaroka Volcanic Supergroup: Hominy Peak Formation	1,326	0.0%
	Ta	Absaroka Volcanic Supergroup: Thorofare Creek Group - Aycross Formation	18,178	0.5%
	Tv	Volcanic conglomerate	2,817	0.1%
	Tgc	Granitic conglomerate above or in upper part of Wasatch Formation	5,162	0.1%
	Tw	Wasatch Formation	25,656	0.7%
	Twd	Wasatch Formation, diamictite and sandstone	35,168	1.0%

Geologic Period or Era	Map Symbol	Map Unit name	Acres within BTNF	Percent of BTNF
Tertiary	Twdr	Wind River Formation - at base locally includes equivalent of Indian Meadows Formation	18,132	0.5%
	Twl	Willwood Formation	1,929	0.1%
	Tp	Pass Peak Formation and equivalents	71,102	2.1%
	Twlc	La Barge and Chappo Members of Wasatch Formation	26,965	0.8%
	Tep	Conglomerate of Roaring Creek	879	0.0%
	Tdb	Devils Basin Formation	12,815	0.4%
	Th	Hoback Formation	45,032	1.3%
	TKp	Pinyon Conglomerate	67,103	1.9%
Cretaceous	Kha	Harebell Formation	70,224	2.0%
	Km	Meeteetse Formation	308	0.0%
	Kmv	Mesaverde Formation (N) or Mesaverde Group (S)	9,976	0.3%
	Kc	Cody Shale	22,052	0.6%
	Kso	Sohare Formation	26,966	0.8%
	Ksb	Sohare Formation and Bacon Ridge Sandstone	25,748	0.7%
	Kh	Hilliard Shale	809	0.0%
	Kbb	Blind Bull Formation	69,231	2.0%
	Kb	Bacon Ridge Sandstone	13,770	0.4%
	Kf	Frontier Formation	29,527	0.9%
	Kft	Frontier Formation, and Mowry and Thermopolis Shales	4,570	0.1%
	Kss	Sage Junction, Quealy, Cokeville, Thomas Fork, and Smiths Formations	10,636	0.3%
	Ka	Aspen Shale	93,958	2.7%
	Kmt	Mowry and Thermopolis Shales	13,168	0.4%
	Kbr	Bear River Formation	56,411	1.6%
	Kg	Gannett Group - Includes Smoot Formation, Draney Limestone, Bechler Conglomerate, Peterson Limestone, and Ephraim Conglomerate	90,026	2.6%
Cretaceous / Jurassic	KJ	Cloverly and Morrison Formations (N, S) or Cloverly Formation (Hartville uplift), or Inyan Kara Group (Black Hills), and Morrison Formation (NE)	5,874	0.2%
	KJg	Cloverly, Morrison, Sundance, and Gypsum Spring Formations	31,243	0.9%
Jurassic	Jst	Stump Formation, Preuss Sandstone or Redbeds, and Twin Creek Limestone	143,508	4.1%
	Jsg	Sundance and Gypsum Spring Formations	8,310	0.2%

Geologic Period or Era	Map Symbol	Map Unit name	Acres within BTNF	Percent of BTNF
Jurassic / Triassic	J^n	Nugget Sandstone	61,676	1.8%
	J^nd	Nugget Sandstone (TB), Ankareh Formation, Thaynes Limestone, Woodside Shale, and Dinwoody Formation (TB), or Nugget Sandstone, and Chugwater and Dinwoody Formations (N)	85,709	2.5%
Triassic	^ad	Ankareh Formation, Thaynes Limestone, Woodside Shale, and Dinwoody Formation	150,019	4.3%
	^cd	Chugwater and Dinwoody Formations	24,097	0.7%
Paleozoic	Pp	Phosphoria Formation and related rocks	55,738	1.6%
	P*Ma	Phosphoria, Wells, and Amsden Formations (TB), Phosphoria Formation and related rocks, Quadrant Sandstone, and Amsden Formation (Y), or Phosphoria Formation and related rocks, Tensleep Sandstone, and Amsden Formation (N)	45,017	1.3%
	P	Wells and Amsden Formations (TB), or Casper Formation and Madison Limestone (N, S)	60,432	1.7%
	PM	Tensleep Sandstone and Amsden Formation	37,137	1.1%
	MD	Madison Limestone or Group, and Darby Formation, or Madison Group, and Three Forks and Jefferson Formations	173,169	5.0%
	O	Bighorn Dolomite, Gallatin Limestone, and Gros Ventre Formation (TB); Bighorn Dolomite, Snowy Range Formation, Pilgrim Limestone, Park Shale, Meagher Limestone, Wolsey Shale, and Flathead Sandstone (Y); Bighorn Dolomite, Gallatin Limestone, Gros Ventre F	81,587	2.4%
Precambrian	Wgn	Granite gneiss	78,573	2.3%
	Ws	Metasedimentary and metavolcanic rocks - metasedimentary rocks	4,242	0.1%
	Wmu	Metasedimentary and metavolcanic rocks - metamorphosed mafic and ultramafic rocks	1,800	0.1%
	Wg	Granitic rocks of 2,600-Ma age group	137,304	4.0%
	Wgd	Granodiorite of the Louis Lake pluton	91,063	2.6%
	WVsv	Metasedimentary and metavolcanic rocks	17,849	0.5%
	WVg	Plutonic rocks	74,249	2.1%
	Ugn	Oldest gneiss complex	44,623	1.3%
	Ugn +	Oldest gneiss complex	14,749	0.4%
	shear	Shear zone	720	0.0%

3.0 FEN MAPPING METHODS

Potential fens in the BTNF were identified by analyzing digital aerial photography and topographic maps. True color aerial photography taken by the National Agricultural Imagery Program (NAIP) in 2012 were used in conjunction with color-infrared imagery from 2001, 2019, and 2015. 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 early 1980s 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 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 BTNF 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, including impoundments, beaver influence, floating mats and springs.

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. 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 9,503 potential fen locations (all confidence levels), covering 13,708 acres or 0.4% of the total land area (Table 3; Figures 5 and 6). This total included 2,966 ***likely fens*** (confidence level = 5), 2,863 ***possible fens***, and 3,674 ***low confidence fens.*** The count of likely fens was slightly higher than the count of possible fens, and the average sizes were similar in all confidence classes, resulting in 4,165 acres of likely fens, 3,437 acres of possible fens, and 6,106 acres of low confidence fens. The size of individual potential fens ranged from over 120 acres to 0.02 acres. The two largest mapped fens are shown in Figures 7 and 8.

Table 3. Potential fen counts and acreage, by confidence levels.

Confidence	*Count*	*Acres*	*Average size (acres)*
5 – Likely Fen	2,966	4,165	1.40
3 – Possible Fen	2,863	3,437	1.20
1 – Low Confidence Fen	3,674	6,106	1.66
TOTAL	**9,503**	**13,708**	**1.44**

Original NWI mapping for the BTNF contained 6,223 acres with a "B" (saturated) hydrologic regime, including 3,374 acres of herbaceous wetlands (PEMB), 1,611 acres of forested wetlands, and 411 acres of shrub wetlands (PSSB) (Table 4). 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 only 13% of those acres (830 acres), while the remaining 87% were determined to not be potential fens. In addition, once photo-interpretation was underway, it was apparent that the NWI codes for Palustrine Emergent Seasonally Flooded (PEMC) and Palustrine Aquatic Bed Semi-Permanently Flooded (PABF) also overlapped many fen polygons. Once that was discovered, all PEMC and PABF polygons were also examined. Of the 24,295 acres mapped as PEMC, 5,142 acres (21%) were mapped as potential fens. In addition, 193 acres (19%) of the acres mapped as PABF were mapped as potential fens. The final fen dataset also included 2,300 acres mapped with other codes in NWI and 4,316 acres not mapped at all within NWI.

The sections that follow (4.2 through 4.6) break down the fen mapping by elevation range, surficial geology, and HUC12 watershed. The last section summarizes observations made by the fen mappers during the mapping process, including potential floating mat fens.

Table 4. Acres mapped by NWI as saturated and other NWI codes and their 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	2,620	525	165	64	754	3,374
PFOB	1,591	18	2	--	21	1,611
PSSB	356	50	4	--	55	411
Total Saturated NWI Acres	**4,567**	**593**	**169**	**64**	**830**	**6.223**
PEMC	19,153	1,692	1,578	1,872	5,142	24,295
PABF	814	34	39	120	193	1,008
Other NWI Code	90,402	1,482	470	348	2,300	92,702
Total NWI Acres	**115,529**	**3,841**	**2,352**	**3,207**	**9,400**	**124,929**
Not Mapped by NWI	n/a	2,269	1,087	960	4,316	n/a
Grand Total		**6,110**	**3,440**	**4,167**	**13,717**	

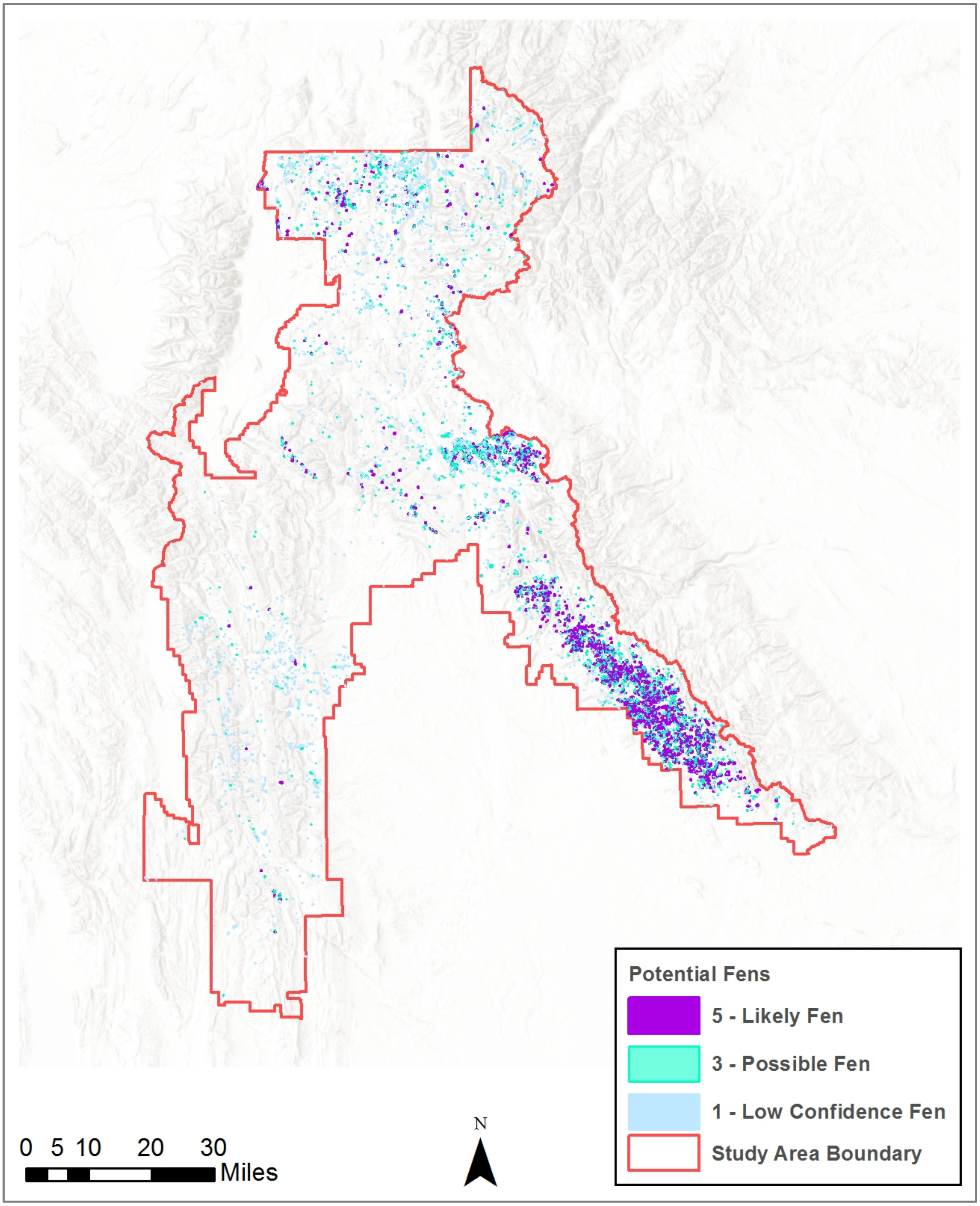

Figure 5. All potential fens within the fen mapping study area.

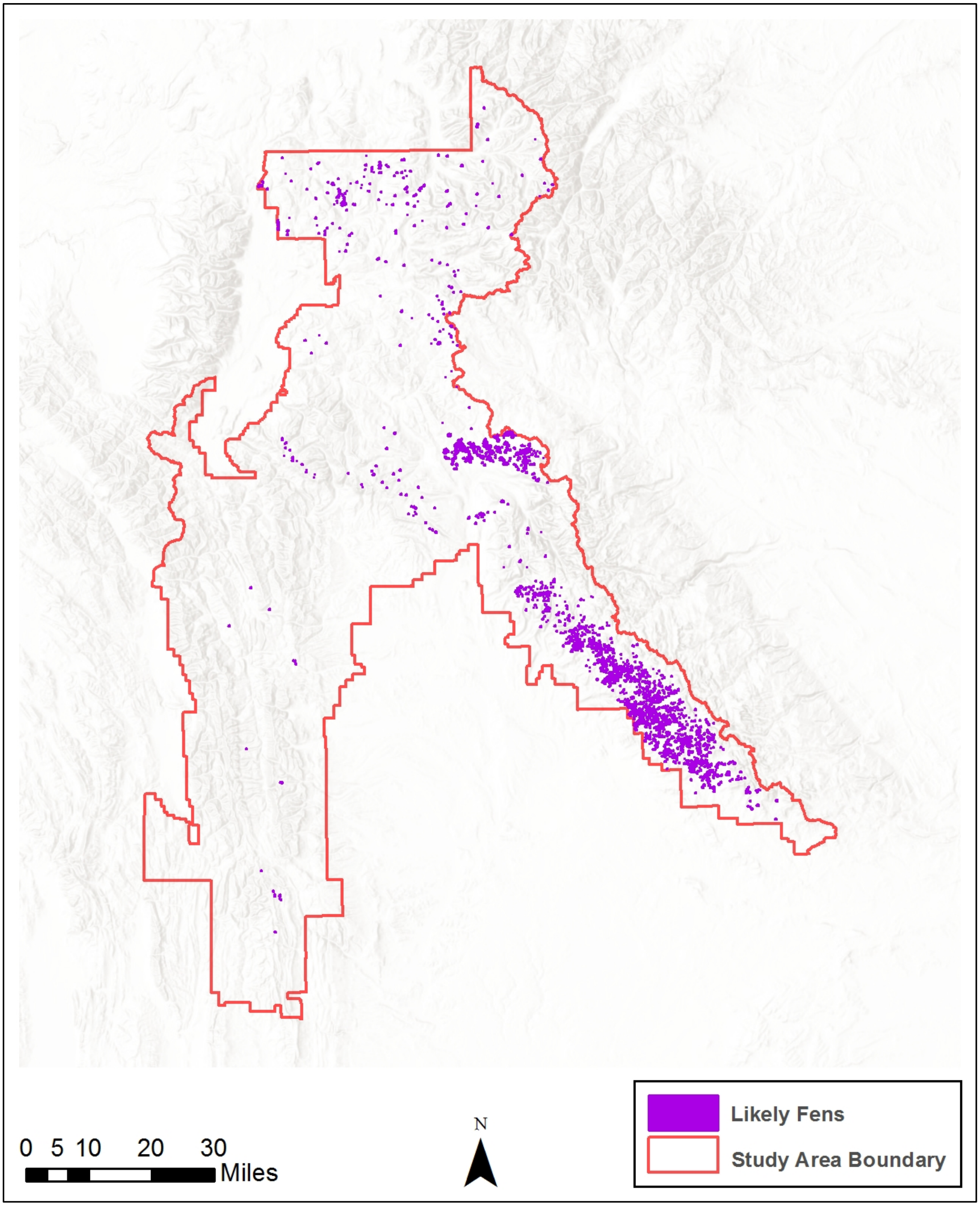

Figure 6. Likely fens (confidence rating = 5) within the fen mapping study area.

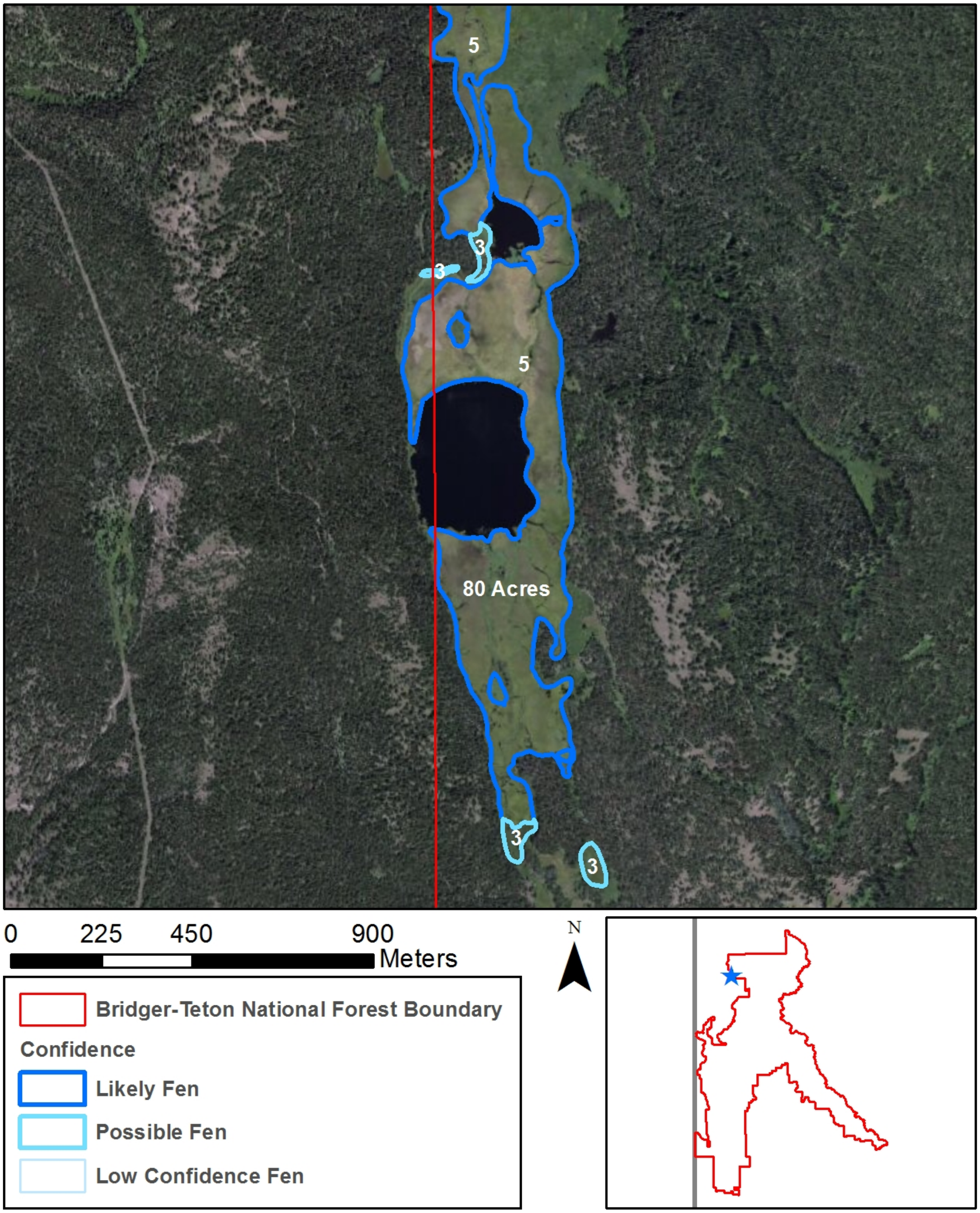

Figure 7. Largest mapped likely fen, 80 acres within one polygon. This fen is located in the Arizona Creek watershed, in Teton County on the western border of BTNF.

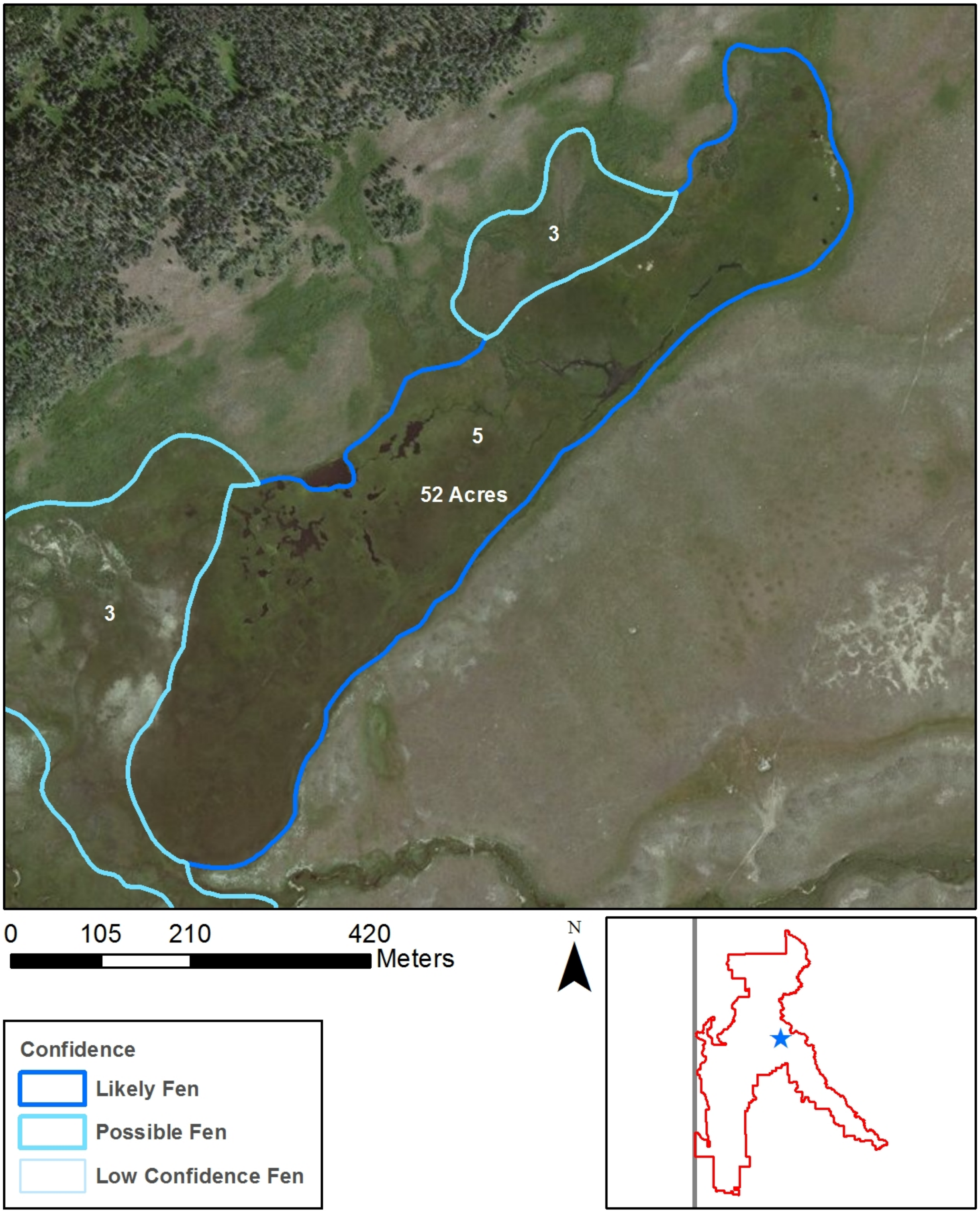

Figure 8. Second largest mapped likely fen, 52 acres within one polygon. This fen is located along Wagon Creek (visible south of the fen) in the Wagon Creek basin, on the border spanning Sublette and Teton Counties

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, 4,685 polygons (5,197 acres) were mapped between 9,000 and 10,000 feet, which represents 49% of potential fen locations and 37% of potential fen acres (Table 5; Figure 13). Of the 2,966 total likely fens mapped, 1,856 polygons (62%) and 2,501 acres (60%) were located between 9,000 and 10,000 feet (Table 5; Figures 9 and 10). This is clearly the zone of maximum fen formation for the BTNF.

The elevation bands of 8,000 to 9,000 feet and 10,000 to 11,000 feet were relatively similar in terms of potential and likely fens. Between 8,000 to 9,000 feet, there were 2,202 mapped potential fens (4,992 acres), which represent 23% of potential fen locations and 36% of potential fen acres. In addition, there were 296 likely fens (740 acres), which represent 10% of likely fen locations and 17% of likely fen acres. Between 10,000 to 11,000 feet, there were 1,617 mapped potential fens (1,245 acres), which represent 17% of potential fen locations and 9% of potential fen acres, and 630 likely fens (584 acres), which represent 21% of likely fen locations and 14% of likely fen acres. The likely fens mapped between 8,000 to 9,000 feet were much larger on average (2.5 acres) than the likely fens mapped between 10,000 to 11,000 feet (0.92).

These three elevation bands combined (8,000 to 11,000 feet) contain 89% of potential fen locations (83% of acres) and 94% of likely fen locations (92% of acres).

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*
< 8,000	725	2,058	39	205
> 8,000 – 9,000	2,202	4,992	296	740
> 9,000 – 10,000	4,685	5,197	1,856	2,501
> 10,000 – 11,000	1,617	1,245	630	584
> 11,000	15	7	--	--
Total	**9,503**	**13,708**	**2,966**	**4,165**

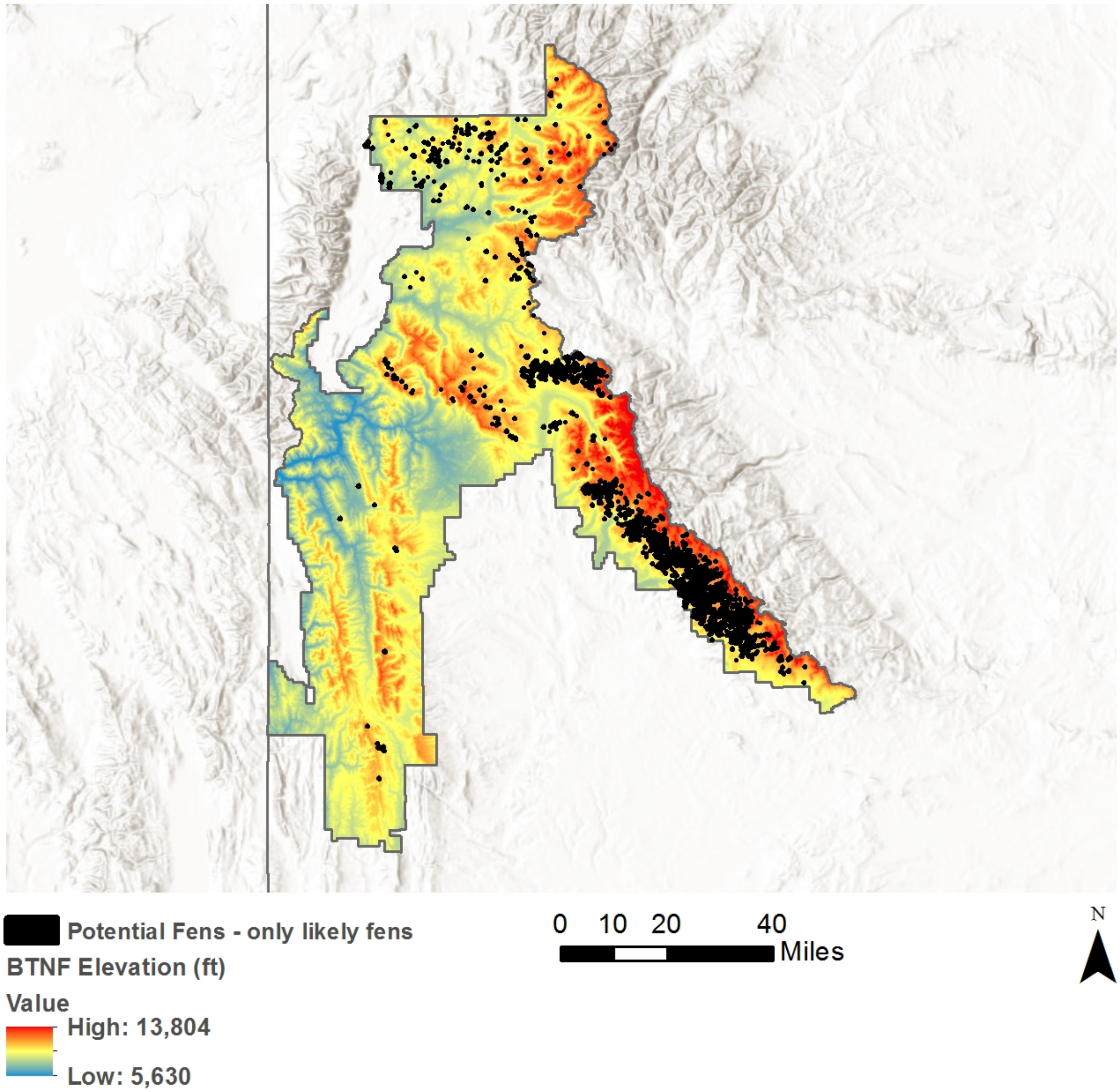

Figure 9. Likely fens (confidence rating = 5) and elevation within the fen mapping study area.

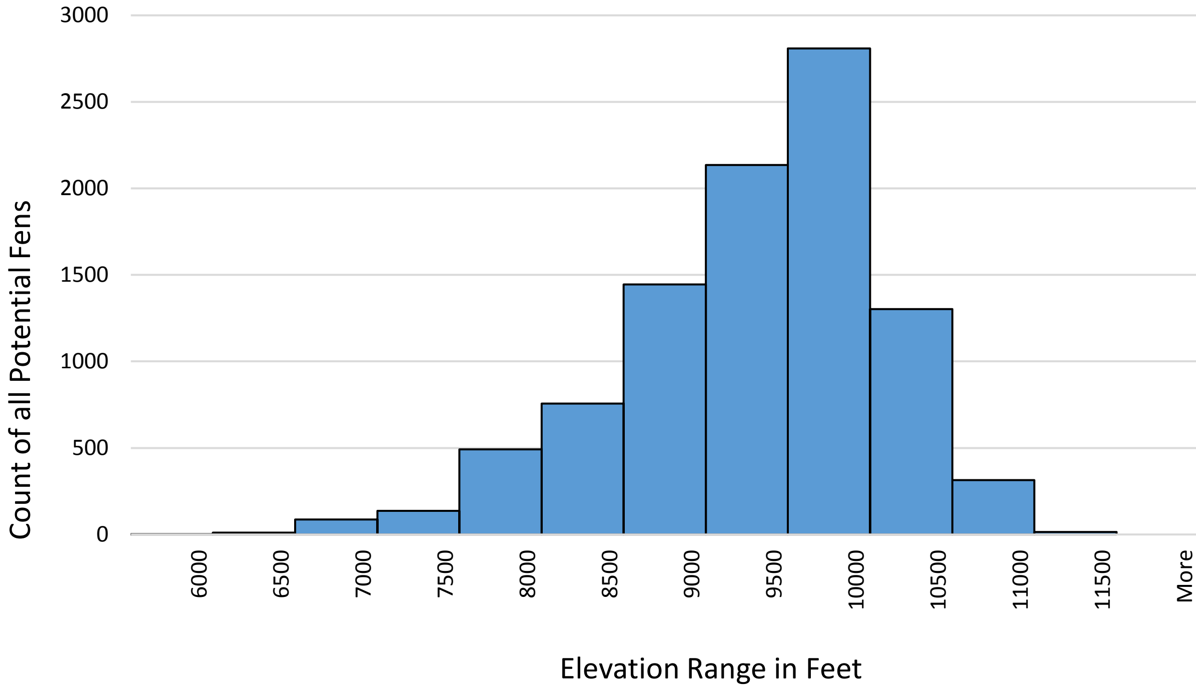

Figure 10. Histogram of all potential fens by elevation within the fen mapping study area.

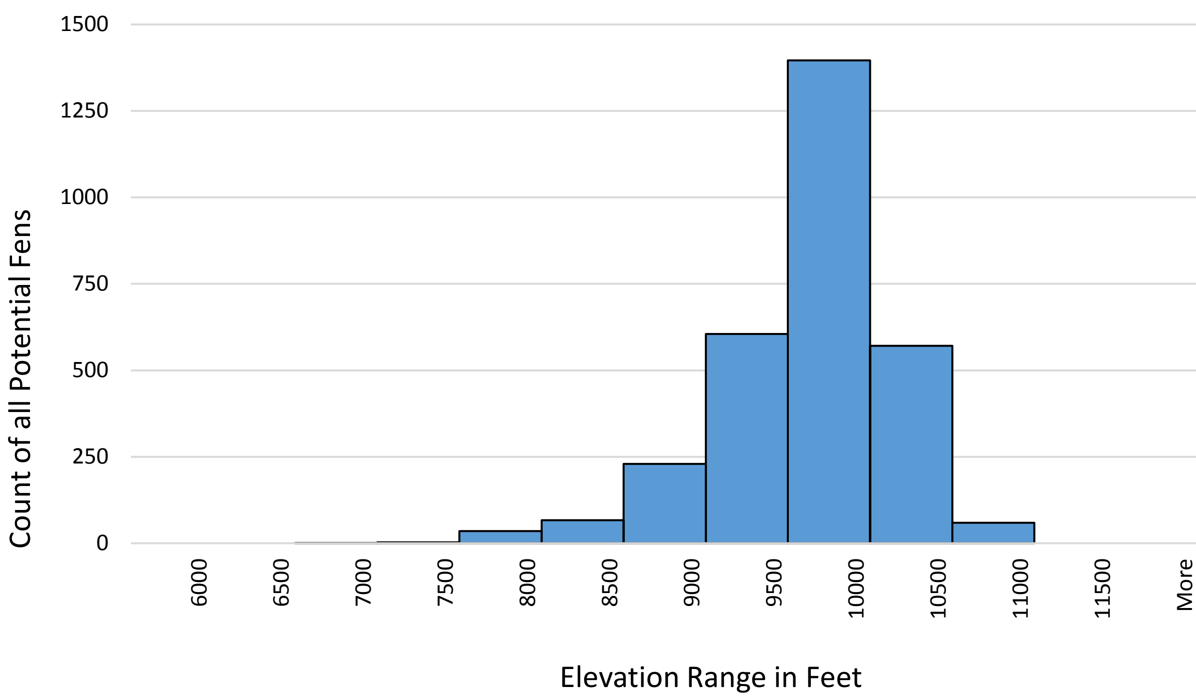

Figure 11. Histogram of the most likely fens by elevation within the fen mapping study area.

4.3 Mapped Potential Fens by Geology

The most common geologic substrate under both potential and likely fens in BTNF was Quaternary glacial deposits, which covers 11% of BTNF and underlies a quarter of all mapped potential fens (2,366 polygons, 4,510 acres) and 22% of likely fens (661 polygons, 1,518 acres) (Table 6). The next three most common substrates were Precambrian granites and gneiss. As a group, these unit cover 13.4% of the Forest and underlie 41% of all potential fens and 65% of likely fens. Additional major geologic units under mapped fens include Quaternary landslides (6% of all potential fens) and Tertiary-aged volcanics of the Absaroka Supergroup (6% of all potential fens).

Table 6. Potential and likely fens by geologic substrate within the fen mapping study area. See Table 1 for Map Unit name.

Bedrock Geology	*Acres of Geologic Substrate Within BTNF[1]*	*# of All Potential Fens*	*All Potential Fen Acres*	*# of Likely Fens*	*Likely Fen Acres*
Qg	381,716	2,366	4,510	661	1,518
Wgd	91,063	1,237	982	640	679
Wg	137,304	1,131	1,017	542	614
Wgn	78,573	831	504	402	304
Qls	207,752	544	687	43	104
WVg	74,249	421	184	211	92
Ttl	128,800	311	783	27	80
Twi	148,729	296	488	32	99
Qa	191,925	290	1,545	36	214
WVsv	17,849	270	123	145	80
MD	173,169	200	259	19	41
Kbb	69,231	153	194	1	1
Kha	70,224	126	175	23	29
Ta	18,178	114	113	19	29
O_	81,587	101	92	12	22
Twdr	18,132	100	59	30	36
Ugn	44,623	84	78	32	29
TKp	67,103	78	118	18	25
Kf	29,527	68	56	4	3
Kbr	56,411	58	50	0	0
PM	37,137	58	100	17	29
^ad	150,019	54	92	2	5
Qt	38,087	53	170	1	5
Ka	93,958	46	70	0	0
Pp	55,738	42	81	5	18
P*M	60,432	41	64	0	0
KJg	31,243	33	56	4	2

Bedrock Geology	Acres of Geologic Substrate Within BTNF[1]	# of All Potential Fens	All Potential Fen Acres	# of Likely Fens	Likely Fen Acres
Kmt	13,168	32	21	0	0
Jst	143,508	29	58	0	0
Kg	90,026	29	15	0	0
KJ	5,874	28	51	5	11
Thr	11,454	27	56	9	37
J^nd	85,709	25	52	3	10
J^n	61,676	23	41	1	4
Qu	9,235	20	415	2	9
Jsg	8,310	16	37	8	13
Kc	22,052	16	36	3	13
Tdb	12,815	16	6	0	0
Tv	2,817	13	5	1	0
Kmv	9,976	11	7	1	0
Twd	35,168	11	13	0	0
^cd	24,097	10	19	2	4
Kft	4,570	9	17	1	1
Th	45,032	9	10	0	0
Twlc	26,965	9	24	0	0
Ksb	25,748	7	70	0	0
Ws	4,242	7	6	0	0
Tgc	5,162	6	10	0	0
Tw	25,656	6	48	0	0
H2O	13,730	5	9	0	0
Kb	13,770	5	2	0	0
P*Ma	45,017	5	12	0	0
Kso	26,966	4	2	0	0
Twl	1,929	4	6	2	3
Wmu	1,800	4	3	2	2
Thl	147	3	3	0	0
Tep	879	2	1	0	0
Tp	71,102	2	2	0	0
Km	308	1	<1	0	0
Kss	10,636	1	1	0	0
Tte	12,593	1	<1	0	0
Ugn +	14,749	1	1	0	0
		9,503	**13,708**	**2,966**	**4,165**

4.4 Mapped Potential Fens by Land Type Association

Land Type Associations combine location, geology, and dominant vegetation and are defined by each Forest. The draft LTAs presented in Figure 3 were not analyzed for this report because map classes have not yet been assigned, but once those are available the potential fens should be looked at by LTA because that is often the most revealing analysis in this report.

4.5 Mapped Potential Fens by Watershed

An analysis of likely fens in HUC12 watersheds revealed interesting patterns. Four watersheds in particular had very high numbers of likely fens (Figure 12). North Fork of Silver Creek (HUC12: 140401020506) had 302 likely fens, which covered 1.32% of the landscape in this watershed. Upper Boulder Creek (HUC12: 140401020402) had 290 likely fens, covering 0.72% of the landscape. Upper Pole Creek (HUC12: 140401020301) had 231 likely fens, representing 0.40% of the landscape. Washakie Creek-East Fork River (HUC12: 140401020501) had 208 likely fens representing 0.79% of the basin. See Appendix A for the full HUC12 watershed and likely fens table.

One HUC 12 watershed stands out in terms of having very high potential fen density: Wagon Creek (HUC 6: 140401010105) contains 403 potential fens (928 acres) which represents 6.3% of the land area in the watershed (Figure 13).

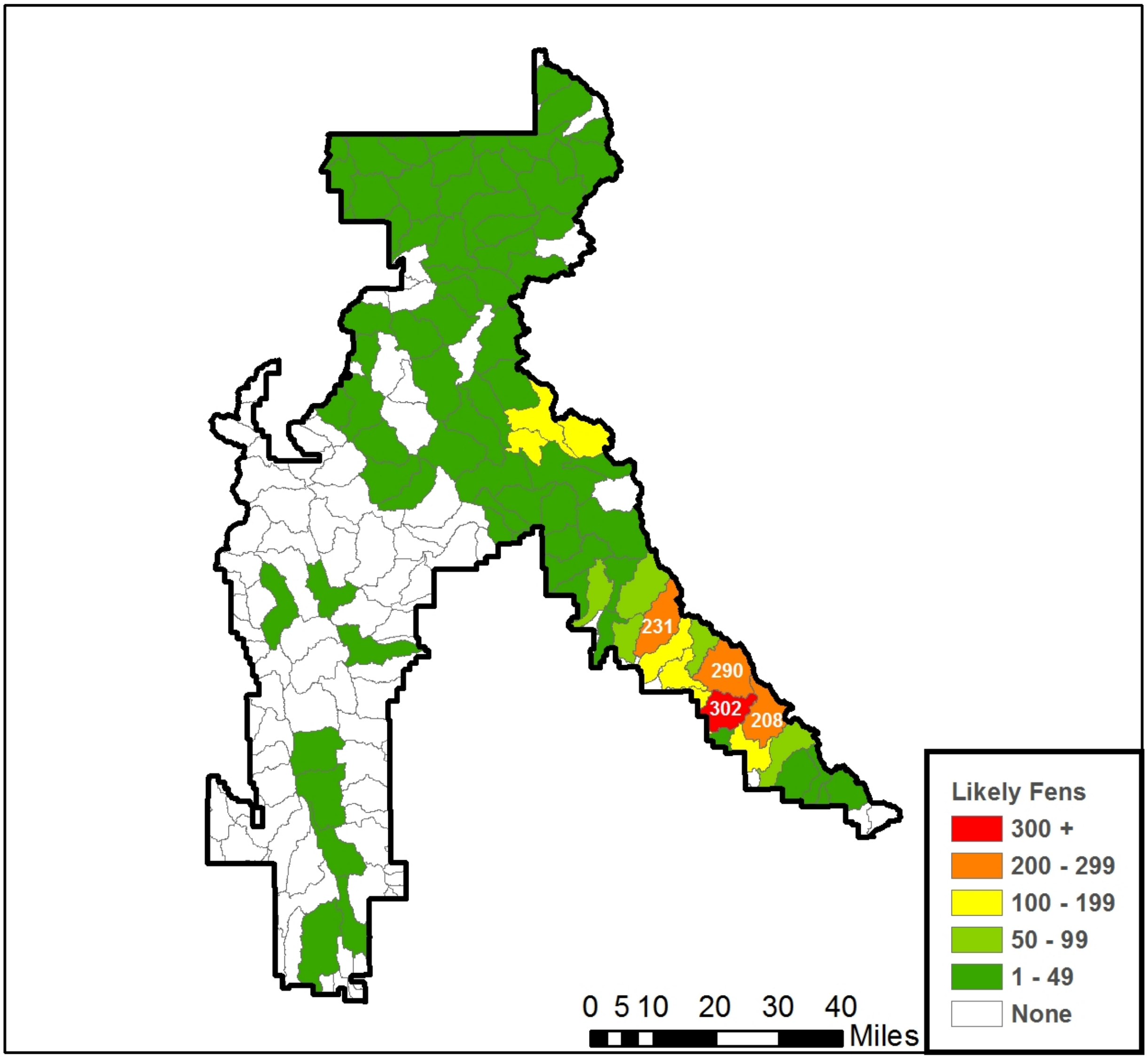

Figure 12. Likely fens by HUC12 watershed within the fen mapping study area.

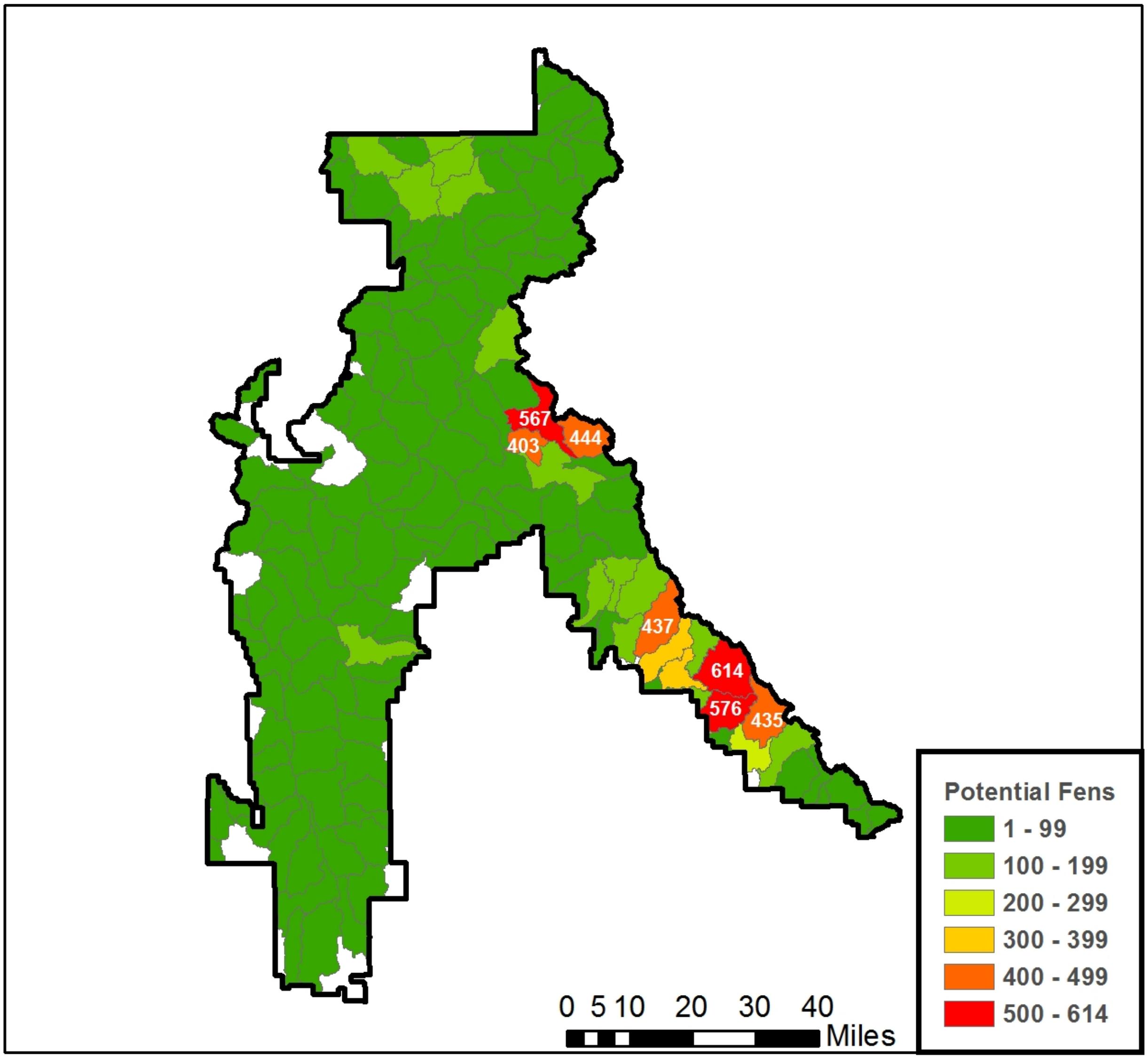

Figure 13. All potential fens by HUC12 watershed within the fen mapping study area.

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 7), though this was not an original objective of the project and may not have been applied comprehensively across the study area.

Of particular interest was markers for potential floating mat fens, a rare type of fen (Figure 14). One hundred and sixty-three potential fens (173 acres) and seventy-five likely fens (94 acres) were identified as potential floating mat fens.

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. Forty-eight potential fens were observed in proximity to springs, four of which were likely fens.

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. One hundred and sixty potential fens (1,239 acres) showed some evidence of beaver influence, although were none were considered to be likely fens.

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	160	1,259	0	--
Possible Floating Mat	163	173	75	94
Spring	48	248	4	47
Total	**371**	**1680**	**79**	**141**

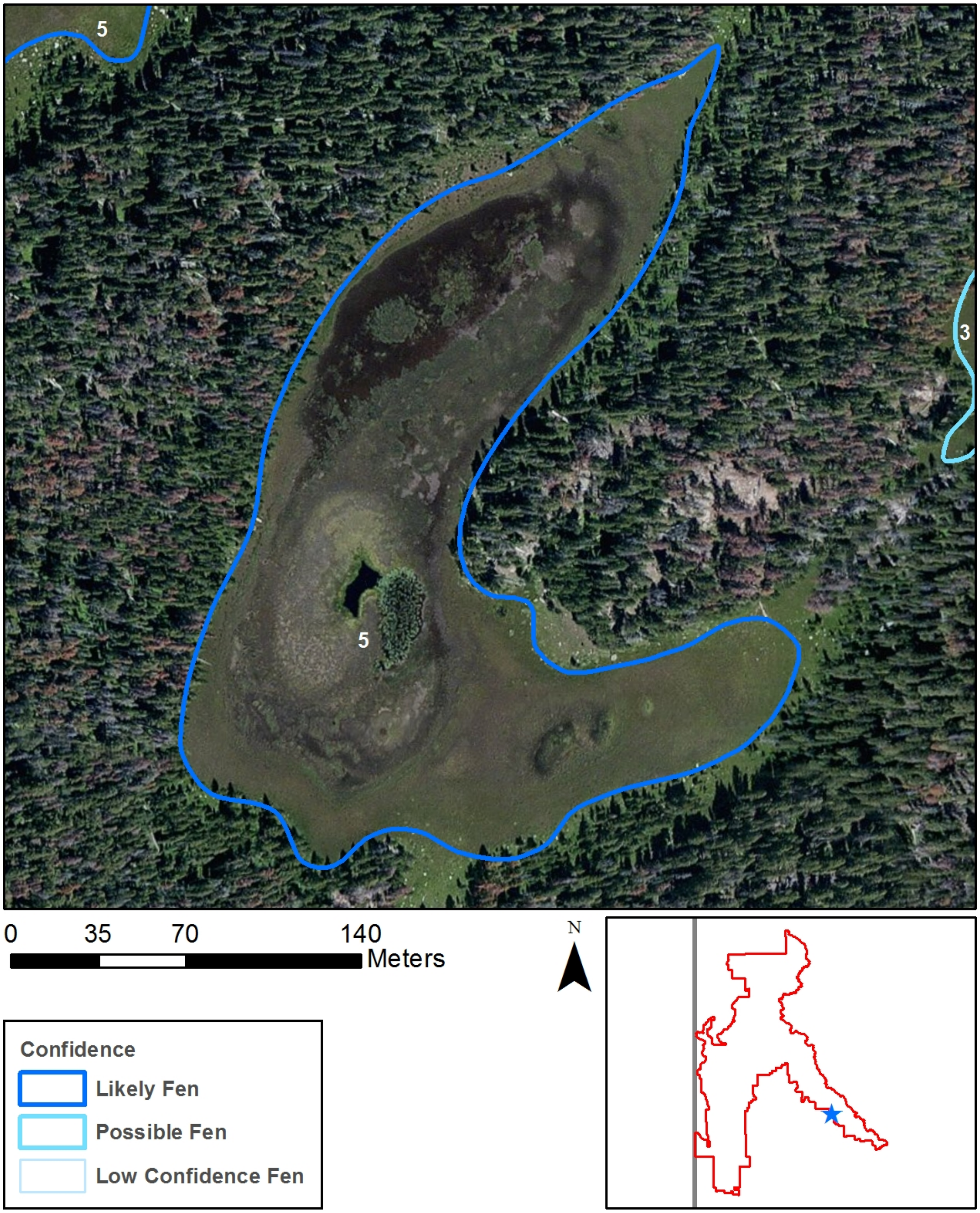

Figure 14. Possible floating mat fens located in the Silver Creek watershed, in Sublette County.

5.0 DISCUSSION

The Bridger-Teton National Forest contains a rich resource of fen wetlands, covering up to 13,708 acres across its jurisdiction. While that represents only 0.4% of the entire landscape, these fen wetlands are an irreplaceable resource for the Forest and the citizens of Wyoming. 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).

In total, 9,503 potential fens were mapped throughout the BTNF, of which 2,966 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 produced a more accurate and precise accounting of fen number and acreage. Analysis of the potential fen data showed clear patterns in fen distribution within the BTNF. There was a strong elevation gradient, with 89% of potential 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 BTNF, including the North Fork Silver Creek, Upper Boulder Creek, Upper Pole Creek and Washakie Creek-East Fork River. These areas should be actively conserved.

Bedrock geology can exert a strong influence on species composition within fens (Chimner et al. 2010; Lemly & Cooper 2011). Bedrock geology in BTNF is complex, with geologic formations that range from relatively recent alluvial, colluvial and glacial deposits to large outcrops of Precambrian granite and gneiss dating back to the original rise of the Rocky Mountains billions of years ago. Extensive areas of the Forest also include volcanic rock originating from intense volcanic activity that helped shape Yellowstone National Park, as well as sedimentary strata of the Triassic and Jurassic periods. The chemical composition of groundwater passing through different geologic substrates can develop distinct signatures, which in turn influence plant species composition. Granitic watershed often exhibit neutral pH values and moderate to low concentrations of ions. Groundwater flowing through sedimentary bedrocks can contain a high concentration of calcium and magnesium ions, and fens formed on these substrates may support a distinct suite of plants (Cooper 1996; Johnson & Steingraeber 2003). The most calcium rich fens are often associated with limestone or dolomite, both of which occur within BTNF. Glacial till can exhibit chemical signatures similar to the surrounding underlying geology. Cooper and Andrus (1994) documented fens within the Barnes Lake region of the Wind River Range in BTNF, a heavily glaciated area with underlying granite. Fens in this area were described as transitional rich fens, with neutral to slightly acidic pH and low cation concentrations. Glacial till within sedimentary watersheds, however, can have higher pH values (Lemly & Cooper 2011).

In addition to water chemistry, bedrock geology also shapes the template of landforms on which fens form, including slopes with active groundwater discharge and open basins with relatively static water levels. This study identified numerous large basin fens with extensive floating map development. In the Rocky Mountains, several rare fen species have high fidelity to floating mats, including woollyfruit sedge (*Carex lasiocarpa*), mud sedge (*Carex limosa*), buckbean (*Menyanthes trifoliata*), marsh cinquefoil (*Potentilla palustris*), sundews (*Drosera* spp.) and pod-grass (*Scheuchzeria palustris*) (Lemly & Cooper 2011; Chimner et al. 2010). These areas should be surveyed for rare species and should be considered for extra resource protections. Previous studies of fens within BTNF (Cooper & Andrus 1994) and from nearby Yellowstone National Park (Lemly 2007; Lemly et al. 2007; Lemly & Cooper 2011) document numerous fen plant communities and rare plant species that may occur in the Forest. Given the complex geology and geography, it is likely that BTNF fen are highly varied.

Fortunately, the condition of wetlands in high elevation forests is generally excellent to good (Lemly 2012). Human stressors were observed in some fen wetlands while mapping fens on the BTNF, such as off-roading vehicle trails, foot trails, fences or impoundments, and those observations were captured in the “Notes” field of the GIS dataset accompanying this report. However most potential fens in BTNF showed little sign of human disturbance, particularly at higher elevations.

This report and associated dataset provide the BTNF with a critical tool for conservation planning at both a local and Forest-wide scale. These data will be useful for the ongoing BTNF 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. (2007) Fens of Yellowstone National Park, USA: regional and local controls over plant species distribution. MS Thesis, Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO.

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.

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.

Wyoming Geological Survey (1998) Preliminary 1:500,000-Scale Digital Surficial Geology Map of Wyoming. Geologic Hazards Section Digital Map 98-1 (HSDM 98-1)

Wyoming State Geological Survey (2014) Wyoming Bedrock Geology. Laramie, WY.

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)
140401070502	East Fork Hams Fork-Hams Fork	47457	1	3	2.73%
170401030401	Spring Creek-Greys River	36026	1	15	1.33%
170401020305	Bierer Creek-Gros Ventre River	25614	1	1	1.32%
170401030302	Shoal Creek	20574	3	2	0.84%
170401020301	Slate Creek	27639	1	2	0.82%
140401010306	Big Twin Creek-Green River	40417	4	8	0.81%
170401010503	Cub Creek	24163	7	17	0.79%
170401010301	Mink Creek	21524	19	56	0.72%
100700010203	Falcon Creek-Yellowstone River	23923	2	8	0.67%
100700010101	Butte Creek	11991	3	4	0.65%
100700010301	Upper Mountain Creek	18596	1	2	0.60%
140401020505	Cottonwood Creek	18925	32	66	0.40%
170401030402	Corral Creek-Greys River	31368	1	1	0.39%
170401010409	Lower Jackson Lake	29629	3	10	0.35%
170401010207	Forest Creek-Snake River	30202	1	1	0.32%
170401010205	Coulter Creek	32421	10	39	0.31%
140401010302	Lime Creek-Green River	22688	4	11	0.27%
170401010507	Blackrock Creek	31284	14	18	0.26%
100700010202	Atlantic Creek	17945	10	46	0.26%
140401010304	Gypsum Creek	24539	15	40	0.22%
170401010501	Lake Creek	16858	2	10	0.21%
100700010102	Upper Thorofare Creek	28203	5	6	0.16%
140401020507	Silver Creek	24468	138	159	0.12%
140401040101	Black Joe Creek-Big Sandy River	28408	65	191	0.12%
170401030408	Upper Little Greys River	23236	2	11	0.12%
170401010601	North Fork Spread Creek	17564	2	5	0.11%
100700010104	Hidden Creek	12828	2	4	0.10%

101800060103	Lander Creek	36389	3	9	0.10%
140401020501	Washakie Creek-East Fork River	30864	208	243	0.09%
170401030303	Upper Granite Creek	25650	11	12	0.09%
140401010305	Boulder Creek-Green River	30481	2	2	0.09%
170401020203	Kinky Creek-Gros Ventre River	29886	3	2	0.08%
170401020105	Bacon Creek-Fish Creek	22967	1	1	0.08%
140401010303	Rock Creek	12494	6	6	0.07%
170401020102	Middle South Fork Fish Creek	30806	148	250	0.07%
170401010201	Plateau Creek-Snake River	23136	15	21	0.07%
170401010302	Upper Pacific Creek	25478	12	31	0.06%
140401020303	Falls Creek	26697	153	103	0.06%
140401020101	Bridger Creek	33599	74	34	0.06%
100700010201	South Fork Yellowstone River-Yellowstone River	38773	3	6	0.05%
140401020401	North Fork Boulder Creek	16757	63	53	0.05%
140401020506	North Fork Silver Creek	27272	302	362	0.05%
170401010402	Sheffield Creek-Snake River	30249	5	22	0.05%
140401011201	Headwaters Fontenelle Creek	28382	7	25	0.05%
170401010509	Lava Creek	17006	2	3	0.05%
170401010602	South Fork Spread Creek	28420	1	5	0.05%
170401010204	Wolverine Creek	17358	3	6	0.05%
170401010508	Upper Buffalo Fork	29118	5	9	0.04%
170401010504	Soda Fork	20484	1	1	0.04%
140401020103	Lower Pine Creek	25737	2	3	0.03%
140401020202	Lake Creek	21229	81	57	0.03%
140401020102	Upper Pine Creek	15919	43	19	0.03%
140401010102	Porcupine Creek-Green River	45156	7	6	0.03%
140401020403	Middle Boulder Creek	16494	175	135	0.03%
140401020502	Irish Canyon Creek-East Fork River	28091	111	237	0.03%
140401040102	Squaw Creek	31606	28	67	0.03%
101800060101	Pool Creek-Sweetwater River	20920	7	9	0.02%
170401030101	Upper Flat Creek	31093	7	3	0.02%
140401010402	Upper Horse Creek	36462	3	5	0.02%

170401030304	Lower Granite Creek	28725	1	0	0.02%
170401010608	Ditch Creek	39536	3	3	0.02%
170401010405	Arizona Creek	17711	4	106	0.02%
170401020201	Clear Creek-Gros Ventre River	36534	12	31	0.02%
170401010506	Lower South Buffalo Fork	23281	3	5	0.02%
170401010505	North Buffalo Fork	34692	7	16	0.01%
100700010106	Lower Thorofare Creek	22939	3	22	0.01%
170401020101	Upper South Fork Fish Creek	27071	198	358	0.01%
140401010103	Roaring Fork	15741	16	14	0.01%
140401020402	Upper Boulder Creek	38326	290	278	0.01%
170401010304	Lower Pacific Creek	27123	4	3	0.01%
170401010303	Middle Pacific Creek	32268	41	70	0.01%
140401010301	Tosi Creek	35938	11	24	0.01%
140401010104	Wagon Creek	14763	115	402	0.01%
170401020103	North Fork Fish Creek	36001	19	22	0.01%
140401010105	Mill Creek-Green River	36228	28	40	0.01%
140401040302	Upper Little Sandy Creek	41902	9	21	0.01%
140401011001	Headwaters La Barge Creek	25982	2	4	0.01%
170401030410	White Creek-Greys River	28962	1	2	0.01%
170401030102	Nowlin Creek	20313	4	3	0.01%
170401020204	Dry Cottonwood Creek-Gros Ventre River	40459	1	0	0.01%
170401010408	Pilgrim Creek	31737	12	26	0.01%
170401020104	Lower South Fork Fish Creek	29831	4	2	0.01%
140401020203	Willow Creek	36025	16	17	0.00%
140401020201	Marsh Creek-New Fork River	38575	8	7	0.00%
140401020302	Middle Pole Creek	16297	77	53	0.00%
100700010105	Open Creek	32213	5	17	0.00%
140401020301	Upper Pole Creek	33700	231	135	0.00%