

Revisiting Edward R. Warren:
A Century of Beaver (*Castor canadensis*) Occupancy near Crested Butte, Colorado

By

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Chapter 1: Introduction

1.1 Context

Beaver (*Castor canadensis*) are a well known and studied keystone species. Historically, sizeable beaver populations were found throughout most of North America north of the Rio Grande watershed, but because of over-trapping beginning in the 1600's extending through the 1800's they were extirpated from most of their range. Due to changes in fashion and the introduction of conservation laws protecting beaver, their populations in Colorado were able to partially rebound and colonies could be found in all suitable habitat by the 1950's (Rutherford 1964). An estimated 6 to 12 million beaver are thought to exist today in most of their historic range throughout North America (Naiman et al. 1988). This is a drastic decrease when compared to the 60 million to 400 million beaver thought to exist prior to European settlement (Boyle and Owens 2007).

Beavers are great engineers capable of modifying their environment to create habitat more suitable to their needs by changing the hydrology of a specific site (Naiman et al. 1988, Ruedemann and Schoonmaker 1938). Numerous species have come to depend on the ponds and wetlands created by beaver occupancy. Both game and non-game wildlife depend on these areas, as well as fish, bird, amphibian, reptile and aquatic invertebrate species (Cunningham et al. 2006). Other studies have found beaver ponds to be significant areas for trout and waterfowl breeding (Neff 1957). For those species dependent on beaver ponds it is important for beaver to be managed for long-term occupancy, and more information needs to be gathered on how long beaver can potentially occupy an area. Federal

natural resource management agencies currently use beaver as a Management Indicator Species (Boyle and Owens 2007). Looking at how long an area retains a beaver colony can provide an indication of ecosystem quality in those areas. Understanding historic population trends can be useful for wildlife managers to determine current population levels, as well as how beaver activity has changed the aquatic ecosystems in the area over time (Broschart et al. 1989).

Long-term studies of beaver habitation and demography have been conducted using aerial photographs or field observations (Busher and Lyons 1999, Cunningham et al. 2006, Hay 2010, Johnson and Naiman 1990a, Neff 1959, Warren 1932). However, no studies have examined long-term beaver occupancy in high mountain colonies utilizing information before 1930 and after 1960. Previous studies were conducted in the late 1800's to early 1900's while beaver populations were experiencing extreme fluctuations. These fluctuations, ranging from near extinction to a population explosion, were the result of over trapping followed by the implementation of conservation measures to protect the beaver. An intense investigation of beaver demographics and habitat requirements occurred in the mid 1950's (Retzer et al. 1956), shortly after beaver populations started to become more stable with increasing abundance; those that studied beaver colony lifespan were limited to short time frames and/or were not in mountainous areas (Busher and Lyons 1999, Cunningham et al. 2006, Fryxell 2001, Hay 2010, Johnston and Naiman 1990a, Johnston and Naiman 1990b, Naiman et al. 1988, Neff 1959, Warren 1932).

This study fills a niche and addresses how long a beaver colony will remain in one specific site, what factors may contribute to occupancy or abandonment, and

how these beaver colonies have changed after 85-plus years. This study documents nearly 100 years of change in colonies in a portion of the Elk Range of the Western Rocky Mountains in and around Crested Butte, Colorado.

1.2 Overview and Research Questions

Aerial photos can readily be used to illustrate locations of ponds created by beaver colonies (Broschart et al. 1989, Cunningham et al. 2006, Lawrence 1952). Aerial photos of the field area, in combination with written documentation by a naturalist from the early 1900's, provide a baseline for a long-term data set for examination of beaver occupancy over the past 100 years.

Edward Royal Warren meticulously documented the work of beaver in the area around Crested Butte, Colorado from 1898 to 1937. His results are found in multiple publications and in his remarkably detailed field journals (Warren 1927, 1928a, 1937a-h). Warren's journals on beaver and their work in the Crested Butte area are archived at the Rocky Mountain Biological Laboratory (RMBL) in Gothic, Colorado and can be found in the appendix of this document. The beaver field journals were either typed by Warren himself or were transcribed by staff at RMBL from Warren's hand written field books. This study uses Warren's journals as a "snapshot" in time of the field area and beaver work locations from a century ago. With this detailed background I then document long-term beaver occupancy/abandonment over the past 85 to 100 years. Other studies that attempt similar longitudinal documentation are limited to aerial photos dating in the late 1930's (Busher and Lyons 1999, Cunningham et al. 2006, Johnston and Naiman

1990a, Johnston and Naiman 1990b, Naiman et al. 1988); therefore this study is likely to be unique, as it begins with a clearly detailed understanding of beaver habitat in the area as documented by Warren beginning in the late 1800's.

This study utilizes Warren's journals supplemented by aerial imagery and ground "truthing" by me to determine long-term occupancy of beaver colonies found in the Slate River Valley and several of its tributaries surrounding Crested Butte. Using this basic methodology, I document:

- 1.) What is the present state of the colonies in the area in comparison to that reported 85 to 100 years ago?
- 2.) What factors of habitat suitability have contributed to the sustainability or abandonment of beaver occupation sites?
- 3.) How have beaver lodge densities in these areas changed over the study period?

Discussion throughout this thesis regarding past beaver work and habitat in the field area is from Warren's journals (Warren 1937a-h) and thus is not cited in every instance in the text, but is to be assumed by the reader. Other references, such as from Warren's other publications, will be cited appropriately.

This thesis is formatted as to give adequate background on beaver biology and ecology, Edward R. Warren and study areas. In order to avoid distracting from the text Appendix 1 is included where the majority of maps for the various streams studied can be found. However, maps relevant to text or for reference are placed on the same or following page in the document. A copy of Warren's journals utilized in this study is also found in Appendix 2.

1.3 Edward Royal Warren

Edward Royal Warren spent a great deal of his life dedicated to inquiry of the natural world. He was born 17 October 1860 in Massachusetts to Royal and Susan (Bates) Warren. After graduating from Massachusetts Institute of Technology in 1881 he moved to Colorado to study mineral assaying at The Colorado College, Colorado Springs (Armstrong 1986). He then moved to Gothic, Colorado in 1882 with his father. There he worked for the Gunnison Company as an assayer and surveyor in the small mining towns around Crested Butte (Armstrong 1986, New York Times 1942). In 1902, he began his career as a professional naturalist after moving back to Colorado Springs working specifically with mammalogy and ornithology (New York Times 1942).

Warren proved to be a skilled naturalist and mammalogist. In addition to publishing many books and articles on his findings on the mammals of Colorado, he was an honorary director of the Museum of Colorado College from 1909-1918, a collaborator and field naturalist with the Roosevelt Wild Life Experimental Station from 1921-1928 (New York Times 1942, Armstrong 1986), and in 1939 he was awarded an honorary doctorate from The Colorado College, Colorado Springs. He has also been immortalized by the addition of his name to taxonomy of three mammal species, one insect, one bird, and one floral species (Armstrong 1986).

While Warren specialized in the study of beaver for seven years with the Roosevelt Wild Life Experimental Station (Armstrong 1986) he had always had

great interest in them. He took notes on the work of beaver in most locations he traveled. He observed in detail the beaver work in the Slate River Valley from 1902 to the late 1930's. He published much of this work thus adding to his credibility (Warren 1905, 1927, 1928a). In 1927, he began a detailed examination of the colonies he saw in this area, as well as other locations along tributaries to the Slate and East Rivers, including measurements of dams, canals and the number of lodges. His enthusiasm is evident through his many publications on the work of the species, including a book Warren authored titled "The Beaver: Its Work and Its Ways" and an article entitled "The Most Interesting Wild Animal in America," which was dedicated to the topic of beaver and their habits (Warren 1927, 1928b). Warren was a meticulous note taker, journaling everyday noting the date, location, weather, temperature, and events of the day. He documented things from interesting animals he saw, places he went with his family, his work, and special events. This assiduousness was also reflected in his notes on beaver work. Interpreting his journals one can find the same locations and envision what the landscape looked like in his time thus providing the foundation for this study.

1.4 Limitations

The intention of this study was to revisit the beaver colonies that were documented by Edward R. Warren and determine whether those colonies still remain and record how they have changed. Unfortunately, I feel that this study cannot be utilized as a population survey. While Warren documented many of the locations where beaver

were found in this region of Colorado, he does not document in his journal every beaver lodge he came across or colony in the area. He is also not consistent with his documentation. In some years and for various streams he is very clear about methods. In these areas he documents a specific length of stream he walked and the measurements of dam and lodge dimensions found. However, in other locations he only talks about the specific colony he is measuring and makes no note if beaver are or could be found in other sections of the same stream. In some instances he makes vague reference to other work nearby but does not mention lodges, dams or the size of area. In many years he simply states that ponds are still full and makes no other comments on whether lodges are still present, active or changed in any way.

Warren also makes note that in areas with large amounts of potential beaver habitat it is difficult to see every lodge, such as in the Slate River Valley. During years when Warren surveyed in the late summer, vegetation was a hindrance to seeing all lodges in these large areas. He has made notes about willow and grasses being so thick and dense that it is difficult to see some lodges. It is now known that counting a beaver colony's winter food cache in the fall is the less intensive and more accurate method of estimating beaver populations. However, this was not common knowledge in Warren's time nor did it ever seem to be his intention to obtain an accurate beaver census.

I was also limited by my interpretation of his journals. I found some of the references to locations undecipherable and had to omit those areas from the study. While in the field I encountered a few difficulties. My field research was done during the end of July and the beginning of August in 2011. The density of

vegetation during this time made it difficult to see all possible lodges. While I believe the majority of lodges were seen in most locations, it is assured that not all lodges were documented. Low lodges and those with vegetation growing on top may have been hidden from view and not documented. Conducting my survey in the autumn after leaf fall would have been more ideal. I also was not granted permission by private landowners to survey some areas of the Slate River Valley on their property. I was able to see a good portion of these areas from public roads, but am sure I missed some lodges due to a lack of a thorough examination.

Due to the inconsistencies of Warren's surveys and limitations in both Warren's and my studies, I cannot conclude an accurate beaver population based on the number of lodges. If one conducted a thorough examination of all areas of these streams now they would find more areas impounded by beaver and the beaver population dispersed to a few more places than in Warren's time. My intension was to revisit Warren's colonies and not to record all beaver occupancy in the Crested Butte area. However, by revisiting the same areas Warren visited and documenting the area almost 100 years later, we can see whether beaver have remained in a majority of the same areas and further investigation can occur.

1.5 Study Area

1.5.1 Overview

Physical Setting

The Slate River Valley and its tributaries are found near the town of Crested Butte,

Colorado in northern Gunnison County (38°52'14"N, 106°58'39" W). Crested Butte is surrounded by the Gunnison National Forest in the Elk Mountain region on the western slope of the Rocky Mountains (Figures 1 and 2). The Raggeds Wilderness Area can be found to the west, the Maroon Bells-Snowmass Wilderness Area to the northeast, and the West Elk Wilderness to the southwest, all within a few miles of the town center. Crested Butte Mountain is found northeast of the town 3,707 m (12,162 ft). Gothic Mountain is to the north 3,848 m (12,625 ft). Specific study sites can be found at elevations ranging from 2,697 to 3,139 m (8,850 to 10,300 ft). Mean annual air temperature ranges from 0 to 22.1 °C (32 to 71.7 °F) in summer to -17.8 to 1.6 °C (0 to 34.8 °F) in winter (Western Regional Climate Center 2012). Average snowfall is 5 m (197.9 inches) in Crested Butte (Western Regional Climate Center 2012) and 11 m (433 inches) in Gothic (Rocky Mountain Biological Laboratory 2012). Gothic (38°57'29" N, 106°59'19" W) is found 10 km north of Crested Butte at an elevation of 2,896 m (9,500 ft). Since 1928, Gothic has been home to the Rocky Mountain Biological Laboratory which supports research on a variety of biological topics. At one point in his career Warren's field office was located at RMBL. This was also where I stayed during my summer 2011 research. The surrounding forests include a mix of aspen, spruce-fir, and lodgepole pine based upon elevation and age structure. Vegetation in the study area is chiefly species of willow (*Salix spp.*), quaking aspen (*Populus tremuloides*), Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*), marsh grasses and sedges.

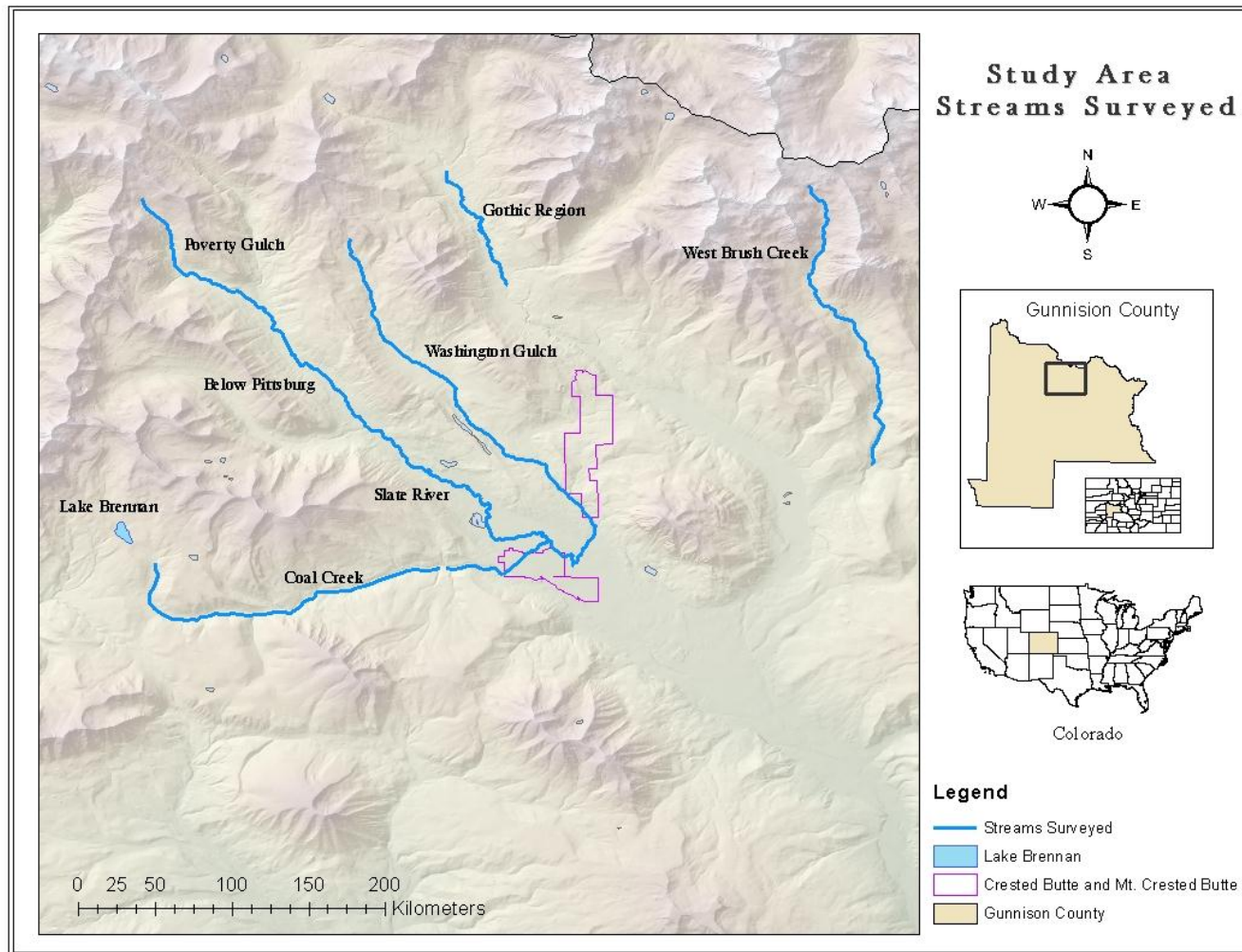


Figure 1 State, county and local perspective for study area displaying main lakes, rivers and streams surveyed.

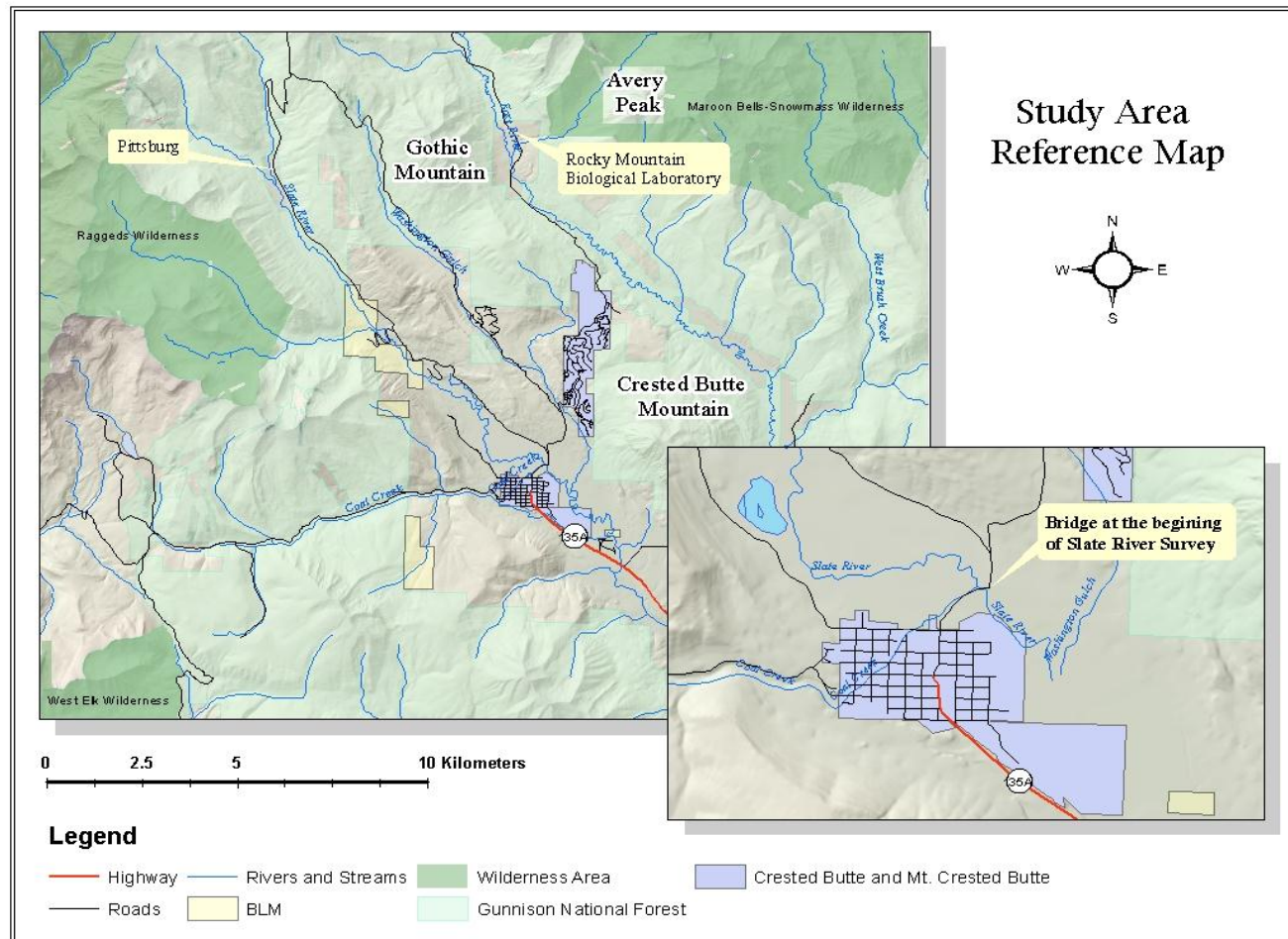


Figure 2 Reference map for specific locations, landforms, roads, and bridges.

History

The story of Crested Butte and the small mining towns around it is one of great diversity. The valleys were first inhabited by the Ute Indians, which were thought to have lived in the mountains of the Western Colorado Rockies (The Crested Butte Mountain Heritage Museum 2012). With the expansion of western settlement and exploration of minerals, the areas became populated with miners. During the 1860's, the area was riddled with small mining towns filled with men looking for silver. With a crash in silver prices in 1893 many of these small towns were abandoned. However, the town of Crested Butte was able to survive due to its high-grade coal mines. Figure 3 is a photo of the town during this time. The town then was dominated by workers for the mining of coal and production of coke. In 1952, when coal consumption began to decrease and had become too expensive to ship, many of the mines closed and the town again had to redefine its existence. In the 1960's, the town switched its trademark to skiing with the opening of a ski area on Crested Butte Mountain with the state's first gondola (The Crested Butte Mountain Heritage Museum 2012). Skiing is still popular today, in addition to other types of outdoor recreation such as mountain biking, hiking, and wildflower viewing. Also, the area is currently - and has historically been - home to the ranching industry. Warren many times documented seeing cattle in the meadows or signs of cattle near the beaver ponds he studied.



Figure 3 Town of Crested Butte Colorado in late 1890's to early 1900's with Slate River in foreground. Courtesy Denver Public Library.

1.5.2 Slate River

The Slate River is a tributary to East River and flows in a southwesterly direction for over 28 km in total length. The section of the valley surveyed begins above Crested Butte (Figure 2) and extends upstream approximately 5.5 km northwest on Slate River and remains at an elevation of 2,697 to 2,743 m (8,850 to 9,000 ft) (Figure 1).

Attempts were made to survey as much of the same area as possible in 2011. This is a meandering river, which keeps high sinuosity through most of its course. Some beaver work is found in sloughs along the main river. Vegetation consists of a great deal of willow, riparian grasses, sedges and conifers in the northern reach. This area provides a great amount of beaver habitat, however the area was too large and the willow grew too densely for Warren to survey every pond. Warren also notes that due to vegetation growing so high it was impossible to discover all beaver work (Warren 1928a and 1937a-h). I also found this to be the case when I surveyed the area.

1.5.3 Below Pittsburg

This portion of the Slate River is approximately one mile south of the historic town of Pittsburg (Figure 1 and 2). Elevation is 2,792 m (9,160 ft) and remains consistent through all beaver work found in this portion of the valley bottom. Vegetation in this section is primarily willow and grasses. There are few patches of spruce below the ponds and the hills sides have small clumps of aspen.

1.5.4 Poverty Gulch

Poverty Gulch is located approximately 13 km northwest and upstream of Crested Butte at 2,905 m (9,530 ft). The confluence of Poverty Gulch Creek with the Slate River is near the old town of Pittsburgh, which in 1929 consisted of only a few houses. In this higher elevation area, above rapids on Poverty Gulch Creek, is where Warren and I documented beaver workings.

1.5.5 Lake Brennan

Lake Brennan (now called Lake Irwin) is 13 km west of Crested Butte at an elevation of 3,146 m (10,323 ft) (Figure 1). In 1879, this area was established as a mining town and the site boomed around a year or two later with as many as 5,000 people living there (Warren 1928a). Vegetation includes Engelmann spruce and balsam fir on the around the shore and willow near the beaver pond.

1.5.6 West Brush Creek

West Brush Creek is a tributary of Brush Creek, which in turn is a tributary to the East River. The confluence of West Brush Creek and Brush Creek is approximately 14 km from Crested Butte at an elevation of 2,792 m (9,160 ft) (Figure 1). The headwaters of West Brush Creek begin 11 km north at an elevation of 3,810 m (12,500 ft). Spruce and aspen trees currently dominate the hillsides in this section and the valley has dense willow shrubs. There are many old aspens with beaver gnawing on the bark and old stumps from beaver cutting them down along the creek.

1.5.7 Washington Gulch

Washington Gulch is a tributary to the Slate River with the confluence approximately one km east of Crested Butte. The stream's headwaters begin on Mount Baldy at an elevation of 3,353 m (11,000 ft) and run 14 km, in a southeasterly direction, until reaching the confluence with Slate River at an elevation of 2,743 m

(9,000 ft) (Figure 1). A reservoir built upstream in the early 1970's has adjusted where beaver reside. Vegetation consists primarily of willow and grasses.

1.5.8 Coal Creek

Coal Creek is a tributary to the Slate River with the confluence located approximately one km northeast of Crested Butte at an elevation of 2,697 m (8,850 ft). The creek begins 210 m south of Lake Irwin at an elevation of 3,124 m (10,250 ft) and travels south two km then turns and flows east toward Crested Butte. The creek passes through the northwest portion of the town until it reaches the Slate River (Figure 1). Vegetation consists of dense willow, grasses, and sedges. Conifers dominate the hillside south of the stream. Figure 4 shows the condition of the creek when Warren lived in the area.



Figure 4 Crested Butte, Colorado in early 1900's with Coal Creek in foreground. "Courtesy, History Colorado (Denver & Rio Grande Collections, Scan # 20004344)"

1.5.9 Gothic Region

Gothic is a small, historic mining town located 13 km north of Crested Butte at 2,896 m (9,500 ft), just north of the confluence of East River and Copper Creek (Figure 1 and 2). This specific survey region is north of Gothic on the East River and is nestled between Gothic Mountain and Avery Peak (Figure 2). The vegetation in this area consists of willow and marsh grass.

Chapter 2: Background

2.1 Fluctuations in Beaver Populations

The attitude towards beaver, and consequently their populations, has fluctuated greatly over the past few centuries. Historically beaver were thought to occupy every possible location that provided suitable habitat throughout most of North America (Rutherford 1964). They were an important species for early Native Americans, providing food and skins for clothing, but were taken at sustainable levels allowing for normal population dynamics (Novak 1987, Rutherford 1964).

The settlement and exploration of the new world by Europeans vastly changed this balance. Beaver fur hats were a sought after fashion item by distinguished social classes from the mid-1600's to the 1850's (Muller-Schwarze 2011, Ray 1987). In 1638, King Charles I of England declared that hats should only be made from beaver fur, resulting in a substantial increase in the price of pelts (Muller-Schwarze 2011). This desire for beaver fur was the beginning of the near extirpation of beaver in both North America and Europe.

Beaver felt hats were made throughout the Middle Ages until the European beaver (*Castor fiber*) was trapped to near extinction in Western Europe in the late 1500's (Novak 1987). By the late 20th century the entire European beaver population was only an estimated 1,200 individuals (Rosell et al. 2005). Because of the depleted beaver population in their homeland, exploration of new beaver territory became critical and many set off to find it. The allure of the new world and its vast beaver territory began the development of the North American fur trade in the mid 1500s (Ray 1987).

Beaver skins soon became an important currency between Native Americans and French, English and Dutch fur traders. The interest in finding more beaver territory and a northwest passage allowed for the establishment of the Hudson Bay Company (HBC) granted by Charles II in 1670. However, due to the high profit margin of beaver pelts, the company eventually focused primarily on fur trading (Muller-Schwarze 2011). Formation of the HBC sparked an intense rivalry between the French and British for the following decades. Competition between many of the nations involved in the fur trade would soon grow to war and eventually led to the French and Indian War from 1756-1763. Through this Great Britain would eventually win Canada, Louisiana, and Cape Breton from the French in the Treaty of Paris in 1763 (Muller-Schwarze 2011).

Once Britain took power from the French, competition for fur became intense and increased the desire for further western expansion. Further expansion required closer trading posts. A group of independent trappers brought competition to the HBC with the formation the North West Company (NWC) (Ray 1987). Those in NWC opened numerous trading posts and pushed exploration even further by trapping in areas to the Saskatchewan River, north to the Arctic Circle and south to Oregon. With the United States of America gaining its independence in the late 18th century and the Lewis and Clark Expedition in the early 19th century, exploration of beaver territory expanded further, which was previously limited to the lower Missouri river (Muller-Schwarze 2011).

In 1820, the HBC and the NWC merged to provide the HBC more territory in the northwest. This merger provided the HBC control of over three million square

miles. In order to decrease settler's interest in the far west the HBC launched a scorched earth policy to intentionally exterminate all valuable fur animals, specifically the beaver, with the thought that land without beaver would hold no interest for settlement. This effort lasted until 1850 when beaver became scarce (Muller-Schwarze 2011). By 1900, beaver were exterminated or drastically reduced throughout most of their North American range (Novak 1987).

With the help of silk replacing beaver felt as the preferred hat material in the 1850's (Ray 1987, Rutherford 1964) and new conservation efforts in the late 19th and early 20th centuries, beaver populations once again became abundant throughout much of their historic range (Novak 1987). European beaver have also increased but not as substantially as their North American counterpart and are estimated at 639,000 (Rosell et al. 2005).

2.2 History of Colorado Beaver Management

Much like the rest of the country, beaver in Colorado were nearly eliminated. They were extirpated through much of the state by 1876 (Fitzgerald 1994) and reached the lowest population between 1890 and 1900 (Rutherford 1964). Many of the western states gave complete protection to beaver allowing their populations to make a steady come back. However, due to the decrease in possible habitat from an increasing human population it is doubtful beaver will ever be back to the historic population sizes (Rutherford 1964). In 1893, Colorado gave protection to beaver, unless trapping was necessary to protect privately owned lands (Fitzgerald 1994). Through the early 20th century private landowners were the only ones permitted to trap beaver. If nuisance beaver were declared the landowner could obtain a permit

to trap the beaver causing harm. This was revoked in 1937 and no trapping could occur unless by a salaried state trapper. The Beaver Control Act of 1941 would grant private landowners half the sale value of the nuisance beaver taken from their land (Rutherford 1964). Such restrictions on trapping allowed beaver populations to reach or exceed the carrying capacity for much of their habitat resulting in much needed change in management practices (Rutherford 1964). This began a new era of research on beaver and their habitat that would allow fish and game agencies to better manage their beaver populations. The first effort to generate understanding and initiate management of the species began with a Pittman-Robertson project in the late 1930's. In this project they inventoried suitable habitat for beaver propagation and reintroduction (Fitzgerald 1994). In 1955, changes in legislature and with beaver populations surpassing carrying capacity, beaver protection was lifted and they were again legal to trap (Rutherford 1964). The extensive research conducted on beaver in the late 1940's and early 1950's assisted in the classification of predator and furbearer species, as well as management plans for those species by the mid 1960's (Fitzgerald 1994).

2.3 Current Management Practices in Colorado

Since the 1960's when beaver were first declared and managed as a furbearer species little has changed in the way they have been managed. In some instances regulations are now more lenient. The first trapping season was limited from November 1 to March 1 (Fitzgerald 1994). Currently beaver can be trapped

statewide from October 1 through April 30 with an unlimited daily bag limit (Colorado Parks and Wildlife 2013).

Current season regulations began in 1997 and were the result of a two-year furbearer management review. This resulted in the changing of species classification from small game/furbearer to non-game status. Those that were unhappy with the review put forth Amendment 14 to restrict trapping methods and locations (Apker 2011). One such restriction was a ban on lethal trapping on public land that has subsequently diminished commercial and sport trapping (Boyle and Owens 2007). However, while leg-hold traps were banned, hunting and live trapping beaver are still allowed (Hay 2010).

From 1956-1996, annual takes ranged from 5,000 to 20,000 beavers statewide (Boyle and Owens 2007). Data taken from 1982-1991 shows Gunnison County in the top five counties for beaver harvest with a total of 2,624 beaver (Fitzgerald 1994). Unfortunately, long-term data on specific beaver populations are non-existent. What data are available is limited in time span, only available by county and was poorly maintained. In the early 1970's, the Colorado Department of Wildlife (CDOW) employed a small game and furbearer manger that maintained records but the position was eliminated in the early 1980's. Rather than focusing on management of furbearer species, efforts of the CDOW were placed on researching threatened or endangered species, which the beaver was no longer considered (Fitzgerald 1994). After 1996, CDOW no longer conducted population surveys or kept records of population numbers on beaver but assume that populations are

stable due to anecdotal observations and damage complaints (Boyle and Owens 2007).

2.4 Beaver Biology and Ecology

2.4.1 Biology

The beavers most noted trait is its ability to build. Beaver build dams to impound water along streams and rivers (Muller-Schwarze 2011). This allows for greater expansion of potential home range, easier mobility, protection from predators, increased area for aquatic vegetation growth, and adequate water depth for winter survival (Boyle and Owens 2007). Dams can be made of any combination of sticks, rocks, mud, algae, and other debris the beaver see fit (Rutherford 1964). Depending on the characteristics of the site a colony may build multiple dams, such as in a wide valley, or no dams if on a pond or if living in bank dens on a river (Muller-Schwarze 2011). Dams are typically not permanent features and will only last a few years. Spring flooding commonly destroys dams in mountainous regions (Rutherford 1964).

Lodges are built as a location for protection, reproduction, rearing young, thermal regulation, feeding, and resting (Muller-Schwarze 2011). All members of the natal colony occupy a single lodge made in the same fashion as the dam, but in a conical shape. Where beaver colonies can grow large due to limited exploitation, multiple lodges may be built (Rutherford 1964). During summer months the parental male and yearlings may build other lodges close to the home lodge after the

female has given birth. In the winter months all members of a natal colony will occupy one main lodge with a shared cache (Hay 1958, Muller-Schwarze 2011, Rutherford 1964). In areas where winters can be intense, the added thermal output of multiple beavers living in one lodge will increase the temperature inside the lodge helping them survive the cold winter (Hay 1958). Lodges can come in two forms: the freestanding lodge that is surrounded by water, or a bank lodge. Bank dens are also utilized with no added woody addition (Muller-Schwarze 2011).

A beaver's home range is considered to be the entire area a beaver uses and once established will remain occupied for many years (Muller-Schwarze 2011). The precise home range is dependent on the water system of each individual site (Novak 1987). Typically beaver do not travel far from their pond for food. Muller-Schwarze (2011) found that beaver on average will travel only 300-500 feet from their pond, but possibly further for preferred food species, such as aspen. Canals are built for easier mobility within their home range. Multiple dams will be built to expand the aquatic area of the main colony site. Beaver are territorial and will defend their main location of occupancy, which includes the pond, food cache, canals, dams, and lodge. They will mark their territory with scent mounds constructed of mud from the bottom of the pond then covered with the animal's castoreum (Muller-Schwarze 2011).

A beaver colony is defined as all beaver occupying the same site and share the same ponds(s), cache, and communally maintaining dams (Rutherford 1964). The typical beaver colony is a single-family unit consisting of the two monogamous parents, the offspring of that year, and the offspring of the year before (yearlings)

(Hay 2010, Muller-Schwarze 2011). The adult female will give birth to one litter per year in late spring. An average litter size in North America is three or four kits (Novak 1987), but typically only two will be recruited into the population due to high kit mortality (Muller-Schwarze 2011).

Availability of food and land has been shown to affect fecundity of those populations. These factors affect how many kits will be born and when previous litters disperse. Muller-Schwarze (2011) found of the dispersing young they sampled, 61% were two years old and 21% were 3 years olds. Dispersal usually occurs in the spring after the snow melts and when the current year's kits are born. In areas of poor food availability, or low preferred forage species, reproduction has shown to be reduced (Muller-Schwarze 2011). Where populations are less saturated and/or food supply is abundant beaver will produce more kits. It has been shown that beaver in areas with abundant aspen will have higher fecundity than similar areas without aspen (Novak 1987). However, those living in lower elevations dominated by willow and cottonwood (below 1,524 m or 5,000 feet) have higher fecundity than those at higher elevation 2,743 m (9,000 ft) dominated by willow and aspen. This is thought to be due to the fact that beaver living in higher elevations are dependent on food caches to survive the winter where those in lower elevations can continually cut fresh wood all year thus having a higher quality food source (Novak 1987, Rutherford 1964).

In order to calculate the density of beaver in an area, one can calculate the number of colonies per unit length of stream or by colonies per area (Muller-Schwarze 2011). Hay (2010) found that in mountain terrain the number of beaver

in one colony could be calculated by counting the number of food caches found, multiplied by the average number of animals found at that elevation. While counting caches is the most accurate method, lodge counts can be used to determine potential population numbers (Fitzgerald 1994). Suitable habitat can typically house 1.2 colonies per km of stream (Muller-Schwarze 2011). In Colorado, Rutherford (1964) found that an average colony size is 5.1 individuals per colony in aspen habitat and 4.5 individuals per colony in willow habitat. This information by Rutherford (1964) will be utilized in this study for determination of changes in beaver colony density.

2.4.2 Ecology and Preferred Habitat

By considering the historic and current range of beaver it is obvious that beaver are capable of occupying areas of varying terrain so long as there is a reliable water source. However, habitat suitability specific to beaver can vary greatly along a single stream.

The most important factor in beaver habitat is a stable and permanent water source (Boyle and Owens 2007, Novak 1987). A beaver must have a water supply sufficient enough to be able to create ponds deep enough to cover lodge entrances, escape predators, float logs, and to remain mobile under ice in winter months (Boyle and Owens 2007, Muller-Schwarze 2011).

A reliable food source is also important to maintaining a beaver population. Preferred food species change in different geographic locations, but are typically woody and herbaceous species (Novak 1987). At high elevations beaver primarily

utilize willow and aspen as food sources and are the preferred species by most beaver through out their range (Muller-Schwarze 2011, Novak 1987, Rutherford 1964). Aspen species are dependent upon wildfires for adequate regeneration. Since wildfires are now typically suppressed, limiting the amount of regeneration, aspen stands can be quickly depleted by beavers (Rutherford 1964). At elevations higher than aspen is able to grow (2,896 m or 9,500 feet), willow is the primary food supply and is more tolerant of long-term utilization by beaver (Rutherford 1964). Beaver need a diverse diet and cannot live on aspen alone. Other plant species that are consumed include: cottonwood, sedges, cattail roots, water lily rhizomes, and even corn in agricultural settings (Muller-Schwarze 2011, Rutherford 1964). When food sources are limited, beaver will utilize conifer species and other hardwood species, such as bog birch and alder, though they are not a sought after food source (Retzer et al. 1956).

Retzer et al. (1956) conducted an in-depth study of physical features of the land related to beaver occupancy in the mountainous regions of Colorado to develop a site suitability classification for beaver. They found that beaver prefer sites with grades below 6 percent (3.4 degrees), valley width wider than the channel and generally over 150 feet, and rock types of glacial till, schist and granite. Beaver will utilize areas with steeper grade and with narrow valleys, but this habitat is not preferred and populations decrease as grade increases. Typically these higher grades are occupied only when population pressures force them to move into less than adequate areas, or are used in route to preferred locations. Beaver will typically inhabit valley floors for the large floodplain, but due to these areas

being developed by humans for ranching and agriculture it has limited suitable beaver colony sites (Rutherford 1964).

In summation, the preferred habitat for beaver will be areas of consistent and stable water sources, areas with slope less than 6 percent (3.4 degrees), floodplains wider than 150 feet, and must have adequate amounts of forage species, specifically aspen or willow. This information will be applied, observed and/or quantified for each site in this study.

2.5 Current Theory of Beaver Occupancy and Abandonment

The numerous studies conducted in the early 1900's and the development of a classification system for suitable beaver habitat in the 1950's provided indispensable information to land managers to understand where beaver will potentially colonize. A new wave of research has been developing on how beaver ecologically impact the area they colonize. Over a century of stable beaver populations and advances in geographic modeling provides researchers a great opportunity to do in-depth research on beaver occupancy.

The effects of beaver on the landscape are numerous when they first colonize an area. However, the effect of beaver leaving the area also provides a drastic change to the landscape. Understanding the effects of beaver occupancy and abandonment and why they do so is important for wildlife and land managers to understand in order to better manage beaver and the species that depend on their presence.

2.5.2 Effects of Occupancy

Beavers are considered “ecosystem engineers” because of the way they alter the landscape. Beaver will physically modify the landscape resulting in the creation of habitat for other species. Thus they are also a keystone species for the reason that without them organisms dependant on the habitat they create will no longer subsist (Schultze and Muller-Schwarze 1999). Beaver significantly affect stream geomorphology by impounding water and sediment (Naiman et al. 1986). Beaver manipulate the landscape in order to create habitat more suitable to their needs. Once beaver occupy an area, they build dams on the stream in order to raise the water level for that site. Plant species unable to survive the flooding (conifer, shrubs and grasses) then die out and are replaced by vegetation that prefers moist soil, like willows, sedges, and other aquatic plants (Rutherford 1964). Higher water levels are also a necessity for beaver because they are more mobile in water than on land, giving them the advantage over their terrestrial predators. The act of damming alters the function of the stream by decreasing the velocity and annual discharge, changes the stream profile, and retains more sediment and organic matter behind each dam (Naiman et al. 1988). These areas of impoundment are important to the ecology of the area because they increase vegetative diversity (Wright et al. 2002), add nutrients and carbon (Naiman et al. 1988), and provide habitat for invertebrate, fish, amphibian, reptile, bird and semi-aquatic and terrestrial mammal species (Rosell et al. 2005, Muller-Schwarze 2011). The sediment buildup behind dams will act as a filter resulting in better water quality

down stream and also helps with erosion control (Schulte and Muller-Schwarze 1999).

2.5.3 Effects of Abandonment

As beaver occupy and abandon areas, sediment retained behind the dams begins to change the composition and function of soils in the area. Once a beaver pond is abandoned and not re-colonized, the normal ecological succession of vegetation takes place. Ives (1942) found that areas that once were occupied by beaver and then abandoned will quickly be invaded by grasses and become “beaver meadows”. This process begins soon after a beaver makes a dam because silt will begin to fill in the pond behind each dam. If beaver continue to occupy the pond no meadow will form since the beaver will continue to build the dams higher to raise the water level (Ruedemann and Schoonmaker 1938). However, if beaver do not reoccupy the site grasses and sedges will quickly invade the abandoned beaver ponds and a meadow will form within a few years (Neff 1957). These meadows have the potential to persist for over 50 years (Wright et al. 2002). It is thought that the wide alluvial valleys found today were caused by silt accumulation from beaver dams over thousands of years of beaver occupation (Ruedemann and Schoonmaker 1938).

2.5.4 Causes of Site Abandonment

It is well known that beaver will fluctuate in population size and locale, much like other populations of organisms responding to their environment. Warren (1932)

documents a colony that occupied, abandoned, and reoccupied one specific site over a span of 18 years. Dams in this study were built close to washed out dams, but rarely in the exact same place.

Beaver are dependent on a reliable water source. Beaver will rarely occupy a site long term if the water supply is consistently fluctuating or the water is fast moving (Novak 1987). Thus, if the water source has changed due to drought, human diversion, or other causes, it is certain that a beaver colony will not remain in that site.

An adequate food source is the primary factor limiting the occupancy of a beaver population in their current colony site. A study conducted by Neff (1957) concludes, "food shortage is a primary cause of abandonment and land managers need to find a way to perpetuate aspen adjacent to the pond." However, Rutherford (1964) states that beaver will abandon sites under any management plan but abandonment is still related to food depletion.

Some researchers believe that the occupation of beaver is a result of the amount of aspen found in the area. While aspen is a preferred species and beavers are shown to reproduce more in areas with aspen, colonies are not completely dependant on that species. Once aspen is no longer available the occupancy of beaver depends on the size of the valley bottom being able to produce enough willow growth for the beaver to survive on (Rutherford 1964). Moderate aspen use will encourage new sprouts continuing a young stand of aspen. However, the ratio of utilization to replacement of aspen in any long-term beaver colony is not expected (Rutherford 1964). Once the beaver has exhausted the aspen in its home

range in a few years they will migrate to a new area, usually only 100 feet away, allowing for the regeneration of new aspen stands in the abandoned area (Ives 1942). This process, if carried out over a long period of time, will continually act as a disturbance to the ecological success hindering the advancement to mid- late succession species. Neff (1959) states that the time interval between abandonment and reoccupation depends on food and can vary from a few years to 20 years.

Chapter 3-Methods

3.1 Documentation of Archived Information

The bulk of the work for this thesis came from the interpretation and analysis of Warren's beaver work journals for documenting the specific locations of beaver lodges and work for the various years he monitored beaver colonies in this area of the Rockies. Once historic colony sites were determined I was able to revisit each of them in order to document what changes have occurred over the many decades since Warren last documented them. Figure 5 is an excerpt from his journals for perspective on his writing style and an example of what I interpreted. All of Warren's beaver journal entries can be found in the appendix, as well as those that were not included in this study due to being inaccessible for surveying or were too vague for me to interpret. Warren's journals were obtained from RMBL in the fall of 2010 in PDF format. I first read these journals to get an idea of years and generalized locations of surveys (e.g. streams, rivers, creeks). I then determined exact historical locations of beaver occupancy based on my interpretation of Warren's descriptions with the aid of historic and current topographic maps for determination of landmarks, physical land features and their names. Specifically, I utilized Google maps to visualize specific locations with the aid of a 1:50,000 scale, 2010 recreational topographic map of trails around the Crested Butte area (Latitude 40° maps Crested Butte, Taylor Park, Colorado Trails recreation topographic map) for names of roads, streams, mountains, trails, and towns.

I also used historic United States Geological Survey (USGS) topographic maps from 1889, 1907, 1912 and 1938 for the determination of railroad locations in

BEAVER WORK IN THE GOTHIC REGION.

In June, 1915, I saw from the road when going up to Rustler Gulch, some beaver dams. They seemed to be in East River, but the stream was high and I did not attempt to go to them. The water was flowing over the dams, as if they were across the stream itself.

I was next on the ground in August, 1929, in company with Herman Bull. On the eighth I began an examination of the work. On the right side of the river, above the bridge by which the Scofield road crosses the stream, was a group of ponds fed by small streams coming from the hill to the west. There was one large pond, two or three smaller ones. Willows grew very thickly along some parts of the ponds and there was much swamp grass. I paced a dam 120 feet long on the largest pond. There was another dam, a small one, close to the river.

On a smaller pond above the large one was a dam 156 feet long. I did not then examine any of the other dams.

At the largest pond was a lodge, 16 by 24 feet, by $4\frac{1}{2}$ feet high. It looked old, but there were beaver tracks in the mud near the house, so that it may have been occupied. In the pond, not far from the house, were several mud heaps, and one pile, larger than the rest, may possibly have been a muskrat house.

Figure 5 Excerpt from Edward R. Warren's field journals on the beaver work in the Gothic Region.

various years as Warren made many references to colonies based on proximity to railroads. Historic topographic maps also provided names of historic locations that have changes over time, such as Lake Brennan (now Irwin) and locations of mining towns like Pittsburg. Warren (1905 and 1928a) provided detailed maps of beaver lodge locations and extent of work for the specific locations associated with those studies. These maps also provided reference to a few property lines, coal mines, roads and other notes he makes in his journals. Figure 6 is the map he created for the Slate River Valley that illustrates where he found beaver lodges at that time. Unfortunately, the map did not register with current aerial imagery. While his maps were detailed enough for me to understand where lodges were found, they were not accurate enough to create imagery by georeferencing to current aerial imagery. This could be due to human error by Warren or elevation issues.

By utilizing the various maps and publications I was able to pinpoint the exact location of each lodge Warren documented for each year by cross referencing what he states in his journal to what I found on the maps or aerial imagery. The maps he provided in his publications were of great help in determining exactly where the lodges were. These maps also used as a frame of reference for other sites.

Once sites were determined, extent of beaver work was noted. Extent of work and lodge locations were documented using a Geographic Information System (GIS) for further analysis and visual aids.

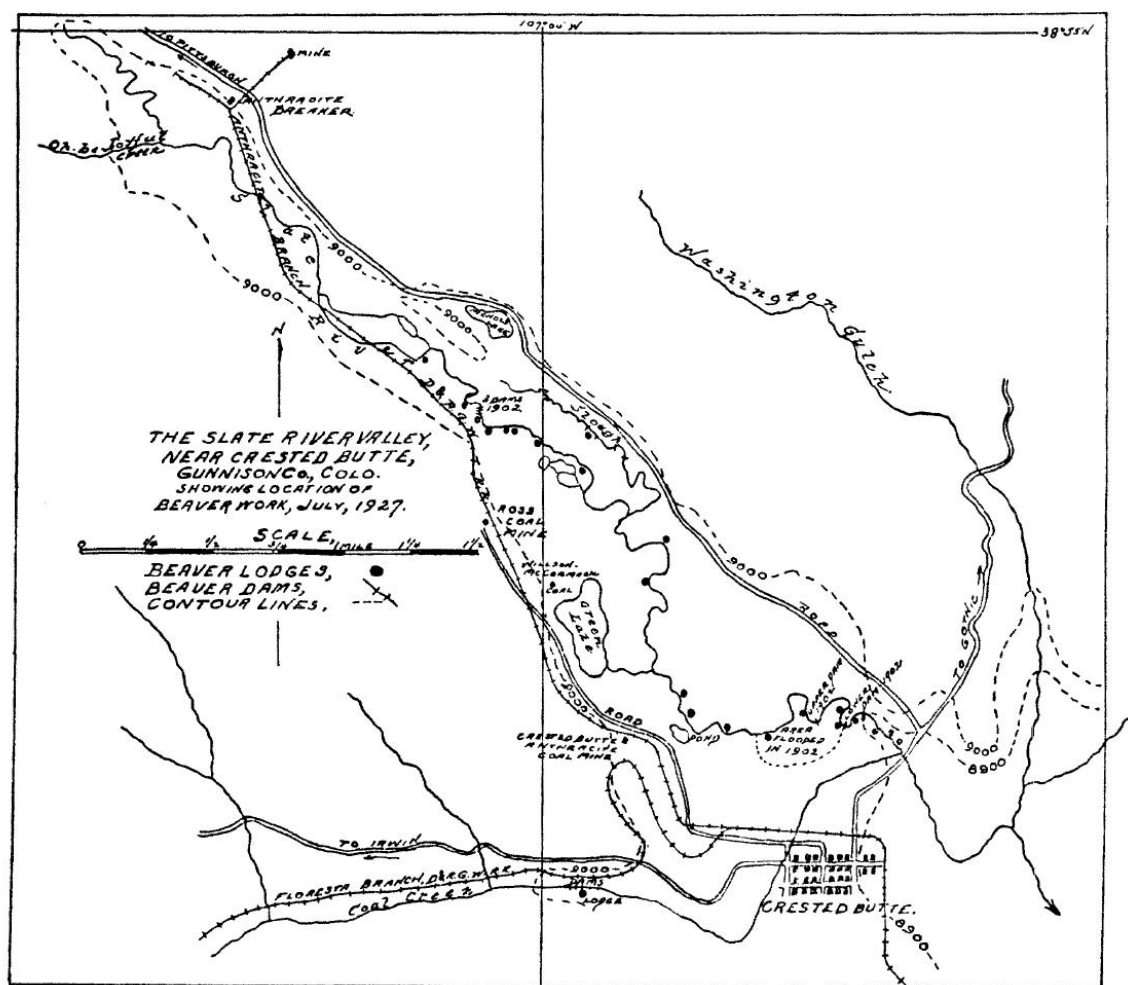


Figure 6 Warren's map of the Slate River Valley from his survey in 1927 describing lodge locations (Warren 1928a).

3.2 Documentation of the Current State of Colonies

In summer 2011 I attempted to visit all the same locations found in Warren's journals and document what, if any, lodges or beaver works were present. In some cases I was not able to survey locations due to inaccessibility from high water or other unsafe situations. Only rivers and creeks that I was able to revisit are included in this study. Attempts were made to examine all the same reaches surveyed by Warren. If a certain reach was not stated and only a single colony was visited I too

visited only that colony location. I was able to walk many of the same roads or trails that Warren himself traveled. While Warren waded into some of these wetlands to take measurements I made all observations from road or streamside and felt that this was adequate for the intention of documenting lodge locations and determining the presence of current beaver work. Avoiding other ongoing scientific studies¹ conducted by other researchers in the area, limiting colony disturbance and preventing potential transfer of organisms from one colony to the other also played into this determination.

At each historic colony site I documented the number of active lodges found and the general extent of any current beaver work (see below for further detail) as well as notes on vegetation and other characteristics (e.g. steepness, rocky or sandy shores, and human made structures) that could influence beaver occupancy. Each site was photographed with a GPS enabled digital camera for documentation and later analysis.

3.3 Data Entry/Creation

3.3.1 Extent of Work and Impoundments

Beaver work is considered to be the presences of dams, beaver ponds, lodges, canals, scent mounds, gnawed vegetation, felled trees, and tracks. When noted in

¹ RMBL scientists are involved in many field-based studies each summer, some of which are in beaver habitat. To avoid disturbing their field sites, in a few cases, I had to observe from a slightly greater distance or limit my perspective for colonies in those areas.

text or in maps, “beaver work” could be any combination of the above criteria. The presence of an active beaver colony generally has many if not all of these criteria.

Shapefiles were created for the extent of work for Warren’s surveys using ArcGIS 10.1. These areas consist mainly of his documented areas of water impoundment via dams and canals and were combined for all years surveyed for each site. The size and shape of the extent of work was estimated based on the measurements, if given, or by generalizing the area described in his journals. For colonies with measurements I would add the distance from dam to dam and areas flooded for the total length of work and would approximate width based on dam length and location on stream. For areas and/or years where he only stated a pond was present I greatly generalized the possible area based on each site’s topography and the given description.

Shapefiles were created in the lab for the current estimated extent of beaver work based on my observations during the 2011 survey. To keep consistent with Warren’s data I also mainly documented areas with water impoundment via dams and the presence of canals. To create these I utilized field notes, pictures taken with the GPS camera, as well as aerial imagery base maps available in ArcGIS 10.1 to document the areas occupied by the beaver colony. Overlaying the present areas occupied on the historic areas occupied allowed me to visualize the extent of occupied areas by beaver and how it has changed over time as well as what areas have remained occupied.

It should be noted that not all criteria for beaver work was found at all locations. Some locations may not have documented scent mounds or tracks. Any

areas with evidence of past beaver work but are no longer occupied or maintained were not included in these shapefiles.

One-meter resolution NAIP aerial photos (2006) were used to determine if locations were still flooded signifying potential beaver occupancy of areas I was not able to visit or examine thoroughly, mainly Washington Gulch and Slate River. However, while the areas may be flooded this cannot assure the presence of beaver, especially the presence of a lodge (Broschart et al. 1989) and thus was not added to the 2011 extent of work shapefile.

3.3.2 Location of Lodges

Lodges are used as an indication of current beaver occupancy. Rutherford (1964) found that beaver occupying new sites often build simple bank dens or burrows for the first year. Therefore, the presence of an active lodge can signify a reproducing colony that will remain for an extended period of time. Only active lodges were included in this study.

All lodges documented by Warren were determined to be active unless otherwise stated. All lodge locations were documented by year of discovery based on the journal descriptions. Warren (1905 and 1928a) provided detailed maps of the lodges on Slate River, as well as one on Coal Creek, for the years of 1927 and 1902 respectively. These maps helped provide reference to exact lodge locations as well as reference to lodges in years before and after those surveys. Journal entries were interpreted and cross-references with current and historic topographic maps and his publications (Warren 1905, 1928a) in order to determine the exact sites of lodges. Once these sites were determined coordinates were extracted from Google

maps and entered into a spreadsheet. All historic lodge coordinates were entered into a spreadsheet by year of discovery and uploaded into ArcGIS 10.1 and displayed with projected coordinate system NAD 83/UTM zone 13N.

The same sites or colonies surveyed by Warren were visually surveyed and active lodge locations were documented with a GPS unit attached to a laser range finder in order to obtain the most accurate locations without having to be directly next to the lodge. These data were then differentially corrected by postprocessing to achieve the most accurate locations.

Lodges were determined to be active based on the presence and maintenance of some combination of beaver work.

3.3.3 Historic vs. Current Work

Maps were created to visualize and compare the total locations of Warren's colonies and lodge locations to the current extent of work and lodge locations. Shapefiles created for each of Warren's locations, as describe above, for all years and were uploaded and displayed with projected coordinate system NAD 83/UTM zone 13N on a hillshade map created from a 30m Digital Elevation Model (DEM). Scale was altered depending on each site in order to give the best visualization of lodge locations. Current work and lodge location data were overlaid on Warren's combined work and lodge data in order to see areas of overlap or change.

3.4 Habitat Suitability

Three aspects of habitat suitability were looked at for this study: slope, valley width, and vegetation. Specific site along the main surveyed creek/river that have supported a colony are now referred to as patches. These patches are areas of the main survey stream that have had a beaver colony at one point in this study but the main colony location may have changed over time. For example, the area of land occupied over time by the colony below Pittsburg is considered a patch. Sites refer to the main river or colony Warren documented (e.g. Coal Creek, Lake Brennan)

3.4.1 Slope

Slope was determined by utilizing ArcGIS 10.1 spatial analyst extension slope tool. The corresponding degree of slope for each lodge location was documented and averaged for each survey site. Slope of patches with lodges in both Warren's surveys and 2011 surveys were averaged from lodges in close proximity to each other.

3.4.2 Valley Width

Valley width (m) was determined by measuring edge to edge of contour lines of similar elevation for areas that contained work and were measured at each lodge location. The corresponding width of each lodge location was documented and averaged for each survey site. Valley width of patches with lodges in both Warren's surveys and the 2011 survey were averaged from lodges in close proximity to each other.

3.4.3. Vegetation

Vegetation was documented for each patch based on observations only. No attempt was made to quantify changes in vegetation composition or structure. Notes on any changes or composition in vegetation were taken directly from Warren's journals and current observations during the field season.

3.5 Changes in Beaver Lodge Density

Aerial photos are a common resource for documenting beaver impoundments but are unreliable for determining beaver densities since one does not know if beaver are present. Aerial surveys can provide a quick and reliable method for density counts of beaver population, however, there can be variability due to differences in observers and issues with canopy cover that can decrease visibility (King et al. 1998). More commonly used are aerial cache surveys, which have an accuracy of 70-92% (Broschart 1989). Caches are built in late summer when family colonies congregate to one lodge to share the winter food store. This method is more reliable and less time intensive than ground surveys. Ground surveys of lodges are possible but impractical for large scale surveys. King et al. (1998) found ground surveys to be more reliable than aerial surveys due to limited visibility from canopy cover.

For this study ground surveys were viewed as the most reliable and accurate assessment of current beaver occupancy represented by the presence of an active lodge. The number of individual beavers per site was determined by multiplying the number of active lodges and the estimated average number (4.5) in a colony in a

willow dominated area (Rutherford 1964). A beaver density for each stream surveyed was determined by dividing the number of estimated beaver present, via the lodge count, and the length of stream surveyed.

Chapter 4-Results

This section is organized to present the data spatially for each site. Results for each study question are reported in the main section and reported for each site from Warren's Journals (e.g. Lake Brennan, Coal Creek, etc.). To report changes in colony locations each site and all patches are described based on Warren's observations and then compared to my observation focusing primarily on the number and location of lodges. Maps are found in Appendix 1 displaying the historic location of colonies and lodges compared to current locations of colonies and lodges. The extent of work and all lodges found during Warren's surveys for all years were combined due to the great amount of overlap from year to year and vagueness in some of his descriptions in certain years. This also allowed me to see, when overlaid with current extent of work and lodges, what areas were held in common. Separate maps were not made for each year at each site.

Slope and valley width were reported on because of the importance in preferred habitat characteristic found by Retzer et al. (1956). My results were evaluated to determine if these criteria are similar or differ for areas occupied over 85 years.

The number of beaver found for each site is reported and determined by multiplying the number of lodges found by the estimated number of beaver found per lodge according to Rutherford (1964). The number of colonies (represented by each lodge) per the length of stream surveyed is how density of beaver was found. The total length of all colonies throughout the years was used in areas that only documented the single colony.

4.1 Summary of Historic and Present State of the Colonies

Whole Study Area:

The majority of all sites that were documented by Warren still have some indication of the presence of beaver over 100 years later. While a few of the sites once occupied by a colony (signified by the presence of a lodge) no longer have maintained lodges, most still have maintained dams and other signs of the presence of beaver. The location of all lodges and main areas of concentrated beaver work found during Warren's surveys and the 2011 survey can be seen in Figure 7. A detailed map displaying lodges and extent of work noted for each stream surveyed is presented in appendix A, Figures 13-20.

The number of lodges found per site for each year and Warren's estimate of first reoccupation can be seen in Table 1.

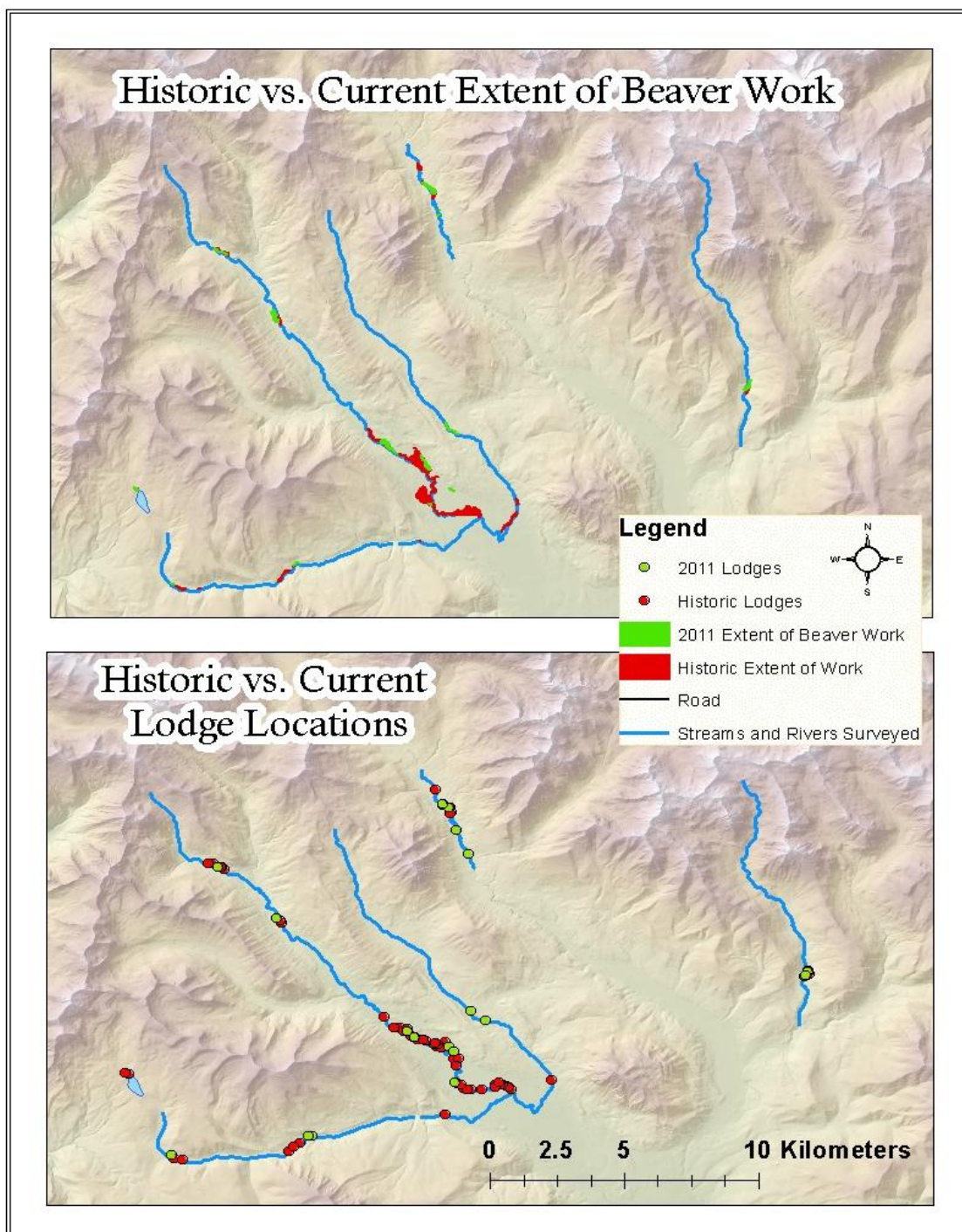


Figure 7 Historic and present lodge locations and extent of work of entire study area.

Table 1 The number of active lodges for each site and year surveyed over 113 years. Numbers and notations are based on interpretation of Edward R. Warren's field journals and my 2011 field season.

Site Name	Year																	
	1898	1899	1900	1902	1905	1910	1915	1917	1927	1929	1930	1931	1932	1934	1935	1936	1937	2011
Slate River	1	1	1	5	4	4			22	22	20	14	17				a	5
Below Pittsburg			0							a	a		a	1		1	2	1
Poverty Gulch		ab	a							4	4		3				a	1
Lake Brennan								b	2	2	2		2				2	0
West Brush Creek			a				a		4								3	2
Washington Gulch										1	a	a			a			2
Coal Creek				b		a			1	1	1	4	4				c	3
Gothic Region							a			6	a	c	4					4

a. No survey conducted. Only notes work or ponds being full with no mention of lodges.

b. Estimated time of re-colonization.

c. Some or all ponds drained.

Slate River:

The location of lodges and the estimated extent of work for the current colony in relation to the historic colonies can be seen in Figure 13. The Slate River Valley was surveyed beginning at the bridge across Slate River near the mouth of Coal Creek (same location today) upstream 5.6 km (Figure 1 and 13). This site has been occupied the longest and surveyed more frequently than any other site. Warren first noted beaver in this valley in 1898 and they have increased in population and range until Warren's last surveys. Numbers of lodges fluctuated with most survey years and range from one in the first year surveyed to a maximum of 22 lodges found in 1927 and 1929 down to 17 a few years later. It is possible that these beaver were able to persist in this wide valley during the extirpation of the other beaver populations in the Elk Mountain region. Those survivors were able to disperse back to those extirpated areas for reoccupation.

It should be noted the number of active lodges for this area is certainly under-estimated during the 2011 survey and possibly for Warren's surveys since he notes that it was difficult to see all lodges due to high willow brush. The vast area this valley occupies makes it difficult to examine thoroughly and dense vegetation can hide active lodges. A lack of a thorough investigation of all areas in this valley, due to private property, limited the amount of areas surveyed and lodges detected in 2011. I would suspect a great many more active lodges to be found if access would have been granted and a more thorough survey was conducted. While I was not able to thoroughly investigate all the same portions on Slate River as Warren did, those areas I was able to revisit did show the presence of beaver and their work. A total of five active lodges were found in the areas I did visit.

Below Pittsburg:

The location of lodges and the estimated extent of work for the current colony in relation to the historic colonies can be seen in Figure 14. This patch is located above the previously documented portion of the Slate River. It is approximately 1.6 km south of the historic town of Pittsburg (Figure 2). Beaver work was first noted here in 1900 but no lodges were discovered until a survey was conducted in 1934 where one lodge was discovered. A second lodge was discovered in a 1937 survey.

Beaver are still utilizing the same general area and at least one active lodge remains here in 2011.

Poverty Gulch:

The location of lodges and the estimated extent of work for the current colony in relation to the historic colonies can be seen in Figure 15. Warren first notes beaver work in this area in 1899. His first thorough survey was in 1929 where he found four lodges. In 1930, three of the same lodges remained, one was not found, and a new lodge was built further up stream. In a 1932 survey he found the same three lodges as his 1930 survey. In 1937, he revisited this area and noted that all the same ponds were full. While no survey was conducted I assume the same lodges are maintained if ponds and dams are maintained.

Currently this area is still maintained and has at least one active lodge. There are many dams impounding the stream creating large ponds. There are also many washed out dams and a large amount of brush was found at the base of the waterfall downstream from the patch, which could be from the beaver work upstream.

Lake Brennan:

The location of lodges and the estimated extent of work for the current colony in relation to the historic colonies can be seen in Figure 16. Warren's colony at Lake Brennan (Irwin) were found near the inlet of the lake where Anthracite Creek flows in, located at the northwest portion of the lake (Figure 16). Two active lodges were found in this area first during a 1927 survey. Subsequent surveys found the colony to be active and the same lodges were also active in 1929, 1930, 1932, and 1937.

When I surveyed the area in July 2011 beaver were still utilizing the area. The area showed much sign of beaver work including a few dams and canals. However, no lodges were built in this portion of the lake or any other by my observations.

West Brush Creek:

The location of lodges and the estimated extent of work for the current colony in relation to the historic colonies can be seen in Figure 17. The beaver work Warren and I documented is located 1.7 km from the mouth of the creek, encompassing an area of approximately 800 m in length (Figure 1 and 17). Warren first notes work in this area in 1900 and again 1915 but made no formal survey or in-depth notes. He first surveys this area in 1927 and discovers four lodges. He next surveys the area in 1937 where he finds three of the same lodges as his previous survey and new ponds downstream.

I found two lodges in the same general area as Warren's lodge locations and work was found in similar areas as well.

Washington Gulch:

The location of lodges and the estimated extent of work for the current colony in relation to the historic colonies can be seen in Figure 19. There were two main locations Warren surveyed on this stream. The first site was located northeast of Crested Butte, 1.2 km from the mouth. This pond was surveyed in 1929 and was found to have one lodge. He did not survey this pond again until 1935 and by which time the ponds were low and the lodge had flattened. With closer examination he found cattle had trampled the shore. In 1930, he was told the pond was full and in 1931 he was told it was empty. The second location was at the mouth of the stream and consisted of eleven dams in an area encompassing 609 meters upstream.

The water in Washington Gulch was described as low, sluggish and waterless in some areas. Warren concluded that the water was being diverted for irrigation of hayfields.

While I was unable to survey these locations, current aerial photography (2006 NAIP DOQs) shows that there is no pond in the northeast location and there is potential for lodges and dams near the confluence of Slate River. I was able to survey the rest of Washington Gulch upstream and found a thriving colony at the base of a reservoir that was built approximately 40 years after Warren surveyed. Here I found two lodges and many dams. It is unknown if Warren ever saw beaver here or ever surveyed this far upstream.

Coal Creek:

The location of lodges and the estimated extent of work for the current colony in relation to the historic colonies can be seen in Figure 19. The work and population of beaver on Coal Creek expanded a great deal in the time of Warren's surveys. Warren first saw beaver work in this area in 1902 and documented a dam near the mouth of the river in 1910. He made his first survey of a pond 0.8 km above town in 1927 and found one lodge and a pond 4 km from this last pond. He next surveyed in 1929 and the previous pond further upstream was deserted, but he notes new work a few meters upstream with one lodge. In 1930, the previous ponds were still full, the lodge present, and new work was found 9 km from the mouth upstream at the turn to Lake Brennan (Irwin). In 1931, he noted work at the mouth of the river and each of the previous patches extent of work expanded, both with two lodges. In 1932, the areas looked much the same with no mention of the work by the mouth of the river. In 1937, he makes a vague statement that while driving past he notes of the ponds all were wholly or partially drained.

I found work at each of the same patches as Warren's surveys. Two lodges were found in the area Warren surveyed first in 1929 and one lodge in the patch farthest upstream near the turn to Lake Brennan (Irwin).

Gothic Region:

The location of lodges and the estimated extent of work for the current colony in relation to the historic colonies can be seen in Figure 20. The colonies surveyed here were located on East River, north of Gothic. The stretch of stream surveyed

reaches approximately 3.5 km in length, beginning at the falls below Gothic moving upstream to just above the first bridge (Figures 1, 2, and 20).

Warren first noted work in this area in 1915. He revisited this area to survey or make notes on the colonies in 1929, 1930, 1931, and 1932. He found six lodges during his first survey in 1929 and four lodges in 1932.

In 2011, I noted four active lodges two of which were found further south than where Warren had documented any lodges. The colony found above the bridge had no lodge or other substantial work present. These ponds were covered in algae suggesting that no beaver were using the area. Two of the current lodges were found very close to the location of lodges Warren found. It is uncertain if these lodges have been maintained since Warren's surveys or if beaver have rebuilt in the same locations. Warren describes the first lodge below the bridge as very large with willow growing at the base. This is very similar to its current conditions (Figure 8).

During my stay at RMBL, beaver built a dam on a portion of the road 1.25 km above the town center. The beaver were trying to impound water coming off a small stream that was collecting along the roadside. The dam was destroyed multiple times by county workers, but was rebuilt each time, thus, demonstrating the determination and work ethic of the beaver.



Figure 8 Lodge found on East River near Gothic in 2011. A lodge was found at this location in 1929, 1932, and 2011. It is unknown if it is the same lodge.

4.2 Habitat Suitability

Three aspects of habitat suitability were utilized in this study: slope, valley width, and vegetation. The slope and valley width for each patch were averaged and are presented in Table 2. The slope for areas that are held in common today with Warren's surveys (i.e. lodges were found in the same local during Warren's surveys as well as in 2011 survey) are displayed in Figure 9. Any notes on vegetation are included in the vegetation summary of each site in this results section. No attempt was made to quantify changes in vegetation composition or structure. Notes on any changes were merely based on observation by Warren and myself.

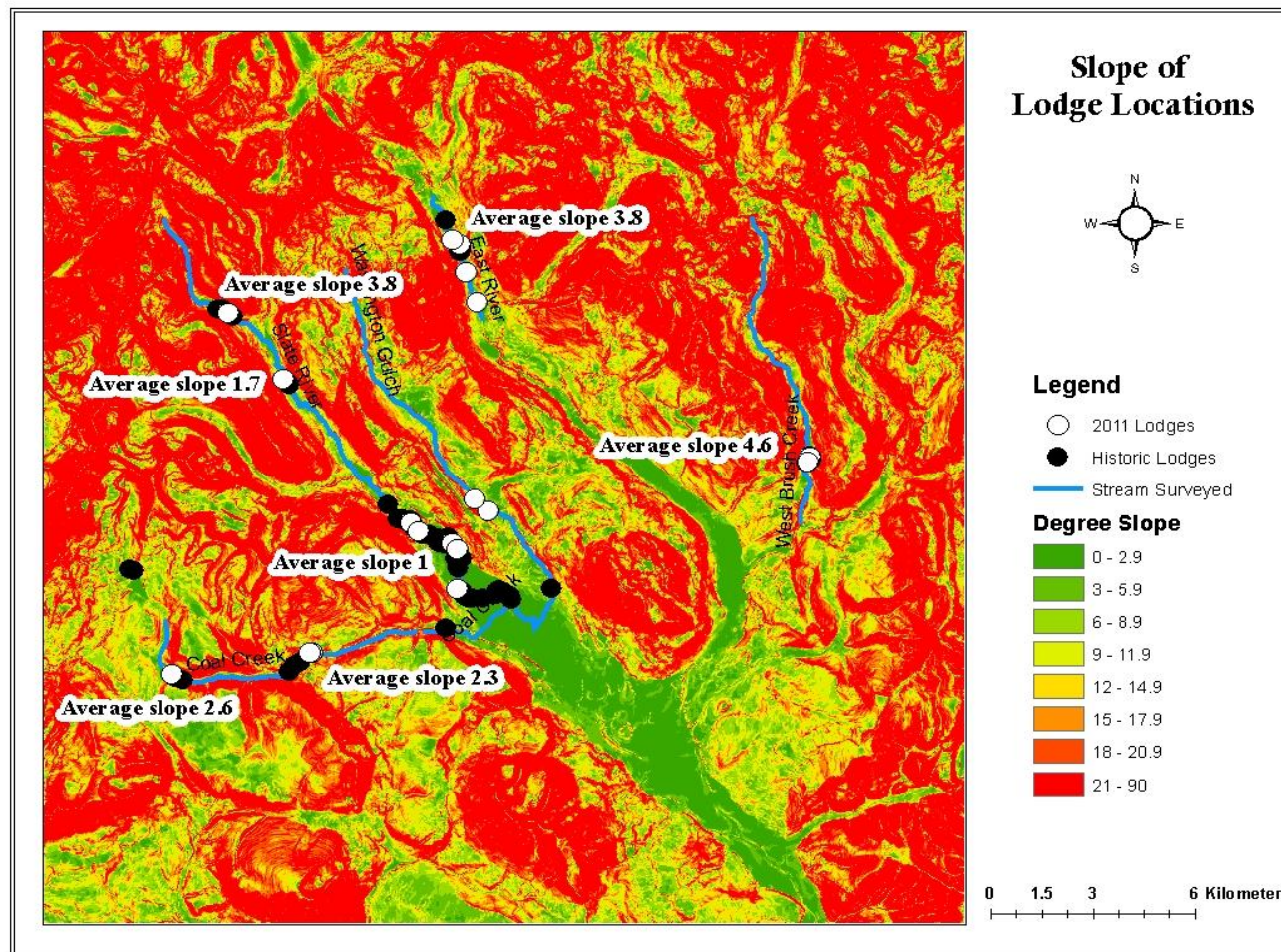


Figure 9 Slope of study area and locations of historic and 2011 lodges. The average slope is displayed next to each area that has lodges historically and presently in common.

Table 2 Average slope and valley width of total occupied areas and areas occupied in common with Warren's surveys in 2011. Mean values of multiple locations where lodges were found are displayed. Continually occupied area values were averaged from historic locations and current locations of lodges in close proximity to each other.

Site name	Total occupied areas		Continually occupied	
	Slope (degree)	Valley Width (m)	Slope (degree)	Valley Width (m)
Slate River	3.2	700	1.0	373
Below Pittsburg	1.7	241	1.7	241
Poverty Gulch	3.8	241	3.8	241
Lake Brennan	1.9	300	NA	NA
West Brush Creek	4.6	310	4.6	252
Washington Gulch	11.2	71	NA	NA
Coal Creek	6.2	128	2.4	137
Gothic Region	1.5	443	3.8	498

4.2.2 Slope

Slate River:

The mean slope is 3.2 degrees. Patches that have been occupied since Warren's surveys have a mean slope of one degree.

Below Pittsburg:

The mean slope is 1.7 degrees. This patch has been occupied since Warren's surveys and encompasses the same general location.

Poverty Gulch:

The mean slope is 3.8 degrees. This patch has been occupied since Warren's surveys and encompasses the same general location.

Lake Brennan:

The mean slope is 1.9 degrees and the mean valley width is 300 meters. While the extent of work is similar to Warren's surveys there are no lodges in common.

West Brush Creek:

The mean slope is 4.6 degrees. The patch that has been occupied since Warren's surveys has a mean slope of 4.6 degrees.

Washington Gulch:

The mean slope is 11.2 degrees. There are no patches in common with Warren's surveys.

Coal Creek:

The mean slope is 6.2 degrees. Patches that have been occupied since Warren's surveys have a mean slope of 2.4 degrees.

Gothic Region:

The mean slope is 1.54 degrees. Patches that have been occupied since Warren's surveys have a mean slope of 3.8 degrees.

4.2.1 Valley Width***Slate River:***

The mean valley width is 700 meters. Patches that have been occupied since Warren's surveys have a mean valley width of 373 meters.

Below Pittsburg:

The mean valley width is 241 meters. This patch has been occupied since Warren's surveys and encompasses the same general location.

Poverty Gulch:

The mean valley width is 241 meters. This patch has been occupied since Warren's surveys and encompasses the same general location.

Lake Brennan:

The mean valley width is 300 meters. While the extent of work is similar to Warren's surveys there are no lodges in common.

West Brush Creek:

The mean valley width is 310 meters. The patch that has been occupied since Warren's surveys has a mean valley width of 252 meters.

Washington Gulch:

The mean valley width is 71 meters. There are no patches in common with Warren's surveys.

Coal Creek:

The mean valley width is 128 meters. Patches that have been occupied since Warren's surveys have a mean valley width of 137 meters.

Gothic Region:

The mean valley width is 443 meters. Patches that have been occupied since Warren's surveys have a mean valley width of 498 meters.

4.2.3 Vegetation

Slate River:

Warren (1928) notes that willow in this area grew from three to ten feet high and so densely it was difficult to see every possible lodge. Warren (1905) makes note that all lodges and dams were made of willow branches and steams and mud with no large trees found.

Presently, the wide valley that most of the surveyed portion was found had a great deal of willow and grasses. Spruce can be found on the hillside in the northern most section surveyed where the valley begins to narrow.

Below Pittsburg:

Warren notes in his journal that this “whole flat here was beaver ponds and meadows.” This describes the area today as well. There is a great deal of willow and swamp grasses growing near the ponds and aspen can be found on the hillside (Figure 10).



Figure 10 The colony found "below Pittsburg" on Slate River.

Poverty Gulch:

The only mention of vegetation in this area by Warren was that beaver were using willow for their work and the area was "brushy."

Presently there is still a great deal of willow in this area where beaver are found. Spruce can be found sparsely near the ponds and in dense patches on the north-facing hillside.

Lake Brennan:

This area Warren once noted to be thick with willow. It is currently sparse with willow and what is found is no more than one foot high. The entire lake is now surrounded by campgrounds and has numerous people using the area for recreation during the summer months. While the entire lake could potentially have some beaver work, all is still located only at the inlet. The beaver most likely remain in

this portion of the lake due to the sediment accumulation from dam impoundments allowing for the growth of willow. Willow is not found as dense around the rest of the lake, which could be due to natural conditions but is most likely a result of over use by campers or is maintained for the recreational uses such as boat landings and beach. It is possible the beaver are not currently building lodges at the inlet because of the depleted food supply and are allowing for a period of re-growth. If willow were able to grow back to a density that can support a beaver colony a lodge could be built in this area again.

West Brush Creek:

Warren describes the whole West Brush Creek Valley as being one large beaver meadow and notes that aspen were cut by the ponds and felled aspen were lying on the hill.

Presently, the valley has good amount of willow but not very many aspen close to the ponds. There were numerous gnawed aspen trees and stumps along the trails to this area.

Washington Gulch:

Near the northeast pond Warren notes that there are many fresh aspen cut along with older stumps and they were sprouting new growth. However, he states that aspen never grew thickly on this hill. He also notes that swamp grass and willow grew thickly on the sides of the pond as well as above and below the pond. The area near the mouth was only noted to have many cut willow and cut grasses.

Currently the vegetation near the colonies below the reservoir consists of a good amount of willow in the valley near the ponds and the hills are covered with conifers.

Coal Creek:

Warren notes that the right bank of the creek had Engelmann Spruce growing and the left had no trees or bushes. He also states that a good many willow were cut. The patch found at the turn to Lake Brennan had willow growing very thickly and were three to six feet high.

Vegetation in this area today consists of conifers on the hillside and willow in the valley bottoms near the beaver ponds. There is also a great deal of grass at the upper colony near the turn to Lake Brennan. The willow is dense in this area but perhaps not as tall as when Warren observed it.

Gothic Region:

The only mention of vegetation in this area is Warren's comments on beaver trails in willow and grasses. He also notes ponds being filled with grasses.

There is presently a great deal of grass in this area, as well as willow. Spruce can be found densely on the hillsides.

4.3 Changes in Beaver Lodge Density

The changes in beaver population density and estimated number of individual beavers for each stream surveyed has changed to some extent (Table 3). At most sites the presence of beaver have decreased slightly with the exception of Washington Gulch and Coal Creek that increased. The mean number of estimated individual beavers for each stream surveyed during Warren's surveys can be seen in Figure 11 as compared to the estimated number of beaver found during the 2011 survey. The mean beaver colony density per km stream surveyed from Warren's surveys compared to the 2011 survey is displayed in Figure 12.

Slate River:

An estimated number of individual beaver for this site historically is 45.4 and 22.5 today. A mean colony density per km stream surveyed is 1.55 historically and 0.77 at present.

Below Pittsburg:

An estimated mean number of individual beaver for this site historically is 4.5 and 4.5 today. A mean colony density per km stream surveyed is 0.40 historically and 0.40 currently.

Poverty Gulch:

An estimated mean number of individual beaver for this site historically is 16.5 and 4.5 today. A mean colony density per km stream surveyed is 6.11 historically and 1.67 currently.

Lake Brennan:

An estimated mean number of individual beaver for this site historically is 9.0 and zero today. A mean colony density per km stream surveyed is 8.00 historically and zero currently.

West Brush Creek:

An estimated mean number of individual beaver for this site historically is 15.7 and 9.0 today. A mean colony density per km stream surveyed is 0.88 historically and 0.50 currently.

Washington Gulch:

An estimated mean number of individual beaver for this site historically is 4.5 and 9.0 today. A mean colony density per km stream surveyed is 0.25 historically and 0.50 currently.

Coal Creek:

An estimated mean number of individual beaver for this site historically is 9.9 and 13.5 today. A mean colony density per km stream surveyed is 0.22 historically and 0.30 currently.

Gothic Region:

An estimated mean number of individual beaver for this location historically is 22.5 and 18.0 today. A mean colony density per km stream surveyed is 1.43 historically and 1.14 currently.

Table 3 Mean number of individual beaver and estimated colony density for each site based on mean number of lodges found during Warren's surveys and 2011 Survey.

Site Name	Warren's Surveys		2011 Survey	
	Mean Number of Beaver	Mean Colonies /km Stream Surveyed	Number of Beaver	Colonies/km Stream Surveyed
Slate River	45.41	1.55	22.50	0.77
Below Pittsburg	4.50	0.40	4.50	0.40
Poverty Gulch	16.50	6.11	4.50	1.67
Lake Brennan	9.00	8.00	0.00	0.00
West Brush Creek	15.75	0.88	9.00	0.50
Washington Gulch	4.50	0.25	9.00	0.50
Coal Creek	9.90	0.22	13.50	0.30
Gothic Region	22.50	1.43	18.00	1.14

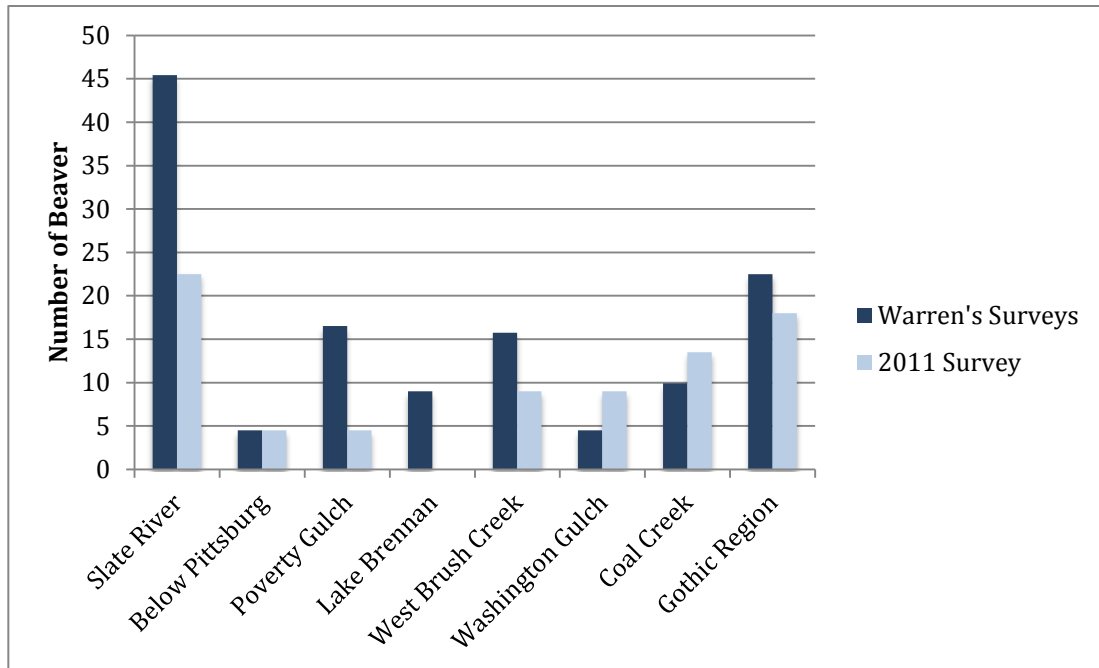


Figure 11 Mean number of beaver found at each site based on Warren's surveys compared to 2011 survey.

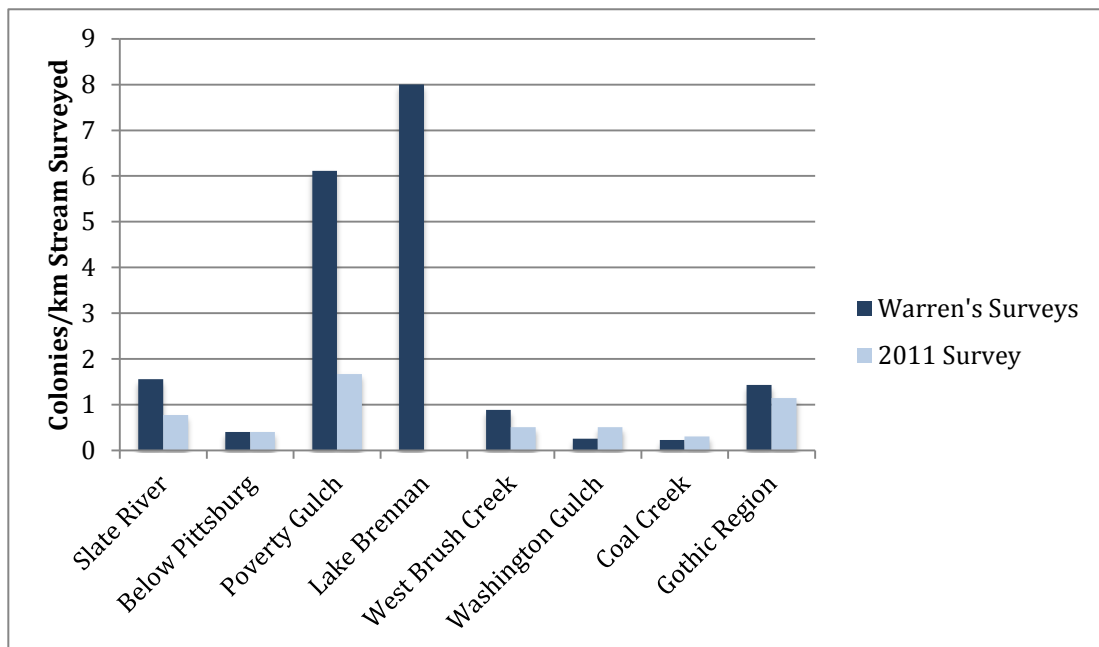


Figure 12 Mean number of colonies found per km of stream surveyed for Warren's survey compared to 2011 survey.

Chapter 5-Discussion and Conclusion

5.1 Discussion

The beaver population around Crested Butte has grown to occupy all suitable habitats over the century since the population was at its lowest. While beaver were almost extirpated in this area a few colonies survived, primarily in the Slate River Valley, allowing for population growth and reoccupation in all suitable habitat. It can be seen that during Warren's surveys beaver were limited or non-existent in many of the waterways during the beginning of the 20th century, with the exception of the Slate River Valley. However, by 1927 Warren found that the population was growing substantially and were expanding their range considerably. During Warren's last surveys in 1937 beaver have become stable and remain in the same locales. Beaver were altering their specific dam and lodge locations most likely due to food availability and damage by flooding but have remained in the same patches over the many decades of Warren's surveys. Currently, beaver are occupying or utilizing almost all the same patches when colonies were first established. While the location of dams and lodges are not exactly similar to Warren's surveys the generally valley locations are the same.

5.1.1 Summary of Historic and Present State of the Colonies

It can be seen that nearly every patch occupied during Warren's surveys are still occupied presently (Figure 7). Figures 13-20 display the locations of historic work versus present work for each site. Here we can see that of the 10 patches occupied historically, seven are still occupied today with reproducing, year round colonies.

Nearly every location revisited has some degree of work being maintained over 85-113 years later. Those that do not have lodges may be going through the abandonment re-occupancy cycle providing the willow is allowed to grow back to a density that can support a beaver colony.

The colony at Lake Brennan, Washington Gulch, and the patch closest to Crested Butte on Coal Creek are the only patches that no longer have active beaver colonies. The lack of a colony is likely due to the limited presence of preferred forage species and willow for building material for Lake Brennan and Washington Gulch. The low availability of water on Washington Gulch most likely has an impact and is why beaver have now established a colony at the base of the reservoir. It is unknown why beaver are no longer occupying the patch on Coal Creek since willow is present and the valley width and slope are similar to other areas occupied.

The exact extent of work found for each patch has fluctuated in some regard. This can be expected as beaver are central place foragers and will alter pond locations to new food supplies, once the near by food supply has been depleted. However, these relocations are typically in close proximity to the old ponds and usually only around 100 meters away (Ives 1942). This is evident for many of the patches in this study and in some cases have not changed at all.

Muller-Schwarze (2011) states that once a beaver's home range is established it will remain occupied for many years. This study can expand on that concept by adding they can remain occupied for many decades and possibly a century or longer.

5.1.2 Habitat Suitability

There are many factors of habitat suitability that can affect the location of beaver colonies. Retzer et al. (1956) found that beaver prefer habitat with grades less than 3.4 degrees (6 percent) and have valley widths generally around 45.7 meters (150 feet). Sites with long-term beaver occupancy, according to this study, were found to have grades up to 5.4 degrees. However, the Slate River Valley, which had the most lodges present during all years studied, has a grade of less than 1.0 degree. The majority of continually occupied sites have a grade of less than 3.8 degrees. Average valley width of continually occupied areas ranged from 137 meters to 498 meters and averaged 290 meters, which is much wider than the 45.7 meters Retzer et al. (1956) found to be preferred.

In this study, sites that retain a long-term beaver colony follows closely to what Retzer et al. (1956) consider to be excellent land suitability for beaver. This study complements that information and adds that excellent sites could retain colonies for over a century. However, sites occupied long-term were much wider than 45.7 meters, most were 3-11 times wider. Sites with low grades and wide valleys retain long-term beaver populations because of the larger floodplain allowing for substantial willow growth. Beaver are able to impound a great deal of water in wide valleys thus allowing for much more willow growth than narrow valleys. These beaver have subsisted on willow as a primary food supply for the century during this examination, thus relating to the importance of willow habitat creation and sustainability for the support of the beaver population.

While changes in vegetation were not quantified, observations on the plant community for each site closely resembles the conditions observed during Warren's surveys. Once a beaver pond is abandoned plant succession begins shortly after, creating "beaver meadows". If beaver continue to reside in an area no meadow will form due to dams continually being built higher to compensate for the continual accumulation of silt behind impoundments (Ruedemann and Schoonmaker 1938). Thus, since no beaver meadows were formed and ponds are still present today we can infer that beaver have continually occupied or reoccupied these patches in the years between Warren's last surveys and my survey in 2011. During the time Warren surveyed beaver work in this area he notes many times that the beaver are using willow as a primary building material and food source (Warren 1905, 1928, 1937a-h). Currently, beaver are still utilizing willow as the primary source of food and material. Therefore, I can deduce that these beaver colonies can survive predominantly on willow and are not dependent on aspen as a primary food source. Packard (1947) surveyed beaver in Rocky Mountain National Park, Colorado in 1939 and 1940 and found that beaver colonies during this time were also dependent upon willow and the lack of aspen did not limit their occupation to specific colony sites. While aspen may be a preferred forage species when available, the limited availability (due to suppressed wildfires limiting regeneration and being quickly depleted when available) coinciding with the continuous occupation of beaver in sites absent of aspen shows that the ability of willow is more important as a determination of long-term beaver occupancy.

The cause of lodges not being built in areas with signs of beaver still present is most likely due to the lack of food supply (such as at Lake Irwin) and/or changes to the water source (such as in Washington Gulch) since most sites are in areas with slope and valley width preferred or accepted by beaver. Beaver birth rates decrease with higher elevation due to a limited growing season as compared to the lower elevation colonies. Food availability affects the weight of the female showing that there is a strong correlation in litter size and mother's weight (Muller-Schwarze 2011). Given that the areas with no lodge, thus no reproducing colonies members, had limited food source for beaver I can conclude that the areas no longer have enough vegetation for a mother to put on the appropriate weight required to reproduce and sustain a colony.

5.1.3 Changes in Beaver Lodge Density

It is difficult to make any definitive conclusions on the density of beaver in these areas. The obscurity of lodges during surveys in summer and limitations to areas surveyed in 2011 did not give an adequate representation of the current beaver population density. The Slate River Valley was certainly underestimated. Using the density of beaver based on the number of lodges found also has limitations since multiple lodges can be built by one colony in the summer (Rutherford 1964). A more accurate estimate of the current population density would be a count of caches after leaf fall (Broschart et al. 1989). If Warren had conducted stream surveys of consistent length and better documented this for all sites, as he did for a few sites, it

would have provided a better estimate of population density. However, for those sites that retained a colony and was surveyed just as Warren's (Poverty Gulch, below Pittsburg, West Brush Creek, Coal Creek) one can see that beaver rarely exceeded the historic number of lodges and was not found to be at densities higher than two colonies per km stream surveyed. All sites had decreased in the number of lodges found slightly and only Washington Gulch and Coal Creek increased in the number of lodges, but not to a great extent.

Muller-Schwarze and Schulte (1999) found that even in high population densities beaver would self maintain inter-colony distance, family size and body weight. Thus the beaver at these long-term occupied sites may be self-regulating their populations in order to best maintain the site for permanent residency and limiting resource exploitation by over reproducing.

5.1.4 Other Long-Term Studies

Hay (2010) conducted a long-term study of beaver occupancy in the mountains of Colorado from 1955-2005. He also found that beaver will remain in specific sections of streams but will build dams in different locations and are not bound to one pond for their entire existence. Every individual colony will respond differently to the site they occupy. In the same study he also found that while one lodge was maintained for 20 years the colony built a new lodge close by and let the old lodge degrade. The reason for this is unknown. Of the four colonies he studied over 50 years all had gone through a series of occupation and abandonment. Over the years he noticed more organic debris filling in these ponds and vegetation

encroaching. While work was found at some of his colonies 50 years later no lodges were found and he notes that ponds were progressing toward turning into a beaver meadow. Unfortunately, he does not document the characteristics of the geography (slope, valley width, vegetation) for each site, which could have provided more insight on what made the beaver continually build opposed to fully abandon the site or why lodges are no longer maintained.

Neff (1959) utilized similar methods as my study but used only documentation of a single colony near Long's Peak Colorado. Neff used descriptions of the colony documented by E.A. Mills from 1885-1912, Edward R. Warren in 1922 and himself in 1955. This colony began with over eight lodges in 1885. It, like many other colonies, went thorough a series of abandonment and re-occupancy due to fire, predation and exploitation by trappers. Neff (1959) found during his survey that the colony looked very similar to Warren's survey 32 years earlier including the maintenance of the same dams, however, only the remains of the lodge were present. While no beaver remain over winter (lack of a lodge and food cache) they still resided there in the summer. Neff concluded that year round beaver occupancy is dependent on having an adequate willow and/or aspen in the area in order for beaver to build caches as an over winter food supply. He also found that once beaver have utilized their supply of aspen they would subsist on willow.

Busher and Lyon (1999) found in their study on long term (what they considered 10 years or more) population dynamics of unexploited beaver populations in Massachusetts and California that both beaver populations in his study fluctuated drastically but some beaver remained, even if only a few animals.

The fluctuation in beaver populations was accepted to be a result from a depletion of food sources by competition from whitetail deer, *Odocoileus virginianus*, and fluctuating water availability. Stream width was also an important factor. Active colonies in the Massachusetts streams were associated with average stream widths of 8.1 meters.

5.2 Conclusion

This study has demonstrated the applicability of historical documentation as a resource for use in the reconstruction of historic wildlife populations. The historical information used in this study, entered into a GIS, allows us to visualize and analyze the changes in biogeography of beaver populations in the western Rocky Mountains. We can conclude that beaver are able to occupy or reoccupy specific patches in their riparian range for over a century, subsisting primarily on *willow spp.*

Reconstruction of the historical beaver population, in the time period directly after their extirpation in this portion of their range, has revealed the preferred areas to be occupied by beaver. The presence of lodges in the same patches today as found 85 years ago or more demonstrates the capacity for a specific patch on a stream with certain characteristics (wide valleys, low slope and sufficient willow) to continually occupy active beaver populations and will not always progress into a permanent beaver meadow. This information can be used to better manage the lands and local beaver populations as well as for those species that depend on the beaver ponds as habitat.

While beaver will fluctuate their main colony locations temporally and spatially, they tend to remain in close proximity to the previous location and may re-occupy the same sites years later. Wildlife and land use managers that deal with beaver (or any species that could be dependent on ecosystems created by the presence of beaver) as well as those interested in preserving biodiversity and hydrology of an area, should use this information to preserve areas currently occupied as well as formerly occupied by beaver. Preserving only the main location beaver are currently occupying could harm the colony in the future if they are unable to relocate to areas nearby to allow for vegetation to regrow once local sources have been depleted. Those sites that are able to support beaver over the long-term should be protected and maintained for beaver indefinitely whenever and wherever possible. Wide valley bottoms over 150 meters with grades under 3.4 degrees are the best areas for long-term beaver occupancy most likely due to the increased availability of willow. Unfortunately, these are also the same locales that humans prefer to occupy and utilize for agricultural purposes. This loss of prime beaver habitat is most likely the driving force behind a severe decrease in total beaver population in North America (Naiman et al. 1986) currently, compared to its historical capacity.

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- . 1937g. The Beaver Work on Coal Creek. Unpublished manuscript. Archived at Rocky Mountain Biological Laboratory, Gothic, CO.
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Appendix 1: Maps and Photographs

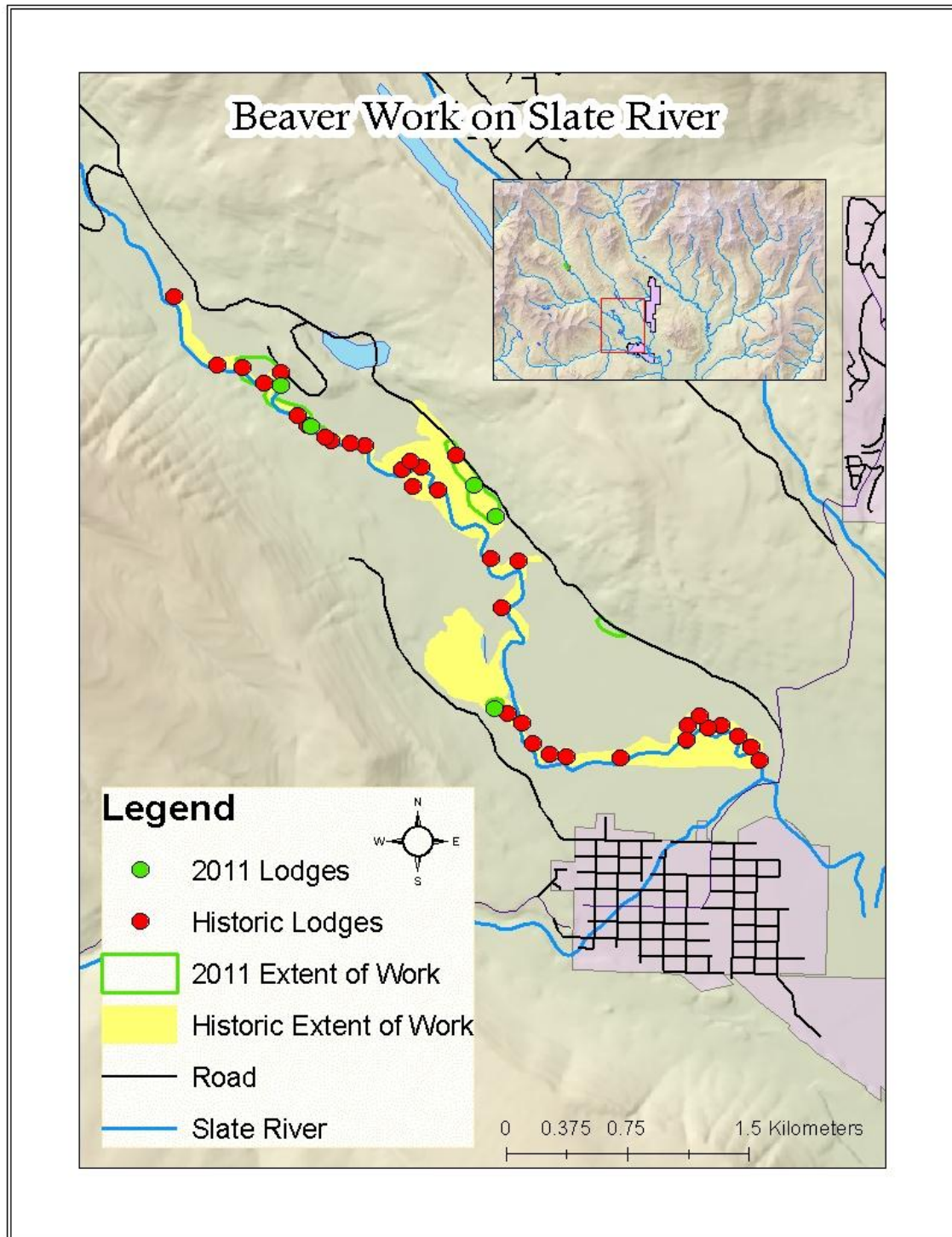


Figure 13 Historic and present lodge locations and extent of work on the Slate River.



Figure 13 a Photograph of beaver habitat in the upper Slate River Valley. Location of northern most work documented for this site.



Figure 13 b Photograph of habitat in the slough located along the road in the northeastern portion of this site.

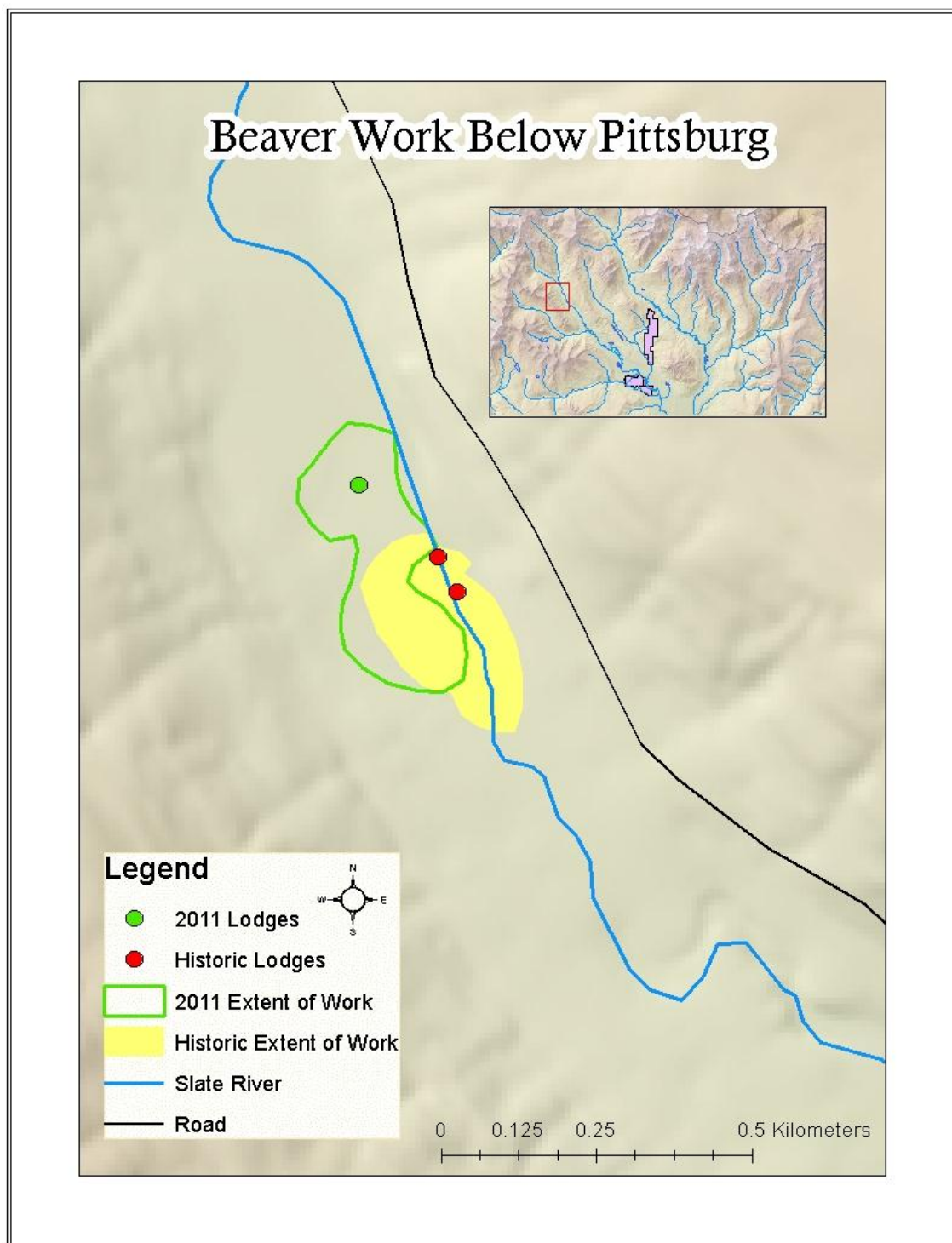


Figure 14 Historic and present lodge locations and extent of work below Pittsburgh.



Figure 14 a Photograph of downstream perspective of Below Pittsburg site where Warren documented beaver work.



Figure 14 b Photograph of the lodge found at the Below Pittsburg site in 2011.

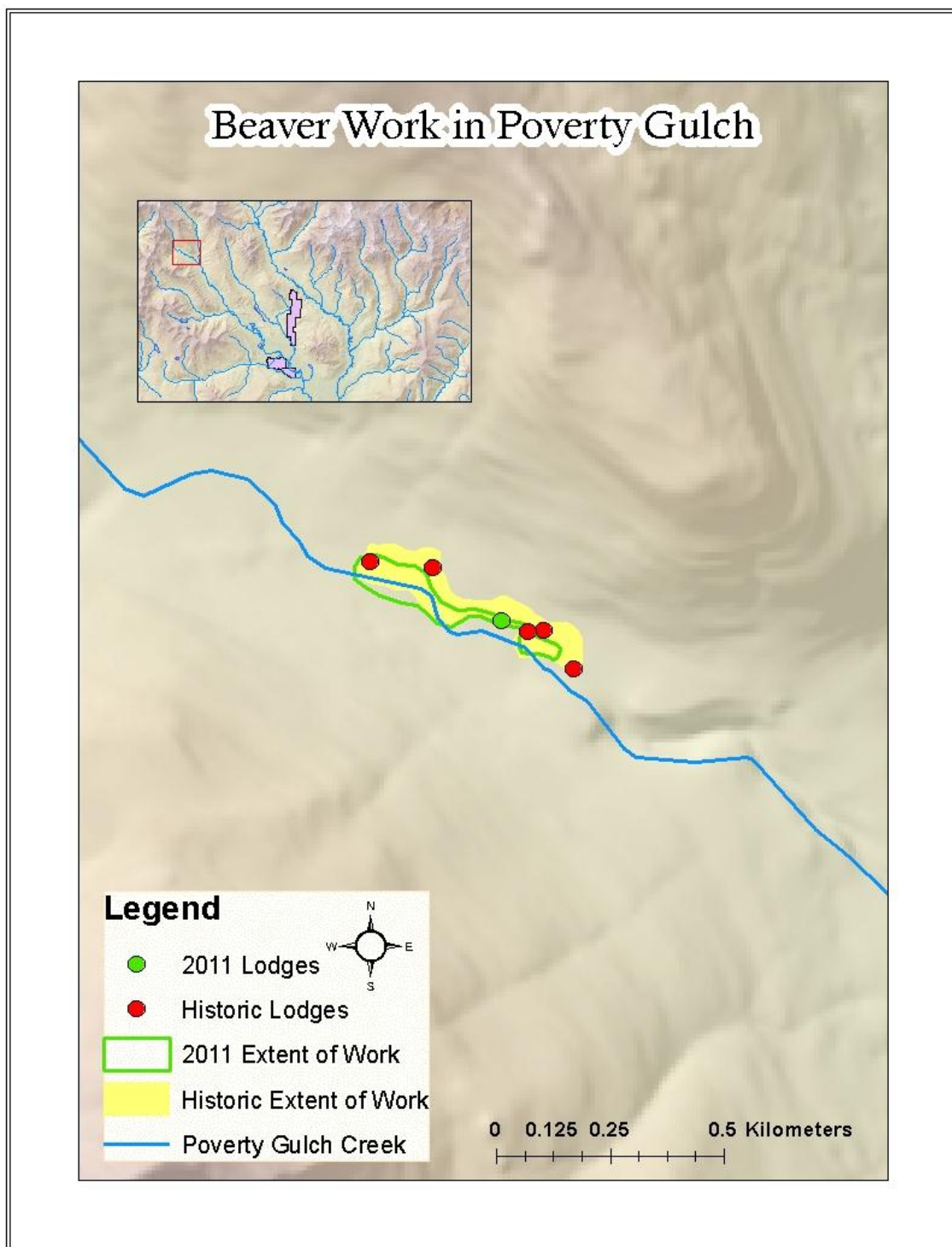


Figure 15 Historic and present lodge locations and extent of work on Poverty Gulch.



Figure 15 a Photograph of habitat in most southern portion of beaver work at the Poverty Gulch site.



Figure 15 b Photograph of habitat in most northern portion of beaver work at Poverty Gulch site.

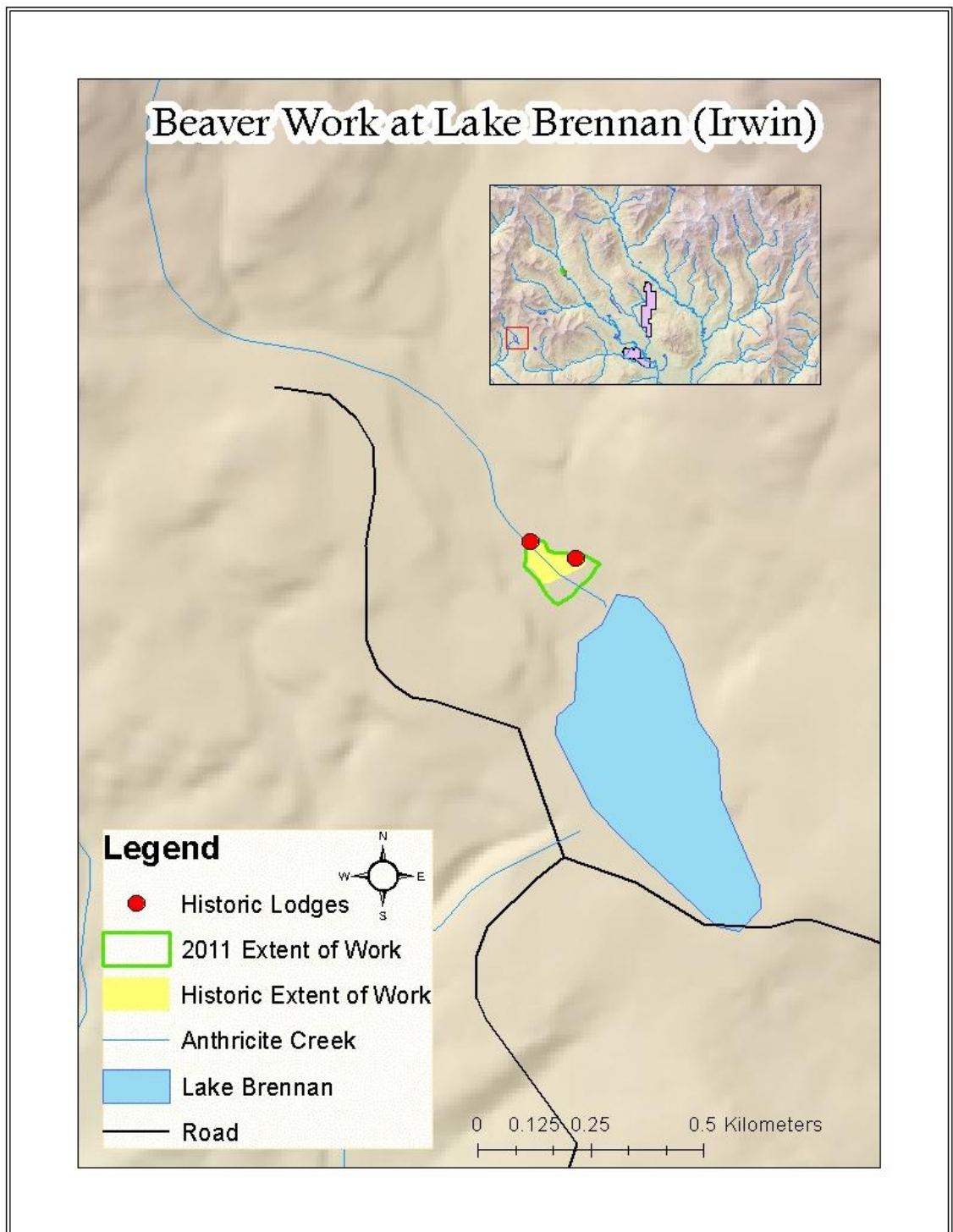


Figure 16 Historic and present lodge locations and extent of work at Lake Brennan.



Figure 16 a Photograph of habitat in upper portion of beaver work at the Lake Brennan site.



Figure 16 b Photograph of habitat in lower portion of beaver work at the Lake Brennan site.

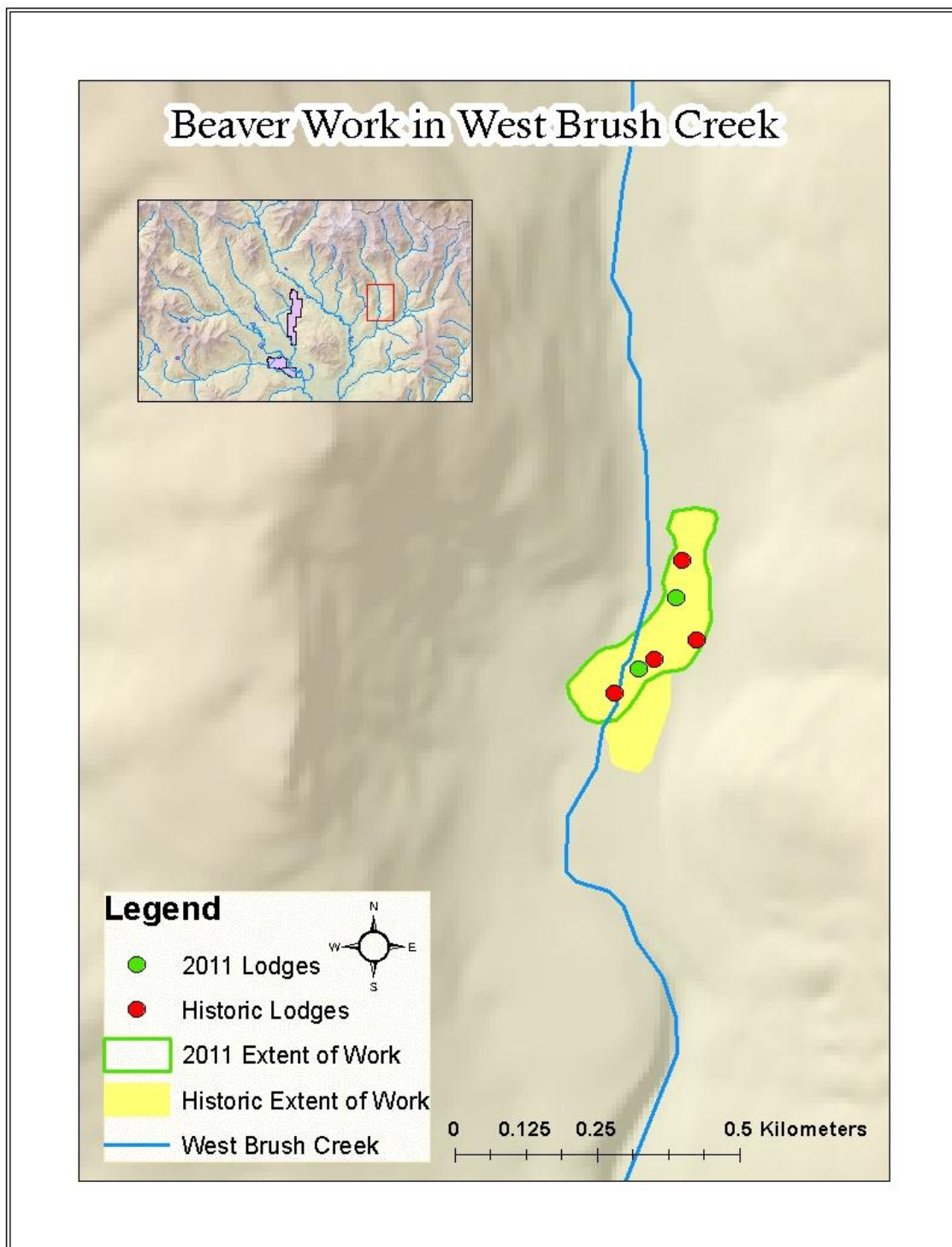


Figure 17 Historic and present lodge locations and extent of work on West Brush Creek.



Figure 17 a Photograph of beaver habitat and work at the lodge farthest upstream at the West Brush Creek site.



Figure 17 b Photograph of beaver habitat and dams in the western portion of the West Brush Creek site.

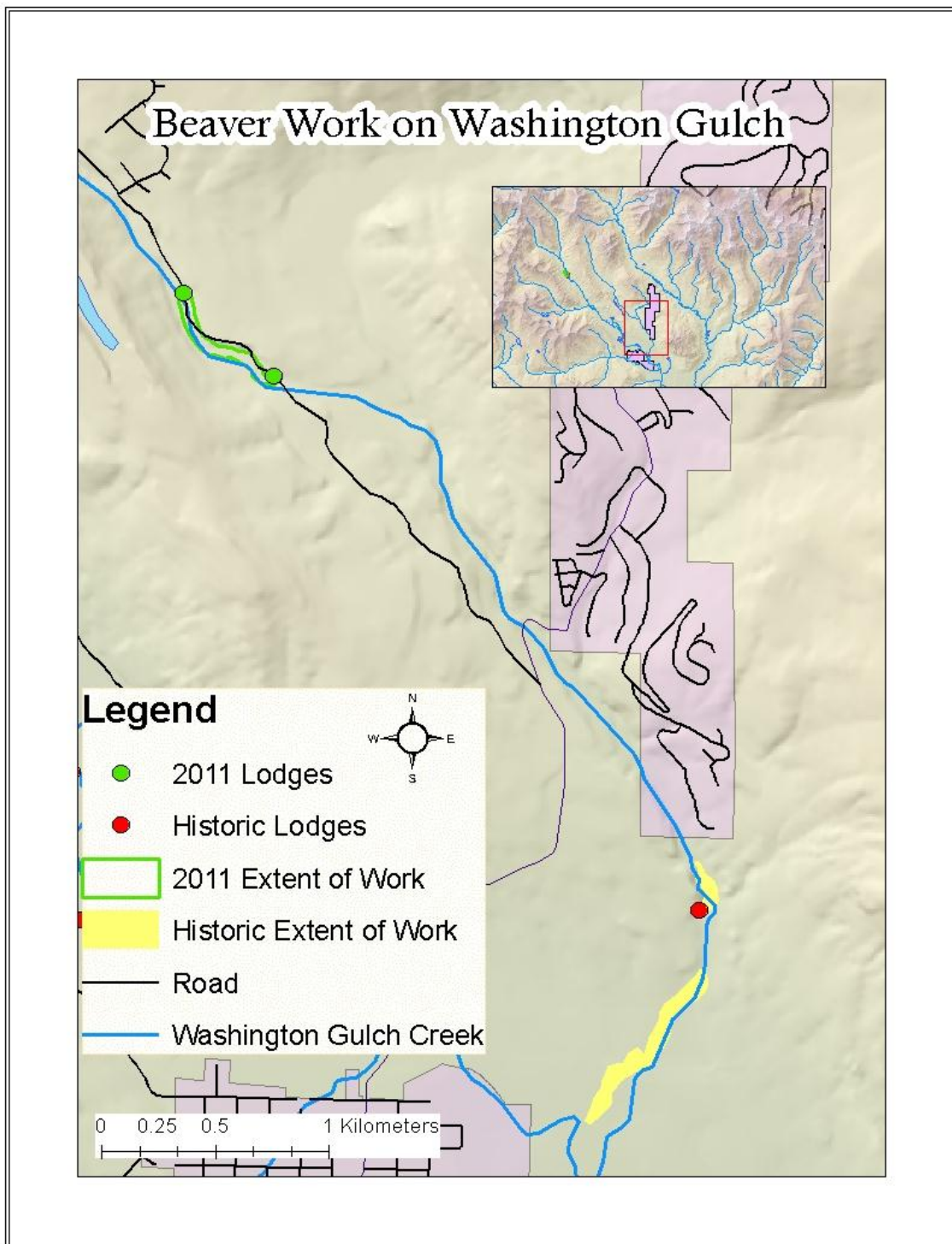


Figure 18 Historic and present lodge locations and extent of work on Washington Gulch.



Figure 18 a Photograph of potential beaver habitat in lower Washington Gulch site.



Figure 18 b Photograph of beaver habitat and work at the downstream lodge at the upper Washington Gulch site located below the reservoir.

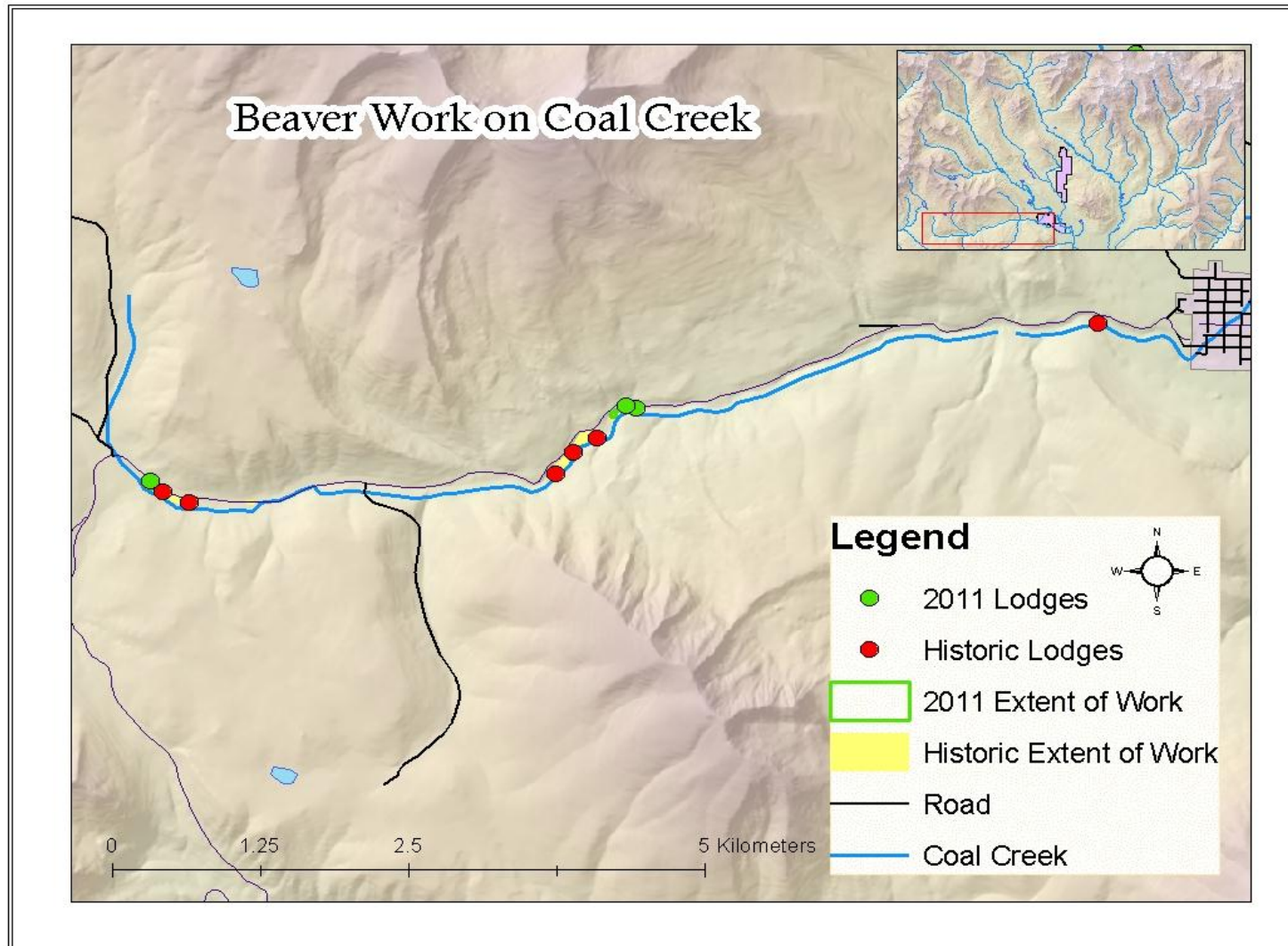


Figure 19 Historic and present lodge locations and extent of work along Coal Creek.



Figure 19 a Photograph of beaver habitat and location of work found during Warren's surveys at the middle patch on Coal Creek.



Figure 19 b Photograph of beaver habitat and work at the lodge farthest upstream on Coal Creek.

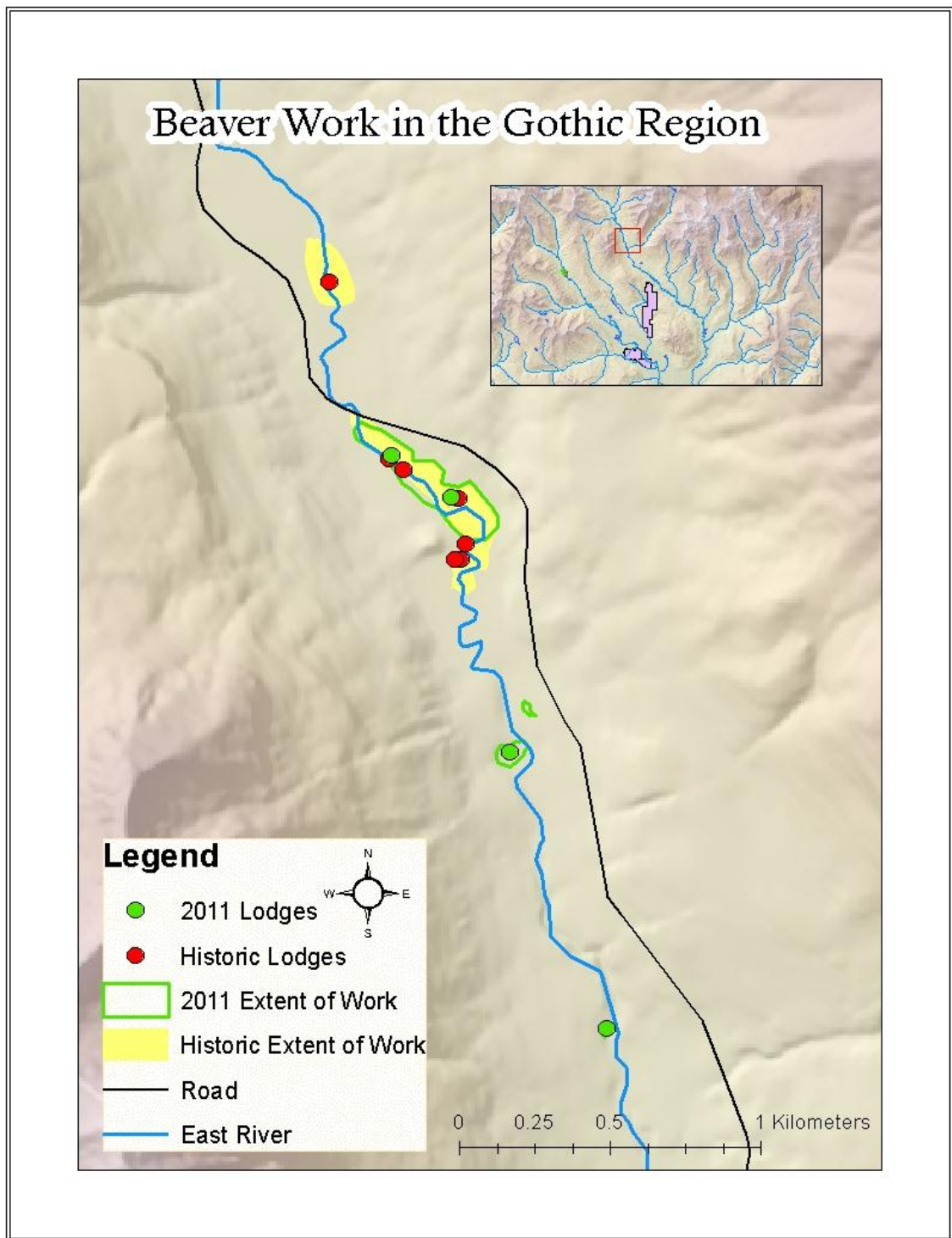


Figure 20 Historic and present lodge locations and extent of work in the Gothic Region.



Figure 20 a Photograph of beaver habitat and work at the second lodge below the bridge at the Gothic Region site.



Figure 20 b Photograph of beaver habitat at the Gothic Region site.

Appendix 2: Warren's Journals