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Erosion Impacts from Recreation in the Enchanted Tower Climbing Area, New Mexico

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by

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Committee Approval

The Master of Water Resources Professional Project Report of Debby Mandeville is approved by the committee:

Tim J. Ward	31 August 2001
Chair	Date
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Julie Coonrod	8/31/01

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Chapter 1 Introduction

There is a threat to the health of watersheds beyond natural occurrences. This threat results from human recreational impacts. There are many ways in which watersheds can be managed and protected to better meet human needs for water, food, and other natural resources, including management of recreational activities, both today and tomorrow.

In Thompson Canyon along Forest Road 59A, a rock climbing area has received national and international recognition. It is heavily used during all seasons. The National Forest Service writes, "This use has had a negative impact on surrounding areas. There are several concerns regarding the Thompson Canyon Rock Climbing area: campers have denuded much of the adjacent meadow area, a potential health hazard exists because there are no sanitary facilities, there is no right of way on Forest Road 59A, there are threatened and endangered species concerns, and a lack of developed parking" (CNF 2000).

Typical land uses in National Forests include wildlife habitat, hunting, livestock grazing, agriculture, mining, timber production, recreational opportunities and aesthetic virtues. National forest land is generally managed under a multi-use concept. The objective of multi-use concept is to manage the various natural resources for the most beneficial combination of present and future uses (Brooks, et al., 1997). Likewise, the Thompson Canyon Watershed has been managed under the Cibola National Forest. Since 1987, when land uses in the canyon began to drastically change, management was never updated or reformed to meet these changing conditions. Simple management techniques can considerably reduce erosion rates to more sustainable levels, without compromising the recreational values that this canyon beholds.

Importance of Watershed Management

Watersheds function as catchments, therefore every area of the land surface can be considered to be a part of a watershed. Many have described watershed boundaries (Potter, 1990; Fleming, 1983; and Sheng, 1986). Watersheds are multifaceted networks of life, landscape, and commingled groundwater, not just surface water alone. Watersheds vary in size, and are often classified into practical land management units for addressing issues such as water quality and quantity, ecosystems, endangered species and many more. Watershed management goals, in general, are to conserve existing land use practices, while overcoming identified problems to create a more sustainable level of land use. Sustainability is best understood as a process of change in which the use of resources, the direction of investments, the orientation of technological development, and institutional change all enhance the potential to meet human needs of the present without compromising our ability to meet future needs (Brooks, et al., 1997). Neglecting watershed health can jeopardize water resources and lead to local and global impacts.

Water is one of the most important life-sustaining natural resources available. Watershed health is important because healthy watersheds sustain flows of water. Water use increases as populations continue to grow. The billions of people who compete for this water directly impact the condition of the supply. Managing watersheds can be a beneficial practice in all areas of the world. A successful approach when managing watersheds not only depends on the physical and biological characteristics of the particular watershed, but also must incorporate economic, social and institutional factors. It is also important to understand and gather information on the land use patterns, cultural needs and community considerations within the watershed. A holistic approach must be taken in order to meet common environmental, economic and social objectives.

A watershed's well-being is not only dependent on a positive human presence, but also is directly influenced by the climate and other environmental characteristics. Steep and mountainous lands generally accentuate watershed processes and problems. Approximately 25% of the land area on earth is located in mountainous regions, and about 600 million people reside there (Brooks, et al., 1997). Water scarcity in arid and semi-arid regions of the world continues to create serious problems due to ever increasing populations. Arid and semi-arid regions cover more than 33% of the earth's land surface, and these regions are inhabited by approximately 900 million people (Brooks, et al., 1997). Humid tropical lands maintain diverse plant cover because water is readily available. Today, however, agricultural fields endure shorter rotation cycles, compared to years past, in order to support the food needs of increasing populations. Improper agricultural practices deplete soil nutrients and lead to the breakdown of soil structure. Deforestation during the 1980s averaged 15 million ha/yr., and was primarily driven by increasing populations (Brooks, et al., 1997).

In all climates and land classifications, soil erosion is a significant environmental problem. More than 97% of the world's food comes from the land (Pimental, 1993). Erosion represents all processes that strip soil and weathered rock from the earth's surface, until they are deposited as sediment elsewhere. There are four types of water-induced erosion: raindrop splash, gully, sheet, and rill erosion (Roberts, 1995). The amount of soil moved by a raindrop splash depends on the kinetic energy of the raindrop, the type of soil being struck, the slope angle and the soil moisture content. Raindrop splash erosion is more severe in semi-arid climates. Gully erosion occurs where flows are intense enough to form deep channels, also referred to as arroyos. Sheet erosion is the removal of soil from sloping land in thin layers (Roberts, 1995). Rill erosion typically occurs in fine-grained soils where small shallow channels form.

Changes in soil and vegetation cover are capable of altering streamflow quantity and quality, including sediment streamflow relationships that can ultimately influence channel processes and structure (Pimental, 1993). Flows that would have remained within the streambanks before, now cause floods. Soil erosion leads to losses in plant productivity and soil stability. Overgrazing has also been shown to increase erosion and sedimentation rates. As a result, the soil erosion control in watershed management rehabilitation plans is essential for sustainability of natural resources and economic productivity. This project in Thompson Canyon focuses on soil erosion.

Brief History of Thompson Canyon Watershed

Thompson Canyon is similar too much of the National Forest land within New Mexico, with respect to land uses. For the past 14 years, this watershed has endured high amounts of recreational traffic throughout the year. During 1987, a geology graduate student from New Mexico Institute of Mining and Technology, Bertrand Gramont, was surveying in the Datil Mountains for his master's thesis entitled "Carbonate Sedimentology of the Virgilian part of the Horquilla Formation" (Gramont, 1987). He found some of the best sport climbing New Mexico has to offer in Thompson Canyon. Soon after discovery, Gramont named this climbing area the Enchanted Tower. By the end of 1987, several climbers, including Gramont, established five climbing routes. During October 1988, *Rock and Ice* published the first climbing guide for the area which included a total of twelve routes. Years passed and routes continued to be established by a number of experienced climbers. From the time of discovery and through the early 1990's, Gramont and a small group of locals exclusively visited the area. In time, the word of excellent climbing reached others around the world. Today, climbers from throughout the world visit this remote canyon to take pleasure in its admirable rock type and routes. The publication of a guidebook in 1993 by two students attending New Mexico Tech entitled, *The Enchanted Tower – Sport Climbing Socorro and Datil, New Mexico,* further promoted the area (Maestas and Jones 1993). This guidebook includes seventy-eight routes established by various climbers within the canyon. During May 1996, *Rock and Ice* published an updated guidebook that documented seventy-six routes. By 1996, The Enchanted Tower was incorporated into a Falcon Guide entitled *Rock Climbing: New Mexico and Texas* (Jackson 1996). This book describes climbing areas throughout both states, but not in great detail. Jackson highlights fifty-one routes all located around the primary climbing area of the Enchanted Tower (Figure 1-1). Jackson writes, "Pleasant surroundings, free camping, and a friendly scene are extra inducements to visit the Enchanted Tower" (p. 185, 1996). Without a doubt, this statement encourages additional visitors every year. Recent verbal communications with Lance Hadfield (local climber) and Jake Snyder (rancher who resides at the entrance of the canyon), and personal experience has led me to believe that the number of visitors to the area increased as a result of the referenced publications.

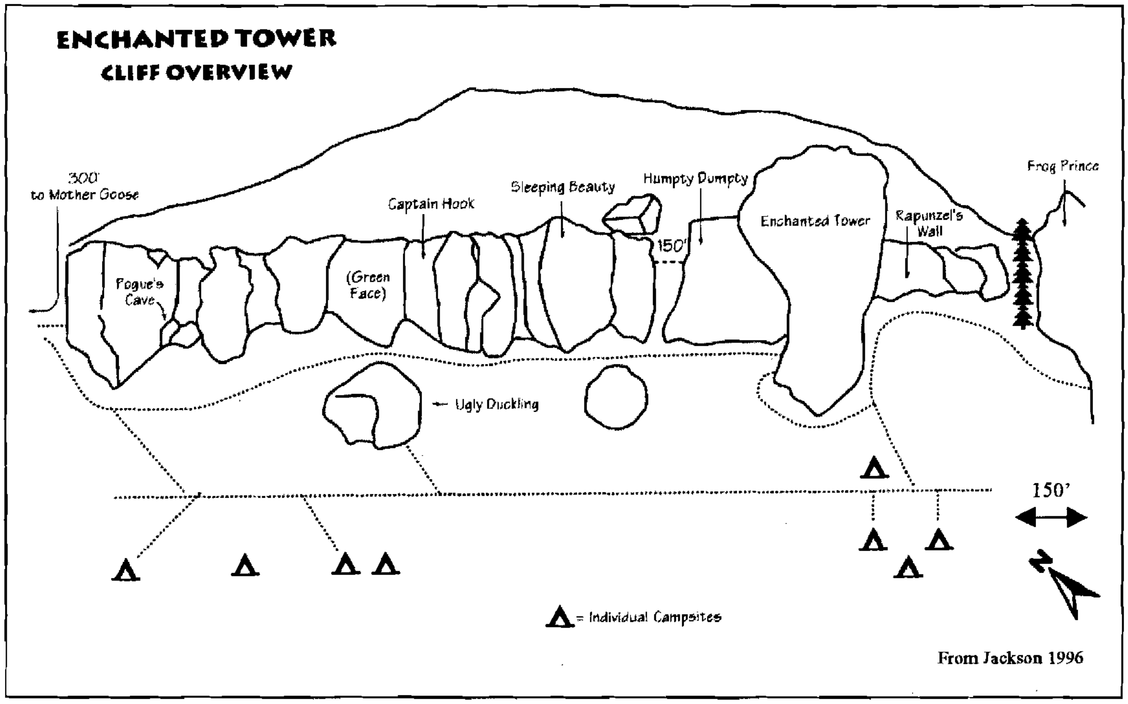


Figure 1-1: Diagram showing the different rocks associated with the Enchanted Tower Rock climbing area, the road entering the canyon and the established campsites in 1996.

My first visit to the Enchanted Tower was in 1993. Since then I have visited the site about 80 times. The greatest number of cars that I have observed in the vicinity of the climbing area has been eighteen during August 2000. There are no designated parking locations that are not also campsite locations. Figure 1-1 shows the locations of the eight practical campsites established through 1996. In more recent years, I have seen the development of numerous additional campsites within the canyon. If the current campsites are occupied, people typically pull off the main road further up the canyon and camp.

In recent years, there has been a development of a number of environmental impacts of increasing severity. These include accelerated trail erosion, unmonitored sanitation problems, sprawling campsites, and decreasing vegetation cover. There has been communication among the US Forest Service, private landowners and recreational climbers about possibly limiting or preventing access to Forest Road 59A, which leads into Thompson Canyon via Highway 60 (Figure 1-2). If pertinent issues concerning the Enchanted Tower climbing area in Thompson Canyon are addressed and properly managed, the possible closure of this superior recreational area can be avoided.

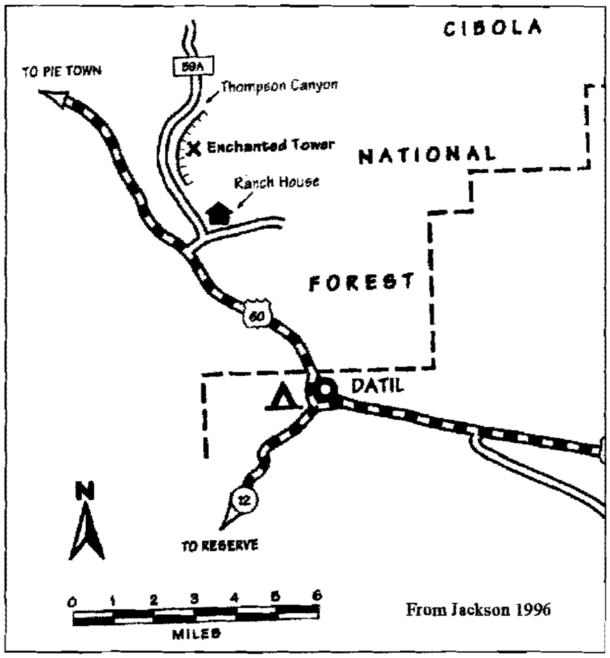


Figure 1-2: Map showing locations. Approximately 5.3 miles west on Highway 60 out of Datil, NM is the intersection of Forest Road 59A that leads into Thompson Canyon, by passing through private land and a small ranch.

This project focuses on soil erosion in the Thompson Canyon watershed. The different sources of erosion are identified with regards to impacting the watershed's health and how these impacts can be reduced or eliminated. The ultimate outcome of the study is to suggest strategies for increasing the health of Thompson Canyon. Such strategies may include reduction in human accelerated soil erosion, providing quality campsites for recreationalists, increasing vegetation cover, installing sensitive area signs, establishing toilet pits and educating rock climbers about the importance of maintaining a healthy watershed.

Goals and Objectives

The goal of this study is to create a plan that will reduce future recreational impacts on the watershed. The primary objective of this study is to identify location of sources and impacts associated with erosion. Subsequent objectives are to qualify and quantify the identified impacts on the watershed. Then in a restoration plan suggest strategies to reduce these impacts to a more sustainable level while establishing a long term monitoring plan.

Chapter 2 Literature Review

A review of recreational uses and the resulting effects on watershed health was conducted for the Thompson Canyon recreational impact and erosion study. A literature search focused on: recreational carrying capacities, soil erosion measuring techniques, trail environments and campground degradation. After researching each of these topics, appropriate studies were selected that provided a framework for techniques to be used in the Thompson Canyon research project.

Capacities for Outdoor Recreational Uses

Substantial increases in outdoor recreation have created congested conditions and increased environmental impacts to natural resources. Recreational carrying capacity is defined as the "level of recreational use an area can withstand while providing a sustained quality of recreation" (Wagar p. 24, 1964). Shelby and Herberlein's, (1986) approach to better managing wildland recreation resource environments include combining all four sub-capacities, these being physical, ecological, social, and facility in a given area.

Of the four sub-capacities, Symmonds et al., (2000) focus on social capacity, the number and distribution of visitors that provides minimal acceptable recreation experiences. Symmonds et al. (2000) examine social capacity factors of recreational environments that are primarily used by mountain bikers. An email survey was used to identify issues such as mountain biker preference of soil erosion management techniques and to distinguish how factors of soil erosion and trail design affect the actual mountain biking experience. Symmonds et al. (2000) conclude that mountain bikers significantly preferred water bars (Brooks et al., 1997) to the other tested soil management techniques. An email survey for the Thompson Canyon watershed project is not feasible for this current study due to time constraints, but would be useful in future studies to gain knowledge concerning distribution of visitors, activities and intensity levels of use.

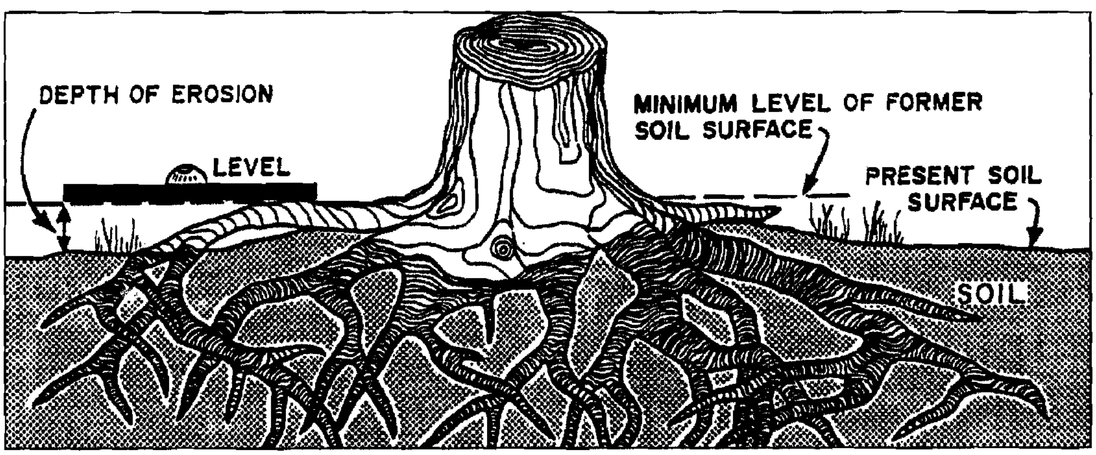
Methods for Estimating Soil Erosion and Sediment Yield Rates

Kuss and Morgan (1980) present a basis for using the Universal Soil Loss Equation (USLE) as a method for estimating the carrying capacity of recreational areas. Overuse of a recreation area results in loss of vegetation cover and soil compaction, which reduces infiltration and increases surface runoff. Many agree that litter or vegetation cover is the most important variable in the USLE because it increases infiltration and reduces overland flow (Heede 1991; Kuss and Morgan 1980; and Weaver and Dale 1978). Kuss and Morgan (1980) conclude that the USLE represents a good first approximation of physical carrying capacity. Trimble and Crosson (p. 248, 2000) agree, "The USLE is an excellent planning tool for estimating the relative values of varying land uses and conservation measures." The USLE attempts to predict sheet and rill erosion by water (Wischmeier and Smith, 1978). The revised universal soil loss equation (RUSLE) presents guidelines for soil loss predictions combining current and previous information (Renard et. al., 1997). This revision is intended to provide estimates of soil loss, and will be used in estimating erosion rates in Thompson Canyon.

The sediment delivery ratio (SDR) is the ratio of sediment delivered at a basin outlet to the erosion (E) occurring within that basin (Walling 1994). The SDR establishes a method for estimating sediment yield (SY) with the relationship, $SY=E\cdot SDR$ (Walling 1994). Walling (1994) and Trimble and Crosson (2000) express similar problems associated with applying this equation in erosion studies. These include the storage of sediment deposited elsewhere within the basin, and the time and processes involved in sediment delivery from erosion site to outlet, or a sediment yield measurement site downstream. Walling (1994) notes that SDR varies with geomorphic and environmental characteristics of any given basin. A similar procedure to the SDR is applied on a smaller-scale to the individual trails within the Thompson Canyon Watershed. A description of the Thompson Canyon Watershed SDR study sites is presented in the methods section later in this report.

Soil Erosion Measurement Techniques

The paper, *Simple visual methods for identification of critical watersheds,* (FAO 1985) focuses on accelerated erosion, or "man-induced erosion" caused by overgrazing, fires, improper road construction and other impacts of land use. A simple method of measuring erosion rates based on tree root exposure is explained in that paper. The height of the previous ground surface can be found by examining the boundary between trunk bark and root bark (Figure 2-1). A level is then placed at the level of the former surface and its height above the present surface can be measured. Although, this method is probably the least invasive, it cannot be applied where trees are not present. For example,



From FAO, 1985

Figure 2-1 Measurement of erosion from tree root exposure.

in the Thompson Canyon Watershed, obvious erosion problems exist around campsite areas where vegetation has been destroyed.

Summer (1986) conducted a study in Rocky Mountain National Park on impacts of horse traffic. The study concludes that intensity of use is not the controlling factor in trail stability. Trails were first classified into low, moderately high and high use intensities (note: moderate use intensities trails were not considered in this study). The erosion measuring technique included the installation of permanent stakes on the outside edges of the classified trails. Then, by attaching a tape across the trail segments, vertical measurements were taken every 3-6 cm. Cross-sectional areas were then determined from the measurements. The process was repeated for seven seasons on all classified trails. This methodology was not considered for the Thompson Canyon recreational impact study due to limited time and resources. Summer (1986) argues that horse use exposes the soil surface while geomorphic processes such as sheetwash, rilling, gullying, and soil creep actively modify the trail. In contrast, Weaver and Dale (1978) determined that horse traffic applies the greatest force and therefore caused greater increases in soil compaction, litter, trail width and depth when compared to hikers and motorcycles.

Jubenville and O'Sullivan (1987) examined soil losses from permafrost melt in Alaska. They measured trail cross-sectional areas to determine cumulative soil losses and the significance of slope gradient and vegetation type. The objective of that study was to meet recreational demands, while assisting land managers in planning new trails to minimize environmental impacts. Future research in Thompson Canyon on specific soils, slope gradients and vegetation types would be beneficial in determining more appropriate trail locations.

Installing erosion pins for estimating soil loss on sloping gully walls was used by Leopold et al., (1966). This study measured erosion rates on channel and hillslope processes over a 7-year period near Santa Fe, New Mexico. Long nails (pins) with washers inserted through the shafts of the nails were installed vertically into the ground until flush with the ground surface. As erosion occurs, the washer drops while the nail stays in its initial position. The distance between the nail head and washer is then recorded over time and then used in determining rates of erosion. This method of determining erosion rates for the stream channel processes in Thompson Canyon seemed most appropriate due to time and expense restraints (Figure 2-2).

Figure 2-2 Erosion pin installed in the Thompson Canyon Watershed.

After a review of erosion measuring techniques, a decision was made to install erosion pins across stream channels in the Thompson Canyon watershed. A description of the Thompson Canyon watershed pin study areas is presented later in this report.

In summary, because of the dynamic nature of the Thompson Canyon Watershed including the intense recreational activity, several different techniques were chosen to quantify erosion rates. Installation of erosion pins lead to understanding natural erosion rates within the stream channels in the canyon. Surveying and quantifying commonly used trails increased awareness about the erosion rates resulting from recreational traffic. These simple, yet accurate, measuring procedures will be valuable in suggesting appropriate management techniques to reduce future erosion rates, caused by recreational traffic in the Thompson Canyon Watershed.

Chapter 3 Site Description and Methodology

Geographic Setting

The majority of the Thompson Canyon watershed is located within the Datil Mountains that are in the Cibola National Forest, 8.5 kilometers west of Datil, NM (Figure 3-1, 3-2 and 3-3). The Thompson Canyon Watershed area is approximately 20.5 square kilometers. Elevations range from about 2154 meters in the meadows to nearly 3015 meters above mean sea level in the mountains.

Land ownership

The primary road that provides access into Thompson Canyon is located on private property. The Cleveland family owns the small ranch at the entrance of the canyon. However, the majority of the Thompson Canyon Watershed is within the Cibola National Forest (Figure 3-4).

Climate

The climate in Thompson Canyon is relatively mild with cool summers and moderate winters, with snow cover generally lasting from October through April. However, the sun shines an average of 75 percent of the time in the Datil Mountains (Cibola National Forest (CNF), 2000). Average annual humidity ranges from 60 percent in the winter to 30 percent in the summer (CNF, 2000). The majority of the warm season precipitation falls during thunderstorms that are often short-lived, but intense. Average annual snowfall is 63.5 centimeters or more within the Datil Mountains (CNF, 2000). May through October are generally the warmest months out of the year. Mean annual temperature is roughly 48° F, but cooler on mountain peaks. Jackson writes, "April through October offers the best climbing weather" (p. 189, 1996).

Figure 3-1: Map showing the location of the Thompson Canyon Watershed. A branch of Cibola National Forest is located in Catron and Socorro Counties of NM. The Datil Mountain Range is one of several mountain ranges within this area. Thompson Canyon is located in the central region of the Datil Mountains.

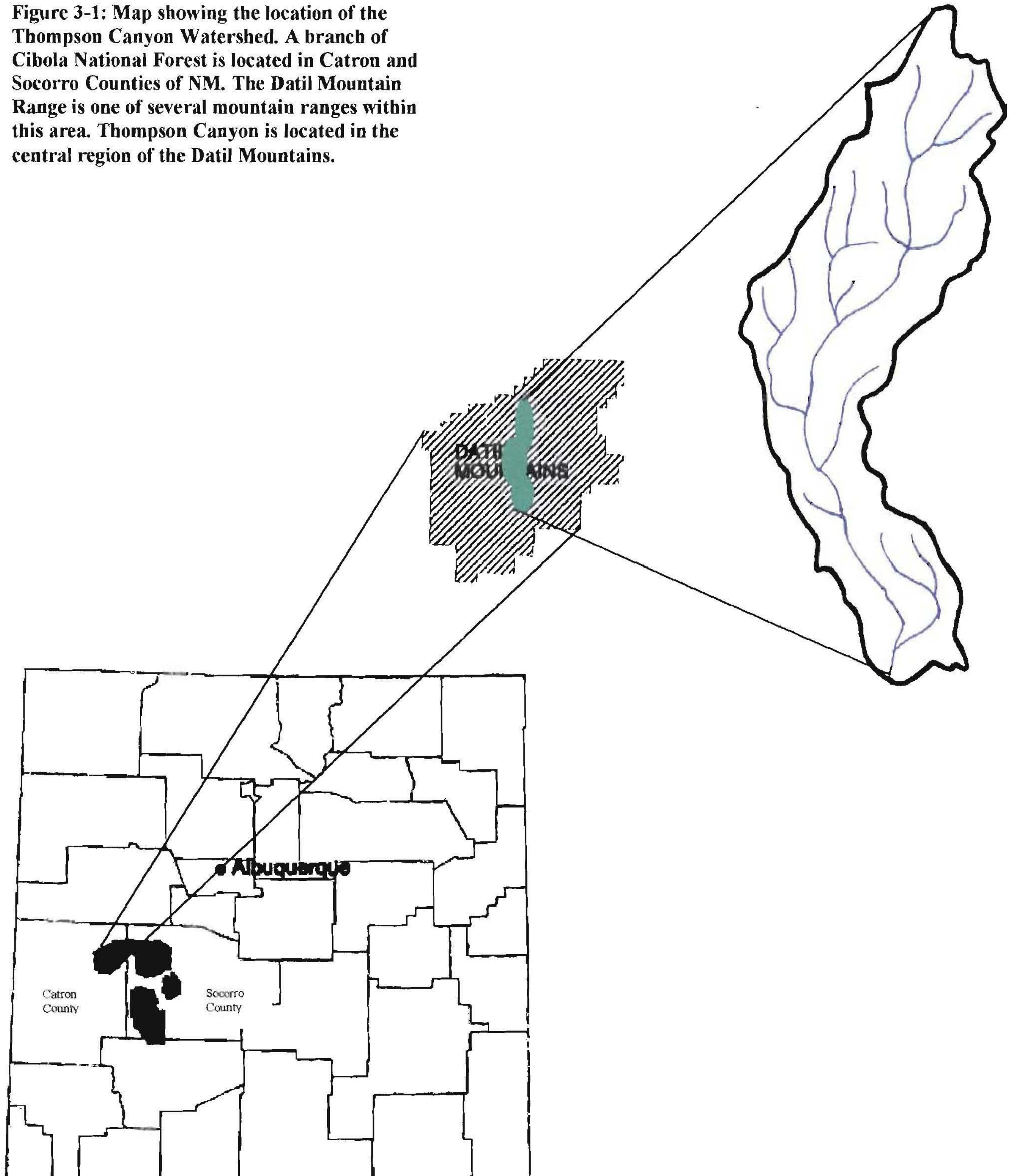


Figure 3-2 Land Use Map of the Thompson Canyon Watershed. These are typical land uses based on Anderson land use codes and a land use map of New Mexico. Note the forest is also grazed.

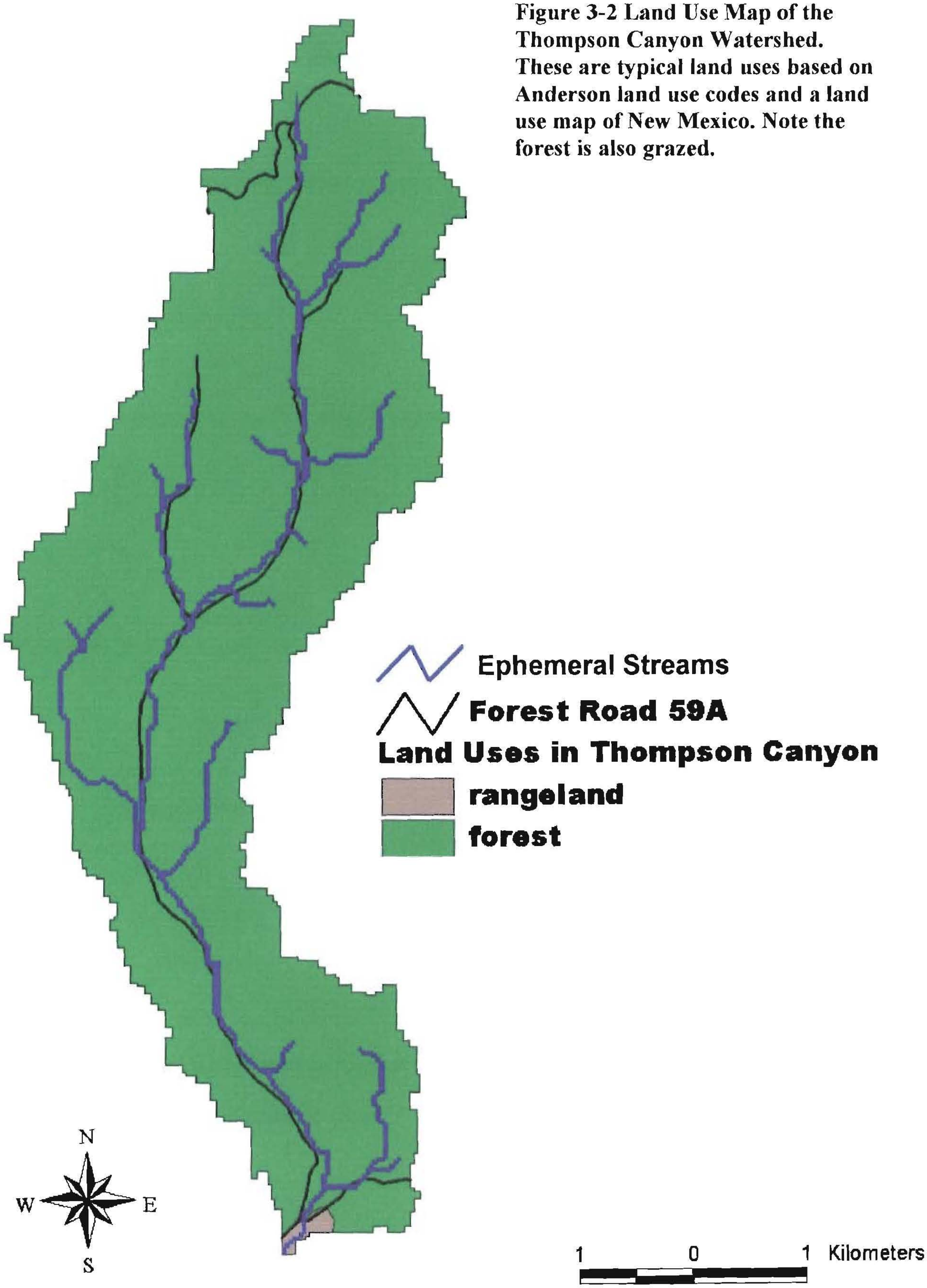


Figure 3-3 Detailed Land Use Map of the Thompson Canyon Watershed. The majority of the points on this map were measured in the field using a GPS unit. Note: the locations of the three erosion pin sites.

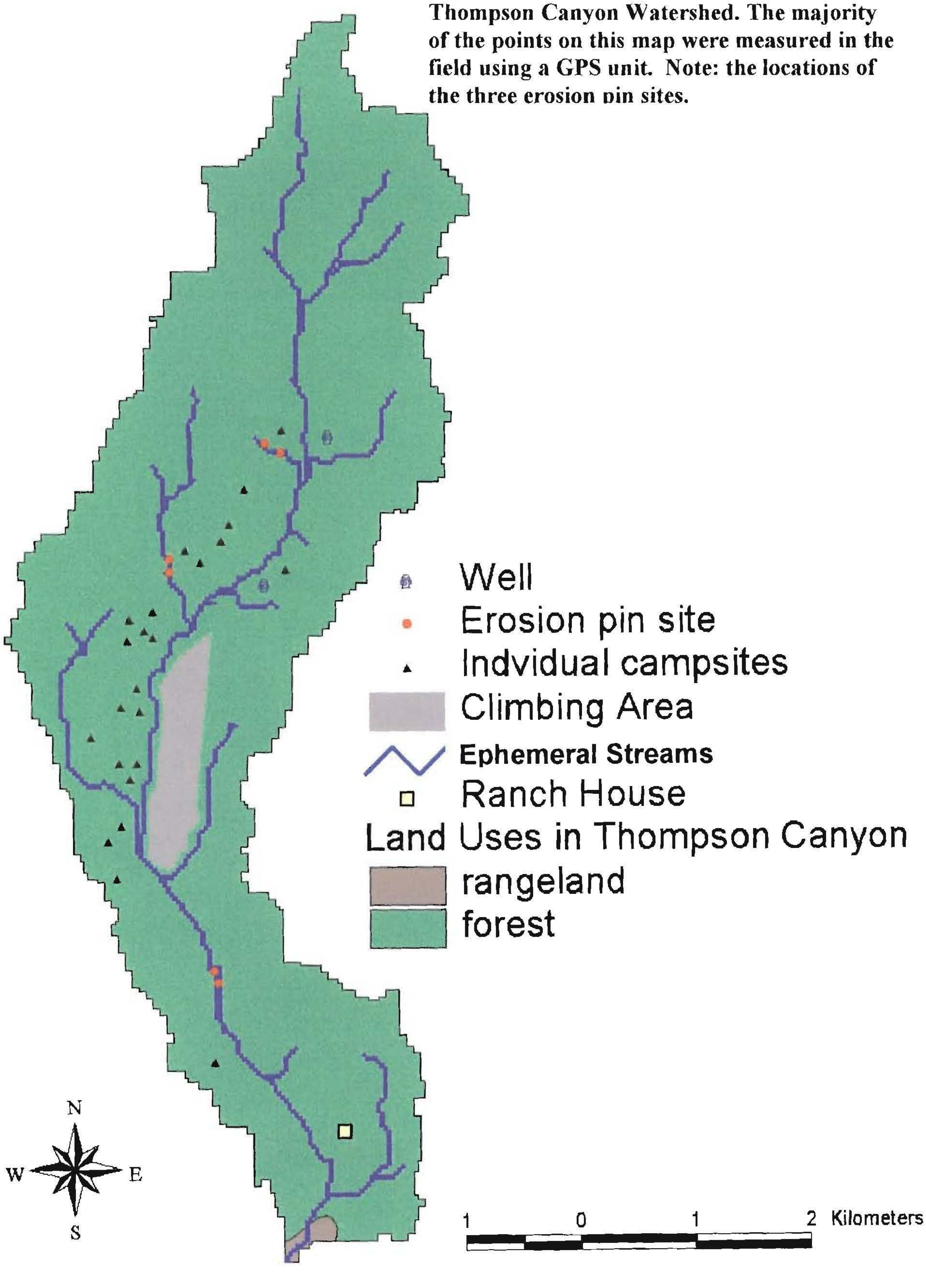
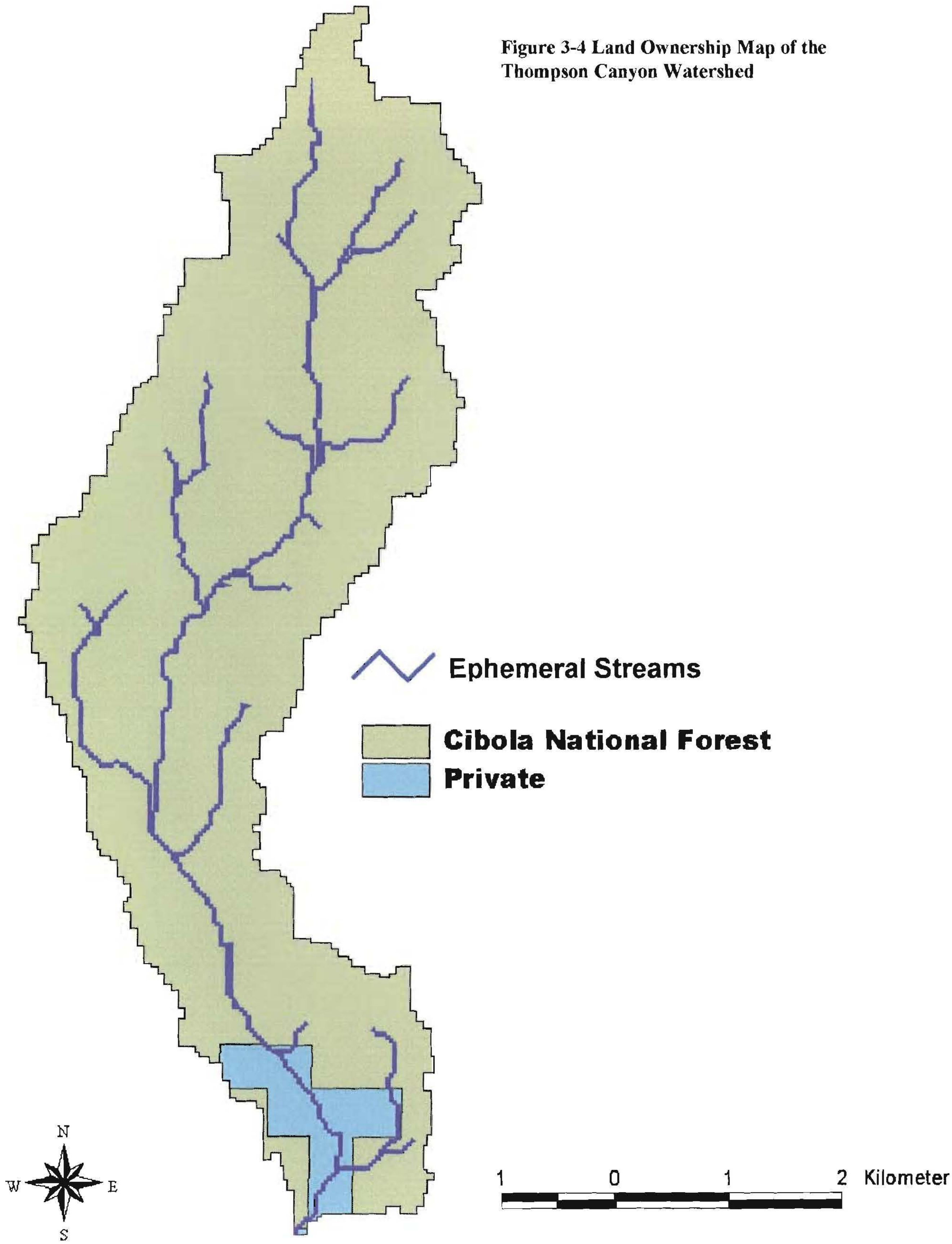
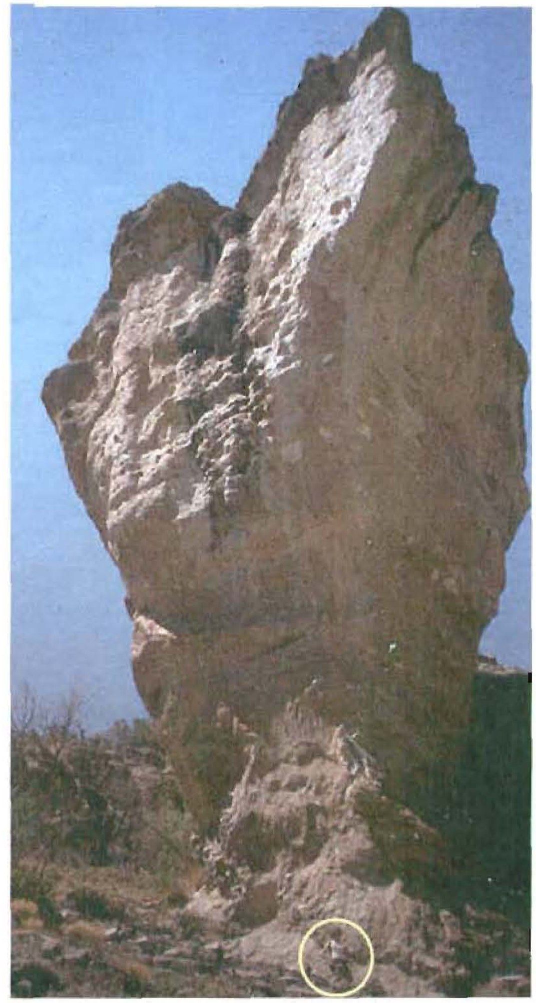


Figure 3-4 Land Ownership Map of the Thompson Canyon Watershed



Geology of the Datil Mountains

Figure 3-5 The Enchanted Tower within Thompson Canyon. The climbing area was named from this huge over-hanging rock. Note the person standing at the base for scale.

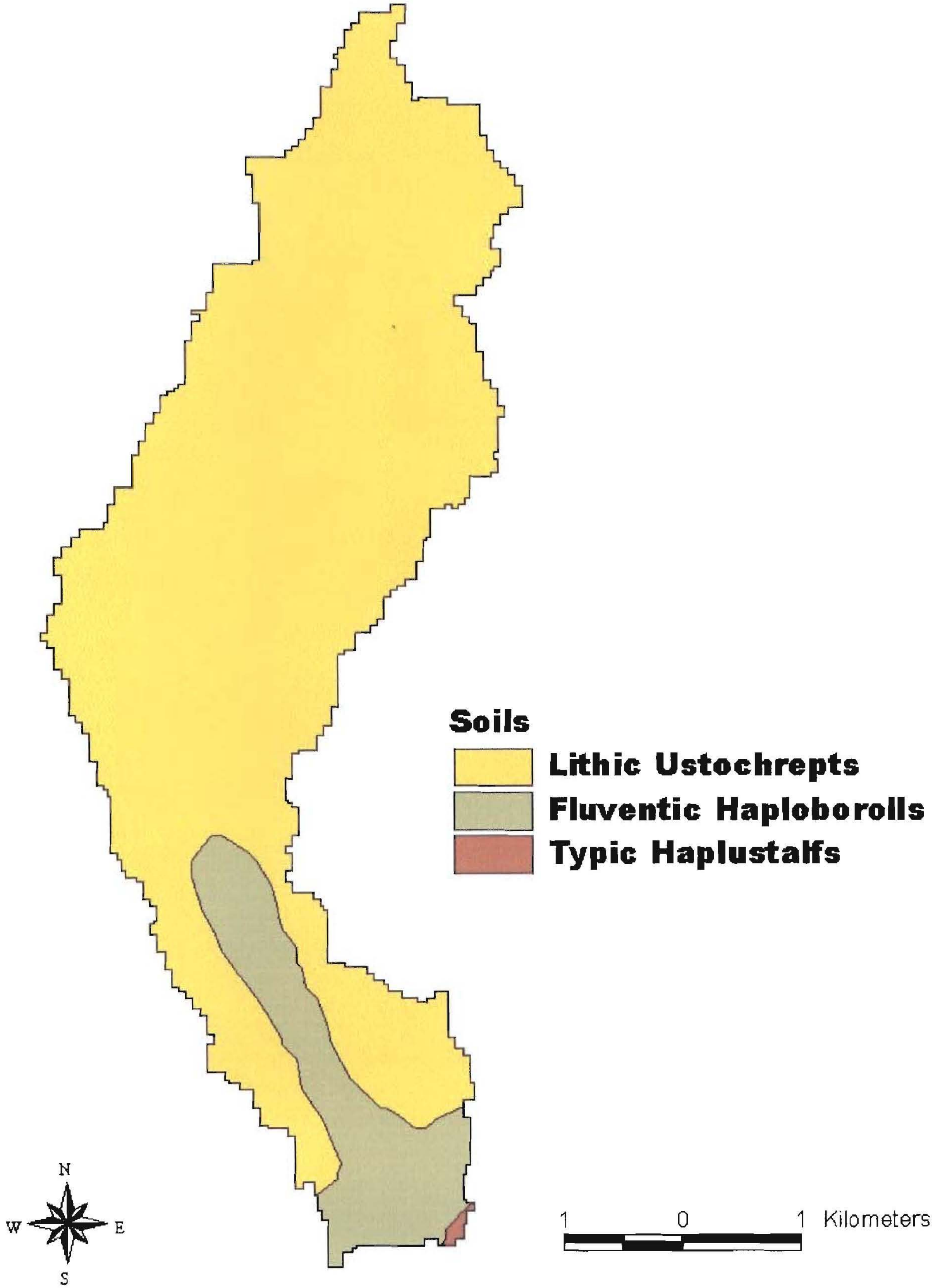


Surficial geology in the Datil Mountain consists of Quaternary alluvium, landslide deposits and colluvium, piedmont alluvial deposits, and older alluvial deposits of upland plains and piedmont areas and calcic soils and eolian cover sediments; Tertiary sedimentary and volcaniclastic sedimentary rocks with local andesitic to intermediate volcanics, basalt and andesite flows, rhyolitic pyroclastic deposits (ash-flow tuffs), and other sedimentary rocks primarily ranging from mudstones to sandstones; and Cretaceous mudstones, siltstones, and sandstones of the Crevasse Canyon Formation with some coal bearing units (CNF 2000). In particular, the area of Thompson Canyon impacted by recreational activity is geologically less diverse, characterized by rhyolitic ash flow tuffs and Quaternary alluvium (Figure 3-5), (Kurt Vollbrecht, State of New Mexico, pers. comm., 2001).

Soils

The Cibola National Forest has gathered information on the soils within the Datil Mountains. Specifically, the three types of soils recognized within the Thompson Canyon Watershed are Lithic Ustochrepts, Fluventic Haploborolls, and Typic Haplustalfs (Figure 3-6). The first being characterized as being a shallow, extremely cobbly, sandy loam and

Figure 3-6 Soils in the Thompson Canyon Watershed. These soils are based on a STATSGO soils map of New Mexico.



reported as having a severe erosional hazard (CNF, 2000). Fluventic Haploborolls is characterized by deep, compacted loam and having a slight erosional hazard (CNF, 2000). A deep compacted loam and a slight erosional hazard characterizes the latter of the soils mentioned. Cibola National Forest writes, "Lithic Ustochrepts has a natural soil loss of 5.2 tons/ha/yr, Fluventic Haploborolls has a natural soil loss of 1.3 tons/ha/yr, and Typic Haplustalfs has a natural soil loss of 0.4 tons/ha/yr" (p.8 2000). Figure 3-6 shows Lithic Ustochrepts covering the majority of the Thompson Canyon Watershed, having the highest natural soil loss.

Vegetation

Vegetation within the Thompson Canyon Watershed reflects elevation differences, available moisture content and land use intensity. Piñon/juniper *(Pinus cembroides / Juniperus scopulorum)* forest rises from an average elevation of 2308 m to ponderosa pine *(Pinus ponderosa)* and mixed conifer at elevations over 2769 m (Figure 3-7). Prairie/grasslands commonly occur in piñon/juniper forests (CNF, 2000). A number of species combine to make up the understory and meadows within the steep canyon sides including: Gambel oak (*Quercus gambelii Nutt.*), Oregon grape, pine dropseed (*Blepharoneuron tricholepis*), squirreltail (*Elymus Elymoides*), blue gramma, western wheatgrass (*Pascopyrum smithii*), wolf tail, Kentucky bluegrass (*Poa pratensis*), sagebrush (*Artemisia*) and a number of wildflowers (Figure 3-8).

Stream Channel Morphology

The streams within the watershed are ephemeral. The depths range from very shallow and narrow in the upper sections, to extremely deep and wide near the outlet. In the 8-km length of the main stream channel, the width ranges from 1m near the top of

Figure 3-7 Vegetation Types within the Thompson Canyon Watershed. These vegetation types are based off of a general vegetation map of New Mexico. This map does not include the diverse understory and grassy meadows within the canyon's steep slopes

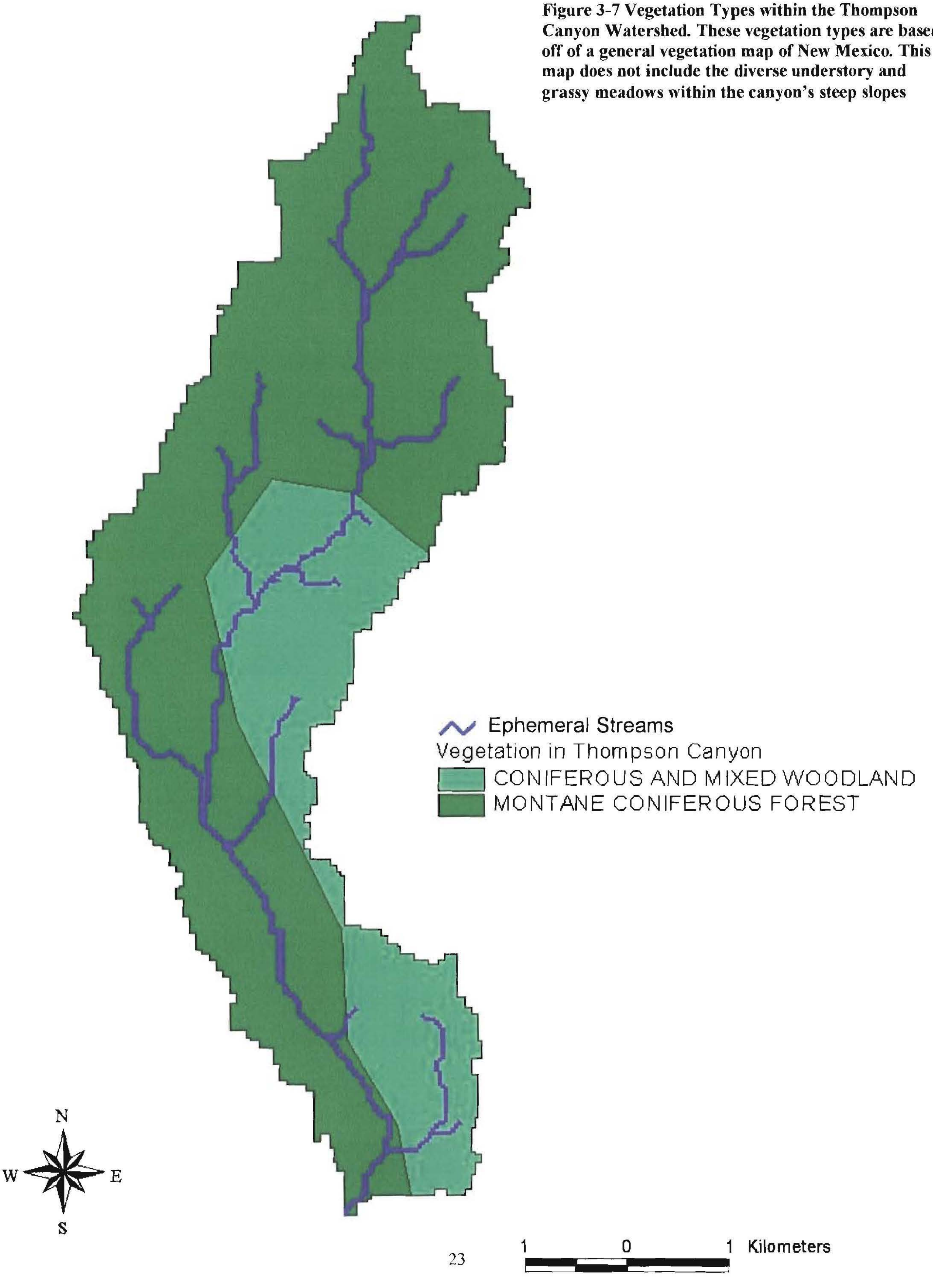


Figure 3-8 Picture taken upstream of the climbing area where the meadow has considerable more vegetation cover than near the climbing area.

the watershed to 6m near the outlet. The depths also change drastically from less than 0.5m near the top in excess of 4m at the outlet.

Stream Channel Study Sites

Two methods were chosen for quantifying erosion in Thompson Canyon. The first was the installation of erosion pins. Three sites were selected based on their location in reference to the primary rock climbing area. Two sites were chosen upstream of the rock climbing area and one site downstream (refer back to Figure3-3). These pin sites were all located in the stream channels. Each site was composed of two rows of pins ranging from 0.80m to 6.00 m apart in distance stretching perpendicular across the entire width of the channel. Each site included 2 rows of pins that were 30.77m in distance from each other along the channel. The erosion pins are 254mm (10 inches) in length. They were inserted through a washer and then hammered into the ground until flush with the ground surface.

This was the original position of the pins that were installed during May 2000. Monthly readings were taken and recorded (See field data in Appendix A). The next month after placement of the erosion pins, it was discovered that some of the pins placed in the middle of the stream channels were buried, rather than eroded. This resulted in taking measurements of sediment on top of the pin's head. In some cases a metal detector was used to locate pins. Pin positions were not otherwise marked to avoid human disturbance. Some pins were placed on the sides of stream channels, thus subsequent erosion took place at an angle compared with the pin-head (see figure 3-9 and 3-10). Two measurements were taken on these pins. One measurement of the distance from the bottom of the pin-head to the upper surface of the washer. The other was from the bottom of the pin-head to the lower surface of the washer. These values were then added together and then divided by two to determine the average amount of erosion.

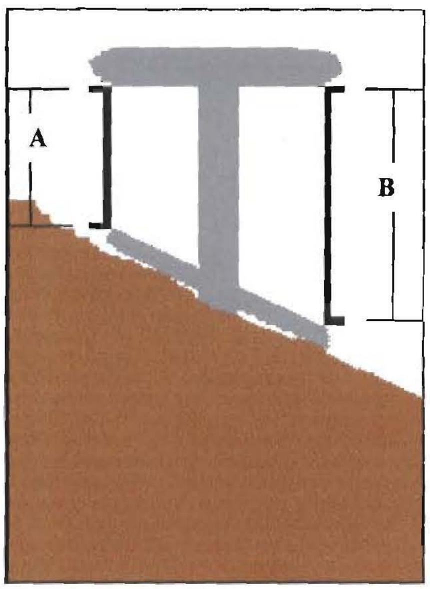


Figure 3-9 Two measurements were taken, the distance from the bottom of the pin head to the surface of the washer (A + B)/2 to get the average loss. These pins were generally located on slopes.

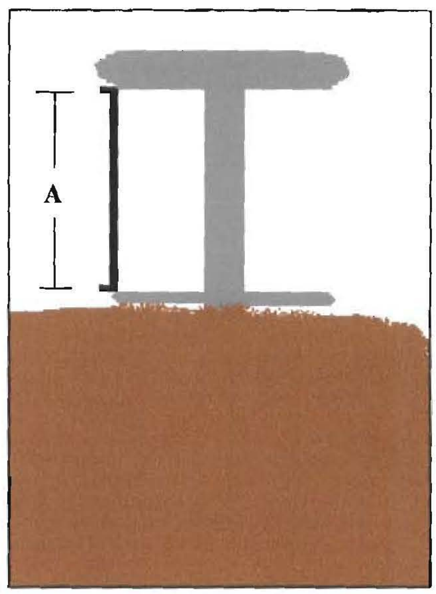


Figure 3-10 One measurements was taken when the pin and washer were parallel to each other and to the ground. A is equal to the total erosion. These pins were generally located in the stream channel bottoms.

Erosion pin database description

Each month the erosion pin data were entered into Excel. A database was built for calculation purposes using the monthly erosion pin measurements from July 2000 – April 2001 (Appendix A). The database was set up so that erosion was given a negative value and deposition received a positive value. Each month the total measured change in erosion or deposition was recorded from the initial installation date. To calculate relative measurements, the current month's measurements were subtracted from the previous month's measurements. The distance between each erosion pin was measured. From these values, areas of erosion or depositional change were calculated for each month (Figure 3-11).

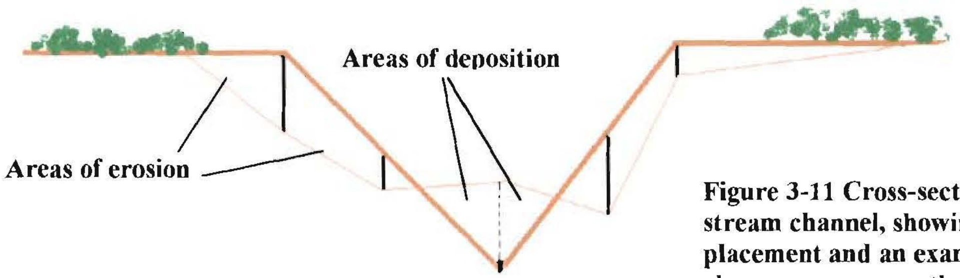


Figure 3-11 Cross-sectional area of the stream channel, showing erosion pin placement and an example of the changes over a month, where the lighter line represents one month of erosion. The differences in shapes are the areas of deposition or erosion that was quantified.

Adding the areas between each pin gives a total amount of erosion or deposition. Next, averaging the total erosion or deposition for each pin row, and then multiplying it by the distance between the pins (30.77 m), yields a volumetric measurement of soil erosion or deposition. The resulting value is equal to the amount of soil loss or deposition that occurred in that 30.77 m section of the channel during the month that was measured. The sites were established similarly to those of Figure 3-12.

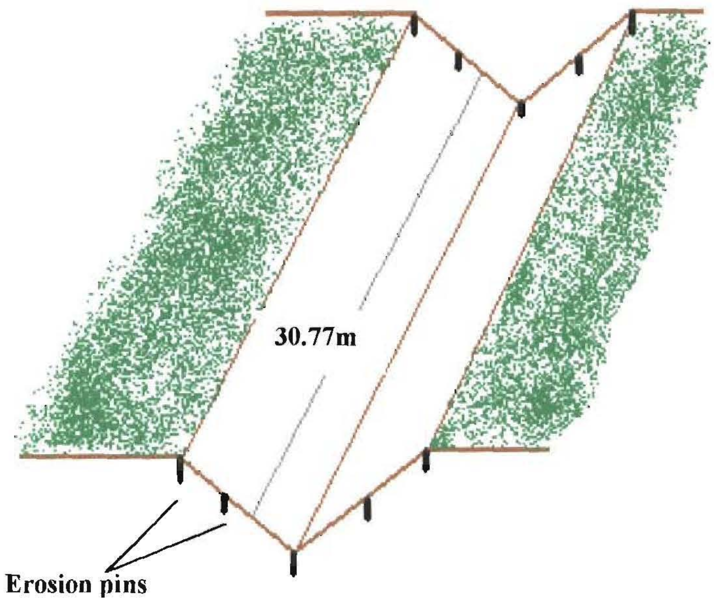


Figure 3-12 Basic diagram of erosion pin sites. This is a cross sectional area of the stream channel showing erosion pins in relation to each other. The rows of erosion pins were installed 30.77 m (100ft) apart from each other. Erosion and deposition are equal to 0 a short distance on the bank away from the stream.

Trail Site Description

Rock climbers primarily use the trails in Thompson Canyon. The trails have been established over the past 14 years, the length of time people have visited the area for rock climbing.

A procedure similar to the SDR is applied in Thompson Canyon where trail systems exist. The trail area above an obvious fan deposit can be measured, and is referred to here as the source area. The volume of the fan deposit is then quantified and a

SDR for that trail can be determined. This simplified technique involves the application of a small scale SDR equation for a trail (Figure 3-13).

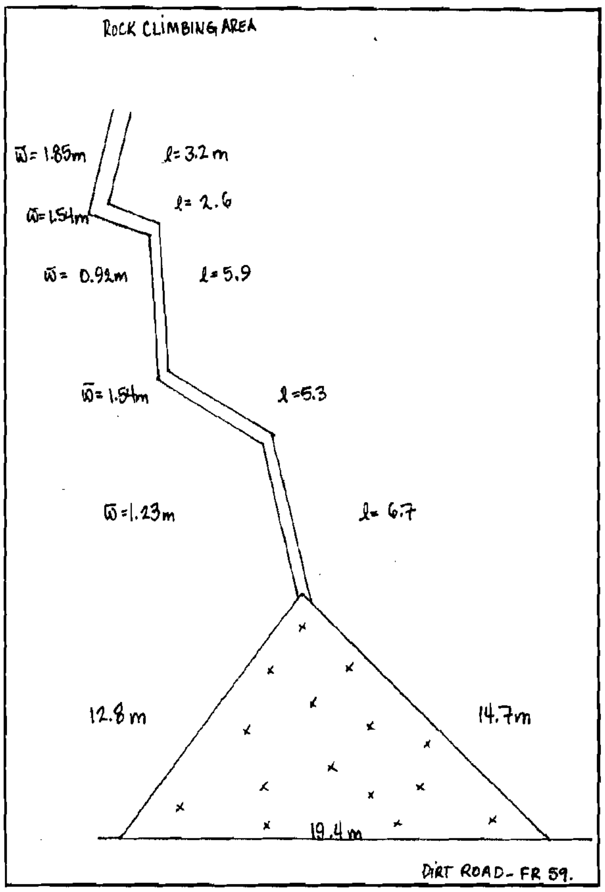


Figure 3.13 Diagram of the Ugly Duckling Trail in Thompson Canyon. The source area includes trail segment lengths and average widths. The triangle represents the depositional area and the X's within the triangle are sites where depths of sediment were measured.

On July 7, 2000, I measured the simpler of the two trails examined in this study. I began by defining the point at which the source area and the depositional area meet. I could then reference future measurements back to this point. I first measured the fan of deposition. In various random locations, within the depositional area, I dug down to find what appeared to be the original ground level prior to trail development. Measurements were taken and recorded. Soil samples were taken from the depositional area and volume sand weights were determined. From the prior established reference point, I began to measure the source area above. I measured lengths until an obvious bend in the trail occurred. I then determined an average width for each trail segment. During a September 26, 2000 visit to the watershed I similarly measured a more complex trail system. However, on May 29th, 2001, the data and measurements of the second trail were lost when a vehicle fire destroyed the data along with the rest of my belongings. (Available field data from the above measurements are contained in Appendix B). On June 16, 2001, an attempt was made to re-measure the trail, which leads up to the Enchanted Tower. However, during the previous weekend a volunteer day was scheduled to re-build some of the trails in the area (more on this in Chapter 5). One of the trails re-built that weekend was the trail leading up to the Enchanted Tower. Therefore, I was unable to quantify the trail system; nevertheless, I am able to qualitatively write about how the trail has changed over the duration of this project. More details of this are in the trail analysis section of Chapter 4.

During March 2001, I further examined the trails using a surveying level, rod and tape. From a similar reference point, I surveyed the depositional area below, and then the source area above. This would have provided information about trail slopes. Unfortunately, these data were also lost in the fire. I was not able to survey these trails again.

Revised Universal Soil Loss Equation (RUSLE)

The RUSLE is an erosion model predicting average annual soil loss resulting from raindrop splash and carried by runoff from particular field slopes in specified croplands, management systems and rangelands (Renard et. al., 1997). The formula for the RUSLE is expressed as:

$$A = R \bullet K \bullet L \bullet S \bullet C \bullet P$$

Where;

A = average soil loss per unit area generally expressed in ton • $acre^{-1}$ • yr^{-1}

R = rainfall-runoff erosivity factor

K = soil erodability factor

L = slope length factor

S = slope steepness factor

C = cover-management factor

P = support practice factor

The rainfall-runoff erosivity value of 20 hundreds ft • tons • in $(ac \cdot h \cdot yr)^{-1}$ used for Thompson Canyon was based on an isoerodent map generated from storm energies and intensities. Soil erodability factors were measured using a 2mm sieve. Measurements of each soil sample were taken three times and then an average k value for each sample was determined. Slope length and slope steepness values at different sites where based on surveying measurements and a 7.5' quad topographic map. Table 4.1 from Renard et. al., (1997) compiled for rangelands was used to determine the LS factors within Thompson Canyon. Vegetation cover was determined by randomly tossing a pencil over my head, and in the direction the pencil pointed I walked ten steps consistently counting the vegetation present. This process was repeated ten times in each location and then an average percent of vegetation cover was determined. With these values, the vegetation cover (C) table from, Brooks et al., (1997) was consulted. This table can be used to determine C factors for permanent pasture, rangeland, idle land and grazed woodland, which depicts Thompson Canyon. According to Renard et. al., (1997), the P factor should be 1.0 at 0% slope because no flow direction is defined. Likewise, P factor should be 1 when slopes are greater than 25%, because they would not store water. For the purposes of this study the support practice factor (P) is equal to 1. The campsites examined in this project have grades of 0%. While the two trails inspected have grades reaching up to 40% (Jim Angel, 2000). Slope length in this case is defined as where overland flow originates to where runoff reaches its destination or where sediment deposition begins. Slope geometry was measured and based on table 12.1 from Marsh (1998). Calculations for the RUSLE can be seen in Appendix C.

Chapter 4 Results and Analysis

Precipitation Data

The two weather stations that are closest to Thompson Canyon are Pietown 19 NE and Augustine 2 E. The weather station located in Pietown is at an elevation of 2426.5m, while the Augustine station is at 2133.6m. The elevations in Thompson Canyon range from 2154 m in the meadows to nearly 3015 m in the mountains. The two stations recorded precipitation values most closely correspond with precipitation events occurring in Thompson Canyon during 2000. Based on climate information and the elevations of the stations, the majority of precipitation occurring during the period of November through February can be assumed to be snowfall. Table 4-1 shows the depth of precipitation recorded in millimeters during 2000. Graphical representations of precipitation events are shown in Figures 4-1 and 4-2.

Table 4-1. Precipitation data from the Pietown 19 NE and Augustine 2 E rain stations.

2000	Pietown (mm) Elevation =2426.5m	Augustine (mm) Elevation = 2133.6m
Jan	6.35	0.0
Feb	1.78	0.0
Mar	48.26	0.0
Apr	1.27	0.0
May	0.0	0.0
Jun	0.0	0.0
Jul	24.13	55.37
Aug	55.12	62.99
Sep	0.0	40.39
Oct	76.45	78.99
Nov	42.67	45.97
Dec	23.88	6.86

26 days or more were missing during the month (legend: yellow shading — highlighted cells: Augustine May, Jun; Pietown Jun, Sep; both Dec)

Figure 4-1 Graph of precipitation recorded during the months of 2000 at the Pietown rain station.

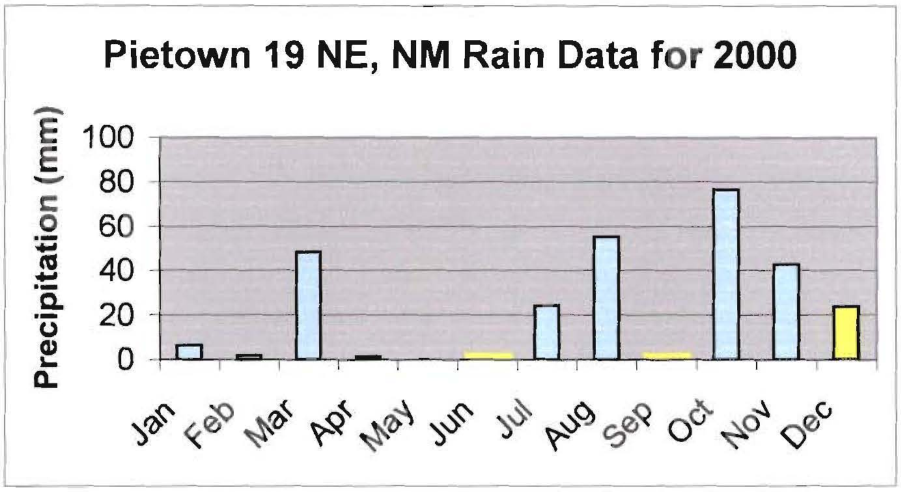
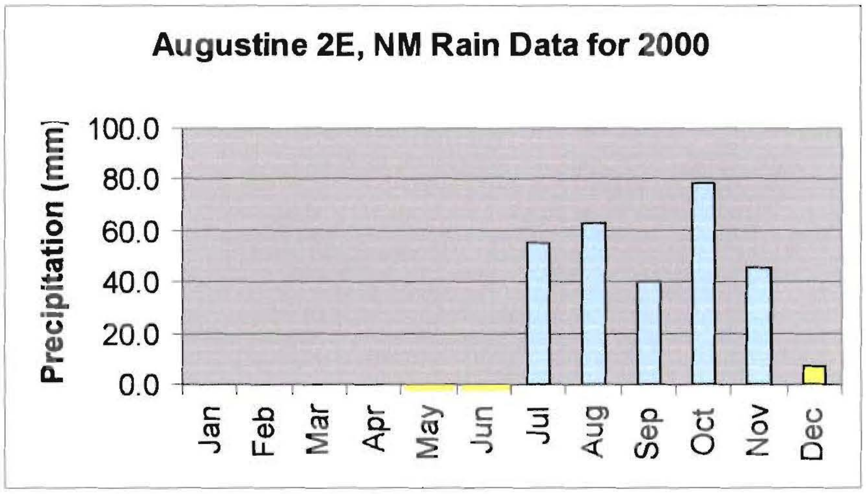


Figure 4-2 Graph of precipitation recorded during the months of 2000 at the Augustine rain station.



Precipitation data during the months of June, September, and December 2001 were incomplete for the Pietown 19 NE rain station. Precipitation data during the months May, June and December 2001 were incomplete for the Augustine 2 E rain station. Figure 4-1 shows that the largest amount of precipitation recorded at the Pietown rain station occurred in October 2000. The largest amount of precipitation recorded at the

Augustine rain station was also during October 2000 (Figure 4-2). The average temperature during October is generally around 56° F at the Pietown 19 NE site and 54° F at the Augustine 2 E site. Because these temperatures are well above freezing it is assumed that the precipitation during this month was rain. The next highest amount of precipitation occurred in August at both sites.

Erosion Pin Analysis

Figures 4-3, 4-4, and 4-5 are pictures that show the locations of each erosion pin site. Monthly measurements of the stream channel are shown in Tables 4-2, 4-3 and 4-4. The measurements are reported in millimeters. Each month's value represents cumulative soil loss from the original installation date of June 20, 2000, at which time erosion and deposition were taken as equal to 0. Negative values indicate erosion. In cases, were deposition occurred, that month's measurement, (based on the original installation) is a smaller value than the previous month's measurement. Because deposition is a positive number. Overall throughout the duration of this project, erosion was greater than deposition.

Figure 4-3 Location of erosion pin site 1; site 1A and site 1B are 30.77 m in distance from each other.

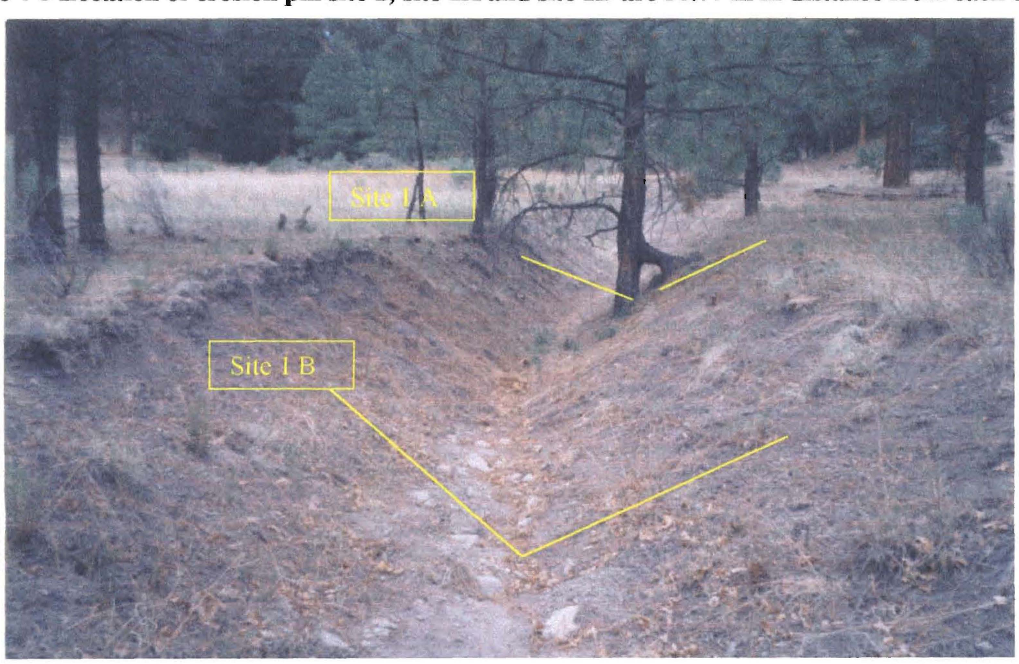


Table 4-2. Monthly pin measurements recorded in mm for Site 1

	Site 1 A					Site 1 B				
Months 2000 - 2001	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5
July	-4	-7	-10.5	-6	-3	-0.25	-4.5	-8.5	-6.5	-6.5
August	-9.5	-15.5	-16.5	-34.5	-29.5	-0.5	-11.5	-10.5	-24	-6.5
September	-9.5	-16.5	-19.5	-43	-37	-0.75	-12	-13	-29	-6.5
October	-9.5	-16.5	-21	-46	-39.5	-0.75	-13	-13	-31.5	-6.5
November										
December										
January										
February	-9.5	-16.5	-23.5	-58.5	-43.5	-1	-14.5	-13	-32.5	-6.5
March	-9.5	-16.5	-28	-58.5	-44.5	-2	-18	-13	-71	-8
April	-9.5	-16.5	-27	-58.5	-44.5	-2	-20.5	-13	-72.5	-8

(Blue shading) Ground was frozen, assumed no movement in soil.

Figure 4-4 Location of erosion pin site 2; site 2A and site 2B are 30.77 m in distance from each other.

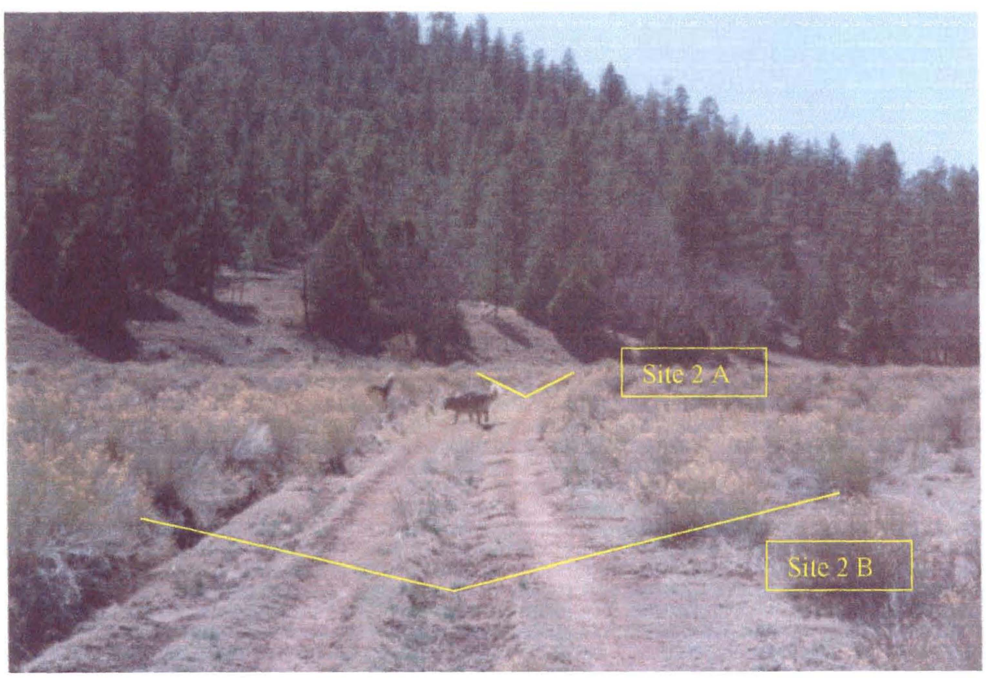


Table 4-3. Monthly pin measurements recorded in mm for Site 2.

	Site 2 A				Site 2 B			
Months 2000 – 2001	Pin 1	Pin 2	Pin 3	Pin 4	Pin 1	Pin 2	Pin 3	Pin 4
July	-0.25	-1.5	0	-1.5	-8	-7.5	-4.5	-4
August	-0.75	-3.5	-2	-6.5	-10	-16	-13.5	-7
September	-1.5	-4	-2.5	-7	-11.5	-17.5	-17.5	-12.5
October	-1.5	-4.5	-2.5	-8	-11.5	-17.5	-17.5	-15
November								
December								
January								
February	-1.5	-4.5	-2.5	-8	-11.5	-17.5	-19	-15
March	-1.5	-7	-2.5	-8	-11	-17.5	-19.5	-21
April	-1.5	-7	-2.5	-8	-11	-17.5	-20.5	-21.5

(blue) Ground was frozen, assumed no movement in soil.

Figure 4-5A Location of erosion pin site 3; site 3A and site 3B are 30.77m in distance from each other.

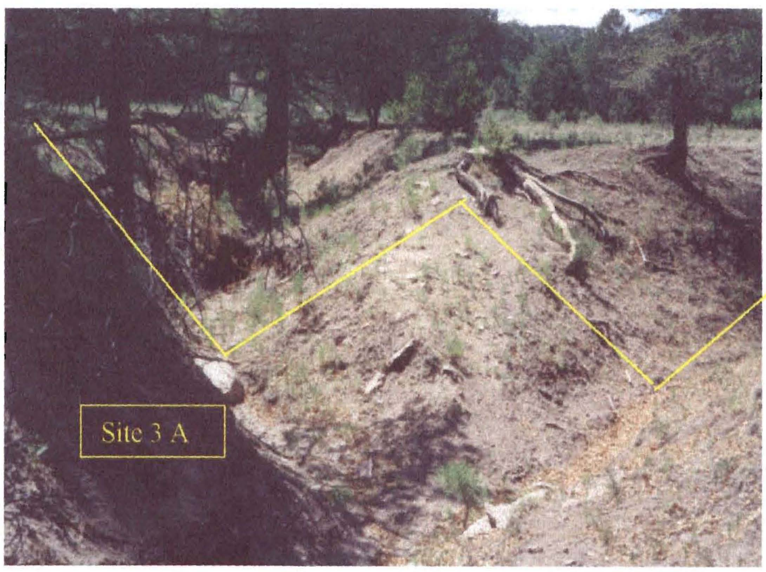


Figure 4-5B Location of erosion pin site 3B, which is 30.77m from site 3A

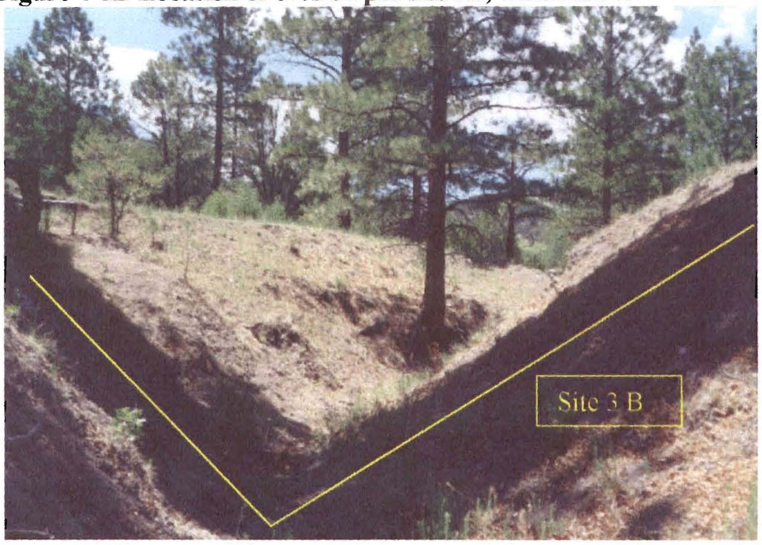


Table 4-4. Monthly pin measurements recorded in mm for Site 3

	Site 3 A								Site 3 B				
Months 2000 - 2001	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5	Pin 6	Pin 7	Pin 8	Pin 1	Pin 2	Pin 3	Pin 4	Pin 5
July	-5.5	-1	0	-21.5	-10	-3	-10	-4	-1.5	-1.5	-10	-2	-3.5
August	-10	-102	-16	-21.5	-11	-21.5	-79.5	-4.5	-1.5	-6.5	-52.5	-14	-6.5
September	-13.5	-137	-16.5	-21.5	-11.5	-24.5	-86	-6	-1.5	-8.5	-60.5	-16.5	-9.5
October	-14	-149	-16.5	-22	-11.5	-25	-87.5	-6	-1.5	-9	-61	-17	-10.5
November													
December													
January													
February	-14	-158	-16.5	-25	-11.5	-27	-88.5	-6.25	-1.5	-9.5	-64	-17.5	-13
March	-19.5	-166	-16.5	-25.5	-11.5	-28	-88.5	-7	-1.5	-10	-64	-22	-13.5
April	-19.5	-166	-16.5	-26	-11.5	-28.5	-88.5	-9.5	-5	-12	-65.5	-22	-13.5

(shaded) Ground was frozen, assumed no movement in soil.

On several occasions, I was unable to locate one or more of the pins. When this occurred, I did not assign a value to that pin, until the following month that I was able to find and measure it. Once field measurements were completed in April 2001, for calculation purposes, the surrounding pin measurements were compared and an appropriate value was assigned to the missing pin whose months were not measured at the time. This was the only logical method for placing a value on the missing pins. These particular pins are highlighted in blue in Appendix A. By April 2001, all pins were discovered and measured, with the exception of; site 2B – pin 2 and site 3A – pin 5.

Site 2A - pin 1, was only measured once during July 2000. This pin was not seen again until April 2001, when it was discovered approximately 6 m downstream and 0.4 m deep (Figure 4-6). It was then concluded that the pin was eroded out of the ground the month following the first measurements, August 2000. As a result, site 2A - pin 1 was determined to have eroded a minimum of -254 mm during August 2000 and then no further erosion or deposition occurred throughout the remaining months of this project.

Figure 4-6 The metal detector in this picture shows the original location of Site 2A–pin 1. In April 2001, the pin was found 6m downstream of its original location and 0.4m in the ground.

Site 2B – pin 2, was in a similar position downstream of site 2A - pin 1. Two attempts, with a metal detector, were made to find pin 2, but to no avail. Similarly to other missing pins, site 2B – pin 2 was assigned values based on its last measurement. The value assigned to site 2B - pin 2, was likely the minimum amount of erosion.

Because of this pin's similar position to that of site 2A - pin 1, it too may have eroded away. No evidence of this was found, and for this reason, the pin was assigned the last recorded value, which was during September 2000.

It was later determined that site 3A – pin 5 was probably knocked out by cattle. An obvious trail through the site crosses in close proximity to were pin 5 was originally installed. However, this cattle trail was not so obvious at the time of installation. Measurements for this pin were recorded for the months of July, August and September of 2000. In October, it was missing. Two attempts were made to locate the pin with a metal detector, but pin 5 was never found. During the subsequent months site 3A - pin 5 was given the value of the last known measurement of an average erosion of –11.0mm. Some months underwent both erosion and deposition events, these months were treated as a whole and the difference between the two were recorded. For instance, during February 2001, the total erosion of site 1B – pin 4 was - 32.5mm. The following month, March 2001, that pin eroded an additional - 38.5mm and then filled in on top of the washer 36 mm. The difference between the two for that month was a net erosion of -2.5 mm, even though much more took place during the coarse of the month.

From monthly measurements, erosion or depositional changes in area were calculated and recorded (Figure 4-7). Adding the erosion or depositional areas between each pin, gives the total change in areas for that row of pins during that month. Next, combining and averaging the total amount of erosion and deposition for the two pin rows, gives the average quantity of area (m^2) that occurred at those pin row sites. Multiplying the average quantity of erosion and depositional area (m^2) by the distance between the

Figure 4- 7 Site 3A - erosion pin 2 The picture on the left was taken in January. The picture on the right was in March; notice the sediment on top of the washer.

rows of pins 30.77 m yields a volumetric (m^3) measurement of soil erosion or deposition that occurred in that section of the stream channel during the month that was measured (Table 4-5).

Table 4-5. Cumulative soil erosion or sediment deposition for the duration of this project, in m^3.

	Site 1	Site 2	Site 3
Jun-00	0.000	0.000	0.000
Jul-00	-1.202	-0.477	-2.399
Aug-00	-2.435	-3.662	-10.172
Sep-00	-0.650	-0.312	-2.157
Oct-00	2.760	-0.083	-0.547
Feb-01	2.328	-0.044	-0.671
Mar-01	-1.216	0.259	0.803
Apr-01	-0.007	-0.018	-0.761

After calculating the areas of erosion and deposition at all three sites during the months of this project, it was determined that site 3, located below the climbing area, had the greatest amount of erosion when compared with the other two sites. The final quantity of erosion measured at site 3 was $0.76m^3$. Based on the erosion pin analysis it is apparent that the watershed is not releasing a relatively large amount of sediment. However, based on the RUSLE analysis there are areas within the watershed that are highly erosive. These locations include the vicinity of rock climbing areas.

The greatest amount of deposition occurred at site 1 during October 2000. For the duration of this project all three sites underwent the greatest amount of erosion during the month of August 2000 (Figure 4-8, 4-9, 4-10). (Note: negative values are erosion and positive values are deposition.) The majority of this erosion can be attributed to the high levels of precipitation, and assumed runoff, during that month.

Figure 4-8 Graph showing cumulative erosion and sediment yield for erosion pin site 1 net deposition is distinguished by positive values and net erosion by negative values.

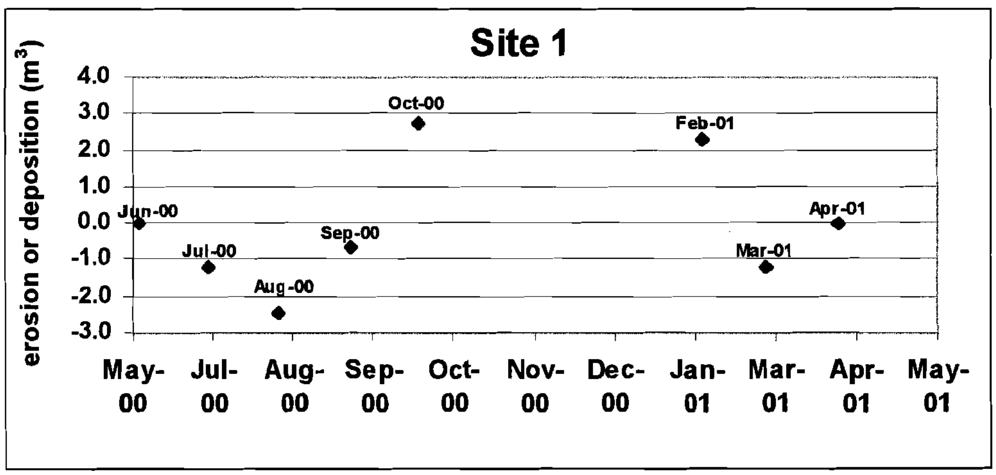


Figure 4-9 Graph showing cumulative erosion and sediment yield for erosion pin site 2 net deposition is distinguished by positive values and net erosion by negative values.

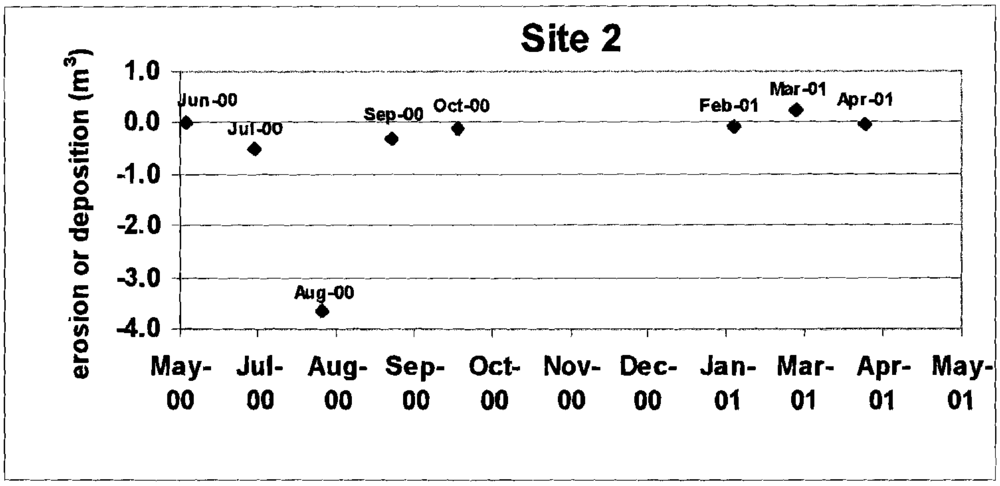
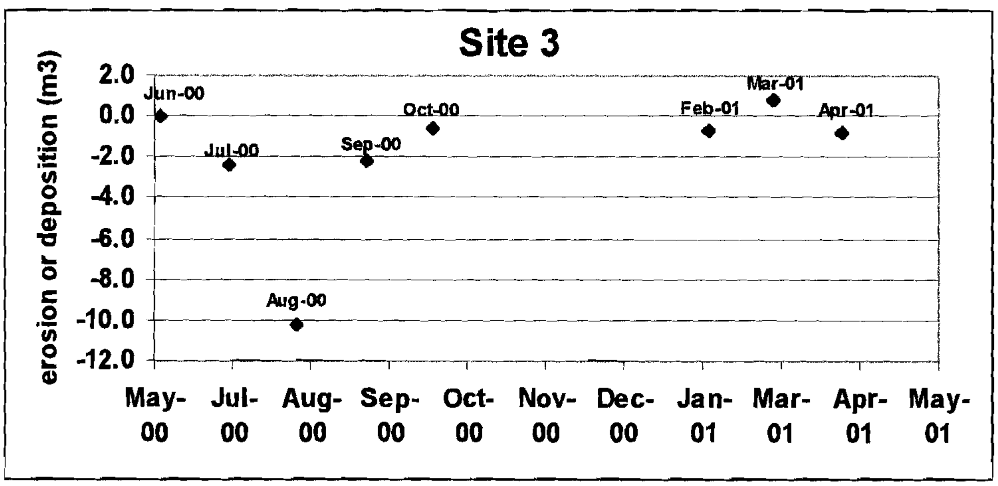


Figure 4-10 Graph showing cumulative erosion and sediment yield, for erosion pin site 3 net deposition is distinguished by positive values and net erosion by negative values.



Trail Analysis

Original measurements were obviously greater in slope grades than the newly constructed trails. The older trails were never properly constructed and thus took direct routes from campsites to climbing walls. Measurements were recorded in July 2000, and then the trails were surveyed during May 2001. Visible differences in the trails were apparent over that short time period of 9 months between the measurements. The latter measurements showed areas where the trail had widened and obvious signs that water had flowed down sections of the trail. Small gullies formed and rocks had been washed onto the trails in some sections. In one location of the Enchanted Tower Trail, a gully had formed above the trail flowing down through the trail. Where the trail veered slightly, the water continued down the slope through Forest Road 59A until joining with the stream channel below. The newly constructed trails have been cut into the hill slope never exceeding a 25% grade. The trails are wider and more easily traveled. Switchbacks were also cut into the newly constructed trails at minimal grades.

RUSLE Analysis

The results from applying the RUSLE to the Thompson Canyon Watershed can be seen in Table 4-6.

Table 4-6 Predicted soil losses in the Thompson Canyon Watershed using the RUSLE

Site	RUSLE (ton • $acre^{-1}$ • yr^{-1})
Campsite (below the Tower)	0.163
Campsite (below Pogue's Cave)	0.141
Ugly Duckling Trail	6.292
Old Enchanted Tower Trail	6.292
New Enchanted Tower Trail	3.860

Soil loss tolerance can be defined as the maximum rate of soil erosion that will still permit a high level of crop production to be sustained economically and ecologically (Brooks et al., 1997). According to Pimental (1993), 1 ton/ha/year (0.4 tons/acre/year) is an appropriate sustainable soil loss rate. Brooks (1997) reports that soil loss tolerance values of 2.5 – 12.5 tons/ha/yr (1-5 tons/acre/year) are often used. Based on the RUSLE, the old trails leading up to the Enchanted Tower were estimated to create the greatest amount of erosion at 6.29 tons/acre/year, which is not a sustainable amount of soil loss occurring per year. The newly cut trail is estimated to produce a soil loss value of 3.86 tons/acre/year, which is considerably less than the old trails, but still results in unsustainable conditions according to Pimental's soil loss tolerance value of 0.4 tons/acre/year. The primary differences between the old and new trails, resulting in a lower erosion rates are the differences in slope steepness and slope length. The trails established over the past 14 years continue to created unsustainable amounts of soil loss according to the RUSLE.

The results of this study show that this canyon is in an extremely dynamic state. The amount of precipitation has a direct influence on erosion rates within the canyon. The soils are highly erodable, slopes are extremely steep, and vegetation has been denuded in many areas that are in close proximity to the climbing area. Intense land uses that are not properly managed add to decreasing vegetation cover. Lack of vegetation increases runoff, decreases infiltration rates and allows soil to be more easily eroded. In Thompson Canyon, deposition and erosion continuously change throughout the months recorded for this project. In order to accurately determine erosion rates within the entire watershed, one would need to install erosion pins throughout the entire watershed. The sites chosen for this system were placed in specific areas of the watershed so that human interference would be kept to a minimum. The sites were installed perpendicularly across stream channels. This made it possible to calculate the area of erosion between the two rows of pins within the stream channel.

Chapter 5 Recommended Treatments

Discussed below are management techniques that can be instituted within the Thompson Canyon Watershed to create more sustainable conditions for current and future uses.

Forest Road 59A is in close proximity to, and crosses, the stream channel many times throughout the canyon (Figure 5-1). As a result, during rainstorm events water generally flows down the road with few diversions (Figure 5-2). The road is rough, washed out and requires a 4 wheel drive or high clearance vehicle. Ideally, the road should be diverted away from the stream channel. However, because the nature of the canyon is very narrow, stretching only 2.5km across in the widest section, regardless of

Figure 5-1 This picture shows the close proximity between the stream channel and Forest Road 59A. It was taken from the top of the Enchanted Tower

Figure 5-2 When the stream channel flows, water often floods Forest Road 59A in several different locations throughout the canyon.

where the road is moved it will still be in close proximity to the stream channel (Figure 5-3). It is also inevitable that the road would still cross the channel is several locations. Graveling the road would be a preferably option for reducing erosion.

Figure 5-3 Picture taken upstream of the climbing area, showing the vegetated meadow and the narrow canyon.

However, the associated costs may not be a beneficial alternative. It may be more reasonable to build up the existing road and maintain it on a regular basis, (minimum of 4 times per year excluding winter). The addition of improved waterbars, where the stream channel crosses or is in close proximity of the road, would allow water to run-off the road and be distributed rather than channeled, over the landscape. If possible, applying gravel near waterbars would minimize erosion resulting from precipitation events.

The trails within Thompson Canyon were never properly planned or constructed. The trails generally begin at the edge of Forest Road 59A, opposite from the campsites and head straight up the steep slopes to the nearest climbing wall. As a result, the pathways that people have created over the years have become channels of flowing water when it rains (Figures 5-4, 5-5). Rebuilding the existing trail system with stairs and

Figure5- 4 Trail leading up to the Ugly Duckling climbing area, this is the first of the trails that is diagrammed in Chapter 3.

switchbacks would be preferred, rather than creating new trails. However, for long-term sustainability it might be more beneficial to plan a new trail system, along with re-vegetating the existing trails because the grades of the existing trails are steep (refer to trail diagrams in Chapter 3). In this case, trail rehabilitation efforts should include planning trails with minimal grades, that include switchbacks and stairs if necessary, so as to minimize erosion. In addition, the trail system should have sufficient waterbars, to divert water off the new trails during rainstorms.

Figure 5- 5 Picture looking down the trail below the Enchanted Tower.

During June 2001, efforts were made to reconstruct new trails surrounding the Enchanted Tower climbing area. Computations from applying the RUSLE have shown that the newly constructed trails are eroding less than the old trails. The major differences between the old and new trails, resulting in lower erosion rates are the differences in slope steepness and slope length. I was unable to attend the organized trail building day. However, the following weekend I visited the canyon and was pleasantly surprised by the new trails. Figure 5-5 is a picture looking down the Enchanted Tower Trail. However,

Figure 5-6 shows the changes that took place to the trail in one weekend. The new trails are wider and were constructed with a reduced grade when compared with the older trails. The new trails were also built up with rocks to minimize further erosion.

Figure 5-6 Picture taken of the newly constructed trail leading up to the Enchanted Tower.

One of the primary issues within the Thompson Canyon Watershed is the creation of new campsites when existing sites are occupied. There are several ways to curb this degradation of the land that should be employed as soon as possible. One commonly utilized option is placing large boulders, trees and other natural obstacles around campsites and parking areas as barriers so that cars are unable to drive over them. For example, Figure 5-7 shows where people have extended the road by driving into the meadow adjacent to their campsite. Planting native vegetation and placing large obstacles around campsites and parking areas define their spaces by preventing further sprawling, and allowing native vegetation to recover. In addition, creating these borders around campsites creates privacy between the campsites and would prevent further damage to the adjacent meadow area. The majority of the campsites near the main climbing area in Thompson Canyon generally have two rock fire rings. To keep this area as primitive as possible, the addition of more fire rings should be avoided.

Figure 5- 7 Campsites are spread throughout this meadow. Here someone has driven into the meadow area, destroying vegetation, to turn around.

Installing "sensitive area" signs will help to make climbers aware of the erosion issues within the canyon associated with intense land uses. One main sign should be installed at the base of the main trail, below the Enchanted Tower. This sign should give details on the erosion problems within the canyon, a detailed map showing the number of campsites and parking areas available, and the number of cars allowed in those locations. The sign should include the message; "stay on established roads and trails only". The sign should also read, "When all campsites and parking areas are full you may not camp or park anywhere else within Thompson Canyon. However, other options exist. They include an RV park at the Country Store in Datil, and the Datil Well campground which is located just off of highway 60, only 2 km west of Datil, NM." This statement should also be accompanied with a detailed map showing those locations similar to Figure 5-8. Similar signs should be installed at every parking area, with details about the number of cars that can be parked in that location.

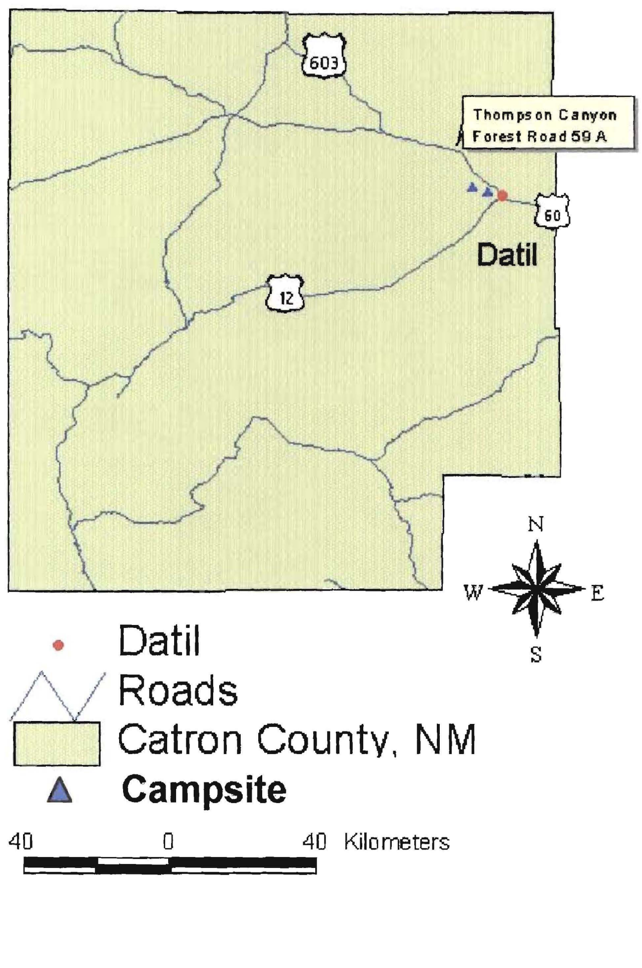


Figure 5-8
Alternative campsites within 8 miles of the Enchanted Tower climbing area.

Another concern, primarily surrounding the campsite area, is the lack of sanitation facilities. With every year that passes, outdoor recreation becomes more and more popular. Often there are over fifteen cars parked in the campsites near the main climbing area. In order to climb at this location, a minimum of two people are needed, one to belay and one to climb. So the minimum number of people camping near the climbing area is thirty. The majority of campers stay for the weekend, resulting in a lot of human waste. As soon as possible, at least one vault toilet should be centrally located within the watershed.

It is important to note that, at this time, solid waste is not a problem in the canyon. Thus far a "pack it in, pack it out" system has been successful. Placing trash receptacles near campsites often creates more problems than it solves. When people begin to leave their trash behind, wildlife, litter and proper maintenance become issues that the National Forest Service must address. This requires additional resources and time. Therefore, it seems that the current system has worked well and keeps the area as primitive as possible. Recreationalists visiting Thompson Canyon over the years have seemed to generally clean their campsites after use.

The southwestern region of the United States has had a long history of grazing use. The moderate climate has allowed for yearlong grazing use. Reduction in grazing density or removal of livestock from the Thompson Canyon Watershed might be one solution for rehabilitation of the natural resources, however, it is not a likely occurrence given the local socioeconomic importance of cattle ranching. In addition, completely restricting the climbing population from the watershed is another sure way to speed the rehabilitation of the natural resources. However, this is not an option either, because one role of National Forests is to meet the country's recreational needs while protecting the long-term integrity of the forest's natural and cultural resources for many uses. Maintaining the integrity of the landscape setting is essential to ecosystem viability and the recreation experience. It is important to work with local governments, non-profit organizations and private landowners to plan together for the future of public rights of way. In addition, with changes in land use patterns in National Forests, it is important that interested parties work together to plan for future uses.

Future Work

Suggestions for future work include a program to monitor the newly built trail systems and then comparing the erosion rates and erosion potentials with the previous trails. This would entail annual inspections of the trail systems. In addition, inspections should be made during months recorded of having high precipitation amounts. This would give a better understanding of the erosion rates between the two and possibly support justification for trail rehabilitation. Generating a benefit cost analysis would be helpful in determining associated costs of building a new road and trail system versus building up the existing road and trail. The need for a fee station could also be solved through the use of a cost benefit ratio. Further understanding of the watershed as a whole through more in depth field survey would help to identify critical areas that may need further management.

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APPENDICIES

A. Erosion Pin Data
B. Trail Measurements
C. RUSLE Calculations

APPENDIX A: Erosion Pin Data

Thompson Canyon Erosion Pin Data July 7, 00

Site 1 A	upper side of pin (mm)	lower side of pin (mm)	Average depth =(upper+lower) /2 (mm)	nail head to surface (mm)	sediment on top of washer (mm)	total erosion from installing the erosion pins May - July 7th, 00	net sedimentation from May- July	Difference between erosion and sediment event within current month (this value is used for caculating area	Distance between erosion pins (mm)	For graphing purposes pin distances added	area of erosion wedge (mm)^2	area of a trapezoid or the triangles (2) of erosion and sediment (yellow) (mm)^2	Total area of erosion or sediment (mm)^2 and then the average amount between the sites at each location	The average amount of erosion or sediment at each site (m)^2 * the distance between the sites (m)^2	Average amount of erosion that took place in the current month * the distace between the sites A and B then converted to m^2
								0	960.00	0.00				Distance (m)	
pin 1	-5.00	-3.00	-4.00			-4.00		-4.00	2470.00	2470.00	-1920.00			30.77	
pin 2	-8.00	-6.00	-7.00			-7.00		-7.00	1450.00	3920.00		-13585.00			
pin 3	-11.00	-10.00	-10.50			-10.50		-10.50	1110.00	5030.00		-12687.50			
pin 4	-6.00	-6.00	-6.00			-6.00		-6.00	1900.00	6930.00		-9157.50			
pin 5	-3.00	-3.00	-3.00			-3.00		-3.00	1800.00	8730.00		-8550.00			
add pin								0.00			-2700.00				
													-48600.00		
Site 1 B								0.00	750.00	0.00			-29583.75	-1202826.92	
pin 1	0.00	-0.50	-0.25			-0.25		-0.25	1380.00	1380.00	-93.75				
pin 2	-5.00	-4.00	-4.50			-4.50		-4.50	860.00	2240.00		-3277.50			-1.20
pin 3	-11.00	-6.00	-8.50			-8.50		-8.50	1220.00	3460.00		-5590.00			
pin 4	-11.00	-2.00	-6.50			-6.50		-6.50	1340.00	4800.00		-9150.00			
pin 5	-8.00	-5.00	-6.50			-6.50		-6.50	850.00	5650.00		-8710.00			
								0.00			-2762.50		Average Site 1		
													-39091.88		
Site 2 A								0.00	490.00	0.00					
pin 1	-0.50	0.00	-0.25			-0.25		-0.25	1020.00	1020.00	-61.25				
pin 2	-3.00	0.00	-1.50			-1.50		-1.50	1580.00	2600.00		-892.50			
pin 3			0.00	1.00		0.00	1.00	1.00	2300.00	4900.00		-395.00			
pin 4	-2.00	-1.00	-1.50			-1.50		-1.50	760.00	5660.00		-575.00			
								0.00			-570.00				
													-2493.75		
Site 2 B								0.00	560.00	0.00			-28540.00		
pin 1	-9.00	-7.00	-8.00			-8.00		-8.00	860.00	860.00	-2240.00				
pin 2	-15.00	0.00	-7.50			-7.50		-7.50	1910.00	2770.00		-6665.00			
pin 3	-6.00	-3.00	-4.50			-4.50		-4.50	1920.00	4690.00		-11460.00			
pin 4	-5.00	-3.00	-4.00		1.00	-4.00	1.00	-3.00	650.00	5340.00		-7200.00			
								0.00			-975.00		Average Site 2		
													-15516.88	-477442.31	-0.48
Site 3 A								0.00	600.00	0.00					
pin 1	-8.00	-3.00	-5.50			-5.50		-5.50	1200.00	1200.00	-1650.00				
pin 2	-4.00		-1.00	2.00		-1.00	2.00	-1.00	2720.00	3920.00		-3900.00			
pin 3	0.00	0.00	0.00			0.00		0.00	2130.00	6050.00		-1360.00			
pin 4	-30.00	-13.00	-21.50			-21.50		-21.50	2060.00	8110.00		-22897.50			
pin 5	-12.00	-8.00	-10.00			-10.00		-10.00	1800.00	9910.00		-32445.00			
pin 6	-3.00	-3.00	-3.00			-3.00		-3.00	2140.00	12050.00		-11700.00			
pin 7	-10.00	-10.00	-10.00			-10.00		-10.00	4580.00	16630.00		-13910.00			
pin 8	-6.00	-2.00	-4.00			-4.00		-4.00	960.00	17590.00		-32060.00			
								0.00			-1920.00				
													-121842.50		
Site 3 B								0.00	910.00	0.00			-34150.00		
pin 1	-2.00	-1.00	-1.50	2.00		-1.50	2.00	0.50	1870.00	1870.00	227.50				
pin 2	-4.00		-1.50	1.00		-1.50	1.00	-1.50	2280.00	4150.00		-935.00			
pin 3	-13.00	-7.00	-10.00			-10.00		-10.00	2820.00	6970.00		-13110.00			
pin 4	-3.00	-1.00	-2.00		1.00	-2.00	1.00	-1.00	1490.00	8460.00		-15510.00			
pin 5	-6.00	-1.00	-3.50			-3.50		-3.50	840.00	9300.00		-3352.50	Average Site 3		-2.40
								0			-1470.00		-77996.25	-2399884.62	

NOTE: Yellow color indicates cells where sediment and erosion took place and the areas were combined
the blue color is where a pin was missing and values were estimated.

Thompson Canyon Erosion Pin Data August 19, 00

Site 1 A	upper side of pin (mm)	lower side of pin (mm)	Average depth =(upper+lower) /2 (mm)	nail head to surface (mm)	Sediment on top of washer (mm)	total erosion from July - August	net sedimentation from July - August	Difference between erosion and sediment event within current month (this value is used for caculating area	Distance between erosion pins (mm)	area of erosion wedge (mm)^2	area of a trapezoid (mm)^2	Total area of erosion or sediment (mm)^2 and then the average amount between the sites at each location	The average amount of erosion or sediment at each site (m)^2 * the distance between the sites (m)^2	Average amount of erosion that took place in the current month * the distace between the sites A and B then converted to m^2
			0.00					0	960.00				Distance (m)	
pin 1	-10.00	-9.00	-9.50			-5.50		-5.50	2470.00	-2640.00			30.77	
pin 2	-15.00	-16.00	-15.50			-8.50		-8.50	1450.00		-17290.00			
pin 3	-19.00	-14.00	-16.50			-6.00		-6.00	1110.00		-10512.50			
pin 4	-39.00	-30.00	-34.50			-28.50		-28.50	1900.00		-19147.50			
pin 5	-32.00	-27.00	-29.50			-26.50		-26.50	1800.00		-52250.00			
			0.00			0.00		0.00		-23850.00				
												-125690.00		
Site 1 B			0.00					0.00	750.00			-32586.25	-2435019.23	
pin 1	-0.50	-0.50	-0.50			-0.25		-0.25	1380.00	-93.75				
pin 2	-18.00	-5.00	-11.50			-7.00		-7.00	860.00		-5002.50			-2.44
pin 3	-14.00	-7.00	-10.50			-2.00		-2.00	1220.00		-3870.00			
pin 4	-28.00	-20.00	-24.00			-17.50		-17.50	1340.00		-11895.00			
pin 5	-8.00	-5.00	-6.50			0.00		0.00	850.00		-11725.00			
						0.00		0.00		0.00		Average Site 1		
												-79138.13		
Site 2 A								0.00	490.00					
pin 1	-254.00	-254.00	-254.00			-253.75		-253.75	1020.00	-62168.75				
pin 2	-5.00	-2.00	-3.50			-2.00		-2.00	1580.00		-130432.50			
pin 3	-2.00	-2.00	-2.00			-1.00		-1.00	2300.00		-2370.00			
pin 4	-8.00	-5.00	-6.50			-5.00		-5.00	760.00		-6900.00			
						0.00		0.00		-1900.00				
												-203771.25		
Site 2 B								0.00	560.00			-34282.50		
pin 1	-10.00	-10.00	-10.00			-2.00		-2.00	860.00	-560.00				
pin 2	-17.00	-15.00	-16.00			-8.50		-8.50	1910.00		-4515.00			
pin 3	-15.00	-12.00	-13.50			-9.00		-9.00	1920.00		-16712.50			
pin 4	-7.00	-7.00	-7.00			-3.00		-3.00	650.00		-11520.00			
						0.00		0.00		-975.00		Average Site 2		
												-119026.88	-3662365.38	-3.66
Site 3 A								0.00	600.00					
pin 1	-12.00	-8.00	-10.00			-4.50		-4.50	1200.00	-1350.00				
pin 2	-107.00	-96.00	-101.50			-100.50		-100.50	2720.00		-63000.00			
pin 3	-20.00	-12.00	-16.00			-16.00		-16.00	2130.00		-158440.00			
pin 4	-30.00	-13.00	-21.50			0.00		0.00	2060.00		-17040.00			
pin 5	-12.00	-10.00	-11.00			-1.00		-1.00	1800.00		-1030.00			
pin 6	-33.00	-10.00	-21.50			-18.50		-18.50	2140.00		-17550.00			
pin 7	-83.00	-76.00	-79.50			-69.50		-69.50	4580.00		-94160.00			
pin 8	-5.00	-4.00	-4.50			-0.50		-0.50	960.00		-160300.00			
								0.00		-240.00				
												-513110.00		
Site 3 B								0.00	910.00			-148105.00		
pin 1	-2.00	-1.00	-1.50			0.00		0.00	1870.00	0.00				
pin 2	-7.00	-6.00	-6.50			-5.00		-5.00	2280.00		-4675.00			
pin 3	-53.00	-52.00	-52.50			-42.50		-42.50	2820.00		-54150.00			
pin 4	-16.00	-12.00	-14.00			-12.00		-12.00	1490.00		-76845.00			
pin 5	-11.00	-2.00	-6.50			-3.00		-3.00	840.00		-11175.00	Average Site 3		-10.17
								0		-1260.00		-330607.50	-10172538.46	

Thompson Canyon Erosion Pin Data September 23, 00														
Site 1 A	upper side of pin (mm)	lower side of pin (mm)	Average depth =(upper+lower) /2 (mm)	nail head to surface (mm)	Sediment on top of washer (mm)	total erosion from August - September	net sedimentation from August - September	Difference between erosion and sediment event within current month (this value is used for caculating area	Distance between erosion pins (mm)	area of erosion wedge (mm)^2	area of a trapezoid (mm)^2	Total area of erosion or sediment (mm)^2 and then the average amount between the sites at each location	The average amount of erosion or sediment at each site (m)^2 * the distance between the sites (m)^2	Average amount of erosion that took place in the current month * the distace between the sites A and B then converted to m^2
			0					0	960.00				Distance (m)	
pin 1	-10.00	-9.00	-9.50			0.00		0.00	2470.00	0.00			30.77	
pin 2	-15.00	-18.00	-16.50			-1.00		-1.00	1450.00		-1235.00			
pin 3	-24.00	-15.00	-19.50			-3.00		-3.00	1110.00		-2900.00			
pin 4	-46.00	-40.00	-43.00			-8.50		-8.50	1900.00		-6382.50			
pin 5	-38.00	-36.00	-37.00			-7.50		-7.50	1800.00		-15200.00			
								0.00		-6750.00				
												-32467.50		
Site 1 B								0.00	750.00			-9826.25	-650673.08	
pin 1	-1.00	-0.50	-0.75			-0.25		-0.25	1380.00	-93.75				
pin 2	-20.00	-4.00	-12.00			-0.50		-0.50	860.00		-517.50			-0.65
pin 3	-18.00	-8.00	-13.00			-2.50		-2.50	1220.00		-1290.00			
pin 4	-36.00	-22.00	-29.00			-5.00		-5.00	1340.00		-4575.00			
pin 5	-8.00	-5.00	-6.50			0.00		0.00	850.00		-3350.00			
								0.00		0.00		Average Site 1		
												-21146.88		
Site 2 A								0.00	490.00					
pin 1	-254.00	-254.00	-254.00			0.00		0.00	1020.00	0.00				
pin 2	-5.00	-3.00	-4.00			-0.50		-0.50	1580.00		-255.00			
pin 3	-3.00	-2.00	-2.50			-0.50		-0.50	2300.00		-790.00			
pin 4	-9.00	-5.00	-7.00			-0.50		-0.50	760.00		-1150.00			
								0.00		-190.00				
												-2385.00		
Site 2 B								0.00	560.00			-17870.00		
pin 1	-12.00	-11.00	-11.50			-1.50		-1.50	860.00	-420.00				
pin 2	-18.00	-17.00	-17.50			-1.50		-1.50	1910.00		-1290.00			
pin 3	-20.00	-15.00	-17.50			-4.00		-4.00	1920.00		-5252.50			
pin 4	-15.00	-10.00	-12.50			-5.50		-5.50	650.00		-9120.00			
								0.00		-1787.50		Average Site 2		
												-10127.50	-311615.38	-0.31
Site 3 A								0.00	600.00					
pin 1	-18.00	-9.00	-13.50			-3.50		-3.50	1200.00	-1050.00				
pin 2	-145.00	-129.00	-137.00			-35.50		-35.50	2720.00		-23400.00			
pin 3	-20.00	-13.00	-16.50			-0.50		-0.50	2130.00		-48960.00			
pin 4	-30.00	-13.00	-21.50			0.00		0.00	2060.00		-532.50			
pin 5	-12.00	-11.00	-11.50			-0.50		-0.50	1800.00		-515.00			
pin 6	-38.00	-11.00	-24.50			-3.00		-3.00	2140.00		-3150.00			
pin 7	-92.00	-80.00	-86.00			-6.50		-6.50	4580.00		-10165.00			
pin 8	-7.00	-5.00	-6.00			-1.50		-1.50	960.00		-18320.00			
								0.00		-720.00				
												-106812.50		
Site 3 B								0.00	910.00			-33432.50		
pin 1	-2.00	-1.00	-1.50			0.00		0.00	1870.00	0.00				
pin 2	-10.00	-7.00	-8.50			-2.00		-2.00	2280.00		-1870.00			
pin 3	-62.00	-59.00	-60.50			-8.00		-8.00	2820.00		-11400.00			
pin 4	-21.00	-12.00	-16.50			-2.50		-2.50	1490.00		-14805.00			
pin 5	-13.00	-6.00	-9.50			-3.00		-3.00	840.00		-4097.50	Average Site 3		-2.16
								0		-1260.00		-70122.50	-2157615.38	

Thompson Canyon Erosion Pin Data October 28, 00														
Site 1 A	upper side of pin (mm)	lower side of pin (mm)	Average depth =(upper+lower) /2 (mm)	nail head to surface (mm)	sediment on top of washer (mm)	total erosion from September - October	Net Sedimentation from September-October	Difference between erosion and sediment event within current month (this value is used for caculating area	Distance between erosion pins (mm)	area of erosion wedge (mm)^2	area of a trapezoid (mm)^2	Total area of erosion or sediment (mm)^2 and then the average amount between the sites at each location	The average amount of erosion or sediment at each site (m)^2 * the distance between the sites (m)^2	Average amount of erosion that took place in the current month * the distace between the sites A and B then converted to m^2
			0					0	960.00				Distance (m)	
pin 1	-10.00	-9.00	-9.50	25.00	34.50	0.00	34.50	34.50	2470.00	16560.00			30.77	
pin 2	-15.00	-18.00	-16.50	10.00	26.50	0.00	26.50	26.50	1450.00		75335.00			
pin 3	-26.00	-16.00	-21.00			-1.50		-1.50	1110.00		36307.70			
pin 4	-50.00	-42.00	-46.00			-3.00		-3.00	1900.00		-2497.50			
pin 5	-40.00	-39.00	-39.50			-2.50		-2.50	1800.00		-5225.00			
								0.00		-2250.00				
												118230.20		
Site 1 B								0.00	750.00			61200.60	2760473.85	
pin 1	-1.00	-0.50	-0.75			0.00		0.00	1380.00	0.00				
pin 2	-22.00	-4.00	-13.00			-1.00		-1.00	860.00		-690.00			2.76
pin 3	-18.00	-8.00	-13.00	50.00	63.00	0.00	63.00	63.00	1220.00		26661.70			
pin 4	-40.00	-23.00	-31.50			-2.50		-2.50	1340.00		36903.90			
pin 5	-8.00	-5.00	-6.50			0.00		0.00	850.00		-1675.00			
								0.00		0.00		Average Site 1		
												89715.40		
Site 2 A								0.00	490.00					
pin 1	-254.00	-254.00	-254.00			0.00		0.00	1020.00	0.00				
pin 2	-5.00	-4.00	-4.50			-0.50		-0.50	1580.00		-255.00			
pin 3	-3.00	-2.00	-2.50			0.00		0.00	2300.00		-395.00			
pin 4	-9.00	-7.00	-8.00			-1.00		-1.00	760.00		-1150.00			
								0.00		-380.00				
												-2180.00		
Site 2 B								0.00	560.00			-3212.50		
pin 1	-12.00	-11.00	-11.50			0.00			860.00	0.00				
pin 2	-18.00	-17.00	-17.50			0.00			1910.00		0.00			
pin 3	-20.00	-15.00	-17.50			0.00		0.00	1920.00		0.00			
pin 4	-20.00	-10.00	-15.00			-2.50		-2.50	650.00		-2400.00			
								0.00		-812.50		Average Site 2		
												-2696.25	-82961.54	-0.08
Site 3 A								0.00	600.00					
pin 1	-18.00	-10.00	-14.00			-0.50		-0.50	1200.00	-150.00				
pin 2	-150.00	-148.00	-149.00			-12.00		-12.00	2720.00		-7500.00			
pin 3	-20.00	-13.00	-16.50			0.00		0.00	2130.00		-16320.00			
pin 4	-32.00	-12.00	-22.00			-0.50		-0.50	2060.00		-532.50			
pin 5	-12.00	-11.00	-11.50			0.00		0.00	1800.00		-515.00			
pin 6	-38.00	-12.00	-25.00			-0.50		-0.50	2140.00		-450.00			
pin 7	-90.00	-85.00	-87.50			-1.50		-1.50	4580.00		-2140.00			
pin 8	-7.00	-5.00	-6.00			0.00		0.00	960.00		-3435.00			
								0.00		0.00				
												-31042.50		
Site 3 B								0.00	910.00			-4555.00		
pin 1	-2.00	-1.00	-1.50			0.00		0.00	1870.00	0.00				
pin 2	-10.00	-8.00	-9.00			-0.50		-0.50	2280.00		-467.50			
pin 3	-62.00	-60.00	-61.00			-0.50		-0.50	2820.00		-1140.00			
pin 4	-21.00	-13.00	-17.00			-0.50		-0.50	1490.00		-1410.00			
pin 5	-14.00	-7.00	-10.50			-1.00		-1.00	840.00		-1117.50	Average Site 3		-0.55
								0.00		-420.00		-17798.75	-547653.85	

Thompson Canyon Erosion Pin Data February 24, 01														
Site 1 A	upper side of pin (mm)	lower side of pin (mm)	Average depth =(upper+lower) /2 (mm)	nail head to surface (mm)	sediment on top of washer (mm)	total erosion from October - February	Net sediment OR EROSION? from October - February	Difference between erosion and sediment event within current month (this value is used for caculating area	Distance between erosion pins (mm)	area of erosion wedge (mm)^2	area of a trapezoid (mm)^2	Total area of erosion or sediment (mm)^2 and then the average amount between the sites at each location	The average amount of erosion or sediment at each site (m)^2 * the distance between the sites (m)^2	Average amount of erosion that took place in the current month * the distace between the sites A and B then converted to m^2
			0					0	960.00				Distance (m)	
pin 1	-10.00	-9.00	-9.50	105.00	114.50	0.00	70.50	70.50	2470.00	33840.00			30.77	
pin 2	-15.00	-18.00	-16.50	47.00	63.50	0.00	20.50	20.50	1450.00		112385.00			
pin 3	-30.00	-17.00	-23.50			-2.50		-2.50	1110.00		13056.50			
pin 4	-59.00	-58.00	-58.50			-12.50		-12.50	1900.00		-8325.00			
pin 5	-48.00	-39.00	-43.50			-4.00		-4.00	1800.00		-15675.00			
								0.00		-3600.00				
												131681.50		
Site 1 B								0.00	750.00			19654.15	2328240.77	
pin 1	-1.00	-1.00	-1.00			-0.25		-0.25	1380.00	-93.75				
pin 2	-26.00	-3.00	-14.50			-1.50		-1.50	860.00		-1207.50			2.33
pin 3	-18.00	-8.00	-13.00	85.00	98.00	0.00	22.00	22.00	1220.00		8814.90			
pin 4	-40.00	-25.00	-32.50			-1.00		-1.00	1340.00		12810.50			
pin 5	-8.00	-5.00	-6.50			0.00		0.00	850.00		-670.00			
								0.00		0.00		Average Site 1		
												75667.83		
Site 2 A								0.00	490.00					
pin 1	-254.00	-254.00	-254.00			0.00		0.00	1020.00	0.00				
pin 2	-5.00	-4.00	-4.50			0.00		0.00	1580.00		0.00			
pin 3	-3.00	-2.00	-2.50			0.00		0.00	2300.00		0.00			
pin 4	-10.00	-6.00	-8.00			0.00		0.00	760.00		0.00			
								0.00		0.00				
												0.00		
Site 2 B								0.00	560.00			-2872.50		
pin 1	-12.00	-11.00	-11.50			0.00		0.00	860.00	0.00				
pin 2	-18.00	-17.00	-17.50			0.00		0.00	1910.00		0.00			
pin 3	-24.00	-14.00	-19.00			-1.50		-1.50	1920.00		-1432.50			
pin 4	-19.00	-11.00	-15.00			0.00		0.00	650.00		-1440.00			
								0.00		0.00		Average Site 2		
												-1436.25	-44192.31	-0.04
Site 3 A								0.00	600.00					
pin 1	-19.00	-9.00	-14.00			0.00		0.00	1200.00	0.00				
pin 2	-159.00	-156.00	-157.50			-8.50		-8.50	2720.00		-5100.00			
pin 3	-20.00	-13.00	-16.50			0.00		0.00	2130.00		-11560.00			
pin 4	-37.00	-13.00	-25.00			-3.00		-3.00	2060.00		-3195.00			
pin 5	-12.00	-11.00	-11.50			0.00		0.00	1800.00		-3090.00			
pin 6	-40.00	-14.00	-27.00			-2.00		-2.00	2140.00		-1800.00			
pin 7	-90.00	-87.00	-88.50			-1.00		-1.00	4580.00		-3210.00			
pin 8	-8.00	-4.50	-6.25			-0.25		-0.25	960.00		-2862.50			
								0.00		-120.00				
												-30937.50		
Site 3 B								0.00	910.00			-12677.50		
pin 1	-2.00	-1.00	-1.50			0.00		0.00	1870.00	0.00				
pin 2	-11.00	-8.00	-9.50			-0.50		-0.50	2280.00		-467.50			
pin 3	-68.00	-60.00	-64.00			-3.00		-3.00	2820.00		-3990.00			
pin 4	-21.00	-14.00	-17.50			-0.50		-0.50	1490.00		-4935.00			
pin 5	-16.00	-10.00	-13.00			-2.50		-2.50	840.00		-2235.00	Average Site 3		-0.67
								0.00		-1050.00		-21807.50	-671000.00	

Thompson Canyon Erosion Pin Data March 16, 01														
Site 1 A	upper side of pin (mm)	lower side of pin (mm)	Average depth =(upper+lower) /2 (mm)	nail head to surface (mm)	sediment on top of washer (mm)	total erosion from February - March	=Net Sediment or Erosion from February - March	Difference between erosion and sediment event within current month (this value is used for caculating area	Distance between erosion pins (mm)	area of erosion wedge (mm)^2	area of a trapezoid (mm)^2	Total area of erosion or sediment (mm)^2 and then the average amount between the sites at each location	The average amount of erosion or sediment at each site (m)^2 * the distance between the sites (m)^2	Average amount of erosion that took place in the current month * the distace between the sites A and B then converted to m^2
			0					0	960.00				Distance (m)	
pin 1	-10.00	-9.00	-9.50	67.00	76.50	0.00	-38.00	-38.00	2470.00	-18240.00			30.77	
pin 2	-15.00	-18.00	-16.50	19.00	35.50	0.00	-28.00	-28.00	1450.00		-81510.00			
pin 3	-22.00	-34.00	-28.00			-4.50	0.00	-4.50	1110.00		10512.10			
pin 4	-59.00	-58.00	-58.50	30.00	88.50	0.00	30.00	30.00	1900.00		14152.20			
pin 5	-50.00	-39.00	-44.50		20.00	-1.00	20.00	19.00	1800.00		3442.54			
								0.00		17100.00				
												-54543.16		
Site 1 B								0.00	750.00			-24482.94	-1215786.15	
pin 1	-1.00	-3.00	-2.00			-1.00		-1.00	1380.00	-375.00				
pin 2	-27.00	-9.00	-18.00			-3.50		-3.50	860.00		-3105.00			-1.22
pin 3	-18.00	-8.00	-13.00	67.00	80.00	0.00	-18.00	-18.00	1220.00		-7328.90			
pin 4	-71.00	-71.00	-71.00		36.00	-38.50	36.00	-2.50	1340.00		-10356.54			
pin 5	-8.00	-8.00	-8.00			-1.50		-1.50	850.00		-2680.00			
								0.00		-637.50		Average Site 1		
												-39513.05		
Site 2 A								0.00	490.00					
pin 1	-254.00	-254.00	-254.00					0.00	1020.00	0.00				
pin 2	-7.00	-7.00	-7.00			-2.50		-2.50	1580.00		-1275.00			
pin 3	-3.00	-2.00	-2.50	6.00	8.50	0.00	8.50	8.50	2300.00		9928.80			
pin 4	-10.00	-6.00	-8.00		3.50	0.00	3.50	3.50	760.00		13800.00			
								0.00		1330.00				
												23783.80		
Site 2 B								0.00	560.00			-6892.50		
pin 1	-11.00	-11.00	-11.00		2.00	0.50	2.00	2.50	860.00	700.00				
pin 2	-18.00	-17.00	-17.50			0.00			1910.00		1075.00			
pin 3	-22.00	-17.00	-19.50			-0.50		-0.50	1920.00		-477.50			
pin 4	-23.00	-19.00	-21.00			-6.00		-6.00	650.00		-6240.00			
								0.00		-1950.00		Average Site 2		
												8445.65	259866.15	0.26
Site 3 A								0.00	600.00					
pin 1	-23.00	-16.00	-19.50			-5.50		-5.50	1200.00	-1650.00				
pin 2	-171.00	-161.00	-166.00		35.00	-8.50	35.00	26.50	2720.00		12600.00			
pin 3	-20.00	-13.00	-16.50			0.00		0.00	800.00		36040.00			
pin 4	-33.00	-18.00	-25.50		12.00	-0.50	12.00	11.50	2060.00		4600.00			
pin 5	-12.00	-11.00	-11.50			0.00		0.00	1800.00		11845.00			
pin 6	-35.00	-21.00	-28.00			-1.00		-1.00	2140.00		-900.00			
pin 7	-91.00	-86.00	-88.50			0.00		0.00	4580.00		-1070.00			
pin 8	-8.00	-6.00	-7.00			-0.75		-0.75	960.00		-1717.50			
								0.00		-360.00				
												59387.50		
Site 3 B								0.00	910.00			-7167.50		
pin 1	-2.00	-1.00	-1.50			0.00		0.00	1870.00	0.00				
pin 2	-11.00	-9.00	-10.00	2.00		-0.50	2.00	1.50	2280.00		1402.50			
pin 3	-68.00	-60.00	-64.00			0.00		0.00	2820.00		1710.00			
pin 4	-26.00	-18.00	-22.00			-4.50		-4.50	1490.00		-6345.00			
pin 5	-18.00	-9.00	-13.50			-0.50		-0.50	840.00		-3725.00	Average Site 3		0.80
								0		-210.00		26110.00	803384.62	

Thompson Canyon Erosion Pin Data April 14, 01

Site 1 A	upper side of pin (mm)	lower side of pin (mm)	Average depth =(upper+lower) /2 (mm)	nail head to surface (mm)	sediment on top of washer (mm)	total erosion from March - April	Net Sediment or Erosion from March - April	Difference between erosion and sediment event within current month (this value is used for caculating area	Distance between erosion pins (mm)	area of erosion wedge (mm)^2	area of a trapezoid (mm)^2	Total area of erosion or sediment (mm)^2 and then the average amount between the sites at each location	The average amount of erosion or sediment at each site (m)^2 * the distance between the sites (m)^2	Average amount of erosion that took place in the current month * the distace between the sites A and B then converted to m^2
			0					0	960				Distance (m)	
pin 1	-10.00	-9.00	-9.50	67.00	76.50	0.00	0.00	0.00	2470.00	0.00			30.77	
pin 2	-15.00	-18.00	-16.50	19.00	35.50	0.00	0.00	0.00	1450.00		0.00			
pin 3	-20.00	-34.00	-27.00			0.00	1.00	1.00	1110.00		725.00			
pin 4	-59.00	-58.00	-58.50	35.00	93.50	0.00	5.00	5.00	1900.00		3330.00			
pin 5	-50.00	-39.00	-44.50		20.00	0.00	0.00	0.00	1800.00		4750.00			
								0.00		0.00				
												8805.00		
Site 1 B								0.00	750.00			-9252.90	-6890.77	
pin 1	-1.00	-3.00	-2.00			0.00		0.00	1380.00	0.00				
pin 2	-27.00	-14.00	-20.50			-2.50		-2.50	860.00		-1725.00			-0.01
pin 3	-18.00	-8.00	-13.00	67.00	80.00	0.00	0.00	0.00	1220.00		-70.80			
pin 4	-74.00	-71.00	-72.50		28.00	-1.50	-8.00	-10.50	1340.00		-422.10			
pin 5	-8.00	-8.00	-8.00			0.00		0.00	850.00		-7035.00			
								0.00		0.00		Average Site 1		
												-223.95		
Site 2 A								0.00	490.00					
pin 1	-254.00	-254.00	-254.00			0.00		0.00	1020.00	0.00				
pin 2	-7.00	-7.00	-7.00			0.00		0.00	1580.00		0.00			
pin 3	-3.00	-2.00	-2.50	6.00	8.50	0.00	0.00	0.00	2300.00		0.00			
pin 4	-10.00	-6.00	-8.00		3.50	0.00	0.00	0.00	760.00		0.00			
								0.00		0.00				
												0.00		
Site 2 B								0.00	560.00			-1137.50		
pin 1	-11.00	-11.00	-11.00		2.00	0.00	2.00	2.00	860.00	560.00				
pin 2	-18.00	-17.00	-17.50			0.00			1910.00		860.00			
pin 3	-24.00	-17.00	-20.50			-1.00		-1.00	1920.00		-955.00			
pin 4	-24.00	-19.00	-21.50			-0.50		-0.50	650.00		-1440.00			
								0.00		-162.50		Average Site 2		
												-568.75	-17500.00	-0.02
Site 3 A								0.00	600.00					
pin 1	-23.00	-16.00	-19.50			0.00		0.00	1200.00	0.00				
pin 2	-171.00	-161.00	-166.00		20.00	0.00	-15.00	-15.00	2720.00		-9000.00			
pin 3	-20.00	-13.00	-16.50			0.00		0.00	800.00		-20400.00			
pin 4	-34.00	-18.00	-26.00		12.00	-0.50	0.00	-0.50	2060.00		-200.00			
pin 5	-12.00	-11.00	-11.50			0.00		0.00	1800.00		-515.00			
pin 6	-35.00	-22.00	-28.50			-0.50		-0.50	2140.00		-450.00			
pin 7	-91.00	-86.00	-88.50			0.00		0.00	4580.00		-535.00			
pin 8	-11.00	-8.00	-9.50			-2.50		-2.50	960.00		-5725.00			
								0.00		-1200.00				
												-38025.00		
Site 3 B								0.00	910.00			-11450.00		
pin 1	-4.00	-6.00	-5.00	1.00		-3.50	1.00	-2.50	1870.00	-1137.50				
pin 2	-15.00	-9.00	-12.00	2.00		-2.00	0.00	-2.00	2280.00		-4207.50			
pin 3	-70.00	-61.00	-65.50			-1.50		-1.50	2820.00		-3990.00			
pin 4	-26.00	-18.00	-22.00			0.00		0.00	1490.00		-2115.00			
pin 5	-18.00	-9.00	-13.50			0.00		0.00	840.00		0.00	Average Site 3		-0.76
								0		0.00		-24737.50	-761153.85	

APPENDIX B: Trail Measurements

Ugly Duckling Trail

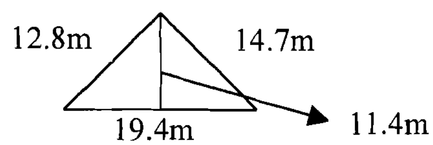
Source Area

Average width (m)	Length (m)	Area of each trail segment (m^2)
1.85	3.2	5.92
1.54	2.6	4.00
0.92	5.9	5.43
1.54	5.3	8.16
1.23	6.7	8.24

Total Source Area = 31.75 m^2

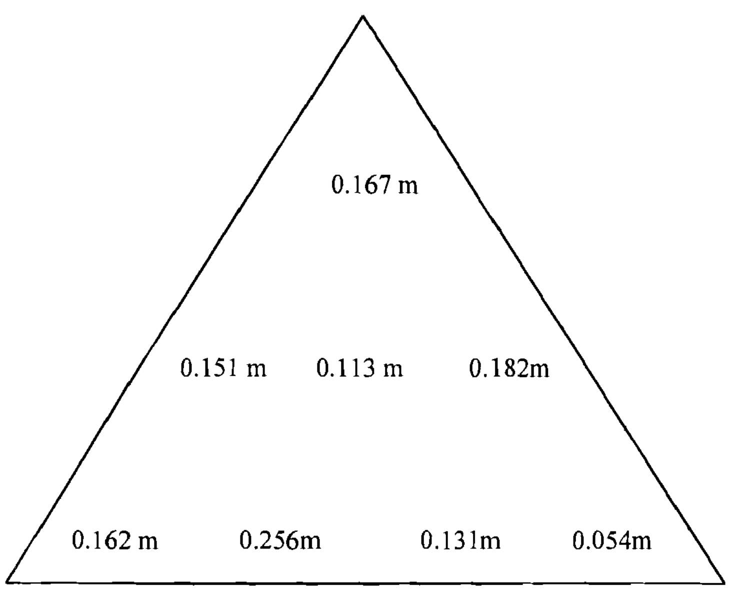
Depositional Area

Alluvial Fan Area (where; ½ b * h = Area of a triangle)



Depositional Surface Area = ½ (11.4 * 19.4) = 110.58 m^2

Depths of the alluvial area are as follows:



Average depth = 0.152

Average depth * depositional surface area = volume (of sediment within the alluvial fan)

Volume = 16.81 m^3

Since, climbers have used the trails over the past 14 years, the rate of deposition is equal to1.2 m^3 / year.

APPENDIX C: RUSLE Calculations

To the best of my judgment I was able to measure, calculate and make assumptions on the following values.

	A (ton • acre^{-1} • yr^{-1})	R (hundreds ft • tons • in (ac • h • yr)$^{-1}$)	K	L (%)	S (ft)	LS	C	P
Enchanted Tower Campsite	0.163	20	0.44	0.2%	<3	.05	0.37	1
Pouge's Cave Campsite	0.141	20	0.38	0.2%	<3	.05	0.37	1
Ugly Duckling Trailhead	6.292	20	0.32	40%	100	6.78	0.145	1
Old Enchanted Tower Trailhead	6.292	20	0.32	40%	100	6.78	0.145	1
New Enchanted Tower Trailhead	3.860	20	0.32	25%	100	4.16	0.145	1

K values where measured from soil samples from the various locations listed above.

LS was taken directly from table 4.1, Renard et. al., (1997) compiled for rangelands

The two campsite locations have no canopy and 5% or less ground cover; therefore the vegetation factor, C is equal to 0.37, based on table 7.5, Brooks et. al, (1997). Trails all have an estimate of 25% canopy cover and approximately 30% ground cover, which has a C factor equal to 0.145.

P – Erosion control practice factor, expressed, as a ratio of soil loss with practices, dimensionless, for the purposes of this study P is equal to 1.