



The impact of recreational camping on the natural resource  
by James Bruce MacKay

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of  
MASTER OF SCIENCE in Agronomy  
Montana State University  
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**Abstract:**

Increased public demand for outdoor recreation opportunities, during the past few years, has led to an astronomical rise in numbers of people engaged in camping. Through campground use, a resultant decline in overall groundcover has been noted.

Some of the impacts of camping activity on established campgrounds located on Hobacker forest soils in the Gallatin National Forest have been quantified through observations of bulk density, sand/(silt + clay) ratio, organic matter content, species diversity index and infiltration measurements. Correlation and regression analyses among these measured factors led to the establishment of projections, based on the sand/ (silt + clay) ratio, which could be used as criteria for selection and design of campsites which could withstand human use with a minimum of site deterioration.

Base-line transects established at the proposed Red Cliff campground will provide the opportunity to study user-effects on a longterm basis after the campground is opened to the public.

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Date April 14<sup>th</sup> 1974

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ON THE NATURAL RESOURCE

by

JAMES BRUCE MACKAY

A thesis submitted to the Graduate Faculty in partial  
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of

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ABSTRACT

Increased public demand for outdoor recreation opportunities, during the past few years, has led to an astronomical rise in numbers of people engaged in camping. Through campground use, a resultant decline in overall groundcover has been noted.

Some of the impacts of camping activity on established campgrounds located on Hobacker forest soils in the Gallatin National Forest have been quantified through observations of bulk density, sand/(silt + clay) ratio, organic matter content, species diversity index and infiltration measurements. Correlation and regression analyses among these measured factors led to the establishment of projections, based on the sand/(silt + clay) ratio, which could be used as criteria for selection and design of campsites which could withstand human use with a minimum of site deterioration.

Base-line transects established at the proposed Red Cliff campground will provide the opportunity to study user-effects on a long-term basis after the campground is opened to the public.

## INTRODUCTION

Camping, as a recreational activity, is a rapidly increasing form of leisure-time use in North America. People are discovering, especially in present times of rising costs, that recreational camping can provide aesthetic and personal rewards at relatively low costs. Although basic camping equipment can range from the family auto and a tent, to elaborate, self-contained mobile homes, campground user fees are low.

The scenic Gallatin Canyon area, on a principal highway leading to and from Yellowstone National Park, is a popular tourist camping area. Presently, the Big Sky Resort is being constructed near Lone Mountain, an area between Bozeman and Yellowstone National Park. Increased tourist activity, through Gallatin Canyon, can reasonably be expected as a result of the Big Sky development. With increased tourist activity, there will be further demands placed on area campgrounds.

Through campground use, a resultant decline in native groundcover quality is expected. In order to attempt sound campground management practices, research is necessary to understand underlying site deterioration factors.

The purpose of this study is to quantify some of the effects of recreational camping on the natural resource. In order to accomplish this end, established campgrounds at Spire Rock and Greek Creek, as well as the proposed campground at Red Cliff, were selected as study sites. Permanent, base-line transects were established at the study

sites and soil bulk density, organic matter content, infiltration rate, particle size fractions as well as species diversity measurements were obtained. Data analysed from established campgrounds led to quantified information of the effects of camping on established campground areas. From these data, projections of future use-effects were obtained for the proposed Red Cliff campground. A simple indicative measurement that could be used to project future campground use suitability was sought and inventory information for the Red Cliff campground was established for future, long-term study.

## LITERATURE REVIEW

De Mattis (1973) reported that through a combination of increased leisure time and extensive highway systems, more and more people are turning to recreational camping. According to the Recreational Vehicle Institute, quoted by De Mattis, there are presently four million mobile homes, campers and travel trailers in the United States. These figures are currently increasing at the rate of one million units per year. De Mattis further stated that there are 15,000 established American campgrounds (increasing by 2000 units per year) containing 1.5 million campsites. De Mattis projected forty million people engaged in camping by 1976 resulting in a \$250 billion gross income to leisure time industries.

Public camping areas are operated by federal, state and local governments. These areas are often overcrowded, over-used and abused (De Mattis, 1973; Clark, 1971; West, 1968; Settergren, 1970). Moeller (1971) reported an increase in both public and commercial campgrounds but noted a trend away from public to the commercial type of enterprise. The commercial campgrounds usually contain some type of water based recreational opportunity and are generally large in size and well cared for.

Although Shafer (1969) has reported that camper populations differ from campground to campground and from month to month, site deterioration appears to be a universal problem which is independent of season and type of user. Trampling, with resultant soil compaction and flora loss, is probably the most obvious physical and aesthetic problem

associated with recreational camping (La Page, 1962; Magill, 1963; Magill and Nord, 1963; La Page, 1967; Martin, 1969; Gamrath, 1970; Wagner, 1970).

The seriousness of compaction is evident when one considers that it has its primary effect on the surface six inches of the soil. This soil is a very important area for root growth and development in plants. When a soil undergoes compaction, water enters the ground more slowly and aeration decreases. Lutz (1945) reported soil compaction in two Connecticut forest park picnic grounds. He noted an increase in soil density and a decrease in pore volume and air capacity through recreational use. Reduced infiltration rates of the trampled sites resulted in potential erosion problems. Dotzenko (1967) studied soil compaction due to trampling in three long established and heavily used Rocky Mountain campgrounds. He pointed out the relationship between use intensity, soil compaction and vegetative cover.

Soil compaction problems can be reduced in five years according to Thorud (1969) if no further compaction is allowed to take place during the five year period. In this Minnesota study, bulk density decreased significantly in the surface three inches of the soil after artificial compaction had taken place.

The effect of trampling on the flora of an area is more obvious than soil compaction. Frissell (1965) has suggested that new campsites, even when lightly used, lose an average of 85% of their original ground-cover during the first year of use. In this Quetico-Superior Canoe

Country study, tree reproduction was reduced to zero. Saplings had been cut or damaged and eventually totally disappeared. Also, there was increased erosion and soil compaction, decreased plant litter and humus depths and increased root exposure. These changes were considered to be serious problems on many sites.

Merriam (1970) studied newly established campsites in the Minnesota Boundary Waters Canoe Area (BWCA). These campsites, located in one of the most heavily used wilderness areas in the United States, received one million visitor days use per year. In this five year study involving 33 campsites Merriam pointed out an increase in bare ground, compaction, site size and dead trees or exposed roots—a direct result of trampling.

Dryness (1965) reported that groundcover was the single greatest deterrent to soil erosion. From his data, Dryness concluded that as groundcover decreased, soil erosion increased.

La Page (1967) has suggested that the intensity of campground use doesn't necessarily reduce overall plant densities. He has hypothesized, after a three year Pennsylvania study, that original plant species markedly decline. The severity of this decline was directly related to the use intensity that the area had undergone. The original plant species were replaced by species like Poa or Trifolium which have good natural resistance to trampling. These tolerant species spread, while the less resistant species decline further in succeeding years. Trees, on the other hand, suffer a decreased diameter growth and eventually disappear

entirely. Echelberger (1971) and Magill (1970) have reported a general improvement in campsite groundcover condition after the first drastic reduction in indigenous plant species.

It is apparent that damage can be expected in campsites due to camping activities. The prospects for recovery are not especially optimistic. Kimmins (1972) has cautioned that the renewability of nature lies in the rate of time concept rather than in the chemical, physical and biological characters per se of the affected area. Beardsley (1971) has informed us that damage recovery in the west is exceptionally slow due to the short growing season. In this three year study undertaken in Idaho, the vegetational response could be increased if the overstory was reduced and watering, fertilization and reseeding programs were undertaken. Eckert (1973) reported that it was possible to reseed a mountain area closed to camper use for a three year period. One year was necessary for fallow to prepare the new seedbed, then an additional two years were required to allow the turf sufficient time to become adequately established.

Less drastic management schemes may be employed which could do away with total re-vegetation programs. La Page (1967) and Thorud (1969) have proposed moving the campsite tables at regular intervals during the camping season to allow recovery of damaged areas in a rest-rotation type of scheme. The success of this type of program would depend upon user preference and the ability of damaged sites to recover. Beardsley (1971) suggested that, with a new campground, it was necessary to plan

and provide routes for foot and vehicular traffic to reduce groundcover deterioration. Without planned routes to follow, people tend to create their own pathways. Wagner (1970) proposed an abundance of paving and graveling to preserve sites and Martin (1969) suggested entirely closing down sites to allow recovery. Goldin (1971) and Heady (1969) have suggested that the time may have come to place more stringent controls on campers. They felt that selective admittance and an increase in price for campground use may help control congestion and help cover the costs of administering campgrounds. Martin (1969) suggested regulating the number of campers in an area.

Magill (1963), Magill and Nord (1963) pointed out the need for continuing research in all problems pertaining to campgrounds and resource deterioration.

Charlesworth (1964) perhaps summed the issue up quite well when he wondered whether leisure was a blessing or indeed, a curse.

## MATERIALS AND METHODS

For the purpose of this study, a "campsite" has been defined as any area that functions as a single camping unit containing a fireplace, table and vehicle parking slot. A "campground" has been defined as any area containing an assemblage of campsites. Campgrounds can be public or privately operated and vary in size, numbers of campsites and services provided.

Spire Rock, Greek Creek and Red Cliff campgrounds (Figure 1), located in the Gallatin National Forest, were the individual areas that were chosen for the purpose of this study. Spire Rock campground, located 28 miles south of Bozeman in the Squaw Creek area 3 miles east of U. S. 191 and Greek Creek campground, located 30 miles south of Bozeman on U. S. 191 are established campground areas. The Spire Rock campground contains 15 campsites while Greek Creek campground contains 14 campsites. The Red Cliff campground, located 48 miles south of Bozeman on U. S. 191, is a 71 unit campground presently being developed by the U. S. Forest Service. Red Cliff consists of a 31-unit south loop and a 40-unit north loop. The roads and parking slots have been established at Red Cliff campground, however the campsites have not been completed to date.

All three study areas are located on Hobacker forest soils. According to Olsen (1971), Hobacker soils are characterized by a gravelly loam surface layer and a substratum composed of sand and gravel which leads to good drainage. Coarse fragments range from 35 to 70% throughout the profile and textures are loam or clay loam. Hobacker soils are

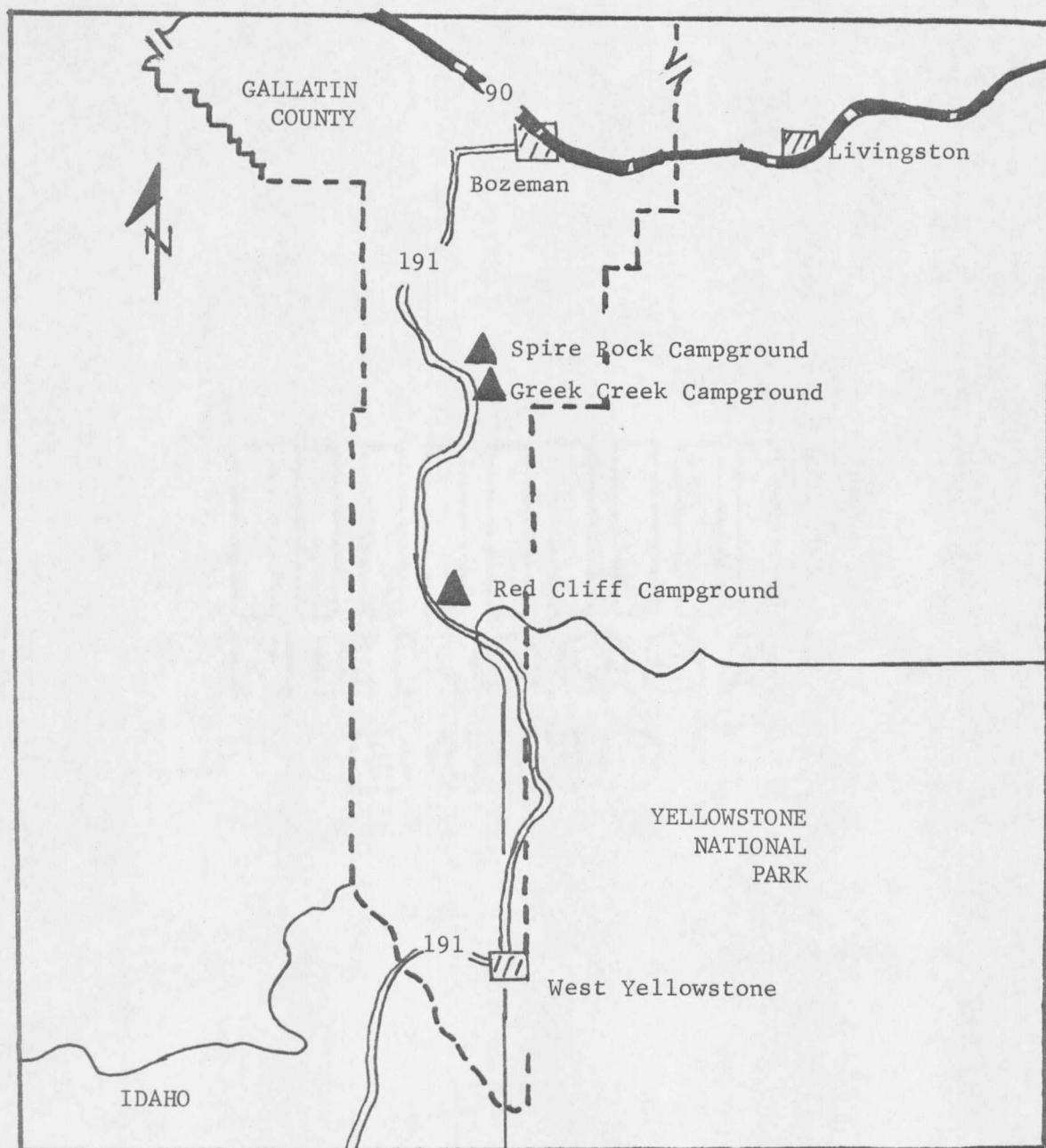


Figure 1. U. S. 191 between Bozeman and West Yellowstone showing location of Spire Rock, Greek Creek and Red Cliff campgrounds. (Scale 1" = 10 miles). Location of Spire Rock, Greek Creek and Red Cliff campgrounds in Gallatin County, Montana. (Scale 1" = 15 miles).

developed in alluvial fans on footslopes below the uplands and at mouths of drainages. Hobacker soils represent approximately 25 percent of the Bigel-Hobacker association and are primarily used as native range and dwelling sites along Highway 191. Hobacker soil slopes range from 5 to 35%. Slopes are generally slight on all study sites although some steep slopes exist at the Red Cliff campground. Elevation of the three campgrounds ranges from 5,500 feet at Spire Rock, 6,200 feet at Greek Creek to 7,000 feet above sea level at Red Cliff (U. S. Geological Survey, 1955). The mean annual air temperature ranges from 35 to 45 degrees F while the average summer temperature ranges from 52 to 58 degrees F (U. S. Weather Bureau, 1961-1971). Mean annual precipitation ranged from 20 to 30 inches, 11 to 20 inches of which appears in the form of snow (U. S. Weather Bureau, 1961-1971). The frost free season is 50 days or shorter (Caprio, 1965) and frost has been reported during each of the summer months. Vegetation includes forbes, shrubs and bunch grasses. The Bigel-Hobacker association, being close to the Gallatin River and along the highway, is used intensively for recreational purposes.

Transects were established at each campground and groundcover measurements, organic matter levels, sand/(silt + clay) ratio, soil bulk density and infiltration rates were obtained. At Greek Creek and Spire Rock campgrounds, one-line transects were established between adjacent campsites (Figures 2 through 6). The transects extended from

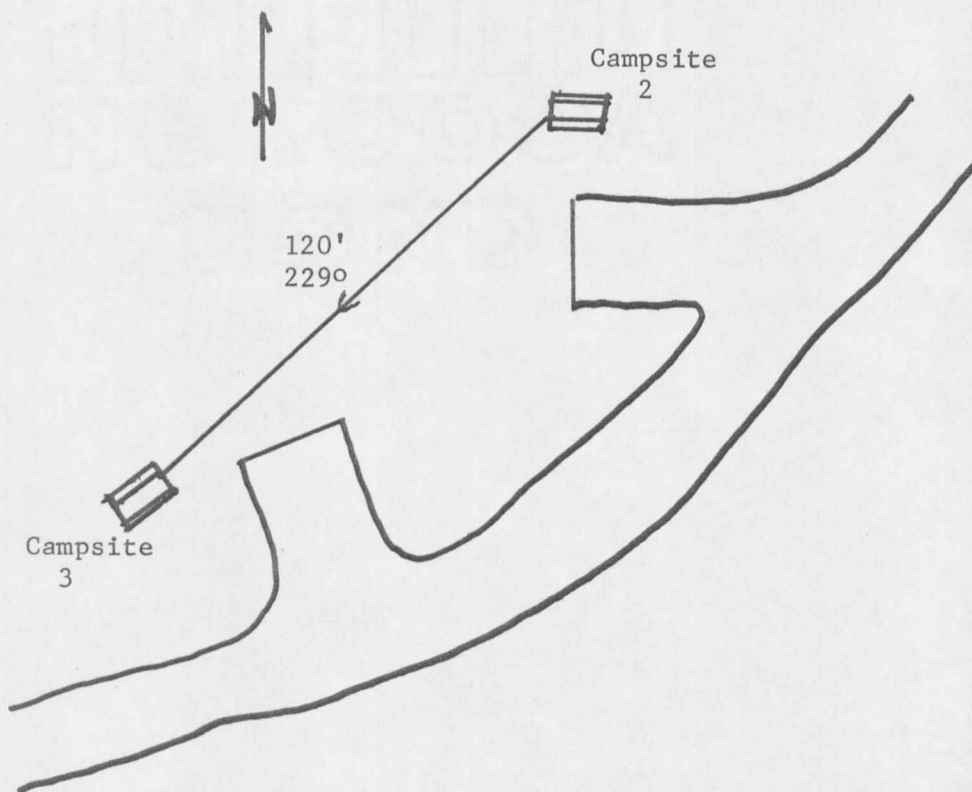


Figure 2. Length and degrees azimuth from true north of transect between paired campsites 2 and 3 at the Spire Rock Campground, Gallatin National Forest. (Scale 1" = 40').

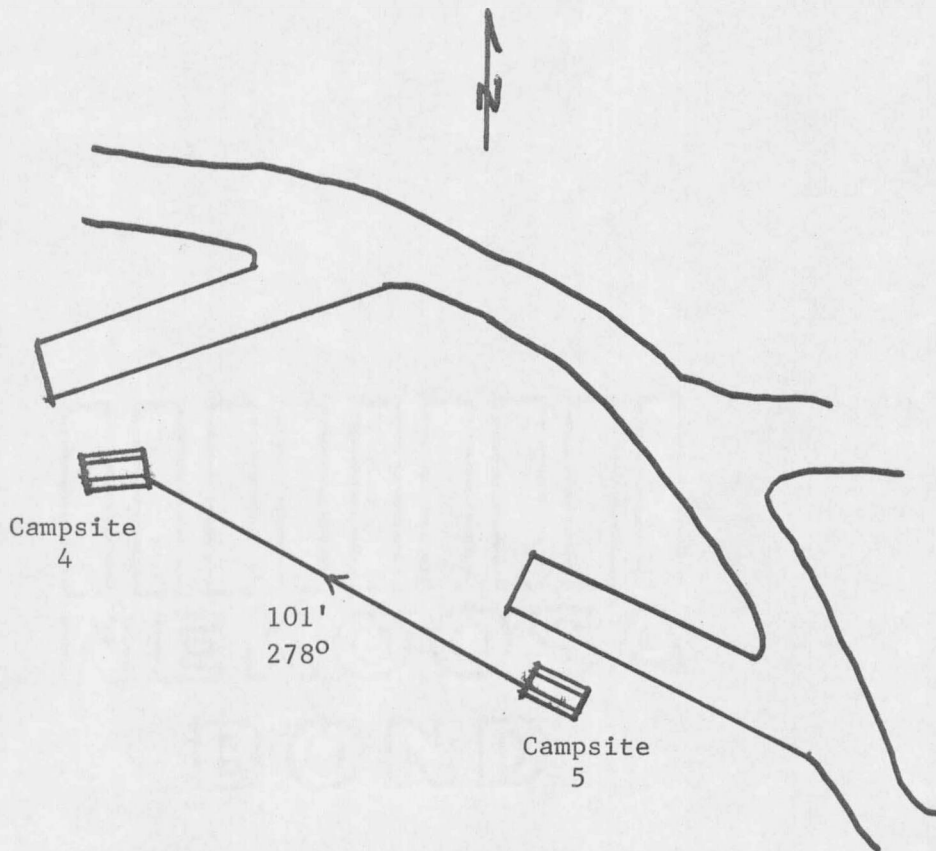


Figure 3. Length and degrees azimuth from true north of transect between paired campsites 4 and 5 (west side US 191) at the Greek Creek Campground, Gallatin National Forest. (Scale 1" = 40').

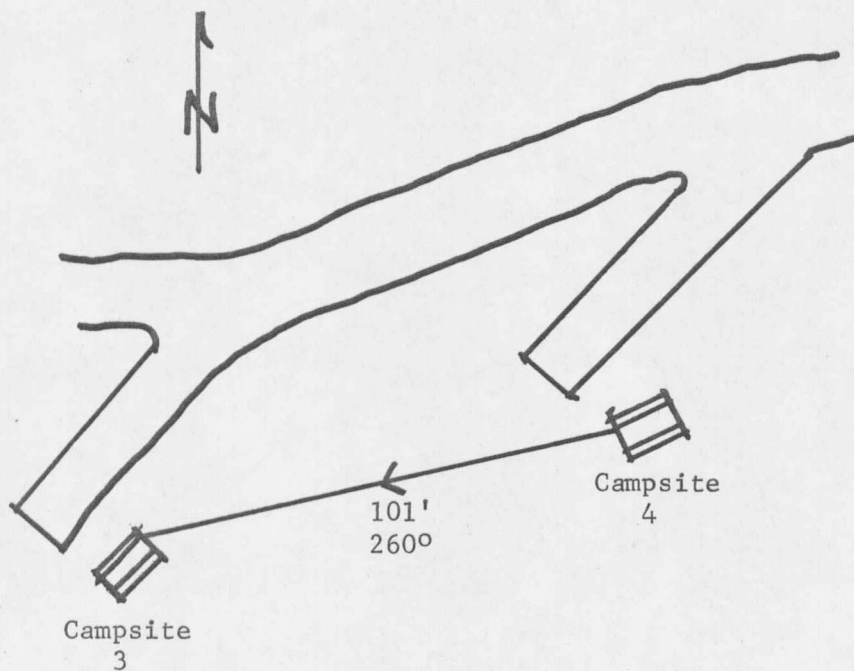


Figure 4. Length and degrees azimuth from true north of transect between paired campsites 3 and 4 (west side US 191) at the Greek Creek Campground, Gallatin National Forest. (Scale 1" = 40').

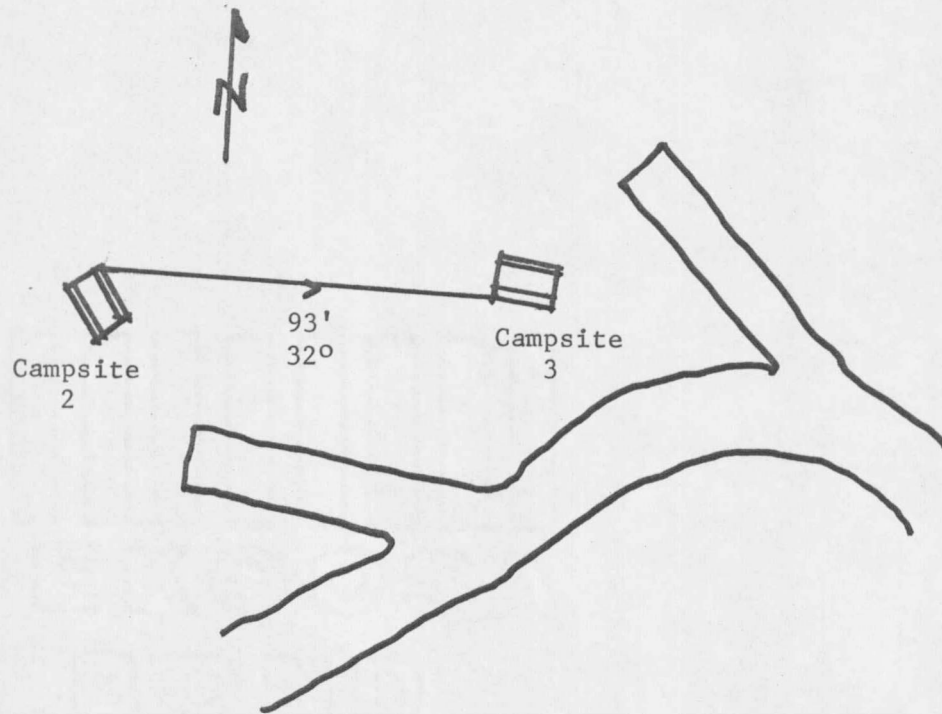


Figure 5. Length and degrees azimuth from true north of transect between paired campsites 2 and 3 (east side US 191) at the Greek Creek Campground, Gallatin National Forest. (Scale 1" = 40').

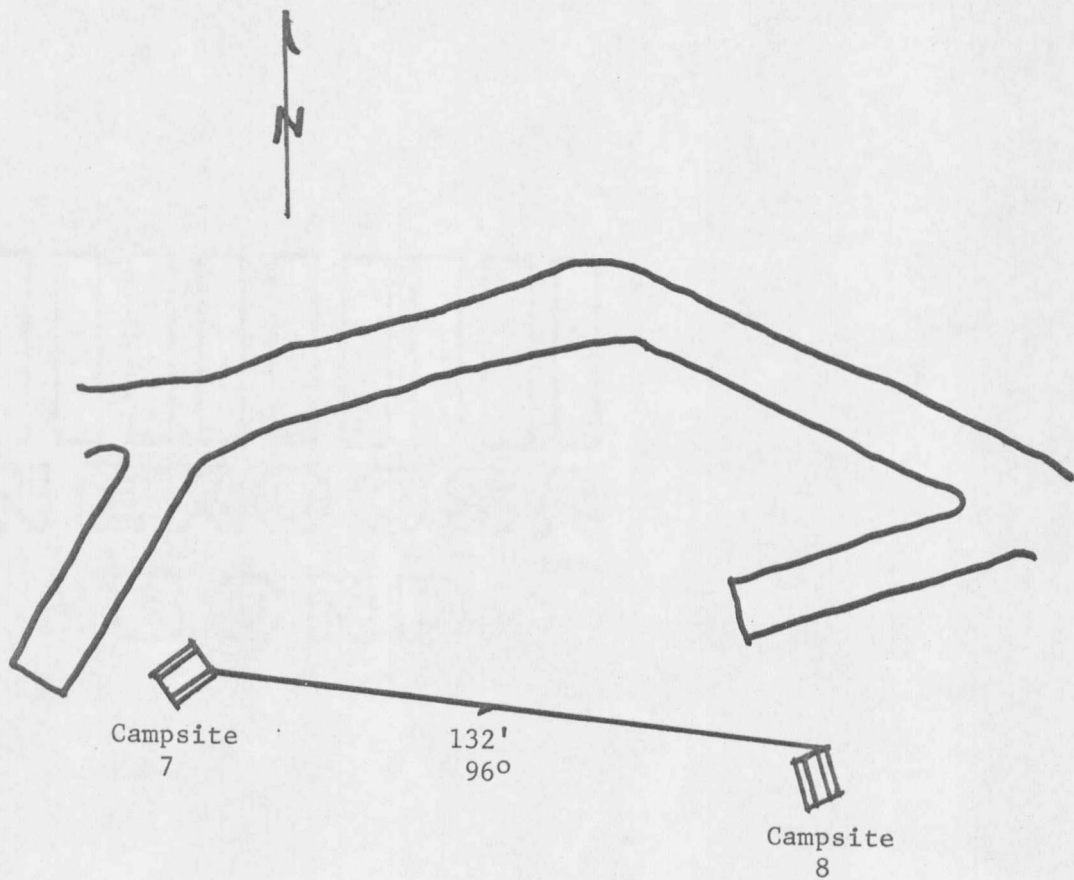


Figure 6. Length and degrees azimuth from true north of transect between paired campsites 7 and 8 (east side US 191) at the Greek Creek Campground, Gallatin National Forest. (Scale 1" = 40').

the picnic table of one campsite to the picnic table of the other. Groundcover measurements and soil bulk density samples were taken at 10 foot intervals along the transect. Infiltration rates were measured at the centres of the campsites, at the mid-point between the adjacent campsites and at one-half the distances between the campsite centres and the mid-point between adjacent campsites. At Greek Creek, four such transects were established and at Spire Rock one transect was established. At the Red Cliff campground, transects were established on a basis of the proposed campsite centres as indicated on the campground site plan. Twelve sites were selected at Red Cliff, six in each loop, on a basis of contrasts in view, tree canopy, ease of access to the proposed picnic area from the parking slot and proximity to steep slopes. A permanent reference point (R) was established at each of the twelve sites. This reference point was located where the centre of the parking slot had its junction with the campground roadway. At point R, a flat iron plate was buried one foot below the road grade for future reference. This starting point was also cross-referenced to a nearby marked tree. From point R, the first transect extends to the centre of the proposed picnic area (point P). From point P, three additional transects radiate outward at various compass degrees to a maximum distance of 80 feet. Figure 7 shows an example of the transects as established at the Red Cliff Campground and Table 1 gives a numerical description of the Red Cliff transects. All angles were recorded in degrees from true north. At the Red Cliff campground, groundcover

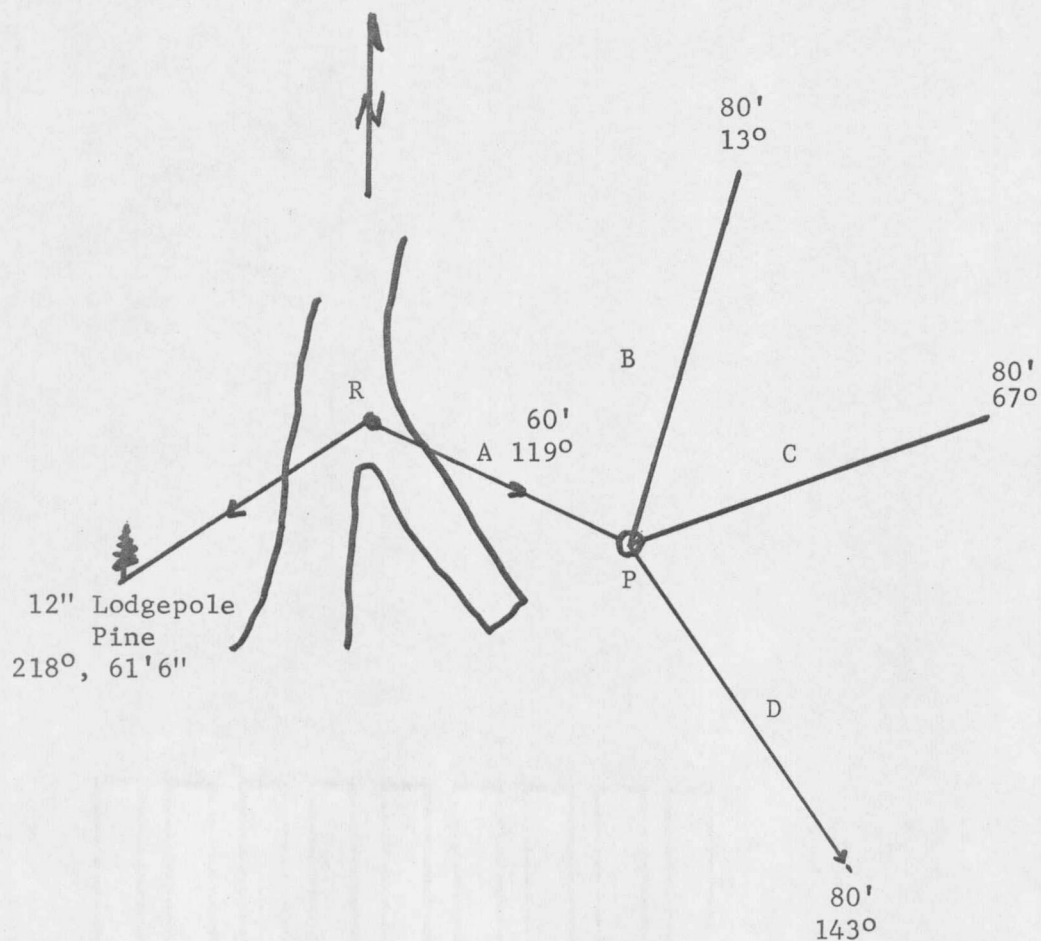


Figure 7. Length and degrees azimuth from true north of transect A and marked orientation tree line from benchmark reference point (R) and transects B, C, and D from campground pivot point (P) at campsite 17 north, Red Cliff Campground, Gallatin National Forest. (Scale 1" = 40').

Table 1. Length and degrees azimuth from true north of transect A and marked orientation tree line from benchmark reference point (R) and transects B, C, and D from point (P) at campsites in the Red Cliff campground, Gallatin National Forest.

Campsite	Transect Length and Degrees				Orientation Tree
	A	B	C	D	
31 S	40' 158°	80' 86°	80' 143°	80' 195°	10" Douglas Fir 156 33.3', 93°
23 S	70' 90°	80' 299°	80' 85°	80' 180°	8" Spruce 554 27.5', 82°
22 S	70' 90°	80' 167°	80' 234°	80' 325°	10" Spruce 556 40.6', 202°
18 S	35' 251°	80' 190°	80' 260°	40' 311°	8" Spruce 518 80.6', 218°
12 S	60' 110°	60' 337°	50' 115°	60' 176°	8" Douglas Fir 481 52', 17°
12 N	30' 240°	80' 180°	60' 326°	40' 352°	16" Douglas Fir 558 20.9', 290°
17 N	60' 119°	80' 13°	80' 67°	80' 143°	12" Lodgepole 61.5', 218°
4 N	60' 117°	60' 350°	60' 92°	30' 196°	12" Spruce 1951 14.3', 53°
28 N	55' 355°	80' 320°	80' 44°	80' 117°	16" Douglas Fir 572 27', 30°
38 N	59' 349°	80' 311°	80' 357°	80' 48°	12" Douglas Fir 579 53', 341°
23 N	40' 316°	40' 207°	80' 23°	80' 74°	20" Douglas Fir 547 55', 325°
3 S	35' 261°	70' 220°	50' 250°	50' 339°	12" Spruce 429 42.5', 337°

estimates were obtained at 10 foot intervals on all transects, soil bulk density samples were taken at 10, 20, 30 and 60 foot intervals on all transects and infiltration tests were performed on one transect per campsite at 0, 30 and 60 foot intervals.

All groundcover estimates were obtained through the use of a Daubenmire frame<sup>1/</sup>. The frame was a 5 dm x 2 dm (100 cm<sup>2</sup>) rectangle that was colour coded for percentage estimation of groundcover. The frame was oriented at right angles to the transect lines and estimates were taken of the space occupied by plant species, litter, rock and bare ground. If a plant species was not recognized and could not be keyed out in place, a nearby sample of the species in the frame was obtained. The sample in question was taken to Professor W. E. Booth, Herbarium Curator at M.S. U., for identification. The groundcover estimates were recorded in classes: Class 1, 0-5%; Class 2, 6-25%; Class 3, 26-50%; Class 4, 51-75% and Class 5, 76-100% of the total frame space occupied. A plant species diversity index was computed. This index was the ratio between the numbers of species identified in the particular campsite sector over the total number of species identified in corresponding sectors of the entire campground.

Soil bulk density samples were obtained through the use of an Eley Volumeter<sup>2/</sup>. This instrument removed core samples of soil that

<sup>1/</sup> Daubenmire, R. 1959. A canopy coverage method of vegetational analysis. Northwest Science. 33:43-64.

<sup>2/</sup> Distributed by the Alpha-Lux Co., Inc. Lincoln Bldg., 60 E. 42nd St. New York, N.Y.

were 3.2 cm long and 2.9 cm in width. Sample volume was 20 cc. The unincorporated surface organic matter was removed and three core samples, in a one metre radius, were taken at ten foot intervals along the transects. Samples came from the upper three inches of the soil surface. With the sampler plunger fully withdrawn, the instrument was depressed into the soil up to the depth flange (about 55 mm). The sampler was then rotated to separate soil in the tube from soil around and beneath the sample. The sampler, containing the soil column, was then pulled from the ground. A 20 cc soil sample was taken from the centre of the 55 cc core. This sample was placed in a soil sample can and later taken to the laboratory. At the laboratory, the sample was weighed and then placed to dry in a drying oven (65°C) for a minimum of three days. After the drying period, the sample was reweighed and the bulk density was calculated:

$$\text{Bulk Density (gm/cc)} = \frac{\text{Ovendry sample weight (gm)}}{\text{Volume (cc)}}$$

The soil samples were later analysed for organic matter content and particle size (sand, silt and clay) fractions<sup>3/</sup>. The organic matter content was determined by placing 1 gram of soil into a 250 ml erlenmeyer flask and adding 10 ml of potassium dichromate and 20 ml sulphuric acid. The solution was mixed and allowed to stand for 10 minutes.

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<sup>3/</sup> The Soil Survey Manual (1951) describes clay as particles below 0.002 mm, silt as particles between 0.002 and 0.05 mm and sand as particles ranging from 0.05 to 2.0 mm. Particles greater than 2.0 mm in size were ignored in this study.

Excess potassium dichromate was then titrated with ferrous ammonium sulphate. A "blank", using potassium dichromate and sulphuric acid, but no soil, was run simultaneously. Percentage organic matter was calculated:

$$\% \text{ O.M.} = \frac{\text{Blank-Titration}}{3}$$

Particle size fractions were determined by the hydrometer or Bouyoucos method of mechanical analysis. Twenty-five grams of soil (composite of the three sample point samples) were placed in a malt-mixing cup and physically (stirred) and chemically (action of Calgon) dispersed, suspended in water in a cylinder and allowed to settle. Forty seconds after stirring, hydrometer and temperature readings were taken in the suspension. This reading reflected the amount of silt and clay left in suspension, the sand fraction having settled to the bottom of the cylinder. After two hours, hydrometer and temperature readings were again taken to determine the amount of clay that remained in suspension. By the end of the two hour period, the silt particles had also settled out of suspension. Hydrometer readings were corrected for temperature and sand, silt and clay percentages were calculated. The sand/(silt + clay) ratio is the particle fraction measurement that is primarily referred to in this paper.

Soil infiltration rates were measured using the double ring infiltrometer method (Bertrand, 1965) for a period of two hours. The average diameter of the inner rings was 30 cm and the average diameter of

the outer rings was 60 cm. The rings were driven into the ground to a depth of about two inches. To facilitate ease of measurement, a twelve inch plastic ruler was taped to the inside of the inner ring. The tape itself was placed across an inch mark on the ruler and this provided a convenient mark for rapid initial filling and subsequent refilling of the inner ring with water. The outer ring was not allowed to run dry during the test period. Inner ring water drop was recorded at ten minute intervals and then the inner ring was immediately refilled to the original water level mark. Individual infiltration results were later calculated to reflect inches of water per hour moving downward through the soil.

All field data were collected from July through October, 1972 and were interpreted through simple correlation and regression coefficients and analyses of variance. The summarized measurement mean values were compared through either Duncan's Multiple Range test or the least significant difference test. Asterisks were utilized to designate levels of significance; .01 level\*\*\*, .05 level\*\* and .10 level\*.

## RESULTS AND DISCUSSION

Analysis of variance mean squares for sample point bulk densities are shown in Table 2. All five sets of sample points, within transects, in the established Spire Rock and Greek Creek campgrounds had significant mean square values for variance among sample point averages. The sample point mean values at the proposed Red Cliff campground were largely (67%) non-significant. These differences indicate the effect of camper use, or at Red Cliff the lack thereof, on the established and proposed campground areas. Trampling has produced significant soil bulk density changes at the established campgrounds, while in the absence of human trampling, the soil at Red Cliff is relatively less variable in bulk density.

An increase in bulk density values at campsite centres, the major area of human activity while camping, is shown in Table 3. Areas between campsite centres, in the established campgrounds, had lower bulk density values than did the campsite centre sectors which were subjected to more severe trampling. A mean bulk density value of .97 at Red Cliff (Table 4) is considerably lower than recorded Greek Creek - Spire Rock levels. The Duncan's Multiple Range test generally divides the bulk density mean values into either the north or south-loop at Red Cliff. This is not surprising as the south-loop is mixed forest in character while the north-loop is primarily grassland.

Table 5 points out that transects at campsites 23N, 38N, 28N, 4N, 18S, 23S, 12S and 3S, in the proposed Red Cliff campground, differ among each other with regard to bulk density. Sites 22S, 12N, 17N and 31S had

Table 2. Summary of bulk density transect sample point analysis of variance mean square values at Greek Creek, Spire Rock and Red Cliff campgrounds in the Gallatin National Forest (1972).

Campground and transect number	Source of Variance			
	Between sample points		Within sample points	
	<u>D.F.</u>	<u>Mean square</u>	<u>D.F.</u>	<u>Mean square</u>
GC1	10	.1680 ***	22	.046
GC2	10	.0167 **	22	.0065
GC3	9	.2543 ***	20	.0123
GC4	13	.1339 ***	28	.0212
SR1	12	.0813 ***	26	.0265
RC 12S B	3	.1135	8	.0413
RC 3S B	3	.0035	8	.0016
RC 28NC	3	.0736 ***	8	.0075
RC 38NB	3	.0373	8	.0078
RC 23ND	3	.0074	8	.0067
RC 22SD	3	.0430	8	.0267
RC 17NC	3	.0204 **	8	.0043
RC 4NC	3	.2608 ***	8	.0174
RC 12NC	3	.0013	8	.0302
RC 23SD	3	.1093	8	.0520
RC 18SB	3	.0077 ***	8	.0008
RC 31SD	3	.0987	8	.3850

Table 3. Bulk density, infiltration rate, species complexity, sand/(silt + clay) and organic matter values of transect sectors in the Spire Rock and Greek Creek campgrounds in the Gallatin National Forest (1972).

	Transect Measurements									
	Bulk Density		Infiltration rate		Species diversity		Sand/(silt + clay)		Organic matter	
	Grams/ c.c.	Multi- iple range	inches/ hour	Multi- iple range	Ratio	Multi- iple range	Ratio	Multi- iple range	Percent	Multi- iple range
Campsite centre (a)	1.39	a	3.7	b	.05	b	2.68	a	5.65	b
$\frac{1}{2}$ distance (a to b)	1.32	a	22.6	a	.21	a	3.04	a	6.55	b
Midpoint (b)	1.09	b	38.3	a	.32	a	2.25	a	5.31	c
$\frac{1}{2}$ distance (b to c)	1.08	b	22.0	a	.33	a	1.49	b	6.58	b
Campsite centre (c)	1.37	a	8.1	b	.02	b	1.65	a	8.46	a
Campsite centre mean	1.38		5.9		.035		2.17		7.06	
Between centre mean	1.16		27.6		.29		2.28		6.15	

1/ Means followed by a common letter are not different at P = .05.

Table 3. Continued

Source of variance	D.F.	<u>Analyses of Variance</u>				
		Bulk density	Infiltration rate	Species density	Sand/ (silt + clay)	Organic matter
Campsite sectors	4	.1168 ***	3,738.17 ***	.0991 ***	3.781 **	1988.29 ***
Campsites	4	.2827 ***	2,186.91	.0023	2.765	38.11
Error	15 <sup>2/</sup>	.0133	818.69	.0011	.79	24.97

<sup>2/</sup> Loss of one degree of freedom in infiltration error variance due to calculation of one missing plot.

Table 4. Summary of bulk density at campsite centres in the proposed Red Cliff campground in the Gallatin National Forest (1972).

Campsite	<u>Bulk density at sample points</u>					Mean	Duncan's Multiple Range
	A0	A10	B10	C10	D10		
23N	1.08	1.36	1.25	1.30	1.25	1.25	                       
18S	1.18	1.28	1.20	1.12	1.07	1.17	
28N	1.15	1.18	1.16	1.03	1.08	1.12	
22S	1.10	1.12	1.08	1.02	1.13	1.09	
3S	1.01	1.04	1.06	1.14	0.83	1.02	
23S	1.09	1.14	1.19	1.01	0.69	1.02	
12N	1.00	1.01	1.02	0.98	0.57	0.92	
31S	0.96	0.87	0.80	0.91	0.94	0.90	
12S	0.79	0.90	1.26	0.71	0.84	0.90	
38N	0.80	0.66	0.88	0.94	1.18	0.89	
4N	0.93	0.96	0.75	0.48	0.88	0.80	
17N	0.76	0.74	0.66	0.75	0.93	<u>0.77</u>	
Mean						0.97	

Table 5. Soil bulk density analysis of variance results of 12 campsites in the proposed Red Cliff campground in the Gallatin National Forest (1972).

Campsite	Source of Variance			
	Between transects		Within transects	
D.F.	Mean square	D.F.	Mean square	
22S	15	.0319	32	.0199
12N	12	.0470	26	.0271
17N	15	.0204	32	.0147
31S	10	.0458	22	.0250
23N	13	.043 ***	28	.008
38N	14	.0653 ***	30	.0188
28N	14	.0781 ***	30	.0122
4N	13	.1099 ***	28	.0149
18S	12	.0508 ***	26	.0171
23S	13	.0934 ***	28	.0230
12S	12	.1532 **	26	.0688
3S	11	.0337 ***	24	.0083

non-significant differences among transect means. The sites with non-significant mean squares were found in areas of the campground in which the dominant vegetational cover was either open grassland or timber in character. The non-significant sites 17N, 12N, and 31S had overall high organic matter levels (Table 6), which in a pristine area could mask bulk density differences resulting from particle size differences.

Correlation coefficients and regression b-values between bulk density, organic matter, sand/(silt + clay), species diversity index and infiltration rate, for all study areas, are shown in Tables 7, 8, 9, and 10.

Correlative coefficients based on the combined data for Greek Creek and Spire Rock campgrounds are shown in Table 7. As organic matter increased, bulk density decreased as shown by an r-value of  $-.769^{***}$ . The relationship between bulk density and the sand/(silt + clay) ratio had an r-value of  $+0.568^{***}$ . As the sand level increased, so did bulk density. Bulk density and the species diversity index were also highly correlated. The  $-0.558^{***}$  r-value indicated that as bulk density increased, the diversity index decreased. Bulk density x infiltration rate was highly correlated at  $r = -0.467^{**}$ . As bulk density increased, infiltration rate decreased.

A similar pattern of relationships can be observed at Spire Rock - Greek Creek campgrounds for bulk density and other measured factors at campsite centre sectors (Table 8) and sectors between campsite centres (Table 9). The relationship between bulk density and sand/(silt + clay)

Table 6. Summary of organic matter levels at campsite centre sectors in the proposed Red Cliff campground in the Gallatin National Forest (1972).

Campsite	Organic matter levels at sample points						Duncan's Multiple Range
	A0	A10	B10	C10	D10	Mean	
17N	15.31	19.51	18.16	17.29	16.00	17.25	
38N	14.67	17.69	12.89	12.22	14.93	14.48	
4N	11.00	8.13	11.29	19.33	8.60	11.67	
12N	7.56	8.62	10.49	11.27	15.05	10.60	
31S	8.64	12.96	10.98	9.67	8.69	10.19	
23S	7.48	4.92	6.83	9.30	17.96	9.30	
12S	9.31	8.27	3.27	12.67	8.16	8.34	
28N	7.04	8.47	7.00	6.98	6.71	7.24	
3S	7.03	6.12	6.94	5.48	9.28	6.97	
22S	5.34	5.20	5.62	5.36	4.49	5.20	
23N	6.78	4.07	5.07	3.74	4.42	4.82	
18S	3.56	2.20	3.23	4.09	4.36	<u>3.49</u>	
Mean						9.13	

Table 7. Correlation coefficients (r) and regression slope-line b values for all combinations of bulk density, organic matter, sand/(silt + clay), diversity index and infiltration rate based on combined data at the Greek Creek and Spire Rock Campgrounds in the Gallatin National Forest (1972).

	Organic matter	Sand/(silt + clay) ratio	Diversity index	Infiltration rate
Bulk Density	r = -.769 b = -12.529	r = .568 *** b = .124	r = -.558 *** b = -.324	r = -.467 ** b = -33.902
Organic Matter		r = -.248 * b = -.799	r = -.005 b = -.148	r = .137 b = 1.144
		Sand/(silt + clay) Ratio	r = -.181 b = -.025	r = -.124 b = -4.087
			Diversity Index	r = .508 *** b = .002

Table 8. Campsite centre sector correlation coefficients (r) and regression slope-line b values for all combinations of bulk density, organic matter, sand/(silt + clay), diversity index and infiltration rate of sample points on transects in the Greek Creek and Spire Rock campgrounds in the Gallatin National Forest (1972).

	Organic matter	Sand/(silt + clay) ratio	Diversity index <sup>1/</sup>	Infiltration rate
Bulk Density	r = -.801 b = -14.763 ***	r = .549 b = .134 ***		r = -.417 b = -19.417
	Organic Matter	r = -.372 b = -.907 **		r = .466 b = .908
		Sand/(silt + clay) Ratio		r = -.270 b = -2.666
			Diversity Index	

<sup>1/</sup> r and b values not shown for diversity index due to 8 of 10 centres having no species present

Table 9. Between campsite centre correlation coefficients (r) and regression slope-line b values for all combinations of bulk density, organic matter, sand/(silt + clay), diversity index and infiltration rate at sample points on transects in the Greek Creek and Spire Rock campgrounds in the Gallatin National Forest (1972).

	Organic matter	Sand/(silt + clay) ratio	Diversity index	Infiltration rate
Bulk Density	r = -.788 *** b = -12.670	r = .677 *** b = .121	r = -.607 ** b = -.274	r = -.356 b = -53.975
Organic Matter		r = -.575 *** b = -1.659	r = .246 b = 8.191	r = -.066 b = -1.575
		Sand/(silt + clay) ratio	r = -.634 b = -.062	r = -.182 b = -5.872
			Diversity Index	r = .173 b = .001

Table 10. Campsite centre correlation coefficients (r) and regression slope-line b values for all combinations of bulk density, organic matter, sand/(silt + clay) , diversity index and infiltration rate at sample points on transects in proposed Red Cliff campground in the Gallatin National Forest (1972).

	Organic matter	Sand/(silt clay) ratio	Diversity index	Infiltration rate
Bulk Density	r = -.836 b = -13.863	r = -.150 b = -.038	r = -.010 b = -.005	r = -.489 b = -32.946
Organic Matter		r = .043 b = .272	r = .012 b = .727	r = .212 b = .527
		Sand/(silt + clay) ratio	r = .460 b = .051	r = .082 b = 1.342
			Diversity Index	r = -.148 b = -21.847

at campsite centres and sectors between campsite centres, is shown graphically in Figure 8. Campsite centre sectors had a higher value than did sectors between the campsites. This indicates a higher bulk density in areas most exposed to human use. The relationship between organic matter and bulk density, for campsite centres and sectors between campsite centres, is shown in Figure 9. An inverse relationship between bulk density and organic matter was evident. Figure 10 shows the relationship between bulk density and infiltration rate at campsite centres versus sectors between campsite centres. A wider range of infiltration values existed at between campsite sectors. Compaction (as measured by bulk density) produced decreased infiltration rates. Infiltration rates at the between campsite locations decreased more rapidly with an increase in bulk density than did the infiltration rate at campsite centres. The reason for this is that the surface of the soil at the campsite centres has been sealed due to contamination from the camping process. Although compaction has increased, bulk densities at campsite centres, the infiltration rate at most sites is adequate to accommodate the precipitation intensities of the area. Surface soil erosion is not a serious problem.

Table 10 shows the correlation coefficients and regression values for campsite centres at the proposed Red Cliff campground. The bulk density x organic matter correlation was highly significant at  $-.836^{***}$  while all other correlations were non-significant. The bulk density x organic matter correlation points out the strong influence of organic

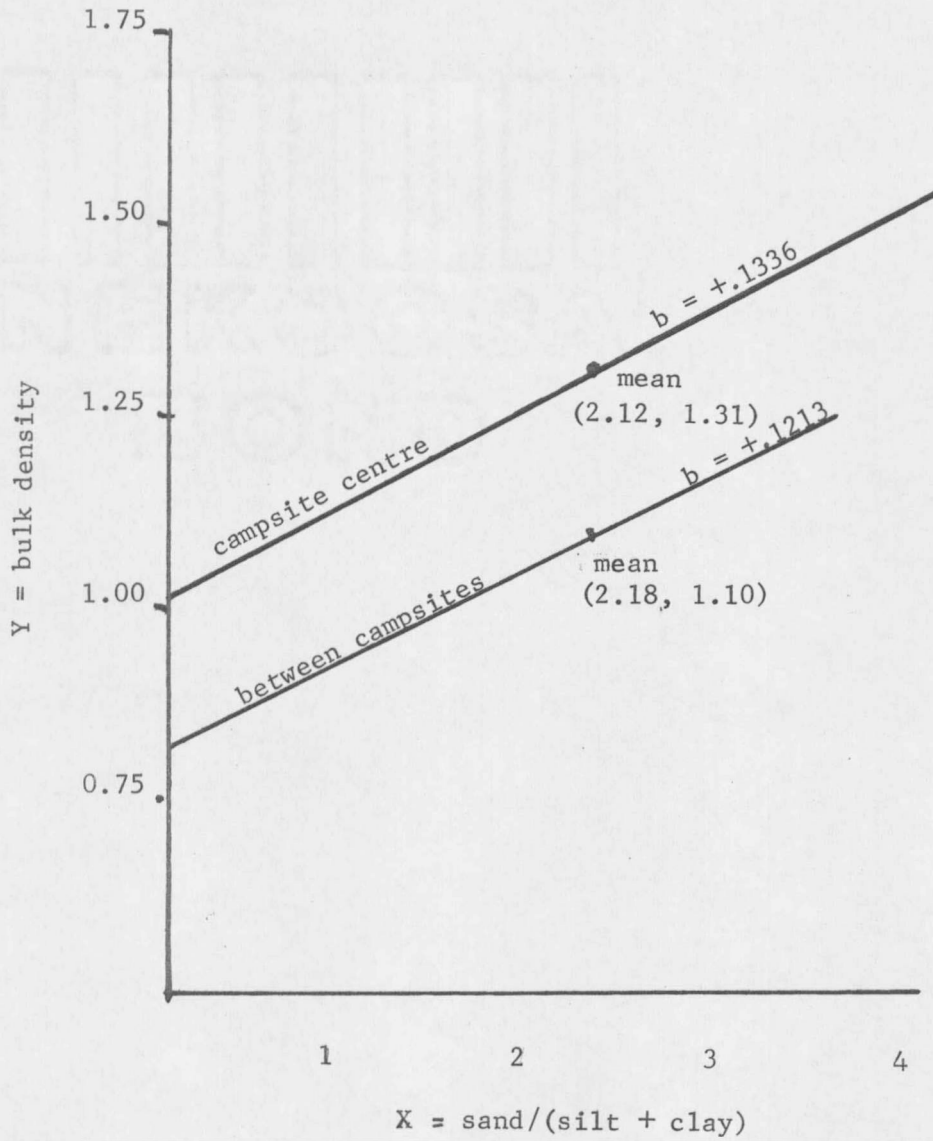


Figure 8. Relationship of sand/(silt + clay) to bulk density at campsite centres and sectors between campsite centres in Spire Rock and Greek Creek campgrounds in the Gallatin National Forest (1972).

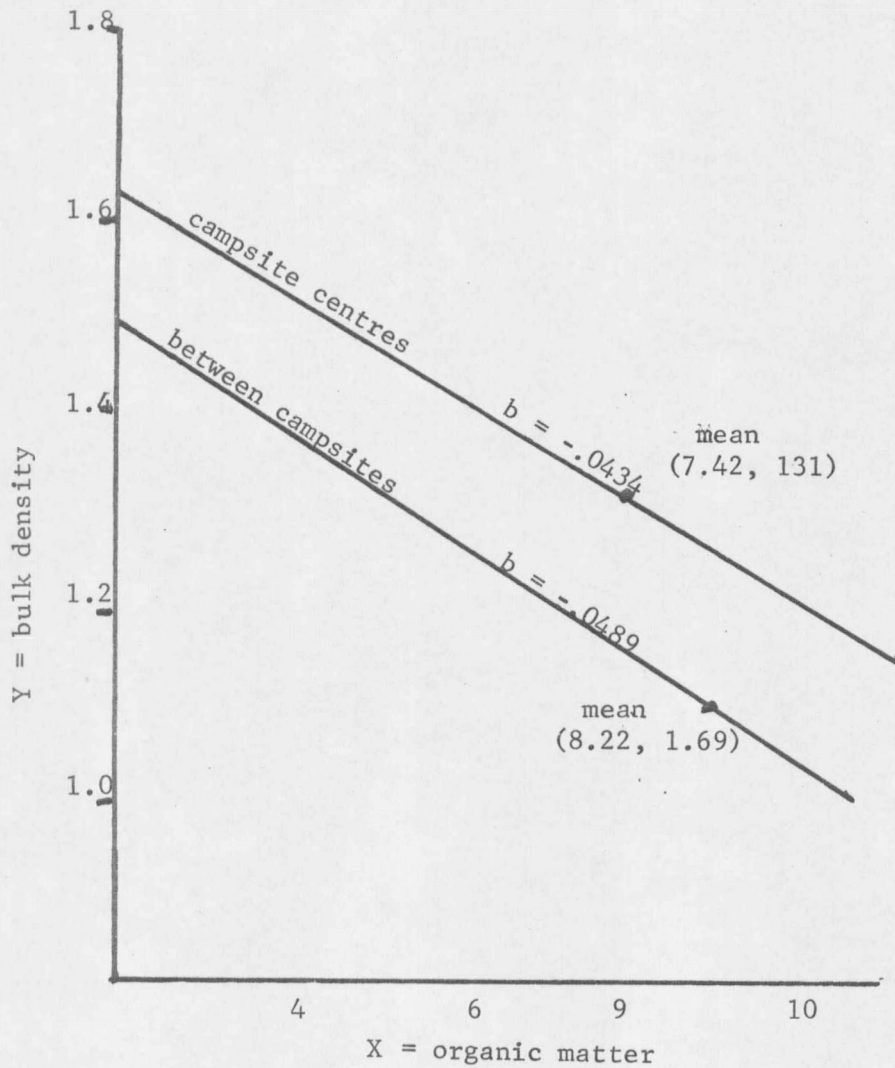


Figure 9. Relationship of organic matter to bulk density at campsite centres and sectors between campsite centres in Spire Rock and Greek Creek campgrounds in the Gallatin National Forest (1972).

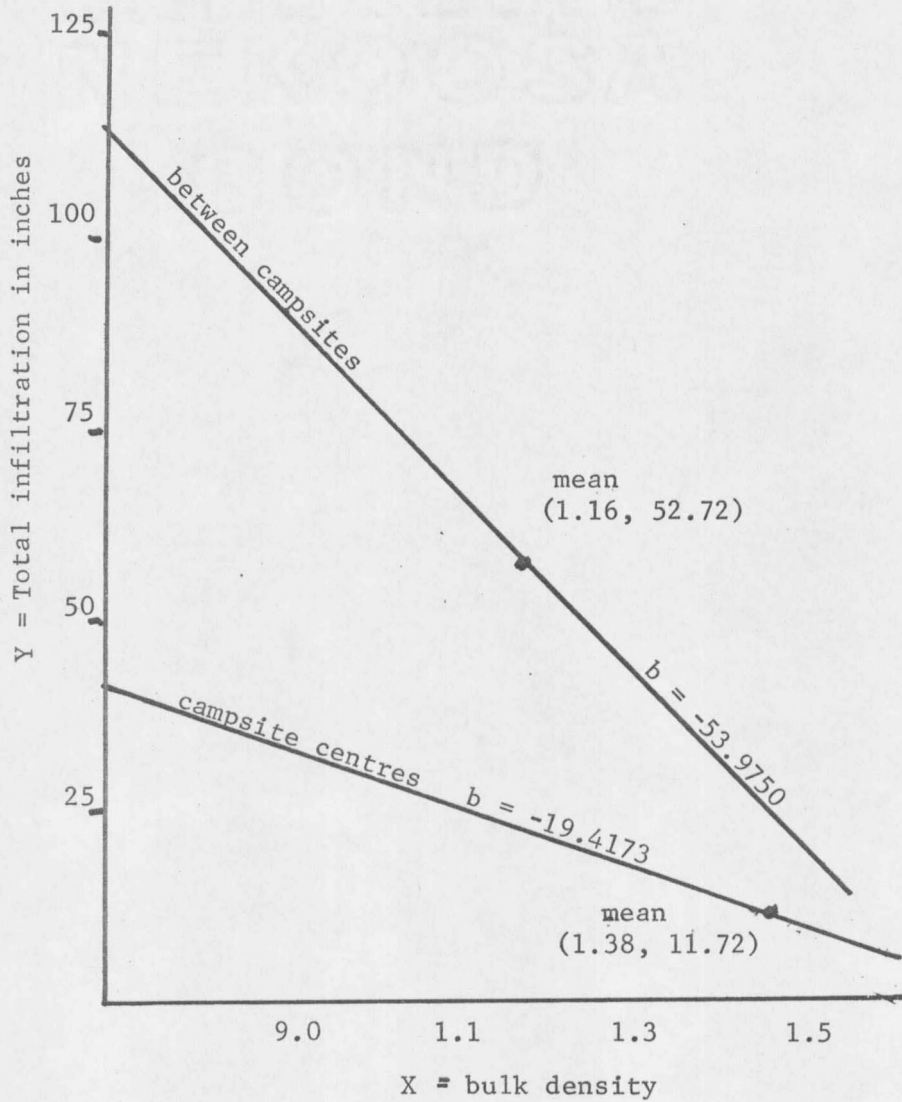


Figure 10. Relationship of bulk density to total infiltration at campsite centres and sectors between campsite centres in Spire Rock and Greek Creek campgrounds in the Gallatin National Forest (1972).

matter on bulk density. Although the bulk density x infiltration rate relationship was non-significant at Red Cliff, the  $-.489$   $r$  - value was within a few hundredths of being significant at  $p = .10$ . Soil structure and aggregation may be exerting a stronger influence than bulk density, per se, on infiltration rate in the undisturbed campground sites.

Table 3 indicates that mean organic matter levels (7.06%) are higher at campsite centres than are the organic matter levels (6.15%) at sectors between campsites in the established campgrounds. It was apparent that there was an organic matter input at established campsite centres. The campsite centres have probably been contaminated with organic residues from the camping process. Discarded ashes and charcoal from the campsite fireplace, cooking residues, trampled leaves and cones and other refuse from human activity has found its way into the soil at campsite centres and has contributed to the organic matter content. The mean organic matter level of all campground centre sample points at Red Cliff (Table 6) was 9.13.

Correlations involving the organic matter relationships, not previously discussed, were largely non-significant. However, the sand/(silt + clay) x organic matter relationships at all locations, except Red Cliff, were significant. The overall sand/(silt + clay) x organic matter correlation  $r$ -value was  $-.248^*$  (Table 7). Campsite centres and sectors between campsite centres had significant  $r$ -values of  $-.372^{**}$  (Table 8) and  $-.575^{***}$  (Table 9), respectively. As levels of sand/(silt + clay) increased, organic matter decreased. Figure 11 shows the

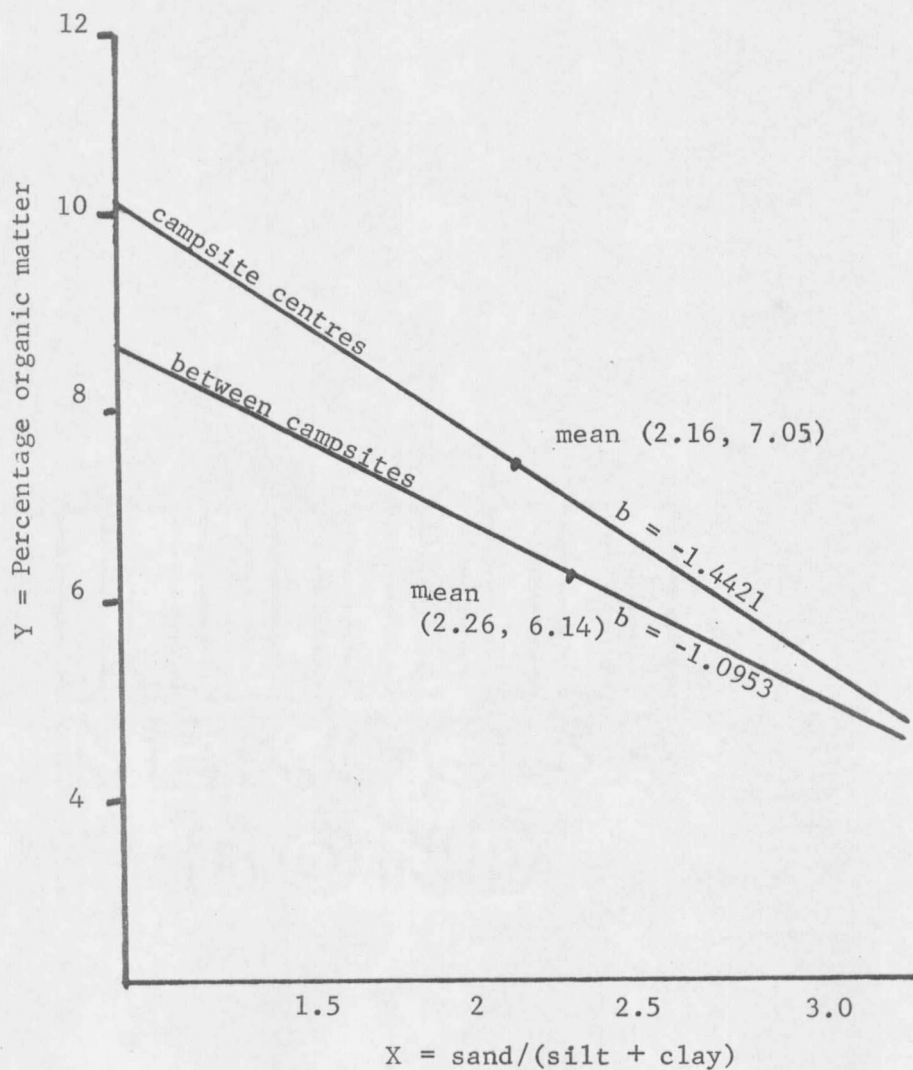


Figure 11. Relationship of sand/(silt + clay) to organic matter at campsite centres and sectors between campsite centres in Spire Rock and Greek Creek campgrounds in the Gallatin National Forest (1972).

relationship between sand/(silt + clay) and organic matter at campsite centres and between campsite centres. Although organic matter levels are higher at the centres, with increasing sand/(silt + clay) the centre organic matter levels declined more rapidly than did organic matter levels at sectors between campsite centres.

An r-value was calculated for silt + clay x organic matter. The +.519 \*\*\* correlation coefficient suggested that organic matter was included to a large measure, in the silt + clay particle size fractions. This relationship is reflected in Figure 12. As silt + clay increased, so did organic matter.

Table 3 indicates relatively similar levels of sand/(silt + clay) at campsite centres and sectors between campsite centres at Spire Rock - Greek Creek. Mean sand/(silt + clay) values are 2.17 at centre sectors and 2.28 at between centre sectors. The mean (1.46) Red Cliff sand/(silt + clay) value (Table 11) was lower than established campground means. Once again, the Duncan's Multiple Range test separated Red Cliff transects into the north and south loops.

The only significant sand/(silt + clay) correlation, not previously mentioned concerns the sand/(silt + clay) x diversity index at sectors between campsite centres in the established campgrounds. This combination produced a negative correlation with  $r = -.634$  \*\* (Table 9). As sand levels increased, species diversity decreased.

Table 3 shows the severity of trampling, particularly at campsite centres, on the species diversity index at the established campgrounds.

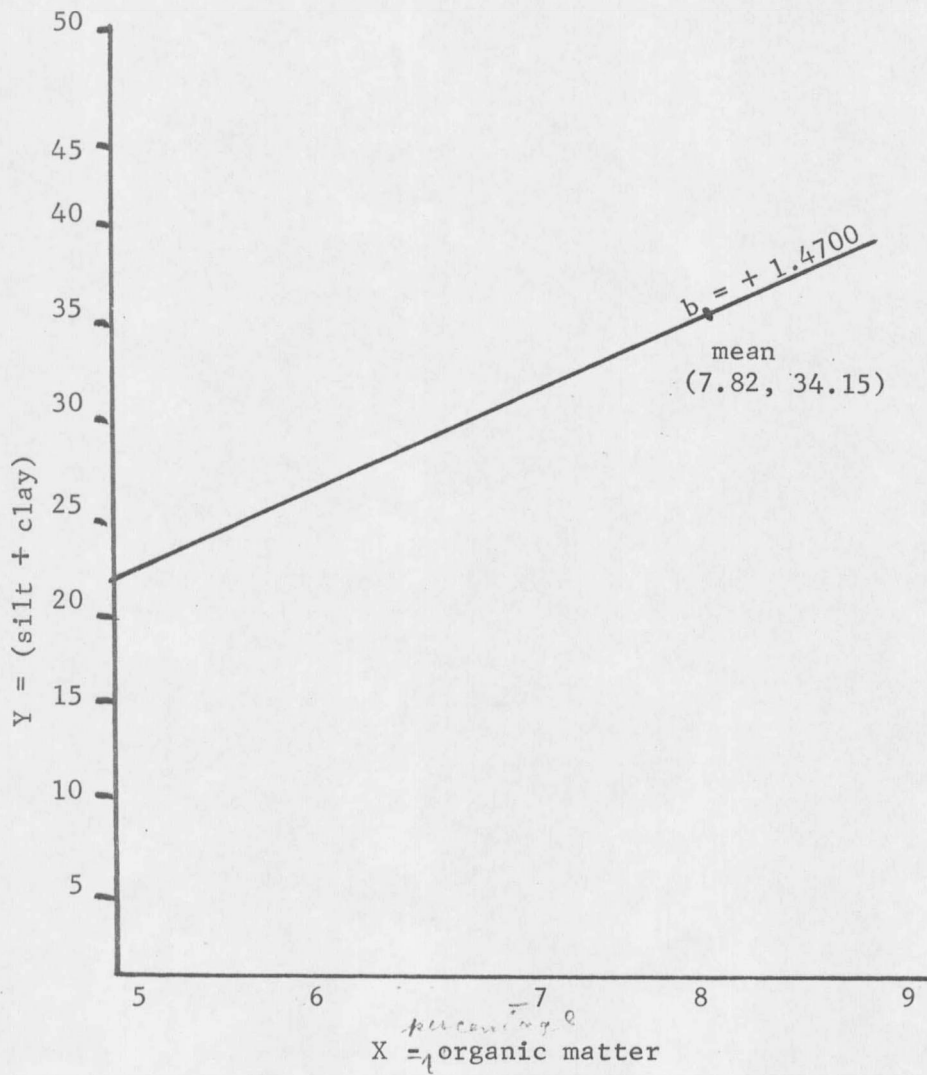


Figure 12. Overall relationship of organic matter to (silt + clay) in the Spire Rock and Greek Creek campgrounds (1972).

Table 11. Summary of sand/(silt + clay) ratios in twelve campsite centre sectors in the proposed Red Cliff campground (1972).

Campsite	Ratio at Sample Points						Duncan's Multiple Range
	0	A10	B10	C10	D10	Mean	
12S	2.82	2.31	3.50	3.50	1.62	2.75	                     
23S	1.62	3.95	1.92	2.51	2.55	2.51	
18S	1.37	1.92	1.26	1.49	2.31	1.67	
22S	1.17	1.67	2.82	1.05	1.62	1.67	
4N	0.82	1.13	0.70	3.35	1.13	1.43	
38N	1.92	1.17	1.17	1.08	1.26	1.32	
17N	1.37	1.17	1.17	1.17	1.37	1.25	
12N	1.08	1.17	1.37	1.26	1.17	1.21	
3S	1.07	0.99	1.17	1.34	0.78	1.07	
28N	0.85	1.09	0.84	1.34	0.85	0.99	
31S	0.78	1.34	0.85	0.88	0.99	0.97	
23N	0.85	0.61	0.72	0.72	0.63	<u>0.71</u>	
Mean						1.46	

The campsite centre mean value for species diversity was .035. The corresponding mean at sectors between campsite centres was .29. The multiple range test clearly separates the centre sectors from the between centre sectors of transects at Greek Creek - Spire Rock. The Red Cliff species diversity mean was .32 (Table 12). At the relatively undisturbed Red Cliff site, however, plant dominance in communities was common. Species diversity is not necessarily a measure of vegetational groundcover density.

Infiltration rate (Table 3) was considerably higher at sectors between campsite centres (27.6) than it was at campsite centres (5.9), another indication of the effect of trampling in established campgrounds. The multiple range test, once again, clearly separates the sectors between campsite centres from the centre sectors. At Red Cliff (Table 13) the mean infiltration rate per hour was 17.18 inches at the proposed centres. Table 14 shows the infiltration test results for all Red Cliff transect test sites. Duncan's Multiple Range test, when applied to Red Cliff infiltration Tables 13 and 14, generally separated campsites into the north or south loops of the campground.

At the established campgrounds, overall diversity index x infiltration rate produced an r-value of +.508 \*\*\* (Table 7). As the species diversity index increased, a corresponding increase in infiltration rate was observed.

Figures 13 and 14 give some indication of the magnitude of differences between bulk density x infiltration rate and bulk density x

Table 12. Summary of species diversity ratios at campsite centre sectors in the proposed Red Cliff campground in the Gallatin National Forest (1972).

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<u>Campsite</u>	<u>Diversity ratio</u>
22S	.42
28N	.36
38N	.36
12S	.36
17N	.35
3S	.33
18S	.33
23S	.33
12N	.29
4N	.27
23N	.21
31S	.18
Mean	.32

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Table 13. Summary of water infiltration rate in inches per hour at proposed campsite centres (P) in the unestablished Red Cliff campground in the Gallatin National Forest (1972).

Campsite number	<u>Infiltration rate in inches</u>			Duncan's Multiple Range
	First hour	Second hour	Mean	
4N	47.25	38.19	42.72	
12N	25.25	23.75	24.50	
22S	23.25	20.44	21.85	
38N	20.69	16.37	18.33	
31S	20.70	16.10	18.40	
3S	20.20	15.70	17.95	
23S	18.56	14.88	16.72	
12S	16.56	13.82	15.19	
23N	10.31	7.13	8.72	
18S	8.63	7.12	7.88	
17N	8.75	5.81	7.28	
28N	7.19	5.69	6.44	
Mean/hr.	18.94	15.42	17.18	

Table 14. Summary of water infiltration rates in inches per hour at 0, 30 and 60-foot intervals on one base-line transect in each of eleven campsites in the proposed Red Cliff campground in the Gallatin National Forest (1972).

<u>Infiltration rate in inches</u>					
Site #	Campsite Transect	First hour	Second hour	Mean	Significant Studentized Ranges
4N	B	40.7	32.8	36.8	
31S	C	26.8	22.5	24.0	
12S	B	17.2	15.1	16.1	
12N	C	13.6	12.5	13.0	
23N	C	14.7	11.0	12.9	
22S	D	13.0	10.9	12.0	
23S	D	12.4	10.2	11.3	
17N	B	12.6	8.6	10.6	
28N	B	11.4	9.4	10.4	
38N	D	10.6	8.4	9.5	
18S	C	10.0	8.3	9.2	
Mean/hr.		16.6	13.6	15.1	

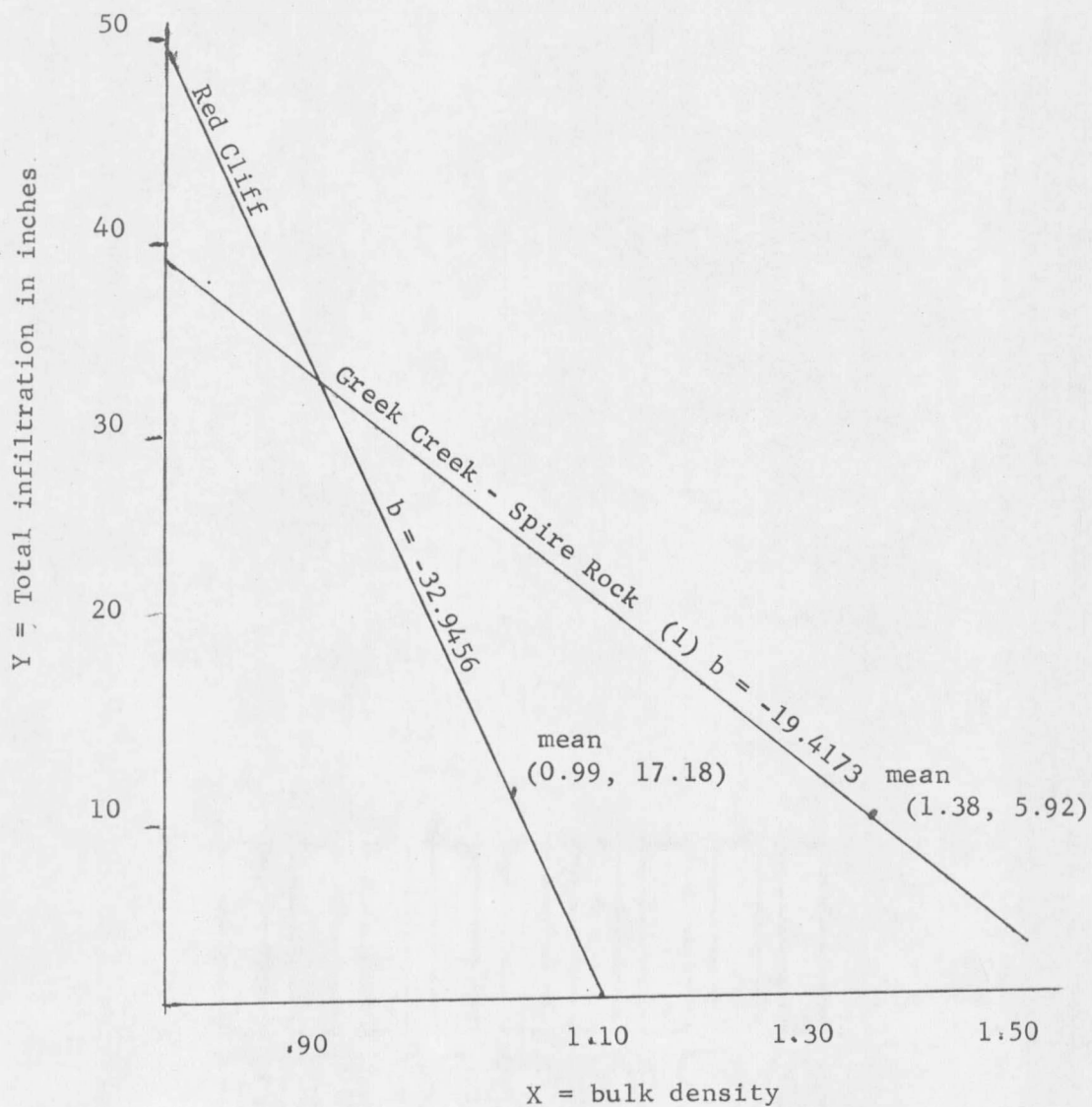


Figure 13. Relationship of bulk density to infiltration rate at campsite centres in Spire Rock - Greek Creek campgrounds and the proposed Red Cliff campground in the Gallatin National Forest (1972).

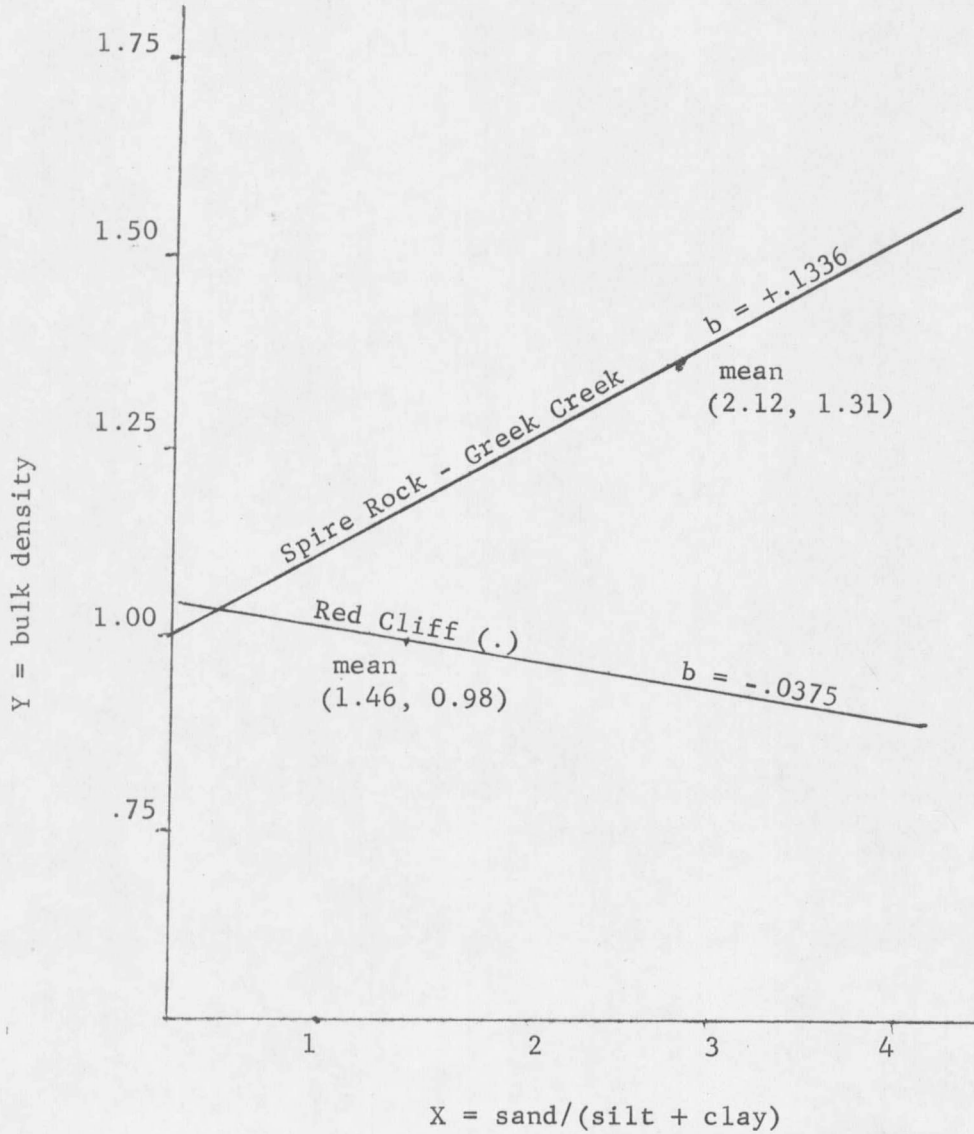


Figure 14. Relationship of sand/(silt + clay) to bulk density at campsite centres in Spire Rock - Greek Creek campgrounds and the proposed Red Cliff campground in the Gallatin National Forest (1972).

sand/(silt + clay) between campsite centre sectors at Spire Rock - Greek Creek campgrounds and the proposed campground at Red Cliff.

Figure 13 is a representation of the regressions of bulk density on infiltration rate at the respective campground centres. A small increase in bulk density at Red Cliff, produces a large decrease in infiltration rate. At the established campgrounds, the effect is similar in that increased bulk density will reduce infiltration rate.

Figure 14 depicts the regression of sand/(silt + clay) on bulk density at established and proposed campsite centres. At the established campsites, an increase in sand/(silt + clay) reflects an increase in bulk density. In the native, less sandy area, however, the sand/(silt + clay) ratio is not a major cause of bulk density differences between sample points. Increased levels of sand/(silt + clay) and bulk density at established campsite centres probably results from the effects of erosion and compaction. Compaction of the soil, through human use, was evident at the established campgrounds.

A series of cause and effect relationships existed at the established Greek Creek and Spire Rock campgrounds. Compaction increased bulk density. As bulk density increased, there were observed decreases in infiltration rate, species diversity and organic matter levels. As bulk density increased, so did the sand/(silt + clay) ratio.

The sand/(silt + clay) ratio is proposed as one criterion of

campground selection and design. Table 15 shows predicted use levels of bulk density, organic matter, species diversity and infiltration rate for the proposed Red Cliff campsites. The values shown in Table 15 are based on the sand/(silt + clay) measurement. The sand/(silt + clay) measurement was selected as the basis for this model as it is the simplest and quickest test to perform of those utilized in this study. Spire Rock - Greek Creek sand/(silt + clay) regression values were utilized to calculate projected Red Cliff bulk density through Spire Rock - Greek Creek mean values. The organic matter, species diversity and infiltration rate predictions were calculated from projected bulk density values. The slope lines for each individual projection were obtained from corresponding Spire Rock - Greek Creek regression coefficients and plotted through the Red Cliff mean points. Site 38N (Table 15), for example, has a sand/(silt + clay) ratio of 1.32. Bulk density was measured at 0.89 and is projected to increase to 1.11 through use. Through camper use, site 38N infiltration rates are projected to drop from 18.53 to 17.85 inches per hour. Species diversity at site 38N was measured at .36 and is projected to decrease to .33. Organic matter levels at site 38N were measured at 14.48 and are projected to decrease to 9.38 through camper use. From Table 15, it is evident that sites with a low sand/(silt + clay) ratio would be expected to withstand human use with the least possible alteration to the natural setting. Sites, such as 28N, 23N and 31S with a sand/(silt + clay) ratio near 1.00 would appear to be suited for camper use

Table 15. Comparison of measured values and impact projections for the proposed Red Cliff campground in the Gallatin National Forest (1972).

Site	Sand/(silt + clay) ratio	Bulk Density		Projected Factors					
		measured	projected	Infiltration Rate		Species Diversity		Organic Matter	
				measured	projected	measured	projected	measured	projected
22S	1.67	1.09	1.15	21.85	16.50	.42	.31	5.20	8.88
28N	0.99	1.12	1.07	6.44	19.21	.36	.34	7.24	9.88
38N	1.32	0.89	1.11	18.53	17.85	.36	.33	14.48	9.38
12S	2.75	0.90	1.28	15.19	12.10	.36	.27	8.38	7.25
17N	1.25	0.77	1.10	7.28	18.19	.35	.33	17.25	9.51
3S	1.07	1.02	1.08	12.95	18.87	.33	.33	6.97	9.76
18S	1.67	1.17	1.15	7.88	16.50	.33	.31	3.49	8.88
23S	2.51	1.02	1.25	16.72	13.12	.33	.27	9.30	7.63
12N	1.21	0.92	1.09	24.50	18.53	.29	.33	10.60	9.63
4N	1.43	0.80	1.12	42.72	17.51	.27	.32	11.67	9.26
23N	0.71	1.25	1.04	8.72	20.23	.21	.35	4.82	10.25
31S	0.97	0.90	1.06	18.40	19.55	.18	.34	10.19	10.01

with a minimum of site deterioration while sites such as 12S and 23S with sand/(silt + clay) ratios above 2.00 do not appear to be as ideally suited for camper purposes.

The sand/(silt + clay) ratio method of predicting camper use effects could be used in selection and design of sites which will withstand camper use with a minimum of deterioration to the natural setting. Subsequent research at the Red Cliff campground, after it has been opened to public use, will provide the opportunity to test projected impact levels.

## CONCLUSIONS

Transect studies of bulk density, sand/(silt + clay) ratio, organic matter percentages, species diversity and infiltration rate, at established and proposed campgrounds in the Gallatin National Forest, lead to the following conclusions:

1. Base-line transects, established at the campground under development at Red Cliff, will provide the opportunity to quantify groundcover changes and test the reliability of infiltration rate and organic matter level predictions.
2. The sand/(silt + clay) ratio of the surface three inches of soil has a strong influence in the degree of compaction resulting from camping use as measured by bulk density.
3. Increase in bulk density is related to an overall decrease in infiltration rate, organic matter content and species diversity.
4. The sand/(silt + clay) ratio is proposed as one criterion of selection and design of campground sites which will bear camper use with a minimum alteration of the natural setting.

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