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Title: Water Quality Impacts of Free Ranging Cattle in
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The purpose of this study was to evaluate the effects that free ranging cattle have on water quality in semi-arid environments. There were three specific objectives: 1) To determine the concentration and distribution of cattle feces in meadows, riparian zones, and the associated uplands. 2) To determine the fecal deposition rate of free ranging cattle directly into a stream. 3) To determine if feces near a stream, up to 2.3 meters away, are a source of pollution during rainfall and subsequent surface runoff.

As the distance from water and slope increased cow-chip concentrations decreased. The highest concentration of cow-chips was found in the meadows where winter supplemental feeding occurred. The second highest concentration of cow-chips was found in the riparian zones. Areas that had steep slopes and were a long

distance from water had the lowest concentration of cow-chips.

The amount of time the cattle spent in the stream and the fecal deposition rate changed by season. The cattle spent the most time in the stream during the summer, and the least amount of time during the fall. The direct fecal deposits were highest for summer and approximately the same for the other seasons.

In the experiment designed to evaluate the effectiveness of buffer strips, feces were placed varying distances from the edge of simulated rainfall plots and subjected to different levels of precipitation. A significant reduction in coliform concentrations was noted between the bacteria which traveled 0.7 meters through a buffer strip, as compared to those which did not have any distance to travel. Bacteria concentrations at the 0.0 meter distance averaged 42,800 coliforms/ml, whereas there were only about 2,250 bacteria/ml delivered from the feces deposited 0.7 meters away. No statistical differences were found between buffer strip widths of 0.7 meters and 2.3 meters. Buffer strip effectiveness for widths greater than 2.3 meters were not investigated and thus remain a subject for further investigation.

Water Quality Impacts of Free Ranging Cattle in Semi-arid Environments.

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Head of Department of Rangeland Resources

Redacted for Privacy

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I. INTRODUCTION

The majority of the land in the Western United States is classified as rangeland. Rangelands are generally suited for grazing, habitat, and watershed. Rangelands are usually unsuitable for farming due to poor soils, steep slopes, and restrictive climates. Some important uses for rangeland includes water yield, forage production for livestock and wildlife, habitat for wildlife, recreation, and timber production. In the Pacific Northwest, the major use of rangelands is for livestock grazing.

Grazing livestock on public and private rangeland is compatible with other uses of the land and contributes to the success of the ranching industry. However, if cattle are not managed properly they can have adverse impacts on water quality. Moore et. al. (1979), stated that animal grazing is a major land use in the western United States that can impact water quality. Potential hazards of bacterial contamination exist when cattle concentrate near streams. Proper management can help maintain acceptable water quality.

Objectives

The broad overall objective of this study was to evaluate the impact that free ranging cattle have on water quality in rangeland streams. There were three specific objectives in this study. First, to determine the concentration and distribution of cattle feces in riparian zones, and throughout the associated uplands. Second, to determine fecal deposition rate of free ranging cattle directly in a stream. Third, to determine if feces near a stream, up to 2.3 meters from the flowing water, are a source of bacterial pollution during rainfall and subsequent runoff.

Study Site

To meet the objectives of this study two different locations were utilized. The first and second objectives, fecal concentration and distribution and instream fecal deposition rate, were evaluated in a field setting in the Bear Creek drainage basin. The third objective, overland bacterial transport, was evaluated in a laboratory at Utah State University, in Logan, Utah.

Bear Creek is located in Crook County, central Oregon, about 21 kilometers southeast of the Prineville Reservoir. The Bear Creek watershed is bordered by the High Lava

Plains to the south and west, and includes the western half of the Maury Mountains in the northeast boundary with the Crooked River Canyon on its northwest boundary (Mattison and Buckhouse 1977). The study site lies between 44°00' and 43°52'30" north latitude, and 120°42'30" and 120°30' west longitude.

Bear creek is a small perennial stream that empties into the Prineville reservoir. It has an average base flow of approximately 28-84 liters per second (1-3 cubic feet per second). The average width, during low flows, is 0.5 to 1.5 meters. The average depth, during low flows, is 4 to 30 centimeters.

Bear creek is characterized by riparian meadows along the creek with juniper, shrub, and grass ecosystems existing in the uplands. The upland forage is generally dry and relatively unpalatable by mid-summer.

The second location, Utah State University, has a indoor programmable spray-type infiltrometer which enabled application control over the testing surfaces. The infiltrometer was consistent, which allowed for controlled replicated experiments. The indoor laboratory also allowed control over the environment. Permission from the Range Science Department at USU was obtained to conduct the overland bacterial transport experiment.

II. LITERATURE REVIEW

Animal Behavior

Riparian Zones

Riparian zones are those areas associated with streams, lakes, or wet areas where plant communities are predominantly influenced by the presence of water (Roath and Krueger,1982). Riparian zones are very small (0.5-2%) when compared to the entire range. Though these areas are small they provide up to 20% of all forage produced on rangelands (Reid and Pickford 1946, Roath 1980).

The results of two studies show that riparian preference by cattle has a seasonal pattern (Marlow and Pogacnik 1986, and Bryant 1982). During the latter part of the grazing season cattle tend to concentrate in the riparian zones. The concentration of cattle in riparian areas during the late season may be due to the presence of higher quality forages (Marlow and Pogacnik, 1986). Kauffman et. al. (1983) reported that the forage in riparian areas was higher in nutrients and more palatable than in the uplands during late August and September. Roath and Krueger (1982) and Krueger (1983) found that when used in conjunction with uplands, riparian areas were highly preferred by cattle with as much as 81% of their diet from these areas.

Temperature is also a factor that determines the distribution of cattle. A more favorable microclimate in the uplands during cold weather will help draw cattle away from riparian zones. Cattle also tend to concentrate on southerly slopes during cold weather to take advantage of the warmer microclimate. Conversely, while the temperature is hot, the cold sinking air in a riparian zone helps create a more favorable cool microclimate for cattle (Bryant 1982, Cargill and Stewart 1966, Johnson et. al. 1962).

Water availability is another very important factor in determining cattle distribution. The accessibility of water sources may be the most important factor influencing the distribution of cattle (Cook and Jeffries 1963, Glendening 1944, Martin and Ward 1970). Cattle prefer the free-flowing water in a riparian zone over the lower quality water that is found in the impoundment ponds and troughs in the uplands (Gillen et. al. 1985). Bryant (1982) found that alternative water sources that were separated from riparian zones by steep slopes had little effect on cattle distribution.

Cattle have a tendency to concentrate in riparian zones during the summer and fall, especially while the temperature is hot. As cattle concentrate near streams they can have a direct impact on water quality (Moore et. al. 1979).

Uplands

Mueggler (1965) has shown that as steepness of slope increases, use by cattle decreases. Cattle will prefer level ground to steep slopes if they have a choice. The slopes in riparian zones and adjacent meadows are usually very gentle, while slopes in the uplands can be greater than 40 percent. Cook (1967) found that as cattle were driven out of the bottom lands, the use of adjacent slopes of 35 percent or less, increased from 7 to 27 percent. Cook (1966) noted that thick brush or lack of trails leading to higher slopes can also limit cattle use of upper slopes and benches, and by providing trails or roads will help increase the use of these areas.

As previously stated, distance from water is another important factor in the distribution of cattle. Cook (1966) found that as the distance from water increased, the utilization of an area by cattle decreased. Cattle will only travel about 3-5 miles per day, thus limiting the distance they will travel from a source of water (Walker et. al. 1985, Sneva 1969). Since cattle will drink at least once each day, they will stay close to a source of water (Sneva 1969, Cully 1938).

Bacterial Contamination

Sources

Bacteria from the enteric tract are used as the primary indicators of livestock impacts on surface water quality. Though fecal coliforms and fecal streptococci are not pathogenic, they are easily analyzed. These organisms are the primary indicators for the potential presence of pathogens (Moore et. al. 1979). Most bacterial water quality criteria are based on the number of these organisms present. The extent or severity of this impact is dependent upon the number of cattle in the pasture and where they deposit their feces.

Bacteria carried in animal waste can be transferred to humans via water (Diesch 1970). As recreational use of rangeland streams increases, the possibility of contracting a bacterial disease from water will increase. Some potential diseases that can be transferred to humans from infected cattle are; Salmonellosis, Leptospirosis, Anthrax, Tuberculosis, Johnes Disease, Brucellosis, Listeriosis, Tetanus, Tularemia, Erysipelas, and Colibacilosis (Azevedo and Stout 1974). However, it must be remembered that the use of bacterial indicators are just that. Coliform tests were originally designed for public health reasons. They were used to test drinking water which may have been contaminated by contagious wastes from human beings. Since specific disease causing organisms are very difficult to trap and culture, the benign but ubiquitous coliform group was chosen. They are easy to test, simple to culture, and indicative of fecal contamination from warm blooded animals. A test designed for public water systems which may have been contaminated by wastes from human beings may not be directly applicable to wildland wastes which may have ruminant fecal contamination present. Bohn and Buckhouse (1985) have published a thoughtful discussion of the uses, and possible abuses, of coliform bacteria as a wildland waste indicator. They were concerned with the possible shortcomings of coliform bacteria as a wildland water indicator. They raised questions of the ability of pathogens to "track" similarly to the coliform group in natural systems. It has also been recognized that fecal contamination originating from ruminants carries a reduced risk of disease transmission to human beings as compared to the same coliform concentrations that originate from other human beings. As a consequence, fecal coliform to fecal streptococcus ratios have been developed in an attempt to quantify species origin of the contaminates (Geldreich 1970).

Transport

Total fecal output of cattle will range from 0.5 - 0.75 percent of body weight per day, on a dry weight basis

(Kronberg et. al. 1986, Johnstone-Wallace and Kennedy 1944). Free ranging cattle will defecate an average of 12 times per day (Arnold and Dudzinski 1978, Julander 1955, Johnstone-Wallace and Kennedy 1944, Hafez 1969). This is an average fecal output of 0.04 to 0.06 percent of the body weight per defecation.

Hafez and Schein (1962) found that fecal deposits from cattle were indiscriminately distributed throughout a pasture. This non uniform distribution can result in approximately 0.4 - 2.0 percent of the area covered by fecal deposits (Omaliko 1981, MacLusky 1960). However, in certain areas e.g. water troughs, gates, fence lines, and bedding areas, feces concentrations may be a lot higher (Hafez and Schein 1962).

Bacteria in fecal material may remain viable for at least one grazing season (Buckhouse and Gifford 1976). This leaves the potential for bacterial contamination long after the cattle have been removed from the site. However, bacteria in fecal material have to reach the stream before any contamination can be caused. Bacteria from feces can reach a stream by either direct deposit or by overland transport from a runoff event.

Peak fecal coliform concentrations are related to runoff events (Stephenson and Street 1978). However, rainfall events large enough to cause runoff in semi-arid sites are very infrequent. This high concentration of coliforms may come from bacteria in the stream bottom sediments. Sherer et. al. (1988) found that fecal coliform counts rose from 1.8 to 760 million organisms per m^2 of bottom sediment that was disturbed. This would indicate that there is a high concentration of coliforms in the bottom sediments.

Buckhouse and Gifford (1976) and Johnson et. al. (1978) have shown that as grazing intensity increases, coliform counts in the stream increase. When cattle are present in riparian areas they can deposit fecal material directly into the stream (Johnson et. al. 1978, Larsen et. al. 1988). The majority of the bacteria in the deposited feces will rapidly settle to the stream bottom and can be re-suspended at a later time (Biskie et. al. 1988).

Sherer et. al. (1988) also noted that when cattle had not had recent access to the stream, bacterial counts were similar to an area protected from grazing. Following the removal of cattle, one to several months may be needed for coliform counts in a stream to return to background levels (Johnson et. al. 1978, Tiedemann et. al. 1987).

Runoff from snow melt or rainfall can carry viable bacteria into the stream. Doran and Linn (1979) found that runoff from a grazed pasture had coliform concentrations 5-10 times higher than from an ungrazed pasture. However, Buckhouse and Gifford (1976) utilized a small plot infiltrometer and concluded that bacteria did not travel farther than 1.0 meter in a sandy loam range site. The relationship of source-distance and transport is not well understood in rangeland environments, and more information is needed (Springer et. al. 1983).

There are very few studies that deal directly with buffer strip width and microbial pollution. Doyle et. al. (1975) studied forested buffer strips in controlling microbial pollution on a gravelly silt loam soil spread with 90 metric tons per hectare of dairy manure. They concluded that no significant movement of bacteria was observed beyond 3.8 m, but had elevated bacterial concentrations at the 0.0 m distance.

Glenne (1984) looked at a model which simulated the generation of water pollution in three watersheds in Northern Utah. Glenne noted that a buffer strip approximately 50 meters wide is needed to reduce bacterial concentrations by 90% on a 10% slope, and 90 meters on a 20% slope.

Buffer strips and total solids, nitrogen, and phosphorus relationships have been observed in other studies. Bingham et. al. (1980) studied buffer strips in relation to control of sediments including phosphorus and nitrogen for poultry wastes spread across clay loam fields. They concluded that the buffer strips needed to be as wide as the spread width of manure, i.e. if manure was spread 13 meters wide, at least 13 meters of a buffer strip was necessary.

Other researchers have looked at vegetative filters and their effectiveness for livestock feedlot treatment. Dickey and Vanderholm (1981) found that vegetative filters, up to 400 meters in distance, reduced nutrients and solids by as much as 80%. They also stated that bacteria levels in the feedlot runoff were not significantly reduced, with concentrations as high as 1.05×10^7 per 100 ml. Dillaha et. al. (1988) reported that vegetative filter strips 9 meters wide, on a silt loam soil were effective at removing total sediments, but ineffective at removing nitrogen and phosphorus. Dillaha et. al. did not look at bacterial concentrations.

It is evident that buffer strip relationships between free-grazing animals and bacterial concentrations in streams are little known. Research designed to further this knowledge needs to be addressed.

III. METHODS

Feces Concentration and Distribution

The distribution of cow-chips from free ranging cattle was determined by using belt transects, as described by Neff (1968). The transects were 0.7 x 30 meters for a total of 21 square meters each. A 30 meter tape was stretched in a straight line, and with the aid of a frame which was 0.7 meters wide, the transects were laid out and cow-chips counted. Cow-chip concentrations were used to determine which areas were frequented by cattle. It was assumed that the number of cow-chips reflect the amount of time the cattle spent in each site, which identifies areas that cattle prefer. The higher the concentration of chips per transect the higher the preference of the cattle for the area.

The rancher's records showed that the pasture evaluated, had 188 cattle from May 2, to June 4, 1986. The pasture also had 230 cattle from December 18, 1986 to January 10, 1987. During 1988, there were 217 cattle from December 7, 1987 through January 21, 1988. Also, there were 242 cattle from January 21, 1988 through February 18, 1988. For Spring 1988, there were 500 cattle in the pasture from April 15, 1988 through May 1, 1988.

The Haughton Sontag pasture was divided into 36 different areas (figure 1), each area representing a different combination of vegetational and topographical characteristics. The characteristics used to make the divisions between each area were: 1) Distance from water. 2) Percent slope. 3) Dominant vegetation type and cover. 4) Aspect. 5) Cultural practice. Cultural practices consisted of farming and harvesting hay, winter supplemental feeding areas, and clearing of Juniper trees. There were 50 transects sampled at each area for 1987, winter 1988, and spring 1988.

Instream Fecal Deposition

During several observation periods, 5 different groups of cattle were monitored for number of defecations in a stream. This was accomplished by choosing observation points that would maximize the viewing of cattle, and minimize disturbance that would alter their behavior. Depending on brush and topographic conditions, the observers were either near the stream or several hundred meters away on top of surrounding hills. In order to be inconspicuous while observing near the stream, each person was camouflaged with brush or sat in a vehicle. When observing from a distance, eight-power field binoculars and twenty-power spotting scopes were used.

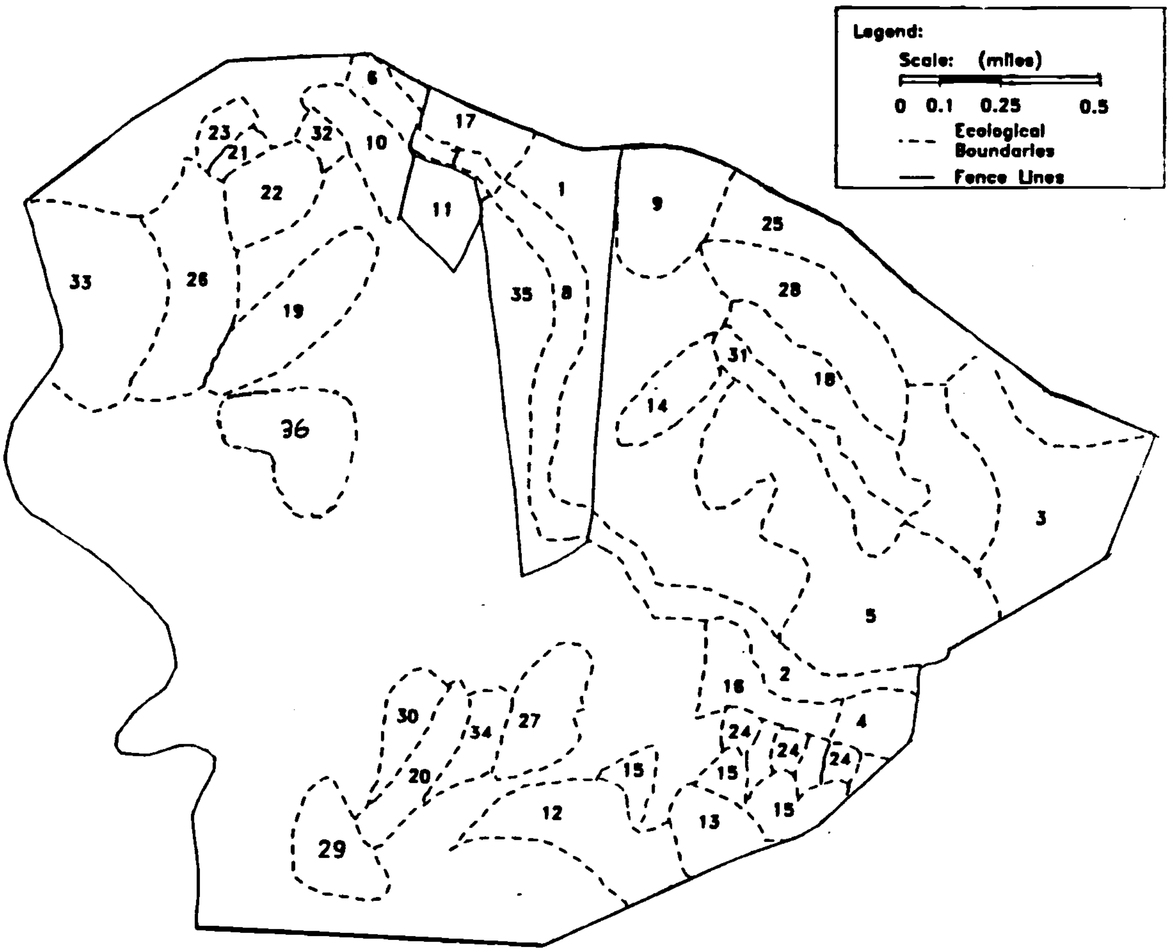


Figure 1. Map showing the 36 areas depicted within the Haughton-Sontag pasture, Bear Creek, 1987-88.

The cattle were observed during the daylight period. Night observations were attempted by using a seven-power Smith and Wesson Star-Tron night scope, model MK303-A. Because of the inability to consistently detect defecations through the Star-Tron scope, night observations were discontinued.

Overland Bacterial Transport

The experiment for the bacterial movement through grass vegetation was conducted in a laboratory. The use of a programmable spray-type infiltrometer enabled application control. The indoor laboratory was maintained at a constant temperature of 21°C. Wind affects were eliminated. Since the Logan city water supply was used to operate the infiltrometer a small amount of chlorine was present, but was considered inconsequential (Miner 1988, personal communication).

There were four plot frames built. Each plot frame was constructed from 2 X 8 boards. These frames were 0.43 m wide and 2.5 m long. Hardware cloth was tacked on the bottom of each frame. A layer of gravel covered by sand was placed over the hardware cloth in order to provide a porus medium for water to percolate through. There was a drainage trough at the end of each frame which helped collect all the runoff water. A drawing depicting the construction of these frames is shown in Figure 2.

Kentucky bluegrass (Poa pratensis) sod was placed on top of the sand. The sod was cut 45 cm wide and compressed into the frame in order to seal the edges. The same sand was used throughout all of the experiments in the project. A new section of sod was placed on top of the sand or plastic for each of the experiments.

The frames were placed on a bench to control slope. The slope was maintained at 5 percent, in order to represent the slope of a typical riparian zone. Each frame was placed 2.4 meters underneath the corresponding infiltrometer pod. Each pod had three nozzles which rotated in order to sprinkle the entire plot evenly. A drawing depicting the arrangement of the frames to infiltrometer pods is shown in Figure 3.

The movement of bacteria was determined by using dairy cattle fecal material as a source of bacteria. Each feces sample was placed on a new piece of sod, to avoid contamination from the previous fecal deposit. The drainage troughs were cleaned at the end of each run by using chlorine bleach and rinsing with 10% solution of $Na_2S_2O_3$.

All of the fecal material was collected at the beginning of the experiment at a local dairy. After mixing with a cement mixer, the fecal material was poured into freezer bags. The volume of each sample was 1135 cm^3

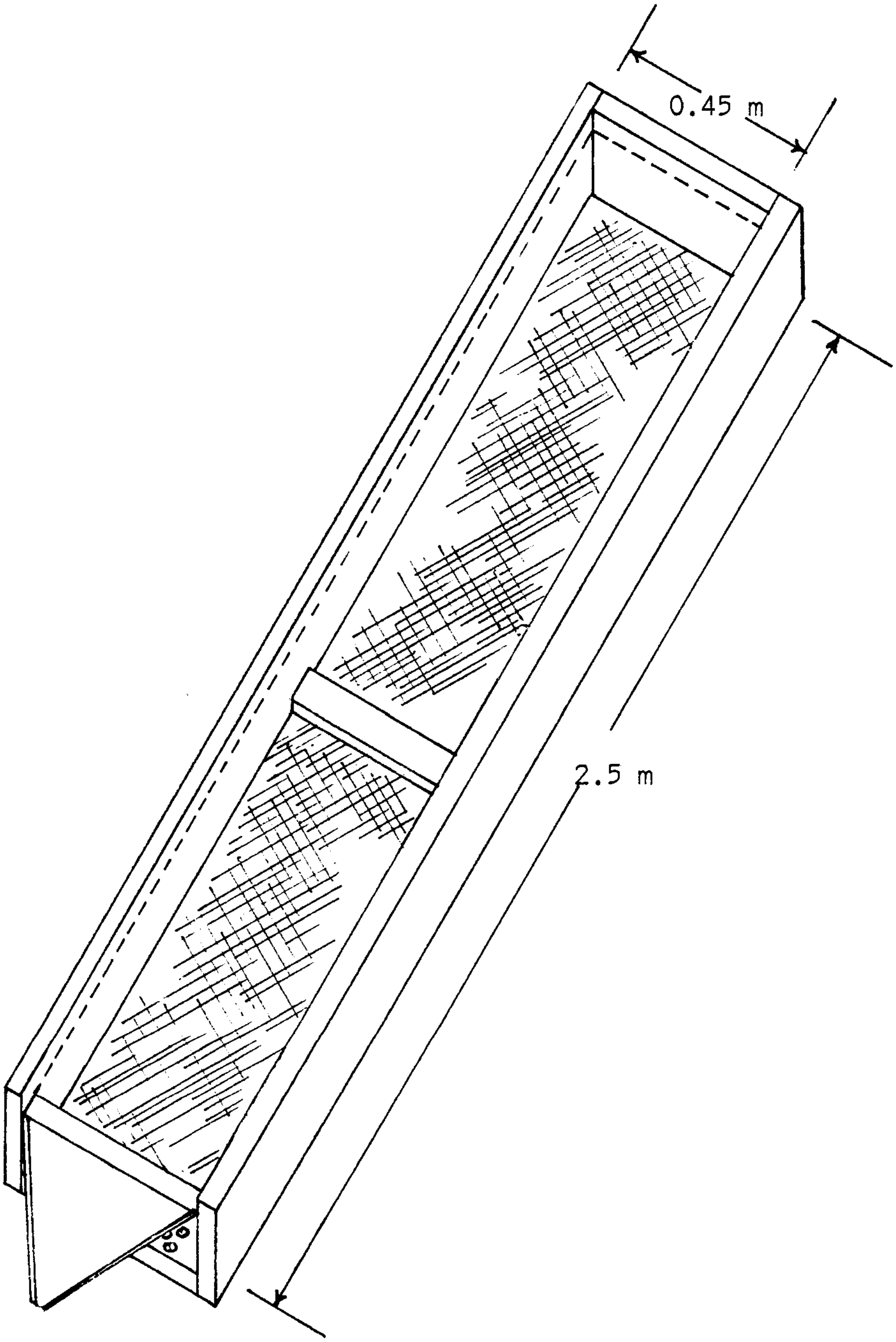


Figure 2. Drawing depicting the construction of each frame.

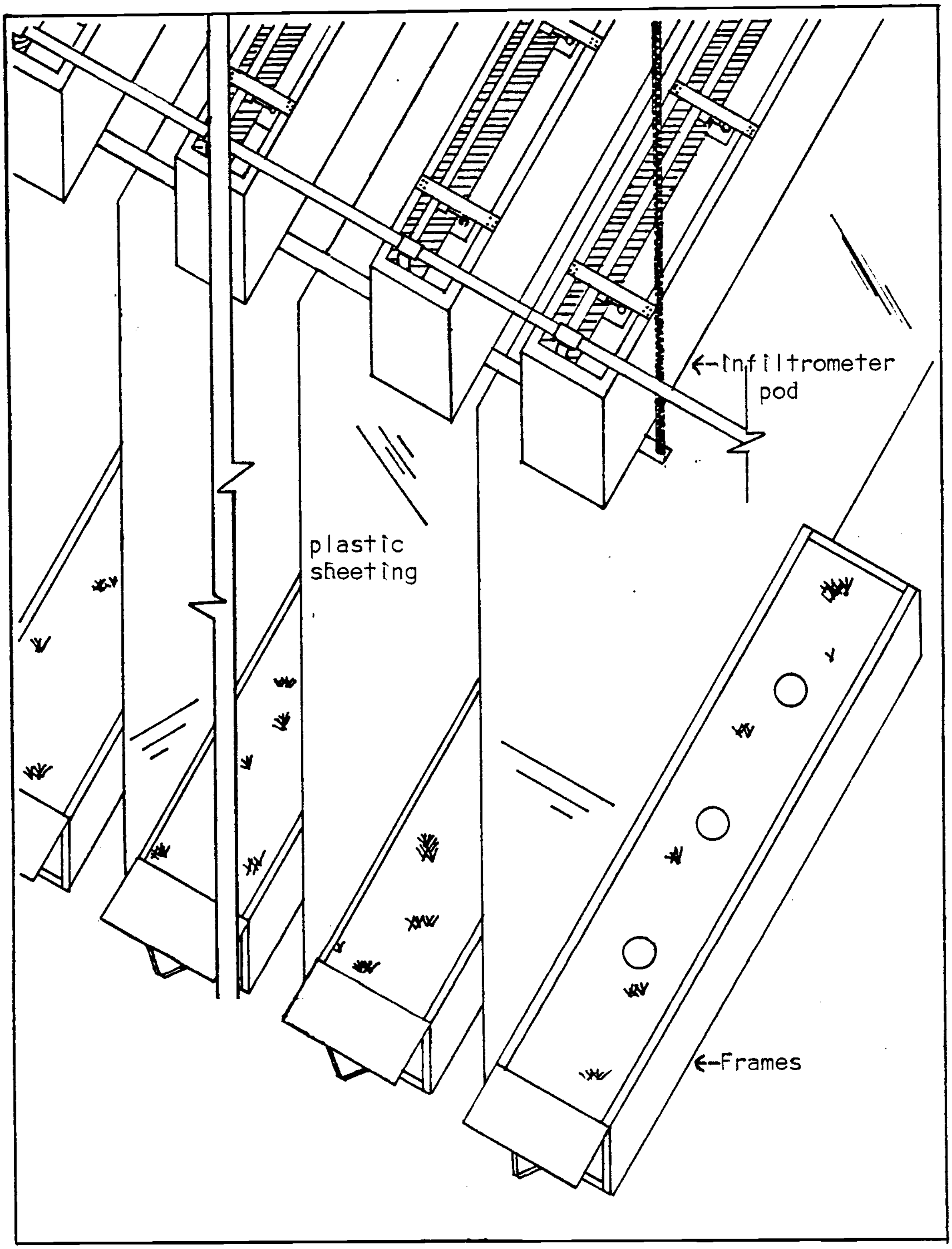


Figure 3. Drawing depicting the arrangement of the frames to the infiltrometer.

and weighed approximately 1.2 kilograms. Each sample was frozen until 24 hours prior to use. All samples were collected at the same time to help reduce the daily variation that exists in bovine feces. Each week a sample of the fecal material was tested for number of bacteria per gram to determine if there was bacterial die-off from freezing.

Each plot was sprinkled for 20 minutes before adding fecal material. During this time the plots became saturated which allowed the infiltration rate to equilibrate. A sample at the end of the equilibration period was used to establish the background bacterial concentration for each plot.

At the end of the 20 minute equilibration period, fecal material was added to each plot and the infiltrometer was restarted. Each plot was then sprinkled for an additional 30 minutes with samples collected at 10, 20, and 30 minutes to determine overland bacterial movement. After collection the runoff water was stored on ice in sterile whirl-pak bags and tested for bacterial concentrations.

Each sample was analyzed for fecal coliform, using the membrane filter technique (APHA 1985). Three volumes of the sample (e.g. 10ml, 1ml, 0.1ml, 0.001ml, or 0.0001ml) were filtered through a 0.45-μm filter and placed on pads saturated with m-Fc broth for incubation at 44.5 °C for 24 hours. One petri dish was used for each volume chosen. These dilutions were chosen in order to bracket bacteria numbers (APHA 1985). For several samples each dilution chosen was triplicated (3 petri dishes) to establish variation of bacterial colonies grown on the m-Fc broth. After incubation, the fecal coliform colonies were counted and the results converted to number of bacteria per 1 ml.

Four lengths, 0.0, 0.7, 1.6, and 2.5 meters, were chosen to determine the distance of overland bacterial transport. The zero length was used to determined the release rate from the fecal deposits. The other lengths were used to established a short, intermediate, and long distance for overland bacterial movement.

Since it was expected that the infiltration rate would be a major factor determining bacteria movement, grass sod was placed on two different soil types. The first soil type (sand) was used to provide a permeable medium for high infiltration rates. The second soil type (plastic), which was less permeable, was used to simulate frozen ground conditions. The less permeable condition was accomplished by placing plastic over the sand but underneath the sod leaving 3 cm of soil for water to infiltrate into.

In addition to the two soil types, rainfall intensities of 5 cm/hr and 10 cm/hr were used. Rainfall and runoff volumes were measured for each plot. Rainfall was measured by placing three containers on each plot. In addition, total runoff was measured by collecting all the water that ran off each plot.

The statistical design to analyze the resulting data was a split-plot, repeated measures design. The whole plot factors were soil type and rainfall intensity. The split plot factor was distance down the sod surface. The repeated measures were the samples collected through time (e.g. 10, 20, and 30 minutes). There were 16 treatments from different combinations of soil type, rainfall intensity, and distance.

Using the four frames, a combination of each distance was run simultaneously, while rainfall intensity and soil type were the same for each distance. For the first run, the four distances were chosen at random, thereafter they were rotated one frame for each additional run (Figure 3). There were 7 replications of each treatment resulting in 112 total plots.

IV. RESULTS AND DISCUSSION

Fecal Concentrations and Distribution

Winter supplemental feeding consisted of providing hay to the animals once or twice each day. They were only fed in areas that had relatively gentle slopes due to the requirements of the feed handling equipment. In the areas that were cleared, each tree had been hand cut and the slash left in place. Natural vegetation was allowed to grow in the newly opened areas. A summary of the vegetational characteristics is shown in Table 1. A summary of the cultural practices and topographical characteristics are shown in Table 2.

Fecal deposits of cattle will last at least two years in semi-arid environments. Therefore, the results for 1987 are an accumulation of cow-chips over two grazing seasons.

The 1987 results showed that area 1 had the highest concentration of cow-chips. This area was a meadow next to a riparian zone where the cattle were fed supplemental hay. Area 2, a riparian zone, had the second highest concentration of cow-chips. These areas had counts of 4008 and 2968 chips per hectare, respectively. Areas 3, 4, 5, 6, 7, and 8, which were either riparian zones or areas of supplemental winter feeding, show the next highest counts.

Table 1. A summary of the vegetational characteristics within the Haughton-sontag pasture, Bear Creek 1987-88.

	Dominant Species		Areal Cover			
Area	Grass	Shrub	Grass (%)	Shrub (%)	Total (%)	Juniper (%)
1	Hay Meadow	-----	98.0	0.0	98.0	0
2	Acda,Popr,Agst	Artr,Chvi	89.8	0.6	90.4	1
3	Agsp	Artr	0.9	7.8	8.7	2
4	Brte	Artr	1.0	3.7	4.7	15
5	Agsp,Brte	Chna	0.7	3.0	3.7	10
6	Acda,Popr,Agst	Artr,Chvi	98.3	0.2	98.5	0
7	Acda,Popr,Agst	Artr,Chvi	90.8	0.2	91.0	0
8	Acda,Popr,Agst	Artr,Chvi	93.5	0.8	94.3	0
9	Kocr,Sihy,Brte	Artrw,Chvi	1.1	8.7	9.8	3
10	Posa,Sihy	Chna,Chvi	1.4	5.7	7.1	20
11	Sial (forb)	Artr	0.0	0.0	2.0	0
12	Agsp	Artr,Chna	4.2	12.8	17.0	1
13	Agsp	Artr	2.6	11.5	14.1	1
14	Agsp, Brte	Chna	0.9	7.1	8.0	10
15	Agsp	Artr,Chna	1.3	4.5	5.8	15
16	Brte	Artr	2.4	7.1	9.5	20
17	Hay Meadow	-----	97.0	0.0	97.0	0
18	Feid,Brte	Artr,Chna	6.0	11.2	17.2	10
19	Agsp	Artrw,Chna	7.3	9.6	16.9	1
20	Agsp,Feid,Kocr	Artrw,Chna	5.2	14.4	19.6	5
21	Agsp,Kocr,Sihy	Artrv,Chna	12.6	7.7	20.3	<1
22	Agsp,Sihy,Kocr	Artrv	2.7	11.1	13.8	2
23	Agsp,Sihy	Chvi,Chna	11.5	1.2	12.7	<1
24	Agsp,Feid	Arar,Chna	5.3	4.5	9.8	10
25	Feid	Artrw	3.1	5.4	8.5	15
26	Agsp	Artrv	6.7	17.0	23.7	1
27	Agsp,Brte	Chna	2.8	12.6	15.4	2
28	Feid	Artr	15.0	5.1	20.1	4
29	Agsp,Feid	Artrv,Chvi	14.0	8.2	22.2	1
30	Agsp,Kocr,Sihy	Artrw	9.5	7.1	16.6	10
31	Agsp	Arar	3.6	3.1	6.7	7
32	Agsp,Feid	Arar	7.8	2.4	10.2	12
33	Agsp,Feid	Artr	11.2	6.9	18.1	20
34	Agsp,Kocr,Sihy	Artrv&w	9.2	5.5	14.7	15
35	Oat Meadow	-----	6.0	0.0	6.0	0
36	Agsp,Sihy,Kocr	Artrw,Chvi	5.8	5.7	11.5	5

Note: See Table A-1 for common and scientific names of grasses and shrubs.

Table 2. A summary depicting the topographical characteristics including distance to water (vertical and horizontal), slope, and aspect. A summary of cultural practices are included. Haughton-Sontag pasture, Bear Creek, 1987-88.

	Distance				
Area	Vert (m)	Horz (m)	Slope (%)	Aspect	Cultural Practice
1	6	120	3.0	meadow	farmed, winter feed
2	0	0	1.0	riparian	native
3	40	1302	9.1	east	native, winter feed
4	18	198	10.6	north	native, winter feed
5	41	433	12.5	south	native, winter feed
6	0	0	1.0	riparian	native
7	0	0	1.0	riparian	native
8	0	0	1.0	riparian	native
9	21	1271	11.4	north	native, winter feed
10	15	228	13.5	north	native
11	12	240	5.0	meadow	abandoned field
12	91	1080	9.2	north	cleared
13	103	624	3.9	north	cleared
14	61	480	7.5	south	native
15	97	420	8.5	north	native
16	18	222	6.7	north	native
17	6	120	3.0	meadow	farmed
18	110	853	3.2	ridge top	native
19	109	864	4.0	north	cleared
20	193	1068	2.0	ridge top	cleared
21	73	516	28.2	west	cleared
22	106	762	6.0	north	cleared
23	73	552	31.7	east	cleared
24	52	486	32.6	north	native
25	40	1593	10.7	north	native
26	180	1081	18.0	north	cleared
27	106	708	10.2	east	cleared
28	88	1271	30.9	north	native
29	219	1573	14.8	north	cleared
30	158	1081	32.4	west	native
31	64	468	30.6	south	native
32	88	240	38.0	north	native
33	256	1321	29.0	north	native
34	158	864	39.0	east	native
35	4	120	3.0	meadow	farmed, oats
36	131	1200	10.1	north	native

Note: The distance to water (vertical and Horizontal) is measured in a straight line from the midpoint of each area, to the stream.

These areas had chip counts between 1876 and 1532 per hectare. Areas 9, 10, and 11 had cow-chip concentrations between 1210 and 1048 per hectare. Areas 12, 13, 14, 15, 16, 17, 18, 19, and 20, which were areas with gentle slopes, had cow-chip counts between 943 and 543 per hectare. Areas 21, 22, 23, 24, 25, 26, 27, 28, 29, and 30, which had fairly steep slopes and were over 700 meters from a water source, had counts between 476 and 314 chips per hectare. Sites 31, 32, 33, 34 and 36, which were sites with very steep slopes, had counts less than 250 chips per hectare. Area 35, which is a meadow, was plowed before we were able to sample in 1987.

A summary of the cumulative cow-chip concentration for 1987 is shown in Figure 4.

During the winter of 1988 the cattle showed the highest preference to areas of supplemental feeding and associated riparian zones. Locations of highest preference were areas 1, 2, 3, 4, 5, 6, 7, 8, and 17. These areas had counts between 1095 and 6067 chips per hectare.

All other areas measured during the winter of 1988 had counts between 819 and 0 chips per hectare. These low counts indicate that the cattle stayed predominantly in the areas where they were fed supplemental hay.

In the spring the order of preference was similar to the winter with a few exceptions. Areas 1, 7, 8, 11, 17,

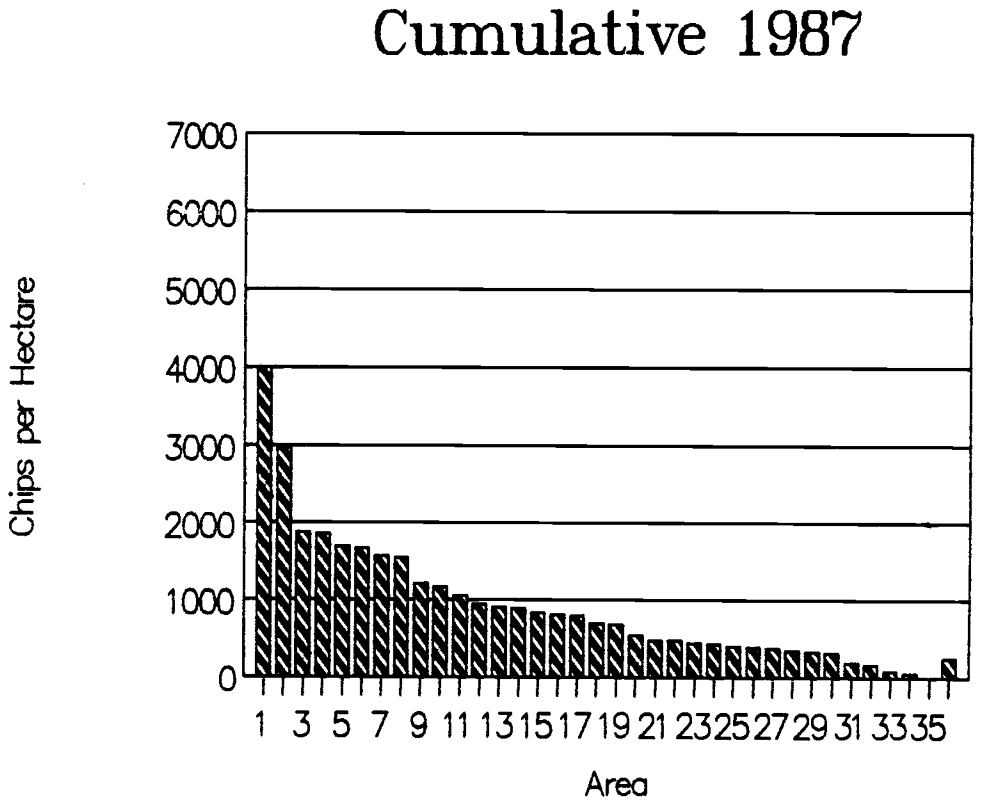


Figure 4. Summary of 1987 cumulative cow-chip concentrations within the Haughton-Sontag pasture, Bear Creek.

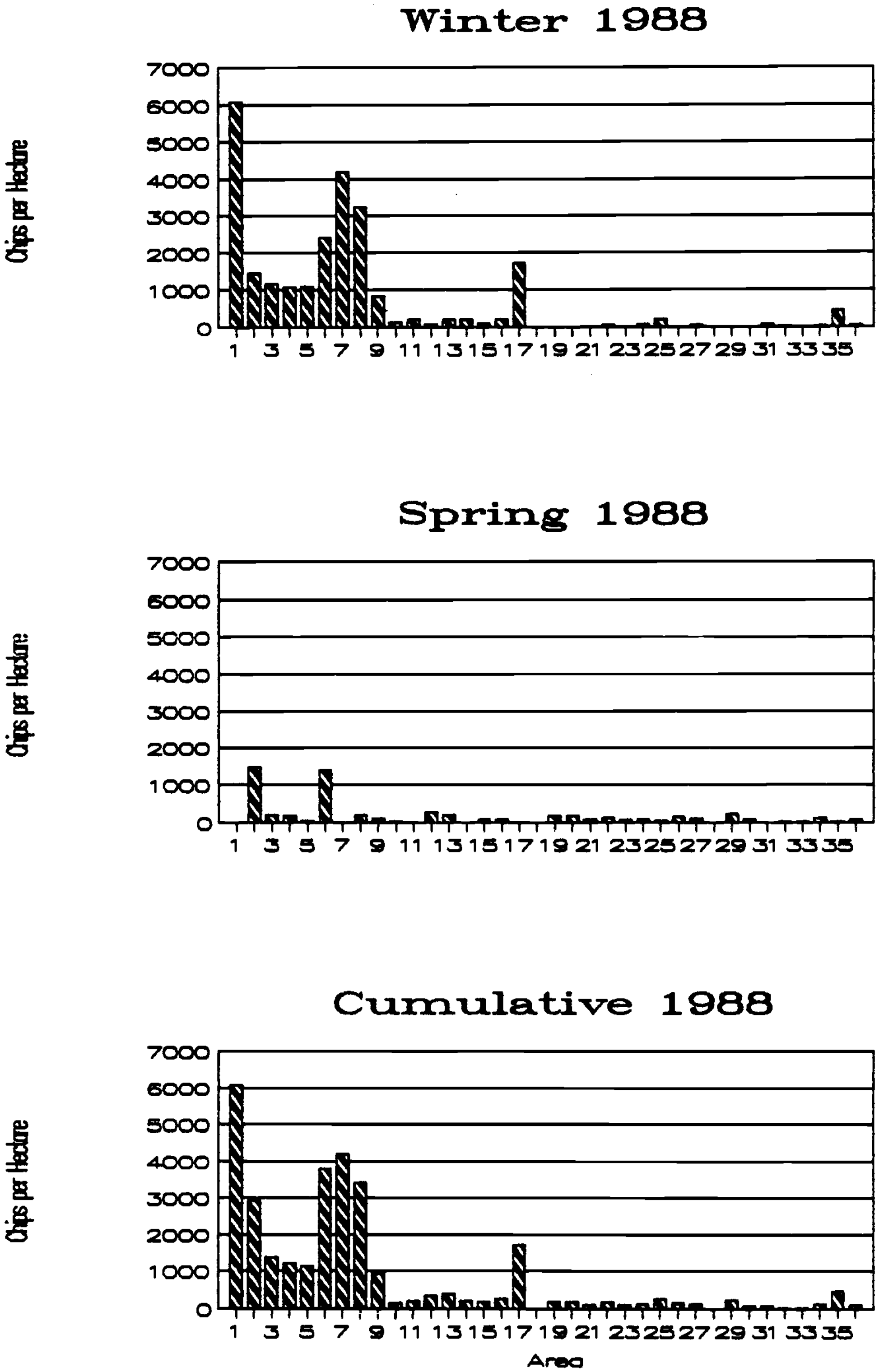
and 35 were closed to cattle during the spring. Subsequently there was no usage in these areas, except for a few strays as shown by area 18 which had a count 195 chips per hectare. With the exclusion of these areas the cattle still preferred the riparian zones shown by areas 6 and 2 which had counts of 1410 and 1476 chips per hectare, respectively.

All other areas during the spring of 1988 had counts between 0 and 276 chips per hectare. Areas 12, 13, 19, 20, 22, 26, and 29 all had counts between 276 and 133 chips per hectare. All other areas had counts that were less than 76 chips per hectare. A summary of the data for winter 1988, and spring 1988 and cumulative 1988 is shown in Figure 5.

The cattle also showed signs of "bunching up" under trees. They used many of the trees in each area as bedding grounds. As such, a higher concentration of cow-chips was found under these trees. A summary of the data depicting the use under these trees is shown in Table 3.

The cattle showed the highest preference for the meadows where they were fed supplemental hay during the winter. During the winter of 1988, area 1 had a count of 6067 chips per hectare in contrast to a very similar area which was just across the stream.

Area 35, which had no supplemental feeding, had 448 chips per hectare. However, area 3, a winter feeding



Winter 1988

Spring 1988

Cumulative 1988

Figure 5. Summary of winter 1988, spring 1988, and 1988 cumulative cow-chip concentrations within the Haughton-Sontag pasture, Bear Creek.

Table 3. Summary of cow-chip concentrations underneath bedding trees, Haughton-Sontag pasture, Bear Creek 1987-88.

	1987		Winter 1988		Spring 1988	
Area	Area (m^2)	#chips/ m^2	Area (m^2)	#chips/ m^2	Area (m^2)	#chips/ m^2
1	No shade tree in area					
2	65.7	0.50	42.0	0.29		
3	65.7	0.22	29.2	0.41		
4			43.5	0.31		
5	86.3	0.37	60.9	0.43		
6	No shade tree in area					
7	No shade tree in area					
8	No shade tree in area					
9	77.8	0.42	56.7	0.47		
10	73.0	0.32	17.8	0.56	29.2	0.10
11	149.6	0.41	149.6	0.43		
12	105.7	0.45	52.9	0.27	77.8	0.04
13	102.0	0.25	99.7	0.13	116.7	0.00
14	60.5	0.30	45.6	0.23		
15	66.5	0.25	33.2	0.22		
16	116.7	0.16	82.7	0.22		
17	No shade tree in area					
18	73.1	0.43				
19	78.0	0.74	0.0	0.00	68.0	0.10
20	65.7	0.40	0.0	0.00		
21	56.2	0.23	40.4	0.16	54.1	0.13
22	63.5	0.39	37.7	0.14	27.8	0.14
23	92.3	0.21	10.5	0.48	25.7	0.06
24	47.4	0.10	0.0	0.00		
25	66.4	0.31	53.8	0.20		
26	79.0	0.26	0.0	0.00	65.3	0.10
27	65.7	0.25	70.5	0.10	82.7	0.12
28	61.0	0.32				
29	116.7	0.25	0.0	0.00	79.2	0.16
30	No shade tree in area					
31	No shade tree in area					
32	No shade tree in area					
33	65.7	0.06	0.0	0.00	42.0	0.14
34	No shade tree in area					
35	No shade tree in area					
36	69.2	0.28	80.3	0.01	80.3	0.05

area, that was over 1200 meters from water had a count of 1181 chips per hectare. This clearly implies that feeding is a major controlling factor of cattle distribution during the winter.

The cattle also showed a high preference for riparian zones. The riparian zones were the only source of water. Also, the riparian zones have gentle slopes, less than 5 percent. In addition, the riparian zones had a high quantity and quality of forage, which attracted cattle.

Areas with high juniper cover, which were close to riparian zones or feeding areas, tended to have a high use by cattle. This is illustrated in Area 10 which had a juniper cover of 20 percent and grass cover of 1.4 percent. This area had counts of 1162 chips per hectare (0.12 chips/m^2) in the open, with a concentration of 0.32 chips per square meter (3200 chips/hectare) under the trees. These data indicate that factors, other than forage, attracted the cattle.

During early spring of 1988, the cattle moved into the uplands where there was good forage and gentle slopes. Areas 12, 13, 19, 20, 22, 26, and 29, were between 624 and 1573 meters from a source of water, and between 91 and 219 meters in elevation. The slopes for these areas varied from 2.0 to 14.8 percent. All of these areas had been cleared of juniper trees which opened the sites for forage production, with relative grass covers between 2.6 and

14.0 percent. With the exception of area 29, these areas were very similar in terms of slope and distance from water. Even though area 29 was a long way from water (1573 horizontal meters and 219 vertical meters) it still received significant cattle use. Available forage may be one reason the cattle were attracted to this area. Area 29 had a 14.8% grass cover with Idaho fescue (*Festuca idahoensis*) and Bluebunch Wheatgrass (*Agropyron spicatum*) as the dominant species.

Cattle use in areas with steep slopes was limited. Areas 21 and 23, with grass cover of 12.6 and 11.5 percent respectively, only had counts of 76 chips per hectare each. In contrast, the cattle use in area 22, which was right next to 21 and 23, was much higher at 133 chips per hectare. Area 22 had a grass cover of 2.7 percent, much less than the adjacent areas 21 and 23. However, in area 22 the slope was only 6.0 percent compared to 28.2 and 31.7 percent in areas 21 and 23 respectively. All other areas with slopes greater than 20 percent had counts of less than 76 chips per hectare.

Instream Fecal Deposition

During August 4-7, 1986, livestock grouping number one was observed for a composite 24 hour period. Twelve individuals were observed for the first two hours and 17 were watched for the remaining 22 hours, for a total of 398 cow hours. Groups two and three were observed consecutively for 3, 11, and 6.25 hours each day during daylight hours, November 6-8 1986. There were 18 cattle observed in group two for a total of 364.5 cow hours. There were 19 cattle observed in group three for a total of 247.5 cow hours. Groups four and five were observed for about 9 hours each day during January 4-5, 1987. There were 109 cattle observed in group four for a total of 2,071 cow hours. There were 400 cattle observed in group five for a total 6,900 cow hours. Group six and seven were observed for 10.5 hours each day during March 28-29, 1987. There were 170 cattle in group six for a total of 3,570 cow hours. There were 115 cattle in group seven for a total of 2,415 cow hours. Group eight was observed for 10 hours March 28, and 6 hours March 29, 1987. There were 116 cattle in group eight for a total of 1,856 cow hours.

Groups two and three were observed during the daylight hours from 4 p.m. on November 6, until 2 p.m. November 8. Groups four and five were observed for the entire daylight period January 4 and 5. Groups six, seven, and eight were observed during daylight hours March 28 and 29, with the exception of group eight which was observed for 6 hours on March 29. Since all the groups, except group 1, were only observed during daylight hours an assumption is needed to determine the number of defecations in the stream per cow per "24 hour day". The assumption is that there were no defecations in the stream during the night. The basis of this assumption comes from the August 1987 data. During that observation period there were no defecations in the stream at night. A summary of this data is shown in Table 4. Fecal deposits in the stream and on the immediate bank are shown in Table 5. The total time that each group of cattle spent in the stream is also shown in table 5. The time that each animal spent on the bank was not recorded.

In August the maximum air and water temperatures were 31°C and 23°C respectively. The minimum air and water temperatures were 7°C and 13°C respectively. In November the maximum air and water temperatures were 14°C and 11°C respectively. The minimum air temperature recorded during the daylight observation was minus 3°C. In January the maximum air and water temperatures were minus 2°C and 0°C respectively. The minimum air and water temperature recorded during the daylight period were minus 9°C and 0°C respectively. In March the maximum air and water temperatures recorded were 8°C and 4°C respectively.

During August, the cattle in group one spent 0.80% of the 398 hours in the stream. For each hour the cattle spent in the stream there were 2.21 defecations that fell directly into the water. There were 7 direct fecal deposits, which calculates to 0.41 defecations per cow per

Table 4. Results of cattle observations at Bear Creek, summer 1987 through spring 1988, showing the amount of time and number of defecations in the stream.

Date	Group	No. Hours Obs.	No. of Cows	Def/ Cow/ Entry	Min/ Cow/ Entry	No. Entry/ Cow	Def/ Cow/ Day
Aug 4-7	1	24	17	0.05	1.44	7.76	0.41
Nov 6-8	2	20	18	0.06	0.88	3.39	0.19+
Nov 6-8	3	20	19	0.00	0.71	3.21	0.00+
Jan 4-5	4	18	109	0.12	3.38	1.67	0.20+
Jan 4-5	5	18	400	----	6.27	----	0.14+
Mar 28-29	6	21	170	0.11	3.08	2.61	0.29+
Mar 28-29	7	21	115	0.27	4.75	1.68	0.46+
Mar 28-29	8	16	116	0.19	4.34	0.90	0.17+

notes: group 1 = cows, calves, and steers. Group 2 = cows, calves Group 3 = bulls. Group 4 = cows. Group 5 = yearling steers and heifers. Group 6 and 7 = yearling steers and heifers, in a feedlot. Group 8 = cows and calves. The plus sign (+) indicates an estimate based on the assumption that thee was no cattle activity in the stream at night.

Table 5. Cattle defecations and time spent in the stream and defecations on the immediate bank, fall 1987 through spring 1988. At Bear Creek.

Date	Group	Number Defecations (Stream)	(Bank)	Time in Stream (hr)	No. of Cows
Aug 4-7	1	7	6	3.17	17
Nov 6-8	2	7	4	1.80	18
Nov 6-8	3	0	0	1.45	19
Jan 4-5	4	44	37	20.50	109
Jan 4-5	5	115	75	----	400
Mar 28-29	6	100	51	45.05	170
Mar 28-29	7	105	17	30.43	115
Mar 28-29	8	39	50	14.67	116

day, in the stream (Table 4).

During November, the cattle in group two spent 0.49% of the 364.5 hours in the stream. For each hour the cattle spent in the stream there were 3.89 defecations which fell directly into the water. There were 7 direct fecal deposits, which is equivalent to 0.19 defecations per cow per day, in the stream. The cattle in group three spent 0.59% of the 247.5 hours in the stream. There were no defecations in the stream from group three.

In January, the cattle in group 4 spent 0.99% of the 2071 hours in the stream. For each hour the cattle spent in the stream there were 2.15 defecations. There were 44 direct fecal deposits, which calculates to 0.20 defecations per cow per day, in the stream. The cattle in group 5 spent 4.93% of the 6900 cow hours in the stream. For this group individual cow time in the creek was not collected, since there were too many cattle to watch each cow individually. However, there was one observer that was able to count individual cow entries for part of the group, and estimated that each cow entry was 6+ minutes. There were 115 direct fecal deposits, which calculates to 0.14 defecations per cow per day, in the stream. The stream was frozen over, except for small holes, and the number of fecal deposits were counted on the ice at the end of each day. Time counted as in the stream was actually cattle standing on the ice.

During March, the cattle in group 6 spent 1.26% of the 3,570 cow hours in the stream. For each hour the cattle spent in the stream there were 2.22 defecations which fell directly in the water. There were 100 direct fecal deposits, which calculates 0.11 defecations per cow per day, in the stream. The cattle in group seven spent 1.26% of the 2,415 cow hours in the stream. For each hour the cattle spent in the stream there were 3.45 defecations which fell directly in the water. There were 105 direct fecal deposits from group 7, which calculates to 0.46 defecations per cow per day. The cattle in group 8 spent 0.79% of 1,856 cow hours in the stream. For each hour group 8 spent in the stream there were 0.38 feces which fell directly in the water. There were 39 direct fecal deposits from group 8, which calculates to 0.17 defecations per cow per day.

At night, the starlight scope did not produce a clear enough picture to accurately observe defecation. Because of the minute amount of cattle activity in the stream at night and the inability to see a clear picture, night observations were discontinued.

In general, the cattle remained in bottom-land meadows and riparian zone during all observations. It was assumed that the unattractive dry forage in the uplands was the main reason that the cattle remained near the riparian zone. The forage in the riparian zone was green in the summer and fall. The cattle were fed supplemental hay in the meadows in January. The creek was the only source of water. There were some exceptions however, a few bulls traveled into the uplands and could not be seen for several hours at a time. Occasionally some would stay in the uplands for the entire night.

During March, groups 6 and 7 were in a feedlot, with the creek as their only source of water. The stream was at the bottom of the feedlot. The cattle were fed twice daily. A short time after feeding the majority of the cattle would enter into the stream to drink. The water was very close, and the cattle spent a lot of time drinking and playing in the water. In contrast, group 8 was fed 1.5 miles from their source of water. Consequently, the number of direct fecal deposits in the stream was much less for group 8 than for groups 6 and 7.

During August the average time spent in the stream by each animal was higher than at any other time. There was an individual steer that spent 44 minutes in the stream in August. This steer had a sore foot and presumably the cool water had a soothing effect for him. There were two other animals that spent 12 and 15 minutes each in the stream. These animals would stand in the stream and graze the banks. Because of these three individuals, the average time spent in the stream during August was greater than any other period. Excluding these three long residence times in August, the cattle spent an average of 53 seconds per entry in the stream. These data are similar to the data for group 2 in November. There were also a few cattle that spent a long time, as much as 1.5 hours, in the stream in March. These were cattle in the feedlot, with no visible signs of injury, in contrast to the steer with the lame foot.

The defecation rate per animal in November and January was approximately half of what it was in August. Cooler temperatures in November and January probably account for this seasonal difference. The bulls were an exception, they were not observed to defecate in the stream. One reason could be that their stream was very small and they could cross it easily and quickly. In addition the bulls did not enter or spend as much time in the stream as the other cattle.

In January the stream was frozen and the cattle drank from small openings in the ice. The water was very cold and they would drink slowly. After drinking, the cattle in group 5 stood around for a long period time in the riparian area, as such, the time they spent "on the ice" (in the stream) was higher than the other groups. The cattle in group 4 showed a different pattern, they would drink and then return to the field where hay had been fed, to forage. In observing group 5, we could not get an individual time in the stream for each animal because there were so many animals on the ice at any one time. The total time the cattle spent on the ice was estimated by counting number of animals seen at one minute intervals. Often there were more than 30 animals on the ice at the same time. It was difficult to accurately see all the cattle, thus the estimate is rough. The fecal deposits for groups 4 and 5 that were counted as in the stream were on the ice. Presumably as the ice melted the feces entered the water and therefore were counted as being in the stream. Through the observations, we noticed that the animals would frequently defecate after drinking. However, the vast majority of these defecations were on the banks, often while the animal was walking away from the riparian zone. Consequently, the defecation rate directly into the stream was quite low.

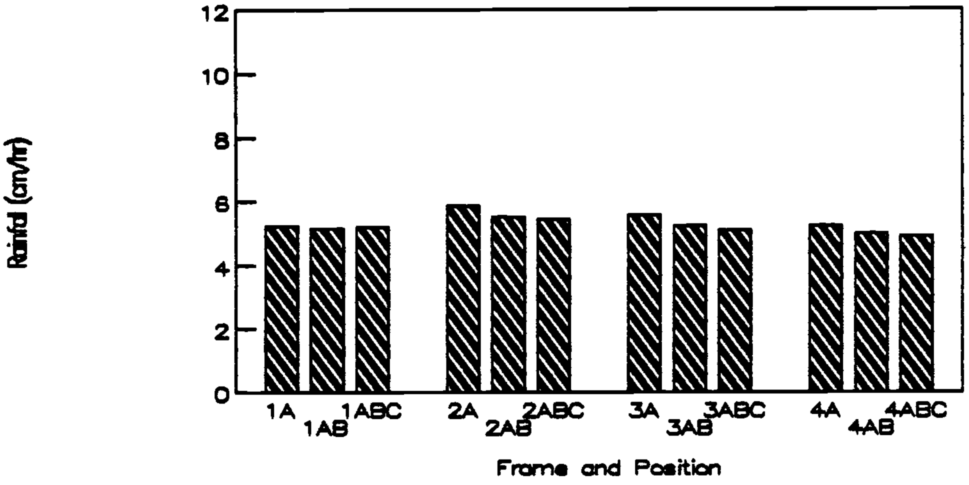
In March, the defecation rates into the stream increased over the fall and winter rates. This is especially noticeable in the feedlots, where the rates were 0.46 and 0.29 defecations per animal per day. In contrast, the defecation rate in the stream was low, 0.17/cow/day, when the cattle traveled over 1.6 kilometers from their feeding area to the stream.

Overland Bacterial Transport

The artificial rainfall pattern, across each frame and throughout the length of each frame, is shown in Table B-1 and Table B-2. There was some variation across each frame and throughout the length of each frame. There were six locations used to collect rainfall data, A, A1, B, B1, C, C1, see Figure B-1. In order to obtain a representative value for rainfall on each feces, average values for locations A, B, and C, were used. To obtain the rainfall value for the 0.0 m distance, the rate at location A was used. To obtain the rainfall value for the 0.7 and 1.6 m distances, the average rate at locations A and B were used. To obtain the rainfall value for the 2.5 m distance, the average rate at locations A, B, and C were used. This was repeated for each frame and each rainfall intensity rate. A summary of the rainfall rate for each frame, distance, and rainfall intensity is shown in Figure 6.

The results of the random observations that were replicated are shown in Table B-3. The mean and standard error of the samples taken showed acceptable variation. There were several feces analyzed for fc/gram during the experiment. The results, see Table B-4, show that bacterial die-off from freezing was not consequential from the beginning of the experiment to the end.

5 cm/hr



10 cm/hr

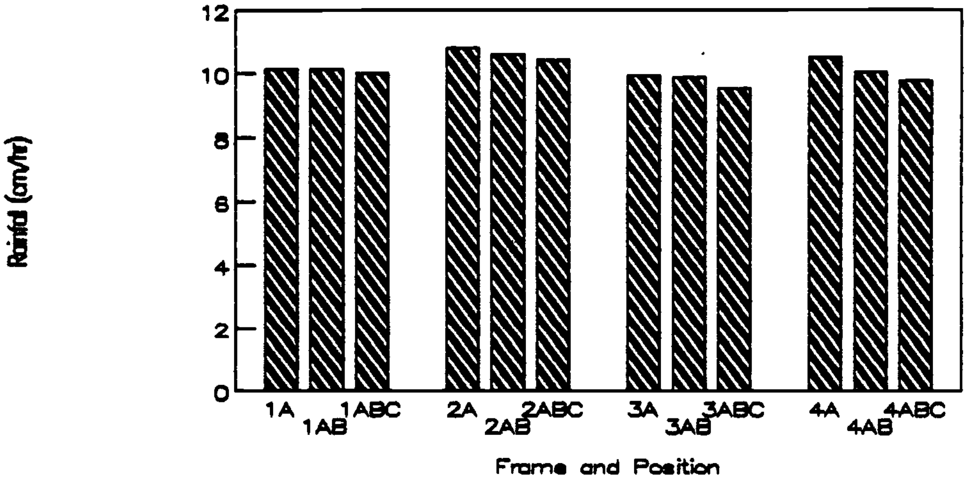


Figure 6. Rainfall intensity applied to each feces according to frame and distance.

Note: The code is: 1A = 0.0 m distance for frame 1. 1AB = 0.7 and 1.6 m distance for frame 1. 1ABC = 2.5 m distance for frame 1. this same pattern exists for frames 2, 3, and 4.

The background counts for each observation are shown in Table B-5. There were several observations where the indigenous fauna in the sod apparently interfered with the enumeration of the fecal coliform (Anderson 1988, personal communication). Therefore, to obtain a representative background value, the average of the remaining observations was used. The background counts ranged from 0 to 300 fc/1 ml, with an average of 9 fc/1 ml.

Analysis of variance for infiltration rates shows a significant difference ($p < 0.001$) between permeable (sand) and less permeable (plastic) soil types, see Figure 7. By further refinement, using the Student-Newman-Keuls multiple comparison test, there was no significant difference of infiltration for permeable and less permeable soil types at the 5 cm/hr rainfall intensity. However, there was a significant difference between permeable and less permeable soil types at the 10 cm/hr rainfall intensity, see Figure 8. Figure 9 represents the corresponding surface runoff relationships for this experiment.

The one-way analysis variance of the fecal coliform concentration data indicate a significant difference for the variables distance ($p < 0.001$), distance * soil interaction ($p = 0.002$), time ($p < 0.001$), and distance * time interaction ($p < 0.001$). The variable rainfall intensity was not significant ($p > 0.9$).

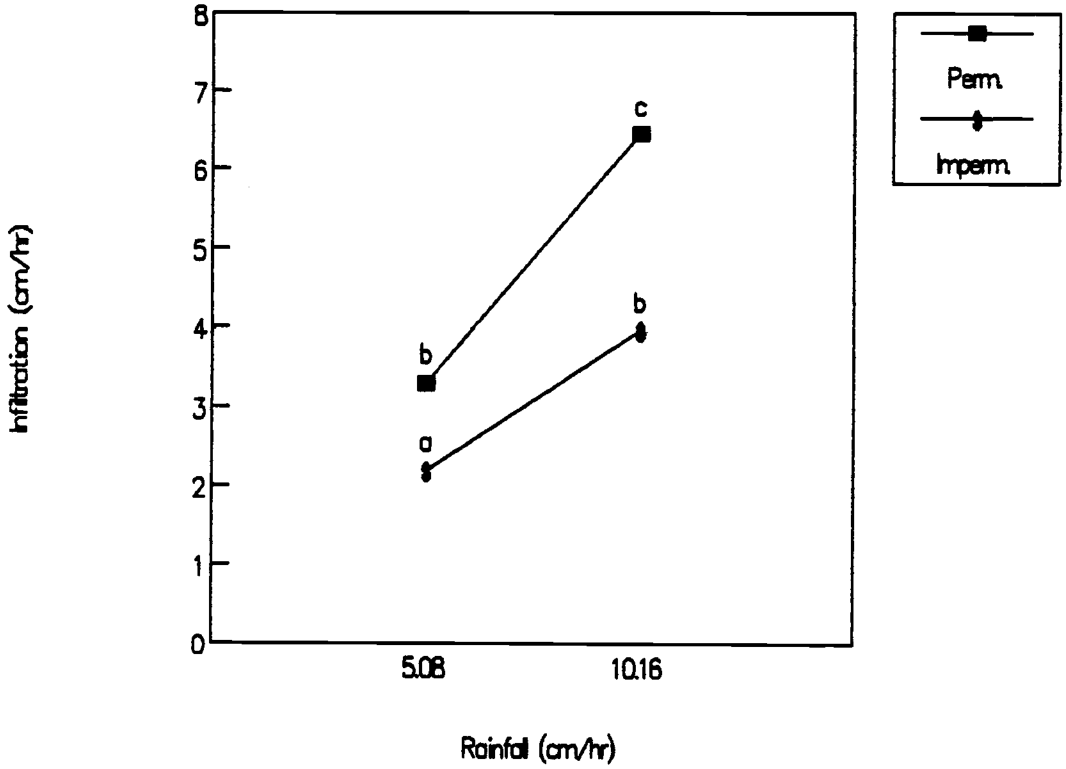
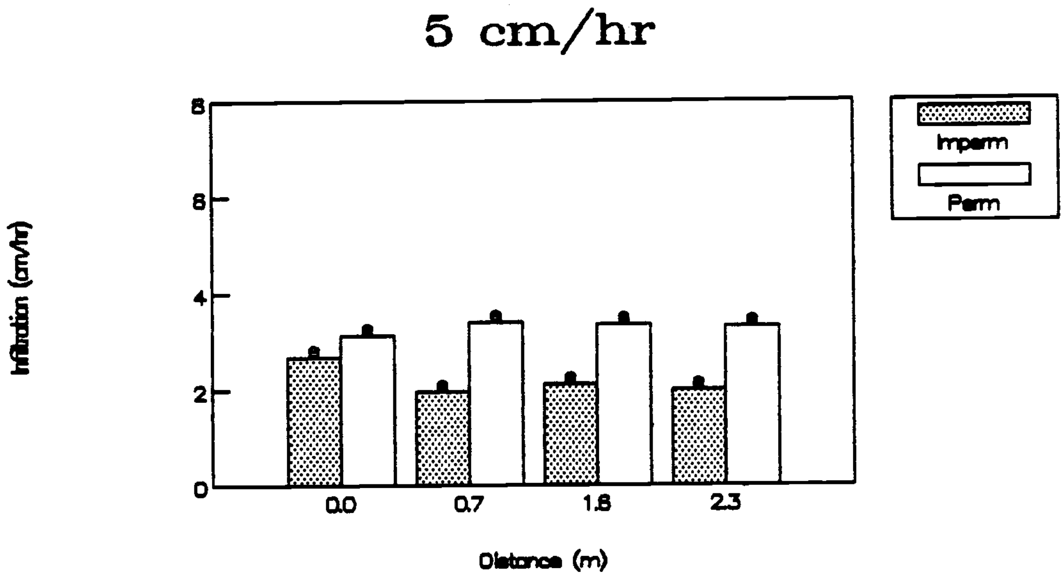


Figure 7. Mean infiltration rates for soil type by rainfall intensity interaction.

Different letters indicate significant treatment differences ($p<0.05$).



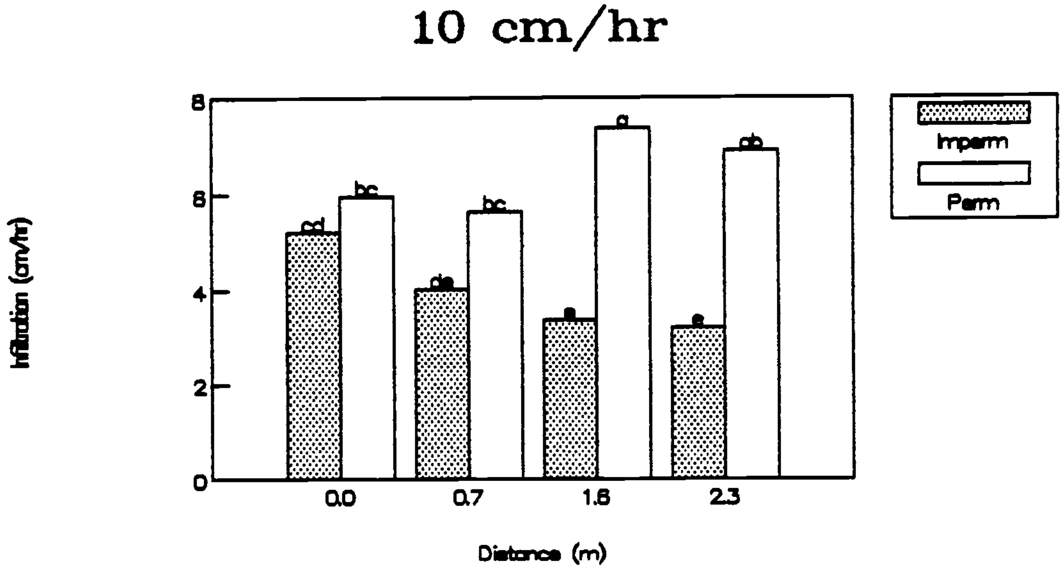
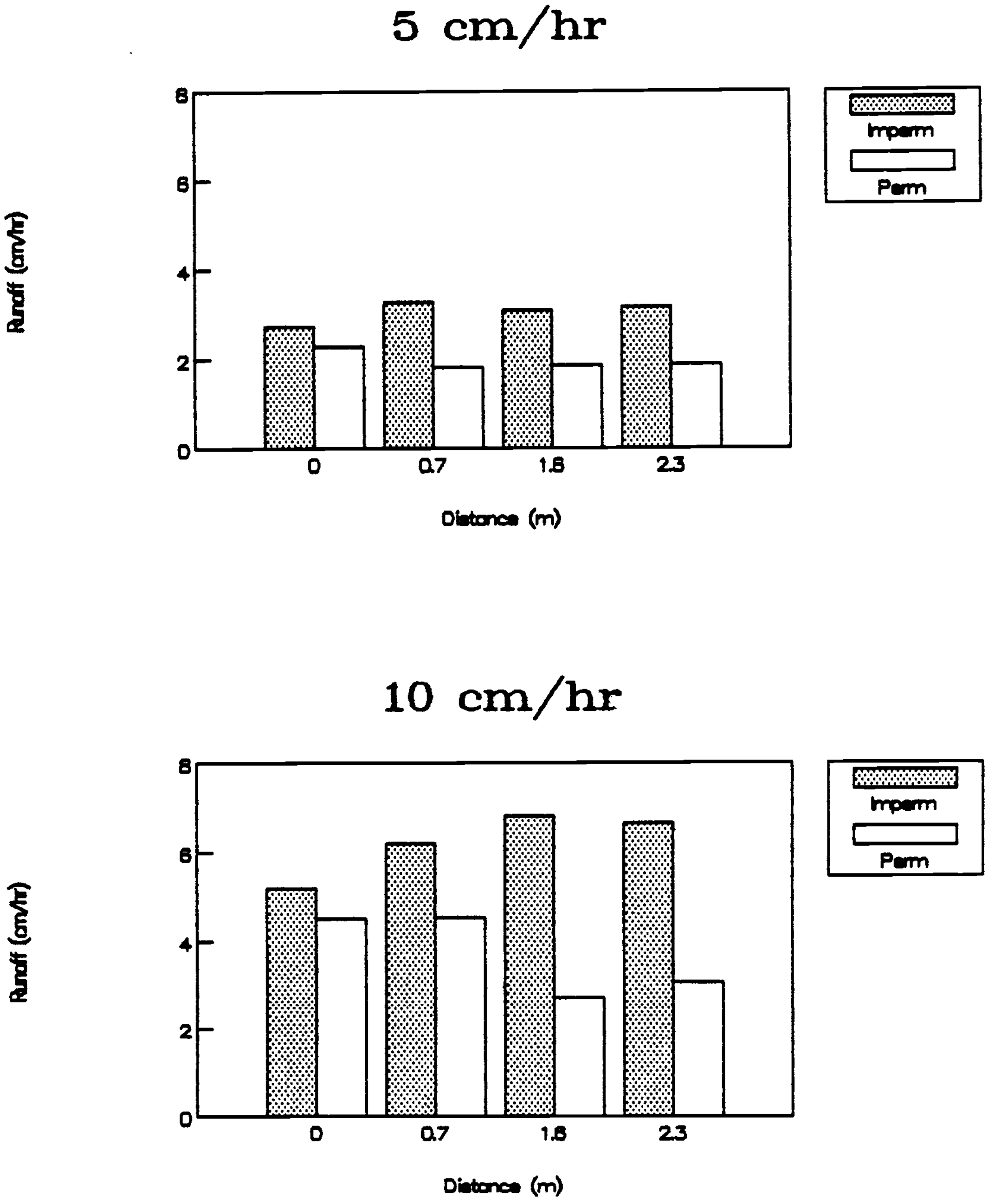


Figure 8. Mean infiltration rates for soil type by rainfall intensity by distance interaction.

Different letters indicate significant treatment differences (p = 0.05).



5 cm/hr

10 cm/hr

Figure 9. Mean surface runoff rates for soil type by rainfall intensity by distance interaction.

Also the soil * rainfall intensity ($p > 0.9$), and distance * rainfall intensity ($p > 0.9$), and time * rainfall intensity ($p > 0.1$) interactions were not significant.

Further analysis of the distance * soil interaction using the Student-Newman-Keuls mean separation test ($p < 0.5$) indicates that the fecal concentration on permeable soil was significantly different from the impermeable soil at the 0.0 m distance. There were not any significant differences between the 0.7, 1.8, and 2.3 m distances. A summary of the distance * soil type interaction is shown in Figure 10.

Further analysis of the distance * time interaction using the Student-Newman-Keuls mean separation test ($p < 0.5$), indicated that the 0.0 m distance is significantly different from the 0.7, 1.6, and 2.5 m distances. There were no significant difference between the 0.7, 1.6., or 2.5 m distances. In addition a significant reduction of bacteria concentrations at the 0.0 m distance occurred over time. A summary of the fecal coliform distance * time interaction is shown in Figure 11.

As shown in figure 8, an experiment was designed to simulate frozen ground by placing plastic under the sod. Some water ran overland, the rest infiltrated the sod and ran down the plot on top of the plastic and was shunted away.

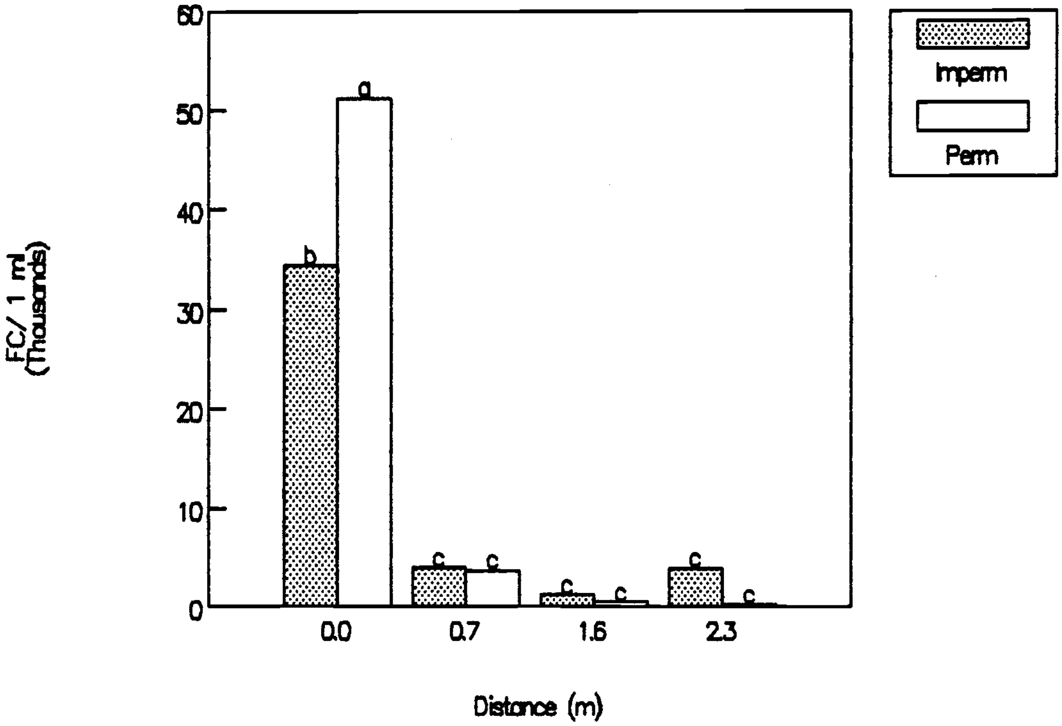


Figure 10. Fecal Coliform means for distance by soil type interaction.

Different letters indicates a significant difference in treatments ($p<0.05$).

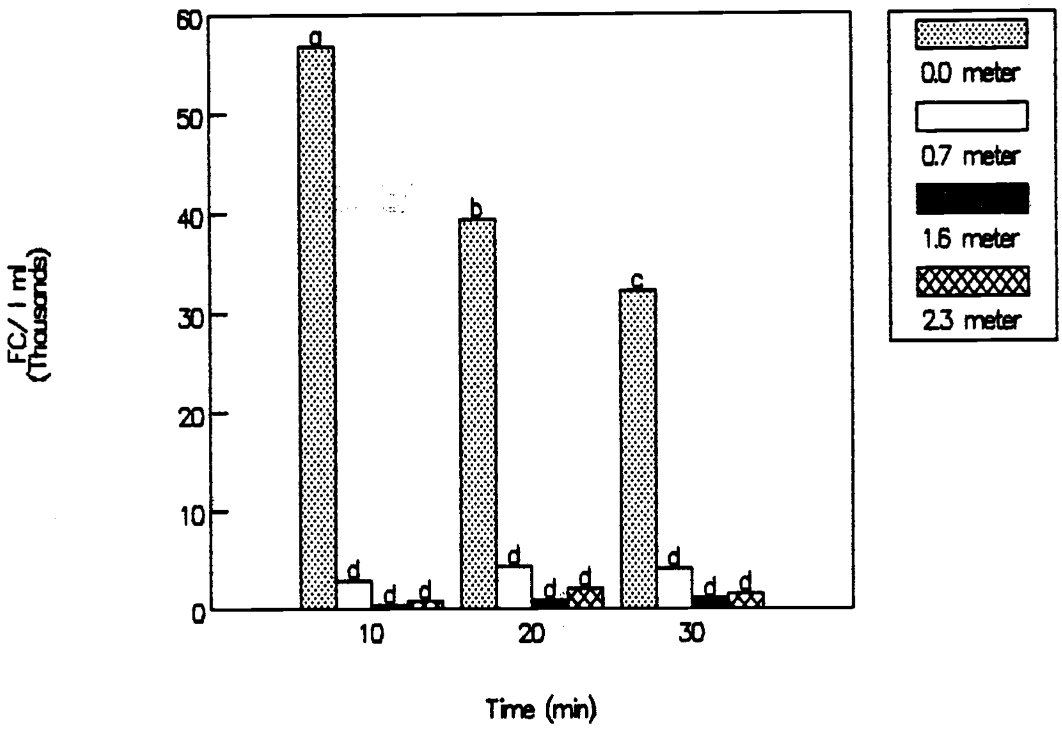


Figure 11. Fecal coliform means for the distance by time interaction.

Different letters indicate a significant difference in treatments ($p<0.05$).

This experiment measured only the overland flow component of runoff. In natural conditions several centimeters would have become saturated and both interflow and overland flow would have contributed to the hydrograph.

As shown if figure 10, the majority of bacterial pollution comes from the feces at the 0.0 m distance. The counts for the 0.0 m distance averaged approximately 42,800 coliforms/ml.

The data indicates that the bacteria counts for less permeable soil at 2.3 m was 3,924 fc/ml (392,400 fc/100 ml), but was only 209 fc/ml (20,900 fc/100 ml) for permeable soils. This leads one to believe that surface runoff across frozen ground may have the greater potential for causing fecal pollution.

Even though the bacterial impact of the 2.3 m distance is minimal, it still exists. The water quality standard for wildland streams is less than 1000 fc/100 ml. The seriousness of the impact would depend on the volume of surface runoff entering a stream.

V. CONCLUSIONS

Feces Concentration and Distribution

The transect data collected during this investigation support other studies which have reported that cattle prefer riparian areas, gentle slopes, and a nearby source of water.

During the winter the cattle remained near the supplemental feeding areas in the meadows.

During spring the cattle, while favoring the riparian zones, increased their usage of the uplands. In the uplands, the cattle favored areas that had been cleared of juniper trees and consequently supported more succulent vegetation. They also favored slopes that were less than 18.0 percent.

Instream Fecal Deposition

The average number of times that the free ranging cattle entered the stream, per animal per day, was 7.7, 3.3, 1.7, and 0.9 for summer, fall, winter, and spring respectively. The average time that the free ranging cattle spent in the stream, per animal per day, was 11.2, 2.6, 5.9, and 4.3 minutes for summer, fall, winter and spring respectively. The time in the stream recorded for winter was "on the ice" not in the flowing water. The average defecation rate for free ranging cattle directly into the stream, per animal per day, was 0.41, 0.19, 0.17, and 0.17 for summer, fall, winter and spring respectively.

The average number of times that the cattle in the feedlot entered the stream, per animal per day, was 2.1 during March. These cattle spent an average of 3.9 minutes, per animal per day, in the stream. The average defecation rate into the stream for these cattle was 0.4 per animal per day.

Overland Bacterial Transport

This experiment measured the overland flow component of two sod covered soil types, porus and simulated frozen ground.

Analyses of the data indicated that the two rainfall intensities had no significant effect on fecal coliform concentrations. However, there was a significant difference ($p < 0.001$) with respect to distance. The SNK mean separation test ($p < 0.5$) showed that the bacteria numbers at the 0.0 m distance were significantly higher than those at 0.7, 1.6, and 2.5 m distances. However, there were no significant differences between 0.7, 1.6, or 2.5 m distances.

The results of the bacteria experiment indicate that bovine feces landing very near the stream have a potential for a major impact, with concentrations of bacteria ranging from 36,000 to 51,000 fc/ml. Feces that are deposited at least 0.7 m from a stream have a reduced chance of entering the stream and therefore should have a less significant impact on water quality. This study indicates that during those times of the year when infiltration rates are high, the hazard decreases. In this experiment, 209 fc/ml were delivered to the stream from deposits placed 2.3 m away under high infiltration conditions; while 3,924 fc/ml were delivered to the stream from deposits placed 2.3 m away but under reduced infiltration (simulated frozen ground) conditions. This study dealt strictly with the delivery of bacteria to the stream and makes no reference to the confounding effects of increased surface runoff, and therefore dilution, which are likely to also accompany lowered infiltration rates. Also, this study only dealt with the overland flow component of runoff and did not address interflow contributions. Further research is appropriate to quantify the effects of dilution and the contribution of interflow.

VI. MANAGEMENT IMPLICATIONS

Feces Concentration and Distribution

Winter supplemental feeding of cattle has the strongest influence on the location of cattle during the winter. Fecal concentration in the riparian zone can therefore be lowered by feeding the cattle well away from the stream.

Clearing juniper, and the subsequent regrowth of herbaceous vegetation, seems to have a positive impact on controlling grazing patterns in the uplands. During the spring the cattle favored the areas that were cleared of juniper trees. Therefore, this study presents strong evidence that rangeland improvement practices which "lure" livestock away from riparian zones have a positive effect on water quality.

Instream Fecal Deposition

Water distribution may be the best available tool in distributing cattle in a pasture. During the winter some ranchers keep their cattle in meadows near streams. These cattle are generally concentrated and can have direct adverse impacts on water quality. Providing water away from the stream may decrease the amount of time cattle spend in the stream. This would reduce the adverse impacts that cattle have on water quality. It is possible that if one were to provide heated water at these troughs that the animals would consume more water and actually demonstrate positive physiological efficiencies.

Concentrating cattle in a feedlot with free access to a stream may also cause adverse impacts on water quality. Providing water in a trough and fencing the feedlot cattle out of the stream would help alleviate this potential problem.

Overland Bacterial Transport

Buffer strips may ultimately prove to be effective tools for preventing fecal contamination from reaching streams via overland flow. It appears that only the feces which land in, or very close, to the water have a major impact on water quality during summer months. Therefore a relatively small buffer strip may be adequate to prevent degradation of water quality for grazing animals. Further research is needed however, to determine the width(s) necessary to "filter" contaminates.

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VIII. APPENDICES

Appendix A. ADDITIONAL DATA FOR THE COW-CHIP CONCENTRATION EXPERIMENT.

Table A-1. Scientific and common names for plant species.

Code	Genus	Species
Scientific names of grasses and shrubs.		
Acda	Agropyron	dasystachyum
Agsp	Agropyron	spicatum
Agst	Agrostis	stolonifera
Brte	Bromus	tectorum L.
Feid	Festuca	idahoensis
Kocr	Koeleria	cristata
Popr	Poa	pratensis L.
Posa	Poa	sandbergii Vasey
Sial	Sisymbrium	altissimum L.
Sihy	Sitanion	hystrix
Arar	Artemisia	arbuscula
Artr	Artemisia	tridentata
Artrv	Artemisia	tridentata ssp.vaseyana
Artrw	Artemisia	tridentata ssp.wyomingensis
Chna	Chrysothamnus	nauseous
Chvi	Chrysothamnus	viscidiflorus
Common names of grasses and shrubs		
Acda		thickspike wheatgrass
Agsp		bluebunch wheatgrass
Agst		
Brte		cheatgrass brome
Feid		Idaho fescue
Kocr		prairie junegrass
Popr		Kentucky bluegrass
Posa		Sandberg's bluegrass
Sial		tumblemustard (forb)
Sihy		bottlebrush squirreltail
Arar		low sagebrush
Artr		big sagebrush
Artrv		mountain big sagebrush
Artrw		Wyoming big sagebrush
Chna		rubber rabbitbrush
Chvi		lanceleaf green rabbitbrush

Table A-2. Number of cow-chips per hectare.

Area	Cumulative 1987	Winter 1988	Spring 1988	Cumulative 1988
1	4008	6067		6067
2	2968	1457	1476	2933
3	1876	1181	200	1381
4	1857	1067	162	1229
5	1693	1095	38	1133
6	1667	2390	1410	3800
7	1571	4190		4190
8	1534	3238	195	3433
9	1210	819	105	924
10	1162	114	29	143
11	1048	210		210
12	943	57	276	333
13	895	200	190	390
14	884	210	0	210
15	829	105	67	171
16	800	190	67	257
17	794	1724		1724
18	686			
19	676	0	171	171
20	543	0	171	171
21	476	29	76	105
22	467	48	133	181
23	448	29	76	105
24	429	57	76	133
25	400	210	38	248
26	390	0	143	143
27	371	48	86	133
28	343			
29	333	0	238	238
30	314	0	57	57
31	190	57		57
32	162	19	10	29
33	76	0	29	29
34	57	10	114	124
35		448	24	471
36	248	48	57	105

Appendix B. ADDITIONAL DATA FOR THE BACTERIAL TRANSPORT EXPERIMENT.

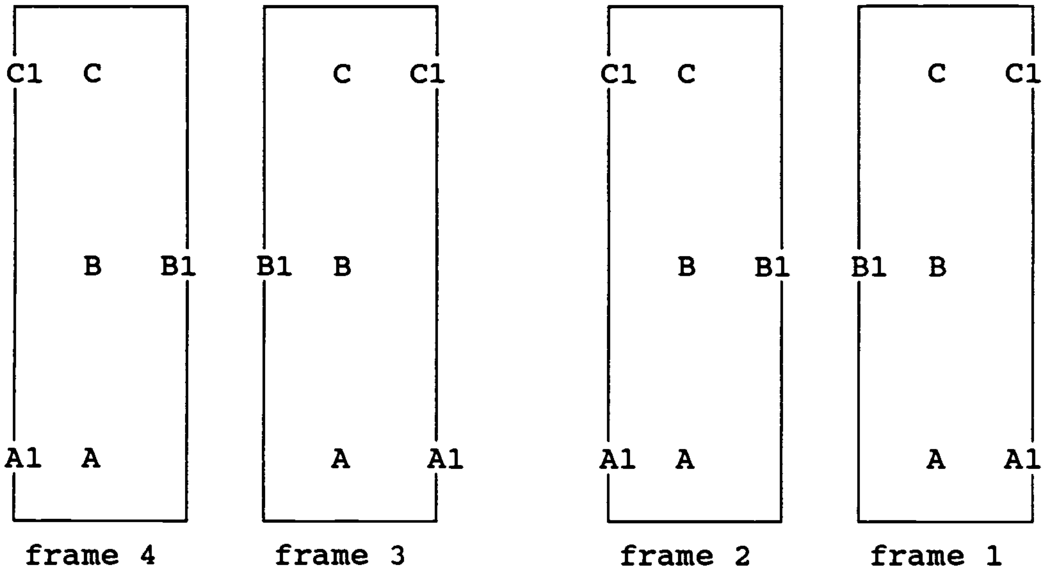

Figure B-1. Collection sites for the rainfall rates on each frame.

Table B-1. Rainfall rates for each site with simulator set at 5 cm/hr.

Frame		cm/hr	+/-		cm/hr	+/-	Average	
1	A	5.23	0.05	A1	4.54	0.06	1A	5.23
	B	5.11	0.13	B1	6.40	0.08	1AB	5.17
	C	5.25	0.10	C1	4.30	0.05	1ABC	5.20
2	A	5.89	0.02	A1	5.97	0.08	2A	5.89
	B	5.12	0.03	B1	5.29	0.14	2AB	5.51
	C	5.30	0.05	C1	5.17	0.12	2ABC	5.44
3	A	5.57	0.11	A1	4.67	0.05	3A	5.57
	B	4.90	0.07	B1	7.38	0.37	3AB	5.24
	C	4.79	0.07	C1	4.00	0.07	3ABC	5.09
4	A	5.24	0.02	A1	5.37	0.06	4A	5.24
	B	4.90	0.04	B1	6.03	0.08	4AB	4.99
	C	4.79	0.04	C1	4.69	0.14	4ABC	4.89

Note: See figure B-1 for site locations.

Table B-2. Rainfall rates for each site with simulator set at 10 cm/hr.

Frame		cm/hr	+/-		cm/hr	+/-	Average	
1	A	10.15	0.19	A1	9.00	0.07	1A	10.15
	B	10.14	0.32	B1	12.64	0.32	1AB	10.14
	C	9.79	0.17	C1	8.06	0.03	1ABC	10.02
2	A	10.83	0.27	A1	11.27	0.13	2A	10.83
	B	10.41	0.28	B1	11.68	0.20	2AB	10.62
	C	10.06	0.18	C1	9.71	0.25	2ABC	10.43
3	A	9.94	0.22	A1	9.53	0.40	3A	9.94
	B	9.83	0.05	B1	11.47	0.64	3AB	9.89
	C	8.91	0.07	C1	7.60	0.08	3ABC	9.56
4	A	10.53	0.17	A1	10.43	0.10	4A	10.53
	B	9.55	0.12	B1	10.67	0.53	4AB	10.04
	C	9.27	0.07	C1	9.84	0.97	4ABC	9.78

Note: See figure B-1 for site locations.

Table B-3. Replications of the bacterial enumeration.

Obs.	Time	Replications			Dilution	Mean	Stderr
	(min)	1	2	3			(+/-)
7	10	58	73	44	0.001	58333	8373.2
	20	49	34	33	0.001	38667	5174.7
	30	36	42	33	0.001	37000	2645.8
8	10	53	23	31	0.010	3567	896.9
	20	19	27	23	0.010	2300	230.9
	30	22	9	20	0.010	1700	404.1
41	10	38	36	17	0.001	30333	6691.6
	20	34	22	27	0.001	27667	3480.1
	30	28	36	10	0.001	24667	7688.4
45	10	51	44	44	1.000	46	2.3
	20	9	10	9	0.010	933	33.3
	30	24	31	26	0.010	2700	208.2
60	10	35	36		0.001	35500	500.0
	20	17	27		0.001	22000	5000.0
	30	17	16		0.001	16500	500.0
62	10	53	29	45	0.001	42333	7055.3
	20	18	20	18	0.001	18667	666.7
	30	21	9	16	0.001	15333	3480.1
65	10	83	86		1.000	85	1.5
	20	100	91		0.100	955	45.0
	30	21	12		0.010	1650	450.0
67	10	32	43		0.010	3750	550.0
	20	26	23		0.010	2450	150.0
	30	18	19		0.010	1850	50.0
74	10	55	55		10.000	6	0.0
	20	8	13		10.000	1	0.3
	30	70	--		10.000	7	
77	10	41	39	--	10.000	4	0.1
	20	120	61	91	1.000	91	17.0
	30	52	82	81	1.000	72	9.8
81	10	34	35		10.000	3	0.1
	20	9	17		0.100	130	40.0
	30	15	27		0.100	210	60.0
85	10	22	13		0.001	17500	4500.0
	20	10	11		0.001	10500	500.0
	30	14	--		0.001	14000	
103	10	11	19		0.100	150	40.0
	20	76	92		0.100	840	80.0
	30	71	61		0.100	660	50.0
104	10	26	28	30	0.100	280	11.5
	20	95	103	95	0.100	977	26.7
	30	93	71	73	0.100	790	70.2

Table B-4. Number of fecal coliforms per 1 gram of feces.

Date	fc/1 g	Date	fc/1 g
9/3	605,000	9/10	333,300
9/3	410,000	9/12	1,055,000
9/3	470,000	9/12	210,000
9/3	5,400,000	9/13	296,700
9/3	360,000	9/13	122,000
9/5	273,300	9/14	88,330
9/6	290,000	9/14	60,500
9/8	130,000	9/15	420,000
9/9	190,000	9/16	100,000
9/10	396,700	9/16	220,000
9/10	433,300	9/17	396,700

average	557,310
standard error	235,134

Table B-5. Background fecal coliform concentrations for each observation.

Obs.	Sample Size (ml) (0.1)	(1)	(10)	(25)	(50)	FC/1 ml (nat)	(ln+1)
1		0	0		7	0	0.0
2		0	1	TRASH		0	0.0
3		0	TNC	TNC			
4		0	TNC	TNC			
5		0	TNC	TNC			
6	0	1	1			1	0.7
7	9	67	0			99	4.6
8		0	0		0	0	0.0
9		17	TNC	TNC		17	2.9
10		0	TNC	TRASH			
11		2	TRASH	TRASH		2	1.1
12		0	0		TNC		
13	30	TNC	TNC			300	5.7
14	0	2	5			2	1.1
15		0	1		1	0	0.0
16		0	TRASH	TRASH			
17		84	TRASH		TRASH	84	4.4
18		0	0	TRASH		0	0.0
19		1	5	11		1	0.7
20	0	0	10		TRASH	0	0.0
21	0	0	257			25	3.3
22		1	10			1	0.7
23		0	1	TRASH			
24		0	TNC	TRASH			
25	0	0	TNC		TNC		
26		3	TNC	TNC			
27	1	1	TNC			1	0.7
28	2	14	TRASH			14	2.7
29	0	19	TNC			19	3.0
30	0	0	6			1	0.7
31	0	3	0			3	1.4
32	0	2	15			2	1.1
33	0	0	TNC	(APPROX. 70)			
34	1	0	0			10	2.4
35	0	3	15			3	1.4
36	0	1	TNC			1	0.7
37	0	0	9			1	0.7
38	2	6	31			6	1.9
39	0	0	0			0	0.0
40	0	0	8			1	0.7
41	0	0	TNC	(APPROX. 20)			
42	0	5	?			5	1.8
43	2	11	TNC			11	2.5

Table B-5. Background fecal coliform counts for each observation.

Obs.	Sample Size (ml)					FC/1 ml	
	(0.1)	(1)	(10)	(25)	(50)	(nat)	(ln+1)
44	0	7	TNC			7	2.1
45	0	0	8			5	1.8
46	0	1	6			1	0.7
47	0	1	TRASH			1	0.7
48	3	25	TNC			25	3.3
49	0	0	3			0	0.0
50	4	38	TNC			38	3.7
51	0	0	3			0	0.0
52	0	1	2			0	0.0
53	0	0	0			0	0.0
54	0	0	TRASH			0	0.0
55	3	15	TRASH			15	2.8
56	1	21	TNC			21	3.1
57	0	6	TNC			6	1.9
58	0	0	6			0	0.0
59		1	1	3		1	0.7
60	0	0	0			0	0.0
61	0	3	0			3	1.4
62	0	0	0			0	0.0
63	0	2	13			2	1.1
64	0	0	TRASH			0	0.0
65	0	1	0			1	0.7
66	0	2	15			2	1.1
67	0	0	0			0	0.0
68	0	0	0			0	0.0
69	0	0	0			0	0.0
70	0	0	0			0	0.0
71	0	0	0			0	0.0
72	4	4	1			4	1.6
73	0	1	9			1	0.7
74	1	9	126			11	2.5
75	0	1	0			1	0.7
76	0	0	2			0	0.0
77	0	0	0			0	0.0
78	0	0	0			0	0.0
79	0	0	TNC				
80	0	0	0			0	0.0
81	0	0	1			0	0.0
82	0	1	0			1	0.7
83	0	0	2			0	0.0
84	0	0	0			0	0.0
85	0	3	33			3	1.4
86		0	0	1		0	0.0
87		0	0	1		0	0.0
88		8	?	?		8	2.2

Table B-5. Background fecal coliform counts for each observation (continued).

Obs.	Sample Size (ml)					FC/1 ml	
	(0.1)	(1)	(10)	(25)	(50)	(nat)	(ln+1)
89		2	5	0		2	1.1
90		0	2		34	1	0.7
91	0	0	4			0	0.0
92	0	0	0			0	0.0
93		0	2		5	0	0.0
94	1	0	0			0	0.0
95		0	?	?		0	0.0
96		1	8	23		1	0.7
97		TNC	TNC	TNC			
98	0	0	3			0	0.0
99	0	0	5			1	0.7
100		1	0	2		0	0.0
101		4	70	TNC		70	4.3
102		9	?	?		9	2.3
103		1	43	50		4	1.6
104		0	TNC	TRASH			
105	0	1	0			1	0.7
106	0	0	0			0	0.0
107		0	1		10	0	0.0
108	0	0	2			0	0.0
109		0	0	2		0	0.0
110		0	0	0		0	0.0
111		0	0	TRASH			
112	0	0	1			0	0.0
				average		8.9	1.0

Table B-6. Summary of fecal coliform data.

					FC/ 1 ml			
Obs #	S/P	RI (cm/hr)	Dist (m)	Frame (#)	10 min	20 min	30 min	Infil (avg)
1	1	1	1	4	34991	60991	16991	3.08
2	1	1	1	3	55991	35991	20991	4.04
3	1	1	1	2	45991	17991	25991	3.73
4	1	1	1	1	31991	32991	20991	3.18
5	1	1	1	4	126491	83491	56991	2.00
6	1	1	1	3	90991	89991	80991	4.01
7	1	1	1	1	58321	38661	36991	1.90
				average	63538	51444	37134	3.13
8	1	1	2	2	348	2291	1691	3.40
9	1	1	2	1	77	321	551	4.11
10	1	1	2	4	1	97	179	4.58
11	1	1	2	3	58	311	771	4.17
12	1	1	2	2	1071	4891	5291	2.23
13	1	1	2	1	351	1891	2691	2.42
14	1	1	2	4	6391	21991	25991	2.94
				average	1185	4542	5309	3.41
15	1	1	3	3	1	581	901	2.12
16	1	1	3	2	0	0	0	4.62
17	1	1	3	1	160	156	96	3.93
18	1	1	3	2	0	161	361	3.49
19	1	1	3	4	0	81	105	3.02
20	1	1	3	4	0	191	161	2.58
21	1	1	3	3	0	8	0	3.77
				average	23	168	232	3.36
22	1	1	4	1	0	0	0	4.69
23	1	1	4	4	0	0	0	4.27
24	1	1	4	3	0	0	0	3.17
25	1	1	4	1	0	311	1221	3.26
26	1	1	4	3	0	0	93	3.17
27	1	1	4	2	9	1491	2891	0.88
28	1	1	4	2	0	0	32	3.68
				average	1	257	605	3.30

Table B-6. Summary of fecal coliform data.

					FC/ 1 ml			
Obs #	S/P	RI (cm/hr)	Dist (m)	Frame (#)	10 min	20 min	30 min	Infil (avg)
29	2	1	1	1	10991	34991	28991	2.20
30	2	1	1	4	63991	28991	29991	3.81
31	2	1	1	3	93991	63991	44991	3.59
32	2	1	1	2	69991	38991	28991	0.79
33	2	1	1	1	46991	36991	26991	0.66
34	2	1	1	4	13991	9991	13991	3.65
35	2	1	1	3	29991	9191	16991	4.11
				average	47134	31877	27277	2.69
36	2	1	2	4	451	6591	7091	2.19
37	2	1	2	3	666	4491	3591	2.62
38	2	1	2	2	571	2591	4591	3.00
39	2	1	2	1	541	7891	7991	1.15
40	2	1	2	4	231	4291	3591	1.81
41	2	1	2	3	294	2758	2458	2.32
42	2	1	2	2	471	4691	5591	0.63
				average	461	4758	4986	1.96
43	2	1	3	2	301	3391	1191	1.96
44	2	1	3	1	651	641	3291	1.92
45	2	1	3	4	37	1019	2691	2.84
46	2	1	3	3	0	66	3391	2.26
47	2	1	3	2	91	1591	3391	1.05
48	2	1	3	1	80	441	1691	3.06
49	2	1	3	4	0	311	631	1.75
				average	166	1066	2325	2.12
50	2	1	4	3	5	94	761	2.20
51	2	1	4	2	74	2091	1691	3.04
52	2	1	4	1	14991	19691	9491	2.12
53	2	1	4	4	260	111	31	2.76
54	2	1	4	3	2	151	371	1.70
55	2	1	4	2	21	201	741	0.78
56	2	1	4	1	23	1206	1891	1.46
				average	2197	3364	2140	2.01

Table B-6. Summary of fecal coliform data.

					FC/ 1 ml			
Obs #	S/P	RI (cm/hr)	Dist (m)	Frame (#)	10 min	20 min	30 min	Infil (avg)
57	1	2	1	3	84991	79991	77991	4.99
58	1	2	1	2	72991	51991	38991	7.97
59	1	2	1	1	80491	49991	42991	6.33
60	1	2	1	4	35491	21991	16491	6.03
61	1	2	1	2	114991	53991	47991	6.09
62	1	2	1	1	42321	18661	15824	4.25
63	1	2	1	4	52991	53991	32991	5.64
				average	69181	47230	39039	5.90
64	1	2	2	1	3991	4091	3891	5.46
65	1	2	2	4	75	946	1641	6.34
66	1	2	2	3	11841	13841	12191	2.32
67	1	2	2	2	3741	2441	1841	4.91
68	1	2	2	4	86	391	521	8.42
69	1	2	2	3	791	2691	2491	6.89
70	1	2	2	2	3991	2991	2691	5.13
				average	3502	3913	3610	5.64
71	1	2	3	2	0	17	44	7.99
72	1	2	3	1	2991	3491	2491	5.12
73	1	2	3	4	3091	3191	1591	5.82
74	1	2	3	3	0	0	0	8.36
75	1	2	3	1	2	31	0	8.27
76	1	2	3	4	101	301	211	7.93
77	1	2	3	3	0	82	63	8.11
				average	884	1016	629	7.37
78	1	2	4	4	0	44	45	8.57
79	1	2	4	3	0	0	0	8.00
80	1	2	4	2	97	1051	621	4.54
81	1	2	4	1	0	123	201	6.43
82	1	2	4	3	0	13	9	7.71
83	1	2	4	2	3	351	201	6.30
84	1	2	4	1	0	1	4	6.72
				average	14	226	154	6.90

Table B-6. Summary of fecal coliform data.

Obs	S/P	RI	Dist	Frame	FC/ 1 ml			Infil
#		(cm/hr)	(m)	(#)	10 min	20 min	30 min	(avg)
85	2	2	1	3	17491	10491	13991	5.34
86	2	2	1	4	37991	24991	22991	5.78
87	2	2	1	3	67991	18991	29991	4.58
88	2	2	1	2	62991	38991	38991	5.87
89	2	2	1	1	46991	36991	23991	5.79
90	2	2	1	4	31991	29991	19991	4.67
91	2	2	1	2	65991	29991	28991	4.43
				average	47348	27205	25562	5.21
92	2	2	2	1	8891		3891	4.87
93	2	2	2	2	4291		3191	2.12
94	2	2	2	1	1791	2591	2391	4.57
95	2	2	2	4	1891	3791	3091	3.55
96	2	2	2	3	601	3791	1591	4.91
97	2	2	2	2	1126	1791	1206	5.84
98	2	2	2	4	27991	8841	3991	2.29
				average	6655	4161	2765	4.02
99	2	2	3	2	2691	2791	3791	2.70
100	2	2	3	3	491	1891	1221	2.32
101	2	2	3	2	461	941	731	5.11
102	2	2	3	1	1456	3891	1391	1.05
103	2	2	3	4	147	831	651	6.82
104	2	2	3	3	271	968	781	2.82
105	2	2	3	1	281	1066	1021	2.82
				average	828	1768	1370	3.38
106	2	2	4	4	8191	29991	21991	3.19
107	2	2	4	1	461	921	836	2.10
108	2	2	4	4	35	281	271	3.52
109	2	2	4	3	51	926	1121	3.10
110	2	2	4	2	5	231	321	5.81
111	2	2	4	1	281	531	641	3.77
112	2	2	4	3	321	871	646	1.13
				average	1335	4822	3690	3.23

Notes: S/P 1 = sand, S/P 2 = plastic
RI 1 = 5 cm/hr, RI 2 = 10 cm/hr
Dist 1 = 0.0 m, 2 = 0.7 m, 3 = 1.6 m, 4 = 2.3 m