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Project Summary

Effect of Animal Grazing on Water Quality of Nonpoint Runoff in the Pacific Northwest

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This study was conducted to evaluate the effects of cattle grazing on runoff volumes and rates, erosion and sedimentation, and chemical and bacteria concentrations and quantities in the surface runoff discharged from agricultural watersheds in the principle grazing areas of the Pacific Northwest. The purpose of this study was to document these water quantity and quality variables over a period of 3 years from a small watershed managed in a typical fashion for this region under sustained economic production without obvious resource abuse. The effects of management alternatives were not evaluated, but the impact of cattle presence was defined by excluding grazing on a smaller, but otherwise similar, grazed watershed. Although a wide variety of water quality parameters were measured on the analyzed samples (approximately 23 types of determinations), special emphasis was given to the bacterial analyses because the animal presence was expected to have more effect on these than on any other parameter.

Streamflow water quality was intensively studied for 3 years (1976-1979) on a grazed [21.5 hectares (ha)] and an ungrazed check (0.9 ha) watershed near Potlatch, Idaho. The objective was to identify water quantity, erosion, and water quality from a typical summer grazed watershed in this region of winter precipitation and to identify animal impacts by comparison with the ungrazed watershed. Special emphasis was placed on bacteriological water quality measurements and interpretations.

The study period contained a near-drought year and two more nearly normal years with significant runoff that provided good water quality determinations. Erosion was minimal on the grazed watershed although cattle trails were an obvious source. Chemicals from the grazed and ungrazed watersheds were of low concentrations and quantities and the water quality was not impaired for most uses. Indicator bacterial numbers were often high and were closely related to cattle presence on the watershed. Unexpected persistence of indicator bacteria was found after fall removal of the livestock and significant numbers were found in the spring months after the temperature raised and before grazing began. These results show that bacterial quality is related to livestock, but there is considerable doubt that indicator bacterial water quality standards developed for point source are appropriate for assessing nonpoint source bacterial contamination. More research is needed to identify appropriate bacterial indicators for nonpoint runoff. Research is also needed to determine the effect of alternative pasture and grazing management on runoff quantity and quality.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to

announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

In this age of environmental awareness and increased population density, it is urgent to define and improve stream water quality if streams are to continue to be a source of beauty, recreation, and water supply. Streamflow which emanate as surface runoff from agriculture pastureland is suspected of having less than desired quality because of the obvious possibility of fecal, chemical, and sediment contamination. Cattle grazing occupies a significant portion of the agricultural landscape in much of the nation, with cattle densities ranging from feedlots to many hectares per animal on the western desert ranges. Management for protection of soil, vegetation, and water resources ranges from (a) total sacrifice and disregard to (b) normal protection for continuous economic protection to (c) near disuse or major conservation efforts.

The effect of cattle grazing on downstream water quality with various management shemes is currently very poorly defined. Scientific judgement would indicate that the water quality and flow rates, erosion and sediment production, chemicals, and bacteria could all be altered by the presence of livestock on a watershed and the management practices associated with this agricultural operation. However, there is no method of predicting these effects other than through experimental data obtained by scientific study. These results, when combined with those of related studies, will provide inferences of cause and effects.

The result of not obtaining the environmental impact knowledge of agricultural production operations such as cattle grazing could be potentially devastating should regulations and controls be mandated without scientific basis. Even the uninitiated recognize the fact that every operation on agricultural land will have some environmental and downstream impact, and changes and demands for restrictions and controls are inevitable. It is imperative that scientific facts and documented alternatives be available so that society can make intelligent choices on what controls, if any, are necessary.

This study of agricultural runoff water quality was one of four similar studies cooperatively sponsored by the U.S. Environmental Protection Agency (EPA). The other three were located in Ohio, Oklahoma, and Nebraska. Each study location measured water quality from grazed pastureland, but each had a different emphasis depending upon the staff and facilities available. This study differed most distinctly from the others by the fact that the study investigated the opposing summer grazing-winter runoff combination.

The report which follows is a summary description of the study objectives; facilities and instrumentation used; data organized by hydrology, sedimentation, and water quality; and interpretations and conclusions. Although much detail is omitted, the summaries in the text and appendices of the full report provide sufficient information so that the reader may review the data to substantiate the conclusions or to develop their own. This opportunity for reinterpretation is important because the implication of these findings may likely change in the future, but the carefully documented facts of these observations will remain permanent.

Conclusions

The three study years encompassed a variety of precipitation amounts and event types from near drought to a near normal snowpack. The mean precipitation quantity for the study period was slightly below the long-term average, but in general, the data are quite representative for the study region and certainly will apply throughout a broad region of the west where winter precipitation and summer grazing dominate.

Surface runoff, whose quality was the object of this study, was 199 and 136 millimeters (mm) of the 676 and 516 mm (near normal) of precipitation for the main watershed for the two near-normal years, or about 20 percent of the precipitation. The quantity from the small, upland check watershed was only one-third of this amount. The important feature was that adequate surface runoff occurred from both the main and check watersheds and that the water quality of both areas was well defined. Because of the difference in size and topographic setting, significant natural differences in runoff volume were expected and no attempt was planned or conducted to relate runoff quantities to watershed treatments of livestock grazing.

Erosion and streamflow sediment were much less from these pasture lands than from similar tilled agricultural lands. Average sediment yields were only 382 kilograms per hectare per year (kg/ha/yr) from the main watershed for the study period compared with an average of 5,900 kg/ha/yr for a typical nearby tilled watershed during a study period of 1961-65. But the check watershed averaged only 19 kg/ha/yr for the study period, thus it showed much less erosion and sediment transport than the main watershed. Part of this reduced sediment from the check watershed was obviously associated with the reduced surface runoff, but beyond that, the observations showed that cattle trails and trampling within the main watershed slopes became small interceptor ditches from surface flow upslope and eroded several centimeters (cm) in depth and width. Several shorter trails within the stream alluvium leading to water places eroded even more. And the small stream banks (most less than 25 cm) had some deterioration due to trampling during grazing and watering. No quantitative assessment was made of these cattle effects and they appeared to be not highly significant to the overall water quality, although this is certainly a quality aspect that could be altered by management techniques of controlled cattle traffic.

Total coliforms (TC) in runoff from grazed and ungrazed areas in the Pacific Northwest did not correlate with the presence or absence of animals. Fecal coliform (FC) and fecal streptococcal (FS) numbers were elevated in runoff from the grazed area when cattle were present above that when they were absent. However, even after animals were absent from the area for several months, FC numbers were elevated in the runoff above recommended levels of 200/100 ml (FC) and 1,000/100 ml (TC) for primary contact. In fact, FC and FS numbers appeared to increase from less than 100/100 ml to several thousand per 100 ml in the runoff from the grazed area for several months in the spring during warm, wet weather after animals were removed the previous fall. Almost 3 years of cattle absence were required for FC numbers in runoff from the check watershed to be consistently below the maximum recommended numbers for primary contact. The data indicate that the use of conventional FC/FS ratios or FC numbers in runoff as a measurement of recent fecal pollution by cattle on a grazed area is of limited or no value. FC/FS ratios of 1, which indicate recent animal fecal pollution, were found after animals had been removed for several months.

Nitrogen (N) and phosphorus (P) deliveries from the watersheds were low--generally much lower than from areas used for other agricultural purposes. Total-N losses from the grazed area were 3.8 and 3.8 kg/ha during water years

1978 and 1979, respectively, while total-P losses during the same periods were 1.29 and 0.93 kg/ha, respectively, with very low losses of ortho-P. More N fell on the grazed watershed in precipitation than was lost in the runoff.

Recommendations

This research project provided hydrologic, erosion, and water quality information from a specific site, with one management level, and for minimal study years. While these baseline data are extremely useful for general recommendations that water quality is quite good from pastureland of moderate grazing and management, additional research must be conducted to determine the effect of management practices on sediment, chemical, and bacteriological water quality parameters and to establish bacterial water quality standards for nonpoint sources. Only through carefully planned and documented studies with varying management levels and techniques will it be possible to adequately understand the effect of management options on local and downstream water quality.

Research is desperately needed to determine the meaning of FC and FS numbers in runoff from nonpoint sources such as grazed areas. This study indicated that these organisms multiplied on the pasture during warm, wet weather several months after the animals were removed. Voluminous literature indicates that pathogenic microorganisms, which the presence of these organisms indicates, cannot survive for long periods outside the warm-blooded host. While the numbers of FC and TC in runoff exceeded those recommended for primary contact, the situation on the watershed should not present a health hazard. Fecal coliform and TC numbers in runoff as defined for point sources do not appear to be viable water quality criteria for nonpoint sources.

Chemicals such as N and P in runoff from those areas were below levels that would usually be of environmental concern. Grazing areas in the Pacific Northwest, managed as the area described in this report, should not present chemical environmental hazards. Future studies should concentrate on bacteriological processes and interpretations for potential health and environmental hazards.

Experimental Design

A paired watershed design was selected to study the water quality impact of animal grazing. The main watershed with an area of 21.5 ha [53.1 acres (a)] was summer grazed with management typical of this region. A check watershed of 0.9 ha (2.2 a) adjacent to the main watershed and a part of the original pasture was fenced to exclude all cattle. These two watersheds were intensively instrumented for complete hydrologic, sediment, and water quality measurements, and were continuously monitored for the period December 1976 to July 1979.

The watersheds were carefully selected to be generally representative of the partially forested grazing areas of the Pacific Northwest. The level of recent and current management was of particular interest because management was not to be varied but was to be typical (i.e. most representative) such that neither the worst nor best case was represented. The areas studied met these criteria.

The pasture was grazed at a rate that fully utilized the grass production which produced overgrazing in dryer years but was not beyond sustained use over a period of years. Little management for grazing distribution or to prevent cattle contact with the stream was done, but this is typical for this region of open pasture, summer grazing. The cattle were usually removed in late October and returned to the pasture in late May. The actual watershed management was carefully recorded and monitored through cattle numbers, forage production and utilization, cattle habits and movements, and dung distribution.

The small check watershed was fenced at the outset of the study and grazing was prohibited during the remainder of the study other than occasional deer and a calf that broke in for 1 day during the first summer. No attempt was made to remove existing manure at the study initiation, thus the animal effects were a decaying function from their last presence in October 1976. To approximately maintain the grass quantities similar between the two watersheds and keep the presence of cattle as the only major difference, the check area grass was moved, baled, and removed about midsummer each year, after most vegetative growth had occurred.

Results and Discussion

Hydrology and Sediment

Daily quantities of precipitation, streamflow, and sediment were measured on the main and check watersheds.

Precipitation

For the three study years, precipitation ranged from near drought during the 1976-77 winter to above normal for 1977-78, and near normal for 1978-79. The annual values for these years are shown in Table 1.

Precipitation during the three study years averaged 65 mm (2.6 in) below the Potlatch normal of 622 mm (24.5 in). The first year was a severe regional drought with very limited snow cover at any time and only 370 mm (14.6 in) on the watershed. The two subsequent years were more nearly normal, but neither of these years had a large snowpack accumulation because of mid-winter thaws. February 1979 had the largest accumulation of snow depth (about 45 cm) and this melt provided the largest surface runoff measured during the study. Discussions with local ranchers indicated that normal accumulative snow depths would be slightly greater than any that were measured.

Streamflow

Observed streamflow from the study watersheds followed the precipitation trends very closely (Table 1). The 1976-77 winter had far below expected runoff amounts, while the two subsequent study years had more normal amounts. The study period provided a wide variety of flow events in different sequences which make the average results applicable to other situations.

Observations drawn from these events, daily, monthly, and annual summaries indicate that the check watershed had significantly less runoff than the main watershed. The one exception was the frozen ground runoff events in 1976-77. This is not unexpected because the check watershed was situated on an upland area with less steep topography and no wet bottomland. These differences are always a problem in paired watershed studies, and especially so when the topography, geologic setting, and total areas differ considerably. The surface runoff of the check area was only 40 and 30 percent of the main watershed for the 1977-78 and 1978-79 seasons. Little or no runoff was observed from its south side except in frozen conditions. The effect of these differences on the water quality interpretations is likely not so severe because the check area did have sufficient runoff these 2 years to provide significant surface flushing and numerous sampling opportunities to contrast simultaneously with those from the main watershed.

Table 1. Annual Streamflow Summary

	1977*		1978		1979†	
	Main	Check	Main	Check	Main	Check
Precipitation, mm	370		676		516	
Runoff						
Volume, m³	2,451	308	38,193	422	40,623	370
Depth, mm						
Total Flow	11	34	178	46	189	41
Surface Flow	10	34	119	46	136	41
Peak flow, l/sec	26	4	103	4	145	3

*Measurements Nov. 4, 1976 to Sept. 30, 1977.
†Measurements Oct. 1, 1978, to July 5, 1979.

Sediment

Sediment concentrations and total quantities were quite low for both watersheds when compared with any other agriculturally used areas. The average concentrations for all 3 years from the main watershed was 424 milligrams/liter (mg/l) (Table 2), with the maximum sample having 12,700 mg/l and minimum sample having 1 mg/l (during baseflow). Average sediment yield was 382 kg/ha. These values compare with mean concentrations and yield of 7,400 mg/l and 5,900 kg/ha, respectively, from wheat land in our region (Missouri Flat Creek, 70 km², 1961-1965). Thus, the grassed pasture area is more than a full magnitude less than that delivered from a much larger farmed watershed.

The check watershed had significantly less sediment discharge of only 19 kg/ha corresponding with the much less total streamflow, but the mean concentrations were also only 10 to 20 percent of those from the main watershed. The maximum sampled concentration was 2,105 mg/1. The much lower concentrations and yields may partially be influenced by the topographic setting, but the observations indicate that much of this difference is attributed to the presence of cattle on the main watershed. Many cattle trails were developed throughout the main watershed, and they were especially concentrated in the spring and channel area where watering occurred. Several trails in this mid-watershed area intercepted the surface runoff and became the controlling channels. They eroded significantly (5 to 10 cm in depth), and this sediment went directly into the small streams.

The stream immediately above the main gaging location had small (15 to 30 cm) banks that were largely unprotected by vegetation. Through watering and grazing, the cattle added some disturbance to this area which added to the natural tendency for this small channel to erode. The upland channel directly west of the weather station also had some exposed banks and a small overfall which eroded some during the study. Again, there was some cattle activity in this channel which undoubtedly aggravated the erosion. Beyond the trails and channels, there was little visible erosion. These upland grass areas probably produced amounts similar to those measured on the check watershed where there were no apparent areas exposed from good grass vegetation.

Manure Distribution

To provide direct measurements of the manure distribution on the main watershed, counts were made three different dates during 1978 at early summer, midsummer, and just after cattle were removed. The watershed was stratified into three sampling zones of (a) high cattle use due to loafing or watering, (b) along drainages, and (c) general grazing. Eight sample sites were made in zone (a), 10 along the waterways, and 20 randomly placed throughout the watershed. Each sample consisted of counting the number of manure drops in a 50-m² area and sampling the weight and size of the droppings. The high use areas were difficult to count due to trampling of the droppings.

The fecal deposits were not evenly distributed over the watershed, but were concentrated in high-use areas and, to some extent, along drainages. The high drainage density was probably due to the location of some animal trails in the pasture. The situation is compounded when it is considered that two of the high-use sites were in or immediately adjacent to drainage bottoms.

On an overall basis, the density of fecal deposits across the entire watershed was 2,645 deposits/ha, providing a coverage of 1.45 percent. Therefore, if the distribution of droppings were more uniform, the concentrations in the drainages would have approached that which was present elsewhere in the nonconcentrated areas. In the opinion of the researchers, one must suspect that the fecal bacteria counts in the runoff are a result of the distribution of feces much more than the overall fecal density. This is one subject which should be seriously considered for additional research.

Table 2. Annual Sediment Summary

	1977*		1978		1979†		3-yr avg	
	Main	Check	Main	Check	Main	Check	Main	Check
Precipitation, mm	370		676		516		517	
Surface Runoff, mm	10	34	119	46	136	41	88	40
Sediment								
Yield, kg	877	15	10,489	25	13,291	12	8,219	17
Yield, kg/ha	41	16	488	28	618	13	382	19
Avg. conc., mg/l	408	49	410	60	455	32	424	47

*Measurements Nov. 4, 1976 to Sept. 30, 1977.
†Measurements Oct. 1, 1978 to July 5, 1979.

Water Chemicals and Oxygen

During the drouth water-year (1977), N and P losses in runoff from the main and check watersheds were insignificant. In water-year 1978, total N loss was only 3.8 and 0.48 kg/ha from the main and check watersheds, respectively, which was more than during 1977 but was still low. Nitrate concentrations were almost negligible with a total loss of only 0.33 and .08 kg/ha NO_3-N, respectively. N parameters were higher from the main watershed than the check, but no parameters were of sufficient magnitude to be of environmental concern. N concentrations were high in runoff when the pond was drained and in the initial runoff samples in the fall after the summer grazing season. These higher concentrations probably resulted from relatively fresh manure particles being carried in the runoff from the pasture and within the main stream channel. The pond was fenced to exclude cattle but they did have access to the main channel below the pond to the sampling site. Throughout this study, the periods of greatest nutrient concentra-

tions were associated with small runoff volumes such as early season events, summer events, or pond drainage. Thus, these events contributed very little to the annual constituent discharge. Average concentrations of N in the baseflow was about one-half that of the surface runoff.

While NO_3-N losses in runoff from the main watershed were slightly greater in water-year 1979 than in 1978 (1.33 kg/ha vs. 0.33 kg/ha), most N losses in runoff were less in 1979, thus total N losses were similar. Again, N losses in runoff were low and were generally lower than would be expected in runoff from areas used for other agricultural purposes. Total N losses were greater from the main watershed than the check watershed. Exchangeable sediment NH_4 was not run during water-year 1979 because it was negligible during water-year 1978.

P deliveries from both watersheds were negligible during water-year 1977. P deliveries in runoff were very low for water-year 1978 with runoff from the grazed area delivering only 0.2 kg/ha/yr ortho-P with a total-P loss of only 1.27 kg/ha/yr. P levels in the runoff did increase when cattle were present during the July 4 event. Very small amounts of P were delivered by baseflow even though baseflow was about one-third of the total water lost during the 1978 water year.

In water-year 1979, P deliveries in runoff and baseflow were low from the main and check watersheds. Generally, average ortho-P concentrations in runoff from the main watershed were higher in water-year 1979 than in 1978; in both years ortho-P in runoff decreased as the length of time animals were off the pasture increased. Total-P lost in runoff from the grazed watershed was slightly greater in water-year 1978 (1.27 kg/ha) than in water-year 1979 (0.93 kg/ha). If baseflow was added, the values were 1.39 and 1.05 kg/ha, respectively. The greater total-P loss in water-year 1978 was likely due to the December 10-15, 1977, event that had a high average total-P concentration of 3.12 mg/l. Ortho-P and total-P losses from the check watershed during water-year 1979 were 0.02 and 0.07 kg/ha, respectively.

The oxygen demand, pH, SC, Cl^-, and cation delivery for the main and check watersheds for water-years 1977, 1978, and 1979 are summarized in the Appendix of the report. During the establishment year, water-year 1977, oxygen demand for the main watershed was about twice that of the check (probably due to stagnation); pH for the main watershed appeared slightly more alkaline than the check, the SC of the main watershed was somewhat greater than the check watershed, as was Cl^- and cation delivery. The oxygen demand of the runoff from the grazed watershed was about three times that of the ungrazed watershed during water-year 1978 while Cl^- cations were about five times greater. Values for these parameters increased in runoff from the main watershed when cattle were present (July 4 event). Oxygen demand of runoff in water-year 1979 was greater from the grazed area than in 1978, but runoff from the ungrazed area was similar. Cations were not run during water-year 1979 because data from the previous year had shown that SC was well correlated with the Na, K, Ca, and Mg present in the runoff.

Table 3. Water Quality Parameter Concentration Responses to Streamflow

Parameter	*Type of Runoff Event*	*Time of Year*	*Response to Streamflow*
Bacteria, oxygen demands, N and P nutrients	*Rainfall*	*Fall and spring*	*Direct response to streamflow changes with successively smaller peak concentration*
"	*Snowmelt or frozen ground rainfall*	*Winter*	*Little or inverse response to streamflow*
"	*Mixed (snowmelt followed by rainfall)*	*Fall, winter, and spring*	*Little response during snowmelt. Direct response to rainfall*
"	*Snowmelt or rainfall*	*Late winter and/or spring*	*Little response to streamflow changes*
Specific conductance, pH, Cl, Na, K, Ca, Mg	*Snowmelt or rainfall*	*Fall, winter, and spring*	*Inverse response to streamflow*

Indicator Bacteria

TC counts in runoff showed little relationship to the presence or absence of cattle as shown by the summarized results of the main and check watershed. TC counts probably responded more to climate than to the cattle. From results of this study, TC counts appear to be useless for determining stream pollution.

In general, the FC and FS numbers decreased as expected throughout the winter months. Their numbers, however, unexpectedly increased again in the spring with warmer weather. Also, the FC/FS ratios varied more than expected, ranging from as high as 4/1 on the check watershed to 1/1 on the main watershed.

FC/FS ratios of about 0.1 to 1.0 indicate cattle fecal contamination. Runoff contaminated with cattle normally has a FC/FS ratio of about 0.7 while that with human had a FC/FS ratio of 4.0 and higher. Animal FC/FS ratios will increase with time, but they should remain less than one. The high FC/FS ratios long after cattle were removed from the area would lead one to question the validity of the FC/FS ratio for nonpoint areas. Furthermore, when animals were introduced back onto the watershed, the June 4, 1977, readings showed high FC and FS numbers but a FC/FS ratio of 0.02, which is indicative of wild animal fecal contamination. During the 3 year study period, except for a few mice and squirrels, wildlife populations on the study areas were almost nil.

The effect of grazing cattle on runoff water quality from the study watersheds can be summarized by the following. TC in runoff had an apparent relationship to cattle grazing operations, but numbers were elevated when they should not have been. FC and FS numbers in runoff from the grazed watershed were elevated when cattle were on the pasture. After cattle were removed, FC and FS numbers generally declined throughout the fall and winter months. However, after several months absence of cattle from the area, FC and FS numbers in runoff from the grazed watershed were elevated and in many cases exceeded suggested water quality standards. FC and FS numbers appeared to increase in runoff from the grazed area in the spring in rainfall runoff following a period of warm, dry weather several months after animals were removed. FC/FS ratios in runoff varied considerably and indicated recent cattle fecal pollution for long periods of time after animals were off the grazed area. FS numbers in runoff from the grazed and check areas did not change appreciably during the study. The check

Table 4. Average Percent Fecal Coverage in the Drainage Sampled Within the Study Watershed, Nov. 4, 1978

Sampling Site No.	Drainage Runoff Areas	Fecal Coverage Percent Area
1	Sacrifice (lower) pasture (plus rest of grazed main watershed)	20*
2	Ungrazed (check) watershed	0
11	Southeast area just above main sampling station	NS§
12	Northeast area just above main sampling station	0.7
13	All of the grazed watershed except the southeast, northeast and sacrifice areas	2.6
14	North pasture area draining into large gulley channel	0.9
15	Northwest pasture area	3.1
16	Southwest pasture area	2.2
17	Woodland area	1.8
18	Logged area (outside of fenced cattle-grazed area; horses, however, were grazed here)	NS

*Total remainder of watershed averaged 1.4 percent.
§NS =Not sampled

was ungrazed from the fall of 1976 throughout the study. FC numbers in runoff from the check were not consistently below the maximum recommended numbers for primary contact until the 1979 water-year, although FC numbers in the check watershed runoff during water-year 1978 were generally below or close to the recommended primary contact standard. The data would suggest that using conventional FC/FS ratios or FC numbers in runoff as a measurement of recent fecal pollution by cattle on a grazed area is of limited value in the Pacific Northwest.

Parameter Response and Spatial Distribution

Parameter Response

The type of runoff event affected the parameter response to streamflow (Table 3). With snowmelt on thawed ground followed by rain, NO_3-N does not follow the hydrograph initially during snowmelt; however, when the ground thawed, NO_3 concentration increased. Ortho-P did not follow the hydrograph at any time during a snowfall-rain on frozen soil event. For the same event, COD also did not appear to respond to streamflow until the ground began to thaw on the second day of the event. The water quality parameter, in this case total-P, did not respond to the streamflow increase caused by snowmelt, but did respond to the later streamflow increase caused by rainfall runoff. During long and large events, the check watershed behaved similarly. The highest check watershed values often occurred in the first few runoff samples as the check watershed channel was flushed since it had no base flow. For small events, parameter concentrations for check runoff, therefore, did not correlate well with flow rates.

Spatial Distribution

Hand samples were collected from various locations within the watershed during events in the 1978 and 1979 water-years to determine the effect of grazing patterns, manure density and land cover on water quality parameter concentrations. Of specific interest was whether the pollution load was primarily a result of cattle activity in and immediately adjacent to the stream channel (the "sacrifice area" between the north and south pastures) or if the stream water quality reflected the grazing activity over the entire watershed.

During the 1978 water-year, samples were taken December 6, 1977, during a small snowmelt/rainfall event; December 13, 1977, during the largest event of the water-year; and on March 15, 1977, during a late winter medium sized rainfall event. In water-year 1979 samples were taken from an event caused primarily by snowmelt on February 13, 1979, during the largest event of the water-year and of the entire study; February 27, 1979, during a large rainfall/snowmelt event; April 6, 1979, during an early spring rainfall event; and on May 4, 1979, at the beginning of a large spring rainfall event. This last sampling occurred after indicator bacterial numbers had increased above their late winter values.

Fecal density and distribution data were collected during the study by the range management component of the project (see Section VI of the Range Management Section in the report). The amount of a drainage area within the pastured watershed covered by feces varied from 20 percent for site 1 (sacrifice pasture) to 0.7 percent for site 12 (northeast area) at the November 7, 1978, sampling date (Table 4). The percent manure cover was determined three times during the summer of 1978. The values obtained on Nov. 7, 1978, after the cattle were removed from the watershed represent the fecal densities present when these water quality samples were taken from the 1979 water-year runoff. FC and FS numbers in runoff from the various sampling sites within the watershed did not correlate clearly with fecal disposition in water-year 1978 or 1979. In fact, no trends are apparent from the sites sampled. Also, N and P in the runoff from the various sampling sites within the pastured watershed did not appear to agree with manure deposition. Presumably vegetation and soil cover had a greater effect on runoff nutrient content than did manure deposition.

These results would indicate that indicator bacteria and nutrients in runoff from the main pasture areas were generally equal to those at the main sampling station. The pollution load can be considered nonpoint source in origin and not primarily a result of the greater grazing activity in the sacrifice area.

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The complete report, entitled "Effect of Animal Grazing on Water Quality of Nonpoint Runoff in the Pacific Northwest," (Order No. PB 83-245 225; Cost: $14.50, subject to change) will be available only from:
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