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CLEMSON

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TERRACED PASTURE FOR DISPOSAL OF DAIRY YARD RUNOFF

by R.O. Hegg, C.L. Barth, V.L. Quisenberry, and W.H. Livingston

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Clemson, South Carolina 29631

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The Office of Water Policy

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Washington, D.C. 20240

Technical Completion Report

A-045-SC

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Water Resources Research Institute
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Clemson, South Carolina 29631

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ABSTRACT

An alternative system of handling and disposing of milking barn wastewater and feedlot runoff water was evaluated for three years. This system was established on a 50-cow dairy farm in South Carolina and consisted of utilizing a pasture area downslope from a dairy to infiltrate and filter the liquid, nutrients and solids from the milking barn and the dairy feedlot runoff water. The pasture was modified by the addition of a spreader terrace and three level terraces to distribute the runoff water.

Wastewater discharged from the milking barn typically infiltered the soil before reaching the terrace system. Several of the smaller rainstorms produced runoff from the dairy feedlot which was completely infiltrated by the terraced pasture. The concentration of the runoff water leaving the dairy feedlot was reduced by the time it left the terraced pasture, for rains which produced runoff at both weirs, by an average percentage of: NH_3-N, 87; TKN, 88; PO_4-P, 79; COD, 83; TS, 50; total coliform, 79; and fecal coliform, 90. The mass of nutrients was reduced by an average of: NO_3-N, 75; NH_3-N, 69; TKN, 76; PO_4; 68; COD, 91 and TS, 14 all as percentages, including rains that produced runoff from the feedlot but not necessarily from the terraced pasture.

The system performed very satisfactorily. The operator did not have to spend any time or money on the disposal system after the initial preparation of the terraced pasture.

ACKNOWLEDGEMENTS

Without the cooperation and help of Mr. Charles Moore, owner and operator of the dairy farm, this project would not have been possible.

W. H. Livingston was responsible for maintenance of the field equipment, weekly trips for sample collection and analyzing the first years data in pursuit of a Master of Agriculture degree from Clemson University. Thanks are also expressed to R. E. Gantt and L. S. McCarthy for their competent laboratory analysis and maintenance of the field project during all weather conditions.

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INTRODUCTION

Runoff from livestock feedlots has been recognized as a potential pollution problem (EPA, 1971; Phillips, 1980). The most common approach to solving this problem has been to construct a holding basin to contain runoff. The operator must then remove enough water from the holding basin to handle the next runoff. This requires the operator to have the necessary wastewater distribution equipment and land available to dispose of the water.

Several alternatives to the holding basin system have been tried. One of these is an overland flow system which is the controlled discharge of effluent on a regular basis (daily) onto land planted with a perennial cover crop. A biological matt develops on the surface to aerobically degrade the wastes. A large portion of the effluent will leave the overland flow site as runoff because infiltration is low in saturated soil. The overland flow system is suitable for situations where there is a daily volume of rather dilute wastewater to treat, such as in a flush-floor animal structure. A specific grassed area will be set aside for use in receiving the wastewater. Another system is the vegetative filter which receives intermittent flow of wastewater (during a rainfall runoff event). There is no established biological matt on the surface to degrade the dissolved organics as in overland flow treatment. Instead, treatment is provided by settling, dilution, absorption of pollutants, and infiltration.

OBJECTIVES

This is the completion report of a 3-year study to determine the feasibility of diverting runoff water from a dairy feedlot area and wastewater from a milking barn over a terraced pasture without any storage or pumping requirements. Gravity flow was used exclusively to carry the milking barn wastewater and the runoff from the feedlot over the specially developed pasture.

The study was set up with the following objectives: (1) to determine the effectiveness of the terraced pasture for treating the runoff water from a feedlot area and the milking barn wastewater, (2) to determine the uptake of nutrients by the soil on the terraced pasture site, and (3) to evaluate the operation problems and potential of the system as an alternate method of handling and disposing of feedlot runoff and barn of milking wastewater.

LITERATURE REVIEW

Land utilization or disposal of animal waste has long been recognized as an economical means of productively using manure constituents and an efficient means of disposing of animal waste. However, the nonpoint source pollution potential can be large with high application rates unless adequate control techniques are utilized. Grass buffer areas can serve to remove pollutants by settling the solids and allowing the dissolved nutrients to be carried into the soil system and eventually ending up in the plant tissue (Bingham, et al., 1978).

An alternative to zero-discharge treatment systems to control feedlot runoff, such as the anaerobic lagoon or holding pond, is the vegetative filter and infiltration area. These components will be referred to as a vegetative filter. A vegetative area such as a pasture, grass waterway, or terraced channel is used to treat feedlot runoff by providing an area in which settling, dilution, absorption of pollutants, and infiltration can occur. Many existing small feedlots already have some form of vegetative filter. At many others, such a component could be added with a minimum of expense and effort. While systems of this type are not advisable or practical for every situation, they could provide low-cost runoff control for many feedlots, especially small feedlots that are not close to streams or lakes.

Several types of overland flow systems (described in the Introduction) for treating feedlot runoff have been tried with varying degrees of success (Overcash et al., 1976; Sievers et al., 1975; Humenik et al., 1975; Dickey and Vanderholm, 1980; and Yang et al., 1980). Some were designed to absorb most of the applied runoff by infiltration into the soil; others were intended to remove very little by infiltration but to provide treatment during the flow over the vegetated surface.

A study was done in Illinois (Vanderholm, 1975) to evaluate vegetative filter systems for animal feedlots and, if feasible, to develop design criteria for them. Four vegetative filter systems were installed, each consisting of a settling facility, a distribution component, and the vegetative filter area. No runoff storage unit was provided; the feedlot runoff from a storm event went directly to the filter area. Two of the systems were of the graded-terrace or waterway configuration, which were termed channelized-flow systems. The remaining two were wide, mildly sloping areas that operated as a shallow overland flow. These were termed overland flow systems.

At the University of Illinois dairy facility (System 1), effluent from the settling basin was pumped by an automatic pump controlled by the water level through a gated irrigation-pipe distribution system, spreading the effluent onto three field plots. A different grass species was seeded on each plot: reed canarygrass, bromegrass, and orchardgrass. Each plot was surrounded by a berm to prevent any outside drainage water from entering the plot area and to keep any applied effluent and rainfall from escaping at any place other than the controlled plot outlet. The 12 m by 9.1 m plots had a relatively small slope, approximately 0.5 percent. The flow over the plots was intended to approximate sheet flow. The ratio between the vegetative filter area and the feedlot area was approximately 1:1.

System 2 was installed to control the runoff from a beef feedlot with a capacity of approximately 450 cattle. This system was strictly gravity flow, with runoff passing through the settling basin and distributed across the upper end of a sloping vegetative area (61 m flow length). The seeding on the vegetative filter area was predominantly a fescue mixture. Since the soil in the filter was sandy, a filter-area: lot-area ratio of 0.7:1.0 was used.

System 3 was on a beef feedlot with a capacity of 500 cattle. The runoff was directed through a concrete settling basin and then to a vegetative area of the graded-terrace type. The flow in this situation tended to be channelized in the vegetative area, rather than sheet flow. The waterway was approximately 564 m long and had a parabolic cross section with a top width of 8.5 m and a depth of 0.5 m. The channel slope was 0.25 percent.

System 4 was an uncovered swine-finishing facility with a capacity of 480 animals. The runoff from the feedlot passed through a concrete settling basin and entered a vegetative terrace channel 152 m long and a 457 m long grassed waterway before reaching a defined water course. The terrace channel slope was 0.25 percent while the waterway slope was approximately 2 percent.

Performance of the vegetative filters during the monitoring period (April, 1976 to September, 1977), had these results. The filter area of System 1 had 19 effluent discharges. The average ammonia-N concentration in the vegetative filter effluent was 19.5 mg/L. The average concentration of total solids was 996 mg/L. In general, the concentrations measured in the filter effluent represented a reduction of about 80 percent in the constituent concentrations present in the settling basin effluent as applied to the filter area. The quantity of filter effluent, however, was considerably less than the quantity of basin effluent, primarily because of the amount of infiltration that occurred in the filter area. The filter effluent volume was 413 m^3, while the influent to the filter area was 2,453 m^3 of feedlot runoff. On a mass-balance basis, the vegetative filter reduced the amount of constituents applied in the settling basin effluent by about 96 percent. Ammonia-N had the greatest reduction, showing a removal of 97.7 percent; total solids had a removal of 95.5 percent.

Samples obtained for bacterial analysis from vegetative filter System 1 averaged 5.75×10^5 fecal coliforms per 100 ml in the control-plot effluent receiving no waste, 1.05×10^7 per 100 ml in the treated plot effluent, and 1.25×10^7 per 100 ml in the applied-lot runoff. From these data we see that the bacteria levels were quite high in the vegetative filter discharge, but also quite high in the discharge from the control plot, of which no waste had been applied.

Results from the Illinois study concluded that a 2-hour contact time was the recommended criterion for determining minimum filter length for overland flow filters. Because of low velocities, leveling, and maintenance problems, slopes of less than 0.5 percent should be used only with caution. Slopes of more than 4 percent should not be used because of high velocities, reduced filter effectiveness, and possible erosion. The minimum recommended length for any vegetative filter using the overland-flow design is 91.4 m.

A similar study was conducted in Indiana (Nye and Jones, 1978) on runoff control systems for open feedlots. The runoff control systems were composed of two components. The first component was the settling basin which operated in a manner similar to the primary clarifier in a sewage treatment plant. Heavy solids were allowed to settle out of the liquid runoff under quiescent conditions. The second element was the infiltration area/vegetatave filter. This component received the runoff after settling and allowed the runoff to either infiltrate into the soils or to be further "screened" in the grass so that any discharge from the area would not pollute streams or lakes.

Settling basins that are designed to be emptied with solid manure handling equipment usually had problems (Nye and Jones, 1978). The major problem was that the solids seldom dried out enough to be hauled out with solid manure spreaders. It was suggested to have at least 12 hours settling before the water be pumped out of the basin after a runoff event. In this system, the solids settled to a shallow depth throughout the basin under quiescent conditions. The liquid flowed over the top of the solids at such a slow speed that the solids were not resuspended.

The slope of the infiltration area or channel was critical. During most rainfalls, very little runoff overflowed the settling basin and entered the infiltration area. During these small runoff events, it was important to get distribution of the water away from the basin. The slope of the first section should probably be between 2-5 percent and be 15-30 m long. A secondary zone should follow the first zone with a slope of about 1 percent. Then the final zone should be very flat with just enough slope to prevent severe ponding.

Extreme care should be taken during construction of an infiltration area. Many contractors approach the construction in the same manner that they would build an earthern waterway, and do not worry about preserving the permeability of soil. This especially was a problem in clay soils. If these soils are worked when wet or compacted the infiltration rate can be permanently affected. Parallel terraces can be constructed on both sides of the channel to prevent outside water from entering the channel and to contain the feedlot runoff in the channel.

The grass filter design criteria in the Ohio Livestock Waste Management Guide (Norman et al., 1978) were based on making travel time proportional to biochemical oxygen demand (BOD) concentration. Factors considered were the number and weight of animals, the feedlot cleaning frequency, the feedlot area that was uncovered, and the watershed area above the grass filter. Climatic factors were not considered as parameters since the farmer has no control over them. It was assumed that settleable solids were removed before the runoff reaches the grass filter. Grass filter length, width, and slope were dependent variables.

Runoff from an unpaved feedlot (Edwards, 1980) had concentrations of nutrients below 100 mg/L for total soluable nitrogen, 20 mg/L for phosphorus and 600 mg/L for potassium. Using a settling basin before application of runoff to filter strips greatly reduced the total solids (TS), chemical oxygen demand (COD), and BOD concentrations but only slightly reduced the ammonia (NH_3), P and K concentrations. Dilution accounted for much of the water quality improvement in the filter strips during large rainfall events.

Chang et al. (1974) found that parlor wastewater had the following characteristics for dairy herds of less than 150 head: TS, 4200; COD, 4577; NH_3-N, 29; TN, 185 and PO_4-P, 0.4 all as mg/L. The volume of water used for washing may vary drastically from dairy to dairy, but an approximate figure may be 23L/cow/day (6 gal/cow/day) for a parlor (double three herringbone) such as used in this study.

EXPERIMENTAL PROCEDURE

A system (Figure 1) was designed* to allow surface runoff water from a dairy feedlot area (hereafter referred to as feedlot) and the milking parlor wastewater to flow over a terraced pasture, by gravity, without any storage or pumping requirements. The watershed above the upper diversion channel was a total area of 0.73 ha (1.8 acres) of which an uncovered, dirt feedlot and an adjoining covered, concrete holding area made up 0.2 ha (0.5 acre). The pasture was 4.4 ha (11.0 acres) and was divided by three terraces and a diversion ditch at the lower end of the pasture. The terraced pasture was

*designed by the USDA Soil Conservation Service.

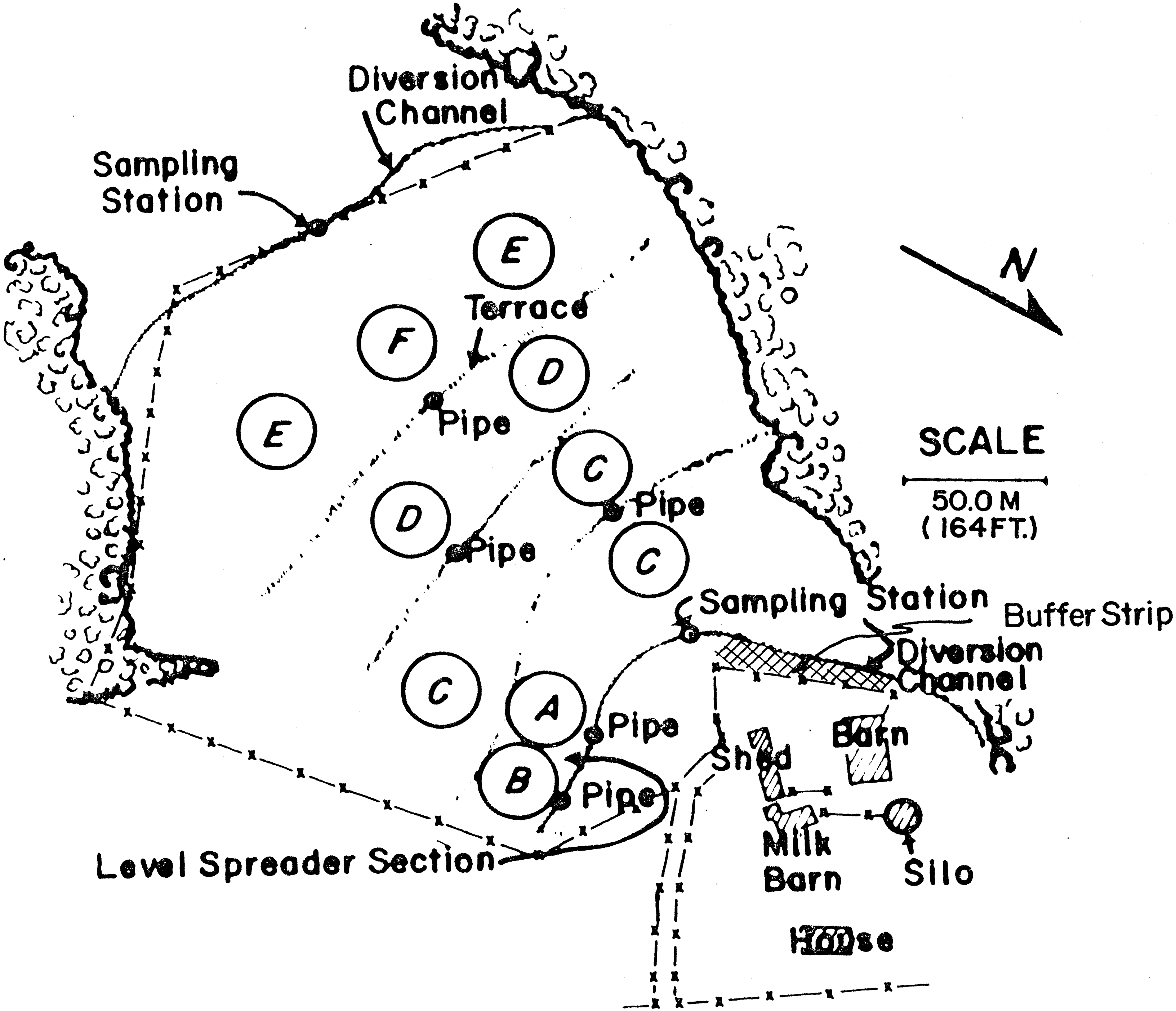

Figure 1. Plan view of terraced pasture wastewater disposal system.

located on a 6-10 percent slope with a Cecil clay soil thermic clayey, kaolimtic, typic Hapludult and seeded with a mixture of tall KY 31 fescue (Festuca arundinacea (L.) Schreb) and ladino clover (Trifoluim repens (L.)). The reseeding was done the spring prior to the start of the project (1977), but the vegetation was not well established until the spring of 1978.

The upper sampling station was located (Figure 1) on the diversion channel below the feedlot and positioned so that only the surface runoff was collected from the upper watershed. The feedlot and sampling station were separated by a 6-12 m wide buffer strip to reduce the movement of manure solids.

The upper sampling station consisted of the following components: (1) a Weather Measure raingage and a Weather Measure event recorder, (2) a stilling well with a Belfort water level recorder, (3) a float switch, (4) an Instrumentation Specialities Company (ISCO) automatic wastewater sampler, and (5) a 2:1 V-notch weir. A calibration curve (Figure 2) was used to convert depth to volume based on the formula ($Q = 2.5 \tan \frac{\theta}{2} H^{2.5}$) (King, 1954). The float switch was mounted on the weir and adjusted to activate the automatic sampler at the time the runoff began flowing over the weir. As the automatic sampler began operation it triggered the water level recorder arm, by the aid of a solenoid, at the time each sampling event took place thereby giving a record of when each sample was taken. The automatic sampler collected a 500-ml sample at each 60-minute interval during the runoff.

The runoff water from the upper sampling station was discharged onto the pasture designed with three level terraces constructed to distribute the flow of the runoff water over as much of the site as possible. The milking parlor wastewater was pumped to an infiltration area that was located at area A (Figure 1). Therefore the parlor wastewater did not pass through the sampling station of the upper weir. During any runoff from the terraced pasture the

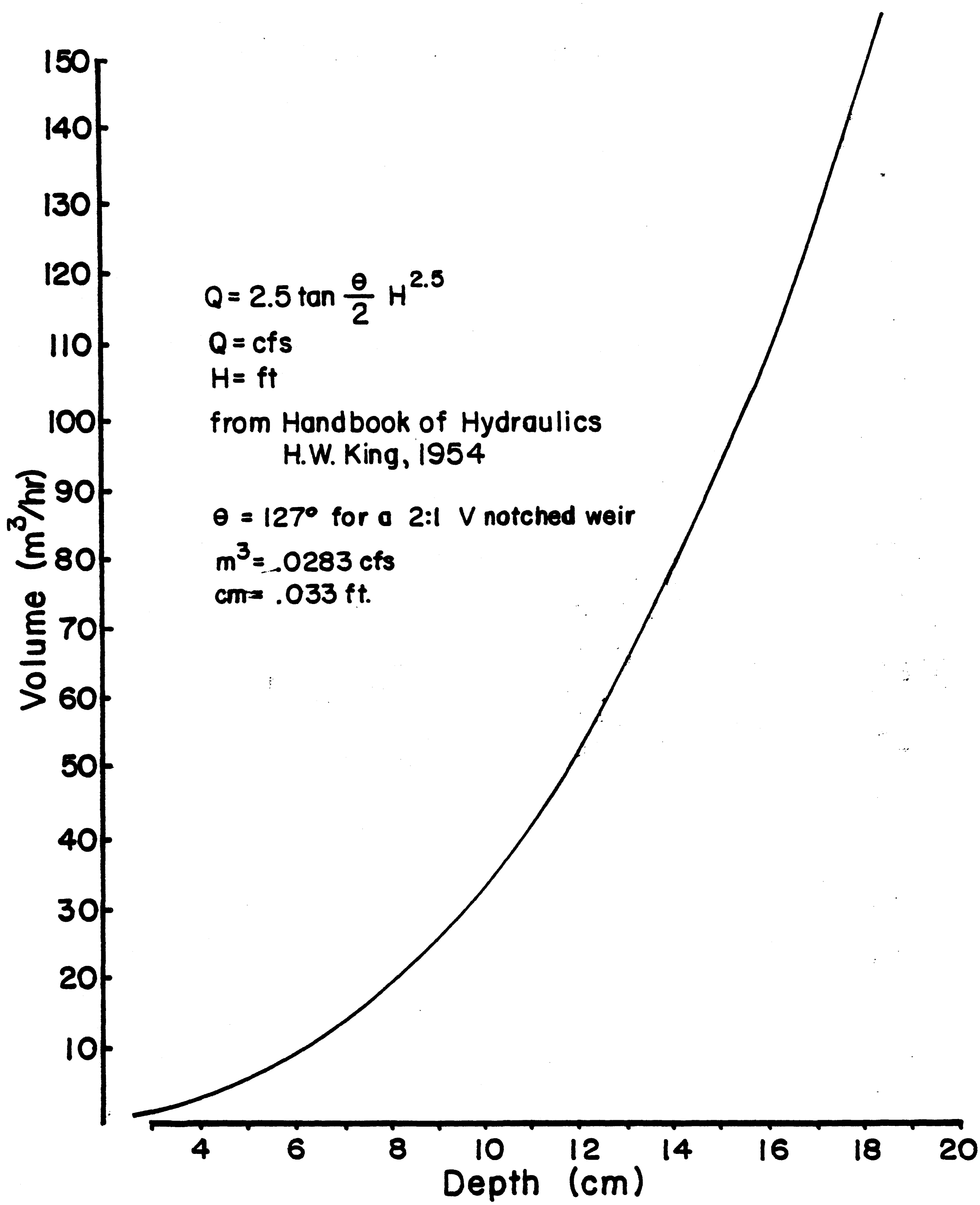

Figure 2. Volume versus depth for a 2:1 V-notched weir.

constituents of the parlor wastewater and manure deposited on the pasture could contribute to the potential pollution of the runoff sampled at the lower weir. This means that any comparisons made in the report between the upper and lower weir do not reflect the addition of constituents on the pasture which would tend to bias results against the effectiveness of the pasture for nutrient removal.

Milking parlor wastewater consists of cow wash water, manure deposited in parlor and wash water for cleaning milking equipment. No analysis of volume or concentration of the parlor wash water was done for this study. A 3.1 m length of 10.1 cm SD pipe was placed at grade level under each terrace for a two-fold purpose: (1) to dewater the terrace to prevent grass kill above the terrace and (2) to discharge the runoff water from small runoff events and allow this runoff to flow over the pasture in a "zig-zag" manner by staggering the placement of these pipes (Figure 1). The diversion ditch located below the last spreader terrace collected the combined runoff water from the feedlot and disposal area and channelled the runoff water to the lower sampling station. The lower sampling station had the same components, except the raingage, as the upper sampling station. The equipment at the lower sampling station measured the quantity of runoff water from the combined feedlot and disposal area and collected water samples.

The automatic sampler had the capacity to collect 28, 500-ml samples. The 500 ml samples were paired (1-2, 3-4, etc.) to make a 1000 ml sample for laboratory analysis. One to 14 laboratory samples, depending on the duration of the runoff event, were analyzed and the results for each pollution parameter were averaged for each runoff event. Laboratory analysis performed on the runoff water samples included: total kjeldahl-nitrogen (TKN-N), ammonia-nitrogen (NH_3-N), nitrate-nitrogen (NO_3-N), phosphate-phosphorus (PO_4-P), calcium (Ca), magnesium (Mg), chemical oxygen demand (COD), total solids (TS), total coliform (TC), fecal coliform (MFC), and pH.

The hydrograph from the stage recorder (12 hours per revolution) provided a continuous tracing of the depth of flow over the weir. To calculate total volume, readings were taken off the charts at hourly intervals. Each successive pair of readings were added together and divided by two to give an average depth for each hour. The averages were then converted to volume using Figure 2. The resulting volumes of flow in m^3/sec were converted to m^3/hour and the volumes for each hour were totaled. To calculate the mass (kg) of a nutrient that ran off the watershed the volume was multiplied by the concentration and the necessary conversion factors.

Soil samples were taken from the disposal area in October 1978 and again in July 1979. Five replications were taken in 15.2-cm increments through 91.4 cm. Additional samples were taken in two areas (A and C) in 1981. The results for each parameter were combined by location (Figure 1) A through F according to depth and an average was calculated. These samples were analyzed for: pH, K, P, Mg, Ca. For nitrate analysis samples were combined by depth because of an inadequate amount of soil. The results of each combined sample by depth were averaged for each sampling date.

RESULTS AND DISCUSSION

The 1978 soil samples represent the background data since they were taken prior to the first runoff event. Table 1 gives the analyses of these samples for each parameter by location and depth. Location A was sited at the point where the milking parlor wastewater was discharged on a daily basis and these soil samples had the highest concentration for each parameter. The parlor wastewater infiltrated into the soil immediately below the discharge pipe, as evidenced by the lush growth of grass throughout the year. No erosion, insect or odor problems were evident. There was a decrease of nutrient concentration in the soil samples as the distance below the surface increased.

The concentrations of P, K, Mg and Ca in the soil showed no major trends over the three years of monitoring. The values listed in Table 1 are in the normal ranges and no problems would be anticipated with soil toxicity due to the feedlot runoff water and the milking parlor wastewater.

There was no major increase in the NO_3-N concentrations from 1978 to 1979 (Table 2). The values on area A (higher loading of wastewater and milking parlor wash water) were similar to those in the other areas (B, C, D, E and F). Results from 1981 soil sampling showed that the NO_3-N more than doubled since 1979 in area A while area C showed a decrease.

Based on the data from the soil analysis there does not seem to be any short term (3 years) problem with using a pasture area for receiving the runoff water from an animal feedlot. Areas that receive the bulk of the runoff will likely show an increase in NO_3-N and P after several years of operation. It is unlikely that nutrient levels will become high enough that the salt level will affect plant growth. A much longer monitoring period would be required to adequately access the potential nutrient buildup in the soil.

Table 1. Soil analysis from disposal area for 1978, 1979 and 1981 (µg/g).

Depth (m)	Area*	P 1978	P 1979	P 1981	K 1978	K 1979	K 1981	Mg 1978	Mg 1979	Mg 1981	Ca 1978	Ca 1979	Ca 1981
.15	A	48	36	41	443	433	750	358	376	233	1113	1547	750
.30		11	8	34	307	323	715	315	232	151	877	660	493
.45		3	2	24	215	251	329	294	233	149	440	557	400
.60		3	2	17	109	121	236	247	254	134	297	383	328
.75		3	1	9	97	64	148	216	221	129	128	213	218
.90		3	1	6	113	71	96	208	237	123	220	180	165
.15	B	18	11		378	307		289	318		727	1000	
.30		4	3		236	275		272	230		413	570	
.45		2	1		197	178		308	248		330	440	
.60		2	1		139	110		317	273		233	350	
.75		2	1		105	78		270	294		173	247	
.90		1	1		97	64		245	269		123	157	
.15	C	20	10	2	281	198	52	365	325	162	833	760	410
.30		2	2	1	205	125	26	322	308	95	450	413	143
.45		1	3	1	121	110	27	332	296	83	250	287	93
.60		1	4	1	91	99	25	315	253	80	143	207	93
.75		1	2	1	87	88	22	289	228	67	110	177	73
.90		1	1	1	87	92	27	251	220	64	103	177	60
.15	D	7	16		187	227		366	304		750	730	
.30		1	3		83	212		359	279		490	565	
.45		.5	1		51	165		355	304		325	375	
.60		1	1		60	116		373	300		245	255	
.75		1	2		78	100		336	274		125	200	
.90		2	2		93	119		309	275		140	190	
.15	E	2	6.5		127	121		225	276		650	890	
.30		.5	2		91	80		221	226		610	710	
.45		1	2		84	51		238	252		595	485	
.60		.5	2		93	36		261	197		560	265	
.75		0	3		85	28		305	196		540	175	
.90		.3	3		92	37		318	198		440	155	
.15	F	4	7		147	141		274	296		770	845	
.30		.5	3		91	76		230	244		505	555	
.45		1	2		65	63		293	224		430	470	
.60		1	2		52	70		264	235		325	445	
.75		1	3		46	58		229	238		170	375	
.90		2	3		48	64		184	224		155	410	

* See Figure 2
**

Table 2. Soil NO_3-N analysis from disposal area for 1978, 1979 and 1981 (µg/g).

Area*	Depth(ft)**	1978	1979	1981
A	.15	3.23	4.34	9.54
	.30	1.27	4.17	9.82
	.45	2.53	3.48	10.61
	.60	2.24	2.36	7.96
	.75	2.51	1.58	5.36
	.90	2.18	1.88	3.78
B	.15	29.03	1.97	
	.30	6.49	2.78	
	.45	5.15	3.71	
	.60	4.11	5.93	
	.75	3.37	4.38	
	.90	3.65	3.22	
C	.15	9.55	0.78	0.35
	.30	3.98	0.34	0.13
	.45	1.32	0.38	0.13
	.60	1.69	0.34	0.11
	.75	1.34	0.75	0.14
	.90	0.97	0.81	0.11
D	.15	14.96	1.17	
	.30	3.64	1.01	
	.45	2.65	1.04	
	.60	1.19	1.92	
	.75	0.71	3.55	
	.90	0.78	3.33	
E	.15	3.61	0.42	
	.30	1.27	0.27	
	.45	0.42	0.24	
	.60	0.35	0.33	
	.75	0.33	0.38	
	.90	0.29	0.41	
F	.15	3.61	1.07	
	.30	1.58	0.29	
	.45	1.97	0.55	
	.60	2.49	0.41	
	.75	1.98	0.86	
	.90	1.25	0.91	

* See Figure 1

Most of the major rainfalls are shown on Figure 3 from December 1978 to June 1981. There were approximately 26 runoff events in 1979 and 19 in 1980 that produced runoff on both the upper weir and lower weir. The first six months of 1981 had only one rain that produced runoff at both weirs and then the project was terminated. 1981 was a very dry year and there were not more than 8 runoff events in the last six months. Figure 3 gives some indication of the number of rainfalls and the amount of rain. Some data is missing due to equipment malfunctions.

Table 3 is a listing of volume of runoff from the weirs and the rainfall for most of the storms during the monitoring period (December 1978 to June 1981). There is very little correlation between volume of runoff and the rainfall amount. This was expected because runoff volume is dependent on many factors that were not monitored for this study such as: density and height of vegetation, preceeding soil moisture conditions, rainfall intensity and manure accumulation on the feedlot. Some rainfalls produced runoff volumes several times higher than for similar storms under different conditions. Several small rainfalls only produced runoff from the upper watershed (feedlot area) which was to be expected because of the lack of vegetation and a hard packed soil.

The Springs of 1979 and 1980 were rather wet compared to 1981 and this is reflected in the sharp rises in the cumulative runoff volume for the upper weir (Figure 4). The cumulative rainfall curve includes only rainfalls that produced runoff (Figure 4) because these rainfalls provided most all of the rain.

A representative storm that resulted in runoff from the feedlot (upper weir) and terraced pasture (lower weir) is described in detail in Figure 5. The 63.5 mm rain took place over a 16 hour period on 4/13-14/80 was preceeded by a 21 mm rain that made the feedlot and terraced pasture nearly saturated.

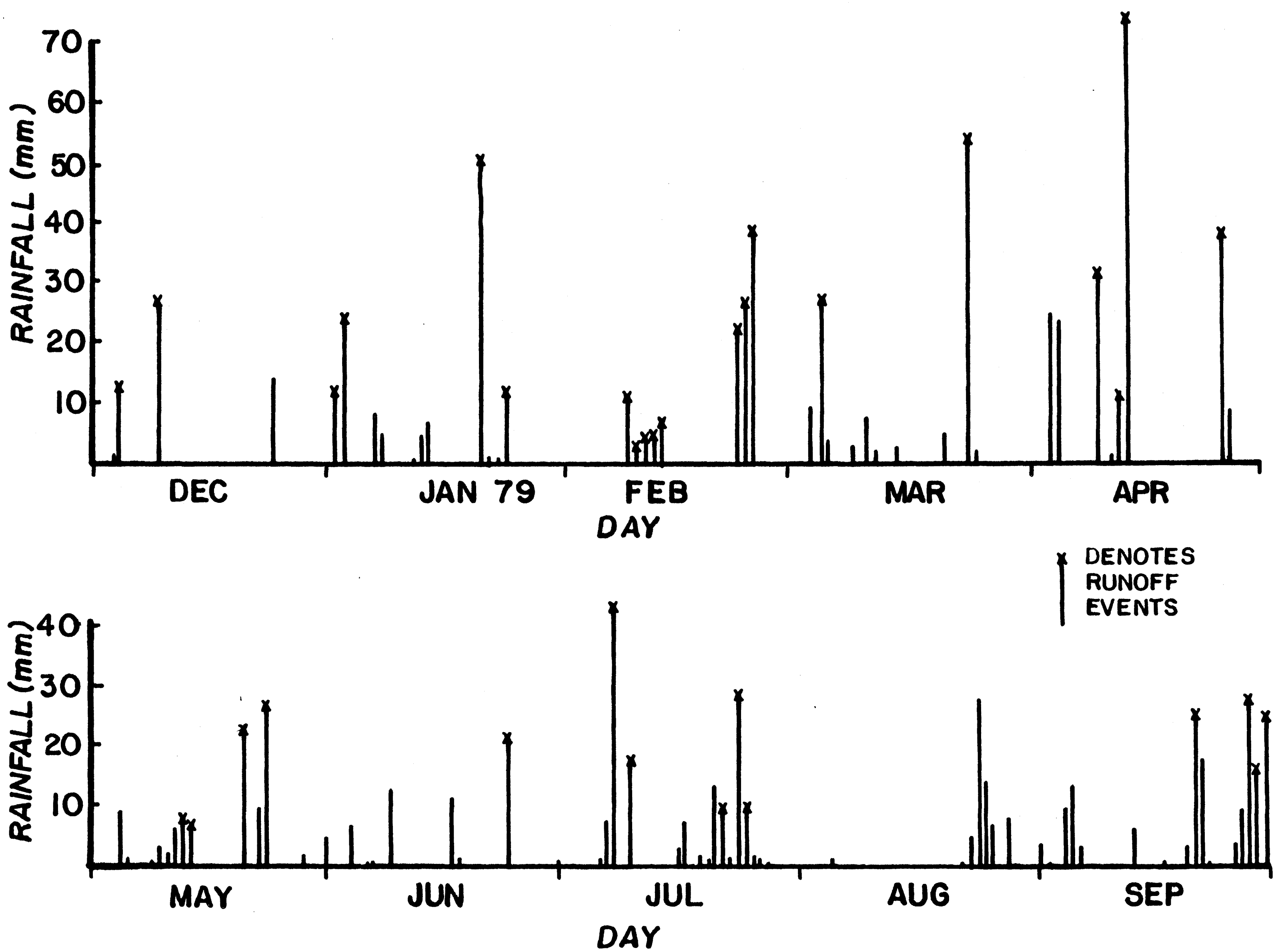

Figure 3. Rainfall versus time, 1978-1981.

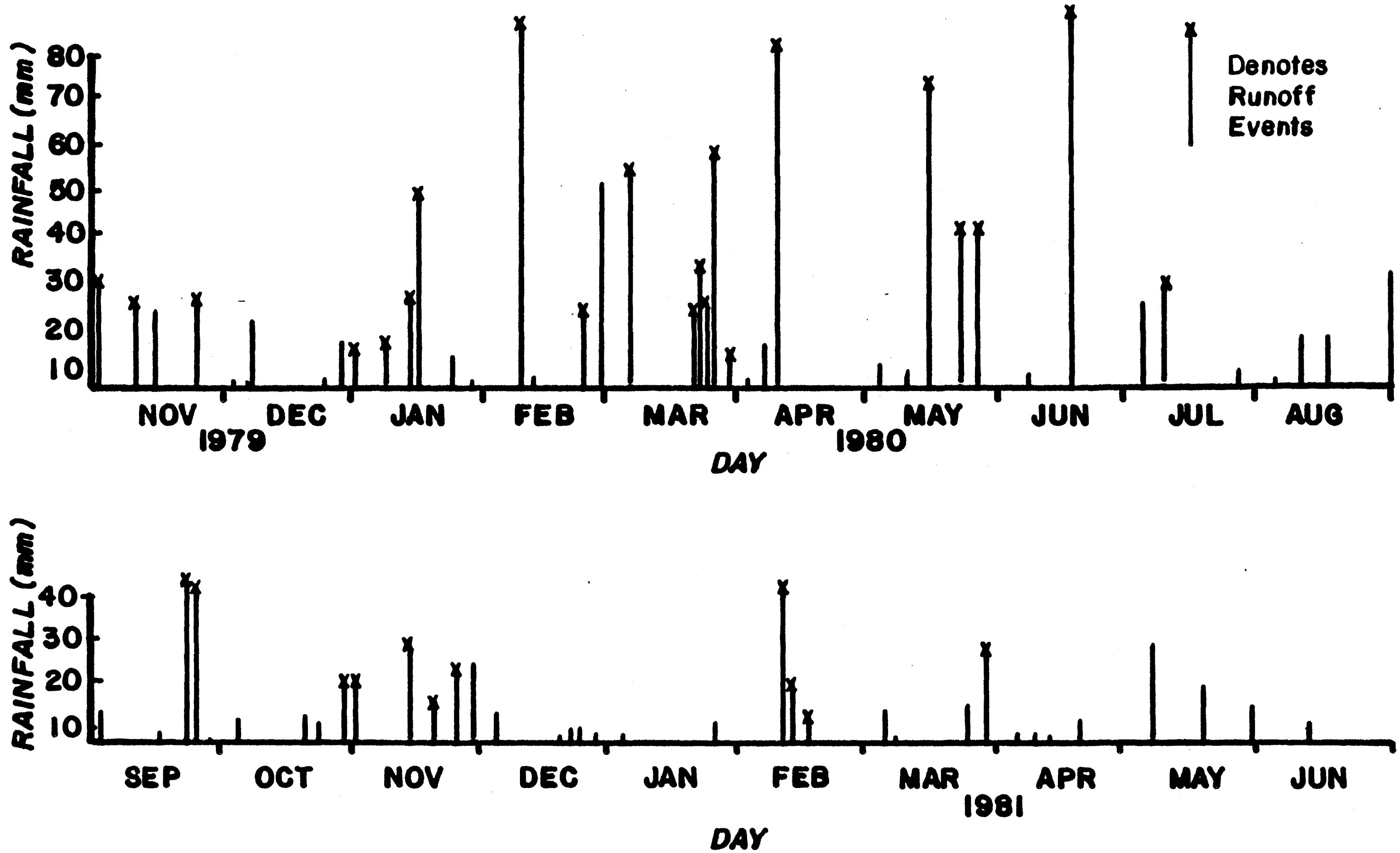

Figure 3. (cont.)

Table 3. Rainfall and Runoff Volumes from Upper and Lower Weir

	Upper Weir		Lower Weir		
Date	Runoff vol. (m^3)	Period of runoff (hrs)	Runoff vol. (m^3)	Period of runoff (hrs)	Rain (mm)
12/09/78	4		20		26
1/01/79	43		29		33
1/20/79	36		49		50
1/23/79	42		449		21
2/08/79	22		*		10
2/09/79	8		*		2
2/10/79	18		*		3
2/13/79	10		*		
2/22/79	45		248		22
2/23/79	65		446		26
2/24/79	241		1080		37
2/25/79	61		845		
3/04/79	10		1370		25
3/23/79	178		383		54
4/09/79	10		489		31
4/13/79	310		2000		73
4/25/79	51		49		38
5/13/79	4		18		14
5/20/79	22		85		23
5/23/79	140		525		26
6/23/79	7		*		20
7/07/79	30		*		44
7/09/79	24		*		18
7/21/79	5		*		9
7/23/79	90		340		28
7/24/79	4		*		20
9/21/79	3		937		24
9/28/79	5		843		28
9/30/79	8		787		39
10/04/79	27	5	220	5	-
11/02/79	70	4	1056	7	33
11/10/79	-	-	1316	9	29
11/11/79	-		3668	14	25

Table 3. (cont)

Date	Upper Weir Runoff vol. (m^3)	Upper Weir Period of runoff (hrs)	Lower Weir Runoff vol. (m^3)	Lower Weir Period of runoff (hrs)	Rain (mm)
11/26/79	43	4	91	8	29
12/24/79	-		39	5	18
12/30/79	-		188	2	14
1/04/80	-		2762	10	18
1/11/80	22	5	44	4	13
1/13/80	64	8	664	9	28
1/17/80	32	19	863	23	57
2/09/80	23**	8	*		109 Snow
2/10/80	8**	5	*		-
3/07/80	-	-	1073	21	54
3/20/80	32	6	293	9	23
3/21/80	122	7	1625	11	35
3/24/80	36	8	173	10	24
3/28/80	135	14	1357	17	61
3/30/80	9	5	11	3	11
4/13/80	309	17	1733	20	84
5/17/80	290	-	-		74
5/20/80	290	-	-		44
5/23/80	291	6	1288	7	44
6/24/80	82	6	221	7	92
7/04/80	40	4	*		33
7/10/80	7	3	*		24
8/13/80	*		*		19
8/27/80	*		*		39
9/03/80	*		*		11
9/24/80	6	3	14	2	52
9/28/80	88	18	-	-	52
9/30/80	9	5	-	-	4
10/22/80	*		*		23
10/30/80	4	3	*		20
11/04/80	32	6	11	2	23
11/15/80	21	5	*		35
11/23/80	14	5	*		14.7

Table 3. (cont)

Date	Upper Weir Runoff vol. (m^3)	Upper Weir Period of runoff (hrs)	Lower Weir Runoff vol. (m^3)	Lower Weir Period of runoff (hrs)	Rain (mm)
11/27/80	37	10	*		23
2/10/81	67	8	*		46
2/18/81	35	7	*		22
2/23/81	7	4	*		7
3/04/81	*		*		12.7
3/18/81	*		*		12
3/30/81	68	6	11	3	33
4-6/81	no runoff				

- no data

* no runoff

** snow melt runoff

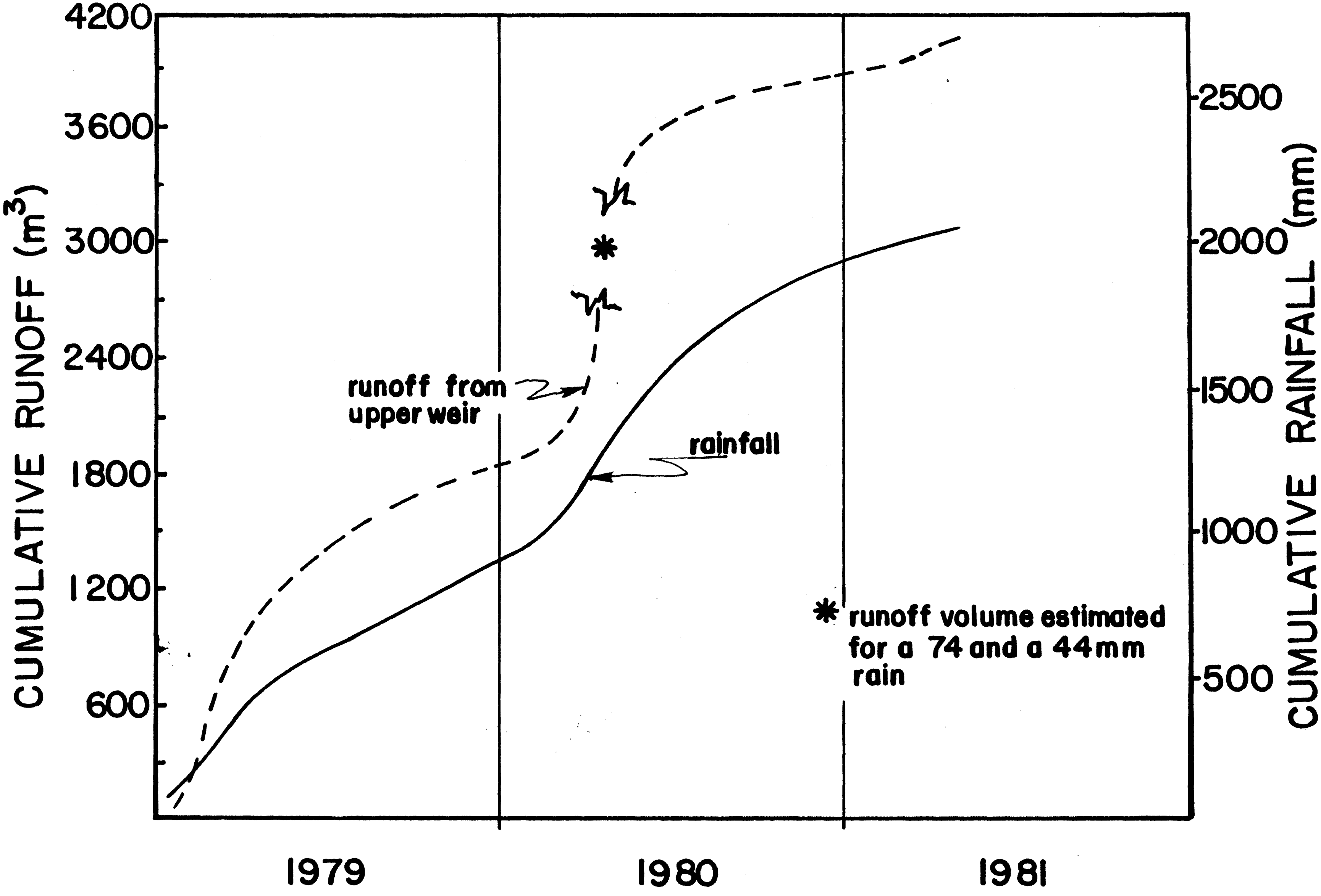

Figure 4. Cummulative rainfall and runoff from the feedlot.

The 63.5 mm rain was rather steady so that runoff from the feedlot rather steady in the range of 20-40 m^3/hr. Runoff from the terraced pasture started approximately four hours after the runoff from the feedlot began and lasted seven hours after the runoff from the feedlot and the rain stopped. The higher volume from the terraced pasture is due to the larger watershed area.

The concentrations of PO_4-P, COD, TS and NH_4-N show similar patterns during the duration of the rainfall (Figure 5). The concentrations from the feedlot were several times higher than that for the terraced pasture due to dilution by the additional rainfall on the pasture and the removal of the pollutants by the soil-vegetation system. The feedlot concentrations were in the range of what is normally expected from a dairy feedlot. It is generally expected that the first runoff samples from a feedlot would have the highest concentrations, but this was not the case with this storm. The rainfall was not real intense so there was not a large surge of runoff, as reflected in the pattern of runoff volume per hour for the feedlot. This storm is an example of what took place when there was a rainfall of enough intensity or duration to produce runoff from both the feedlot and terraced pastures. For the rest of the storms the concentrations were averaged over the duration of the runoff and this value was used in calculating the total mass of pollutant leaving either the feedlot or terraced pastures. The fairly uniform concentrations over the duration of the runoff justified the decision to average the concentrations.

The mean concentrations of NO_3-N, NH_3-N, PO_4-P, TKN, COD, TS, total coliform, fecal coliform, and pH for each storm are listed in Table 4. The concentration from each of the mixed pairs of water samples (as explained in Experimental Procedure) for a particular storm were averaged. The percent change in concentration from upper weir to lower weir is an indication of the dilution and removal of nutrients or solids as the runoff water leaves the

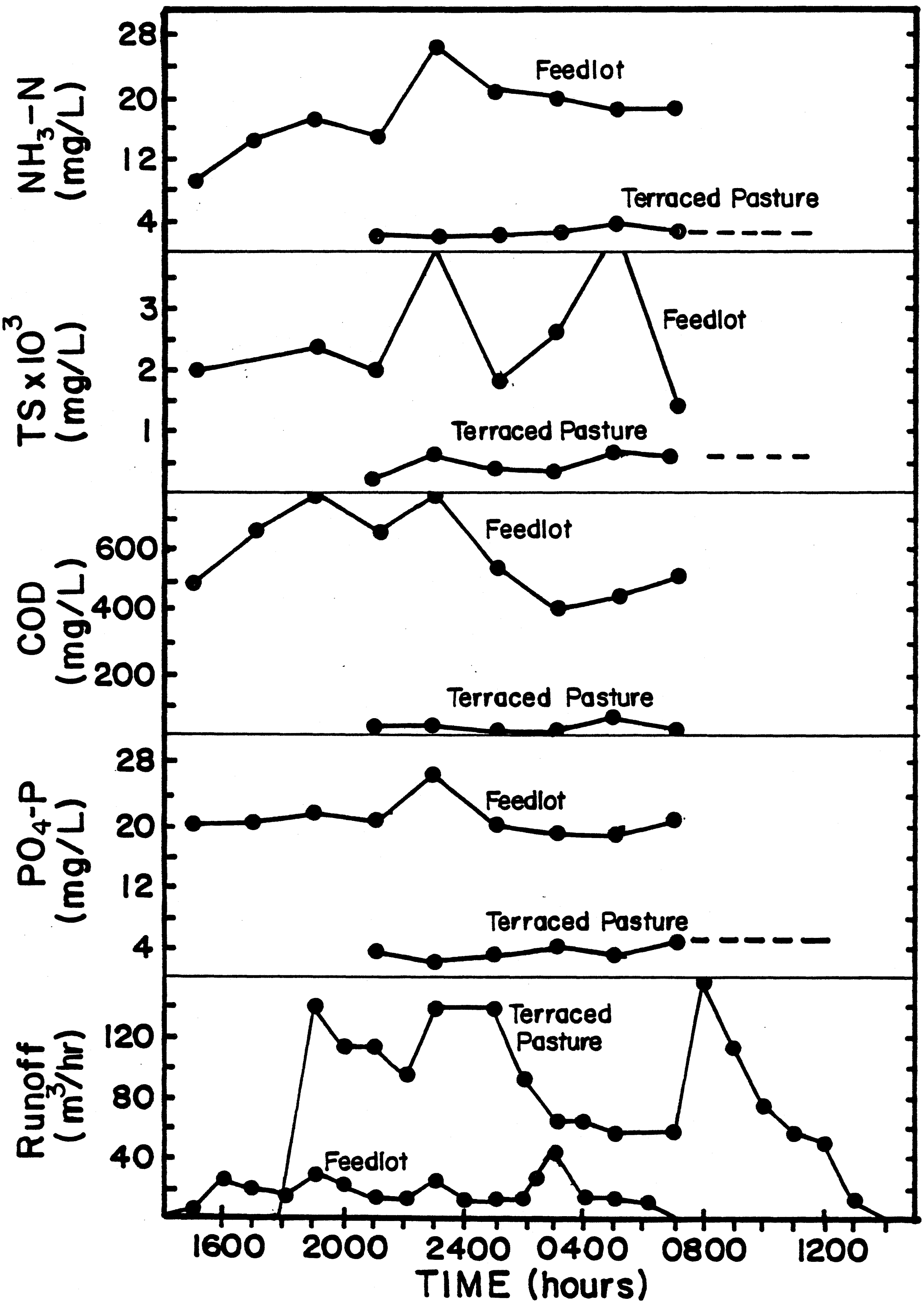

Figure 5. Pollutant concentrations and runoff volume during a selected rainfall.

feedlot and flows over the terraced pasture. The grass cover on the terraced pasture was not very good so the owner-operator made an application of 448 kg/ha of 17-17-17 fertilizer on March 27, 1979. It is interesting to note that prior to this (7 recorded runoff events) there had been a slight decrease in NO_3-N concentrations from the upper to the lower weir. The next storm after the fertilizer application showed a sharp increase in NO_3-N (less than 1 to 5.93 mg/L) and PO_4-P (less than 5 to 37.2 mg/L) concentrations in the runoff from the lower weir. This increase in NO_3-N concentrations due to the fertilizer application lasted for the following five storms. This is similar to the results of research work on small plots receiving ammonium nitrate fertilizer (McLeod, 1981).

NH_3-N concentrations were several times higher than the NO_3-N concentrations in the runoff water from the feedlot. The NH_3-N concentrations were in the range of 4 to 90 mg/L. This variability was expected because of the varied conditions on the feedlot (accumulated manure, preceeding moisture conditions, time of year, number of cattle, rainfall intensity, etc.). The average percent decrease in NH_3-N concentration was 87 for all the rains that produced runoff at both weirs (Table 4). There were several rains which did not produce any runoff from the terraced pasture although there was runoff from the feedlot. The mean percent decrease in PO_4-P, TKN, COD and TS concentrations were 79, 88, 83 and 50, respectively. The TS concentrations (100-3000 mg/L) were higher than expected from the terraced pasture based on other research work showing typical values of 20-60 mg/L (Reese et al., 1982). This was due to the difficulty in establishing a good grass stand and therefore the soil was more susceptible to erosion. The seeding was done in the spring of 1978, but it was not until late in 1979 that the grass cover was dense enough to cover the surface.

Table 4. Concentrations of Runoff Samples.

DATE	SAMPLE LOCATION (WEIR)	pH	NO_3-N mg/1	NH_3-N mg/1	PO_4-P mg/1	TKN-N mg/1	COD mg/1	TOTAL SOLIDS mg/1	T.C. col/100ml	M.F.C. col/100ml
12/4/78	UPPER	7.25	0.31	75.5	53.8	154.0	852.	3538.	$9.5x10^6$	$7.5x10^6$
	LOWER	5.85	0.16	0.22	1.8	3.9	157.	1362.	$3.5x10^6$	$2.0x10^6$
	% CHANGE		-46	-99	-97	-97	-82	-62	-63	-73
12/9/79	UPPER	7.10	0.85	32.5	38.4	121.7	1504.	3211.		
	LOWER	5.29	0.69	0.44	2.8	2.0	24.	1093.		
	% CHANGE		-19	-99	-93	-98	-98	-66		
1/1/79	UPPER	7.32	0.47	19.7	24.	77.1	1259.	624.		
	LOWER	5.79	0.56	0.67	3.	2.3	61.	588.		
	% CHANGE		+19	-97	-88	-97	-95	-6		
1/12/79	UPPER	7.19	0.85	32.1	19.7	82.2	765.	2314.	$4.0x10^6$	$1.5x10^6$
	LOWER	5.73	0.72	1.48	5.0	4.0	24.	451.	$1.9x10^3$	$1.4x10^3$
	% CHANGE		-15	-95	-75	-95	-97	-81	-99	-99
1/23/79	UPPER	7.20	0.53	42.2	35.7	98.1	1190.			$3.5x10^7$
	LOWER	6.50	0.52	3.51	3.6	10.1	53.			$4.0x10^3$
	% CHANGE		-2	-92	-90	-90	-96			-99
2/22/79	UPPER	7.82	0.62	45.3	31.6	101.5	1076.	1925.		
	LOWER	6.76	0.56	2.9	3.4	12.6	388.	1128.		
	% CHANGE		-11	-94	-89	-88	-64	-41		
3/23/79	UPPER		0.53	40.4		111.7	909.	3071.	$2.3x10^6$	$1.6x10^6$
	LOWER		0.20	3.5		15.2	156.	1969.	$1.0x10^5$	$4.2x10^4$
	% CHANGE		-63	-91		-86	-83	-36	-96	-97
*4/3/79	UPPER	7.54	0.94	51.6	29.1	112.2	1212.	2657.	$3.6x10^6$	$5.2x10^6$
	LOWER	6.93	5.93	13.2	37.2	22.1	85.	3060.	$4.1x10^5$	$4.0x10^5$
	% CHANGE		+528*	-74	+28*	-80	-93	+15	-88	-92

*these values left out in determining mean % changes because of application of 448 kg/ha of 17-17-17 fertilizer on disposal area on 3/27/79

Table 4. (cont)

DATE	SAMPLE LOCATION (WEIR)	pH	NO_3-N mg/1	NH_3-N mg/1	PO_4-P mg/1	TKN-N mg/1	COD mg/1	TOTAL SOLIDS mg/1	T.C. col/100ml	M.F.C. col/100ml
4/9/79	UPPER	7.66	0.84	26.7	41.5	60.1	716.	1857.	$4.5x10^7$	
	LOWER	6.94	1.55	4.6	4.9	11.7	150.	1371.	$3.4x10^5$	
	% CHANGE		+85*	-83	-88	-81	-79	-26	-99	
4/13/79	UPPER	7.59	0.29	14.8	21.1	39.4	146.	971.	$4.5x10^5$	$2.7x10^5$
	LOWER	6.83	1.51	5.3	25.7	7.1	94.	945.	$6.9x10^4$	$4.5x10^4$
	% CHANGE		+421	-64	+20	-82	-36	-3	-84	-83
5/13/79	UPPER	7.54	0.40	7.3	18.6	34.3	555.			
	LOWER	6.63	4.52	1.9	11.1	7.9	100.			
	% CHANGE		+104	-74	-40	-77	-82			
5/20/79	UPPER	7.40	0.55	14.8	10.7	46.9	683.	1771.	$4.8x10^7$	$3.4x10^7$
	LOWER	6.29	1.40	0.9	0.4	4.3	86.	2300.	$8.3x10^5$	$6.4x10^5$
	% CHANGE		+156	-94	-96	-91	-87	+30	-98	-98
5/23/79	UPPER		0.95	21.3	17.9	56.9		1343.		
	LOWER		0.81	1.4	3.1	6.9		1143.		
	% CHANGE		-15	-93	-83	-88		-15		
9/28/79	UPPER	7.62	11.50	7.7	58.1	22.1	312.	1286.	$1.3x10^5$	$1.0x10^5$
	LOWER	6.74	1.80	1.0	51.7	5.7	32.	200.	$3.0x10^3$	$4.0x10^3$
	% CHANGE		-84	-87	-11	-74	-90	-84	-98	-96
10/04/79	UPPER	7.71	4.70	6.95	19.9	18.4	258.	800.		
	LOWER	6.74	0.59	1.8	3.2	2.8	32.	100.		
	% CHANGE		-87	-74	-84	-85	-88	-88		
11/02/79	UPPER	7.00	2.8	4.9	23.0	31.6	77.	1533.	$2.05x10^6$	
	LOWER	6.38	2.0	1.0	1.9	4.8	67.	200.	$1.5x10^6$	
	% CHANGE		-29	-80	-92	-85	-12	-87	-29	

Table 4. (cont)

DATE	SAMPLE LOCATION (WEIR)	pH	NO_3-N mg/l	NH_3-N mg/l	PO_4-P mg/l	TKN-N mg/l	COD mg/l	TOTAL SOLIDS mg/l	T.C. col/100ml	M.F.C. col/100ml
11/26/79	UPPER	7.19	0.81	15.1	31.3	54.4	1036.	2940.	2.13×10^6	3.4×10^6
	LOWER	6.65	1.5	1.2	3.5	6.7	79.	425.	8.75×10^5	8.5×10^5
	% CHANGE		+85	-92	-89	-88	-99	-86	-59	-75
1/11/80	UPPER	6.45	1.4	39.3	48.5	127.0	1316.	4757.		
	LOWER	5.80	___	1.8	2.3	___	180.	755.		
	% CHANGE		-99	-95	-95		-86	-84		
1/13/80	UPPER	6.54	1.0	28.9	35.2	114.5	1270.	2981.	2.3×10^7	2.6×10^7
	LOWER	5.50	0.27	1.4	0.27		74.	800.		
	% CHANGE		-73	-95	-99		-94	-73		
2/09/80	UPPER	7.23	1.4	4.6	.28	13.3	1193.	2681.	3.76×10^5	4.88×10^5
	LOWER	no runoff								
3/30/80	UPPER	7.63	1.1	22.2	22.2	50.0	833.	2067.		
	LOWER	no runoff								
4/13/80	UPPER	7.35		19.2	21.4	53.3	511.	2154	2.8×10^7	
	LOWER	6.86		2.3	3.3	4.7	1.	466.	1.1×10^7	
	% CHANGE			-88	-85	-91	-100	-78	-61	
7/10/80	UPPER	7.05	13.0	4.3	13.0	17.4	291.	800.		
	LOWER	no runoff								
9/24/80	UPPER	7.2	56.6	3.8	18.7	18.7	491.	1604.		
	LOWER	6.48	0.71	0.99	0	2.8	6.	438.		
	% CHANGE		-99	-74	-100	-85	-99	-73		
9/28/80	UPPER	7.16	22.8	4.6	16.0	18.3	320.	1301.		
	LOWER	no runoff								

Table 4. (cont)

DATE	SAMPLE LOCATION (WEIR)	pH	NO_3-N mg/1	NH_3-N mg/1	PO_4-P mg/1	TKN-N mg/1	COD mg/1	TOTAL SOLIDS mg/1	T.C. col/100ml	M.F.C. col/100ml
9/30/80	UPPER	7.24	11.1	11.1	16.7	27.8	322	1200		
	LOWER	no runoff								
10/30/80	UPPER	7.38		3.8	16.8	18.9	409	1394		
	LOWER	no runoff								
11/04/80	UPPER	7.59		11.3	22.6	34.0	771	1800		
	LOWER	6.52		1.5	1.3	1.9	43	799		
	% CHANGE			-87	-94	-94	-94	-56		
11/15/80	UPPER	7.44	5.6	8.4	22.5	36.5	626	1666		
	LOWER	no runoff								
11/23/80	UPPER	7.23	3.2	28.2	42.3	112.7	1151	3063		
	LOWER	no runoff								
11/27/80	UPPER	7.55	3.6	13.7	21.9	41.1	729	959		
	LOWER	no runoff								
2/11/81	UPPER	7.53		40.5	16.5	110.9	1904	2009		
	LOWER	no runoff								
2/18/81	UPPER	7.33		55.4	17.8		2812	2891		
	LOWER	no runoff								
2/23/81	UPPER	7.42		90.4	42.2	180.7		3072		
	LOWER	no runoff								
3/30/81	UPPER	7.36	1.7	7.0	27.2	14.0				
	LOWER	6.1	2.2	1.0	1.7	0.9				
	% CHANGE		+29	-86	-94	-94				
	MEAN % CHANGE		+9	-87	-79	-88	-83	-50	-79	-90

There was a large decrease in the concentration of the TC and FC from the upper weir to the lower weir (mean percent decrease of 79 and 90, respectively) (Table 4). There was difficulty in making the coliform analysis because of laboratory problems and the distance from the dairy farm to the laboratory. The minimum time between the occurrence of runoff and setting up the coliform test was 4 hours and several times it may have been as much as 24 hours. Therefore the coliform numbers are of value only as an indication of the relative changes. Dairy cows were grazing on the terraced pasture at certain times of the year so coliforms and nutrients from the manure from these animals contributed to the runoff. The coliform numbers are too high to meet the permissible water supply standards (TC $1x10^4$/100 ml and FC $x10^3$/100 ml).

The mass of nutrients or solids leaving the feedlot and terraced pasture was calculated by multiplying the average concentration times the volume (Table 5). Rainfalls which only had runoff from the feedlot are not included in Table 5. There are several other storms which were left out due to equipment malfunctions. In order to get a complete set of data the stage recorder and automatic sampler on both the upper weir and lower weir had to function properly. If one of the four pieces of equipment failed, no summary of the data could be done for Table 5.

The mass of nutrients or solids actually leaving the feedlot and disposal areas was relatively small (less than 1 kg/storm for NO_3-N, less than 7 kg/storm for PO_4-P, and less than 20 kg/storm for TKN). The NO_3-N was affected by the fertilizer application on 3/27/80 because the following rainfall produced an N loss 10 times higher than had been experienced previously (0.23 kg on 1/23/79 to 2.39 kg on 4/03/79). The total loss over the four storms following application was only 5.5 kg compared to 335 kg (448 kg/ha times 4.4 ha times 17% N) of nitrogen applied which resulted in a 2% loss. This compares

Table 5. Mass of Nutrients in Runoff Water.

Date	Sample Location (Weir)	NO_3-N kg	NH_3-N kg	PO_4-P kg	TKN-N kg	COD kg	TS kg
12/09/78	UPPER	<0.01	0.12	0.14	0.43	5.4	11
	LOWER	0.01	0.01	0.06	0.04	0.5	22
	% CHANGE		-92	-57	-91	-91	+91
1/01/79	UPPER	0.02	0.85	1.03	3.32	54.3	27
	LOWER	0.02	0.02	0.09	0.07	1.8	17
	% CHANGE	0	-98	-91	-98	-97	-36
1/12/79	UPPER	0.03	1.14	0.70	2.93	27.2	82
	LOWER	0.03	0.05	0.24	0.20	1.2	22
	% CHANGE	0	-96	-65	-93	-95	-73
1/23/79	UPPER	0.02	1.75	1.49	4.08	49.5	
	LOWER	0.23	1.57	1.62	4.54	23.7	
	% CHANGE	+950.	-10	+9	+11	-52	
2/22/79	UPPER	0.03	2.03	1.4	4.56	48.3	86
	LOWER	0.01	0.71	0.8	3.12	96.4	279
	% CHANGE	-67	-65	-40	-37	+99	+22
3/23/79	UPPER	0.94	7.18		19.88	161.8	547
	LOWER	0.08	1.32		5.83	59.7	754
	% CHANGE	-92	-82		-71	-63	+38
4/03/79	UPPER	0.07	3.72	2.09	8.08	87.2	191
	LOWER	2.39	0.95	15.01	8.91	34.2	1234
	% CHANGE	+3414*	-74	+618*	+10	-61	+545
4/09/79	UPPER	0.09	2.69	4.17	6.04	72.0	186
	LOWER	0.75	2.27	2.38	5.71	73.3	671
	% CHANGE	+802*	-15	-43	-6	+2	+250

* these values left out in determining mean % changes because of application of 448 kg/ha of 17-17-17 fertilizer on 3/27/79.

Table 5. (cont)

Date	Sample Location (Weir)	NO_3-N kg	NH_3-N kg	PO_4-P kg	TKN-N kg	COD kg	TS kg
10/04/79	UPPER	0.13	.19	0.5	.49	7.0	22
	LOWER	0.26	.39	-	.61	7.0	22
	% CHANGE	+100	+105		+24	0	0
11/02/79	UPPER	0.20	0.34	1.6	2.2	54	107
	LOWER	2.10	1.00	2.0	5.10	71	281
	% CHANGE	+950	+194	+25	+132	+31	+163
11/26/79	UPPER	0.03	.65	1.3	2.30	44.5	107
	LOWER	0.14	.11	0.3	0.61	7.2	39
	% CHANGE	+366	-83	-77	-73	-84	-64
1/11/80	UPPER	0.03	.86	1.1	2.80	28.9	105
	LOWER	<0.01	.08	0.1	-	7.9	33
	% CHANGE		-91	-91		-73	-68
1/13/80	UPPER	.06	1.8	2.3	7.30	81.3	191
	LOWER	.68	0.93		-	49.0	531
	% CHANGE	+1033	-48	-91		-40	+178
4/13/80	UPPER	-	5.93	6.6	16.47	176.6	666
	LOWER	-	3.99	5.7	8.15	1.9	808
	% CHANGE		-33	-14	-50	-99	+22
9/24/80	UPPER	0.34	.02	0.1	.11	2.9	10
	LOWER	0.01	.01	<0.1	.04	0.8	6
	% CHANGE	-97	-50		-64	-72	-40
11/04/80	UPPER	-	0.40	0.7	1.09	22.9	58
	LOWER	-	0.02	<0.1	0.02	0.5	9
	% CHANGE		-95		-98	-99	-84

Table 5. (cont)

Date	Sample Location (Weir)	NO_3-N kg	NH_3-N kg	PO_4-P kg	TKN-N kg	COD kg	TS kg
3/30/81	UPPER	0.12	0.50	1.8	1.00	-	-
	LOWER	0.15	.07	0.1	.06	-	-
	% CHANGE	+25	-86	-94	-94		
	MEAN % CHANGE	+352	-39	-49	-40	-49	+67

favorably to values of 3-4% N loss from surface applied dairy manure (Reese et al., 1982) and 6% for surface applied ammonium nitrate (McLeod, 1981).

The mean percent decrease in NH_3-N, PO_4-P, TKN and COD on a mass basis was 39, 49, 40 and 49, respectively for storms that produced runoff from both the feedlot and the terraced pasture. The TS showed a wide variation in change from a 545 percent increase on 4/3/79 to a 84 percent decrease on 11/4/80. The overall mean showed that 67 percent more solids were discharged from the terraced pasture than from the feedlot. Overall, the mass of nutrients leaving the terraced pasture (terraced pasture area six times the area of feedlot) would not be a serious problem from an environmental standpoint.

A more representative analysis of the mass of nutrients removed by the terraced pasture would be to evaluate all the storms over a given time period that produced runoff from the feedlot whether or not there was runoff from the terraced pasture. From January, 1980 to April, 1981 there were 17 storms that resulted in runoff from the feedlot but of these only 6 had runoff from the terraced pasture. This time period was nine months after the commercial fertilizer application. The concentration of pollutants in the runoff water was multiplied by the corresponding volume of runoff for that storm (Table 6). The percent removals were as follows: NO_3-N, 75; NH_3-N, 69; PO_4-P, 68; TKN, 76; COD, 91 and TS, 14. These removals were quite high compared to Table 5 which did not include the storms which had runoff from the feedlot only. It should also be remembered that additional pollutants were added to the terraced pasture from the milking parlor wastewater and from the animals grazing on the pasture. Therefore the percent removals would be on the conservative side when evaluating the pollutant removal efficiency of the terraced pasture.

The management and operation of this system proved to be very satisfactory. It was expected that solids would accumulate in the upper

Table 6. Mass of Nutrients in Runoff Water from 1/80 - 3/81 for all Storms.

Date	Sample Location (weir)	NO_3-N kg	NH_3-N kg	PO_4-P kg	TKN kg	COD kg	TS kg
1/11/80	UPPER	0.03	.86	1.1	2.80	28.9	105
	LOWER	<0.01	.08	0.1	-	7.9	33
1/13/80	UPPER	0.06	1.80	23	7.30	81.3	191
	LOWER	0.68	0.93	-	-	49.0	531
2/09/80	UPPER	0.30	0.11	10.1	0.31	27.4	62
	LOWER	no runoff					
3/30/80	UPPER	0.01	0.20	0.2	0.45	7.5	19
	LOWER	no runoff					
4/13/80	UPPER	-	5.93	6.6	16.47	176.6	666
	LOWER	-	3.99	5.7	8.15	1.9	808
7/10/80	UPPER	0.09	0.03	0.09	0.12	2.0	6
	LOWER	no runoff					
9/24/80	UPPER	0.34	0.02	0.1	0.11	2.9	10
	LOWER	0.01	0.01	<0.1	0.04	0.8	6
9/28/80	UPPER	2.00	0.40	1.4	1.60	28.0	114
	LOWER	no runoff					
9/30/80	UPPER	0.10	0.10	0.2	0.25	2.9	11
	LOWER	no runoff					
11/04/80	UPPER	-	0.40	0.7	1.09	22.9	58
	LOWER	-	0.02	<0.1	0.02	0.5	9
11/15/80	UPPER	0.12	0.18	0.5	0.77	13.1	35
	LOWER	no runoff					
11/23/80	UPPER	0.04	0.39	0.6	1.60	16	43
	LOWER	no runoff					

Table 6. (cont)

Date	Sample Location (weir)	NO_3-N kg	NH_3-N kg	PO_4-P kg	TKN kg	COD kg	TS kg
11/27/80	UPPER	0.13	0.50	0.8	1.50	27	35
	LOWER	no runoff					
2/11/81	UPPER	-	2.70	1.1	7.40	128	135
	LOWER	no runoff					
2/18/81	UPPER	-	1.90	0.6	-	98	101
	LOWER	no runoff					
2/23/81	UPPER	-	0.60	0.3	1.30	-	21
	LOWER	no runoff					
3/30/81	UPPER	0.12	0.50	1.8	1.00	-	-
	LOWER	0.15	0.07	0.1	0.06	-	-
Total	UPPER	3.35	16.62	18.5	33.97	662.5	1612
Total	LOWER	0.84	5.10	5.9	8.27	60.1	1387
	% Reduction	75	69	68	76	91	14

diversion channel located downslope from the feedlot, however this occurred only once early in the experiment. The runoff from the feedlot carried manure solids to the diversion channel upstream from the upper weir. These solids accumulated just behind the weir and had to be manually removed. Encouragingly, this was the only time that solids had to be removed throughout the nearly three years of monitoring.

No other operational problems were encountered. The spreader terraces with one drainage pipe per terrace did an adequate job of dewatering the terrace channel so the grass cover was maintained. The owner mowed the pasture periodically to remove the rough and coarse weeds. The pasture was used as one of the grazing areas for the milking herd with no problems.

CONCLUSIONS

1. Runoff water from a feedlot was reduced in concentration after traveling over a terraced pasture by the following average percentages: NH_3-N, 87; TKN, 88; PO_4-P, 79; COD, 83 and TS, 50. Total coliform and fecal coliform were reduced by 79 and 90 percent, respectively.
2. Comparing storms that produced runoff from both the feedlot and terraced pasture on a mass basis the removals by the terraced pasture were: NH_3-N, 39; TKN, 40; PO_4-P, 49 and COD, 49 all as percentages. On an average the NO_3-N and TS amounts increased during passage over the terraced pasture due to the addition of commercial fertilizer an average to poor grass stand.
3. Comparing all storms of a mass basis for a 15 month period that produced runoff from the feedlot, the removals by the terraced pasture were: NO_3-N, 75; NH_3-N, 69; PO_4-P, 68; TKN, 76; COD, 91 and TS, 14 all as percentages.

4. The terraced pasture area that receives the initial runoff water from the feedlot and parlor wastewater had a slight increase in NO_3-N and PO_4-P concentrations from 1978-1981. There were no significant changes in the nutrient content of the soil (P, K, Mg, and NO_3-N) over the terraced pasture except as noted above.
5. There were no major operational problems with utilizing a terraced pasture to receive from runoff from a feedlot.

RECOMMENDATIONS

The terraced pasture treatment system has the potential for providing effective reduction of nutrients at a low cost and minimum maintenance requirements. More land is required than for the traditional holding basin, but the land can be used for grazing.

Recommendations are: (1) begin with a well established vegetative buffer strip between the feedlot and the first terrace; (2) the slope should be in the range of 2-6 percent to reduce the runoff velocity, sediment movement, and to allow the wastewater to have time for contact with soil surface and vegetative growth; (3) the terraces could be revised to have a series of 5 cm pipes spaced 8 m apart at ground level to distribute the water more uniformily and thereby utilize more of the pasture than currently. This would reduce the area required for disposal.

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