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Characteristics of Rainfall Runoff from a Beef Cattle Feedlot

National Environmental Research Center
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U.S. Environmental Protection Agency
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CHARACTERISTICS OF RAINFALL RUNOFF FROM A BEEF CATTLE FEEDLOT

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ABSTRACT

Rainfall runoff from a 12,000-head capacity commercial beef cattle feedlot was characterized and a treatment-disposal system used by the feedlot was evaluated. Fifty percent of the rainfall events produced measurable runoff from the feedpens. A four to ten inch manure mantle on the feedpen surface was found to prevent runoff from 0.2 to 0.3 inch rainfalls depending on intensity and antecedent moisture conditions. The total runoff from the feedpens was equivalent to 39 percent of the total rainfall during the study period.

Direct runoff from the feedpens contained pollutant concentrations in the form of oxygen demand, solids, and nutrients that were generally an order of magnitude greater than concentrations typical of untreated municipal sewage. Dilution from direct rainfall and a few days of sedimentation in the runoff collection ponds reduced the concentrations of the pollutants up to 90 percent. The total weight of solids and oxygen demanding materials was reduced by about one-half, but the total weight of nutrients was not significantly reduced. The remainder of the treatment disposal system produced no appreciable improvement in the quality of the waste water. Final discharges still contained pollutant concentrations two to three times those of untreated municipal sewage.

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SECTION I

CONCLUSIONS

1. Manure was not removed from the feedpens during the eight-month study period resulting in a four- to ten-inch mantle of manure which demonstrated a variable capacity to absorb rainfall. Depending on rainfall intensity and antecedent moisture conditions, the minimum rainfall to result in rainfall runoff from the 3 percent slopes was 0.2 inches, while the maximum rainfall that did not result in runoff was 0.32 inches.

2. Chemical oxygen demand (COD), total organic carbon (TOC), and 5-day biochemical oxygen demand (BOD_5) concentrations were high, averaging 7,210, 2,010, and 1,075 mg/l, in direct feedpen runoff. BOD_5 concentrations were about four times the concentration typical for raw domestic sewage.

3. A very good correlation was demonstrated for three parameters of organic pollution--COD, TOC, and BOD_5. Direct feedpen runoff, ditch influent, ditch effluent, and farm pond effluent provided a broad range of concentrations of the same waste for comparison of these different parameters.

4. Direct feedlot runoff contains high and variable concentrations of solids and nutrients. Total suspended solids and total solids averaged 5,900 and 11,429 mg/l, respectively. Total phosphate concentrations ranged from 21 to 223 mg/l which is 3 to 20 times concentrations normally found in municipal wastes. Essentially all of the nitrogen was in the total organic and ammonia form which averaged 228 and 108 mg/l, respectively.

5. Detention of runoff in holding ponds resulted in a reduction of mean concentrations of solids, nutrients, and organic pollution in the form of COD, TOC, and BOD. Dissolved solids concentrations were reduced by 90 percent and organic pollutant concentrations were decreased by 70 percent.

6. Detention of runoff in the holding ponds reduced the total amount of solids and organic pollutants by about one-half. The greater reductions in mean concentrations were a result of solids sedimentation plus dilution with direct rainfall on the pond surfaces. The total amounts of nutrients such as ammonia, nitrate, and phosphate were not significantly reduced. There was a reduction in the total amount of nitrogen, as the organic nitrogen was converted to ammonia, some of which was subsequently lost to the atmosphere.

7. Pumping the effluent from the runoff collection ponds through the 2-mile long treatment channel had no significant effect on the quality of the waste water.

8. Although the quality of the discharge from the total collection-treatment system was greatly improved over the direct feedpen runoff, organic and nutrient concentrations remained two to three times those typical of untreated municipal wastes and much too concentrated for stream discharge.

9. Bacterial counts from holding pond samples collected one day following rainfall were higher than counts from direct feedpen runoff, indicating possible aftergrowth.

10. The ditch-pond treatment system resulted in no significant improvement in the bacterial quality of the feedlot runoff.

SECTION II

RECOMMENDATIONS

1. The study reported herein represents only one beef cattle feedlot in one climatic area; i.e., 37-inch annual rainfall, but data agree generally with published data from other researchers. Rainfall runoff from cattle feedlots contains pollutant concentrations two to three orders of magnitude too great for stream discharges, therefore these waste waters must be managed in a manner that will protect the quality of receiving surface and ground waters.

2. Open, uncovered cattle feedlots should have diversion and storage facilities to prevent feedlot runoff from reaching a watercourse.

3. Extraneous runoff from outside the feedpens should be diverted away from manure and waste holding facilities to reduce the volume of waste water for treatment and/or disposal.

4. Runoff collection ponds should be arranged in series to accomplish optimum reduction of pollutant concentrations by solids sedimentation. Additional research should seek to determine optimum detention time for maximizing solids separation while minimizing the dissolution of the solid material.

5. This project indicated that sedimentation plus dilution by direct rainfall could reduce pollutant concentrations by as much as 90 percent. Since these levels are now within treatable limits, additional research should be directed toward further reduction in pollutant concentrations by a number of processes that will produce an acceptable effluent.

SECTION III

INTRODUCTION

In the last decade, the public demand for more and better quality meat has resulted in a radical change in animal production methods. Prior to marketing, an increasing majority of animals for slaughter are being fed under confined conditions. The results of confined feeding are most evident in the beef cattle industry where feeding efficiency is greatly increased, but so are environmental pollution problems.

Confinement feeding no longer allows the animals to deposit wastes over several acres of pasture land where the natural assimilative capacity of the soil can absorb and degrade the wastes without adverse environmental effects. One beef animal will produce over a half ton of manure, on a dry weight basis, during its stay of from three to five months in a feedlot. This waste is deposited on an area usually less than 300 square feet. The major water pollution problem results from rainfall runoff which comes in contact with the manure and carries high concentrations of oxygen demanding materials, solids, nutrients, and disease organisms into surface waters and sometimes into the ground water.

Since animal feedlots represent the largest single source of solid wastes generated in the nation (over 2,000,000,000 tons annually) runoff from these feeding operations is a widespread water pollution problem of major significance (23). The overwhelming majority of the growth in the present 114 million head beef cattle feeding industry has been in large scale feedlots of 5,000- to 100,000-head capacity. Uncontrolled runoff from only a few acres of feedlot surface has been responsible for numerous cases of surface and ground water pollution (16) and has been implicated in the transmission of diseases to both animals (3, 8, 9, and 18) and humans (25).

In May 1969, Robert S. Kerr Water Research Center personnel met with officials of Meat Producers, Inc., of Dallas, Texas, who operate several beef cattle feedlots in Texas. One of their operations was a recently constructed feedlot which afforded one of the more advanced designs in feedpens and drainage control in the United States. This feedlot was near the city of McKinney in north central Texas.

The site, in the undulating Trinity River Basin, was originally covered by a shallow mantle of eroded Austin silty clay soil on the Austin Chalk bedrock (11). The soil was removed at one end of the feedlot and some of the feedpens were constructed on bedrock. Crushed rock from other areas was used as the base material for the remainder of the feedpens.

The average annual rainfall in the McKinney area is 37 inches (10) with a mean annual runoff of 6 to 8 inches and a normal Class A pan evaporation of 70-80 inches (15). Mean July and January temperatures are 83.7 and 45.6 degrees Fahrenheit, respectively, with a temperature extreme range of 118 to -7 degrees Fahrenheit (10). The mean number of frost-free days per year is 228 (10).

The 12,000-head capacity beef cattle feedlot consisted of 96 feedpens, each pen measuring 100 feet wide by 125 feet deep and containing 125 head of cattle. Pens are located in rows of six and each row is sloped uniformly at 3 percent toward an alleyway which collects rainfall runoff and transports it into four holding ponds which total 24 surface acres (Figure 1). Fences between pens are set in concrete curbs which prevent drainage across feedpens and facilitate the removal of manure by tractor-mounted loaders. Alleyway fences are set on swivels which permit the bottom of the fence to swing up for manure removal. The feedpen area, including alleyways, totals approximately 32 acres. Extraneous drainage is diverted around the feedpens so that the holding ponds receive only direct rainfall and runoff from the feedlot (Figure 2).

To prevent objectionable odors from developing in the holding ponds, after several days of detention, runoff was pumped into a ditch approximately 4 feet wide by 1 foot deep by 12,000 feet long with sloping sides (Figure 3). The ditch which is located on a pastured hillside has a relatively constant slope of about one half percent and transports the waste water to a farm pond of about 2 surface acres (Figure 4). The ditch-pond system was designed and constructed by the feedlot operator to provide waste water treatment through natural aeration, filtration action of the grass in the ditch, and biological degradation and dilution in the farm pond. The waste from the farm pond overflows into a natural draw which is a tributary to an adjacent 40-acre flood control reservoir.

The design and operation of the feedlot offered a well-controlled, full-scale site for research on the characteristics of cattle feedlot runoff, treatment of the runoff, and the effect of effluents on receiving waters. Despite the well-drained feedpens, extensive drainage control and waste water storage facilities, and existence of a system for treating waste water, the owners of Meat Producers, Inc., remained concerned about and interested in improving ultimate disposal of the waste effluents. As a result of their concern, they agreed to the use of their feedlot facilities for research purposes, and a three-study project was initiated by the Robert S. Kerr Water Research Center personnel in July 1969.

The purposes of the study reported herein were to determine the characteristics of rainfall runoff and to evaluate the efficiency of treatment process in operation at that time. A coincident study by the Environmental Protection Agency (5) reported on the effect of feedlot

FIGURE 1. FEED PENS & DRAINAGEWAYS

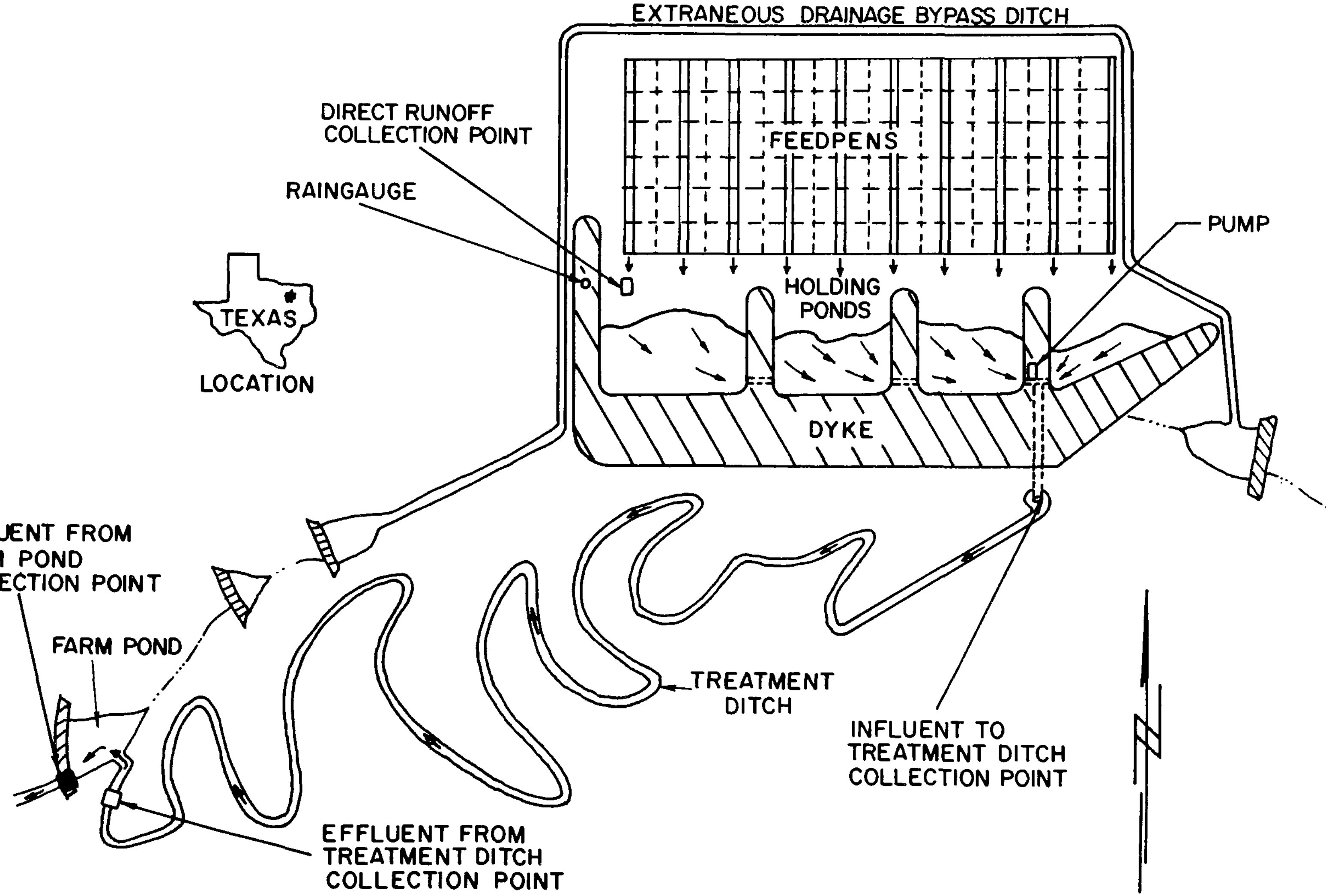

FIGURE 2 - DIAGRAM OF STUDY AREA

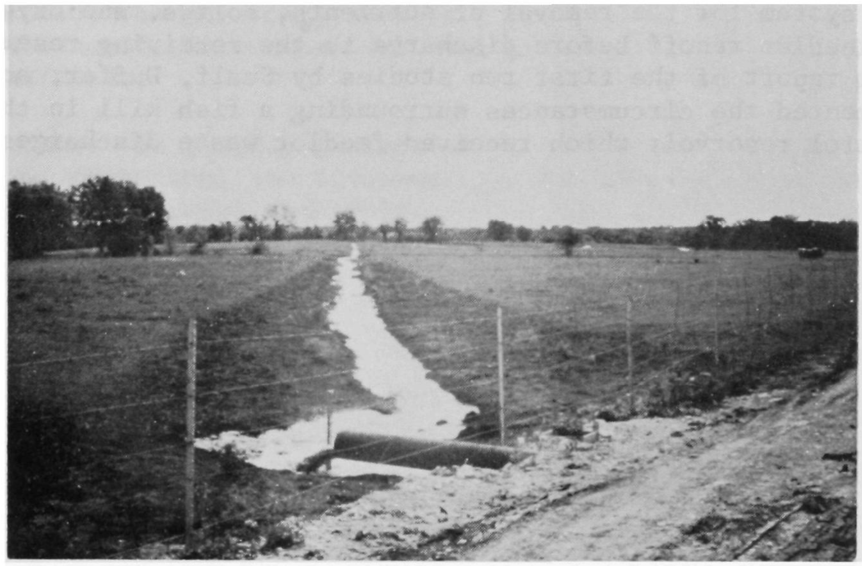

FIGURE 3. INFLUENT END OF DITCH

FIGURE 4. DITCH EFFLUENT AT FARM POND

effluents on the water quality and aquatic life of the receiving reservoir. The third phase, anticipated at the outset and confirmed by the first two concurrent studies, is currently in progress. This phase involves the addition and evaluation of an automated spray runoff soil treatment system for the removal of nutrients, solids, and oxygen demand from the feedlot runoff before discharge to the receiving reservoir. An interim report of the first two studies by Scalf, Duffer, and Kreis (19) documented the circumstances surrounding a fish kill in the 40-acre flood control reservoir which received feedlot waste discharges.

SECTION IV

OBJECTIVES

1. Determine the physical, chemical, and biological characteristics of rainfall runoff from an actual beef cattle feedlot under normal operating conditions.

2. Determine the quality changes as the waste water traversed the collection, retention, and treatment system from the feedpens to the receiving flood control reservoir.

SECTION V

EXPERIMENTAL PROCEDURES

One row of six feedpens was isolated for sampling and flow measurement to determine the characteristics of the direct runoff from the feedlot. This permitted a representative sampling of feedlot runoff from the entire feedlot. An 18-inch H-flume equipped with a Stevens F-1 8-day water level recorder was installed in the channel between the feedpens and collection pond. The amount and intensity of rainfall during the study period was recorded with a Science Associates, Inc., No. 551 recording rain gauge located near the 18-inch H-flume (Figure 5).

Initially, a gravity type composite sampler was installed on the H-flume to collect samples of the direct feedpen runoff. This sampler consisted of a perforated vertical pipe inside the flow measuring flume. Perforations increased in number up the pipe so that the sampling rate was proportional to the flow rate through the flume. Sample water was transported from the perforated pipe to two glass containers, located in the ground beside the flume, through a 1-inch pipe inserted through the bottom of the H-flume. Plugging problems created by the high solids waste rendered this sampling procedure unreliable. Therefore, a Nappe Model PPD automatic, float-actuated, pump-type liquid sampler powered by a wet-cell automotive battery was installed immediately downstream from the H-flume (Figure 6). This sampler was programmed to sample at 15-minute intervals during periods of rainfall runoff.

Sample flow was split between two duplicate 5-gallon bottles and excess waste. One of the bottles contained a sufficient amount of sulfuric acid to preserve the sample for laboratory analyses of chemical oxygen demand (COD), total organic carbon (TOC), total phosphate ($T-PO_4-P$), nitrate (NO_3-N), total organic nitrogen (TON-N), ammonia (NH_3-N), and chloride. The unpreserved samples were analyzed for total solids (T-solids), total dissolved solids (TDS), total suspended solids (TSS), volatile suspended solids (VSS), calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). When unpreserved samples could be collected and processed on the same day as a runoff event, they were also analyzed for 5-day biochemical oxygen demand (BOD_5).

The effects of the retention-treatment system on the quality of the waste water was determined during four pumping periods which succeeded, within a few days, rainfall runoff events. In November 1969, after the first three pumping events, the waste water pump used to dewater the runoff collection ponds malfunctioned. The feedlot operator did not repair the pump until March 1970, just prior to the fourth and final pumping event.

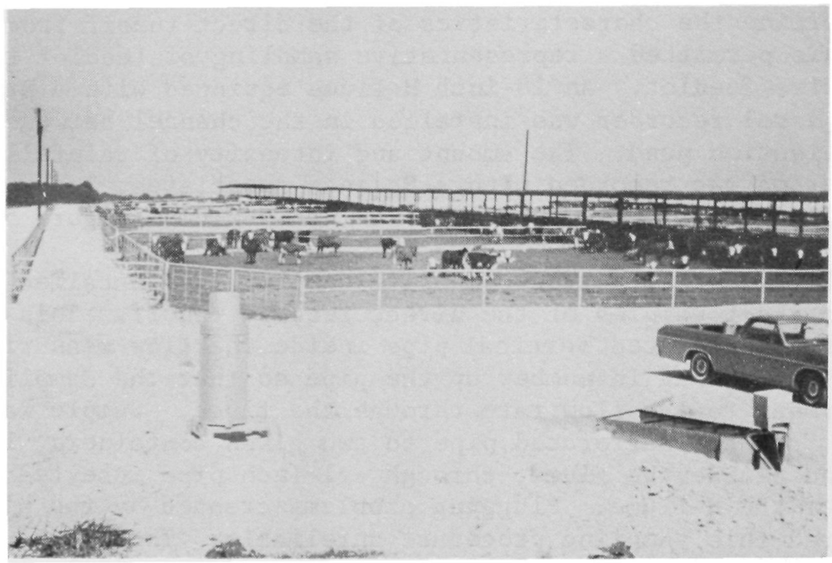

FIGURE 5. RAIN GAUGE, FLUME, & SAMPLER

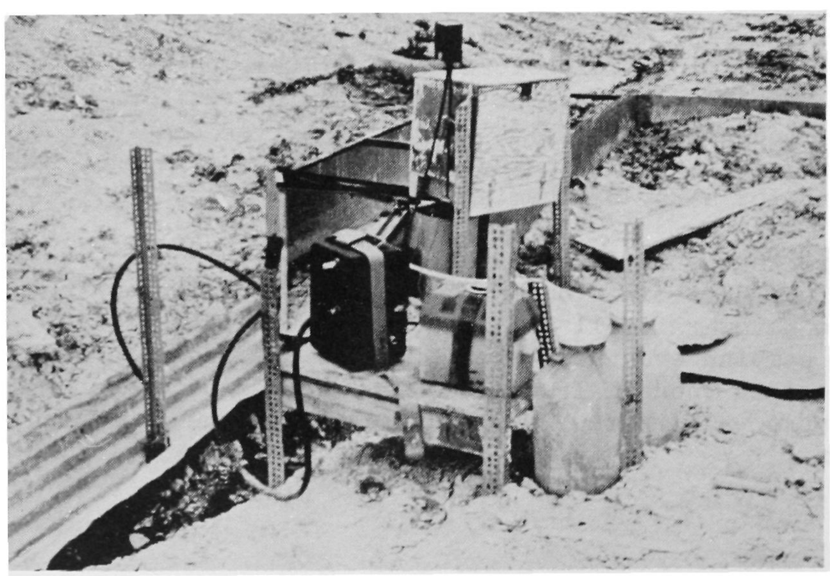

FIGURE 6. RAINFALL RUNOFF SAMPLER & H-FLUME

During the first two pumping periods, composite samples were collected from the ditch influent and effluent with Serco Model NW-3 vacuum-type refrigerated sequential samplers which were programmed to collect 100 ml of sample each hour for 24 hours. The collections were split into duplicate samples and composited. Hand-dipped grab samples were collected coincident with the composited sequential samples from flow-agitated areas of the ditch influent and effluent. Sequential sampling was discontinued in favor of the more convenient grab sampling after the first two pumping events due to a lack of appreciable difference in results obtained between the two techniques. Flow through the ditch was measured with an 18-inch Parshall flume equipped with a Stevens water level recorder.

A Nappe Model PPD liquid sampler, installed in a manner similar to the one used to collect direct feedpen runoff, was used to collect samples of the farm pond effluent. Additionally, grab samples of this effluent were taken from flow-agitated areas. Overflow discharges from the farm pond were measured with a 150° V-notch weir also equipped with a Stevens water level recorder (Figure 7).

The composite and grab samples collected from these sources were analyzed for the same chemical constituents as the direct feedlot runoff. When unpreserved samples could be processed on the same day as collected, they were also analyzed for BOD_5, nitrite (NO_2-N), orthophosphate (O-PO_4-P), pH, conductivity, and total alkalinity.

Analyses for COD, BOD_5, TOC, T-solids, TDS, TSS, VSS, O-PO_4-P, T-PO_4-P, NH_3-N, chloride, total alkalinity, pH, and conductivity were by wet lab techniques; NO_3-N was by automated technique; and Ca, Mg, Na, and K were by atomic adsorption techniques according to Federal Water Quality Administration Methods (21). TOC was analyzed according to the method of Van Hall, Safranko, and Stenger (22). TON was analyzed by Technicon Auto Analyzer Methodology (20); the accuracy of this method was periodically checked by FWQA methods.

Microbiological grab samples were collected from the direct feedpen runoff during three rainfall events, and from the holding pond ditch influent and effluent and the farm pond effluent during the first two pumping periods. Densities of coliform, fecal coliform, and fecal streptococci were obtained using standard membrane filter methods (2). K. F. Streptococcus agar (Difco) was used instead of M-enterococcus agar due to the higher recovery of *Streptococcus bovis* by the former medium (13). The procedure of Geldreich *et al.* (6) was used to obtain densities of coliforms. The results obtained by this method have been shown to be comparable to those obtained by using most probable number (MPN) fecal coliform techniques described in Standard Methods (2 and 7).

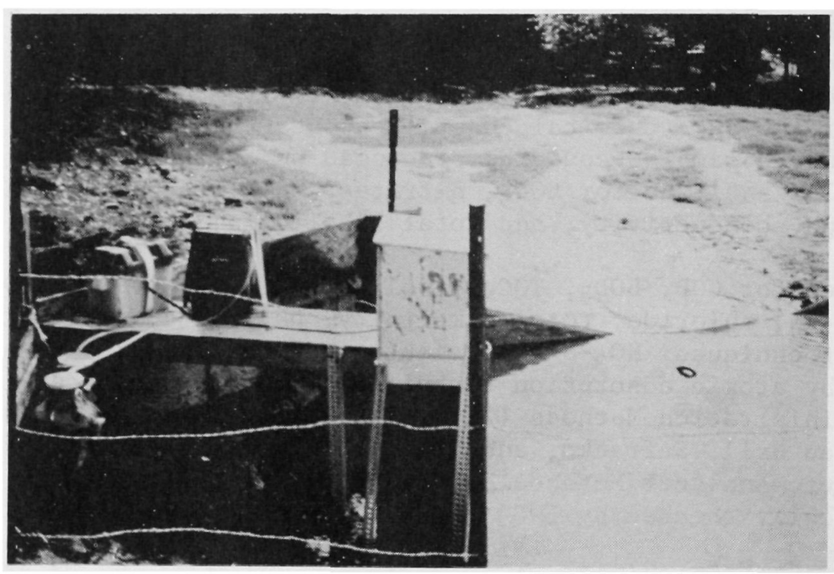

FIGURE 7. SAMPLER AND WEIR AT FARM POND OVERFLOW

SECTION VI

RESULTS AND DISCUSSION

This study was initiated about six months after the first cattle were placed in the feedpens. The six feedpens which were isolated for this study were maintained at the full 125-animal per pen capacity throughout the study period. Each animal was fed a 21-pound daily ration consisting of 62 percent milo, 22.5 percent silage, 10.5 percent protein supplement, 4 percent molasses, and 1 percent tallow. The mean starting and finishing weight of the animals was approximately 400 and 750 pounds, respectively. Manure was not removed from the pens during the study period.

There were 40 rainfall events during the study period, of which 21 produced measurable runoff (Appendix Table 1). The minimum rainfall which resulted in measurable runoff was 0.2 inches and the maximum rainfall which did not result in measurable runoff was 0.32 inches. The relationship of rainfall to runoff (Figure 8) may be expressed by the equation:

$$RU = 0.500\ RA - 0.124$$

RU is runoff and RA is rainfall, both expressed in inches.

Between July 24, 1969, and July 15, 1970, of the rainfall which resulted in runoff, the runoff to rainfall ratio from the feedpens was 1:2. Runoff totaling 10.1 inches from the feedpens between August 1969 and April 1970 equaled 39 percent of the total rainfall during that period (Table 1).

The concentrations of pollutants in the rainfall runoff were high and variable. Five-day biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total organic carbon (TOC) were used as parameters of organic pollution. Biochemical oxygen demand is recognized as a poor measure of organic pollution of animal waste waters because of the inherent difficulties with the analytical procedures, antibiotics, high solids concentration which interfere with the analyses, and the extremely high BOD concentrations encountered in animal wastes which necessitate very high dilutions for analyses. Nevertheless, it is a widely used pollution parameter and was included for comparison with COD, TOC, and other waste waters.

In the direct feedlot runoff, COD and TOC concentrations ranged from 1,439 to 16,320 mg/l and 150 to 4,400 mg/l. Mean COD and TOC values in the direct runoff were 7,210 and 2,010 respectively. Concentrations of BOD ranged from 1,075 to 3,450 mg/l with a mean value of 2,370 mg/l. Total suspended solids concentrations, which were also very high, ranged from 745 to 17,200 mg/l, with a mean value of 5,900 mg/l (Table 2).

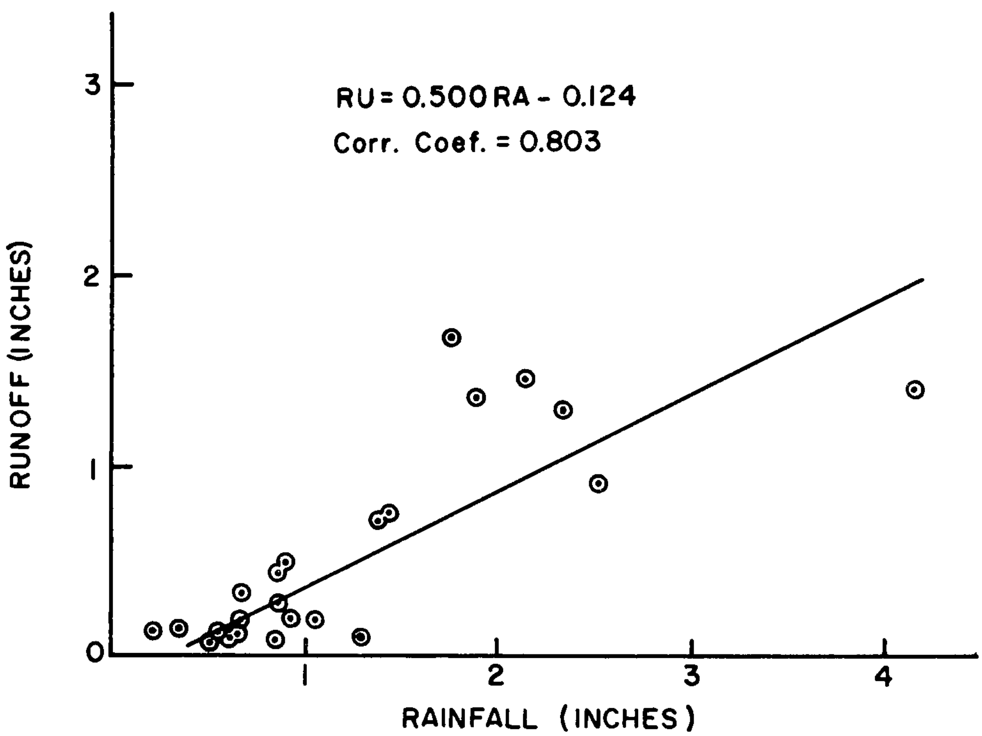

FIGURE 8 – FEEDLOT RUNOFF VERSUS RAINFALL

TABLE 1

SUMMARY OF VOLUMES OF RAINFALL ON THE FEEDPENS AND RUNOFF FROM ALL FEEDPENS

PRE-PUMPING PERIOD	RAINFALL		TOTAL FEEDPEN RUNOFF		PERCENT OF RAINFALL THAT RAN OFF
	inches	acre-ft.	inches	acre-ft.	
7/24-10/4/69	3.91	10.75	1.54	4.25	39
10/5-10/25/69	4.18	11.50	1.37	3.76	33
10/26-11/12/69	1.80	4.95	0.89	2.44	49
11/13-4/7/70	16.14	44.39	6.28	17.27	39
Combined Periods	26.03	71.59	10.08	27.72	39

TABLE 2

CONCENTRATIONS OF CHEMICAL CONSTITUENTS
MEASURED IN DIRECT RUNOFF FROM THE FEEDPENS
(mg/1)

	Number of Samples	Mean	Min.	Max.
T-Solids	8	11,429	3,110	28,882
TSS	8	5,912	745	17,202
VSS	7	3,426	475	9,286
TDS	8	5,526	882	22,372
Chloride	7	450	97	648
$T\text{-}PO_4\text{-}P$	16	69.2	21	223
$NO_3\text{-}N$	15	0.64	<0.05	2.3
$NH_3\text{-}N$	15	108	4	173
TON-N	15	228	31	493
COD	15	7,210	1,439	16,320
BOD_5	4	2,201	1,075	3,450
TOC	15	2,010	150	4,400
Ca	6	698	194	1,619
Mg	6	69	28	89
Na	6	408	130	655
K	6	761	226	1,352

The wide range of BOD, COD, and TOC values from the feedpens to the farm pond overflow presented a unique opportunity to correlate these parameters on the same waste water. The relationship of BOD to COD in this waste water (Figure 9) can be expressed by the equation:

$$BOD = 0.024 + 0.265 \; COD$$

Regression analysis of the above equation resulted in a correlation coefficient of 0.946. The approximate ratio of 3.5 for COD to BOD is less than one-half the value found by Miner *et al.* (17), and Ward and Jex (24), but is in close agreement with Witzel *et al.* (26) and Agnew and Loehr (1).

Total organic carbon is a parameter which is gaining widespread acceptance as a measure of organic pollution and in many cases is replacing the 5-day BOD test. The increased use of TOC results not only from the variability of the BOD test, but from the much greater ease and speed of measuring TOC. The relationships of TOC to the BOD and COD of feedlot runoff are presented in Figures 10 and 11, respectively, and can be expressed by the following equations:

$$TOC = 0.229 + 0.817 \; BOD$$

$$TOC = 0.190 + 0.238 \; COD$$

Regression analyses of the above equations resulted in correlation coefficients of 0.892 and 0.926, respectively.

The collection of either TOC or COD samples which may be preserved chemically for later analysis in many circumstances is advantageous over BOD samples which, to obtain reliable results, must be analyzed in a short period of time following collection. These data presented in Figures 9, 10, and 11 indicate a direct relationship between TOC, COD, and BOD in feedlot wastes. Therefore, TOC and COD can be used as a substitute for BOD if the number of BOD analyses included in the program are sufficient to develop a regression line applicable to the waste being studied and to maintain quality control.

Nutrient concentrations were measured in terms of total phosphate, total organic nitrogen, ammonia nitrogen, and nitrate nitrogen. Total phosphate concentrations ranged from 21 to 223 mg/l with a mean concentration of 69.2 mg/l which is 3 to 20 times concentrations normally found in municipal wastes. Essentially all of the nitrogen was in the total organic and ammonia form. Total organic nitrogen and ammonia concentrations ranged from 31 to 493 mg/l and from 4 to 173 mg/l respectively. Mean total organic nitrogen and ammonia nitrogen concentrations were 228 and 108 mg/l, respectively.

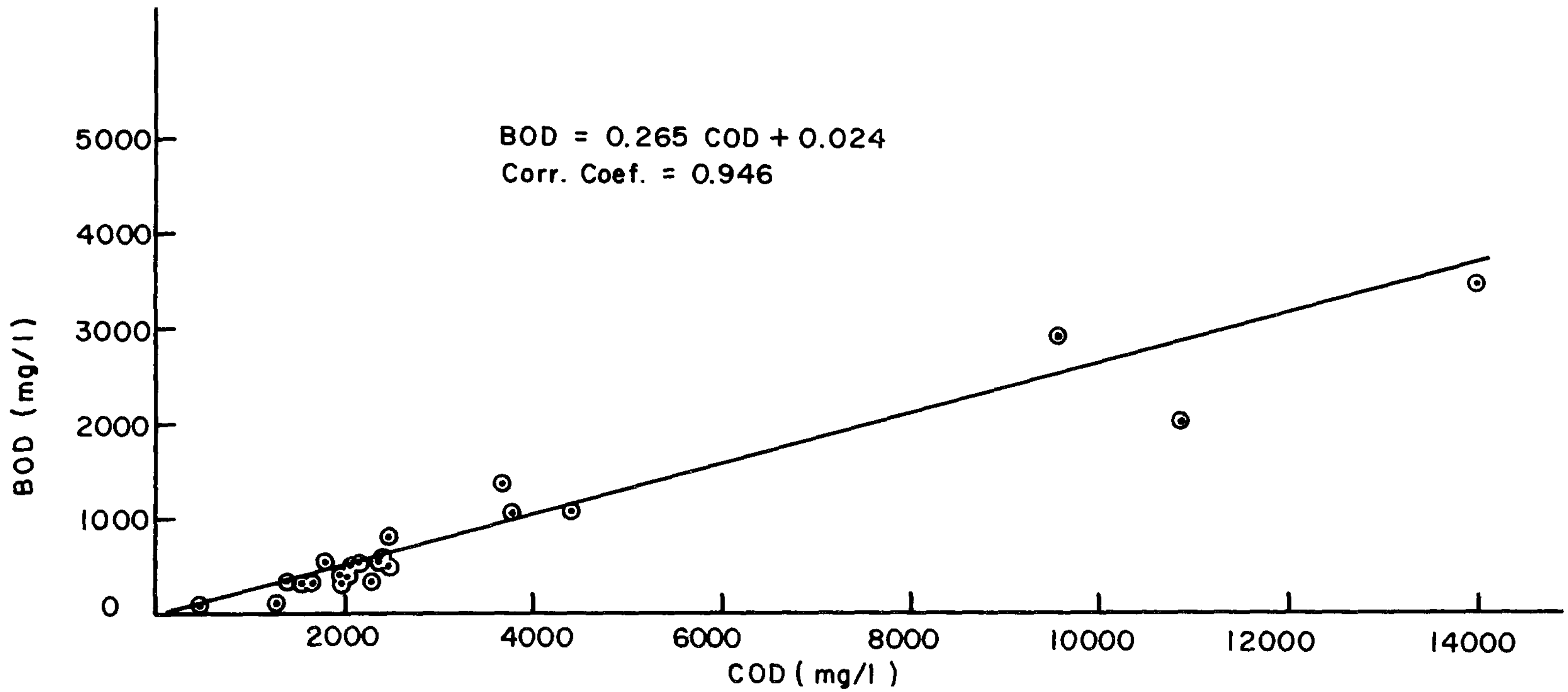

FIGURE 9 - RELATIONSHIP OF BOD AND COD IN FEEDLOT RUNOFF

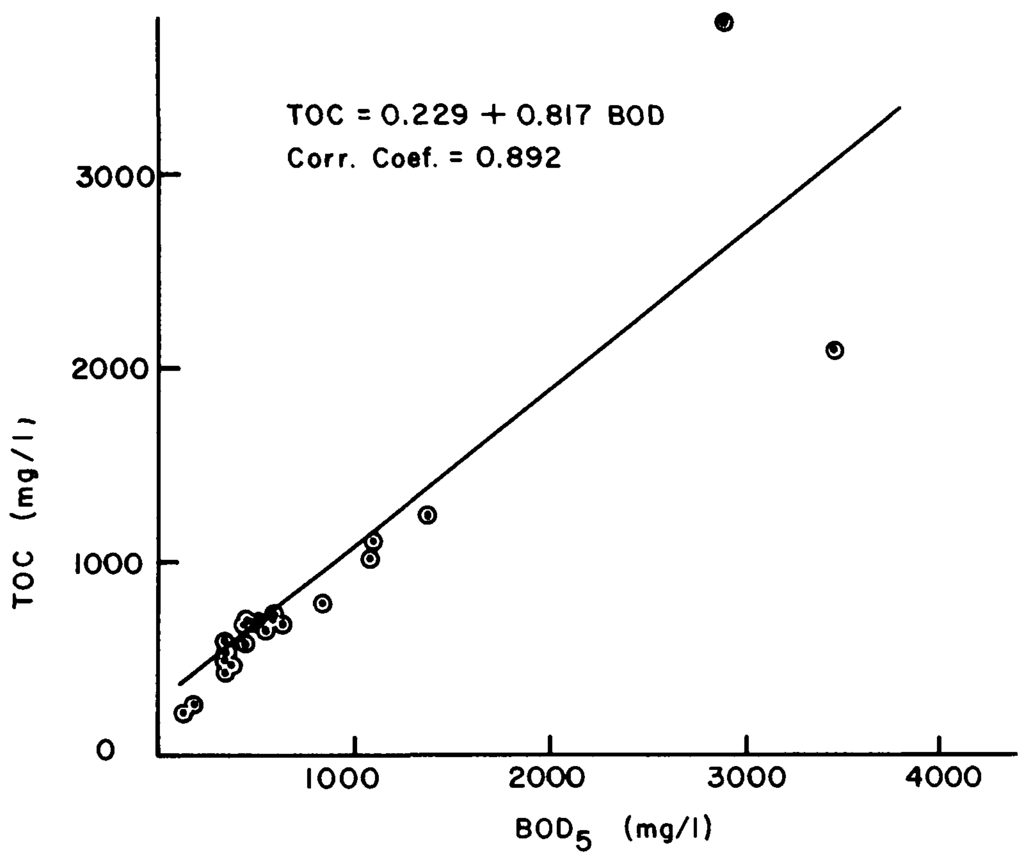

FIGURE 10 - RELATIONSHIP OF BOD AND TOC IN FEEDLOT RUNOFF

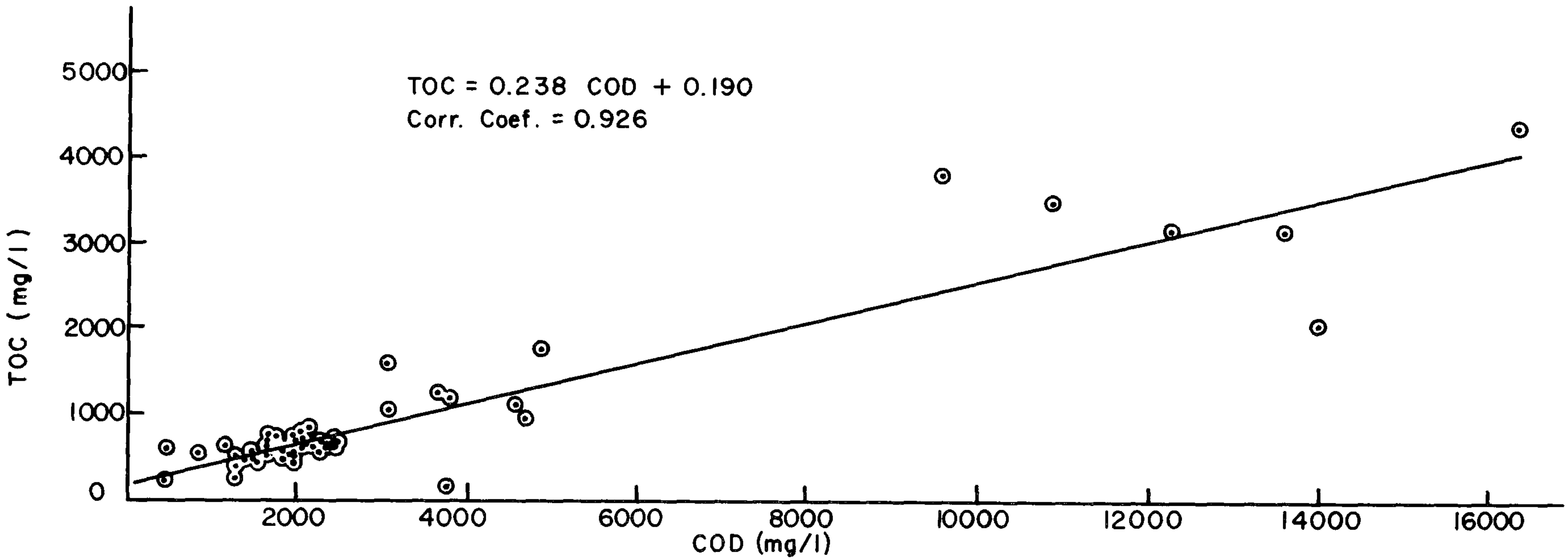

FIGURE 11 — RELATIONSHIP OF TOC AND COD IN FEEDLOT RUNOFF

Miner et al. (17) reported that pollutant concentrations were higher during warm weather. Most of the samples reported in this study were collected during the winter months in a relatively mild climate. Chemical oxygen demand and nitrogen concentrations were consistent with those reported by Miner et al. (17) for paved feedlots. The feedpens of the subject study were unpaved, but the surface was of soft chalk bedrock material which retarded infiltration. The well graded and uniformly sloped lots contained several inches of manure cover throughout the study period, and it is probably that water retention characteristics of the manure cover and the slope of the lots affected runoff drainage more than the subsurface material.

Collection of the feedlot runoff in the holding ponds has a significant impact on the quality of the waste water. Reduction in pollutant concentrations was a result of dilution by direct rainfall on the holding ponds, but more important, several days' detention in the ponds settled out most of the particulate matter. A total of 56.7 acre-feet of feedlot runoff and direct rainfall was pumped from the holding ponds into the ditch-pond treatment system during the four pumping events. Eighty-eight percent of the waste was pumped during two events: 17.4 acre-feet in October and 32.5 acre-feet in March-April. The volume pumped in March-April was almost the total winter accumulation of runoff in the holding pond. The remainder of the waste was pumped during the September-October and November-December pumping periods (4.6 and 2.2 acre-feet, respectively).

Detention of runoff in holding ponds resulted in a reduction in concentrations of solids ranging from 60 to 90 percent. The greatest reduction of 90 percent was in the mean concentration of total suspended solids, Table 3. Mean nutrient concentrations were reduced from 40 to 80 percent, Table 4. Mean concentrations of organic pollutants, in the form of COD, TOC, and BOD, were decreased by approximately 70 percent, Table 5. The range and mean concentrations of all measured physical conditions and chemical constituents in the ditch influent and effluent and in the farm pond effluent are presented in Appendices Tables 2-4.

The reduction in oxygen demand and suspended solids is consistent with Witzel et al. (26) who reported that 70 to 80 percent of the BOD and COD were associated with the suspended solids. A large proportion of all pollutants was associated with suspended solids contained in the feedlot runoff.

It is evident that most of these solids settled to the bottom of the collection pond without dissolving. The cool weather during most of the project period and the limited sedimentation time probably inhibited dissolution of the solids. If the waste water is to be treated for stream discharge and odor problems are to be minimized, it would appear

TABLE 3

COMPARISON OF SOLIDS CONCENTRATIONS (mg/1) MEASURED IN DIRECT FEEDPEN RUNOFF AND DURING PUMPING PERIODS

		Number of Samples	Mean	Max	Min
Direct Feedpen Runoff	T-Solids	8	11429	28882	3110
	TSS	8	5912	17202	745
	VSS	7	3426	9286	475
	TDS	8	5526	22372	882
Pumped Ditch Influent	T-Solids	6	2892	2970	2652
	TSS	6	735	922	540
	VSS	6	540	617	276
	TDS	6	2106	2212	2048
Ditch Effluent	T-Solids	7	3172	5101	2380
	TSS	7	1297	2969	470
	VSS	7	703	1220	260
	TDS	7	1875	2204	1236
Pond Effluent	T-Solids	8	1835	2874	1157
	TSS	8	543	1585	188
	VSS	8	283	460	108
	TDS	8	1299	1884	565

TABLE 4

COMPARISON OF NUTRIENT CONCENTRATIONS (mg/1) MEASURED IN DIRECT FEEDPEN RUNOFF AND DURING PUMPING PERIODS

		Number of Samples	Mean	Max	Min
Direct Feedpen Runoff	$T\text{-}PO_4\text{-}P$	16	69.2	223	21
	TON	15	228	493	31
	$NH_3\text{-}N$	15	108	173	4
	$NO_3\text{-}N$	15	0.64	2.3	<0.05
Pumped Ditch Influent	$T\text{-}PO_4\text{-}P$	6	37.4	45	29
	TON	14	62	136	36
	$NH_3\text{-}N$	14	63.4	112	45
	$NO_3\text{-}N$	14	0.21	0.5	0.09
Ditch Effluent	$T\text{-}PO_4\text{-}P$	15	38	65	21
	TON	15	64	142	38
	$NH_3\text{-}N$	15	50	70	30
	$NO_3\text{-}N$	14	0.2	0.9	<0.05
Pond Effluent	$T\text{-}PO_4\text{-}P$	11	25.5	39.6	5.3
	TON	11	39	80.5	11
	$NH_3\text{-}N$	11	35	57.5	9.5
	$NO_3\text{-}N$	10	0.22	0.36	<0.05

TABLE 5

COMPARISON OF ORGANIC POLLUTANT CONCENTRATIONS (mg/l) MEASURED IN DIRECT FEEDPEN RUNOFF AND DURING PUMPING PERIODS

		Number of Samples	Mean	Max	Min
Direct Feedpen Runoff	TOC	15	2010	4400	150
	COD	15	7210	16320	1439
	BOD_5	4	2201	3450	1075
Pumped Ditch Influent	TOC	14	711	1030	520
	COD	14	1980	3055	812
	BOD_5	6	582	820	337
Ditch Effluent	TOC	14	694	1100	520
	COD	14	2310	4410	996
	BOD_5	6	558	1069	337
Pond Effluent	TOC	11	429	680	128
	COD	11	1379	1956	436
	BOD_5	6	276	405	110

advisable to separate the solids from the supernatant before pollutant concentrations of the liquid are increased by dissolution and leaching of the solids and anaerobic degradation creates noxious gaseous products.

The mean tons of solids, nutrients, and organic pollutants in feedlot runoff which were available for discharge to the system before and after detention in the holding ponds are presented in Table 6. The tons of solids and organic pollutants in the form of COD, BOD_5, TON, and TOC were significantly reduced. However, the tonnage of nutrients such as NH_3-N, NO_3-N, and T-PO_4-P was not significantly changed even though the concentration of these constituents was reduced. This would indicate that either detention time was sufficient to facilitate dissolution of these nutrients from the solids or that these particular constituents were not associated with settleable solids and their concentrations were reduced mainly by rainfall dilution.

The 12,000-foot ditch, which transports pumped feedlot runoff from the retention pond to the small farm pond, was carefully designed and constructed to provide treatment through natural aeration and filtration through grass. The time required to fill the ditch and saturate the soil lining the ditch was approximately eight hours during the initial pumping period. This flow-through time was approximately four hours during the other three pumping periods when the soil lining the ditch was saturated by previous pumping events or rainfall. The retention time of effluent from the ditch was approximately equal to/or less than four hours. Comparison of the mean chemical concentrations of ditch influent and effluent presented in Tables 3-5 indicates no significant change in the quality of water. Although mean solids concentrations appeared to increase through the ditch, this can be attributed to a few high concentrations in the ditch effluent during the first pumping event when a significant amount of silt was flushed from the ditch. It is concluded that this treatment ditch system is ineffective in reducing the concentrations of pollutants.

The quality of overflow from the farm pond was improved over the ditch effluent, but most of this improvement can be attributed to dilution by rainfall runoff from another tributary of the farm pond. The total pounds of organic and nutrient pollution contributed by the farm pond overflow to the downstream reservoir was almost equivalent to that introduced through the treatment ditch to the pond.

Although the chemical quality of waste water at the farm pond overflow was greatly improved over the runoff at the feedpens, organic and nutrient concentrations remained 2 to 3 times those of raw municipal wastes and much too concentrated for discharge to surface or ground water. However, the improved quality at this point does suggest that it may be feasible to further treat the waste water by a number of processes that will produce a dischargeable effluent.

TABLE 6

TONS OF SOLIDS, ORGANIC POLLUTANTS, AND NUTRIENT WASTES BEFORE AND AFTER DETENTION

	Direct Feedpen Runoff	Holding Pond Effluent
T-Solids	430	223
TSS	222	56.6
TDS	208	162
$T\text{-}PO_4\text{-}P$	2.6	2.9
$NO_3\text{-}N$	0.02	0.02
$NH_3\text{-}N$	4.06	4.4
TON-N	8.6	4.8
COD	271	152
BOD_5	83	45
TOC	76	55

Fecal coliform and fecal streptococcus densities in direct feedlot runoff were extremely high as shown in Table 7. The fecal coliform to fecal streptococcus ratios were .08 or less in each case. This concurs with Geldreich (7) who found that ratios less than 0.7 are indicative of fecal pollution from animals other than man, provided the sample is taken before the original populations are altered by ecological conditions in the receiving system.

Bacterial counts from holding pond samples collected one day following rainfall were higher than any counts obtained from direct feedpen runoff. Lower counts would normally be expected due to the dilution factor of direct rainfall to the surface of the holding pond and the normal die-away of organisms outside the animal gut. Although the higher counts may be due to sampling error, inadequate data, and/or disintegration of solids, they raise the possibility of aftergrowth in the holding ponds.

The use of coliforms and fecal streptococci as pollution indicators is based partially on the density of the indicator organisms being roughly proportional to the amount of fecal pollution present and high densities of fecal coliform and streptococci being indicative of relatively recent pollution. Therefore, if aftergrowth or slow die-off occurs the use of such indicator systems to determine the age and extent of pollution would be limited. Furthermore, the use of fecal coliform to streptococcus ratios to differentiate between feedlot runoff and domestic sewage as sources of pollution might be altered.

Studies have shown aftergrowth of coliforms when discharged into systems where nutrients were available and other conditions governing survival of bacteria, such as pH, temperature, and absence of predators or toxic chemical were favorable (4) and (14). Nutrients in soluble form and a pH range of 7-8, existed in the direct runoff and retention pond. In addition, predators such as protozoa would be limited in the low-oxygen concentrations existing in the holding pond.

A more serious question raised by the possibility of aftergrowth or slow die-off is the unknown fate of possible pathogens. Little is known about the survival of pathogens compared to the survival of fecal coliforms and fecal streptococci. If the absence of these indicator groups does not guarantee safe water, then their presence in large numbers could indicate a great potential hazard.

The ditch-pond treatment system had no significant effect in improving the bacterial quality of the feedlot runoff, evidently because of the short flow-through time. Any reductions were due to normal die-off plus the dilution factor of the farm pond.

TABLE 7

NUMBER OF MICROORGANISMS

10^6/100 ml

	Total Coliform	Fecal Coliform	Fecal Streptococci	FC/FS Ratio
Direct Runoff (3 samples)				
Mean	12.5	1.35	73.7	---
Min.	4.3	0.2	6.8	.003
Max.	33	17	280	.08
Holding Pond - 1st Day Following Runoff (2 samples)				
Mean	84.5	55	92	---
Min.	83	10	61	.16
Max.	86	100	122	.83
Holding Pond - 7-8 Days Following Runoff (2 samples)				
Mean	.88	.38	.39	---
Min.	.55	.11	.34	---
Max.	1.2	.64	.44	---
Ditch Influent (9 samples)				
Mean	7.4	2.0	4.2	---
Min.	.47	.03	.23	---
Max.	31.0	14.	8.2	---
Ditch Effluent (7 samples)				
Mean	11.7	1.7	1.6	---
Min.	.26	.02	.28	---
Max.	39.	9.7	9.1	---
Overflow from Farm Pond (9 samples)				
Mean	.26	.072	0.25	---
Min.	0.026	.004	0.046	.09
Max	8.9	5.5	3.7	1.48

SECTION VII

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SECTION VIII

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SECTION IX

APPENDICES

TABLE 1

DIRECT RUNOFF EVENTS FROM FEEDPENS

Date	Rainfall Amount (Inches)	Runoff Amount (Inches)
9/7/69	0.85	0.14*
9/22-23/69	2.15	1.78*
10/12/69	4.15	2.06*
10/27/69	0.53	0.22
10/28/69	0.65	0.03
10/29-30/69	1.99	1.08*
12/5-6/69	1.96	1.14
12/18-19/69	0.53	0.12
12/28-29/69	1.76	1.59*
1/5/70	0.65	0.17
2/1/70	2.35	1.95
2/15/70	0.76	0.56*
2/22-25/70	2.53	1.38*
2/27-28/70	0.90	0.74
3/2/70	1.30	0.19*
3/3/70	0.35	0.23*
3/16-17/70	1.05	0.30*
3/20-21/70	0.75	0.10*
4/18/70	0.86	0.71*
4/25/70	3.02	2.06*
4/30/70	0.85	0.44*

* Chemical samples were collected during these events.

TABLE 2

RANGE AND MEAN CONCENTRATIONS OF CHEMICAL CONSTITUENTS* AND PHYSICAL CONDITIONS MEASURED IN THE DITCH INFLUENT

	N	$\overline{M}$	Min.	Max.
pH	5	7.3	7.2	7.5
Conductivity	5	6720	4800	8400
T-Alkalinity	4	852	768	1028
T-Solids	5	2892	2652	2970
TSS	6	735	540	922
VSS	6	540	376	617
TDS	6	2106	2048	12
Chlorides	6	314	295	323
O-PO_4-P	13	36.4	12.2	55.8
T-PO_4-P	6	37.4	29	45
NO_2-N	3	2.36	0.01	7.01
NO_3-N	14	0.21	0.09	0.5
NH_3-N	14	63.4	45	122.5
T-Org N-N	14	62	36	136
COD	14	1980	812	3055
BOD	6	582	337	820
TOC	14	711	520	1030
Ca	8	186	163	218
Mg	8	38	32	45
Na	8	141	125	219
K	8	292	244	322

* All Concentrations reported as mg/l except pH (units) and conductivity (μmhos/cm).

TABLE 3

RANGE AND MEAN CONCENTRATIONS OF CHEMICAL CONSTITUENTS* AND PHYSICAL CONDITIONS MEASURED ON THE DITCH EFFLUENT

	N	$\overline{M}$	Min.	Max.
pH	4	7.7	7.6	7.8
Conductivity	4	6088	5900	6500
T-Alkalinity	4	791	740	822
T-Solids	7	3172	2380	5101
TSS	7	1297	470	2969
VSS	7	703	260	1220
TDS	7	1875	1236	2204
Chlorides	6	308	290	325
O-PO_4-P	4	25	13.3	35
T-PO_4-P	15	38	21	65
NO_2-N	3	0.16	0.02	0.45
NO_3-N	14	0.2	<0.05	0.9
NH_3-N	15	50	30	70
T-Org N-N	15	64	38	142
COD	14	2310	996	4410
BOD	6	558	337	1096
TOC	14	694	520	1100
Ca	6	269	180	567
Mg	6	37	22	50
Na	6	182	150	202
K	6	207	125	284

* All concentrations reported as mg/l except pH (units) and Conductivity (μmhos/cm).

TABLE 4

RANGE AND MEAN CONCENTRATION OF CHEMICAL CONSTITUENTS* AND PHYSICAL CONDITIONS MEASURED IN THE FARM POND EFFLUENT

	N	$\overline{M}$	Min.	Max.
pH	2	7.9	7.8	7.9
Conductivity	2	4875	4400	5350
T-Alkalinity	2	500	610	690
T-Solids	8	1835	1157	2847
TSS	8	543	188	1585
VSS	8	283	108	460
TDS	8	1299	565	1884
Chlorides	3	240	186	277
$O-PO_4-P$	2	16.7	16.4	17
$T-PO_4-P$	11	25.5	5.3	39.6
NO_2-N	2	0.01	0.01	0.01
NO_3-N	10	0.22	<0.05	0.36
NH_3-N	11	35	9.5	57.5
T-Org N-N	11	39	11	80.5
COD	11	1379	436	1956
BOD	6	276	110	405
TOC	11	429	128	680
Ca	11	152	95	150
Mg	11	25	12	37
Na	11	120	76.2	150
K	11	182	85	250

* All concentrations reported as mg/l except pH (units) and Conductivity (μmhos/cm).

SELECTED WATER RESOURCES ABSTRACTS

INPUT TRANSACTION FORM

Rep. No.

W

Characteristics of Rainfall Runoff from a Beef Cattle Feedlot

5. Report Date

6.

8. Performing Organization Report No.

Kreis, R. Douglas, Scalf, Marion R., McNabb, James

13040 FHP

Environmental Protection Agency
Robert S. Kerr Water Research Center
Ada, Oklahoma

13. Type Report and Period Covered

12. Sponsoring Organization

Environmental Protection Agency report number EPA-R2-72-061, September 1972.

Rainfall runoff from a 12,000-head capacity commercial beef cattle feedlot was characterized and a treatment-disposal system used by the feedlot was evaluated. Fifty percent of the rainfall events produced measurable runoff from the feedpens. A four- to ten-inch manure mantle on the feedpen surface was found to prevent runoff from 0.2- to 0.3-inch rainfalls depending on intensity and antecedent moisture conditions. The total runoff from the feedpens was equivalent to 39 percent of the total rainfall during the study period.

Direct runoff from the feedpens contained pollutant concentrations in the form of oxygen demand, solids, and nutrients that were generally an order of magnitude greater than concentrations typical of untreated municipal sewage. Dilution from direct rainfall and a few days of sedimentation in the runoff collection ponds reduced the concentrations of the pollutants up to 90 percent. The total weight of solids and oxygen demanding materials was reduced by about one-helf, but the total weight of nutrients was not significantly reduced. The remainder of the treatment disposal system produced no appreciable improvement in the quality of the waste water. Final discharges still contained pollutant concentrations two to three times those of untreated municipal sewage.

17a. Descriptors

*Cattle, *Confinement Pens, *Rainfall-Runoff Relationships, *Pollutants, Farm Wastes, Nutrients, Bio-chemical Oxygen Demand, Chemical Oxygen Demand, Coliforms, Streptococcus

17b. Identifiers

*Feedlot, *Manure Wastes, *Wastes Characteristics, Solids, Total Organic Carbon

05B

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