EPA-600/2-77-159
August 1977

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BEEF CATTLE FEEDLOT RUNOFF AND CONTROL IN EASTERN NEBRASKA

Robert S. Kerr Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

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BEEF CATTLE FEEDLOT RUNOFF AND CONTROL IN EASTERN NEBRASKA

By

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L. P. Schram Feed Lot, Inc.
Papillion, Nebraska

Grant No. S-802197

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DISCLAIMER

FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

William C. Galegar, Director
Robert S. Kerr Environmental
Research Laboratory

PREFACE

Introducing man-made structures into the natural environment may disrupt environmental activity. One such disruption is pollution, which occurs when activities instigated by civilization create environmental imbalances that would not normally occur. While primary attention has been given to pollution from urban activities, increasing emphasis is being placed on that from agricultural enterprises. One such area of emphasis is that of pollution from confined livestock feeding. Animals concentrated in small areas produce wastes that must be removed from the lot and used or disposed of elsewhere. Solid residues and lot runoff, which both contain elements usable in agriculture, are included in these wastes. The mismanagement of these materials allows excess elements to enter surface and groundwater, and concerns both the environmentalist and the feedlot owner.

In many cases the feedlot owner has also become an environmentalist, concerned with the quality of the surrounding area as well as animal health and business prosperity. Larry Schram, Papillion, Nebraska, has become this type of lot owner. His Sarpy County feedlot is bordered by two streams. Runoff from his lots posed a potential pollutional threat. Also, Papillion, 3 miles to the northeast, and Richfield, 2½ miles south, were concerned about air and water quality in their areas. A dam to be built near the feedlot will be used for recreation, and the water in its reservoir must be clean. Alleviation of the Schram feedlot problems required professional help. Agricultural engineers from the University of Nebraska, the United States Department of Agriculture, Agricultural Research Service and Soil Conservation Service were asked to assist in the design of a system that would reduce potential pollution from the Schram feedlot.

The control project began in 1973. Designed using known research techniques demonstrated on small plots and new concepts with merit, it has been modified to its present condition. This includes a system of conveyance channels, debris basins, holding ponds, and disposal system. The various components of the system have been tested and this report has been prepared to record those findings.

ABSTRACT

This study was initiated to determine operational characteristics of runoff control facility components for beef cattle feedlots.

A runoff control facility was designed and constructed for a 3,000 head capacity feedlot in eastern Nebraska. Components of the runoff control facility included debris basins inside the pen and outside the pen, a holding pond, and a disposal system.

Results indicated that design volumes for the debris basins and holding ponds were effective in controlling runoff from the lots caused by snowmelt and rainfall for climatic conditions within eastern Nebraska. Characteristics of runoff transported solids from this large lot compared favorably with values developed earlier on small research lots. All values for total and volatile solids, electric conductivity, pH, nitrogen, phosphorus, and COD were within published ranges.

This report was submitted in fulfillment of Grant No. S802197-01-4 by L. P. Schram under partial sponsorship of the U.S. Environmental Protection Agency. This report covers the period March 15, 1973 to September 30, 1976.

CONTENTS

FIGURES

TABLES

LIST OF CONVERSION FACTORS

Distance

1 inch = 2.54 cm
1 ft = 0.3048 m
1 mile = 1.61 km

Volume

1 ac-in. = 101.6 m^3
1 ft^3 = 0.28 m^3
1 yd^3 = 0.76 m^3
1 gallon = 3.785 ℓ = 0.0038 m^3

Weight

1 lb = 0.454 kg
1 English ton = 0.907 metric tons

Ratios

1 in./ac = 251 m^3/ha.
1 English ton/ac = 2.24 metric tons/ha.
1 ton/ac-in. = 8.9 kg/m^3
1 gal./min = 3.785 ℓ/min = 0.0038 m^3/min

ACKNOWLEDGMENTS

The cooperation of the University of Nebraska, Soil Conservation Service, USDA, and the Agricultural Research Service, USDA, is gratefully acknowledged.

Particular appreciation is extended to Dr. W. E. Splinter, Chairman of the Agricultural Engineering Department, UN-L, for his active support and sustained interest in the project; C. B. Gilbertson and J. A. Nienaber, agricultural engineers, USDA-ARS, for a design of the facility; J. L. Gartung, former agricultural engineer, UN-L, now agricultural engineer, Kansas River Valley Experiment Farm, Topeka, Kansas, for his follow through on construction and instrumentation; Dr. J. R. Ellis, microbiologist, USDA-ARS, for laboratory analyses of samples obtained; R. H. Tharnish, technician, UN-L, for on-site recording of data; and Gary L. Goranson, editorial assistant, UN-L.

The University of Nebraska Extension Service is commended for the efforts of E. A. Olson, Extension Agricultural Engineer, for assisting with tours throughout the duration of the project with local, national, and foreign visitors.

SECTION 1

INTRODUCTION

Crop production on land and animal production in confined areas may pollute both surface and ground water. While agricultural industries may have to correct these pollution problems, agencies governing environmental quality must provide reasonable quality standards and workable control methods through research.

Methods exist for controlling feedlot runoff, but the need extends beyond control. Information is needed on maintenance of waste management facilities, improvement of feedlot operations, and overall reduced costs. A good control system must be composed of the right components in the right places to be successful.

Thorough documentation shows that feedlot runoff must be controlled (1, 2, 4, 7, 11, 13, 16, 17, 21). The quantity and quality of feedlot runoff has been shown to be unaffected by slope (4). The effect of the distance between the "source and pollution point" has not been documented, but guidelines are in effect and research underway to define the effect of distance on the quantity and quality of feedlot discharge.

Runoff control systems for feedlots with high pollution potential have been built (3, 5, 10, 14, 18, 19). Basic runoff control structures included a debris basin, a holding pond, and a disposal area. When properly managed, this system provides adequate protection. Environmental protection, however, is affected by the methods used to remove settled solids from the debris basin and liquid from the holding pond. Problems exist when debris basin settled solids are removed in the form of a slurry, or if disposal fields are saturated and holding ponds filled to capacity.

Research is being conducted to solve these problems, but information on available systems and potential problems must be made available to feedlot operators. A demonstration site accessible to both feedlot owners and designers can show systems and management methods that may be suited to many design needs.

Methods for applying holding pond effluent to cropland and its effects on the crop have been reported (9, 15, 20). Eisenhauer (2) reported that the quality of runoff from a low permeability grassed disposal area was not affected by the application of holding pond effluent. McCaskey (12), however, measured a significant increase in pollution in precipitation runoff from small plots where dairy barn waste had been applied. Precipitation runoff from an area where effluent from a beef cattle feedlot has been applied may be high in pollutants.

SECTION 2

SUMMARY AND CONCLUSIONS

A runoff control system was installed under EPA sponsorship on the L. P. Schram Feedlot, Papillion, Nebraska, to determine runoff characteristics from a large feedlot, to determine the adequacy of current runoff control system design criteria, and to test debris basin design taken from small research sites, on a commercial basis. System components include debris basins, conveyance channels, holding ponds, and a disposal system.

Precipitation patterns were above normal for the construction period (April through October of 1973) and about 30% below normal for the test period of 1974 and 1975. Runoff averaged about 30% of the annual precipitation compared with 40% recorded for small feedlots in previous years. Reduced annual precipitation and relatively light snowmelt explain the discrepancy between these two observations.

The amount of dry matter removed from the debris basins varied, but was higher than that recorded in literature. While no immediate explanation for this recording is available, heavy precipitation following extended dry periods may transport a larger than normal quantity of solid material.

The quantity of settled solids removed from basins located within the lots ranged from 2.4 to 7 tons/acre-inch of runoff compared to 1.6 to 6.5 tons/acre-inch for basins located outside the lots. A considerable quantity of material was removed from fencelines where debris basins were located outside the feedlot. The moisture content of the materials within debris basins was generally higher in basins inside the lot. Extremely dry conditions showed that inside-lot basins dried faster than those outside, due to the continual aeration caused by cattle movement. A surface crust on basins outside the lot reduced evaporation losses.

Characteristics of holding pond and debris basin effluent were similar to values developed by earlier research (7, 8, 11, 17). The total solids content of the holding ponds, however, was 25% below that of published values. All values for total and volatile solids, electric conductivity, pH, nitrogen, phosphorus, and COD were within published ranges.

Design volumes used for the debris basins and holding ponds were considered adequate for the L. P. Schram feedlot and other sites in eastern Nebraska. No overflow events were recorded when all components of the system were operational.

Debris basins were designed with a capacity of 1.25 ac-in. for each acre of feedlot. Volumes for debris basins remote from the holding ponds were designed with a safety factor of 2.5, while the basin adjacent to a holding pond was designed with no safety factor. Overflow from this basin went directly to the holding pond.

The center pivot performed adequately as a distribution system for runoff.

In general, the system proved adequate, and design criteria functioned for climate conditions within eastern Nebraska.

SECTION 3

RECOMMENDATIONS

The design of runoff control components (debris basins, holding ponds, and disposal systems) must be tailored to individual operations. General design for systems capacity, however, must consider chronic wet periods expected to occur over a 10-year period; interaction of system components to reduce chance of overflow and resulting pollution; pollution potential of the feedlot; and, the type of feedlot the design is intended for.

Debris basin capacity depends on location with respect to the holding pond and the pollution potential of the lot. A design capacity of 1.25 in/acre of feedlot is adequate for gravity-drained debris basins adjacent to a holding pond. A safety factor of 2.5 is recommended for debris basins remote from a holding pond using a pumping station to transfer effluent.

A holding pond capacity equal to 100% of the 10-year, 24-hour reoccurrence interval storm is recommended for all sites with climate similar to that of eastern Nebraska. The ponds may be 10 or more feet deep to reduce surface area requirements.

Disposal system design should include a permanent pumping station with a distribution system that can apply effluent under saturated soil conditions. The distribution system should have low labor requirements and use available farm equipment to save money. The system should not be designed to irrigate cropland unless irrigation is already used or planned. The disposal area should be close to the holding pond, thereby reducing pumping cost. A transfer pond may be built at the disposal site if it is remote from the holding pond.

Equipment and pumping systems may include conventional centrifugal pumps with cast iron or bronze impellers if settled solids and debris are removed before pumping. Manure pumps with agitators should be used if the system uses a combination debris basin-holding pond. Plastic pipe should be used to transfer liquids to holding ponds and the disposal site. Galvanized metal riser pipes will resist damage better than plastic, and do not need to be shielded from animals. Therefore, they would be recommended for debris basins located within or outside the lot.

SECTION 4

MANAGEMENT CONCERNS

PHYSICAL COMPONENTS

The L. P. Schram Feedlot, Inc., is a cattle feeding operation covering more than 20 acres in Sarpy County, Nebraska, near the town of Papillion (Figure 1). Lot capacity ranges from 3000-5000 head of finishing cattle, with an animal concentration of from 120-200 animals/acre. Runoff from the lots flows into Walnut Creek, a low flow permanent stream to the west and north of the lot, and an intermittent flow stream to the north. Both streams empty into the Papio Creek, which drains into the Missouri River. A flood control-recreation dam is to be built ½ mile downstream from the Schram lot.

Residue Quantity and Quality

The Schram lot produces about 2800 dry tons of manure annually. The initial moisture control of the lot manure is about 85%. After evaporation, seepage, and mixing with soil by cattle movement, the residue is reduced to a moisture content of about 50%. About 3%-6% of the material deposited on the lot is estimated to be transported in runoff, a figure that varies with the lot conditions and amount of snowmelt runoff. This runoff will have a solids content of 1.5% to 2.0%. Mielke, et al. (13) showed that seepage through the lot surface to groundwater is minimal. The surface runoff from the lot that affects the quality of the surface waters can be managed. A system was designed to accomplish this management.

Soil and Water

The Schram lot is in an area of rolling hills and valleys, covered with deposits of wind-blown soils (loess) with good infiltration. Perched water tables above clay tills are evident at shallow depths in much of the area and depth to water table varies from 0 to 200 ft. This variable water table means that dissolved materials in the groundwater may be present over a wide area, or in localized water pockets. As a result, some build-up of salts and other elements has occurred in soil in the areas of shallow groundwater. Wells usually provide reliable, but moderate supplies of good quality water for domestic use, but water for irrigation is not available.

Wind

Predominant winds blow to the northeast in the spring and summer, toward Papillion and the city of Omaha. Early spring winds are moderate and normal-

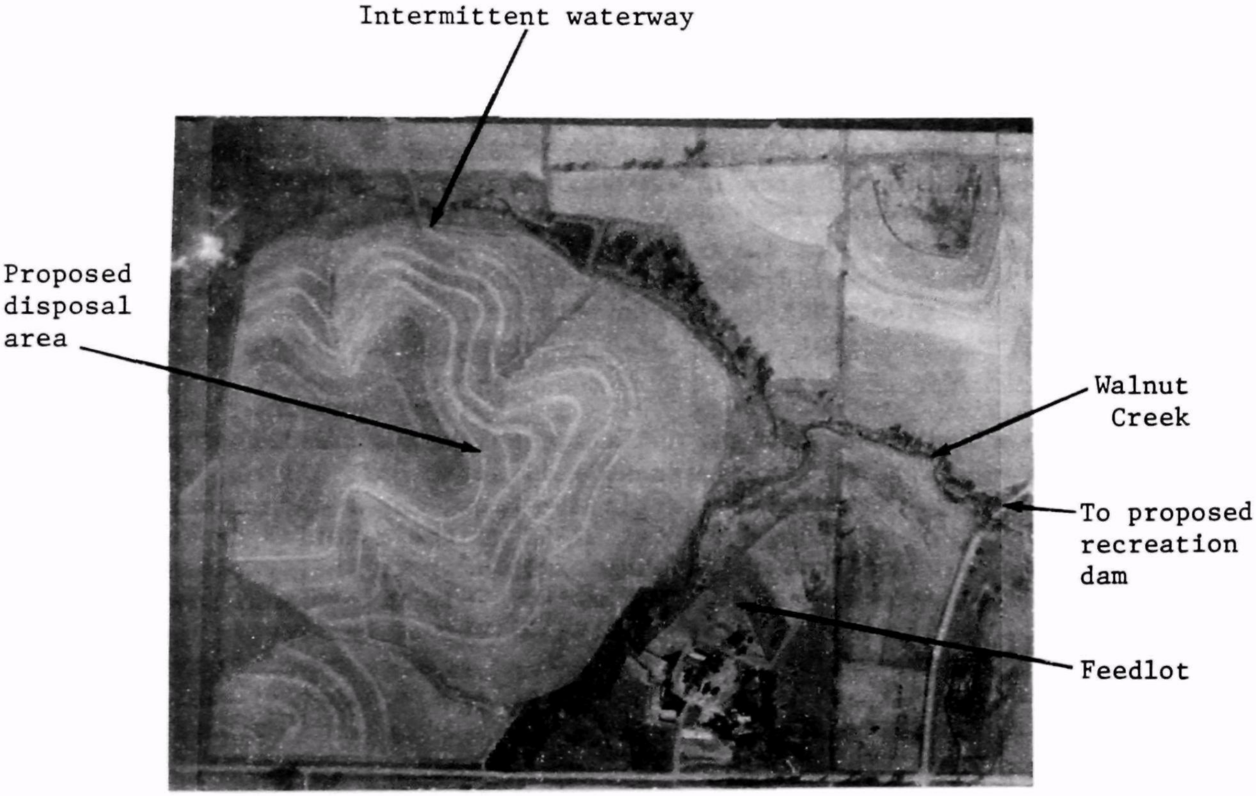

Figure 1. Feedlot before construction of runoff control system.

ly will not carry feedlot odors into populated areas. As urban sprawl encroaches on the lot, however, some odor problem may develop.

SYSTEM COMPONENTS

The system designed uses conveyance channels, debris basins, a holding pond, and a disposal system. All runoff from the lots or farm-yard runs into conveyance channels, to the debris basins, or directly into debris basins. Liquid from the debris basins either flows by gravity or is pumped to the holding pond, and stored for later application to land. Application of the stored residue is accomplished by using a center pivot irrigation system. The lots are cleaned semi-annually and the solid residue applied to the cropland.

The basins and holding pond were designed to hold lot runoff from a 10-year, 24-hour storm (4.7 inches in 24 hours for L. P. Schram lot location).

System Effects

The Schram lot is near the junction of two streams (Figure 1) that join the Papio Creek and eventually the Missouri River. If the proposed conservation-recreation dam is built, the estimated 240 acre-inches of runoff from the Schram lots could collect in the water of the reservoir, causing eutrophication and possible fish kills. The design of the control system should keep an estimated 400 tons of sediment from polluting the streams each year, delaying sedimentation of the streams and the proposed reservoir site.

The effect of the control system is not limited to the flowing streams and proposed reservoir. Area groundwater, currently of good quality, could also be altered. Elements could leach into the sand and gravel pockets of the area, raising the concentration of salts and adversely affecting groundwater quality. The decline in groundwater quality could be attributed to the following:

1. As the capacity of the lot increases, leaching from the lot would increase.
2. Percolation from the holding pond could increase the amount of elements in groundwater.
3. Animal residue applied to the disposal field could increase leaching of elements from that area.

Some of these concerns can be discounted. Leaching from the lot is minimal since the surface of the current lot has been packed and sealed by the animals. The bottoms of the basins and holding pond usually seal, preventing the percolation of elements. Although the application of additional residue to the disposal field could increase leaching from the site, the application of only the amount of nutrients needed for optimum crop growth will reduce the potential leaching of nutrients to groundwater.

The quality of the atmosphere surrounding the lot is also of concern. No serious odor problem now exists; however, odor from the lot could be increased by the following:

1. Anaerobic conditions of the holding pond.
2. Anaerobic conditions of the conveyance channels and debris basins.
3. Clean-out operations, and application of residue through the center pivot.

Odor may be at a maximum during the spring and fall cleaning of the lots and holding structures.

Usually, the odor from the lots is dissipated by the wind before it reaches populated areas. However, the city of Omaha is expanding toward the feedlot and a housing development is located 1 mile east from the Schram site.

The positive aspects of a control project are water pollution reduction in the surrounding waterways, and fertilizer and additional water for crops. The adverse environmental effects must be controlled to make the project feasible.

SECTION 5

DESIGN

The feedlot control systems designed for use at the Schram Feedlot incorporated many variables to provide a site for the demonstration, observation and comparison of several runoff control system components. Debris basins (inside and outside of the animal pens), riser intake designs, holding ponds, and a method for disposal of controlled runoff (Figure 2) were included in the system.

DEBRIS BASINS

Four types of basins were constructed, using information provided by Gilbertson and Nienaber, Swanson et.al., and the Soil Conservation Service (3, 5, 14, 18, 19) (Figure 2). Because neither in-pen or outside-pen debris basin positioning is established as superior, both methods were designed into the Schram system for comparison under one manager.

Basin design volumes were determined considering the relative positions of the basins to the holding ponds. A minimum design figure of 1.25 inches per acre was used for debris basins. Safety factors of up to 2.5 were used to adjust design capacity according to pollution potential (or to hold from 1 to 2.5 times the amount of the 1.25 inches per acre design capacity). A safety factor of 2.5 was used for basins remote from the holding pond because overflow could cause stream pollution. Basins adjacent to the holding pond used the minimum design volume with no safety factor, since any overflow would run directly into the holding pond.

The SCS basins (lot 2-23, Figure 2) were designed with a capacity equal to 70% of the 10-year, 24-hour storm with discharge to a holding pond. The SCS basin in pen 23 was designed as a combination debris basin and holding pond with a capacity of 125% of the 10-year, 24-hour storm.

All basins, except that below pens 7-10, were designed as shallow basins less than 3.5 feet deep. These were to serve primarily as demonstration and comparison units. The deep debris basin below pens 7-10 was a research unit, using new design criteria. Conveyance channels were installed below the pens to transport runoff to the deep (8 ft.) debris basin below pens 7-10. This basin was built to reduce both the area requirement and the groundwater pollution potential caused by the wet and dry cycles of a shallow basin.

Several riser designs were installed in the debris basins to compare management characteristics (Table 1). Liquids were transported from the

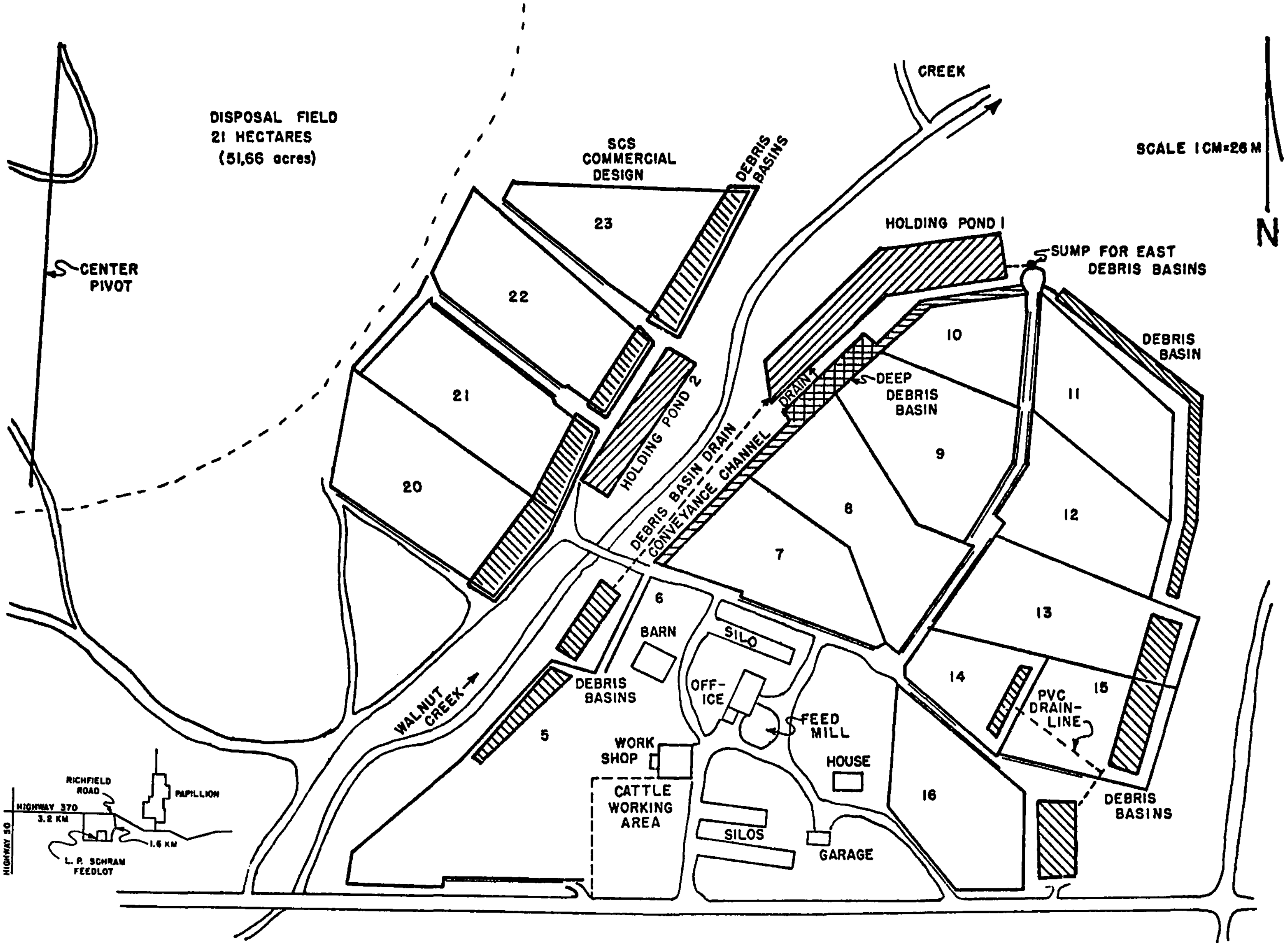

Figure 2. Runoff control design for the feedlot.

TABLE 1. DEBRIS BASINS AND RISERS (3, 10, 14)

Pen	Description
5	One 8-inch corrugated plastic riser with 3/4-inch holes and located outside the lot.
6	One 4-inch corrugated plastic riser with 3/4-inch holes and located outside the lot.
7 through 10	One 6-inch-diameter PVC overflow pipe (6 feet from basin bottom to top of pipe) and located outside the lot.
11 and 12	Two risers are spaced 75 feet from the ends and 150 feet apart. From north to south, the risers are: an 8-inch flexible drain tile line 12 feet in length; 4-inch flexible drain tile, 8 feet in length; and, two 8-inch PVC risers with 5/8 inch holes. Risers are outside the pen.
13 and 15	Two 12-inch corrugated metal risers set in concrete with 3/4 inch holes. The riser in pen 15 is protected by a wooden fence.
14	One 12-inch-diameter metal riser with slots cut by torch 3/4 inch by 8 inches, and located inside the lot.
16	One 6-inch PVC riser with 3/4-inch holes and located outside the lot.
20 through 23	One 12-inch-diameter corrugated metal riser with 5/8-inch holes set in concrete and located inside the lot.

debris basins to the holding pond through underground polyvinylchloride (PVC) pipe. Debris basins for pens 5 and 6 were gravity drained. The deep debris basin was connected to the holding pond by a 6-inch drain line, 6 feet from the bottom of the basin. Pens 11-16 drained to a sump near the pond (holding pond 1) with a 60 gpm submersible pump. A 10-year, 24-hour storm could be pumped to the holding pond in 4 days. Debris basins in pens 20, 21 and 22 drained by gravity to the pond (holding pond 2). The drains were designed to drain the runoff from a 10-year, 24-hour storm in 3 days. The debris basin in pen 23 also drains by gravity to holding pond 2.

Debris basins were built to compare operation and management characteristics in different locations. The merits of in-pen and outside-pen placement, pen slope length, and the distance between risers were also considered. Pens 14 and 15 (short slope) were compared with pen 13 (long slope). The effect of slope length on solids transport was measured by the quantity of solids removed from the basins below these pens. Risers were placed at distances of 150, 175 and 200 feet in the debris basin (below pens 11 and 12) to show the effect of riser placement on basin drainage.

HOLDING PONDS

The SCS design for holding pond 2 provided a volume capacity equal to 75% of the runoff from a 10-year, 24-hour storm. Holding pond 1 has a capacity of 100% of the runoff from a 10-year, 24-hour storm.

DISPOSAL SYSTEM

A sprinkler irrigation system was the only disposal system practical for use on the disposal site (Figures 1 and 2). Such a system should be incorporated into an existing irrigation system, if possible. Center pivot, solid set, and big gun were the irrigation systems considered. The solid set system was unsuitable because of the potential management problems of changing sets and potential riser damage during tillage operations. The big gun was impractical because the liquid application rate was higher than the infiltration rate of the soil. A center pivot system was chosen to fulfill the disposal system requirements. The pivot distributes from 0.13 to 1.04 inches per revolution over a disposal field about twice the size of the feedlot. The center pivot was equipped with both sprinkler and spray nozzles for comparison. Two sizes of rubber tires were used (regular and floatation,to determine the effect of tire size on terraces and farming techniques.

SECTION 6

CONSTRUCTION

DEBRIS BASINS AND HOLDING PONDS

The feedlot area and facility construction are shown on Table 2. Construction started on holding pond 1 on May 27, 1973 (Figure 1). Glacial till and perched water were encountered near the bottom of the holding pond, at an elevation above the adjacent creek bed. Work on the pond was stopped until the water was drained by a channel cut in the pond bottom. After about one month, the area had dried, the outlet was closed, and the berm completed.

During this time, work was completed on basins for pens 11 through 16. The drainage system for these pens consisted primarily of 6-inch diameter PVC pipe, with an expansion to 8 inch between basins 12 and 13. Pen 14 was drained by 4-inch PVC pipe connected to the pipe from pen 16. An 8-inch drainline transported runoff into a sump built near the north side of basin 11-12. The sump was built of a 15-foot length of 84-inch road culvert and equipped with a 60 gpm capacity sump pump. Liquids were transferred to the holding pond through a 6-inch PVC pipe with an outlet 3 feet below the top of the holding pond.

The deep debris basin was completed about the same time as holding pond 1. A single 6-inch PVC drainline connected the two.

Debris basins for pens 5 and 6 were not completed until cattle held in those areas were moved. These basins were drained by 6-inch PVC pipe. When this drainline was installed, the berm of the conveyance channel serving pens 7 and 8 was completed.

The channel of Walnut Creek was straightened, to increase the throat area of the waterway for erosion prevention and to supply fill soil for holding pond 1 and the conveyance channel. During construction of the basins, new fences, concrete feedbunks and aprons were installed in the lots.

DISPOSAL SYSTEM

After delays caused by material shortages, the center pivot system (Table 3) became operational June 14, 1974 (Figure 3). The system used effluent from holding ponds 1 and 2 and was flushed with fresh pond water after use. An intake system consisting of 4-inch PVC pipe carried liquid from the holding ponds and the fresh pond to the centrifugal pump that served

TABLE 2. CONSTRUCTION DESIGN CRITERIA FOR DEBRIS BASINS

Pen	Surface Area (ac)		Lot Slope	Slope Length	Lot Exposure	Basin Location 1/	Design Volume 2/	Constructed Volume
	Pen	Basin	%	(ft)			(Ac-In)	(Ac-In)
5	3.33	0.17	8	400	NW	O-R	10.4	11.54
6	0.61	0.17	10	150	NW	O-R	1.9	4.77
7	1.34	0.46	10	360	W	O-A	9.6	10.86
8	1.63			400				
9	1.51		10	330	NW			
10	1.02		10	240	N			
11	1.22	0.76	10	230	NE	O-R	3.8	7.06
12	1.29		12	300	E		3.2	
13	1.38	0.73	11	360	E	I-R	4.3	6.86
15	0.82		9	200	E		2.5	
14	0.54	0.12	14	180	E	I-R	1.7	1.83
16	1.26	0.32	13	304	SE	O-R	3.9	5.17
Holding Pond 1	15.95	0.78	—	—	—	—	75.0	84.3
20	1.47	0.45	10	360	SE	I-R	5.1	12.20
21	1.40		10	360	SE		4.6	
22	1.53	0.18	10	380	SE	I-R	5.0	5.72
23	1.19	0.35	10	330	SE	I-C	6.9	8.75
Holding Pond 2	5.69	0.31	—	—	—	—	24.1	26.5

1/ O-R, outside the lot-remote from holding pond; O-A, outside the lot-adjacent to holding pond; I-R, inside the lot-remote from holding pond; I-C, inside the lot-combination debris basin and holding pond.

2/ Pens 5 through 16 designed on base of (1.25 ac-in/ac) (5).

3/ Pens 20 through 23 designed by SCS on basis of a percentage of the design storm (10 year -24 hour storm equal to 4.7 in.), and a runoff coefficient of 0.7 for debris basins and 1.25 for combination holding pond and debris basins.

TABLE 3. CHARACTERISTICS OF THE INSTALLED DISPOSAL SYSTEM

Type:	6 tower, electric drive center pivot
Length:	797 feet, 52 acres
Crop clearance:	9 feet
Tires:	Standard-11.2 x 24; 1, 3 and 5 towers Flotation-14.9 x 24; 2, 4 and 6 towers
Speed of rotation:	12-96 hours
Capacity:	260 gpm at 65 psi
Power source:	PTO driven, 480 volt - 3 phase generator (pump driven by same PTO drive)
Pump:	Centrifugal, 260 gpm at 110 psi
Special feature:	Spray nozzles between towers 4 and 5
Pipeline to system:	Slipjoint cement asbestos - 6" diameter

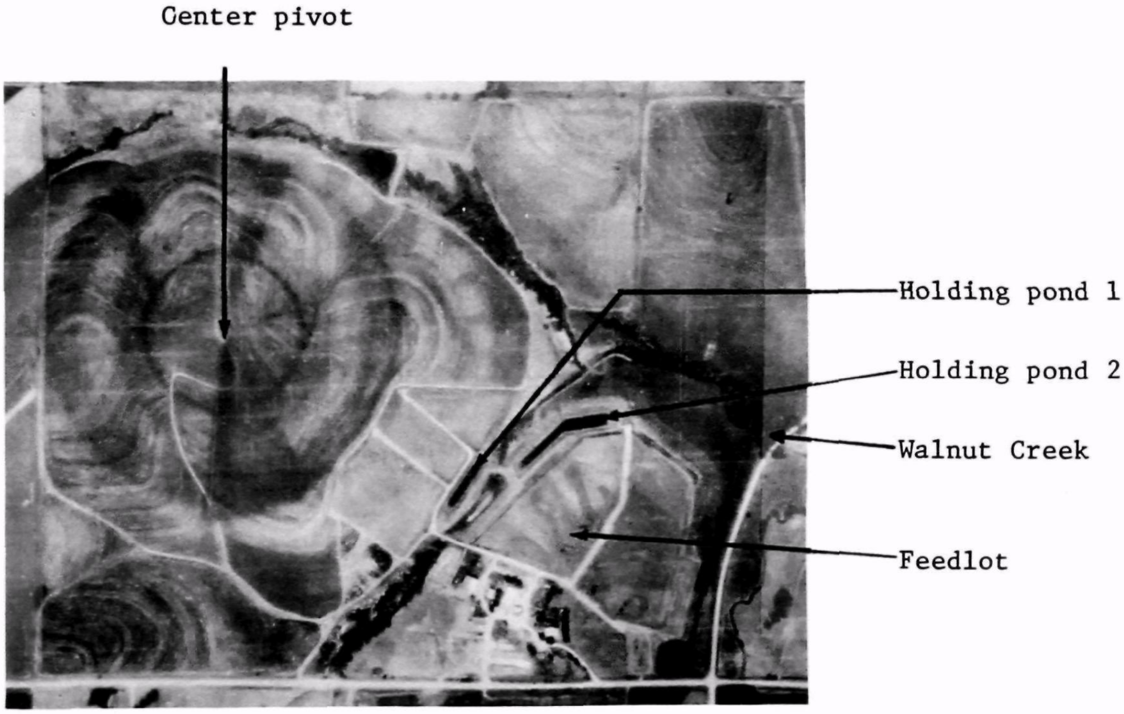

Figure 3. Feedlot after construction of a runoff control system.

the pivot. This pump was placed on a trailer adjacent to a three-phase generator. Both were belt-driven by a common jackshaft from a tractor power take-off (pto) drive. Liquids were carried to the center pivot through 6-inch asbestos pipe buried 4 to 6 feet. This pipe featured slip-joint design and was resistant to individual section failure. The electric motors on each of the 6 center pivot towers were driven by electricity from the generators since three-phase electricity was not available.

SECTION 7

RESULTS AND DISCUSSION

RUNOFF CHARACTERISTICS

Runoff Volume

Table 4 shows the climatic conditions and resulting runoff for the feedlot from April 1973 to December 1975. Runoff averaged about 30% of the annual precipitation for the site as compared with the 40% value for a small feedlot study (4, 7, 8). Rainfall averaged about 70% of the normal precipitation and caused a reduction in the quantity of runoff. In addition, snowmelt runoff was less than snowmelt runoff on research sites near Mead, Nebraska (7).

When reduced annual precipitation and relatively mild snowmelt conditions are considered, the relationships for runoff previously established are realistic.

Runoff Solids Transported

Table 5 summarizes the settled solids removed from debris basins during August 1974 and July 1975. Dry matter removed from pens 11-16 ranged from 18.6 to 55.2 tons/acre of feedlot area in August 1974 and 2.9 to 57.2 tons/acre of feedlot in July 1975. The low quantities of solids removed from basin 12 may be attributed to cross-slope runoff from pen 12 to pen 11 and into the debris basins (see Figures 2 and 3). A greater quantity of solids was removed from the basins in pens 20, 21, and 22 than from the research basins. There was, however, no visible explanation for the large quantity of materials removed form basins 20 through 22 compared to those in pens 11 through 16, except that lots 20 through 22 were new. Continuous high stocking rates and a relatively long slope could have contributed to the higher amount of solids transported from basin 20 through 22. In addition, 3 to 5 inches of dry material that had accumulated on the lots during a dry period could have floated off during runoff events. Manure voided into the debris basin located in the feedlot may also be a factor. Extremely wet, sloppy conditions within the debris basin for pen 23 prevented topographic surveys and sampling.

Table 6 summarizes the animal numbers and estimated amount of manure voided per pen. The large area debris basins contained larger quantities of voided manure, and this affected the amount of material removed during cleaning.

TABLE 4. MONTHLY PRECIPITATION AND SUMMARY OF LOT RUNOFF

	Precipitation				Runoff[2]					
	Normal[1]	1973	1974	1975	1973		1974		1975	
		(inches)			(ac-in)	(inches)	(ac-in)	(inches)	(ac-in)	(inches)
January	0.69	--	1.44	1.07	--	--	0.00	0.00	0.00	--
February	0.96	--	0.38	0.91	--	--	0.00	0.00	0.00	--
March	1.62	--	0.61	2.31	--	--	0.00	0.00	19.28	1.21
April	2.82	3.60[3]	2.31	3.07	[4]	[4]	8.26	0.52	22.86	1.43
May	3.99	6.68[3]	4.28	2.84	[4]	[4]	31.96	2.00	11.85	0.74
June	4.93	1.86[3]	1.34	3.35	[4]	[4]	2.20	0.14	6.89	0.43
July	3.71	5.66[3]	0.43	0.77	[4]	[4]	0.00	0.00	0.00	0.00
August	4.01	0.74	5.25	4.17	[4]	[4]	38.02	2.38	32.78	2.06
September	3.86	9.75	1.20	0.55	65.01	4.08	3.86	0.24	0.00	0.00
October	1.76	4.49	3.04	1.65	9.92	0.62	13.23	0.83	0.00	0.00
November	1.01	1.73	1.08	7.90	8.26	0.52	16.53	1.04	11.02	0.69
December	0.77	0.53	0.68	1.15	0.00	0.00	0.00	0.00	0.00	0.00
Total	30.13	17.06	22.04	24.14	83.19	5.22[5]	114.06	7.15	104.68	6.65

[1] From Climatological Data, Nebraska Annual Summary, Vol. 80, No. 13, U. S. Dept. of Commerce, 1975.

[2] Ac-in. x 101.6 = m^3; inches x 2.54 = cm

[3] Estimated from Climatological Data, WSO AP Station, Omaha, Nebraska, Vol. 78, Nos. 4, 5, 6, and 7 for facility construction period prior to rain gauge installation on site.

[4] Runoff control facilities under construction.

[5] Runoff resulting from 17.06 inches of precipitation.

TABLE 5. SETTLED SOLIDS REMOVED FROM RUNOFF DEBRIS BASINS

	August 1974			July 1975	
Basin	Basin Area (acres)[1]	Tons/acre[1] (wet weight)	Tons/acre (dry weight)	Tons/acre (wet weight)	Tons/acre (dry weight)
16	1.26	71.0	18.8[2]	101.0	53.7[1]
15	0.82	307.0	55.2	61.2	53.7
14	0.54	125.0	22.4	127.0	57.2
13	1.38	104.0	18.6	72.2	41.6
12	1.29	23.5	12.5	8.1	2.9
11	1.22	52.4	37.0	32.5	26.6
5	3.33	104.0	18.7	--	--
6	(Not cleaned during study period)				
20	2.97	--	--	202.0	180.4
21	2.97	--	--	215.0	190.3
22	1.53	--	--	146.0	86.8
23	(Unable to obtain topographic surveys and reliable sample due to continuous wet conditions)				

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[1] Ac. x .405 - ha; tons/ac. x 2.24 = metric tons/ha.

[2] Values for material removed may reflect considerable soil other than transported in runoff.

TABLE 6. ESTIMATED QUANTITY OF MANURE PRODUCED

Pen Number	Pen Area	Animals/Pen Maximum	Animals/Pen Average 1974-75	Total Solids Voided[2/] Maximum	Total Solids Voided[2/] Calculated Average 1974-75
	(acres)[1/]				(tons/year)[1/]
5	3.33	580	--	423	--
6	0.61	106	--	77	--
7	1.34	230	125	160	62.3
8	1.63	284	127	208	48.9
9	1.51	263	131	192	81.5
10	1.02	178	96	130	48.3
11	1.22	212	60	155	30.9
12	1.29	225	165	164	93.1
13	1.38	240	126	175	40.7
14	0.54	94	76	69	22.7
15	0.82	143	55	104	40.5
16	1.26	220	127	161	105.9
20	1.57	274	158	200	119.2
21	1.40	244	159	178	113.6
22	1.53	267	191	195	153.9
23	1.19	207	140	151	207.7
Total:	21.64	3767	1736	2750	1169.2

1/ 1 ac x 0.405 = ha; 1 ton x 0.907 = metric tons

2/ Estimated from known numbers of animals and ration (6)

Settled solids removed from basins inside the lot ranged from 2.36 to 7 tons/acre-inch of runoff compared to 1.59 to 6.47 tons/acre-inch of runoff for debris basins outside the lot. Slope length did not have a significant effect on the quantities of settled solids removed from basin 13 compared to basins 14 and 15. Basin 13 (360 ft. slope length) contained less residue than basins 14 and 15 (180 and 200 ft. slope lengths).

The total solids content of the material within the debris basins varied, ranging from 26.5 to 81.6% for debris basins located outside the feedlot to 18.0 to 67.3% for debris basins inside the feedlot. During cleaning, basins outside the feedlot were generally drier and easier to manage than those inside the feedlot.

Suspended Solids

Total solids content of the holding pond effluent was periodically determined from June 1974 through August 1975. The pond liquid contained an average 0.32% total solids concentration or 0.36 tons of suspended solids/acre-inch of runoff. The effluent from the debris basins contained an average 0.54% total solids. This indicated that settling took place in the holding pond. It was estimated that 0.5 tons of solids settled in the holding pond per acre-inch of transported and stored runoff. The quantity of settled solids will vary depending on the runoff storage time in the holding pond (8). Prompt disposal of the holding pond effluent may reduce the quantity of settled solids in the holding pond.

BEEF FEEDLOT RESIDUE CHARACTERISTICS

Table 7 summarizes characteristics of effluent in the holding ponds and debris basins, as well as those of the settled solids and the water in Walnut Creek above and below the feedlot. Values for the total solids in the holding ponds were 25% below those values from other research feedlots (3, 4, 7, 8, 17). The total solids content of the debris basin effluent indicated that the debris basins satisfactorily removed solids before the effluent was transported to the holding pond. Published results have indicated that solids content of feedlot runoff averages about 1.52% for small research lots (7); therefore, it was assumed that about 60% of the solids transported settled in the debris basins before transport to the holding pond.

Total Solids

Settled solids removed from the inside and outside the lot debris basins were almost the same moisture content. Moisture contents of the samples, however, were dependent upon antecedent conditions and do not indicate an average moisture content of material at any given time during a year. In general, the basins inside the lot dried faster during dry weather because animal hoof action stirred the debris and resulted in increased evaporation. The debris within these same basins, however, seemed to remain damp longer than in outside lot basins during cool, wet periods of the year.

TABLE 7. HOLDING POND EFFLUENT, DEBRIS BASIN EFFLUENT, DEBRIS BASIN SOLIDS, AND WALNUT CREEK WATER CHARACTERISTICS

	Total Solids			Volatile Solids			pH Range			Electric Conductivity			Total N			Total P			COD		
	Range			Range						Range			Range			Range			Range		
	High	Low	Ave.	High	Low	Ave.	High	Low	Ave.	High	Low	Ave.	High	Low	Ave.	High	Low	Ave.	High	Low	Ave.
	(%)			(%)						(mmhos/cm)			(ppm)			(ppm)			(ppm)		
Holding Pond 1	0.39	0.27	0.32	0.16	0.05	0.11	7.9	6.5	7.4	2.78	1.78	2.45	148	42	104	42	17	31	2055	1477	1685
Holding Pond 2	0.38	0.30	0.34	0.23	0.18	0.22	7.6	6.9	7.4	6.70	0.70	2.98	624	70	300	106	20	45	6060	1410	2635
Debris Basin Effluent	0.63	0.40	0.54	0.47	0.14	0.28	7.1	6.4	6.8	2.90	1.50	2.14	196	86	140	39	25	28	4503	876	2195
Settled Solids																					
Inside Lot Basins	72.90	40.70	59.30	18.60	8.20	12.50	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Outside Lot Basins	87.70	34.80	61.00	27.50	6.40	14.60	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Walnut Creek																					
Above Feedlot	0.34	0.06	0.14	0.05	0.02	0.03	8.3	5.9	7.1	0.60	0.20	0.41	88	1	60.7	36.7	0.2	7.3	2289	8	740.3
Below Feedlot	0.26	0.09	0.14	0.16	0.01	0.08	7.8	6.4	7.5	0.78	0.36	0.56	293	2	32	35	0.4	4.0	221	36	147.5
Intermittent Stream	0.10	0.07	0.09	0.04	0.01	0.02	8.1	7.6	7.8	0.55	0.50	0.52	7	3	5	0.3	0.1	0.2	136	12	54.9
Tile Drainage from Holding Pond 1	0.30	0.28	0.29	0.29	0.17	0.23	7.6	6.8	7.2	2.20	1.80	2.03	135	67	100	21	11	17	1350	876	1134

The total solids content of the creek water before and after entering the feedlot area indicated that the pollution control system performed satisfactorily. The average solids content of the creek water above and below the feedlot was about the same. The intermittent stream leading into Walnut Creek and the drainage tile below holding pond 1 were considered to be major factors in changing the water quality of Walnut Creek, but these could not be isolated as a significant influence on the water flow of Walnut Creek. Additional data must be obtained before these influences can be interpreted.

Volatile Solids

Volatile solids value of the holding pond effluent was somewhat below published values (7), but within a usable range. Sixty percent of the total solids within debris basin effluent were volatile. It was assumed that biological activity and/or settling removed some of the volatile solids within the holding pond. The volatile solids content (21 to 24%) of the settled solids indicated that either soil was mixed with the settled solids or biological degradation had taken place. It was estimated that the large quantity of soil in the solids was a result of the steep slopes of the feedlot.

pH and Electrical Conductivity

The pH of the liquids ranged from 5.9 to 8.3, well within the range of published values.

Electrical conductivity of holding pond effluent and debris basin effluent ranged from 1.5 to 6.7. The electric conductivity of Walnut Creek water below the feedlot did not seem to be affected since the range was 0.2 to 0.78 mmhos/cm.

Elemental Content

Nitrogen content within all samples tested varied as shown in Table 7. The total phosphorus in holding pond and debris basin effluent also varied although the range was less than that of nitrogen. Average phosphorus within holding pond effluent ranged from 17 to 106 ppm, while debris basin effluent total phosphorus ranged from 25 to 39 ppm. Phosphorus content of Walnut Creek was relatively low, and ranged from 0.2 to 36.7 ppm. The COD of holding pond effluent was low compared to published values for rainstorm runoff from feedlots. Average COD for holding pond effluent and debris basin effluent ranged from 1410 to 6060 ppm,compared to an average of 3100 for rainfall runoff from outdoor unpaved feedlots (7). The COD of the Walnut Creek water was relatively low although highly variable and ranged from 8 to 2289 ppm. A usable average, however, was established.

SYSTEM OPERATION

The runoff control system satisfactorily controlled runoff from rainfall and snowmelt. Samples from the stream above and below the lot indicated that pollution from the lot was insignificant.

Debris Basins

Before all system components were operational, some overflow from the debris basins occurred before the disposal system was established. The debris basins for pens 11 through 16 overflowed during September of 1973 before the sump pump to transfer basin effluent to the holding pond was installed. The storm that caused the overflow exceeded the 10-year, 24-hour design storm. The debris basin adjacent to the holding pond which controlled runoff from lots 7 through 10 also overflowed; however, runoff control was effected as overflow went directly to the holding pond. A considerable location advantage was shown for a debris basin near or adjacent to the holding pond. This system would not, however, be appropriate for pens 11 through 16, as topography limits its application. An additional holding pond could be installed for these particular pens to reduce the distance from the debris basin to the holding pond.

The location of the debris basin with respect to the pen is also an important consideration. Both inside and outside the lot debris basins functioned well in separating the settled solids in runoff. There is, however, a difference in the management of the two debris basin locations. Basins located inside the lots had repeated drainage problems. These resulted from cattle churning settled solids into a mud slurry during runoff events. The slurry plugged riser and drain openings.

Another problem occurred in fall of 1973. Rain prevented cleaning of pens 20 through 23 and created slurry conditions in the basins. The top of the slurry froze during late fall. Two 800 lb. steers melted through the thin layer of frozen slurry and died.

During summer of 1974, the first major cleaning of pens and debris basins was completed. The slurry from basins inside the lots was spread on to the slope of the pen. This material dried, and was mounded. This process is not possible unless the pens are empty. If not, the operator would have to haul the slurry to the disposal field. During this same cleaning period, pens 8, 9, and 10 with basins outside the pen had slurry from the lower fenceline hauled out of the pen. Cleaning of basins 11, 12, and 16 was accomplished by pushing the settled solids over the basin berm and using it for fill material. It was not hauled to the field for disposal because such a small quantity of material was available.

After two seasons of operation, the feedlot owner indicated that he favors the location of basins outside the pen. He said customers touring his commercial operation don't like to see cattle standing in a slurry buildup. No evidence exists, however, that indicates this arrangement has an adverse effect on cattle performance.

The deep debris basin performed satisfactorily as a solids settling unit; however, maintenance problems will prohibit application unless special manure pump equipment is adapted to the system.

Table 8 summarizes the advantages and disadvantages of inside and outside the lot debris basins, as determined by the two-year study.

TABLE 8. ADVANTAGES OR DISADVANTAGES OF THE DIFFERENT DEBRIS BASINS

INSIDE THE LOT	OUTSIDE THE LOT
Efficient use of the land.	Extra space is required for runoff control.
Slurry conditions can exist during summer and winter.	Slurry conditions exist primarily during periods of winter mud slurry runoff conditions.
Basin cleanings can be spread on lot and mounded, or applied directly to land.	Disposal from basin is minimized.
Risers plug from winter conditions and from slurry if draining is slow or incomplete in the summer.	Risers plug only from winter slurry runoff. No drain plugging problems from cattle rubbing on riser.
Cattle using basin for shelter (from high winds, etc.) can be endangered by deep slurry.	Solid may accumulate at the fenceline due to the berm formed by animal traffic.
With basins inside - there can be a problem of where to place fenceline.	Basins are difficult to keep free of weeds. Extreme snowmelt slurry runoff can bury fencelines.
Pens and basins can be stacked on a hill more efficiently.	Basin location may be located at any convenient location.
Cattle can use berms of basin as mounds during extended wet periods.	Mounds should be constructed on the lot for cattle to seek dry ground during severe weather.

Design Volumes

The volume of the basins was considered adequate for the feedlot. The design criteria used (1.25 inches per feedlot site with a design safety factor of 2.5) was adequate when all components were operational. A design safety factor of 1.5 would be adequate for basins inside or outside the lot if the basins are remote from the holding pond. Debris basins located adjacent to the holding pond had an adequate volume without application of a safety factor. These conditions would be satisfactory if the basins were cleaned once, or preferably twice a year.

Design capacity and operational characteristics of the holding pond at the lot were successful. The design volume of 100% of the 10-year, 24-hour storm is adequate and will, under stress conditions, relieve pollution problems when disposal systems are non-functional. Some minor problems were caused when weeds and other debris plugged intakes to the pump but were minimized by use of screen filters.

The type of riser is an important factor. There were no performance differences observed between metal and PVC risers. However, the corrugated metal risers resisted damage from animal traffic and other rough service. PVC risers must be protected by a fence to avoid breakage. Distance between risers could not be clearly differentiated within the time frame of this study.

The flexible tube risers did not perform satisfactorily within debris basin 12. Snowmelt slurry covered the pipe and prevented further use. The metal riser plugged several times. Slots cut in this riser were large, with rough edges. Even though design of risers have been documented (10) additional research may be required to reduce maintenance problems.

Disposal System

The center pivot performed satisfactorily as a system for disposal of liquid runoff with settled solids removed. The unit was not fully tested during the research period since rainfall was only 70% of normal. The disposal area of 52 acres was twice the area shown as sufficient by previous research (16).

Several disposal problems were encountered and may be a problem for other sites using a similar system. A major problem occurred when effluent was pumped from more than one source. Air leaks in intake lines caused priming problems for the pump and plugged intake lines. The three-phase power required for operation of the center pivot may or may not be available on a particular site. At the Schram site it was not, so a generator was necessary. The same power shaft drove both the effluent pump and the generator and caused coordination problems. It is recommended that the electrical generation equipment be self-contained with an individual power unit and a pumping station established for each pond using a moveable pump rather than a common point for a single pump operation.

A conventional centrifugal pump was used and was unsatisfactory for pumping solids from the deep debris basin, although the center pivot was satisfactory for application of a higher solids content material (3-5%), when the deep debris basin was emptied. A manure-type pump with agitators was used and nozzles on the center pivot were changed to 5/8 in. diameter. The conventional centrifugal pump was not adequate unless the debris basin mass was highly diluted.

The spray nozzles were unsuccessful because the spray nozzles plugged even when materials from holding ponds 1 and 2 were highly diluted.

The center pivot is a high cost disposal system if designed specifically for applying controlled runoff to land as it was at the Schram site. During the dry weather of 1974 and 1975, the spring-fed creek dried up and water was not available for irrigation. Alternate methods of disposal, such as a solid set system with a main pipeline using a tow line and several riser pipes, or large sprinkler guns may have merit.

In general, the center pivot adequately disposed of liquid runoff. The flexibility of application rates (1/8 in. to 1.5 in. per hour) would meet the demands for almost any soil type, and were a major asset for this site because of high pollution potential.

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TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA-600/2-77-159

2.

3. RECIPIENT'S ACCESSION NO.

4. TITLE AND SUBTITLE
BEEF CATTLE FEEDLOT RUNOFF AND CONTROL IN EASTERN NEBRASKA

5. REPORT DATE
August 1977 issuing date

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
L. P. Schram

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
L. P. Schram Feed Lot, Inc.
Papillion, Nebraska 68046

10. PROGRAM ELEMENT NO.
1HB617

11. CONTRACT/GRANT NO.
S-802197

12. SPONSORING AGENCY NAME AND ADDRESS
Robert S. Kerr Environmental Research Lab.-Ada, OK
Office of Research and Development
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

13. TYPE OF REPORT AND PERIOD COVERED
Final (3/15/73 - 9/30/76)

14. SPONSORING AGENCY CODE
EPA/600/15

15. SUPPLEMENTARY NOTES

16. ABSTRACT

This study was initiated to determine operational characteristics of runoff control facility components for beef cattle feedlots.

A runoff control facility was designed and constructed for a 3,000 head capacity feedlot in eastern Nebraska. Components of the runoff control facility included debris basins inside the pen and outside the pen, a holding pond, and a disposal system.

Results indicated that design volumes for the debris basins and holding ponds were effective in controlling runoff from the lots caused by snowmelt and rainfall for climatic conditions within eastern Nebraska. Characteristics of runoff transported solids from this large lot compared favorably with values developed earlier on small research lots. All values for total and volatile solids, electric conductivity, pH, nitrogen, phosphorus, and COD were within published ranges

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Livestock, Runoff, Agricultural wastes, Waste disposal	Feedlot, Debris basins, Holding pond	02/C 02/E

18. DISTRIBUTION STATEMENT
RELEASE TO PUBLIC

19. SECURITY CLASS *(This Report)*
UNCLASSIFIED

20. SECURITY CLASS *(This page)*
UNCLASSIFIED

21. NO. OF PAGES
41

22. PRICE

EPA Form 2220-1 (9-73)

☆ U. S. GOVERNMENT PRINTING OFFICE: 1977-757-056/6518 Region No. 5-11