Controlling Runoff for Livestock Feedlots
A State of the Art
Abstract

This publication summarizes the current state of the art for runoff control from beef, dairy, swine, sheep, and turkey feedlots. Amendments to the Federal Water Pollution Control Act have established a goal to eliminate pollutant discharges into the Nation's waterways by 1983. Sections on the legal implications of feedlot-runoff control, quantity and quality of runoff, runoff-control facilities and their applications, and disposal of the controlled runoff are included.

KEYWORDS: runoff, feedlot-runoff control, animal wastes, settling pond, detention pond, surface drainage

Legend for front cover
Adequate drainage is necessary for proper feedlot operation. Runoff entrapment is required for environmental protection.
Preface
This publication summarizes the current state of the art for runoff control from beef, dairy, swine, sheep, and turkey feedlots. Layers and broilers are not included in the discussions because they are produced under housed conditions and thus do not create a runoff-control problem. Sections are included on the legal implications of feedlot-runoff control, quantity and quality of runoff, runoff-control facilities and their applications, and disposal of the controlled runoff.

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Controlling Runoff for Livestock Feedlots
A State of the Art
C. B. Gilbertson, J. C. Nye, R. N. Clark, and N. P. Swanson

Introduction
Amendments to the Federal Water Pollution Control Act have established a goal to eliminate pollutant discharges into the Nation's waterways by 1983. Enough information is available to design and control runoff from feedlot surfaces and to dispose of this controlled runoff without further pollution problems.

Runoff control from a feedlot surface includes such considerations as diverting outside runoff, establishing good drainage on the feedlot area, and establishing methods of detention, storage, and disposal or use of runoff and waste. These methods can include a settling or debris basin to remove solids, a detention or holding pond for temporary storage of the runoff, and a disposal area or a method of using the waste.

Runoff-control structures must be designed to handle the maximum 24-hour runoff that can occur during a 25-year reoccurrence interval.

Volume of Feedlot Wastes
Nearly half (44 pct) of the 1,430 lb (643 kg) of food consumed annually by each American is in the form of animal products (45). Since 1960, the quantities of red meat consumed in the United States increased 15 percent, poultry increased 53 percent, and fish increased 26 percent, while our population increased about 20 percent (fig.1).

Livestock and poultry in the United States produce more than 100 million tons (dry weight) of manure each year. This is a valuable byproduct that, if properly handled, can be used for energy and to supplement or replace inorganic fertilizer and livestock feed.

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2 Italic numbers in parentheses refer to Literature Cited, p. 15.
If, on the other hand, manure is managed improperly, pollution can result. Of the total manure produced annually, only 46 percent is estimated to be recoverable (47). The rest is voided on rangeland or other areas where recovery is not economical or is lost through biological degradation and runoff. Runoff from open feedlots may transport large quantities of organic matter that pollute public waters and result in fishkills (17, 48).

Regulatory Requirements
Many questions have been raised regarding pollution from feedlots and the resulting broad legal implications involved (30). Feedlot operators, property owners, neighboring residents, and some communities should be aware of the legal aspects. If feedlot runoff produces adverse consequences, litigation may result.

During the 1960's, feedlots were identified as sources of water pollution by several States, including reports of fishkills sometimes attributed to the uncontrolled feedlot runoff. By the early 1970's, a few States had passed water pollution laws aimed at livestock producers. The requirements varied, but most regulations specifically prohibited discharge of feedlot runoff or livestock manure into any public stream, lake, or pond (11, fig. 1).

In 1972, the 92d Congress passed PL 92-500, the Federal Water Pollution Control Act Amendments. A national goal to eliminate the discharge of pollutants to waters of the United States was established with the intent that by 1983 all waters would be safe.

Figure 1.—Locate feedlots away from streams.
for fishing and swimming. To achieve this goal, a program was introduced to issue permits to all point sources of pollution. Feedlots were included under the industrial category and identified as a point source.

Each State has developed regulations by interpreting PL 92-500. Although the rainfall-runoff relationships are fairly well documented, it is doubtful that a consistent design will be applicable to all States. Such local regulatory agencies as the Soil Conservation Service (SCS) or the State Extension Service should be contacted to confirm the design of any runoff control and disposal systems before construction and operation.

The U.S. Environmental Protection Agency (EPA) was charged with the responsibility of enforcing PL 92-500 (34). Many regulations were proposed, and, after several legal challenges, a permit program was established under the National Pollutant Discharge Elimination System (NPDES). The regulation affecting livestock producers was promulgated on March 18, 1976. Three situations require a producer to obtain a permit:

1. Feedlot with a discharge or potential discharge and capacity of 1,000 beef cattle, 750 mature dairy cows, 2,500 swine over 55 pounds, 5,000 sheep, 55,000 turkeys, 100,000 chickens, and 5,000 ducks (34).

2. Feedlot with a one-time capacity between 300 and 1,000 animal units that also has:
   a. Stream flowing through the lot,
   b. Artificial conveyance of runoff to a stream.

3. Any feedlot that significantly contributes pollutants.

Feedlot operators must submit a permit application to either the approved State water-pollution control agency (in States with an approved NPDES permit program) or to the regional EPA office. The NPDES issuing authority then prepares a preliminary permit, which is reviewed by the permittee, the interested State and Federal agencies, and the general public. The intention to issue such a permit is announced in a public notice. The permit is issued for 5 years after the public-notice period and after any serious problems in permit conditions are resolved.

The permit has several basic elements. Effluent limits must be stated, and they must be specific to the site and comply with a published effluent guideline. The effluent guideline for the feedlot industry is based on a study by Hamilton Standard (8), which concluded that the best practical treatment (BPT) for feedlots was discharge of runoff only after an unusually large storm. This storm had to be large enough to overflow a structure designed to control
runoff from a 24-hour, 10-year recurrence interval storm. This BPT level was to be achieved by July 1, 1978. A second level of control, the best available technology (BAT), is to be implemented by July 1, 1983. The BAT level of control requires that the structures be designed to contain the 24-hour, 25-year recurrence interval storm runoff.

The greatest problem associated with the NPDES permit program has been interpreting the effluent guideline. It is still uncertain exactly what level of management, what dewatering schedule to empty runoff retention ponds, and what monitoring records would be used in cases of reported discharge. The EPA stated that the discharge would be investigated and legal action would be taken on a case-by-case basis (25). Any pollution discharge from either point sources or nonpoint sources, urban or rural, will share in responsibility to achieve the goals of water quality.

**Feedlot Hydrology**

Controlling runoff from any feedlot site requires a working knowledge of feedlot hydrology. Runoff from both paved and unpaved open lots results from rainfall and snowmelt. The relation between rainfall and runoff is directly proportional (fig. 2). During rainfall, the first 0.4 inch (1 cm) is retained on the feedlot surface. The slopes of rainfall-runoff equations varied from 0.36 to 0.86 and fluctuated with the existing moisture conditions and the shape, slope, and type of feedlot.

![Rainfall-runoff relationship at several locations](image)

**Figure 2.**—Rainfall-runoff relationship at several locations (6).
In several studies, the SCS equation (39) for runoff was adapted to predict feedlot-runoff volumes. The SCS equation is

\[ Q = \frac{(l - 0.25)^2}{(l + 0.85)} \]

where \( Q \) = direct runoff; 
\( l \) = the storm rainfall; and

\[ S = \frac{1,000}{N} - 10. \]

\( N \) is an arbitrary curve number varying from 0 to 100.

The value of \( N \) varies for concrete and unpaved lots. For example, \( N \) values calculated from measurements made on paved dairy lots ranged from 95 to 99.9 (46). Another study determined an \( N \) value of 90 for paved beef cattle feedlots (9). Since the \( N \) value was smaller because beef cattle feedlots are not cleaned as often as dairy lots, the volume of runoff is lower. Considerable difference was found between the estimated and actual quantity of runoff measured from several Texas research sites with unpaved lots (15). Runoff volume predicted from the SCS equation was 1.8 times higher than the actual runoff reported from the sites, and a recommendation was made to use an \( N \) value of 82 for Texas unpaved feedlots.

The SCS equation may be used to estimate the quantity of runoff expected from a rainfall event. For example, the runoff from a 2-inch (5 cm) rainfall for an unpaved beef cattle feedlot would be calculated as follows:

Since \( l = 2 \) in

and \( S = \frac{1,000}{N} - 10 \) (\( N = 90 \) for an unpaved beef cattle feedlot)

\[ S = \frac{1,000}{90} - 10 = 1.11, \]

then \( Q = \text{runoff} = \frac{(l - 0.25)^2}{l + 0.85} \)

\[ = \frac{[5 - 0.2(1.11)]^2}{5 + 0.8(1.11)} \]

\[ = \frac{4.78}{6.111} = 0.94 \text{ in.} \]
Figure 3.—Disposal area orientation to feedlot- and runoff-control facilities. Treatment areas A and C received precipitation; areas B and D received precipitation and holding-pond effluent.

The 2-inch rainstorm would result in about 1 inch (2 cm) of runoff from the feedlot. If the feedlot was 5 acres, this would be 5 acre-inches (514 m³), or about 136,000 gallons (514,000 L) of runoff that would collect in the holding pond.

Snowmelt runoff is a component of the total annual runoff that must be considered in areas north of 42° N latitude (13). Snowmelt runoff is different from rainfall runoff because it depends on the quantity of snow and ice buildup within a lot and the climatological conditions during thaws. Snowmelt becomes important in the northern States where snowfall exceeds 20 inches (50 cm). Snowmelt runoff can amount to 30 percent of the annual runoff (23).
The cumulative quantity of annual runoff is greater than that from the design storm used to calculate volumes of holding ponds. About 30 percent of the annual rainfall runs off unpaved lots and 80 percent off paved lots (2, 14, 32, 44).

A regression curve was developed for predicting annual runoff based on the annual moisture deficit (4, 5). This approach would be especially useful in arid areas since moisture deficits may be greater than 6 feet (200 cm).

Very little, if any, information is available in the literature on the quantities of runoff from sheep and turkey feedlots. A curve number of 85 to 87 may be used in the SCS predictive equation for estimating runoff from these lots. Even though sheep and turkey lots are relatively smooth as compared with beef and dairy cattle feedlots, previous moisture conditions are generally lower.

Runoff Quality
Chemical constituents transported in feedlot runoff vary widely (38). Several studies reported trends in runoff constituents as a function of the feedlot hydrology (3, 12, 18, 21, 41, 50). The wide range of transported material reported in published values (table 1) is due to the type of ration fed, the type of feedlot surface (paved or unpaved), climatological conditions, antecedent moisture conditions, and storm intensities and duration. The impact of each of the many variables on chemical constituents transported in runoff has not been isolated, but there are definite interactions. The most important variables are the previous moisture conditions and the type of runoff—snowmelt or rainfall. An extremely dry- and powdery-feedlot surface may have a low initial water intake. Studies show that runoff from a relatively dry mass produced
Table 1—Selected chemical constituents in runoff from unpaved beef cattle feedlots

<table>
<thead>
<tr>
<th>Type of runoff and location</th>
<th>Total solids</th>
<th>Volatile solids</th>
<th>Total N</th>
<th>Total P</th>
<th>K</th>
<th>Na</th>
<th>pH</th>
<th>Electrical conductivity</th>
<th>Chemical oxygen demand</th>
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<tbody>
<tr>
<td></td>
<td>Percent</td>
<td>P/m</td>
<td>Nmhos/cm</td>
<td>P/m</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Snowmelt:</td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
<td></td>
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<td>Nebraska:</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>0.8</td>
<td>0.6</td>
<td>190</td>
<td>5</td>
<td>—</td>
<td>—</td>
<td>4.1</td>
<td>3</td>
<td>14,100</td>
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<tr>
<td>High</td>
<td>21.8</td>
<td>14.3</td>
<td>6,528</td>
<td>917</td>
<td>—</td>
<td>—</td>
<td>9</td>
<td>19</td>
<td>77,100</td>
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<tr>
<td>Rainfall:</td>
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<tr>
<td>Low</td>
<td>.24</td>
<td>.12</td>
<td>11</td>
<td>4</td>
<td>50</td>
<td>90</td>
<td>4.8</td>
<td>.9</td>
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<tr>
<td>High</td>
<td>3.3</td>
<td>1.5</td>
<td>8,593</td>
<td>5,200</td>
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<td>.5</td>
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<td>600</td>
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<td>900</td>
<td>400</td>
<td>—</td>
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<td>High</td>
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<td>200</td>
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<td>1,100</td>
<td>—</td>
<td>10</td>
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<tr>
<td>Low</td>
<td>.84</td>
<td>.36</td>
<td>165</td>
<td>9</td>
<td>42</td>
<td>63</td>
<td>—</td>
<td>2</td>
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<tr>
<td>High</td>
<td>1.92</td>
<td>.96</td>
<td>1,580</td>
<td>242</td>
<td>1,983</td>
<td>1,597</td>
<td>—</td>
<td>13</td>
<td>16,000</td>
</tr>
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1 See Gilbertson and others (12).  
2 See Clark and others (5).  
3 See Manges and others (25).
channeling, resulting in transport of quantities of suspended pollutants (19). On the other hand, a relatively rough feedlot surface will retain pockets of water, reducing runoff and the chance that channelized flow will occur. Storm intensity and duration, however, are still the dominating factors.

Snowmelt runoff can occur as a lava-type flow. The solids content can be as high as 20 percent; however, this type of flow usually occurs only in areas north of 42° N latitude and in areas with 20 inches (50 cm) of snowfall or more.

The quantity of solids transported in runoff annually does not exceed 10 percent of the manure voided by the animals. Total solids transported annually in feedlot runoff from unpaved feedlots may be estimated by using a total solids concentration of 1.5 percent for beef cattle and 0.75 percent for swine, sheep, and turkeys (14). For paved lots, best usable values for total solids concentration in runoff are 3.5 percent for beef and dairy cattle and sheep and 7 percent for swine-feedlot runoff. Because paved lots are not recommended for turkeys, and we assume that all layers and broilers are raised in confinement, estimates are not given.

Chemical constituents transported in feedlot runoff can be estimated as a function of the total solids transported. Although more variable than total solids transported, values for the quantity of elements transported may be estimated by assigning coefficients to them (6, 10, 32, 36, 38, 41). Expressed as a percent of the manure voided, the maximum quantities transported annually from a dairy and beef feedlot are about 10 percent for N, 20 percent for P, and 50 percent for K. Maximum quantities transported for swine, sheep, and turkey lots are 5 percent for N, 10 percent for P, and 25 percent for K. For elements such as Fe, Zn, Mn, Ca, Na, Mg, and Cu, we can assume that 100 percent of the elements voided in the manure may be transported from beef and dairy lots, whereas 50 percent of those elements voided may be transported from swine and turkey lots. Although amounts of these elements in runoff are sometimes more than 100 percent of the manure elements voided, this can be explained by adding soil, bedding, or other debris mixed with manure by normal animal movement. These materials contain more elements than the voided manure itself. Some ranges in selected chemical constituents from feedlot runoff are shown in table 1.
Runoff-Control Facilities
Runoff from feedlots can be controlled by combinations of the following (17, 20, 32, 34, 37, 40, 44, 49):

1. Diverting runoff from outside the feedlot area.
2. Providing proper feedlot drainage.
4. Using detention or holding ponds.
5. Providing proper techniques for land application.

Diverting outside surface water from the lot often comprises the runoff control system. An upstream dam or protective dikes along
the side of the stream are often required because some feedlots are on the sloping land next to an intermittent stream.

Providing proper drainage of the feedlot surface is of primary importance. Each pen should have an independent drainage system. Feedlot slope does not effectively change the volume of water that runs off a feedlot surface (12), but steeper slopes may increase solids transport. Adequate slopes for feedlots are between 3 and 10 percent. Mounding the manure within the feedlot is recommended, especially if the feedlot slope is less than 3 percent. Good drainage may be provided by allowing about 30 feet² (2.9 m²) per animal for the mound design. The height of the mound should not exceed 4.5 feet (1.5 m) and should be perpendicular to the feedbunk to provide adequate drainage.

Debris basins are recommended for all feedlot runoff control systems. They remove up to 75 percent of the total solids transported in a runoff event (12, 27, 33, 43). Debris basins remove about 40 percent of the total solids transported in runoff within 30 minutes and 50 percent or more within 1 to 2 hours of detention. Small particles (less than 200 μm) are slow to settle; thus, the quantity of settled solids is somewhat site specific. Reducing the transported solids in the runoff reduces odors from the detention pond, increases the life of the detention pond, and makes the runoff easier to pump through irrigation systems.

The debris basin, however, must be well managed. For satisfactory performance, it may be located within or outside the feedlot area (2, 42), depending somewhat on the layout of the particular feedlot and to some extent on the climate of the area. If snowmelt runoff is a primary factor, basins inside the lot are most efficient. Normally, the maximum depth within the debris basin is about 4 feet (1.2 m). Solids should be removed from the debris basin before they accumulate to about a 9-inch (0.3 m) depth within the basin. If a deep debris basin more than 4 feet (1.2 m) deep must be installed, a concrete ramp should be placed within the basin to allow access with conventional front-end loading farm tractors.

The volume of the debris basin must allow for the accumulation of settled solids, short-term storage of runoff, and freeboard volume (22). The cumulative settled-solids volume should be designed for semiannual or annual accumulation. The short-term runoff volume should handle the largest 24-hour recurrence interval storm for that area. The freeboard volume is determined by adding a 6-inch (0.15 m) berm to the existing volume.

Detention or holding ponds should be designed for temporary storage of runoff. Under normal circumstances, these ponds should not be designed as a waste treatment facility, such as an anaerobic lagoon or oxidation pond (26). The minimum volume
depends on the maintenance; however, we recommend pumping the holding ponds after each runoff event. The EPA regulations require detention of a 24-hour, 25-year recurrence interval storm.

The expected runoff volume may be approximated by using the SCS runoff equation (39). Antecedent moisture condition III, soil group D, and curve number 90 may be used to estimate unpaved feedlot runoff volume. A curve number of 94 to 96 should be used for paved lot runoff volume (50).

A combination debris basin and holding pond is acceptable where not enough space is available to provide area for a debris basin and a separate holding pond. The volume of a combination debris-basin holding pond must be at least 125 percent of the 24-hour, 25-year recurrence interval storm (29).

Disposal of Feedlot Runoff
The problem of disposing of or using runoff from feedlots is important for complete control of the runoff. Since feedlot runoff is relatively low in crop nutrient levels, managing effluent from holding ponds dictates that disposal be the primary objective rather than optimizing use of the runoff constituents. Deciding on the method of disposal requires consideration of the environmental impact that will result, that is, maintain pollution control.

Several methods are acceptable for disposal of the runoff detention-pond liquid and the settled solids that accumulate in the debris basin. The method depends on the size of the unit and the regional location. In areas where the annual evaporation exceeds the annual precipitation by 20 inches (50 cm) or more, installing an evaporation pond may be advantageous. However, if irrigation equipment is available, then using the holding pond effluent on cropland as a fertilizer supplement is advisable (16).

Field sinks, vegetative filters, or switchback (serpentine) waterways are popular disposal methods for liquids if the topography permits and the operation is not overly large (9, 44). Field sinks, switchback waterways, and vegetative filters allow direct land disposal of the effluent by gravity flow from the debris basin, eliminating the need for a holding pond and pumping equipment. The area of the field sink or waterway is normally not more than twice that of the feedlot. Such installations have been used for dairy, beef, and swine operations (9, 29, 46).

Pumping the effluent from the holding pond to cropland is another method of disposal. Tank transport systems are not recommended because the volume of runoff results in high labor and application costs. Operator dependence on feedlot runoff as a source of irrigation water is not recommended. Normally, fields are wet when water is available, and holding ponds are empty during dry periods.
The land area required for disposal of holding pond effluent depends on the nutrient needs and water use of crops, holding capacity of the soil, application rates, amount and characteristics of the runoff, and State laws or regulations. Because runoff can be classified as low-nutrient fertilizer, economics may dictate the use of a small disposal area seeded to grass or other high-water and nutrient-use crops. The minimum land area required is about a 1:1 ratio of feedlot runoff area to land disposal area (2, 31).
Discussion
Maintaining runoff control facilities is a prerequisite to satisfactory operation and pollution control. If maintenance is neglected, the debris basin and holding ponds will produce odors and create nuisance problems.

Consider the ground-water level when planning the location of the settling basin, holding pond, and disposal area. There are no set guidelines for the distance from the bottom of a basin or holding pond to a potable water table. A large area would not likely be affected by nutrients leaching into a water table from a holding pond or a debris basin; however, the local water would be suspect. Ponds may be sealed with an approved sealant, such as plastic or rubber, or with material such as clay and bentonite. Manure also will seal ponds (1, 3, 7, 27, 35). However, local regulatory agencies should be consulted before using any of these materials.

It is doubtful that problems will arise on the disposal area provided the nitrogen uptake of the crop prevents buildup of nitrogen in the soil profile. Therefore, the land disposal area should be designed based on the type of crop, soil conditions, and the quantity and quality of the runoff applied. Salinity problems can develop in areas of low rainfall and must be considered in the design and operation of the facility.
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