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Introduction
Small open feedlots are used across Iowa to grow and finish beef animals for meat production. These feedlots are characterized by earthen and/or paved feedlot surfaces that are partially or completely exposed to rainfall.

Iowa law defines an open feedlot as an unroofed or partially roofed lot, yard, corral, or other area in which animals are confined and fed and maintained for 45 days or more in any 12-month period and where crop, vegetation, or forage growth or residue is not maintained during the period that the animals are confined. Iowa Administrative Code (IAC) Chapter 65 (IAC [567] 65.100)

Confinement animal feeding operations that are completely under roof and pasture operations where vegetation is maintained are regulated differently and are not the focus of this guide. Open feedlots that are classified as concentrated animal feeding operations (CAFO) because of their size or pollutant discharge conditions are subject to additional regulations and are not the focus of this guide. Refer to the Iowa Department of Natural Resources (DNR) website for more details about regulation of animal feeding operations, or call the Iowa DNR at (515) 281-5918.

Purpose of this Handbook
This handbook is intended to serve as a guide for operators of small open feedlots in Iowa, helping them to understand:
• How their open lots can impact water quality in Iowa,
• How state and federal regulations apply to their open feedlots,
• How they can begin to assess the environmental impact of their feedlots,
• Control and containment solutions that can help them better manage their manure and runoff,
• Management practices that can help them better manage manure and runoff, and
• Sources for additional technical assistance

The Water Quality Connection
Like other Iowans, beef producers are dedicated to protecting Iowa’s environment. As they work to produce meat for a hungry world, they must be stewards of animals, land, and water, and must carefully balance the use and protection of these resources.

Being exposed to sun, wind, snow, and rainfall, open feedlots must be equipped to control and manage the manure nutrients and pollutants that move out of feedlot pens with runoff water during snow melt and rainfall events. Manure loss not only presents an economic loss for the feeding operation, but also poses a risk to receiving water resources (streams and lakes).
1. What’s in open lot runoff?
Runoff water leaving feedlot pens carries nutrients and pollutants that are contained in animal manure. Some of these nutrients and pollutants are dissolved in the water itself, making them invisible and detectable only through water testing. Other nutrients and pollutants are carried on the manure organic matter and soil particles (suspended solids) that are washed off the feedlot surface, giving the runoff water its characteristic brown color. The primary nutrients and pollutants of concern are:

**Total Solids** – Manure solids and soil particles may be carried in runoff water in dissolved or suspended form. These solids carry organic matter, nutrients, and other pollutants. While manure slurry may contain as much as 10 percent total solids, manure runoff water, even after effective solids settling, typically contains 0.2 to 1 percent total solids (2,000 to 10,000 parts per million [ppm]).

**Nitrogen** – Runoff water carries nitrogen (N) primarily as organic N in suspended solids and as dissolved N mostly in the form of ammonia (NH₃). The ratio between organic N and ammonia N varies with the condition of the feedlot pen surface and the rate at which runoff water leaves the feedlot. Typically 80 to 90 percent of the N is in the ammonia form. The amount of organic N may be increased if manure solids are not allowed to settle from the runoff. Concentration of total nitrogen (and ammonia N) in runoff water is typically 50 to 500 ppm.

**Phosphorus** – Runoff water carries phosphorus (P) on solids particles and to a much lesser degree as dissolved P. Total P concentrations in open lot runoff are typically in the range of 20 to 100 ppm. Total P concentrations in runoff water tend to be higher from concrete open lots than from earthen open lots. Compared to nitrogen, a higher fraction of phosphorus is captured in settled solids removed from open lot runoff with effective solids settling.

**Oxygen Demand** – Organic matter carried as part of the total solids in runoff water is a ready food source for microorganisms found in Iowa’s lakes and streams. As these organisms consume the organic matter, they use dissolved oxygen from the surrounding water to support their growth and reproduction. In turn, as these extra organisms die, other organisms use additional oxygen as they break down the dead organisms. This increased demand for dissolved oxygen used to consume or break down the organic matter is labeled as Biological Oxygen Demand (BOD) or Chemical Oxygen Demand (COD) and measured in parts per million. Chemical Oxygen Demand in open feedlot runoff is typically in the range of 1,000 to 5,000 ppm.

**Bacteria and other Organisms** – Like waste from people, manure from livestock contains bacteria, viruses, and other living organisms found in their digestive systems. Bacteria most frequently measured in water are a group of common bacteria labeled total coliforms, and a subset of this group that comes specifically from the intestines of warm-blooded animals called fecal coliforms. Total coliform concentrations in open feedlot runoff vary greatly by feedlot condition and rainfall event, but often range from 10⁵ to 10⁶ colony forming units per milliliter (CFU/ml). Fecal coliforms typically represent 1/10 to 1/2 of the total coliforms.

Other nutrients and pollutants are also present in open lot runoff, but the ones previously mentioned are most commonly used as environmental indicators because of their potential impact on surface water resources. Some of these pollutants can be measured with field test kits, while others require controlled laboratory testing. Concentrations of nutrients and pollutants
can vary widely between feedlots and between runoff events for a given feedlot. The ranges quoted above are intended as rough approximations only.

2. Pollutant impact on streams and lakes

Nutrients and pollutants in feedlot runoff can impact streams and lakes by excessively feeding organisms in the water, by posing a toxic threat to organisms in the water, or even by degrading the usefulness of the water for organism habitat, human recreation, or other intended uses.

Organic matter, nitrogen, and phosphorus in open lot runoff all contribute to over-feeding of algae that are naturally present in lakes and streams. The negative impact of over-feeding the aquatic system is referred to as eutrophication. When additional food in runoff water reaches a stream or lake, algae can multiply in what is called an algae bloom. In severe blooms, the algae multiply to the point that they cloud the water, reducing sunlight penetration essential for growth of submerged plants that help produce dissolved oxygen in the water and serve as food supplies for fish. Excessive algae also make the water less suitable for fishing, boating, and swimming. Excessive algae may cause unpleasant taste and odor in the water and, in some cases, may even release toxins into the water. As the food supply is consumed and the excess algae begin to die, they are decomposed by other organisms that use dissolved oxygen, resulting in increased oxygen demand and reduced oxygen available for fish and other organisms. In general terms, most warm water fish require at least 4 mg/l dissolved oxygen (DO) while cold water fish require at least 5 mg/l dissolved oxygen for good health.

The excessive nutrient and organic matter supply along with the accompanying increase in oxygen demand can shift the suitability of the aquatic environment for different species. Often the resulting water quality is less suitable for desirable game fish and beneficial macroinvertebrates (bugs and larvae) and more suitable for undesirable fish species (such as carp) and more tolerant but less beneficial macroinvertebrates. The effects often compound one another as desirable species disappear that, in turn, served as food supply for other desirable species. While some nutrients and organic matter are always present and necessary for aquatic life in Iowa waters, the sudden addition of nutrient-rich feedlot runoff can upset the balance and trigger a cascade of undesirable effects.

Nitrogen in the ammonia form is directly toxic to fish. High concentrations of ammonia damages fish gills and tissues. Susceptibility to ammonia damage varies by fish species, and negative effects may begin with concentrations as low as 0.01 mg/l. Iowa streams typically have background concentrations of ammonia between 0.1 and 0.5 mg/l. Acute toxicity in many species will be present at concentrations exceeding 3-8 mg/l. When manure contamination causes fish kills, ammonia concentration is frequently the primary cause.

Bacterial contamination is used as a risk indicator for waters used for recreation such as fishing, boating, and swimming. The indicator bacteria most commonly evaluated are fecal coliforms and a smaller subset of fecal coliforms, E. coli. While these indicator bacteria themselves do not pose serious health risks, they indicate fecal contamination that may signal the presence of other disease-causing organisms (bacteria, viruses, parasites) for which specific testing would be much more expensive.

Bacterial contamination of water resources can come from livestock manure, sewer discharges, storm water runoff, wildlife, and other sources. Bacterial concentrations in open lot runoff, while typically not as high as in sewer overflows, can be high enough to cause significant impact to streams and lakes.
Concentrations of E. coli bacteria in sewer overflow, storm water runoff, and feedlot runoff may be in the range of 10,000 to 1,000,000 CFU/100 ml, while water quality alert levels for swimming are in the range of 100 to 200 CFU/100 ml.

### 3. Size and place matter
When feedlot runoff water carrying high concentrations of nutrients and pollutants reaches a water body, the stream or lake provides some dilution and buffering of the effects of the pollutants. The degree to which the receiving water body can dilute and tolerate the added pollutants is greatly affected by the relative size of the receiving water body and the temperature of the water. A small feedlot discharging directly into the Mississippi or Missouri river may have little or no measurable impact, while the same feedlot discharging into a small stream or lake may have significant impact. The risk of significant impact is much lower when the receiving stream is very large or is at very high flow (flooding).

The effects of reduced dissolved oxygen (DO) and elevated ammonia are also related to time of day, water temperature, and water pH. Dissolved oxygen is added to streams mainly through interaction of the water surface and the air. In ponds and lakes, photosynthesis from submerged plants supplies additional dissolved oxygen. These plants release oxygen during the daytime and consume oxygen at night, causing a cycle of DO concentration that is highest in late afternoon and lowest just before dawn. Fish needs for DO are also related to water temperature, being higher when water temperatures are high. But the ability of water to hold dissolved oxygen is also related to water temperature, the capacity being lower as water temperature rises.

Ammonia in water balances between two forms, NH₃ and NH₄⁺. The balance shifts with water temperature and pH. Higher water temperature and pH lead to a higher percentage of ammonia in the more toxic NH₃ form.

With all the complex relationships of water flow, temperature, pH, and DO, the general trend is that water bodies and aquatic life are most at risk when stream flows are low and water temperatures are high. This makes summer low-flow times particularly critical for preventing feedlot runoff additions to streams and lakes.

### Applicable Regulations
Open feedlot operations in Iowa are regulated under a combination of federal and state rules. Responsibility for enforcing applicable federal regulations included in the Federal Clean Water Act is delegated by the Environmental Protection Agency (EPA) to the Iowa Department of Natural Resources (DNR). Responsibility for enforcing applicable state regulations also rests with the Iowa DNR. Provisions of the rules fall into four general categories.

#### 1. Settling solids
Iowa rules require that runoff from all open feedlots, regardless of size, have settleable solids removed prior to releasing the runoff to a water of the state (stream, lake, wetland, or watercourse). Settleable solids are those larger particles that will settle out of the runoff liquid if the water slows down or sets still. Adequate solids settling is assumed to occur if the velocity of the runoff water is slowed to less than ½ foot per second for at least 5 minutes. Solids settling can be accomplished on the land surface where conditions allow, or in a constructed solids settling facility. Solids settling rules are specified in the Iowa Administrative Code (IAC) Chapter 65 (IAC[567] 65.101).

#### 2. Protecting water quality
In addition to removing settleable solids, Iowa rules for all open feedlots, regardless of size, require that if the resulting liquid (settled feedlot effluent) reaches a water of the state, it may not cause water quality criteria limitations to be exceeded (water quality violation) in the receiving water. These water quality criteria, commonly referred to as “free froms,” state that the waters receiving the discharge shall remain free from, among other things, sludge, floating debris or scum, and materials producing objectionable color, odor, or other aesthetically objectionable conditions. These water quality criteria are specified in chapter 61 of the Iowa Administrative Code (IAC[567] 61.2, IAC[567] 61.3).
3. Separation distances
Iowa law also requires separation distance between certain manure handling and storage structures or application areas and vulnerable water sources such as wells, streams, agricultural drainage wells, sinkholes, wetlands, and lakes. These rules apply to open feedlots of any size. Open feedlots and solids settling basins must be 100 feet from deep wells and 200 feet from shallow wells. Open feedlot runoff storage basins must be 400 feet from private wells or deep public wells and 1,000 feet from shallow public wells. Stockpiles of dry manure from open feedlots must be 200 feet from terrace tile inlets, surface tile inlets, and sinkholes; 400 feet from wells, wetlands, lakes, rivers, and agricultural drainage wells; and 800 feet from high quality water resources. Non-incorporated surface application of manure must be 200 feet from wells, lakes, streams, designated wetlands, sinkholes, and agricultural drainage wells or inlets; and 800 feet from high quality water resources. Details of required separation distances are found in various parts of IAC Chapter 65 (IAC[567] 65) and are referenced on the small feedlot website. [http://www.agronext.iastate.edu/immag/smallfeedlotsdairy.html](http://www.agronext.iastate.edu/immag/smallfeedlotsdairy.html)

4. Permitting where required
Both the Iowa rules and the Federal Clean Water Act rules require that a beef feeding operation that has any open lot space and a total animal capacity (open lot plus confinement) of 1,000 animals or more, or is otherwise classified as a Concentrated Animal Feeding Operation (CAFO) shall not discharge manure or open feedlot effluent into any waters of the United States, unless the discharge is allowed by an NPDES (National Pollutant Discharge Elimination System) permit. Small and medium sized open feedlots that have certain discharge conditions may be classified as CAFOs. Specifically, if the pollution potential is large, or if the total animal capacity (open lot plus confinement) is between 300 and 999 beef cattle and the discharge reaches a water of the United States by passing through a man-made ditch, flushing system, or other similar man-made device, the operation may be a CAFO. See the link in the introduction to this document for more details. These rules are specified in IAC[567] 65.101(3)

In the open feedlot rules cited above, discharges are regulated if they reach waters of the state or waters of the United States. Water quality narrative and numeric criteria apply to Iowa stream segments (watercourses). Iowa definitions of these waters are complex and are specified in IAC[567] 65.100, IAC[567] 61.3(1), and IAC[567] 65.1. Waters of the United States are specified in IAC[567] 65.100 and in the Code of Federal Regulations 40 CFR 122.2. While the legal definitions may be lengthy and confusing, a simplified guiding principle is that settleable solids must be removed before discharging settled effluent to any water, and that water quality must be protected in any lake and any stream with a bed and banks, even if the stream only flows part of the year. If you need help determining the regulatory status of any water body or channel, contact your field office of the Iowa DNR to ask for assistance. Field office contact information can be found in your phone directory government section under Iowa, State of, Natural Resources Department, Field Office, or at [http://www.iowadnr.gov/InsideDNR/DNRStaffOffices/EnvironmentalFieldOffices.aspx](http://www.iowadnr.gov/InsideDNR/DNRStaffOffices/EnvironmentalFieldOffices.aspx). Iowa open feedlot regulations are outlined in web pages of the Iowa DNR. [http://www.iowadnr.gov/Environment/LandStewardship/AnimalFeedingOperations/OpenFeedlots.aspx](http://www.iowadnr.gov/Environment/LandStewardship/AnimalFeedingOperations/OpenFeedlots.aspx)

Assessing Your Risk
A key step in making environmental improvements to an open feedlot operation is accurate assessment of the environmental risks.

1. Using self-assessment tools
Several self-assessment tools exist for open feedlot operations. These tools guide a producer through key inspection points and management questions. Self-assessment allows the producer flexibility in the timing and intensity of the assessment and encourages repeated improvement and re-assessment. Self-assessment accuracy can be limited by the tendency of producers to overlook familiar issues or to rank items based on what they would like to believe rather than on reality.
Two good self-assessment tools are the Feedlot EMS Assessment Worksheet available from the Iowa Beef Center at Iowa State University, [http://www.iowabeef-center.org/Docs_environment/Feedlot_Assessment_Worksheet.pdf](http://www.iowabeef-center.org/Docs_environment/Feedlot_Assessment_Worksheet.pdf) and Assessing Your Open Feedlot Manure Management available from the Farm*A*Syst program through Iowa Farm Bureau, [http://www.iowafarmbureau.com/files/pages/194/EDC267.pdf](http://www.iowafarmbureau.com/files/pages/194/EDC267.pdf). Both assessment tools cover multiple aspects of the feedlot operation including site characteristics, protection of water supplies, feedlot runoff controls, manure and effluent storage, land application, and management. For each aspect, the tools give producers a choice of descriptions from which they can select the choice that best describes their operation. The choices are ranked from high risk to low risk so that producers can identify areas of strength and areas for potential improvement at their existing feedlots.

2. **Seeking outside opinions**

Often it is difficult for feedlot operators to accurately assess the environmental risks at their operation because familiar situations escape their notice or they have a limited frame of reference for comparing their situation with other alternatives. For this reason, an outside opinion is often helpful.

Knowledgeable staff from Iowa DNR, the Natural Resources Conservation Service (NRCS), the Coalition to Support Iowa’s Farmers, and Iowa State University Extension and Outreach, along with private consultants, are available to help make objective assessments of open feedlot operations. The choice of an outside observer may depend on the urgency of the timing, the degree of regulatory decision making desired, or the financial resources available for the assessment. Fees required for services from the different sources may vary from none to significant.

Generally, outside assessors will visit the site and make observations and measurements that may or may not be followed by a written report. Limited assessment advice may be available by phone with the assistance of verbal descriptions or aerial photographs of the feedlot. All assessors can help make assessment observations and give general advice for solutions and improvements. Some may feel more qualified than others when it comes to making design recommendations. Many times, assessors will refer to staff from other agencies for specific parts of an assessment or solution design. All assessors strive to stay abreast of open feedlot regulations, but only DNR staff can make regulatory determinations.

3. **How small open lots often discharge pollutants to surface waters**

As the old adage goes, “water (or another liquid) always runs downhill.” Being subject to rainfall, open feedlots occasionally discharge large amounts of runoff water. When the feedlot surface is already wet and all rainfall runs off, each inch of rain on each acre of feedlot will produce more than 27,000 gallons of runoff. If not contained or redirected, this runoff will follow the closest natural flow path down hill toward a receiving stream or water body. When soil conditions are dry, significant amounts of runoff may soak into the soil along the way. But when rainfall is large, or when chronic rainy periods have saturated the soil, runoff almost surely can be expected to reach a stream or lake in most of Iowa’s topography.

Common practice in Iowa has been to allow feedlot runoff to follow grassed waterways and natural flow channels that carry water from farm fields and pastures to streams. Because these flow paths are made to carry water rather than to absorb water, and because these flow paths will already be carrying runoff water in larger rainfall events, they are not suited
for treating feedlot runoff or preventing it from reaching waters of the state. If these flow paths are steep or become eroded and lose their vegetative cover, their ability to absorb feedlot runoff is further diminished.

In places where the flow path includes a road ditch or a pipe such as a road culvert or drainage tile, federal CAFO rules may come into play. Even an eroded waterway channel or solids settling basin outlet tube may qualify as a man-made device triggering federal CAFO rules if it allows feedlot effluent to reach a water of the United States more quickly or easily than if the channel or tube were not present (makes the situation worse).

4. Looking for impact
As you assess environmental risk from feedlot effluent discharges, follow the flow path from your feedlot all the way down hill until you reach a stream or lake. This task is best done at the end of a large rainfall event when actual water flow can be observed. Remember that the federal rules speak of ANY discharge of pollutants to a water of the United States. This includes every size of rainfall event. Dilution from field runoff and high stream flow caused by large rainfall events may help to prevent water quality violations under state rules, but they do not excuse discharges covered by the federal rules.

If assessment must be done during dry periods, look for evidence of the flow path and past effluent movement. Small amounts of manure solids (often undigested corn hulls) are evidence of feedlot effluent movement. Eroded soil may indicate areas where channelized flow has occurred or where flow has spread and slowed. Some landscapes may be difficult to evaluate. Be cautious about assuming that feedlot runoff cannot reach a stream.

Beyond determining how and where runoff may reach a lake or stream, you need to determine what impact may be resulting. In some cases, you may see evidence of manure solids in the stream or on the stream bank. If you can observe the discharge as it happens, you can look for changes in the appearance of the stream water. In extreme cases, there may be dead fish near the point of runoff entry. In many cases, chemical tests of the water quality upstream and downstream of the point of runoff entry may be required to determine potential impact. An additional test of the runoff water itself may be taken to evaluate the likelihood that it contains feedlot effluent rather than simply storm runoff. Testing kits for self-assessment of water quality are available from commercial sources. Care is necessary to obtain reliable test results, but a track record of repeated testing can be very valuable in evaluating environmental risk and performance.

Reliable bacterial assessments can be performed only in a laboratory setting. Contact the water testing laboratory for instructions on proper handling and shipment of bacterial samples. Dissolved Oxygen (DO) and Ammonia testing can be done either with laboratory analysis or with on-site test kits. The on-site kits do not yield the same level of precision as a laboratory test, but they give quick, inexpensive estimates that are sufficient for many purposes.

Dissolved Oxygen (DO) concentrations in stream water are influenced by a number of factors. A lower DO reading in the downstream sample compared to the upstream sample may indicate runoff impact. Dissolved oxygen reactions in a stream require time and distance downstream to occur. Accurate DO testing may require professional assistance or advice. Ammonia concentrations above 10 mg/l in runoff
water may indicate manure pollution in the runoff water. A higher ammonia reading in the downstream sample compared to the upstream sample may indicate runoff impact, and ammonia concentrations in the stream above 1-2 mg/l indicate an impact of concern for fish.

An instructional video on using on-site ammonia test kits for feedlot water quality monitoring is available from the Iowa DNR. These kits are available for checkout from some ISU Extension and Outreach county offices. For the list of county offices and a link to the instructional video, see the small feedlot and dairy website, http://www.agronext.iastate.edu/immag/smallfeedlotsdairy.html.

## Parts of the Solution

### 1. Clean water diversion

Open lot runoff is generated by a combination of rain that falls on the lot surface and water that runs onto or through the lot from other areas such as neighboring fields, driveways, and buildings. Minimizing the amount of clean (manure-free) water that enters the feedlot can reduce the amount of feedlot runoff water that must be managed.

Locating feedlot pens high on the landscape, on hillsides or ridge tops, reduces the amount of other field and landscape runoff water that might otherwise enter feedlot pens. When pens cannot be located at the top of the landscape, structures called clean water diversions can be built to redirect clean runoff water around feedlot pens and runoff management systems. These diversions may be simply small terraces or ditches to channel the clean water, or may sometimes include underground drainage lines to carry the bypass water. When underground drainage lines pass beneath feedlot pens, they should be non-perforated to avoid picking up feedlot runoff, and should not pass beneath liquid storage locations such as solids settling basins or settled effluent storage basins. Roof gutters and downspouts can be used to direct building roof water away from pens and manure.

Even management practices such as routine checking for leaking water lines or fountains and careful management of sprinklers used for heat stress reduction can reduce the amount of clean water added to feedlot pens and runoff.

Make sure clean water is actually clean. Runoff from driveways or feed handling areas may contain sufficient manure or other organic matter to justify running it into the runoff management system.

### 2. Good pen design

Feedlot pen design can influence runoff water quality. Insufficient pen slope can lead to wet pens that are difficult to clean. Excessive slope can lead to erosion of earthen pen surfaces. Pen slope of approximately 5 percent for earthen surfaces and 1 to 2 percent for paved surfaces are generally ideal. Selective use of pavement in high traffic areas such as around water access and along feed bunks can reduce the amount of pen surface soil erosion.

Pen and gate layout that allows easy access for frequent dressing (shaping) and cleaning can promote manure removal from the pen surface before it can be carried off the pen in runoff water. Frequent pen cleaning and dressing recovers more manure nutrients for fertilizer and promotes better cattle performance. Frequent pen cleaning when manure is dry allows transport and land application of manure nutrients with much less added water weight. Earthen pen surfaces retain their shape and firmness better when only a thin layer of manure is maintained on the surface.

### 3. Dry manure stacking

A well-designed and maintained dry manure stacking location promotes timely cleaning of feedlot pens. Stacked manure loses less nutrient value in storage than manure spread over the pen surface. Stacking areas should be located conveniently for manure movement from the pens and also within the manure control system so that any runoff from the stacking area is controlled along with the pen runoff.
Dry manure can be temporarily stacked and stored within feedlot pens if necessary, but does not make a good mound for cattle traffic. Mounds should be formed with a compacted soil base and cap with only a thin layer of manure pack over the surface.

4. **Solids settling**

Separation of settleable solids from open lot runoff is required by Iowa law and important in managing and maintaining a runoff control system.

The first step in good solids settling is pen design and maintenance. Attention to clean water diversion and pen cleaning and maintenance mentioned previously can drastically reduce the amount of both runoff water and manure solids that enter the solids settling structure.

Solids settling occurs whenever the velocity of the runoff water slows down. This velocity reduction may happen in a naturally occurring flat bench or bottom, or in a constructed settling (stilling, sedimentation, debris) basin. Iowa law allows for solids settling in any of these settings, but requires that the area be managed to periodically remove and land apply settled solids. It is important to note that solids settling does not typically occur in a grassed waterway where flow velocities are relatively high.

Solids settling also requires that manure solids are suspended in fairly dilute solution. With earthen lots, there is generally enough rainwater dilution to create an effluent mixture from which solids will readily settle. From totally concrete lots, where animals are given less lot space, manure may stay wet and sometimes move off the lot as a concentrated slurry rather than a dilute mixture. It may not be possible to settle solids from this thick slurry manure unless additional dilution water is added. Slurry manure may be best handled, stored, and applied as a manure slurry rather than as separated solids and settled effluent.

Iowa law specifies the design procedure for determining the minimum size of a solids settling basin based on the contributing runoff area and the flow rate generated by the 10-year 1-hour storm event for the location. It is often useful to design basins larger than the required minimum size to allow for additional solids storage and/or additional temporary settled effluent storage.

In order to allow access for removing settled solids with common feedlot loaders, the depth of settling basins is often limited to 3 to 4 feet. The surface area and volume of the basin are designed to provide adequate flow velocity reduction (or retention time) to allow for solids to settle to the bottom. The shape and location of the basin can be adjusted to accommodate gravity flow of the pen runoff to the basin on the existing landscape, while diverting other clean runoff away from the basin.

The settling basin may be constructed with concrete walls and floor, or with earthen berms and floor, or a combination of the two. Full concrete floors make removal of settled solids easier and allow more flexibility in the timing of solids removal. Even in an earthen settling basin, a concrete floor around the basin outlet and a concrete access ramp down into the basin greatly facilitate cleaning and maintenance.

The basin is equipped with outlets to serve two purposes. An overflow outlet must be able to handle the maximum expected runoff flow rate passing through the basin. This peak flow rate is approximately 2.5 cfs (cubic feet per second) per acre of contributing land area. A dewatering outlet must allow the basin to be
emptied following a runoff event. The dewatering may take place over a few hours or even a few days. This dewatering is important to allow the captured solids to dry for later handling, and to prevent the increase in ammonia concentration that can occur when settled feedlot effluent is allowed to stand stagnant for extended periods of time (several days or more), especially during warm weather. The settling basin may be equipped with a single outlet that serves both the overflow and dewatering purposes, or with separate outlets.

The basin outlet(s) must be designed to handle the peak expected flow rate through the basin when the basin is full, but must also provide for velocity reduction and solids settling when smaller runoff events occur and the basin is only partially full. A weir type outlet (notch weir or overflow spillway) works well for handling the peak overflow. A restricted outlet (perforated riser pipe, slotted picket dam, weep hole, pump) works well for the dewatering task at a much lower flow rate.

When settled effluent is being directed to a treatment area, it is often beneficial to control the rate and/or timing of the distribution of settled effluent. To accomplish this, the settling basin may be designed with additional storage capacity and with a dewatering outlet that can be controlled using a plug, valve, gate, or pump. In addition to allowing flexibility and control of the timing and rate of settled effluent application, the longer settling time allowed by a controlled release can increase the settling efficiency and the amount of nutrients captured.

Settling basin outlets should be designed to avoid plugging with solids and for ease of maintenance. Pumps should be easy to remove and service, even from a full basin. Outlet pipes, risers, valves, and restricting devices should be easy to remove or flush. Areas around outlets should be paved to aid in settled solids removal. Materials of construction should be resistant to damage from corrosive manure and from contact by cleaning equipment.

5. Settled effluent storage
Storage of settled effluent within the settling basin is limited by Iowa law to no more than seven days. For longer term storage, the effluent should be transferred to a separate storage structure (holding pond).

If the feedlot operation requires an NPDES permit or utilizes financial assistance from government agencies, construction specifications will apply to this storage structure. The specifications relate to having capacity to contain the runoff from a certain size rainfall event and a liner that controls infiltration (seepage) from the structure. Unpermitted small and medium open lot operations that do not utilize financial assistance do not have construction requirements for storage basins, but should consider the same criteria when building settled effluent storage. Avoid areas and soils that may allow excessive seepage to groundwater. Build capacity to capture frequently expected rainfall events and manage the storage structure so that there is always room available for the next expected rainfall event. As a planning guide, consider that in an average year, Iowa sites receive 10 rainfall events larger than 1 inch, 3 events larger than 2 inches, and 1 to 2 events larger than 3 inches. Once every 25 years, Iowans can expect a rainfall event larger than 5.5 inches.

When settled effluent is stored for more than a few days, ammonia concentrations can increase, especially in summer temperatures. Release of effluent with higher ammonia concentration to lakes or streams poses higher risk to fish. Distribution of higher ammonia concentrations to crop ground or vegetated treatment areas poses little risk, as the ammonia is captured on soil particles. Careful attention is important to distribution of effluent from longer-term storage either by planned means or by overflow during rainfall events. Remember that medium sized open lots that discharge effluent to a water of the United States through a man-made device under any circumstance must have an NPDES permit.

6. Settled effluent treatment/application
Because settled feedlot effluent still contains manure nutrients, fine suspended solids, and manure microbes,
it has value as a fertilizer and organic matter amendment for crops and plants, but poses a risk to water resources. Applying this effluent to crop, pasture, or treatment area soils at appropriate rates utilizes the value and minimizes the environmental risks.

Land application of effluent during the growing season should be managed so that the amount applied during any single application does not exceed the infiltration capacity of the soil. On sloping land, this may require low application rates (fractions of an inch per hour) or small applications (fractions of an inch applied at one time) using irrigation equipment. On flat land or berm'd areas, higher application rates and larger applications may be possible with adequate time between applications to allow full infiltration. In all cases, potential for runoff from the application site and risk to water resources should be carefully evaluated.

Chronic rainy periods often pose a critical design limit for storage and land application systems. Maximum storage capacity should be maintained heading into likely times for chronic rainy periods.

Land application during frozen soil periods should be avoided or limited to areas where runoff is controlled. Adequate storage should be provided to collect settled effluent through winter months.

While risk of storage overflow and application area runoff are highest during chronic rainy periods, the risk of water quality violations and harm to fish and aquatic habitat may be highest during dry periods with low stream flow and high water temperatures. Adequate control and management of application is critical in these times as well.

Application to Crop Ground
Settled feedlot effluent can be successfully applied to crop ground using conventional and innovative irrigation methods. Iowa soils have adequate buffering capacity to accept relatively high application rates (pounds per acre) of settled effluent nutrients, corresponding to many inches of total effluent application per season. Lower application rates that balance nutrient content of the effluent with nutrient needs of the crop make more efficient use of the valuable nutrients and water and minimize the risk of runoff from over-application.

Application rates (inches per hour) and application amounts (inches per application) that can be applied without effluent runoff depend on the soil moisture condition, soil type, and slope. Because effluent may need to be applied soon after, or even during a rainfall event, design application rates and amounts should probably be low on sloping fields without runoff protection. Flat fields, fields with runoff control, or fields with extremely high infiltration rate soils may accommodate higher application rates and amounts. Careful observation of application events and thoughtful planning of application rates and amounts is critical to irrigation success and avoiding runoff.

Distribution of effluent onto large crop fields is often done with automatic moving sprinkler systems. Smaller systems may use manually moved sprinklers, border (headland) irrigation with solid set sprinklers or flood systems, or even manually moved flood systems. The choice of system will depend on the desired application uniformity and balance between capital investment and labor inputs.

Experience with irrigation systems on permitted large CAFO beef operations has demonstrated good success and crop benefits from irrigated settled open feedlot effluent. Yield benefits of effluent application to field crops in Iowa will probably be small in normal years. While irrigation could have big benefits in dry periods, settled effluent will generally not be available in large quantities during those dry periods. The greater the settled effluent storage capacity, the greater the likelihood of having effluent available during dry times. Larger operations may consider building in access to other irrigation water sources to allow irrigation benefits during dry seasons. Crop damage is not likely to result from settled effluent application unless effluent is allowed to pond on the soil surface for extended periods or manure solids are allowed to accumulate.
When crop land application systems are managed to avoid overflow or runoff, all effluent nutrients and pollutants are infiltrated into the soil. Soil drainage characteristics dictate whether these nutrients and pollutants are completely captured or partially released through subsurface drainage or deep percolation.

Application to Vegetated Treatment Areas
Settled effluent can be successfully applied to dedicated infiltration areas commonly called Vegetated Treatment Areas (VTA). In these areas, perennial vegetation, usually grass, is grown to provide a combination of additional solids settling and infiltration of effluent. The area may be sloped or flat, with or without berms to collect overflow and prevent/control discharges. Vegetation may or may not be harvested from the VTA. Harvesting is an integral part of systems wherein nutrient inputs and outputs are balanced.

While some deposition of manure solids and attached nutrients and pollutants takes place as effluent moves through standing vegetation in the VTA, the primary method of nutrient and pollutant capture is through infiltration into the soil. For this reason, treatment areas should be designed and managed to maximize uniform infiltration. Effective solids settling should precede the treatment area to minimize problems associated with manure solids accumulating in the treatment area.

Land with uniform gentle slope and uniform soil type is best suited for a sloped VTA. Sloped VTAs must be maintained to avoid wheel tracks, erosion channels, and other irregularities that would allow channeling of the effluent flow. Land with little slope, variable slope, or variable soil properties may be better suited to a series of flat VTA sections. Grazing is not advised in the VTA. Effluent distribution can be accomplished in the VTA using moving sprinklers, manually moved sprinklers, solid set sprinklers, or flood irrigation.

Land area required for a VTA depends on the soil properties, but is generally in the range of 1 to 1.5 acres of VTA for each acre of drainage area in the feedlot operation. Designers use a number of soil properties and other factors to determine VTA design.

As with applications to crop ground, VTA systems that are managed to prevent overflow or runoff infiltrate all effluent nutrients and pollutants into the soil. Soil drainage characteristics dictate whether these nutrients and pollutants are completely captured or partially released through subsurface drainage or deep percolation. VTA systems that allow discharge of excess water will release a percentage of incoming nutrients approximately equal to the percentage of incoming water that escapes the VTA (typically 0 to 50%). The performance goal is to infiltrate all of the settled effluent in the VTA.

Sprinkler Distribution Systems
Sprinkler irrigation equipment works well for applying settled feedlot effluent when adapted to handle the suspended solids content of the effluent. In-line filters can be used to allow irrigation through smaller sprinkler heads. Larger sprinkler heads may be able to handle un-filtered settled effluent.
Pumps (electric or engine-powered) are required to generate the pressures (typically 50 to 100 psi) needed for sprinkler irrigation. Standard clear water irrigation pumps may not be suitable for pumping settled effluent. Pumps capable of handling the suspended solids in the effluent are required. Professional assistance is recommended for designing sprinkler distribution systems. Demonstration systems of various sizes have been documented in Nebraska and Iowa.

Systems using solid set sprinklers, towline sprinklers, and rolling or pivoting sprinkler systems have all been successfully used.

**Flood Distribution Systems**

Flood irrigation methods also may be used for applying settled effluent to crop ground or VTAs. These methods are more accepting of suspended solids and require lower operating pressure than sprinkler systems. Variations in ground slope and soil infiltration rate often make it difficult to balance application rates with crop nutrient needs using flood irrigation in Iowa. Frequent movement of the application area can help balance application with crop needs.

Small feedlots may be able to use inexpensive sewage pumps and plastic pipe for distribution. Larger feedlots may need irrigation pumps and pipe.

In some cases, gravity pressure may be adequate for flood application to areas down slope from the effluent storage. Experience with larger permitted gravity VTA systems in Iowa has shown that managers prefer to have control valves on effluent storage so that application to the VTA can be controlled and delayed until soils in the VTA have drained following a rainfall event. Controlling application amounts with gravity systems requires close attention to manual control valves or automation of the control system.

Flood irrigation systems may cost less, but are more limited in the location and landscape choices for application area compared to sprinkler systems.

**Managing for Success**

As important as good design and construction may be, success with open feedlot runoff control may be even more dependent on good management and planning.

1. **Room for growth**

As with any business manager, open feedlot operators should plan for future growth. When considering open feedlot runoff management options, consider the long-range plan for the operation and the impact of size on your runoff control system options.

Site selection can have a huge impact on expansion ability. Look for sites that have ample room for not only increased feedlot size, but room for increased feed handling and storage, increased water supply, increased traffic flow, and improved and expanded runoff control options. Beginning on a site with ample room for growth can help you avoid costly control systems that may be required in cramped spaces. Sometimes relocation of a feedlot is more economical that expensive controls on a challenging site.

Remember that re-designation or expansion from one category to another (AFO, medium CAFO, large CAFO) will bring additional design and construction requirements. In many cases, existing runoff control structures may need to be removed and re-built to new permit standards.

2. **Continuous monitoring and adjusting**

Successful businesses continuously monitor their performance and adjust their management to adapt. Continuous monitoring and evaluation of your runoff control system will help you identify potential problems, areas for potential improvement, and successful strategies that can be duplicated.

The first step is accurate monitoring, measurement, and documentation of performance. Look for measurable criteria that indicate your level of performance. Measurable benchmarks, against which you can judge later performance, include things like rainfall amounts, liquid levels in effluent storage, tons of...
manure recovered from pens and settling basins, length of effluent travel in fields or treatment areas, number and frequency of overflows or discharges, and water quality measurements in effluent and streams.

Outside consultants or even fellow feedlot operators often can provide a fresh set of eyes to look for performance issues and a helpful perspective on formulating improvement ideas. Templates for systematic improvement plans, sometimes called Environmental Management Systems (EMS) are available from ISU Extension and Outreach and other sources.

3. Recordkeeping

Documentation of performance, whether for permit compliance or for continuous improvement efforts, requires accurate, thorough, and meaningful recordkeeping. Just as health and feed records are critical to managing your beef herd, environmental control records are critical to managing your manure and runoff controls.

Permit processes have detailed recordkeeping requirements and forms. While not required for unpermitted operations, these same recordkeeping methods and forms can be helpful for documenting performance of small and medium open feedlots. Use these forms and procedures, or develop your own forms and procedures custom fit to your operation. The key is having a process that allows you to record vital information in a way that is so convenient that it becomes a natural part of your daily management. Beyond any records required by permits, focus on records that will help you make key management and improvement decisions.

Keep all your manure and environmental management records in an orderly system. Not only will they help you make important environmental decisions, they serve as protection in the event that you ever need to explain or defend your actions or impacts to other parties.

Additional Resources

1. Assessment tools
Feedlot EMS Assessment Worksheet, Iowa Beef Center, Iowa State University 515-294-BEEF (2333)
http://www.iowabeefcenter.org/Docs_environment/Feedlot_Assessment_Worksheet.pdf

Assessing Your Open Feedlot Manure Management, Farm*A*Syst, Iowa Farm Bureau 515-225-5432

2. Bulletins and websites
Small feedlot and dairy assistance website, ISU Extension and Outreach
http://www.agronext.iastate.edu/immag/smallfeedlotsdairy.html

Iowa open feedlot regulations, Iowa DNR
or see the map of field office contact information on page 19

Open feedlot medium CAFO criteria, Iowa DNR
Manure resources and research, Iowa Manure Management Action Group, Iowa State University
http://www.agronext.iastate.edu/immag/homepage.html

Feedlot producer information, Iowa Beef Center, Iowa State University (515) 294-BEEF (2333)
http://www.iowabeefcenter.org/feedlot.html

Livestock Producer Environmental Assistance Project, University of Nebraska-Lincoln
http://afo.unl.edu/lpeapj/pages/index.jsp

Responsible livestock production, Coalition to Support Iowa’s Farmers (800) 932-2436
http://www.supportfarmers.com/

3. Technical assistance

Manure management resources for beef and dairy operations, PM 1872, ISU Extension and Outreach
https://store.extension.iastate.edu/ItemDetail.aspx?ProductID=5454

Iowa DNR field offices and staff
http://www.iowadnr.gov/InsideDNR/DNRStaffOffices/EnvironmentalFieldOffices.aspx
or see the map of DNR field office contact information on page 19

Natural Resources Conservation Service field office contact information
http://offices.sc.egov.usda.gov/locator/app?state=IA
or contact NRCS at your local USDA service center

ISU Extension and Outreach ag engineering field specialist contact information
http://www.extension.iastate.edu/ag/fsae/fsae.html

ISU Extension and Outreach beef field specialist contact information
http://www.extension.iastate.edu/ag/fsbeef/fsbeef.html

ISU Extension and Outreach dairy field specialist contact information
http://www.extension.iastate.edu/ag/fsdairy/fsdairy.html

ISU Extension and Outreach dairy team
http://www.extension.iastate.edu/dairyteam/

Private consultants in engineering and manure management
http://www.agronext.iastate.edu/immag/sp.html

Responsible livestock production, Coalition to Support Iowa’s Farmers (800) 932-2436
http://www.supportfarmers.com/
4. **Financial assistance**

State Revolving Fund loan program for livestock producers, Iowa Finance Authority 515-281-6148  
[http://www.iowasrf.com/program/other_water_quality_programs/livestock_water_quality.cfm](http://www.iowasrf.com/program/other_water_quality_programs/livestock_water_quality.cfm)

Environmental Quality Incentives Program, NRCS  

Iowa DNR Watershed Improvement projects  

Iowa Department of Natural Resources Field Offices

Field Office #1, Manchester - (563) 927-2640  
Field Office #2, Mason City - (641) 424-4073  
Field Office #3, Spencer - (712) 262-4177  
Field Office #4, Atlantic - (712) 243-1934  
Field Office #5, Des Moines - (515) 725-0268  
Field Office #6, Washington - (319) 653-2135