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Environmental Protection Technology Series

Beef Cattle Feedlot Site Selection

for Environmental Protection

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BEEF CATTLE FEEDLOT SITE SELECTION

FOR

ENVIRONMENTAL PROTECTION

R. Douglas Kreis and Lynn R. Shuyler

National Animal Feedlot Wastes Research Program
Robert S. Kerr Environmental Research Laboratory
P. O. Box 1198
Ada, Oklahoma 74820

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INTRODUCTION

During the early development stages of the animal feeding industry, there was little or no emphasis placed on pollution control. At that time, the majority of livestock feeding units were located with disregard for pollution potentials. In fact, many were located to take advantage of natural drainage ways to transport solid and runoff-carried wastes to the nearest stream. The cost of pollution control structures now required at these sites can exceed the cost of changing sites. Recent awareness of environmental degradation coupled with ever increasing sizes of individual feedlots and related decreases in available land area for wastes disposal have placed emphasis on the environmental hazards associated with livestock feeding. Wastes handling and disposal practices have, in the past, resulted in pollution of surface (and in some instances ground) waters which in many cases were accompanied by extensive environmental damage and fish kills.

Environmental pollution can be significantly reduced in the initial planning stages by adequate facility planning, management, and, most importantly, by proper site selection. Climatic, topographic, and local weather extremes of the general area, selected with regard to economic and market factors, should be considered when planning the type of feeding facility. A site should then be selected which would decrease the pollution potentials and be readily adapted to necessary controls. Many of the natural and artificial pollution controls discussed herein may initially appear costly; however, their long-range value can result in considerable savings. The emphasis of this report is placed on those basic considerations of site selection which are compatible with pollution control designs and which lessen the impact of other environmental hazards. This report should be used when locating a new facility or when modifying an existing feedlot. Many of the concepts and ideas presented herein cannot be economically superimposed on an existing operation. A more comprehensive treatise of animal wastes management may be obtained from the Beef Wastes Management Manual which is in preparation and will, upon publication, be available from the Environmental Protection Agency, National Animal Feedlot Wastes Research Program.

BASIC CONSIDERATIONS

Many considerations influence the selection of a feedlot site which will be suitable for adequate pollution control and protection of the surrounding environment. These considerations may be grouped into six categories:

Regulations
Spatial Requirements
Topographic Features
Microclimates
Soils and Geologic structures
Social Considerations

Although these categories are interrelated, each will be discussed individually.

Regulations

Laws written to protect each individual in our society have been passed at nearly all levels of government. Regulations imposing responsibility for the quality of the environment and the use of both renewable and depletable resources have been imposed on all who use them. This involvement has placed a responsibility for pollution control and environmental enhancement on each individual and corporation presently designing, developing, or managing a livestock feeding facility. State and local regulations should be carefully studied for they will in most instances affect feeding facility site selection. Several states have placed restrictions on the minimum distance that a feedlot can be located from surface water, residential dwellings, municipalities, recreation areas, and arterial highways. Other states are considering similar courses of action. Additional requirements now in effect may include storm water runoff control facilities, structures for prevention of ground water contamination, storage for solid and runoff-carried wastes, and specified ultimate disposal procedures. In most cases, these regulations are controlled by statutory permits issued through appropriate agencies within state and/or local governments. A list of state agencies to be contacted is included at the end of this report. Additional information concerning zoning and other local restrictions may be obtained from the county officials serving the immediate district.

Spatial Requirements

The spatial needs of various livestock feeding units will vary with the facility type and climate in which it is located. The total area required for an integrated system may be determined as the sum of the areas required for each of the following components:

1. The production area,
2. Extraneous storm water runoff diversion ditches,
3. Storm water runoff collection and retention structures,
4. Wastes storage, treatment, and ultimate disposal sites, and
5. Buffer zone around the feeding facility and/or ultimate disposal site.

Estimates for the area needed by each component are:

1. The production area requirements can be based on the pen area. Pen area designs vary from 20 to 200 square feet per animal. An additional 15 percent of the pen area is needed for alleyways, feed bunks, and animal shipping and receiving docks. Mills, scales, office, housing, driveways, and parking space require an additional tract 20 to 30 percent of the size of the pen area.

2. Extraneous storm water runoff diversion ditches are constructed to reduce the volume of contaminated runoff which must be collected and disposed of or treated. Diversion ditches should be constructed around all areas to prevent uncontaminated storm water runoff from contacting manure and other pollutants. These are the feeding, feed preparation and storage, solid manure storage, and runoff wastes retention areas. The amount of extraneous storm water runoff to be diverted may be reduced by selecting a site which has a minimum of upslope drainage area. Nevertheless, overdesigning the capacity of the diversion structures (where rain storms of high intensity occur) could be an economical safety factor. In many areas

these structures are built around covered facilities primarily to maintain a dry wastehandling area near the facility. Runoff diversion structures generally require an area which is less than or equal to five percent of the total pen and runoff collection area.

3. Storm water runoff collection and retention structures are designed to retain and provide temporary storage for all storm water runoff which comes in contact with manure and other pollutants. The size of these structures is dependent on the rainfall of the region and resulting runoff from the facility. Smaller runoff control structures may be used on a paved open feedlot more successfully than on an unpaved lot having the same animal population, for increased animal densities are possible on paved surfaces. Several states regulate the size of sedimentation and retention ponds and the runoff retention time in each structure. These structures should, in the absence of regulation, be designed to retain all runoff resulting from the rainfall from a 10-year 24-hour design storm or its equivalent. The area needed for these structures will range from 2 to 15 percent of the total pen area depending on structure depth and volume of rainfall resulting from the design storm.

4. Wastes storage, treatment, and ultimate disposal sites are of major concern when computing the area needs for beef animal production units. The amount of acreage required for these uses will depend on the volume and moisture characteristics of the wastes generated, which in turn are dependent on the type of facility and wastes management system design. Both runoff and solid manure wastes are generated from open feedlots. On the other hand, wastes generated from total confinement facilities are in the form of a slurry which contains both manure and urine. The volume of these slurries which must be treated or disposed of is controlled by the number of animals on feed, type of feed, and in some instances by the volume of dilution water added. The amount of solid manure wastes produced in open feedlots is dependent on the number of animals, type of feed, and pen surface moisture conditions; volume of runoff wastes originating

from open feedlots is dictated by drainage area, amount and intensity of precipitation, and pen surface conditions.

Wastes management facilities will be discussed according to moisture characteristics as follows:

Runoff wastes
Solid manure wastes
Slurry wastes

Although the basic site selection concepts concerning waste management are applicable to beef production facilities, the general precepts should be considered for the whole of the animal production industry.

Runoff wastes control involves the integration of runoff retention and storage structures with a treatment method and ultimately with a means of disposal. The land area requirements of runoff retention have been previously discussed.

Because of the extreme pollution potential of animal wastes, conventional municipal waste treatment designs are not considered to be economically feasible for use by beef cattle feedlot operators without significant modifications.

Spray runoff treatment, a promising treatment method recently demonstrated, may be used to treat runoff in areas where freezing conditions exist for less than two months during the year. The land area needed for this method ranges from 20 to 50 percent of the pen area plus an additional 15 percent for a pretreatment storage structure.

Irrigation of crops, pasture, or wooded land is the most practical means of runoff disposal in most climates. Desirable application rates have been found to range from 4 to 8 inches per year. The land area needed for irrigation of runoff is equal to the volume of runoff generated from the feedlot annually divided by the appropriate application rate. The spatial requirements of a runoff irrigation system must often include a pre-irrigation storage pond to facilitate coordination of runoff applications with crop and soil moisture conditions and to avoid application of runoff to frozen or snow covered surfaces. The acreage required for this storage pond will range from 0.1 to 0.3 times the pen area. Maximum runoff disposal rates may be necessary during periods of extreme weather conditions resulting in occasional crop damage. The additional cost for ownership of the necessary real estate by the feedlot operator may be justified to avoid conflicts.

Areas in the Western United States, where the moisture deficit (evaporation minus precipitation) is greater than 10 inches, have a high potential for using evaporation for ultimate disposal of liquid wastes. An evaporation pond area of approximately one-third the size of the total feedlot will be needed in a region of a 40-inch moisture deficit. When considering this disposal method, the potential for ground water contamination and other problems must also be investigated.

The following equations may be used to estimate the total area needed to utilize runoff wastes management systems incorporating irrigation or evaporation disposal techniques and spray runoff treatment methods. These equations are based on the fact that: "A_r" equals the total area for management of runoff wastes; "P" equals the area of the runoff retention structure which is 0.02 to 0.15 times the total pen area in acres; and "S," which is the additional storage area needed to manage the disposal system, equals 0.05 to 0.15 times the pen area. Annual runoff from feedlots may be 2 or 3 times that of adjacent cropland. Annual runoff values for a specific location may be obtained from the local office of the Soil Conservation Service or from a consulting engineer.

Irrigation Disposal

$$A_r = P + \frac{\text{annual runoff}}{\text{application rate}} + S \qquad (1)$$

$$A_r = 0.02 \text{ to } 0.15(\text{pen area}) + \frac{\text{a-in. runoff/yr.}}{4 \text{ to } 8 \text{ in./yr.}} + 0.05 \text{ to } 0.15(\text{pen area})$$

Spray Runoff Treatment

$$A_r = P + \text{treatment area} + S + \text{emergency irrigation disposal area}$$

$$A_r = 0.02 \text{ to } 0.15(\text{pen area}) + 0.2 \text{ to } 0.5 \text{ (pen area)} + 0.05 \text{ to } 0.15(\text{pen area}) + 0.1 \text{ to } 0.2 \text{ (irrigation disposal area)}$$

Evaporation Disposal

$$A_r = P + \frac{\text{annual runoff}}{\text{moisture deficit}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$A_r = 0.02 \text{ to } 0.15(\text{pen area}) + \frac{\text{a-in. runoff/yr.}}{\text{in./yr. lake evap. - in./yr. rainfall}}$$

Example: Assume that one wishes to build a 10,000-head capacity feedlot with 125 square feet per animal equaling 33 acres of pen area including feed bunks, alleyways, etc. in a 30-inch rainfall area with 6 inches of annual runoff and a 10-inch moisture deficit (40-inches evaporation per year). Considering the maximum space-consuming conditions, the estimated land area requirement for irrigation disposal using Equation (1) is 60 acres; for spray runoff treatment using Equation (2) is 37 acres; and evaporation disposal using Equation (3) is 25 acres.

Irrigation Disposal

(1) $A_r = 0.15(33) + \frac{6(33)}{4} + 0.15(33) \simeq 60$ acres

Spray Runoff Treatment

(2) $A_r = 0.15(33) + 0.5(33) + 0.1(33) + 0.2(60) \simeq 37$ acres

Evaporation Disposal

(3) $A_r = 0.15(33) + \frac{6(33)}{10} \simeq 25$ acres

Solid manure wastes generated from animal feedlots are one of the most critical wastes disposal problems confronting the animal feeding industry. The lack of long-term site availability for solid manure disposal can create an impassible obstacle to efficient feedlot operation. Land application of solid manure, as it is with runoff, is the most practical method of disposal known to present technology. The selection of a feedlot site should include extensive investigation of the land area available for manure disposal.

Fewer problems will be encountered by the feedlot owner who owns sufficient land area for manure disposal. However, total ownership of disposal areas, especially with larger lots (5,000 to 10,000 head plus) may not be practical, and firm advance commitments for manure disposal should be obtained before the first land purchase or construction dollar is spent. These commitments, for example, may be in the form of land leases with renewal options or cooperative contracts between feedlot owners and grain growers which would be in the best interest of all concerned parties. These may require grain growers to accept or buy an allotment of manure in return for special grain prices or manure hauling and spreading services.

The amount of land area needed for solid manure disposal is equal to the amount of manure cleaned from the feed pens divided by the application rate. The amount of beef cattle manure cleaned from feed pens ranges, on a dry weight basis, from 6.5 to 12 pounds per day per animal, depending on animal size, amount of roughage in the feed, and the percentage of soil removed from the pen surface with the manure. The amount of manure to be handled and the disposal land area may be reduced by carefully cleaning the pens to leave from 2 to 3 inches of manure packed on the pen surface, thus reducing the amount of soil to be handled with the manure.

The quantity of manure cleaned from a feedlot may be estimated by using the following equation; where "M" equals tons of dry manure per year:

$$M = \frac{\text{(animal days/yr.) (lbs. manure produced/animal day)}}{\text{factor to convert pounds to tons}} \quad \ldots\ldots(4)$$

$$M = \frac{\text{365 days/yr. (feedlot head capacity) (6.5 to 12 lbs. manure/animal day)}}{\text{2,000 lbs./ton}}$$

Example: Assuming that each animal produces a dry weight equivalent of 12 lbs. of manure daily, the solid manure cleaned from a 10,000 head beef feedlot in one year according to equation (4) equals approximately 21,900 tons.

$$(4) \quad M = \frac{365(10{,}000)(12)}{2{,}000} = 21{,}900 \text{ tons/yr.}$$

The application rate of solid manure ranges from 10 to 40 tons dry weight per acre depending on the type of crops, soil types, and rainfall amounts. The amount of land area required to dispose of solid manure "A_m" is equal to the volume of manure to be disposed of annually, "M" in tons per year, divided by the annual application rate in tons per acre "R" or:

$$A_m = \frac{M}{R} \quad \ldots\ldots (5)$$

Example: Using the 21,900 tons of manure produced on a 10,000 head capacity feedlot, which was estimated in the preceeding example, and a 10 ton/acre/year manure application rate (Figure 1) the estimated acreage required for manure disposal by using equation (5) is 2,190 acres.

$$(5) \quad A_m = \frac{21,900}{10} = 2,190 \text{ acres}$$

Frequent pen cleaning and disposal by direct application to crops can eliminate the need for solid wastes storage. However, the seasonal nutrient needs of crops and soil moisture conditions in wetter or colder climates do not correspond to a systematic schedule of wastes disposal by land application. The application of solid wastes to saturated or frozen soils will, like feedlot runoff, create a contaminated storm run-off problem from the disposal site. Thus, solid wastes storage is a necessity in most climatic and agricultural regions. There is wide variability in the factors which influence the land area needed for this type of storage. In general, one should consider a storage area which is approximately 15-20 percent of the feed pen area in size and which is suitable for the construction of a storage structure which will eliminate surface and ground water pollution.

Manure slurries are most commonly produced in total confinement buildings with slotted floors and in concrete open feedlots with flush type manure removal. Slurries are generally scraped, flushed, or pumped from the pen area at regular intervals ranging from daily to monthly. Thus, specially designed storage structures are a necessity to maintain environmental quality between disposal periods.

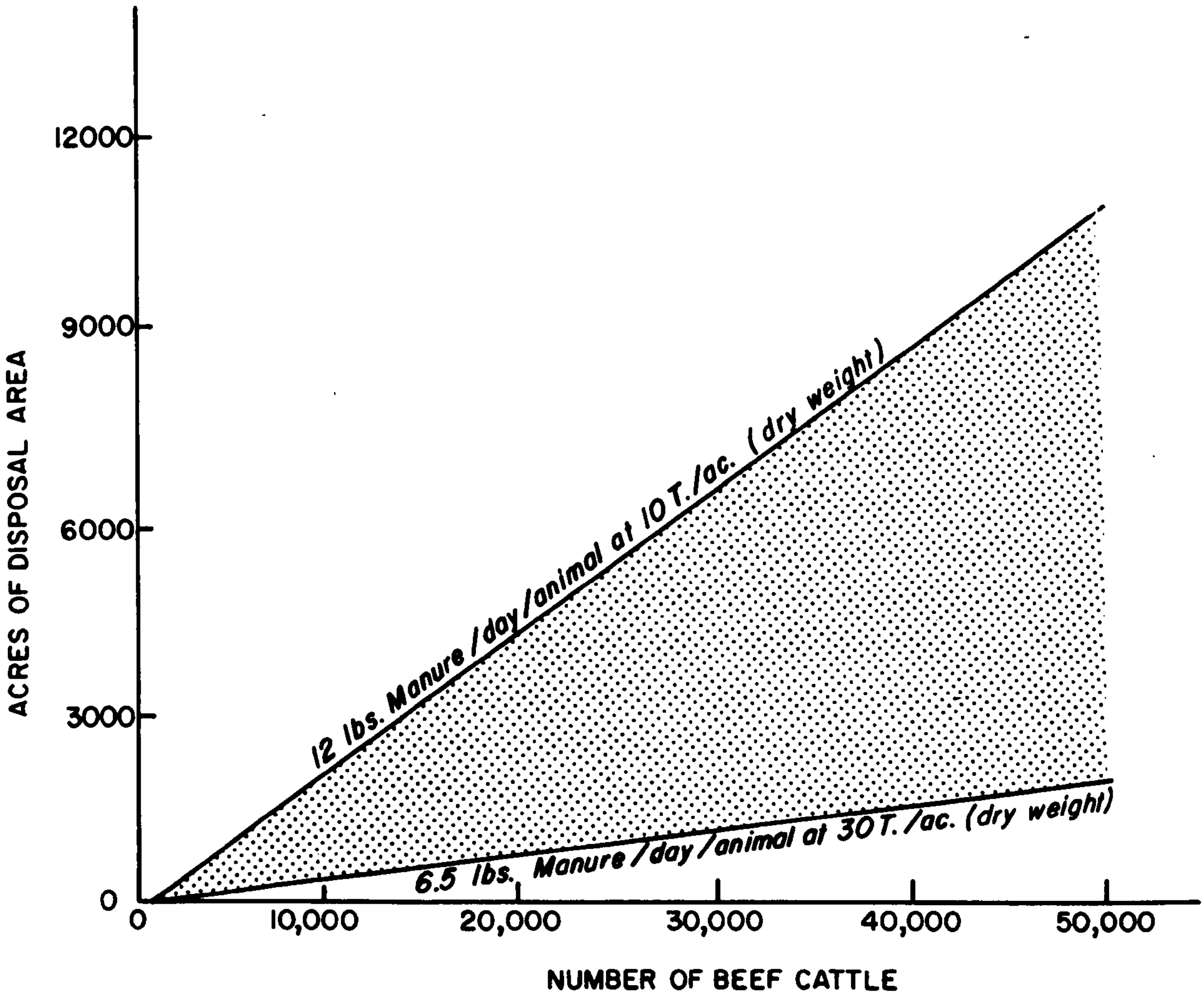

FIGURE 1. LAND AREA REQUIREMENTS FOR DISPOSAL OF SOLID MANURE WASTES

Either deep lagoons or concrete tanks are used for storage. Tanks should be covered to reduce odors and prevent children and animals from becoming trapped in them; for a given storage volume, tanks which have straight sidewalls require less area than lagoons, which generally are designed with sloping sides. Mechanically aerated oxidation ditches are also used for slurry manure storage and have been successfully used directly under the slotted floor in hog confinement buildings where they do not require additional land area. The primary advantage of using this process is one of reducing odors.

The basic equations used to estimate spatial requirements for solid manure disposal on cropland may be used in estimating the area needed for slurry disposal. Manure slurries are a total composite of manure, as excreted, without the changes caused by rainfall leaching. Soil application rates, for this reason, should be reduced from the 10-40 tons per acre suggested for solid manure wastes to 10-20 tons per acre. Additionally, the daily amount of manure produced is approximately 60 pounds per animal. The end result of the decreased application rate and greater amount of manure to be handled is a significant increase in the size of the disposal area.

The required amount of land for both solid and slurry wastes disposal may be greatly reduced by increasing the rate and/or frequency of application; however, this should be done only if the feeder has control of the crops or the land either by leasing or through ownership. This approach in some cases is uneconomical, but firm wastes disposal agreements should be obtained from neighboring landowners before the final decision is made on a site.

The distance that wastes must be hauled for disposal should be kept to an economically feasible minimum. The economic break point for hauling distance may be estimated as follows:

$$D = \frac{F - L - S + M - M^1}{H} \qquad (6)$$

Where: D = maximum economic hauling distance; F = value of commercial fertilizer with equivalent amount of nitrogen, phosphorous, and potassium in one ton of manure in \$/ton; L = loading costs in \$/ton; S = spreading costs in \$/ton; H = hauling costs in \$/ton/mile; and M = price paid farmer by feedlot owner to accept manure in \$/ton; or M^1 = price paid feedlot owner by farmer for manure in \$/ton.

Example: Assume that the nutrient content of a ton of manure is equivalent to four dollars worth of commercial fertilizer, that it costs \$0.35 per ton to load and \$0.90 per ton to spread manure, that the manure hauling can be contracted for \$0.10 per ton/mile and that the amount paid by the farmer to the feedlot owner for the manure is \$1.50 per ton. Then according to equation (6) the maximum economical hauling distance is 12.5 miles.

$$(6) \quad D = \frac{\$4.00 - \$0.35 - \$0.90 - \$1.50}{\$0.10 \text{ per mile}} = \frac{\$1.25}{\$0.10} = 12.5 \text{ miles}$$

A manure irrigation system for pumping a slurry or waste water for field application costs about one-half as much as mechanically hauling and spreading a slurry within one-half mile of the feeding facility. Thus, a site with an area suitable for irrigating slurries within this distance could result in considerable savings for manure disposal.

5. Buffer zone (green belt) around the feeding facility. The basic purpose of developing a buffer zone is to reduce or eliminate the probability of nuisance complaints from the general public. Feedlot operations, in many states, have received nuisance complaints resulting from odors produced on their facilities. Specifically, to mention only a few, beef cattle feedlots in Arizona, Texas, and Kansas and a hog feedlot in Missouri have received court decisions which were in favor of the complainant; some decisions have resulted in cease and desist orders.

Where odors may be of concern, the buffer zone can approximate the configuration of an egg with the facility and all odor producing processes centered near the small end (Figure 2). The actual orientation

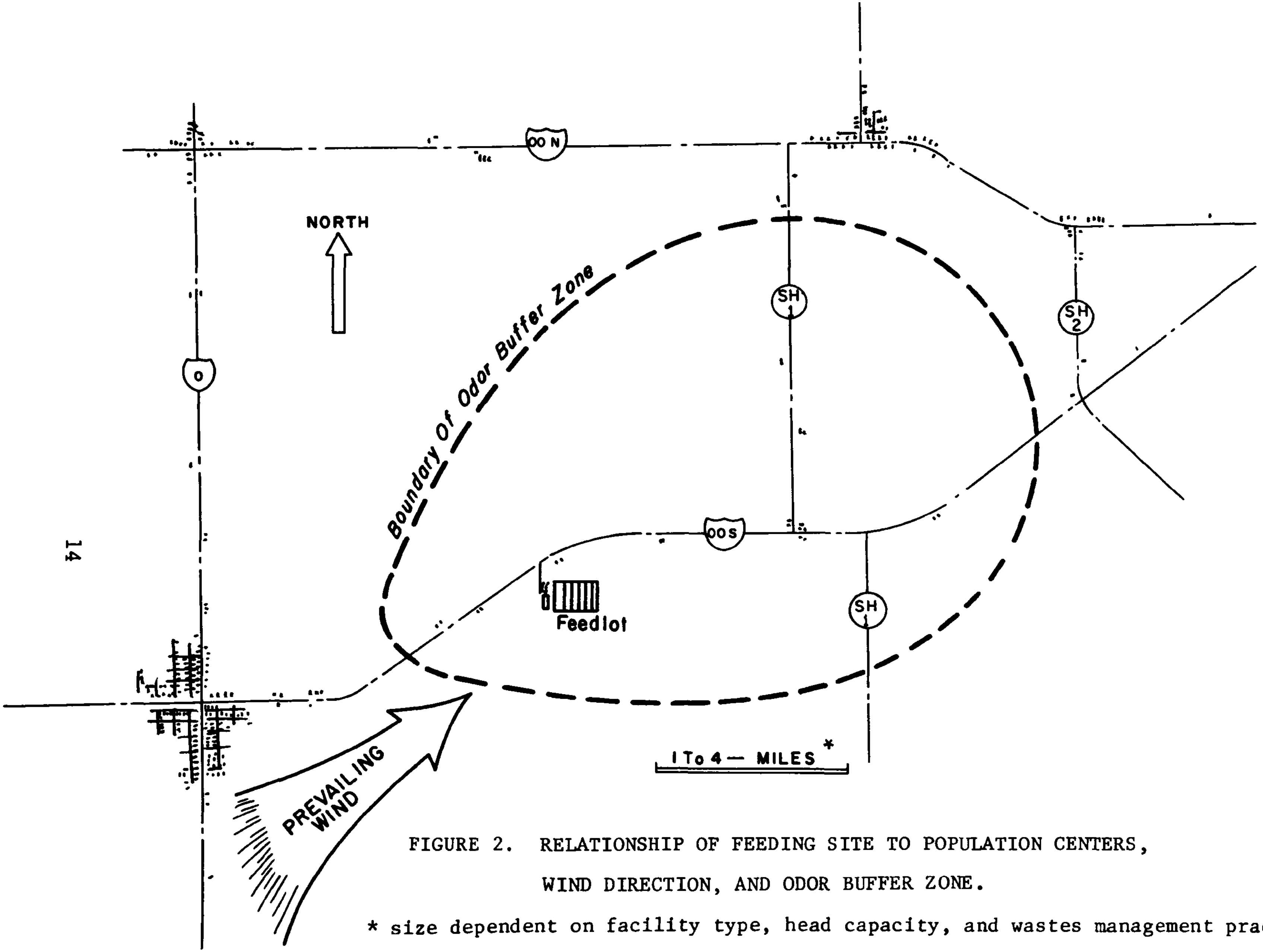

FIGURE 2. RELATIONSHIP OF FEEDING SITE TO POPULATION CENTERS, WIND DIRECTION, AND ODOR BUFFER ZONE.

* size dependent on facility type, head capacity, and wastes management practice

of the axis of the area is dependent upon the direction of the prevailing wind. The size of the buffer zone, usually from 4 to 20 miles along its long axis, is dependent on the size of the feeding operation and type of manure management employed. Obviously, good drainage and housekeeping practices coupled with a prompt disposal schedule may significantly reduce the intensity of odors and thus reduce the size of the buffer zone. In some locations zoning agreements may be entered into with local governing bodies. Zoning may stipulate a specific distance from the operation or a group of feeding operations which is reserved for agricultural uses. Such agreements would allow protection against legal action from residential and recreational development after a feeding operation is established.

Enough space should be allowed around the facility to act as a "green belt." The size of this area need not be expansive but should be large enough for a shelter belt or visual improvement vegetative plantings. Some of this area will be the same as that used for waste disposal or other feedlot operations. The concept is especially important in areas where the operation may be seen from major arterial highways.

Topographic Features

Topography (lay of the land) plays an important role in two respects for selection of a feeding site. The slope and natural drainage to surface waters of any given parcel of land governs its value as a feeding site. Land which is too flat may be poorly drained, and poor drainage results in sloppy pen conditions and increased probability for ground water contamination. On the other hand, surface runoff is difficult to control on land with extreme gradients.

The second role that topography plays in site selection is basically one of economics. Feeding facilities are readily adaptable to sites which for topographical reasons are marginal for most intensive farming. Because of the marginal classification these lands often are priced at a much lower dollar value than is land used for intensive farming. The rugged topography of these sites may create a need for a large amount of earth moving; however, there are earth moving requirements associated with all feeding sites regardless of topography. Additional earth moving costs should be balanced against the lower land costs.

Topographical quadrangle maps in the 7.5 or 15 minute series are available for most of the United States from the United States Geological Survey. Accurate information concerning the contour of the land and its location with respect to water courses, access routes, residential and recreational areas may be obtained by careful inspection of these maps. Preliminary planning layouts may be made for several different sites on topographical maps before making final site selection decisions. After selecting a site, a topographical survey with a contour interval of 1 or 2 feet would expedite the detailed designing of the facility and processes.

During the evaluation of the topographic suitability of sites, one should eliminate all those which do not meet, or cannot be adapted to meet, the following constraints:

1. A minimum of land uphill which will contribute extraneous runoff.

2. A slope for the feed pens with a 2 to 6 percent gradient. Sloppy pen conditions may occur with less than 2 percent pen slope, and uncontrollable runoff may occur with greater than 6 percent pen slope.

3. Space with suitable slope and deep soils for construction of runoff collection and storage facilities.

4. An area used for manure storage, having soil, bedrock, and a deep groundwater table which is located away from natural drainage channels.

5. A dry feedlot access route which may be easily maintained for manure removal during all weather conditions. Access roads through low wet areas or with steep gradients will cause manure removal problems during wet and freezing weather.

6. A low gradient site for runoff disposal which is located away from natural drainage areas.

Not all of the above constraints will apply to total confinement and certain other facility designs, but each should always be considered when appropriate.

A final topographical consideration for site selection is the location of a facility with respect to surface waters. Several states have set control requirements based on specific distances or have developed mathematical formulae which are to be followed when locating near surface waters. This distance will not remove the pollution potential to a surface water course since travel in a drainage channel will not significantly treat the pollutants in the feedlot runoff. In the absence of regulations, a realistic consideration is the selection of a site over which enough control can be exerted to prevent accidental contact of manure and waste water runoff with surface waters.

Microclimates

As discussed earlier, the site selection decisions associated with climate are mainly those related to the type of facility and the wastes handling method. However, the microclimate (ambient climatic or environmental conditions of a specific locale) of a prospective site may have some bearing on its acceptability. Three aspects of the microclimate of a locale are worthy of consideration. These are extremes in wind conditions, solar radiation, and precipitation.

Depending on major climatic conditions, wind affects the operation of a feeding facility in many ways. Too much wind causes dusty pen conditions in dry climates and drifting snow. Inaccessibility and adverse comfort indexes can lead to reduced feed conversion efficiencies in cold climates. In a few instances too little wind can cause animal discomfort in hot and humid areas and may contribute to sloppy pen conditions in cooler areas because of decreased evaporation potentials. Prevailing wind direction is an important factor to consider in any locale when predicting possible sources of odor complaints. Additionally, in mountainous areas, updrafts and downdrafts should be considered in the prediction of possible odor complaints (Figure 3). Wind may be controlled to a certain degree by selecting a site with natural wind protection from vegetative shelter belts or natural land forms. In the North artificial windbreaks have been successfully constructed along the windward side of feed pens in the absence of natural protection.

Solar radiation not only affects the productive efficiencies of animals but is an important factor in the efficiency of waste management and pollution control facilities. The evaporation potential from a wet manure surface is determined by humidity, air movement, and solar radiation. Solar radiation may be controlled to a certain degree by selecting a site with the desired amount of shade or desired placement with respect to the sun's travel. Additional shade may be provided artificially. Feedlots located on northern or eastern slopes receive less intense sunlight, thus reaching maximum temperatures for shorter periods during the day than those located on southern or western slopes. Thus, feedlot sites on northern and eastern slopes are more desirable in warmer climates but require more shelter for the animals in colder climates. In warmer climates this location requires less control of the animal's environment. In colder climates the situation is reversed, and operations should be placed on southern or western slopes to obtain maximum temperature benefits for animal comfort. In these locations proper placement may extend the northerly range of wastes handling, treatment, and disposal processes which have minimum temperature (freezing) constraints.

Precipitation is more important in selection of the general region than it is in selection of a specific locality for location of a feedlot; however, in some regions rainfall may vary considerably (as much as 10 to 15 inches annually) over a very short distance. Snowfall amounts may also vary greatly in a short distance; thus when locating in northern climates, care should be exercised to determine snowfall amounts of local areas so that localities which are snowbond a portion of the

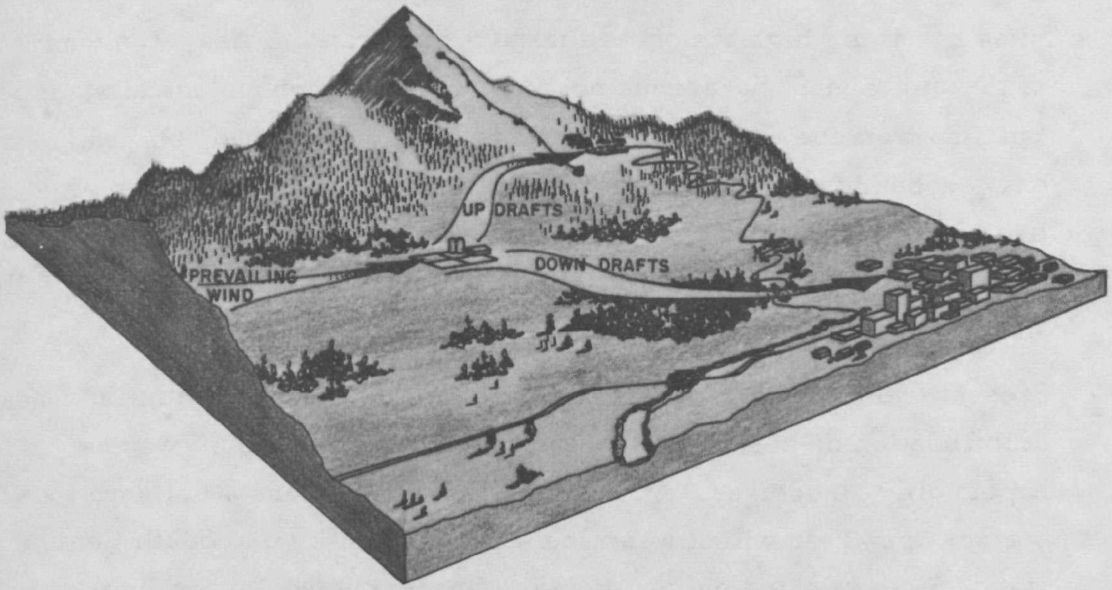

Figure 3. Relationship of Up-drafts and Down-drafts to Prevailing Winds in Mountainous or Hilly Areas

year may be avoided. This point may be insignificant for most of the country and yet unquestionably important for specific localities which characteristically have large variance in annual precipitation.

The localized climate surrounding a feeding site does not affect the performance of animals fed in total confinement facilities. Accessibility is an important consideration of the effects of local climate on these facilities. Sites typified by drifting snow or dust and/or prolonged periods of wet or damp soil conditions tend to limit waste removal access; these should be avoided.

Soils and Geologic Structures

Soil types and the underlying geologic structure of each potential feeding site should be examined to insure maximum protection from groundwater pollution. Highly permeable loose soils, shallow soils over fractured bedrock, and shallow water tables should be avoided in pen areas, runoff and solid manure storage pits, and field disposal sites receiving high runoff and manure application rates. Contamination of groundwater is hazardous not only from the bacteriological standpoint but also from the threat of nitrate poisoning or methemoglobinemia (an oxygen-deprived condition in infants sometimes referred to as blue babies) which is caused by excessive amounts of nitrates in drinking water supplies. This malady afflicts livestock and humans (especially small children and pregnant mothers).

Present trends in some states are directed toward regulating the amount of infiltration or percolation from pen surfaces and liquid wastes impounding structures. An example is the maximum of 0.1 acre foot per acre per year which was recently proposed by one South Central state. Sites selected on heavy soils (fine-particled, expanding, or tight soils) with a low infiltration or seepage rate are, in most cases, ideal for construction of wastes retention and storage structures. The seepage from a structure may be determined, before use, by filling it with unpolluted water, allowing several days to sufficiently saturate or wet the underlying soils, and then measuring the amount of water loss minus class A pan evaporation (lake evaporation on large structures). Seepage tests may be run, for purposes of site selection, on smaller scale by the use of small test ponds if a test pond bottom is at the same soil depth desired for the full scale structure.

In the absence of suitable soil conditions, soil sealing or concrete or asphalt liners can be included in the design of these structures for 300 dollars and up per acre. The advantage realized in careful site selection is, for this reason, of economic importance.

The depth of the water table is also important. A shallow aquifer is more vulnerable to contamination and should be avoided. In areas with fluctuating shallow water tables, concrete manure storage pits and confinement buildings designed with solid bottom manure pits may shift from their original position and suffer damage ultimately resulting in contamination of the aquifer.

Shallow water tables are also vulnerable to contamination when the land is irrigated with large amounts of pollutant-rich runoff waters; this damage is especially serious in areas of glacial till and within the flood plains of rivers, where water tables may be only inches below the surface and the soils are generally sandy or gravelly alluvium.

Social Considerations

Concern for environmental protection has resulted in state regulations and court actions which frequently lead to great expense for compliance. These actions have forced many feedlots to change their methods of operation, and a few have had to reestablish at a more suitable site or go out of business. Environmental controls have not only been placed on surface and ground water pollution but have included odor nuisances. Feedlots have had restraints placed on them solely on the basis of odor complaints from their neighbors.

Strong demands for increased meat production and improved meat quality from the general public do not offset the attendant problems with any lessened demand for environmental improvement. Animal production units seldom yield any monetary benefits directly to the complainants, who will not accept disagreeable odors around their residences, places of work, or recreational areas. In many cases odors may become such a nuisance to individuals that life patterns and established transporation routes are changed to avoid them. This circumstance is not unique to the animal feeding industry but is observed in a great many industrial operations such as oil and gas production, slaughter houses, chemical and plastics manufacturing, etc. All of these industries are feeling the effects of public pressure to eliminate nuisances created by odors, sound, and unsightliness.

The successes of odor control efforts utilizing chemical deodorizers and odor masking agents have, in most cases, been questionable. In many cases, where application of chemicals have masked odors, the measures were temporary and the odors of some of the chemicals were as disagreeable as the manure odors. Perfumed aerosols have been used with some success for short distances in Southwestern states; however, the odors of manure are generally more persistent than the aerosols tested and are easily detected long distances from the source.

The best odor controls are, at present, a policy of good housekeeping coupled with proper pen design and the careful selection of the feeding site. Regular manure removal and disposal and very short runoff retention times can significantly reduce the amount of odor produced. A minimum pen slope of 2 percent enhances adequate drainage and reduces sloppy pen conditions and resulting odors. Manure slurry storage in oxidation ditches produces less odor than anaerobic storage pits. In the Northeast, anaerobic storage pits have been covered to reduce the amount of odor.

Recent years have seen the successful advance of programs for "national beautification." In short, these programs require the use of privacy fences to conceal such unsightly places as junk yards, dumps, freight yards, and salvage yards from public view. In the forseeable future unsightliness and noise emitting from livestock feeding operations may bring about public initiated court actions. The selection of a site with vegetative shelter belts and/or land formations suitable for visual concealment purposes or of one located a sufficient distance from highways may prevent problems which do not yet exist.

The selection of a site should include consideration of prevailing wind direction, of distance from residential areas and public gathering places, and of the attitudes of immediate neighbors. Agreements for free manure application and/or a steady market for neighbors' grain or hay in return for freedom from nuisance complaints may have merit.

Zoning may be used effectively in some areas to prevent the encroachment of residential, shopping, and recreational areas. A very expensive but positive approach to zoning would be the purchase of enough land to create a buffer zone between the animals and society.

The task of co-existing with society will be resolved by locating a site which is remote from the greatest possible number of potential complainants, by isolation through controlling as much surrounding area as possible, and by public relations. Advertising the benefits of feeding operations over personal discomforts may not make manure smell any better, but it may help make the odor more acceptable. In most cases, informing the public of the various pollution controls that are being used on the facility to enhance environmental quality will improve the image of feeding operations and animal production units.

PRACTICAL APPLICATION

Changes in the attitudes and interests of the people of this and many nations over the world have aroused a much needed awareness of our surroundings and the heritage that we are leaving behind for future generations. This awareness has created a need for changes in the ways that industry and agriculture dispose of their wastes. Early in the past decade, wastes disposal practices which were recommended as acceptable included locating feeding sites on steep slopes and near streams or lakes for natural drainage and disposal of runoff wastes in surface waters. Recommended manure disposal practices included filling ravines and ditches, from which the manure eroded away and washed into the streams. Little concern existed for contamination of ground water supplies except where obvious damage would occur to the water supply for the feeding facility.

A typical beef feedlot layout is depicted in Figure 4. The wastes management design used here may have been a recommended practice as late as ten years ago. The extent of environmental unbalance which was created by the various practices utilized in this operational plan was in reality unnecessary but economical. Relocation of the facility on the same site and seven changes of minor economic significance (which included addition of a few wastes handling and management facilities) could have eliminated most of the hazards to the environment.

The same beef feedlot relocated on the same site is depicted in Figure 5. This operation was planned with the use of the present environment protecting concepts of site selection and wastes management. The pen area has been moved onto the more level land, which has clay soil underlaid with a solid dolomite rather than the sandy soil and cavernous limestone which is present on the hill slope. The new site is located away from the small creek and takes advantage of the vegetative shelter belt both as shield against cold north winds and as a visual screen from the road. A ditch to divert extraneous drainage

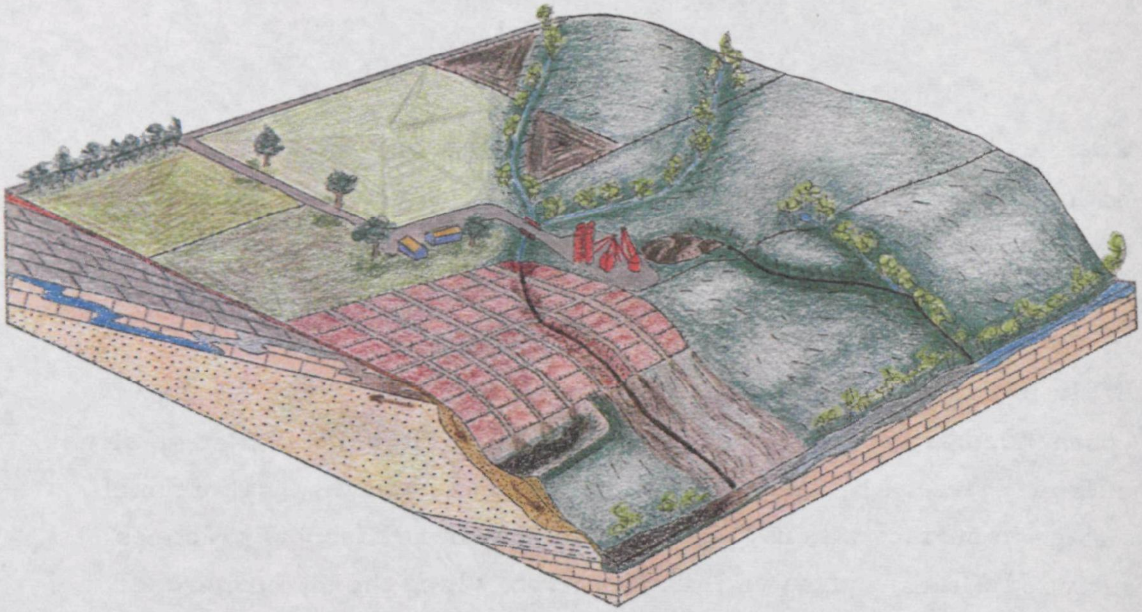

FIGURE 4. TYPICAL BEEF FEEDLOT LAYOUT INCORPORATING OUTMODED DESIGN CONCEPTS

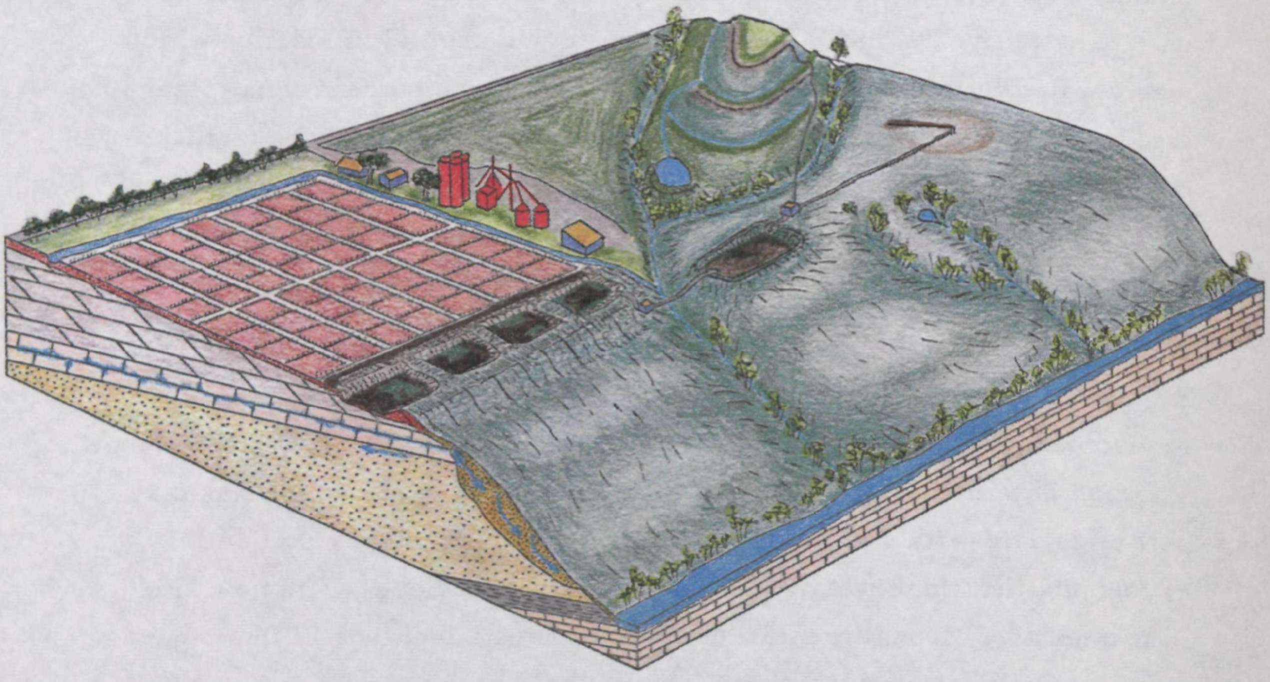

FIGURE 5. TYPICAL BEEF FEEDLOT LAYOUT INCORPORATING ENVIRONMENT PROTECTING DESIGN CONCEPTS

has been constructed around the pen area, and runoff collection ponds have been added all the way across the lower end of the pens. The runoff from the collection ponds is pumped into a holding pond, from which it is distributed onto a pastured area with a large irrigation gun or metered onto a spray runoff treatment slope. The pens are cleaned regularly and the manure is temporarily stored or immediately hauled away and disposed of on agricultural land.

The actual application of good site selection principles is a matter of common sense and the ability to apply existing state regulations. There are no standard numerical guidelines and mathematical formulae applicable to each site selection in every part of the country. This report has been a compilation of the major site selection considerations which are representative of a large percentage of facility designs and most geographic locations. Professional assistance from consulting engineers and/or the governmental agencies listed in the appendices may be needed to solve unique site selection problems.

SELECTED BIBLIOGRAPHY

Climatic

1. Blair, T. A., Climatology, Prentice-Hall, Inc., Englewood, Cliffs, New Jersey (1942).

2. Bond, T. E., R. L. Givens, and S. R. Morrison, Comparative Effects of Mud, Wind and Rain on Beef Cattle Performance, Paper No. 70-406, ASAE (July 1970).

3. Esmay, M. L., Principles of Animal Environment, The AVI Publishing Company, Inc., Westport, Connecticut (1969).

4. Givens, R. L., "Height of Artificial Shades for Cattle in the Southeast," Trans. of the ASAE, No. 3, pp. 312-313 (1965).

5. Givens, R. L., et al., "Influence of Feedlot Pen Design and Winter Shelter of Beef Cattle Performance," Calif. Agr., No. 22, pp. 6-7 (Feb. 1968).

6. Grussing, Don, "Shelter Pay---?" Feedlot, No. 12, pp. 30-32 and 34-35 (Feb. 1970).

7. Henderson, H. E., and M. R. Geasler, Effect of Environment and Housing on the Performance of Feedlot Cattle Under Midwest Conditions, Midwestern Sectional Meeting, American Society of Animal Science, Chicago, Illinois (Nov. 29, 1968).

8. Hoffman, M. P., and H. L. Self, "Shelter and Feedlot Surface Effects on Performance of Yearling Steers," Jour. of Animal Sci., No. 31, pp. 967-972 (Nov. 1970).

9. Kelly, C. F., "Effects of Thermal Environment on Beef Cattle," Agr. Engr., No. 41, pp. 613-614 (Sept. 1960).

10. Kohler, M. A., T. J. Nordenson, and D. R. Baker, Evaporation Maps for the United States, Technical Paper No. 37, Weather Bureau, U. S. Department of Commerce, Washington, D. C. (1959).

11. Miller, R. F., "Space Requirements and Dust Control for Feedlot Cattle," Calif. Agr., No. 16, pp. 14-15 (Dec. 1962).

12. Nelson, G. L., "Effects of Climate and Environment on Beef Cattle," Agr. Engr., No. 40, pp. 540-544 (Sept. 1959).

13. Pratt, G. L., "Confinement Beef Housing for Air and Water Pollution Control in Cold Climates," Conference of General Collaborators from North Central Agricultural Experiment Station, Northern Utilization Research and Development Division, Peoria, Illinois (Mar. 23-24, 1970).

14. Two to Ten Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States, Technical Paper No. 49, Weather Bureau, Department of Commerce, Washington, D. C. (1965).

Legal Aspects

15. Bernard, H., "Effects of Water Quality Standards on the Requirements for Treatment of Animal Wastes," Animal Wastes Management, Cornell University Conference on Agricultural Wastes Management, Syracuse, New York (1969).

16. Fish, H., "Water Pollution Prevention Requirements in Relation to Farm-waste Disposal," Proceedings of Symposium on Farm Wastes, Paper 6, University of Newcastle, pp. 38-43 (1970).

17. Hannah, H. W., "Possible Defenses Against Nuisance Complaints," Poult. Dig., p. 601 (Dec. 1970).

18. Happer, L., "Supreme Court Upholds Judgements in HBI Case," Mo. Ruralist, p. 12 (Jan. 23, 1971).

19. King, D. R., "Environmental Pollution---Now and in the Years Ahead," Animal Wastes Management, Cornell University Conference on Animal Wastes Management, Syracuse, New York (1969).

20. Levi, D. R., Pork Producers and Pollution: Legal Aspects, Agr. Econ. Paper No. 1970-6, University of Missouri-Columbia (1970).

21. Levi, D. R., and J. C. Holstein, "Stockmens-Liability Under the Missouri Nuisance-Law," Science and Tech Guide, University of Missouri-Columbia Ext. Div., Agr., Econ. File.

22. Levi, D. R., "Legal-Aspects Pertaining to Environmental Regulations in Pork-Production," American Pork Congress, Des Moines, Iowa (Mar. 3, 1971).

23. Miner, J. R., "Raising Livestock in the Urban Fringe," Agr. Engr., 51, (12), pp. 702-703 (Dec. 1970).

24. Moorman, R., Jr., "Controlling Odors from Cattle Feedlots and Manure Dehydration Operations," Air Pol. Cont. Assn. Jour., Vol. 15, pp. 34-35 (1965).

25. Paulson, D. J., "Commerical Feedlots - Nuisance, Zoning, and Regulations," Washburn Law Jour., 6, pp. 493-507 (1967).

26. Schwiesow, W. F., "State Regulations to Livestock Feedlot Design and Management December 1970," Bulletin 42-189, USDA, ARS (April 1971).

27. Stubblefield, T. M., "Problems of Cattle Feeding in Arizona as Related to Animal-Waste Management," Proceedings National Symposium on Animal Waste Management, ASAE Sp-0366, pp. 120-122 (1966).

28. Walker, W. R., "Legal-Restraints on Agricultural-Pollution," Relationship of Agriculture to Soil and Water Pollution, Cornell University Conference on Agricultural Waste Management, Syracuse, New York (1970).

Pollutional Effects

29. Duffer, W. R., R. D. Kreis, and C. C. Harlin, Effects of Feedlot Runoff on Water Quality of Impoundments, Environmental Protection Agency, Water Pollution Control Research Series, Report No. 16080GG07/71 (1971).

30. Law, J. P., Jr., and H. Bernard, "Impact of Agricultural Pollutants on Water Uses," Trans. of ASAE, Vol. 13, (4) pp. 474-478 (July-Aug. 1970).

31. Resnik, A. V., and J. M. Rademacher, "Animal-Waste Runoff - A Major Water-Quality Challenge," Water Quality Management Problems in Arid Regions, USDI (Oct. 1970).

32. Scalf, M. R., W. R. Duffer, and R. D. Kreis, Characteristics and Effects of Cattle Feedlot Runoff, 25th Annual Purdue Industrial Waste Conference, Lafayette, Indiana (May 1970).

Social Aspects

33. Agricultural Waste in an Urban Environment, Conference Proceedings, New Jersey Department of Agriculture, Trenton, New Jersey (Sept. 1970).

34. Alexander, R. M., "Social Aspects of Environmental Pollution," Agr. Sci. Rev., Vol. 9, No. 1, pp. 9-18 (1971).

35. Fairbank, W. C., Waste Disposal Problems in Highly Populated Areas, Extension Agricultural Engineering, University of California, Riverside, California (1970).

36. Miner, J. R., "Environment's Challenge: Acceptance as a Neighbor or Rejection as a Nuisance," Feedlot, No. 13, pp. 14-15, 34 (May 1970).

37. Proceedings of Farm Animal Waste and By-Product Management Conference, University Extension, University of Wisconsin (Nov. 1969).

Soils and Groundwater

38. Lehman, O. R., B. A. Stewart, and A. C. Mathers, Seepage of Feedyard Runoff Water Impounded in Playas, Bulletin Mp-944, Texas Agricultural Experiment Station, Texas A&M University, College Station, Texas (Feb. 1970).

39. Mathers, A. C., and B. A. Stewart, Nitrogen Transformation and Plant Growth as Affected by Applying Large Amounts of Cattle Feedlot Wastes to Soil, USDA, ARS, SWCRD, Southern Plains Branch, Bushland, Texas (1970).

40. Mielke, L. N., et al., "Groundwater Quality and Fluctuation in a Shallow Unconfined Aquifer Under a Level Feedlot," Relationship of Agriculture to Soil and Water Pollution, Cornell University Conference on Agricultural Waste Management, Syracuse, New York (1970).

41. Stewart, B. A., et al., "Nitrate and Other Water Pollutants Under Fields and Feedlots," Jour. Env. Sci. and Tech., No. 1, pp. 736-739 (1967).

General Information

42. Bates, D. W., and L. K. Lindor, The Influence of Housing on Gains of Beef Cattle in Five Different Structures, ASAE Paper No. 70-902 (Dec. 1970).

43. Beef Handbook, Housing and Equipment, Midwest Plan Service, Iowa State University, Ames, Iowa (1968).

44. Butchbaker, A. F., et al., Evaluation of Beef Waste Management Alternatives, Oklahoma State University, Stillwater, Oklahoma. Environmental Protection Agency, Water Pollution Control Research Series, Report No. 13040FXG10/71 (In press).

45. George, R. M., et al., The Missouri Approach to Animal Wastes Management, Bulletin MP 232/71/1M, Missouri Water Pollution Board and Extension Division, University of Missouri, Columbia (1971).

46. Gilbertson, C. B., et al., The Effect of Animal Density and Surface Slope on Characteristics of Runoff, Solid Wastes and Nitrate Movement on Unpaved Beef Feedlots, Bulletin SB 508, Agricultural Experiment Station, University of Nebraska, Lincoln (1970).

47. Hanson, R. W., Livestock Waste Disposal and Water Pollution Control, Bulletin 4802, Cooperative Extension Service, Colorado State University, Fort Collins, Colorado (Oct. 1971).

48. Loehr, R. C., Pollution Implications of Animal Wastes--A Forward Oriented Review, Robert S. Kerr Water Research Center, FWPCA, USDI, Ada, Oklahoma (1968).

49. Mahoney, G. W. A., G. L. Nelson, and S. A. Ewing, "Performance of Experimental Close-Confinement (Caged) Cattle Feeding Systems," Trans. of the ASAE, No. 12, pp. 631-633 and 637 (1969).

50. Olson, E. A., Waste Management for Feedlots, Bulletin E. C. 71-785, Cooperative Extension Service, University of Nebraska, Lincoln (1971).

51. Shuyler, L. R., Design for Feedlot Waste Management--Using Feedlot Waste, Continuing Education Seminar, Kansas Engineering Society, Topeka (Jan.23, 1969).

52. Spahr, S. L., "Animal Waste Disposal Becomes a More Difficult Problem," Ill. Res., Vol. 12: 4, pp. 4-5 (1970).

53. Structures and Environment Handbook, Midwest Plan Service, Ames, Iowa (Sept. 1970).

54. Thomas, R. E., J. P. Law, Jr., and C. C. Harlin, "Hydrology of Spray-Runoff Wastewater Treatment," Journal of Irrigation and Drainage Division, Proceedings of American Society of Civil Engineer, Vol. 96, pp. 289-298 (Sept. 1970).

55. Wells, D. M., et al., Control of Water Pollution from Southwestern Cattle Feedlots, Fifth International Conference on Water Pollution Research, San Francisco, California (July 1970).

APPENDICES

Current research findings concerning animal wastes management, treatment, and disposal may be obtained by contacting:

The Environmental Protection Agency, National Animal Feedlot Wastes Research Program, Robert S. Kerr Environmental Research Laboratory, Box 1198, Ada, Oklahoma 74820 or Agricultural and Marine Pollution Control Section, Applied Science and Technology Branch, Office of Research and Monitoring, Washington, D. C. 20460.

The state and local offices of the U.S. Department of Agriculture's Cooperative Extension Service, Soil Conservation Service, and Agricultural Research Service.

Climate and rainfall data may be obtained by request to the U.S. Department of Commerce, Weather Bureau Technical Papers from the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D. C. Microclimatic conditions may be obtained from local offices of the U.S. Weather Bureau.

Topographic maps may be obtained from the U.S. Geological Survey, Denver Distribution Section, Federal Center, Denver, Colorado 80225, for those areas which lie west of the Mississippi River, and from the U.S. Geological Survey, Washington Distribution Section, Washington, D. C. 20242, for those areas which lie east of the Mississippi River.

Information concerning state regulations and permits may be obtained from the following state agencies:

Alabama. The Water Resources Division, Alabama Geological Survey; State Department of Public Health; Water Improvement Commission; Alabama Department of Agriculture and Industries; State Office Building, Montgomery, Alabama 36104.

Alaska. State Department of Health and Welfare, Division of Environmental Health, Pouch H, Juneau, Alaska 99801.

Arizona. The Arizona Livestock Sanitary Board, Capitol Annex-Room 322, Phoenix, Arizona 85007. The Sanitation Division, State Health Department, 4019 N. 33rd Avenue, Phoenix, Arizona 85029.

Arkansas. Arkansas Department of Pollution Control and Ecology, 8001 National Drive, Little Rock, Arkansas 72209.

California. The California Resources Agency, State Water Resources Control Board, 1416 9th Street, Sacramento, California 95814.

Colorado. The Water Pollution Control Division, State Department of Health, 4210 East 11th Avenue, Denver, Colorado 80220.

Connecticut. The Dairy Division, and The Water Resources Commission, State Department of Agriculture and Natural Resources, 165 Capitol Avenue, Hartford, Connecticut 06115. State Department of Health, 79 Elm Street, Hartford, Connecticut 06115.

Delaware. Water Resources Section, Division of Environmental Control, Department of Natural Resources, Natural Resources Building, Dover, Delaware 19901.

Florida. The State Department of Air and Water Pollution Control, 315 S. Calhoun Street, Tallahassee, Florida 32301. The Division of Health, State Department of Health and Rehabilitative Services, Box 210, Jacksonville, Florida 32201.

Georgia. The Industrial Waste Section, Georgia Water Quality Board, and the Georgia Department of Public Health, 47 Trinity Avenue, S.W., Atlanta, Georgia 30334.

Hawaii. Hawaii State Department of Health, P. O. Box 3378, Honolulu, Hawaii 96813.

Idaho. Water Pollution Control Section, Environmental Improvement Division, Idaho Department of Health, Statehouse, Boise, Idaho 83701.

Illinois. Illinois Environmental Protection Agency, 215 S. First Street, Champaign, Illinois 61820.

Indiana. Industrial Waste Disposal Section, Indiana State Board of Health, 1330 West Michigan Street, Indianapolis, Indiana 46206. State Department of Natural Resources, State Office Building, 100 N. Senate Avenue, Indianapolis, Indiana 46204. The Air Pollution Control Division, State Board of Health, 1330 W. Michigan Street, Indianapolis, Indiana 46206.

Iowa. The Iowa Water Pollution Control Commission, Department of Health, Lucas State Office Building, Des Moines, Iowa 50319. The Iowa Natural Resources Council, Grimes State Office Building, Des Moines, Iowa 50319. The Environmental Engineering Service, Iowa State Health Department, Lucas State Office Building, Des Moines, Iowa 50319.

Kansas. The Division of Environmental Health, Kansas State Department of Health, and the Livestock Sanitary Commission, Animal Health Department, State Office Building, Topeka, Kansas 66612.

Kentucky. The Kentucky Water Pollution Control Commission; the Water Pollution Division and the Solid Waste Division, Kentucky Department of Health, 275 E. Main Street, Frankfort, Kentucky 40601. The Division of Livestock Sanitation, Kentucky Department of Agriculture, Capitol Annex Building, Frankfort, Kentucky 40601.

Louisiana. The Louisiana Stream Control Commission, P. O. Drawer FC, University Station, Baton Rouge, Louisiana 70803. The Louisiana Livestock Sanitary Board, P. O. Box 44003, Capitol Station, Baton Rouge, Louisiana 70800. The Louisiana State Department of Health, State Office Building, P. O. Box 60630, New Orleans, Louisiana 70160.

Maine. Site Selection Program, Maine Environmental Improvement Commission, State House, Augusta, Maine 04330.

Maryland. The Maryland Department of Water Resources, State Office Building, Annapolis, Maryland 21404.

Massachusetts. The Water Pollution Control Division, Department of Natural Resources, 100 Cambridge Street, Boston, Massachusetts 02202.

Michigan. The Water Resources Commission, Department of Natural Resources, Steven T. Mason Building, Lansing, Michigan. The Air Pollution Control Section, Division of Engineering, State Department of Public Health, 3500 N. Logan, Lansing, Michigan 48914.

Minnesota. The Minnesota Pollution Control Agency, 717 Delaware Street, S.E., Minneapolis, Minnesota 55440.

Mississippi. Mississippi Air and Water Pollution Control Commission, P. O. Box 827, Jackson, Mississippi 39205.

Missouri. The Missouri Water Pollution Board and the Division of Health, State Department of Public Health and Welfare, 112 West High, P. O. Box 154, Jefferson City, Missouri 65101.

Montana. The State Department of Health, Helena, Montana 59601.

Nebraska. The Nebraska Water Pollution Control Council, State Department of Health, State House Station, Lincoln, Nebraska 68509.

Nevada. Bureau of Environmental Health, Division of Health, State Department of Health and Welfare, 201 S. Fall Street, Carson City, Nevada 89701.

New Hampshire. The State Department of Water Supply and Pollution Control, Prescott Park, 105 Loudon Road, Concord, New Hampshire 03301. The Division of Public Health, Department of Health and Welfare, 61 S. Spring Street, Concord, New Hampshire 03301.

New Jersey. The New Jersey Department of Environmental Protection, P. O. Box 1390, John Fitch Plaza, Trenton, New Jersey 08625.

New Mexico. The Environmental Services Division, State Department of Health and Social Services, and the Environmental Improvement Agency, P. O. Box 2348, Santa Fe, New Mexico 87501.

New York. Bureau of Industrial Waste, Division of Pure Waters, Department of Environmental Conservation, Albany, New York 12201. New York State Department of Health, 845 Central Avenue, Albany, New York 12206.

North Carolina. Water Quality Division, State Department of Water and Air Resources, P. O. Box 27048, Raleigh, North Carolina 27611.

North Dakota. The Division of Water Supply and Pollution Control, Environmental Health and Engineering Services, State Department of Health, Bismarck, North Dakota 58501.

Ohio. The Ohio Department of Health and the Ohio Water Pollution Control Board, P. O. Box 118, Columbus, Ohio 43216.

Oklahoma. Regulatory Services Division, Oklahoma State Department of Agriculture, 122 Capitol Building, Oklahoma City, Oklahoma 73105. Sanitation Division, Environmental Health Services, Oklahoma State Department of Health, 3400 North Eastern, Oklahoma City, Oklahom 73105.

Oregon. The State Department of Environmental Quality, State Office Building, 1400 S.W. 5th Avenue, Portland, Oregon 97201.

Pennsylvania. The State Department of Environmental Resources, P. O. Box 2351, Harrisburg, Pennsylvania 17120.

Rhode Island. Environmental Health Services, State Department of Health, State Office Building, Providence, Rhode Island 02903.

South Carolina. The South Carolina Pollution Control Authority, Owen Building, 1321 Lady Street, P. O. Box 11628, Columbia, South Carolina 29211.

South Dakota. The South Dakota Committee on Water Pollution, State Office Building No. 2, Pierre, South Dakota 57501. State Department of Health, State Capitol, Pierre, South Dakota 57501.

Tennessee. Division of Stream Pollution Control, Tennessee Department of Public Health, Cordell Hull Building, Nashville, Tennessee 37219.

Texas. The Texas Water Quality Board, 1108 Lavaca Street, Austin, Texas. The Texas State Department of Health, 1100 W. 49th Street, Austin, Texas 78756. The Texas Air Control Board, 320 E. 53rd Street, Austin, Texas. The Texas Animal Health Commission, Sam Houston Building, Austin, Texas.

Utah. The Water Pollution Committee, Division of Health, State Department of Social Services, 44 Medical Drive, Salt Lake City, Utah 84113.

Vermont. The State Department of Agriculture and the Agency of Environmental Conservation, Montpelier, Vermont 05602.

Virginia. The Pollution Abatement Division, Virginia Water Control Board, P. O. Box 11143, Richmond, Virginia 23230.

Washington. State Department of Agriculture, General Administration Building, P. O. Box 218, Olympia, Washington 98501. The Water Resources Division, State Department of Ecology, General Administration Building, Olympia, Washington 98501.

West Virginia. The Sanitary Engineering Division, State Department of Health, Charleston, West Virginia 25305. The Division of Water Resources, Department of Natural Resources, Charleston, West Virginia 25305.

Wisconsin. The Department of Natural Resources, Box 450, Madison, Wisconsin 53701.

Wyoming. The Division of Health and Medical Services, State Department of Health and Social Services, State Office Building, Cheyenne, Wyoming 82001.