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Full Length Research Paper

Comparisons of alternative feedlot runoff management systems

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Two vegetative treatment and containment systems were designed in Oliver and Dunn Counties of North Dakota, USA. The results showed that unit costs for the systems designed in Oliver County were 8.83 and 7.18 $/m^2 for vegetative treatment system and containment systems, respectively. Same values for Dunn County design were 7.22 and 5.82 $/m^2. According to the results, vegetative treatment systems are not always the best practice to manage feedlot runoff. The topography and climate of the location should be carefully studied before making a decision.

Key words: Agricultural runoff, vegetative treatment systems, storage pond.

INTRODUCTION

Storing feedlot runoff is an environmental concern because of the potential for contamination of water resources. The use of containment structures such as ponds and lagoons is a common practice at feedlot operations (Parker et al. 1999a). Seepage of liquid and contamination of potential drinking water supplies is one of the environmental concerns with containment structures (Parker et al., 1999b; Ciravolo et al., 1979; Clark, 1975; Robinson, 1973). Westerman et al. (1995) reported that accurate estimation of environmental impacts of seepage from containment structures is complicated because of the difficulty of obtaining information on hydraulic domain. Construction of pond liners from compacted clay or geo-membranes is one alternative solution to this problem. However, liners may also fail over the time (Woodbury et al., 2002). Another way of managing feedlot runoff is to develop a system where there is no long-term storage structures needed. This method is often called “vegetative treatment system (VTS)”. VTSs are the areas that designed to infiltrate the runoff and utilize the nutrients flowing from the feedlot. A VTS consists of three segments: a sediment settling basin, a flow distribution device, and an infiltration area. There are six types of VTS available including, sloped vegetated treatment areas (VTA), vegetative infiltration basins (VIB), terraces, constructed wetlands, sprinkler VTAs, and tree treatment areas (Henry et al., 2006). This alternative is generally appropriate for small operations or operations in which use of an irrigation system is not economical (Miner et al., 2000). The keys for a successful VTS application are flat slope and bottom, dense vegetation, and uniform spreading of the effluent across the width. Also, outside water should be excluded by building clean water diversion channels or dikes. The effectiveness of the system depends on maintenance. The system fails when the channelization occurs (Lorimor et al., 2002). The sheet flow may be achieved by using flow distribution device or channel. It also helps distribute solids and nutrients. One or more gated pipes or re-distribution channels should be used depending on the size of the infiltration area and topography. The major disadvantage of this system is the amount of land and earth work required (Harpner et al., 2000).

Feedlot operators are interested in using VTSs which require relatively less capital investment. However, in some cases, cost of these systems may not be as low as expected. Also, applicability of these systems may not be possible for all operations. Availability of spreading or infiltration area, number of days on feed, uniformity of discharge to the infiltration area, proximity to creeks, roads, and neighbors are limiting factors. When a VTS is not an option, use of a containment system is necessary (Kizil, 2006a). The objectives of this study were to 1) discuss about alternative feedlot runoff management systems, 2) compare construction costs of containment and VT systems, and 3) provide basic design criteria for both

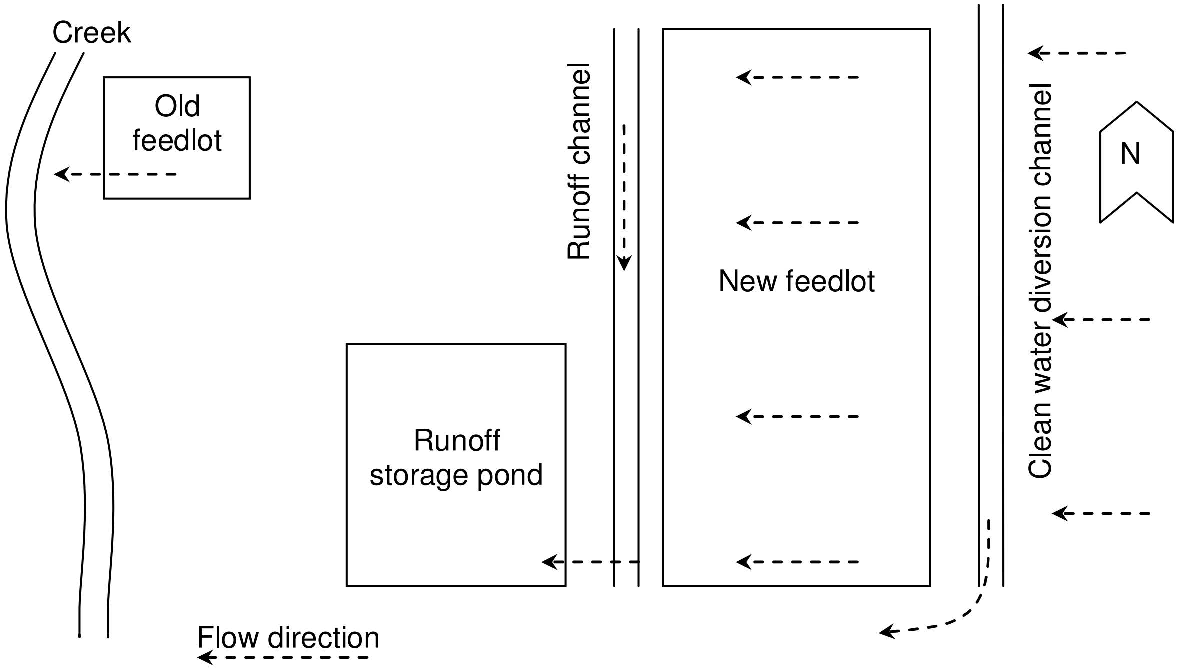

Figure 1. Containment system design layout for operation 1.

systems.

MATERIALS AND METHODS

Operations

Operation 1: Operation 1 was located in Oliver County, North Dakota, USA. This feedlot operation was used 12 months/year and averages 140 heads beef cattle and covered 4 - 6 ha area. The producer wanted to abandon the feedlot, and replace them to the east. The potential problem with the old feedlot was the runoff from the existing lots draining into creek next to operation. The new feedlot was designed to accommodate up to 300 heads. The environmental concern and possibly a violation of North Dakota Department of Health (NDDH) regulations, was that this feedlot runoff was entering waters of the state and impacting water quality. Two alternative options were designed for this operation including VTS and containment. The items that needed to be addressed to implement containment system were as follows: (1) contain runoff from feedlot areas, (2) divert clean water around operation, (3) lay out new feedlot to provide good drainage, (4) provide adequate area to replace abandon areas (Figure 1).

NDDH regulations requires that a VTS system should be able to contain a runoff from a 25-year, 24 h rainfall event, and nutrients in the runoff should be utilized by the crops grown within the VTS. If the soils and topography are not suitable to ensure uniform distribution of runoff and utilization of nutrients alternative options should be considered. Therefore; the above mentioned 4 items implemented in the designing of VTS system for this operation like in the containment system (Figure 2). Runoff distribution, re-distribution, and containment channels designed to provide a uniform sheet flow and 25-year, 24 h runoff storage.

Laboratory tests showed that material from test pits were a lean clay (CL) (Figure 3). There were more than 3.4 m of continuous CL between the potential water table and planned pond bottom, therefore a clay liner was not required to seal the pond.

Operation 2: This was a feeding operation used mainly 3 - 4 months/year and averages 700 head in a 14 - 16 ha area. Natural drainage flows into the Knife River, then into the Missouri River. The operator wanted to use old feedlots which were located on the north of his section with a vegetative filter strip that will be constructed on the east of the feedlot (this is what the design reflects). Also, the producer had another feedlot located on the south-east of above-mentioned north feedlot. There were some expansions to the east of these lots. A new feedlot having 8 pens was proposed to the south of these old south lots. North feedlots drained into the VTS, and the runoff from old and new south feedlots were collected in a containment pond (Figure 4).

The goals of this project were to improve water quality of the nearby water bodies in a manner that would be both beneficial environmentally and cost effective for the producer and fiscal sponsor and to expand facility to accommodate up to 700 heads.

Like in the operation 1, following items addressed to implement containment system: (1) contain runoff from feedlot areas, (2) divert clean water around operation, (3) lay out new feedlot to provide good drainage, (4) provide adequate area to replace abandon areas.

With respect to the pond location, the soil profile did not consist of a continuous clay layer (Test pits 1, 2, and 3). Clay soil was found from the south west of the pond area (Test pit 4) (Figure 5). Laboratory tests showed that material from two test pits were fat clay (CH) that is suitable for lining the pond bottom and side slopes. The project areas were surveyed with a Trimble 5700 RTK-GPS (Trimble Navigation Ltd., Sunnyvale, California) survey system. The survey data uploaded to Autodesk Land Desktop and Civil 3D (Autodesk Inc. 111 McInnis Parkway, San Rafael, CA, USA) software to create contour maps and conduct design. In the hydrological calculations HydroCAD Stormwater Modeling software (HydroCAD Software Solutions LLC, Chocorua, NH, USA) was used.

In the design of containment systems annual runoff, 25-year, 24 h storm runoff, rainfall on pond surface area, solids runoff, and 30.5 cm (1 ft) of freeboard were considered. Clean water diversion

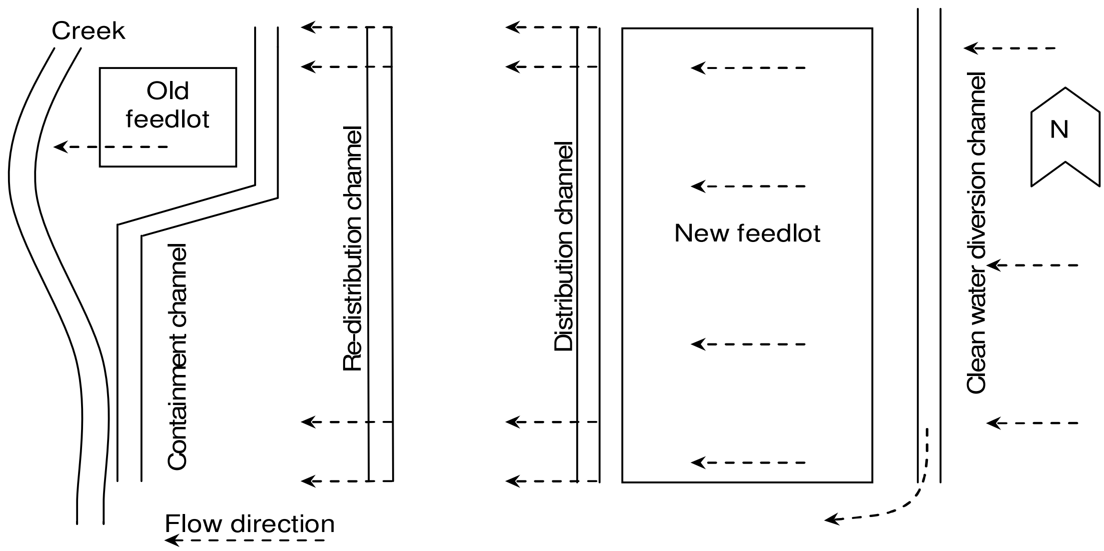

Figure 2. VTS design layout for operation 1.

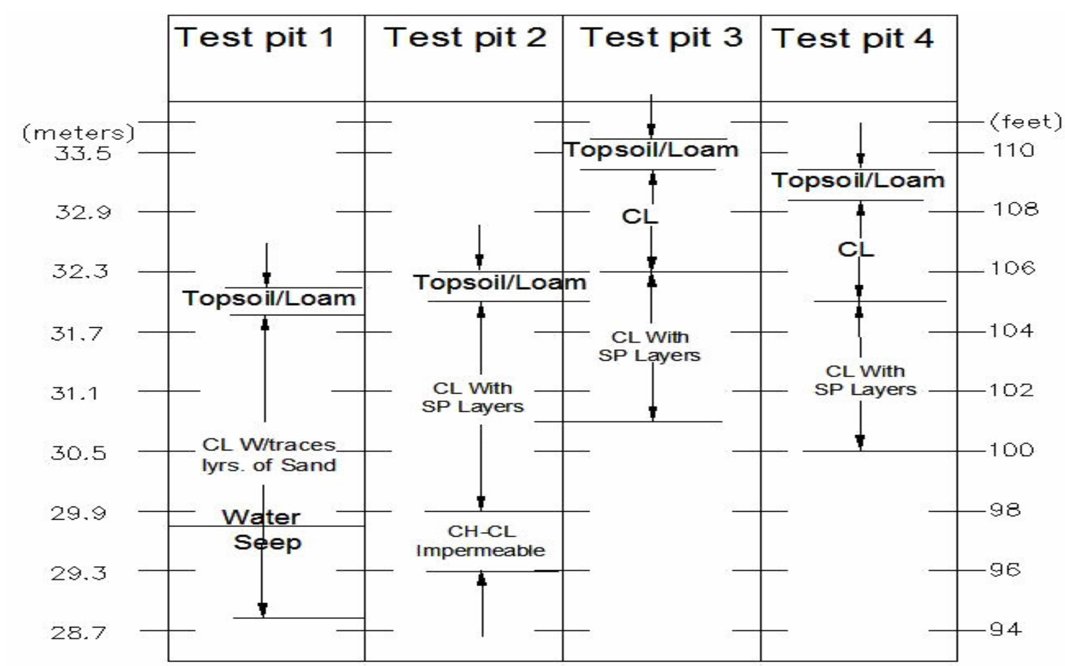

Figure 3. Log of test pits for operation 1.

channels and dikes were designed to minimize volume requirements (AWMFH, 2009).

RESULTS AND DISCUSSION

The results from the cost estimations for VT and containment systems are depicted in Table 1 for operation 1. The total cost estimations were $ 123,115 and $ 100,110 for VT and containment systems, respectively. The cost estimations were based on the unit costs published in NPSPC (2005). The major cost items in feedlot runoff management systems are generally excavation/earth fill, concrete, and fencing. The producer didn't want to install a fence-line feeding system to reduce the cost by minimizing the concrete usage.

Therefore, in this operation the primary costs item were excavation/earth fill and fencing. Even tough it is believed that the VTSs require less earth work; in this particular design and many others, topography makes big amounts of earth work necessary. In order to maintain uniform

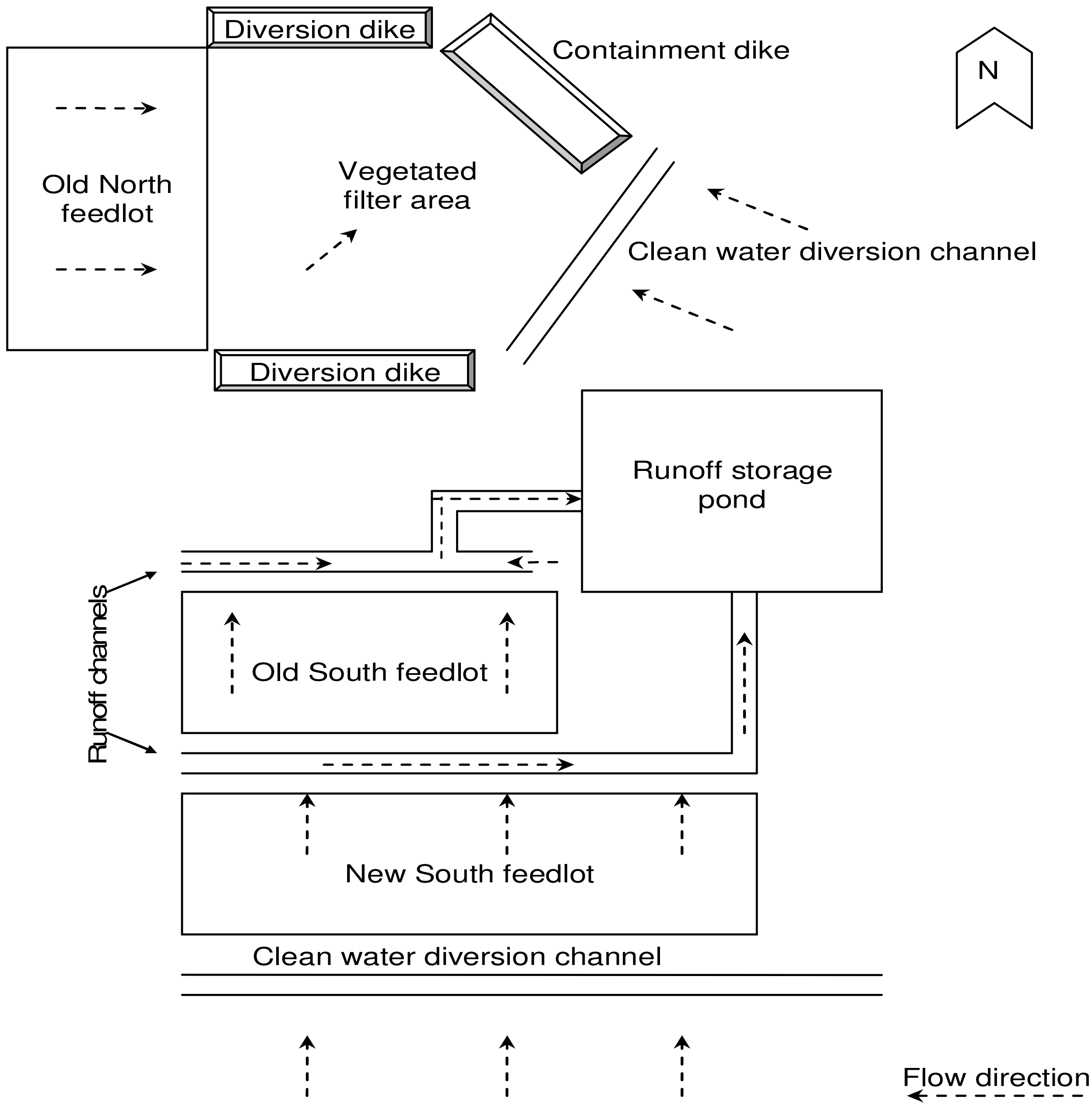

Figure 4. Containment and VTS design layout for operation 2.

sheet flow throughout the system, two runoff distribution channels were designed. The topography and prior experiences made the installation of second distribution channel necessary. The channel bottoms had 0% slope followed by a perforated pipe (Figure 6). To meet state regulations and maintain uniform sheet flow, more earth work required in VTS. Since there is no settling facility precedes the channel, the debris that will accumulate in the channel should be cleared occasionally. Also, good maintenance of the pipe is a must in the performance of the system. The 0% slope of pipe is generally difficult to maintain because of the cattle movement around it.

The producer of operation 1 decided to apply containment pond system. Therefore, as-built values for VTS are not available. Some as-built values are given in Table 2.

In operation 2, a VTS was designed for old north feedlot, and a containment system was designed for south feedlots. Cost items and their percentages in total cost for both systems are given in Table 3. In the operation 1 cut/fill amount was 129/42 m^3 for containment pond that stores runoff from a 300-head feedlot. The same ratio for the pond in operation 2 that stores runoff from a 500-head feedlot was 530/301 m^3. Therefore, topography of the location was the primary factor that affected the cost.

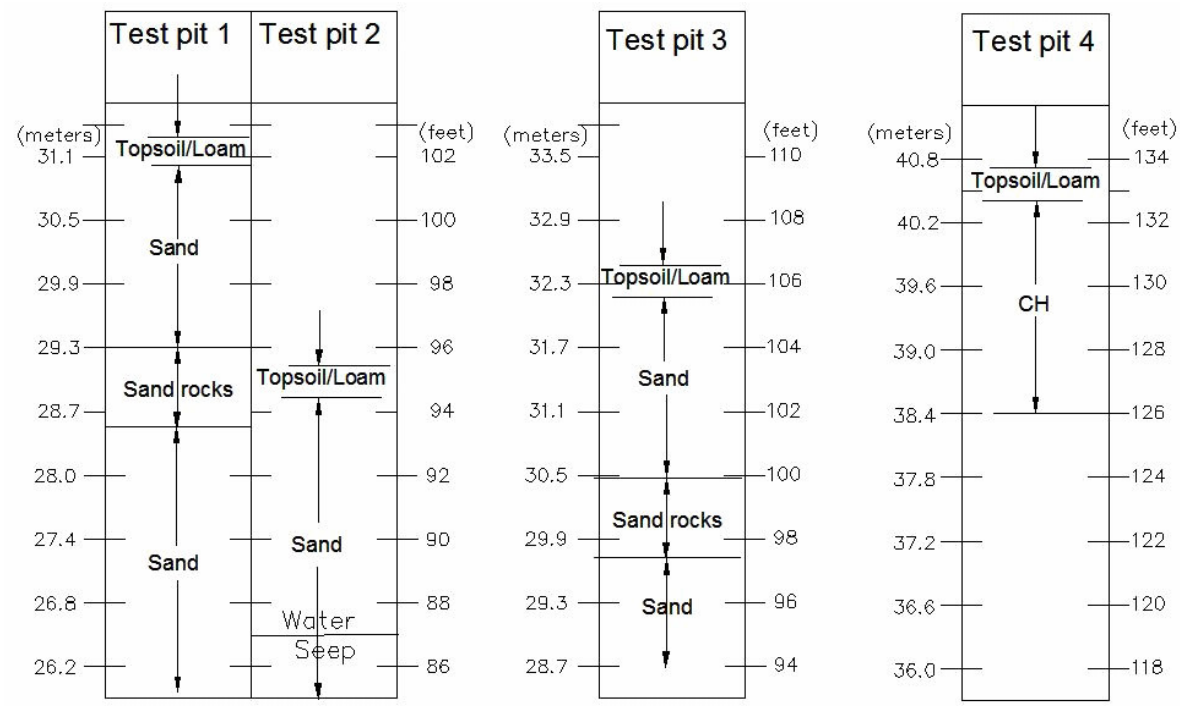

Figure 5. Log of test pits for operation 2.

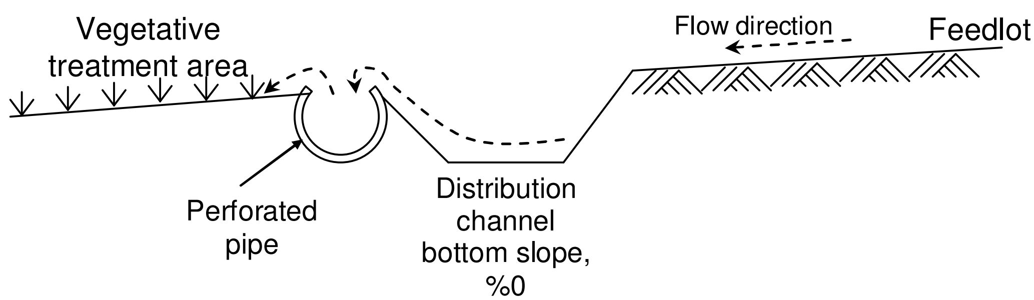

Figure 6. Runoff distribution channel and pipe locations.

The VTS also required a big amount of earth work to treat and store runoff. The other major cost item in second operation's VT system was solid separator. Since three reinforced concrete solid separators were designed to eliminate solids from the runoff, one of the major cost items for VT system was separators. Since the system is under construction the as-built values are not available.

The total feedlot surface areas for north feedlot (VTS) and south feedlots (containment system) were 7,230 m^2 and 25,652 $m^{2,}$ respectively. The total costs were $ 52,192 and $ 149,322 for spreading and containment systems. In the calculation of space requirement for cattle, a unit area of 46.5 m^2/head was used (MWPS-6, 1995). Unit costs per animal head and unit area were calculated. The summary of the calculations and comparisons are given in Table 4.

Table 1. Cost items and their percentages in total cost for operation 1.

Cost item	Percentage of total cost	
	VTS	Containment system
Excavation/earth fill	36.5	28.5
Erosion blanket	10.5	11.6
Solid separator	-	5.8
Access road	9.8	13.9
Heavy use areas	-	6.2
Fencing	28.2	26.0
Water supply	3.8	3.4
Shaping/seeding/grading	2.7	4.6
Perforated pipe	8.5	-
Total, %	100	100
Total, $	123,115	100,110

Table 2. Some as-built values for operation 1.

Work item	Estimate (m^3)		As-built (m^3)	
	Cut	Fill	Cut	Fill
Runoff pond	3478	1134	3690	1010
Clean water diversion channel	1902		1770	
Runoff channels	373		605	
Access roads	4640		4615	

Table 3. Cost items and their percentages in total cost for operation 2.

Cost item	Percentage of total cost	
	VTS	Containment system
Excavation/earth fill	44.2	72.3
Solid separator	42.0	9.9
Heavy use areas	3.4	0.3
Fencing	-	9.2
Shaping/seeding/grading	7.8	7.4
Culverts	2.6	0.9
Total, %	100	100
Total, $	52,192	149,322

Table 4. Comparisons of costs of spreading and containment systems in both operations.

	Operation 1		Operation 2	
	VTS	Containment	VTS	Containment
Capacity, head	300	300	155	500
Feedlot area, m^2	13,935	13,935	7,230	25,650
Cost, $/head	410	334	337	299
Cost, $/$m^2$	8.83	7.18	7.22	5.82
Total cost, $	123,115	100,110	52,192	149,322

As outlined in Table 4, a containment system for both operations is more cost effective than VTS. The major factor that affects the cost of a containment system in North Dakota is climate. Less precipitation, more evaporation makes the pond size smaller. For example, the design weather data for operation 1 is 41 and 9 cm for annual and 25-year, 24 h precipitations, respectively. However, if we were to design same system in central Texas the same values were going to be 76 and 18 cm, respectively. Thus, containment systems are always alternative for agricultural runoff control in North Dakota.

However, there are cases where earth work for VTS is minimal due to the topography. Kizil (2006b) designed a VTS in North Dakota where the only excavation/earth fill was only 36 m^3 to build a containment dike.

Conclusion

The containment systems designed for feedlot runoff control demonstrated less construction costs comparing to VTSs. Unit costs per feedlot unit area and head of animal calculations convinced operator 1 for installation of containment pond.

Excavation/earth fill is the major item that affects the overall cost of a runoff control system in agriculture. The topography significantly affects the earth work and total cost. Considering the fact that North Dakota mainly has a flat topography, the required earth work will be relatively less.

Maintenance of runoff distribution channels and pipes is vital in the performance of VTSs. Cattle and farm machines movements around the channels and pipes are major problems in the maintenance of the slope and uniformity. Therefore; the producers should be informed before conducting an engineering design.

The other factor that affects the cost of a system is the climate of location. In climates where the precipitation is less and evaporation high, the containment ponds are always a good alternative. However, there may be cases where VTSs are more feasible.

Land availability and the local regulations are the other criteria that affect the decision of the operator or producers. Before making a decision the topography of the construction site should be carefully studied and all alternatives should be discussed with the operator.

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