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Research and Development

# Design and Cost of Feedlot Runoff Control Facilities

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# DESIGN AND COST OF FEEDLOT RUNOFF CONTROL FACILITIES

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## FOREWORD

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

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

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

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

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

William C. Galegar

William C. Galegar, Director
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ABSTRACT

Cattle feedlots are typically located to utilize natural surface drainage conditions. These conditions necessitate control facilities to intercept and store surface runoff so manure-contaminated waters are prevented from entering streams and lakes. Engineering design to prevent the discharge of effluent from open feedlot facilities requires a matching of individual structures to proposed management techniques and regional climatic data.

Two computer models were developed for these purposes. The first, the sufficient design program, was a simulation model which sized feedlot runoff retention ponds based upon previous climatic data and management dewatering policies. In addition to minimum pond volume, the sufficient design model listed average number of yearly pumpings for each simulated management alternative at a selected pumping rate. The second model, an economic budget generator, determined cost of open feedlot runoff control systems. The models were tested at seven selected locations in the United States to determine the effects of five pumping rates and seven management dewatering alternatives on minimum storage volumes required to prevent discharges as defined by EPA Effluent Guidelines. Stations were selected from each major climatic region in the U. S. and represented a broad spectrum of precipitation patterns. Lastly, effects of relaxing the discharge criterion were also studied at each location.

This report was submitted in fulfillment of Grant Number R-803819 by Oregon State University under the partial sponsorship of the U. S. Environmental Protection Agency. This report covers the period from June 15, 1975 to December 31, 1977; work was completed as of December 31, 1977.

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In conclusion, technical assistance of Ted L. Willrich, Extension Agricultural Engineer, and editorial and production assistance of Carol Small, Secretary, Department of Agricultural Engineering, Oregon State University, were instrumental in the completion of this report.

## SECTION 1

## INTRODUCTION

Cattle feedlots are typically located to utilize natural surface drainage conditions. These conditions necessitate control facilities to intercept and store surface runoff so manure-contaminated waters are prevented from entering streams and lakes. Intercepted runoff is generally applied to agricultural lands to replenish facility volume and to insure utilization of dissolved plant nutrients.

In 1972 the U. S. Congress enacted the National Pollution Discharge Elimination System (NPDES). As a result, the U. S. Environmental Protection Agency (EPA) promulgated effluent guidelines which permit discharge from a feedlot only in connection with an "unusual rainfall" event. For 1983, the "unusual rainfall" criterion is the 25 year-24 hour storm. This is a performance standard and does not provide exact design criteria; that is, the classical design of flood prevention structures based upon the design runoff rate return period technique is not sufficient since this technique primarily considers runoff generated from a single precipitation event. Wensink and Miner (1975) and Koelliker, Manges and Lipper (1975) showed that chronic precipitation conditions, rather than single catastrophic storms, typically determine feedlot runoff control facility design capacities.

Engineering design to prevent discharge of effluent from open feedlot facilities requires a matching of individual structures to both management techniques and regional climatic data. Wensink and Miner (1975) developed a model which uses hydrologic data to determine minimum feedlot facility volumes required to satisfy the above criterion without management considerations. This study was, therefore, initiated to investigate effects (both engineering and economic) of alternate dewatering policies on the minimum volumetric capacity of feedlot runoff control facilities.

A cattle feedlot runoff control model was first developed to integrate the effects of alternate dewatering policies on minimum facility volumes. This simulation model determined engineering relationships between historical climatological data, dewatering schedules, and minimum feedlot runoff control volumes.

In addition, an economic model to simulate cost of cattle feedlot runoff control designs was formulated to analyze effects of alternate dewatering policies and pumping sizes on required reservoir volumes. This model determined economic relationships between dewatering schedules, minimum reservoir volumes, pumping capacity, and disposal areas and was used to estimate cost of feedlot pollution control systems which comply with EPA regulations at seven locations in the United States.

## SECTION 2

## CONCLUSIONS

The first objective of this project was to develop a technique which provided a rational design method for feedlot pollution control facilities. The technique should integrate historical climatic data in such a way as to predict the effectiveness of various combinations of runoff-handling components. The second objective of this study was to demonstrate this computerized technique in four representative climatic regions in the United States. The third objective was to develop a computerized method to analyze economic cost of feedlot runoff pollution control systems and alternatives.

The first two objectives were accomplished by developing a computer simulation model which sized feedlot runoff retention ponds based upon previous climatic data and management dewatering policies. The model utilized daily rainfalls, average temperatures, and pan evaporations to predict the effects of management dewatering policies on the design of minimum retention volumes which satisfy environmental protection standards. The simulation model accepted a pond dewatering volumetric rate and a management dewatering alternative as inputs and determined the disposal area and facility volume required to hold all feedlot runoff resulting from storms less than the 25 year-24 hour criterion.

The design model was implemented at the following seven selected locations: Pendleton, Oregon; Lubbock, Texas; Bozeman, Montana; Ames, Iowa; Corvallis, Oregon; Experiment, Georgia; and Astoria, Oregon. Locations ranged in average annual precipitation from 13.4 to 75.4 inches.* At each site, five volumetric pumping rates and seven management dewatering alternatives were evaluated to determine minimum storage volume required to prevent discharge as defined by EPA Effluent Guidelines.

The third objective was accomplished by formulating a computerized economic model to estimate cost of open feedlot runoff control

*Current feedlot pollution control technology and regulatory language involves English units. Therefore, the models developed in the course of the research upon which this report is based utilize English units of measure. For the convenience of those readers who deal with international units, a select list of conversions is provided in Appendix E.

systems. The model required market prices of equipment, services, land, and taxes, and the following basic engineering design parameters: feedlot area, design pumping rate, required storage volume, annual pumping days, total disposal land area, and single day's disposal area.

The economic model generated investment and annual operating costs for standardized runoff control systems. Charges were estimated for hand move, side roll, big gun, and traveling big gun at seven locations in the U. S. Budgets were developed for each system with five different pumping rates, seven management alternatives (with respect to timing of disposal), and two disposal policies on 1.0, 10, and 100 acre feedlots (symbolizing 200, 2,000, and 20,000 animal feedlots, respectively).

Results indicate that economies of feedlot size exist in controlling runoff and that pumping capacity could not economically substitute for reservoir volume. At most locations, the all-year pumping policy produced the lowest cost; additional costs associated with more restrictive management policies were not significant.

# SECTION 3

## SUFFICIENT DESIGN MODEL DEVELOPMENT AND DESCRIPTION

The purpose of this model is to design the volumetric capacity of a feedlot runoff control system. The model must accommodate various input data used as the basis for a design. Included in the model are the abilities to consider both long term and daily climatic data, management policies that would be appropriate for various geographic regions, and selection of a design which meets specified discharge conditions.

A block diagram of the feedlot runoff model is shown in Figure 1. The model simulates a feedlot surface onto which precipitation falls and runoff results. As runoff moves off the feedlot surface, it is intercepted by a holding pond. Effluent is removed from the reservoir by pumping to a nearby field for restoration of available storage capacity.

### INITIALIZATION

In preparing the model, several initial values must be specified. These values make the run unique to the location and management plan selected. In order to consider evaporation from the runoff retention pond surface, it is necessary to specify long term monthly average temperatures, average daily evaporation rate (on a monthly basis), and average daily evaporation rate (in inches per day). The technique used for determining daily evaporation rate is to compare daily temperature with the average temperature for the month, and to use this as a factor to adjust the average daily evaporation rate.

The model utilizes the 25 year-24 hour storm value as the discharge criterion. If a rainfall event exceeds this value and the existing pond can not hold the runoff, retention pond volume is <u>not</u> adjusted upward; instead, discharge is allowed and recorded. If one were to design for another discharge criterion, this is where an adjustment would be made.

As an initialization, the management policy must be inserted. In this model, seven management policies have been defined as shown in Table 1. Not all seven management policies are applicable to each climatic region; however, they were designed to provide a full range of potential operating policies.

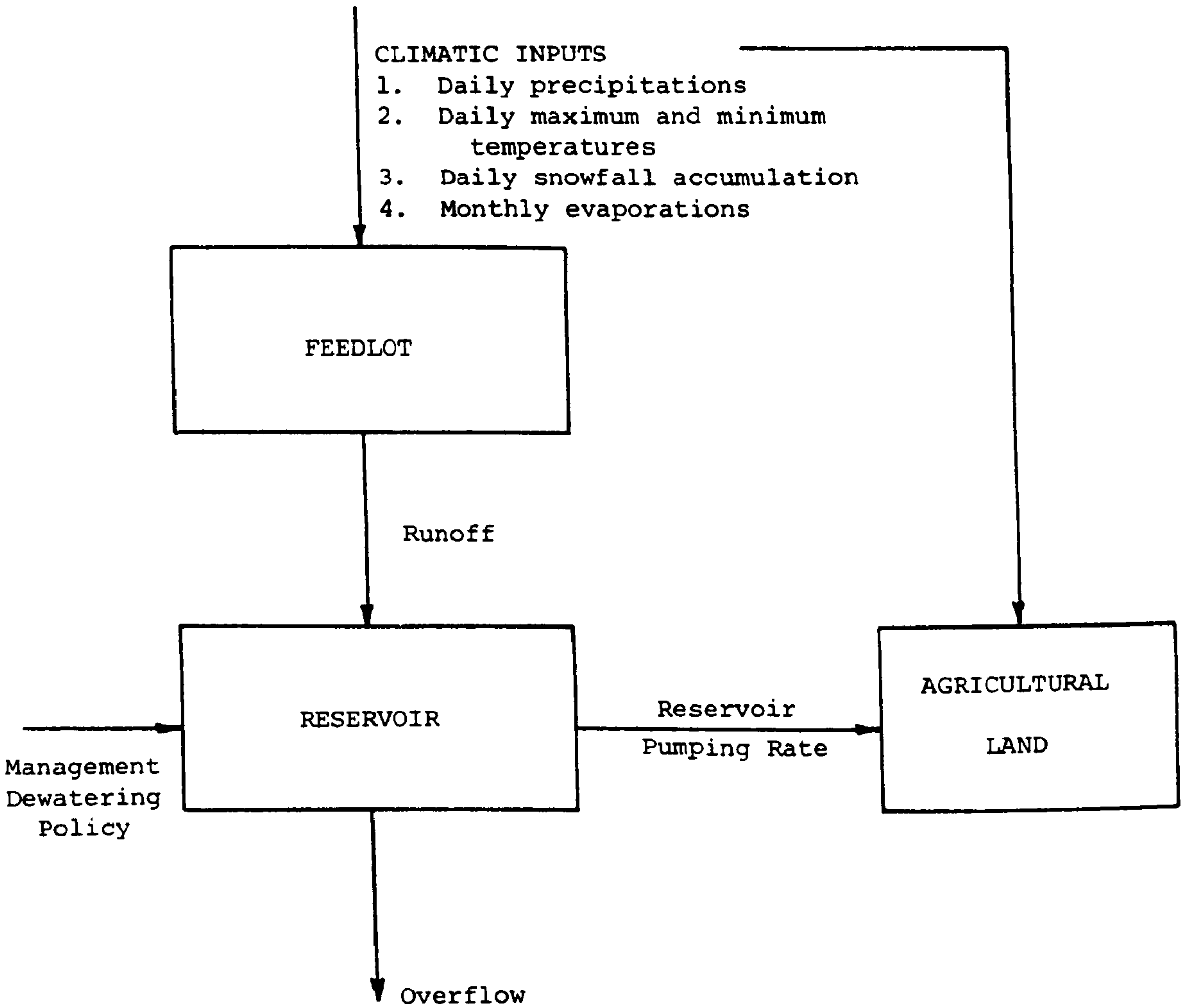


Figure 1. Block diagram of feedlot runoff model.

TABLE 1. PHYSICAL INTERPRETATION OF THE SEVEN RUNOFF MANAGEMENT POLICIES

| Policy | Situation simulation | Dates runoff disposal permitted |
|---|---|---|
| 1 | All-year disposal | All year |
| 2 | Apply effluent to corn crop plus pre-planting (April) disposal | April, June, July, August |
| 3 | Apply effluent to corn crop plus after harvest (Oct 15-Nov 15) disposal and pre-planting (April) disposal | April, June, July, August, Oct 15-Nov 15 |
| 4 | Apply effluent to corn crop | June, July, August |
| 5 | Apply effluent to corn crop plus post-harvest (Oct 15-Nov 15) | June, July, August, Oct 15-Nov 15 |
| 6 | Apply effluent to hay crop and winter months disposal | Jan 1-May 15; Jun 15-30; Jul 15-31; Aug 15-31; Sep 15-30; Oct 15-Jan 1 |
| 7 | Apply effluent to hay crop | Apr 1-May 15; Jun 15-30; Jul 15-31; Aug 15-31; Sep 15-30; Oct 15-31 |

Pumping rate must be defined. This value establishes overall size of irrigation disposal equipment, which in turn establishes quantity of land that must be available for an individual dewatering. Pumping rate is here defined as a fraction of the 25 year-24 hour storm, reported in inches per day. Interpreted as a pumping capacity, pumping rate becomes essentially a volumetric capacity, in acre-inches per acre of feedlot per day.

Next, the model requires the nitrogen concentration of the effluent applied to the disposal site and the maximum total annual nitrogen loading of the disposal area. These values indirectly determine total disposal area required to satisfy the system's design parameters.

The model requires that starting and stopping dates of climatic data also be initially inserted. Climatic data for a particular location must be read from a file. The station name is listed on the first line (record) of each data file to reduce the potential for error. The next entry is an average daily temperature (reported in °F), calculated as daily maximum plus daily minimum, divided by two. The daily precipitation value in inches is the next item on the record. Snowfall data are also included at this point and are tabulated as snowfall accumulation, essentially an inventory (in inches of snow) that exists on any particular date. This latter value is used to determine whether a previous snow is still being stored on the feedlot surface, or alternately, if it is time to calculate runoff based upon previously accumulated snowfall.

Preliminary pond depth is established as six feet. An evaporation coefficient is next inserted to correct pan evaporation rate data to that anticipated from an open pond. A value of 0.7 has typically been used.

PRELIMINARY STEPS

To proceed, a preliminary pond surface area must be calculated. This has been done by multiplying the 25 year-24 hour storm by two and then calculating an appropriate pond surface area using the preliminary depth of six feet. In order to make this preliminary pond surface area estimate, the following formula is used:

$$\text{Surface area} = \frac{2(43{,}560)(\text{25 yr-24 hr storm value})}{12\ (\text{preliminary pond depth})} \qquad (1)$$

The area calculated in this manner is later used for estimating evaporation losses. For locations in which calculated pond depth is in excess of 13 feet, a revised surface area is used to replace the preliminary value and the model is re-run. Pumping rate is next established by multiplying together pumping rate as specified earlier and the already inserted 25 year-24 hour storm value. Thus, a pumping rate (in inches per day) is established which is equivalent to acre-inches per acre of feedlot per day. The 25 year-24 hour storm is converted to a statistical 24-hour value by dividing it by 1.14. In making this correction, the 24-hour storm value and daily climatic data become consistent.

Reading from Climatic Data File

The first step in reading climatic data is to read the name of the station. This assures that the appropriate data have been located. Second, it is determined whether the first year of data is a leap year; if so, number of days per year is replaced with 366. Once this information has been established, data for year one are read from the data file. It is at this point that the program will return for subsequent iterations. The computer reads only one year's data and makes that series of manipulations before returning for the following year.

## THE ITERATIVE PROCESS

The bulk of the program is an iterative process considering each day's climatic data and then adjusting the calculated values of antecedent rainfall, pond volume, accumulated snowfall, and total runoff.

The antecedent rainfall condition used to determine runoff coefficients must be updated by adding the value for the day in question and subtracting the value of the rainfall recorded six days previously. Thus, the antecedent rainfall condition is a continuing total of rainfall for the previous five days. While a day's rainfall is being manipulated, annual rainfall is also increased by that amount.

Daily pan evaporation is next determined by multiplying average daily evaporation rate by daily temperature, divided by average monthly temperature. Pond volume must next be updated (based upon evaporation and rainfall for that day) by adding to the previous day's pond volume a factor equal to the precipitation for the day minus daily surface evaporation. This latter factor is multiplied by the preliminary pond surface area in acres. Following this manipulation, there is a check to make certain that pond volume has not decreased to a value less than zero; if so, this means the pond is empty and the negative value is replaced with a zero.

Determining If This is an Acceptable Day for Irrigation

The next step involves a series of checks to determine whether irrigation is a possibility.

1. Management policy is checked to determine if it allows irrigation on the date under consideration. This is a go or no-go check, and if the date does not allow irrigation, subsequent checks are unnecessary.

2. A check is made to determine if precipitation for that day exceeds a cutoff value. A cutoff value of zero has typically been used. Under this condition, if there is rainfall, irrigation has not been permitted.

3. A check is made to determine if the ground is frozen. This is done by calculating whether the sum of average daily temperatures for the previous three days exceeds 96 °F. If the ground is proven frozen by this criterion, 96 °F is replaced with a value of 114 °F to use as the check for the following day. In this way, the program determines that for ground to freeze, average daily temperature for three days must be less than 32 °F, and that for ground to thaw, the three-day average temperature must be at least 38 °F.

4. Average temperature for the day under consideration is checked. If it is less than 32 °F, no irrigation is allowed.

5. Snowfall accumulation is next evaluated. If there is snow cover on the ground, no irrigation is permitted.

At this point, if all criteria for an acceptable day have been met, the day is counted as an allowable day for irrigation.

To further determine if irrigation should be conducted on this day, pond volume is checked to determine that there is at least one day's pumping volume in storage. This aspect of the model is one of the management conditions that has been considered. It requires that the operator not pump small volumes of water involving less than one day's operation of equipment. If it is an allowable pumping day and there is water in the pond, the model then checks disposal plots for water and nitrogen limits. Maximum water limitation (accumulated precipitation and effluent) of two inches and seven inches per week is permitted on a single disposal plot. Nitrogen loading increases as effluent is applied to each site. When nitrogen loading reaches the designated maximum value (input parameter) and the above water limitation criteria permit dewatering, the model increases its total disposal area by one plot size so that a disposal site exists. Number of days pumped is then incremented by one.

Assuming all the above criteria have been met, pond volume is reduced by one day's pumping and disposal plot parameters (nitrogen and water) are incremented by the appropriate amounts. One day's pumping is determined by multiplying pumping rate times the 25 year-24 hour storm.

## Determining Runoff Value

Prior to calculating runoff from a particular storm, the program performs a series of checks. These are itemized below:

1. The program determines if snowfall accumulation on the day under consideration is greater than zero. If there is accumulated snowfall, the precipitation value is added to the accumulated precipitation value and no runoff is added to the pond volume value.

2. If snowfall accumulation is equal to zero and the value of accumulated precipitation is greater than zero, then precipitation for that day is increased by the value of the accumulated precipitation. The precipitation accumulated value is returned to zero, and the new precipitation value for that day (including both actual and previously accumulated) is sent through the higher runoff prediction equation for evaluating that day's runoff.

3. If precipitation is less than 0.05 inches, there is no runoff for that day according to the model.

4. The next step is to determine which runoff prediction equation to use, based upon whether it is a warm or cold day. If the average daily temperature is greater than 45 °F, it is considered a warm day; if less than 45 °F, a cold day. At this point, the antecedent moisture condition is also considered. If the previous five-day total antecedent precipitation for a cold season exceeds 1.1 inches, the higher runoff prediction value is used. For a warm season, the higher prediction value is used if the antecedent moisture condition exceeds 2.1 inches.

5. At this point, the program calculates runoff for the day under consideration. Feedlot runoff is predicted by using Soil Conservation Service Runoff Equations. The method was developed from correlation of runoff from various storms on agricultural watersheds in many parts of the U. S. and is described in Schwab et al. (1966) as:

$$Q = \frac{(P - .2S)^2}{P + .8S} \qquad (2)$$

   where Q = direct surface runoff, inches
   P = storm rainfall, inches
   S = maximum potential difference between rainfall and runoff, inches.

   S is a measure of surface infiltration and storage; thus, as S increases, runoff, Q, decreases.

The Soil Conservation Service also defines:

$$S = \left(\frac{1000}{N}\right) 10 \quad (3)$$

where N = an arbitrary curve number varying from 0 to 100.

As N increases, Q also increases and when N = 100, equation (2) reduces to Q = P, i.e., all precipitation results in runoff.

The utilization of N = 91 for an average soil moisture condition and N = 97 for a wet soil is defined by the following antecedent rainfall and seasonal temperature criteria:

Warm Season

(Preceding 5-day average temperature greater than 45 °F)

N = 91 if 5-day antecedent precipitation < 2.1 inches
N = 97 if 5-day antecedent precipitation ≥ 2.1 inches

Cold Season

(Preceding 5-day average temperature less than 45 °F)

N = 91 if 5-day antecedent precipitation < 1.1 inches
N = 97 if 5-day antecedent precipitation ≥ 1.1 inches

If runoff is in part from snowfall melt, an N value of 97 is used and the pond is forced to hold all runoff irrespective of the 25 year-24 hour value.

6. The next step is to determine if precipitation is in excess of the 25 year-24 hour value. If so, the program does not require the pond to increase its volume to retain runoff. Storm date and runoff are recorded, and if overflow occurs, statistics are accumulated.

Termination

After weather data for the last day of the year have been processed, it is determined whether this is the end of the program or if another run through the yearly iterative process is required. If necessary, the program returns to the beginning of the iterative process and repeats. If this is the last year of available data, the program proceeds to calculate statistics for the run including total rainfall, total runoff, number of overflows, number of pumping days permissible, number of pumping days, and disposal areas and then writes these total statistics plus a series of yearly statistics.

In this model, seven management dewatering policies have been defined as shown in Table 1. Management policies are stored on a magnetic file and a specific policy is selected for each computer simulation. Not all seven management policies are applicable to each climatic region in the U. S.; however, they were designed to provide a full range of potential operating policies. Each policy contains a yearly array of zeroes and ones; a zero designates that pumping is not permitted while a one indicates that pumping is allowed on the specific day. The sufficient design model is flowcharted in Figure 2.

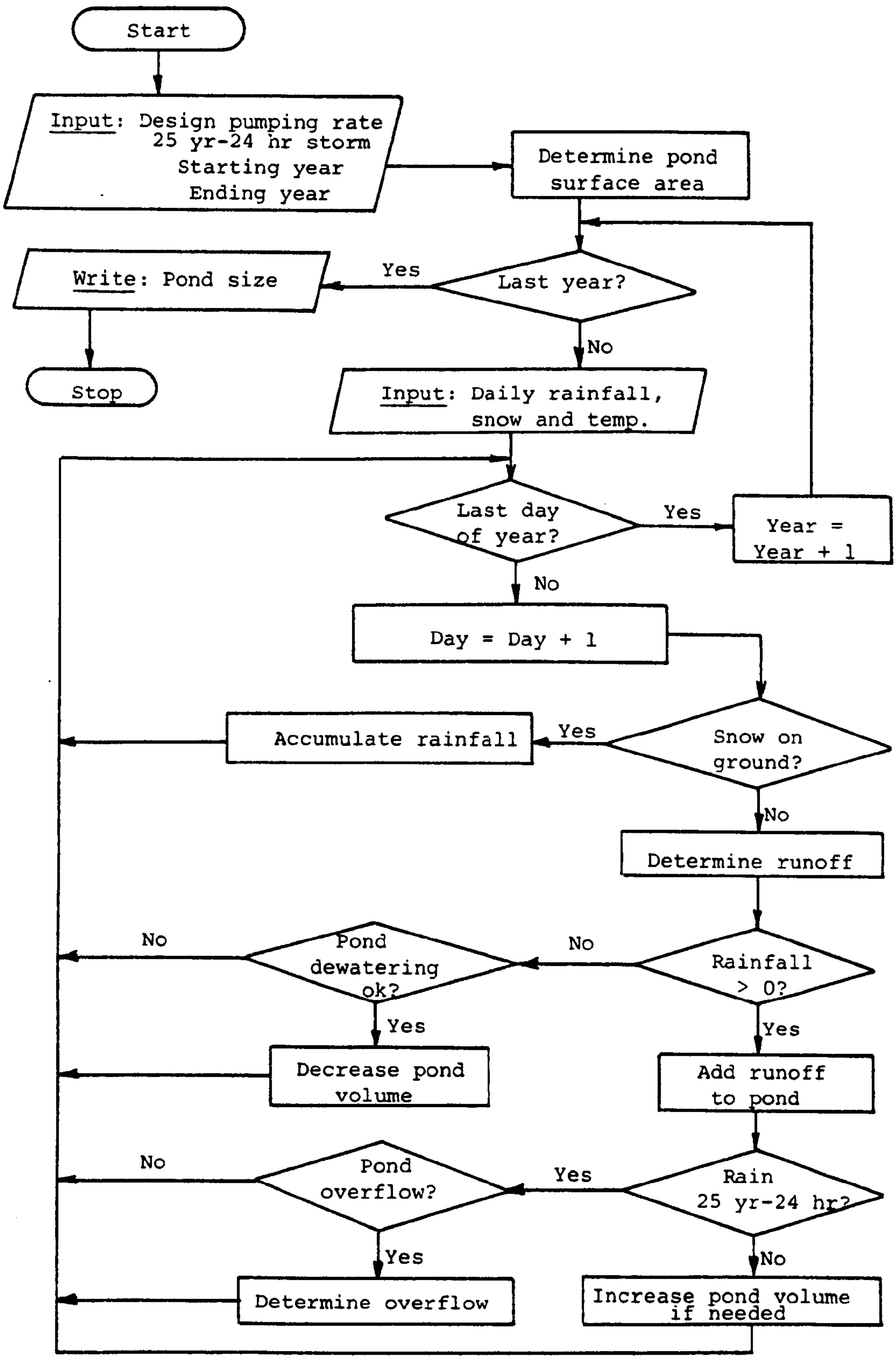


Figure 2. Flowchart of feedlot runoff retention sufficient design model.

## SECTION 4

## SUFFICIENT DESIGN MODEL INPUTS

Weather data from seven unique climatological regions of the U. S. were used in the model to evaluate the effect of alternate pumping schedules on required pond volume. The seven locations, ranging in annual precipitation from 13 to 75 inches, are listed with selected climatic attributes in Table 2. Each location represents a major climatic region. Two stations, Astoria, Oregon, and Corvallis, Oregon, are areas with chronic wet winters. Pendleton, Oregon, represents an arid high plains region while Bozeman, Montana, and Ames, Iowa, are stations which experience snowfall accumulations and cold winters. Experiment, Georgia, and Lubbock, Texas, on the other hand, represent mild winter conditions with occasional catastrophic rainfall events.

In addition to the above climatic data, the sufficient design model requires selection of a pumping-dewatering rate, expressed as a fraction of the 25 year-24 hour recurrence storm. Values of 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hour value were studied at each of the selected stations. Before a simulation run at a particular location commenced, a management policy was selected from Table 1.

TABLE 2. CLIMATIC ATTRIBUTES OF SELECTED FEEDLOT LOCATIONS

| Location | Average annual rainfall, inches | Average January temp, °F | 25 yr-24 hr rainfall, inches | Years cumulative data | Average annual runoff, inches |
|---|---|---|---|---|---|
| Pendleton, OR | 13.39 | 30.9 | 1.5 | 1914-71 | 1.60 |
| Lubbock, TX | 18.62 | 39.0 | 5.0 | 1914-72 | 5.99 |
| Bozeman, MT | 19.23 | 19.0 | 2.7 | 1908-70 | 4.76 |
| Ames, IA | 30.91 | 19.9 | 5.4 | 1901-70 | 11.05 |
| Corvallis, OR | 39.66 | 37.9 | 4.5 | 1914-71 | 12.52 |
| Experiment, GA | 49.90 | 48.0 | 6.7 | 1926-70 | 19.40 |
| Astoria, OR | 75.39 | 39.9 | 5.5 | 1914-71 | 32.95 |

## SECTION 5

## SUFFICIENT DESIGN MODEL OUTPUTS

The simulation model analyzed five management dewatering policies at seven selected locations. For each location, the model progressed through the years of climatic data listed in Table 2, with pumping rates set at 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hour storm. Tables 3-9 show model outputs for Pendleton, Oregon; Lubbock, Texas; Bozeman, Montana; Ames, Iowa; Corvallis, Oregon; Experiment, Georgia; and Astoria, Oregon, respectively. Each table includes the pond surface area corresponding to its unique location. The tables also contain the minimum pond volume to hold all runoff from storms less than the 25-year event and the corresponding average number of pumping days annually for each selected management dewatering policy. Management policies 1, 6, and 7 (permitting all-year pumping, applying effluent to a hay crop with winter disposal, and applying effluent to a hay crop without winter disposal, respectively), were analyzed at each station. In addition, two of the three policies which applied effluent to corn fields were considered at each station. Policy 1 was then re-evaluated with pumping permitted on all days; there was runoff in the pond even though the volume was less than the one-day pumping capacity criterion.

Lastly, Table 10 shows the effects of relaxing the 25 year-24 hour discharge criterion. For each location, the table contains the minimum pond volume to hold all runoff except during the critical (worst) year and the design volume which permits discharges during 5% of the years.

TABLE 3 . REQUIRED RETENTION POND CAPACITY,

ACRE-IN./FEEDLOT ACRE, AND AVERAGE NUMBER OF PUMPING DAYS,

FOR PENDLETON, OREGON

AS A FUNCTION OF MANAGEMENT DISPOSAL POLICIES AND PUMPING CAPACITIES[1]

| Management[3] policy | | Pumping rates, acre-in./feedlot acre-day[2] 0.075 | 0.15 | 0.30 | 0.60 | 1.50 |
|---|---|---|---|---|---|---|
| 1 | capacity[4] | 2.13 | 1.98 | 2.05 | 2.35 | 2.64 |
| | pumping days[5] | 21.1 | 10.0 | 4.6 | 1.9 | 0.6 |
| 4 | capacity[4] | 3.44 | 3.44 | 3.44 | 3.44 | 3.78 |
| | pumping days[5] | 16.3 | 8.3 | 3.9 | 1.8 | 0.5 |
| 5 | capacity[4] | 3.07 | 3.14 | 3.14 | 3.44 | 3.78 |
| | pumping days[5] | 16.6 | 8.3 | 3.9 | 1.8 | 0.5 |
| 6 | capacity[4] | 2.13 | 1.98 | 2.05 | 2.35 | 2.64 |
| | pumping days[5] | 20.4 | 9.8 | 4.6 | 1.9 | 0.6 |
| 7 | capacity[4] | 2.86 | 2.93 | 2.93 | 3.23 | 3.57 |
| | pumping days[5] | 19.3 | 9.4 | 4.4 | 1.9 | 0.5 |
| | capacity[4] | 2.13 | 1.93 | 1.80 | 1.80 | 1.80 |
| 1[6] | pumping days[5] | 42.6 | 34.7 | 31.7 | 30.7 | 30.5 |

[1]Retention pond area = 1,815.0 sq. ft./feedlot acre.

[2]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times 25 yr-24 hr storm.

[3]Management dewatering policies are defined in Table 1.

[4]Capacity of retention pond in acre-in./feedlot acre.

[5]Average number of pumping days per year.

[6]Policy similar to 1 above, except dewatering was permitted without a full day's pumping volume.

TABLE 4. REQUIRED RETENTION POND CAPACITY,

ACRE-IN./FEEDLOT ACRE, AND AVERAGE NUMBER OF PUMPING DAYS,

FOR LUBBOCK, TEXAS

AS A FUNCTION OF MANAGEMENT DISPOSAL POLICIES AND PUMPING CAPACITIES[1]

| Management[3] policy | | Pumping rates, acre-in./feedlot acre-day[2] 0.25 | 0.50 | 1.00 | 2.00 | 5.00 |
|---|---|---|---|---|---|---|
| 1 | capacity[4] | 9.48 | 8.98 | 7.98 | 7.98 | 10.99 |
| | pumping days[5] | 21.8 | 9.9 | 4.3 | 1.6 | 0.5 |
| 2 | capacity[4] | 10.64 | 10.64 | 10.64 | 11.19 | 11.19 |
| | pumping days[5] | 15.7 | 7.4 | 3.3 | 1.4 | 0.4 |
| 3 | capacity[4] | 10.64 | 10.64 | 10.64 | 11.19 | 11.19 |
| | pumping days[5] | 18.6 | 8.9 | 3.9 | 1.6 | 0.4 |
| 6 | capacity[4] | 10.12 | 9.62 | 8.62 | 8.62 | 11.90 |
| | pumping days[5] | 19.9 | 9.4 | 4.1 | 1.6 | 0.4 |
| 7 | capacity[4] | 10.12 | 9.62 | 8.62 | 8.62 | 11.90 |
| | pumping days[5] | 18.1 | 8.7 | 3.9 | 1.6 | 0.4 |
| | capacity[4] | 9.48 | 8.98 | 7.98 | 7.59 | 7.59 |
| 1[6] | pumping days[5] | 34.8 | 24.2 | 19.4 | 17.7 | 17.0 |

[1]Retention pond area = 6,050.0 sq. ft./feedlot acre.

[2]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times 25 yr-24 hr storm.

[3]Management dewatering policies are defined in Table 1.

[4]Capacity of retention pond in acre-in./feedlot acre.

[5]Average number of pumping days per year.

[6]Policy similar to 1 above, except dewatering was permitted without a full day's pumping volume.

TABLE 5. REQUIRED RETENTION POND CAPACITY,
ACRE-IN./FEEDLOT ACRE, AND AVERAGE NUMBER OF PUMPING DAYS,
FOR BOZEMAN, MONTANA
AS A FUNCTION OF MANAGEMENT DISPOSAL POLICIES AND PUMPING CAPACITIES[1]

| Management[3] policy | | Pumping rates, acre-in./feedlot acre-day[2] 0.135 | 0.27 | 0.54 | 1.08 | 2.7 |
|---|---|---|---|---|---|---|
| 1 | capacity[4] | 9.06 | 8.17 | 8.30 | 8.26 | 8.18 |
| | pumping days[5] | 32.7 | 15.9 | 7.6 | 3.6 | 1.4 |
| 4 | capacity[4] | 13.46 | 13.56 | 13.77 | 13.77 | 13.77 |
| | pumping days[5] | 30.2 | 15.3 | 7.4 | 3.6 | 1.4 |
| 5 | capacity[4] | 13.32 | 13.29 | 13.23 | 12.69 | 13.77 |
| | pumping days[5] | 30.7 | 15.4 | 7.5 | 3.6 | 1.4 |
| 6 | capacity[4] | 9.68 | 8.71 | 8.30 | 8.26 | 8.18 |
| | pumping days[5] | 31.5 | 15.7 | 7.6 | 3.7 | 1.4 |
| 7 | capacity[4] | 9.81 | 8.98 | 8.84 | 9.34 | 10.53 |
| | pumping days[5] | 31.2 | 15.6 | 7.6 | 3.6 | 1.4 |
| | capacity[4] | 8.97 | 8.13 | 7.79 | 7.25 | 6.68 |
| 1[6] | pumping days[5] | 47.3 | 33.7 | 27.3 | 24.7 | 23.8 |

[1]Retention pond area = 3,267.0 sq. ft./feedlot acre.

[2]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times 25 yr-24 hr storm.

[3]Management dewatering policies are defined in Table 1.

[4]Capacity of retention pond in acre-in./feedlot acre.

[5]Average number of pumping days per year.

[6]Policy similar to 1 above, except dewatering was permitted without a full day's pumping volume.

TABLE 6. REQUIRED RETENTION POND CAPACITY,

ACRE-IN./FEEDLOT ACRE, AND AVERAGE NUMBER OF PUMPING DAYS,

FOR AMES, IOWA

AS A FUNCTION OF MANAGEMENT DISPOSAL POLICIES AND PUMPING CAPACITIES[1]

| Management[3] policy | | Pumping rates, acre-in./feedlot acre-day[2] 0.27 | 0.54 | 1.08 | 2.16 | 5.4 |
|---|---|---|---|---|---|---|
| 1 | capacity[4] | 10.33 | 10.13 | 9.52 | 10.29 | 13.27 |
| | pumping days[5] | 44.0 | 21.5 | 10.3 | 5.0 | 1.9 |
| 4 | capacity[4] | 16.42 | 16.42 | 16.63 | 17.31 | 20.86 |
| | pumping days[5] | 40.1 | 20.3 | 10.0 | 4.9 | 1.9 |
| 5 | capacity[4] | 14.07 | 13.85 | 13.79 | 15.27 | 17.56 |
| | pumping days[5] | 40.9 | 20.6 | 10.1 | 4.9 | 1.9 |
| 6 | capacity[4] | 10.69 | 10.67 | 11.36 | 12.14 | 14.23 |
| | pumping days[5] | 42.3 | 21.0 | 10.2 | 5.0 | 1.9 |
| 7 | capacity[4] | 11.15 | 11.22 | 11.65 | 12.14 | 14.23 |
| | pumping days[5] | 41.8 | 20.9 | 10.2 | 5.0 | 1.9 |
| 1[6] | capacity[4] | 10.07 | 9.80 | 9.26 | 8.72 | 8.72 |
| | pumping days[5] | 59.2 | 39.9 | 30.9 | 27.4 | 26.3 |

[1]Retention pond area = 2,163.86 sq. ft./feedlot acre.

[2]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times 25 yr-24 hr storm.

[3]Management dewatering policies are defined in Table 1.

[4]Capacity of retention pond in acre-in./feedlot acre.

[5]Average number of pumping days per year.

[6]Policy similar to 1 above, except dewatering was permitted without a full day's pumping volume.

TABLE 7. REQUIRED RETENTION POND CAPACITY,

ACRE-IN./FEEDLOT ACRE, AND AVERAGE NUMBER OF PUMPING DAYS,

FOR CORVALLIS, OREGON

AS A FUNCTION OF MANAGEMENT DISPOSAL POLICIES AND PUMPING CAPACITIES[1]

| Management[3] policy | | Pumping rates, acre-in./feedlot acre-day[2] 0.225 | 0.45 | 0.90 | 1.80 | 4.50 |
|---|---|---|---|---|---|---|
| 1 | capacity[4] | 20.24 | 17.84 | 16.48 | 13.78 | 15.54 |
| | pumping days[5] | 69.8 | 34.9 | 17.2 | 8.3 | 3.2 |
| 4 | capacity[4] | 45.85 | 33.77 | 34.22 | 34.22 | 34.87 |
| | pumping days[5] | 68.8 | 38.6 | 20.0 | 9.9 | 3.7 |
| 5 | capacity[4] | 35.30 | 29.55 | 29.72 | 30.62 | 31.75 |
| | pumping days[5] | 71.4 | 39.1 | 20.1 | 9.9 | 3.7 |
| 6 | capacity[4] | 20.24 | 17.84 | 16.48 | 13.78 | 15.50 |
| | pumping days[5] | 68.5 | 34.8 | 17.2 | 8.3 | 3.2 |
| 7 | capacity[4] | 40.47 | 29.72 | 29.75 | 30.62 | 32.77 |
| | pumping days[5] | 70.2 | 39.8 | 20.8 | 10.3 | 3.8 |
| | capacity[4] | 20.05 | 17.80 | 15.78 | 13.08 | 11.92 |
| 1[6] | pumping days[5] | 80.1 | 51.9 | 39.0 | 33.6 | 31.3 |

[1]Retention pond area = 5,445.0 sq. ft./feedlot acre.

[2]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times 25 yr-24 hr storm.

[3]Management dewatering policies are defined in Table 1.

[4]Capacity of retention pond in acre-in./feedlot acre.

[5]Average number of pumping days per year.

[6]Policy similar to 1 above, except dewatering was permitted without a full day's pumping volume.

[7]Retention pond surface area = 10,890 sq. ft./feedlot acre.

TABLE 8. REQUIRED RETENTION POND CAPACITY,

ACRE-IN./FEEDLOT ACRE, AND AVERAGE NUMBER OF PUMPING DAYS,

FOR EXPERIMENT, GEORGIA

AS A FUNCTION OF MANAGEMENT DISPOSAL POLICIES AND PUMPING CAPACITIES[1]

| Management[3] policy | | Pumping rates, acre-in./feedlot acre-day[2] 0.335 | 0.67 | 1.34 | 2.68 | 6.7 |
|---|---|---|---|---|---|---|
| 1 | capacity[4] | 11.90 | 10.56 | 10.68 | 10.51 | 16.44 |
| | pumping days[5] | 66.1 | 32.1 | 15.6 | 7.7 | 3.0 |
| 2 | capacity[4] | 24.50 | 23.83 | 22.69 | 22.55 | 25.34 |
| | pumping days[5] | 61.1 | 31.0 | 15.4 | 7.6 | 3.0 |
| 3 | capacity[4] | 23.54 | 22.52 | 22.00 | 21.95 | 24.16 |
| | pumping days[5] | 62.3 | 31.3 | 15.5 | 7.6 | 3.0 |
| 6 | capacity[4] | 11.90 | 10.56 | 10.68 | 11.55 | 16.44 |
| | pumping days[5] | 64.4 | 31.8 | 15.6 | 7.6 | 3.0 |
| 7 | capacity[4] | 23.54 | 22.87 | 22.00 | 22.03 | 24.16 |
| | pumping days[5] | 61.8 | 31.3 | 15.5 | 7.6 | 3.0 |
| 1[6] | capacity[4] | 14.27 | 10.24 | 10.24 | 10.24 | 10.24 |
| | pumping days[5] | 88.7 | 58.6 | 45.0 | 39.7 | 38.3 |

[1]Retention pond area = 8,107.0 sq. ft./feedlot acre.

[2]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times 25 yr-24 hr storm.

[3]Management dewatering policies are defined in Table 1.

[4]Capacity of retention pond in acre-in./feedlot acre.

[5]Average number of pumping days per year.

[6]Policy similar to 1 above, except dewatering was permitted without a full day's pumping volume.

TABLE 9. REQUIRED RETENTION POND CAPACITY,

ACRE-IN./FEEDLOT ACRE, AND AVERAGE NUMBER OF PUMPING DAYS,

FOR ASTORIA, OREGON

AS A FUNCTION OF MANAGEMENT DISPOSAL POLICIES AND PUMPING CAPACITIES[1]

| Management[3] policy | | Pumping rates, acre-in./feedlot acre-day[2] 0.275 | 0.55 | 1.10 | 2.20 | 5.5 |
|---|---|---|---|---|---|---|
| 1 | capacity[4] | --[8] | 72.91[7] | 49.11 | 43.74 | 45.40 |
| | pumping days[5] | -- | 107.6 | 45.9 | 22.8 | 9.0 |
| 4 | capacity[4] | -- | -- | 101.21 | 99.90 | 99.90 |
| | pumping days[5] | -- | -- | 52.6 | 26.5 | 10.5 |
| 5 | capacity[4] | -- | -- | 86.41 | 84.21 | 83.91 |
| | pumping days[5] | -- | -- | 52.7 | 26.6 | 10.6 |
| 6 | capacity[4] | -- | -- | 49.11 | 43.74 | 45.40 |
| | pumping days[5] | -- | -- | 45.7 | 22.8 | 9.0 |
| 7 | capacity[4] | -- | -- | 95.50 | 82.38 | 84.28 |
| | pumping days[5] | -- | -- | 52.8 | 26.7 | 10.6 |
| | capacity[4] | -- | 72.91[7] | 48.53 | 42.48 | 40.12 |
| 1[6] | pumping days[5] | -- | 114.2 | 61.5 | 44.7 | 36.4 |

[1]Retention pond area = 13,310 sq. ft./feedlot acre.

[2]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times 25 yr-24 hr storm.

[3]Management dewatering policies are defined in Table 1.

[4]Capacity of retention pond in acre-in./feedlot acre.

[5]Average number of pumping days per year.

[6]Policy similar to 1 above, except dewatering was permitted without a full day's pumping volume.

[7]Retention pond surface area = 19,965 sq. ft./feedlot acre.

[8]Feasible design did not exist.

TABLE 10. MINIMUM POND VOLUME WHEN DISCHARGES ARE ALLOWED FOR ALL-YEAR DEWATERING POLICY WITH 0.4 TIMES 25 YEAR-24 HOUR EVENT PUMPING RATE (acre-inches/feedlot acre)

| Location | Hold all volume <25 yr storm | Discharge permitted during worst year | Discharge permitted during 5% of years |
|---|---|---|---|
| Pendleton, OR | 2.35 | 2.27 | 1.88 |
| Lubbock, TX | 7.98 | 7.70 | 6.14 |
| Bozeman, MT | 8.26 | 7.10 | 4.79 |
| Ames, IA | 10.29 | 8.55 | 6.35 |
| Corvallis, OR | 13.78 | 13.29 | 10.51 |
| Experiment, GA | 10.51 | 10.21 | 9.69 |
| Astoria, OR | 43.74 | 40.08 | 38.90 |

## SECTION 6

## INTERPRETATION OF SUFFICIENT DESIGN OUTPUT

The sufficient design technique calculated minimum pond volumes required to retain all runoff except that attributable to precipitation events in excess of the 25 year-24 hour storm. The model analyzed five management dewatering policies with selected pumping capacities at each site location. Dewatering Policy 1 (all-year pumping), evaluated at each location, represented the extreme in management dedication since pond dewatering was allowed on any day with permissible climatic conditions; pump-operating personnel were assumed available throughout the complete year. At all stations, this policy required minimum pond volumes to satisfy the design criterion. However, this policy required the largest number of annual pumping days.

Four dewatering policies simulated effluent disposal onto a corn crop. Policy 4 permitted disposal only during June, July, and August while Policy 5 expanded this period to include a post-harvest (October 15-November 15) disposal. Policies 2 and 3 were identical to Policies 4 and 5, respectively, with an additional preplanting (April) disposal. Policies 2 and 3 were tested on southern regions where early spring disposal seemed appropriate. At all stations, the corn scenarios without post-harvest disposal (Policies 2 or 4) required the largest pond volumes. When post-harvest disposals were permitted (Policies 3 or 5), sufficient pond volumes were reduced an average of 5.8%, 0.0%, 3.0%, 15.0%, 13.6%, 4.0%, and 15.4% at Pendleton, Lubbock, Bozeman, Ames, Corvallis, Experiment, and Astoria, respectively.

The last two dewatering policies simulated disposal of effluent onto hay fields. Management Policy 7 permitted irrigation from April 1-May 15, then 15-day on-off cycling commencing April 1 and terminating October 31. Dewatering Policy 6 extended Policy 7 to include irrigating during winter months. Since Policy 6 permitted pond dewatering during every month, resultant pond volumes and average number of yearly pumpings were identical to management Policy 1 (all-year pumping) at Pendleton, Bozeman, Corvallis, Experiment, and Astoria, while pond volumes at Lubbock and Ames increased 7.5% and 10%, respectively, over those of Policy 1.

Management Policies 2, 3, 4, 5 and 7 did not permit winter disposals and required substantially larger pond volumes than the all-year pumping policy. Specifically, Pendleton, Lubbock, Bozeman, Ames, Corvallis, Experiment, and Astoria required average volume increases of 49%, 15%, 45%, 39%, 99.7%, 97.4%, and 97.7%, respectively, above corresponding volumes in Policy 1.

In addition to minimum pond volume, the model also listed average number of pumping days per year for each simulated management policy with a selected pumping rate. As pumping rates were increased, design volumes and number of pumping days generally decreased. In selected cases design volumes actually increased as pumping rates were increased. These enlarged volumes resulted from requiring the pumping system to always discharge a full day's capacity. As daily pumping capacities were increased from 0.05 to 1.0 times the 25 year-24 hour storm, pond volumes experienced only marginal reductions. However, a several-fold reduction in average annual pumping days occurred as pumping capacity was increased throughout the same spectrum. For example, increasing pumping rates from 0.05 to 1.0 times the 25 year-24 hour storm on the all-year dewatering policy at Bozeman reduced the sufficient pond volume from 9.06 to 8.18 acre-inches per acre of feedlot while the corresponding average number of yearly irrigations was reduced from 32.7 to 1.4. Therefore, the major benefit of increased pumping capacity was a substantial reduction in annual number of pumpings.

At a specific pumping capacity, average number of yearly pumpings was relatively constant among alternate dewatering policies. This, again, was a result of requiring the pumping system to always discharge a full day's capacity. Since total annual runoff was identical for all dewatering policies at a selected climatic location, annual variation in effluent disposal was a function of only the interaction of management dewatering policies and daily pond surface evaporations. That is, management dewatering policies requiring effluent to remain in the pond for extended periods resulted in larger total annual surface evaporations. For example, a pumping rate of .05 times the 25 year-24 hour event at Lubbock required 21.8 average pumpings per year for the all-year dewatering policy, but only 15.7 average pumpings per year when effluent was applied to a corn field in April, June, July, and August (Policy 2).

Effects of requiring the irrigation system to pump only when effluent inventory exceeded daily pumping capacity were pursued by analyzing management dewatering Policy 1 with this constraint removed. The last rows of Tables 3-9 list the results of removing condition 6 describing a suitable irrigation day. That is, irrigation was permitted on days having suitable climatic conditions and any amount, no matter how minute, of pond effluent. Sufficient pond volumes were reduced an average of 14%, 7.2%, 12%, and 6.6% while number of average annual pumpings increased 1487%, 972%, 411%, and 275% for Pendleton, Lubbock, Ames, and Corvallis, respectively. The relaxation of condition 6 resulted in an excessive number of partial capacity pumpings with only marginal reductions in sufficient pond volumes.

At a selected location, the sufficient design technique recorded each year's minimum pond volume as the model progressed through the climatic data. Upon completion of the simulation process, the model selected the largest volume which occurred during the run and listed that value as the sufficient design minimum volume. Therefore, volumes reported in Tables 3-9 corresponded to maximum values encountered during each complete simulation run. Effects of relaxing the 25 year-24 hour discharge criterion were studied at each location by disregarding years containing critical design volumes corresponding to the all-year dewatering policy with the 0.4 times the 25 year-24 hour storm pumping rate. Table 10 shows pond volumes to hold all runoff less than the 25 year-24 hour event, pond volume which excluded the critical (worst) year, and volume which resulted from excluding the largest 5% of yearly minimum volumes at each location. When discharge during the critical year was permitted (i.e., the year was excluded from the analysis), minimum volumes were reduced 3%, 4%, 14%, 17%, 4%, 3%, and 8% at Pendleton, Lubbock, Bozeman, Ames, Corvallis, Experiment, and Astoria, respectively. If discharges were permitted during 5% of the year, minimum volumes for the above locations could be reduced by 20%, 23%, 42%, 38%, 24%, 8%, and 11%, respectively. The magnitude of the volumetric reductions at Bozeman, Montana, and Ames, Iowa, (the cold weather locations) was approximately twice that of the remaining locations.

## SECTION 7

## DESIGN EVALUATION MODEL

To detail a fuller relationship among major design variables (pumping rates, storage volumes, and pumping days), a computer simulation model was developed to evaluate specific design parameters. The model required the selection of pumping rates, pond volumes, and management policies. For each design, the model determined number and volume of yearly discharge. Program listing and documentation are contained in Appendix B.

## SECTION 8

## ECONOMIC MODEL DEVELOPMENT AND DESCRIPTION

The basic function of this model is to calculate initial investment and annual operating costs for feedlot runoff control facilities. The model is comprised of a set of engineering cost equations reflecting assumptions about the design of various system components. It provides investment and operating cost information on a standardized runoff control system for open-air, earth-surfaced lots. The model considers a variety of systems to control runoff from feedlots, all of which have the following basic components:

1. A diversion structure to prevent clean water from entering the feedlot;
2. A structure to collect and intercept runoff from the feedlot;
3. A settling basin to remove suspended solids from runoff;
4. A retention pond to store accumulated runoff until it evaporates or can be disposed of without entering surface waters;
5. A disposal system, commonly composed of irrigation equipment, to dewater the retention pond and dispose of accumulated runoff onto land.

Regardless of feedlot size or location, items 1-4 will always be constructed using basic design assumptions described in the latter part of this section. For cost comparison purposes, hand move, side roll, stationary big gun, and traveling big gun irrigation systems are analyzed as potential disposal tools. Hand move, stationary big gun, and side roll systems are "costed" at each site, regardless of feedlot size or pumping requirements. Traveling big gun is included subject to a minimum pumping rate.

### COMPONENT COST VARIABLES

Cost variables representing various component and service costs were provided by extension specialists in waste management and irrigation, equipment dealers, and various contractors in the northwestern U. S. Most service costs, excavation, engineering, surveying, and so forth provide estimates for the entire U. S.

All irrigation component costs are actual market prices as quoted by manufacturers and equipment dealers. Tables in Appendix D contain a listing of all cost inputs used in this study.

## DERIVATION OF ENGINEERING COST EQUATION

Cost equations are divided into two groups: (1) those used to calculate initial investment, and (2) those used to calculate annual operating costs. Subsequent sections describe the assumptions and procedures used to derive these equations.

## INVESTMENT

Investment costs are grouped into the following four categories: (1) earthwork, (2) land, (3) irrigation equipment, and (4) miscellaneous items.

### Earthwork

Retention Pond--
The retention pond is assumed to contain the following configuration:

1. Water depth is a maximum of 14 feet when the pond is full;
2. One foot of freeboard is provided, rendering total depth 15 feet;
3. The pond is square; inside slope is 2:1, and outside slope is 3:1;
4. Top width of the berm is six feet.

Required storage volume is provided as a program input. However, design assumptions require one foot of freeboard. Thus, a volume larger than the storage volume must be excavated to satisfy these two requirements. This procedure has three basic steps:

1. Given the required storage volume, length of pond at the waterline is calculated;
2. This length is used to calculate length of the pond at the freeboard level;
3. The length of the pond at freeboard level is used to calculate the required excavation.

Pond volume is represented by

$$V = wld + sd^2(w + l) + 4/3s^2d^3 \qquad (4)$$

where w = width, feet
l = length, feet
d = depth, feet
s = slope of bank, feet/foot

Utilizing the above design assumptions, equation (4) simplifies to*:

$$V = 14L^2 - 784L + 14630 \qquad (5)$$

where V = pond volume, $ft^3$
L = top length (at water line) of pond, feet

Equation (5) is solved for L and combined with the length resulting from pond freeboard. The total excavation volume, in $ft^3$, is*:

$$EV = 15(L_{Fb}^{2} - 60L_{Fb} + 1200) \qquad (6)$$

where EV = necessary excavation volume, $ft^3$
$L_{Fb}$ = length of pond at freeboard level, feet

Equation (6) represents total excavation volume required to construct the pond.

Settling Basin--
One acre-inch of settling basin volume is assumed for each feedlot acre. Excavation volume is calculated as follows:

$$SBVOL = FLAREA\ (134.4) \qquad (7)$$

where SBVOL = excavation volume, cubic yards
FLAREA = feedlot area, acres
134.4 = cubic yards/acre-inch

Clean Water Diversion--
Clean water diversion runoff collection terraces are assumed eight feet wide and required on three sides of the feedlot. Assuming a square feedlot, the cost of contructing clean water diversion is calculated by the following equation:

$$DCIV = (3)\left[(43{,}560)(FLAREA)\right]^{1/2}(COST\ B) \qquad (8)$$

where FLAREA = feedlot area, acres
43,560 = square feet per acre
COST B = construction cost per lineal foot

Cost of constructing the retention pond and settling basin is calculated by multiplying total excavation volume times cost per excavated cubic yard. The sum of this cost and the cost of clean water diversion is the total investment in earthwork. Cost of disposing of excavated material either on-site or elsewhere is highly site-specific and is not included in this analysis.

*Equation simplifying steps are included in McDowell (1977).

Land

A cost is assessed for land occupied by the retention pond, settling basin, collecting diversion structures, and, depending upon disposal policy, disposal site.

Retention Pond--
Pond configuration and construction are quite site-specific, depending upon local topography and other considerations. Some sites can be excavated simply as a "hole in the ground"; others may require earthen berms, while some may even contain square dimensions.

For purposes of calculating retention pond land area, the following method is used to determine area required in an "average" situation: land area is assumed square, with side dimensions of (L + 101) feet. The sum of 101 comprises:

1. Six feet (for top width of berm), plus
2. Forty-five feet (horizontal distance covered by 15-foot berm with 3:1 outside slope), plus
3. Fifty feet (25-foot setback for fence at each end of pond).

Thus land area required for the retention pond and perimeter, LARPAP, (in acres) is calculated as

$$LARPAP = \frac{(L + 101)^2}{43,560} \tag{9}$$

where L = length of the retention pond at freeboard level.

Settling Basin--
Settling basins are assumed to have a uniform depth of four feet, a length to width ratio of 2:1, an inside slope of 3:1, and square ends. Volume is calculated by the equation

$$V = L(W - DS)D \tag{10}$$

where L = length of basin at top, feet
W = width at top, feet
S = inside slope, feet/foot
D = depth, feet
V = volume, $ft^3$

Substituting 2W for L and replacing variables S and D with the appropriate constants yields the quadratic

$$0 = 2W^2 - 24W - V/4 \tag{11}$$

Once the settling basin volume is selected, the top width, W, is determined by equation (1).

Diversion/Collecting Terraces--
Using design assumptions previously described, land area occupied by collecting terraces is calculated as follows:

$$LADIV = \frac{8 \times 3(\sqrt{FLAREA \times 43,560})}{43,560} \quad (12)$$

where LADIV = area required for clean water diversion, acres

$3(\sqrt{FLAREA \times 43,560})$ = lineal feet of diversion required

8 = width of diversion, ft

43,560 = $ft^2$/acre

Disposal of Effluent--
Under a nutrient utilization disposal policy, land is used primarily for crop production, thus is not included as a cost. With a strict disposal policy, the disposal site is assumed unproductive and becomes part of the required investment.

Total land cost is the sum of land areas required for the retention pond, settling basin, collecting/diversion terraces, and disposal (if applicable) times a per-acre cost.

## Sprinklers

The cost of an irrigation system will be computed in two parts:

1. The cost of the system capable of achieving one day's pumping;
2. The cost of extending the system to cover the entire disposal site.

Each irrigation system consists of three basic components: (1) piping, (2) pump, and (3) sprinkling unit. This is the core of the system necessary to apply a day's effluent to the disposal plot. Cost of extending the system requires additional mainline to irrigate the total disposal site with the basic system. Implicit in this procedure is the assumption that the same volume is pumped on any one day.

Hand Move Sprinklers--
The basic assumptions used in designing a hand move waste disposal system are outlined below:

1. Laterals are comprised of 40-foot sections of 3- or 4-inch aluminum pipe with a sprinkler on each 40-foot section;
2. Laterals are moved 60 feet along mainline to the next set (sprinkler spacing is 60 by 40 feet);

3. Area irrigated per sprinkler is approximately .0551 acre;

4. Hourly application rate is 0.33 inches per hour.

The number of 40-foot sections that must be purchased to irrigate the disposal plot is a function of set duration. This analysis assumes a maximum of two sets per day, regardless of set duration. If the disposal plot is irrigated with two sets per day and a minimum of two hours is allowed to move laterals to the next set, a maximum of ten hours is permissible for each set. Thus, with set time, TSET $\leq$ ten hours, the disposal plot can be irrigated in two sets; if TSET > ten hours, the disposal plot must be irrigated with one set. Hours required per set, TSET, are dependent upon pumping rates. With pumping rate, MAXDA, expressed in acre-inches per acre day, and hourly application rate of 0.33 acre-inches, TSET = MAXDA/0.33. With irrigated area per sprinkler equal to 0.0551 acres, number of sprinklers required to cover a one acre set is 18.15.

$$\frac{60' \times 40'}{43{,}560\ (\text{ft}^2/\text{ac})} = 0.0551 \text{ acres} \qquad (13)$$

where sprinkler spacing is 60' x 40'.

Given the cost per 40-foot section, COST D, cost per acre per set equals 18.15 times (COST D). The total cost of laterals required to irrigate a given disposal plot, ADP, is calculated by one of the following equations:

$$\text{IRCA} = 18.15\ (\text{COST D})\ (\text{ADP}) \qquad (14a)$$

where: TSET > 10 hours; ADP irrigated in one set/day

$$\text{IRCB} = 9.075\ (\text{COST D})\ (\text{ADP}) \qquad (14b)$$

where: TSET $\leq$ 10 hours; ADP irrigated in two sets/day

Side Roll Sprinklers--
Design assumptions for the side roll system are identical to those for hand move, with two additions:

1. Laterals are mounted on 72-inch wheels;

2. A small gasoline-powered drive unit is used to advance the lateral to the next set.

A 1,320-foot lateral covers 1.8 acres per set; therefore, cost per set-acre is equal to

$$0.556 \text{ COST E} = \frac{\text{COST E}}{1.8} \qquad (15)$$

where COST E = cost of a 1,320-foot lateral complete with wheels, sprinklers and drive unit.

Total cost of laterals for the side roll system is calculated with one of the following equations:

IRCC = 0.556 (COST E) (ADP) (16a)
where: TSET > 10 hours; ADP irrigated in one set

IRCD = 0.278 (COST E) (ADP) (16b)
where: TSET ≤ 10 hours; ADP irrigated in two sets

Stationary Big Gun--
Assuming an operating pressure of 100 psi, eleven discrete sizes (in gpm) are available from a major manufacturer. In actual practice, however, a continuum of set sizes may be achieved by manipulating operating pressure and nozzle sizes.

The cost of a big gun system is calculated on the assumption that by minor modifications, the operator can obtain a system (with one or more big guns) that will irrigate an area equal to the disposal plot size, ADP. Hence, the basic design variable for the big gun system is gpm discharge, not size of disposal plot.

The big gun(s) required for a given system are selected on the basis of total system discharge (gpm). Given a required discharge, guns are selected and cost calculated using the following assumptions:

1. Average application rate of 0.33 inches/hr for all big guns;
2. Allowable sets per day and hours per set are the same as described for the hand move and side roll systems;
3. 1,000 gpm is the maximum discharge rate of a single big gun;
4. All systems requiring a discharge rate less than 1,000 gpm will use one big gun.

When the required discharge rate is greater than 1,000 gpm, more than one gun is necessary. In such cases, the minimum number of possible guns will be used, all with an identical discharge rate. For example, with a required discharge rate of 2,400 gpm three guns are necessary, each at a discharge rate of 800 gpm.

Total cost of the big gun(s) is based on number of guns and their individual discharge capacity. Cost information on big guns is contained in Appendix D.

Traveling Big Gun--
The traveling big gun is assumed equipped with a big gun-type sprinkler whose characteristics are identical to the stationary big gun described above. Models are available with discharge capacities of approximately 250 to 1,000 gpm. Using an average

stationary application rate of 0.33 acre-inches/hr, moving big gun systems are designed using the following assumptions:

1. The moving big gun is capable of varying travel speed to apply from one to six inches of waste per acre per day;
2. Two hours each day are included for moving the unit to the next set, hence 22 hours/day are allotted for pumping;
3. Units are available with a capacity of 250 to 1,000 gpm;
4. If more than one unit is required, all will have identical capacity;
5. The system is not applicable when required pumping rates are less than 250 gpm (22-hour pumping day).

With the design pump rate in acre-inches per day, the required discharge capacity is equal to

$$MBGGPM = \frac{DPRATE \times 27{,}153}{22 \times 60} = 20.57\ DPRATE \qquad (17)$$

where MBGGPM = required discharge capacity of gun, gpm
DPRATE = design pumping rate, acre-inches per day
27,153 = gallons per acre-inch
22 = pumping hours per day
60 = minutes per hour

The above design assumptions dictate a capacity of 1,000 gpm; when MBGGPM is greater than 1,000 gpm, the number of* units required is equal to NMBG, calculated by the FORTRAN equation

$$NMBG = IFIX \left[\frac{MBGGPM}{1{,}000}\right] + 1.0 \qquad (18)$$

The total cost of moving big gun units is NMBG times its unit price, listed in Appendix D.

Pumps--
All systems utilize electrically powered centrifugal pumps. The hand move and side roll systems operate at 50 psi, big gun and moving big gun systems at 100 psi. Pumps are selected primarily on the basis of two criteria: total dynamic head (a collection of friction losses, static lifts, and operating pressures), and gpm discharge.

*The FORTRAN command IFIX simply truncates the value contained in the parentheses following the command. The addition of 1.0 to MBGGPM/1,000 insures that any decimal value will be rounded to the next highest integer.

Assuming a level field, no lift to the pump, 20% loss of pressure due to mainline friction and pressure loss due to couplings, etc., total dynamic head (in feet) is calculated as follows:

FEET OF HEAD = 2.31 (operating pressure + pressure losses in system), expressed in pounds per square inch
= 2.31 (1.2) (operating pressure)

For hand move and side roll systems operating at 50 psi, total dynamic head is 138 feet.

The discharge capacity (gpm) for a given system is based on the design assumptions previously listed for each system type. Pump discharge for hand move, side roll or big gun is dependent on coverage of the disposal plot with one or two sets. With the disposal plot irrigated in one set, discharge capacity (gpm) is as follows:

$$GPM = \frac{452.5\ (DPRATE)}{TSET} \qquad (19)$$

where DPRATE = design pumping rate (acre-inches per day)
TSET = hours per set
452.5 = 43,560 ($ft^2$/ac)(1 ft/12 in.)(7.48 gal./$ft^3$)(1 hr/60 min)

With the disposal plot irrigated in two sets, gpm is as follows:

$$GPM = \frac{226.3\ (DPRATE)}{TSET} \qquad (20)$$

Discharge capacity for a traveling big gun is calculated using the procedure previously described. Costs of various size pumps are presented in Appendix D (assuming pumping heads of 138 and 277 feet, respectively). These costs include pump, motor, all electrical switches, control panel pump base, and installation. Cost of all accessories to the basic pump-motor combination is estimated at 100% of the pump-motor cost. Table D-6 (Appendix D) contains an itemization of these costs for two different pump sizes.

Mainlines--
The procedure for determining pump cost for a given system is outlined as follows:

1. Pump costs for hand move and side roll system are taken from Table D-3. Pump costs for big gun and moving big gun systems are taken from Table D-4.
2. In each case, the smallest size pump with capacity greater than or equal to required gpm for the system in question is selected.

3. When the required discharge rate cannot be achieved by the use of one pump, multiple pumps of identical size will be selected. In each case, the smallest number of pumps possible will be used.

4. Total pump cost is the product of number of pumps required and price of that pump(s) as determined by its capacity.

All systems utilize portable aluminum mainline; cost is determined by pipe diameter and length. Appendix D presents maximum capacities (in gpm) and costs of commercially available aluminum mainline. Because pipe diameter required for a given system is based on total pump capacity (gpm), the model selects the smallest diameter pipe with capacity greater than or equal to required gpm. Length of mainline is based on the following assumptions:

1. Distance from pump to disposal site is 300 feet.

2. All disposal sites for hand move, side roll, and big gun systems are square.

3. The disposal site for a traveling big gun is rectangular, width being limited to 1,620 feet by the length of the flexible irrigation base. (A maximum length of 660 feet allows a travel path of 1,320 feet, which, when added to a 300-foot wetted diameter, equals 1,620 feet.)

4. Mainline for hand move and side roll systems must extend the length of the disposal site.

5. Mainline for the big gun system must extend the length plus the width of the disposal site.

Using these assumptions, lineal footage of mainline required for the various systems is calculated as follows:

1. Hand move and side roll systems

$$LMAINA = 300 + [(ADS)\ (43,560)]^{\frac{1}{2}} \quad (21)$$

where LMAINA = feet of mainline required for hand move and side roll systems
300 = distance from pump to edge of disposal site
ADS = area of disposal site, acres
43,560 = $ft^2$/acre

2. Big gun

$$LMAINB = 300 + 2\ [(ADS)\ (43,560)]^{\frac{1}{2}} \quad (22)$$

where LMAINB = feet of mainline required for big gun systems
300 = distance from pump to disposal site, feet
ADS = disposal site area, acres
43,560 = $ft^2$/acre

3. Traveling big gun

$$LMAINC = 300 + [(ADS)\ (43{,}560)]\ /1{,}620 \qquad (23)$$

where LMAINC = feet of mainline required for traveling big gun systems

300 = distance from pump to disposal site in feet

and [(ADS) (43,560)] /1,620 is the length of the disposal site as:

ADS = disposal site area, acres

43,560 = $ft^2$/acre

1,620 = width of disposal site, feet

The total cost of mainline for any system is determined by multiplying total pipe length by per-foot cost, as determined by pipe diameter and the above selection process.

Fencing--
Fencing is required for the retention pond and perimeter. Given the area occupied by pond and perimeter at $(L + 101)^2$, the required lineal feet of fence, LF, is calculated as $LF = 4(L + 101)$.

Seeding and Erosion Control--
Seeding exposed earthwork to grass is required to prevent erosion. An expenditure of one percent of the total earthwork cost is assumed for seeding.

Engineering--
A fixed cost of $200 is included to cover surveying, other travel, etc., associated with construction of facilities. No engineering costs are included for design of earthworks for the disposal system. Such costs would be highly site-specific; in addition, in most cases, Soil and Water Conservation and University Extension personnel are available to perform such duties at no cost to the proprietor.

Settling Basin Check Dams--
This analysis assumes that two expanded metal screen dams are installed in each settling basin, with total feet of check dams equal to twice basin width. The cost, which includes materials and installation, is calculated on a per-foot basis. Settling basin widths are described in the calculation of land area occupied by the settling basin.

ANNUAL OPERATING COSTS

Operating and ownership costs are grouped into the following six categories: (1) interest and depreciation, (2) repair and maintenance, (3) taxes, (4) insurance, (5) labor, and (6) energy.

## Interest and Depreciation

The cost of depreciation and interest is expressed as a series of equivalent annual costs, amortizing principal and interest payments over the lifetime of the investment. This is calculated by multiplying total investment times amortization factor, reflecting a lifetime of ten years and a 10% interest rate for all items exclusive of land, which is not depreciated. All items are assumed to have zero salvage value at the end of ten years.

Although actual lifetimes of some investment items are in excess of ten years, all are depreciated over the ten-year period to reflect the uncertainty that exists with respect to future prices, irrigation and waste disposal technology, livestock production practices, and institutional factors which may alter existing socially acceptable forms of waste disposal.

Periodic replacement of materials is only required in the case of the traveling big gun system, which utilized a flexible irrigation hose with a lifetime of two to five years, depending on soil conditions and operating practices. For this study, a lifetime of three years was assumed. To account for replacement of this flexible irrigation hose, initial cost of the system includes an outlay for replacing the hose in four and seven years following initial purchase. This cost is the sum of the present values of the hose, discounted at 10% for the appropriate number of years (see McDowell, 1977 for details).

## Repair and Maintenance

Annual repair and maintenance costs are calculated on the basis of initial investment, using the following coefficients:

1. Pumps: 6%
2. Mainline: 2%
3. Hand move laterals: 2%
4. Side roll laterals: 3%
5. Big gun: 2%
6. Traveling big gun: 1%
7. Earthworks: 0.5%

## Taxes

An annual cost for property taxes assumes that a uniform tax rate of 1.5% is applied to the full value of all land and investment items.

Insurance

An annual insurance cost of 0.3% of the initial investment in irrigation equipment is used in the model.

Labor

In addition to labor costs represented in maintenance and repair, labor is required for operating the irrigation system. Using labor requirements estimated for hand move, big gun, and traveling big gun systems by Lorimer (1974) and for the side roll system by Gossett (1976), equations were developed to calculate labor costs for each system; these are summarized in Table 11.

TABLE 11. LABOR REQUIREMENTS FOR OPERATING VARIOUS IRRIGATION SYSTEMS

| System | Area/set (acres) | Labor/set (minutes) | Labor/acre (hours) |
|---|---|---|---|
| Hand move[1] | 1.8 | 70 | 0.65 |
| Side roll[2] | 1.8 | 20 | 0.18 |
| Stationary big gun[3] | 2.2 | 70 | 0.53 |
| Traveling big gun[4] | 10.0 | 60 | 0.10 |

[1] 1,320-foot lateral with 60 feet between sets.
[2] 1,320-foot lateral with 60 feet between sets.
[3] 350-foot wetted diameter.
[4] 350-foot wetted diameter and 1,320-foot travel.

Hand Move--
With 70 minutes required per 1.8 acre set (0.633 hours per acre), the labor required per pumping day is .65 times the disposal plot area (ADP). Yearly labor cost, CLABHM, is represented by the following equation:

$$CLABHM = 0.65\ (ADP)\ (PDAYS)\ (COST\ N) \qquad (24)$$

where PDAYS = number of pumping days per year
COST N = hourly wage rate
ADP = disposal plot area, acres.

Side Roll--
Labor requirements for the side roll system (1,320-foot lateral, 60-foot move) are 20 minutes per lateral per move. Since the operator is required only to start and stop the power unit which advances the lateral to the next set, labor requirements are calculated, not on a per-acre basis, but with respect to number of laterals. With a maximum lateral length of 1,320 feet (1.8 acres per set), the number of laterals, N, is represented by one of the following FORTRAN equations:

$$N^{*} = \text{IFIX (ADP/1.8 + 1)} \qquad (25a)$$

$$N^{**} = \text{IFIX}\left[\frac{0.5\text{ADP}}{1.8} + 1\right] = \text{IFIX (.278ADP + 1)} \qquad (25b)$$

Annual cost of labor is then calculated by one of the following equations:

$$\text{CLABSR} = \left[\text{(COST N) (PDAYS) (.33)}\right] (N^{*}) \qquad (26a)$$

$$\text{CLABSR} = \left[\text{(2) (COST N) (PDAYS) (.33)}\right] (N^{**}) \qquad (26b)$$

$N^{*}$ - irrigated in one set; $N^{**}$ - irrigated in two sets.

where 0.33 = hours required to move each lateral
Other variables as previously defined.

Big Gun--
Using the value 0.53 hr per acre from Table 11, the labor required per pumping day equals 0.53 (ADP). Yearly labor costs, CLABBG, are then calculated as follows:

$$\text{CLABBG} = 0.53 \text{ (ADP) (PDAYS) (COST N)} \qquad (27)$$

(With all variables defined as above.)

Traveling Big Gun--
Using the labor requirement of one hour per day per unit, the annual cost of labor, CLABTG, is calculated as follows:

$$\text{CLABTG} = \text{(NMBG) (PDAYS) (COST N)} \qquad (28)$$

where NMBG = number of traveling big guns in system
PDAYS = average number pumping days per year
COST N = hourly wage rate

Labor costs for all systems assume that sprinkler units are moved to an adjacent disposal plot each day the system is operated. For hand move and big gun, labor costs are the same regardless of number of sets on the disposal plot. With systems designed to cover the disposal plot in two sets, two moves are required; however, the system contains only half the equipment as a one set system.

Energy

Annual cost of energy represents the cost of electricity for pumping. Energy requirements for pumping are based on three parameters: (1) total volume pumped, (2) total feet of dynamic head at the pump, and (3) efficiency of the pump and its drive unit. The amount of energy required to lift one acre-inch of water one foot equals

$$E = (1 \text{ acre-inch})\ (27{,}158 \text{ gal./ac-inch})\ (8.337 \text{ lbs/gal.})\ (1 \text{ foot})$$
$$= 226{,}497.72 \text{ foot-lbs}$$

Converting to horsepower-hours:

$$E = (226{,}497.72 \text{ foot-lbs})/(33{,}000 \text{ foot-lbs/min-hp})\ (60 \text{ min/hr})$$
$$E = 1.14393 \times 10^{-1} \text{ hp-hour per acre-inch per foot of lift}$$

Converting this relation to kilowatt-hours:

$$E = (1.4393 \times 10^{-1} \text{ hp-hour})\ (1 \text{ kilowatt-hour}/1.34 \text{ hp-hour})$$

$$E = 8.5368 \times 10^{-2} \text{ kilowatt-hrs per acre-inch per foot of lift.}$$

With feet of lift represented by total feet of dynamic head (previously calculated in the section describing pump selection), assuming a pump efficiency of 70% and a motor efficiency of 88%, (61.6% combined efficiency), the per acre-inch cost of energy for pumping is

$$CELEC = \frac{(8.5368 \times 10^{-2})(TDH)(CKWH)}{0.616} \qquad (29)$$

where CELEC = dollar cost per acre-inch pumped
8.5368 = kilowatt-hours required to lift one acre-inch of water one foot at 100% efficiency
TDH = total dynamic head, feet
CKWH = cost per kilowatt-hour
0.616 = combined efficiency of pump and motor

Thus, the annual energy cost at any site is calculated from pumping head, average acre-inches pumped per year, and cost per kilowatt-hour of electricity.

## SECTION 9

## ECONOMIC MODEL INPUTS

The model requires basic design parameters to calculate initial and annual costs of a feedlot runoff control system. These parameters include: (1) feedlot area, (2) design pumping rate (volume per day), (3) required storage volume, (4) annual pumping days, (5) total disposal land area, and (6) a single day's "set" disposal area. The model can evaluate two disposal policies: (1) nutrient utilization, and (2) strict waste disposal. The nutrient utilization policy assumes that waste nutrients are used (applied at 200 lbs of nitrogen per acre) for crop production, and therefore does not charge the feedlot runoff control system for the disposal site. The strict waste disposal policy assumes that the disposal site is used only for effluent application without regard for nutrient and salt accumulations; this policy permits 1,200 lbs of nitrogen per acre. The initial investment for this policy includes a land cost for the disposal site.

This model was designed as a subprogram to the feedlot runoff sufficient design program developed above; however, it can perform independent economic analyses of feedlot runoff control systems by providing the necessary input data. All economic coefficients in the model are stored on magnetic files which can be readily adjusted to reflect unique designs or specific locations. All data used in this study represent 1977 prices and are listed in McDowell (1977). This analysis assumes labor costs of 3.50 dollars per hour and .0308 dollars per kilowatt-hour for electricity (1976 U. S. average farm electrical schedule).

Although the model can evaluate any feedlot size or location, three specific sizes (1, 10, and 100 acres) were evaluated at Ames, Iowa; Astoria, Oregon; Bozeman, Montana; Corvallis, Oregon; Experiment, Georgia; Lubbock, Texas; and Pendleton, Oregon.

## SECTION 10

## ECONOMIC MODEL OUTPUTS

The economic model analyzed five management dewatering policies at seven selected locations which satisfied EPA effluent guideline discharge criteria only in connection with the 25 year-24 hour storm. For each location, the model evaluated initial investment and annual cost of feedlot control designs with pumping rates of 0.05, 0.1, 0.2, 0.4, and 1.0 times the 25 year-24 hour storm. Tables 12-18 show the annual cost in dollars per head of capacity for management policy 1 (permitting all-year pumping) with the above pumping rates at seven locations. In addition, Table 19 presents a comparison of least cost disposal systems (in dollars per head of capacity per year) for each management policy at both Ames, Iowa, and Lubbock, Texas. Table 20 shows the results of each irrigation disposal system on 1, 10, and 100 acre feedlots using management policy 7 (apply effluent to a hay crop without winter disposal) at each of seven stations when dewaterings are limited to a maximum of ten per year. Table 21 presents the least cost disposal system in both initial investment per head of capacity and annual cost per head of capacity for the above selected feedlot sizes. Finally, Table 22 shows a comparison of annual cost per head of capacity for approximately equivalent pumping rates when management policy 1 (all-year pumping) was evaluated at each location.

TABLE 12. ANNUAL POLLUTION CONTROL COST
(DOLLARS PER HEAD OF CAPACITY[1])
AT AMES, IOWA
AS A FUNCTION OF PUMPING CAPACITY,
IRRIGATION SYSTEM, AND FEEDLOT SIZE[2]

| Pumping rate[3] ac-in./feedlot ac-day | Irrigation system[4] | Feedlot size, acre | | |
|---|---|---|---|---|
| | | 1.0 | 10 | 100 |
| 0.27 | 1 | 4.57 | 1.64 | 1.30 |
| | 2 | -- | 1.72 | 1.34 |
| | 3 | 5.13 | 1.69 | 1.41 |
| | 4 | -- | -- | 1.42 |
| 0.54 | 1 | 4.55 | 1.70 | 1.44 |
| | 2 | -- | 1.84 | 1.58 |
| | 3 | 5.06 | 1.84 | 1.64 |
| | 4 | -- | -- | 1.65 |
| 1.08 | 1 | 4.70 | 2.00 | 2.00 |
| | 2 | -- | 2.33 | 2.32 |
| | 3 | 5.10 | 2.13 | 2.40 |
| | 4 | -- | -- | 2.17 |
| 2.16 | 1 | 5.21 | 2.54 | 2.79 |
| | 2 | 5.93 | 3.23 | 3.47 |
| | 3 | 5.16 | 3.49 | 3.34 |
| | 4 | -- | 3.40 | 3.24 |
| 5.40 | 1 | 6.30 | 4.30 | 5.54 |
| | 2 | 8.07 | 6.07 | 7.31 |
| | 3 | 6.81 | 4.82 | 6.93 |
| | 4 | -- | 5.68 | 7.23 |

[1]Assumes a feedlot capacity of 200 head per acre.

[2]All-year management dewatering policy with nutrient utilization policy; dashes indicate system not available.

[3]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times the 25 yr-24 hr storm.

[4]Irrigation systems: 1=hand move; 2=side roll; 3=big gun; 4=traveling big gun.

TABLE 13. ANNUAL POLLUTION CONTROL COST

(DOLLARS PER HEAD OF CAPACITY[1])

AT ASTORIA, OREGON

AS A FUNCTION OF PUMPING CAPACITY,

IRRIGATION SYSTEM, AND FEEDLOT SIZE[2]

| Pumping rate[3] ac-in./feedlot ac-day | Irrigation system[4] | Feedlot size, acre | | |
|---|---|---|---|---|
| | | 1.0 | 10 | 100 |
| 0.28 | 1 | 9.75 | 6.34 | 5.87 |
| | 2 | -- | 6.38 | 5.80 |
| | 3 | 10.49 | 6.59 | 6.10 |
| | 4 | -- | -- | 6.13 |
| 0.55 | 1 | 8.01 | 4.78 | 4.50 |
| | 2 | -- | 4.82 | 4.53 |
| | 3 | 8.74 | 5.07 | 4.92 |
| | 4 | -- | -- | 5.05 |
| 1.10 | 1 | 7.51 | 4.57 | 4.72 |
| | 2 | -- | 4.80 | 4.93 |
| | 3 | 8.15 | 4.93 | 5.57 |
| | 4 | -- | -- | 5.62 |
| 2.21 | 1 | 7.66 | 4.89 | 5.52 |
| | 2 | 8.39 | 5.49 | 6.09 |
| | 3 | 7.86 | 5.20 | 6.87 |
| | 4 | -- | 5.88 | 8.28 |
| 5.52 | 1 | 8.25 | 6.85 | 8.81 |
| | 2 | 10.55 | 8.54 | 10.49 |
| | 3 | 9.67 | 7.87 | 11.53 |
| | 4 | -- | 8.26 | 14.43 |

[1]Assumes a feedlot capacity of 200 head per acre.

[2]All-year management dewatering policy with nutrient utilization policy; dashes indicate system not available.

[3]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times the 25 yr-24 hr storm.

[4]Irrigation systems: 1=hand move; 2=side roll; 3=big gun; 4=traveling big gun.

TABLE 14. ANNUAL POLLUTION CONTROL COST
(DOLLARS PER HEAD OF CAPACITY[1])
AT BOZEMAN, MONTANA
AS A FUNCTION OF PUMPING CAPACITY,
IRRIGATION SYSTEM, AND FEEDLOT SIZE[2]

| Pumping rate[3] ac-in./feedlot ac-day | Irrigation system[4] | Feedlot size, acre | | |
|---|---|---|---|---|
| | | 1.0 | 10 | 100 |
| 0.14 | 1 | 4.16 | 1.29 | 0.92 |
| | 2 | -- | -- | 0.95 |
| | 3 | 4.68 | 1.35 | 0.96 |
| | 4 | -- | -- | 1.03 |
| 0.27 | 1 | 4.11 | 1.27 | 0.93 |
| | 2 | -- | 1.36 | 1.00 |
| | 3 | 4.66 | 1.29 | 1.00 |
| | 4 | -- | -- | 1.02 |
| 0.54 | 1 | 4.11 | 1.33 | 1.07 |
| | 2 | -- | 1.49 | 1.23 |
| | 3 | 4.55 | 1.43 | 1.20 |
| | 4 | -- | -- | 1.23 |
| 1.09 | 1 | 4.21 | 1.57 | 1.52 |
| | 2 | -- | 1.92 | 1.87 |
| | 3 | 4.55 | 1.63 | 1.79 |
| | 4 | -- | -- | 1.61 |
| 2.72 | 1 | 4.85 | 2.31 | 2.74 |
| | 2 | 5.75 | 3.20 | 3.63 |
| | 3 | 4.66 | 2.49 | 3.19 |
| | 4 | -- | 3.06 | 2.94 |

[1]Assumes a feedlot capacity of 200 head per acre.

[2]All-year management dewatering policy with nutrient utilization policy; dashes indicate system not available.

[3]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times the 25 yr-24 hr storm.

[4]Irrigation systems: 1=hand move; 2=side roll; 3=big gun; 4=traveling big gun.

TABLE 15. ANNUAL POLLUTION CONTROL COST

(DOLLARS PER HEAD OF CAPACITY[1])

AT CORVALLIS, OREGON

AS A FUNCTION OF PUMPING CAPACITY,

IRRIGATION SYSTEM, AND FEEDLOT SIZE[2]

| Pumping rate[3] ac-in./feedlot ac-day | Irrigation system[4] | Feedlot size, acre | | |
|---|---|---|---|---|
| | | 1.0 | 10 | 100 |
| 0.22 | 1 | 5.34 | 2.31 | 1.93 |
| | 2 | -- | 2.38 | 1.95 |
| | 3 | 5.94 | 2.38 | 2.03 |
| | 4 | -- | -- | 2.09 |
| 0.45 | 1 | 5.15 | 2.15 | 1.88 |
| | 2 | -- | 2.26 | 1.97 |
| | 3 | 5.72 | 2.33 | 2.01 |
| | 4 | -- | -- | 2.05 |
| 0.90 | 1 | 5.06 | 2.22 | 2.07 |
| | 2 | -- | 2.47 | 2.31 |
| | 3 | 5.55 | 2.39 | 2.42 |
| | 4 | -- | -- | 2.36 |
| 1.80 | 1 | 5.23 | 2.55 | 2.69 |
| | 2 | -- | 3.10 | 3.23 |
| | 3 | 5.32 | 2.71 | 3.25 |
| | 4 | -- | 3.45 | 3.21 |
| 4.49 | 1 | 5.84 | 3.90 | 5.01 |
| | 2 | 7.31 | 5.36 | 6.46 |
| | 3 | 6.70 | 3.83 | 6.42 |
| | 4 | -- | 4.28 | 7.03 |

[1]Assumes a feedlot capacity of 200 head per acre.

[2]All-year management dewatering policy with nutrient utilization policy; dashes indicate system not available.

[3]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times the 25 yr-24 hr storm.

[4]Irrigation systems: 1=hand move; 2=side roll; 3=big gun; 4=traveling big gun.

TABLE 16. ANNUAL POLLUTION CONTROL COST
(DOLLARS PER HEAD OF CAPACITY[1])
AT EXPERIMENT, GEORGIA
AS A FUNCTION OF PUMPING CAPACITY,
IRRIGATION SYSTEM, AND FEEDLOT SIZE[2]

| Pumping rate[3] ac-in./feedlot ac-day | Irrigation system[4] | Feedlot size, acre | | |
|---|---|---|---|---|
| | | 1.0 | 10 | 100 |
| 0.33 | 1 | 4.91 | 1.92 | 1.67 |
| | 2 | -- | 1.98 | 1.70 |
| | 3 | 5.57 | 2.10 | 1.88 |
| | 4 | -- | -- | 1.95 |
| 0.67 | 1 | 4.73 | 1.83 | 1.84 |
| | 2 | -- | 1.98 | 1.99 |
| | 3 | 5.32 | 2.02 | 2.19 |
| | 4 | -- | -- | 2.25 |
| 1.34 | 1 | 4.83 | 2.15 | 2.35 |
| | 2 | -- | 2.52 | 2.71 |
| | 3 | 5.30 | 2.43 | 2.94 |
| | 4 | -- | 3.30 | 3.42 |
| 2.68 | 1 | 5.30 | 2.72 | 3.61 |
| | 2 | 6.18 | 3.54 | 4.43 |
| | 3 | 5.28 | 3.21 | 4.21 |
| | 4 | -- | 3.56 | 4.87 |
| 6.70 | 1 | 7.03 | 6.35 | 7.60 |
| | 2 | 9.20 | 8.52 | 9.76 |
| | 3 | 7.47 | 6.54 | 10.19 |
| | 4 | -- | 6.66 | 11.95 |

[1]Assumes a feedlot capacity of 200 head per acre.

[2]All-year management dewatering policy with nutrient utilization policy; dashes indicate system not available.

[3]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times the 25 yr-24 hr storm.

[4]Irrigation systems: 1=hand move; 2=side roll; 3=big gun; 4=traveling big gun.

TABLE 17. ANNUAL POLLUTION CONTROL COST
(DOLLARS PER HEAD OF CAPACITY[1])
AT LUBBOCK, TEXAS
AS A FUNCTION OF PUMPING CAPACITY,
IRRIGATION SYSTEM, AND FEEDLOT SIZE[2]

| Pumping rate[3] ac-in./feedlot ac-day | Irrigation system[4] | Feedlot size, acre | | |
|---|---|---|---|---|
| | | 1.0 | 10 | 100 |
| 0.25 | 1 | 4.28 | 1.40 | 1.05 |
| | 2 | -- | 1.48 | 1.11 |
| | 3 | 4.80 | 1.43 | 1.14 |
| | 4 | -- | -- | 1.17 |
| 0.50 | 1 | 4.26 | 1.40 | 1.14 |
| | 2 | -- | 1.55 | 1.28 |
| | 3 | 4.75 | 1.52 | 1.28 |
| | 4 | -- | -- | 1.39 |
| 1.00 | 1 | 4.25 | 1.53 | 1.43 |
| | 2 | -- | 1.85 | 1.75 |
| | 3 | 4.62 | 1.60 | 1.61 |
| | 4 | -- | -- | 1.69 |
| 2.00 | 1 | 4.68 | 2.03 | 2.17 |
| | 2 | 5.35 | 2.69 | 2.84 |
| | 3 | 4.64 | 2.03 | 2.49 |
| | 4 | -- | 2.98 | 2.77 |
| 5.00 | 1 | 5.43 | 3.42 | 4.34 |
| | 2 | 7.10 | 5.08 | 6.00 |
| | 3 | 6.03 | 3.73 | 5.03 |
| | 4 | -- | 5.24 | 4.94 |

[1]Assumes a feedlot capacity of 200 head per acre.

[2]All-year management dewatering policy with nutrient utilization policy; dashes indicate system not available.

[3]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times the 25 yr-24 hr storm.

[4]Irrigation systems: 1=hand move; 2=side roll; 3=big gun; 4=traveling big gun.

TABLE 18. ANNUAL POLLUTION CONTROL COST (DOLLARS PER HEAD OF CAPACITY[1]) AT PENDLETON, OREGON AS A FUNCTION OF PUMPING CAPACITY, IRRIGATION SYSTEM, AND FEEDLOT SIZE[2]

| Pumping rate[3] ac-in./feedlot ac-day | Irrigation system[4] | Feedlot size, acre | | |
|---|---|---|---|---|
| | | 1.0 | 10 | 100 |
| 0.07 | 1 | 3.48 | 0.70 | 0.35 |
| | 2 | -- | -- | -- |
| | 3 | 3.97 | 0.75 | 0.36 |
| | 4 | -- | -- | -- |
| 0.15 | 1 | 3.49 | 0.72 | 0.37 |
| | 2 | -- | -- | 0.42 |
| | 3 | 3.92 | 0.74 | 0.38 |
| | 4 | -- | -- | 0.49 |
| 0.30 | 1 | 3.52 | 0.75 | 0.44 |
| | 2 | -- | 0.85 | 0.53 |
| | 3 | 3.93 | 0.82 | 0.47 |
| | 4 | -- | -- | 0.57 |
| 0.60 | 1 | 3.59 | 0.87 | 0.61 |
| | 2 | -- | 1.07 | 0.81 |
| | 3 | 3.94 | 0.92 | 0.66 |
| | 4 | -- | -- | 0.76 |
| 1.50 | 1 | 4.02 | 1.24 | 1.16 |
| | 2 | -- | 1.74 | 1.66 |
| | 3 | 3.97 | 1.19 | 1.20 |
| | 4 | -- | 2.43 | 1.35 |

[1]Assumes a feedlot capacity of 200 head per acre.

[2]All-year management dewatering policy with nutrient utilization policy; dashes indicate system not available.

[3]Pumping rates represent 0.05, 0.1, 0.2, 0.4 and 1.0 times the 25 yr-24 hr storm.

[4]Irrigation systems: 1=hand move; 2=side roll; 3=big gun; 4=traveling big gun.

TABLE 19. MINIMUM ANNUAL POLLUTION CONTROL COST (DOLLARS PER HEAD OF CAPACITY[1]) FOR VARIOUS DISPOSAL POLICIES FOR AMES, IOWA, AND LUBBOCK, TEXAS

| Station | Dewatering policy[2] | Disposal policy[3] | Feedlot area, acres | | |
|---|---|---|---|---|---|
| | | | 1.0 | 10 | 100 |
| Ames, IA | 1 | NU | 4.57 | 1.64 | 1.30 |
| (pumping rate: | 4 | NU | 4.92 | 1.96 | 1.50 |
| .27 ac-in./ | 5 | NU | 4.72 | 1.78 | 1.42 |
| feedlot ac-day) | 6 | NU | 4.54 | 1.64 | 1.43 |
| | 7 | NU | 4.54 | 1.63 | 1.28 |
| | 1 | SWD | 5.08 | 2.20 | 1.86 |
| | 7 | SWD | 5.08 | 2.22 | 1.86 |
| Lubbock, TX | 1 | NU | 4.32 | 1.45 | 1.09 |
| (pumping rate: | 2 | NU | 4.32 | 1.45 | 1.09 |
| .25 ac-in./ | 3 | NU | 4.35 | 1.46 | 1.10 |
| feedlot ac-day) | 6 | NU | 4.31 | 1.43 | 1.07 |
| | 7 | NU | 4.29 | 1.42 | 1.06 |
| | 1 | SWD | 4.67 | 1.85 | 1.49 |
| | 7 | SWD | 4.70 | 1.88 | 1.51 |

[1]Assumes a feedlot capacity of 200 head per acre.

[2]Management dewatering policies are defined in Table 1.

[3]Disposal application rates:
NU = Nutrient Utilization (200 lbs nitrogen/acre)
SWD = Strict Waste Disposal (1200 lbs nitrogen/acre).

TABLE 20. ANNUAL POLLUTION CONTROL COSTS (DOLLARS PER HEAD OF CAPACITY[1]) WHEN DEWATERING TEN OR FEWER DAYS PER YEAR FOR VARIOUS IRRIGATION SYSTEMS AT SEVEN U. S. LOCATIONS[2]

| Location | Dewater day/yr | Pump. rate ac-in./ fdlt ac-day | Irrig. systems[3] | Feedlot size, ac | | |
|---|---|---|---|---|---|---|
| | | | | 1.0 | 10 | 100 |
| Ames, IA | 10.0 | 1.08 | 1 | 4.70 | 2.00 | 2.00 |
| | | | 2 | -- | 2.33 | 2.32 |
| | | | 3 | 5.10 | 2.13 | 2.40 |
| | | | 4 | -- | -- | 2.17 |
| Astoria, OR | 7.5 | 0.55 | 1 | 10.64 | 8.45 | 10.14 |
| | | | 2 | 12.34 | 10.13 | 11.82 |
| | | | 3 | 11.38 | 9.43 | 12.51 |
| | | | 4 | -- | 9.79 | 14.38 |
| Bozeman, MT | 7.6 | 0.54 | 1 | 4.25 | 1.45 | 1.18 |
| | | | 2 | -- | 1.61 | 1.34 |
| | | | 3 | 4.70 | 1.55 | 1.31 |
| | | | 4 | -- | -- | 1.34 |
| Corvallis, OR | 8.2 | 1.80 | 1 | 6.23 | 3.41 | 3.48 |
| | | | 2 | -- | 3.96 | 4.03 |
| | | | 3 | 6.29 | 3.54 | 3.98 |
| | | | 4 | -- | 4.32 | 3.88 |
| Experiment, GA | 7.6 | 2.70 | 1 | 6.23 | 3.52 | 4.29 |
| | | | 2 | 7.10 | 4.34 | 5.11 |
| | | | 3 | 6.18 | 3.97 | 4.80 |
| | | | 4 | -- | 4.34 | 5.25 |
| Lubbock, TX | 8.9 | 0.50 | 1 | 4.31 | 1.44 | 1.17 |
| | | | 2 | -- | 1.59 | 1.32 |
| | | | 3 | 4.78 | 1.56 | 1.30 |
| | | | 4 | -- | -- | 1.42 |
| Pendleton, OR | 9.4 | 0.15 | 1 | 3.53 | 0.80 | 0.44 |
| | | | 2 | -- | -- | 0.49 |
| | | | 3 | 3.97 | 0.81 | 0.45 |
| | | | 4 | -- | -- | 0.56 |

[1]Assume a feedlot capacity of 200 head per acre.

[2]Management policy: apply effluent to hay crop without winter disposal.

[3]Irrigation systems: 1 = hand move; 2 = side roll; 3 = big gun; 4 = traveling big gun.

TABLE 21. MINIMUM INVESTMENT AND ANNUAL POLLUTION CONTROL COST (DOLLARS PER HEAD OF CAPACITY[1]) AT SEVEN U. S. LOCATIONS

| Location | Feedlot size, acre | | | | | |
|---|---|---|---|---|---|---|
| | 1.0 | | 10 | | 100 | |
| | Invest. | Ann. cost | Invest. | Ann. cost | Invest. | Ann. cost |
| Ames, IA | 22.91 | 4.54 | 8.41 | 1.63 | 6.59 | 1.28 |
| Astoria, OR | 37.93 | 7.47 | 23.08 | 4.53 | 23.15 | 4.50 |
| Bozeman, MT | 20.81 | 4.11 | 6.70 | 1.27 | 4.91 | 0.92 |
| Corvallis, OR | 25.58 | 5.06 | 11.12 | 2.15 | 9.65 | 1.88 |
| Experiment, GA | 23.40 | 4.73 | 8.69 | 1.83 | 8.16 | 1.67 |
| Lubbock, TX | 21.85 | 4.29 | 7.52 | 1.42 | 5.68 | 1.06 |
| Pendleton, OR | 17.74 | 3.48 | 3.65 | 0.70 | 1.84 | 0.35 |

[1]Assumes a feedlot capacity of 200 head per acre.

TABLE 22. ANNUAL POLLUTION CONTROL COSTS (DOLLARS PER HEAD OF CAPACITY[1]) AT SEVEN U. S. LOCATIONS WITH SIMILAR PUMPING CAPACITIES

| Location | Dewater day/yr | Pump. rate ac-in./ fdlt ac-day | Irrig. system[2] | Feedlot size, ac | | |
|---|---|---|---|---|---|---|
| | | | | 1.0 | 10 | 100 |
| Ames, IA | 10.3 | 1.08 | 1 | 4.70 | 2.00 | 2.00 |
| | | | 2 | --[3] | 2.33 | 2.32 |
| | | | 3 | 5.10 | 2.13 | 2.40 |
| | | | 4 | -- | -- | 2.17 |
| Astoria, OR | 37.7 | 1.10 | 1 | 7.51 | 4.57 | 4.72 |
| | | | 2 | -- | 4.80 | 4.93 |
| | | | 3 | 8.15 | 4.93 | 5.57 |
| | | | 4 | -- | -- | 5.62 |
| Bozeman, MT | 3.6 | 1.09 | 1 | 4.21 | 1.57 | 1.52 |
| | | | 2 | -- | 1.92 | 1.87 |
| | | | 3 | 4.55 | 1.62 | 1.79 |
| | | | 4 | -- | -- | 1.61 |
| Corvallis, OR | 17.3 | 0.90 | 1 | 5.06 | 2.22 | 2.07 |
| | | | 2 | -- | 2.47 | 2.31 |
| | | | 3 | 5.55 | 2.39 | 2.42 |
| | | | 4 | -- | -- | 2.36 |
| Experiment, GA | 15.7 | 1.34 | 1 | 4.83 | 2.15 | 2.35 |
| | | | 2 | -- | 2.53 | 2.71 |
| | | | 3 | 5.30 | 2.43 | 2.94 |
| | | | 4 | -- | 3.30 | 3.42 |
| Lubbock, TX | 4.4 | 1.00 | 1 | 4.25 | 1.53 | 1.43 |
| | | | 2 | -- | 1.85 | 1.75 |
| | | | 3 | 4.62 | 1.60 | 1.61 |
| | | | 4 | -- | -- | 1.69 |
| Pendleton, OR | 1.5 | 1.50 | 1 | 4.02 | 1.24 | 1.16 |
| | | | 2 | -- | 1.74 | 1.66 |
| | | | 3 | 3.97 | 1.19 | 1.20 |
| | | | 4 | -- | 2.43 | 1.35 |

[1]Assume a feedlot capacity of 200 head per acre.

[2]Irrigation systems: 1 = hand move; 2 = side roll; 3 = big gun; 4 = traveling big gun.

[3]Dashes indicate system not applicable.

## SECTION 11

## INTERPRETATION OF ECONOMIC MODEL OUTPUT

### RESERVOIR VOLUME vs PUMPING RATES

Tables 12-18 present the effects of increasing pumping rates on the total cost of each system. In most cases, large pumping capacities substantially increased annual cost of the runoff control system. At all but one location, the majority of designs reached minimum (or near minimum) feedlot runoff control costs with pumping rates of 0.1 times the 25 year-24 hour storm. The feedlot runoff sufficient design program did not permit dewatering unless a full day's pumping volume was available in the reservoir. Though this constraint was included to more accurately model pragmatic feedlot operations, this limitation did not permit a complete substitution of feedlot reservoir volume for pumping rates. The feedlot runoff sufficient design model output pumping rates did not, in general, decrease volumes, since chronic precipitation conditions, rather than single catastrophic storms, determined runoff reservoir volumes. In selected cases, required reservoir capacities actually increased as pumping rates were enlarged.

At Astoria, Oregon, (Table 13), minimum cost designs occurred with pumping rates of 0.2 times the 25 year-24 hour storm on feedlot sizes of 1.0 and 10 acres; this is primarily the result of the atypical nature of the station (annual precipitation, 75.39 inches). Isolated examples of marginal cost decreases accompanying increasing pumping rates also existed at selected stations (Table 15), with 1.0 acre feedlots. This result may be an artifact of the cost estimating program; the program's minimum dewatering (irrigation) system provided sufficient capacity to permit higher pumping rates. The increase in pumping rates decreased number of pumping days and subsequently, total labor cost.

The above data indicate that reservoir volume cannot economically substitute for pumping capacity except in extreme atypical cases. The economic viability of these extreme stations is even more questionable than substitutions of reservoir-pumping volumes.

### ECONOMIES OF SIZE

Tables 12-20 show significant economies of feedlot size for controlling feedlot runoff. These economies turn to diseconomies with higher pumping rates; however, at lower pumping rates, economy of size is consistent. Most of the size advantage was achieved by increasing feedlot size to 10 acres. Pendleton, Oregon, (annual precipitation, 13.39 inches), deviated from this generalization primarily due to its low runoff and minimal pumping rates.

The 10-acre feedlot at Ames, Iowa, (Table 12), which was representative of the remaining stations, had a least cost per head capacity of 79% of the 10-acre feedlot; in addition, the annual cost of the 10-acre feedlot was only 28% of the 1.0-acre feedlot. The burden of feedlot runoff control facilities to small feedlots (approximately 200-head capacity) is substantial, and some operations may be forced out of business in lieu of implementing runoff control measures.

One measure of the potential impact of imposing water pollution guidelines on the feedlot industry is the relation of estimated runoff control costs to existing costs of production. Table 23 presents the estimated additional costs of production ($/head marketed) at six locations and three feedlot sizes, accounted for by the imposition of feedlot runoff control measures. All costs assume 100% use of capacity (200 head per acre and three times yearly animal turnover). These costs also represent the least cost system at each site and feedlot size: hand move irrigation equipment, all-year pumping policy, nutrient utilization disposal policy, and a pumping rate of 0.05 times the 25 year-24 hour storm.

Gee (1977) has prepared recent estimates of the costs of production for U. S. beef feedlot sector. He reported a weighted average production cost per head of $431.77 during 1976. Of this, 92% was for feed and feeder cattle, 2% was fixed, and 6% of the cost varied with lot size. These estimates were developed assuming 100% use of capacity.

For lots with 1,000-1,999 head capacity, a total cost of $440.75 was estimated; for lots with 8,000-15,999 head capacity, Gee estimated cost of production (dollars per head marketed) at $362.39. Comparing the average added cost of production (Table 23) for lots in humid regions (Ames, Iowa; Experiment, Georgia; Corvallis, Oregon) and arid regions (Lubbock, Texas; Pendleton, Oregon; and Bozeman, Montana) to Gee's estimates showed the following:

1. For humid locations, average added cost of production ($/head marketed) was $.65 and $.54 for 10 and 100 acre lots, respectively. These costs represent 0.152% and 0.149% of the estimated total production costs for 10 and 100 acre lots, respectively.

2. For arid locations, average added cost of production was $.37 and $.26 for 10 and 100 acre lots, respectively. This represents 0.084% and 0.072% of the estimated total costs of production for beef on the two sizes, respectively.

These data show that imposition of feedlot runoff control guidelines upon larger feedlots would be insignificant from the standpoint of additional production costs. However, the impact on small feedlot operators would be substantial. Costs shown in Table 23 assume a three times yearly animal turnover. Many small lots (farmer-feeders) feed only one group of animals per year, thus their costs would be three times those shown. For a one acre feedlot located at Ames, Iowa, annual added cost of production (per head) is estimated at $4.56 when only one group of animals is fed per year. If the lot is operated at 100% capacity--200 animals per acre--total added cost for this size feedlot would be $912.00. Costs of this magnitude may force many small feedlot operators to cease feeding beef in open feedlots.

TABLE 23. ADDED PRODUCTION COST (DOLLARS PER HEAD[1]) ASSOCIATED WITH POLLUTION CONTROL SYSTEMS[2] AS A FUNCTION OF FEEDLOT SIZE AND LOCATION

| Feedlot location | Feedlot size, ac | | |
| --- | --- | --- | --- |
| | 1.0 | 10 | 100 |
| Ames, IA | 1.52 | .55 | .43 |
| Bozeman, MT | 1.39 | .43 | .31 |
| Corvallis, OR | 1.78 | .77 | .64 |
| Experiment, GA | 1.64 | .64 | .56 |
| Lubbock, TX | 1.43 | .47 | .35 |
| Pendleton, OR | 1.16 | .23 | .12 |

[1]Assumes a feedlot capacity of 200 head per acre, three times yearly animal turnover, and 100% use of capacity.

[2]All systems are the least cost system for each location: pumping rate equals 0.05 times 25 year-24 hour storm, irrigation system 1, management alternative 1, and nutrient utilization disposal policy.

## GEOGRAPHIC LOCATIONS

Comparisons between different geographic locations show significant variations in costs. Table 21 summarizes output from the cost-estimating program, presenting the least expensive runoff control and disposal system for each location. This includes all pumping rates, management alternatives, disposal policies, and irrigation systems. Required investment per head ranged from $37.93 at Astoria, Oregon, to $17.74 at Pendleton, Oregon, for one-acre feedlots. For 10 acre feedlots, minimum investment per head ranged from $23.08 at Astoria, Oregon, to $3.65 at Pendleton, Oregon; and for 100 acre feedlots, investment per head ranged from $23.15 to $1.84 from Astoria to Pendleton, Oregon, respectively.

A significant portion of cost differential is due to variations in pumping rates. Table 22 presents expected annual costs per head of capacity for all locations, with pumping rates approximately equated. The maximum cost differential between locations with equivalent pumping rates was $3.54, $3.38, and $3.56 per head of capacity for 1.0, 10, and 100 acre feedlots, respectively.

If Corvallis and Astoria, Oregon, were excluded from the analysis, (they were not representative of regions where open feedlots are common), costs became even more comparable: without these stations, maximum differences in annual cost per head of feedlot capacity were $.87, $.97, and $1.16 for 1.0, 10, and 100 acre feedlot, respectively. Within this group, arid locations (Bozeman, Montana; Lubbock, Texas; and Pendleton, Oregon) had annual runoff control costs 20 to 50% lower than humid stations (Ames, Iowa and Experiment, Georgia).

The fact that Midwestern feedlots will face higher runoff control costs than Southwestern feedlots indicates imposition of such guidelines may alter the current comparative advantage Midwest feeders have over Southwest feeders. Feed costs in the Midwest are generally lower than those in the Southwest, giving Midwestern feedlot operators an edge. Higher runoff control costs faced by Midwestern feedlot operators will reduce their current advantage.

MANAGEMENT ALTERNATIVES

A comparison of the expected annual costs for various management alternatives is presented in Table 19 for two locations, Ames and Lubbock. Ames represents the Midwest, where small feedlots predominate. Lubbock typifies the Southwest, where large feedlots are more common. Pumping rates at each station were almost identical, so irrigation technology was equivalent at both sites. Table 19 indicates that Lubbock had an absolute cost advantage in every management policy, but differences in expected costs were less than 20% in most cases. Economies of size were more pronounced at Lubbock, so the cost differential between Ames and Lubbock was more significant for larger feedlots.

At each station, costs of using various management alternatives were fairly uniform, deviating by no more than about 10%. Thus, there appears to be little economic incentive (strictly on the basis of cost) for selecting any one particular management alternative. The data suggest that an operator could build a system to match the most flexible management alternatives (pumping only in the summer months) at little extra cost, and could then be free to switch to another management alternative at a later date, if desired.

DISPOSAL POLICY

Table 19 also contains the annual cost per feedlot capacity for a strict waste disposal policy in conjunction with management alternatives 1 (all-year disposal) and 7 (apply effluent to a hay crop without winter disposal). The strict disposal policy permitted a maximum of 1,200 lbs of nitrogen per acre and charged the runoff control system for the disposal site. Table 19 indicates that strict disposal was more expensive, especially for larger feedlots, than the nutrient utilization policy.

For both locations, cost of land was assumed to be $750 per acre; this may be too low for Ames and too high for Lubbock. If more realistic land prices were used, strict waste disposal would be more costly than shown at Ames and less costly than shown for Lubbock. Outlays shown for the nutrient utilization policy did not consider fertilizer value of the runoff applied to cropland. If this were done, the cost differential between nutrient utilization and strict waste disposal would be more significant than shown in Table 19.

IRRIGATION SYSTEMS

The hand move irrigation system is consistently the least expensive to own and operate, as seen in Tables 12-20. Stationary big gun is next, followed by side roll and traveling big gun. The stationary big gun system is commonly used for waste disposal, but it appears more costly due to higher pump costs and the increased mainline required.

In a few cases (see Tables 12, 14, 15, 17, and 18), on 100-acre feedlots, the traveling big gun system was less costly than side roll and stationary big gun. Traveling big gun operated 22 hours per day, while other systems operated only 12 hours daily. Longer operating conditions permitted this system to run at lower discharge rates, subsequently requiring smaller pumps and mainlines. Using single components, traveling big gun was superior in those isolated cases in which competing disposal systems operated with multiple pumps and mainlines. Such pumping rates are considerably higher than those normally used for conventional irrigation systems, and their suitability as disposal systems is questionable, i.e., some of the higher pumping rates are equivalent to 20,000 gpm or more for 100-acre feedlots. At lower pumping rates, however, cost differences among various systems were minimal.

System selection will naturally be based not only on cost, but also on such variables as owner preference, alternate uses, etc. Tables 12-20 suggest that as long as a feedlot operator selects a low pumping rate, increased costs associated with side roll, big gun, and traveling big gun (where applicable) are not significant, especially on larger feedlots.

## OPERATOR CONVENIENCE

Currently, many feedlot operators have elected to dewater their runoff reservoirs infrequently (Gee, 1976). Table 20 presents annual costs at the seven stations with design parameters which need to operate ten or fewer days per year. Cost primarily reflects pumping rates required to achieve this objective. Costs vary widely, but those at stations in the major beef-producing regions (Ames, Bozeman, Experiment, Lubbock, and Pendleton) follow the same pattern as uniform pumping rates. Experiment, Georgia, had the highest cost, with the remaining stations fairly close behind. Pendleton again had the lowest cost, approximately 25% less than the other stations. Midwestern and Southwestern stations' cost data differed by only 10 to 15%.

## COST OF RUNOFF CONTROL AT VARYING LEVELS OF CONTROL

Thus far, this analysis has dealt only with the costs of full compliance with proposed EPA guidelines for 1983. The literature to date has dealt only superficially with the question of the marginal cost of controlling runoff at levels representing less than full compliance with proposed regulations. Klocke (1971) presented some "marginal cost" data with respect to changes in cost of controlling runoff at a given level for various feedlot sizes. This did point out the existence of economies of size but did not address the question of marginal cost of runoff control at various levels of control for the same size feedlot. Wensink and Miner (1977) investigated the effect of relaxing performance standards on the design parameters developed with their feedlot runoff design program. They found that by excluding the worst five years of hydrologic data (with respect to precipitation), design storage volumes were reduced by an average of 25%. This did not provide data that was economically useful, however, because cost of the retention pond is only a small part of the total cost of most runoff control systems.

To generate data that could be used to derive the marginal cost relationships desired, Wensink and Miner's (1975) return period design program was used to model performance of runoff control systems whose design parameters are insufficient to satisfy 1983 runoff guidelines. The cost-estimating model was used to generate the initial cost of these various systems. Cost and performance data thus generated were combined to illustrate the marginal relationships between cost and performance.

Figure 3 presents the case for a 100 acre feedlot in Pendleton, Oregon. The data points represent twenty runoff control systems. Design parameters were derived by reducing pond volume and daily pumping rate of a given system (which complied with the 1983 guidelines) by 5% increments. The twenty data points in Figure 3 represent systems whose design parameters are 100, 95, 90,...5, and 0% of the pumping and pond volume necessary to meet EPA Runoff Guidelines. The performance of each system was measured by the percent of total runoff that occurred within the time period (1914-71) that the system contained. As seen in Figure 3, a large part of the investment required to achieve full compliance has been spent on controlling the last very small portion of total runoff. Of the estimated $2.34 per head investment required to control 100% of the runoff from 1914 to 1971, $1.40, or 60%, was necessary to control 90% of the runoff. To raise the level of control from 90% to 95% required an additional investment of $.35 per head--15% of the total per head cost of 100% control. To raise the level of control from 95% to 100% required an additional investment per head of $.59. This is 25% of the total per head cost for 100% control and is 1.7 times the cost of raising control from 90% to 95% containment.

These costs represent only the investment required for a runoff control system using hand move irrigation equipment, operated under management alternative 1 (all-year pumping) with nutrient utilization waste disposal. Each system is assumed to use the same size disposal site and disposal plot area as the full-sized system. While this distorts system cost, resulting costs are <u>higher</u> than would be the case if the disposal plot and site area <u>had been</u> recalculated for each of the twenty systems. If lower costs were used for the nineteen systems which were of insufficient size to meet runoff guidelines, relative costs of controlling the last few percent of runoff would have been even more exaggerated than those shown in Figure 3. This clearly illustrates that significant reduction in costs can be achieved with only minor increase in total runoff allowed to escape from feedlots.

It is interesting to speculate on the correspondence between various levels of runoff and environmental impact upon a watershed. However, such variables as total feedlot area draining into a stream, distances between feedlots along a stream, stream characteristics (temperature, flow rate, other pollutants present, etc.), local rainfall patterns, and other factors <u>all</u> have an effect. The number and interplay between these factors <u>make</u> any general conclusion impossible.

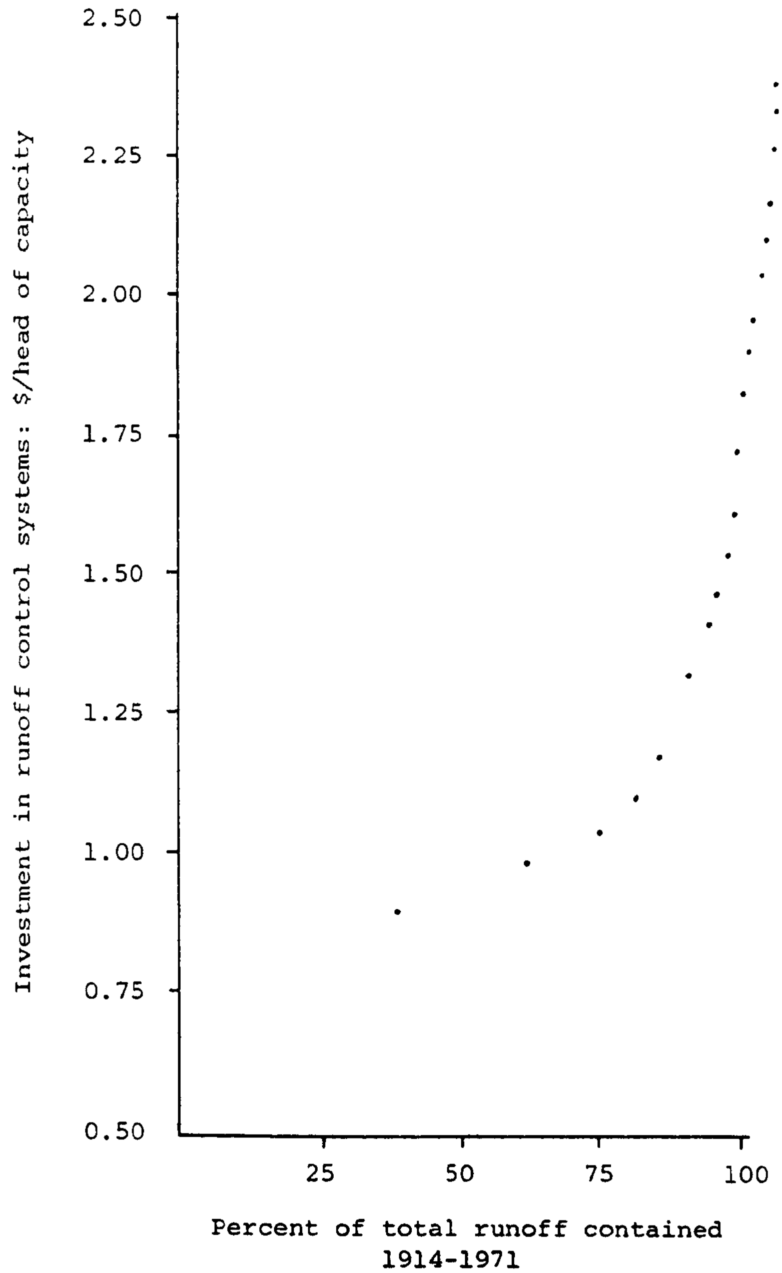


Figure 3. Simulated cost and performance of feedlot runoff control systems at Pendleton, Oregon, for time period 1914-1971.

SECTION 12

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## APPENDIX A. SUFFICIENT DESIGN TECHNIQUE SIMULATION MODEL

GENERAL PROGRAM INFORMATION

Title: Cattle Feedlot Runoff Reservoir Sufficient Design Simulation Model

Authors: R. B. Wensink, J. R. Miner, and T. W. Booster

Installation: CDC Cyber 70 series at Oregon State University

Programming Language: Standard FORTRAN IV

Date Written: 1976-77

Remarks:

This simulation model operates continuously from one year to the next and requires daily precipitation, average temperatures, and snowfall accumulations. The model determines minimum disposal area and reservoir storage volume required to meet Environmental Protection Agency performance standards with a specific irrigation pumping capacity. Pumping capacity, expressed in a fraction of the location's 25 year-24 hour storm, and management dewatering policy are the only major design parameters required in the model.

PROGRAM OUTPUT

The output variable names are defined in the program.

A. Yearly Results

1. Total number of reservoir overflows
2. Maximum reservoir depth
3. Inches of legal overflow
4. Maximum rainfall
5. Total rainfall
6. Total runoff
7. Total runoff from precipitation over 25 year-24 hour storm
8. Total rainfall over 25 year-24 hour storm
9. Total number of pumping days
10. Total number of permissible pumping days
11. Total amount of nitrogen applied annually
12. Number of disposal sites
13. Total number of acres used for disposal purposes

B. Total Run Results

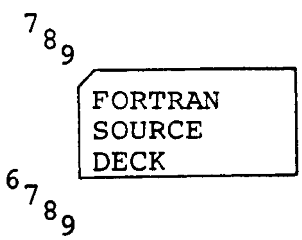
1. Total years simulated
2. Total rainfall
3. Total runoff
4. Total legal overflow from precipitation over 25 year-24 hour storm
5. Total runoff from precipitation over 25 year-24 hour storm
6. Average precipitation
7. Average legal overflow from precipitation over 25 year-24 hour storm
8. Average runoff
9. Average runoff from precipitation over 25 year-24 hour storm
10. Minimum design reservoir design required to hold all precipitation less than 25 year-24 hour storm.
11. Average number of pumping days
12. Average number of permissible pumping days
13. Size of disposal site (acres)
14. Maximum amount of nitrogen allowable on disposal site (lb/acre)

PROGRAM INPUT

Input variable names are defined in the program. Even though the model was developed and utilized on Oregon State's Time Sharing Computer System, the following cards would be required to operate the program from a CDC Cyber 70 Batch Processing System.

A. Order of Job Control Language Cards

```
(JOB CARD)
(ACCOUNT CARD)
GET,TAPE2 = <climatic data>.
GET,TAPE3 = <management policy>.
FTN.
LGO.
```




B. Inputs

1. Pumping rate (fraction of 25 year-24 hour storm)
2. Nitrogen concentration (mg/liter) of effluent
3. Maximum nitrogen per acre (lb/acre)

C. In addition, the following DATA statements need to be defined:

1. ISTART and IFINAL should be set to the first and last year, respectively, of the data utilized in a particular run.

2. LIN and LOUT correspond to computer installation input and output logical unit numbers, respectively.

3. RAINMAX should be set to 0.0 unless dewatering is permitted on days in which rainfall occurs. If this condition is desired, set RAINMAX to the maximum level of rainfall at which dewatering is still permitted.

4. EXPRAIN should be set to the station's 25 year-24 hour recurrence storm.

5. MONTEMP is a one-dimensional array which contains average monthly mean temperatures.

6. AVAP is a one-dimensional array which contains average daily evaporation for each month.

7. SURDPT is the pond depth used to determine pond surface area.

8. EVAPCON is the evaporation constant which converts pan evaporation to pond surface evaporation.

9. DAYLIM is the maximum daily application of water (precipitation and effluent) to disposal plot.

10. WKLIM is the maximum weekly application of water (precipitation and effluent) to disposal plot.

D. Data Files

1. The climatic data file must be created prior to running this simulation program. Each file must contain the years of weather data from a particular station. These data consist of rainfalls, snowfalls, and temperatures. Each record contains eight consecutive days of rainfall-temperature data punched in the following format: (8(I3,F4.2,F3.0)).

2. The management dewatering policy data file consists of a set of zeroes and ones, with the first ten characters describing management policy. The format is: (A10/(80I1)).

```
      PROGRAM DISITES(INPUT,OUTPUT,TAPE2,TAPE3,TAPE4=INPUT,
     *  TAPE61)
C
C
C
C                    CATTLE FEEDLOT RUNOFF RESERVOIR
C
C                    SUFFICIENT DESIGN TECHNIQUE
C                        SIMULATION MODEL
C
C
C
C            THIS MODEL DETERMINES THE MINIMUM RESERVOIR
C            STORAGE VOLUME AND DISPOSAL AREA REQUIRED TO MEET
C            ENVIRONMENTAL PROTECTION AGENCY PERFORMANCE STANDARDS
C            WITH A SPECIFIC IRRIGATION PUMPING CAPACITY.
C
C
C
C
C
C                          VARIBLE DEFINITIONS
C
C
C
C      LIN = INPUT UNIT
C      LOUT = OUTPUT UNIT
C      IDAYPM = NUMBER OF DAYS PER MONTH
C      ISTART = FIRST YEAR OF DATA
C      IFINAL = LAST YEAR OF DATA
C      RAINMX = MAXIMUM RAINFALL THAT OCCURED DURING EACH YEAR
C      RAINMAX = DEWATERING PERMITTED ON DAYS WITH RAINFALL
C              LESS THAN THIS VALUE
C      EXPRAIN = 25 YEAR-24 HOUR EXPECTED RECURRENCE RAINFALL VALUE
C      ANTCON = 5 DAY ANTICEDENT MOISTURE ACCUMULATION
C      DEPTH = DEPTH OF POND
C      IWARMC = SEASONAL CRITERION IN RUNOFF EQUATION
C      MINTEMP = FREEZING CRITERION
```

```
C     IDAYEAR = NUMBER OF DAYS IN A YEAR
C     PUMPDF = DAILY PUMPING CAPACITY
C     INO = NUMBER OF YEARS OF DATA
C     ITEMP = TEMPERATURE DATA
C     RAIN = RAINFALL DATA
C     BGANTC = STORE END OF YEAR RAINFALL
C     IBGTMP = STORE END OF TEMPERATURE
C     ISUM = THREE DAY ANTICEDENT TEMPERATURE
C     Q = DAILY RUNOFF
C     RAINOV = YEARLY ACCUMULATION OF RAINFALL OVER
C            25 YEAR-24 HOUR EXPECTED STORM VALUE
C     IDAYOV = NUMBER OF DAYS PER YEAR THAT THE POND OVERFLOWED
C            WHEN RAINFALL WAS GREATER THAN 25 YEAR-24 HOUR VALUE
C     DEPTHC = DEPTH OF POND WHEN RAIN EXCEEDED 25 YEAR-24 HOUR VALUE
C     DPTMXYR = MAXIMUM DEPTH THAT POND REACHED DURING YEAR
C     OVERFLW = AMOUNT THAT THE POND OVERFLWED
C     DPTMAX = MAXIMUM POND DEPTH
C     RUNOFC = AMOUNT OF RUNOFF FOR EACH YEAR
C     TTRAIN = TOTAL RAINFALL FOR EACH YEAR
C     TRUNOF = TOTAL RUNOFF FOR EACH YEAR
C     TOTRFC = TOTAL RUNOFF FROM STORMS GREATER THAN
C            25 YEAR-24 HOUR VALUE
C     TOTALR = TOTAL RAINFALL FOR ALL YEARS
C     TOTALC = TOTAL LEGAL OVERFLOW FROM POND FOR ALL YEARS
C     TOTALF = TOTAL RUNOFF FOR ALL YEARS
C     AVGPRC = AVERAGE RAINFALL
C     AVGOVR = AVERAGE LEGAL OVERFLOW
C     AVGROF = AVERAGE RUNOFF
C     AVGRFC = AVERAGE OVERFLOW FROM STORMS GREATER THAN 25 YEAR
C            -24 HOUR EXPECTED STORM VALUE
C     SNOWACC = DAILY SNOW ON GROUND
C     RAINACC = RAINFALL WHICH ACCUMULATES WHILE SNOW ON GROUND
C     IFLAGSN = SNOWFALL RUNOFF FLAG
C             = 0, WHEN NO RUNOFF FROM SNOFALL
C             = 1, WHEN RUNOFF FROM SNOWFALL
C     IPUMPDY = TOTAL PERMISSIBLE PUMPING DAYS EACH YEAR
C     IPUMPC = TOTAL ACTUAL PUMPING DAYS EACH YEAR
C     OVERFL = YEARLY TOTAL POND OVERFLOW
```

```
C       MANGT = MANAGEMENT DEWATERING POLICY
C       AMEVAP = AVERAGE DAILY EVAPORATION FOR EACH MONTH FOR SPECIFIC DAY
C       MONTEMP = AVERAGE MONTHLY MEAN TEMPERATURE
C       IMONTF = AVERAGE MONTHLY MEAN TEMP FOR SPECIFIC DAY
C       AVAP = AVERAGE DAILY EVAPORATIONS FOR EACH MONTH
C       SURDPT = POND DEPTH USED TO DETERMINE SURFACE AREA
C       EVAPCON = EVAPORATION CONSTANT TO CONVERT PAN TO POND
C       SURAREA = POND SURFACE AREA
C       RATEPM = FRACTION OF POND VOLUME (25 YEAR-24 HOUR STORM)
C               PERMITTED IN ONE DAY OF PUMPING
C       EVAP = ACTUAL DAILY EVAPORATION
C       POLICY = MANAGEMENT POLICY FOR EACH STATION
C       STAT1 AND STAT2 = LOCATION OF EACH STATION
C       TOTPD = TOTAL NUMBER OF PUMPING DAYS
C       AVGPD = AVERAGE NUMBER OF PUMPING DAYS PER YEAR
C       TOTPPD = TOTAL NUMBER OF PERMISSIBLE PUMPING DAYS
C       AVGPPD = AVERAGE NUMBER OF PERMISSIBLE PUMPING DAYS PER YEAR
C       ACRES = ACRES PER DISPOSAL SITE
C       DAYLIM = MAXIMUM DAILY MOISTURE (PRECIPITATION AND DEWATERING)
C                 PERMITTED ON DISPOSAL SITE
C       LDAY = LAST DAY DISPOSAL SITE WAS IRRIGATED
C       NCONC = NITROGEN CONCENTRATION OF POND WATER (MG/LITER)
C       NLEV = AMOUNT OF NITROGEN DISPOSED OF ON SITE (LBS)
C       NLIM = MAXIMUM NITROGEN PER ACRE (LBS/ACRE)
C       NLPS = NITROGEN LIMIT PER DISPOSAL SITE (LBS)
C       NODAYS = NUMBER OF DAYS DISPOSAL SITE WAS IRRIGATED
C       SITES = NUMBER OF DISPOSAL SITES USED PER YEAR
C       WKLIM = MAXIMUM WEEKLY MOISTURE (PRECIPITATION AND DEWATERING)
C                PERMITTED ON DISPOSAL SITE
C       XCONC = NITROGEN CONCENTRATION OF POND WATER (LBS/ACRE-IN)
C
C
      DIMENSION ITEMP(366),RAIN(366),IDAYEM(13),RGANTC(6),IPUMPDY(75),
     1IBGTMF(6),OVERFL(75),IDAYCV(75),RAINMX(75),TTRAIN(75),IPUMPD(75),
     2MANGT(366),AMEVAP(366),MONTEMP(12),IMONTF(366),AVAP(12),
     2SNOWACC(366),TRUNOF(75),DPTMXYR(75),RUNOFC(75),RAINCV(75)
      DIMENSION IFLAG(10),LDAY(10,3),NODAYS(10)
      REAL NCONC,NLIM,NLPS,N,NLEV(10)
```

```
      INTEGER SITES(75)
      DATA(IDAYPM=31,29,31,30,31,30,31,31,30,31,30,31,0)
      DATA(ISTART=1908),(IFINAL=1973)
      DATA(MONTEMP=19,22,30,40,48,57,64,62,52,42,31,20)
      DATA(AVAP=0.0,0.0,0.0,0.1366,0.1947,0.2152,0.2847,0.2452,0.1610,
     *  0.0904,0.0,0.0)
      DATA(EXPRAIN=2.7)
      DATA(LIN=60),(LOUT=61)
       DATA(RAINMAX=0.0)
      DATA(SURDPT=6.0),(EVAPCON=.7)
      DATA(DAYLIM=2.0),(WKLIM=7.0)
      REWIND 3
      REWIND 2
      PRINT 4
    4 FORMAT(≠ ENTER PUMPING RATE.≠)
      READ(4,5)RATEPM
    5 FORMAT(F8.2)
C
      PUMPDP=RATEPM*EXPRAIN
C
      PRINT 6
    6 FORMAT(≠ ENTER NIT CONC AND MAX NIT PER ACRE≠)
      READ(4,5) NCONC,NLIM
      XCONC=NCONC*0.2266
      ACRES=PUMPDP/DAYLIM
      NLPS=NLIM*ACRES
      N=PUMPDP*XCONC
C
      ANTCON=0.0
      DEPTH=0.0
      IWARMC=45
      MINTEMP=96
      RAINACC=0.0
      TOTRFC=TOTALR=TOTALO=TOTPD=TOTPPD=TOTALF=0.0
      K=0
      DO 7 IK=1,12
      M=IDAYPM(IK)
      DO 8 IM=1,M
```

```
      IT=K+IM
      IMONTF(IT)=MONTEMP(IK)
    8 AMEVAF(IT)=AVAP(IK)
      K=K+M
    7 CONTINUE
C
C                       READ IN MANAGEMENT POLICY
C
      READ(3,3)POLICY,(MANGT(IO),IO=1,366)
  3   FORMAT(A10/(80I1))
C
C**************** DETERMINE POND SURFACE AREA *************************
C
      SURAREA=43560*(EXPRAIN*2.0)/12.0/SURDPT
C
C
C                    CONVERT EXPECTED VALUES TO 24 HOUR PERIOD
      EXPRAIN=EXPRAIN/1.14
C
      INO=IFINAL-ISTART+1
      IYEAR=ISTART-1
C                      READ IN STATION NAME
      READ(2,6001)STAT1,STAT2
6001  FORMAT(2A10)
      WRITE(LOUT,6108)
6108  FORMAT(1H1/////3X,≠YEAR≠,4X,≠DAY≠,4X,≠RAIN≠,4X,≠DEPTH≠,4X,
     1≠  Q  ≠,4X,≠MAX DEPTH≠,4X,≠OVERFLOW≠)
C
C                       START YEARLY LOOP
C
      DO500K=1,INO
C
      DO 9 II=1,10
        IFLAG(II)=0
        NODAYS(II)=0
        NLEV(II)=0.0
        DO 12 JJ=1,3
 12       LDAY(II,JJ)=-7
```

```
 9    CONTINUE
C
C                           SET YEAR TO NON-LEAP YEAR
C
      IDAYPM(2)=28
      IDAYEAR=365
      NN=0
C
C                        CHECK FOR LEAP YEAR
C
      IYEAR=IYEAR+1
      LYEAR=IYEAR/4*4
      IF(LYEAR.NE.IYEAR) GO TO 10
      IDAYPM(2)=29
      IDAYEAR=366
 10   CONTINUE
C
C                             READ IN DATA
C
      READ(2,6002)(ITEMP(I),RAIN(I),SNOWACC(I),I=1,IDAYEAR)
6002  FORMAT(8(I3,F4.2,F3.0))

C
C                 SET INITIAL ANTICEDENT RAIN AND TEMPERATURE CONDITIONS
C
      IF(K.GT.1)GO TO 15
      DO 20 IJ=1,6
      J=IDAYEAR-IJ+1
      II=6-IJ+1
      BGANTC(II)=RAIN(J)
   20 IBGTMP(II)=ITEMP(J)
      DO 21 I=1,5
   21 ANTCDN=ANTCDN+BGANTC(I)
C
C                  START DAILY SIMULATION FOR THIS YEAR
C
   15 DO 400 I=1,IDAYEAR
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```
      IF(I.GT.6) GO TO 30
      IF(I.EQ.1) GO TO 25
      ANTCDN=RAIN(I-1)+ANTCDN-BGANTC(I)
      GO TO 40
   25 ANTCDN=BGANTC(6)+ANTCDN-BGANTC(1)
      GO TO 40
   30 ANTCDN=ANTCDN+RAIN(I-1)-RAIN(I-6)
   40 CONTINUE
C
C                    ACCUMULATE TOTAL RAINFALL FOR YEAR
C
      TTRAIN(K)=TTRAIN(K)+RAIN(I)
C
C****************** DETERMINE EVAPORATION *****************************
C
C                     DETERMIND DAILY PAN EVAPORATION
C
      EVAP=AMEVAP(I)*ITEMP(I)/IMONTP(I)
C                     CORRECT POND DEPTH FOR EVAPORATION AND RAINFALL
      DEPTH=DEPTH+(RAIN(I)-EVAP*EVAPCON)*SURAREA/43560.0
      IF(DEPTH.LT.0.0)DEPTH=0.0
C
C******************* CHECK IRRIGATION CONDITION **********************
C
C                      CHECK GROUND FROZEN
C
      IF(I.LE.3)GOTO60
      ISUM=ITEMP(I-3)+ITEMP(I-2)+ITEMP(I-1)
      GOTO80
   60 IF(I.EQ.1)GOTO70
      IF(I.EQ.2)GOTO75
      ISUM=IBGTMP(6)+ITEMP(1)+ITEMP(2)
      GO TO 80
   70 ISUM=IBGTMP(6)+IBGTMP(5)+IBGTMP(4)
      GOTO80
   75 ISUM=IBGTMP(6)+IBGTMP(5)+ITEMP(1)
   80 IF(ISUM.GT.MINTEMP)GOTO100
      MINTEMP=114
```

```
      GOTO180
  100 MINTEMP=96
C
      IF(MANGT(I).EQ.0
     *  .OR. RAIN(I).GT.RAINMAX
     *  .OR.ITEMP(I).LE.32
     *  .OR. SNOWACC(I).GT.0.0) GOTO 180
C
C                    PUMPING IS PERMITTED TODAY
C
      IPUMPDY(K)=IPUMPDY(K)+1
C
C                CHECK WATER LEVEL
C
      IF(DEPTH.LT.PUMPDP) GOTO 180
C
C                    CHECK IF SITE AVAILABLE
C
      IF(ANTCON+DAYLIM.GT.WKLIM) GOTO 180
      DO 128 IS=1,10
        IF(NODAYS(IS).EQ.0) GOTO 130
        ND=0
        JJ2=NODAYS(IS)
        DO 125 JJ=1,JJ2
          IF(I-LDAY(IS,JJ2).LT.7) ND=ND+1
  125     CONTINUE
        IF(ANTCON+ND*DAYLIM.LT.WKLIM) GOTO 130
  128   CONTINUE
      STOP1
C
C                    SITE AVAILABLE
C
  130 IPUMPD(K)=IPUMPD(K)+1
      DEPTH=DEPTH-PUMPDP
      IF(IFLAG(IS).NE.0) GOTO 140
        IFLAG(IS)=1
        SITES(K)=SITES(K)+1
```

```
 140   JJ2=NODAYS(IS)=NODAYS(IS)+1
       IF(JJ2.GT.3) STOP2
       LDAY(IS,JJ2)=I
       NLEV(IS)=NLEV(IS)+N
       IF(NLEV(IS).LT.NLFS) GOTO 180
         DO 170 II=IS,9
           II2=II+1
           IFLAG(II)=IFLAG(II2)
           NODAYS(II)=NODAYS(II2)
           NLEV(II)=NLEV(II2)
           DO 160 JJ=1,3
 160         LDAY(II,JJ)=LDAY(II2,JJ)
         IF(IFLAG(II2).EQ.0) GOTO 180
 170     CONTINUE
  180 CONTINUE
C
C*********** ACCUMULATE RAINFALL IF SNOW ON GROUND *****************
C
       IFLAGSN=0
       IF(SNOWACC(I).LE.0.0) GOTO 190
       RAINACC=RAINACC+RAIN(I)
       GOTO 400
 190   IF(RAINACC.LE.0.0) GOTO 200
       RAIN(I)=RAIN(I)+RAINACC
       RAINACC=0.0
       IFLAGSN=1
C
C**********RAINFALL LESS THAN .05 IS CONSIDERED INSIGNIFICANT*********
C
  200 IF(RAIN(I).LE.0.05)GOTO400
C
C
C********************* DETERMINE RUNOFF ***************************
C
       IF(IFLAGSN.EQ.1
     *  .OR. ITEMP(I).GT.IWARMC .AND. ANTCON.GT.2.1
     *  .OR. ITEMP(I).LE.IWARMC .AND. ANTCON.GT.1.1) GOTO 320
```

```
C                          ANTICEDENT CONDITION NO.  II
      Q=(RAIN(I)-0.1979)**2/(RAIN(I)+.7912)
      GOTO340
C                          ANTICEDENT CONDITION NO. III
  320 Q=(RAIN(I)-.0613)**2/(RAIN(I)+.247)
C
C                          POND MUST HOLD ALL RUNOFF FROM SNOWFALL
      IF(IFLAGSN.EQ.1) GO TO 342
C
C                           CHECK FOR MAXIMUM
C
  340 IF(RAIN(I).LE.EXPRAIN)GO TO 342
      RAINOV(K)=RAINOV(K)+RAIN(I)
      NYEAR=ISTART+K-1
      DEPTHO=DEPTH+Q
      IF(DEPTHO.GT.DPTMAX)GO TO 341
      IF(DPTMXYR(K).LT.DEPTHO)DPTMXYR(K)=DEPTHO
      OVERFLW=0.0
      DEPTH=DEPTHO
      GO TO 345
  341 DEPTH=DPTMAX
      OVERFLW=DEPTHO-DPTMAX
      OVERFL(K)=OVERFL(K)+OVERFLW
      IDAYOV(K)=IDAYOV(K)+1
      DPTMXYR(K)=DPTMAX
  345 WRITE(61,6111)NYEAR,I,RAIN(I),DEPTHO,Q,DPTMAX,OVERFLW
 6111 FORMAT(4X,I4,4X,I3,3X,F5.2,3X,F5.2,5X,F5.2,4X,F6.2,8X,F5.2)
      RUNOFO(K)=RUNOFO(K)+Q
      GO TO 343
  342 DEPTH=DEPTH+Q
      IF(DEPTH.GT.DPTMAX)DPTMAX=DEPTH
      IF(DEPTH.GT.DPTMXYR(K))DPTMXYR(K)=DEPTH
  343 CONTINUE
      IF(RAINMX(K).LE.RAIN(I))RAINMX(K)=RAIN(I)
      TRUNOF(K)=TRUNOF(K)+Q
  400 CONTINUE
      DO 450 I=1,6
      J=IDAYEAR-I+1
```

```
      II=6-I+1
      BGANTC(II)=RAIN(J)
  450 IBGTMP(II)=ITEMP(J)
  500 CONTINUE
C
C********************** CALCULATE STATISTICS ************************
C
      DO550I=1,INO
      TOTRFC=TOTRFO+RUNOFC(I)
      TOTALR=TOTALR+TTRAIN(I)
      TOTALC=TOTALC+OVERFL(I)
      TOTPD=TOTPD+IPUMPD(I)
      TOTPPD=TOTPPD+IPUMPDY(I)
  550 TOTALF=TOTALF+TRUNOF(I)
      AVGRFC=TOTRFO/INO
      AVGPRC=TOTALR/INO
      AVGOVR=TOTALC/INO
      AVGROF=TOTALF/INO
      AVGPD=TOTPD/INO
      AVGPPD=TOTPPD/INO
      EXPRAIN=EXPRAIN*1.14
C
C********************** WRITE OUT RESUTLS **************************
C
      WRITE(LOUT,6104)ISTART,IFINAL,STAT1,STAT2,POLICY,SURAREA,
     1RATEPM,EXPRAIN,TOTALR,TOTALO,TOTALF,TOTRFC,AVGPRC,
     2AVGOVR,AVGROF,AVGRFO,AVGPD,AVGPPD,DPTMAX
 6104 FORMAT(1H0/////30X,≠TOTAL STATISTICS FOR YEARS≠,I5,≠ TO≠,I5.
     +≠ FOR ≠,2A10//30X,≠MANAGEMENT DEWATERING POLICY = ≠,A10//
     +30X,≠SURFACE AREA=≠,F10.2,≠ SQ. FEET/FEEDLOT ACRE≠/30X,
     +≠PUMPING RATE=≠,F5.2,≠ TIMES≠,F9.2, ≠ ACRE-INCHES/FEEDLOT ACRE≠/
     +30X,≠TOTAL RAINFALL=≠,F10.2,≠ INCHES≠/
     +30X,≠TOTAL OVERFLOW=≠,F10.2,≠ INCHES≠/
     +30X,≠TOTAL RUNOFF=≠,F9.2,≠ INCHES≠/
     +30X,≠TOTAL RUNOFF FROM ALL STORMS > 25YR EXPECTED STORM=≠,F9.2,
     +≠ INCHES≠/
     +30X,≠AVERAGE PRECIPITATION =≠,F9.2,≠ INCHES/YEAR≠/
     +30X,≠AVERAGE LEGAL OVERFLOW FROM EXCEEDING POND DEPTH=≠,F9.2,
```

```
     +≠ INCHES/YEAR≠/
     +30X,≠AVERAGE RUNOFF≠,F10.2,≠ INCHES/YEAR≠/
     +30X,≠AVERAGE RUNOFF FROM STORMS > 25YR EXPECTED STORM =≠,F9.2,
     +≠ INCHES/YEAR≠/
     +30X,≠AVERAGE NUMBER OF PUMPING DAYS =≠,F5.1/
     +30X,≠AVERAGE NUMBER OF PERMISSIBLE PUMPING DAYS =≠,F6.1/
     +30X,≠POND DEPTH TO HOLD ALL RUNOFF < 25YR STORM =≠,F8.2,
     +≠ ACRE-INCHES/FEEDLOT ACRE≠)
      WRITE(LOUT,6100)STAT1,STAT2,POLICY,RATEPM
 6100 FORMAT(1H1,20X,2A10,5X,≠MANAGEMENT DEWATERING POLICY = ≠,A10,5X,
     +≠PUMPING RATE = ≠,F5.2/1H0,≠YEAR  TOTAL NO.  MAX DEPTH  IN. LEGAL
     1 MAXIMUM   TOTAL   TOTAL≠,5X,≠TOTAL RUNOFF≠,4X,
     2≠TOTAL RAINFALL≠,5X,≠TOTAL≠,6X,≠TOTAL PERMISSIBLE≠/
     37X,≠OVERFLOWS  PER YEAR   OVERFLOW    RAIN≠,5X,
     4≠RAIN    RUNOFF  OVER 25YR STORM  OVER 25YR STORM  ≠,
     5≠PUMPING DAYS    PUMPING DAYS≠)
      DO 600 I=ISTART,IFINAL
      J=I-ISTART+1
      WRITE(LOUT,6103)I,IDAYOV(J),DPTMXYR(J),
     1OVERFL(J),RAINMX(J),TTRAIN(J),TRUNOF(J),RUNOFO(J),RAINOV(J),
     2IPUMPD(J),IPUMPDY(J)
 6103 FORMAT(1X,I4,5X,I3,6X,F6.2,5X,F6.2,4X,F6.2,3X,F6.2,3X,F6.2,
     16X,F6.2,11X,F6.2,11X,I3,16X,I3)
  600 CONTINUE
C
      WRITE(LOUT,6200) STAT1,STAT2,ISTART,IFINAL,POLICY,RATEPM,
     *  EXPRAIN,ACRES,NLIM
 6200 FORMAT(≠1STATION:  ≠,2A10/
     *  ≠ YEARS:  ≠,I4,≠-≠,I4/
     *  ≠ MANAGEMENT DEWATERING POLICY:  ≠,A10/
     *  ≠ PUMPING RATE:  ≠,F4.2,≠ TIMES ≠,F5.2,
     *  ≠ ACRE INCHES/FEEDLOT ACRE≠/
     *  ≠ ACRES/SITE:  ≠,F5.2/
     *  ≠ NITROGEN LIMIT:  ≠,F7.2,≠ LBS/ACRE≠////
     *  ≠ YEAR≠,5X,≠NITROGEN≠,5X,≠NO. OF SITES≠,5X,≠TOT. ACRES USED≠/
     *  12X,≠(LBS)≠/)
```

```
      DO 700 I=ISTART,IFINAL
        J=I-ISTART+1
        XN=IPUMPD(J)*N
        XAC=SITES(J)*ACRES
 700    WRITE(LOUT,6300) I,XN,SITES(J),XAC
C
 6300 FORMAT(1X,I4,5X,F8.2,9X,I4,13X,F8.2)
      STOP
      END
```

# APPENDIX B. DESIGN EVALUATION SIMULATION MODEL

## GENERAL PROGRAM INFORMATION

Title: Cattle Feedlot Runoff Reservoir Design Evaluation Simulation Model

Authors: R. B. Wensink, J. R. Miner, and T. W. Booster

Installation: CDC Cyber 70 at Oregon State University

Programming Language: Standard FORTRAN IV

Date Written: 1976-77

Remarks:

This simulation model evaluates the ability of runoff reservoir designs to meet EPA performance standards. The model can evaluate several reservoir designs with one computer run and requires the following input information for each reservoir design: pond volume, dewatering rate, management dewatering policy, and daily climatic data. For each design the model determines number and volume of yearly discharges.

## PROGRAM OUTPUT

The output variables are defined in the program:

A. Yearly Results

1. Number of legal overflows
2. Amount of legal overflow
3. Number of illegal overflows
4. Amount of illegal overflow
5. Total overflow (legal and illegal)
6. Maximum pond volume
7. Maximum rainfall
8. Total rainfall
9. Total runoff
10. Pumping days
11. Permissible pumping days

B. Total Run Results

1. Years simulated
2. Pond depth
3. Management dewatering policy
4. Surface area of pond
5. Pumping rate
6. Total number of legal overflows
7. Total amount of legal overflow

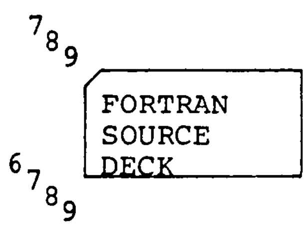
8. Total number of illegal overflows
9. Total amount of illegal overflow
10. Total amount of overflow (legal and illegal)

PROGRAM INPUT

Input variable names are defined in the program. Even though the model was developed and utilized on Oregon State University's Time Sharing Computer System, the following cards would be required to operate the program from a CDC Cyber 70 Batch Processing System.

A. Order of Job Control Language Cards

```
(JOB CARD)
(ACCOUNT CARD)
GET,TAPE2 = <climatic data>.
GET,TAPE3 = <management policy>.
FTN.
LGO.
```




B. Inputs

1. Number of ponds
2. Pond depth
3. Pumping rates

C. In addition, the following DATA statements need to be defined:

1. ISTART and IFINAL should be set to the first and last year, respectively, of the data utilized in a particular run.
2. LIN and LOUT correspond to computer installation input and output logical unit numbers, respectively.
3. RAINMAX should be set to 0.0 unless dewatering is permitted on days in which rainfall occurs. If this condition is desired, set RAINMAX to the maximum level of rainfall at which dewatering is still permitted.
4. EXPRAIN should be set to the station's 25 year-24 hour recurrence storm.
5. MTEMP is a one-dimensional array which contains average monthly mean temperatures.

6. MEVAP is a one-dimensional array which contains average daily evaporation for each month.

7. SURDPT is the pond depth used to determine pond surface area.

8. EVAPCON is the evaporation constant which converts pan evaporation to pond surface evaporation.

D. Data Files

1. The climatic data file must be created prior to running this simulation program. Each file must contain the years of weather data from a particular station. These data consist of rainfalls, snowfalls, and temperatures. Each record contains eight consecutive days of rainfall-temperature data punched in the following format: (8(I3,F4.2,F3.0)).

2. The management dewatering policy data file consists of a set of zeroes and ones, with the first ten characters of each file describing management policy. The format is (A10/(80I1)).

```
      PROGRAM PONDS(INPUT,OUTPUT,TAPE2,TAPE3,TAPE61)
C
C
C
C                 CATTLE FEEDLOT RUNOFF RESERVOIR
C
C                       SIMULATION MODEL
C
C
C
C           THIS MODEL ALLOWS YOU TO SIMULATE UP TO TEN
C           STORAGE PONDS EACH WITH A GIVEN VOLUME AND
C           IRRIGATION PUMPING CAPACITY.
C
C
C
C
C
C
C
C
C
C
C
C                         VARIBLE DEFINITIONS
C
C
C
C     LIN = INPUT UNIT
C     LOUT = OUTPUT UNIT
C     IDAYPM = NUMBER OF DAYS PER MONTH
C     ISTART = FIRST YEAR OF DATA
C     IFINAL = LAST YEAR OF DATA
C     RMAX = MAXIMUM RAINFALL THAT OCCURED DURING EACH YEAR
C     RAINMAX = DEWATERING PERMITTED ON DAYS WITH RAINFALL
C             LESS THAN THIS VALUE
```

```
C     EXPRAIN = 25 YEAR-24 HOUR EXPECTED RECURRENCE RAINFALL VALUE
C     ANTCON = 5 DAY ANTICEDENT MOISTURE ACCUMULATION
C     DEPTH = DEPTH OF POND
C     IWARMC = SEASONAL CRITERION IN RUNOFF EQUATION
C     MINTEMP = FREEZING CRITERION
C     IDAYEAR = NUMBER OF DAYS IN A YEAR
C     PUMPDF = DAILY PUMPING CAPACITY
C     INO = NUMBER OF YEARS OF DATA
C     ITEMP = TEMPERATURE DATA
C     RAIN = RAINFALL DATA
C     ANTRAIN = STORE END OF YEAR RAINFALL
C     ANTEMP = STORE END OF TEMPERATURE
C     ISUM = THREE DAY ANTICEDENT TEMPERATURE
C     Q = DAILY RUNOFF
C     TRAIN = TOTAL RAINFALL FOR EACH YEAR
C     SNOWACC = DAILY SNOW ON GROUND
C     RAINACC = RAINFALL WHICH ACCUMULATES WHILE SNOW ON GROUND
C     IFLAGSN = SNOWFALL RUNOFF FLAG
C             = 0, WHEN NO RUNOFF FROM SNOFALL
C             = 1, WHEN RUNOFF FROM SNOWFALL
C     PPD = TOTAL PERMISSIBLE PUMPING DAYS EACH YEAR
C     PD = TOTAL ACTUAL PUMPING DAYS EACH YEAR
C     OVFL = YEARLY TOTAL POND OVERFLOW
C     MANGT = MANAGEMENT DEWATERING POLICY
C     DEVAP = AVERAGE DAILY EVAPORATION FOR EACH MONTH FOR SPECIFIC DAY
C     MTEMP = AVERAGE MONTHLY MEAN TEMPERATURE
C     DTEMP = AVERAGE MONTHLY MEAN TEMP FOR SPECIFIC DAY
C     MEVAP = AVERAGE DAILY EVAPORATIONS FOR EACH MONTH
C     SURDPT = POND DEPTH USED TO DETERMINE SURFACE AREA
C     EVAPCON = EVAPORATION CONSTANT TO CONVERT PAN TO POND
C     SURAREA = POND SURFACE AREA
C     RATEPM = FRACTION OF POND VOLUME (25 YEAR-24 HOUR STORM)
C            PERMITTED IN ONE DAY OF PUMPING
C     EVAP = ACTUAL DAILY EVAPORATION
C     POLICY = MANAGEMENT POLICY FOR EACH STATION
C     STAT1 AND STAT2 = LOCATION OF EACH STATION
C     DEPTH = POND DEPTH
```

```
C      DMAX = MAXIMUM POND DEPTH FOR YEAR
C      DPMAX = MAXIMUM POND DEPTH FOR RUN
C      NP = NUMBER OF PONDS
C      IONR = ILLEGAL OVERFLOW NOT RETAINED
C      IOR = ILLEGAL OVERFLOW RETAINED
C      LONR = LEGAL OVERFLOW NOT RETAINED
C      LOR = LEGAL OVERFLOW RETAINED
C      NIO = NUMBER OF ILLEGAL OVERFLOWS
C      NLO = NUMBER OF LEGAL OVERFLOWS
C      TOVFL = TOTAL OVERFLOW FOR YEAR
C      TQ = TOTAL RUNOFF FOR RUN
C
C
C
       INTEGER DAY,
      *  ITEMP(366),MANGT(366),DTEMP(366),
      *  MTEMP(12),IDAYPM(13),
      *  ANTEMP(6),
      *  NLO(10,75),NIO(10,75),PD(10,75),PPD(10,75),
      *  TOTNLO(10),TOTNIO(10)
       REAL
      *  RAIN(366),SNOWACC(366),DEVAP(366),
      *  MEVAP(12),
      *  ANTRAIN(6),
      *  DEPTH(10),DPMAX(10),
      *  LOR(10,75),LONR(10,75),IOR(10,75),IONR(10,75),TOVFL(10,75),
      *  DMAX(10,75),RMAX(10,75),TRAIN(75),TQ(75),
      *  TOTLOR(10),TOTLONR(10),TOTIOR(10),TOTIONR(10),TOTOVFL(10),
      *  PUMPDP(10),RATEPM(10)
       DATA(IDAYPM=31,29,31,30,31,30,31,31,30,31,30,31,0)
       DATA(ISTART=1914),(IFINAL=1971)
       DATA(MTEMP=31,37,44,50,57,64,72,70,62,51,40,34)
       DATA(MEVAP=0.0,0.0,0.1037,0.1603,0.2284,0.2927,0.3290,
      *  0.2810,0.1832,0.0983,0.0250,0.0)
       DATA(EXPRAIN=1.5)
       DATA(SURDPT=6.0),(EVAPCON=0.7),(RAINMAX=0.0),(IWARMC=45)
C
```

```
      REWIND 2
      REWIND 3
C
C
C  INPUT:
C     (1)  NUMBER OF PONDS
C     (2)  POND DEPTHS
C     (3)  PUMPING RATE
C
 2    PRINT 6010
      READ *,NP
      PRINT 6030
      READ *,(DPMAX(I),RATEPM(I),I=1,NP)
      PRINT 6070
      READ 6075,DCHK
      IF(DCHK.EQ.≠NO        ≠) GOTO 2
C
C  INITIALIZE VARIABLES
      ANTCON=RAINACC=0.0
      MINTEMP=96
      SURAREA=43560.0*(EXPRAIN*2.0)/12.0/SURDPT
      DO 3 I=1,NP
 3      PUMPOP(I)=RATEPM(I)*EXPRAIN
      CEXRAIN=EXPRAIN/1.14
      INO=IFINAL-ISTART+1
C
      DAY=0
      DO 10 M=1,12
        I2=IDAYPM(M)
        DO 5 I=1,I2
          DAY=DAY+1
          DTEMP(DAY)=MTEMP(M)
 5        DEVAP(DAY)=MEVAP(M)
 10     CONTINUE
C
C  INPUT STATION NAME
      READ(2,6080) STAT1,STAT2
```

```
C
C  INPUT MANAGEMENT POLICY
      READ(3,6100) POLICY,(MANGT(I),I=1,366)
C
C  START YEARLY LOOP
      DO 500 IYEAR=ISTART,IFINAL
      IY=IYEAR-ISTART+1
C
C  CHECK FOR LEAP YEAR
      IDAYPM(2)=28
      IDAYEAR=365
      IF(IYEAR.NE.IYEAR/4*4) GOTO 20
      IDAYPM(2)=29
      IDAYEAR=366
 20   CONTINUE
C
C  INPUT CLIMATIC DATA FOR YEAR
      READ(2,6120)(ITEMP(I),RAIN(I),SNOWACC(I),I=1,IDAYEAR)
C
C  SET INITIAL ANTECEDENT RAIN AND TEMPERATURE CONDITIONS
      IF(IYEAR.GT.ISTART) GOTO 50
      J=IDAYEAR-6
      DO 30 I=1,6
        J=J+1
        ANTRAIN(I)=RAIN(J)
 30     ANTEMP(I)=ITEMP(J)
      DO 40 I=1,5
 40     ANTCON=ANTCON+ANTRAIN(I)
 50   CONTINUE
C
C  START DAILY SIMULATION FOR YEAR
C
      DO 400 DAY=1,IDAYEAR
C
      TRAIN(IY)=TRAIN(IY)+RAIN(DAY)
      IF(RAIN(DAY).GT.RMAX(IY)) RMAX(IY)=RAIN(DAY)
```

```
      IF(DAY.LE.6) GOTO 60
      ANTCON=ANTCON+RAIN(DAY-1)-RAIN(DAY-6)
      GOTO 70
 60   IF(DAY.EQ.1) ANTCON=ANTCON+ANTRAIN(6)-ANTRAIN(1)
      IF(DAY.GT.1) ANTCON=ANTCON+RAIN(DAY-1)-ANTRAIN(DAY)
 70   CONTINUE
C
C  CORRECT POND DEPTH FOR EVAPORATION AND RAINFALL
      EVAP=CEVAP(DAY)*ITEMP(DAY)/OTEMP(DAY)
      T=(RAIN(DAY)-EVAP*EVAPCON)*SURAREA/43560.0
      DO 80 I=1,NP
        DEPTH(I)=DEPTH(I)+T
        IF(DEPTH(I).LT.0.0) DEPTH(I)=0.0
 80     CONTINUE
C
C  CHECK IRRIGATION CONDITIONS AND PUMP IF PERMISSIBLE
C
C  DO NOT IRRIGATE IF:
C      (1)  GROUND FROZEN
C      (2)  MANAGEMENT POLICY EQUALS 0
C      (3)  RAIN EXCEEDS RAINMAX
C      (4)  TEMPERATURE IS LESS THAN 32 F
C      (5)  SNOWFALL ACCUMULATION IS GREATER THAN 0
C
      IF(DAY.LE.3) GOTO 90
      ISUM=ITEMP(DAY-3)+ITEMP(DAY-2)+ITEMP(DAY-1)
      GOTO 100
 90   IF(DAY.EQ.1) ISUM=ANTEMP(6)+ANTEMP(5)+ANTEMP(4)
      IF(DAY.EQ.2) ISUM=ANTEMP(6)+ANTEMP(5)+ITEMP(1)
      IF(DAY.EQ.3) ISUM=ANTEMP(6)+ITEMP(1)+ITEMP(2)
 100  IF(ISUM.GT.MINTEMP) GOTO 110
      MINTEMP=114
      GOTO 180
 110  MINTEMP=96
C
```

```
      IF(MANGT(DAY).EQ.0
     *  .OR. RAIN(DAY).GT.RAINMAX
     *  .OR. ITEMP(DAY).LE.32
     *  .OR. SNOWACC(DAY).GT.0.0) GOTO 180
C
C  POND VOLUME MAY BE REDUCED IF DEPTH IS GREATER THAN
C     DAILY PUMPING CAPACITY
C
      DO 120 I=1,NP
        PPD(I,IY)=PPD(I,IY)+1
        IF(DEPTH(I).LT.PUMPDP(I)) GOTO 120
        DEPTH(I)=DEPTH(I)-PUMPDP(I)
      PD(I,IY)=PD(I,IY)+1
 120    CONTINUE
 180  CONTINUE
C
C  ACCUMULATE RAINFALL IF SNOW ON GROUND
      IFLAGSN=0
      IF(SNOWACC(DAY).LE.0.0) GOTO 190
      RAINACC=RAINACC+RAIN(DAY)
      GOTO 400
 190  IF(RAINACC.LE.0.0) GOTO 200
      RAIN(DAY)=RAIN(DAY)+RAINACC
      RAINACC=0.0
      IFLAGSN=1
 200  CONTINUE
C
C  RAINFALL LESS THAN 0.05 INCHES IS CONSIDERED INSIGNIFICANT
      IF(RAIN(DAY).LE.0.05) GOTO 400
C
C  DETERMINE RUNOFF:
C
      IF(IFLAGSN.EQ.1
     *  .OR. ITEMP(DAY).GT.IWARMC .AND. ANTCON.GT.2.1
     *  .OR. ITEMP(DAY).LE.IWARMC .AND. ANTCON.GT.1.1) GOTO 250
C
C  ...USING ANTECEDENT CONDITION NO. II
      Q=(RAIN(DAY)-0.1978)**2/(RAIN(DAY)+0.7912)
      GOTO 300
```

```
C
C  ...USING ANTECEDENT CONDITION NO. III
 250  Q=(RAIN(DAY)-0.0618)**2/(RAIN(DAY)+0.247)
 300  CONTINUE
C
      TQ(IY)=TQ(IY)+Q
C
C  ADD RUNOFF TO POND AND CHECK FOR OVERFLOW
      DO 350 I=1,NP
        DEPTH(I)=DEPTH(I)+Q
        IF(DEPTH(I).LE.DPMAX(I)) GOTO 340
        OVFL=DEPTH(I)-DPMAX(I)
        TOVFL(I,IY)=TOVFL(I,IY)+OVFL
        DEPTH(I)=DPMAX(I)
        IF(IFLAGSN.EQ.1
     *    .OR. RAIN(DAY).LE.CEXRAIN) GOTO 330
        NLO(I,IY)=NLO(I,IY)+1
        IF(OVFL.LT.Q) LOR(I,IY)=LOR(I,IY)+Q-OVFL
        LONR(I,IY)=LONR(I,IY)+OVFL
        GOTO 340
 330    NIO(I,IY)=NIO(I,IY)+1
        IF(OVFL.LT.Q) IOR(I,IY)=IOR(I,IY)+Q-OVFL
        IONR(I,IY)=IONR(I,IY)+OVFL
 340    IF(DEPTH(I).GT.DMAX(I,IY)) DMAX(I,IY)=DEPTH(I)
 350    CONTINUE
 400  CONTINUE
C
C  CALCULATE TOTALS
      DO 420 I=1,NP
        TOTNLO(I)=TOTNLO(I)+NLO(I,IY)
        TOTLOR(I)=TOTLOR(I)+LOR(I,IY)
        TOTLONR(I)=TOTLONR(I)+LONR(I,IY)
        TOTNIO(I)=TOTNIO(I)+NIO(I,IY)
        TOTIOR(I)=TOTIOR(I)+IOR(I,IY)
        TOTIONR(I)=TOTIONR(I)+IONR(I,IY)
 420    TOTOVFL(I)=TOTOVFL(I)+TOVFL(I,IY)
```

```
C
C  SET ANTECEDENT RAIN AND TEMPERATURE FOR NEXT YEAR
       J=IDAYEAR-6
       DO 440 I=1,6
         J=J+1
         ANTRAIN(I)=RAIN(J)
 440     ANTEMP(I)=ITEMP(J)
 500   CONTINUE
C
C  OUTPUT RESULTS
       DO 600 I=1,NP
         WRITE(61,6140) STAT1,STAT2,ISTART,IFINAL,DPMAX(I),POLICY,
     *     SURAREA,RATEPM(I),EXPRAIN
         WRITE(61,6160)(J+ISTART-1,NLO(I,J),LOR(I,J),LONR(I,J),NIO(I,J),
     *     ICR(I,J),IONR(I,J),TOVFL(I,J),DMAX(I,J),RMAX(J),TRAIN(J),
     *     TC(J),PD(I,J),PPD(I,J),J=1,INO)
 600     WRITE(61,6180) TOTNLO(I),TOTLOR(I),TOTLONR(I),TOTNIO(I),
     *     TOTIOR(I),TOTIONR(I),TOTOVFL(I)
       STOP
 6010  FORMAT(/≠ ENTER NUMBER OF PONDS  ≠)
 6030  FORMAT(/≠ ENTER POND DEPTHS AND PUMPING RATES≠)
 6060  FORMAT(F4.2)
 6070  FORMAT(/≠ IS DATA CORRECT≠)
 6075  FORMAT(A10)
 6080  FORMAT(2A10)
 6100  FORMAT(A10/(80I1))
 6120  FORMAT(8(I3,F4.2,F3.0))
 6140  FORMAT(1H1,T10,2A10,≠(≠,I4,≠-≠,I4,≠)≠/
     *  T10,≠POND DEPTH =≠,F6.2/
     *  T10,≠MANAGEMENT DEWATERING POLICY = ≠,A10/
     *  T10,≠SURFACE AREA =≠,F9.2,≠ SQ. FT./FEEDLOT-ACRE≠/
     *  T10,≠PUMPING RATE =≠,F5.2,≠ *≠,F6.2,≠ ACRE-IN./FEEDLOT-ACRE≠/
     *  1H-,T18,≠LEGAL OVERFLOWS≠,T48,≠ILLEGAL OVERFLOWS≠/
     *  1H0,T21,≠AMT.≠,T30,≠AMT. NOT≠,T52,≠AMT.≠,T61,≠AMT. NOT≠,
     *  T76,≠TOTAL≠,T91,≠MAX DEPTH≠,T103,≠MAX≠,T110,≠TOTAL≠,
     *  T118,≠TOTAL≠,T127,≠PUMPING≠/
```

```
     *  T3,≠YEAR≠,T13,≠NO.    RETAINED    RETAINED≠,T44,
     *  ≠NO.    RETAINED    RETAINED≠,T75,≠OVERFLOW≠,T91,≠PER YEAR≠,
     *  T103,≠RAIN≠,T110,≠RAIN≠,T118,≠RUNOFF≠,T128,≠DAYS≠)
 6160 FORMAT(1H0,(T3,I4,T12,I3,T19,F6.2,T30,F6.2,T43,I3,T50,F6.2,
     *  T61,F6.2,T75,F6.2,T92,F6.2,T101,F6.2,T109,F6.2,
     *  T117,F6.2,T127,I3,≠/≠,I3))
 6180 FORMAT(1H ,T12,≠---≠,T19,≠------≠,T30,≠------≠,T43,≠---≠,
     *  T50,≠------≠,T61,≠------≠,T75,≠------≠/
     *  1H0,≠TOTALS≠,T12,I3,T19,F6.2,T30,F6.2,T43,I3,T50,F6.2,T61,F6.2,
     *  T75,F6.2)
      END
```

# APPENDIX C. ECONOMIC EVALUATION MODEL

## GENERAL PROGRAM INFORMATION

Title: Cattle Feedlot Runoff Control Cost Estimating Model

Authors: R. M. McDowell, R. B. Wensink, and J. R. Miner

Installation: CDC 3300 at Oregon State University

Programming Language: Standard FORTRAN IV

Date Written: 1976-1977

Remarks:

The cost-estimating model determines initial investment and annual operating costs of runoff control facilities for unroofed, earth-surfaced feedlots. The model develops costs for clean water diversions, settling basin, and runoff retention structures as well as an irrigation system for disposing of runoff. Costs of four different irrigation systems are estimated by the model, which is capable of approximating the cost of two different disposal policies. Major design parameters are: daily pumping rate in acre-inches per feedlot-acre-day, storage volume in acre-inches per feedlot acre, average pumping days per year, area (in acres) required for one day's pumping, and total area required for disposal of runoff. The model estimates cost of runoff control only, and does not calculate outlay for a complete waste management program.

## PROGRAM OUTPUT

Output variable names are listed in the program. The output is comprised of initial cost data and annual operating cost estimates.

A. Initial Cost

1. Earthwork (excavation cost of clean water diversion ditch, settling basin, and retention pond);
2. Land occupied by these structures plus the disposal site;
3. Irrigation equipment (pumps, sprinkler units, and mainline);
4. Miscellaneous items (screen dams for settling basins; fencing for retention pond; seeding of earthwork; surveying).

B. Annual Cost

1. Depreciation and interest,
2. Taxes,
3. Insurance on irrigation equipment,
4. Labor for operating disposal system, and
5. Electricity for operating disposal system

PROGRAM INPUT

Input variable names are defined in the program. Even though the model was developed and utilized on Oregon State's Time Sharing Computer System, the following cards would be required to operate the program from a CDC 3300 Batch Processing System.

A. Order of Job Control Language Cards

$^{7}_{8}$(JOB CARD)

$^{7}_{8}$(ACCOUNT CARD)

$^{7}_{8}$FORTRAN,L,R

$^{7}_{8}\ ^{7}_{8}$

$^{7}_{8}$LOGOFF

B. Inputs

1. Feedlot area (acres);
2. Required storage volume (acre-inches per feedlot acre);
3. Pumping rate (acre-inches/feedlot acre-day);
4. Average pumping days per year;
5. Area required for one day's pumping (acres);
6. Area required for total disposal site (acres);
7. Disposal policy (nutrient utilization or strict waste disposal);
8. Maximum daily application (acre-inches per acre-day)

C. DATA Statements

The following DATA statements must be defined:

1. NGPMP is a one-dimensional array which contains discharge capacities of selected sizes used with hand move and side roll irrigation systems.
2. NCOSTP is a one-dimensional array containing costs of various pumps listed in NGPMP.
3. NHPP is a one-dimensional array containing horsepower ratings of pumps listed in NGPMP.
4. MGPM is a one-dimensional array which contains the maximum capacity (gpm) of various sizes of mainline.
5. MSIZE is a one-dimensional array which contains the diameter of the mainlines corresponding to the elements of MGPM.

6. MCPF is a one-dimensional array which contains cost per 100-foot section of the mainline listed in MGPM.

7. KGPMP is a one-dimensional array containing discharge capacities of pumps (gpm) for the two high pressure irrigation systems (stationary and traveling big gun).

8. KHPP is a one-dimensional array which contains horsepower ratings of pumps contained in KHPP.

9. KCOSTP is a one-dimensional array which contains costs of pumps represented by discharge capacities in KGPMP.

D. Additional Cost Variables

1. COSTA represents excavation cost per cubic yard ($).
2. COSTB is the cost of constructing clean water diversion ditch ($/foot).
3. KOSTC is the cost of land ($/acre).
4. COSTD is averaged cost of 40-foot sections of 3- and 4-inch aluminum irrigation pipe, with sprinkler.
5. COSTE is the cost of a 1,320 side roll irrigation lateral.
6. KOSTF is the cost of a big gun irrigation nozzle with capacity less than 500 gpm.
7. KOSTG is the cost of a big gun irrigation nozzle with capacity greater than 500 gpm.
8. KOSTH is the cost of a traveling big gun system*.
9. COSTI is the cost of four-strand barbed wire fence, installed ($/foot).
10. COSTJ is the cost of seeding earthworks for grass ($/per $ value of earthwork).
11. COSTK is the cost of screen check dams ($/foot).
12. COSTL is the cost of insuring irrigation equipment ($ per one dollar insured value).
13. COSTM is the cost of electricity ($/kilowatt-hour).
14. COSTN is the wage rate for irrigation labor ($/hour).
15. AMORT is the amortization factor to calculate annual cost of investment with a lifetime of ten years at an interest rate of 10%.
16. TRATE is the annual tax rate per $1.00 assessed value.

---

*Details on cost of traveling big gun contained in Appendix D.

```
      PROGRAM CONCOST
C                    CATTLE FEEDLOT RUNOFF CONTROL
C                       COST ESTIMATING MODEL
C
C
C              VARIABLES      NOTATION AND EXPLANATION
C
C
      NGPMF  DISCHARGE CAPACITY OF PUMPS AVAILABLE FOR HAND MOVE
C            AND SIDE ROLL IRRIGATION SYSTEMS
C     NGPMP  DISCHARGE CAPACITY OF PUMPS FOR USE WITH HAND MOVE AND
C            SIDE ROLL IRRIGATION SYSTEMS
C     NCOSTP COST OF PUMPS FOR USE WITH HAND MOVE AND SIDE ROLL SYSTEMS
C     NHPP   HORSEPOWER RATING OF PUMPS USED WITH HAND MOVE AND
C            SIDE ROLL SYSTEMS
C     MGPM   MAXIMUM CAPACITY OF MAINLINES
C     MCPF   COST PER 100 FEET OF MAINLINE
C
C     MSIZE  DIAMETER OF MAINLINE
C     KGPMP  DISCHARGE CAPACITY OF PUMPS FOR USE WITH STATIONARY AND
C            MOVING BIG GUN SYSTEMS
C     KCOSTP COST OF PUMPS USED WITH STATIONARY AND MOVING BIG GUNS
C     KHPP   HORSEPOWER RATING OF PUMPS USED WITH STATIONARY AND MOVING
C            BIG GUN SYSTEMS
C     LASB   LAND AREA OCCUPIED BY SETTLING BASIN
C     L      LENGTH OF RETENTION POND AT FREEBOARD LEVEL
C     LADIV  LAND AREA OCCUPIED BY CLEAN WATER DIVERSION
C     LARPAP LAND OCCUPIED BY RETENTION POND AND PERIMETER
C     LATOT  LAND AREA OCCUPIED BY TOTAL FACILITIES
C     MAXDA  MAXIMUM DAILY APPLICATION OF WASTE PER ACRE PER DAY
C     DISP   DISPOSAL POLICY IDENTIFIER
C     RQVOL  REQUIRED STORAGE VOLUME PER FEEDLOT ACRE
C     DPRATE DESIGN PUMPING RATE PER FEEDLOT ACRE
C     PDAYS  AVERAGE PUMPING DAYS PER YEAR
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C      ADP    DISPOSAL PLOT ACREAGE REQUIRED PER FEEDLOT ACRE
C      ADS    DISPOSAL SITE ACREAGE REQUIRED PER FEEDLOT ACRE
C      FLAREA FEEDLOT AREA IN ACRES
C      MANPOL MANAGEMENT POLICY IDENTIFIER
C      COSTA  EXCAVATION CHARGE: $/CUBIC YARD
C      COSTB  DIVERSION DITCH COST: $/LINEAL FOOT
C      KOSTC  LAND COST: $/ACRE
C      COSTD  COST OF 40 FOOT SECTION OF ALUMINUM HAND
C             MOVE IRRIGATION PIPE
C      COSTE  COST OF 1320 FOOT SIDE ROLL IRRIGATION LATERAL
C      KOSTF  COST OF BIG GUN IRRIGATION SPRINKLER WITH CAPACITY
C             LESS THAN 500 GALLONS PER MINUTE
C      KOSTG  COST OF BIG GUN IRRIGATION SPRINKLER WITH CAPACITY
C             GREATER THAN 500 GALLONS PER MINUTE
C      KOSTH  COST OF TRAVELLING BIG GUN SYSTEM, COMPLETE WITH HOSE
C      COSTI  FENCING COST: $/LINEAL FOOT
C      COSTJ  SEEDING COST COEFFICIENT
C      COSTK  COST OF SCREEN DAMS FOR SETTLING BASIN:
C             $ PER LINEAL FOOT
C      COSTL  INSURANCE COST: $/ $ INSURED VALUE
C      COSTM  ELECTRICITY COST: $/ KWH
C      COSTN  HOURLY WAGE RATE FOR IRRIGATION LABOR
C      AMORT  AMORTIZATION FACTOR
C      TRATE  TAX RATE PER ONE DOLLAR OF ASSESED VALUE
C      XADP   TOTAL DISPOSAL PLOT ACREAGE
C      XADS   TOTAL DISPOSAL SITE ACREAGE
C      XPRATE TOTAL PUMPING RATE REQUIRED PER DAY
C      PVOL   TOTAL VOLUME PUMPED PER YEAR
C      SBVOL  SETTLING BASIN VOLUME IN CUBIC YARDS
C      SBCOST COST OF EXCAVATING SETTLING BASIN
C      CDIV   COST OF EXCAVATING CLEAN WATER DIVERSION
C      HLDVOL TOTAL REQUIRED HOLDING VOLUME IN CUBIC YARDS
C      EXVOL  VOLUME TO BE EXCAVATED TO PROVIDE POND WITH CAPACITY OF
C             HLDVOL AND PROVIDING ONE FOOT OF FREEBOARD
C      RPCOST COST OF EXCAVATING THE RETENTION POND
C      EWCOST TOTAL COST OF ALL EXCAVATION WORK
C      KLASB  COST OF LAND OCCUPIED BY SETTLING BASIN
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C     KLADIV COST OF LAND OCCUPIED BY CLEAN WATER DIVERSION
C     KLARPAP COST OF LAND OCCUPIED BY RETENTION POND AND PERIMETER
C     KLADIS COST OF LAND AREA OCCUPIED BY DISPOSAL SITE
C            *WHEN APPROPRIATE**
C     LCTOT  TOTAL COST OF LAND CHARGED TO RUNOFF CONTROL SYSTEM
C     TSET   HOURS PER IRRIGATION SET
C     LCHM   COST OF LETERALS FOR HAND MOVE IRRIGATION SYSTEM
C     LCSR   COST OF LATERALS FOR SIDE ROLL IRRIGATION SYSTEM
C     GPM    PUMPING RATE FOR SIDE ROLL, HAND MOVE, AND BIG GUN SYSTEMS
C     IGPM   INTEGER VALUE OF VARIABLE "GPM"
C     NPCNT  COUNTER FOR PUMP SELECTOR LOOP SELECTING PUMPS FOR
C            HAND MOVE AND SIDE ROLL SYSTEMS
C     IPUMP  DO LOOP FOR HAND MOVE AND SIDE ROLL PUMP SELECTION
C     NPCNT  TOTAL NUMBER OF PUMPS REQUIRED FOR HAND MOVE AND SIDE
C            ROLL IRRIGATION SYSTEMS
C     ITPCST TOTAL COST OF PUMPS FOR THE HAND MOVE AND SIDE ROLL SYSTEMS
C     JGPM   REQUIRED PUMPING RATE FOR SIDE ROLL SYSTEM
C     JPCNT  NUMBER OF PUMPS REQUIRED FOR SIDE ROLL SYSTEM
C     JHPP   HORSEPOWER RATING OF PUMP(S) FOR SIDE ROLL SYSTEM
C     JCOSTP COST OF INDIVIDUAL PUMP(S) SELECTED FOR SIDE ROLL SYSTEM
C     JGPMP  DISCHARGE RATE OF INDIVIDUAL PUMPS SELECTED FOR SIDE ROLL
C     JTPCST TOTAL COST OF PUMPS FOR SIDE ROLL SYSTEM
C     LMAINA LENGTH OF MAINLINE REQD. FOR HAND MOVE AND
C            SIDE ROLL SYSTEMS
C     KOUNTA COUNTER FOR MAINLINE SELECTION LOOF: NUMBER OF MAINS REQD.
C     IMAIN  DO LOOP FOR MAINLINE SELECTION FOR HAND MOVE AND
C            SIDE ROLL SYSTEMS
C     ICMA   COST OF MAINLINE FOR HAND MOVE AND SIDE ROLL SYSTEMS
C     IGPMT  TOTAL SYSTEM DISCHARGE RATE FOR HAND MOVE AND SIDE ROLL
C            IRRIGATION SYSTEMS
C     JGPMT  TOTAL DISCHARGE RATE FOR SIDE ROLL IRRIGATION SYSTEMS
C     JKOUNT COUNTER FOR SIDE ROLL SYSTEM MAINLINE SELECTION LOOP
C     JGPM   MAINLINE CAPACITY FOR SIDE ROLL SYSTEM
C     JCPF   COST PER 100 FEET OF MAINLINE FOR SIDE ROLL SYSTEM
C     JSIZE  DIAMETER OF MAINLINE FOR SIDE ROLL SYSTEM
C     JCMA   TOTAL COST OF MAINLINE FOR SIDE ROLL SYSTEM
C     JMAIN  LENGTH OF MAINLINE REQD. FOR SIDE ROLL SYSTEM
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C       ITCHM   TOTAL COST OF HAMD MOVE IRRIGATION SYSTEM
C       ITCSR   TOTAL COST OF SIDE ROLL IRRIGATION SYSTEM
C       GPMBG   PUMPING RATE FOR BIG GUN SYSTEMS IN GALLONS PER MINUTE
C       NBG     NUMBER OF BIG GUNS REQUIRED FOR SYSTEM
C       IGPMBG  DISCHARGE PER BIG GUN IN GALLONS PER MINUTE
C       ITCBG   TOTAL COST OF BIG GUNS
C       KGPMBG  PUMP RATE FOR BIG GUN SYSTEM: FOR PUMP SELECTOR LOOP
C       KPCNT   COUNTER FOR BIG GUN SYSTEM PUMP SELECTOR LOOP
C       KPUMP   DO LOOP FOR BIG GUN SYSTEM PUMP SELECTION
C       KTPCST  TOTAL COST OF PUMP(S) FOR BIG GUN SYSTEM
C       KHPPL   HORSEPOWER RATING OF INDIVIDUAL PUMP(S) FOR
C               BIG GUN IRRIGATION SYSTEM
C       MSIZEL  DIAMETER OF MIANLINE REQD. FOR BIG GUN SYSTEM
C       MCPFL   COST PER 100 FEET OF MAINLINE FOR BIG GUN SYSTEM
C       KGPMT   TOTAL DISCHARGE CAPACITY FOR BIG GUN SYSTEM
C       KMGPM   MAINLINE CAPACITY REQD. FOR BIG GUN SYSTEM
C       LMAINB  LENGTH OF MAINLINE REQD. FOR BIG GUN SYSTEM
C       KCUNTB  COUNTER FOR BIG GUN SYSTEM MAINLINE SELECTOR: TOTAL
C               NUMBER OF MAINLINES REQUIRED
C       KMAIN   DO LOOP FOR MAINLINE SELECTION FOR BIG GUN SYSTEM
C       ICMB    TOTAL COST OF MAINLINE FOR BIG GUN SYSTEM
C       ITCBGS  TOTAL COST OF BIG GUN SYSTEM
C       MBGGPM  PUMPING RATE FOR MOVING BIG GUN SYSTEM
C       CMBG    REAL NUMBER VALUE OF "MBGGPM"
C       NMBG    NUMBER OF MOVING BIG GUNS NECESSARY
C       ICMB    TOTAL COST OF MOVING BIG GUNS
C       LGPM    TOTAL DISCHARGE CAPACITY FOR MOVING BIG GUN SYSTEM:
C               USED IN PUMP SELECTOR LOOP
C       LPCNT   COUNTER FOR PUMP SELECTOR LOOP FOR MOVING BIG GUN SYSTEM:
C               NUMBER OF PUMPS REQUIRED FOR MOVING BIG GUN SYSTEM
C       LPUMP   DO LOOP FOR PUMP SELECTION FOR MOVING BIG GUN SYSTEM
C       LTPCST  TOTAL COST OF PUMPS FOR MOVING BIG SYSTEM
C       LMAINC  LENGTH OF MAINLINE REQUIRED FOR MOVING BIG GUN SYSTEM (FT.)
C       KOUNTC  COUNTER FOR MAINLINE SELECTOR FOR MOVING BIG GUN SYSTEM
C       LMAIN   DO LOOP FOR MAINLINE SELECTIOM FOR MOVING BIG GUN SYSTEM
C       LMGPM   TOTAL DISCHARGE FROM MAINLINE FOR MOVING BIG GUN SYSTEM:
C               IN GALLONS PER MINUTE
C       ICMC    TOTAL COST OF MAINLINE FOR MOVING BIG GUN SYSTEM
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C      ITCMB  TOTAL COST OF MOVING BIG GUN SYSTEMS
C      CFENCE TOTAL COST OF FENCING
C      CERP   TOTAL COST OF SEEDING EARTHWORKS TO GRASS
C      CDAMS  TOTAL COST OF SCREEN DAMS FOR SETTLING BASIN
C      CENG   TOTAL COST OF ENGINEERING AND SURVEYING
C      CMISC  TOTAL MISCELLANEOUS COST
C      ICOST  TOTAL INVESTMENT EXCLUSIVE OF IRRIGATION SYSTEM
C             FOR HAND MOVE AND BIG GUN SYSTEMS
C      JCOST  TOTAL INVESTMENT EXCLUSIVE OF IRRIGATION SYSTEM
C             FOR SIDE ROLL SYSTEM
C      LCOST  TOTAL INVESTMENT EXCLUSIVE OF IRRIGATION SYSTEM
C             FOR MOVING BIG GUN SYSTEM
C      TCOSTA TOTAL COST FOR RUNOFF CONTROL FACILITIES USING
C             HAND MOVE IRRIGATION SYSTEM
C      TCOSTB TOTAL COST FOR RUNOFF CONTROL FACILITIES USING
C             SIDE ROLL IRRIGATION SYSTEM
C      TCOSTC TOTAL COST FOR RUNOFF CONTROL FACILITIES USING
C             BIG GUN IRRIGATION SYSTEMS
C      TCOSTD TOTAL COST OF RUNOFF CONTROL FACILITIES USING
C             MOVING BIG GUN IRRIGATION SYSTEMS
C      ACDIEW ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C             NON-IRRIGATION ITEMS
C      ACDIHM ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C             HAND MOVE IRRIGATION SYSTEM
C      ACDISR ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C             SIDE ROLL SYSTEM
C      ACDIBG ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C             BIG GUN SYSTEM
C      ACDITG ANNUAL COST OF DEPRECIATION AND INTEREST FOR
C             MOVING BIG GUN SYSTEM
C      ACTEW  ANNUAL TAX ON NON-IRRIGATION ITEMS
C      ACTHM  ANNUAL TAX ON HAND MOVE IRRIGATION SYSTEM
C      ACTSR  ANNUAL TAX ON SIDE ROLL IRRIGATION SYSTEM
C      ACTBG  ANNUAL TAX ON BIG GUN IRRIGATION SYSTEM
C      ACTMBG ANNUAL TAX ON MOVING BIG GUN IRRIGATION SYSTEM
C      ACMRHM ANNUAL COST OF MAINT. AND REPAIR ON HAND MOVE SYSTEM
C      ACMRSR ANNUAL COST OF MAINT. AND REPAIR ON SIDE ROLL SYSTEM
C      ACMRBG ANNUAL COST OF MAINT. AND REPAIR ON BIG GUN SYSTEM
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C      ACMRTG ANNUAL COST OF MAINT. AND REPAIR ON MOVING BIG GUN SYSTEM
C      ACMREW ANNUAL COST OF MAINT. AND REPAIR ON EARTHWORKS
C      ACINHM ANNUAL COST OF INSURANCE FOR HAND MOVE SYSTEM
C      ACINSR ANNUAL COST OF INSURANCE FOR SIDE ROLL SYSTEMS
C      ACINBG ANNUAL COST OF INSURANCE FOR BIG GUN SYSTEM
C      ACINTG ANNUAL COST OF INSURANCE FOR MOVING BIG GUN SYSTEM
C      ELECHM ANNUAL COST OF ELECTRICITY FOR HAND MOVE SYSTEM
C      ELECSR ANNUAL COST OF ELECTRICITY FOR SIDE ROLL SYSTEM
C      ELECBG ANNUAL COST OF ELECTRICITY FOR BIG GUN SYSTEM
C      ELECTG ANNUAL COST OF ELECTRICITY FOR MOVING BIG GUN SYSTEM
C      CLABHM ANNUAL COST OF LABOR FOR HAND MOVE SYSTEM
C      CLABSR ANNUAL COST OF LABOR FOR SIDE ROLL SYSTEM
C      CLABBG ANNUAL COST OF LABOR FOR BIG GUN SYSTEM
C      CLABTG ANNUAL COST OF LABOR FOR MOVING BIG GUN SYSTEM
C      TACHM  TOTAL ANNUAL COST OF OPERATING HAND MOVE SYSTEM
C      TACSR  TOTAL ANNUAL COST OF OPERATING SIDE ROLL SYSTEM
C      TACBG  TOTAL ANNUAL COST OF OPERATING BIG GUN SYTEM
C      TACTG  TOTAL ANNUAL COST OF OPERATING MOVING BIG GUN SYSTEM
C      TACEW  TOTAL ANNUAL COST OF EARTHWORKS FOR RUNOFF CONTROL SYSTEMS
C             USING HAND MOVE AND BIG GUN SYSTEMS
C      TACEWJ TOTAL ANNUAL COST OF EARTHWORKS FOR RUNOFF CONTROL SYSTEMS
C             USING THE SIDE ROLL IRRIGATION SYSTEM
C      TACEWL TOTAL ANNUAL COST OF EARTHWORKS FOR RUNOFF CONTROL SYSTEMS
C             USING THE MOVING BIG GUN IRRIGATION SYSTEM
C      TACA   TOTAL ANNUAL COST OF FACILITIES USING HAND MOVE SYSTEM
C      TACB   TOTAL ANNUAL COST OF FACILITIES USING SIDE ROLL SYSTEM
C      TACC   TOTAL ANNUAL COST OF FACILITIES USING BIG GUN SYSTEM
C      TACD   TOTAL ANNUAL COST OF FACILITIES USING
C             MOVING BIG GUN SYSTEM
C      CCAPA  ANNUAL COST PER HEAD OF CAPACITY USING HAND MOVE SYSTEM
C      CCAPB  ANNUAL COST PER HEAD OF CAPACITY USING SIDE ROLL SYSTEM
C      CCAPC  ANNUAL COST PER HEAD OF CAPACITY USING BIG GUN SYSTEM
C      CCAPD  ANNUAL COST PER HEAD OF CAPACITY USING MOVING BIG GUN
C      CHEADA ANNUAL COST PER HEAD USING HAND MOVE SYSTEM
C      CHEADB ANNUAL COST PER HEAD USING SIDE ROLL SYSTEM
C      CHEADC ANNUAL COST PER HEAD USING BIG GUN SYSTEM
C      CHEADD ANNUAL COST PER HEAD USING MOVING BIG GUN SYSTEM
C      TICAPA TOTAL INVESTMENT PER HEAD WITH HAND MOVE SYSTEM
C      TICAPB TOTAL INVESTMENT PER HEAD WITH SIDE ROLL SYSTEM
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C     TICAPC TOTAL INVESTMENT PER HEAD WITH BIG GUN SYSTEM
C     TICAPC TOTAL INVESTMENT PER HEAD WITH MOVING BIG GUN SYSTEM
C     XMIN   MINIMUM YEARLY LABOR COST FOR ANY SYSTEM

C
      DIMENSION NGPMP(11),NCOSTP(11),NHPP(11)
      DATA(NGPMP=50,100,200,300,400,500,600,800,1000,1200,1400)
      DATA(NCOSTP=1400,1600,1450,1650,1900,2100,2550,2900,3300,4000,
     *6400)
      DATA(NHPP=5,7,10,15,20,25,30,43,50,60,75)
C
      DIMENSION MGPM(7),MCPF(7),MSIZE(7)
      DATA(MGPM=100,200,300,400,600,1200,2000)
      DATA(MCPF=55,72,94,125,170,263,410)
      DATA(MSIZE=2,3,4,5,6,8,10)
C
      DIMENSION KGPMP(7),KCOSTP(7),KHPP(7)
      DATA(KGPMP=100,150,300,450,600,850,1150)
      DATA(KCOSTP=1400,1840,2280,2700,3280,3160,6520)
      DATA(KHPP=15,20,30,40,60,75,100)
C
C
C
      REAL LASB,L,LADIV,LARPAP,LATOT,MAXDA
C
C
C     * MANAGEMENT DISPOSAL ALTERNATIVE IDENTIFIER *
C        NUTRIENT UTIL. : DISP=2
C        STRICT WASTE DIDPOSAL :  DISP=1.
C
C
C
      WRITE(61,1000)
 1000 FORMAT(≠ ENTER DESIGN VARIABLES--STORAGE VOL., PUMPING RATE,≠/
     *≠ PUMFING DAYS, CISPOSAL PLOT ACREAGE, DISPOSAL SITE ACREAGE,≠,
     *≠ DISFOSAL POLICY IDENTIFIER, MAXIMUM DAILY WASTE APPLICATION≠,
     *≠ , FEEDLOT AREA≠,)
```

```
C
      READ(60,1010)ROVCL,DPRATE,PDAYS,ADP,ADS,DISF,MAXDA,FLAREA
 1010 FORMAT(F9.3)
C
      WRITE(61,1020)
 1020 FORMAT(≠ ENTER MANAGEMENT POLICY≠)
      READ(60,1030)MANPOL
 1030 FORMAT(I1)
C
C             INPUT COST VARIABLES
C
      COSTA=.5
      COSTB=.25
      KOSTC=750
      COSTD=45.
      COSTE=3800.
      KOSTF=400
      KOSTG=700
      KOSTH=15452
      COSTI=.60
      COSTJ=.01
      COSTK=4.15
      COSTL=.006
      COSTM=.0308
      COSTN=3.5
      AMORT=.16275
      TRATE=.0093
C
C           MAXIMUM DAILY APPLICATION OF WASTE IN ACRE-INCHES PER ACRE
C
      XADP=FLAREA*ADP
      XADS=FLAREA*ADS
      XPRATE=FLAREA*DPRATE
      PVOL=XPRATE*PDAYS
C
C
C
```

```
C                        CALCULATION OF INVESTMENT COST
C
C
C
C          **CALCULATE COST OF CONSTRUCTING EARTHWORKS**
C
C
C
C           SETTLING BASIN
C
C
      SBVOL=FLAREA*134.4
      SBCOST=SBVOL*COSTA
C
C
C           CLEAN WATER DIVERSION DITCH/TERRACE
C
C
      CDIV=SQRT(FLAREA*43560.)*3.*COSTB
C
C
C           RETENTION RESIVOIR
C
C
      HLDVOL=ROVOL*FLAREA*3630.
      L=32.+SQRT((HLDVOL-3654.)/14.)
      EXVOL=.555*(L*L-60.*L+1200.)
      IF(EXVOL.LT.600.) GO TO 1040
      CONTINUE
      GO TO 1050
 1040 EXVOL=600.
 1050 RPCOST=EXVOL*COSTA
C
C
C           COMPLTE TOTAL COST FOR EARTHWORKS
C
C
      EWCOST=SBCOST+CDIV+RPCOST
```

```
C
C
C         **CALCULATE COST LAND REQUIRED FOR TOTAL FACILITIES**
C
C
C                LAND AREA FOR SETTLING BASIN
C
C
      LASB=(12.+SQRT(144.+3621.*FLAREA/2.))**2/87120.
C
C
C
      KLASB=LASB*KOSTC
C
C                LAND AREA FOR CLEAN WATER DIVERSION DITCH/TERRACE
C
C
      LADIV=24.*SQRT(FLAREA*43560.)/43560.
      KLADIV=LADIV*KOSTC
C
C
C                LAND AREA FOR RETENTION RESIVOIR AND PERIMETER
C
C
      LARPAP=(L*L+202.*L+10201.)/43560.
      KLARP=LARPAP*KOSTC
C
C
C                LAND FOR DISPOSAL
C
      IF(DISP.EQ.1.) GO TO 1100
      CONTINUE
      KLADIS=0
      GO TO 1110
C
 1100 KLADIS=XADS*KOSTC
C
C
```

```
 C
 C                  CALCULATE TOTAL LAND COST
 C
 C
  1110 LATOT=LARPAP+LADIV+LASB
       LCTOT=LATOT*KOSTC+KLADIS
 C
 C
 C              IRRIGATION EQUIPMENT
 C               CALCULATE HOURS PER SET
 C
       TSET=MAXDA/.33
 C
 C
       IF(TSET.GT.10.) GOTO 1130
 C
 C                 COST OF LATERALS FOR HM & SR SYSTEMS
 C                         WHEN TSET<10 HOURS
 C
  1120 LCHM=IFIX(9.075*COSTO*XADP)
       LCSR=IFIX(0.278*COSTE*XADP)
       GO TO 1140
 C
 C
 C                 COST OF LATERALS FOR HM & SR SYTEMS
 C                         WHEN TSET>10 HOURS
 C
 C
  1130 LCHM=IFIX(18.15*COSTO*XADP)
       LCSR=IFIX(.566*COSTE*XADP)
 C
       GO TO 1150
 C
 C                 CALCULATE HM & SR SYSTEM CAPACITY WHEN TSET<10 HOURS
 C
  1140 GPM=226.3*XPRATE/TSET
       GO TO 1160
 C
 C                 CALCULATE HM & SR SYSTEM CAPACITY WHEN TSET>10 HOURS
```

```
C
 1150 GPM=452.5*XPRATE/TSET
C
C
C
C                    PUMPS FOR HM & SR SYTEMS
C
 1160 IGPM=IFIX(GPM)
      NPCNT=1
 1170 DO 1180 IPUMP=1,11
      IF(IGPM.LE.NGPMP(IPUMP)) GO TO 1190
 1180 CONTINUE
      NPCNT=NPCNT+1
      IGPM=GPM*(1.0/NPCNT)
      GO TO 1170
 1190 ITPCST=NPCNT*NCOSTP(IPUMP)
C
C          CREATION OF VARIABLES FOR SIDE ROLL DOCUMENTATION
C
      JGPM=IFIX(GPM)
      JPCNT=NPCNT
      JHPP=NHPP(IPUMP)
      JCOSTP=NCOSTP(IPUMP)
      JGPMP=NGPMP(IPUMP)
      JTPCST=ITPCST
C                CALCULATE COST OF MAINLINE FOR HM & SR SYSTEMS
C
      LMAINA=IFIX(SQRT(XADS*43560.)+300.)
      KOUNTA=1
 1200 DO 1210 IMAIN=1,7
      IF(JGPM.LE.MGPM(IMAIN)) GO TO 1220
 1210 CONTINUE
      KOUNTA=KOUNTA+1
      JGPM=GPM*(1.0/KOUNTA)
      GO TO 1200
C
 1220 ICMA=FLOAT(LMAINA)/100.*MCPF(IMAIN)*KOUNTA
```

```
C
      IGPMT=IFIX(GPM)
      JGPMT=IGPMT
C
C          CREATION OF VARIABLES FOR SIDE ROLL DOCUMENTATION
C
      JKOUNT=KOUNTA
      JMGPM=MGPM(IMAIN)
      JCPF=MCPF(IMAIN)
      JSIZE=MSIZE(IMAIN)
      JCMA=ICMA
      JMAIN=LMAINA
C
C               CALCULATE TOTAL COST OF HM + SR SYSTEMS
C
      ITCHM=LCHM+ICMA+ITPCST
      ITCSR=LCSR+ICMA+ITPCST
C
C             BIG GUN SYSTEM
C
      IF(TSET.GT.10.) GO TO 1240
C
C               CALCULATE BG SYSTEM CAPACITY WHEN TSET<10 HOURS
C
C
      GPMBG=226.28*XPRATE/TSET
      GO TO 1250
C
C               CALCULATE BG SYSTEM CAPACITY WHEN TSET>10 HOURS
C
 1240 GPMBG=452.55*XPRATE/TSET
C
C               CALCULATE NUMBER OF BIG GUNS REQUIRED
C
 1250 NBG=IFIX(GPMBG/1000.+1.)
      IBGGPM=GPMBG/NBG
C
      IF(IBGGPM.GT.499) GO TO 1260
```

```
C
C            CALCULATE COST OF BIG GUN(S)
C
      ITCBG=NBG*KOSTF
      GO TO 1270
C
 1260 ITCBG=NBG*KOSTG
C
C
C
C
C             PUMP SELECTOR FOR BG SYSTEM
C
 1270 KGPM=IFIX(GPMBG)
      KPCNT=1
 1280 DO 1290 KPUMP=1,7
      IF(KGPM.LE.KGPMP(KPUMP)) GO TO 1300
 1290 CONTINUE
      KPCNT=KPCNT+1
      KGPM=GPMBG*(1.0/KPCNT)
      GO TO 1280
C
 1300 KTPCST=KPCNT*KCOSTP(KPUMP)
      KHPPL=KHPP(LPUMP)
      MSIZEL=MSIZE(LMAIN)
      MCPFL=MCPF(LMAIN)
C
C
C
      KGPMT=KGPM*KPCNT
C
C         MAINLINE SELECTION FOR BG SYSTEMS
C
      KMGPM=KGPM*KPCNT
      LMAINB=300+IFIX((SQRT(XADS*43560.))*2.)
C
      KCUNTB=1
 1310 DO 1320 KMAIN=1,7
```

```
      IF(KMGPM.LE.MGPM(KMAIN)) GO TO 1340
 1320 CONTINUE
      KOUNTB=KOUNTB+1
      KMGPM=KGPMT*(1.0/KOUNTB)
      GO TO 1310
C
 1340 ICMB=FLOAT(LMAINB)/100.*MCPF(KMAIN)*KOUNTB
C
C
C
C              CALCULATE TOTAL COST OF BIG GUN SYSTEM
C
C
      ITCBGS=ITCBG+KTPCST+ICMB
C
C
C
C              CALCULATIONS FOR TRAVELING BIG GUN
C          TEST FOR MINIMUM PUMP RATE FOR TBG SYSTEM
C
      IF(XPRATE.LT.12.15) GO TO 1410
C

      MBGGPM=IFIX(XPRATE*20.57)
      CMBG=FLOAT(MBGGPM)
      NMBG=IFIX(CMBG/1000.+1.0)
      ICMBG=NMBG*KOSTH
C
C                  PUMP SELECTION FOR TBG
C
      LGPM=MBGGPM
      LPCNT=1
 1350 DO 1360 LPUMP=1,7
      IF(LGPM.LE.KGPMP(LPUMP)) GO TO 1370
 1360 CONTINUE
      LPCNT=LPCNT+1
      LGPM=MBGGPM*(1.0/LPCNT)
      GO TO 1350
C
```

```
 1370 LTPCST=LPCNT*KCOSTP(LPUMP)
C
C
C                    MAINLINE SELECTION FOR TBG SYSTEM
C
      LMAINC=300+IFIX((XADS*43560.0)/1620.0)
      LMGPM=MBGGPM
C
      KOUNTC=1
 1380 DO 1390 LMAIN=1,7
      IF(LMGPM.LE.MGPM(LMAIN)) GO TO 1400
 1390 CONTINUE
      KOUNTC=KOUNTC+1
      LMGPM=MBGGPM*(1.0/KOUNTC)
      GO TO 1380
 1400 ICMC=FLOAT(LMAINC)/100.*MCPF(LMAIN)*KOUNTC
C
C
C              CALCULATE TOTAL COST OF TRAVELING BIG GUN SYSTEM
C
      ITCMBG=ICMBG+LTPCST+ICMC
C
C
C             MISCELLANEOUS COSTS
C
C
C
C
C                    CALCULATE COST OF FENCING
C
C
 1410 CFENCE=(L+101.)*4.*COSTI
C
C
C
C                    CALCULATE COST OF EROSION CONTROL(SEEDING)
C
```

```
C
C
      CERP=EWCOST*COSTJ
C
C
C
C                   SETTLING BASIN CHECK DAMS
C
C
      CDAMS=(12.+SQRT(144.+(3621.*FLAREA)/2))*COSTK
C
C
C
C          COST OF ENGINEERING
C
      CENG=200.
C
C
C                   CALCULATE TOTAL MISCELANEOUS COST
C
      CMISC=CFENCE+CERP+CDAMS+CENG
C
C
C
C
      ICOST=EWCOST+LCTOT+CMISC
      JCOST=ICOST
      LCOST=ICOST
C
C
C         CALCULATE TOTAL INVESTMENT
C
      TCOSTA=ICOST+ITCHM
      TCOSTB=ICOST+ITCSR
      TCOSTC=ICOST+ITCBGS
      TCOSTD=ICOST+ITCMBG
C
```

```
C               CATTLE FEEDLOT RUNOFF RETENTION FACILITIES ANNUAL COSTS
C
C
C                              VARIABLES AND NOTATION
C
C
C
C
C                          COMPUTATION OF ANNUAL OPERATING COSTS
C
C
C     CALCULATE EQUIVALENT ANNUAL COST OF DEPRECIATION AND INTERSET
C
      ACDIEW=(EWCOST+CMISC+LCTOT)*AMORT
      ACDIHM=ITCHM*AMORT
      ACDISR=ITCSR*AMORT
      ACDIBG=ITCBGS*AMORT
      ACDITG=ITCMBG*AMORT
C
C
C
C
C
C                 COMPUTE ANNUAL TAX COST
C
      ACTEW=(EWCOST+CMISC+LCTOT)*TRATE
      ACTHM=ITCHM*TRATE*.5
      ACTSR=ITCSR*TRATE*.5
      ACTBG=ITCBGS*TRATE*.5
      ACTMBG=ITCMBG*TRATE*.5
C
C
C
C
C                 COMPUTE ANNUAL COST OF MAINTATNENCE AND REPAIR
C
C
C
```

```
      ACMRHM=.06*ITFCST+.02*LCHM+.02*ICMA
      ACMRSR=.06*ITFCST+.03*LCSR+.02*ICMA
      ACMRBG=.06*KTPCST+.02*ITCBG+.02*ICMB
      ACMRTG=.06*LTPCST+.03*ICMBG+.02*ICMC
      ACMREW=(EWCOST+CMISC)*.005
C
C
C
C
C                    COMPUTE ANNUAL COST OF INSURANCE
C
C
      ACINHM=COSTL*ITCHM*.5
      ACINSR=COSTL*ITCSR*.5
      ACINBG=COSTL*ITCBGS*.5
      ACINTG=COSTL*ITCMBG*.5
C
C
C
C                    COMPUTE ENERGY COSTS FOR PUMPING
C
      ELECHM=19.12*PVOL*COSTM
      ELECSR=19.12*PVOL*COSTM
      ELECBG=38.24*PVOL*COSTM
      ELECTG=38.24*PVOL*COSTM
C
C
C
C                    COMPUTE ANNUAL COST OF LABOR
C
C
C
      CLABHM=.633*XADP*PDAYS*COSTN
C
      IF(TSET.GT.10.) GO TO 1420
      CLABSR=.66*COSTN*PDAYS*IFIX(.278*XADP+1.)
      GO TO 1430
 1420 CLABSR=.33*COSTN*PDAYS*IFIX(XADP/1.8+1.0)
```

```
C
 1430 CLABBG=.52*XADP*PDAYS*COSTN
      CLABTG=NMBG*PDAYS*COSTN
C
C
C        COMPUTE TOTAL ANNUAL COSTS OF IRRIGATION SYSTEMS
C
C
      TACHM=ACDIHM+ACTHM+ACMRHM+ACINHM+ELECHM+CLABHM
      TACSR=ACDISR+ACTSR+ACMRSR+ACINSR+ELECSR+CLABSR
      TACBG=ACDIBG+ACTBG+ACMRBG+ACINBG+ELECBG+CLABBG
      TACTG=ACDITG+ACTMBG+ACMRTG+ACINTG+ELECTG+CLABTG
C
C
      TACEW=ACDIEW+ACTEW+ACMREW
      TACEWJ=TACEW
      TACEWL=TACEW
C
C
C        COMPUTE TOTAL ANNUAL COSTS
C
      TACA=TACHM+TACEW
      TACB=TACSR+TACEW
      TACC=TACBG+TACEW
      TACD=TACTG+TACEW
C
      CCAPA=TACA/(FLAREA*200.)
      CCAPB=TACB/(FLAREA*200.)
      CCAPC=TACC/(FLAREA*200.)
      CCAPD=TACD/(FLAREA*200.)
C
      CHEADA=CCAPA/3.
      CHEADB=CCAPB/3.
      CHEADC=CCAPC/3.
      CHEADD=CCAPD/3.
C
C
C          CALCULATE INVESTMENT/HEAD OF CAPACITY
```

```
C
C
      TICAPA=TCOSTA/(FLAREA*200.)
      TICAPB=TCOSTB/(FLAREA*200.)
      TICAPC=TCOSTC/(FLAREA*200.)
      TICAPD=TCOSTD/(FLAREA*200.)
C
C        CHECK FOR MIN. OF 1 HR. LABOR PER DAY FOR HM, SR +BG SYSTEMS
      XMIN=CCSTN*IFIX(PDAYS+1.)
      IF(CLABHM.LT.XMIN) CLABHM=XMIN
      IF(CLABSR.LT.XMIN) CLABSR=XMIN
      IF(CLABBG.LT.XMIN) CLABBG=XMIN
C
C        CHECK FOR MINIMUM DISPOSAL PLOT SIZE FOR SIDE ROLL SYSTEM
C            (SYSTEM NOT APPLICABLE UNLESS PLOT SIZE >=IS MIN. .1 ACRE)
C
      IF(XADP.GE.1.000) GO TO 1440
      ITCSR=0
      TACSR=0.
      LCSR=0
      JTPCST=0
      JGPMP=0
      JPCNT=0
      JCOSTP=0
      JHPP=0
      JKOUNT=0
      JMGPM=0
      JCMA=0
      JCPE=0
      JSIZE=0
      TCOSTB=0.
      ACDISR=0.
      ACTSR=0.
      ACMRSR=0.
      ACINSR=0.
      ELECSR=0.
      CLABSR=0.
      TACB=0.
```

```
      CCAPB=0.
      CHEADB=0.
      TICAPB=0.
      JMAIN=0
      JGPMT=0
      TACEWJ=0.
      JCOST=0
C
 1440 IF(XPRATE.GE.12.15) GO TO 2000
C
      ITCMBG=0
      NMBG=0
      ICMBG=0
      LTPCST=0
      LMAINC=0
      ICMC=0
      ITCMBG=0
      KHPPL=0
      MSIZEL=0
      MCPFL=0
      TCOSTC=0.
      TICAPD=0.
      TACD=0.
      CCAPD=0.
      CHEADD=0.
      ACDITG=0.
      ACTMBG=0.
      ACMRTG=0.
      ACINTG=0.
      ELECTG=0.
      CLABTG=0.
      TACTG=0.
      TICAPD=0.
      TACEWL=0.
      LCOST=0
C
C
 2000 WRITE(6,2100)
```

```
 2100 FORMAT(≠1≠,//////,9X,≠** DISPOSAL SYSTEM DESIGN PARAMETERS **≠,/,
     *10X,≠=========================================≠,//)
C
      WRITE(6,2200)FLAREA,ADP,ADS,MAXDA,DPRATE,XADP,XADS,XPRATE,TSET
     *,PDAYS,ROVOL,MANPOL,DISP
 2200 FORMAT(≠ FEEDLOT AREA= ≠,F17.0,≠ ACRES≠,/,
     1≠ DISPOSAL PLOT AREA= ≠,F14.2,≠ ACRES PER FEEDLOT ACRE≠,/,
     1≠ DISPOSAL SITE AREA= ≠,F14.2,≠ ACRES PER FEEDLOT ACRE≠,/,
     3≠ MAXIMUM DAILY APPLICATION= ≠,F4.0,≠ INCHES PER ACRE≠,/,
     4≠ DESIGN PUMPING RATE= ≠,F13.2,≠ AC.-IN. PER FEEDLOT ACRE≠,1X,
     *≠PER DAY≠,/
     5≠ TOTAL DISPOSAL PLOT AREA= ≠,F8.2,≠ ACRES≠,/,
     6≠ TOTAL DISPOSAL SITE AREA= ≠,F8.2,≠ ACRES≠,/,
     7≠ TOTAL DAILY PUMPING RATE= ≠,F8.2,≠ ACRE-INCHES PER DAY≠,/
     8≠ HOURS REQUIRED PER SET= ≠,F9.1,/,
     *≠ PUMPING DAYS PER YEAR= ≠,F10.1,/,
     *≠ REQD. STORAGE VOL.= ≠,F14.2,≠ AC-IN PER FEEDLOT ACRE≠,/,
     *≠ MANAGEMENT POLICY= ≠,I12,/,
     $≠ DISPOSAL POLICY= ≠,F14.0,//)
C
      WRITE(6,2300)
 2300 FORMAT(7X,≠** INVESTMENT IN EARTHWORK, LAND, AND MISC. ITEMS **≠/,
     *7X,≠=====================================================≠,//
     ≥6X,≠-EARTHWORK-≠,25X,≠SIZE≠,12X,≠COST≠,/
     *6X,≠-----------≠,)
C
      WRITE(6,2400)SBVOL,SBCOST,CDIV,EXVOL,RPCOST,EWCOST
 2400 FORMAT(≠ SETTLING BASIN≠,21X,F8.0,≠ CU. YDS.≠,1X,≠$≠,F9.0,/,
     *≠ CLEAN WATER DIVERSION≠,32X,≠$≠,F9.0,/,
     *≠ RETENTION POND EXCAVATION≠,10X,F8.0,≠ CU. YDS.≠,1X,≠$≠,F9.0,/,
     *≠ TOTAL COST OF EARTHWORK≠,30X,≠$≠,F9.0)
C
      WRITE(6,2500)LASB,KLASB,LADIV,KLADIV,LARPAP,KLARP,XADS,KLADIS,
     *LATOT,LCTOT
 2500 FORMAT(6X,≠-LAND-≠,/,
     *6X,≠------≠,/
     *≠ LAND FOR SETTLING BASIN≠,12X,F8.2,≠ ACRES≠,4X,≠$≠,I9,/,
     *≠ LAND FOR CLEAN WATER DIV.≠,10X,F8.2,≠ ACRES≠,4X,≠$≠,I9,/,
     *≠ LAND FOR RET. POND AND PERIMETER≠,3X,F8.2,≠ ACRES≠,4X,≠$≠,I9,/,
```

```
     *≠ LAND FOR EFFLUENT DISPOSAL≠,9X,F8.2,≠ ACRES≠,4X,≠$≠,I9,/,
     *≠ TOTAL LAND FOR FACILITIES≠,10X,F8.2,≠ ACRES≠,4X,≠$≠,I9)
C
      WRITE(5,2600)CFENCE,CERP,CDAMS,CENG,CMISC,ICOST
 2600 FORMAT(6X,≠-MISCELLANEOUS ITEMS-≠,/,
     *6X,≠---------------------≠,/
     *≠ FENCING FOR RET. POND≠,32X,≠$≠,F9.0,/,
     *≠ SEEDING EARTHWORKS≠,35X,≠$≠,F9.0,/,
     *≠ CHECK DAMS FOR SETTLING BASIN≠,24X,≠$≠,F9.0,/,
     *≠ ENGINEERING≠,42X,≠$≠,F9.0,/,
     *≠ TOTAL COST OF MISC. ITEMS≠,28X,≠$≠,F9.0,//,
     *≠ TOTAL COST OF EARTHWORK,LAND,MISC.≠,19X,≠$≠,I9,//)
C
C
C
      WRITE(6,2700)
 2700 FORMAT(12X,≠** DISPOSAL SYSTEM INVESTMENT **≠,/
     *12X,≠================================≠,//
     *18X,≠HAND MOVE≠,3X,≠SIDE-ROLL≠,3X,≠BIG GUN≠,4X,
     *≠MOVING B.G.≠,/
     *18X,≠---------≠,3X,≠---------≠,3X,≠-------≠,4X,
     *≠-----------≠)
C
      WRITE(6,2800)IGPMT,JGPMT,KGPMT,MBGGPM
 2800 FORMAT(≠ TOT. SYS. GPM≠,5X,I8,4X,I8,2X,I8,6X,I8,)
      WRITE(6,2900)NBG,NMBG,LCHM,LCSR,ITCBG,ICMBG
 2900 FORMAT(≠ SPRINKLER UNITS:≠,/,2X,≠NUMBER REQD.≠,
     *27X,I8,6X,I8,/,
     *1X,≠ TOTAL COST≠,6X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,
     *5X,≠$≠,I8)
C
      WRITE(6,3000)NPCNT,JPCNT,KPCNT,LPCNT,
     *NGPMP(IPUMP),JGPMP,KGPMP(KPUMP),KGPMP(LPUMP),
     *NHPP(IPUMP),JHPP,KHPP(KPUMP),KHPPL,
     *ITPCST,JTPCST,KTPCST,LTPCST
 3000 FORMAT(≠ PUMPS:≠,/,
     *2X,≠NUMBER REQD.≠,5X,I8,4X,I8,4X,I6,5X,I9,/,
     *≠  DIS. VOL.≠,8X,I8,4X,I8,4X,I6,6X,I8,/
```

```
     *≠  PUMP HP≠,10X,I8,4X,I8,4X,I6,6X,I8,/
     *2X,≠TOTAL COST≠,6X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,5X,≠$≠,I8,/)
C
      WRITE(6,3100)KOUNTA,JKOUNT,KOUNTB,KOUNTC,
     *LMAINA,JMAIN,LMAINB,LMAINC,
     *MSIZE(IMAIN),JSIZE,MSIZE(KMAIN),MSIZEL,
     *MCPF(IMAIN),JCPF,MCPF(KMAIN),MCPFL,
     *ICMA,JCMA,ICMB,ICMC,
     *ITCHM,ITCSP,ITCBGS,ITCMBG
 3100 FORMAT(≠ MAINLINE:≠,/,
     *2X,≠NUMBER REQD.≠,5X,I8,4X,I8,4X,I6,6X,I8,/
     *≠  LENGTH (FEET)≠,4X,I8,4X,I8,4X,I6,6X,I8,/
     *≠  DIAM. (INCHES)≠,3X,I8,4X,I8,4X,I6,6X,I8,/
     *≠  $ PER 100 FT.≠,3X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,5X,≠$≠,I8,/
     *2X,≠TOTAL COST≠,6X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,5X,≠$≠,I8,//,
     *≠ IRR. INVESTMENT≠,2X,≠$≠,I8,3X,≠$≠,I8,3X,≠$≠,I6,5X,≠$≠,I8,////)
C
      WRITE(6,3200)
 3200 FORMAT(≠1≠,////////////,24X,≠** TOTAL INVESTMENT **≠,/,
     *24X,≠======================≠,/
     *18X,≠HAND MOVE≠,4X,≠SIDE-ROLL≠,4X,≠BIG GUN≠,4X,≠MOVING B.G.≠,/
     *18X,≠---------≠,4X,≠---------≠,4X,≠-------≠,4X,
     *≠-----------≠,)
C
C
      WRITE(6,3300)ICOST,JCOST,ICOST,LCOST,
     *ITCHM,ITCSP,ITCBGS,ITCMBG,
     *TCOSTA,TCOSTB,TCOSTC,TCOSTD,
     *TICAPA,TICAPB,TICAPC,TICAPD
 3300 FORMAT(≠ LAND. EARTH-≠,/,≠ WORK, MISC.≠,6X,
     *≠$≠,I8,4X,≠$≠,I8,3X,≠$≠,I7,4X,≠$≠,I9,/
     *≠ DISP. SYS.≠,7X,≠$≠,I8,4X,≠$≠,I8,3X,≠$≠,I7,4X,≠$≠,I9,/
     *≠ TOTAL INV.≠,7X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,≠$≠,F9.0,/
     *≠ INV./HEAD≠,8X,≠$≠,F8.2,4X,≠$≠,F8.2,3X,≠$≠,F7.2,4X,≠$≠,F9.2,
     *//)
      WRITE(6,3400)
 3400 FORMAT(22X,≠** ANNUAL COSTS **≠,/,
     *22X,≠==================≠,/,
```

```
     *29X,≠SYSTEM≠,/,29X,≠------≠,//,2X,≠ITEM≠,
     *12X,≠HAND MOVE≠,4X,≠SIDE-ROLL≠,4X,≠BIG GUN≠,4X,≠MOVING B.G.≠,/
     *2X,≠----≠,12X,≠----------≠,4X,≠----------≠,4X,≠--------≠,4X,
     *≠------------≠,//)
C
C
      WRITE(6,3500)ACDIHM,ACDISP,ACDIBG,ACDITG
 3500 FORMAT(≠ DEP. ≤ INT.≠,6X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
     *≠$≠,F9.0)
C
      WRITE(6,3600)ACMRHM,ACMRSR,ACMRBG,ACMRTG
 3600 FORMAT(≠ MAINT. ≤ REP.≠,4X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,
     *4X,≠$≠,F9.0)
C
      WRITE(6,3700)ACTHM,ACTSR,ACTBG,ACTMBG
 3700 FORMAT(≠ TAXES≠,12X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,≠$≠,F9.0)
C
      WRITE(6,3800)ACINHM,ACINSR,ACINBG,ACINTG
 3800 FORMAT(≠ INSURANCE≠,8X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
     *≠$≠,F9.0)
C
      WRITE(6,3900)CLABHM,CLABSR,CLABBG,CLABTG
 3900 FORMAT(≠ LABOR≠,12X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,≠$≠,F9.0)
C
      WRITE(6,4000)ELECHM,ELECSR,ELECBG,ELECTG
 4000 FORMAT(≠ ELECTRICITY≠,6X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
     *≠$≠,F9.0,/)
C
      WRITE(6,4100)TACHM,TACSR,TACBG,TACTG
 4100 FORMAT(≠ SUBTOTAL≠,9X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
     *≠$≠,F9.0,/)
      WRITE(6,4200)TACEW,TACEWJ,TACEW,TACEWL,TACA,TACB,TACC,TACD
 4200 FORMAT(≠ TOT. A.C.≠,/,≠ LAND, EARTH-≠,/,
     *≠ WORK, MISC.≠,
     *6X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,≠$≠,F9.0,/,/,
     *≠ TOTAL≠,12X,≠$≠,F8.0,4X,≠$≠,F8.0,3X,≠$≠,F7.0,4X,
```

```
     *≠$≠,F9.0,//)
      WRITE(6,4300)CCAPA,CCAPB,CCAPC,CCAPD,CHEADA,CHEADB,CHEADC,CHEADD
 4300 FORMAT(≠ COST PER HEAD≠,/,≠ OF CAPACITY≠,6X,≠$≠,F8.2,4X,≠$≠,F8.2,
     *3X,≠$≠,F7.2,4X,≠$≠,F9.2,//
     *≠ ADD. PROD. COST≠,/,≠ PER HEAD≠,9X,≠$≠,F8.2,4X,≠$≠,F8.2,
     *3X,≠$≠,F7.2,4X,≠$≠,F9.2)
      WRITE(6,4400)
 4400 FORMAT(///,18X,≠ ZEROS INDICATE SYSTEM IS NOT APPLICABLE≠)
      END
```

## APPENDIX D. IRRIGATION COST DATA

TABLE D-1. ALUMINUM MAINLINES SIZES, CAPACITIES[1] AND COSTS

| Capacity (gpm) | Diameter (inches) | Cost ($/100 feet) |
|---|---|---|
| 50 | 2 | 55 |
| 100 | 3 | 72 |
| 200 | 4 | 94 |
| 300 | 5 | 125 |
| 400 | 6 | 170 |
| 800 | 8 | 263 |
| 1,200 | 10 | 410 |

[1] Capacities based on gpm discharges with velocity in pipe at approximately five feet per second. Source: Buchner Irrigation Company.

TABLE D-2. COMPONENT COSTS OF CONTINUOUSLY MOVING BIG GUNS[1]

| Component | Capacity, 500 gpm ($) | Capacity, 500-1,000 gpm ($) |
|---|---|---|
| Traveling unit | 2,798 | 2,798 |
| Waste drive unit | 96 | 96 |
| Hose reel | 1,654 | 1,654 |
| Flexible hose | 4,607 | 4,831 |
| Hose couplings | 120 | 136 |
| Sprinkler | 400 | 700 |
| TOTAL | 9,674 | 10,188 |

[1]Source: Molehill Irrigation Company.

TABLE D-3. SPECIFICATIONS OF PUMPS FOR HAND MOVE AND SIDE ROLL SYSTEMS

| Discharge capacity (gpm) | Pump size (hp) | Cost ($) |
|---|---|---|
| 50 | 5 | 1,400 |
| 100 | 7 | 1,600 |
| 200 | 10 | 1,450 |
| 300 | 15 | 1,650 |
| 400 | 20 | 1,900 |
| 500 | 25 | 2,100 |
| 600 | 30 | 2,550 |
| 800 | 43 | 2,900 |
| 1,000 | 50 | 3,300 |
| 1,200 | 60 | 4,000 |
| 1,400 | 75 | 6,400 |

TABLE D-4. SPECIFICATIONS OF PUMPS FOR STATIONARY AND TRAVELING BIG GUN SYSTEMS

| Discharge capacity (gpm) | Pump size (hp) | Cost ($) |
|---|---|---|
| 100 | 15 | 1,400 |
| 150 | 20 | 1,840 |
| 300 | 30 | 2,280 |
| 450 | 40 | 2,700 |
| 600 | 60 | 3,280 |
| 850 | 75 | 3,160 |
| 1,150 | 100 | 6,520 |

TABLE D-5. CALCULATION OF PRESENT VALUE OF TRAVELING BIG GUN AND NECESSARY HOSE REPLACEMENTS

| End of year | Item | Cost ($) | P.V.factor[1] | P.V. of cost ($) |
|---|---|---|---|---|
| 0[2] | Traveler | 10,000[3] | 1 | 10,000 |
| 3[4] | Hose | 4,700[5] | 0.638 | 3,210 |
| 6[4] | Hose | 4,700 | 0.476 | 2,237 |
| Present value of system with two hoses............. | | | | 15,447 |

[1] Present value factors are for a discount rate of 10%. From Agricultural Finance, Sixth Edition, by A. G. Nelson, W. F. Lee, and W. M. Murray, Iowa State University Press, 1973.

[2] Discounting convention refers to the beginning of the discounting period as the end of year zero.

[3] Average investment cost for traveling big gun (see Table D-2 of the Appendix) is $9,931. $10,000 was used as the prices from Table 2 are manufacturers' prices, F. O. B., Portland, Oregon.

[4] Average lifetime of hose is estimated at three years. Replacement is assumed to be required at the ends of years 3 and 6 of the ten year total equipment lifetime.

[5] Average price of the flexible hose is $4,719. A value of $4,700 was used for expediency (see Table D-2 for values).

TABLE D-6. PUMP COMPONENT COSTS[1]

| Item | Pump size 5 hp | Pump size 75 hp |
|---|---|---|
| Control panel[2] | $ 50 | $ 512 |
| Switch[2] | 170 | 1,475 |
| Electrical work | 200 | 200 |
| Install | 60 | 120 |
| Suction discharge assembly[2] | 250 | 890 |
| Subtotal | $ 730 | $3,197 |
| Pump | 700 | 3,200 |
| TOTAL | $1,430 | $6,397 |

[1] Source: Moore-Rane Manufacturing Company, Corvallis, Oregon.

[2] Marvin N. Shearer, Department of Agricultural Engineering, Oregon State University, Corvallis, Oregon.

TABLE D-7. COST PARAMETERS USED IN MODEL TO GENERATE OUTPUT DATA

| Fortran variable name | Item | Estimated value ($) |
|---|---|---|
| CostA | Cost/$yd^3$ excavated | 0.50 |
| CostB | Per ft cost of constructing diversion ditch | 0.25 |
| KostC | Land cost per acre | 750.00 |
| CostD | 40-ft section of hand move irrig. pipe, w/ sprinkler | 45.00 |
| CostE | Cost of 1,320-ft side roll lateral | 3,800.00 |
| KostF | Big gun w/ capacity < 500 gpm | 400.00 |
| KostG | Big gun w/ capacity > 500 gpm | 700.00 |
| KostH | Cost of complete traveling big gun | 15,450.00 |
| CostI | Wire fence (per ft) | 0.60 |
| CostJ | Cost of seeding earthworks per $ value of earthworks | 0.01 |
| CostK | Per foot cost of screen check dams | 3.00 |
| KostL | Insurance cost/$100 insured value | 0.60 |
| CostM | Cost per kilowatt hour | 0.0308 |
| CostN | Hourly wage rate for irrig. labor | 3.50 |

APPENDIX E.

| Units stated | Units desired | Multiply by |
|---|---|---|
| Length | | |
| Inches | centimeters | 2.54 |
| Inches | meters | 0.0254 |
| Feet | centimeters | 10.48 |
| Feet | meters | 0.3048 |
| Area | | |
| Square feet | square meters | 0.0929 |
| Square feet | hectares | $9.29 \times 10^{-5}$ |
| Acres | square meters | 4,046.87 |
| Acres | hectares | 0.404687 |
| Volume | | |
| Acre-inches | cubic meters | 102.79 |
| Acre-inches | hectare-centimeter | 1.0279 |
| Volumetric flow rate | | |
| Acre-inches/acre | cubic meters/hectare | 253.81 |
| Gallons/minute | cubic meters/minute | $1.78 \times 10^{-1}$ |
| Temperature | | |
| Degrees Fahrenheit | degrees centigrade | $(^{\circ}F - 32)/1.8$ |
| Power | | |
| Horsepower | watts | 746 |
| Weight | | |
| Pounds | grams | 454 |
| Pounds | kilograms | 0.454 |
| Pounds/acre | kilograms/hectare | 1.122 |

## TECHNICAL REPORT DATA
*(Please read Instructions on the reverse before completing)*

| | | |
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16. ABSTRACT


Cattle feedlot runoff pollution control necessitates facilities to intercept and store surface runoff so manure-contaminated waters are prevented from entering streams and lakes. Design of these facilities requires a matching of individual structures to proposed management techniques and regional climatic data.

Two computer models were developed for these purposes. The first, the sufficient design program, was a simulation model which sized feedlot runoff retention ponds based upon climatic data and management dewatering policies. In addition to minimum pond volume, the sufficient design model listed average number of yearly pumpings for each simulated management alternative at a selected pumping rate. The second model, an economic budget generator, determined cost of open feedlot runoff control systems. The models were tested at seven selected locations in the United States to determine effects of five pumping rates and seven management dewatering alternatives on minimum storage volumes required to prevent discharges as defined by EPA Effluent Guidelines. Stations selected represented a broad spectrum of climatic conditions. Lastly, effects of relaxing the discharge criterion were also studied at each location.


17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Agricultural wastes | Animal waste management | 68D |
| Animal husbandry | Feedlot runoff | 98B |
| Waste disposal | Runoff retention designs | 98C |
| Models | | |

| | | |
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