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APPLICATION OF A COMPUTER MODEL IN DESIGNING
KANSAS FEEDLOT WASTE CONTROL SYSTEMS

by

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INTRODUCTION

In compliance with Public Law 92-500, the Environmental Protection Agency (EPA) has set guidelines to control the problem of feedlot pollution. The effluent guidelines that are to be met by 1983 state that no discharge will occur except in the case of an extreme rainfall event (25 year - 24 hr storm or greater).

The Kansas feedlot industry is one of the major industries of the state [in 1975 - 2,264,000 animals, worth approximately $747 million (1)]. The resulting pollution hazard is of major concern. The magnitude of the problem for the United States as a whole might be best understood if the BOD loads from feedlots are compared to BOD loads caused by wastewater discharged by municipalities. Figure 1 is a comparison between these two sources, in which the two percent curves for feedlots represent the percentage of the total animal waste BOD generated which could be considered to be involved with the feedlot runoff (2). The two curves give a range for the expected BOD loads, since the exact quantity is not known. Figure 1 indicates the magnitude of the environmental problem associated with feedlots, is a matter of concern in an agricultural state such as Kansas. Presently, very few feedlot runoff control systems exist. This problem may be due in part to the lack of any type of design values for sizing control facilities and the effects management would play in their operation.

The objective of this thesis is to provide a uniform basis for the evaluation of feedlot runoff control systems and to propose a method for preliminary design of such facilities.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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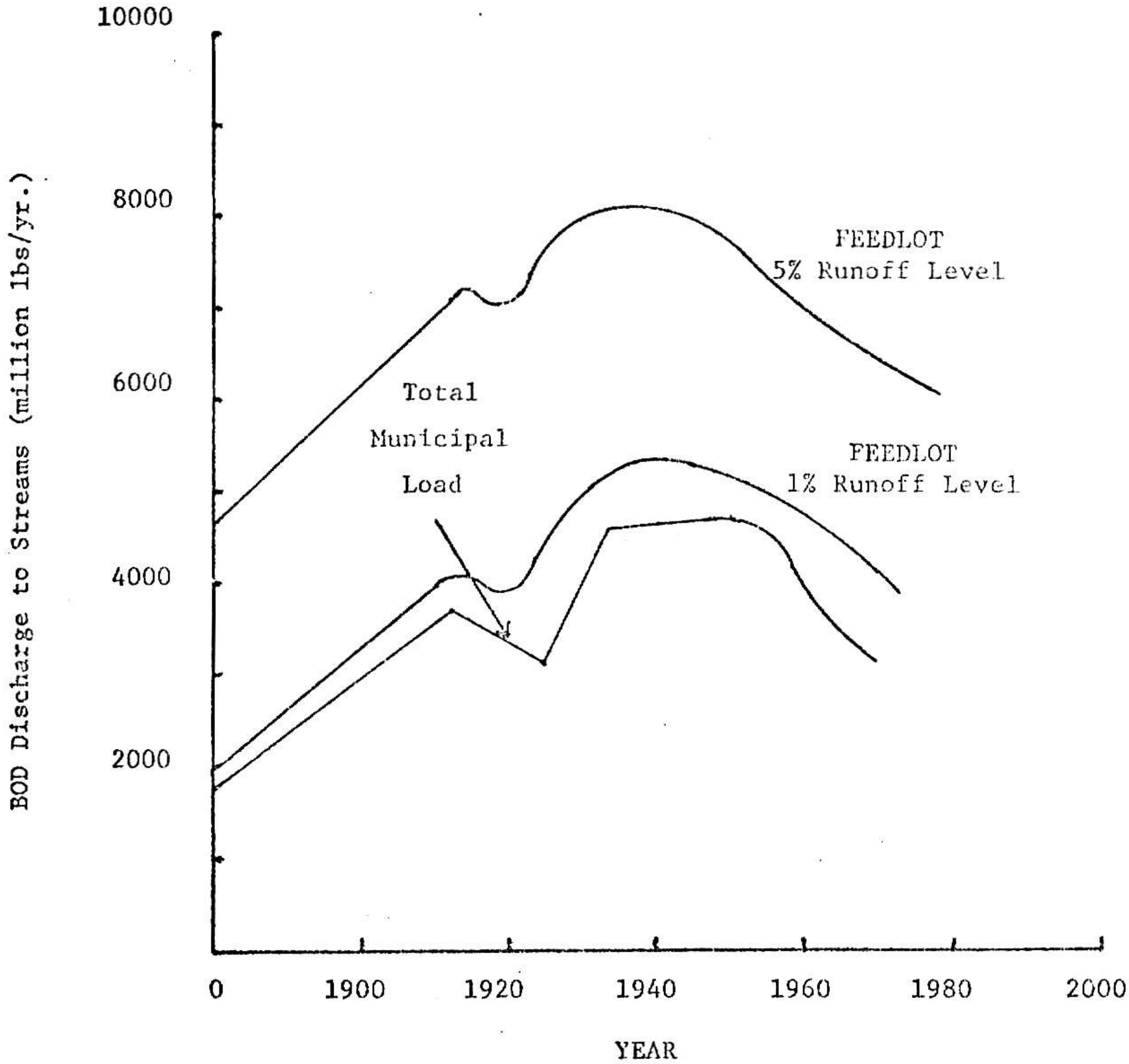


Fig. 1. - Comparison of BOD Discharge to Streams From Municipalities and Animal Feedlots.

BACKGROUND

Through a grant from EPA, a computer model to simulate feedlot wastewater production and disposal techniques was developed at Kansas State University by Bean (3). The main objective of the grant was to develop a computer simulation program to evaluate the performance of feedlot disposal facilities for any location in Kansas. In addition, the program was to generate design criteria for sizing feedlot pond storage, and evaporation or land disposal facilities in Kansas.

An equation was postulated to establish the design criteria for the case of disposal to a cropped disposal area. The equation determines the pond size required to meet specific levels of wastewater control as a function of important variables as follows,

$$V = V_{Location_{95-100}} \times C_{Soil} \times C_{Crop} \times C_{DA/LA} \times C_{DSRATE} \times C_{H/HMAX} \times C_{PAVLU} \qquad (1)$$

where

V = volume of the pond;

$V_{Location_{95-100}}$ = a basic pond volume which depends on climate (location) and percent control required

C_{Soil} = a coefficient for the particular disposal area soil

C_{Crop} = a coefficient related to the crop grown on the disposal area

$C_{DA/LA}$ = a coefficient to account for the ratio of disposal area to feedlot area

C_{DSRATE} = a coefficient reflecting the effect of disposal rate to the disposal area

$C_{H/HMAX}$ = a coefficient to account for variability of pond evaporation with pond shape

C_{PAVLU} = a coefficient accounting for the level of management, which in turn depends upon the available soil moisture (AVSM), where AVSM is defined as Field Capacity (FC) minus Permanent Wilting Point (PWP).

The case of feedlot disposal by pond evaporation was tested only where climatic conditions permit disposal in this manner. An equation for pure evaporation similar to Eq. (1) is

$$SA = f(V_{Location}) \qquad (2)$$

where SA = surface area, which depends only on location (that is, climate), if the pond depth is assumed constant.

In addition to these disposal techniques, this thesis also deals with revision of the program to incorporate multiple disposal areas into the program. The original computer program consisted of a single disposal area for irrigation from the pond. The revised multiple disposal area program has four disposal plots instead of only one. A more detailed description is given later on its operation. With the revised multiple disposal area program, comparisons are made to the original single area program to investigate the effect it has on the amount of water used for irrigation and the percent of wastewater controlled.

PROGRAM DESCRIPTIONS

The main components represented in the model are the feedlot, the pond, and the disposal area as shown in Fig. 2 (4).

The operation of each of these components is briefly described in this text, a more detailed description has been presented by Bean (3). Figure 3 (3, p.5) is a flow chart showing the components of the program to be described.

Feedlot.--In the operation of the feedlot runoff section the first item to be considered is whether the precipitation or the soil is frozen, in which case it would be allocated to the snow accumulation account. If the average temperature is $<-1^\circ$C (30°F), the precipitation is snow. If the sum of the previous two day's average temperatures are $<0^\circ$C (64°F), the soil is frozen. If the combined temperatures are greater than 0°C (64°F), precipitation from rainfall on that day or snowmelt from the pack, or a combination of both, are involved in the runoff event. However, when conditions are dry, that is, the 3-day antecedent moisture conditions (AMC) and the precipitation is <1.3 cm (0.5 in.), the runoff is considered to be zero in the program.

A modified version of the Soil Conservation Service (SCS) equation is used to calculate runoff from the feedlot. During the dormant season (November-March), a runoff curve number N=91 is used when the 3-day AMC $\leq$ 1.3 cm (0.5 in.) and a maximum runoff of 2.5 cm (1.0 in.) is calculated by the equation. The fraction of any rainfall >2.5 cm (1 in.) is added to the runoff for the day. During the growing season (April-October), a maximum runoff of 3.2 cm (1.25 in.) is calculated using N=91 when AMC $\leq$ 1.9 cm. (0.75 in.). Precipitation >3.2 cm (1.25 in.) is allocated to runoff.

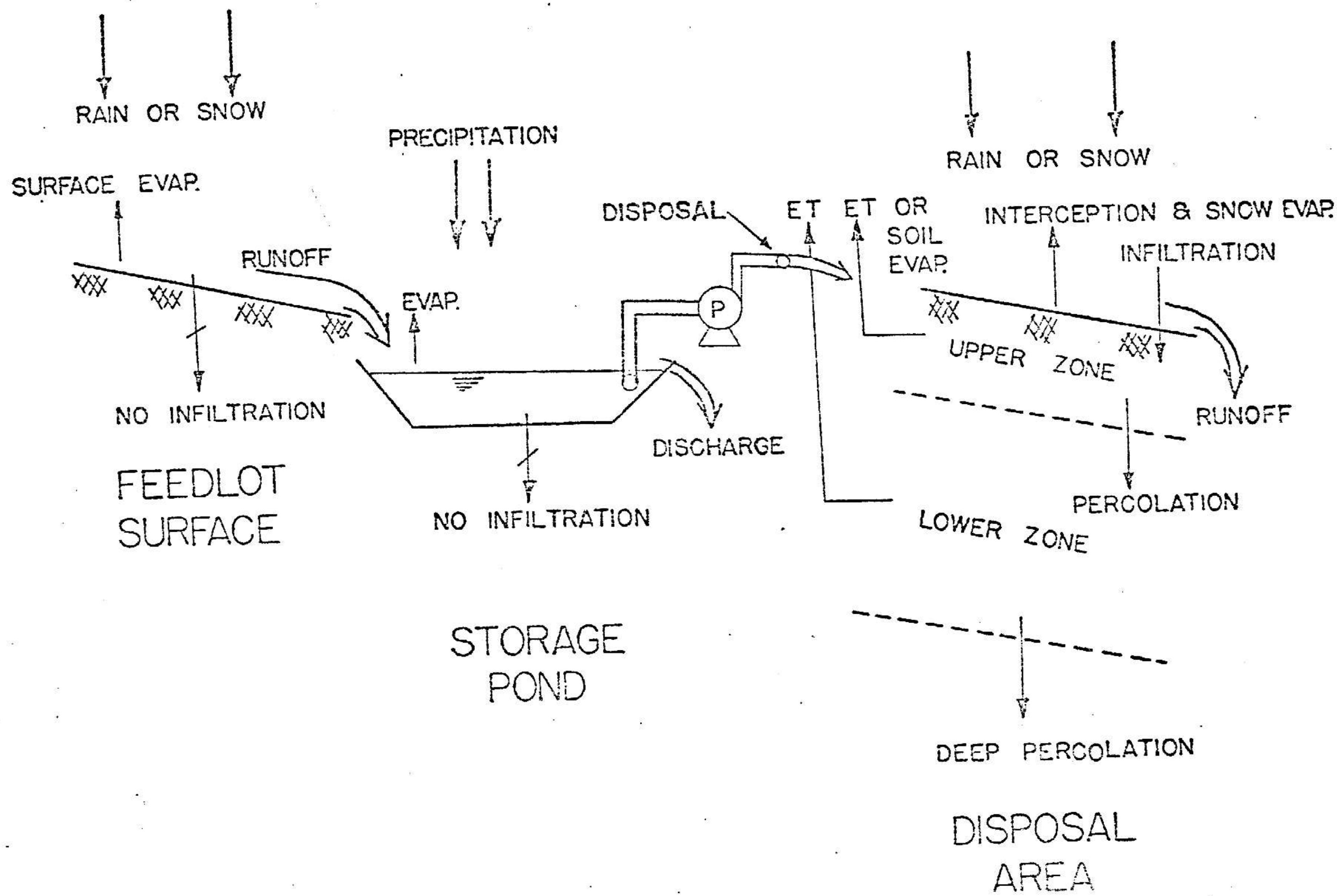
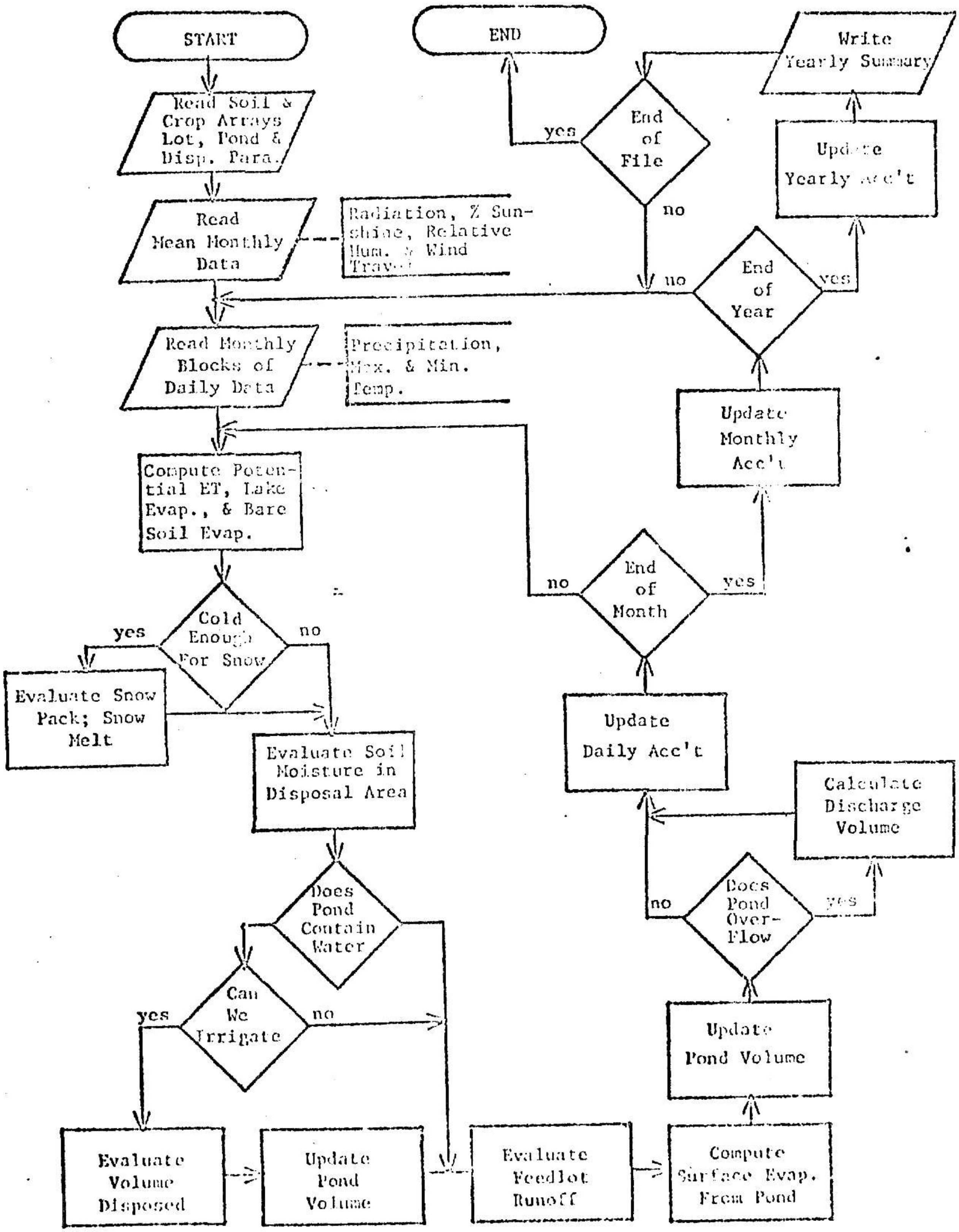


Fig. 2 - Process Schematic of Feedlot Runoff Model [Adapted From Zovne, et al. (4)]

Fig. 3. General Algorithm for Model [Adapted from Bean (3)].



A runoff curve number N=97 is used in either season when AMC > 1.3 cm (0.5 in.) in the dormant season, or > 1.9 cm (0.75 in.) in the growing season

The N values are used as follows

$$S = \frac{1000}{N} - 10 \qquad (3)$$

where S is substituted into the SCS equation

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad (4)$$

where Q = direct surface runoff

P = precipitation

S = the maximum potential difference between precipitation and runoff.

Figure 4 is a flowchart of the described operations of the feedlot.

<u>Pond</u>.--In the pond storage section, the inputs are wastewater runoff from the feedlot and direct rainfall. The losses from the pond are evaporation, irrigation disposal, and overflow discharge. The configuration of the standard pond is shown in Fig. 7.

Evaporation from the pond is at the lake evaporation rate. Irrigation water depends upon disposal area wetness and other factors to be discussed subsequently. Overflow discharge occurs when the pond's maximum depth is exceeded. Exfiltration losses from the pond are considered to be zero.

<u>Disposal Area</u>.--The variables included in the moisture balance of the disposal area is shown in the Disposal Area section of Fig. 2. The soil horizon is divided into an upper 30 cm (1 ft) zone and a lower 90 cm (3 ft) zone. Soil moisture is increased by the infiltrated portion of precipitation and runoff, and decreased by percolation and evapotranspiration (ET).

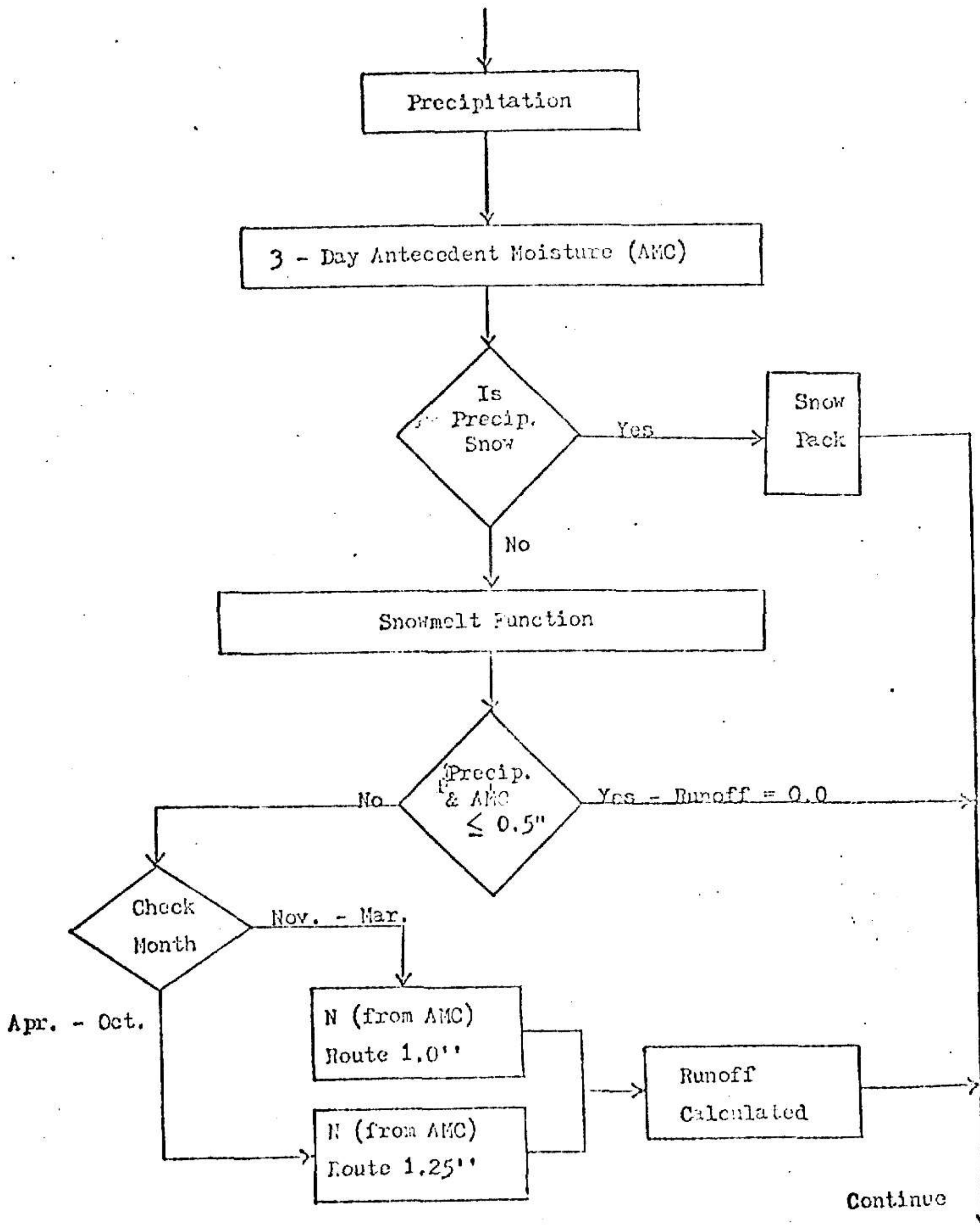


Fig. 4. Flow Chart of Calculated Feedlot Runoff.

Potential evapotranspiration is calculated using the Penman Combination Equation,

$$
\begin{aligned}
PET = {} & 0.039\ Ta^{0.673}\ [(1-r)\ Ra(0.22 + 0.54\ PSUNS) \\
& - 2.010 \times 10^{-9}\ T^{4}\ (0.98 - a - b\ \sqrt{ES \times RHD}) \\
& \cdot (0.1 + 0.9\ PSUNS)] + (1 - 0.039\ Ta^{0.673}) \\
& \times 0.26(e + 0.01\ WVD)(ES - ES \times RHD)
\end{aligned} \tag{5}
$$

where PET = potential evapotranspiration, in inches

Ta = mean daily air temperature, in °F

T = mean daily air temperature, in °K

Ra = solar radiation, in mm of water

PSUNS = percent sunshine, in %/100

ES = saturated vapor pressure at Ta, in millibars

RHD = relative humidity, in %/100

WVD = wind travel, in miles/day.

The variables a, b, e are constants determined for the location. The variable r is the reflectance coefficient (albedo). A value of r = 0.05 is used for free water surfaces (pond evaporation), 0.23 for crops, and 0.20 for bare soil (5). The variable ES is the saturation pressure of air at the mean daily air temperature and is calculated by (3)

$$
ES = 33.9[(0.00738\ Ta + 0.8072)^{8} - 0.000019|1.8\ Ta + 48| + 0.001316 \tag{6}
$$

The total evaporation budget of the disposal area is composed of evaporation from water in interception storage, bare soil evaporation, and crop transpiration. Evaporation from interception storage is accomplished at the PET rate, with r = 0.20.

Evaporation from the bare soil and crop transpiration is in two phases. When available soil moisture (θ_a) is greater than 0.3 of the maximum available soil moisture (θ_{max}), rates of water losses are at the PET rate. In the second phase, when $\theta_a < 0.3\ \theta_{max}$, water losses of the bare soil are calculated by the following equation

$$E_s = c't^{1/2} - c'(t-1)^{1/2} \tag{7}$$

where E_s = soil evaporation

c' = a hydraulic coefficient of the soil

t = the time after phase 1 evaporation.

The c' values for the twelve SCS soils have been tabulated by Bean (3, p.14).

Crop transpiration and evaporation from the soil upon which the crop is grown is designated as actual evapotranspiration (AET). In the second phase of evaporation, AET from the disposal area is calculated by the Blaney-Criddle Method (6)

$$AET = PET \times K \times \left(\frac{\theta_a}{0.3\ \theta_{max}}\right) \tag{8}$$

where θ_a = actual available soil moisture

K = crop coefficient which depends upon crop stage of growth.

The SCS equation, Eq. 4, is also used to compute runoff from the disposal area. N values for the various soils have been tabulated by Bean (3, p.14). The initial abstractions (IA) must first be satisfied before surface runoff can occur. The IA consists of surface storage, interception losses, and water that infiltrates the soil prior to runoff. The maximum amount of this storage is fixed at 2.54 mm (0.1 in.).

The SCS method involves assigning runoff curve numbers to specific antecedent moistures, soil types, and land-use and conservation practices (4). The input N values are based on condition II antecedent moisture.

Condition II is an upper zone soil moisture between 0.6 and 0.9 of available moisture during the dormant season, and 0.5 to 0.8 during growing season. When the soil moisture is less than 0.5 or 0.6 of available moisture, depending upon the season, N is assumed to be a condition I antecedent soil moisture given by

$$N_I = N \times 0.39\ e^{(-0.009 \times N)} \tag{9}$$

When the soil moisture is greater than the upper limit set for the season, the condition III curve number is obtained by

$$N_{III} = N \times 1.95\ e^{(-0.00663 \times N)} \tag{10}$$

The N values are then used in Eqs. 3 and 4 (4).

After runoff and interception amounts are deducted, the remaining excess precipitation infiltrates into the upper soil zone. The amount of water in this zone is limited to 0.9 of saturation, with any excess amount being released directly to the lower zone. If infiltration causes the upper zone moisture to be greater than field capacity, the moisture in excess of field capacity and not depleted by AET is cascaded in two days to the lower zone. When the field capacity of the lower zone is exceeded, the excess moisture above 0.9 field capacity and not depleted by AET is also cascaded downward in two days. Moisture in excess of 0.9 saturation is released directly downward. Excess from this zone is considered to percolate out of the root zone and is sometimes called groundwater recharge.

Snowmelt.--Snowmelt from the snowpack on the disposal area is approached on a degree day basis. As defined previously, precipitation occurring on a day with an average temperature $\leq$ 0°C (32°F) is considered snow. The snowmelt function (4) used in the model is

$$M = C(Ta - Tb) \tag{11}$$

in which M = snowmelt

C = degree day coefficient

Ta = mean daily atmospheric temperature

Tb = base temperature.

This computes snowmelt as a result of atmospheric conditions. If snow is initially considered to be at 0°C (32°F), the equation to compute snowmelt by rainfall (4) is

$$D = (1/144)(P)(Ta - 32) \tag{12}$$

in which D = snowmelt by rainfall

P = amount of precipitation

Ta = mean daily temperature.

The constants used in this equation are 79 cal/g (144 BTU's/lb) for the heat of fusion of ice and 1 cal/g (1 BTU/lb) for the specific heat of water. The total snowmelt runoff (M+D) is added to the precipitation and disposal wastewater for the day.

Multiple Disposal Areas.--The program developed by Bean (3), used a single disposal area. As an attempt to more closely approximate typical agricultural management practices, a program having multiple disposal areas was developed from the original program.

Figure 5 is a flowchart of the multiple disposal area subroutine. The disposal area section of the program is set up so that it cycles through this section the number of times equal to the number of plots. If irrigation water is available, irrigation will occur on the plot having the lowest available soil moisture. If only one plot is used, the program is equivalent to the single area disposal program. If multiple plots are used, the individual plot area is specified and the size can be varied from

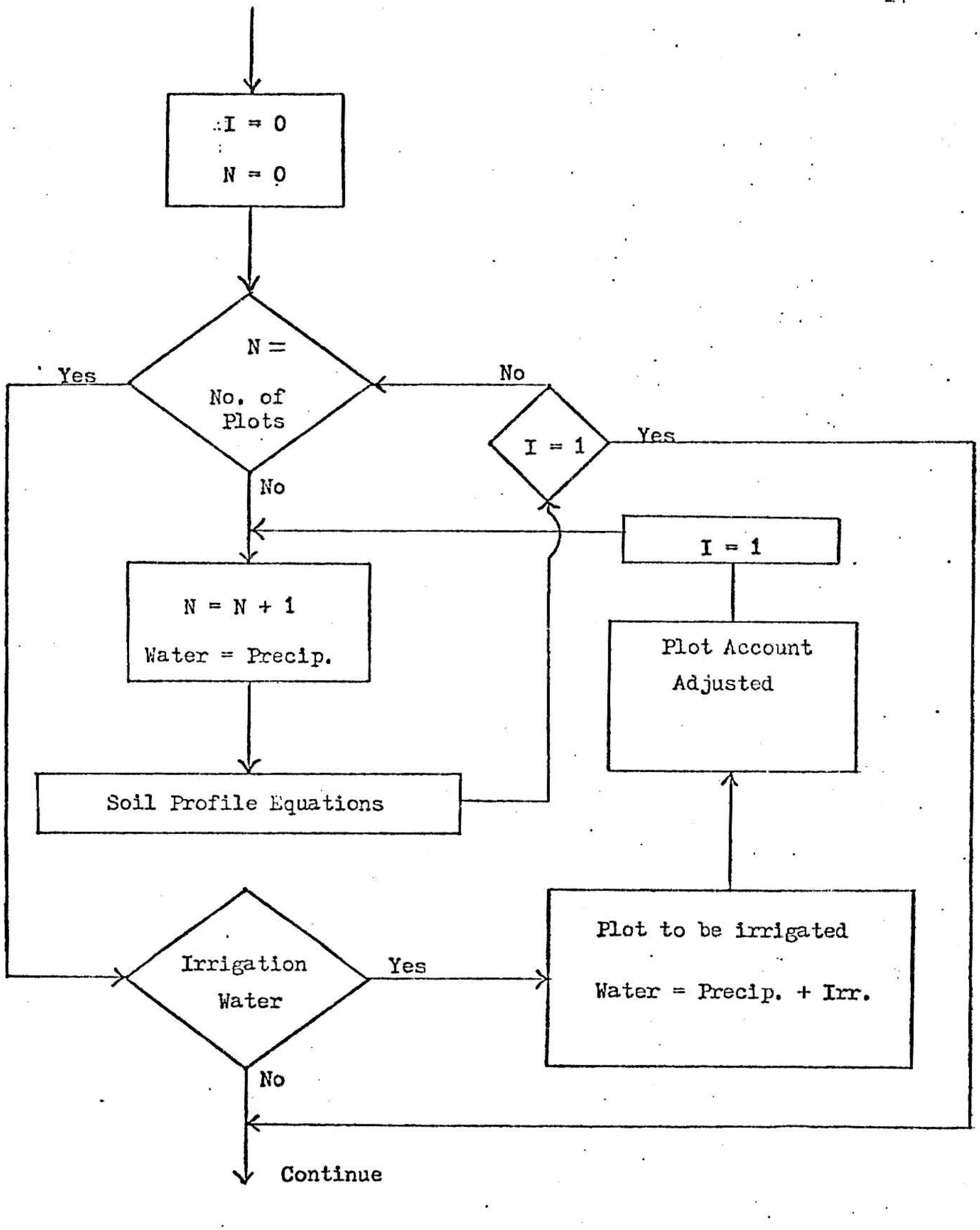


Fig. 5 - Flow Chart of Modification for Multiple Disposal Areas

plot to plot. Each individual plot can have any one of the seven crops on any one of the 12 soils programmed into the computer package. From the practical standpoint, however, plots should have equal areas and the same soil type.

CALIBRATION

The model was tested on five base stations; Colby, Ellsworth, Garden City, Independence, and Topeka. Five supplemental or satellite stations were required to adequately define irrigation facility requirements for Fig. 8. They are Belleville, Dodge City, Goodland, Hays, and Horton. They represent a good geographical cross-section of the state. In addition, they cover the statewide variations in the moisture deficit, which is defined as the difference between the long-term mean annual lake evaporation and the long-term mean annual precipitation. Each of these stations has the long term climatological data required for the simulation program. These are the maximum and minimum daily temperature and daily precipitation. Four of the base stations have at least 60 years of continuous data, while Topeka has a record on file of only 25 years.

Calibration of the model is an important first step in any simulation program. The most important calibration factor in the model is the adjustment of the computed average annual lake evaporation to the published values (7). Table 1 gives values for the ten stations.

In a calibration method developed by Bean (Personal communication), appropriate values of a, b, and e are selected for use in the Penman equation for PET. To justify calibration with respect to evaporation (lake), it should be noted that evaporation accounts for 80% loss from rainfall and streamflow into the state (personal communication -- Hyde S. Jacobs, Prof. of Agronomy, Kansas State University). In western Kansas, where rainfall and streamflow are both small, 98% is assumed to be lost by evapotranspiration. Calibration with respect to evaporation is not only justified, but vital, inasmuch as it plays such a large part in the water budget.

TABLE 1.--Meteorological Values

Location (1)	Estimated Annual Lake Evaporation (cm (in) (2)		Annual Precipitation cm (in) (3)		Moisture Deficit (2)-(3) cm (in) (4)	
BASE STATIONS						
Colby	139.4	(54.9)	46.2	(18.2)	93.2	(36.7)
Ellsworth	115.1	(45.3)	68.6	(27.0)	46.5	(18.3)
Garden City	153.4	(60.4)	46.2	(18.2)	107.2	(42.2)
Independence	108.5	(42.7)	91.2	(35.9)	17.3	(6.8)
Topeka	110.7	(43.6)	87.1	(34.3)	23.6	(9.3)
SUPPLEMENTAL STATIONS						
Belleville	103.1	(40.6)	76.2	(30.0)	26.9	(10.6)
Dodge City	158.0	(62.2)	52.6	(20.7)	105.4	(41.5)
Goodland	130.8	(51.5)	40.4	(15.9)	90.4	(35.6)
Hays	146.8	(57.8)	59.4	(23.4)	87.4	(34.4)
Horton	94.5	(37.2)	93.2	(36.7)	1.3	(0.5)

In calibrating the program, deep percolation and surface runoff averages from the disposal area were adjusted to reasonably expected values for the climate at the location. Since these values are indirectly determined, there is no way of confirming them, except to say they are reasonable. In Table 2, the long-term percolation and runoff averages for each base station are compared. Values are compared for natural conditions (that is, no irrigation), and when the disposal area is irrigated. Under irrigated conditions, both percolation and runoff increase. Since irrigation rates are assumed to produce no runoff, the increased runoff is attributable to days when both irrigation and rainfall occur.

TABLE 2.--Long-Term (25 years or more) Average Values of Percolation and Runoff on Disposal Area[a].

Location and Time Period (1)	Natural Conditions: Average Annual Percolation cm (in) (2)	Natural Conditions: Average Annual Runoff cm (in) (3)	Irrigated Conditions: Average Annual Irrigation cm (in) (4)	Irrigated Conditions: Average Annual Percolation cm (in) (5)	Irrigated Conditions: Average Annual Runoff cm (in) (6)
Colby (1950-1974)	0.0 (0.0)	1.5 (0.6)	6.4 (2.5)	0.0 (0.0)	2.0 (0.8)
Ellsworth (1946-1970)	0.2 (0.1)	7.6 (3.0)	10.2 (4.9)	1.5 (0.6)	9.7 (3.8)
Garden City (1950-1974)	0.0 (0.0)	1.8 (0.7)	6.6 (2.6)	0.0 (0.0)	2.8 (1.1)
Independence (1948-1972)	0.5 (0.2)	22.9 (9.0)	18.8 (7.4)	3.0 (1.2)	28.2 (11.1)
Topeka (1949-1973)	0.8 (0.3)	19.6 (7.7)	17.3 (6.8)	2.8 (1.1)	25.6 (10.1)

[a]Crops were all corn on the area soil types were 5 for Colby, Ellsowrth, and Garden City; and 3 for Topeka and Independence.

TESTING

Evaporation.--The first phase of testing was to evaluate the percentage of wastewater controlled when disposal was by means of evaporation from the pond. The only variable of importance for this system is the pond's surface area, which is governed by the maximum depth and volume. In all runs, the pond maximum depth (HMAX) was held constant at 1.8 m (6 ft). The pond side slopes are 3:1 (run:rise) and length to width of base of the pond is 3:1, in all the test runs.

Single Disposal Area.--This phase of the testing was concerned with irrigation from the pond onto a single disposal area. The testing procedure was conducted to establish constants for use in Eq. 1.

The initial step was to establish standards for comparison. For a location, the standard run yielded the smallest pond volume required for 100% wastewater control. The latest 25 years of data for a given location was used as a standard testing period. Of these 25 years, the worst 10-12 year period was used for all comparison runs. The worst years were those requiring the greatest utilization of the pond storage capacity.

In the standard run for each location the crop on the disposal area was corn, the soil was a Type 5 with medium permeability for Kansas, the feedlot was 16.2 ha (40 ac) and the disposal area was 32.4 ha (80 ac), the irrigation rate was 1.3 cm/day (0.5 in/day), the irrigation management level was 90% (comparisons for Ellsworth were made at the 50% level), the maximum pond depth was 2.7 m (9 ft), and no irrigation occurred if the volume of water in the pond was less than 5% of the maximum volume. Table 3 shows the resulting dimensions.

TABLE 3.--Dimensions for Standard Ponds.

Location (1)	Length in m (ft) (2)	Width in m (ft) (3)	Maximum Depth in m (ft) (4)	Maximum Pond Surface Area in m^2 (ac) (5)	Maximum Pond-Volume m^3 (ac-in) (6)
Colby	124 (405)	41 (135)	2.7 (9)	8000 (1.99)	17800 (174)
Ellsworth	183 (600)	61 (200)	2.7 (9)	15400 (3.81)	36200 (353)
Garden City	119 (390)	40 (130)	2.7 (9)	7600 (1.88)	16700 (163)
Independence	188 (615)	63 (205)	2.7 (9)	16100 (3.98)	37900 (370)
Topeka	265 (870)	88 (290)	2.7 (9)	29500 (7.30)	72300 (706)
SUPPLEMENTAL STATIONS					
Belleville	174 (570)	58 (190)	2.7 (9)	14100 (3.50)	33000 (322)
Dodge City	137 (450)	46 (150)	2.7 (9)	9500 (2.36)	21500 (210)
Goodland	114 (375)	38 (125)	2.7 (9)	7100 (1.76)	15600 (152)
Hays	165 (540)	55 (180)	2.7 (9)	12500 (3.19)	30000 (292)
Horton	261 (855)	87 (285)	2.7 (9)	28600 (7.07)	70000 (683)

In the comparison runs, one of the standard variables was changed to obtain the range in percent wastewater controlled from a wide range of crops, soils, irrigation rates and management levels, and feedlot to disposal area ratios. The crops consisted of corn, wheat, grain sorghum, soy beans, pasture, and alfalfa. The twelve irrigation soil classes described in reference (3) were tested. The disposal rates tested were 1.3 cm/day (0.5 in./day), 2.5 cm/day (1.0 in./day), 3.8 cm/day (1.5 in./day), 5.1 cm/day (2.0 in./day). The feedlot area to disposal area ratios were 1:1, 1:2, 1:3, and 1:4. The irrigation management levels were 50% and 90% of available soil moisture. The 50% level represents a normal irrigation scheme in which water is only put on the crop when it is needed. The 90% level represents a high rate disposal option which puts water on the field whenever there is available storage.

Multiple Disposal Areas.--The third and final phase of testing was the use of the multiple disposal area program. The program was tested with these same standard variables, with the exception that the disposal area was subdivided into 4 equal sized areas each having the same crop on the same soil and 50% Management Level was used. It was not possible to consider different crops or soils within the plots. With 6 crops and 12 soil types the number of combinations is almost infinite and not seriously worth considering. The disposal rate in all runs was held constant at 5.1 cm/day (2 in./day) over the 4 hectares (10 acre) disposal area.

RESULTS

Evaporation.--The climatic variables for each station are given in Table 1 for comparison. Evaporation is governed by moisture deficit, so moisture deficit was used to develop a relationship between pond size and percent control. A large variation in this parameter (moisture deficit) is evident for Kansas, although more humid climates can have negative values.

From the test runs, Fig. 6 was constructed to show the resulting relationship between moisture deficit and the required pond size for design purposes. For any particular value of moisture deficit (LKET-PREC), a value of maximum pond surface area to feedlot area (ordinate value from Fig. 6) can be chosen within the 95-100% control limits. The pond area thus computed would control 95-100% of the total feedlot runoff generated over a long period of time. This range was used because below 95%, the number of discharges that occur are quite numerous. Caution must be taken, that the graphs are not extrapolated past there present points, especially at lower moisture deficits.

From this plot, meteorological averages for any location in Kansas can be used to size the necessary pond for wastewater control by evaporation. The only necessary data are the annual lake evaporation, precipitation, and the feedlot size.

$$F(V_{Location}) = (\text{Feedlot Area})[F(MD)] \tag{13}$$

$$SA = F(V_{Location}) \tag{14}$$

where SA = pond surface area for a 1.8 m (6 ft) depth

MD = moisture deficit

F(MD) = the ordinate value from Fig. 6, given the moisture deficit.

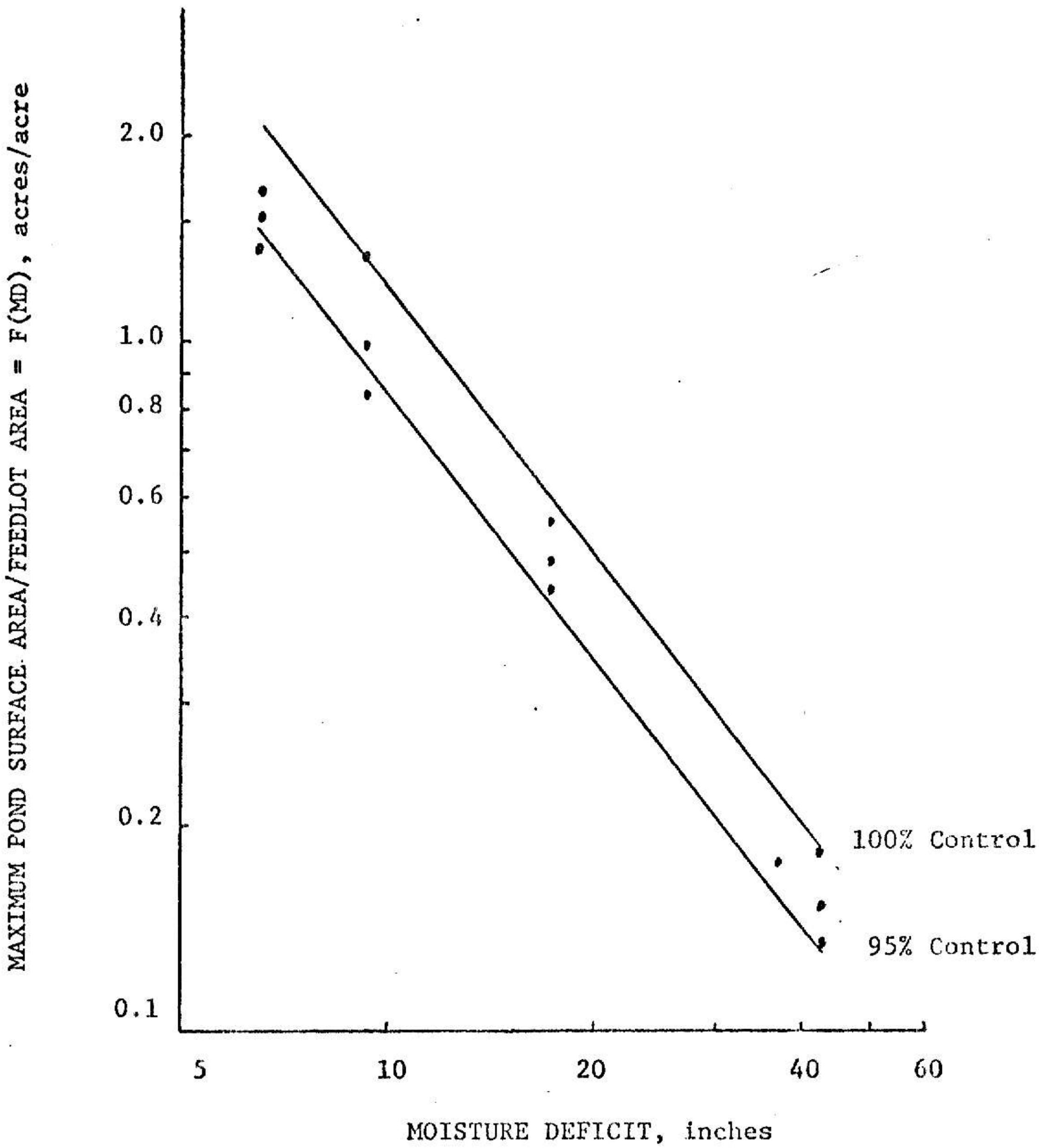


Fig. 6 - Relationship Between Moisture Deficit and Maximum Pond Surface Area/Feedlot Area For Evaporation Pond Design (Data Point Values Given in Table 4)

TABLE 4.--Data Used to Construct Evaporation Design Curve (Fig. 6).

Location (1)	Percentage Obtained % (2)	Feedlot Area in acres (3)	Maximum Pond Surface Area in acres (4)	Max. Pond Area / Feedlot Area (4)/(3) (5)
Topeka	99.8	40	52.6	1.32
	97.8	40	41.2	1.03
	83.9	40	33.6	0.84
Ellsworth	99.5	40	20.4	0.51
	96.8	40	18.1	0.45
	93.6	40	16.4	0.41
Independence	99.4	40	62.1	1.55
	98.8	40	58.8	1.47
	97.0	40	52.6	1.32
Garden City	100.0	40	7.2	0.18
	97.7	40	5.9	0.15
	94.5	40	5.2	0.13
Colby	99.5	40	7.2	0.18

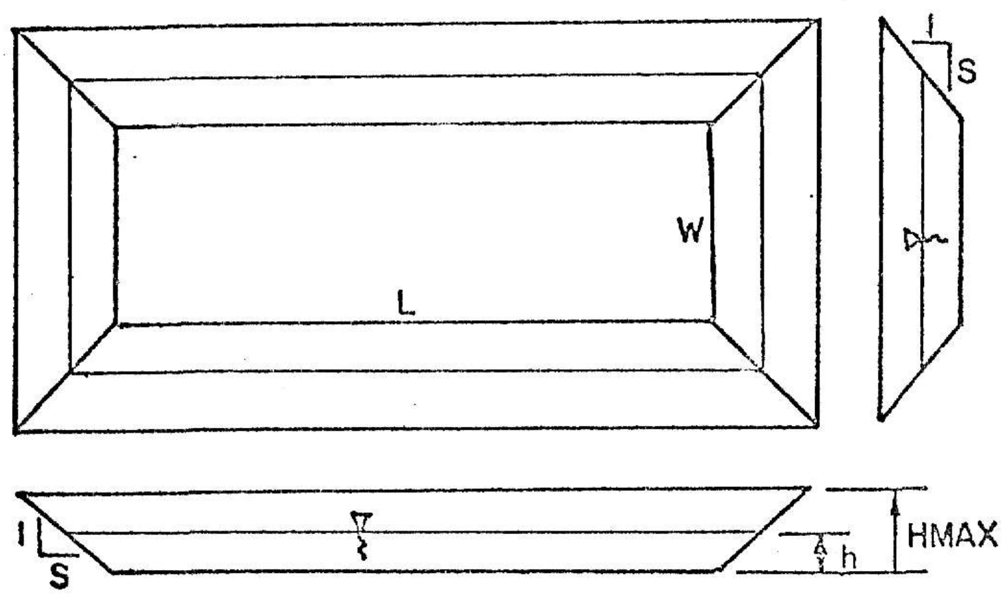


Fig. 7 - Configuration of Storage Facility
[Adapted From Zovne, et al. (4)]

To illustrate the use of Fig. 6 and Eq. (14), the design of a pond for Ellsworth will be shown.

At Ellsworth, LKET = 115 cm (45.3 in.) and PREC = 69 cm (27.0 in.). Taking the difference between the two, moisture deficit = 46 cm (18.3 in.). With value from the abscissa of Fig. 6, values of 0.39 (95% wastewater control) and 0.55 (100% wastewater control) are read from the graph. With a feedlot size of 8.1 ha (20 ac), Eq. 13 yields a pond surface area of 3.2 ha (8 ac) for 95% control and 4.4 ha (11 ac) for 100 control.

To determine the pond volume from this surface area, the equation for a general prismatoid shown in Fig. 7 is used (5).

$$V = \frac{1}{6} h(B1 + 4Bm + B2) \tag{14}$$

in which V = volume, in m^3 (ft^3)

h = height, in m (ft)

$B1$ = bottom surface area, in m^2 (ft^2)

$B2$ = top surface area, in m^2 (ft^2)

Bm = area of a plane at h/2 above the bottom.

The computed values for Ellsworth with 95% control are,

$B2 = SA = 3.2$ ha (8.0 ac)

$B2 = L \times W$

$L = 3W$ (assumed)

$B2 = 3L^2$

$W = 103.9$ m (340.8 ft)

$L = 311.9$ m (1022.5 ft)

$$V = \frac{1}{6} (1.83)[(311.9 - 11.0)(103.9 - 11.0) + ((311.9 - 5.5)(103.9 - 5.5)) + (311.9)(103.9)]$$

$V = 55192\ m^3$ (537 ac-in)

where L = length of pond at the maximum wet depth

W = width of the pond at the maximum wet depth

Single Disposal Area.--The results for the irrigation disposal tests are summarized in Table 5. The numbers in Table 5 are ratios of the largest pond volume required for the test run to the largest pond volume required for the standard run. Both values were taken from the worst (requiring the largest pond volume) year in a particular run. This approach was taken rather than using the percent of wastewater controlled, as for evaporation, because it is a better indicator of the effects of various assumptions on the systems response.

In interpreting Table 5, the average of the values (Average of the Locations--column 7) will correspond to the variable it represents in Eq. 1, e.g., C_{Soil} for a soil 2 is 0.8. This would indicate a pond volume requirement that was 80% of the standard volume at the location if the soil was the only variable changed from the standard conditions.

For initial design purposes, Fig. 8 was constructed. In this graph, as with pure evaporation, the moisture deficit was assumed to be the key variable in determining pond volume. The two solid lines on Fig. 8 are to be used for design. The solid line for 100% Control has an $r^2 = 0.85$, giving a correlation coefficient of 0.92. These values are for all the stations except Independence. With Independence, the dashed line represents an $r^2 = 0.71$ for all ten stations. Comparing r^2 terms for both plots, it was felt that Independence was not a representative station, and was therefore dropped from the plot. $V_{Location_{95-100}}$ is evaluated from Fig. 8 and the following relationship

TABLE 5.--Ratio of Pond Size for Other than Standard Conditions to Standard Conditions for Irrigation Disposal Design.

Parameter (1)	Topeka (2)	Colby (3)	Ellsw. (4)	Garden City (5)	Indep. (6)	Average of the Locations (7)
						C_{soil}
Soil 1	1.00	1.00	1.00	1.00	1.00	1.00
Soil 2	0.86	0.91	0.84	0.72	0.84	0.83
Soil 3	1.00	1.00	1.02	1.00	1.00	1.00
Soil 4	1.00	1.00	1.02	0.94	1.00	0.99
Soil 5	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
Soil 6	1.00	1.00	1.00	1.00	1.00	1.00
Soil 7	1.00	1.00	1.00	0.94	1.00	0.99
Soil 8	1.00	1.00	1.00	0.94	1.00	0.99
Soil 9	1.00	1.00	1.00	0.94	1.00	0.99
Soil 10	0.96	1.00	1.02	0.88	0.99	0.98
Soil 11	0.86	0.91	0.88	0.72	0.99	0.87
Soil 12	0.69	0.91	0.79	0.72	0.83	0.79
						C_{crop}
Wheat	0.81	0.91	1.13	0.42	0.80	0.81
Sorghum	0.86	0.91	1.15	0.83	1.02	0.99
Corn	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
Beans	0.86	0.91	1.44	0.83	1.06	1.02
Pasture	0.79	0.91	0.91	0.54	0.82	0.78
Alfalfa	0.79	0.91	0.88	0.54	0.83	0.79

TABLE 5 (Continued)

Disposal Rate						C_{DSRATE}
1.27 cm/day (0.50 in.)	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
2.54 cm/day (1.00 in.)	0.83	1.00	0.95	0.94	0.78	0.90
3.81 cm/day (1.50 in.)	0.83	1.00	0.91	0.87	0.74	0.87
5.08 cm/day (2.00 in.)	0.83	1.00	0.86	0.84	0.73	0.85
Disposal Area / Lot Area						$C_{DA/LA}$
1:1	1.20	1.00	1.05	1.06	1.28	1.12
2:1	1.00*	1.00*	1.00*	1.00*	1.00*	1.00*
3:1	1.00	1.00	0.86	0.93	0.95	0.97
4:1	1.00	1.00	0.91	0.89	0.94	0.85
Depth Relation-ship						$C_{H/HMAX}$
1.22 m (4 ft)	1.12	1.04	1.19	1.04	1.20	1.12
1.83 m (6 ft)	1.05	1.02	1.08	1.02	1.13	1.06
Management						C_{PAVLV}
50% vs. 90%	2.36	1.38	1.27	1.06	1.14	1.44

*Standard Run

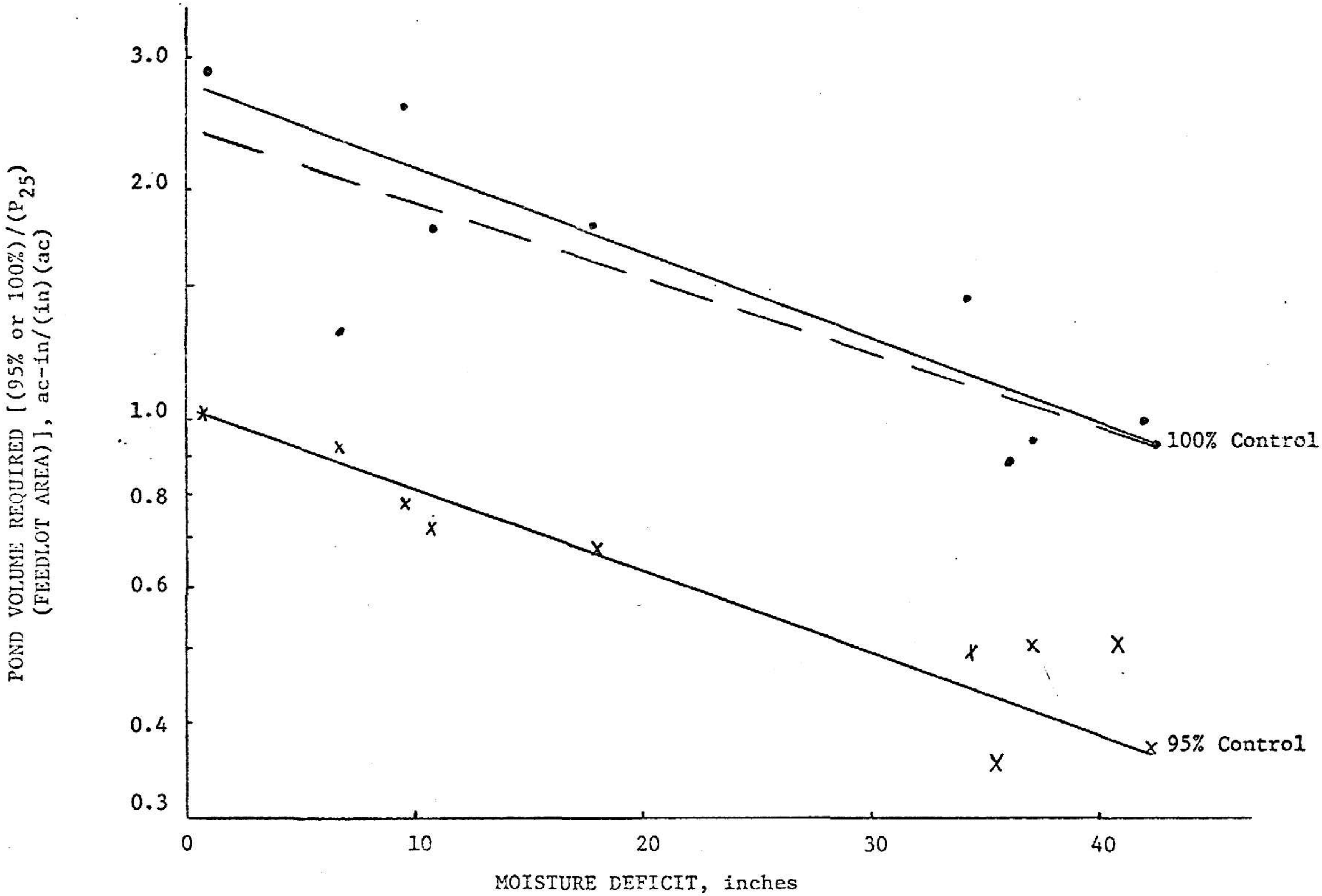


Fig. 8 - Relationship Between Moisture Deficit and Design Pond Volume/Constants (Data Point Values Given in Tables 6 & 7)

TABLE 6.--Data Used to Construct Irrigation Design Curve for 100% Control (Fig. 8)[a].

Location (1)	25 year - 24 hour storm (P-25)[b] in. (2)	Feedlot Area ac. (3)	Volume Required ac-in. (4)	Ordinate Value Fig. 8, $\frac{(4)}{(2)x(3)}$ (5)	Number of storms $\geq$ 25 yr - 24 hr. storm in the test period (6)	A storm $\geq$ 25 yr - 24 hr storm, occured in the critical year (7)
Colby	4.5	40	169.7	0.94	0	No
Ellsworth	5.4	40	385.5	1.78	1	Yes
Garden City	4.5	40	169.8	0.94	0	No
Independence	6.7	40	363.2	1.36	0	No
Topeka	6.1	40	680.9	2.54	0	No
Belleville	5.1	40	354.4	1.74	2	No
Dodge City	4.6	40	193.1	1.05	1	No
Goodland	4.3	40	145.3	0.84	0	No
Hays	4.7	40	284.3	1.51	1	No
Horton	5.9	40	689.1	2.92	1	Yes

[a]Moisture deficits obtained from Table 1.

[b]Values from Ref. (7).

TABLE 7.--Data Ued to Construct Irrigation Design Curve for 95% Control (Fig. 8).

Location (1)	25 yr. - 24 hr storm in. (2)	Feedlot Area ac. (3)	Volume Required ac-in (4)	Ordinate Value Fig. 8, $\frac{(4)}{(2)x(3)}$ (5)	Percentage Obtained % (6)
Colby	4.5	40	95.0	0.52	97.4
Ellsworth	5.4	40	144.1	0.67	96.7
Garden City	4.5	40	66.2	0.37	95.6
Independence	6.7	40	249.0	0.93	98.6
Topeka	6.1	40	185.7	0.76	94.6
Belleville	5.1	40	144.1	0.71	95.6
Dodge City	4.6	40	96.8	0.53	96.0
Goodland	4.3	40	60.6	0.35	95.6
Hays	4.7	40	96.8	0.51	95.7
Horton	5.9	40	240.9	1.02	96.4

$$V_{Location_{95-100}} = P_{25}(\text{Feedlot area})[f(MD)] \quad . \qquad (15)$$

where P_{25} = the 25 year-24 hour storm for the location (Table 6); and

$f(MD)$ = the appropriate ordinate value from Fig. 8 for either 95% or 100% control.

To determine if Eq. 1 is valid, comparisons are made between calculated values using Eq. 1 and actual runs. The following three examples are included to demonstrate the use of Eq. 1 and Fig. 8 for determining pond volume requirements.

Example 1:

Location: Ellsworth, Kansas

Feedlot Area: 40 acres

Disposal Area: 40 acres; Sorghum, Soil Type 5; 0.50 in./day, 50% Management Level

Design for 100% Control

$$V = V_{Location_{100}} \times C_{PAVLU} \times C_{DA/LA} \times C_{Crop} \begin{bmatrix}\text{other} \\ \text{terms in} \\ \text{Eq. 1} = 1\end{bmatrix}$$

$$V_{Location_{100}} = (P\text{-}25) \times (\text{Feedlot Area}) \times (\text{Ordinate Value from Fig. 8})$$

$$V = (5.4 \text{ in.} \times 40 \text{ ac} \times 2.7) \times (1.44) \times (1.12) \times (0.99)$$

$$V = 930 \text{ ac-in.}$$

Actual Volume Required from Test Program:

$$V = 805 \text{ ac-in.}$$

Example 2:

Location: Garden City, Kansas

Feedlot Area: 40 acres

Disposal Area: 40 ac; Corn; Soil Type 5; 0.50 in./day; 50% Management Level

Design for 100% Control

$$V = V_{Location_{100}} \times C_{PAVLU} \times C_{DA/LA}$$

$$V = (4.5 \text{ in.} \times 40 \text{ ac} \times 0.95) \times (1.44) \times (1.12)$$

$$V = 276 \text{ ac-in.}$$

Actual Volume Required from Test Program:

$$V = 334 \text{ ac-in.}$$

Example 3:

Location: Topeka, Kansas

Feedlot Area: 40 ac

Disposal Area: 80 ac; Corn; Soil Type 3; 0.50 in./day; 90% Management Level

Design for 100% Control

$$V = V_{Location_{100}} \times C_{Soil}$$

$$V = (6.1 \text{ in.} \times 40 \text{ ac} \times 2.25) \times (1.00)$$

$$V = 550 \text{ ac-in.}$$

Actual Volume Required from Test Program:

$$V = 680 \text{ ac-in.}$$

TABLE 8.--Comparison of Design Equation to Actual Results

Location	Volume from Actual Test m^3 (ac-in.)		Volume from Eq. 1 & Fig. 8 m^3 (ac-in.)		$\frac{\text{Equation Volume}}{\text{Actual Volume}} \times 100\%$
Ellsworth	82500	(805)	95300	(930)	116
Garden City	34200	(334)	28300	(276)	83
Topeka	69700	(680)	56400	(550)	81

These examples and Table 9 show that the design procedure will result in a pond size within ±20% of the value predicted by the simulation program.

Multiple Disposal Areas.--The final results are concerned with comparisons of multiple disposal to single area disposal. Specifically, the tests were performed to determine whether multiple disposal would significantly reduce the size of facilities. Table 10 summaries the results of these tests. All but one of the stations (Ellsworth) showed an increase in the amount of wastewater used for irrigation, resulting in better wastewater control.

TABLE 9.--Comparison of Single to Multiple Disposal Area Programs[a]

Location (1)	Single Area: Irrigation Volume over Disposal Area in cm (in.) (2)		Single Area: Percentage of Wastewater Controlled (3)	Multiple Areas: Irrigation Volume over Disposal Area in cm (in.) (4)		Multiple Areas: Percentage of Wastewater Controlled (5)
Colby	10.80	(4.25)	97.3	11.48	(4.52)	98.8
Ellsworth	16.89	(6.65)	100.0	16.10	(6.34)	90.3
Garden City	10.03	(3.95)	100.0	10.46	(4.12)	100.00
Independence	18.59	(7.32)	79.5	24.31	(9.57)	89.1
Topeka	17.78	(7.00)	81.6	23.62	(9.30)	87.8

[a]Standard volumes and conditions used for both programs, except irrigation management was at the 50% level instead of 90%, and a 40 ac disposal area (4 plots at 10 ac each for the multiple disposal area program) was used instead of 80 ac.

CONCLUSIONS

Evaporation.--A graphical method for selecting the pond surface area for a given location was developed from the test runs. The relationship between moisture deficit and pond volume requirements for 95-100% control was derived as shown in Fig. 6. The preliminary sizing of evaporation ponds was shown to be a relatively simple procedure which involves the determination of moisture deficit from readily available published records of annual precipitation and evaporation.

Figure 6 indicates that the pond size for wastewater control >95% becomes very large for locations with a moisture deficits <51 cm (20 in.). An irrigation control system may be the more viable alternative for these locations.

In summary for control facilities for a 16.2 ha (40 ac) feedlot, the range of required surface area of a 1.8 m (6 ft) deep evaporation pond for Eastern Kansas is 10-17.8 ha (25-44 ac); for Central Kansas, the range is approximately 6-10 ha (15-25 ac); and for Western Kansas, less than 6 ha (15 acres).

Single Disposal Area.--The results shown in Table 5 may be interpreted as follows. 1) Soils. Essentially all soils except types 2, 11, and 12, produce the same results as the standard type 5 soil. Type 2 and type 11 and 12 soils reduced pond volume requirements. Thus, the soils really fall into only three major groups. The primary difference between types 2, 11, 12 and the others is that they have a smaller capacity for water storage (as available soil moisture), hence, these soil profiles fill up and dry up faster than the others, and more moisture is lost to percolation. 2) Crops. The difference for crops is mainly between small grains (wheat, pasture, alfalfa) and row crops (sorghum, corn, soy beans). Small grains generally use more water because of their longer growing season, therefore the C_{Crop} factors are less than one and facility requirements would be somewhat smaller for these crops. 3) Disposal Rate and Disposal Area. Increasing disposal rates or disposal areas by the previously prescribed increments, such as 1.3 cm/day (0.5 in./day) increased to 2.5 cm/day (1.0 in./day) produces the same change as increasing the feedlot to disposal area ratio as from 1:1 to 1:2. This is due to the fact that an equal amount of irrigation water is withdrawn from the pond as a result of doubling either one of these variables. The effect of increasing the disposal rate past 2.5 cm/day (1.0 in./day) or increasing the disposal area to greater than twice the feedlot area is inconsequential. This result appears due to the fact that the pond is pumped dry by the increased rates. 4) Pond Depth. Decreasing the maximum pond depth resulted in a larger volume requirement. As pond depth decreased (holding pond volume constant), the surface area is increased. Although evaporation is increased, so is the area exposed to precipitation. During wet periods when LKET is small, this larger surface area results in more water received from rainfall as well as the water from feedlot runoff. 5) Irrigation Management. Disposal Management shows that on the average, a pond having 44% more volume is required when irrigation is at soil moistures less than 50% versus irrigation at less than 90%. Topeka shows extreme changes due to management. This is due to the moisture deficit. The pond will have water in it more often and the disposal area will be wetter more often (due to the lower moisture deficit). The smaller moisture deficit keeps the available soil moisture high, above the 50% level more often, which limits irrigation.

Multiple Disposal Areas.--Using multiple disposal areas usually increases the percentage of wastewater controlled, thus decreasing the required pond size. The largest effect was at Independence where the increase in percent controlled was 9.6%. Otherwise, multiple disposal did not greatly effect facility requirements. On the average, a multiple disposal scheme reduces the required pond volume by approximately 2%, which is not large enough to justify its inclusion to correct the pond volume as calculated by Eq. 1.

One factor which should be discussed is Public Law 92-500 and control of feedlot runoff by using the 25 year - 24 hour storm storage criteria. Table 6 lists six of these storms as occurring during the simulation period. These were not always a factor in producing the worst year for runoff (that is, the year requiring the largest pond storage volume). In looking at Ellsworth and Horton, where the storms occurred in the most critical years, they were only indirectly responsible. They filled the ponds, but a later rainstorm or generally wet condition produced the maximum required storage.

SUMMARY

A feedlot runoff control model has been developed to improve the design of these facilities in Kansas. The testing of the program has resulted in guidelines and design approaches for sizing evaporation and irrigation disposal systems. The program for irrigation disposal schedules irrigation on the basis of soil moisture in the disposal area. This idealized control operation can only be achieved in reality by good management of the system by feedlot operators. Poor management would result in more frequently occurring discharges. Evaporation systems do not require this level of management, which makes this method attractive, particularly in Central and Western Kansas. In Eastern Kansas moisture deficits are low and the rainfalls high, which causes control facilities, either evaporation or irrigation, to be much larger.

APPENDIX I.--REFERENCES

1. Kansas Department of Agriculture, Farm Facts 1975-1976, Topeka, Kansas, 1977, p. 71 and p. 90.

2. U.S. Environmental Protection Agency, "Significance of Non-Point Source Pollution," Technology Transfer, September 1976.

3. Bean, Theodore A., "A Continuous Watershed Model for Evaluation and Design of Feedlot Runoff Control Systems," Master's Thesis, Kansas State University, Manhattan, Kansas, 1976.

4. Zovne, J. J., Bean, T. A., Koelliker, J. K., Anschutz, J. A., "Model To Evaluate Feedlot Runoff Control Systems," Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, Vol. 103, No. IR1, March 1977, p. 79-92.

5. Gray, D. M., Principles of Hydrology, Water Information Center, Inc., 1973, p. 3.10.

6. Schwab, G. O., et al., "Infiltration, Evaporation and Transpiration," Soil and Water Conservation Engineering, John Wiley and Sons, Inc., New York, N.Y., 1966, p. 79-80.

7. U.S. Environmental Protection Agency, "Use of Climatic Data in Estimating Storage Days for Soils Treatment Systems," EPA-600/2-76-250, November, 1976.

APPENDIX II.--INPUT/OUTPUT

Input.--All input data, including dimensions of the facilities and calibration constants are input by the namelist option. Namelists ALPHA and BETA contain the following variables, which are grouped by type, as follows.

Feedlot Variables

LTAREA - feedlot area in acres

Pond Variables

L - pond length in feet

W - pond width in feet

HMAX - maximum pond height in feet

S - side slope in feet/foot

PCVMAX - minimum pond volume as a fraction of the maximum volume, below which no irrigation will occur. A value of 0.05 (5%) is normally used.

Disposal Area Variables

CROP - crop grown on the disposal area; wheat = 1, sorghum = 2, corn = 3, soybeans = 4, pasture = 5, alfalfa = 6, fallow soil = 7 (the number following the crop is the actual reference number in the program).

SOIL - soil type; SCS Soils 1-12. The soil type is input by integer corresponding to type. Soil parameters are pre-programmed into the source deck by type number.

DSAREA - disposal area in acres

DSRATE - depth of irrigation waster applied to DSAREA in inches

PAVLU - percentage upper zone available soil moisture

BRUNTA, BRUNTB, and E - values used for calibration of the model (Penman Equation)

STORM - values used for 25 year-24 hour storm at the location.

Other Variables

YSTART - year the data is started for the computer test run

YEND - year terminating the run

INDST - the number corresponding to the data set of the tape input

Caution must be used with these variables. The program only operates in the English system units tabulated above.

Multiple Disposal Area Program.--The only change in that CROP, DSAREA, and SOIL must be input for each plot up to NPLOTS, which is the number of separate plots.

As an aid to the programmer, the input variables are not only printed at the beginning of the program output, but at the end as well. Figure 9 is an example of the format of the input parameter print-out.

Output.--The computer output consists of monthly and annual summaries for each year, and a final summary for the total simulation period. Figure 10 is an example of an individual year (1958) account and the final summary for the simulation period is shown by Fig. 11.

In interpreting the value from a yearly summary, discharges and storms of a magnitude equal to or greater than the 25 year-24 hour storm are printed at the top. Figure 10 has one such storm. A water balance of the pond is printed next. This balance is expressed in inches over the disposal area. The number of disposal days in the actual number of days irrigation occurred. As a check, the sum of the inflows will equal the outflows in this account. As a comparison, the value for precipitation doesn't usually

Figure 9.--Input Parameter Print-out.

```
STATION:   BELLEVILLE, KANSAS            1949  TO  1973

CRITICAL EVENT- 5.10 INCHES

FEEDLOT AREA- 40.00 ACRES

POND VARIABLES:
            (A) BASE DIMENSION-- 300.00  FEET BY  150.00  FEET
            (B) SIDE SLOPE--   RUN: RISE = 3.0 : 1
            (C) MAXIMUM DEPTH--   9.00  FEET
            (D) MAXIMUM POND VOLUME--    144.10 ACRE-INCHES
            (E) DIRECT RECEIVING AREA (FOR PRECIPITATION) --     1.66 ACRES

DISPOSAL AREA VARIABLES:
            (A) DISPOSAL AREA--    80.00  ACRES
            (B) CROP--  CORN
            (C) SOIL TYPE--    5   (SCS) SOIL TYPE
            (D) DISPOSAL RATE--   0.50  INCHES/DAY ON DISPOSAL DAYS
            (E) IRRIGATION MANAGEMENT--   IRRIGATION BELOW   0.90  AVAILABLE MOISTURE
```

Figure 10.--Individual Year Account.

***** ANNUAL SUMMARY *****

7/ 4/58 - DISCHARGE OF 1.81 ACRE-IN
7/ 5/58 - DISCHARGE OF 1.03 ACRE-IN
9/ 5/58 CRITICAL EVENT EXCEEDED 7.03 INCH STORM
9/ 5/58 - DISCHARGE OF 121.89 ACRE-IN
9/ 6/58 - DISCHARGE OF 32.35 ACRE-IN

WATER ACCOUNT FOR STORAGE FACILITY (IN INCHES OVER DISPOSAL AREA) - 1958

	INFLOWS			OUTFLOWS			
MONTH	PRECIPITATION	FEEDLOT RUNOFF	NO. DISPOSAL DAYS	DISPOSAL VOL.	SURFACE EVAP.	DISCHARGE	CHANGE IN VOL.
JAN.	0.02	0.08	0.	0.0	0.00	0.0	0.10
FEB.	0.02	0.29	0.	0.0	0.00	0.0	0.30
MAR.	0.06	1.15	1.	0.50	0.01	0.0	0.70
APR.	0.04	0.04	3.	1.11	0.05	0.0	-1.08
MAY	0.09	1.00	2.	0.61	0.06	0.0	0.42
JUNE	0.08	0.34	2.	0.83	0.04	0.0	-0.46
JULY	0.20	2.50	6.	2.58	0.08	0.04	0.00
AUG.	0.03	0.06	0.	0.0	0.05	0.0	0.04
SEPT	0.24	4.05	3.	1.50	0.08	1.93	0.79
OCT.	0.00	0.0	2.	0.81	0.03	0.0	-0.84
NOV.	0.02	0.05	0.	0.0	0.00	0.0	0.07
DEC.	0.00	0.02	0.	0.0	0.00	0.0	0.02
TOT.	0.81	9.58	19.	7.93	0.42	1.96	0.08

WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1958

	INPUTS		OUTPUTS				
MONTH	PRECIPITATION	IRRIGATION	INTERCEPTION	SURFACE RUNOFF	PERCOLATION	AET	CHANGE IN SM
JAN.	1.17	0.0	0.37	0.01	0.0	0.26	0.68
FEB.	0.84	0.0	0.24	0.03	0.0	0.37	0.25
MAR.	3.07	0.50	0.57	0.40	0.0	0.71	2.06
APR.	1.82	1.11	0.99	0.10	0.0	2.17	-0.33
MAY	4.18	0.61	0.76	1.02	0.0	1.79	1.22
JUNE	3.63	0.83	1.01	0.40	0.0	3.69	-0.65
JULY	9.70	2.58	1.97	3.72	0.0	6.28	0.30
AUG.	1.62	0.0	0.65	0.0	0.0	5.53	-4.56
SEPT	11.68	1.50	1.11	3.52	0.0	3.10	5.44
OCT.	0.17	0.31	0.30	0.0	0.0	1.07	-0.38
NOV.	0.92	0.0	0.13	0.00	0.0	0.84	-0.22
DEC.	0.08	0.0	0.21	0.0	0.0	0.29	-0.25
TOT.	38.88	7.93	8.32	9.29	0.0	26.10	3.55

PERCENT OF WASTEWATER CONTROLLED= 81.09

POTENTIAL DISPOSAL DAYS= 122

PACK ON DECEMBER 31 = 0.0 CHANGE IN SNOW STORAGE=-0.45

INPUTS-OUTPUTS-CHANGE IN SNOW STORAGE=CHANGE IN SOIL MOISTURE

PERCENT OF MAXIMUM POND VOLUME REQUIRED = 100.00

ESTIMATED POTENTIAL EVAPOTRANSPIRATION, INCHES = 35.73

ESTIMATED LAKE EVAPORATION, INCHES = 39.16

Figure 11.--Final Summary.

```
                        ***** FINAL SUMMARY *****
METEOROLOGICAL SUMMARY
          AVERAGE ANNUAL LAKE EVAPORATICN= 40.55 INCHES
          AVERAGE MAY - OCTOBER LAKE EVAPORATICN, INCHES = 33.24 OR 82.0 % OF ANNUAL



          AVERAGE ANNUAL PRECIPITATION= 30.03 INCHES
          AVERAGE ANNUAL POTENTIAL EVAPOTRANSPIRATION= 37.12 INCHES
          PRECIPITATICN RANGE= 32.57 INCHES   (FROM A LOW OF 15.90 INCHES  TO A HIGH OF  48.47 INCHES)
SUMMARY OF POND OPERATICNS
          NC. OF YEARS HAVING A DISCHARGE=      8
          AVERAGE NC. OF DISCHARGES / YEAR HAVING A DISCHARGE=  6.38
          AVERAGE DISCHARGE= 15.69 ACRE-INCHES
          AVERAGE PERCENT OF WASTEWATER CONTROLLED= 95.61
          TOTAL DISCHARGE VOLUME=   800.41 ACRE-INCHES
          TOTAL NO. OF DISCHARGES= 51.
          MAXIMUM DISCHARGE=132.21 ACRE-INCHES
SUMMARY OF DISPOSAL AREA
          AVERAGE ANNUAL DEPTH OF WASTEWATER APPLIED=  5.43 INCHES OVER ENTIRE DISPOSAL AREA
          AVERAGE ANNUAL DISPOSAL AREA RUNOFF=  4.57 INCHES
          AVERAGE ANNUAL DISPOSAL AREA PERCOLATION=  1.33 INCHES
          AVERAGE ANNUAL NO. OF DISPOSAL DAYS=  15.5
```

equal the precipitation value for the disposal area because the former values is the amount of rainfall on the pond surface divided by the disposal area, which is usually larger.

The next account balance is that of the disposal area. SM is the soil moisture. Input minus Outputs minus change in Snow Storage equals the change in soil moisture. Below this account, account history pertaining to snow storage is given.

After the monthly accounts an overall summary is printed, which includes percent of wastewater controlled. This is calculated as follows;

$$\text{Percent of Wastewater Controlled} = \frac{\Sigma\text{Inflows} - \Sigma\text{Discharges}}{\Sigma\text{Inflows}} \times 100\%$$

Potential Disposal Days are the number of days in the year the soil moisture falls below maximum available soil moisture times the management level PAVLU. Maximum Pond Volume is the maximum volume the wastewater occupies in a year as compared to the maximum pond volume. Values up to 100% are only obtained, any additional water is discharged. Estimated lake evaporation is the amount of water that would evaporate from the pond, if water was always available.

In interpreting the values from the Final Summary, Fig. 11, values labeled as averages are the yearly sums of that quantity divided by the number of years involved in the computer run. Values labeled as totals are sums of the yearly values for that particular quantity. In interpreting values in the multiple disposal program, values for all the plots are summed and then divided by the number of years and the number of plots, and are then entered in the Disposal Section as was done in the single area program.

APPENDIX III.--NOTATION

a	constant in the Penman Equation
AET	actual evapotranspiration, in inches
AMC	antecedent soil moisture, in inches
b	constant in the Penman Equation
C	degree day coefficient for snowmelt, in in./day-°F
C_{Crop}	coefficient related to disposal area crop
$C_{CA/LA}$	coefficient related to ratio of feedlot area to disposal area
C_{DSRATE}	coefficient related to disposal rate
$C_{H/HMAX}$	coefficient to adjust for differing pond depths
C_{PAVLV}	coefficient related to management of disposal
C_{Soil}	coefficient related disposal area soil type
c'	hydraulic coefficient of the soil, in mm day$^{-1/2}$
D	snowmelt by rainfall
e	constant in Penman Equation
ES	saturation air pressure, in millibars
E_s	soil evaporation
ET	evapotranspiration
K	crop coefficient
M	snowmelt, in inches
MD	moisture deficit, in inches
N	runoff curve number
P	precipitation, in inches
PET	potential evapotranspiration, in inches
PSUNS	percent sunshine
Q	direct surface runoff, in inches
r	reflectance coefficient

R_a	solar radiation
RHD	relative humidity
S	maximum potential difference between precipitation and runoff
SA	pond surface area, in acres
T	average daily temperature (°K)
Ta	average daily temperature (°C)
V	pond volume, in ac-in.
$V_{Location_{95-100}}$	basic pond volume which depends on location and percent control required
θ_a	actual available soil moisture, in inches
θ_{max}	maximum available soil moisture, in inches

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             C     FROMKSU - FEEDLOT RUNOFF MODEL     KANSAS STATE UNIVERSITY - VERSI000000003
             C
             C                MULTIPLE DISPOSAL AREAS
             C
             C     JOINTLY PROGRAMMED BY THE CIVIL AND AGRICULTURAL ENGG. DEPT.        00000004
             C               KANSAS STATE UNIVERSITY                                    00000005
             C                    MARCH 1976                                            00000006
             C                                                                          00000007
0001                INTEGER CROP,FROZE,SOIL,STIND,T,YEAR,YEARS,YEND,YSTART
0002                INTEGER PLOT,PREVYR,BYPASS,NROPTS
0003                REAL IA,IAADD,IAET,KCROP,KS,LAKEVP,LKEVPT,LTAREA,L,M,MA            00000009
0004                REAL NIA,NDPERC,NRNOF,LZSM
0005                REAL IRRVCL,IRRSUM,MAXVCL,MR
0006                DIMENSION AREA(9),IAREA(9,2)
0007                DIMENSION EC(9),DE(9),T(9),Z(9)
0008                DIMENSION ADDIA(9),ETIA(9),AETU(9),AETL(9),IAADD(9),IAET(9)
0009                DIMENSION SM(9),SMUZ(9),SMLZ(9)
0010                DIMENSION UZSM(9),LZSM(9),ETA2(9),NIA(9),NRNOF(9),NDPERC(9),
                   1NAMES(6),SMPD(9)
0011                DIMENSION DPERC1(9),DPERC2(9),IA1(9),IA2(9),RNOF1(9),RNOF2(9),ETA1
                   1(9)
0012                DIMENSION AMONTH(13),AVLFCL(12),AVLFCU(12),C(12),FCL(12),FCU(12)  00000011
0013                DIMENSION KCROP(7,12),NDIM(12),PDACCT(13,8),PREC(31),PSUNS(12)     00000012
0014                DIMENSION PWPLZ(12),PWPUZ(12),RA(12),RCN(12,7),RCN(12,7),RHD(12)   00000013
0015                DIMENSION SMACCT(13,8,9),SMSATL(12),SMSATU(12),TAVG(31),TMAX(31)    000000
0016                DIMENSION TMIN(31),U(12),WIND(12)                                  00000015
0017                COMPLEX*16 KROP*16(7)/'WHEAT','SORGHUM','CORN','SOY BEANS',        00000016
                   1     'PASTURE','ALFALFA','FALLOW'/                                 00000017
0018                DATA NAMES/'IRR.','INT.','RAFF','PERC','AET ',' SM '/
0019                DATA AMONTH/'JAN.','FEB.','MAR.','APR.','MAY ','JUNE','JULY',      00000018
                   1     'AUG.','SEPT','OCT.','NOV.','DEC.','TOT.'/                     00000019
0020                DATA AVLFCL/2.6,1.5,2.5,2.4,2.5,2.6,2.4,2.4,2.4,2.2,1.5,1.0/      00000020
0021                DATA AVLFCL/2.7,2.9,5.7,2.5,6.7,4.2,6.6,3.3,5.2,4.1,4.1,2.5/      00000021
0022                DATA C/0.2,0.2,0.177,0.177,0.177,0.177,0,159,0.159,0.138,0.138,   00000022
                   1     0.134,0.131/                                                  00000023
0023                DATA FCU/4.6,4.4,4.5,4.6,4.5,4.3,4.0,4.0,3.8,3.5,2.3,1.7/         00000024
0024                DATA FCL/9.4,9.4,14.2,7.0,13.9,9.1,13.7,6.8,9.2,7.0,7.0,4.3/      00000025
0025                DATA NDIM/31.28.31,30,31,30,31,31,30,31,30,31/                    00000026
0026                DATA PWPUZ/2.0,2.9,2.0,2.2,2.0,1.7,1.6,1.6,1.4,1.3,0.8,0.7/       00000027
0027                DATA PWPLZ/6.7,6.5,8.5,4.5,7.2,4.9,7.1,3.5,4.0,2.9,2.9,1.8/       00000028
0028                DATA SMSATU/5.8,6.2,5.7,5.7,5.7,5.5,5.4,5.4,5.3,5.2,4.8,4.3/      00000029
0029                DATA SMSATL/11.8,11.5,16.3,8.2,15.8,10.4,15.4,7.7,13.9,13.2,13.2, 00000030
                   1     12.9/                                                         00000031
0030                DATA L/0.47,0.47,0.39,0.39,0.39,0.39.0.35,0.35,0.31,0.31,0.28,    00000032
                   1     0.24/                                                         00000033
0031                DATA AET,AETLZ,AETUZ,B2,DISVCL,DPERC,EXCESS,IA,M,MA,
                   1     MR,PACK,PACKPY,PDVOL,PERC,PONVCL,P1,P2,P3,SNCMLT,TOPERC,
                   2     TRNCF,T1,T2/24*0.0/
0032                DATA CROP,IDAY,MM,PLOT,SOIL/5*0/
0033                DATA PDT,SMMAXL,SMUZPR,SMPREV/37.5,2.2.3.25,12.60/
0034                DATA AVAILL,AVAILU,CM,DSCVOL.DSDAYS,DSPERC,DSRNFF,EVAPLK,H,IRRSUM,
                   1     PEAK,PREVDS,SNCW,TPAREA,TPREC,UZSMCH,WASTWH,WET/18*0.0/
0035                DATA BYPASS/1/
0036                NAMELIST/ALPHA/BRUNTA,BRUNTB,CROP,DORM,E,GROW,NPLOTS,PAVLU,PCVMAX,
                   *RCROP
0037                NAMELIST/BETA/DSRATE,HMAX,INDST,L,LTAREA,MSTART,S,STORM,W,YEND,
                   *YSTART
             C                                                                          00000042
```

```
            C         ***** INPUTS *****                                                  00000043
            C
            C
0038              READ(5,20) NAME,OF,CITY,AND,STATE                                       00000047
0039           20 FORMAT(20X,5A4)                                                         00000048
0040              READ(5,40) ((KCROP(I,J),J=1,12),I=1,7)                                  00000049
0041           40 FORMAT(12F4.2)                                                          00000050
0042              READ(5,60) ((RCN(I,K),K=1,7),I=1,12)                                    00000051
0043           60 FORMAT(7(F2.0,1X))                                                      00000052
            C***  READ THE LOT,POND AND DISPOSAL PARAMETERS                               00000053
0044              READ(5,ALPHA)                                                           00000054
0045              READ(5,BETA)                                                            00000055
0046              PREVYR=YSTART
            C***  READ THE MONTHLY AVERAGE METEOROLOGICAL DATA                            00000056
0047              READ(5,80) (PSUNS(I),RHD(I),RA(I),WIND(I),I=1,12)                       00000057
0048           80 FORMAT(2X,F2.2,F2.0,F4.2,F3.1)                                          00000058
            C***  DATA INPUTS FOR SOIL TYPE, CROP, AND DISPOSAL AREA FOR EACH PLOT
0049              READ(5,81) ((IAREA(I,J),J=1,2),I=1,NPLOTS)
0050           81 FORMAT(2X,I1,2X,I2)
0051              READ(5,82)  (AREA(I),I=1,NPLOTS)
0052           82 FORMAT(1X,F6.0)
0053              SOIL=IAREA(1,2)
0054              CROP=IAREA(1,1)
0055              DSAREA=AREA(1)
            C                                                                             00000059
            C***  A1,A2,A3,A4,AND A5 ARE COEFFICIENTS USED IN VOLUME ROUTINE              00000060
0056              A1=L*W                                                                  00000061
0057              A2=S*(L+W)                                                              00000062
0058              A3=4./3.*S**2                                                           00000063
0059              A4=2.*A2                                                                00000064
0060              A5=4.*S**2                                                              00000065
            C***  VOLMAX IS THE MAXIMUM VOLUME HELD BY THE STORAGE FACILITY               00000066
0061              VOLMAX=(A1*HMAX+A2*HMAX**2+A3*HMAX**3)/3630.                            00000067
            C***  PSAREA IS THE DIRECT RECEIVING AREA OF THE FACILITY                     00000068
0062              PSAREA=((W+2.*S*HMAX)*(L+2.*S*HMAX))/43560.                             00000069
0063              DO 85 II=1,NPLOTS
0064              TPAREA=TPAREA+AREA(II)
0065              Z(II)=0.0
0066              T(II)=0.0
0067              EC(II)=0.0
0068              DE(II)=0.0
0069              IAET(II)=0.0
0070              IAADD(II)=0.0
0071              SMLZ(II)=9.35
0072              SMUZ(II)=3.25
0073           85 SMPD(II)=SMLZ(II)+SMUZ(II)
0074              YEARS=YEND-YSTART+1                                                     00000071
0075              WRITE(6,100)NAME,OF,CITY,AND,STATE,YSTART,YEND,STORM,LTAREA,L,W,S,00000072
                 *HMAX,VOLMAX,PSAREA,TPAREA,KRCP(CROP),SOIL,DSRATE,PAVLU
0076          100 FORMAT('1',10X//////////10X,'STATION:',3X,5A4,10X,I4,'  TO  ',I4,00000074
                 1////10X,'SIZE OF CRITICAL EVENT  ',F4.2////10X,'FEEDLOT AREA',2X, 00000075
                 2F6.2,'ACRES'////10X,'POND VARIABLES:'//25X,'(A) BASE DIMENSION- ',00000076
                 3F7.2,'  FEET BY ',F7.2,'  FEET'//25X,'(B) SIDE SLOPE--   RUN: RISE00000077
                 4 = ',F3.1,' : 1'//25X,'(C) MAXIMUM DEPTH--  ',F5.2,'  FEET'//25X, 00000078
                 5'(D) MAXIMUM POND VOLUME--  ',F9.2,' ACRE-INCHES'//25X,'(E) DIRECT00000079
                 6 RECEIVING AREA (FOR PRECIPITATION) --  ',F8.2,' ACRES'////10X,   00000080
                 7'DISPOSAL AREA VARIABLES:'//25X,'(A) DISPOSAL AREA--   ',F6.2,    00000081
                 8'  ACRES'//25X,'(B) CROP--  ',2A8//25X,'(C) SOIL TYPE--  ',I3,    00000082
```

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                9'   (SCS) SOIL TYPES)'//25X,'(D) DISPOSAL RATE--   ',F5.2,
               11'   INCHES/DAY ON DISPOSAL DAYS'//25X,'(E) IRRIGATION MANAGEMENT--
               12    IRRIGATION BELOW   ',F5.2,'  FIELD CAPACITY')
           C
           C         ***** ENTER YEARLY LOOP *****
           C
0077             DO 1500 NY=1,YEARS
0078             DO 140 I=1,13
0079             DO 120 J=1,8
0080         120 PDACCT(I,J)=0.0
0081         140 CONTINUE
0082             DO 145 I=1,13
0083             DO 148 J=1,8
0084             DO 149 K=1,NPLOTS
0085         149 SMACCT(I,J,K)=0.0
0086         148 CONTINUE
0087         145 CONTINUE
0088             IDISDA=0.0
0089             MAXVOL=0.0
0090             LKEVPT=0.0
0091             VOLIRR=0.0
0092             IF(NY.GT.1) MSTART=1
0093             WRITE(6,160)
0094         160 FORMAT('1',46X,'***** ANNUAL SUMMARY *****')
           C
           C         ***** ENTER MONTHLY LOOP *****
           C
0095             DO 1280 NM=MSTART,12
           C
           C
0096         180 READ(1,200,END=1520) KAN,STIND,YEAR,MONTH,(PREC(I),I=1,31),
                1(TMAX(I),I=1,31),(TMIN(I),I=1,31)
0097         200 FORMAT(I2,I4,2I2,31F4.2,62F3.0)
0098             IF(STIND.NE.INDST) GO TO 180
0099             IF(YEAR.LT.YSTART-1900) GO TO 180
0100             IF(YEAR.GT.YEND-1900) GO TO 1520
0101             IF(MONTH.LT.MSTART.AND.YEAR.EQ.YSTART-1900) GO TO 180
0102             ACTIRR=0.0
0103             DSDAY=0
0104             NDIM(2)=28
0105             IF(NM.EQ.2.AND.TMAX(29).LT.900) NDIM(2)=29
0106             NDAYS=NDIM(NM)
           C
           C         ***** ENTER DAILY LOOP *****
           C
0107             DO 1240 ND=1,NDAYS
           C
           C***  TAVG IS THE AVERAGE DAILY AIR TEMPERATURE, DEGREE FAHRENHEIT
0108             TAVG(ND)=(TMAX(ND)+TMIN(ND))/2.0-100.0
           C***  THE FOLLOWING STATEMENTS CORRECT  FOR MISSING DATA ON INPUT TAPE
0109             IF(TAVG(ND).GT.120) TAVG(ND)=PDT
0110             IF(PREC(ND).GT.99.97) PREC(ND)=0.0
           C***  THE FOLLOWING CARD EVALUATES WHETHER THE 24 HOUR DESIGN STORM
           C***  HAS BEEN EXCEEDED.
0111             IF(PREC(ND).GE.STORM/1.14) WRITE(6,220) NM,ND,YEAR,PREC(ND)
0112         220 FORMAT(20X,I2,'/',I2,'/',I2,'  CRITICAL EVENT EXCEEDED  ',
                12X,F10.2,'  INCH STORM  ')
           C
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            C *** CALCULATION OF POTENTIAL EVAPOTRANSPIRATION BY MEANS OF PENMAN CCM00000133
            C                                                EQUATION ***                00000134
            C                                                                            00000135
0113                P=RCROP                                                              00000136
            C***    THE FOLLOWING CARD CHECKS FOR SNOW COVER                             00000137
0114                IF(PACK.GT.0.1) R=0.70                                               00000138
            C***    THE NEXT TWO CARDS CONVERT TAVG TO ABSOLUTE, DEGREE KELVIN           00000139
0115                CENT=(TAVG(ND)-32.0)*100.0/180.0                                     00000140
0116                ABST=CENT+273.16                                                     00000141
            C***    ES IS THE DAILY CALCULATED SATURATED VAPOR PRESSURE, IN MILLIBARS 00000142
0117                ES=33.9*((0.00738*CENT+0.8072)**8-0.000019*ABS(1.8*CENT+48)         00000143
                   1 +0.00136)                                                           00000144
0118                IF(ES.LE.0.0) ES=0.0                                                 00000145
            C***    ESA IS THE DAILY CALCULATED ACTUAL VAPOR PRESSURE, IN MILLIBARS     00000146
0119                ESA=ES*RHD(NM)/100.0                                                 00000147
            C***    RN IS THE CALCULATED DAILY NET RADIATION, IN MM OF WATER            00000148
0120                RN=(1-R)*RA(NM)*(0.22+0.54*PSUNS(NM))-2.0105-09*ABST**4*            00000149
                   1(0.98-BRUNTA-BRUNTB*SQRT(ESA))*(0.1+0.9*PSUNS(NM))
0121                IF(RN.LT.0.0) RN=0.0
            C***    WINDD IS THE MONTHLY AVERAGE WINDRUN, MILES/DAY AT 2 METERS HEIGHT00000151
0122                WINDD=(WIND(NM)*24)*0.555                                            00000152
            C***    EA IS THE CONVECTIVE LOSSES, MM WATER                                00000153
0123                EA=0.26*(E+0.01*WINDD)*(ES-ESA)                                      00000154
0124                IF(TAVG(ND)) 240,240,260                                             00000155
0125            240 DELTA=0.0                                                            00000156
0126                GO TO 280                                                            00000157
0127            260 DELTA=0.039*TAVG(ND)**0.673                                          00000158
0128            280 GAMMA=1-DELTA                                                        00000159
            C***    PET IS THE CALCULATED DAILY POTENTIAL EVAPOTRANSPIRATION, INCHES    00000160
0129                PET=((DELTA*RN)+(GAMMA*EA))/25.4                                     00000161
            C***    CALCULATE LAKE AND BARE SOIL EVAPORATION
0130                RNSOIL=RN*((1.0-0.20)/(1.0-R))                                       00000163
0131                RNLAKE=RN*((1.0-0.05)/(1.0-R))                                       00000164
0132                PETBS=((DELTA*RNSOIL)+(GAMMA*EA))/25.4                               00000165
0133                LAKEVP=((DELTA*RNLAKE)+(GAMMA*EA))/25.4                              00000166
0134                PDT=TAVG(ND)                                                         00000167
0135                IF(TAVG(ND).LT.20.0) PET=0.0                                         00000168
0136                IF(TAVG(ND).LT.20.0) PETBS=0.0                                       00000169
0137                IF(TAVG(ND).LT.20.0) LAKEVP=0.0                                      00000170
0138                DO 290 MQ=1,NPLOTS
0139                IAADD(MQ)=IAET(MQ)-PET
0140                IF(KCROP(CROP,NM).EQ.0.0)  IAADD(MQ)=IAET(MQ)-PETBS
0141                IF(IAADD(MQ).GT.0.1) IAADD(MQ)=0.1
0142                IF(IAADD(MQ).LT.0.0) IAADD(MQ)=0.0
0143            290 CONTINUE
            C                                                                            00000175
            C                      ***  CALCULATION OF MOISTURE ADDED TO DISPOSAL AREA
            C                                 DUE TO SNOWMELT ON THE AREA  ***           00000177
            C                                                                            00000178
            C                                                                            00000179
0144                SNOVAP=0.0                                                           00000180
0145                M=0.0                                                                00000181
0146                PRECIP=PREC(ND)                                                      00000182
0147                WATER=PRECIP                                                         00000183
0148                IF(PACK.GT.0.1) SNOVAP=PET                                           00000184
0149                PACK=PACK-SNOVAP                                                     00000185
0150                IF(TAVG(ND)-32) 300,300,320                                          00000186
0151            300 IF(PRECIP) 420,420,340                                               00000187
```

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  320 IF(PACK) 460,460,360                                              00000188
  340 PACK=PACK+PRECIP                                                  00000189
      WATER=0.0                                                         00000190
      GO TO 460                                                         00000191
C***  MA IS SNOWMELT DUE TO ATMOSPHERIC CONDITIONS                      00000192
  360 MA=0.05*(TAVG(ND)-34)                                             00000193
      IF(MA.LT.0.0) MA=0.0                                              00000194
      IF(PACK-MA) 400,400,380                                           00000195
C***  MR IS SNOWMELT DUE TO RAIN
  380 MR=(PRECIP*(TAVG(ND)-32))/144                                     00000197
      M=MR+MA                                                           00000198
      IF(PACK-M) 400,420,420                                            00000199
  400 M=PACK                                                            00000200
      PACK=0.0                                                          00000201
      GO TO 440                                                         00000202
  420 PACK=PACK-M                                                       00000203
  440 WATER=M+PRECIP                                                    00000204
C                                                                       00000205
C                                                                       00000206
C        *** EVALUATION OF SOIL MOISTURE AND CALCULATION OF ACTUAL      00000207
C                               EVAPOTRANSPIRATION FROM DISPOSAL AREA ***
C                                                                       00000209
  460 FLOW=DISVOL
      DO 445 LK=1,NPLOTS
      Z(LK)=T(LK)
      OE(LK)=EC(LK)
      ADDIA(LK)=IAADD(LK)
      ETIA(LK)=IAET(LK)
      LZSM(LK)=SMUZ(LK)
  445 LZSM(LK)=SMLZ(LK)
      LL=0
      JJ=0
      NNN=0
      RAIN=WATER
  455 NNN=NNN+1
      IF(NNN.GT.NPLOTS) GO TO 981
      DISVOL=0.0
      JJ=JJ+1
  457 CROP=IAREA(JJ,1)
      SOIL=IAREA(JJ,2)
      DSAREA=AREA(JJ)
      IF(DISVOL.GT.0.0.AND.PRECIP.LT.0.4) GO TO 600
      IF(RAIN.LE.0.0) GO TO 580                                         00000212
C***  CALCULATE SURFACE RUNOFF VOLUME BY SCS METHOD                     00000213
      IF(KCROP(CROP,NM).LE.0.0) GO TO 520                               00000214
      IF(SMUZ(JJ).LT.(PWPUZ(SOIL)+0.5*AVLFCU(SOIL))) GO TO 480
      IF(SMUZ(JJ).GT.(PWPUZ(SOIL)+0.8*AVLFCU(SOIL))) GO TO 500
      GO TO 540                                                         00000217
C***  MODIFY RUNOFF CURVE NUMBER TO CONDITION I ANTECEDENT MOISTURE
  480 RCM(SOIL,CROP)=RCN(SOIL,CROP)*0.39*EXP(0.009*RCN(SOIL,CROP))      00000219
      GO TO 560                                                         00000220
C***  MODIFY RUNOFF CURVE NUMBER TO CONDITION III ANTECEDENT MOISTURE
  500 RCM(SOIL,CROP)=RCN(SOIL,CROP)*1.95*EXP(-0.00663*RCN(SOIL,CROP))   00000222
      GO TO 560                                                         00000223
  520 IF(SMUZ(JJ).LT.0.6*FCU(SOIL)) GO TO 480
      IF(SMUZ(JJ).GT.0.9*FCU(SOIL)) GO TO 500
  540 RCM(SOIL,CROP)=RCN(SOIL,CROP)                                     00000226
  560 S1=1000.0/RCM(SOIL,CROP)-10.0                                     00000227
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FORTRAN IV G LEVEL  21              MAIN              DATE = 77173         16/34/22          PAGE 0006

0200         ER=RAIN-0.2*SI                                                   00000228
0201         IF(ER.LT.0.0) GO TO 600                                          00000229
0202         RNOF=ER**2/(RAIN+0.8*SI)                                         00000230
0203         GO TO 620                                                        00000231
       C***  EVALUATE INTERCEPTION STORAGE                                    00000232
0204     580 RNOF=0.0                                                         00000233
0205         IA=0.0                                                           00000234
0206         GO TO 640                                                        00000235
0207     600 RNOF=0.0                                                         00000236
0208     620 IA=0.1                                                           00000237
0209         IF(IA.GT.RAIN) IA=RAIN                                           00000238
0210         IF((IA+IAADD(JJ).GE.0.1)) IA=0.1-IAADD(JJ)
       C***  EVALUATE PERCOLATION INTO UPPER ZONE                             00000240
0211     640 PERC=RAIN-RNOF-IA                                                00000241
0212         UZEVAP=0.0                                                       00000242
       C***  CALCULATE PRESENT STORAGE AVAILABLE IN UPPER ZONE                00000243
0213         SMMAXU=0.9*SMSATU(SOIL)-SMUZ(JJ)
       C***  EVALUATE WATER CASCADED TO LOWER ZONE FOR STORAGE                00000245
0214         PERCL=PERC-SMMAXU                                                00000246
0215         IF(PERC.GT.SMMAXU) PERC=SMMAXU                                   00000247
0216         IF(PERCL.LT.0.0) PERCL=0.0                                       00000248
0217         IF (SMUZ(JJ).GT.FCU(SOIL)) GO TO 660
0218         EXCESS=0.0                                                       00000250
0219         GO TO 680                                                        00000251
       C***  EVALUATE GRAVITATIONAL WATER IN UPPER ZONE                       00000252
0220     660 EXCESS=SMUZ(JJ)-FCU(SOIL)
       C***  IF THE CROP IS DORMANT OR THE SOIL LIES FALLOW, SOIL             00000254
       C***  EVAPORATION IS EVALUATED                                         00000255
0221     680 IF(KCROP(CROP,NM).LE.0.0) GO TO 860                              00000256
0222         T(JJ)=0.0
       C***  MODIFY PET BY THE PLANT CONSUMPTIVE USE COEFFICIENT              00000258
0223         AET=KCROP(CROP,NM)*PET                                           00000259
0224         IF(PET.LE.IAET(JJ)) AET=0.0
       C***  CHECK WHETHER SOIL MOISTURE LIMITS AET FROM THE UPPER ZONE       00000261
0225         IF(SMUZ(JJ)-(0.3*(AVLFCU(SOIL))+PWPUZ(SOIL)))700,700,760
       C***  CALCUATE AET FROM THE UPPER ZONE WHEN LIMITED BY SOIL MOISTURE   00000263
0226     700 AVAILU=SMUZ(JJ)-PWPUZ(SOIL)
0227         IF(AVAILU.LE.0.0) AVAILU=0.0                                     00000265
0228         AETUZ=0.7*AET*(AVAILU/(0.3*AVLFCU(SOIL)))                        00000266
       C***  EVALUATE AVAILABLE WATER IN THE LOWER ZONE                       00000267
0229         AVAILL=SMLZ(JJ)-PWPLZ(SOIL)
0230         IF(AVAILL.LE.0.0) AVAILL=0.0                                     00000269
       C***  CHECK WHETHER SOIL MOISTURE LIMITS AET FROM THE LOWER ZONE       00000270
0231         IF(SMLZ(JJ)-(0.3*(AVLFCL(SOIL))+PWPLZ(SOIL))) 720,720,740
       C***  CALCUATE AET FROM THE LOWER ZONE WHEN LIMITED BY SOIL MOISTURE   00000272
0232     720 AETLZ=0.3*AET*(AVAILL/(0.3*AVLFCL(SOIL)))                        00000273
0233         GO TO 780                                                        00000274
0234     740 AETLZ=AET-AETUZ                                                  00000275
0235         GO TO 780                                                        00000276
       C***  EVALUATE AET FROM BOTH ZONES UNDER WET CONDITIONS                00000277
0236     760 AETUZ=0.7*AET                                                    00000278
0237         AETLZ=0.3*AET                                                    00000279
0238         AVAILL=SMLZ(JJ)-PWPLZ(SOIL)
0239         IF(SMLZ(JJ).LE.0.3*(AVLFCL(SOIL))+PWPLZ(SOIL)) GO TO 720
0240     780 IF(PERC-SMMAXU) 800,820,820                                      00000282
       C***  EVALUATE SOIL MOISTURE                                           00000283
0241     800 SMUZ(JJ)=SMUZ(JJ)+PERC-AETUZ-EXCESS
0242         SMLZ(JJ)=SMLZ(JJ)-AETLZ+EXCESS
```

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0243            GO TO 960                                                      00000286
0244        820 SMUZ(JJ)=SMUZ(JJ)+SMMAXU-EXCESS-AETUZ
0245        830 SMMAXL=0.9*FCL(SOIL)-SMLZ(JJ)
0246            IF(PERCL+EXCESS-SMMAXL) 840,840,850                            00000289
0247        840 SMLZ(JJ)=SMLZ(JJ)+PERCL-AETLZ+EXCESS
0248            GO TO 960                                                      00000291
0249        850 SMLZ(JJ)=SMLZ(JJ)+SMMAXL-AETLZ
0250            DPERC=PERCL+EXCESS-SMMAXL                                      00000293
0251            GO TO 970                                                      00000294
C***     CALCULATE EVAPORATION FROM BARE SOIL SURFACE(SEVAP) FOR MONTHS OCTOBER
C***     THROUGH MARCH OR WHEN THE DISPOSAL AREA IS FALLOW                      00000296
0252        860 AETUZ=0.0                                                      00000297
0253            AETLZ=0.0                                                      00000298
0254            IF(PACK,GT.0.0) GO TO 920                                      00000299
0255            IF(SMUZ(JJ).LT.(FCU(SOIL)-U(SOIL))) GO TO 880
0256            EO(JJ)=FCU(SOIL)-SMUZ(JJ)
0257            IF(SMUZ(JJ).GE.FCU(SOIL)) EO(JJ)=0.0
C***     CALCULATE STAGE 1 SOIL EVAPORATION                                   00000303
0258            UZEVAP=PETBS                                                   00000304
0259            EO(JJ)=EO(JJ)+UZEVAP
0260            IF(EO(JJ).GT.U(SOIL)) UZEVAP=EO(JJ)-U(SOIL)
0261            T(JJ)=0.0
0262            GO TO 900                                                      00000308
C***     CALCULATE STAGE 2 SOIL EVAPORATION                                   00000309
0263        880 T(JJ)=T(JJ)+1
0264            UZEVAP=C(SOIL)*(T(JJ)**0.5)-C(SOIL)*((T(JJ)-1)**0.5)
0265        900 IF(UZEVAP.GT.(PETBS-IAET(JJ))) UZEVAP=PETBS-IAET(JJ)
0266            IF(UZEVAP.LT.0.0) UZEVAP=0.0                                   00000313
0267            IF(SMUZ(JJ)-PWPUZ(SOIL).LT.UZEVAP) UZEVAP=SMUZ(JJ)-PWPUZ(SOIL)
0268            GO TO 940                                                      00000315
0269        920 UZEVAP=0.0                                                     00000316
0270        940 SMUZ(JJ)=SMUZ(JJ)-UZEVAP+PERC-EXCESS
0271            IF(SMUZ(JJ).LE.PWPUZ(SOIL)) SMUZ(JJ)=PWPUZ(SOIL)
0272            GO TO 830                                                      00000319
0273        960 IF(SMLZ(JJ).LT.PWPLZ(SOIL)) AETLZ=AETLZ-(PWPLZ(SOIL)-SMLZ(JJ))
0274            IF(SMLZ(JJ).LE.PWPLZ(SOIL)) SMLZ(JJ)=PWPLZ(SOIL)
0275            DPERC=SMLZ(JJ)-0.9*FCL(SOIL)
0276            IF(DPERC.LT.0.0) DPERC=0.0                                     00000323
0277            IF(SMLZ(JJ).GT.0.9*FCL(SOIL)) SMLZ(JJ)=0.9*FCL(SOIL)
0278        970 AETUZ=AETUZ+UZEVAP                                             00000325
C***     SM IS SOIL THE MOISTURE IN THE GROWING ZONE, IN INCHES               00000326
0279            SM(JJ)=SMUZ(JJ)+SMLZ(JJ)
0280            IAET(JJ)=IA+IAADD(JJ)
0281            AETU(JJ)=AETUZ
0282            AETL(JJ)=AETLZ
0283            NDPERC(JJ)=DPERC
0284            NIA(JJ)=IA
0285            NPNDF(JJ)=PNDF
0286            IF(NNN.GT.(NPLOTS+1)) GO TO 998
0287            GO TO 455
0288        981 DISVOL=FLOW
0289            RAIN=WATER+DISVOL/DSAREA
0290            IF(DISVOL.LE.0.0) GO TO 998
0291            LL=1
0292            JJ=PLOT
0293            EO(JJ)=CE(JJ)
0294            T(JJ)=Z(JJ)
0295            IAET(JJ)=ETIA(JJ)
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0296            IAADD(JJ)=ADDIA(JJ)
0297            SMUZ(JJ)=UZSM(JJ)
0298            SMLZ(JJ)=LZSM(JJ)
0299            GO TO 457
0300        998 CONTINUE
0301            SCIL=IAREA(1,2)
0302            SWATER=SMUZ(1)-PWPUZ(SOIL)
0303            NROPTS=NPLCTS-1
0304            DO 1253 MT=1,NRCPTS
0305            SOIL=IAREA(MT,2)
0306            IF(SMUZ(MT)-PWPUZ(SOIL).LE.SWATER) PLOT=MT
0307            IF(SMUZ(MT)-PWPUZ(SOIL).LE.SWATER) SWATER=SMUZ(MT)-PWPUZ(SOIL)
0308       1253 CONTINUE
          C                                                                          00000329
          C                                                                          00000330
          C                                      *** EVALUATICN OF VOLUME DISPOSED ***
          C                                                                          00000332
          C***  T1 IS THE PREVIOUS DAY'S AVERAGE TEMPERATURE, IN FAHRENHEIT          00000333
          C***  DEGREES, T2 IS THE AVERAGE TEMPERATURE OF THE DAY TWO DAYS           00000334
          C***  PRIOR TO TCDAY                                                       00000335
0309            THAWED=TAVG(ND)+T1+T2                                               00000336
0310            FREEZE=TAVG(ND)+T1                                                  00000337
0311            T2=T1                                                               00000338
0312            T1=TAVG(ND)                                                         00000339
0313            IF(FREEZE.LT.64.0) FROZE=1                                          00000340
0314            IF(THAWED.GT.114.0) FROZE=0                                         00000341
          C***  WHEN FROZE EQUALS 1 THE SCIL IS CONSIDERED TO BE FROZEN IT IS THAWED
          C***  WHEN FROZE EQUALS 0                                                  00000343
0315            IF(FROZE.EQ.1) GO TO 980                                            00000344
          C***  SMUZ IS THE SCIL MOISTURE IN THE TOP 12 INCHES OVER THE DISPOSAL    00000345
          C***  AREA; AVLFCU IS THE AVAILABLE WATER CAPACITY OF THAT SOIL.
          C***  IRRIGATICN WILL NOT OCCUR ON DAYS THAT THE SOIL MCISTURE IS AT
          C***  A LEVEL GREATER THAN THAT OF THE PERCENTAGE OF AVAILABLE WATER
          C***  SPECIFIED BY THE VARIABLE PAVLU.
0316            SOIL=IAREA(PLCT,2)
0317            IF(SMUZ(PLCT).GT.(PAVLU*AVLFCU(SOIL))+PWPUZ(SOIL)) GO TO 980
0318            IDISDA=IDISDA+1                                                     00000351
0319            IF(PCNVOL.LT.PCVMAX*VCLMAX) GO TO 980
0320            DISVOL=DSRATE*TPAREA
          C***  IF THE POND VCLUME IS LESS THAN THE VOLUME REQUIRED FOR ONE FULL    00000354
          C***  DAY OF IRRIGATION, IT WILL BE ASSUMED THAT NO IRRIGATION WILL OCCUR
          C***  CN THAT DAY.                                                         00000356
0321            PCNVOL=PCNVCL-DISVOL                                                00000357
0322            IF(PONVOL.GT.0.0) GO TC 1000
0323            DISVOL=DISVCL+PONVOL
0324            PCNVCL=0.0
0325            GO TO 1000                                                          00000358
0326        980 DISVCL=0.0                                                          00000359
          C                                                                          00000361
          C                                                                          00000362
          C***  UPDATE DISPCSAL CAY ACCCUNT                                          00000363
0327       1000 IF(DISVCL.GT.0.0) DSDAY=DSDAY+1
          C                                                                          00000365
          C                                                                          00000366
0328            IF(BYPASS.EQ.1) GO TO 1110
          C                                      ***CALCULATION OF FEEDLOT RUNOFF***
          C                                                                          00000368
          C***  CALCULATE 3 DAY ANTECEDENT MCISTURE                                  00000369
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0329            AM=P1+P2+P3                                                             00000370
0330            P1=P2                                                                   00000371
0331            P2=P3                                                                   00000372
0332            P3=PRECIP                                                               00000373
0333            IF (SNOW.GT.0.0.AND.FROZE.EQ.0) GO TO 1020                              00000374
0334            IF(PRECIP.LE.0.0) GO TO 1100                                            00000375
0335            IF (FROZE.EQ.1) GO TO 1080                                              00000376
0336            IF(AM.LE.0.5.AND.PRECIP.LE.0.5) GO TO 1100                              00000377
          C***  CALCULATE FEEDLOT RUNOFF USING 3 DAY ANTECEDENT MOISTURE CONDITIONS
          C***  MODIFICATION OF THE SCS METHOD                                          00000379
0337       1020 AM1=AM+PRECIP                                                           00000380
0338            PRESIP=PRECIP+SNOW                                                      00000381
0339            RC=97.0                                                                 00000382
0340            IF(MONTH.LT.4.OR.MONTH.GT.10) GO TO 1040                                00000383
0341            IF(AM.LT.0.75) RC=91.0                                                  00000384
0342            IF(AM1.GT.GROW.AND.PRECIP.GT.GROW) PRESIP=GROW                          00000385
0343            GO TO 1060                                                              00000386
0344       1040 IF(AM.LT.0.50) RC=91.0                                                  00000387
0345            IF (SNOW.GT.0.0) RC=97.0                                                00000388
0346            IF(AM1.GT.DORM.AND.PRECIP.GT.DORM) PRESIP=DORM                          00000389
0347       1060 CS=1000.0/RC-10.0                                                       00000390
0348            RUNOFF=(PRESIP-0.2*CS)**2/(PRESIP+0.8*CS)                               00000391
0349            RUNOFF=RUNOFF+PRECIP-PRESIP+SNOW                                        00000392
0350            SNOW=0.0                                                                00000393
0351            IF(RUNOFF.GT.0.06) RUNOFF=RUNOFF-0.06                                   00000394
0352            IF(PRESIP-0.2*CS.LT.0.0) GO TO 1100                                     00000395
0353            GO TO 1120                                                              00000396
0354       1080 SNOW=SNOW+PRECIP                                                        00000397
0355       1100 RUNOFF=0.0                                                              00000398
0356            IF(BYPASS.EQ.0) GO TO 1120
0357       1110 RUNOFF=NRNOF(2)+NRNOF(3)
          C                                                                             00000399
          C                                                                             00000400
          C                                                                             00000401
          C            *** CALCULATION OF SURFACE AREA AND DETERMINATION OF             00000402
          C                          SURFACE EVAPORATION FROM STORAGE FACILITY ***
          C                                                                             00000404
          C***  THE FOLLOWING CALCULATION EXPRESSES THE VOLUME OF WATER IN THE          00000405
          C***  STORAGE FACILITY IN CUBIC FEET.                                         00000406
0358       1120 IF(PONVOL.LE.0.0) GO TO 1160                                            00000407
          C                                                                             00000408
0359            V=PONVOL*3630                                                           00000409
          C*** THE FOLLOWING CALCULATIONS DETERMINE THE SURFACE AREA OF THE STORAGE
          C***  FACILITY AS A FUNCTION OF STORAGE VOLUME.  AREA IS IN SQUARE FEET 00000411
          C***  VOLUME IS IN CUBIC FEET.  THE STORAGE FACILITY IS SHAPED LIKE AN INVERTED
          C***  FRUSTRUM OF A PYRAMID.  INPUT PARAMETERS TO SIZE THE FACILITY ARE LENGTH
          C***  (L) OF THE BASE IN FEET, WIDTH OF THE BASE(W) IN FEET AND SLOPE OF
          C***  INSIDE EMBANKMENTS GIVEN AS A RATIO OF RUN TO RISE(S).  IT IS ASSUMED
          C***  THE POND DOES NOT LEAK.  INPUTS TO THE STORAGE WILL BE RUNOFF AND 00000416
          C***  PRECIPITATION.  LOSSES FROM IT INCLUDE EVAPORATION AND DISPOSAL     00000417
          C***  VOLUME.  B2 IS THE AREA OF THE SURFACE LIQUID IN SQUARE FEET.       00000418
0360            HAPRX=(PONVOL/VOLMAX)*HMAX                                              00000419
0361       1140 VC=A1*HAPRX+A2*HAPRX**2+A3*HAPRX**3                                     00000420
0362            DV=V-VC                                                                 00000421
0363            DVDH=A1+A4*HAPRX+A5*HAPRX**2                                            00000422
0364            H=HAPRX+DV/DVDH                                                         00000423
0365            IF(ABS(H-HAPRX).LT.0.1) GO TO 1160                                      00000424
0366            HAPRX=H                                                                 00000425
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0367              GO TO 1140                                                          00000426
0368        1160  IF (H.GT.HMAX) H=HMAX                                               00000427
0369              B2=(W+2.*S*H)*(L+2.*S*H)                                            00000428
0370              IF(FROZE.EQ.1) LAKEVP=C.0                                           00000429
0371              LKEVPT=LKEVPT+LAKEVP                                                00000430
0372              SEVAP=B2*(LAKEVP/12)                                                00000431
           C***   SEVAP IS THE VOLUME OF WATER EXTRACTED FROM THE STORAGE FACILITY BY
           C***   FREE SURFACE EVAPORATICN.                                           00000433
0373              IF((SEVAP/3630).GT.PONVOL) SEVAP=PONVOL*3630                        00000434
0374              PONVOL=PONVOL-(SEVAP/3630)                                          00000435
0375              IF(PONVOL.LE.0.0) PONVOL=0.0                                        00000436
           C                                                                          00000437
           C***   THE VOLUMES OF CALCULATED RUNOFF FROM THE FEEDLOT AND PRECIPITATION
           C***   FALLING ON THE FACILITY ARE ADDED TO THE VOLUME OF WATER IN THE STORAGE
           C***   FACILITY(ACRE-IN).                                                  00000440
0376              PONVOL=PONVOL+(RUNOFF*LTAREA)+(PRECIP*PSAREA)                       00000441
           C                                                                          00000442
           C***   THE VOLUME OF WATER REMAINING AT THE END OF THE DAY IS EXPRESSED    00000443
           C***   IN ACRE-IN.                                                         00000444
           C                                                                          00000445
           C                                                                          00000446
           C***   THE FOLLOWING STATEMENTS DETERMINE WHETHER THE STORAGE FACILITY HAS
           C***   OVERFLOWED AND IF SO, THE QUANTITY DISCHARGED
0377              DSCHRG=0.0                                                          00000449
0378              IF(PONVOL-VOLMAX)  1220,1220,1180                                   00000450
0379        1180  DSCHRG=PONVOL-VOLMAX                                                00000451
0380              DSCVOL=DSCVOL+DSCHRG
0381              PONVOL=VOLMAX                                                       00000452
0382              WRITE(6,1200) NM,ND,YEAP,DSCHRG                                     00000453
0383        1200  FORMAT(20X,I2,'/',I2,'/',I2,'  -  DISCHARGE OF',F10.2,' ACRE-IN') 00000454
0384              IF(DSCHRG.GE.PEAK) PEAK=DSCHRG
0385              IF(YEAR.GT.PREVYR.OR.CM.LT.1.0) MM=MM+1
0386              PREVYR=YEAR
0387              CM=CM+1.0
           C                                                                          00000455
           C                                                                          00000456
0388        1220  CONTINUE
0389              NUM5=PLOT
0390              DO 1230 KI=1,NPLOTS
0391              SMACCT(NM,2,KI)=SMACCT(NM,2,KI)+PRECIP
0392              IF(KI.EQ.PLOT) SMACCT(NM,3,KI)=SMACCT(NM,3,KI)+DISVOL/AREA(KI)
0393              IF(KI.NE.PLOT) SMACCT(NM,3,KI)=SMACCT(NM,3,KI)+0.0
0394              SMACCT(NM,4,KI)=SMACCT(NM,4,KI)+NIA(KI)
0395              SMACCT(NM,5,KI)=SMACCT(NM,5,KI)+NRNOF(KI)
0396              SMACCT(NM,6,KI)=SMACCT(NM,6,KI)+NOPERC(KI)
0397              SMACCT(NM,7,KI)=SMACCT(NM,7,KI)+AETU(KI)+AETL(KI)+SNOVAP
0398              SMACCT(NM,8,KI)=SMACCT(NM,8,KI)+SM(KI)-SMPD(KI)
0399        1230  SMPD(KI)=SM(KI)
0400              ACTIRR=ACTIRR+DISVOL
0401              PDACCT(NM,3)=PDACCT(NM,3)+RUNOFF*LTAREA/TPAREA
0402              PDACCT(NM,6)=PDACCT(NM,6)+SEVAP/(3630*TPAREA)
0403              PDACCT(NM,7)=PDACCT(NM,7)+DSCHRG/TPAREA
0404              PDACCT(NM,8)=PDACCT(NM,8)+(PONVOL-PDVOL)/TPAREA
0405              PDVOL=PONVOL                                                        00000469
0406              IF(PONVOL.GT.MAXVOL) MAXVOL=PONVOL                                  00000470
0407              NUM6=PLOT
           C                                                                          00000471
0408        1240  CONTINUE                                                            00000472
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               C                                                                      00000473
               C                                                                      00000474
               C       ***** EXIT DAILY LOOP *****                                    00000475
               C                                                                      00000476
 0409                PDACCT(NM,1)=AMONTH(NM)                                          00000478
 0410                PDACCT(NM,2)=SMACCT(NM,2,1)*PSAREA/TPAREA
 0411                PDACCT(NM,4)=DSDAY                                               00000480
 0412                PDACCT(NM,5)=ACTIRR/TPAREA
 0413                DO 1260 J=2,8                                                    00000482
 0414           1260 PDACCT(13,J)=PDACCT(13,J)+PDACCT(NM,J)
 0415                DO 1270 MP=1,NPLOTS
 0416                DO 1265 J=2,8
 0417           1265 SMACCT(13,J,MP)=SMACCT(13,J,MP)+SMACCT(NM,J,MP)
 0418                SMACCT(NM,1,MP)=AMONTH(NM)
 0419           1270 SMACCT(13,1,MP)=AMONTH(13)
 0420                PDACCT(13,1)=AMONTH(13)                                          00000486
 0421                VOLIRR=VOLIRR+ACTIRR
               C                                                                      00000487
 0422           1280 CONTINUE                                                         00000488
               C                                                                      00000489
               C       ***** EXIT MONTHLY LOOP *****                                  00000490
               C                                                                      00000491
 0423                DSNOW=PACK-PACKPY                                                00000492
 0424                PACKPY=PACK                                                      00000493
 0425                PCWW=((PDACCT(13,2)+PDACCT(13,3)-PDACCT(13,7))/                  00000494
                    1    (PDACCT(13,2)+PDACCT(13,3)))*100.                            00000495
 0426                WASTWW=WASTWW+PCWW
 0427                DO 1290 KT=1,NPLOTS
 0428                DSRNFF=DSRNFF+SMACCT(13,5,KT)
 0429           1290 DSPERC=DSPERC+SMACCT(13,6,KT)
 0430                IRRSUM=IRRSUM+VOLIRR
 0431                DSDAYS=DSDAYS+PDACCT(13,4)
 0432                TPREC=TPREC+SMACCT(13,2,1)
 0433                IF((YEAR+1900).EQ.YSTART) DRY=SMACCT(13,2,1)
 0434                IF(SMACCT(13,2,1).GE.WET) WET=SMACCT(13,2,1)
 0435                IF(SMACCT(13,2,1).LE.DRY) DRY=SMACCT(13,2,1)
 0436                WRITE(6,1300) YEAR                                               00000496
 0437           1300 FORMAT('0',27X,'WATER ACCOUNT FOR STORAGE FACILITY (IN INCHES OVER00000497
                    1 DISPOSAL AREA) - 19',I2//9X,'-----------------------------------00000498
                    2-----------------------------------------------------------------00000499
                    3---------------'/29X,'INFLOWS',50X,'OUTFLOWS'/17X,'--------------00000500
                    4--------------',23X,'----------------------------------------'/  00000501
                    59X,'MONTH',3X,'PRECIPITATION',2X,'FEEDLOT RUNOFF',3X,'NO. DISPOSAL00000502
                    6 DAYS',3X,'DISPOSAL VOL.',2X,'SURFACE EVAP.',2X,'DISCHARGE',4X,  00000503
                    7'CHANGE IN VOL.')                                                00000504
 0438                WRITE(6,1320) ((PDACCT(I,K),K=1,8),I=1,13)                       00000505
 0439           1320 FORMAT(10X,A4,7X,F6.2,8X,F6.2,15X,F3.0,12X,F6.2,10X,             00000506
                    1 F6.2,7X,F6.2,9X,F6.2)                                           00000507
 0440                DO 1370 JM=1,NPLOTS
 0441                CROP=IAREA(JM,1)
 0442                SOIL=IAREA(JM,2)
 0443                WRITE(6,1330) JM,KROP(CROP),SOIL,AREA(JM)
 0444           1330 FORMAT(////,60X,'PLOT NO.',I3,////,25X,'CROP--',2A8,5X,'SOIL TYPE-
                    1-',I3,5X,'DISPOSAL AREA--',F6.2,' ACRES')
 0445                WRITE(6,1340) YEAR                                               00000508
 0446           1340 FORMAT('0',35X,'WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 19',00000509
                    1I2/10X,'---------------------------------------------------------00000510
                    2----------------------------------------------------'/32X,      00000511
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                3 'INPUTS',38X,'OUTPUTS'/21X,'---------------------------',3X,    '00000512
                4-----------------------------------------------------'/9X,'MONTH',00000513
                57X,'PRECIPITATION',4X,'IRRIGATION',3X,'INTERCEPTION',2X,'SURFACE R00000514
                6UNOFF',3X,'PERCOLATION',8X,'AET',8X,'CHANGE IN SM')               00000515
0447             WRITE(6,1360) ((SMACCT(I,K,JM),K=1,8),I=1,13)
0448       1360 FORMAT(10X,A4,7F15.2)                                              00000517
0449       1370 CONTINUE
0450             WRITE(6,1380) PCWW                                                00000518
0451       1380 FORMAT('0',10X,'PERCENT OF WASTEWATER CONTROLLED=',F10.2)          00000519
0452             WRITE (6,1400) IDISDA                                             00000520
0453       1400 FORMAT('0',10X,'POTENTIAL DISPOSAL DAYS=',I4)                      00000521
0454             WRITE(6,1420) PACK,DSNOW                                          00000522
0455       1420 FORMAT('0',10X,'PACK ON DECEMBER 31 =',F5.2,15X,                   00000523
                1'CHANGE IN SNOW STORAGE=',F5.2)                                   00000524
0456             WRITE(6,1440)                                                     00000525
0457       1440 FORMAT('0',10X,'INPUTS-OUTPUTS-CHANGE IN SNOW STORAGE=CHANGE IN    00000526
                1SOIL MOISTURE')                                                   00000527
0458             MAXVOL=MAXVOL*100.0/VOLMAX                                        00000528
0459             WRITE(6,1460) MAXVOL                                              00000529
0460       1460 FORMAT('0',10X,'PERCENT OF MAXIMUM POND VOLUME REQUIRED =',F7.2)   00000530
0461             EVAPLK=EVAPLK+LKEVPT
0462             WRITE(6,1480) LKEVPT                                              00000531
0463       1480 FORMAT('0',10X,'ESTIMATED LAKE EVAPORATION, INCHES =',F6.2)        00000532
0464       1500 CONTINUE                                                           00000533
          C                                                                        00000534
          C        ***** EXIT YEARLY LOOP *****                                    00000535
          C                                                                        00000536
0465       1520 CONTINUE
0466             EVAP=EVAPLK/YEARS
0467             CMNEW=CM
0468             IF(MM.EQ.0)  MM=1
0469             COUNT=CM/MM
0470             IF(COUNT.EQ.0.0) MM=0
0471             IF(CM.EQ.0.0) CM=YEARS
0472             DSCRG=DSCVOL/CM
0473             CM=CMNEW
0474             CONTRL=WASTWW/YEARS
0475             IRRVOL=IRRSUM/(YEARS*TPAREA)
0476             PERCOS=DSPERC/(YEARS*NPLOTS)
0477             RNFFOS=DSRNFF/(YEARS*NPLOTS)
0478             DAYSDS=DSDAYS/YEARS
0479             APREC=TPREC/YEARS
0480             RANGE=WET-DRY
0481             WRITE(6,100)NAME,OF,CITY,AND,STATE,YSTART,YEND,STORM,LTAREA,L,W,S,00000072
                *HMAX,VOLMAX,PSAREA,TPAREA,KROP(CROP),SOIL,DSRATE,PAVLU
0482             WRITE(6,1540)
0483       1540 FORMAT(////,47X,'***** FINAL SUMMARY *****')
0484             WRITE(6,1550)
0485       1550 FORMAT('0',10X,'METEOROLOGICAL SUMMARY')
0486             WRITE(6,1560) EVAP
0487       1560 FORMAT('0',25X,'AVERAGE ANNUAL LAKE EVAPORATION=',F6.2,' INCHES')
0488             WRITE(6,1624) APREC
0489       1624 FORMAT('0',25X,'AVERAGE ANNUAL PRECIPITATION=',F6.2,' INCHES')
0490             WRITE(6,1626) RANGE,DRY,WET
0491       1626 FORMAT('0',25X,'PRECIPITATION RANGE=',F6.2,' INCHES    (FROM A LOW
                1OF',F6.2,' INCHES  TO A HIGH OF ',F6.2,' INCHES)')
0492             WRITE(6,1610)
0493       1610 FORMAT('0',10X,'SUMMARY OF POND OPERATIONS')
```

```
      WRITE(6,1580) MM
 1580 FORMAT('0',25X,'NO. OF YEARS HAVING A DISCHARGE=',I6)
      WRITE(6,1600) COUNT
 1600 FORMAT('0',25X,'AVERAGE NO. OF DISCHARGES / YEAR HAVING A DISCHARG
     1E=',F6.2)
      WRITE(6,1620) DSCRG
 1620 FORMAT('0',25X,'AVERAGE DISCHARGE=',F6.2,1X,'ACRE-INCHES')
      WRITE(6,1640) CCNTRL
 1640 FORMAT('0',25X,'AVERAGE PERCENT OF WASTEWATER CONTROLLED=',F6.2)
      WRITE(6,1621) DSCVOL
 1621 FORMAT('0',25X,'TOTAL DISCHARGE VOLUME=',F9.2,' ACRE-INCHES')
      WRITE(6,1622) CM
 1622 FORMAT('0',25X,'TOTAL NO. OF DISCHARGES=',F4.0)
      WRITE(6,1623) PEAK
 1623 FORMAT('0',25X,'MAXIMUM DISCHARGE=',F6.2,' ACRE-INCHES')
      WRITE(6,1660) IRRVOL
 1660 FORMAT('0',25X,'AVERAGE ANNUAL DEPTH OF WASTEWATER APPLIED=',F6.2,
     1' INCHES OVER ENTIRE DISPOSAL AREA')
      WRITE(6,1619)
 1619 FORMAT('0',10X,'SUMMARY OF DISPOSAL PLOTS')
      WRITE(6,1680) RNFFDS
 1680 FORMAT('0',25X,'AVERAGE ANNUAL DISPOSAL AREA RUNOFF=',F6.2,' INCHE
     1S')
      WRITE(6,1700) PERCDS
 1700 FORMAT('0',25X,'AVERAGE ANNUAL DISPOSAL AREA PERCOLATION=',F6.2,'
     1INCHES')
      WRITE(6,1720) DAYSDS
 1720 FORMAT('0',25X,'AVERAGE ANNUAL NO. OF DISPOSAL DAYS=',F6.1)
      STOP
      END
```

```
STATION:   TOPEKA, KANSAS                    1973  TO  1973

SIZE OF CRITICAL EVENT  6.10

FEEDLOT AREA   40.00ACRES

POND VARIABLES:
              (A) BASE DIMENSION-  870.00  FEET BY  290.00  FEET
              (B) SIDE SLOPE--   RUN: RISE = 3.0 : 1
              (C) MAXIMUM DEPTH--   9.00  FEET
              (D) MAXIMUM POND VOLUME--     705.60 ACRE-INCHES
              (E) DIRECT RECEIVING AREA (FOR PRECIPITATION) --      7.30 ACRES

DISPOSAL AREA VARIABLES:
              (A) DISPOSAL AREA--    40.00  ACRES
              (B) CROP--  CORN
              (C) SOIL TYPE--    5   (SCS) SOIL TYPES)
              (D) DISPOSAL RATE--   0.50  INCHES/DAY ON DISPOSAL DAYS
              (E) IRRIGATION MANAGEMENT--   IRRIGATION BELOW   0.50  FIELD CAPACITY
```

***** ANNUAL SUMMARY *****

9/27/73	-	DISCHARGE OF	32.67 ACRE-IN
9/28/73	-	DISCHARGE OF	7.90 ACRE-IN
10/10/73	-	DISCHARGE OF	110.47 ACRE-IN
10/11/73	-	DISCHARGE OF	26.97 ACRE-IN
12/ 4/73	-	DISCHARGE OF	24.97 ACRE-IN
12/14/73	-	DISCHARGE OF	0.36 ACRE-IN
12/18/73	-	DISCHARGE OF	0.95 ACRE-IN
12/19/73	-	DISCHARGE OF	0.36 ACRE-IN
12/23/73	-	DISCHARGE OF	2.99 ACRE-IN
12/24/73	-	DISCHARGE OF	1.24 ACRE-IN
12/25/73	-	DISCHARGE OF	0.07 ACRE-IN
12/26/73	-	DISCHARGE OF	0.66 ACRE-IN
12/27/73	-	DISCHARGE OF	0.07 ACRE-IN
12/30/73	-	DISCHARGE OF	6.06 ACRE-IN
12/31/73	-	DISCHARGE OF	0.07 ACRE-IN

WATER ACCOUNT FOR STORAGE FACILITY (IN INCHES OVER DISPOSAL AREA) - 1973

	INFLOWS			OUTFLOWS			
MONTH	PRECIPITATION	FEEDLOT RUNOFF	NO. DISPOSAL DAYS	DISPOSAL VOL.	SURFACE EVAP.	DISCHARGE	CHANGE IN VOL.
JAN.	0.49	0.95	0.	0.0	0.05	0.0	1.39
FEB.	0.31	1.39	0.	0.0	0.11	0.0	1.59
MAR.	1.54	3.27	0.	0.0	0.53	0.0	4.27
APR.	0.74	1.45	0.	0.0	0.74	0.0	1.45
MAY	0.80	1.46	0.	0.0	0.97	0.0	1.29
JUNE	0.54	1.55	4.	2.00	1.27	0.0	-1.18
JULY	1.55	6.90	5.	2.50	1.30	0.0	4.95
AUG.	0.52	0.80	6.	3.00	1.14	0.0	-2.83
SEPT	2.32	8.22	4.	2.00	0.88	1.01	5.65
OCT.	0.83	2.93	0.	0.0	0.64	3.44	-0.32
NOV.	0.39	0.95	4.	2.00	0.32	0.0	-0.98
DEC.	0.78	1.55	0.	0.0	0.03	0.95	1.35
TOT.	11.11	31.42	23.	11.50	7.99	5.40	17.64

PLOT NO. 1

CROP--CORN SOIL TYPE-- 5 DISPOSAL AREA-- 10.00 ACRES

WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1973

	INPUTS		OUTPUTS				
MONTH	PRECIPITATION	IRRIGATION	INTERCEPTION	SURFACE RUNOFF	PERCOLATION	AET	CHANGE IN SM
JAN.	2.67	0.0	0.51	0.08	0.0	0.34	1.74
FEB.	1.71	0.0	0.40	0.39	0.0	0.74	0.17
MAR.	8.44	0.0	1.55	1.43	1.14	1.50	2.83
APR.	4.03	0.0	0.64	0.35	1.11	2.11	-0.18
MAY	4.37	0.0	0.66	1.28	1.94	0.76	-0.26
JUNE	2.96	2.00	0.56	1.22	0.73	2.89	-0.43
JULY	10.16	0.0	0.90	3.49	0.75	6.53	-1.51
AUG.	2.83	4.00	1.03	0.66	0.0	5.65	-0.51
SEPT	12.71	2.00	1.38	5.99	1.09	3.88	2.37

OCT.	4.57	0.0	0.39	2.28	1.03	1.77	-0.90
NOV.	2.14	2.00	0.30	0.77	1.36	0.97	0.74
DEC.	4.30	0.0	0.26	1.00	1.38	0.37	0.35
TOT.	60.89	10.00	8.59	18.94	10.51	27.51	4.41

PLCT NC. 2

CROP--CCRN SOIL TYPE-- 5 DISPOSAL AREA-- 10.00 ACRES

WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1973

	INPUTS		OUTPUTS				
MONTH	PRECIPITATION	IRRIGATION	INTERCEPTION	SURFACE RUNOFF	PERCOLATION	AET	CHANGE IN SM
JAN.	2.67	0.0	0.51	0.08	0.0	0.34	1.74
FEB.	1.71	0.0	0.40	0.39	0.0	0.74	0.17
MAR.	8.44	0.0	1.55	1.43	1.14	1.50	2.83
APR.	4.03	0.0	0.64	0.35	1.11	2.11	-0.18
MAY	4.37	0.0	0.66	1.28	1.94	0.76	-0.26
JUNE	2.96	2.00	0.56	1.22	0.73	2.89	-0.43
JULY	10.16	2.00	0.90	4.27	1.96	6.53	-1.51
AUG.	2.83	4.00	1.03	0.66	0.0	5.65	-0.51
SEPT	12.71	2.00	1.38	5.99	1.09	3.88	2.37
OCT.	4.57	0.0	0.39	2.28	1.03	1.77	-0.90
NOV.	2.14	2.00	0.30	0.77	1.31	1.02	0.74
DEC.	4.30	0.0	0.26	1.00	1.38	0.37	0.35
TOT.	60.89	12.00	8.59	19.73	11.69	27.55	4.41

PLCT NC. 3

CROP--CCRN SOIL TYPE-- 5 DISPOSAL AREA-- 10.00 ACRES

WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1973

	INPUTS		OUTPUTS				
MONTH	PRECIPITATION	IRRIGATION	INTERCEPTION	SURFACE RUNOFF	PERCOLATION	AET	CHANGE IN SM
JAN.	2.67	0.0	0.51	0.08	0.0	0.34	1.74
FEB.	1.71	0.0	0.40	0.39	0.0	0.74	0.17
MAR.	8.44	0.0	1.55	1.43	1.14	1.50	2.83
APR.	4.03	0.0	0.64	0.35	1.11	2.11	-0.18
MAY	4.37	0.0	0.66	1.28	1.94	0.76	-0.26
JUNE	2.96	2.00	0.56	1.22	0.73	2.89	-0.43
JULY	10.16	4.00	1.00	4.90	1.24	6.53	-1.51
AUG.	2.83	2.00	0.96	0.17	0.0	5.65	0.05
SEPT	12.71	2.00	1.38	5.99	1.65	3.88	1.81
OCT.	4.57	0.0	0.39	2.28	1.03	1.77	-0.90
NOV.	2.14	2.00	0.30	0.77	1.28	1.05	0.74
DEC.	4.30	0.0	0.26	1.00	1.38	0.37	0.35
TOT.	60.89	12.00	8.62	19.86	11.49	27.59	4.41

PLOT NO. 4

CROP--CORN SOIL TYPE-- 5 DISPOSAL AREA-- 10.00 ACRES

WATER BALANCE (INCHES) IN THE DISPOSAL AREA - 1973

MONTH	INPUTS		OUTPUTS				
	PRECIPITATION	IRRIGATION	INTERCEPTION	SURFACE RUNOFF	PERCOLATION	AET	CHANGE IN SM
JAN.	2.67	0.0	0.51	0.08	0.0	0.34	1.74
FEB.	1.71	0.0	0.40	0.39	0.0	0.74	0.17
MAR.	8.44	0.0	1.55	1.43	1.14	1.50	2.83
APR.	4.03	0.0	0.64	0.35	1.11	2.11	-0.18
MAY	4.37	0.0	0.66	1.28	1.94	0.76	-0.26
JUNE	2.96	2.00	0.53	1.22	0.73	2.89	-0.40
JULY	10.16	4.00	1.10	4.90	1.27	6.53	0.36
AUG.	2.83	2.00	0.93	0.17	0.0	5.65	-1.92
SEPT	12.71	2.00	1.35	5.99	1.56	3.88	1.88
OCT.	4.57	0.0	0.39	2.28	1.03	1.77	-0.90
NOV.	2.14	2.00	0.30	0.77	1.25	1.08	0.74
DEC.	4.30	0.0	0.26	1.00	1.33	0.37	0.35
TOT.	60.89	12.00	8.66	19.86	11.42	27.62	4.41

PERCENT OF WASTEWATER CONTROLLED= 87.31

POTENTIAL DISPOSAL DAYS= 23

PACK ON DECEMBER 31 = 0.93 CHANGE IN SNOW STORAGE= 0.93

INPUTS-OUTPUTS-CHANGE IN SNOW STORAGE=CHANGE IN SOIL MOISTURE

PERCENT OF MAXIMUM POND VOLUME REQUIRED = 100.00

ESTIMATED LAKE EVAPORATION, INCHES = 47.47

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STATION:   TOPEKA, KANSAS                1973  TO  1973

SIZE OF CRITICAL EVENT  6.10

FEEDLOT AREA   40.00ACRES

POND VARIABLES:

               (A) BASE DIMENSION-  870.00  FEET BY  290.00  FEET
               (B) SIDE SLOPE--   RUN: RISE = 3.0 : 1
               (C) MAXIMUM DEPTH--    9.00  FEET
               (D) MAXIMUM POND VOLUME--     705.60 ACRE-INCHES
               (E) DIRECT RECEIVING AREA (FOR PRECIPITATION) --      7.30 ACRES

DISPOSAL AREA VARIABLES:

               (A) DISPOSAL AREA--     40.00  ACRES
               (B) CROP--  CORN
               (C) SOIL TYPE--    5   (SCS) SOIL TYPES)
               (D) DISPOSAL RATE--   0.50  INCHES/DAY ON DISPOSAL DAYS
               (E) IRRIGATION MANAGEMENT--   IRRIGATION BELOW   0.50  FIELD CAPACITY

                          ***** FINAL SUMMARY *****

 METEOROLOGICAL SUMMARY
                AVERAGE ANNUAL LAKE EVAPORATION= 47.47 INCHES
                AVERAGE ANNUAL PRECIPITATION= 60.89 INCHES
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        PRECIPITATION RANGE=  0.0  INCHES   (FROM A LOW OF 60.89 INCHES  TO A HIGH OF  60.89 INCHES)
SUMMARY OF POND OPERATIONS
        NO. OF YEARS HAVING A DISCHARGE=
        AVERAGE NO. OF DISCHARGES / YEAR HAVING A DISCHARGE= 15.00
        AVERAGE DISCHARGE= 14.39 ACRE-INCHES
        AVERAGE PERCENT OF WASTEWATER CONTROLLED= 87.31
        TOTAL DISCHARGE VOLUME=   215.83 ACRE-INCHES
        TOTAL NO. OF DISCHARGES= 15.
        MAXIMUM DISCHARGE=110.47 ACRE-INCHES
        AVERAGE ANNUAL DEPTH OF WASTEWATER APPLIED= 11.50 INCHES OVER ENTIRE DISPOSAL AREA
SUMMARY OF DISPOSAL PLOTS
        AVERAGE ANNUAL DISPOSAL AREA RUNOFF= 19.60 INCHES
        AVERAGE ANNUAL DISPOSAL AREA PERCOLATION= 11.28 INCHES
        AVERAGE ANNUAL NO. OF DISPOSAL DAYS=  23.0
```

APPLICATION OF A COMPUTER MODEL IN DESIGNING KANSAS FEEDLOT WASTE CONTROL SYSTEMS

by

Michael J. Peterson

B.S., Kansas State University, 1975

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Civil Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

ABSTRACT

With the use of continuous watershed models, Kansas stations were tested to evaluate and design feedlot runoff control systems. The control systems consisted of a pond and disposal area for controlling feedlot runoff pollution. The testing was in three phases: 1) control was achieved by evaporation from the pond, 2) control was achieved by irrigation disposal from the pond to a single disposal area, 3) multiple disposal areas were compared to a single area for irrigation disposal. From these tests, design of the control systems are possible given the necessary data concerning the control systems and the location (meteorological).