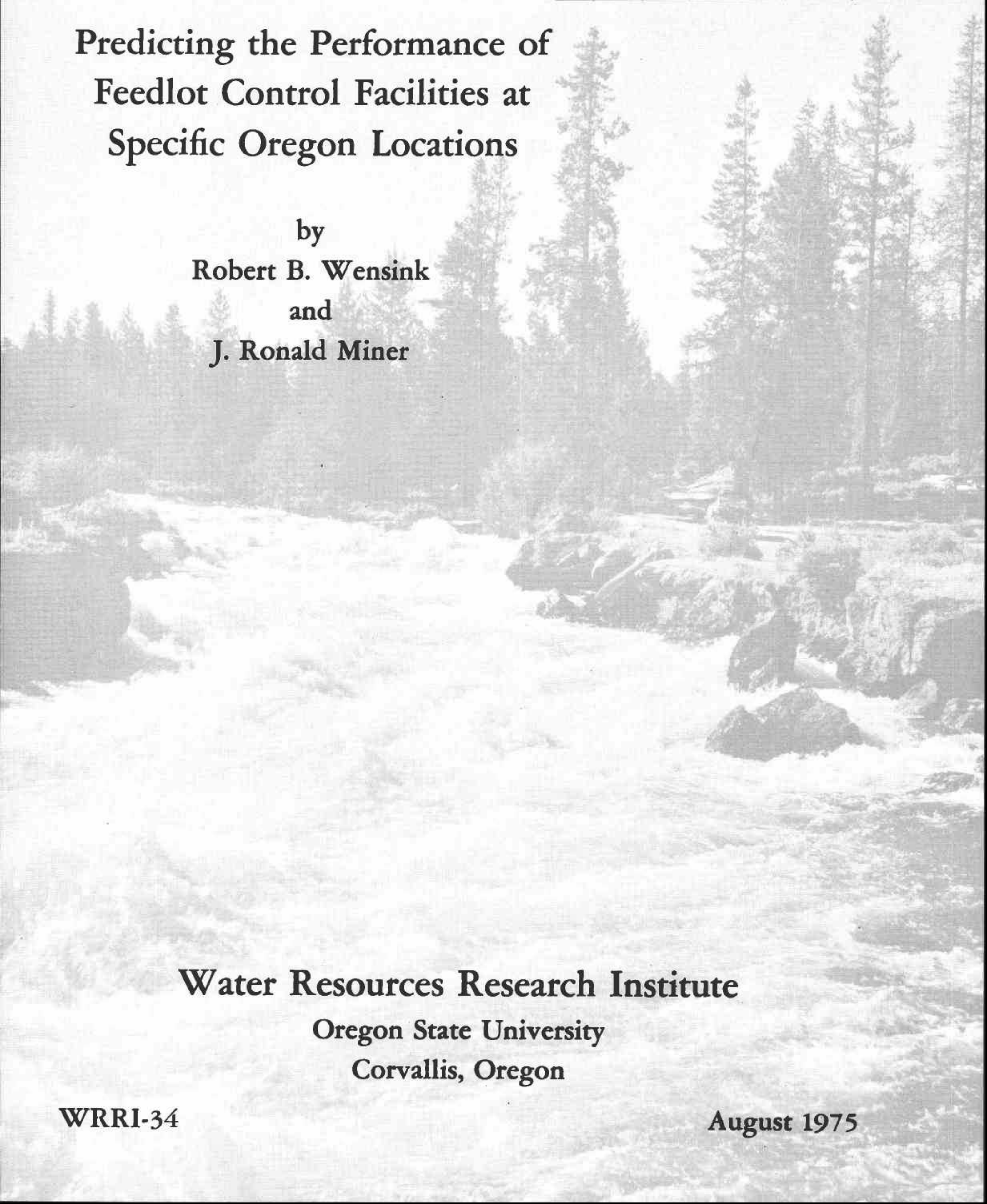

Predicting the Performance of Feedlot Control Facilities at Specific Oregon Locations

by
Robert B. Wensink
and
J. Ronald Miner

Water Resources Research Institute
Oregon State University
Corvallis, Oregon

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for

A Simulation Model to Evaluate Alternative Means of Feedlot Impoundment and Disposal

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ABSTRACT

In 1972 the United States Congress enacted the "Federal Water Pollution Control Act Amendments of 1972". This Act required the Environmental Protection Agency to promulgate effluent guidelines for discharges from feedlots. These guidelines permit discharge from feedlots only in connection with an "unusual rainfall" event. For 1977, the criterion is the 10 year-24 hour storm; for 1983, the criterion is the 25 year-24 hour storm. These criteria, however, are performance standards and do not represent reservoir design.

A mathematical simulation model was developed to size feedlot runoff retention reservoirs based upon previous climatological records. Two versions of the model were programmed. The first, called the return period design technique, investigated the results of employing EPA's performance standards as design criteria. The second model, entitled the sufficient design method, determined the minimum reservoir storage volume required to prevent illegal discharge as defined by the EPA Effluent Guidelines. The two techniques demonstrated that to use design procedures based upon a factor times the 10 year-24 hour or the 25 year-24 hour storm led to designs that were either unreasonably expensive or which led to illegal discharges for which the livestock producer was subject to monetary penalties.

The sufficient design technique was also used to determine pollution control performance with various combinations of pumping rates and storage facility volumes. In some Oregon locations, the use of high capacity irrigation equipment allowed reduction of storage volume by over 45 percent; in other Oregon locations, due to precipitation patterns, no benefit was obtained from high capacity pumping equipment.

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INTRODUCTION

Feedlot Description

Cattle feedlots are typically located to take advantage of natural surface drainage conditions. Control facilities are, therefore, needed to intercept and store surface runoff so that organic material-, nutrient-, and sediment-laden water is prevented from entering streams and reservoirs. The intercepted runoff is typically applied to crop land for disposal and for utilization of dissolved plant nutrients.

A feedlot runoff control system consists of two basic components: (1) a runoff collection and storage facility which intercepts the effluent moving off the feedlot surface, and (2) a disposal subsystem for removing contaminated water from the storage pond. The collected runoff is removed by surface evaporation and/or pumping the water to crop land. Both disposal practices are controlled in part by climatic and soil conditions. It is theoretically impossible to design a retention facility capable of containing all feedlot runoffs from all climatological conditions.

Federal Water Pollution Control

In October of 1972 the United States Congress enacted the "Federal Water Pollution Control Act Amendments of 1972" (Public Law 92-500). The declared objective of the Act is "to restore and maintain the chemical, physical and biological integrity of the nation's waters". To achieve this objective, the Act established two national goals, which are: "to eliminate the discharge of pollutants into navigable waters by 1985" and "to have water quality that provides for the protection of fish, shellfish, and wildlife and for recreation in and on the water by 1983". The Act further prescribes a strategy to encourage research and development in water pollution control technology to move the nation toward the 1983 and 1985 goals. This strategy requires interim levels of technological achievement by industries based on the application of effluent limitations: "The best practicable technology currently available by 1977 and the best available technology economically achievable by 1983".

To perform the interim levels of technological achievement through effluent limitations, the Act required the Environmental Protection Agency (EPA) to designate specific levels of effluent limitations relative to the best practicable technology and best available technology. As a result, EPA prepared effluent guidelines for 27 waste water producing industries; among the industries listed was the feedlot industry.

Because the feedlot industry utilizes large unroofed areas for feeding which are subject to rainfall runoff, special problems have arisen in preparing adequate design criteria to meet the overall objectives of the Act. Since feedlot runoff is a climatically controlled phenomenon, EPA has promulgated effluent guidelines which allow discharge from a feedlot only in connection with an "unusual rainfall" event. For 1977, the criterion is the 10 year-24 hour storm. For 1983, the criterion is the 25 year-24 hour storm. This criterion is a performance standard and does not provide exact design criteria.

OBJECTIVES AND SCOPE

Since the Environmental Protection Agency's effluent guidelines represent only performance standards, this study was initiated to pursue the following objectives:

1. To develop a feedlot runoff reservoir model which compiles climatic data in a meaningful way so that alternative schemes of runoff collection and storage can be evaluated as pollution control measures.
2. To utilize the model
   a. to evaluate the Environmental Protection Agency's performance standards as runoff retention reservoir design criteria in Oregon.
   b. to develop minimum design standards for Oregon feedlot runoff retention reservoirs which satisfy EPA performance standards.

CONSTRUCTION OF THE MODEL

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

The feedlot runoff model is programmed in standard FORTRAN IV and models the effects of daily climatological inputs on specific feedlot runoff reservoir designs. The model utilizes daily precipitations and

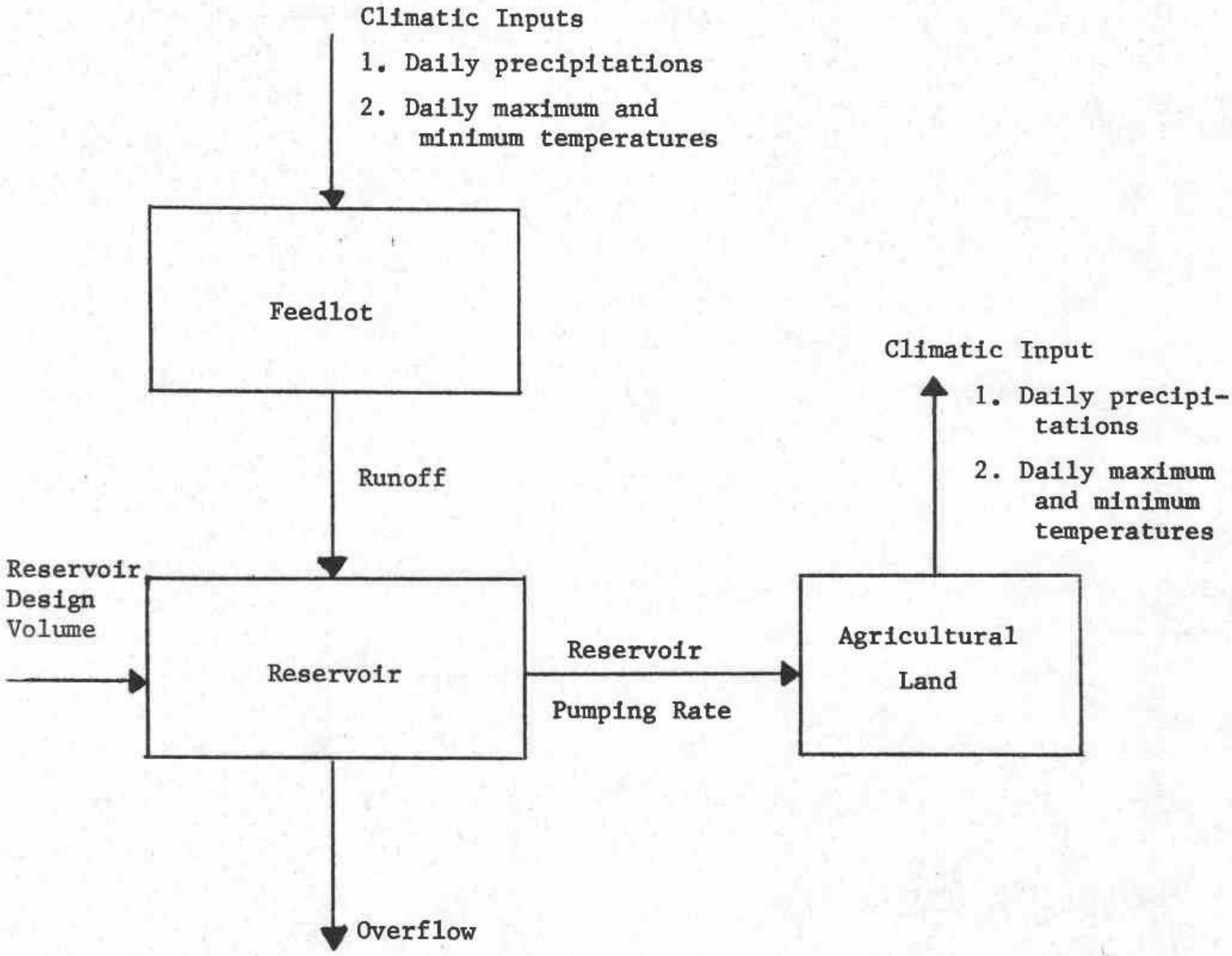

Figure 1. Block Diagram of Feedlot Runoff Model.

average temperatures while operating continuously through the year and from one year to the next.

The first component of the model determines runoff from the feedlot surface. Runoff volumes and holding pond depths are presented on the basis of one acre of feedlot surface. The model's output is, therefore, not restricted to a specific feedlot size, but directly applicable to any size feedlot operation by multiplying the output by the feedlot size. Thus, model output of feedlot reservoir volume (acre-inches) per acres of feedlot surface is expressed as a depth (inches) of pond volume per feedlot runoff area.

Feedlot runoff was predicted by using the Soil Conservation Service Runoff Equations. The method was developed from correlation of runoff amounts of various sized storms on agricultural watersheds in many parts of the United States and is described in Schwab (7) as:

$$Q = \frac{(P - .2S)^2}{P + .8S} \qquad (1)$$

where Q = direct surface runoff in inches

P = storm rainfall in inches

S = maximum potential difference between rainfall and runoff in inches.

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

The Soil Conservation Service also defines

$$S = \frac{1000}{N} - 10 \qquad (2)$$

where N = an arbitrary curve number varying from 0 to 100. As N increases, Q also increases and when N = 100, equation (1) reduces to Q = P, i.e. all precipitation results in runoff.

The SCS runoff curve number table (Schwab, 1966) predicts a value of N equal to approximately 90-92 for open cattle feedlots under average moisture conditions (condition II). Bergsrud (1) determined a value of N = 91 for feedlots in Kansas and Fields (2) reported values of N = 91 and N = 92 for cattle feedlots. Larson *et al.* (4) and Koelliker *et al.* (3) utilized a value of N = 91 for average (condition II) environments. A value of N = 97 was used for wet soil moisture environments (condition III) by conversion tables in Schwab (7). This value also agrees with values reported by other researchers.

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

Warm Season (Preceding 5-day average temperature greater than 40° F)

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

N = 97 if 5-day antecedent precipitation $\geq$ 2.1 inches

Cold Season (Preceding 5-day average temperature less than 40° F)

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

N = 97 if 5-day antecedent precipitation $\geq$ 1.1 inches

Because Oregon experiences mild winters, the feedlot runoff model utilizes the above techniques to calculate runoff throughout the year. Snowfall is infrequent in Western Oregon and usually melts within a matter of hours; thus, the model does not distinguish snowfall from rainfall.

All feedlot runoff is assumed intercepted by the retention reservoir. Stored runoff is removed from this reservoir by pumping the water onto agricultural lands. The model accepts a design pumping rate value, expressed as a fraction of the design reservoir depth, as an input parameter. Pumping is only permitted on days suitable for irrigation. The following climatic and reservoir conditions specify this requirement:

1. The pond contains effluent.
2. The ground is not frozen.
3. Average daily temperature is above 32° F.
4. Precipitation does not occur.

The model satisfies condition 2 by requiring the average temperature for the preceding three days to be greater than 32° F. Once the ground becomes frozen, the model assumes the ground remains frozen until the average temperature for three consecutive days exceeds 38° F.

Two specific versions of the model were programmed; the first was called the return period design technique and the second, the sufficient design method. Figures 2 and 3, respectively, present flow charts of the return period design method and the sufficient design technique. Input, output, and programming steps for each model are listed in the Appendices.

The first model, the return period design technique, required the selection of a design pond volume in acre-inches to hold runoff from a single feedlot acre and a daily reservoir pumping rate expressed in a fraction of the design volume. This particular model was developed to test the hypothesis that EPA performance standards could be utilized as a design standard for Oregon feedlots (objective 2.a).

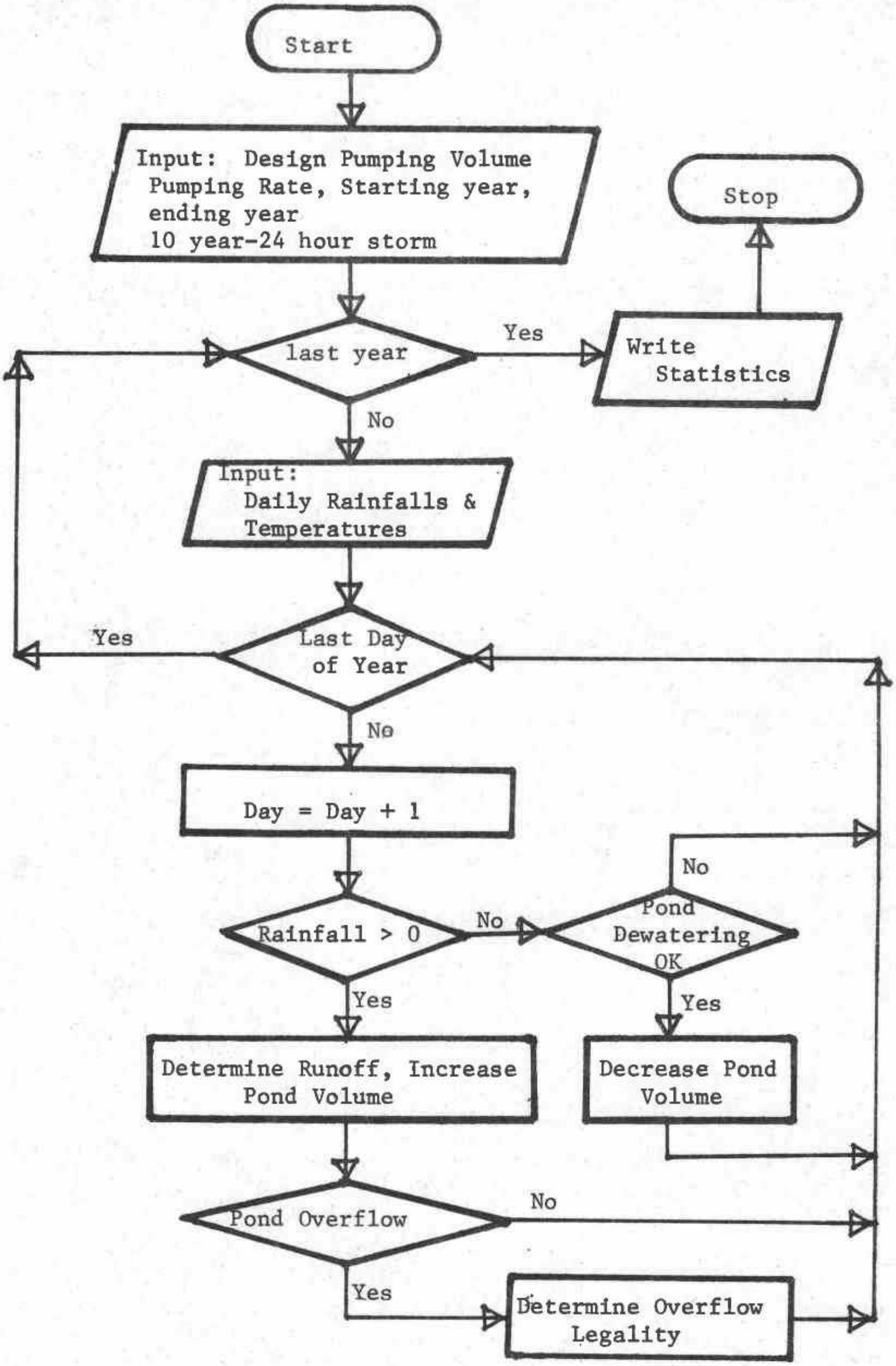

Figure 2. Flowchart of Feedlot Runoff Retention Return Period Design Model.

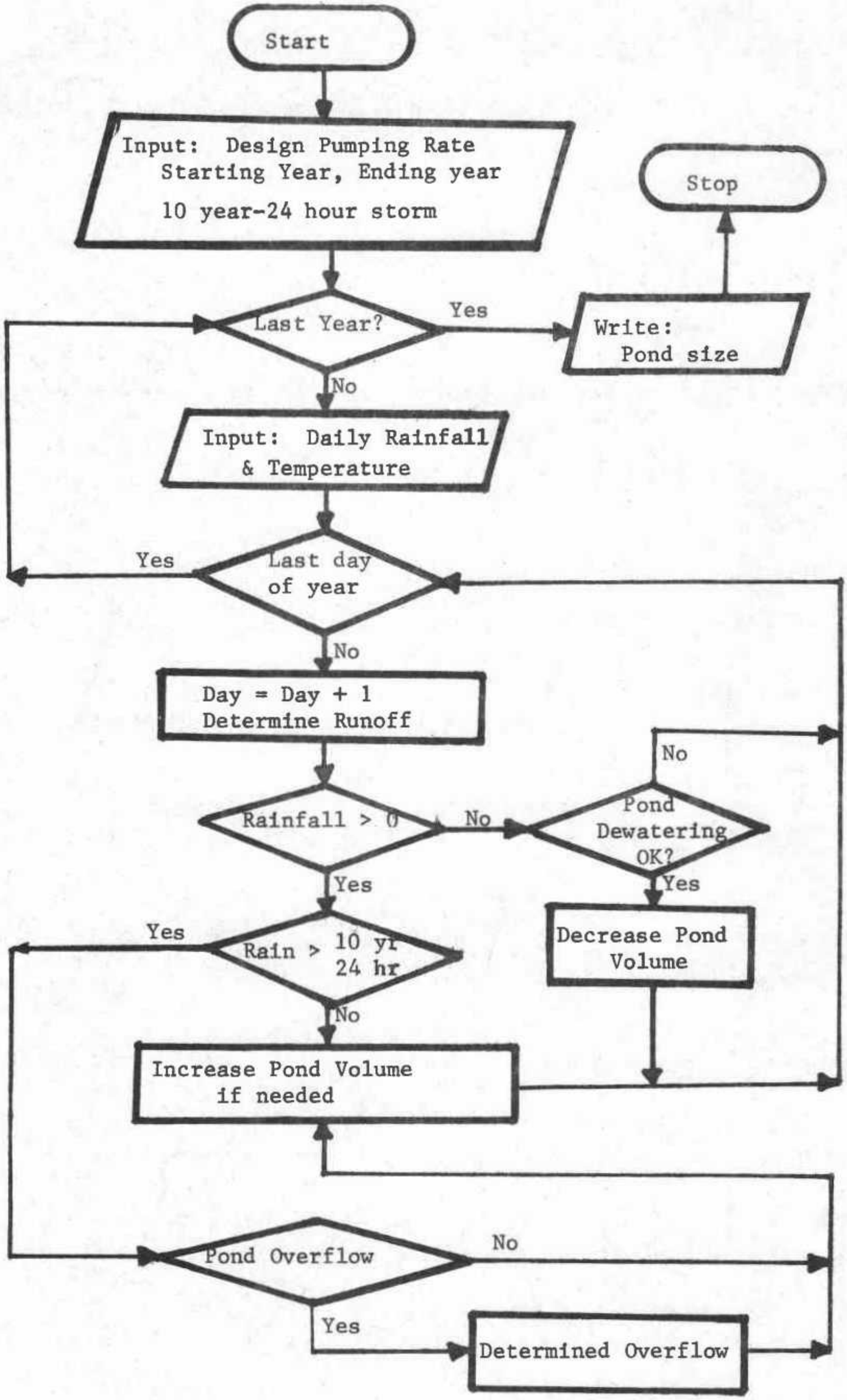

Figure 3. Flowchart of Feedlot Runoff Retention Sufficient Design Model.

As the return period model progressed through the daily climatic data, the selected design reservoir volume would overflow if a chronic wet period accumulated more volume than the reservoir capacity or if a single catastrophic storm exceeded the available reservoir volume. When a reservoir overflow occurs, the model calculates the following statistics:

1. Amount of overflow
2. Date of overflow
3. Precipitation causing overflow
4. Legality of overflow.

The second and third statistics, when collected for a complete computer run, are used to determine the effects of chronic rainfall conditions on reservoir designs. The fourth statistic, legality of overflow, is determined by comparing the precipitation causing overflow to the 10 year-24 hour rainfall event. The overflow is then recorded as illegal if the day's rainfall is less than the 10 year-24 hour value, otherwise it is declared a legal overflow.

The second model, the sufficient design technique, determined the minimum reservoir depth to contain all runoff from precipitation less than the 10 year-24 hour storm. This was accomplished by increasing the minimum depth, whenever the pond was full, to accommodate all runoff resulting from precipitation less than the 10 year-24 hour storm. Runoff from precipitation greater than the 10 year-24 hour storm was considered legal overflow. When precipitation exceeding the design storm occurred, effluent overflow would result only if the reservoir could not contain the storm's complete runoff. When overflow occurred, the sufficient design method model calculated the following:

1. Amount of overflow
2. Date of overflow
3. Precipitation causing overflow.

Since all discharges in this model were considered legal, legality of overflow was not included in the above statistics. The model did, however, determine the following attributes for each precipitation larger than the 10 year-24 hour storm:

1. Amount of runoff
2. Date of storm.

After each computer run, the runoff for storms exceeding the 10 year-24 hour value was accumulated.

Reservoir seepage losses, pond evaporation losses, and precipitation onto the pond surface are not included in either model. Seepage losses are difficult to accurately measure, while evaporation losses are minimal during Oregon's cloud-covered rainy winter months. Precipitation onto the reservoir surface is not included because the pond volume is measured in terms of a single feedlot acre. Thus, a reservoir surface area is not required nor determined by the model. Seepage losses and evaporation losses tend to collectively compensate for direct pond precipitation gains; the resultant gain (loss) is assumed to be a negligible amount.

MODEL INPUTS

Both models utilize weather data from three unique climatological regions to evaluate feedlot pollution control designs in Oregon. Six locations ranging in annual precipitation from 8 inches to over 90 inches are studied. Two stations, Ontario and Pendleton (average annual precipitation less than 15 inches) are representative of the arid region in the eastern section of the state. At the other extreme, Astoria and Tillamook (annual precipitation, 91 inches) are coastal areas with chronic wet winter rainfalls. Corvallis and Medford represent moderate rainfall conditions. On all but one station, 58 years of daily minimum temperatures, maximum temperatures, and precipitations were compiled from Oregon Climatological Journals (6). Selected climatic attributes of the six locations are shown in Table 1.

Table 1. Climatic attributes of selected Oregon feedlot locations.*

Location	Average annual rainfall (inches)	Average January temperature (°F)	10 year-24 hour rainfall (inches)	25 year-24 hour rainfall (inches)
Ontario	8.04	27	1.5	1.8
Pendleton	12.35	31	1.3	1.5
Medford	17.70	36	3.1	3.5
Corvallis	38.67	38	3.7	4.5
Astoria	74.43	40	4.8	5.5
Tillamook	90.64	41	5.5	6.0

* Wensink, R. B. and J. R. Miner. A model to predict the performance of feedlot control facilities at specific Oregon locations. ASAE Paper No. 75-4027. June 1975.

In addition to the above climatic data, the return period technique required the selection of a design pond volume in acre-inches to hold runoff from a single feedlot acre and a pumping rate expressed in a fraction of the design volume. Several pond design depths were considered;

each depth was associated with some fraction of either the 10 year-24 hour storm or the 25 year-24 hour storm. Pumping rates were varied for each design depth considered. Rates of .1, .2, and .4 of the design reservoir depth per day were analyzed.

Since the minimum reservoir volume was determined by the sufficient design model, the pumping rate could not be directly related to the pond depth. Therefore, the 10 year-24 hour recurrence value was utilized as a basis for pumping rates. Values of .1, .2, and .4 times the 10 year-24 hour value were studied at each of the selected locations.

MODEL OUTPUTS

The feedlot runoff sufficient design model was first utilized to determine the pond depth required to hold all runoff, except that associated with storms larger than the 10 year-24 hour value, at each of the six locations. In each case, the model progressed through 58 years (except Tillamook) of climatic data with pumping rates set at .1, .2, .4, .5, and .6 of the 10 year-24 hour storm. Table 2 shows the following outputs for each of the selected stations: total precipitation, total runoff, total legal overflow, total runoffs from all storms greater than the 10 year-24 hour recurrence value, and a pond depth required to contain all rainfalls less than the 10 year-24 hour recurrence value. Table 3 is the above model's output expressed in yearly averages.

The return period design model was then utilized to evaluate the specific runoff reservoir designs at each of the six locations. Tables 4 through 9 correspond to Ontario, Pendleton, Medford, Corvallis, Astoria, and Tillamook, respectively. Each table lists the following model output for selected pond designs: total overflow, average annual overflow, total legal overflow, average annual legal overflow, number of overflows, number of legal overflows, a pond design efficiency, and a corrected pond design efficiency. A legal overflow was defined as an overflow resulting from precipitation greater than the 10 year-24 hour recurrence storm. Pond design efficiency was again expressed in the percent of total runoff contained by the pond. The corrected pond design efficiency was similarly determined, except that all legal overflow was excluded from the overflow calculation.

All design volumes considered in this study were associated with either 10 year-24 hour or 25 year-24 hour recurrence interval storm values. In this manner, the design volumes are directly related to recurrence intervals which are typically utilized for reservoir designs. The following four design volumes expressed in acre-inches per acre were evaluated for each station:

1. A depth equal to the runoff resulting from a 10 year-24 hour storm with N = 91 in the runoff equation.
2. A depth equal to the runoff resulting from a 10 year-24 hour storm with N = 97 in the runoff equation.
3. A depth equal to the 10 year-24 hour precipitation value.
4. A depth equal to the 25 year-24 hour precipitation value.

Three selected pumping rates of .1, .2, and .4 times the design pond depth were evaluated for each of the above design volumes.

Table 2. Results of Sufficient Modelling Program to Predict the Retention Pond Volume Required to Prevent All Illegal Discharges From a One Acre Feedlot at Six Oregon Locations.

Station	10 yr - 24 hr storm (inches)	Pumping Rate (x 10 yr - 24 hr storm)	Total* Rainfall (inches)	Total Runoff (inches)	Total Legal Overflow (inches)	Total Runoff from Storms Greater 10 yr - 24 hr (inches)	Pond Volume Required (inches)
Ontario	1.5	≥.1	466.41	47.61	0.25	1.72	.75
Pendleton	1.3	≥.1	716.06	79.45	0.0	1.40	1.62
Medford	3.1	≥.1	4316.68	1910.97	0.0	5.21	5.04
Corvallis	3.7	.1	2242.90	726.17	.00	3.93	6.11
		.2			.63		4.15
		≥.4			.99		3.80
Astoria	4.8	.1	4316.68	1910.97	0.0	21.48	17.79
		.2			0.0		9.23
		≥.4			0.57		7.98
Tillamook**	5.5	.1	2809.85**	1381.11**	0.0	0.0	10.07
		.2			0.0		7.57
		.4			0.0		5.65
		.5			0.0		5.10
		.6			0.0		4.55

* Based on 58 years of record except for Tillamook, 31 years.
** Used 31 years (1941 - 1971) of climatic data.

Table 3. Average Annual Results of Sufficient Modelling Program.

Station	10 yr - 24 hr storm (inches)	Pumping Rate (x 10 yr - 24 hr storm)	Average Rainfall (inches)	Average Runoff (inches)	Percent Runoff	Average Legal Overflow (inches)	Average Runoff from Storms Greater 10 hr - 24 hr (inches)	Pond Depth Required (inches)	Design Efficiency
Ontario	1.5	≥.1	8.04	.82	10.21	.0043	.03	.75	99.47
Pendleton	1.3	≥.1	12.35	1.37	11.09	0.0	.02	1.62	100.00
Medford	3.1	≥.1	17.70	3.96	22.37	0.0	.09	5.04	100.00
		.1				0.0		6.11	100.00
Corvallis	3.7	.2	38.67	12.52	32.38	0.01	.07	4.15	99.91
		≥.4				0.017		3.80	99.86
		.1				0.0		17.79	100.00
Astoria	4.8	.2	74.43	32.95	44.27	0.0	.37	9.23	100.00
		≥.4				0.0098		7.98	99.87
		.1				0.0		10.07	100.00
		.2				0.0		7.57	100.00
Tillamook*	5.5	.4	90.64*	44.55*	49.15	0.0	0.0	5.65	100.00
		.5				0.0		5.10	100.00
		.6				0.0		4.55	100.00

* Used 31 years (1941 - 1971) of climatic data.

Table 4. Feedlot Runoff Return Period Design Model Output for Selected Designs at Ontario, Oregon

Years cumulative data: 58 (1914 - 1971)
Total Rainfall: 467 inches
Total Runoff: 47.67 inches

Design Depth	Pumping Rate	Total Overflow (inches/58 yrs)	Total Legal Overflow (inches/50 yr)	Number Overflow	Number Legal Overflow	Pond Efficiency	Corrected Pond Efficiency
.74	.1	.28	.27	3	3	99.43	99.98
	.2	.28	.27	3	2	99.4	99.98
1.184	≥ .1	.0	.0	0	0	100.00	100.00
1.5	≥ .1	.0	.0	0	0	100.00	100.00
1.8	≥ .1	.0	.0	0	0	100.00	100.00

Table 5. Feedlot Runoff Return Period Design Model Output for Selected Designs at Pendleton, Oregon

Years cumulative data: 58 (1914 - 1971)
Total Rainfall: 716.06 inches
Total Runoff: 79.45 inches

Design Depth	Pumping Rate	Total Overflow (inches/58 yrs)	Total Legal Overflow (inches/50 yr)	Number Overflow	Number Legal Overflow	Pond Efficiency	Corrected Pond Efficiency
.6755	.1	2.32	.48	11	1	97.08	97.69
	.2	2.20	.48	11	1	97.23	97.83
	.4	2.17	.48	10	1	97.27	97.88
1.1066	.1	.67	.05	7	1	99.16	99.22
	.2	.66	.05	7	1	99.17	99.23
	.4	.66	.05	7	1	99.17	99.23
1.3	.1	.32	.0	2	0	99.60	99.60
	.2	.32	.0	2	0	99.60	99.60
	.4	.32	.0	2	0	99.60	99.60

Table 6. Feedlot Runoff Return Period Design Model Output for Selected Designs at Medford, Oregon

Years cumulative data: 58 (1914 - 1971)
Total Rainfall: 1026.49 inches
Total Runoff: 229.64 inches

Design Depth	Pumping Rate	Total Overflow (inches/58 yrs)	Total Legal Overflow (inches/50 yr)	Number Overflow	Number Legal Overflow	Pond Efficiency	Corrected Pond Efficiency
2.165	.1	9.48	2.75	15	2	95.87	97.07
	.2	7.95	2.75	10	2	96.54	97.74
	.4	7.52	2.75	8	2	96.72	97.92
2.758	≥ .1	4.71	1.74	5	1	97.95	98.71
3.1	≥ .1	3.38	1.40	4	1	98.53	99.14
3.5	≥ .1	2.54	1.00	3	1	98.89	99.33

Table 7. Feedlot Runoff Return Period Design Model Output for Selected Designs at Corvallis, Oregon

Years cumulative data: 58 (1914 - 1971)
Total Rainfall: 2242.90 inches
Total Runoff: 727.14 inches

Design Depth	Pumping Rate	Total Overflow (inches/58 yrs)	Total Legal Overflow (inches/58 yr)	Number Overflow	Number Legal Overflow	Pond Efficiency	Corrected Pond Efficiency
2.73	.1	31.51	2.06	80	1	95.66	95.94
2.73	.2	12.89	2.06	23	1	98.23	98.51
2.73	.4	6.60	2.06	13	1	99.09	99.37
3.35	.1	13.81	1.44	30	1	98.10	98.30
3.35	.2	4.64	1.44	8	1	99.36	99.56
3.35	.4	2.37	1.44	4	1	99.67	99.87
3.7	.1	7.79	1.09	15	1	98.93	99.08
3.7	.2	1.94	1.09	6	1	99.73	99.88
3.7	.4	1.21	1.09	3	1	99.83	99.98
4.5	.1	1.35	.29	4	1	99.81	99.85
4.5	≥.2	.29	.29	1	1	99.96	100.00

Table 8. Feedlot Runoff Return Period Design Model Output for Selected Designs at Astoria, Oregon

Years cumulative data: 58 (1914 - 1971)
Total Rainfall: 4316.68
Total Runoff: 1910.97

Design Depth	Pumping Rate	Total Overflow (inches/58 yrs)	Total Legal Overflow (inches/58 yr)	Number Overflow	Number Legal Overflow	Pond Efficiency	Corrected Pond Efficiency
3.78	.1	98. 2	13.75	138	4	94.83	95.55
	.2	91.76	12.23	53	4	97.81	98.45
	.4	26.16	10.73	34	4	98.63	99.19
4.45	.1	56.21	12.30	65	3	97.06	97.70
	.2	26.62	9.56	32	3	98.61	99.11
	.4	17.05	8.71	19	3	99.11	99.56
4.8	.1	44.61	10.87	49	3	97.67	98.23
	.2	21.25	8.16	29	3	98.89	99.31
	.4	13.97	7.66	18	3	99.27	99.67
5.5	.1	30.40	8.11	33	3	98.41	98.83
	.2	12.58	5.56	19	3	99.34	99.63
	.4	9.30	5.56	12	3	99.51	99.80

Table 9. Feedlot Runoff Return Period Design Model Output for Selected Designs at Tillamook, Oregon

Years cumulative data: 31 (1941 - 1971)
Total Rainfall: 2809.85 inches
Total Runoff: 1381.11 inches

Design Depth	Pumping Rate	Total Overflow (inches/31 yrs)	Total Legal Overflow (inches/31 yr)	Number Overflow	Number Legal Overflow	Pond Efficiency	Corrected Pond Efficiency
4.47	.1	56.70	0.0	73	0	95.89	95.89
	.2	9.80	0.0	11	0	99.29	99.29
	.4	2.29	0.0	3	0	99.83	99.83
5.15	.1	27.51	0.0	29	0	98.01	98.01
	.2	5.09	0.0	5	0	99.63	99.63
	.4	.64	0.0	1	0	99.95	99.95
5.5	.1	19.09	0.0	14	0	98.62	98.62
	.2	3.67	0.0	4	0	99.73	99.73
	.4	.15	0.0	1	0	99.99	99.99
6.0	.1	11.92	0.0	11	0	99.14	99.14
	.2	2.17	0.0	3	0	99.84	99.84
	.4	0.0	0.0	0	0	100.00	100.00

INTERPRETATION OF OUTPUT

The second computer model was called the sufficient design technique because it calculated the minimum pond volumes required to retain all runoff except that attributable to precipitation events in excess of the 10 year-24 hour storm. Three stations (Pendleton, Medford, and Tillamook) had design efficiencies of 100 percent (i.e. no overflow) while Ontario had the lowest average design efficiency of 99.47 percent. This design procedure, by its basic premise, satisfied the amended Federal NPDES requirements for 1977. In addition to holding all runoff from storms less than the 10 year-24 hour, the sufficient design technique held 93.33 percent of runoff from storms greater than the 10 year-24 hour.

Table 10 shows statistics on the maximum recorded precipitation at each station. In all but one case, with pumping rates of .1 times the 10 year-24 hour storm, the depth required to hold the maximum 24 hour rainfall's runoff was less than the sufficient design depths in Table 3. For example, a depth of 1.15 inches was required to hold the maximum rainfall's runoff at Pendleton, but the sufficient design depth was 1.62 inches. In addition, Astoria needed a depth of 9.68 inches to hold its maximum runoff, however, the sufficient depth was 17.79 inches. These data indicate that chronic rainfall conditions are the predominant factors determining acceptable pond designs.

As pumping rates increased at Corvallis and Astoria, the design efficiencies decreased. This resulted from smaller required pond depths to hold all runoff from storms less than the 10 year-24 hour rainfall; thus, larger legal overflows occurred.

Table 10. Statistics on Maximum Precipitations which exceed 10 year - 24 hour recurrence values at selected Oregon stations.

Station	Pumping Rate	Maximum Rainfall (inches)	Maximum Runoff (inches)	Number Storms Exceeding 10 yr - 24 hr value	Depth Required to hold Maximum Rainfall (inches)	Pond Depth at time of Maximum Precipitation (inches)
Ontario	.1 - .6	1.7	0.91	2	0.91	0.0
Pendleton	.1 - .4	1.55	0.78	2	1.15*	0.37
Medford	.1 - .6	3.30	2.35	2	2.58*	0.35
Corvallis	.1	4.28	3.93	1	4.79*	0.86
	.2 - .6	4.28	3.93	1	4.79	0.86
Astoria	.1	6.98	6.62	4	9.68*	3.06
	.2	6.98	6.62	4	7.28*	.66
	.4 - .6	6.98	6.62	4	6.78*	.16
Tillamook**	.1 - .6	4.69				

* Depth was less than final pond depth, i.e. no resultant overflow.

** Maximum precipitation did not exceed 10 year - 24 hour value in 31 years data.

Increasing pumping rates did not influence the sufficient pond depth at Ontario, Pendleton, or Medford. These stations, however, have small annual precipitations with minimum chronic influence. When a catastrophic storm (above 10 year-24 hour) occurred, the pond was either nearly empty or pumping was not permitted the previous day so that increasing the pumping rate did not reduce overflow, decrease the sufficient pond depth, or improve pond efficiency.

On the other hand, Corvallis, Astoria, and Tillamook did obtain reductions in sufficient pond depths with increased pumping rates. Corvallis and Astoria reached minimum sufficient depths at pumping rates of .4 (times the 10 year-24 hour storm) while sufficient depths at Tillamook continued to decrease as the pumping rates were increased. Tillamook, with average annual precipitation of 90.6 inches, exemplifies the need for appropriate pond volume-pumping rate design. For the sufficient depth was reduced from 10.1 inches to 7.56 inches to 5.65 inches with pumping rates increased from .1 to .2 to .4

Tables 4-9 show the first model's results of specific designs at the six locations. Comparison of the total runoff from all storms in excess of the 10 year-24 hour storm (column 7 in Table 2) with the total overflow (column 3) for specific designs in Tables 4-9 produced interesting results. For example, a design of .74 inches depth with a .1 pumping rate at Ontario (Table 4) had three overflows (two were legal) with a total overflow of .28 inches. Table 2 shows that the total runoff from storms greater than the 10 year-24 hour return value was 1.72 inches. Thus, even though the total overflow of .28 inches was much less than the 1.72 inches, this design was inadequate because an illegal overflow occurred. Astoria had 21.48 inches of runoff from the storms with return periods greater than the 10 year-24 hour return value. A design of 5.5 inches depth and .2 pumping rate had only 12.58 inches of overflow. However, 16 illegal discharges occurred. In both cases, the total discharge was less than legal, but the designs would be judged inferior by present Guidelines since illegal pond overflows resulted. These calculations suggest that the present overflow criteria are not optimum from either an economic or pollution control point of view.

At Ontario, the feedlot model determined a sufficient design depth of .75 inches to satisfy NPDES Guidelines, while the N = 97 (in runoff equation) design produced a 58 percent overdesign and the 10 year-24 hour precipitation design of 1.5 inches was 100 percent larger than the sufficient design. At Pendleton, the model determined a sufficient design of 1.62 inches for all pumping rates. The designs based on standard storms were again inaccurate, but this time produced insufficient capacities. The N = 97 design had a design depth of 1.11 inches and the 10 year-24 hour precipitation design depth was 1.3 inches. The 25 year-24 hour precipitation design depth of 1.5 inches was also insufficient since this design permitted two illegal discharges.

The sufficient design depth at Corvallis decreased with increasing pumping rates. The sufficient design depth decreased from 6.11 inches to 4.15 inches when the pumping rate was increased from .1 to .2. The return period design technique was also inconsistent at this station. For designs of N = 91, N = 97, and the 10 year-24 hour precipitation value, all resulted in insufficient design volumes, while the 25 year-24 hour precipitation design was more than adequate.

At stations where chronic conditions predominate, the return period design method also produced erroneous results. For example, at Astoria this technique determined insufficient capacities; the 25 year-24 hour precipitation design of 5.5 inches was substantially less than the 9.23 inch sufficiency design with a .2 pumping rate. The 5.5 design had 16 illegal discharges.

In most cases, the 25 year-24 hour storm design value in the return period technique produced insufficient storage volumes. At one station, however, the 25 year-24 hour value provided twice the necessary volume. Thus, the currently used return period design technique was inadequate, and its design results were unpredictable. On the other hand, the sufficient design technique was much more effective as a design tool. The sufficient technique minimizes the pond volume required, at a selected pumping rate, to satisfy environmental protection standards.

CONCLUSIONS

A computer simulation model has been developed which can be used to size feedlot runoff retention basins based upon previous climatological records. The sufficient design method was used to determine the minimum storage volume required to prevent illegal discharges as defined by the EPA Effluent Guidelines. This technique demonstrated that to use design procedures based upon a factor times the 10 year-24 hour or the 25 year-24 hour storm led to designs that were either unreasonably expensive or which led to illegal discharges for which the livestock producer was subject to monetary penalties.

The model was used to determine pollution control performance with various combinations of pumping rates and storage facility volumes. In some locations, the use of high capacity irrigation equipment allowed reduction of the storage capacity by over 45 percent when a larger pumping system was specified. In other locations, due to the precipitation pattern, no benefit was obtained by the use of pumping equipment with capacity in excess of 0.10 (10 year-24 hour storms).

Utilization of the sufficient design technique requires the compilation of weather data for a unique climatological region under consideration. The model is relatively inexpensive to operate and a complete climatological region can be analyzed for less than $20, once the region's climatic data are computerized.

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7. Schwab, G. O., R. K. Frevert, J. W. Edminister, and K. K. Barnes. Soil and water conservation engineering. 2nd Edition. John Wiley and Sons, 1966.

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APPENDIX A.1

Return Period Design Method Simulation Program Listing and Documentation

General Program Information

Title: Cattle Feedlot Runoff Reservoir Return Period Design Simulation Model

Authors: R. B. Wensink and J. R. Miner

Installation: CDC 3300 at Oregon State University

Programming Language: Standard FORTRAN IV

Date Written: Fall 1974

Remarks:

This simulation model operates continuously from one year to the next and requires inputs of daily precipitations and average temperatures. Major design parameters required in the model are reservoir volume and irrigation pumping capacity.

Program Output:

The output variable names are defined in the program.

A. Yearly Results (for each year simulated)

1. Total number of reservoir overflows
2. Total number of illegal reservoir overflows
3. Inches legal reservoir overflow
4. Inches illegal reservoir overflow
5. Inches total reservoir overflow
6. Maximum reservoir depth
7. Maximum precipitation
8. Total rainfall
9. Total runoff

B. Total run results

1. Years simulated
2. Total rainfall
3. Total reservoir overflow
4. Total runoff
5. Average precipitation
6. Average reservoir overflow
7. Average runoff
8. Pond efficiency
9. Corrected (for legal overflow) pond efficiency

<u>Program Input</u>:

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

A. Order of Job Control Language Cards

$^{7}_{8}$ JOB Card

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

FORTRAN
SOURCE
DECK

7 7
8 8

DATA
DECK

7 7
8 8

$^{7}_{8}$ LOG OFF

B. Preparation of the Data Deck

1. The data deck consists of file names and years of weather data. Each card contains a file name which corresponds to a particular station-year and the corresponding data year. The format is (R8, 2X, I4).

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

   a. ISTART and IFINAL should be set to the first and last year, respectively, of the data utilized in a particular run.
   b. LIN and LOUT correspond to computer installation input and output logical unit numbers, respectively.
   c. DDEPTH should be set to the design pond volume in inches (acre-inches/acre).
   d. RAINMAX should be set to 0.0 unless dewatering is permitted on days in which rainfall occurs. If this condition is desired, set RAINMAX to the maximum level of rainfall at which dewatering is still permitted.
   e. EXPRAIN should be set to the station's 10 year-24 hour recurrence storm.

2. The climatic data files must be created prior to running this simulation program. Each file must contain one year of weather data from a particular station. These data consist of rainfalls and temperatures. Each record contains four consecutive days of rainfall-temperature data punched in the following format 4(I4, F5.2).

```
      PROGRAM RUNOFF
C
C
C
C                    CATTLE FEEDLOT RUNOFF RESERVOIR
C
C                    RETURN PERIOD DESIGN METHOD
C
C                         SIMULATION MODEL
C
C
C
C             THIS MODEL EVALUATES A SPECIFIC FEEDLOT RETENTION
C             RESERVOIR DESIGN.MAJOR DESIGN PARAMETERS ARE
C             RESERVOIR VOLUME AND IRRIGATION PUMPING CAPACITY.
C
C
C
C
C
C                              VARIBLE DEFINITIONS
C
C
C

C     LIN = INPUT UNIT
C     LOUT = OUTPUT UNIT
C     IDAYPM = NUMBER OF DAYS PER MONTH
C     ISTART = FIRST YEAR OF DATA
C     IFINAL = LAST YEAR OF DATA
C     DDEPTH = DESIGN DEPTH OF POND
```

```
C       RAINMX = MAXIMUM RAINFALL THAT OCCURED DURING EACH YEAR
C       RAINMAX = DEWATERING PERMITTED ON DAYS WITH RAINFALL
C                LESS THAN THIS VALUE
C       EXPRAIN = 10 YEAR-24 HOUR EXPECTED RECURRENCE RAINFALL VALUE
C       ANTCON = 5 DAY ANTICEDENT MOISTURE ACCUMULATION
C       DEPTH = DEPTH OF POND
C       IWARMC = SEASONAL CRITERION IN RUNOFF EQUATION
C       MINTEMP = FREEZING CRITERION
C       IDAYEAR = NUMBER OF DAYS IN A YEAR
C       PUMPDP = DAILY PUMPING CAPACITY
C       INO = NUMBER OF YEARS OF DATA
C       XNAME = FILE NAME FOR WEATHER DATA
C       ITEMP = TEMPERATURE DATA
C       RAIN = RAINFALL DATA
C       BGANTC = STORE END OF YEAR RAINFALL
C       IBGTMP = STORE END OF YEAR TEMPERATURE
C       ISUM = THREE DAY ANTICEDENT TEMPERATURE
C       Q = DAILY RUNOFF
C       IDAYOV = NUMBER OF DAYS PER YEAR THAT THE POND OVERFLOWED
C              WHEN RAINFALL WAS GREATER THAN 10 YEAR-24 HOUR VALUE
C       DPTHMX = MAXIMUM DEPTH OF POND FOR EACH YEAR
C       OVERFL = TOTAL AMOUNT OF OVERFLOW FOR EACH YEAR
C       OFILLEGL = TOTAL AMOUNT OF ILLEGAL OVERFLOW FOR EACH YEAR
C       OFLEGAL = TOTAL AMOUNT OF LEGAL OVERFLOW FOR EACH YEAR
C       ILLEGAL = NUMBER OF ILLEGAL OVERFLOWS THAT OCCURRED
C               DURING EACH YEAR
```

```
C     PONDEF = POND EFFICIENCY
C     CPONDEF = CORRECTED POND EFFICIENCY
C     TTRAIN = TOTAL RAINFALL FOR EACH YEAR
C     TRUNOF = TOTAL RUNOFF FOR EACH YEAR
C     TOTALR =  TOTAL RAINFALL FOR ALL YEARS
C     TOTALO = TOTAL OVERFLOW FROM POND FOR ALL YEARS
C     TOTALF = TOTAL RUNOFF FOR ALL YEARS
C     AVGPRC = AVERAGE RAINFALL
C     AVGOVR = AVERAGE OVERFLOW
C     AVGROF = AVERAGE RUNOFF
C
C     XOVER,XRAIN,KYEAR,KDAY ARE USED FOR PRINTING OUT
C            INTERMEDIATE RESULTS ON ILLEGAL OVERFLOWS
C     YOVER,YRAIN,NYEAR,NDAY ARE USED FOR PRINTING OUT
C            INTERMEDIATE RESULTS ON LEGAL OVERFLOWS
C
C
      DIMENSION ITEMP(366),RAIN(366),IDAYPM(13),BGANTC(6),
     1IBGTMP(6),OVERFL(60),IDAYOV(60),DPTHMX(60),RAINMX(60),TTRAIN(60),
     2TRUNOF(60),ILLEGAL(60),
     3KYEAR(60),KDAY(60),XRAIN(60),XOVER(60),OFLEGAL(60),OFILLEGL(60)
     4,NYEAR(60),NDAY(60),YRAIN(60),YOVER(60)
      DATA(IDAYPM=31,28,31,30,31,30,31,31,30,31,30,31,0)
      DATA(LIN=60),(LOUT=61)
      DATA(DDEPTH=.74),(RAINMAX=0.0)
      DATA(ISTART=1914),(IFINAL=1971)
      DATA(EXPRAIN=1.5)
      ANTCDN=0.0
      DEPTH=0.0
      IWARMC=45
      MINTEMP=96
      IDAYEAR=365
```

```
      PUMPDP=.2*DDEPTH
      INO=IFINAL-ISTART+1
      WRITE(61,1)
    1 FORMAT(3X,4(5X,≠YEAR≠,2X,≠DAY≠,3X,≠RAIN≠,2X,≠OVERFLOW≠))
      DO500K=1,INO
      NN=0
C
C        **************  READ IN YEARLY DATA  **************
C
C                        READ IN FILE NAME
C
      READ(LIN,6001)XNAME, IYEAR
 6001 FORMAT(R8,2X,I4)
      LYEAR=IYEAR/4*4
      IF(LYEAR.NE.IYEAR) GO TO 10
      IDAYPM(2)=29
      IDAYEAR=366
   10 CALL EQUIP(2,XNAME     )
C
C                          READ IN DATA
C
      READ (2,6002)(ITEMP(I),RAIN(I),I=1,IDAYEAR)
 6002 FORMAT(8(I5,F5.2))
      DPTHMX(K)=0.0
      IF(K.GT.1)GO TO 15
      DO 20 IJ=1,6
      J=IDAYEAR-IJ+1
      II=6-IJ+1
      BGANTC(II)=RAIN(J)
   20 IBGTMP(II)=ITEMP(J)
      DO 21 I=1,5
   21 ANTCDN=ANTCDN+BGANTC(I)
```

```
   15 DO 400 I=1,IDAYEAR
      IF(I.GT.6) GO TO 30
      IF(I.EQ.1) GO TO 25
      ANTCDN=RAIN(I-1)+ANTCDN-BGANTC(I)
      GO TO 40
   25 ANTCDN=BGANTC(6)+ANTCDN-BGANTC(1)
      GO TO 40
   30 ANTCDN=ANTCDN+RAIN(I-1)-RAIN(I-6)
   40 IF(RAIN(I).GT.RAINMAX)GOTO180
C
C      ************* CHECK IRRIGATION CONDITION ******************
C
C                            CHECK WATER LEVEL
C
      IF(DEPTH.LE.0.01)GOTO180
C
C                         CHECK TEMPERATURE
C
      IF(ITEMP(I).LE.32)GOTO180
C
C                        CHECK GROUND FROZEN
C
      IF(I.LT.3)GOTO60
      ISUM=ITEMP(I-3)+ITEMP(I-2)+ITEMP(I-1)
      GOTO80
   60 IF(I.EQ.1)GOTO70
      IF(I.EQ.2)GOTO75
      ISUM=IBGTMP(6)+ITEMP(1)+ITEMP(2)
      GO TO 80
   70 ISUM=IBGTMP(6)+IBGTMP(5)+IBGTMP(4)
      GOTO80
   75 ISUM=IBGTMP(6)+IBGTMP(5)+ITEMP(1)
```

```
   80 IF(ISUM.GT.MINTEMP)GOTO100
      MINTEMP=114
      GOTO180
  100 MINTEMP=96
      IF(DEPTH.LE.PUMPDP)GOTO130
      DEPTH=DEPTH-PUMPDP
      GOTO180
  130 DEPTH=0.0
C**********RAINFALL LESS THAN .05 IS CONSIDERED INSIGNIFICANT**********
  180 IF(RAIN(I).LE.0.05)GOTO400
C
C      **************** DETERMINE RUNOFF ***************
C
C                     DETERMINE WARM OR COLD SEASON
C
      IF(ITEMP(I).GT.IWARMC)GOTO0250
C                                    COLD SEASON
      IF(ANTCDN-1.1)260,260,320
C                                WARM SEASON
  250 IF(ANTCDN.GT.2.1)GOTO320
C                     ANTICEDENT CONCITION NO.  II
  260 Q=(RAIN(I)-0.1978)**2/(RAIN(I)+.7912)
      GOTO340
C                     ANTICEDENT CONCITION NO. III
  320 Q=(RAIN(I)-.0618)**2/(RAIN(I)+.247)
  340 DEPTH=DEPTH+Q
C
C                      CHECK FOR MAXIMUM
C
      IF(RAINMX(K).LE.RAIN(I))RAINMX(K)=RAIN(I)
      TTRAIN(K)=TTRAIN(K)+RAIN(I)
      TRUNOF(K)=TRUNOF(K)+Q
```

```
      IF(DPTHMX(K).LE.DEPTH)DPTHMX(K)=DEPTH
      IF(DEPTH.LE.DDEPTH) GOTO400
      OVER=DEPTH-DDEPTH
C
C              CHECK FOR RAINFALL OVER 10YEAR-24HOUR VALUE
C
      IF(RAIN(I).LT.EXPRAIN)GO TO 350
C
C             LEGAL OVERFLOW OCCURRED
C
      NN=NN+1
      NYEAR(NN)=ISTART+K-1
      NDAY(NN)=I
      YRAIN(NN)=RAIN(I)
      YOVER(NN)=OVER
      OFLEGAL(K)=OFLEGAL(K)+OVER
      GO TO 380
C
C            ILLEGAL OVERFLOW OCCURRED
C
  350 ILLEGAL(K)=ILLEGAL(K)+1
      M=ILLEGAL(K)
      KYEAR(M)=ISTART+K-1
      KDAY(M)=I
      XRAIN(M)=RAIN(I)
      XOVER(M)=OVER
      OFILLEGL(K)=OFILLEGL(K)+OVER
  380 IDAYOV(K)=IDAYOV(K)+1
      OVERFL(K)=OVERFL(K)+OVER
      DEPTH=DDEPTH
  400 CONTINUE
C
```

```
C             WRITE OUT INTERMEDIATE RESULTS
C
      JJ=ILLEGAL(K)
      IF(JJ.EQ.0)GO TO 410
      WRITE(51,6106)(KYEAR(M),KDAY(M),XRAIN(M),XOVER(M),M=1,JJ)
 6106 FORMAT(8X,≠ILLEGAL OVERFLOW≠,/,3X,4(5X,I4,2X,I3,2X,F6.2,2X,F6.2))
  410 IF(NN.EQ.0)GO TO 420
      WRITE(51,6105)(NYEAR(N),NDAY(N),YRAIN(N),YOVER(N),N=1,NN)
 6105 FORMAT(8X,≠LEGAL OVERFLOW≠,/,3X,4(5X,I4,2X,I3,2X,F6.2,2X,F6.2))
  420 CALL UNEQUIP(2)
      DO 450 I=1,6
      J=IDAYEAR-I+1
      II=6-I+1
      BGANTC(II)=RAIN(J)
  450 IBGTMP(II)=ITEMP(J)
      IDAYEAR=365
  500 CONTINUE
C
C       ***************CALCULATE STATISTICS****************
C
      DO550I=1,INO
      TOTALR=TOTALR+TTRAIN(I)
      TOTALO=TOTALO+OVERFL(I)
      TLEGAL=TLEGAL+OFLEGAL(I)
  550 TOTALF=TOTALF+TRUNOF(I)
      AVGPRC=TOTALR/INO
      AVGOVR=TOTALO/INO
      AVGROF=TOTALF/INO
      PONDEF=100-TOTALO*100/TOTALF
      CPONDEF=100-(TOTALO-TLEGAL)*100/TOTALF
```

```
C
C                           WRITE OUT RESULTS
C
      WRITE(LOUT,6100)
 6100 FORMAT(1H1,19X,≠TOTAL NO.≠,4X,≠NO. ILLEGAL≠,
     14X,≠IN. LEGAL≠,3X,≠IN. ILLEGAL≠,3X,≠IN. TOTAL≠,3X,≠MAXIMUM≠,3X,
     2≠MAXIMUM≠,4X,≠TOTAL≠,5X,≠TOTAL≠)
      WRITE(LOUT,6101)
 6101 FORMAT(10X,≠YEAR≠,5X,≠OVERFLOWS≠,5X,≠OVERFLOWS≠,5X,≠OVERFLOW≠,
     15X,≠OVERFLOW≠,5X,≠OVERFLOW≠,5X,≠DEPTH≠,6X,≠RAIN≠,6X,≠RAIN≠,
     25X,≠RUNOFF≠)
      DO 600 I=ISTART,IFINAL
      J=I-ISTART+1
      WRITE(LOUT,6103) I,IDAYOV(J),ILLEGAL(J),OFLEGAL(J),OFILLEGL(J),
     1OVERFL(J),DPTHMX(J),RAINMX(J),TTRAIN(J),TRUNOF(J)
 6103 FORMAT(10X,    I4,8X,I4,10X,I4,6X,F8.2,6X,F8.2,4X,F8.2,2X,F8.2,3X,
     1F8.2,3X,F8.2,3X,F8.2)
  600 CONTINUE
      WRITE(LOUT,6104)ISTART,IFINAL,TOTALR,TOTALO,TOTALF,AVGPRC,AVGOVR,
     1AVGROF,PONDEF,CPONDEF
 6104 FORMAT(≠0≠,30X,≠TOTAL STATISTICS FOR YEARS≠,I8,2X,≠TO≠,I8//
     130X,≠TOTAL RAINFALL=≠,F10.2/
     230X,≠TOTAL OVERFLOW=≠,F10.2/
     330X,≠TOTAL RUNOFF=≠,F10.2/
     430X,≠AVERAGE PRECIPITATION=≠,F10.2/
     530X,≠AVERAGE OVERFLOW=≠,F10.2/
     630X,≠AVERAGE RUNOFF≠,F10.2/
     730X,≠POND EFFICIENCY =≠,F6.2/
     830X,≠CORRECTED POND EFFICIENCY =≠,F6.2)
      STOP
      END
```

APPENDIX A.2

Sufficient Design Technique Simulation Program Listing and Documentation

General Program Information

Title: Cattle Feedlot Runoff Reservoir Sufficient Design Simulation Model

Authors: R. B. Wensink and J. R. Miner

Installation: CDC 3300 at Oregon State University

Programming Language: Standard FORTRAN IV

Date Written: Spring 1975

Remarks:

This simulation model also operates continuously from one year to the next and requires daily precipitations and average temperatures. The model determines the minimum reservoir storage volume required to meet Environmental Protection Agency's performance standards with a specific irrigation pumping capacity. The pumping capacity, expressed in a fraction of the location's 10 year-24 hour storm, is the only major design parameter required in the model.

Program Output:

The output variable names are defined in the program.

A. Yearly Results (for each year simulated)

1. Total number of reservoir overflows
2. Maximum reservoir depth
3. Inches of legal overflow
4. Maximum rainfall
5. Total rainfall
6. Total runoff
7. Total rainfall over 10 year-24 hour storm
8. Total runoff from precipitation over 10 year-24 hour storm

B. Total run results

1. Total years simulated
2. Total rainfall
3. Total runoff
4. Total legal overflow from precipitation over 10 year-24 hour storm
5. Total runoff from precipitation over 10 year-24 hour storm
6. Average precipitation
7. Average legal overflow from precipitation over 10 year-24 hour storm
8. Average runoff
9. Average runoff from precipitation over 10 year-24 hour storm
10. Minimum design reservoir depth required to hold all precipitation less than 10 year-24 hour storm.

Program Input:

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

A. Order of Job Control Language Cards

7
8 JOB Card

7
8 FORTRAN, L, R

FORTRAN
SOURCE
DECK

7 7
8 8

DATA
DECK

7 7
8 8

7
8 LOGOFF

B. Preparation of the Data Deck

1. The data deck consists of file names and years of weather data. Each card contains a file name which corresponds to a particular station-year and the corresponding data year. The format is (R8, 2X, I4).

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

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

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

c. DDEPTH should be set to the expected 10 year-24 hour recurrence storm.

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

e. EXPRAIN should be set to the station's 10 year-24 hour recurrence storm.

2. The climatic data files must be created prior to running this simulation program. Each file must contain one year of weather data from a particular station. These data consist of rainfalls and temperatures. Each record contains four consecutive days of rainfall-temperature data punched in the following format 4(I4, F5.2).

```
      PROGRAM RUNOFF
C
C
C
C                   CATTLE FEEDLOT RUNOFF RESERVOIR
C
C                   SUFFICIENT DESIGN TECCHNIQUE
C
C                        SIMULATION MODEL
C
C
C
C             THIS MODEL DETERMINES THE MINIMUM RESERVOIR
C             STORAGE VOLUME REQUIRED TO MEET ENVIROMENTAL
C             PROTECTION AGENCY PERFORMANCE STANDARDS WITH A
C             SPECIFIC IRRIGATION PUMPING CAPACITY.
C
C
C
C
C
C                             VARIBLE DEFINITIONS
C
C
C
C     LIN = INPUT UNIT
C     LOUT = OUTPUT UNIT
C     IDAYPM = NUMBER OF DAYS PER MONTH
C     ISTART = FIRST YEAR OF DATA
C     IFINAL = LAST YEAR OF DATA
C     DDEPTH = 10 YEAR-24 HOUR EXPECTED RECURRENCE RAINFALL VALUE
C     RAINMX = MAXIMUM RAINFALL THAT OCCURED DURING EACH YEAR
```

```
C       RAINMAX = DEWATERING PERMITTED ON DAYS WITH RAINFALL
C                LESS THAN THIS VALUE
C       EXPRAIN = 10 YEAR-24 HOUR EXPECTED RECURRENCE RAINFALL VALUE
C       ANTCON = 5 DAY ANTICEDENT MOISTURE ACCUMULATION
C       DEPTH = DEPTH OF POND
C       IWARMC = SEASONAL CRITERION IN RUNOFF EQUATION
C       MINTEMP = FREEZING CRITERION
C       IDAYEAR = NUMBER OF DAYS IN A YEAR
C       PUMPDP = DAILY PUMPING CAPACITY
C       INO = NUMBER OF YEARS OF DATA
C       XNAME = FILE NAME FOR WEATHER DATA
C       ITEMP = TEMPERATURE DATA
C       RAIN = RAINFALL DATA
C       BGANTC = STORE END OF YEAR RAINFALL
C       IBGTMP = STORE END OF YEAR TEMPERATURE
C       ISUM = THREE DAY ANTICEDENT TEMPERATURE
C       Q = DAILY RUNOFF
C       RAINOV = YEARLY ACCUMULATION OF RAINFALL OVER
C              10 YEAR-24 HOUR EXPECTED STORM VALUE
C       IDAYOV = NUMBER OF DAYS PER YEAR THAT THE POND OVERFLOWED
C              WHEN RAINFALL WAS GREATER THAN 10 YEAR-24 HOUR VALUE
C       DEPTHO = DEPTH OF POND WHEN RAIN EXCEEDED 10 YEAR-24 HOUR VALUE
C       DPTMXYR = MAXIMUM DEPTH THAT POND REACHED DURING THE YEAR
C       OVERFLOW = AMOUNT THAT THE POND OVERFLOWED
C       DPTMAX = MAXIMUM POND DEPTH
C       RUNOFO = AMOUNT OF RUNOFF FOR EACH YEAR
C       TTRAIN = TOTAL RAINFALL FOR EACH YEAR
C       TRUNOF = TOTAL RUNOFF FOR EACH YEAR
C       TOTRFO = TOTAL RUNOFF FROM STORMS GREATER THAN
C              10 YEAR-24 HOUR VALUE
C       TOTALR =  TOTAL RAINFALL FOR ALL YEARS
C       TOTALO = TOTAL LEGAL OVERFLOW FROM POND FOR ALL YEARS
```

```
C     TOTALF = TOTAL RUNOFF FOR ALL YEARS
C     AVGPRC = AVERAGE RAINFALL
C     AVGOVR = AVERAGE LEGAL OVERFLOW
C     AVGROF = AVERAGE RUNOFF
C     AVGRFO = AVERAGE OVERFLOW FROM STORMS GREATER THAN 10 YEAR
C              EXPECTED STORM
C
C
C
      DIMENSION ITEMP(366),RAIN(366),IDAYPM(13),BGANTC(6),
     1IBGTMP(6),OVERFL(60),IDAYOV(60),RAINMX(60),TTRAIN(60),
     2TRUNOF(60),DPTMXYR(60),RUNOFO(60),RAINOV(60)
      DATA(IDAYPM=31,28,31,30,31,30,31,31,30,31,30,31,0)
      DATA(LIN=60),(LOUT=61)
      DATA(ISTART=1916),(IFINAL=1920)
      DATA(DDEPTH=1.3),(RAINMAX=0.0)
      DATA(EXPRAIN=4.8)
      ANTCDN=0.0
      DEPTH=0.0
      IWARMC=45
      MINTEMP=96
      IDAYEAR=365
      PUMPDP=.4*DDEPTH
      INO=IFINAL-ISTART+1
      DO500K=1,INO
      NN=0
C
C       *************  READ IN YEARLY DATA  *************
C
C                      READ IN FILE NAME
C
      READ(LIN,6001)XNAME, IYEAR
```

```
 6001 FORMAT(R8,2X,I4)
      LYEAR=IYEAR/4*4
      IF(LYEAR.NE.IYEAR) GO TO 10
      IDAYPM(2)=29
      IDAYEAR=366
   10 CALL EQUIP(2,XNAME     )
C
C                                READ IN DATA
C
      READ (2,6002)(ITEMP(I),RAIN(I),I=1,IDAYEAR)
 6002 FORMAT(8(I5,F5.2))
      IF(K.GT.1)GO TO 15
      DO 20 IJ=1,6
      J=IDAYEAR-IJ+1
      II=6-IJ+1
      BGANTC(II)=RAIN(J)
   20 IBGTMP(II)=ITEMP(J)
      DO 21 I=1,5
   21 ANTCON=ANTCON+BGANTC(I)
   15 DO 400 I=1,IDAYEAR
      IF(I.GT.6) GO TO 30
      IF(I.EQ.1) GO TO 25
      ANTCON=RAIN(I-1)+ANTCON-BGANTC(I)
      GO TO 40
   25 ANTCON=BGANTC(6)+ANTCON-BGANTC(1)
      GO TO 40
   30 ANTCON=ANTCON+RAIN(I-1)-RAIN(I-6)
   40 IF(RAIN(I).GT.RAINMAX)GOTO180
```

```
C    -
C       ************** CHECK IRRIGATION CONDITION ******************
C
C                            CHECK WATER LEVEL
C
      IF(DEPTH.LE.0.01)GOTO180
C
C                         CHECK TEMPERATURE
C
      IF(ITEMP(I).LE.32)GOTO180
C
C                        CHECK GROUND FROZEN
C
      IF(I.LT.3)GOTO60
      ISUM=ITEMP(I-3)+ITEMP(I-2)+ITEMP(I-1)
      GOTO80
   60 IF(I.EQ.1)GOTO70
      IF(I.EQ.2)GOTO75
      ISUM=IBGTMP(6)+ITEMP(1)+ITEMP(2)
      GO TO 80
   70 ISUM=IBGTMP(6)+IBGTMP(5)+IBGTMP(4)
      GOTO80
   75 ISUM=IBGTMP(6)+IBGTMP(5)+ITEMP(1)
   80 IF(ISUM.GT.MINTEMP)GOTO100
      MINTEMP=114
      GOTO180
  100 MINTEMP=96
      IF(DEPTH.LE.PUMPDP)GOTO130
      DEPTH=DEPTH-PUMPDP
      GOTO180
  130 DEPTH=0.0
C**********RAINFALL LESS THAN .05 IS CONSIDERED INSIGNIFICANT**********
  180 IF(RAIN(I).LE.0.05)GOTO400
```

```
C
C      **************** DETERMINE RUNOFF ***************
C
C                       DETERMINE WARM OR COLD SEASON
C
      IF(ITEMP(I).GT.IWARMC)GOTO250
C                                 COLD SEASON
      IF(ANTCDN-1.1)260,260,320
C                             WARM SEASON
  250 IF(ANTCDN.GT.2.1)GOTO320
C                       ANTICEDENT CONDITION NO.  II
  260 Q=(RAIN(I)-0.1978)**2/(RAIN(I)+.7912)
      GOTO340
C                       ANTICEDENT CONDITION NO. III
  320 Q=(RAIN(I)-.0618)**2/(RAIN(I)+.247)
C
C                        CHECK FOR MAXIMUM
C
C
C                    CHECK FOR RAINFALL OVER 10YEAR-24HOUR VALUE
C
  340 IF(RAIN(I).LE.EXPRAIN)GO TO 342
      RAINOV(K)=RAINOV(K)+RAIN(I)
      NYEAR=ISTART+K-1
      DEPTHO=DEPTH+Q
      IF(DEPTHO.GT.DPTMAX)GO TO 341
      IF(DPTMXYR(K).LT.DEPTHO)DPTMXYR(K)=DEPTHO
      OVERFLOW=0.0
      GO TO 345
```

```
C
C                 LEGAL OVERFLOW OCCURRED
C
  341 DEPTH=DPTMAX
      OVERFLOW=DEPTHO-DPTMAX
      OVERFL(K)=OVERFL(K)+OVERFLOW
      IDAYOV(K)=IDAYOV(K)+1
      DPTMXYR(K)=DPTMAX
C
C               WRITE OUT INTERMEDIATE RESULTS
C
  345 WRITE(61,6111)NYEAR,I,RAIN(I),DEPTHO,Q,DPTMAX,OVERFLOW
 6111 FORMAT(4X,≠YEAR≠,4X,≠DAY≠,4X,≠RAIN≠,4X,≠DEPTH≠,
     14X,≠  Q ≠,4X,≠MAX DEPTH≠,4X,≠OVERFLOW≠,/,4X,I4,4X,I3,3X,
     2F5.2,3X,F5.2,5X,F5.2,4X,F6.2,8X,F5.2)
      RUNOFO(K)=RUNOFO(K)+Q
      GO TO 343
C
C               RAINFALL WAS LESS THAN 10YEAR-24HOUR VALUE
C
  342 DEPTH=DEPTH+Q
      IF(DEPTH.GT.DPTMAX)DPTMAX=DEPTH
      IF(DEPTH.GT.DPTMXYR(K))DPTMXYR(K)=DEPTH
  343 CONTINUE
      IF(RAINMX(K).LE.RAIN(I))RAINMX(K)=RAIN(I)
      TTRAIN(K)=TTRAIN(K)+RAIN(I)
      TRUNOF(K)=TRUNOF(K)+Q
  400 CONTINUE
      CALL UNEQUIP(2)
      DO 450 I=1,6
      J=IDAYEAR-I+1
      II=6-I+1
      BGANTC(II)=RAIN(J)
```

```
  450 IBGTMP(II)=ITEMP(J)
      IDAYEAR=365
  500 CONTINJE
C
C   *    **************CALCULATE STATISTICS*****************
C
      DO550I=1,INO
      TOTRFO=TOTRFO+RUNOFO(I)
      TOTALR=TOTALR+TTRAIN(I)
      TOTALO=TOTALO+OVERFL(I)
  550 TOTALF=TOTALF+TRUNOF(I)
      AVGRFO=TOTRFO/INO
      AVGPRC=TOTALR/INO
      AVGOVR=TOTALO/INO
      AVGROF=TOTALF/INO
C
C                         WRITE OUT RESULTS
C
      WRITE(LOUT,6100)
 6100 FORMAT(1H1,6X,≠YEAR≠,5X,≠TOTAL NO.≠,5X,≠MAX DEPTH≠,5X,
     1≠IN. LEGAL≠,5X,≠MAXIMUM≠,4X,≠TOTAL≠,6X,≠TOTAL≠,7X,≠TOTAL RUNOFF≠,
     27X,≠TOTAL RAINFALL≠,/,16X,≠OVERFLOWS≠,5X,≠PER YEAR≠,6X,
     3≠OVERFLOW≠,7X,≠RAIN≠,6X,≠RAIN≠,6X,≠RUNOFF≠,5X,≠OVER 10YR STORM≠,
     45X,≠OVER 10YR STORM≠)
      DO 600 I=ISTART,IFINAL
      J=I-ISTART+1
      WRITE(LOUT,6103)I,IDAYOV(J),DPTMXYR(J),
     1OVERFL(J),RAINMX(J),TTRAIN(J),TRUNOF(J),RUNOFO(J),RAINOV(J)
 6103 FORMAT(7X,I4,8X,I3,9X,F6.2,8X,F6.2,6X,F6.2,5X,F6.2,
     15X,F6.2,9X,F6.2,13X,F6.2)
  600 CONTINUE
      WRITE(LOUT,6104)ISTART,IFINAL,TOTALR,TOTALO,TOTALF,TOTRFO,
     1AVGPRC,AVGOVR,AVGROF,AVGRFO
```

```
 6104 FORMAT(≠0≠,30X,≠TOTAL STATISTICS FOR YEARS≠,I8,2X,≠TO≠,I8//
     130X,≠TOTAL RAINFALL=≠,F10.2/
     230X,≠TOTAL OVERFLOW=≠,F10.2/
     330X,≠TOTAL LEGAL OVERFLOW FROM EXCEEDING POND DEPTH=≠,F9.2/
     430X,≠TOTAL OVERFLOW FROM ALL STORMS > 10YR EXPECTED STORM=≠,F9.2/
     530X,≠AVERAGE PRECIPITATION =≠,F9.2/
     530X,≠AVERAGE LEGAL OVERFLOW FROM EXCEEDING POND DEPTH=≠,F9.2/
     630X,≠AVERAGE RUNOFF≠,F10.2/
     730X,≠AVERAGE OVERFLOW FROM STORMS > 10YR EXPECTED STORM=≠,F9.2)
      WRITE(61,6611)DPTMAX
6611  FORMAT(30X,≠POND DEPTH TO HOLD ALL ILLEGAL OVERFLOW=≠,F8.2)
      STOP
      END
```