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A LAND DISPOSAL SYSTEM FOR MEAT PACKING WASTES

by

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INTRODUCTION

The meat packing and processing industry is a major industry in the United States with approximately 14,000 establishments processing red meats (Witherow, 1973). Of these 14,000 establishments, 10,000 are estimated to be small plants as defined by an annual liveweight kill (LWK) of less than 25,000,000 pounds (Witherow, 1973). In 1975, Kansas was ranked fifth in the nation in cattle slaughter with a total of 2.8 million head (Kansas State Board of Agriculture, 1976).

Because of the trend in meat processing to locate plants near the source of the animals, many operations find themselves the major industry of small communities in the Great Plains area of the United States. Slaughtering and processing produce large amounts of highly organic, highly nitrogenous, biodegradable wastewater with a high concentration of suspended and dissolved solids (Gloyna et al., 1968). The plants located in small communities, therefore, often find themselves faced with the choice of installing their own wastewater treatment systems or paying high surcharges if they try to use the municipal treatment system. Most packing plants located in rural areas where land is relatively inexpensive use stabilization ponds for both primary and secondary treatment. New federal water quality regulations relating to effluent discharge may make previously acceptable systems in need of modification to lower the suspended solids concentration of the effluent. For industries located in agricultural areas, use of wastewater for land disposal is a viable alternative to costly tertiary treatment processes.

REVIEW OF LITERATURE

General Information

The meat processing industry has been classified in four major categories, principly by the amount of processing done to the carcass (North Star, 1973). Simple slaughterhouses, or abattoirs, are confined to the operations of slaughtering with a minimum of secondary by-product recovery. The carcass is shipped fresh or frozen elsewhere to be processed. Complex slaughterhouses conduct secondary by-product recovery operations such as blood and hide recovery, rendering and casing saving. Again, as in simple slaughterhouses, the carcass is shipped elsewhere for processing. The remaining two categories are packinghouses where the carcass is processed with the main difference between the two being the amount of processed products relative to kill. Low-processing packinghouses have a processed products-to-liveweight-kill ratio of less than .4 and high-processing packinghouses have a ratio greater than .4. Because of the nature of these operations, wastewater from each type becomes more polluted as the degree of complexity increases with wastewater from simple slaughterhouses being the least polluted.

The wastewater from each of these operations has been classified by several common pollution parameters (North Star, 1973). These are: five day biochemical oxygen demand (BOD_5), suspended solids, grease, total Kjeldahl nitrogen, chlorides, and total phosphorus. In addition, information on ammonia, nitrate nitrogen, total dissolved solids (TDS), and chemical oxygen demand (COD) is useful.

BOD is defined as "the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions" (Sawyer and McCarthy, 1967). BOD is used to determine the pollution strength of a waste in terms of the oxygen demand it will place on the receiving body of water. The major limitation in the test is the amount of time required to determine the ultimate demand. From experience, it has been found that the greatest percentage of ultimate oxygen demand will be used up in five days, hence BOD_5. Five-day BODs represent only part of the total demand, depending on how complex the organic constitutients of the waste are and the type of bacteria doing the decomposing. In the case of typical domestic and many industrial wastes, BOD_5 has been found to represent from 70 to 80 percent of the ultimate BOD (Sawyer and McCarthy, 1967).

Chemical oxygen demand (COD) is another means of measuring the oxygen demand the waste will impose on the receiving water. It measures the oxygen requirements of organic and some inorganic wastes under a controlled oxidation by a dichromate-sulfuric acid reagent (Sawyer and McCarthy, 1967). In laboratory analysis, COD offers considerable time advantage over BOD, in the order of three hours for COD as compared to five days for BOD. A given wastewater system usually maintains a narrow range of COD:BOD ratios. For the meat packing industry wastewater, COD is usually from 1.5 to 5 times the BOD_5 with effluent approaching the high end and raw waste having the lowest ratio (North Star, 1973).

Suspended solids is a measure of undissolved substances in waste as determined by measurements on filtered and unfiltered samples (Sawyer and McCarthy, 1967).

Grease can be a wide variety of organic substances including hydrocarbons, esters, oils, fats, waxes, and high molecular-weight fatty acids (Sawyer and McCarthy, 1967). Grease is a problem in sewer systems because it tends to coat pipe walls thus restricting flow rate. Both trickling filters and activated sludge treatment systems are adversely affected by large amounts of grease which tend to "coat" microorganisms thus hindering oxygen transfer to the cells. Because of this, many industries are prevented from discharging grease to municipal systems and grease recovery is required.

Kjeldahl nitrogen is a measure of organic nitrogen plus ammonia nitrogen. This test is important because of the oxygen required during the conversion of ammonia to nitrites and further to nitrates and the nutrient value of nitrogen in producing undesirable algae blooms in potable waters (Balakrishnan and Eckenfelder, 1969).

Chlorides in reasonable concentration are not harmful to humans. At levels above 250 milligrams per liter (mg/l) water takes on a salty taste which is objectionable to most humans. This has led to a United States Public Health Service recommeded limit of 250 mg/l for potable waters (Sawyer and McCarthy, 1967). However, where water supplies are scarce, human consumption of water containing 2,000 mg/l of chlorides has been reported with no adverse effects.

Total phosphorus is important in propogation of algae blooms. Critical levels for phosphorus have been established at .01 mg/l for potable waters (Sawyer and McCarthy, 1967).

Ammonia nitrogen can be determined from Kjeldahl nitrogen and is important as stated earlier for the oxygen demand it imposes when converting to nitrites then to nitrates.

Nitrate is the most dangerous form of nitrogen in waste in that it is the stable form of nitrogen found in water. It has been found to cause methemoglobinemia in infants or "blue babies" (Sawyer and McCarthy, 1967). For this reason, the public health limit for nitrogen in water supplies is not over ten mg/l.

Total dissolved solids (TDS) can be approximated by determining the electrical conductivity of the waste. This is important where the water may be used to irrigate crops. Depending on soil types, conductivity of over 800 micromhos per centimeter can be considered a salinity hazard (Jacobs and Whitney, 1975). Salinity will be discussed more thoroughly later.

Background

This report concerns work done at the Dubuque Packing Company, Mankato, Kansas, during the summer and fall of 1976. Dubuque Packing Company is classified under the EPA heading of a simple slaughterhouse with the primary function being slaughtering of animals with a minimum of recovery operations and carcasses being shipped fresh or frozen elsewhere for processing. The Dubuque Packing Company slaughters only beef cattle with a maximum capacity presently of approximately 654,000 pounds liveweight killed per day (LWK/day) due to increase to approximately 800,000 pounds LWK/day. Dubuque does some rendering and processing of meat scraps so a minimum of expansion could reclassify the plant to a complex slaughterhouse. Because of this, any further facts presented will focus on only simple and complex slaughterhouse operations, excluding low and high-processing packinghouses. Table 1 shows the plant and raw waste characteristics that can be expected from simple and complex slaughterhouses (North Star, 1973).

Table 2 shows Dubuque's waste quality as averaged over 1976. Dubuque Packing Company is a simple slaughterhouse of average size with below average waste discharge. The raw waste characteristics are similarly below average supporting the statement by North Star (1973) that increased water use causes an increase in waste loadings.

Presently Dubuque Packing Company treats its waste with an anaerobic-aerobic lagoon system. Raw waste is discharged into an anaerobic lagoon 12 feet deep with a volume of approximately 325,000 cubic feet. BOD_5

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Table 1. Summary of Plant and Raw Waste Characteristics for Simple and Complex Slaughterhouses*

Base	Flow gal/1000 lb LWK	Kill 1000 lb/day	BOD_5 lb/1000 lb LWK	Suspended Solids lb/1000 lb LWK	Grease lb/1000 lb LWK	Kjeldahl Nitrogen as N lb/1000 lb LWK	Chlorides as Cl lb/1000 lb LWK	Total Phosphorus as P lb/1000 lb LWK
SIMPLE:								
(Number of Plants)	(24)	(24)	(24)	(22)	(12)	(5)	(3)	(5)
Average	640	480	6.0	5.6	2.1	0.68	2.6	0.05
Standard Deviation	440	300	3.0	3.1	2.2	0.46	2.7	0.03
Range, low-high	160-1,750	40-1,220	1.5-14.3	0.6-12.9	0.24-7.0	0.23-1.36	0.01-5.4	0.014-0.086
COMPLEX:								
(Number of Plants)	(19)	(19)	(19)	(16)	(11)	(12)	(6)	(5)
Average	880	1,310	10.9	9.6	5.9	0.84	2.8	0.33
Standard Deviation	330	780	4.5	4.1	5.7	0.66	2.7	0.49
Range, low-high	430-1,500	310-3,300	5.4-18.8	2.8-20.5	0.7-16.8	0.13-2.1	0.81-7.9	0.05-1.2

*after North Star, 1973.

Table 2. 1976 Summary of Plant and Raw Waste Characteristics for Dubuque Packing Company, Mankato, Kansas*

Month	Flow gal/1000 lb LWK	Kill 1000 lb/day	BOD_5 lb/1000 lb LWK	Suspended Solids lb/1000 lb LWK	Grease Hexane Sol lb/1000 lb LWK	Kjeldahl Nitrogen as N lb/1000 lb LWK	Chloride as Cl lb/1000 lb LWK	Total Phosphorus lb/1000 lb LWK	Total Ammonia lb/1000 lb LWK	Free Ammonia as NH_3 lb/1000 lb LWK
June	404	480	4.9	3.5	.5	NA	.3	NA	.3	.1
Oct.	352	502	4.1	8.4	2.6	NA	1.3	NA	.2	.1
Aver.	378	491	4.5	6.0	1.6	NA	.8	NA	.3	.1

*Data supplied by Environmental Laboratories, Topeka, Kansas, 1976.

loadings ranged from 6.33 pounds per day per 1,000 cubic feet to 7.24 pounds per day per 1,000 cubic feet during the year 1976. This compares to a loading of 7.9 to 15 pounds BOD_5 per day per 1,000 cubic feet for a total anaerobic system in Union City, Tennessee, and a BOD_5 loading rate of 14 pounds per day per 1,000 cubic feet in a combination anaerobic-aerobic system at Moultie, Georgia (Gloyna et al., 1967). Dubuque does not provide any mechanical removal of grease prior to discharge into the lagoon system, restricting rendering to salvageable scraps from the plant area only. The result is a thick scum on the surface of the anaerobic lagoon. The scum is beneficial in reducing odors, stabilizing the temperature, and preventing penetration of air and sunlight into the anaerobic system (Gloyna et al., 1967).

From the anaerobic lagoon, the effluent passes into a series of four aerobic lagoons. The first lagoon is four feet deep and covers approximately nine surface acres followed by three more lagoons, each five feet deep, covering approximately 17.5 surface acres total. Final disposal from the last lagoon consists of delivery to the downstream landowner by an intermittently flowing stream passing through the property (Figure 1).

A pond serving a large cattle herd lies on the stream directly below the last lagoon's discharge. As the system is set up now, water can only be discharged when the downstream landowner requests it. During periods of heavy rainfall when Dubuque Packing Company needs to discharge the most water, the downstream landowner may not accept the excess water because of potential damage to the emergency spillway of his pond. During the summer months, water was given to a neighboring landowner who used it for irrigation of adjacent land. This worked for several years until the neighbor became concerned about the high total dissolved solids concentration and the high soluble sodium percentage of the water. Tests by several independent laboratories showed the wastewater had conductivities well over 3,000

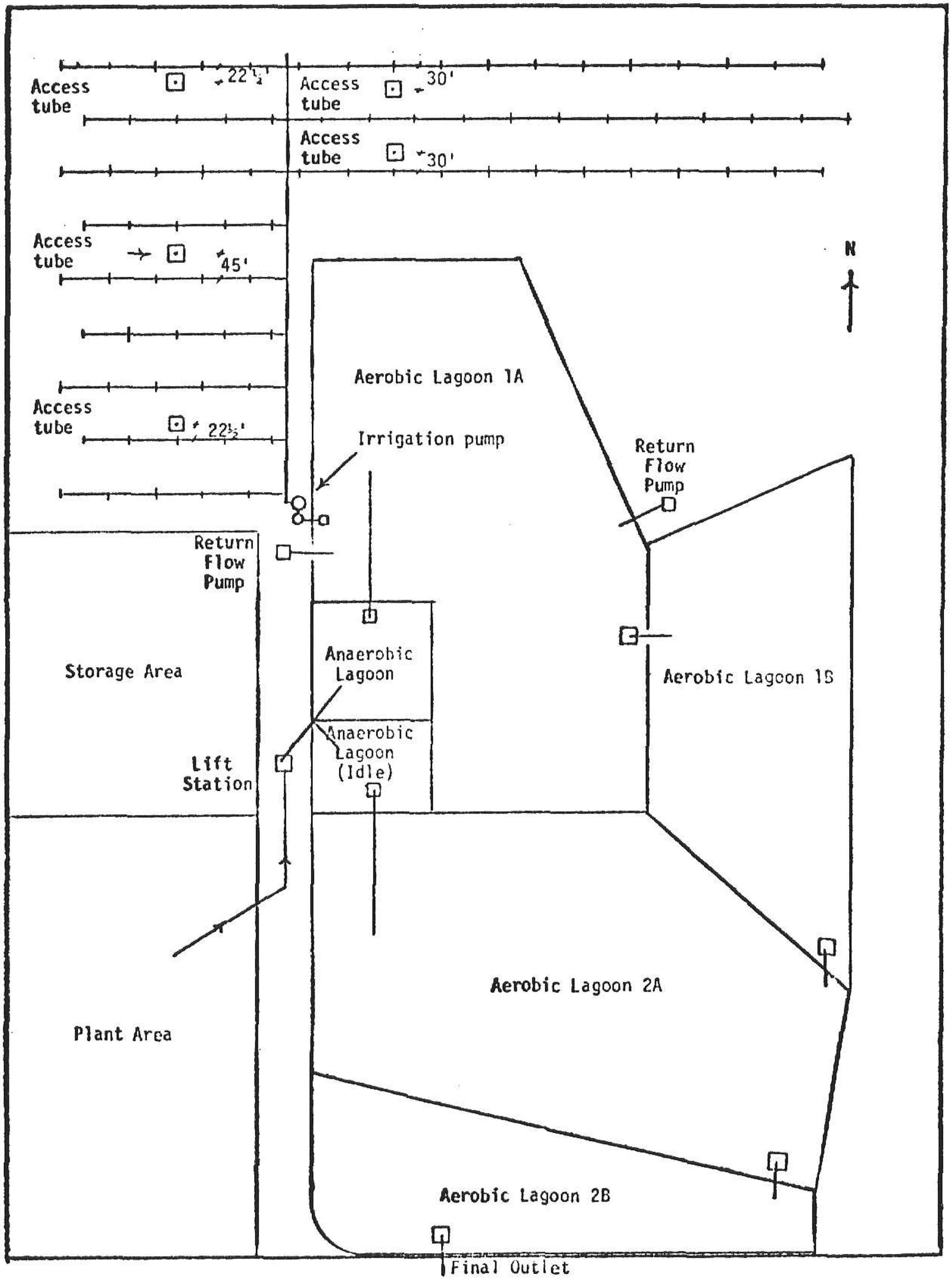

Figure 1. *Wastewater Treatment and Disposal System at* Dubuque Packing Company, Mankato, Kansas

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micromhos per centimeter and a soluble sodium percentage of over 60 percent for each sample taken through 1975, the last year the neighbor used the water. According to Jacobs and Whitney (1975), water of this quality has a high to very high sodium hazard and a high to very high salinity hazard to field crops when used on any soil from loam to clay.

Salinity hazard relates to the total number of ions present in the water which may become harmful to plant life and necessitate the use of "salt tolerant" crops. Sodium hazard is dangerous because lower valence sodium ions tend to replace the higher valence calcium and magnesium ions on the colloidal (clay) fraction of the soil. Since the lower valence sodium ions cannot attract and hold water molecules as closely as the calcium and magnesium ions, the distance between the clay particles and the bonded ions is greater when sodium is present than when higher valence ions are present. The greater distance causes the particles to "disperse" and not flocculate or bind together in clumps, decreasing infiltration rate and increasing resistance to root penetration.

Soils in the area are classified as Hastings or Crete silty clay loam which would make the use of the water very hazardous. Therefore, irrigation was discontinued.

Since the downstream landowner may not be willing to accept water during wet periods, some new form of final disposal was needed that would be under the control of the plant management. Approximately 15 acres of idle grassland was located north of the plant adjacent to the first aerobic lagoon. This suggested some type of permanent land disposal system to augment delivery to the landowner downstream. With that in mind, Dubuque Packing Company contacted Kansas State University and established a research project to provide some of the answers.

Investigation of Alternatives

Since the plant already had a well-functioning primary and secondary treatment system, it became apparent that what was needed was an advanced treatment system that would either improve the water quality to a point where it would be in demand from the neighboring landowners or dispose of it permanently on the company's property. The literature search revelaed three major methods of final disposal used by municipalities and industries. These are:

1. Direct discharge to municipal sewers or a receiving body of water
2. Tertiary treatment
3. Ultimate disposal (no discharge) by land application

Direct Discharge

Direct discharge has severe limitations for Dubuque unless some arrangement can be made with the adjacent and downstream landowners to accept surplus water from the waste treatment system. Since many legal and economic questions could arise in the future, a thorough study should be made of contract agreements for water rights downstream in the event that future landowners should refuse to accept the surplus water. In any event, this solution still involves a disposal system not totally owned or operated by the packing company, an undesirable feature. An alternative would be discharge to Mankato's municipal sewage system, another expensive operation which would require construction of approximately three miles of new sewer line.

Tertiary Treatment

Tertiary treatment is a recognized method of treating water to improve the quality so reuse is possible. Three common treatment processes used extensively elsewhere are: ion exchange, reverse osmosis, and electrodialysis.

Ion exchange is a method to deionize the wastewater to obtain a total dissolved solids concentration acceptable for the use intended. In meat packing wastes, ion exchange could be used to remove sodium chloride. To achieve satisfactory salt content for irrigation, 30 percent of a typical packing plant's wastewater would require treatment in an ion exchange system upstream from the irrigation site (North Star, 1973). This was based on a maximum salt content of .15 percent deemed suitable for irrigation water. Problems are encountered when clogging lowers flow rates through the resin columns. To prevent this, sand filtration or a carbon absorption system in front of the exchange resins is needed. Ion exchange processes have been used in water softening for years so their dependability is well known. If water were needed for recycling in the plant, 95 percent of the total effluent would be cycled through the resin (North Star, 1973).

Reverse osmosis is a process by which semipermeable membranes are used to remove impurities from water. The principle is to reverse the normal osmotic process through an increase in pressure on the contaminated side of the semipermeable membrane. The membrane is usually made of cellulose acetate, although other types are available. Problems with reverse osmosis systems are that water is not purified at a high enough rate to make the system economical, and microbial growth on the membrane further hinders the purification rate. Chlorination, which would prevent growth on the membrane, as yet cannot be used due to damage caused to the membrane material by the chlorine. Until new materials are developed, reverse osmosis can be practical only where a closed loop system and total recycling of water is necessary (North Star, 1973).

Electrodialysis uses electric current to separate ionic species in a solution. The process involves using two streams of water, one-- a brine solution, the other-- the waste to be treated. These streams are separated by membranes permeable to the ionic species to be removed. Two electrodes are placed outside the streams isolated by membranes impermeable to the ions desired removed. When current is applied, the ion moves through the permeable membrane towards the electrode and stops when it comes to the impermeable membrane. In this manner, the wastewater is depleted in ions while the brine is enriched. Removal efficiencies for sodium chloride of up to 40 percent have been reported for a single pass (North Star, 1973). Again, problems arise due to bacterial growth on the membranes and power costs of operating the system.

Other tertiary treatments found pertained to biological stabilization, something that Dubuque Packing Company has had no problems with yet as the lagoon system functions well. Systems such as chemical control and flocculation, anaerobic contact, extended aeration, activated sludge, carbon adsorption, sand filters, and rotating biological contactor would find suitable use in a plant without necessary land to construct waste stabilization ponds, or in a situation where existing stabilization ponds were overloaded with pollutants to the point where unsatisfactory treatment resulted. In Dubuque Packing Company's case, this further degree of biological treatment is not needed at this time.

Ultimate Disposal

Land application of sewage effluent is the earliest recorded method of waste disposal. Use of municipal waste for irrigation purposes was reported in Germany in the 16th century (Pound et al., 1973). The use of effluent for beneficial purposes began in the United States in the 19th century.

Table 3 lists historical data on uses of municipal effluent for sewage farming (Pound et al., 1973).

A survey of 100 facilities where wastewater was being discharged to the land as opposed to releasing effluent into receiving waters found these reasons apparent for changing to land application (Sullivan et al., 1973):

1. To provide supplemental irrigation water
2. To provide an economical alternative to discharging waste effluents into receiving streams, lakes, and costal waters
3. To overcome the lack of or unavailability of suitable receiving waters and avoid construction of expensive conveying pipelines to suitable receiving waters

The major means of accomplishing land disposal by municipalities were found to be (Sullivan et al., 1973):

1. Overland flow
2. Use of infiltration basins or evaporation ponds
3. Ridge and furrow irrigation of cropland
4. Irrigation of land areas by spraying, using either stationary or portable types of distribution equipment

For disposal of industrial wastewater, the number of alternatives was narrowed to two: overland flow, and irrigation and infiltration-percolation. The only distinction between irrigation and infiltration-percolation made for industry is in the maintenance of a cover crop in irrigation (Pound et al., 1973). Reasoning for this conclusion relates to the high suspended solids content of industrial wastewater as compared to municipal wastewater making the high infiltration rates obtained in municipal infiltration-percolation impossible to achieve.

In considering the best method of applying the wastewater to the land, the circumstances leading to the initiation of this project and the site

Table 3. Historical Data on Sewage Farming*

Date	Location	Description	Wetted area, acres	Flow, mgd	Average loading, in./wk.
	Non-United States				
1559	Bunzlau, Germany	Sewage farm	--	--	--
1861	Croydon-Beddington, England	Sewage farm	420	4.5	2.8
1864	South Norwood, England	Sewage farm	152	0.7	1.2
1869	Berlin, Germany	Sewage farm	27,250[a]	150[a]	1.4
1875	Leamington Springs, England	Sewage farm	400	0.8	0.5
1880	Birmingham, England	Sewage farm	1,200	22	4.7
1893	Melbourne, Australia	Irrigation	10,376[b]	50[b]	1.2
	Melbourne, Australia	Overland flow	3,472[b]	70[b]	5.2
1902	Mexico City, Mexico	Irrigation	112,000[b]	570[b]	1.3
1923	Paris, France	Irrigation	12,600	120	2.5
1928	Cape Town, South Africa	Irrigation	--	--	--
	United States				
1872	Augusta, Maine[c]	Irrigation	3	0.007	0.6
1880	Pullman, Illinois[c]	Irrigation	40	1.85	12.0
1881	Cheyenne, Wyoming	Irrigation	1,330[d]	7.0[d]	1.3
1887	Pasadena, California	Irrigation	300	--	--
1895	San Antonio, Texas	Irrigation	4,000[a]	20[a]	1.3
1896	Salt Lake City, Utah	Irrigation	180	4	5.7
1912	Bakersfield, California	Irrigation	2,400[d]	11.3[d]	1.2
1928	Vineland, New Jersey	Irrigation	14	0.8	14.7

a. Data for 1926.
b. Data for 1971.
c. Abandoned around 1900.
d. Data for 1972.

*after Pound et al., 1973.

characteristics and limitations were:

1. The packing plant must dispose of the water. No method of discharge to a receiving body of water can be depended upon with any degree of certainty.
2. The site available for any type of land disposal is at the maximum 15 acres. Other land near the plant either is not available presently or the expense of obtaining it is not desirable at this time.
3. The 15 acres is a gently rolling area with slopes that would be subject to erosion if a grass cover were not maintained.
4. The wastewater is not highly contaminated with organic pollutants due to primary treatment by the anaerobic lagoon. However, it is moderately contaminated by organics and highly contaminated by dissolved solids, primarily sodium chloride, making it undesirable to nearby farmers for use as irrigation water.
5. Soils in the area are Hastings-Crete silty clay loam with maximum permeabilities of approximately .1 inch per hour.
6. Depth to the water table is estimated to be between 60 and 100 feet.

<u>Overland flow</u>. In overland flow, water is biologically treated by passing over a vegetated area then discharging into a receiving body. Since this requires some type of discharge, overland flow would offer no advantages to the present system and offers the disadvantage of concentrating the waste even more through the process of evaporation. Since the total dissolved solids concentration is already dangerously high, further

unnecessary concentration must be avoided. A more detailed description of overland flow systems is presented by Eisenhauer (1973).

Irrigation and infiltration-percolation. The design parameters for irrigation and infiltration-percolation do not vary enough to distinguish between the methods for industrial purposes. Usually irrigation with industrial wastewater is for disposal of water not primarily for crop production so application rates are higher than in municipal uses.

Irrigation is the most common form of land application for municipal wastewater with approximately 360 communities utilizing it in 1964 (Pound et al., 1973). Most locations are in the southwestern states where often wastewater is the only source available for irrigation. Factors important in selecting a potential site for irrigation are climate, soil characteristics and depth, topography, and hydrologic and geologic conditions (Pound et al., 1973).

Climatic conditions relate to the potential evaporation and transpiration that can be expected for the crop grown. Besides determining if water is needed for irrigation, land areas necessary for disposal of total wastewater should be calculated. Also, length of growing season should be determined to give an estimate of storage facilities needed during winter months.

Soil characteristics should also be considered when determining loading rates for different types of crops. Irrigation can be carried out on any type of soil, but the method and management of water application differs significantly between soil types. Generally, soils containing a large fraction of clay absorb water slowly and retain it for long periods of time as compared with a sandy soil. The sandy soil may require more water to prevent drought stress in the crops while more water applied to a clay could result in higher runoff rates and a waterlogged condition. An example of plants harmed by too heavy an application rate occurred at Detroit Lakes, Minnesota, where a rate of six inches per day resulted in a number of trees dying (Pound et al., 1973).

The property of the wastewater used will determine to some extent the method of irrigation used on different soils. Water with a high electrical conductivity indicating a high concentration of total dissolved solids will require special management considerations on all soils to prevent dispersion and salinity problems. A more detailed discussion of the implications of salinity will be presented later.

Depth of the soil strata is important in maintaining root development, water holding capacity, and obtaining biological treatment to the organic pollutants. Retention of wastewater pollutants such as phosphorus, heavy metals, and viruses has been shown to be a function of detention time of wastewater in the soil and the contact period between soil colloids and the exchangeable cations in the solution (Pound et al., 1973). Soils with a high exchange capacity such as those with a montmorillic type of clay or high amounts of organic matter exhibit properties that make them favorable for removing ionic pollutants such as calcium, magnesium, ammonia nitrogen, and heavy metals. This could be important in groundwater pollution and determination of the type of crop to be grown. Some crops exhibit tolerance to high levels of trace elements as compared to other crops. Retention in the root zone of elements toxic to a plant could result in problems that could be avoided by choosing the correct site or crop.

Groundwater level is important in site selection due to several factors. Therefore, the site investigation should include groundwater surveys to determine depth, lateral flow, and seasonal variations of depth and quality. To maintain aerobic treatment of wastes, a minimum depth of five feet to the water table should be maintained (Pound et al., 1973). If a site has too high a groundwater level, it can be controlled by tile underdrain installation, a common practice. Underdrains have been used in Europe since the 19th century (Pound et al., 1973). In areas where deep percolation of the wastewater to the groundwater supply is expected, groundwater quality monitoring wells should be installed and records kept on quality changes.

Other hydrologic conditions, such as rainfall runoff, should be considered as to effects on the site. Relatively clean rainfall runoff should be channeled around the site to prevent its pollution and keep additional water from saturating the profile. If slopes and topography indicate a potential erosion hazard, this should be remedied by terracing or changing to a grass cover that will inhibit erosion.

Geologic conditions relate mainly to groundwater pollution. The existence of a fractured limestone formation near the surface could result in a "short circuit" of the treatment process allowing untreated waste to flow into the groundwater (Pound et al., 1973).

These factors combine to determine the allowable organic and hydraulic loading rates for the system. Organic loadings should consider factors relating to oxygen depletion in the root zone and damage that anaerobic conditions in the root zone could cause to the cover crop as well as surface sealing and the resultant decrease in infiltration rate. Hydraulic loading rates should consider factors relating to crop requirements, root zone saturation, and leaching requirements for salt management.

Proper site selection should include consideration of all factors involved to obtain the best disposal area.

The three types of common application of irrigation are spray, flood, and ridge and furrow. Of the three, spray is by far the most common, usually because of cost and the susceptibility of surface techniques to deep percolation losses. Because of the desire at Dubuque to minimize labor requirements and maintain a grass cover on the land, spray irrigation is the only method of application that would be desirable. Distribution efficiencies of spray systems and the ability to apply varying amounts of water high in suspended solids are also advantages.

When spray irrigation systems are used, some type of cover crop needs to be maintained to prevent sealing of the surface by the action of the water droplets. Root structures also tend to aerate and expand the soil increasing infiltration rates. In the case of irrigation with highly saline water, this could be a significant factor in maintaining salt movement through the root zone. Vegetation can account for a significant increase in hydraulic capacity of the system through depletion of soil water by evapotranspiration during rest periods when the surface is not saturated. An extreme example of this is a food processing facility at Fairmont, Minnesota, where essentially all of the wastewater is lost through evapotranspiration and runoff is collected and resprayed (Pound et al., 1973).

Type of cover crop should reflect the use intended for the system. If maximum water disposal is the objective, such as at Dubuque Packing Company, a hydrotropic plant species that will tolerate the high total dissolved solids content of the wastewater should be chosen. Reed canarygrass is the most widely used species with high tolerance to heavy organic loadings. Nutrient removal capacities of several plant species are shown in Table 4 (U.S. Army Corps of Engineers, 1972).

Table 4. Plant Uptake of Selected Elements*

	Uptake of Elements, lb/acre/yr											
Plant	N	P	S	B	K	Ca	Na	Mg	Fe	Mn	Zn	Cu
Alfalfa	220	21	16	0.6	110	150	3	15.0	0.9	0.5	0.3	0.1
Corn	155	25	18	0.4	52	21	7	23.0	1.4	1.4	0.6	0.1
Potatoes	200	16	10	--	220	52	3	4.0	--	--	--	--
Red Clover	126	13	9	0.2	81	92	4	22.0	1.0	0.6	0.3	0.1
Reed canarygrass	226	36	--	9.4	--	69	64	3.8	17.0	--	--	--
Soybeans	110	18	10	0.1	48	26	--	16.0	0.6	0.2	--	0.03
Wheat	76	14	11	0.3	42	12	1	8.0	0.7	0.5	0.2	0.03

*after U.S. Army Corps of Engineers, 1972.

INVESTIGATION

Objectives

The objectives of the research done at Dubuque Packing Company during the summer and fall of 1976 were:

1. To develop a model capable of predicting the amount of wastewater discharged from the plant's treatment system under various climatic conditions
2. To design and construct a solid-set-sprinkler-irrigation system, flexible enough to be a valuable research tool in determining optimum application rates and operation schedules, yet durable enough to apply the highly corrosive wastewater to land with a minimum of labor
3. To determine an operation schedule that will minimize harmful effects of the high total dissolved solids concentration and high sodium percentage of the wastewater while maximizing the disposal rate
4. To determine the coefficient of uniformity for widely spaced sprinklers and make recommendations as to the best combination and size of nozzles to be used

Theory and Procedure

Determination of Water Balance

The first research effort was to see if the potential evapotranspiration for the area was high enough to contribute significantly to water disposal. Evapotranspiration (ET) is defined as "the total process of water transfer into the atmosphere from vegetated land surfaces" (Rosenberg, 1974). A more detailed explanation of the ET process is offered by Rosenberg (1974).

Briefly, less than one percent of the water passing through plants is actually used in metabolic processes (Kanemasu et al., 1974). The rest is passed through to the atmosphere. During rest periods when evaporation from the soil surface decreases greatly due to nonsaturated conditions existing on the soil surface, the major means of water depletion in the soil environment is transpiration. Potential evapotranspiration as defined by Rosenberg (1974) is "the evaporation from an extended surface of short green crop which fully shades the ground, exerts little or negligible resistance to the flow of water, and is always well supplied with water. Potential evapotranspiration cannot exceed free water evaporation under the same weather conditions."

Methods of estimating potential evaporation from a free water surface are numerous with several different approaches offered to achieve the same end. Equations using radiation, temperature, humidity, and combinations of all three have been used. The Penman combination equation offers advantages in sensitivity to changes in the transfer coefficient of water vapor to air as caused by an increase in wind velocity. The combination equation as given by Penman (1948) is:

$$PEVAP = \frac{\Delta}{\Delta + \gamma} (Rn - G) + \frac{\Delta}{\Delta + \gamma} (EA) \qquad (1)$$

where:

PEVAP = Potential evaporation from a free water surface

G = Soil heat flux

Rn = Daily heat budget at the surface

Δ = Slope of the vapor pressure-temperature curve

γ = The psychrometric constant

EA = A function of wind speed and humidity

Bowen (1926) recognized that soil heat flux (G) was a small fraction of net radiation (Rn) when soil moisture was not limiting. Most users do likewise, thus the G term can be neglected.

Values available from local climatological data may be used to obtain the other values in Penman's combination equation. The complete derivation of the final form of Penman's combination equation adapted for Topeka, Kansas, is given in Bean (1976).

Rosenberg (1974) then disputed the validity of assuming that free water evaporation will always exceed actual evapotranspiration in subhumid areas. In some cases the water evapotranspired from an isolated, irrigated area has exceeded the evaporation from an extended free water surface due to sensible heat advection from surrounding areas. A more detailed explanation of the conditions involved in the experiment is offered in Rosenberg (1974).

Soil samples were taken on October 9, 1976. Samples were taken from five areas of the site, one in each of the three station combinations in the west section and two in the east laterals near the main line (Figure 1). Samples were taken to determine original soil composition for comparison with later samples after irrigation with effluent.

The soil was sampled to a depth of 16 feet with a truck mounted hydraulic press type sampler using a slotted tube, 1-5/8 inches in diameter.

In order to estimate the losses by percolation, neutron probe access tubes were installed to a depth of 14 feet in holes left from the soil sampling. Future research will require the use of these to determine moisture content at various depths of the soil. They can also be used to determine height of the saturated of near saturated zone of the soil to see if damage to the root zone is being caused by waterlogged conditions. The probe was calibrated by taking samples for determining gravimetric moisture contents at one foot intervals throughout the length of the access tube. The neutron probe was then placed inside the tube to obtain a count reading to calibrate with the known volumetric moisture content. A more detailed explanation of neutron probe theory and operation is offered in Goldberg et al. (1976).

The water table in the area is practically non-existant. Kansas Water Resources Board (1967) gives generalized well yields for central Jewell County at 0-10 gallons per minute with the only major water supplies nearby for livestock use. Depth to the water table is estimated at from 60 to 100 feet. The city of Mankato, Kansas, must bring its water from the northeast part of the county so no large users of groundwater are nearby. State Board of Health regulations in the future may require installation of a groundwater quality monitoring well, but at present, the need for one has not been shown (Kansas State Board of Health, 1976).

System Design

Construction specifications are given in Appendix B. The thought kept in mind while designing the system was to end up with a system flexible enough to do research and dependable enough to serve as a waste disposal system for the packing plant for many years. Because of the desire for a guaranteed energy source, electrical power was chosen to operate the irrigation pump. This also offered advantages in choosing a controlling system.

Figure 10 in Appendix B shows the overall layout of the site and the sprinkler and lateral spacing. The wide spacing of 80 x 90 feet was chosen for economic reasons. Disadvantages of non-uniform application were not considered important enough to warrant the additional expense of closer spacing. The wide spacing may have some effect on salt leaching requirements by not distributing water evenly over the area. Further discussion of distribution efficiency will be presented later.

Buffer zones of 100 feet were allowed on all sides of the system to prevent wind drift into adjoining property. The remote location of the site from any residences allowed the buffer zone to be this small. Pound et al. (1973) discussed more thoroughly the implications of sprinkler drift pertaining to aerosal contamination by viruses and pathogens. Had dwellings been located nearby or had the prospect of development nearby in future years been considered a possibility, a chlorination system and wider buffer zones might have been necessary.

To minimize labor, a solid set system was chosen. Cost dictated the use of Johns-Manville "Ring-Tite" 160 psi polyvinylchloride (PVC) pipe in all underground mains, laterals, and risers while strength was the reason for using galvanized steel pipe in the above ground risers. Twenty-four inch diameter concrete pipe was used around each riser to prevent mechanical damage from mowing machines, etc. and fill material was placed inside the pipe to inhibit vibration of the riser caused by the hammer on the sprinkler. Sand was used as fill because of availability. Rain Bird model 70CSP-TNT sprinklers were chosen because of their low angle profile and sealed bearing characteristics which would inhibit fouling from grit in the wastewater.

A 48-inch diameter, concrete wet well was used so any solids drawn into the area could settle before entering the pump. It also provided a place for a screen which allowed nothing larger than 1/4-inch particles to pass into the pump. The dry well was constructed of a 72-inch diameter manhole four feet high to provide adequate room for a check valve, pump, and connectors and to minimize construction costs. Also, the manholes would require no maintenance.

Pipe was installed with recommended thrust blocking and depth of cover as indicated in ASAE Standard-- ASAE S376 Design, Installation and Performance of Underground, Thermoplastic Irrigation Pipelines (Agricultural Engineer's Yearbook, 1976).

The control system consisted of a Rain Bird model RC 7 automatic controller capable of programming the laterals for periods of operation of from three minutes to one hour. Each lateral was equipped with a Rain Bird model EPTW series solenoid controlled valve. The valve operated by using main line pressure to close the lateral line. To prevent fouling of the control, a three-way solenoid was used with a screen to filter the water passing through it to the bonnet of the valve. The three-way design would allow only the water needed to fill the bonnet to enter the solenoid. This, along with the glass filled nylon construction of the body, was intended to prevent corrosion caused by the wastewater. In order to entirely automate the system, a rain-shut-off device was installed to prevent the system's operation during rainy weather.

Two return flow pumps were located in waterways catching runoff from the area. One is a 1/3-horsepower (hp) Kenco submersible sump pump, model 82A2E, located on the west side of lagoon 1A in a shallow pit to catch runoff from a diversion ditch along the south side of the disposal area. The second is located on the east side of lagoon 1A in a small pond that was already present in the non-flowing stream passing through Dubuque's property. This pump is a 1/2-hp Kenco submersible sewage pump, model 22N3G, controlled to pump from two to four inches of the pond's water. Most runoff in this area will be during wet periods when the stream has some flow from springs and seeps located upstream and this water is polluted by irrigation with effluent. Both return flow pumps have liquid level controls with the east pump being remotely controlled and adjustable. Construction specifications are given in Appendix B.

It was desired not to pump relatively clean surface runoff from large rainfall events. To accomplish this, the return flow pumps were wired to a magnetic contactor controlled by the rain detector circuit mentioned previously. The detector was equipped with a time delay that shut off the irrigation and return flow system when rain started and resumed pumping and irrigation after a certain set time period elapsed after rain ended. This period can be set from 1/5 to 5 hours, depending on user preference. No research regarding the best time period was done due to the lack of precipitation during the 1976 test period. Figure 12, Appendix B shows a simple schematic of the control system and rain-shut-off circuit.

It is anticipated that changes will be made in the return flow system in the future. If the dissolved solids concentration of the wastewater remains high, it may be necessary during wet periods to pump clean water from the east pond in order to dilute the wastewater. If so, a simple adjustment will make return flow pumps independent of the rain detection circuit. Also, if rainfall runoff from the west laterals has a high suspended solids concentration, it may require recycling through the system. Water rights of downstream landowners will require some type of system to allow runoff from upstream areas to pass through the east pond.

System protection from conditions of too high or too low line pressure is provided by a Murphy Tr-1762A controller. The device provides protection to the pipes from damage caused by too high of pressure, should the pressure relief valve malfunction, and from pumping a large amount of water if a main line should break, lowering the pressure greatly. All gauges are oil filled to prevent corrosion.

To record hours of operation, an hour meter was installed in the main pump circuit. Plans call for the installation of hour meters on all lateral lines to record their hours of operation. They could be used to give an indication of water applied to the station areas. Timers could be installed on return flow pumps to give an indication of return flow.

The system is presently designed to apply an average of 330 gallons per minute (gpm). This rate can be increased or decreased with a corresponding change in pressure through changes in nozzle size. Presently the system applies 22 gpm through each sprinkler at 60 pounds per square inch (psi).

Unless excessive precipitation during the summer necessitates winter disposal, the system will be drained each winter. Last winter the lines were drained by the use of a small vacuum pump operating from the low spot on each lateral. Acting on the advice of Rain Bird Corporation's representatives, the lines were also flushed by using compressed air to blow the water out of the bonnets of the solenoid controlled valves. Experience with a similar valve system at the Sandyland Experiment Field, St. John, Kansas, operated by Kansas State University, suggests that the entire line may be blown out with compressed air (TenEyck, personal communication). In this procedure the main line is filled with compressed air while the controller is cycled through each station opening the laterals to the compressed air flow.

Determining Operation Schedule

Operating schedules must be carefully planned because the soil requires close management to maintain its effectiveness as a treatment media. As long as the soil environment is not overloaded with oxygen demand, it will remain aerobic and nuisance odors will not be a problem. Also, plant life requires an aerobic root zone and saturation by excess effluent will harm the cover crop.

Even when free drainage exists, water applied at a higher rate than can infiltrate will simply run off or pond, creating breeding grounds for mosquitos as well as anaerobic odor problems in the saturated areas.

The silty clay loam soil at the packing plant site has been classified as a Hastings-Crete association (USDA et al., 1946) with the physical characteristics of the area resembling a Hastings-Crete-Geary association with a rolling landscape and deeply entrenched water courses (Soil Survey, Republic County, Kansas, 1967). This association has an average permeability of from .05 to .2 inches per hour (Soil Survey, Republic County, Kansas, 1967). The expected long term permeability would realistically be no more than .05 inches per hour due to the clogging effect of suspended solids and possible reduction of the infiltration rate by dispersion. Surface infiltration rates should exceed this value due to increased permeability of the surface layer from root penetration and organic matter present. This would lead to saturated conditions in the upper layers if permeability decreases with depth.

Organic loading rates should also be considered. For this system, where secondary effluent is being applied to the land, BOD loadings of much lower value will be obtained than are common in systems where raw sewage is applied. Summer of 1976 average BOD values indicate a loading of approximately 40 pounds BOD per acre per day can be expected for a loading of 2.5 inches per day. Pound et al. (1973) indicated loadings of 200 pounds BOD per acre per day have been used without overloading the soil system. The figure was obtained from extensive laboratory testing of a pulp mill effluent on four different soil types. Seasonal operations are generally able to use much higher organic loading rates, up to 860 pounds BOD per acre per day (Pound et al., 1973). Since our figure is well below these values, organic loading should not be a problem.

In order to obtain near equal flow rates per station, the laterals were divided into six stations with three short laterals combined to form one station of 15 sprinklers. The west laterals then formed three stations.

The longer east laterals, containing 12 sprinklers per lateral, formed one station per lateral. Since there were six stations, an initial set of ten minutes per station was used for a period of several days during October of 1976. Orignially the plan was to start out at this rate and operate the system during daylight hours to maximize evaporation losses from the sprinklers. This would give a gross application rate per day of from .5 to .7 inches since daylight hours from April to October vary from approximately 10 to 14 hours (Gray, 1970). Fry et al. (1971) indicated sprinkler application efficiencies ranged from 65 to 70 percent for climates similar to north central Kansas. That would amount to an average net application rate of from .35 to .5 inches per day. Actual efficiency may vary, but by applying this amount, runoff should be reasonably minimized and evaporation kept maximized.

The intent was to increase operation time from that level until runoff occurred. The soil strata would then be monitored to see if saturated conditions developed at an undesirable height above the water table. This would indicate that lower levels of the soil structure could not percolate the rate absorbed by the surface, thus a lower rate should be tried. A moderate hydraulic loading is desirable due to salt leaching requirements and the low BOD level of the waste. However, problems with clogging of the surface layer by suspended solids and oxygen depletion in the root zone may occur, so close observation must be included in the system's operation.

Bouwer (1973) recommended on site determination of rest periods to allow for biodegradation of the waste and restoration of the infiltration rate, slowed by clogging with suspended solids. It was hoped to analyze the effect of rest periods when low rates of moderately contaminated wastewater were applied. Because of construction delays, the system could not be operated until October. In order to dispose of a large amount of wastewater before winter, the system was operated according to the previously mentioned cycle (.05 inches per hour) for 24 hours per day until malfunctions would stop operation. The longest "down" period during this time was approximately one week. While irrigation was going on, moderate amounts of runoff occurred from the west laterals but little from the east laterals due to drought conditions in the area and the narrowness of the east strip of irrigated land. What water that did run off the irrigated area in the east section would infiltrate before it reached the pond where it could be observed. However, even the west section would dry after only a few days rest and ponding would disappear over night. An explanation as to why the site stabilized so quickly most probably relates to a combination of the depleted condition of the water supply in the first five feet of topsoil due to drought conditions, and the effects of uneven distribution patterns being responsible for the runoff that did occur.

Determination of Coefficient of Uniformity

Distribution patterns are the major problem when applying water with widely spaced sprinklers. Fry et al. (1971) listed four factors that determine uniformity of water application. Ranked in order of importance they are:

1. The sprinkler selected
2. Sprinkler spacing
3. Nozzle size and operating pressure
4. Wind speed and direction

The sprinkler selected is a Rain Bird model 70CSP. This sprinkler has a low trajectory range tube with an angle of 21^{o} from horizontal for better resistance to wind effects. The thought is to throw water closer to the ground thus reducing travel distance of the droplets. The nozzle includes a non-clog plastic vane to reduce friction loss and increase diameter of throw. Diameter of throw for 9/32-inch and 5/16-inch nozzles is 135 and 143 feet respectively at 60 psi (Rain Bird, 1977-78).

Sprinkler spacing for maximum distribution efficiency should be from 30 to 60 percent of the diameter of throw on lateral lines perpendicular to prevailing wind direction (Fry et al., 1971). The higher the average wind velocity, the closer the spacing should be up to 30 percent of the diameter of throw. For this system (designed for a nozzle size of 5/16-inch), sprinkler spacing would be 30 percent of 143 feet or approximately 40 feet. Spacing of laterals should not exceed 65 percent of diameter of throw--90 feet. The spacing of 80 x 90 feet for the Dubuque waste application system was based on the requirement of half as many risers, sprinklers, and nozzles to install, purchase, and maintain. Also, it was felt that where a grass cover was being irrigated, uniform application for water needs was not as important as if a shallow rooted, high value crop was involved. The high application rate anticipated for wastewater disposal also favored the wider spacing.

Nozzle size and operating pressure relate to droplet size. When low wind conditions exist, the pressure and nozzle size determine the amount the stream of water will break up and scatter. A low operating pressure and large nozzle diameter will cause a characteristic "doughnut" formation or band of high application as recorded by Christiansen (1942). Too high of an operating pressure for the nozzle size results in the stream breaking up into small droplets decreasing range and increasing the application depth near the riser.

Wind speed and direction are important because wind will blow the droplets around, decreasing range in the upwind and cross wind directions and increasing range in the downwind direction. Larger droplets will be affected less by the wind than smaller droplets. For this reason, larger nozzles operating at lower pressures are affected less by the wind than smaller nozzles operating at higher pressures.

Distribution patterns for the widely spaced sprinklers were obtained by experimental testing at the wastewater disposal site in October of 1976. Tests were made by distributing two-quart cottage cheese containers in a 10 foot x 10 foot grid across an area equal to two adjacent equilateral triangles for the staggered spacing of the sprinklers (Figure 2). Each container would represent 100 square feet of area. Tests were made in various wind conditions with two different nozzle combinations. The results were analyzed by determing the coefficient of uniformity (Cu) developed by Christiansen (1942). The equation is stated as:

$$Cu = 100\ (1.0 - \frac{\Sigma x}{mn}) \qquad (2)$$

where:

x = Deviation of individual observations from the mean value m

n = Number of observations

When Cu = 100 percent, application is uniform across the entire area. A lesser value indicates non-uniform application.

Wind run during the test period was obtained by use of a Weather Measure model W164-B/E cup type anemometer placed at an elevation of approximately nine feet above the ground surface.

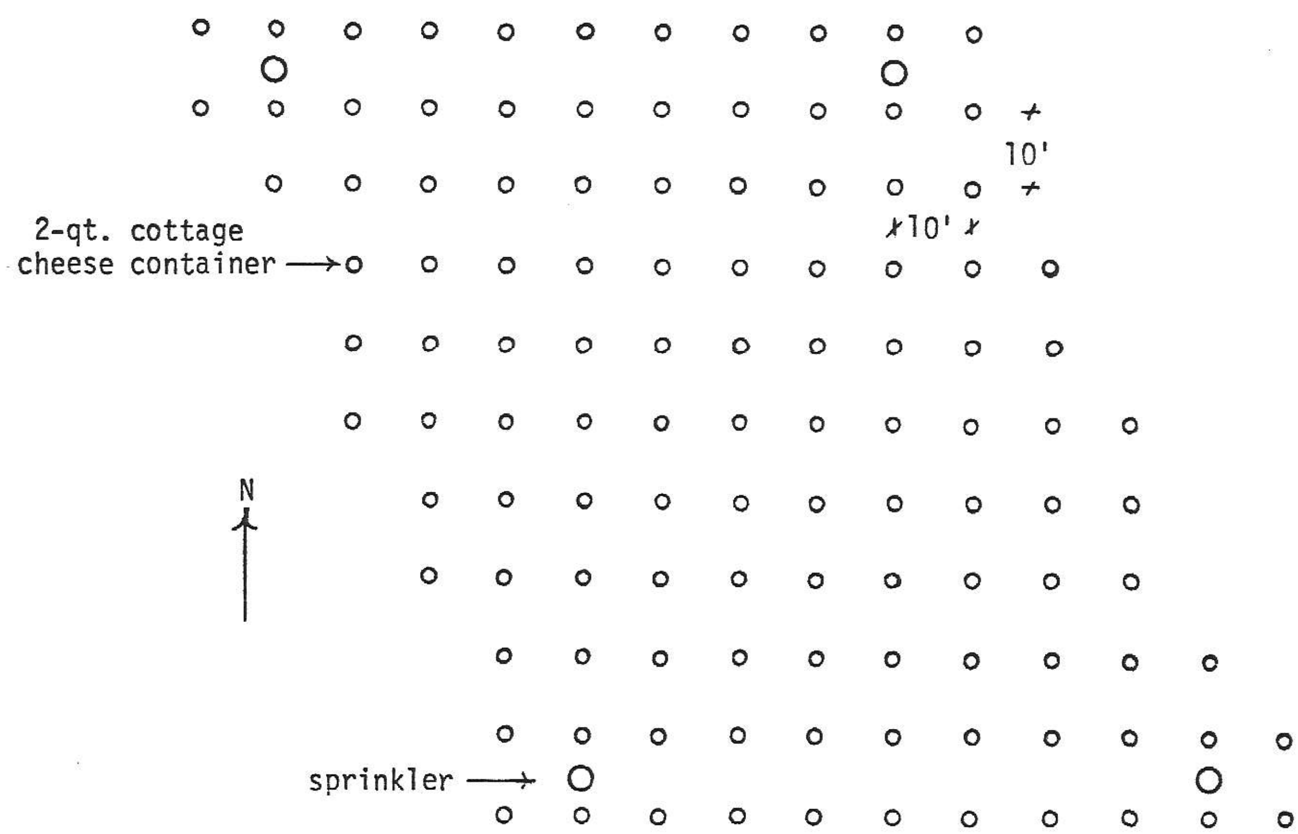

Figure 2. Collection Pattern for Sprinkler Distribution Tests

RESULTS AND DISCUSSION

Waterbalance

The Penman combination equation modified by Bean (1976) requires the input of a great deal of local climatological data. The historical weather information needed for the Mankato area is inadequate. Historical records kept at Burr Oak, Kansas, nine miles northwest of Mankato, are also inadequate. The nearest station with adequate historical records is Concordia, Kansas, 35 miles southeast of Mankato. It was decided that differences between Concordia and Mankato would tend to make the study conservative because of the greater rainfall expected at Concordia. Errors in calculations would probably be greater than errors from the assumed location difference.

A computer analysis of potential evapotranspiration using the modified Penman combination equation was used to predict evapotranspiration and the resulting lagoon discharge that could be expected under different climatic conditions. Investigation of climatic records kept at Concordia revealed that the most accurate data was kept in recent years, since 1962, when the location of the weather station was moved outside of the city to the airport. This gave a period of 12 years of complete data with daily values, required by Bean's (1976) adaptation of the Penman combination equation, available in bound copies of the local climatological data (U.S. Department of Commerce, 1963-1974). Data required by this equation are average temperature, average wind speed, percent of possible sunshine, average relative humidity, and mean monthly extraterrestrial radiation on a horizontal plane. All values except the radiation term were taken from climatological data. The radiation term was taken from Gray (1970).

Other studies dispute the necessity of using daily values of all terms needed for the analysis. Anchutz (personal communication) indicated that monthly averages of wind speed, relative humidity, and percent sunshine combined with daily average temperatures give good correlation with results using entirely daily values. A sample study of one year of data used to compare accuracies, showed on a day-to-day basis the differences were great, but on a weekly or monthly basis the differences between the two data sets decreased, with yearly totals varying less than one percent. Since daily values of maximum and minimum temperature and precipitation were available on tapes in the computer library at Kansas State University for Concordia, it was decided to use the method requiring the least physical data input and expand the study to include the entire 12-year period.

The final data input required was average monthly wind speed, relative humidity, percent sunshine and mean extraterrestrial radiation, with daily maximum and minimum temperatures and precipitation taken from data tapes in the computer library.

The computer analysis with data printouts is presented in Appendix A. Briefly, the program assumes that the downstream landowner will accept water twice a year and the lagoons will all be full on January 1, except lagoon 2B which will be drained each year by December 31. During years of above normal precipitation, these conditions may not be severe enough; but, during years of below normal precipitation, they may be too severe. Future experience with the adjacent and downstream landowners will be required to predict their acceptance of surplus wastewater for beneficial use.

The program predicts discharge for a slaughtering capacity of 600 head per day. That was the maximum operation level at the plant when Kansas State University entered the project. The plant capacity is now at 750 head per day. Operating at capacity will greatly increase the water output unless the quantity of water used per head slaughtered decreases. Communications with plant personnel indicated this will be the case; however, no data is available presently to confirm this, so the 1976 production level and water use per head is used realizing that these conditions could change in the next year.

Results from the computer analysis are summarized in Table 5 for the period 1963-1974. Predicted wastewater discharge from the lagoons ranges from 800 to 1,900 acre-inches per year. This represents disposal of from 77 to 48 percent of the annual plant discharge, respectively. Included are two releases to the downstream landowner and continuous operation of the irrigation system during daylight hours of the irrigation season, April 1 to October 31, without rest periods. Irrigation will be discontinued only on days when precipitation exceeds one-tenth inch. Although there is reason to believe that potential evapotranspiration estimates are conservative (Rosenberg, 1974), the lack of resting periods to restore the infiltration rate and no allowance for "down" time for system repairs would tend to made the overall estimates of discharge conservative.

Another source of inaccuracy in the program may be the return flow term. The assumption that the average infiltration rate will remain above the application rate reduces this term to zero. Little value should be placed on this assumption until data is collected on the average infiltration rate and the effects of the uneven distribution patterns on runoff are analyzed. On-site measurement of return flow should be substituted for calculated values of return flow until enough data can be collected to predict return flow as a function of application rate and possibly yearly rainfall.

The twelve years of data were used to develop an equation relating discharge from lagoon 2B to the yearly precipitation. The regression

Table 5. Summary of Climatological Factors and Predicted Discharge from Lagoon 2B for the Study Period 1963-1974.

Year	PEVAP (in.)	Precipitation (in.)	Irrigation (in./ac.)	Discharge (ac. in.)	Disposal (efficiency)
1963	54.6	23.3	107	1230	66%
1964	57.1	28.6	106	1320	63%
1965	51.6	33.2	105	1620	55%
1966	55.8	15.2	117	850	76%
1967	49.7	38.2	108	1750	51%
1968	54.4	30.0	109	1400	61%
1969	45.6	29.5	112	1580	56%
1970	55.4	28.6	110	1320	63%
1971	54.8	35.3	110	1510	58%
1972	51.7	32.7	110	1520	58%
1973	51.9	44.4	106	1890	48%
1974	57.8	15.8	116	820	77%
Mean	52.5	29.6	110	1400	61%

equation, developed by using the least squares method, is:

$$y = 307.8 + 36.95x \tag{3}$$

where:

y = Annual discharge from lagoon 2B, acre-inches

x = Annual precipitation, inches

The equation has a regression coefficient (R^2) of .94 with the standard deviation of $\overline{Y}$ equal to 322.8. R^2 "measures the proportion of total variation about the mean $\overline{Y}$ explained by the regression" (Draper and Smith, 1966). A graphical representation of the equation is shown in Figure 3.

An additional calculation included in the program is total pounds of nitrogen as ammonia applied in the irrigation water. The total shows an extremely large amount that can be expected due to the average total ammonia concentration of 143.2 milligrams per liter found in the 1976 water quality data. Additional nitrogen may be present as non-decomposed organic matter. The potential for nitrate pollution of runoff water is apparent and future monitoring of this hazard should be considered necessary.

In order to use the neutron moisture probe in the future, a calibration curve must be calculated using the values of volumetric soil moisture content obtained when the tubes were installed and count ratios obtained when the probe was initially used. Moisture data obtained from the five different holes and their corresponding count ratios are listed in Appendix C.

The equations relating volumetric moisture content to count ratio were obtained through computer analysis of regression using the statistical routine AARDVARK (Kemp, 1975). This routine uses the least squares method of determining the best equation through a set of data points and gives statistical parameters testing the relationship between the equation and the experimental data set. The equation obtained relating count ratio to

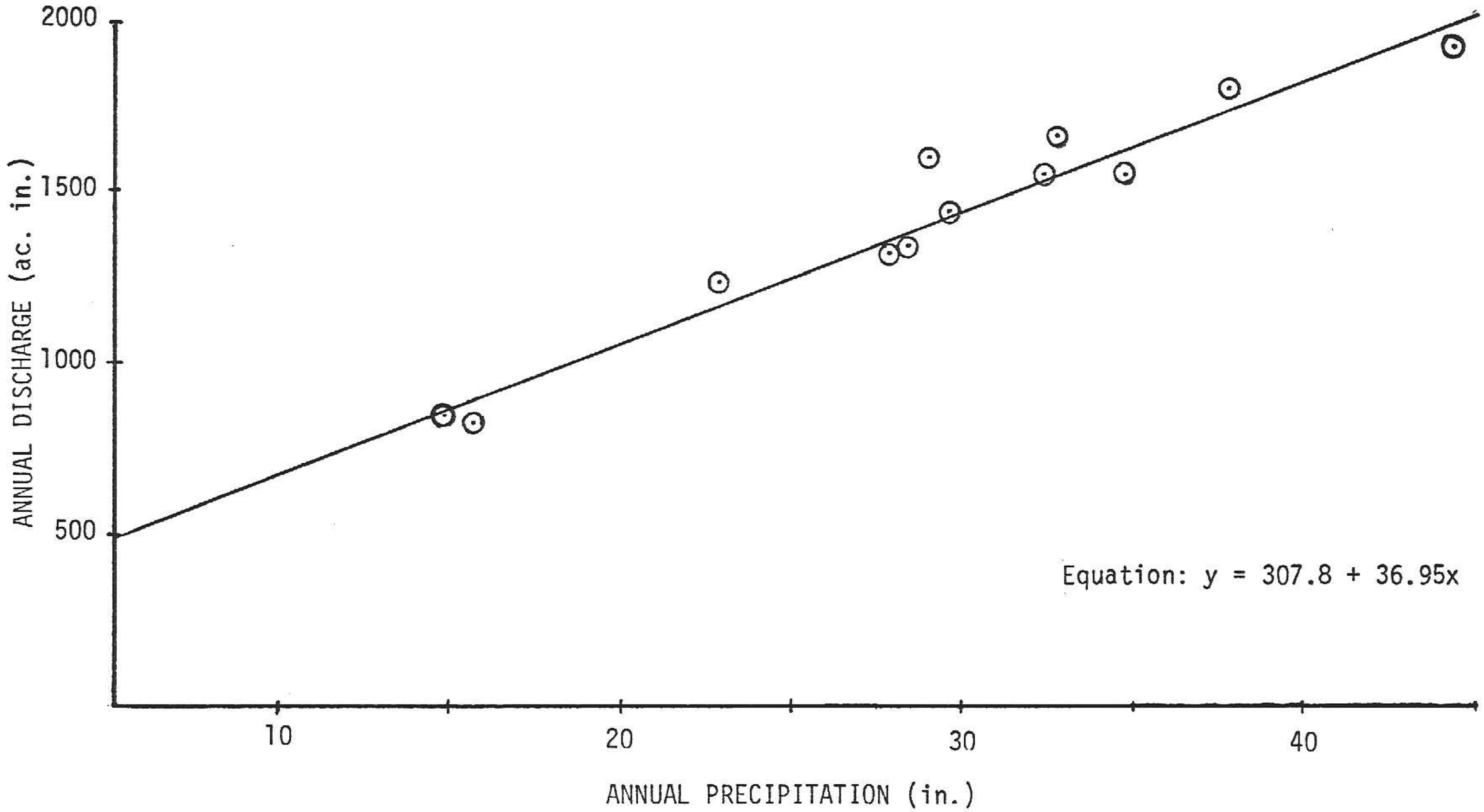

Figure 3. Relationship Between Annual Precipitation and Annual Wastewater Discharge for Stabilization Lagoons at Dubuque Packing Company, Mankato, Kansas

volumetric moisture content for all data points is:

$$y = .31305 + .02237x \quad (4)$$

where:

y = Count ratio

x = Volumetric moisture content

The equation obtained when data from the first two feet of soil are excluded is:

$$y = .2799 + .02410x \quad (5)$$

Regression coefficients (R^2) for the equations developed vary from .5368 when all points for all five sample holes are used to .8952 for all points except the first two feet of observations for all five holes. We conclude that the model, excluding observations taken in the first two feet of soil, is better than the model including these observations. This would indicate that moisture contents from the first two feet should be determined gravimetricly due to the difference in soil type or inadequate depth below the soil surface for the moisture probe to function properly.

Sprinkler System

The system operated from the week of October 9, 1976, until improper operation in freezing weather forced its shutdown the week of November 9, 1976, giving approximately 200 hours of operation time. As stated earlier, this included 24-hour-a-day operation, first to dispose of the largest amount of water possible before winter, then later to prevent the risers from freezing. During this time, the system experienced several malfunctions mostly due to an overloaded relay in the rain detector system, which has since been replaced. One lateral line was broken and one riser pulled out of a connector, both repaired by the contractor. The Murphy pressure shut-down system required adjustment because of wide pressure fluctuations when stations would cycle.

Some problems are anticipated with vibration of the risers inside the concrete protectors. The sand-fill material is relatively unconsolidated and unless sufficient precipitation occurs over the winter, water packing of the fill material may be necessary.

The Rain Bird remote control valves may experience problems due to clogging of the screening system to the solenoids with organic matter, primarily algae. Some type of serviceable filter for the valves will probably have to be installed.

The east return flow system is not functioning due to voltage leaks in the power lines across the lagoon floor. Whether or not the leaks are caused by bad splices or general deterioration of the insulation has not yet been determined. Solutions may involve laying a new power line around the water area.

Operation Schedule

The 24-hour-per-day schedule is not suitable for sustained operation in hot weather. The ponding which occurred would create an odor problem and serve as a breeding ground for mosquitos. Most importantly, sustained saturation during the growing season would destroy the cover crop which might ruin the entire system's ability to infiltrate water. Surface sealing by organic matter where no cover crop exists has been widely documented (Pound et al., 1973; Bouwer, 1973; Sullivan et al., 1973). Under no circumstances should the cover crop on the disposal area be subjected to 24-hour-per-day irrigation if saturated soil conditions cannot be avoided.

The benefits of rest periods have not been determined for this strength of organic waste. Rest periods of from one to two weeks per month are used in some disposal areas (Bouwer, 1973). However, these sites apply water at a relatively continuous rate when compared to our application period of ten minutes per hour. Total shutdown of the system for the purpose of restoring the infiltration rate must be evaluated more thoroughly.

No rainfall occurred during the month the system was operated so no analysis of how the rain detection system functioned can be offered.

Drainage of the system seemed to go well. Future precautions need to be taken to get the system drained before it freezes up.

Distribution Patterns

The results of the distribution studies show that non-uniform distribution patterns will be common during high wind conditions. Problems with non-uniform application of irrigation water may eventually lead to a shut-off system for high wind conditions similar to that used for rain now. This would reduce problems with insufficient application rates for salt leaching in some areas and excessive application rates in other areas that could cause waterlogged conditions harmful to the cover crop.

The 5/16-inch x plug nozzle combination produced better uniformity than the smaller 9/32 x 1/8-inch combination in high wind conditions. Still, during extremely high wind conditions (17.5 miler per hour), even the 5/16-inch x plug nozzle combination exhibited poor uniformity of application. No other combinations of nozzle sizes were investigated and the limited number of trials would make this data indicative rather than conclusive.

Research carried on to determine the coefficient of uniformity for the widely spaced sprinklers is summarized in Table 6. The tests alone are

Table 6. Summary of Sprinkler Distribution Tests

Date	Nozzle (in.)	Wind speed-direction (mph)	CU %
10/15/76	9/32 x 1/8	12.0 - N	54
10/21/76	9/32 x 1/8	3.3 - E	83
10/15/76	5/16 x plug	9.5 - N	70
10/21/76	5/16 x plug	17.5 - SE	51
11/05/76	5/16 x plug	7.0 - SW	76

inconclusive, due to the small number of trials; but, good agreement with other tests of similar nozzles and limited tests on the same nozzle-sprinkler combination by Rain Bird Corporation (von Bernuth, personal communication) showed enough agreement that an indication of the true relationship between nozzle size and wind velocity is shown. Distribution patterns for tests run in October 1976 are shown in Appendix D. The larger nozzle, applying the same amount of water, obtained better coverage in high wind conditions. The smaller nozzle gave good distribution in low wind conditions but was subject to more variation by the wind due to the smaller droplet size. These findings agree with observations made under similar conditions (Christiansen, 1942; Fry et al., 1971).

System Operation, Salinity and Sodium Problems

The other major problem area of this system is in the dissolved solids content of the wastewater. As mentioned previously, this soil will be subject to dispersion problems if careful management is not included in the irrigation plans. The salt content of the wastewater could be lowered by changing practices in the slaughterhouse. If salinity levels cannot be controlled and danger of losing the cover exists, these practices may have to be adopted, even though it will involve additional cost to the company. Some measures have already been taken with limited success. The plant uses an ion exchange resin water softener to remove calcium and magnesium ions from their boiler water supply to prevent harmful deposits from collecting there. Unfortunately the ion used to replace the calcium and magnesium is sodium. The recharge brine used to backwash the softener is high in dissolved sodium chloride. A system was installed to remove this backwash water to a separate evaporation pit. Also, the hide processing part of the plant which used large amounts of salt was moved to another Dubuque plant where a municipal sewer outlet was available. Wide variations in the TDS content still occur with individual readings of up to 3,500 micromhos found in water sampled during November of 1976. Some of this variation is due to salt being used in the holding pens to break up ice. Salt is also used to prevent slippery conditions on the kill floor.

It is doubtful that future modifications in plant procedure could lower the conductivity of the wastewater below 2,000 micromhos unless enough precipitation fell to provide sufficient dilution. The water in the surrounding area has characteristic conductivities above normal for irrigation water and their use for irrigation would also require caution. Table 7 shows the conductivities and soluble sodium percentages of water samples taken during August of 1975 when precipitation in the area was below normal and dilution was not sufficient to lower the TDS concentration.

Percent soluble sodium was determined by procedures commonly used for testing irrigation water. In the tests, sodium was not measured directly; the other ions present were measured and the remainder was assumed sodium. The values for percent soluble sodium seem unreasonably high and little value should be placed in them until a more satisfactory laboratory analysis is available.

The high conductivities are probably due to the concentrating effect of evaporation and the high initial conductivity present in the city water supply. Even if all unnecessary salts were eliminated from the plant operations, evidence suggests that concentration due to evaporation would make the water hazardous to use for irrigation during periods of below normal precipitation.

The elimination of the salt used in floor operations and boiler "blowdown" water (water used to flush out the boilers every day) would help lower the sodium percentage of the total dissolved solids; but since the water

Table 7. Water Quality Analysis for Dubuque Packing Co., Mankato, Kansas.*

Source	Conductivity micromhos/centimeter	Soluble Sodium %
City water	1050	26.1
City disposal outlet	1920	74.3
Lange Pond (Below outlet of 2B)	1330	85.3
Lagoon 1A	3240	85.7
Lagoon 1B	2690	87.1
Lagoon 2A	2230	100.0
Lagoon 2B	2600	98.2
Buffalo Creek	1980	66.2

*Environmental Laboratories, Topeka, Kansas, August 5, 1975.

already contains some sodium, it is difficult to estimate how much it could be lowered.

Water with a high TDS concentration is generally not used for irrigation unless nothing else is available. Research in Israel by Goldberg et al. (1976) showed that water with conductivities of up to 3,500 micromhos per centimeter has been successfully used to grow vegetable crops. The system, employed in Israel, uses drip irrigation where the water never actually touches the leaves of the plant so damage to the plant tissue by the high salt content was avoided. This would indicate that the sprinkler system at Dubuque Packing Company may experience problems with "burning" the grass cover if the TDS concentration of the wastewater remains above 3,000 micromhos.

When water comes in contact with the soil, there is a force that causes the water to enter the soil. This attraction of the soil for water is called the "soil water potential." The opposite effect of withdrawing water from the soil must overcome the negative of soil water potential before water will move from the soil. This force, the negative of soil water potential, is referred to as the "matric potential" (Taylor et al., 1972). As the water content of the soil decreases, the attraction of the soil for the water that is still present increases, thus increasing matric potential. Plants are capable of exerting their own potential to supply water for transpiration and metabolic processes. When the matric potential becomes greater than the potential the plant is capable of applying, the plant suffers drought stress.

This moisture content of the soil is commonly referred to as the "permanent wilting point." The moisture content required in a layer of soil before water can be moved through it by gravity to a lower layer is referred to as the "field capacity" of the soil. "Available water" is the difference between field capacity and permanent wilting point. Above field capacity saturated conditions will result, an undesirable situation when wastewater is being used. When salt is present in the soil water, an additional potential must be overcome by the plant, the "osmotic potential" caused by the increased resistance of the root tissue to water transfer caused by the dissolved salts in the soil water. The reaction of the plants under salt stress strongly resembles plants under drought stress because the plant is experiencing internal water deficits. The presence of the ions in the solution is the problem, not the chemical composition of the ions. Osmotic potential adds to matric potential thus lessening the water available to the plant.

Drip irrigation with saline water has been successful because moisture content can be maintained near field capacity with frequent applications of small amounts of water. Also, the concentrating effects of evaporation can be reduced by maintaining the near saturated conditions on the surface layer. The frequent movement of water through the root zone leaches the salt to the outer edges of the zone of influence of each dripper. When other forms of irrigation are used, salts are leached effectively for a short period while the water is being applied, then actually concentrated in the root zone by transpiration until the next water application leaches them again. If, during this period, moisture content falls low enough that the plant cannot overcome the combination of matric potential plus osmotic potential, moisture stress develops and the plant may be damaged.

Drip irrigation could be used to apply wastewater only if the suspended solids were removed to prevent clogging of the drippers. However, if a conventional sprinkler system applied water frequently in small enough amounts that saturated and anaerobic conditions did not develop, yet in large enough amounts that the moisture content could be maintained at or near field capacity, the resultant system could achieve effects similar to drip irrigation with the advantage of lower equipment costs and the ability to handle water high in suspended solids. The major drawback will be if salinity levels are high enough to cause direct damage to plant leaf tissue that is contacted by the water. Research has indicated that leaves are more susceptable to damage by direct contact with saline water than roots (Goldberg et al., 1976). Drip irrigation overcomes this problem by applying water directly to the soil surface and relying on lateral and vertical movement away from the dripper to create an "onion" shaped distribution pattern.

Low application with sprinkler irrigation has shown other advantages as offered by Fry et al. (1971) in the concept of aeration irrigation. Higher pressures and smaller nozzles reduce droplet size thus reducing the sealing effect of droplets on the soil surface. Also, low application rates will lessen the period of near saturation in the upper soil layer where aerobic decomposition of organic material takes place. The shorter period of near saturation will also shorten the time the layer is depleted in oxygen which should improve waste decomposition. If drip irrigation could be used for wastewater application, the existence of the zone of oxygen depletion directly under the dripper and from four to six inches below the surface as found by Goldberg (1976) would be undesirable.

The danger of soil dispersion caused by the high sodium concentration may be more difficult to resolve. A solution would be to remove all ions from the water and restrict addition of sodium ions throughout the processing system. Then if a high sodium percentage exists along with a lower conductivity, beneficial ions, calcium and magnesium, could be added to reduce this percentage. Again, the objection to this is cost. Replacement of the present ion exchange water softener with other resin type exchangers could increase the cost of the process. However, if legal requirements lead to the need for ultimate disposal of all wastes, it would be more practical to remove all of the ions from the clean water entering the plant than from the polluted water leaving the plant due to problems of clogging the treatment system with suspended solids. Also, the clean water could be treated with other types of softeners besides exchange resins such as electrodialysis if damage to the membranes could be avoided by residual chlorine levels.

CONCLUSIONS

The computer analysis shows that during periods of normal precipitation evaporation from the lagoon surfaces and irrigation of the 14.5-acre disposal site can be expected to dispose of between 50 and 60 percent of the total yearly plant discharge, provided water use remains at the level of 1976, 0.27 million gallons per day (MGD). Any increase in water use or decrease in irrigation due to breakdowns or rest periods will reduce this figure correspondingly.

The small size of the disposal area will limit the possibility of increasing the disposal efficiency. In order to dispose of the average annual discharge, the additional acreage required (using values from Table 5) would be approximately 13 acres. Unless this additional acreage is developed or wastewater quality is improved so that it is in demand by neighboring landowners, outflow from the final lagoon can be expected during years of normal precipitation.

Salinity levels required for safe use of the water for irrigation without special management practices will most likely never be obtained without expensive treatment processes since water in the area has characteristically high conductivities when not diluted by rainfall runoff.

Non-uniform distribution patterns may cause problems with the salt loading in areas of low application and cause problems with saturated conditions in areas of high application rates during windy periods. Research indicates that the nozzle combination of 5/16-inch x plug should be used to increase droplet size and reduce wind effects in distribution patterns.

The system itself should function reasonably free of maintenance with a problem area being the clogging of the solenoid valves with suspended solids. A filter that can be serviced periodically may be required to prevent fouling of the controls.

Insufficient research has been carried on to predict lengths of resting periods needed for restoration of the infiltration rate and maintenance of aerobic conditions necessary for the growth of a cover crop. Establishment of a hydrotropic species such as Reed canarygrass may allow for longer periods between rests and allow for high application rates.

In order for the Dubuque Packing Company to have a guaranteed disposal outlet during periods of above normal precipitation, some form of backup system should be insured. Flooding of land disposal areas by excessive application of wastewater for short periods of time could result in permanent damage to the cover crop. As renovation of a damaged land disposal area could take years, careful management is required.

FUTURE STUDY AREAS

Operation

The system needs to be monitored for a period of several years to determine if the highly polluted water will cause mechanical deterioration of any components of the system. Some sprinkler heads "froze" during operation but returned to normal rotation after being loosened from the risers. The head may have been tightened down too far to allow the self-cleaning up-and-down motion of the bearing to function. If not, periodic inspection and maintenance of the heads will be required to prevent flooding of small areas.

The site will require weekly observations to determine if excessive runoff rates are occurring from the operation schedule or if uneven distribution patterns are causing saturated conditions in some areas.

The rain shut-off system requires future observation of its sensitivity and the time period of shutoff necessary for passage of rainfall runoff. A system to shut down irrigation during high wind conditions may be worth investigation if saturated conditions in some areas develop from the uneven distribution patterns.

The cover crop will require visual inspection to see if damage is being caused to the plant tissue from direct contact with the saline water.

Research

The soil layer will require, at a minimum, yearly sampling and testing to monitor the build-up of salinity levels in the root zone. Testing to a deeper depth should be included to observe the flow of salts below the root zone and determine if leaching allowances are adequate.

The soil testing should also include monitoring the build-up of nitrogen from the applied wastewater to determine how much of the ammonia from the wastewater is actually reaching the soil profile. A nitrogen balance would be beneficial in furnishing information on ammonia losses from sprinkler application of water high in ammonia nitrogen.

Water samples should be taken and analyzed on a monthly basis throughout the irrigation season. Parameters analyzed should be: five-day biochemical oxygen demand (BOD_5), chemical oxygen demand, suspended solids, total dissolved solids, grease, ammonia nitrogen, Kjeldahl nitrogen, nitrates and nitrites, phosphorus, and chlorides. This data will be beneficial in maintaining a balance on the nutrients applied to the soil and combined with analysis of plant tissue of the cover crop removed, could be used to develop a nutrient balance on the system. Also, water quality data on percent sodium should be obtained by use of a flame photometer, not empirical methods commonly used for analyzing irrigation water. These methods are fairly accurate when water containing separate ionic species such as calcium, magnesium, and sodium are analyzed, but have resulted in percentages of soluble sodium greater than 100 percent when wastewater from Dubuque Packing Company's lagoons have been tested. The flame photometer should give a direct reading on the quantity of sodium in the water.

The plant should continue its effort to reduce water used, not only to reduce the discharge of wastewater, but to reduce the cost of purchasing water in a semiarid area. Research should be carried on to find new ways to eliminate sodium usage in the plant processes. Eventual use of tertiary treatment to enable limited recycling of the wastewater should be investigated. If water supplies in the area continue to diminish, as they have in the last few years, this may be the only practical method of maintaining the plant operating capacity desired.

Table 8 lists several types of waste treatment systems along with their primary use and effectiveness (North Star, 1973).

Table 9 lists the costs of advanced treatment systems available in terms of total investment and cost per 1,000 pound liveweight killed (LWK) as determined by North Star (1973). The cost advantage of spray irrigation is apparant as is the extremely high cost of removing the dissolved solids from the wastewater. What is not immediately apparent from the tables is that in order to use any of the ion exchange resins and maintain flow rates through them, the suspended solids concentration must be lowered through the use of a carbon adsorption or sand filtration system or a combination of both. This also holds true of the ion removal systems using a semi-permeable membrane, electrodialysis and reverse osmosis, with the addition of a formaldehyde treatment to periodically destroy biological growth on the cellulose acetate membrane. When considering cost of the entire recycling system, future investigation should include total costs of all systems involved.

Table 8. Waste Treatment Systems, Their Use and Effectiveness*

Treatment System	Use	Effluent Reduction
Dissolved air floataion	Primary treatment or by-product recovery	Grease, 60% removal, to 100 to 200 mg/l BOD_5, 30% removal SS, 30% removal
DAF with pH control and flocculants added	Primary treatment or by-product recovery	Grease, 95-99% removal, BOD_5, 90% removal SS, 98% removal
Anaerobic + aerobic lagoons	Secondary treatment	BOD_5, 95% removal
Anaerobic + aerated + aerobic lagoons	Secondary treatment	BOD_5, to 99% removal
Anaerobic contact process	Secondary treatment	BOD_5, 90-95% removal
Activated sludge	Secondary treatment	BOD_5, 90-95% removal
Extended aeration	Secondary treatment	BOD_5, 95% removal
Anaerobic lagoons + rotating biological contactor	Secondary treatment	BOD_5, 90-95% removal
Chlorination	Finish and disinfection	--
Sand filter	Tertiary treatment & Secondary treatment	BOD_5, to 5-10 mg/l SS, to 3-8 mg/l
Microstrainer	Tertiary treatment	BOD_5, to 10-20 mg/l SS, to 10-15 mg/l
Electrodialysis	Tertiary treatment	TDS, 90% removal
Ion exchange	Tertiary treatment	Salt, 90% removal
Ammonia stripping	Tertiary treatment	90-95% removal
Carbon adsorption	Tertiary treatment	BOD_5, to 98% removal as colloidal & dissolved organic
Chemical precipitation	Tertiary treatment	Phosphorus, 85-95% removal, to 0.5 mg/l or less
Reverse osmosis	Tertiary treatment	Salt, to 5 mg/l TDS, to 20 mg/l
Spray irrigation	No discharge	Total
Flood irrigation	No discharge	Total
Ponding and evaporation	No discharge	Total

*after North Star, 1973

Table 9. Advanced Waste Treatment System Costs (Investment, \$1000; Annual Costs, ¢/1000 lb LWK)*

	Simple Slaughterhouse		Complex Slaughterhouse	
Waste Treatment System	Total Investment	Annual Cost	Total Investment	Annual Cost
Sand Filter	140	2.7	195	1.3
Microstrainer	105	3.0	146	1.4
Reverse Osmosis	640	12.9	1600	11.6
Electrodialysis	275	15.4	625	14.9
Ion Exchange	57	2.0	102	1.1
Ammonia Stripping	75	2.4	112.5	1.2
Carbon Adsorption	238	6.0	475	4.1
Chemical Precipitation	65	4.0	81	2.8
Spray Irrigation	91	1.9	254	1.4

*after North Star, 1973.

SUMMARY

Wastewater produced by the meat packing industry is characterized by high organic pollution and high concentrations of suspended and dissolved solids. Many of these industries are located in rural areas where the most economical method of waste treatment up until now has been stabilization lagoons. Stricter state and federal water quality guidelines may make these previously adequate treatment systems inadequate due to the concentration of suspended solids in the effluent. For these and other industries and municipalities, some form of advanced treatment system is needed that will dispose of the wastewater in an economical method.

The Dubuque Packing Company, Mankato, Kansas, has installed a high rate irrigation system to dispose of wastewater that has received primary treatment from an anaerobic lagoon on 14.5 acres of grassland. The wastewater is applied with a permanent solid set irrigation system at an application rate of from .5 to .7 inches per day for a period of seven months each year.

A computer analysis using a modified version of the Penman combination equation was used to predict the quantity of wastewater the system could be expected to dispose of under different climatic conditions. Results show that an additional 13 acres of disposal area would be needed to dispose of the total average annual effluent discharge assuming several variables including acceptance of water twice each year by the downstream landowner.

Research was carried out to determine the best sprinkler nozzle combination necessary to obtain more uniform distribution patterns for widely spaced sprinklers. The recommended nozzle combination and size for use in windy conditions is 5/16-inch x plug.

Preliminary soil sampling was carried out and future yearly sampling will be required to monitor salt build-up in the soil profile.

Moisture probe access tubes were installed and future studies will include monitoring water flow through the soil profile. An attempt to check the accuracy of the predicted estimates of potential evapotranspiration should be carried out.

The prospects of disposing of all of Dubuque Packing Company's wastewater appear dim unless more land for the disposal area can be obtained.

The possibility of adjacent landowners accepting the wastewater as irrigation water depends upon the future quality of the wastewater, particularly the sodium fraction of the total dissolved solids.

The present ion exchange water softening system should be eliminated as soon as an economical substitution can be found. Efforts to reduce the sodium additions throughout the plant should be continued and the possibility of an entirely closed loop recycling system should be investigated.

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APPENDIX A

COMPUTER PROGRAM

ILLEGIBLE DOCUMENT

THE FOLLOWING DOCUMENT(S) IS OF POOR LEGIBILITY IN THE ORIGINAL

THIS IS THE BEST COPY AVAILABLE

```
          COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                             SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
ISN 0002            DIMENSION RA(12),WIND(12),RH(12),IRRDAY(12),Q(12),PSUNS(12)
ISN 0003            LOGICAL FIRST
ISN 0004            INTEGER EFF
ISN 0005            REAL NH3
ISN 0006            REAL  MONTHS(12,3)
ISN 0007            GO TO 3
ISN 0008          1 OUT2A=STOR2B+EVAP2A
ISN 0009            IN2B=STOR2B+(PRECIP*AREA2B/12)
ISN 0010            GO TO 2
ISN 0011          4 OUT2B=D2B*AREA2B
ISN 0012            GO TO 5
ISN 0013          6 IRR=0.0
ISN 0014            GO TO 7
ISN 0015          3 READ (5,100) ((MONTHS(II,III),III=1,3),II=1,6)
ISN 0016        100 FORMAT(18A4)
ISN 0017            READ (5,101) ((MONTHS(II,III),III=1,3),II=7,12)
ISN 0018        101 FORMAT(18A4)
              C RA=MONTHLY MEAN EXTRATERRESTRIAL RADIATION
ISN 0019            READ (5,102) (RA(II),II=1,12)
ISN 0020        102 FORMAT(12F3.1)
              C  Q=MONTHLY AVERAGE DAY LENGTH OF IRRIGATION CYCLE,% OF 12 HR DAY
ISN 0021            READ (5,103) (Q(II),II=1,12)
ISN 0022        103 FORMAT(12F3.2)
              C IRRDAY =CODE FOR DAYS IRRIGATION TAKES PLACE...0=NO, 1=YES
ISN 0023            READ (5,104) (IRRDAY(II),II=1,12)
ISN 0024        104 FORMAT(12I1)
              C ENTER AREAS OF LAGOONS
ISN 0025            AREA1A=9*43560
ISN 0026            AREA1B=3.8*43560
ISN 0027            AREA2A=10*43560
ISN 0028            AREA2B=3.7*43560
              C CALCULATE LAGOON CAPACITIES
ISN 0029            CAP1A=4.0*AREA1A
ISN 0030            CAP1B=5.0*AREA1B
ISN 0031            CAP2A=AREA2A*5.0
ISN 0032            CAP2B=AREA2B*5.0
              C ARATE= APPLICATION RATE,INCHES PER HOUR/12
ISN 0033            ARATE=.05/12
              C AREAI=IRRIGATED AREA
ISN 0034            AREAI=14.5*43560
              C
              C HPD=HEAD SLAUGHTERED PER DAY
              C THIS PROGRAM CALCULATES LAGOON DISCHARGE AT THE PRODUCTION CAPACITY OF
              C 1976 WHEN KANSAS STATE UNIVERSITY FIRST ENTERED THE PROJECT
ISN 0035            HPD=600
              C
              C GPH = GALLONS PER HEAD
ISN 0036            GPH=450
              C
              C PERC=INFILTRARION RATE OF SOIL,IN./HR.
ISN 0037            PERC=0.1
              C
              C ENTER TOTAL AMMONIA IN WASTEWATER , MILLIGRAMS PER LITER
ISN 0038            NH3=145.2
ISN 0039            FIRST=.TRUE.
              C
```

```
                C INITIALIZE YEARLY AND MONTHLY TOTALS
ISN 0040              YPE=0.0
ISN 0041              YIRR=0.0
ISN 0042              YNIT=0.0
ISN 0043              YEARP=0.0
ISN 0044              YPREC=0.0
ISN 0045              YR2B=0.0
ISN 0046              TPE=0.0
ISN 0047              TOT2B=0.0
ISN 0048              TOT2A=0.0
ISN 0049              TOT1B=0.0
ISN 0050              TOT1A=0.0
ISN 0051              TOTIRR=0.0
ISN 0052              TOTAN=0.0
ISN 0053              TOTALP=0.0
ISN 0054              TPREC=0.0
                C.................................................................
                C ENTER YEARLY LOOP
ISN 0055              DO 999 JJ=63,74
ISN 0056              READ (5,105) (WIND(II), II=1,12)
ISN 0057          105 FORMAT(12F3.1)
ISN 0058              READ (5,106) (PSUNS(II),II=1,12)
ISN 0059          106 FORMAT(12F2.2)
ISN 0060              READ (5,107) (RH(II),II=1,12)
ISN 0061          107 FORMAT(12F2.0)
ISN 0062              WRITE(6,108) JJ
ISN 0063          108 FORMAT('1',64X,'19',I2,/)
ISN 0064              PRINT 109
ISN 0065          109 FORMAT(' MONTH',6X,'PEVAP',3X,'PRECIP',4X,'IRR  ',1X,'NITROGEN-N',
                     X13X,'LAGOON LEVELS',9X,10X,'LAGOON DISCHARGE  AC. IN.',/)
ISN 0066              PRINT 110
ISN 0067          110 FORMAT(13X,'IN.',6X,'IN.',5X,'IN.',5X,'LB./AC.',6X,'1A',6X,'1B',6X
                     X,'2A',6X,'2B',12X,'1A',7X,'1B',7X,'2A',7X,'2B')
ISN 0068              PRINT 99
ISN 0069           99 FORMAT(' ',11X,'=====',3X,'======',4X,'===',3X,'==========',4X,
                     X'====',4X,'====',4X,'====',4X,'====',10X,'====',5X,'====',5X,'====
                     X',5X,'====',/)
                C
                C ASSUME ALL LAGOONS EXCEPT 2B WILL BE FULL AT FIRST OF YEAR
ISN 0070              D1A=4.0
ISN 0071              D1B=5.0
ISN 0072              D2A=5.0
ISN 0073              D2B=0.0
                C.................................................................
                C ENTER MONTHLY LOOP
ISN 0074              DO 11  II=1,12
ISN 0075              IF (II.EQ.1)N=31
ISN 0077              IF (II.EQ.2) N=28
ISN 0079              IF (II.EQ.3)  N=31
ISN 0081              IF (II.EQ.4) N=30
ISN 0083              IF (II.EQ.5) N=31
ISN 0085              IF (II.EQ.6) N=30
ISN 0087              IF (II.EQ.7)  N=31
ISN 0089              IF (II.EQ.8) N=31
ISN 0091              IF (II.EQ.9) N=30
ISN 0093              IF (II.EQ.10) N=31
ISN 0095              IF (II.EQ.11) N=30
ISN 0097              IF (II.EQ.12) N=31
```

```
              C.......................................................................
              C ENTER DAILY LOOP
ISN 0099            DO 10 J=1,N
ISN 0100            CALL TEMPRE(TN,TX,PCP,J,JJ,109,FIRST)
ISN 0101            PRECIP=PCP
ISN 0102            TMAX=TX
ISN 0103            TMIN=TN
              C
              C FOR NATIVE GRASS ASSUME R=.15
              C
              C ASSUME SOIL SURFACE WILL REMAIN SATURATED
              C
              C ASSUME SATURATION VAPOR PRESSURE AT THE SOIL SOIL SURFACE EQUALS
              C THE SATURATION VAPOR PRESSURE OF AIR AT THE AVERAGE AIR TEMPERATURE
              C
              C ASSUME SOIL HEAT FLUX VARIES INSIGNIFICANTLY FROM DAY TO DAY
              C THIS ASSUMPTION IS BEST DURING MONTHS WHEN IRRIGATION USUALLY OCCUR
ISN 0104            R=.15
ISN 0105            TAVG=(TMAX+TMIN)/2.0
ISN 0106            CENTT=(TAVG-32.0)*100.0/180.0
ISN 0107            ESD=33.8639*((ABS(0.00738*CENTT+0.8072))**8-0.000019*ABS(1.8*CEN
                   XTT+48.0)+0.001316)
              C
              C WIND SPEED IS MEASURED 21 FEET ABOVE THE SURFACE AT CONCORDIA
ISN 0108            WINDY=WIND(II)*24.0*(ALOG10(6.6)/ALOG10(21.0))
ISN 0109            EA=15.36*( .5+0.01*WINDY)*(ESD*(1-RH(II)/100))*0.0171
ISN 0110            IF (TAVG)  111,111,112
ISN 0111        111 DELTA=0.0
ISN 0112            GO TO 113
ISN 0113        112 DELTA=0.035*TAVG**0.673
ISN 0114        113 X=(1.0-R)    *(0.22+0.54*PSUNS(II))*RA(II)
ISN 0115            Y=0.58-0.68-0.036*SQRT(ESD*RH (II)/100)
ISN 0116            Z=(0.1+0.5*PSUNS(II)) *(2.01E-09)
ISN 0117            RN=X-Y*Z*(CENTT+273.16)**4
ISN 0118            GUM=1.0-DELTA
ISN 0119            PEVAP=((DELTA*RN)+(GUM*EA))/25.4
              C END CALCULATIONS OF PEVAP
              C.......................................................................
              C BEGIN CALCULATIONS OF WATER BALANCE ON LAGOONS
ISN 0120            PLTFLO =HFD*GPH/7.48
              C
              C CALCULATE AVAILABLE STORAGE VOLUMES
ISN 0121            STOR1A=CAP1A-D1A*AREA1A
ISN 0122            STOR1B=CAP1B-(D1B*AREA1B)
ISN 0123            STOR2A=CAP2A-(D2A*AREA2A)
ISN 0124            STOR2B=CAP2B-(D2B*AREA2B)
ISN 0125            EVAP1A=PEVAP*AREA1A/12
ISN 0126            IN1A=PLTFLO +(PRECIP*AREA1A/12)
              C
              C IF SIGNIFICANT PRECIPITATION OCCURS IRRIGATION WILL BE STOPPED
ISN 0127            IF(PRECIP.GT.0.1) GO TO 6
ISN 0129            IRR=IRRDAY(II)*12*Q(II)*ARATE*AREAI
              C
              C RETURN FLOW IS A FUNCTION OF THE SOIL INFILTRATION RATE
              C IF THE INFILTRATION RATE DECREASES,DUE TO CLOGGING OR DISPERSION,
              C THE RETURN FLOW TERM MAY INCREASE
ISN 0130          7 REFLOW=IRR-(PEVAP*AREAI/12)-(PERC*AREAI*12*Q(II)/12)
ISN 0131            IF (REFLOW.LE.0.0) REFLOW=0.0
```

```
ISN 0133          OUT1A=IN1A-IRR-EVAP1A-STOR1A+REFLOW
ISN 0134          IF (OUT1A.LE.0.0) OUT1A=0.0
ISN 0136          IN1B=OUT1A+((PRECIP/12)*AREA1B)
ISN 0137          EVAP1B=PEVAP*(AREA1B/12)
ISN 0138          OUT1B=IN1B-EVAP1B-STOR1B
ISN 0139          IF (OUT1B.LE.0.0) OUT1B=0.0
ISN 0141          IN2A=OUT1B+(PRECIP*AREA2A/12)
ISN 0142          EVAP2A=PEVAP*AREA2A/12
            C
            C LAGOON 2B WILL BE FILLED APRIL 1 AND DRAINED DURING THE SUMMER
ISN 0143          IF (II.EQ.4.AND.J.EQ.1) GO TO 1
ISN 0145          OUT2A=IN2A-EVAP2A-STOR2A
ISN 0146          IF (OUT2A.LE.0.0) OUT2A=0.0
ISN 0148          IN2B=OUT2A+(PRECIP*AREA2B/12)
ISN 0149        2 EVAP2B=PEVAP*AREA2B/12
ISN 0150          IF (II.EQ.8.AND.J.EQ.1) GO TO 4
            C
            C LAGOON 2B WILL BE DRAINED DECEMBER 31
ISN 0152          IF  (II.EQ.12.AND.J.EQ.31) GO TO 4
ISN 0154          OUT2B=IN2B-EVAP2B-STOR2B
ISN 0155          IF (OUT2B.LE.0.0) OUT2B=0.0
ISN 0157        5 DPT1A=(IN1A+REFLOW-EVAP1A-IRR-OUT1A)/AREA1A
ISN 0158          DPT1B=(IN1B-EVAP1B-OUT1B)/AREA1B
ISN 0159          DPT2A=(IN2A-EVAP2A-OUT2A)/AREA2A
ISN 0160          DPT2B=(IN2B-EVAP2B-OUT2B)/AREA2B
ISN 0161          D1A=D1A+DPT1A
ISN 0162          D1B=D1B+DPT1B
ISN 0163          D2A=D2A+DPT2A
ISN 0164          D2B=D2B+DPT2B
ISN 0165          TPF=TPF+(FLTFLC*12/43560)
ISN 0166          TPREC=TPREC+PRECIP
ISN 0167          TOTALP=TOTALP+PEVAP
ISN 0168          TOTALN=((NH3/1000)*(3.78/454)*7.48*IRR)/(AREAI/43560)
ISN 0169          TOTNM=TOTNM+TOTALN
ISN 0170          TOTIRR=TOTIRR+(IRR/AREAI)*12
ISN 0171          TOT1A=TOT1A+(OUT1A*12/43560)
ISN 0172          TOT1B=TOT1B+(OUT1B*12/43560)
ISN 0173          TOT2A=TOT2A+(OUT2A*12/43560)
ISN 0174          TOT2B=TOT2B+(OUT2B*12/43560)
ISN 0175       10 CONTINUE
            C EXIT DAILY LOOP
            C.....................................................................
ISN 0176          WRITE(6,114)(MONTHS(II,III),III=1,3),TOTALP,TPREC,TOTIRR,TOTNM,D1A
                 X,D1B,D2A,D2B,TOT1A,TOT1B,TOT2A,TOT2B
ISN 0177      114 FORMAT(' ',A4,A4,A4,F5.2,3X,F5.2,4X,F5.2,4X,F4.0,8X,F4.2,4X,F4.2,
                 X4X,F4.2,3X,F5.2,4X,F10.0,2X,F 7.0,2X,F 7.0,2X,F 7.0,/)
ISN 0178          YIRR=YIRR+TOTIRR
ISN 0179          YPF=YPF+TPF
ISN 0180          YEARP=YEARP+TOTALP
ISN 0181          YPREC=YPREC+TPREC
ISN 0182          YNIT=YNIT+TOTNM
ISN 0183          YP2B=YP2B+TOT2B
ISN 0184          TPF=0.0
ISN 0185          TPREC=0.0
ISN 0186          TOTALP=0
ISN 0187          TOT1A=0
ISN 0188          TOT1B=0
ISN 0189          TOT2A=0
```

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ISN 0190          TOT2B=0
ISN 0191          TOTNM=0
ISN 0192          TOTIRR=0
ISN 0193       11 CONTINUE
            C EXIT MONTHLY LOOP
            C.................................................................
            C THIS TERM INDICATES YEARLY DISPOSAL EFFICIENCY OF THE SYSTEM
            C EXPRESSED AS PERCENT OF WASTEWATER DISCHARGED FROM THE PLANT
ISN 0194          EFF=100*(1-(YR2B/YPF))
ISN 0195          PRINT 115
ISN 0196      115 FORMAT(1X,'ANNUAL TOTALS'/)
ISN 0197          PRINT 116
ISN 0198      116 FORMAT(18X,'PEVAP',4X,'PRECIP',4X,'IRRIGATION',4X,'NITROGEN-N',4X,
                 X'DISCHARGE 2B',4X,'DISPOSAL',/)
ISN 0199          PRINT 117
ISN 0200      117 FORMAT(18X,1X,'IN.'7X,'IN.'7X,'IN./AC.'7X,'LB./AC.',7X,'AC. IN.',6
                 XX,'EFFICIENCY',/)
ISN 0201          WRITE(6,118)YEARP,YPREC,YIRR,YNIT,YR2B,EFF
ISN 0202      118 FORMAT(18X,F5.2,4X,F5.2,7X,F6.2,7X,F6.0,9X,F6.0,10X,I3,'%')
ISN 0203          YEARP=0.0
ISN 0204          YPREC=0.0
ISN 0205          YIRR=0.0
ISN 0206          YNIT=0.0
ISN 0207          YR2B=0.0
ISN 0208          YPF=0.0
ISN 0209      999 CONTINUE
            C EXIT YEARLY LOOP
            C .................................................................
            C SUMMARY OF PROGRAM:
            C      ELEVATION OF LAGOON SURFACES AS OF JANUARY 1 :
            C                                        LAGOON 1A...4.00
            C                                        LAGOON 1B...5.00
            C                                        LAGOON 2A...5.00
            C                                        LAGOON 2B...0.00
            C      NUMBER OF PLANNED DRAINAGES OF LAGOON 2B:  2
            C .................................................................
ISN 0210          STOP
ISN 0211          END
```

1963

MONTH	PEVAP	PRECIP	IRR	NITROGEN-N	LAGOON LEVELS				LAGOON DISCHARGE AC. IN.			
	IN.	IN.	IN.	LB./AC.	1A	1B	2A	2B	1A	1B	2A	2B
JANUARY	0.82	0.57	0.0	0.	4.00	5.00	5.00	5.00	306.	305.	303.	80.
FEBRUARY	2.03	0.03	0.0	0.	4.00	5.00	5.00	5.00	260.	253.	233.	225.
MARCH	3.89	2.19	0.0	0.	4.00	5.00	5.00	5.00	293.	286.	269.	263.
APRIL	5.55	1.55	15.60	512.	3.59	4.96	4.87	4.71	40.	28.	7.	4.
MAY	6.13	1.46	17.50	574.	3.98	4.89	4.49	4.32	14.	0.	0.	0.
JUNE	7.73	4.17	14.74	484.	3.90	4.91	4.58	4.03	61.	46.	0.	0.
JULY	8.17	4.41	15.44	507.	3.93	4.86	4.55	3.71	47.	35.	0.	0.
AUGUST	7.10	3.07	16.20	532.	3.82	4.75	4.54	-0.34	49.	39.	0.	165.
SEPTEMBER	4.95	2.18	13.80	453.	4.00	4.99	4.58	-0.57	54.	33.	0.	0.
OCTOBER	4.71	2.93	13.94	458.	4.00	5.00	5.00	-0.39	90.	83.	14.	0.
NOVEMBER	2.29	0.09	0.0	0.	4.00	5.00	5.00	5.00	279.	270.	248.	1.
DECEMBER	1.19	0.20	0.0	0.	4.00	5.00	5.00	0.20	299.	296.	266.	495.

ANNUAL TOTALS

PEVAP	PRECIP	IRRIGATION	NITROGEN-N	DISCHARGE 2B	DISPOSAL
IN.	IN.	IN./AC.	LB./AC.	AC. IN.	EFFICIENCY
54.58	23.25	107.22	3520.	1233.	66%

1964

MONTH	PEVAP	PRECIP	IRR	NITROGEN-N	LAGOON LEVELS				LAGOON DISCHARGE AC. IN.			
	IN.	IN.	IN.	LB./AC.	1A	1B	2A	2B	1A	1B	2A	2B
JANUARY	1.93	0.07	0.0	0.	4.00	5.00	5.00	5.00	292.	284.	266.	37.
FEBRUARY	2.01	0.44	0.0	0.	4.00	5.00	5.00	5.00	264.	258.	243.	237.
MARCH	3.69	1.14	0.0	0.	4.00	5.00	5.00	5.00	285.	276.	250.	241.
APRIL	5.18	3.73	13.20	433.	4.00	5.00	5.00	5.00	94.	88.	74.	67.
MAY	7.73	2.52	16.85	553.	3.98	4.94	4.58	4.57	19.	2.	0.	0.
JUNE	7.65	8.51	14.74	484.	3.78	4.80	4.80	4.80	114.	123.	106.	99.
JULY	9.78	3.01	18.25	599.	3.62	4.24	4.24	4.24	0.	0.	0.	0.
AUGUST	7.09	3.03	14.26	468.	4.00	4.43	3.90	-0.34	24.	0.	0.	193.
SEPTEMBER	4.93	3.67	13.80	453.	4.00	5.00	4.26	-0.44	87.	56.	0.	0.
OCTOBER	4.12	0.22	14.94	490.	4.00	5.00	4.28	-0.77	57.	42.	0.	0.
NOVEMBER	1.88	1.50	0.0	0.	4.00	5.00	5.00	3.78	295.	293.	203.	0.
DECEMBER	1.14	0.77	0.0	0.	4.00	5.00	5.00	0.20	305.	303.	300.	458.

ANNUAL TOTALS

PEVAP	PRECIP	IRRIGATION	NITROGEN-N	DISCHARGE 2B	DISPOSAL
IN.	IN.	IN./AC.	LB./AC.	AC. IN.	EFFICIENCY
57.14	28.61	106.04	3481.	1325.	63%

1965

MONTH	PEVAP	PRECIP	IRR	NITROGEN-N	LAGOON LEVELS				LAGOON DISCHARGE AC. IN.			
	IN.	IN.	IN.	LB./AC.	1A	1B	2A	2B	1A	1B	2A	2B
JANUARY	1.15	0.87	0.0	0.	4.00	5.00	5.00	5.00	306.	305.	302.	79.
FEBRUARY	1.46	1.98	0.0	0.	4.00	5.00	5.00	5.00	283.	285.	290.	292.
MARCH	2.55	0.88	0.0	0.	4.00	5.00	5.00	5.00	293.	287.	270.	264.
APRIL	5.02	1.34	16.20	532.	3.99	4.79	4.69	4.69	32.	27.	28.	27.
MAY	7.22	5.19	15.55	510.	4.00	5.00	4.90	4.52	63.	46.	0.	0.
JUNE	6.93	8.48	11.93	392.	4.00	5.00	5.00	5.00	139.	145.	148.	133.
JULY	8.63	3.21	16.85	553.	3.83	4.69	4.69	4.67	33.	27.	10.	5.
AUGUST	7.35	5.24	16.20	532.	3.97	4.95	4.67	-0.18	39.	19.	0.	207.
SEPTEMBER	3.90	4.72	12.70	417.	4.00	5.00	5.00	1.90	119.	120.	89.	0.
OCTOBER	4.11	0.22	14.94	490.	4.00	5.00	4.99	1.65	57.	42.	4.	0.
NOVEMBER	1.97	0.03	0.0	0.	4.00	5.00	5.00	5.00	281.	273.	253.	97.
DECEMBER	1.27	1.08	0.0	0.	4.00	5.00	5.00	0.20	307.	306.	304.	516.

ANNUAL TOTALS

PEVAP	PRECIP	IRRIGATION	NITROGEN-N	DISCHARGE 2B	DISPOSAL
IN.	IN.	IN./AC.	LB./AC.	AC. IN.	EFFICIENCY
51.55	33.24	104.37	3426.	1620.	55%

1966

MONTH	PEVAP	PRECIP	IRR	NITROGEN-N	LAGOON LEVELS				LAGOON DISCHARGE AC. IN.			
	IN.	IN.	IN.	LB./AC.	1A	1B	2A	2B	1A	1B	2A	2B
JANUARY	1.04	0.50	0.0	0.	4.00	5.00	5.00	5.00	303.	301.	296.	72.
FEBRUARY	1.70	1.61	0.0	0.	4.00	5.00	5.00	5.00	278.	277.	276.	276.
MARCH	4.45	0.30	0.0	0.	4.00	5.00	5.00	5.00	271.	255.	214.	193.
APRIL	4.34	0.84	16.20	532.	4.00	5.00	4.83	4.77	32.	19.	4.	0.
MAY	7.91	0.26	19.44	638.	3.61	4.36	4.19	4.13	0.	0.	0.	0.
JUNE	8.18	2.38	18.25	599.	3.43	3.88	3.71	3.65	0.	0.	0.	0.
JULY	9.05	2.10	17.55	576.	3.35	3.30	3.13	3.07	0.	0.	0.	0.
AUGUST	6.89	3.47	16.20	532.	3.75	3.01	2.84	-0.29	0.	0.	0.	136.
SEPTEMBER	4.78	2.36	14.90	489.	4.00	3.54	2.64	-0.49	33.	0.	0.	0.
OCTOBER	4.60	0.40	14.44	474.	4.00	4.53	2.29	-0.84	61.	0.	0.	0.
NOVEMBER	1.78	0.05	0.0	0.	4.00	5.00	4.27	-0.98	283.	255.	0.	0.
DECEMBER	1.09	0.89	0.0	0.	4.00	5.00	5.00	0.21	306.	306.	216.	162.

ANNUAL TOTALS

PEVAP	PRECIP	IRRIGATION	NITROGEN-N	DISCHARGE 2B	DISPOSAL
IN.	IN.	IN./AC.	LB./AC.	AC. IN.	EFFICIENCY
55.81	15.16	116.99	3840.	845.	76%

1967

MONTH	PEVAP IN.	PRECIP IN.	IRR IN.	NITROGEN-N LB./AC.	LAGOON LEVELS 1A	1B	2A	2B	LAGOON DISCHARGE AC. IN. 1A	1B	2A	2B
JANUARY	1.06	0.38	0.0	0.	4.00	5.00	5.00	5.00	302.	300.	293.	68.
FEBRUARY	2.15	0.20	0.0	0.	4.00	5.00	5.00	5.00	261.	253.	234.	227.
MARCH	3.84	1.11	0.0	0.	4.00	5.00	5.00	5.00	284.	273.	246.	236.
APRIL	4.89	3.56	15.00	492.	3.99	4.88	4.86	4.81	70.	71.	74.	75.
MAY	5.85	2.70	16.20	532.	4.00	5.00	4.79	4.63	44.	26.	4.	0.
JUNE	6.35	14.14	13.34	438.	3.98	4.98	4.97	4.94	177.	208.	264.	279.
JULY	7.28	4.63	18.25	599.	3.92	4.93	4.90	4.74	26.	19.	1.	0.
AUGUST	7.53	1.91	19.44	638.	3.64	4.52	4.45	-0.47	5.	3.	0.	211.
SEPTEMBER	4.41	6.61	11.59	381.	4.00	5.00	4.97	1.02	112.	98.	58.	0.
OCTOBER	3.54	1.48	13.94	458.	4.00	5.00	5.00	2.09	88.	80.	55.	0.
NOVEMBER	1.71	0.37	0.0	0.	4.00	5.00	5.00	5.00	286.	281.	268.	134.
DECEMBER	1.13	1.15	0.0	0.	4.00	5.00	5.00	0.22	308.	308.	309.	521.

ANNUAL TOTALS

PEVAP IN.	PRECIP IN.	IRRIGATION IN./AC.	NITROGEN-N LB./AC.	DISCHARGE 2B AC. IN.	DISPOSAL EFFICIENCY
49.74	38.24	107.76	3537.	1751.	51%

1968

MONTH	PEVAP	PRECIP	IRR	NITROGEN-N	LAGOON LEVELS				LAGOON DISCHARGE AC. IN.			
	IN.	IN.	IN.	LB./AC.	1A	1B	2A	2B	1A	1B	2A	2B
JANUARY	1.02	0.17	0.0	0.	4.00	5.00	5.00	5.00	301.	297.	289.	64.
FEBRUARY	1.59	0.44	0.0	0.	4.00	5.00	5.00	5.00	268.	264.	252.	248.
MARCH	4.67	0.02	0.0	0.	4.00	5.00	5.00	5.00	266.	249.	202.	185.
APRIL	5.36	3.15	13.80	453.	3.97	4.87	4.87	4.87	81.	79.	72.	68.
MAY	6.03	2.61	16.65	553.	3.99	4.99	4.69	4.58	31.	13.	0.	0.
JUNE	8.12	3.09	16.85	553.	3.70	4.73	4.55	4.17	40.	32.	0.	0.
JULY	8.21	3.81	16.85	553.	3.93	4.36	4.18	3.80	0.	0.	0.	0.
AUGUST	7.37	8.31	16.20	532.	3.98	4.97	4.69	0.08	77.	53.	0.	169.
SEPTEMBER	5.53	3.03	14.35	471.	4.00	4.93	4.89	0.07	65.	57.	9.	0.
OCTOBER	3.94	3.12	13.54	458.	4.00	5.00	4.99	1.63	99.	92.	72.	0.
NOVEMBER	1.49	1.29	0.0	0.	4.00	5.00	5.00	5.00	296.	296.	252.	142.
DECEMBER	1.02	0.97	0.0	0.	4.00	5.00	5.00	0.22	308.	308.	307.	519.

ANNUAL TOTALS

PEVAP	PRECIP	IRRIGATION	NITROGEN-N	DISCHARGE 2B	DISPOSAL
IN.	IN.	IN./AC.	LB./AC.	AC. IN.	EFFICIENCY
54.37	30.01	108.64	3573.	1395.	61%

1969

MONTH	PEVAP IN.	PRECIP IN.	IRR IN.	NITROGEN-N LB./AC.	LAGOON LEVELS 1A	1B	2A	2B	LAGOON DISCHARGE AC. IN. 1A	1B	2A	2B
JANUARY	0.76	0.71	0.0	0.	4.00	5.00	5.00	5.00	308.	308.	307.	85.
FEBRUARY	1.13	1.75	0.0	0.	4.00	5.00	5.00	5.00	284.	286.	253.	295.
MARCH	2.44	1.67	0.0	0.	4.00	5.00	5.00	5.00	301.	298.	291.	288.
APRIL	4.89	1.89	16.20	532.	3.99	4.84	4.84	4.84	38.	34.	23.	17.
MAY	5.21	5.82	14.90	489.	3.98	4.97	4.97	4.96	98.	95.	85.	82.
JUNE	6.79	2.89	18.95	622.	3.87	4.64	4.64	4.63	0.	0.	0.	0.
JULY	7.49	6.17	16.15	530.	3.86	4.87	4.87	4.70	64.	49.	6.	0.
AUGUST	6.57	3.38	16.85	553.	4.00	5.00	4.62	-0.27	20.	2.	0.	209.
SEPTEMBER	4.87	1.30	16.01	525.	4.00	4.96	4.51	-0.56	34.	22.	0.	0.
OCTOBER	2.74	3.26	12.45	409.	4.00	5.00	5.00	1.26	132.	133.	79.	0.
NOVEMBER	1.87	0.12	0.0	0.	4.00	5.00	5.00	5.00	283.	276.	258.	86.
DECEMBER	0.86	0.57	0.0	0.	4.00	5.00	5.00	0.21	306.	304.	302.	513.

ANNUAL TOTALS

PEVAP IN.	PRECIP IN.	IRRIGATION IN./AC.	NITROGEN-N LB./AC.	DISCHARGE 2B AC. IN.	DISPOSAL EFFICIENCY
45.63	29.53	111.51	3660.	1575.	56%

1970

MONTH	PEVAP IN.	PRECIP IN.	IRR IN.	NITROGEN-N LB./AC.	LAGOON LEVELS 1A	1B	2A	2B	LAGOON DISCHARGE AC. IN. 1A	1B	2A	2B
JANUARY	1.10	0.22	0.0	0.	4.00	5.00	5.00	5.00	300.	297.	288.	63.
FEBRUARY	2.23	0.44	0.0	0.	4.00	5.00	5.00	5.00	262.	256.	238.	231.
MARCH	2.54	1.13	0.0	0.	4.00	5.00	5.00	5.00	296.	290.	276.	271.
APRIL	5.43	2.02	15.60	512.	4.00	4.92	4.82	4.82	41.	32.	20.	14.
MAY	7.58	9.74	14.90	489.	4.00	5.00	5.00	5.00	112.	116.	116.	116.
JUNE	8.22	2.76	16.85	553.	3.74	4.76	4.62	4.56	33.	23.	14.	13.
JULY	9.16	3.59	18.55	622.	3.58	4.30	4.16	4.10	0.	0.	0.	0.
AUGUST	8.35	1.53	18.14	596.	3.43	3.73	3.59	-0.57	0.	0.	0.	182.
SEPTEMBER	4.97	4.42	12.14	399.	4.00	4.91	3.54	-0.61	56.	0.	0.	0.
OCTOBER	2.67	2.46	12.95	425.	4.00	5.00	4.47	-0.63	119.	114.	0.	0.
NOVEMBER	1.68	0.20	0.0	0.	4.00	5.00	5.00	3.77	285.	279.	201.	0.
DECEMBER	1.41	0.04	0.0	0.	4.00	5.00	5.00	0.20	296.	291.	277.	431.

ANNUAL TOTALS

PEVAP IN.	PRECIP IN.	IRRIGATION IN./AC.	NITROGEN-N LB./AC.	DISCHARGE 2B AC. IN.	DISPOSAL EFFICIENCY
55.35	28.55	109.54	3596.	1321.	63%

1971

MONTH	PEVAP	PRECIP	IRR	NITROGEN-N	LAGOON LEVELS				LAGOON DISCHARGE AC. IN.			
	IN.	IN.	IN.	LB./AC.	1A	1B	2A	2B	1A	1B	2A	2B
JANUARY	1.04	0.76	0.0	0.	4.00	5.00	5.00	5.00	306.	305.	302.	79.
FEBRUARY	1.35	2.50	0.0	0.	4.00	5.00	5.00	5.00	299.	293.	305.	309.
MARCH	3.23	0.77	0.0	0.	4.00	5.00	5.00	5.00	286.	277.	252.	243.
APRIL	5.57	1.18	16.20	532.	3.99	4.95	4.71	4.63	25.	11.	1.	0.
MAY	6.29	6.47	16.20	532.	3.98	4.94	4.87	4.87	76.	77.	59.	49.
JUNE	8.66	3.98	15.44	507.	3.75	4.69	4.69	4.69	57.	51.	26.	17.
JULY	8.39	10.17	14.74	484.	3.56	4.96	4.96	4.96	89.	83.	68.	63.
AUGUST	7.92	0.38	18.79	617.	3.66	4.33	4.33	-0.63	0.	0.	0.	220.
SEPTEMBER	5.97	0.74	15.46	507.	3.91	3.90	3.90	-1.06	0.	0.	0.	0.
OCTOBER	3.87	2.74	12.95	425.	4.00	5.00	4.18	-1.16	101.	46.	0.	0.
NOVEMBER	1.73	4.88	0.0	0.	4.00	5.00	5.00	5.00	327.	339.	272.	10.
DECEMBER	0.74	0.71	0.0	0.	4.00	5.00	5.00	0.21	308.	308.	308.	520.

ANNUAL TOTALS

PEVAP	PRECIP	IRRIGATION	NITROGEN-N	DISCHARGE 2B	DISPOSAL
IN.	IN.	IN./AC.	LB./AC.	AC. IN.	EFFICIENCY
54.76	35.28	109.78	3604.	1511.	58%

1972

MONTH	PEVAP	PRECIP	IRR	NITROGEN-N	LAGOON LEVELS				LAGOON DISCHARGE AC. IN.			
	IN.	IN.	IN.	LB./AC.	1A	1B	2A	2B	1A	1B	2A	2B
JANUARY	1.17	0.23	0.0	0.	4.00	5.00	5.00	5.00	300.	296.	287.	61.
FEBRUARY	1.90	0.30	0.0	0.	4.00	5.00	5.00	5.00	264.	258.	242.	236.
MARCH	4.19	0.79	0.0	0.	4.00	5.00	5.00	5.00	278.	265.	231.	218.
APRIL	4.59	4.29	14.40	473.	4.00	5.00	5.00	5.00	87.	86.	83.	80.
MAY	5.94	4.07	14.26	468.	3.97	4.96	4.96	4.96	88.	83.	69.	64.
JUNE	8.65	1.70	19.66	645.	3.52	4.38	4.38	4.38	0.	0.	0.	0.
JULY	8.48	6.90	16.15	530.	3.93	4.59	4.25	4.25	16.	0.	0.	0.
AUGUST	7.26	6.65	16.85	553.	3.95	4.98	4.46	-0.05	52.	31.	0.	189.
SEPTEMBER	4.85	1.03	14.90	489.	4.00	5.00	4.40	-0.37	46.	31.	0.	0.
OCTOBER	2.57	2.11	13.94	458.	4.00	5.00	5.00	0.11	102.	100.	23.	0.
NOVEMBER	1.13	3.51	0.0	0.	4.00	5.00	5.00	5.00	320.	329.	353.	144.
DECEMBER	0.89	1.13	0.0	0.	4.00	5.00	5.00	0.21	310.	311.	314.	527.

ANNUAL TOTALS

PEVAP	PRECIP	IRRIGATION	NITROGEN-N	DISCHARGE 2B	DISPOSAL
IN.	IN.	IN./AC.	LB./AC.	AC. IN.	EFFICIENCY
51.65	32.71	110.15	3616.	1520.	58%

1973

MONTH	PEVAP IN.	PRECIP IN.	IRR IN.	NITROGEN-N LB./AC.	LAGOON LEVELS 1A	1B	2A	2B	LAGOON DISCHARGE AC. IN. 1A	1B	2A	2B
JANUARY	1.03	1.01	0.0	0.	4.00	5.00	5.00	5.00	308.	308.	308.	86.
FEBRUARY	1.51	0.65	0.0	0.	4.00	5.00	5.00	5.00	271.	267.	259.	256.
MARCH	2.39	7.37	0.0	0.	4.00	5.00	5.00	5.00	353.	372.	422.	440.
APRIL	5.00	2.41	14.40	473.	4.00	5.00	4.97	4.88	66.	56.	34.	28.
MAY	7.01	3.14	16.85	553.	3.90	4.61	4.61	4.61	40.	43.	49.	46.
JUNE	8.75	1.78	17.55	576.	3.58	4.37	4.03	4.03	16.	0.	0.	0.
JULY	8.57	8.50	16.15	530.	3.83	4.84	4.23	4.02	47.	25.	0.	0.
AUGUST	8.38	2.44	17.50	574.	3.82	4.39	3.73	-0.50	2.	0.	0.	178.
SEPTEMBER	3.89	8.49	9.38	308.	4.00	5.00	4.99	1.44	184.	174.	69.	0.
OCTOBER	3.00	4.30	13.94	458.	4.00	5.00	5.00	4.58	118.	123.	135.	0.
NOVEMBER	1.56	1.27	0.0	0.	4.00	5.00	5.00	5.00	296.	295.	292.	272.
DECEMBER	0.78	3.06	0.0	0.	4.00	5.00	5.00	0.23	329.	337.	360.	580.

ANNUAL TOTALS

PEVAP IN.	PRECIP IN.	IRRIGATION IN./AC.	NITROGEN-N LB./AC.	DISCHARGE 2B AC. IN.	DISPOSAL EFFICIENCY
51.87	44.42	105.77	3472.	1686.	48%

1974

MONTH	PEVAP	PRECIP	IRR	NITROGEN-N	LAGOON LEVELS				LAGOON DISCHARGE AC. IN.			
	IN.	IN.	IN.	LB./AC.	1A	1B	2A	2B	1A	1B	2A	2B
JANUARY	0.86	0.33	0.0	0.	4.00	5.00	5.00	5.00	303.	301.	296.	72.
FEBRUARY	2.05	0.01	0.0	0.	4.00	5.00	5.00	5.00	260.	252.	232.	224.
MARCH	3.45	0.63	0.0	0.	4.00	5.00	5.00	5.00	283.	273.	245.	235.
APRIL	5.46	2.26	13.80	453.	4.00	4.94	4.84	4.84	70.	60.	47.	41.
MAY	7.27	2.35	16.20	532.	3.83	4.76	4.74	4.43	47.	37.	0.	0.
JUNE	8.42	3.78	18.25	599.	3.53	4.57	4.48	4.04	24.	16.	0.	0.
JULY	11.25	0.21	21.06	691.	2.63	3.65	3.56	3.13	0.	0.	0.	0.
AUGUST	7.28	2.37	16.85	553.	2.82	3.24	3.15	-0.41	0.	0.	0.	139.
SEPTEMBER	5.68	0.55	16.01	525.	3.00	2.81	2.72	-0.84	0.	0.	0.	0.
OCTOBER	3.20	1.98	13.94	458.	3.88	2.71	2.62	-0.94	0.	0.	0.	0.
NOVEMBER	1.75	0.84	0.0	0.	4.00	5.00	3.96	-1.01	277.	169.	0.	0.
DECEMBER	1.12	0.46	0.0	0.	4.00	5.00	5.00	0.20	302.	300.	168.	112.

ANNUAL TOTALS

PEVAP	PRECIP	IRRIGATION	NITROGEN-N	DISCHARGE 2B	DISPOSAL
IN.	IN.	IN./AC.	LB./AC.	AC. IN.	EFFICIENCY
57.79	15.82	116.11	3811.	823.	77%

APPENDIX B

EQUIPMENT AND CONSTRUCTION SPECIFICATIONS

EQUIPMENT AND CONSTRUCTION SPECIFICATIONS

These specification cover the installation of a sprinkler irrigation system including pumping plant for a research project at the Dubuque Packing Company plant near Mankato, Kansas. The irrigation system shall be capable of delivering wastewater from an aerobic lagoon to approximately 14 acres of land through a system of underground pipelines.

Pump and Power Unit

The pump and power unit shall be installed in a pump house constructed adjacent to the aerobic lagoon. The pump shall be a horizontal certrifugal pump capable of delivering 330 gpm against a total dynamic head of 175 feet (model 2 1/2 ZPBL Berkeley with 7-15/16 inch diameter impeller or equivalent). The pump shall be all iron including a cast iron case, cast iron impeller, stainless steel shaft sleeve, and corrosion resistant bolts, nuts, and capscrews. The pump shall be fitted with mechanical seals.

The pump shall be powered by a 20 horsepower horizontal, NEMA "C" face, ball bearing, close coupled pump motor. The motor shall be drip proof with a Service Factor of 1.15. The motor shall be designed for three phase A.C. power and capable of delivering rated horsepower on 230 or 460 volts. The motor shall be equipped with a magnetic starter.

Plastic Pipe

All plastic pipe installed in the irrigation system shall be of Polyvinyl Chloride (PVC) with a Standard Dimension Ratio (SDR) of 26 and a rated operating pressure of 160 psi at 73.4^{o}F. The pipe shall have rubber sealing ring bell couplers (Johns-Manville Ring-Tite or equivalent) with couplers spaced no further than 40 feet apart. All tees, elbows, and other fittings shall be of equal or greater wall thickness and pressure rating than the pipe. All connections shall be made in accordance with manufacturers recommendations.

Installation of Plastic Pipelines

The pipeline draining water from the floor of the wet well and the pump house, and the pipeline delivering water from the pump into the main line of the irrigation system shall be at the elevations necessary to make the required water deliveries. The main line and all lateral lines of the sprinkler irrigation system shall be laid in trenches a minimum of 36 inches deep.

All trenches shall be backfilled by either the hand or mechanical backfilling method or the water packing method as described in ASAE Standard: ASAE S376.

The sprinkler irrigation system shall be tested by the procedure given in ASAE Standard: ASAE S376 with all repairs made as needed to correct defects in the system.

Access Pipeline to Wet Well (Figure 4)

An access pipeline, 50 feet long, shall be installed to deliver wastewater over the west bank of the aerobic lagoon to the wet well. This pipeline shall be 8 inches ID and laid on the soil surface with the inlet end anchored a minimum of 3 feet below the water surface and the outlet end anchored near the bottom of the wet well. The pipeline shall be airtight with the necessary fittings so it can be evacuated to serve as a siphon.

We anticipate installing a permanent pipeline from the aerobic lagoon to the wet well in the future. A 6-inch diameter cast iron pipe 2 feet long shall be grouted into the hole on the south side of the wet well with centerline 9 inches from the floor. The pipe shall be capped or serve as the entrance to the wet well from the siphon.

Wet Well and Pump House (Figures 5, 6, and 7)

A wet well and pump house shall be installed by Kansas State University on a reinforced concrete slab near the aerobic lagoon. The wet well will be a 4-foot ID reinforced concrete manhole and the pump house will be a 6-foot ID reinforced concrete manhole. Holes will be left during casting for piping to enter and leave both structures.

Drainage System (Figures 5 and 6)

The drain pipe shall be a 6-inch ID plastic pipe. The inlet to both the wet well and pump house shall be a 3-inch ID plastic pipe grouted into the west side of the manholes at the surface of the floor. A one-fourth turn valve with above ground control lever shall be installed in each line ahead of a 90^{0} elbow at the edge of the concrete floor. A short section of 3-inch ID pipe shall be connected to the 90^{0} elbow and a fitting in the 6-inch ID drain pipe. The 6-inch diameter drain pipe shall be 1 foot below the surface of the floor of the manholes and shall be buried to a sufficient depth to maintain a minimum slope of 0.3% to the south until it intercepts the land surface, approximately 150 feet.

Pipe and Pump Installation (Figures 6 and 7)

A 3-inch diameter cast iron pipe shall be attached to the pump inlet in the pump house and grouted into a hole in the wet well with centerline of the pump 7.5 inches from the floor. A cast iron gate valve shall be installed in the pipe between the pump inlet and the wet well.

The horizontal centrifugal pump and direct connected electric motor shall be bolted to the pump house floor. The discharge side of the pump shall be attached to a 6-inch cast iron check valve through a plastic pipe reducer. Next to the check valve shall be a 6-inch x 6-inch x 2-inch plastic tee. The 2-inch side of the tee shall be directed downward and fitted with a drain plug. A bell coupler shall be installed inside the wall of the pump house. The 6-inch ID plastic pipe shall pass through the pump house wall and contine approximately 25 feet where it shall connect to the main line of the irrigation system through a 90^0 elbow. A 4-inch pressure relief valve shall be installed into the pipeline just outside the pump house wall. The valve shall be mounted 6 inches above the ground on a 4-inch ID plastic pipe connected to the pipeline through a 6-inch x 6-inch x 4-inch plastic tee.

Main Line and Lateral Line Installation (Figures 8, 10, and 11)

All main line and lateral lines shall be of plastic pipe. Coupler spacing shall not exceed 40 feet. Any change of direction by the pipe, tees and risers, or valves and plugs will require thrust blocking by concrete as provided in the manufacturer's recommendations or ASAE Standard: ASAE S376.

The 6-inch ID plastic main line pipe shall be connected to the 90^0 elbow approximately 25 feet outside the pump house. Starting 10 feet north of the south elbow, six 6-inch x 6-inch x 3-inch tees shall be installed at 90-foot intervals in the main line. Starting 90 feet from the sixth tee, three 6-inch x 6-inch x 6-inch x 6-inch crosses will be installed at 90-foot intervals.

One foot beyond the last cross, a 6-inch ID plastic elbow shall turn upward to a hydrant. The hydrant assembly shall start at the elbow with a

6-inch adaptor. A 6-inch diameter galvanized steel pipe shall lead to a 6-inch x 6-inch x 4-inch tee at ground level. From the 6-inch side of the tee, a short piece of 6-inch diameter steel pipe with a hydrant cap welded on the end shall extend to a height of 12 inches above the ground surface. A 6-inch manual hydrant control shall attach to the surface. To the 4-inch side of the tee, a 4-inch diameter nipple and elbow shall be installed. A combination air release and vacuum relief valve shall be installed above the ground to the same elevation as the top of the hydrant. The combination valve and hydrant shall be enclosed with a protective cover consisting of a 2-foot ID concrete pipe 3 feet long placed on end 2 feet into the ground and filled with gravel.

A 3-inch ID plastic pipe 3 feet long shall be attached through a 3-inch male adapter to each 6-inch x 6-inch x 3-inch tee and connected to a 3-inch Rain Bird Plastic Remote Control Valve - EP Series (valves furnished by Kansas State University). An 18-inch diameter manhole with a weatherproof cover shall provide access to each valve. The top of the manhole shall extend 6 inches above the ground. On the outlet side of the valve shall be a 3-inch male adapter and a reducer bushing connecting to a 2 1/2-inch diameter plastic pipe which shall continue to the end of the lateral.

At each 6-inch x 6-inch x 6-inch x 6-inch cross, a 6-inch to 3-inch reducer shall be attached to the cross and a 3-foot piece of 3-inch diameter plastic pipe for the laterals. The 3-inch pipe shall be connected to a Rain Bird Plastic Remote Control Valves - EP Series (valves furnished by Kansas State University) installed in a manhole as specified above. On the laterals to the west, the assembly out of the valve shall be to the 2 1/2-inch diameter plastic pipe as described above. On the east laterals, a 4-inch x 3-inch reducer shall connect the remote control valve through a male adapter to a 4-inch diameter plastic pipe. These 4-inch laterals shall continue to the fourth sprinkler, a distance of 260 feet for the north and south lateral, and 300 feet for the middle lateral. From the fourth riser, a 4-inch x 3-inch reducer shall connect to a 3-inch diameter plastic pipe which shall continue to the end of the lateral.

Thrust blocks shall be of concrete with a minimum compressive strength of 2,000 psi. No block shall have a volume of less than one cubic foot. Thrust blocks shall be constructed so the bearing surface is in direct line with the major force created by the pipe or fitting. The earth bearing surface shall be undisturbed with only the simplest of forms required.

Thrust blocks are required at the following locations in the irrigation system:

1. The two elbows in the 6-inch main line. These blocks shall have an area of not less than 3 square feet exposed to the soil.
2. All crosses and tees in the 6-inch main line, total of 9. The minimum surface area shall be 1 square foot at each corner of the crosses and 2 square feet at each tee.
3. The end of each lateral line. The minimum surface area shall be 1 square foot.
4. At each change in pipe size in the three east laterals. The minimum surface area shall be 1 square foot.
5. At each riser tee. The minimum surface area shall be 1 square foot with a minimum of 1 cubic foot encasing each riser.

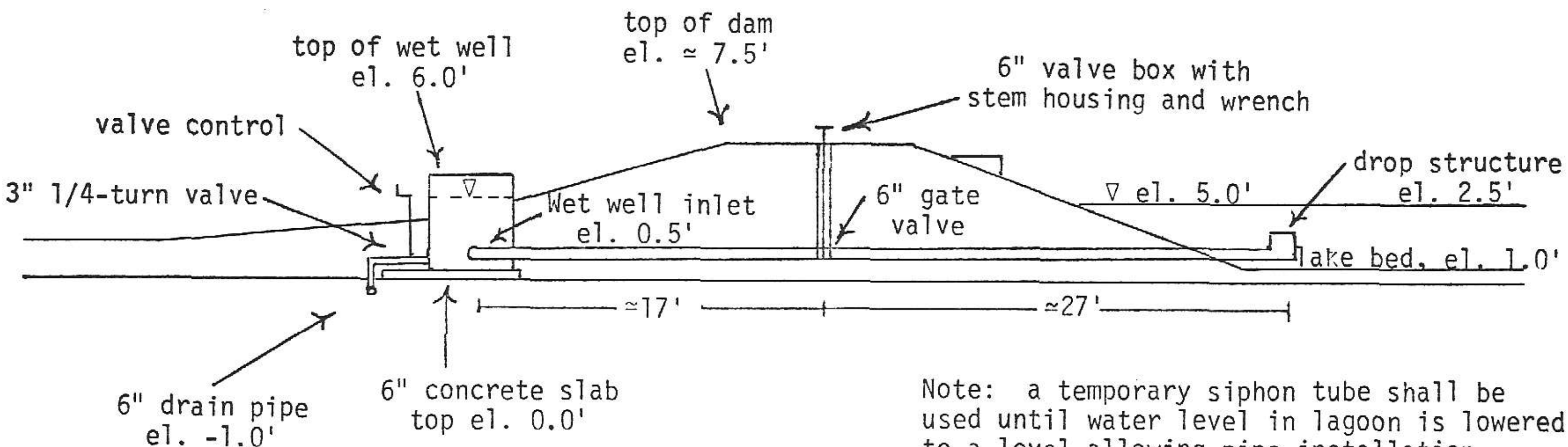
Riser Installation (Figures 9, 10 and 11)

All risers shall be constructed of a 1-inch ID plastic pipe coming out of a tee in the lateral lines to the ground surface, approximately 36 inches. The male end of the plastic riser shall be joined to a 1-inch diameter galvanized steel riser 3 feet long by a galvanized iron coupler. Sprinkler heads provided by Kansas State University (Rain Bird, model 70 CSP-TNT) shall be attached to the galvanized steel riser.

The risers in the west laterals shall connect to 2 1/2-inch x 2 1/2-inch x 1-inch tees. Each line has 5 riser assemblies spaced 80 feet apart. Initial spacing between riser and main line shall alternate between 60 feet and 20 feet with 60 feet being the spacing for the south lateral.

On the east laterals, 4-inch x 4-inch x 1-inch tees shall connect to the risers for the first four sprinklers with 3-inch x 3-inch x 1-inch tees at the last eight sprinklers. These sprinklers shall be staggered on the lateral with the initial distance being 20 feet for the north and south lateral and 60 feet for the middle lateral. The risers shall be spaced 80 feet apart on the laterals.

All risers shall have protection from mechanical damage. This shall be in the form of a concrete pipe 24 inches ID and 3 feet long buried to a depth of 1 foot with the riser centered in the pipe. The pipe shall be filled with gravel to the top of the pipe.



Note: a temporary siphon tube shall be used until water level in lagoon is lowered to a level allowing pipe installation through the dam. This shall be included in a later bid.

Figure 4. Cross Section of Dam at Wet Well Inlet

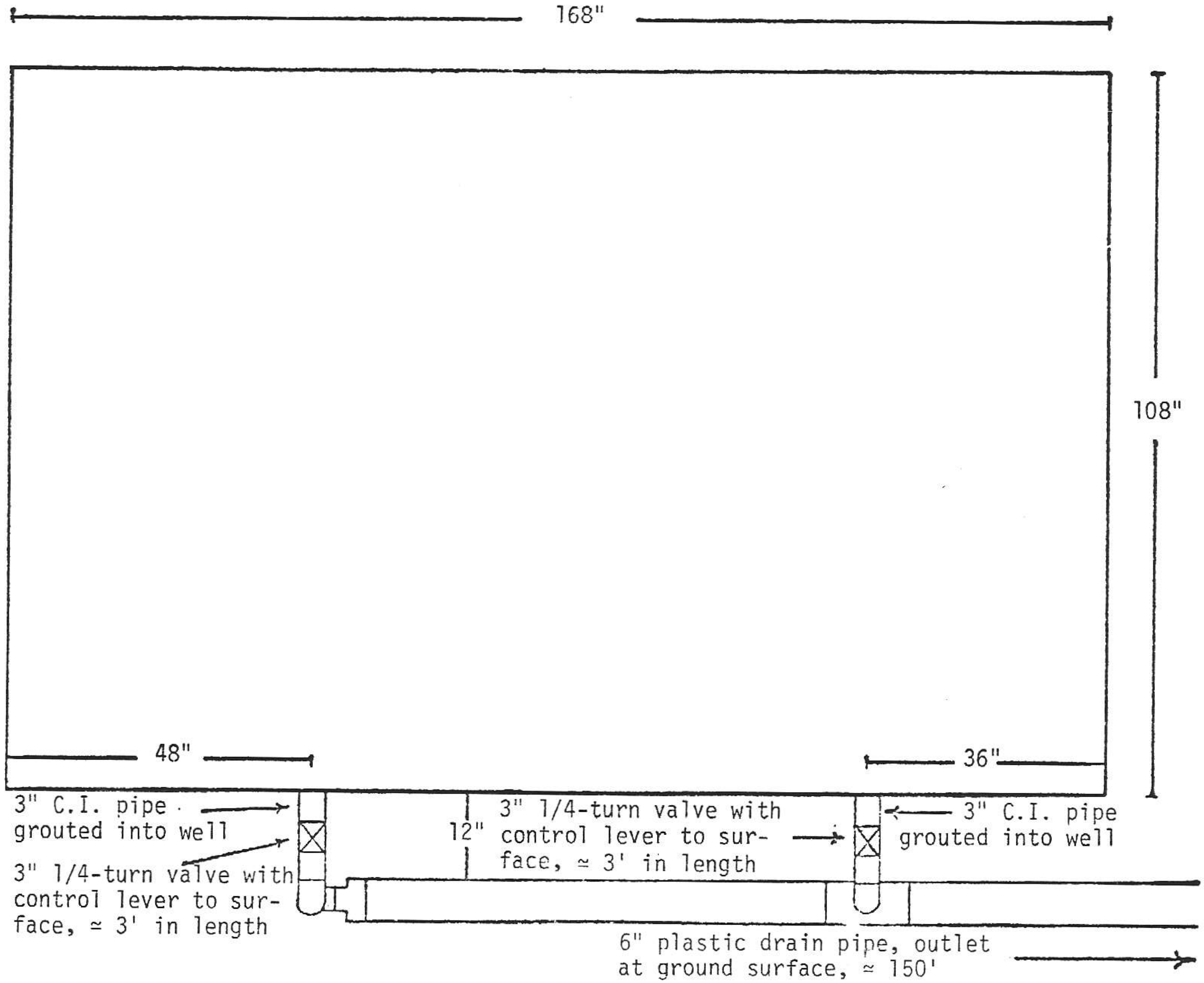


Figure 5. Concrete Floor Design

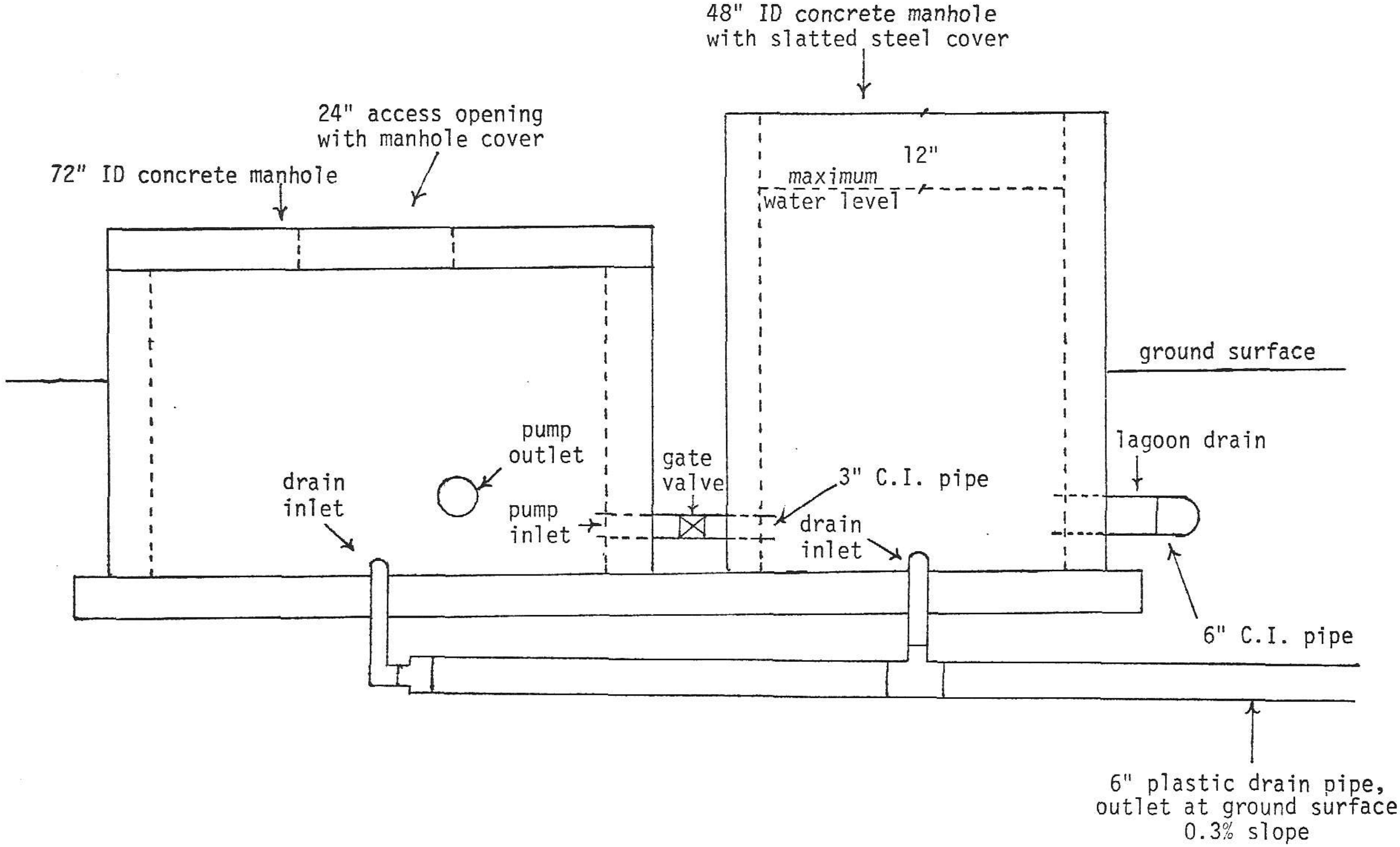


Figure 6. Wet Well and Pump House (West View)

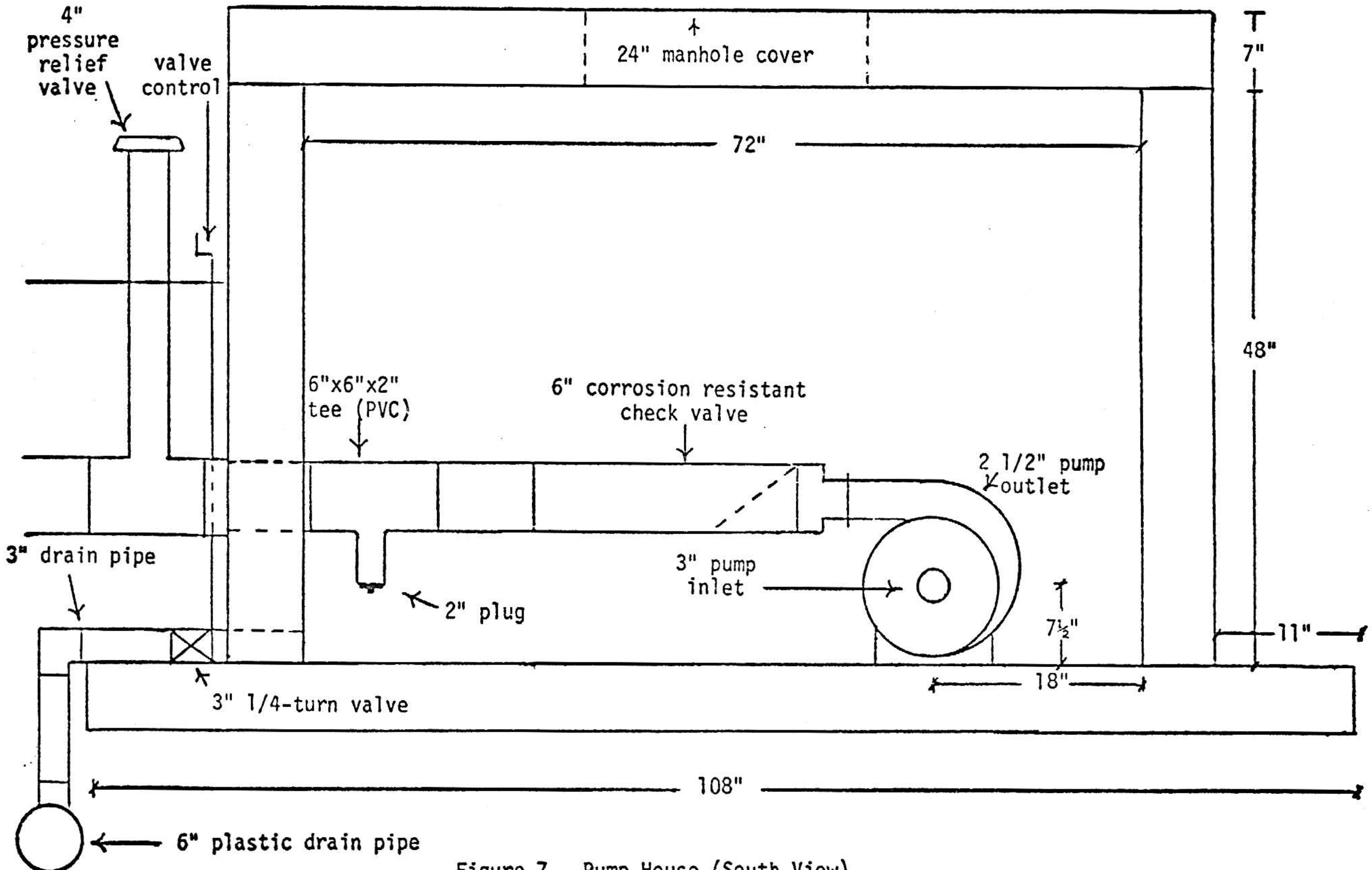


Figure 7. Pump House (South View)

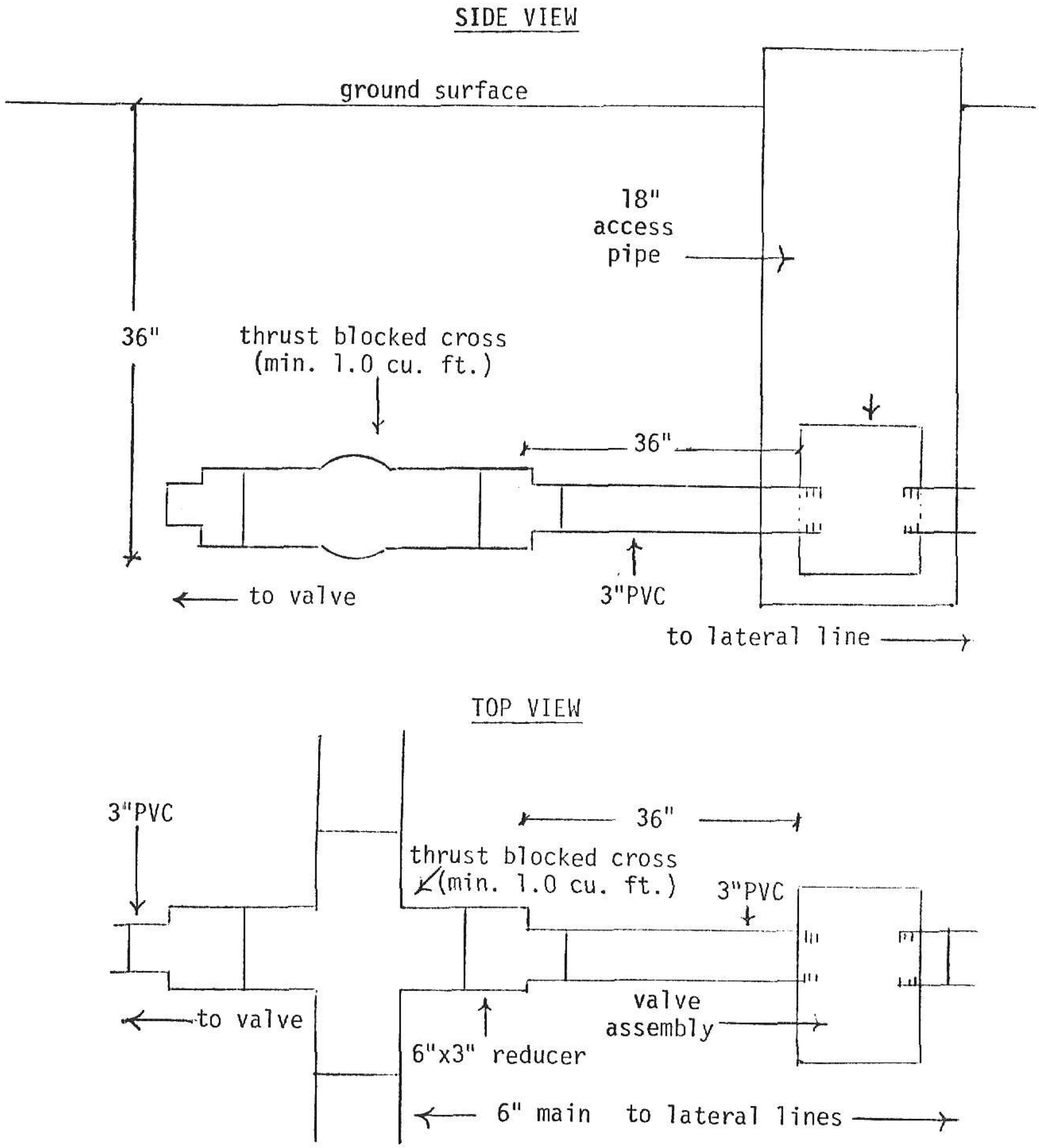


Figure 8. Valve Installation

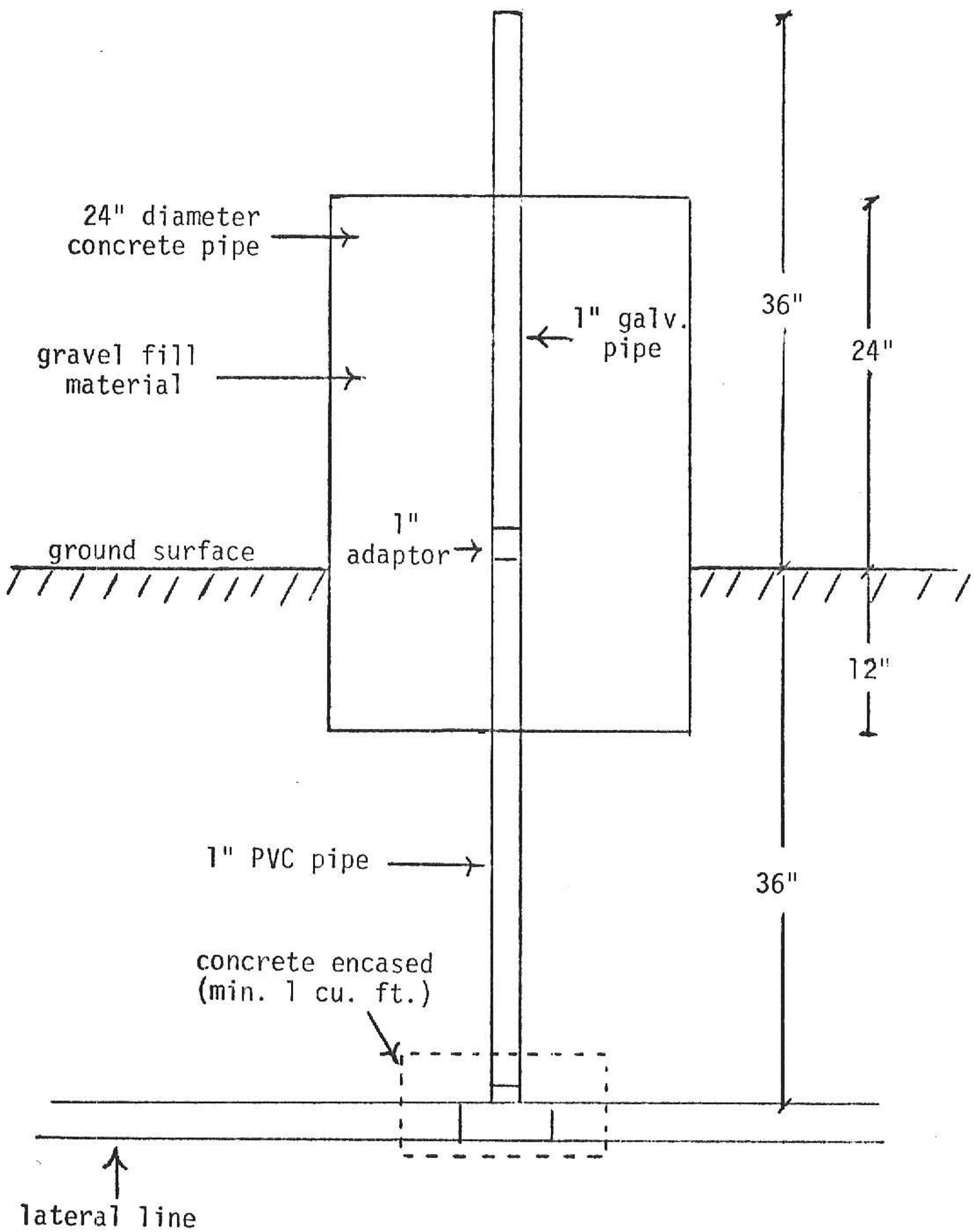


Figure 9. Riser Installation

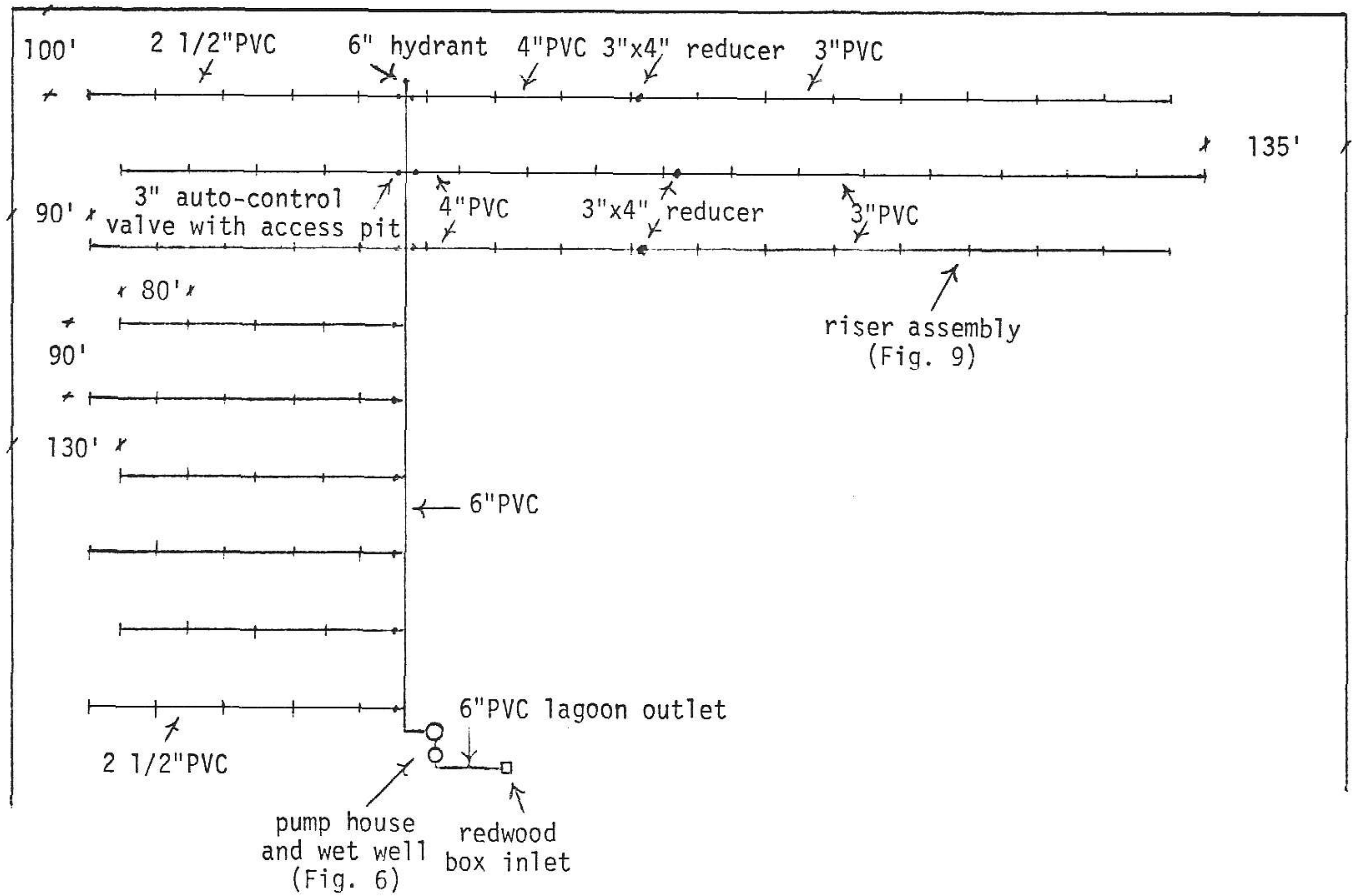


Figure 10. Sprinkler Irrigation System

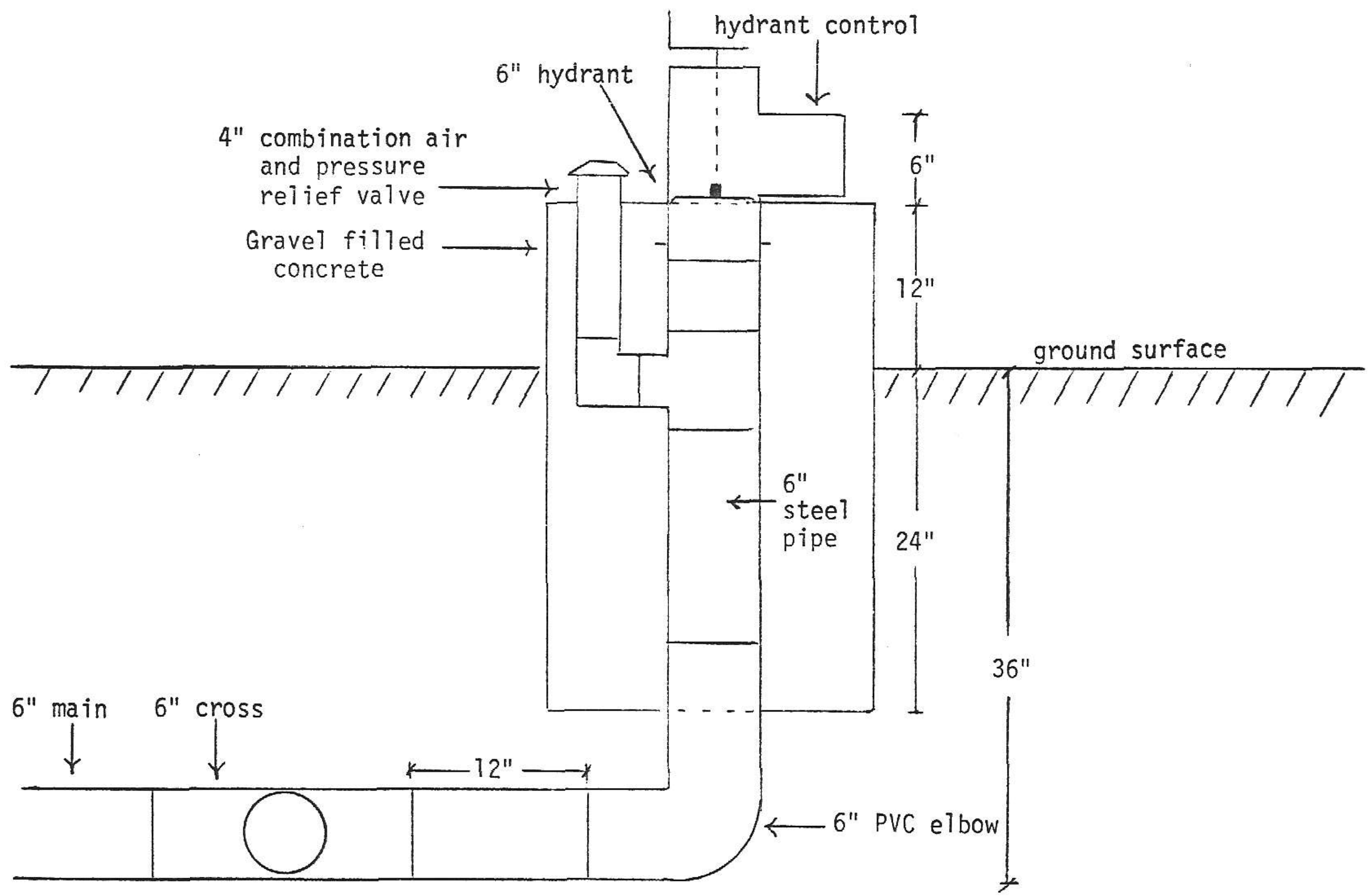


Figure 11. Hydrant Assembly

RETURN FLOW SYSTEMS

There shall be two return flow systems to handle excess irrigation water that may run off from the sprinklers. One system shall be located near the pump house in the return flow ditch west of the aerobic lagoon. It shall pump excess irrigation water back into the lagoon from there. The second system shall be located in the fresh water pond east of the aerobic lagoon. It shall return excess irrigation water to the east side of the aerobic lagoon.

West System

This pump shall sit on a concrete slab 3 feet x 3 feet, 6 inches thick located in the bottom of the return flow ditch. The elevation of the slab shall be fixed so that no more than 6 inches of water is left in the ditch at its lowest level. This shall require the surface of the slab to be at an elevation of 4 inches above the bottom of the ditch. A sump pump shall be attached to this slab by bolting it to the concrete. The pump shall be a cast iron, industrial type with 1 1/4-inch discharge capable of pumping 3,500 gallons per hour at 10 feet of head. It shall be controlled by a self-contained liquid level control to start pumping at a level of 9 inches of water above the pump base and stop pumping at a level of 1 1/2 inches above the base. (Kenco model 82A2E or equivalent).

East System

The east system shall set on a 3-foot x 3-foot concrete slab 6 inches thick located on the west bank of the pond near the north end in a channel excavated to a depth of 18 inches below the top of the pond outlet. The top of the slab shall have an elevation of 12 inches below the top of the pond outlet and pump shall be bolted to this slab with the intake not less than 10 inches below the top of the pond outlet.

The pump shall be a cast iron submersible sewage pump with totally enclosed impeller capable of passing solids 1 1/2 inches in diameter. The pump shall have a 3-inch outlet and a capacity of not less than 60 gpm at 15 feet of head.

The pump shall be powered by a 1/2 horsepower, three phase, oil filled, electric motor with a magnetic starter. The magnetic starter shall have a remote automatic liquid level control to turn the pump on when the water level reaches a level 3 inches below the top of the pond outlet and shut the pump off when the level reaches 5 inches below the top of the pond outlet. (Kenco model 22N3G with a 3-inch discharge and #102 series remote automatic liquid level controls with 4-inch turn-on and 2-inch shut-off or equivalent). In order to protect the controller from wave action, a box shall enclose it with a 1/4-inch access hole to the water.

Both pumps shall discharge into the aerobic lagoon by means of a plastic pipe laid over the dam far enough to discharge into the water. The west system will require approximately 50 feet of 4-inch plastic pipe and the east system approximately 100 feet of 4-inch plastic pipe. The pipes shall be anchored or buried under 6 inches of soil to allow mowing operations over them. The outlet shall be above the pond surface to prevent siphoning.

Wiring and Controls

A 230-volt 3-phase power line shall be constructed to the east pumping system. It shall extend from the pump house across the aerobic lagoon to the pumping system in a straight line. In order to protect the cable from the corrosive water it shall be type XHHW cross linked synthetic polymer, single conductor, number 10 copper wire. Anchors shall be used to secure the cable, and fasteners used to bind the 4 conductors together. The cable shall be buried until it enters the lagoon and after it leaves the lagoon. Total distance shall be approximately 600 feet and maximum voltage drop shall be 4 percent.

The west system shall require single phase 230-volt power. It shall be the same cable as used on the east system and will require approximately 100 feet. The cable shall be buried.

Both pumping systems shall be wired so that they will not operate when the irrigation controller is shut off. This will allow normal runoff from precipitation to pass without pumping into the lagoon. To accomplish this, a relay system shall be used to control the pump starters with the main irrigation pump.

SPECIFICATIONS OF CONTROLS

These specifications cover the installation, operation, and maintenance of the control system installed by Kansas State University, Department of Agricultural Engineering, Manhattan, Kansas, in the wastewater disposal system at the Dubuque Packing Company, Mankato, Kansas. They refer to the controls as they presently are and are intended to serve as a source of information for plant personnel and other interested parties should future modifications in the present system be necessary.

All electrical wiring was done by a licensed electrician, Lyle D. Powell, Route 3, Mankato, Kansas. All electronics wiring was done by Dennis Matteson, Manhattan, Kansas-- the electronic technician for the Agricultural Engineering Department, Kansas State University, Manhattan, Kansas.

Main Pump Circuit

The irrigation pump is run by a 20-horsepower (hp), 440-volt, 3-phase, electric motor with a single phase, 110-volt magnetic starter. Overcurrent protection and disconnecting means are provided according to Article 430, National Electric Code (1975). A block diagram of the control system with overcurrent protection is shown in Figure 12.

Two power transformers are located in the control circuit. A 3-phase, 440 high-220 low, 3-kva power transformer provides power conversion for two 220-volt motors. One is a 3-phase, 1/2-hp, 220-volt squirrel cage motor located on the east side of lagoon 1A, approximately 600 feet from the control cabinet. The other is a single phase, 1/3-hp, 220-volt split phase motor located approximately 50 feet from the control cabinet. Both motors operate return flow pumps.

The other transformer is a 440 high-115 low, 0.5-kva transformer that provides power for the control circuits. This transformer is not a large unit and is protected by a 5-amp fusetron. Should any large 115-volt loadings be installed in the future, a larger transformer will be needed.

Branch over-current protection is also provided according to the National Electric Code, Article 430 (1975).

Several controllers are located in series with the two motor circuits. A Murphy TR-1762A high-low pressure disconnect provides protection to the irrigation system from conditions of too high and too low pressure. The controller is connected to the main pump circuit as shown in Figure 12.

The controller switch is located in the 115-volt magnetic starter circuit of the 20-hp motor. Also located in this circuit is the irrigation programmer, a Rain Bird model RC 7 automatic irrigation scheduler. In parallel with the pump start circuit is an hour meter to record total time of operation of the irrigation system.

The irrigation programmer controls a set of twelve remote 24-volt AC solenoids. These solenoids control 12 automatic valves located on the sprinkler lateral lines. Information on programming the controller is printed on the inside cover of the unit. Located on the RC 7 is a "mode switch" to allow a manual shut-off of the system. In series with the mode switch is a Cramer series 360, automatic reset timer. This timer is controlled by a relay as shown in Figure 13. The relay is controlled by a 6-volt DC moisture detection circuit (Radio Shack, 1968) model Science Fair #28-132. Also connected to the Cramer timer is the control circuit of the Cutler Hammer magnetic contactor, size NEMA 00, wired in series with the power supply for both return flow pumps. A schematic is shown is Figure 13.

This moisture detection circuit has a sensor plate located on the top of the control cabinet, exposed to the weather. This plate consists of two strips of copper separated by a narrow gap. When moisture is on the plate, current will be conducted across, throwing a relay and shutting off the timer. This stops irrigation and return flow pumps from operating. When the plate dries, the relay is de-energized, starting the timer which then runs out its preset time, which can vary from 1/5 to 5 hours, before power returns to the irrigation and return flow systems.

Power for the Rain Bird controller, Cramer timer and 6-volt DC power supply comes from four 115-volt receptacles powered by the previously mentioned 440 high-115 low transformer, Figure 12.

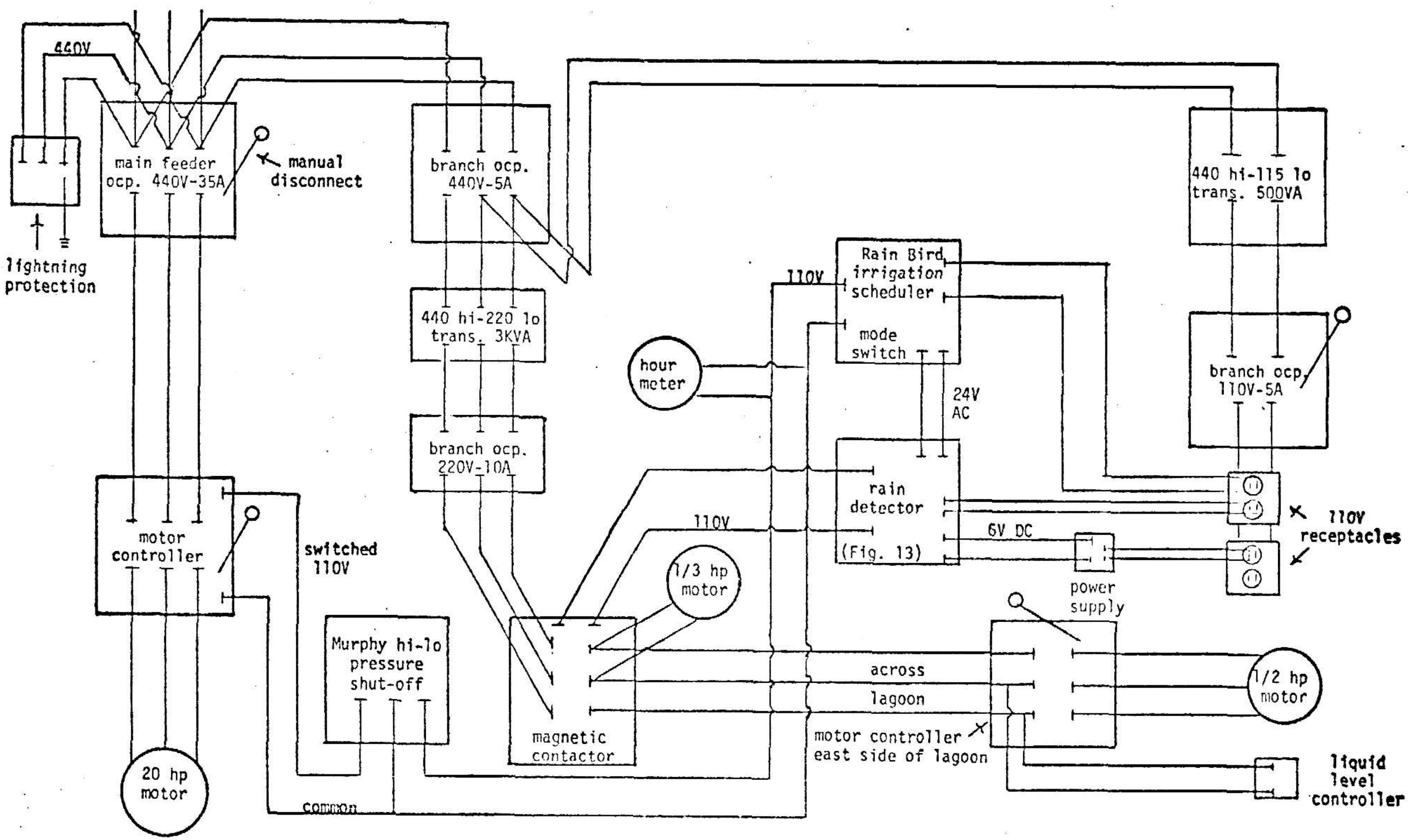


Figure 12. Control System Schematic

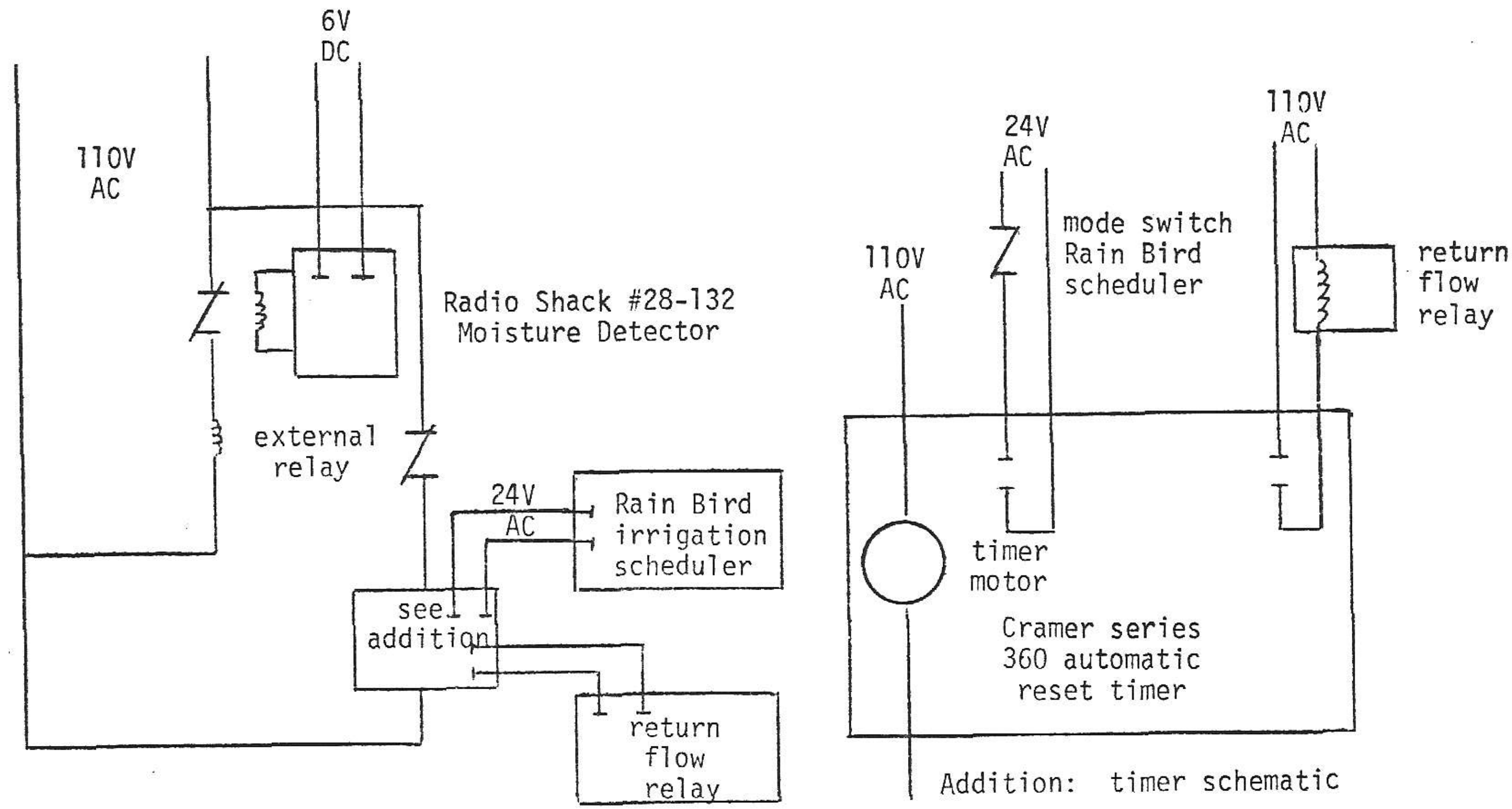


Figure 13. Rain Detector Control Circuit

APPENDIX C

SOIL MOISTURE DATA

Table 10. Summary Sheet for Neutron Probe Calibration

Depth (Ft)	Hole I		Hole II		Hole III		Hole IV		Hole V	
	CR	VM	CR	VM	CR	VM	CR	VM	CR	VM
0-1	.781	32.35	.822	34.42	.850	30.39	.465	32.61	.648	32.12
1-2	.848	21.21	.875	21.49	.881	20.89	.853	24.38	.867	21.89
2-3	.737	22.60	.738	19.98	.780	20.21	.765	20.95	.723	19.86
3-4	1.016	31.89	.821	26.16	.907	26.53	.847	24.85	.851	26.44
4-5	1.067	34.92	1.055	34.26	1.040	28.83	1.024	30.89	.970	28.00
5-6	1.056	32.19	1.057	34.22	1.129	32.33	1.029	34.35	.991	30.16
6-7	1.096	37.47	1.071	34.67	1.191	35.50	1.057	34.35	1.034	32.93
7-8	1.153	39.35	1.113	34.29	1.206	35.39	1.096	NA	1.097	38.17
8-9	1.143	34.29	1.160	37.54	1.206	33.86	1.124	37.75	1.112	34.90
9-10	1.131	34.98	1.161	34.56	1.173	32.81	1.114	35.46	1.122	34.70
10-11	1.115	33.71	1.179	37.03	1.190	33.32	1.095	34.45	1.096	35.51
11-12	1.134	33.01	1.222	37.76	1.203	33.32	1.113	35.15	1.115	37.07
12-13	1.170	36.96	1.228	41.79	1.213	34.64	1.120	38.38	1.131	37.90
13-14	1.230	41.66	1.238	37.34	1.305	37.15	1.158	31.88	1.192	34.39
14-15		40.95		39.92		38.28	1.169	32.16		36.99
						33.49		43.36		
						29.32				

CR = count ratio
VM = volumetric moisture content, %

APPENDIX D

SPRINKLER DISTRIBUTION PATTERNS

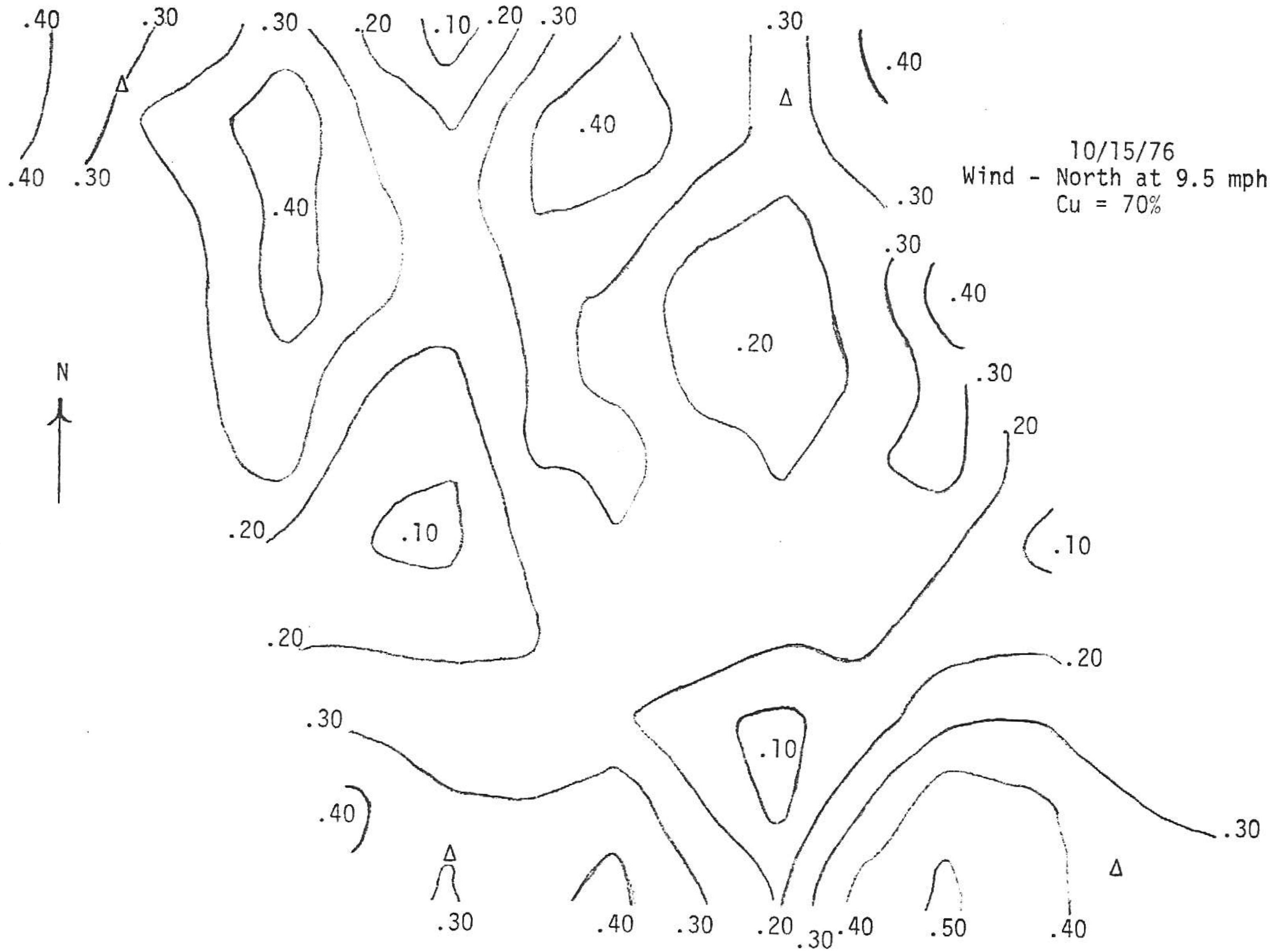


Figure 14. Distribution Pattern of 5/16-Inch x Plug Nozzle Combination

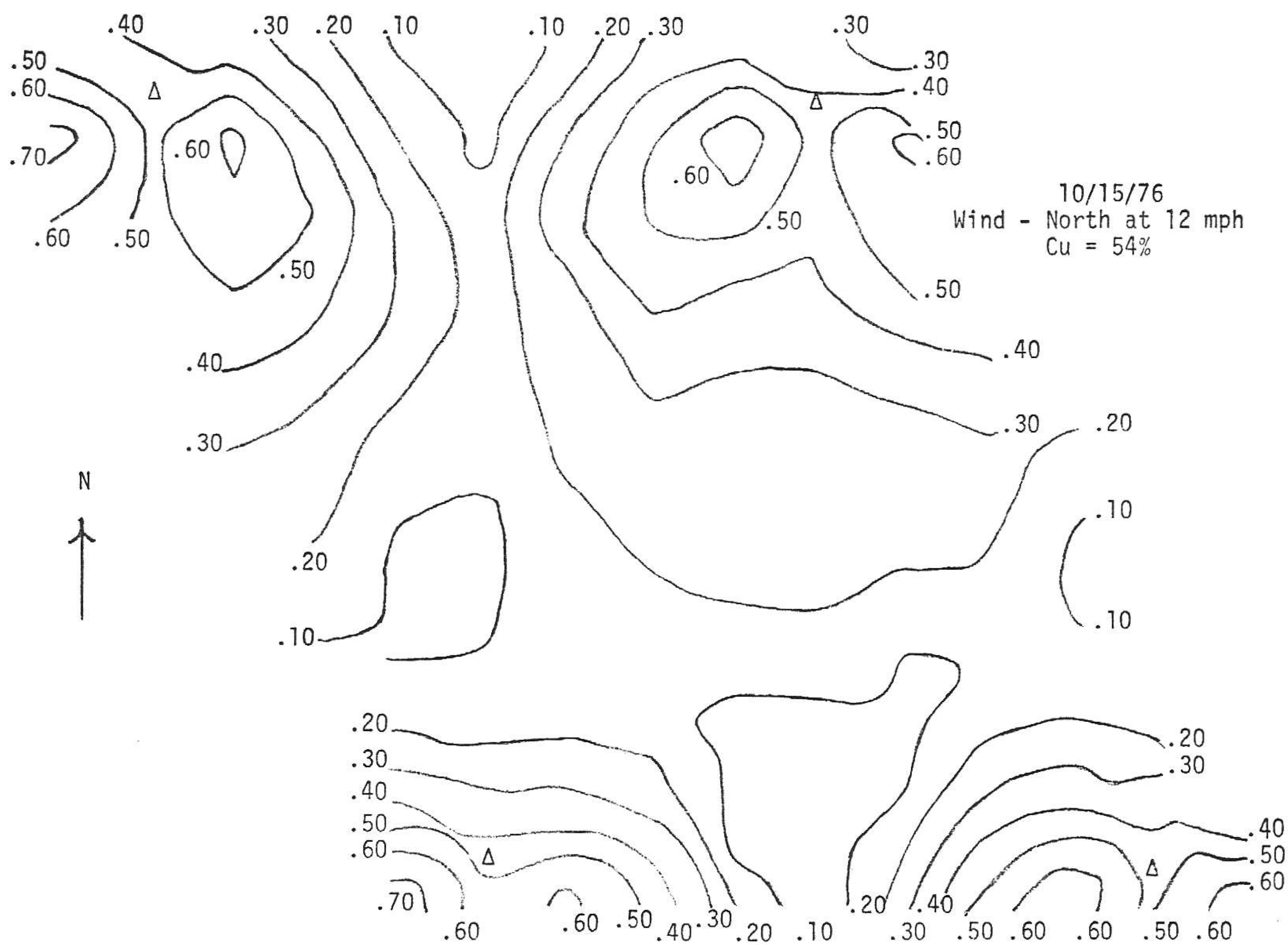


Figure 15. Distribution Pattern of 9/32-Inch x 1/8-Inch Spreader Nozzle Combination

A LAND DISPOSAL SYSTEM FOR MEAT PACKING WASTES

by

LESTER FRANK YOUNG

B.S., Kansas State University, 1975

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

ABSTRACT

The meat packing industry produces large amounts of wastewater that is characteristically high in organic pollutants. Due to the nature of the processing operations, the wastewater also contains high concentrations of dissolved solids, primarily sodium.

Many packing plants are not able to discharge their wastewater into municipal treatment systems so they must install their own facilities. For plants located in rural areas, stabilization lagoons are a common treatment system. Unfortunately, effluent from these systems often cannot meet federal guidelines for waste discharge due to the suspended solids concentration.

For these and other companies where effluent discharge to a receiving body of water is not allowable or possible, land disposal is an economical alternative to expensive tertiary treatment processes.

The Dubuque Packing Compnay, Mankato, Kansas, uses a combination anaerobic-aerobic lagoon treatment system with the final effluent being of good quality but high in dissolved solids, primarily sodium. The outlet of the lagoon system lies on an intermittant stream with a large pond located immediately downstream. The landowner will not allow frequent discharges from the lagoons due to damage caused to the pond's emergency spillway by the frequent washings. The use of the wastewater for irrigation by a neighboring farmer was discontinued due to the high dissolved solids content and the high sodium percentage of the water.

As a result of the plant's need for an alternative disposal method for their wastewater, a sprinkler irrigation system was installed in the fall of 1976. The system's design incorporated durability with flexibility of control in order to maintain a balance between the applied wastewater and capabilities of the soil as a treatment system.

Preliminary research efforts were carried out to predict the quantity of water that the system could be expected to dispose of and monitor the build-up of salts in the soil profile. Additional research was undertaken to determine the coefficient of uniformity of different sprinkler nozzle sizes and combinations for widely spaced sprinklers under climatic conditions characteristic to the area.

The system was found to operate effectively with equipment problems expected to relate to the highly corrosive nature of the wastewater. Problems may be encountered due to the high suspended solids concentration of the water.

The system can be expected to dispose of approximately 50 percent of the plant's total wastewater based on operation levels observed in 1976. The total depth of irrigation for this disposal efficiency was 110 inches per year with no allowance made for rest periods.

The best nozzle combination was found to be 5/16-inch x plug which allowed better uniformity of application in conditions of high wind, common for the area.

More research is needed to determine leaching requirements for salt loading, rest periods to restore infiltration rate, sodium dispersion problems, and general operation procedures.