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WASTEWATER TREATMENT CAPABILITY
OF A MODIFIED OVERLAND FLOW
EVAPOTRANSPIRATION LAND TREATMENT SYSTEM

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WASTEWATER TREATMENT CAPABILITY

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BY

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ABSTRACT

WASTEWATER TREATMENT CAPABILITY
OF A MODIFIED OVERLAND FLOW
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By

David Perry Bratt

A modified overland flow evapotranspiration land treatment system was constructed to treat the wastewater produced at a highway rest area. Water was released through gated pipes on a clay soil covered by a sand layer one- to four-feet thick. A water budget showed approximately 12% runoff, 50% infiltration and 38% evapotranspiration. Loading rates were varied from 2.4-inches per week to 4.3-inches per week, and it was found that similar quality effluent was produced at each loading rate. In each case the effluent was of a very high quality with greater than 96% reductions in BOD_5, i-PO_4, TKN, and NH_3 noted for the heavier loading condition. Sampling and analysis of ground water and immediate surface waters indicated no contamination was occurring. Fecal coliform to fecal strep ratios were used to demonstrate that the microbial contamination observed on the land treatment area was from a non-human source.

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INTRODUCTION

The importance of maintaining the water quality of rivers and lakes as well as ground water supplies has become increasingly apparent to our society. Many cases could be cited where the discharge of untreated or primary treated wastewater has resulted in severe water pollution problems. This has resulted in losses of a valuable resource for recreation and industrial and domestic supply. The increasing water pollution problem is the result of several factors. Our growing population and industrial society requires large quantities of water and produces great quantities of waste. The advances in agricultural technology and resulting increase in fertilizer use has resulted in large increases in crop production and also non-point source pollution. The urbanization of our society has resulted in dense population centers where the quantity of waste produced greatly exceeds the natural renovative processes of area lakes and streams. The problem can be viewed as a result of man's influence on the natural nutrient cycle. Through mining and industrial fixation processes for fertilizer production, man has made available large quantities of nutrients for crop production. These nutrients are utilized by the crops, harvested, and transported to major population centers for consumption.

The result is a high nutrient content in the cities' wastewater and eutrophication of area lakes and streams into which this wastewater is discharged.

While conventional wastewater treatment plants can greatly reduce the organic load of a wastewater, the nutrients causing eutrophication are not effectively treated. Land application of wastewater has received increased attention as a possible solution to this problem. The application of a wastewater to crop land can effectively recycle the nutrients by supplying plant needs. This nutrient removal results in a high quality effluent which is not likely to cause eutrophication. Direct discharge into receiving waters is also avoided as the majority of the water in land treatment systems is lost through infiltration and evapotranspiration.

Research has shown rather conclusively that with proper soil and environmental conditions, land treatment can be very effective. Work remains to be done, however, in such areas as determining the long-term effects of wastewater application on soil properties and thoroughly evaluating land treatment systems under varying climatic conditions, soil types, and application rates.

This study evaluates the performance of a land application system used in treating wastewater generated at the J. C. Mackey Travel Information Center. This highway rest area is located near Clare, Michigan, on U. S. 27, which is a four-lane divided highway receiving much of the north-south traffic in the center of the state. The facility is located on the highway median and services both the north and south bound lanes. The northern migration of summer vacationers results in extremely heavy use during the months of July and August.

Prior to the installation of the overland flow evapotranspiration system, the wastewater was treated using either a septic tank and tile field or a system of two lagoons operating in parallel with continuous discharge to a sand filter. The lagoons and sand filter were used during the heavy use period in the summer with the septic tank and tile field in use the rest of the year. Studies showed that both of these systems were severely overloaded and functioning poorly. As plans called for the eventual connection with the Clare Municipal Sewer System, a temporary solution was needed to insure adequate treatment during the transition period.

After consideration of several alternatives, it was decided to construct a land treatment system designed to conform to existing soil and landscape characteristics near the rest area. A grassy area north of the information center with a four percent slope was chosen and a modified overland flow evapotranspiration system was designed. In an attempt to minimize costs and reduce construction time and environmental damage, no earth moving activities were performed to smooth the land surface. Instead the water was distributed through gated pipes placed along the contour lines and shallow ditches were plowed on the contours to continually redistribute the water and minimize channeling. The modified system was necessary to meet the zero discharge requirement imposed by the Department of Natural Resources because the county drain flowing through the rest area had an outlet into a nearby chain of lakes which were very popular for water-based recreational activities. The soil in the area was a Nester clay loam covered by a one- to four-foot sand layer. The water would rapidly infiltrate the sand layer and eventually move to the ground water by percolation or into the atmosphere by evapotranspiration. There was very little runoff, and the runoff that did occur (usually during a heavy rain) was contained in the catchments at the bottom of the slope.

This study had the following objectives:

1. Demonstrate the design of a modified overland flow evapotranspiration land treatment system, built to conform to area soil and landscape characteristics.
2. Evaluate overall treatment efficiency and the effect on the environment.
3. Determine optimal and maximum acceptable loading rates, and system performance during these loading rates.

4. Demonstrate the feasibility of land treatment systems for small rural institutions such as highway rest areas.

LITERATURE REVIEW

The increased interest in maintaining the water quality of our lakes and rivers and achieving advanced treatment of wastewater has focused attention on utilizing the soil for land treatment of wastewater. Properly managed land treatment can effectively achieve advanced treatment of wastewater. The wastewater itself can provide nutrients which are needed for plant growth, and organic matter which can improve soil structural properties. The physical and chemical processes involved are many and complicated, but they must be thoroughly understood in order to utilize the soil correctly. Care must be taken that the soil is not mismanaged or misused in any way. Many studies have been conducted to document the fact that land treatment systems will provide advanced treatment, and also to learn more about the many factors involved. The soil has been demonstrated to be an effective physical, chemical, and biological filter.

The soil as a physical filter is effective in removing the suspended solids from a wastewater. If properly managed, a soil can receive and filter a large volume of water. The efficiency of removal depends to a large extent on the texture of the soil and the resulting pore size distribution. Irrigation systems, septic tank tile fields, and ground water recharge systems have all utilized the soil as an effective physical filter. If the soil is not properly managed, however, certain problems can result. Studies at Cortaro, Arizona, show that after 14 years of irrigation with secondary effluent at rates necessary to fulfill crop requirements, there was an increase in soluble salts and a decrease in infiltration rate when compared to a similar plot irrigated with well water (Day, Stroehlein, and Tucker, 1972). The decreased infiltration rate was thought to be caused by worsening soil structure due to an increased sodium content. These effects were not serious enough, however, to cause a significant decrease in crop yield, and they could easily be corrected.

More severe problems occur when water is applied at higher rates. If the soil is inundated for an extended period of time, an organic mat can form on the surface and clog the soil pores (Thomas, 1973). Work by DeVries has also shown formation of an organic mat under high rates of application at lower temperatures. Bacterial action is extremely important in keeping the soil pores open by decomposing the organic matter and removing the suspended solids. If low temperatures or low oxygen conditions persist, bacterial action is inhibited and the suspended solids will form an organic mat. Under ideal conditions, a medium sand can receive up to eight inches of effluent per day for five days per week without filter failure (DeVries, 1972). This eight inches was applied over a two-hour period and the following 22-hour drying period was shown to be the minimum required to avoid filter failure. If clogging does occur, a resting period of drying under favorable conditions is necessary to regain the previous filtering capacity. DeVries observed that the previous filtering capacity could be recovered about eight days after a severe filter failure. When applying large amounts of water, a soil must be managed with concern for any factor which might inhibit the bacterial decomposition of suspended solids. The most common causes of reduction in biological activity which lead to clogging are low temperatures and anaerobic conditions produced by heavy loading.

Biochemical reactions by soil microorganisms along with the inorganic reactions occurring in the soil matrix can remove most of the harmful constituents in a wastewater. The biochemical oxygen demand exerted on the receiving waters by a treatment plant effluent has long been used as a primary indicator of the quality of treatment provided by that plant. This oxygen demand is the amount required to fulfill the respiratory needs of the bacterial population decomposing the organic compounds. The soil contains a large population of bacteria as well as fungi and actinomycetes. Estimates of bacterial biomass range from 300 to 9,000 pounds per acre with an average value being 2,800 pounds per acre (Miller, 1973). This large microbial population can very effectively reduce the BOD of wastewater applied in a land treatment system. Decomposition of organic compounds and subsequent reduction of BOD can occur in the soil under both aerobic and anaerobic conditions. The reactions involved in aerobic decomposition are more rapid and complete than those occurring under anaerobic conditions. Anaerobic decomposition will still reduce the BOD very effectively in flooded or saturated soils, however (Bouwer and Chaney, 1974). The end products of aerobic decomposition are H_2O, CO_2, NO_3, and SO_4, while the end products of anaerobic decomposition are reduced compounds such as H_2S and NH_4, as well as H_2O and CO_2.

The organic load exerted by a wastewater under typical land treatment conditions will seldom exceed the decomposition capabilities of the soil microorganisms. Assuming 80 inches of effluent applied per year with a COD of 70 mg/l, the amount of organic matter added would be 1,600 pounds per acre. This is well below the amount required to fulfill the normal energy requirements of a typical population of soil microorganisms. Refractory organics, as indicated by the difference between BOD and COD, are also effectively removed by the soil. Absorption and physical retention in the soil matrix will permit the decomposition of these slowly degradable compounds (Miller, 1973).

Perhaps the most appealing aspect of land treatment is the potential for removal of nitrogen and phosphorus from the wastewater. Not only are the primary contributors to eutrophication removed, but essential nutrients are supplied to the crops being irrigated. Plant utilization is often the major mechanism of removal in land treatment systems. Sopper and Kardos (1973) at Penn State found that 148 pounds of nitrogen and 35 pounds of phosphorus per acre were removed by a corn crop, while 408 pounds of nitrogen and 56 pounds of phosphorus per acre were removed by Reed Canary Grass. These crops were irrigated with two inches of secondary effluent per week. The removal efficiency for the corn crop was over 100% of both the nitrogen and phosphorus supplied. The Reed Canary Grass removed 75% of the nitrogen and 63% of the phosphorus applied. If plant uptake is relied upon as the major mechanism of nutrient removal, care must be exercised in balancing the nutritional needs of the crops and the amount of wastewater applied.

Phosphorus not utilized by the plants can be effectively retained in the soil. Hook, et al. (1973) in a detailed study on the fate of applied phosphorus, showed that very little was lost through leaching. Even when the applied phosphorus significantly exceeded crop requirements, there was little or no increase in phosphorus concentration at a depth of two feet. Most of the phosphorus in a wastewater is in the orthophosphate form. The phosphorus originally present as organic phosphate or polyphosphates is quickly converted to orthophosphate during preliminary treatment (Murrmann and Koutz, 1972).

Fixation of phosphorus in the soil occurs through several mechanisms. Under acidic conditions phosphorus can combine with iron to form strengite or aluminum to form variscite. In calcareous soils under more basic conditions, dicalcium phosphate and octacalcium phosphate are formed (Ellis, 1973). Lindsay and Moreno (1960) used activity isotherms of strengite, variscite, dicalcium phosphate, octacalcium phosphate, and various apatites to construct a phosphate phase diagram. This type of diagram can be used to predict the formations of and transformations between the various phosphorous compounds at different pH levels.

There is an upper limit to the amount of phosphorus that a soil can absorb or fix. This phosphorus retention capacity depends on the texture and chemical composition of the soil and it will vary greatly for different soils. Highly weathered soils with high concentrations of iron and aluminum and calcareous soils have the capability to fix large amounts of phosphorus. Ellis and Erickson (1969) used the Langmuir absorption isotherm to predict the maximum amount of phosphorus fixed with a continual application of a 10 ppm phosphorous solution. Large variations were observed as a dune sand fixed 77 pounds of phosphorus, while a loam soil fixed over 900 pounds of phosphorus per acre foot. There was also a great variation noted in the abilities of different horizons to fix phosphorus. The B horizons of some soils were able to fix much more phosphorus than the A horizons, presumably due to the leaching of iron and aluminum. Once a soil is saturated with phosphorus, it can regain its absorption capacity after a resting period of about three months. This is probably due to the formation of more insoluble phosphorus compounds and the availability of additional iron and aluminum through continued weathering.

Nitrogen removal is especially important because of the potential nitrate contamination of ground water aquifers. A nitrate concentration greater than 10 ppm in drinking water represents a health hazard to infants. Most of the nitrogen in wastewater is in the form of either ammonia or organic nitrogen. When wastewater is applied to the soil, mineralization will occur and unavailable organic nitrogen is converted to the ammonia form. This mineralization with a net release of inorganic nitrogen will occur unless the carbon-to-nitrogen ratio is very high, as in some cannery and food processing wastes. With these wastes there may be a net uptake of mineral nitrogen and a possible nitrogen deficiency on the land treatment system (Bouwer and Chaney, 1974). The ammonium ion with its positive charge can be effectively held by the colloidal particles in the soil. In well-aerated soils the ammonia will be nitrified. The negatively charged nitrate ion is not retained by the soil and is extremely vulnerable to leaching.

Under anoxic conditions certain bacteria can utilize the nitrate ion as an electron acceptor. This results in the conversion of the nitrate ion to inert nitrogen gas, a process called denitrification. Bacteria from the genera Pseudomonas and Micrococcus are well known for this capability. A wide variety of bacteria, however, have now been shown to possess the capacity to utilize nitrate as an electron acceptor with the subsequent denitrification occurring (Tiedje, 1978). If the proper conditions are maintained in the soil, denitrification can be a very effective means of nitrogen removal. In order for denitrification to occur, three conditions must be met. There must be an aerobic zone where the ammonia will be nitrified. After the ammonia is nitrified, there must be an anoxic zone where the nitrate is utilized as an electron acceptor, and there must be an energy source in the anoxic zone to supply the denitrifying bacteria (Lance, 1972). Approximately one milligram of organic carbon is required for each milligram of nitrate utilized (Bouwer and Chaney, 1974).

The soil was modified to enhance denitrification by Erickson, et al. (1972) in the construction of a Barriered Landscape Water Renovation System (BLWRS). This system is composed of a well-aerated mound of soil built up above an impermeable barrier. As water is applied, it builds up above the impermeable barrier forming an anoxic zone. An organic carbon supply was provided in this zone to act

as an energy source for the denitrifiers. Swine waste with a total nitrogen content of 650 ppm was applied to the BLWRS with the resulting effluent containing 2 ppm nitrogen. This is well over 99% removal and gives some indication of the potential nitrogen removal through denitrification under ideal conditions.

Denitrification is a subject of increasing interest and experimentation. This interest is due to both the desirable effects, as in the removal of nitrogen from wastewater, and the undesirable effects, such as the loss of nitrogen fertilizer. While denitrification is usually associated with saturated soils, it has also been shown to occur to some extent in unsaturated soils. Broadbent (1973) found an 86% removal of tagged nitrogen in a free-draining soil column that he attributed to denitrification. Detection of tagged nitrogen gas in the lower depths of the soil column confirmed this idea. Nitrification and denitrification often occur in the same soil, often in close proximity to each other. This results from micro-environments in the soil where anoxic conditions exist due to the oxygen-use rate exceeding the oxygen-diffusion rate. The necessary conditions for denitrification, such as an organic carbon energy source and anoxic conditions, are very commonly found in land treatment systems. Meek, et al. (1969) demonstrated a relationship between the amount of denitrification occurring and both the oxidation reduction status of the soil and the amount of dissolved carbon in the water. Periodic wetting and drying, which is characteristic of land treatment processes, has also been shown to enhance denitrification (Bouwer and Chaney, 1974; Meek, et al., 1969).

Additional losses of nitrogen can occur due to volatilization of ammonia and fixation of ammonia by organic compounds in the soil. At pH values of 7.5 to 8.0, which are common in land treatment systems, there is only a slight amount of gaseous loss of ammonia through volatilization. However, if the pH is higher than this and there is sufficient air-water contact, there can be considerable loss of ammonia through volatilization (Lance, 1972). There is also the potential for fixation of ammonia by both the organic and mineral portions of the soil. Vermiculite clay is known to fix large quantities of ammonia. Burge and Broadbent (1961) have demonstrated the fixation of ammonia by organic soils and have shown a linear dependence on the amount of carbon available in the soil. This form of ammonia was shown to be slowly released and available for plant use.

There have been several detailed studies performed on specific land treatment systems to document the quality of treatment provided. The most extensive and well known of these is certainly the study started at Penn State in 1962 and still continuing today. Investigators there have applied secondary effluent to forest land, meadows, and various agricultural crops. Vegetation responses, fate of applied nutrients, and overall degree of rennovation of the wastewater were all considered. Kardos and Sopper (1973) reported excellent results with proper vegetative cover. Reed Canary Grass, with its tolerance for wet conditions and large capacity for growth and nutrient uptake, was one of the most successful species used.

Most of the early commercial land treatment systems were built by canneries and food-processing companies. In the late 1950s and early 1960s, the H. J. Heinz Company built two land treatment systems. These were both spray irrigation systems. One was built on a level and permeable soil, thus meeting the existing design criteria, but the other was built on a sloping impermeable soil. Both systems showed excellent BOD reductions of greater than 97% on a waste which had an extremely high organic carbon content (Luley, 1963). The system on the sloping, impermeable soil depended on grass filtration and decomposition by the microbial population inhabiting the grass and soil surface for BOD reduction.

In 1964 the Campbell Soup Company built an overland flow land treatment system in Paris, Texas. Law, Thomas, and Myers (1970) conducted an extensive investigation of this system. With grease separation and course screening as the only pretreatment, they found a 98% reduction in BOD, a 50% reduction in both ammonia and total phosphorus, and an 85% reduction in Kjeldahl nitrogen. They also kept an accurate water balance which showed 61% runoff, 18%

evapotranspiration, and 21% percolation. This system was built on a clay soil with a vegetative cover of Reed Canary Grass, Red Top, and Tall Fescue.

Bendixen, et al. (1969) studied a similar overland flow system built by a tomato processing plant in Ohio. The system was divided into two distinct areas due to differences in soil properties. One of the areas had an impermeable soil with most of the water running off the surface, while the other had a more permeable soil with a greater infiltration rate. On the impermeable soil they found reductions of 81%, 73%, and 65% in COD, total nitrogen, and total phosphorus respectively. Treatment was more complete on the soil with the greater infiltration rate with reductions of 95%, 93%, and 84% in COD, total nitrogen, and total phosphorus respectively. The increase in treatment efficiency was due to the increased treatment received when the wastewater infiltrated the surface and came into contact with the soil matrix.

Carlson, Hunt, and Delaney (1974) conducted a laboratory study to evaluate the feasibility of using overland flow systems for waste disposal on Army reservations. They built a five by twenty foot model with a heavy clay soil, grass sod cover, and a 4% slope. They then studied treatment efficiency under controlled laboratory conditions. This model showed a water balance of 20% infiltration, 30% evapotranspiration, and 50% runoff. With an application rate of two inches per week they found a 75% reduction in phosphorus, 91% reduction in organic nitrogen, and 95% reduction in nitrate.

Thomas, Bledsoe and Jackson (1976) conducted a very extensive study on the overland flow system in Ada, Oklahoma. They applied raw comminuted wastewater and studied treatment efficiency under varied loading conditions. This system provided a 90% reduction in BOD, a 70% to 90% removal of nitrogen, and a 50% reduction in phosphorus concentration. To increase the amount of phosphorus removal they injected $AlSO_4$ into the system. This increased the phosphorus removal to 90%, although several mechanical difficulties were encountered.

While land treatment has often been used successfully in small systems, it can also perform very well on a large scale, as evidenced in Muskegon County, Michigan. An irrigation system provides excellent rennovation for wastewater from the entire county. This land treatment system has alleviated serious pollution problems in the area and greatly contributed to improving water quality in nearby rivers and lakes. This irrigation system has also produced corn crops of 80 bushels per acre on sandy soils that previously supported only oak scrub vegetation.

MATERIALS AND METHODS

Treatment System Characteristics

The entire wastewater treatment system consists of two lagoon cells operated in series, a holding tank where chlorination takes place, and the overland flow area itself. An overview of the entire system can be seen in Figure 1. The water moves by gravity flow from the rest area facility to the first lagoon. An overflow pipe located on the dike between the two lagoons permits water to flow to the second lagoon when the first is full. Each lagoon has a surface area of approximately 12,200 square feet or 0.28 acres. Each day of operation the water is pumped from the second lagoon to a 22,000 gallon holding tank located at the top of the slope of the overland flow area. The water is chlorinated in this tank and released after sufficient contact time, usually two hours.

There are two lines of four-inch pipe to distribute the water over the overland flow area. At the top of the slope there is a length of thick-walled PVC pipe with one-quarter inch holes drilled four to six inches apart. One third of the way down the slope is a length of flexible drainage pipe. This pipe was run along a contour line and drilled with one-eighth inch holes to provide an even

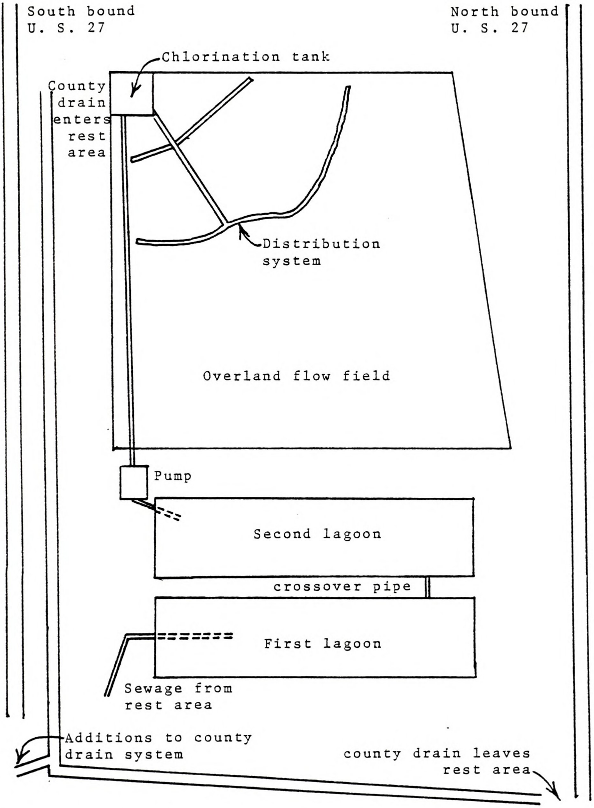
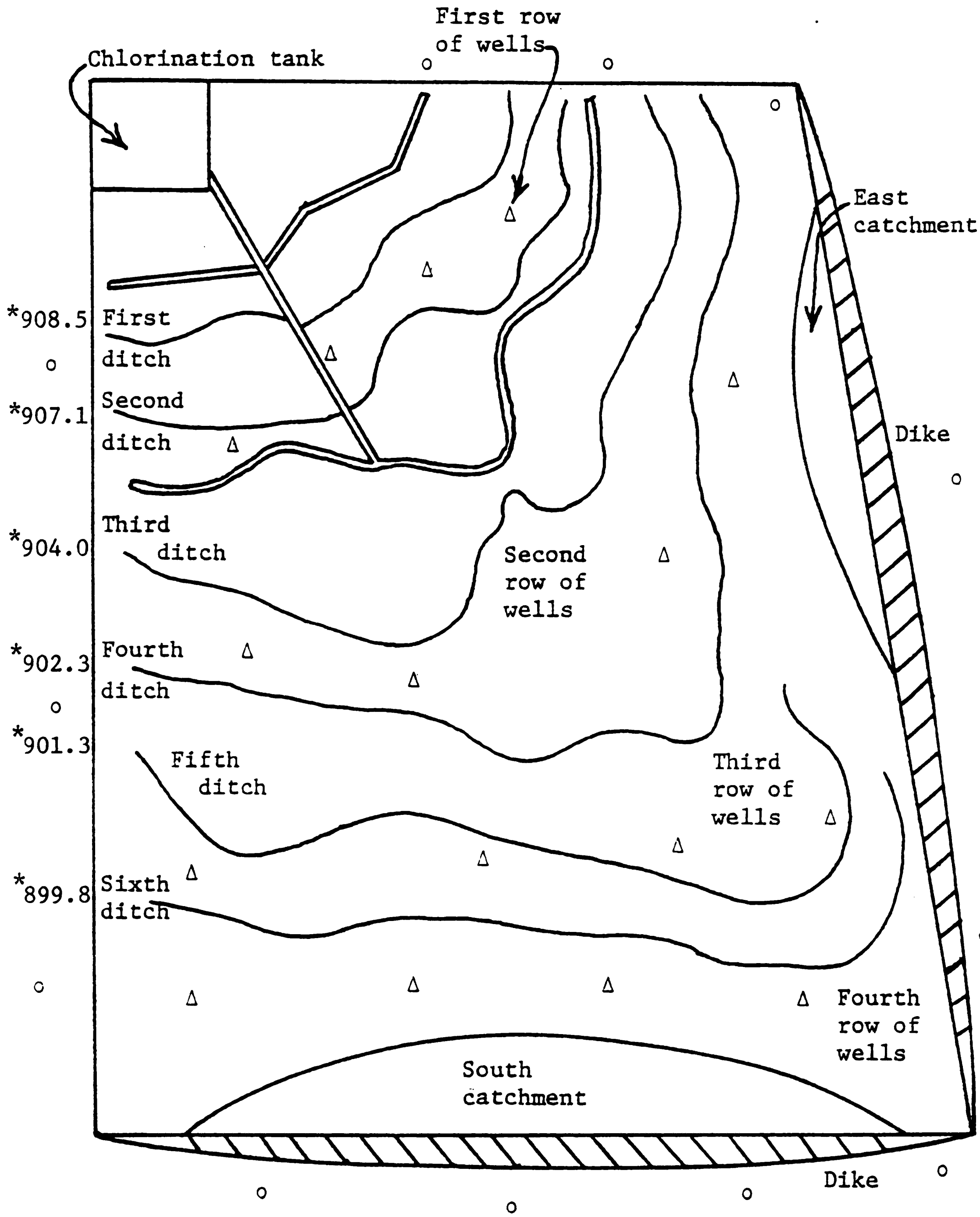


Figure 1. Plan View of Lagoons and Overland Flow Evapotranspiration System.

distribution and insure the use of the entire land area. There were no land forming or earthmoving operations performed to smooth the land surface as the slope was used in its natural condition. While land forming could have resulted in less channeling due to the smoother land surface, its adverse effects of soil compaction, destruction of natural vegetation, and large costs were avoided. There are six ditches plowed at fairly even intervals along the slope. Each of these is six to eight inches deep and is plowed along a contour line. The purpose of these ditches is to prevent channeling and allow for a more even flow. The area was seeded to Reed Canary Grass in the summer of 1977. By the following summer the upper half of the system, which was always very wet, had a lush growth of this species. The lower half of the treatment area had a mixture of grasses characteristic of an open meadow. The area of the overland flow treatment area is about 1.7 acres and has a slope of 4%.

Sampling Procedures

A system of 14 wells from 6 to 28 feet deep were drilled to the water table. These wells were placed completely around the overland flow area for the purpose of monitoring ground water quality. The placement of the wells is shown in Figure 2. These wells were sampled two times per month when the system was in operation and about once a month during the off season. They were sampled by



o Perimeter well to ground water table
Δ Shallow well to perched water table
* Elevation of ditches

Figure 2. Plan View of Overland Flow Field.

lowering a small centrifuge tube down the well. The test tubes were sterilized in the lab before use, and the sampling apparatus was sterilized before each sample was taken by immersion in a chlorox solution. To insure a fresh water sample representative of the quality of the aquifer, the wells were pumped out each time before sampling. Two samples were taken at each well. One of these was analyzed for nitrate concentration, while the other was checked for microbial contamination.

The lagoons and county drain system were sampled approximately once a month during the off season and twice a week during operation. The county drain entered on the northwest side of the rest area, flowed through to the south of the lagoons, and exited on the east side of the rest area. This can be seen in Figure 1. This drain was sampled as it entered and left the rest area, and at an intermediate point where runoff from an adjacent farmer's field entered the system. Samples were also taken from each lagoon and from the ditches surrounding the lagoon cells. Water from these ditches flowed into a small stream which later joined with the county drain. This stream was also sampled. These samples were all taken as random grab samples. The sample for the microbial analyses was taken in a sterile water bottle, while the sample for the chemical analyses was taken in a polyethylene container.

The overland flow area itself was intensively sampled twice a week while the system was in use. The soil was a

Nester clay loam beneath a sand layer from one- to four-feet deep. The sand layer was sandy loam to loamy sand in texture. The water, when applied, would infiltrate the sandy soil quite rapidly and form a perched water table over the clay layer. A system of shallow wells 8- to 40-inches deep was used to sample this water. A line of four evenly spaced wells was placed at each of four different levels, for a total of 16 wells. The shallow wells were pumped out each time before sampling to insure that a fresh, representative sample was obtained. The sample was obtained by pumping the fresh water into a polyethylene bottle. The water that flowed along the surface was intercepted by the ditches previously described. Each of the six ditches was sampled at three evenly spaced points. The layout of the shallow wells and ditches can be seen in Figure 2. The ditch samples were all taken as random grab samples and again a glass bottle for microbial analyses and a polyethylene bottle for chemical analyses were collected.

Meteorological Data

A weather station was installed at the treatment area to monitor climatic conditions. A standard class A Weather Bureau Evaporation Pan was used, along with a rain guage to measure the amount of precipitation and evaporation. Daily measurements were taken of these. An anemometer was installed next to the evaporation pan to give a reading of the amount of wind each day. Radiation energy was measured using a pyranometer sensor connected to a totaling integrator. A recording thermo-hygrograph was installed to give a continuous reading of temperature and relative humidity.

Handling and Storage of Samples

After the samples were taken in the field, they were packed on ice in a styrofoam cooler for transport from the sampling site to the laboratory. BOD_5 analyses were performed immediately upon returning from the field. The samples were then stored in a cooler at $4^{\circ}C$ until ammonia, nitrate, nitrite, Kjeldahl nitrogen, and inorganic phosphate determinations could be made. This was usually within two or three days. The samples were then acidified using 6 normal hydrochloric acid and stored in the cooler for a longer period of time until total phosphate and total organic carbon content could be analyzed.

Microbiological Analyses

The microbiological analyses were performed as outlined in Microbiological Methods for Monitoring the Environment (1978).

Total Coliforms

Total coliforms were determined using a multiple tube dilution technique on lauryl tryptose broth. Proper dilutions were innoculated on the broth for 48 hours at

$35^{\circ}C$. The amount of bacterial contamination was determined by performing a most probable number count (MPN).

Fecal Coliforms

Most probable number of the fecal coliforms was determined by transferring samples of the positive total coliform test to EC media and incubating these samples at $44.5^{\circ}C$ for 24 hours.

Total Enterococci

Total enterococci were also determined using the multiple tube dilution technique. The correct dilutions were made on azide dextrose broth and incubated at $35^{\circ}C$ for 48 hours. Most probable number was then determined.

Fecal Enterococci

Fecal enterococci were determined by a most probable number count of samples transferred from the positive total enterococci test to violet azide broth. These samples were incubated at $35^{\circ}C$ for 24 hours.

Chemical Analyses

The chemical analyses, unless indicated otherwise, were performed as described in Methods for Chemical Analyses of Water and Wastes (1974).

BOD_5

Five-day BOD was determined as follows: A nutrient solution is made up by adding one milliliter per liter of the following four solutions to distilled water.

1. A phosphate buffer solution is made by dissolving 8.5 grams of potassium dihydrogen phosphate (KH_2PO_4), 21.75 grams of dipotassium hydrogen phosphate (K_2HPO_4), 33.4 grams of disodium hydrogen phosphate heptahydrate ($Na_2HPO_4 \cdot 7H_2O$), and 1.7 grams of ammonium chloride (NH_4Cl) in 500 milliliters of distilled water and diluting to one liter.
2. A magnesium sulfate solution is made by dissolving 22.5 grams of magnesium sulfate heptahydrate ($MgSO_4 \cdot 7H_2O$) in one liter of distilled water.
3. A calcium chloride solution is made by dissolving 27.5 grams of anhydrous calcium chloride ($CaCl_2$) in one liter of distilled water.
4. A ferric chloride solution is made by dissolving 0.25 grams of $FeCl_3 \cdot 6H_2O$ in one liter of distilled water.

To the nutrient solution, composed of these four solutions, is added one milliliter per liter of effluent from the first lagoon to act as a seed and insure an adequate population of microorganisms to oxidize the organic material. Thirty milliliters of lagoon samples or 60 milliliters of other surface samples were transferred to a 300 milliliter bottle which was then filled with nutrient solution. Dissolved oxygen readings were taken after the sample was incubated for five days at 20°C and BOD_5 was determined in milligrams per liter.

Suspended Solids

Suspended solids were determined by filtering either 50 or 100 milliliters of sample through a Buchner funnel using previously weighed #2 Whatman filter paper. This was reported in milligrams per liter.

Nitrate and Nitrite

Nitrate and nitrite concentrations were determined colorimetrically on the Technicon Auto Analyzer. The color reagent used is made by dissolving 20 grams of sulfanilamide ($C_6H_8N_2O_2S$), 200 milliliters of concentrated phosphoric acid (H_3PO_4), one gram of N-1-Naphthylethylenediamine dihydro-chloride ($C_{12}H_{14}N_2 \cdot 2CHl$), and one milliliter of Brij-35 in two liters of distilled water. The nitrite will form a reddish-purple azo dye in the presence of this compound. The concentration of nitrate and nitrite is determined by passing the sample through a copper cadmium reduction column. The nitrate is then reduced to nitrite, and the total of these two is measured. A sample is also analyzed without being reduced to give the nitrite concentration. This can be subtracted from the total to give the nitrate ion concentration.

Ammonia

The concentration of ammonia was also determined colorimetrically on the Technicon Auto Analyzer. A green colored compound is formed when the ammonium ion reacts with sodium hypochlorite. The sodium phenoxide is formed by adding 200 grams of sodium hydroxide (NaOH) and 276 milliliters of liquified phenol to 500 milliliters of distilled water. This is diluted to one liter, and 0.5 grams of Brij-35 are added. The concentration of this green colored compound formed is then measured on the colorimeter.

Kjeldahl Nitrogen

For the determination of Kjeldahl nitrogen present, ten milliliters of sample were digested by heating with Kjeldahl catalyst. The Kjeldahl catalyst was prepared as follows: A solution of mercuric sulfate was prepared by dissolving eight grams of mercuric oxide (HgO) and ten milliliters of concentrated sulfuric acid (H_2SO_4) in 40 milliliters of distilled water. This mixture is then diluted to 100 milliliters with distilled water. Fifty milliliters of this mercuric sulfate solution is added with 267 grams of dipotassium sulfate (K_2SO_4) and 400 milliliters of concentrated sulfuric acid (H_2SO_4) to 1,300 milliliters of distilled water. This is then diluted to two liters to compose the Kjeldahl catalyst. The sample is digested with this solution until the mixture becomes colorless or sulfuric oxide fumes are given off. The sample is made basic by the addition of 15 milliliters of 10 Normal NaOH and distilled. The distillate is titrated with a dilute solution of H_2SO_4 of known normality. The indicator used is made up of 2% H_3BO_3 and methyl purple.

Inorganic Phosphorus

The concentration of inorganic phosphorus was also determined colorimetrically on the Technicon Auto Analyzer. The color reagent was made by combining 50 milliliters of 5 Normal sulfuric acid (H_2SO_4) with five milliliters of Antimony potassium tartrate [$K(SbO)C_4H_4O_6 \cdot 1/2H_2O$] solution, five milliliters ammonium molybdate [$(NH_4)_6MO_7O_{24} \cdot 4H_2O$] solution and 30 milliliters of 0.1 M Ascorbic Acid. This solution will react with the orthophosphate ion to form a blue antimony-phospho-molybdate complex which is measured on the colorimeter.

Total Phosphate

Total phosphate was determined colorimetrically on the Technicon Auto Analyzer after the organic phosphorus was converted to orthophosphate. The following solution is prepared to digest the sample. Three hundred fifty (350) milliliters of hydrogen peroxide (H_2O_2), 0.42 grams of selenium powder, and 14 grams of lithium sulfate ($Li_2SO_4 \cdot H_2O$) are mixed together. Four hundred twenty (420) milliliters of concentrated sulfuric oxide (H_2SO_4) is then added while carefully cooling the mixture. This procedure is described in detail by Parkinson and Allen (1975).

RESULTS AND DISCUSSION

Organization of Data

The Clare overland flow evapotranspiration system was operated during the summers of 1977 and 1978 and sampled intensively while in use. For analyses and discussion, these data are divided into three distinct periods of different loading rates. Each period is discussed individually. The data from each period are averaged and the mean value and standard deviation are reported in the tables. Each period had at least six samplings. The individual sampling values and the calculated means and standard deviations are shown in Tables A, B, and C in the Appendix.

The standard deviations for many of the sampling sites are quite high. This variability should be expected when taking random grab samples under the widely varying climatic conditions experienced in the field. Some of the variation is systematic and can be explained by changes in the volume of use received by the rest area and seasonal weather variation. These effects are mentioned later in this section when they are applicable. A period of very heavy loading during September 1978 is also discussed in this report. There was only one sampling obtained during this period so these values are reported directly into the tables.

System Performance Under Moderate Loading

During the summer of 1978, from June 22 to the end of July, the system was run under moderate loading conditions. The holding tank was filled and discharged once each day, five days per week for a weekly loading of 2.4 inches. The system was rested on weekends. Ten individual sets of samples, about two sets per week, were collected during this period of moderate loading. During this time, 13.9 inches of wastewater were applied and 3.1 inches of rain fell. Evapotranspiration was estimated from open pan evaporation data to be 7.0 inches. The runoff was estimated as 1.7 inches. This results in a relative water distribution of 10% runoff, 42% evapotranspiration, and 48% infiltration and subflow, as shown in Table 1. At no time during this period was there excessive channeling or ponding, indicating that the system was never hydraulically overloaded.

Table 1. Distribution of Wastewater Applied During the Period of Moderate Loading.

	Amount (Inches)	Percent of Total
Runoff	1.7	10
Infiltration and Subflow	8.3	48
Evapotranspiration	7.0	42

With this low amount of runoff it is evident that this is not a typical overland flow system. The low percentage of runoff is due to the soil characteristics. A sand layer one- to four-feet thick lies above a heavy clay loam. The water rapidly infiltrates the upper sandy layer and builds up as a perched water table above the heavy clay loam. As this water flows down the slope beneath the soil surface, it is still in the root zone and available for plant use. The rate of evapotranspiration for the system is quite high. This is largely because the area is at a higher elevation than the surrounding countryside and the moist grasses and soil surface are usually exposed to windy conditions.

In Table 2 the concentrations of BOD_5, TOC, i-PO_4, TKN, NH_3, and NO_3 are tabulated at several stages in the treatment process. TKN, NH_3, and NO_3 are reported as ppm nitrogen in all tables throughout the report. The first lagoon contains the raw wastewater as it enters the system, while the second lagoon contains water that has received the amount of treatment provided by the two lagoons in series. An indication of the amount of treatment provided by the two lagoons in series is obtained by comparing the differences in concentrations of nutrients between the first and second lagoons. It is noted that while there was little or no reduction in BOD_5 or TOC between the two lagoons, there is nearly a 50% reduction in i-PO_4 and an even larger decrease in TKN. There is

Table 2. Mean and Standard Deviation of Wastewater Nutrient Concentrations at Several Stages of Treatment During the Period of Moderate Loading (ppm).

Site	BOD_5		TOC		$i\text{-}PO_4$		TKN *		NH_3 *		NO_3 *	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
1st Lagoon	34	16	56.7	28.3	4.02	1.66	43.6	21.1	33.3	18.4	0.39	0.12
2nd Lagoon	38	21	53.4	19.0	2.11	1.16	16.4	6.7	6.9	6.4	0.39	0.12
Chlorination Tank	27	14	53.3	10.8	2.04	0.81	15.7	4.6	5.5	5.2	0.41	0.13
South Catchment	3	2	27.9	5.6	0.05	0.02	2.0	0.7	0.15	0.14	0.41	0.07
East Catchment	5	3	29.7	4.3	0.11	0.04	2.5	1.2	0.18	0.14	0.35	0.06

*Reported in ppm as Nitrogen

a reduction in NH_3 concentration of similar magnitude to the reduction in TKN. The reductions in both of these is presumably due to volatilization of ammonia, plant uptake of ammonia, and denitrification occurring in the lower depths of the lagoons.

The south and east catchments represent the final runoff. The distance from the gated pipes where the water was released to the south catchment was greater than the distance to the east catchment. This resulted in a slightly but consistenly higher water quality in the south catchment than in the east catchment. A comparison of the water quality in the catchment areas with that in the first lagoon indicates the treatment provided by the entire system. The actual efficiency of the entire system is somewhat higher than indicated since the water in the first lagoon has already received some treatment and is not representative of the raw wastewater. This treatment resulted in reductions of 89%, 97%, 95%, and 99% in BOD_5, i-PO_4, TKN, and NH_3 respectively. The changes in water quality from the second lagoon to the runoff indicate the treatment obtained from the land treatment process itself (excluding treatment received in the lagoons). The land treatment process reduced BOD_5, i-PO_4, TKN, and NH_3 by 89%, 95%, 86%, and 98% respectively. These treatment efficiencies are tabulated in Table 3. There was approximately a 50% reduction in TOC in the runoff. This reduction

represents the easily oxidized organics also indicated by BOD_5. The organic carbon remaining is mostly refractory organics more resistant to decomposition.

Table 3. Treatment Efficiency of Overland Flow Evapotranspiration System Considering the Land Treatment Process Only and the Entire System (Including the Lagoons) During the Period of Moderate Loading (percent reduction).

	BOD_5	i-PO_4	TKN	NH_3
Runoff				
Land Treatment Only	89	95	86	98
Entire System	89	97	95	99
Infiltration and Subflow				
Land Treatment Only	--	98	93	98
Entire System	--	99	97	99
Total Reduction (mass basis)				
Land Treatment Only	--	98	92	99
Entire System	--	99	98	99

In Table 4 the concentrations of i-PO_4, TKN, NH_3, and NO_3 are tabulated for the shallow wells. These wells are one- to four-feet deep and represent the water that has infiltrated the sandy layer and is flowing down the slope above the less pervious clay loam. Each well site represents a row of four wells with site number one located near the top of the slope and the other sites moving progressively downhill. There is no discernible difference between the water quality in the first row of wells or that of the other rows of wells as they move downhill and away from the point of release. This indicates that the treatment occurs as the water initially infiltrates the soil, and the amount of treatment received is not a function of distance traveled from the point of release.

The reductions in nutrient concentrations in the infiltration and subflow due to the land treatment process only are 98%, 93%, and 98% for i-PO_4, TKN, and NH_3 respectively. The amount of treatment received from the entire system (including the lagoons) was very high with reductions of 99%, 97%, and 99% for i-PO_4, TKN, and NH_3 respectively. These results are tabulated in Table 3. It is evident from examination of this table that the water infiltrating the soil is renovated to a greater degree than the runoff.

In Table 5 the concentrations of nutrients in each of the six ditches is listed. These ditches represent the surface runoff as it moves down the slope. Ditch Number 1 is located near the top of the slope with the others moving progressively downhill. Each ditch is approximately 40 feet apart, but the distance varies considerably since the

Table 4. Mean and Standard Deviation of Nutrient Concentrations in Shallow Wells (one- to four-feet deep) Located on the Overland Flow Field During the Period of Moderate Loading (ppm).

Well Site	i-PO_4		TKN		NH_3		NO_3	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
1	0.09	0.03	1.1	0.5	0.13	0.05	0.46	0.08
2	0.09	0.03	1.4	0.4	0.16	0.07	0.43	0.07
3	0.10	0.04	1.0	0.5	0.11	0.05	0.40	0.05
4	0.14	0.03	1.0	0.5	0.16	0.11	0.41	0.15

Table 5. Mean and Standard Deviation of Nutrient Concentrations in the Ditches on the Overland Flow Field During the Period of Moderate Loading (ppm).

Ditch Site	i-PO_4		TKN		NH_3		NO_3	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
2nd Lagoon	2.11	1.16	16.4	6.7	6.9	6.4	0.39	0.12
1	1.01	0.51	5.7	2.1	1.38	1.07	0.44	0.10
2	0.79	0.43	4.0	1.7	0.76	0.63	0.40	0.08
3	0.73	0.30	4.0	1.0	0.70	0.58	0.49	0.13
4	0.25	0.12	2.4	0.5	0.24	0.13	0.37	0.05
5	0.11	0.05	1.9	0.7	0.15	0.07	0.38	0.05
6	0.09	0.05	1.9	0.8	0.13	0.05	0.39	0.08

ditches follow contour lines. Figures 3 and 4 offer a graphical representation of the degree of treatment received as the water flows down the slope. The amount of treatment received is very similar for the second and third ditches. This is due to the fact that water is released through two different gated pipes. One is at the top of the slope, while the other is located between the second and third ditches. This causes the water in the third ditch to be a mixture of that which has flowed over a considerable amount of land and that just released. This accounts for the seeming lack of treatment between the second and third ditches. These data show that the amount of treatment received by the surface runoff is a function of the distance traveled from the point of release. A large proportion of the total treatment received occurs between the point of release and the first ditch. This is illustrated by comparing the water quality in the second lagoon with that in the first ditch.

The nitrate concentration is fairly constant throughout the system. There is certainly plant uptake and denitrification of the NO_3 originally applied, but there is also mineralization of organic nitrogen and nitrification of ammonia. In this system the rates of these processes are roughly equal, resulting in the constant NO_3 concentration. When considering the total amount of nitrogen present at the beginning and at the end of

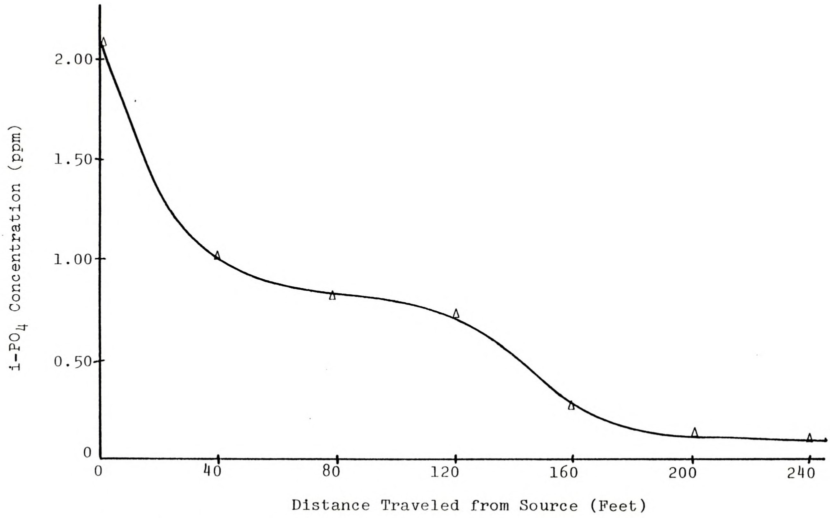


Figure 3. Concentration of i-PO_4 as a Function of Distance Traveled from Point of Release During the Period of Moderate Effluent Loading.

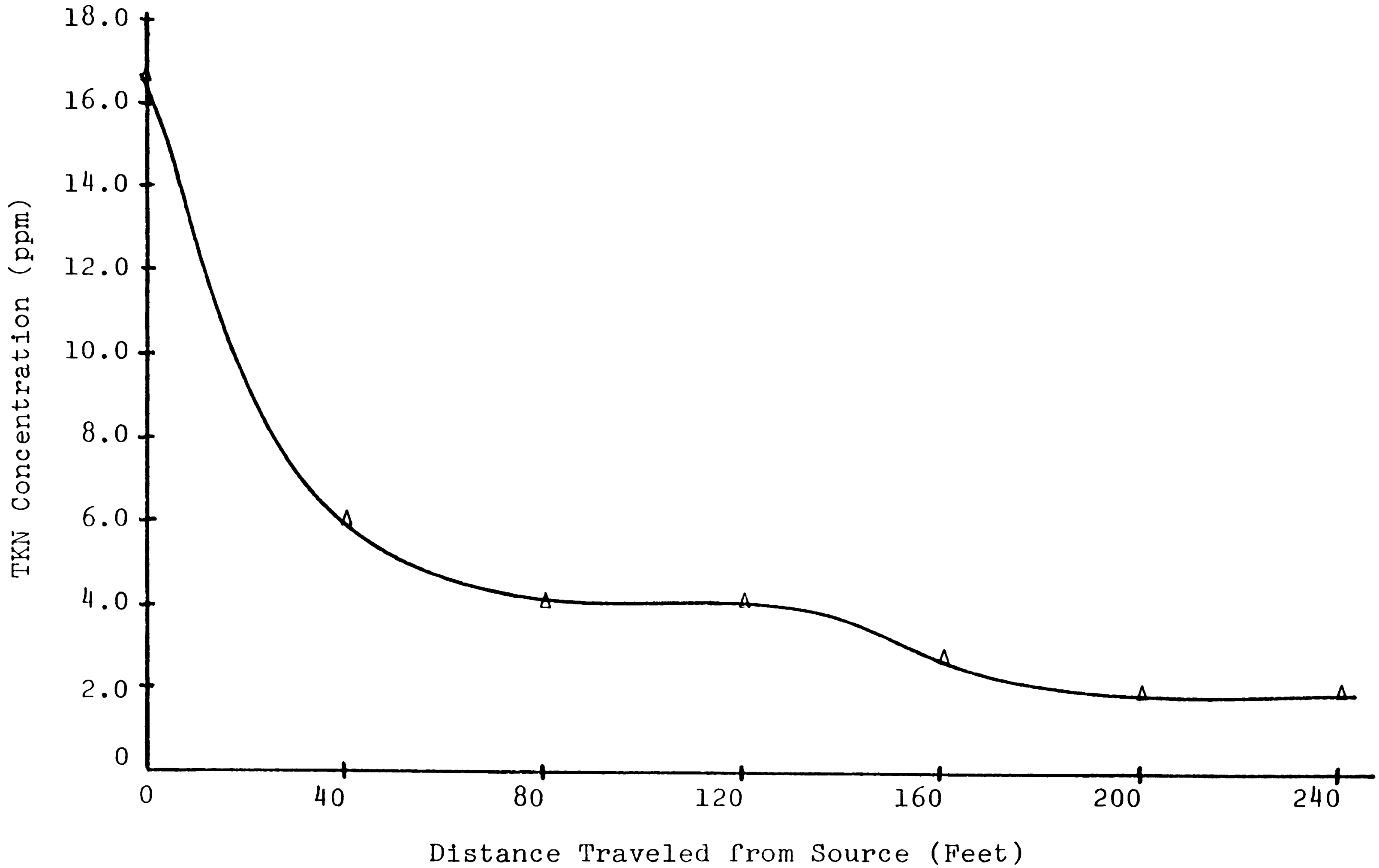


Figure 4. Concentration of TKN as a Function of Distance Traveled from Point of Release During the Period of Moderate Effluent Loading.

treatment, however, it is obvious that a much larger portion of the total nitrogen is in the nitrate form after treatment.

The perimeter wells to the ground water were sampled twice each month and analyzed for NO_3 content. The nitrate concentrations of the perimeter wells at each sampling are tabulated in Table D of the Appendix. There were only slight increases in NO_3 concentrations and never did the NO_3 concentration of any one well exceed 1.1 ppm during this period of moderate loading. This is well below the 10 ppm limit specified for health reasons.

The nutrient concentrations in the county drain flowing through the rest area were monitored to determine if any surface water pollution was occurring due to the land treatment system. In Table 6 the concentrations of BOD_5, i-PO_4, TKN, NH_3, and NO_3 are shown as the drain enters and leaves the rest area and at an intermediate point. The intermediate point is where water drained from an adjacent farmer's field enters the main county drain system. These data show that the nutrient level of the stream was not significantly increased due to the operation of the land treatment system and that the surface water leaving the rest area was of an acceptable quality.

System Performance Under Heavy Loading

During the month of August, in the summer of 1978, the loading rate was increased. The holding tank was filled

Table 6. Mean and Standard Deviation of Nutrient Concentrations in the County Drain System During the Period of Moderate Loading (ppm).

Site	BOD_5		TOC		$i\text{-}PO_4$		TKN		NH_3		NO_3	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
Drain Entering Rest Area	1	2	15.3	3.7	0.14	0.03	1.2	0.8	0.11	0.10	0.41	0.07
Additions to County Drain	3	4	20.9	10.1	0.12	0.04	1.5	1.1	0.25	0.16	0.53	0.08
Drain Leaving Rest Area	2	3	10.5	1.4	0.18	0.04	0.8	0.6	0.24	0.11	0.51	0.13

and discharged twice each day for an average weekly application of 4.3 inches. The system was rested on weekends. A total of 11.9 inches of wastewater were applied and 0.82 inches of rain fell during this period. A total of six individual sets of samples were collected during this period. Evapotranspiration was estimated from open pan evaporation data as 3.3 inches, and runoff during this period amounted to 2.2 inches. Under this heavier loading condition 26% of the water was lost through evapotranspiration, 17% ran off the surface, and 57% infiltrated the soil. The distribution of applied water is shown in tabular form in Table 7. Toward the end of each week there was a noticeable increase in channeling and ponding on the system due to the heavier loading. This did not affect the overall performance of the system, however, as can be seen by comparing overall treatment efficiency during this period with the treatment efficiency during the previous period of lighter loading where no ponding occurred. Two days of rest on the weekend were sufficient for the soil to dry, and channeling and ponding were not evident until the end of the following week. This indicated that the two days of rest on the weekend were necessary to prevent hydraulic overloading under this heavier loading condition.

Table 7. Distribution of Wastewater Applied During the Period of Heavy Loading.

	Amount (Inches)	Percent of Total
Runoff	2.2	17
Infiltration and Subflow	7.2	57
Evapotranspiration	3.3	26

In Table 8 the average nutrient concentrations are tabulated at various stages in the treatment process for the period of heavy loading. Comparing these values with those for the period of moderate loading listed in Table 2 reveals that the concentrations of nutrients in the first and second lagoons have increased considerably. An examination of individual sampling values reveals a significant and steady increase in nutrient levels in the lagoons during the month of July. This can be explained by the increasingly heavy use received by the rest area during the months of July and August. As the volume of use increases, the retention time of the water in the lagoons decreases and the amount of treatment received in the lagoons will also decrease. As the volume of use levels out in late July and August at a consistently heavy volume, the concentrations of the pollutants stabilize at the values shown in Table 8. The strength of the wastewater, as well as the rate of application, is significantly increased during this period.

Table 8. Mean and Standard Deviation of Wastewater Nutrient Concentrations at Several Stages of Treatment During the Period of Heaving Loading (ppm).

Site	BOD_5		TOC		$i\text{-}PO_4$		TKN		NH_3		NO_3	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
1st Lagoon	51	22	58.5	8.4	6.06	1.01	73.7	5.9	60.6	5.3	0.49	0.09
2nd Lagoon	54	17	62.5	28.0	4.21	0.64	41.6	4.7	28.0	3.9	0.46	0.05
Chlorination Tank	7.2	14	52.2	4.8	4.78	0.15	36.7	2.8	28.6	3.2	0.47	0.13
South Catchment	2.5	2.2	32.7	8.3	0.09	0.07	1.9	0.5	0.12	0.04	0.45	0.08
East Catchment	2.0	1.3	30.8	5.1	0.10	0.07	2.0	0.4	0.17	0.07	0.49	0.07

The system performed very well under the increased loading condition. A greater percentage of applied water infiltrated and ran off the surface, but this did not detract from the overall performance. This loading was much heavier than the moderate loading rate in that not only was the hydraulic loading rate twice as great, but the concentration of nutrients in the water was considerably higher. This resulted in actual increases of 450% in nitrogen loading and 360% in phosphorus loading. The amount of treatment received in the lagoons is somewhat less than during the moderate loading case due to decreased retention time. There is little or no reduction of BOD_5 or TOC between the two lagoons, but there is a 30% reduction in i-PO_4 and a 50% reduction in TKN and NH_3. The reduction in i-PO_4 is probably a result of utilization of this nutrient for growth by algae. The decrease in TKN is due to the decrease in NH_3. This reduction of NH_3 occurs partly through nitrification and utilization by algae, but also through volatilization. The pH of the lagoons will become quite high, especially during the day when photosynthesis by algae is occurring at a high rate. This will result in the ammonia being in the gaseous (NH_3) form and subject to volatilization if sufficient air-water contact is maintained by windy conditions. The water quality in the runoff from the system was very good again. The final runoff is represented in Table 8 as the south and east catchments.

The data in Table 9 show the nutrient concentrations in the shallow wells under heavy loading conditions. These data indicate that the infiltration and subflow still received a high degree of treatment, very similar to the moderate loading condition, even though the hydraulic loading was twice as great and the nitrogen and phosphorus loadings were almost four times as great.

Table 9. Mean and Standard Deviation of Nutrient Concentrations in Shallow Wells (one- to four-feet deep) located on the Overland Flow Field During the Period of Heavy Loading (ppm).

Well Site	$i\text{-}PO_4$		TKN		NH_3		NO_3	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
1	0.22	0.14	1.4	0.3	0.17	0.10	0.49	0.09
2	0.22	0.13	1.7	0.4	0.21	0.04	0.42	0.13
3	0.21	0.13	1.2	0.5	0.10	0.03	0.49	0.07
4	0.28	0.19	0.9	0.5	0.13	0.12	0.52	0.07

The treatment efficiency received during the period of heavy loading is shown in Table 10 for the land treatment process only and for the entire system. The reduction in $i\text{-}PO_4$, TKN, and NH_3 resulting from the land treatment process only was a very high 97%, 97%, and 99% respectively. In considering the entire system (including the treatment received in the lagoons) the reductions are 98%, 98%, and 99% for these same parameters.

Table 10. Treatment Efficiency of Overland Flow Evapotranspiration System Considering the Land Treatment Process Only and the Entire System (including the lagoons) during the Period of Heavy Loading (percent reduction).

	BOD_5	i-PO_4	TKN	NH_3
Runoff:				
Land Treatment Only	96	96	86	99
Entire System	96	98	97	99
Infiltration and Subflow				
Land Treatment Only	--	95	97	99
Entire System	--	96	98	99
Total Reduction (mass basis)				
Land Treatment Only	--	97	97	99
Entire System	--	98	99	99

The nutrient levels in the ditches at the top of the slope were considerably higher during the period of heavy loading than during the period of moderate loading. This was due to the combined effect of the increased hydraulic loading and increased nutrient loading. Because of the treatment occurring as the water moves down the slope, however, the water in the lower ditches is of a very good quality and similar to that under moderate loading conditions. The average nutrient concentrations in the ditches are tabulated in Table 11 and shown graphically in Figures 5 and 6. These figures give an indication of the treatment received as the water moves down the slope. The effect produced by the release of

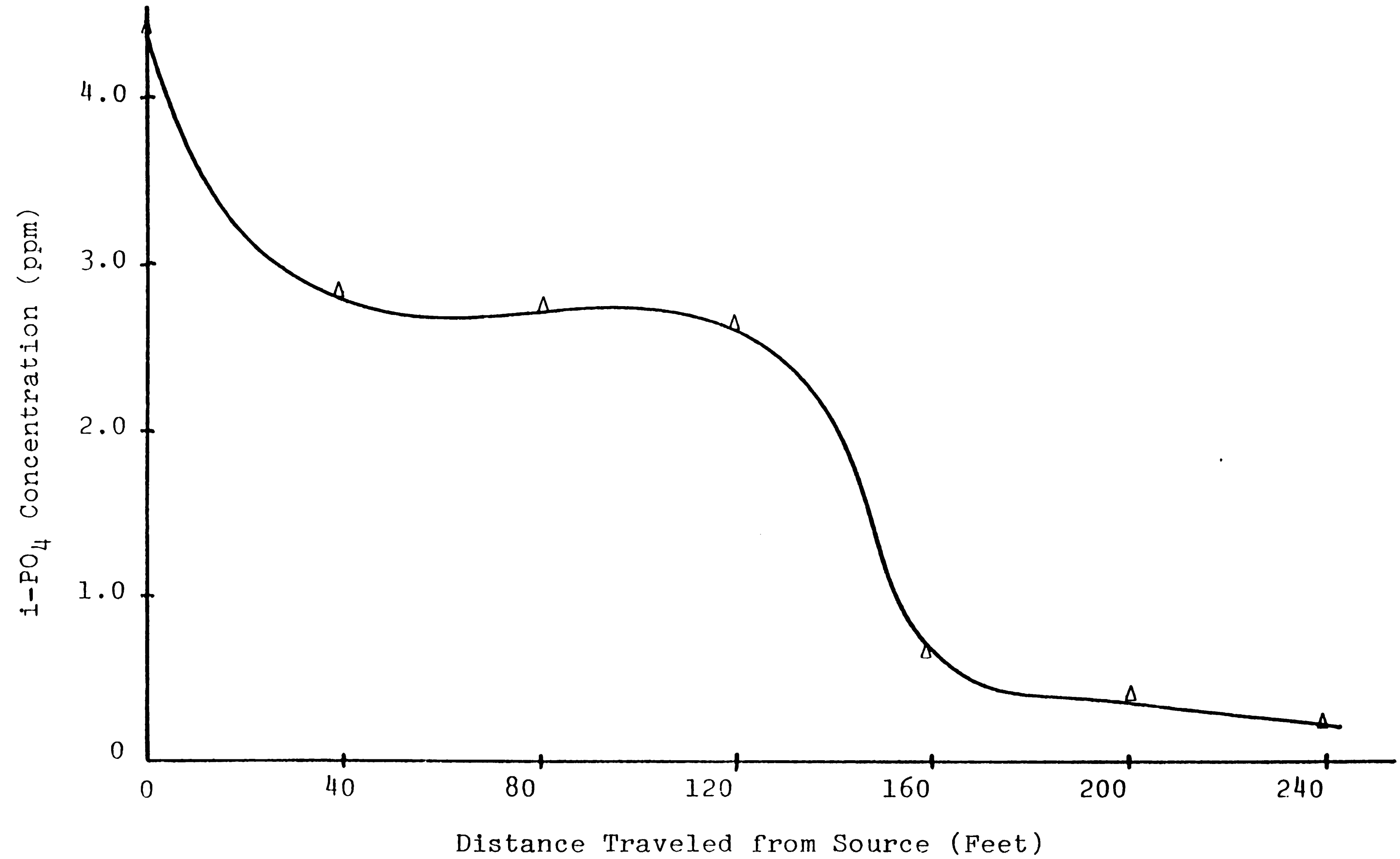


Figure 5. Concentration of $i\text{-}PO_4$ as a Function of Distance Traveled from Point of Release During the Period of Heavy Effluent Loading.

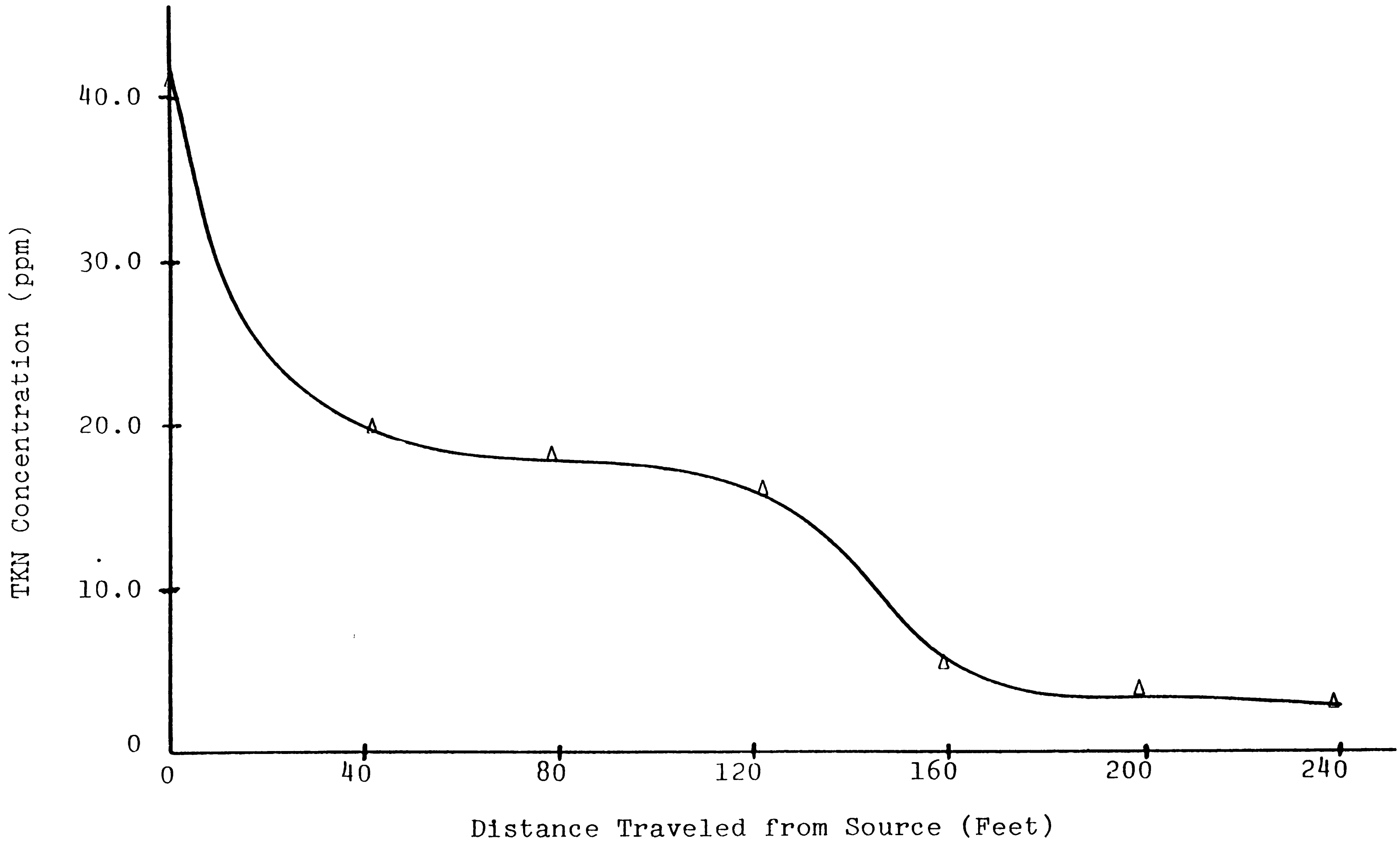


Figure 6. Concentration of TKN as a Function of Distance Traveled from Point of Release During the Period of Heavy Effluent Loading.

wastewater between the second and third ditches, as explained previously, is evident again in these figures.

Table 11. Mean and Standard Deviation of Nutrient Concentrations in the Ditch on the Overland Flow Field During the Period of Heavy Loading (ppm).

Ditch Site	i-PO_4		TKN		NH_3		NO_3	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
2nd Lagoon	4.21	0.64	41.6	4.7	28.0	3.9	0.46	0.05
1	2.84	1.47	19.5	9.5	13.8	8.02	1.98	1.78
2	2.74	1.49	18.5	9.5	13.4	8.05	1.45	1.00
3	2.61	0.48	15.8	4.0	10.9	3.04	1.59	0.93
4	0.67	0.68	5.1	3.1	2.05	2.55	0.82	0.47
5	0.38	0.31	3.9	2.2	1.01	1.33	0.57	0.23
6	0.20	0.09	2.8	0.6	0.43	0.36	0.56	0.07

Because of the heavier nitrogen loading there were some higher concentrations of nitrate observed. Values of up to two ppm were noted in the ditches at the top of the slope. Denitrification and plant uptake of nitrate were very effective in reducing the nitrate concentration, however, and the nitrate levels in the shallow wells and in the runoff at the bottom of the slope were usually below 0.50 ppm. These were very similar to the nitrate concentrations during the period of moderate loading. The nitrate concentration of the ground water was again monitored by sampling the perimeter wells. The nitrate concentration in the ground water did not increase during this period of heavy loading and the concentration never exceeded 1.0 ppm. These concentrations are shown in Table D in the Appendix.

The county drain was sampled as before. In Table 12 the nutrient concentrations as the stream enters and leaves the rest area and at an intermediate point are listed. It is obvious from these data that there is no surface water pollution occurring in the county drain from the land treatment system during the period of heavy loading.

Final effluent characteristics and treatment efficiency are compared for the medium and heavy loading conditions in Table 13. It is interesting to note that the pollutant concentrations are very similar in both cases. The differences are not large enough to be significant. The treatment efficiency, expressed as percent reduction, is greater under the heavy loading condition because of the higher initial nutrient loads and similar effluent characteristics. This comparison reveals that the system could handle a heavy load of 4.3 inches of wastewater per week as efficiently as a more moderate load of 2.4 inches per week. It also gives an indication of the high quality of effluent that can be produced by the land treatment system.

Table 12. Mean and Standard Deviation of Nutrient Concentrations in the County Drain System During the Period of Heavy Loading (ppm).

Site	BOD_5		TOC		i-PO_4		TKN		NH_3		NO_3	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
Drain Entering Rest Area	<1.0	--	18.8	9.1	0.25	0.14	1.0	0.7	0.07	0.04	0.53	0.04
Additions to County Drain	<1.0	--	16.0	4.7	0.25	0.12	0.9	0.2	0.11	0.07	0.52	0.09
Drain Leaving Rest Area	<1.0	--	12.3	3.6	0.29	0.14	0.7	0.3	0.06	0.03	0.48	0.09

Table 13. Comparison of Nutrient Concentrations in Runoff and Subflow, and Overall Treatment Efficiency Under Moderate and Heavy Loading Conditions.

	Nutrient Concentration in runoff (ppm)		Nutrient Concentration in subflow (ppm)		Treatment Efficiency (percent reduction, mass basis)	
	Moderate	Heavy	Moderate	Heavy	Moderate	Heavy
BOD_5	4.0	2.0	--	--	--	--
i-PO_4	0.07	0.10	0.10	0.23	96	97
TKN	2.2	2.0	1.1	1.3	96	97
NH_3	0.17	0.15	0.15	0.15	90	99
NO_3	0.38	0.47	0.43	0.48	--	--

System Performance During Initial Summer of Use

The system was initially used in the summer of 1977 and additional data are available from this period. These data are not as complete as in the periods discussed previously, but they do serve to verify earlier findings. Between July 25 and September 15, 1977, 14.8 inches of wastewater were applied and 7.25 inches of rain fell. The application rate was 1.8 inches of wastewater per week. Runoff and evaporation were not measured during this period so a water balance could not be obtained. It is assumed, however, that the water balance would be very similar to the period of moderate loading in 1978 when 2.4 inches of wastewater were applied weekly.

The pollutant concentrations at various stages of treatment are listed in Table 14. Between the first and second lagoons there is a 59% reduction in TKN due to loss of NH_3 and a 30% reduction in i-PO_4. Nitrate concentration remains fairly constant throughout the system due to the simultaneous increases due to nitrification of ammonia and decreases due to plant uptake and denitrification. The south catchment represents the final runoff of the system. This water is of a very good quality and is comparable to the runoff in the previous periods studied except that the i-PO_4 is somewhat higher for this period. The Reed Canary Grass cover was seeded during this summer and was not yet well established. This resulted in decreased i-PO_4 uptake by the plant community and a higher i-PO_4 concentration in the runoff. The 19.0 ppm of TOC found in the runoff is mainly refractory organics. While BOD_5 is efficiently removed by soil microorganisms, these organics are resistant to decomposition and remain in the runoff.

The nutrient concentrations in the shallow wells are tabulated in Table 15. These data represent the quality of the water infiltrating the soil surface. As noted before, there is no significant difference between the well sites near the top of the slope and those further down. This indicates, again, that the treatment is occurring as the water initially infiltrates the soil and not as it moves down the slope.

Table 14. Mean and Standard Deviation of Wastewater Nutrient Concentrations at Several Stages of Treatment During the Summer of 1977 (ppm).

Site	TOC		i-PO_4		TKN		NH_3		NO_3	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
1st Lagoon	37.8	21.9	6.42	1.65	63.2	21.8	50.7	11.1	0.81	0.38
2nd Lagoon	25.8	9.9	4.35	1.05	26.1	11.8	20.5	11.8	0.87	0.20
Chlorination Tank	27.0	1.4	4.59	1.21	30.8	8.0	26.1	10.0	0.81	0.29
South Catchment	19.0	1.0	0.74	0.19	1.7	1.4	0.6	0.1	0.50	0.30

Treatment efficiencies during this period for the entire system and for the land treatment process only are listed in Table 16. These reductions are figured separately for runoff and subflow on a concentration basis because a total reduction on a mass basis is not possible without the water balance. The runoff from the system showed reductions of 50%, 89%, 97%, and 99% for TOC, i-PO_4, TKN, and NH_3 respectively. The infiltration and subflow showed reductions of 92%, 96%, and 99% for i-PO_4, TKN, and NH_3 respectively. While this efficiency is very high, it is lower than the two periods discussed previously in which the loading rate was heavier. This was due to certain problems experienced during the first days of use. The grass cover was initially rather sparse and it was at this time that the area was seeded to Reed Canary Grass. A good thick stand of Reed Canary Grass was not established until the following summer. There was also a good deal of channeling initially and it was at this time that the ditches were plowed which greatly reduced the deleterious effects produced by channeling.

The nutrient concentrations at the three sampling sites in the county drain are tabulated in Table 17. These data indicate that there is no surface water pollution occurring due to the land treatment system. The water quality in the county drain is actually slightly better as it leaves the rest area. This is mainly due to NH_3 content

Table 15. Mean and Standard Deviation of Nutrient Concentrations in Shallow Wells (one- to four-feet deep) Located on the Overland Flow Field During the Summer of 1977 (ppm).

Well Site	i-PO_4		TKN		NH_3		NO_3	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
1	0.49	0.28	2.1	1.7	0.3	0.2	0.77	0.26
2	0.55	0.44	3.5	1.7	0.4	0.3	0.80	0.28
3	0.50	0.19	3.0	1.5	0.3	0.2	1.03	0.39
4	0.58	0.21	1.8	1.7	0.3	0.2	0.76	0.26

Table 16. Treatment Efficiency of Overland Flow Evapotranspiration System Considering the Land Treatment Process Only and the Entire System (including the lagoons) During the Summer of 1977 (percent reduction).

	TOC	i-PO_4	TKN	NH_3
Runoff:				
Land Treatment Only	26.4	83	94	97
Entire System	50	89	97	99
Infiltration and Subflow				
Land Treatment Only	--	88	90	98
Entire System	--	92	96	99

Table 17. Mean and Standard Deviation of Nutrient Concentrations in the County Drain System During the Summer of 1977 (ppm).

Site	TOC		i-PO_4		TKN		NH_3		NO_3	
	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S	$\overline{X}$	S
Drain Entering Rest Area	19.0	7.1	0.38	0.13	2.0	0.7	2.4	2.3	0.66	0.15
Addition to County Drain	30.0	22.6	0.53	0.10	1.7	1.4	0.5	0.1	0.60	0.03
Drain Leaving Rest Area	17.0	12.7	0.53	0.19	0.3	0.1	0.4	0.1	0.64	0.07

at the sampling point where the stream entered the rest area, probably the result of pollution of animal origin.

The nutrient concentrations in the ditches are listed in Table 18. These data follow the same general pattern discussed for the ditch samples taken in previous periods. Significant treatment occurs as the water moves down the slope with a large portion of the treatment occurring between the point of release and the first ditch.

The nitrate concentrations in the perimeter well samples were very low. In December there was an increase in the NO_3 content of the groundwater, possibly due to the leaking of nitrogen applied the previous summer. Even with these increases, the NO_3 concentration never exceeded 1.7 ppm and represented no health hazard.

Table 18. Mean and Standard Deviation of Nutrient Concentrations in the Ditches on the Overland Flow Field During the Summer of 1977 (ppm).

Ditch Site	i-PO_4		TKN		NH_3		NO_3	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
2nd Lagoon	6.42	1.65	63.2	21.8	50.7	11.1	0.81	0.38
1	1.86	1.17	8.8	5.2	2.4	2.2	0.59	0.12
2	1.56	0.91	6.5	2.8	0.8	0.5	0.55	0.17
3	1.59	0.99	7.1	6.0	2.2	1.8	0.51	0.12
4	1.02	0.71	4.5	3.1	0.6	0.7	0.57	0.11
5	0.73	0.47	2.8	1.6	0.5	0.3	0.55	0.13
6	0.81	0.36	2.0	0.9	0.4	0.3	0.57	0.19

Another period of interest is that in September 1978. For a two-week period in early September the system was loaded very heavily. The holding tank was usually filled and discharged three times each day. This was an average weekly loading of 7.2 inches. Due to the heavy loading, there was a slight increase in runoff from the system. There was also increased channeling and ponding, but it didn't reduce the overall efficiency. There was only one complete set of samples collected during this period, so all values reported in the tables are the actual values obtained from the one sampling.

Table 19 lists the nutrient concentrations in the lagoons, in the runoff, and in the infiltration and subflow. These values are all very comparable to those in the earlier periods of lighter loadings except that the i-PO_4 levels in the runoff and subflow are higher than before. This is due to the decreased plant uptake of phosphorus in the cooler September weather and the decreased ability of the soil to fix phosphorus with the heavier loading condition and resulting saturated soil. Other than this, the system functioned as well as during the previous loading conditions.

The nutrient concentrations in the ditches during this period of heavy loading are listed in Table 20. The nutrient levels in the upper ditches are considerably higher than during the earlier periods of lighter loading. These nutrients are very effectively removed as the water

Table 19. Nutrient Concentrations at Various Stages of Treatment with a Weekly Loading Rate of 7.2 inches (ppm).

Site	i-PO_4	TKN	NH_3	NO_3
1st Lagoon	4.72	56.8	53.5	1.03
2nd Lagoon	5.40	40.4	37.8	0.55
Chlorination Tank	5.37	38.9	30.2	0.60
Runoff	0.57	0.9	0	0.50
Infiltration and Subflow	0.73	0.6	0	0.48

Table 20. Nutrient Concentrations in the Ditches on the Overland Flow Field with a Weekly Loading Rate of 7.2 inches (ppm).

Ditch	i-PO_4	TKN	NH_3	NO_3
2nd Lagoon	5.40	40.4	37.8	0.55
1	4.05	22.8	18.0	6.86
2	3.59	19.7	15.3	4.57
3	1.71	5.8	2.8	3.38
4	0.90	1.8	0.03	0.24
5	0.91	1.7	0.07	0.24
6	0.80	1.2	0.10	0.11

moves down the slope, as demonstrated by the lower concentrations in the lower ditches. The resulting runoff at the bottom of the slope is of a very good quality. Especially interesting is the high NO_3 content in the upper ditches. This was the only period during which a high NO_3 concentration was noted anywhere on the system. The low NO_3 concentration in the lower ditches and in the subflow demonstrate the system's ability to remove NO_3 from the wastewater through the processes of denitrification and plant uptake. Perimeter well samples taken during this period show that nitrate contamination of the ground water aquifer did not occur. These data are shown in Table D in the Appendix. The high level of treatment efficiency on the flow area itself is demonstrated by reductions of 80%, 95%, 99%, and 98% for i-PO_4, TKN, NH_3, and NO_3 respectively between the first and last ditches.

Microbiological Analyses

The results of selected microbial analyses are shown in the Appendix in Table E and F. These analyses were performed on samples from the lagoons, the chlorination tank, the ditches on the overland flow area, and the perimeter wells to the ground water table. The analyses on samples from the perimeter wells were performed to assure that no biological contamination of the groundwater was taking place. With the exception of one well there were never any measurable populations of fecal coliforms in the groundwater samples. These data are shown in Table E in the Appendix. One well showed a small population of fecal coliforms for two samplings. The fact that only one well was affected and that it occurred for only two samplings indicates that the contamination probably occurred during the sampling procedure.

Microbial analyses were also performed on samples from the lagoons, ditches, and chlorination tank. The averages of these samples from the summer of 1978 are reported in Table 21. The microbial analysis of the samples from the chlorination tank gives an indication of the effectiveness of the disinfection process. If the operator followed the correct procedure, the chlorination was very effective. Often the correct procedure was not followed, however, and disinfection was less than complete due to insufficient mixing, contact time, or both.

There were large numbers of fecal coliforms on the overland flow area as indicated by the results of the microbial analysis of the ditch samples, as shown in Table 21. These were postulated to result largely from animal, rather than human sources. Even when chlorination of the wastewater was complete, large numbers of fecal coliforms were present on the land treatment area. This indicates that the wastewater is not the source of the fecal coliforms. There was often an increase noted in microbial numbers as the wastewater flowed down the slope. This was obviously the result of contamination from animal sources as fecal bacteria do not multiply rapidly outside

Table 21. Average MPN of Total Coliforms, Fecal Coliforms, Total Enterococci, and Fecal Enterococci in the Lagoons and on the Overland Flow Field During the Summer of 1978.

Site	Total Coliforms	Fecal Coliforms	Total Enterococci	Fecal Enterococci
1st Lagoon	48,000	20,000	24,000	50,000
2nd Lagoon	2,600	280	2,700	390
Chlorination Tank	2,600	38	160	60
1st Ditch	47,000	390	16,000	9,700
2nd Ditch	80,000	370	15,000	6,800
3rd Ditch	170,000	570	23,000	15,000
4th Ditch	23,000	4,900	11,000	5,000
5th Ditch	6,300	2,000	5,600	2,100
6th Ditch	6,100	2,100	6,100	2,100

of their natural environment. There were large numbers of birds, mice, and other small rodents observed inhabiting the grassy cover provided by the land treatment system, indicating the presence of a sufficient animal population to account for the contamination.

An analysis was performed on these data by comparing the ratio of fecal coliforms to fecal enterococci at various stages in the treatment process. The ratio obtained will give an indication of the source of the contamination (Geldreich, et al., 1964). Ratios of 4.4 or above indicate a human source, while values below 0.7 indicate an animal source. Ratios between these values indicate a mixture of sources. The results of this analysis are shown in Table 22. The results reported are the ratios of the geometric means of the samples. Samples from the first lagoon, second lagoon, and chlorination tank are analyzed separately for the summers of 1977 and 1978. The results for each are reported. Ratios from the first and last ditches are analyzed for the periods of moderate loading and heavy loading in 1978 and the results for each are reported. The MPN values and the calculations performed in this analysis are shown in Table F of the Appendix.

While the ratios in the first lagoon indicate a human source of contamination, the ratios in the second lagoon and chlorination tank are considerably lower. The ratio is well below 0.7 in the chlorination tank, indicating that little bacterial contamination of human origin will survive this long. These data indicate that treatment in the lagoons themselves is effectively reducing the human biological contamination. The ratios in the ditches are also well below 0.7, indicating that this contamination is due to animal activity on the land treatment area. The use of these ratios to indicate the source of pollution is not a widespread practice. This can be an important tool in evaluating the treatment efficiency of land treatment systems. Public health officials are often quick to label the presence of fecal coliforms as an indication of human contamination. These ratios can be used to show that the bacteria are from a non-human source and represent no danger from a public health standpoint.

Table 22. Ratio of Fecal Coliforms to Fecal Enterococci at Various Stages in the Treatment Process.

	Summer 1977	Summer 1978
1st Lagoon	6.72	3.70
2nd Lagoon	2.52	0.94
Chlorination Tank	0.35	0.23
	Moderate Loading 1978	Heavy Loading 1978
1st Ditch	0.034	0.17
6th Ditch	0.22	0.26

Mechanisms Involved in Nutrient Removal

The mechanisms involved in the removal of the nitrogen and phosphorus applied to this system can be determined by making several assumptions. It will be assumed that one ton of Reed Canary Grass was produced over the summer. Since there was no harvest, this is a very rough estimate. It will serve, however, to give a general indication of the amount of nutrients removed by the crop. Assuming that Reed Canary Grass is 3.7% nitrogen and 0.5% phosphorus (Sopper and Kardos), it is estimated that 74 pounds of nitrogen and 10 pounds of phosphorus could be removed by the crop. This is undoubtedly a low estimate as one ton of Reed Canary Grass is probably less than what was produced. During the two periods considered in 1978, a total of 37.2 pounds of nitrogen and 4.1 pounds of phosphorus were applied. It is obvious that even using the low estimate for plant uptake, this mechanism could easily account for the removal of all the nutrients applied. These estimates reveal that the system could handle a much heavier nutrient load than that which was applied. While the Reed Canary Grass was not harvested during this study, it would be a recommended procedure during long term use to avoid buildup of nutrients within the system.

There is also a tremendous capacity in this system for nitrogen removal through denitrification. The conditions necessary for denitrification are all met by the land treatment system. The soil surface was usually fairly dry, providing an aerobic zone where nitrification of the ammonia occurred. A short distance below the surface the soil was saturated. This provided the anoxic conditions necessary for the denitrifiers to utilize the NO_3 ion as an electron. An adequate energy source was supplied to the denitrifiers through the carbon in the wastewater and plant root exudates. Although plant uptake was the major mechanism of nitrogen removal, it is reasonable to assume that some denitrification did occur. During the short periods of heavy loading in August and September, the capacity for plant uptake was certainly exceeded. The concentrations of both nitrate and total nitrogen were still very low in both the runoff and subflow. As plant uptake could not account for all the nitrogen removal, denitrification is thought to play a major role, partic-uaarly during the periods of heavy loading.

It is interesting to note that the overall treatment efficiency of this land treatment system did not decrease as the loading rate was increased. A high quality effluent was produced as the loading rate was increased from 2.4 to 4.6 and again to 7.2 inches per week. The limiting factor involved here was the hydraulic capacity of the soil rather than the nutrient removal capacity of the soil plant system. This limit was approached at the heavier loading rates as increased channeling was observed. Smoothing the soil surface could increase the hydraulic capacity by decreasing channeling. In this case, however, it was decided that the

negative aspects of land forming such as soil compaction, destruction of native vegetation, time, and cost outweighed the benefits due to decreased channeling.

As the loading rate was increased, the amount of runoff increased considerably. The system was somewhat limited due to the stipulation that the effluent in the catchments, though of good quality, could not be discharged into nearby surface waters. This limitation precluded the use of still heavier loading rates as the capacity of the catchments would have been exceeded and discharge would have been necessary.

CONCLUSIONS

The modified overland flow land treatment system performed very effectively in achieving advanced treatment of the wastewater generated at the J. C. Mackey Rest Area. The system performed equally well at a moderate loading rate of 2.4-inches per week and at a heavier loading rate of 4.3-inches per week. The effluent quality was very similar for both conditions and in each case was well within state requirements for effluent discharge. The efficiency of the system, as described by percent reduction of various pollution parameters, was actually greater under heavier loading. At this heavier loading rate reductions of greater than 96% were noted in BOD_5, i-PO_4, TKN, and NH_3 concentrations. A brief period with a loading rate of 7.2-inches per week indicated the ability of the system to handle this large quantity of wastewater at a similar level of efficiency.

The water quality of the ground water aquifer was monitored continuously, and at no time did any chemical or biological contamination of the ground water aquifer occur. The nitrate concentrations were very low and there were no measurable coliform populations in the ground water samples. Sampling and analysis of nearby surface waters assured that there would be no contamination or eutrophication of area lakes and streams.

Most of the applied wastewater (80-90%) was lost through infiltration and evapotranspiration. The runoff which collected in the catchments at the bottom of the slope was demonstrated to be equal in quality to the nearby surface waters. Discharge of this runoff into the county drain system, though not legally permissible, would have been advantageous for the system at heavier loading rates.

Fecal coliform to fecal enterococci ratios were used in analyzing the results of the microbial analyses. These ratios demonstrated that the microbial contamination encountered in the samples from the land treatment area were from a non-human source. The source of microbial contamination in land treatment systems is often of great concern to local public health officials. These ratios could prove to be a valuable tool in the evaluation of land treatment systems as their use becomes more widespread.

This study showed that land treatment can be a very effective and inexpensive method of wastewater treatment for highway rest areas and other small rural institutions not located near a municipal sewer system. Consideration of wastewater characteristics and flow, as well as area soil characteristics, led to the development of a unique land treatment system. Though the soils of this area were not ideally suited for conventional overland flow or irrigation systems, this modified overland flow evapotranspiration system utilized the soil and landscape characteristics adjacent to the rest area to achieve very effective treatment of the wastewater generated there.

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APPENDIX

Table A. Individual Nutrient Concentrations and Caluclated Means and Standard Deviations of Nutrient Concentrations at Various Sampling Sites During the Summer of 1977.

TOC of Lagoon and Surface Samples

Site	8-1	8-4	8-9	8-11	8-16	8-18	8-23	8-29	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
Lagoon 1	163	163	128	141	161	260	230	--	138	22	69	37	23	139	77
Lagoon 2	158	140	116	142	128	146	120	--	103	36	32	20	15	101	53
Chlorination Tank	116	--	118	109	143	114	143	175	28	--	--	26	--	108	50
Drain 8	--	186	--	--	--	--	--	--	--	24	--	--	14	75	97
Drain 6	--	--	--	--	--	--	--	--	--	46	--	--	14	30	23
Drain 5	--	70	--	--	--	--	--	--	--	26	--	--	8	35	32
South Pond East	--	--	--	--	--	79	--	--	18	--	20	--	19	34	30
South Pond West	--	--	--	--	--	78	--	--	--	--	--	--	--	78	--
East Pond	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A. (continued)

$i\text{-}PO_4$ of Lagoon and Surface Samples

Site	8-1	8-4	8-9	8-11	8-16	8-18	8-23	8-29	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
Lagoon 1	4.76	5.05	6.35	6.35	6.28	8.50	10.2	5.70	7.43	4.25	4.00	6.00	6.48	6.42	1.65
Lagoon 2	6.65	5.85	4.28	3.55	3.92	3.84	5.7	3.16	4.53	3.29	3.42	4.47	5.08	4.35	1.05
Chlorination Tank	5.53	--	7.15	3.85	4.29	--	3.73	3.43	3.73	--	--	5.93	--	4.59	1.21
Drain 8	--	0.30	--	--	--	--	--	0.54	--	0.25	--	--	0.44	0.38	0.13
Drain 6	--	--	--	--	--	--	--	0.64	--	0.47	--	--	0.47	0.53	0.10
Drain 5	--	0.30	--	--	--	--	--	0.75	--	0.50	--	--	0.56	0.53	0.19
South Pond East	--	--	--	--	--	1.18	--	1.08	0.61	--	0.75	--	0.36	0.74	0.25
South Pond West	--	--	--	--	--	1.18	--	1.00	--	--	--	--	--	1.09	0.13
East Pond	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A. (continued)

Total Phosphorus of Lagoon and Surface Samples*

Site	8-1	8-4	8-9	8-11	8-16	8-18	8-23	8-29	9-2	9-6	9-9	9-15	9-22	$\bar{X}$	S
Lagoon 1	7.4	6.5	7.0	6.6	7.2	10.9	10.9	7.6	6.2	5.0	5.9	6.9	6.6	7.61	1.95
Lagoon 2	8.1	7.4	5.4	5.0	4.7	6.0	5.1	4.2	5.5	3.6	3.8	5.5	5.1	5.87	1.93
Chlorination Tank	6.3	--	7.3	4.9	5.8	5.4	5.2	3.0	3.6	--	--	5.0	--	5.11	1.24
Drain 8	--	1.8	--	--	--	--	--	0.3	--	0.3	--	--	0.1	0.63	0.79
Drain 6	--	--	--	--	--	--	--	0.1	--	0.4	--	--	0.2	0.23	0.15
Drain 5	--	--	--	--	--	--	--	0.2	--	0.4	--	--	0.2	0.27	0.12
South Pond East	--	--	--	--	--	0.5	--	0.2	1.0	--	0.9	--	0.1	0.54	0.40
South Pond West	--	--	--	--	--	0.1	--	0.1	--	--	--	--	--	0.1	--
East Pond	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

* The method used to analyze these samples produced questionable results at low concentrations.

Table A. (continued)

TKN of Lagoon and Surface Samples

Site	8-1	8-4	8-9	8-11	8-16	8-18	8-23	8-29	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
Lagoon 1	42.4	56.8	53.9	58.8	57.0	96.8	88.5	74.2	60.6	52.7	63.2	78.8	66.4	63.2	21.8
Lagoon 2	49.6	49.3	24.3	19.2	25.9	30.0	22.6	24.7	15.7	17.5	23.4	26.2	11.2	26.1	11.8
Chlorination Tank	35.8	--	44.3	31.4	37.8	32.4	34.8	18.3	21.4	--	--	28.7	--	30.8	8.0
Drain 8	--	13.8	--	--	--	--	--	2.7	--	1.4	--	--	1.9	2.0	0.7
Drain 6	--	--	--	--	--	--	--	3.2	--	1.3	--	--	0.5	1.7	1.4
Drain 5	--	--	--	--	--	--	--	0.4	--	0.2	--	--	0.3	0.3	0.1
South Pond East	--	--	--	--	--	0.35	--	3.2	1.4	--	2.0	--	1.6	1.7	1.0
South Pond West	--	--	--	--	--	0.15	--	2.8	--	--	--	--	--	1.5	1.9
East Pond	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A. (continued)

NH_3 of Lagoon and Surface Samples

Site	8-1	8-4	8-9	8-11	8-16	8-18	8-23	8-29	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
Lagoon 1	36.3	40.8	45.6	45.4	--	--	--	--	48.3	41.7	54.5	69.4	66.4	50.7	11.1
Lagoon 2	40.5	40.1	25.4	19.0	--	--	--	--	7.2	9.5	17.7	21.5	11.2	20.5	11.8
Chlorination Tank	26.9	--	38.4	31.4	--	--	--	--	11.9	--	--	21.7	--	26.1	10.0
Drain 8	--	4.9	--	--	--	--	--	--	--	0.4	--	--	1.9	2.4	2.3
Drain 6	--	--	--	--	--	--	--	--	--	0.4	--	--	0.5	0.5	0.1
Drain 5	--	0.4	--	--	--	--	--	--	--	0.5	--	--	0.3	0.4	0.1
South Pond East	--	--	--	--	--	--	--	--	--	--	0.6	--	--	0.6	--
South Pond West	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
East Pond	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A. (continued)

NO_3^- of Lagoons and Surface Samples

Site	8-1	8-4	8-9	8-11	8-16	8-18	8-23	8-29	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
Lagoon 1	0.7	1.9	1.0	0.6	0.83	0.73	0.88	0.74	0.78	0.70	0.90	0.82	0.56	0.81	0.38
Lagoon 2	0.6	1.0	1.1	0.8	0.71	1.00	0.93	0.93	0.64	0.79	0.96	0.98	0.62	0.87	0.20
Chlorination Tank	0.5	--	1.2	0.6	0.82	0.69	1.27	1.07	0.77	--	--	0.68	--	0.81	0.29
Drain 8	--	0.8	--	--	--	--	--	0.77	--	0.58	--	--	0.49	0.66	0.15
Drain 6	--	--	--	--	--	--	--	0.62	--	0.61	--	--	0.56	0.60	0.03
Drain 5	--	1.1	--	--	--	--	--	0.72	--	0.58	--	--	0.62	0.64	0.07
South Pond East	--	--	--	--	--	0.52	--	0.65	0.42	--	0.50	--	0.43	0.50	0.09
South Pond West	--	--	--	--	--	0.56	--	1.31	--	--	--	--	--	0.94	0.53
East Pond	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Table A. (continued)

i-PO_4 of Ditch Samples

Ditch	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	3.13	3.32	1.44	1.81	1.14	--	--	0.30	1.86	1.17
2	2.13	2.75	1.16	1.38	0.40	--	--	--	1.56	0.91
3	2.91	3.04	0.91	0.85	1.59	1.07	--	0.74	1.59	0.99
4	2.25	2.06	0.84	0.61	0.73	0.65	0.56	0.45	1.02	0.71
5	1.78	0.81	0.75	0.76	0.65	0.44	0.36	0.27	0.73	0.47
6	1.48	0.93	0.99	0.91	0.72	0.70	0.37	0.35	0.81	0.36

Total Phosphorus of Ditch Samples

Ditch	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	3.2	3.3	2.4	1.2	1.2	--	--	0.3	1.9	1.2
2	2.1	2.8	0.6	5.3	0.6	--	--	--	2.3	1.9
3	3.1	3.4	1.0	0.6	1.3	0.9	--	0.1	1.5	1.3
4	2.2	2.1	0.1	0.2	0.6	0.4	1.0	0.3	0.9	0.8
5	3.1	0.4	0.1	3.6	0.5	0.3	0.6	0.4	1.1	1.4
6	1.5	0.2	0.1	0.4	0.4	0.2	0.7	0.2	0.5	0.5

Table A. (continued)

TKN of Ditch Samples

Ditch	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	15.7	14.9	5.3	7.0	6.7	--	--	3.4	8.8	5.2
2	8.0	10.3	3.8	3.8	6.7	--	--	--	6.5	2.8
3	11.8	18.5	3.4	2.0	6.2	5.4	--	2.4	7.1	6.0
4	10.8	7.5	2.5	2.1	4.1	3.1	2.7	2.8	4.5	3.1
5	6.4	4.0	2.4	1.2	2.4	2.3	1.9	2.1	2.8	1.6
6	3.5	2.7	2.9	1.1	2.0	1.3	1.3	1.2	2.0	0.9

NH_3 of Ditch Samples

Ditch	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	--	--	--	3.9	0.8	--	--	--	2.4	2.2
2	--	--	--	1.1	0.4	--	--	--	0.8	0.5
3	--	--	--	0.5	4.1	2.0	--	--	2.2	1.8
4	--	--	--	0.4	1.6	0.3	<0.1	--	0.6	0.7
5	--	--	--	0.5	0.8	0.5	0.1	--	0.5	0.3
6	--	--	--	0.5	0.6	0.3	<0.1	--	0.4	0.3

Table A. (continued)

NO_3^- of Ditch Samples

Ditch	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	0.75	0.48	0.70	0.48	0.64	--	--	0.51	0.59	0.12
2	0.78	0.35	0.66	0.53	0.44	--	--	--	0.55	0.17
3	0.59	0.57	0.71	0.56	0.59	0.59	--	0.59	0.51	0.12
4	0.81	0.44	0.61	0.54	0.57	0.54	0.52	0.56	0.57	0.11
5	0.72	0.27	0.63	0.50	0.53	0.61	0.60	0.56	0.55	0.13
6	0.69	0.23	0.89	0.50	0.61	0.58	0.52	0.50	0.57	0.19

Table A. (continued)

i-PO_4 of Shallow Wells

Row Number	8-1	8-3	8-9	8-11	8-17	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	0.28	0.22	0.33	0.24	0.60	0.50	0.53	0.54	0.47	0.49	1.35	0.36	0.38	0.49	0.28
2	0.16	0.25	0.27	0.19	0.64	2.04	0.50	0.58	0.38	0.52	0.63	0.37	0.51	0.55	0.44
3	0.13	0.45	0.23	0.26	0.76	0.76	0.61	0.65	0.54	0.50	0.52	0.40	0.56	0.50	0.19
4	--	--	0.34	0.30	0.80	0.85	0.62	0.60	0.51	0.50	0.41	0.43	0.65	0.58	0.21
Total Phosphorus of Shallow Wells															
1	2.6	0.8	1.6	1.0	0.2	1.1	0.5	0.4	0.4	0.3	1.2	0.2	0.1	0.8	0.7
2	4.7	1.5	2.5	1.5	<0.1	2.0	1.1	0.5	0.6	0.8	0.6	0.8	0.5	1.2	1.2
3	5.6	0.8	--	4.2	0.6	2.3	0.3	0.3	0.6	2.0	0.3	0.5	0.3	1.4	1.6
4	--	--	0.9	1.3	<0.1	0.5	0.1	0.1	0.4	1.2	0.1	0.1	<0.1	0.4	0.5

Table A. (continued)

TKN of Shallow Wells

Row Number	8-1	8-3	8-9	8-11	8-17	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	7.5	3.0	1.5	2.6	1.6	1.5	1.6	3.2	0.9	1.4	2.4	1.4	0.8	2.1	1.7
2	9.7	4.8	7.1	6.1	1.6	3.9	3.5	2.8	2.2	2.6	3.3	2.5	3.1	4.0	2.3
3	14.7	2.8	5.6	5.6	1.5	4.9	1.9	2.8	2.2	4.7	1.8	1.3	2.6	3.0	1.5
4	--	--	2.0	2.0	4.1	0.4	0.5	2.1	2.0	1.7	0.2	0.6	6.1	1.8	1.7

NH_3 of Shallow Wells

Row Number	8-1	8-3	8-9	8-11	8-17	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	0.3	0.3	0.6	0.5	--	--	--	--	0.4	0.3	<0.1	0.5	--	0.3	0.2
2	0.9	0.5	0.4	0.4	--	--	--	--	0.5	0.8	<0.1	0.1	--	0.4	0.3
3	0.4	0.4	0.3	0.3	--	--	--	--	0.5	0.3	<0.1	<0.1	--	0.3	0.2
4	--	--	0.3	0.3	--	--	--	--	0.5	0.5	<0.1	<0.1	--	0.3	0.2

Table A. (continued)

NO_3^- of Shallow Wells

Row Number	8-1	8-3	8-9	8-11	8-17	8-23	8-26	8-31	9-2	9-6	9-9	9-15	9-22	$\overline{X}$	S
1	0.65	1.27	1.17	0.85	0.66	0.71	0.61	0.74	0.57	0.61	0.56	0.46	0.57	0.77	0.26
2	0.80	1.40	1.03	0.93	0.78	0.79	0.77	0.75	0.38	0.76	0.50	0.63	0.53	0.80	0.28
3	0.90	2.10	1.15	0.80	0.97	1.18	1.16	1.18	0.87	0.79	0.52	0.73	0.63	1.03	0.39
4	--	--	1.1	0.80	1.16	0.57	0.65	0.89	0.71	0.74	1.10	0.33	0.67	0.76	0.26

Table B. Individual Nutrient Concentrations and Calculated Means and Standard Deviations of Nutrient Concentrations at Various Sampling Sites During the Period of Moderate Loading in June and July of 1978.

BOD_5 of Lagoon and Surface Samples

Site	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
Lagoon 1	28	14	21	14	36	46	46	39	33	63	34	16
Lagoon 2	57	51	20	62	26	29	15	75	28	17	38	21
Chlorination Tank	9	36	42	39	34	26	<1	32	22	-		
Drain 8	5	1	1	2	<1	1	<1	<1	2	<1	27	14
Drain 6	11	1	8	<1	<1	2	<1	2	<1	1	3	4
Drain 5	7	1	<1	3	<1	2	<1	<1	6	2	2	3
South Pond East	8	4	1	3	2	3	3	-	4	4	4	2
South Pond West	8	3	3	4	2	2	-	<1	-	2	3	2
East Pond	10	2	3	7	4	6	2	6	3	4	5	3

Table B. (continued)

i-PO_4 of Lagoon and Surface Samples

Site	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
Lagoon 1	4.78	1.80	1.54	2.41	4.67	4.08	4.26	4.17	5.79	6.66	4.02	1.66
Lagoon 2	1.08	1.04	1.49	1.67	1.85	1.82	1.67	2.07	3.95	4.46	2.11	1.16
Chlorination Tank	1.40	1.33	1.65	1.65	2.06	2.18	1.87	2.17	4.04	--	2.04	0.81
Drain 8	0.12	0.20	0.16	0.11	0.08	0.13	0.14	0.15	0.16	0.15	0.14	0.03
Drain 6	0.08	0.18	0.12	0.06	0.09	0.12	0.12	0.12	0.15	0.15	0.12	0.04
Drain 5	0.17	0.26	0.20	0.15	0.11	0.18	0.16	0.16	0.21	0.17	0.18	0.04
South Pond East	0.05	0.05	0.05	0.02	0.01	0.06	0.04	--	--	0.09	0.05	0.02
South Pond West	0.07	0.08	0.06	0.04	0.01	0.08	--	0.03	0.03	0.08	0.05	0.03
East Pond	0.15	0.12	0.14	0.18	0.09	0.11	0.08	0.08	0.07	0.09	0.11	0.04

Table B. (continued)

Total Phosphorus of Lagoon and Surface Samples

Site	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
Lagoon 1	6.3	2.0	2.3	3.0	5.7	5.7	7.7	5.5	6.8	8.0	5.3	2.2
Lagoon 2	2.4	2.5	1.9	4.2	2.6	2.4	2.5	4.2	4.8	5.0	3.3	1.2
Chlorination Tank	2.4	2.1	2.5	2.8	3.7	3.0	4.1	3.9	5.0	--	3.3	1.0
Drain 8	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	0.1	<0.1	0.1	<0.1	--
Drain 6	<0.1	<0.1	0.2	0.1	<0.1	<0.1	<0.1	<0.1	0.6	0.1	0.1	--
Drain 5	<0.1	<0.1	0.2	0.1	<0.1	<0.1	<0.1	0.3	0.2	0.1	0.1	--
South Pond East	<0.1	<0.1	0.2	0.1	<0.1	<0.1	<0.1	--	<0.1	0.3	0.1	--
South Pond West	0.4	<0.1	0.3	0.2	<0.1	<0.1	0.1	<0.1	<0.1	0.1	0.1	--
East Pond	0.1	0.1	1.7	0.4	0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.3	0.5

Table B. (continued)

TKN of Lagoon and Surface Samples

Site	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
Lagoon 1	31.4	18.0	15.4	20.0	52.2	49.0	65.3	47.2	63.9	73.1	43.6	21.1
Lagoon 2	11.4	13.6	6.5	19.4	12.8	11.7	14.1	24.0	24.6	26.1	16.4	6.7
Chlorination Tank	11.9	10.4	13.5	14.8	17.7	14.2	16.6	15.6	26.4	--	15.7	4.6
Drain 8	0.4	0.6	1.5	0.9	0.8	2.9	1.2	2.1	1.1	0.9	1.2	0.8
Drain 6	1.0	0.6	2.4	0.9	1.4	1.4	0.9	1.3	4.3	0.7	1.5	1.1
Drain 5	0.2	--	1.9	0.4	1.5	0.5	0.6	0.6	1.3	0.6	0.8	0.6
South Pond E	1.3	1.3	2.8	1.4	3.2	2.4	3.2	--	2.6	2.2	2.3	0.8
South Pond West	0.6	0.9	2.6	1.6	2.4	1.8	--	1.4	--	2.2	1.7	0.7
East Pond	1.1	1.5	3.3	2.3	5.4	2.4	2.2	2.4	2.6	1.5	2.5	1.2

Table B. (continued)

NH_3 of Lagoon and Surface Samples

Site	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
Lagoon 1	24.8	12.6	7.36	12.3	43.8	38.7	40.1	37.6	54.2	61.6	33.3	18.4
Lagoon 2	3.4	2.0	1.26	1.8	4.80	5.38	6.27	7.67	16.6	20.1	6.9	6.4
Chlorination Tank	1.6	1.1	2.77	3.22	5.43	5.57	5.36	5.94	18.5	--	5.5	5.2
Drain 8	<0.1	<0.1	0.10	0.17	0.07	0.10	0.31	0.19	0.09	0.03	0.11	0.10
Drain 6	0.6	<0.1	0.25	0.37	0.12	0.27	0.14	0.34	0.18	0.21	0.25	0.16
Drain 5	0.2	0.4	0.20	0.20	0.07	0.13	0.56	0.18	0.15	0.06	0.24	0.16
South Pond East	0.02	0.01	0.06	0.29	0.19	0.24	0.28	--	0.19	0.12	0.16	0.11
South Pond West	0.01	<0.01	0.07	0.53	0.12	0.16	--	0.18	--	0.09	0.15	0.17
East Pond	0.02	<0.01	0.12	0.51	0.24	0.21	0.23	0.17	0.18	0.10	0.18	0.14

Table B. (continued)

NO_3^- of Lagoon and Surface Samples

Site	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
Lagoon 1	0.38	0.29	0.51	0.45	0.25	0.55	0.38	0.28	0.23	0.55	0.39	0.12
Lagoon 2	0.53	0.41	0.50	0.46	0.20	0.45	0.25	0.25	0.44	0.45	0.39	0.12
Chlorination Tank	0.15	0.38	0.57	0.49	0.36	0.52	0.39	0.29	0.50	--	0.41	0.13
Drain 8	0.43	0.41	0.42	0.52	0.37	0.49	0.36	0.44	0.43	0.26	0.41	0.07
Drain 6	0.53	0.48	0.50	0.68	0.38	0.50	0.59	0.55	0.61	0.50	0.53	0.08
Drain 5	0.47	0.44	0.68	0.59	0.47	0.61	0.46	0.51	0.63	0.24	0.51	0.13
South Pond East	0.43	0.43	0.45	0.58	0.49	0.44	0.37	--	0.48	0.32	0.44	0.07
South Pond West	0.35	0.34	0.40	0.54	0.44	0.39	--	0.29	--	0.30	0.38	0.08
East Pond	0.32	0.32	0.45	0.44	0.38	0.40	0.28	0.33	0.31	0.31	0.35	0.06

Table B. (continued)

i-PO_4 of Ditch Samples

Ditch	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	0.55	0.91	0.89	--	0.74	1.99	0.78	1.68	1.11	0.44	1.01	0.51
2	0.54	0.55	0.89	0.51	0.51	1.68	0.70	1.27	1.00	0.21	0.79	0.43
3	0.33	0.90	0.7o	--	0.63	0.80	0.82	1.16	0.98	0.21	0.73	0.30
4	0.30	0.29	0.19	0.18	0.29	0.05	0.23	0.45	0.41	0.11	0.25	0.12
5	0.22	0.05	0.11	--	0.11	0.04	--	0.11	0.13	0.12	0.11	0.05
6	0.18	0.03	0.07	0.07	0.09	0.04	--	0.05	0.14	0.12	0.09	0.05
Total Phosphorus of Ditch Samples												
1	0.93	1.0	1.0	--	0.9	2.3	1.0	2.3	1.4	0.8	1.3	0.6
2	0.70	0.6	1.0	0.6	0.6	2.0	0.9	1.8	1.3	0.3	1.0	0.6
3	0.50	0.9	0.8	--	0.8	0.8	1.1	1.6	1.2	0.5	0.9	0.3
4	0.37	0.3	0.1	0.2	0.3	0.3	0.3	0.7	0.4	0.6	0.4	0.2
5	0.20	0.1	<0.1	--	0.1	<0.1	--	<0.1	<0.1	0.5	0.1	0.2
6	0.20	<0.1	0.1	0.1	0.1	<0.1	--	<0.1	0.4	<0.1	0.1	0.1

Table B. (continued)

TKN of Ditch Samples

Ditch	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	4.4	5.1	4.6	--	4.6	8.9	6.2	8.7	6.8	2.4	5.7	2.1
2	3.5	3.5	3.9	2.3	2.8	6.6	4.2	6.5	5.3	1.6	4.0	1.7
3	3.1	4.4	4.2	--	3.7	3.5	4.1	6.2	4.5	2.7	4.0	1.0
4	2.7	2.1	2.7	1.9	2.5	1.8	2.0	3.3	3.1	2.2	2.4	0.5
5	2.2	0.8	1.7	--	2.7	2.0	--	1.5	1.5	3.0	1.9	0.7
6	3.0	1.2	1.1	1.8	1.7	1.9	--	1.3	3.2	1.5	1.9	0.8

NH_3 of Ditch Samples

Ditch	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	0.6	0.51	0.65	--	0.52	2.51	0.97	3.19	2.63	0.82	1.38	1.07
2	0.5	0.38	0.52	0.27	0.30	1.37	0.46	1.82	1.72	0.21	0.76	0.63
3	0.3	0.57	0.46	--	0.39	0.53	0.64	1.76	1.59	0.08	0.70	0.58
4	0.3	0.26	0.18	0.18	0.19	0.09	0.43	0.44	0.25	0.07	0.24	0.13
5	0.3	0.12	0.16	--	0.18	0.07	--	0.18	0.10	0.08	0.15	0.07
6	0.2	0.10	0.08	0.17	0.21	0.07	--	0.12	0.16	0.10	0.13	0.05

Table B. (continued)

NO_3^- of Ditch Samples

Ditch	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	0.41	0.59	0.41	--	0.36	0.59	0.33	0.52	0.36	0.39	0.44	0.10
2	0.37	0.45	0.41	0.43	0.37	0.60	0.34	0.40	0.32	0.31	0.40	0.08
3	0.38	0.55	0.58	--	0.49	0.56	0.51	0.71	0.33	0.30	0.49	0.13
4	0.35	0.37	0.43	0.37	0.37	0.30	0.42	0.43	0.30	0.31	0.49	0.13
5	0.33	0.31	0.41	--	0.42	0.34	--	0.38	0.44	0.39	0.38	0.05
6	0.40	0.27	0.43	0.34	0.47	0.36	--	0.42	0.39	0.42	0.39	0.06

$i\text{-}PO_4$ of Shallow Wells

Row Number	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	0.08	0.09	0.07	0.05	0.06	0.06	0.12	0.09	0.11	0.13	0.09	0.03
2	0.10	0.10	0.08	0.05	0.07	0.07	0.13	0.07	0.11	0.13	0.09	0.03
3	0.07	0.10	0.07	0.06	0.07	0.06	0.16	0.10	0.14	0.12	0.10	0.04
4	0.14	0.18	0.12	0.10	0.11	0.11	0.17	0.15	0.17	0.17	0.14	0.03

Table B. (continued)

Total Phosphorus of Shallow Wells

Row Number	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	0.2	0.3	0.5	<0.1	<0.1	<0.1	<0.1	0.08	0.05	0.2	0.1	0.1
2	0.3	0.05	0.1	0.03	<0.1	0.03	0.03	<0.1	<0.1	0.7	0.2	0.3
3	0.1	0.08	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.05	<0.1	0.1	0.2
4	--	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	--

TKN of Shallow Well Samples

Row Number	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	0.6	0.6	2.4	1.1	0.8	1.0	1.0	1.2	1.0	1.4	1.1	0.5
2	1.0	0.8	2.1	1.4	2.1	1.4	1.3	1.2	1.4	1.6	1.4	0.4
3	0.2	0.6	2.0	1.2	1.2	0.9	0.8	0.9	0.7	1.0	1.0	0.5
4	1.0	<0.1	1.9	1.1	0.8	0.9	1.2	0.8	1.2	1.0	1.0	0.5

Table B. (continued)

NH_3 of Shallow Wells

Row Number	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	<0.1	0.10	0.10	0.14	0.13	0.17	0.17	0.16	0.17	0.14	0.13	0.05
2	<0.1	0.12	0.14	0.19	0.14	0.22	0.14	0.19	0.23	0.25	0.16	0.07
3	<0.1	0.13	0.10	0.13	0.08	0.11	0.14	0.11	0.12	0.19	0.11	0.05
4	<0.1	0.44	0.14	0.14	0.14	0.13	0.17	0.12	0.16	0.14	0.16	0.11

NO_3^- of Shallow Wells

Row Number	6-22	6-27	6-29	7-7	7-11	7-13	7-17	7-20	7-25	7-27	$\overline{X}$	S
1	0.62	0.47	0.49	0.48	0.53	0.40	0.40	0.39	0.36	0.41	0.46	0.08
2	0.53	0.48	0.37	0.50	0.40	0.36	0.50	0.34	0.40	0.43	0.43	0.07
3	0.42	0.41	0.40	0.48	0.40	0.33	0.46	0.34	0.35	0.42	0.40	0.05
4	0.62	0.09	0.48	0.55	0.41	0.39	0.49	0.27	0.31	0.47	0.41	0.15

Table C. Individual Nutrient Concentrations and Calculated Means and Standard Deviations of Nutrient Concentrations at Various Sampling Sites During the Period of Heavy Loading in August of 1978.

BOD_5 of Lagoon and Surface Samples

Site	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
Lagoon 1	20	70	52	28	61	72	50.5	21.9
Lagoon 2	62	53	41	29	75	66	54.3	17.0
Chlorination Tank	<1	33	<1	<1	--	3	7.2	14.5
Drain 8	<1	<1	<1	<1	<1	<1	<1	—
Drain 6	<1	<1	1	<1	<1	<1	<1	—
Drain 5	<1	<1	1	<1	<1	<1	<1	--
South Pond East	<1	5	<1	2	2	4	2.2	2.0
South Pond West	<1	6	4	<1	3	4	2.8	2.4
East Pond	1	3	<1	2	3	3	2.0	1.3

Table C. (continued)

i-PO_4 of Lagoon and Surface Samples

Site	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
Lagoon 1	5.50	5.45	5.52	6.07	5.75	8.07	6.06	1.01
Lagoon 2	4.62	4.48	4.58	4.16	2.95	4.49	4.21	0.64
Chlorination Tank	4.87	4.53	4.82	4.78	--	4.92	4.78	0.15
Drain 8	0.12	0.13	0.37	0.46	0.20	0.23	0.25	0.14
Drain 6	0.14	0.13	0.35	0.44	0.20	0.22	0.25	0.12
Drain 5	0.16	0.15	0.42	0.51	0.24	0.27	0.29	0.14
South Pond East	0.03	0.02	0.13	0.21	0.02	0.10	0.09	0.08
South Pond West	0.03	0.03	0.12	0.19	0.05	0.18	0.10	0.07
East Pond	0.01	0.01	0.17	0.22	0.04	0.13	0.o0	0.07

Table C. (continued)

Total Phosphorus of Lagoon and Surface Samples

Site	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
Lagoon 1	7.1	8.9	6.9	7.5	7.1	9.3	7.8	1.0
Lagoon 2	6.0	5.5	5.9	5.1	5.6	6.2	5.7	0.4
Chlorination Tank	5.6	5.0	5.3	5.4	--	5.5	5.4	0.2
Drain 8	<0.1	<0.1	0.1	<0.1	0.1	0.2	<0.1	--
Drain 6	<0.1	<0.1	0.1	<0.1	<0.1	0.1	<0.1	--
Drain 5	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	--
South Pond East	<0.1	<0.1	0.5	<0.1	<0.1	<0.1	<0.1	--
South Pond West	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	--
East Pond	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	--

Table C. (continued)

TKN of Lagoon and Surface Samples

Site	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
Lagoon 1	68.5	72.2	70.8	75.7	70.3	84.6	73.7	5.9
Lagoon 2	37.3	37.1	43.4	40.9	49.8	41.2	41.6	4.7
Chlorination Tank	33.4	35.1	39.9	39.3	--	35.6	36.7	2.8
Drain 8	0.7	0.8	0.4	1.0	0.4	2.4	1.0	0.7
Drain 6	0.9	1.2	0.8	1.2	0.6	0.8	0.9	0.2
Drain 5	1.1	0.6	0.8	0.4	0.4	0.7	0.7	0.3
South Pond East	1.8	2.3	2.6	1.6	1.9	2.2	2.1	0.4
South Pond West	1.9	2.7	1.6	1.7	1.8	0.7	1.7	0.6
East Pond	2.2	1.7	2.7	2.0	1.6	1.7	2.0	0.4

Table C. (continued)

NH_3 of Lagoon and Surface Samples

Site	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
Lagoon 1	60.0	55.6	60.2	60.0	57.0	70.6	60.6	5.3
Lagoon 2	27.8	29.9	34.3	27.3	22.7	26.0	28.0	3.9
Chlorination Tank	27.5	27.2	34.3	27.3	--	26.7	28.6	3.2
Drain 8	0.08	0.11	0.10	0.02	0.03	0.07	0.07	0.04
Drain 6	0.25	0.10	0.10	0.06	0.10	0.07	0.11	0.07
Drain 5	0.09	0.05	0.03	0.02	0.04	0.10	0.06	0.03
South Pond East	0.16	0.20	0.13	0.07	0.08	0.11	0.13	0.05
South Pond West	0.12	0.13	0.10	0.06	0.12	0.14	0.11	0.03
East Pond	0.21	0.25	0.21	0.07	0.11	0.17	0.17	0.07

Table C. (continued)

NO_3^- of Lagoon and Surface Samples

Site	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
Lagoon 1	0.63	0.37	0.47	0.53	0.48	0.48	0.49	0.09
Lagoon 2	0.48	0.35	0.46	0.49	0.48	0.47	0.46	0.05
Chlorination Tank	0.48	0.33	0.53	0.66	—	0.37	0.47	0.13
Drain 8	0.49	0.52	0.57	0.59	0.51	0.49	0.53	0.04
Drain 6	0.61	0.37	0.57	0.58	0.56	0.44	0.52	0.09
Drain 5	0.58	0.35	0.55	0.53	0.44	0.44	0.48	0.09
South Pond East	0.44	0.33	0.44	0.57	0.54	0.38	0.45	0.09
South Pond West	0.46	0.34	0.44	0.57	0.52	0.41	0.46	0.08
East Pond	0.52	0.39	0.46	0.59	0.48	0.48	0.49	0.07

Table C. (continued)

i-PO_4 of Ditch Samples

Ditch	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	1.19	3.08	3.92	4.18	0.83	3.86	2.84	1.47
2	1.15	3.22	3.78	4.10	0.59	3.16	2.74	1.49
3	2.07	2.27	3.06	3.14	--	2.56	2.61	0.48
4	0.13	1.03	0.71	1.83	0.14	0.17	0.67	0.68
5	--	0.60	0.20	0.83	0.13	0.16	0.38	0.31
6	--	0.34	0.20	0.17	0.11	0.16	0.20	0.09

Total Phosphorus of Ditch Samples

Ditch	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	1.4	3.4	4.1	4.1	--	4.1	3.4	1.2
2	1.4	3.5	4.0	4.2	--	3.8	3.4	1.1
3	2.2	2.6	3.2	3.4	--	2.6	2.8	0.5
4	0.2	1.2	0.6	1.9	--	0.5	0.9	0.7
5	--	0.7	0.2	1.0	--	0.3	0.6	0.4
6	--	0.3	0.2	0.2	--	0.2	0.2	0.1

Table C. (continued)

TKN of Ditch Samples

Ditch	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	7.2	20.3	28.6	29.8	9.3	21.8	19.5	9.5
2	7.5	21.4	26.7	28.6	6.3	21.3	18.6	9.5
3	10.7	14.1	20.0	19.6	--	14.5	15.8	4.0
4	2.4	5.8	4.3	11.0	3.1	3.7	5.1	3.1
5	--	4.3	2.7	6.8	12.8	1.9	3.9	2.2
6	--	3.0	1.7	3.0	3.3	2.9	2.8	0.6

NH_3 of Ditch Samples

Ditch	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	3.82	15.57	21.33	22.47	4.56	15.21	13.83	8.02
2	4.10	16.43	20.07	22.03	3.04	14.95	13.44	8.05
3	7.35	9.52	13.80	14.36	--	9.46	10.90	3.04
4	0.14	2.65	1.76	6.87	0.41	0.48	2.05	2.55
5	--	1.18	0.10	3.26	0.35	0.15	1.01	1.33
6	--	0.61	0.15	0.98	0.13	0.29	0.43	0.36

Table C. (continued)

NO_3^- of Ditch Samples

Ditch	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	0.54	0.83	2.34	1.60	1.16	5.38	1.98	1.78
2	0.59	0.79	1.91	1.46	0.76	3.21	1.45	1.00
3	0.93	0.93	1.98	1.74	--	2.47	1.59	0.93
4	0.46	0.82	0.97	1.67	0.48	0.50	0.82	0.47
5	--	0.70	0.48	0.91	0.35	0.42	0.57	0.23
6	--	0.58	0.51	0.65	0.47	0.61	0.56	0.07

$i\text{-}PO_4$ of Shallow Wells

Row Number								
1	0.10	0.30	0.31	0.04	0.17	0.41	0.22	0.14
2	0.11	0.31	0.32	0.03	0.18	0.35	0.22	0.13
3	0.11	0.34	0.38	0.03	0.19	0.18	0.21	0.13
4	0.15	0.47	0.51	0.03	0.21	0.28	0.28	0.19

Table C. (continued)

NH_3 of Shallow Wells

Row Number	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	0.35	0.22	0.12	0.10	0.15	0.09	0.17	0.10
2	0.18	0.18	0.15	0.25	0.22	0.26	0.21	0.04
3	0.10	0.15	0.06	0.08	0.10	0.12	0.10	0.03
4	0.12	0.11	0.07	0.37	0.10	0.03	0.13	0.12

NO_3^- of Shallow Wells

Row Number	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	0.43	0.59	0.57	0.57	0.38	0.41	0.49	0.09
2	0.34	0.46	0.50	0.58	0.43	0.20	0.42	0.13
3	0.38	0.54	0.59	0.49	0.45	0.48	0.49	0.07
4	0.45	0.52	0.61	0.54	0.59	0.43	0.52	0.07

Table C. (continued)

Total Phosphorus of Shallow Wells

Row Number	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	0.1	<0.1	<0.1	<0.1	--	<0.1	<0.1	--
2	<0.1	<0.1	<0.1	<0.1	--	<0.1	<0.1	--
3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--
4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--

TKN of Shallow Wells

Row Number	8-1	8-3	8-8	8-10	8-15	8-17	$\overline{X}$	S
1	1.5	1.1	1.1	1.1	1.9	1.5	1.4	0.3
2	1.3	1.5	1.3	1.7	2.2	2.0	1.7	0.4
3	1.0	0.9	0.8	0.9	2.2	1.3	1.2	0.5
4	1.0	0.6	0.5	0.7	1.9	0.7	0.9	0.5

Table D. Nitrate Concentration in Ground Water Monitoring Wells During 1977 and 1978 (ppm).

	Well Number									
Date	3	4	5a	6a	7	8	9	10	11	12
7- 2-77	0.02	0.05	<0.01	--	0.61	0.15	--	0.67	--	<0.01
7- 5-77	<0.01	<0.01	0.31	0.06	0.26	0.42	0.03	0.58	<0.01	<0.01
7-11-77	<0.01	0.01	0.10	<0.01	0.05	0.06	<0.01	0.58	0.01	<0.01
8- 4-77	0.01	0.02	0.05	0.02	0.29	0.01	0.01	0.58	0.02	0.01
8-11-77	0.01	0.02	0.10	0.02	0.22	0.03	0.04	0.64	0.02	0.02
8-17-77	0.04	0.01	0.08	0.04	0.07	0.03	0.02	0.62	0.03	0.03
8-29-77	--	<0.01	0.02	<0.01	0.02	0.02	0.01	0.63	0.03	0.01
9- 6-77	0.65	0.65	0.44	0.54	0.65	0.70	0.54	1.23	0.42	0.61
9-15-77	0.50	0.50	0.60	0.29	0.89	0.61	0.47	1.18	0.63	0.49
9-22-77	0.53	0.42	0.59	0.51	0.60	0.44	0.53	1.21	0.58	0.63
10-14-77	--	--	0.38	0.47	0.37	0.42	--	--	--	--
12-22-77	0.10	0.05	0.10	0.10	1.22	--	--	1.71	--	--
2-28-78	0.85	0.77	0.62	0.68	--	0.64	1.15	1.34	0.73	0.87
3-16-78	0.04	0.03	0.03	0.03	--	0.03	0.11	0.27	0.03	0.04
4-15-78	<0.01	0.03	0.03	0.03	0.03	0.05	0.09	0.25	0.04	0.04
5-24-78	0.07	0.56	<0.01	<0.01	<0.01	0.46	<0.01	0.14	0.36	<0.01
6- 8-78	0.04	0.49	<0.01	<0.01	0.95	<0.01	0.10	0.44	<0.01	<0.01
6-22-78	0.47	0.55	0.42	0.40	0.97	0.62	0.44	0.76	0.42	0.86
7- 7-78	0.43	0.31	0.40	0.36	0.48	0.45	0.37	0.78	<0.2	0.41
7-13-78	--	--	--	0.93	0.28	0.77	--	--	--	--
7-17-78	--	--	--	0.35	0.76	0.47	--	--	--	--
7-20-78	--	--	--	0.24	0.67	0.34	--	--	--	--
7-25-78	--	--	--	0.54	0.94	0.58	--	--	--	--
7-27-78	0.36	0.55	0.70	0.52	1.06	0.46	0.47	0.94	0.51	0.58
8- 1-78	--	--	--	0.32	0.66	0.39	--	--	--	--
8- 3-78	0.44	0.35	0.54	0.36	0.96	0.45	0.53	0.92	0.46	0.79

Table D. (continued)

	Well Number									
Date	3	4	5a	6a	7	8	9	10	11	12
8- 8-78	--	--	--	0.64	0.84	0.57	--	--	--	--
8-10-78	--	--	--	0.55	0.79	0.52	--	--	--	--
8-17-78	0.43	0.34	0.43	0.51	0.65	0.44	0.49	0.73	0.37	0.70
9- 5-78	0.57	0.39	0.49	0.44	0.74	0.36	0.48	0.69	0.35	--

Table E. Total Coliform Concentration in Ground Water Monitoring Wells During 1977 and 1978 (MPN/100 ml).

	Well Number									
Date	3	4	5a	6a	7	8	9	10	11	12
7- 1-77	9	<2	15	<2	>2,400	23	4	4	93	<2
7- 5-77	4	<2	240	<2	>240,000	460	1,100	4	460	<2
7-11-77	4	<2	150	4	>2,400	9	>2,400	4	1,100	150
8- 4-77	9	<2	7	<2	40	<2	460	<2	75	43
8-11-77	<2	<2	<2	<2	<20	<2	210	<2	23	4
8-17-77	<2	<2	<2	<2	<2	<2	43	<2	<2	<2
8-29-77	<2	<2	<2	<2	<2	<2	15	<2	<2	<2
9- 6-77	<2	<2	<2	<2	<2	<2	43	<2	23	<2
9-15-77	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
9-22-77	<2	<2	<2	<2	<2	<2	<2	<2	23	<2
10-14-77	-	-	<2	<2	<2	<2	-	-	-	-
2-28-78	<2	<2	<2	<2	-	<2	<2	<2	<2	<2
3-16-78	<2	<2	<2	<2	4	<2	<2	<2	<2	<2
4-15-78	<2	<2	<2	<2	43	<2	<2	<2	<2	<2
5-24-78	<2	<2	<2	<2	-	<2	<2	<2	<2	<2
6- 8-78	<2	<2	<2	<2	93	23	<2	<2	<2	<2
6-22-78	<2	<2	<2	<2	43	<2	4	<2	<2	<2
7- 7-78	<2	<2	<2	<2	9	<2	<2	<2	<2	<2
7-27-78	<2	<2	43	<2	9	<2	<2	<2	750	<2
8- 3-78	<2	<2	9	4	<2	4	<2	<2	23	<2
8-17-78	<2	<2	23	4	43	<2	<2	<2	460	23
9- 5-78	<2	<2	<2	<2	<2	<2	<2	<2	<2	4

Table F. MPN Values Used in the Determination of Fecal Coliform to Fecal Strep Ratios in Ditch and Lagoon Samples.

First Lagoon 5-24-78 through 8-17-78

Date	FC	FS	FC/FS
5-24	46,000	700	6.6
6- 8	43,000	2,300	18.7
6-22	4,300	2,300	1.9
6-27	12,000	2,300	5.2
6-29	900	900	1.0
7- 7	<200	<200	—
7-11	2,300	2,300	1.0
7-13	2,300	46,000	0.05
7-17	15,000	15,000	1.0
7-20	9,300	1,100	8.5
7-25	15,000	7,500	2.0
7-27	150,000	15,000	10.0
8- 1	24,000	4,300	5.6
8- 3	110,000	2,300	47.8
8- 8	460,000	110,000	4.2
8-10	24,000	7,500	3.2
8-15	240,000	46,000	5.2
8-17	110,000	46,000	2.4
log $\overline{X}$	4.3565	3.7888	
S	0.763	0.674	
$\overline{X}$	22723	6149	

$\overline{X}FC/\overline{X}FS = 3.70$

Table F. (continued)

First Lagoon 7-25-77 through 9-15-77

Date	FC	FS	FC/FS
7-25	>24,000	2,400	≥10.0
7-28	110,000	11,000	10.0
8- 1	930,000	24,000	38.8
8- 4	>240,000	46,000	≥5.2
8- 9	150,000	4,300	5.18
8-11	93,000	46,000	2.0
8-12	110,000	24,000	4.58
8-16	240,000	46,000	5.22
8-18	>2,400,000	46,000	≥52
8-23	93,000	4,300	21.6
8-26	9,300	2,000	4.65
8-29	9,300	900	10.3
8-31	9,300	9,300	1.0
9- 2	24,000	9,300	2.58
9- 6	1,500	1,500	1.0
9- 9	110,000	24,000	4.58
9-15	240,000	46,000	5.2
log $\overline{X}$	4.86	4.03	
S	0.800	0.588	
$\overline{X}$	72,052	10,717	

$\overline{X}FC/\overline{X}FS = 6.72$

Table F. (continued)

Second Lagoon 7-25-77 through 9-15-77

Date	FC	FS	FC/FS
7-28	>24,000	4,600	≥5.2
8- 1	24,000	2,400	10.0
8- 4	9,300	2,300	4.04
8- 9	7,500	7,500	1.0
8-11	7,500	2,300	3.26
8-12	4,300	4,300	1.0
8-16	24,000	9,300	2.58
8-18	11,000	2,400	4.58
8-23	2,400	1,500	1.60
8-26	300	2,300	0.13
8-29	4,300	900	4.78
8-31	2,300	200	11.5
9- 2	4,300	1,500	2.87
9- 6	<200	200	<1.0
9- 9	1,500	400	3.75
9-15	4,300	--	--
log $\overline{X}$	3.63	3.23	
S	0.607	0.508	
$\overline{X}$	4,304	1,710	

$\overline{X}FC/\overline{X}FS = 2.52$

Table F. (continued)

Second Lagoon 5-24-78 through 8-17-78			
Date	FC	FS	FC/FS
5-24	1,400	--	--
6- 8	930	40	23.3
6-27	40	430	0.09
6-29	75	43	1.74
7- 7	<20	<20	--
7-11	40	70	0.57
7-13	1,500	46,000	0.033
7-17	40	150	0.27
7-20	90	1,100	0.082
7-25	4,600	930	4.95
7-27	4,300	1,500	2.87
8- 1	900	2,300	0.39
8- 3	700	400	1.75
8- 8	7,500	2,300	3.26
8-10	2,300	1,500	1.53
8-15	2,100	1,500	1.40
8-17	2,100	1,500	1.40
log $\overline{X}$	2.718	2.743	
S	0.858	0.861	
$\overline{X}$	522.3	553.8	

$\overline{X}FC/\overline{X}FS = 0.94$

Table F. (continued)

Chlorination Tank 5-24-78 through 8-17-78

Date	FC	FS	FC/FS
6-22	<2	--	--
6-27	430	230	1.87
6-29	<20	70	≤0.28
7- 7	90	2,400	0.0375
7-13	40	11,000	0.0036
7-17	<20	150	<0.133
7-20	90	230	0.39
7-25	11,000	930	11.83
8- 1	40	<20	≥2.0
8- 3	210	930	0.23
8-15	<20	--	--
8-17	90	90	1.0
log $\overline{X}$	2.04	2.67	
S	0.992	0.724	
$\overline{X}$	109.54	471.0	

$\overline{X}FC/\overline{X}FS = 0.23$

Table F. (continued)

Chlorination Tank 7-25-77 through 9-15-77			
Date	FC	FS	FC/FS
7-25	<2	<2	--
7-28	4	<2	≥2.0
8- 1	≥24,000	15	≥1,600
8- 9	430	2,000	0.22
8-11	3,900	110,000	0.036
8-16	--	4,000	--
8-17	<200	900	≤0.22
8-23	<2	460	≤0.0043
8-26	<20	460	≤0.044
8-31	<200	400	<0.5
9- 9	9,300	2,300	4.04
9-15	<20	--	--
log $\bar{X}$	2.09	2.54	
S	1.46	1.44	
$\bar{X}$	122.8	348.6	

$\bar{X}FC/\bar{X}FS = 0.352$

Table F. (continued)

Ditch Number 1 6-22-78 through 7-27-78			
Date	FC	FS	FC/FS
6-22	430	46,000	0.0093
	40	1,500	0.027
	<2	15,000	<0.0001
6-27	400	4,300	0.093
	<200	9,300	<0.22
	2,300	15,000	0.15
6-29	4	11,000	0.0004
	75	11,000	0.0068
	43	11,000	0.0039
7-11	<200	2,300	<0.087
	<200	9,300	<0.022
	<200	2,100	<0.095
7-13	<200	46,000	<0.0043
	400	15,000	0.027
	<200	24,000	<0.0083
7-17	<200	15,000	<0.0133
	<200	4,300	<0.0465
	900	9,300	0.0968
7-20	2,300	4,300	0.53
	4,300	2,300	1.87
	<200	24,000	<0.0083
7-25	9,300	110,000	0.0845
	2,300	9,300	0.25
	4,000	9,000	0.44
7-27	--	--	--
	<200	400	<0.5
	<2,000	4,000	<0.5
log $\overline{X}$	2.46	3.93	
S	0.899	0.518	
$\overline{X}$	288.4	8511	

$\overline{X}FC/\overline{X}FS = 0.034$

Table F. (continued)

Ditch Number 1 8-1-78 through 8-17-78			
Date	FC	FS	FC/FS
8- 1	900	24,000	0.037
	400	110,000	0.0036
	23,000	240,000	0.095
8- 3	400	7,500	0.053
	<200	24,000	<0.0083
	9,000	9,000	1.0
8- 8	9,300	15,000	0.62
	900	9,300	0.097
	9,000	9,000	1.0
8-10	24,000	20,000	1.20
	400	4,300	0.093
	4,000	23,000	0.17
8-15	400	2,300	0.17
	<200	400	<0.5
	<2,000	--	--
8-17	400	2,300	0.17
	400	700	0.57
	9,000	9,000	1.0
log $\overline{X}$	3.20	3.97	
S	0.731	0.697	
$\overline{X}$	1,585	9,332	

$\overline{X}FC/\overline{X}FS = 0.17$

Table F. (continued)

Ditch Number 6 6-22-78 through 7-27-78			
Date	FC	FS	FC/FS
6-22	20	11,000	0.0018
	4,000	930	4.30
	1,500	2,100	0.71
6-27	90	4,600	0.020
	2,100	2,300	0.91
	--	--	--
6-29	9	1,500	0.006
	23	43	0.53
	--	--	--
7- 7	90	280	0.32
	15,000	<200	≥75
	900	700	1.28
7-11	230	9,300	0.025
	4,300	15,000	0.29
	400	1,500	0.27
7-13	--	--	--
	2,300	4,300	0.53
	<200	24,000	<0.0083
7-20	230	2,400	0.0096
	--	--	--
	--	--	--
7-25	750	4,600	0.16
	--	--	--
	--	--	--
7-27	40	210	0.19
	--	--	--
	400	400	1.0
log $\overline{X}$	2.55	3.21	
S	0.885	0.725	
$\overline{X}$	354.8	1,622	

$\overline{X}FC/\overline{X}FS = 0.219$

Table F. (continued)

Ditch Number 6 8-1-78 through 8-17-78			
Date	FC	FS	FC/FS
8-13	90	110,000	0.0008
	46,000	110,000	0.42
	--	--	—
8- 8	2,100	4,600	0.46
	90	4,600	0.020
	1,500	2,300	0.65
8-10	2,400	4,600	0.52
	40	2,400	0.017
	700	900	0.78
8-15	200	430	0.47
	1,500	150	10.0
	--	--	—
8-17	200	930	0.22
	930	210	4.43
	900	2,300	0.39
log $\overline{X}$	2.81	3.40	
S	0.805	0.877	
$\overline{X}$	645.7	2,512	

$\overline{X}FC/\overline{X}FS = 0.257$