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Municipal Wastewater Treatment by the Overland Flow Method of Land Application

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MUNICIPAL WASTEWATER TREATMENT BY THE OVERLAND FLOW METHOD OF LAND APPLICATION

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DISCLAIMER

FOREWORD

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

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

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

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

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

William C. Galegar
Director
Robert S. Kerr Environmental Research Laboratory

ABSTRACT

The primary objectives of this study were to assess on a seasonal basis (winter and summer applications), the capabilities of treating raw (screened) municipal wastewater and secondarily treated wastewater (wastewater stabilization pond effluent), by applying the wastewaters to experimental overland flow treatment modules, on two slopes: 2 per cent and 3 per cent. Three application techniques in the raw treatment phase were employed for comparison: (a) rotating spray booms with fan nozzles, (b) fixed risers with fan nozzles, and (c) troughs with trickling orifices. Fixed riser and trough methods were used for the secondary treatment phase. Comparison was made between the performance of the raw wastewater overland flow system and the performance of the wastewater stabilization pond receiving the same wastewater.

In addition to wastewater treatment parameters, analyses were conducted to determine the effects of overland flow applications on soil composition, before and after wastewater applications.

Microbial studies were conducted to determine the quantitative and qualitative structure of the microbial community, within the raw and secondary treatment systems, primarily enteric bacterial and viral organisms. Tests were conducted to determine removal efficiencies for the two treatment systems. Also ambient air samples were collected around the spray boom method of application to determine the presence or absence of airborne enteric bacteria and virus.

The raw overland flow treatment system demonstrated the ability to achieve under winter and summer operation, BOD and suspended solids levels equal to or lower than those associated with conventional secondary treatment processes. Fecal coliform analyses indicated low reductions across the plots. No meaningful reductions were observed for phosphorus. Most treatment plots indicated varying levels of increase. Reductions of approximately 50 per cent were observed for organic nitrogen during summer and winter. Ammonia reductions were somewhat higher in the summer than the winter. The indicated nitrogen removal mechanism was loss of ammonia to the atmosphere rather than nitrification-denitrification. An analysis of BOD, COD and ammonia treatment parameters above and below freezing temperatures, indicated that temperature had a direct effect on removal efficiency. Of the three methods of application employed, no single method demonstrated consistent superiority to the other.

The secondary treatment system provided limited beneficial effects as an advanced wastewater treatment procedure. In comparison of wastewater stabilization pond and the raw overland flow system, neither demonstrated consistently superior performance.

Of the parameters analysed for the soil studies, a consistent pattern of increase or decrease was observed for several parameters, namely, phosphorus, potassium, manganese, calcium and copper.

The microbial analyses revealed a consistent reduction in bacterial colony counts for all methods of application on the 2 and 3 per cent slopes. Of the viral concentrations observed in the influent to the raw system, 100 per cent reductions occurred on all methods of application except during peak loading. The analyses also revealed a seasonal trend of occurrence of enteric viruses in the wastewater. In the aerosolization studies, airborne bacteria were isolated in significantly greater quantities downwind from the spray boom applications, while no viruses were isolated from air samples taken at the same locations. No enteric viruses were isolated in the influent to the secondary system, at any location.

This report was submitted in fulfillment of Grant No. R803218 by the Oklahoma State Department of Health under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period June 26, 1974, to March 31, 1979, and work was completed as of July 10, 1979.

CONTENTS

CONTENTS (Continued)

FIGURES

TABLES

TABLES (Continued)

LIST OF ABBREVIATIONS

BOD	--biochemical oxygen demand
cm	--centimeter
COD	--chemical oxygen demand
EMB	--eosin methylene blue
FC	--fecal coliform
ft	--feet
gal	--gallon
ha	--hectare
hr	--hour
in	--inch
kg	--kilogram
l	--liter
lbs	--pounds
m	--meter
mg	--milligram
mgd	--million gallons per day
min	--minute
ml	--milliliter
n	--number (statistical)
NA	--nutrient agar
NC	--not calculated
NR	--not collected
PFU	--plaque forming units
s	--slope (statistical)
sec	--second
SS	--suspended solids
Std. Dev.	--standard deviation
TBC	--total bacteria counts
TCC	--total coliform counts
u	--units
$\underline{V}$	--coefficient of variation
$\overline{X}$	--arithmetic mean
110-V	--110 volts

ACKNOWLEDGMENTS

The authors wish to thank the individuals and agencies involved in compiling the data of this study. The support of Garvin County Health Department personnel, Mr. Dewey Smith, Head Sanitarian, is gratefully acknowledged.

Sample collection, wastewater analyses and project maintenance and operation was conducted by Oklahoma State Health Department personnel, Larry Gales, Sanitarian, William Thomas, Sanitarian, and Gary Burnett, Sanitarian, stationed in Pauls Valley, Oklahoma. The wastewater analyses were conducted at the Garvin County Health Department, Laboratory facilities.

Bacterial analyses were conducted by Aaron Mitchum and Gary McKee at the Oklahoma State Health Department Laboratory. Viral analyses were conducted by Herbert Beauchamp in the Virology Laboratory of the State Health Department. Mr. Beauchamp provided additional help in preparing the written text for the viral analyses.

Dr. Ronald L. Coleman, Associate Professor of Research Biochemistry and Molecular Biology, University of Oklahoma Health Sciences Center, provided valuable consultation throughout the study and the authors wish to acknowledge his efforts.

Dr. Milford H. Hatch, Chief of Enteric Virology Branch, Center of Disease Control, Atlanta, Georgia, provided cultures of Poliovirus Type 1 (Sabin strain), for use in laboratory studies conducted to determine a sampling protocol for the viral analyses.

A special thanks from the authors goes to the Pauls Valley, Weather Station for the weather data provided during the study.

The authors wish to express their gratitude and appreciation to the Robert S. Kerr Environmental Research Laboratory for its support of this project, and especially to Dr. William R. Duffer, Project Officer, for his patience and guidance throughout the course of the study. Also, thanks to Bert Bledsoe for his technical assistance in the laboratory analyses.

SECTION 1

INTRODUCTION

In the past decade, subsequent changes in federal water quality standards and criteria (1) have brought forth a re-evaluation of current technology, aimed at more efficient methodology in wastewater disposal. The inadequacies of current treatment methods are found primarily in the area of cost effectiveness of mechanical, chemical and biological applications, as related to the size of the population served. Such a re-evaluation involves a search for alternative methods of treatment that are within the realm of practicality for all municipalities regardless of size, and would minimize cost along with optimizing the results of the treatment process, in order to meet the discharge standards pursuant to the Federal Water Pollution Control Act of 1972 (1).

Since the inception of the wastewater stabilization pond concept in the early 1950's, few acceptable methods of inexpensive wastewater treatment have been researched. The wastewater stabilization pond, though relatively simple in design, inexpensive to operate and reasonably efficient in treatment results, has fallen short of accomplishing effective treatment within current Environmental Protection Agency guidelines (1).

The current trends in the field of wastewater management are developing toward the re-use of wastewater, a concept relatively ancient in application yet virtually untouched in terms of subject matter gained through scientifically controlled testing. One area of wastewater re-use under consideration, is the simultaneous treatment and re-use of wastewater through land application.

Land application systems have been generally classified into three categories based on particular requirements for hydraulic conductivity and chemical properties of soils (2).

a) slow rate (crop irrigation),
b) rapid infiltration, and
c) overland flow.

Each of these classifications involves a different approach in terms of basic design and practical application. The application of wastewater to land encompasses a broad realm of implications and has stirred controversy and question as to the effects of such treatment on various components of the ecosystem, primarily groundwater supplies, soils, and air quality. The application of raw sewage to the land has also given rise to numerous questions regarding potential hazards to public health. All such questions form a basis for conducting controlled studies to determine the effectiveness of land application as an alternative method of wastewater treatment.

Numerous case histories of land application systems around the country and in other areas of the world have been documented (2). Among such studies, only three have dealt with land application by the overland flow method. A study conducted at the Campbell's Soup Company in Paris, Texas, involved the monitoring of treatment of industrial food processing waste by overland flow (3). Also, a pilot study designed to evaluate treatment capabilities of overland flow systems, was conducted by EPA, at Ada, Oklahoma (4, 5). A particularly successful, long range application of overland flow treatment has been in operation at Melbourne, Victoria, Australia (6). In this particular land treatment system, crop irrigation and wastewater stabilization pond methods have been used along with overland flow methods, to treat wastewater from the Melbourne municipality. The overland flow portion of the system has been used to treat the majority of the normal winter flow, when a reduction in the evaporation rates has inhibited the effectiveness of the other methods. It is apparent from such literature that there is a need for more intensive studies of overland flow processes, particularly in the field of municipal wastewater disposal.

This study involved the treatment of municipal wastewater by the overland flow method of land application. The scale of the project was designed to accommodate approximately one-third the average flow of domestic sewage from Pauls Valley, Oklahoma; a community with a population of approximately 6000, located in south-central Oklahoma. The primary objectives were to assess, on a seasonal basis (winter and summer applications), the capabilities of treating raw (screened) municipal wastewater by application to experimental overland flow treatment modules, on two different slopes: 2 per cent and 3 per cent. Three application techniques were employed: (a) rotating spray booms with fan nozzles, (b) fixed risers with fan nozzles, and (c) troughs with trickling orificies. A comparison was made between treatment results of each application technique on each slope. The performance of the overland flow process in the treatment of raw wastewater was compared to the performance of the wastewater stabilization pond, receiving the same wastewater. Adjacent to the raw system an additional series of test modules (employing the same slopes and all but the rotating spray boom method of application) were used to render a similar evaluation of overland flow treatment of wastewater that had undergone secondary treatment (wastewater stabilization ponds) prior to application.

In addition to monitoring wastewater treatment parameters, studies were conducted to determine the potential of overland flow treatment for assimilation of bacterial and viral components found in domestic sewage. Also, the potential human health hazards associated with domestic wastewater, made it necessary to attempt to determine whether the element of exposure to pathogenic microbes was enhanced or inhibited by the overland flow treatment process. To accomplish this evaluation it was necessary to isolate and quantify known pathogenic microbes (bacterial and viral), and trace their path through the treatment system. One area of concern, which relates to the physical nature of the application techniques, is the quality of the air surrounding the applicators. The application technique which seemed to present the greatest possibility for aerosol generation, and therefore the greatest possibility of adversely affecting the surrounding air quality, was the rotating spray boom. By isolating and quantifying microbial entities within the wastewater and the air surrounding the spray boom, and measuring the removal efficiency of the overland flow treatment process, the human health hazards were definable.

Another phase of this study involved an assessment of the effects of wastewater application on the soil of the treatment system. The underlying implications of the effects of land application on the soil composition are limited by the nature of the overland flow treatment process, which relies on treatment through surface interaction rather than soil infiltration. The overland flow process is designed for use in areas where the predominant soil type (clay) limits the capacity for percolation. For this reason, the emphasis on monitoring soil composition was not as rigorous. The scope of this assessment was to identify any gross change in the topsoil and subsurface soil composition at the completion of the study.

All comparisons of treatment effectiveness were made in an attempt to produce a comprehensive analysis of the overland flow process, in terms of operation, maintenance and comparative degree of treatment afforded. This analysis in turn forms a basis for making objective decisions in the development of engineering as well as practical application guidelines.

SECTION 2

SUMMARY AND CONCLUSIONS

WASTEWATER ANALYSIS

Raw Treatment System

1. The raw system, under the application methods utilized in this investigation, demonstrated the ability to achieve, under winter and summer operation, suspended solids levels equal to or lower than those commonly associated with effluent limits and conventional secondary treatment processes.

2. The biochemical oxygen demand (BOD) levels observed during the summer operation also compare favorably; however, additional treatment for the winter operation was indicated.

3. Fecal coliform reductions observed during winter and summer operations were generally less than one order of magnitude compared to four orders of magnitude being required in order to approach acceptable effluent levels. If fecal coliform is to be a control parameter, additional treatment is clearly indicated.

4. Phosphorus levels observed for all application methods and slopes utilized in this study demonstrated no meaningful reductions. In fact, most plots indicated varying levels of increase. The fact that the phosphorus required by the cover crop during the growing season could be easily met through other sources, indicates that the cover crop played only a minor role with respect to this parameter.

5. The nitrogen balance for all plots and for the winter and summer operation indicates a reduction in organic nitrogen of approximately 50 per cent. The ammonia reduction for the winter system was essentially the same; however, somewhat higher removals were noted during summer operation. Effluent nitrates were consistently low. The indicated nitrogen removal mechanism was loss of ammonia to the atmosphere rather than nitrification-denitrification or plant uptake.

6. No single method of application or slope demonstrated a performance consistently superior to the other; therefore, any future selection of method should be based primarily on factors such as installation and

maintenance costs.

7. Based on the results of this study, the treatment obtained by applying raw wastewater to sloped impervious soils could be described as a combination of physicochemical and microbiological factors, both occurring at the soil-liquid interface. The principal role of the crover crop appears to be plot stability rather than nutrient uptake.

Treatment Above and Below Freezing--

1. The data indicates that efficient removal of BOD, COD, and ammonia is hampered by subfreezing operating conditions; however, if it were going to be used in northern areas, it might have to be used under a controlled environment.

2. Subfreezing operating conditions had no apparent effect on removal efficiences of the overland flow system for any of the other wastewater parameters examined.

Secondary Treatment System

1. The secondary system, as operated in this study, was effective in removing only relatively small amounts of BOD from wastewater stabilization pond effluents under winter or summer conditions.

2. Suspended solids reductions were sufficient to produce acceptable effluents during the winter phase when the influent levels were comparatively low but were insufficient during the summer months when influent levels were higher.

3. The concentration of fecal coliform organisms was essentially unchanged by the treatment applied during winter and summer treatment phases. This is consistent with the observations made for the raw system and indicates the inability of this system to meet coliform effluent limits.

4. The overall phosphorus reductions achieved by the secondary system were equal to or better than those achieved by the raw system especially during the warmer temperatures; however, neither system performed at a significant level of reduction with respect to this nutrient parameter.

5. The nitrogen balance indicates a low level of nitrification with effluent levels below 1 mg/l being reported for both methods of application, slopes and seasons. As expected, the ammonia levels in the influent and the various effluents were lower for the summer than for the winter and even though the removal efficiencies were higher for summer than for the winter, the amount of ammonia nitrogen lost (as measured in mg/l) was greater for the winter. The organic nitrogen data are complimentary in that lower influent and effluent levels are indicated for the winter than for the summer. Since the removal efficiencies were comparable for the two seasons, more organic nitrogen (in mg/l) was removed during the summer than the winter. Thus, a change

in total nitrogen of approximately 5 mg/l is indicated for the winter and summer operations.

6. Neither method of application or slope performed consistently better than the other thus indicating the same conclusion as drawn for the raw system.

7. Based on the results of this investigation, the application of wastewater stabilization pond effluent to sloped impervious soils under the conditions employed during this study would have only very limited beneficial effects as an advanced wastewater treatment procedure.

Wastewater Stabilization Pond

1. Under the climatic, soil, loading, and wastewater conditions studied, the wastewater stabilization pond achieved higher BOD reductions under winter conditions than did the overland flow plots; the reverse was true for the summer operation. The pond, however, produced effluent levels below 30 mg/l for summer and winter while the plots achieved such levels only for the summer.

2. Compared to the pond, the plots provided superior reductions in suspended solids, especially during the summer. The plot effluents were below 30 mg/l for both the winter and summer seasons while the pond was able to accomplish this low level only during the winter. Additional treatment of the pond effluent is indicated for the summer operation.

3. The pond produced much lower levels of fecal coliform during both summer and winter; however, neither system was capable of reductions to levels below 10^4 per 100 ml. Additional treatment is indicated for both processes if levels of 10^2 per 100 ml are to be achieved.

4. Phosphorus removal by the pond changed from negative for the winter to positive for the summer while the plots operated more consistently throughout both seasons; however, neither process effected an appreciable overall reduction.

5. The pond produced lower effluent nitrate levels during both seasons than did the plots with very little seasonal influence evident for either process. The plots produced lower ammonia levels during the winter than did the pond; however, the reverse was observed for the summer when all removal rates increased. Organic nitrogen removal was comparable for the two processes for the winter with little change by the plots for the summer; however, the warmer temperatures induced pond effluent levels that were higher than the influent.

6. In summary, neither system demonstrated a consistently superior performance. The pond compared favorably for year around BOD reduction but not for suspended solids removal. The increased residence time of the wastewater stabilization pond compared to the overland flow plots, several days versus a few hours, must also be considered in evaluating

differences in performance for the two systems. Both systems would require additional treatment if effluent limits on fecal coliform, phosphorus, and nitrogen are imposed.

SOIL ANALYSIS

1. Of the soil parameters analyzed, before and after wastewater applications, a consistent pattern of decrease in phosphates, potassium and manganese occurred in surface soil samples from all sample locations, while a consistent pattern of increase was observed for calcium and copper. Only two parameters, iron and manganese, collected at subsurface levels reveal any pattern of consistent change (both decreased). The other parameters analyzed varied increasingly and decreasingly with no apparent consistency. Based on the scope of the analysis, the significance of these findings are limited in terms of formulating any specific guidelines.

2. Based on plant productivity observed on the treatment plots, no apparent toxic responses were induced by the increases or decreases in the soil components analyzed, in fact, productivity was apparently inhanced due to the improved quality and quantity of growth observed, particularly toward the end of the study.

3. Insufficient data was available to draw any conclusion as to long range effects of overland flow application in terms of the potential for leaching of metal build-up (from surface soil) into receiving waters.

MICROBIAL ANALYSIS

1. Average effluent bacterial colony counts were consistently reduced, when compared to influent bacterial colony counts, at a probability (p) level of 0.01 throughout the study on the 2 per cent spray boom plot.

2. Average effluent bacterial colony counts were consistently reduced, when compared to influent bacterial colony counts, at a p level of 0.01 throughout the study on 2 and 3 per cent fixed riser, trough and spray boom plots.

3. No statistical difference existed between average upwind and downwind airborne particle counts throughout the study on the 2 per cent spray boom plot.

4. Average downwind coliform airborne bacteria was significantly higher than upwind coliform data throughout the study on the 2 per cent spray boom plot. The numerical difference, however, did not suggest a health hazard.

5. The concentration of enteric viruses (10^1 to 10^2 PFU/1 range) isolated from the raw treatment system displayed an apparent seasonal distribution, first occurring in the influent to the plots in May, 1978, peaking in August, 1978, and gradually declining in concentration toward

the end of the year. Certain times of the year, particularly between January and May, no viruses were isolated in the influents to the system. While this pattern of distribution was observed primarily for the spray boom method of application, the same general pattern of distribution was observed for all methods of application, on 2 and 3 per cent slopes.

6. The overland flow treatment plots displayed removal efficiencies of 100 per cent, up to the time of peak loading when the observed percentage reductions sharply decreased. The removal efficiency recovered inversely proportional to the concentration of viruses in the influent. No apparent differences were observed in removal efficiencies with respect to method of application or slope of treatment plots.

7. Within the capabilities of the isolation techniques employed for the analysis of aerosolized virus, no viruses were obtained from air samples collected at upwind, downwind or random sample locations on the 2 per cent spray boom applications of the raw system. Based on the scope of the analysis, the absence of viruses suggest no apparent health hazard, with respect to airborne viruses downwind from the spray boom applicator.

8. Within the capabilities of the isolation techniques employed, no enteric viruses were isolated from secondary treatment system influents (wastewater stabilization pond effluents) or effluents, from either method of application on either slope.

SECTION 3

RECOMMENDATIONS

Considering the overland flow method of land application for relative degree of treatment afforded, as an advanced wastewater treatment procedure, several recommendations can be made.

1. The treatment of raw municipal wastewater by overland flow land application has demonstrated the ability to achieve, under winter and summer operations, BOD and suspended solids levels equal to or lower than conventional secondary treatment processes. Based on these results and the results of other studies, with proper design criteria, overland flow treatment could be recommended as a viable alternative for reclamation of municipal wastewater.

2. Based on the results of this study, for winter and summer operation, the capabilities of overland flow in the reduction of fecal coliform are insignificant, and if fecal coliform is to be a control parameter, additional treatment is clearly indicated.

3. The data from this study clearly indicates the efficient removal of BOD, COD and ammonia is hampered by subfreezing temperatures. It would appear that this type of application might not be recommended in northern climates. If the system were enclosed and the environment more completely controlled it would probably help not only the effluent parameters but would reduce the operational problems.

4. The extended treatment of secondary effluent by overland flow would have only limited beneficial effects as an advanced wastewater treatment procedure; however, some benefits are conceivable in terms of re-use for irrigation or industrial use.

5. Based on the scope of this study, it is recommended that more long-range in depth analyses be conducted to identify potential problems in the area of heavy metal build up in the surface soils of overland flow treatment systems.

6. From microbiological standpoint, the spray boom method of application can be recommended, based on the reduction of viral and bacterial organisms monitored in this study. In addition, based on numerical values obtained, there appeared to be no significant health hazards to personnel

working on or around the spray boom applications, in terms of exposure to airborne pathogens.

Regardless of the design characteristics no system will be completely free of operational problems, therefore, in designing and implementing overland flow methods, several recommendations should be considered.

1. The area of application system should be adequate to insure the availability of a source for application at all times. Each application plot should be at least 1 ha (2.47 acres) in area, with a sufficient number of plots, based on the volume of wastewater to be treated, to allow a rotating schedule of application. If the overland flow system is to function independently, as the sole source of treatment, it is essential to have available a sufficient number of plots to virtually eliminate the possibility of bypassing untreated wastewater to receiving waters. Additionally, to achieve a goal of reclamation and re-use, it is recommended that holding ponds should be employed to receive effluents from the treatment system. This water would then be available for industrial or agricultural use.

2. To reduce maintenance, raw wastewater should be screened before entering distribution lines (preferably at pump site) to applicators, reducing the clogging of nozzles. The size of the distribution lines within the system should be adequate to insure even flow, avoiding reductions in pipe size within the distribution lines, from the pumping site to the application nozzles. The nozzles employed within this study (3/16 inch, approximately 5 mm) produced some problems with clogging. Adequate pressure at the nozzle head would eliminate some of the problem of clogging. In addition to selection of proper pipe size, the valve system should be as simple as possible, eliminating the use of electrical valves where possible. The selection of wiring for the system is important, and where underground installations are necessary, the wire should be encased in conduit, to reduce problems of electrical failure from damages caused by corrosion and/or burrowing animals.

   Based on these studies, the fixed riser method of application, provided the most trouble-free technique and the most uniform application of wastewater. The spray boom method was the most undesirable, particularly during the winter months when clogging of nozzles created problems with freezing, in turn causing pipe breakage and subsequent shut down of the system. If designed and constructed properly, the trough system would provide several beneficial aspects in terms of equipment mobility on the plots. By constructing the troughs close to the ground surface, harvesting equipment could easily maneuver over and around the applicators, eliminating damage to the applicators as well as to the equipment.

3. The preparation and maintenance of plot surfaces is a consideration of high priority. Based on the results from this study, no significant differences in treatment on 2 or 3 per cent slopes was observed, therefore, the 2 per cent slope would be recommended to reduce problems with channeling of wastewater, produced by erosion. This was observed as a

problem, particularly during the rainy seasons.

Overall, slope preparations should be as uniform as possible, avoiding low or high grades across any given plot. Any irregularity that might induce channeling should be avoided. Within this study several advantages were obtained by maintaining shallow furrows across the slope of the plots (oblique to the slope) creating a herringbone effect. The furrows should not be prominent enough to inhibit the constant movement of the wastewater across the plots. The herringbone effect can be accomplished with grain drilling equipment, during the planting operation.

4. Seeding the plots should include uniformity, insuring that adequate cover is provided on all areas of the plots. This was successfully accomplished in this study by use of grain drills to insure that the seed was not washed off the plots before germination. It also reduced the amount of seed lost to birds feeding on the plots. Once a substantial stand of grass is obtained the maintenance is relatively low. Also, the use of perennial grasses obviously reduces the maintenance involved with keeping the plots covered.

5. The harvesting of cover crops is an important maintenance consideration, in sustaining smooth operations. Due to the high nutrient loading, growth is rapid on the overland flow plots, therefore, it is essential to implement a well coordinated harvesting schedule. It is important to regularly cut and remove the crops produced on the plots, avoiding a build-up of grass cuttings that could result in a mass of decomposing materials. Also, tall stands of grass are subject to wind damage making cutting and removal operations difficult, therefore, the grasses should be harvested when a 20-to 30-cm (8-to 12-inch) stand has been produced.

   The use of conventional harvesting equipment is an acceptable method if used properly. The plots should be allowed to dry sufficiently (approximately 5-10 days) before using heavy equipment that might damage the plot surface. Also, by operating the equipment perpendicular to the slope of the plot, any damage that is caused would not result in channeling of wastewater. The type of equipment used during this study that produced the best results was a sickle type cutter, a rake and baling machine. The grass should be cut, raked and baled as quickly as possible.

SECTION 4

STUDY SITE DESCRIPTION

Design characteristics of this study were established to form a basis for comparison of: (a) treatment of raw (screened) wastewater versus wastewater stabilization pond effluent (secondary treatment), (b) slopes at 2 per cent versus 3 per cent, and (c) three application techniques. The three techniques employed were: (a) spray booms with fan nozzles, (b) fixed risers with fan nozzles, and (c) troughs with trickling orifices (Figures 1, 2, and 3).

Physical design of the study site consisted of eight, 0.4-ha (1-acre) modules of land subdivided into two slopes: one-half at 2 per cent and one-half at 3 per cent (Figure 4). Each module was further divided according to the application technique employed. The size of each division, number and type of application were the same for both slopes. The modules were drained by a series of troughs at the lower end of the slope, which channeled drainage to centrally located V-notched weirs within each module. Barrier terraces were constructed between each subdivision to maintain independent flow across plots for each technique of application. One of four wastewater stabilization ponds was utilized to receive the effluent from the test modules.

Early preparation of treatment surfaces included the grading of modules to produce the necessary slopes and to insure a certain degree of homogeneity of topsoil. All plots were seeded with a combination of three grasses: (a) Kentucky-31 fescue at 34 kg/ha (30 lbs/acre), (b) annual rye grass at 17 kg/ha (15 lbs/acre), and (c) bermuda grass at 7 kg/ha (6 lbs/acre), which provided supplemental cover during the summer months when annual rye die-off occurred. It was necessary at times to restore grass cover by additional seeding to insure adequate cover on the modules. Reseeding operations primarily occurred during spring, when heavy rainfall caused damages from washing, and during the fall to replace annual rye grass crops. Crops were harvested periodically based on height of stand: approximately 40 cm (16 inches) for fescue and rye grass, and 30 cm (12 inches) for bermuda grass. Infrequent cutting hindered efficient operation of mowing and baling equipment.

The project was designed to accommodate a flow of approximately 8.81 l/sec (0.2 mgd). Approximately 6.07 l/sec (0.138 mgd) of raw (screened) wastewater was applied to 2.4 ha (6 acres) of test modules, and 3.08 l/sec (0.07 mgd) of wastewater stabilization pond water was applied to the

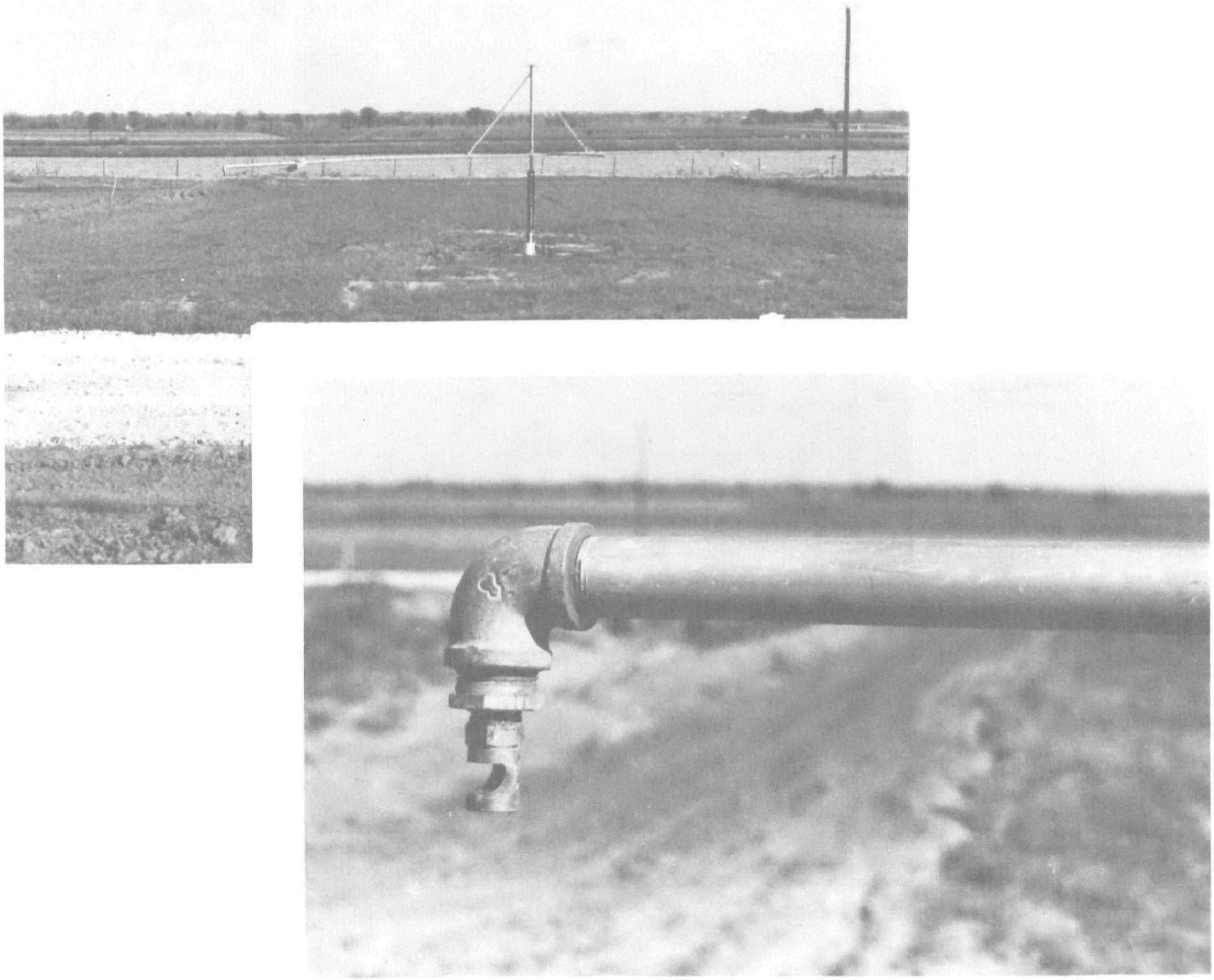

Figure 1. Rotating spray boom
with fan nozzle (inset)

Figure 2. Fixed riser with fan nozzle

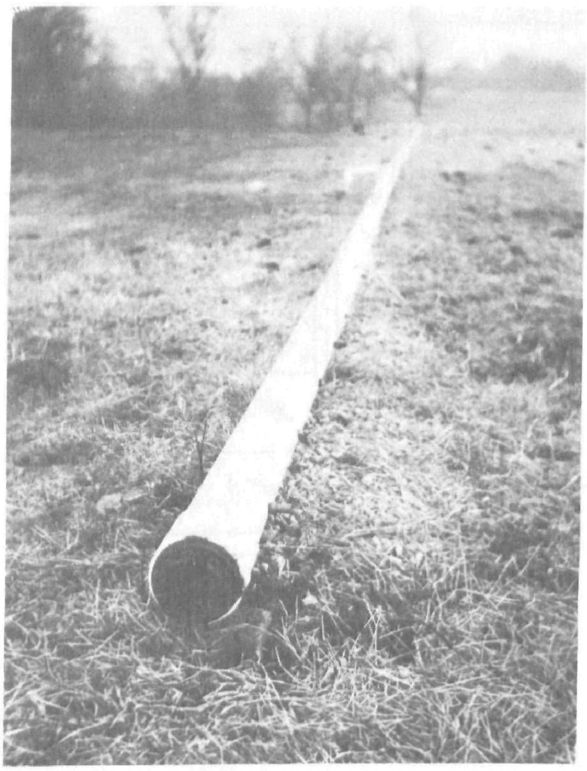

Figure 3. Trough with trickling orifices

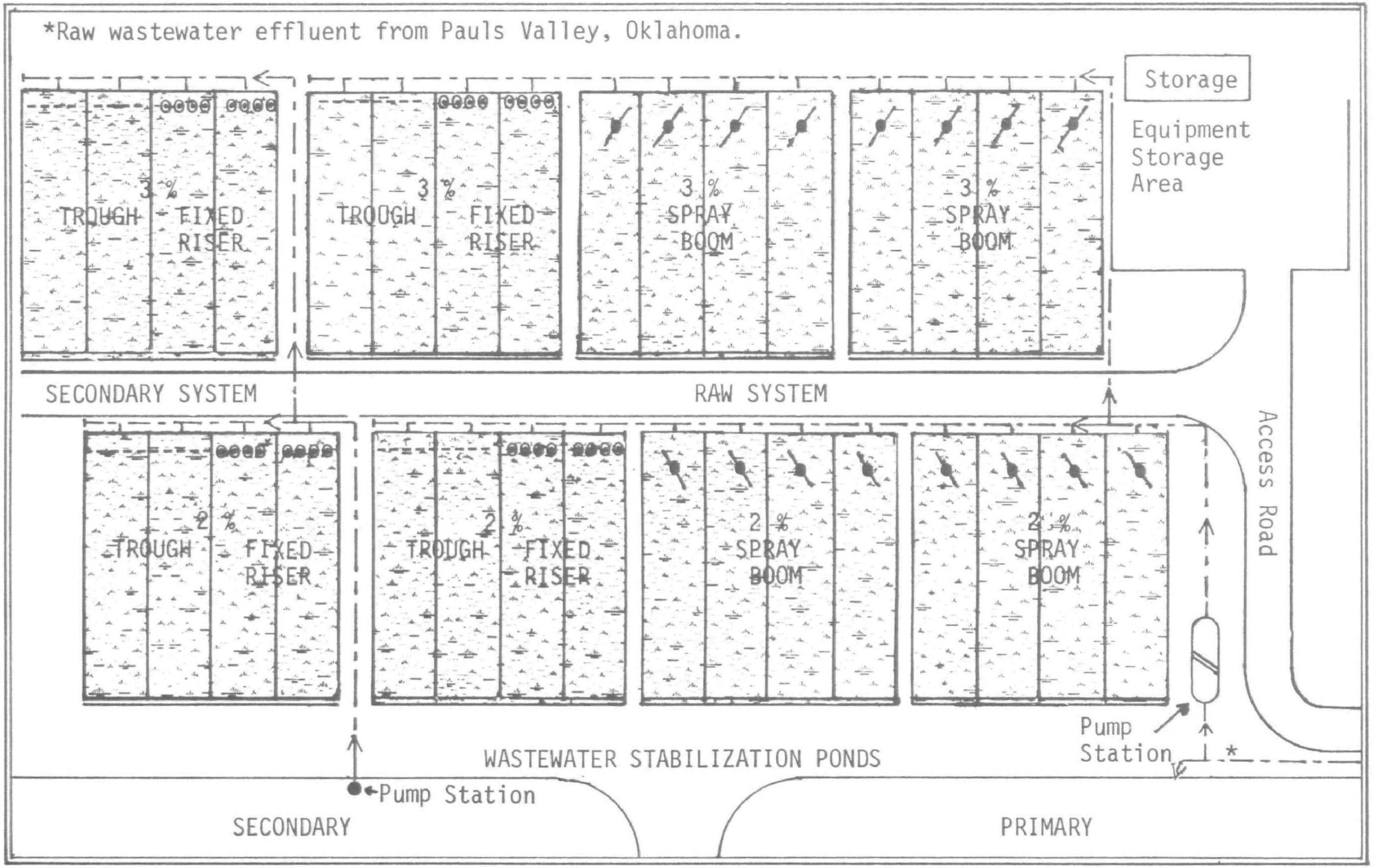

FIGURE 4. Diagram of Pauls Valley, Oklahoma, experimental overland flow treatment facility.

remaining 0.8 ha (2 acres). The two sources of wastewater were supplied to the raw and secondary systems by use of three* 40-gal/min submersible type pumps**.

Because it was necessary to apply raw (screened) wastewater as it was received from the municipality, constant application was maintained at all times. In order to maintain a constant application, certain limitations were inherent with respect to the number of applications that could be made during a given period of time. This was accomplished by the use of a rotating cycle of applications, whereby the raw system was operated on an 8-hour-on-16-hour-off schedule***. Flow was diverted through each module and its corresponding plots by means of electrically actuated gate valves which were controlled by time clocks. The secondary system was operated on a 12-hour-on-12-hour-off cycle to provide extended application time, therefore, a greater volume per surface hectare per 24 hours of application. This requirement for increased volume was primarily due to the nature of the secondary effluent, having already undergone appreciable BOD reductions during the secondary treatment process.

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*Two of the three pumps were used within the raw system; one as a standby unit in the event of failure of the other.

**The pumps under normal operating conditions for this study, operated at very low head pressure and, therefore, provided a much greater volume than indicated by the pump ratings.

***Refer to Figure 2. The flow cycle began on modules 1 a & b (a=2 per cent slope, b=3 per cent slope) and rotated to the left through number 2 and 3.

SECTION 5

METHODS

The sampling protocol for this study was designed to monitor treatment from three primary sources: (a) three application techniques on two slopes from the raw system, (b) two application techniques on two slopes from the secondary system, and (c) the existing conventional wastewater treatment system (wastewater stabilization ponds). The samples to be collected were classified into three major categories for analysis: (a) wastewater, (b) soil, and (c) microbiology.

WASTEWATER ANALYSIS

During each 3-week interval of operation, wastewater samples were collected from each of the application methods on the raw and secondary treatment systems, three times per week, sequentially and corresponding to the application cycle. The samples were collected approximately one-half way through the 8-hour application cycles of the raw system and the 12-hour cycles of the secondary system. This allowed adequate time for the plots to become saturated and provided adequate time for the samples to be collected and processed.

Utilizing the laboratory facilities of the Garvin County Health Department in Pauls Valley, Oklahoma, a total of 12 parameters were analyzed, employing methods and procedures in accordance with those specified by EPA (7), and Standard Methods for the Examination of Water and Wastewater (8). The 12 parameters analyzed included: BOD, COD, suspended solids, turbidity, fecal coliform, total phosphorus, pH, dissolved solids, nitrate-(N), ammonia-(N), organic nitrogen, and Kjeldhal-nitrogen. Data resulting from these analyses were tabulated by analytical parameter, method of application, slope, and sampling date. These were then grouped according to raw or secondary system and winter or summer applications (Appendices A through D).

Preliminary analysis of the data indicated the regulatory parameters: BOD, suspended solids, and fecal coliform, and the nutrient parameters (total phosphorus, nitrate-(N), ammonia-(N), and organic nitrogen*), to be the

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*Since Kjeldahl-nitrogen was obtained by addition of the ammonia and organic nitrogen forms, it was not, therefore, an independent parameter and was not subjected to statistical analysis.

most significant for describing and evaluating the performance of the two systems as operated in this study. Each of these analytical categories in each of the four treatment groups were described by calculation of arithmetic mean, standard deviation, and number of observations. Comparison of various effluent averages with their respective influent averages allowed calculation of treatment efficiencies achieved by the various application methods, rates, and slopes employed in the two systems. Two-way analysis of variances (3 X 2 factorial with replication for the raw system and 2 X 2 factorial with replication for the secondary system) permitted a comparison of effluent levels of each analytical parameter for each method and rate of application on each slope. If needed, the project was designed to allow limited $\underline{t}$ and multiple range comparison of the effluents from the various methods and application rates on a given slope and/or a comparison of effluent parameters from the two slopes for a given method and rate of application. Since the project employed field rather than laboratory treatment facilities and an actual rather than a synthetic wastewater, it was anticipated that inherent changes in the plots, the weather, and the characteristics of the wastewater would result in considerable experimental variation: consequently, an alpha level of 0.10 was selected for all statistical decisions concerning the wastewater phase of the study.

The nature of this study, being a field study rather than a laboratory study, afforded an opportunity to examine the degree of variation in treatment effect, due to seasonal changes in temperature. The geographic location of this project presented ideal testing conditions for this evaluation due to the wide range of temperature variation throughout the year.

The analysis consisted of examining certain effluent parameters, namely BOD, COD, and ammonia, when the system was operating above and below 0^{o} C (32^{o} F). Effluent parameters were grouped, according to temperatures above and below 0^{o} on all sample dates during winter application. The winter application schedule was selected as representing probably the worst operating conditions for the system, especially at temperatures below freezing. When the high temperature for the day exceeded freezing, the data were grouped in an above 0^{o} C category. When the high temperature for the day did not exceed freezing, the data were grouped in a category of 0^{o} C or below. The analysis included a comparison of results from all three application techniques within the raw treatment system.

In addition to the grouping of temperature ranges, a coefficient of variation (standard deviation divided by the mean) was calculated, to detect the possibility of variation in the data being reduced by such grouping. Coefficient of variation, with the advantage of being unitless, allows for the comparison of each application technique.

SOIL ANALYSIS

By sampling topsoil and subsurface soil from each of the eight test modules, a soil profile was established prior to beginning wastewater application. Thirteen parameters were analyzed in order to develop a data base upon which to compare system changes and experimental results. These analyses included: calcium, magnesium, sodium, potassium, iron, zinc, nickle, copper, manganese, ammonia-(N), Kjeldhal-nitrogen, organic nitrogen, and phosphorus. In addition to the soil analysis, samples from the first stand of grass were collected and analyzed for the same set of parameters. At the termination of the project a complete set of grass and soil samples were collected and analyzed to complete the evaluation.

MICROBIAL ANALYSIS

The analysis of microbial conditions of the raw and secondary treatment systems involved the monitoring of quality and quantity of bacterial and viral components of the wastewater. In addition to wastewater monitorring, ambient air conditions around the spray boom applications were monitored, to determine the presence or absence of aerosolized bacterial and viral organisms. With the increased involvement of air-to-water interface, in relation to time of exposure and volume of water, the spray boom applications provided a much greater potential for aerosol generation of microbes. This technique of application was therefore chosen as the primary focal point of the microbial analysis. The analysis of wastewater and ambient air conditions were expected to provide a comprehensive data-base for tracing the movement of microbes through the treatment systems.

Wastewater samples from the raw treatment system were collected at three primary locations: (a) the pump station (Figure 4) which provided wastewater to the entire raw treatment system, (b) the point of application for each application technique, and (c) at the end of each plot, after the wastewater traversed the plots. The samples from the pump station were collected to provide a comparison with those taken at the actual point of application to the plots. This comparison was necessary to determine, particularly in the viral analysis, if there was an appreciable loss of organisms during passage through the distribution lines. Wastewater samples from the secondary system were collected at the point of application and after the wastewater had passed across the plots.

Ambient air samples were collected from the 2 per cent spray boom applications which were equipped with 110-V electrical outlets 15 m (50 ft) upwind and at three 15-m increments downwind from the spray boom applicators. The samples taken upwind represented the normal air loading for the parameter being monitored. Those samples taken by the same method at the same time interval downwind from the applicator, indicated the effect of the spray boom application technique on the normal air loading for the parameter.

The parameters of major interest in the microbial analyses were: (a) total and coliform bacteria colony counts of influent versus effluent wastewater, (b) total and coliform bacteria, upwind versus downwind ambient air bacterial counts, (c) upwind versus downwind ambient air particle counts, (d) influent versus effluent wastewater viral plaque counts, and (e) upwind versus downwind ambient air viral plaque counts.

Wastewater Bacterial Colony Counts

To determine the effects of overland flow treatment on enteric bacteria in wastewater, influent and effluent, total and coliform bacteria colony counts were monitored for all application methods, on both the raw and secondary treatment systems. Samples were collected once each week from each method of application. The samples were collected in pre-sterilized polyethylene containers, packed in ice and transported to the Oklahoma State Health Department Laboratories in Oklahoma City, for analysis. In the laboratory, serial dilutions (0.1, 0.01, 0.001, etc) of each sample were made and surface plated on two different media, nutrient agar (NA) and eosin methylene blue agar (EMB). The plates were incubated for 18 to 20 hours at 35° C (95° F), and the dilutions producing between 30 and 300 colonies per plate for each media were counted. The NA and EMB plate counts were reported as total bacterial count (TBC) and total coliform counts (TCC), respectively.

Ambient Air Bacterial Colony Counts

Total and coliform airborne bacterial samples were collected using an Andersen Drum sampler; a device that by means of a vacuum pump, aspirated bacteria into a sealed stainless steel canister through a limiting orifice, and impacted the organisms on a rotating drum coated with growth media. The rotating drum had a surface area of 387.5 cm^2 (62 $inch^2$), and during sampling, rotated downward at the rate of 3.125 mm (0.125 inch) per revolution, creating a maximum of 27 line deposits per drum. Each drum sampler was matched with a specific Andersen vacuum pump, calibrated against a wet flow meter in the laboratory.

Air samples were collected from upwind, downwind and random locations, on the 2 per cent spray boom plots, as indicated by wind direction at the time of sampling. Two drum samplers were placed at each sampling location, one containing NA, to collect TBC, and the other containing EMB to collect TCC. The drums used to collect upwind samples were calibrated to aspirate 294 liter/hr and those used to collect downwind and random samples were calibrated at 318 liter/hr (Appendix F). Recalibration was randomly performed during the study period. The samplers were operated for a 1-hour period, and upon completion, were placed on ice and delivered to the Oklahoma State Health Department Laboratory for analysis. In the laboratory the canisters were incubated at 35° C for a period of 18 to 20 hours, and counts were made of the colonies produced. The colony types grown on EMB agar were biochemically identified to genus.

Ambient Air Particle Counts

Ambient air particle counts were of interest to this study, since it was probably the droplet nuclei from aerosols generated by the spray boom, that served as airborne carriers for some microorganisms. These samples were collected with the same frequency and at the same locations as those collected for the ambient air bacterial analysis. A known volume of air (Appendix F) was pulled through a plastic cassette containing a 37-mm, 0.45-micron, cellulose acetate filter-pad (using the same vacuum equipment employed to operate the Andersen Drum samplers). Upon completion of a 1-hour sample run, the cassettes were sealed, and along with pertinent site data, delivered to the University of Oklahoma, Health Sciences Center, in Oklahoma City, where particle counts and sizing were performed.

Wastewater Viral Plaque Counts

Influent and effluent samples for viral analysis were collected from the raw and secondary systems, 4-liter (1.04 gal)* samples of influent (including one 4-liter sample from the pump station) and 4 liters of effluent from each of the application methods on the two treatment systems. Upon collection, the samples were placed on ice and transported to the Oklahoma State Health Department, Virology Laboratory, for analysis. The analysis consisted primarily of concentrating enteric viruses from the wastewater samples by a Bentonite Adsorption technique (9), and conducting an assay of the concentrate to determine the quantity of virus present in the sample.

Bentonite Adsorption Technique--

The Bentonite Adsorption technique is a procedure that has previously been used in land application studies as a method of concentrating viral organisms from wastewater (9). Bentonite is basically a refined Montmorillonite clay which serves as an adsorptive media for separation of viral organisms from fluid suspension. In this particular study, certain procedural modifications were necessary as indicated by personal communication with Schaub (10). The procedures, along with the appropriate modifications, were as follows: a 70 mg/l concentration of bentonite (USP Grade) was added to the wastewater sample, along with a 0.01 M concentration of calcium chloride ($Cacl_2$). The samples were magnetically mixed at slow speed for 20 minutes at room temperature, to allow any virus present in the sample to adsorb to the bentonite particles. To maintain separation of clay particles, thus decreasing clogging of filters, diatomaceous earth was added to each sample (10, 11, 12). Samples were then filtered (negative pressure of -6.75 kg) through a 142-mm diameter fiberglass prefilter, into a 50-ml suction flask, to collect the bentonite. Upon completion of filtering procedures, 18 ml of a 3 per cent beef extract solution (pH=9) was added to the filtered bentonite to elute the adsorbed virus; the elution time was 10 minutes (10, 13). Eluates were transferred to polystyrene tubes, treated with antibiotics (2500u of penicillin, 2500u of streptomycin, 250u of bacitracin, and 25u of mycostatin per ml was added to prevent inhibitive growths of bacteria and fungus) at a pH of 7, and frozen at

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*During the initial period of the viral studies (first 3 months), influent samples (1-liter volume) consistently produced negative results for isolation of virus. This suggested a modification in sampling, whereby the volume of water collected was increased from 1 liter (0.26 gal) to 4 liters; effluent sample volumes remained the same.

-70° C (-94° F) until assayed. Stainless steel filter holders and attachments were sterilized at 121° C (250° F) for 30 minutes, rinsed in distilled water, and allowed to air dry between filtration of samples.

Viral Assay--

In preparation for culturing of wastewater concentrates, Rhesus monkey kidney cells, obtained commercially as a 10^6-cell per ml suspension, were diluted to 3 X 10^5 cells per ml with nutrient media, consisting of Eagles MEM (Earles) with 5 per cent fetal calf serum inactivated at 56° C (133° F) for 30 minutes, supplimented with sodium bicarbonate ($NaHCO_3$) and antibiotics (14). Plastic cell culture flasks (25 cm^2) were seeded with 5 ml of the cell suspension. After 3 days of incubation at 36° C (97° F), the media was replaced with fresh media to remove cytotoxic material (14). The flasks were incubated for an additional 6 to 8 days, at which time cell monolayers were confluent.

Upon completion of culture media preparations, sample eluates from the concentration procedures were removed from freezer storage and thawed at 4° to 8° C (39° to 46° F). The culture flasks were then inoculated with 0.2 ml of each eluate; four flasks were also inoculated with 0.2 ml of Eagles medium to serve as negative controls. All flasks were incubated at 36° C for 1.5 hours, agitating each flask every 20 minutes to allow for virus adsorption to cell monolayers (10). Eluates were decanted from the flasks and an overlay, similar to that described by Cooper (15), was added to each flask. The overlay consisted of 5 ml of Eagles BASAL medium without phenol red, but containing 1 per cent purified agar, 5 per cent fetal calf serum, sodium bicarbonate (2 mg/ml) and antibiotics (250u of penicillin, 250u of streptomycin, 250u of bacitracin, and 25u of mycostatin per ml). All ingredients of the overlay were obtained commercially. After incubation at 36° C for 5 days, the monolayers were stained with neutral red (1:2000 dilution). Flasks were then incubated at room temperature for 2 to 3 hours and were examined for viral plaques (16). Plaques were counted in each flask and the viral concentration for each eluate was expressed as plaque forming units (PFU) per ml (15).

Ambient Air Viral Plaque Counts

The examination of ambient air conditions of the spray boom application method, for aerosolized virus, is a procedure that has not been previously described. It was, therefore, necessary to conduct preliminary studies to determine an appropriate sampling protocol.

Three menstruums were arbitrarily selected for collection of virus from air samples: (a) normal saline, (b) distilled water, and (c) raw wastewater (Pauls Valley, Oklahoma). A volume of 250 ml of each menstruum was seeded with an 8 X 10^4 PFU concentration of Poliovirus, Type 1 (Sabin strain). The actual PFU of Poliovirus added to each menstruum was determined by plaque assay. The procedures employed for concentration and assay of samples were the same as those described earlier, with the exception of filter size (47 mm) and the volume of beef extract (2 ml) used to elute the viruses (10).

The percentage recovery of Poliovirus seeded in each menstruum is shown in Table 1. Viruses were recovered equally well from saline, distilled water, and raw wastewater; therefore, saline was selected as the menstruum for collection of samples due to ease of preparation and resistance to freezing.

TABLE 1. PERCENTAGE RECOVERY OF POLIOVIRUS

Type of menstruum	Virus added (PFU)*	Virus recovered (PFU)	Percentage recovery
Saline	8×10^4	6.6×10^4	83
Distilled water	8×10^4	6.8×10^4	85
Raw wastewater**	8×10^4	6.2×10^4	78

*Plaque Forming Units. Based on replicate assay (4 flasks per assay).
**The raw wastewater was collected from the study site at Pauls Valley, Okla., and autoclaved prior to seeding with poliovirus.

The methods used for collection of air samples for viral analyses, employed similar mechanical techniques as those employed to collect aerosolized bacteria. A volume of air was aspirated into a sealed glass impinger bottle (500 ml) through an inlet tube into a 250-ml volume of the previously selected saline menstruum. The inlet tube extended below the surface of the saline solution, creating a bubbling action, thus setting up a suspension of any virus that might be aspirated during a 1-hour sampling interval. The aspirations were made by means of vacuum pumps, the same as those used for aerosol bacteria examinations.

One set of aerosol samples for virus isolation were collected per month of operation for the spray boom application method. Samples were collected at upwind, downwind and random locations from the spray boom application; sampling was in conjunction with the aerosol bacteria sampling schedule. The two sampling schedules were coordinated to expedite sampling, thus decreasing the amount of effort involved in collection and handling of samples. Upon collection, samples were placed on ice and transported to the Oklahoma State Health Department, Virology Laboratory, for concentration and assay.

SECTION 6

RESULTS AND DISCUSSION

WASTEWATER ANALYSIS

Raw Treatment System

As shown in Table 2, a comparison of the influent with the various effluent BOD levels during winter operation indicates removal efficiencies which varied from 68 per cent for the fixed risers on the 2 per cent slope to 82 per cent for the spray booms on the 3 per cent slope. In terms of overall BOD reduction (which is one of the major criteria of performance), these removal efficiencies are somewhat lower than those anticipated for secondary treatment facilities and may be attributed, at least in part, to winter temperatures and the dilute nature of the raw wastewater.

From the standpoint of effluent limitations, residual BOD is more important than percentage reduction. During winter operation, the BOD in the effluents from the various plots averaged 42.1 mg/l for the fixed risers on the 2 per cent slope to 24.0 mg/l for the spray booms on the 3 per cent slope. The analysis of variance indicated that the slope of the plot rather than the method of application significantly influenced the level of effluent BOD. In this case the steeper slope produced the lower levels; however, with the exception of the spray booms on the 3 per cent slope, the effluent levels were within 5 mg/l of each other and were above 30 mg/l. Thus, the practical significance of this statistical conclusion is minimal and further statistical analysis is contraindicated. The oxygen demand remaining in the effluent indicates that under the conditions tested, all methods of application during winter operation except those for the spray booms on the 3 per cent slope, would require subsequent treatment in order to achieve effluent limits.

A review of the suspended solids data (Table 2) indicates a more favorable performance. Compared to an influent average of 90.7 mg/l, the various effluents ranged from 11.0 mg/l for the troughs on the 3 per cent slope to 15.6 mg/l for the fixed risers on the 3 per cent slope. All effluent levels were well below 20 mg/l and all were within 5 mg/l of each other. The analysis of variance indicated no statistically significant differences among the different methods of application or between the slopes. From the standpoint of removal efficiencies, all plots achieved, on the average, suspended solids reductions in the 83 to 88 per cent range.

TABLE 2 . ANALYTICAL RESULTS FROM THE RAW SYSTEM FOR THE WINTER APPLICATION - NOVEMBER 28, 1977 - MARCH 10, 1978

Anal. Par.	% Slope	Stat. Par.	APPLICATION METHOD: RISER Eff. Conc.	RISER % Red.	TROUGH Eff. Conc.	TROUGH % Red.	BOOM Eff. Conc.	BOOM % Red.	Infl. Conc.	Analysis of Variance: Source	p = 0.1
BOD mg/l	3	$\bar{X}$	37.7	71	39.1	70	24.0	82	130		
		s	14.6		10.5		12.7		26.6	Slope	Sig.
		n	9		9		10		20		
	2	$\bar{X}$	42.1	68	40.4	69	39.8	69		Appl. Mtd.	-
		s	10.2		19.8		14.4				
		n	9		8		11			Interact.	-
Sus. Solids mg/l	3	$\bar{X}$	15.6	83	11.0	88	12.1	87	90.7		
		s	8.13		5.20		6.86		40.4	Slope	-
		n	9		9		11		20		
	2	$\bar{X}$	11.2	88	11.9	87	12.0	87		Appl. Mtd.	-
		s	5.33		9.03		4.24				
		n	9		8		11			Interact.	-
Fecal Coli-form per 100 ml	3	$\bar{X}$	1.5×10^{6}	62	1.2×10^{6}	69	2.3×10^{6}	41	3.9×10^{6}		
		s	8.6×10^{5}		1.0×10^{6}		2.5×10^{6}		3.2×10^{6}	Slope	-
		n	8		8		9		17		
	2	$\bar{X}$	1.3×10^{6}	67	1.0×10^{6}	74	2.4×10^{6}	38		Appl. Mtd.	Sig.
		s	6.7×10^{5}		7.2×10^{5}		2.5×10^{6}				
		n	8		7		9			Interact.	-

(Continued)

TABLE 2 . (continued)

Anal. Par.	% Slope	Stat. Par.	RISER Eff. Conc.	RISER % Red.	TROUGH Eff. Conc.	TROUGH % Red.	BOOM Eff. Conc.	BOOM % Red.	Infl. Conc.	Analysis of Variance Source	p = 0.1
Total P mg/l	3	$\bar{X}$	7.55	11	6.87	19	9.55	-13	8.46		
		s	1.12		0.77		1.29		1.96	Slope	-
		n	7		7		11		13		
	2	$\bar{X}$	7.64	10	7.75	8	9.64	-14		Appl. Mtd.	Sig.
		s	1.10		1.13		1.30			Interact.	-
		n	7		7		11				
NO_3 N mg/l	3	$\bar{X}$	0.24		0.21		0.74		0.04		
		s	0.24		0.16		0.56		0.02	Slope	-
		n	8		8		10		18		
	2	$\bar{X}$	0.19		0.26		0.44			Appl. Mtd.	Sig.
		s	0.21		0.25		0.57			Interact.	-
		n	8		8		10				
NH_3 N mg/l	3	$\bar{X}$	6.89	58	8.47	49	11.4	31	16.5		
		s	4.80		3.28		4.02		3.09	Slope	-
		n	9		9		11		20		
	2	$\bar{X}$	9.56	42	8.56	48	13.4	19		Appl. Mtd.	Sig.
		s	3.94		5.95		4.36			Interact.	-
		n	9		8		11				
Org. N mg/l	3	$\bar{X}$	3.47	52	3.65	50	2.66	63	7.28		
		s	0.78		0.63		1.85		1.93	Slope	-
		n	9		9		11		20		
	2	$\bar{X}$	4.01	45	3.64	50	3.12	57		Appl. Mtd.	-
		s	0.69		1.11		2.36			Interact.	-
		n	9		8		11				

These reductions compare favorably with conventional secondary treatment facilities considering the relatively low suspended solids levels in the raw wastewater.

Of the normal regulatory parameters, fecal coliform analyses indicated the poorest performance. With influent and effluent levels all in the range of 10^6 per 100 ml, the reductions achieved do not compare favorably with either the conventional secondary system or with effluent limitations. Even though statistically the fixed riser and trough application methods on both slopes achieved higher reductions than the spray boom method of application, the results indicate that under the test conditions employed, none of the methods could achieve effluent fecal coliform levels in the range of 10^2 per 100 ml unless additional treatment was applied.

The nutrient parameters reported in Table 2 reveals that the fixed riser and trough application methods resulted in reductions of only 8 to 19 per cent in total phosphorus. The effluent from the spray boom plots was significantly different and, in fact, demonstrated increases in phosphorus compared to the influent. Given the levels of phosphorus in the influent and various effluents, the relatively small changes produced by the plots have no practical interpretation. The basic observation is that under the experimental conditions of this investigation, none of the treatments achieved appreciable reductions in total phosphorus and if such is desired, additional treatment would be indicated.

Examination of the nitrate data indicates that the fixed riser and trough application methods performed similarly in that the average nitrate-nitrogen in the effluents ranged from 0.19 to 0.26 mg/l. Even though the level was significantly higher for the two spray boom plots, all levels were below 1 mg/l, a comparatively low level of nitrate-nitrogen for a biological treatment system even under winter conditions. The ammonia data illustrates a similar pattern. The fixed riser and trough plots produced average ammonia-nitrogen levels which varied from 9.56 mg/l for the fixed risers on the 2 per cent slope to 6.89 mg/l for the fixed risers on the 3 per cent slopes. The ammonia levels in the effluents from the two spray boom plots were significantly higher and reductions of only 19 to 31 per cent were achieved. The organic nitrogen data presents the complimentary view in that both spray boom plots produced somewhat lower effluent levels (2.66 to 3.12 mg/l) and consequently, higher reductions (57 to 63 per cent) than did the plots having the fixed riser or trough application methods. In the latter case the effluent levels averaged 4.01 to 3.47 mg/l with corresponding reductions of 45 to 52 per cent. Given the relatively small range of effluent values, no practical or statistical significance could be associated with any slope or method of application during winter operation.

Overall, it would appear that of the approximately 7 mg/l organic nitrogen in the influent, about 50 per cent was removed by treatment presumably by conversion to other nitrogen forms. Of the 16.5 mg/l ammonia-nitrogen in the influent, about one-half was removed presumably by loss to the atmosphere and/or conversion to nitrate which would be subject to plant uptake and/or loss to the atmosphere as molecular nitrogen following anaerobic biological denitrification in the soil. Since the concentration of nitrate-nitrogen in the effluent was nominal and since under winter conditions, biological denitrification and plant uptake are also minimal, it appears that the change in the nitrogen balance was limited to approximately a 50 per cent conversion of organic nitrogen to ammonia which, along with about one-half of the ammonia present in the raw waste, was lost to the atmosphere.

The performance of the raw system during summer operation is illustrated in Table 3. As may be seen in this table the BOD effluent averages for the various plots ranged from 8.3 mg/l for the spray booms on the 2 per cent slope to 21.0 mg/l for the troughs on the 3 per cent slope. The analysis of variance indicated that the spray boom method of application produced a significantly lower effluent BOD with no differences attributable to slope. Since all effluent levels were well below 30 mg/l, all the plots tested demonstrated the ability to meet common effluent limitations on BOD, at least under warmer temperatures. Even though the influent BOD dropped to 117 mg/l, the BOD removal efficiences ranged from 82 per cent for the troughs on the 3 per cent slope to 93 per cent for the spray booms on the 2 per cent slope, all of which compare more favorably with the anticipated performance of the secondary system.

The suspended solids data also indicated an improved performance compared to winter operations. Effluent levels ranged from 3.6 to 10.6 mg/l and even though statistically significantly lower levels were indicated for both the 2 per cent slope and the spray boom method, the absolute difference in effluent levels is of little if any practical significance. All effluent levels were well below 30 mg/l and removal efficiencies were at or above 90 per cent; therefore, the ability of the systems tested to remove suspended solids compares favorably with conventional secondary treatment.

The fecal coliform data did not conform to the above pattern. Similar to the observations made during winter operations, both influent and effluent levels were on the range of 10^6 per 100 ml and additional treatment is indicated if levels in the 10^2 per 100 ml range are to be achieved. Even though the percentage reductions achieved for the various plots show an increase compared to winter operation and even though statistical significance is indicated for the 2 per cent slope, these observations have little practical meaning in view of the overall effluent levels.

A review of the phosphorus data in Table 3 indicates very little variation amoung the effluents from the various plots during summer operation and very few differences between the levels observed during the summer and winter, including the observation that the spray boom application method resulted in significantly higher phosphate levels during both winter and summer operations. The principal difference is that during the summer, all but one plot demonstrated an increase in phosphorus compared to the influent. This indicates that under the conditions of this study, the plots demonstrated essentially no phosphorus removal even during the growing season.

TABLE 3 . ANALYTICAL RESULTS FROM THE RAW SYSTEM FOR THE SUMMER APPLICATION - MARCH 20, 1978 - OCTOBER 27, 1978

Anal. Par.	% Slope	Stat. Par.	APPLICATION METHOD: RISER Eff. Conc.	RISER % Red.	TROUGH Eff. Conc.	TROUGH % Red.	BOOM Eff. Conc.	BOOM % Red.	Infl. Conc.	Analysis of Variance: Source	p = 0.1
BOD mg/l	3	$\bar{X}$	14.2	88	21.0	82	8.6	93	117		
		s	8.64		11.0		6.18		30.9	Slope	-
		n	20		20		18		38		
	2	$\bar{X}$	18.2	84	18.3	84	8.3	93		Appl. Mtd.	Sig.
		s	13.0		12.0		5.85			Interact.	-
		n	20		19		18				
Sus. Solids mg/l	3	$\bar{X}$	9.4	91	10.6	90	3.6	97	105		
		s	7.05		5.21		2.33		65.6	Slope	Sig.
		n	18		18		21		39		
	2	$\bar{X}$	6.4	94	6.6	94	3.6	97		Appl. Mtd.	Sig.
		s	5.47		4.75		2.27			Interact.	-
		n	18		17		21				
Fecal Coli-form per 100 ml	3	$\bar{X}$	1.4x10^{6}	72	1.8x10^{6}	64	1.2x10^{6}	76	5.0x10^{6}		
		s	1.3x10^{6}		1.4x10^{6}		1.7x10^{6}		6.2x10^{6}	Slope	Sig.
		n	12		12		15		28	Appl. Mtd.	-
	2	$\bar{X}$	1.2x10^{6}	76	1.2x10^{6}	76	4.9x10^{5}	90		Interact.	-
		s	1.2x10^{6}		9.6x10^{5}		5.9x10^{5}				
		n	12		12		16				

(Continued)

TABLE 3. (continued)

Anal. Par.	% Slope	Stat. Par.	APPLICATION METHOD: RISER Eff. Conc.	RISER % Red.	TROUGH Eff. Conc.	TROUGH % Red.	BOOM Eff. Conc.	BOOM % Red.	Infl. Conc.	Analysis of Variance: Source	p = 0.1
Total P mg/l	3	$\bar{X}$	7.9	5	8.5	-2	9.2	-11	8.3		
		s	1.33		2.06		1.38		1.63	Slope	-
		n	20		20		21		41		
	2	$\bar{X}$	8.7	-5	8.9	-7	9.2	-11		Appl. Mtd.	Sig.
		s	1.11		1.09		1.30				
		n	20		19		21			Interact.	-
NO_3 N mg/l	3	$\bar{X}$	0.18		0.16		1.04		<0.05		
		s	0.16		0.13		0.57		0	Slope	-
		n	14		14		14		28		
	2	$\bar{X}$	0.18		0.24		0.67			Appl. Mtd.	Sig.
		s	0.17		0.23		0.46				
		n	14		12		14			Interact.	Sig.
NH_3 N mg/l	3	$\bar{X}$	4.2	75	7.4	56	3.1	81	16.7		
		s	2.98		2.50		2.71		3.44	Slope	Sig.
		n	20		20		21		41		
	2	$\bar{X}$	6.9	59	6.9	59	3.4	80		Appl. Mtd.	Sig.
		s	2.03		3.03		2.52				
		n	20		18		21			Interact.	Sig.
Org. N mg/l	3	$\bar{X}$	4.0	53	4.8	44	2.9	66	8.5		
		s	0.96		1.16		0.89		2.68	Slope	Sig.
		n	20		20		21		41		
	2	$\bar{X}$	4.6	46	5.0	41	3.1	64		Appl. Mtd.	Sig.
		s	1.31		1.46		0.85				
		n	20		18		21			Interact.	-

The nitrate-nitrogen data reveals a pattern very similar to that of the winter operations in that the effluents from the fixed riser and trough plots contained low levels with relatively little difference observed between plots. Even though the spray boom method and especially the 3 per cent slope showed statistically higher effluent levels, all plots averaged approximately 1 mg/l or less of nitrate-nitrogen. This indicates either a low level of nitrification or a high level of plant uptake and/or biological denitrification. In view of the type of soil, slope, vegetative cover, and applications utilized, and in view of the similarity with the results from the winter operation, a low level of nitrification is indicated.

Comparison of the ammonia-nitrogen levels in the effluent during summer operation indicates a range of 3.1 mg/l for the spray booms on the 3 per cent slope to 7.4 mg/l for the troughs on the 3 per cent slope with statistically lower levels being associated with the spray boom method and to a lesser extent with the 3 per cent slope and interaction of slope and application method. The corresponding percentage reductions ranged from 81 to 56. The lower effluent levels and the resulting higher removal efficiencies compared to the winter system indicate the benefit of higher ambient temperatures. This, along with the results of the nitrate analyses, suggest the principal ammonia removal mechanism to be loss to the atmosphere rather than conversion to nitrate.

Analysis of the organic nitrogen data reveals a pattern of effluent levels and removal efficiencies almost identical to that observed for the winter data. The major difference is in the area of statistical significance associated with the higher removals obtained by all plots on the 3 per cent slope and by the spray boom method of application. The higher ambient temperature of the summer had no apparent benefit in the reduction of organic nitrogen.

Other than the somewhat higher reductions in ammonia-nitrogen the total nitrogen balance during the summer appears to have been virtually identical to that for the winter operation. This suggests loss of ammonia to the atmosphere to be the principal nitrogen removal process with nitrification-denitrification and plant uptake playing much less significant roles.

Treatment Above and Below Freezing--

As shown in Table 4, the mean BOD for the below freezing category was, for all application methods, higher than the mean BOD for those operating above 0^{o} C. This would indicate that, in all cases, the system was less effective in removal of BOD when temperatures remained below the freezing mark. In every case but one (that being the spray booms on the 2 per cent slope, above freezing), there was a reduction in the coefficient of variation, indicating less variability in the grouped data.

Regrouping the data for days when the low temperature was above and below freezing respectively produced very similar results. The overall means were identical and the means above and below 0^{o} C were very similar.

TABLE 4. RAW TREATMENT SYSTEM,
WINTER OPERATION, HIGH TEMPERATURE VS. BOD

Fixed Riser

Slope	Temperature	Mean	Grouped Means	Std. Dev.	V	Std. Dev.	V
2%	>0° C	42	38.2	31	74	18	47
	<0° C		50.0			15	30
3%	>0° C	38	33.5	41	108	32	94
	<0° C		46.0			20	43

Trough

Slope	Temperature	Mean	Grouped Means	Std. Dev.	V	Std. Dev.	V
2%	>0° C	40	29.0	54	130	19	66
	<0° C		59.3			25	42
3%	>0° C	39	33.8	30	77	8	24
	<0° C		49.7			18	36

Spray Boom

Slope	Temperature	Mean	Grouped Means	Std. Dev.	V	Std. Dev.	V
2%	>0° C	39	37.1	14	35	16	41
	<0° C		47.0			9	19
3%	>0° C	24	18.0	11	46	4	25
	<0° C		38.0			16	41

V = coefficient of variation expressed as a percentage

Table 5 presents data for COD effluent from the plots. Again the means in the grouped data show that the system was less effective in removing the COD when the temperature was below freezing. The coefficient of variation improved in every case except for the spray boom application method.

Table 6 presents the independent temperature variable "high temperature" versus ammonia. It could be hypothesized that ammonia would come off to the atmosphere at a faster rate when temperatures for the day had exceeded 0^{o} C than it would when the high for the day never exceeded the freezing mark. The hypothesis appears to be true since the group means show consistently higher ammonia values when the temperature remains below freezing. It appeared to be even more striking when the ammonia values for below freezing are compared with the means for the summer operations in Table 3.

Other parameters were examined but did not appear to show any significant trends. This is also true of the data from those plots receiving secondary effluent.

Secondary Treatment System

Inspection of the BOD data in Table 7 indicates that during winter operation all effluent levels from all plots were consistently well below 30 mg/l, with those from the 2 per cent slopes being significantly lower than those from the 3 per cent slopes. The BOD level in the influent (wastewater stabilization pond effluent) was, however, also well below 30 mg/l. This indicates that in the winter season when ambient temperatures were below freezing and land application would not be indicated, additional BOD reduction of the pond effluent would not be necessary. The flow could bypass the plots without imposing an additional oxygen demand on the environment. In this manner, additional storage capacity for the winter season would not be required.

Analysis of the suspended solids data leads to the same general observations concerning the winter operation of the secondary system. In this case, however, the plots on the 2 per cent slope did indicate significantly lower effluent levels than those from the same application methods on the 3 per cent slope. The comparatively high removal efficiencies obtained suggest possible benefits of application of this type of effluent to relatively low grade slopes should suspended solids levels less than 10 mg/l be desired.

Similar to the raw system the fecal coliform analysis indicated reductions of less than one order of magnitude. Considering that reduction of influent levels of 10^4 to effluent levels of 10^2 or less is desired, the statistically significant lower levels from the 2 per cent slopes have no practical significance. If fecal coliform effluent limits are applied to wastewater stabilization pond effluents, additional treatment other than the methods employed in this study are indicated.

TABLE 5. RAW TREATMENT SYSTEM,
WINTER OPERATION, HIGH TEMPERATURE VS. COD

Slope	Temperature	Mean	Grouped Means	Std. Dev.	V	Std. Dev.	V
Fixed Riser							
2%	>0° C	136	135.0	73	54	73	54
	<0° C		138.0			11	8
3%	>0° C	110	108.0	31	28	23	21
	<0° C		113.0			21	19
Trough							
2%	>0° C	114	99.8	62	54	30	30
	<0° C		137.0			19	14
3%	>0° C	112	107.0	35	31	32	30
	<0° C		120.0			29	24
Spray Boom							
2%	>0° C	124	118.0	28	23	31	27
	<0° C		138.0			16	12
3%	>0° C	102	89.6	31	31	18	20
	<0° C		134.7			43	32

V = coefficient of variation expressed as a percentage

TABLE 6. RAW TREATMENT SYSTEM, WINTER OPERATION, HIGH TEMPERATURE VS. NH_3

Slope	Temperature	Mean	Grouped Means	Std. Dev.	V	Std. Dev.	V
Fixed Riser							
2%	$>0^o$ C	9.56	8.36	3.69	38	4.37	42
	$<0^o$ C		11.96			1.09	9
3%	$>0^o$ C	6.89	5.23	4.52	66	4.79	92
	$<0^o$ C		10.21			3.15	31
Trough							
2%	$>0^o$ C	8.56	6.08	5.57	65	6.39	105
	$<0^o$ C		12.69			1.08	9
3%	$>0^o$ C	8.47	7.32	3.09	36	3.48	48
	$<0^o$ C		10.78			0.95	9

V = coefficient of variation expressed as a percentage

TABLE 7. ANALYTICAL RESULTS FROM THE SECONDARY SYSTEM FOR THE WINTER APPLICATION - NOVEMBER 28, 1977 - MARCH 10, 1978

Anal. Par.	% Slope	Stat. Par.	APPLICATION METHOD: RISER Eff. Conc.	RISER % Red.	TROUGH Eff. Conc.	TROUGH % Red.	Infl. Conc.	Analysis of Variance: Source	p = 0.1
BOD mg/l	3	$\bar{X}$	13.8	15	17.2	-6	16.2		
		s	5.24		5.77		5.70	Slope	Sig.
		n	9		10		20		
	2	$\bar{X}$	9.30	43	9.40	42		Appl. Mtd.	-
		s	2.26		2.01				
		n	10		10			Interact.	-
Sus. Solids mg/l	3	$\bar{X}$	15.7	40	19.9	24	26.1		
		s	7.68		12.1		18.7	Slope	Sig.
		n	9		10		19		
	2	$\bar{X}$	6.67	74	6.33	76		Appl. Mtd.	-
		s	3.97		3.46				
		n	9		9			Interact.	-
Fecal Coliform per 100 ml	3	$\bar{X}$	4.5×10^4	25	6.4×10^4	-7	6.0×10^4		
		s	2.8×10^4		5.6×10^4		4.7×10^4	Slope	Sig.
		n	7		8		17		
	2	$\bar{X}$	2.5×10^4	58	1.8×10^4	70		Appl. Mtd.	-
		s	2.4×10^4		1.6×10^4				
		n	9		9			Interact.	-

(Continued)

TABLE 7. (continued)

Anal. Par.	% Slope	Stat. Par.	APPLICATION METHOD: RISER Eff. Conc.	RISER % Red.	TROUGH Eff. Conc.	TROUGH % Red.	Infl. Conc.	Analysis of Variance: Source	p = 0.1
Total P mg/l	3	$\bar{X}$	10.4	14	10.9	10	12.1		
		s	1.40		1.32		1.41	Slope	-
		n	9		10		19		
	2	$\bar{X}$	10.7	12	10.1	17		Appl. Mtd.	-
		s	1.06		1.07				
		n	9		9			Interact.	-
NO_3 N mg/l	3	$\bar{X}$	0.57		0.15		0.06		
		s	0.36		0.10		0.05	Slope	Sig.
		n	8		9		31		
	2	$\bar{X}$	0.94		0.60			Appl. Mtd.	Sig.
		s	0.57		0.43				
		n	8		8			Interact.	-
NH_3 N mg/l	3	$\bar{X}$	8.41	38	10.8	20	13.5		
		s	4.80		4.33		3.42	Slope	-
		n	9		10		20		
	2	$\bar{X}$	11.0	19	9.28	20		Appl. Mtd.	-
		s	1.89		2.52				
		n	10		10			Interact.	Sig.
Org. N mg/l	3	$\bar{X}$	2.81	28	4.04	-3	3.93		
		s	2.12		1.23		2.01	Slope	Sig.
		n	9		10		20		
	2	$\bar{X}$	2.42	38	2.24	43		Appl. Mtd.	-
		s	1.72		1.64				
		n	10		10			Interact.	-

The nutrient parameters outlined in Table 7 reveal that like the raw system, the secondary system indicated comparatively uniform effluent levels for both application methods and slopes. The low removal percentages indicate very little, if any, meaningful uptake under the test conditions.

The nitrogen values suggest that the effluents from the fixed riser plots were significantly higher in nitrate than were the effluents from the plots having the trough method of application. Likewise the 2 per cent slopes were higher in nitrate-nitrogen than were the 3 per cent slopes; however, considering that all levels were below 1 mg/l, an overall low level of nitrification is indicated and the differences observed appear to have no practical application. This is consistent with the finding from the raw system even though the influents to the systems were dissimilar.

The ammonia and organic nitrogen levels exhibited the same general pattern for the secondary system as was seen for the raw system in that the effluent levels for the winter operations were fairly consistent between plots and between the two systems. The somwhat lower percentage reductions reported for the secondary system are understandable in view of the different nature of the two influents.

Overall, the nitrogen balance indicates that during the winter, the secondary system achieved low levels of nitrification, and reductions in ammonia and organic nitrogen levels which were even lower than those observed for the raw system under winter conditions. This leads to the same general observations expressed for the raw system, that is, nitrogen changes resulting from the overland flow of wastewater stabilization pond effluent during the winter season were primarily limited to less than 50 per cent conversion of organic nitrogen to ammonia with the loss of this plus a loss of less than 40 per cent of the influent ammonia to the atmosphere.

As may be seen in Table 8, the summer effluent BOD levels ranged from 18.6 mg/l for the troughs on the 2 per cent slope to 25.0 mg/l for the troughs on the 3 per cent slope with no statistically significant differences observed between the two application methods or slopes. Even though these were somewhat higher effluent levels than were reported under winter operations, all were still below 30 mg/l. Considering the relatively low level of BOD in the influent, the comparatively low removal efficiencies were not unexpected since it is the inherent nature of biological treatment systems that the rate at which residual oxygen demand is satisfied is a function of the level of the demand remaining.

The effluent suspended solids levels varied from 60.9 to 101.0 mg/l, with the fixed riser method producing statistically significantly lower levels than the trough method; however, the practical significance of this finding is lost since all effluent levels were well above 30 mg/l. A comparison with the suspended solids levels from the raw system for the summer data indicates that the type of suspended solids rather than application method or slope was the principal factor affecting treatment.

TABLE 8. ANALYTICAL RESULTS FROM THE SECONDARY SYSTEM, FOR THE SUMMER APPLICATION - MARCH 20, 1978 - OCTOBER 27, 1978

Anal. Par.	% Slope	Stat. Par.	APPLICATION METHOD: RISER Eff. Conc.	RISER % Red.	TROUGH Eff. Conc.	TROUGH % Red.	Infl. Conc.	Analysis of Variance: Source	p = 0.1
BOD mg/l	3	$\bar{X}$	18.7	32	25.0	10	27.7		
		s	7.75		8.52		11.4	Slope	-
		n	20		20		29		
	2	$\bar{X}$	19.8	29	18.6	33		Appl. Mtd.	-
		s	7.44		6.90				
		n	18		18			Interact.	Sig.
Sus. Solids mg/l	3	$\bar{X}$	60.9	47	101	11	114		
		s	43.4		53.5		60.1	Slope	-
		n	18		20		29		
	2	$\bar{X}$	63.0	45	66.3	42		Appl. Mtd.	Sig.
		s	41.8		50.9				
		n	18		18			Interact.	-
Fecal Coliform per 100 ml	3	$\bar{X}$	9.3×10^4	-182	1.0×10^5	-203	3.3×10^4		
		s	2.2×10^5		1.9×10^5		2.8×10^4	Slope	-
		n	11		11		13		
	2	$\bar{X}$	1.6×10^4	52	1.9×10^4	42		Appl. Mtd.	-
		s	1.4×10^4		1.1×10^4				
		n	10		10			Interact.	-

(Continued)

TABLE 8. (continued)

Anal. Par.	% Slope	Stat. Par.	APPLICATION METHOD: RISER Eff. Conc.	RISER % Red.	TROUGH Eff. Conc.	TROUGH % Red.	Infl. Conc.	Analysis of Variance Source	p = 0.1
Total P mg/l	3	$\bar{X}$	4.21	33	4.62	27	6.31		
		s	2.76		2.74		3.47	Slope	Sig.
		n	20		20		29		
	2	$\bar{X}$	5.87	7	5.60	11		Appl. Mtd.	-
		s	3.69		2.92			Interact.	-
		n	18		18				
NO_3 N mg/l	3	$\bar{X}$	0.10		0.13		0.08		
		s	0.14		0.13		0.10	Slope	-
		n	14		14		23		
	2	$\bar{X}$	0.29		0.17			Appl. Mtd.	-
		s	0.44		0.23			Interact.	-
		n	12		12				
NH_3 N mg/l	3	$\bar{X}$	0.21	88	0.27	84	1.70		
		s	0.30		0.36		2.12	Slope	Sig.
		n	20		20		29		
	2	$\bar{X}$	0.48	72	0.44	74		Appl. Mtd.	-
		s	0.67		0.59			Interact.	-
		n	18		18				
Org. N mg/l	3	$\bar{X}$	10.5	24	14.0	-1	13.8		
		s	3.17		4.91		4.92	Slope	Sig.
		n	20		20		29		
	2	$\bar{X}$	9.1	34	9.4	32		Appl. Mtd.	Sig.
		s	3.13		4.61			Interact.	Sig.
		n	18		18				

The results of the fecal coliform analyses from the summer operations were consistent with those from the winter operations in that all effluent levels were in the range of 10^4 or 10^5 per 100 ml. Compared to an influent average in the range of 10^4 per 100 ml, reductions, where such existed, were insufficient to merit practical consideration.

Effluent phosphorus levels, which ranged from 4.21 to 5.87 mg/l, were lower for the summer operations than for the winter; however, the influent phosphorus during the summer also averaged lower than during the winter. Consequently the overall performances were comparable in that total phosphorus reduction by the system studies was relatively small. The plots on the 3 per cent slope produced statistically significantly lower effluent levels than did the ones on the 2 per cent slope; however, the differences between plots being less than 2 mg/l are of little practical significance.

Examination of the nitrate levels in Table 8 reveals a picture similar to that observed for winter operations in that the influent level averaged less than 0.1 mg/l and all effluent means were less than 1 mg/l. The indicated degree of nitrification is small and is consistent with that observed for the raw system operated under winter and summer conditions.

On the other hand, the ammonia-nitrogen levels in the effluent averaged below 0.5 mg/l compared to the winter system where the effluent levels ranged from 8.41 to 11.0 mg/l. The removal efficiencies varied from 72 per cent for the fixed risers on the 2 per cent slope to 88 per cent for the fixed risers on the 3 per cent slope. The apparent improvement in performance between the summer and winter operation can be attributed to the warmer ambient temperatures and lower influent levels during the summer. The ammonia levels in the effluents from the plots on the 3 per cent slope were significantly lower than those from the 2 per cent slope; however, the practicality of this finding is negated by the relatively small differences in effluent concentrations.

Analysis of the organic nitrogen data for the summer operation indicates a comparatively high level (13.8 mg/l) in the influent with little if any reduction in the effluents. Statistical significance was indicated for method of application, slope and interaction; however, the comparatively small range of effluent levels and the low removal efficiencies minimize practical interpretation and application of these findings.

Overall, the nitrogen balance for the secondary system during the summer indicates comparatively high influent levels of organic nitrogen presumably in the form of algal protein, with very little if any reduction by the treatment methods employed. The influent ammonia level which was relatively low, was reduced to less than 0.5 mg/l probably, by loss to the atmosphere. A very low level of nitrification was indicated; therefore, the principal change in the nitrogen balance appears to have been the loss of approximately 4 mg/l organic nitrogen and about 1.5 mg/l ammonia-nitrogen.

Comparison of Overland Flow and Wastewater Stabilization Pond

Since the raw wastewater from the City of Pauls Valley was influent to both the raw system of the land application project and to a two-celled wastewater stabilization pond operated in parallel to the project, and since the influent to the secondary system was considered to be representative of the effluent from the second cell, the performance of the pond could be evaluated and compared to the results from the raw system of the overland flow project.

As may be seen in Table 9, the effluent from the pond had an average BOD of 16.2 mg/l for the winter operation. This was well below the usual effluent limitations of 30 mg/l and compared favorably with all six plots of the land application system, with the exception of the spray booms on the 3 per cent slope where the effluent levels were above 30 mg/l. The percentage reduction of 88 per cent also compares favorably with the performance of all six plots as well as with conventional secondary treatment, especially considering the dilute nature of the raw wastewater.

In contrast, the pond as operated under winter conditions did not reduce suspended solids as well as did overland flow. The reduction of 71 per cent by the pond is appreciably lower than the 83 to 88 per cent range demonstrated by the six plots; however, the pond effluent average was still below 30 mg/l and could be considered acceptable even at this lower level of reduction.

The fecal coliform data in Table 9 indicated that the pond achieved an average reduction of 98 per cent compared to a range of 38 per cent for the spray booms on the 2 per cent slope to 74 per cent for the troughs also on the 2 per cent slope. Even though the removal efficiency was relatively high for the pond, the effluent level was in the range of 10^4 per 100 ml compared to 10^6 per 100 ml for the various plot effluents; consequently, neither treatment process achieved effluent levels considered acceptable without further treatment.

A review of the phosphorus data for the winter observation period reveals that the concentrations in the plot effluents were much lower than the average level from the pond; however, neither the land nor the pond processes exhibited meaningful uptake. In fact, the spray boom application method as well as the pond produced higher effluent levels of total phosphorus than was in the influent. This suggests that even though phosphorus is a biologically essential and actively transported nutrient, neither system was phosphorus limited under the conditions of this study.

The nitrogen data gathered under winter operations revealed that the nitrate level in the pond effluent was lower than the level from any of the six plots; however, all effluent concentrations were well below 1 mg/l and relative differences are of little practical significance unless future effluent limits of less than 0.1 mg/l are established for nitrate-nitrogen. If this occurs, the plot effluents would require additional treatment.

TABLE 9. COMPARISON OF OVERLAND FLOW AND WASTEWATER STABILIZATION POND FOR TREATMENT OF RAW DOMESTIC WASTEWATER

Appl. Rate	Anal. Par.	Infl. Conc.	% Slope	RISER		TROUGH		BOOM		POND	
				Eff. Conc.	% Red.	Eff. Conc.	% Red.	Eff. Conc.	% Red.	Eff. Conc.	% Red.
Winter	BOD mg/l	130	3	37.7	71	39.1	70	24.0	82	16.2	88
			2	42.1	68	40.4	69	39.8	69		
	S.S. mg/l	90.7	3	15.6	83	11.0	88	12.1	87	26.1	71
			2	11.2	88	11.9	87	12.0	87		
	FC/100ml $\times 10^6$	3.9	3	1.5	62	1.2	69	2.3	41	0.060	98
			2	1.3	67	1.0	74	2.4	38		
	Total P mg/l	8.46	3	7.55	11	6.87	19	9.55	-13	12.1	-43
			2	7.64	10	7.75	8	9.64	-14		
	NO_3-N mg/l	0.04	3	0.24		0.21		0.74		0.06	
			2	0.19		0.26		0.44			
	NH_3-N mg/l	16.5	3	6.89	58	8.47	49	11.4	31	13.5	18
			2	9.56	42	8.56	48	13.4	19		
	Org. N mg/l	7.28	3	3.47	52	3.65	50	2.66	63	3.93	46
			2	4.01	45	3.64	50	3.12	57		

(Continued)

TABLE 9. (Continued)

Appl. Rate	Anal. Par.	Infl. Conc.	% Slope	RISER		TROUGH		BOOM		POND	
				Eff. Conc.	% Red.	Eff. Conc.	% Red.	Eff. Conc.	% Red.	Eff. Conc.	% Red.
Summer	BOD mg/l	117	3	14.2	88	21.0	82	8.6	93	27.7	76
			2	18.2	84	18.3	84	8.3	93		
	S.S. mg/l	105	3	9.4	91	10.6	90	3.6	97	114	- 9
			2	6.4	94	6.6	94	3.6	97		
	FC/100ml X 10^6	5.0	3	1.4	72	1.8	64	1.2	76	0.033	99
			2	1.2	76	1.2	76	0.49	90		
	Total P mg/l	8.3	3	7.9	5	8.5	- 2	9.2	-11	6.31	24
			2	8.7	- 5	8.9	- 7	9.2	-11		
	NO_3-N mg/l	0.05	3	0.18		0.16		1.04		0.08	
			2	0.18		0.24		0.67			
	NH_3-N mg/l	16.7	3	4.2	75	7.4	56	3.1	81	1.70	90
			2	6.9	59	6.9	59	3.4	80		
	Org. N mg/l	8.5	3	4.0	53	4.8	44	2.9	66	13.8	-62
			2	4.6	46	5.0	41	3.1	64		

The ammonia-nitrogen data in Table 9 indicated that for the winter operation the plot effluent levels, which ranged from 13.4 mg/l for the spray booms on the 2 per cent slope to 6.89 mg/l for the fixed risers on the 3 per cent slope, were generally lower than the pond effluent which averaged 13.5 mg/l. Considering the increased amount of air contact afforded by the land application procedures, the relatively low ammonia removal efficiency of the pond is understandably even considering the probability of lower wastewater temperatures on the plots.

The organic nitrogen data lead to basically the same analysis as for the ammonia in that the plots generally had lower effluent levels and therefore, higher removal efficiencies than did the pond. The nature of the two processes suggests that at least a portion of the organic nitrogen in the pond effluent was in the form of algal protein while that in the plot effluents was primarily unconverted metabolic waste products which, understandably, would have a much greater environmental impact. Overall, the difference between the effluent levels from the two processes had no apparent practical significance.

Referring to Table 9, for a comparison of the two processes under the summer operation, it may be seen that with respect to BOD, the performance of the pond decreased to 76 per cent removal while the plots improved to a minimum of 82 per cent from the trough on the 3 per cent slope and a maximum of 93 per cent for both spray boom plots. While the effluent BOD for the pond increased during the summer, presumably due to higher levels of phytoplankton, the effluent level averaged less than 30 mg/l and could be considered acceptable especially considering the relatively innocuous nature of the solids contributing to the BOD.

The suspended solids data present a contrasting view. The effluent from the pond averaged 114 mg/l with the increase apparently due to the increased concentration of algae in the pond during the warmer season. This indicates the need for additional treatment if effluent levels as low as 30 mg/l are to be achieved. The plots, on the other hand, exhibited removal efficiencies which ranged from 90 to 97 per cent with all plot effluents averaging well below 30 mg/l.

Comparison of the fecal coliform data indicates only a slight improvement in performance of the plots and the pond for the summer operation. Again, the pond achieved effluent levels in the range of 10^4 per 100 ml while the plot effluent levels averaged in the 10^6 per 100 ml range. Unfortunately, neither process achieved levels compatible with anticipated effluent criteria and additional treatment is indicated if fecal coliform levels of 10^2 per 100 ml are to be realized by either process for either season.

As discussed earlier, the phosphorus levels in the plot effluents indicated that little if any change occurred between summer and winter operations; however, the performance of the pond varied markedly between the two seasons. While the removal efficiency changed from -45 per cent for the winter to +24 per cent for the summer, the pond system was similar to the plots in that both were ineffective in achieving meaningful reductions in total phosphorus.

The nitrate data in Table 9 also indicated a parallel between summer and winter operations. The effluent levels from the plots were higher than for the pond but all were in the range of 1 mg/l or less and in the absence of effluent limits for nutrient parameters, no meaningful differences were represented.

An analysis of the ammonia data reveals the expected observation that the pond and the overland flow plots exhibited higher removal efficiencies for the summer than for the winter. It may not have been anticipated that in contrast to the winter performance, the ammonia removal efficiency of 90 per cent for the pond during the summer exceeded that for all six plots. This suggests that biological ammonia removal processes are less effective than physical processes at winter temperatures but more effective than physical processes at the higher temperatures associated with the summer operation. In the absence of effluent limitations for ammonia, however, this observation has little practical application.

The organic nitrogen data reveals the unique operational characteristics of the pond in that the average effluent level was appreciably higher than the influent concentration for the summer operation. This is in contrast to the winter operation when a removal of 46 per cent was achieved and may be explained by the high concentration of phytoplankton which develop in such ponds during warmer temperatures. The plots performed at an average removal rate of 52 per cent which represents very little change from the winter operation. Reduction of effluent algae, which would greatly improve the nitrogen, suspended solids, and BOD removal efficiencies, would be required if the pond is to compare favorably with the plots for the conditions studied.

SOIL ANALYSIS

Due to the nature of the sampling protocol of the soil analyses, the data obtained does not readily lend itself to statistical testing. For this reason, the evaluation is limited to a brief discussion of observed changes in concentrations of surface and subsurface soil components before and after wastewater application. Of the 13 parameters analyzed, a consistent pattern of increase or decrease was observed at all sampling locations for several parameters, namely; phosphorus, calcium, potassium, manganese and copper (Appendix E). The concentration of phosphorus, potassium and manganese decreased, while calcium and copper increased. This pattern, among these parameters, was observed primarily in the surface soil samples (15 cm depth). Only two parameters, iron and manganese, collected at subsurface levels (30 cm depth), reveal a consistent pattern of change. The concentration of manganese showed a consistent decrease in surface and subsurface concentrations. In some instances, this decrease amounted to greater than 40 per cent. Other significant variations in composition can be seen throughout the data, but with very little consistency with respect to sample depth and location. Under the scope of this study, the significance of these observations is limited by the number of existing variables and care should be taken in making any conclusions.

Aside from the analysis of soil composition, other areas of consideration, particularly plant productivity, provide additional means of evaluating the detrimental and/or beneficial effects of overland flow processes on the soil community. Based on visual observations throughout the study, the overall quality and quantity of growth produced on the experimental plots displayed a significant improvement, particularly during the last 8 weeks of the study. Root penetration of cover crops improved from 10 to 30 cm (4 to 12 inches) over the entire length of the study with heavy root structures at depths of 15 cm (6 inches). Most of these changes were perceivable, considering the constant input of nutrients to the system.

Overall, based on analytical procedures as well as visual observations, no detrimental aspects were identifiable that would indicate harmful build-up of any of the parameters analyzed. Whether overland flow applications of wastewater would produce long term build-up of elements that would create toxic responses to plant growth or would result in eventual leaching into the effluent run-off, was not determinable under the scope of this study.

MICROBIAL ANALYSIS

Wastewater Bacterial Colony Counts

Table 10 compares influent versus effluent counts for TBC and TCC data. A significant difference existed in all cases at a $p = 0.01$ level, when the Wilcoxon paired-replicated rank test was applied to data collected during the study period. Because of the range of variability associated with extensive serial dilutions, both arithmetic and geometric means were computed. In general, a reduction by a factor of 10 or greater from influent to effluent was observed. From these observations, it appears that a real reduction in TBC and in TCC did occur when wastewater was applied by the spray boom method to the 2 per cent slope. Of particular interest was the observation that the number of coliform organisms, collected on EMB agar (TCC), were reduced by a minimum of 70 per cent by the spray boom method of application.

Bacterial identification of colony types isolated on EMB does not indicate the presence of pathogenic organisms, but does indicate that fecal organisms were being monitored during the study. Table 11 indicates the organism identification frequency.

Tables 12 and 13 present the collective data on colonies/ml from other application methods in the sytem. These summaries span the complete study period, and were not divided into seasonal entities. Of the data analyzed, a minimal reduction of 76 per cent was observed in TCC: which is an acceptable correlation with the 2 per cent spray boom data. In all cases and on both medias, a significant reduction existed between the influent and effluent colony counts at the $p = 0.01$ level.

TABLE 10. WASTEWATER BACTERIA COLONIES OF THE SPRAY BOOM APPLICATIONS ON THE 2 PER CENT SLOPE

		INFLUENT*			EFFLUENT*			REDUCTION, %		
		APPLICATION RATE FOR:			APPLICATION RATE FOR:			APPLICATION RATE FOR:		
		SUMMER 1977	WINTER 1977-78	SUMMER 1978	SUMMER 1977	WINTER 1977-78	SUMMER 1977	SUMMER 1977	WINTER 1977-78	SUMMER 1978
TBC (NA)	MEAN	129	45.7	195	26.4	7.88	10.4	80	83	95
	GEO. MEAN	106	41.4	145	13.4	3.55	4.1			
	NO. OF OBS.	10	6	15	9	6	15			
TCC (EMB)	MEAN	39.3	7.57	17.4	6.92	2.55	1.46	82	70	92
	GEO. MEAN	19.4	5.89	15	0.35	0.79	0.50			
	NO. OF OBS.	10	6	15	9	6	15			

Since a marked reduction occurs in all cases where effluent values are compared to influent (original numerical data), the Wilcoxon paired - replicated rank test indicates a significant difference at P = 0.01.

* Concentrations expressed as colonies/ml (x10^5).

TABLE 11. FREQUENCY OF OCCURRENCE OF BACTERIA GROUPS IDENTIFIED FROM EMB PLATES FROM SPRAY BOOM WASTEWATER SAMPLES, 2 PER CENT SLOPE

	E.COLI.			KES GROUP			PSEUDOMONAS			C. FRUNDII		
APPLICATION RATES FOR:	INF.	EFF.	RED.,%	INF.	EFF.	RED.,%	INF.	EFF.	RED.,%	INF.	EFF.	RED.,%
SUMMER, 1977	8	5	38	8	5	38	3	0	100	2	0	100
NO. OF OBS.	8	8		8	8		8	8		8	8	
WINTER, 1977-78	5	5	0	3	4	-33	3	4	-33	1	0	100
NO. OF OBS.	6	6		6	6		6	6		6	6	
SUMMER, 1978	8	7	12	6	5	17	8	7	12	0	0	0
NO. OF OBS.	10	10		10	10		10	10		10	10	

TABLE 12. WASTEWATER BACTERIA COLONIES OF THE FIXED RISER, TROUGH AND SPRAY BOOM APPLICATIONS, 2 AND 3 PER CENT SLOPES

		INFLUENT *						EFFLUENT *						REDUCTION, %					
		RISER		TROUGH		SPRAY		RISER		TROUGH		SPRAY		RISER		TROUGH		SPRAY	
		2%	3%	2%	3%	2%	3%	2%	3%	2%	3%	2%	3%	2%	3%	2%	3%	2%	3%
TBC (NA)	MEAN	70.7	99.5	205.4	99.3	201.1	209.8	8.2	20.4	11.5	21.4	37.9	4.9	88	79	94	78	81	97
	GEO. MEAN	27.6	42.4	38.6	43.9	140.7	88.4	4.2	7.1	2.1	7.3	2.5	1.8						
	NO. OF OBS.	8	7	8	7	8	8	8	7	8	7	8	9						
TCC (EMB)	MEAN	12.9	11.9	10.3	8.7	15.8	21.3	.98	2.4	0.6	2.1	1.2	.94	92	80	94	76	92	96
	GEO MEAN	5.1	3.5	4.2	2.5	13.4	12.7	.002	.66	.12	.38	.32	.21						
	NO. OF OBS.	8	7	8	7	7	9	8	7	8	7	8	9						

Since a marked reduction occur in all cases where effluent values are compared to influent (original numerical data), the Wilcoxon paired-replicated rank test indicates a significant difference at P = 0.01.

* Concentrations expressed as colonies/ml ($x10^5$)

TABLE 13. BACTERIA IDENTIFIED FROM EMB PLATES FROM FIXED RISER AND TROUGH WASTEWATER SAMPLES, 2 AND 3 PER CENT SLOPES

	E. COLI			KES GROUP			PSEUDOMONAS		
	INF.	EFF.	RED.%	INF.	EFF.	RED.%	INF.	EFF.	RED.%
RISERS									
2%	3	3	0	6	7	-17	2	4	-100
No. of OBS.	7	7		7	7		7	7	
3%	6	4	33	5	3	40	4	3	25
No. of OBS.	6	6		6	6		6	6	
TROUGHS									
2%	4	6	-50	7	3	57	4	3	25
No. of OBS.	7	7		7	7		7	7	
3%	5	3	40	2	2	0	5	4	20
No. of OBS.	5	5		5	5		5	5	

Ambient Air Bacterial Colony Counts

The airborne bacterial population data are presented in Table 14. The TBC was either reduced, or revealed no significant difference between upwind and downwind data (possibly due to particulate washout from aerosol droplets). In all cases, as expected, a significant increase in TCC was observed throughout the study. While it is recognized that coliform organisms are commonly found in the soil and can become airborne, an increase was routinely observed downwind from the spray boom wastewater applicator. Numerically, this increase borders on having any significant meaning; that is, the average concentration measured was 731 colonies/m^3, or approximately 20 coliform colonies/ft^3. Wind dispersion and turbulance modeling indicates that this modest input would be insignificant 60 m (approximately 200 ft) downwind from the spray boom applicator.

Ambient Air Particle Counts

Table 15 presents data collected during two summer and one winter application periods. Both summer application rates, taken during warmer months of the year, show a modest increase in downwind airborne particulates, while the winter data would indicate a decrease in downwind particulate numbers. This could be explained by the more rapid evaporation of aerosols during the warmer months, and by a particulate washout effect during the colder months. This observation is of passing interest, however, since no statistical difference was observed between upwind and downwind particle counts, and therefore suggests that downwind particulate concentration was not a health hazard during this study.

Wastewater Viral Plaque Counts

Although the potential is high for transmission of viral agents through sewage effluents, it appears, from the results of this study, that the concentrations of viable viruses were extremely low at the point of application to the overland flow modules. One possible explanation, which is relatively inconclusive, could be the lapse of time between excretion and transport of fecal matter to a point where the sewage is to be treated. This is a highly variable consideration based on the number of physicochemical factors present, that could potentially affect the viability of virus. Another consideration that could be made, in terms of the degree of variability which exists in describing viral constituents in wastewater, is the technique employed for isolation and description of the viruses. Certain definable limitations exist with respect to the techniques available for isolation and culturing of a potentially broad spectrum of viruses. The methods for concentrating viruses in wastewater, and even more so, host systems used in viral assays can be very selective (17, 18). No one host system will detect all of the viral types potentially present in wastewater (18). Likewise, no one method of concentration would necessarily be capable of isolating all viral types.

The methods employed in this study, the Bentonite adsorption technique for concentration and the Rhesus monkey kidney cell cultures for assay,

TABLE 14. AIRBORNE BACTERIA COLONIES OF THE SPRAY BOOM APPLICATIONS ON THE 2 PER CENT SLOPE

		UPWIND*			DOWNWIND*			INCREASE, %		
		APPLICATION RATE FOR:			APPLICATION RATE FOR:			APPLICATION RATE FOR:		
		SUMMER 1977	WINTER 1977-78	SUMMER 1978	SUMMER 1977	WINTER 1977-78	SUMMER 1978	SUMMER 1977	WINTER 1977-78	SUMMER 1978
TBC (NA)	MEAN	1334	371	516	878	323	664	-34	-13	29
	GEO. MEAN	459	45	24	268	185	116			
	NO. OF OBS.	21	7	13	19	7	12			
TCC (EMB)	MEAN	203	63	55	565	160	731	178	154	1229
	GEO. MEAN	21	9.6	12	104	25	296			
	NO. OF OBS.	21	7	13	21	7	13			

*Concentrations expressed as colonies/m^3

WILCOXON PAIRED-REPLICATE RANK TEST
CONTROL VS. DOWNWIND MEAN COLONIES/M^3

MEDIA	SUMMER, 1977	WINTER, 1977-78	SUMMER, 1978
TBC (NA)	Significant Decrease at P = 0.05	No Significant Difference	No Significant Difference
TCC (EMB)	Significant Increase at P = 0.05	Significant Increase at P = 0.05	Significant Increase at P = 0.05

TABLE 15. AIRBORNE PARTICLES OF THE SPRAY BOOM APPLICATIONS ON THE 2 PER CENT SLOPE

APPLICATION RATE FOR:		UPWIND*	DOWNWIND*	INCREASE, %
SUMMER, 1977	MEAN	335.6	449.5	34
	GEO. MEAN	259.7	308.6	
	NO. OF OBS.	18	19	
	MEAN SIZE	1.86μ	1.8μ	
WINTER, 1977-78	MEAN	1009.8	717.5	-29
	GEO. MEAN	564.1	518.2	
	NO. OF OBS.	7	5	
	MEAN SIZE	1.8μ	1.4μ	
SUMMER, 1978	MEAN	910.1	1002.	10
	GEO. MEAN	704.5	734.0	
	NO. OF OBS.	11	11	
	MEAN SIZE	1.4	1.4	

*Concentrations expressed as particles/m^3 $(x10^4)$

The Wilcoxon paired-replicated rank test indicated no significant difference between the control and downwind particle counts gathered for either of the three periods studied.

were sensitive for detection of: poliovirus (three serotypes), echoviruses (34 serotypes) and group B coxsackieviruses (six serotypes) (10, 14). The Bentonite adsorption technique was chosen for its ability to isolate approximately 60 to 70 per cent of the indigenous enteroviruses present in sewage (10). Even though the methods herein would appear acceptable in isolating and culturing of an adequate cross-section of enteroviruses, it is not necessarily an adequate cross-section of the potentially harmful viruses, based on the scope of implications set-forth in defining an acceptable level of exposure to pathogenic organisms. Care must therefore be taken in drawing conclusions as to the effectiveness of overland flow treatment for the removal and destruction of potential disease causing viruses.

As seen in Table 16, viruses first appeared in the influent to the spray boom applications (raw system), beginning in May, 1978, at concentrations in the range of 10^2 PFU/l. Viral concentrations peaked at 4 X 10^2 PFU/l in August, 1978, followed by a gradual decline in concentration to 10^1 PFU/l in October, 1978. This finding generally agrees with the reported seasonal incidence of enteroviruses in wastewater (19). The concentrations of viruses isolated (10^1 to 10^2 PFU/l) were lower than reported by Shuval (20).

The absence of viruses in the influent samples early in the study, from January 31, 1978 through May 8, 1978, suggested the possibility of inadequate sample volumes in addition to possible variation due to seasonal distribution of viruses. Consequently, sample volumes were modified, from 1 to 4 liters, as indicated earlier. A comparison of resultant concentrates, taken from the location of distribution pumps and from the point of application to the plots, did not indicate, as earlier suspected, any appreciable loss of viruses through the distribution lines to the individual treatment applications.

With respect to viral reductions observed after application to the overland flow modules, Table 16 indicates a total reduction, from influent to effluent, of samples collected from May 23, 1978 through July 24, 1978 on the spray boom plots. The apparent rise and fall of viral reductions during this particular time of the year suggests a possible threshold at which the plots are capable of removal of viral organisms. As the viral concentrations at the point of influence to the plots decreased throughout the remainder of the year, the reductions across the plots increased to 100 per cent. Although the data appears to reflect a seasonal distribution pattern, the results remain relatively inconclusive based on the number of samples that were collected.

No significant differences were observed in virus isolations from the 2 per cent slope when compared to the 3 per cent slope. This was found to be the case for all three methods of application on the raw treatment system.

Tables 17 and 18, for the fixed riser and trough applications, respectively, reflect the same general influent and effluent patterns and

TABLE 16. RAW SYSTEM WASTEWATER VIRAL ASSAY, SPRAY BOOM APPLICATION

Date	% Slope	Influent PFU/l	Effluent PFU/l	% Reduction	Pump Station PFU/l
2-14-78	2	0	0	NC	NR
3-14-78	2	0	0	NC	NR
3-21-78	2	0	0	NC	NR
5-2-78	2	0	0	NC	NR
	3	0	0	NC	
6-1-78	2	0	0	NC	NR
	3	0	0	NC	
8-1-78	3	113	45	60	158
9-19-78	2	60	0	100	NR
	3	30	0	100	
10-17-78	2	30	0	100	NR
	3	30	0	100	

Note: Negative controls (see methods) were included with each plaque assay and were negative for plaques.

NC - Not Calculated

NR - Not Collected

TABLE 17. RAW SYSTEM WASTEWATER VIRAL ASSAY, FIXED RISER APPLICATION

Date	% Slope	Influent PFU/l	Effluent PFU/l	% Reduction	Pump Station PFU/l
1-10-78	3	90	0	100	NR
1-31-78	2	0	0	NC	NR
	3	0	0	NC	
3-28-78	2	0	0	NC	NR
5-8-78	2	0	0	NC	NR
	3	0	0	NC	
5-23-78	2	90	0	100	NR
	3	68	0	100	NR
7-18-78	2	113	0	100	158
	3	158	0	100	
7-25-78	2	203	0	100	203
	3	158	0	100	
8-8-78	2	405	225	44	NR
	3	225	135	40	
8-29-78	2	90	23	74	NR
	3	113	23	80	
9-12-78	2	NR	0	NC	135
	3	90	0	100	
9-26-78	2	45	23	49	NR
	3	45	23	49	
10-3-78	2	0	0	NC	23
	3	23	0	100	
10-24-78	2	23	0	100	45
	3	23	0	100	

NOTE: Negative controls (see methods) were included with each plaque assay and were negative for plaques.

NC - Not Calculated

NR - Not Collected

TABLE 18. RAW SYSTEM WASTEWATER
VIRAL ASSAY, TROUGH APPLICATION

Date	% Slope	Influent PFU/l	Effluent PFU/l	% Reduction	Pump Station PFU/l
2-14-78	2	0	0	NC	NR
3-14-78	2	0	0	NC	NR
3-21-78	2	0	0	NC	NR
5-2-78	2	0	0	NC	NR
	3	0	0	NC	
6-1-78	2	0	0	NC	NR
	3	0	0	NC	
8-1-78	3	135	45	67	158
9-19-78	2	NR	0	NC	NR
	3	NR	0	NC	
10-17-78	2	30	0	100	NR
	3	30	0	100	

Note: Negative controls (see Methods) were included with each plaque assay and were negative for plaques.

NC - Not Calculated

NR - Not Collected

percentage reductions seen with the spray boom application. The first occurrence of viruses in the influent for both the fixed riser and trough applications appeared later than on the spray boom application. Viruses were detected in May, 1978, in the influent to the spray boom plots (no samples were collected from this plot in June, 1978), whereas none were found in may or June, 1978, in the influent to the fixed riser and trough applications. Due to the few number of samples available for this analysis, it would be difficult to adequately explain such deviations. Also, the data present a somewhat distorted picture in that the sampling dates shown for the fixed riser and trough applications do not coincide with those for the spray boom application. Due to the rotating sample schedule adopted for monitoring the system, all plots were sampled on the same dates, however, the general trend of the presence or absence of viruses in the influent to the plots was the same with respect to monthly patterns.

With respect to percentage reductions in viruses across the plots for the fixed riser and trough applications, the results were much the same as seen in the data for the spray boom application. Interestingly, where viruses were detected in the influent to the fixed riser and trough applications, on August 1, September 19, and October 17, 1978, a 100 per cent reduction was observed, with exception of the samples collected on August 1, 1978; the highest recorded concentrations isolated. This compares closely with the results shown in the data collected in early August, 1978, from the spray boom application. Again, this suggests a possible threshold level at which the plots are no longer capable of retaining the full loading of viruses being applied.

In analysis of the data collected for the secondary system (Appendix F), no viruses were isolated from influent or effluent samples, from the fixed riser and trough applications, on either the 2 per cent or 3 per cent slopes. In view of the few number of samples available (a total of six from each plot over an 8-month period), it would be premature to draw any conclusions as to the presence or absence of viruses in wastewater that has received secondary treatment, through biologigal oxidation. The results seen in this study warrant some consideration when the physicochemical nature of the secondary wastewater is considered. Such considerations bring forth the need for more definitive answers in regards to viability of viruses in wastewater, at various levels of treatment.

Ambient Air Viral Plaque Counts

The analysis conducted for aerosolization of viruses from the spray boom application on the raw treatment system produced no isolations of viruses, at either upwind, downwind, or random sample locations (Table 19). In spite of the presence of viruses, in concentrations of 10^1 to 10^2 PFU/l, in the wastewater being applied through the spray nozzles, such viruses were not detected through the aspiration techniques employed in this study. Within the scope of this study this suggests several possible explanations: (a) the equipment used to aspirate any aerosolized virus was inadequate, with respect to the physical aspects, primarily the volume of air sampled,

TABLE 19. AEROSOLIZATION OF VIRUS FROM SPRAY BOOM APPLICATIONS ON THE 2 PER CENT SLOPE

Date	Spray Boom PFU/l Influent	Air Samples		
		Upwind PFU/250 ml	Downwind PFU/250 ml	Random PFU/250 ml
1-10-78	90	0	0	0
1-31-78	0	0	0	0
5-2-78	0	0	0	0
7-18-78	113	0	0	0
7-25-78	203	0	0	0
8-8-78	405	0	0	0
9-12-78	90	0	0	0
10-3-78	0	0	0	0

Note: Negative controls (see Methods) were included with each plaque assay and were negative for plaques.

(b) the sample collection menstruum (saline) was inadequate to support the viruses aspirated, (c) the retention time of the virus, from collection to assay (approximately 24 to 48 hours), was too long to maintain viable viruses in the saline menstruum, and (d) aerosolization of enteroviruses from the wastewater did not occur or if it did occur, the viruses did not survive in the atmosphere from the point of application to the point of sampling. In view of the results received from tests conducted in the laboratory prior to selection of a sample menstruum, some confidence can be placed on the technique of suspension of viruses employed in this study. This leaves several alternatives for consideration and further study.

Overall, the data observed in this study warrants further investigation if any definitive answers are revealed. This investigation provides strong baseline data for future studies and under more closely controlled conditions, the human health hazards associated with overland flow processes, can be defined.

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APPENDIX A

TABLE A-1. BOD, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/1	TROUGH Eff. mg/1	Date	BOOM Eff. mg/1	Date	Infl. mg/1
	11/28	14	29	12/5	13	11/28	141
	11/30	36	32	12/9	54	11/30	147
	12/2	58	39	12/12	19	12/2	200
	1/9	62	48	12/14	14	12/5	159
3	1/16	31	35	2/1	23	12/7	117
	1/27	38	38	2/3	26	12/9	119
	2/15	38	63	2/6	19	12/12	126
	2/22	33	35	2/27	15	12/14	101
	2/24	29	33	3/1	20	1/9	124
				3/3	37	1/16	81
						1/27	168
	11/28	31	19	12/5	18	2/1	127
	11/30	36	35	12/7	55	2/3	100
	12/2	28	36	12/9	40	2/6	155
	1/9	44	77	12/12	28	2/15	113
2	1/16	39	-	12/14	38	2/22	133
	1/27	44	60	2/1	44	2/24	115
	2/15	62	41	2/3	51	2/27	120
	2/22	47	37	2/6	55	3/1	124
	2/24	48	18	2/27	17	3/3	135
				3/1	35		
				3/3	57		

TABLE A-2. SUSPENDED SOLIDS, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	8	9	12/5	5	11/28	139
	11/30	32	17	12/7	13	11/30	44
	12/2	23	6	12/9	25	12/2	113
	1/9	18	16	12/12	4	12/5	168
3	1/16	15	15	12/14	21	12/7	64
	1/27	11	7	2/1	14	12/9	152
	2/15	13	17	2/3	10	12/12	62
	2/22	15	8	2/6	12	12/14	75
	2/24	5	4	2/27	7	1/9	51
				3/1	5	1/16	95
				3/3	17	1/27	115
	11/28	21	6	12/5	9	2/1	98
	11/30	8	4	12/7	16	2/3	82
	12/2	5	12	12/9	16	2/6	134
	1/9	15	32	12/12	9	2/15	32
2	1/16	12	-	12/14	17	2/22	80
	1/27	14	13	2/1	13	2/24	27
	2/15	13	15	2/3	15	2/27	133
	2/22	9	7	2/6	11	3/1	62
	2/24	4	6	2/27	6	3/3	88
				3/1	5		
				3/3	15		

TABLE A-3. FECAL COLIFORM PER 100 ML, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. x10^6	TROUGH Eff. x10^6	Date	BOOM Eff. x10^6	Date	Infl. x10^6
	11/28	1.8	2.3	12/5	0.89	11/28	8.2
	11/30	2.8	3.3	12/7	5.2	11/30	3.1
	12/2	2.2	0.53	12/9	2.8	12/2	6.0
3	1/16	0.52	0.81	12/12	2.0	12/5	7.2
	1/27	2.2	0.89	12/14	2.0	12/7	11
	2/15	0.74	0.79	2/1	0.21	12/9	1.9
	2/22	0.82	0.89	2/3	0.2	12/12	2.3
	2/24	0.89	0.42	2/27	7.3	12/14	9.8
				3/1	0.25	1/16	0.76
						1/27	2.7
	11/28	2.4	2.0	12/5	1.3	2/1	2.1
	11/30	0.98	1.8	12/7	8.4	2/3	1.8
	12/2	2.0	1.3	12/9	4.3	2/15	1.4
2	1/16	0.51	-	12/12	2.6	2/22	0.71
	1/27	1.7	0.41	12/14	1.3	2/24	2.5
	2/15	0.61	0.12	2/1	0.56	2/27	2.7
	2/22	0.99	0.53	2/3	1.2	3/1	2.5
	2/24	1.4	1.2	2/27	1.1		
				3/1	0.82		

TABLE A-4. TOTAL PHOSPHORUS, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	8.8	5.6	12/5	8.4	11/28	8.8
	11/30	6.0	6.2	12/7	9.1	11/30	7.6
	12/2	7.7	7.2	12/9	11.7	12/2	13.0
	1/27	8.7	7.7	12/12	8.6	1/27	8.7
3	2/15	6.2	6.6	12/14	8.1	2/1	8.5
	2/22	8.2	7.3	2/1	8.5	2/3	8.1
	2/24	7.3	7.6	2/3	9.0	2/6	9.0
				2/6	11.8	2/15	5.5
				2/27	10.4	2/22	6.8
				3/1	9.7	2/24	6.5
				3/3	9.8	2/27	11.3
	11/28	6.4	6.8	12/5	8.8	3/1	7.8
	11/30	6.4	6.0	12/7	8.7	3/3	8.3
	12/2	7.7	8.6	12/9	11.7		
	1/27	9.1	8.7	12/12	9.0		
2	2/15	6.9	6.9	12/14	8.4		
	2/22	8.4	8.6	2/1	9.0		
	2/24	8.6	8.6	2/3	9.0		
				2/6	12.4		
				2/27	10.4		
				3/1	9.2		
				3/3	9.5		

TABLE A-5. NITRATE NITROGEN, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	0.80	0.56	12/5	2.10	11/28	<0.05
	11/30	0.23	0.26	12/7	0.86	11/30	<0.05
	12/2	0.21	0.24	12/12	0.20	12/2	<0.05
	1/9	0.10	0.17	12/14	0.80	12/5	<0.05
3	1/27	0.21	0.19	2/1	0.51	12/7	<0.05
	2/15	0.12	0.14	2/3	0.19	12/12	<0.05
	2/22	<0.05	<0.05	2/6	0.85	12/14	<0.05
	2/24	0.18	0.05	2/27	0.93	1/9	0
				3/1	0.70	1/27	0
				3/3	0.22	2/1	0
						2/3	0
	11/28	0.68	0.80	12/5	1.31	2/6	0
	11/30	0.15	0.40	12/7	1.25	2/15	0.06
	12/2	0.23	0.35	12/12	0.23	2/22	<0.05
	1/9	0.10	0.14	12/14	1.20	2/24	<0.05
2	1/27	0.12	0.09	2/1	<0.05	2/27	<0.05
	2/15	0.12	0.12	2/3	<0.05	3/1	<0.05
	2/22	<0.05	<0.05	2/6	<0.05	3/3	<0.05
	2/24	<0.05	0.13	2/27	0.18		
				3/1	0.08		
				3/3	<0.05		

TABLE A-6. AMMONIA NITROGEN, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	0	5.4	12/5	2.8	11/28	13.7
	11/30	1.6	3.5	12/7	9.7	11/30	18.5
	12/2	5.2	6.0	12/9	16.1	12/2	20.3
	1/9	13.8	9.7	12/12	6.7	12/5	20.8
3	1/16	2.7	5.8	12/14	9.6	12/7	17.3
	1/27	9.0	11.1	2/1	12.8	12/9	18.2
	2/15	7.9	11.5	2/3	16.0	12/12	17.4
	2/22	11.9	12.5	2/6	13.6	12/14	15.7
	2/24	10.1	10.7	2/27	11.9	1/9	18.1
				3/1	12.2	1/16	6.1
				3/3	14.2	1/27	16.2
	11/28	6.3	0	12/5	5.9	2/1	15.2
	11/30	4.8	1.7	12/7	12.6	2/3	18.6
	12/2	4.9	2.9	12/9	9.0	2/6	18.6
	1/9	10.7	13.5	12/12	9.5	2/15	15.5
2	1/16	6.4	-	12/14	10.4	2/22	14.7
	1/27	12.6	13.1	2/1	15.3	2/24	16.5
	2/15	12.6	11.4	2/3	17.8	2/27	16.1
	2/22	14.7	14.4	2/6	20.7	3/1	15.0
	2/24	13.1	11.4	2/27	14.6	3/3	18.3
				3/1	14.6		
				3/3	16.6		

TABLE A-7. ORGANIC NITROGEN, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	2.2	3.0	12/5	0	11/28	8.4
	11/30	3.3	3.4	12/7	3.9	11/30	6.9
	12/2	3.5	3.3	12/9	0	12/2	10.3
	1/9	5.0	3.8	12/12	0	12/5	7.6
3	1/16	3.7	3.6	12/14	2.9	12/7	6.0
	1/27	3.8	4.0	2/1	4.7	12/9	7.4
	2/15	3.6	4.9	2/3	3.2	12/12	7.5
	2/22	3.5	4.0	2/6	3.8	12/14	6.6
	2/24	2.7	2.8	2/27	2.6	1/9	5.3
				3/1	3.1	1/16	3.7
				3/3	5.0	1/27	8.2
	11/28	3.7	2.2	12/5	0	2/1	12.4
	11/30	3.5	3.3	12/7	3.7	2/3	6.4
	12/2	2.9	3.1	12/9	0	2/6	8.7
	1/9	5.2	5.5	12/12	0	2/15	6.2
2	1/16	4.1	-	12/14	2.2	2/22	6.7
	1/27	4.0	4.5	2/1	6.4	2/24	5.4
	2/15	4.6	4.1	2/3	4.6	2/27	7.0
	2/22	4.5	4.0	2/6	6.1	3/1	5.7
	2/24	3.6	2.4	2/27	3.1	3/3	9.2
				3/1	3.2		
				3/3	5.0		

TABLE A-8. KJELDAHL NITROGEN, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	2.2	8.4	12/5	2.8	11/28	22.1
	11/30	4.9	6.9	12/7	13.6	11/30	25.4
	12/2	8.6	9.4	12/9	16.1	12/2	30.6
	1/9	18.8	13.5	12/12	6.7	12/5	28.4
3	1/16	6.4	9.4	12/14	12.5	12/7	23.3
	1/27	12.8	15.1	2/1	17.5	12/9	25.6
	2/15	11.5	16.4	2/3	19.2	12/12	24.9
	2/22	15.4	16.5	2/6	17.4	12/14	22.3
	2/24	12.8	13.5	2/27	14.5	1/9	23.4
				3/1	15.3	1/16	9.7
				3/3	19.2	1/27	24.4
	11/28	10.0	2.2	12/5	5.9	2/1	27.6
	11/30	8.3	5.0	12/7	16.3	2/3	25.0
	12/2	7.8	6.0	12/9	9.0	2/6	27.4
	1/9	15.9	19.0	12/12	9.5	2/15	21.7
2	1/16	10.4	-	12/14	12.6	2/22	21.4
	1/27	16.6	17.6	2/1	21.7	2/24	21.9
	2/15	17.2	15.6	2/3	22.4	2/27	23.1
	2/22	19.2	18.4	2/6	26.8	3/1	20.7
	2/24	16.8	13.7	2/27	17.7	3/3	27.5
				3/1	17.7		
				3/3	21.7		

TABLE A-9 COD, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	109	126	12/5	76	11/28	615
	11/30	111	114	12/7	115	11/30	229
	12/2	103	87	12/9	183	12/2	416
	1/9	130	111	12/12	99	12/5	205
3	1/16	126	118	12/14	86	12/7	269
	1/27	107	106	2/1	100	12/9	358
	2/15	103	144	2/3	115	12/12	392
	2/22	104	100	2/6	76	12/14	265
	2/24	95	99	2/27	79	1/9	178
				3/1	71	1/16	228
				3/3	121	1/27	378
	11/28	158	105	12/5	80	2/1	253
	11/30	171	111	12/7	130	2/3	285
	12/2	76	76	12/9	125	2/6	397
	1/9	133	148	12/12	103	2/15	243
2	1/16	138	-	12/14	128	2/22	336
	1/27	134	142	2/1	134	2/24	209
	2/15	148	122	2/3	150	2/27	228
	2/22	128	112	2/6	168	3/1	235
	2/24	138	95	2/27	83	3/3	301
				3/1	102		
				3/3	156		

TABLE A-10. TURBIDITY, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	10	14	12/5	7	11/28	67
	11/30	27	21	12/7	21	11/30	65
	12/2	28	21	12/9	35	12/2	105
	1/9	25	22	12/12	14	1/9	32
3	2/15	22	25	12/14	18	2/15	37
	2/22	17	15	2/27	9	2/22	58
	2/24	13	14	3/1	12	2/24	37
				3/3	22	2/27	50
						3/1	45
						3/3	53
	11/28	17	8	12/5	9		
	11/30	18	19	12/7	27		
	12/2	17	19	12/9	23		
	1/9	20	30	12/12	20		
2	2/15	27	22	12/14	22		
	2/22	21	17	2/27	10		
	2/24	19	8	3/1	16		
				3/3	28		

TABLE A-11. DISSOLVED SOLIDS, RAW SYSTEM WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	11/28	454	426	12/5	376	11/28	462
	11/30	412	391	12/7	320	11/30	518
	12/2	362	369	12/9	511	12/2	469
	1/9	426	440	12/12	412	12/5	440
3	1/16	462	405	12/14	348	12/7	376
	1/27	497	483	2/1	483	12/9	419
	2/15	476	490	2/3	362	12/12	462
	2/22	440	397	2/6	359	12/14	405
	2/24	440	454	2/27	440	1/9	398
				3/1	440	1/16	270
				3/3	454	1/27	440
	11/28	433	426	12/5	390	2/1	462
	11/30	391	383	12/7	312	2/3	362
	12/2	355	348	12/9	511	2/6	370
	1/9	469	426	12/12	426	2/15	476
2	1/16	497	-	12/14	369	2/22	405
	1/27	483	447	2/1	476	2/24	426
	2/15	490	476	2/3	348	2/27	440
	2/22	397	426	2/6	351	3/1	426
	2/24	447	461	2/27	462	3/3	411
				3/1	440		
				3/3	447		

TABLE A-12. pH, RAW SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff.	TROUGH Eff.	Date	BOOM Eff.	Date	Infl.
	11/28	8.1	7.8	12/5	7.6	11/28	7.5
	11/30	7.9	7.4	12/7	7.8	11/30	7.3
	12/2	7.7	7.3	12/9	7.7	12/2	7.3
	1/9	7.6	7.3	12/12	7.6	12/5	7.2
3	1/16	7.8	7.7	12/14	7.7	12/7	7.2
	1/27	8.1	8.2	2/1	7.8	12/9	7.3
	2/15	7.6	7.4	2/3	7.6	12/12	7.3
	2/22	7.4	7.2	2/6	7.7	12/14	7.4
	2/24	7.4	7.3	2/27	7.6	1/9	7.4
				3/1	7.5	1/16	7.1
				3/3	7.6	1/27	8.0
	11/28	7.9	8.1	12/5	7.6	2/1	7.3
	11/30	7.7	7.8	12/7	7.8	2/3	7.4
	12/2	7.7	7.7	12/9	7.8	2/6	7.4
	1/9	7.6	7.7	12/12	7.6	2/15	7.6
2	1/16	7.8	-	12/14	7.7	2/22	7.3
	1/27	8.7	8.8	2/1	7.6	2/24	7.3
	2/15	7.5	7.6	2/3	7.5	2/27	7.3
	2/22	7.4	7.4	2/6	7.6	3/1	7.2
	2/24	7.5	7.5	2/27	7.6	3/3	7.1
				3/1	7.5		
				3/3	7.5		

APPENDIX B

TABLE B-1. BOD, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l
	3/20	32	43	3/29	21
	3/22	34	44	3/31	21
	3/24	15	21	5/19	8
	5/3	29	23	5/22	15
	5/5	17	18	5/24	5
	5/31	15	18	7/19	6
	6/2	20	35	7/24	16
	6/5	16	25	7/27	7
	7/28	12	28	8/4	5
3	7/31	6	20	8/7	5
	8/2	11	26	8/9	7
	8/18	14	30	8/25	15
	8/21	10	15	8/28	4
	8/23	10	17	8/30	5
	9/15	13	13	9/1	8
	9/20	6	10	9/25	2
	9/22	6	9	9/27	2
	10/11	8	11	10/2	3
	10/18	5	5		
	10/20	6	9		
	3/20	45	43	3/29	23
	3/22	49	-	3/31	20
	3/24	26	22	5/19	8
	5/3	31	37	5/22	14
	5/5	22	25	5/24	9
	5/31	11	13	7/19	7
	6/2	31	34	7/24	11
	6/5	27	37	7/27	7
	7/28	11	18	8/4	9
	7/31	6	9	8/7	4
2	8/2	10	10	8/9	4
	8/18	24	20	8/25	12
	8/21	12	16	8/28	4
	8/23	11	22	8/30	4
	9/15	5	6	9/1	5
	9/20	10	6	9/25	3
	9/22	8	5	9/27	3
	10/11	8	10	10/2	3
	10/18	9	7		
	10/20	8	8		

Date	Infl. mg/l
3/20	136
3/22	150
3/24	123
3/29	130
3/31	138
5/3	92
5/5	76
5/19	160
5/22	129
5/24	136
5/31	90
6/2	154
6/5	134
7/19	140
7/24	88
7/27	146
7/28	134
7/31	96
8/2	98
8/4	130
8/7	119
8/9	127
8/18	153
8/21	144
8/23	118
8/25	122
8/28	142
8/30	147
9/1	152
9/15	100
9/20	93
9/22	91
9/25	116
9/27	122
10/2	61
10/11	46
10/18	40
10/20	71

TABLE B-2. SUSPENDED SOLIDS, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	3/20	19	14	3/29	2	3/20	94
	3/22	17	12	3/31	2	3/22	96
	3/24	15	14	5/19	6	3/24	195
	5/3	8	8	5/22	5	3/29	70
	5/5	10	14	5/24	4	3/31	110
	6/5	6	11	7/19	2	5/3	210
	7/28	6	9	7/24	9	5/5	66
	7/31	7	7	7/27	7	5/19	360
	8/2	7	11	8/4	4	5/22	155
3	8/18	28	24	8/7	2	5/24	38
	8/21	6	9	8/9	2	6/5	28
	8/23	8	11	8/25	6	7/19	123
	9/15	1	5	8/28	8	7/24	70
	9/20	3	2	8/30	3	7/27	37
	9/22	1	1	9/1	2	7/28	74
	10/11	17	11	9/25	2	7/31	78
	10/18	6	14	9/27	1	8/2	100
	10/20	5	14	10/2	2	8/4	150
				10/23	2	8/7	100
				10/25	2	8/9	66
				10/27	2	8/18	86
	3/20	2	4	3/29	2	8/21	105
	3/22	16	-	3/31	3	8/23	88
	3/24	5	3	5/19	4	8/25	105
	5/3	20	3	5/22	4	8/28	78
	5/5	3	4	5/24	5	8/30	85
	6/5	3	12	7/19	8	9/1	83
	7/28	5	5	7/24	7	9/15	30
	7/31	5	5	7/27	10	9/20	118
	8/2	5	5	8/4	3	9/22	40
2	8/18	12	15	8/7	2	9/25	148
	8/21	2	8	8/9	1	9/27	140
	8/23	3	13	8/25	5	10/2	195
	9/15	1	1	8/28	8	10/11	82
	9/20	4	3	8/30	2	10/18	68
	9/22	1	1	9/1	2	10/20	60
	10/11	12	11	9/25	3	10/23	62
	10/18	11	15	9/27	4	10/25	249
	10/20	5	5	10/2	1	10/27	62
				10/23	2		
				10/25	2		
				10/27	2		

TABLE B-3. FECAL COLIFORM PER 100 ml, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. $x10^6$	TROUGH Eff. $x10^6$	Date	BOOM Eff. $x10^6$	Date	Infl. $x10^6$
	3/20	2.0	2.3	3/29	1.3	3/20	6.9
	5/3	1.8	2.0	7/19	0.55	3/29	0.03
	5/31	3.9	3.6	7/24	6.0	5/3	0.80
	6/2	3.5	2.0	7/27	0.93	5/31	3.4
	6/5	2.2	2.2	8/4	0.11	6/2	7.4
	7/31	0.14	1.1	8/7	0.65	6/5	7.0
	8/2	0.40	0.23	8/9	0.50	7/19	1.5
	8/21	1.5	5.0	8/28	0.30	7/24	1.5
	8/23	0.40	0.57	8/30	1.0	7/27	8.0
3	9/15	0.30	0.37	9/1	0.95	7/31	3.0
	9/22	0.31	0.89	9/25	4.2	8/2	0.45
	10/18	0.79	0.93	9/27	0.20	8/4	0.31
				10/2	0.84	8/7	1.2
				10/25	0.003	8/9	1.2
				10/27	0.01	8/21	25
	3/20	2.5	1.9	3/29	1.9	8/23	10
	5/3	0.11	2.8	7/19	0.65	8/28	1.5
	5/31	1.6	0.74	7/24	1.3	8/30	2.0
	6/2	0.73	1.5	7/27	0.18	9/1	1.2
	6/5	1.3	2.7	8/4	0.10	9/15	8.2
	7/31	4.0	0.81	8/7	0.02	9/22	4.9
	8/2	0.23	0.37	8/9	0.20	9/25	2.9
2	8/21	2.2	2.2	8/28	1.3	9/27	4.3
	8/23	0.11	0.21	8/30	1.0	10/2	9.6
	9/15	0.77	0.72	9/1	0.08	10/18	2.6
	9/22	0.51	0.50	9/25	0.17	10/23	0.77
	10/18	0.01	0.23	9/27	0.20	10/25	23
				10/2	0.60	10/27	0.89
				10/23	0.06		
				10/25	0.001		
				10/27	0.02		

TABLE B-4. TOTAL PHOSPHORUS, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	DATE	RISER Eff. mg/l	TROUGH Eff. mg/l	DATE	BOOM Eff. mg/l	Date	Infl. mg/l
	3/20	9.1	9.6	3/29	8.4	3/20	8.2
	3/22	9.3	10.9	3/31	8.6	3/22	7.5
	3/24	6.1	4.6	5/19	8.3	3/24	6.0
	5/3	5.7	5.2	5/22	7.4	3/29	7.4
	5/5	8.3	8.5	5/24	7.9	3/31	8.4
	5/31	5.2	6.1	7/19	11.3	5/3	8.9
	6/2	7.9	10.0	7/24	9.2	5/5	9.0
	6/5	6.1	7.0	7/27	6.1	5/19	8.3
	7/28	9.6	10.5	8/4	11.3	5/22	5.2
3	7/31	7.9	9.6	8/7	10.2	5/24	8.3
	8/2	8.3	10.5	8/9	9.6	5/31	5.2
	8/18	7.4	7.9	8/25	10.5	6/2	7.9
	8/21	7.0	7.0	8/28	10.0	6/5	7.9
	8/23	8.3	8.4	8/30	9.2	7/19	11.3
	9/15	9.6	13.5	9/1	10.0	7/24	9.6
	9/20	9.6	8.7	9/25	10.1	7/27	7.9
	9/22	7.9	7.9	9/27	9.8	7/28	7.4
	10/11	8.8	7.8	10/2	11.0	7/31	7.9
	10/18	7.4	8.3	10/23	7.4	8/2	7.4
	10/20	8.7	8.7	10/25	9.2	8/4	8.7
				10/27	8.3	8/7	9.6
	3/20	9.1	8.9	3/29	8.0	8/9	9.2
	3/22	7.8	-	3/31	8.8	8/18	9.6
	3/24	6.0	6.8	5/19	8.7	8/21	9.2
	5/3	7.4	7.4	5/22	7.0	8/23	10.0
	5/5	8.7	9.2	5/24	7.9	8/25	10.0
	5/31	6.6	6.6	7/19	11.3	8/28	10.5
	6/2	9.6	10.0	7/24	9.2	8/30	8.7
	6/5	9.2	9.6	7/27	6.6	9/1	10.9
	7/28	9.6	9.6	8/4	11.3	9/15	7.9
2	7/31	8.7	8.7	8/7	10.0	9/20	8.3
	8/2	8.7	8.3	8/9	9.6	9/22	7.9
	8/18	9.2	9.6	8/25	10.4	9/25	7.5
	8/21	7.9	8.7	8/28	10.5	9/27	6.8
	8/23	9.6	10.5	8/30	8.7	10/2	7.4
	9/15	9.2	9.2	9/1	10.5	10/11	6.9
	9/20	10.5	10.0	9/25	10.0	10/18	7.0
	9/22	9.6	10.0	9/27	9.4	10/20	7.9
	10/11	8.7	8.8	10/2	10.5	10/23	4.1
	10/18	7.9	8.3	10/23	8.7	10/25	11.8
	10/20	9.6	9.6	10/25	8.3	10/27	10.9
				10/27	8.8		

TABLE B-5. NITRATE NITROGEN, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	3/20	<0.05	<0.05	3/29	0.90	3/20	<0.05
	3/22	<0.05	<0.05	3/31	0.84	3/22	<0.05
	3/24	<0.05	0.08	5/19	0.29	3/24	<0.05
	5/3	0.49	0.51	5/22	0.32	3/29	<0.05
	5/5	<0.05	0.11	5/24	0.08	3/31	<0.05
	5/31	<0.05	<0.05	7/19	0.67	5/3	<0.05
3	6/2	<0.05	<0.05	7/24	1.11	5/5	<0.05
	6/5	<0.05	<0.05	7/27	1.27	5/19	<0.05
	7/28	0.24	0.17	8/4	1.39	5/22	<0.05
	7/31	0.22	0.11	8/7	1.39	5/24	<0.05
	8/2	0.28	0.20	8/9	1.54	5/31	<0.05
	8/18	0.22	0.18	8/25	1.09	6/2	<0.05
	8/21	0.44	0.26	8/28	2.00	6/5	<0.05
	8/23	0.31	0.33	8/30	1.73	7/19	<0.05
	3/20	0.12	0.07	3/29	0.65	7/24	<0.05
	3/22	<0.05	-	3/31	0.10	7/27	<0.05
	3/24	<0.05	0.10	5/19	0.11	7/28	<0.05
	5/3	0.46	0.81	5/22	<0.05	7/31	<0.05
	5/5	<0.05	<0.05	5/24	<0.05	8/2	<0.05
	5/31	<0.05	-	7/19	0.60	8/4	<0.05
2	6/2	<0.05	<0.05	7/24	0.88	8/7	<0.05
	6/5	<0.05	<0.05	7/27	0.47	8/9	<0.05
	7/28	0.18	0.33	8/4	0.66	8/18	<0.05
	7/31	0.18	0.26	8/7	1.16	8/21	<0.05
	8/2	0.18	0.49	8/9	1.11	8/23	<0.05
	8/18	0.22	0.22	8/25	1.18	8/25	<0.05
	8/21	0.38	0.22	8/28	1.20	8/28	<0.05
	8/23	0.54	0.18	8/30	1.13	8/30	<0.05

TABLE B-6. AMMONIA NITROGEN, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	3/20	10.1	9.9	3/29	5.4	3/20	15.9
	3/22	10.9	10.1	3/31	5.1	3/22	16.5
	3/24	9.9	9.8	5/19	2.0	3/24	10.7
	5/3	3.6	3.3	5/22	1.0	3/29	14.4
	5/5	5.3	6.8	5/24	1.6	3/31	18.6
	5/31	2.6	4.3	7/19	7.0	5/3	6.0
	6/2	5.2	9.9	7/24	8.9	5/5	6.7
	6/5	4.3	8.3	7/27	2.1	5/19	19.0
	7/28	3.6	7.8	8/4	3.7	5/22	10.9
3	7/31	2.9	9.5	8/7	5.4	5/24	19.0
	8/2	4.6	9.8	8/9	4.5	5/31	10.6
	8/18	3.7	9.9	8/25	8.4	6/2	17.2
	8/21	4.8	7.2	8/28	0.2	6/5	18.5
	8/23	3.3	4.0	8/30	0.5	7/19	20.6
	9/15	3.0	9.6	9/1	2.8	7/24	19.9
	9/20	2.9	8.7	9/25	<0.1	7/27	17.2
	9/22	2.4	4.9	9/27	1.4	7/28	17.6
	10/11	1.2	4.7	10/2	2.0	7/31	19.6
	10/18	0.1	4.5	10/23	1.9	8/2	18.9
	10/20	<0.1	4.5	10/25	0.4	8/4	20.3
				10/27	0.5	8/7	20.1
	3/20	9.2	9.2	3/29	5.5	8/9	19.4
	3/22	11.7	-	3/31	6.9	8/18	19.6
	3/24	9.3	10.3	5/19	4.5	8/21	19.0
	5/3	5.3	4.8	5/22	2.2	8/23	16.0
	5/5	7.2	7.5	5/24	4.3	8/25	16.4
	5/31	3.9	-	7/19	7.2	8/28	19.3
	6/2	7.8	8.7	7/24	5.7	8/30	17.5
	6/5	7.5	13.0	7/27	2.1	9/1	18.4
	7/28	5.3	6.6	8/4	4.8	9/15	18.4
2	7/31	6.2	6.3	8/7	4.5	9/20	16.1
	8/2	6.9	6.4	8/9	1.0	9/22	16.7
	8/18	9.3	8.6	8/25	8.7	9/25	20.0
	8/21	6.9	10.2	8/28	1.1	9/27	18.4
	8/23	3.7	10.4	8/30	<0.1	10/2	17.1
	9/15	5.0	3.0	9/1	<0.1	10/11	15.3
	9/20	6.2	3.9	9/25	<0.1	10/18	14.7
	9/22	5.8	2.7	9/27	2.7	10/20	16.1
	10/11	6.4	2.6	10/2	4.4	10/23	13.8
	10/18	9.2	6.2	10/23	1.2	10/25	17.8
	10/20	5.6	4.3	10/25	1.9	10/27	17.1
				10/27	2.2		

TABLE B-7. ORGANIC NITROGEN, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	3/20	4.0	3.7	3/29	2.5	3/20	7.4
	3/22	5.1	3.9	3/31	2.7	3/22	7.7
	3/24	3.7	3.7	5/19	2.4	3/24	7.9
	5/3	4.3	3.9	5/22	1.9	3/29	7.2
	5/5	5.4	4.8	5/24	2.2	3/31	10.4
	5/31	3.5	3.7	7/19	3.0	5/3	5.2
	6/2	3.5	4.3	7/24	5.2	5/5	5.2
	6/5	4.4	5.1	7/27	2.4	5/19	8.4
	7/28	3.8	6.6	8/4	3.4	5/22	4.9
3	7/31	4.5	5.2	8/7	2.5	5/24	6.4
	8/2	2.7	5.0	8/9	3.7	5/31	5.0
	8/18	4.8	6.9	8/25	4.7	6/2	8.2
	8/21	3.3	3.7	8/28	2.8	6/5	6.3
	8/23	3.4	5.0	8/30	2.9	7/19	12.9
	9/15	3.9	7.3	9/1	3.5	7/24	8.3
	9/20	3.5	3.1	9/25	3.2	7/27	8.9
	9/22	2.9	4.6	9/27	2.7	7/28	8.3
	10/11	6.5	6.1	10/2	3.5	7/31	7.0
	10/18	3.1	4.6	10/23	1.7	8/2	8.3
	10/20	2.9	4.6	10/25	1.9	8/4	9.4
				10/27	2.1	8/7	8.5
	3/20	2.4	3.6	3/29	2.8	8/9	8.8
	3/22	4.3	-	3/31	3.4	8/18	9.9
	3/24	3.4	3.7	5/19	2.8	8/21	8.8
	5/3	5.2	5.6	5/22	2.4	8/23	11.2
	5/5	5.6	6.2	5/24	2.5	8/25	10.1
	5/31	3.2	-	7/19	2.8	8/28	8.4
	6/2	4.1	5.4	7/24	3.9	8/30	8.2
	6/5	5.6	6.1	7/27	3.1	9/1	8.3
	7/28	3.9	4.8	8/4	4.6	9/15	7.5
2	7/31	3.9	5.0	8/7	2.6	9/20	9.2
	8/2	3.5	3.4	8/9	2.8	9/22	7.3
	8/18	6.3	5.8	8/25	5.3	9/25	11.0
	8/21	4.4	3.7	8/28	3.1	9/27	10.4
	8/23	3.9	4.8	8/30	2.7	10/2	10.2
	9/15	4.1	3.9	9/1	2.9	10/11	6.4
	9/20	5.1	4.5	9/25	3.9	10/18	7.6
	9/22	3.7	2.8	9/27	2.1	10/20	6.4
	10/11	5.8	6.5	10/2	4.2	10/23	5.4
	10/18	7.6	5.8	10/23	1.6	10/25	20.5
	10/20	6.6	8.9	10/25	3.1	10/27	11.6
				10/27	3.4		

TABLE B-8. KJELDAHL NITROGEN, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	3/20	14.1	13.7	3/29	7.9	3/20	23.4
	3/22	16.0	14.0	3/31	7.8	3/22	24.2
	3/24	13.5	13.5	5/19	4.4	3/24	18.6
	5/3	7.8	7.2	5/22	2.9	3/29	21.7
	5/5	10.8	11.6	5/24	3.9	3/31	29.0
	5/31	6.1	8.0	7/19	10.0	5/3	11.2
	6/2	8.7	14.2	7/24	14.1	5/5	11.9
	6/5	8.7	13.4	7/27	4.5	5/19	27.4
	7/28	7.4	14.4	8/4	7.1	5/22	15.8
3	7/31	7.4	14.7	8/7	7.9	5/24	25.3
	8/2	7.2	14.8	8/9	8.2	5/31	15.6
	8/18	8.5	16.8	8/25	13.1	6/2	25.4
	8/21	8.0	10.9	8/28	3.0	6/5	24.8
	8/23	6.6	9.0	8/30	3.4	7/19	33.5
	9/15	6.9	16.9	9/1	6.3	7/24	28.1
	9/20	6.4	11.8	9/25	3.3	7/27	26.0
	9/22	5.3	9.5	9/27	4.1	7/28	25.9
	10/11	7.7	10.8	10/2	5.5	7/31	26.6
	10/18	3.2	9.1	10/23	3.6	8/2	27.2
	10/20	3.0	9.1	10/25	2.3	8/4	29.8
				10/27	2.6	8/7	28.6
	3/20	11.5	12.8	3/29	8.4	8/9	28.2
	3/22	16.0	-	3/31	10.4	8/18	29.4
	3/24	12.8	14.0	5/19	7.2	8/21	27.9
	5/3	10.6	10.4	5/22	4.6	8/23	27.2
	5/5	12.8	13.7	5/24	6.8	8/25	26.5
	5/31	7.2	-	7/19	10.0	8/28	27.7
	6/2	11.9	14.1	7/24	9.6	8/30	25.7
	6/5	13.1	19.1	7/27	5.2	9/1	26.7
	7/28	9.2	11.4	8/4	9.4	9/15	25.9
2	7/31	10.1	11.3	8/7	7.1	9/20	25.3
	8/2	10.4	9.8	8/9	3.8	9/22	24.0
	8/18	15.6	14.4	8/25	14.0	9/25	31.0
	8/21	11.2	13.9	8/28	4.2	9/27	28.8
	8/23	7.6	15.2	8/30	2.8	10/2	27.3
	9/15	9.1	6.9	9/1	3.0	10/11	21.7
	9/20	11.3	8.4	9/25	4.0	10/18	22.3
	9/22	9.5	5.5	9/27	4.8	10/20	22.5
	10/11	12.2	9.1	10/2	8.6	10/23	19.2
	10/18	22.3	12.0	10/23	2.8	10/25	38.3
	10/20	12.2	13.2	10/25	5.0	10/27	28.7
				10/27	5.6		

TABLE B-9 COD, RAW SYSTEM, SUMMER
APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Eff. mg/l	Date	Infl. mg/l
	3/20	112	154	3/29	77	3/20	317
	3/22	131	131	3/31	61	3/22	305
	3/24	84	80	5/19	60	3/24	330
	5/3	130	111	5/22	41	3/29	286
	5/5	112	124	5/24	89	3/31	355
	5/31	102	110	7/19	80	5/3	181
	6/2	94	129	7/24	91	5/5	181
	6/5	97	105	7/27	63	5/19	389
	7/28	82	113	8/4	85	5/22	181
	7/31	86	109	8/7	50	5/24	331
3	8/2	88	106	8/9	60	5/31	213
	8/18	83	111	8/25	47	6/2	383
	8/21	67	86	8/28	65	6/5	269
	8/23	59	74	8/30	47	7/19	433
	9/15	75	97	9/1	54	7/24	268
	3/20	81	120	3/29	116	7/27	320
	3/22	159	-	3/31	80	7/28	276
	3/24	107	88	5/19	68	7/31	253
	5/3	138	138	5/22	48	8/2	260
	5/5	127	131	5/24	74	8/4	358
	5/31	102	94	7/19	80	8/7	310
2	6/2	113	121	7/24	103	8/9	295
	6/5	144	156	7/27	63	8/18	368
	7/28	89	74	8/4	89	8/21	318
	7/31	82	78	8/7	50	8/23	307
	8/2	86	81	8/9	53	8/25	315
	8/18	103	95	8/25	48	8/28	369
	8/21	78	86	8/28	73	8/30	310
	8/23	59	86	8/30	47	9/1	323
	9/15	86	78	9/1	54	9/15	250

TABLE B-10. TURBIDITY, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	3/20	21	30	3/29	6	3/20	72
	3/22	20	23	3/31	8	3/22	63
	3/24	22	24	5/19	3	3/24	115
	5/3	57	24	5/22	3	3/29	49
	5/5	12	19	5/24	7	3/31	74
	5/31	10	12	7/19	4	5/3	98
	6/2	12	15	7/24	9	5/5	58
	6/5	12	16	7/27	4	5/19	67
	7/28	9	13	8/4	5	5/22	44
3	7/31	7	12	8/7	6	5/24	56
	8/2	12	15	8/9	7	5/31	45
	8/18	12	13	8/25	7	6/2	67
	8/21	7	8	8/28	5	6/5	52
	8/23	7	11	8/30	3	7/19	74
	9/15	6	13	9/1	7	7/24	45
	9/20	5	8	9/25	3	7/27	85
	9/22	6	7	9/27	3	7/28	57
	10/11	62	16	10/2	3	7/31	50
	10/18	4	4	10/23	3	8/2	54
	10/20	5	6	10/25	2	8/4	85
				10/27	2	8/7	74
	3/20	11	17	3/29	13	8/9	62
	3/22	23	-	3/31	11	8/18	74
	3/24	28	24	5/19	3	8/21	67
	5/3	14	22	5/22	3	8/23	62
	5/5	10	12	5/24	4	8/25	67
	5/31	8	8	7/19	5	8/28	70
	6/2	13	14	7/24	7	8/30	69
	6/5	15	17	7/27	4	9/1	77
	7/28	7	8	8/4	5	9/15	50
2	7/31	7	7	8/7	5	9/20	43
	8/2	8	8	8/9	4	9/22	62
	8/18	11	11	8/25	5	9/25	67
	8/21	8	8	8/28	3	9/27	63
	8/23	7	11	8/30	3	10/2	59
	9/15	6	6	9/1	4	10/11	48
	9/20	4	4	9/25	3	10/18	40
	9/22	6	5	9/27	4	10/20	49
	10/11	15	13	10/2	4	10/23	35
	10/18	10	8	10/23	3	10/25	165
	10/20	7	8	10/25	3	10/27	50
				10/27	3		

TABLE B-11. DISSOLVED SOLIDS, RAW SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	BOOM Eff. mg/l	Date	Infl. mg/l
	3/20	469	497	3/29	419	3/20	462
	3/22	440	411	3/31	355	3/22	404
	3/24	334	327	5/19	447	3/24	348
	5/3	3/21	277	5/22	3/21	3/29	405
	5/5	355	355	5/24	462	3/31	383
	5/31	483	476	7/19	490	5/3	284
	6/2	553	560	7/24	476	5/5	248
	6/5	518	511	7/27	355	5/19	483
	7/28	518	490	8/4	447	5/22	447
3	7/31	511	482	8/7	419	5/24	525
	8/2	511	470	8/9	411	5/31	568
	8/18	476	476	8/25	482	6/2	603
	8/21	546	497	8/28	404	6/5	546
	8/23	497	454	8/30	426	7/19	497
	9/15	497	461	9/1	447	7/24	497
	9/20	468	482	9/25	447	7/27	433
	9/22	454	447	9/27	454	7/28	454
	10/11	440	418	10/2	454	7/31	454
	10/18	468	440	10/23	298	8/2	468
	10/20	418	440	10/25	397	8/4	476
				10/27	390	8/7	469
	3/20	469	462	3/29	405	8/9	461
	3/22	418	-	3/31	364	8/18	468
	3/24	348	327	5/19	454	8/21	482
	5/3	320	312	5/22	355	8/23	461
	5/5	369	390	5/24	454	8/25	447
	5/31	539	539	7/19	490	8/28	497
	6/2	546	560	7/24	462	8/30	447
	6/5	546	539	7/27	355	9/1	489
	7/28	497	490	8/4	454	9/15	461
	7/31	482	482	8/7	419	9/20	454
2	8/2	482	468	8/9	411	9/22	433
	8/18	483	476	8/25	461	9/25	525
	8/21	532	547	8/28	426	9/27	525
	8/23	447	468	8/30	440	10/2	518
	9/15	475	497	9/1	482	10/11	390
	9/20	482	468	9/25	447	10/18	411
	9/22	440	433	9/27	454	10/20	411
	10/11	411	411	10/2	454	10/23	397
	10/18	440	454	10/23	319	10/25	440
	10/20	411	404	10/25	404	10/27	461
				10/27	404		

TABLE B-12. pH, RAW SYSTEM, SUMMER
APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff.	TROUGH Eff.	Date	BOOM Eff.	Date	Infl.
	3/20	7.6	7.1	3/29	7.5	3/20	7.3
	3/22	7.7	7.4	3/31	7.5	3/22	7.3
	3/24	7.5	7.3	5/19	7.5	3/24	7.3
	5/3	7.4	7.1	5/22	7.6	3/29	7.3
	5/5	7.4	7.4	5/24	7.7	3/31	7.1
	5/31	7.7	7.5	7/19	7.6	5/3	7.1
	6/2	7.7	7.6	7/24	7.6	5/5	7.2
	6/5	7.7	7.5	7/27	7.2	5/19	7.1
	7/28	7.5	7.4	8/4	7.4	5/22	7.3
3	7/31	7.5	7.3	8/7	7.2	5/24	7.0
	8/2	7.5	7.3	8/9	7.3	5/31	7.3
	8/18	7.4	7.2	8/25	7.3	6/2	7.3
	8/21	7.4	7.4	8/28	7.3	6/5	7.3
	8/23	7.5	7.3	8/30	7.4	7/19	7.2
	9/15	7.6	7.4	9/1	7.4	7/24	7.3
	9/20	7.6	7.4	9/25	7.6	7/27	7.1
	9/22	7.6	7.4	10/2	7.4	7/28	7.2
	10/11	7.6	7.2	10/23	7.2	7/31	7.2
	10/18	7.7	7.3	10/25	7.2	8/2	7.3
	10/20	7.6	7.4	10/27	7.3	8/4	7.2
	3/20	7.5	7.4	3/29	7.4	8/7	7.2
	3/22	7.5	-	3/31	7.5	8/9	7.3
	3/24	7.4	7.4	5/19	7.5	8/18	7.3
	5/3	7.3	7.3	5/22	7.5	8/21	7.3
	5/5	7.4	7.4	5/24	7.6	8/23	7.2
	5/31	7.6	7.6	7/19	7.7	8/25	7.2
	6/2	7.6	7.6	7/24	7.6	8/28	7.2
	6/5	7.6	7.6	7/27	7.3	8/30	7.2
	7/28	7.6	7.5	8/4	7.4	9/1	7.3
2	7/31	7.5	7.5	8/7	7.3	9/15	7.3
	8/2	7.5	7.5	8/9	7.4	9/20	7.3
	8/18	7.4	7.4	8/25	7.4	9/22	7.3
	8/21	7.5	7.4	8/28	7.4	9/25	7.2
	8/23	7.5	7.4	8/30	7.4	9/27	7.2
	9/15	7.5	7.6	9/1	7.5	10/2	7.3
	9/20	7.6	7.6	9/25	7.5	10/11	7.4
	9/22	7.5	7.6	9/27	7.5	10/18	7.4
	10/11	7.6	7.4	10/2	7.5	10/20	7.3
	10/18	7.7	7.7	10/23	7.3	10/23	7.2
	10/20	7.5	7.5	10/25	7.4	10/25	7.1
				10/27	7.4	10/27	7.2

APPENDIX C

TABLE C-1. BOD, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	12/5	11	13	12/5	26
	12/7	-	25	12/7	24
	12/9	19	21	12/9	21
	12/14	25	25	12/14	14
3	2/1	12	12	12/21	13
	2/3	10	10	12/23	12
	2/6	8	10	1/4	10
	2/27	12	17	1/6	11
	3/1	12	18	2/1	14
	3/3	15	21	2/3	11
				2/6	12
	12/21	6	8	2/8	16
	12/23	13	12	2/10	14
	1/4	7	6	2/13	17
	1/6	11	11	2/27	21
2	2/8	11	12	3/1	25
	2/10	9	8	3/3	25
	2/13	11	9	3/6	18
	3/6	10	11	3/8	7
	3/8	8	9	3/10	12
	3/10	7	8		

TABLE C-2. SUSPENDED SOLIDS, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date.	Infl. mg/l
	12/5	9	14	12/5	24
	12/7	-	34	12/7	42
	12/9	26	44	12/9	72
	12/14	28	32	12/14	69
3	2/1	10	10	12/21	18
	2/3	9	11	1/4	3
	2/6	13	14	1/6	18
	2/27	15	15	2/1	14
	3/1	9	15	2/3	12
	3/3	22	10	2/6	15
				2/8	29
	12/21	4	4	2/10	24
	1/4	3	3	2/13	30
	1/6	6	8	2/27	16
	2/8	14	11	3/1	14
2	2/10	12	8	3/3	30
	2/13	4	3	3/6	20
	3/6	6	11	3/8	40
	3/8	8	7	3/10	5
	3/10	3	2		

TABLE C-3. FECAL COLIFORM PER 100 ml, SECONDARY SYSTEM WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1977

% Slope	Date	RISER Eff. $x10^4$	TROUGH Eff. $x10^4$	Date	Infl. $x10^4$
3	12/5	3.4	2.0	12/5	7.0
	12/7	-	6.2	12/7	6.8
	12/9	8.3	7.9	12/9	8.1
	12/14	2.9	1.4	12/14	3.2
	2/1	1.1	2.5	12/21	2.2
	2/3	5.6	7.2	12/23	3.1
	2/27	7.9	5.3	1/4	6.1
	3/1	2.0	19	2/1	3.3
				2/3	3.1
				2/8	2.3
				2/10	10
2	12/21	2.2	1.6	2/13	3.5
	12/23	2.7	2.1	2/27	8.3
	1/4	2.8	1.0	3/1	20
	2/8	2.6	5.6	3/6	1.2
	2/10	1.5	2.6	3/8	11
	2/13	8.3	1.2	3/10	2.6
	3/6	0.10	0.30		
	3/8	1.5	1.0		
	3/10	0.40	0.77		

TABLE C-4. TOTAL PHOSPHORUS, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	12/5	8.8	9.6	12/5	10.5
	12/7	-	10.0	12/7	10.8
	12/9	11.2	11.2	12/9	11.7
	12/14	10.8	10.9	12/14	11.0
3	2/1	10.9	11.3	12/21	10.3
	2/3	13.0	13.0	1/4	12.6
	2/6	10.7	13.3	1/6	13.6
	2/27	9.5	10.4	2/1	14.1
	3/1	8.3	9.5	2/3	13.9
	3/3	10.0	10.2	2/6	14.7
	12/21	9.0	9.0	2/8	13.5
	1/4	10.3	9.7	2/10	13.5
	1/6	12.7	11.8	2/13	12.2
	2/8	11.3	11.3	2/27	11.3
2	2/10	11.1	11.1	3/1	10.9
	2/13	11.0	9.0	3/3	10.6
	3/6	10.6	10.2	3/6	12.3
	3/8	9.6	9.2	3/8	10.9
	3/10	10.6	9.5	3/10	11.3

TABLE C-5. NITRATE NITROGEN, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	12/5	0.25	0.32	12/5	0.05
	12/7	-	0.13	12/7	0.06
	12/14	0.30	0.29	12/14	0.07
	2/1	0.33	0.09	12/21	0.10
3	2/3	0.16	0.09	12/23	0
	2/6	0.60	<0.05	2/1	0.21
	2/27	0.91	0.13	2/3	0.06
	3/1	1.14	0.15	2/6	<0.05
	3/3	0.86	0.11	2/8	<0.05
				2/10	0
				2/13	0.07
	12/21	0.40	0.30	2/27	<0.05
	12/23	0	0	3/1	<0.05
	2/8	0.88	0.43	3/3	<0.05
2	2/10	0.91	0.39	3/6	<0.05
	2/13	0.86	0.60	3/8	<0.05
	3/6	1.81	1.40	3/10	0.10
	3/8	1.34	0.84		
	3/10	1.34	0.84		

TABLE C-6. AMMONIA NITROGEN, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	12/5	2.0	4.7	12/5	8.4
	12/7	-	7.1	12/7	8.3
	12/9	3.7	7.9	12/9	9.0
	12/14	4.1	4.5	12/14	5.6
3	2/1	12.8	13.8	12/21	10.9
	2/3	17.1	15.5	12/23	12.5
	2/6	9.4	15.3	1/4	13.5
	2/27	9.4	13.7	1/6	13.6
	3/1	7.0	13.1	2/1	17.0
	3/3	10.3	12.9	2/3	16.8
				2/6	16.8
	12/21	9.2	7.1	2/8	15.6
	12/23	9.8	9.9	2/10	17.6
	1/4	7.8	4.7	2/13	13.1
	1/6	8.9	6.6	2/27	15.1
2	2/8	13.0	11.6	3/1	15.4
	2/10	12.9	12.3	3/3	16.1
	2/13	12.4	8.2	3/6	15.2
	3/6	12.2	10.6	3/8	15.9
	3/8	11.3	10.2	3/10	14.2
	3/10	12.4	11.6		

TABLE C-7 ORGANIC NITROGEN, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	12/5	0	4.8	12/5	5.7
	12/7	-	5.6	12/7	5.7
	12/9	0	6.6	12/9	6.5
	12/14	0.9	2.9	12/14	3.6
3	2/1	5.4	2.8	12/21	0
	2/3	3.8	3.7	12/23	0
	2/6	3.3	3.4	1/4	3.8
	2/27	3.0	3.7	1/6	0
	3/1	3.2	3.7	2/1	5.6
	3/3	5.7	3.2	2/3	4.0
				2/6	3.5
	12/21	0	0	2/8	3.6
	12/23	0	0	2/10	3.3
	1/4	4.1	3.9	2/13	3.8
	1/6	0	0	2/27	4.8
2	2/8	2.8	2.6	3/1	4.7
	2/10	2.8	2.1	3/3	5.6
	2/13	3.6	3.3	3/6	3.3
	3/6	3.7	3.8	3/8	4.4
	3/8	3.1	3.0	3/10	7.0
	3/10	4.0	3.7		

TABLE C-8 KJELDAHL NITROGEN, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/1	TROUGH Eff. mg/1	Date	Infl. mg/1
	12/5	2.0	9.5	12/5	14.0
	12/7	-	12.7	12/7	14.0
	12/9	3.7	14.4	12/9	15.5
	12/14	5.0	7.4	12/14	9.2
3	2/1	18.2	16.6	12/21	10.9
	2/3	20.9	19.1	12/23	12.5
	2/6	12.7	18.7	1/4	17.3
	2/27	12.3	17.5	1/6	13.6
	3/1	10.2	16.8	2/1	22.6
	3/3	15.9	16.1	2/3	20.8
				2/6	20.2
	12/21	9.2	7.1	2/8	19.2
	12/23	9.8	9.9	2/10	20.9
	1/4	11.9	8.6	2/13	16.9
	1/6	8.9	6.6	2/27	19.9
2	2/8	15.8	14.2	3/1	20.1
	2/10	15.8	14.4	3/3	21.7
	2/13	15.9	11.5	3/6	18.5
	3/6	15.9	14.4	3/8	20.3
	3/8	14.4	13.2	3/10	21.2
	3/10	16.4	15.3		

TABLE C-9. COD, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	12/5	117	121	12/5	117
	12/7	-	126	12/7	138
	12/9	136	152	12/9	152
	12/14	164	160	12/14	128
3	2/1	103	96	12/21	114
	2/3	108	108	12/23	123
	2/6	73	84	1/4	97
	2/27	91	91	1/6	84
	3/1	63	86	2/1	73
	3/3	98	109	2/3	108
				2/6	88
	12/21	98	110	2/8	123
	12/23	107	126	2/10	111
	1/4	97	104	2/13	107
	1/6	80	84	2/27	122
2	2/8	116	116	3/1	102
	2/10	100	96	3/3	129
	2/13	89	85	3/6	121
	3/6	82	86	3/8	97
	3/8	70	70	3/10	97
	3/10	73	73		

TABLE C-10. TURBIDITY, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	12/5	19	23	12/5	28
	12/7	-	29	12/7	33
	12/9	30	38	12/9	47
3	12/14	39	38	12/14	35
	2/27	15	20	12/21	42
	3/1	11	17	12/23	33
	3/3	16	19	1/4	26
				1/6	32
				2/8	24
				2/10	20
				2/13	35
	12/21	31	33	2/27	35
	12/23	30	32	3/1	28
	1/4	26	26	3/3	33
	1/6	27	26	3/6	33
2	2/8	23	25	3/8	32
	2/10	21	28	3/10	23
	2/13	28	33		
	3/6	15	13		
	3/8	10	14		
	3/10	13	13		

TABLE C-11. DISSOLVED SOLIDS, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	12/5	504	511	12/5	497
	12/7	-	383	12/7	355
	12/9	639	618	12/9	483
	12/14	476	476	12/14	469
3	2/1	660	646	12/21	554
	2/3	554	462	12/23	476
	2/6	550	458	1/4	653
	2/27	540	568	2/1	639
	3/1	518	553	2/23	462
	3/3	532	497	2/6	460
				2/8	544
	12/21	533	553	2/10	582
	12/23	462	497	2/13	540
	1/4	653	646	2/27	533
	2/8	540	553	3/1	525
2	2/10	540	554	3/3	447
	2/13	540	554	3/6	533
	3/6	504	511	3/8	497
	3/8	447	440	3/10	440
	3/10	397	397		

TABLE C-12. pH, SECONDARY SYSTEM, WINTER APPLICATION RATE, NOVEMBER 28, 1977 - MARCH 10, 1978

% Slope	Date	RISER Eff.	TROUGH Eff.	Date	Infl.
3	12/5	7.8	7.7	12/5	7.6
	12/7	-	7.7	12/7	7.8
	12/9	7.9	7.9	12/9	7.9
	12/14	7.8	7.9	12/14	7.7
	2/1	7.9	7.6	12/21	7.6
	2/3	7.6	7.5	12/23	7.6
	2/6	7.5	7.5	1/4	7.5
	2/27	7.6	7.5	1/6	7.7
	3/1	7.6	7.5	2/1	7.5
	3/3	7.5	7.3	2/3	7.5
				2/6	7.5
2	12/21	7.7	7.5	2/8	7.2
	12/23	7.7	7.6	2/10	7.5
	1/4	7.9	7.7	2/13	7.4
	1/6	8.0	8.0	2/27	7.4
	2/8	7.7	7.7	3/1	7.3
	2/10	7.5	7.5	3/3	7.5
	2/13	7.5	7.4	3/6	7.5
	3/6	7.5	7.4	3/8	7.3
	3/8	7.6	7.7	3/10	7.5
	3/10	7.6	7.4		

APPENDIX D

TABLE D-1. BOD, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/1	TROUGH Eff. mg/1	Date	Infl. mg/1
	3/29	24	28	3/29	35
	3/31	26	30	3/31	36
	5/10	20	22	4/3	37
	5/12	31	35	4/5	33
	5/17	29	32	4/7	25
	6/26	8	8	5/10	23
	6/28	7	9	5/12	35
	6/29	6	7	5/17	36
	7/19	27	33	5/19	46
3	7/21	24	37	5/22	39
	7/24	14	24	5/24	33
	8/11	20	26	6/17	12
	8/14	21	26	6/21	8
	8/16	25	31	6/23	10
	9/6	19	31	6/26	8
	9/8	21	24	6/28	9
	9/11	20	28	6/29	10
	10/4	13	25	7/19	35
	10/6	7	24	7/21	48
	10/9	12	20	7/24	27
	4/3	21	19	8/11	32
	4/5	23	21	8/14	30
	4/7	17	16	8/16	40
	5/19	37	35	9/6	28
	5/22	27	25	9/8	23
	5/24	24	20	9/11	32
	6/16	9	11	10/4	23
	6/21	6	6	10/6	22
	6/23	6	6	10/9	29
2	8/11	21	24		
	8/14	22	23		
	8/16	21	24		
	9/6	22	18		
	9/8	22	17		
	9/11	24	18		
	10/4	20	17		
	10/6	19	21		
	10/9	15	14		

TABLE D-2. SUSPENDED SOLIDS, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	3/29	30	39	3/29	60
	3/31	32	29	3/31	95
	5/10	34	48	4/3	62
	5/12	57	97	4/5	122
	5/17	97	143	4/7	21
	6/26	32	62	5/10	75
	6/28	4	10	5/12	80
	6/29	5	13	5/17	170
	7/19	173	200	5/19	205
3	7/21	59	87	5/22	225
	7/24	84	130	5/24	63
	8/11	115	135	6/17	32
	8/14	100	150	6/21	79
	8/16	-	150	6/23	100
	9/6	70	110	6/26	96
	9/8	73	113	6/28	44
	9/11	-	80	6/29	54
	10/4	82	148	7/19	230
	10/6	20	156	7/21	125
	10/9	29	122	7/24	193
	4/3	20	20	8/11	155
	4/5	48	52	8/14	193
	4/7	8	5	8/16	166
	5/19	117	98	9/6	146
	5/22	115	80	9/8	177
	5/24	27	11	9/11	85
	6/16	10	11	10/4	112
	6/21	22	16	10/6	68
2	6/23	17	17	10/9	69
	8/11	80	125		
	8/14	85	125		
	8/16	90	110		
	9/6	70	56		
	9/8	80	90		
	9/11	18	3		
	10/4	133	160		
	10/6	98	116		
	10/9	96	98		

TABLE D-3. FECAL COLIFORM PER 100 ml, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. x10^4	TROUGH Eff. x10^4	Date	Infl. x10^4
3	3/29	5.8	2.0	3/29	1.0
	7/19	6.2	1.6	4/3	8.9
	7/24	4.9	7.0	4/5	1.1
	8/11	1.2	7.4	7/19	0.71
	8/14	3.0	5.5	7/24	7.4
	8/16	2.2	1.7	8/11	1.0
	9/6	75	68	8/14	1.1
	9/11	1.0	8.9	8/16	4.8
	10/4	0.60	2.1	9/6	6.1
	10/6	1.3	1.4	9/11	5.0
	10/9	0.70	3.9	10/4	2.7
2	4/3	1.2	1.9	10/6	1.1
	4/5	2.2	1.8	10/9	2.4
	8/11	1.3	1.2		
	8/14	1.3	1.3		
	8/16	1.9	2.9		
	9/6	5.0	1.2		
	9/11	2.0	4.0		
	10/4	0.50	1.1		
	10/6	0.70	3.4		
	10/9	0.10	0.40		

TABLE D-4. TOTAL PHOSPHORUS, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/1	TROUGH Eff. mg/1	Date	Infl. mg/1
	3/29	8.9	8.9	3/29	9.8
	3/31	9.5	9.5	3/31	11.5
	5/10	7.9	9.2	4/3	12.5
	5/12	9.6	9.2	4/5	13.3
	5/17	7.9	7.4	4/7	11.1
	6/26	3.1	3.1	5/10	9.8
	6/28	3.1	3.1	5/12	10.0
	6/29	3.2	3.0	5/17	8.3
	7/19	3.1	3.1	5/19	7.9
3	7/21	2.2	2.6	5/22	8.7
	7/24	3.1	3.5	5/24	9.2
	8/11	2.2	2.6	6/17	7.0
	8/14	1.8	2.2	6/21	6.6
	8/16	3.1	3.5	6/23	7.0
	9/6	2.2	2.2	6/26	3.1
	9/8	2.6	3.1	6/28	3.1
	9/11	4.0	4.0	6/29	3.1
	10/4	2.3	7.4	7/19	3.5
	10/6	1.9	1.9	7/21	3.1
	10/9	2.7	3.0	7/24	4.0
	4/3	13.4	10.3	8/11	3.5
	4/5	12.5	11.1	8/14	3.5
	4/7	12.0	10.2	8/16	4.0
	5/19	7.4	7.0	9/6	2.6
	5/22	7.9	7.0	9/8	3.1
	5/24	7.9	7.6	9/11	4.8
	6/16	6.1	6.2	10/4	2.3
	6/21	6.2	6.3	10/6	2.3
2	6/23	5.7	5.7	10/9	4.2
	8/11	1.8	2.2		
	8/14	2.2	2.2		
	8/16	3.1	3.1		
	9/6	2.3	1.8		
	9/8	2.6	2.6		
	9/11	4.0	4.0		
	10/4	4.2	5.5		
	10/6	3.7	4.6		
	10/9	2.8	3.2		

TABLE D-5. NITRATE NITROGEN, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	3/29	0.19	0.31	3/29	<0.05
	3/31	0.57	0.24	3/31	0.05
	5/10	0.05	0.36	4/3	<0.05
	5/12	0.10	0.40	4/5	<0.05
	5/17	<0.05	<0.05	4/7	<0.05
	6/26	<0.05	<0.05	5/10	0.49
	6/28	<0.05	<0.05	5/12	<0.05
3	6/29	<0.05	<0.05	5/17	0.29
	7/19	<0.05	<0.05	5/19	<0.05
	7/21	<0.05	<0.05	5/22	<0.05
	7/24	<0.05	<0.05	5/24	<0.05
	8/11	<0.05	<0.05	6/17	<0.05
	8/14	<0.05	<0.05	6/21	<0.05
	8/16	<0.05	<0.05	6/23	<0.05
	4/3	0.82	0.47	6/26	<0.05
	4/5	1.31	0.63	6/28	<0.05
	4/7	0.89	0.54	6/29	<0.05
	5/19	0.13	<0.05	7/19	<0.05
	5/22	<0.05	<0.05	7/21	<0.05
2	5/24	0.05	<0.05	7/24	<0.05
	6/16	<0.05	<0.05	8/11	<0.05
	6/21	<0.05	<0.05	8/14	<0.05
	6/23	<0.05	<0.05	8/16	<0.05
	8/11	<0.05	<0.05		
	8/14	<0.05	<0.05		
	8/16	<0.05	<0.05		

TABLE D-6. AMMONIA NITROGEN, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/1	TROUGH Eff. mg/1	Date	Infl. mg/1
	3/29	0.8	0.8	3/29	4.2
	3/31	0.0	0.7	3/31	5.0
	5/10	<0.1	<0.1	4/3	6.0
	5/12	<0.1	<0.1	4/5	6.3
	5/17	<0.1	<0.1	4/7	4.9
	6/26	<0.1	<0.1	5/10	0.9
	6/28	<0.1	<0.1	5/12	1.4
	6/29	<0.1	<0.1	5/17	0.3
	7/19	<0.1	<0.1	5/19	0.7
3	7/21	<0.1	<0.1	5/22	0.8
	7/24	<0.1	<0.1	5/24	1.0
	8/11	<0.1	<0.1	6/17	1.4
	8/14	<0.1	<0.1	6/21	1.7
	8/16	<0.1	<0.1	6/23	1.0
	9/6	<0.1	<0.1	6/26	<0.1
	9/8	<0.1	<0.1	6/28	<0.1
	9/11	<0.1	<0.1	6/29	<0.1
	10/4	1.2	1.5	7/19	<0.1
	10/6	0.5	0.3	7/21	<0.1
	10/9	<0.1	0.5	7/24	<0.1
	4/3	1.8	0.9	8/11	<0.1
	4/5	1.0	1.1	8/14	<0.1
	4/7	1.6	1.3	8/16	<0.1
	5/19	<0.1	<0.1	9/6	<0.1
	5/22	<0.1	<0.1	9/8	<0.1
	5/24	<0.1	<0.1	9/11	<0.1
	6/16	<0.1	<0.1	10/4	3.5
	6/21	<0.1	<0.1	10/6	5.9
2	6/23	<0.1	<0.1	10/9	3.0
	8/11	<0.1	<0.1		
	8/14	<0.1	<0.1		
	8/16	<0.1	<0.1		
	9/6	<0.1	<0.1		
	9/8	<0.1	<0.1		
	9/11	<0.1	<0.1		
	10/4	2.0	1.8		
	10/6	1.0	1.5		
	10/9	<0.1	<0.1		

TABLE D-7. ORGANIC NITROGEN, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	3/29	12.9	8.5	3/29	12.6
	3/31	7.7	8.4	3/31	12.1
	5/10	11.2	13.1	4/3	9.4
	5/12	10.7	12.4	4/5	15.6
	5/17	12.1	14.3	4/7	6.9
	6/26	5.9	6.8	5/10	13.1
	6/28	6.8	6.9	5/12	14.1
	6/29	5.2	6.6	5/17	16.1
	7/19	15.8	18.4	5/19	13.3
3	7/21	13.6	16.4	5/22	11.9
	7/24	11.0	14.9	5/24	12.2
	8/11	13.0	16.7	6/17	9.0
	8/14	15.2	19.1	6/21	6.6
	8/16	13.7	19.3	6/23	8.8
	9/6	10.2	16.2	6/26	7.4
	9/8	12.4	23.0	6/28	7.0
	9/11	8.6	13.5	6/29	6.9
	10/4	10.1	19.5	7/19	16.7
	10/6	7.7	16.8	7/21	18.4
	10/9	6.1	9.2	7/24	16.1
	4/3	6.6	6.2	8/11	18.0
	4/5	8.6	8.1	8/14	20.5
	4/7	5.9	5.0	8/16	23.1
	5/19	10.2	9.8	9/6	19.3
	5/22	9.2	8.8	9/8	24.3
	5/24	7.9	7.0	9/11	19.4
	6/16	4.8	5.0	10/4	14.4
	6/21	4.7	4.5	10/6	14.3
2	6/23	4.4	5.0	10/9	13.9
	8/11	12.0	13.9		
	8/14	14.8	18.2		
	8/16	13.5	15.8		
	9/6	9.8	9.6		
	9/8	12.6	10.8		
	9/11	8.2	5.3		
	10/4	11.8	18.7		
	10/6	11.2	11.5		
	10/9	7.7	5.7		

TABLE D-8. KJELDAHL NITROGEN, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	3/29	13.7	9.3	3/29	16.8
	3/31	7.7	9.0	3/31	17.0
	5/10	11.3	13.2	4/3	15.4
	5/12	10.8	12.5	4/5	21.9
	5/17	12.2	14.4	4/7	11.8
	6/26	6.0	6.9	5/10	14.0
	6/28	6.9	7.0	5/12	15.5
	6/29	5.3	6.7	5/17	16.4
	7/19	15.8	18.5	5/19	14.0
3	7/21	13.8	16.6	5/22	12.7
	7/24	11.1	15.0	5/24	13.2
	8/11	13.1	16.8	6/17	10.5
	8/14	15.3	19.2	6/21	8.3
	8/16	13.8	19.4	6/23	9.9
	9/6	10.3	16.3	6/26	7.6
	9/8	12.5	23.1	6/28	7.1
	9/11	8.7	13.6	6/29	7.0
	10/4	11.3	21.0	7/19	16.8
	10/6	8.2	17.1	7/21	18.5
	10/9	6.2	9.7	7/24	16.2
	4/3	8.3	7.1	8/11	18.1
	4/5	9.6	9.2	8/14	20.6
	4/7	7.5	6.3	8/16	23.2
	5/19	10.3	9.9	9/6	19.4
	5/22	9.3	8.9	9/8	24.4
	5/24	8.0	7.1	9/11	19.5
	6/16	4.9	5.1	10/4	17.9
	6/21	4.8	4.6	10/6	20.2
2	6/23	4.4	5.1	10/9	16.9
	8/11	12.1	14.0		
	8/14	14.9	18.3		
	8/16	13.6	15.9		
	9/6	9.9	9.7		
	9/8	12.7	10.9		
	9/11	8.3	5.4		
	10/4	13.8	20.5		
	10/6	12.2	13.0		
	10/9	7.8	5.8		

TABLE D-9. COD, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/1	TROUGH Eff. mg/1
	3/29	127	162
	3/31	134	149
	5/10	200	219
	5/12	183	217
	5/17	203	237
	6/26	125	136
	6/28	132	140
	6/29	127	139
3	7/19	331	371
	7/21	274	337
	7/24	213	301
	8/11	222	274
	8/14	241	274
	8/16	241	288
	9/6	182	254
	9/8	208	242
	9/11	150	128
	4/3	116	108
	4/5	128	124
	4/7	81	81
	5/19	185	181
	5/22	126	122
	5/24	143	132
	6/16	96	112
2	6/21	92	91
	6/23	99	101
	8/11	214	259
	8/14	233	274
	8/16	233	261
	9/6	166	163
	9/8	208	189
	9/11	143	113

Date	Infl. mg/1
3/29	216
3/31	206
4/3	168
4/5	173
4/7	104
5/10	231
5/12	236
5/17	257
5/19	223
5/22	200
5/24	206
6/17	123
6/21	111
6/23	153
6/26	117
6/28	143
6/29	161
7/19	394
7/21	389
7/24	316
8/11	304
8/14	326
8/16	356
9/6	288
9/8	340
9/11	274

TABLE D-10. TURBIDITY, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/1	TROUGH Eff. mg/1
3	3/29	17	25
	3/31	19	22
	5/10	28	45
	5/12	27	42
	5/17	27	37
	6/26	42	58
	6/28	27	45
	6/29	26	42
	7/19	128	138
	7/21	90	115
	7/24	115	123
	8/11	91	120
	8/14	112	140
	8/16	106	140
	9/6	78	136
	9/8	85	102
	9/11	51	35
	10/4	33	53
	10/6	21	48
	10/9	20	40
2	4/3	17	16
	4/5	19	19
	4/7	18	19
	5/19	25	24
	5/22	21	18
	5/24	23	21
	6/16	35	37
	6/21	31	27
	6/23	30	32
	8/11	75	106
	8/14	110	124
	8/16	105	114
	9/6	72	65
	9/8	89	73
	9/11	47	19
	10/4	48	50
	10/6	40	55
	10/9	37	30

Date	Infl. mg/1
3/29	34
3/31	42
4/3	33
4/5	34
4/7	32
5/10	57
5/12	49
5/17	52
5/19	42
5/22	45
5/24	50
6/17	76
6/21	64
6/23	88
6/26	105
6/28	72
6/29	81
7/19	150
7/21	135
7/24	130
8/11	130
8/14	144
8/16	165
9/6	152
9/8	180
9/11	128
10/4	52
10/6	43
10/9	47

TABLE D-11. DISSOLVED SOLIDS, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff. mg/l	TROUGH Eff. mg/l	Date	Infl. mg/l
	3/29	469	467	3/29	440
	3/31	454	454	3/31	469
	5/10	475	489	4/3	511
	5/12	518	490	4/5	532
	5/17	490	504	4/7	518
	6/26	554	540	5/10	461
	6/28	575	540	5/12	511
	6/29	582	553	5/17	454
	7/19	632	618	5/19	518
3	7/21	682	639	5/22	490
	7/24	731	682	5/24	483
	8/11	646	639	6/17	504
	8/14	646	696	6/21	497
	8/16	681	681	6/23	497
	9/6	681	674	6/26	483
	9/8	653	660	6/28	483
	9/11	646	660	6/29	497
	10/4	702	695	7/19	596
	10/6	724	653	7/21	625
	10/9	660	681	7/24	639
	4/3	497	489	8/11	617
	4/5	511	518	8/14	632
	4/7	483	476	8/16	624
	5/19	540	518	9/6	610
	5/22	483	483	9/8	617
	5/24	497	511	9/11	610
	6/16	461	490	10/4	646
2	6/21	497	511	10/6	617
	6/23	497	511	10/9	624
	8/11	639	639		
	8/14	682	675		
	8/16	646	674		
	9/6	660	667		
	9/8	631	658		
	9/11	631	660		
	10/4	653	681		
	10/6	617	653		
	10/9	610	589		

TABLE D-12. pH, SECONDARY SYSTEM, SUMMER APPLICATION RATE, MARCH 20, 1978 - OCTOBER 27, 1978

% Slope	Date	RISER Eff.	TROUGH Eff.	Date	Infl.
3	3/29	7.5	7.3	3/29	8.7
	3/31	7.5	7.4	3/31	8.1
	5/10	7.8	7.9	4/3	7.6
	5/12	7.8	8.1	4/5	7.6
	5/17	7.5	7.4	4/7	7.3
	6/26	7.6	7.8	5/10	8.7
	6/28	7.6	7.6	5/12	8.3
	6/29	7.4	7.5	5/17	8.5
	7/19	7.5	7.6	5/19	8.6
	7/21	7.5	7.7	5/22	8.4
	7/24	7.7	7.9	5/24	8.3
	8/11	7.6	7.8	6/17	7.7
	8/14	7.4	7.6	6/21	8.1
	8/16	7.6	7.8	6/23	7.7
	9/6	8.0	8.2	6/26	8.7
	9/8	7.6	7.4	6/28	8.6
	9/11	7.5	7.5	6/29	8.5
	10/4	7.9	7.6	7/19	9.2
	10/6	7.7	7.8	7/21	8.8
	10/9	7.7	7.8	7/24	8.6
2	4/3	7.4	7.2	8/11	9.0
	4/5	7.4	7.2	8/14	9.0
	4/7	7.3	7.3	8/16	8.8
	5/19	7.6	7.5	9/6	9.2
	5/22	7.5	7.3	9/8	8.7
	5/24	7.6	7.4	9/11	8.2
	6/16	7.4	7.3	10/4	8.5
	6/21	7.9	7.8	10/6	8.6
	6/23	7.6	7.7	10/9	8.1
	8/11	7.5	7.7		
	8/14	7.5	7.5		
	8/16	7.6	7.7		
	9/6	8.0	8.1		
	9/8	7.6	7.6		
	9/11	7.4	7.5		
	10/4	8.2	8.0		
	10/6	7.7	7.7		
	10/9	7.5	7.7		

APPENDIX E

TABLE E-1. SURFACE AND SUBSURFACE SOIL COMPOSITION OF THE RAW AND SECONDARY OVERLAND FLOW TREATMENT SYSTEM BEFORE AND AFTER WASTEWATER APPLICATIONS

Raw Treatment System

Sample** Plot	Date***	Parameter mg/kg									
		Fe	PO_4	Zn	Ca	K	Mn	Cu	Mg	Na	Ni
Surface Soils*											
2% SB	12/75	7300	170	29	110	2100	730	13	1200	230	13
3% SB	12/75	8500	110	47	750	2500	780	24	1900	100	18
2% SB	11/78	4700	72	34	830	2000	490	24	1500	<1000	25
3% SB	11/78	8900	31	26	910	1100	400	25	1900	<1000	10
Secondary System											
Surface Soils											
2% FR	12/75	12800	100	33	380	3000	900	20	2500	500	21
3% FR	12/75	16000	100	75	630	3500	730	23	2900	350	25
2% FR	11/78	8300	29	28	8900	1600	120	51	2700	<1000	36
3% FR	11/78	6800	26	24	1220	1100	540	44	2300	<1000	20

*Surface samples collected at 15 cm depth.

**SB = Spray boom plot; FR = Fixed riser plot.

***12/75 = Samples collected before wastewater applications.
11/78 = Samples collected at the end of the study.

(continued)

TABLE E-1. (Continued)

Sample Plot	Date	Parameter mg/kg									
		Fe	PO_4	Zn	Ca	K	Mn	Cu	Mg	Na	Ni
Raw Treatment System											
Subsurface Soils*											
2% SB	12/75	8000	50	27	350	2000	630	10	1100	280	12
3% SB	12/75	8500	70	37	1200	2500	950	25	1900	280	17
2% SB	11/78	7000	57	34	1050	1500	230	17	1900	<1000	16
3% SB	11/78	6000	305	21	750	850	300	20	1500	<1000	18
Secondary System											
Subsurface Soils											
2% FR	12/75	11000	120	38	1800	2800	850	20	2900	830	21
3% FR	12/75	13000	30	24	250	2300	900	21	2000	380	21
2% FR	11/78	4500	42	42	960	1200	230	23	2300	<1000	17
3% FR	11/78	1060	59	42	1970	2900	270	60	4200	<1000	33

*Subsurface samples collected at 30 cm depth.

APPENDIX F

TABLE F-1. ROTATING BOOM, 2%
COLONIES/ML. ($x10^5$) WASTEWATER

SAMPLING PERIOD	DATE	INFLUENT NUTRIENT AGAR	INFLUENT EMB AGAR	EFFLUENT NUTRIENT AGAR	EFFLUENT EMB AGAR
SUMMER 1977	7/27/77	116	105	72	55
	8/1/77	87	24	4.2	0.011
	8/11/77	250	6.1	33	0.28
	8/18/77	160	9.8	3.9	0.0036
	8/24/77	80	45	67	0.2
	8/31/77	170	140	2.2	0.62
	9/14/77	210	19	11	0.39
	9/21/77	38	34	-	-
	9/29/77	26	1.5	5.8	0.46
	10/12/77	153	8.3	38	5.3
WINTER 1977-78	1/24/78	56	5.8	28	2.5
	1/31/78	62	6.5	5.1	2.0
	2/14/78	15	1.1	2.5	0.6
	2/24/78	41	6.0	0.3	0.1
	3/9/78	40	14	9.4	8.2
	3/15/78	60	12	2.0	0.1
SUMMER 1978	3/21/78	40	11	10	0.62
	3/28/78	310	8.6	42	7.4
	5/2/78	250	8.0	23	5.0
	5/10/78	754	33	0.38	0.15
	5/23/78	18	3.3	23	0.7
	5/31/78	155	14.4	2.0	0.9
	7/18/78	110	20	19	4.2
	7/25/78	110	8.3	5.2	0.3
	8/1/78	180	26	5.6	0.74
	8/9/78	170	16	7.5	0.37
	8/29/78	190	27	4.2	0.52
	9/19/78	210	17	4.2	0.17
	9/26/78	180	19	0.2	0.02
	10/17/78	130	28	9.4	0.71
	10/24/78	120	21	0.07	0.03

TABLE F-2. ROTATING BOOM, 2%
BACTERIA IDENTIFIED FROM EMB PLATES WASTEWATER

DATE	INFLUENT				EFFLUENT			
	E. COLI	C. FRUNDII	KES GROUP	PSEUDOMONAS	E. COLI	C. FRUNDII	KES GROUP	PSEUDOMONAS
7/27/77	X	X	X					X
8/1/77	X		X		X		X	
8/11/77	X		X	X	X		X	
8/18/77	X		X		X		X	
8/24/77	X		X		X		X	
8/31/77	X		X		X		X	X
9/14/77	X	X	X					X
10/11/77	X		X	X	X		X	X
1/24/78	X		X	X	X		X	X
1/31/78	X		X	X	X		X	X
2/14/78	X		X	X	X		X	X
2/28/78	X	X			X			
3/8/78			X	X	X			X
3/15/78	X				X			
3/21/78			X	X	X			X
3/28/78	X			X	X			X
5/2/78	X		X	X	X		X	
5/10/78	X		X	X			X	X
5/31/78	X		X	X	X		X	X
7/18/78			X	X	X			X
7/25/78	X							X
8/1/78	X		X				X	
8/9/78	X		X		X			X
8/29/78	X			X	X			X

TABLE F-3. RISER, TROUGH & BOOM: 2% & 3% COLONIES/ML. ($x10^5$) WASTEWATER

SAMPLING AREA	DATE	INFLUENT NUTRIENT AGAR	INFLUENT EMB AGAR	EFFLUENT NUTRIENT AGAR	EFFLUENT EMB AGAR
2% RISER	3/9/78	1.8	0.46	1.4	0.082
	3/15/78	19	9.4	2.8	0.35
	3/21/78	61	8.4	21	2.4
	5/2/78	70	12	11	3
	5/23/78	1	0.1	0.2	0.01
	5/31/78	123	30	3.3	0.14
	9/19/78	190	11	10	0.51
	10/17/78	100	32	16	1.4
3% RISER	2/28/78	5.2	0.3	1.2	0.1
	5/2/78	6	0.41	1.0	0.09
	3/28/78	13	0.29	4.4	0.21
	5/31/78	92	22.4	72	8.78
	8/9/78	190	16	50	6.1
	9/19/78	250	18	4.7	0.6
	10/17/78	140	26	9.8	0.94
2% TROUGH	3/9/78	1.8	0.46	0.53	0.02
	3/15/78	18	3.7	0.55	0.12
	5/2/78	80	9	3	0.026
	5/23/78	1	0.1	0.08	0.007
	5/31/78	1,180	11.4	5.4	0.089
	8/1/78	82	9.1	7.3	0.88
	9/19/78	140	27	2.1	0.47
	10/17/78	140	22	73	3.2
3% TROUGH	2/28/78	5.2	0.3	2	0.1
	3/28/78	11	0.32	11	0.14
	5/2/78	9	0.2	9.1	0.11
	5/31/78	90	6.35	68.4	8.14
	8/1/78	140	10	20	2.8
	9/19/78	210	24	0.1	0.01
	10/17/78	230	20	29	3.5
2% SPRAY	3/28/78	120	16	51	4.1
	5/10/78	754	21	0.72	0.07
	5/23/78	45	2.6	1.8	0.12
	7/18/78	100	-	230	3.7
	7/25/78	130	12	10	0.2
	8/1/78	110	18	8.8	0.75
	9/26/78	240	21	0.3	0.02
	10/24/78	110	19	0.8	0.3
3% SPRAY	3/28/78	120	53	1.7	0.34
	5/10/78	754	50	0.24	0.01
	5/23/78	44	2.6	0.24	0.007
	7/18/78	-	23	23	5.6
	7/25/78	120	14	1.6	0.17
	8/1/78	470	18	4	0.88
	8/9/78	3	1.1	6	0.73
	9/26/78	60	10	0.4	0.08
	10/17/78	92	20	7.5	0.61

TABLE F-4. RISERS AND TROUGHS, 2 & 3%
BACTERIA IDENTIFIED FROM EMB PLATES WASTEWATER

DATE	INFLUENT E COLI	INFLUENT C FRUNDII	INFLUENT KES GROUP	INFLUENT PSEUDOMONAS	EFFLUENT E COLI	EFFLUENT C FRUNDII	EFFLUENT KES GROUP	EFFLUENT PSEUDOMONAS
RISER, 2%								
3/8/78			X	X			X	X
3/15/78	X	X			X		X	
3/21/78			X				X	X
5/2/78	X		X	X	X		X	
5/31/78	X		X	X	X		X	
8/1/78			X				X	X
RISER, 3%								
5/2/78	X		X	X	X		X	
5/31/78	X		X		X		X	
8/1/78			X	X	X			
8/9/78	X		X				X	X
TROUGH, 2%								
3/8/78			X	X	X			X
3/15/78	X		X				X	
3/21/78	X			X	X			X
5/2/78	X		X		X		X	
5/23/78	X		X	X	X		X	
8/1/78			X	X	X			X
TROUGH, 3%								
5/2/78	X		X	X	X		X	
5/31/78	X		X	X	X		X	
8/1/78				X				X

TABLE F-5. VACUUM PUMP CALIBRATIONS FOR PARTICLE COUNTS

Pump #	Calibrated 3-2-77 liters/min	Calibrated 10-19-77 liters/min
1	5.2470	4.9049
2	5.3161	5.3234
3	5.2605	5.3517
4	4.9843	10.2149
5	5.2186	8.7680
6	5.1666	5.7312

TABLE F-6. VACUUM PUMP CALIBRATIONS FOR ANDERSEN DRUM SAMPLERS

Pump #	Calibrated 3-2-77 liters/min	Calibrated 10-19-77 liters/min
1	3.9501	4.1545
2	3.0077	3.4919
3	3.8266	4.0362
4	2.0206	5.8501
5	2.9977	6.0732
6	4.1700	4.3745

TABLE F-7. ROTATING BOOM, 2%
PARTICLES/M^3 (x10^4) AIRBORNE PARTICLES

SAMPLING PERIOD	DATE	UPWIND	DOWNWIND
	4/20/77	217.18	59.29
	4/27/77	41.59	82.10
	5/9/77	69.31	145.91
	5/19/77	-	372.35
	5/26/77	-	-
	6/1/77	-	-
	6/9/77	134.16	273.65
	6/22/77	817.91	259.97
	6/27/77	573.00	-
SUMMER 1977	7/2/77	73.94	328.38
	7/6/77	-	641.08
	7/12/77	531.14	779.91
	7/21/77	392.78	141.39
	8/1/77	166.35	310.14
	8/11/77	337.33	155.07
	8/18/77	346.57	433.28
	8/24/77	438.69	187.00
	8/31/77	194.08	378.55
	9/15/77	332.71	401.36
	9/21/77	301.90	2,377.74
	9/28/78	494.44	396.80
	10/11/77	577.62	816.40
	11/29/77	617.91	191.30
	1/23/78	168.07	209.51
WINTER 1977-78	1/31/78	2,461.74	1,315.38
	2/14/78	355.91	527.71
	2/28/78	74.15	-
	3/8/78	1,270.41	1,343.62
	3/14/78	2,120.65	-
	3/21/78	1,557.74	760.62
	3/28/78	919.44	-
	4/11/78	225.41	378.94
	5/2/78	-	160.32
	5/8/78	-	-
	5/16/78	-	-
SUMMER 1978	5/30/78	342.73	127.53
	7/18/78	579.50	1,357.98
	7/28/78	370.74	1,862.84
	8/1/78	1,527.46	2,127.01
	8/7/78	1,606.55	1,557.68
	8/15/78	1,767.70	983.80
	8/29/78	233.98	1,053.64
	9/12/78	879.90	651.31

TABLE F-8. ROTATING BOOM, 2%
PARTICLES/M3 AIRBORNE BACTERIA

SAMPLING PERIOD	DATE	UPWIND NUTRIENT	UPWIND EMB	DOWNWIND NUTRIENT	DOWNWIND EMB
SUMMER 1977	3/30/77	247.3	4.2	389.2	-
	4/6/77	49.5	4.2	-	5.5
	4/20/77	2,474.5	-	1,667.9	94.2
	4/27/77	2,433.9	33.8	1,640.6	83.1
	5/9/77	2,474.5	105.5	1,667.9	1,662.4
	5/19/77	2,474.5	4.2	556.0	1,662.4
	5/26/77	2,474.5	1,265.8	1,265.8	1,662.4
	6/1/77	140.2	4.2	1,667.9	127.4
	6/8/77	2,474.5	4.2	250.2	138.5
	6/22/77	90.7	84.4	100	5.5
	6/28/77	1,649.7	33.8	305.8	55.4
	7/6/77	8.2	21.1	1,667.9	55.4
	7/12/77	2,474.5	4.2	1,667.9	1,662.4
	7/21/77	2,474.5	1,265.8	1,667.9	1,662.4
	7/27/77	2,474.5	4.2	1,667.9	5.5
	8/2/77	8.2	1,264.8	5.6	5.5
	8/11/77	329.9	126.6	5.6	55.4
	8/18/77	2,474.5	4.2	5.6	5.5
	8/24/77	16.5	16.9	5.6	5.5
	8/31/77	164.9	4.2	83.4	1,662.4
	9/29/77	602.1	4.2	-	1108.3
	10/12/77	-	4.2	-	138.5
WINTER 1977-78	11/29/77	2.8	405.2	411.6	4.8
	1/18/78	-	-	-	-
	1/23/78	854.7	4	52.1	4.8
	1/31/78	854.7	12.0	272.4	47.7
	2/14/78	2.8	4	13.7	4.8
	2/28/78	854.7	4	823.3	334.1
	3/9/78	2.8	4	274.4	4.8
	3/14/78	25.6	6	411.6	715.9
SUMMER 1978	3/21/78	854.7	4	-	1,431.9
	3/28/78	91.2	3.2	658.6	381.8
	4/11/78	-	-	-	-
	4/12/78	2.8	4	425.4	878.2
	5/2/78	2.3	3.2	658.6	381.8
	5/8/78	854.7	4	823.3	4.8
	5/16/78	2.8	4	274.4	477.3
	5/23/78	854.7	40.1	823.3	38.2
	5/30/78	2.8	4	823.3	4.8
	7/18/78	788.9	14.8	759.9	1,321.7
	7/25/78	854.7	4	247	572.8
	8/1/78	854.7	200.6	823.3	1,431.9
	8/7/78	854.7	64.2	823.3	1,431.9
	8/15/78	683.7	370.3	823.3	1,145.5

TABLE F-9. SECONDARY SYSTEM WASTEWATER VIRAL ASSAY RISER AND TROUGH APPLICATIONS

Date	% Slope	Influent PFU/l	Effluent PFU/l	% Reduction
Riser				
2-28-78	2	0	0	NC
3-9-78	2	0	0	NC
3-28-78	3	0	0	NC
5-16-78	3	0	0	NC
5-23-78	2	0	0	NC
10-11-78	2	0	0	NC
	3	0	0	NC
Trough				
2-28-78	2	0	0	NC
3-9-78	2	0	0	NC
3-28-78	3	0	0	NC
5-16-78	3	0	0	NC
5-23-78	2	0	0	NC
10-11-78	2	0	0	NC
	3	0	0	NC

NC - Not calculated

APPENDIX G

TABLE G-1. RAW DATA FOR TEMPERATURE VS. TREATMENT ANALYSES

Temperature	BOD FR2	BOD TR2	BOD FR3	BOD TR3
68	48	18	29	33
64 64	28	36	58	39
53	47	37	33	35
45	36	35	36	32
42	31	19	14	29
37	39	60	31	35
32	44	41	38	38
32	62	77	62	63
27	44	--	38	48

Temperature	COD FR2	COD TR2	COD FR3	COD TR3
68	138	95	95	99
64	76	76	103	87
53	128	112	104	100
45	171	111	111	114
42	158	105	109	126
37	138	142	126	118
32	134	122	107	106
32	148	148	103	144
27	133	---	130	111

Temperature	NH_3 FR2	NH_3 TR2	NH_3 FR3	NH_3 TR3
68 68	13.11	11.38	10.07	10.69
64	4.9	2.92	5.15	6.05
53 53	14.7	14.4	11.9	12.5
45	4.8	1.7	1.6	3.5
42	6.32	0	0	5.37
37	6.35	13.11	2.69	5.8
32	12.63	11.45	8.97	11.11
32	12.56	13.5	7.87	11.52
27	10.7	-----	13.8	9.7

Abbreviations

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
NH_3	Ammonia
FR2	Fixed Riser - 2% Slope
TR2	Trough - 2% Slope
FR3	Fixed Riser - 3% Slope
TR3	Trough - 3% Slope

NOTE: Data are based on high temperature observations.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

The primary objectives of this study were to assess on a seasonal basis (winter and summer applications), the capabilities of treating raw (screened) municipal wastewater and secondarily treated wastewater (wastewater stabilization pond effluent), by applying the wastewaters to experimental overland flow treatment modules, on two slopes: 2 per cent and 3 per cent. Three application techniques in the raw treatment phase were employed for comparison: (a) rotating spray booms with fan nozzles, (b) fixed riser and trough methods were used for the secondary treatment phase. Comparison was made between the performance of the raw wastewater overland flow system and the performance of the wastewater stabilization pond receiving the same wastewater

In addition to wastewater treatment parameters, analyses were conducted to determine the effects of overland flow applications on soil composition, before and after wastewater applications.

Microbial studies were conducted to determine the quantitative and qualitative structure of the microbial community, within the raw and secondary treatment systems, primarily enteric bacterial and viral organisms. Tests were conducted to determine removal efficiencies for the two treatment systems. Also ambient air samples were collected around the spray boom method of application to determine the presence or absence of airborne enteric bacteria and virus.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Land use, nutrient removal Sewage treatment Water chemistry Sewage effluents Microorganism control	Raw municipal wastewater Pauls Valley, Oklahoma Sewage oxidation pond effluent Overland flow system Environmental health	68D 91A 43F

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