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Aerated Lagoon Treatment of Food Processing Wastes

ENVIRONMENTAL PROTECTION AGENCY • WATER QUALITY OFFICE

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AERATED LAGOON TREATMENT OF FOOD PROCESSING WASTES

Prepared by

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for the

WATER QUALITY OFFICE

ENVIRONMENTAL PROTECTION AGENCY

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ABBREVIATIONS

BOD	5-day, 20^{o}C biochemical oxygen demand, mg/l
COD	chemical oxygen demand, mg/l
SS	suspended solids, mg/l
TS	total solids, mg/l
VSS	volatile suspended solids, mg/l
TVS	total volatile solids, mg/l
Temp.	temperature, ^{o}C
NH_3-N	ammonia nitrogen, mg/l as N
T.K.-N	total Kjeldahl nitrogen, mg/l as N
T. PO_4	total phosphate, mg/l as PO_4
O. PO_4	ortho phosphate, mg/l as PO_4
Alk.	total alkalinity, mg/l as $CaCO_3$
TOC	total organic carbon, mg/l
DOC	dissolved organic carbon, mg/l
D.O.	dissolved oxygen, mg/l
SVI	sludge volume index

ACKNOWLEDGMENTS

The assistance and cooperation of Kelley-Farquhar & Co. and the State of Washington Water Pollution Control Commission are appreciated.

INTRODUCTION

Problem

The food-processing industry is the second largest industrial source of waterborne organic wastes in the Pacific Northwest. Wastes from the processing of foods are usually large in volume and of high oxygen-consuming pollutional strength. Adequate secondary treatment of these wastes by conventional processes is complicated by the seasonal nature of most of the food-processing plants and the large capital expenditures for waste treatment facilities which may be used for only a few months each year.

Recently, several other industries have constructed waste treatment plants consisting of small, deep ponds with oxygen supplemented by mechanical surface aerators. Process efficiency can be varied over a wide range by control of nutrient feeds, oxygen addition, aeration basin detention time, and solids recycle. The pulp and paper industry estimates construction and operational costs of aerated lagoons at 60 and 40 percent, respectively, of those for activated sludge treatment in the 90 percent BOD removal range.(1) Land requirements are reported to be about 5 to 10 percent of that used by conventional stabilization basins loaded at 50 pounds of BOD per acre per day.(1)

Although two food-processing plants, both in the State of Washington, have recently installed aerated lagoon facilities, there is a scarcity of good, reliable operational data. There is a very distinct need for this information so that the design of new facilities can be adequately assessed by State regulatory agencies prior to construction.

Purpose

The purpose of this study was to gather good operational data on a full-scale aerated lagoon which is used to treat food-processing wastes.

Authority

Following discussions between personnel of the Federal Water Pollution Control Administration (FWPCA) and representatives of the various State regulatory agencies concerned with water pollution in the Pacific Northwest, a study was initiated on treatment of food-processing wastes by aerated lagoons. This study was of specific interest to the State of Washington Water Pollution Control Commission as evidenced by the letter shown in the Appendix, page A-1. The Commission said, "...we have a very distinct need for additional performance and design information."

Federal authorization for this type of study comes from the Federal Water Pollution Control Act, as amended.

SUMMARY

This report presents the data collected and the conclusions drawn from a six-week period of sampling of an aerated lagoon used to treat wastes from the frozen pea processing plant of Kelley-Farquhar located at Ferndale, Washington.

Eleven hour composite samples were collected one day per week from July 6 to August 17, 1967, of the influent to the 5.6 million gallon aerated lagoon, effluent from the lagoon and effluent from a 135,000 gallon polishing pond.

Conclusions drawn from the sampling program include:

1. Water use per 1,000 pounds of peas processed averaged 3,500 gallons. Suspended solids, BOD and COD contributions to the waste stream per 1,000 pounds of peas averaged 10, 24, and 41 pounds, respectively.

2. Reductions in total BOD and COD across the aerated lagoon averaged 76 and 59 percent, respectively. Dissolved BOD was reduced by 95 percent and dissolved COD by 82 percent.

3. Inorganic nutrients were not reduced appreciably by the aerated lagoon.

4. The polishing pond readily filled with solids and ceased to function as a removal device. Suspended solids increased from 340 to 580 mg/l across the aerated lagoon and the average reduction by the polishing pond was 10 percent.

5. Current operation of the aerated lagoon results in foaming problems during the first week or two of operation and the growth of filamentous floc which causes a highly bulked sludge (SVI>1000).

6. When all four aerators are in operation, the reduction in organics across the complete-mixed lagoon can be predicted using available formulations. Necessary constants were obtained from this study.

THE KELLEY-FARQUHAR & COMPANY PLANT AND WASTE TREATMENT FACILITIES

Processing Plant

Kelley-Farquhar & Company owns and operates several food processing plants in western Washington and the Pacific Northwest. Their plant at Ferndale, Washington, processes peas, carrots, asparagus, broccoli, strawberries, and raspberries. All of the finished products are frozen. The plant normally processes vegetables and berries which are grown on about 6,000 acres in Whatcom and Skagit Counties and disburses nearly $2,000,000 annually in payroll and payments to farmers and others.

By far the strongest wastes are those derived from the processing of peas for freezing. In 1967 pea processing started July 6 and continued until August 17. For about the first week, processing was only done during the day shift. Then as the quantity of peas available for processing increased markedly, two shifts per day, six days per week, and one shift on Sunday were utilized for processing. Normally the day shift started at 8:00 a.m. and continued to about 5:30 p.m. Following clean-up the evening shift started at 7:00 p.m. and ran until 4:30 a.m. the following morning.

Waste Treatment Plant

Description

Wastes flow by gravity from the processing plant to a sump from which they are pumped to a rotary screen. Liquid effluent from the screen flows by gravity to the aerated lagoon. Screened solids are loaded on trucks and hauled away for use as a food supplement for cattle. Domestic wastes are kept separate from the processing wastes and are added to the city's sewers.

Effluent from the aerated lagoon flows through a polishing pond and then to the Nooksack River. The outfall is located about six miles upstream from the mouth of the river which discharges into Bellingham Bay.

The aerated lagoon has a surface area of 1.75 acres, an average depth of ten feet and a volume of 5.6 million gallons (mg). Side slopes of the lagoon are two horizontal to one vertical. Four 50 horsepower (hp) aerators, mounted on fixed platforms in the lagoon, have a rated aeration capacity of 12,000 pounds of oxygen per day. Effluent from the aerated lagoon flows into the north end of the polishing pond as shown on Figure 1 (Appendix, page A-2). Effluent from the 135,000-gallon pond overflows at the south end. The original design called for recirculation of settled solids from the polishing pond back to the aerated lagoon but this practice was never initiated.

Operation

The aerators are only used during the pea processing period since the quantity and strength of wastes from the other processed foods are considerably lower. For the first week or two of pea processing, less than four aerators are usually kept in operation depending upon the quantity of peas processed and the dissolved oxygen (D.O.) levels in the aerated lagoon. D.O. levels in the aerated lagoon are routinely checked twice a day by plant personnel. After the initial period of intermittent aerator operation, all four are run continuously until pea processing is terminated. Then the aerators are operated intermittently again for about another week to assure stabilization of the organic material present in the aerated lagoon.

STUDY OF TREATMENT OPERATIONS

Data Collection Methods

On July 13, 1967, and each Thursday thereafter for the period of study, a set of composite samples was taken of the aerated lagoon influent, lagoon effluent, and polishing pond effluent. Each set of samples was composited across the day shift, including clean-up, from 8:00 a.m. to 7:00 p.m. The samples were collected hourly on July 13 and composited according to flow. On July 20 and following Thursdays all samples were composited with time. The primary reason for the change in method of compositing is shown on Figure 2. Hourly variations in water use were less than 10 percent from the average for July 13. All but one of the 30-minute periods of water use during a previous trip to the plant, August 17, 1966, showed deviations from the average use of less than ten percent.

All samples were kept on ice during collection and were transported to the Laboratory in Corvallis on ice immediately after collection. Analyses were started on the morning following the day of collection. All analyses were performed according to Standard Methods[(2)] with the following exceptions: nitrate nitrogen,[(3)] Kjeldahl nitrogen,[(4)] total and ortho phosphate,[(5)] and total organic carbon and dissolved organic carbon.[(6)] In addition to the regular BOD and COD analyses some of the samples were centrifuged and these two analyses were repeated on the centrates. The samples were centrifuged at about 3,000 revolutions per minute for fifteen minutes.

Grab samples were also taken from the aerated lagoon and the polishing pond effluents for onsite pH and temperature measurements and for quiescent sedimentation tests. Grab samples of the aerated lagoon and polishing pond effluents were also taken and returned to Corvallis for examination of the numbers and kinds of biological organisms. Some dissolved oxygen readings were taken with a D.O. probe at various depths and locations in the aerated lagoon. The probe was calibrated by Winkler(3) D.O. measurements onsite prior to use in the lagoon. The sampling stations shown in Figure 1 were about midway between the aerators and the bank. Previous sampling(8) had shown that the lagoon was completely mixed when all four aerators were used and these sampling locations would give representative D.O. concentrations.

Study Results

The quantities of peas and raspberries processed, the amount of water used and the number of aerators in operation for each of the days that samples were taken are shown in Table 1. From 96,000 to 180,000 pounds of peas were processed during the 8:00 a.m. to 5:30 p.m. shift. The quantity of raspberries processed varied from 0 to 21,000 pounds during the day shift.

Water use was relatively constant and independent of quantity of food processed, varying from 456,000 to 563,000 gallons during the 8:00 a.m. to 7:00 p.m. period. On July 13, only three of the four aerators were in operation, the southeast one was off, and the following week, two were in operation, both the southeast and northwest ones were turned off. All four aerators were placed in operation on July 26 and continued in operation until after the end of pea processing.

The pH and temperature data collected onsite in the grab samples of the lagoon influent, lagoon effluent, and polishing pond effluent are shown in Tables 2 through 7 in the Appendix. Overall, the temperature range in the lagoon influent was from 17°C to 29.5° with a pH range from 6.7 to 8.2. The lagoon effluent had a temperature range of 19.5 to 23°C and a pH range of 6.6 to 8.1. Temperature and pH readings on the effluent from the polishing pond were nearly identical to those of the effluent from the aerated lagoon. For the six days of sampling the temperature drop across the lagoon averaged 0°C with daily averages ranging from a drop of 2°C to a temperature increase of 2°C. The air temperature was not followed as closely, but it generally ranged from 18 to 23°C. The aerated lagoon acted as a buffer zone, evening out the pH and temperature fluctuations that occurred in the influent stream.

Table 8 presents temperature measurements that were taken in the aerated lagoon at the sampling points shown on Figure 1.

Even though less than four aerators were in operation on July 13 and 20, the temperature data indicate fairly good mixing at least in the upper layer of the lagoon. On August 3 there appeared to be good mixing throughout the lagoon, evidenced by the temperatures taken at 11:00 a.m. and 3:00 p.m.

Dissolved oxygen data collected with the probe are shown in Table 9. On July 13, the dissolved oxygen content near the southeast aerator, the one not running, was 0.3 to 2.1 mg/1 lower than at the other three sampling points. There was a range in oxygen content from 0.6 to 1.2 mg/1 in the morning and from 1.0 to 2.4 mg/1 in the afternoon at the other three stations both of which were probably due to the southeast aerator. Both the southeast and the northwest aerators were off on July 20. Near the surface the oxygen content was lower near these two aerators (stations 1 and 3) than it was at stations 2 and 4. At the five foot depth, the oxygen content was low, about 0.2 mg/1, and rather uniform at all four stations.

With all four aerators running on July 27 and August 3, the oxygen content ranged from 1.6 to 5.9 mg/1 in the lagoon. Although the values at the 8-foot depth were less than at the 1-foot depth, there was excess oxygen available at all of the sampling points. The D.O. content of the effluent from the polishing pond was about 4 mg/1 lower than the contents of the aerated lagoon during the afternoon of August 3. This resulted from the gas released upon anaerobic decomposition of the sludge which had accumulated in and filled the polishing pond.

Samples of the lagoon and pond effluents collected on August 3 and analyzed by the Winkler method showed an oxygen content of about 1.5 mg/1. The oxygen demand in the lagoon had increased over that of the previous week, but the D.O. was still in a range that would not inhibit biological activity. D.O. concentrations on August 17 were down to 0.6 mg/1 and showed good mixing of the lagoon contents, both near the surface and at a depth of 8 feet. The measured concentration was near the level which may start to cause a slowdown in biological breakdown of the organics.

Quiescent settling tests were run in 2-liter graduated cylinders on grab samples of the lagoon effluent taken on the last four sampling trips. Figure 2 presents a plot of sludge volume in percent versus settling time in minutes for three of these tests. The results from the settling test conducted on August 3 were very similar to those obtained on August 17 and, therefore, are not shown. These tests were also conducted on the effluent from the polishing pond, but in every case they were virtually identical to those on the aerated lagoon effluent. On the first two sampling trips, these tests were not conducted since it was impossible to discern an interface upon settling.

For the July 27 sedimentation curve the sludge volume index (SVI) was about 120, indicative of a good settling sludge. On the other three days, August 3, 10, and 17, the SVI was in excess of 1,000 which indicates that solids removal by conventional clarification methods would be almost impossible. A possible explanation for the bulking sludge will be discussed later.

Table 10 presents the results of the solids analyses on the six sets of samples. Note the increase in suspended solids on passage through the aerated lagoon, an average from 340 to 580 mg/l. The polishing pond improved reductions very little, especially during the last three weeks when it was full of sludge.

Data collected on inorganic nutrients, nitrogen, and phosphates, is shown in Table 11. Total Kjeldahl nitrogen averaged about 48 mg/l in the waste stream entering the lagoon and total phosphates averaged 26 mg/l. Nearly all of the orthophosphate was incorporated into biological floc upon passage through the aerated lagoon. There was about 9 mg/l in the influent and only 0.2 mg/l in the lagoon effluent.

The pH, alkalinity, and organic carbon data are shown in Table 12. The lagoon acted as a buffering system as it evened out the pH fluctuations of the incoming waste. There was a slight increase in total alkalinity upon passage through the lagoon from 260 to 270 mg/l as $CaCO_3$.

All COD and BOD_5 data collected are shown in Table 13. The average BOD of the aerated lagoon influent was 820 mg/l and the effluents from the lagoon and the polishing pond averaged 196 and 182 mg/l, respectively. BOD of the supernatant following centrifuging averaged about 30 mg/l for both effluents. On July 20, when only 2 aerators were in operation, the soluble BOD was over 100 mg/l. On the effluent samples from July 27 to August 17, when all 4 aerators were operating, the soluble BOD averaged about 10 mg/l. The polishing pond did not alter the COD reductions significantly as its influent averaged 580 and the effluent averaged 550 mg/l.

Sphaerotilus, the filamentous bacterium commonly seen as a gray slime growth in streams, was present in all samples from the lagoon and polishing pond effluents. On July 13 and 20, the majority of the filaments were short, less than 15 microns long. The density ranged from about 350,000 per milliliter on July 13 to over 2,000,000 per milliliter on July 20. In the samples collected on July 27, the biological floc was much denser and the *Sphaerotilus* appeared as long intertwined filaments. This was also the case for the samples collected on August 3, 10, and 17.

Several types of protozoans were identified along with a few green attached and planktonic algae. On July 13 and 20 all of the protozoans identified were flagellates. In the samples collected on the last four sampling days, attached ciliates, crawling ciliates, free-swimming ciliates, and rhiezopods were also found but the flagellates continued to account for more than 70 percent of the protozoans.

EVALUATION OF TREATMENT OPERATIONS

The quantity of water used per 1,000 pounds of peas processed varied from 2,900 to 5,300 gallons and averaged 3,500 gallons. Based on the analyses of the aerated lagoon influent (after screening), the contribution of SS, BOD, and COD per 1,000 pounds of peas processed averaged 10, 24, and 41 pounds, respectively. The range for SS was from 7 to 17.5 pounds, for BOD 18.5 to 31 pounds, and for COD 33 to 48 pounds. In general, as the total quantity of peas processed per shift increased, the contributions of flow, SS, BOD, and COD per 1,000 pounds decreased.

Table 14 presents the average percent reduction in the various parameters analyzed on the composite samples. The polishing pond was of very little benefit as shown by the difference between the reductions across the aerated lagoon and the reductions across the aerated lagoon plus the polishing pond. During the first few days of operation, the polishing pond did remove some suspended solids which also increased the organic removal somewhat, but the pond rapidly filled with solids and no further benefit was obtained.

The total volatile solids were reduced about 50 percent but both the suspended solids and the volatile suspended solids increased substantially. Total phosphate and total nitrogen were not reduced significantly, but this was expected since the aerated lagoon was completely mixed and the polishing pond readily filled with the bulking solids. Total organic carbon, COD, and BOD were reduced by 66, 59, and 76 percent, respectively. The dissolved BOD was reduced by 96 percent for the entire period and by 98 percent for the period when four aerators were in operation.

Inasmuch as most of the BOD in the effluent samples was associated with the suspended solids, the overall treatment efficiency could have been markedly improved by a good solids removal step following the aerated lagoon. Normally this could be done rather easily, much as initially planned, by returning solids from the polishing pond back to the aerated lagoon. Once the suspended solids reach the condition where sedimentation is very slow (high SVI), good solids removal becomes almost impossible. This condition was present on August 3, 10, and 17. The reason or reasons why this condition is brought on were not pinpointed in this study. One possible explanation lies in the organic loading pattern. When the pea processing starts up initially, a large volume of high-strength wastes is discharged to the aerated lagoon. Although sufficient oxygen may be added to the lagoon, the food to micro-organism (F/M) ratio is very high since relatively little biological life is present in the lagoon. On July 20, the F/M ratio was about 0.8 pounds of BOD per day per pound of volatile suspended solids in the lagoon. Depending upon the type of waste being treated, F/M ratios between 0.5 and 1.0 lead to growth of filamentous organisms which in turn cause bulking sludge. During the four sampling periods which all aerators were in operation, the F/M ratio ranged from 0.22 to 0.34 and averaged 0.28. In this range the likelihood of causing filamentous growths is probably much less although the critical ratio for this specific waste was not determined from this study.

The fact that less than four aerators are used during the first week or two of pea processing accentuates the loading problem. With only two or three aerators in operation, the aerated lagoon does not function as a complete-mixed system since most of the large biological floc will settle out in the lagoon. This, in turn, results in higher F/M ratios. The biological floc or suspended solids are also needed to absorb dissolved organics to minimize foaming problems. During the sampling on July 13 and 20, when less than four aerators were operating, two to three feet of foam covered most of the aerated lagoon. On successive sampling days when all four aerators were in operation, virtually no foam was in evidence on the lagoon. Use of four aerators markedly increased the solids in suspension which, in turn, absorbed more dissolved organics thereby eliminating the foam problem.

The BOD:N:P ratio averaged 100:5.8:1.0 for the five days of sampling for which BOD's were run. A range from 100:5.1 to

100:6.4 was observed for BOD:N ratio and the BOD:P ratio varied from 100:0.8 to 100:1.2. The most commonly quoted ratio depicting inorganic nutrient requirements for aerobic biological treatment is 100:5:1. Assuming all of the total Kjeldahl nitrogen and all of the total phosphate was available for biological synthesis, the average ratios observed indicate that the inorganic nutrients levels were adequate. Usually some of the organic nitrogen and the phosphates are present in a form not readily available for cell synthesis. This, coupled with the fact that the ratios on several samples were less than optimum, indicates that possibly some nutrient addition, especially phosphate, might improve the degree of treatment obtained by the facility.

In a completely mixed basin, the BOD removal relationship has been shown by W.W. Eckenfelder, Jr.,[9] to be:

$$\frac{Sa-Se}{Xat} = k\ Se \qquad (1)$$

where:

Sa = influent BOD

Se = soluble BOD in effluent

Xa = MLSS

t = aeration time

k = removal rate coefficient

the solids in the basin (MLSS) and in the effluent are

$$Xa = \frac{So + aSr}{1 + bt} \qquad (2)$$

where:

So = influent suspended solids

a = yield coefficient, synthesis per unit substrate removed.

b = cellular auto-oxidation rate, fraction per day.

Total BOD in the effluent from the completely mixed basin will be:

$$BOD = Se + c(Xa) \qquad (3)$$

where:

c = fractional BOD equivalent of suspended solids in the effluent.

These three equations were used along with the results from the analyses of the samples from July 27 to August 17, the period when all four aerators were in operation, to determine values for the four constants. The values obtained were:

$k = 0.018$

$a = 0.70$

$b = 0.027$

$c = 0.24$

The following tabulation shows both the calculated and measured values in mg/l for the soluble effluent BOD (Se), effluent suspended solids (Xa) and total effluent BOD.

Date	Soluble BOD		Sus. Solids		Total BOD	
	Calcu.	Meas.	Calcu.	Meas.	Calcu.	Meas.
7-20-67	12	140	800	240	205	240
7-27-67	12	5	700	650	180	140
8-3-67	10	11	890	830	225	260
8-10-67	10	11	730	800	185	190
8-17-67	9	8	720	770	180	150
Average 7-27 to 8-17	10	9	760	760	190	185

Also shown are the calculated and measured values for July 20, when only two aerators were in operation. The calculated MLSS was 800 mg/l and the observed value was 240 which accounts for the measured soluble BOD in the effluent of 140 mg/l compared to a calculated value of 12 mg/l. It was coincidental that the calculated total BOD was fairly close to the measured, 205 versus 240 mg/l. For the four days when all the aerators were in operation, calculated and measured values agree fairly well. Percentage-wise, the largest error was in the soluble BOD but the accuracy of the test in the 10 mg/l area is rather poor. All suspended solids results agreed within ten percent and the BODs agreed within 20 percent except for the July 27 values. This may be partially explained by the fact that all four aerators were not placed in operation until July 26. On the average, agreement was very good considering only one shift per week was sampled.

These constants can also be used to determine the degree of suspended solids removal that would be required to obtain a specified effluent BOD. For example, if 90 percent BOD reduction was required, the total effluent BOD would have to be about 80 mg/l. With about 10 mg/l of soluble BOD, the effluent suspended solids would have to be reduced to:

$$\text{Eff SS} = \frac{80-10}{0.24} = 290 \text{ mg/l}$$

or the aerated lagoon effluent suspended solids would be reduced by 62 percent. This could readily be accomplished by many conventional clarification systems as long as a low SVI was maintained through proper operation of the treatment facility.

The problems of foaming, possible inorganic nutrient deficiency, low suspended solids reduction and high F/M ratio which cause sludge bulking could be partially solved by the following operation of the system:

Prior to startup of pea processing, all four aerators should be placed in operation, at least intermittently. The number of hours operation per day will depend upon the quantity and strength of the wastes being produced at that time. A solids recirculation pump should be installed and also started when the aerators are placed in operation. This will allow the buildup of some solids in the aerated lagoon before the pea wastes are introduced which will aid in absorbing dissolved organics and maintain the F/M ratio as low as possible. Once pea processing has started, continuous recycle of suspended solids from the polishing pond back to the aerated lagoon will reduce foaming, possibly hold the F/M ratio low enough to stop the filamentous growth, return some inorganic nutrients to the aerated lagoon through auto-oxidation, and increase both the suspended solids reduction and total BOD reduction. There would be some increase in oxygen demand in the aerated lagoon due to the sludge recycle, but the present aerators should be able to cope with it. The main unanswered question is whether enough solids can be built up in the aerated lagoon prior to the two critical periods (start of pea processing and change from one to two shifts per day) to keep the F/M ratio low enough to eliminate the filamentous growths. If this cannot be accomplished, then the use of a holding tank before the aerated lagoon may be advisable to spread the load out during the two critical periods.

Since the polishing pond was not designed specifically for solids removal, it will be difficult to return most of the settled solids to the aerated lagoon. Multiple draw-off points in the lagoon bottom will be needed either through the use of separate lines or a line with several openings. Prior to the start of pea processing, the sludge return could be pumped intermittently depending upon the quantity and quality of solids in the effluent from the aerated lagoon.

The waste treatment facility is an efficient and economical method of treatment. With some modifications, both the SS and BOD reductions could be markedly improved.

Additional studies of this type are needed to more fully assess problems associated with biological treatment of seasonal industries such as food processing. Rapidly changing hydraulic and organic loads, and inorganic nutrient concentrations cause many operational problems in waste treatment. These problems will need solutions before higher levels of treatment can be obtained.

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APPENDIX

STATE OF WASHINGTON
POLLUTION CONTROL COMMISSION
409 PUBLIC HEALTH BUILDING
OLYMPIA, WASHINGTON

January 19, 1966

Mr. R. F. Poston, Officer-in-Charge
Federal Water Pollution Control Administration
Room 570 Pittock Block
Portland, Oregon 97205

C O P Y

Dear Mr. Poston:

We understand that a research project on aerated lagoons is being proposed for the Federal Water Pollution Control Administration laboratory in Corvallis.

We heartily support research in the Northwest on lagoons of this type because there is at present a scarcity of good, reliable data for facility design, and we believe that these systems have a promising future for economical treatment of large organic waste loads. At present there are three aerated lagoons in Washington treating pulp mill, vegetable, and fruit process wastes, and within the past few months we have reviewed plans for six additional facilities of this general type. Consequently, we have a very distinct need for additional performance and design information.

If we can be of assistance in the development or implementation of such research, please call on us at your convenience.

Very truly yours,

ROY M. HARRIS
Director

RMH:JPD:cj

cc: Mr. Boydston
FWPCA - Corvallis

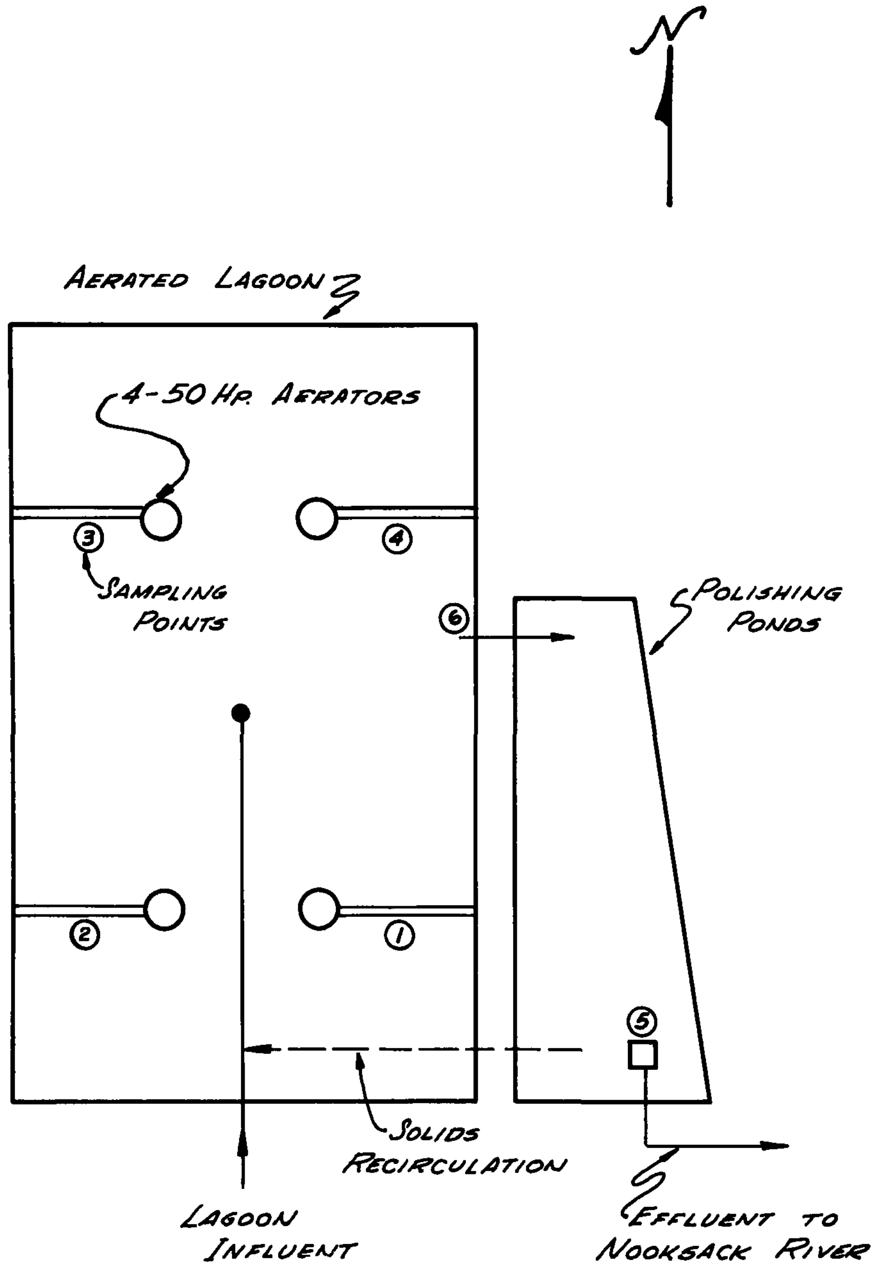

FIGURE 1. INDUSTRIAL WASTE TREATMENT FACILITES

FERNDALE, WASHINGTON

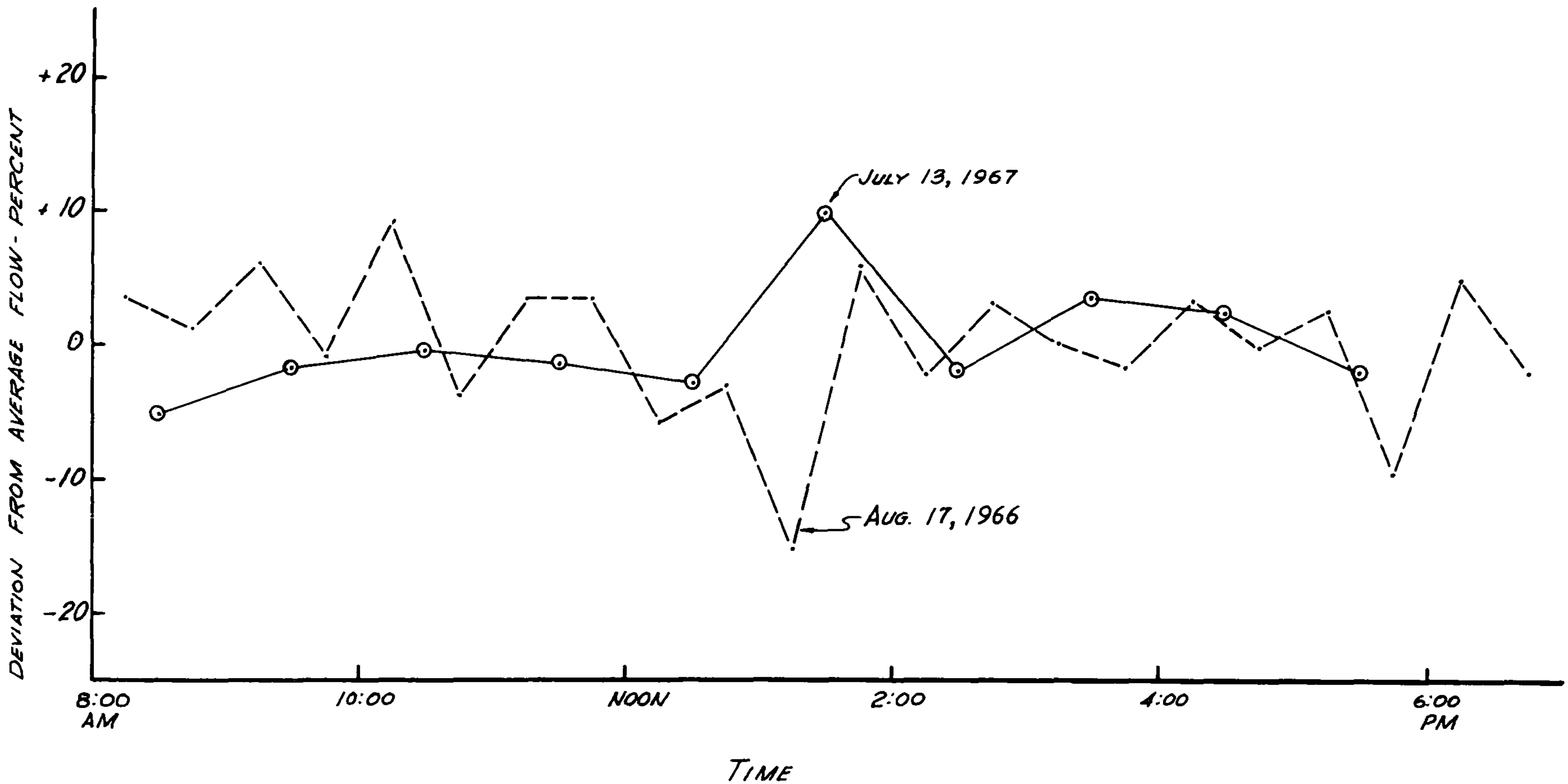

FIGURE 2. VARIATION IN WATER USE WITH TIME

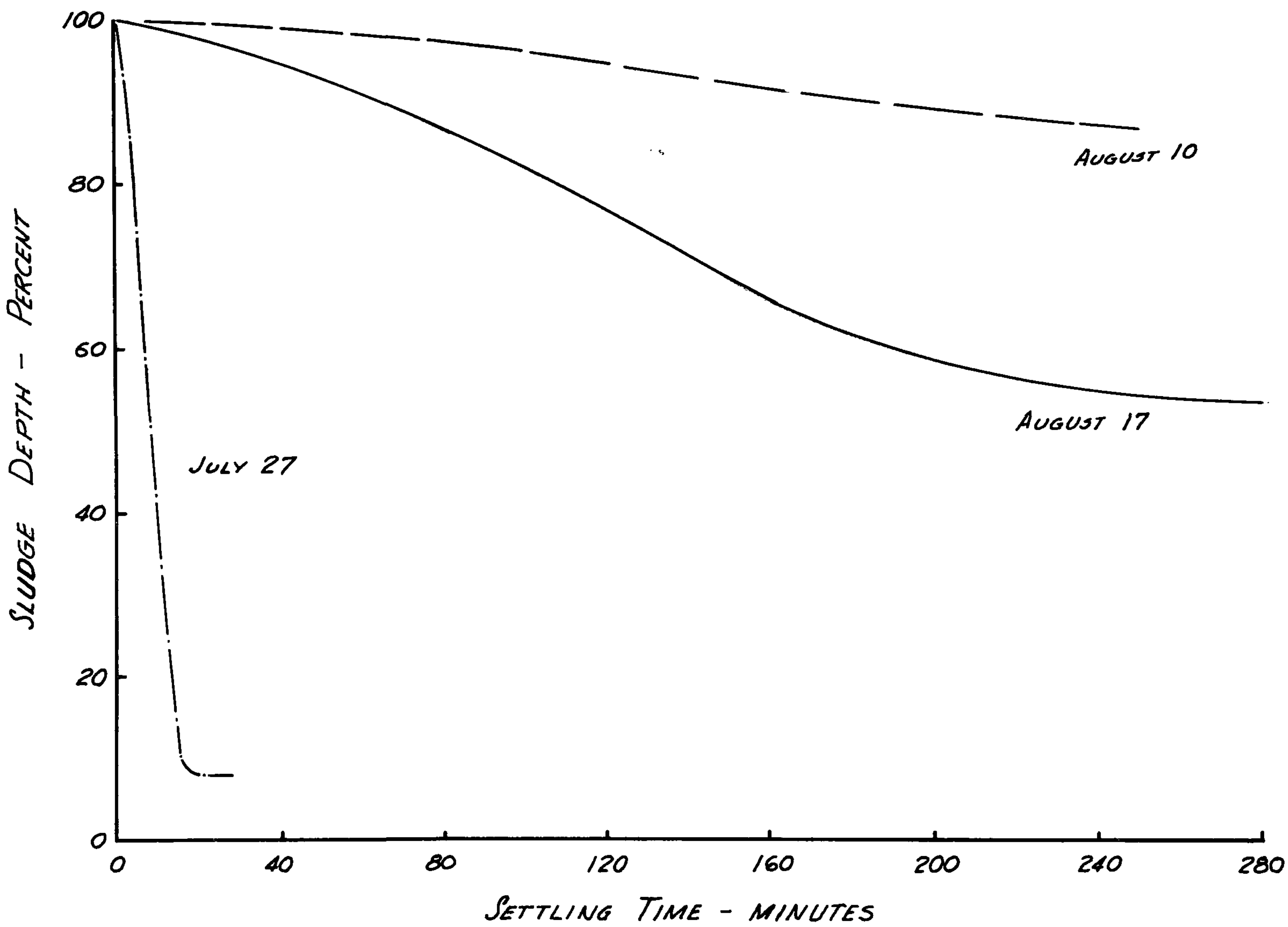

FIGURE 3. QUIESCENT SEDIMENTATION TESTS

Table 1

FOODS PROCESSED AND WATER USED[(a)]

Date	Processed - lbs. Peas	Raspberries	Water Used Gals.	No. of Aerators
7-13-67	159,500	0	563,000	3
7-20-67	128,000	9,100	545,000	2
7-27-67	145,500	21,200	518,000	4
8-3-67	180,500	4,700	456,000	4
8-10-67	175,000	300	502,000	4
8-17-67	96,100	0	506,000	4
Average:	147,400		515,000	

(a) Values for 1 shift (8:00 A.M. - 7:00 P.M.)

Table 2

TEMPERATURE AND pH DATA

JULY 13, 1967

Time	Lagoon Influent Temp.	Lagoon Influent pH	Lagoon Effluent Temp.	Lagoon Effluent pH	Pond Effluent Temp.	Pond Effluent pH
0800	19	7.5	20	7.4	19.5	7.2
0930	20	7.6	20	7.2	19.5	7.3
1030	20	7.7	20	7.4	20	7.4
1130	17.5	7.7	20	7.4	20	7.4
1230	20.5	7.3	20.5	7.3	21.5	7.4
1330	17	7.7	21.5	7.3	22	7.3
1430	19	7.9	21.5	7.6	22.5	7.6
1530	20	7.7	22	7.5	22.5	7.4
1630	19.5	7.9	22	7.6	22.5	7.4
1730	18	7.7	22	7.5	22	7.6

Table 3

TEMPERATURE AND pH DATA

JULY 20, 1967

Time	Lagoon Influent Temp.	Lagoon Influent pH	Lagoon Effluent Temp.	Lagoon Effluent pH	Pond Effluent Temp.	Pond Effluent pH
0815	21	7.5	21	7.1	21	7.1
0845	20	7.5				
0915	18.5	7.5	21	7.3	20	7.1
0945	18.5	7.4	21	7.2	20.5	7.2
1045	19	7.3	21	7.1	20.5	7.0
1115	19	7.3				
1145	20	7.4	21	7.2	20.5	7.1
1215	20					
1245	21	7.3	21	7.2	21	7.1
1315	20		21		21	
1345	19.5	7.3	21	7.2	21	7.1
1415	19	7.4				
1445	19	7.4	21	7.1	21	7.0
1515	18.5	7.5	21	7.2	21	7.1
1615	21	7.4	21	7.1	21	7.1
1715	18.5	7.5	21	7.1	21	7.0
1745	17	7.4				
1815	17	7.4	21	7.2	21	7.1

Table 4

TEMPERATURE AND pH DATA

JULY 27, 1967

Time	Lagoon Influent Temp.	Lagoon Influent pH	Lagoon Effluent Temp.	Lagoon Effluent pH	Pond Effluent Temp.	Pond Effluent pH
0815	20	7.4	19.5	7.3	19.5	7.3
0915	20.5	7.3	20	7.3	20	7.3
1015	20.5	7.4	20	7.3	20	7.3
1115	20	7.5	20	7.4	20	7.4
1215	21	7.4	20	7.3	20	7.3
1315	18	7.6	20	7.2	20	7.2
1415	22.5	7.0	20.5	7.0	20.5	7.0
1515	24	6.7	20.5	6.6	20.5	6.5
1615	22.5	7.0	20.5	6.9	21	6.5
1715	23	6.7	21	6.9	21	6.7
1815	20	7.0	21	7.0	21	6.9

Table 5

TEMPERATURE AND pH DATA

AUGUST 3, 1967

Time	Lagoon Influent Temp.	Lagoon Influent pH	Lagoon Effluent Temp.	Lagoon Effluent pH	Pond Effluent Temp.	Pond Effluent pH
0815	19.5	7.8				
0830			20	7.5	20.5	7.5
0845	20	7.5				
0915	20	7.5				
0930			20.5	7.5	21	7.3
1015	22	7.4				
1030			22	7.4	21.5	7.2
1115	20	7.5				
1130			22	7.4	21	7.3
1215	24.5	7.6				
1230			21.5	7.4	23	7.2
1245	26	7.7				
1315	24.5	7.6				
1345	24	7.7				
1415	25	7.7				
1430			23	7.6	24	7.5
1515	26	7.6				
1530			23	7.7	23	7.4

Table 5 (Cont.)

TEMPERATURE AND pH DATA

AUGUST 3, 1967

	Lagoon Influent		Lagoon Effluent		Pond Effluent	
Time	Temp.	pH	Temp.	pH	Temp.	pH
1545	26	7.6				
1615	26	7.6				
1630			23	7.6	24	7.7
1645	22	7.7				
1730			23	7.7	23	7.7
1745	29.5	7.7				
1815	27	7.9				
1830			23	7.6	23	7.6

Table 6

TEMPERATURE AND pH DATA

AUGUST 10, 1967

Time	Lagoon Influent Temp.	Lagoon Influent pH	Lagoon Effluent Temp.	Lagoon Effluent pH	Pond Effluent Temp.	Pond Effluent pH
0815	19	7.9	20	7.8	20.5	7.9
0915	21.5	7.8	20.5	7.7	21	7.6
1015	19.5	7.8	21	7.7	21	7.7
1115	21.5	7.6	21.5	7.7	21.5	7.7
1215	21	7.8	22	7.5	22	7.4
1315	21	7.7	22	7.6	22	7.4
1415	23	7.2	22.5	7.5	22.5	7.5
1515	22.5	7.3	22.5	7.5	22.5	7.5
1615	24	7.7	22	7.4	22.5	7.5
1715	18	7.3	23	7.4	23	7.4
1815	21.5	7.5	22.5	7.5	22.5	7.5

Table 7

TEMPERATURE AND pH DATA

AUGUST 17, 1967

Time	Lagoon Influent Temp.	Lagoon Influent pH	Lagoon Effluent Temp.	Lagoon Effluent pH	Pond Effluent Temp.	Pond Effluent pH
0815	20	8.2	21	8.1	21	7.7
0915	20	7.9	21	8.0	21	7.5
1015	20.5	7.9	21	7.9	21.5	7.7
1115	21	7.3	21.5	7.7	21.5	7.5
1215	21	7.5	21.5	7.5	22	7.3
1315	21	7.8	21.5	7.5	22	7.3
1415	20.5	7.6	21.5	7.5	22	7.4
1515	20.5	7.5	21.5	7.6	21.5	7.4
1615	21	7.5	21.5	7.7	22	7.3
1715	21	7.5	22	7.5	22	7.4
1815	18	7.8	21.5	7.6	21	7.4

Table 8

LAGOON TEMPERATURE DATA, °C

Date	Time	Depth ft.	SAMPLING STATION (1)	(2)	(3)	(4)	(5)
7-13-67	1145	1	20	20	20	20	20
	1545	1	22	21.5	21.5	22.5	22
7-20-67	1030	1	20	20.5	20	19.5	--
	1500	1	20	20.5	20	19.5	--
	1715	1	20	20.5	20.5	20	--
8-3-67	1100	1	19	19.5	19.5	19.5	--
		8	19	20	20	20	--
	1500	1	22	20.5	20.5	20.5	22
		8	21.5	21	20.5	21	--

Table 9

LAGOON DISSOLVED OXYGEN DATA, mg/1

Date	Time	Depth ft.	SAMPLING STATION (1)	(2)	(3)	(4)	(5)	(6)
7-13-67	1145	1	0.3	0.9	0.6	1.2	0.3	
	1545	1	0.3	1.0	1.4	2.4	0.3	
7-20-67	1030	1	0.1	---	0.1	0.6	---	
		5	0.1	0.2	0.2	---	---	
	1500	1	0.2	0.9	0.2	1.1	---	
		5	0.1	0.1	0.1	0.3	---	
	1715	1	0.3	0.9	0.2	0.7	---	
		5	0.1	0.2	0.1	0.3	---	
7-27-67	1130	1	2.6	3.4	3.8	4.6	3.8	
		8	2.0	2.3	3.5	3.8	---	
	1530	1	3.0	2.7	3.7	4.9	4.8	
		8	2.4	1.6	2.3	3.7	---	
	1730	1	3.8	4.0	3.8	4.4	4.8	
		8	3.5	3.4	3.4	4.4	---	
8-3-67	1100	1	5.2	3.9	4.3	5.2	---	
		8	3.7	4.0	4.1	4.8	---	
	1500	1	4.7	5.0	5.6	6.3	1.8	
		8	4.5	4.8	5.3	5.9	---	
8-10-67*	1000	1					1.7	1.3
	1300	1					1.7	1.4

Table 9 (Cont.)

LAGOON DISSOLVED OXYGEN DATA, mg/1

Date	Time	Depth ft.	SAMPLING STATION (1)	(2)	(3)	(4)	(5)	(6)
8-10-67*	1600	1					1.8	1.4
8-17-67	1100	1	0.7	0.7	0.6	0.7	0.6	
		8	0.6	0.7	0.6	0.7		
	1500	1	0.6	0.6	0.6	0.7	0.6	
		8	0.6	0.6	0.6	0.7		
	1700	1	0.6	0.7	0.6	0.7	0.6	
		8	0.6	0.7	0.6	0.7		

* D.O. run by Winkler[1] method.

Table 10

SOLIDS DATA, mg/l

Date	Location	T.S.	T.V.S.	S.S.	V.S.S.
7-13-67	Lagoon Influent	2460	1610	440	270
	Lagoon Effluent	1950	1220	280	220
	Pond Effluent	1970	1160	150	120
7-20-67	Lagoon Influent	2850	1450	310	---
	Lagoon Effluent	1940	560	240	---
	Pond Effluent	1860	510	180	---
7-27-67	Lagoon Influent	2560	1380	250	160
	Lagoon Effluent	2250	680	650	440
	Pond Effluent	2000	500	440	310
8-3-67	Lagoon Influent	2830	1540	330	180
	Lagoon Effluent	2330	680	830	550
	Pond Effluent	2330	670	820	540
8-10-67	Lagoon Influent	3120	1350	300	110
	Lagoon Effluent	2460	680	800	500
	Pond Effluent	2400	650	790	520
8-17-67	Lagoon Influent	2760	1110	400	230
	Lagoon Effluent	2330	640	770	510
	Pond Effluent	2340	660	740	490
Average Overall:					
	Lagoon Influent	2760	1410	340	190
	Lagoon Effluent	2210	740	580	440
	Pond Effluent	2150	690	520	400
7-27 to 8-17:					
	Lagoon Influent			320	170
	Lagoon Effluent			760	500
	Pond Effluent			700	465

Table 11

INORGANIC NUTRIENT DATA

Date	Location	NH_3-N	T.K.-N	T. PO_4	O. PO_4
7-13-67	Lagoon Influent	4.0	49.6	25.1	6.3
	Lagoon Effluent	0.7	31.9	16.4	---
	Pond Effluent	0.4	26.6	14.2	0.3
7-20-67	Lagoon Influent	3.1	44.0	21.7	9.1
	Lagoon Effluent	0.5	23.6	12.6	0.2
	Pond Effluent	2.2	20.6	9.6	0.1
7-27-67	Lagoon Influent	3.6	52.1	24.5	14.0
	Lagoon Effluent	1.1	44.0	22.9	0.1
	Pond Effluent	4.1	32.6	18.3	0.2
8-3-67	Lagoon Influent	4.2	53.0	39.1	12.7
	Lagoon Effluent	1.5	53.0	40.9	0.1
	Pond Effluent	3.7	53.0	43.9	0.2
8-10-67	Lagoon Influent	3.2	48.1	20.4	4.1
	Lagoon Effluent	5.9	48.1	24.3	0.3
	Pond Effluent	5.6	51.6	19.5	0.1
8-17-67	Lagoon Influent	2.8	38.0	17.0	5.5
	Lagoon Effluent	3.3	64.3	22.5	0.2
	Pond Effluent	6.7	61.4	24.3	0.9
Average:					
	Lagoon Influent	3.5	47.5	25.6	8.6
	Lagoon Effluent	2.2	44.2	23.3	0.2
	Pond Effluent	3.8	39.4	21.7	0.3

Table 12

ORGANIC CARBON, pH AND ALKALINITY DATA

Date	Location	pH	Alk.	TOC	DOC
7-13-67	Lagoon Influent	---	---	640	
	Lagoon Effluent	7.3	280	200	
	Pond Effluent	7.3	280	170	
7-20-67	Lagoon Influent	7.7	250	560	
	Lagoon Effluent	7.1	270	160	
	Pond Effluent	7.1	270	190	
7-27-67	Lagoon Influent	7.8	250	---	
	Lagoon Effluent	7.5	270	190	
	Pond Effluent	7.5	290	150	
8-3-67	Lagoon Influent	7.6	260	570	
	Lagoon Effluent	7.5	270	230	
	Pond Effluent	7.5	280	200	
8-10-67	Lagoon Influent	7.8	270	540	
	Lagoon Effluent	7.6	290	170	
	Pond Effluent	7.6	290	180	
8-17-67	Lagoon Influent	7.0	260	400	280
	Lagoon Effluent	7.2	260	160	24
	Pond Effluent	7.3	300	130	23
Average:					
	Lagoon Influent		260	540	
	Lagoon Effluent		270	185	
	Pond Effluent		285	170	

Table 13

BOD AND COD DATA

Date	Location	BOD Total	BOD Dissolved	COD Total	COD Dissolved
7-13-67	Lagoon Influent			1470	
	Lagoon Effluent			510	
	Pond Effluent			430	
7-20-67	Lagoon Influent	870	870	1350	
	Lagoon Effluent	240	140	410	
	Pond Effluent	190	110	310	
7-27-67	Lagoon Influent	810	740	1540	
	Lagoon Effluent	140	5	650	
	Pond Effluent	140	12	490	
8-3-67	Lagoon Influent	1020	850	1580	1500
	Lagoon Effluent	260	11	650	160
	Pond Effluent	260	7	670	170
8-10-67	Lagoon Influent	780	710	1540	1370
	Lagoon Effluent	190	11	740	--
	Pond Effluent	150	11	740	150
8-17-67	Lagoon Influent	620	550	1060	1000
	Lagoon Effluent	150	8	540	120
	Pond Effluent	170	16	640	120
Average Overall:					
	Lagoon Influent	820	745	1420	1290
	Lagoon Effluent	196	35	580	140
	Pond Effluent	182	31	550	150
7-27 to 8-17:					
	Lagoon Influent	810	570	1410	
	Lagoon Effluent	185	9	640	
	Pond Effluent	180	12	640	

Table 14

AVERAGE PERCENT REDUCTIONS

Parameter	Aerated Lagoon	Lagoon & Polishing Pond
Total Solids	20	22
Total Volatile Solids	48	51
Suspended Solids	-71	-53
Volatile Suspended Solids	-132	-110
Total Phosphate	9	15
Total Kjeldahl Nitrogen	7	17
Total Organic Carbon	66	69
Dissolved Organic Carbon	91	92
COD, Total	59	62
COD, Dissolved	82	89
BOD, Total	76	78
BOD, Dissolved	95	96
Overall 7-27 to 8-17	98.4	98