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TECHNICAL ASSISTANCE PROJECT

AT THE

AUGUSTA WASTEWATER TREATMENT PLANT

AUGUSTA, GEORGIA

JUNE - JULY, 1976

Environmental Protection Agency
Region IV
Surveillance and Analysis Division
Athens, Georgia

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INTRODUCTION

A technical assistance study of operation and maintenance problems at the Wastewater Treatment Plant (WTP) serving Augusta, Georgia was conducted June 28 - July 1, 1976 by the Region IV, Surveillance and Analysis Division, U. S. Environmental Protection Agency. On August 11, 1976, additional sampling was conducted on the anaerobic digesters to clarify discrepancies in data collected during the initial study. Operation and Maintenance technical assistance studies are designed to assist wastewater treatment plant operators in maximizing treatment efficiencies as well as assisting with special operational problems. Municipal wastewater treatment plants are selected for technical assistance studies after consultation with state pollution control authorities. Visits are made to each prospective plant prior to the study to determine if assistance is desired and if study efforts would be productive.

The Augusta WTP was selected because of difficulty in achieving design treatment efficiencies. The specific study objectives for the WTP were to:

- Optimize treatment through control testing and recommended operation and maintenance modifications,
- Introduce and instruct plant personnel in new operational control techniques,
- Determine influent and effluent wastewater characteristics,
- Assist laboratory personnel with any possible laboratory procedure problems, and
- Compare design and current loadings.

A follow-up assessment of plant operation and maintenance practices will be conducted by October 1976. This will be accomplished by utilizing data generated by plant personnel and, if necessary, subsequent visits to the facility will be made. The follow-up assessment will determine if recommendations were successful in improving plant operations and if further assistance is required.

The cooperation of the Georgia Environmental Protection Division is gratefully acknowledged. The technical assistance team is especially appreciative of the cooperation and assistance received from Mr. Mark Boner (Zimmerman, Evans & Leopold Consulting Engineers), the City of Augusta engineering department, and the wastewater treatment personnel in Augusta, Georgia.

SUMMARY

The Augusta Wastewater Treatment Plant (WTP) was designed as a 30 mgd activated sludge system. The hydraulic load at the WTP was about 23.9 mgd (average three day flow) during the technical assistance (TA) study. The average BOD_5 and TSS reduction during the TA study was 83 and 59 percent, respectively.

The major problems observed during the study were as follows:

- The activated sludge appeared old, inactive, and settled extremely fast leaving a significant amount of colloidal material in the supernatant.
- The food to microorganism ratio was higher than recommended values.
- Dissolved oxygen concentrations in the aeration basins and aerobic digester were, in general, too low for optimum treatment efficiency.
- The aeration basins were organically overloaded due to low BOD_5 removal in the primary treatment units and an influent waste stronger than anticipated.
- The return activated sludge was inactive and had an immediate oxygen demand. This situation was caused by low dissolved oxygen concentrations throughout the secondary system.
- Prior to this TA study, sludge wasting to the aerobic digester was not monitored or controlled on a regular schedule.
- The anaerobic digesters and related mixing, gas collection, and monitoring systems had not been in full efficient operation for some time.
- Most of the automatic monitoring and control metering equipment was out of service for various reasons including repair, calibration, or lack of knowledge on operation.

RECOMMENDATIONS

Based on observations and data collected during the study, it is recommended that the following measures be taken to improve wastewater treatment and plant operation.

1. Sludge wasting should be controlled to maintain a mean cell residence time (MCRT) of about 8 days. This will provide a baseline of data on which to make additional operational changes.

2. Dissolved oxygen in the aeration basins and aerobic digester should be increased to about 2 mg/l. The depth of submergence of the brush aerators should be increased to transfer more oxygen.

3. As the old sludge is removed, the MLSS should be increased to about 3,000 mg/l, if adequate DO can be maintained.

4. Final clarifier effluent weirs should be checked closely and leveled where necessary.

5. The return sludge flow rate should be reduced as the settleability of the activated sludge improves. Aerobic conditions in the clarifier must be maintained and this will dictate the minimum return sludge flow.

6. The mixing system in the primary anaerobic digesters should be checked closely and repaired, if necessary, to insure adequate mixing.

7. Automatic monitoring and control equipment throughout the plant should be repaired, calibrated and placed in operation.

8. An in-plant control testing schedule should be initiated and trend charts established and maintained.

9. Standardization of titrants should be incorporated as a routine laboratory procedure.

10. Sulfuric acid (10%) or hydrochloric acid (10%) should be used to clean BOD glassware instead of chromerge.

TREATMENT FACILITY

TREATMENT PROCESSES

A schematic diagram of the 30 mgd activated sludge wastewater treatment plant (WTP) serving Augusta, Georgia is presented in Figure 1. Design data are enumerated in Table I. The original primary plant began operation in March 1969 and was expanded to the existing secondary system in March 1975.

After passing through a grit chamber and mechanically cleaned bar screens, the influent wastewater is split into four parallel primary sedimentation basins. Sludge from the primary sedimentation basins is pumped to the anaerobic digesters.

Wastewater from the primary units flows to two activated sludge aeration basins operated in parallel. The aeration basins are operated in an oxidation ditch type flow scheme with oxygen supplied by rotating brush aerators. The wastewater then flows through two parallel secondary clarifiers, is chlorinated and discharged to the Savannah River via Butler Creek.

Sludge from the secondary clarifier is pumped to an aerobic digester. After concentration in a sludge thickener, this sludge is usually pumped directly to the vacuum filters. During the study, one filter was down for repair; consequently, thickened aerobic digester sludge was pumped to the number 3 (secondary) anaerobic digester and then to the filter. Sludge from the vacuum filters is used as a soil conditioner by the City of Augusta.

Supernatant from the anaerobic digesters and sludge thickener, filtrate from the vacuum filters and scum from the primary sedimentation basins is discharged into the Butler Creek sewer, which flows back to the head of the plant.

PERSONNEL

The City of Augusta WTP is staffed by thirty-four persons. Of the thirty-four, twelve hold the following certifications: 1-Class I, 1-Class II, 7-Class III, and 3-Class IV.

FIGURE 1

CITY OF AUGUSTA
WASTEWATER TREATMENT PLANT

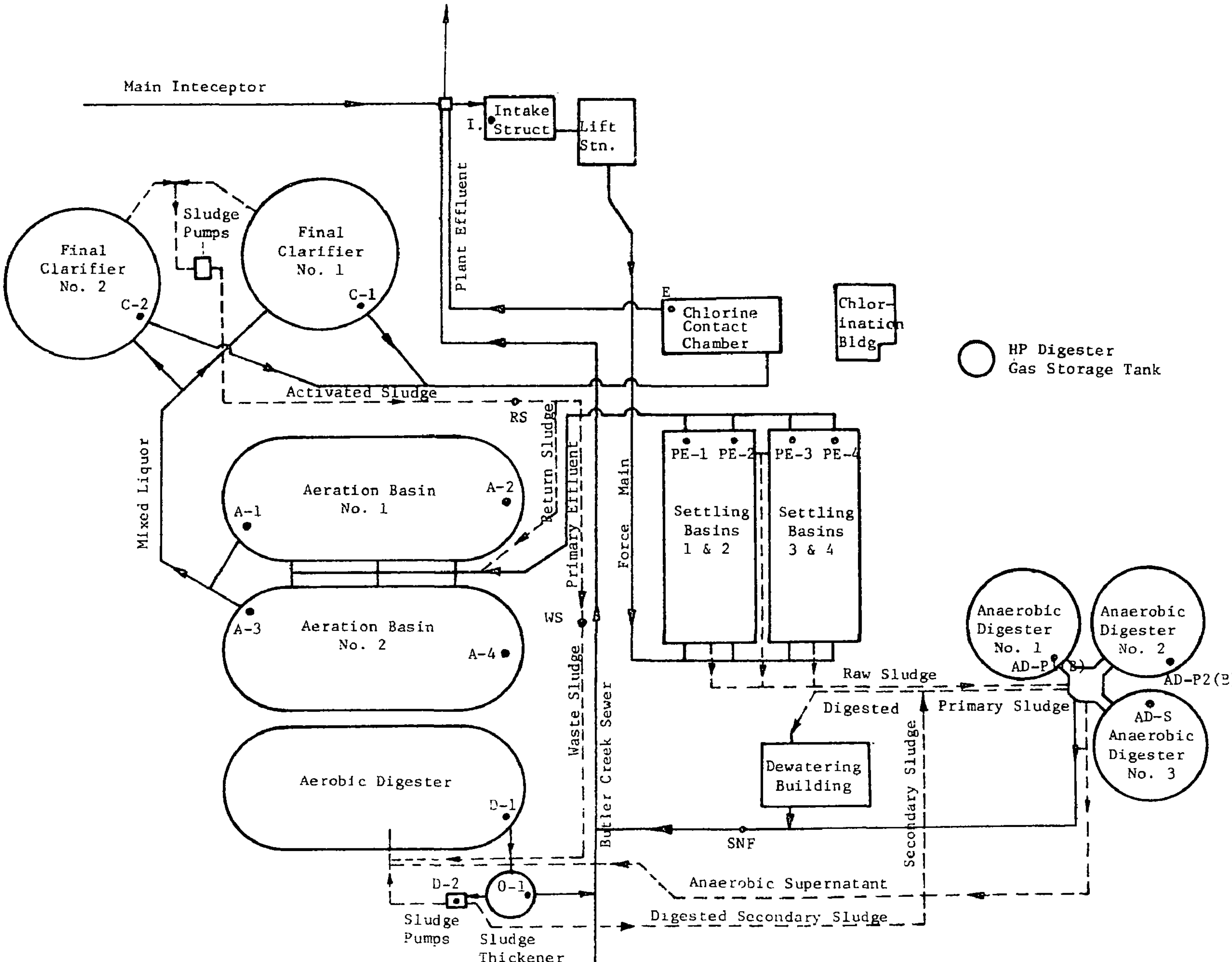


TABLE I
DESIGN DATA
AUGUSTA WASTEWATER TREATMENT PLANT
AUGUSTA, GA

I. GENERAL DESIGN

Design Year	1995
Population	203,000
Industrial Equivalent Population	20,000
Total Equivalent Population	223,000
Average Flow	30 mgd
Peak Flow	42 mgd
BOD	37,200 lbs/day

II. FLOW MEASUREMENTS

Influent	5 ft. Parshall flume, recorder, totalizer
Effluent	5 ft. Parshall flume, indicator, totalizer
Primary Effluent	Venturi meter - 48 in. pipe line
Return Sludge	Venturi meter - 30 in. pipe line
Waste Sludge	
(Anaerobic Digester)	Venturi meter - 8 in. pipe line
(Aerobic Digester)	Venturi meter - 8 in. pipe line
Aerobic Digester Recycle	Venturi meter - 8 in. pipe line
Waste Sludge	
(Thickener)	Venturi meter - 6 in. pipe line

III. PRELIMINARY TREATMENT

Bar Screen (1)	1 3/8 in. spacing, mechanically cleaned
Aerated Grit Chamber (2)	mechanically cleaned

IV. PRIMARY SEDIMENTATION BASINS

Number	4
Volume (each)	700,000 gal.
Design Detention	2.24 hrs.
Settling Rate	850 gal/sq. ft./day
Total Effluent Weir Length	1,440 lin. ft.

V. AERATION BASINS

Number	2
Volume	2.16 M Gal.
Aeration (each basin)	6 Rotating Brush Aerators

VI. FINAL CLARIFIERS

Number	2
Diameter	160 ft.
Area (each)	20,106 sq. ft.
Volume (each)	1.87 M. Gal.
Detention Time	3 hrs.
Weir Length (each)	967 lin. ft.
Depth	13 ft.

VII. CHLORINATION

Capacity	4,020 lbs/day
Detention	30 min.

VIII. AEROBIC DIGESTION

Number Basins	1
Volume	2.16 M. Gal.
Aeration	6 Rotating Brush Aerators

IX. SLUDGE THICKENER

Type	Circular
Surface Area (effective)	1,385 sq. ft.
Diameter	42 ft.

X. ANAEROBIC DIGESTION

Number Units	3 (2 heated and mixed)
Total Volume	659,200 cu. ft.

XI. SLUDGE DRYING

Type	Vacuum Filters
Number Units	2
Total Filter Area	500 sq. ft.

STUDY RESULTS AND OBSERVATIONS

A complete listing of all analytical data and study methods are presented in Appendices A, B, and C. Formulae used for general calculations are enumerated in Appendix D. Significant results and observations made during the study are discussed in the following sections.

FLOWS

Plant flow was measured with a 5 foot Parshall flume, equipped with a recorder and totalizer. Average hourly influent flows during the study are depicted in Figure 2. The average influent flow was 23.9 mgd; the minimum flow was 16 mgd and the maximum flow was greater than 50 mgd, which occurred during a heavy rain. Part of the wastewater collection system is combined, thereby causing a tremendous inflow problem.

Approximately 6 mgd of the influent wastewater flow was from industrial sources, comprised of wastewaters from baking, textile and paper product operations.

Return sludge flow rates were manually controlled at about 70 percent of the total plant inflow. A Venturi meter with recorder and totalizer in a 30 inch pipe line, normally used to automatically control return flow, was out of service for repairs. The average return sludge flow during the study was approximately 16.7 mgd.

Waste sludge flow rates were not monitored until the week prior to the O&M technical assistance (TA) study. For the week prior to the study, wasting was arbitrarily controlled at 0.216 mgd (150 gpm). On June 29, 1976, after reviewing preliminary study findings and on recommendation of the TA team, waste sludge flow was doubled to 0.432 mgd (300 gpm).

Total flows from the anaerobic digester supernatant overflow, filtrate from the vacuum filters, and overflow from the primary sedimentation scum troughs were measured using a portable Manning flow meter. The average 24-hour flow from these contributing sources was 0.33 mgd.

WASTE CHARACTERISTICS AND REMOVAL EFFICIENCIES

Table II presents a chemical description of the WTP influent and effluent with calculated average percent reductions. The removal efficiencies were calculated using data from stations I-1 and E-1, which were collected on a 24-hour proportional to flow composite basis for the first two consecutive sampling periods (June 28 - July 1, 1976).

FIGURE 2

INFLUENT & RETURN SLUDGE FLOW

AUGUSTA, GA WTP

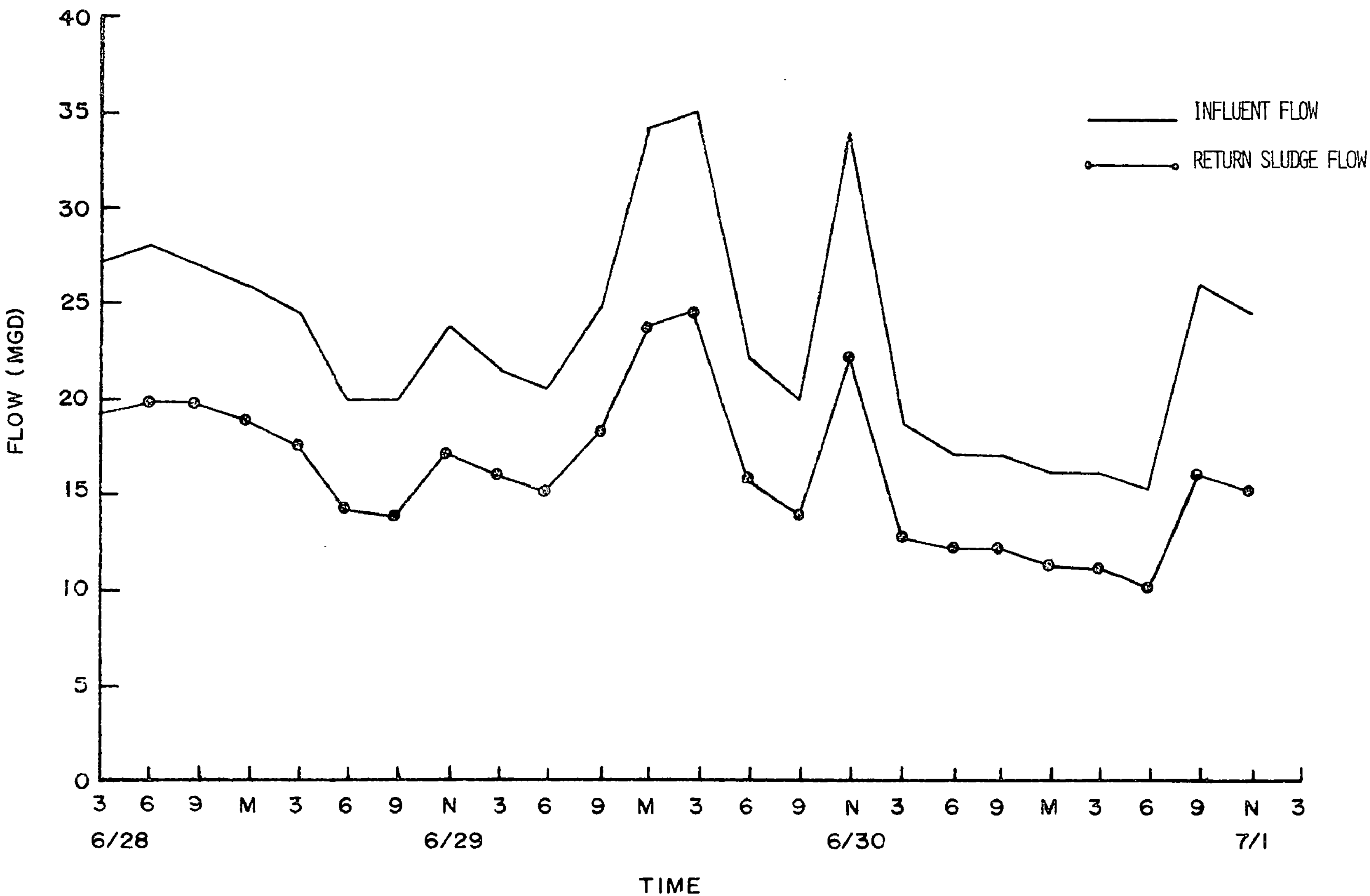


TABLE II

WASTE CHARACTERISTICS AND REMOVAL EFFICIENCIES

PARAMETER	INFLUENT[1/]	EFFLUENT	% REDUCTION
BOD_5 (mg/l)	168	28.5	83
Total Solids (mg/l)	627	422	33
TVS (mg/l)	266	94	65
TSS (mg/l)	126	52	59
TVSS (mg/l)	75	42	44
Settleable Solids (ml/l)[2/]	3.0	<0.1	>97
COD (mg/l)	401	131	67
TKN-N (mg/l)	29.5	26.5	10
NH_3-N (mg/l)	20.6	23.6	-14
NO_3-NO_2-N (mg/l)	<0.01	<0.01	--
Total Phosphorus (mg/l)	6.4	6.1	5
Pb (μg/l)	100	<50	>50
Cr (μg/l)	102	<55	>46
Cd (μg/l)	<10	<10	--
Cu (μg/l)	108	50	54
Zn (μg/l)	210	75	64
Oil & Grease (mg/l)	34	<5.5	>84

1/ The supernatant from the anaerobic digester is included in the influent waste characteristics.

2/ Analysis conducted on June 28-29 sampling period only.

The removal efficiency calculation for oil and grease was the only exception. It was based on data from three grab samples taken during the period (June 28 - July 1).

According to the data in Table II, nitrification was not being achieved in the treatment system. This is probably due to the short aeration period, low dissolved oxygen and the poor quality activated sludge.

PRIMARY SEDIMENTATION

Table III presents a general description of the influent and effluent from each primary sedimentation basin, with calculated percent reductions shown for all parameters. Analyses were made on 24-hour composite samples collected on three consecutive days (June 28 - July 1) except for sampling station PE-1. Because of an inoperative sampler, no sample was taken from basin #1 during the June 30 - July 1 sampling period, therefore, only a two-day average is given for this basin.

The average detention time in the primary sedimentation basins was about 1.7 hours, which is within recommended detention times of 1-2 hours (4). The extremely low influent settleable solids raises two questions; the necessity of the primary sedimentation basins and removal of enough primary solids to effectively operate both primary anaerobic digesters.

AERATION BASINS

Grab samples taken from the discharge end of both aeration basins (Stations A-1 and A-3) were analyzed for total suspended solids (TSS), volatile suspended solids (VSS), percent solids by centrifuge, and settleability as determined by the settlometer.

Presented in Table IV are various activated sludge operational parameters calculated during the study period and the corresponding recommended values for the complete mix activated sludge process. The actual design parameters for the Augusta WTP are slightly different than those recommended in Table IV. The plant was designed as a modified (high-rate) version of the conventional step-feed activated sludge process and approaches completely mixed conditions.

TABLE III
WASTE CHARACTERISTICS AND REMOVAL EFFICIENCIES
FOR THE PRIMARY SEDIMENTATION BASINS

	Influent	Influent 1/	PE-1 1/	PE-1 1/	PE-2	PE-2	PE-3	PE-3	PE-4	PE-4	Average 3/
	Conc.	Conc.	Conc.	% Reduction	Conc.	% Reduction	Conc.	% Reduction	Conc.	% Reduction	% Reduction
BOD (mg/l)	185	(168)	149	11	167	10	144	22	158	14	14
COD (mg/l)	487	(401)	304	24	366	25	351	28	387	20	24
TSS (mg/l)	204	(126)	51	60	66	68	91	55	103	50	58
VSS (mg/l)	123	(75)	45	40	56	54	69	44	84	32	42
Settleable Solids (ml/l) 2/	<0.1	--	<0.1	--	<0.1	--	<0.1	--	<0.1	--	--
Pb (ug/l)	133	(100)	80	20	93	30	77	42	93	30	30
Cr (ug/l)	130	(102)	100	2	88	32	92	29	94	28	23
Cd (ug/l)	<10	(<10)	<10	--	<10	--	<10	--	<10	--	--
Cu (ug/l)	152	(108)	65	40	83	45	83	45	142	6	34
Zn (ug/l)	313	(210)	130	38	172	45	148	53	252	19	39
TKN-N (mg/l)	31.1	(29.5)	28.9	2	31.2	-0.3	31.1	0	32.6	-4.8	-0.8
NH_3-N (mg/l)	23.4	(20.6)	28.2	-37	27.5	-18	26.5	-13	26.2	-12	-20
NO_3-NO_2-N (mg/l)	<0.02	(<0.01)	<0.01	--	<0.03	--	<0.01	--	<0.05	--	--
Total Phosphrous (mg/l)	7.2	(6.4)	6.4	0	6.4	11	6.5	9.7	9.6	-33	-3.1

1/ Average based on data for the first two days of sampling.

2/ Analysis conducted on 2nd day composite sample.

3/ Based on average percent reductions from each individual basin.

TABLE IV
MEASURED AND RECOMMENDED PARAMETERS FOR THE
COMPLETE-MIX ACTIVATED SLUDGE PROCESS

	Measured	Recommended (1)(7)
Hydraulic Retention Time (hrs.)	2.5	3-5
Mean Cell Residence Time (days)	*	5-15
Sludge Age (days)	4.2	3.5-7.0
Lbs. BOD_5/day/lb. MLVSS (F/M)	0.7	.2-.6
Lbs. COD/day/lb. MLVSS	1.6	.5-1.0
Lbs. BOD_5/day/1000 cu. ft. aeration basin	53	50-120
MLSS (mg/l)	1,855	3,000-6,000
Return sludge rate (% of average flow)	70	25-100

* - Waste sludge flow rate had not been measured prior to study; consequently, MCRT could not be calculated.

Data collected during the study indicate that the aeration basins were organically overloaded by approximately 20 percent. The basins were designed to treat 26,000 lbs. of BOD_5/day, but were receiving about 30,900 lbs/day during the study. Since the plant was operating at only 80% of the hydraulic design capacity, the organic overload was due to less than anticipated removal in the primary treatment and a slightly stronger than anticipated influent waste strength. In design of the plant, it was assumed that primary treatment would remove 30 percent of the influent BOD_5; however, only 14 percent was removed during the study. The raw influent BOD_5 was 168 mg/l during the study versus 148 mg/l assumed in design. These two factors resulted in a wastewater flow into the aeration basins with a BOD_5 concentration of 155 mg/l as opposed to 104 mg/l assumed in design. This plant was designed for a loading rate (45 lbs. BOD_5/1,000 cu. ft.), somewhat above conventional activated sludge loadings (20-40 lbs. BOD_5/1,000 cu. ft.), and for a rather weak influent waste. These two design criteria have resulted in minimum sized basins. This results in a short hydraulic detention time of 2.5 hours using average plant flow and return sludge rates observed during the study. Consequently, there is very little reserve capacity to handle an organic or hydraulic overload.

The F/M ratio is much too high. In order to maintain an F/M of about 0.4, the MLSS concentration should be approximately 3,000 mg/l.

The sludge age of 4.2 days (Table IV) is not a true representation of sludge in the system. Settleability and visual observation of the mixed liquor activated sludge indicate an old, inactive sludge. The total suspended solids in the final effluent were about 82 percent volatile. This implies that the young, biologically active solids were being lost in the effluent while the older, heavier, less biologically active solids were being retained in the secondary system.

The activated sludge settleability for both aeration basins was the same. The average settleability during the study period is presented in Figure 3. The activated sludge was too old and settled too rapidly, leaving a considerable amount of suspended solids in the supernatant. A slower rate of settling would remove most of these solids, leaving a clearer supernatant. A settled sludge volume of about 20 percent after 60 minutes of settling should approach optimum and can be achieved with a younger activated sludge.

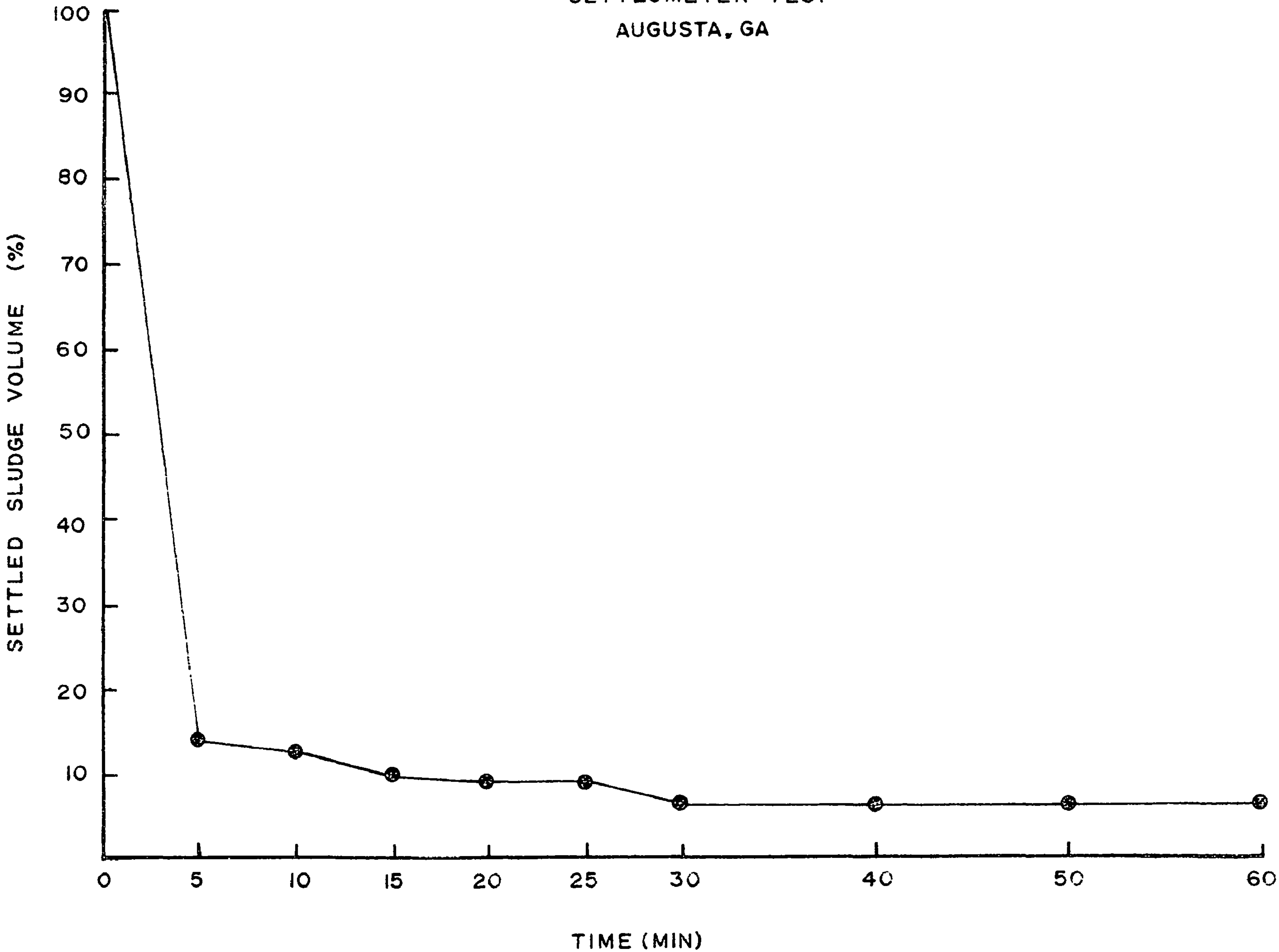
The condition of an activated sludge process can be assessed by several means. One of these is sludge activity by microscopic examination. A combination of select protozoa types in a given activated sludge at a given aeration time is the barometer by which the observation is based. A very active sludge will accommodate a wide variety of protozoan organisms, depending on the abundance of biodegradable food. As the sludge approaches stability or reaches its optimum age, the selection of protozoan types becomes more restrictive. The organisms most commonly observed at optimum age are stalked ciliates, free-swimming ciliates, and rotifers. When the sludge gets too old, the balance shifts; free bacterial cells become limited, and free-swimming ciliates and rotifers decrease or desist. With this die-off, another group of floc-eating organisms, including crawling ciliates, mites, and nematodes, becomes prevalent.

Examination of the Augusta WTP mixed liquor demonstrated a very limited and selective population of stalked ciliates, crawling ciliates, and flagellates. Protozoan populations of this type are generally associated with old activated sludges. The observation of individual sludge particles revealed the settled solids to be small, separate, dense granules without bacterial floc.

The oxygen uptake procedure is another indicator of sludge condition. General sludge activity using this procedure can be determined by utilizing the difference in oxygen uptake rates before and after introduction of the raw waste. The ratio of these two variables or "load ratio" is calculated as follows:

$$\text{Load ratio} = \frac{\text{DO/min. of fed sludge}}{\text{DO/min. of unfed sludge}}$$

FIGURE 3
SETTLOMETER TEST
AUGUSTA, GA



The calculated load ratios presented in Table V indicate that the Augusta WTP activated sludge (A/S) was inactive. These data indicate that the sludge is not of high quality or the incoming waste is toxic or not readily biodegradable. A conventional A/S process commonly performs best in the load ratio range of 2-4. On the initial aerated samples dissolved oxygen was depleted very rapidly. This rapid oxygen utilization was characteristic of a very active A/S or an oxygen demand that was non-biological. After several reaerations of the samples, a biological demand was measured as shown (Average O_2 uptake) in Table V. From the calculated load ratio and the microscopic examination, it was concluded that the inactivity of the sludge was due to the low dissolved oxygen conditions which existed. Mixed liquor dissolved oxygen (DO) was normally less than 0.5 mg/l, resulting in a septic sludge in the clarifier. This septic condition tends to deactivate the sludge and produces an immediate oxygen demand.

TABLE V
OXYGEN UPTAKE RATES

Date	Time	RS 1/	Average O_2 Uptake PPM/Min. 2/ URS	Average O_2 Uptake PPM/Min. 3/ FRS	Load Ratio FRS/URS
6/30	9:15 a.m.	70	1.5	1.7	1.13
6/30	12:15 p.m.	70	1.42	1.47	1.03

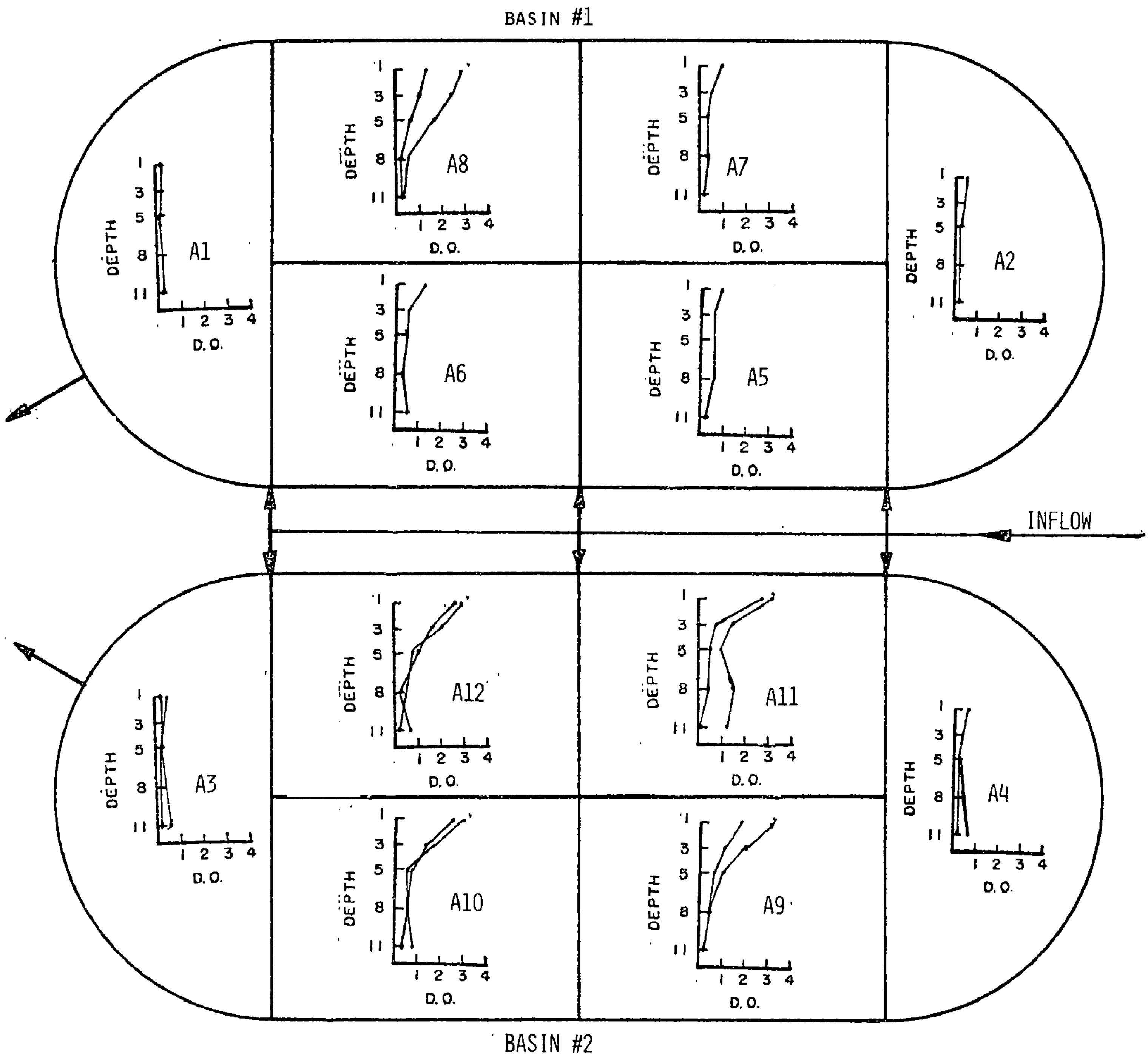
1/ RS - Return Activated Sludge
2/ URS - Unfed Return Sludge
3/ FRS - Fed Return Sludge

Results of the dissolved oxygen (DO) measurements in the aeration basins are presented in Figure 4 and Appendix B. Except for surface (1.0 foot depth) measurements at points between the aerators, dissolved oxygen concentrations were too low. The submergence on the aerators was about seven inches. Oxygen in the aeration basins can be increased by increasing the aerator submergence.

Activated sludge mixed liquor solids must be wasted at a controlled rate to remove the old, inactive sludge presently in the system. Maintaining constant conditions will allow operational control parameters to be evaluated and then subsequent operational changes can be made more efficiently and accurately. Based on a mean cell residence time (MCRT) of eight days and plant conditions at the time of the TA study, the waste sludge flow should be maintained at about 230 gpm. The waste sludge rate should be calculated at least once weekly, based on the previous 5-7 days' data, and the appropriate changes made. A subsequent gradual buildup of a younger, more active, slower settling sludge should improve treatment but will require close operational control. Initially, the MLSS level should be built up to around 3,000 mg/l. A younger sludge

FIGURE 4.

AERATION BASIN D.O.



will probably increase the oxygen demand in the aeration basins; consequently, aeration capacity may dictate the maximum MLSS concentration that can be maintained. Sludge settleability and aeration basin DO must be monitored closely in order to maintain optimum treatment efficiency.

FINAL CLARIFIERS

The two final clarifiers are circular with center feed and rim take-off. The effluent weir trough consists of two parallel weirs around the periphery of the clarifier.

Observation of unequal flow over the effluent weirs indicated that the weirs were not level. The weirs were checked with an engineer's level and found to vary 0.15 feet (1.8 inches) and 0.11 feet (1.3 inches) in elevation in clarifiers #1 and #2, respectively.

Suspended solids appear to flow over the outside effluent weir more frequently than the inner-most weir. This is a common occurrence when weirs are placed along the tank wall. The density of the activated sludge mixed liquor is much greater than that of the liquid in the clarifier. Consequently, it flows along the bottom until hitting the wall, then flows up and over the weir.

The depth of the sludge blanket below the water surface was measured daily. No sludge blanket existed during the study period. This was due to the high return sludge rate, which was maintained at about 70 percent of the plant influent flow. The return sludge total suspended solids concentrations (sampling Station RS), on two days of grab samples, were 4,300 and 6,400 mg/l. These concentrations of solids were due to the extremely fast settleability of the activated sludge. A lower return sludge rate will be necessary to allow better concentration of solids as a younger sludge is developed. Monitoring the depth of the sludge blanket and watching for signs of denitrification are critical in secondary clarifier operation and will dictate the return sludge flow rate.

Measured and recommended parameters for final clarifiers following activated sludge wastewater treatment are presented in Table VI.

TABLE VI
MEASURED AND RECOMMENDED PARAMETERS FOR SECONDARY CLARIFIERS

	Measured	Recommended (1)(3)(4)
Hydraulic Loading (gpd/sq. ft.)	600	400-800
Solids Loading (lbs./day/sq. ft.)	15.7	20-30
Weir Overflow Rate (gpd/lin. ft.)	12,400	<15,000
Hydraulic Detention Time (hrs.)	2.2	2-3

The weir overflow rate approaches the maximum recommended value by ASCE (4). The existing placement of the weirs does not develop the entire surface area of the clarifier and results in high up-flow velocities along the periphery of the basins.

CHLORINE CONTACT CHAMBER

The primary concern with a chlorine contact chamber (CCC) is the detention of WTP effluent flow to allow adequate time for disinfection. At the Augusta WTP, chlorine was added to the wastewater stream just prior to the CCC. Detention time in the CCC was approximately 30 minutes at design flow. According to WTP personnel, the chlorine gas feed rate is manually controlled at 2,000 lbs./day. This dosage rate resulted in the chlorine residual varying from 2 mg/l to less than 0.1 mg/l.

AEROBIC DIGESTER

Digestion and conditioning of waste activated sludge is accomplished in an aerobic digester. The aerobic digester is similar to the aeration basins except for 30-hp brush aerators, only one inlet port, and no automatic effluent valve or level control. Prior to the TA study, waste activated sludge flow to the aerobic digester was not monitored. This lack of control sometimes resulted in overfilling, thereby overloading the motors and causing motor malfunctions and repairs. During the study, two of the six brush aerators in the aerobic digester were inoperable, needing repairs.

A DO profile in the aerobic digester demonstrated consistently low DO concentrations (Appendix B).

Conditioned sludge from the aerobic digester flows to a sludge thickener. Overflow from the thickener was returned to the WTP influent; thickened sludge was being temporarily pumped to the secondary anaerobic digester due to breakdown of one of the vacuum filters.

The average total suspended solids concentration in the aerobic digester was 17,525 mg/l. The solids were concentrated to 27,000 mg/l (2.7 percent) by the sludge thickener.

ANAEROBIC DIGESTERS

Primary sludge is treated by three anaerobic digesters. The two primary digesters (#1 and #2), operated in parallel, are heated and mixed. The secondary digester (#3) is operated as a holding and solids separation basin prior to pumping to the vacuum filters. Mixing is accomplished by recirculating sludge through the heat exchangers and by the Perth gas mixing system. Gas measuring equipment was inoperative during the study, and all gas produced was burned by the waste gas burner. Observation of the orange flame indicated poor methane production.

Analytical results of anaerobic digester sampling during the TA study are presented in Table VII. Volatile acids results in both primary digesters were exceptionally high and not compatible with previous WTP volatile acid data. Consequently, samples were collected again on August 11 for volatile acids analysis.

TABLE VII
ANAEROBIC DIGESTERS

	Primary #1	Primary #2	Secondary	Combined Supernatant
Total Solids (mg/l)	3,588	49,132	51,132	7,904
Total Volatile Solids (mg/l)	2,040	30,534	29,904	4,496
Alkalinity (mg/l as $CaCO_3$)	1,830	1,350	2,250	--
Volatile Acids (mg/l)	2,232	2,620	1,344	--
pH	6.6	6.0	6.2	--
Temperature (°F)	93	91	86	--
Lead (μg/l)	1,250	22,800	--	3,260
Copper (μg/l)	1,230	24,150	--	3,275
Chromium (μg/l)	550	8,230	--	1,460
Cadmium (μg/l)	<100	720	--	100
Zinc (μg/l)	3,430	72,000	--	7,450

Analytical data (Table VII) reveal significant concentrations of heavy metals in the digesters. However, a consulting engineer (9), experienced with anaerobic digester operation, stated that properly operated anaerobic digesters can function efficiently with the concentration of metals listed in Table VII.

According to plant personnel and operating records, the two primary digesters had been fed raw primary sludge equally. However, total solids data (Table VII) indicate that this is not the case. Assuming efficient mixing and equal raw sludge feed to each digester, these differences are unexplainable. Consequently, additional digester sampling was performed on August 11, 1976. Samples were collected from an unused supernatant line located in the top portion of the digester and from the recirculation line located at about mid-depth. Samples were split with WTP laboratory personnel. These results are presented in Appendix A. The average total solids (TS) concentration in the #1 and #2 digesters were 4,260 and 3,212 mg/l, respectively. Review of recent data obtained by WTP personnel indicate variation in TS concentrations of 0.3 to 7 percent solids. These data suggest poor mixing in both primary digesters, with most of the digester solids settling below the mid-depth level. Two possible causes are insufficient gas production and a malfunction in the gas mixing system.

Alkalinity, volatile acids, and pH were within acceptable ranges; however, the quantity and quality of methane production was unknown. A Fischer Gas Partitioner, coupled directly to the digesters, has never operated properly. In order to effectively run equipment using digester gas (methane), the quantity and quality of gas must be monitored.

The following anaerobic digester sampling schedule (1) should be initiated and the data continually plotted on trend charts.

A. Daily

1. Temperature

B. Twice Per Week (Minimum)

1. Recirculated sludge.

a. Volatile Acids
b. Alkalinity
c. Calculate Volatile Acid/Alkalinity Relationship

C. Weekly

1. Raw sludge

a. pH
b. Total Solids[1/]
c. Volatile Solids[1/]

2. Recirculated sludge

a. pH
b. Total Solids
c. Volatile Solids

3. Supernatant

a. pH
b. Total Solids
c. Volatile Solids

1/ Collect raw sludge samples daily at the start, middle, and end of the pumping cycle. Once a week prepare a composite sample by mixing the daily samples together and run total and volatile solids tests.

D. Monthly to Quarterly

1. Sound digester by sampling from bottom up at five-foot intervals and test for:

    a. Total Solids
    b. Volatile Solids

2. Use sample results from (D.1.) to determine:

    a. Sludge concentrations at various levels in the digester.

    b. Depth of grit accumulation at bottom of digester. (A gradual build-up of grit will occur, and plant personnel should estimate the date when the digester will have to be cleaned.)

    c. Presence of scum blanket and its thickness.

    d. The effectiveness of digester mixing equipment in mixed primary digesters.

LABORATORY

The laboratory is located within the main control building and has a staff of two chemical technicians. Observations revealed an adequate records system; however, some changes in routine laboratory operations would be of benefit in assuring quality data and increase laboratory efficiencies.

At the time of the study, standardization of some titrants was not a routine procedure. To be confident of data generated in analyses involving titrations, standardization of the titrant against a primary standard is necessary.

The laboratory had a dissolved oxygen (DO) meter with laboratory and field probes. Laboratory personnel stated that they had experienced problems with the instrument. The meter and laboratory probe was checked by EPA personnel, standardized, and found to be working satisfactorily. At the conclusion of the study, laboratory personnel were using the instrument for DO determinations in the BOD_5 test.

The DO meter with field probe could be of great benefit in determining dissolved oxygen levels in the aeration basins. The meter gives valuable data since profiles throughout the basins can be determined and areas of low DO revealed.

Routine control testing was limited at the time of the study. The use of the settlometer and centrifuge tests was explained to WTP personnel, and at the conclusion of the study, these analyses were implemented on a routine basis.

All data that is generated is best utilized when plotted on graphs or trend charts. These trend charts reveal changing conditions in a plant, and process changes can be initiated, as necessary, to correct impending problems.

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9. Personal Communication, T. M. Reagan, Consulting Engineer, Lexington, KY, August 2, 1976.

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APPENDIX A
Laboratory Data
Augusta, GA WTP

Influent and Effluent

O&M #	STATION	MONTH	DAY	YEAR	TIME	BOD mg/l	COD mg/l	TKN-N mg/l	NH_3-N mg/l	NO_3-NO_2-N mg/l	Total-P mg/l	Pb µg/l	Ci µg/l	Cd µg/l	Cu µg/l	Zn µg/l	Suspended Solids mg/l	Volatile Suspended Solids mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Oil & Grease mg/l	Settleable Solids ml/l/hr
0970	I	6	28/29	76	24 hr. Comp.	160	418	31.2	19.0	<0.01	6.8	100	85	<10	105	225	132	75	644	270	–	3.0
0978	↓	6	29	76	1600	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	35	–
0989		6	30	76	0915	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18	–
1003		6	29/30	76	24 hr. Comp.	176	384	27.8	22.1	<0.01	5.9	100	120	<10	110	195	120	75	610	262	–	<0.1
1005		6/7	30/1	76	24 hr. Comp.	220	660	34.2	29.0	0.04	8.8	200	185	<10	240	520	359	218	732	308	–	–
1011	↓	7	1	76	24 hr. Comp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	50	–
0972	PE-1	6	28/29	76	24 hr. Comp.	153	308	30.0	32.0	<0.01	6.7	80	85	<10	65	135	57	48	–	–	–	–
1004	↓	6	29/30	76	24 hr. Comp.	145	300	27.8	24.5	<0.01	6.2	80	115	<10	65	124	45	42	–	–	–	<0.1
0973	PE-2	6	28/29	76	24 hr. Comp.	130	328	30.7	27.0	<0.01	6.5	80	85	<10	70	170	39	36	–	–	–	–
0997		6	29/30	76	24 hr. Comp.	193	324	28.3	27.0	0.04	5.6	100	80	<10	75	155	32	30	–	–	–	<0.1
1007	↓	6/7	30/1	76	24 hr. Comp.	177	447	34.6	28.5	0.04	7.2	100	100	<10	105	190	128	102	–	–	–	–
0974	PE-3	6	28/29	76	24 hr. Comp.	120	300	30.8	26.5	<0.01	6.4	50	80	<10	60	124	60	55	–	–	–	–
0998		6	29/30	76	24 hr. Comp.	160	332	28.3	24.0	<0.01	5.6	100	115	<10	80	130	70	52	–	–	–	<0.1
1008	↓	6/7	30/1	76	24 hr. Comp.	153	420	34.2	29.0	<0.01	7.4	80	80	<10	110	190	144	100	–	–	–	–
0975	PE-4	6	28/29	76	24 hr. Comp.	153	332	32.2	25.0	<0.01	6.3	50	60	<10	125	215	80	72	–	–	–	–
0999		6	29/30	76	24 hr. Comp.	175	436	29.2	24.5	<0.01	6.0	100	100	<10	129	220	78	58	–	–	–	–
1009	↓	6/7	30/1	76	24 hr. Comp.	147	393	36.4	29.0	0.12	16.5	100	123	<10	173	320	150	122	–	–	–	–

APPENDIX A
Laboratory Data
Augusta, Georgia WTP

~~Aeration Basins~~

O+M #	STATION	MONTH	DAY	YEAR	TIME	% Solid 2/2 Centrifuge %	Total Suspended Solids mg/l	Volatile Suspended Solids mg/l	SETTLOMETER (Settled Sludge Volume %) 5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	40 min.	50 min.	60 min.	COMMENTS
0956	A-1	6	28	76	1500	1.8	-	-	14	13	12	10	10	9	8	8	8	Settled to 15% in 3 min, Supernatant Turbid.
0966	A-1 Bottom	6	29	76	1130	2.3	-	-	-	-	-	-	-	-	-	-	-	-
0982	A-1	6	30	76	0900	2.0	1850	1225	15	11	10	9	8	7	7	7	7	Settled Rapidly, leaving a Turbid Supernate.
0960	A-1	6	29	76	0915	2.0	1918	1248	12	-	7	-	-	6	6	6	6	" " " "
0957	A-2	6	28	76	1500	2.0	-	-	15	13	12	10	10	9	8	8	8	Settled to 16% in 3 min., supernatant Turbid.
0967	A-2 Bottom	6	29	76	1130	1.8	-	-	-	-	-	-	-	-	-	-	-	-
0958	A-3	6	28	76	1500	2.0	-	-	16	13	12	10	10	9	8	8	8	Settled to 18% in 3 min., Supernatant turbid.
0961	A-3	6	29	76	0915	2.0	1800	1175	12	-	7	-	-	6	6	6	6	Settled rapidly, supernatant turbid.
0968	A-3 Bottom	6	29	76	1130	1.9	-	-	-	-	-	-	-	-	-	-	-	-
0983	A-3	6	30	76	0900	1.9	1850	1288	15	11	10	9	8	7	7	7	7	Settled rapidly, supernatant turbid
0959	A-4	6	28	76	1500	2.0	-	-	15	12	12	10	10	9	8	8	8	Settled to 16% in 3 min., supernatant turbid.
0969	A-4 Bottom	6	29	76	1130	2.0	-	-	-	-	-	-	-	-	-	-	-	-
0962	WS	6	29	76	0930	4.5	4,700	3,150	-	-	-	-	-	-	-	-	-	-
0963	RS	6	29	76	0930	4.5	4,300	2,867	-	-	-	-	-	-	-	-	-	-
0984	RS	6	30	76	0900	7.0	6,400	4,440	-	-	-	-	-	-	-	-	-	-

APPENDIX A
Laboratory Data
Augusta, GA WTP

Clarifiers and Digesters

O+M #	STATION	MONTH	DAY	YEAR	TIME	Turbidity NTU	% Solids 2/2 Centrifuge	Total Volatile Solids mg/1	Total Solids mg/1	Pb µg/1	Cu µg/1	Cr µg/1	Cd µg/1	Zn µg/1	Alkalinity mg/1 $CaCO_3$	Volatile Acids mg/1	VA/Alk	Ph	Total Suspended Solids mg/1	Volatile Suspended Solids mg/1
0964	FC-1	6	29	76	0915	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0985	FC-1	6	30	76	0900	32	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0965	FC-2	6	29	76	0915	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0986	FC-2	6	30	76	0900	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
0976	D-1	6	29	76	1530	-	15.0	-	-	-	-	-	-	-	-	-	-	-	17,250	10,150
0987	D-1	6	30	76	0900	-	16.0	-	-	-	-	-	-	-	-	-	-	-	17,800	10,450
0977	D-2	6	29	76	1530	-	26.0	-	-	-	-	-	-	-	-	-	-	-	27,300	15,750
0988	D-2	6	30	76	0900	-	26.0	-	-	-	-	-	-	-	-	-	-	-	26,700	15,250
0991	AD-P1-B	6	30	76	0930	-	-	2,040	3,588	-	-	-	-	-	1830	2232	1.2	-	-	-
0994	AD-P1-B	6	30	76	1015	-	-	-	-	1,250	1,230	550	<100	3,430	-	-	-	-	-	-
0992	AD-P2-B	6	30	76	0930	-	-	30,534	49,132	-	-	-	-	-	1,350	2,620	1.9	6.4	-	-
0995	AD-P2-B	6	30	76	1015	-	-	-	-	22,800	24,150	8,230	720	72,000	-	-	-	-	-	-
0993	AD-S	6	30	76	0945	-	-	29,904	51,132	-	-	-	-	-	2,250	1,344	0.6	6.6	-	-

APPENDIX A
Laboratory Data
Augusta, GA WTP

Effluent, Supernatant, and Overflow

O&M #	STATION	MONTH	DAY	YEAR	TIME	BOD mg/1	COD mg/1	TKN-N mg/1	NH_3-N mg/1	NO_3-NO_2-N mg/1	Total-P mg/1	Pb µg/1	Cr µg/1	Cd µg/1	Cu µg/1	Zn µg/1	Suspended Solids mg/1	Volatile Suspended Solids mg/1	Total Solids mg/1	Total Volatile Solids mg/1	Oil & Grease mg/1	Cl_2 mg/1	Settleable Solids ml/1/hr.	Cl_2 Residual PPM
0971	E	6	28/29	76	24 hr. Comp.	30	121	27.8	25	<0.01	7.0	<50	<50	<10	50	70	46	36	396	86	—	—	<0.1	—
0979	↓	6	29	76	1600	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<5.0	—	—	—
0990		6	30	76	0915	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<5.0	—	—	—
0996		6	30	76	1500	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.36
1000		6	29/30	76	24 hr. Comp.	27	141	26.0	22.2	0.01	5.2	<50	60	<10	50	80	57	49	447	102	—	—	—	—
1,012	↓	7	1	76	1040	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6.4	—	—	—
0980	SNF	6	29	76	Man. Comp. 1000-1600	520	3,912	129	65.0	0.85	74	—	—	—	—	—	—	—	—	—	—	—	—	—
1,001	SNF	6	30	76	Man. Comp. 1000-1600	1,950	7,718	235	65.0	0.14	93	3,260	1,465	100	3,275	7,450	6,700	3,800	7,904	4,496	—	—	—	—
0981	O-1	6	29	76	Man. Comp. 1000-1600	966	4,226	314	130	<0.01	165	—	—	—	—	—	2,233	1,500	—	—	—	—	—	—
1,002	O-1	6	30	76	Man. Comp. 1000-1600	500	2,540	257	125	<0.01	165	—	—	—	—	—	867	667	—	—	—	—	—	—

APPENDIX A
Laboratory Data
Augusta WTP
Augusta, GA

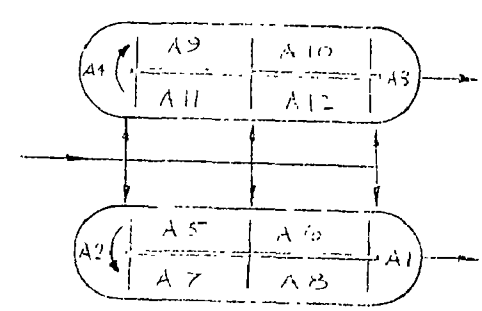
Digesters

O&M #						Total Solids mg/l	Total Volatile Solids mg/l	Alkalinity mg/l	Volatile Acid mg/l	VA/Alk Ratio	Ph
1109	AD-P1-Top	8	11	76	1055	4,450	2,326	1,805	288	0.16	6.9
1110	AD-P2-Top	8	11	76	1050	3,090	1,650	2,066	192	0.09	6.9
1111	AD-P1-Top	8	11	76	1100	3,156	1,694	–	–	–	6.9
1112	AD-P2-Top	8	11	76	1100	3,218	1,740	–	–	–	6.9
1113	AD-P2-Bottom	8	11	76	1110	3,272	1,766	2060	192	0.09	7.0
1114	AD-P2-Bottom	8	11	76	1130	3,266	1,786	–	–	–	7.1
1115	AD-P1-Bottom	8	11	76	1120	4,570	2,432	1,958	120	0.06	7.1
1116	AD-P1-Bottom	8	11	76	1130	4,862	2,570	–	–	–	7.0
Below are the results of analyses conducted on the above split samples by											
	Augusta WTP laboratory personnel										
1109	AD-P1-Top	8	11	76	1055	3,000	–	1,742	103	0.06	-
1110	AD-P2-Top	8	11	76	1050	4,000	–	1,980	103	0.05	-
1111	AD-P1-Top	8	11	76	1100	4,000	–	–	–	–	–
1112	AD-P2-Top	8	11	76	1100	4,000	–	-	–	–	-
1113	AD-P2-Bottom	8	11	76	1110	2,100	–	-	111	–	-
1114	AD-P2-Bottom	8	11	76	1130	4,000	–	–	-	-	-
1115	AD-P1-Bottom	8	11	76	1120	2,000	–	1,899	-	-	-

APPENDIX B
DISSOLVED OXYGEN PROFILES
AUGUSTA, GEORGIA

DATE	TIME	STA	DEPTH	D.O.	TEMP
6-29	1330	A-4	1	0.3	27
			3	0.2	27
			5	0.1	27
			11	0.1	27
	1430	A-9	1	1.8	27
			3	1.1	27
			5	0.6	27
			8	0.2	27
			11	0.3	27
	1515	A-11	1	3.2	27
			3	1.5	27
			5	1.0	27
			8	1.5	27
			11	1.3	27
		A-12	1	2.8	27
			3	1.9	27
			5	1.0	27
			8	0.3	27
			11	0.6	27
		A-10	1	2.9	27
			3	1.6	27
			5	0.6	27
			8	0.4	27
			11	0.9	27
		A-3	1	0.4	27
			3	0.2	27
			5	0.2	27
			11	0.2	27
	1530	A-1	1	0.2	27
			5	0.1	27
			11	0.2	27
		A-8	1	1.3	27
			3	1.0	27
			5	0.6	27
			8	0.2	27
			11	0.2	27
		A-5	1	0.9	27
			3	0.4	27
			8	0.4	27
			11	0.2	27
		A-2	1	0.4	27
			5	0.2	27
			11	0.2	27
6-29	1545	D-1	1	0.2	27
			5	0.1	27
			11	0.1	27
		D-2	1	0.3	26
			5	0.2	26
			11	0.1	26
		D-3	1	0.2	26
			5	0.1	26
			11	0.1	26
		D-6	1	0.2	26
			5	0.1	26
			8	0.1	26
6-30	1030	A-1	1	0.2	26
			5	0.2	26
			11	0.2	26
		A-8	1	2.8	26
			3	2.3	26
			5	1.6	26
			8	0.4	26
			11	0.2	26
		A-6	1	1.3	26
			3	0.5	26
			5	0.4	26
			8	0.3	26
			11	0.4	26
		A-7	1	1.0	26
			3	0.4	26
			5	0.3	26
			8	0.3	26
			11	0.2	26
		A-5	1	0.8	26
			3	0.4	26
			5	0.2	26
			8	0.2	26
			11	0.2	26
	1100	A-4	1	0.5	26
			5	0.2	26
			11	0.5	26
		A-9	1	3.0	26
			3	2.0	26
			5	1.0	26
			8	0.3	26
			11	0.1	26
6-30		A-11	1	2.8	26
			3	0.8	26
			5	0.4	26
			8	0.3	26
			11	0.1	26
		A-10	1	2.6	26
			3	1.4	26
			5	0.7	26
			8	0.5	26
			11	0.3	26
		A-12	1	3.0	26
			3	2.2	26
			5	0.7	26
			11	0.2	26
		A-3	1	0.2	26
			5	0.2	26
			11	0.4	26
	1300	D-1	1	0.4	26
			5	0.2	26
			11	0.4	26
		D-1*	1	0.2	26
			5	0.2	26
			11	0.2	26
		D-6	1	0.2	26
			5	0.2	26
			8	0.2	26

SAMPLING LOCATIONS



*Inside turning wall.

APPENDIX C

GENERAL STUDY METHODS

To accomplish the stated objectives, the study included extensive sampling, physical measurements, daily observations, and consultations. Plant influent, three of four primary effluents, and the plant effluent sample stations were sampled for three consecutive 24-hour periods with ISCO Model 1392-X automatic samplers. The fourth primary effluent, sample station (PE-4), was sampled using a SERCO automatic sampler for three consecutive 24-hour periods.

Aliquots of sample were drawn at hourly intervals into individual refrigerated glass bottles, which were composited proportional to flow at the end of each sampling period, at all composite sampling stations.

Dissolved oxygen concentrations were measured at stations throughout the WTP aeration basins and aerobic digester using a YSI Model 51A dissolved oxygen meter.

The WTP flow totalizer was used to determine total daily influent flow, and the recorder was used for hourly flows. A combined flow of anaerobic digester supernatant, scum trough overflow and vacuum filter filtrate was determined with a Manning flow recording meter.

Temperature was measured while determining dissolved oxygen concentrations. Individual samples over two 24-hour compositing periods were used to determine hourly influent and effluent pH variations.

Depth of the secondary clarifier sludge blankets were determined daily using equipment suggested by Alfred W. West, EPA, NFIC, Cincinnati (8).

Sludge activity was determined by the oxygen uptake procedure presented in Appendix E.

A series of standard operational control tests were run daily:

- Settleability of mixed liquor suspended solids (MLSS) as determined by the settlometer test,
- Percent solids of the mixed liquor and return sludge determined by centrifuge,
- Suspended solids and volatile suspended solids analysis on the aeration basin mixed liquor and return sludge,
- Turbidity of each final clarifier effluent.

An amperometric titrator (Fischer & Porter Model 17T1010) was used to determine effluent chlorine concentrations.

The procedure for the BOD_5 determination deviated from standard methods (5). Samples were set up and carried in an incubator back to Athens, GA for completion of the analyses.

Visual observations of individual unit processes were recorded.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the Environmental Protection Agency,

APPENDIX D
Activated Sludge
Formulae Used for General Calculations

Aeration Basin

1. lbs. of solids in aeration basin
   Basin volume = m.g.; MLSS (conc.) = mg/l
   (MLSS conc.) x (Basin vol.) x 8.34 = lbs. of solids

2. Aeration basin loading (lbs. BOD or COD/day)
   Inf. flow to aeration basin = mgd
   Inf. BOD or COD = mg/l
   (BOD or COD) x flow x 8.34 = lbs. BOD of COD/day

3. Sludge Age (days)
   MLSS conc. (avg. of daily values) = mg/l
   Aeration Basin Vol. = m.g.
   TSS, Primary Eff. or Basin Inf. conc. = mg/l
   Plant Flow = mgd

   $$\frac{(\text{MLSS}) \times (\text{Basin Vol.}) \times (8.34)}{(\text{TSS}) \times (\text{Flow}) \times 8.34}$$

4. Sludge Vol. Index (SVI)
   30 min. settleable solids (avg. of daily values) = %
   MLSS conc. = mg/l

   $$\frac{(\%,\ 30\text{ min. set. solids}) \times (10{,}000)}{\text{MLSS}}$$

5. Sludge Density Index (SDI)
   SVI Value $\frac{100}{\text{SVI}}$

6. Detention time (hours)
   Volume of basins = gal.
   Plant flow = gal./day
   Return sludge flow = gal./day

   $$\frac{\text{Basin volume} \times 24}{(\text{Flow}) + (\text{Return sludge flow})}$$

7. F/M Ratio (Food/Microorganism) BOD or COD
   Basins Inf. BOD_5 conc. (avg. or daily value) = mg/l
   Basins Inf. COD conc. (avg. or daily value) = mg/l
   Plant Flow = mgd
   <u>MLVSS</u> conc. (avg. or daily value, <u>note Volatile SS</u>) = mg/l
   Basin Vol. = m.g.

   $$\frac{(BOD_5\text{ conc.}) \times (\text{plant flow}) \times (8.34)}{(\text{MLVSS}) \times (\text{Basin Vol.}) \times 8.34} = \text{lbs. BOD/lb. MLVSS}$$

$$\frac{\text{(COD conc.) x (plant flow) x (8.34)}}{\text{(MLVSS) x (Basin Vol.) x (8.34)}} = \text{lbs. COD/lb. MLVSS}$$

8. Mean cell residence time (MCRT) = days
   MLSS conc. (avg. or daily value) = mg/l
   Basin vol. = m.g.
   Clarifier vol. = m.g.
   Waste activated sludge conc. = mg/l
   Waste activated sludge flow rate = mgd
   Plant effl. TSS = mg/l
   Plant flow = mgd

$$\frac{\text{(MLSS) x (Basin vol. + Clarifier vol.) x 8.34}}{\text{(Waste activated sludge conc.) x (waste flow) x 8.34 + (Plant effl. TSS x plant flow x 8.34)}} = \text{days}$$

Clarifier

1. Detention time = hours
   Plant flow to each clarifier = gals./day
   Individual clarifier vol. = gals.

$$\frac{\text{(clarifier Vol. (each) x 24}}{\text{Plant flow + Return Sludge Flow}} = \text{hours}$$

2. Surface loading rate = gal./day/sq. ft.
   Surface area/clarifier = sq. ft.
   plant flow to clarifier = gal./day

$$\frac{\text{Plant flow to clarifier}}{\text{Clarifier surface area}} = \text{gal./day/sq. ft.}$$

3. Weir Overflow Rate (gal./day/lin. ft.)
   Weir Length = ft.
   Plant flow to clarifier = gal./day

$$\frac{\text{Plant flow}}{\text{Weir length}} = \text{gal./day/lin. ft.}$$

APPENDIX E

OXYGEN UPTAKE PROCEDURE [1/]

A. Apparatus

1. Electronic DO analyzer and bottle probe
2. Magnetic stirrer
3. Standard BOD bottles (3 or more)
4. Three wide mouth sampling containers (approx. 1 liter each)
5. DO titration assembly for instrument calibration
6. Graduated cylinder (250 ml)
7. Adapter for connecting two BOD bottles

B. Procedure

1. Collect samples of return sludge, aerator influent and final clarifier overflow. Aerate the return sludge sample promptly.

2. Mix the return sludge and measure that quantity for addition to a 300 ml BOD bottle that corresponds to the return sludge proportion of the plant aerator, i.e. for a 40% return sludge percentage in the plant the amount added to the test BOD bottle is:

$$\frac{300 \times .4}{1.0 + .4} = \frac{120}{1.4} = 86 \text{ ml}$$

3. Carefully add final clarifier overflow to fill the BOD bottle and to dilute the return sludge to the plant aerator mixed liquor solids concentration.

4. Connect the filled bottle and an empty BOD bottle with the BOD bottle adapter. Invert the combination and shake vigorously while transferring the contents. Re-invert and shake again while returning the sample to the original test bottle. The sample should now be well mixed and have a high D.O.

5. Insert a magnetic stirrer bar and the previously calibrated DO probe. Place on a magnetic stirrer and adjust agitation to maintain a good solids suspension.

6. Read sample temperature and DO at test time t=0. Read and record the DO again at 1 minute intervals until at least 3 consistent readings for the change in DO per minute are obtained (ΔDO/min). Check the final sample temperature. This approximates sludge activity in terms of oxygen use after stabilization of the sludge during aeration (unfed sludge activity).

7. Repeat steps 2 through 6 on a replicate sample of return sludge that has been diluted with aerator influent (fed mixture) rather than final effluent. This Δ DO/minute series reflects sludge activity after mixing with the new feed. The test results indicate the degree of sludge stabilization and the effect of the influent waste upon that sludge.

The load factor (LF), a derived figure, is helpful in evaluating sludge activity. It is calculated by dividing the DO/min of fed sludge by the DO/min of the unfed return sludge. The load ratio reflects the conditions at the beginning and end of aeration. Generally, a large factor means abundant, acceptable feed under favorable conditions. A small LF means dilute feed, incipient toxicity, or unfavorable conditions. A negative LR indicates that something in the wastewater shocked or poisoned the "bugs".

1/ Taken from "Dissolved Oxygen Testing Procedure," F. J. Ludzack and script for slide tape XT-43 (Dissolved Oxygen Analysis - Activated Sludge Control Testing) prepared by F. J. Ludzack, NERC, Cincinnati.