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TECHNICAL ASSISTANCE PROJECT AT THE WINSTON-SALEM, NORTH CAROLINA WASTEWATER TREATMENT PLANT

NOVEMBER 1975

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

TECHNICAL ASSISTANCE PROJECT
AT THE
ARCHIE ELLEDGE WASTEWATER TREATMENT PLANT
WINSTON-SALEM, NORTH CAROLINA
NOVEMBER, 1975

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 Archie Elledge Wastewater Treatment Plant (WTP) serving Winston-Salem, NC, was conducted November 10-18, 1975, by the U. S. Environmental Protection Agency, Region IV. Assistance was requested by the City of Winston-Salem through the North Carolina Department of Natural and Economic Resources (NC-DNER). Operation and maintenance technical assistance studies are designed to assist local wastewater treatment plant operators in maximizing treatment efficiencies as well as assist with special operational problems.

The specific study objectives were to:

- Optimize treatment via control testing and operation and maintenance modifications,
- Determine influent and effluent waste characteristics,
- Assist laboratory personnel with any possible laboratory procedural problems, and
- Compare design and current loadings.

A follow-up assessment of plant operation and maintenance practices will be made at a later date. This will be accomplished using data generated by plant personnel and, if necessary, additional facility visits. The follow-up assessment will determine if the recommendations made in this report were successful in improving plant operations and if further assistance is required. Close contact has been maintained by phone with plant personnel since the study in order to relate preliminary study findings and stay abreast of process changes and results. Some of the recommendations made in this report have already been implemented.

The cooperation of the NC-DNER is gratefully acknowledged. The technical assistance team is especially appreciative of the cooperation and assistance received from Archie Elledge WTP personnel.

SUMMARY

The 36 mgd, activated sludge WTP serves the entire Winston-Salem area. The plant originally constructed as an 18 mgd trickling filter system was redesigned in 1969 as a 36 mgd activated sludge system with roughing filters.

During the study, plant influent flow rates varied between 15 and 38 mgd with the lower flows occurring on the weekend due to the absence of industrial discharges. The decreased volume and strength of the waste on the weekend caused considerable variations in food supplied to the biological treatment units. This upset the activated sludge system since the food to microorganism (F/M) ratio continually fluctuated. Even though the sewer excludes stormwater, infiltration causes considerable problems with flows of 60 mgd being reported during wet periods. Influent flow in excess of 38 mgd is presently bypassed untreated to prevent upset of the activated sludge system.

The wastewater entering the WTP is a strong waste with an average BOD_5 of 380 mg/l, COD of 1,078 mg/l and TSS of 236 mg/l. The wastewater is considerably stronger during the weekdays than on weekends (BOD_5 520 versus 270 mg/l). The primary clarifiers and roughing filters were performing satisfactorily; however, the activated sludge process did not achieve acceptable BOD_5 reduction.

Aeration basin dissolved oxygen (DO) profiles indicated large areas where DO concentrations were zero, or approaching zero. These conditions were observed with six of the ten aerators operating. The profiles also indicated poor mixing in the basins with zones of low DO observed a short distance from the aerators. The DO concentration at the three to five foot depth was sometimes considerably less than at the one foot level. A DO profile, collected through the different plant treatment units, also indicated septic conditions at the primary clarifier effluent.

The trickling filters performed well except for frequent mechanical failures. The most common problem was failure of the cables supporting the distributor arms due to corrosion. One cable failed during the night of November 10, 1975. Plant personnel reported that this occurred frequently. The filters accounted for approximately 50 percent of the BOD_5 removed through the complete treatment process.

Effluent chlorine residual was excessive each time it was measured.

The sludge age was young (3.7 days) and most of the sludge was lost in the effluent. The average MLSS was 752 mg/l and settled poorly. Profuse growths of filamentous fungi were present in the mixed liquor. The low MLSS produced a food to microorganism ratio above acceptable limits.

The primary clarifiers performed well in removing settleable solids; however, the effluent wastewater was septic. The detention time is excessive (3.4 hours) at the average weekday flow of 25 mgd. The solids loading on the intermediate clarifiers is low due to the small amount of biological solids sluffed from the trickling filters. The final clarifier's surface settling rate is 800 gpd/ft^2 for average design flow (36 mgd) and 1,200 gpd/ft^2 for peak design flow (54 mgd) which are the extreme upper recommended limits. The corresponding design weir overflow rates were 23,900 and 35,800 gpd/ft. With the overflow weirs located on the periphery of the clarifiers in the upturn zone, the maximum recommended rate is 20,000 gpd/ft. During the study, excessive solids were lost over the effluent weir, and there was no sludge blanket in the clarifiers. The final clarifiers are not equipped with surface skimmers.

RECOMMENDATIONS

- Mixed liquor solids should be increased by using polymers in the final clarifier or addition of digested solids to the aeration basins. Digested solids should be aerated for a day or two before addition if possible. In order to maintain a reasonable F/M ratio, a mixed liquor concentration of approximately 2,000 mg/l is desirable.

- Dissolved oxygen concentrations in the aeration basins should not normally be permitted to fall below 1.0 mg/l. This will necessitate running all ten aerators during normal weekday flow conditions.

- Dissolved oxygen profiles should be run periodically in the aeration basins to insure that minimum DO concentrations are being maintained, and that proper mixing is accomplished.

- The use of draft tubes on the mechanical aerators should be considered in order to improve circulation and mixing in the aeration basins.

- The possibility of utilizing all, or a portion of, the intermediate clarifiers as final clarifiers to relieve the overloaded conditions on the existing clarifiers should be investigated.

- Industrial wastewater flow equalization should be encouraged and implemented if possible.

- During low flow periods intermediate clarifier or filter effluent should be recirculated back to the primary clarifier to reduce detention times and septic conditions in the primary clarifier. Chlorine or peroxide additions could be used to freshen the wastewater.

- A sludge reaeration basin or anaerobic digester could be used to maintain a larger volume of activated sludge. The old, abandoned chlorine contact chamber or the unused sludge conditioning unit may be suitable.

- As a temporary measure to improve plant operation until remedial action can be taken to correct the collection system infiltration problem, excessive wastewater flow should bypass the activated sludge system to prevent washout of the sludge. It is suggested that, with the present clarifier arrangement, flows through the system be limited to the peak design flow of 54 mgd during periods of good sludge settleability and to approximately

36 mgd during periods of poor sludge settleability. Before this recommendation is implemented, the City of Winston-Salem must obtain the concurrence of the US-EPA Region IV Enforcement Division and the NC-DNER.

- Chlorine residuals should be determined by use of an Amperometric titrator or the iodimetric titration method. The orthotolidine colorimetric titration is not an accepted method for determining chlorine residuals in wastewater. The use of a continuous residual chlorine analyzer and control system would reduce chlorine costs.

- Effluent chlorine residual should be reduced to an acceptable level of approximately 0.5 mg/l.

TREATMENT FACILITY

TREATMENT PROCESSES

A schematic diagram of the 36 mgd WTP is presented in Figure 1. Plant design data is shown in Appendix F. The WTP was originally designed in 1956 as an 18 mgd, high rate trickling filter facility. In 1969 the plant was redesigned. An activated sludge process was added and the trickling filters were converted to roughing filters.

The WTP, which serves the entire Winston-Salem area, receives wastewater via the Schlitz, Kimel and Salem outfalls. The Schlitz outfall contains predominately brewery waste with very little domestic wastewater. The Schlitz wastewater flow (1.2 - 1.5 mgd) is passed through a small aeration basin prior to combining with the other two outfalls. These two outfalls contain domestic and industrial wastes from tobacco processing, textile finishing, metal products, dairies, and soft drink bottling plants.

The combined influent flow enters the plant via a 60 inch diameter concrete pipe into an influent box. This box also receives digester supernatant, sludge drying bed underflow, and septic tank cleaning truck discharges. Influent wastes pass through three automatically cleaned bar screens and longitudinal velocity controlled grit chambers in route to the primary pump station. Screenings and grit are conveyed to refuse containers. Grit chamber velocity is controlled by the combined effect of trapezoidal channel bottoms and Parshall flumes, which also measure influent flow. Four propeller type, vertical shaft pumps (3 - 22 mgd, 1 - 13 mgd) lift the wastewater into a discharge box where it flows by gravity into the primary clarifiers.

Settled primary sludge is collected by scraper collecting equipment and flows by gravity into a sump from which the sludge is pumped (4 - 700 gpm pumps) into anaerobic digesters. The pumps are controlled by time clocks and sludge density gauging equipment. Scum is removed from the clarifier by manually controlled, rotating, slotted pipes and is conveyed by gravity to a scum box. The thickened scum is subsequently pumped to the digesters.

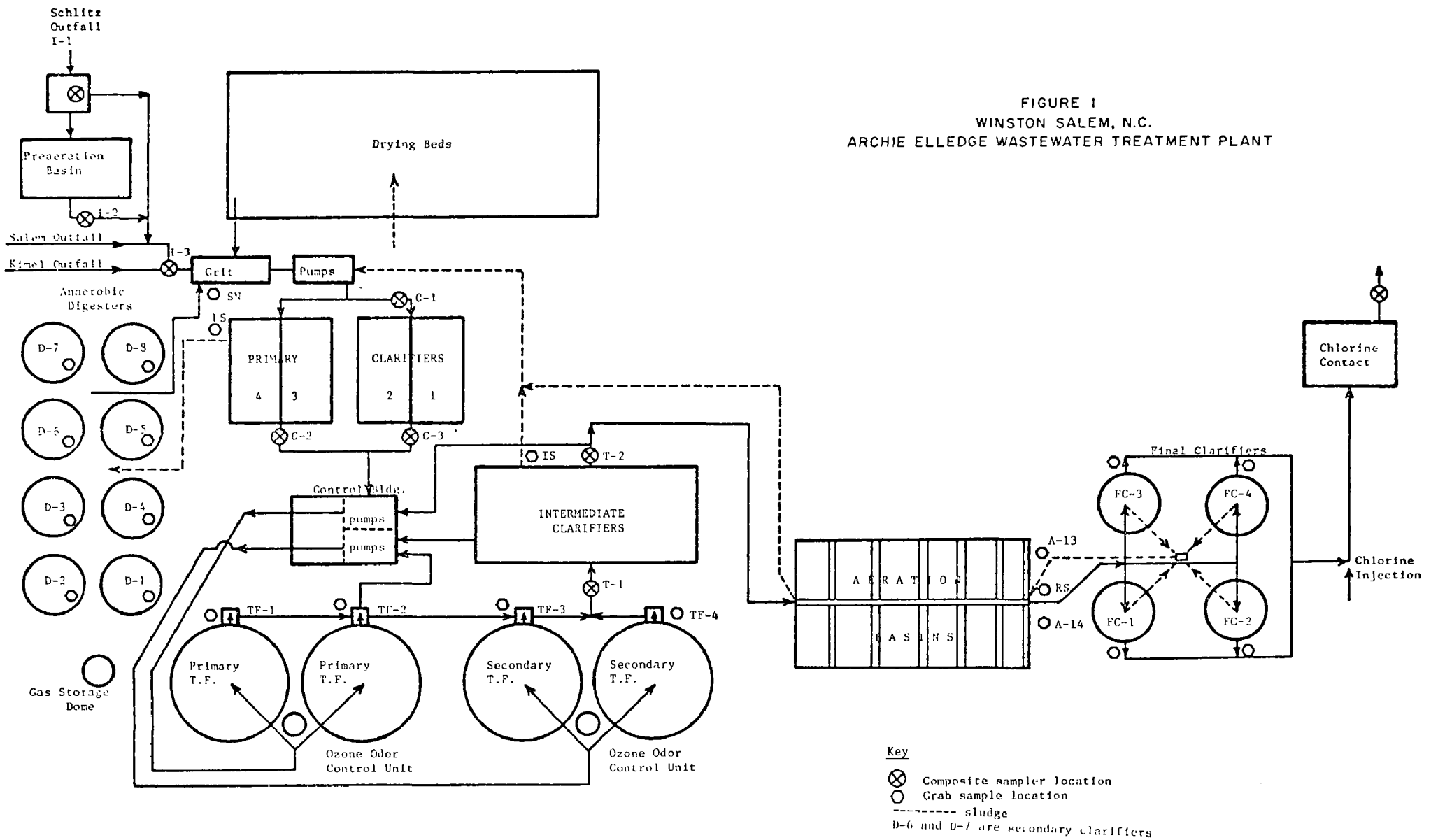


FIGURE 1
WINSTON SALEM, N.C.
ARCHIE ELLEDGE WASTEWATER TREATMENT PLANT

The clarifier effluent flows by gravity to the intermediate pump station located in the central control building. Two 25 mgd, variable speed pumps lift wastewater to the two primary trickling filters (TF #1 and #2). Effluent from these two filters can flow either directly into the wet well for the secondary trickling filters (TF #3 and #4) or into the intermediate clarifiers. Recirculation from the intermediate clarifier can go to either of the intermediate pump station wet wells for subsequent pumping onto the trickling filters (see Figure 1).

All four trickling filters are covered by concrete domes to control the filter environment and to permit control of odors produced in the filters. Ozone, odor control units, located between each set of filters, eliminate odors from the air drawn through the filters. Effluent air discharges through a chimney to the atmosphere.

The intermediate settling tanks discharge over two separate sets of weirs, one at the influent end, and the other at the effluent end. The length of the weirs at the influent end is one half that of the weirs at the effluent end. As long as the filter recirculation is less than 0.5:1, almost all of the recirculated flow originates from the influent end. At ratios greater than 0.5:1, additional recirculation is taken from the overflow of the weirs at the effluent end of the tanks. The remainder of the flow, which is approximately equal to the plant influent, flows by gravity to the aeration basins.

Intermediate clarifier sludge flows by gravity into the primary pump station wet well where it is mixed with plant influent, and pumped into the primary clarifiers. A sludge conditioning building equipped with diffused aeration is available, for conditioning intermediate clarifier sludge, but is no longer used.

Intermediate clarifier effluent and return sludge (RS) from the final clarifiers enter the two aeration basins through butterfly valves located below the center walkway of the basins. The walkway covers the two distribution channels and the wall between the basins. The upper channel conveys return sludge; the lower conveys wastewater. Five sets of valves are located along the walkway to control wastewater RS distribution. Aeration is provided by five 100 hp mechanical surface aerators in each basin. Aerator operation is controlled by manually programmed clock timers. The aeration basin discharge is over wooden weirs at one end of the basins.

Aeration basin effluent flows into four, center fed, circular clarifiers operated in parallel. These units are not equipped with any means for removing floatable solids. Settled sludge is continuously removed through suction type sludge collectors and pumped to the aeration basins or wasted to the primary clarifiers for subsequent pumping to the digesters, along with primary sludge.

Final clarifier effluent flows through a chlorine mixing box where a flash mixer blends the chlorine solution with the effluent. A portion of the chlorinated effluent is diverted into the wet well of the plant effluent pump station; pumps deliver pressurized effluent to the plant wide distribution system for washing and cooling where potable water is not required.

The chlorine contact chamber allows 30 minutes retention at design flow before discharging into Salem Creek. Chlorine feed rates are manually controlled.

Two stage, anaerobic digesters treat all primary, intermediate, and waste activated sludges. Influent sludge to the primary digesters is preheated, and each primary digester is continuously mixed and heated to approximately 95^{o} F. Secondary digesters are unheated, but are mixed.

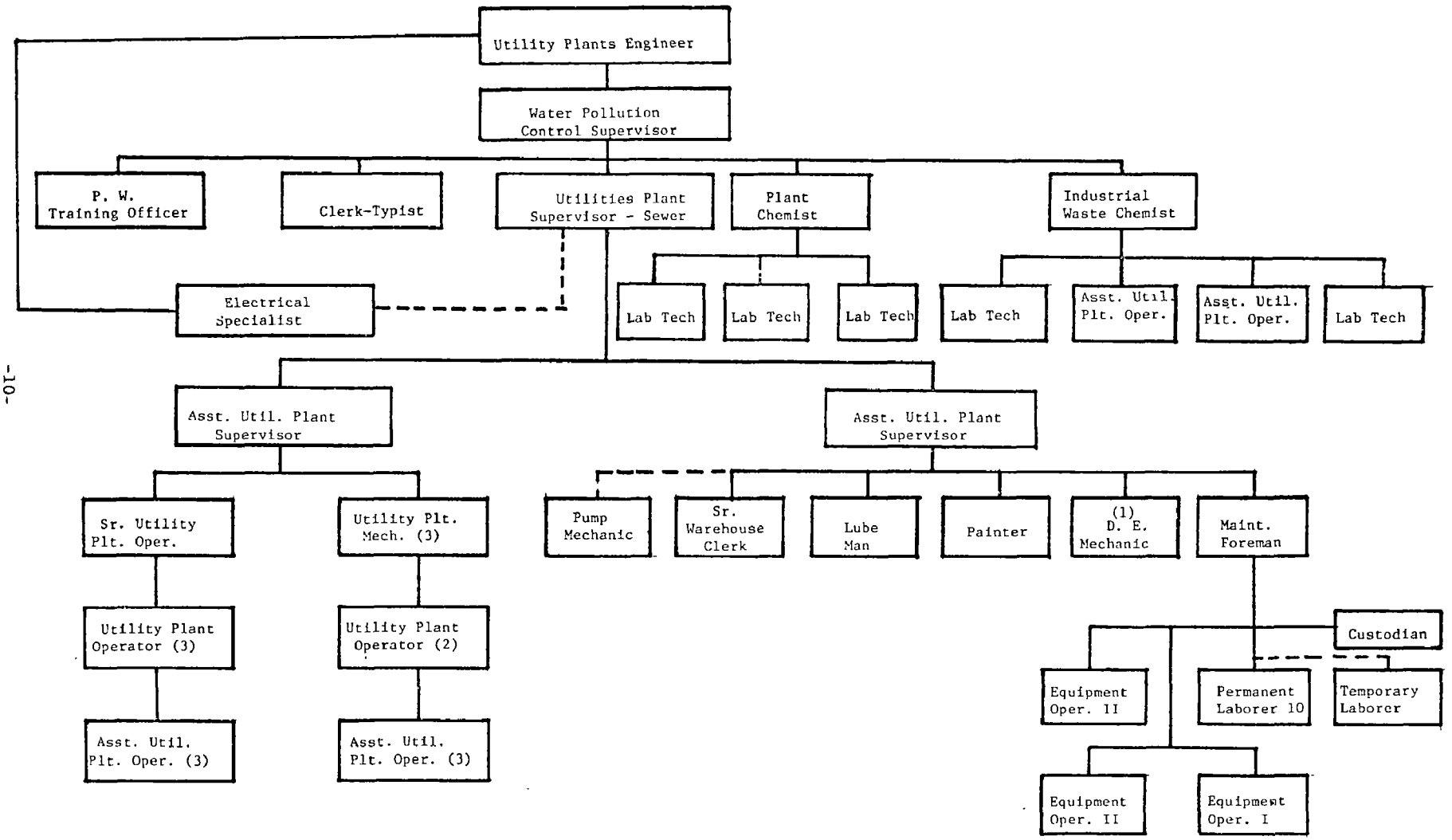
Digested sludge flows by gravity or is pumped from the digesters to sand drying beds. Dried sludge is either removed manually or lifted by a sludge mechanism onto a belt conveyor which loads it onto trucks. Trucks deliver sludge to an adjacent site where the sludge is available to the public. Eventually an on site processing plant for further drying and conditioning will be used.

Digester gas, supplemented by natural gas and/or fuel oil, is used to power the five, dual fuel, diesel driven generators which furnish all electrical power used at the treatment plant. There is no outside electrical connection to the plant.

PERSONNEL

The City of Winston-Salem employs approximately 55 people to operate the WTP. The employees serve several functions in support of maintenance and operation (Figure 2).

FIGURE 2
STAFFING PLAN
ARCHIE ELLEDGE WTP
WINSTON-SALEM, NC
NOVEMBER, 1975



The employees are certified and/or classified from supervisory Grades IV through technician Grade I. At the time of the study there were two Grade IV operators, 12 Grade III operators, 12 Grade II operators and 5 Grade I operators.

STUDY RESULTS AND OBSERVATIONS

A complete listing of all anlaytical data and study methods are presented in the Appendices. Significant results and observations made during the study are presented in the following sections.

FLOW

Figure 3 presents the wastewater flow variation during the study. The weekday flow averaged 27 mgd and varied from 15 to 38 mgd. During the weekend, when the tobacco, brewery, and other industrial operations were minimal, the flow ranged from 12 to 24 mgd and averaged 19 mgd.

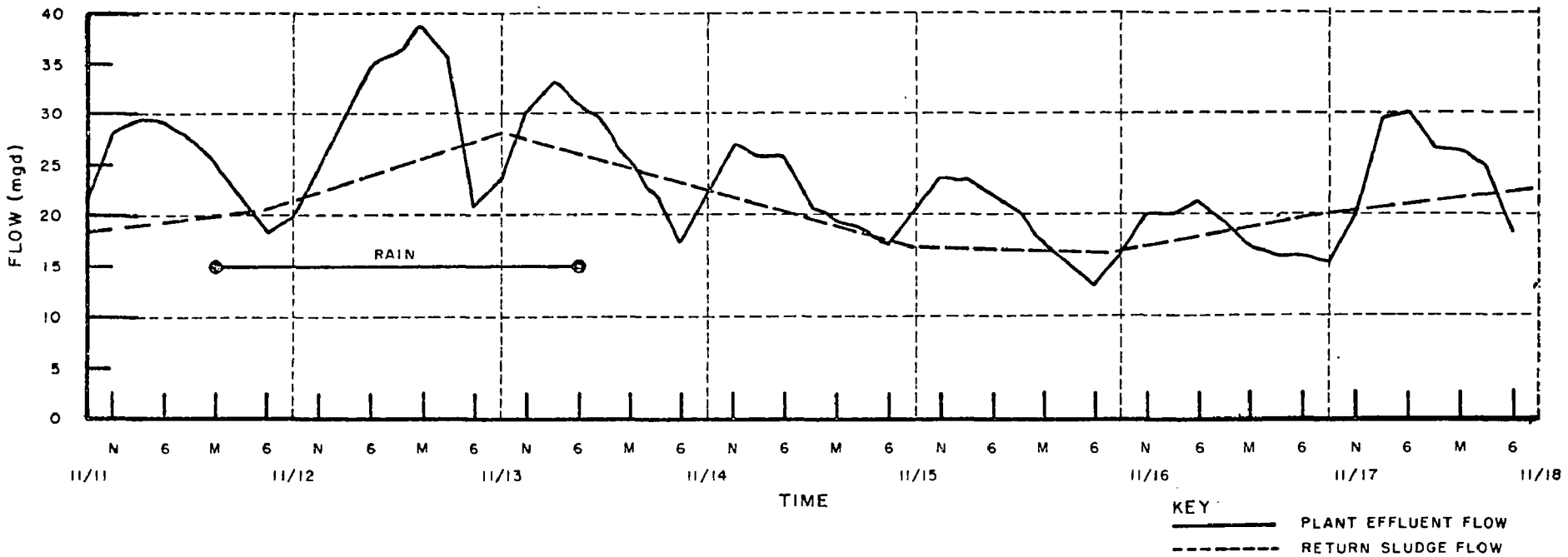
Wastewater influent flows of 26-30 mgd are typical during dry weather periods; however, excessive infiltration occurs during periods of heavy rainfall, and flows to the plant can exceed 60 mgd. Although the plant was designed for a hydraulic peak flow of 54 mgd, these high flows usually cause a washout of the activated sludge system. Therefore, the mode of operation has been modified to allow no more than 38 mgd of influent wastes to be pumped through the plant. Influent wastewater in excess of 38 mgd is bypassed untreated to Salem Creek.

Influent wastewater flow is measured with three parallel Parshall flumes; the effluent with a propeller type meter. Both have chart recorders and totalizers located in the control building. The influent flumes are subject to flooding. Therefore, during the study, effluent flow measurements were used.

Trickling filter recirculation is measured with three Parshall flumes. One measures the flow from TFs #1 and #2; one measures flow from the influent end of the intermediate clarifier, and the third measures flow from the effluent end of the intermediate clarifier.

Total return sludge flow is measured by a propeller type meter located on the combined sludge return line from the final clarifiers. A second propeller type meter, at the influent end of the aeration basins, measures waste activated sludge flow. The difference in these two meter readings is the volume of sludge returned to the aeration basins. Digester supernatant flow is also measured with a propeller type meter.

FIGURE 3
WASTEWATER AND RETURN SLUDGE FLOW
WINSTON SALEM, N. C.



Magnetic flow meters are used to measure flow between the preheaters and the digesters and from each set of digesters to the drying beds.

WASTE CHARACTERISTICS AND REMOVAL EFFICIENCIES

Waste characteristics and removal efficiencies are presented in Table 1. Sample station locations are depicted in Figure 1.

The data in Table 1 are based on 24 hour, flow proportional, composite samples from stations I-3 and E-1. These stations represent the plant influent and effluent with differences showing treatment plant removal efficiencies.

Samples from station C-1 reflect the digester supernatant return and show the increased loading on the plant from the supernatant.

Table 1
Waste Characteristics and Removal Efficiencies

Parameter	Influent* (mg/l)	Effluent (mg/l)	% Reduction
BOD_5	380 (400)	45	88
COD	1075 (1048)	362	66
TSS	236 (343)	129	45
TKN	19.8 (30.5)	17.8	10
NH_3	11.3 (17.3)	11.8	--
NO_3-NO_2	0.21 (0.29)	0.43	--
Total-P	9.0 (10.8)	8.1	10
Pb	.158	.130	18
Cr	.186	.164	12
Cu	.751	.536	29
Cd	<.020	<.020	--
Zn	.386	.320	17

*Values in () are samples from station C-1 and include influent plus supernatant return.

Wastewater entering the plant was relatively strong with an average BOD_5 of 380 mg/l, a COD of 1,078 mg/l, and a TSS of 236 mg/l. The C:N:P nutrient ratio of the waste, after supernatant return, was roughly 100:8:3.

Concentration profiles of BOD_5, COD, TSS, and nitrogen through the plant are presented in Figures 4 through 6. From these curves, the efficiency of each unit process can be calculated. Increased concentrations between stations I-3 and C-1 were attributed to supernatant return. The two BOD_5 curves (Figure 4) on 11/11-12/75 and 11/13-14/75 reflect the weekday industrial and domestic waste loads. The other two curves were representative of a weekend period with reduced industrial discharge. Figure 4 shows that the primary clarifiers and trickling filters were effecting significant BOD_5 removal while the activated sludge system was performing poorly. The trickling filters were shut down during most of the weekend period of November 15-16, 1975, reducing the efficiency of those units during that time period.

Figure 5 shows a TSS removal in the primary clarifier of approximately 250 mg/l (72 percent) and then essentially no change through the rest of the plant. Figure 6 shows a sizable increase in ammonia between stations I-3 and C-1. This was due to supernatant return to the waste stream. There appeared to be a small amount of nitrification occurring in the trickling filters and slightly more occurring in the activated sludge system. Very little nitrification was expected from the activated sludge system due to the young sludge age which was caused by washout of solids. The average ammonia concentrations in the effluent were almost identical to the average influent concentration. The NO_2-NO_3 curve in Figure 6 shows some decrease between stations C-1, C-2 and C-3. This was probably due to biological denitrification caused by septic conditions in the primary clarifier. An increase in NO_2-NO_3 in the activated sludge system was caused by the slight amount of ammonia nitrification.

DISSOLVED OXYGEN

All dissolved oxygen (DO) measurements taken in the aeration basins are presented in Appendix B. Figure 7 depicts the mean DO concentrations throughout the basins under the most common aerator configuration (six of 10 aerators operating) during the study. A significant portion of the basins exhibited less than 0.5 mg/l DO (shaded area in Figure 7). The highest DO concentrations were observed nearest the basin effluent in Bays A6 and A12. A number of stations (A1-f, A1-g, A3-b, A3-c, A3-d, A8-f, A9-c, A10-c, A11-d) showed significant differences in DO at the one and five foot depths, indicating poor mixing. Extremely low DO concentrations were often observed at distances of approximately 20 feet from operating aerators at depths of three to five feet. This condition seems to indicate dead spots created by the mixing

FIGURE 4
BOD_5 PROFILES THROUGH PLANT
WINSTON SALEM, N.C.

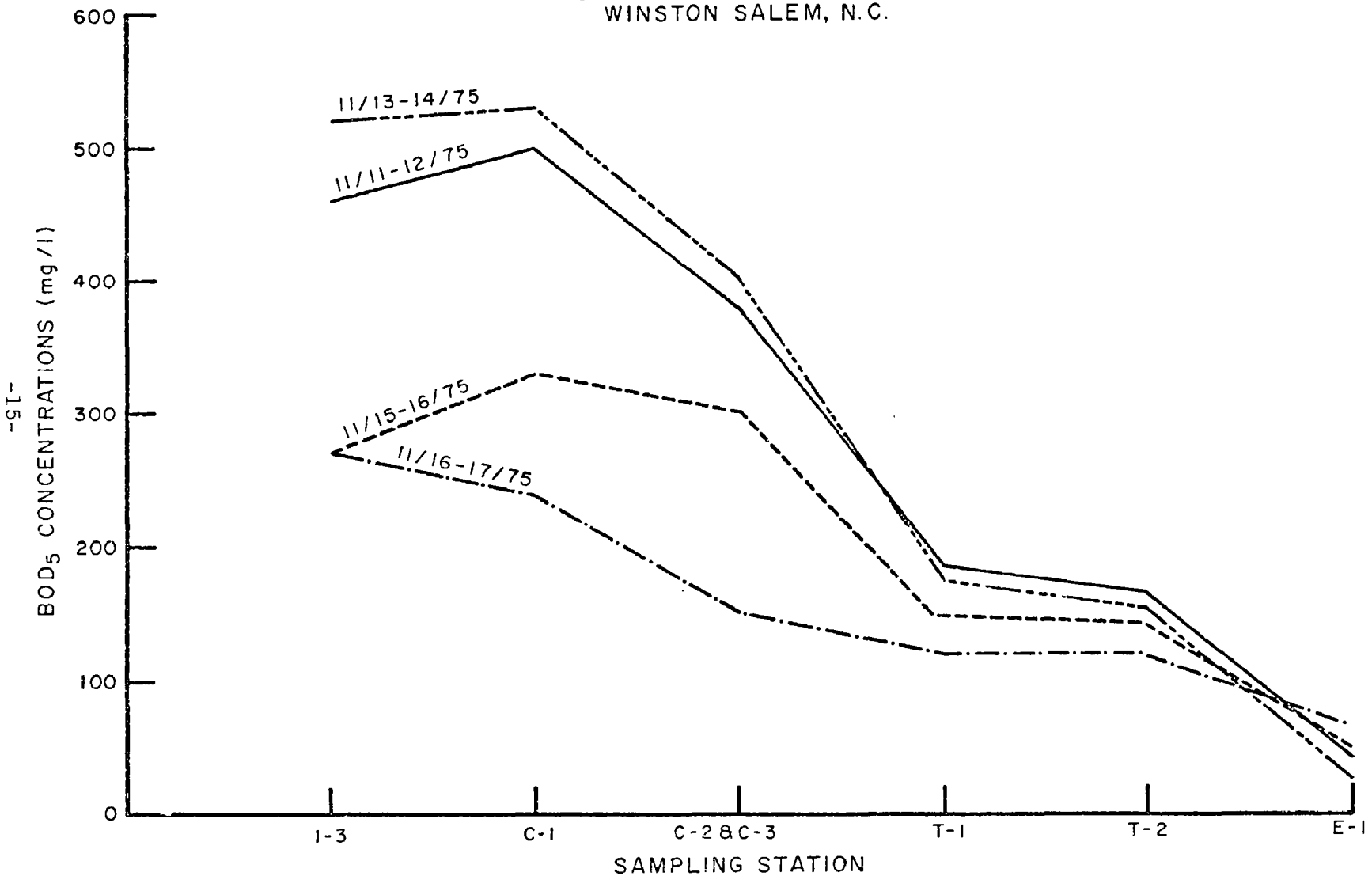


FIGURE 5
AVERAGE C.O.D. & TOTAL SUSPENDED SOLIDS PROFILE THROUGH PLANT
WINSTON SALEM, N.C.

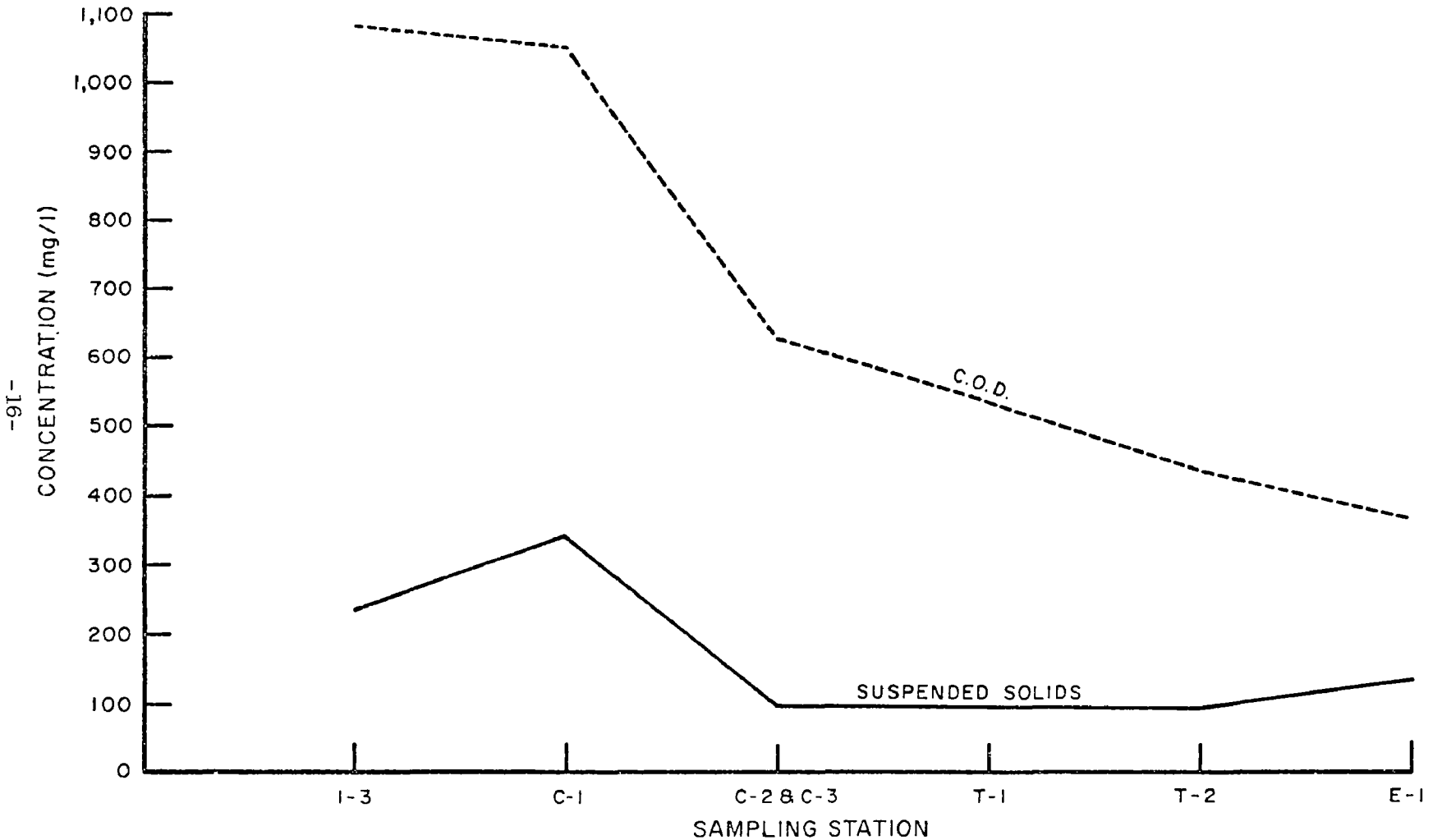


FIGURE 6
AMMONIA AND NITRATE-NITRITE PROFILES THROUGH WTP
WINSTON SALEM, N.C.

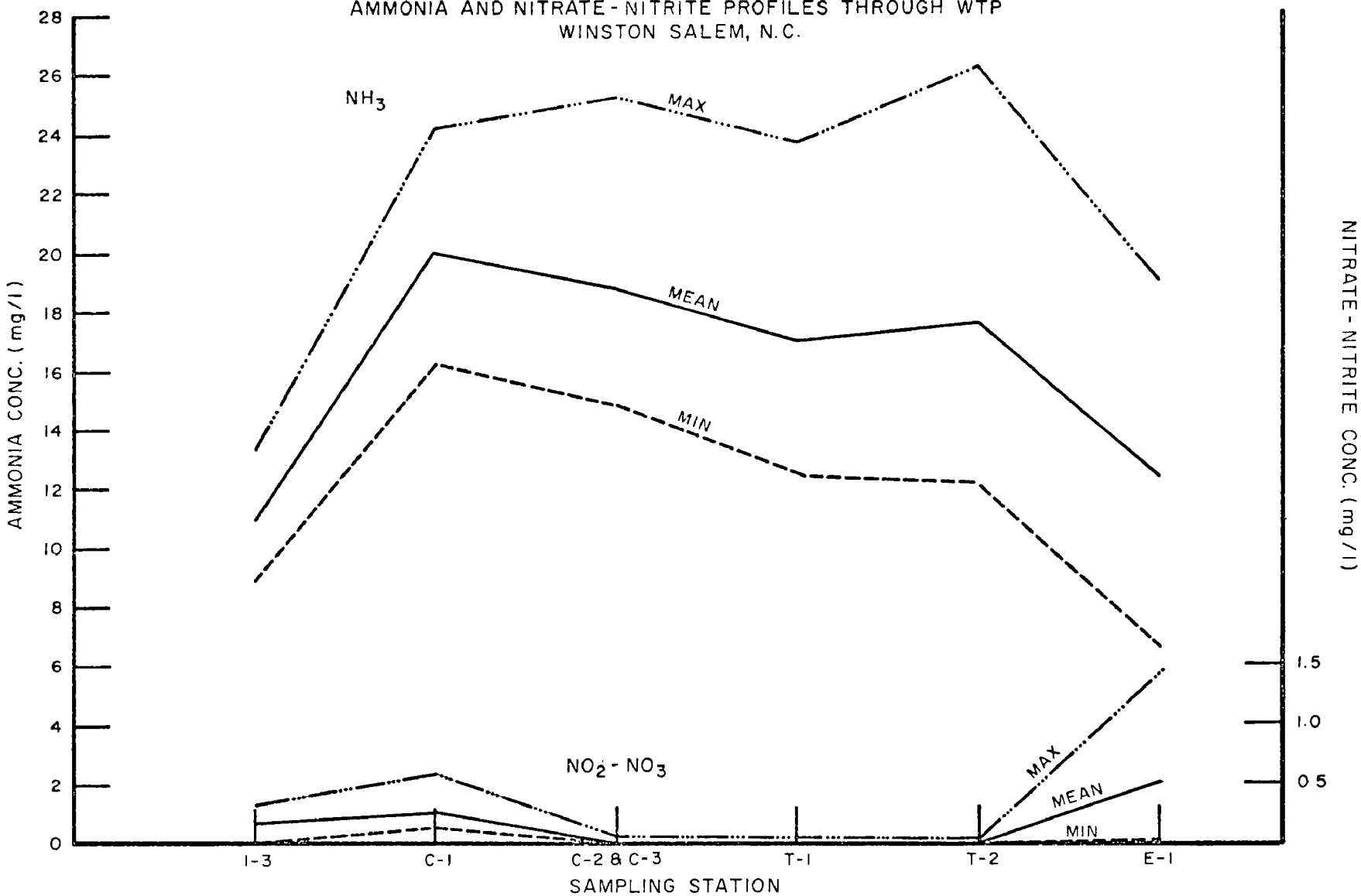
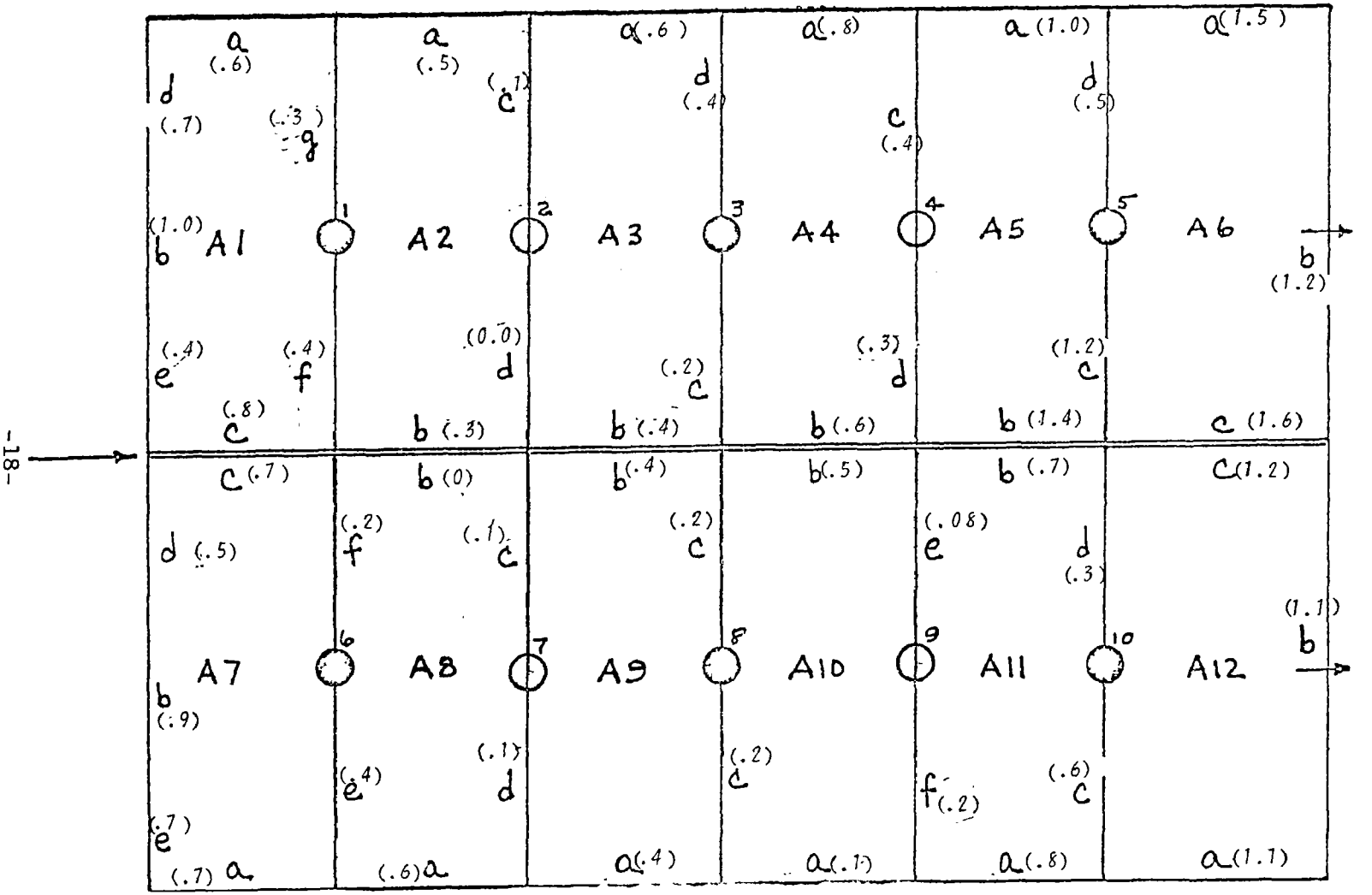


FIGURE 7
AERATION BASIN DISSOLVED OXYGEN



( ) - DO concentrations
● - Aerators on
- <0.5 mg/1 DO

pattern of the aerators. Slightly higher DO concentrations were measured along the basin walls due to flow patterns created by the surface aerators.

Additional testing should be performed in the aeration basins to determine the extent of poor mixing. Consideration should be given to the installation of draft tubes to attain better mixing. This could be tried on one or more aerators when one of the basins is shut down for servicing.

Dissolved oxygen concentrations for aeration configurations which were used experimentally are presented in Figures 8 and 9. Even with eight aerators operating, numerous areas of low DO were evident. With all aerators on (Figure 9), excessive DO concentrations (4.3 - 5.5 mg/l) were observed; however, the MLSS in the basins were extremely low (approximately 500 mg/l), and the plant waste load was relatively low since it was on a weekend.

These data for normal aerator operations indicate unacceptably low dissolved oxygen and poor mixing in the aeration basins. Low DO levels have been found to be the major cause of sludge bulking. Dissolved oxygen concentrations in aeration basins of 2-4 mg/l are recommended (3).

For the past year, this plant has been plagued with profuse filamentous growths in the aeration basins. These growths can sometimes be controlled by reducing the dissolved oxygen concentration in the aeration basins to the bare minimum. However, low DO concentrations had been maintained for an extended period without showing any decrease in the amount of filamentous growth. Also, careful monitoring throughout the basins is required when maintaining low DO levels to prevent the occurrence of septic zones in the basins. DO was monitored continuously at the basin effluent.

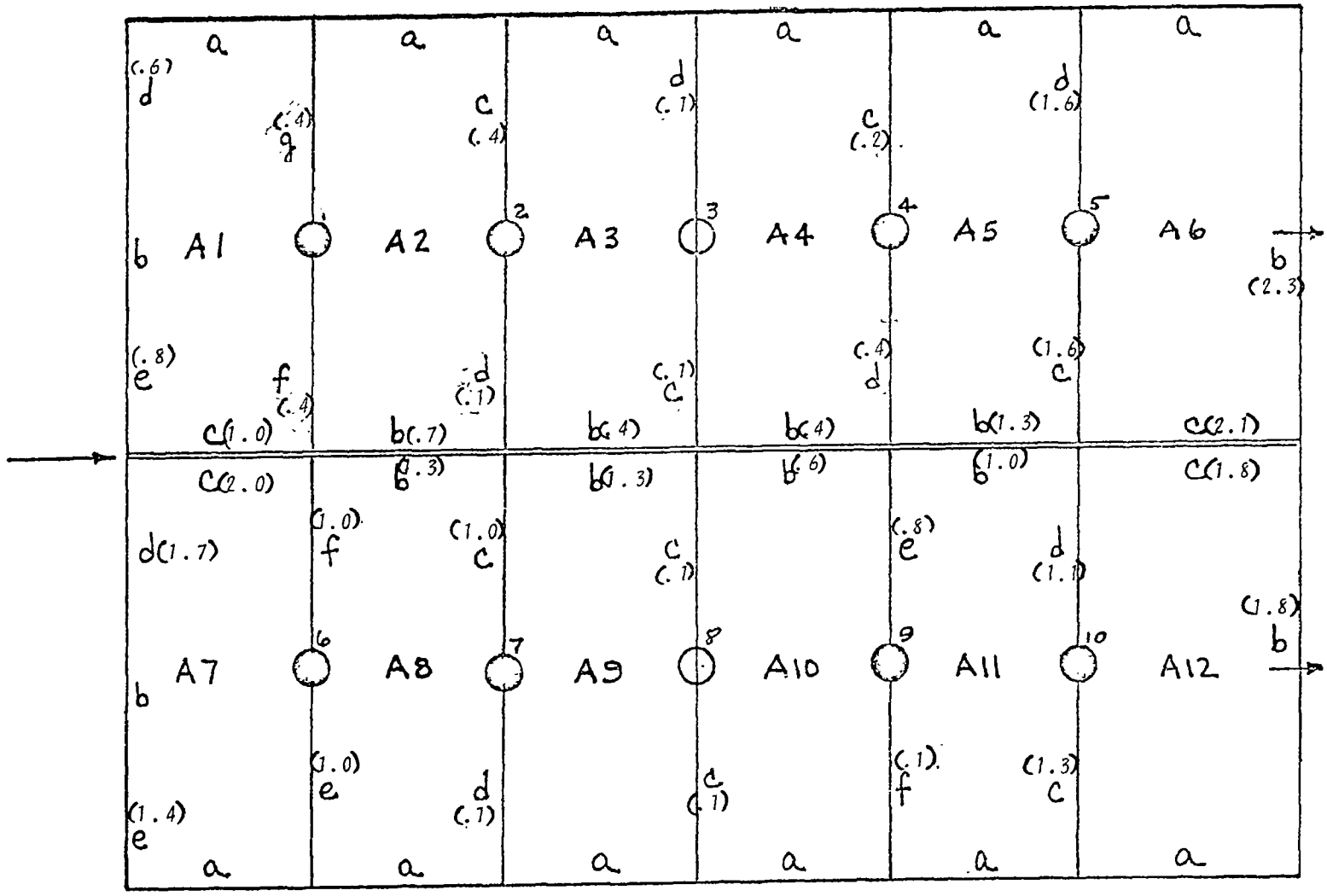
Figure 10 presents a profile of the average effluent DO from each unit process in the WTP; a Complete listing of this data is presented in Appendix C. Zero DO was always measured in the primary clarifier. Less than 0.5 mg/l DO was measured in the combined influent (station I-3).

AERATION BASINS

Grab samples were taken at the discharge from each of the two aeration basins (stations A-13 and A-14). Settlometer, TSS, VSS, and percent total solids by centrifuge tests were run on each sample.

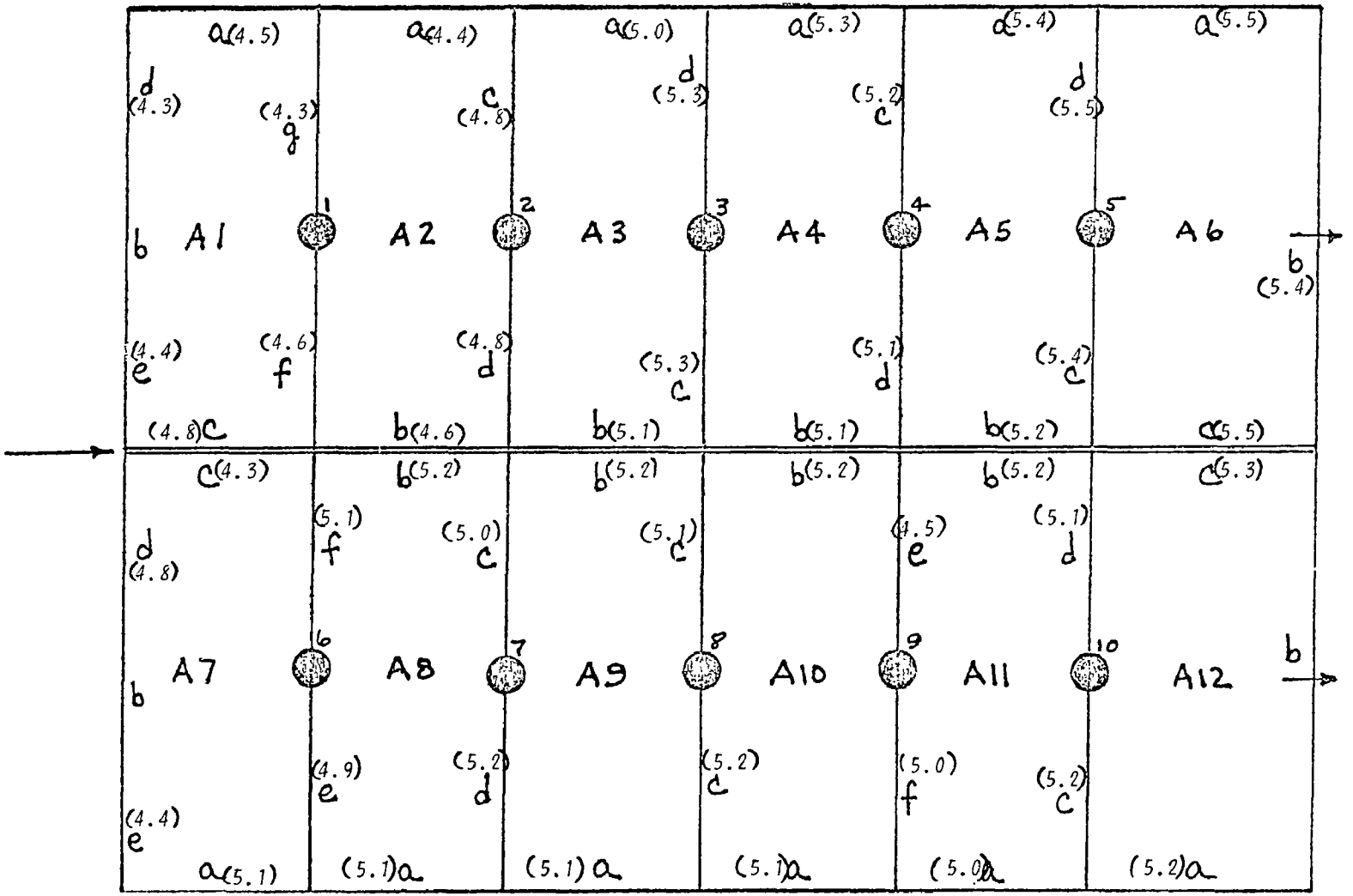
The average mixed liquor suspended solids (MLSS) and mixed liquor volatile suspended solids (MLVSS) were 752 and 613 mg/l, respectively. The percent solids by volume, as

FIGURE 8
AERATION BASIN DISSOLVED OXYGEN



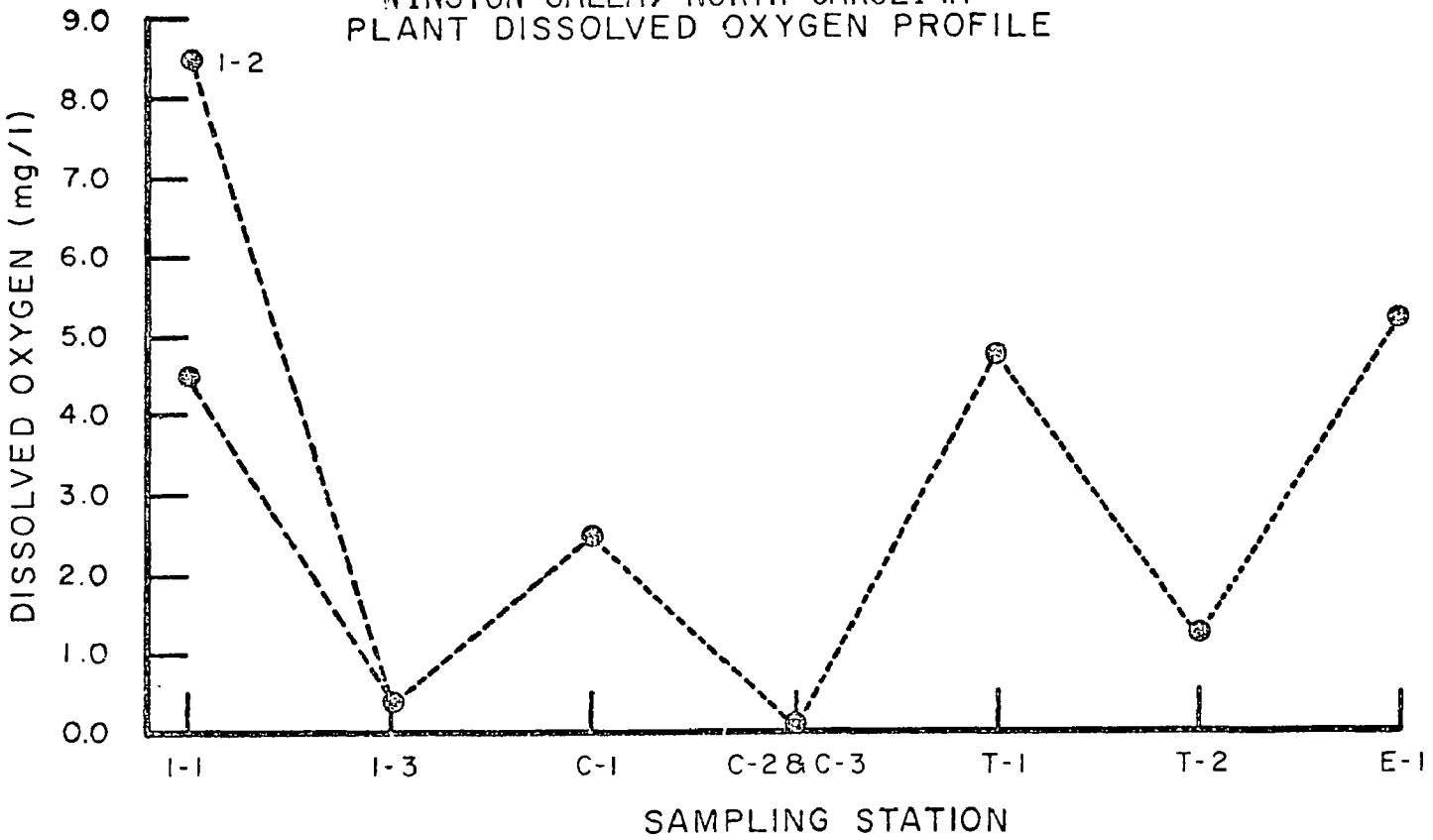
( ) - DO concentrations
● - aerators on
- <0.5 mg/1 DO

FIGURE 9
AERATION BASIN DISSOLVED OXYGEN



● - Aerators on
( ) - DO concentrations

FIGURE 10
ARCHIE ELLEDGE WTP
WINSTON-SALEM, NORTH CAROLINA
PLANT DISSOLVED OXYGEN PROFILE



determined by centrifuge, ranged from 1.4 to 2.5 percent. Based on a design flow of 36 mgd and an influent BOD_5 of 200 mg/l in the aeration basins, an MLVSS concentration of approximately 2,000 mg/l should be maintained in order to have a food to microorganism ($F/M)_o$ ratio from 0.2 - 0.6 (7).

Presented in Table 2 are various activated sludge operating parameters calculated during the study and corresponding recommended values for the complete mix activated sludge process.

Table 2
ACTUAL AND RECOMMENDED PARAMETERS FOR THE COMPLETE MIX ACTIVATED SLUDGE PROCESS

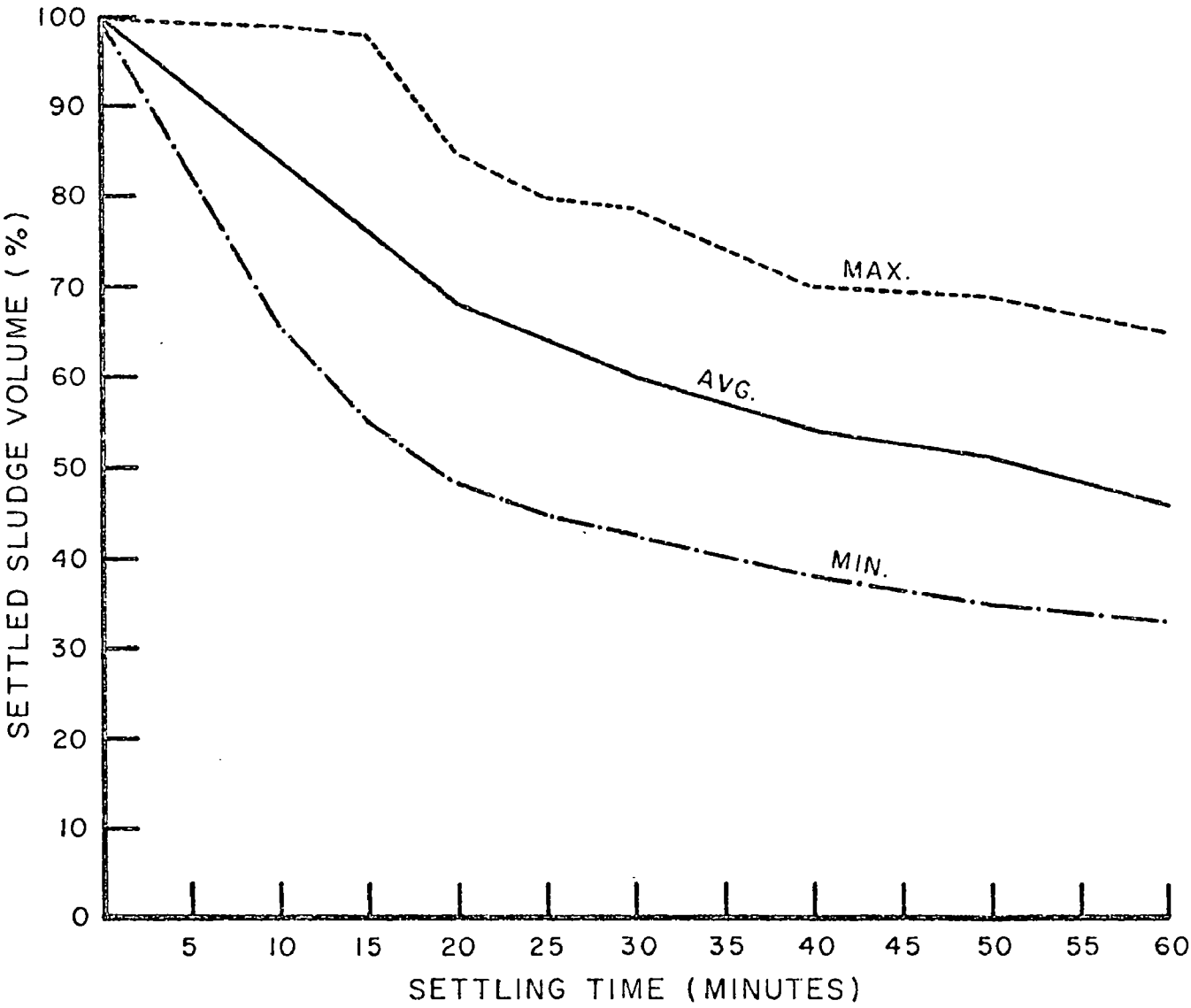
	Actual		
	Weekday	Weekend	Recommended (1)(7)
Hydraulic Detention Time (hours)	5.7	7.5	4-8
Sludge Age (Days)	3.7	--	3.5-7
Lbs. BOD/Lbs. MLVSS	.54	.44	0.2-0.4
Lbs. COD/Lbs. MLVSS	1.57	.92	0.5-1.0
Lbs. BOD/1000 cu. ft. aeration basin	22.3	13.6	20-40
MCRT	3.5	13.6	5-15

The mean cell residence time (MCRT) and sludge age were less than recommended values. The F/M ratio was near maximum recommended limits based on BOD_5 and exceeded maximum recommended values based on COD. This condition was due to low MLVSS in the aeration basins.

Wastewater flow equalization for the major industrial customers would greatly benefit operation of the activated sludge system. By retaining a portion of the weekday industrial wastewater flow and discharging it over the weekend, the weekday shock load would be reduced. A reasonably constant F/M ratio could then be maintained. Currently, the weekday BOD load is approximately four times greater than the weekend load. Another method of controlling the F/M ratio to handle the cyclic waste load would be to maintain a larger volume of sludge either in an aerobic digester or in a sludge reaeration basin. This would enable the operator to rapidly increase the MLSS when heavy load conditions warrant. The abandoned chlorine contact basin could be equipped with a surface aerator and used for this purpose.

The average, maximum and minimum readings of all settlometer tests are presented in Figure 11. The average volume of settled, mixed liquor sludge, after 60 minutes of settling, was 46 percent. The results shown in Figure 11 indicate an activated sludge with poor settling characteristics.

FIGURE 11
SETTLOMETER TEST
WINSTON SALEM, N.C.



PREAERATION BASIN

Wastewaters discharged from the Schlitz brewery flow into a 1.3 mg preaeration basin at the WTP. The basin has a 16-18 hour detention time and is equipped with six 100 hp floating surface aerators. The purpose of the basin is to satisfy a portion of the high BOD_5 of the waste that ranges from 1,000 to 2,500 mg/l. The flow from the brewery varies from 1.2 to 1.5 mgd during weekdays. Piping is arranged so that either all or a portion of the brewery waste can be passed through the basin. Urea is added to supply nitrogen to the brewery waste. The objective of this pretreatment basin is to reduce the total brewery waste to a BOD_5 concentration of approximately 1,000 mg/l. During the study, all of the waste was passed through the basin, and the average BOD_5 concentration of the effluent was 1,160 mg/l.

TRICKLING FILTERS

The four domed trickling filters were operated as a pair of primary filters in series with two secondary filters. (Figure 1). The system is arranged to provide the operator the option of operating all filters in series, in parallel, or in combination. The actual and recommended filter loadings are presented in Table 3. The filters, originally designed as high-rate filters, are now utilized as roughing filters to reduce the organic load on the activated sludge system.

The filters were shut down on November 16-17, 1975. This was a relatively low flow weekend period. The operator felt that this was necessary in order to strip excessive biological growth from the filters and to possibly reduce the fungi concentration in the aeration basin. There is no evidence to show that the fungi are produced in the trickling filters.

During the study, the two primary filters were receiving the total plant influent plus from one to ten mgd of recirculated flow for a total of 25 to 35 mgd. Recirculation rates were controlled to load the secondary filters at approximately 25 mgd. The organic loading to the two primary filters was above the recommended level for high-rate filters placing them in the roughing filter category.

TABLE 3
ACTUAL AND RECOMMENDED FILTER LOADINGS

	Actual	Recommended (7)
Primary Filters		
Hydraulic (gpd/ft^2)	400-560	230-920
Organic (lbs. BOD_5/1000 ft^3-day)	195-270	23-115
Secondary		
Hydraulic (gpd/ft^2)	400	230-920
Organic (lbs. BOD_5/1000 ft^3-day)	<194*	23-115

*No samples taken at intermediate filter stations.

The filter system is an integral part of the biological process and breakdown or upset of one or more filters has a deteriorating effect on the activated sludge unit. Changes in BOD_5, COD, TSS, and nitrogen concentrations can be seen from the profiles in Figures 4 through 6. The filters are between sampling stations C-2 and C-3 and T1. The BOD_5 reduction for the two day period (November 12 and 13) when the filters were in full operation, amounted to 54 percent of the filter influent BOD_5 or 46 percent of the total BOD_5 removed through the complete process.

Frequent mechanical problems have been experienced with the filters. Cables supporting the distributor arms fail frequently in the corrosive environment under the domes. As recirculation rates increased, mechanical failures were more common.

CLARIFIERS

The four rectangular primary clarifiers are operated in parallel and receive raw influent plus return waste sludge from the intermediate and final clarifiers. The clarifiers were designed for an overflow rate of 800 gal/ft^2/day at the design flow of 36 mgd with a detention period of two hours and twenty minutes. Plant inflows, during the study, ranged from 12 to 38 mgd which produced loadings within the design limits. The detention time was 3.5 hours at a plant flow of 24 mgd.

Wastes flowing into the primary clarifiers had a DO of 2.5 mg/l and the effluent DO was zero (Figure 10). Evidence of this anaerobic condition can be observed from Figure 6 which shows a decrease in NO_2-NO_3. The decrease is probably due to denitrification. Figure 5 shows a 72 percent reduction in suspended solids and a 40 percent reduction in COD. Figure 4 shows an average 23 percent reduction in BOD_5 in the clarifier.

The intermediate clarifiers are similar in design to the primary clarifiers. These basins are designed to settle biological solids that have sluffed off the trickling filters. Figures 4 through 6 indicate that these clarifiers had little effect upon the wastewater quality. Suspended solids and BOD_5 concentrations were unchanged. A small volume of thin sludge (500-1,000 mg/l) was returned from the intermediate to the primary clarifier.

Plant flow and return sludge flow rates are shown in Figure 3. The return rate during the study averaged approximately 88 percent of plant flow. The final clarifiers are designed for a surface settling rate of 800 gpd/ft^2 at the average design

flow of 36 mgd, and 1,200 gpd/ft^2 at the design peak flow of 54 mgd. Corresponding weir overflow rates are 23,900 and 35,800 gpd/ft, respectively. These rates are at the upper limit of the recommended range and leave very little room for satisfactory operation during process upsets. The ten state standards criteria (6) recommend a maximum loading of 800 gpd/ft^2 during "significant flow periods" and a preferable maximum weir overflow rate of 15,000 gpd/ft." The US-EPA (2) recommends a loading of 400-800 gpd/ft^2 during average flow conditions and 1,000 to 1,200 gpd/ft^2 for peak flow conditions. Metcalf and Eddy (7) recommend a surface settling rate of 800 gpd/ft^2 for activated sludge, peak flow conditions with a MLSS concentration of 3,000 mg/l and a recirculation rate of 50 percent. A maximum weir overflow rate of 30,000 gpd/ft is recommended if the weir is located away from the upturn zone and 20,000 gpd/ft if located in the upturn zone. The weirs on the final clarifiers are located on the outer wall of the clarifiers in the upturn zone.

Solids carryover occurred in the final clarifiers continually during the survey and had been occurring for several months prior. Settleability of the mixed liquor was poor (Figure 11) due to profuse filamentous growth. High sludge return rates were creating additional turbulance in the clarifier. Turbidity measurements were taken at the effluent weir of each clarifier (station FC-1 through FC-4). Turbidity values ranged from 1 to 215 standard turbidity units (STU). Most of these samples, after a 30 minute quiescent settling time, produced values of less than 5 STU. This test indicated that clarifier performance was poor, and that additional settling time would significantly improve the effluent.

Considering the overloaded condition of the final clarifiers and the underused condition of the intermediate clarifiers it would appear reasonable to investigate using all or a portion of the intermediate clarifiers for final settling. This modification would require pumping and some repiping but should be much less costly than constructing additional clarifiers.

On November 16 at 2:00 p.m., a small amount of Rhodamine WT fluorescent dye was dumped into the aeration basin effluent to observe flow distribution in the clarifiers. The waste appeared to be distributed fairly evenly in all four clarifiers.

DISINFECTION

Disinfection of the treated wastewater effluent is accomplished by the introduction of chlorine gas into the final clarifier effluent, upstream from the chlorine contact tank. The vacuum operated duplex chlorination system fed an average of 3,067 pounds of liquified chlorine per day to the wastewater stream. Chlorine usage for the study period ranged from 1,800 lbs/day to 4,300 lbs/day. The resulting chlorine residual at the chlorine contact tank overflow weir ranged from 2.3 ppm to 16.0 ppm. The high of 16.0 ppm was measured on Sunday, November 16, 1975, during a period of extremely low flow, and was due to a malfunction of the automated chlorinator. Plant personnel use the orthotolidine colorimetric test for free chlorine residual as a central measure in the chlorination process. Combined chlorine residual, rather than free chlorine residual, should be measured for control purposes. The amperometric or iodimetric titration method for total chlorine residual should be used.

DIGESTERS AND DRYING BEDS

Immediately prior to the study the solids content of all digesters had been reduced considerably in order to store solids during the coming wet months. This was done in order to avoid the problem which occurred at the plant last year, when all drying beds were full of wet sludge and the emergency sludge holding pond had to be used. Because of this condition, digester sampling during the survey was limited, and the data obtained are not typical of digesters operated under steady, fill and drain conditions. The results are more typical of start-up conditions. The total solids content was less than one percent in the six primary digesters and about five percent in the two secondary units. Gas produced from the primary units was utilized in the onsite power plant. The pH was above the desirable 6.8 to 7.2 range in four of the primary units, and the volatile acid/alkalinity ratio of digester D-2 was 0.53 which is approaching the danger zone (8). This condition can be corrected by reducing the raw feed rate or by recirculating solids from the secondary units to buffer the volatile acids in the primary units.

EXAMINATION OF MICROSCOPIC ORGANISMS

Slide samples of return sludge, aeration basin mixed liquors, floating clarifier solids, and influent samples were observed.

Return sludge and mixed liquor from the aeration basin had a very high concentration of filamentous growth and a high density of free-swimming ciliates and flagellates. No specific organism dominated since all types were well represented. The stalked ciliates with a limited number of rotifer and higher animal forms were present in lower concentrations.

Floating clarifier solids were primarily filamentous and of the same general protozoan makeup as the mixed liquor and return sludge.

Examination of the influent waste showed a limited number of protozoan types. Free-swimming bacteria, yeast cells, and macrofilaments were present in large numbers.

Sludge samples from the primary and intermediate units showed good mass flocculation, few protozoans, numerous fibers, and large fungal filaments. In the intermediate unit, numerous fly larvae, nematodes, flagellates, and the very small filamentous growth were observed.

The protozoan population of the activated sludge system was indicative of a waste system with a high organic load. Flagellates are the dominant organisms under these conditions. Free-swimming ciliates are found when there are a large number of free-swimming bacteria. Together, flagellates and free-swimming ciliates are found normally at the low side of the efficiency scale. Stalked ciliates which indicate an activated sludge which will produce low BOD effluent arise as a result of the number of available bacteria being reduced below the demands of the free-swimming ciliates (4).

From these observations, the source of innoculation of the small bulking filamentous growth cannot be ascertained. The small filamentous growth encountered appeared to be sheathed with separate individual cells enclosed. The mycelium did not branch, and fragmentation was not observed. Bacteria and flagellates were observed adhering at right angles to the filaments. These filaments, except for size of the mycelium, are similar to the Sphaeratilus organisms.

Dr. Pfaender, of the Mycology Dept., University of North Carolina at Chapel Hill, made an identification and enumeration of the filamentous growth. The growth was identified as fungi of the family Moniliaceae and genus Monilia. These organisms ranged from 2 to 5 x 10^4 cells per milliter of activated sludge.

OXYGEN UPTAKE RATES

General sludge activity can be measured by determining the difference in Oxygen (O_2) uptake rates of the sludge before and after introduction of raw waste. The ratios of these two variables or "load ratio" is calculated as follows:

$$\text{Load Ratio} = \frac{\Delta DO/min.\ fed\ sludge}{\Delta DO/min.\ unfed\ sludge}$$

The test procedure and its significance are presented in Appendix E.

Table 4 is a listing of the O_2 uptake rates and calculated load ratios for each type of waste. As shown in the table, O_2 uptake rates were determined on the three sewers entering the WTP as well as for the combined influent.

The calculated load ratios for the combined waste ranged from 1.14 Sunday morning, November 16, to 5.90 Sunday evening, to 6.67 Monday, November 17. On the morning of November 16, total plant inflow was very low; industrial process waste loads were low, and the trickling filter units had been shut down at 8:30 a.m. These conditions may have resulted in the one conspicuously low ratio. The afternoon of November 16 showed a calculated ratio of 5.9 which was attributed to the shutdown of all trickling filters. On Monday, the trickling filters were also down, and flow was again normal.

The aerated brewery waste, as opposed to the brewery waste before aeration, is very readily biodegradable, while the nonaerated brewery waste was slowly biodegradable. This was shown by average O_2 uptake rates for aerated and nonaerated brewery waste of 0.75 ppm and 0.13 ppm, respectively.

Calculated load ratios for the Salem and Kimel wastewaters were comparable to that of the combined waste.

These load ratios indicated a readily biodegradable waste and a fairly active sludge. The oxygen uptake rates for the unfed return sludge was somewhat lower than might be expected due to the low solids concentration (low microorganism density) in the sludge.

TABLE 4
OXYGEN UPTAKE RATES

Date	Time	% RS[1]	Average O_2 Uptake PPM/Min. URS	Average O_2 Uptake PPM/Min.[2] FRS	Load Ratio FRS/URS[3]
		Combined Plant Wastewater			
11/11/75	2:30 p.m.	100	0.20	0.84	4.2
11/12/75	3:00 p.m.	70	0.20	0.68	3.4
11/13/75	11:00 a.m.	55	0.11	0.44	4.0
11/14/75	2:20 p.m.	77	0.15	0.55	3.7
11/16/75	10:15 a.m.	78	0.14	0.16	1.14
11/16/75	2:00 p.m.	78	0.10	0.59	5.9
11/17/75	2:15 p.m.	100	0.12	0.75	6.25
		Schlitz Wastewater			
11/12/75	3:00 p.m.	70	0.20	1.34	6.7
11/13/75	11:00 a.m.	55	0.11	0.75	6.8
11/14/75	2:20 p.m.	77	0.15	0.40	2.7
11/16/75	2:00 p.m.	78	0.10	0.45	4.5
		Salem Wastewater			
11/12/75	3:00 p.m.	70	0.20	0.70	3.5
11/13/75	11:00 a.m.	55	0.11	0.44	4.0
		Kimel Wastewater			
11/12/75	3:00 p.m.	70	0.20	0.68	3.4
11/13/75	11:00 a.m.	55	0.11	0.40	3.6

1/ - RS - Return activated sludge
2/ - URS - Unfed return sludge (sludge plus final effluent)
3/ - FRS - Fed return sludge (sludge plus raw influent from the intermediate settling basin).

LABORATORY

The laboratory at the Winston-Salem WTP is located within the main control building. The lab was neat and appeared to be operated efficiently. Observations of lab records revealed a well organized data handling system.

The laboratory staff included a plant chemist, responsible for control testing and plant monitoring analyses, and an industrial chemist in charge of monitoring industrial dischargers. The staff also included six laboratory technicians.

During the study a discrepancy in the results of TKN analyses was observed. In comparing plant data with EPA data it was discovered that EPA data on TKN samples were consistently 30-40 percent lower than data run by the WTP personnel. Subsequent split samples also confirmed this variation. EPA normally uses an automated procedure for TKN analysis and the WTP uses a manual procedure. On the split samples the problem was isolated to the comparability of the manual and automated TKN procedure for this particular waste. The EPA Laboratory Services Branch is continuing to investigate and will identify the problem.

REFERENCES

1. "Operation of Wastewater Treatment Plants", A Field Study Training Program, US-EPA, Technical Training Grant No. 5TT1-WP-16-03.

2. "Process Design Manual for Suspended Solids Removal", US-EPA Technology Transfer, January 1975.

3. "Process Design Manual for Upgrading Existing Wastewater Treatment Plants", US-EPA Technology Transfer, October 1974.

4. Ross E. McKinney and Andrew Gram. "Protozoa and Activated Sludge", Sewage and Industrial Wastes, 28 (1956):1219-1231.

5. "Sewage Treatment Plant Design", American Society of Civil Engineers, Manual of Engineering Practice - No. 36, 1959.

6. "Standards for Sewage Works", Upper Mississippi River Board of State Sanitary Engineers, Revised Edition, 1971.

7. "Wastewater Engineering", Metcalf and Eddy, Inc., 1972.

8. "Operation of Wastewater Treatment Plants", A Field Study Training Program, US-EPA, Technical Training Grant No. 5TT1-WP-16-03, 1970.

Appendix A
Chemical Laboratory Data
Archie Elledge STP
Winston-Salem, NC

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids mg/l	Total Solids mg/l	Total Volatile Solids mg/l	COD mg/l	BOD_5 mg/l	Pb µg/l	Cr µg/l	Cu µg/l	Cd µg/l	Zn µg/l	TKN-N mg/l	NH_3-N mg/l	NO_3-NO_2-N mg/l	Total-P mg/l
0530	I-1	11	11/12	75	24hr. Comp.	605	185	1,504	624	1,979	-	<80	50	180	<20	288	10.0	.03	.14	10.1
0559		11	13/13	75	24hr. Comp.	285	200	914	426	1,400	-	<80	<50	180	<20	253	8.5	.01	.13	8.6
0579		11	13/14	75	24hr. Comp.	850	630	2,552	1,358	3,238	3,033	215	98	252	<20	595	19.7	.49	.22	11.7
0609		11	14/15	75	24hr. Comp.	588	338	3,136	1,650	3,071	-	<80	50	300	<20	400	19.7	.56	.16	13.3
0639		11	15/16	75	24hr. Comp.	344	152	1,388	548	1,259	600	<80	<50	130	<20	260	8.3	.62	.11	11.6
0666		11	16/17	75	24hr. Comp.	194	94	912	444	1,540	1,080	<80	98	158	<20	288	8.8	.78	.10	13.1
0687		11	17/18	75	24hr. Comp.	455	235	1,392	720	2,460	-	280	<50	218	<20	195	13.3	.85	.14	11.0

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	BOD_5 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
0531	I-2	11	11/12	75	24hr. Comp.	1,020	1,855	-	-	-	-
0560		11	12/13	75	24hr. Comp.	-	1,764	13.5	.08	.02	9.0
0580		11	14	75	0845*	1,583	2,593	13.3	1.8	1.38	10.1
0610		11	14/15	75	24hr. Comp.	-	3,934	18.6	1.3	1.5	10.9
0640		11	15/16	75	24hr. Comp.	1,250	3,044	17.0	1.2	2.0	10.9
0667		11	16/17	75	24hr. Comp.	790	1,320	9.0	.30	1.2	8.6
0688		11	17/18	75	24hr. Comp.	-	1,870	46.7	.03	.01	9.9

* = Grab sample, sampler inoperative.

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	BOD5 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	Suspended Solids mg/l	Volatile Susp. Solids mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Pb µg/l	Cr µg/l	Cu µg/l	Cd µg/l	Zn µg/l	Settleable Solids ml/l			
0532	I-3	11	11/12	75	24hr. Comp.	460	1040	22.0	11.2	<.01	10.1	287	187	886	422	227	360	774	<20	400	8.0			
0561		11	12/13	75	24hr. Comp.	-	864	18.2	8.9	.31	7.8	225	190	822	441	148	107	672	<20	485	8.0			
0581		11	13/14	75	24hr. Comp.	520	979	17.0	9.5	.08	9.1	270	180	924	510	120	142	740	<20	346	7.0			
0611		11	14/15	75	24hr. Comp.	-	1,095	20.5	12.3	.32	9.9	240	230	989	563	200	122	940	<20	436	11			
0641		11	15/16	75	24hr. Comp.	270	632	20.0	12.9	.12	9.0	144	136	622	324	<80	172	515	<20	350	6.0			
0668		11	16/17	75	24hr. Comp.	270	1,980	18.2	13.3	.11	6.8	250	140	1,002	616	<80	250	636	<20	281	6.5			
0689		11	17/18	75	24hr. Comp.	-	960	23.0	11.2	.33	10.2	236	184	949	541	95	148	982	<20	404	-			

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids mg/l	Total Solids mg/l	Total Volatile Solids 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	Cr µg/l	Cu µg/l	Cd µg/l	Zn µg/l	Settleable Solids ml/l
0549	SN	11	12	75	1545	12,000	7,069	12,238	6,666	11,390	540	510	.13	129	4,892	6,300	30,680	184	19,160	>40
0558	↓	11	13	75	0930	10,567	6,300	10,598	5,790	10,476	800	528	.13	122	4,857	390	28,400	182	17,660	>40
0587		11	14	75	0930	1,060	900	2,194	1,152	1,812	466	428	.17	73	452	669	3,450	25	1,387	40
0617		11	15	75	1000	980	940	2,060	1,088	1,777	400	400	.06	75	462	550	2,397	20	1,282	40
0647		11	16	75	0945	8,560	4,960	9,642	5,272	9,769	524	486	.13	116	4,250	5,560	26,000	158	14,460	>40
0674	↓	11	17	75	1130	1,720	1,120	2,794	1,487	2,185	510	480	.17	80	780	1,020	1,480	30	2,580	>40

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids 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	Settleable Solids ml/l	BOD mg/l
0533	C-1	11	12	75	1000	480	425	1,470	-	-	-	-	40	500
0555		11	12/13	75	24hr. Comp.	470	240	1,030	29.8	16.2	0.6	11.0	24	-
0583		11	13/14	75	24hr Comp.	390	220	1,241	31.5	17.6	.17	11.7	26	530
0612		11	14/15	75	24hr. Comp.	340	260	1,260	33	24.2	.18	11.4	21	-
0642		11	15/16	75	24hr. Comp.	207	167	784	31	21.6	.34	12.2	16	330
0669		11	16/17	75	24hr. Comp	255	190	580	33.5	24	.17	8.4	11	240
0690		11	17/18	75	24hr. Comp.	255	205	970	24	16.4	.26	10.2	-	-
0534	C 223	11	11/12	75	24hr. Comp.	95	55	827	-	-	-	-	<0.1	380
0562		11	12/13	75	24hr. Comp.	165	75	606	24.7	15.6	.03	8.6	<0.1	-
0582		11	13/14	75	24hr. Comp.	106	70	679	24.7	14.8	.01	9.1	<0.1	400
0613		11	14/15	75	24hr. Comp.	87	57	803	27.5	18.8	.05	8.6	<0.1	-
0643		11	15/16	75	24hr. Comp.	70	35	583	28	21.6	<.01	10.5	<0.1	300
0670		11	16/17	75	24hr. Comp.	45	40	240	29.6	25.2	<.01	9.1	<0.1	153
0691		11	17/18	75	24hr. Comp.	105	65	636	24.7	16.4	.03	8.0		

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	COD mg/l	Suspended Solids mg/l	Volatile Susp. Solids mg/l
0511	TF-1	11	11	75	1000-1600 *	649	104	56
0550	↓	11	12	75	0800-1400 *	532	114	58
0574	↓	11	13	75	0800-1400 *	450	108	52
0598	↓	11	14	75	0800-1600 *	758	73	40
0629	↓	11	15	75	0800-1500 *	710	176	148
0512	TF-2	11	11	75	1000-1600 *	590	97	70
0551	↓	11	12	75	0800-1600 *	572	110	75
0575	↓	11	13	75	0800-1400 *	450	100	52
0599	↓	11	14	75	0800-1600 *	758	6,020	5,979
0628	↓	11	15	75	0800-1500 *	723	80	64

* = Manual Composite

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids mg/l	COD mg/l
0513	TF-3	11	11	75	1000-1600 *	65	35	548
0552		11	12	75	0800-1400 *	132	80	643
0576		11	13	75	0800-1400 *	80	48	446
0600		11	14	75	0800-1600 *	107	73	736
0629		11	15	75	0800-1500 *	64	40	675
0514	TF-4	11	11	75	1000-1600 *	125	85	657
0553		11	12	75	0800-1400 *	68	40	528
0577		11	13	75	0800-1400 *	80	44	482
0601		11	14	75	0800-1600 *	96	64	726
0630		11	15	75	0800-1500 *	68	36	660

* = Manual Composite

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids 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	Settleable Solids ml/l	BOD_5 mg/l
0535	T-1	11	11/12	75	24hr. Comp.	104	52	552	–	–	–	–	0.5	183
0554		11	12/13	75	24hr. Comp.	108	48	506	25.2	13.5	.01	7.5	1.0	–
0584		11	13/14	75	24hr. Comp.	108	48	508	22	12.5	.01	8.6	1.2	173
0614		11	14/15	75	24hr. Comp.	77	53	660	25.2	13.9	.03	10.1	2.5	–
0644		11	15/16	75	24hr. Comp.	60	48	467	27	19.8	.02	10.2	1.5	140
0671		11	16/17	75	24hr. Comp.	60	45	284	32	25.7	.01	9.4	0.5	120
0692		11	17/18	75	24hr. Comp.	92	72	736	24.7	16.4	.02	9.4	–	–
0536	T-2	11	11/12	75	24hr Comp.	97	43	524	–	–	–	–	<0.1	166
0556		11	12/13	75	24hr. Comp.	88	36	448	24.8	13.2	.01	7.1	<0.1	–
0585		11	13/14	75	24hr. Comp.	84	36	448	20	12.1	.01	7.7	<0.1	153
0615		11	14/15	75	24hr. Comp.	185	150	448	–	–	–	–	<0.1	–
0645		11	15/16	75	24hr. Comp.	44	36	456	26.2	18.9	.01	10.2	<0.1	143
0672		11	16/17	75	24hr. Comp.	35	28	272	29.4	26.2	<.01	8.0	0.2	120

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids mg/l	% Solids by Centrifuge
0539	PS	11	12	75	1340	17,346	12,133	32.0
0566		11	13	75	1135	21,300	13,850	38.0
0597		11	14	75	1000	11,950	8,400	18.0
0665		11	16	75	1340	19,850	11,550	21.0
0683		11	17	75	0915	24,900	14,550	18.0
0540	15	11	12	75	1330	970	820	1.5
0567		11	13	75	1100	960	540	1.5
0596		11	14	75	1000	780	510	1.5
0626		11	15	75	1100	680	520	-
0664		11	16	75	1340	640	460	-
0684*		11	17	75	0950	1,950	1,400	17.0

*= Trickling filter flushed, contained many worms.

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids mg/l	SETTLEOMETER (Time in Minutes) 5	10	15	20	25	30	40	50	60	Comments	% Solids By Centrifuge
0506	A-13	11	11	75	1130	895	775	88	75	64	60	55	52	46	44	42	No Denitrification	2.5
0515		11	11	75	1615	1010	930	95	84	78	72	70	66	60	53	—	observed -	2.0
0523		11	12	75	0901	867	644	94	94	83	75	70	65	60	56	52	-fluffy Sludge-	2.0
0568		11	13	75	1400	660	500	90	80	70	65	60	58	50	50	45	Color left in	1.8
0588		11	14	75	0945	675	475	99	98	85	80	75	70	65	60	58	supernatant.	1.9
0606		11	14	75	1500	—	—	95	90	83	80	76	74	70	65	—		1.5
0618		11	15	75	1030	—	—	99	99	90	85	80	79	65	65	65		1.5
0635		11	15	75	1630	—	—	96	89	85	85	76	65	54	46	45		1.4
0652		11	16	75	0900	500	410	95	80	65	59	55	50	45	45	43		1.8
0661		11	16	75	1300	—	—	92	80	70	62	57	49	46	42	39		1.7
0679		11	17	75	0800	630	580	83	75	55	46	45	43	38	35	33		2.0
0685		11	17	75	0950	—	—	85	68	57	50	45	45	41	40	35		—

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids mg/l	SETTLEOMETER (Time in Minutes) 5	10	15	20	25	30	40	50	60	Comments	% Solids By Centrifuge
0507	A-14	11	11	75	1130	955	809	85	73	62	56	53	50	45	43	41	Same as for A-13	2.5
0516		11	11	75	1615	930	710	90	80	75	70	68	63	58	53	–		2.0
0524		11	12	75	0902	930	850	94	94	85	75	73	68	63	59	55		2.0
0541	*	11	12	75	1400			–	96	90	80	75	70	65	60	55		–
0541 A	*	11	12	75	1400			–	98	98	85	79	70	68	61	58		–
0569		11	13	75	1400	680	490	90	75	70	62	55	54	50	50	43		1.5
0589		11	14	75	0945	640	440	99	98	90	80	79	75	68	62	60		1.8
0607		11	14	75	1500			95	92	86	84	80	76	72	69	–		1.5
0619		11	15	75	1030			99	99	85	75	70	70	60	58	55		1.5
0636		11	15	75	1630			99	89	87	85	74	60	55	47	42		1.5
0653		11	16	75	0900	560	420	95	79	65	57	54	48	44	44	42		1.7
0662		11	16	75	1300			90	75	62	55	51	45	42	37	37		1.8
0680		11	17	75	0800	600	550	85	76	56	48	45	43	38	35	33		1.9
0686		11	17	75	0950			85	66	55	50	45	43	41	–	–		–

* Sample split into portions for experiment.

0541 aerated to 7.0 mg/l D.O.
0541-A not aerated – D.O. = 1.0 mg/l or less

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Suspended Solids mg/l	Volatile Susp. Solids mg/l	% Solids by Centrifuge	COD mg/l
0505	RS	11	11	75	1130	2,640	2,400	6.0	
0517		11	11	75	1615	1,540	1,400	3.0	
0525		11	12	75	0900	2,220	2,060	4.5	
0570		11	13	75	1400	1,260	1,180	3.0	
0590		11	14	75	0945	1,500	1,075	3.1	
0608		11	14	75	1500	–	–	2.0	
0620		11	15	75	1030	–	–	2.0	
0637		11	15	75	1630	–	–	2.2	
0654		11	16	75	0900	–	–	2.9	1,419
0660		11	16	75	1300	–	–	2.8	
0681		11	17	75	0800	1,080	1,000	3.2	

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Turbidity JTU	Turbidity after sitting 30 min.
0501	FC-1	11	11	75	1115	130	2
0521		11	11	75	1615	115	–
0526		11	12	75	0850	10	–
0543		11	12	75	1400	165	–
0570		11	13	75	1400	13	–
0591		11	14	75	0945	6	–
0602		11	14	75	1600	185	140
0621		11	15	75	1030	11	2
0631		11	15	75	1630	120	2
0648		11	16	75	0900	3	–
0656		11	16	75	1300	2	–
0675		11	17	75	1130	1	–

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Turbidity JTU	Turbidity after sitting 30 min.
0502	FC-2	11	11	75	1115	10	1
0522		11	11	75	1615	85	—
0527		11	12	75	0850	9	—
0544		11	12	75	1400	165	—
0571		11	13	75	1400	15	—
0592		11	14	75	0945	4	—
0603		11	14	75	1600	215	—
0622		11	15	75	1030	94	2
0632		11	15	75	1630	30	4
0649		11	16	75	0900	5	—
0657		11	16	75	1300	1	—
0676		11	17	75	1130	1	—

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Turbidity JTU	Turbidity after sitting 30 min.
0503	FC-3	11	11	75	1115	5	1
0519		11	11	75	1615	180	—
0528		11	12	75	0850	11	—
0545		11	12	75	1400	190	—
0572		11	13	75	1400	80	—
0593		11	14	75	0945	35	4
0604		11	14	75	1600	160	—
0623		11	15	75	1030	27	2
0633		11	15	75	1630	92	12
0650		11	16	75	0900	2	—
0658		11	16	75	1300	1	—
0677		11	17	75	1130	1	—

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Turbidity JTU	Turbidity after sitting 30 min.
0504	FC - 4	11	11	75	1115	15	1
0520		11	11	75	1615	90	-
0529		11	12	75	0850	8	-
0546		11	12	75	1400	150	-
0573		11	13	75	1400	23	-
0594		11	14	75	0945	58	2
0605		11	14	75	1600	175	-
0624		11	15	75	1030	88	2
0634		11	15	75	1630	26	3
0651		11	16	75	0900	2	-
0659		11	16	75	1300	1	-
0678		11	17	75	0800	1	-

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Total-P mg/l	TKN-N mg/l	NH_3-N mg/l	NO_3-NO_2-N mg/l	COD mg/l	Suspended Solids mg/l	Volatile Suspended Solids mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Pb µg/l	Cr µg/l	Cu µg/l	Cd µg/l	Zn µg/l	Residual Cl_2 mg/l	Turbidity JTU	Turbidity-JTU after 30 min. Settle time	Settleable Solids ml/l	BOD_5 mg/l
0500	E-1	11	11	75	1100														2.34					
0518	!	11	11	75	1615																			
0537		11	11/12	75	24hr. Comp.	9.1	14	7.8	.16	374	133	93	606	184	120	54	655	<20	365	–	58	–	>40	42
0538		11	12	75	1000								–	–					3.44				–	
0557		11	12/13	75	24hr. Comp.	7.4	16.3	6.4	.08	544	220	153	692	254	160	397	930	<20	452				>40	–
0578		11	13	75	1545								–	–					3.4	29				–
0586		11	13/14	75	24hr. Comp.	6.6	15.3	10.5	.1	251	80	80	512	172	<80	134	320	<20	222				>40	24.4
0595		11	14	75	1000								–	–					4.1	6	–			–
0616		11	14/15	75	24 hr. comp.	9.6	19.7	10.2	.02	417	190	165	668	288	160	212	690	<20	308				>40	–
0625		11	15	75	1045								–	–						96	16			–
0638		11	15	75	1645								–	–						60	11			–
0646		11	15/16	75	24 hr. comp.	8.6	15.6	10.3	.04	420	104	96	698	266	80	122	508	<20	232				>40	49
0655		11	16	75	0900								–	–					16.0	7				
0663		11	16	75	1330								–	–					3.3	5	–			–
0673		11	16/17	75	24 hr. comp.	7.1	20.7	19	1.6	176	34	28	484	156	<80	90	150	<20	428				0.2	65
0682		11	17	75	0900								–	–										
0694		11	17/18	75	24hr.	8.5	23	18.2	1.0	351	140	104	482	188	<80	142	502	<20	232					

Appendix A, Chemical Laboratory Data, Archie Elledge STP, Winston-Salem, NC (continued)

O&M SAD #	STATION	MONTH	DAY	YEAR	TIME	Total Solids mg/l	Total Volatile Solids mg/l	Pb µg/l	Cr µg/l	Cu µg/l	Cd µg/l	Zn µg/l	Volatile Acids (mg/l as acetic acid)	Alkalinity mg/l as $CaCO_3$	Vol. Acid to Alk. ratio	pH	% Solids by Centrifuge	Suspended Solids mg/l	Volatile Suspended Solids
0508	D-1	11	11	75	1445	6,684	3,836	2,256	3,072	4,570	120	8,660	552	1,665	0.33	7.6	6		
0509	D-6	11	11	75	1445	46,728	25,590	1,440	34,160	8,300	1,060	96,800	–	–	–	–	39		
0510	D-7	11	11	75	1445	50,430	27,392	1,440	30,400	8,300	1,080	97,920	–	–	–	–	40		
0547	D-2	11	12	75	1430	2,994	1,488	936	1,205	1,800	40	3,810	1,008	1,911	0.53	7.1	1.5		
0548	D-3	11	12	75	1430	3,216	1,680	1,092	1,564	2,328	55	4,900	720	1,693	0.42	7.2	2.0		
0563	D-5	11	13	75	1015	–		255	312	1,412	<20	833	300	1,607	0.19	7.4	<1	729	444
0564	D-8	11	13	75	1015	–		976	1,383	1,732	35	3,180	684	1,784	0.38	7.5	2.5	2,300	1,325
0565	D-4	11	13	75	1015	–		2,227	2,832	13,100	103	8,280	180	1,638	0.11	7.7	4.0	5,233	2,835

Appendix B
Dissolved Oxygen Profiles
Winston-Salem, NC

Station	Date (1975)	Time 1/	Temp. °C	DO (mg/l) 1 ft.	3 ft.	5 ft.	8 ft.	10 ft.
A1-d	11/11	1030-1130	25	1.2		0.8		
A1-b			24	1.1		1.0		
A1-e				0.6		0.3		
A1-c				1.4		1.0	0.8	
A1-f				1.2		0.2		
A1-g				1.0		0.3		
A2-a				0.5		0.6		
A2-b				0.6		0.3		
A2-c				0.2		0.2		
A2-d				0.2		0.1		
A3-b				0.6		0.3		
A3-c				0.7		0.1		
A3-d				0.8		0.2		
A4-a				0.9		0.8		
A4-c				0.2		0.2		
A4-d				0.2		0.1		0.1
A4-b				0.4		0.4		0.4
A5-a				1.3		1.0		
A5-b				1.3		1.4		1.3
A5-c				1.5		1.0		1.0
A5-d				0.6		0.2		0.5
A6-a				1.4		1.3		
A6-b				1.0				
A6-c				1.4		1.2		
A7-a	11/11	1130-1215	24	0.9		0.8		
A7-b				1.1		0.7		
A8-a					1.0			0.8
A8-c				0.2		0.0		
A8-d				0.1		0.0		
A8-e				0.2		0.0		
A8-f				1.0		0.0		
A9-c				0.4		0.0		
A9-b					0.8			0.6
A10-c				0.3		0.0		
A11-c				1.0		0.6		
A11-d				0.7		0.1		
A11-e				0.3		0.2		
A11-f				0.2		0.1		
A12-a				1.4		1.2		
A12-b				1.8				
A12-c				1.1		1.0		

Station	Date (1975)	Time 2/	Temp. (°C)	DO (mg/l) 1 ft.	3 ft.
A1-c	11/12	1330-1430	25		1.0
A1-d					0.6
A1-e					0.8
A1-f					0.4
A1-g					0.4
A2-b					0.7
A2-c					0.4
A2-d					0.1
A3-b					0.4
A3-c					0.1
A3-d					0.1
A4-b					0.4
A4-c					0.2
A4-d					0.4
A5-b					1.3
A5-c					1.6
A5-d					1.6
A6-b				2.3	
A6-c					2.1
A7-c					2.0
A7-d					1.7
A7-e					1.4
A8-b					1.3
A8-c					1.0
A8-d					0.1
A8-e					1.0
A8-f					1.0
A9-b					1.3
A9-c					0.1
A10-b					0.6
A10-c					0.1
A11-b					1.0
A11-c					1.3
A11-d					1.1
A11-e					0.8
A11-f					0.1
A12-b				1.8	
A12-c					1.8

1/ Aerators 1, 3, 5, 6, 8, 10 on.

2/ Aerators 1, 2, 4, 5, 6, 7, 9, 10 on

Appendix B (continued)
Dissolved Oxygen Profiles
Winston-Salem, NC

Station	Date (1975)	Time 1/	Temp. (°C)	DO (mg/l) 2/
A3 - a	11/13	1530-1630	23 5	0.8
A3 - b				0 4
A3 - c				0.4
A3 - d				0 4
A4 - a				0.0
A4 - b				1.0
A4 - c				0.0
A4 - d				0.2
A5 - a				0.0
A5 - b				1.4
A5 - c				1.6
A5 - d				0 8
A6 - c				1.7
A8 - c				0.4
A8 - d				0.6
A9 - a				1.0
A9 - b				0.0
A9 - c				0 4
A10 - a				0.8
A10 - b				0.9
A10 - c				0 4
A11 - a				1.4
A11 - b				0 8
A11 - c				1.0
A11 - d				0.8
A11 - e				0.0
A11 - f				0.6
A12 - c				1.2

Station	Date (1975)	Time 3/	Temp. (°C)	DO (mg/l) 2/
A1 - a	11/14	1400-1520	23	0 4
A1 - c				0 4
A1 - d				0.3
A1 - e				0 3
A1 - f				0.3
A1 - g				0.0
A2 - a				0.3
A2 - b				0 0
A2 - c				0 0
A2 - d				0 0
A3 - a				0.3
A3 - b				0 3
A3 - c				0.0
A3 - d				0.0
A4 - a				0.4
A4 - b				0.5
A4 - c				0.0
A4 - d				0.0
A5 - a				0.3
A5 - b				0.6
A5 - c				0.2
A5 - d				0.0
A6 - a				0.9
A6 - b				0.8
A6 - c				1.5
A7 - a				0.3
A7 - c				0.7
A7 - d				0 2
A7 - e				0 4
A8 - a				0.3
A8 - b				0.0
A8 - c				0.0
A8 - d				0.0
A8 - e				0.2
A8 - f				0.0
A9 - a				0.3
A9 - b				0.2
A9 - c				0.0
A10 - a				0.0
A10 - b				0 3
A10 - c				0.0

Station	Date (1975)	Time 3/	Temp. (°C)	DO (mg/l) 2/	DO (mg/l) 1 ft.	DO (mg/l) 3 ft.	DO (mg/l) 5 ft.
A11 - a	11/14	1400-1530	23			0.4	
A11 - b						0 2	
A11 - c						0.0	
A11 - d						0.1	
A11 - e						0.0	
A11 - f						0.0	
A12 - a						0.8	
A12 - b						0.8	
A12 - c						1.1	
A1 - a	11/15	1100-1230	22		0.9		0.8
A1 - c					0.6		0.6
A1 - d					0.7		0.6
A1 - f					0.6		0.0
A1 - g					0.2		0.2
A2 - a					0.5		0.5
A2 - b					0 4		0.3
A2 - c					0.0		0.0
A2 - d					0.0		0.0
A3 - a					0.8		0.8
A3 - b					0.6		0.5
A3 - c					0.3		0 0
A3 - d					1.2		0 0
A4 - a					1.3		1.0
A4 - b					1.0		1.0
A4 - c					0.8		0.7
A4 - d					0.6		0.6
A5 - a					1.3		1.3
A5 - b					1.9		1.9
A5 - c					1.8		1.5
A5 - d					0.9		0 8
A6 - a					1.9		1.8
A6 - b					1 6		
A6 - c					2 2		2.0
A7 - a					1.0		1.0
A7 - c					1.0		0.8
A7 - d					0.6		0.6
A7 - e					1.0		0.8
A8 - a					0.9		0.7
A8 - b					0.2		0.0
A8 - c					0.3		0 0
A8 - d					0.2		0.1
A8 - e					0.5		0 5
A8 - f					0 0		0 0

1/ Aerators 3, 5, 8, 10 on

2/ Determined at 3 ft depth

3/ Aerators 1, 3, 5, 6, 8, 10 on

Appendix B (continued)
Dissolved Oxygen Profiles
Winston-Salem, NC

Station	Date (1975)	Time	Temp. (°C)	DO (mg/l) 1 ft.	DO (mg/l) 5 ft.
A9 - a	11/15	1100-1230 1/	22	0.5	0.4
A9 - b				0.5	0.4
A9 - c				0.4	0.0
A10 - a				0.3	0.2
A10 - b				0.5	0.7
A10 - c				0.6	0.0
A11 - a				1.1	1.0
A11 - b				1.0	0.7
A11 - c				0.3	0.6
A11 - d				0.4	0.4
A11 - e				0.0	0.0
A11 - f				0.4	0.2
A12 - a				1.2	1.2
A12 - b				1.2	
A12 - c				1.5	1.1
A1 - a	11/16	1500-1620 2/	21	4.6	4.5
A1 - c				4.8	4.8
A1 - d				4.4	4.2
A1 - e				4.5	4.3
A1 - f				4.9	4.3
A1 - g				4.4	4.3
A2 - a			22	4.5	4.4
A2 - b				4.6	4.6
A2 - c				5.0	4.6
A2 - d				5.4	4.3
A3 - a				5.0	5.0
A3 - b				5.2	5.1
A3 - c				5.6	5.0
A3 - d				5.6	5.0
A4 - a			21	5.6	5.3
A4 - b				5.2	5.1
A4 - c				5.4	5.0
A4 - d				5.2	5.0
A5 - a				5.4	5.4
A5 - b				5.2	5.2
A5 - c				5.4	5.4
A5 - d				5.2	5.3
A6 - a				5.6	5.5
A6 - b				5.4	
A6 - c				5.5	5.5

Station	Date (1975)	Time	Temp. (°C)	DO (mg/l) 1 ft.	DO (mg/l) 3 ft.	DO (mg/l) 5 ft.
A7 - a	11/16	1500-1620 2/	22	5.2		5.0
A7 - c				4.3		4.3
A7 - d				4.9		4.8
A7 - e				4.7		4.1
A8 - a				5.1		5.1
A8 - b				5.3		5.2
A8 - c				5.3		4.7
A8 - d				5.5		5.0
A8 - e				5.1		4.7
A8 - f				5.4		4.8
A9 - a			21	5.1		5.1
A9 - b				5.2		5.2
A9 - c				5.5		4.8
A10 - a				5.1		5.0
A10 - b				5.3		5.2
A10 - c				5.5		5.0
A11 - a				5.0		5.0
A11 - b				5.2		5.2
A11 - c				5.4		5.0
A11 - d				5.5		4.7
A11 - e				5.0		4.0
A11 - f				5.0		5.0
A12 - a				5.2		5.2
A12 - b				5.2		
A12 - c				5.3		5.3
A1 - a	11/17	1135-1240 1/	20		0.4	
A1 - c					0.4	
A1 - d					0.4	
A1 - f					0.6	
A1 - g					0.3	
A2 - a					0 0	
A2 - b					0.4	
A2 - c					0.0	
A2 - d					0.0	
A3 - a					0.0	
A3 - b					0.5	
A3 - c					0.5	
A3 - d					0.4	
A4 - a					0.0	
A4 - b					0.5	
A4 - c					0.5	
A4 - d					0 9	
					0 6	

Station	Date (1975)	Time	Temp. (°C)	DO (mg/l) 3/
A5 - a	11/17	1135-1240 1/	20	2.8
A5 - b				1.6
A5 - c				1.4
A5 - d				0 6
A6 - a				1.8
A6 - b				1.4
A6 - c				1.6
A7 - a				0.5
A7 - c				0.4
A7 - d				3.5
A7 - e				0.5
A8 - a				0.3
A8 - b				0.0
A8 - c				0.0
A8 - d				0.0
A8 - e				1.0
A8 - f				0.3
A9 - a				0 2
A9 - b				0.2
A9 - c				0.6
A10 - a				0.0
A10 - b				0.5
A10 - c				0.0
A11 - a				0.3
A11 - b				0.8
A11 - c				0 8
A11 - d				0.3
A11 - e				0.0
A11 - f				0.3
A12 - a				1.0
A12 - b				0.5
A12 - c				1.6

1/ Aerators 1, 3, 5, 6, 8, 10 on
2/ All aerators on
3/ Determined at 3 ft. depth.

Appendix C
Dissolved Oxygen Profile through WTP
Winston-Salem, NC

Date (1975)	I1	I2	I3	C1	C2	C3	T1	T2	E1	TF1	TF2	TF3	TF4
11/11	4.7	1.1 1/	0.2	2.8	0	1.8	4.8	1.4		3.6	3.8	4.2	6.4
11/12	4.0		0.2	2.6	0	2.0	4.0	1.6					
11/13	4.4	1.2 1/	0.2	0.3	0		5.2	2.0					
11/14	5.6	8.6	0.3	2.5	0	0	4.4	0.5		4.1	3.1	4.0	4.2
11/15									4.7				
11/16	3.4	9.0	0.7	2.6	0	0	5.0	1.0					
11/17	4.8	8.6	0.2	2.0	0	0	5.4	1.2	5.9				

1/ All preaeration aerators not operating

Appendix D

General Study Methods

To accomplish the stated objectives outlined in the introduction, the study necessitated extensive sampling physical measurements, daily visual observations and discussions with the plant operator (5).

The plant influent stations I-1, I-2, I-3; the primary unit process stations C-1, C-2 & 3; intermediate unit process station T-1, T-2; and the effluent stream station E-1, were sampled for seven consecutive 24 hour periods with ISCO Model 1392-XG automatic samplers. Aliquots of sample were pumped at hourly intervals into individual refrigerated glass bottles which were composited proportional to flow at the end of each sampling period.

Effluent from each trickling filter unit, stations TF-1, TF-2, TF-3, and TF-4 were grab sampled on four equally spaced time periods between 8 a.m. and 6 p.m. for five consecutive days. Nine hundred milliliters were composited for each time period into a gallon jug.

Each digester was grab sampled once during the study period and supernatant flow was grab sampled once per day for six consecutive days.

Standard operational control tests were run twice daily, once in the morning and once in the afternoon for seven consecutive days. The control tests consisted of:

- o sludge settleability as determined by the 60 minute settlometer test,
- o percent solids by centrifuge on the mixed liquor and return sludge,
- o TSS and VSS analyses on mixed liquor and return sludge,
- o depth of clarifier sludge blanket and
- o turbidity of the effluent from the final clarifiers.

The return sludge flow was grab sampled twice per day for six days to determine sludge activity. Sludge activity was measured by the oxygen uptake procedure presented in Appendix E. The rate of oxygen uptake for fed and unfed sludge was determined and a loading factor was calculated.

Microscopic examinations were made on influent, primary sludge, intermediate sludge, return sludge, and trickling filter slime.

Physical observations of individual unit processes and flowmeter readings were recorded daily and whenever operational changes were made.

The BOD_5 analysis was modified in that the incubation temperature was not maintained at exactly 20°C during the 6-hour transit time from Winston-Salem to Athens. Currently, comparative tests are being run to determine what effect, if any, temperature variation and agitation has upon BOD_5 results. This is being done by setting up duplicate samples at selected plants. One sample is then returned to Athens for analysis and the other is analyzed by the plant.

Mention of trade names does not constitute endorsement or recommendation by the EPA.

APPENDIX E

OXYGEN UPTAKE PROCEDURE[3]

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 (Δ DO/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."

(3) 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.

Appendix F
Design Data
Archie Elledge Wastewater Treatment Plant
Winston-Salem, North Carolina

DESIGN FLOWS

Average	36 mgd
Peak	54 mgd

SCREENING AND GRIT REMOVAL

Designed to handle flows and process screenings and grit from flow of 100 mgd. Velocities through the bar screens range from 1.7 - 2.5 ft./sec., and velocities in the grit channels range from 0.8 - 1.0 ft./sec.

PRIMARY PUMP STATION

Pumping Capacity variable	0-80 mgd maximum
Control valve recirculation Capacity, variable	0-18 mgd

PRIMARY CLARIFIER

Number of hydraulically separate tanks		4
Dimensions		
Length	140 ft.	
Width	83 ft.	
Depth	10 ft.	
Wetted volume		116,200 $ft.^3$ each 869,000 gal. each 465,000 $ft.^3$ total 3,477,000 gal. total
Detention time at 36 mgd		2 hours 20 minutes
Surface overflow rate		800 gal/sq ft/day
Sludge collector's rate of travel		
Main collector		2 ft/minute
Cross collector		4 ft/minute
Sludge pumps		
Number		4
Capacity, constant		700 gpm @ 90' TDH 1 gpm @ 90' TDH

Appendix F (continued)

INTERMEDIATE PUMP STATION

Number of pumps	4
Pumping capacity, variable	0-25 mgd each 0-100 mgd total

TRICKLING FILTERS

Number	4
Dimensions	
Diameter 200 ft.	
Depth 5.25 ft.	
Area	.72 acre, each 2.9 acre, total
Volume	3.8 acre ft. each 15.1 acre ft. total
Hydraulic capability of distributors	25,000 gal. each 100,000 gal. total
Estimated BOD removal capability	110 lb/1000 cu. ft./day or 72,500 lb/day

INTERMEDIATE CLARIFIERS

Number hydraulically separate tanks	12
Dimensions	
Length 124 ft.	
Width 31 ft. 6 inches	
Depth 8 ft. 10 inches	
Volume	34,500 $ft.^3$ each 258,100 gals. each 414,000 $ft.^3$ total 3,100,000 gals. total
Detention time without recirculation	@ 36 mgd 2 hrs.
Detention time with 100% recirculation	1 hr.
Surface overflow rate	770 $gal/ft^2/day$
Sludge collector's rate of travel	1 ft/min.

Appendix F (continued)

AERATION BASINS

Number of basins		2
Dimensions each		
Length	525 ft.@ surface	
Width	105 ft.@ surface	
Depth	14.5 ft. @ center	
Volume		752,000 $ft.^3$ each
		5,625,000 gals. each
		1,504,000 $ft.^3$ total
		11,250,000 gals. total
Detention time without recirculation @ 36 mgd		7.5 hrs
Detention time with 25% recirculation		6 hrs.
Estimated BOD removal		
assuming adequate final settling and 1700 - 2000 mg/l MLSS, 70% MLVSS, 65°F., SVI 100-200		44,000 lbs/day
Aerators		
Number		10
Horsepower		100 each
Calculated O_2 requirement		77,000 lbs/day
Rated total O_2 transfer capacity		82,000 lbs/day

FINAL CLARIFIERS

Number		4
Dimensions		
Diameter	120 ft.	
Depth	11 ft.	
weir length	378 ft.	
Volume		124,300 $ft.^3$ each
		929,800 gals. each
		497,200 $ft.^3$ total
		3,719,000 gals. total
Detention time without recirculation @ 36 mgd		2½ hrs.
Detention time with 25% recirculation		2 hrs.
Surface overflow rate		800 gal/ft^2/day

CHLORINE CONTACT TANK

Number		1
Dimensions		
Length	120 ft.	
Width	84 ft.	
Depth	10.5 ft.	
Volume	105,800 ft^3 or	791,700 gals.
plus approx. 1300 ft. of 60 inch pipe to CCT		190,800 gals.
		982,500 gals.
Detention time @ 36 mgd approx.		40 minutes

RETURN SLUDGE PUMP STATION

Number of pumps	3
Capacity, variable	0 - 36 mgd total

DIGESTERS

Number	8
Volume old digesters	153,000 $ft.^3$ each 1,144,000 gals. each
Volume new digesters	200,000 $ft.^3$ each 1,496,000 gals. each
Total digester volume	1,412,000 $ft.^3$ 10,560,000 gals.
Volume of primary digesters	1,012,000 $ft.^3$ 7,569,800 gals.
Volume of secondary digesters, 2 new	400,000 $ft.^3$ 2,992,000 gals.

Estimated design loading @ 36 mgd

55,000	lb/day primary sludge	
60,000	lb/day TF sludge	
25,000	lb/day Waste AS	
140,000	Total	140,000 lb/day

Estimated volatile content 60%	84,000 lbs/day
Loading on primary digesters	83 lb. MLVSS/1000 $ft.^3$

Appendix F (continued)

SLUDGE DRYING BEDS

Number		69
Dimensions		
Length	100 ft.	
Width	100 ft.	
Area		10,000 $ft.^2$ each
		690,000 $ft.^2$ total
		15.8 acres total