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BIOLOGICAL TREATMENT OF COMBINED SEWER OVERFLOW AT KENOSHA, WISCONSIN

National Environmental Research Center
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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

This report portrays an effective alternative for control of storm flow pollution by modification of an existing biological treatment process.

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ABSTRACT

This report describes the design, construction, operation and two year evaluation of a biological process used for the treatment of potential combined sewer overflow. The project was conducted in the City of Kenosha, Wisconsin. A 75,700 cu m/day (20 mgd) modified contact stabilization process was constructed on the grounds of the city's existing 87,055 cu m/day (23 mgd) conventional activated sludge plant at a total cost of 1.1 million dollars.

The demonstration system consisted of pumping facilities, the conversion of an unused flocculation basin into a grit basin, construction of a contact tank and stabilization tank, installation of a final clarifier and all associated yard piping and automatic control equipment. The demonstration system's raw sewage pump and clarifier were used by the dry weather plant when the demonstration system was not in use. The chlorination and sludge handling facilities of the dry weather plant were utilized by the demonstration system.

Results from the evaluation program proved the demonstration system to be a feasible concept for the treatment of potential combined sewer overflow. The system was operated and evaluated during 49 runs in which 681,300 cu m (180,000,000 gal.) of potential overflow was treated. Based on these tests, expected removal efficiencies for suspended solids, BOD, and TOC are 90%, 85%, and 76%, respectively. The optimum ranges for operation of the various process variables were also determined. Operating costs for running the system 300 hours per year are estimated at 3.567¢/cu m (13.5¢/1000 gal.). An additional benefit derived from the demonstration system was improved removal efficiencies by the dry weather plant through utilization of the demonstration system facilities.

This report was submitted in fulfillment of Project No. 11023 EKC under the partial sponsorship of the U.S. Environmental Protection Agency. The study program associated with this project was performed by Envirex Inc. acting as a subcontractor to the grantee, the City of Kenosha. Work was completed as of November 1973.

CONTENTS

		Page
Abstract		iv
List of Figures		vii
List of Tables		x
Acknowledgments		xi
Sections		
I	CONCLUSIONS	1
II	RECOMMENDATIONS	4
III	INTRODUCTION	5
IV	EXISTING TREATMENT FACILITIES AND SEWERAGE SYSTEM	7
	Water Pollution Control Plant	7
	Sewerage System	8
V	SYSTEM DESIGN AND CONSTRUCTION	12
	Contact Stabilization Process Theory	12
	Contact Stabilization Operating Experience	16
	System Design for Kenosha	17
	Pumping Plant	19
	Grit Tank	19
	Contact Tank	19
	Stabilization Tank	22
	Sludge Transfer Pumps	28
	Oxygen Requirements	28
	Final Clarifier Equipment	30
	Instrumentation and Control	30
	System Deployment	34
	Construction Costs and Timing	36
VI	OVERFLOW QUALITY STUDY	39
	Instrumentation	39
	Monitoring Procedure	44
	Precipitation Data	45
	Overflow Quality Analysis	48

CONTENTS (continued)

Section		Page
VII	EVALUATION PROGRAM AND RESULTS	54
	Plan of Operation	54
	Method of Operation	56
	Feasibility Study	60
	Study of Process Variables	63
	Optimum Treatment Conditions	66
	Relationship to Dry Weather Plant	69
	Ancillary Studies	74
	BOD:COD:TOC Relationships	74
	Time Series Analyses	77
	Economic Considerations	77
	Operating Costs	77
	Total Costs	80
	Overflow Volumes	82
VIII	STABILIZATION TANK SLUDGE STUDIES	88
	Sludge Behavior Under Static Conditions	88
	Continuous Flow Through the Stabilization Tank	91
	Bench Scale Studies	98
IX	FUTURE DESIGN CONSIDERATIONS	110
X	REFERENCES	113
XI	PUBLICATIONS	116
XII	GLOSSARY	117
XIII	APPENDICES	118
	A. Description of Analytical Techniques	118
	B. Overflow Quality Data 1970	121
	C. Demonstration System Operating Data	146
	D. Procedure for Sludge Studies	244

FIGURES

No.		Page
1	Map of Kenosha Indicating Combined Sewer Area	9
2	Illustration Showing Interceptor Sewer and Combined Sewer Overflow Discharge Locations	10
3	Typical Kenosha Overflow Mechanism	11
4	Schematic Diagram of Contact Stabilization Process	13
5	View of Gas Driven Pump Engine	20
6	New Gas Driven Engine and Pump Shown in Relation to Existing Pumping Facilities	20
7	View of Grit Tank From Influent End	21
8	View of Larger Compartment of Contact Tank	23
9	Contact Time Versus Various Flow Rates	24
10	View of One Stabilization Tank Compartment While Empty	25
11	View of Full Stabilization Tank From Platform Between Stabilization and Contact Tanks	26
12	Stabilization Tank Depth Versus Reaeration Time at Various Flows	27
13	Plan and Elevation Views of Stabilization Tank and Contact Tank	29
14	Overall View of Final Clarifier	31
15	Detailed View of Clarifier Showing Scum Baffle, Effluent Trough, Deflector Skirt, and Feed Trough	31
16	View of Demonstration System Control Panel	32
17	Plan View of Kenosha Water Pollution Control Plant	35
18	Aerial View of Kenosha WPCP Depicting Demonstration System Facilities	38
19	Map of Kenosha Showing Raingauge Locations	40

No.		Page
20	Exterior View of Overflow Monitoring Station	42
21	Interior View of Monitoring Station Showing Sampling and Flow Recording Instrumentation	42
22	Schematic Drawing of a Typical Monitoring Site	43
23	Histogram of Rainfalls in Kenosha for June 1, 1970 to October 14, 1970	47
24	View into Typical Sampler Constructed for Use in Conjunction with the Demonstration System	58
25	Raw and Final Sample Quality Variance with Time	78
26	Raw and Effluent Sample Quality Variance Through the Dry Weather Plant Primary Sedimentation Tanks During Run No. 47.	79
27	Estimated Demonstration System Operating Costs Versus Hours of Operation	81
28	Percentage of Overflow Treated Versus Rainfall Amounts for 28 Events	83
29	Rainfall, 67th Street Overflow Level and Demonstration System Flow Rate Versus Time for Run No. 9	86
30	Oxygen Uptake Rate and Sludge Temperature Versus Sludge Age for August 18, 1972 to September 11, 1972	90
31	SS, VSS, and Percent Volatile Solids Versus Sludge Age for August 18, 1972 to September 11, 1972	90
32	Calculated Surface Overflow Rate Versus Sludge Age for August 18, 1972 to September 11, 1972	90
33	Stabilization Tank Sludge SS, VSS, and Percent Volatile Solids, and DWP WAS SS Versus Days of Continuous Flow for July 9, 1973 to July 20, 1973	95
34	Oxygen Uptake Rate per Gram of Volatile Suspended Solids Versus Days of Continuous Flow for July 9, 1973 to July 20, 1973	96

No.		Page
35	Supernatant SS Concentration Versus Days of Continuous Flow for July 9, 1973 to July 20, 1973	96
36	Calculated Surface Overflow Rate Versus Days of Continuous Flow for July 9, 1973 to July 20, 1973	96
37	Calculated Sludge Volume Index Versus Days of Continuous Flow for July 9, 1973 to July 20, 1973	96
38	SS, VSS, Total COD, and Total Alkalinity Concentrations Versus Sludge Age for Bench Scale Tests, July 11, 1973 to July 31, 1973	102
39	SS, VSS, Total COD and Total Alkalinity Concentrations Versus Sludge Age for Bench Scale Tests, August 8, 1973 to August 23, 1973	103
40	SS, VSS, Total COD, and Total Alkalinity Concentrations Versus Sludge Age for Bench Scale Tests, August 28, 1973 to September 19, 1973	104
41	Oxygen Uptake Rate Per Gram of Volatile Suspended Solids Versus Sludge Age for Bench Scale Tests, July 11, 1973 to July 31, 1973	107
42	Oxygen Uptake Rate Per Gram of Volatile Suspended Solids Versus Sludge Age for Bench Scale Tests, August 8, 1973 to August 23, 1973	107
43	Oxygen Uptake Rate Per Gram of Volatile Suspended Solids Versus Sludge Age for Bench Scale Tests, Augsut 28, 1973 to September 19, 1973	107
44	Flotation Test Percent Float Solids and Effluent SS Versus Sludge Age for July 11, 1973 to July 31, 1973	108
45	Effluent SS and Percent Float Solids Versus Sludge Age for Bench Scale Tests, August 8, 1973 to August 23, 1973	108
46	Flotation Test Percent Float Solids and Effluent SS Versus Sludge Age for August 28, 1973 to September 19, 1973	108

TABLES

No.		Page
1	Breakdown of Construction Costs	37
2	Kenosha Rainfall Summary for 1970	46
3	Kenosha Overflow Quality Summary for 1970	49
4	Sampling Points and Analyses Performed	55
5	Ranges of Operation, Runs No. 1-19	61
6	Operating Results, First 19 Runs	62
7	Results of Step Wise Regression Analysis	67
8	Operating Values for Satisfactory Performance	68
9	Performance for 30 Runs at Acceptable Operating Levels	70
10	Effect of Demonstration System Clarifier on Kenosha WPCP Performance	71
11	Mean and Standard Deviations for BOD/COD, BOD/TOC, and COD/TOC Ratios	75
12	Overflow Quantity Data from 1972 and 1973	84
13	Measured Parameters for Stabilization Tank Sludge July 9 to July 20, 1973	94
14	Aerobic Digestion and Flotation Results, July 11 to July 31, 1973	99
15	Aerobic Digestion and Flotation Results August 8 to August 23, 1973	100
16	Aerobic Digestion and Flotation Results August 28 to September 19, 1973	101
B1-B25	Overflow Quality 1970	121-145
C1-C49	Operating Data for Runs No. 1-49	146-242

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SECTION I - CONCLUSIONS

1. A 75,700 cu m/day (20 mgd) modified contact stabilization process for the treatment of potential combined sewer overflow was designed and constructed on the grounds of the 87,055 cu m/day (23 mgd) Kenosha Water Pollution Control Plant at a total cost of $1,178,779.11, including engineering.

2. Prior to operation of the demonstration system, a study of the overflow quality from Kenosha's three combined sewer overflows and from the raw flow to the Water Pollution Control Plant during periods of overflow was performed. The results of this study indicated that these discharges were of higher contaminant concentration than dry weather sewage, there was great variance in contaminant concentrations at the four sampling locations, and the high percentage of oxygen demanding materials in the particulate form would be advantageous to demonstration system efficiency.

3. The feasibility of the demonstration system was verified by the first nineteen uses of the system during which 277,062 cu m (73,200,000 gal.) of potential overflow was treated. The removals achieved during these runs, based upon weighted mean concentrations, were 93% suspended solids, 83% BOD, and 81% TOC.

4. Eighteen test runs were carried out to determine the optimum ranges of demonstration system operation for various process variables. These ranges were found to be:

MLSS Concentration	>2,100 mg/l
Reaeration Time	1-4 hours
Stabilization Time	$\leq$5 days
Contact Time	>10 minutes

5. Thirty of the 49 total system runs were found to fall within the optimum ranges of operation. These 30 runs, treating 403,103 cu m (106,500,000 gal.), had arithmetic mean percentage removals of 90.4% suspended solids, 84.8% BOD, and 76.5% TOC. Arithmetic mean effluent quality for these runs was 23 mg/l suspended solids, 16 mg/l BOD, and 23 mg/l TOC.

6. The dry weather treatment plant efficiency was improved by utilization of the demonstration system final clarifier during periods when the demonstration system was not in use. Dry weather plant removal percentages increased from 82 to 94% and 64 to 88%, for BOD and suspended solids, respectively, after the demonstration system was installed.

7. Operating costs, including pumping, chlorination, sludge disposal, aeration, and labor, are estimated to be 3.567¢/cu m (13.5¢/1000 gal.) based on 300 hours of operation per year. However, direct determination of operating costs was difficult because of integration of the demonstration system with the dry weather plant. The annual capital recovery of $1,178,779.11 construction costs, based upon a 25 year term and 7% cost of money would be $101,151.03 per annum. Based again upon the 300 hours of operation per year the recovery costs would be 10.6¢/cu m (40.4¢/1000 gal.), or a total of 14.2¢/cu m (53.9¢/1000 gal.) when operating costs are added. It is worth noting that the capital recovery costs would decrease directly with an increase in the number of hours of use per year.

8. Overflow volume studies indicated that up to 0.76 cm (0.3 in.) of rainfall on the 486 ha (1,200 acres) of combined sewer area may be handled with no resultant overflow. However, it appears that the orifices used to limit the amount of flow entering the interceptor may be too limiting. That is, the orifices may in fact be causing overflows to occur before treatment plant capacity is reached and before the interceptor is surcharged. An accurate determination of the amount of overflow treatment facilities needed to completely abate combined sewer overflow in Kenosha will only be possible after modifications are made to the existing orifices allowing maximum possible flow into the interceptor sewer, and after the demonstration system begins to be put into service well in advance of a rain event, to guarantee maximum treatment capacity.

9. Extensive studies conducted on the sludge in the stabilization tank revealed that 5 days appears to be the maximum duration that the sludge may be held in the tank in a static condition and still remain viable. If waste activated sludge is continually fed to and withdrawn from the stabilization tank, the sludge will remain in a viable condition indefinitely. However, in either case the stabilization tank functions similar to an aerobic digestor with a reduction in volatile suspended solids concentration.

10. When the concept of treatment (contact stabilization) tested in this study is used in future applications to treat potential combined sewer overflows, the results achieved will be directly proportional to the quality of treatment being achieved by the existing dry weather plant adjoining the potential overflow

treatment system. This is a direct result of the potential overflow treatment system utilizing the waste activated sludge generated by the adjoining dry weather treatment plant.

11. Operation of the system during winter months was not attempted because of anticipated problems of ice buildup and possible sinking of the surface aerators. Fixed air disperser systems would probably be more applicable in future systems.

12. The method of manually cleaning the grit basin should be replaced by a mechanical process.

SECTION II - RECOMMENDATIONS

It is recommended that:

1. The modification of the contact stabilization process used in the Kenosha demonstration project be recognized by the federal and state governments as a feasible alternative to sewer separation and be used in future applications for the treatment of potential combined sewer overflows in locations having an adequate sewage conveyance system and an existing dry weather biological treatment process.

2. The City of Kenosha make modifications to its existing overflow regulator mechanisms to reduce the amount of overflow at the beginning of a rainfall, and that the demonstration system be put into operation in anticipation of rainfall events. The remaining amount of overflow still occurring under this mode of operation should then be determined, and the required amount of storage/treatment still needed to completely abate combined sewer overflow in Kenosha be implemented.

3. An engineering investigation should then be performed to give a detailed cost comparison of complete abatement of combined sewer overflow in Kenosha by sewer separation as opposed to the cost of integrating storage and the demonstration system for complete abatement.

4. This method of treating potential combined sewer overflow be used in series with in-line and off-line storage schemes, developed under previous US EPA demonstration projects, to develop an optimum scheme of treating combined sewer overflow.

5. A demonstration project be performed testing the feasibility of converting a conventional activated sludge plant to the contact stabilization mode during periods of high flow. It is anticipated that, using common facilities, it would be possible to have a high flow or wet weather capacity between 5 and 10 times the dry weather flow rate.

6. A pilot scale study be conducted testing the effectiveness of dissolved-air flotation for mixed liquor clarification utilizing the mixed liquor from the contact tank of the demonstration system.

SECTION III - INTRODUCTION

The City of Kenosha, Wisconsin is an industrial city located in the southeastern corner of the state on the shores of Lake Michigan, midway between Milwaukee, Wisconsin and Chicago, Illinois. It is the fifth largest city in Wisconsin with a population of over 80,000. The City encompasses an area of 37.32 sq km (14.41 sq mi) with the sewerage system serving 33.51 sq km (12.94 sq mi). During the course of this project 5.38 sq km (2.08 sq mi) of the City's sewerage system were served by combined sewers. This area encompassed the heart of the City's residential, commercial, and industrial activities.

During the 1960's, Kenosha had been undergoing a sewer separation program. Based upon a private consulting engineering firm's report in 1966, it was estimated that it would cost the City 13.8 million dollars to separate the remaining 5.39 sq km (2.08 sq mi) of combined sewers (1). A portion of this sewer separation was required to provide for local flooding and sewer relief from overloading regardless of the method implemented for treatment of the combined sewer overflow. In 1968 the State of Wisconsin Department of Natural Resources ordered the City to begin a program for separation or control of pollution from combined sewers, with completion of control facilities by July 1977 (2).

Faced with both the expense and public nuisance of separating the combined sewers in question, the City chose to determine if there was an alternative to separation which would effectively treat the combined sewer overflow and have a cost equal to or less than that of separation. The City's decision to look at an alternative to separation was facilitated by the fact that if separation were completed, the storm sewer discharges still would empty into Lake Michigan at locations which are used as the City's beaches and lakefront recreational areas. It was feared that the discharge from the storm sewers would still necessitate treatment. Also, the existing interceptor sewer leading to the Kenosha Water Pollution Control Plant (WPCP) had the capacity to carry over 2.5 times the average dry weather flow. Since the existing WPCP was operating at near design capacity, the idea of locating a treatment process on the grounds of the WPCP to treat the excess wet weather flows appeared most feasible.

As a result, the City of Kenosha together with the Environmental Sciences Division of Envirex Inc. developed a proposal to demonstrate the effectiveness of using a modification of the contact stabilization process to treat the combined sewer overflow. The proposal called for the construction of a 75,700 cu m/day (20 mgd) contact stabilization process on the grounds of the existing WPCP which was a 87,055 cu m/day (23 mgd) conventional activated sludge plant.

The demonstration process would be operated for almost two years during which time it would be determined if this method of treating potential combined sewer overflow was feasible; what the optimum operating conditions would be; and what effect a system of this size would have on reducing the amount of combined sewer overflow. The proposal was approved and funded by the US EPA under grant No. 11023 EKC in September of 1969. The funding for the project, with an approximate total cost of $1,327,500.00, including engineering, construction, and evaluation, was 62.9% US EPA, 22.2% State of Wisconsin, and 14.9% City of Kenosha.

The engineering firm of Alvord, Burdick and Howson of Chicago, Illinois was retained by the City of Kenosha and in September of 1969 design of the system began. From this date through November of 1971 the system was designed, constructed and put through a mechanical shakedown period. The system stood idle during the winter of 1971-1972 and was first put into operation on April 12, 1972. Evaluation of the demonstration system continued until October 1, 1973, except for the 1972-1973 winter period when the system was shut down.

SECTION IV - EXISTING TREATMENT FACILITIES AND SEWERAGE SYSTEM

WATER POLLUTION CONTROL PLANT

The Kenosha WPCP is located in the southeastern corner of the City, bordered on the north and west by high income residential areas, on the south by vacant land, and on the east by Lake Michigan. Prior to the construction of facilities for the demonstration project, the WPCP utilized primary sedimentation, having a maximum design capacity of 113,500 cu m/day (30 mgd), followed by a 87,055 cu m/day (23 mgd) conventional activated sludge process and chlorination capable of handling the maximum dry weather flow. Raw sewage enters the WPCP by gravity from a 183 cm (72 in.) diameter interceptor sewer. Flow rates in excess of the WPCP capacity are diverted by means of a hydraulic control gate located at the termination of the interceptor in the WPCP wet well facility. Closing of this gate decreases the flow to the WPCP and causes the interceptor to surcharge and overflow (discussed later).

The raw sewage entering the WPCP passes through three comminutors before entering a wet well. From the wet well the sewage is pumped to grit removal facilities by pumps having a total capacity of 189,250 cu m/day (50 mgd). The grit removal facilities consist of two tanks in parallel having a total capacity of 151,400 cu m/day (40 mgd). Discharge from the grit tank flows by gravity to the primary sedimentation facilities consisting of 6 rectangular tanks having a total surface area of 2,303 sq m (24,760 sq ft) and a volume of 7,213 cu m (257,600 cu ft). The maximum hydraulic capacity of the primary sedimentation facilities is rated at 113,550 cu m/day (30 mgd), resulting in surface overflow rates (SOR) of 49.7 cu m/day/sq m (1,212 gpd/sq ft) and a detention time of 1.54 hours.

Effluent from primary sedimentation is conveyed to the mixed liquor aeration tanks where it is mixed with return activated sludge (RAS). There are four mixed liquor tanks having a total volume of 13,328 cu m (476,000 cu ft) and utilizing a fixed air disperser system. The aeration time in these tanks is 3.72 hours at a maximum design capacity of 87,055 cu m/day (23 mgd). The mixed liquor from the aeration tanks flows to three 25.9 m (85 ft) diameter final clarifiers, having a total surface area of 1,581 sq m (17,020 sq ft). At a flow rate of 87,055 cu m/day (23 mgd) the surface overflow rate is 55.1 cu m/day/sq m (1,350 gpd/sq ft) and the detention time (not including RAS) is 1.32 hours. The waste activated sludge (WAS) from the final clarifiers is thickened by means of two dissolved air flotation units having a total capacity of

8,080 kg (20,000 lbs) of solids per day. The thickened WAS and primary sludge are anaerobically digested by a two stage system having a primary digester volume of 5,275 cu m (188,400 cu ft) and a secondary digester volume of 2,249 cu m (80,000 cu ft).

The effluent from final clarification is chlorinated in a contact tank having a volume of 605.6 cu m (160,000 gal.). At a flow of 113,550 cu m/day (30 mgd) (maximum through primary sedimentation) the detention time in this tank is 7.7 minutes plus an additional 7.3 minutes in the discharge conduit to Lake Michigan.

SEWERAGE SYSTEM

The 5.39 sq km (2.08 sq mi) of combined sewers in Kenosha are denoted by the cross-hatched markings in Figure 1. There are three major trunk sewers draining this area. These trunk sewers intersect the interceptor sewer which runs parallel to Lake Michigan and slopes towards the WPCP. The three trunk sewers and the interceptor are shown in Figure 2. There were also two other combined sewer overflow discharges which were removed during an earlier sewer separation program. Prior to construction of the interceptor sewer in 1939, the trunk sewers discharged directly to Lake Michigan.

At all three overflow locations, 57th Street, 59th Street, and 67th Street, the type of regulator mechanism used for entrance to the interceptor is a horizontal drop inlet. This consists of a dam across the width of the trunk sewer at the crown of the interceptor. Upstream of this dam a circular orifice is cut into the interceptor allowing the dry weather sewage to enter. During periods of runoff and high flow the depth of flow in the trunk sewer exceeds that of the dam and the excess flow discharges to Lake Michigan. When the flow in the interceptor exceeds the capacity of the WPCP the hydraulic gate at the entrance to the treatment plant is manually closed. This causes the interceptor to begin filling, and eventually surcharge if the high flows continue. Figure 3 contains a schematic diagram of the typical overflow mechanism in Kenosha.

The interceptor itself is approximately 2,743 m (9,000 ft) long, beginning at 57th Street and terminating at the WPCP. At 57th Street the interceptor is fed by a 152 cm (60 in.) sewer referred to as the North Side interceptor. However, the area served by this interceptor is entirely separated. At 57th Street the interceptor is 137 cm (54 in.) in diameter having a slope of 0.091%. Approximately 305 m (1,000 ft) downstream, the diameter increases to 152 cm (60 in.) and the slope reduces to 0.053%. The interceptor remains at this slope for another 1,128 m (3,700 ft) before increasing to a 183 cm (72 in.) diameter with a slope of 0.043% for the last 1,311 m (4,300 ft) leading to the WPCP. This last leg of the interceptor has a rated capacity of 189,250 cu m/day (50 mgd).

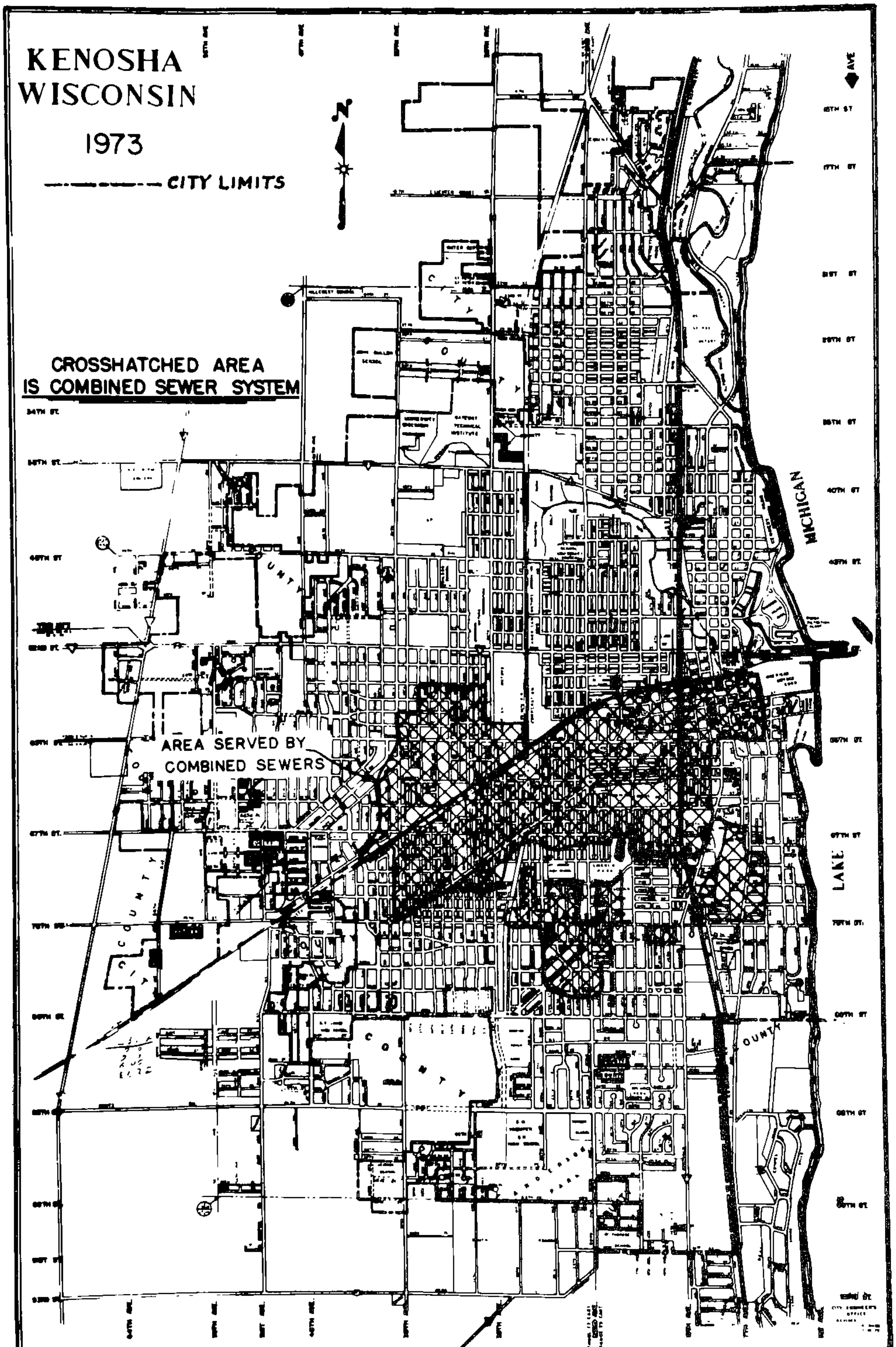

Figure 1. Map of Kenosha indicating combined sewer area

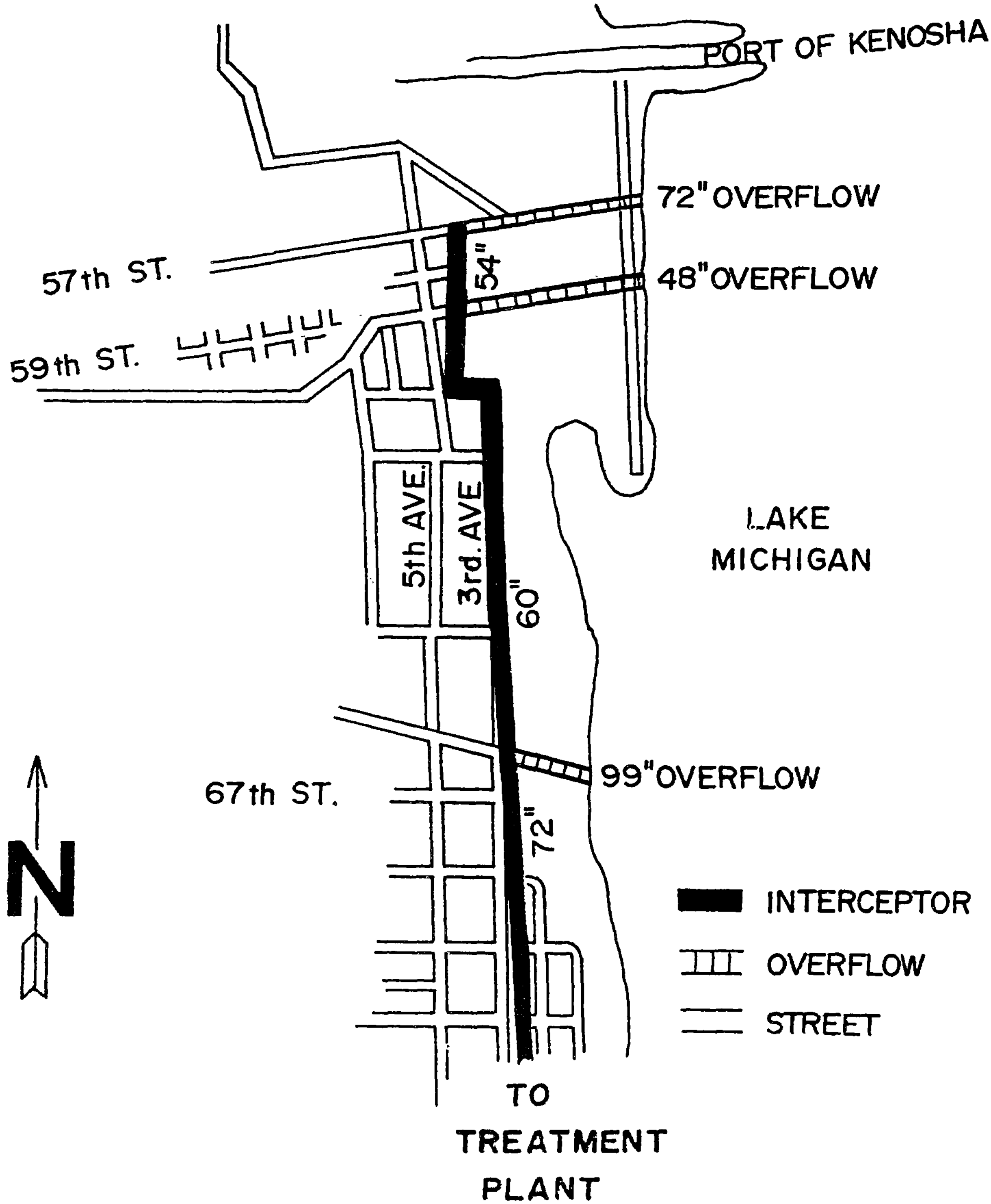

Figure 2. Illustration showing interceptor sewer and combined sewer overflow discharge locations

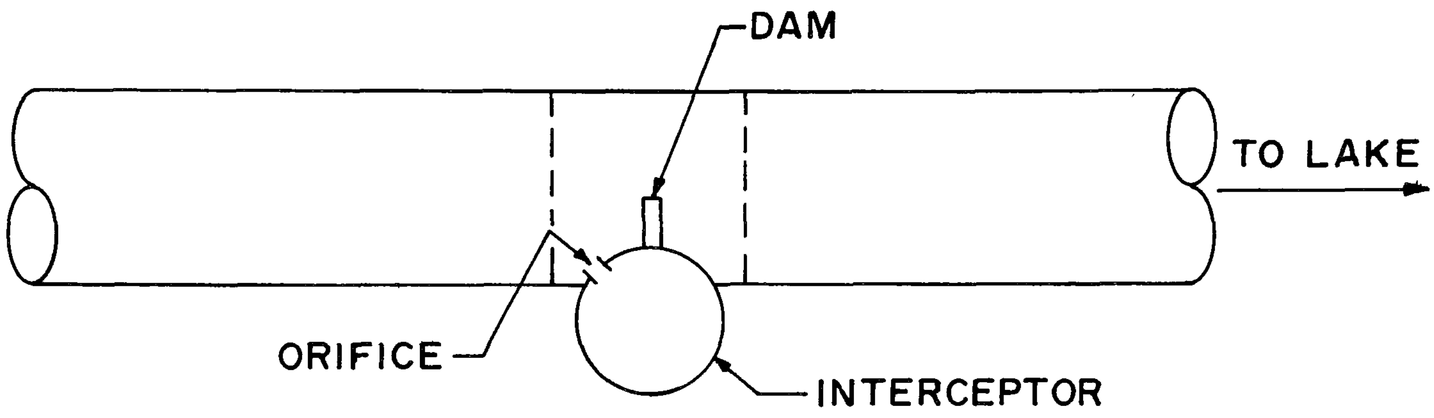

Figure 3. Typical Kenosha overflow mechanism

SECTION V - SYSTEM DESIGN AND CONSTRUCTION

CONTACT STABILIZATION PROCESS THEORY

Contact stabilization is a term describing one of the many modifications of the conventional activated sludge process. Descriptions synonymous with contact stabilization include physical adsorption, biosorption, and sludge reaeration. What these terms describe is a process in which return activated sludge from final clarification is aerated prior to mixing with the wastewater to be treated. This reaeration time can vary in a range from 1 hour up to many days. The mixing of the aerated sludge with the wastewater is similar to conventional activated sludge, excepting that the time for this mixing is usually between 15 and 60 minutes, rather than many hours. It is often assumed that when contact stabilization is used a very high mixed liquor concentration is necessary. However, it is usually true that the mixed liquor concentration is within the normal range of conventional mixed liquor concentrations, 2000-4000 mg/l for domestic wastes. Following the mixing, or contact tank, is final clarification, functioning in the same manner as in normal treatment processes, with the return sludge going to the stabilization tank.

The main advantage of this process is the small amount of aeration capacity needed. Instead of using the entire length of an aeration tank for the mixed liquor to complete the oxidation and digestion of the organic matter in the wastewater, this process concentrates the mixed liquor (active sludge and wastewater solids) in the clarification tank and then allows for completion of the biochemical metabolic processes in the stabilization tank. This tank only requires a volume of 10-25% of normal aeration tanks. The contact tank volume is only 5-20% of the normal aeration tanks. Thus, the aeration facilities needed are usually 1/5 to 1/2 of that in conventional plants. A schematic diagram of the contact stabilization process is shown in Figure 4.

What makes this entire process possible is the rapid initial uptake of organic matter, both soluble and insoluble, immediately upon the mixing of a wastewater with an active sludge. This rapid initial uptake has been a matter of controversy through the years. The question is whether this uptake is a physical surface phenomenon (adsorption) or a biological reaction (absorption). The rapid initial uptake upon mixing an active sludge and wastewater has been known and studied since 1868 (3) when researchers began developing the biological clarification theory (4)(5)(6). In a review of the literature on this subject, Theriault in 1935

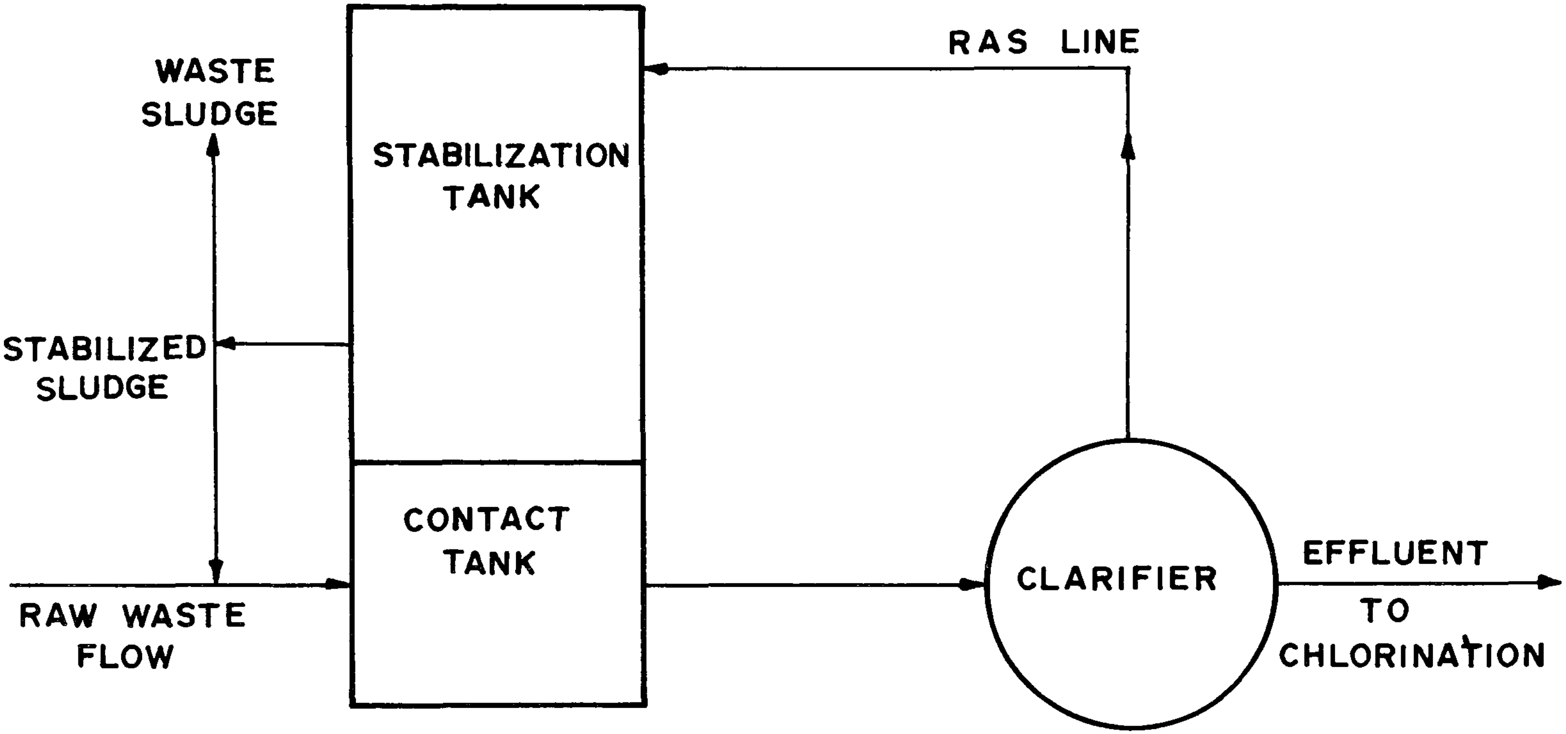

Figure 4. Schematic diagram of contact stabilization process

(7) summarized the high initial removal of organic matter by activated sludge as having some indication of biological action in adsorption. However, it appeared to be mostly physical. If in fact biological reactions were present in this initial removal of solubles, then the soluble removal could be termed absorption. In an editorial in 1935 the Sewage Works Journal (8) called for a detailed study and conclusions to this question.

Heukelekian responded by directing a long and thorough study between 1936 and 1938. In his first two experiments (9)(10) he found that inorganic removal was a result of physical surface adsorption, but that oxygen was necessary for clarification. Further tests were conducted to study the importance of oxidation (11). Using a pilot plant activated sludge system, return activated sludge and sewage were mixed, with CO_2 production measured as a gauge of biological activity or BOD removal. Since the highest rate of CO_2 production occured during the initial period of mixing and removal, it was concluded that a high degree of biological activity is taking place during this removal phase. Further tests were then conducted to show the importance of biological activity in removal (12)(13)(14).

What this long and involved study concluded was that biological activity was present to some degree in the initial clarification stage of an activated sludge process. It had been shown that biological activity was the most important factor in the removal of solubles, and it also had been indicated that biological activity was important in the removal of the insolubles, by adsorption. However, no explanation of how this last activity occurred was given. In 1940 a most important work appeared (15) which proposed an explanation of biological activity in physical adsorption. From his tests the author concluded that adsorption is dependent upon biological processes and precludes reduction, and that floc is viewed as consisting of an inorganic nucleus surrounded by a layer of enzynatically active material.

Following the period of 1930-1940 when a great deal of research was carried out regarding the initial clarification stage in activated sludge, there was a lack of literature until the contact stabilization process started to gain acceptance (16). During the mid-1950's literature concerning contact stabilization and/or its associated theories began appearing once again. Katz and Rohlich conducted a very detailed study of the kinetics of activated sludge adsorption. They assumed that the controlling mechanism in the rate of adsorption of impurities on to a floc particle was a stagnant film of water surrounding the floc. Although their results showed adsorption to be described in terms of firm, physical mathematics, their discussion was prefaced by the statement that enzynatic action was not precluded, and, in fact, mass transfer (adsorption) may be largely a result of the pressure of enzymes.

Eckenfelder explained why there is a leveling off of BOD removal after the initial clarification. He summarized the removal of BOD when organic wastes are contacted with sludge as follows (18):

1. Suspended and finely divided solids are removed by adsorption and coagulation.

2. A portion of the soluble organic matter is initially removed by adsorption and stored in the cell as a reserve food source.

3. Additional dissolved organic matter is progressively removed during the aeration process resulting in the synthesis of sludge and the production of CO_2 and water. The rate of BOD removal after the initial adsorption is dependent upon the concentration of BOD to be removed and the concentration of the sludge solids.

What is important in Eckenfelder's theory is the storage capacity of the cells present in the sludge. Thus, a sludge which is still viable but yet limiting on food, or a sludge which is in its log growth phase, will produce excellent initial removals of BOD, since storage capacity will be optimum.

As late as 1966, the majority of the literature still referred to adsorption as a completely physical process. Siddiqi published an article at this time (19) which stated the definite role of biological enzymes in the adsorptive removal of soluble materials. From actual bench scale activated sludge tests, he concluded that there is a substantial significance to the role of enzymes in soluble organic removal. His data showed that the enzymatic processes are particularly significant in substrate removal as opposed to the widely accepted surface removal phenomenon. It was also shown that specific hydrolyzing enzymes are needed for the breakdown and adsorption or organic materials, and that if sludge is stabilized too long before mixing with sewage, there can be a loss of bioactivity, and as a result, a lack of the necessary enzymes.

In conclusion, the century of study on the initial clarification of a wastewater by activated sludge can be summarized as follows:

1. Particulate matter is rapidly removed from the liquid phase by adsorption onto the surface of a floc material. The reaction appears to include the use of some enzymes.

2. Soluble material is adsorbed to the surface of a floc particle and simultaneously absorbed into the cellular material present. This reaction is dependent upon biological enzymes and the condition of the biological sludge present. This reaction rate can be described, however, in the same terms used to describe physical adsorption.

CONTACT STABILIZATION OPERATING EXPERIENCE

The actual use of some form of the contact stabilization process was reported as early as 1910 (20). In 1910, Black and Phelps achieved good removals in an activated sludge plant using only 3 hours mixing time, and an aeration rate of .00169 cu m of air per liter (0.23 cu ft of air per gallon). At Houston, Texas in 1915, test runs showed 98% suspended solids, and 94% oxygen demand removals with a return sludge flow rate of 30% and only one hour of aeration time. The most publicized contact stabilization process in the United States is located in Austin, Texas (16). Here a conventional activated sludge plant operated for 12 years with unsatisfactory results due to sludge bulking. After much study it was felt that this bulking was due to over aeration. Laboratory experiments found mixed liquor settling characteristics to be the best after only 15-30 minutes of aeration.

In 1950, a 0.95-1.25 l/sec (15-20 gpd) contact stabilization pilot plant was built to test this process on the waste being treated by the conventional plant. Results from this pilot plant indicated that 1) using a good activated sludge and raw sewage with a detention time of 15-30 minutes that BOD and suspended solids removals of 90-95% were possible, 2) a good return activated sludge flow would be the same as in a conventional plant, based on the maximum flow, 3) 90 minutes of reaeration is needed to reactivate the adsorptive and absorptive properties of the sludge, 4) the settling characteristics of the absorbed floc are better than in a conventional plant, and 5) the buildup in sludge (waste) is the same as in a conventional plant. Based upon the successful operation of the pilot plant the conventional treatment plant was converted to a contact stabilization plant. Operational results from 1955 indicated 93% BOD removal (raw = 307 mg/l) and 92% suspended solids removal (raw = 226 mg/l), a raw flow of 29,144 cu m/day (8.7 mgd) with a return sludge flow of 41% and a MLSS concentration of 1,896 mg/l (21).

Another conventional treatment plant that was overloaded and converted to contact stabilization was in Bergen County, New Jersey (22). Comprehensive laboratory tests were run on the wastewater at this plant in order to determine design criteria for conversion to contact stabilization. Based upon these results the process was designed and operated successfully with an aeration time of 0.44-1.68 hours, a sludge reaeration time of 2-6 hours, an air supply of 61.7 cu m/kg (1,000 cu ft/lb) of BOD removed, and a BOD loading of 0.46-4.00 kg/day/cu m (29-250 lb/day/1000 cu ft) of aeration volume.

Other reported operating parameters from successful contact stabilization plants include a textile mill (23) treating a waste with a BOD of greater than 500 mg/l and a suspended solids concentration of 90-120 mg/l. BOD removals of 85-90% are achieved with the following:

BOD loading	2.43 kg/day/cu m (150 lb/day/1000 cu ft) aeration
Optimum MLSS	2500-4000 mg/l
Optimum stabilized sludge	6000-8000 mg/l
Optimum reaeration time	2-4 hours
Optimum contact time	45-75 minutes
Air requirements	49.3-61.7 cu m/kg (800-1000 cu m/lb) BOD removed
Clarifier SOR	30.6 cu m/day/sq m (750 gpd/sq ft)

Wastes from a potato processing industry having BOD, COD and suspended solids concentrations greater than 1000 mg/l have had better than 80% removal of these parameters using contact stabilization with contact times of one hour and reaeration times of 6-8 hours.

Because of the ability of contact stabilization to adjust to variations in loadings and flow rates, the process has gained much use as a package treatment plant. This is exemplified by two contact stabilization plants constructed in a suburb of Houston, Texas (25). These plants which treat only domestic wastes have a design contact time of 1.5 hours and a reaeration time of 6.0 hours. What is especially unique about these plants is their design. Clarification, contact, reaeration, digestion, and chlorination are all carried out in one basic unit. The disadvantage of these plants is their inability to completely remove soluble organics when present in high amounts (26).

SYSTEM DESIGN FOR KENOSHA

The main difference between normal contact stabilization processes and the application for treating potential combined sewer overflow in Kenosha is the periodic usage of the system. In conventional contact stabilization RAS is continually transferred from the underflow in the final clarifier to the stabilization tank where it is reaerated for a period of hours and then transferred to the contact tank. However, since the demonstration system was only to be used periodically, it was necessary to provide some means of always having a viable stabilized sludge ready for use. It was decided to utilize the WAS from the existing dry weather plant (DWP) as a source of biological solids in the stabilization tank. The WAS from the DWP would be diverted to the stabilization tank during dry weather. The sludge would be detained in the stabilization tank for a period of time (to be determined during the evaluation program) before going on to the DWP flotation thickeners. The WAS would continually enter and leave the stabilization tank, and the detention time would be governed by the volume of sludge in the stabilization tank. (The detention time between uses of the demonstration system is termed the stabilization time and the detention time during use of the system is termed the reaeration time.)

Another important consideration governing the design of the demonstration system was the use of some of the demonstration system facilities by the DWP when the demonstration system was not in operation.

Design of the demonstration facilities required a great amount of flexibility in operating conditions for purposes of the evaluation program. Provisions had to be made for the following conditions.

1. Raw flow rates between zero and 75,700 cu m/day (20 mgd).

2. Contact times of at least 15 minutes at a raw flow of 75,700 cu m/day (20 mgd) and variable contact times for flows less than 75,700 cu m/day (20 mgd).

3. The ability to transfer sludge from the stabilization tank to the contact tank during system operation at any rate between zero and 75,700 cu m/day (20 mgd).

4. Sludge stabilization periods of any duration up to seven days based upon an average WAS rate of 378.5 cu m/day (100,000 gpd) by the DWP.

5. Sludge reaeration times which could be varied for any return sludge rate between zero and 75,700 cu m/day (20 mgd).

6. Aeration to the contact tanks at a variable rate depending upon the raw flow rate.

7. Aeration to the stabilization tank where the sludge level and volume would be variable.

8. Return sludge rates from the final clarifier to the stabilization tank of zero to 75,700 cu m/day (20 mgd).

9. Use of the final clarifier by the DWP when the demonstration system was not operating, but yet be able to isolate this clarifier for use by only the demonstration system during periods of potential overflow.

10. Keeping variables such as sludge transfer rate, air supply, and return sludge rate a constant percentage of the raw flow even though the raw flow rate would vary during operation.

Following is a description of the design of each unit operation of the demonstration system.

Pumping Plant

Although the DWP had a total raw flow pumping capacity of 189,250 cu m/day (50 mgd) comprised of a 75,700 cu m/day (20 mgd) gas driven pump, a 37,850 cu m/day (10 mgd) gas driven pump, and two 37,850 cu m/day (10 mgd) electrically driven pumps, limitations on the electrical input capacity made it impossible to operate the two 37,850 cu m/day (10 mgd) electrically driven pumps simultaneously. Thus, if the 75,700 cu m/day (20 mgd) gas driven pump was out of service, the pumping capacity of the plant would only be 75,700 cu m/day (20 mgd). Therefore, a 94,625 cu m/day (25 mgd) gas driven pump was specified to replace one of the 37,850 cu m/day (10 mgd) electrically driven pumps. This pump was able to utilize the existing 76 cm (30 in.) diameter discharge header pipe already present. Only minor extensions to the existing pipe layout were necessary to allow the discharge from this pump to go to the existing DWP grit chambers or to the demonstration system. Figures 5 and 6 show the new pump motor and its location in the WPCP pump room.

Grit Tank

DWP operational experience had indicated that grit removal became a problem during the year when flows exceeded 94,625 cu m/day (25 mgd). As a result, an existing chemical mixing basin no longer in use was converted into a grit tank for use by the demonstration system. Conversion of this tank required raising the level of the existing walls and channels to put the tank in hydraulic balance with the rest of the system, and installation of inlet and outlet piping. In an effort to reduce costs no provisions were made for mechanical removal of the settled grit.

The tank is 17.22 m (56.5 ft) long, 6.86 m (22.5 ft) wide, and has a mean depth of 2.74 m (9 ft). At a flow of 75,700 cu m/day (20 mgd) the horizontal velocity is less than 0.061 m/sec (0.2 ft/sec). The floor of the tank is sloped from all extremities toward the middle 6.10 m (20 ft) of one wall. A well screen drains the tank after use. Figure 7 is a view of the grit tank from the influent end of the tank.

Contact Tank

The contact tank was designed to provide a minimum of 15 minutes contact time based upon a raw flow of 75,700 cu m/day (20 mgd). As part of the evaluation program it was necessary to study the effects of different contact times. Therefore, the contact tank was subdivided by a concrete wall into two compartments of different volumes. This allowed for equal flows to be run at three different contact times. This was done by using each compartment separately, or using them both simultaneously, resulting in three different effective volumes. One compartment of the contact tank

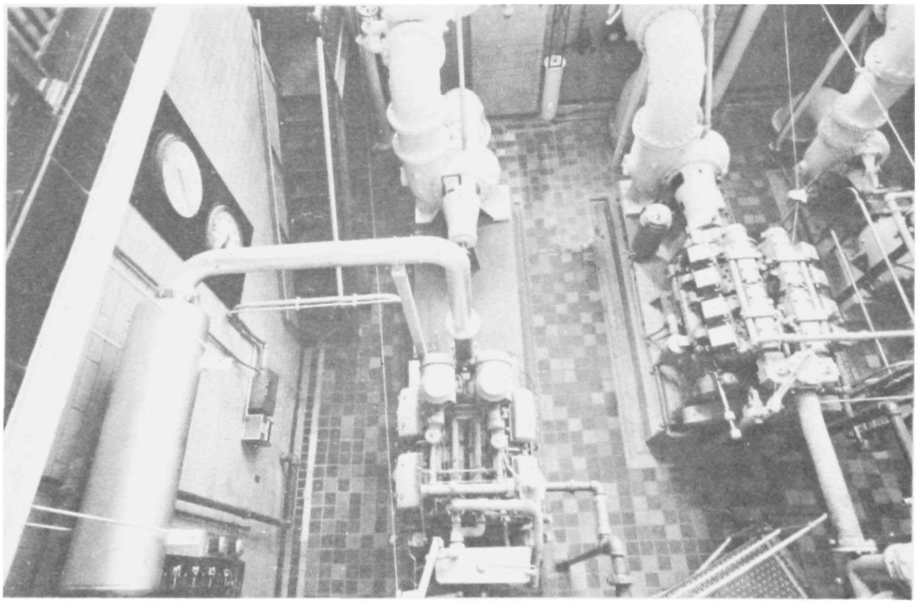

Figure 5. View of gas driven pump engine

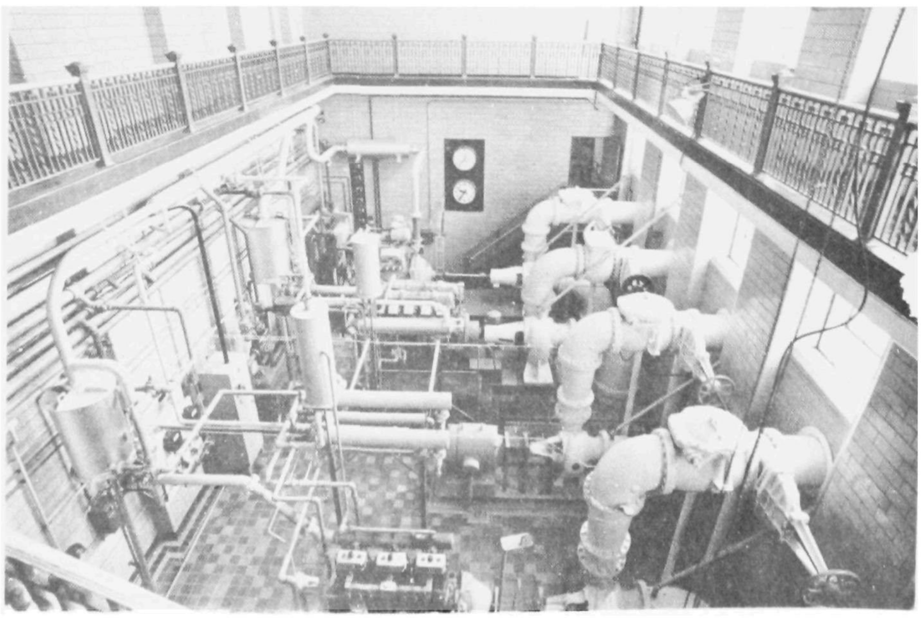

Figure 6. New gas driven engine and pump shown in relation to existing pumping facilities (new pump is at the top of photo)

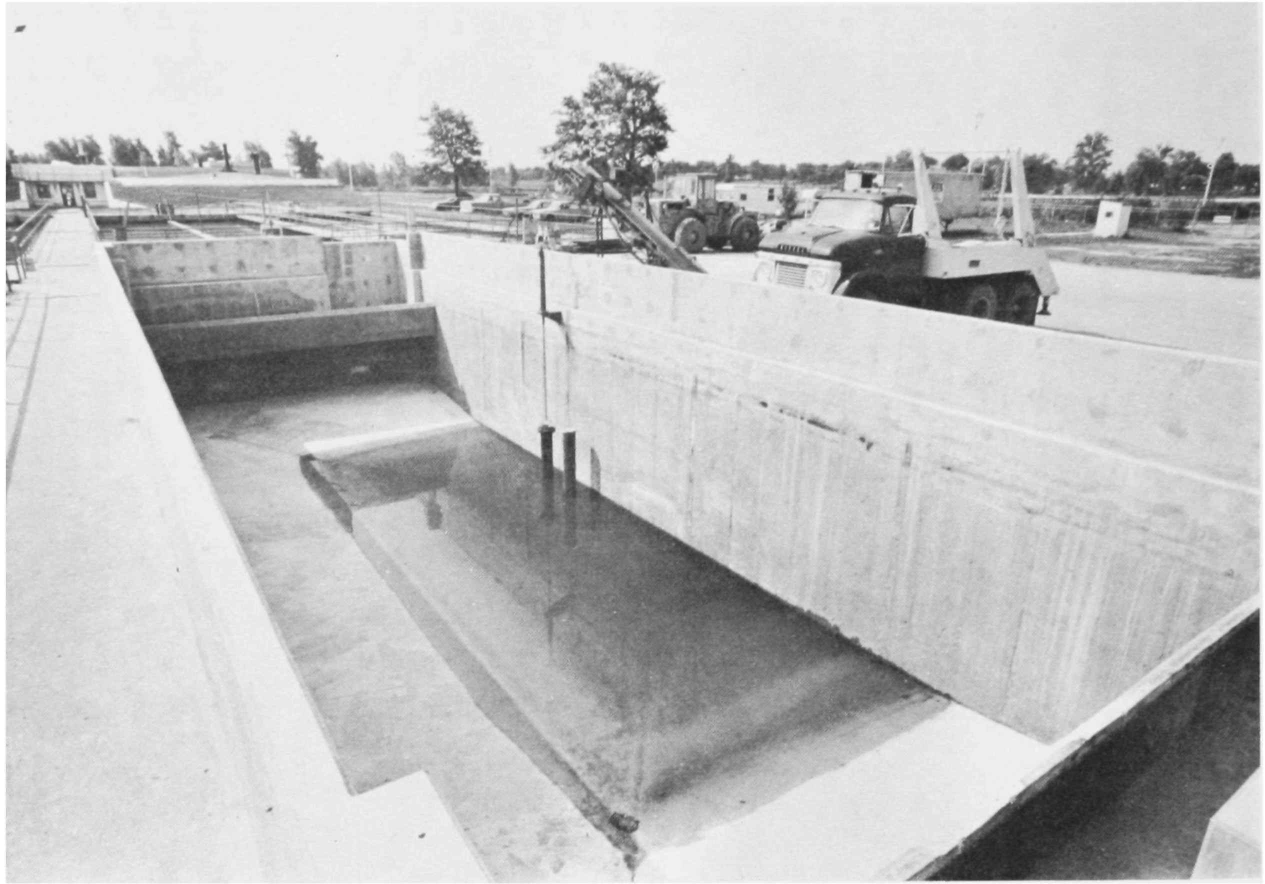

Figure 7. View of grit tank from influent end

has a volume of 620.7 cum (164,000 gal.) and the other compartment a volume of 304.7 cu m (80,500 gal.) resulting in a total volume of 925.4 cu m (244,500 gal.). The compartments are both 9.14 m (30 ft) wide and are divided into lengths of 7.01 and 17.07 m (23 and 56 ft), having sidewall depths of 5.33 m (17.5 ft). Located along one wall of the tank is a feed trough where the grit tank effluent and the transferred sludge from the stabilization tank are mixed before entering the contact tank. Eight portholes, four leading into each compartment, are located in the wall of the feed trough. These portholes can be easily closed off to prevent flow from entering one of the compartments if desired.

Figure 8 is a view into the larger compartment of the contact tank. At the left is the feed trough and portholes. At the bottom right is the fixed air disperser system. At the top right is the weir over which the mixed liquor passes into the trough leading to the final clarifier. On the far side of the concrete wall in the middle of the picture is the smaller compartment. In the far background is the stabilization tank. Figure 9 shows the various contact times that can be achieved at different flow rates.

Stabilization Tank

Design of the stabilization tank required dividing the tank into two smaller compartments so that different volumes could be utilized. Also, the intakes for the sludge transfer pumps were located near the bottom of the stabilization tank so that the level of the tank could be varied, producing any desired volume of sludge. The stabilization tank was built with two 29.26 m (96 ft) long sections divided by a concrete wall. At the bottom of the wall is a mechanical sluice gate which, when open, allows the two compartments to function as one tank. At a depth of 2.13 m (7 ft), there are permanent openings in the concrete wall connecting the two compartments. Both compartments are 9.14 m (30 ft) wide with side wall depths of 5.33 m (17.5 ft). Each compartment has a volume of 1386.4 cu m (366,300 gal.). RAS from the final clarifier can be pumped into both compartments simultaneously or just into the compartment closest to the contact tank if desired.

Figure 10 is a view into one of the empty compartments of the stabilization tank. The concrete wall divides the stabilization tank into the two compartments. Directly behind the second compartment is the contact tank. The floating mechanical aerators can be seen in the center of the tank. At the bottom right is the RAS feed line to the stabilization tank. Figure 11 is a view into the stabilization tank from a platform between the stabilization and contact tanks. Figure 12 depicts the different reaeration times that are achieved at different levels for various RAS and sludge transfer rates.

Figure 8. View of larger compartment of contact tank. Disperser system is shown at lower right and overflow weir at top right

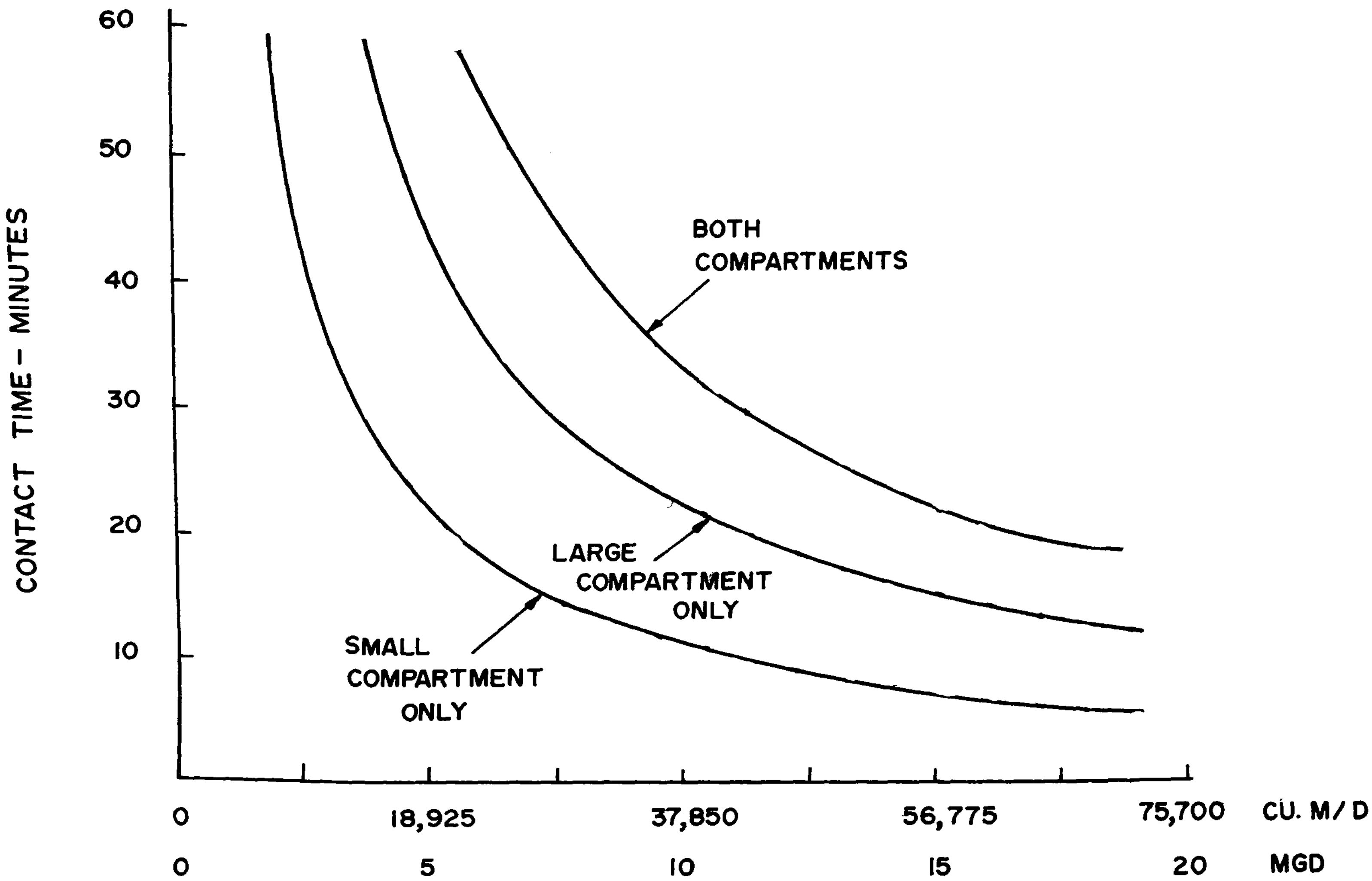

Figure 9. Contact times versus various flow rates

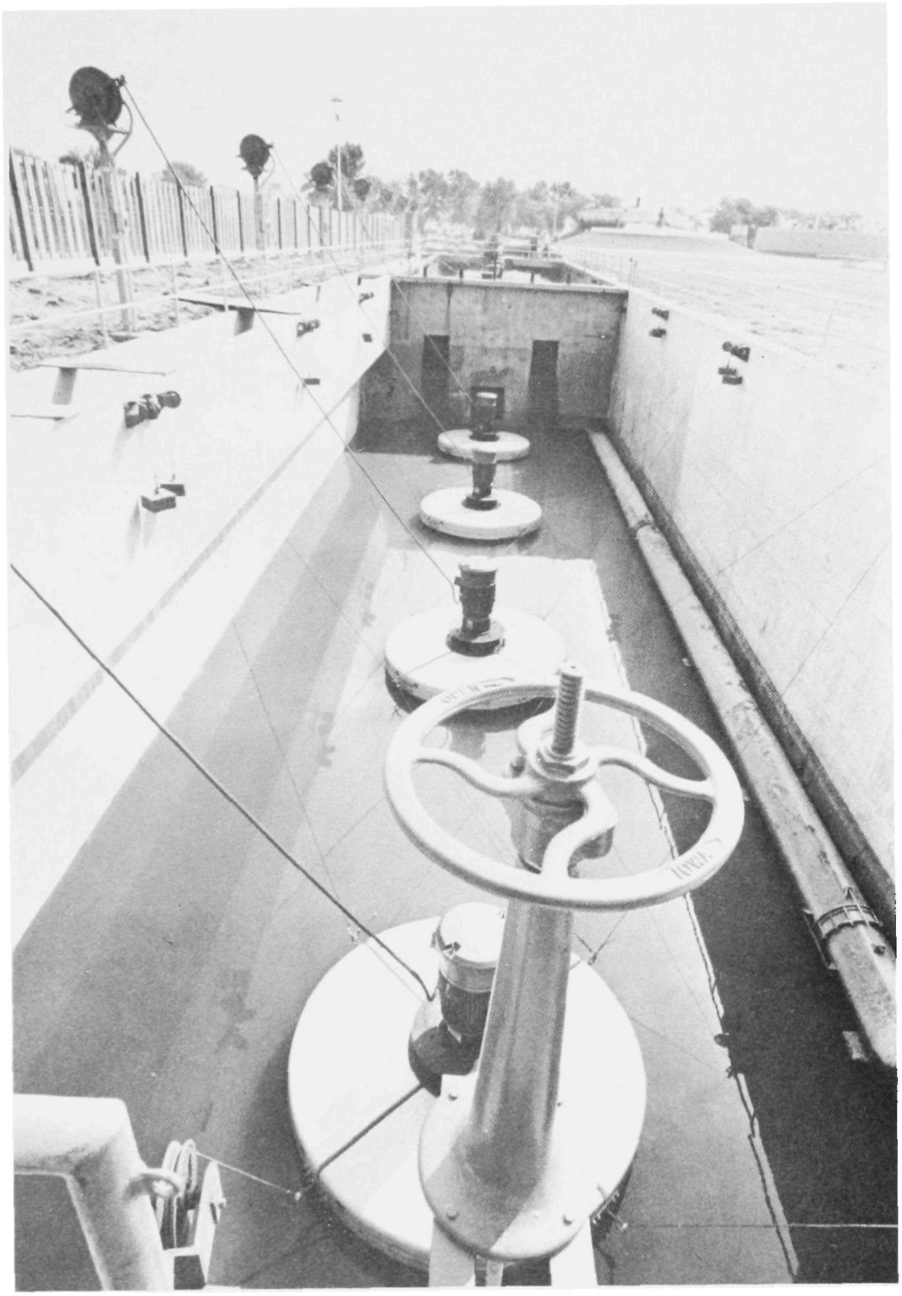

Figure 10. View of one stabilization tank compartment while empty. Floating surface aerators are shown at bottom of tank.

Figure 11. View of full stabilization tank
from platform between stabilization and contact tanks

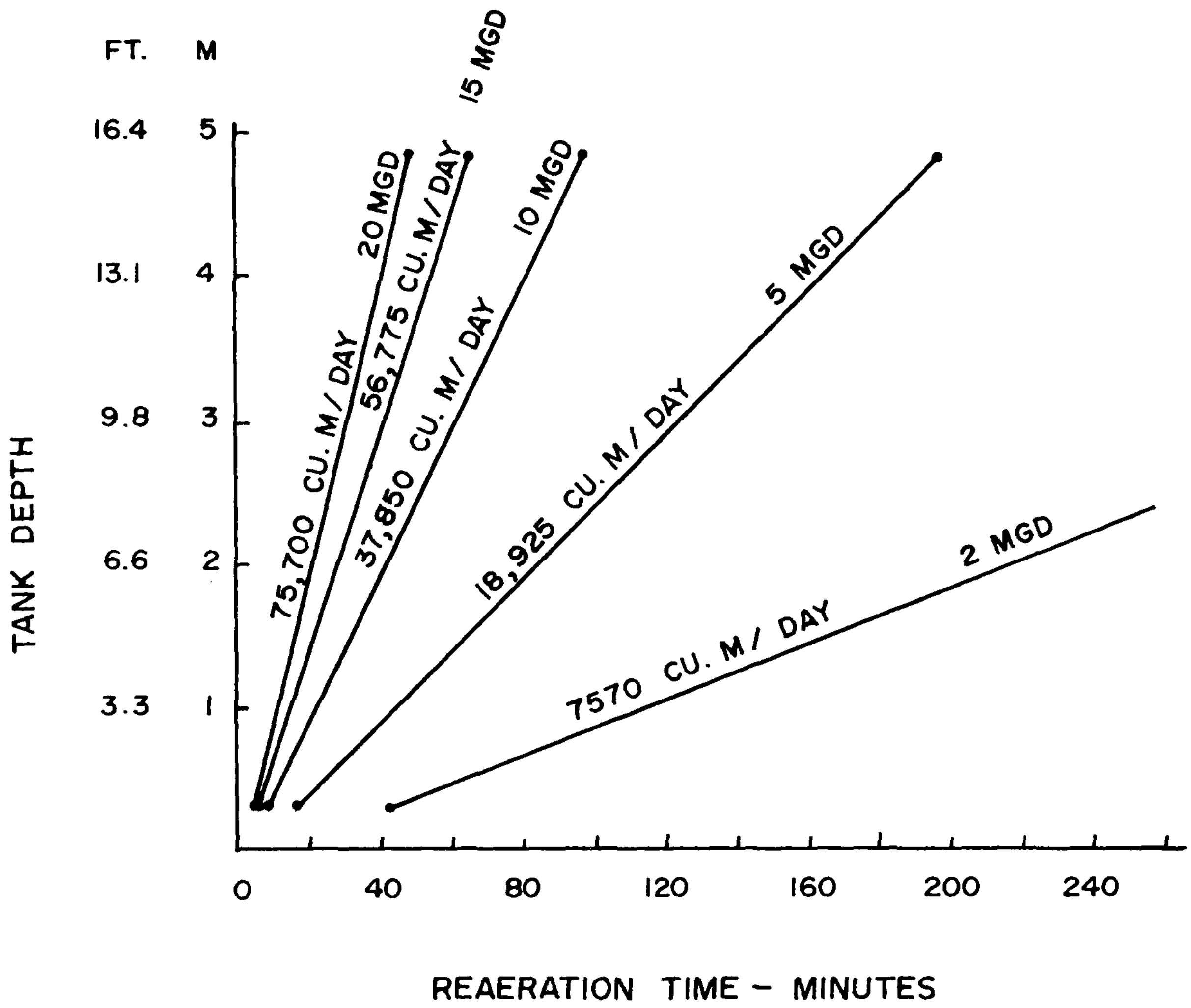

Figure 12. Stabilization tank depth versus reaeration time at various flows

Sludge Transfer Pumps

Two constant speed 37,850 cu m/day (10 mgd) pumps were installed between the stabilization tank and contact tanks for transferring the sludge from the stabilization tank to the contact tank feed trough during system operation. A throttling valve is located on the discharge line from these pumps to permit the desired rate of sludge to reach the contact tank. This rate is set as a percentage of the raw flow rate.

A 1892 cu m/day (0.5 mgd) pump was also installed at the same location. The function of this pump is to transfer stabilized sludge to the DWP thickening facilities when the demonstration system is not in use. A throttling valve is located on the discharge line of this pump, enabling this flow rate to equal the DWP RAS flow rate to the stabilization tank. Figure 13 is a schematic drawing showing plan and elevation views of the contact and stabilization tank arrangement.

Oxygen Requirements

The oxygen requirements for the system were calculated to be 8,080 kg/day (20,000 lb/day). It was estimated that 3,178 kg/day (7,000 lb/day) would be required by the contact tank and 5,902 kg/day (13,000 lb/day) by the stabilization tank. The total air blower capacity of the existing treatment plant was 373.8 cu m/min (13,350 cfm). The maximum air requirements by the DWP was 273.0 cu m/min (9,750 cfm) with an average demand of 147.0 cu m/min (5,250 cfm). Assuming an oxygen transfer efficiency of 7%, the demonstration system demand would be about 112.0 cu m/min (4,000 cfm) in the contact tank and 224 cu m/min (8,000 cfm) in the stabilization tank. Since it was obvious that the existing air blower capacity was not sufficient for the total demand, it was decided to use the existing air blowers for the contact tank and to supply floating mechanical surface aerators for the stabilization tank.

The air disperser system in the contact tank consists of 340 dispersers. The air supply to these dispersers comes from the existing plant's blowers. As built, the sytem is capable of delivering between zero and 105.0 cu m/min (3,750 cfm) of air to the contact tank. The rate of air supply is automatically controlled by the raw flow rate to the demonstration system.

Eight 37.3 kw (50 hp) floating mechanical surface aerators, four in each compartment, were specified for the stabilization tank. At an oxygen transfer rate of 1.52 kg/hr/kw (2.5 lb/hr/hp) a total of 10,896 kg/day (24,000 lb/day) of oxygen can be supplied to the stabilization tank by these aerators. Floating surface aerators were chosen since they 1) would not require an addition to the existing air blower facilities, 2) were all suited for the changing depth in the stabilization tank and 3) would insure adequate mixing and prevent deposition of solids. Each aerator is controlled individually so that the number of aerators in use can be varied depending upon the specific application (stabilization or reaeration).

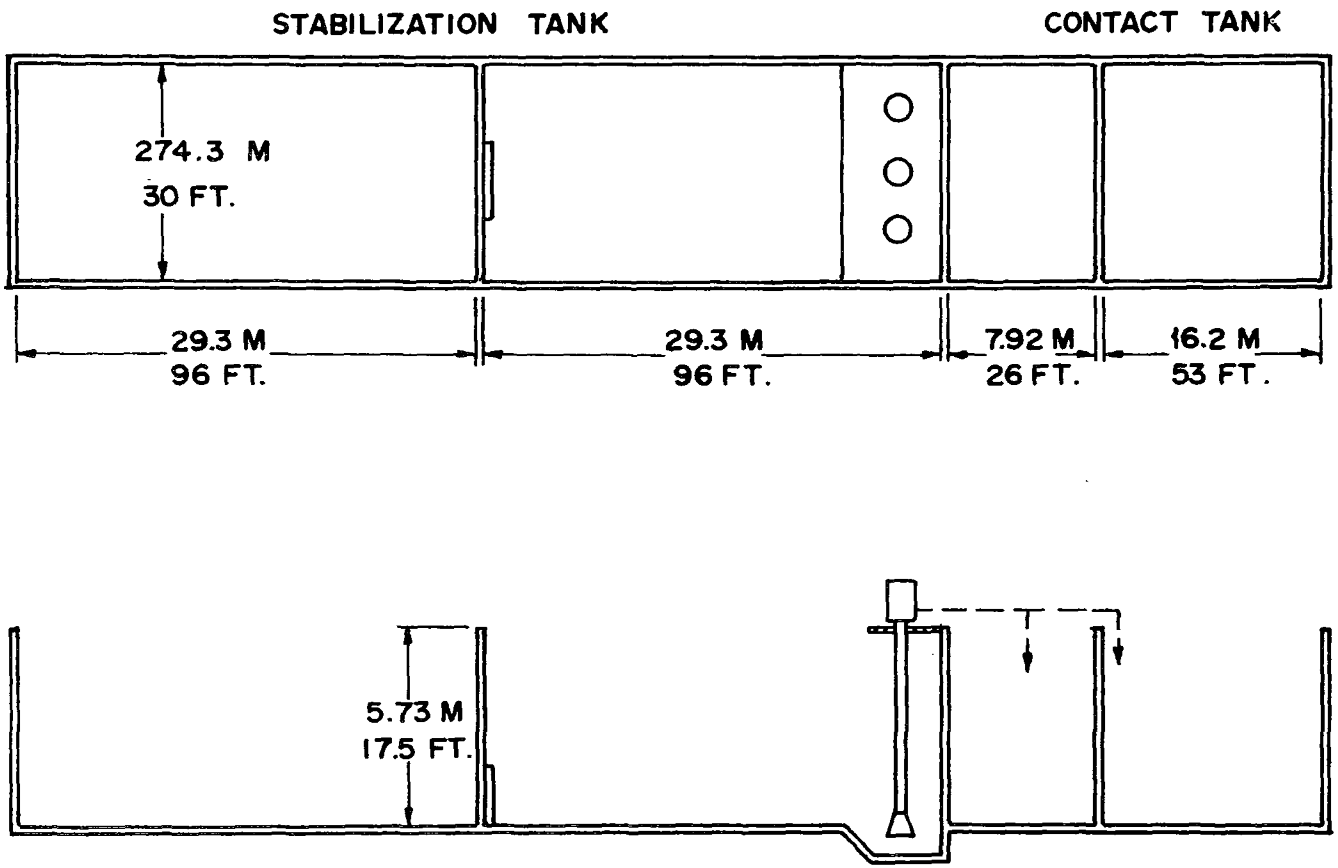

Figure 13. Plan and elevation views of stabilization tank and contact tank

Final Clarifier Equipment

Design of the final clarifier was performed so that the clarifier could easily be integrated into dry weather use. Construction of the clarifier required connection to the existing DWP mixed liquor feed channel, hook-up with the DWP RAS system, and a separate 75,700 cu m/day (20 mgd) RAS pump and associated yard piping to the demonstration system. A sluice gate was installed at the entrance point of the DWP mixed liquor feed channel to the clarifier. This gate remains open during periods of dry weather flow. When the demonstration system goes into operation the gate automatically closes, isolating the new clarifier from the DWP. A valve located within the conduit leading from the new clarifier to the DWP RAS pumping facilities also automatically closes.

The size of the final clarifier was based upon bench scale laboratory tests using mixed liquor from the Kenosha WPCP. As a result a 42.7 m (140 ft) peripheral feed and efflent clarifier with a surface overflow rate of 53.0 cu m/day/sq m (1300 gpd/sq ft) at a flow rate of 75,700 cu m/day (20 mgd) was specified and constructed. The clarifier has a gross surface area of 1,431 sq m (15,400 sq ft), a volume of 5,299 cu m (1,400,000 gal.) and a sidewall depth of 4.18 m (13.7 ft).

Figure 14 gives an overall view of the clarifier. A more detailed picture of the clarifier, Figure 15, shows, from left to right, the scum baffle, effluent trough, deflector shirt, and feed trough.

For purposes of conveying the RAS from the new final clarifier to the stabilization tank a 75,700 cu m/day (20 mgd) pump was installed in the DWP RAS building. A throttling valve on the discharge side of this pump works in the same manner as the valve associated with the sludge transfer pumps. Unless it is desired to change the level in the stabilization tank, the flow rate from the RAS pump and the sludge transfer pumps will be identical. Piping provisions were also made to allow RAS to be pumped from the DWP system to the stabilization tank if necessary.

Instrumentation and Control

A sophisticated and highly automated control system was specified for the demonstration system. This was partially necessitated by the evaluation program to be carried out, which required the maintaining of some process variables as fixed percentages of the varying raw flow. Also, a large amount of valve and gate position changes were required in a matter of minutes when the demonstration system went into operation and this precluded manual operation.

A control panel was constructed in the Administration Building of the WPCP. This panel can be seen in Figure 16. The functions handled by this panel are listed below:

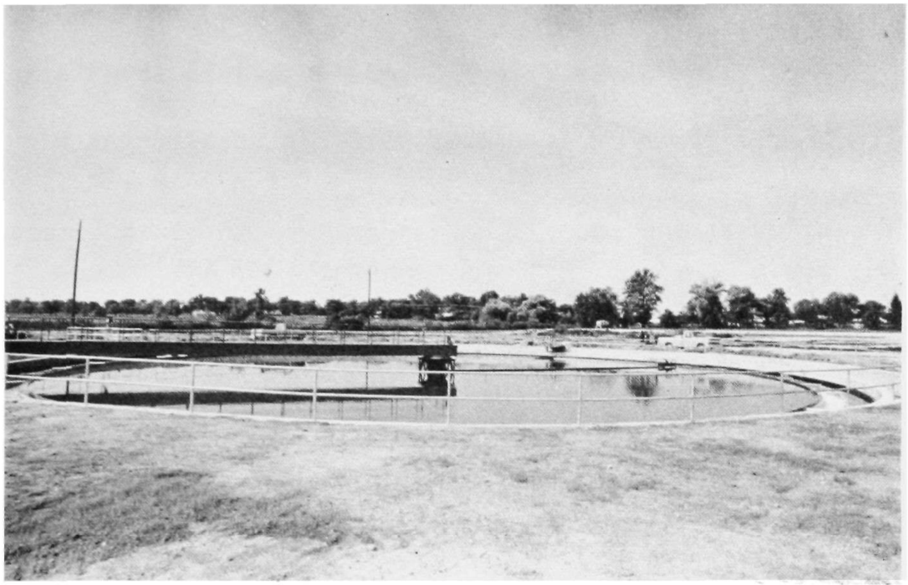

Figure 14. Overall view of final clarifier

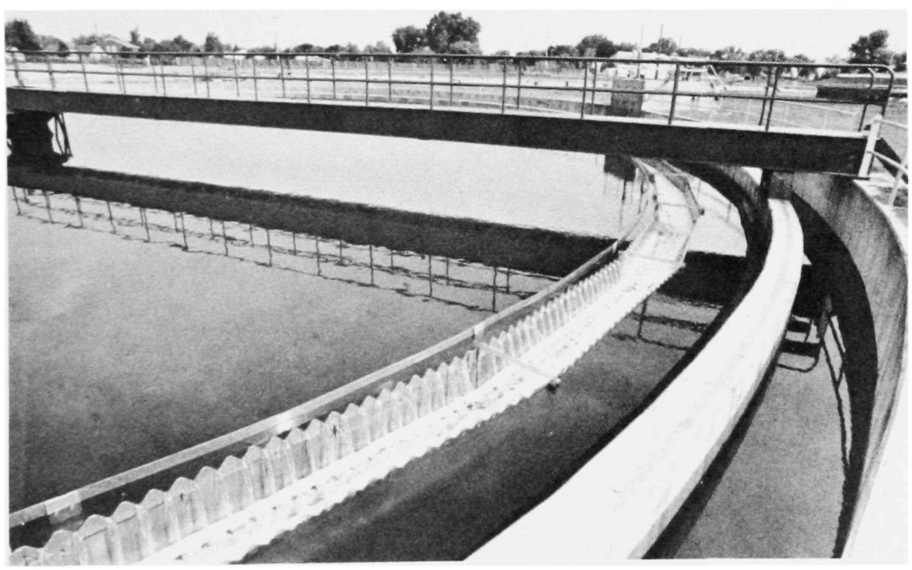

Figure 15. Detailed view of clarifier showing scum baffle, effluent trough, deflector skirt, and feed trough

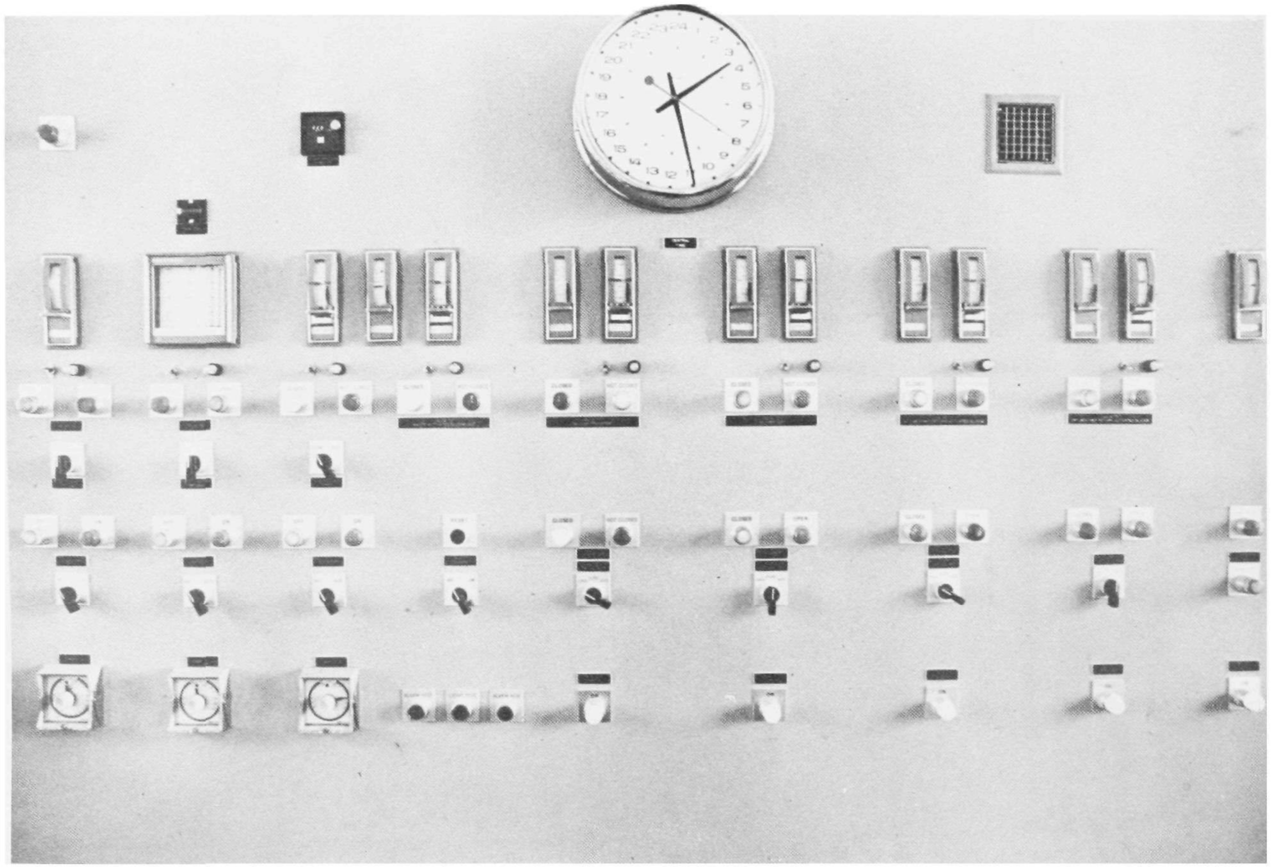

Figure 16. View of demonstration system control panel

1. Record raw flow rate.

2. Indicate level of flow in the DWP grit tank.

3. Activate annunciator at onset of high flow conditions.

4. Totalize flow and duration of demonstration system use.

5. Open/close valves in discharge line from new gas driven raw flow pump which direct flow to either the DWP or the demonstration system.

6. Control throttling valve for WAS rate from the DWP to the demonstration system.

7. Control throttling valve for WAS rate from the stabilization tank to the sludge thickening facilities.

8. Control throttling valve for the RAS rate from final clarifier to the stabilization tank.

9. Control throttling valve for sludge transfer rate from the stabilization tank to the contact tank.

10. Control throttling valve for the rate of RAS borrow from the DWP by the demonstration system.

11. Control throttling valve for rate of air flow to contact tank.

12. Indicate effluent flow rate from Parshall Flume on final clarifier.

13. Start/stop automatic samplers.

14. Open/close sluice gate at entrance to new clarifier from DWP mixed liquor feed channel.

15. Open/close sluice gate at entrance to new clarifier from demonstration system mixed liquor feed channel.

16. Open/close valve in RAS conduit leading from new clarifier to DWP RAS pumping system.

17. Open/close valve in RAS conduit leading from new clarifier to demonstration system RAS pump.

18. Control three timer mechanisms responsible for automatic startup of the demonstration system.

19. Control automatic start/stop operation of the raw flow pump, the two sludge transfer pumps, the RAS pump, and the sludge transfer pump from the stabilization tank to the DWP thickener.

The throttling valve controlling the WAS rate from the DWP to the stabilization tanks during dry weather is manually positioned for the desired flow rate at the control panel. The throttling valve for the WAS flow rate from the stabilization tank to the DWP thickener is paced by the WAS rate to the stabilization tank. The WAS flow rate to the thickener can be set anywhere in a range between zero and 300% of the flow rate to the stabilization tank. For normal dry weather use when the two flow rates should be equal, this ratio is set at 100%. It is also possible to manually set a desired WAS flow from the stabilization tank regardless of the flow rate into the tank.

The throttling valves for the RAS flow rate from the clarifier to the stabilization tank and for the sludge transfer rate from the stabilization tank to the contact tank are both paced as a percentage of the raw flow rate. These rates are set in a range of zero to 100% of the raw flow rate (0-75,700 cu m/day) (0-20 mgd). The actual setting is dependent upon the desired mixed liquor suspended solids (MLSS) concentration desired. During normal operation, these two settings are the same in order to maintain a constant level in the stabilization tank. It is also possible to manually set these flows at a desired rate. A throttling valve for the rate of RAS borrow from the DWP works in the identical manner, having the same capacities.

The throttling valve for the rate of air flow performs similar to the above valves. The ratio controller can be set between zero and 300%. At a raw flow rate of 75,700 cu m/day (20 mgd) and the controller set at 100%, the air flow is 105.0 cu m/min (3,750 cfm). This is the maximum air flow capacity. At lower flows such as 37,850 cu m/day (10 mgd), the controller can be set at 200%, resulting in the same 105.0 cu m/min (3,750 cfm) rate. It is also possible to manually set the air flow rate anywhere between zero and 105.0 cu m/min (0-3,750 cfm).

SYSTEM DEPLOYMENT

Integration of the demonstration system into the DWP operation makes quick implementation of the process possible when potential overflow conditions exist. Figure 17 illustrates the relationship of the demonstration system to the existing DWP.

The level indicator located in the DWP grit tank continually relays the DWP flow rate to the demonstration system control board. If this rate goes above 87,055 cu m/day (23 mgd) an alarm is sounded and the delay timer at the control board begins operation. The purpose of this timer is to allow operating personnel to respond to the alarm, and determine if there is any reason why the system should not be allowed to begin operation. If there is no reason for aborting the run, the timer will complete its cycle and then immediately start the process.

The raw flow pump will automatically start, if not already being used by the DWP. The valve leading to the DWP on the discharge line from

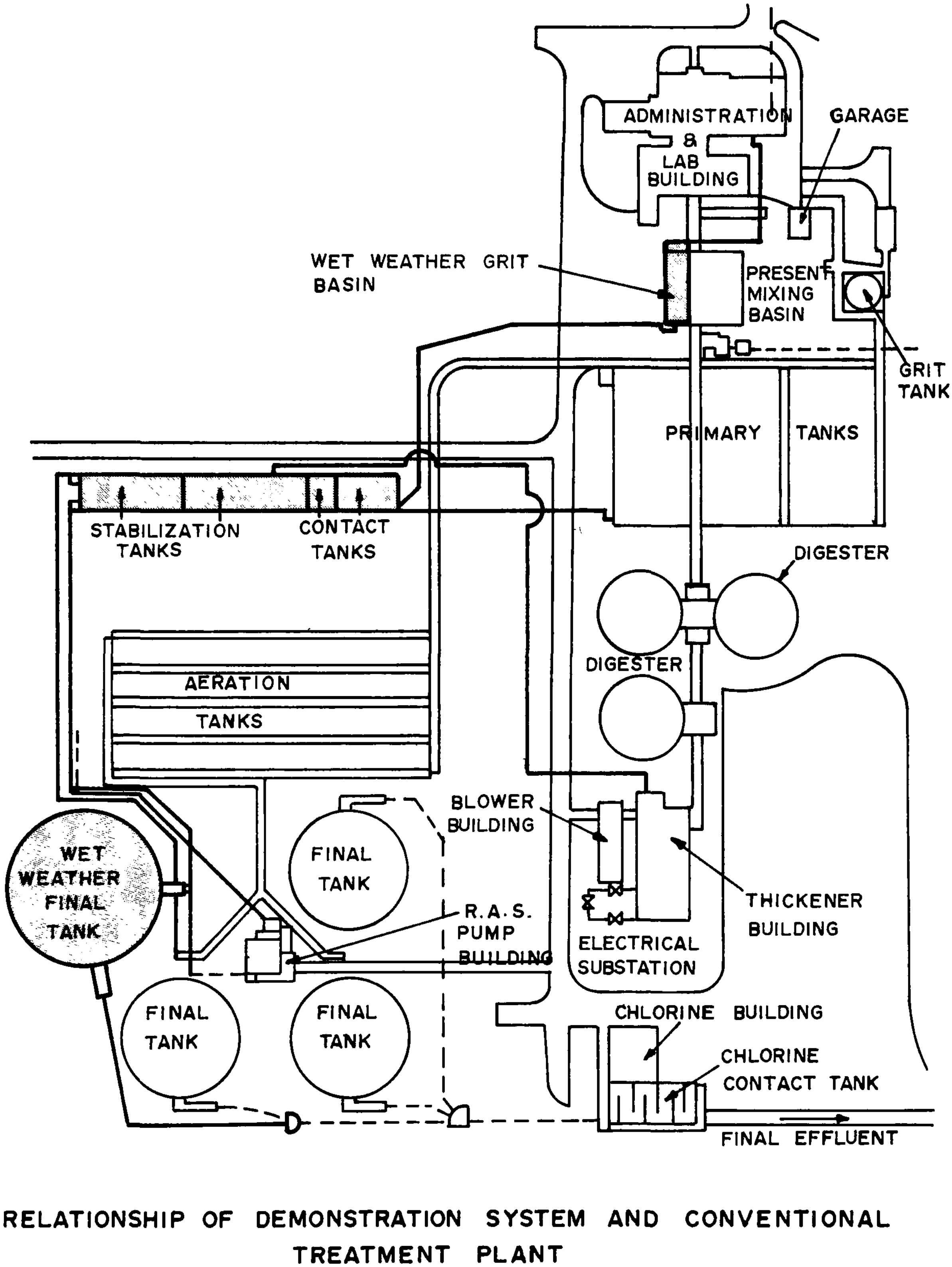

Figure 17. Plan view of Kenosha Water Pollution Control Plant

the pump will close, and the valve leading to the demonstration system will open. Raw flow will fill the grit tank and then begin flowing to the feed trough at the contact tank.

An electrical probe is located in this trough, and when the flow makes contact with this probe the remaining start-up functions take place. The sluice gate in the mixed liquor feed channel from the DWP to the demonstration system clarifier begins a 30 minute closing cycle, and the sluice gate in the mixed liquor feed channel from the contact tank opens. Simultaneously, the RAS line leading from the demonstration system clarifier to the DWP RAS pump is automatically valved shut, the valve in the RAS line leading to the demonstration system RAS pump opens, the demonstration system RAS pump and sludge transfer pumps begin operation, and the throttling valve for the air supply to the contact tank opens. Also, the RAS line leading from the DWP to the stabilization tank is valved shut, and the transfer pump for the WAS going from the stabilization tank to the DWP sludge thickener shuts off. At the beginning of operation it is also necessary to manually increase the chlorine dosage to the chlorine contact tank.

When the high flow condition has subsided, the demonstration system is manually taken out of service at the main control board. After turning the process off, the start-up procedures automatically reverse themselves and the plant returns to normal dry weather operation. The remaining mixed liquor in the contact tank is pumped by one of the sludge transfer pumps to the DWP primary sedimentation tanks. The grit tank is drained and the settled grit on the bottom of the tank is manually scraped to the side of the tank where it is removed by a Vac-all and transported to a landfill site.

CONSTRUCTION COSTS AND TIMING

During the period of September 9, 1969 to March 5, 1970 the initial design report was prepared and then reviewed by the City of Kenosha and the US EPA. Following the report review the plans and specifications were completed and reviewed by the State of Wisconsin Department of Natural Resources and the US EPA. Bids for construction were received on August 11, 1970 and the actual construction contracts were signed on October 26, 1970, with construction starting immediately. The contractor was required to complete all facilities within 240 calendar days, or 8 months. Unfortunately, due to winter weather and construction delays, the actual period of construction was 11 months with construction completed on August 18, 1971. The remainder of August, and and the months of September and October were spent in debugging the equipment, checking instrument calibration, and familiarizing personnel with the methods of operation.

The biggest delay in making the system operational following completion of construction was caused by problems with automatic flow controllers and throttling valves. During shakedown tests using dry weather flow, it was found that the thorttling valves were not being paced properly. This required repeated repair visits by service representatives of the instrument manufacturer. Not until the end of October was it felt that the system was ready for actual operation. However, by this time it was necessary to take the system out of service for the winter months. The system was put back on line and ready for operation following the spring thaw during the first week of April, 1972.

Total construction costs came to $1,178,779.11. General construction costs were $1,023,150.00, and the electrical construction cost was $69,600.00. The engineering costs including design and inspection amounted to $86,029.00. Table 1 contains a detailed cost breakdown for the various aspects of construction. The general contractor was C & C Bohrer Inc., Fort Wayne, Indiana, and the electrical contractor was Dietz Electric of Milwaukee, Wisconsin. Figure 18 is an aerial photograph of the entire Kenosha WPCP after construction of the demonstration system was completed.

Table 1. BREAKDOWN OF CONSTRUCTION COSTS

Item	Final cost
Excavation	$ 67,620.00
Backfill	21,367.00
Reinforced concrete	280,150.00
Concrete pipe	93,200.00
Demolition	13,505.00
Miscellaneous metal	20,338.00
Paint and finish	14,306.00
Landscape	5,000.00
Steel pipe	29,269.00
Cast iron pipe	51,030.00
Spiral piping	5,000.00
Valves	78,765.00
Meters and instruments	55,000.00
Pumps	85,000.00
Sludge collectors	105,000.00
Diffusers	5,000.00
Weirs and troughs	25,000.00
Mechanical aerators	76,000.00
Change orders	2,600.11
	$1,023,150.11
Electrical work	69,600.00
TOTAL.....	$1,092,750.11

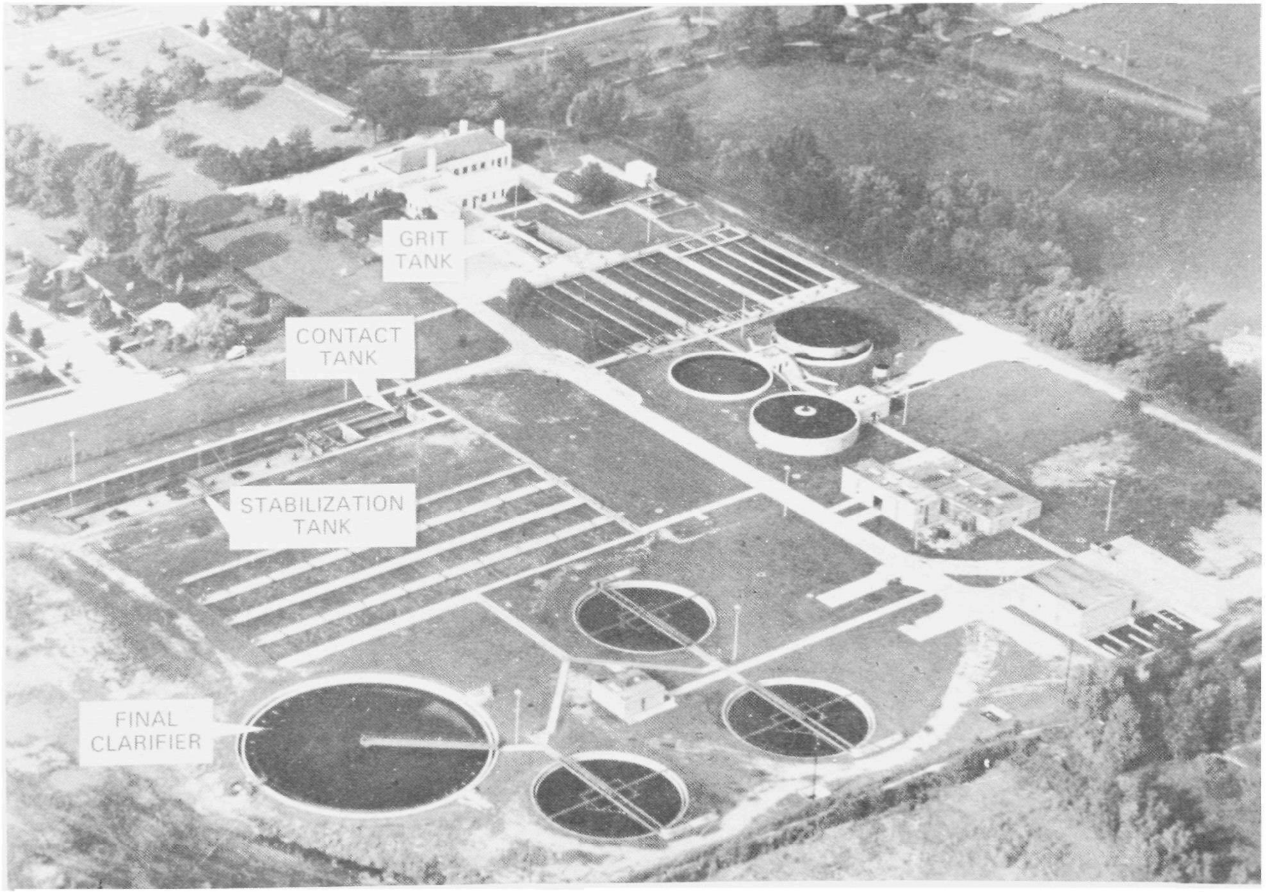

Figure 18. Aerial view of Kenosha WPCP depicting demonstration system facilities

SECTION VI - OVERFLOW QUALITY STUDY

During 1970 while design and construction of the demonstration system facilities was occurring, a program to determine the quality of the combined sewer overflows in Kenosha was carried out. This included measurement of rainfall, combined sewer overflow quantity and quality, and influent quality to the WPCP during rainfalls.

INSTRUMENTATION

Two raingages were installed to substantiate the results from the official U.S. Weather Service raingage located on the grounds of the WPCP. The raingage locations are shown in Figure 19, and are designated as follows: Gage A - on the roof of a Kenosha Fire Department firehouse at 48th Avenue and 60th Street, in the northwest corner of the combined sewer area. Gage B - on the roof of the Kenosha Water Utility Building at 100 51st Place just outside the northeast corner of the combined sewer area. Gage C - ground level at the WPCP, 3rd Avenue and 79th Street, just outside the southeastern corner of the combined sewer area.

The two raingages installed were both Bendix Raingages, Model No. 775-C. These instruments have a range of 30.5 cm (12 in.) and convert the weight of water collected to linear readings. The readings are recorded on a cylindrical chart divided into 24 equal segments, recording cumulative depth of precipitation vertically and time horizontally. The cylindrical chart recorder is powered by a spring driven clock which has a 24 hour rotation and an 8 day wind cycle. Each site was maintained on a seven day interval, or after each rainfall, depending upon which came first. This maintenance included changing the recording chart, refilling the recording pen, and checking instrument calibration. The raingage at the WPCP used for data in this project was similar to the others which were installed.

The method chosen for averaging the rainfall recordings from the three instruments was the Theissen Method (27). This method was used because of its accuracy when using non-uniform raingage distribution, as was the case here. The percentage, or weight factor, applied to gages A, B, and C were 0.37, 0.38, and 0.25 respectively.

The three overflow locations, 57th, 59th, and 67th Street, were located in readily accessible areas and were subject to vandalism and tampering.

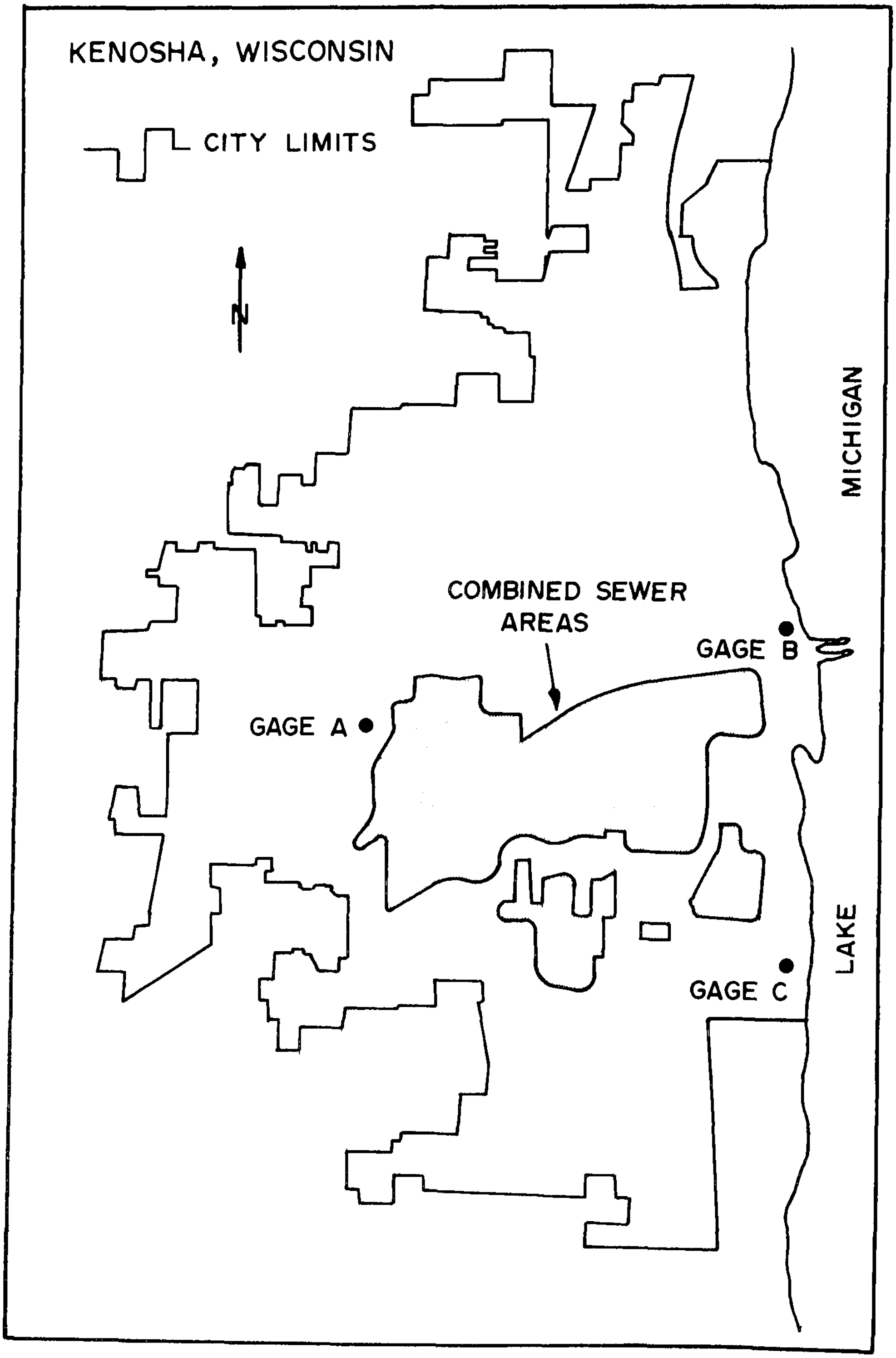

Figure 19. Map of Kenosha showing raingage locations

In order to minimize this problem, the overflow samplers and depth of flow recording instruments were housed in 1.52 m (5 ft) diameter by 1.83 m (6 ft) precast manhole sections. Figures 20 and 21 picture, respectively, an exterior view of a typical monitoring installation and an interior view showing the flow recording and sampler instrumentation.

Sampling occurred at each location automatically during an overflow. The sampling apparatus were commercial Serco Model No. NW-3-8 samplers. These samplers operated by creating a vacuum in the sample jars and connecting a sample line from each jar down into the overflow sewer. During an overflow the vacuum on each sample bottle was released at 10 minute intervals. There were 24 sample jars, thus allowing for a sample period of 240 minutes. Each jar had a volume of approximately 500 mls. The sampler was initially triggered by means of a float anchored in the overflow sewer. As an overflow began, the flow buoyed the float upwards and thus opened a pinch valve which controlled a vacuum bottle contained in the starting apparatus. This release of vacuum drove a piston which in turn released a spring loaded arm that tripped the vacuum switch on each separate sample jar, causing the jar to fill up with the sampled liquid.

The depth recorders were manufactured by Honeywell and operated on a differential pressure basis. Inert nitrogen gas was introduced into tubing which ran between the recorder and the bottom of the outfall sewer. As the flow (head) in the sewer increased, the nitrogen ascaping from the end of the tubing in the sewer was decreased, proportional to the depth of flow, causing the pressure within the tube to increase. This increase in pressure was converted to depth readings and recorded on a circular chart. The chart was divided into 24 equal sections and driven by an 8 day clock.

The 57th Street overflow was located at 57th Street and the lakefront. The outfall pipe itself at this location is 1.83 m (72 in.) in diameter. In order to install the float and sampling equipment a 0.61 m (24 in.) diameter hole had to be bored from ground level down to the sewer, and a portion of the top of the sewer had to be knocked out. A section of culvert pipe was then installed from the sewer up to ground level.

The 59th Street overflow was located just east of the 59th Street and 3rd Avenue intersection, about 914.4 m (1000 yards) west of the lakefront. Monitoring equipment was installed at this location a month after the others because a new manhole was being installed at this time. The float and sampling equipment was installed in the 1.22 m (48 in.) diameter outfall directly through the existing manhole.

The 67th Street overflow was located where 67th Street (extended) would intersect the lakefront. The monitoring equipment was located on a concrete pad containing the manhole above the 2.51 m (99 in.) diameter outfall sewer. A general schematic diagram of a typical monitoring station is shown in Figure 22.

Figure 20. Exterior view of overflow monitoring station

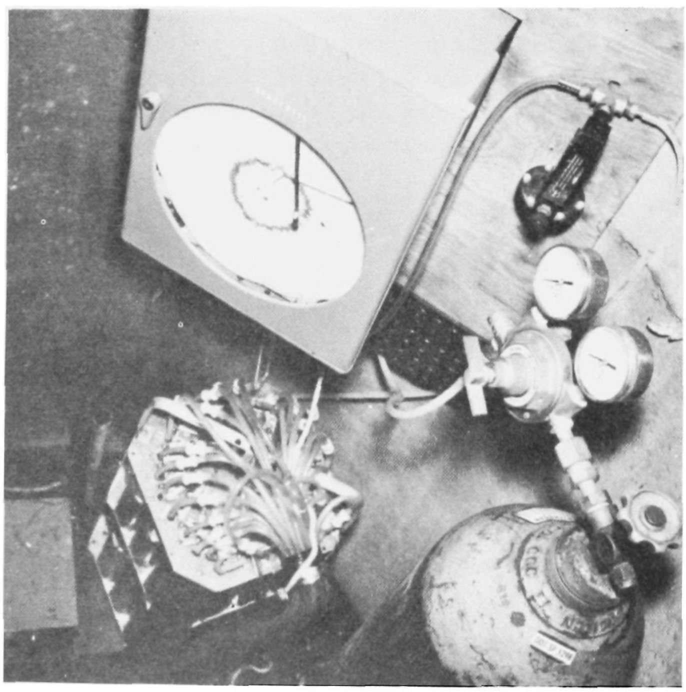

Figure 21. Interior view of monitoring station showing sampling and flow recording instrumentation

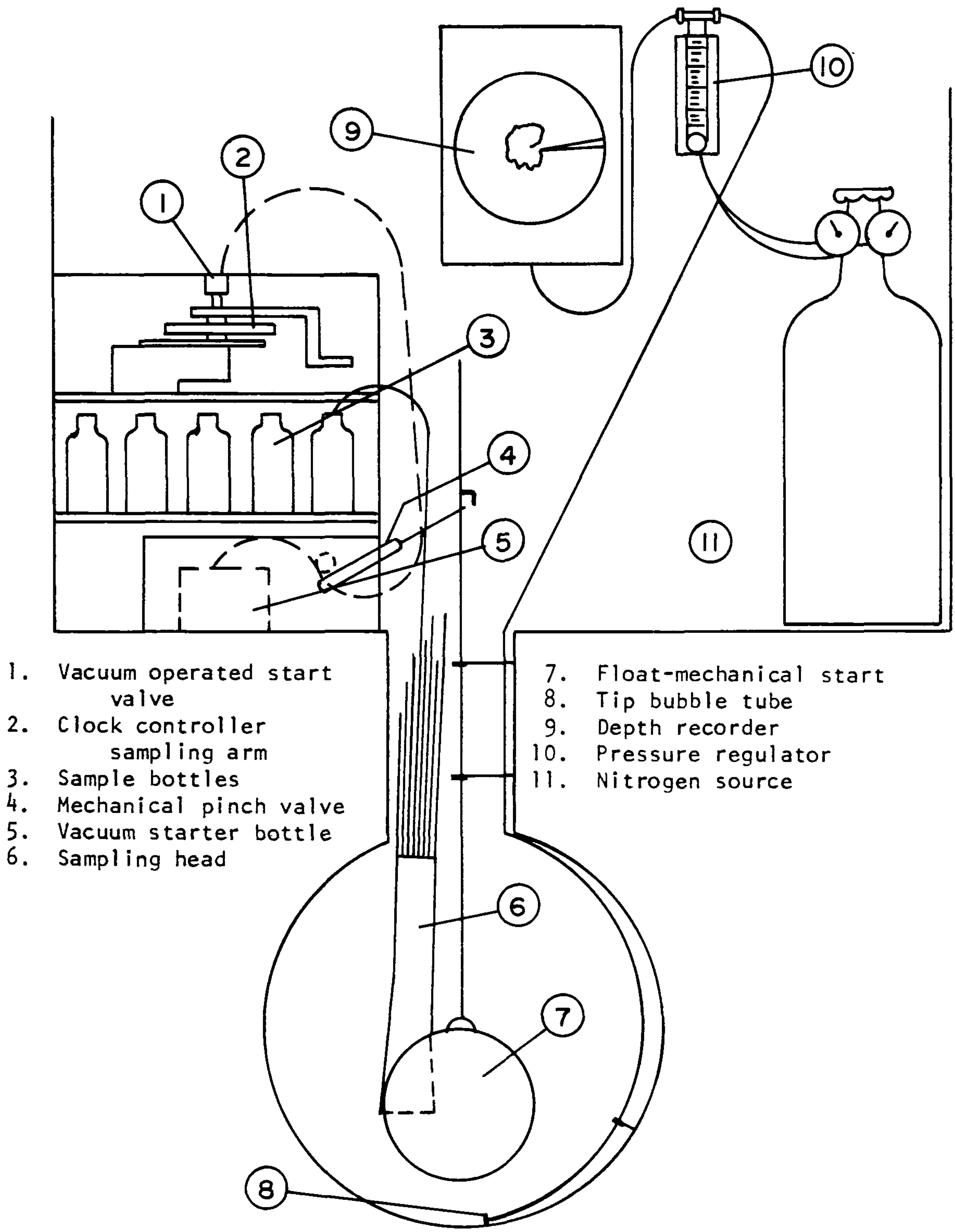

Figure 22. Schematic drawing of a typical monitoring site

A sampling site was also installed at the WPCP itself. The sampler was located at the influent end of the indoor grit chamber. The purpose of this location was to sample the sewage entering the treatment plant during rainfall periods. The pollutional characteristics of this flow gave a good indication of the quality of sewage to be treated later by the demonstration system. The sampler installed at this location was identical to the others and was manually started by treatment plant personnel during rainfall periods.

MONITORING PROCEDURE

Following completion of installation of the raingages and sampling equipment at the end of May, 1970, a continuous rainfall alert notification system went into effect. During normal working hours the operator at the WPCP telephoned the appropriate personnel at Envirex Inc. in Milwaukee upon commencement of a rainfall. After working hours, or on weekends, the WPCP operator telephoned the company security police who in turn contacted Envirex personnel. Upon notification of the rainfall the designated person from Envirex would immediately travel the 64.4 km (40 miles) from Milwaukee to the sites to collect the samples when the overflow ceased. At this time charts from both the raingages and depth recorders were removed and marked with the proper identification numbers regarding storm numbers, date, and time. These charts were returned and the data was later extracted and recorded.

Sewer overflow samples were collected and composited proportional to the flow. Using the flow recorder chart it was possible to determine the flow rate at the time each sample was taken, and to take a volume of sample proportional to this reading. After compositing the samples in one gallon plastic containers, they were placed in styrofoam coolers and transported to the Envirex laboratory in Milwaukee. The samples were immediately prepared for BOD, total coliform and fecal coliform analyses, with the remaining sample being refrigerated until used in later analysis for determination of other pollutional characteristics. A list of the quality characteristics measured is below.

1. pH
2. Settleable solids
3. Total solids
4. Total volatile solids
5. Suspended solids
6. Suspended volatile solids
7. Total BOD
8. Dissolved BOD
9. Total COD
10. Dissolved COD
11. Total organic carbon
12. Dissolved organic carbon
13. Total inorganic carbon

14. Soluble inorganic carbon
15. Total Kjeldahl nitrogen
16. Total phosphorus
17. Total coliform
18. Fecal coliform

Although the laboratory procedures generally followed those in the 12th Edition of Standard Methods (28), a description of the exact laboratory analytical procedures used is given in Appendix A.

PRECIPITATION DATA

Rainfall data (29) available through 1968 indicates that the City of Kenosha received an average annual rainfall of 76.40 cm (30.08 in.). For the period from 1958 to 1967, 5 years had annual rainfalls greater than 76.40 cm (30.08 in.) and 5 years had annual rainfalls less than 76.40 cm (30.08 in.). The maximum annual rainfall in this period was 103.40 cm (40.71 in.) in 1960. The minimum annual rainfall was 48.51 cm (19.10 in.) recorded in 1963.

During the four and one-half month monitoring period from June 1, 1970 through October 14, 1970, twenty-five rainfall events were recorded. These included all events in which over 0.25 cm (0.1 in.) of rain fell. A summary of these rainfall events is shown in Table 2. The cummulative recorded rainfall during this period was 37.31 cm (14.69 in.), with the mean rainfall equaling 1.50 cm (0.59 in.). The standard deviation of the rainfall was 1.22 cm (0.48 in.) indicating a high variance in rainfall events. A frequency histogram of the rainfall amounts is shown in Figure 23. As can be seen, the mode class of rainfalls was the 0.66 to 1.27 cm (0.26 to 0.50 in.) range, with nine of the rainfalls occurring in this range. The second most frequent range was the 1.30 to 1.90 cm (0.51 to 0.75 in.) group with six of the rainfalls occurring in this range. Twenty-two of the total rainfall events were less than 2.54 cm (1.0 in.).

Storm lengths ranged between 0.17 and 22.2 hours, with the mean storm lasting 3.09 hours. The duration of the storm includes the entire time period over which any rainfall continued. Eight of the storms, 32 percent, lasted less than 30 minutes, and 19 storms, 76 percent, lasted less than 3 hours.

A corrleation between rainfall patterns and overflow patterns was attempted. However, no direct correlation between rainfall volume or intensity and the resulting overflow volume or flow rate was found. This fact lead to speculation that, perhaps, the accuracy of the overflow measuring devices was in question. Depth-discharge relationships had been developed for these sewers by means of dye tests. This was

Table 2. KENOSHA RAINFALL SUMMARY FOR 1970

Storm No.	Date	Raingauge A cm	Raingauge A in.	Raingauge B cm	Raingauge B in.	Raingauge C cm	Raingauge C in.	Average cm	Average in.
1	6/01	1.85	0.73	1.60	0.63	1.09	0.43	1.55	0.61
2	6/17	0.00	0.00	0.51	0.20	1.65	0.65	0.58	0.23
3	6/20	2.16	0.85	1.78	0.78	0.89	0.35	1.73	0.68
4	6/26	1.65	0.65	2.29	0.90	2.62	1.03	2.08	0.82
5	7/08	0.69	0.27	0.89	0.35	0.89	0.35	0.90	0.35
6	7/08	0.13	0.05	0.76	0.30	0.38	0.15	0.41	0.16
7	7/13	0.94	0.37	1.12	0.44	0.89	0.35	0.99	0.39
8	7/19	0.76	0.30	0.69	0.27	0.25	0.10	0.61	0.24
9	7/27	0.76	0.30	0.64	0.25	0.64	0.25	0.69	0.27
10	7/28	0.19	0.47	2.67	1.05	1.52	0.60	1.52	0.72
11	7/30	0.89	0.35	1.27	0.50	0.51	0.20	0.94	0.37
12	8/18	0.94	0.37	0.94	0.37	0.53	0.21	0.84	0.33
13	9/02	1.35	0.53	1.40	0.55	1.07	0.42	1.30	0.51
13B	9.03	0.71	0.28	0.51	0.20	0.18	0.07	0.51	0.20
14	9.03	0.25	0.10	0.25	0.10	0.71	0.28	0.38	0.15
15	9/06	3.02	1.19	2.92	1.15	2.03	0.80	2.74	1.08
16	9/09	1.83	0.72	1.98	0.78	1.40	0.55	1.78	0.70
17	9/14	2.82	1.11	2.34	0.92	1.30	0.51	2.24	0.88
18	9/15	1.19	0.47	1.68	0.66	1.24	0.49	1.37	0.54
19	9/15	1.12	0.44	1.14	0.45	1.09	0.43	1.12	0.44
20	9/17	6.10	2.40	6.43	2.53	5.46	2.15	6.07	2.39
21	9/22	1.32	0.52	1.14	0.45	1.35	0.53	1.24	0.49
22	9/23	3.28	1.29	4.10	1.61	2.87	1.13	3.51	1.38
23	9/25	0.61	0.24	1.14	0.45	0.97	0.38	0.91	0.36
24	10/14	1.27	0.50	1.27	0.50	0.33	0.13	1.04	0.41
Cumulative		37.08	14.60	41.43	16.31	31.85	12.54	37.31	14.69
Mean		1.47	0.58	1.65	0.65	1.27	0.50	1.50	0.59

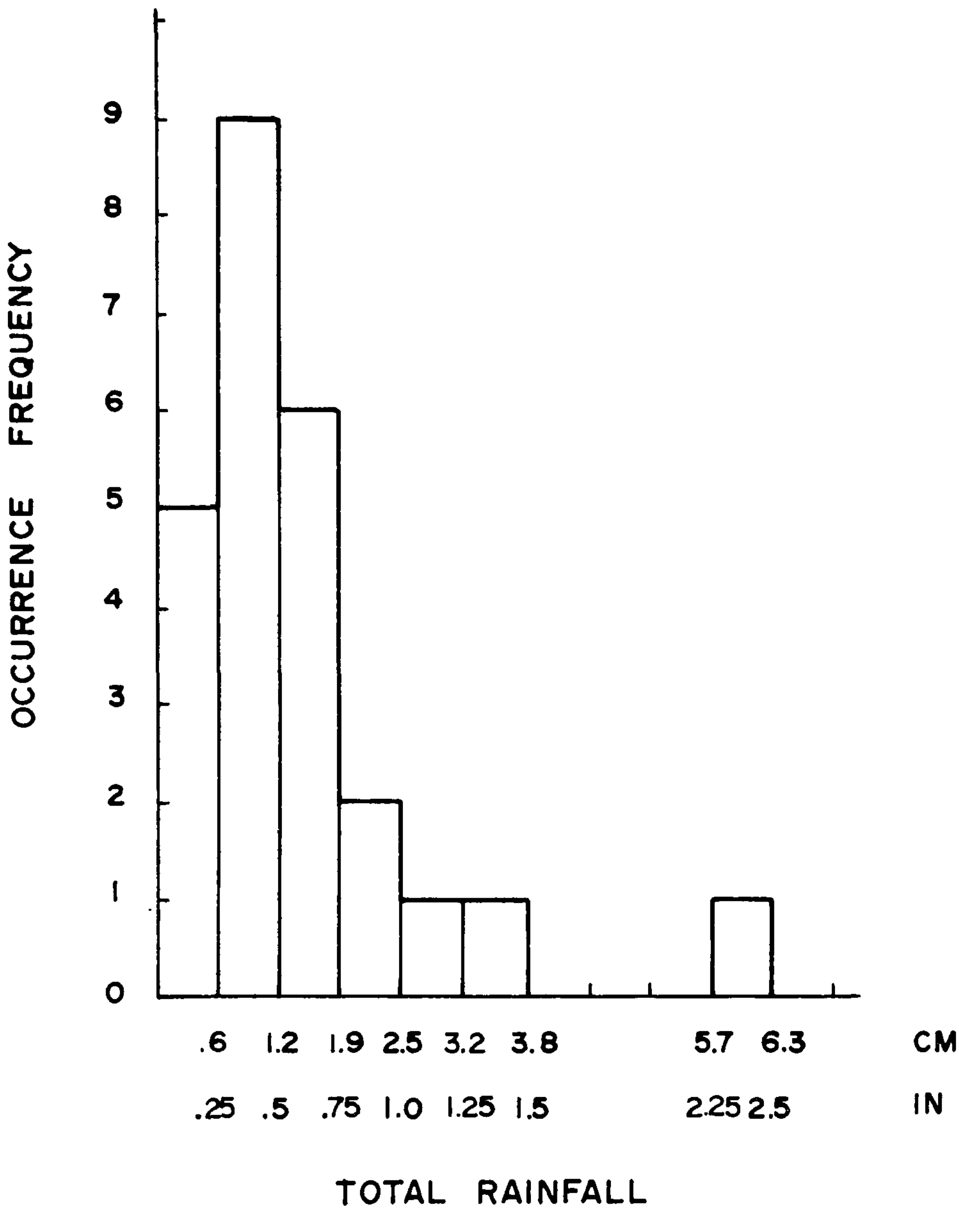

Figure 23. Histogram of rainfalls in Kenosha for June 1, 1970 to October 14, 1970

necessitated by the fact that the construction drawings of these sewers were incomplete and questionable. In fact, some of the sewers were shown to slope from the lake back towards the overflow mechanisms.

Study of the overflow data indicated that in some cases the volume of overflow measured exceeded the volume of rainfall over the combined sewer area. Since it was obvious that the depth-discharge relationships were not accurate and that the overflow data was invalid, no analysis of the data was performed. However, the data did show that for all 25 storms recorded, there was a resultant overflow condition. The lowest recorded rainfall was 0.38 cm (0.15 in.). Despite the lack of the accurateness of the overflow measurements, it was obvious that the major overflow was occurring at 67th Street. Using the depth of flow as a relative indication of discharge it appeared that the overflows at 57th and 59th Street were negligible relative to 67th Street.

OVERFLOW QUALITY ANALYSIS

All twenty-five rainfall events were monitored either completely or partially for the eighteen quality characteristics listed earlier. As explained, the sampler operated for a period of four hours after the overflow began, or until the overflow ceased if less than four hours in duration. If a sampler malfunctioned and did not automatically start sampling, it would be manually triggered by personnel arriving at the sites, and the actual period of sampling reported. When all sites operated properly and the overflow period was of significant duration, composite samples from the WPCP, 67th Street, and 57th Street were from 0 to 4 hours after the overflow began, and 59th Street was from 0 to 2 hours after the overflow began. The shortness of the sampling duration at 59th Street is explained by the small volume and duration of overflow at this site.

Complete results from the sampling program are given in Appendix B, Tables B1 to B25. The data in these tables was analyzed to give an indication of the quality of sewage to be treated by the demonstration system. Only data from samples taken between 0 to 4 hours (0 to 2 hours for 59th Street), 0.5 to 4.5 hours, or 1 to 5 hours was used. No grab samples, or samples taken more than one hour after the specified range were used. Table 3 contains the mean concentrations of the 18 quality characteristics measured at each site, along with standard deviations, and the 95% confidence interval for the means. The magnitude of the standard deviations indicates the high variance of overflow quality with each storm.

The highest overall pollutional concentration during overflow was found at the influent to the WPCP. At this location the mean values for some of the basic quality parameters were: total solids - 938 mg/l, suspended solids - 558 mg/l, total BOD - 175 mg/l, dissolved BOD - 31 mg/l,

Table 3. KENOSHA OVERFLOW QUALITY SUMMARY FOR 1970

Parameter	Units	Site	Samples	Mean	Standard deviation	95% Confidence level
pH		WPCP	19	7.14	0.24	7.02- 7.26
		67th St.	14	7.26	0.34	7.07- 7.45
		59th St	8	7.17	0.29	6.92- 7.43
		57th St.	9	7.34	0.49	6.96- 7.72
Settleable solids	ml/l	WPCP	19	10.80	6.1	7.90-13.70
		67th St.	12	3.90	2.7	2.20- 5.60
		59th St.	4	5.40	3.0	0.60-10.20
		57th St.	6	9.10	6.3	2.50-15.70
Total solids	mg/l	WPCP	19	938	391	750-1126
		67th St.	14	486	124	414- 557
		59th St.	7	597	170	440- 755
		57th St.	9	898	474	534-1262
Total volatile solids	mg/l	WPCP	19	566	326	408- 723
		67th St.	14	255	77	181- 269
		59th St.	7	302	108	202- 402
		57th St.	9	436	246	247- 626
Suspended solids	mg/l	WPCP	19	558	346	391- 724
		67th St.	14	280	148	194- 360
		59th St.	8	405	170	263- 548
		57th St.	9	590	437	254- 925
Suspended volatile solids	mg/l	WPCP	19	401	287	263- 538
		67th St.	14	147	90	95- 199
		57th St.	9	307	235	126- 488
Total BOD	mg/l	WPCP	17	175	91	128- 221
		67th St.	12	74	38	49- 98
		59th St.	6	96	41	53- 139
		57th St.	8	172	115	76- 267
Dissolved BOD	mg/l	WPCP	15	31	18	21- 41
		67th St.	10	22	16	10- 33
		59th St.	4	30	12	10- 50
		57th St.	5	22	11	8- 36

Table 3 (continued). KENOSHA OVERFLOW QUALITY SUMMARY FOR 1970

Parameter	Units	Site	Samples	Mean	Standard deviation	95% Confidence level
Total COD	mg/l	WPCP	19	731	531	476- 988
		67th St.	15	237	100	181- 293
		59th St.	9	338	148	228- 447
		57th St.	9	550	359	274- 826
Dissolved COD	mg/l	WPCP	19	81	36	63- 98
		67th St.	12	79	43	52- 106
		59th St.	5	84	50	22- 146
		57th St.	7	56	18	39- 73
Total organic carbon	mg/l	WPCP	16	195	142.1	119- 271
		67th St.	10	71	21.9	56- 87
		59th St.	7	113	47.2	70- 157
		57th St.	9	200	164.2	74- 327
Dissolved organic carbon	mg/l	WPCP	14	25	14.7	16.5-33.4
		67th St.	9	19	11.2	10.4-27.6
		59th St.	5	19	3.1	15.1-22.8
		57th St.	6	19	6.3	12.4-25.6
Total inorganic carbon	mg/l	WPCP	13	33	10.2	26.8-39.2
		67th St.	11	23	10.6	15.9-30.1
		59th St.	7	18	5.7	12.7-23.3
		57th St.	9	32	11.7	23.0-41.0
Dissolved inorganic carbon	mg/l	WPCP	14	28	9.7	22.4-33.6
		67th St.	9	18	6.9	12.7-23.3
		59th St.	5	12	5.4	5.3-18.7
		57th St.	6	28	9.7	17.8-38.2
Kjeldahl nitrogen	mg/l	WPCP	17	16.3	5.2	13.6-19.0
		67th St.	12	7.3	3.8	4.9- 9.7
		59th St.	3	7.6	4.7	0-19.0
		57th St.	6	10.3	5.3	4.7-15.8
Total phosphorus	mg/l	WPCP	9	9.1	6.5	4.1-14.1
		67th St.	7	3.1	1.5	1.7- 4.5
		59th St.	2	2.4	2.6	--
		57th St.	4	8.9	4.7	1.4-16.4

Table 3 (continued). KENOSHA OVERFLOW QUALITY SUMMARY FOR 1970

Parameter	Units	Site	Samples	Mean	Standard deviation	95% Confidence level
Total coliform	#/ml	WPCP	19	53,000		
		67th St.	14	12,990		
		59th St.	8	15,670		
		57th St.	9	12,590		
Fecal coliform[a]	mg/l	WPCP	17	4,300		
		67th St.	13	1,346		
		59th St.	7	1,920		
		57th St.	8	6,708		

a. Geometric mean.

total COD - 731 mg/l, dissolved COD - 81 mg/l, and total phosphorus - 9.1 mg/l. These characteristics are much higher in concentration than the average dry weather flow at the WPCP. In 1970 the WPCP had an average influent suspended solids of 123 mg/l, and BOD of 94 mg/l. The WPCP did not run any type of phosphorus determination at this time.

The reason for these high concentrations is best explained by the first flush theory which includes the scouring of residual matter from the sewers themselves. As earlier explained, the interceptor sewer leading to the WPCP has a maximum design capacity of approximately 189,250 cu m/day (50 mgd), and the average daily flow to the WPCP in 1970 was only 62,301 cu m/day (16.46 mgd). Also, the main trunk sewer with the largest contribution of dry weather flow to the interceptor is the 2.51 m (99 in.) sewer which intersects the interceptor at 67th Street. This location is in close proximity of the WPCP, being less than 1.61 km (1 mile) north. These two facts, low flow and location of the main trunk sewer, make possible a high buildup of settled matter in the entire length of the interceptor north (upstream) of 67th Street. During an actual rainfall runoff period, the interceptor will be scoured by the increased flow with the pollutional matter being carried to the WPCP. Only after flow to the WPCP exceeds 113,550 cu m/day (30 mgd) is the interceptor surcharged by means of the hydraulic gate at the WPCP inlet. When the interceptor is surcharged it prevents the entrance of any additional sewage, and forces all of the sewage in the trunk sewers to flow to the outfall sewers, except for a rate equal to that entering the WPCP. Since the interceptor has not reached capacity when the first flush from the 2.51 m (99 in.) trunk sewer occurs, a portion of the scoured material from this sewer will also be evident at the WPCP during the first periods of runoff.

A very encouraging and affirming indication received from this data was the extremely low dissolved BOD to total BOD ratio. This indicated that 82 percent of the BOD was in the particulate form. This is the type of material which is optimally removed by the contact stabilization process. In addition to the indication of potentially good BOD removals, it was felt that the high suspended solids concentration, which is responsible for a high pollutional loading during overflows, should be efficiently removed in the clarification phase of the demonstration system.

The 67th Street site, which has the largest overflow volume, had the lowest pollutional concentration. This is due in part to a portion of the flush of the trunk sewer being absorbed by the interceptor before it reaches capacity. As discussed, when the interceptor does reach capacity, the main trunk sewers overflow directly to the lake without mixing with the interceptor contents. Thus, during rainfall runoff periods, the overflow from 67th Street consists primarily of stormwater runoff and presently discharged sewage. The mean values for some of the basic parameters of 67th Street were: total solids - 486 mg/l, suspended solids - 280 mg/l, total BOD - 75 mg/l, dissolved BOD - 22 mg/l, total COD - 236 mg/l, dissolved COD - 79 mg/l, and total phosphorus - 3.1 mg/l. Here again the dissolved BOD to total BOD was low, with 70 percent of the BOD being in the particulate form.

The overflow at 59th Street appeared to contribute the smallest volume of overflow. The pollutional concentration in this flow was equal or slightly higher than that at 67th Street. The mean values were: total solids - 597 mg/l, suspended solids - 405 mg/l, total BOD - 96 mg/l, dissolved BOD - 30 mg/l, total COD - 338 mg/l, dissolved COD - 85 mg/l, and total phosphorus - 2.4 mg/l. At this location the trunk sewer terminates at the intersection of the invert of the trunk sewer and crown of the interceptor. The outfall sewer to the lake for use during rainfall runoff periods is located above the trunk sewer center elevation and thus the head of sewage must be above this level before overflow will occur. This reason along with the small area served accounted for the apparent small amount of overflow. At this site the most frequently occurring overflow period was 0 to 2 hours, while at the others it was 0 to 4 hours.

The 57th Street overflow had the highest pollutional concentration of the three outfall sites. The volume of overflow at this location was estimated to always be larger than at 59th Street, but never approached the apparent magnitude of 67th Street. The overflow mechanism at this location is identical in form to that of 67th Street. The reason for the higher pollutional concentrations is not fully understood. Possible contributing factors include the fact that the dry weather flow in this trunk sewer contains a high amount of industrial wastewaters which may contribute to the high suspended solids and BOD concentration. Also, a great portion of the stormwater runoff comes from the highly urbanized downtown area which has a high coefficient of runoff and a high amount of surface contaminants. The mean values at this location were: total solids - 898 mg/l, suspended solids - 590 mg/l, total BOD - 172 mg/l, dissolved BOD - 22 mg/l, total COD - 56 mg/l, and total phosphorus - 8.9 mg/l.

From the results of the data analysis on the overflow quality it was felt that the original hypothesis for the implementation of a high rate biological adsorption process for treating combined sewer overflow had been affirmed. Other conclusions from this phase of the project included:

1. Qualitative proof that the pollutional load caused by combined sewer overflow to Lake Michigan was significant.

2. The oxygen demanding materials, based upon the BOD and COD tests, were found to be almost 80 percent in the particulate form. This is the type of material which the biosorption system is designed to remove at very high efficiencies.

3. By reducing the volume of combined sewer overflow, and thus the suspended solids and coliform loadings, the incidence of closing the Kenosha public beaches on Lake Michigan should be greatly reduced.

4. A plan for accurate flow measurement of the remaining combined sewer overflow had to be implemented during operation of the demonstration system to determine the amount of untreated overflow still occurring, and to determine if there is unused capacity within the interceptor.

SECTION VII - EVALUATION PROGRAM AND RESULTS

PLAN OF OPERATION

The evaluation program to determine the effectiveness of the demonstration system as an alternative to combined sewer separation was conducted between April 12, 1972 and October 1, 1973. The program was divided into three general portions. These were 1) determine if the concept of using the contact stabilization process on a periodic basis was feasible, 2) if the process was feasible, what was the optimum range of operation for the various process variables, and 3) how effective was the 75,700 cu m/day (20 mgd) system in reducing the volume of combined sewer overflow when operated at maximum flow rate conditions. It was not possible to complete the above three tasks simultaneously. For instance, during the first portion of the study program when the feasibility of the process was being studied, the process variables were held within the normal range of operation commonly associated with the contact stabilization process as much as possible. During the second portion of the study when the variables were tested over a wide range of values, it was often necessary to run the system much below the 75,700 cu m/day (20 mgd) design rate in order to examine longer contact and reaeration times and higher mixed liquor concentrations. In addition, for the majority of the evaluation program the demonstration system was not started until Envirex Inc. employees had arrived from Milwaukee at the WPCP.

For purposes of determining the treatment efficiency of the demonstration system a thorough sampling and laboratory analysis program was developed. Samples were taken at the effluent end of the grit tank, from the contact tank, from the stabilization tank, from the Parshall flume at the demonstration system final clarifier, and from the Parshall flume at the dry weather clarifier. Table 4 indicates the sample location and the characteristics measured. The laboratory analytical techniques used are described in Appendix A.

Process variables for study during the evaluation program included MLSS concentration, contact time (based on total hydraulic flow), reaeration time, and stabilization time. The purpose of running the system at different values for the above parameters was to determine the range of satisfactory operation, the results of which would be useful in future designs, and to determine if there were specific values at which system operation was unsatisfactory. Listed below are the process variables for study and the intended ranges of operation.

Table 4. SAMPLING POINTS AND ANALYSES PERFORMED

Characteristics Measured	Sample location				
	Grit tank	Contact tank	Stabilization tank	Final clarifier	Dry weather clarifier
pH	x	x	x	x	
Settleable solids	x			x	
Total solids	x			x	
Total volatile solids	x			x	
Suspended solids	x	x	x	x	x
Suspended volatile solids	x	x	x	x	x
Total BOD	x		x	x	x
Dissolved BOD	x			x	
Total organic carbon	x		x	x	
Dissolved organic carbon	x			x	
Total Kjeldahl nitrogen	x			x	
Total phosphates as P	x			x	
Total coliform	x			x	
Fecal coliform	x			x	
COD	x (1973)			x (1973)	

x = analyses performed

VARIABLE	UNIT OF MEASURE	RANGE FOR STUDY
MLSS Concentration	mg/l	500-5,000
Contact Time	minutes	10-30
Reaeration Time	hours	1-7
Stabilization Period	days	>0-15

The other parameters of operation which were to be determined each time the demonstration system was used are listed below.

Volume Treated
Average Flow Rate
Average Sludge Transfer Rate
Transfer Rate as a % of Raw Flow
F/M Ratio
Air Supply
Stabilization Tank Turnovers
Clarifier Surface Overflow
Clarifier Detention Time (based on total flow)
Clarifier Turnovers
Clarifier Solids Loading

No specific number of system runs or rigid factorial experimentation procedures were developed for the evaluation program. Instead, it was planned to use the system as many times as necessary until the removal efficiencies being achieved were consistent and statistically valid. The evaluation of the process variables would be carried out in a random fashion until it was evidenced that certain operating values of specific variables significantly affected process performance.

METHOD OF OPERATION

When it appeared that a rainfall event was imminent, or when a rain began, personnel at the WPCP would telephone Envirex Inc. or the home of designated Envirex employees and inform them of the possible demonstration system run. Travel time from Milwaukee to the Kenosha WPCP averaged one hour. Also, an additional off-duty WPCP operator would be called in. Not until Envirex personnel arrived at the WPCP would the demonstration system be started. This procedure was continued during all of 1972. However, during 1973 the operating personnel at the WPCP had become familiar enough with the equipment to start the system themselves after notifying Envirex personnel. Although the demonstration system had provisions for automatic start-up, this feature was never used. It could not be used in 1972 since operation of the system was delayed until Envirex personnel arrived, and in 1973 the WPCP would start the system in anticipation of the high flow rates before these rates actually occurred.

For all runs, except when a test was being conducted at a specific flow rate, or when mechanical problems with the raw flow pump developed, the rate of flow for treatment by the demonstration system occurred in the following manner. A wet well is located below the pump room at the Kenosha WPCP. Flow from the interceptor sewer passes through the comminutors directly into this basin. The raw flow pumps (including the demonstration system pump) are paced off of this level. When the level exceeds 1.13 m (3.7 ft) in depth the pumps are running at maximum capacity and it is necessary to begin closing the hydraulic gate at the entrance to the WPCP. This gate is held in a partially closed position until the level begins to drop, at which time the gate is opened. As the wet well level drops, the pumps are automatically throttled down to lower pumping rates.

Although provisions were made to allow the demonstration system to treat only the flow in excess of 87,055 cu m/day (23 mgd), the system was not run in this manner. Instead, the demonstration system was run in parallel with the DWP. This meant that when flows to the WPCP exceeded the DWP capacity, the demonstration system would be started and the entering flows would be split about equally between the DWP and demonstration system.

At maximum flow periods of 162,755 cu m/day (43 mgd), 87,055 cu m/day (23 mgd) would be going to the DWP and 75,700 cu m/day (20 mgd) to the demonstration system. As the flow to the WPCP began to decrease, say to 113,550 cu m/day (30 mgd), approximately 56,775 cu m/day (15 mgd) would be going to each system. When the total incoming flow was reduced to 87,055 cu m/day (23 mgd) the demonstration system was then taken out of service and the total 87,055 cu m/day (23 mgd) went to the DWP (which now made use of the demonstration system final clarifier).

Sampling of the process was done by a combination of manual and automatic sampling. Automatic samples were located at the grit tank, contact tank, and demonstration system final clarifier. At the beginning of a run a sample would be manually taken from the grit tank and then automatically every half hour afterward. The sample was drawn from the effluent trough of the grit tank which fed a 91.44 cm (36 in.) diameter conduit leading to the contact tank. After the demonstration system was taken out of use, the samples were proportioned according to the raw flow rate at the time of sampling. The automatic sampler at the contact tank would be started while the tank was filling and would sample every 30 minutes. The samples were composited on an equal volume basis. The sample was taken at one end of the contact tank just inside the overflow weir, approximately 0.30 m (1 ft) below the surface. The automatic sampler at the final clarifier would take its first sample approximately 45 minutes after the system started, and then every 30 minutes thereafter. The sample was drawn from the side of the flume, approximately 0.61 m (2 ft) upstream of the beginning of the throat. The samples were composited in the same manner as the grit tank samples.

Manual samples were taken at 30 minute intervals for the transferred sludge from the stabilization tank. A tap was located on the discharge pipe from the transfer pump from which an equal volume of sample was drawn and composited. The manual sampling of the dry weather final clarifier during operation of the demonstration system was done at 30 minute intervals also. The samples were drawn from the throat of the Parshall flume and composited on an equal volume basis.

The automatic samplers were built specifically for the project by Envirex. The sampler intakes consisted of a 0.30 m (1 ft) section of 1.27 cm (0.5 in.) diameter pipe with 0.64 to 0.95 cm (0.25 to 0.375 in.) holes drilled in the pipe. The intake was connected by garden hose to a positive pressure pump having a flow rate of about 0.19 l/sec (3 gpm) at a suction lift of 4.57 m (15 ft). A sample distributing arm rotated in a 360° circle depositing samples in 24 separate one liter plastic bottles. The time between samples could be varied between 3 to 60 minutes. The actual pumping cycle would only take three minutes with the lines first being purged followed by the filling of the sample bottles and then a final purging. The samplers were enclosed in wooden frames. A photograph of a typical sampler is shown in Figure 24.

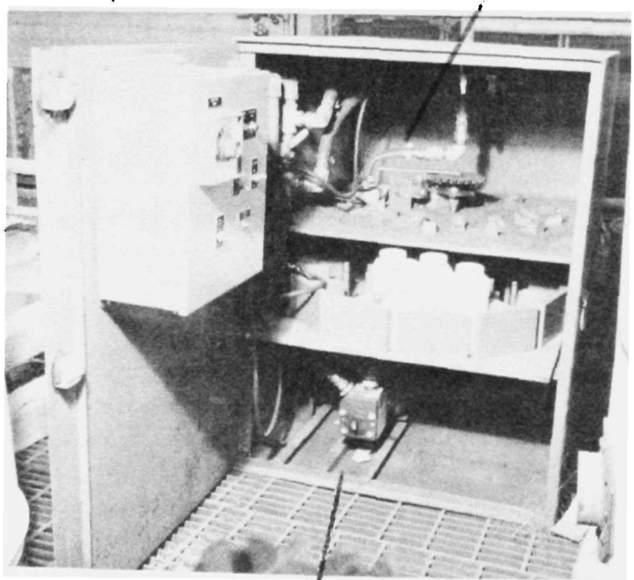

Figure 24. View into typical sampler constructed for use in conjunction with the demonstration system

At the end of a run the samples would be transported to the laboratories in Milwaukee. If the samples were brought to the laboratory on any day between the hours of 7 am and 7 pm analyses would begin on all samples immediately. If the samples were brought in between 7 pm and midnight, the pH would be measured and the BOD and coliform analyses started. The remaining sample would be refrigerated until the following morning. If the samples were brought in after midnight they would be refrigerated until the following morning when all the analyses would be started.

Problems with the automatic flow rate controlling equipment persisted throughout the entire project. During 1972 it was impossible during dry weather to balance the WAS flow rate into and out of the stabilization tank. As a result, the stabilization times were actually the length of time the sludge was held in the stabilization tank between runs. During 1973 the flow balancing equipment worked periodically. When it was working, the stabilization time was based on a dynamic condition, where sludge was continually being fed into and taken out of the tank, and the stabilization time was calculated as the hydraulic detention time.

Problems controlling the RAS rates and sludge transfer rates during use of the demonstration system also occurred. It was determined that the sludge transfer rates were being properly paced as a percentage of the raw flow, but that the RAS rates to the stabilization tank were not. This was overcome by setting the RAS controller in the manual mode of operation and continuously setting the rate to correspond with the sludge transfer rate.

The air supply controller to the contact tank also operated erratically. Therefore for the majority of the runs the air supply was controlled manually and usually set at a rate of 52.5 to 56.0 cu m/min (1,875 to 2,000 cfm) which proved to be sufficient for good mixing and satisfactory removals.

It was fortunate that it was possible to override the automatic controllers by placing the malfunctioning equipment in the manual mode of operation. This prevented having to shut the system down for repairs or abandoning the various aspects of the evaluation program. However, operating the equipment in the manual position put an added burden and mental strain on the operator who had to continually check flow rates to ensure that all flow rates were in proper balance.

The provision for borrowing sludge from the DWP was never necessitated. During every run there was a sufficient volume of sludge in the stabilization tank when the system started up to provide a sufficient reaeration time during operation.

Although eight aerators were present in the stabilization tank, only six were used for the majority of the runs in 1972, and only four in 1973. During dry weather, only 4 aerators were used in 1972 and only

2 aerators in 1973. Measurement of DO levels and calculation of oxygen uptake rates (OUR) indicated that this amount of aeration was sufficient. This is further discussed later in this report.

A total of 49 runs occurred during the evaluation program. In this period over 681,300 cu m (180,000,000 gal.) of potential overflow were treated and sampled during 278 hours of operation. The demonstration system was operated from April 12, 1972 thorugh August 17, 1972, at which time it was forced out of service because the raw flow pump associated with the demonstration system was being used by the DWP while its 75,700 cu m/day (20 mgd) raw flow pump underwent extensive maintenance. The system was put back into operation during the later part of October and then taken out of service permanently for the winter on November 6, 1972. The system was put back into operation during the week of March 19, 1973 and operated until October 1, 1973. Only the times when Envirex personnel were present and sampling was use of the system considered a run. There were times during the two year evaluation period when the WPCP used the system during dry weather to relive high flow conditions in the sewers. Also, the system occasionally was operated for a period of time by WPCP personnel after sampling had stopped in order to draw the hydraulic grade in the interceptor down to a low level. However, these uses of the system were not recorded as part of the evaluation program. Data tables from all 49 runs are contained in Appendix C, Tables C-1 to C-49. These tables contain all pertinent operating circumstances, laboratory data, and removal efficiencies. Following is an analysis and discussion of this data.

FEASIBILITY STUDY

After the first 19 runs of the demonstration system, between April 12 and August 16, 1972, it was felt that the system had proven that the concept of using the contact stabilization process on a periodic basis was feasible. During these 19 runs no attempts were made to determine the conditions under which performance would not be satisfactory. Instead, the process operating values were kept within conservative limits and emphasis was placed on achieving good removal efficiencies. Sludge transfer rates varied between 25-55% of the raw flow, contact times were 12.1 to 19.6 minutes based on total flow, and reaeration times ranged from 1.0 to 3.08 hours. Because the stabilization time during this period was actually mandated by the time between storms, stabilization periods of up to 15 days were experienced. Actual operating conditions can be found in Appendix C. The ranges of operation for various process variables from runs 1-19 are listed in Table 5.

A total of 277,062 cu m (73,200,000 gal.) were treated during these first 19 runs. The weighted mean concentrations for the raw flow and effluent samples are given in Table 6. The removals achieved, 93% for suspended solids, 83% for total BOD, and 81% for TOC were equal to what had been

Table 5. RANGES OF OPERATION, RUNS NO. 1-19

Operating variable	Range
Volume treated	6,805-28,607 cu m (1.798-7.558 mg)
Average flow rate	52,233-73,429 cu m/day (13.3-19.4 mgd)
Sludge transfer percentage	25-55
MLSS	975-5,370 mg/l
Contact time	12.1-19.6 minutes
F/M	0.64-5.25
Stabilization time	0.5-15.0 days[1]
Reaeration time	1.0-3.08 hours
Surface overflow rate	35.3-51.3 cu m/day/sq m (864-1,256 gpd/sq ft)
Clarifier solids loading	56,120-363,560 g/day/sq m (11.5-74.5 lb/day/sq ft)

1. Static conditions

Table 6. OPERATING RESULTS, FIRST 19 RUNS

Parameter	Units	Weighted mean raw concentration[1]	Weighted mean final concentration[2]	Percent removal
Suspended solids	mg/l	332	24	93
Suspended volatile solids	mg/l	144	14	90
Total solids	mg/l	696	458	34
Total volatile solids	mg/l	269	141	48
Total BOD	mg/l	107	18	83
Dissolved BOD	mg/l	25	8	68
Total organic carbon	mg/l	117	22	81
Dissolved organic carbon	mg/l	23	17	26
Kjeldahl nitrogen as N	mg/l	11.6	6.2	47
Total Phosphate as P	mg/l	4.8	2.6	46

Parameter	Units	Geometric mean raw concentration[1]	Weighted mean final concentration[2]
Total coliform	#/ml	26,632	2,416
Fecal coliform	#/ml	2,006	450

1. Raw sample taken after grit tank.
2. Final samples taken prior to chlorination.

anticipated and were considered satisfactory. Even higher percentage removals could have been achieved if the raw sample had been taken prior to grit removal and the final sample taken after chlorination. A grab sample of the raw flow to the grit tank during Run No. 43 had a suspended solids concentration of 517 mg/l. The effluent sample had a concentration of 387 mg/l, indicating a removal of 130 mg/l across the grit tank. However, since the project objective was to measure the true efficiency of the contact stabilization process in treating potential combined sewer overflows, sampling was done at the specified locations.

STUDY OF PROCESS VARIABLES

Of the next 30 runs, 18 were conducted under test conditions to determine what operating conditions would not produce satisfactory results. Also, the ability of the system to perform for long durations of time was tested. After Run No. 31 was completed the demonstration system was left running for a total of 108 hours. Twice during this period the system was sampled to determine treatment efficiency. These sampling periods constitute Runs No. 32 and 33. Run No. 37 was similar, with the system running a total of 58 hours. Two sampling periods during this duration constituted Runs No. 38 and 39.

Listed below are the test runs and a description of the test conditions for each run. Complete operating conditions can be found in Appendix C.

Run No.	Test Conditions
20	Low sludge transfer percentage to obtain low MLSS concentration and long reaeration time.
21	Low sludge transfer percentage to obtain low MLSS concentration and long reaeration time.
22	Only one contact tank compartment to obtain shorter contact time; treated primarily dry weather flow.
23	Treatment of dry weather flow only; no rainfall.
27	High sludge transfer percentages to obtain high MLSS concentration.
28	Low sludge transfer percentage to obtain low MLSS concentration and long reaeration time.
29	Only one contact tank compartment to obtain a shorter contact time.
30	Only one contact tank compartment and a low sludge transfer percentage to obtain a short contact time, a low MLSS concentration, and a long reaeration time.

Run No.	Test Conditions
31	Only one contact tank compartment, a high sludge transfer percentage to obtain a short contact time, a high MLSS concentration, and a short reaeration time.
32	High sludge transfer percentage to obtain a high MLSS concentration and a short reaeration time. This was a continuation of run No. 31, sampling took place from 39.2 to 43.2 hours after the start of Run No. 31.
33	High sludge transfer percentage to obtain a high MLSS concentration and a short reaeration time. This was a continuation of Run No. 31, sampling took place from 87.2 to 90.7 hours after the start of Run No. 31.
34	Low sludge transfer percentage to obtain a low MLSS concentration and a long reaeration time. Only one contact tank compartment to obtain a shorter contact time.
35	Only one contact tank compartment to obtain a shorter contact time.
37	This was essentially a run under normal conditions, however, it began another long duration run.
38	This was an extension of Run No. 37 with sampling taking place from 5.8 to 10.6 hours after the start of Run No. 37.
39	This was an extension of Run No. 37 with sampling taking place from 56.2 to 58.6 hours after the start of Run No. 37.
40	High sludge transfer percentage to obtain a high MLSS concentration and a short sludge reaeration time.
41	High sludge transfer percentage to obtain a short reaeration time.
42	High sludge transfer percentage to obtain a high MLSS concentration. Only one contact tank compartment to obtain a short contact time.

It is obvious that since the return sludge transfer is set as a percentage of the raw flow, a change in the raw flow rate automatically changes the reaeration time and contact time. This point exemplifies one of the basic problems encountered during the test program. Almost all of the process variables were interrelated, and changing one operating condition caused many others to be changed. For instance, at a constant flow rate, if it were desired to see the effect of a higher MLSS concentration the return sludge ratio would be increased. However, in addition to increasing the MLSS concentration, the contact time would be shortened, the reaeration time would be shortened, and the solids loading on the final clarifier would be increased.

The removal efficiency data from the test storms was studied following completion of the test program and Runs No. 20, 21, 23, 28, 30 and 34 and 42 were found to have unsatisfactory performance. Effluent concentrations of greater than 30 mg/l suspended solids or BOD were nominally chosen as the cutoff point for satisfactory performance. Of the seven runs which produced unsatisfactory results, five of the runs had basic similarities. Runs No. 20, 21, 28, 30 and 34 all had sludge transfer percentages of less than 20% and MLSS concentrations of 2100 mg/l or less. All five had reaeration times greater than four hours, as compared to the mode reaeration time of 1 to 3 hours for all runs. This is an example of the interdependence of the process variables since the low MLSS concentrations are a result of low sludge transfer percentages which cause the long reaeration times unless a very small volume of sludge is present in the stabilization tank.

The reason for the poor performance during Run No. 23 was attributed to a period of solids washout in the final clarifier. The raw flow pump was allowed to pump at maximum capacity (approaching 94,625 cu m/day (25 mgd)) resulting in SOR's of 65.3 cu m/day/sq m (1600 gpd/sq ft) and solids loadings of over 366,000 g/day/sq m (75 lb/day/sq ft) based upon the average MLSS concentration. When the flow rate was reduced below 75,700 cu m/day (20 mgd) the effluent quality improved, however, the effluent composite sample included the high suspended solids concentration during the washout period.

The unsatisfactory results from Run No. 42 were due to a poor settling sludge that plagued the DWP and demonstration system during the later part of 1973. The poor settling characteristics of the sludge were evidenced by the DWP laboratory results which showed poorer removal percentages beginning in June 1973 when compared to 1972 and sludge volume indices well above 100. This forced the DWP to keep flow rates to the secondary plant during dry weather under 75,700 cu m/day (20 mgd) to prevent solids washout. Run No. 40 in June 4, 1973 saw a solids washout of the DWP clarifiers when the demonstration system went into operation. The same problem occurred during Runs No. 41, 42, 43, 44, 47 and 48. During Runs No. 42, 44, 47 and 48 solids washout occurred from the demonstration system final clarifier also. After the demonstration system was put into operation the DWP clarifiers would produce good quality effluent for up to two hours before washout would occur. The demonstration system would usually begin washing out after about three hours. These occurrences point out the high degree of dependence that the demonstration system has on the quality of sludge being produced in the DWP. The relationship of the DWP and the demonstration system is further discussed later.

The two tests of extended continuous use of the demonstration system, Runs No. 31, 32, and 33, and Runs No. 37, 38 and 39, were performed to determine the ability of the system to perform over long periods of time. This was important to determine since this system may eventually find application in a storage/treatment scheme where the bulk of the overflow will be held in storage and fed back to the treatment process over a long period of time. The efficiency of the system as the duration of operation continued is shown below.

Run No.	Hours into Operation	Effluent SS, mg/l	Percent Removal	Effluent BOD, mg/l	Percent Removal
31	0-6	27	76.5	12	77.3
32	39.2-43.2	17	81.5	7	87.2
33	87.2-90.7	17	81.5	11	85.5
37	0-2.5	26	92.6	17	81.3
38	5.8-10.6	21	89.1	16	92.5
39	56.2-58.6	22	85.1	15	86.0

The consistency of effluent concentration throughout the entire duration of these runs is an encouraging indication as to the system's ability to generate a high quality viable sludge when operated for long periods.

OPTIMUM TREATMENT CONDITIONS

The results from the tests concerning the process variables had only indicated that at low MLSS concentrations (<2100 mg/l) and high reaeration times (>4 hours) process efficiency may falter. However, during the evaluation period the condition of the sludge in the stabilization tank was constantly studied during dry weather periods between demonstration system runs. The main purpose of the sludge study was to see if the degradation of the physical properties of the sludge in the stabilization tank could be used to determine the maximum stabilization time. Section VIII contains a description and discussion of these studies. One of the conclusions drawn from the sludge studies was that 5 days appeared to be the maximum stabilization time before the viability of the sludge became questionable.

To further examine the validity of choosing the optimum ranges of operation based upon visual inspection of the data, step-wise regression analysis was carried out. Data from Runs No. 23, 42, 44, 47 and 48 was omitted, since these were the runs during which solids washout occurred. Run No. 49 was not included since the laboratory data was not available at the time of analysis. Although none of the regression indicated very good correlations, the step-wise regression technique did show which independent variables had the most significant effect on the dependent variables. Table 7 contains a list of the variables used, the independent and dependent variables, the resultant equations showing the significant independent variables in order of importance, and the multiple correlation coefficients.

Table 7. RESULTS OF STEP WISE REGRESSION ANALYSIS

Variable Name	Number
Effluent BOD concentration, mg/l	1
Effluent SS concentration, mg/l	2
Percent BOD removal	3
Percent SS removal	4
Raw BOD concentration, mg/l	5
Raw SS concentration, mg/l	6
F/M ratio	7
Stabilization time, days	8
Surface overflow rate, gpd/ft^2	9
Reaeration time, hours	10

Dependent Variable	Independent variables
1	5,7,8,9,10
2	6,7,8,9,10
3	5,7,8,9,10
4	6,7,8,9,10

Equation	Multiple correlation coefficient
1 = 1.60(7) + 0.92(8) + 9.1	0.670
2 = 2.43(10) + 1.83(7) + 13.9	0.544
3 = 0.081(5) - 1.0(8) - 1.3(7) + 80.6	0.745
4 = 0.02(6) - 0.97 (10) - 0.7(7) + 87.1	0.691

The resultant equations do indicate that as the F/M ratio, stabilization time, and reaeration time increase, the effluent concentrations increase and the percentage removals decrease. The indication that percentage removals of BOD and suspended solids are most significantly influenced by raw concentrations may mean that the system has a constant effluent level that it can attain and is not altered by higher or lower raw concentrations.

Based upon the test storms, the sludge studies, regression analysis, and personal operating experience, ranges of variable operation were chosen as being acceptable for satisfactory performance by the demonstration system. These values are given in Table 8.

Table 8. OPERATING VALUES FOR SATISFACTORY PERFORMANCE

Operating variables	Units	Value
MLSS concentration	mg/l	>2100
Reaeration time	hours	1-4
Stabilization time	days	$\leq$ 5
Contact time	minutes	> 10

Although an optimum contact time range was not specifically determined, it is obvious that any time below 10 minutes would probably not provide sufficient mixing. It can be assumed from the discussion in Section V on contact stabilization process theory and from general knowledge of the activated sludge process that longer contact times will provide for additional removal of the soluble organics present. However, since the purpose of the contact stabilization process is to reduce the size of aeration facilities, and since satisfactory organic removals were achieved under those conditions, contact times greater than 20 minutes are not warranted in this application.

Oxygen supply, like contact time, was not found to have a limiting minimum value in either the contact tank or stabilization tank. Air supply rates as low as 4.4 cu m/kg BOD applied (72 cu ft/lb BOD applied) in the contact tank, and theoretical oxygen transfer rates as low as 227 kg/hr (500 lb/hr) in the stabilization tank during system operation resulted in satisfactory performance. The maximum OUR measured in the stabilization tank during system operation was 152 kg/hr (335 lb/hr) and during the stabilization period between runs it was 157 kg/hr (340 lb/hr). This made is possible during the evaluation program to reduce the number of aerators to 4 during operation and to 2 during periods between operation. It is estimated that an air supply rate of 56 cu m/min (2,000 cfm) to the contact tank and a theoretical oxygen transfer supply fo 250 kg/hr (550 lb/hr) are sufficient to guarantee satisfactory performance at Kenosha. The volume of sludge needed to be stored in the stabilization tank between runs is only that needed to provide a reaeration time of at least one hour when the demonstration system goes into operation. Therefore, if it is assumed that the raw flow rate will be 75,700 cu m/day (20 mgd) and a sludge transfer rate of 40%, or 30,280 cu m/day (8 mgd), will be used, the needed sludge volume for one hour of reaeration would be 1,270 cu m (333,000 gal.). At flow rates less than 75,700 cu m/day (20 mgd) or transfer rates less than 40%, the resulting reaeration time would be longer than one hour.

Using the design criteria in Table 8, the 49 demonstration system runs were scanned to determine which ones fell within those operating ranges, excluding the runs when solids washout occurred. Thirty of the runs satisfied the above conditions. These were Runs No. 2, 3, 8, 9, 11, 12, 14-17, 19, 24-27, 29, 31-33, 35-41, 43, 45, 46, and 49. The results of these runs were compiled in order to determine what type of performance can be expected from the demonstration system while being operated within the acceptable levels. Shown in Table 9 are the arithmetic mean raw and final concentrations, arithmetic mean percent removals, and ranges of values encountered. These runs represent a treated volume of 403,102 cu m (106,500,000 gal.) and 163 hours of system operation. The mean effluent vales and mean percentage removals represent the degree of treatment that can be expected from operation of the demonstration system.

RELATIONSHIP TO DRY WEATHER PLANT

A most important aspect of the project was to determine the effect of the demonstration system on the DWP. This effect was measured in two ways. The first was to calculate the improvement in DWP performance because of the additional facilities available during dry weather. The second was to determine if the DWP would be upset due to the drastic changes in flow that the DWP would experience when the demonstration system was put into and taken out of service.

Use of the demonstration system final clarifier by the DWP was continuous, except when the demonstration system was treating potential combined sewer overflow. The surface area of the new final clarifier, 1,431 sq m (15,400 sq ft) is equal to 90% of the total surface area of the three DWP final clarifiers. Therefore, during dry weather the flow is split with approximately 50% of the flow going to the new clarifier and 50% to the three other clarifiers. This increased clarification area significantly reduced the SOR and increased the final settling times. Table 10 contains a comparison of effluent quality data from 1970, the last full year without the extra clarifier, and 1972, the first full year with the clarifier. Although the average secondary flow rate increased from 61,697 cu m/day (16.3 mgd) to 73,808 cu m/day (19.5 mgd), the SOR's decreased by 37% and the removal efficiencies for BOD and suspended solids increased by 15% and 37%, respectively.

Table 9. PERFORMANCE FOR 30 RUNS AT ACCEPTABLE OPERATING LEVELS

		Raw		Final		Percent removal	
Parameter	Units	Arithmetic mean	Range	Arithmetic mean	Range	Arithmetic mean	Range
Suspended solids	mg/l	299	92- 920	23	7- 66	90.4	80.2-97.3
Suspended volatile solids	mg/l	148	50- 337	13	0- 54	90.0	76.7-100.0
Total solids	mg/l	685	483-1265	464	360-631	29.2	0.0-64.7
Total volatile solids	mg/l	252	103- 650	130	75-185	41.6	0.0-78.7
Total BOD	mg/l	119	44- 383	16	4- 38	84.8	64.5-89.8
Dissolved BOD	mg/l	31	5- 65	7	1- 21	72.1	20.0-96.6
Total organic carbon	mg/l	117	43- 295	23	14- 41	76.5	46.7-91.2
Dissolved organic carbon	mg/l	29	9- 51	15	5- 31	39.7	5.3-83.3
Kjeldahl nitrogen as N	mg/l	13.70	6.55-22.00	7.6	2.70-12.50	43.7	12.6-63.5
Total phosphate as P	mg/l	4.64	1.92-12.04	1.8	0.46- 4.95	58.6	0.0-86.0

Parameter	Units	Raw[a] geometric mean	Final[b] geometric mean
Total coliform	#/ml	31,038	3,726
Fecal coliform	#/ml	2,238	443

a. Raw samples taken from grit tank.
b. Final samples taken prior to chlorination.

Table 10. EFFECT OF DEMONSTRATION SYSTEM CLARIFIER ON KENOSHA WPCP PERFORMANCE

Parameter	1970	1972
Average secondary flow rate	61,696 cu m/day (16.3 mgd)	73,808 cu m/day (19.5 mgd)
Average surface overflow rate	39.1 cu m/day sq m (958 gpd/sq ft)	24.7 cu m/day/sq m (605 gpd/sq ft)
Percent BOD removal	82	94
Effluent BOD concentration, mg/l	17	6
Percent suspended solids removal	64	88
Effluent suspended solids concentration, mg/l	44	15

Another advantage of the demonstration system final clarifier being integrated into the DWP is the allowance of more frequent and lengthy maintenance and cleaning of the DWP clarifiers. Before the new clarifier was added, taking one of the clarifiers out of service would cause hydraulic overloads on the two other clarifiers and in some cases cause bypassing. However, the new clarifier allows up to two of the DWP clarifiers to be out of service at one time without any change in normal operating procedure. Also, the 94,625 cu m/day (25 mgd) raw flow pump affords the same flexibility in operation to the pumping plant as the clarifier does to the rest of the plant. The value of the additional pump was best exemplified during the period in 1972 when the DWP's 75,700 cu m/day (20 mgd) raw flow pump became inoperative and had to be taken out of service for repair and extensive maintenance.

At the onset of the evaluation program there was great concern over the effect of doubling the hydraulic flow to the three DWP clarifiers within minutes after the demonstration system went into operation. Typical circumstances would have a dry weather flow of 75,700 cu m/day (20 mgd) being split with 37,850 cu m/day (10 mgd) going to the new clarifier and 12,490 cu m/day (3.3 mgd) to each of the DWP clarifiers. This would result in a SOR of 24.1 cu m/day/sq m (590 gpd/sq ft) in the DWP clarifiers. When a run began, a total flow of up to 87,055 cu m/day (23 mgd) could be shifted to the DWP clarifiers if the demonstration system was also running at capacity. This would increase the SOR to 55.1 cu m/day/sq m (1350 gpd/sq ft) and more than double that solids loading on the clarifiers.

During Runs No. 1, 2, and 3, the DWP clarifiers were upset when the demonstration system was put into operation. Examination of DWP operational data revealed that the DWP was carrying an MLSS concentration of 5,000-6,000 mg/l. The DWP then reduced the MLSS concentration to 3,000 mg/l and the DWP clarifiers were no longer upset when the demonstration system went into operation. This condition lasted until the later part of 1973 when the poor settling sludge caused problems. Effluent quality from the DWP during operation of the demonstration system is given in Appendix C. Of the remaining 20 runs in 1972, Runs No. 4-23, DWP clarifier data was taken for all runs except Run No. 17. During these 19 runs the DWP clarifier sampled had an average suspended solids and BOD concentration of 15.3 mg/l and 17.3 mg/l, respectively.

At the time of this report the reasons for the poor settling quality of the DWP sludge have not been fully determined. However, there were some DWP operating differences between 1972 and 1973. In January of 1973 pickle liquor ($FeSO_4$) addition to the primary sedimentation effluent began in an effort to improve phosphorus removal. In July, addition of a non-ionic polymer to the mixed liquor feed channels was started. The polymer was added in an attempt to improve the settling characteristics of the sludge which had gradually deteriorated during the year. During the first three months after polymer addition began no significant improvement in settling characteristics was apparent. Whether the addition of pickle liquor was the cause of poor settling is not known, however, the effect of the poorer settling sludge is readily apparent from the solids washouts that occurred in both the DWP and demonstration system clarifier periodically during 1973. What this points out is the fact that the effectiveness of the demonstration system process is directly dependent upon the quality of sludge being produced by the DWP. It is the DWP sludge which is wasted to the stabilization tank to provide the needed source of biological solids when the demonstration system begins operation. Only after the demonstration system has been operated for many hours will the stabilization tank have completed enough turnovers so that the sludge in use is actually that produced by the demonstration system. Therefore, the general statement can be made that future applications of this process can only be expected to perform to a degree directly proportional to that of the treatment plant that they are integrated with.

Another concern of the evaluation program regarding the effect on the DWP was the disposition of the sludge being produced by the demonstration system. However, at no time during the evaluation program did the extra sludge being produced cause a problem. As a matter of fact, tracing of the solids proved to be difficult. Assuming that an average run would treat 13,248 cu m (3.5 million gal.) removing 3,977 kg (8,760 lbs) of suspended solids and producing another 663 kg (1,460 lbs) of solids, these extra solids could easily be absorbed by the demonstration system without any noticeable changes. For instance, if it is assumed that the volume of sludge in the bottom of the clarifier and in the stabilization tank does not change during a run, the additional solids will increase the sludge concentration by only 1,200 mg/l. Considering that the RAS and stabilization tank sludge concentration is usually above 10,000 mg/l, this amount is not significant. If it is assumed that the sludge concentration does not increase, but that instead the sludge blanket in the clarifier increases in depth, this increase would amount to only 0.32 m (1.06 ft) assuming a 1% sludge concentration.

If the sludge concentration does increase in the stabilization tank and in the clarifier blanket, these extra solids will eventually end up at the sludge thickening facilities by way of being pumped from the stabilization tank. However, during the stabilization period some of the new formed solids will be destroyed by aerobic digestion (see Section VIII). Even if no solids destruction occurred, the increased loading on the thickeners would only amount to 465 kg/day (1,025 lb/day) at a WAS rate of 378 cu m/day (100,000 gpd). If the result of the extra solids is an increase in sludge blanket depth, normal DWP operating procedure would call for an increase in the WAS rate over the next few days until the blanket was back down to normal level. In either of the above cases it is apparent that, although extra solids are produced by the demonstration system and must be disposed of, the method of delivering the solids to the thickening facilities in a continuous manner over a period of days prevents any sludge handling problems.

Some indication of where the solids do go was given by the two periods of long duration, continuous operation of the demonstration system, Runs No. 31-33, and 37-39. In both of these events the solids concentration in the stabilization tank increased significantly from the first hours of operation until the end of operation. An increase from 11,400 mg/l to 14,600 mg/l occurred between the first hours of operation, Run No. 31, and the 90th hour of operation, Run No. 33. An increase from 11,750 mg/l to 21,900 mg/l occurred between the first hours of operation, Run No. 37, and the 58th hour of operation, Run No. 39. No discrete samples of the stabilization tank sludge were analyzed during a normal run of 4-5 hours. This type of analysis would have shown how the sludge concentration actually changed with time as a run progressed.

If the demonstration system is to be used only during periods of high flow conditions as a result of stormwater runoff or peak dry weather flow, then the existing method of sludge handling is satisfactory. If the demonstration system were to be put in series with a storage facility, and allowed to operate for long periods of time while emptying the storage facility, additional provisions will have to be made for wasting sludge. Since the increase in sludge concentration cannot continue indefinitely, a conventional sludge wasting system will be needed to control the MLSS concentration. At the present time when the demonstration system goes into operation, the final clarifier is isolated from the DWP return sludge and waste sludge facilities. Thus, it will be necessary to allow WAS to be drawn from the demonstration system final clarifier in a continuous manner and handled by the DWP facilities.

ANCILLARY STUDIES

BOD:COD:TOC Relationship

Beginning in 1973 COD analyses were performed on the raw and final samples to determine the BOD:COD, BOD:TOC, and COD:TOC relationships. There were three reasons for this. One reason was to determine the relationship of the BOD:COD ratio in combined sewer overflows. The second reason was to see if a strong BOD:TOC correlation was evident. The third reason was to examine the relationship between the COD and TOC.

Data from the raw flow samples for all 26 runs in 1973 was used and data from the effluent samples for all runs except the 4 solids washout occurrences was used. The arithmetic means of the ratios from each run were then calculated. An attempt was also made at fitting the data to some form of an equation which would be applicable if a direct linear relationship did not exist. Table 11 contains the means, standard deviations, and equations of best fit.

The BOD:COD ratio of 0.324 for the raw flow is less than might be expected for normal dry weather municipal wastewater. As is the case with many combined sewer overflows, the solid particles which can be oxidized may be complex or difficult to biochemically oxidize in the 5 day BOD period. The equation that has shown to fit the BOD:COD ratio best in the range of values studies indicates that as the concentrations increase, the COD increase is much greater than the BOD increase, with the result of a continual lowering of the BOD:COD ratio. The equation for the BOD:TOC ratio is of the same form as the BOD:COD equation, indicating a similarity of pattern between the TOC and COD. The fact that the BOD:TOC ratio was not linear and the lack of a good fit for a curvilinear equation makes predictions of the BOD based upon TOC measurements unrealiable in this case.

The COD:TOC ratio for the raw flow samples was found to be linear and to have a good fit. The mean value of 2.66 found for the ratios is very near that often used in estimating COD concentrations based upon TOC measurements. It appears that it would be possible to make an estimate of the COD values in the raw flow based upon TOC measurements, for the range of values encountered.

The ratios of BOD:COD and BOD:TOC in the effluent samples are reduced significantly, as would be expected from a biological treatment process. This indicates higher removal percentages for BOD than TOC and COD, which is verified by the treatment efficiency data. The resultant equations

Table 11. MEAN AND STANDARD DEVIATIONS FOR BOD/COD, BOD/TOC, AND COD/TOC RATIOS

Raw	Mean	Standard deviation	Equation of best fit	Multiple correlation coefficient
BOD/COD[1]	0.324	0.079	BOD = BOD/(2.08 + .0037 x COD)	0.858
BOD/TOC[2]	0.896	0.252	BOD = TOC/(0.729 + .004 x TOC)	0.795
COD/TOC[3]	2.660	0.440	COD = 42.1 + 2.26(TOC)	0.933
Final				
BOD/COD	0.279	0.078	BOD = -4.5 + 0.365(COD)	0.803
BOD/TOC	0.606	0.184	BOD = 0.17 $(TOC^{1.38})$	0.771
COD/TOC	2.200	0.390	COD = 99.5 - (1056.6/TOC)	0.750

1. BOD values from Runs No. 35 and 37 and COD value from Run No. 48 not used.
2. BOD values from Runs No. 35 and 37 and TOC value from Run No. 42 not used.
3. COD value from Run No. 48 and TOC value from Run No. 42 not used.

show that BOD values increase at a faster rate than the COD or TOC values as the concentrations in the effluent become higher. However, the equations have relatively poor correlation coefficients and do not follow any logical pattern. Generally it appears that the ratio relationships in the effluent are much less predictable than those from the raw flow data.

During Run No. 41, 20 day BOD tests were run on the raw and effluent samples in addition to the usual 5 day tests. This was done in an effort to further understand the nature of combined sewer overflow oxygen demand potential. The results from these analyses are as follows:

	5 day, mg/l	20 day, mg/l
Raw total BOD	186	449
Raw dissolved BOD	60	95
Final total BOD	23	99
Final dissolved BOD	5	32

The ratios of the 20 day BOD to 5 day BOD for the raw and final are, respectively, 2.4 and 4.3. Since the BOD measurements were only taken at 5 and 20 days it was not possible to plot the BOD versus time. Thus, it cannot be readily determined if the high 20 day readings are due to low deoxygenation rates of the carbonaceous demand or to nitrification. However, this does bring up the point that perhaps the 5 day BOD measurement is not a good measurement for determining the oxygen demand potential of storm generated discharges. In future endeavors, evaluating the quality or impact of storm generated discharges, it is recommended that the kinetics of the oxygen demand be determined rather than using the assumptions commonly associated with municipal wastewaters.

One of the characteristics that was responsible for the satisfactory treatment performance was the low percentage of BOD and TOC occurring in the dissolved form. For the 49 raw flows sampled, the arithmetic mean BOD, TOC, and dissolved BOD and TOC concentrations are listed below.

BOD concentration, mg/l	112
Dissolved BOD concentration, mg/l	31
Percent dissolved	27.7
TOC concentration, mg/l	116
Dissolved TOC concentration, mg/l	28
Percent dissolved	24.1

These low percentages of dissolved BOD and TOC make the type of treatment process used by the demonstration system very practical. These characteristics would probably also lend well to some form of physical-chemical treatment. Interestingly, the 30 runs at the operating conditions found to be satisfactory achieved an arithmatic mean of 72.1% dissolved COD and 39.7% dissolved organic carbon removal. The 72.1% removal of dissolved COD is encouraging. However, the 39.7% dissolved organic carbon removal is unsatisfactory and not fully understood considering that the total COD and TOC removals were comparable.

Time Series Analyses

During two runs, Nos. 43 and 47, the discrete raw samples were analyzed separately for TOC and suspended solids concentration to examine the change in influent quality as a run progressed. The effluent samples from Run No. 43 were also analyzed separately in an attempt to see if raw flow characteristics influenced effluent quality. The results from Run No. 43 are shown in Figure 25. The time scale used for the final effluent samples has been moved up by 1.5 hours. This is approximately the process detention time through the system. Also plotted is the flow rate, corresponding to the effluent time scale. A first flush phenomenon did appear to be present in this run. No correlation is apparent between raw concentration and effluent concentration for either suspended solids or TOC concentrations. However, the suspended solids and TOC concentrations in the effluent appear to have the same variance with time. The increase in flow between 8:30 pm and 9:30 pm corresponds with increases in effluent suspended solids and TOC concentrations. Since this was the only run during which raw and final samples were analyzed separately, no further speculation is warranted.

In addition to the discrete samples from the raw flow during Run No. 47, discrete samples were also taken from the effluent of the DWP primary sedimentation facilities. This was carried out in an effort to determine how much removal was occurring as a result of pure settling and how much as a result of biological action. Figure 26 contains raw and effluent suspended solids and TOC concentrations plotted versus time. The detention time through the primary sedimentation tanks was approximately two hours at the flow rates experienced. The raw and effluent time scales have been constructed to coincide with the two hour detention time. The figure does indicate that a significant amount of the removal occurring in the demonstration system is accomplished by settling alone. However, it is also evident from the range of effluent values in the figure that the biological activity that takes place in the contact process of the demonstration system is necessary to achieve acceptable effluent quality.

ECONOMIC CONSIDERATIONS

Operating Costs

The integration of the DWP and demonstration system made it impossible to monitor the specific costs being incurred by the demonstration system. For costs such as pumping, chlorination, and sludge disposal, the 1972 costs as developed by the Kenosha WPCP, which included the flows treated

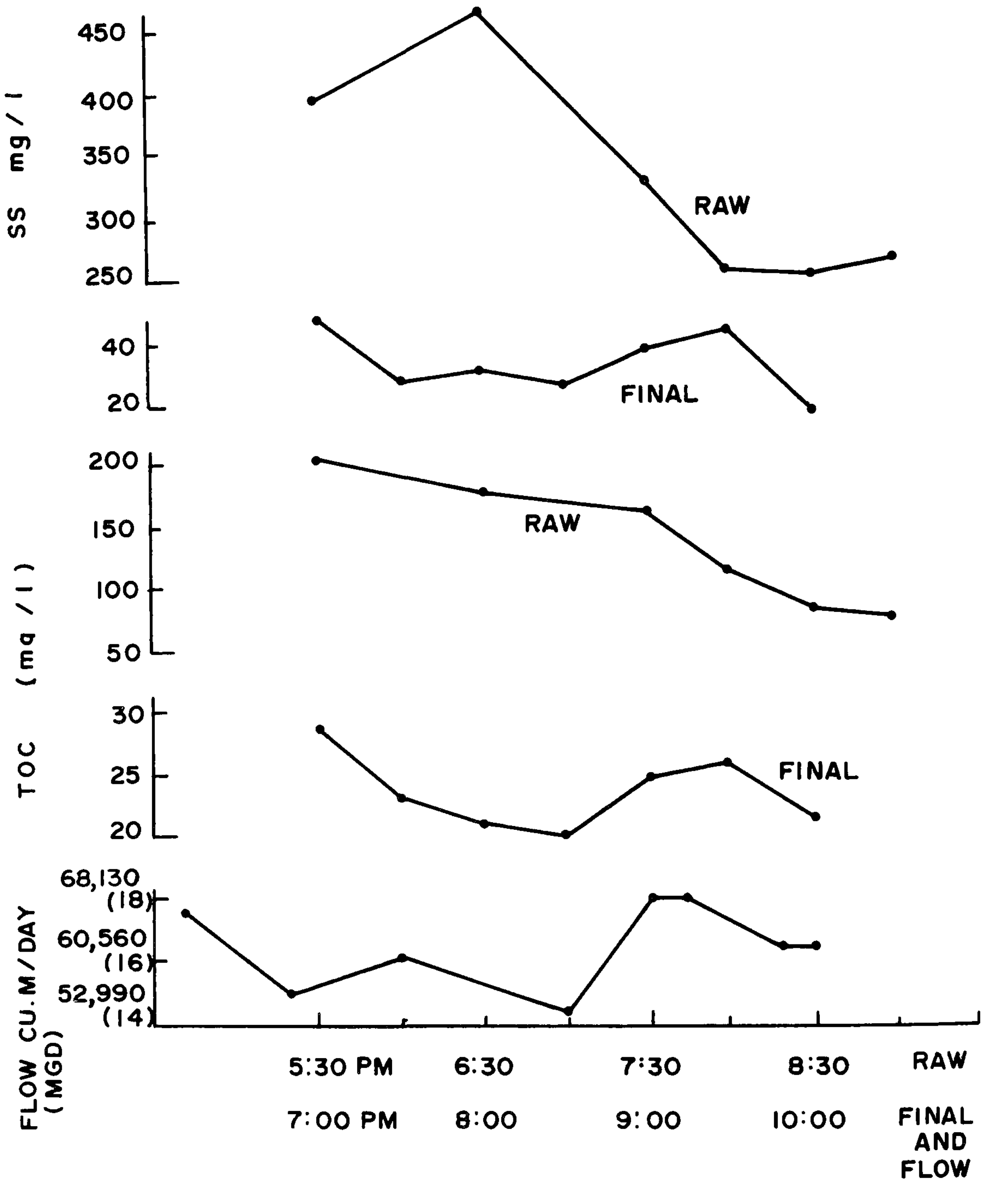

Figure 25. Raw and final sample quality variance with time

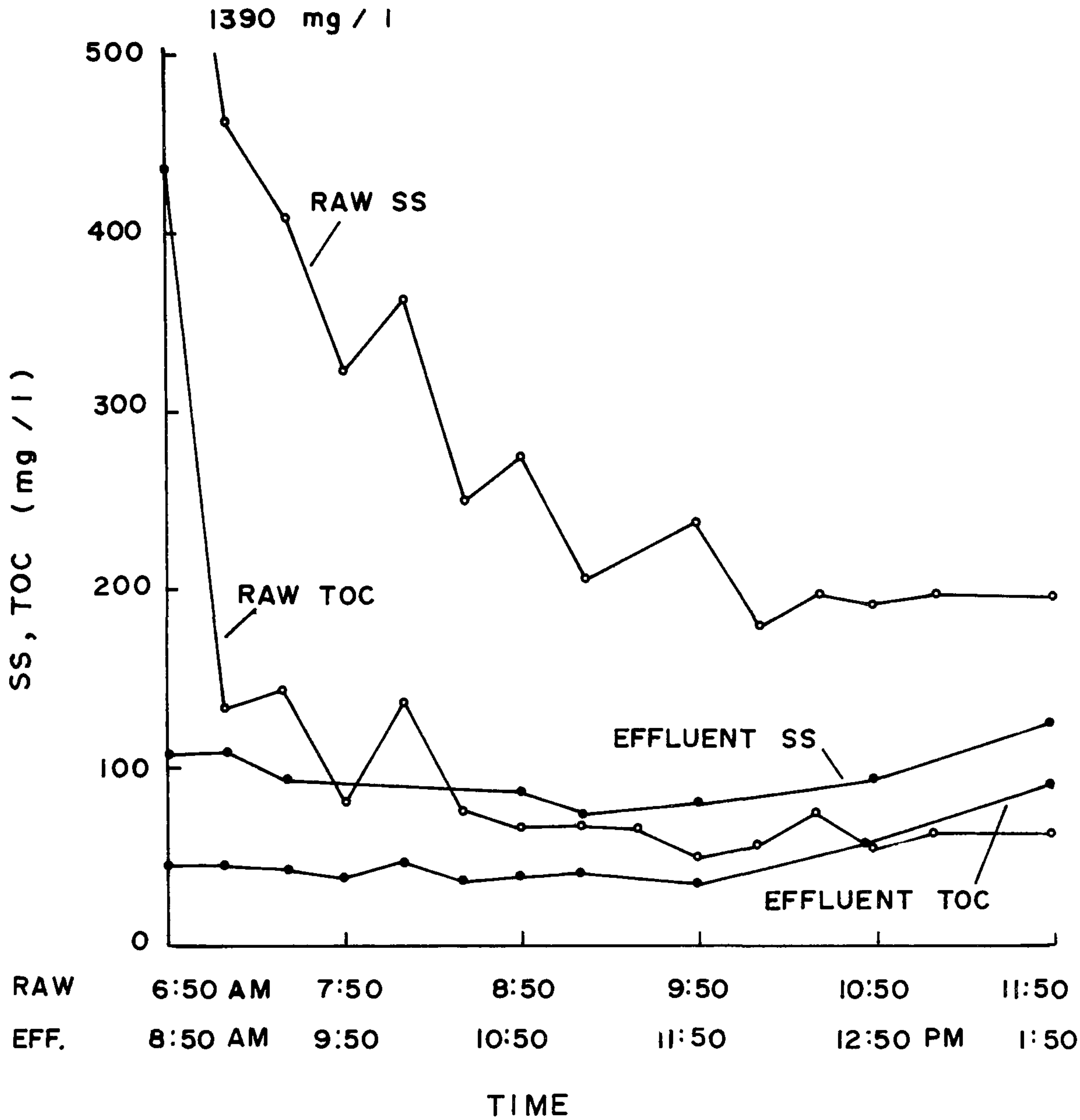

Figure 26. Raw and effluent sample quality variance through the dry weather plant primary sedimentation tanks during Run No. 47

by the demonstration system, were used. The biggest cost of the demonstration system is the power for aeration during dry weather. This is the power needed for operation of the aerators in the stabilization tank between runs. Even if the demonstration system was not used during an entire year, the power costs for the stabilization tank, based on two aerators running at 90% efficiency and an electrical cost of $0.02/kwh, would be $14,500.00. During operation of the demonstration system, actual aeration costs are only 0.199¢/cu m (0.754¢/1000 gal.) using four aerators and including the cost of air to the contact tank. The more the demonstration system is used, the lower the aeration costs become in terms of ¢/cu m (¢/1000 gal.), neglecting equipment depreciation. Below is a list of aeration costs for various hours of operation during a year. These costs include aeration during demonstration system operation, during periods between demonstration system use, the aeration to the contact tank, and assume a treatment rate of 75,700 cu m/day (20 mgd).

Hours of operation	Total aeration, cost/year	¢/1000 gal.	¢/cu m
0	$14,515.00	∞	∞
100	$14,979.59	17.9	4.73
300	$15,906.77	6.4	1.69
600	$17,298.54	3.5	0.93
1000	$19,153.90	2.3	0.61

These costs indicate that the most advantageous use of the process would come about if the demonstration system were in series with a storage unit which would capture more potential overflow and allow the system to treat a greater volume of flow over a longer duration.

Pumping costs are estimated to be 0.422¢/cu m (1.6¢/1000 gal.), chlorination at 0.005¢/cu m (0.02¢/1000 gal.) and sludge disposal at 0.793¢/cu m (3.0¢/1000 gal.). These are also the exact operating costs incurred by the Kenosha WPCP in 1972. Labor costs are estimated to be 0.661¢/cu m (2.5¢/1000 gal.) based on a full time operator present during system operation. Note that none of the above costs include the capital costs of facilities or equipment. If the system were to be operated for 300 hours in one year the total operating costs would be 3.567¢/cu m (13.5¢/1000 gal.). Figure 27 has been constructed to show the operating costs for various hours of operation during a year.

Total Costs

The total cost of system operation, which includes both operating and capital recovery costs, is even more sensitive to the number of hours of usage per year than the operating costs alone. Amortizing the construction and engineering costs of $1,178,779.11 over 25 years at 7% interest yields an annual cost of $101,151.03. Below is a listing showing what the capital recovery costs are in ¢/cu m (¢/1000 gal.) for various hours of operation in a year.

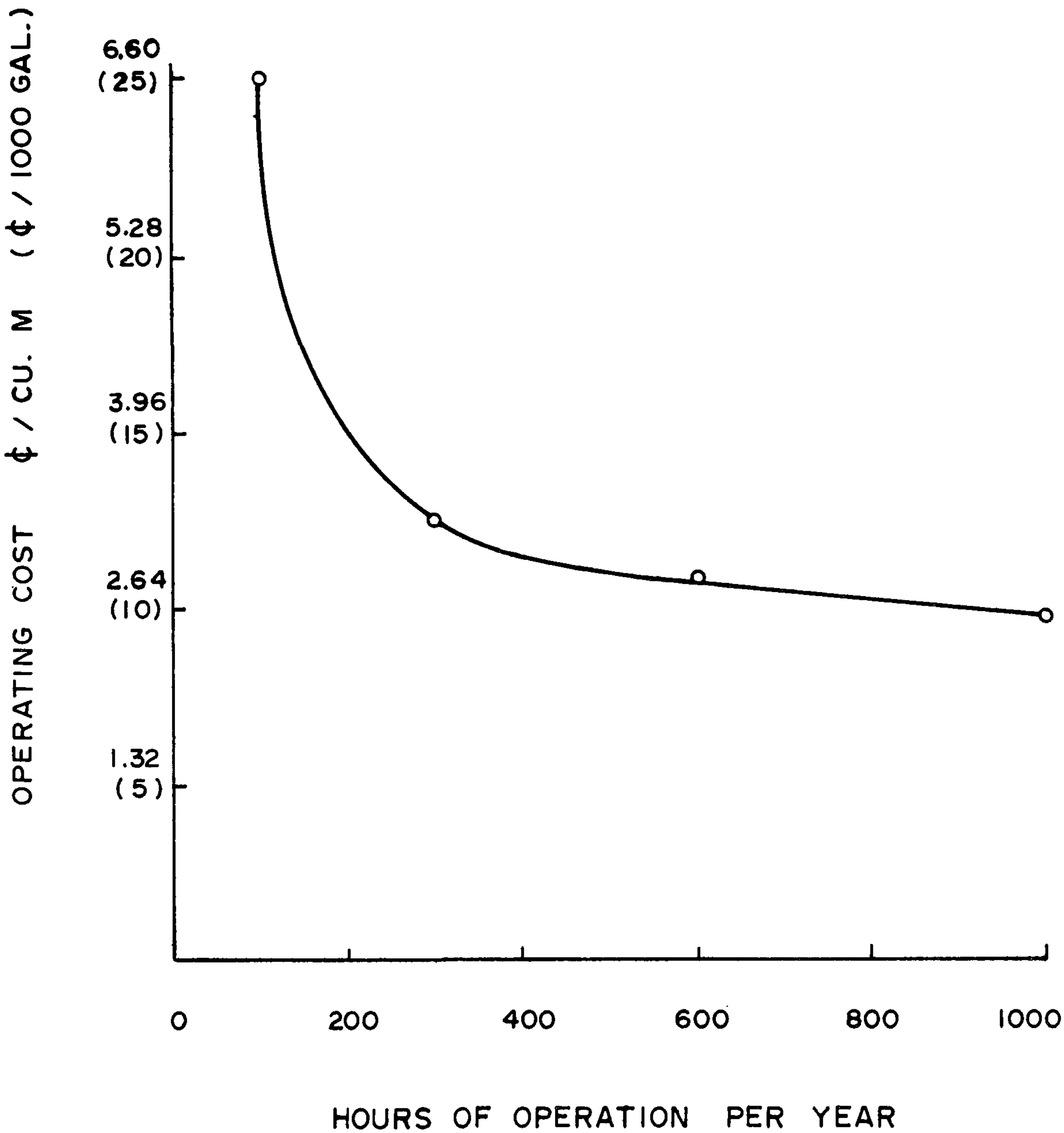

Figure 27. Estimated demonstration system operating costs versus hours of operation

Hours of operation	Capital recovery cost ¢/cu m	(¢/1000 gal.)
100	32.0	121.2
300	10.6	40.4
600	5.3	20.2
1000	3.2	12.1

Adding the above capital recovery costs to the previously developed operational costs, the total costs for system operation are developed and listed below.

House of operations	Total costs ¢/cu m	(¢/1000 gal.)
100	38.6	146.2
300	13.9	52.9
600	8.2	31.2
1000	5.8	22.1

The total cost data shows the obvious economic desirability of using this type of system in series with some type of flow attenuation or storage scheme which allows treatment over a longer period of time.

OVERFLOW VOLUMES

Based upon the inaccurate overflow data from 1970 and the indication of the relatively small amounts of overflow occurring at 57th and 59th Streets, it was decided to abandon the 57th and 59th Street sites during the evaluation program and to relocate the 67th Street site. At the beginning of 1972 the flow meauring equipment at 67th Street was moved back to the overflow mechanism itself. The end of the bubble tube was located 0.305 m (1.0 ft) behind and 0.305 m (1.0 ft) below the top of the overflow drum. Using the formulae for broad crested weirs, the level over the weir was converted into flow rates and volumes. The only raingage used during the evaluation program was the one at the Kenosha WPCP.

The amount of potential overflow treated by the demonstration system was determined by adding together the average flow rate through the demonstration system and the average flow rate through the DWP. This rate was reduced by 87,055 cu m/day (23 mgd), the maximum capacity of the DWP before the demonstration project, and then converted into a volume based upon the hours of operation of the demonstration system. Actually, the absolute amount of potential overflow treated would be larger in many cases since many of the rainfalls occurred during the early morning hours when the DWP flow could be as low as 56,775 cu m/day (15 mgd). Thus, the amount of potential overflow being treated would be 30,280 cu m/day (8 mgd) plus whatever the flow rate through the demonstration system was. However, since this capacity was present before the demonstration system was installed, only the flow in excess of 87,055 cu m/day (23 mgd) was considered. The amount of potential overflow treated was then expressed as a percentage of the total overflow by dividing these values by the amount of overflow occurring at 67th Street plus the overflow treated. Although this percentage does not take into consideration the overflow at the two other discharge sites, 57th and 59th Streets, it does act as a relative indicator of the effectiveness of the demonstration system in reducing overflow. As this percentage approaches 100, the volume of overflow at 67th Street approaches zero, and the volumes at 57th and 59th Street decrease proportionately.

Using the method of calculation described above, Table 12 has been constructed indicating the percent of potential combined sewer overflow treated. During most of the project the system was not put into operation until an Envirex engineer was present at the WPCP. As a result, overflow began during most of the events before the demonstration system started operation. Therefore, Table 12 contains two columns of percentages. The first column indicates the percentage treated during the entire overflow event regardless of when the demonstration system went into operation, and the second column indicates the percentage treated just during the period while the demonstration system was in operation. The arithmetic means are 57.5% for the entire overflow event and 69.5% for the period while the demonstration system operated. Total rainfall for the 28 events ranged from 0.13 cm (0.05 in.) to 5.74 cm (2.26 in.). Figure 28 contains a plot of the percentage treated during system operation versus total rainfall. Note that these data do not take into consideration rainfall intensity or antecedent conditions in the interceptor sewer, which can greatly affect the volume of overflow.

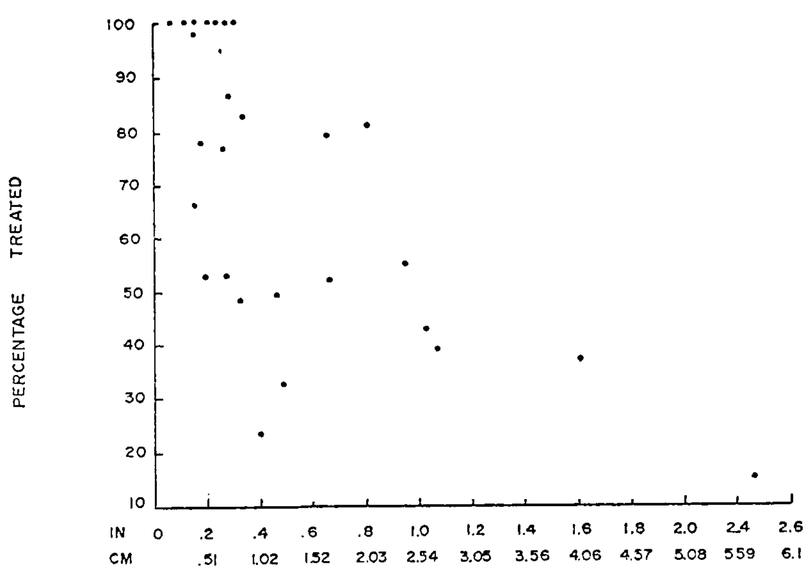

Figure 28. Percentage of overflow treated versus rainfall amounts for 28 events

Table 12. OVERFLOW QUANTITY DATA FROM 1972 AND 1973

Run No.	Rainfall cm	Rainfall in.	Potential overflow treated cu m	Potential overflow treated gal. x 10^6	Total overflow at 67th Street cu m	Total overflow at 67th Street gal. x 10^6	Overflow treated during entire overflow period, percent	Overflow treated during demonstration system operation, percent
1	1.65	(0.65	5,072	(1.34)	10,182	(2.69)	33.2	79.7
2	2.56	(1.01)	10,749	(2.84)	23,656	(6.25)	31.2	42.5
3	5.75	(2.26)	19,531	(5.16)	110,295	(29.14)	15.1	15.6
4	1.02	(0.40)	6,775	(1.79)	23,941	(6.32)	22.1	23.8
5	0.81	(0.32)	5,678	(1.50)	7,305	(1.93)	43.7	48.6
6	0.68	(0.27)	14,837	(3.92)	3,974	(1.05)	78.9	86.9
7	0.64	(0.25)	8,365	(2.21)	10,220	(2.70)	45.0	94.7
9	1.19	(0.47)	7,267	(1.92)	15,254	(4.03)	32.3	32.3
10	0.66	(0.26)	4,920	(1.30	8,365	(2.21)	37.0	53.1
12	4.06	(1.60)	19,909	(5.26)	63,588	(16.8)	23.8	37.1
13	0.38	(0.15)	8,289	(2.19)	13,664	(3.61)	37.8	66.3
14	2.67	(1.05)	10,674	(2.82)	29,674	(7.84)	26.5	39.0
25	0.48	(0.19)	3,936	(1.04)	9,917	(2.62)	28.4	52.9
26	0.64	(0.25)	11,128	(2.94)	11,393	(3.01)	49.4	76.9
27	0.38	(0.15)	4,958	(1.31)	0	(0.00)	100.0	100.0
28	0.66	(0.26)	5,640	(1.49)	0	(0.00)	100.0	100.0
35	0.81	(0.32)	6,737	(1.78)	7,267	(1.92)	48.1	82.9
36	1.65	(0.65)	19,493	(5.15)	20,325	(5.37)	48.9	52.0
37	0.76	(0.30)			0	(0.00)	100.0	100.0
38	0.13	(0.05)	77,971	(20.60)[1]	0	(0.00)	100.0	100.0
39	0.51	(0.20)			0	(0.00)	100.00	100.0
40	2.41	(0.95)	13,702	(3.62)	21,499	(5.68)	38.9	55.3
41	2.03	(0.80)	27,555	(7.28)	7,835	(2.07)	77.8	81.3
42	0.38	(0.15)	5,526	(1.46)	681	(0.18)	89.0	97.9
43	0.64	(0.25)	12,490	(3.30)	0	(0.00)	100.0	100.0
44	0.46	(0.18	7,948	(2.10)	2,839	(0.75)	73.6	78.0
45	0.30	(0.12)	12,793	(3.38)	0	(0.00)	100.0	100.0
AM	1.27	(0.50)					57.5	69.5

1. System ran continuously during three separate rainfalls.
2. AM = arithmetic mean.

Six of the events in Figure 28, those having total rainfalls of less than 1.52 cm (0.6 in.) and treatment percentages of less than 60%, were investigated to determine possible cause for the relatively low treatment percentages. It was found that for three of these events, mechanical problems with the raw sewage pumps presented the treatment of more than 13,550 cu m/day (30 mgd) of flow. The other three events occurred during periods of extremely high dry weather flow in the interceptor sewer which decreased the amount of capacity in the interceptor and the treatment capacity at the plant.

In order to better determine the true effectiveness of the demonstration system in reducing the overflow, eleven runs were examined in which the demonstration system was started prior to, or simultaneously with, the start of overflow. These were Runs No. 9, 27, 28, 36, 37, 38, 39, 42, 44, and the second portion of the rainfall that occurred during Runs No. 14 and 41. The arithmetic mean of the percentage treated for these runs was 74.6%, with the total amount of rainfall ranging between 0.13 cm (0.05 in.) and 1.65 cm (0.65 in.). Five of the storms having total rainfalls of 0.76 cm (0.3 in.) or less resulted in no measured overflow at 67th Street.

Because of the type of overflow mechanism used in Kenosha, it was suspected that discharge to Lake Michigan was occurring before the treatment plant and demonstration system had reached full capacity and before the interceptor sewer was surcharged. This phenomenon was exemplified by Run No. 9 occurring on June 2 and 3, 1972. Anticipating a rainstorm on the evening of June 2, the demonstration system was started two hours and fifty minutes before rainfall began. By the time rainfall began at 1:03 am on June 3, the interceptor level had been lowered to the extent that the wet well level at the treatment plant was down to 0.27 m (0.9 ft), almost three feet below normal operating level. The raw sewage pumps which are paced by this level were discharging less than 56,775 cu m/day (15 mgd). This meant that the interceptor was very near empty, with the only flow in the 189,250 cu m/day (50 mgd) interceptor being the 56,775 cu m/day (15 mgd) of dry weather flow common for this time of the morning.

Between 1:03 am and 1:30 am, 0.74 cm (0.29 inches) of rain fell. At 1:25 am, overflow began at 67th Street and within 15 minutes (1:40 am) the flow level over the dam had reached 83.82 cm (33 in.). However, during this same 15 minute period of time, the wet well level at the treatment plant had only risen to 0.91 m (3.0 ft), and the total flow to the treatment plant was only 113,550 cu m/day (30 mgd), well below maximum capacity. Not until 2:00 am did the flow to the treatment plant exceed the plant's capacity and necessitate partial closing of the gate at the entrance to the wet well. Figure 29 shows the rainfall amount, overflow level and flow rate through the demonstration system between 1:00 am and 2:00 am. Ideally, overflow would begin only after the demonstration system and DWP had reached maximum capacity. The shaded portion above the demonstration system flow rate indicates the unused

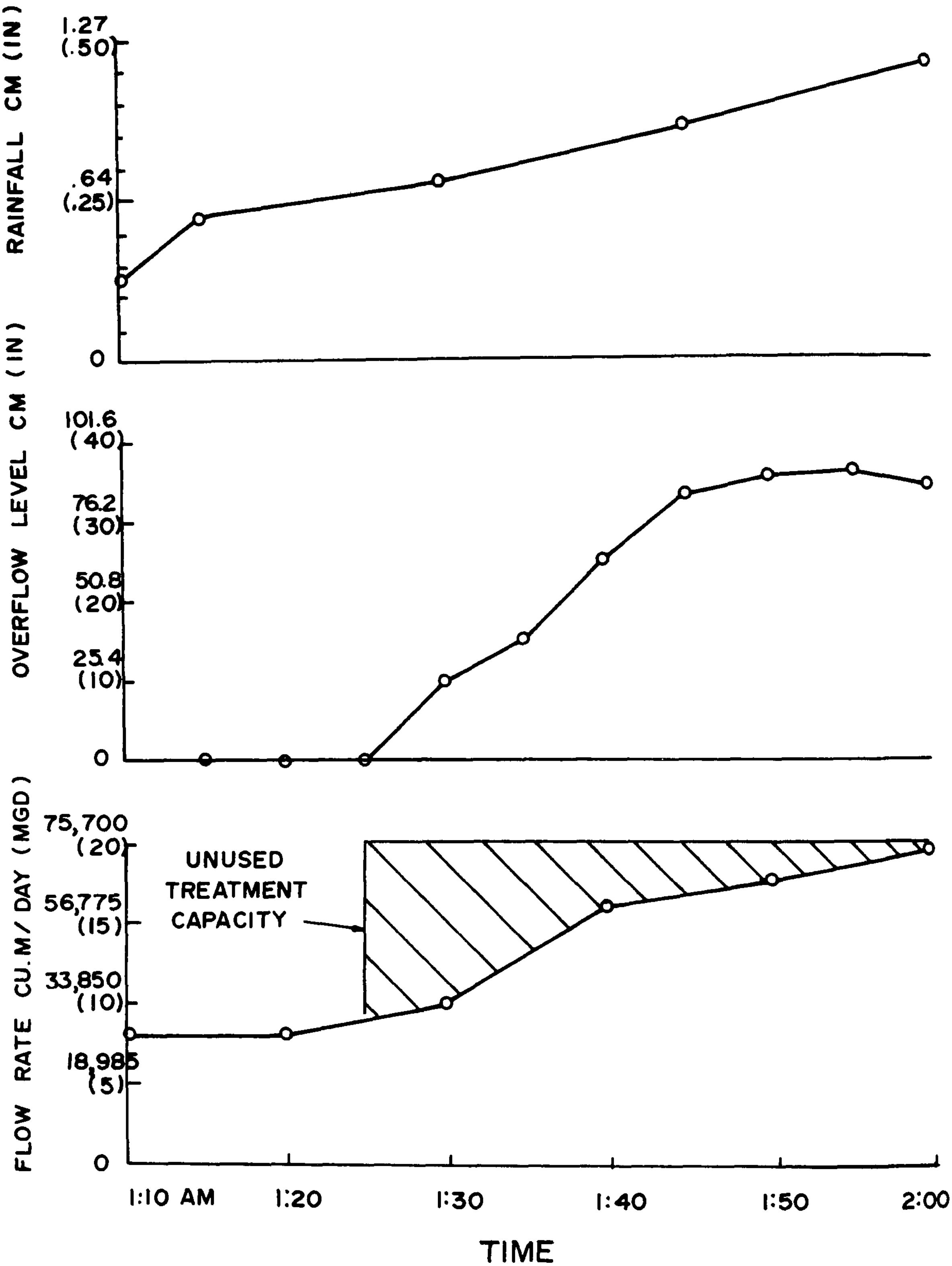

Figure 29. Rainfall, 67th Street overflow level and demonstration system flow rate versus time for Run No. 9

treatment capacity while overflow was occurring. This indicates a need for implementation of some type of device, such as inflatable dams and level sensors, which would guarantee that all flow is diverted to the interceptor until the treatment plant has reached its capacity and the interceptor is surcharged.

The overflow data, especially for the events when the demonstration system was started before overflow began, indicates that under present conditions up to 0.76 cm (0.3 in.) of rain may fall without a resultant overflow. However, because of the type of overflow mechanisms in use and the method of operation during the demonstration project, the following recommendations are made:

1. Some type of mechanism be installed at the overflow points which will ensure that the treatment plant has reached capacity and the interceptor sewer is surcharged before overflow takes place.

2. The demonstration system be put into operation in anticipation of a storm event, guaranteeing maximum possible capacity in the interceptor at the onset of a storm.

3. The amount of overflow still occurring under these circumstances be determined.

4. Based upon the results from No. 3, implement the most economic storage/treatment capacity still needed to completely eliminate combined sewer overflow in Kenosha.

SECTION VIII - STABILIZATION TANK SLUDGE STUDIES

The sludge condition in the stabilization tank was studied during 1972 and 1973. The data collected in 1972 was analyzed separate from that collected in 1973. This separation was necessary because the sludge storage conditions were different during the two periods. In 1972 the tank was filled with WAS from the DWP and held under static conditions until the sludge was needed for wet weather flow operation. During the majority of 1973, WAS from the DWP was continuously pumped through the stabilization tank in order to maintain the sludge in a dynamic state. Bench scale tests utilizing WAS were also carried out during 1973 in order to closely study aspects of aerobic digestion and flotation. The daily procedures and techniques for performing the sludge studies can be found in Appendix D.

SLUDGE BEHAVIOR UNDER STATIC CONDITIONS

Static sludge conditions in the stabilization tank ranged between 2 and 27 days in 1972. The period of time under static conditions is referred to as the sludge age. Three periods were of sufficient duration so as to be studied for changes in sludge characteristics.

The first period was from June 19 to June 26, 1972, a period of seven days. During this period the only parameter monitored regularly was the oxygen uptake rate (OUR). No settling tests were being run and SS and VSS concentrations were checked only twice. The change in the OUR during the period showed a rapid decrease in the OUR between a sludge age of 2 and 4 days and then an increase between 4 and 7 days. The decrease indicated a very rapid stabilization of the sludge. The increase may have been caused by an increase in sludge temperature which caused an increase in the bioactivity. Data from longer periods showed that over an extended period, the initial drop in OUR is drastic but then levels out after about 5-7 days and further decreases in OUR are slight. During this time an increase in temperature may override the expected OUR decrease due to endogenous respiration and give a net result of an increase in the OUR.

The two samples taken for SS and VSS concentration analysis were taken during Run No. 12 on June 19, 1972 and on June 26, 1972. The composite during the run yielded a sludge concentration of 13,575 mg/l SS and 8,110 mg/l VSS. After the seven days the SS concentration was 6,725 mg/l and the VSS concentration was 2,275 mg/l. The reduction in volatile solids percentage, 59.7 to 33.8, indicates that extensive endogenous respiration took place while the sludge was in the static state. The 33.8% volatile solids on June 26 raised doubt as to the usefulness of the sludge for the demonstration system after holding it for seven days. These test results led to the decision to empty the stabilization tank and refill it with a fresh supply of WAS.

The second period of study occurred from July 19 to July 31, 1972, a period of 12 days. During this period, the OUR was monitored daily and the SS and VSS concentrations were checked twice. SS and VSS concentrations were taken only at a sludge age of 1 day and a sludge age of 9 days. The OUR's showed a marked decrease in the bioactivity of the sludge. The decrease reached a maximum at 7 days after which the uptake rate remained fairly constant. An increase in OUR from 8 mg/l/hr at a sludge age of 7 days to 12 mg/l/hr at a sludge age of 8 days showed a direct correlation with the temperature change of 18.5°C to 22.0°C that occurred during that period. This observation reinforced the assumption that the OUR decreased to a minimum in a period of about 5-7 days after which the sludge temperature is mainly responsible for the OUR fluctuations.

The two samples analyzed for SS and VSS concentrations during this period showed the extent of the endogenous respiration taking place in the stabilization tanks. On July 20 the SS concentration was 14,633 mg/l and the VSS concentration was 8,333 mg/l. This resulted in a percent volatile solids of 56.9. After 9 days under static conditions the values were 6,675 mg/l SS, 3,200 mg/l VSS, and percent volatile, 47.9. Taking these results in conjunction with the OUR results, it can be concluded that the viability of the sludge for use in the demonstration system would be insufficient. The period of static detention ended with the occurrence of Run No. 18 on August 2, 1972. The results of the demonstration system using the deteriorated sludge were relatively poor as anticipated: percent BOD removal, 61.2; percent SS removal, 82.7; and percent TOC removal, 64.5.

The third period of study was from August 15 to September 11, 1972, a period of 27 days. The OUR and temperature are shown in Figure 30, the SS concentration, the VSS concentration, and percent volatile suspended solids in Figure 31, and the settling rates, which were measured beginning on August 18, in Figure 32. The OUR once again dropped drastically during the first 7 days of stabilization and then only fluctuated as a function of the temperature. The SS concentration dropped steadily from a value of 16,375 mg/l to 12,825 mg/l after 19 days. This was a reduction of 21.7%. The VSS concentration dropped from 8,775 mg/l to 7,250 mg/l over the period of 9 days that VSS concentrations were monitored. The volatile solids percentage dropped from 53.6 to 51.5. These results showed a 17.5% decrease in the VSS concentration and a 3.9% decrease in the percent volatile solids. Since the first sample was taken at a sludge age of 8 days, the percentages from day zero are higher than those calculated. These observations again reinforce the fact that extensive digestion of the sludge occurs in the stabilization tank and thus the viability of the sludge for use in the demonstration system rapidly decreases.

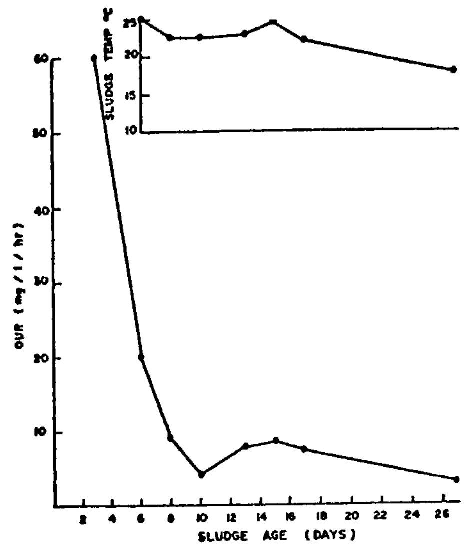

Figure 30. Oxygen Uptake Rate and Sludge Temperature versus Sludge Age for August 18, 1972 to September 1972

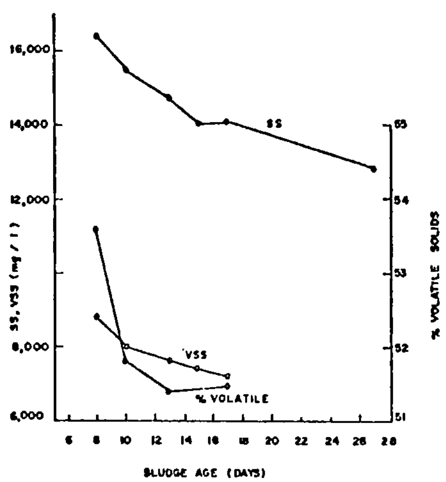

Figure 31. SS, VSS, and Percent Volatile Solids versus Sludge Age for August 18, 1972 to September 11, 1972

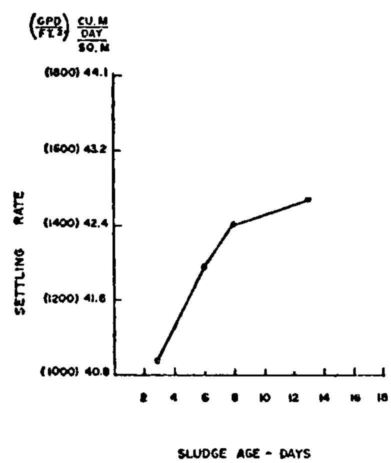

Figure 32. Calculated Surface Overflow Rate versus Sludge Age for August 18, 1972 to September 11, 1972

As stated previously, settling tests were run beginning on August 18, 1972. The graph of the settling rates revealed an interesting point: the settling rate increased as the digestion time increased, however, by observation the supernatant became increasingly more turbid until the point was reached where the settling rate could not be calculated because the interface could not be seen during the settling test. This phenomenon led to the following:

1. The possibility that increased digestion led to fast settling by inert solids which did not produce a clear supernatant.

2. The decision to observe the relationship between settling rate, SVI, and supernatant SS concentration during the sludge studies in 1973.

The following conclusions were drawn from the 1972 sludge studies:

1. After 5 to 7 days it appears the aerobic digestion of the sludge is almost completely achieved.

2. After 5 to 7 days the usefulness of the sludge mass for the demonstration system is doubtful.

3. Sludge appears to settle faster as aerobic digestion proceeds. This may be due to increasing amounts of inert material (i.e., a decrease in percent volatile solids).

CONTINUOUS FLOW THROUGH THE STABILIZATION TANK

Operation of the demonstration system employing continuous flow through the stabilization tank during dry weather began in May of 1973 and continued throughout most of the remaining year. WAS was continuously pumped from the DWP to the stabilization tank. In the tank it was aerated for a period of time, the hydraulic detention time averaged 2.5 days, and then pumped to the DWP sludge thickening flotation unit.

Daily monitoring of the stabilization tank sludge began on May 13, 1973. As in 1972, the sludge temperature, volume in the tank, and OUR were monitored. New parameters were also added in order to better understand what was happening to the sludge. These measurements were mean air temperature, flow rate into and out of the stabilization tank, suspended and volatile suspended solids concentration, plant influent suspended solids concentration (this value was used to calculate a SVI value), mixed liquor settling rate using 750 ml of DWP influent and 250 ml of stabilization tank sludge, suspended solids concentration in the settling test supernatant, and the sludge volume after 30 minutes of mixed liquor settling. From the data obtained the following parameters were calculated: OUR (mg/hr/gm VSS), the hydraulic detention time, the settling rate, and the SVI. Four periods of sufficient duration for study of continuous flow conditions occurred during 1973. Other periods were too short in duration as a result of demonstration system runs occurring close together. In the selection of time periods when continuous flow conditions existed, it was assumed that continuous flow began one sludge age (tank turnover) after the end of static conditions.

The first period studied was from May 16 to May 25, 1973. The OUR (mg/hr/gm) steadily increased during this period. It was expected that this value would remain relatively constant under continuous flow conditions. However, a plot of sludge temperature versus time showed that the unexpected increases in the OUR correlated well with the increases in the sludge temperature. Thus during continuous flow situations the sludge temperature may be an important parameter affecting the viability of the sludge. The effect of the sludge temperature on the treatment potential of the sludge in demonstration process operation is hard to establish because most runs were during the summer months when the sludge temperature was 20°C or above. This point should be considered, however, if the system is used for early spring snowmelts or rains, or late fall rains. As with conventional activated sludge plants, this problem can be handled by increasing the recommended mixed liquor SS concentrations. The settling rate increased, the settling test supernatant SS concentrations decreased, and the SVI's decreased during this period. These results also add to the conclusion that the treatment potential of the sludge was increasing as the sludge temperature was increasing with the beginning of summer conditions. The SS concentration, VSS concentration, percent volatile solids, and the SS concentration of the WAS coming into the stabilization tank were very erratic. These results reveal two facts about the system that should be considered because they constantly appeared throughout the study:

1. The viability of the stabilization tank sludge and thus the potential performance of the demonstration system is almost entirely dependent on the condition of the sludge obtained from the DWP.

2. The WAS characteristics are damped by the stabilization tank because of the similarity to a complete mix situation which exists in the stabilization tank. Therefore, significant changes in the characteristics of the sludge coming into the stabilization tank can be diluted so that the change in stabilization tank sludge is more gradual.

The treatment efficiency by the demonstration system after this dry period indicated very good treatment, therefore the continuous flow system was successful in maintaining a viable solids mass. As shown during 1972, a period of 11 days under static conditions would have resulted in very poor system performance. This underscores the point that the continuous flow system is a major part of the demonstration system and every effort should be made to keep it operable.

The next period of study was from June 28 to July 3, 1973. Data from this period showed decreasing concentrations of SS, VSS, percent volatile solids in the stabilization tank, and a slightly decreasing SS concentration in the WAS coming into the stabilization tank. The settling rate was lower, and the SVI and supernatant SS concentrations higher than those obtained during the first period of testing. Once again the OUR seemed to follow the temperature of the sludge. These results indicated that the sludge monitored during this time was not as advantageous to the demonstration system as the sludge during the first period of study. This deteriorated sludge was used during Run No. 40 on July 3 and did not settle well, resulting in solids being carried out in the effluent.

During this run the three DWP clarifiers also experienced extensive solids washout. This problem of poor setlting sludge continued to plague the demonstration system for the next month and a half and exemplified the dependency of the system on the condition of the sludge supplied by the DWP.

The next period of study for continuous flow was July 9 to July 20, 1973. The data obtained during this period is presented in Table 13 and plotted in Figures 33 to 37. The OUR (Figure 34) showed a drop from 9.30 to 5.80 mg/hr/gm during the first four days of continuous flow conditions, and then a leveling off at a constant value of about 6.0 mg/hr/gm. The consistent values that were recorded after 4 days is what would be expected in a continuous flow situation. The settling test supernatant SS concentration (Figure 35) showed good results after 2 days, the settling rate (Figure 36) showed improvement after 2 days, but the SVI values for this period were all over 100 ml/gm with an average value of 122 ml/gm. The initial rapid changes in the first two days of continuous flow could have been due to the fact the equilibrium conditions were not established immediately. This would also be true for the changes for the OUR. The values obtained after two days indicated 1) the sludge was settling faster, 2) good treatment could be expected, 3) but the volume of the settled sludge was large.

Figure 33 shows 1) the stabilization tank by its mixing action was damping the fluctuations in the WAS SS concentration coming into the tank, 2) the overall pattern of solids decrease in the WAS coming into the tank was reflected in the stabilization tank sludge SS and VSS concentrations, and 3) the percent volatile suspended solids remained fairly constant throughout the period. The study period ended with Run No. 41, which achieved satisfactory removal efficiencies. However, the efficiency was based upon a composite sample from the first four hours of system operation. After about 4 1/2 hours, solids began washing out of all four clarifiers. The explanation of what happened during Run No. 41 refers back to the monitoring of supernatant SS concentration, SVI, and settling rate. The sludge achieved good treatment and settled well but the settled volume was large, therefore, it took up an excessive volume in the clarifier. This volume increased to the point where solids were

Table 13. MEASURED PARAMETERS FOR STABILIZATION TANK SLUDGE
JULY 9 TO JULY 20, 1973

Date	SS, mg/l	VSS, mg/l	Percent volatile	OUR (mg/hr/gm)	Settling rate cu m/day/sq m (gpd/sq ft)	SVI ml/gm	Settling test supernatant SS conc., mg/l	DWP RAS SS concentration, mg/l
7/9	8,230	4,410	53.6	9.30	40.7 (997)	102.7	106	7,600
7/10								7,300
7/11	8,780	4,550	51.8	7.91	30.5 (748)	128.3	54	7,200
7/12								7,200
7/13	9,000	4,790	53.2	5.85	33.2 (814)	121.1	68	8,200
7/14								6,700
7/15								7,400
7/16	8,220	4,370	53.2	5.72				6,500
7/17								7,100
7/18	7,470	3,970	53.1	5.79	40.9 (1002)	121.8		6,400
7/19								6,900
7/20	7,170	3,780	52.7	6.48	46.4 (1138)	116.4	66	6,300
AM[a]	8,145							7,067

a. AM = arithmetic mean.

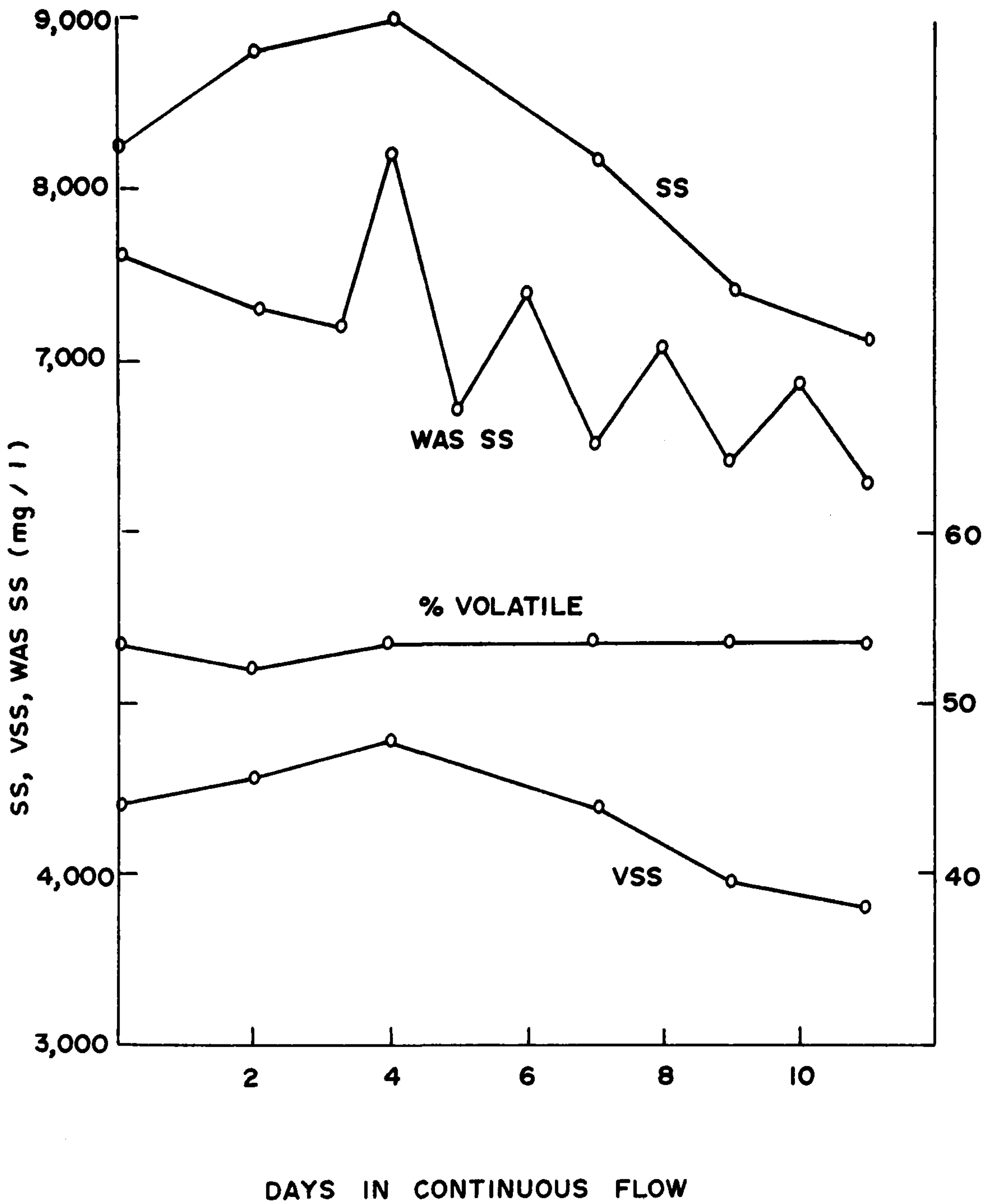

Figure 33. Stabilization Tank Sludge, SS, VSS, and Percent Volatile Solids, and DWP WAS SS versus Days of Continuous Flow for July 9, 1973 to July 20, 1973

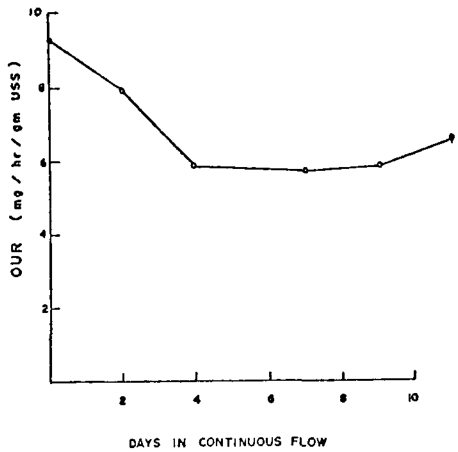

Figure 34. Oxygen Uptake Rate versus Days of Continuous Flow for July 9, 1973 to July 20, 1973

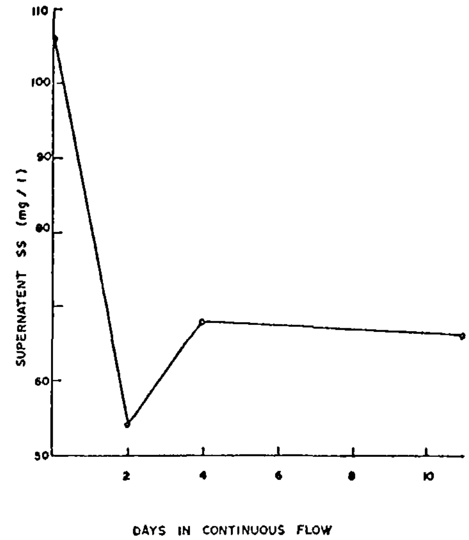

Figure 35. Supernatant SS Concentration versus Days of Continuous Flow for July 9, 1973 to July 20, 1973

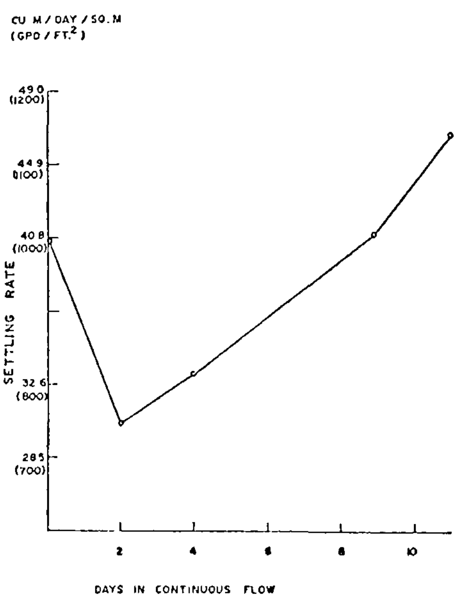

Figure 36. Calculated Surface Overflow Rate versus Days of Continuous Flow for July 9, 1973 to July 20, 1973

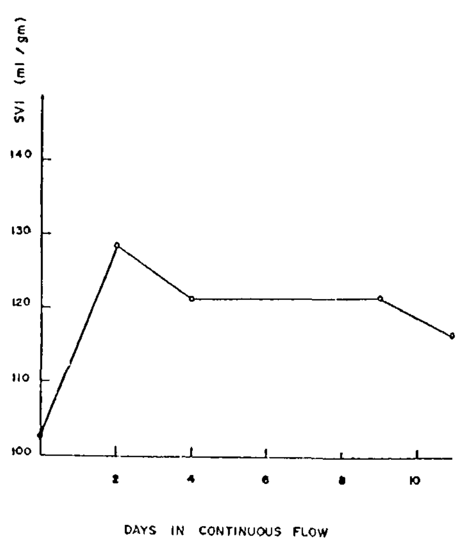

Figure 37. Calculated Sludge Volume Index versus Days of Continuous Flow for July 9, 1973 to July 20, 1973

picked up and carried out in the effluent. This seems to be what happened to both the DWP clarifiers and the demonstration system clarifier. This problem plagued the demonstration system for part of the year because of the condition of the sludge obtained from the DWP.

The last period available for study was August 13 to August 23, 1973. On August 20, or day 7 of continuous flow conditions, the addition of a non-ionic polymer to the DWP mixed liquor was begun in an attempt to improve settling characteristics of the sludge. The SVI remained constant throughout the period as would be expected in a well operating continuous flow system. No change was shown after the seventh day when polymer was added. However, the OUR was approximately 7.50 mg/hr/gm for the first three samples before polymer addition, but after the addition began it dropped to 4.10 mg/hr/gm. The settling test supernatant SS concentration held constant at 117 mg/l for the first three samples, but after polymer addition it increased to 220 mg/l. The three calculated settling rates before addition were 68.1 (1,670), 56.7 (1,390) and 58.3 cu m/day/sq m (1,430 gpd/sq ft) while the day after polymer addition began the settling rate was 52.2 (1,280) and after three days of polymer addition it was 45.9 cu m/day/sq m (1,125 gpd/sq ft).

This data led to speculation that the addition of the polymer may have maintained the SVI. The addition was followed by a reduction of the bioactivity of the sludge as measured by the OUR and the settling supernatant SS concentration. Because of these results the effectiveness of employing the polymer as a solution to the problem of poor sludge should be studied carefully before it is continued. This is another case of the demonstration process being dependent on what was happening to the DWP sludge.

The conclusions after the study of continuous flow conditions in the demonstration system are:

1. The demonstration system is dependent on the condition of the sludge obtained from the DWP. Therefore, the effect on the demonstration system must be considered when changes are made concerning the DWP sludge.

2. The stabilization tank is able to reduce shock changes in the characteristics of the WAS due to its mixing conditions. However, long term changes will be reflected in the quality of the stabilization tank sludge.

3. The average OUR for the study was 6.0 mg/hr/gm.

4. If the continuous flow system is kept in a good operating condition, satisfactory treatment is possible after long periods of dry weather. It has been shown that static conditions cause a drastic decrease in demonstration process efficiency after 5-7 days of dry weather.

5. The values obtained during the study program can be used to determine the air requirements of the system during dry weather.

   Upper VSS concentration 95% confidence limit = 7.824 mg/l

   Upper OUR 95% confidence limit = 9.3 mg/hr/gm

   Oxygen supplied by two 50 hp mechanical aerators:

   2.5 lb/hp-hr x 2 aerators x 60 hp/aerator =
   250 lb/hr = 113.5 hr/hr

   Oxygen required by the sludge:

   9.3 mg/hr/gm x 7.824 gm/l = 72.8 mg/l/hr

   Maximum allowable volume of sludge for two aerators:

   72.8 mg/l/hr x V (million gal.) x 8.34 = 250 lb/hr
   v = 1,558 cu m (411,700 gal.)

   Therefore, if only two aerators are used, the allowable volume of sludge in the stabilization tank is 1,558 cu m (411,700 gal.). For volumes over 1,558 cu m (411,700 gal.), three aerators should be used.

BENCH SCALE STUDIES

In addition to monitoring the sludge in the stabilization tank, sludge studies were also conducted on a bench scale at the DWP. The purpose of these studies was twofold:

1. To obtain a better understanding of the sludge digestion that occurs in the stabilization tank during dry weather.

2. To study the effect of this digestion on thickening the sludge with dissolved air flotation. This aspect is of concern because after a hydraulic detention time of two to three days in the stabilization tank, the WAS is pumped to the DWP dissolved air flotation unit for thickening.

Three test periods were used for the digestion and flotation studies and the results are shown in Tables 14 to 16. The SS, VSS, total COD, and total alkalinity concentrations of the sludge for the three test periods are plotted in Figures 38 to 40. The three figures strongly indicate extensive aerobic digestion. The SS and VSS concentrations yield an average destruction rate of 215 mg/l/day SS and 157 mg/l/day VSS. Since the SS destruction is due mainly to the destruction of volatiles by aerobic digestion, the percent volatile fraction of the total suspended solids also drops. Therefore, in the demonstration system stabilization tank a similar rate of decrease could be expected. Of course, these rates will vary with changes in temperature.

Table 14. AEROBIC DIGESTION AND FLOTATION RESULTS
JULY 11 TO JULY 31, 1973

Date	SS mg/l	VSS mg/l	Percent volatile	OUR (mg/hr/gm)	Total alkalinity, mg/l	Total COD mg/l	Percent float solids	Effluent SS, mg/l	Percent solids recovery	Rise Rate cm/sec (fpm)
7/11	7,076				528		2.16	28	99.0	0.18 (0.36)
7/12	6,727									
7/13	6,312	3,475	55.1	5.99			2.28	80	96.8	0.17 (0.34)
7/15	6,030	3,220	53.4	2.52	30		2.34	112	95.3	0.07 (0.13)
7/17	5,506	2,756	50.1	2.10	16	4,630				
7/18							2.38	88		0.16 (0.31)
7/20	5,340	2,660	49.8	2.18			2.25	65	96.9	0.14 (0.27)
7/23	4,800	2,320	48.3	2.50		3,766	2.20	95	94.8	0.12 (0.33)
7/26	4,680	2,190	46.8	1.92			1.87	115	93.5	0.12 (0.23)
7/31	3,855	1,870	48.5	1.60	8	2,888	2.13	110	92.4	0.12 (0.23)

Table 15. AEROBIC DIGESTION AND FLOTATION RESULTS
AUGUST 8 TO AUGUST 23, 1973

Date	SS, mg/l	VSS, mg/l	Percent volatile	OUR (mg/hr/gm)	Total alkalinity, mg/l	Total COD, mg/l	Percent float solids	Effluent SS, mg/l	Percent solids, recovery	Rise Rate cm/sec (fpm)
8/8	10,600	7,012	66.2	28.67	260		2.25	13		0.07 (0.14)
8/9	10,100	6,712	66.4	6.56			2.76	45	98.9	0.20 (0.39)
8/13	8,788	5,588	63.6	3.58	29		2.71	190	94.5	
8/15						8,048				
8/16	7,240	4,440	61.3	2.52			2.40	85	96.9	0.19 (0.37)
8/17	7,070	4,370	61.8	2.75			2.57	65	97.6	0.18 (0.36)
8/21	6,460	3,940	61.0	1.65	0	5,910	2.38	152	93.8	0.21 (0.41)
8/23	6,300	37,20	59.0	1.13	33	5,755	2.68	150	93.8	0.16 (0.32)

Table 16. AEROBIC DIGESTION AND FLOTATION RESULTS
AUGUST 28 TO SEPTEMBER 19, 1973

Date	SS, mg/l	VSS, mg/l	Percent Volatile	OUR (mg/hr/gm)	Total alkalinity mg/l	Total COD mg/l	Percent float solids	Effluent SS, mg/l	Percent solids recovery	Rise Rate, cm/sec (fpm)
8/28	9,690	6,450	66.6	39.07	216	9,176	2.94[1]	140	96.3[1]	0.21(0.41)[1]
8/29	8,860	5,480	61.8	7.70		8,632	2.70	60	98.3	0.37(0.72)
8/31	8,490	5,320	62.7	5.17	35		2.75	105	96.8	
9/4	7,310	4,560	62.4	2.85		6,652	2.49	138	95.1	0.37(0.72)
9/6					6					
9/7	6,380	3,750	58.8	1.65		6,008	2.70	145	94.0	0.55(1.09)
9/10					5					
9/12	6,040	3,570	59.1	0.90			2.70	225	89.9	0.37(0.72)
9/14	5,980	3,940	65.9	0.89	0	5,910	2.58	215	90.3	0.47(0.93)
9/17	5,260	3,290	62.5	1.06	0	4,787				
9/19							2.43	270	86.2	0.30(0.60)

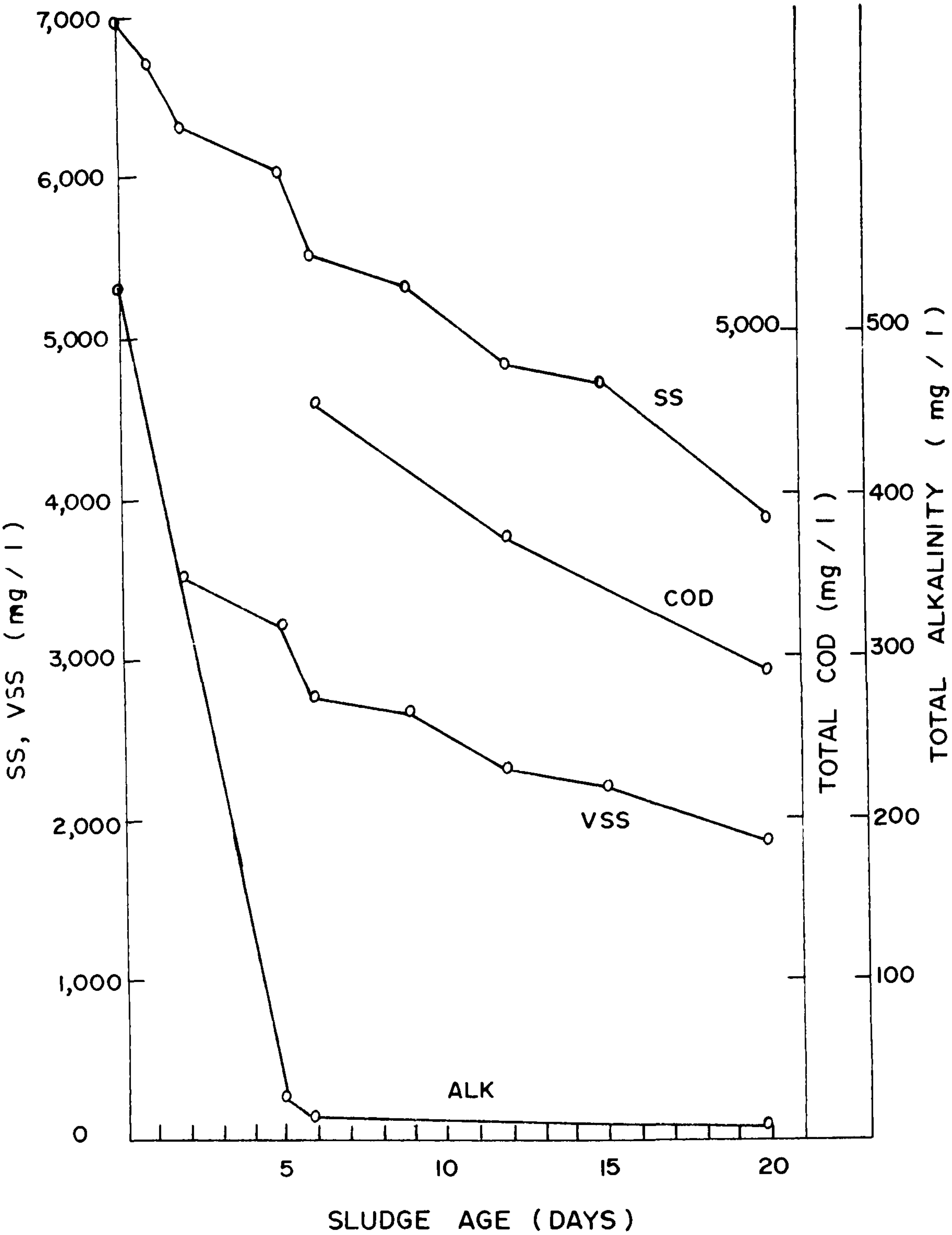

Figure 38. SS, VSS, Total COD, and Total Alkalinity Concentration versus Sludge Age for Bench Scale Tests July 11, 1973 to July 31, 1973

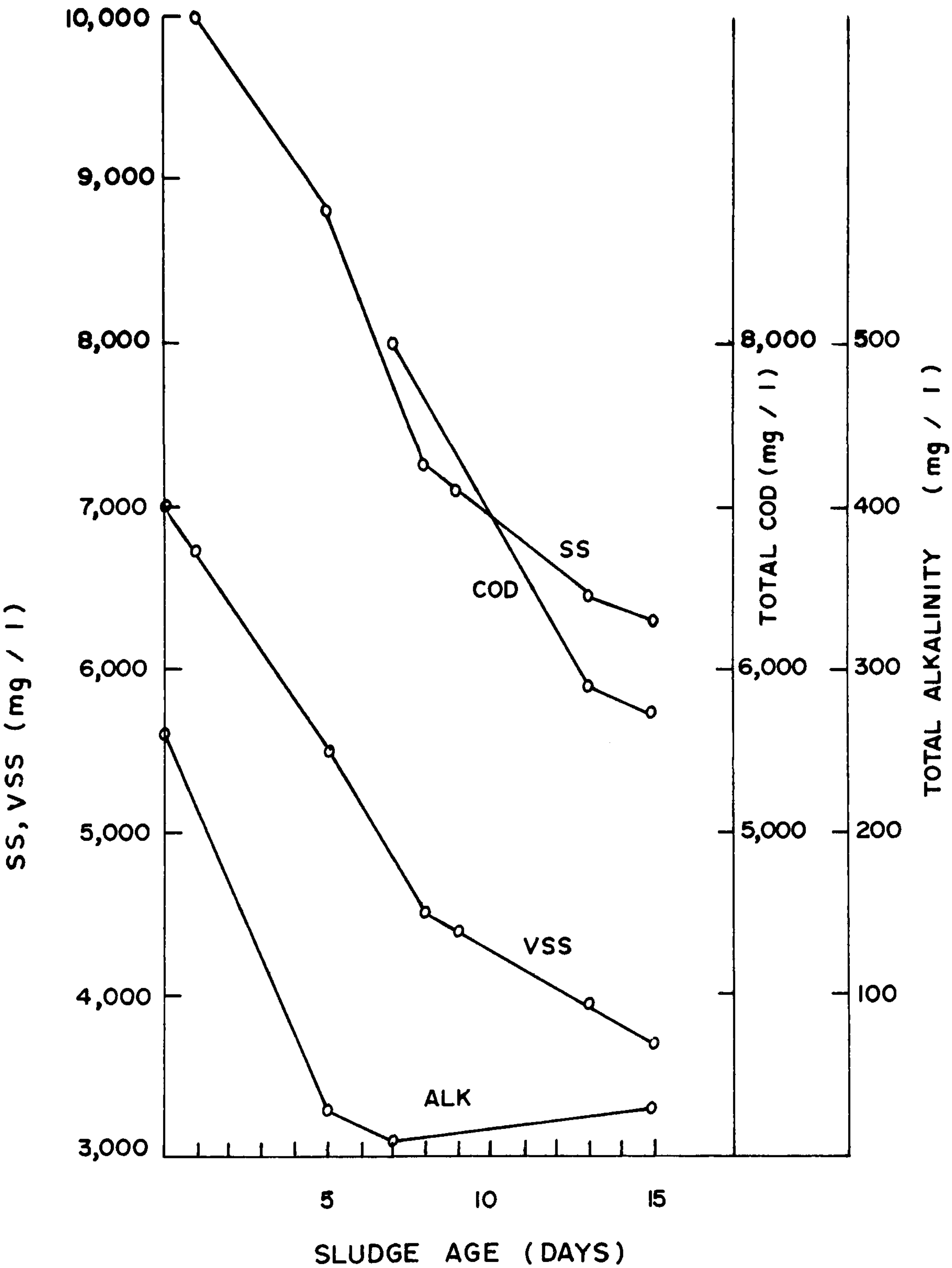

Figure 39. SS, VSS, Total COD, and Total Alkalinity Concentrations versus Sludge Age for Bench Scale Tests, August 8, 1973 to August 23, 1973

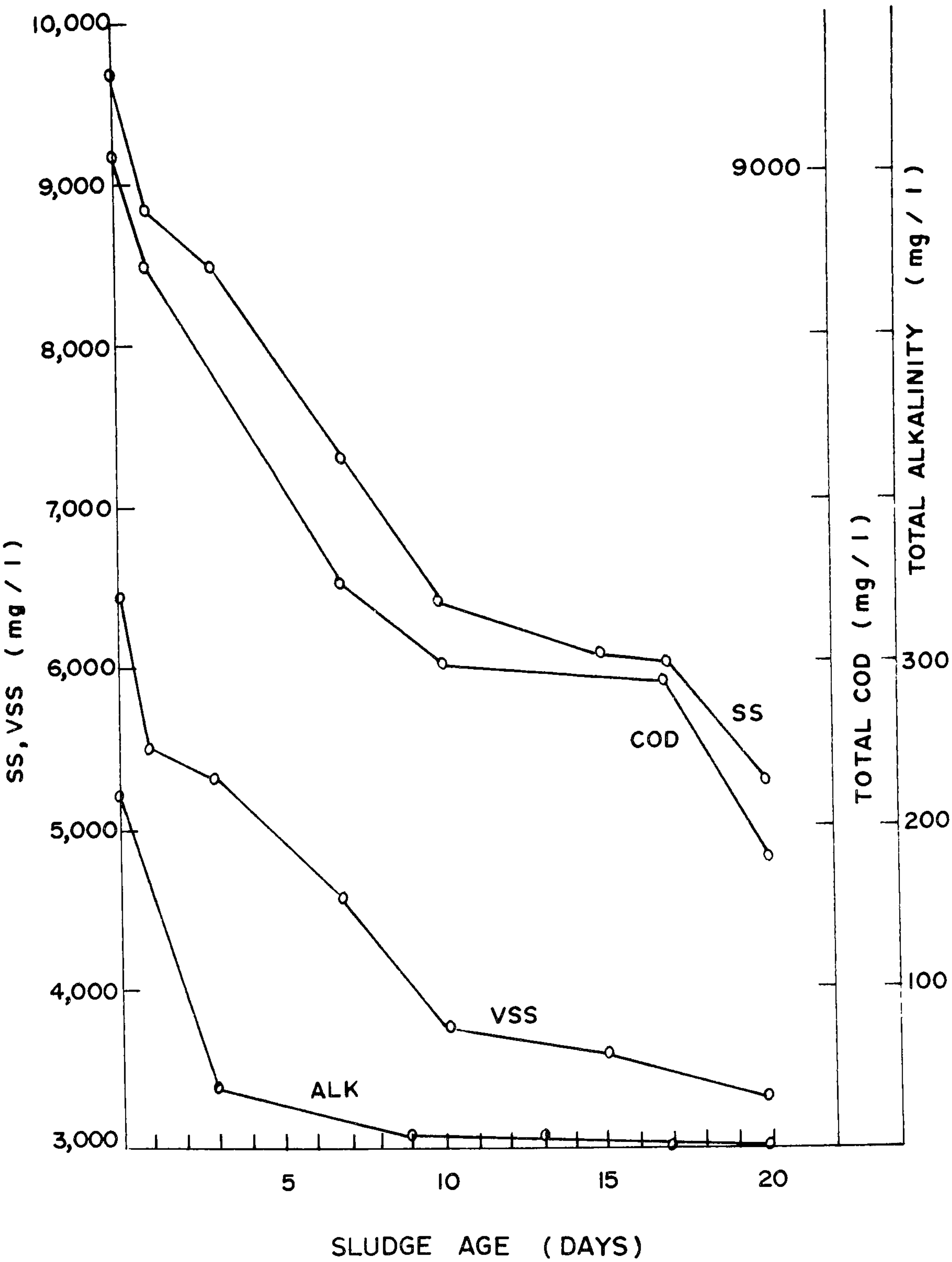

Figure 40. SS, VSS, Total COD, and Total Alkalinity Concentrations versus Sludge Age for Bench Scale Tests August 28, 1973 to September 19, 1973

An attempt was made at determining a rate constant for the system using the equation:

$$\ln[S_r - S_n)/(S_t - S_n)] = K_1 t, \text{ where}$$

S_r = VSS concentration at time t

S_n = nonoxidizable VSS concentration

S_t = initial VSS concentration

t = time of aeration in days

K_1 = rate of digestion (a constant)

This formula is derived from the endogenous respiration equation $Ma_t = Ma_o (e^{-kt})$ where Ma_t = the active biological mass at time t, and Ma_o = the initial active biological mass.

In the former equation the rate K_1 is dependent, to some extent, upon the value chosen for Sn, the nonoxidizable VSS concentration. For this formulation S_n is considered to be five percent less than the difference between the initial VSS concentration and the final VSS concentration. This estimate of the nonoxidizable VSS concentration has been suggested by Barnhart (30). This formula was applied to the results of the three studies. In the case of the first study (July 11 to July 31) the result of $(S_r - S_n)$ was a negative number and, therefore, the rate constant was not calculated. Studies 2 and 3 (August 8 to August 23 and August 28 to September 9) resulted in rate constants of -0.125/day and -0.134/day, respectively. For domestic sludges the usual value is about -0.25 to -0.40/day.

The total alkalinity pattern was interesting. The alkalinity of the sludge dropped very rapidly in the first 5 days and at 7 days no detectable alkalinity remained. For zero total alkalinity the pH of the sludge would be expected to be around 4.5. This occurrence indicates that extensive nitrification may be taking place in the stabilization tank. During nitrification ammonia nitrogen is converted to nitrates by nitrifying bacteria.

The following equations (not balanced) show why the pH drops in the nitrification process:

$$\text{Organic N} + H_2O \rightarrow NH_3 + OH^- \quad (1)$$

$$HCO_3 + OH \rightarrow CO_3 + H_2O \quad (2)$$

$$NH_3 + O_2 \rightarrow NO_3 + H^+ \quad (3)$$

$$HCO_3 + H^+ \rightarrow H_2CO_3 \quad (4)$$

$$H_2CO_3 \rightarrow H_2O + CO_2 \quad (5)$$

Equation 1 indicates the change of the organic nitrogen to ammonia. This reaction produces OH^- ions, which in turn react with HCO_3 to produce CO_3 (eq. 2). These reactions then cause a shift in the total alkalinity form from HCO_3 to CO_3 and this will first cause the pH to rise. Without nitrification, the pH would continue to rise as organic nitrogen is converted into ammonia.

Equations 3, 4, and 5 indicate the reactions occurring because of ongoing nitrification. NH_3 reacts with O_2 to produce NO_3 and an H^+ ion. This is accomplished by the nitrifying bacteria. The H^+ ion produced then reacts with HCO_3 to produce H_2CO_3 which further reacts to produce H_2O and CO_2 which escape from the system. Therefore, nitrification destroys alkalinity and the pH will drop. The lower pH will inhibit the biological activity of the system and thus lower the digestion rate constant to a value less than that expected.

The OUR's for the three studies are plotted in Figures 41-43. The plots show a very high initial uptake rate which drops rapidly during the first 5 to 7 days of digestion. They also show that the uptake rate has reached a steady rate after about 7 days of digestion in the first and third studies. The uptake rate data was also analyzed in order to develop an equation for predicting the uptake rate at different sludge ages. The following equation, having a multiple correlation coefficient of 0.946 was developed:

$$\text{OUR (mg/hr/gm)} = 8.09\ (SA)^{-0.62}\ (1.024^{T-T_o})$$

where:
T = sludge temperature, ^oC
T_o = 20^oC
SA = sludge age $\geq$ 1 day
1.024 = temp. coefficient

From the data presented, it appears that when this value reaches the range of 1 to 2 mg/hr/gm, the sludge has been completely stabilized and its usefulness in the demonstration system is doubtful.

The percent solids in the float and the effluent SS concentrations are plotted in Figures 44-46. Figure 46 shows a change in the two patterns. This was due to a change in the sludge condition in the DWP. The sludge obtained for the last study contained the polymer which was not present during the first two studies, and a noticeable change occurred in the results of the flotation tests. The first two studies indicate increasing percent solids in the float for up to five days of digestion, and then decreasing values. The third study, with the polymer present, shows a steady drop in percent solids. The effluent SS concentrations were erratic, but the first two tests show a general increase in suspended solids with time, and the third test shows a similar pattern after a drop which occurred on the first day of digestion. Referring to Tables 14-16, the SS recovery percentages also follow the pattern with gradually decreasing values as stabilization continues. The rise rate

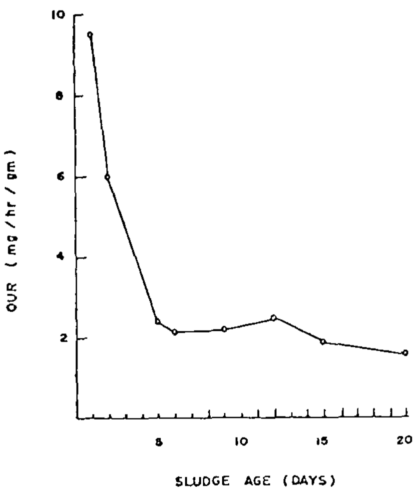

Figure 41. Oxygen Uptake Rate versus Sludge Age for Bench Scale Tests, July 11, 1973 to July 31, 1973

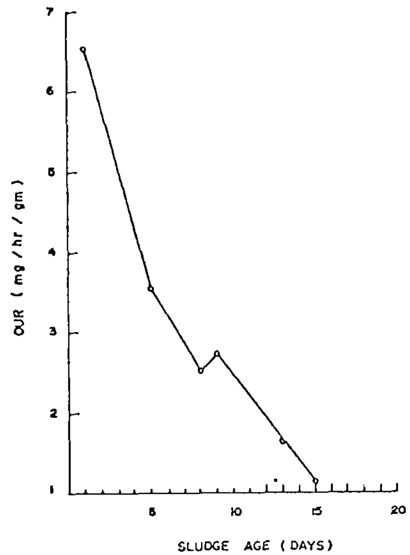

Figure 42. Oxygen Uptake Rate versus Sludge Age for Bench Scale Tests, August 8, 1973 to August 23, 1973

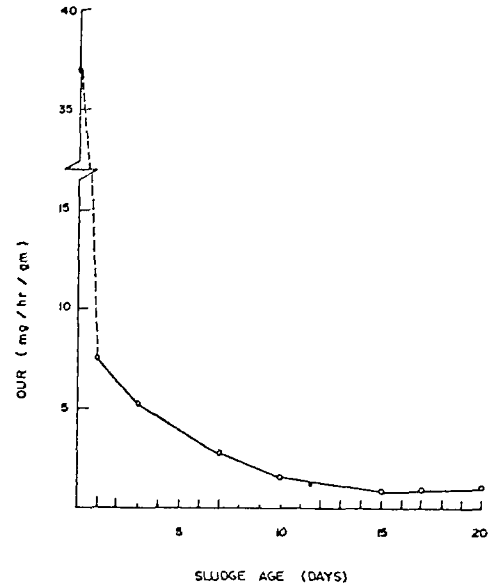

Figure 43. Oxygen Uptake Rate versus Sludge Age for Bench Scale Tests August 28 to September 19, 1973

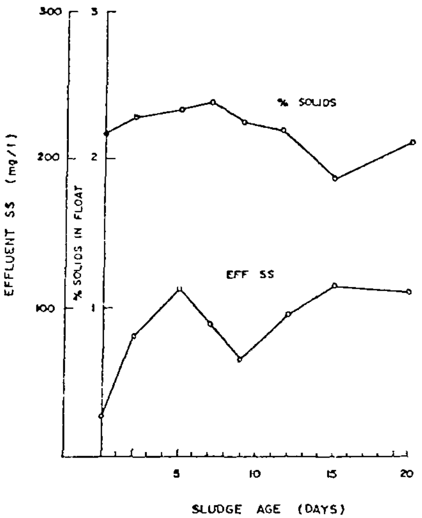

Figure 44. Flotation Test Percent Float Solids and Effluent SS versus Sludge Age for July 11, 1973 to July 31, 1973

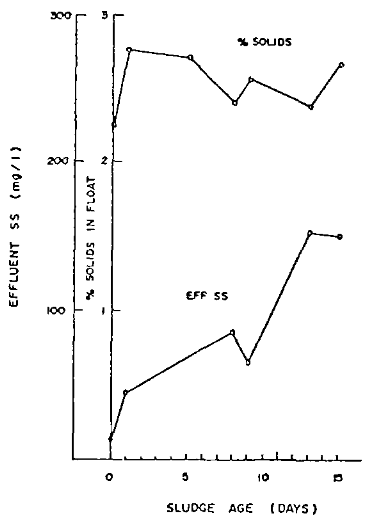

Figure 45. Effluent SS and Percent Float Solids Versus Sludge Age for Bench Scale Tests August 8, 1973 to August 23, 1973

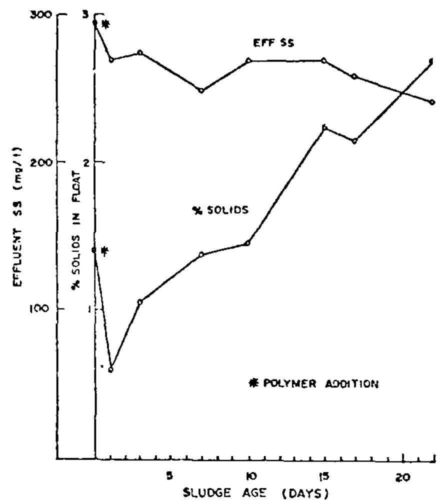

Figure 46. Flotation Test Percent Float Solids and Effluent SS versus Sludge Age for August 28, 1973 to September 19, 1973

values (Tables 14-16) are very erratic mainly because of the time necessary before the interface develops and the speed at which it rises, making exact timing very difficult. From observation of the data, however, the following general statements can be made: 1) aeration of the sludge for up to 10 days does not reduce the rise rate, in fact, it may improve it, and 2) after 10 days the rise rate gradually decreases, but not below the value obtained for the fresh sludge before stabilization began (t = 0).

The conclusions from this study are:

1. A SS destruction rate of 215 mg/l/day and volatile suspended solids destruction rate of 157 mg/l/day can be expected in the stabilization tank, based upon the bench scale tests. Therefore, the solids loading on the air flotation unit will be decreased by means of aerobic digestion. These rates are averages over the twenty days of digestion; however, graphs show that they are fairly constant.

2. An average rate constant (K) of -0.13/day was obtained for the aerobic digestion of the sludge.

3. The OUR (mg/hr/gm) was found to be related to the time of digestion by the relationship:

$$\text{OUR (mg/hr/gm)} = 8.09\ (\text{sludge age})^{-0.62}\ (1.024^{T-T_o})$$

4. Extensive nitrification was suspected in the stabilization tank. This would reduce the pH. The pH of 4.5 (indicated by total alkalinity = 0) may be the reason that the sludge did not perform well in the demonstration system after 5 to 7 days of stabilization.

5. No detrimental effect on the percent solids in flotation was found. In fact, it appeared that the float solids concentration was improved by up to five days of sludge aeration.

6. The flotation effluent SS concentration increased as the sludge was digested; this correlates well with the settling tests where it was found that as digestion proceeded, settling was improved but the effluent became increasingly more turbid.

7. The rise rate of the sludge in flotation was not decreased by digestion. Like the float solids, it seemed to increase over the first five days of stabilization.

SECTION IX - FUTURE DESIGN CONSIDERATIONS

AERATION

As discussed previously, eight 50 hp floating mechanical aerators were provided and utilized in the stabilization tank. The main reasons for using the surface aerators were to avoid the necessity of having to construct additional blower facilities and the ability of these aerators to easily adapt to changes in the sludge level. These aerators provided sufficient oxygen and mixing and operated reliably with little maintenance during the duration of the project. However, after completion of the evaluation program, operating experience indicated that fixed air disperser systems may be better suited for use in the stabilization tank. This type of disperser system would allow for winter operation. Also, in future designs it will not be necessary to make provisions for varying depth of sludge, since a design volume (depth) will be chosen and used at all times.

Although winter operation was never attempted, it was anticipated that the WAS being aerated would freeze on the aerators themselves and on the support wires and possibly cause the aerators to sink. This problem is not prevalent in normal aeration applications where the hydraulic detention time is much shorter and the liquid is not afforded as long of a period of time to cool down to ambient temperatures. The submerged air diffuser system will most likely allow surface icing to occur. However, it will still be possible to use the system during winter rainfalls and snow melts since the volume of sludge under the ice layer would be usable. In climates where cold weather and possible freezing is not of main concern, the choice of aeration system type should be done by the same means as for any other application.

INSTRUMENTATION AND FACILITIES

In future uses of this type of system all of the sophisticated automatic controls used in the demonstration system will not be needed. These automatic controls were required by the test program which called for a high degree of control on the process variables. It will be sufficient to provide direct manual controls for selecting the sludge transfer and sludge return rates, the air supply rate, and the sludge wasting rate. It appears that no provision for borrowing sludge from the DWP is needed. In addition, the controls for automatic start-up at high flows may not be needed if this system is to be put into operation in anticipation of high flow periods.

Future systems of this type will not require the high capacity sludge return and sludge transfer pumping facilities used in the demonstration system. For purposes of the test program these pumps had a capacity equal to 100% of the maximum raw flow rate. These capacities can be determined for future installations through a knowledge of the desired MLSS concentration and the estimated settled sludge concentration in the final clarifier.

It will not be necessary to divide the contact tank into two compartments. The design of the contact tank can be based on the maximum design flow rate. At flows less than this the additional contact time provided will be beneficial. If the system is designed to have a high range of flows it may be necessary to use a partitioned stabilization tank. If the stabilization tank is designed to provide the proper amount of reaeration time at maximum flow it is possible that this would produce too long of a reaeration time at lower flows when the sludge transfer and sludge return rates are greatly reduced, thus, the need for the partitioned tank.

Grit removal facilities should definitely be constructed with some type of mechanical removal equipment. Although no specific measurements were carried out to determine the amount of grit deposited during a run, it was estimated by WPCP personnel that 0.75-1.5 cu m (1-2 cu yds) were deposited per 3785 cu m (million gal.) treated. Manual removal of this grit was both a lengthy and bothersome process for the WPCP operators.

SIZING WITH RESPECT TO EXISTING TREATMENT PLANT

The maximum size of this type of system relative to the existing activated sludge plant that it is integrated with is determined by two constraints. These are:

1. The volume of sludge being held in the stabilization tank, between storms, under continuous flow through conditions, should not provide a hydraulic detention time of more than 5 days.

2. When the demonstration system goes into operation the volume of sludge in the stabilization tank must be sufficient to provide at least one hour of reaeration. Using the Kenosha WPCP as an example, the maximum volume of sludge that can be held in the stabilization tank with a hydraulic detention of less than 5 days is 1892 cu m (500,000 gal.). This is based on an average DWP WAS rate of 379 cu m/day (100,000 gpd). During operation of the demonstration system the maximum rate of RAS into and out of the stabilization tank at a reaeration time of one hour would be 45,420 cu m/day (12 mgd). Assuming that a sludge transfer (RAS) percentage of 33% is required to achieve the desired MLSS concentration, then the maximum design flow

rate would be 136,260 cu m/day (36 mgd). An important factor in determining how large the potential overflow treatment system can be, is the percent sludge transfer required. This, of course, is a function of the desired MLSS concentration, and the expected RAS concentration from the final clarifier. Using Kenosha, as an example again, if an MLSS concentration of 2500 mg/l was desired, and the RAS concentration was 15,000 mg/l, the sludge transfer rate would only be 20% of the raw flow rate. This would enable the potential overflow treatment system to be five times the RAS rate, or 227,100 cu m/day (60 mgd). Thus, it is important for any future design of this type of system to be prefaced by bench scale tests for determination of design MLSS concentration, and expected RAS sludge concentration.

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SECTION XII - GLOSSARY

BOD	Biochemical Oxygen Demand - refers to the standard 5 day Biochemical Oxygen Demand test unless described otherwise.
COD	Chemical Oxygen Demand
DWP	Dry Weather Plant - this term is used to describe the facilities present at the Kenosha Water Pollution Control Plant prior to construction of the demonstration system facilities. It is also used to describe operation of the treatment plant, after the demonstration system was installed, during periods of no runoff when the demonstration system was not in use
F/M	Food to Microorganism Ratio - calculated as the rate of BOD loading in kg (lbs) per day divided by the kg (lbs) of mixed liquor suspended solids under aeration in the contact tank only.
MLSS	Mixed Liquor Suspended Solids - the concentration, mg/l, of suspended solids under aeration in the contact tank or in the dry weather plant aeration tanks.
MLVSS	Mixed Liquor Volatile Suspended Solids
OUR	Oxygen Uptake Rate - refers to the rate of oxygen utilization (mg/gm/hr or mg/l/hr) by the sludge in the stabilization tank.
RAS	Return Activated Sludge - this refers to the sludge from the normal dry weather plant's return system, or to the settled sludge from the demonstration system final clarifier during demonstration system operation.
SS	Suspended Solids
SVI	Sludge Volume Index - this is the volume occupied per gram of settled sludge (ml/gm) in settling tests performed in one liter graduated cylinders.
SOR	Surface Overflow Rate - calculated from settling tests using actual mixed liquor or stabilized sludge and raw sewage, the settling velocity m/day (ft/day) is multiplied by 1 cu m^3/cu m^3 (7.48 g/ft^3) to develop a volume to area loading rate, cu m/day/cu m (gpd/ft^2).
TOC	Total Organic Carbon
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge - that portion of the dry weather plants return activated sludge which is sent directly to the sludge thickening facilities or to the stabilization tank. Also refers to the sludge transferred from the stabilization tank to the sludge thickening facilities when the demonstration system is not in use.
WPCP	Water Pollution Control Plant

SECTION XIII - APPENDICES

APPENDIX A. Description of Analytical Techniques

SM = "Standard Methods for the Examination of Water and and Wastewater", American Public Health Association, New York, New York, 12th Ed, 1965, 13th Ed., 1971.

WQO = "Methods for Chemical Analysis of Water and Wastes, 1971", Environmental Protection Agency.

FWPCA = "FWPCA Methods for Chemical Analysis of Water and Wastes, 1969", Federal Water Pollution Control Administration.

pH	1970, SM 12th Ed., p. 422 1972, 1973, SM 13th Ed., p. 500
Settleable Solids	1970, SM 12th Ed., p. 425 1972, 1973, SM 13th Ed., p. 539.
Total Solids	1970, SM, 12th Ed., p. 423 1972, 1973, SM, 13th Ed., p. 535 (dried at 105°C)
Total Volatile Solids	1970, SM 12th Ed., p. 423 (ignition at 600°C). 1972, 1973, SM 13th Ed., p. 536 (ignition at 550°C)
Suspended Solids	1970, SM 12th Ed., p. 424 (asbestos mat in gooch crucible) 1972, 1972, SM 13th Ed., p. 290 (0.45 μ membrane filter, dried at 105°C) A portion of the filtrate from filtration through a washed 0.45 μ membrane filter was used for the COD test. The dilute COD method was used (p. 498, 13th Ed.)
Total Organic Carbon and Dissolved Organic Carbon	1970, FWPCA, p. 211 1972, 1973, WQO, p. 221 A Model 915 Beckman TOC analyzer was used.

Total Inorganic Carbon and	The inorganic carbon values from the TOC and dissolved organic carbon measurements performed on unacidified samples was used.
Kjeldahl Nitrogen	1970, FWPCA, p. 145 1972, 1973, WQO, p. 149.
Total Phosphate	Sample digestion: 1970, FWPCA, p. 230 1972, 1973, WQO, p. 242. Phosphate measurement: 1970, 1972, 1973, SM 12th Ed., p. 231
Total Coliform	1970, "Microbiological Analysis of Water", Application Report AR-81, Millipore Corp., 1969, p. 3. 1972, 1973, SM 13th Ed., p. 679 (membrane filter method).
Fecal Coliform	1970, "Microbiological Analysis of Water", Application Report AR-81, Millipore Corp., 1969, p. 3 1972, 1973, SM 13th Ed., p. 684
Suspended Volatile Solids	1970, SM 12th Ed., p. 425 (ignition at 600°C). 1972, 1973, SM 13th Ed., p. 292, (ignition at 550°C)
BOD and Dissolved BOD	1970, SM 12th Ed., p. 415. 1972, 1973, SM 13th Ed., p. 498.

1. Chlorinated samples were dechlorinated with sodium sulfite, dechlorination was checked by spot-plate using ortho-tolidine. Excess sulfite was removed by aeration. Samples were allowed to stand 10 minutes after aeration.

2. Dissolved BOD samples were filtered through washed 0.45 μ membrane filters. The filtrate was dechlorinated (if necessary) and aerated to restore D.O.

	3. Samples filtered through 0.45 μ membrane filters, and samples that were dechlorinated were seeded with 1 ml of settled raw sample. Seeded blanks were also run.
COD and Dissolved COD	1970, SM 12th Ed., p. 510. 1972, 1973, SM 13th Ed., p. 495.

Table B1. OVERFLOW QUALITY 1970
Storm 1, June 1; Total Rainfall - 1.55 cm (0.61 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4	6-10		
Parameter	**Unit**				
pH		7.4	7.3		
Settleable solids	ml/l	6.3	1.5		
Total solids	mg/l	814	471		
Total volatile solids	mg/l	413	196		
Suspended solids	mg/l	375	120		
Suspended volatile solids	mg/l	259	40		
Total BOD	mg/l	136	27		
Dissolved BOD	mg/l	30	18		
Total COD	mg/l	507	117		
Dissolved COD	mg/l	71	45		
Total organic carbon	mg/l				
Dissolved organic carbon	mg/l				
Total inorganic carbon	mg/l				
Dissolved inorganic carbon	mg/l				
Kjeldahl nitrogen as N	mg/l	16.8	4.3		
Total phosphorus as P	mg/l				
Total coliform	#/ml	205,000	1,200		
Fecal coliform	#/ml	1,300	1,100		

Table B2. OVERFLOW QUALITY 1970
Storm 2, June 16; Total Rainfall - 0.58 cm (0.23 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-5.5	4-8		1-5
Parameter	**Unit**				
pH		7.6	7.4		7.5
Settleable solids	ml/l	8.5	3.5		7.0
Total solids	mg/l	951	660		595
Total volatile solids	mg/l	425	244		253
Suspended solids	mg/l	388	234		266
Suspended volatile solids	mg/l	269	60		145
Total BOD	mg/l	167			104
Dissolved BOD	mg/l	32			25
Total COD	mg/l	463	310		257
Dissolved COD	mg/l	100			77
Total organic carbon	mg/l	185	98		81
Dissolved organic carbon	mg/l	29			23
Total inorganic carbon	mg/l	57	41		42
Dissolved inorganic carbon	mg/l	52			39
Kjeldahl nitrogen as N	mg/l	19.4	13.0		
Total phosphorus as P	mg/l	9.9			7.2
Total coliform	#/ml	24,200			34,000
Fecal coliform	#/ml	888			4,600

Table B3. OVERFLOW QUALITY 1970
Storm 3, June 20; Total Rainfall - 1.73 cm (0.68 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4	0-4		
Parameter	Unit				
pH		6.9	7.3		
Settleable solids	ml/l	8.5	0.7		
Total solids	mg/l	724	345		
Total volatile solids	mg/l	420	147		
Suspended solids	mg/l	437	40		
Suspended volatile solids	mg/l	302	21		
Total BOD	mg/l	140	36		
Dissolved BOD	mg/l	21	18		
Total COD	mg/l	680	82		
Dissolved COD	mg/l	69	53		
Total organic carbon	mg/l	187	57		
Dissolved organic carbon	mg/l	24	18		
Total inorganic carbon	mg/l	25	48		
Dissolved inorganic carbon	mg/l	26	23		
Kjeldahl nitrogen as N	mg/l	15.1	4.3		
Total phosphorus as P	mg/l	63	1.4		
Total coliform	#/ml	43,000	9,400		
Fecal coliform	#/ml	4,800	1,530		

Table B4. OVERFLOW Quality 1970
Storm 4, June 26; Total Rainfall - 2.08 cm (0.82 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-5	1-5		
Parameter	Unit				
pH		7.0	7.4		
Settleable solids	ml/l	12	7		
Total solids	mg/l	1,073	642		
Total volatile solids	mg/l	646	316		
Suspended solids	mg/l	890	498		
Suspended volatile solids	mg/l	698	316		
Total BOD	mg/l	194	143		
Dissolved BOD	mg/l	26	17		
Total COD	mg/l	1,129	295		
Dissolved COD	mg/l	92	113		
Total organic carbon,	mg/l				
Dissolved organic carbon	mg/l				
Total inorganic carbon	mg/l				
Dissolved inorganic carbon	mg/l				
Kjeldahl nitrogen as N	mg/l	21.8	9.2		
Total phosphorus as P	mg/l	7.8	4.0		
Total coliform	#/ml	15,000	3,170		
Fecal coliform	#/ml	2,650	340		

Table B5. OVERFLOW QUALITY 1970
Storm 5, July 8; Total Rainfall - 0.89 cm (0.35 in.)

		Site			
		WPCP	Street	59th Street[a]	57th Street
Composite sample period, hrs		0-4	0-4		2-6
Parameter	Units				
pH		6.6	6.6	6.7	6.8
Settleable solids	ml/l	18.5	9.0	1.4	27.0
Total solids	mg/l	1,966	676	404	
Total volatile solids	mg/l	1,415	363	202	
Suspended solids	mg/l	1,016	492	104	
Suspended volatile solids	mg/l	728	266	62	
Total BOD	mg/l	360	135	46	233
Dissolved BOD	mg/l	51	64	32	21
Total COD	mg/l	2,561	419	134	778
Dissolved COD	mg/l	116	131	103	65
Total organic carbon	mg/l				
Dissolved organic carbon	mg/l				
Total inorganic carbon	mg/l				
Dissolved inorganic carbon	mg/l				
Kjeldahl nitrogen as N	mg/l	12.0	11.6	4.5	24.8
Total phosphorus as P	mg/l	10.7	4.3	0.7	15.1
Total coliform	#/ml	19,000	2,000	18,000	900
Fecal coliform	#/ml	2,600	180	700	100

a. Grab sample at 3 hours.

Table B6. OVERFLOW QUALITY 1970
Storm 6, July 8; Total Rainfall - 0.41 cm (0.16 in.)

		Site			
Composite sample period, hrs.		WPCP[a]	67th Street	59th Street[b]	57th Street[c]
Parameter	Units				
pH		7.2		7.3	7.1
Settleable solids	ml/l	2.5		1.8	4.1
Total solids	mg/l	555		271	543
Total volatile solids	mg/l	195		102	183
Suspended solids	mg/l	128		208	116
Suspended volatile solids	mg/l	92		98	90
Total BOD	mg/l	86		50	85
Dissolved BOD	mg/l	40		36	37
Total COD	mg/l	173		197	189
Dissolved COD	mg/l	84		83	80
Total organic carbon	mg/l				
Dissolved organic carbon	mg/l				
Total inorganic carbon	mg/l				
Dissolved inorganic carbon	mg/l				
Kjeldahl nitrogen as N	mg/l	16.3		5.5	15.7
Total phosphorus as P	mg/l	8.3		3.5	7.8
Total coliform	#/ml	17,000			41,000
Fecal coliform	#/ml	12,000			720

a. Grab sample at 30 minutes.
b. Grab sample at 45 minutes.
c. Grab sample at 45 minutes.

Table B7. OVERFLOW QUALITY 1970
Storm 7, July 13; Total Rainfall - 0.99 cm (0.39 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs.		0-4	0-4	0-2	
Parameter	Units				
pH		7.1	7.0	7.0	
Settleable solids	ml/l	14.0	6.0		
Total solids	mg/l	1,196	661	608	
Total volatile solids	mg/l	731	339	297	
Suspended solids	mg/l	712	476	492	
Suspended volatile solids	mg/l	508	260	204	
Total BOD	mg/l				
Dissolved BOD	mg/l				
Total COD	mg/l	1,003	307	266	
Dissolved COD	mg/l	147	147		
Total organic carbon	mg/l				
Dissolved organic carbon	mg/l				
Total inorganic carbon	mg/l				
Dissolved inorganic carbon	mg/l				
Kjeldahl nitrogen as N	mg/l	24.6	10.0		
Total phosphorus as P	mg/l	4.1	3.7		
Total coliform	#/ml	180,000	300,000	230,000	
Fecal coliform	#/ml	3,800	8,400	22,800	

Table B8. OVERFLOW QUALITY 1970
Storm 8, July 19; Total Rainfall - 0.61 cm (0.24 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample periods, hrs.		0-4			0-4
Parameter	**Units**				
pH		6.9			7.3
Settleable solids	ml/l	5.0			17.0
Total solids	mg/l	1,123			354
Total volatile solids	mg/l	718			209
Suspended solids	mg/l	693			167
Suspended volatile solids	mg/l	530			83
Total BOD	mg/l				
Dissolved BOD	mg/l				
Total COD	mg/l	803			109
Dissolved COD	mg/l	153			38
Total organic carbon		310			41
Dissolved organic carbon	mg/l				
Total inorganic carbon	mg/l	30			33
Dissolved inorganic carbon	mg/l				
Kjeldahl nitrogen as N	mg/l	26.6			4.4
Total phosphorus as P	mg/l	22.0			6.0
Total coliform	#/ml	78,000			1,500
Fecal coliform	#/ml	2,400			200

Table B9. OVERFLOW QUALITY 1970
Storm 9, July 27; Total Rainfall - 0.69 cm (0.27 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs.		0-4	0-4	0-2	
Parameter	Units				
pH		6.9	6.9	7.0	
Settleable solids	ml/l	15.0	3.0	8.0	
Total solids	mg/l	1,063	443	650	
Total volatile solids	mg/l	617	177	259	
Suspended solids	mg/l	975	345	434	
Suspended volatile solids	mg/l	745	195	155	
Total BOD	mg/l	269	115	133	
Dissolved COD	mg/l	52	36	48	
Total COD	mg/l	1,090	290	360	
Dissolved COD	mg/l	132	89	170	
Total organic carbon	mg/l	313	84	124	
Dissolved organic carbon	mg/l	36	24	23	
Total inorganic carbon	mg/l	27	18	18	
Dissolved inorganic carbon	mg/l	20	13	8	
Kjeldahl nitrogen as N	mg/l	21.0	10.0	11.3	
Total phosphorus as P	mg/l	15.6	4.2	4.2	
Total coliform	#/ml	6,200	4,300	2,500	
Fecal coliform	#/ml	575	650	275	

Table B10. OVERFLOW QUALITY 1970
Storm 10, July 28; Total Rainfall - 1.83 cm (0.72 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs.		0-4	0-4	0-2	0-4
Parameter	Units				
pH		7.5	7.4	7.5	7.5
Settleable solids	ml/l	4.0	0.1	1.0	0.5
Total solids	mg/l	598	230	291	475
Total volatile solids	mg/l	242	89	126	196
Suspended solids	mg/l	217	80	85	114
Suspended volatile solids	mg/l	106	52	56	87
Total BOD	mg/l	55	25	28	53
Dissolved BOD	mg/l		13	27	40
Total COD	mg/l	155	62	82	113
Dissolved COD	mg/l	42	32	54	70
Total organic carbon	mg/l	56	30	29	52
Dissolved organic carbon	mg/l	17	12	21	26
Total inorganic carbon	mg/l	37	12	13	29
Dissolved inorganic carbon	mg/l	34	10	11	22
Kjeldahl nitrogen as N	mg/l	12.0	3.0	4.2	9.5
Total phosphorus as P	mg/l	2.1	0.6	0.5	1.6
Total coliform	#/ml	2,000	680	220	50
Fecal coliform	#/ml	220	200		

Table B11. OVERFLOW QUALITY 1970
Storm 11, July 30; Total Rainfall - 0.94 cm (0.37 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample periods, hrs.		0-4	0-4		0-4
Parameter	Units				
pH		7.4	7.1		7.5
Settleable solids	ml/l	4.5	3.5		4.5
Total solids	mg/l	520	422		501
Total volatile solids	mg/l	262	245		248
Suspended solids	mg/l	195	162		212
Suspended volatile solids	mg/l	104	55		68
Total BOD	mg/l	70	66		56
Dissolved BOD	mg/l	14	13		11
Total COD	mg/l	319	170		202
Dissolved COD	mg/l	46	48		30
Total organic carbon	mg/l	83	73		64
Dissolved organic carbon	mg/l	19	18		11
Total inorganic carbon	mg/l	32	16		28
Dissolved inorganic carbon	mg/l	28	14		26
Kjeldahl nitrogen as N	mg/l	7.7	4.9		5.0
Total phosphorus as P	mg/l	2.9	3.3		6.5
Total coliform	#/ml	15,000	17,000		14,000
Fecal coliform	#/ml	1,400	2,400		2,100

Table B12. OVERFLOW QUALITY 1970
Storm 12, August 18; Total Rainfall - 0.84 cm (0.33 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-0.5	0-0.5	0-0.5	0-0.5
Parameter	Units				
pH		7.2	7.5	7.3	7.7
Settleable solids	ml/l				
Total solids	mg/l	1,058	434	274	1,422
Total volatile solids	mg/l	719	225	133	588
Suspended solids	mg/l	757	171	46	907
Suspended volatile solids	mg/l	590	101	38	514
Total BOD	mg/l				
Dissolved BOD	mg/l				
Total COD	mg/l	1,264	254	106	650
Dissolved COD	mg/l	97	97	74	75
Total organic carbon	mg/l	260	97	46	264
Dissolved organic carbon	mg/l	39	37	30	30
Total inorganic carbon	mg/l	32	20	17	43
Dissolved inorganic carbon	mg/l	24	17	14	37
Kjeldahl nitrogen as N	mg/l				
Total phosphorus as P	mg/l				
Total coliform	#/ml	42,900	5,200	5,400	31,000
Fecal coliform	#/ml	34,600	466	300	12,075

Table B13. OVERFLOW QUALITY 1970
Storm 13, September 2; Total Rainfall - 1.30 cm (0.51 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4			
Parameter	Units				
pH		6.9			
Settleable solids	ml/l	23			
Total solids	mg/l	1,683			
Total volatile solids	mg/l	1,252			
Suspended solids	mg/l	1,394			
Suspended volatile solids	mg/l	1,086			
Total BOD	mg/l	251			
Dissolved BOD	mg/l	78			
Total COD	mg/l	967			
Dissolved COD	mg/l	105			
Total organic carbon	mg/l	630			
Dissolved organic carbon	mg/l	70			
Total inorganic carbon	mg/l				
Dissolved inorganic carbon	mg/l	17			
Kjeldahl nitrogen as N	mg/l	16.4			
Total phosphorus as P	mg/l				
Total coliform	#/ml	8,000			
Fecal coliform	#/ml				

Table B14. OVERFLOW QUALITY 1970
Storm 13B, September 3; Total Rainfall - 0.51 cm (0.20 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs			1-5		
Parameter	**Units**				
pH			7.4		
Settleable solids	ml/l		1.5		
Total solids	mg/l		386		
Total volatile solids	mg/l		187		
Suspended solids	mg/l		149		
Suspended volatile solids	mg/l		78		
Total BOD	mg/l				
Dissolved BOD	mg/l				
Total COD	mg/l		182		
Dissolved COD	mg/l		142		
Total organic carbon	mg/l		49		
Dissolved organic carbon	mg/l		47		
Total inorganic carbon	mg/l		21		
Dissolved inorganic carbon	mg/l		19		
Kjeldahl nitrogen as N	mg/l		9.1		
Total phosphorus as P	mg/l				
Total coliform	#/ml		19,000		
Fecal coliform	#/ml				

Table B15. OVERFLOW QUALITY 1970
Storm 14, September 3; Total Rainfall - 0.38 cm (0.15 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4			
Parameter	Units				
pH		7.2			
Settleable solids	ml/l	4.5			
Total solids	mg/l	622			
Total volatile solids	mg/l	328			
Suspended solids	mg/l	221			
Suspended volatile solids	mg/l	187			
Total BOD	mg/l	98			
Dissolved BOD	mg/l	27			
Total COD	mg/l	756			
Dissolved COD	mg/l	74			
Total organic carbon	mg/l	156			
Disoslved organic carbon	mg/l	23			
Total inorganic carbon	mg/l				
Dissolved inorganic carbon	mg/l	30			
Kjeldahl nitrogen as N	mg/l	10.8			
Total phosphorus as P	mg/l				
Total coliform	#/ml	380,000			
Fecal coliform	#/ml	61,000			

Table B16. OVERFLOW QUALITY 1970
Storm 15, September 6; Total Rainfall - 2.74 cm (1.08 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4	0-4	0-2	0-4
Parameter	Units				
pH		7.0	7.2	7.2	7.1
Settleable solids	ml/l	7.5	6.5	6.0	15.0
Total solids	mg/l	534	509	823	1,199
Total volatile solids	mg/l	319	280	319	584
Suspended solids	mg/l	249	276	598	905
Suspended volatile solids	mg/l	228	189	270	441
Total BOD	mg/l	110	76	75	160
Dissolved BOD	mg/l	11	17	21	18
Total COD	mg/l	397	361	369	641
Dissolved COD	mg/l	50	61	62	69
Total organic carbon	mg/l	113	101	129	260
Dissolved organic carbon	mg/l	11	14	16	18
Total inorganic carbon	mg/l	28	18	14	24
Dissolved inorganic carbon	mg/l	23	13	6	15
Kjeldahl nitrogen as N	mg/l	13.8	8.8	7.4	17.2
Total phosphorus as P	mg/l				
Total coliform	#/ml	92,000	77,000	37,000	160,000
Fecal coliform	#/ml	40,000	6,000	1,000	14,000

Table B17. OVERFLOW QUALITY 1970
Storm 16, September 9; Total Rainfall - 1.78 cm (0.70 in.)

Composite sample period, hrs		WPCP	Site 67th Street 0-4	59th Street 0-2	57th Street 0-4
Parameter	**Units**				
pH			7.7	7.5	7.8
Settleable solids	ml/l		3.5	6.5	10.5
Total solids	mg/l		460	709	899
Total volatile solids	mg/l		200	387	329
Suspended solids	mg/l		394	610	656
Suspende volatile solids	mg/l		188	270	252
Total BOD	mg/l		57	91	107
Dissolved COD	mg/l		18	23	16
Total COD	mg/l		260	430	438
Dissolved COD	mg/l		54	86	46
Total organic carbon	mg/l		93	120	133
Dissolved organic carbon	mg/l		15	19	11
Total inorganic carbon	mg/l		14	20	35
Dissolved inorganic carbon	mg/l		12	16	28
Kjeldahl nitrogen as N	mg/l		5.9		10.3
Total phosphorus as P	mg/l				
Total coliform	#/ml		9,000	23,000	130,000
Fecal coliform	#/ml		1,500	2,000	6,800

Table B18. OVERFLOW QUALITY 1970
Storm 17, September 14; Total Rainfall - 2.24 cm (0.88 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4	3-7		3.5-7.5
Parameter	Units				
pH		7.0	7.8		7.6
Settleable solids	ml/l	23.0	2.3		8.5
Total solids	mg/l	1,260	503		943
Total volatile solids	mg/l	877	206		352
Suspended solids	mg/l	910	172		550
Suspended volatile solids	mg/l	707	104		224
Total BOD	mg/l	266	73		153
Dissolved BOD	mg/l				
Total COD	mg/l	908	255		382
Dissolved COD	mg/l	60	50		48
Total organic carbon	mg/l	232	73		123
Dissolved organic carbon	mg/l	18	16		15
Total inorganic carbon	mg/l	24	27		45
Dissolved inorganic carbon	mg/l	20	24		35
Kjeldahl nitrogen as N	mg/l	19.3	6.8		12.8
Total phosphorus as P	mg/l				
Total coliform	#/ml	300,000	6,000		21,000
Fecal coliform	#/ml	26,000	2,800		3,700

Table B19. OVERFLOW QUALITY 1970
Storm 18, September 15; Total Rainfall - 1.37 cm (0.54 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4	0-4	0-2	0-4
Parameter	**Units**				
pH		7.3	7.1	6.6	6.4
Settleable solids	ml/l	8.0			
Total solids	mg/l	660	516	482	1,360
Total volatile solids	mg/l	385	226	259	782
Suspended solids	mg/l	320	249	320	972
Suspended volatile solids	mg/l	207	119	178	647
Total BOD	mg/l	135	71	110	302
Dissolved BOD	mg/l	33			
Total COD	mg/l	384	313	324	1,045
Dissolved COD	mg/l	72			
Total organic carbon	mg/l	120	89	104	480
Dissolved organic carbon	mg/l	25			
Total inorganic carbon	mg/l	32	22	11	16
Dissolved inorganic carbon	mg/l	27			
Kjeldahl nitrogen as N	mg/l				
Total phosphorus as P	mg/l				
Total coliform	#/ml	133,000	22,000	33,000	25,000
Fecal coliform	#/ml	20,000	4,100	1,100	17,000

Table B20. OVERFLOW QUALITY 1970
Storm 19, September 15; Total Rainfall - 1.37 cm (0.54 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4	0-4	0-2	0-4
Parameter	Units				
pH		7.2	7.1	7.3	6.9
Settleable solids	ml/l	8.5			
Total solids	mg/l	636	519		922
Total volatile solids	mg/l	324	192		504
Suspended solids	mg/l	403	307	359	637
Suspended volatile solids	mg/l	241	134	198	395
Total BOD	mg/l	141	67		236
Dissolved BOD	mg/l	40			
Total COD	mg/l	345	205	307	742
Dissolved COD	mg/l	32			
Total organic carbon	mg/l	128	77	100	288
Dissolved organic carbon	mg/l	11			
Total inorganic carbon	mg/l	20	16	19	24
Dissolved inorganic carbon	mg/l	19			
Kjeldahl nitrogen as N	mg/l				
Total phosphorus as P	mg/l				
Total coliform	#/ml	37,000	19,800	30,600	51,000
Fecal coliform	#/ml	4,400	1,850	3,900	26,000

Table B21. OVERFLOW QUALITY 1970
Storm 20, September 17; Total Rainfall - 6.07 cm (2.39 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs			3-7	5.5-7.5	3-7
Parameter	Units				
pH			7.2	7.7	7.3
Settleable solids	ml/l		1.5		12.0
Total solids	mg/l		507	619	899
Total volatile solids	mg/l		262	351	504
Suspended solids	mg/l		378	344	555
Suspended volatile solids	mg/l		206	240	288
Total COD	mg/l		40	66	140
Dissolved BOD	mg/l		12		11
Total COD	mg/l		279	283	404
Dissolved BOD	mg/l		33	49	34
Total organic carbon	mg/l		62	79	152
Dissolved organic carbon	mg/l		11	14	12
Total inorganic carbon	mg/l		19	24	21
Dissolved inorganic carbon	mg/l		14	21	13
Kjeldahl nitrogen as N	mg/l		3.4		13.9
Total phosphorus as P	mg/l		2,200	2,650	76,500
Total coliform	#/ml		200	100	28,500
Fecla coliform	#/ml				

Table B22. OVERFLOW QUALITY 1970
Storm 21, September 22, Total Rainfall - 1.24 cm (0.49 in.)

		Site			
Composite sample period, hrs		WPCP	67th Street	59th Street	57th Street
Parameter	**Units**				
pH					
Settleable solids	ml/l				
Total solids	mg/l				
Total volatile solids	mg/l				
Suspended solids	mg/l				
Suspended volatile solids	mg/l				
Total BOD	mg/l				
Dissolved BOD	mg/l				
Total COD	mg/l				
Dissolved COD	mg/l				
Total organic carbon	mg/l				
Dissolved organic carbon	mg/l				
Total inorganic carbon	mg/l				
Dissolved inorganic carbon	mg/l				
Kjeldahl nitrogen as N	mg/l				
Total phosphorus as P	mg/l				
Total coliform	#/ml				
Fecal coliform	#/ml				

Table B23. OVERFLOW QUALITY 1970
Storm 22, September 23; Total Rainfall - 3.51 cm (1.38 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4	0-4		
Parameter	Units				
pH		7.4	7.8		
Settleable solids	ml/l	10.5	2.2		
Total solids	mg/l	771	451		
Total volatile solids	mg/l	146	170		
Suspended solids	mg/l	470	209		
Suspended volatile solids	mg/l	332	89		
Total BOD	mg/l	163	44		
Dissolved BOD	mg/l	15	11		
Total COD	mg/l	410	167		
Dissolved COd	mg/l	51	38		
Total organic carbon	mg/l	170	53		
Dissolved organic carbon	mg/l	18	11		
Total inorganic carbon	mg/l	46	27		
Dissolved inorganic carbon	mg/l	35	25		
Kjeldahl nitrogen as N	mg/l	15.4	5.7		
Total phosphorus as P	mg/l				
Total coliform	#/ml	126,000	37,500		
Fecal coliform	#/ml	11,000	1,850		

Table B24. OVERFLOW QUALITY 1970
Storm 23, September 25; Total Rainfall - 0.91 cm (0.36 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		0-4	0.5-4.5	0-4	0.5-4.5
Parameter	Units				
pH		7.1	7.6	7.2	8.0
Settleable solids	ml/l	5.5	3.5		
Total solids	mg/l	638	541	617	1,774
Total volatile solida	mg/l	302	207	468	822
Suspended solids	mg/l	229	238	343	1,377
Suspended volatile solids	mg/l	129	96	229	648
Total BOD	mg/l	83	49	138	361
Dissolved BOd	mg/l	9	12		
Total COD	mg/l	323	162	618	1,106
Dissolved COD	mg/l	41	40	49	63
Total organic carbon	mg/l	115	57	188	39
Dissolved organic carbon	mg/l	17	12	16	30
Total inorganic carbon	mg/l	42	35	28	19
Dissolved inorganic carbon	mg/l	39	30	56	40
Kjeldahl nitrogen as N	mg/l	10.8	5.2		
Total phosphorus as P	mg/l				
Total coliform	#/ml	88,000	205,000	33,500	840,000
Fecal coliform	#/ml	1,400	1,550	1,600	52,000

Table B25. OVERFLOW QUALITY 1970
Storm 24, October 14; Total Rainfall - 1.04 cm (0.41 in.)

		Site			
		WPCP	67th Street	59th Street	57th Street
Composite sample period, hrs		1.0-5.0			
Parameter	Units				
pH		7.1			
Settleable solids	ml/l	17.5			
Total solids	mg/l	982			
Total volatile solids	mg/l	653			
Suspended solids	mg/l	618			
Suspended volatile solids	mg/l	454			
Total BOD	mg/l	333			
Dissolved BOd	mg/l	29			
Total COD	mg/l	702			
Dissolved COD	mg/l	73			
Total organic carbon	mg/l	276			
Dissolved organic carbon	mg/l	25			
Total inorganic carbon	mg/l	28			
Dissolved inorganic carbon	mg/l	19			
Kjeldahl nitorgen as N	mg/l	17.9			
Total phosphorus as P	mg/l				
Total coliform	#/ml	65,000			
Fecal coliform	#/ml	7,000			

Table C1. OPERATING DATA FOR RUN NO. 1

General

Date: April 12, 1972
Start: 7:30 pm Stop: 10:20 pm Duration: 2.83 hours
Volume treated: 6,805 cu m (1,798,000 gallons)
Average flow rate: 59,614 cu m/day (15.75 mgd)
Average transfer rate: 17,903 cu m/day (4.73 mgd) Percent return; 30
Average dry weather plant flow rate: 71,915 cu m/day (19 mgd)

Contact Tank

MLSS: 4,940 mg/l Contact time[a]: 17.20 min
BOD loading: 15,184 g/cu m/day (949 lb/day/1000 ft^3)
F/M[b]: 3.10 kg BOD/day/kg MLSS Air flow: 82.7 cu m/min (2953 cfm)
Air supply: 10.7 cu m/kg BOD applied (173 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 7 days - S Reaeration time: 2.95 hours
Stabilization tank turnovers: 0.93
Oxygen supply: 454 kg/hr (1000 lb/hr)

Final Clarifier

Surface overflow rate: 41.7 cu m/day/sq m (1023 gpd/ft^2)
Clarifier detention time[a]: 1.60 hours Clarifier turnovers: 1.71
Clarifier solids loading: 267,424 g/day/sq m (54.8 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C1 (continued). OPERATING DATA FOR RUN NO. 1

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH							
Settleable solids	ml/l						
Total solids	mg/l						
Total volatile solids	mg/l						
Suspended solids	mg/l	1035	4940			20	98.1
Suspended volatile solids	mg/l						
Total BOD	mg/l	237				25	89.5
Dissolved BOD	mg/l						
Total organic carbon	mg/l	355				23	93.5
Dissolved organic carbon	mg/l						
Kjeldahl nitrogen as N	mg/l						
Total phosphorus as P	mg/l						
Total coliform	#/ml						
Fecal coliform	#/ml						

Table C2. OPERATING DATA FOR RUN NO. 2

General

Date: April 14, 1972 to April 15, 1972
Start: 11:35 pm Stop: 4:40 am Duration: 4.75 hours
Volume treated: 13,066 cu m (3,452,000 gallons)
Average flow rate: 65,859 cu m/day (17.4 mgd)
Average transfer rate: 23,051 cu m/day (6.09 mgd) Percent return; 30
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 5,370 mg/l Contact time[a]: 14.99 min
BOD loading: 10,272 g/cu m/day (642 lb/day/1000 ft^3)
F/M[b]: 1.92 kg BOD/day/kg MLSS Air flow: 91.3 cu m/min (3262 cfm)
Air supply: 7.3 cu m/kg BOD applied (119 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.0 days - S Reaeration time: 1.77 hours
Stabilization tank turnovers: 2.67 OUR:
Oxygen supply: 454 kg/hr (1000 lb/hr)

Final Clarifier

Surface overflow rate: 46.1 cu m/day/sq m (1130 gpd/ft^2)
Clarifier detention time[a]: 1.41 hours Clarifier turnovers: 3.36
Clarifier solids loading: 333,304 g/day/sq m (68.3 lb/day/ft^2)

---

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C2 (continued). OPERATING DATA FOR RUN NO. 2

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH							
Settleable solids	ml/l	7.6				2.05	77.2
Total solids	mg/l	925				416	55.0
Total volatile solids	mg/l	435				128	70.3
Suspended solids	mg/l	515	5370	9375	40	14	97.3
Suspended volatile solids	mg/l	150	3780	4775		7	95.3
Total BOD	mg/l	145			44	17	88.3
Dissolved BOD	mg/l	14				6	57.1
Total organic carbon	mg/l	204				18	91.2
Dissolved organic carbon	mg/l	15				12	20.0
Kjeldahl nitrogen as N	mg/l	16.9				7.3	56.8
Total phosphorus as P	mg/l	9.3				2.9	68.8
Total coliform	#/ml	68000				3100	95.4
Fecal coliform	#/ml	3500				1220	65.1

Table C3. OPERATING DATA FOR RUN NO. 3

General

Date: April 16, 1972
Start: 8:33 am Stop: 4:56 pm Duration: 8:38 hours
Volume treated: 20,818 cu m (5,500,000 gallons)
Average flow rate: 59,803 cu m/day (15.8 mgd)
Average transfer rate: 26,911 cu m/day (7.11 mgd) Percent return: 45
Average dry weather plant flow rate: 83,270 cu m/day (22 mgd)

Contact Tank

MLSS: 2,650 mg/l Contact time[a]: 15.37 min
BOD loading: 4,496 g/cu m/day (281 lb/day/1000 ft^3)
F/M[b]: 1.71 kg BOD/day/kg MLSS Air flow: 82.9 cu m/min (2962 cfm)
Air supply: 21.6 cu m/kg BOD applied (351 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.0 days - S Reaeration time: 1.35 hours
Stabilization tank turnovers: 6.2 OUR:
Oxygen supply: 454 kg/hr (1000 lb/hr)

Final Clarifier

Surface overflow rate: 41.9 cu m/day/sq m (1026 gpd/ft^2)
Clarifier detention time[a]: 1.45 hours Clarifier turnovers: 5.8
Clarifier solids loading: 160,552 g/day/sq m (32.9 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C3 (continued). OPERATING DATA FOR RUN NO. 3

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.6					
Settleable solids	ml/l	4.5				Trace	
Total solids	mg/l	587				406	30.8
Total volatile solids	mg/l	231				154	33.3
Suspended solids	mg/l	380	2650	7530	264	14	96.3
Suspended volatile solids	mg/l	218	1050	3750		0	100.0
Total BOD	mg/l	70			80	9	87.1
Dissolved BOD	mg/l	10				2	80.0
Total organic carbon	mg/l	69				15	78.2
Dissolved organic carbon	mg/l	14				10	28.6
Kjeldahl nitrogen as N	mg/l	9.5				3.7	61.1
Total phosphorus as P	mg/l	4.44				1.08	75.7
Total coliform	#/ml	3500				>7	<99.8
Fecal coliform	#/ml	220				32	85.5

Table C4. OPERATING DATA FOR RUN NO. 4

General

Date: April 21, 1972
Start: 10:53 am Stop: 5:35 pm Duration: 6.70 hours
Volume treated: 19,671 cu m (5,197,000 gallons)
Average flow rate: 73,240 cu m/day (19.35 mgd)
Average transfer rate: 36,601 cu m/day (9.67 mgd) Percent return; 50
Average dry weather plant flow rate: 37,850 cu m/day (10 mgd)

Contact Tank

MLSS: 2,000 mg/l Contact time[a]: 12.13 min
BOD loading: 5,824 g/cu m/day (364 lb/day/1000 ft^3)
F/M[b]: 2.94 kg BOD/day/kg MLSS Air flow: 101.6 cu m/min (3628 cfm)
Air supply: 27.9 cu m/kg BOD applied (452 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 5.0 days = S Reaeration time: 0.99 hours
Stabilization tank turnovers: 6.8 OUR:
Oxygen supply: 397 kg/hr (875 lb/hr)

Final Clarifier

Surface overflow rate: 51.3 cu m/day/sq m (1257 gpd/ft^2)
Clarifier detention time[a]: 1.14 hours Clarifier turnovers: 5.86
Clarifier solids loading: 153,720 g/day/sq m (31.5 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C4 (continued). OPERATING DATA FOR RUN NO. 4

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.0					
Settleable solids	ml/l	5				Trace	
Total solids	mg/l	802				618	22.9
Total volatile solids	mg/l	252				78	69.0
Suspended solids	mg/l	224	2000	6965	24	40	82.1
Suspended volatile solids	mg/l	119	1127	3989		25	79.0
Total BOD	mg/l	74			16	21	71.6
Dissolved BOD	mg/l	28				9	67.8
Total organic carbon	mg/l	81				22	72.8
Dissolved organic carbon	mg/l	28				16	42.8
Kjeldahl nitrogen as N	mg/l	14.9				8.4	43.6
Total phosphorus as P	mg/l	7.18				3.52	51.0
Total coliform	#/ml	2900				83	97.1
Fecal coliform	#/ml	68				60	11.7

Table C5. OPERATING DATA FOR RUN NO. 5

General

Date: May 6, 1972
Start: 4:00 am Stop: 7:02 am Duration: 3.03 hours
Volume treated: 7,593 cu m (2,006,000 gallons)
Average flow rate: 60,560 cu m/day (16.0 mgd)
Average transfer rate: 21,196 cu m/day (5.6 mgd) Percent return; 35
Average dry weather plant flow rate: 71,915 cu m/day (19 mgd)

Contact Tank

MLSS: 986 mg/l Contact time[a]: 16.31 min
BOD loading: 4,160 g/cu m/day (260 lb/day/1000 ft^3)
F/M[b]: 4.26 kg BOD/day/kg MLSS Air flow: 84.0 cu m/min (3000 cfm)
Air supply: 39.0 cu m/kg BOD applied (632 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 15.0 days - S Reaeration time: 1.88 hours
Stabilization tank turnovers: 1.61 OUR:
Oxygen supply: 397 kg/hr (875 lb/hr)

Final Clarifier

Surface overflow rate: 42.4 cu m/day/sq m (1039 gpd/ft^2)
Clarifier detention time[a]: 1.54 hours Clarifier turnovers: 1.97
Clarifier solids loading: 56,120 g/day/sq m (11.5 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C5 (continued). OPERATING DATA FOR RUN NO. 5

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.55					
Settleable solids	ml/l	7.4				Trace	
Total solids	mg/l	517				490	5.2
Total volatile solids	mg/l	215				145	32.6
Suspended solids	mg/l	155	986		14	15	90.5
Suspended volatile solids	mg/l	78	548			7	91.0
Total BOD	mg/l	64			18	18	72.0
Dissolved BOD	mg/l	41				12	70.7
Total organic carbon	mg/l	89				21	76.4
Dissolved organic carbon	mg/l	34				17	50.0
Kjeldahl nitrogen as N	mg/l	10.8				5.2	51.8
Total Phosphorus as P	mg/l	3.39				1.86	45.1
Total coliform	#/ml	3800			2600	2700	28.9
Fecal coliform	#/ml	500			520	700	

Table C6. OPERATING DATA FOR RUN NO. 6

General

Date: May 8, 1972
Start: 4:04 pm Stop: 10:30 pm Duration: 6.48 hours
Volume treated: 17,824 cu m (4,709,000 gallons)
Average flow rate: 66,616 cu m/day (17.6 mgd)
Average transfer rate: 26,646 cu m/day (7.04 mgd) Percent return; 40
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 975 mg/l Contact time[a]: 14.29 min
BOD loading: 5,088 g/cu m/day (318 lb/day/1000 ft^3)
F/M[b]: 5.26 kg BOD/day/kg MLSS Air flow: 92.4 cu m/min (3300 cfm)
Air supply: 31.9 cu m/kg BOD applied (518 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.0 days - S Reaeration time: [illegible].70 hours
Stabilization tank turnovers: 3.77 OUR:
Oxygen supply: 397 kg/hr (875 lb/hr)

Final Clarifier

Surface overflow rate: 46.6 cu m/day/sq m (1143 gpd/ft^2)
Clarifier detention time[a]: 1.35 hours Clar-fier turnovers: 4.77
Clarifier solids loading: 63,440 g/day/sq m (13.0 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C6 (continued). OPERATING DATA FOR RUN NO. 6

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.58					
Settleable solids	ml/l	2.0				Trace	
Total solids	mg/l	597				548	8.2
Total volatile solids	mg/l	328				264	19.5
Suspended solids	mg/l	110	975		14	28	74.5
Suspended volatile solids	mg/l	45	470		6	13	71.1
Total BOD	mg/l	71			15	23	67.6
Dissolved BOD	mg/l	39				9	76.9
Total organic carbon	mg/l	107				26	75.7
Dissolved organic carbon	mg/l	29				16	44.8
Kjeldahl nitrogen as N	mg/l	10.1				7.4	26.7
Total phosphorus as P	mg/l	5.15				4.36	15.3
Total coliform	#/ml	17000			850	470	97.5
Fecal coliform	#/ml	525			500	250	52.4

Table C7. OPERATING DATA FOR RUN NO. 7

General

Date: May 13, 1972
Start: 10:58 am Stop: 3:34 pm Duration: 4.60 hours
Volume treated: 10,852 cu m (2,867,000 gallons)
Average flow rate: 54,882 cu m/day (14.5 mgd)
Average transfer rate: 30,015 cu m/day (7.93 mgd) Percent return; 55
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 1,887 mg/l Contact time[a]: 15.70 min
BOD loading: 6,016 g/cu m/day (376 lb/day/1000 ft^3)
F/M[b]: 3.21 kg BOD/day/kg MLSS Air flow: 76.1 cu m/min (2719 cfm)
Air supply: 27.0 cu m/kg BOD applied (438 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 5.0 days - S Reaeration time: 1.45 hours
Stabilization tank turnovers: 3.17 OUR:
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 38.4 cu m/day/sq m (942 gpd/ft^2)
Clarifier detemtion time[a]: 1.48 hours Clarifier turnovers: 3.11
Clarifier solids loading: 111,752 g/day/sq m (22.9 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C7 (continued). OPERATING DATA FOR RUN NO. 7

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.5					
Settleable solids	ml/l	9				Trace	
Total solids	mg/l	738				544	26.3
Total volatile solids	mg/l	300				161	46.3
Suspended solids	mg/l	257	1887			25	90.3
Suspended volatile solids	mg/l	100	1077			11	89.0
Total BOD	mg/l	102				14	86.3
Dissolved BOD	mg/l	19				6	68.4
Total organic carbon	mg/l	107				24	77.5
Dissolved organic carbon	mg/l	27				18	33.3
Kjeldahl nitrogen as N	mg/l	17.3				7.2	58.4
Total phosphorus as P	mg/l	7.4				3.6	51.4
Total coliform	#/ml	2250				1350	40.0
Fecal coliform	#/ml	950				715	24.7

Table C8. OPERATING DATA FOR RUN NO. 8

General

Date: May 15, 1972
Start: 11:45 am Stop: 2:56 pm Duration: 3.18 hours
Volume treated: 8,353 cu m (2,207,000 gallons)
Average flow rate: 62,982 cu m/day (16.64 mgd)
Average transfer rate: 32,750 cu m/day (8.65 mgd) Percent return; 52
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 2,161 mg/l Contact time[a]: 13.92 min
BOD loading: 10,080 g/cu m/day (630 lb/day/1000 ft^3)
F/M[b]: 4.70 kg BOD/day/kg MLSS Air flow: 87.4 cu m/min (3120 cfm)
Air supply: 16.3 cu m/kg BOD applied (265 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.0 days - S Reaeration time: 1.46 hours
Stabilization tank turnovers: 2.18 OUR:
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 44.1 cu m/day/sq m (1081 gpd/ft^2)
Clarifier detention time[a]: 1.31 hours Clarifier turnovers: 2.43
Clarifier solids loading: 144,448 g/day/sq m (29.6 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C8 (continued). OPERATING DATA FOR RUN NO. 8

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH							
Settleable solids	ml/l	8				Trace	
Total solids	mg/l	786				561	26.1
Total volatile solids	mg/l	283				185	34.6
Suspended solids	mg/l	266	2161		14	28	89.5
Suspended volatile solids	mg/l	154	1234			17	88.9
Total BOD	mg/l	149			10	22	85.2
Dissolved BOD	mg/l	57				8	85.9
Total organic carbon	mg/l	138				29	78.9
Dissolved organic carbon	mg/l	45				19	57.7
Kjeldahl nitrogen as N	mg/l	20.1				8.1	59.7
Total phosphorus as P	mg/l	12.04				4.8	60.1
Total coliform	#/ml	10300			85	2050	80.1
Fecal coliform	#/ml	1500			<4	1300	13.3

Table C9. OPERATING DATA FOR RUN NO. 9

General

Date: June 2, 1972 to June 3, 1972
Start: 10:10 pm Stop: 7:55 am Duration: 8.72 hours
Volume treated: 18,282 cu m (4,830,000 gallons)
Average flow rate: 50,340 cu m/day (13.3 mgd)
Average transfer rate: 17,638 cu m/day (4.66 mgd) Percent return; 35
Average dry weather plant flow rate: 56,775 cu m/day (15 mgd)

Contact Tank

MLSS: 2,700 mg/l Contact time[a]: 19.62 min
BOD loading: 13,088 g/cu m/day (818 lb/day/1000 ft^3)
F/M[b]: 4.89 kg BOD/day/kg MLSS Air flow: 69.8 cu m/min (2494 cfm)
Air supply: 12.4 cu m/kg BOD applied (201 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.0 days - S Reaeration time: 2.68 hours
Stabilization tank turnovers: 3.25 OUR:
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 35.3 cu m/day/sq m (864 gpd/ft^2)
Clarifier detention time[a]: 1.85 hours Clarifier turnovers: 4.72
Clarifier solids loading: 128,344 g/day/sq m (26.3 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C9 (continued). OPERATING DATA FOR RUN NO. 9

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.05					
Settleable solids	ml/l	26				Trace	
Total solids	mg/l	1265				446	64.7
Total volatile solids	mg/l	650				138	78.7
Suspended solids	mg/l	920	2700	15700	11	41	95.5
Suspended volatile solids	mg/l	320	1400	10100		22	93.1
Total BOD	mg/l	242			26	30	87.6
Dissolved BOD	mg/l	62				21	66.1
Total organic carbon	mg/l	205				36	87.8
Dissolved organic carbon	mg/l	43				31	27.9
Kjeldahl nitrogen as N	mg/l						
Total phosphorus as P	mg/l	7				4	42.8
Total coliform	#/ml	26000				4700	81.9
Fecal coliform	#/ml	1300				1100	15.4

Table C10. OPERATING DATA FOR RUN NO. 10

General

Date: June 12, 1972
Start: 9:21 am Stop: 12:21 pm Duration: 3.00 hours
Volume treated: 8,005 cu m (2,115,000 gallons)
Average flow rate: 64,042 cu m/day (16.92 mgd)
Average transfer rate: 26,874 cu m/day (7.10 mgd) Percent return; 42
Average dry weather plant flow rate: 64,345 cu m/day (17 mgd)

Contact Tank

MLSS: 2,625 mg/l Contact time[a]: 14.65 min
BOD loading: 10,320 g/cu m/day (645 lb/day/1000 ft^3)
F/M[b]: 3.96 kg BOD/day/kg MLSS Air flow: 88.8 cu m/min (3172 cfm)
Air supply: 13.3 cu m/kg BOD applied (216 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 9.0 days - S Reaeration time: 2.02 hours
Stabilization tank turnovers: 1.48 OUR:
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 44.8 cu m/day/sq m (1099 gpd/ft^2)
Clarifier detention time[a]: 1.38 hours Clarifier turnovers: 2.17
Clarifier solids loading: 166,896 g/day/sq m (34.2 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C10 (continued). OPERATING DATA FOR RUN NO. 10

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.2	6.9	7.15	7.65		
Settleable solids	ml/l	11.8			Trace	Trace	
Total solids	mg/l	770			462	446	42.1
Total volatile solids	mg/l	345			148	158	54.2
Suspended solids	mg/l	417	2625	7625	5	15	96.4
Suspended volatile solids	mg/l	215	1550	4500	4	10	95.3
Total BOD	mg/l	150		1820	8	15	90.0
Dissolved BOD	mg/l	35			8	13	62.8
Total organic carbon	mg/l	163		1838	13	27	83.4
Dissolved organic carbon	mg/l	33			13	20	39.4
Kjeldahl nitrogen as N	mg/l	17.6			10.2	10.5	40.3
Total phosphorus as P	mg/l	5.1			3.3	5.0	1.9
Total coliform	#/ml	28000					
Fecal coliform	#/ml	1800			35	1720	4.4

Table C11. OPERATING DATA FOR RUN NO. 11

General

Date: June 14, 1972
Start: 2:23 pm Stop: 5:13 pm Duration: 2.74 hours
Volume treated: 7,604 cu m (2,009,000 gallons)
Average flow rate: 66,616 cu m/day (17.6 mgd)
Average transfer rate: 29,977 cu m/day (7.92 mgd) Percent return; 45
Average dry weather plant flow rate: 64,345 cu m/day (17 mgd)

Contact Tank

MLSS: 2,425 mg/l Contact time[a]: 13.80 min
BOD loading: 6,592 g/cu m/day (412 lb/day/1000 ft^3)
F/M[b]: 2.67 kg BOD/day/kg MLSS Air flow: 92.4 cu m/min (3300 cfm)
Air supply: 21.7 cu m/kg BOD applied (352 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.0 days - S Reaeration time: 1.88 hours
Stabilization tank turnovers: 1.46 OUR:
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 46.6 cu m/day sq m (1143 gpd/ft^2)
Clarifier detention time[a]: 1.30 hours Clarifier turnovers: 1.45
Clarifier solids loading: 163,480 g/day/sq m (33.5 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C11 (continued). OPERATING DATA FOR RUN NO. 11

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH							
Settleable solids	ml/l	2.8			Trace	Trace	
Total solids	mg/l	669			378	459	31.4
Total volatile solids	mg/l	252			120	130	48.4
Suspended solids	mg/l	166	2425	12975	8	7	95.7
Suspended volatile solids	mg/l	117	1750	7850	3	3	97.4
Total BOD	mg/l	92		2800	12	16	82.6
Dissolved BOD	mg/l	62			6	13	79.0
Total organic carbon	mg/l	91		4450	15	24	73.6
Dissolved organic carbon	mg/l	49			12	19	61.2
Kjeldahl nitrogen as N	mg/l	13.5			5.1	8.3	38.5
Total phosphorus as P	mg/l	5.69			0.26	1.41	75.2
Total coliform	#/ml	57000			520	2100	96.3
Fecal coliform	#/ml	400			29	29	92.8

Table C12. OPERATING DATA FOR RUN NO. 12

General

Date: June 19, 1972 to June 20, 1972
Start: 8:10 pm Stop: 3:40 am Duration: 7.47 hours
Volume treated: 19,387 cu m (5,122,000 gallons)
Average flow rate: 62,301 cu m/day (16.46 mgd)
Average transfer rate: 28,047 cu m/day (7.41 mgd) Percent return; 45
Average dry weather plant flow rate:

Contact Tank

MLSS: 2,825 mg/l Contact time[a]: 14.76 min
BOD loading: 3,744 g/cu m/day (234 lb/day/1000 ft^3)
F/M[b]: 1.34 kg/BOD/day/kg MLSS Air flow: 86.4 cu m/min (3086 cfm)
Air supply: 35.6 cu m/kg BOD applied (578 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 5.0 days - S Reaeration time: 2.01 hours
Stabilization tank turnovers: 3.72 OUR:
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 43.6 cu m/day/sq m (1069 gpd/ft^2)
Clarifier detention time[a]: 1.39 hours Clarifier turnovers: 5.37
Clarifier solids loading: 178,120 g/day/sq m (36.5 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C12 (continued). OPERATING DATA FOR RUN NO. 12

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.30	7.05	6.95	7.70	7.40	
Settleable solids	ml/l	3.0			Trace	Trace	
Total solids	mg/l	547			433	370	32.3
Total volatile solids	mg/l	161			76	107	33.5
Suspended solids	mg/l	213	2825	13575	12	20	90.6
Suspended volatile solids	mg/l	78	1725	8110	9	17	78.2
Total BOD	mg/l	56		2500	17	17	69.6
Dissolved BOD	mg/l	28			11	16	42.8
Total organic carbon	mg/l	64		4250	17	24	62.5
Dissolved organic carbon	mg/l	20			16	16	20.0
Kjeldahl nitrogen as N	mg/l	7.27			7.19	5.87	19.3
Total phosphorus as P	mg/l	2.23			3.26	2.37	
Total coliform	#/ml	13500			650	5900	56.3
Fecal coliform	#/ml	1050			25	460	56.2

Table C13. OPERATING DATA FOR RUN NO. 13

General

Date: July 12, 1972 to July 13, 1972
Start: 11:05 pm Stop: 2:03 am Duration: 2.96 hours
Volume treated: 7,555 cu m (1,996,000 gallons)
Average flow rate: 61,317 cu m/day (16.2 mgd)
Average transfer rate: 15,329 cu m/day (4.05 mgd) Percent return; 25
Average dry weather plant flow rate:

Contact Tank

MLSS: 3,950 mg/l Contact time[a]: 17.39 min
BOD loading: 9,824 g/cu m/day (614 lb/day/1000 ft^3)
F/M[b]: 2.50 kg BOD/day/kg MLSS Air flow: 85.1 cu m/min (3038 cfm)
Air supply: 13.4 cu m/kg BOD applied (218 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 14.0 days - S Reaeration time: 3.08 hours
Stabilization tank turnovers: 0.96 OUR:
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 42.9 cu m/day/sq m (1052 gpd/ft^2)
Clarifier detention time[a]: 1.64 hours Clarifier turnovers: 1.81
Clarifier solids loading: 211,304 g/day/sq m (43.3 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C13 (continued). OPERATING DATA FOR RUN NO. 13

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		6.85	6.70	6.98	7.52	7.21	
Settleable solids	ml/l	11			Trace	Trace	
Total solids	mg/l	724			463	489	32.4
Total volatile solids	mg/l	362			112	190	47.5
Suspended solids	mg/l	479	3950	14775	34	49	89.7
Suspended volatile solids	mg/l	269	2350	8900	27	22	91.8
Total BOD	mg/l	149		3250	30	49	73.2
Dissolved BOD	mg/l	41			10	22	46.3
Total organic carbon	mg/l	161		4550	20	48	70.2
Dissolved organic carbon	mg/l	33			15	31	6.1
Kjeldahl nitrogen as N	mg/l	13.2			7.1	11.2	15.2
Total phosphorus as P	mg/l	4.76			2.07	6.39	
Total coliform	#/ml	40000			11000	23300	41.7
Fecal coliform	#/ml	13000			1300	600	95.4

Table C14. OPERATING DATA FOR RUN NO. 14

General

Date: July 13, 1972
Start: 10:02 am Stop: 7:32 pm Duration: 9.56 hours
Volume treated: 24,640 cu m (6,510,000 gallons)
Average flow rate: 61,696 cu m/day (16.3 mgd)
Average transfer rate: 25,284 cu m/day (6.68 mgd) Percent return; 42
Average dry weather plant flow rate:

Contact Tank

MLSS: 3,525 mg/l Contact time[a]: 15.32 min
BOD loading: 6,496 g/cu m/day (406 lb/day/1000 ft^3)
F/M[b]: 1.86 kg BOD/day/kg MLSS Air flow: 85.6 cu m/min (3056 cfm)
Air supply: 20.4 cu m/kg BOD applied (331 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 0.5 days - S Reaeration time: 2.15 hours
Stabilization tank turnovers: 4.43 OUR: 48 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 43.2 cu m/day/sq m (1058 gpd/ft^2)
Clarifier detention time[a]: 1.44 hours Clarifier turnovers: 6.62
Clarifier solids loading: 214,232 g/day/sq m (43.9 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C14 (continued). OPERATING DATA FOR RUN NO. 14

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH							
Settleable solids	ml/l	4.5			Trace	Trace	
Total solids	mg/l	628			367	360	42.6
Total volatile solids	mg/l	227			112	118	48.0
Suspended solids	mg/l	310	3525	12650	33	25	91.9
Suspended volatile solids	mg/l	121	1825	7125	23	13	89.3
Total BOD	mg/l	98		2450	10	22	77.6
Dissolved BOD	mg/l	15			8	6	60.0
Total organic carbon	mg/l	140		3950	18	21	85.0
Dissolved organic carbon	mg/l	19			13	18	5.3
Kjeldahl nitrogen as N	mg/l	13.3			2.1	5.7	57.1
Total phosphorus as P	mg/l	4.98			0.75	1.41	71.7
Total coliform	#/ml	795000			104000	157000	80.3
Fecal coliform	#/ml	600			320	770	

Table C15. OPERATING DATA FOR RUN NO. 15

General

Date: July 14, 1972 to July 15, 1972
Start: 11:03 pm Stop: 8:26 am Duration: 9.38 hours
Volume treated: 24,023 cu m (6,347,000 gallons)
Average flow rate: 61,317 cu m/day (16.2 mgd)
Average transfer rate: 18,395 cu m/day (4.86 mgd) Percent return; 30
Average dry weather plant flow rate:

Contact Tank

MLSS: 4,325 mg/l Contact time[a]: 16.72 min
BOD loading: 2,896 g/cu m/day (181 lb/day/1000 ft^3)
F/M[b]: 0.68 kg BOD/day/kg MLSS Air flow: 85.1 cu m/min (3038 cfm)
Air supply: 44.8 cu m/kg BOD applied (727 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 1.0 days - S Reaeration time: 2.96 hours
Stabilization tank turnovers: 3.16 OUR: 52 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr

Final Clarifier

Surface overflow rate: 42.9 cu m/day/sq m (1052 gpd/ft^2)
Clarifier detention time[a]: 1.57 hours Clarifier turnovers: 5.96
Clarifier solids loading: 240,584 g/day/sq m (49.3 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C15 (continued). OPERATING DATA FOR RUN NO. 15

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.67			7.70	7.70	
Settleable solids	ml/l	3.5			Trace	Trace	
Total solids	mg/l	682			432	372	45.4
Total volatile solids	mg/l	195			124	100	48.7
Suspended solids	mg/l	334	4325	14775	13	10	97.0
Suspended volatile solids	mg/l	62	2350	7575	1	5	91.9
Total BOD	mg/l	44		2550	23	8	81.8
Dissolved BOD	mg/l	8			4	4	50.0
Total organic carbon	mg/l	64		4850	24	14	78.1
Dissolved organic carbon	mg/l	13			12	12	7.7
Kjeldahl nitrogen as N	mg/l	6.55			3.6	2.7	58.8
Total phosphorus as P	mg/l	2.46			2.38	1.96	20.3
Total coliform	#/ml	8700			2600	1300	85.0
Fecal coliform	#/ml	6400			1100	1200	81.3

Table C16. OPERATING DATA FOR RUN NO. 16

General

Date: July 17, 1972 to July 18, 1972
Start: 8:25 pm   Stop: 1:00 am   Duration: 4.33 hours
Volume treated: 10,753 cu m (2,841,000 gallons)
Average flow rate: 59,803 cu m/day (15.8 mgd)
Average transfer rate: 20,931 cu m/day (5.53 mgd)   Percent return; 35
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 4,984 mg/l   Contact time[a]: 16.51 min
BOD loading: 5,664 g/cu m/day (354 lb/day/1000 ft^3)
F/M[b]: 1.14 kg BOD/day/kg MLSS   Air flow: 82.9 cu m/min (2962 cfm)
Air supply: 23.0 cu m/kg BOD applied (373 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 3.0 days - S   Reaeration time: 2.43 hours
Stabilization tank turnovers: 1.78   OUR: 34 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 41.9 cu m/day/sq m (1026 gpd/ft^2)
Clarifier detention time[a]: 1.55 hours   Clarifier turnovers: 2.78
Clarifier solids loading: 281,088 g/day/sq m (57.6 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C16 (continued). OPERATING DATA FOR RUN NO. 16

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		6.9	6.8	6.75	7.20	7.15	
Settleable solids	ml/l	5.2			Trace	Trace	
Total solids	mg/l	600			568	474	21.0
Total volatile solids	mg/l	121			162	135	
Suspended solids	mg/l	231	4984	15767	14	11	95.2
Suspended volatile solids	mg/l	102	2651	8050	3	3	97.1
Total BOD	mg/l	88			12	15	82.9
Dissolved BOD	mg/l	11		4200	1	3	72.7
Total organic carbon	mg/l	88			11	18	79.5
Dissolved organic carbon	mg/l	18			7	16	11.1
Kjeldahl nitrogen as N	mg/l						
Total phosphorus as P	mg/l	3.29			1.75	1.75	45.9
Total coliform	#/ml	83000			3800	1400	98.3
Fecal coliform	#/ml	4200			80	36	99.1

Table C17. OEPRATING DATA FOR RUN NO. 17

General

Date: July 19, 1972
Start: 3:52 pm Stop: 7.52 Duration: 4.01 hours
Volume treated: 10,114 cu m (2,672,000 gallons)
Average flow rate: 60,560 cu m/day (16.0 mgd)
Average transfer rate: 30,280 cu m/day (8.00 mgd) Percent return; 50
Average dry weather plant flow rate:

Contact Tank

MLSS: Contact time[a]: 14.67 min
BOD loading: 24,928 g/cu m/day (1558 lb/day/1000 ft^3)
F/M[b]: Air flow: 84.0 cu m/min (3000 cfm)
Air supply: 5.2 cu m/kg BOD applied (84 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.0 days - S Reaeration time: 1.77 hours
Stabilization tank turnovers: 2.26 OUR:
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 42.4 cu m/day/sq m (1-39 gpd/ft^2)
Clarifier detention time[a]: 1.38 hours Clarifier turnovers: 2.90
Clarifier solids loading: 116,632 g/day/sq m (23.9 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C17 (continued). OPERATING DATA FOR RUN NO. 17

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		8.4	8.3	8.3	8.4	8.3	
Settleable solids	ml/l	4.0			0.1	Trace	
Total solids	mg/l	776			607	624	19.6
Total volatile solids	mg/l	128			89	75	41.4
Suspended solids	mg/l	248	1840	14633	20	20	91.9
Suspended volatile solids	mg/l		1220	8333	20	20	
Total BOD	mg/l	383		1078	68	15	96.0
Dissolved BOD	mg/l	21			27	9	57.1
Total organic carbon	mg/l	73		4250	20	20	72.6
Dissolved organic carbon	mg/l						
Kjeldahl nitrogen as N	mg/l	13.2			4.4	11.0	16.7
Total phosphorus as P	mg/l	4.0			1.0	1.3	67.5
Total coliform	#/ml	180000			7900	9300	94.8
Fecal coliform	#/ml	130000			3900	4600	96.4

Table C18. OPERATING DATA FOR RUN NO. 18

General

Date: August 2, 1972
Start: 6:50 am Stop: 6:00 pm Duration: 11.04 hours
Volume treated: 28,607 cu m (7,558,000 gallons)
Average flow rate: 62,188 cu m/day (16.43 mgd)
Average transfer rate: 31,113 cu m/day (8.22 mgd) Percent return; 50
Average dry weather plant flow rate:

Contact Tank

MLSS: 5,150 mg/l Contact time[a]: 14.29 min
BOD loading: 3,280 g/cu m/day (205 lb/day/1000 ft^3)
F/M[b]: 0.64 kg BOD/day/kg MLSS Air flow: 86.3 cu m/min (3081 cfm)
Air supply: 40.7 cu m/kg BOD applied (660 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 10.0 days - S Reaeration time: 1.63 hours
Stabilization tank turnovers: 6.77 OUR: 72 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overlfow rate: 43.5 cu m/day/sq m (1067 gpd/ft^2)
Clarifier detention time[a]: 1.34 hours Clarifier turnovers: 8.20
Clarifier solids loading: 335,256 g/day/sq m (68.7 $lb/day/ft^2$)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C18 (continued). OPERATING DATA FOR RUN NO. 18

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.20	6.92	6.80	7.30	7.50	
Settleable solids	ml/l	3.20			0.1	Trace	
Total solids	mg/l	556			360	442	20.3
Total volatile solids	mg/l	219			122	168	23.3
Suspended solids	mg/l	202	5150	14750	18	35	82.7
Suspended volatile solids	mg/l	88	2900	8575	16	19	78.4
Total BOD	mg/l	49		2200	12	19	61.2
Dissolved BOD	mg/l	11			2	3	72.7
Total organic carbon	mg/l	62		3500	12	22	64.5
Dissolved organic carbon	mg/l	16			11	15	6.3
Kjeldahl nitrogen as N	mg/l	8.2			1.9	4.1	50.0
Total phosphorus as P	mg/l	1.9			2.0	1.8	5.3
Total coliform	#/ml	230000			53000	26000	88.7
Fecal coliform	#/ml	76000			7300	2400	96.8

Table C19. OPERATING DAGA FOR RUN NO. 19

General

Date: August 6, 1972 to August 7, 1972
Start: 11:52 pm Stop: 4:56 am Duration: 5.02 hours
Volume treated: 12,990 cu m (3,432,000 gallons)
Average flow rate: 62,112 cu m/day (16.41 mgd)
Average transfer rate: 18,622 cu m/day (4.92 mgd) Percent return; 30
Average dry weather plant flow rate:

Contact Tank

MLSS: 4,225 mg/l Contact time[a]: 16.51 min
BOD loading: 4,400 g/cu m/day (275 lb/day/1000 ft^3)
F/M[b]: 1.05 kg BOD/day/kg MLSS Air flow: 86.2 cu m/min (3077 cfm)
Air supply: 29.5 cu m/kg BOD applied (478 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 4.0 days - S Reaeration time: 2.68 hours
Stabilization tank turnovers: 1.87 OUR: 50 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 43.5 cu m/day/sq m (1066 gpd/ft^2)
Clarifier detention time[a]: 1.55 hours Clarifier turnovers: 3.23
Clarifier solids loading: 238,144 g/day/sq m (48.8 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C19 (continued). OPERATING DATA FOR RUN NO. 19

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.20	7.10	7.25	7.45	7.40	
Settleable solids	ml/l	5.1			0.1	Trace	
Total solids	mg/l	483			446	428	11.4
Total volatile solids	mg/l	209			134	152	27.3
Suspended solids	mg/l	159	4225	13400	21	18	88.7
Suspended volatile solids	mg/l	74	2250	7850	16	5	93.2
Total BOD	mg/l	66		2350	9	9	86.4
Dissolved BOD	mg/l	7			1	1	85.7
Total organic carbon	mg/l	75		4550	8	14	81.3
Dissolved organic carbon	mg/l	9			7	10	
Kjeldahl nitrogen as N	mg/l	10.2			4.0	5.4	47.1
Total phosphorus as P	mg/l	2.9			1.7	1.8	37.9
Total coliform	#/ml	83000			550	2530	96.9
Fecal coliform	#/ml	7200			40	280	96.1

Table C20. OPERATING DATA FOR RUN NO. 20

General

Date: August 11, 1972
Start: 9:36 am Stop: 5:36 pm Duration: 8.00 hours
Volume treated: 23,391 cu m (6,180,0-0 gallons)
Average flow rate: 70,174 cu m/day (18.54 mgd)
Average transfer rate: 7,721 cu m/day (2.04 mgd) Percent return; 11
Average dry weather plant flow rate:

Contact Tank

MLSS: 2,100 mg/l Contact time[a]: 17.11 min
BOD loading: 7,776 g/cu m/day (486 lb/day/1000 ft^3)
F/M[b]: 3.73 kg BOD/day/kg MLSS Air flow: 97.3 cu m/min (3476 cfm)
Air supply: 19.2 cu m/kg BOD applied (312 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 4.0 days - S Reaeration time: 6.53 hours
Stabilization tank turnovers: 1.22 OUR: 48 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 49.1 cu m/day/sq m (1204 gpd/ft^2)
Clarifier detention time[a]: 1.61 hours Clarifier turnovers: 4.96
Clarifier solids loading: 114,192 g/day/sq m (23.4 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C20 (continued). OPERATING DATA FOR RUN NO. 20

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.28	7.02	6.80	7.55	7.50	
Settleable solids	ml/l	10			0.2	0.1	99.0
Total solids	mg/l	736			462	466	36.7
Total volatile solids	mg/l	321			147	146	52.9
Suspended solids	mg/l	364	2100	14575	12	32	91.2
Suspended volatile solids	mg/l	166	1175	8225	<1	22	86.7
Total BOD	mg/l	103		3950	13	16	84.5
Dissolved BOD	mg/l	24			3	5	79.2
Total organic carbon	mg/l	133		7500	14	16	88.0
Dissolved organic carbon	mg/l	12			8	10	16.7
Kjeldahl nitrogen as N	mg/l	21.0				4.6	78.1
Total phosphorus as P	mg/l	7.9			0.96	1.8	77.2
Total coliform	#/ml	76000			3000	4300	94.3
Fecal coliform	#/ml	8300			210	77	99.1

Table C21. OPERATING DATA FOR RUN NO. 21

General

Date: August 14, 1972
Start: 2:44 pm   Stop: 10:24 pm   Duration: 7.58 hours
Volume treated: 22,014 cu m (5,816,000 gallons)
Average flow rate: 69,644 cu m/day (18.4 mgd)
Average transfer rate: 6,964 cu m/day (1.84 mgd)   Percent return; 10
Average dry weather plant flow rate:

Contact Tank

MLSS: 1,725 mg/l   Contact time[a]: 17.40 min
BOD loading: 4,944 g/cu m/day (309 lb/day/1000 ft^3)
F/M[b]: 2.88 kg BOD/day/kg MLSS   Air flow: 96.6 cu m/min (3450 cfm)
Air supply: 29.8 cu m/kg BOD applied (483 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 3.0 days - S   Reaeration time: 7.30 hours
Stabilization tank turnovers: 1.04   OUR: 67 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 48.8 cu m/day/sq m (1195 gpd/ft^2)
Clarifier detention time[a]: 1.64 hours   Clarifier turnovers: 4.63
Clarifier solids loading: 92,232 g/day/sq m (18.9 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C21 (continued). OPERATING DATA FOR RUN NO. 21

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.75	7.30	7.00	7.55	7.52	
Settleable solids	ml/l	3.3			Trace	Trace	
Total solids	mg/l	763			389	280	63.3
Total volatile solids	mg/l	280			148	116	58.6
Suspended solids	mg/l	288	1725	18025	5	48	83.3
Suspended volatile solids	mg/l	44	700	10875	<1	36	18.2
Total BOD	mg/l	66		3150	13	12	81.8
Dissolved BOD	mg/l	18			2	6	66.7
Total organic carbon	mg/l	95		6000	15	21	77.9
Dissolved organic carbon	mg/l	20			11	15	25.0
Kjeldahl nitrogen as N	mg/l	7.9			5.9	5.2	34.2
Total phosphorus as P	mg/l	3.4			0.43	1.45	57.4
Total coliform	#/ml	151000			3200	24400	83.8
Fecal coliform	#/ml	8000			100	600	92.5

Table C22. OPERATING DATA FOR RUN NO. 22

General

Date: August 16, 1972
Start: 10:45 am Stop: 2:40 pm Duration: 3.87 hours
Volume treated: 10,795 cu m (2,852,000 gallons)
Average flow rate: 66,994 cu m/day (17.7 mgd)
Average transfer rate: 6,699 cu m/day (1.77 mgd) Percent return; 10
Average dry weather plant flow rate:

Contact Tank

MLSS: 1,725 mg/l Contact time[a]: 12.14 min
BOD loading: 6,768 g/cu m/day (423 lb/day/1000 ft^3)
F/M[b]: 2.65 kg BOD/day/kg MLSS Air flow: 92.9 cu m/min (3319 cfm)
Air supply: 30.8 cu m/kg BOD applied (500 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 1.5 days - S Reaeration time: 7.32 hours
Stabilization tank turnovers: 0.53 OUR: 72 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 46.9 cu m/day/sq m (1150 gpd/ft^2)
Clarifier detention time[a]: 1.70 hours Clarifier turnovers: 2.27
Clarifier solids loading: 88,816 g/day/sq m (18.2 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static conditon; C = continuous flow.

Table C22 (continued). OPERATING DATA FOR RUN NO. 22

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.50	7.32	6.92	7.75	7.80	
Settleable solids	ml/l	1.8			0.1	Trace	
Total solids	mg/l	630			618	570	9.5
Total volatile solids	mg/l	172			184	137	20.4
Suspended solids	mg/l	68	1725	19425	6	9	86.7
Suspended volatile solids	mg/l	42	1163	11675	3	6	85.7
Total BOD	mg/l	63		3480	6	10	84.1
Dissolved BOD	mg/l	17			<1	3	82.4
Total organic carbon	mg/l	50		5200	37	34	32.0
Dissolved organic carbon	mg/l	21			13	14	33.3
Kjeldahl nitrogen as N	mg/l	9.7			2.2	3.9	59.8
Total phosphorus as P	mg/l	3.7			0.56	1.50	59.5
Total coliform	#/ml	460000			180	800	99.8
Fecal coliform	#/ml	3600			10	33	99.1

Table C23. OPERATING DATA FOR RUN NO. 23

General

Date: November 3, 1972
Start: 8:55 am Stop: 2:55 pm Duration: 6.00 hours
Volume treated: 15,749 cu m (4,161,000 gallons)
Average flow rate: 62,831 cu m/day (16.6 mgd)
Average transfer rate: 25,132 cu m/day (6.64 mgd) Percent return; 40
Average dry weather plant flow rate: 52,990 cu m/day (14 mgd)

Contact Tank

MLSS: 4,075 mg/l Contact time[a]: 15.15 min
BOD loading: 5,872 g/cu m/day (367 lb/day/1000 ft^3)
F/M[b]: 1.45 kg BOD/day/kg MLSS Air flow: 87.1 cu m/min (3112 cfm)
Air supply: 22.9 cu m/kg BOD applied (372 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 1.- days - S Reaeration time: 2.02 hours
Stabilization tank turnovers: 2.98 OUR: 50 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overlfow rate: 44.0 ru m/day/sq m (1078 gpd/ft^2)
Clarifier detention time[a]: 1.43 hours Clarifier turnovers: 4.20
Clarifier solids loading: 250,344 g/day/sq m (51.3 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C23 (continued). OPERATING DATA FOR RUN NO. 23

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH							
Settleable solids	ml/l	3.0			Trace	Trace	
Total solids	mg/l	759			455	548	27.8
Total volatile solids	mg/l	265			113	159	40.0
Suspended solids	mg/l	129	4075	14150	13	45	65.1
Suspended volatile solids	mg/l	78	2375	8550	5	29	62.8
Total BOD	mg/l	87		3850	10	34	60.9
Dissolved BOD	mg/l	39			10	11	71.8
Total organic carbon	mg/l	82		5100	16	34	58.5
Dissolved organic carbon	mg/l	35			19	20	42.9
Kjeldahl nitrogen as N	mg/l	16.1			1.91	8.85	45.0
Total phosphorus as P	mg/l	4.8			0.42	2.63	45.2
Total coliform	#/ml	34000			2300	20000	41.2
Fecal coliform	#/ml	1500			38	445	70.3

Table C24. OPERATING DATA FOR RUN NO. 24

General

Date: March 31, 1973
Start: 3:01 pm Stop: 6:02 pm Duration: 3.02 hours
Volume treated: 6,412 cu m (1,694,000 gallons)
Average flow rate: 50,946 cu m/day (13.46 mgd)
Average transfer rate: 19,417 cu m/day (5.13 mgd) Percent return; 38
Average dry weather plant flow rate:

Contact Tank

MLSS: 4,460 mg/l Contact time[a]: 18.91 min
BOD loading: 7,248 g/cu m/day (453 lb/day/1000 ft^3)
F/M[b]: 1.63 kg BOD/day/kg MLSS Air flow: 42.0 cu m/min (1500 cfm)
Air supply: 9.0 cu m/kg BOD applied (146 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 4.50 days - C Reaeration time: 2.88 hours
Stabilization tank turnovers: 1.05 OUR: 30 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 35.8 cu m/day/sq m (877 gpd/ft^2)
Clarifier detention time[a]: 1.78 hours Clarifier turnovers: 1.70
Clarifier solids loading: 219,600 g/day/sq m (45.0 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C24 (continued). OPERATING DATA FOR RUN NO. 24

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.60	7.40	7.38	7.50	7.55	
Settleable solids	ml/l	8.5				0.2	97.6
Total solids	mg/l	757				506	33.1
Total volatile solids	mg/l	252				86	66.0
Suspended solids	mg/l	347	4460	12630	27	22	93.6
Suspended volatile solids	mg/l	150	2210	6600	6	2	98.8
Total BOD	mg/l	132		2664	20	14	89.4
Dissolved BOD	mg/l	24				1	95.8
Total organic carbon	mg/l	129		4400		22	82.9
Dissolved organic carbon	mg/l	27				12	45.5
Kjeldahl nitrogen as N	mg/l	16.3				6.1	62.6
Total phosphorus as P	mg/l	5.72				1.12	80.4
Total coliform	#/ml	45000				22000	51.1
Fecal coliform	#/ml	2600				4700	
COD*	mg/l	407				53	86.9

* 1973 only

Table C25. OPERATING DATA FOR RUN NO. 25

General

Date: April 1, 1973
Start: 12:01 am Stop: 2:21 am Duration: 2.33 hours
Volume treated: 5,053 cu m (1,335,000 gallons)
Average flow rate: 51,968 cu m/day (13.73 mgd)
Average transfer rate: 19,758 cu m/day (5.22 mgd) Percent return; 38
Average dry weather plant flow rate:

Contact Tank

MLSS: 4,550 mg/l Contact time[a]: 18.58 min
BOD loading: 3,744 g/cu m/day (234 lb/day/1000 ft^3)
F/M[b]: 0.83 kg BOD/day/kg MLSS Air flow: 56.0 cu m/min (2000 cfm)
Air supply: 23.1 cu m/kg BOD applied (375 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 1.0 days - S Reaeration time: 2.99 hours
Stabilization tank turnovers: 0.78 OUR: 30 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 36.4 cu m/day/sq m (892 gpd/ft^2)
Clarifier detention time[a]: 1.75 hours Clarifier turnovers: 1.33
Clarifier solids loading: 227,896 g/day/sq m (46.7 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C25 (continued). OPERATING DATA FOR RUN NO. 25

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.70	7.30	7.15	7.60	7.80	
Settleable solids	ml/l	5				Trace	
Total solids	mg/l	569				445	21.7
Total volatile solids	mg/l	173				88	49.1
Suspended solids	mg/l	231	4550	11912	31	15	93.5
Suspended volatile solids	mg/l	114	2525	6500	18	6	94.9
Total BOD	mg/l	67		2650	14	9	86.5
Dissolved BOD	mg/l	9				2	77.7
Total organic carbon	mg/l	77		4150		19	75.3
Dissolved organic carbon	mg/l	14				14	
Kjeldahl nitrogen as N	mg/l	11.1				5.9	46.8
Total phosphorus as P	mg/l	3.73				1.07	71.3
Total coliform	#/ml	21000				12700	39.5
Fecal coliform	#/ml	2200				2100	4.5
COD	mg/l	221				49	77.8

Table C26. OPERATING DATA FOR RUN NO. 26

General

Date: April 2, 1973
Start: 10:00 am Stop: 4:30 pm Duration: 6.50 hours
Volume treated: 14,239 cu m (3,762,000 gallons)
Average flow rate: 52,612 cu m/day (13.9 mgd)
Average transfer rate: 19,985 cu m/day (5.28 mgd) Percent return; 38
Average dry weather plant flow rate:

Contact Tank

MLSS: 3,700 mg/l Contact time[a]: 18.36 min
BOD loading: 3,440 g/cu m/day (215 lb/day/1000 ft^3)
F/M[b]: 0.94 kg BOD/day/kg MLSS Air flow: 56.0 cu m/min (2000 cfm)
Air supply: 25.1 cu m/kg BOD applied (407 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 1.0 days - S Reaeration time: 2.89 hours
Stabilization tank turnovers: 2.25 OUR: 19 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 36.8 cu m/day/sq m (903 gpd/ft^2)
Clarifier detention time[a]: 1.73 hours Clarifier turnovers: 3.76
Clarifier solids loading: 187,880 g/day/sq m (38.5 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow

Table C26 (continued). OPERATING DATA FOR RUN NO. 26

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.65	7.22	7.05	7.40	7.72	
Settleable solids	ml/l	2.0				Trace	
Total solids	mg/l	569				465	18.2
Total volatile solids	mg/l	206				101	51.1
Suspended solids	mg/l	120	3700	12087	79	17	85.8
Suspended volatile solids	mg/l	79	2075	6650	42	13	83.6
Total BOD	mg/l	61		1800	23	4	93.4
Dissolved BOD	mg/l						
Total organic carbon	mg/l	76		4250		16	78.9
Dissolved organic carbon	mg/l	22				12	45.4
Kjeldahl nitrogen as N	mg/l	13.7				6.6	51.8
Total phosphorus as P	mg/l	4.26				1.34	68.5
Total coliform	#/ml	71700				23000	67.9
Fecal coliform	#/ml	4300				380	91.2
COD	mg/l	191				44	76.9

Table C27. OPERATING DATA FOR RUN NO. 27

General

Date: April 4, 1973
Start: 10:07 am   Stop: 2:37 pm   Duration: 4.50 hours
Volume treated: 7,116 cu m (1,880,000 gallons)
Average flow rate: 37,850 cu m/day (10.0 mgd)
Average transfer rate: 37,850 cu m/day (10.00 mgd)   Percent return; 100
Average dry weather plant flow rate:

Contact Tank

MLSS: 4,770 mg/l   Contact time[a]: 17.61 min
BOD loading: 2,528 g/cu m/day (158 lb/day/1000 ft^3)
F/M[b]: 0.53 kg BOD/day/kg MLSS   Air flow: 56.0 cu m/min (2000 cfm)
Air supply: 34.4 cu m/kg BOD applied (557 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.0 days - S   Reaeration time: 1.34 hours
Stabilization tank turnovers: 3.36   OUR: 18 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 26.5 cu m/day/sq m (650 gpd/ft^2)
Clarifier detention time[a]: 1.66 hours   Clarifier turnovers: 2.71
Clarifier solids loading: 252,296 g/day/sq m (51.7 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C27 (continued). OPERATING DATA FOR RUN NO. 27

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.87	7.55	7.40	7.55	7.65	
Settleable solids	ml/l	1.8				Trace	
Total solids	mg/l	579				526	9.1
Total volatile solids	mg/l	225				158	29.8
Suspended solids	mg/l	145	4770	9150	38	25	82.7
Suspended volatile solids	mg/l	86	2770	5140	19	17	80.2
Total BOD	mg/l	62		2150	14	9	85.4
Dissolved BOD	mg/l	32				3	90.6
Total organic carbon	mg/l	75		3850		19	74.6
Dissolved organic carbon	mg/l	30				11	63.3
Kjeldahl nitrogen as N	mg/l	12.5				7.3	41.6
Total phosphorus as P	mg/l	3.15				1.04	66.9
Total coliform	#/ml	720				510	29.2
Fecal coliform	#/ml	135				56	58.6
COD	mg/l	183				48	73.7

Table C28. OPERATING DATA FOR RUN NO. 28

General

Date: April 11, 1973
Start: 8:10 am Stop: 11:10 am Duration: 3.00 hours
Volume treated: 8,940 cu m (2,362,000 gallons)
Average flow rate: 71,499 cu m/day (18.89 mgd)
Average transfer rate: 4,164 cu m/day (1.1 mgd) Percent return; 6
Average dry weather plant flow rate:

Contact Tank

MLSS: 1,500 mg/l Contact time[a]: 17.62 min
BOD loading: 6,448 g/cu m/day (403 lb/day/1000 ft^3)
F/M[b]: 4.33 kg BOD/day/kg MLSS Air flow: 56.0 cu m/min (2.000 cfm)
Air supply: 13.4 cu m/kg BOD applied (218 ft^3/lb BOD applied)

Stabilization

Stabilization time[c]: 7.0 days - S Reaeration time: 12.60 hours
Stabilization tank turnovers: 0.24 OUR: 14 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 50.1 cu m/day/sq m (1,227 gpd/ft^2)
Clarifier detention time[a]: 1.66 hours Clarifier turnovers: 1.81
Clarifier solids loading: 79,056 g/day/sq m (16.2 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow

Table C28 (continued). OPERATING DATA FOR RUN NO. 28

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		.85	7.75	7.50		7.75	
Settleable solids	ml/l	9.0				0.3	96.6
Total solids	mg/l	848				599	29.3
Total volatile solids	mg/l	335				210	37.3
Suspended solids	mg/l	318	1500	10650	23	69	78.3
Suspended volatile solids	mg/l	211	930	5975	16	49	76.7
Total BOD	mg/l	84		2150	7	27	67.8
Dissolved BOD	mg/l	22				9	59.0
Total organic carbon	mg/l	127		3550		50	60.6
Dissolved organic carbon	mg/l	27				18	33.3
Kjeldahl nitrogen as N	mg/l	20.3				10.5	48.2
Total phosphorus as P	mg/l	5.7				2.5	56.1
Total coliform	#/ml	4400				635	85.5
Fecal coliform	#/ml	1000				100	90.0
COD	mg/l	305				82	73.1

Table C29. OPERATING DATA FOR RUN NO. 29

General

Date: April 13, 1973
Start: 10:20 am Stop: 2:50 pm Duration: 4.50 hours
Volume treated: 12,869 cu m (3,400,000 gallons)
Average flow rate: 68,622 cu m/day (18.13 mgd)
Average transfer rate: 29,334 cu m/day (7.75 mgd) Percent return; 40
Average dry weather plant flow rate:

Contact Tank

MLSS: 3,140 mg/l Contact time[a]: 9.31 min
BOD loading: 13,120 g/cu m/day (820 lb/day/100 ft^3)
F/M[b]: 4.12 kg BOD/day/kg MLSS Air flow: 56.0 cu m/min (2,000 cfm)
Air supply: 10.1 cu m/kg BOD applied (163 ft^3/lb BOD applied)

Stabilization tank

Stabilization time[c]: 2.0 days - S Reaeration time: 2.10 hours
Stabilization tank turnovers: 2.14 OUR: 39 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 48.0 cu m/day sq m (1,177 gpd/ft^2)
Clarifier detention time[a]: 1.31 hours Clarifier turnovers: 3.44
Clarifier solids loading: 210,816 g/day/sq m (43.2 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C29 (continued). OPERATING DATA FOR RUN NO. 29

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.82	7.45	7.25		7.75	
Settleable solids	ml/l	4.2				Trace	
Total solids	mg/l	832				608	26.9
Total volatile solids	mg/l	237				140	40.9
Suspended solids	mg/l	224	3140	10800	13	13	94.1
Suspended volatile solids	mg/l	97	1570	5400	5	4	95.8
Total BOD	mg/l	117		2500	6	10	91.4
Dissolved BOD	mg/l	44				4	90.9
Total organic carbon	mg/l	146		3600		17	88.3
Dissolved organic carbon	mg/l	38				12	68.4
Kjeldahl nitrogen as N	mg/l	12.6				7.5	40.4
Total phosphorus as P	mg/l	3.95				1.16	70.6
Total coliform	#/ml					2250	88.3
Fecal coliform	#/ml					750	64.2
COD	mg/l	225				34	84.8

Table C30. OPERATING DATA FOR RUN NO. 30

General

Date: April 16, 1973
Start: 9:05 am Stop: 3:05 pm Duration: 6.00 hours
Volume treated: 17,941 cu m (4,740,000 gallons)
Average flow rate: 71,764 cu m/day (18.96 mgd)
Average transfer rate: 14,345 cu m/day (3.79 mgd) Percent return; 20
Average dry weather plant flow rate:

Contact Tank

MLSS: 1,280 mg/l Contact time[a]: 10.39 min
BOD loading: 10,608 g/cu m/day (663 lb/day/1000 ft^3)
F/M[b]: 8.31 kg BOD/day/kg MLSS Air flow: 56.0 cu m/min (2,000 cfm)
Air supply: 12.2 cu m/kg BOD applied (198 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 3.0 days - S Reaeration time: 4.11 hours
Stabilization tank turnovers: 1.45 OUR: 46 mg/l/hr
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 50.2 cu m/day/sq m (1,231 gpd/ft^2)
Clarifier detention time[a]: 1.46 hours Clarifier turnovers: 4.11
Clarifier solids loading: 77,104 g/day/sq m (15.8 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C30 (continued). OPERATING DATA FOR RUN NO. 30

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.66	7.35	7.35		7.80	
Settleable solids	ml/l	4.0				0.1	97.5
Total solids	mg/l	685				550	19.7
Total volatile solids	mg/l	220				151	31.4
Suspended solids	mg/l	244	1280	13725	35	67	72.5
Suspended volatile solids	mg/l	227	1140	8525	35	67	70.5
Total BOD	mg/l	92		3300	12	25	72.8
Dissolved BOD	mg/l	33				7	78.8
Total organic carbon	mg/l	296		3950		31	89.5
Dissolved organic carbon	mg/l	33				14	57.6
Kjeldahl nitrogen as N	mg/l	13.5				9.3	31.1
Total phosphorus as P	mg/l	4.17				1.98	50.3
Total coliform	#/ml	5400				6000	
Fecal coliform	#/ml	580				2600	
COD	mg/l	690				71	89.7

Table C31. OPERATING DATA FOR RUN NO. 31

General

Date: April 29, 1973 to April 30, 1973
Start: 7.35 pm Stop: 1:35 am Duration: 6.00 hours
Volume treated: 9,133 cu m (2,413,000 gallons)
Average flow rate: 36,525 cu m/day (9.65 mgd)
Average transfer rate: 36,525 cu m/day (9.65 mgd) Percent return; 100
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS; 5,550 mg/l Contact time[a]: 12.24 min
BOD loading: 3,088 g/cu m/day (193 lb/day/1000 ft^3)
F/M[b]: 0.56 kg BOD/day kg MLSS Air flow: 56.0 cu m/min
Air supply: 41.6 cu m/kg BOD applied (675 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 3.0 days - S Reaeration time: 1.39 hours
Stabilization tank turnovers: 4.32 OUR:
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 25.6 cu m/day/sq m (627 gpd/ft^2)
Clarifier detention time[a]: 1.72 hours Clarifier turnovers: 3.49
Clarifier solids loading: 283,040 g/day/sq m (58.0 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C31 (continued). OPERATING DATA FOR RUN NO. 31

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.70	7.20	7.20	7.20	7.70	
Settleable solids	ml/l	2.5				Trace	
Total solids	mg/l	494				514	
Total volatile solids	mg/l	103				125	
Suspended solids	mg/l	115	5550	11400	35	27	76.5
Suspended volatile solids	mg/l	56	2750	5780	15	13	76.7
Total BOD	mg/l	53		2500	14	12	77.3
Dissolved BOD	mg/l	13				5	61.5
Total organic carbon	mg/l	62		3950		33	46.7
Dissolved organic carbon	mg/l	18				15	16.6
Kjeldahl nitrogen as N	mg/l	14.5				9	37.9
Total phosphorus as P	mg/l	2.4				0.46	80.8
Total coliform	#/ml	7800				1870	76.0
Fecal coliform	#/ml	1680				490	70.8
COD	mg/l	133				48	63.9

Table C32. OPERATING DATA FOR RUN NO. 32

General

Date: May 1, 1973
Start: 10:00 am Stop: 2:00 pm Duration: 4.00 hours
Volume treated: 11,310 cu m (2,988,000 gallons)
Average flow rate: 67,865 cu m/day (17.93 mgd)
Average transfer rate: 33,914 cu m/day (8.96 mgd) Percent return; 50
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 4,750 mg/l Contact time[a]: 13.10 min
BOD loading: 4,016 g/cu m/day (251 lb/day/1000 ft^3)
F/M[b]: 1.27 kg BOD/day kg MLSS Air flow: 56.0 cu m/min (2,000 cfm)
Air supply: 21.6 cu m/kg BOD applied (350 ft3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 0.0 days Reaeration time: 1.46 hours
Stabilization tank turnovers: 2.75 OUR:
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 47.5 cu m/day/sq m (1,165 gpd/ft^2)
Clarifier detention time[a]: 1.23 hours Clarifier turnovers: 3.24
Clarifier solids loaindg: 337,696 g/day/sq m (79.2 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C32 (continued). OPERATING DATA FOR RUN NO. 32

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.75	7.20	7.10		7.80	
Settleable solids	ml/l	1.5				Trace	
Total solids	mg/l	549				430	21.6
Total volatile solids	mg/l	140				96	31.4
Suspended solids	mg/l	92	4750	12800	24	17	81.5
Suspended volatile solids	mg/l	52	2450	6550	11	8	84.6
Total BOD	mg/l	55		3050	8	7	87.2
Dissolved BOD	mg/l	30				<1	>96.6
Total organic carbon	mg/l	43		3900		20	53.4
Dissolved organic carbon	mg/l					8	68.0
Kjeldahl nitrogen as N	mg/l	7.75				3.65	52.9
Total phosphorus as P	mg/l	1.92				0.78	59.3
Total coliform	#/ml	1480				<14	>99.0
Fecal coliform	#/ml	440				<10	>97.7
COD	mg/l	130				32	75.3

Table C33. OPERATING DATA FOR RUN NO. 33

General

Date: May 3, 1973
Start: 10:00 am   Stop: 1:35 pm   Duration: 3.57 hours
Volume treated: 10,473 cu m (2,767,000 gallons)
Average flow rate: 70,401 cu m/day (18.60 mgd)
Average transfer rate: 35,200 cu m/day (9,30 mgd)   Percent return; 50
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 4,930 mg/l   Contact time[a]: 12.62 min
BOD loading: 5,744 g/cu m/day (359 lb/day/1000 ft^3)
F/M[b]: 1.17 kg BOD/day/kg MLSS   Air flow: 56.0 cu m/min (2000 cfm)
Air supply: 15.0 cu m/kg BOD applied (244 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 0.0 days   Reaeration time: 1.40 hours
Stabilization tank turnovers: 2.54   OUR:
Oxygen supply: 340 kg/hr (750 lb/hr)

Final Clarifier

Surface overflow rate: 49.3 cu m/day/sq m (1,208 gpd/ft^2)
Clarifier detention time[a]: 1.19 hours   Clarifier turnovers: 3.00
Clarifier solids loading: 363,560 g/day/sq m (74.5 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C33 (continued). OPERATING DATA FOR RUN NO. 33

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.85	7.48	7.40		7.80	
Settleable solids	ml/l	1.5				Trace	
Total solids	mg/l	651				631	3.0
Total volatile solids	mg/l	195				168	13.8
Suspended solids	mg/l	92	4930	14600	33	17	81.5
Suspended volatile solids	mg/l	50	2300	7180	9	7	86.0
Total BOD	mg/l	76		3393	11	11	85.5
Dissolved BOD	mg/l	43				3	93.0
Total organic carbon	mg/l	56		4250		19	66.0
Dissolved organic carbon	mg/l	34				13	61.7
Kjeldahl nitrogen as N	mg/l	10.3				7.4	28.1
Total phosphorus as P	mg/l	2.8				1.08	61.4
Total coliform	#/ml	7500				1500	56.0
Fecal coliform	#/ml	4700				510	89.1
COD	mg/l	183				40	78.1

Table C34. OPERATING DATA FOR RUN NO. 34

Date: May 7, 1973
Start: 1:30 pm   Stop: 5:30 pm   Duration: 4.00 hours
Volume treated: 11,900 cu m (3,144,000 gallons)
Average flow rate: 71,385 cu m/day (18.86 mgd)
Average transfer rate: 3,558 cu m/day (0.94 mgd)   Percent return; 5
Average dry weather plant flow rate: 83,270 cu m/day (22 mgd)

Contact Tank

MLSS: 1,350 mg/l   Contact time[a]: 11.93 min
BOD loading: 8,576 g/cu m/day (536 lb/day/1000 ft^3)
F/M[b]: 6.39 kg BOD/day/kg MLSS   Air flow: 56.0 cu m/min (2,000 cfm)
Air supply: 15.0 cu m/kg BOD applied (244 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 3.0 days - S   Reaeration time: 10.65 hours
Stabilization tank turnovers: 0.38   OUR:
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 50.0 cu m/day/sq m (1,225 gpd/ft^2)
Clarifier detention time[a]: 1.67 hours   Clarifier turnovers: 2.39
Clarifier solids loading: 70,760 g/day/sq m (14.5 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C34 (continued). OPERATING DATA FOR RUN NO. 34

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.45	7.10			7.40	
Settleable solids	ml/l	3.3			Trace		
Total solids	mg/l	649				581	10.5
Total volatile solids	mg/l	188				134	28.7
Suspended solids	mg/l	131	1350	3725	27	42	67.9
Suspended volatile solids	mg/l	62	600	1825	12	22	64.5
Total BOD	mg/l	75		700	10	25	66.6
Dissolved BOD	mg/l	30				6	80.0
Total organic carbon	mg/l	72		1050		27	62.5
Dissolved organic carbon	mg/l	26				15	42.3
Kjeldahl nitrogen as N	mg/l	10.5				8.4	20.0
Total phosphorus as P	mg/l	3.99				2.08	47.8
Total coliform	#/ml	44000				3350	92.3
Fecal coliform	#/ml	4000				1500	62.5
COD	mg/o	206				67	67.4

Table C35. OPERATING DATA FOR RUN NO. 35

General

Date: May 25, 1973
Start: 5:03 am   Stop: 8:12 am   Duration: 3.15 hours
Volume treated: 8,251 cu m (2,180,000 gallons)
Average flow rate: 62,869 cu m/day (16.61 mgd)
Average transfer rate: 18,849 cu m/day (4.98 mgd)   Percent return; 30
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 2,670 mg/l   Contact time[a]: 10.94 min
BOD loading: 25,792 g/cu m/day (1,612 lb/day/1000 ft^3)
F/M[b]: 9.71 kg BOD/day/kg MLSS   Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 4.7 cu m/kg BOD applied (76 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 3.14 days - C   Reaeration time: 2.42 hours
Stabilization tank turnovers: 1.30   OUR: 50 mg/l/hr
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 44.0 cu m/day/sq m (1,079 gpd/ft^2)
Clarifier detention time[a]: 1.54 hours   Clarifier turnovers: 2.05
Clarifier solids loading: 152,256 g/day/sq m (31.2 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C35 (continued). OPERATING DATA FOR RUN NO. 35

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.70	7.30	7.10	7.40	7.60	
Settleable solids	ml/l	12.0				Trace	
Total solids	mg/l	864				416	51.8
Total volatile solids	mg/l	352				98	72.1
Suspended solids	mg/l	588	2670	11000	33	22	96.2
Suspended volatile solids	mg/l	274	1420	3400	21	16	94.1
Total BOD	mg/l	256		3400	20	21	91.7
Dissolved BOD	mg/l	22				14	36.3
Total organic carbon	mg/l	129		3100		25	80.6
Dissolved organic carbon	mg/l	20				18	10.0
Kjeldahl nitrogen as N	mg/l	14.0				5.85	58.2
Total phosphorus as P	mg/l	5.30				0.88	83.3
Total coliform	#/ml						
Fecal coliform	#/ml	450				210	53.3
COD	mg/l	340				59	82.6

Table C36. OPERATING DATA FOR RUN NO. 36

General

Date: May 27, 1973
Start: 3:25 pm   Stop: 9:25 pm   Duration: 6.00 hours
Volume treated: 17,581 cu m (4,645,000 gallons)
Average flow rate: 70,325 cu m/day (18.58 mgd
Average transfer rate: 21,082 cu m/day (5.57 mgd)   Percent return; 30
Average dry weather plnat flow rate: 94,625 cu m/day (25 mgd)

Contact Tank

MLSS: 3,210 mg/l   Contact time[a]: 14.58 min
BOD loading: 4,832 g/cu m/day (302 lb/day/1000 ft^3)
F/M[b]: 1.52 kg BOD/day/kg MLSS   Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 16.8 cu m/kg BOD applied (272 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 1.0 days - S   Reaeration time: 1.62 hours
Stabilization tank turnovers: 3.70   OUR: 39 mg/l/hr
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 49.2 cu m/day/sq m (1,207 gpd/ft^2)
Clarifier detention time[a]: 1.37 hours   Clarifier turnovers: 4.37
Clarifier solids loading: 204,960 g/day/sq m (42.0 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C36 (continued). OPERATING DATA FOR RUN NO. 36

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.60	7.35	7.25		7.70	
Settleable solids	ml/l	10.0				Trace	
Total solids	mg/l	587				475	19.0
Total volatile solids	mg/l	234				129	44.8
Suspended solids	mg/l	354	3210	12100	32	36	89.8
Suspended volatile solids	mg/l	170	1640	6330	22	21	87.6
Total BOD	mg/l	64		1700	11	12	81.2
Dissolved BOD	mg/l	5				4	20.0
Total organic carbon	mg/l	98		3200		26	73.4
Dissolved organic carbon	mg/l	24				17	29.1
Kjeldahl nitrogen as N	mg/l	20.6				11.1	46.1
Total phosphorus as P	mg/l	2.86				1.44	49.6
Total coliform	#/ml	4000				140	96.5
Fecal coliform	#/ml	140				<10	>92.8
COD	mg/l	237				65	72.5

Table C37. OPERATING DATA FOR RUN NO. 37

General

Date: June 4, 1973
Start: 4:32 am Stop: 7:04 am Duration: 2.50 hours
Volume treated: 7,305 cu m (1,930,000 gallons)
Average flow rate: 70,136 cu m/day (18.53 mgd)
Average transfer rate: 24,565 cu m/day (6.49 mgd) Percent return; 35
Average dry weather plant flow rate: 64,345 cu m/day (17 mgd)

Contact Tank

MLSS: 4,020 mg/l Contact time[a]: 14.08 min
BOD loading: 6,864 g/cu m/day (429 lb/day/1000 ft^3)
F/M[b]: 1.70 kg BOD/day/kg MLSS Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 11.8 cu m/kg BOD applied (192 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.76 days - C Reaeration time: 1.47 hours
Stabilization tank turnovers: 1.70 OUR:
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 49.1 cu m/day/sq m (1,204 gpd/ft^2)
Clarifier detention time[a]: 1.33 hours Clarifier turnovers: 1.89
Clarifier solids loading: 265,960 g/day/sq m (54.5 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C37 (continued). OPERATING DATA FOR RUN NO. 37

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.50	7.10	7.25		7.60	
Settleable solids	ml/l	5.0				Trace	
Total solids	mg/l	652				466	28.5
Total volatile solids	mg/l	250				141	43.6
Suspended solids	mg/l	340	4020	11750	25	26	92.6
Suspended volatile solids	mg/l	162	2070	6500	11	9	94.4
Total BOD	mg/l	91		2080	9	17	81.3
Dissolved BOD	mg/l	11				6	45.4
Total organic carbon	mg/l	109		3300		24	78.0
Dissolved organic carbon	mg/l	30				12	60.0
Kjeldahl nitrogen as N	mg/l	10.4				8.6	17.3
Total phosphorus as P	mg/l	2.74				1.61	41.2
Total coliform	#/ml	96700				12200	87.4
Fecal coliform	#/ml	8200				1500	81.7
COD	mg/l	309				57	81.6

Table C38. OPERATING DATA FOR RUN NO. 38

General

Date: June 4, 1973
Start: 10:22 am Stop: 3:11 pm Duration: 4.80 hours
Volume treated: 13,974 cu m (3,692,000 gallons)
Average flow rate: 69,871 cu m/day (18.46 mgd)
Average transfer rate: 29,334 cu m/day (7.75 mgd) Percent return; 42
Average dry weather plant flow rate: 56,775 cu m/day (15 mgd)

Contact Tank

MLSS: 3,800 mg/l Contact time[a]: 13.44 min
BOD loading: 16,064 g/cu m/day (1,004 lb/day/1000 ft^3)
F/M[b]: 4.26 kg BOD/day/kg MLSS Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 5.1 cu m/kg BOD applied (82 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 0.0 Reaeration time: 1.55 hours
Stabilization tank turnovers: 3.09 OUR: 36 mg/l/hr
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 48.9 cu m/day/sq m (1,199 gpd/ft^2)
Clarifier detention time[a]: 1.26 hours Clarifier turnovers: 3.79
Clarifier solids loading: 263,520 g/day/sq m (54.0 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C38 (continued). OPERATING DATA FOR RUN NO. 38

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.60	7.30	7.20		7.65	
Settleable solids	ml/l	4				Trace	
Total solids	mg/l	632				441	30.2
Total volatile solids	mg/l	242				131	45.9
Suspended solids	mg/l	192	3800	10500	15	21	89.1
Suspended volatile solids	mg/l	135	1550	5680	9	10	92.6
Total BOD	mg/l	214		2378	7	16	92.5
Dissolved BOD	mg/l	47				5	89.4
Total organic carbon	mg/l	115		3000		22	80.9
Dissolved organic carbon	mg/l	42				17	59.5
Kjeldahl nitrogen as N	mg/l	16.8				10.6	36.9
Total phosphorus as P	mg/l	6.39				3.22	49.6
Total coliform	#/ml	24500				8400	65.7
Fecal coliform	#/ml	1350				2250	
COD	mg/l	292				54	81.5

Table C39. OPERATING DATA FOR RUN NO. 39

General

Date: June 6, 1973
Start: 12:45 am   Stop: 3:05 pm   Duration: 2.33 hours
Volume treated: 5,371 cu m (1,419,000 gallons)
Average flow rate: 55,337 cu m/day (14.62 mgd)
Average transfer rate: 26,571 cu m/day (7.02 mgd)   Percent return; 48
Average dry weather plant flow rate: 64,345 cu m/day (17 mgd)

Contact Tank

MLSS: 4,810 mg/l   Contact time[a]: 16.28 min
BOD loading: 6,368 g/cu m/day (398 lb/day/1000 ft^3)
F/M[b]: 1.33 kg BOD/day/kg MLSS   Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 12.8 cu m/kg BOD applied (207 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 0.0 days   Reaeration time: 1.14 hours
Stabilization tank turnovers: 2.04   OUR: 68 mg/l/hr
Oxygen supply: 284 kg/hr (625 lb/hr)

Final Clarifier

Surface overflow rate: 38.8 cu m/day/sq m (950 gpd/ft^2)
Clarifier detention time[a]: 1.53 hours   Clarifier turnovers: 1.52
Clarifier solids loading: 275,232 g/day/sq m (56.4 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C39 (continued). OPERATING DATA FOR RUN NO. 39

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.55	7.25	7.00		7.60	
Settleable solids	ml/l	3.0				Trace	
Total solids	mg/l	637				486	23.7
Total volatile solids	mg/l	191				105	45.0
Suspended solids	mg/l	148	4810	21900	13	22	85.1
Suspended volatile solids	mg/l	107	2870	14130	5	16	85.0
Total BOD	mg/l	107		4887	7	15	86.0
Dissolved BOD	mg/l	65				4	93.8
Total organic carbon	mg/l	103		7350		24	76.7
Dissolved organic carbon	mg/l	51				15	70.6
Kjeldahl nitrogen as N	mg/l	13.2				9.6	27.3
Total phosphorus as P	mg/l	6.0				3.63	39.5
Total coliform	#/ml	30000				13000	56.7
Fecal coliform	#/ml	3600				2100	41.7
COD	mg/l	293				44	85.0

Table C40. OPERATING DATA FOR RUN NO. 40

General

Date: June 16, 1973
Start: 3:48 pm Stop: 11:28 pm Duration: 6.79 hours
Volume treated: 14,849 cu m (3,923,000 gallons)
Average flow rate: 53,498 cu m/day (13.87 mgd)
Average transfer rate: 39,364 cu m/day (10.40 mgd) Percent return; 75
Average dry weather plant flow rate: 83,270 cu m/day (22 mgd)

Contact Tank

MLSS: 4,780 mg/l Contact time[a]: 14.51 min
BOD loading: 8,016 g/cu m/day (501 lb/day/1000 ft^3)
F/M[b]: 1.68 kg BOD/day/kg MLSS Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 10.1 cu m/kg BOD applied (164 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.50 days - C Reaeration time: 0.96 hours
Stabilization tank turnovers: 7.04 OUR:
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 36.8 cu m/day/sq m (901 gpd/ft^2)
Clarifier detention time[a]: 1.37 hours Clarifier turnovers: 4.97
Clarifier solids loading: 306,952 g/day/sq m (62.9 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C - continuous flow.

Table C40 (continued). OPERATING DATA FOR RUN NO. 40

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.35	7.10	7.05		7.60	
Settleable solids	ml/l	6.5				Trace	
Total solids	mg/l	812				502	38.1
Total volatile solids	mg/l	328				158	51.8
Suspended solids	mg/l	445	4780	11518	596	16	96.4
Suspended volatile solids	mg/l	274	2870	7336	456	11	95.9
Total BOD	mg/l	142		2400	145	19	86.6
Dissolved BOD	mg/l	29				8.0	72.4
Total organic carbon	mg/l	199		4050		30	84.9
Dissolved organic carbon	mg/l	30				5	83.3
Kjeldahl nitrogen as N	mg/l	15.4				7.6	50.6
Total phosphorus as P	mg/l	3.07				1.03	66.4
Total coliform	#/ml	90000				29500	67.2
Fecal coliform	#/ml	1280				185	85.5
COD	mg/l	390				76	80/5

Table C41. OPERATING DATA FOR RUN NO. 41

General

Date: June 16, 1973 to June 17, 1973
Start: 12:15 pm Stop: 12:15 am Duration: 12.00 hours
Volume treated: 27,646 cu m (7,304,000 gallons)
Average flow rate: 55,299 cu m/day (14.61 mgd)
Average transfer rate: 27,630 cu m/day (7.30 mgd) Percent return; 50
Average dry weather plant flow rate: 90,840 cu m/day (24 mgd)

Contact Tank

MLSS: 3,353 mg/l Contact time[a]: 16.07 min
BOD loading: 3,504 g/cu m/day (219 lb/day/1000 ft^3)
F/M[b]: 1.05 kg BOD/day/kg MLSS Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 23.2 cu m/kg BOD applied (376 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 1.0 days - S Reaeration time: 1.58 hours
Stabilization tank turnovers: 7.59 OUR: 59 mg/l/hr
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 38.7 cu m/day/sq m (949 gpd/ft^2)
Clarifier detentiom time[a]: 1.51 hours Clarifier turnovers: 7.93
Clarifier solids loading: 194,224 g/day/sq m (39.8 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C41 (continued). OPERATING DATA FOR RUN NO. 41

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.55	7.15	7.10		7.75	
Settleable solids	ml/l	3.5				Trace	
Total solids	mg/l	604				443	26.6
Total volatile solids	mg/l	233				124	46.7
Suspended solids	mg/l	156	3353	11510	551	15	90.3
Suspended volatile solids	mg/l	123	1842	7190	456	14	88.6
Total BOD	mg/l	59		2750	59	11	81.3
Dissolved BOD	mg/l	18				8	55.5
Total organic carbon	mg/l	83		4100		27	67.4
Dissolved organic carbon	mg/l	22				17	22.7
Kjeldahl nitrogen as N	mg/l	10.3				5.4	47.5
Total phosphorus as P	mg/l					0.95	82.9
Total coliform	#/ml	37600				4600	87.7
Fecal coliform	#/ml	5600				1300	76.7
COD	mg/l	211				46	78.1

Table C42. OPERATING DATA FOR RUN NO. 42

General

Date: July 3, 1973
Start: 12:39 pm Stop: 3:38 pm Duration: 2.97 hours
Volume treated: 7,831 cu m (2,069,000 gallons)
Average flow rate: 63,285 cu m/day (16.72 mgd)
Average transfer rate: 31,643 cu m/day (8.36 mgd) Percent return; 50
Average dry weather plant flow rate

Contact Tank

MLSS: 3,690 mg/l Contact time[a]: 9.42 min
BOD loading: 11,456 g/cu m/day (816 lb/day/1000 ft^3)
F/M[b]: 2.09 kg BOD/day/kg MLSS Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 10.5 cu m/kg BOD applied (171 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.90 days - C Reaeration time: 1.08 hours
Stabilization tank turnovers: 2.75 OUR:
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 44.3 cu m/day/sq m (1,086 gpd/ft^2)
Clarifier detentiom time[a]: 1.32 hours Clarifier turnovers: 2.25
Clarifier solids loading: 244,488 g/day/sq m (50.1 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow

Table C42 (continued). OPERATING DATA FOR RUN NO. 42

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.35		6.90	7.15	7.40	
Settleable solids	ml/l	5.1				1.1	78.4
Total solids	mg/l	576				495	14.1
Total volatile solids	mg/l	240				198	17.5
Suspended solids	mg/l	291	3690	10500		274	5.8
Suspended volatile solids	mg/l	168	1950	5820		176	
Total BOD	mg/l	113		2200		39	65.5
Dissolved BOD	mg/l	46				16	65.2
Total organic carbon	mg/l	56		2750		36	35.7
Dissolved organic carbon	mg/l	36				21	41.7
Kjeldahl nitrogen as N	mg/l	67.3				39.3	41.6
Total phosphorus as P	mg/l	7.76				4.21	45.7
Total coliform	#/ml	100000				8100	91.9
Fecal coliform	#/ml	28000				610	97.8
COD	mg/l	416				97	76.7

Table C43. OPERATING DATA FOR RUN NO. 43

Date: July 20, 1973
Start: 4:48 pm Stop: 10:08 pm Duration: 5.35 hours
Volume treated: 15,469 cu m (4,087,000 gallons)
Average flow rate: 69.379 cu m/day (18.33 mgd)
Average transfer rate: 27,744 cu m/day (7.33 mgd) Percent return; 40
Average dry weather plant flow rate: 71,915 cu m/day (19 mgd)

Contact Tank

MLSS: 2,670 mg/l Contact time[a]: 13.72 min
BOD loading: 13,872 g/cu m/day (867 lb/day/1000 ft^3)
F/M[b]: 5.23 kg BOD/day/kg MLSS Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 5.9 cu m/kg BOD applied (95 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.50 day - C Reaeration time: 1.37 hours
Stabilization tank turnovers: 3.91 OUR:
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 48.6 cu m/day/sq m (1,191 gpd/ft^2)
Clarifier detention time[a]: 1.29 hours Clarifier turnovers: 4.14
Clarifier solids loading: 181,048 g/day/sq m (37.1 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C43 (continued). OPERATING DATA FOR RUN NO. 43

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.25	7.20	7.22		7.55	
Settleable solids	mg/l	9.0				Trace	
Total solids	mg/l	676				384	43.2
Total volatile solids	mg/l	360				153	57.5
Suspended solids	mg/l	420	2670	3240	486	17	96.0
Suspended volatile solids	mg/l	300	1600	4940	294	10	96.7
Total BOD	mg/l	136		2050	156	23	87.6
Dissolved BOD	mg/l	60				5	91.7
Total organic carbon	mg/l	193		2500		25	87.0
Dissolved organic carbon	mg/l					19	61.2
Kjeldahl nitrogen as N	mg/l	21.1				7.7	63.5
Total phosphorus as P	mg/l	5.37				0.75	86.0
Total coliform	#/ml	840000				51000	93.9
Fecal coliform	#/ml	78000				2500	96.8
COD	mg/l	515				52	89.9

Table C44. OPERATING DATA FOR RUN NO. 44

Date: August 9, 1973
Start: 10:00 am Stop: 2.56 pm Duration: 4.94 hours
Volume Treated: 12,195 cu m (3,222,000 gallons)
Average flow rate: 59,235 cu m/day (15.65 mgd)
Average transfer rate: 27,858 cu m/day (7.36 mgd) Percent return; 47
Average dry weather plnat flow rate: 49,205 cu m/day (13 mgd)

Contact Tank

MLSS: 3,210 mg/l Contact time[a]: 15.31 min
BOD$_{b}$ loading: 11,712 g/cu m/day (732 lb/day/1000 ft^3)
F/M[b]: 3.67 kg BOD/day/kg MLSS Air flow: 52.5 cu m/min (1,875 cfm)
Air supply: 6.9 cu m/kg BOD applied (112 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.80 days - C Reaeration time: 1.30 hours
Stabilization tank turnovers: 3.81 OUR:
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 41.5 cu m/day/sq m (1,017 gpd/ft^2)
Clarifier detentiom time[a]: 1.44 hours Clarifier turnovers: 3.43
Clarifier solids loading: 195,200 g/day/sq m (40.0 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C44 (continued). OPERATING DATA FOR RUN NO. 44

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.20	7.25	7.15		7.90	
Settleable solids	ml/l	6.0				9.0	
Total solids	mg/l	640				525	18.0
Total volatile solids	mg/l	282				192	31.9
Suspended solids	mg/l	317	3210	9370	995	164	48.3
Suspended volatile solids	mg/l	164	1820	5650	590	95	42.1
Total BOD	mg/l	184		2200	348	66	64.1
Dissolved BOD	mg/l	67				42	37.3
Total organic carbon	mg/l	168		4000		72	57.1
Dissolved organic carbon	mg/l	46				33	28.3
Kjeldahl nitrogen as N	mg/l	22.4				15.6	30.4
Total phosphorus as P	mg/l	4.92				5.51	
Total coliform	#/ml	40000				22300	44.2
Fecal coliform	#/ml						
COD	mg/l	485				183	62.3

Table C45. OPERATING DATA FOR RUN NO. 45

Date: August 23, 1973
Start: 10:51 am   Arop: 3:51 pm   Duration: 5.00 hours
Volume treated: 11,949 cu m (3,157,000 gallons)
Average flow rate: 57,343 cu m/day (15.15 mgd)
Average transfer rate: 26,381 cu m/day (6.97 mgd)   Percent return; 46
Average dry weather plant flow rate: 60,560 cu m/day (16 mgd)

Contact Tank

MLSS: 3,700 mg/l   Contact time[a]: 15.92 min
BOD loading: 8,128 g/cu m/day (508 lb/day/1000 ft^3)
F/M[b]: 2.21 kg BOD/day/kg MLSS   Air flow: 39.2 cu m/min (1,400 cfm)
Air supply: 7.5 cu m/kg BOD applied (121 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.61 days - C   Reaeration time: 1.37 hours
Stabilization tank turnovers: 3.65   OUR:
Oxygen supply: 227 kg/hr (500 lb/hr

Final Clarifier

Surface overflow rate: 40.1 cu m/day/sq m (984 gpd/ft^2)
Clarifier detention time[a]: 1.50 hours   Clarifier turnovers: 3.33
Clarifier solids loading: 216,184 g/day/sq m (44.3 lb/day/ft^2)

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a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C45 (continued). OPERATING DATA FOR RUN NO. 45

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.65	7.40	7.10		7.75	
Settleable solids	ml/l	5.5				Trace	
Total solids	mg/l	569				451	20.7
Total volatile solids	mg/l	238				161	32.4
Suspended solids	mg/l	229	3700	11275	16	32	86.0
Suspended volatile solids	mg/l	144	2450	6925	12	20	86.1
Total BOD	mg/l	132		3000	9	19	85.6
Dissolved BOD	mg/l	46				6	87.0
Total organic carbon	mg/l	152		4250		30	80.3
Dissolved organic carbon	mg/l	41				17	58.5
Kjeldahl nitrogen as N	mg/l	17.3				11.0	36.4
Total phosphorus as P	mg/l	4.44				1.17	73.6
Total coliform	#/ml	750000				80000	89.3
Fecal coliform	#/ml	1600				500	68.8
COD	mg/l	400				71	82.2

Table C46. OPERATING DATA FOR RUN NO. 46

General

Date: September 4, 1973
Start: 11:46 am   Stop: 5:51 pm   Duration: 6.06 hours
Volume treated: 15,999 cu m (4,227,000 gallons)
Average flow rate: 63,361 cu m/day (16.74 mgd)
Average transfer rate: 19,001 cu m/day (5.02 mgd)   Pe-cent return; 30
Average dry weather plant flow rate: 60,560 cu m/day (16 mgd)

Contact Tank

MLSS: 3,025 mg/l   Contact time[a]: 16.18 min
BOD loading: 11,040 g/cu m/day (690 lb/day/1000 ft^3)
F/M[b]: 3.67 kg BOD/day/kg MLSS   Air flow: 31.5 cu m/min (1,125 cfm)
Air supply: 4.4 cu m/kg BOD applied (72 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 1.67 days - C   Reaeration time: 1.88 hours
Stabilization tank turnovers: 3.22   OUR:
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 44.3 cu m/day/sq m (1,087 gpd/ft^2)
Clarifier detention time[a]: 1.52 hours   Clarifier turnovers: 3.98
Clarifier solids loading: 174,216 g/day/sq m (35.7 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C46 (continued). OPERATING DATA FOR RUN NO. 46

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.33	7.12	7.12		7.55	
Settleable solids	ml/l	13				Trace	
Total solids	mg/l	1037				375	63.8
Total volatile solids	mg/l	469				160	65.9
Suspended solids	mg/l	659	3025	10800	30	54	91.8
Suspended volatile solids	mg/l	337	2050	7100	30	54	84.0
Total BOD	mg/l	162		2800	16	26	84.0
Dissolved BOD	mg/l	48				10	79.2
Total organic carbon	mg/l	240		3750		32	86.7
Dissolved organic carbon	mg/l	34				16	52.9
Kjeldahl nitrogen as N	mg/l	22				11.2	49.1
Total phosphorus as P	mg/l	5.90				2.19	62.9
Total coliform	#/ml	19000				3600	54.7
Fecal coliform	#/ml	7000				140	98.0
COD	mg/l	628				84	86.6

Table C47. OPERATING DATA FOR RUN NO. 47

Date: September 17, 1973
Start: 7:51 am Stop: 3.08 pm Duration: 7.28 hours
Volume treated: 18,032 cu m (4,764,000 gallons)
Average flow rate: 59,462 cu m/day (15.71 mgd)
Average transfer rate: 27,933 cu m/day (7.38 mgd) Percent return; 47
Average dry weather plant flow rate: 68,130 cu m/day (18 mgd)

Contact Tank

MLSS: 3,450 mg/l Contact time[a]: 15.25 min
BOD loading: 6,832 g/cu m/day (427 lb/day/1000 ft^3)
F/M[b]: 1.99 kg BOD/day/kg MLSS Air flow: 31.5 cu m/min (1,125 cfm)
Air supply: 7.2 cu m/kg BOD applied (116 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 3.5 days - S Reaeration time: 1.36 hours
Stabilization tank turnovers: 5.35 OUR:
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 41.7 cu m/day/sq m (1,021 gpd/ft^2)
Clarifier detention time[a]: 1.44 hours Clarifier turnovers: 5.07
Clarifier solids loading: 210,816 g/day/sq m (43.2 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C47 (continued). OPERATING DATA FOR RUN NO. 47

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.50	7.10	7.00		7.22	
Settleable solids	ml/l	4.5				Trace	
Total solids	mg/l	539				435	19.3
Total volatile solids	mg/l	237				169	28.7
Suspended solids	mg/l	334	3450	10075	35	66	80.2
Suspended volatile solids	mg/l	188	2000	6075	12	38	79.8
Total BOD	mg/l	107		2850	24	38	64.5
Dissolved BOD	mg/l	47				11	76.6
Total organic carbon	mg/l	115				41	64.3
Dissolved organic carbon	mg/l	41				21	48.8
Kjeldahl nitrogen as N	mg/l	14.3				12.5	12.6
Total phosphorus as P	mg/l	5.23				4.95	5.4
Total coliform	#/ml	47000				22800	51.5
Fecal coliform	#/ml	8700				3100	64.4
COD	mg/l	400				115	71.2

Table C48. OPERATING DATA FOR RUN NO. 48

General

Date: September 21, 1973
Start: 3:52 pm Stop: 9:10 pm Duration: 5.28 hours
Volume treated: 11,983 cu m (3,166,000 gallons)
Average flow rate: 54,466 cu m/day (14.39 mgd)
Average transfer rate: 23,959 cu m/day (6.33 mgd) Percent return; 44
Average dry weather plant flow rate: 68,130 cu m/day (18 mgd)

Contact Tank

MLSS: 3,800 mg/l Contact time[a]: 17.00 min
BOD loading: 10,416 g/cu m/day (651 lb/day/1000 ft^3)
F/M[b]: 2.76 kg BOD/day/kg MLSS Air flow: 36.4 cu m/min (1,300 cfm)
Air supply: 5.4 cu m/kg BOD applied (88 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 3.0 days - S Reaeration time: 1.59 hours
Stabilization tank turnovers: 3.33 OUR:
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 38.1 cu m/day/sq m (935 gpd/ft^2)
Clarifier detention time[a]: 1.60 hours Clarifier turnovers: 3.30
Clarifier solids loading: 208,376 g/day/sq m (42.7 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C48 (continued). OPERATING DATA FOR RUN NO. 48

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.15	7.20	7.15		7.62	
Settleable solids	ml/l	7.5				Trace	
Total solids	mg/l	577				368	36.2
Total volatile solids	mg/l	235				80	66.0
Suspended solids	mg/l	321	3800	11775	186	52	83.8
Suspended volatile solids	mg/l	183	2400	7750	137	42	77.0
Total BOD	mg/l	178		3600	30	81	54.5
Dissolved BOD	mg/l	49				10	79.6
Total organic carbon	mg/l	120		3900		36	70.0
Dissolved organic carbon	mg/l	22				16	27.3
Kjeldahl nitrogen as N	mg/l	13.2				6.3	52.3
Total phosphorus as P	mg/l	3.96				1.56	60.6
Total coliform	#/ml	1350000				160000	88.1
Fecal coliform	#/ml	135000				11000	91.8
COD	mg/l	1416				86	93.9

Table C49. OPERATING DATA FOR RUN NO. 49

General

Date: September 24, 1973 to September 25, 1973
Start: 10:30 pm Stop: 10:00 am Duration: 11.50 hours
Volume Treated: 30,178 cu m (8,973,000 gallons)
Average flow rate: 62,982 cu m/day (16.64 mgd)
Average transfer rate: 22,029 cu m/day (5.82 mgd) Percent return; 35
Average dry weather plant flow rate: 75,700 cu m/day (20 mgd)

Contact Tank

MLSS: 3,100 mg/l Contact time[a]: 15.68 min
BOD loading: 5,152 g/cu m/day (322 lb/day/1000 ft^3)
F/M[b]: 1.67 kg BOD/day/kg MLSS) Air flow: 36.4 cu m/min (1,300 cfm)
Air supply: 11.0 cu m/kg BOD applied (179 ft^3/lb BOD applied)

Stabilization Tank

Stabilization time[c]: 2.5 days - S Reaeration time: 1.64 hours
Stabilization tank turnovers: 7.02 OUR:
Oxygen supply: 227 kg/hr (500 lb/hr)

Final Clarifier

Surface overflow rate: 44.1 cu m/day/sq m (1,081 gpd/ft^2)
Clarifier detention time[a]: 1.48 hours Clarifier turnovers: 7.70
Clarifier solids loading: 183,976 g/day/sq m (37.7 lb/day/ft^2)

a. Based on total flow.
b. Based on MLSS in contact tank only.
c. S = static condition; C = continuous flow.

Table C49 (continued). OPERATING DATA FOR RUN NO. 49

Characteristics	Units	Grit tank	Contact tank	Stabilization tank	DWP clarifier	Final clarifier	Percent removal
pH		7.15	6.90	6.90	7.42	7.71	
Settleable solids	ml/l	5.1				Trace	
Total solids	mg/l	487				357	26.7
Total volatile solids	mg/l	173				100	42.2
Suspended solids	mg/l	222	3100	11225	10	22	90.1
Suspended volatile solids	mg/l	88	1700	6500	4	8	90.9
Total BOD	mg/l	76		3850	9	17	77.6
Dissolved BOD	mg/l	26				15	42.3
Total organic carbon	mg/l	90		4450		30	66.7
Dissolved organic carbon	mg/l	33				27	18.2
Kjeldahl nitrogen as N	mg/l	6.7				5.0	25.4
Total phosphorus as P	mg/l	2.65				1.23	53.6
Total coliform	#/ml	1090000				760000	30.2
Fecal coliform	#/ml	39000				7100	81.7
COD	mg/l	301				51	83.0

APPENDIX D. Procedures for Sludge Studies

DAILY PROCEDURES FOR STABILIZATION TANK STUDIES

1. Record the sludge volume in the stabilization tank.

2. Record the rate of flow of WAS into the stabilization tank (1973 only).

3. Record the mean air temperature.

4. Record the DWP's influent suspended solids (1973 only).

5. Record the number of days that the sludge has been under static or dynamic conditions.

6. Obtain a sludge sample for analysis of suspended solids and volatile suspended solids.

7. Use a YSI dissolved oxygen meter to determine the temperature and OUR of the sludge. The OUR was based on the change in dissolved oxygen in a period of three minutes (or six minutes if the rate of change was low).

8. Run a settling test. This consisted of taking one liter of sludge from the stabilization tank and mixing it with three liters of raw sewage from the influent to the DWP grit tank. The mixture was aerated for 15 minutes and;then one liter of the mixed liquor was poured into a settling column. The settling rate was recorded and after 30 minutes the settled sludge volume was recorded. A sample of the supernatant was also analyzed for suspended solids concentration.

9. If the sludge was in a static condition the time under static condition was recorded as the sludge age. If the sludge was under dynamic conditions, the recorded rate of WAS flow into the tank and the sludge volume were used to calculate the sludge detention time in the tank. This values was then used as the sludge age. If the conditions changed from static to dynamic, the sludge age was based on an average of old sludge remaining before a complete tank turnover and the detention time for the new sludge that was being pumped in.

10. The recorded value of oxygen uptake (mg/l/hr) was divided by the value of volatile suspended solids to get an OUR in terms of (mg/l/hr)/(gm VSS).

11. Using the data obtained, the sludge volume index (SVI) was calculated and recorded. The calculations were as follows:

MLSS = (.25) SS concentration of sludge
+ (.75) SS concentration of plant influent

SVI = settled sludge volume x 1000/MLSS

PROCEDURES FOR BENCH SCALE STUDIES

The equipment used for the bench scale testing included three 12 liter plastic reactors, a Millipore vacuum-pressure pump, six ball diffusers, a 1000 ml settling column with a bottom drawoff point, a YSI dissolved oxygen meter and dissolved oxygen probe, magnetic stirrer, a plastic air pressure chamger with a pressure gauge, and a bicylce air pump.

The first procedure used was for studying the extent of aerobic digestion. Six to seven liters of DWP WAS was placed in two of the plastic reactors. This sludge would be identical to the sludge entering the demonstration system stabilization tank. The Millipore pump was then turned on to deliver a continuous supply of air to the two units through two ball diffusers at the bottom of each reactor. After this initial setup the units were allowed to run for periods ranging from 15 to 20 days. Samples of the sludge were taken daily and analyzed for suspended solids concentration, volatile suspended solids concentration and OUR. In addition, spot checks were made to determine total alkalinity and total COD concentrations. The data collected was then analyzed to determine, 1) the rate of solids destruction, 2) if there is a noticeable relationship between the OUR and the decrease in solids, and 3) what is happening to the total COD and the total alkalinity.

The second aspect of the bench scale testing was the effect of sludge stabilization on the dissolved air flotation thickening process. Every second day during the digestion period a bench scale flotation test was run using 330 ml of the sludge under aeration in the plastic reactors. These tests were run using parameters similar to those used by the Kenosha WPCP in the operation of their flotation units. The operational parameters were: 200% recycle of primary effluent pressurized at 3.16 kg/sq m (45 psig).

The 330 ml sample of sludge was placed in the 1000 ml cylinder. A sample of primary effluent was obtained from the DWP and this sample was placed in the plastic pressurizing chamber. The pressure was the increased to 3.16 kg/sq cm (45 psig) in the chamber and the chamber was shaken vigorously for one minute and then allowed to sit for 3 minutes. After 3 minutes the saturated recycle was released into the bottom of the cylinder until the volume of the cylinder reached 1000 ml. Once the cylinder was filled, 15 minutes were allowed for the solids to float to the surface. Upon completion of the test, a sample of the top float was taken with a spoon and an effluent sample was drawn off from the bottom of the cylinder.

From the flotation test the following data was obtained: the interface rise rate during the 15 minutes of flotation, the percent solids in the float, calculated as (weight of dried solids/weight of wet solids) x 100, suspended solids concentration in the effluent, volume of the float, volume of the effluent, and the percent SS recovery. This last term was calculated as follows:

(mg SS in - mg SS out)/mg SS in =
([volume of recycle) (SS of primary effluent) +
(volume of sludge) (SS of sludge) - (volume of effluent)
(SS of effluent)] ÷ [(volume of recycle) (SS of primary effluent)
+ (volume of sludge) (SS of sludge)].

The final portion of the study was the bench scale tests run only during actual operation of the demonstration system, insuring the raw flow used had combined sewage characteristics. During a run, six liters of raw flow (grit tank effluent) were taken and placed in a plastic reactor. Two liters of stabilized sludge were drawn off from the digestion units and mixed with the six liters of raw flow. This mixture was then aerated vigorously for 15 minutes (contact time) and then allowed to settle for one hour (clarifier detention time). After the 15 minutes of aeration, 1000 ml of the mixed liquor was also drawn off and placed in the settling column, and 30 minutes later the volume of settled sludge was recorded. Samples were taken of the raw flow, mixed liquor, and supernatant after one hour of settling. Data compiled during these tests included SS and VSS concentrations of the raw flow, SS and VSS concentrations of the mixed liquor, SS and VSS concentrations of the supernatant, and SVI. These results were used in calculating the percent SS and VSS removals for each run and the percent volatile solids in the mixed liquor. The results of these tests were used to determine the effect of different stabilization times on the effectiveness of the sludge in the demonstration system.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This report describes the design, construction, operation and two-year evaluation of a biological process used for the treatment of potential combined sewer overflow. A 75,700 cu m/day (20 mgd) modified contact stabilization process was constructed on the grounds of an existing 87,055 cu m/day (23 mgd) conventional activated sludge plant at a total cost of 1.1 million dollars. The demonstration system consisted of pumping facilities, the conversion of an unused flocculation basin into a grit basin, construction of a contact tank and stabilization tank, installation of a final clarifier and all associated yard piping and automatic control equipment. The demonstration system's raw sewage pump and clarifier were used by the dry weather plant when the demonstration system was not in use. Results from the evaluation program proved the demonstration system to be a feasible concept for the treatment of potential combined sewer overflow. The system was operated and evaluated during 49 runs in which 681,300 cu m (180,000,000 gal.) of potential overflow was treated. Based on these tests, expected removal efficiencies for suspended solids, BOD, and TOC are 90%, 85%, and 76%, respectively. Operating costs for running the system 300 hours per year are estimated at 3.567¢/cu m (13.5¢/1000 gal.). An additional benefit derived from the demonstration system was improved removal efficiencies by the dry weather plant through utilization of the demonstration system facilities.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Sewage treatment Activated sludge process *Runoff Overflows *Combined sewers Water pollution *Surface water runoff	*Biological treatment *Contact stabilization Kenosha (Wisconsin) Dual use Dry/wet weather treatment Combined sewage Combined sewer overflow	13B
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