AN INVESTIGATION OF THE OPERATING CHARACTERISTICS AND EFFICIENCY OF A SMALL SEWAGE TREATMENT PLANT

by

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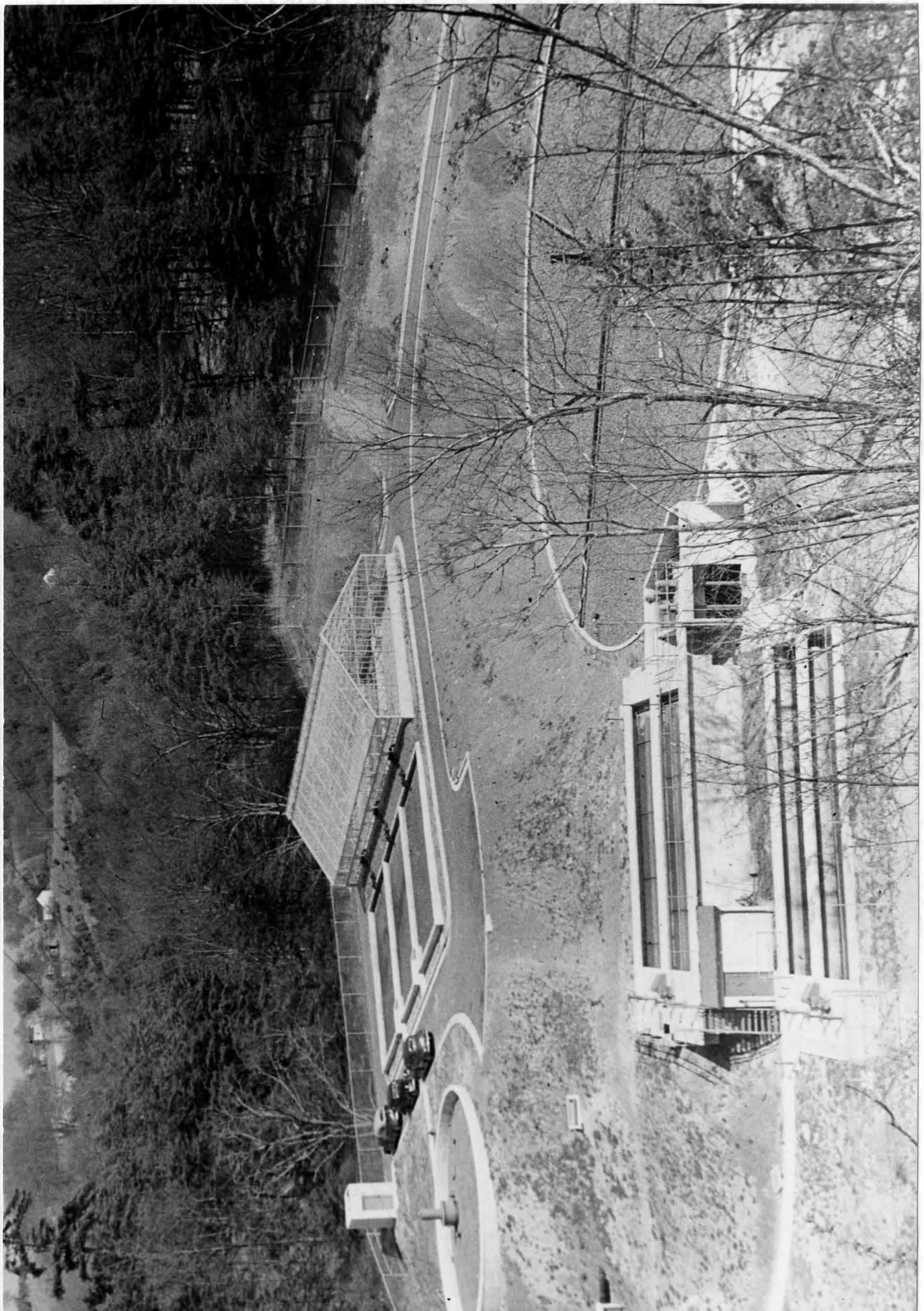

Plate 1

BLACKSBURG - V. P. I. SEWAGE TREATMENT PLANT

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III. INTRODUCTION

The new Blacksburg - V.P.I. sewage treatment plant, Plate 1, located on the east bank of Strouble's Creek at State Road 657, was completed in July 1948 to replace obsolete treatment facilities at the south end of the main campus. The earlier plant, of the Imhoff Tank type, with intermittent contact-bed filtration, was constructed in 1928. By 1940, this plant was of insufficient capacity to process the increased volume of sewage from the campus and from the sewered population of Blacksburg adequately. Consequently, most of the sewage was diverted with only minimum treatment to Strouble's Creek.

The new plant was designed to serve a population of approximately 8,000 with an average daily sewage flow of 1 MGD. In addition to the plant proper, the project included construction of a pump house at the site of the former plant on the main campus and a pipeline to the new site.

The new plant is of the separate sludge digestion type and provides primary and secondary treatment. The principal units are: primary and secondary clarifiers, trickling filter, separate heated sludge digester, open and covered sludge drying beds, and facilities for pre- and post-chlorination. Alternate piping arrangements were included in the design to provide greater operational flexibility for accommodating unusual flow conditions created by population fluctuations and moderately severe storm water problems.

When construction was completed in July 1948, manufacturer's representatives made final adjustments of equipment to assure specified operational performance. Initial "seeding" of the new plant, i.e., inoculation of the new plant with a stabilized bacterial population, was accomplished by flushing digesting sludge from the Imhoff Tank to the new plant along with the normal sewage flow. The new digester was filled and emptied twice (to permit further adjustments) before the plant was "re-seeded" and placed in continuous operation on August 17, 1948.

Sewage treatment plants employ a combination of physical, chemical, and biological processes. During the initial period of operation, considerable experimentation is required to establish optimum operating and control procedures for a wide range of conditions.

Field and laboratory tests were conducted at the V.P.I. sewage treatment plant and in the Sanitary Engineering Division of the Civil Engineering Department to determine the physical, chemical, and biological characteristics of the sewage at various stages in its treatment.

This study was conducted from August 1948 through November 1949, with many of the routine tests being performed during the entire period. Special tests were conducted for shorter intervals during this time.

Objectives

This investigation was conducted primarily to determine the effectiveness of the treatment processes and the efficiencies of the component units. The development of operating procedures and application of standard and modified laboratory techniques for the control of the plant were included. Additional factors studied were: storm water infiltration, modifications in design, and recommendations for improved plant and system operation.

Objectives of this study are to determine the effectiveness of treatment provided by the Blacksburg - V.P.I. sewage treatment plant by the evaluation of unit and over-all efficiencies. These data are compared with generally accepted theoretical and observed values for sewage works of this type.

IV. THE REVIEW OF LITERATURE

Stream standards for the Ohio and the Kanawha River Basin — to which Strouble's Creek and the New River are tributary — have been described by Streeter[49] and the West Virginia Water Commission[21] respectively. Criteria for Class A include: average dissolved oxygen 6.5 ppm; average B.O.D. 3.0 ppm and a pH range from 6.5 to 8.6.

Variations in the rate of sewage flow as discussed by Sperry[46] are particularly significant at small treatment plants which inherently are not capable of "damping" or equalizing the effects of sharp fluctuations.

The effects of storm water entering sanitary sewerage systems and overloading sewage treatment processes and subjecting hydraulic equipment to excessive wear and mechanical damage has been summarized by Martin[28]. Methods of determining the source of storm water and infiltration were outlined by Randall[37]. Although the Virginia Statewide Plumbing Code of 1938[52] specifically prohibits the connection of storm drains from roofs and other paved areas to sanitary sewers, considerable diversion of this type was believed to exist in the Blacksburg - V.P.I. system. In summarizing Blacksburg weather observations, Brown[7] has shown that 58 thunderstorms producing more than 2.00 inches of rainfall during 24 hours occurred in the period 1893 - 1944. Thunderstorms, of all magnitudes, occurred in Blacksburg most frequently in July, June, and August — with 135, 127, and 110 storms respectively. Kuichling's empirical formulae for estimating storm frequency and a rational method of computing storm run-of[30] were adapted to observations in this investigation.

The success of Williams[55] using coal-tar dye as an indicator in determining flow velocities in submarine out-fall experiments led to the use of the same dye in this investigation. Variations in the computation of hydraulic characteristics of pipelines — including the use of empirical formulae developed by Manning and Kutter, effects of roughness, and ratios of hydraulic elements — are reviewed by Babbitt[5] and also Metcalf and Eddy[31].

Methods of collecting sewage samples — "grab" and "composite" — for various analytical determinations were reviewed in an operator's forum in 1946[1].

Although modifications of other tests have been developed and proposed as a "standard" method, analytical procedures established by the American Public Health Association[47] are generally employed for comparative purposes. In addition to their widespread use and general acceptance, A.P.H.A. procedures impart a certain degree of legality in determining the validity of analyses when required.

Application of the B.O.D. test in determining efficiencies of sewage treatment processes has been described by Sawyer and Bradney[42] — including modifications of standard techniques.

The development and experimental application of the oxidation - reduction potential method in sewage analyses have been outlined by Hood[17] in reporting experiences with this procedure in New Jersey.

The use of sewage treatment plant data as a guide to operational improvement has been evaluated by Symons[50].

Imhoff[20], in discussing treatment, has given particular emphasis to the continuous flow principles of sewage purification. Problems of sewage sedimentation in primary clarifiers under variable flow conditions[2], and in secondary tanks have been outlined by Kin[22].

Montgomery[32], has presented a method for determining clarifier efficiency ratings using analyses of clarifier influent and effluent samples before and after theoretical detention periods — expressing actual tank performance as a percentage of maximum or "ideal" efficiency. Moore et al[33] reported a series of efficiency tests on shallow trickling filters at Elizabethtown, Kentucky in which flow of sewage applied to the filter was determined by the radial pan method. Factors affecting the efficiency of sewage chlorination have been examined and reported by Rudolfs[41] and the use of Cloroben as an aid in suppressing sewage odors, slime, and septicity has been discussed by Frei[14].

Early studies of separate, single stage digestion processes conducted by Fischer[13] in 1925 - 1926, demonstrated that digestion was most efficient using raw sludge containing approximately 6 per cent solids. The importance of maintaining optimum temperatures of 95 - 100 °F. for thermophilic bacterial digestion is described by Heukelekian and Kaplovsky[16]. Operating experiences of the digestion process have been discussed by specialists in this phase of the treatment process and include: scum control by Rankin and Schlenz[38], external heating methods by Kunsch[26], and gas production by Cohn[11]. Effects of the digestion process in reducing sludge solids with the concomitant production of sludge gas are reported by Walker[53]. The feasibility of installing sludge-gas storage facilities at small sewage plants was discussed by Louis[27] in correspondence with the writer.

Experiments and experiences in the drying, removal, and ultimate disposal of digested sludge are discussed by Kunsch[25]. A practical approach to improving sludge bed use was developed at Ft. Wayne (Ind.) drying successive batches of digested sludge directly on previously dried sludge cake and is reported in detail by Hoot[18]. In these tests, seven successive layers of sludge in one test bed produced 12.1 pounds of sludge per square foot of bed area per year as contrasted to 13.0 pounds obtained by conventional batch removals.

Cost comparisons of sludge as a fertilizer are detailed in a manual of practice for sewage plant operators[51].

One of the early experiences of severe frothing on sewage tanks is reported at Mount Penn, Pennsylvania[3] in 1947. Further detailed studies of the effects of synthetic detergents on sewage treatment processes were described by Rudolfs et al[40] in 1949. The growth of large quantities of snails in trickling filters is a relatively infrequent occurrence. The problem of excessive snail growths in trickling filters at Dayton, Ohio is reported by Huffman[19]. Snail shells settling in secondary tanks were pumped to the raw influent sewage channel and were removed successfully in grit chambers. Control of filter flies (Psychoda alternata) — a perennial problem at many plants with trickling filters, particularly during warm summer months — was reported by Rhame[39] through the use of specific insecticides and by controlled flooding of filter beds.

The occupational hazards of sewage treatment and methods for protecting plant operators have been outlined by Smith[44]. Specific precautions have been developed by the Federation of Sewage Works Associations in a manual of practice[32].

Data from abstracts of operating reports from sewage treatment plants in small and medium-size towns and cities have been summarized in Table for comparison performance with the Blacksburg - V.P.I. plant. These plants were located in Ann Arbor, Michigan[56], Aurora, Illinois[45], Battle Creek, Michigan[12], Belvidere, Illinois[35], DeKalb, Illinois[15], Jackson, Michigan[8], Marion, Indiana[6], and Urbana - Champaign, Illinois[24]. Data from the Imhoff Tank plant at Charlottesville, Virginia[54] were not included in this comparison.

V. THE INVESTIGATION

This section of the report is presented in the following sequence:

A. Sewage Treatment Plant
   - Design Factors
   - Flow Diagram (Figure 1)
   - Operational Features

B. Procedures
   - Hydrologic Studies
   - Collection of Samples
   - Analytical Determinations

C. Results and Discussion
   - Tributary Population
   - Sewage Flow Measurement
   - Hydrologic Studies
   - Sewage Velocity Determination
   - Sewage Characteristics and Treatment
   - Sludge Digestion System
   - Operational Problems
   - Comparative Performance

A. - Sewage Treatment Plant

Summary of Design Factors

Design Capacity 1.0 MGD

Pump House:
- Flow Gage and Recording Meter,
- Comminutor and Bar Screen,
- Storm Water Pump - 3.7 MGD Rating

Pipeline:
- Length 11,535 feet
- Diameter 16 inch, Cast Iron
- Slope (mean) 9.3 ft/1000 ft.

Chlorinators (2) Pre- and Post
- Chlorine gas 250# cylinders

Clarifiers:
- Primary (2) 50 ft x 14 ft x 10 ft
- Secondary (2) 50 ft x 12 ft x 7.5 ft

Tributary Population 8,000

Trickling Filter:
- Diameter 130 feet
- Distributor Rotary, 4-arm
- Media 5.5 ft.

Digester; Floating Cover:
- Diameter 45 feet
- Side Water Depth 22 feet
- Bottom Cone 5 feet
- Heat Exchanger
- Supernatant Selector

Pumps:
- Sludge (2) Piston
- Recirculation (5) Centrifugal

Sludge Beds: 6 @ 27 ft x 40 ft

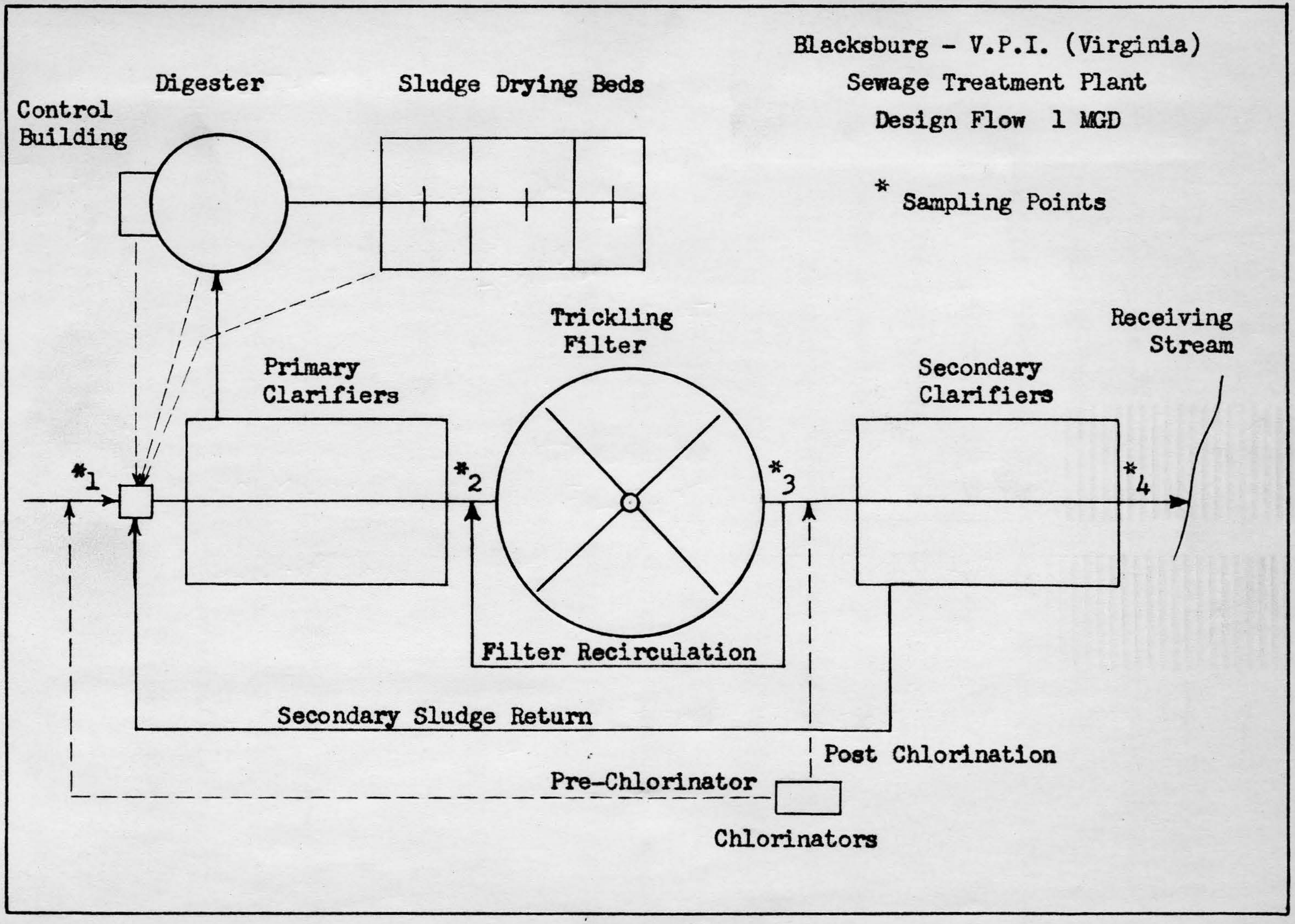

FIGURE 1. FLOW DIAGRAM

Description of Sewage Treatment Plant. The new sewage plant was designed by Professors R. B. H. Begg and P. H. McGauhey of the Civil Engineering Department of V.P.I. The entire project, including the pump house at the site of the former plant, transmission pipeline, and the new plant and appurtenances cost approximately $350,000.

Pump House. A Kennison-Nozzle gage and an automatic continuous recorder, with a maximum recording flow-rate limit of 2.48 MGD, are installed in the campus pump house, Plate 2.

A standard sewage bar screen and a comminutor are located on the upper level of the campus pump house. An alternate comminutor setting is provided for future installation of a second unit. Normal sewage flow is by gravity from the pump house wet-well through the pipeline to the sewage treatment plant. During storm water flows, a centrifugal pump, with a rating of 3.7 MGD, surcharges the line. Higher flows are diverted directly to Strouble's Creek.

The 11,535-foot 16-inch cast-iron transmission pipeline is laid on varying slopes from the pump house to the plant, with the final 350 feet crossing Strouble's Creek on concrete piers.

The pipeline terminates in an influent manhole which affords mixing and channeling of portions of the combined flow as may be required. This manhole also receives secondary clarifier sludge, digester supernatant liquor, sludge bed drainage, and sanitary wastes from the control building. During periods of extremely low flow, secondary clarifier effluent is recirculated to the receiving manhole to dilute strong sewage and to reduce detention time in the primary clarifiers.

Plate 2

CAMPUS PUMP HOUSE

(Former Treatment Plant in Background)

Primary Clarifiers. Two rectangular clarifiers in parallel provide theoretical detention periods of 2.5 hours at design capacity, (1.0 MGD), for plain sedimentation of the raw influent sewage, Figure 2. Reduction of entrance velocity and uniform distribution across the width of the clarifiers are accomplished by tapered prismoidal channels and six vertical entrance ports, Plates 3 and 4. Surface velocity is further reduced by concrete baffle walls extending vertically to ten inches below the normal water surface, 1.5 feet from the influent ports.

Each primary clarifier has two inverted pyramidal sludge hoppers for consolidation and storage of settled solids. Scum and sludge collection are accomplished by tank-width wooden flights, Plate 5. Scum and floating solids are removed by cut-pipe "skimmers" ahead of the effluent weir and are consolidated in a tank-side scum pit for daily pumping to the digester.

Trickling Filter. The split-flow primary clarifier effluent is combined in the filter dosing chamber, Plate 6, from which it is fed to the trickling filter. This discharge is regulated by an inverted dosing siphon to the center column of the rotary distributor, Plate 7. At normal flow rates, four distributor arms are used continuously, whereas at lower flows, discharge through two arms is generally sufficient to propel the distributor by hydraulic reaction. Recirculation to the filter is accomplished by pumping portions of filter effluent to the dosing tank.

A five-inch vitrified tile underdrain system, sloped inward toward the east-west diameter, collects the filtered flow into the filter

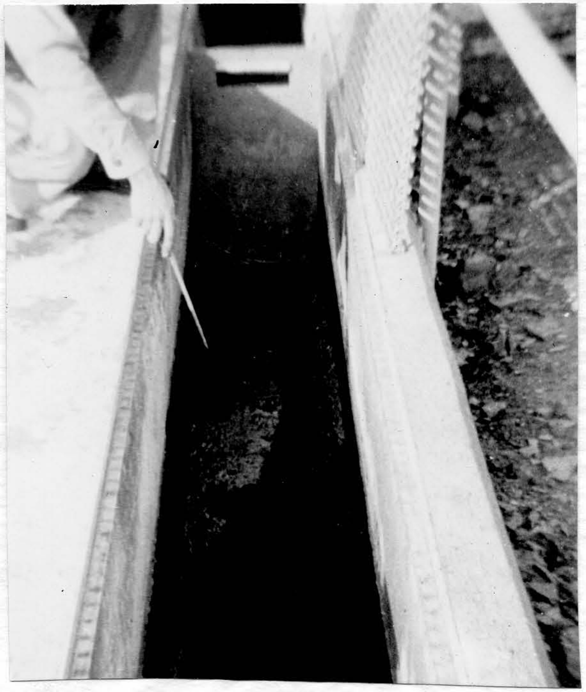

Plate 3

PRIMARY CLARIFIER
INFLUENT CHANNEL

Plate 4

PRIMARY CLARIFIER
INFLUENT PORTS

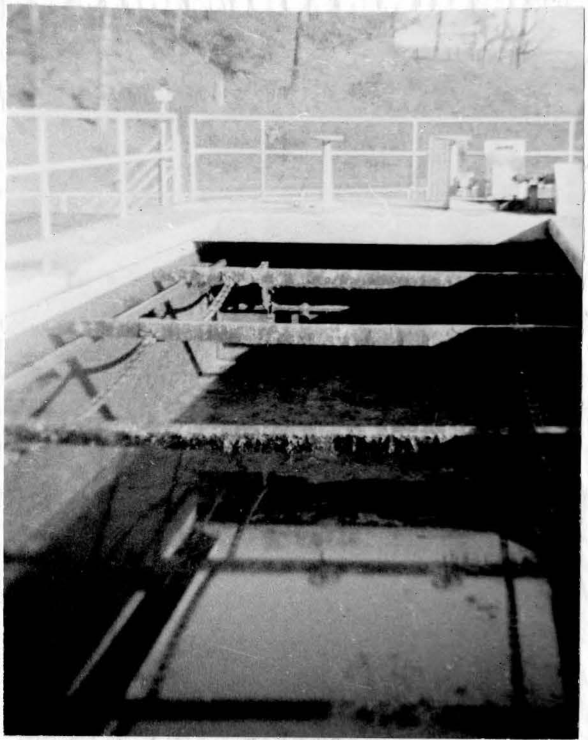

Plate 5

PRIMARY CLARIFIER FLIGHT SYSTEM

(Showing accumulation of solids removed from inlet baffle zone during partial emptying)

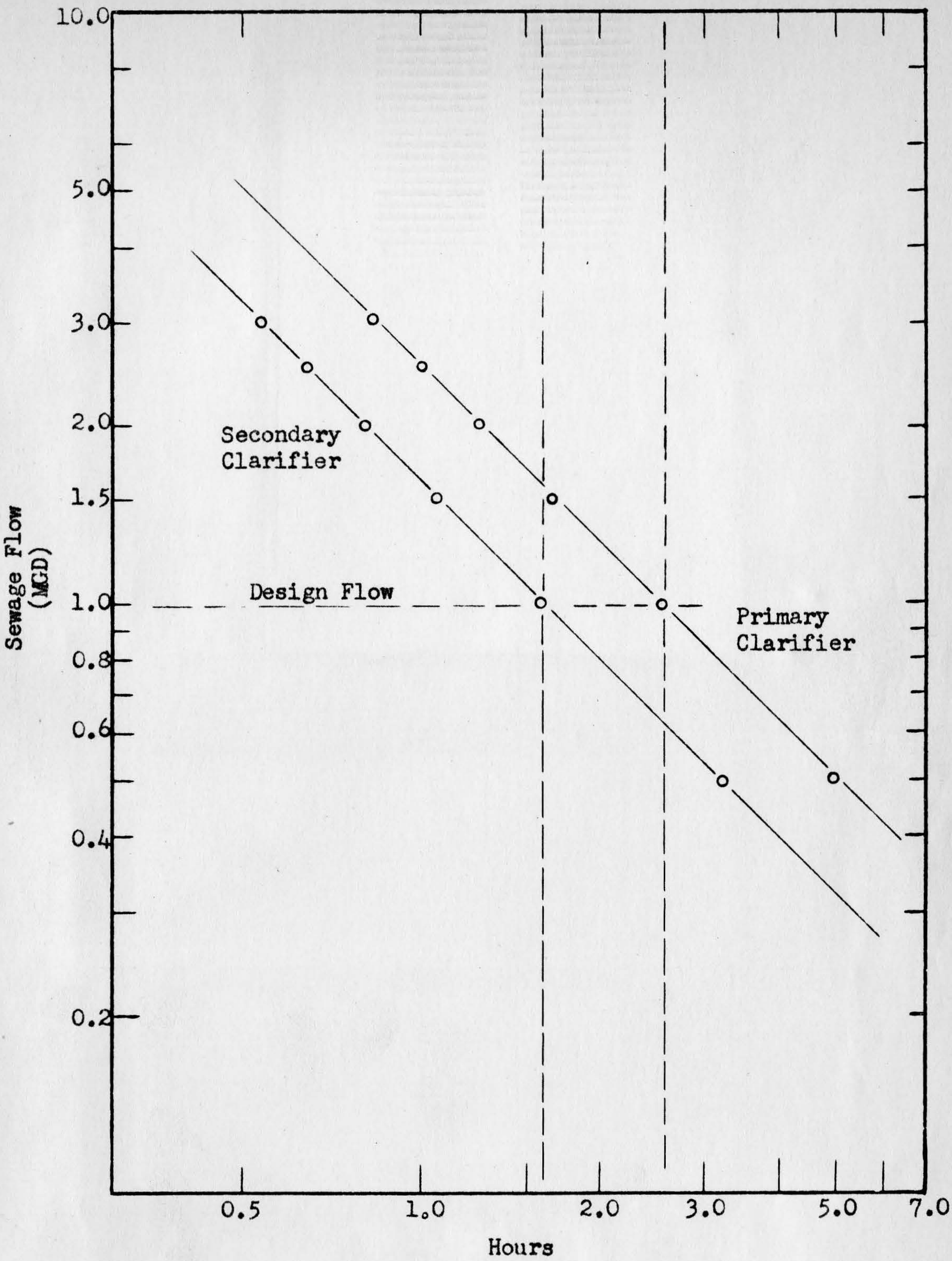

FIGURE 2. CLARIFIER DETENTION TIME

Plate 6

FILTER DOSING CHAMBER

(Showing froth formation during recirculation discharge)

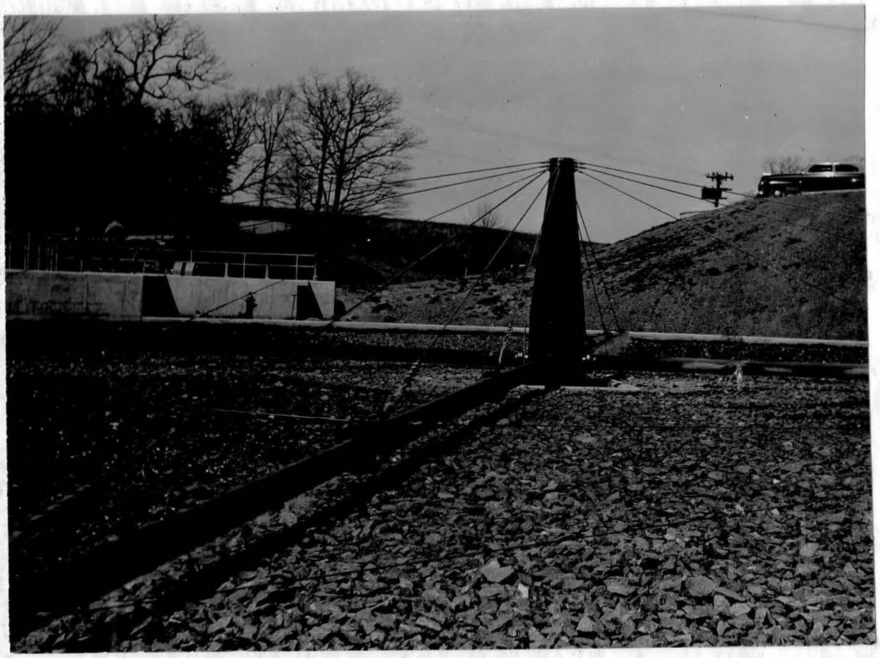

Plate 7

TRICKLING FILTER AND ROTARY DISTRIBUTOR

(Low-head center column design)

effluent channel. The underdrain system and peripheral four-inch vitrified tile pipe vents provide air circulation for proper filter operation.

Chlorination. Post-chlorination is practiced routinely by injection of chlorine solution into the filter effluent channel by a standard gaseous-feed chlorinator. Pre-chlorination, when used, is accomplished with a second chlorinator by pressure-injection of chlorine solution into the sewage pipeline twenty feet ahead of the receiving manhole, Plate 8.

Secondary Clarifiers. The secondary clarifiers, Plate 9, are smaller in size although similar in design to the primary clarifiers and provide a theoretical detention period of 90 minutes at "design" capacity, Figure 2. Collecting flights are used only for sludge consolidation in the general absence of floating solids and scum. Secondary sludge is normally recirculated to the receiving manhole for mixing with raw sewage as an aid to primary sedimentation.

Final plant effluent is discharged through the 60-foot plant outfall line to Strouble's Creek. The partially submerged outfall is equipped with tide-gate check valves to prevent backwater from entering the plant through this line during periods of abnormally high stream flow, Plate 10.

Sludge Digestion System. The single stage, heated digester has a patented floating cover equipped with a standard gas collection dome, Plate 11.

In contrast to conventional internal hot water coils, the digester is equipped with a sludge-gas/oil external heat exchanger which heats mixtures of digesting sludge and raw sludge. The heat exchanger,

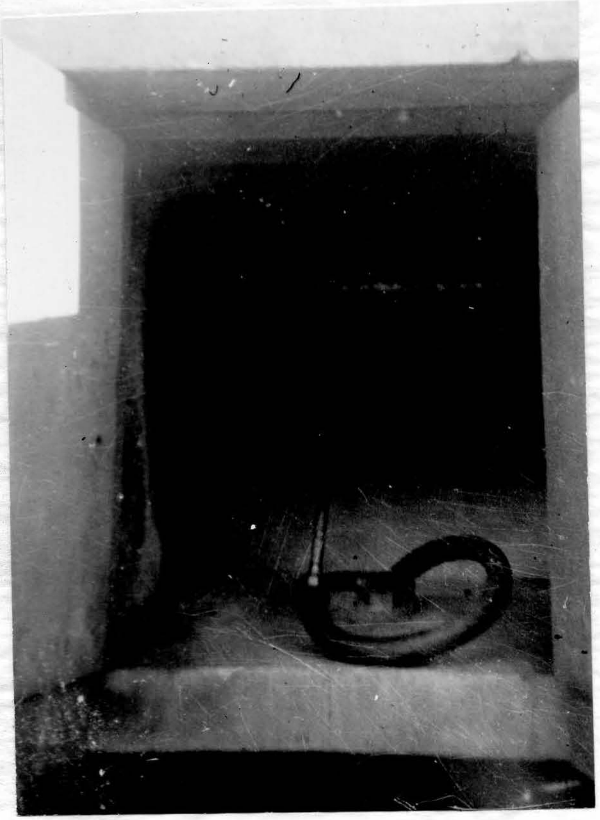

Plate 8

PRE-CHLORINATION INJECTOR

Plate 9

SECONDARY CLARIFIERS

Plate 10

PLANT OUTFALL

(Tide-gates on plant by-pass and secondary clarifier outfall lines)

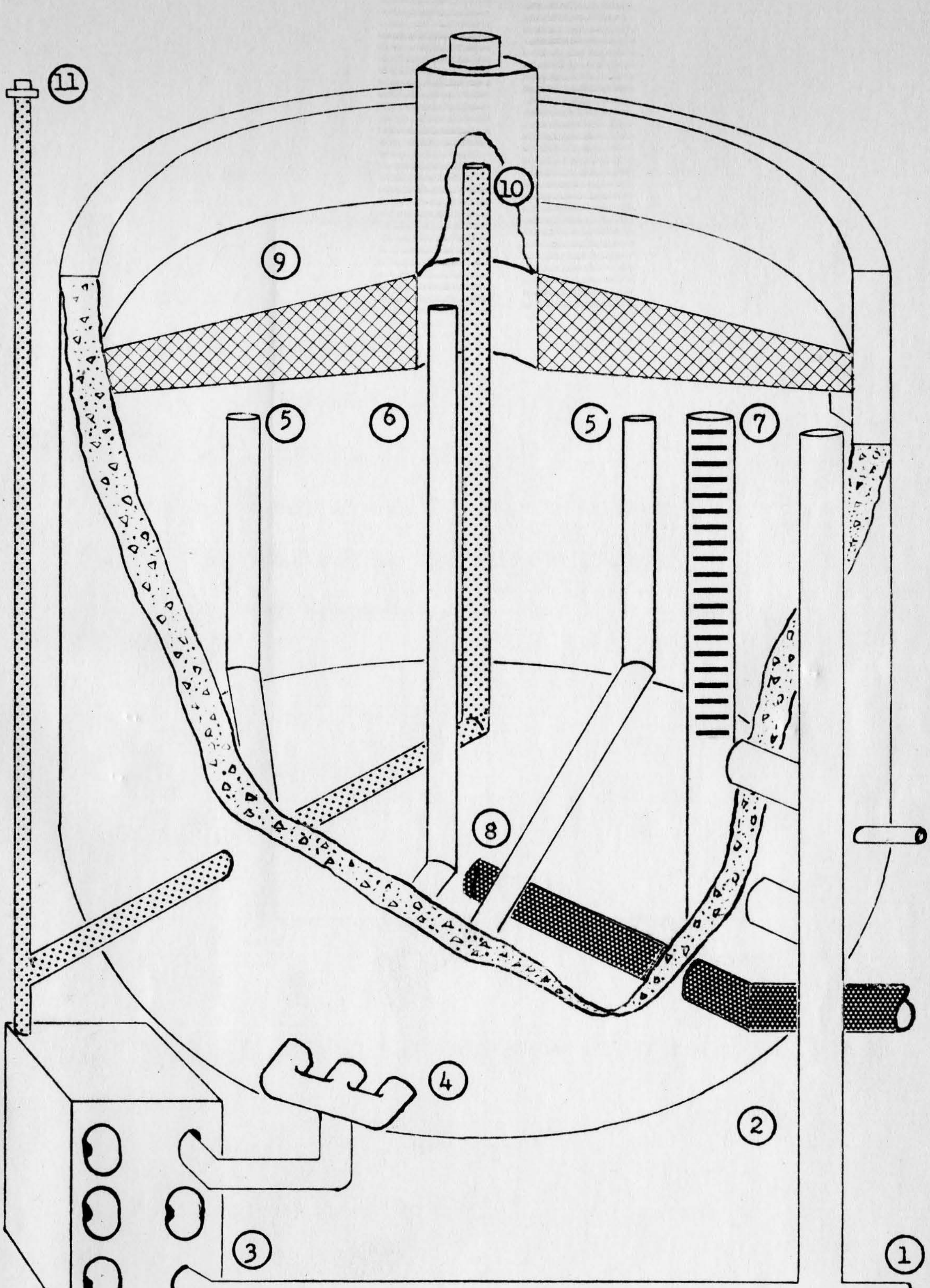

Plate 11

SLUDGE DIGESTION SYSTEM
(Key on following page)

KEY TO PLATE 11, PAGE 27

SLUDGE DIGESTION SYSTEM

1. Raw Sludge Line from Primary Clarifiers
2. Digester Recirculation Drawoff Line
3. Gas - Oil External Heat Exchanger
4. Sludge Recirculation Manifold
5. Sludge Recirculation Discharge - (Submerged)
6. Sludge Recirculation Discharge - (Free)
7. Supernatant Selector
8. Digested Sludge Drawoff Line
9. Floating Cover Assembly
10. Gas Collection Dome
11. Waste Gas Burner

Plate 12, also provides hot water for heating the control building. There is no provision for storage of excess sludge gas and the unused portion is burned in the waste gas burner.

As sludge solids are decomposed and consolidated toward the bottom of the digester, the upper levels of the contents tend to clarify. This portion, "supernatant liquor," is normally withdrawn continuously through the supernatant selector, Plate 13, and returned to the receiving manhole. Supernatant discharge provides "seeding" of the raw sewage and serves to stimulate anaerobic processes when settled in the primary clarifier sludge hoppers. Although this effect is desirable under normal flow conditions, supernatant discharge tends to accelerate septicity in the primary tanks causing production of gases during periods of low flows in hot weather. The release of gases in the clarifiers interferes with the settling of raw sewage in the sedimentation process.

Sludge Drying Beds. The site of the six sludge-drying beds, at an elevation above the digester is somewhat unique, and was selected for accessibility, gravity drainage, and to utilize the drying qualities of wind currents prevailing through the valley of the plant site. Consequently, in contrast to standard gravity withdrawal from the digester, sludge is pumped up to the drying beds. Drainage from the sludge drying beds is returned by gravity to the receiving manhole.

The three eastern beds are enclosed with a conventional "greenhouse" type structure which affords protection of the drying sludge during periods of inclement weather, Plate 14.

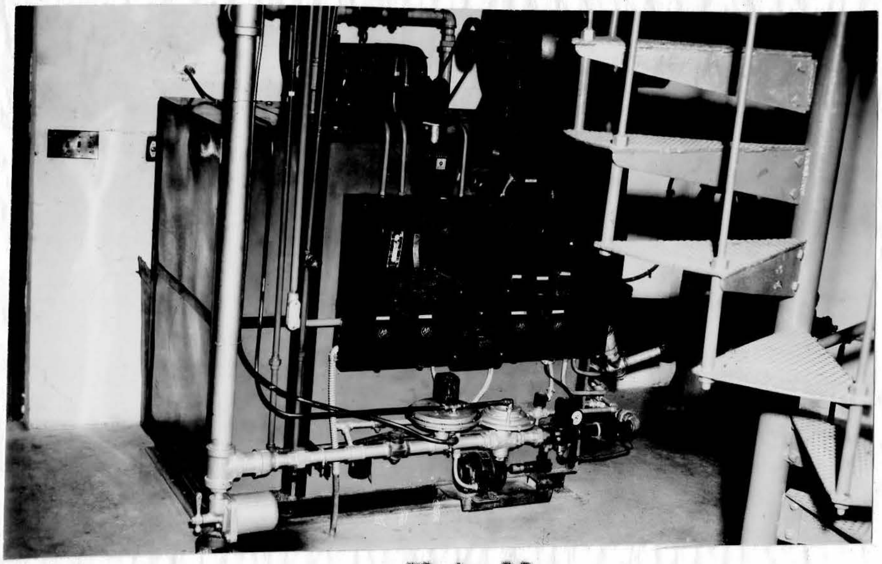

Plate 12

DIGESTER HEAT EXCHANGER

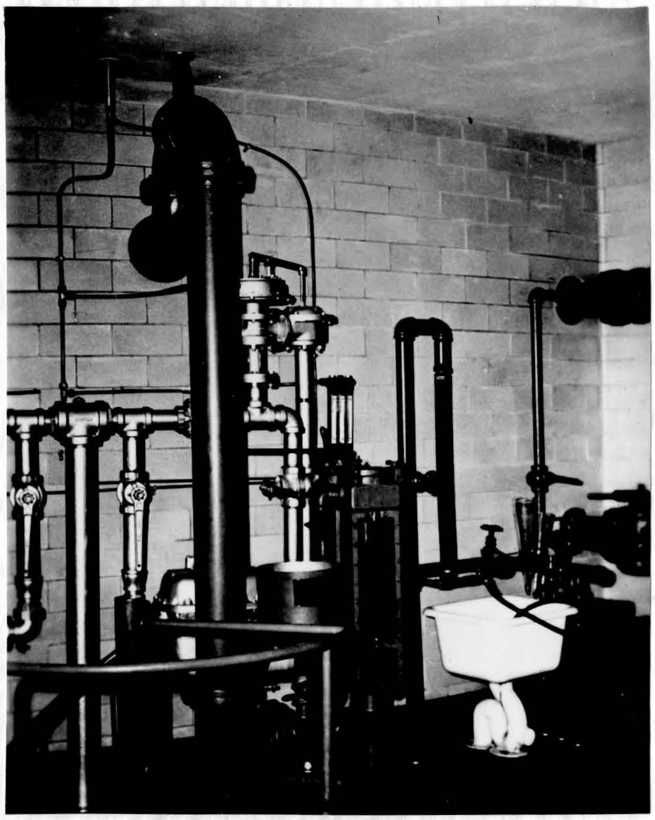

Plate 13

SUPERNATANT DISCHARGE SELECTOR

Plate 14

SLUDGE DRYING BEDS

B. - Procedures

Hydrologic Studies

Greatly increased sewage flow during periods of precipitation suggested that storm water was being diverted into the sewerage system. To verify the presence of storm water in the V.P.I. - Blacksburg sanitary sewerage system, simultaneous observations of rainfall, surface runoff, and sewage flow were made as a means of distinguishing between diversion and residual groundwater infiltration.

Total daily precipitation as observed and recorded at the rainfall gage of the Agricultural Experiment Station on the main campus is included in Table A. Storm-intensity (time-rainfall) was measured by a clock-actuated rain gage (Stephens) mounted on the roof of the Mineral Industries Building, Plate 15. Mechanical difficulties with this gage prevented continuous records of these observations.

Surface run-off from the Blacksburg drainage area was estimated by gaging the height of flood crest on the V.P.I. pond dam spillway. This crest was measured by a clock-actuated water level recorder (Friez) mounted in an "Armco" stilling well, Plate 16, approximately 50 feet west of the V.P.I. pond dam. The water level recorder was located 100 yards from the Kennison sewage flow nozzle at the pump house. These gages measured flow from the same portions of the Blacksburg drainage area — 2.8 square miles — as shown in Figure 3.

Atmospheric Temperature. Atmospheric temperatures observed at the plant site were found to be substantially the same as those from

Plate 15

<u>AUTOMATIC RAINFALL GAGE</u>
(Stephens, Type L)

Plate 16

<u>WATER LEVEL RECORDER</u>
(Friez)

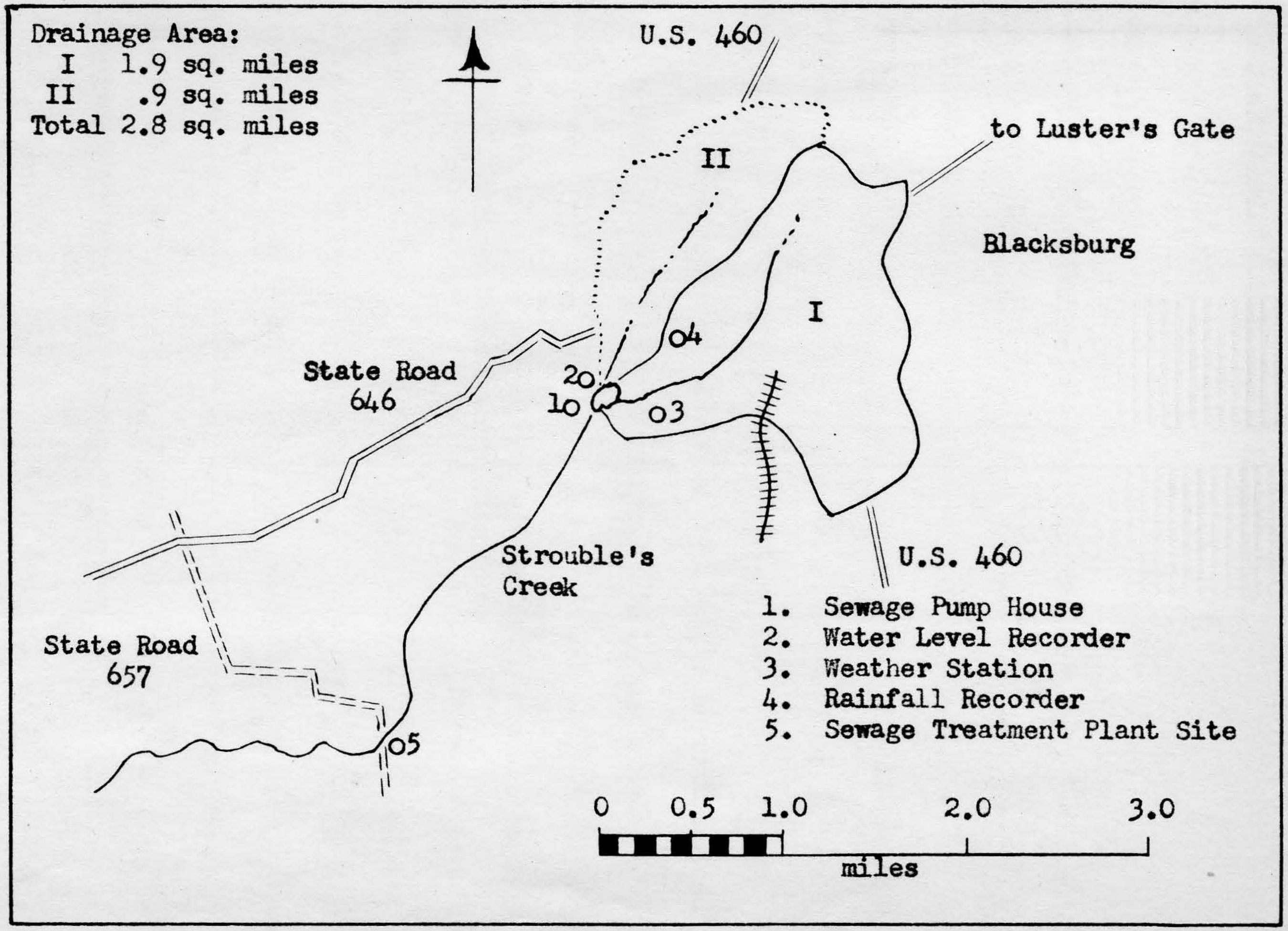

FIGURE 3. BLACKSBURG - V.P.I. DRAINAGE AREA

corresponding observations at the Agricultural Experiment Station on the V.P.I. campus. The latter data are available in U. S. Weather Bureau Meteorological Summaries for Virginia[9,10] and have been used directly from this source.

Collection of Samples

Efficiencies of sewage treatment processes are generally determined by comparisons of sewage characteristics at the influent and effluent of each unit and similarly for the entire plant. Certain analytical tests are particularly appropriate in measuring performance of a sewage treatment unit. Analyses performed in the course of this study are summarized on page 37 for each sampling point.

Sampling points were established at the receiving manhole, primary clarifier influent channel, primary clarifier effluent launder, filter dosing tank, filter effluent channel, and secondary clarifier effluent launder. However, under normal flow and operating conditions, i.e., low recirculation rates and low supernatant liquor or sludge bed drainage return, samples of the primary influent were representative of the sewage entering the plant at the receiving manhole. Similarly, the primary effluent was the same as the sewage in the filter dosing tank. Therefore, except as noted, analyses are reported for samples of the primary clarifier influent, primary clarifier effluent, filter effluent, and secondary effluent.

Although some samples were collected and composited in proportion to estimated flows the majority of analyses were performed on "grab" samples collected in accordance with recommended practice.

Analytical Determinations

Analyses of water, liquid sewage, and sludge samples were performed in accordance with procedures set forth in the 9th Edition of Standard Methods for the Examination of Water and Sewage [47]. Modifications of some analyses were required to compensate for factors such as sewage strength and unavailability of special reagents or apparatus. Laboratory techniques and schedules were developed for performing standard tests routinely in the continued operational control of the plant.

The majority of analyses reported in this study were performed by the writer. The three plant operators assisted in performing supplementary tests.

Apparatus and supplies at the plant laboratory included: standard glassware, controlled temperature incubator, accessory equipment and fundamental reagents and indicators required for most of the analyses. Reagents and other supplies required for special tests were obtained from the Sanitary Engineering Division of the Civil Engineering Department.

Certain tests, particularly solids/moisture content determinations, were performed in the V.P.I. Sanitary Engineering Laboratories using additional or more sensitive apparatus than was available in the plant laboratory. In these instances, samples were appropriately protected or preserved during transportation to the main campus.

Routine sampling points and analytical determinations are summarized as follows:

Analysis	Sampling Points*				
	Primary Influent (1)	Primary Effluent (2)	Filter Effluent (3)	Secondary Effluent (4)	Digester
Temperature	x	x	x	x	x
Settleable Solids	x	x	x	x	
Suspended Solids	x	x	x	x	
Dissolved Solids	x	x	x	x	x
pH	x	x	x	x	x
Relative Stability	x	x	x	x	
Dissolved Oxygen			x	x	
B.O.D.	x	x	x	x	
Chlorine Demand			x	x	
Chlorine Residual		x		x	
Chlorides	x	x	x	x	
Alkalinity	x	x	x	x	
O-R Potential	x	x			

* Sampling points - shown on Flow Diagram, Figure 1.

C. - Results and Discussion

Tributary Population

Estimates of the population contributing flow to a sewage treatment plant are fundamental to the computation of sewage characteristics and unit loadings — expressed as "units per capita" — and for comparative purposes.

Estimates of the population tributary to the V.P.I. sewage treatment plant have been derived from college enrollment and Blacksburg records. Component populations for college terms during the study period shown in Table A are summarized as follows:

September 1948 - May 1949 7,800
June 1949 - August 1949 4,800
September 1949 - November 1949. . . 7,900

Sharp population fluctuations which occur between school terms, during summer short courses, or at times of holidays and special events, although reflected in sewage flow, are not included in these estimates.

Measurement of Sewage Flow.

As in many continuous flow processes, measurement of rates and total volumes of sewage flow are fundamental to determining the range of extreme and normal variations through which operational adjustments must be made to assure effective treatment.

In this study, continuous sewage flow measurements were made at the campus pump-house gage approximately 2 miles upstream from the new plant. Without telemetering facilities, the remoteness of this gage from the present plant is an extremely undesirable feature which precludes opportunity for anticipatory operational adjustments until specific flows have arrived at the receiving manhole.

Representative flow charts illustrating daily and hourly variations in flow rates during periods of normal and abnormal flows are shown in Figure 4 and Figure 5. Average total daily volume and extreme flow rates are reported to the nearest 0.01 MGD and summarized in Table 1. Daily values for the study period are tabulated in Tables C and E. The magnitude and time of peak flows are included in these tables. In general, minimum daily flow rates are reported for the 3:00 - 6:00 A.M. period.

Hourly. For comparative purposes, hourly variations in sewage flow, expressed as percentages of average daily flow for an average dry weather week day, were computed from the flow chart of the week January 12 - 19, 1949. These data are summarized in Table 2 and shown in Figure 6. The regimen of the institutional population, class schedules, mass feeding, curfews, etc., is reflected in the sharp fluctuations in these flows.

TABLE 1

SUMMARY OF PRECIPITATION, TEMPERATURE, AND SEWAGE FLOW

July 1948 - November 1949

Month	Atmospheric* Temperature °F. Max.	Min.	Precipitation* (in.-Rainfall) Total	From Normal	(+.01 in.) Days	Sewage Flow (M.G.D.) Total Volume (MG)	Average Daily Volume	Average Maximum Rate	Average Minimum Rate
1948									
July	92	47	3.68	-1.52	10	**8,342	.463	.84	.26
August	94	48	5.99	1.89	10	21,363	.689	1.02	.47
September	85	45	2.43	- .78	9	13,549	.452	.79	.23
October	76	24	2.17	-1.03	4	17,831	.575	.97	.23
November	69	28	5.01	2.70	15	18,416	.614	.94	.27
December	65	27	5.88	2.44	11	28,189	.909	1.23	.61
1949									
January	69	16	4.50	1.21	12	28,472	.918	1.22	.60
February	69	13	2.95	- .13	11	25,563	.913	1.22	.57
March	76	10	2.65	-1.03	6	22,618	.720	1.03	.42
April	80	26	5.72	2.53	11	27,892	.930	1.24	.55
May	87	36	4.12	.44	12	26,700	.861	1.31	.54
June	88	42	5.03	.45	7	16,072	.536	.91	.27
July	92	62	6.57	1.37	15	21,926	.707	1.05	.50
August	89	52	5.47	1.37	16	18,922	.610	.97	.37
September	85	33	2.51	- .70	9	14,471	.482	.80	.27
October	81	31	3.53	.33	15	18,473	.596	.99	.27
November	73	21	2.53	.22	7	19,214	.640	.96	.31
							Avg. .648	Avg. 1.03	Avg. .40

* U. S. Weather Bureau Summaries(9)

** 18 days

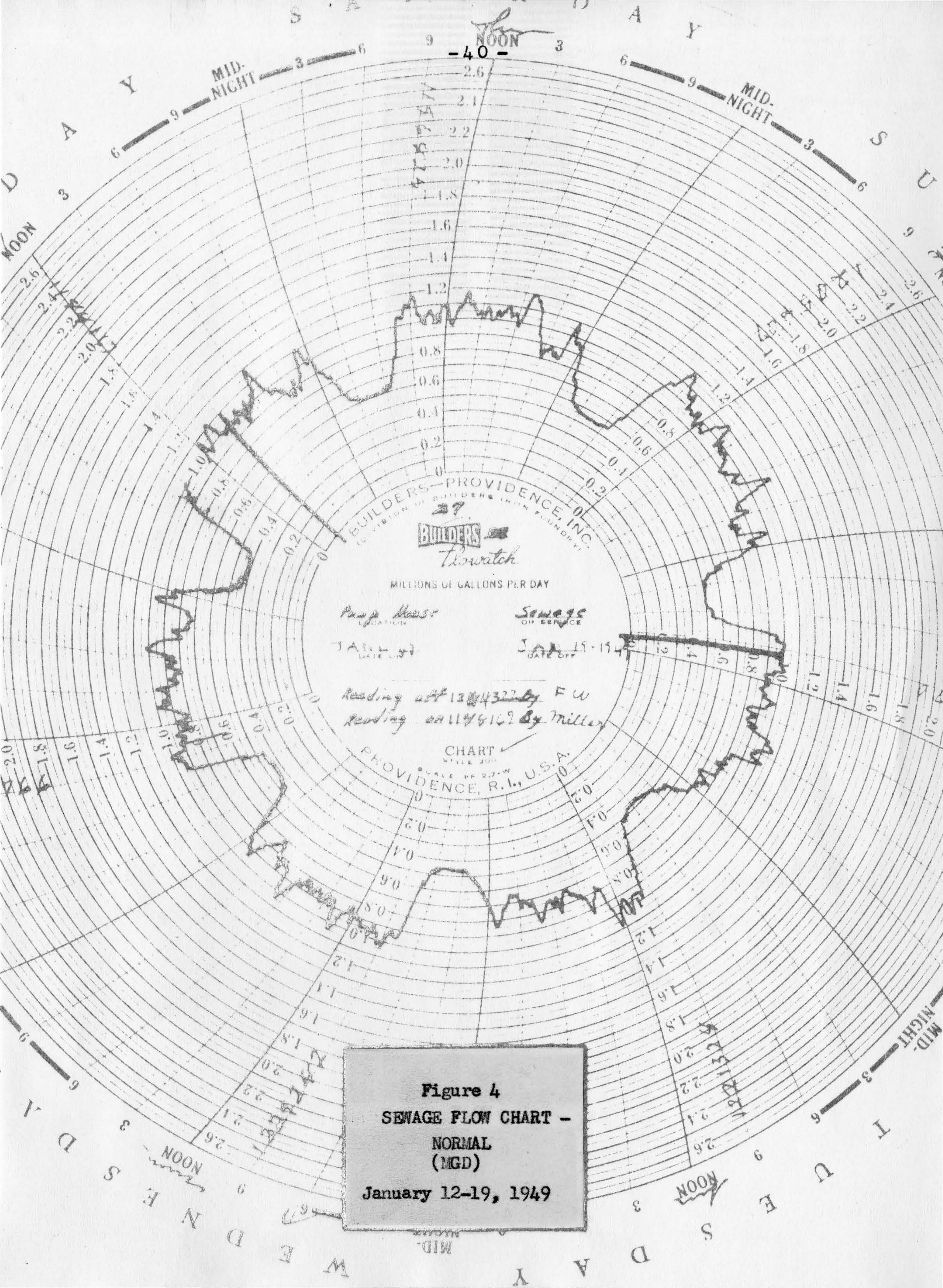

Figure 4
SEWAGE FLOW CHART -
NORMAL
(MGD)
January 12-19, 1949

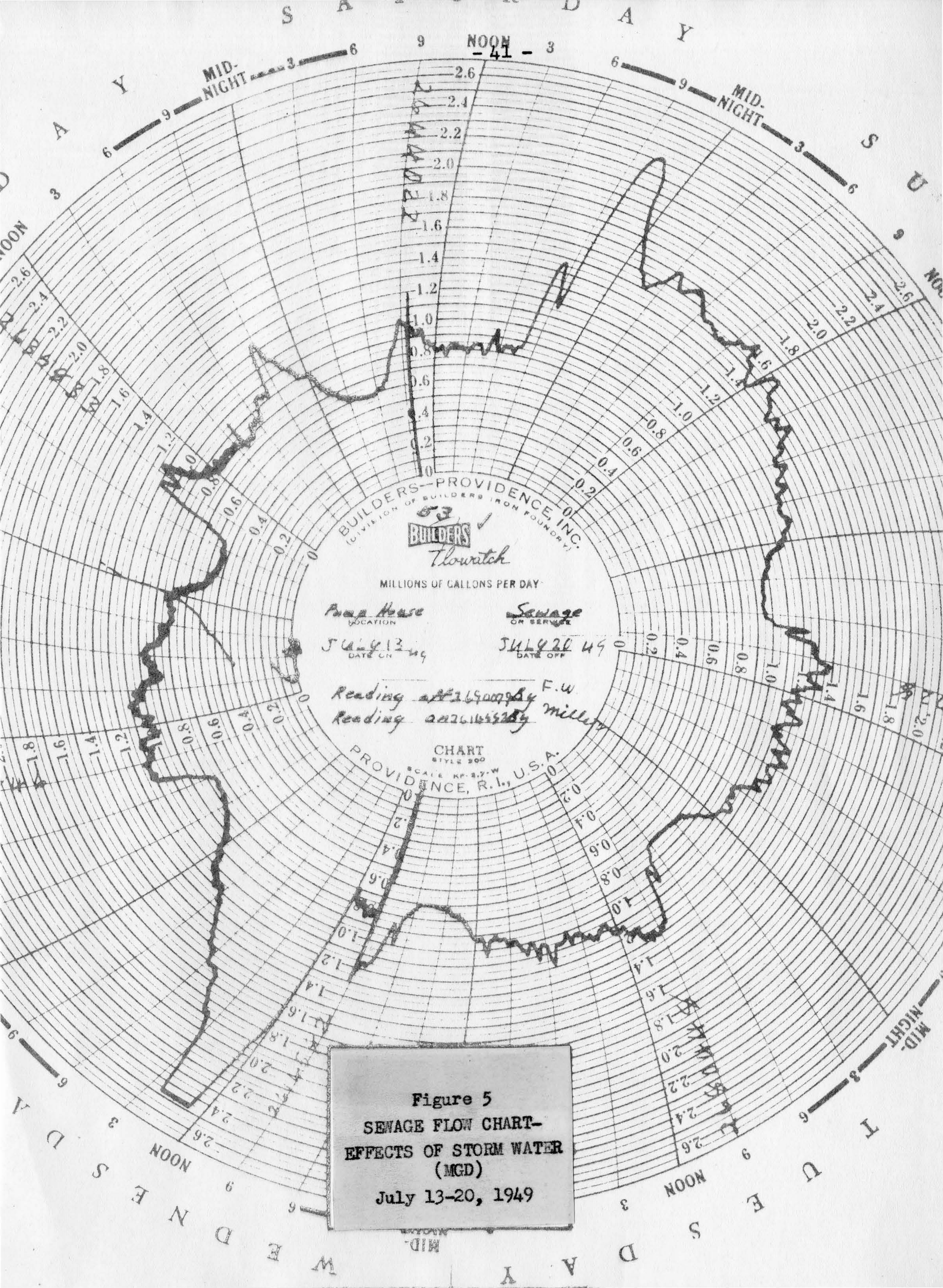

Figure 5
SEWAGE FLOW CHART-
EFFECTS OF STORM WATER
(MGD)
July 13-20, 1949

Daily. Day-to-day variations for a normal "dry-weather" week expressed as percentages of average weekly flow rates have been computed similarly for the period January - March 1949. These data are also given in Table 2.

Monthly. The monthly distribution of total sewage flow observed in this study is contrasted with general values commonly used in American design practice for temperate climates[30]. These data are also summarized in Table 2 and shown in Figure 7. Blacksburg - V.P.I. values are "out of phase" with the general distribution and reflect, to some degree, the seasonal character of the tributary population.

Hydrologic Studies

Addition of storm water via infiltration or illegal diversion of storm drains to normal sewage flows imposes unusual burdens on plants designed for treatment of domestic sewage. Deleterious effects include: (1) potential mechanical damage and excessive wear to hydraulic equipment caused by grit, gravel, sticks, and street washings; (2) decreased sedimentation period for organic constituents of the combined flow; (3) increased addition of inorganic solids to biological digestion processes; and (4) sluicing action on trickling filter media. Similarly, portions of the inorganic load may settle in pipes or channels decreasing hydraulic efficiencies in periods of normal flow. Detrimental effects of storm water may be offset to some extent by increased dilution factors and higher dissolved oxygen values generally afforded in the receiving stream during periods of intense or prolonged rainfall.

Comparisons of rainfall-runoff relationships for the drainage area provide a measure of the severity of this problem.

TABLE 2

DISTRIBUTION OF SEWAGE FLOW
(Ratio to Average)

Hourly
7-Day Average
Dry Weather Flow*
January 12 - 19, 1949

Time	Ratio to Daily Average
1:00 a.m.	.85
2:00	.68
3:00	.62
4:00	.61
5:00	.59
6:00	.61
7:00	.75
8:00	1.11
9:00	1.23
10:00	1.18
11:00	1.19
NOON	1.20
1:00 p.m.	1.18
2:00	1.23
3:00	1.12
4:00	1.09
5:00	1.14
6:00	1.12
7:00	1.29
8:00	1.06
9:00	1.00
10:00	.96
11:00	1.16
MIDNIGHT	1.02

Daily
7-Day Average
Dry Weather Flow*
January - March 1949

Day	Ratio to Daily Average
Sunday	1.08
Monday	1.04
Tuesday	1.02
Wednesday	.97
Thursday	1.00
Friday	.98
Saturday	.91

Monthly

Month	Empirical** U.S.	V.P.I.*** Blacksburg
January	.90	1.25
February	.92	1.24
March	.89	.99
April	.87	1.26
May	1.00	1.17
June	1.13	.73
July	1.24	.96
August	1.18	.83
September	1.08	.65
October	.96	.81
November	.90	.87
December	.92	1.24

* Dry weather flow - days of rainfall less than .10 inch.
** Metcalf and Eddy[30].
*** December 1948 - November 1949

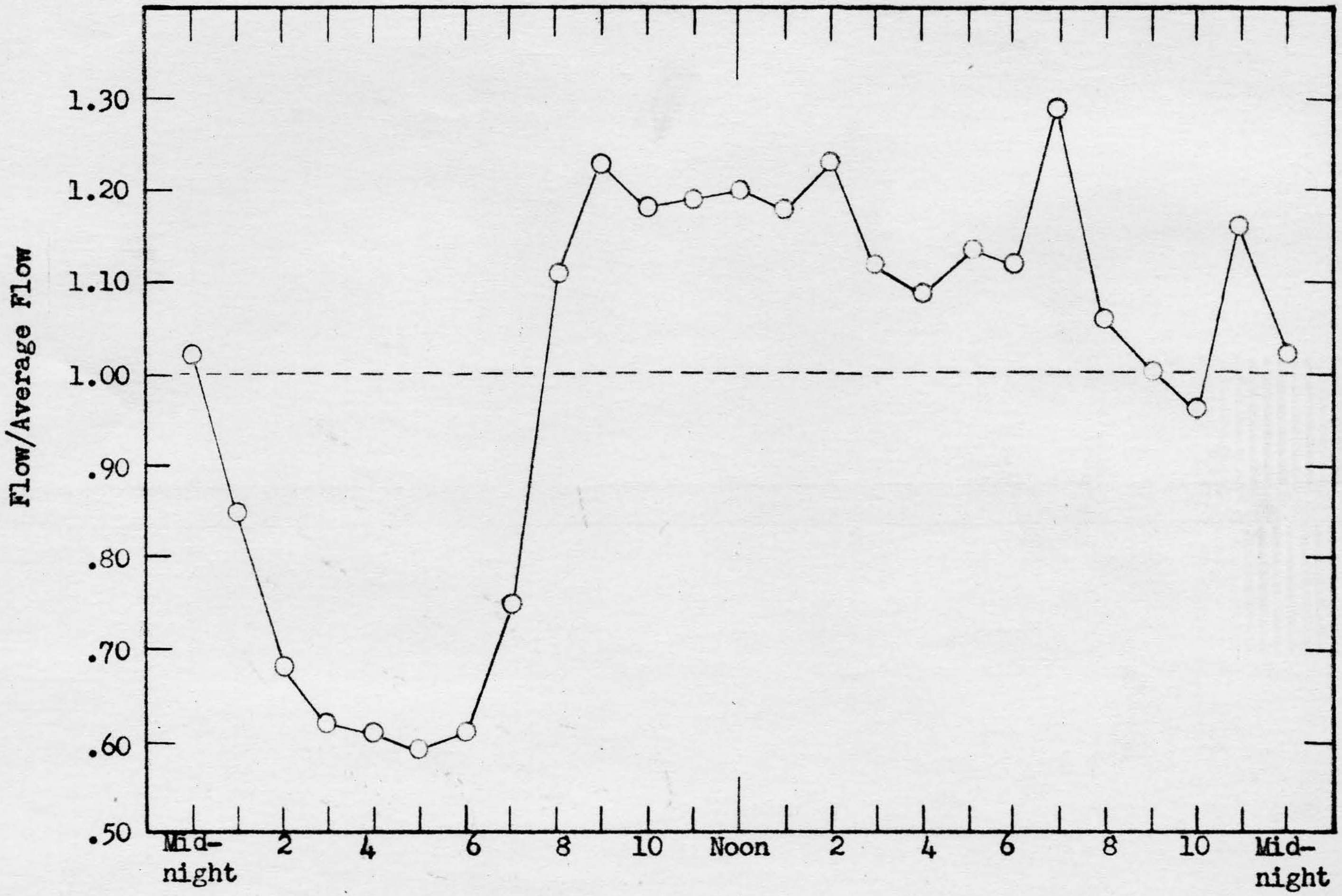

FIGURE 6. HOURLY VARIATION OF SEWAGE FLOW

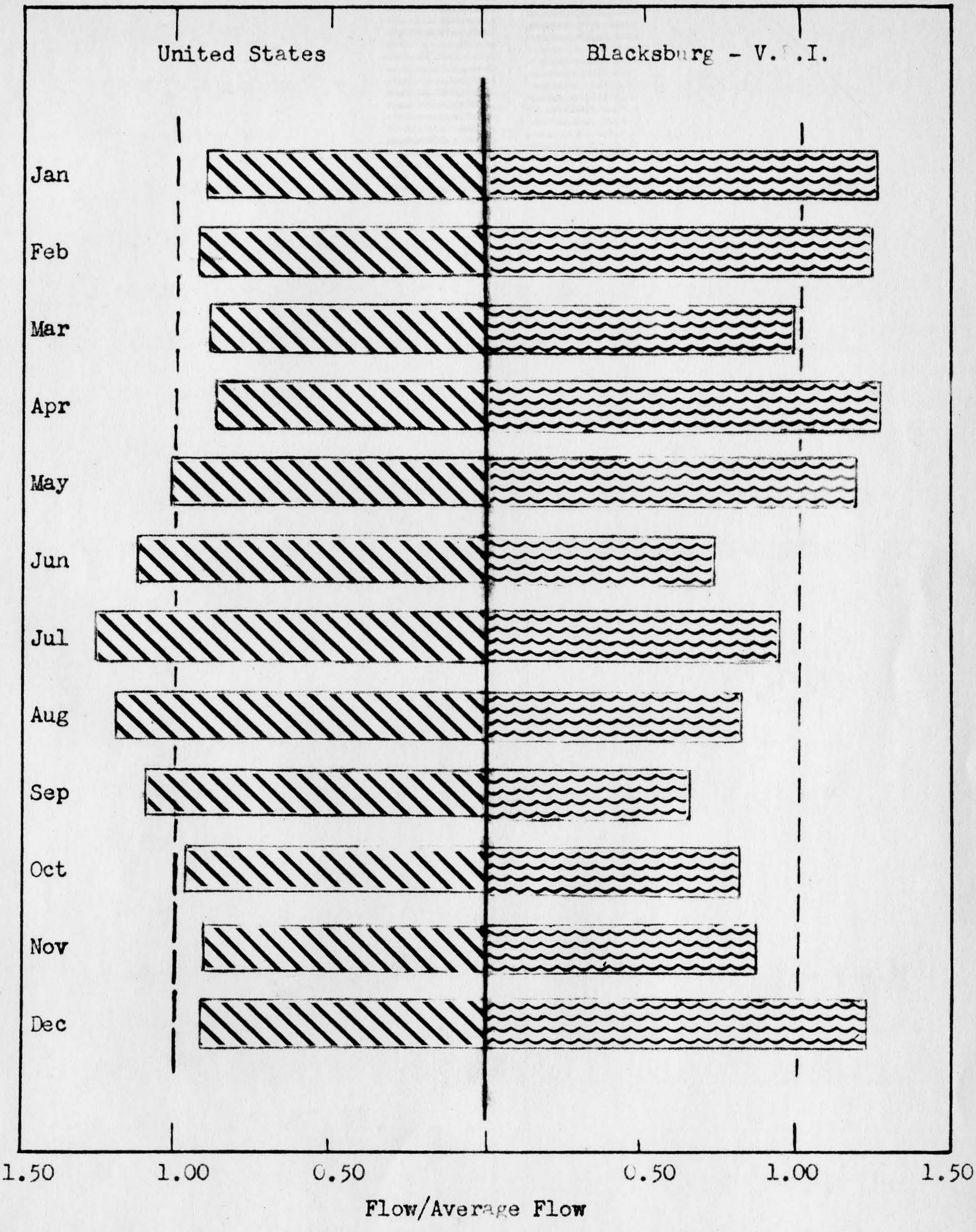

FIGURE 7. MONTHLY VARIATION OF SEWAGE FLOW

<u>Storm Intensity</u>. Although storm intensity observations over a period of years are desirable for a complete hydrologic analysis, i.e., expected frequencies (return periods) for storms of various magnitudes, these measurements are not made routinely in Blacksburg.

Data observed during the moderately severe summer storm which occurred on Wednesday, July 13, 1949, Table D are shown in Figure 8. This storm produced a total of 1.43 inches of rainfall in two hours with an average intensity of approximately .72 inches per hour. Maximum intensity was observed slightly more than one hour after the storm began.

In this study, empirical formulae for 10 and 15 year return periods developed by Kuichling[30] for the Eastern United States have been adapted as follows:

10 years $R = \frac{105}{t + 20}$ 15 years $R = \frac{120}{t + 20}$

in which: R = rainfall in inches, and t = time in minutes.

These formulae have been extrapolated for a 9-year return period as:

$$R = \frac{102}{t + 20}$$

which approximates the storm intensity of 0.72 inches per hour and 2-hour duration of rainfall observed in Blacksburg on July 13, 1949. Thus, the theoretical interval between storms of this magnitude is approximately 9 years.

<u>Storm Water</u>. For comparative purposes, sewage flow rates for July 13, 1949 (Figure 5) have been superimposed on Figure 8.

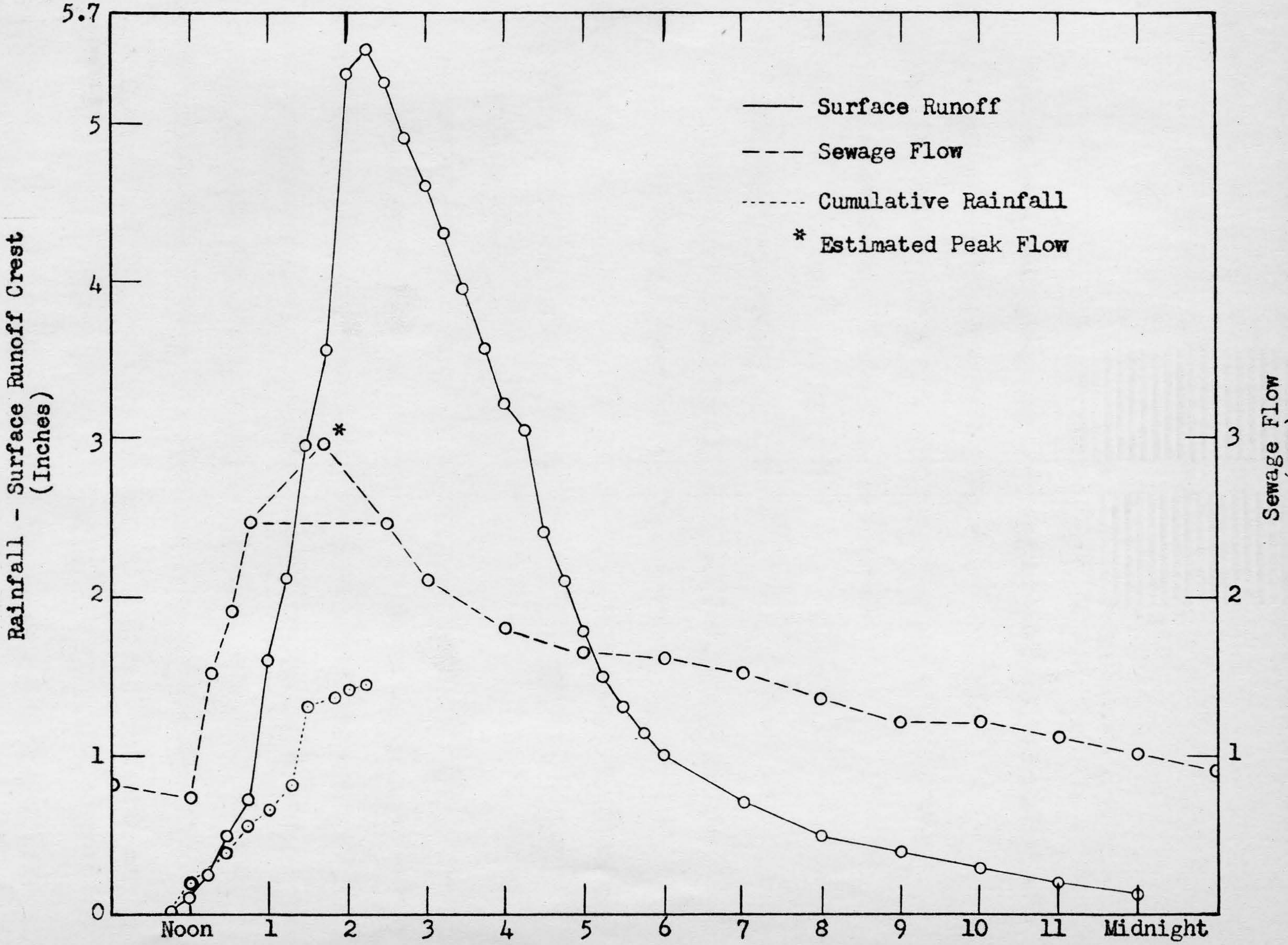

FIGURE 8. RAINFALL - RUNOFF - SEWAGE FLOW
July 13, 1949

The maximum sewage flow crest was estimated by the rational run-off formula $Q = CAIR$[30], in which

$Q =$ runoff discharge, cfs
$C =$ unit conversion factor
$A =$ drainage area, acres
$I =$ coefficient of imperviousness (or run-off)
$R =$ rainfall, inches per hour

The value C, when using the above units, generally approximates 1.0, allowing the formula to be expressed as: $Q = AIR$.
Although the coefficient of imperviousness (or run-off) logically changes as a function of time, (t), in minutes,

$$I \ (C) = 0.175t^{.33}$$

this refinement is generally not made[30].

The coefficient of run-off, "I" = 0.0033, was computed from observed values for the first hour of the storm of July 13, 1949. This factor, 0.0033, was applied to determine the approximate maximum discharge, 2.98 MGD, above the upper measurable limit of 2.46 MGD, shown in Figure 8.

As may be noted in Figure 8, the very rapid increase in the rate of sewage flow (within recordable limits) is almost directly proportional to observed rainfall, and occurred considerably (more than one hour) before surface runoff crested at the dam. This relationship very strongly suggests the existence of considerable storm water diversion through improper or illegal connections to the sewage system and through manhole covers and catch basins. If this flow were due to ground water infiltration alone, the sewage flow inlet time would approximate, if not, and more probably, lag the surface runoff inlet time by a considerable margin. Recognizing that surface discharge may be delayed somewhat by flowing through the V.P.I. ponds, this effect is negligible as shown by the sensitive and immediate initial rise of the pond level from rainfall directly on the water surface.

Infiltration. Quantities of continuous or residual groundwater infiltration may be estimated from comparison of average water consumption rates with average, "dry-weather" sewage flows.

Although V.P.I. water consumption was not metered during the study period, average daily consumption for the preceding school year (September 1947 - June 1948) was estimated as 493,000 gallons per day. Accordingly, average water consumption for the school year 1948 - 1949 has been assumed as approximately 500,000, although precise pumping rates are not available for confirmation.

Total Blacksburg water consumption during the same school year averaged 253,700 gallons per day as computed from available pumping data. From records during other years, it is likely that some of the higher rates of Blacksburg water consumption may be attributed in part to supplementary pumpage supplied to V.P.I.

Average daily "dry-weather" sewage flow was computed during the 1948-1949 school year as 700,000 gallons per day as compared to combined average daily water consumption of 753,700 gallons per day. The overall water loss was approximately six gallons per capita per day. Following periods of excessive rainfall — and low evaporation rates — in winter months, sewage flow exceeded water consumption in January and February 1949. Residual groundwater infiltration was estimated at 130,000 - 110,000 gallons per day respectively during these months. For comparative purposes, infiltration into the estimated 12 miles of collection and trunk sewers is expressed as approximately 10,000 gallons per mile of pipe per day, Table 3.

This relatively low infiltration indicates that the sewerage system is in relatively good repair and tight joints. This infiltration is further confirmation of direct diversion of storm water into the sanitary sewerage system.

Sewage Velocity Determination

In the absence of accurate flow measuring devices at the sewage plant or telemetering from the pump house gage, there was no precise method for estimating the rate of sewage flow arriving at the plant. Variations in flow rates are significantly important in making required operational adjustments for more effective process control and in estimating of plant and unit loadings.

A series of "elapsed time" tests of sewage velocity in the pipeline were performed using a coal tar dye indicator (Ameranth)[55]. Data from these tests are summarized in Table 4 and shown in Figure 9.

Mean pipeline velocities observed in each test were applied in computing the average cross-sectional area of flow by the standard formula $Q = AV$. The mean depth computed for each test was applied in computing the mean slope of the pipeline using Manning's formula for open channel flow[5] :

$$Q = A \frac{1.486}{n} R^{.67} S^{.5}$$

in which:

Q = discharge. . . . . cfs
A = flow cross section . . . . sq. ft.
R = hydraulic radius . . . . . feet
n = roughness coefficient. . . 0.012
S = slope

TABLE 3

<u>WATER CONSUMPTION - SEWAGE FLOW</u>

<u>AND INFILTRATION</u>

(School Year 1948 - 1949)

Month 1948 - 1949	Water Consumption Average Daily (MGD) Blacksburg	V.P.I.*	Combined	Sewage* Average Daily MGD	Infiltration Average Daily MGD
September	.219	.432	.65	.44	-
October	.232	.457	.69	.57	-
November	.259	.510	.77	.53	-
December	.261	.514	.78	.78	-
January	.248	.489	.74	.87	.13
February	.262	.516	.78	.89	.11
March	.290	.572	.86	.70	-
April	.249	.491	.74	.76	.02
May	.264	.520	.78	.80	.02

* Dry weather flow - days of rainfall less than .10 inch.

** Assumed monthly distribution of school year average directly as Blacksburg (metered) consumption.

The pipeline was not laid on a uniform slope for its entire length because of practical and economic considerations. As was anticipated[31], computed slope values varied considerably. The computed slopes ranged from 0.00078 to 0.00136, with a mean value from six observations of 0.00093. This value, 0.00093, was used in the nomographic solution of Manning's formula for "Circular Sections Flowing Full," i.e., not surcharged[4].

Full-section values were applied to a standard chart of hydraulic elements for circular sections at various depths of flow[4]. Velocity and discharge ratios computed in increments of 2-inch depth are summarized in Table F. These values were used to compute flow-time relationships for the pipeline, Figure 9.

The value of "n", 0.012, used in these computations was selected as the most appropriate coefficient of roughness for relatively new cast iron pipe in good condition. A slightly higher value of "n", 0.015 for example, would result in full section values of Q = 1.35 MGD and V = 1.40 fps. Such variations in flow characteristics are inherent and, to some degree, anticipated in applications of the Manning formula — originally developed for open channel flow[31] — to circular conduits flowing full.

Effects of turbulence caused by pipeline bends and the slope of the outfall draw-down curve were assumed to be negligible and have not been included in these computations.

The discharge-depth-flow rate relationships, although lacking in the precision of a flow-gage, provide useful approximations of influent sewage flow rates.

TABLE 4

PIPELINE FLOW VELOCITY DETERMINATIONS

Test No.	Date 1949	Flow Rate (MGD)	Time Elapsed (min)	Velocity Mean (fps)	Area* (sq.ft.)	Depth		Slope**
						Computed (inches)	Observed (inches)	
I	7-18	1.24	——— dye not visible - insufficient dosage ———					
II	7-19	1.10	107	1.80	0.944	10.27	9.0	.00078
III	9-13	0.61	110	1.75	0.537	6.56	-	.00030
IV	10-11	0.68	107	1.80	0.538	7.14	10.0	.00100
V	10-11	0.75	102	1.88	0.617	7.30	9.5	.00109
VI	10-18	0.275	123	1.56	0.276	4.05	8.75	.00136
VII	11-29	0.80	101	1.90	0.653	7.62	-	.00106
								Avg. .00093

* Q = AV Q (Discharge) in cubic feet/second
A (Cross-sectional area) in square feet
V (Velocity) in feet/second

** Roughness coefficient, n = 0.012, Cast Iron Pipe, good condition

Pipeline length - 11,515 feet

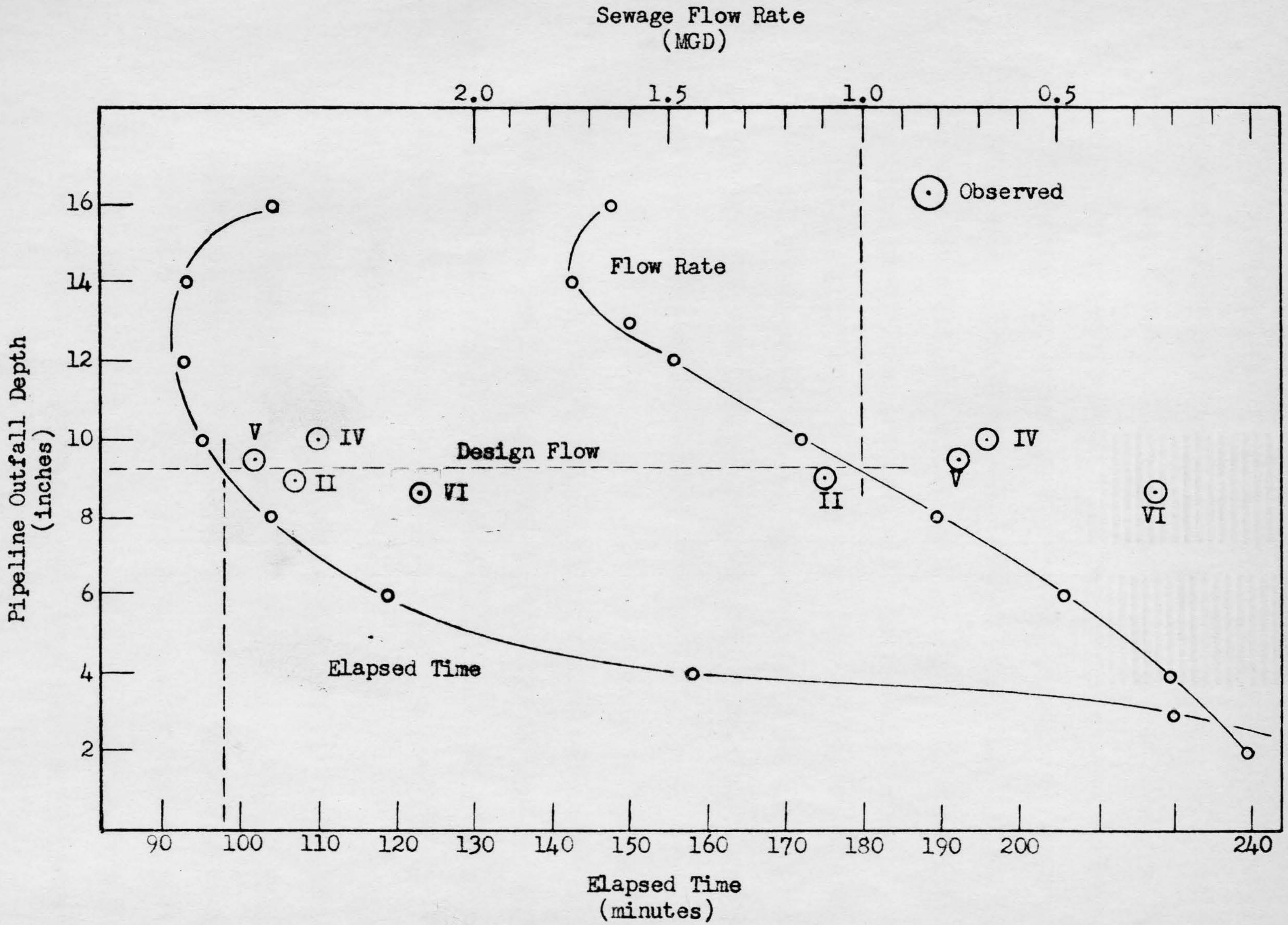

FIGURE 9. PIPELINE FLOW VELOCITY

<u>Sewage Characteristics and Treatment</u>

The effectiveness of sewage treatment processes is generally determined by studying the efficiencies of component units and of the entire plant. Tests used as indices of proper functioning of the plant reflect the type and degree of treatment afforded by each stage.

In this study, a variety of physical, chemical and biological analyses were performed on sewage samples throughout the process to determine the efficiency of each unit and the residual pollution discharged in the final effluent to the receiving stream.

<u>Settleable Solids</u>. Settleable solids were determined routinely on plant influent and effluent samples and are reported in Table G. As may be noted, the total plant efficiency of settleable solids removal was consistently above 90 per cent.

Removal of settleable solids from raw sewage was consistently above 90 per cent in the primary clarifiers when the measured settleable solids content was 1 ml/L or greater. When the influent contained less than 1 ml/L of settleable solids, removal efficiencies were not computed on a percentage basis because they were normally 0.2 ml/L or less.

Relatively high settleable solids were noted in the primary clarifier effluent during periods of low flow and correspondingly longer detention periods. These increased values were caused by decomposition gases evolved in the primary sludge hoppers which created turbulence and interfered with normal settling conditions. Settleable solids in the primary tanks were generally higher when digester supernatant liquor and secondary clarifier sludge returned to the receiving manhole had high solids content, Tables G and H.

Settleable solids values, greater than 0.2 ml/L, noted occasionally in the filter effluent — reflecting sporadic filter sloughing action — were generally removed satisfactorily in the secondary clarifiers.

Hourly variations in the settleable solids content of raw sewage at the receiving manhole shown in Figure 10 are summarized below:

Average Settleable Solids (ml/L) - Raw Sewage

Time	Settleable Solids	Time	Settleable Solids
7 A.M.	0.5	2 P.M.	4.8
8	3.7	3	8.2
9	5.2	4	4.8
10	10.0	5	6.6
11	10.4	6	4.7
Noon	7.8	7	6.7
1 P.M.	6.2	8	2.4

Suspended and Dissolved Solids. Determination of inert and organic components of suspended and dissolved solids in the various treatment stages were made by standard evaporation and ignition procedures.

Inherently, dissolved and suspended solids do not settle in clarifiers, although the settling action of larger particles and to some extent, natural flocculation phenomena, generally effect slight

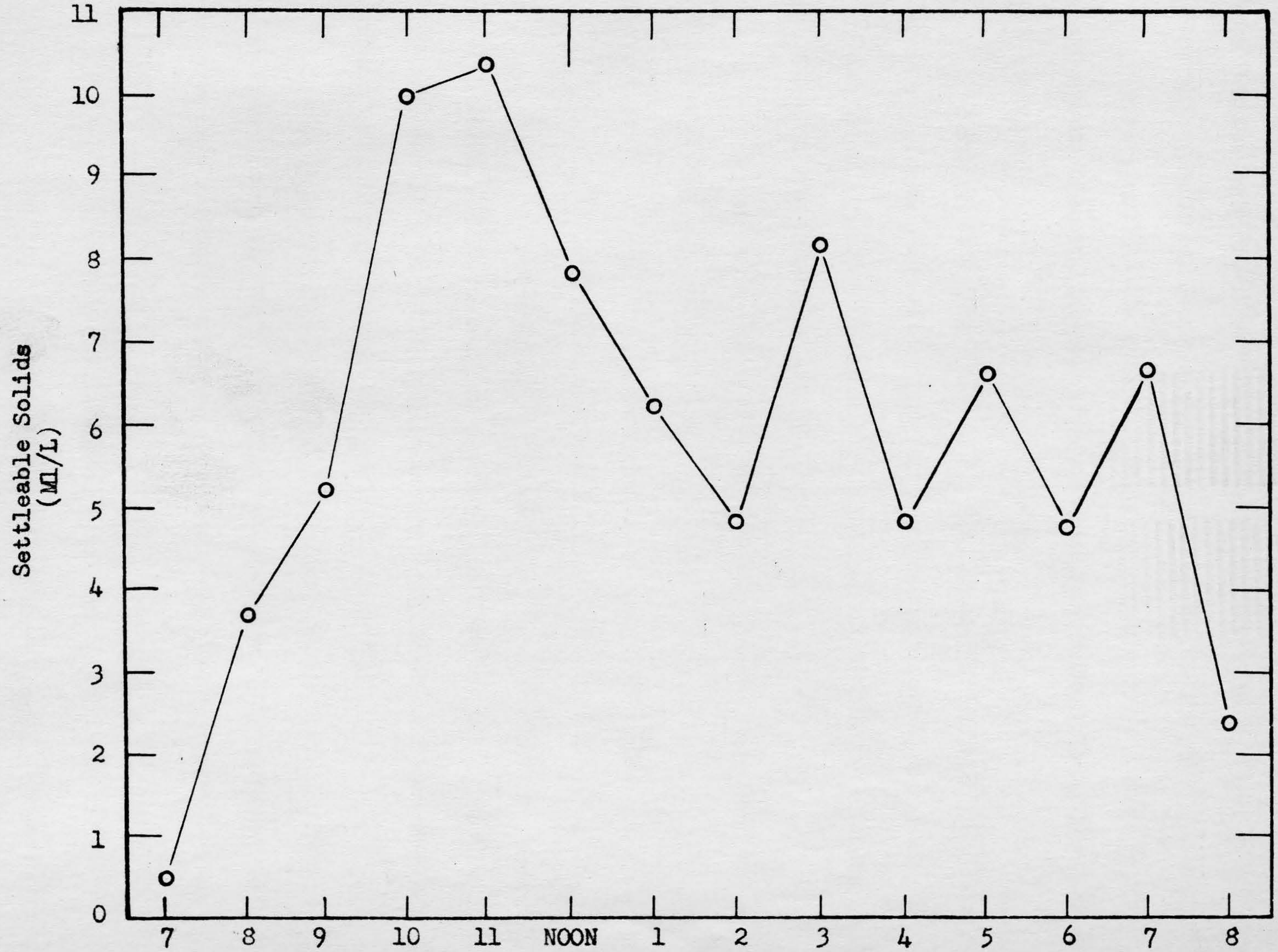

FIGURE 10. SETTLEABLE SOLIDS - HOURLY VARIATION (RAW SEWAGE)

reductions of these constituents. Solids in these forms are adsorbed by biological action of the zoogleal filter film although the net effect, as determined by influent and effluent analyses, may at times be negligible because of media dissolution or film sloughing. During the treatment process, the combined effects of physical, chemical, and biological actions generally lower the suspended and dissolved solids content.

As may be noted in Table J, the suspended and dissolved solids in the primary clarifier influent approximate the combined solids contents of raw influent sewage and secondary clarifier effluent recirculated to the receiving manhole.

The following unit reductions of suspended and dissolved solids were observed:

Primary clarifier	26 - 67 %
Trickling filter	14 %
Secondary clarifier	5 - 20 %

Overall plant removal of suspended and dissolved solids was approximately 70 per cent and the removal of volatile constituents ranged from 68 per cent to 84 per cent.

pH Values. The degree of acidity or alkalinity of sewage is somewhat indicative of its character and stage of treatment. Lower values in the liquid component generally reflect septicity, i.e., undergoing anaerobic reduction rather than aerobic oxidation.

As may be noted in tabulations of these values, Table G, samples of plant influent, primary clarifier influent, and less frequently, primary clarifier effluent were found to be slightly acid at times of low flow in hot weather — ranging from 6.7 to 6.9. There is a possibility that some low pH values were caused by commercial, industrial, or laboratory wastes.

Primary clarifier influent pH values of 7.0 and higher indicate to some extent the dilution and equalization afforded by the recirculation of secondary clarifier sludge to the receiving manhole.

The pH in the various treatment units on October 18, 1949, are as follows:

			pH of Sewage			
Time	Pump House	Receiving Manhole	Primary Clarifier Influent	Primary Clarifier Effluent	Trickling Filter Effluent	Secondary Clarifier Effluent
October 18, 1949						
6:45 A.M.	6.8	-	-	-	-	-
9:00	-	6.9	7.1	7.3	7.3	-
10:30	-	6.7	7.1	7.3	7.5	7.3
Noon	-	7.1	7.1	7.2	7.2	7.4
1:30 P.M.	-	7.1	7.1	7.1	7.3	7.4

Relative Stability. Although the relative stability test has been supplanted by the more precise B.O.D. analysis in many plants, it was used routinely at the Blacksburg - V.P.I. plant in 1948 but was discontinued as routine test late in 1949.

Relative stability values are not qualitative and serve primarily to reflect the degree of sewage stabilization at various stages in the treatment process. The high strength of sewage arriving at the plant in the late morning and afternoon — as measured by other tests — is reflected by lower relative stability values during these periods, Table K. The normally low pollutional load of night and early morning flows is evidenced by an average relative stability value of 63 per cent at these flows.

When the exact time of decoloration of the methylene-blue indicator — evidence of oxygen depletion — was not known (11 P.M. - 6 A.M.), the relative stability of these samples was extrapolated from standard time/percentage values[47] based on the known length of coloration and an estimate of the time of depletion.

The low relative stability of primary clarifier effluent during night and early morning flows reflects stagnation and septic conditions in this unit as a result of increased detention resulting from low flow rates.

Relative stability values of trickling filter and secondary clarifier effluents were uniformly high, showing consistently satisfactory operation. Although the majority of relative stability values of the final effluent during the daily cycle were in the range 96 - 99 per cent, occasional low values observed during summer months reduced the overall average to 89 per cent.

Average daily values of relative stability observations reported in Table K are summarized as follows:

	Average Relative Stability (%)			
Time Period	Receiving Manhole	Primary Clarifier Effluent	Trickling Filter Effluent	Secondary Clarifier Effluent
Midnight - 7:45 A.M.	63	11	80	90
7:45 A.M. - 1:45 P.M.	18	17	91	96
1:45 P.M. - Midnight	14	11	68	84

Dissolved Oxygen and Biochemical Oxygen Demand. The amount of oxygen required to oxidize organic sewage constituents biologically is one of the most important determinations in sewage treatment and stream pollution studies. Measurement of this oxygen requirement — the Biochemical Oxygen Demand test (B.O.D.) — is used as a basic index of sewage strength. B.O.D. values may be used as guides in the operational control of treatment processes; compared with corresponding data from other plants as a measure of relative performance; and evaluated in the designing new treatment facilities for sewages of similar characteristics.

Similarly, the dissolved oxygen content and B.O.D. of the receiving stream, above and below a point of pollution are important in determining the residual pollutional effects on the stream and the capabilities of the stream to complete the purification cycle.

Following considerable experimentation in the development of a satisfactory diluting water, the B.O.D. test was performed routinely on samples from the treatment units and occasionally on samples collected from the pump house, secondary sludge return line, and the receiving stream. Results of these tests are reported in Tables 5 and L.

Filter and secondary effluent samples were generally found to contain 3.0 to 9.0 p.p.m. (60 - 80 per cent of saturation) dissolved oxygen.

As an illustration of B.O.D. reduction afforded by units in the treatment process, the results of a special series of tests performed on October 18, 1949, shown in Figure 11, are summarized as follows:

Time	p.p.m. B.O.D. (5-day, 20 °C.) Receiving Manhole	Primary Influent	Primary Effluent	Filter Effluent	Secondary Effluent
9:00 A.M.	256**	120	24	26	5.4
10:30	270	200	193	49	3.5
Noon	250	150	160	48	14.0**
1:30 P.M.	140	160	80	37	11.3**
3:00	60	30	50	33	9.5**

** Greater than value shown.

The effects of operational practices and the net changes in B.O.D. in each unit may be noted from this series and other B.O.D. observations, Table L. Recirculation of secondary clarifier sludge appears to produce a B.O.D. reduction at the primary clarifier influent whereas a high rate of supernatant liquor discharge tends to increase the total B.O.D. at this point. Under some conditions, B.O.D. values in the primary tanks increased approximately 10 per cent. The average reduction of B.O.D. in the primary process generally ranged from 20 - 40 per cent.

B.O.D. reduction by the trickling filter was consistently high, affording removals from 30 - 80 per cent of the B.O.D. applied with an average reduction of approximately 65 per cent.

The secondary tanks afforded further B.O.D. reductions of 30 - 80 per cent.

Overall B.O.D. reduction through the plant averaged 90 - 95 per cent — with some fluctuation due to operating and flow conditions.

The plant effluent generally — with rare exception — contained less than 15 p.p.m. B.O.D., as determined on samples of secondary clarifier effluent.

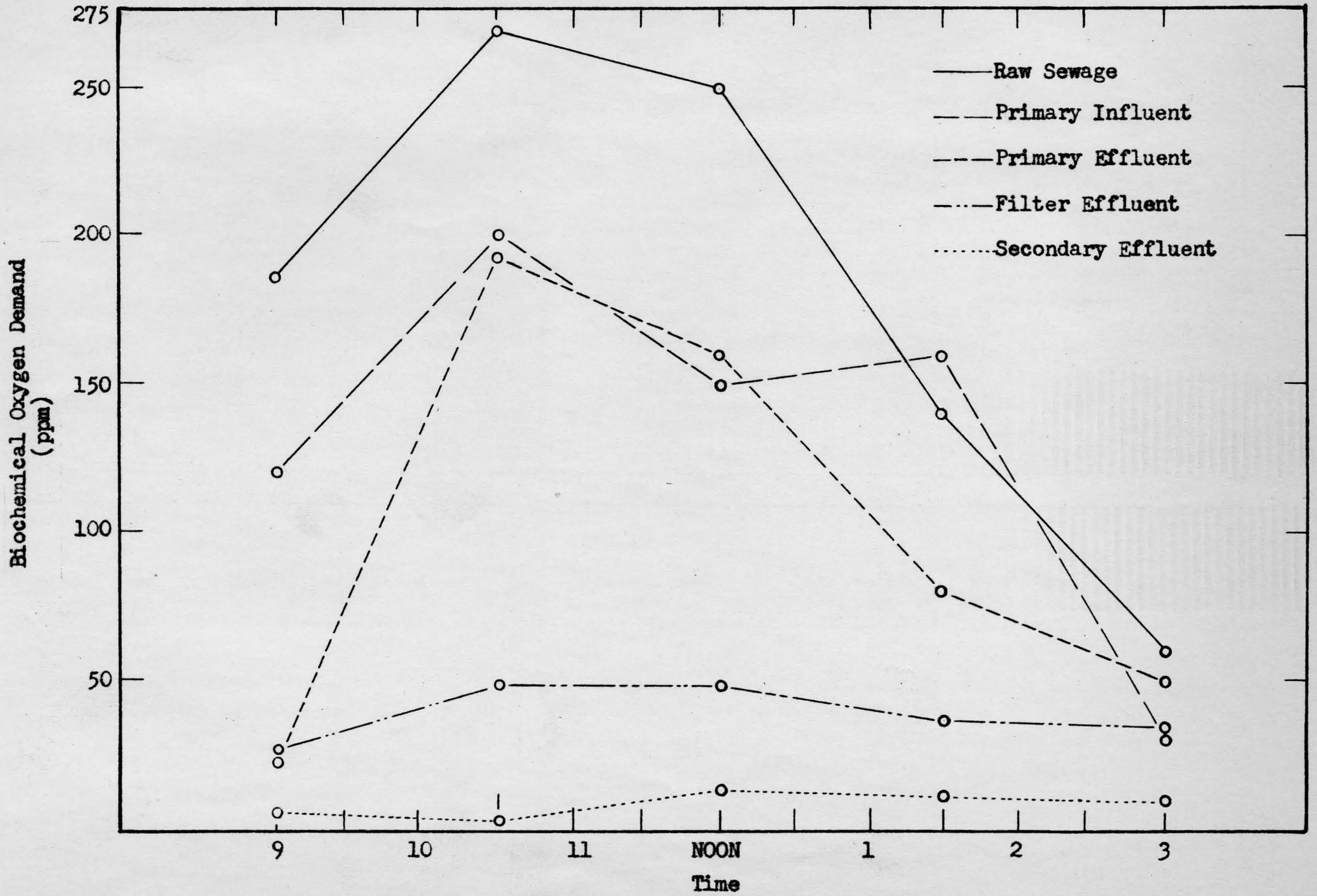

FIGURE 11. BIOCHEMICAL OXYGEN DEMAND - HOURLY VARIATION

TABLE 5

EFFECTS OF PLANT DISCHARGE ON RECEIVING STREAM

1949

Date	Time	Temperature (°C)			Dissolved Oxygen						B.O.D.**		
					ppm			% Saturation			ppm		
1949		1*	2*	3*	1	2	3	1	2	3	1	2	3
1-20	1300	10	12	10	10.4	6.4	10.4	91.7	59.1	91.7	3.0	-	8.2
1-21	1400	15	14	15	11.4	7.0	10.6	112.3	67.5	104.4	3.4	-	-
1-28	1100	8	10	8	13.0	9.0	13.6	109.5	79.4	114.6	4.0	4.3	10.2
3-1	1000	2	8	2	10.8	9.2	13.0	78.0	77.5	93.9	1.6	4.3	9.2
3-5	1000	8	12	8	6.0	7.6	8.4	50.5	70.1	70.8	-	-	-
3-24	1000	12	14	12	10.2	7.8	10.4	94.1	75.2	96.0	4.0	7.4	3.8
3-30	1000	13	15	13	11.2	7.0	8.2	105.6	68.9	77.3	4.2	6.4	4.4
4-6	1000	9	12	9	11.0	8.0	11.0	94.9	73.8	94.9	2.6	7.4	3.0
4-13	1000	-	12	-	-	6.6	-	-	60.9	-	-	5.8	-
5-16	1000	19	19	19	10.2	6.2	9.6	94.1	66.4	102.6	2.6	4.4	3.8
5-25	1000	15	17	15	11.0	6.4	10.4	108.3	65.7	102.4	2.0	6.0	3.8
9-8	1130	-	-	-	10.2	-	9.2	-	-	-	1.0	3.2	3.4

* Sampling Points - 1. Strouble's Creek - 50 yards upstream above outfall.
2. Secondary Clarifier Effluent.
3. Strouble's Creek - 50 yards downstream below outfall.

** B.O.D. - 5 day, 20 °C.

The net effects of residual B.O.D. discharged to the receiving stream are included with dissolved oxygen and temperature data in Table As may be noted, B.O.D. discharged to the stream generally raised the downstream values slightly although the combined B.O.D. value was usually less than 10 p.p.m. The nature of the stream — rapids and additional tributary flow — tended to dissipate these effects before Strouble's Creek joined the New River near the Radford Ordnance Works.

Chlorine Demand. Levels of minimum residual chlorine to be maintained at all times in sewage plant effluent discharges are commonly specified by stream pollution-control agencies. In this area a chlorine residual of 0.1 p.p.m. was considered satisfactory for the Blacksburg-V.P.I. Sewage Treatment Plant.

Determination of the post-chlorination dosage required to maintain a chlorine residual in the final plant effluent were performed on filter effluent samples. Although these tests were made using the standard 15-minute chlorine contact time, actual detention periods in the secondary tanks generally ranged from 80 to 100 minutes. Chlorine demand values and corresponding 15-minute residual values, expressed as p.p.m. chlorine required to produce a minimum residual of 0.5 p.p.m. in the chlorine demand test, are shown in Table N. The chlorine demand generally ranged between 2 and 5 p.p.m. For post-chlorination, 20 to 50 pounds of chlorine were applied per day. Residual chlorine values determined on samples of the primary clarifier effluent ranged from 0.0 p.p.m. to 0.2 p.p.m. These data, with corresponding influent flow rates and detention periods, are shown in Table

Post-Chlorine Residual. Although the rate of chlorination was adjusted manually, the post-chlorinator was usually set to provide 0.1 p.p.m. final residual. Accordingly, during periods of relatively low flow, the prolonged chlorine contact time in the secondary tanks — varying with the chlorine demand at any specific time — tended to lower chlorine residual values. Residual chlorine in secondary effluent samples generally exceeded the specified minimum value of 0.1 p.p.m. Higher values, also varying with specific chlorine demands, were noted during periods of higher flow and reduced contact time. Residual chlorine values are included with chlorine demand data in Table N.

Pre-Chlorination Residual. During periods of low flow and hot weather in the summer of 1949, pre-chlorination of raw sewage was employed to reduce septicity and attendant undesirable effects in the primary tanks.

On occasion, a solution of proprietary chlorinated hydrocarbon (Cloroben) was added experimentally to sewage flow at the campus pump house to inhibit excessive decomposition of the sewage while flowing at relatively low velocities to the treatment plant. The remoteness of the pump house and other limitations inherent in this practice led to its abandonment after several trials.

Satisfactory improvement in primary clarifier operation during hot summer weather was noted when chlorine was applied at rates of 25 - 35 pounds per day through the pre-chlorination injector at the plant site.

Oxidation - Reduction Potential. Recently, the oxidation-reduction potential test has been used as a measure of sewage characteristics and treatment process efficiency. Although this test does not measure the character of sewage qualitatively, it provides a relatively quick estimate of the degree of decomposition of the sewage.

Assisted by the writer, Professor L. G. Rich performed the oxidation - reduction potential test on samples of plant influent and effluent sewage on November 14, 1949. The first test was made at 12:30 P.M. and the second at 3:00 P.M. The oxidation - reduction potential of digester supernatant liquor was also determined. Results, reported in millivolts, are summarized as follows:

Time Date	Oxidation - Reduction Potential (mv) Plant Influent	Plant Effluent	Digester Supernatant
November 14, 1949			
12:30 P.M.	-211 mv.	-45 mv.	-431 mv.
3:00 P.M.	-196 mv.	-36 mv.	-

Overall reduction of the negative oxidation - reduction potential through the plant in these two tests — 78.7 per cent and 81.6 per cent, respectively — generally parallels the reductions of pollutional characteristics provided by the treatment process as measured by other, more specific analyses.

Treatment Process Changes. A special series of analyses were performed on September 6, 1949, to determine concurrent effects of treatment as measured by simultaneous tests. This series did not

TABLE 6

SEWAGE TREATMENT PROCESS CHANGES

September 6, 1949

	Primary Clarifier					
	Influent			Effluent		
Time	10:30 A.M.	1:00 P.M.	3:00 P.M.	10:30 A.M.	1:00 P.M.	3:00 P.M.
Air Temperature (°C.)	23	24	25	-	-	-
Sewage Temperature (°C.)	22	23	22	21	23	24
Sewage Flow (MGD)	0.80	0.70	0.68	-	-	-
Detention Period (Hours)	3.2	3.6	.37	-	-	-
pH	7.6	7.1	7.1	7.1	7.0	7.2
Carbon Dioxide (ppm)	5	22	31	17	23	20
Alkalinity (ppm)	332	290	320	310	300	312
Chlorides (ppm)	34	28	33	44	32	37
Residual Chlorine (ppm)	0.0	0.0	0.0	0.0	0.0	0.0
Settleable Solids (ml/L)	8.0	0.4	6.0	0.4	5.0	0.2
Dissolved Oxygen (ppm)	0.0	0.0	0.0	0.0	0.0	0.0
Relative Stability (%)	4	6	4	-	-	-

	Secondary Clarifier					
	Influent			Effluent		
Time	Noon	2:00 P.M.	4:00 P.M.	Noon	2:00 P.M.	4:00 P.M.
Air Temperature (°C.)	24	26	25	-	-	-
Sewage Temperature (°C.)	21	23	22	21	23	22
Sewage Flow (MGD)	0.70	0.80	0.70	-	-	-
Detention Period (Hours)	2.3	2.0	2.3	-	-	-
pH	7.4	7.3	7.4	7.3	7.0	7.3
Carbon Dioxide (ppm)	9	11	18	9	8	14
Alkalinity (ppm)	120	235	245	114	240	234
Chlorides (ppm)	43	41	37	50	41	40
Residual Chlorine (ppm)	0.0	0.0	0.0	0.1	0.1	0.15
Settleable Solids (ml/L)	-	-	-	-	-	-
Dissolved Oxygen (ppm)	5.8	3.4	5.2	6.0	5.6	5.6
Relative Stability (%)	100	100	100	100	100	100

include B.O.D. analyses which were performed in a similar series on October 18, 1949, and are reported separately.

Variation of influent flow conditions and progressive stabilization of sewage throughout the process are apparent from analytical values summarized in Table 6.

Sludge Digestion System

Successful operation of a sludge digestion system is primarily dependent upon close operational control — particularly during the initial operating period. Factors affecting efficient digestion include: acid/alkaline conditions, digester temperature, raw sludge feeding schedule, sludge recirculation cycle, supernatant liquor discharge, and digested sludge withdrawal. Gas production, solids/moisture content, specific gravity, and sludge "drainability" are indices of efficient operation and completion of the digestion process.

Digester pH. Digester pH values were determined on samples withdrawn from four-foot vertical zones and on the supernatant liquor. During the early phases, supernatant was not always withdrawn from the upper digester level — but generally from a clear, intermediate zone.

During initial phases of operation, adaptation and reducing actions of anaerobic organisms produced an acid condition in the digester. As the process stabilized, pH values of the contents increased normally to the desirable, slightly alkaline condition. Digester pH values at monthly intervals summarized in Table 7 are shown graphically for lower and upper digester zones and supernatant liquor in Figure 12. Results of more frequent observations at each level are detailed in Table 0.

Plate 17

SLUDGE DRAINABILITY TEST

TABLE 7

SUMMARY OF DIGESTER pH VALUES

1948 - 1949

Digester Operation (months)	pH Values		
	Digester Levels*		Supernatant Liquor
	1 - 2	3 - 4	
1948			
1	6.4	6.5	6.6
2	6.8	6.8	-
3	7.0	7.0	7.0
4	7.0	7.0	7.0
1949			
5	6.9	6.8	6.8
6	-	6.8	6.8
7	-	6.9	7.0
8	6.9	6.9	6.9
9	-	-	-
10	-	-	-
11	7.0	-	7.0
12	6.8	-	7.0
13	6.8	-	7.0
14	7.0	-	7.0
15	6.8	-	7.0

* Digester levels - above plant datum elevation:
1 - 2 lower zone - 82. - 86. feet
3 - 4 upper zone - 90. - 94. feet.

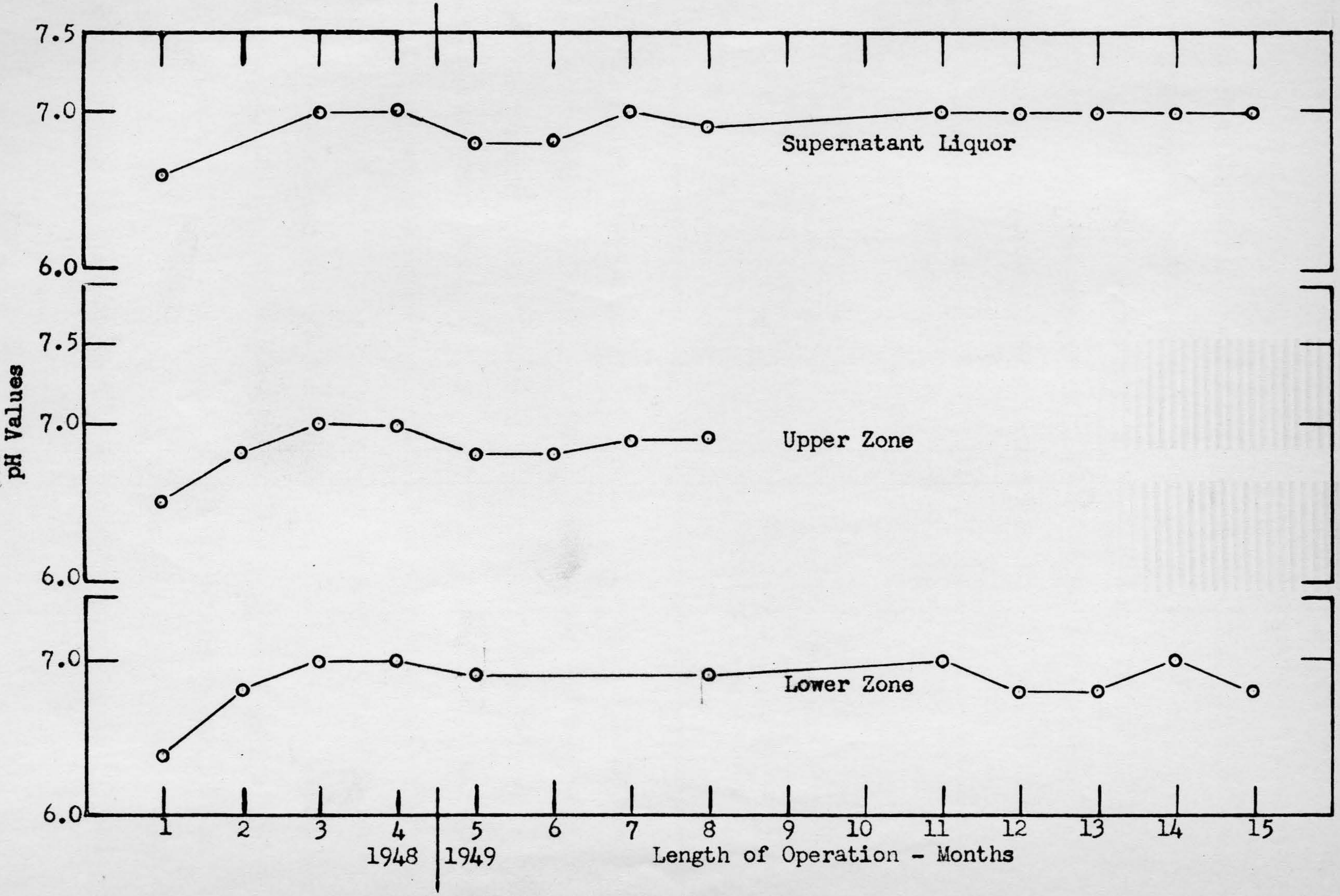

FIGURE 12. DIGESTER pH CONDITIONS

<u>Sludge Gas Production</u>. Daily production of sludge gas from the digestion process is a significant index of satisfactory performance. Average monthly values of sludge gas production — gas utilized by the heat exchanger and excess gas wasted to the atmosphere — are summarized in Table 8. Daily gas production values are included in Table P.

Total sludge gas production in 1949, shown in Figure 13, is summarized on a per capita basis as follows:

<u>Average Sludge Gas Production - 1949</u>
(cubic feet/capita/day)

January.	1.01	July.	1.29
February	1.25	August.	1.40
March.	1.41	September	1.04
April.	1.32	October	1.40
May	1.20	November	1.40
June	1.03	-	

Monthly variations of gas production rates may be attributed in part to variations of the settleable solids content of raw sewage, digester heating and feeding cycles, withdrawal intervals, and seasonal dietary patterns. Increased production in the winter followed improved digester heating and recirculation schedules. Lower sludge gas production in the late spring was probably due to "weaker" sewage caused by prolonged and excessive storm water dilution. Increased gas production in August 1949 may be attributed to the withdrawal of 2,800 cubic feet of digested sludge in the last two weeks of July, Table P. This withdrawal reduced hydrostatic pressure in the lower zone with the concomitant release of entrained gases by agitation of the consolidated

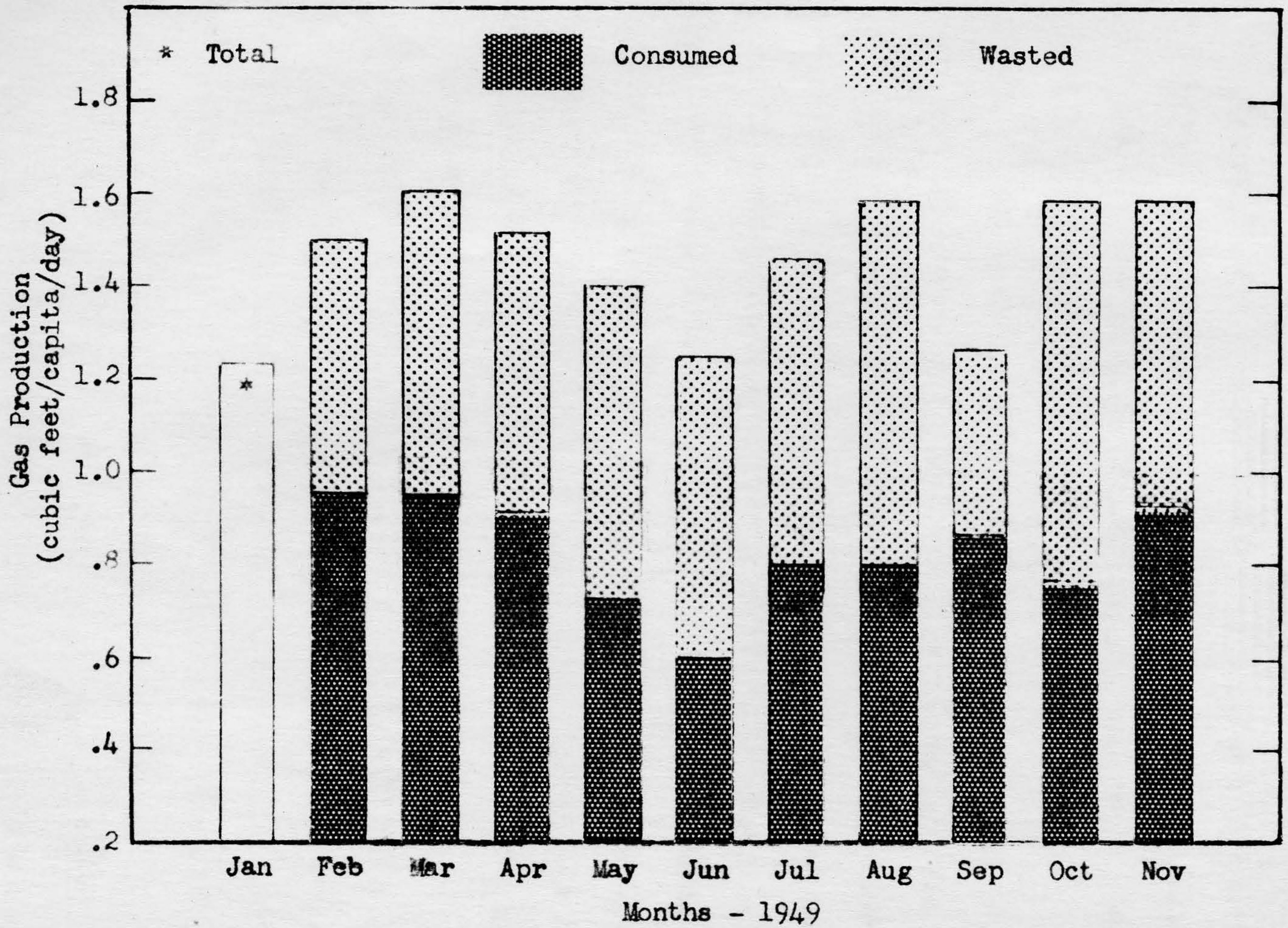

FIGURE 13. DIGESTER GAS PRODUCTION

contents and the general improvement of digestion conditions. Low sludge gas production during September 1949 may be attributed to losses of gas evolved from anaerobic decomposition in the primary clarifiers during periods of hot weather and low flow.

Digested Solids. Digested sludge was withdrawn when required — as indicated by the depth of digested sludge. Completed digestion was determined by sludge moisture content and the "buttermilk" test of drainability, Plate 17.

The average specific gravity value of digested sludge — 1.024 — was determined by a series of hydrometer tests. Using assumed specific gravity values of 1.000 and 2.500 for volatile and inert solids respectively[43], the specific gravity of total solids was computed as 1.525. This value, 1.525, was used in computing the specific gravity of digested sludge at various solids/moisture ratios. The average specific gravity determined by this method was 1.023 — slightly less than the observed value. This confirmation was prerequisite to calculation of solids contents of successive batch withdrawals of digested sludge.

Although sludge withdrawal began from the most consolidated portion of digester contents, prolonged or rapid pumping produced a draw-down effect in zones of lower solids content within the digester. Accordingly, there is no direct relationship between the solids content of withdrawn digested sludge and withdrawal intervals.

Ratios of the volatile/total solids content of raw sludge to digested sludge reflect the degree of reduction accomplished by the

TABLE 8

SUMMARY OF DIGESTER SLUDGE AND GAS PRODUCTION

	Gas Production Total (cu. ft.)					Digested Sludge Withdrawal
Month	Service	Waste	% Waste	Total	Daily Average	Tot. (cu. ft.)
1948						
July	-	-	-	-	-	-
August	-	-	-	-	-	1,057.80
September	-	-	-	*138,532	7,291	-
October	-	-	-	** 48,770	4,877	623.27
November	-	-	-	-	-	-
December	-	-	-	-	-	1,234.02
1949						
January	-	-	-	***181,078	7,873	610.75
February	159,871	113,817	41.6	273,688	9,775	623.27
March	179,168	160,548	47.3	339,716	10,959	1,234.02
April	168,903	135,602	44.5	304,505	10,150	-
May	129,713	157,805	54.9	287,518	9,275	610.75
June	76,412	118,814	60.9	195,226	6,508	623.27
July	92,060	104,255	53.1	196,315	6,333	2,820.92
August	94,178	124,567	56.9	218,745	7,056	1,424.78
September	122,796	74,849	37.9	197,645	6,588	2,137.17
October	137,823	206,183	59.9	344,006	11,097	2,835.24
November	195,318	137,830	41.4	333,148	11,105	1,410.46
						17,245.72

Digester Capacity:
Total........... 376,400 cubic feet
per capita...... 47 cubic feet

* 19 days
** 10 days
*** 23 days

(Avg. 1077.86)

per capita:
1.83 cu.ft/cap/yr

digestion process. Raw sludge was found to contain 67.8 per cent volatile solids (dry weight) whereas the average volatile content of digested sludge was 42.6 per cent. Assuming that inert solids remained constant during digestion, volatile solids were reduced 62.8 per cent by the digestion process. Actually, a minor portion of inorganic solids are normally reduced during the digestion process. This effect was not included in these calculations.

Total digester capacity is 376,400 cubic feet or an average of 47 cubic feet per capita, during 1949. Digested solids amounted to 58,773 pounds, on a twelve month basis. These data are shown in Table Q. Withdrawals of digested sludge — computed for the mean population, 7060 — was 1.83 cubic feet per capita per year, of which 3.53 pounds were volatile. As computed from reductions of raw sludge by digestion, the average per capita addition of total dry solids was 14.27 pounds per year.

Sludge Drying Rates. Moisture content of withdrawn digested sludge was determined periodically to estimate rates of air drying in open and covered beds. Sludge drying rates were computed by average and interpolated values for three conditions. Drying rates, subtracted from the initial moisture content, Table R, Figure 14, expressed as "Loss of Moisture Content (%), for these test conditions in Covered Beds (January - February); Covered Beds (July - August); and Open Beds (July - September), are summarized in columns I, II, and III in the following table.

Plate 18

SLUDGE DRYING CHARACTERISTICS

Sludge Drying Rates

Drying Time (days)	Loss From Initial Moisture (%) I	II	III
2	5.7	5.7	5.7
7	9.1	-	-
8	-	19.0	14.2
14	12.7	-	-
21	15.2	-	-
28	19.2	60.9	46.8
33	26.4	-	-

The generally uniform initial (2-day) loss of approximately 6 per cent moisture content may be attributed to mechanical consolidation and drainage of the digested sludge, residual biological activity, and evaporation. Surface cracks were usually noted in approximately one week as the moisture content approached 85 per cent, Plate 18. Although drying sludge could be removed when the moisture content reached 75 per cent, it was usually retained for longer periods.

Results of these tests indicate that covered beds, providing sustained "greenhouse temperature effects" and protection from inclement weather, effectively reduce sludge drying time as compared to open sludge drying beds.

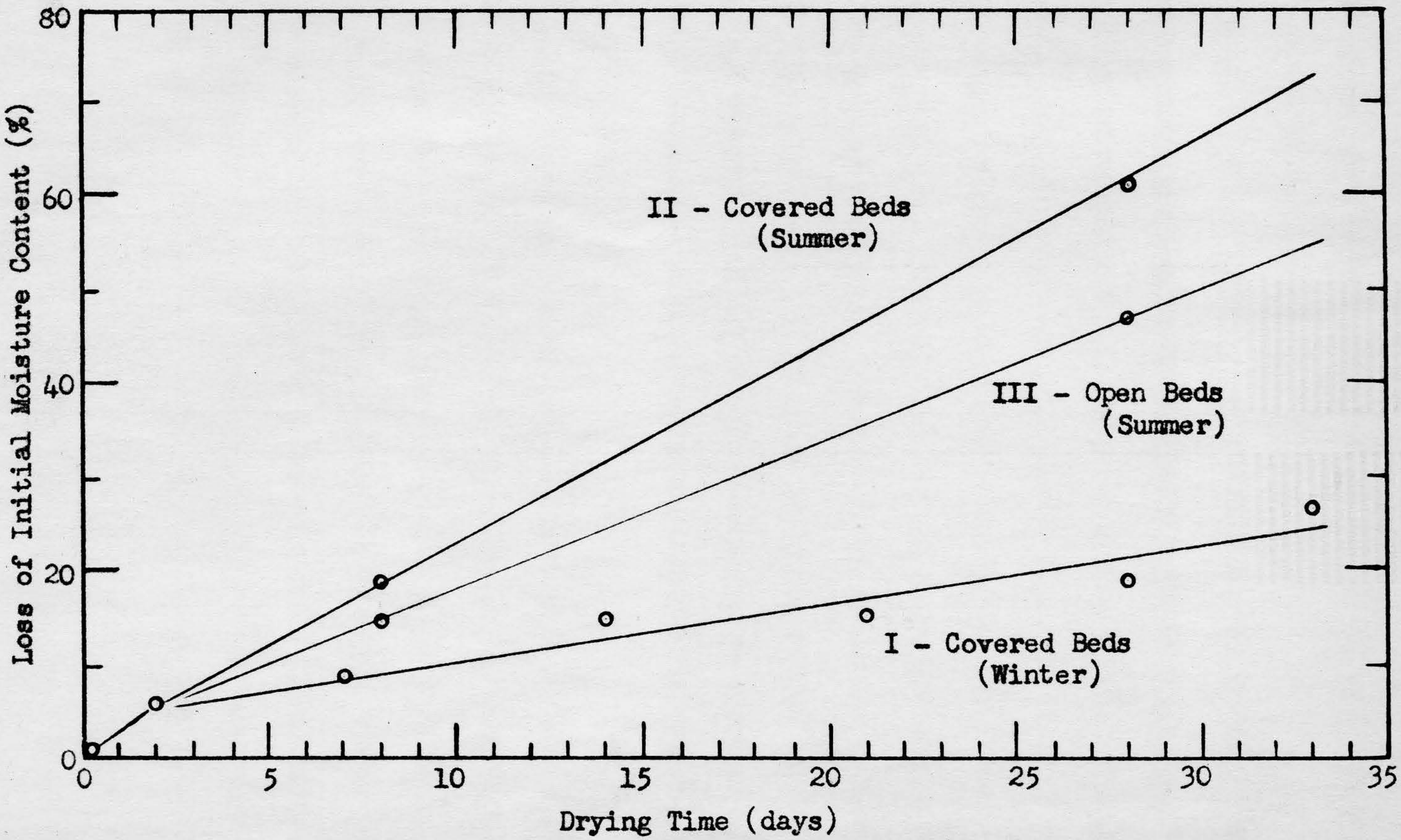

FIGURE 14. SLUDGE DRYING RATES

<u>Operational Problems</u>

Excepting items which are described separately, the majority of minor operational problems encountered at the plant were solved by experimental adjustment and repair of equipment.

The general lack of gaging devices for determining flow and pumping rates was a particularly significant deficiency. Appropriate flow-measuring equipment would afford a means of operating the plant with greater precision than was possible at the time of this study thereby improving and maintaining plant efficiencies at consistently high levels.

<u>Primary Clarifier</u>. Serious difficulties were encountered at the influent channel of the primary clarifiers in obtaining satisfactory tank-width flow distribution. Perpendicular impingment of influent flow from the receiving manhole reduced velocity in the influent trough to the extent of permitting grit and other inorganic materials to settle in the channel invert, Plate 3.

The concrete operating platform — extending across both tanks — and the vertical submerged baffle at the influent end of the primary clarifiers concealed the inlet zone from visual observation, restricted necessary manual operations, and prevented convenient "soundings" of the sludge hoppers as a means for developing optimum sludge pumping schedules. Accumulations of floating solids and grease which became confined beneath the operating platform were difficult to break up, Plate 5. During periods of low flow in hot weather these accumulations decomposed anaerobically and interfered with sedimentation in the primary tanks.

Remedial measures employed to reduce the above problems include:

1. Enlargement of clarifier entrance ports.

2. Reducing the net depth of the influent baffle.

3. Drilling access holes for "sludge sounding rods" through the operating platform directly above each hopper.

These particular difficulties might have been reduced by providing removable grating panels across the full width of the operating platform, directly above the influent baffle in the original design.

Grit. Considerable quantities of grit and street washings were contained in storm water flows. Diversion of storm water through improper connections and unprotected catch basins, Plate 19, undoubtedly contributed to the moderately severe grit problem noted in the sewerage system. Excessive wear on comminutor blades, deposition in pipes and channels, and frequent obstruction of piston sludge pumps were attributed to excessive quantities of grit in the sewage.

Frothing. Frothing occurred periodically in the filter dosing chamber and in the filter effluent channel and was noted most frequently on traditional "wash days", Mondays, and Tuesdays.

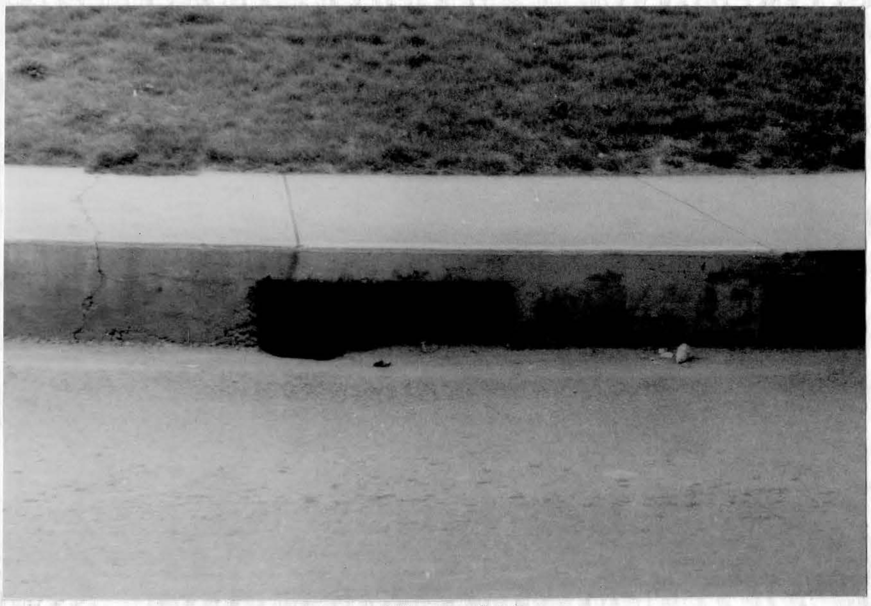

Plate 19

UNPROTECTED CATCH BASIN

Frothing was particularly severe in the filter dosing chamber during periods of high recirculation because of aeration and agitation produced by pump discharge, Plate 6, (Tuesday, September 13, 1949). Froth was usually broken in the dosing chamber by hose spraying. Froth in the filter effluent channel was dispersed mechanically by "plant-made" paddle wheels and siphon-fed spray lines from the dosing chamber.

The major source of these frothing agents was suspected to be the V.P.I. Dining Hall. The types and characteristics of cleansers and synthetic detergents used by the dining hall (serving 10,000 - 12,000 meals per day) are summarized as follows:

Washing Use	Brand Name	Type	Frequency
pots	"Whitespot"*	high strength soap	daily
silverware	"Whitespot"*	high strength soap	daily
dishware	"Keego"*	detergent	daily
trays	"4X"	soap	daily
trays	"Terj"**	inhibited soap	daily
trays (stains)	"Pronto"	detergent	occasionally
counters	green soap	soap	daily
floors	"Lesfoil"	liquid detergent	daily
general	lye	caustic	quarterly

* began July 1, 1949
** replaced "4X" beginning August 15, 1949

Extreme sudsing characteristics were reported for "White-spot", "Keego", and "Terj" and undoubtedly contributed to the frothing conditions observed at the sewage treatment plant.

Biology. Analyses of sewage effluents from each unit have reflected generally satisfactory biological conditions throughout the plant.

During the course of initial operation, zooglea film developed normally on the filter media. Occasional and seasonal "sloughing" of the film was noted visually in April and May 1949 and was reflected in generally increased settleable solids in the filter effluent during this period.

Microscopic examination of film samples taken from the upper six inches of the filter showed an abundant growth of microorganisms with the following types predominating: Nematodes, Lionotus, Rotifers, and Oscillatoria. Sludge worms (Tubifex tubifex) were noted occasionally in the primary clarifiers, particularly during periods of low flow.

"Filter flies" (Psychoda alternata) were abundant during periods of warm weather. Successful methods of controlling these flies included kerosene spraying of nearby vegetation, light chlorination of filter influent, and overnight flooding of the filter at 2-week intervals.

A relatively unusual growth of freshwater snails (Physella heterostropha) occurred in the filter during the spring of 1949. This identification was confirmed by Dr. Paul R. Burch of Radford State Teacher's College. These snails created no apparent detrimental effects in the biological operation of the filter. The quantity of snails may have contributed to some obstruction of flow in the underdrain system and to sporadic localized filter ponding. During the late summer they decreased in number and caused no further operational difficulty.

Digester Heating. Additional adjustments of the digester heating system were required in January, 1949 because of repeated mechanical failure of heat exchanger controls. Prior to these adjustments, digester temperature had been maintained routinely at approximately

90 °F. between 6 A.M. and 11 P.M. by semi-automatic operation of the heat exchanger. Failure of the automatic controls prevented operation of this unit in the absence of an operator between 11 P.M. and 6 A.M.

Prior to repairing the heat exchanger controls, primary clarifier sludge had been added to the digester hourly between 11 P.M. and 6 A.M. automatically but without normal heating. Although the heat exchanger was not operating during this period, raw sludge additions received some benefit from residual heat retained in the exchanger, shown as small hourly peaks on the digester temperature chart for January 15, 1949, Figure 15. When the heat exchanger was turned off at 11 P.M., digester temperatures dropped sharply and gradually leveled off in the range of 63 - 71 °F. until the exchanger was restarted manually at 6 A.M.

When repairs to the heat exchanger controls were completed, the exchanger was operated automatically and continuously on a 24-hour basis to maintain the digester temperature at 90 °F., Figure 16. An immediate response to this operational correction was demonstrated by a sharp increase in total daily gas production as shown in Figure 17, and summarized in the following table:

Date (1949)	Minimum Sustained Digester Temperature °F.	Total Gas Production (cu. ft.)
Jan. 15	65	7,190
16	67	6,540
17	71	6,200
18	64	5,090
19	63	7,360
20	90	8,270
21	90	10,740
22	90	11,020

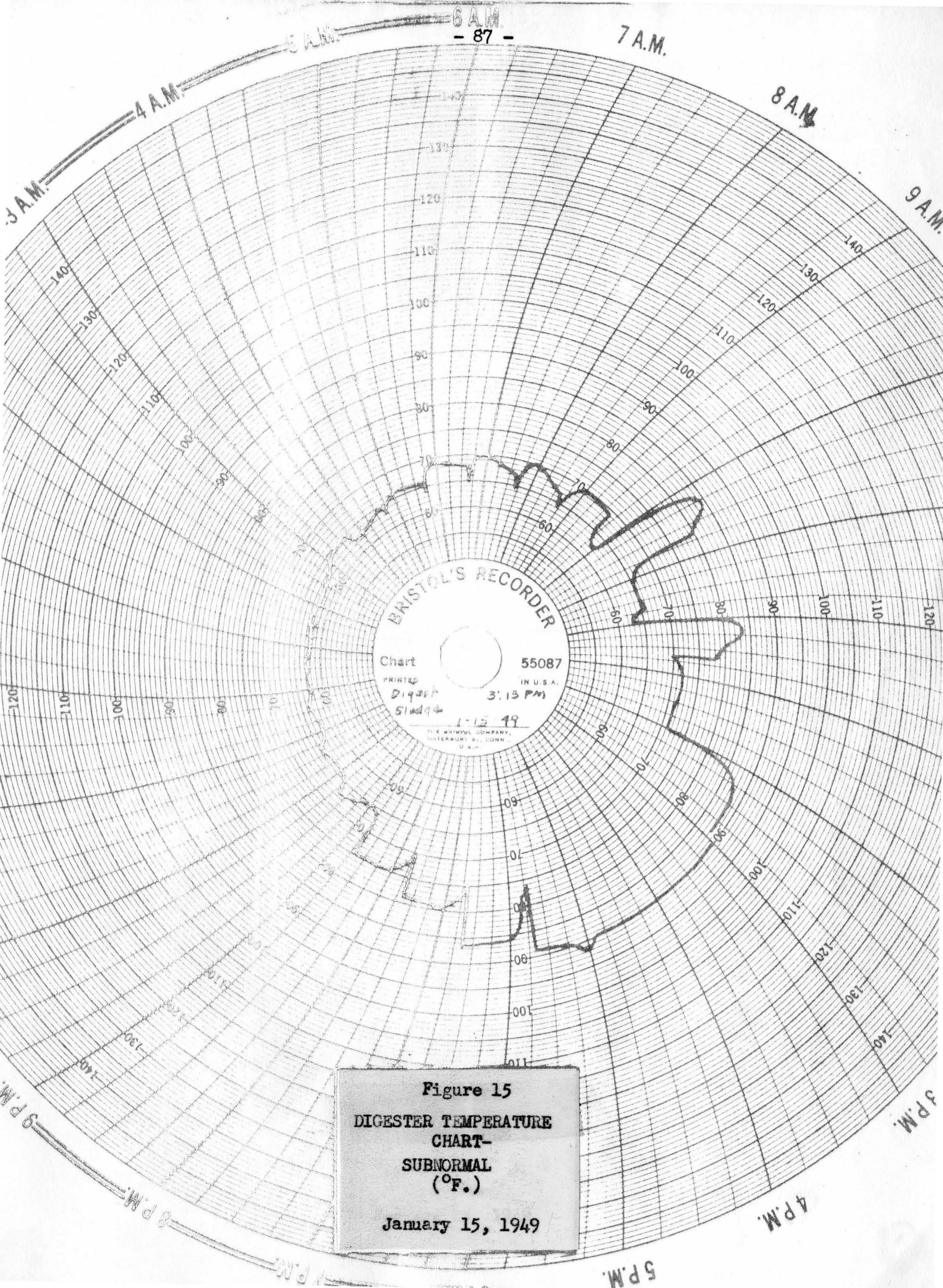

Figure 15

DIGESTER TEMPERATURE CHART-
SUBNORMAL
(^{o}F.)

January 15, 1949

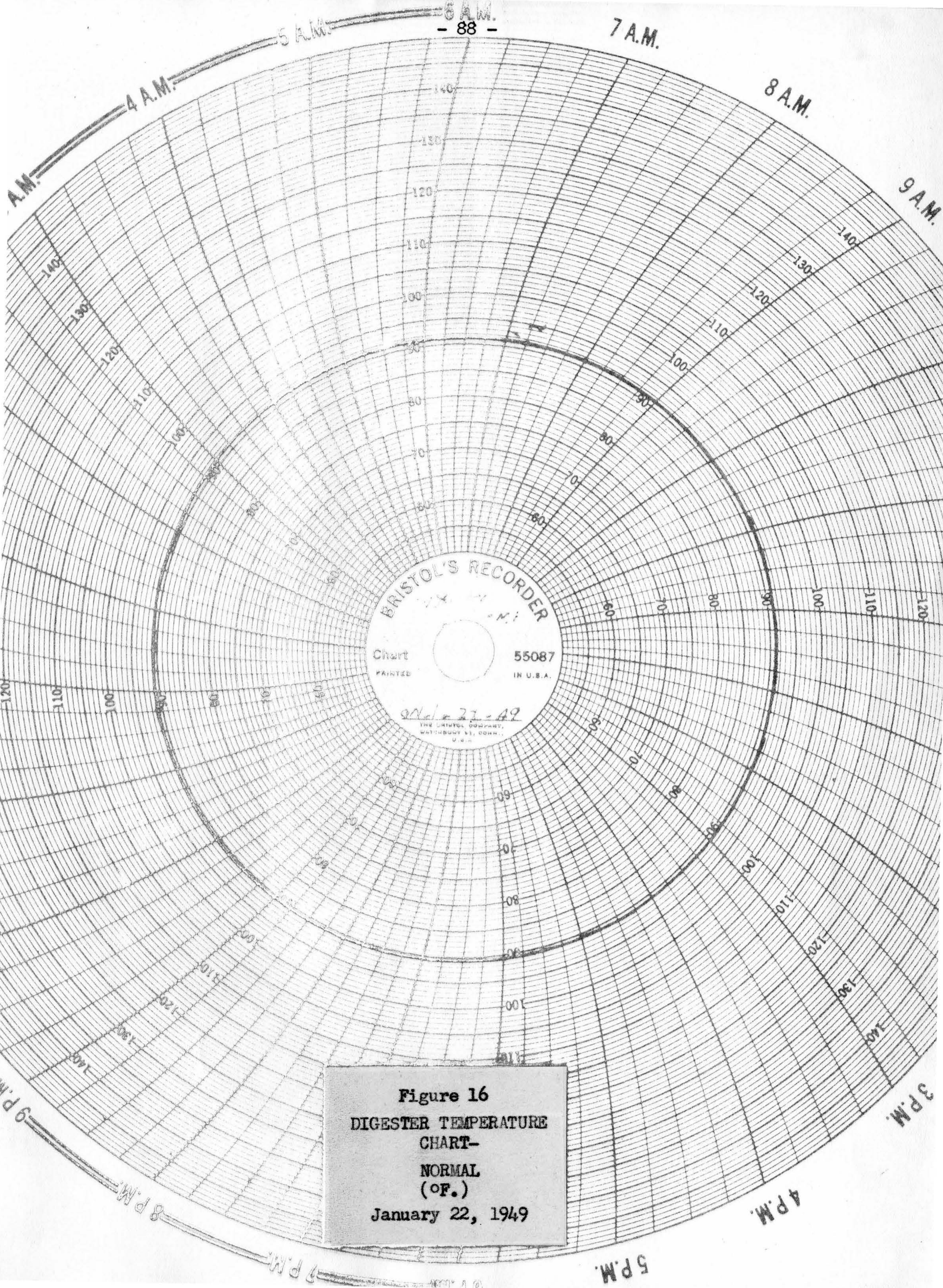

Figure 16
DIGESTER TEMPERATURE CHART-
NORMAL
(°F.)
January 22, 1949

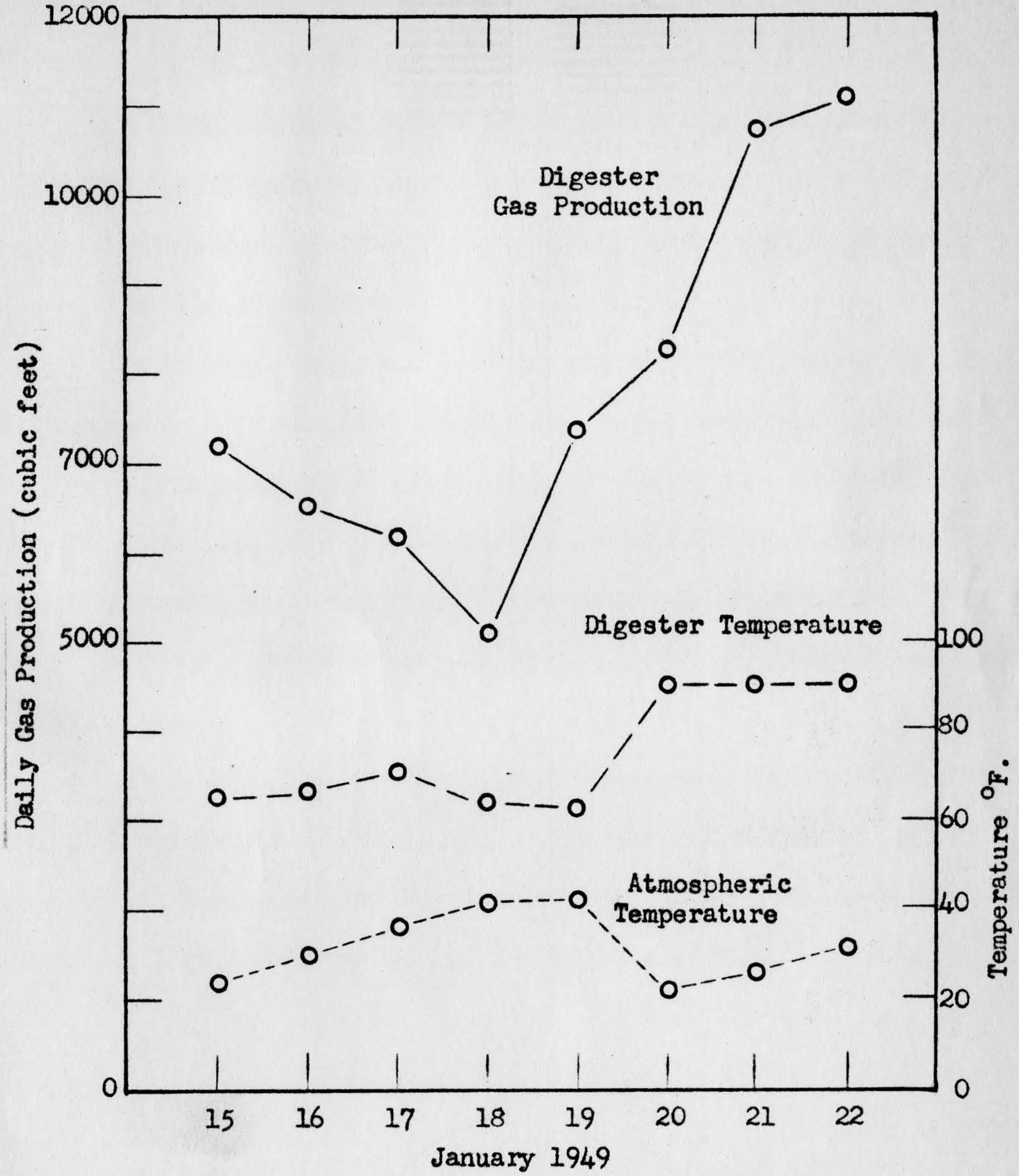

FIGURE 17. EFFECTS OF DIGESTER HEATING

Comparative Performance

As a means of comparing the effectiveness of sewage treatment processes at the Blacksburg - V.P.I. plant, operational data with corresponding values from eight other plants have been summarized in Table 9. These plants although not located in Virginia serve tributary populations less than 60,000. In some of these towns, resident enrollment in colleges or universities comprise substantial portions of the population.

Among these selected plants, there are similarities and differences in the types of processes employed in the various stages of treatment.

Although detailed unit data is generally not available, overall reductions of suspended solids and B.O.D. are frequently used in comparisons of plant performance. Rates of gas production — on a per capita basis — are frequently included as a measure of digester performance.

These data indicate that the Blacksburg - V.P.I. plant provided satisfactory sewage treatment during the initial period of operation and generally equalled or exceeded reported performance of other plants, all of which had been in operation for several years.

TABLE 9

COMPARATIVE PLANT PERFORMANCE

	Blacksburg V.P.I. Va.	Ann Arbor, Mich. (56)	Aurora, Ill. (45)	Battle Creek, Mich. (12)	Belvidere, Ill. (35)	DeKalb, Ill. (15)	Jackson, Mich. (8)	Marion, Ind. (6)	Urbana-Champaign, Ill. (24)
Tributary Population	7,900	48,200	51,000	57,300	8,100	13,300	50,000	30,300	45,000
Design Flow (MGD)	1.00	4.50	*	*	1.18	*	*	*	*
Average Flow (MGD)	0.71	5.33	6.72	6.69	1.09	1.39	7.61	4.54	3.45
Annual Rainfall (inches)	43.0	24.5	*	*	21.7	34.1	*	33.5	*
Treatment Process	1	5	1,2	3	5	1	5	5	1,4
Suspended Solids (ppm):									
Raw	180	200	196	284	198	211	225	178	205
Final	36	23	21	84	3	35	14	12	17
Removal (%)	80	88	89	70	99	94	93	90	84
B.O.D. (ppm):									
Raw	215	216	120	171	200	268	135	184	263
Final	12	40	14	103	5	37	5	13	23
Removal (%)	95	81	88	40	98	94	96	90	87
Sludge, Raw									
Dry Solids (%)	5.6	3.5	4.7	*	3.8	*	5.3	4.5	5.3
Volatile Solids (%)		78.5	73.7	*	55.1	*	61.0	66.8	58.1
Gas Production (cubic feet/cap/day)	1.21	1.07	0.91	1.41	1.61	1.05	1.05	2.38	1.14

Treatment Process: 1 - Trickling Filter; 2 - Two Stage Digestion; 3 - Primary Only; 4 - Imhoff Tank; 5 - Activated Sludge

* Not reported.

VI. CONCLUSIONS AND RECOMMENDATIONS

Conclusions derived from this investigation are:

1. The relatively high quantity of storm water detected in sewage flow indicates substantial diversion of storm water drainage through improper and/or illegal connections to the sanitary sewers.

2. Rates of residual groundwater infiltration — estimated at 10,000 gallons per mile of pipe per day — are considered moderate and indicate that the sewer system is in good condition generally.

3. The lack of complete and adequate flow gaging equipment (of water consumption, sewage flow, and pumping) is a significant disadvantage to attaining operational precision of the sewage treatment plant.

4. Treatment efficiencies afforded by each unit and by the entire plant were generally equal to, or exceeded, performance at other plants and commonly accepted values. Average reduction of pollutional characteristics were: settleable solids 90 per cent, suspended solids 80 per cent, and B.O.D. 95 per cent.

5. Residual pollution discharged from the treatment plant showed only infrequent, minor effects on the receiving stream.

6. Successful operation of the sludge digester was indicated by a volatile solids reduction of 68 per cent and an average daily gas production of 1.2 cubic feet per capita. The sensitivity of the digestion process is dependent upon close operational control of temperature, pH, and sludge addition and recirculation cycles.

7. Rates of sludge drying in covered beds were superior to open beds even during summer months.

8. Operational difficulties were generally remedied by replacement of equipment damaged during plant construction, experimental adjustment of controls, correction of minor deficiencies in design and construction, and by several innovations developed to meet specific conditions.

Recommendations:

1. A complete investigation and elimination of storm water and grit from the sewage entering the sanitary sewerage system.

2. Provision of adequate gaging equipment to determine rates of water consumption at V.P.I. and of sewage flow and pumping rates at the sewage treatment plant is essential.

3. Additional protection of plant operating personnel from inherent health and safety hazards, including:

a. Periodic typhoid and paratyphoid fever vaccination.
b. First aid training.
c. Rescue and emergency equipment.
d. Supplementary safety and warning devices — night lights, remote switch controls and telephone extensions.
e. Forced ventilation of the control building and pump room.
f. Increased storage space and handling equipment for chlorine cylinders.

4. Development of an experimental program for agricultural use of digested sludge in liquid and dried form.

5. Evaluation of digester gas holders of 2,000 - 5,000 cubic feet capacity.

VII. SUMMARY

This investigation was primarily a study of the performance of the new sewage treatment plant serving Blacksburg, Virginia and V.P.I. during the initial period of operation, 1948 - 1949.

This plant, designed for a sewage flow of 1 MGD, provides primary and secondary treatment. The plant is comprised of the following units: two primary clarifiers; a single standard rate trickling filter with rotary distributor; two secondary clarifiers; separate single-stage heated sludge digester; open and covered sludge drying beds; and facilities for pre- and post-chlorination.

Standard analyses of sewage characteristics were performed on samples at various stages in the treatment process in determining the efficiency of purification afforded by each unit. These tests indicate satisfactory operation of the plant in the reduction of pollutional constituents of the influent sewage. Effects of treated sewage discharged to the receiving stream, Strouble's Creek, were found to be negligible. Performance of the Blacksburg - V.P.I. plant was generally equal to or greater than that of other sewage treatment facilities serving populations less than 60,000.

Operational and analytical data are summarized as follows:

Tributary Population.	7,900
Average Flow	0.71 MGD
Settleable Solids (ml/L)	
Raw	11.5
Final.	0.0
Removal.	100.0 %

Suspended Solids (ppm)	
Raw	180
Final	36
Removal	80 %
Biochemical Oxygen Demand (ppm)	
Raw	215
Final	12
Removal	94.5 %
Effluent	
pH	7.4
Residual Chlorine (ppm)	0.1
Sludge Solids	
Raw	5.6 %
Volatile, Reduction	68.2 %
Gas Production (cubic feet/capita/year). . .	1.21

Supplementary studies in this investigation included: the effects of population fluctuation on sewage flow; verification of suspected storm water diversion into the sanitary sewers; and the appraisal and correction of operating problems encountered in the initial period of plant operation.

In contrast to variations in sewage flow noted in larger cities, lowest flows in the Blacksburg - V.P.I. system occurred during summer months. Storm water diversion into the sanitary sewage system was detected by noting the relationship among storm intensity, inlet time of surface runoff, and concurrent sharp increases in sewage flow. Operational problems encountered in the study included: clarifier septicity during summer months; periodic frothing caused by synthetic detergents; extensive growth of fresh-water snails in the trickling filter; maintenance of optimum digester temperatures; and development of digesting sludge recirculation cycles.

VIII. ACKNOWLEDGEMENTS

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The continued assistance and constructive criticism of Professor John D. Eye have been particularly valuable in the completion of the manuscript.

Drafts of the manuscript were prepared by and my wife, The final manuscript was typed by

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XI. APPENDIX

TABLE A

ESTIMATED TRIBUTARY POPULATION

Term	V.P.I. Enrollment* Campus	Town	Dependent**	Blacksburg***	Total Tributary	Estimate
1948 - Fall	2685	1573	500	3200	7958	8000
1949 - Winter	2538	1547	500	3250	7835	7800
1949 - Spring	2359	1530	500	3275	7664	7700
1949 - Summer - I	(1437)		300	3200	4937	4900
1949 - Summer - II	(1184)		300	3200	4684	4700
1949 - Fall	2497	1573	500	3300	7870	7900

* Student population quartered in temporary dormitories at Radford Ordnance Works excluded from this table.

** The "Dependent" population is a stochastic estimate of students' wives and children residing in the Blacksburg area.

*** Estimates of the Blacksburg population are interpolations between the April 1940 and April 1950 U. S. Decennial Census values; 2133 and 3358, respectively.

TABLE B

CHARACTERISTICS OF WATER SOURCES

The sources, treatment, and characteristics of the three water sources pertinent to this investigation are summarized as follows:

	Blacksburg[36]	V.P.I.[36]	Sewage Plant
Source	Limestone Spring	Limestone Spring	90 ft. drilled well
Treatment	Grit Sedimentation	Grit Sedimentation	None
Softening	Zeolite	(power plant and laundry)	None
Chlorination	Yes	Yes	No
Analysis (ppm)			
M. O. Alkalinity ($CaCO_3$)	217.0	193.0	194
Bicarbonate (HCO_3)	264.7	235.5	236.3
Free CO_2	-	-	12.3
Soap Hardness (ppm)			
Total	229.3	208.8	200
Calcium	188.0	166.0	172
Magnesium	41.3	42.8	28

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

July 1948

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1					
2					
3					
4					
5					
6	.15				
7					
8					
9					
10					
11					
12					
13	.12				
14	.45	-	-	-	-
15	.56	.53a	.99	11.00	.26
16	.35	.53a	.92	17.00	.29
17	.35	.46	.71	09.00	.26
18		.44	.60	11.00	.24
19		.52	.74	09.00	.25
20	.39	.51	.80	09.25	.26
21	.60	.59	1.25	15.00	.34
22		.51	.78	09.00	.26
23		.48	.83	08.50	.26
24		.38	.79	08.75	.22
25		.33	.47	11.00	.21
26		.41	.64	11.00	.24
27		.45	.64	09.00	.26
28	.68	.42	.75	14.00	.26
29		.44	.84	09.25	.22
30		.43	.84	10.50	.27
31	.03	.48	1.68	18.25	.27

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

August 1948

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1	1.35	.54	1.26	15.00	.32
2		.54	.88	11.00	.28
3	.59	.95	1.67	09.00	.60
4	2.00	1.63	1.68	08.00	1.67
5	1.12	1.39	1.66	09.00	1.02
6		1.04	1.54	09.00	.77
7		.80	1.27	09.00	.66
8		.80	.96	10.00	.56
9		.79	1.03	09.00	.54
10	.05	.75	1.04	09.00	.51
11		.73	1.04	10.00	.49
12	.50	.79	1.04	09.00	.50
13		.69	1.04	09.00	.44
14		.60	1.03	09.00	.42
15		.57	.80	10.00	.39
16		.61	.98	10.00	.38
17		.62	.86	14.00	.40
18		.58	.94	11.00	.36
19	.05	.61	.98	09.00	.36
20		.58	.90	10.00	.38
21		.53	.80	08.00	.36
22		.52	.69	11.00	.33
23	.13	.60	.90	09.50	.34
24	.09	.56	.84	08.75	.31
25		.53	.92	09.25	.31
26		.54	-	-	-
27		.52	.81	08.75	.31
28		.47	.78	08.75	.29
29		.46	.68	10.00	.28
30	.11	.52	.80	08.75	.27
31		.51	.77	09.00	.30

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

September 1948

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.53	.84	09.00	.32
2		.52	.83	08.50	.30
3		.48	.80	09.00	.28
4		.43	.72	09.00	.25
5	.16	.44	.64	10.00	.26
6	.56	.46	.67	09.00	.25
7		.49	.81	09.00	.24
8		.44	.82	09.00	.22
9	.72	.52	1.65	18.00	.26
10	.05	.40	.69	10.00	.24
11		.36	.64	09.50	.23
12		.33	.46	10.50	.21
13		.38	.59	12.00	.21
14		.37	.70	10.50	.21
15		.41	.80	09.00	.22
16		.35	.71	09.00	.19
17		.36	.60	12.00	.22
18		.35	.70	09.50	.21
19		.34	.50	10.50	.19
20	.12	.46	.74	09.00	.21
21	.06	.46	.78	09.00	.21
22	.08	.42	.91	08.75	.21
23		.44	.72	09.00	.20
24		.51	.85	14.00	.22
25		.47	.90	13.50	.20
26		.48	.85	10.00	.19
27		.55	.90	09.50	.19
28	.05	.58	.93	08.50	.21
29	.63	.61	1.12	13.50	.22
30		.60	.95	08.50	.23

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

October 1948

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.59	.98	08.50	.22
2		.46	1.00	11.00	.22
3		.47	.75	12.00	.17
4		.79	.89	09.00	.43
5	1.37	.70	1.55	08.00	.26
6		.65	1.14	09.25	.29
7		.61	1.09	08.00	.25
8	.37	.63	1.09	13.50	.26
9		.51a	.97	08.00	.24
10		.51a	.84	10.75	.21
11	.03	.61	1.03	09.00	.22
12		.64	1.02	11.50	.24
13		.59a	1.04	08.50	.24
14		.59a	1.04	09.00	.22
15		.57	.96	09.00	.23
16		.53a	1.08	08.50	.21
17		.53a	.88	11.00	.25
18	.40	.62	.92	14.50	.23
19		.61	.97	10.50	.21
20		.61	.95	09.00	.24
21		.63	1.06	09.25	.26
22		.59	1.02	09.00	.23
23		.46	1.03	08.50	.21
24		.52	.79	11.00	.21
25		.58	1.00	09.50	.21
26		.58	.98	08.75	.20
27		.56	1.00	08.75	.21
28		.57	.95	09.25	.20
29		.57	.95	09.00	.21
30		.49	.89	10.00	.21
31		.46	.75	11.00	.19

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

November 1948

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1	.10	.58	.90	09.25	.21
2		.57	.99	09.00	.21
3	.31	.58	.97	09.00	.20
4		.58	.95	09.25	.20
5		.54	.99	09.50	.20
6	.12	.51	.95	09.25	.20
7		.48	.81	11.00	.19
8		.59	.94	09.50	.25
9	.13	.57	.84	18.50	.23
10	.10	.56	.84	09.00	.23
11		.57	.85	19.00	.24
12		.58	.84	19.00	.22
13	.08	.43	.80	19.00	.20
14		.45	.76	11.00	.18
15		.63	.90	19.00	.26
16		.60	.88	19.00	.29
17	.17	.54	.89	09.00	.21
18		.53	.79	19.00	.18
19	.68	.68	1.34	19.00	.25
20	.19	.53	.85	18.75	.24
21		.49	.85	10.50	.18
22	.25	.55	.82	09.50	.19
23		.59	.84	19.00	.23
24	.33	.52	.85	10.50	.24
25		.34	.68	09.25	.19
26	.08	.47	.68	10.00	.34
27	.39	.45	.62	09.00	.26
28	1.45	1.51	2.16	13.00	1.12
29	.63	1.13	1.54	08.50	.60
30		.83	1.21	14.00	.49

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

December 1948

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.82	1.04	08.50	.42
2	.02	.91	1.01	09.00	.40
3	1.93	1.48	2.46	16.50	1.16
4		1.42	1.97	10.00	1.01
5		1.12	1.46	11.00	.76
6	.07	1.01	1.32	08.50	.66
7		1.02	1.19	10.00	.60
8		.83	1.18	08.50	.56
9		.88	1.13	14.00	.53
10		.87	1.12	14.00	.49
11		.73	1.09	10.50	.47
12		.72	1.12	10.50	.40
13		.83	1.03	09.50	.41
14		.95	1.08	08.75	.44
15	1.75	1.68	2.48	09.50	1.02
16	.06	1.21	1.48	09.00	.85
17	.11	1.07	1.45	10.00	.80
18		.86	1.25	09.50	.70
19	.32	.73	.96	09.25	.61
20		.82	1.02	10.50	.57
21		.68	.96	10.50	.55
22		.63	.89	10.00	.50
23		.61	.80	09.50	.49
24	.23	.62	.68	09.50	.51
25	.26	.59	.65	10.50	.46
26		.53	.66	10.00	.44
27		.55	.68	10.50	.44
28		.58	.84	10.50	.44
29	.31	1.46	2.13	03.00	-
30	.82	1.11	1.64	09.00	.90
31		.93	1.20	10.50	.76

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

January 1949

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.77	.98	11.50	.62
2		.74	.88	11.00	.55
3	.07	.85	1.10	10.00	.57
4	.13	.95	1.12	12.00	.65
5	1.06	1.62	2.36	17.00	1.10
6	.07	1.21	1.61	09.00	.88
7		1.02	1.40	13.50	.76
8		.80	1.18	18.25	.66
9		.94	1.17	11.00	.60
10		.95	1.22	19.00	.59
11		.96	1.19	09.50	.60
12		.87	1.18	09.00	.44
13		.90	1.20	19.00	.55
14		.80	1.19	08.75	.50
15		.76	1.07	17.50	.47
16		.90	1.08	12.00	.46
17	.02	.75	1.04	13.50	.44
18		.76	1.01	09.00	.42
19		.81	1.04	18.50	.41
20		.78	.99	09.00	.41
21	.95	1.07	1.55	19.00	1.00
22	.44	1.00	1.43	09.00	.70
23	.05	.95	1.25	10.50	.58
24		.92	1.18	14.00	.54
25		.90	1.15	10.00	.72
26	.36	1.00	1.23	09.00	.62
27	.15	.94	1.27	13.50	.67
28	.18	.96	1.26	09.00	.58
29		.78	1.13	10.50	.54
30		.66	1.10	10.50	.52
31	1.02	1.05	1.11	19.00	.55

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

February 1949

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.89	1.20	18.50	.55
2		.92	1.20	18.50	.51
3		.93	1.19	09.50	.58
4	.12	1.04	1.39	15.50	.78
5		.97	1.37	21.00	.69
6		.99	1.14	11.00	.60
7	.23	.93	1.26	19.00	.60
8		.94	1.22	13.50	.59
9	.11	1.22	1.18	09.00	.56
10	.40	.85	1.44	13.50	.73
11		.93	1.32	09.00	.57
12		.76	1.15	09.50	.53
13	.02	.86	1.12	10.50	.51
14		.84	1.10	09.00	.51
15		.92a	1.29	18.25	.59
16		.92a	1.21	09.00	.54
17	.42	.84	1.13	19.00	.51
18		.83	1.13	19.00	.50
19	.73	1.10	1.63	19.00	.80
20	.11	.96	1.25	10.50	.63
21		1.15	1.21	09.00	.60
22		.80	1.24	09.50	.60
23	.06	.83	1.19	09.00	.54
24		.90	1.15	09.00	.51
25		.85	1.14	09.00	.46
26		.77a	1.05	09.00	.46
27	.06	.77a	1.02	12.00	.51
28	.69	.86	1.14	14.00	.48

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

March 1949

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.81	1.09	23.50	.48
2		.84	1.06	13.50	.45
3		.81	1.07	19.00	.43
4		.73	1.08	09.00	.43
5		.70	1.03	09.00	.39
6		.66	.97	11.00	.36
7		.73	.96	14.50	.36
8		.69	1.11	19.00	.38
9		.73	1.00	09.00	.34
10	.15	.69	.94	09.00	.36
11		.68	1.02	19.00	.37
12		.66	.98	09.00	.35
13		.68	.95	10.50	.34
14		.65	.96	09.30	.32
15		.67	.99	09.00	.32
16		.73	.97	09.00	.32
17		.73a	.95	09.00	.49
18	.85	.73a	1.31	08.00	.40
19		1.00	.95	12.00	.34
20		.41	.97	10.00	.34
21		.94a	1.03	12.00	.32
22	.88	.94a	1.74	23.00	.91
23	.43	.89	1.39	10.00	.61
24		.72	.97	09.00	.51
25		.59	.85	09.00	.47
26	.16	.76	.78	09.00	.46
27		.50	.72	10.50	.43
28	.18	.71	.90	09.00	.42
29		.72	1.13	11.50	.40
30		.81	1.04	08.00	.40
31		.73	1.05	09.00	.38

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

April 1949

		Sewage Flow (MGD)			
Date	Precipitation Inches	Total Daily Flow	Maximum Rate	Time	Minimum Rate
1	.16	.67	.99	09.00	.36
2		.81	.96	09.50	.35
3		.50	.94	10.50	.35
4		.69	.95	09.25	.33
5	.63	.84	1.48	19.75	.48
6	.23	.80	1.06	13.50	.40
7	.30	.77	1.06	08.75	.42
8	.06	.72	1.08	08.75	.38
9		.93	1.00	09.00	.38
10		.39	1.00	10.50	.34
11	.12	.72	1.02	09.25	.34
12	.13	.91	1.10	19.00	.55
13	2.01	1.99	2.47	15.00	1.44
14		1.42	1.84	08.75	.97
15		1.10	1.53	09.50	.80
16		.87a	1.30	09.00	.67
17		.87a	1.12	10.00	.60
18		.89	1.20	10.00	.55
19		.87	1.21	14.00	.54
20		.94	1.24	13.50	.53
21		.86	1.20	13.50	.50
22	.55	.89	1.30	10.50	.53
23		1.03	1.26	10.50	.50
24		.54	1.05	10.75	.44
25		.81	1.02	09.25	.42
26		.76	1.20	18.50	.41
27	.59	.84	1.17	16.00	.44
28		.78	1.05	09.25	.41
29		.73	1.05	09.25	.40
30	.94	2.94	2.43	22.00	1.69

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

May 1949

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1	.69	.90	2.46	11.00	1.31
2	.18	.92	1.98	09.25	.62
3	.03	.99	1.23	08.25	.54
4		1.01	1.17	08.25	.49
5		.73	1.20	09.00	.46
6		.77	1.18	09.25	.45
7	.03	.85	1.05	08.50	.42
8		.49	.90	10.00	.36
9	.77	1.27	2.39	21.25	.92
10	.64	1.08	1.36	08.00	.76
11	.34	1.10	1.42	09.00	.65
12		.83	1.26	09.00	.55
13		.98	1.27	20.75	.62
14		.96	1.15	21.00	.53
15	.05	.65	1.08	10.75	.46
16	1.04	1.20	2.29	15.25	.72
17		.98	1.29	09.50	.59
18		1.44	1.88	13.50	1.19
19		.96	1.65	07.75	.48
20		.76	1.16	08.00	.47
21		.95	1.04	10.25	.46
22	.08	.51	1.04	10.50	.41
23		.71	1.03	09.25	.42
24		.82	1.05	09.00	.41
25	.17	.83a	1.05	09.00	.41
26	.10	.83a	1.00	07.50	.37
27		.52	1.04	09.25	.37
28		.96	.95	08.75	.36
29		.49a	.96	10.00	.34
30		.49a	.96	09.00	.33
31		.71a	.97	13.50	.33

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

June 1949

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.71a	.98	08.50	.32
2		.66a	.93	15.50	.31
3		.66a	.92	10.50	.30
4		.85	.91	09.00	.29
5		.57	.91	11.00	.28
6		.61	.86	14.50	.29
7		.58a	.89	09.50	.29
8		.58a	.95	10.50	.29
9		.58a	1.00	09.00	.28
10		.48	.84	10.00	.27
11		.59	.73	21.00	.28
12		.44	.83	09.50	.24
13		.46	.92	09.50	.25
14	.50	.47	.75	15.25	.27
15	.24	.50	.95	19.25	.25
16	.42	.60	1.02	21.50	.38
17	.98	.50	.83	09.25	.27
18		.44	.75	09.00	.27
19		.45	.58	10.50	.24
20		.53	.72	09.00	.27
21		.47	.74	09.25	.25
22		.46	.82	09.00	.24
23		.47	.71	09.00	.22
24		.46	.80	09.00	.23
25		.46	.68	08.75	.19
26		.32	.58	10.00	.21
27		.45	.74	09.00	.17
28	.03	.62	2.01	21.50	.40
29	2.19	.71	1.00	09.00	.30
30	.67	.68	1.81	09.00	.33

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

July 1949

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.53	.84	09.00	.31
2		.47a	.84	09.00	.27
3		.47a	.60	09.00	.27
4		.47a	.68	09.00	.26
5		.51	.85	09.00	.26
6	.15	.35	.80	09.00	.30
7		.60	.85	09.50	.35
8		.57	.90	09.00	.38
9		.56a	.81	09.00	.33
10		.56a	.88	12.50	.36
11		.64	.90	12.00	.37
12	.12	.60	.85	09.00	.35
13	.45	1.23	2.47	12.75	.75
14	.56	.90	1.01	07.50	.53
15	.35	.82	1.24	21.00	.59
16	.35	1.29a	2.22	22.00	1.51
17		1.28a	1.65	10.00	.94
18		1.07	1.37	09.25	.79
19		1.00	1.30	09.00	.70
20	.39	.96	1.25	09.00	.63
21	.60	.86	1.18	08.75	.58
22		.85	1.40	18.50	.57
23		.78a	1.03	09.25	.53
24		.78a	.78	09.75	.51
25		.45	.99	11.00	.49
26		.62	.85	09.75	.46
27		.60a	.85	09.00	.46
28	.68	.59a	.93	10.50	.41
29		.56	.78	10.50	.41
30		.51a	.70	09.25	.39
31	.03	.50a	.60	10.00	.37

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

August 1949

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.51	.70	09.50	.37
2		.61	.82	09.25	.40
3	.03	.64	.92	09.00	.39
4	.04	.63a	.89	09.00	.37
5	.25	.63a	.89	09.00	.36
6	T	.55a	.80	08.75	.36
7		.55a	.74	10.00	.40
8		.64	.92	09.25	.40
9	T	.56	.88	09.25	.33
10		.59	.86	08.75	.33
11		.58	.89	09.50	.31
12	.02	.51	.90	09.25	.32
13	.32	.53a	1.54	17.75	.35
14		.53a	.61	10.00	.31
15	.40	.88	1.41	19.50	.41
16	1.00	.78	1.40	10.50	.45
17	.15	.69	1.05	09.00	.42
18	.04	.59	.90	05.00	.37
19		.62	.91	09.00	.38
20	.11	.55a	.88	09.00	.34
21		.55a	.65	06.00	.32
22	.47	.72	.98	02.50	.35
23	.20	.53	.96	06.50	.29
24		.50	.83	11.00	.27
25	.03	.45	.82	09.25	.25
26		.38	.73	09.50	.24
27		.74a	.64	09.25	.23
28	1.60	.74a	2.21	18.50	.75
29	.31	.75	1.11	08.50	.44
30		.60	.95	09.25	.39
31	.50	.80	1.35	13.00	.44

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

September 1949

Date	Precipitation Inches	Sewage Flow (MGD) Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.59a	.88	09.00	.40
2		.59a	.95	10.00	.37
3		.50a	.79	10.00	.34
4		.50a	.70	10.50	.31
5	.35	.57a	.95	14.50	.32
6		.57a	.80	09.50	.31
7		.56	.89	12.00	.30
8		.55	.79	08.75	.32
9		.42	.81	09.50	.28
10		.37a	.60	09.50	.26
11		.37a	.51	09.50	.24
12		.46	.77	10.75	.26
13	.35	.40	.73	08.75	.26
14		.41	.57	09.25	.25
15		.38	.59	10.50	.23
16	.63	.43	1.08	18.25	.31
17	.13	.35a	.60	10.00	.23
18		.35a	.45	11.00	.24
19	.17	.42	.60	10.50	.25
20		.42	.67	11.00	.25
21		.47	.65	08.75	.25
22		.45	.75	10.00	.25
23	.16	.49	.79	08.75	.24
24		.51a	1.01	11.50	.25
25		.51a	.89	09.25	.22
26		.60	.92	08.50	.24
27	.03	.53	.92	08.75	.22
28	.05	.53	.95	09.00	.21
29	.64	.64	1.52	10.25	.23
30		.55	.91	09.25	.24

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

October 1949

		Sewage Flow (MGD)			
Date	Precipitation Inches	Total Daily Flow	Maximum Rate	Time	Minimum Rate
1		.48	.85	09.00	.22
2		.50	.80	09.50	.21
3		.54	.86	09.00	.20
4		.58	.88	19.00	.22
5		.55	.90	08.50	.17
6	.13	.55	.88	09.00	.19
7	.05	.43	.82	09.00	.21
8	.05	.21a	.99	10.25	.16
9		.20a	.67	10.50	.17
10		.95	.84	09.00	.16
11		.51	.84	09.00	.17
12	.07	.56	.87	08.25	.18
13	.09	.52	.89	07.50	.18
14	.02	.58	.88	08.75	.23
15		.59a	1.01	08.75	.21
16		.59a	.80	09.25	.17
17	.30	.44	.85	09.00	.20
18	.03	.54	.88	08.75	.20
19		2.33	2.47	09.25	2.01
20		.50	2.47	07.75	.17
21		.48	.86	09.00	.17
22	.05	.47	.80	09.00	.19
23		.45	.78	10.50	.16
24		.56	.78	09.00	.18
25	.08	.51	.95	23.50	.21
26	.50	.55	.88	09.00	.17
27		.51	.82	09.00	.17
28	1.05	.70	1.43	14.75	.28
29	.05	.43	.80	09.50	.24
30	.37	.85	.77	11.50	.51
31	.69	.77	1.45	04.50	.35

TABLE C

BLACKSBURG PRECIPITATION AND SEWAGE FLOW DATA

November 1949

		Sewage Flow (MGD)			
Date	Precipitation Inches	Total Daily Flow	Maximum Rate	Time	Minimum Rate
1	1.28	.77	2.47	15.00	.85
2		1.50	1.40	09.25	.54
3	.08	.98	1.17	09.00	.46
4	.02	.86	1.12	19.25	.41
5		.74	1.02	09.00	.36
6		.66a	.92	10.50	.34
7		.65a	.96	09.25	.34
8		.67a	1.02	18.75	.33
9		.66a	1.01	18.50	.33
10		.74	1.01	09.00	.32
11		.64a	.98	08.75	.32
12		.64a	.88	20.00	.31
13	.20	.62	.76	10.50	.27
14		.52	.90	09.00	.29
15		.70	.94	08.50	.28
16		.61	.95	08.25	.27
17		.62	.94	09.00	.26
18	.02	.67	.90	09.25	.26
19		.55	.86	10.00	.24
20		.53	.86	10.50	.24
21		.53	.87	09.00	.23
22		.60	.85	13.50	.24
23		.45a	.87	09.00	.24
24		.45a	.62	09.50	.26
25	.28	.42	.66	09.25	.26
26		.38	.61	10.00	.22
27		.37	.52	10.50	.22
28		.65	.88	19.00	.23
29	.65	.57	.91	09.00	.23
30		.62	.86	09.00	.25

TABLE D

STORM INTENSITY - RUNOFF RELATIONSHIPS

Storm of July 13, 1949

Time	Cumulative Rainfall (inches)	Dam Crest Above Normal (inches)	Sewage Flow Rate (MGD)
11:00 a.m.	.00	.00	.80
11:45	.00	.00	-
NOON	.19	.10	.75
12:15 p.m.	.46	.25	1.25
12:30	.55	.50	1.90
12:45	.64	.73	2.46
1:00	.80	1.60	over 2.46
1:15	1.28	2.12	over 2.46
1:30	1.36	2.95	over 2.46
1:45	1.42	3.32	over 2.46
2:00	1.43	5.30	over 2.46
2:15	-	5.45	over 2.46
2:30		5.25	2.46
2:45		4.90	-
3:00		4.60	2.10
3:15		4.30	-
3:30		3.95	-
3:45		3.57	-
4:00		3.20	1.80
4:15		3.05	-
4:30		2.40	-
4:45		2.10	-
5:00		1.80	1.65
5:15		1.50	-
5:30		1.30	-
5:45		1.15	-
6:00		1.00	1.60
7:00		.70	1.50
8:00		.50	1.35
9:00		.40	1.20
10:00		.30	1.20
11:00		.20	1.10
MIDNIGHT		.10	1.00

TABLE E

RAINFALL STORM-WATER SUMMARY

August 1948 - November 1949

Month	Rainfall*** Total (inches)	Dep. From Normal (RF in.)	Dry Weather Flow* Avg. Daily (MGD)	Excess Flow** Total (MG)	Excess Flow MG/inch RF
1948					
August	5.56	1.89	.60	2.80	.50
September	2.03	-0.78	.44	.29	.14
October	2.14	-1.03	.57	.47	.22
November	3.62	2.70	.53	2.14	.59
December	4.53	2.44	.78	3.97	.88
1949					
January	4.29	1.21	.87	1.88	.44
February	1.30	-0.13	.89	1.06	.82
March	2.50	-1.03	.70	.83	.33
April	5.35	2.53	.76	4.56	.85
May	3.66	0.44	.80	1.67	.46
June	3.28	0.45	.54	.37	.11
July	2.82	1.37	.58	3.30	1.17
August	4.68	1.37	.57	1.43	.31
September	1.15	-0.70	.48	.26	.23
October	2.74	0.33	.51	.87	.32
November	1.48	0.22	.60	1.09	.74

* Rainfall less than .10 inch and substantial previous storm day run-off.

** Excess above dry weather average flow on days of rainfall exceeding .10 and successive days with total flow greater than 150% average dry weather flow.

*** Total rainfall on days exceeding 0.10 inch rainfall.

TABLE F

HYDRAULIC ELEMENTS OF PIPELINE

(Gravity Flow)

Using: n = 0.012 Cast Iron pipe, good condition
s = 0.00093, average slope computed from observed velocities

From: Nomograph of Kutter's formula for circular pipes flowing full[5]

Q = 2.53 cfs
V = 1.85 fps
D = Depth of flow
d = Pipe diameter (16 inches)

Hydraulic Elements Chart

Depth (D) (in.)	D/d	Flow (Q) (cfs)	Flow (Q) (MGD)	Velocity (fps)	Elapsed Time (sec.)	Elapsed Time (min.)
16	1.00	2.53	1.64	1.85	6,235	104
14	.875	2.71	1.75	2.07	5,572	93
13	.813	2.48	1.60	2.09	5,519	92
12	.75	2.30	1.49	2.07	5,572	93
10	.625	1.80	1.16	2.03	5,682	95
8	.50	1.26	0.81	1.85	6,235	104
6	.375	0.76	0.49	1.61	7,165	119
4	.250	0.33	0.21	1.22	9,455	158
2	.125	0.08	0.05	0.78	14,788	246

TABLE G

SETTLEABLE SOLIDS

September 1948

Date 1948	Time	Settleable Solids (ml/L)**			
		MH*	PE*	FE*	SE*
9-1	0730	0.7	0.1	0.4	0.0
	1815	0.9	0.2	0.2	0.0
9-2	0635	0.2	0.1	0.6	0.0
	1000	12.0	0.2	0.2	0.0
	1800	0.8	0.1	0.1	0.0
9-3	0615	0.2	0.1	1.5	0.0
	1000	13.0	0.1	0.2	0.0
	1800	0.8	0.1	0.2	0.0
9-4	0600	0.2	0.0	-	0.0
	1000	-	0.0	-	0.0
	1800	5.0	0.0	1.0	0.0
9-5	0600	0.3	0.1	-	0.0
	1000	5.0	-	0.6	0.0
	1800	7.0	0.0	1.5	0.0
9-6	0600	0.4	0.0	0.2	0.5
	1000	10.0	0.0	0.15	0.0
	1800	6.0	0.1	0.5	0.0
9-7	0600	0.4	0.1	0.2	0.5
	1000	14.0	0.0	0.1	0.0
	1800	7.5	0.1	0.6	0.0
9-8	0600	0.3	0.05	0.0	0.0
	1000	11.0	0.0	0.1	0.0
	1800	8.0	0.0	0.2	0.1
9-9	0600	1.5	0.05	0.15	0.0
	1800	6.0	0.0	0.1	0.0
9-10	0600	1.0	0.0	0.2	0.0
	1000	10.0	0.0	0.1	0.0
	1800	4.5	0.0	1.5	0.0
9-11	0600	0.2	0.1	0.5	0.0
	1800	0.5	0.1	0.2	0.0

* Sampling Point - MH - Receiving Manhole
PE - Primary Clarifier Effluent
FE - Filter Effluent
SE - Secondary Clarifier Effluent

** Settleable Solids - 2 hour detention, Imhoff Cone

TABLE G

SETTLEABLE SOLIDS

September 1948 (cont.)

Date 1948	Time	Settleable Solids (ml/L)**			
		MH*	PE*	FE*	SE*
9-12	0600	0.1	0.0	0.5	0.0
	1000	7.0	0.1	0.2	0.0
	1800	0.4	0.0	0.1	0.0
9-13	0600	0.1	0.0	0.0	0.0
9-14	0600	0.2	0.0	0.1	0.0
9-15	0600	0.1	0.0	0.0	0.0
	1000	6.5	0.1	0.1	0.0
	1800	4.5	0.0	0.2	0.0
9-16	0700	0.5	0.0	0.0	0.0
	1800	5.0	0.1	0.0	0.0
9-17	0630	0.1	0.0	0.0	0.0
	1800	0.5	0.1	0.2	0.0
9-18	0630	0.4	0.0	0.3	0.0
9-19	0630	0.7	0.0	0.3	0.0
	1800	5.0	0.0	0.2	0.0
9-20	0630	0.5	0.0	0.0	0.0
	1800	6.0	0.2	0.1	0.0
9-21	0700	0.5	0.1	0.1	0.0
9-22	0700	0.4	0.0	0.3	0.0
	1800	5.0	0.1	0.2	0.0
9-23	0630	0.6	0.1	0.0	0.0
	1800	5.0	0.2	0.0	0.0
9-24	0700	0.4	0.1	0.0	0.0
	1800	6.0	0.2	0.3	0.0
9-25	1000	5.0	0.1	0.2	0.0
	1700	6.0	0.0	0.1	0.0
9-26	0700	1.5	0.0	0.0	0.0
	1800	6.0	0.1	0.0	0.0
9-27	0630	0.4	-	-	-
	1800	6.5	-	-	-
9-28	0630	0.8	-	-	-
	1800	5.0	-	-	-
9-29	0600	0.2	-	-	-
	1800	5.0	-	-	-
9-30	0600	0.2	-	-	-
	1800	6.0	-	-	-

* Sampling Point - MH - Receiving Manhole
PE - Primary Clarifier Effluent
FE - Filter Effluent
SE - Secondary Clarifier Effluent
** Settleable Solids - 2 hour detention, Imhoff Cone

TABLE G

SETTLEABLE SOLIDS AND pH VALUES

January - February 1949

Date 1949	Time	Settleable Solids (ml/L)** MH*	PE*	FE*	SE*	pH*** MH*	SE*
1-9	1000	0.5	0.0	0.5	0.0	-	-
	1700	8.0	0.0	0.5	0.1	-	-
1-10	1700	7.5	0.1	0.2	0.1	-	-
1-11	1000	10.0	0.0	0.1	0.0	-	-
	1700	8.0	0.1	0.0	0.0	-	-
1-12	1000	10.0	0.3	0.2	0.0	-	-
	1800	7.5	0.0	0.1	0.0	-	-
1-13	1000	13.0	0.0	0.5	0.1	-	-
	1700	10.5	0.0	0.1	0.1	-	-
1-14	1000	11.0	0.0	0.2	0.1	-	-
	1700	8.5	0.3	0.2	0.0	-	-
1-15	1000	10.0	0.0	0.1	0.2	-	-
	1700	5.0	0.0	0.3	0.2	-	-
1-16	0700	0.3	0.0	-	-	-	-
	1100	-	-	-	-	-	-
1-17	0700	0.1	0.0	-	-	-	-
	1100	16.5	0.0	0.3	0.3	-	-
1-18	0700	0.1	0.0	-	-	-	-
	1100	12.0	0.0	0.8	0.6	-	-
1-19	0700	0.0	0.0	-	-	-	-
	1100	12.0	0.1	0.9	0.0	-	-
1-20	0700	0.5	0.0	-	-	-	-
	1100	9.5	0.1	0.4	0.1	-	-
1-21	0700	0.1	0.0	-	-	-	-
	1100	16.0	0.0	0.6	0.1	-	-
1-22	0700	1.0	0.3	-	-	-	-
	1100	6.0	0.4	0.5	0.3	-	-
2-20	1000	-	-	-	-	7.2	-
	1500	-	-	-	-	7.4	-
	1900	-	-	-	-	7.4	-
2-21	1900	-	-	-	-	7.4	-
2-26	1000	-	-	-	-	7.4	-
2-27	1000	-	-	-	-	7.2	-
	1500	-	-	-	-	7.2	-
	1900	-	-	-	-	7.4	-
2-28	1000	-	-	-	-	7.4	-
	1500	-	-	-	-	7.4	-
	1900	-	-	-	-	7.4	-

* Sampling Points - MH - Receiving Manhole; PE - Primary Clarifier Effluent; FE - Filter Effluent; SE - Secondary Clarifier Effluent

** Settleable Solids - 2 hour detention, Imhoff Cone

*** pH - Colorimetric

TABLE G

SETTLEABLE SOLIDS AND pH VALUES

March - April 1949

Date 1949	Time	Settleable Solids (ml/L)**				pH***	
		MH*	PE*	FE*	SE*	MH*	SE*
3-1	1000	-	-	-	-	7.2	-
	1500	-	-	-	-	7.4	-
	1900	-	-	-	-	7.4	-
3-5	1000	-	-	-	-	7.2	-
3-8	1000	10.5	-	-	0.0	7.0	7.6
3-9	1000	10.0	-	-	0.1	7.2	7.4
3-11	1000	8.5	-	-	1.5	-	-
3-12	0900	9.0	-	-	0.1	7.4	7.6
3-15	1000	18.0	-	-	0.5	7.0	7.4
3-17	1000	17.0	-	-	0.2	7.1	7.2
3-19	1000	12.0	-	-	0.1	7.2	7.4
3-22	1000	22.0	-	-	0.1	7.2	7.4
3-24	1100	5.0	-	-	0.1	-	-
3-29	1000	8.0	-	-	0.2	-	-
3-31	1000	16.0	-	-	0.1	-	-
4-2	1000	10.5	-	-	0.1	-	-
4-5	1000	15.0	-	-	0.0	-	-
4-7	1000	9.0	-	-	0.0	-	-
4-9	1000	6.0	-	-	0.0	-	-
4-12	1000	13.0	-	-	0.7	-	-
4-14	1230	1.4	-	-	0.5	-	-
4-16	1000	6.5	-	-	0.0	-	-
4-19	1000	14.0	-	-	0.4	-	-
4-23	1000	10.00	-	-	0.2	-	-
4-26	1000	12.5	-	-	0.1	-	-

* Sampling Points - MH - Receiving Manhole
PE - Primary Clarifier Effluent
FE - Filter Effluent
SE - Secondary Clarifier Effluent

** Settleable Solids - 2 hour detention, Imhoff Cone

*** pH - Colorimetric

TABLE G

SETTLEABLE SOLIDS AND pH VALUES

May - June 1949

Date 1949	Time	Settleable Solids (ml/L)**				pH***	
		MH*	PE*	FE*	SE*	MH*	SE*
5-7	1000	10.0	-	-	0.0	-	-
5-10	1000	7.0	-	-	0.0	-	-
5-11	0900	-	-	-	-	7.2	7.7
5-12	1000	10.00	-	-	0.1	-	-
5-14	1000	13.0	-	-	0.0	7.2	7.4
5-17	1245	10.0	-	-	0.1	7.2	7.4
5-19	1000	10.0	-	-	0.0	7.1	7.3
5-21	1000	13.0	-	-	0.1	7.2	7.3
5-24	1100	19.0	-	-	0.1	7.4	7.4
5-26	1000	15.0	-	-	0.2	7.3	7.2
5-28	1000	15.1	-	-	0.1	7.4	7.4
5-31	1030	13.0	-	-	0.1	7.2	7.4
6-2	1000	10.0	-	-	0.0	7.2	7.4
6-4	1000	7.0	-	-	0.1	7.1	7.2

* Sampling Points - MH - Receiving Manhole
PE - Primary Clarifier Effluent
FE - Filter Effluent
SE - Secondary Clarifier Effluent

** Settleable Solids - 2 hour detention, Imhoff Cone

*** pH - Colorimetric

TABLE G

SETTLEABLE SOLIDS AND pH VALUES

July 1949

Date	Settleable Solids (ml/L)** (10:30 a.m.)			pH*** (10:30 a.m.)			
	MH*	PE*	SE*	MH*	PE*	FE*	SE*
1							
2							
3							
4	15.0	0.6	0.2	7.0	7.0		7.2
5							
6	16.0	0.6	0.0	7.0	7.1		7.4
7							
8	15.0	0.5	0.0	7.0	7.1		7.2
9	10.0	4.0	0.0	7.2	7.0		7.4
10							
11	7.0	0.0	0.1	7.2	7.1		7.6
12	11.0		0.1	7.2			7.4
13				6.8	7.0		7.2
14	7.5		0.0	7.2			7.4
15	14.0	0.3	0.1	6.8	7.0		7.4
16							
17	9.5		0.0	7.4			7.6
18	10.0	0.2	0.0	6.8	7.0		7.4
19			0.1				7.3
20							
21	6.0	0.3	0.2	7.2	7.2	7.4	7.3
22						7.2	
23							
24							
25	10.0	0.3	0.3	7.0	7.2		7.2
26							
27							
28							
29	8.0	0.6	0.0	6.8	7.0		7.2
30							
31	6.0		0.2	7.2			7.3

* Sampling Points - MH - Receiving Manhole
PE - Primary Clarifier Effluent
FE - Filter Effluent
SE - Secondary Clarifier Effluent

** Settleable Solids - 2 hour quiescent settling

*** pH - Colorimetric

TABLE G

SETTLEABLE SOLIDS AND pH VALUES

August 1949

Date	Settleable Solids (ml/L)** (10:30 a.m.)			pH*** (10:30 a.m.)		
	MH*	PE*	SE*	MH*	PE*	SE*
1	15.0	0.1	0.0	7.0	7.4	7.4
2						
3	10.0	0.3	0.0	6.8	7.0	7.5
4						
5	10.0	0.3	0.0	6.8	7.2	7.4
6						
7						
8						
9						
10						
11						
12	11.0		0.1	7.0		7.4
13						
14	8.0	0.3	0.3	7.2	7.2	7.4
15						
16	13.0	0.1	0.1	7.0	7.2	7.4
17						
18	12.5	0.1	0.0	7.2	7.4	7.4
19						
20	10.0	0.0	0.0	7.0	7.2	7.4
21						
22	11.5	0.1	0.1	7.2	7.2	7.4
23						
24						
25						
26	8.0	0.1	0.1	7.2	7.2	7.4
27						
28	5.0	0.1	0.0	7.0	7.3	7.4
29	4.5	0.1	0.0	7.2	7.2	7.4
30	5.0	0.1	0.0	7.2	7.2	7.4
31	6.5	0.0	0.0	7.2	7.3	7.4

* Sampling Points - MH - Receiving Manhole
PE - Primary Clarifier Effluent
SE - Secondary Clarifier Effluent

** Settleable Solids - 2 hour quiescent settling.

*** pH - Colorimetric

TABLE G

SETTLEABLE SOLIDS AND pH VALUES

September 1949

Date	Settleable Solids (ml/L)** (10:30 a.m.)			pH*** (10:30 a.m.)		
	MH*	PE*	SE*	MH*	PE*	SE*
1						
2	9.5	0.1	0.0	7.0	7.2	7.4
3						
4						
5	6.5	0.3	0.1	6.8	7.2	7.3
6	16.0	0.3	0.0	7.0	7.2	7.4
7	9.5	0.4	0.1	7.0	7.2	7.4
8						
9	4.0	0.1	0.0	7.1	7.2	7.4
10						
11	3.0	0.0	0.0	7.0	7.2	7.4
12	3.5	0.1	0.0	7.0	7.2	7.4
13				7.2	7.2	7.4
14	8.0	0.4	0.1	7.0	7.2	7.4
15	5.0	0.1	0.0	7.0	7.2	7.4
16	7.2	0.2	0.0	7.0	7.2	7.4
17						
18						
19				6.8	7.0	7.4
20						
21	6.0	0.1	0.0	7.0	7.2	7.4
22						
23	12.5	0.4	0.1	6.8	7.0	7.3
24						
25						
26						
27	13.0	0.1	0.0	7.0	7.2	7.4
28						
29	13.0	0.2	0.1	7.0	7.2	7.4
30						

* Sampling Points - MH - Receiving Manhole
PE - Primary Clarifier Effluent
SE - Secondary Clarifier Effluent

** Settleable Solids - 2 hour quiescent settling

*** pH - Colorimetric

TABLE G

SETTLEABLE SOLIDS AND pH VALUES

October 1949

Date	Settleable Solids (ml/L)** (10:30 a.m.)			pH*** (10:30 a.m.)		
	MH*	PE*	SE*	MH*	PE*	SE*
1						
2						
3	14.0	0.5	0.1	6.8	7.0	7.4
4						
5						
6						
7	13.5	0.4	0.0	6.8	7.2	7.4
8						
9						
10	10.5	0.3	0.0	7.0	7.2	7.6
11						
12	10.0	0.2	0.0	7.0	7.4	7.7
13	10.0	0.5	0.2	7.0	7.2	7.4
14	14.0	0.3	0.2	7.0	7.2	7.3
15						
16	5.0	0.0	0.0	7.0	7.2	7.4
17						
18	16.0	0.1	0.0	7.0	7.3	7.6
19						
20	10.5	0.2	0.1	7.0	7.2	7.4
21						
22						
23	5.0	0.2	0.0	7.0	7.2	7.6
24						
25						
26	11.0	0.2	0.0	7.4	7.6	7.6
27						
28						
29						
30	2.5	0.4	0.3	7.2	7.4	7.6
31						

* Sampling Points - MH - Receiving Manhole
PE - Primary Clarifier Effluent
SE - Secondary Clarifier Effluent
** Settleable Solids - 2 hour quiescent settling
*** pH - Colorimetric

TABLE G

SETTLEABLE SOLIDS AND pH VALUES

November 1949

	Settleable Solids (ml/L)** (10:30 a.m.)			pH*** (10:30 a.m.)		
Date	MH*	PE*	SE*	MH*	PE*	SE*
1						
2	10.0	0.0	0.0	7.2	7.3	7.6
3	10.0	0.2	0.0			
4				7.1	7.2	7.3
5						
6	0.3	0.3	0.0	7.2	7.4	7.6
7	8.0	0.1	0.0	7.2	7.4	7.6
8	10.5	0.2	0.0	7.2	7.4	7.6
9						
10						
11	9.0	0.1	0.0	7.2	7.4	7.6
12						
13	0.5	0.1	0.0	7.3	7.4	7.6
14	10.5	0.3	0.0	7.2	7.3	7.6
15						
16	8.0	0.1	0.0	7.2	7.2	7.8
17						
18	10.0	0.3	0.0	7.0	7.3	7.8
19						
20						
21	12.0	0.2	0.0	7.2	7.4	7.8
22						
23	8.0	0.1	0.0	7.4	7.0	7.8
24						
25	12.0	0.2	0.0	7.2	7.4	7.6
26						
27				7.0		
28						
29						
30	8.0	0.1	0.0	7.0	7.3	7.6

* Sampling Points - MH - Receiving Manhole
PE - Primary Clarifier Effluent
SE - Secondary Clarifier Effluent

** Settleable Solids - 2 hour quiescent settling

*** pH - Colorimetric

TABLE H

RAW SEWAGE - HOURLY VARIATION OF SETTLEABLE SOLIDS

January 23 - 29, 1949

Time	Settleable Solids (ml/L)**						
	Sun.	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.
	Jan. 23	Jan. 24	Jan. 25	Jan. 26	Jan. 27	Jan. 28	Jan. 29
0700	0.05	0.2	0.5	0.1	-	0.1	0.2
0800	0.1	2.5	10.0	2.0	2.5	2.0	3.0
0900	2.5	3.5	4.0	5.0	5.0	11.0	2.5
1000	9.5	9.0	12.5	9.5	14.5	8.5	7.0
1100	2.5	8.0	10.0	9.0	8.5	7.5	9.5
1200	4.0	10.5	7.5	9.0	6.0	8.5	5.0
1300	7.0	15	3.5	5.0	4.5	4.0	5.0
1400	5.0	4.5	4.0	5.5	3.0	5.5	6.0
1500	5.0	6.0	7.0	8.0	10.0	9.0	3.0
1600	2.0	3.0	8.0	5.0	5.0	4.0	3.5
1700	5.0	2.0	3.0	6.0	3.0	7.0	11.0
1800	2.0	4.0	1.0	2.5	4.0	3.0	3.0
1900	5.0	5.0	8.5	7.0	8.0	8.0	3.0
2000	1.0	3.0	2.0	2.0	3.0	2.0	2.5

** Settleable Solids: (ml/L) 2 hours, Imhoff Cone.

TABLE I

RAW SEWAGE - DAILY VARIATION OF SETTLEABLE SOLIDS

October 1948 - March 1949

Time	Settleable Solids (ml/L)**						
	Sun.	Mon.	Tue.	Wed.	Thur.	Fri.	Sat.
	Oct. 3	Oct. 4	Oct. 5			Oct. 1	Oct. 2
0700	0.5	-	1.0	-	-	0.2	1.5
1800	6.0	5.0	-	-	-	5.0	-
		Dec. 6	Dec. 7	Dec. 8	Dec. 9	Dec. 10	Dec. 11
1000	-	-	8.0	9.0	9.0	7.0	6.5
1800	-	6.0	6.0	5.5	-	6.0	7.0
	Jan. 9	Jan. 10	Jan. 11	Jan. 12	Jan. 13	Jan. 14	Jan. 15
1000	0.5	-	10.0	10.0	13.0	11.0	10.0
1700	8.0	7.5	8.0	7.5	10.5	8.5	5.0
	Jan. 16	Jan. 17	Jan. 18	Jan. 19	Jan. 20	Jan. 21	Jan. 22
0700	0.3	0.1	0.1	0.0	0.5	0.1	1.0
1100	-	16.5	12.0	12.0	9.5	16.0	6.0
	Jan. 30	Jan. 31	Feb. 1	Feb. 2	Feb. 3	Feb. 4	Feb. 5
1000	2.0	8.0	8.0	5.5	10.0	9.0	4.5
1500	4.5	5.0	5.5	7.5	8.0	7.0	5.0
1900	6.5	8.5	6.0	5.0	4.5	4.5	6.0
	Feb. 6	Feb. 7	Feb. 8	Feb. 9	Feb. 10	Feb. 11	Feb. 12
1000	0.5	4.5	9.0	6.0	19.5	-	8.5
1500	3.0	4.0	12.0	8.5	10.5	15.0	10.0
1900	4.5	6.0	4.0	5.5	3.0	6.5	6.0
	Feb. 13	Feb. 14	Feb. 15	Feb. 16	Feb. 17	Feb. 18	Feb. 19
1000	1.5	17.0	15.0	13.5	12.0	8.0	8.0
1500	-	9.0	10.0	10.0	-	9.5	9.0
1900	5.0	6.5	6.0	-	-	4.5	7.5
	Feb. 20	Feb. 21	Feb. 22	Feb. 23	Feb. 24	Feb. 25	Feb. 26
1000	1.0	-	-	-	-	-	8.5
1500	6.0	-	-	-	-	-	6.0
1900	4.5	5.0	-	-	-	-	4.5
	Feb. 27	Feb. 28	Mar. 1	Mar. 2	Mar. 3	Mar. 4	Mar. 5
1000	2.0	10.5	14.0	12.5	10.5	11.0	10.0
1500	4.5	9.0	10.5	11.0	9.0	-	-
1900	5.0	7.0	7.5	6.0	5.5	-	-

** Settleable Solids: (ml/L) 2 hours, Imhoff Cone.

TABLE J

SUSPENDED AND DISSOLVED SOLIDS

	Suspended Solids (ppm)*				Dissolved Solids (ppm)			
Date.	1-22-49		1-29-49		1-22-49		1-29-49	
Time.	5:20 P.M.		11:30 A.M.		5:20 P.M.		11:30 A.M.	
	Vol.**	Inert	Vol.	Inert	Vol.	Inert	Vol.	Inert
Sampling Point								
Pump House	123	4	-	-	596	137	-	-
Receiving Manhole	-	-	133	37	-	-	185	278
Secondary Return	-	-	88	33	-	-	163	227
Primary Influent	-	-	140	33	-	-	888	103
Primary Effluent	-	-	52	25	-	-	144	244
Filter Effluent	-	-	9	30	-	-	144	218
Secondary Effluent	-	-	18	2	-	-	144	216

	Dissolved and Suspended Solids (ppm)							
Date.	1-22-49		1-29-49		2-9-49		2-16-49	
Time.	5:20 P.M.		11:30 A.M.		11:00 A.M.		11:00 A.M.	
	Vol.	Inert	Vol.	Inert	Vol.	Inert	Vol.	Inert
Sampling Point								
Pump House	719	141	-	-	-	-	-	-
Receiving Manhole	-	-	318	315	-	-	-	-
Secondary Return	-	-	251	260	-	-	-	-
Primary Influent	-	-	1028	136	736	608	284	440
Primary Effluent	-	-	196	269	304	144	212	320
Filter Effluent	-	-	153	248	296	226	116	344
Secondary Effluent	-	-	162	218	236	192	84	304

* Suspended Solids - Gooch crucible method.
** Vol. - Volatile component of dried solids.

TABLE K

RELATIVE STABILITY OF SEWAGE

September 1948

Date 1948	Time	Relative Stability (%)* Man-hole	Primary Effluent	Filter Effluent	Secondary Effluent
9-1	0620	98%	6%	2%	5%
	1800	*	*	15	60
9-2	0630	89	10	99	83
	1000	3	17	99	99
	1730	*	*	14	50
9-3	0640	33	9	16	99
	1000	2	6	99	99
	1800	*	*	21	64
9-4	0600	73	4	-	33
	1000	5	8	-	-
	1800	*	*	*	-
9-5	0600	97	4	-	-
	1000	-	16	99	78
	1800	*	*	79	97
9-6	0600	16	9	17	99
	1000	-	-	47	-
	1800	*	*	-	99
9-7	0600	25	8	99	99
	1800	*	*	82	55
9-8	0630	41	16	16	99
	1000	5	7	23	66
	1800	5	5	*	55
9-9	0600	45	7	99	95
	1700	5	5	99	99
9-10	0600	41	16	99	99
9-12	0600	80	10	99	99
	1700	*	*	99	99
9-13	0600	47	-	99	99
9-16	0700	47	16	99	99
9-20	1700	52	11	99	97
9-21	1700	20	-	*	99
9-26	1700	-	-	-	99
9-27	1700	-	-	-	99

* Methylene-blue decolorized in absence of observer between 10:00 P.M.-6:00 A.M.
(Relative Stability range 3 - 10%)

TABLE K

RELATIVE STABILITY OF SEWAGE

October - November 1948

Date 1948	Time	Relative Stability (%)* Man-hole	Primary Effluent	Filter Effluent	Secondary Effluent
10-6	1800	-	30%	30%	99%
10-10	1800	*	*	*	47
10-12	1800	33	30	99	99
10-19	0800	33	6	99	-
11-6	0800	16	16	99	99
11-13	0900	9	9	99	99
11-14	1300	8	8	99	99
11-16	1300	12	2	97	99
11-17	1700	16	16	96	99
11-22	0800	16	16	99	99

* Methylene-blue decolorized in absence of observer between 10:00 P.M.-6:00 A.M.
(Relative Stability range 3 - 10%)

TABLE K

RELATIVE STABILITY OF SEWAGE

December 1948

Date 1948	Time	Relative Stability (%)* Man-hole	Primary Effluent	Filter Effluent	Secondary Effluent
12-6	1000	16%	16%	99%	99%
	1700	*	*	55	67
12-7	1000	16	16	99	99
	1700	*	*	80	*
12-8	1000	16	16	98	98
	1700	*	*	98	99
12-9	1000	9	16	97	98
12-10	1000	16	7	97	97
	1700	*	30	78	*
12-11	1000	7	16	97	97
	1700	*	-	-	97
12-12	1000	16	16	96	96
	1700	*	*	96	96
12-13	0800	-	9	96	-
	2000	-	-	-	96
12-14	0800	-	16	-	-
	2000	64	-	-	-
12-17	0800	21	73	-	-
12-19	0900	98	66	-	-
12-28	0900	90	37	-	-
	1700	15	12	-	-
12-29	0900	-	21	-	-
12-31	1000	52	37	-	-
	1700	33	-	-	-

* Methylene-blue decolorized in absence of observer between 10:00 P.M.- 6:00 A.M.
(Relative Stability range 3 - 10%)

TABLE K

RELATIVE STABILITY OF SEWAGE

January 1949

Date 1949	Time	Relative Stability (%)* Man-hole	Primary Effluent	Filter Effluent	Secondary Effluent
1-1	1000	76%	-	-	-
1-9	0700	99	13%	99%	99%
	1100	16	16	99	99
	1800	4	4	99	99
1-10	0700	92	16	99	99
	1800	22	3	64	91
1-11	0700	40	13	99	99
	1100	4	4	99	99
	1800	3	3	99	89
1-12	0700	79	16	99	99
1-13	0700	-	9	99	99
	1100	5	5	99	99
	1800	*	2	91	99
1-14	0700	96	16	99	99
	1100	2	2	99	99
	1800	*	*	98	99
1-15	0700	-	9	99	99
	1100	5	5	99	99
	1800	*	*	99	99
1-16	1800	*	-	-	99
1-17	1100	4	-	-	99
	1800	*	-	-	99
1-18	1100	3	-	-	86
	1800	*	-	-	99
1-19	1100	1	-	-	99
	1800	*	-	-	99
1-20	1100	7	-	-	-
1-21	1100	2	-	-	-
	1800	*	-	-	-
1-22	1100	19	-	-	-
1-23	1300	-	-	-	99
1-24	1400	-	-	-	99
1-25	1300	-	-	-	99
1-26	1300	-	-	-	99
1-27	1300	-	-	-	99
1-29	1400	-	-	-	98

* Methylene-blue decolorized in absence of observer between 10:00 P.M.-6:00 A.M.
(Relative Stability range 3 - 10%)

TABLE K

RELATIVE STABILITY OF SEWAGE

February - September 1949

Date	Time	Relative Stability (%)*			
		Man-hole	Primary Effluent	Filter Effluent	Secondary Effluent
1949					
2-5	1000	-	-	-	99%
2-15	1300	-	-	-	99
2-16	1230	-	-	-	99
2-20	1200	-	-	-	99
2-27	1200	-	-	-	80
3-15	1000	16%	-	-	97
3-17	1000	18	-	-	57
3-19	1000	16	-	-	99
3-22	1000	5	-	-	99
3-24	1100	22	-	-	99
3-29	1000	18	-	-	99
3-31	1000	27	-	-	80
4-5	1000	4	-	-	99
4-7	1000	18	-	-	99
4-9	1000	18	-	-	99
4-12	1000	8	-	-	99
4-14	1230	2	-	-	99
4-16	1000	24	-	-	99
4-26	1000	-	-	-	99
5-10	1000	22	-	-	99
5-12	1200	-	-	-	99
5-17	1245	44	-	-	99
5-19	1020	16	-	-	99
5-21	1000	16	-	-	99
5-24	1100	4	-	-	99
5-26	1000	2	-	-	99
5-28	1000	16	-	-	99
5-31	1030	16	-	-	99
6-2	1000	16	-	-	99
6-4	1000	2	-	-	99

TABLE K

RELATIVE STABILITY OF SEWAGE

February - September 1949 (cont.)

Date 1949	Time	Relative Stability (%)*			
		Man-hole	Primary Effluent	Filter Effluent	Secondary Effluent
9-6	1030	4%	6%	-	-
	1200	-	-	99%	99%
	1300	4	-	-	-
	1400	-	-	99	99
	1500	-	-	-	-
	1600	-	-	99	99

* (Relative Stability range 3 - 10%)

TABLE L

BIOCHEMICAL OXYGEN DEMAND

July - September 1949

Date	Time	B.O.D. (ppm)*					
		PH	MH	PI	PE	FE	SE
7-7	1000	-	40.0**	-	-	-	-
	1300	-	-	-	-	-	15.2
7-12	1000	-	144	-	-	-	-
	1030	-	-	-	-	-	10.4
7-14	1130	-	186	-	-	-	-
7-31	1040	-	-	-	-	-	1.2
8-1	1000	-	-	-	38	-	-
8-6	1220	-	-	94	-	-	-
8-12	1040	-	109.2	-	-	-	-
	1220	-	-	-	-	-	25.4
	1540			254.0****			
8-28	0900		76	-	-	-	-
9-8	0930		-	80	-	-	-
	1020		-	-	24	-	-
	1045		-	-	-	13.6	-
	1130		-	-	-	-	3.2
9-11	0930		76	-	-	-	-
9-15	1140	144	-	-	-	-	-
	1315		160	144	80	18.4	8.4
	1515		-	-	76	-	-
9-21	1120	100	-	-	-	-	-
	1225		100	80	105	21	5
9-29	0900	345**	-	-	-	-	-
	1045		355**	350**	-	-	-
	1145		-	-	227	-	-
	1215		-	-	-	45	-
	1245		170	125	-	-	15.3**

* Biochemical Oxygen Demand (5-day, 20 °C.).
** 100% Oxygen depletion in dilution, B.O.D. greater than given value.
*** Following prolonged rainfall, high storm water flow.
**** High rate of supernatant return.

TABLE L

BIOCHEMICAL OXYGEN DEMAND

October - November 1949

Date	Time	B.O.D. (ppm)*					
		PH	MH	PI	PE	FE	SE
10-5	1115		140	-	-	-	10.9
10-10	1000		230	-	-	-	-
	1045		-	-	-	-	6.8
	1200		300	-	-	-	-
10-17	0920	-	120	-	-	-	-
	1030	-	-	-	-	-	8.4
	1000	-	-	-	-	11.2**	-
10-18	0645	236	-	-	-	-	-
	0900	-	256**	120	24	26	5.4
	1030	-	270	200	193	49	3.5
	1200	-	250	150	160	48	14.0**
	1330	-	140	160	80	37	11.3**
	1500	-	60	30	50	33	9.5**
11-10	0830	210	-	-	-	-	-

* B.O.D. (5-day, 20 °C.).
** 100% Oxygen depletion in dilution, B.O.D. greater than given value.

TABLE M

PRE-CHLORINATION RESIDUAL

July - September 1949

Date 1949	Time	Incoming Flow (MGD)	Detention Period (hrs.)	Pre-Chlorination Residual (ppm)* Primary Clarifier Effluent
7-11	1500	0.75	3.4	0.00
7-15	1500	0.85	3.0	0.10
7-18	1500	1.25	2.0	0.10
7-21	1030	1.05	2.4	0.15
7-25	1500	0.75	3.4	0.10
7-29	1500	0.60	4.2	0.20
8-1	1000	0.70	3.6	0.05
	1500	0.60	4.2	0.10
8-3	1500	0.85	3.0	0.10
8-12	1300	0.65	3.9	0.10
8-16	1100	1.20	2.1	0.20
9-4	1100	0.65	3.9	0.10

* Chlorine Residual — Colorimetric (Orthotolidine)

TABLE N

POST-CHLORINE DEMAND AND CHLORINE RESIDUAL

February - June 1949

Date	Time	Chlorine Demand*(ppm)		Chlorine Residual**(ppm)
1949		Trickling Filter Effluent	15 min. Contact Residual	Secondary Clarifier Effluent
2-7	1300	4.0	0.65	-
2-8	0700	3.0	0.5	-
	1100	5.0	0.6	-
2-9	0700	3.0	0.5	-
	1100	4.0	0.75	-
2-10	0700	2.0	0.5	-
	1100	3.0	0.6	-
2-11	0700	3.0	1.0	-
	1100	3.0	0.5	-
2-12	0700	3.0	0.75	-
	1100	3.0	0.5	-
2-13	0700	2.0	0.5	-
	1100	3.0	0.75	-
2-14	0700	3.0	0.5	-
	1100	4.0	0.75	-
2-15	0700	3.0	0.5	-
	1100	4.0	0.75	-
2-16	0700	3.0	0.5	-
	1100	4.0	0.5	-
3-9	1400	5.0	0.5	-
3-12	0900	-	-	0.35
3-15	1000	-	-	0.00
3-19	1000	-	-	0.15
5-16	0900	3.0	0.75	-
5-17	1300	-	-	0.0
5-21	1000	-	-	0.20
5-24	1100	-	-	0.00
5-26	1000	-	-	0.10
5-31	1000	-	-	0.00
6-2	1000	-	-	0.10
6-4	1000	-	-	0.10

* Chlorine Solution (1 ml = 500 ppm)
** Colorimetric (Orthotolidine)

TABLE N

POST-CHLORINE DEMAND AND CHLORINE RESIDUAL

July - August 1949

Date 1949	Time	Chlorine Demand* (ppm) Trickling Filter Effluent	Chlorine Residual (ppm)** Secondary Clarifier Effluent
7-4	1030	-	0.30
7-6	1000	3.0	0.20
7-8	1030	-	0.30
7-9	1030	-	0.35
7-12	1030	3.0	0.20
7-13	1500	-	0.10
7-14	1130	-	0.30
7-15	1500	-	0.10
7-17	1200	-	0.30
7-19	1000	3.0	0.20
7-21	1000	-	0.30
7-22	0930	3.0	-
7-25	1500	-	0.20
7-29	1500	-	0.30
7-31	1040	3.0	0.10
8-1	1500	-	0.30
8-3	1500	-	0.15
8-12	1300	-	0.10
8-16	1100	-	0.20
8-18	-	-	0.20
8-20	-	-	0.30
8-22	-	-	0.20
8-26	-	-	0.10
8-28	-	-	0.35
8-30	-	-	0.10

* Chlorine Solution (1 ml = 500 ppm)
** Colorimetric (Orthotolidine)

TABLE N

POST-CHLORINE DEMAND AND CHLORINE RESIDUAL

September - November 1949

Date 1949	Chlorine Demand*(ppm) Trickling Filter Effluent	Chlorine Residual**(ppm) Secondary Clarifier Effluent
9-2	-	0.30
9-5	-	0.15
9-6	-	0.15
9-7	-	0.10
9-9	-	0.10
9-11	-	0.15
9-12	-	0.10
9-13	-	0.35
9-15	4.0	0.35
9-20	-	0.10
9-22	-	0.10
9-23	3.0	-
10-7	5.0	0.10
10-13	4.0	0.10
10-14	-	0.30
10-16	-	0.20
10-18	-	0.10
10-20	-	0.10
10-23	4.0	0.10
10-26	-	0.15
10-28	5.0	-
10-30	-	0.20
11-2	-	0.20
11-3	4.0	-
11-4	-	0.15
11-6	-	0.15
11-7	-	0.15
11-8	-	0.35
11-9	-	0.15
11-10	5.0	-
11-11	-	0.20
11-17	4.0	-

* Chlorine Solution (1 ml = 500 ppm)
** Colorimetric (Orthotolidine)

TABLE O

DIGESTER pH VALUES

September 1948

Date 1948	Time	pH Value Digester Level* 1	2	3	4	Supernatant Liquor
9-10	0800	6.4	6.4	6.4	6.4	6.4
9-11	1130	6.4	6.4	6.4	6.4	6.4
	1700	6.4	6.4	6.4	6.4	6.6
9-12	0800	6.4	6.4	6.4	6.4	6.4
	1600	6.4	6.4	6.4	6.6	6.4
9-14	0800	6.4	6.4	6.4	6.4	6.4
	1800	6.6	6.6	6.6	6.4	6.4
9-15	0800	6.6	6.6	6.6	6.4	6.4
	1800	6.6	6.4	6.6	6.6	6.6
9-16	0900	6.6	6.6	6.8	6.8	6.6
	1700	6.4	6.4	6.6	6.4	6.4
9-17	0800	6.6	6.6	6.6	6.6	6.6
	1700	6.4	6.4	6.4	6.6	6.6
9-18	0700	6.4	6.4	6.4	6.4	6.4
9-19	0730	6.6	6.6	6.6	6.6	6.6
	1700	6.6	6.4	6.6	6.6	6.6
9-20	1700	6.6	6.4	6.4	6.4	6.4
9-21	1000	6.6	6.4	6.6	6.6	6.6
	1700	6.6	6.4	6.8	6.6	6.6
9-22	1700	6.6	6.6	6.6	6.6	6.6
9-23	1700	6.6	6.4	6.6	6.6	6.4
9-24	0700	6.6	6.4	6.6	6.6	6.6
	1800	-	6.4	6.4	6.6	6.4
9-25	0900	6.8	6.4	6.4	6.6	6.6
	1800	6.6	6.8	6.8	6.8	6.8
9-28	1020	-	6.6	6.6	6.6	6.6
9-30	0800	6.6	6.6	6.6	6.6	6.6

* Digester Levels (above plant datum elevation): 1, 82 feet; 2, 86 feet; 3, 90 feet; 4, 94 feet.

TABLE O

DIGESTER pH VALUES

October - December 1948

Date	pH Value				
	Digester Level*				Supernatant
1948	1	2	3	4	Liquor
10-1	-	6.6	6.6	6.6	6.6
10-10	6.6	6.6	6.6	6.6	6.6
10-13	-	6.6	6.6	6.6	6.6
10-18	-	6.8	6.8	6.8	-
11-17	-	7.0	7.0	7.0	7.0
12-6	-	7.0	7.0	7.0	7.0
12-7	-	7.0	7.0	7.0	7.0
12-8	-	7.0	7.0	7.0	7.0
12-9	-	7.0	7.0	7.0	7.0
12-10	-	7.0	7.0	7.0	7.0
12-11	-	7.0	7.0	7.0	7.0
12-12	-	-	7.0	7.0	7.0
12-14	-	7.0	7.0	7.0	7.0
12-17	-	7.0	7.0	7.0	7.0
12-18	-	7.0	7.0	7.0	7.0
12-19	-	7.0	7.0	7.0	7.0
12-20	-	7.0	7.0	7.0	7.0
12-21	-	7.0	6.8	7.0	7.0
12-22	-	7.0	7.0	7.0	7.0
12-23	-	6.8	7.0	7.0	7.0
12-24	-	7.0	7.0	7.0	7.0
12-26	-	7.2	7.0	7.0	7.0
12-27	-	7.0	7.0	7.0	7.0
12-28	-	7.2	7.0	7.0	7.0
12-29	-	7.0	7.0	7.0	7.0
12-31	-	7.0	7.2	7.0	7.0

* Digester Levels (above plant datum elevation): 1, 82 feet; 2, 86 feet; 3, 90 feet; 4, 94 feet.

TABLE O

DIGESTER pH VALUES

January - April 1949

Date	pH Value				
	Digester Level*				Supernatant
1949	1	2	3	4	Liquor
1-1	-	7.0	7.0	7.0	7.0
1-2	-	7.0	7.2	7.0	7.2
1-7	-	6.8	6.8	6.8	6.8
1-8	-	6.8	6.8	6.8	7.0
1-9	6.9	6.9	6.8	6.8	6.9
1-11	-	6.8	6.8	6.9	6.8
1-12	6.9	6.8	6.8	6.9	6.9
1-13	6.9	6.8	6.8	6.8	6.8
1-14	-	-	-	-	6.8
1-15	6.9	6.9	6.8	6.8	6.8
1-17	-	6.9	6.8	6.8	6.8
1-18	6.9	6.9	6.8	6.8	6.8
1-19	-	6.9	6.8	6.9	6.8
1-21	-	6.9	6.8	6.8	6.8
2-10	-	-	6.8	6.8	6.8
2-15	-	-	6.8	6.8	6.8
2-19	-	-	6.8	6.8	6.8
2-23	-	-	6.8	6.8	6.8
3-1	-	-	6.8	6.8	6.8
3-6	-	-	6.8	6.8	6.8
3-13	-	-	6.6	6.8	6.8
3-20	-	-	7.0	6.8	7.0
4-11	6.8	-	7.0	7.0	7.0
4-15	-	-	7.0	6.8	6.8
4-23	6.9	6.9	6.9	6.9	6.9
4-29	7.0	7.0	7.0	7.0	7.0

* Digester Levels (above plant datum elevation): 1, 82 feet; 2, 86 feet; 3, 90 feet; 4, 94 feet.

TABLE O

DIGESTER pH VALUES

July - November 1949

Date	pH Value				
	Digester Level*				Supernatant
1949	1	2	3	4	Liquor
7-10	-	-	7.3	-	7.3
7-17	-	7.0	-	-	7.0
7-18	-	-	7.0	-	7.0
7-24	6.8	-	-	-	7.0
7-25	6.8	-	-	-	7.0
8-7	6.8	-	-	-	7.0
8-14	7.0	-	-	-	7.0
8-28	7.0	-	-	-	7.0
9-4	7.0	-	-	-	6.8
9-11	6.8	-	-	-	6.8
9-18	6.8	-	-	-	7.0
9-25	6.8	-	-	-	7.0
10-2	6.8	-	-	-	7.0
10-9	6.8	-	-	-	7.0
10-16	7.0	-	-	-	7.0
10-23	7.0	-	-	-	7.0
10-26	7.0	-	-	-	7.0
10-30	7.0	-	-	-	7.0
11-6	7.0	-	-	-	7.1
11-13	6.8	-	-	-	7.0
11-20	-	-	-	-	7.0
11-27	7.0	-	-	-	-

* Digester Levels (above plant datum elevation): 1, 82 feet; 2, 86 feet; 3, 90 feet; 4, 94 feet.

TABLE P

DIGESTER GAS PRODUCTION

September 1948 - May 1949
Daily Total - 1000 Cubic Feet

	1948		1949				
Date	Sept.	Dec	Jan.	Feb.	Mar.	Apr.	May
1	-	-	-	9.1	10.3	9.6	10.9
2	-	-	-	9.2	10.8	11.0	10.3
3	-	-	-	8.7	12.0a	11.2	9.2a
4	-	-	-	8.8	12.0a	10.4	9.2a
5	6.9	-	-	9.4	10.6	10.6	8.6
6	8.4	-	-	10.9	11.2	11.9	8.5
7	4.5	-	-	9.9	11.4	12.0	9.8
8	7.0	-	-	10.1	12.1	10.3	6.2
9	6.5	-	6.6	10.5	9.9	11.0	6.4
10	9.7	-	6.4	10.7	13.0	12.3	6.8
11	8.3	-	5.4	10.1	13.2a	9.9	8.4a
12	8.0	-	8.3	10.2	13.2a	10.0	8.4a
13	7.5a	-	9.0	11.4	13.3	11.4	9.5
14	7.5a	-	8.9	8.4	12.0	10.4	9.5
15	6.8	-	7.2	11.1	13.0	9.8	9.6
16	6.2	-	6.5	8.4	11.3	9.7	9.3
17	5.7	-	6.2	11.9	10.7	9.2	9.1
18	5.0	-	5.1	8.4	10.0	8.4	10.4
19	5.6	-	7.4	10.8	10.7	7.8	8.1
20	7.5	-	8.3	9.7a	12.5	9.2	8.9a
21	7.5	-	10.7	9.7a	11.6	7.9a	8.9a
22	10.5	5.2	11.0	9.8	12.1	7.9a	9.2
23	9.5	4.8a	8.4	7.7	10.3	10.7	8.7
24	-	4.8a	7.9	8.3	10.8	9.9	8.9
25	-	4.8a	7.0	8.9	10.3	9.8	9.8
26	-	4.8a	7.5	10.5	9.4	9.6	9.5
27	-	4.9a	8.3	10.4	8.0	9.9	10.8
28	-	4.9a	7.8	10.3	7.6a	10.7	8.3
29	-	4.9a	9.1	-	7.6a	11.3	9.1
30	-	4.9a	9.4	-	8.4	10.6	8.8
31	-	4.9a	8.6	-	10.0	-	8.3

TABLE P
DIGESTER GAS PRODUCTION

June - November 1949

Daily Total - 1000 Cubic Feet

Date	June	July	Aug.	Sept.	Oct.	Nov.
1	9.2	4.7	5.0	6.9	7.6	10.1
2	8.8	7.3	5.3a	6.9	8.7	10.3
3	9.8	5.7	5.3a	6.7	8.8	10.7
4	8.2	7.5	5.6	6.3	9.6	10.2
5	10.6	6.4	5.7	6.3	10.7	9.4
6	9.0	7.2	7.8	6.5	11.2a	9.8
7	8.8	7.6	7.0a	5.7	11.2a	10.2
8	9.6a	8.6	7.0a	5.7	10.6	10.3
9	9.6a	7.3	5.8	6.9	10.3	10.1
10	9.6a	6.2	7.2	7.2	9.6	11.0
11	9.5	4.4	6.9	4.9	10.2	10.0
12	8.9a	6.4	7.4	6.0	7.2a	12.6
13	8.9a	6.4	8.4	5.7	7.2a	12.5
14	9.5a	7.3	6.8	6.0	10.7	12.4
15	9.5a	7.2	7.7	5.2	13.1	12.2
16	9.4a	6.3a	7.8	6.4	11.7	11.9
17	9.4a	6.3a	9.9	5.0	10.9	12.1
18	7.7	7.2	7.7	6.3	11.0	11.6
19	5.7	6.7	5.1	6.3	11.9	11.2
20	6.9	6.3	6.5	4.7	12.0	12.2
21	1.6a	6.4	7.0	2.8	12.1	11.5
22	1.6a	7.8	6.5a	5.0	12.8	10.0
23	1.6a	5.5	6.5a	6.7	10.9	12.0
24	1.8a	6.5	6.5a	7.5	12.6	13.5
25	1.8a	5.7	6.4	7.4	9.4	12.6
26	1.7	5.6	6.9	7.8	13.2	12.1
27	1.3a	5.0a	7.3	7.1a	12.3	10.9
28	1.3a	5.0a	7.8	7.1a	11.5	9.8
29	1.3a	5.4a	8.3	7.2a	11.9	8.6
30	1.3a	5.4a	8.6	7.2a	11.1	9.8
31	-	5.1	7.0	-	10.1	-

TABLE Q

DIGESTED SLUDGE WITHDRAWAL - TOTAL AND VOLATILE SOLIDS

Date	Interval*	Bed** - Depth	Sludge Withdrawal			Total Solids		Volatile Solids	
1949	(days)	(in.)	Quantity (cu.ft.)	Sp.Gr.	1000#	%	wt.(#)	%	wt.(#)
1-18	36	C-C-7"	610.8	1.024	39.03	6.79	2,650	46.01	1,219
2-17	29	C-E-7"	623.3	1.017	39.55	6.84	2,705	45.81	1,239
3-8	18	O-W-7"	623.3	1.023*	39.79	6.82*	2,714	42.61*	1,156
3-22	14	C-C-7"	610.8	1.022	38.95	6.14	2,392	45.92	1,098
5-4	41	C-C-7"	610.8	1.021	38.91	6.07	2,362	42.60	1,006
6-15	42	C-E-7"	623.3	1.020	39.67	5.74	2,277	41.55	946
7-20	35	C-C-8"	698.1	1.027	44.73	8.33	3,726	37.74	1,406
7-20	35	O-C-8"	698.1	1.031	44.91	8.11	3,642	38.89	1,416
7-26	6	C-E-8"	712.4	1.023*	45.48	6.82*	3,102	42.61*	1,322
7-26	6	O-E-8"	712.4	1.023*	45.48	6.82*	3,102	42.61*	1,322
8-17	22	O-W-8"	712.4	1.022	45.43	6.52	2,962	42.06	1,246
8-17	22	C-W-8"	712.4	1.024	45.52	6.42	2,922	42.94	1,255
9-1	15	C-E-8"	712.4	1.023*	45.48	6.82*	3,102	42.61*	1,322
9-13	12	O-E-8"	712.4	1.026	45.61	7.28	3,320	42.61	1,415
9-21	8	C-W-8"	712.4	1.023*	45.48	6.82*	3,102	42.61*	1,322
				Avg.* 1.023		Avg.* 6.82%	Total 44,080#	Avg.* 42.61%	Total 18,690#
							Annual		Annual
				Total.			58,773#		24,920#
				Per Capita . .			8.32#		3.53#

* Interval from previous withdrawal.

** Bed designation
First Column - C, Covered
O, Open
Second Column- E, East
C, Center
W, West

TABLE R

SLUDGE DRYING ANALYSES
(% Moisture)

Date - 1949	1-18	2-17	3-22	5-4	6-15	7-20	7-20	8-17	8-17	9-13
Row........	Covered	Covered	Covered	Covered	Covered	Open	Covered	Covered	Open	Open
Bed........	Center	East	Center	Center	East	Center	Center	West	West	East
Depth......	7"	7"	7"	7"	7"	8"	8"	8"	8"	8"
Days										
0	93.21	93.16	93.86	93.93	94.26	91.89	91.67	93.58	93.48	92.72
1	90.53	-	-	-	-	88.01	88.75	-	-	-
2	87.54	-	-	-	-	86.68	85.96	-	-	86.56
3	86.98	-	-	-	-	-	-	-	-	-
4	85.89	-	-	-	-	-	-	-	-	-
5	84.68	-	-	-	-	81.89	79.96	-	-	-
6	84.44	-	-	-	-	-	-	-	-	-
7	83.44	85.52	83.98	75.98	-	-	-	-	-	-
8	-	-	-	-	-	79.82	-	75.95	76.90	78.72
10	81.08	-	-	-	-	-	-	-	-	-
11	-	-	-	-	-	74.07	70.87	-	-	-
14	80.64	80.30	-	*	-	-	-	-	-	-
15	-	-	75.36		-	70.68	69.57	-	-	-
19	-	-	-		-	65.82	51.96	-	-	-
21	78.74	76.14	-		-	-	-	-	-	-
24	-	-	-		-	47.89	26.35	-	-	-
28	74.90	73.13	58.13		-	-	-	27.39	58.10	-
33	-	64.15	-		-	-	-	-	-	-
37	64.98	-	-		-	-	-	-	-	-

* Series discontinued due to accidental backflushing of sludge line onto test bed.

AN INVESTIGATION OF THE OPERATING

CHARACTERISTICS AND EFFICIENCY OF A SMALL

SEWAGE TREATMENT PLANT

by

Ralph Kirkland Longaker

This investigation was primarily a study of the performance of the new sewage treatment plant serving Blacksburg, Virginia and V. P. I. during the initial period of operation, 1948 - 1949.

This plant, designed for a sewage flow of one million gallons per day, provides primary and secondary treatment.

Standard analyses were performed on samples at various stages in the treatment process to determine the efficience of purification afforded by each unit. These tests indicate satisfactory operation of the plant in the reduction of pollutional constituents of the influent sewage. Effects of treated sewage discharged to the receiving stream, Strouble's Creek, were found to be negligible. Performance of the Blacksburg - V. P. I. plant generally equalled that of several other sewage treatment facilities serving populations less than 60,000.

Supplementary studies in this investigation included: the effects of population fluctuation on sewage flow; verification of suspected storm water diversion into the sanitary sewerage system; and the appraisal and correction of operating problems encountered in the initial period of plant operation.