CLEAN WATER WATER POLLUTION CONTROL RESEARCH SERIES 11024DOC08/71

Storm Water Management Model

Volume II—Verification and Testing

ENVIRONMENTAL PROTECTION AGENCY • WATER QUALITY OFFICE

WATER POLLUTION CONTROL RESEARCH SERIES

The Water Pollution Control Research Reports describe the results and progress in the control and abatement of pollution of our Nation's waters. They provide a central source of information on the research, development and demonstration activities of the Water Quality Office of the Environmental Protection Agency, through in-house research and grants and contracts with the Federal, State and local agencies, research institutions, and industrial organizations.

Previously issued reports on the Storm and Combined Sewer Pollution Control Program:

11023 FDB 09/70	Chemical Treatment of Combined Sewer Overflows
11024 FKJ 10/70	In-Sewer Fixed Screening of Combined Sewer Overflows
11024 EJC 10/70	Selected Urban Storm Water Abstracts, First Quarterly Issue
11023 --- 12/70	Urban Storm Runoff and Combined Sewer Overflow Pollution
11023 DZF 06/70	Ultrasonic Filtration of Combined Sewer Overflows
11024 EJC 01/71	Selected Urban Runoff Abstracts, Second Quarterly Issue
11020 FAQ 03/71	Dispatching System for Control of Combined Sewer Losses
11022 EFF 12/70	Prevention and Correction of Excessive Infiltration and Inflow into Sewer Systems - A Manual of Practice
11022 EFF 01/71	Control of Infiltration and Inflow into Sewer Systems
11022 DPP 10/70	Combined Sewer Temporary Underwater Storage Facility
11024 EQG 03/71	Storm Water Problems and Control in Sanitary Sewers - Oakland and Berkeley, California
11020 FAL 03/71	Evaluation of Storm Standby Tanks - Columbus, Ohio
11024 FJE 04/71	Selected Urban Storm Water Runoff Abstracts, Third Quarterly Issue

To be continued on inside back cover...

STORM WATER MANAGEMENT MODEL

Volume II - Verification and Testing

by

Metcalf & Eddy, Inc., Palo Alto, California
University of Florida, Gainesville, Florida
Water Resources Engineers, Inc., Walnut Creek, California

for the

Environmental Protection Agency

Contract No. 14-12-501 Project No. 11024EBI
Contract No. 14-12-502 Project No. 11024DOC
Contract No. 14-12-503 Project No. 11024EBJ

August 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Price $1.50
Stock Number 5501-0108

EPA REVIEW NOTICE

ABSTRACT

A comprehensive mathematical model, capable of representing urban storm water runoff, has been developed to assist administrators and engineers in the planning, evaluation, and management of overflow abatement alternatives.

Hydrographs and pollutographs (time varying quality concentrations or mass values) were generated for real storm events and systems from points of origin in real time sequence to points of disposal (including travel in receiving waters) with user options for intermediate storage and/or treatment facilities. Both combined and separate sewerage systems may be evaluated. Internal cost routines and receiving water quality output assisted in direct cost-benefit analysis of alternate programs of water quality enhancement.

Demonstration and verification runs on selected catchments, varying in size from 180 to 5,400 acres, in four U.S. cities (approximately 20 storm events, total) were used to test and debug the model. The amount of pollutants released varied significantly with the real time occurrence, runoff intensity duration, pre-storm history, land use, and maintenance. Storage-treatment combinations offered best cost-effectiveness ratios.

A user's manual and complete program listing were prepared.

This report was submitted in fulfillment of Projects 11024 EBI, DOC, and EBJ under Contracts 14-12-501, 502, and 503 under the sponsorship of the Environmental Protection Agency.

The titles and identifying numbers of the final report volumes are:

Title	EPA Report No.
STORM WATER MANAGEMENT MODEL Volume I - Final Report	11024 DOC 07/71
STORM WATER MANAGEMENT MODEL Volume II - Verification and Testing	11024 DOC 08/71
STORM WATER MANAGEMENT MODEL Volume III - User's Manual	11024 DOC 09/71
STORM WATER MANAGEMENT MODEL Volume IV - Program Listing	11024 DOC 10/71

CONTENTS

FIGURES

PHILADELPHIA

TABLES

PHILADELPHIA

SECTION 1

INTRODUCTION

SECTION 1

INTRODUCTION

Under the sponsorship of the Environmental Protection Agency a consortium of contractors--Metcalf & Eddy, Inc., the University of Florida, and Water Resources Engineers, Inc.--has developed a comprehensive mathematical model capable of representing urban storm water runoff and combined sewage overflow phenomena. Correctional devices in the form of user selected options for storage and/or treatment are provided with associated estimates of cost. Effectiveness is portrayed by computed treatment efficiencies and modeled changes in receiving water quality.

PRESENTATION FORMAT

The project report is divided into four volumes. This volume, Volume II, "Verification and Testing," describes the methods and results of model application in four urban catchment areas.

Volume I, the "Final Report," contains the background, justifications, judgments, and assumptions used in model development. It further includes descriptions of unsuccessful modeling techniques that were attempted and recommendations for forms of user teams to implement systems analysis techniques most efficiently.

Volume III, the "User's Manual," contains program descriptions, flow charts, instructions on data preparation and program usage, and test examples.

Volume IV, "Program Listing," lists the main program, all subroutines, and JCL as used in the demonstration runs.

SELECTION OF DEMONSTRATION SITES

The selection of demonstration sites was based on five major considerations. First, the availability of data necessary to run the Model and against which to compare the results was checked. Basic needs included rainfall data, and concurrent runoff hydrographs and pollutographs. Second, in order to test the general applicability of the Model, wide geographical separation between study areas and contrasts in storm patterns was required.

Third, the size and character of each area was checked to stress differences in land use, topography, population density, and income. Fourth, existing problem areas were sought so that techniques of analysis could be stressed and possible solutions could be compared. Fifth, the close cooperation of the city representatives had to be assured to support the data collection efforts.

The four sites thus selected were San Francisco, Cincinnati, Washington, D.C., and Philadelphia.

San Francisco

A valuable EPA-sponsored report (Grant No. WPO-112-01-66) (Ref. 1) characterizing combined sewer overflows in the city had been completed in November 1967, and work was continuing toward construction of a demonstration facility (in-line dissolved air flotation) by fall of 1970. The demonstration facility was to serve a rather small (187-acre) combined sewer area with sharply varying topography.

Cincinnati

A comprehensive sampling and analysis survey for a 2,600-acre combined sewer area in Cincinnati was initiated on another EPA project (Project No. 11024 DQU) in March 1970. Several points in the collection system were monitored simultaneously, thus providing a good test of the flow and quality routing efficiency of the Model.

Washington, D.C.

A storm water reclamation project (Project No. 11023 FIX) was under consideration which would impound portions of the combined sewer overflow from a 4,200-acre area. The impounded sewage would be treated and released to one of two lakes for recreational use. Between storm events, effluent from this lake would be repumped through the treatment facility and released with improved quality to the second lake.

Philadelphia

The City of Philadelphia had monitored storm and runoff conditions on a 5,400-acre combined sewer area in varying detail since 1954. Weekly sampling runs had also been made in the receiving waters, the Delaware River estuary. Further, in a separate area of the city, a demonstration treatment system for combined sewer overflows using a microstrainer had recently completed its first year of operation.

Initially, the intention was to model separate storm sewers as well as combined sewers in the demonstration series. However, *combined sewers could be converted to separate storm sewers in the model by simply leaving out the dry weather flow.* Therefore, these tests were suspended and the additional combined systems were substituted.

PURPOSE OF TESTS

The purpose of the Storm Water Management Model tests was to demonstrate the model's ability to simulate real systems under known storm events.

In addition, possible solutions to existing problems were compared by manipulating the flow control and treatment alternatives in the model. From these, the apparent best solutions were indicated on the basis of cost effectiveness information and the following limitations:

1. The "apparent best solutions" to test cases were generated without regard to the several sociopolitical factors which would have to be considered in arriving at the final solution.
2. While this task was approached in a systematic manner, formal systems analysis techniques, such as linear or dynamic programming (optimization), were beyond the scope of work and were not used.

In no instance was a complete analysis of a drainage basin attempted. Investigations were pressed only to gain preliminary results and to test and refine the more significant options within the program.

This volume describes each of the study areas modeled, the sources and methods used in ferreting out data, the verification results obtained, and the corrective actions modeled.

SECTION 2

SAN FRANCISCO

SECTION 2

SAN FRANCISCO

The results of two drainage basin modeling efforts are reported in this section. The first, Selby Street, was the trial basin used in the basic development of many of the subroutines and, as such, was frequently mentioned in Volume I. The second basin, Baker Street, is the principal subject of this section and demonstrates a technique of transferring results between neighboring basins.

DESCRIPTION OF STUDY AREAS

Selby Street

The Selby Street basin drains a major portion (3,800 acres) of the southeast quadrant of the city and discharges into inner portions of San Francisco Bay. The land use is predominantly (77 percent) residential. The total population is 88,000, or 24 persons per acre. The basin is approximately 35 percent impervious, and varies in elevation from 600 feet on its western boundary to sea level at its point of discharge.

The main trunk is 4 miles long and branches into approximately 130 miles of lateral conduits. It drops below sea level over its last mile and is therefore protected by an elevated weir and tide gates. This feature creates a significant impoundment (approximately 400,000 cubic feet) prior to overflows. The DWF interceptor has a maximum capacity equivalent to the expected runoff from 0.02 inch of rainfall per hour (Ref. 1).

The system carries an average DWF of 12 cfs and is designed to handle a 5-year design storm flow of 2,700 cfs.

Baker Street

The Baker Street basin drains a small, 187-acre, average-to-high income residential area adjacent to the Presidio in the northeast quadrant of the city. The main trunk sewer, 0.8 mile long, discharges into San Francisco Bay approximately 1 mile east of the Golden Gate Bridge. Characteristic photographs of the study area and outfall are shown in Figures 2-1 and 2-2, respectively. The most notable topographical feature of the area is the sharp rise in elevation, from 90 feet to 350 feet in four city blocks, toward the southern boundary.

The drainage basin is 60 percent impervious and has a total population of 11,700 (including a population equivalent of 3,000 persons from the Presidio), or a density of approximately 50 persons per acre. The DWF averages 2.7 cfs and the design system capacity is 450 cfs.

A dissolved air flotation treatment facility, designed to treat combined sewer overflows at a flow rate up to 37 cfs (maximum hydraulic capacity of 60 cfs), is now under construction adjacent to the outfall. This project was undertaken by the City of San Francisco with grant assistance from the EPA (Project No. 11023 DXC).

DATA SOURCES

The City of San Francisco, Department of Public Works, furnished maps of the sewer system, catchbasin construction and locations, aerial

Figure 2-1. BAKER STREET STUDY AREA LOOKING NORTH ON BRODERICK STREET FROM BROADWAY

Figure 2-2. BAKER STREET COMBINED SEWER OUTFALL

photographs of the study area, summaries of street cleaning data, and the sampling results of three storms on Baker Street (Ref. 2) and eight storms on Selby Street (Ref. 1).

The Baker Street storms were:

Date	Total Rainfall, in.
February 24-25, 1969	0.25
April 4-5, 1969	0.33
October 15, 1969	1.67

Rainfall data from the city sources were supplemented by hourly rainfall data collected by the U. S. Weather Bureau and published by the U. S. Department of Commerce as local climatological data. The largest storm reported in the 1968 and 1969 data (December 19-20, 1969) as recorded at the Federal Building, San Francisco, was modeled for Baker Street for the treatment and receiving water tests.

The following census tract data for 1960, published by the U. S. Department of Commerce (Ref. 3), were used for the DWF computations:

Item	Census Tract Table No.
Total Population	P-1
Population Per Household	P-1
Median Income, Families	P-1
All Housing Units	H-1
Condition and Plumbing	H-1
Year Structure Built	H-1
Median Value	H-2
Renter Occupied	H-2

Subcatchments and sewer system representation for use in the model were determined from sewer maps, aerial photographs, and a half-day inspection of each field site.

Selby Street

The Selby Street system was subdivided into 26 subcatchments (15 acres minimum, 466 acres maximum) as listed in Table 2-1. Complete listings of the input data for selected computer runs are provided in Appendix A. Surface quality data are listed in Table 2-2. The sewer system was represented by 74 elements (37 manholes, 36 pipes, and 1 internal storage unit) as shown in Figure 2-3. The internal storage unit, element 74, was used to model the impoundment prior to overflow as previously described.

Baker Street

A total of 16 subcatchments (no minimum, 25 acres maximum), as shown in Figure 2-4, were selected for the watersheds, and 39 elements (20 manholes and 19 pipes, varying from 250 feet to 1,510 feet long) were selected for the sewer system. The sewer elements, with identifying numbers and inlet points, are shown in the figure. In this case approximately 30 percent of the total pipes in the system were modeled as compared to 7-1/2 percent for Selby Street.

Two sets of rainfall data were reviewed for the Baker Street modeling. The first gage was located adjacent to the project site but only about 15 feet (ground elevation) above sea level. The second gage was located 1-3/4 miles from the project site but at 70 feet above sea level.

Table 2-1. SELBY STREET SUBCATCHMENT DATA

SUBAREA NUMBER	GUTTER OR MANHOLE	WIDTH (FT)	AREA (AC)	PERCENT IMPERV.	SLOPE (FT/FT)	RESISTANCE FACTOR IMPERV.	RESISTANCE FACTOR PERV.	SURFACE STORAGE(IN) IMPERV.	SURFACE STORAGE(IN) PERV.
1	1	6000.	139.	35.0	0.040	0.013	0.250	0.062	0.184
2	3	3400.	65.	35.0	0.040	0.013	0.250	0.062	0.184
3	5	3000.	68.	35.0	0.040	0.013	0.250	0.062	0.184
4	6	8000.	124.	35.0	0.040	0.013	0.250	0.062	0.184
5	9	5000.	140.	35.0	0.040	0.013	0.250	0.062	0.184
6	11	6000.	173.	35.0	0.040	0.013	0.250	0.062	0.184
7	13	6000.	185.	35.0	0.035	0.013	0.250	0.062	0.184
8	17	3000.	86.	35.0	0.030	0.013	0.250	0.062	0.184
9	21	5000.	287.	35.0	0.030	0.013	0.250	0.062	0.184
10	23	4000.	89.	35.0	0.030	0.013	0.250	0.062	0.184
11	27	3000.	39.	35.0	0.030	0.013	0.250	0.062	0.184
12	29	3000.	90.	35.0	0.030	0.013	0.250	0.062	0.184
13	30	6000.	232.	35.0	0.035	0.013	0.250	0.062	0.184
14	34	3000.	77.	35.0	0.030	0.013	0.250	0.062	0.184
15	41	6000.	414.	35.0	0.033	0.013	0.250	0.062	0.184
16	43	2000.	38.	35.0	0.030	0.013	0.250	0.062	0.184
17	46	5000.	207.	35.0	0.030	0.013	0.250	0.062	0.184
18	49	1000.	15.	35.0	0.030	0.013	0.250	0.062	0.184
19	51	3600.	35.	40.0	0.030	0.013	0.250	0.062	0.184
20	53	4600.	109.	35.0	0.030	0.013	0.250	0.062	0.184
21	59	6000.	118.	35.0	0.025	0.013	0.250	0.062	0.184
22	61	9400.	237.	35.0	0.030	0.013	0.250	0.062	0.184
23	65	9000.	366.	35.0	0.035	0.013	0.250	0.062	0.184
24	67	5400.	64.	35.0	0.040	0.013	0.250	0.062	0.184
25	69	6800.	196.	35.0	0.030	0.013	0.250	0.062	0.184
26	71	9600.	213.	35.0	0.030	0.013	0.250	0.062	0.184

TOTAL NUMBER OF SUBCATCHMENTS, 26

TOTAL TRIBUTARY AREA (ACRES), 3806.00

Table 2-2. SELBY STREET SURFACE QUALITY DATA

NUMBER OF SUBAREAS, KTNUM = 27
NUMBER OF INLETS, NINLTS = 26
TIME INTERVAL (MIN), DT = 5.00
STORM START TIME (HR:MIN) = 8:55

DRYDAY = 50., CLFREQ= 15., NOPASS = 1

AVERAGE NO. CB/ACRE, CBDEN = 1.
CB CONTENTS BOD (MG/L), CBBCD = 125.
CB STORED VOLUME (GAL), CBVOL = 150.

KNUM	INPUT	KLAND	ASUB	GUTTER
1	1	2	139.00	360.00
2	3	2	65.00	100.00
3	5	2	68.00	164.00
4	6	1	124.00	320.00
5	9	2	140.00	500.00
6	11	1	173.00	604.00
7	13	2	195.00	750.00
8	17	2	86.00	292.00
9	21	1	287.00	716.00
10	23	2	89.00	929.50
11	27	2	39.00	66.00
12	29	2	90.00	316.00
13	30	2	232.00	566.20
14	34	2	77.00	356.00
15	41	2	277.00	1296.00
16	43	3	38.00	148.00
17	46	2	207.00	916.00
18	49	2	15.00	88.00
19	51	3	40.00	148.00
20	53	2	109.00	480.00
21	59	2	118.00	460.00
22	61	2	237.00	1052.00
23	65	2	366.00	1798.00
24	67	2	64.00	244.00
25	69	4	196.00	780.00
26	71	4	200.00	624.00
27	71	3	13.00	50.00

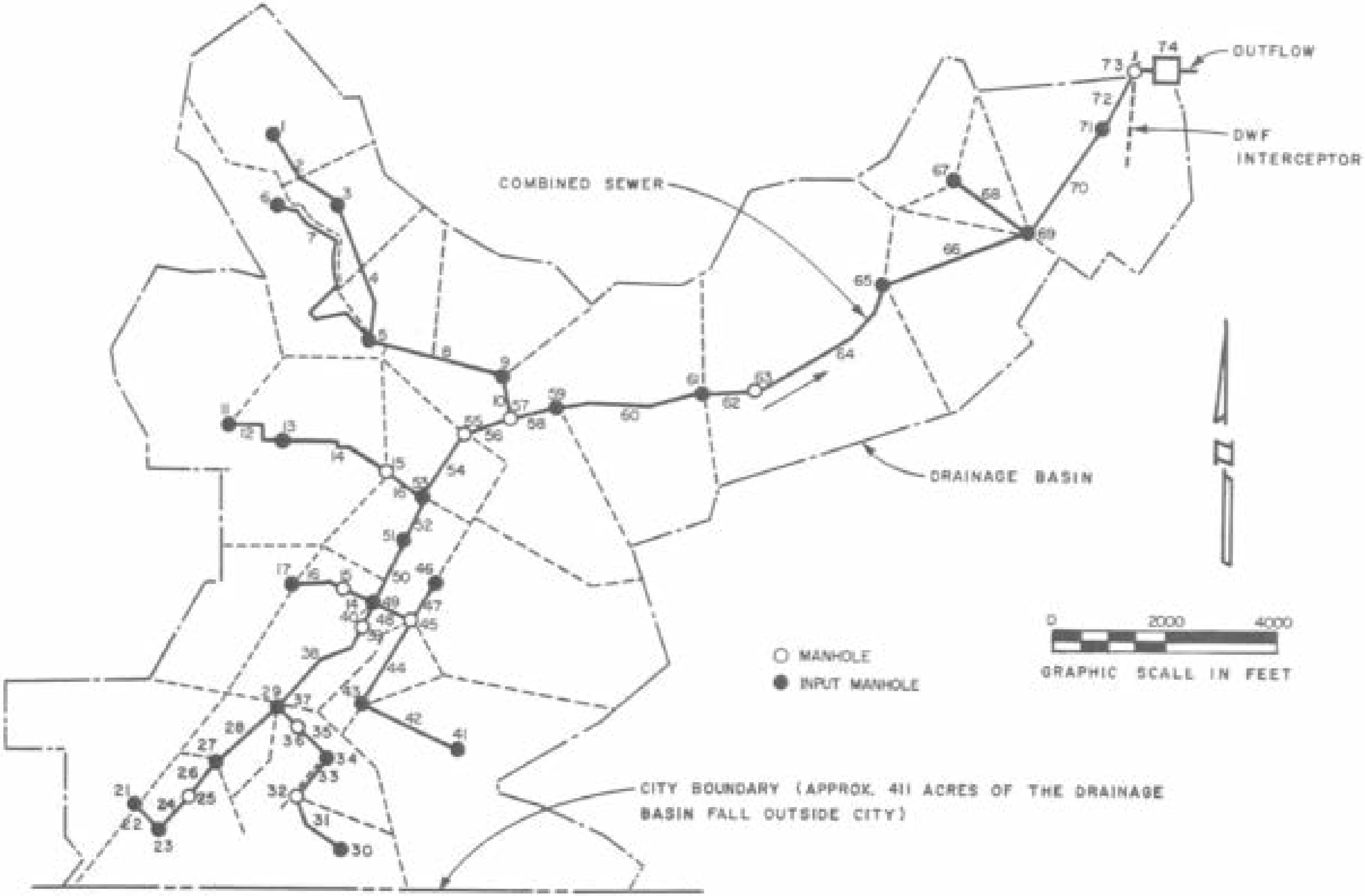


Figure 2-3. PLAN OF SELBY STREET SYSTEM

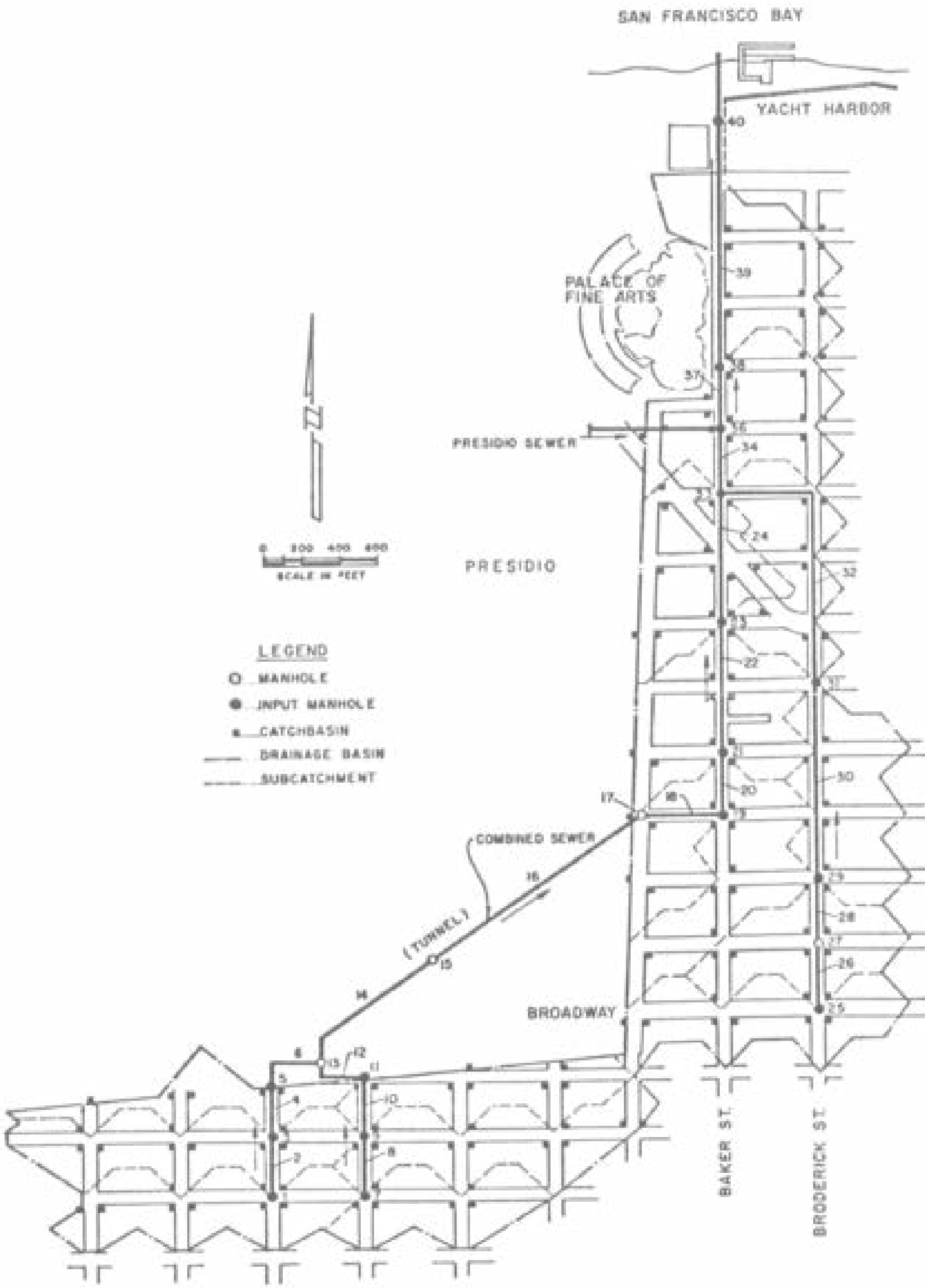


Figure 2-4. PLAN OF BAKER STREET SYSTEM

VERIFICATION RESULTS

Dry Weather Flow

Dry weather flow for Selby Street, shown in Table 2-3, was computed and adjusted to within 2 percent of the reported average daily values. Hourly variations in quantity and quality were set equal to the average of the reported values. The correction factors obtained are shown in Table 2-4. Note that the maximum hourly BOD is 1.34 x 1.77 = 2.37 times the average at 9 p.m. and 0.30 x 0.30 = 0.09 times the average at 5 a.m., an overall variation of 26 to 1. For suspended solids, the overall variation is greater, reaching a maximum of 45 to 1. *The quality significance of the dry weather flow's contribution to combined sewage overflows is therefore largely dependent on the time (hours) of occurrence of the storm event.*

Table 2-5 shows the computed settled solids in the Selby Street pipe system before and after the November 6, 1966, storm. The large accumulations prior to the storm are typical for these first-of-the-season storms on the West Coast. The quality contribution to the overflow, where significant, is seen as the *first flush effect.*

The computed DWF results from Baker Street are compared to the reported values in Figure 2-5. The uncertain (no maps or population figures were furnished) contribution from the Presidio was represented as an industrial source entering at element 36 with somewhat stronger than average domestic waste characteristics. The hourly variation factors were transferred from the nearby Laguna Street area where a more

Table 2-3. SELBY STREET DRY WEATHER FLOW RESULTS

QUANTITY AND QUALITY OF D W F FOR EACH SUBAREA

AIBOD = 958.12LBSPERD. FS
AISS = 1197.53 LBSPERC CFS
AICOLI = 2.10E 14 MPN/DA PER CAPITA
ADWF = 12.20 CFS

KNUM	INPUT	DWF + CFS	INFIL = CFS	QQDWF CFS	KLA	DWBOD LBS/MIN	DWSS LBS/MIN	TOTPOP PERSONS	BODCONC MG/L	SSCONC MG/L	COLIFORMS MPN/100ML
1	21	0.48	0.07	0.55		0.27	0.34				
2	23	0.26	0.04	0.29		0.18	0.22				
3	27	0.11	0.02	0.13		0.08	0.10				
4	30	0.48	0.07	0.55		0.33	0.42				
5	34	0.20	0.03	0.22		0.15	0.17				
6	29	0.26	0.04	0.30		0.18	0.22				
SUBTOTALS											
		1.79	0.25	2.04		5.46 LBS	7.32 LBS	17601.	153.	192.	7.41E 10
7	41	0.93	0.13	1.06	2	0.64	0.80				
8	43	0.12	0.02	0.14	2	0.08	0.10				
9	46	0.71	0.10	0.81	2	0.38	0.48				
10	17	0.21	0.03	0.24	2	0.11	0.14				
11	49	0.40	0.06	0.46	2	0.27	0.34				
SUBTOTALS											
		4.16	0.58	4.74		13.34 LBS	16.67 LBS	37364.	150.	188.	6.76E 10
12	51	0.11	0.01	0.12	2	0.07	0.09				
13	11	0.34	0.05	0.39	1	0.24	0.30				
14	13	0.44	0.06	0.50	2	0.26	0.30				
15	53	0.27	0.04	0.30	2	0.14	0.18				
SUBTOTALS											
		5.31	0.74	6.05		16.81 LBS	21.01 LBS	48286.	148.	186.	6.85E 10
16	4	0.23	0.03	0.26	1	0.17	0.21				
17	1	0.12	0.02	0.14	2	0.08	0.10				
18	3	0.12	0.02	0.13	2	0.08	0.10				
19	5	0.14	0.02	0.16	2	0.08	0.10				
20	9	0.38	0.05	0.44	2	0.21	0.26				
21	59	0.45	0.06	0.51	2	0.25	0.31				
SUBTOTALS											
		6.75	0.94	7.69		21.12 LBS	26.40 LBS	63041.	147.	183.	7.06E 10
22	61	0.73	0.10	0.84	2	0.40	0.51				
23	65	1.03	0.14	1.17	2	0.57	0.71				
231	65	0.05	0.0	0.05	4	0.09	0.07				
SUBTOTALS											
		8.56	1.18	9.75		26.46 LBS	32.86 LBS	80555.	145.	180.	7.09E 10
24	67	0.36	0.05	0.41	2	0.20	0.25				
251	69	0.05	0.0	0.05	4	0.04	0.07				
252	69	0.03	0.0	0.03	4	0.06	0.07				
253	69	1.12	0.0	1.12	4	0.84	1.26				
25	69	0.16	0.02	0.18	2	0.09	0.11				
SUBTOTALS											
		10.29	1.26	11.54		32.56 LBS	41.67 LBS	85960.	151.	193.	6.39E 10
26	71	0.23	0.03	0.26	2	0.13	0.16				
261	71	0.10	0.0	0.10	4	0.19	0.22				
SUBTOTALS											
		10.62	1.29	11.91		34.14 LBS	43.58 LBS	88345.	153.	196.	6.37E 10
TOTALS											
		10.62	1.29	11.91		34.14 LBS	43.58 LBS	88346.	153.	196.	6.37E 10

COMPARISON OF MEASURED AND CALCULATED TOTAL SEWAGE FLOW: ADWF= 12.20 CFS SMTDWF= 11.91 CFS
CORRECTION FACTOR (CF2) OF 1.02 APPLIED TO THE DWF (QUANTITY AND QUALITY) AT EACH INLET

Table 2-4. SELBY STREET DRY WEATHER FLOW VARIATION FACTORS

DAILY AND HOURLY CORRECTION FACTORS
FOR SEWAGE DATA

DAY	DVDWF	DVBOD	DVSS	DVCOLI
1	1.000	1.000	1.000	
2	1.000	1.000	1.000	
3	1.000	1.000	1.000	
4	1.000	1.000	1.000	
5	1.000	1.000	1.000	
6	1.000	1.000	1.000	
7	1.000	1.000	1.000	
HOUR				
1	0.760	0.730	0.840	0.840
2	0.500	0.550	0.570	0.570
3	0.400	0.340	0.370	0.370
4	0.320	0.300	0.270	0.270
5	0.300	0.300	0.230	0.230
6	0.320	0.300	0.150	0.150
7	0.470	0.610	0.570	0.570
8	1.040	0.880	0.990	0.990
9	1.410	1.220	1.310	1.310
10	1.370	1.220	1.460	1.460
11	1.380	1.250	1.540	1.540
12	1.370	1.250	1.580	1.580
13	1.310	1.220	1.480	1.480
14	1.210	1.190	1.310	1.310
15	1.170	1.160	1.070	1.070
16	1.110	1.130	1.010	1.010
17	1.140	1.070	0.970	0.970
18	1.150	1.040	0.920	0.920
19	1.270	1.280	1.040	1.040
20	1.370	1.520	1.240	1.240
21	1.340	1.770	1.460	1.460
22	1.210	1.490	1.410	1.410
23	1.120	1.220	1.170	1.170
24	0.980	0.940	1.010	1.010

Table 2-5. SELBY STREET - COMPUTED SETTLED SOLIDS IN THE PIPE SYSTEM BEFORE AND AFTER STORM

INITIAL BED OF SOLIDS (LBS) IN SEWER DUE TO 50.0 DAYS OF DRY WEATHER PRIOR TO STORM		BED OF SOLIDS IN SEWER AT END OF STORM	
ELEMENT NUMBER	SOLIDS IN BOTTOM (LBS)	ELEMENT NUMBER	SOLIDS IN BOTTOM (LBS)
2	0.0	2	0.0
4	0.02668	4	0.00001
7	0.29763	7	0.00038
8	0.14997	8	0.00010
10	0.0	10	0.0
12	0.13717	12	0.00007
14	0.99266	14	0.00120
16	2.36231	16	0.00365
18	0.90106	18	0.00149
20	10.70633	20	0.01414
22	1.15119	22	0.00143
24	0.32877	24	0.00012
26	0.59344	26	0.00044
28	3.48855	28	0.00546
31	0.53567	31	0.00051
33	0.80866	33	0.00096
35	1.74615	35	0.00248
37	0.25363	37	0.00013
38	2.71647	38	0.00372
40	2.83775	40	0.00387
42	1.49950	42	0.00162
44	4.81593	44	0.00754
47	4.01854	47	0.00687
48	1.03989	48	0.00097
50	0.0	50	0.0
52	3.15479	52	0.00336
54	1.14104	54	0.00056
56	11.25840	56	0.01684
58	3.57339	58	0.00370
60	10.62061	60	0.01346
62	0.04679	62	0.0
64	26.60228	64	0.04175
66	55.98730	66	0.09837
68	7.81516	68	0.00892
70	1080.21924	70	1.54411
72	1704.82935	72	2.60031

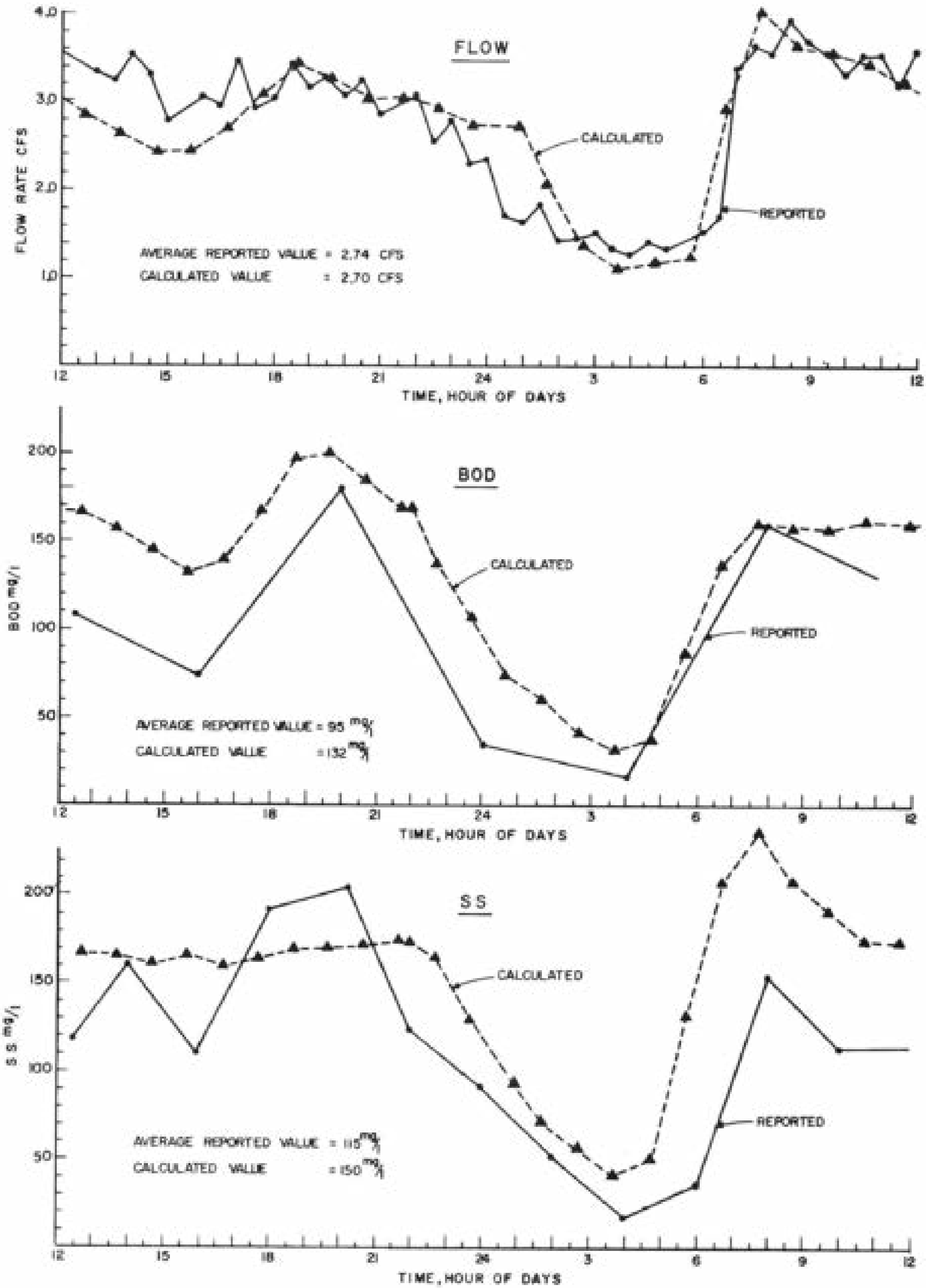


Figure 2-5. BAKER STREET DRY WEATHER FLOW COMPARISONS WITH REPORTED VALUES

comprehensive dry weather flow sampling program had been completed. The results as shown in Figure 2-5 were quite satisfactory.

Combined Sewer Overflows

Selby Street. The results of the computed and reported hydrographs for Selby Street for the storm of November 6, 1966 (0.94 total inch of rainfall) are shown along with the hyetograph in Figure 2-6. The results for BOD and suspended solids are compared to reported values in Figure 2-7. Units of pounds per minute rather than concentrations were used in the comparison as these reflect the total pounds discharged (flow times concentration). *In terms of pounds discharged, an error of 20 percent in predicting concentrations at the time of maximum overflow, could have an effect several magnitudes greater than an error of 100 percent or more at the tails of the curve where flows are low.* The fit of computed to reported data was considered exceptionally good.

Baker Street. Four storms were computed for the Baker Street test area. The verification results of the April 4-5, 1969, and the October 14-15, 1969, storms (0.33 and 1.67 inches of rainfall, respectively) are shown in Figures 2-8 and 2-9. The model results of the December 19-20, 1969 (2.51 inches) storm are shown in Figure 2-10; no sampling was reported for this storm.

The Federal Building rain gage (elevation 70 feet) gave the best correlation to the reported results, which is not surprising since over 70 percent of the project area is above this elevation. The lower rain gage (elevation 15 feet) correlated poorly with the recorded runoff,

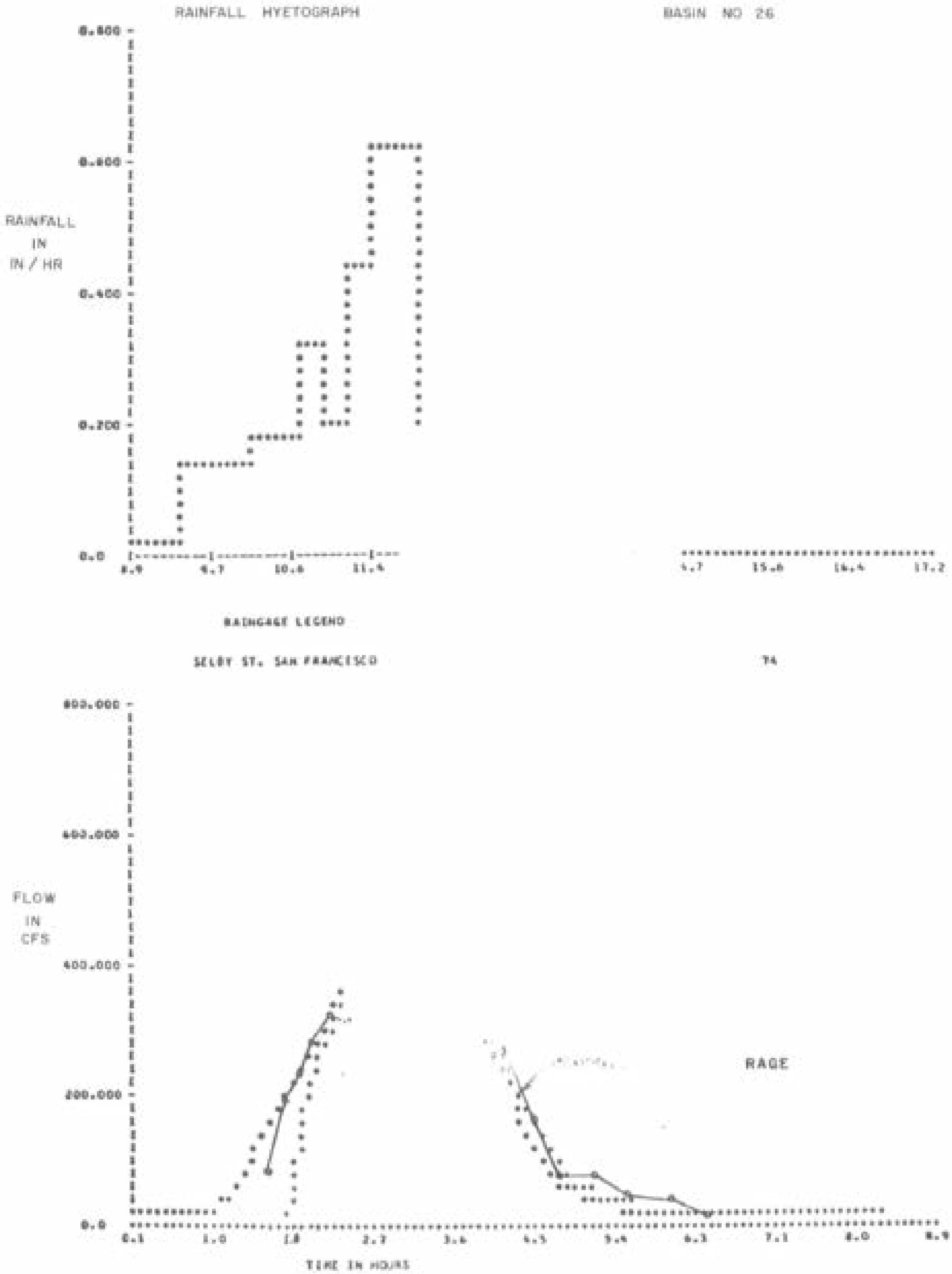
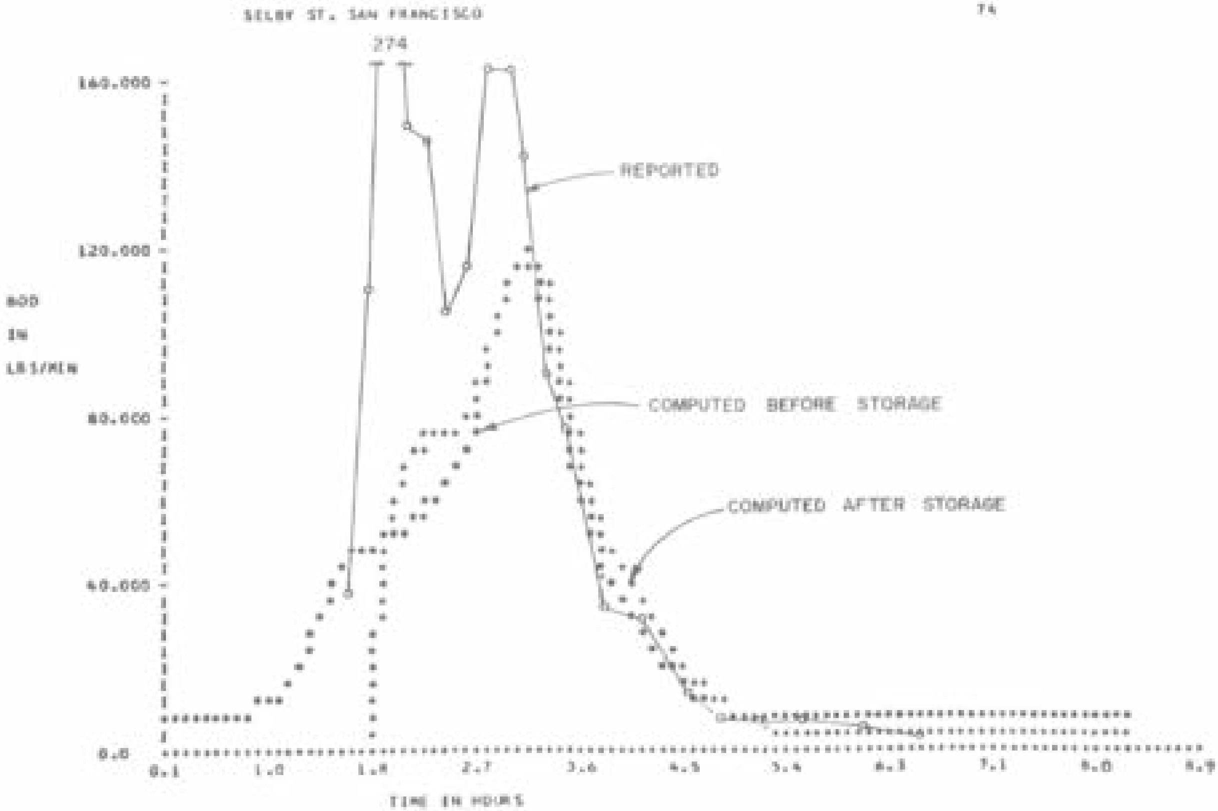


Figure 2-6. SELBY STREET COMBINED SEWER OVERFLOW RESULTS - QUANTITY



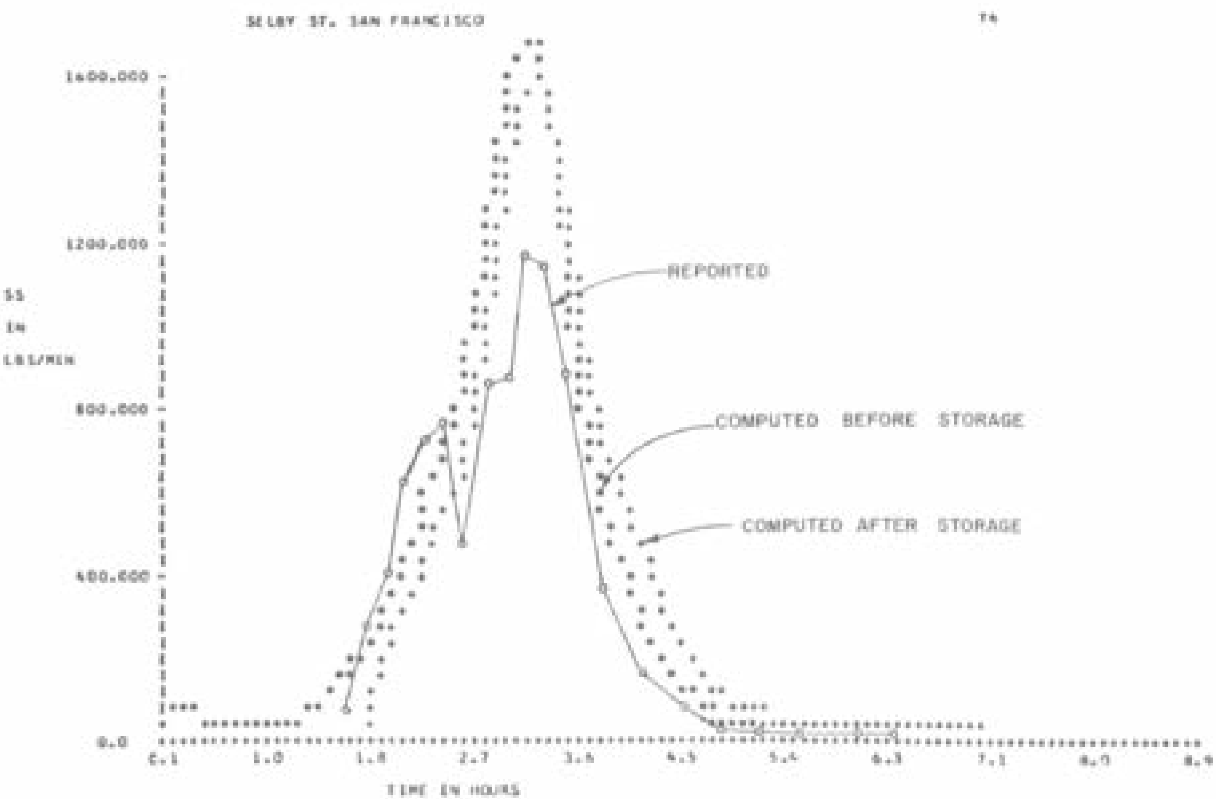


Figure 2-7. SELBY STREET COMBINED SEWER OVERFLOW RESULTS - QUALITY

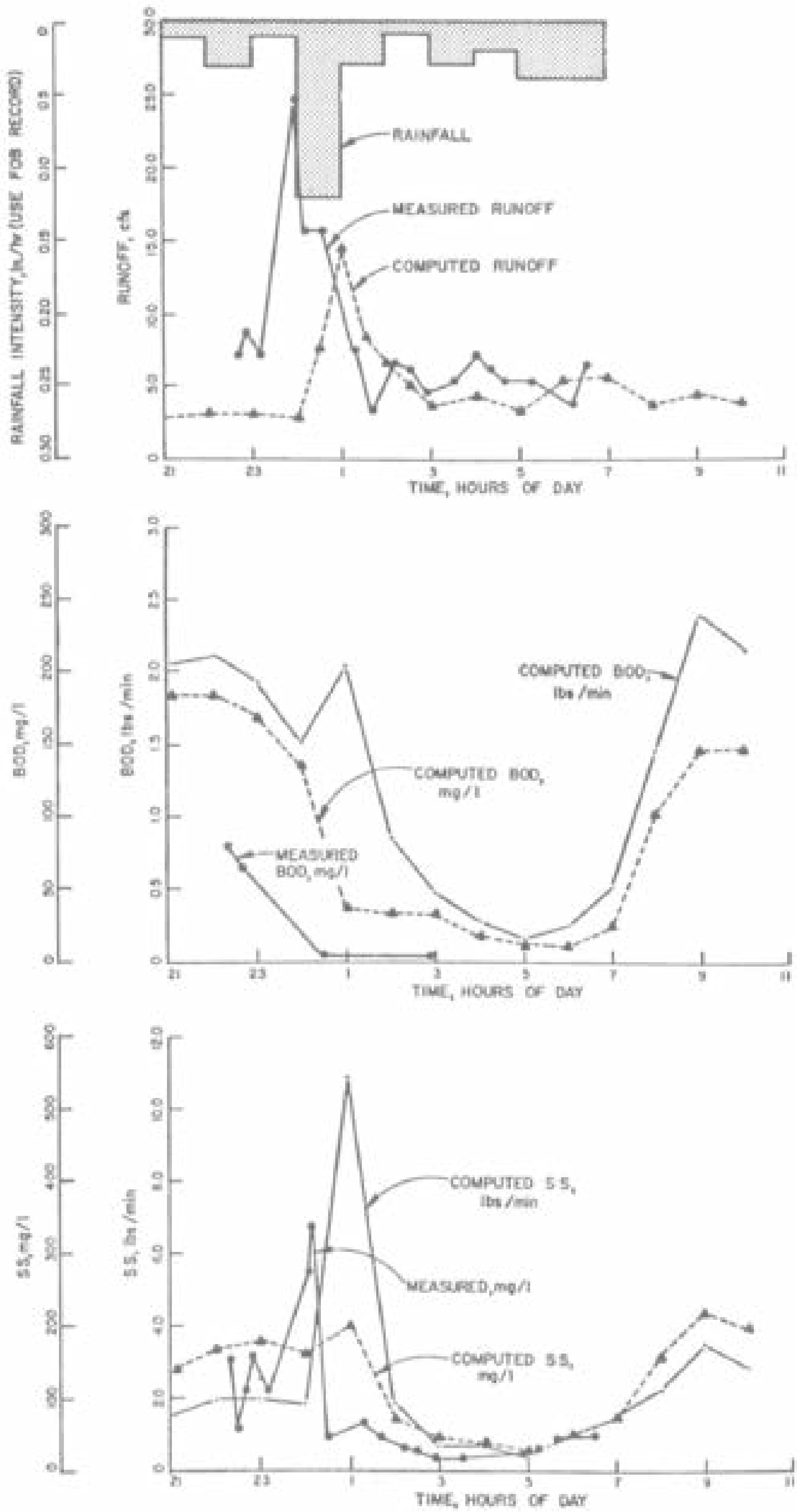


Figure 2-8. BAKER STREET COMBINED SEWER OVERFLOW RESULTS - STORM OF APRIL 4-5, 1969

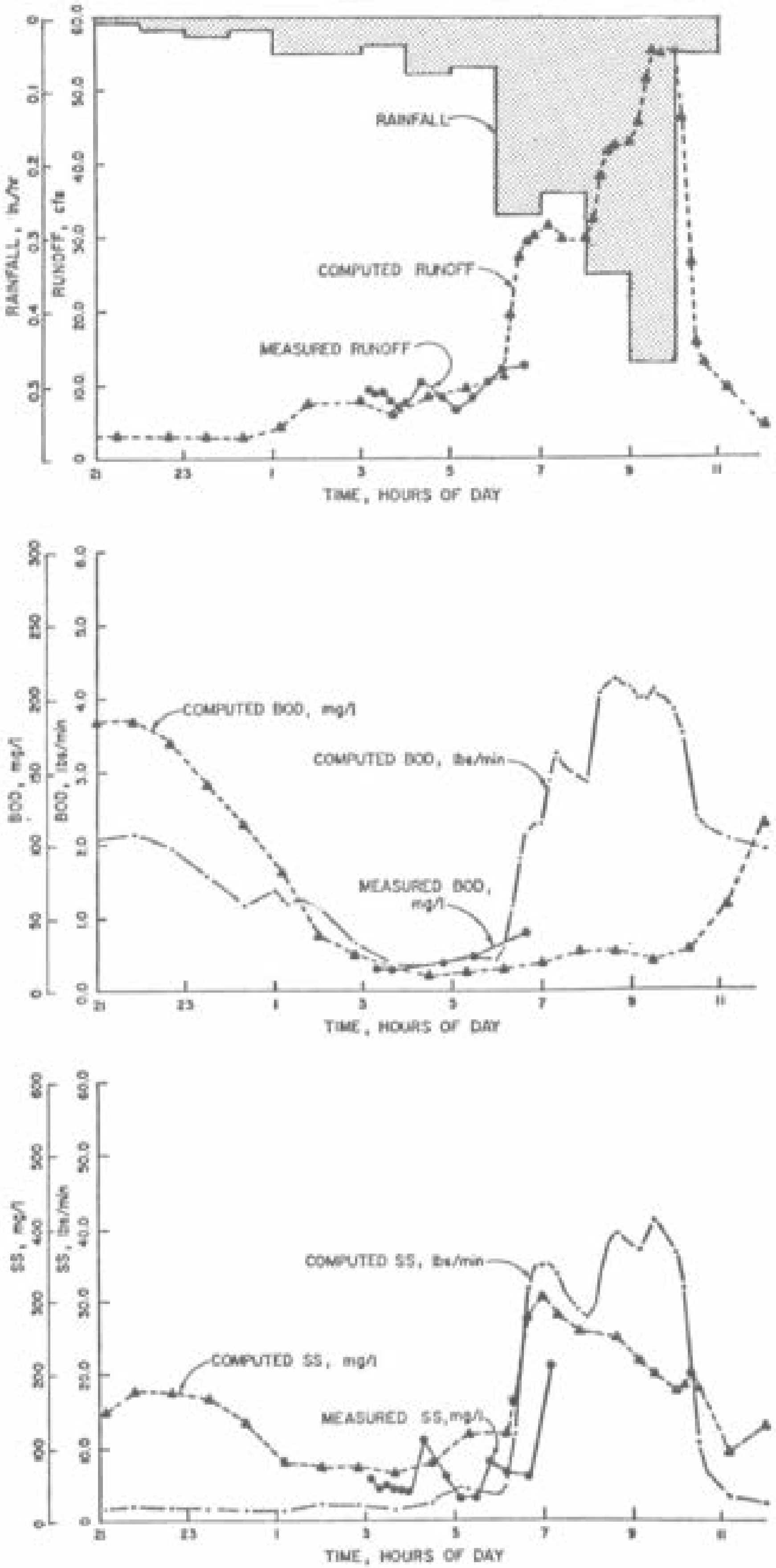


Figure 2-9. BAKER STREET COMBINED SEWER OVERFLOW RESULTS - STORM OF OCTOBER 14-15, 1969

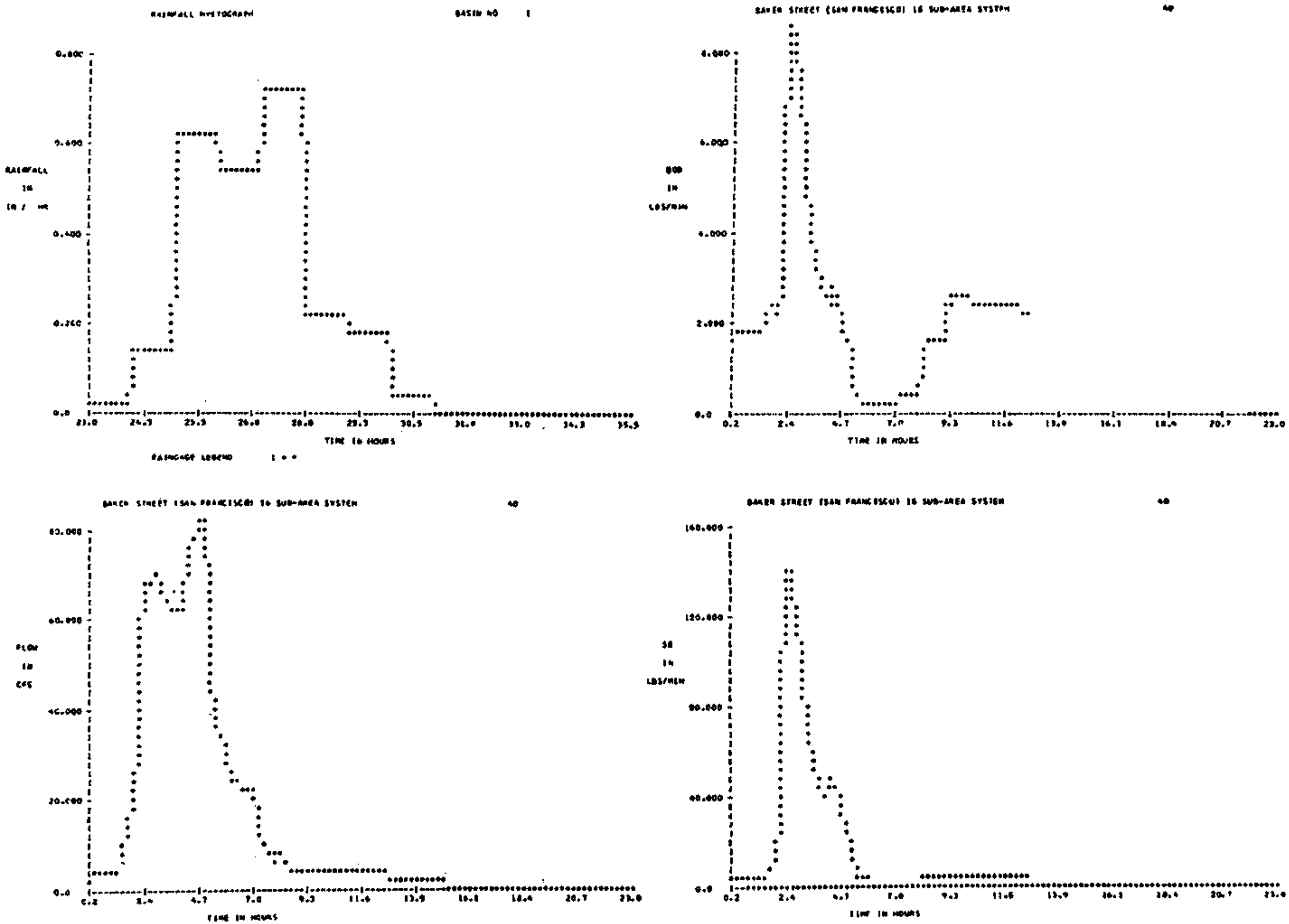


Figure 2-10. BAKER STREET COMBINED SEWER OVERFLOW RESULTS - STORM OF DECEMBER 19-20, 1969

once runoff was recorded before the storm reached the gage area. *The significance of these findings is that topography and storm patterns can greatly influence the runoff results, and rainfall data must represent the entire drainage basin in order to be applicable to the Model.*

Receiving Waters

The receiving waters were modeled only for the storm of December 19-20, 1969 (the largest) and only for Baker Street. The grid system used is shown in Figure 2-11. The storm flow was so small in comparison with the tidal flows through the Golden Gate as to make quality influences indiscernible. The pattern of the flow in the estuary was defined, however, and is shown in Table 2-6. Time cycle 1, hour 0, is the start of the rainfall event (3 hours before the first low water at Golden Gate). Initial junction concentration values were preset to zero; thus a number at any junction indicates the arrival of the pollutant field at that point. For example, at time step 2 the pollutant field encompassed junctions 27, 28, and 33, in addition to the outfall near junction 40 (see Figure 2-11). The boundary of the pollutant field of BOD concentrations greater than 0.01 mg/L plotted at 3, 4, and 5 hours after the start of rain is shown in Figure 2-12. This figure shows the tidal influence on the movement of the field. Trace concentrations appeared at all junctions at the end of 20 time steps (5 hours). The tendency for the higher concentrations to remain near shore is because there is less mixing water available.

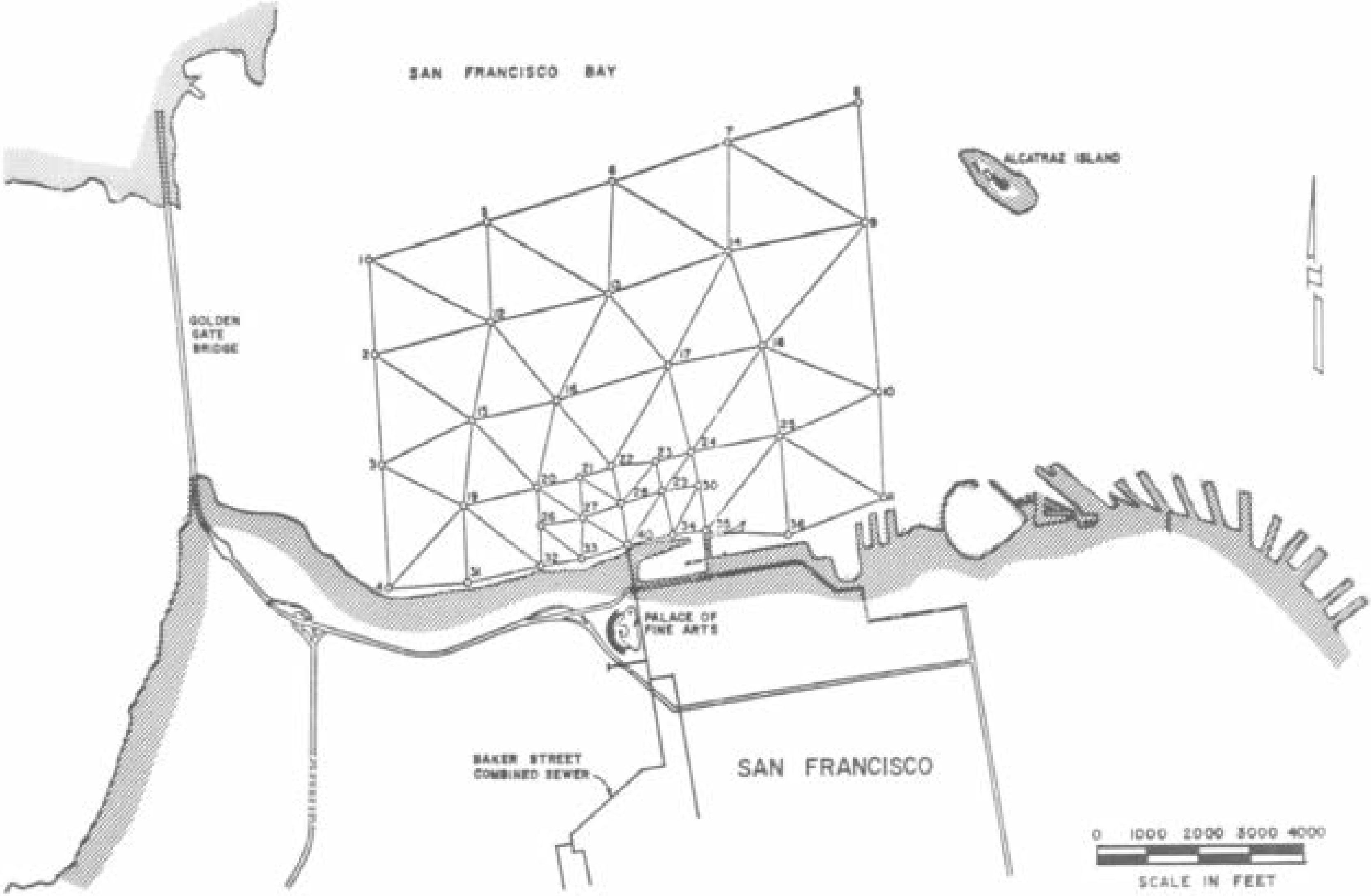


Figure 2-11. BAKER STREET RECEIVING WATER GRID SYSTEM

Table 2-6. COMPUTED BOD CONCENTRATIONS IN RECEIVING WATER

CONSTITUENT NUMBER 1 BOD AT BAKER ST

SINK CONCENTRATION .00

INITIAL CONCENTRATIONS (MGD), BY JUNCTION

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11 TO 20	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
21 TO 30	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
31 TO 40	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 1 ,HOUR 2 ,CONSTITUENT NUMBER 1 BOD AT BAKER ST

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11 TO 20	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
21 TO 30	.0000	.0000	.0000	.0000	.0000	.0000	.1835-02	.2835-08	.0000	.0000
31 TO 40	.0000	.0000	.9594-02	.0000	.0000	.0000	.0000	.0000	.0000	.8598-01

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 1 ,HOUR 4 ,CONSTITUENT NUMBER 1 BOD AT BAKER ST

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000
11 TO 20	.0000	.0000	.0000	.0000	.1721-05	.1951-11	.0000	.0000	.4102-04	.1903-03
21 TO 30	.5500-04	.7446-11	.0000	.0000	.0000	.4314-02	.5562-02	.1562-10	.0000	.0000
31 TO 40	.3913-03	.4751-02	.4390-01	.0000	.0000	.0000	.0000	.0000	.0000	.8140-01

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 1 ,HOUR 6 ,CONSTITUENT NUMBER 1 BOD AT BAKER ST

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	.1670-13	.1882-05	.7308-04	.3556-03	.0000	.0000	.0000	.0000	.0000	.0000
11 TO 20	.0000	.2541-12	.0000	.0000	.7123-04	.1574-11	.0000	.0000	.8936-03	.1130-02
21 TO 30	.1030-03	.2629-12	.0000	.0000	.0000	.8101-02	.5481-02	.3879-14	.0000	.0000
31 TO 40	.6142-02	.1594-01	.5235-01	.0000	.0000	.0000	.0000	.0000	.0000	.6384-01

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 1 ,HOUR 8 ,CONSTITUENT NUMBER 1 BOD AT BAKER ST

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	.6253-13	.2237-04	.5810-03	.2134-02	.0000	.0000	.0000	.0000	.0000	.0000
11 TO 20	.0000	.2401-12	.0000	.0000	.2263-03	.4956-12	.0000	.0000	.2132-02	.1490-02
21 TO 30	.9419-04	.7662-14	.0000	.0000	.0000	.7634-02	.7311-02	.3171-18	.0000	.0000
31 TO 40	.1376-01	.1812-01	.5928-01	.0000	.0000	.0000	.0000	.0000	.0000	.1403+00

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 1 ,HOUR 10 ,CONSTITUENT NUMBER 1 BOD AT BAKER ST

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	.6194-13	.5195-04	.1098-02	.3737-02	.0000	.0000	.0000	.0000	.0000	.0000
11 TO 20	.0000	.1333-12	.0000	.0000	.2957-03	.1575-12	.0000	.0000	.2358-02	.1858-02
21 TO 30	.1088-03	.2309-15	.0000	.0000	.0000	.1324-01	.1277-01	.2794-22	.0000	.0000
31 TO 40	.1633-01	.1980-01	.7648-01	.0000	.0000	.0000	.0000	.0000	.0000	.3718+00

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 1 ,HOUR 15 ,CONSTITUENT NUMBER 1 BOD AT BAKER ST

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	.2819-13	.9343-04	.1585-02	.3897-02	.0000	.0000	.0000	.0000	.0000	.0000
11 TO 20	.0000	.4009-12	.0000	.0000	.5933-03	.3156-13	.0000	.0000	.3559-02	.4564-02
21 TO 30	.3304-03	.4895-18	.0000	.0000	.0000	.2891-01	.2262-01	.1502-27	.3478-05	.0000
31 TO 40	.1464-01	.2146-01	.7980-01	.1282+00	.7224-03	.0000	.0000	.0000	.0000	.6692+00

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 1 ,HOUR 20 ,CONSTITUENT NUMBER 1 BOD AT BAKER ST

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	.0000	.9398-04	.1582-02	.3897-02	.1247-05	.4460-06	.2028-07	.1455-16	.3554-06	.1182-02
11 TO 20	.6893-01	.6100-04	.2965-04	.4884-05	.7912-03	.4986-03	.1955-03	.3813-04	.2338-02	.2676-02
21 TO 30	.3479-02	.3134-02	.3314-02	.2061-02	.4710-02	.1034-01	.1693-01	.2034-01	.2498-01	.3145-01
31 TO 40	.4245-02	.5419-02	.1169-01	.1334+00	.9896-01	.1756+00	.0000	.0000	.0000	.8121-01

Figure 2-12. BAKER STREET RECEIVING WATER BOD MOVEMENT

The concentration versus time history at three junction points for suspended solids is shown in Figure 2-13.

CORRECTIVE ACTIONS MODELED

As in the case of the Receiving Water Model, only the storm of December 19-20, 1969, for Baker Street was used in the treatment analysis.

Three options were investigated:

1. Treatment by mechanically cleaned bar racks followed by an on-line 25.0 mgd dissolved air flotation unit and no chemicals added.
2. Same as 1 but with chemicals and chlorination added.
3. Same as 2 but with a 3.5 million gallon (maximum) capacity storage basin and effluent pumps added ahead of the dissolved air flotation facility to minimize bypassing of the treatment unit.

The treatment efficiencies of the three options are compared in Tables 2-7, 2-8, and 2-9, and the costs in Tables 2-10, 2-11, and 2-12, respectively. For the large storm modeled, the increase in efficiencies under option 3 over option 1 or 2 (shown below) appears to more than justify the additional (28 percent) incremental cost.

Option	REMOVAL EFFICIENCIES		
	BOD	SS	Coli
1	36.5%	49.2%	58.1%
2	36.7	49.2	72.8
3	58.4	64.9	99.9

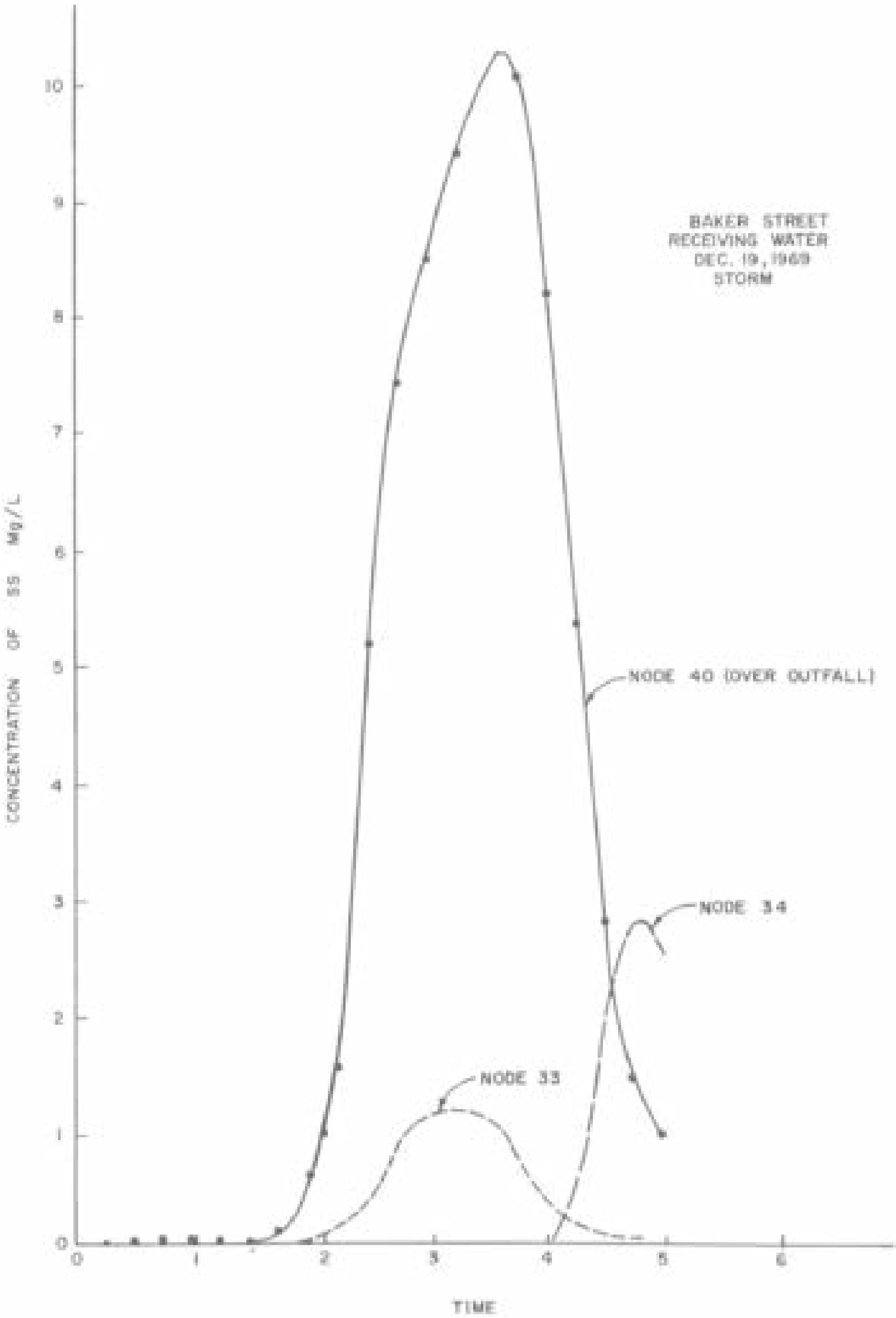


Figure 2-13. CONCENTRATION HISTORY AT THREE JUNCTION POINTS

Table 2-7. SUMMARY OF TREATMENT EFFECTIVENESS - OPTION 1

SUMMARY OF TREATMENT EFFECTIVENESS

TOTALS	FLOW (M.G.)	BOD (LB)	SS (LB)	COLIF (MPN)
INPUT	8.161	70998.1	1340754.0	2.46E 15
OVERFLOW (BYPASS)	2.448	27623.7	519971.6	6.69E 14
TREATED	5.713	43367.1	760826.6	1.79E 15
REMOVED	0.086	25985.6	560744.3	1.43E 15
RELEASED	8.075	45115.0	660550.3	1.03E 15

REMOVALS	FLOW(M.G.)	BOD (LB)	SS (LB)	
LEVEL 1	0.000	12.8	257.0	= BAR RACKS
LEVEL 3 (TOTAL)	0.086	25972.8	639987.4	= DISS AIR FLOAT'N
LEVEL 4	0.000	0.0	0.0	= BYPASS LEVEL 4
LEVEL 5	0.000	0.0	0.0	= NO EFFL. SCREENS
LEVEL 7	0.000	0.0	0.0	= NO CONTACT TANK
TRASH:				
BAR RACKS	34.262 CU.FT (AT 50 LB/CU.FT.)			
EFFLUENT SCREENS	0.000 CU.FT (AT 50 LB/CU.FT.)			

REMOVAL PERCENTAGES	FLOW (VOL)	BOD (LB)	SS (LB)	COLIF (MPN)
OF OVERALL INPUTS	1.05	36.46	42.22	58.06
OF TREATED FRACTIONS	1.50	59.60	82.00	79.72

CONSUMPTIONS (LB)	CHLORINE	POLYMERS	
LEVEL 3	0.0	0.0	= DISS AIR FLOAT'N
LEVEL 4	0.0	0.0	= BYPASS LEVEL 4
LEVEL 7	0.0	0.0	= NO CONTACT TANK
TOTAL	0.0	0.0	

REPRESENTATIVE VARIATION OF TREATMENT PERFORMANCE WITH TIME (OVERALL).

TIME	23: 5	0:15	1:25	2:35	3:45	4:55	6: 5	7:15	8:25	9:35	10:45
WATER											
AV. FLOW (CFS)	2.69	3.63	64.24	61.83	80.03	29.38	21.11	6.48	4.29	3.54	3.40
BOD											
ARRIVING (MG/L)	167.39	338.74	2981.69	1238.65	594.16	93.47	72.98	80.87	163.29	180.54	193.65
RELEASED (MG/L)	67.65	137.25	1923.91	782.04	424.90	47.34	34.18	32.68	66.10	73.10	74.36
% REDUCTION (LB)	60.06	60.03	35.96	37.36	28.90	48.78	53.80	60.13	60.07	60.06	60.06
S. SOLIDS											
ARRIVING (MG/L)	231.42	2112.95	53170.29	23699.04	11720.56	1617.71	1375.64	499.64	315.65	268.08	237.81
RELEASED (MG/L)	56.09	384.57	27245.06	11691.79	7138.47	294.20	250.03	94.27	77.42	69.55	63.78
% REDUCTION (LB)	72.54	82.05	49.14	51.05	39.49	82.06	82.07	81.39	75.80	74.41	73.54
COLIFORMS											
ARR (MPN/100ML)	3.14E 07	2.18E 07	1.59E 07	6.79E 06	3.32E 06	7.13E 05	1.15E 06	1.31E 07	3.62E 07	3.77E 07	3.52E 07
REL (MPN/100ML)	8.73E 06	3.97E 06	7.60E 06	3.35E 06	2.02E 06	1.20E 05	2.08E 05	2.48E 06	8.88E 06	9.77E 06	9.42E 06
% REDUCTION (LB)	72.60	82.09	49.17	51.08	39.50	82.10	82.11	81.43	75.86	74.47	73.60

Table 2-8. SUMMARY OF TREATMENT EFFECTIVENESS - OPTION 2

SUMMARY OF TREATMENT EFFECTIVENESS

TOTALS	FLOW (M.G.)	BOD (LB)	SS (LB)	COLIF (MPN)
INPUT	8.161	70998.1	1300754.0	2.46E 15
OVERFLOW (BYPASS)	2.448	27633.7	519971.6	4.69E 14
TREATED	5.713	43367.1	780826.6	1.79E 15
REMOVED	0.086	26025.3	640322.9	1.79E 15
RELEASED	8.075	44975.3	660471.0	6.71E 14

REMOVALS	FLOW(M.G.)	BOD (LB)	SS (LB)	
LEVEL 1	0.000	12.8	257.0	= BAR RACKS
LEVEL 3 (TOTAL)	0.086	26012.4	640065.9	= DISS AIR FLOAT'N
LEVEL 4	0.000	0.0	0.0	= BYPASS LEVEL 4
LEVEL 5	0.000	0.0	0.0	= NO EFFL. SCREENS
LEVEL 7	0.000	0.0	0.0	= NO CONTACT TANK

TRASH:
BAR RACKS 34.262 CU.FT (AT 50 LB/CU.FT.)
EFFLUENT SCREENS 0.000 CU.FT (AT 50 LB/CU.FT.)

REMOVAL PERCENTAGES	FLOW (VOL)	BOD (LB)	SS (LB)	COLIF (MPN)
OF OVERALL INPUTS	1.05	36.66	49.23	72.76
OF TREATED FRACTIONS	1.50	60.01	82.01	99.90

CONSUMPTIONS (LB)	CHLORINE	POLYMERS	
LEVEL 3	650.2	571.2	= DISS AIR FLOAT'N
LEVEL 4	0.0	0.0	= BYPASS LEVEL 4
LEVEL 7	0.0	0.0	= NO CONTACT TANK
TOTAL	650.2	571.2	

REPRESENTATIVE VARIATION OF TREATMENT PERFORMANCE WITH TIME (OVERALL).

TIME	23: 5	0:15	1:25	2:35	3:45	4:55	6: 5	7:15	8:25	9:35	10:45
WATER											
AV. FLOW (CFS)	2.69	3.63	64.24	61.83	80.03	29.38	21.11	6.48	4.29	3.54	3.40
BOD											
ARRIVING (MG/L)	167.09	338.74	2981.68	1239.65	594.16	83.47	72.98	80.87	163.29	180.54	183.65
RELEASED (MG/L)	67.65	137.75	1923.91	792.04	424.00	33.74	29.48	32.68	66.10	73.10	74.36
% REDUCTION (LB)	60.06	60.03	35.06	37.36	28.90	60.13	60.15	60.13	60.07	60.06	60.05
S. SOLIDS											
ARRIVING (MG/L)	201.42	2112.95	53170.39	23699.04	11729.66	1617.71	1375.64	499.64	315.65	268.08	237.81
RELEASED (MG/L)	35.27	384.57	27245.06	11691.79	7112.47	294.20	250.03	90.18	56.61	47.93	42.41
% REDUCTION (LB)	82.49	82.05	49.14	51.05	39.49	82.06	82.07	82.19	82.31	82.36	82.41
COLIFORMS											
ARR (MPN/100ML)	3.14E 07	2.18E 07	1.50E 07	6.70E 06	3.32E 06	7.13E 05	1.15E 05	1.31E 07	3.62E 07	3.77E 07	3.52E 07
REL (MPN/100ML)	3.05E 04	2.17E 04	6.07E 06	2.59E 06	1.74E 06	7.09E 02	1.14E 03	1.30E 04	3.55E 04	3.68E 04	3.43E 04
% REDUCTION (LB)	99.90	99.90	59.97	62.20	48.10	99.90	99.00	99.90	99.90	99.90	99.90

Table 2-9. SUMMARY OF TREATMENT EFFECTIVENESS - OPTION 3

SUMMARY OF TREATMENT EFFECTIVENESS

TOTALS	FLOW (M.G.)	BOD (LB)	SS (LB)	COLIF (MPN)
INPUT	7.860	765.6	3942.4	1.51E 14
OVERFLOW (BYPASS)	0.000	0.0	0.0	0.00E-01
TREATED	7.860	765.6	3942.4	1.61E 14
REMOVED	0.118	447.6	2558.7	1.60E 14
RELEASED	7.741	318.0	1383.7	1.41E 11

REMOVALS	FLOW(M.G.)	BOD (LB)	SS (LB)	
LEVEL 1	0.000	17.7	353.5	= BAR RACKS
LEVEL 3 (TOTAL)	0.118	429.9	2205.2	= DISS AIR FLOAT'N
LEVEL 4	0.000	0.0	0.0	= BYPASS LEVEL 4
LEVEL 5	0.000	0.0	0.0	= NO EFFL. SCREENS
LEVEL 7	0.000	0.0	0.0	= NO CONTACT TANK

TRASH:

BAR RACKS 47.137 CU.FT (AT 50 LB/CU.FT.)

EFFLUENT SCREENS 0.000 CU.FT (AT 50 LB/CU.FT.)

REMOVAL PERCENTAGES	FLOW (VOL)	BOD (LB)	SS (LB)	COLIF (MPN)
OF OVERALL INPUTS	1.50	58.47	64.90	99.91
OF TREATED FRACTIONS	1.50	58.47	64.90	99.91

CONSUMPTIONS (LB)	CHLORINE	POLYMERS	
LEVEL 3	655.6	785.9	= DISS AIR FLOAT'N
LEVEL 4	0.0	0.0	= BYPASS LEVEL 4
LEVEL 7	0.0	0.0	= NO CONTACT TANK
TOTAL	655.6	785.9	

REPRESENTATIVE VARIATION OF TREATMENT PERFORMANCE WITH TIME (OVERALL).

TIME	23: 5	0:15	1:25	2:35	3:45	4:55	6: 5	7:15	8:25	9:35	10:45
WATER											
AV. FLOW (CFS)	0.00	0.00	36.56	36.51	36.60	35.62	36.62	36.62	36.62	0.00	0.00
BOD											
ARRIVING (MG/L)	0.00	0.00	34.81	15.51	9.14	6.12	5.08	5.68	13.15	0.00	0.00
RELEASED (MG/L)	0.00	0.00	14.57	6.58	3.86	2.55	2.11	2.37	5.58	0.00	0.00
% REDUCTION (LB)	0.00	0.00	58.70	58.18	58.33	58.81	59.14	58.93	58.13	0.00	0.00
S. SOLIDS											
ARRIVING (MG/L)	0.00	0.00	86.76	100.16	71.56	50.49	40.62	36.50	39.48	0.00	0.00
RELEASED (MG/L)	0.00	0.00	31.42	36.15	25.90	17.96	14.14	12.53	13.31	0.00	0.00
% REDUCTION (LB)	0.00	0.00	64.27	64.40	64.39	64.91	65.60	66.14	65.90	0.00	0.00
COLIFORMS											
ARR (MPN/100ML)	0.00E-01	0.00E-01	2.03E 06	2.97E 05	1.71E 05	1.28E 05	1.33E 05	2.63E 05	1.18E 06	0.00E-01	0.00E-01
REL (MPN/100ML)	0.00E-01	0.00E-01	1.90E 03	2.81E 02	1.59E 02	1.14E 02	1.15E 02	2.24E 02	1.01E 03	0.00E-01	0.00E-01
% REDUCTION (LB)	0.00	0.00	99.91	99.91	99.91	99.91	99.91	99.92	99.92	0.00	0.00

Table 2-10. SUMMARY OF TREATMENT COSTS - OPTION 1

COST PARAMETERS . .
INTEREST RATE = 7.00 PERCENT
AMORTIZATION PERIOD = 25 YEARS
CAP. RECOVERY FACTOR = 0.0858
YEAR OF SIMULATION = 1970
SITE LOCATION FACTOR = 1.1452

UNIT COSTS . .
LAND = 20000.00 $/ACRE
POWER = 0.020 $/KWH
CHLORINE = 0.200 $/LB
POLYMERS = 1.250 $/LB
ALUM = 0.03 $/LB

		CAPTIAL COSTS		ANNUAL COSTS			STORM EVENT COSTS		
TREATMENT	LEVEL	INSTAL	LAND	INSTAL	LAND	MIN MAINT	CHLORINE	CHEM	OTHER
BAR RACKS	1	141915.	1293.	12178.	91.	1419.	0.	0.	33.
NO INLET PUMPING	2	0.	0.	0.	0.	0.	0.	0.	0.
DISS AIR FLOAT'N	3	1549642.	5280.	132976.	370.	30993.	0.	0.	38.
BYPASS LEVEL 4	4	0.	0.	0.	0.	0.	0.	0.	0.
NO EFFL. SCREENS	5	0.	0.	0.	0.	0.	0.	0.	0.
NO OUTLET PUMPS	6	0.	0.	0.	0.	0.	0.	0.	0.
NO CONTACT TANK	7	0.	0.	0.	0.	0.	0.	0.	0.
	SUBTOTAL	$ 1691557.	$ 6573.	$ 145154.	$ 460.	$ 32412.	$ 0.	$ 0.	$ 70.
	TOTAL	$ 1698130.		$ 178026.			$ 70.		
	TOTAL PER TRIB ACRE	$ 9295.		$ 974.			$ 0.		

TOTAL LAND REQUIREMENT = 0.33 ACRES.

Table 2-11. SUMMARY OF TREATMENT COSTS - OPTION 2

COST PARAMETERS . .
INTEREST RATE = 7.00 PERCENT
AMORTIZATION PERIOD = 25 YEARS
CAP. RECOVERY FACTOR = 0.0859
YEAR OF SIMULATION = 1970
SITE LOCATION FACTOR = 1.1452

UNIT COSTS . .
LAND = 20000.00 $/ACRE
POWER = 0.020 $/KWH
CHLORINE = 0.200 $/LB
POLYMERS = 1.250 $/LB
ALUM = 0.03 $/LB

		CAPITAL COSTS		ANNUAL COSTS			STORM EVENT COSTS		
TREATMENT	LEVEL	INSTAL	LAND	INSTAL	LAND	MIN MAINT	CHLORINE	CHEM	OTHER
BAR RACKS	1	141915.	1293.	12178.	91.	1419.	0.	0.	33.
NO INLET PUMPING	2	0.	0.	0.	0.	0.	0.	0.	0.
DISS AIR FLOAT'N	3	1562142.	5280.	134048.	370.	31243.	130.	714.	38.
BYPASS LEVEL 4	4	0.	0.	0.	0.	0.	0.	0.	0.
NO EFFL. SCREENS	5	0.	0.	0.	0.	0.	0.	0.	0.
NO OUTLET PUMPS	6	0.	0.	0.	0.	0.	0.	0.	0.
NO CONTACT TANK	7	0.	0.	0.	0.	0.	0.	0.	0.
	SUBTOTAL	$ 1704057.	$ 6573.	$ 146226.	$ 460.	$ 32662.	$ 130.	$ 714.	$ 70.
	TOTAL	$ 1710630.		$ 179348.			$ 915.		
	TOTAL PER TRIB ACRE	$ 9363.		$ 982.			$ 5.		

TOTAL LAND REQUIREMENT = 0.33 ACRES.

Table 2-12. SUMMARY OF TREATMENT COSTS - OPTION 3

```
COST PARAMETERS . .
     INTEREST RATE          =      7.00 PERCENT
     AMORTIZATION PERIOD    =        25 YEARS
     CAP. RECOVERY FACTOR   =    0.0858
     YEAR OF SIMULATION     =      1970
     SITE LOCATION FACTOR   =    1.1452

UNIT COSTS . .
     LAND      =  20000.00  $/ACRE
     POWER     =      0.020 $/KWH
     CHLORINE  =      0.200 $/LB
     POLYMERS  =      1.250 $/LB
     ALUM      =      0.03  $/LB
```

TREATMENT	LEVEL	CAPITAL COSTS INSTAL	CAPITAL COSTS LAND	ANNUAL COSTS INSTAL	ANNUAL COSTS LAND	ANNUAL COSTS MIN MAINT	STORM EVENT COSTS CHLORINE	STORM EVENT COSTS CHEM	STORM EVENT COSTS OTHER
BAR RACKS	1	141915.	1293.	12178.	91.	1419.	0.	0.	37.
INLET PUMPING	2	192097.	138.	16493.	10.	3942.	0.	0.	16.
DISS AIR FLOAT'N	3	1562142.	5280.	134048.	370.	31243.	131.	982.	46.
STORAGE	3	258606.	24122.	22191.	1969.	2586.	0.	0.	39.
NO EFFL. SCREENS	5	0.	0.	0.	0.	0.	0.	0.	0.
NO OUTLET PUMPS	6	0.	0.	0.	0.	0.	0.	0.	0.
NO CONTACT TANK	7	0.	0.	0.	0.	0.	0.	0.	0.
	SUBTOTAL	$ 2154750.	$ 34833.	$ 184900.	$ 2440.	$ 39090.	$ 131.	$ 982.	$ 138.
	TOTAL	$ 2189583.		$ 226430.			$ 1251.		
	TOTAL PER TRIB ACRE	$ 11965.		$ 1237.			$ 7.		

TOTAL LAND REQUIREMENT = 1.81 ACRES.

Because of the infrequent occurrence (once in two years) of storms of this magnitude on the drainage basin, *similar analyses should be made using a complete representative series of storms in arriving at the final decision.* This is because the efficiency of option 1 will continue to improve with increasingly smaller storms due to the reduction in the amount bypassed, yet the cost comparisons will be substantially unchanged. Because of the relatively short duration of storm events, the use of chemicals to assist removals seems to be justified. This is not seen for BOD and SS in comparisons of options 1 and 2 because the design parameters selected for option 1 achieved the maximum removals permitted by the Model in the treated fraction of the flow.

SECTION 3

CINCINNATI

SECTION 3

CINCINNATI

A section of Cincinnati was selected as a demonstration site for the verification of the Storm Water Model. Demonstration runs, in cooperation with the University of Cincinnati (EPA Project 11024DQU), were made on the Runoff and Transport Blocks of the Model. Internal storage, flow dividers, or other transport options were not utilized. In comparison with the other demonstration runs, no corrective actions were made with the Cincinnati test site. The drainage basin used for these test runs is referred to as the Bloody Run Sewer System because of a meat packing plant that was once located in the area.

DESCRIPTION OF STUDY AREA

The test site is a drainage basin located in the northeast section of the city as shown in Figure 3-1. The area is composed of 2,380 acres of hilly land. Fifty-five percent of the area is residential, 17 percent is commercial, 5 percent is industrial, and 22 percent is open land or parks. The drainage basin has two main valleys running approximately east and west. Most of the commercial and industrial sections of the test site are located in these valleys; the residential housing is found on the ridges. The total population for the test site is approximately 26,000, or an average of 11 persons per acre.

The drainage basin is serviced by a combined sewer system. The sewerage network has a main trunk line that splits into three branches

Figure 3-1. GENERAL LOCATION MAP OF
CINCINNATI BLOODY RUN DRAINAGE BASIN

running down the valleys of the test area. The outfall to the test site is located at the southwestern tip of the area which discharges to an interceptor leading to the Mill Creek Waste Water Treatment Plant. Overflows from storms are discharged directly to Mill Creek via an open channel. Photographs of the drainage basin are shown in Figure 3-2.

DATA SOURCES

The University of Cincinnati was contracted by EPA to collect data for the verification runs on the Storm Water Model. It was their responsibility to define a test site in Cincinnati, to set up several sampling points in the sewerage system, and to collect the required data for the verification runs. Their principal source of information was the Department of Public Works which furnished maps of the sewer system, types of trunk lines and their slopes, street cleaning data, types of catchment basins, and other required data. Information was also taken from the 1960 census and from the U.S. Weather Bureau. For the verification runs, four storms were sampled, both for the rainfall hyetographs and runoff hydrographs, and for the quality constituents in the runoff waters. Three sampling stations were set up for these storms and were located as shown in Figure 3-3. Data were also collected on subsequent dry weather days to define the amount and quality of the DWF in this drainage basin.

After the collection of the data for the purpose of modeling the test site, the drainage basin was divided into 38 subcatchments by using sewer, topographical, and zoning maps, with the ideal that each area

Storm Water Outfall from the Bloody Run
Drainage Basin

Typical Residential Street

Figure 3-2. CHARACTERISTIC PHOTOGRAPHS OF THE CINCINNATI DRAINAGE BASIN

Typical Parking Lot Next to a Shopping Center

Typical Park Land

Figure 3-2. (continued)

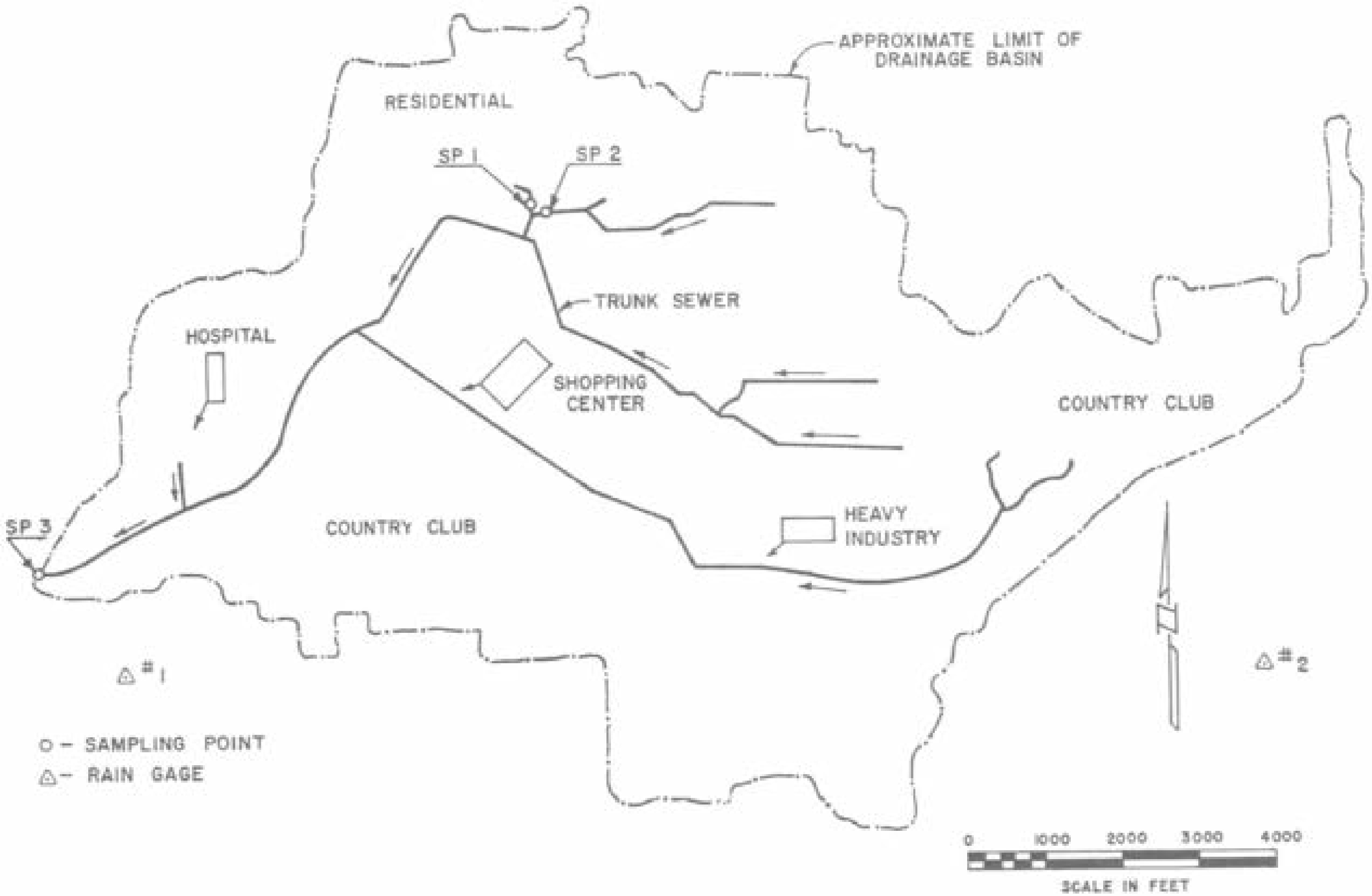
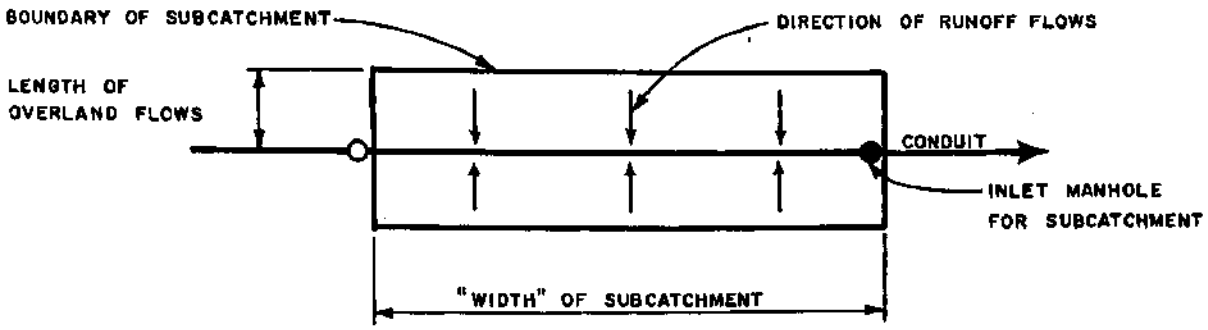


Figure 3-3. CINCINNATI RAIN GAGE AND RUNOFF SAMPLING POINT LOCATIONS

should include one major type of land use and should incorporate an individual inlet manhole. However, the nature of the test site and the sewerage network prevented following this ideal in many cases. The resulting division is shown in Figure 3-4. The maximum size of a subarea was 250 acres; the minimum was 3.6 acres. Each subcatchment was then further subdivided according to land use, as shown in Figure 3-5, resulting in 71 subareas.

The required information for each of the subcatchments was then furnished, paying particular attention to the width of the subcatchment which is, in effect, twice the length of the main sewer system through that subcatchment. The input width is used to calculate the length that the overland runoff flows must travel before entering a modeled gutter, gutter pipe, or the inlet manhole as shown in the following sketch.



In the illustration, the runoff flows are shown to run overland across the "length" of the subcatchment to an imaginary gutter which instantaniously transfer the flows to the inlet manhole. Had a gutter or gutter-pipe been modeled, the flows would then have entered the gutter/gutter-pipe and been routed by the RUNOFF Block to the inlet manhole.

Data input for the subareas was basically straightforward except in

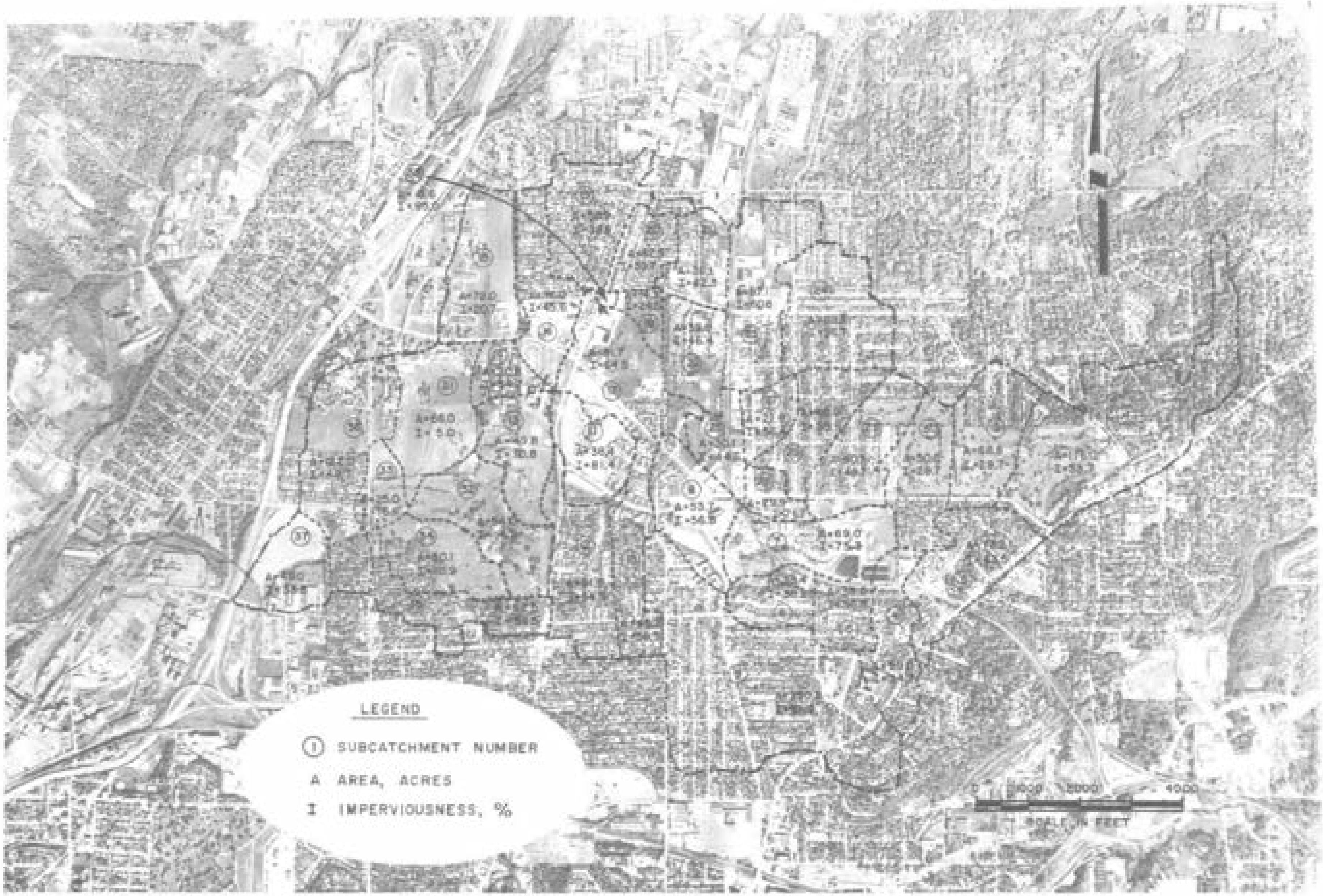


Figure 3-4. DIVISION OF CINCINNATI DRAINAGE BASIN INTO SUBCATCHMENTS

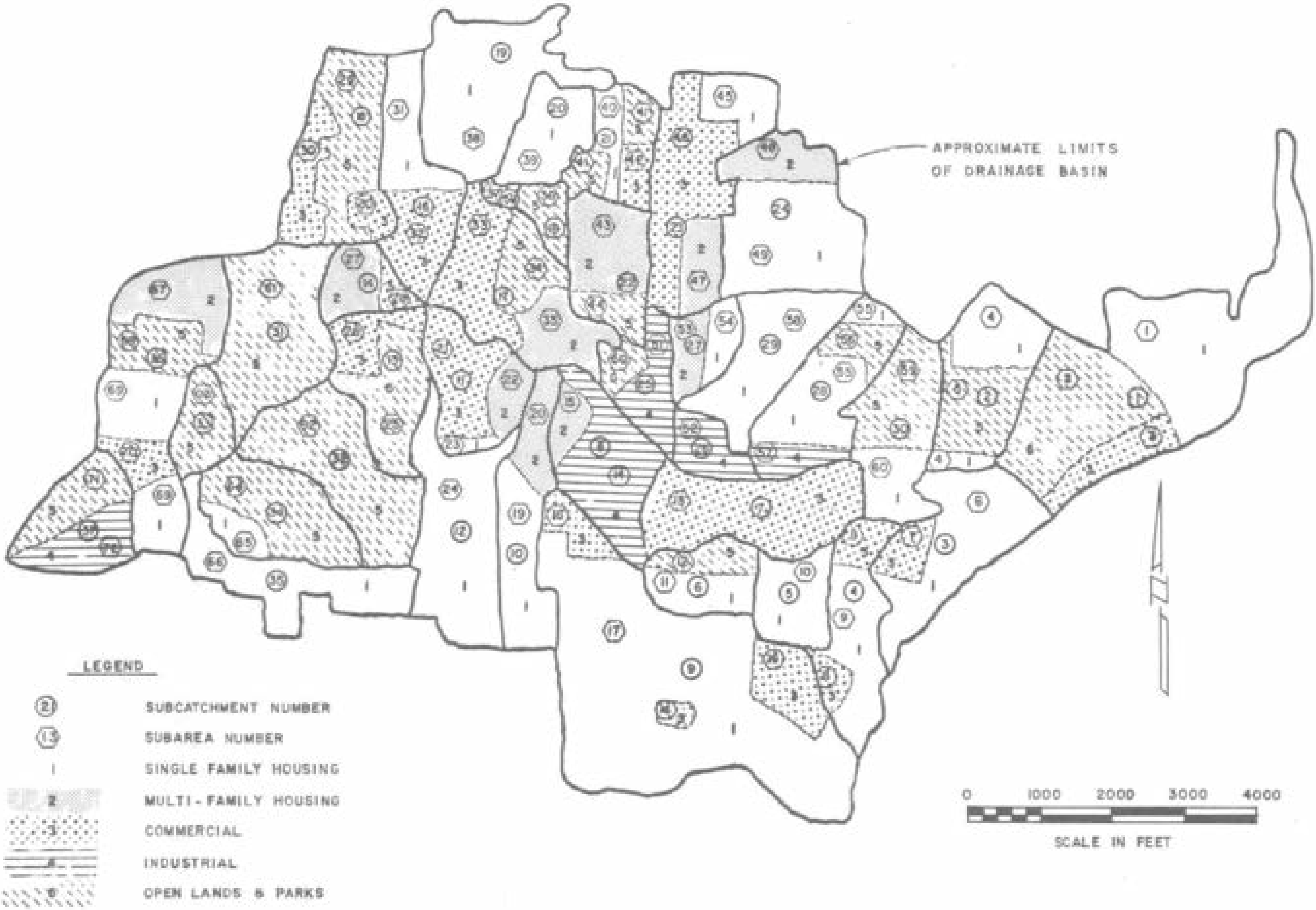


Figure 3-5. DIVISION OF CINCINNATI SUBCATCHMENTS INTO SUBAREAS

areas of extensive parking lots and/or open lands. For the purpose of modeling the amount of solids accummulation on these lands, the actual gutter lengths, as measured from a city map or aerial photo, was increased. For parking lots, a single gutter was assumed to run the length of the lot every 25 feet. This amounted to 1,740 feet of gutters per acre of parking lots. For open lands with no vegetational cover, 1,740 feet of gutters per acre were used. A minimum of 1,000 feet of gutters for park lands, since many parks contributed suspended solids and BOD even though gutters are absent from the area.

The development of a sewer system is based upon sewer maps of the test area. For the Transport Block, main sewer lines must be determined and laid out in what usually results in a tree-like structure. For the Cincinnati Bloody Run drainage basis, all pipes smaller than 27 inches were omitted from the pipe network. Manholes were located whenever there was a significant change in pipe size, direction, or slope. Inlet manholes were located so that every subcatchment had its individual inlet manholes. Figure 3-6 shows the Cincinnati Bloody Run sewer system. The majority of the pipes used in this test site were either circular or rectangular round bottom. Some of the actual shapes were not the same as those supplied by the computer model; however, instead of supplying the flow characteristics for these new pipe shapes, an equivalent modeled section was used.

In addition to storm flow monitoring stations, six DWF stations were set up as shown in Figure 3-7. Data from these stations were used both to compute the daily and hourly variation factors as required by subroutine FILTH and to compare the calculated DWF values with the real numbers.

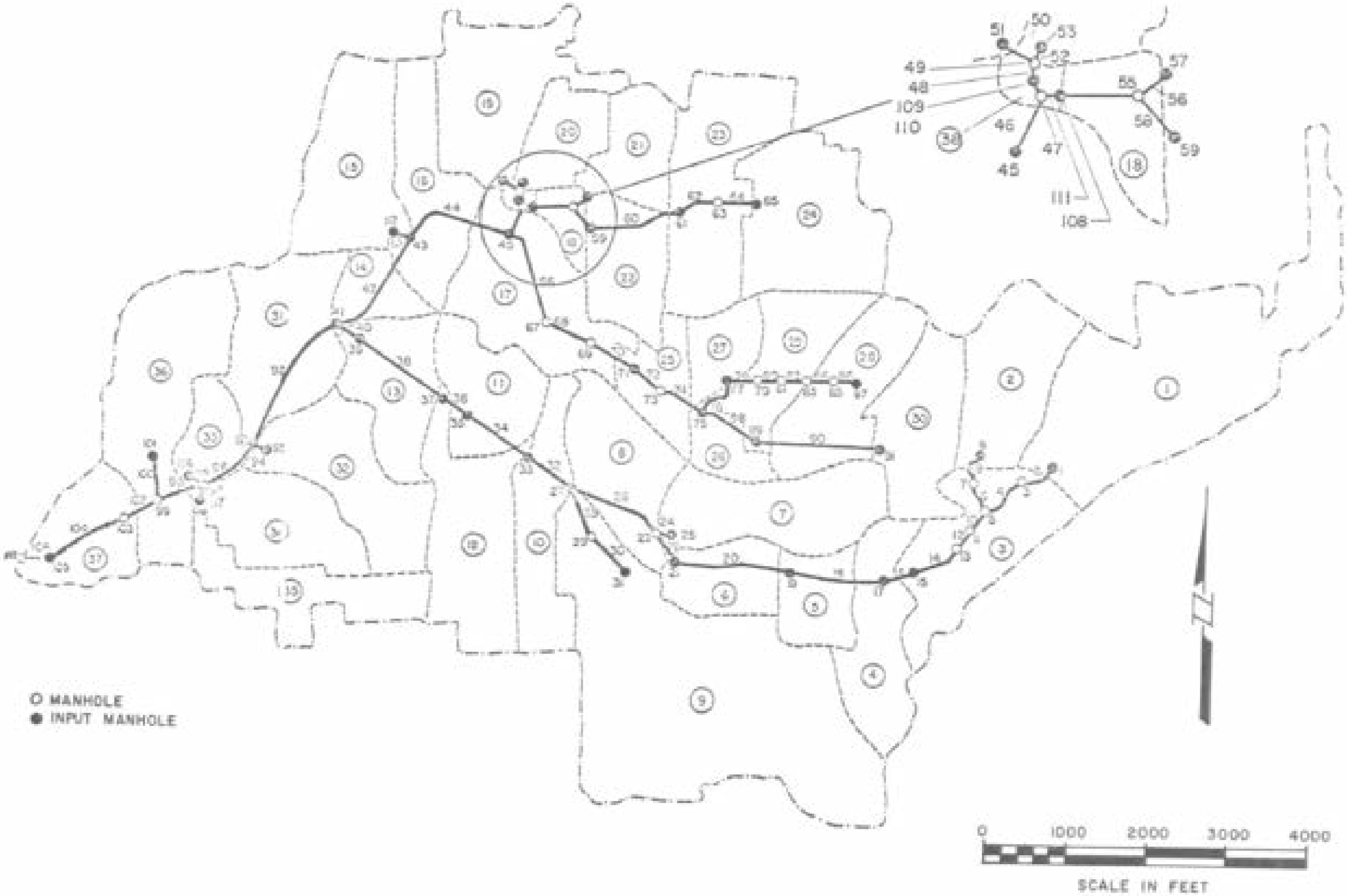


Figure 3-6. PLAN OF CINCINNATI BLOODY RUN SYSTEM

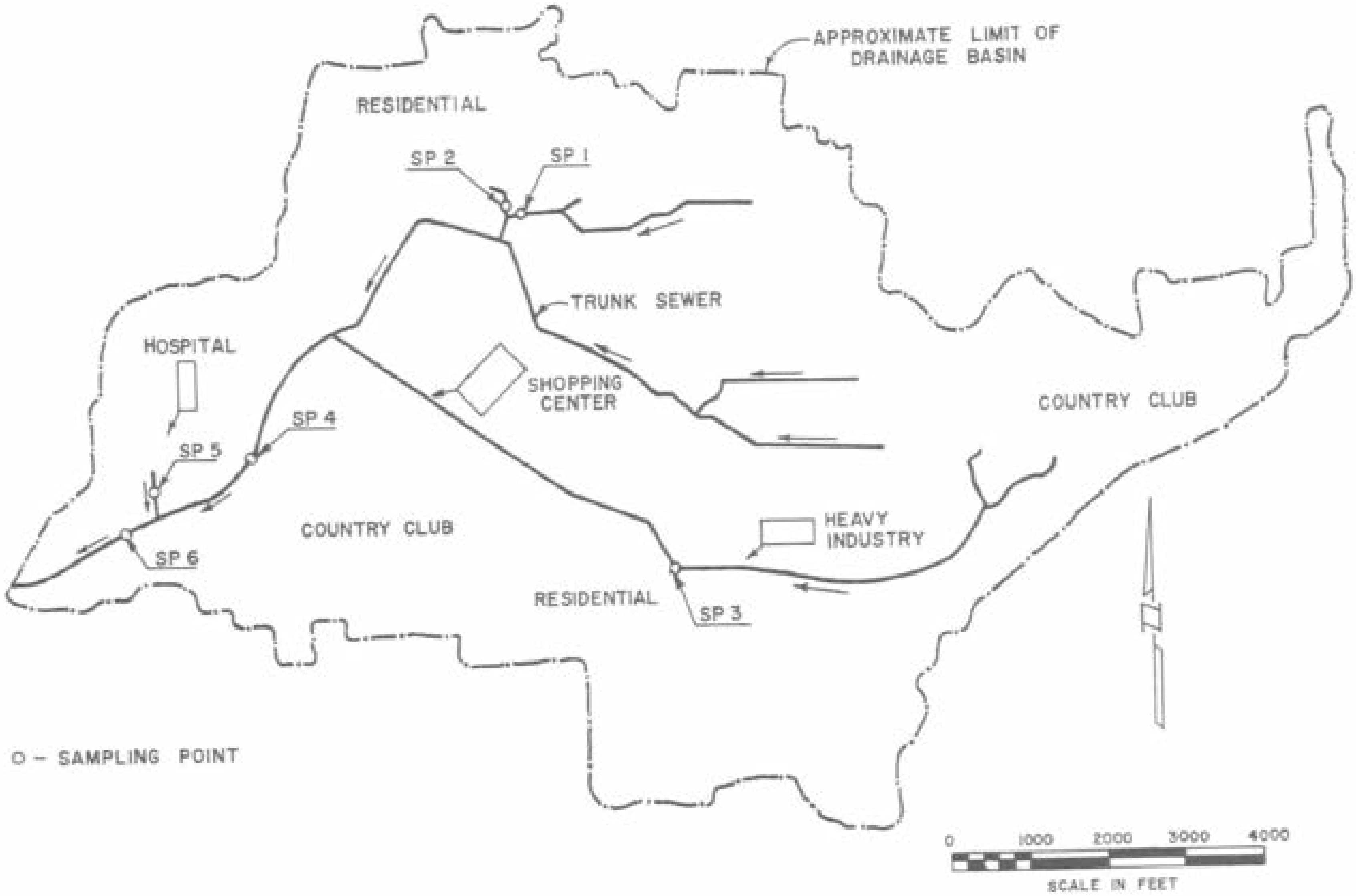


Figure 3-7. LOCATION OF SAMPLING POINTS FOR DRY WEATHER FLOW

The choice of time-step length and the number of time-steps was based upon the duration of measured runoff from the storm. The average length of time-steps was usually between 1 minute and 10 minutes. Much of the sampling at Cincinnati was done on a 2-1/2 minute increment; however, for the purpose of shortening computer runs, a 5-minute interval was used. Fifty time-steps were required to extend the simulation beyond the recorded storm water flows.

VERIFICATION RESULTS

Dry Weather Flow

The computed DWF was adjusted as described elsewhere in this volume. The results matched the measured flows within several percentage points at the six sampling locations. A comparison is shown in Table 3-1. As was the case in the San Francisco verification runs, the start time of the storm was of particular importance because of large daily and hourly variations for the flow and contaminant concentrations. The results for the DWF were considered good.

Combined Sewer Overflows

Of the four storms sampled, only two were used for verification runs. Figures 3-8 and 3-9 show the comparisons between the measured hydrographs and the computed hydrographs for the storms of April 1, 1970, and May 12, 1970, respectively. The match was considered only fair. In Figure 3-8, three sets of hydrographs are given for the storm of April 1 at three different locations in the sewer system. This figure shows that the comparison between the measured and computed flows was

Table 3-1. CINCINNATI DRY WEATHER FLOW RESULTS

Sampling	Flow, cfs		BOD, mg/L		SS, mg/L		Coli, MPN/100 ml
Location	Reported*	Computed	Reported*	Computed	Reported*	Computed	Computed
1	0.93	0.90	360.	403.	224.	206.	9.5×10^7
2	0.54	0.50	350.		230.		
3	1.45	2.12	1160.		236.		
4	15.50	12.58	618.	529.	265.	226.	7.0×10^7
5	0.50	0.80	292.		181.		
6	13.94	13.61	412.	517.	252.	224.	7.6×10^7

*Reported values are averages of approximately 10 grab samples each over a two-week period.

NOTE: Data listing for the above results can be found under Section 8, Cincinnati data.

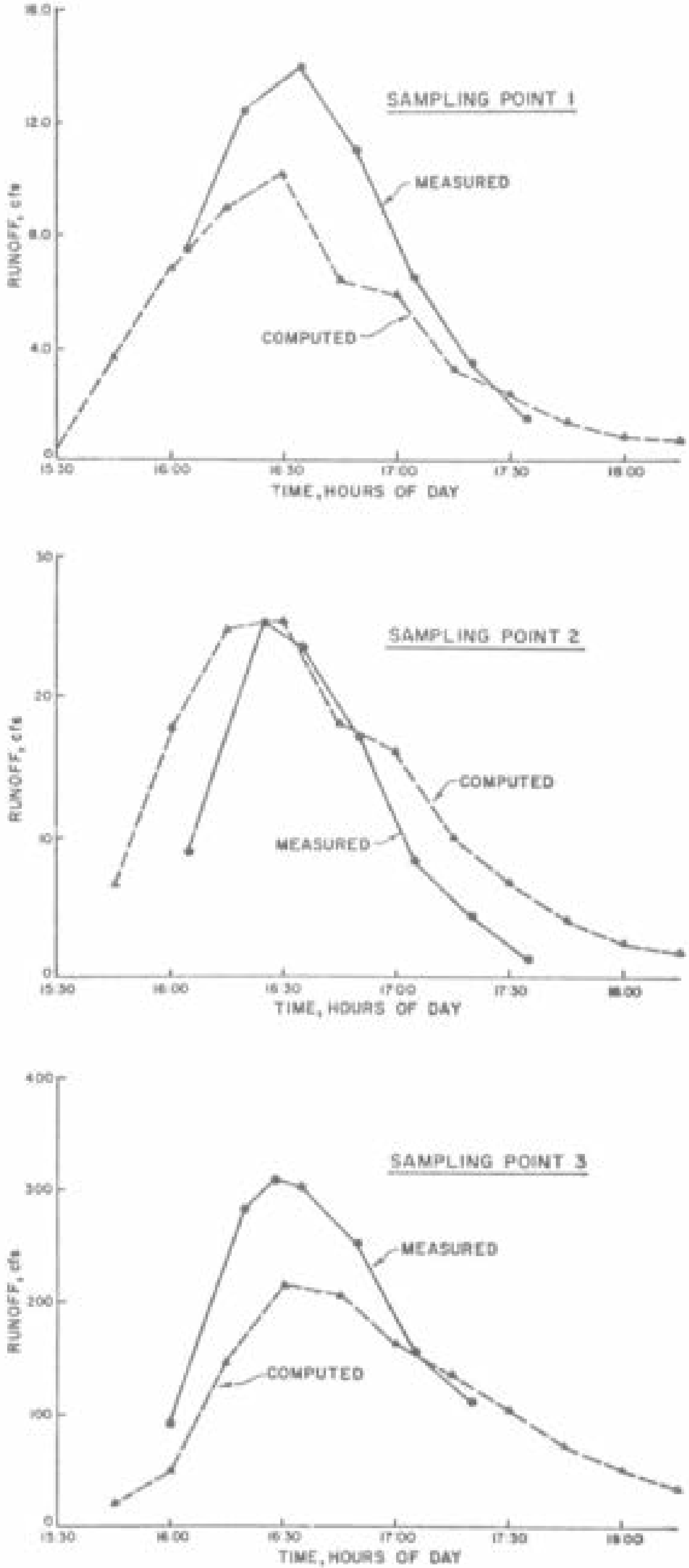


Figure 3-8. CINCINNATI - COMPARISONS BETWEEN MEASURED AND COMPUTED HYDROGRAPHS - STORM OF APRIL 1, 1970

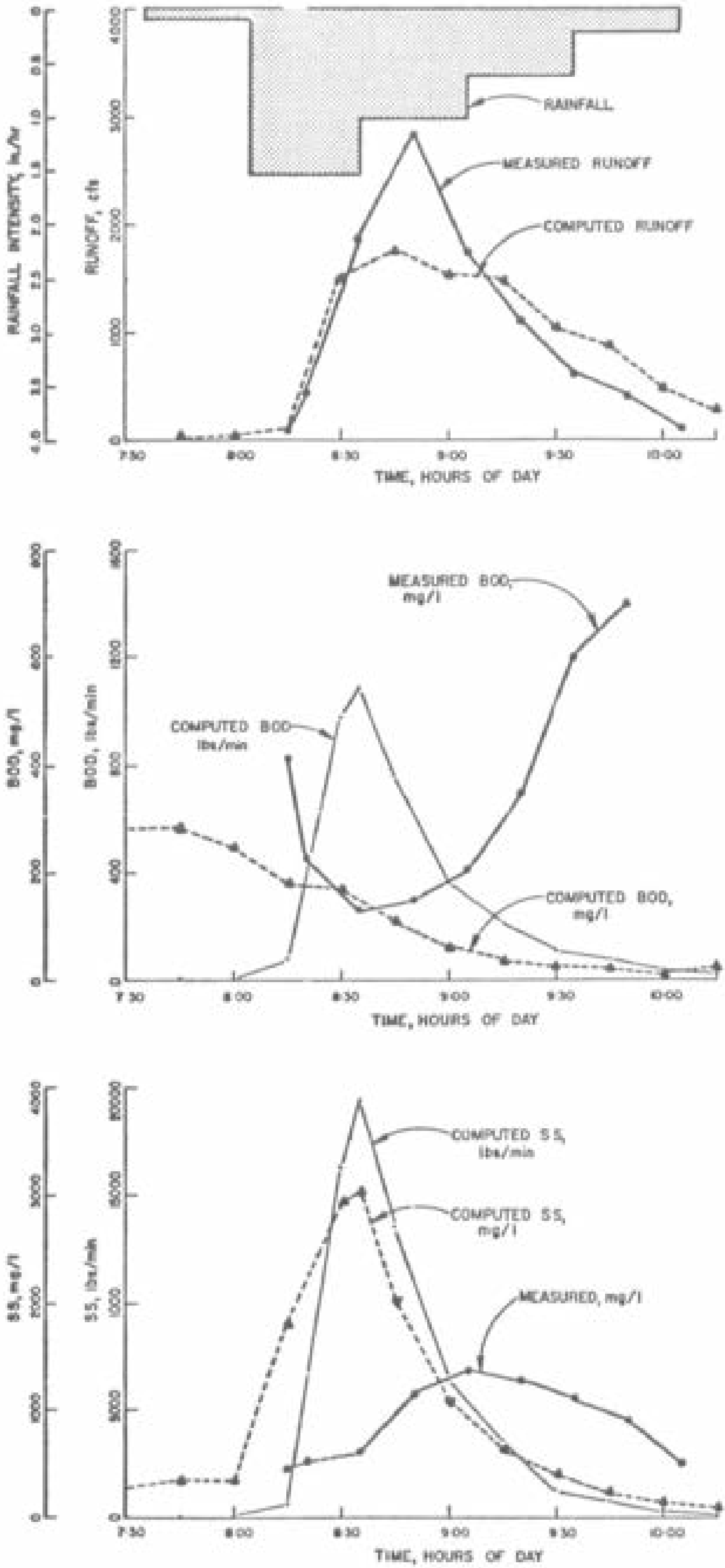


Figure 3-9. CINCINNATI - COMBINED SEWER OVERFLOW RESULTS - STORM OF MAY 12, 1970, SAMPLING POINT 3

reasonably consistent throughout the drainage basin. Figure 3-9, which shows the runoff hydrograph and pollutographs, was for the May 12 storm where only one sampling point was in operation. For both storms, the time of peak flows coincided with good accuracy, but the volume of flow for each calculated hydrograph was below the measured hydrograph. Several factors may have attributed to this low peak:

1. Accuracy of the input hyetograph. The collected hyetographs for all four rainstorms were based on 30-minute intervals for two rain gages located outside of the test area. These rain gages apparently produced the same measurements and were several hundred feet below the average elevation of the test site. As was noted in Section 2, difference in elevation between the rain gages and the actual test site can make a difference in the amount of rainfall for the higher elevations. Also, it is possible that the charts were misread and that the reported intensities were, in fact, accumulations over 30-minute or other time periods and were not corrected to hourly rates.
2. Flow measurements. The flow measurements were made by recording the depth of flow in the drainage conduits and calculating the flow rate. An improper C factor for that particular pipe will give a faulty hydrograph.
3. Lack of gutter pipes for the larger subcatchment basins. This can cause a delay in the runoff peak and also a flatter and broader hydrograph than will actually occur. The flow rate over land surfaces as calculated by the Runoff Block has a

much slower flow rate than the runoff through a pipe or a gutter. Thus, for large subcatchment areas the water is stored on the surface and is allowed to come off at a much slower rate than would actually be found in a gutter of one of the smaller drainage pipes.

Figures 3-9 and 3-10 show a comparison between the measured pollutographs and the computer pollutographs for the two storms. To improve the pollutographs' fit, three dummy subareas were required to increase the concentration of the suspended solids and BOD in the runoff waters. These dummy subareas were located upstream of the three sampling points at manholes 25, 53, and 59 (Figure 3-6) and each consisted of a one-acre area with long lengths of gutters to increase pollutant runoff. Gutter length is used in the Model to determine the amount of pollutants washed off in a storm. The need for these dummy subareas was attributed to the unusually large amount of open land and parts, 22 percent, that seem to contribute a continuous amount of pollutants varying only with the amount of runoff and/or the possible data errors previously discussed.

A second possible explanation for the mismatch between the measured and calculated pollutographs may be caused by inaccurate runoff figures which undermine the validity of the pollutographs. The equations that determine the amount of solids washed off during a storm utilize the simulated runoff quantities calculated by the Runoff Block. The quanitities of solids removed are in direct proportion to the quantity of runoff. Therefore, if simulated hydrographs were flatter and broader (less peak flows), smaller amounts of pollutants would be introduced into the storm sewers.

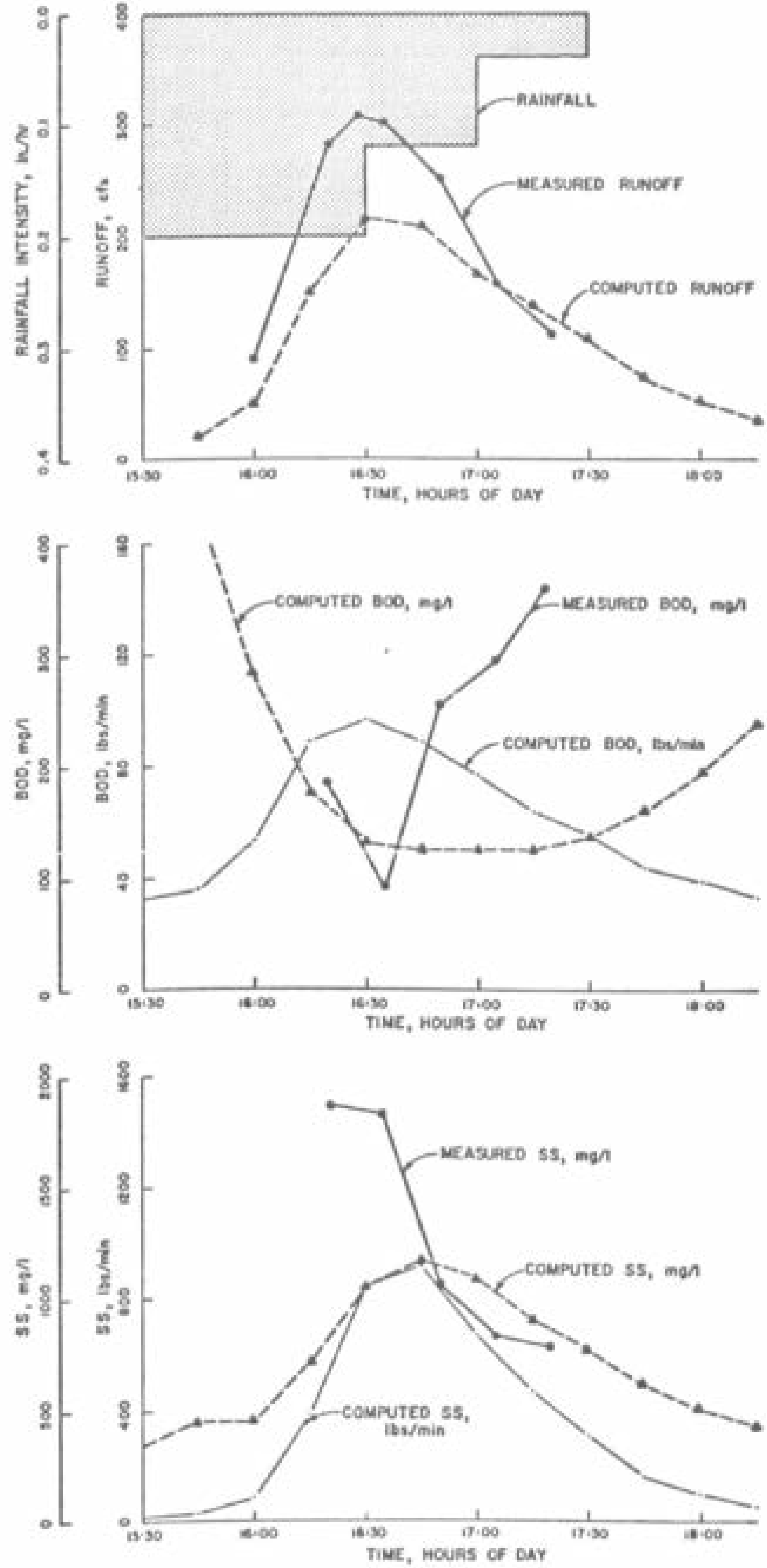


Figure 3-10. CINCINNATI COMBINED SEWER OVERFLOW RESULTS - STORM OF APRIL 1, 1970, SAMPLING POINT 3

Figure 3-8 shows that the simulated hydrographs are flatter and of longer duration. These hydrographs, in turn, govern the calculated BOD mg/L curves as shown in Figure 3-9. The curve has been depressed by the flatter hydrograph for a longer period of time than was observed at the test site. As was noted above, the addition of gutter pipes to the larger subcatchments should increase the peak flows and thus improve the pollutographs.

The sampling and modeling work is continuing and the questions raised will be resolved in a report under Project No. 11024 DQU.

SECTION 4

WASHINGTON, D.C.

SECTION 4

WASHINGTON, D.C.

The results of two storms modeled on the Kingman Lake drainage basin are discussed in this section.

DESCRIPTION OF STUDY AREA

The Kingman Lake drainage basin (4,200 acres) is served by the Northeast Boundary Trunk Sewer and lies wholly within the one-third portion of the District of Columbia still using combined sewers. It is by far the largest combined sewer basin in the District and overflows under the influence of storm water runoff approximately 57 times per year for an overall duration of 300 hours (Ref. 1). The land use is predominantly (69 percent) residential, with family incomes ranging from average to low, followed by industrial (13 percent), parks and open space (12 percent), and commercial (6 percent). The total population is 146,700, or 35 persons per acre. Several large schools, hospitals and similar institutions lie within the basin.

As estimated by the District, the basin is highly impervious. Over half of the subcatchments are considered to be 90 percent impervious; the average of all subcatchments is high--75 to 80 percent. The topography is gentle, and drainage is southeasterly from a high elevation of 310 feet at the northwest to a low elevation of 0 feet at its discharge to the Anacostia River.

Only about 15 percent of the Northeast Boundary Trunk Sewer has the hydraulic capacity to carry off the runoff from a 15-year return-frequency storm (8,600 cfs versus an available maximum trunk capacity of 4,000 cfs, Ref. 1). The trunk sewer is about 4.9 miles long and terminates in a triple-barrel section, each barrel 16.5 feet by 8 feet in size. The DWF, computed at 29.8 cfs, is intercepted by a 6-foot diameter conduit (96 cfs capacity) a half-mile west of the Anacostia River for eventual treatment at the District's Water Pollution Control Plant (Ref. 2). When the combined sewer flow reaches approximately 800 cfs, a regulator stops all diversion to the interceptor and the full flow is bypassed to the Anacostia River.

Photographs taken in the study area are shown in Figure 4-1.

DATA SOURCES

A conceptual design for combined sewer storage and reclamation in the Kingman Lake basin was conducted for the EPA in January-June 1970 (Ref. 1) and the initial data collection was performed in cooperation with this study. The recommended storage and treatment facilities of the conceptual engineering report were modeled as discussed later in this section.

The Department of Sanitary Engineering for the District of Columbia furnished sewer plans, watershed data, and aerial photomaps of the complete drainage basin. Libraries and statistical abstracts were consulted for data on the three major schools and six major hospitals in the drainage basin for dry weather flow computations. Average

Outfall to Anacostia River

Typical Street of Rowhouse Apartments

Typical Garage Way After Storm

Surface Ponding After Storm

Figure 4-1. CHARACTERISTIC PHOTOGRAPHS OF KINGMAN LAKE DRAINAGE BASIN

DWF characteristics were taken from Ref. 3, and population and income figures were taken from census tract data as in the previous tests.

The Kingman Lake system was subdivided into 53 subcatchments varying from 5 acres to 225 acres in size and from 2 percent to 7 percent in slope. Fifty-seven subareas were used in the surface quality computations to allow for multiple land uses in some subcatchments.

The sewer system was represented by 152 elements as shown in Figure 4-2. Pipe configurations modeled included circular, rectanglular, egg-shaped, gothic-shaped, and modified basket-handle.

Two rain gages were used as shown in Figure 4-3. The first was located at D. C. General Hospital (ground elevation 35 feet), and the second was located at the D. C. Water Filtration Plant (ground elevation 170 feet).

VERIFICATION RESULTS

The two storms modeled for the Kingman Lake drainage basin were:

Date	Total Rainfall, in.
July 22, 1969	3.20
August 20, 1969	0.64

Direct sampling data were not available for quality comparisons. However, a chart recording the depth of sewage flow at element 115 was available for each storm. The computer program was modified to print out depths of flow for this element for direct comparisons with this measured data.

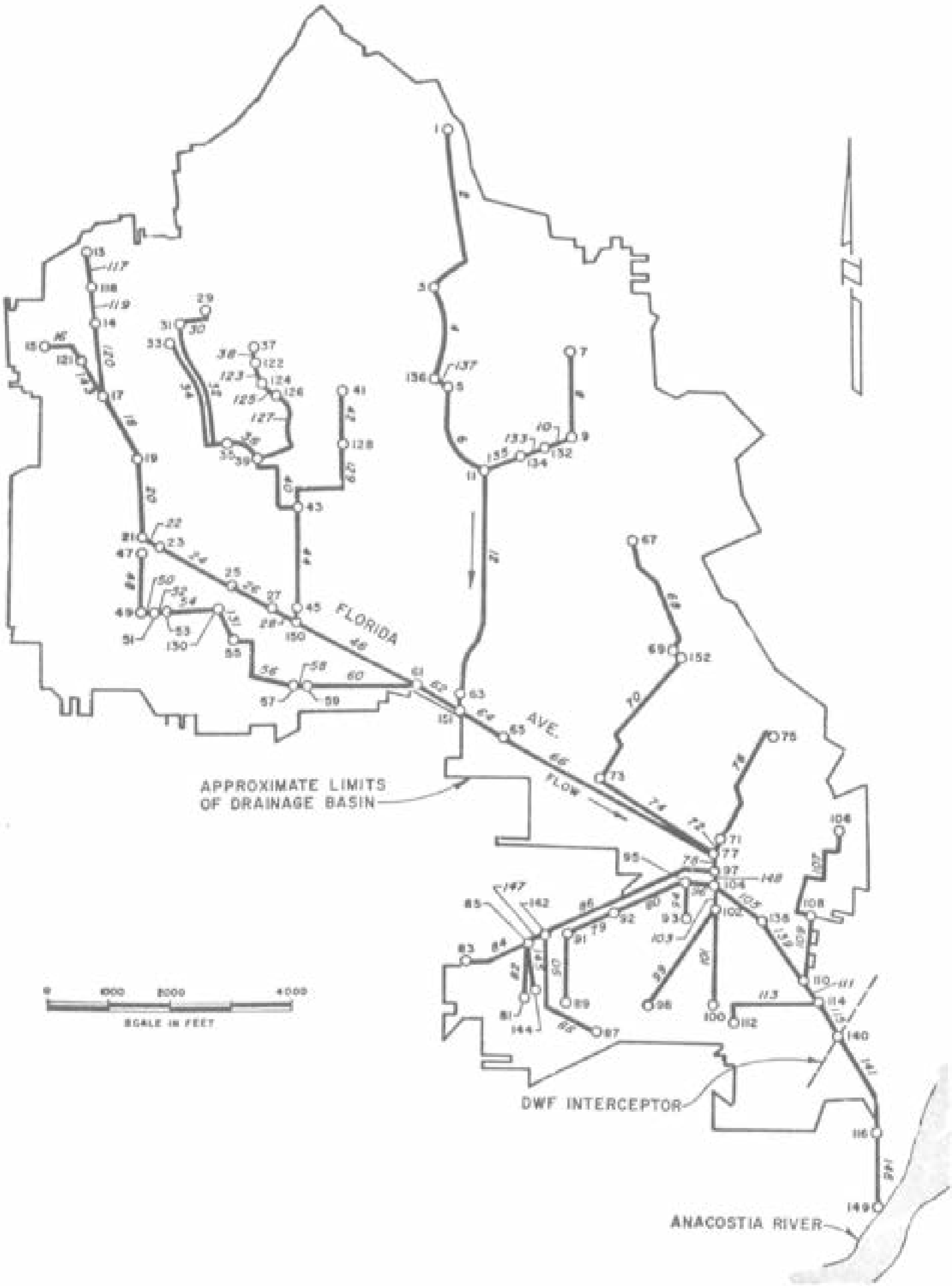


Figure 4-2. PLAN OF KINGMAN LAKE SYSTEM

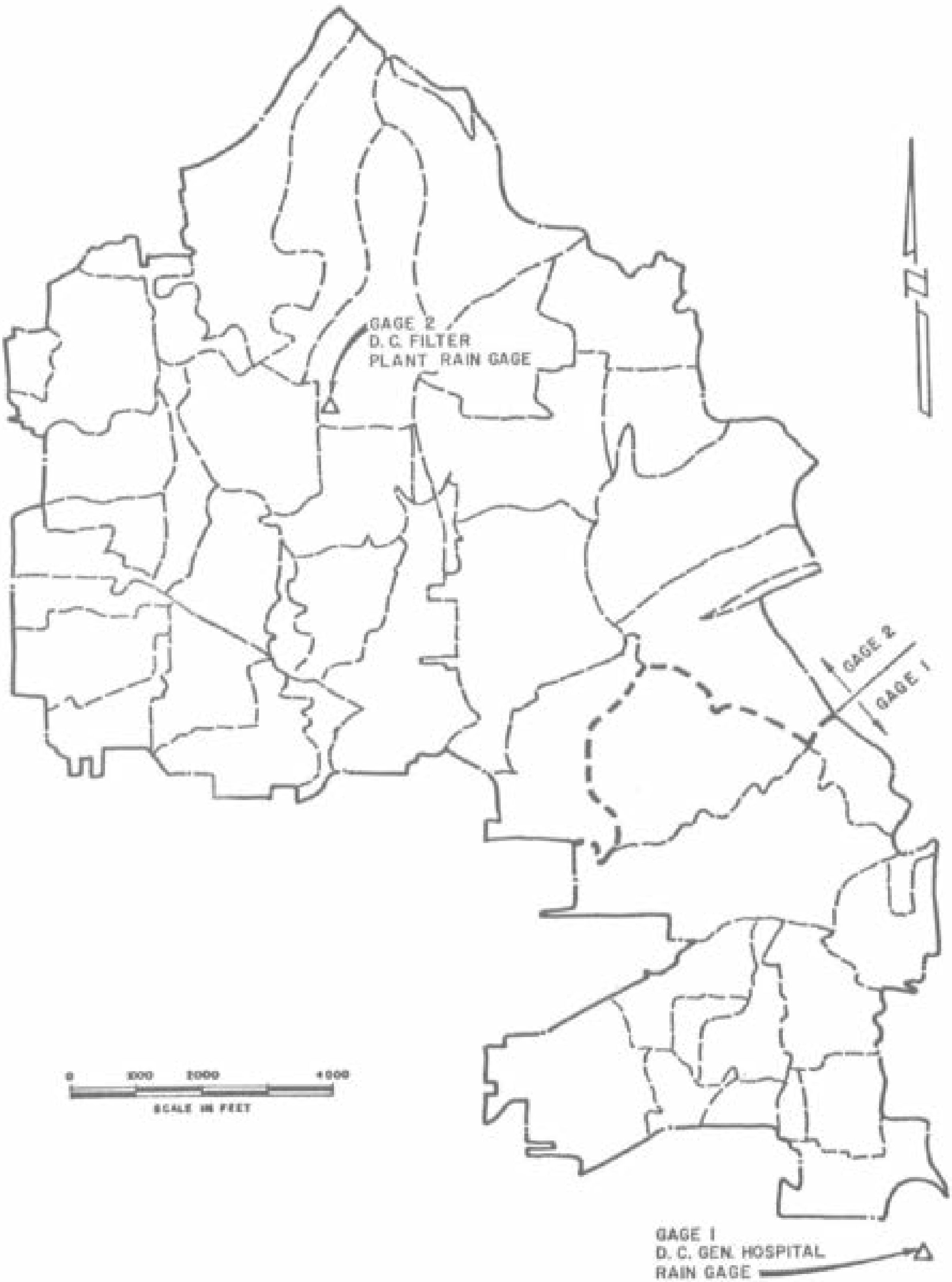


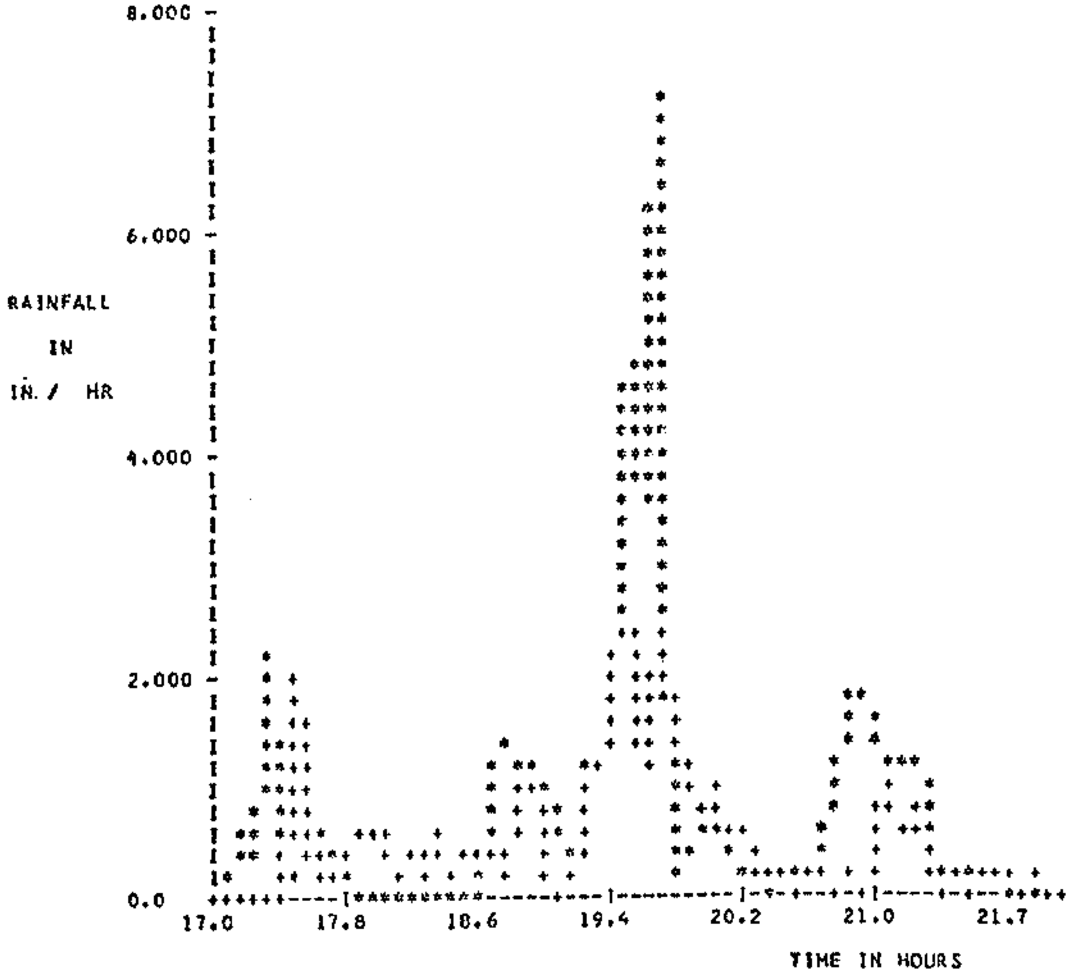
Figure 4-3. KINGMAN LAKE RAIN GAGE LOCATIONS AND SUBCATCHMENTS

Combined Sewage Overflows - Quantity

Figure 4-4 shows the rainfall hyetographs used in the model for the storm of July 22, 1969. The comparison of the computed and recorded depths of flow in element 115 is shown in Figure 4-5. With the exception of the maximum computed stage value, the fit was good. The overestimation of the peak stage may have resulted from restrictive capacities and storage in the feeder lines which were not modeled. From discussions with District personnel, it was understood that sections of the Northeast Boundary Trunk Sewer cannot flow full without surcharging and backing up flows in large sections of the feeder system. This assumption was reinforced by the fact that the recorded stage remained high for a period well after the computed stage dropped off, which is typical of outflow from storage.

During the large storm of July 22, 1969, the capacities of several sewer elements as represented by the model were exceeded and surcharging developed. In order to maintain continuity, the model stored the excess flow at each manhole immediately upstream of a surcharged element until capacity became available. The locations, times, and durations of the modeled surcharging are shown on Figure 4-6.

Hyetographs and stage comparisons for the storm of August 20, 1969, are shown in Figures 4-7 and 4-8, respectively. Again, the fit was good with the feeder system storage effects still evident. No trunk sewer surcharging was computed for this lesser storm.



RAINGAGE LEGEND 1 = * 2 = +

FOR 64 RAINFALL STEPS, THE TIME INTERVAL IS 5.00 MINUTES

FOR RAINGAGE NUMBER 1 RAINFALL HISTORY IS

0.0	0.0	0.60	0.48	2.16	0.0	0.24	0.72	0.36	0.36
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.96	1.44	0.72	1.21	0.36	0.72	0.48	1.20	1.20	2.40
4.80	3.60	7.20	0.24	0.36	0.60	0.60	0.48	0.24	0.12
0.0	0.12	0.12	0.12	0.60	1.20	1.80	1.80	1.20	1.20
1.20	0.96	0.24	0.12	0.12	0.24	0.12	0.0	0.0	0.0
0.0	0.0	0.0	0.0						

FOR RAINGAGE NUMBER 2 RAINFALL HISTORY IS

0.0	0.0	0.0	0.0	0.0	0.20	2.04	0.36	0.30	0.30
0.60	0.60	0.60	0.24	0.49	0.24	0.60	0.24	0.36	0.36
0.36	0.24	1.08	1.09	0.24	0.0	0.24	0.96	1.20	2.40
2.40	1.20	2.40	1.80	1.20	0.84	0.96	0.60	0.60	0.12
0.12	0.12	0.0	0.12	0.12	0.0	0.12	0.0	1.09	0.60
0.84	0.36	0.0	0.12	0.0	0.12	0.12	0.12	0.0	0.12
0.0	0.0	0.0	0.12						

Figure 4-4. KINGMAN LAKE RAINFALL HYETOGRAPHS - STORM OF JULY 22, 1969

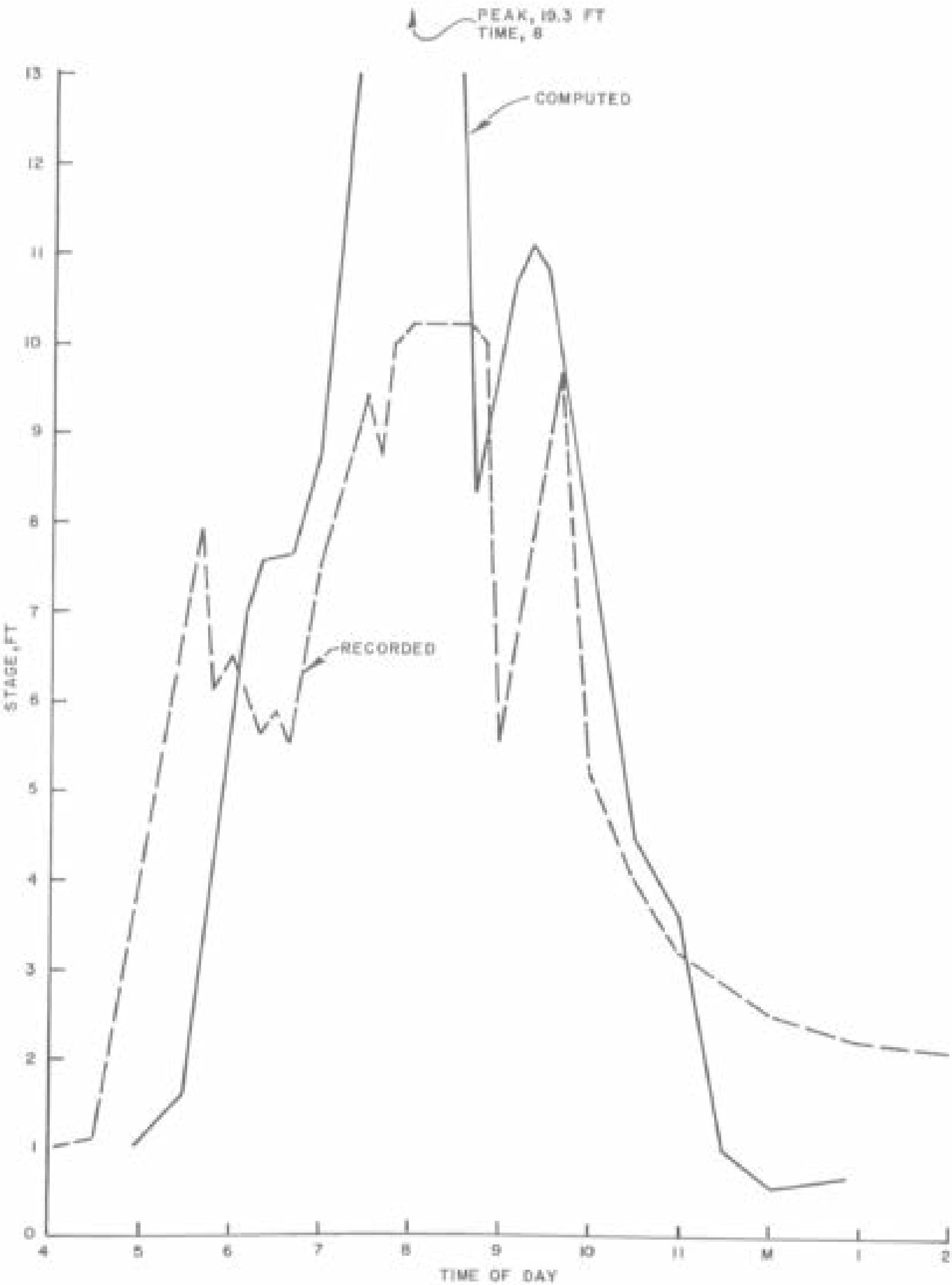
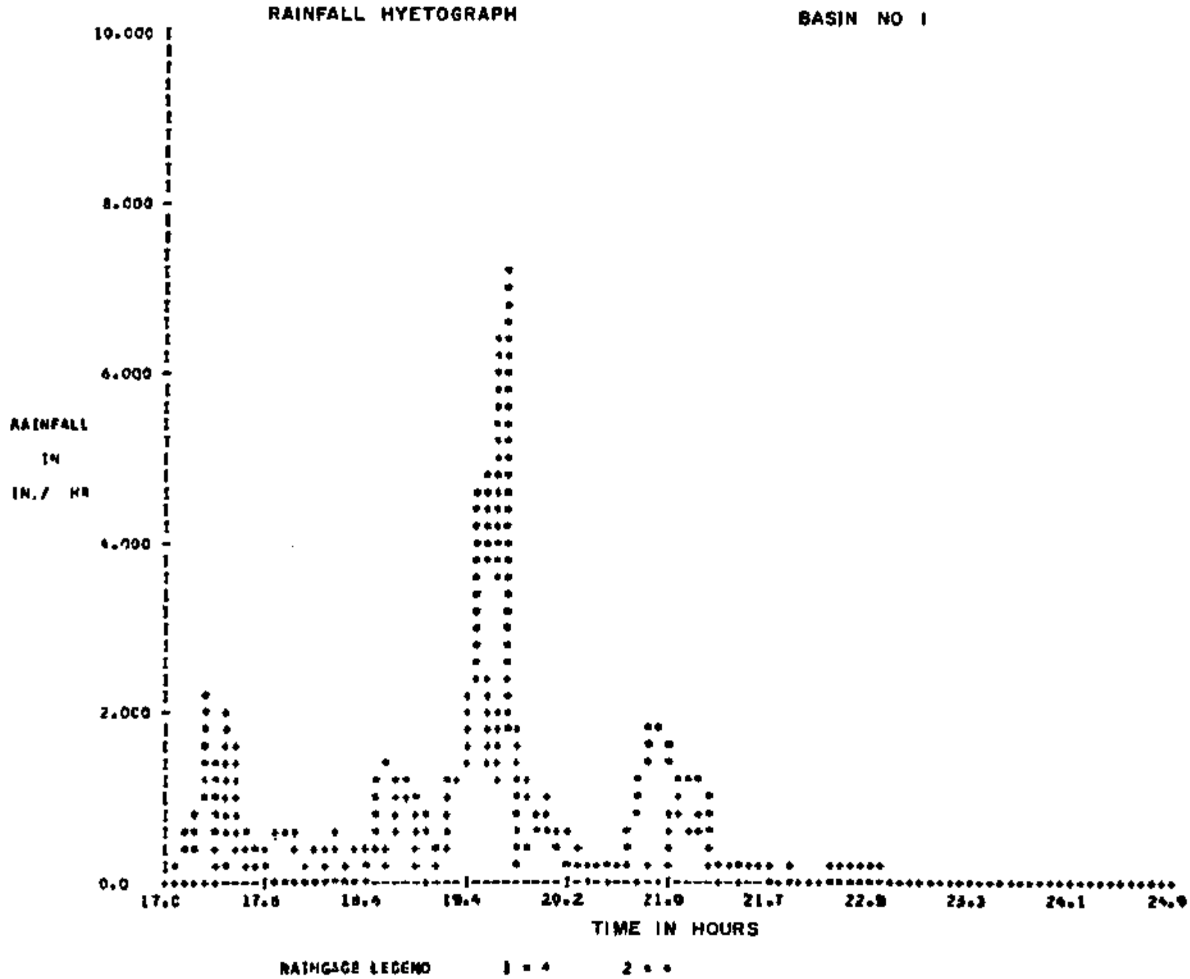
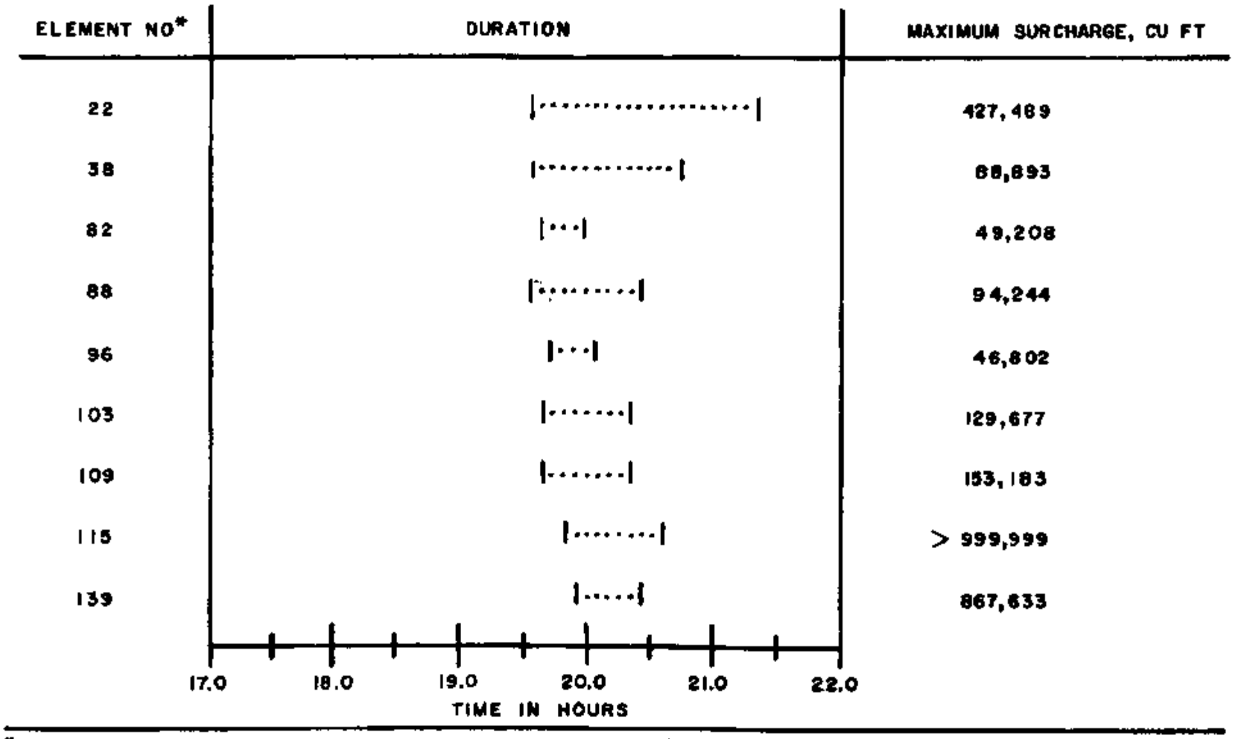


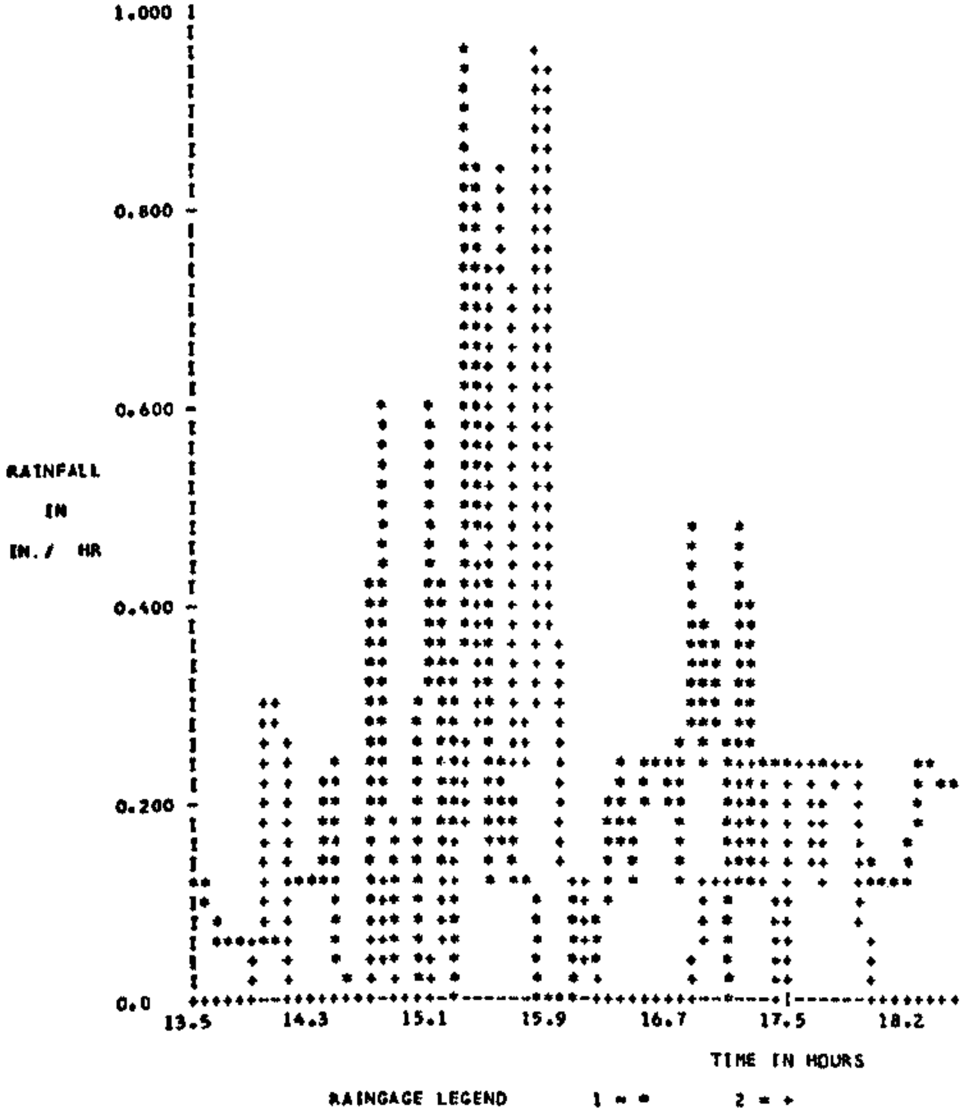
Figure 4-5. KINGMAN LAKE COMBINED SEWER OVERFLOW RESULTS (QUANTITY) - STORM OF JULY 22, 1969





*SEE FIGURE 4-2

Figure 4-6. KINGMAN LAKE SURCHARGES IN CONDUIT SYSTEM - STORM OF JULY 22, 1969



FOR 59 RAINFALL STEPS, THE TIME INTERVAL IS 5.00 MINUTES

FOR RAINGAGE NUMBER 1 RAINFALL HISTORY IS

0.12	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.12	0.12
0.12	0.24	0.0	0.0	0.0	0.60	0.0	0.0	0.0	0.60
0.24	0.0	0.96	0.60	0.12	0.24	0.12	0.12	0.0	0.0
0.0	0.12	0.0	0.12	0.24	0.12	0.24	0.24	0.24	0.12
0.48	0.24	0.36	0.0	0.48	0.12	0.24	0.24	0.24	0.24
0.24	0.24	0.24	0.24	0.12	0.12	0.12	0.12	0.24	

FOR RAINGAGE NUMBER 2 RAINFALL HISTORY IS

0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.30	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.12	0.0	0.0	0.0	0.0
0.12	0.12	0.24	0.36	0.72	0.84	0.24	0.24	0.96	0.36
0.12	0.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.12	0.12	0.12	0.24	0.24	0.12	0.0	0.24	0.24
0.12	0.24	0.24	0.24	0.0	0.0	0.0	0.0	0.0	

Figure 4-7. KINGMAN LAKE RAINFALL HYETOGRAPHS - STORM OF AUGUST 20, 1969

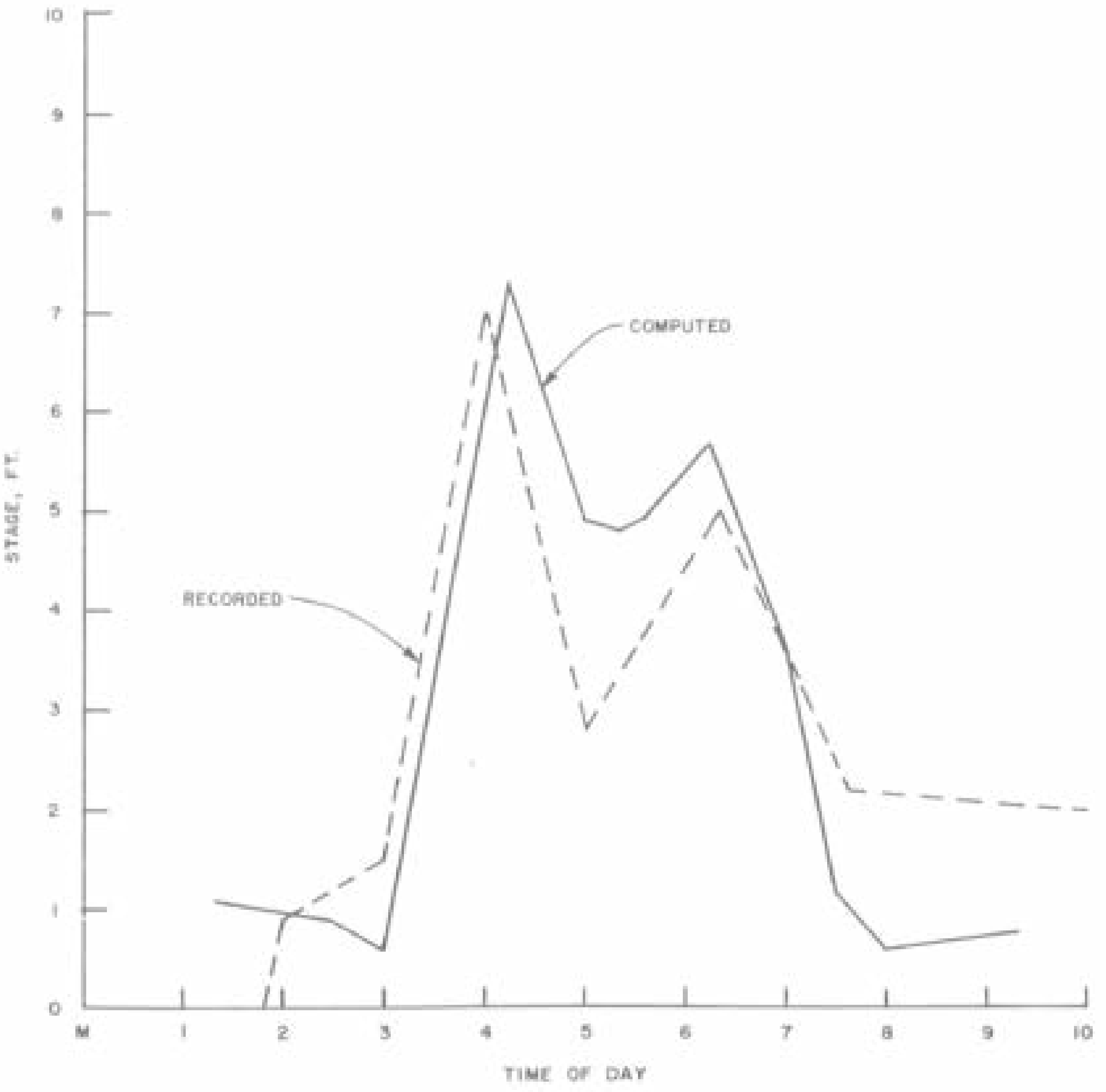


Figure 4-8. KINGMAN LAKE COMBINED SEWER OVERFLOW RESULTS (QUANTITY) - STORM OF AUGUST 20, 1969

Combined Sewage Overflows - Quality

Although no direct sampling of the Kingman Lake combined sewer overflows was accomplished, others (Ref. 1) had monitored two combined sewers in the District (drainage basins of about 200 acres) over a six-month period. The results are compared to the computed storm values in Table 4-1. The verification was favorable except that the July 22, 1969, concentrations were weaker due to the extremely high runoff volume.

Figure 4-9, a chart of recorded rainfall for the District for the summer of 1969, further explains the observed variations in the mean concentrations of pollutants overflowing in the two storms. A large storm occurred just two days prior to the July 22 storm, effectively flushing much of the accumulated surface pollution from the drainage basin. A storm of similar magnitude did not occur until 18 days prior to the August 20 storm. These variations in antecedent conditions were accounted for in the Storm Water Model by adjusting the dry day estimates supplied in the input data (see Volume III).

Typical variations of pollutant concentrations in the overflow with time computed for the two storms are shown in Table 4-2. From these data it is obvious that the source of surface pollutants was effectively exhausted after 3 hours of the extremely intense July 22 storm.

In terms of mass quantities, the total computed (untreated) releases in the two storms were:

Table 4-1. COMBINED SEWER OVERFLOW QUALITY COMPARISONS

	Reported*		Computed**			
			July 22, 1969		August 20, 1969	
Waste Constituent	Range	Mean***	Range	Mean***	Range	Mean***
BOD, mg/L	10-470	71	4-220	47	43-245	97
SS, mg/L	35-2,000	622	6-977	267	173-827	394
Total coliforms, MPN/100 ml	420,000-5,800,000	2,800,000			380,000-4,670,000	1,730,000

*Roy F. Weston, "Preliminary Draft Conceptual Engineering Report, Kingman Lake Project," FWQA, May 1970 (Ref. 1).
**Based on 95 five-minute time-steps.
***Not weighted according to flow.

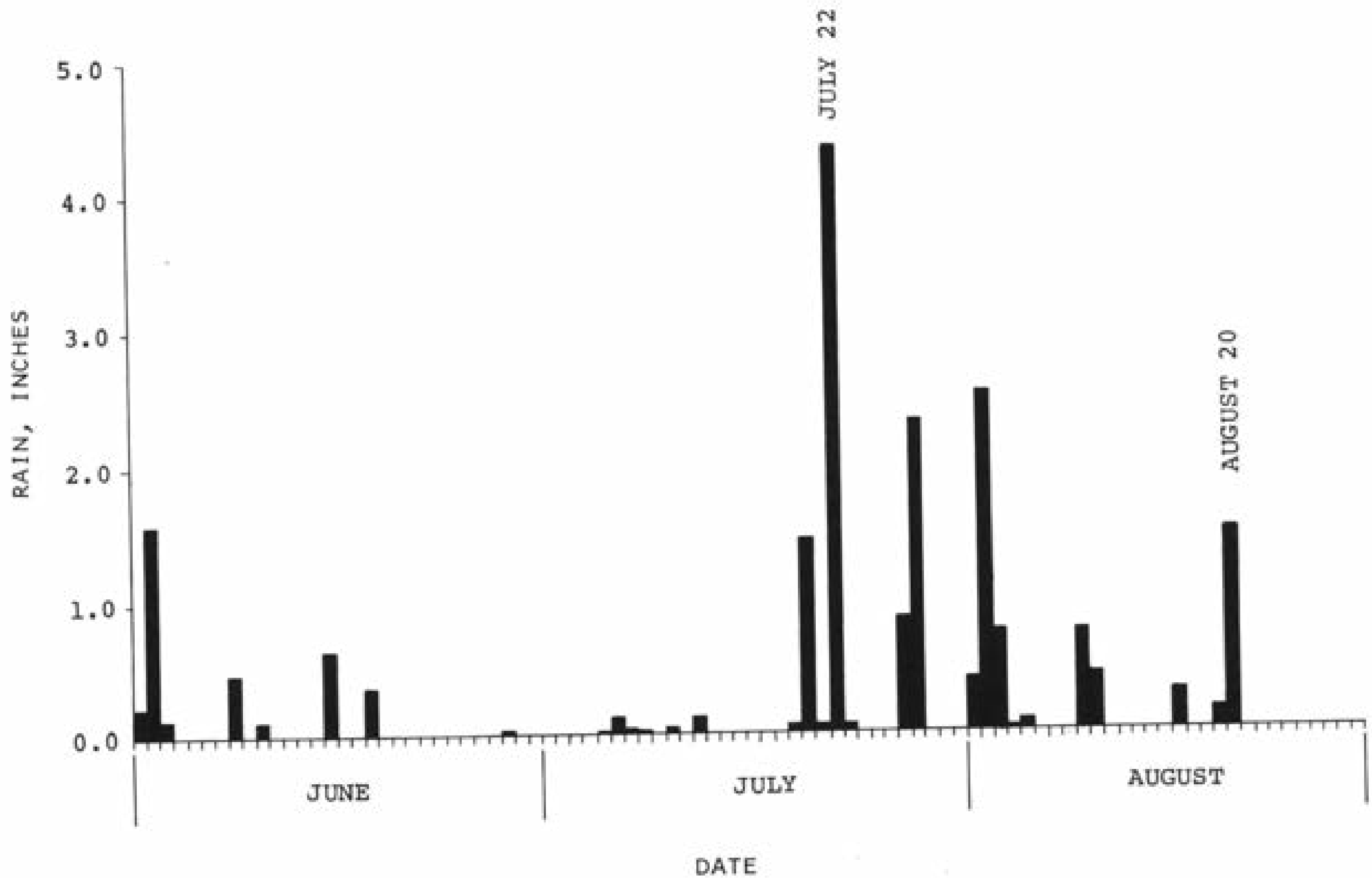


Figure 4-9. RECORD OF RAIN AT WASHINGTON, D.C., NATIONAL AIRPORT - SUMMER 1969

Table 4-2. COMPUTED TIME VARIATION OF OVERFLOW QUALITY

Time from Start of Overflow, min	Storm of July 22, 1969		Storm of Aug. 20, 1969	
	BOD, mg/L	SS, mg/L	BOD, mg/L	SS, mg/L
0	220	261	245	321
30	135	425	239	327
60	79	921	218	289
90	54	755	150	277
120	48	798	87	506
150	40	698	70	675
180	14	252	60	779
210	4	25	54	576
240	6	9	55	518
270	6	7	47	450
300	10	13	43	410
330	18	20	47	325
360	27	28	58	241
390	37	38	67	201
420	42	44	72	179
450	63	60	96	175
480	90	80	125	180

Storm	Total SS Released, lb	Total BOD Released, lb
July 22, 1969	581,000	46,500
August 20, 1969	250,000	30,900

Receiving Waters

Although no sampling data were available, the Anacostia-Potomac Rivers were modeled by the 47 node system shown in Figure 4-10. An appropriate tide was imposed at node 32, fresh water inflows were imposed at nodes 1 and 47, and the Kingman Lake basin discharge was imposed at node 15. The computed oxygen balance in the receiving water system for 5 and 25 hours following the storm of July 22 is shown in Figure 4-11. The maximum deficit occurred at node 17, 3,000 feet from the point of release and 25 hours after the start of the storm. The oxygen deficit was continuing to increase and move seaward at the end of the simulation. Similarly, the computed travel of suspended solids is shown in Figure 4-12.

It should be noted that these changes were the direct result of one outfall discharging for one very large storm. The residual effects from earlier storms and pollution releases from coincident discharges would have to be evaluated to determine the full impact on the river system.

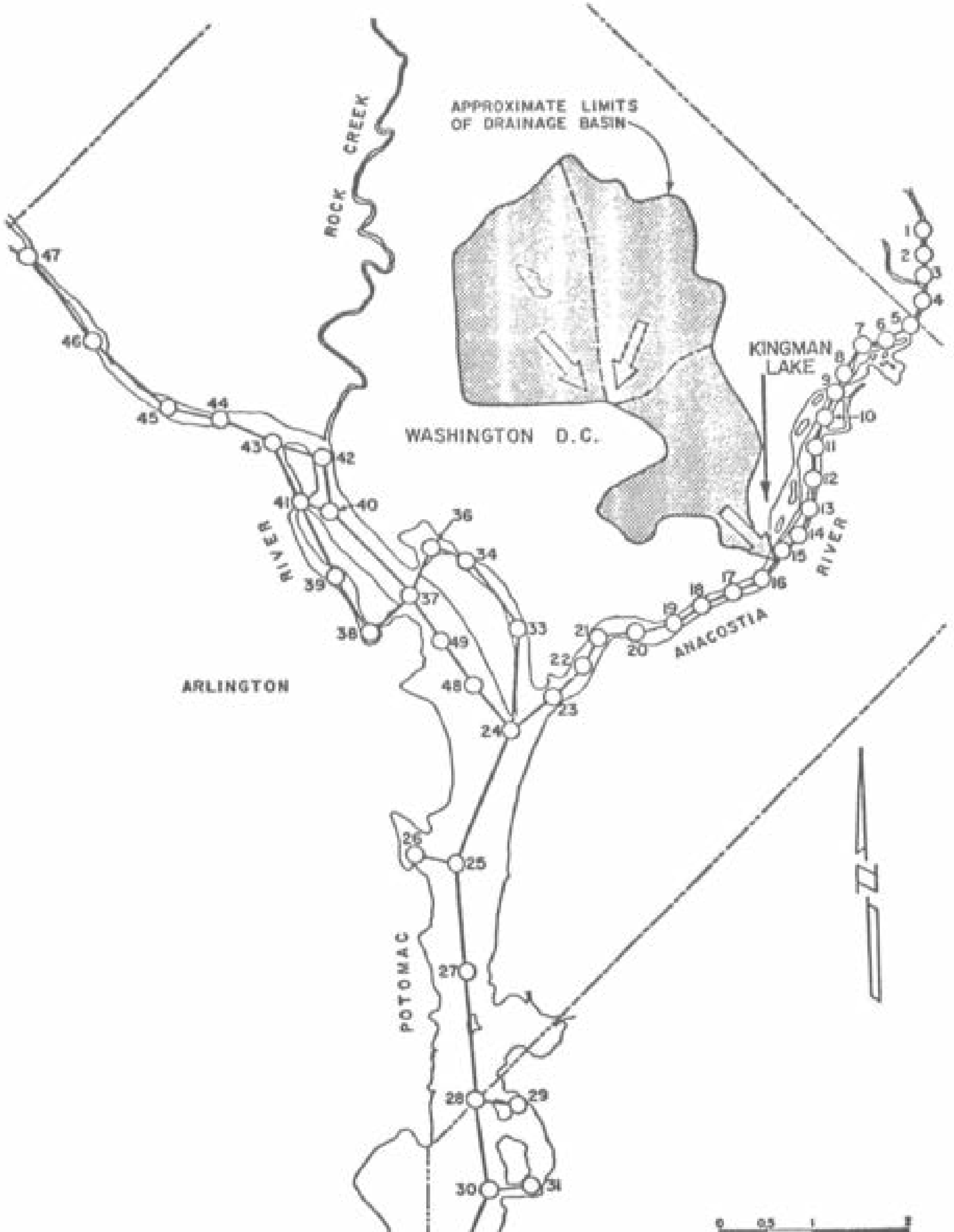


Figure 4-10. KINGMAN LAKE RECEIVING WATER SYSTEM

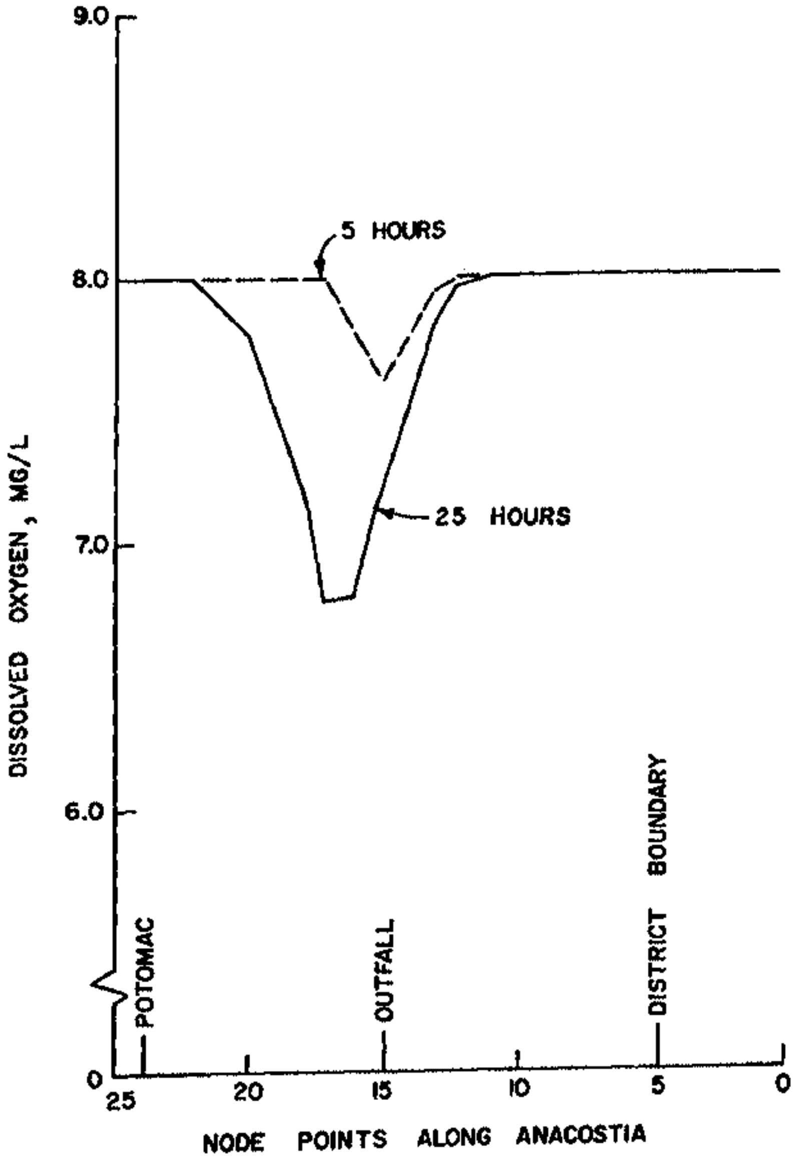


Figure 4-11. KINGMAN LAKE RECEIVING WATER DISSOLVED OXYGEN PROFILE

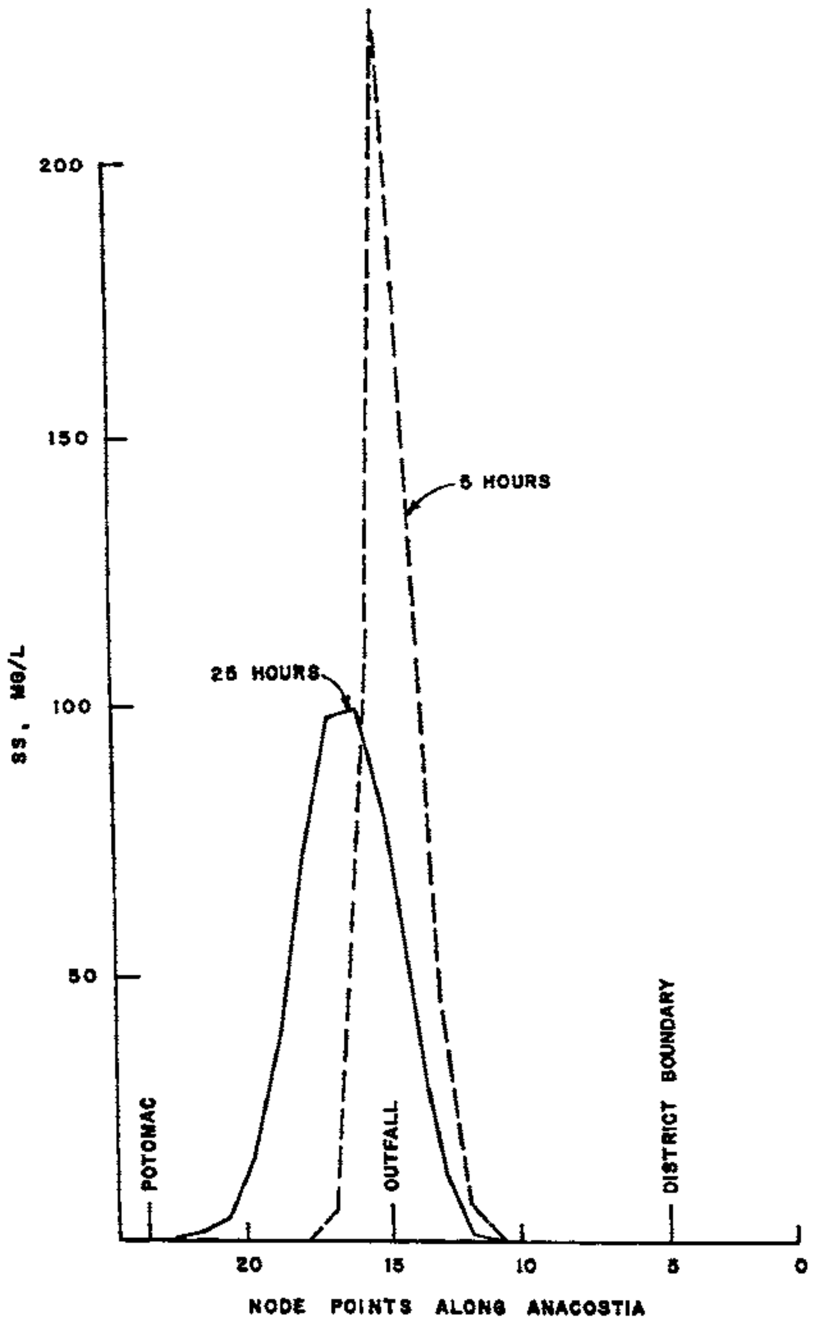


Figure 4-12. KINGMAN LAKE RECEIVING WATER SS PROFILE

CORRECTIVE ACTIONS MODELED

Three modifications to the existing system were modeled:

1. Complete sewer separation.
2. Construction of a relief sewer to relieve surcharges in the main trunk.
3. Construction of an external storage and treatment facility at Kingman Lake.

Again, the modifications were pressed only to demonstrate modeling techniques and not to real system solutions.

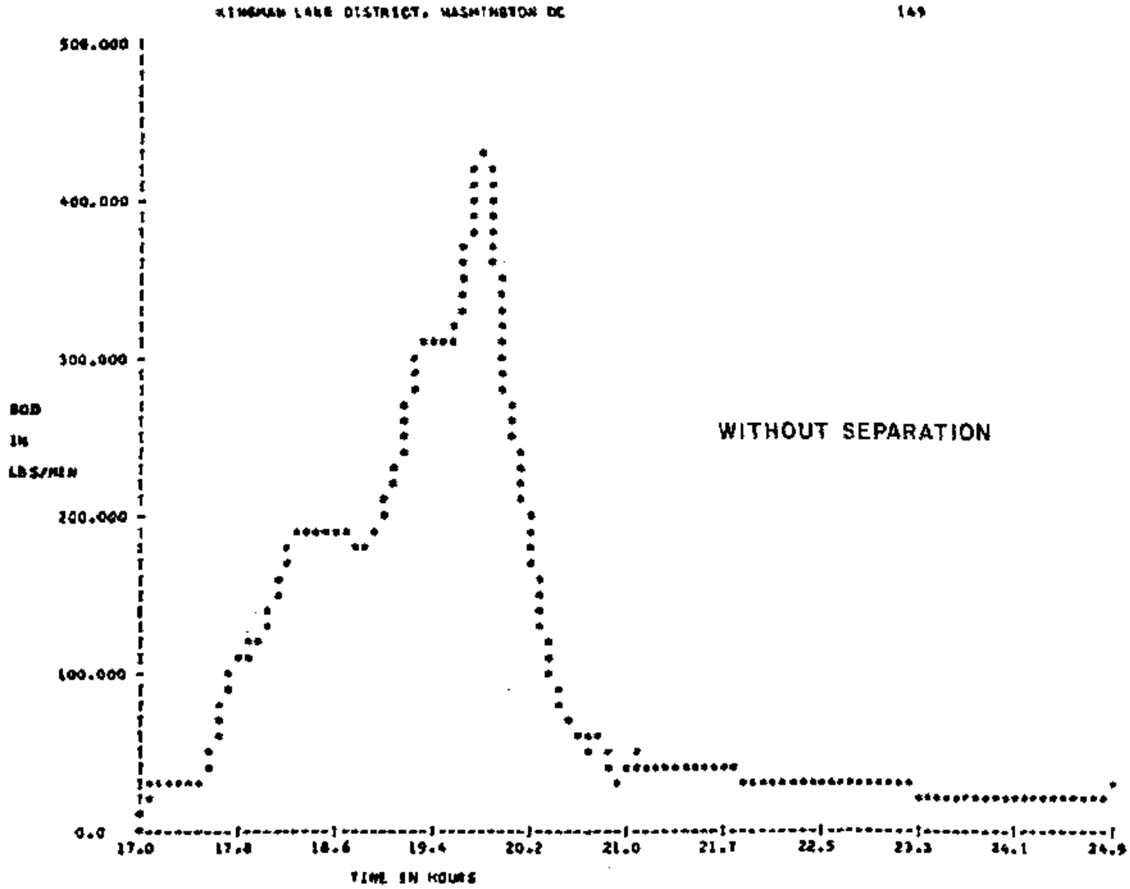
Complete Sewer Separation

Complete sewer separation was simulated by setting NFILTH = 0 for the storm of July 22, 1969. Because of the great magnitude of the storm and the relatively short time span over which overflows occurred, quality improvements were small. The total suspended solids released were reduced by 16,000 pounds or only 3 percent. The total BOD released was reduced by 15,600 pounds or 33 percent.

The line printer graphs of the BOD results are shown in Figure 4-13.

Construction of a Relief Sewer

The District representatives spoke of the possible construction of a relief sewer to reduce flooding and surcharge along the main trunk sewer. A dummy pipe system, shown in Figure 4-14, was modeled, intercepting all flows upstream of elements 45, 63, and 69. The resultant flow reduction in the main trunk and the total diverted flow are shown in



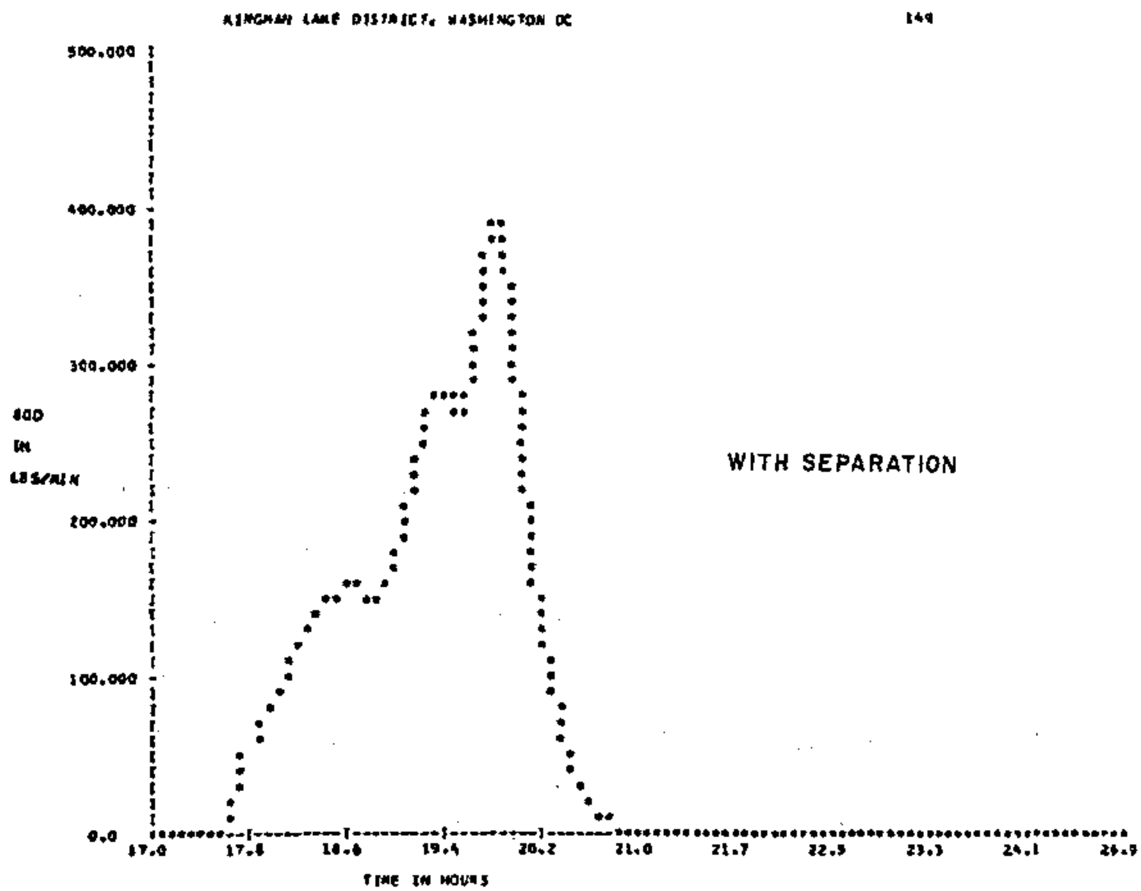


Figure 4-13. KINGMAN LAKE BOD COMPARISONS WITH AND WITHOUT SEPARATION

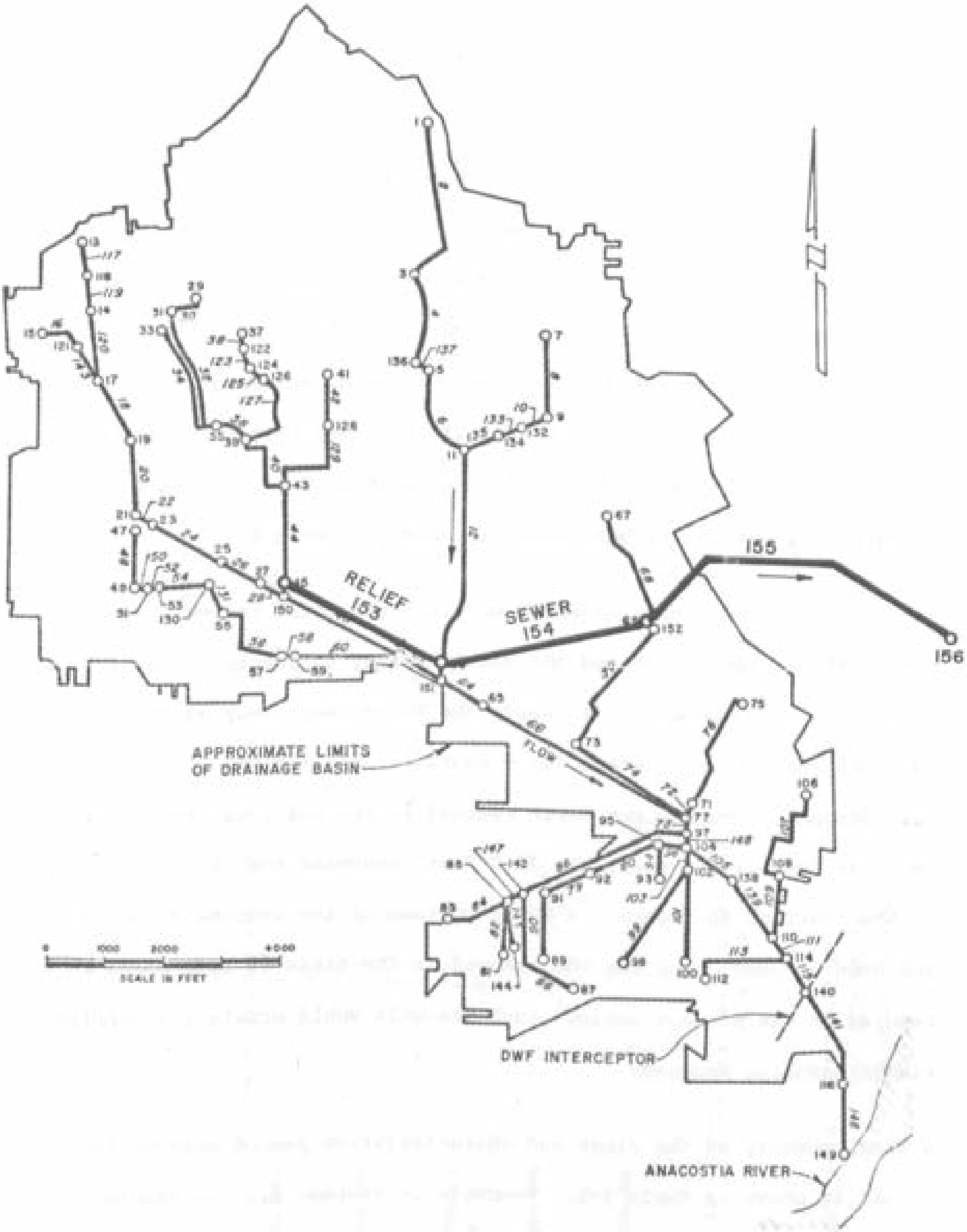


Figure 4-14. KINGMAN LAKE SIMULATED RELIEF SEWER

Figure 4-15. The diversion, as expected, eliminated the surcharge in elements 139 and 115 on the main trunk sewer.

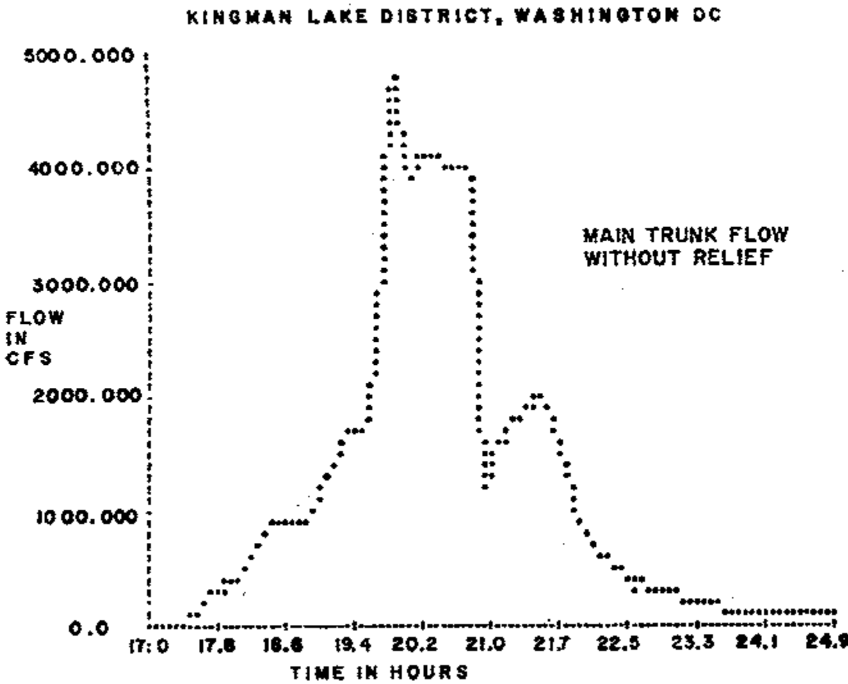
<u>External Storage and Treatment</u>

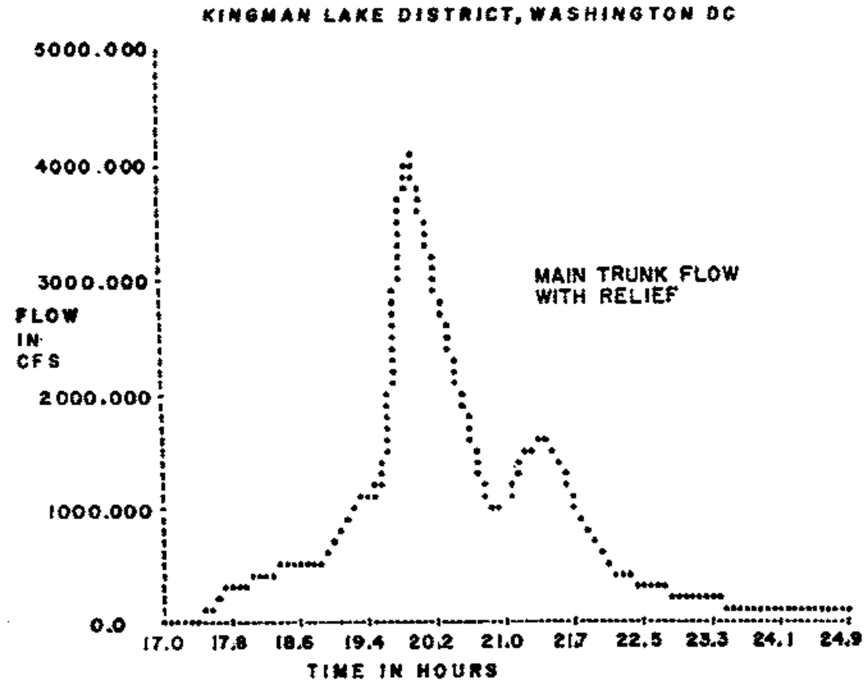
Based on the recommendations stated in the Kingman Lake Report, Ref. 1 (Contract No. 14-12-829), a storage-treatment scheme consisting of a 175-million gallon storage basin and a 50-mgd treatment plant was modeled and the output of the August 20, 1969 storm was applied. The treatment system consisted of the storage basin, mechanically cleaned bar racks, effluent pumps, high rate filters, and postchlorination. The basic design data for the units are shown in Table 4-3, and the summary of treatment effectiveness is shown in Table 4-4.

For the 95 five-minute time-steps modeled, the total inflow to storage was 7,741,961 cubic feet and the total outflow to treatment was 1,776,956 cubic feet or 23 percent. To empty the basin completely would require an additional 257 time-steps (21.4 hours) if all inflows to the basin were stopped. The maximum depth reached in the basin during the storm was 8.94 feet of the available 35.0 feet, assuming the basin was empty at the start of the storm. A major portion of the suspended solids and over 50 percent of the BOD removed in the first 95 time-steps were removed in the storage basin. Such removals would create a significant sludge handling problem.

A final summary of the flows and characteristics passed between treatment levels is shown in Table 4-5. Removals in storage are represented by level 3, the high rate filters in level 4, and chlorination in level 7.

KINGMAN LAKE
STORM OF JULY 22, 1969





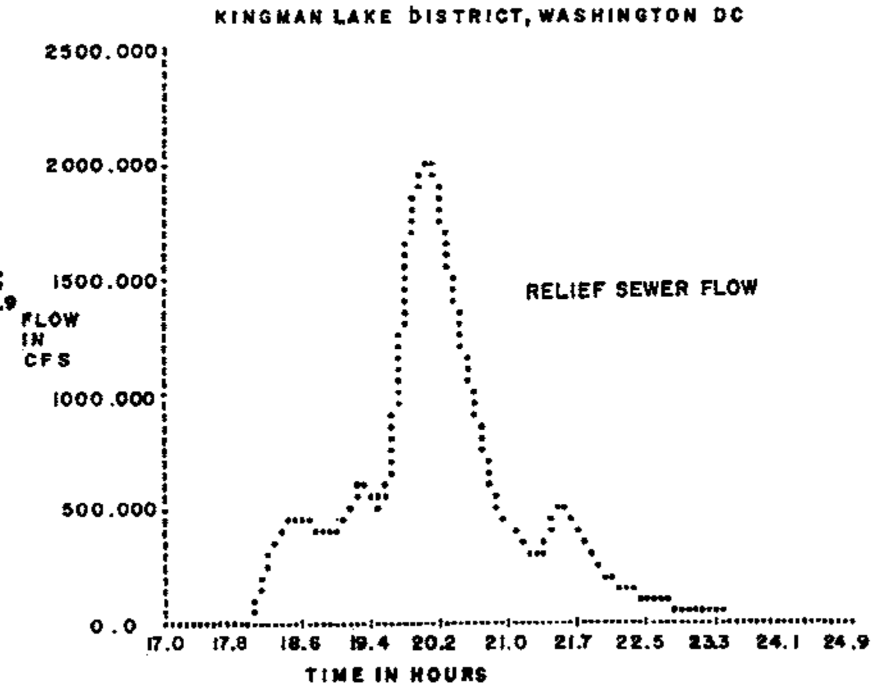


Figure 4-15. KINGMAN LAKE HYDROGRAPH WITH AND WITHOUT RELIEF SEWER-STORM OF JULY 22, 1969

Table 4-3. KINGMAN LAKE BASIC DESIGN DATA

```
SPECIFIED TREATMENT CAPACITY USED.

          DESIGN FLOWRATE =      75.00 CFS.
          TREATMENT SYSTEM INCLUDES MODULE UNITS
               DESIGN FLOW IS THEREFORE INCREASED TO NEXT LARGEST MODULE SIZE
               ADJUSTED DESIGN FLOWRATE =      77.35 CFS., =      50.00 MGD.
               IKMCO =  81
               CHARACTERISTICS OF STORAGE UNIT ARE
                    OUTLET TYPE  =  6
                    STORAGE MODE =  1
                    STORAGE TYPE =  2

               IEOL = 2, PRINT CONTROL (ISPRINT) = 1

          MAN-MADE RESERVOIR, WITH MAX. DEPTH =  35.00 FT.,  AND CHARACTERISTICS
                    BASE AREA =   670000. SQ.FT.,        BASE CIRCUMF. =     3272. FT.,      COT(SIDESLOPE) =   0.00000
               RESERVOIR OUTFLOW BY FIXED-RATE PUMPING
               PUMPING RATE =  77.40 CFS, PUMPING START DEPTH = 10.00 FT, PUMPING STOP DEPTH =  0.00 FT
               DEPTH(FT) STOR(CU.FT)    DEPTH(FT) STOR(CU.FT)    DEPTH(FT) STOR(CU.FT)    DEPTH(FT) STOR(CU.FT)
                 0.00         0.          3.50   2345000.          7.00   4690000.         10.50   7035000.
                14.00    9380000.        17.50  11725000.         21.00  14070000.         24.50  16415000.
                28.00   18760000.        31.50  21104999.         35.00  23450000.
               STORAGE BETWEEN PUMP START AND STOP LEVELS =      248.54 TIMES (QPUMP*DT)
               ASSUMED UNIT COST (EXCAVATION, LINING, ETC.) =15.00 $/CU.YD.

          PRELIMINARY TREATMENT BY MECHANICALLY CLEANED BAR RACKS  (LEVEL 1)
               NUMBER OF SCREENS    =        2
               CAPACITY PER SCREEN =      38.67 CFS
               SUBMERGED AREA       =      12.89 SQ.FT. (PERPENDICULAR TO THE FLOW)
               FACE AREA OF BARS    =      18.05 SQ.FT.

          INFLOW BY INLET PUMPING (LEVEL 2)
               PUMPED HEAD =  35.00 FT. WATER

          TREATMENT BY SEDIMENTATION IN ASSOCIATED STORAGE - SEE LEVEL 0 ABOVE
               NO CHLORINE ADDED

          TREATMENT BY HIGH RATE FILTERS (LEVEL 4)
               NUMBER OF UNITS               =        4
               FILTER AREA PER UNIT          =    434.13 SQ.FT
               MAX. OPERATING RATE           =     20.00 GPM/SQ.FT.
               SOLIDS REMOVAL EFFICIENCY     =     95.00 PERCENT
               BOD REMOVAL EFFICIENCY        =     80.00 PERCENT
               MAX. DESIGN HEAD LOSS         =     12.00 FT.
               MAX. SOLIDS HOLDING CAP.      =      3.00 LB/SQ.FT. (AT MAX H AND Q)
               CHEMICALS WILL BE ADDED

          NO EFFLUENT SCREENS  (LEVEL 5)

          OUTFLOW BY GRAVITY (NO PUMPING)  (LEVEL 6)

          TREATMENT BY CHLORINE CONTACT TANK (LEVEL 7)
               NUMBER OF DOSING UNITS =        2
               DOSING RATE PER UNIT    =   8000.00 LB/DAY
               MAXIMUM DEMAND RATE     =  10241.05 LB/DAY
               VOLUME OF CONTACT TANK =    69615. CU.FT. AT 15 MIN. DETENTION TIME
```

Table 4-4. KINGMAN LAKE SUMMARY OF TREATMENT EFFECTIVENESS

SUMMARY OF TREATMENT EFFECTIVENESS

TOTALS	FLOW (M.G.)	BOD (LB)	SS (LB)	COLIF (MPN)
INPUT	13.374	8999.3	62706.2	5.59E 14
OVERFLOW (BYPASS)	0.009	5.8	40.5	3.61E 11
TREATED	13.365	8991.5	62665.6	5.59E 14
REMOVED	0.114	7206.2	54845.7	5.58E 14
RELEASED	13.260	1793.2	7860.3	4.31E 11

REMOVALS	FLOW(M.G.)	BOD (LB)	SS (LB)	
LEVEL 1	0.001	30.1	601.2	= BAR RACKS
LEVEL 3 (TOTAL)	0.113	3739.7	47169.5	= STORAGE
LEVEL 4	0.000	2089.5	7075.0	= HIGHRATE FILTERS
LEVEL 5	0.000	0.0	0.0	= NO EFFL. SCREENS
LEVEL 7	0.000	1347.0	0.0	= CONTACT TANK

TRASH:
BAR RACKS 80.157 CU.FT (AT 50 LB/CU.FT.)
EFFLUENT SCREENS 0.000 CU.FT (AT 50 LB/CU.FT.)

REMOVAL PERCENTAGES	FLOW (VOL)	BOD (LB)	SS (LB)	COLIF (MPN)
OF OVERALL INPUTS	0.85	80.08	87.46	99.92
OF TREATED FRACTIONS	0.85	80.13	87.52	99.99

CONSUMPTIONS (LB)	CHLORINE	POLYMERS	
LEVEL 3	0.0	0.0	= STORAGE
LEVEL 4	0.0	442.4	= HIGHRATE FILTERS
LEVEL 7	671.7	0.0	= CONTACT TANK
TOTAL	671.7	442.4	

REPRESENTATIVE VARIATION OF TREATMENT PERFORMANCE WITH TIME (OVERALL).

TIME	0: 5	0:50	1:35	2:20	3: 5	3:50	4:35	5:20	6: 5	6:50	7:35
WATER											
AV. FLOW (CFS)	0.00	0.00	77.31	77.11	76.99	77.01	77.03	77.07	77.08	77.10	77.10
BOD											
ARRIVING (MG/L)	0.00	0.00	120.85	133.73	79.48	68.12	64.05	58.93	57.38	57.66	58.25
RELEASED (MG/L)	0.00	0.00	32.20	34.86	15.91	11.90	10.45	8.63	8.08	8.17	8.37
% REDUCTION (LB)	0.00	0.00	73.37	74.09	80.17	82.68	83.81	85.46	86.02	85.92	85.71
S. SOLIDS											
ARRIVING (MG/L)	0.00	0.00	168.79	505.24	701.98	674.77	626.75	573.27	541.14	521.85	509.66
RELEASED (MG/L)	0.00	0.00	25.17	63.55	88.83	85.33	79.15	72.28	68.15	65.68	64.12
% REDUCTION (LB)	0.00	0.00	85.10	87.50	87.46	87.46	87.47	87.48	87.49	87.49	87.50
COLIFORMS											
ARR (MPN/100ML)	0.00E-01	0.00E-01	2.25E 06	2.22E 06	8.46E 05	5.37E 05	6.15E 05	6.83E 05	7.42E 05	7.93E 05	8.21E 05
REL (MPN/100ML)	0.00E-01	0.00E-01	1.79E 03	1.72E 03	6.58E 02	4.96E 02	4.79E 02	5.31E 02	5.76E 02	6.16E 02	6.37E 02
% REDUCTION (LB)	0.00	0.00	99.92	99.92	99.92	99.92	99.92	99.92	99.92	99.92	99.92

Table 4-5. KINGMAN LAKE SUMMARY OF LEVEL PERFORMANCE

SUMMARY OF FLOWS - MAXIMA, AVERAGES, AND MINIMA

	ARRIVING	OVERFLOW	TO TREATMENT	LEVEL 3 REMOVAL	LEVEL 3 OUTFLOW	LEVEL 4 REMOVAL	LEVEL 4 OUTFLOW	LEVEL 7 REMOVAL	LEVEL 7 OUTFLOW	RECOMBINED RELEASE
FLOW RATES (M.G.D.)										
MAXIMUM	50.032	0.032	50.000	0.533	49.882	0.000	49.882	0.000	49.882	49.915
AVERAGE	40.552	0.032	40.526	0.342	40.182	0.000	40.182	0.000	40.182	40.208
MINIMUM	0.000	0.000	0.000	0.115	49.465	0.000	49.465	0.000	49.465	0.000
BOD CONCENTRATIONS (MG/L)										
MAXIMUM	221.9	221.9	221.9	20312.6	130.0*************		78.0	0.0	62.4	62.4
AVERAGE	65.5	80.8	65.5	3771.5	38.3*************		23.0	0.0	13.1	13.1
MINIMUM	0.0	0.0	0.0	2789.9	33.4*************		20.1	0.0	8.1	0.0
SUSPENDED SOLIDS CONCENTRATIONS (MG/L)										
MAXIMUM	708.1	708.1	708.1	50043.4	169.9*************		89.2	0.0	89.2	89.6
AVERAGE	456.2	562.9	456.2	40561.2	109.2*************		57.3	0.0	57.3	57.6
MINIMUM	0.0	0.0	0.0	50043.4	47.7*************		25.1	0.0	25.1	0.0
COLIFORM CONCENTRATIONS (MPN/100ML)										
MAXIMUM	4.10E 06	4.10E 06	4.10E 06						5.21E 02	3.18E 03
AVERAGE	8.95E 05	1.10E 06	8.95E 05						1.13E 02	6.95E 02
MINIMUM	0.00E-01	0.00E 00	0.00E-01						0.00E-01	0.00E-01

The asterisks, signifying a number larger than the field width, in the removal fraction of level 4 result from the intermittent nature of filter backwashing.

The recommended combination of storage and treatment appears quite feasible if the problem of residual solids in the storage basin can be solved.

SECTION 5

PHILADELPHIA

SECTION 5

PHILADELPHIA

The results of two significant storms modeled on the Wingohocking drainage basin and the Frankford Creek-Delaware River receiving waters are discussed in this section.

DESCRIPTION OF STUDY AREA

The Wingohocking drainage basin is the largest combined sewer area in Philadelphia and the largest area attempted by the model to date. The past sampling and analysis performed by the City of Philadelphia for drainage catchments and receiving waters are discussed briefly in Ref. 1.

A further description of the study area quoted from Ref. 2 follows:

> "The combined sewered area with a population of 173,000 named Wingohocking is situated in north central Philadelphia and drains some 5400 highly developed residential acres (8.4 sq. miles), via 45 miles of branch sewers. The dry weather flow is intercepted by a low, broad crested weir and interceptor arrangement for treatment at the Northeast Water Pollution Control Plant. During significant rains, the interceptor is mainly bypassed and a mixture of sanitary waste and stormwater discharges into the receiving Frankford Creek through a 21 ft. by 24 ft. outfall.
>
> Four recording raingages are distributed over the catchment area. A depth of flow recorder and a composite sampler are located at the outfall just upstream of the weir. This instrument system has been operated by the R & D Unit of the Philadelphia Water Department since 1966. Prior to that time, the runoff and sampling instruments were maintained by the FWQA for the purpose of studying combined sewer overflows."

The average imperviousness of 75 percent (range 40-80 percent) and population density of 32 persons per acre (predominantly in single-family row houses) compare closely with the Kingman Lake study area. Six industrial waste sources were reported in the basin, but their combined reported discharge of less than 0.1 cfs (suspected data error) had negligible effect on the waste stream. Quality characteristics of the discharge were not reported.

The basin topography, varying from an elevation of 60 feet at the point of discharge to an elevation of 380 feet at the northwest corner, is also similar to the Kingman Lake area.

DATA SOURCES

The Research and Development Division of the City of Philadelphia Water Department furnished essentially all data used for the model takeoffs. These included rainfall data, topographic maps, system maps, aerial photographs, catchbasin and street sweeping data, daily operating statistics at the Northeast Water Pollution Control Plant, weekly quality analyses of the receiving waters, and the storm runoff and quality composite data discussed below. *The collection, collation, and presentation of this data represented approximately 200 engineering man-hours on the part of the City. This total does not include approximately 400 additional man-hours by the authors for the data reduction, evaluation, simulation, and execution of the computer program.*

These efforts are in no way proportional to the basin size but are contingent on the complexities of the system and the availability of the data. No sampling, measuring, or analyses efforts are included.

A principal advantage of the model is that numerous additional storms and basin modifications can be readily executed for a small percentage *increase in man-hours once the original basin modeling and correlation has been accomplished.*

The Wingohocking drainage basin was subdivided into 57 subcatchments (range 38-210 acres). The sewer system was represented by 129 elements as shown in Figure 5-1. The total length of sewer lines modeled was 73,385 feet or approximately 32 percent of the total in the drainage basin.

The four rain gages used in the study were:

Model No.	Name	Approximate Ground Elevation, ft.
1	Roosevelt	300
2	Heinz	140
3	Harrow Gate	80
4	Queen Lane	220

The locations of the gages and the approximate areas where they were applied are shown in Figure 5-2. The cities rain gage network is described in Ref. 3.

VERIFICATION RESULTS

Time and budget restrictions did not permit the measurement, sampling, and correlation of dry weather flows, including estimates of industrial discharges and infiltration. The preliminary computed dry weather flow based on census data and assumed uniform single-family residential development is shown in Table 5-1. These values had no allowance for infiltration or for industrial or commercial wastes and totaled only about one-half the expected value based on prior Kingman Lake study.

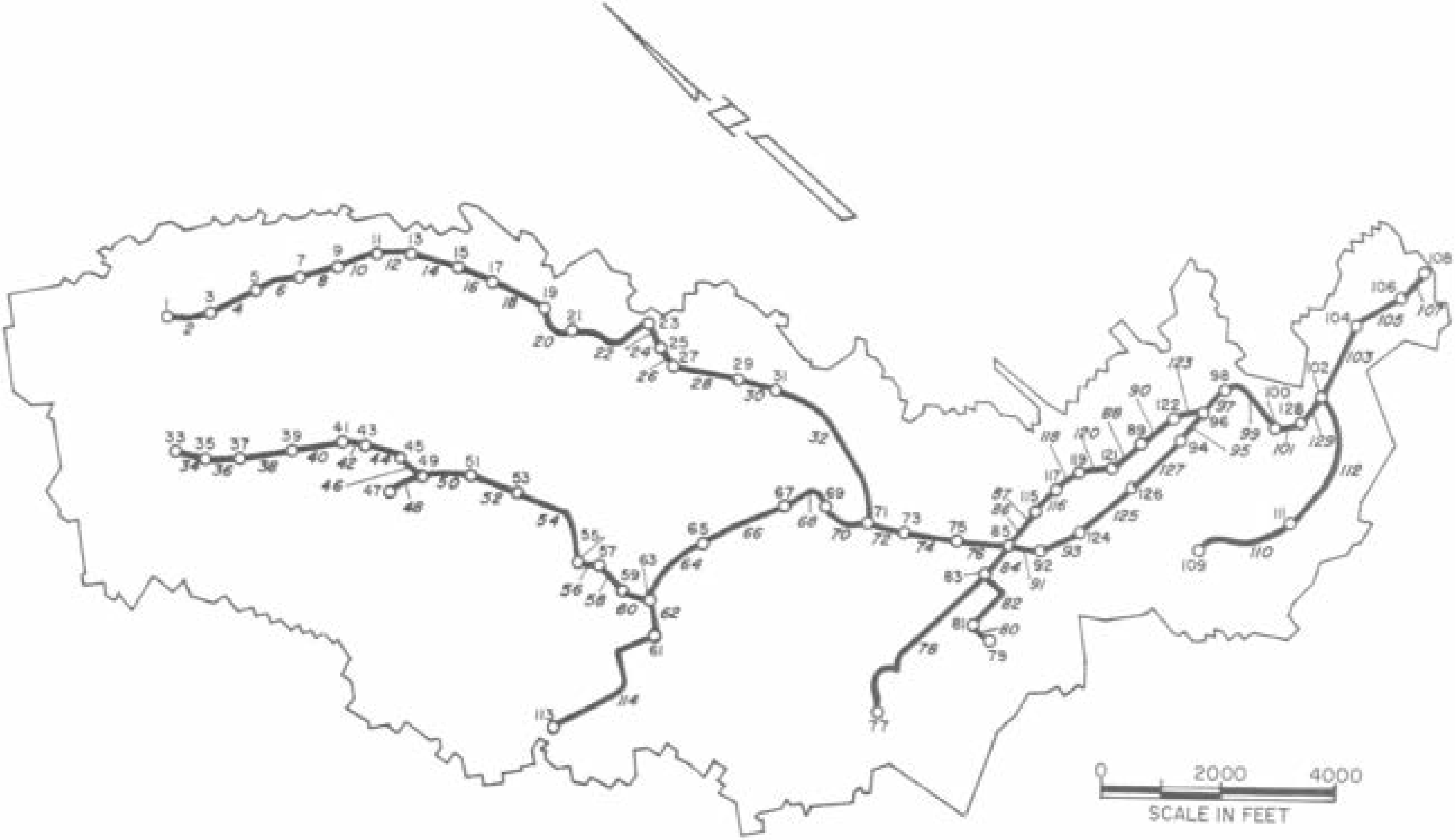


Figure 5-1. PLAN OF WINGOHOCKING SYSTEM

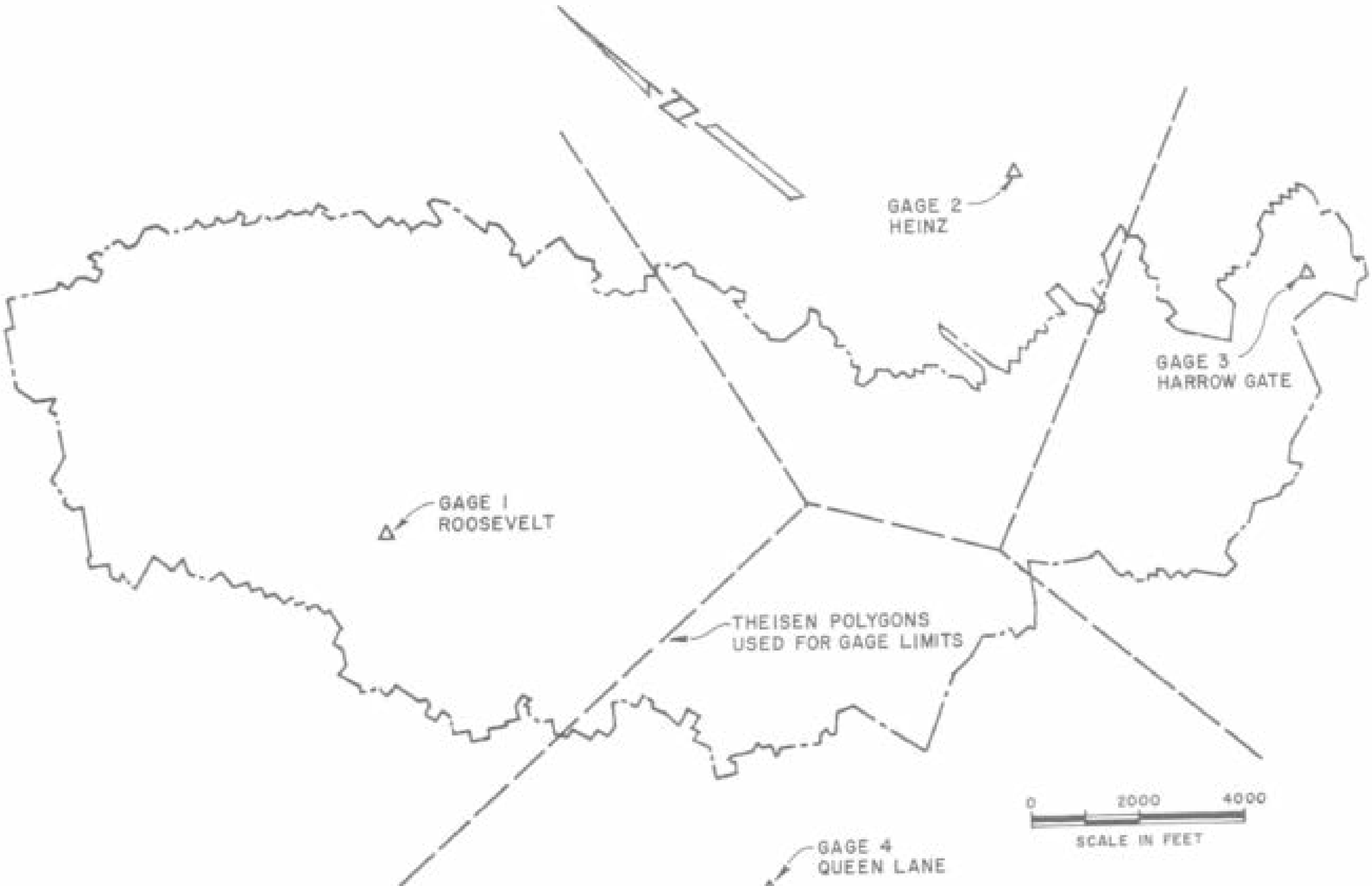


Figure 5-2. WINGOHOCKING RAIN GAGE LOCATIONS

Table 5-1. PRELIMINARY DRY WEATHER FLOW RESULTS

KNUM	INPUT	DWF CFS	+ INFIL CFS	= QQDWF CFS	KLAND	DWBOD LBS/MIN	DWSS LBS/MIN	TOTPOP PERSONS	BODCONC MG/L	SSCONC MG/L	COLIFORMS MPN/100ML
221	21	0.37	0.0	0.37	1	0.27	0.29				
222	53	0.11	0.0	0.11	1	0.08	0.09				
223	51	0.25	0.0	0.25	1	0.18	0.20				
224	43	0.61	0.0	0.61	1	0.44	0.48				
225	37	0.34	0.0	0.34	1	0.25	0.27				
226	33	0.09	0.0	0.09	1	0.07	0.07				
231	43	0.52	0.0	0.52	1	0.39	0.41				
232	53	0.88	0.0	0.88	1	0.64	0.70				
233	57	0.22	0.0	0.22	1	0.16	0.17				
234	65	0.60	0.0	0.60	1	0.44	0.48				
235	65	0.36	0.0	0.36	1	0.26	0.28				
SUBTOTALS											
		4.35	0.0	4.35		15.71 LBS	17.16 LBS	59853.	193.	211.	1.12E 08
236	69	0.54	0.0	0.54	1	0.39	0.42				
333	104	0.04	0.0	0.04	1	0.03	0.03				
334	106	0.00	0.0	0.00	1	0.00	0.00				
335	100	0.01	0.0	0.01	1	0.01	0.01				
336	96	0.20	0.0	0.20	1	0.15	0.16				
381	77	0.08	0.0	0.08	1	0.06	0.06				
424	89	0.06	0.0	0.06	1	0.04	0.05				
425	98	0.06	0.0	0.06	1	0.04	0.05				
427	106	0.17	0.0	0.17	1	0.12	0.13				
428	96	0.32	0.0	0.32	1	0.23	0.25				
SUBTOTALS											
		5.83	0.0	5.83		21.08 LBS	23.33 LBS	72050.	193.	211.	1.01F 08
429	98	0.22	0.0	0.22	1	0.15	0.17				
431	94	0.55	0.0	0.55	1	0.39	0.43				
432	79	0.42	0.0	0.42	1	0.30	0.33				
434	109	0.01	0.0	0.01	1	0.00	0.00				
491	31	0.01	0.0	0.01	1	0.01	0.01				
492	31	0.61	0.0	0.61	1	0.44	0.48				
493	31	0.76	0.0	0.76	1	0.55	0.60				
494	71	0.18	0.0	0.18	1	0.13	0.14				
SUBTOTALS											
		8.57	0.0	8.57		30.98 LBS	33.83 LBS	107858.	193.	211.	1.03E 08
495	85	0.41	0.0	0.41	1	0.30	0.33				
496	85	0.46	0.0	0.46	1	0.33	0.36				
497	92	0.84	0.0	0.84	1	0.60	0.65				
498	89	0.38	0.0	0.38	1	0.27	0.30				
509	3	0.09	0.0	0.09	1	0.06	0.07				
510	5	0.33	0.0	0.33	1	0.39	0.33				
511	9	0.54	0.0	0.54	1	0.39	0.43				
512	13	0.58	0.0	0.58	1	0.42	0.46				
513	21	0.30	0.0	0.30	1	0.22	0.24				
514	29	0.11	0.0	0.11	1	0.08	0.09				
516	23	0.30	0.0	0.30	1	0.22	0.24				
591	77	0.46	0.0	0.46	1	0.33	0.36				
592	77	0.15	0.0	0.15	1	0.11	0.12				
593	67	0.49	0.0	0.49	1	0.35	0.39				
594	61	0.15	0.0	0.15	1	0.11	0.12				
595	61	0.40	0.0	0.40	1	0.29	0.31				
596	113	0.06	0.0	0.06	1	0.04	0.05				
599	53	0.04	0.0	0.04	1	0.03	0.03				
600	41	0.00	0.0	0.00	1	0.00	0.00				
602	35	0.01	0.0	0.01	1	0.00	0.00				
433	85	0.10	0.0	0.10	1	0.08	0.08				
SUBTOTALS											
		14.77	0.0	14.77		53.63 LBS	58.57 LBS	152701.	194.	212.	9.01E 07
100	77	0.12	0.0	0.12	1	0.11	0.12				
TOTALS											
		14.89	0.0	14.89		54.18 LBS	59.18 LBS	152701.	194.	212.	8.93E 07

The two storms modeled for Wingohocking were:

Date	Total Rainfall, in.
July 3, 1967	1.30
August 3-4, 1967	0.97

Measured flow data (depth of flow correlated to diversion weir) were available for each storm. In addition, quality results from composite samples (not proportional to flow) were available for rough comparisons.

Combined Sewage Overflows - Quantity

Table 5-2 and Figure 5-3 show the rainfall hyetographs for the storm of July 3, 1967. The resulting runoff hydrograph at element 108 is compared to the reported data in Figure 5-4.

Table 5-3 and Figures 5-5 and 5-6 show the same data for the storm of August 3-4, 1967. In the comparisons the computed data are higher and of longer durations than the reported values. This is probably because the diversions to the DWF interceptor (102-inch diameter, maximum carrying capacity = 270 cfs) are not accounted for in the model. The interceptor receives flow not only from the Wingohocking basin but also from an upstream (60-inch diameter, maximum carrying capacity = 150 cfs) DWF interceptor. The actual diversion during storm events could therefore vary from 0 to 250 cfs depending upon the storm pattern. At the time of the demonstration the allowance for this diversion was beyond

Table 5-2. RAINFALL DATA STORM OF JULY 3, 1967

WINGOHOCKING AREA, PHILADELPHIA, PA.
STORM OF JULY 3, 1967, NO GUTTERS

INLET NUMBER 1

NUMBER OF TIME STEPS 99

INTEGRATION TIME INTERVAL (MINUTES), 5.00

25.0 PERCENT OF IMPERVIOUS AREA HAS ZERO DETENTION DEPTH

FOR 66 RAINFALL STEPS, THE TIME INTERVAL IS 5.00 MINUTES

FOR RAINGAGE NUMBER 1 RAINFALL HISTORY IS

0.0	0.12	0.0	0.24	0.48	0.72	0.72	0.35	0.24	0.24
0.12	0.12	0.12	0.0	0.0	0.24	0.36	0.35	1.20	2.16
0.84	0.48	0.36	0.72	0.0	0.12	0.12	0.0	0.12	0.0
0.0	0.0	0.0	1.08	2.28	0.84	0.48	0.35	0.0	0.24
0.12	0.0	0.0	0.0	0.0	0.12	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.12	0.0	0.03	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0				

FOR RAINGAGE NUMBER 2 RAINFALL HISTORY IS

0.12	0.12	0.12	0.0	0.24	0.48	0.60	0.72	0.60	0.48
0.24	0.12	0.0	0.24	0.0	0.12	0.24	0.24	0.12	0.19
1.56	0.24	1.20	1.08	1.32	1.08	0.12	0.60	0.24	0.24
0.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	0.48
0.0	0.60	0.24	0.12	0.0	0.0	0.0	0.0	0.0	0.12
0.12	0.0	0.0	0.0	0.0	0.0	0.24	0.03	0.0	0.0
0.24	0.24	0.12	0.12	0.0	0.0				

FOR RAINGAGE NUMBER 3 RAINFALL HISTORY IS

0.0	0.0	0.0	0.0	0.60	0.95	0.72	0.48	0.03	0.03
0.24	0.24	0.0	0.12	0.12	0.12	0.03	0.12	0.24	2.04
0.84	0.24	0.84	2.04	1.20	0.72	0.0	0.12	0.60	0.24
0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.12	0.0	0.12
0.0	0.12	0.0	0.12	0.0	0.12	0.0	0.12	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.48	0.48	0.74	0.0
0.03	0.24	0.0	0.0	0.0	0.0				

FOR RAINGAGE NUMBER 4 RAINFALL HISTORY IS

0.0	0.12	0.0	0.48	0.96	1.08	0.48	0.24	0.24	0.12
0.12	0.12	0.12	0.12	0.12	0.12	0.03	0.03	1.80	1.80
1.08	0.48	0.48	0.12	0.24	0.24	0.0	0.12	0.0	0.0
0.0	0.0	0.0	0.12	0.12	0.12	0.0	0.72	0.03	0.12
0.84	0.24	0.0	0.0	0.0	0.0	0.0	0.12	0.24	0.24
0.24	0.0	0.0	0.24	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0				

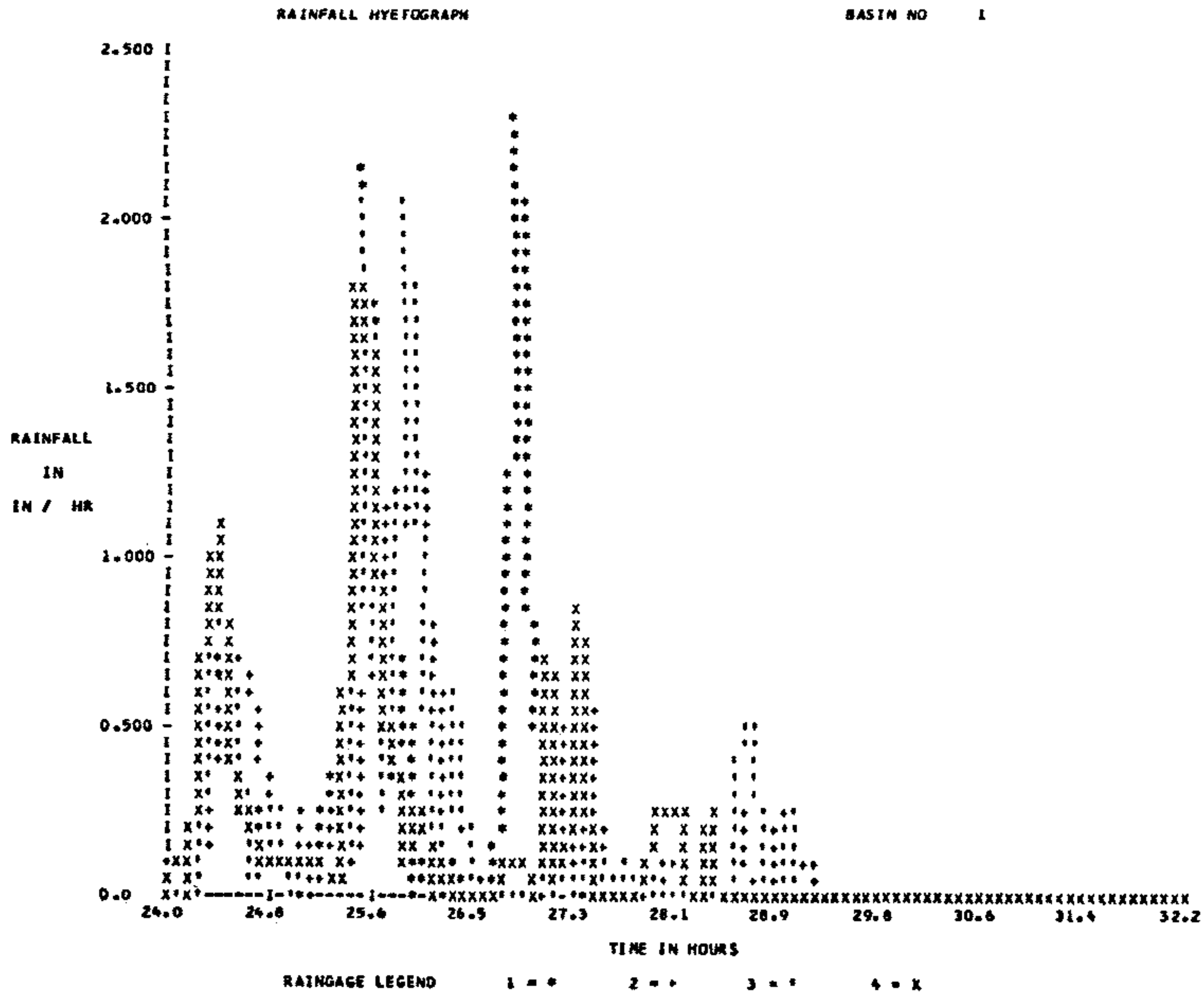


Figure 5-3. WINGOHOCKING RAINFALL HYETOGRAPHS -
STORM OF JULY 3, 1967

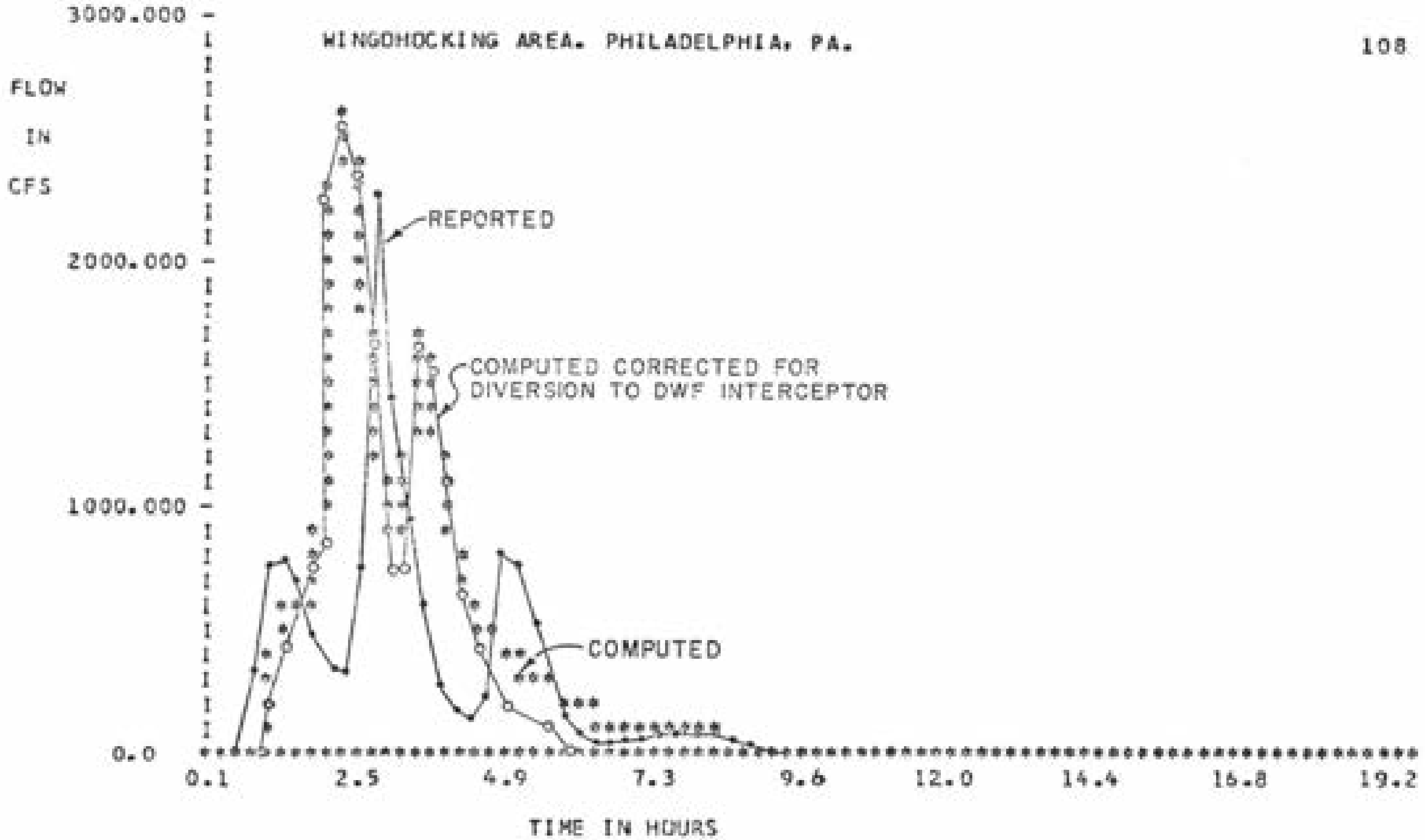


Figure 5-4. WINGOHOCKING COMBINED SEWER OVERFLOW RESULTS (QUANTITY) - STORM OF JULY 3, 1967

Table 5-3. RAINFALL DATA STORM OF AUG. 3-4, 1967

FOR 192 RAINFALL STEPS, THE TIME INTERVAL IS 5.00 MINUTES

FOR RAINGAGE NUMBER 1 RAINFALL HISTORY IS

0.0	0.0	0.0	0.60	1.20	0.84	0.84	1.90	0.60	0.0
0.0	0.0	0.0	0.24	0.36	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.60	0.0	0.60	0.0	0.0	0.0	0.12	0.12
0.12	0.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.12	0.12	0.24	2.52	2.52	0.60	0.12	0.24	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12
0.12	0.12	0.12	0.0	0.12	0.0	0.12	0.48	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.24	0.24	0.12	0.12	0.36	0.12	0.12	0.24	0.24
0.0	0.12	0.24	0.24	0.0	0.0	0.0	0.0	0.12	0.12
0.12	0.24	0.0	0.0	0.12	0.12	0.12	0.12	0.12	0.0
0.0	0.12	0.36	0.12	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.12	0.12	0.0	0.12	0.12	0.0	0.12	0.0
0.0	0.0								

FOR RAINGAGE NUMBER 2 RAINFALL HISTORY IS

0.0	0.0	0.0	0.0	0.0	0.0	0.24	0.36	0.12	0.12
0.24	0.84	0.24	0.12	0.0	0.12	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	0.24
0.24	0.24	0.12	0.12	0.0	0.0	0.0	0.0	0.24	0.24
0.24	0.24	0.24	0.60	0.48	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.12	0.12	0.12	0.12	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12
0.12	0.12	0.0	0.0	0.0	0.24	0.24	0.12	0.12	0.12
0.0	0.12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.24	0.24	0.24	0.12	0.12	0.24	0.24	0.24	0.12
0.12	0.12	0.12	0.12	0.12	0.12	0.0	0.0	0.12	0.12
0.12	0.12	0.06	0.06	0.0	0.0	0.12	0.24	0.12	0.12
0.0	0.0	0.0	0.0	0.12	0.12	0.12	0.12	0.12	0.0
0.0	0.0	0.0	0.0	0.0	0.24	0.12	0.12	0.0	0.0
0.12	0.0								

FOR RAINGAGE NUMBER 3 RAINFALL HISTORY IS

0.0	0.0	0.0	0.12	0.12	0.0	0.0	0.12	0.12	1.20
0.24	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.06	0.06	0.0	0.0	0.0	0.0	0.0	0.12	0.0
0.36	1.08	0.60	0.12	0.0	0.12	0.12	0.06	0.06	0.12
0.0	0.36	0.06	0.06	0.06	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	0.06	0.06
0.0	0.0	0.0	0.12	0.12	0.12	0.12	0.12	0.06	0.06
0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.12	0.36
0.24	0.24	0.12	0.12	0.24	0.12	0.24	0.12	0.24	0.12
0.12	0.12	0.12	0.12	0.12	0.0	0.12	0.12	0.0	0.12
0.06	0.06	0.18	0.06	0.12	0.12	0.06	0.12	0.06	0.06
0.18	0.36	0.12	0.06	0.06	0.0	0.12	0.06	0.06	0.0
0.0	0.0	0.0	0.12	0.12	0.06	0.06	0.12	0.0	0.0
0.12	0.12								

FOR RAINGAGE NUMBER 4 RAINFALL HISTORY IS

0.0	0.36	0.12	0.12	0.12	0.0	0.12	0.48	0.72	2.52
0.84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.70	2.52
0.24	1.20	0.72	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.12	0.12	0.0	0.0	0.24	0.84	0.36	0.36	0.12	0.06
0.12	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.06	0.06	0.12	0.0	0.0	0.0
0.0	0.12	0.12	0.12	0.12	0.24	0.12	0.12	0.0	0.0
0.06	0.06	0.0	0.0	0.0	0.12	0.0	0.0	0.0	0.24
0.24	0.24	0.24	0.24	0.24	0.12	0.24	0.24	0.12	0.24
0.12	0.12	0.12	0.12	0.0	0.12	0.12	0.0	0.0	0.12
0.12	0.06	0.12	0.06	0.06	0.12	0.06	0.0	0.12	0.12
0.12	0.0	0.0	0.12	0.0	0.0	0.12	0.12	0.0	0.0
0.0	0.0	0.0	0.0	0.12	0.12	0.12	0.12	0.0	0.0
0.12	0.0								

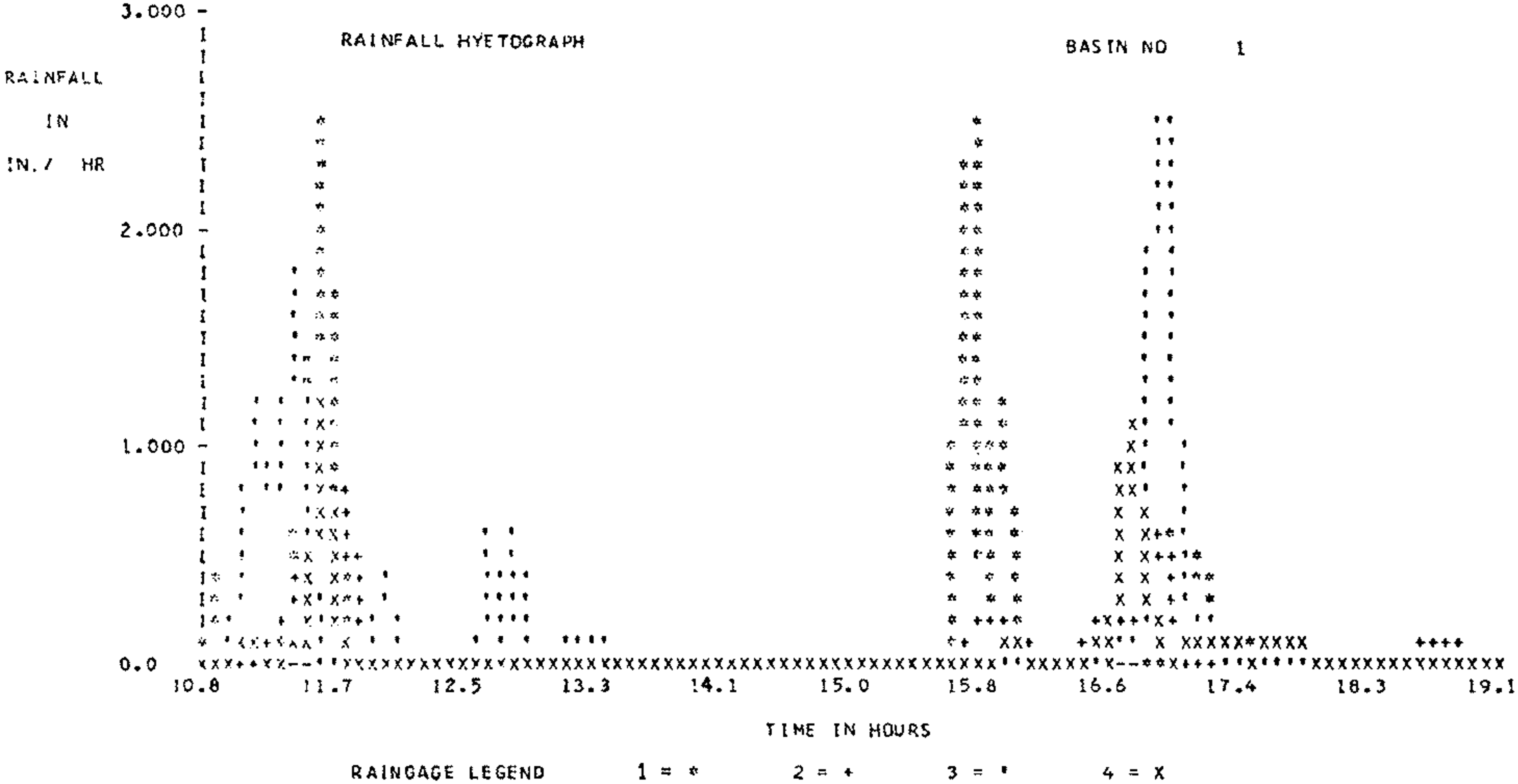


Figure 5-5. WINGOHOCKING RAINFALL HYETOGRAPHS - STORM OF AUGUST 3-4, 1967

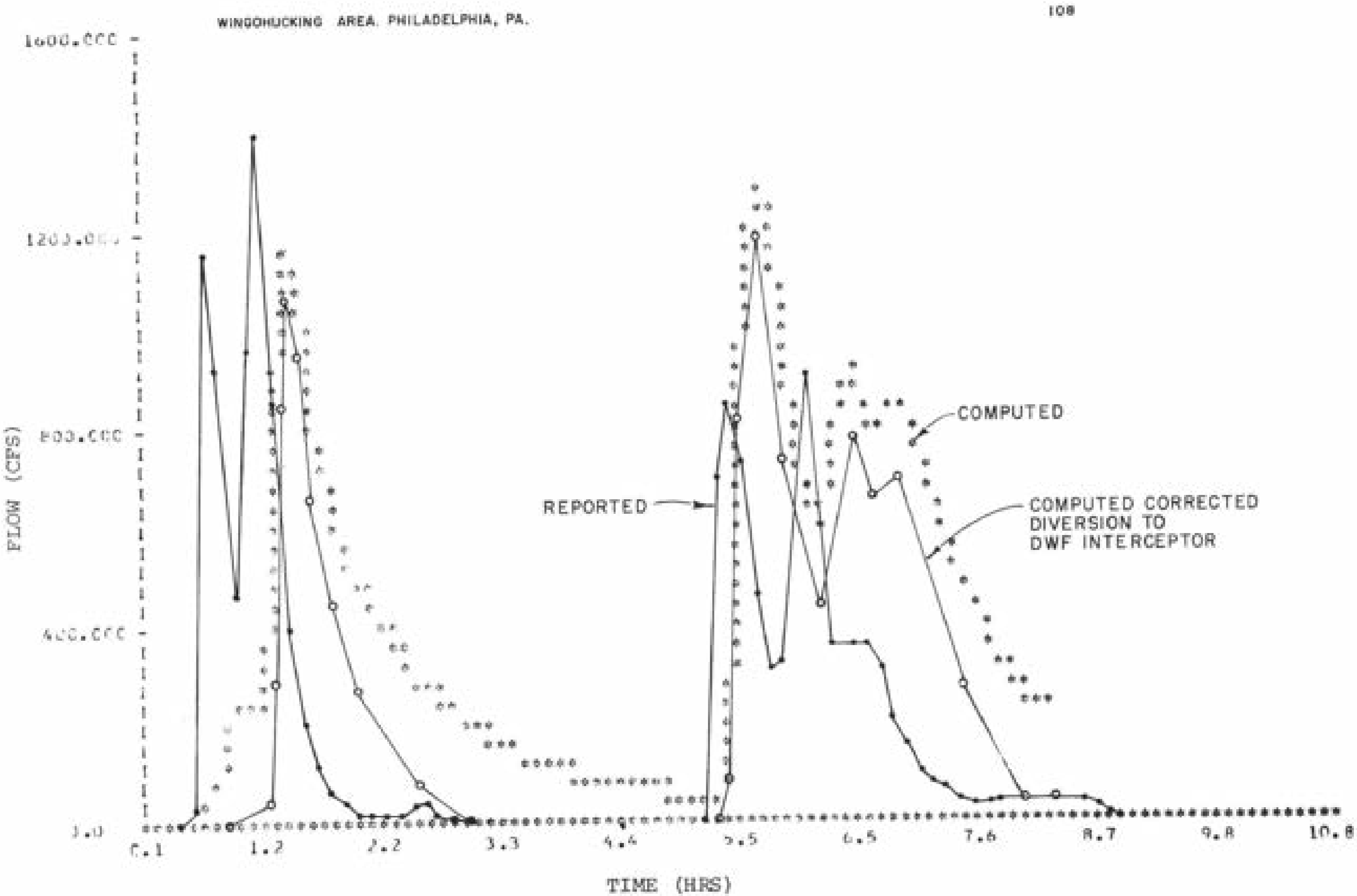


Figure 5-6. WINGOHOCKING COMBINED SEWER OVERFLOW RESULTS (QUANTITY) - STORM OF AUGUST 3-4, 1967

the scope of work. For a rough approximation of this effect, however, it was estimated as follows:

Wingohocking Computed Flow Without Diversion, cfs	Estimated Diversion, cfs
0-500	up to 200
500-1,000	150
1,000-1,500	100
>1,500	50

Applying these diversion allowances to the computed results produced the corrected curves shown in Figures 5-4 and 5-6. These preliminary results, while not exceptional, correlate well and, for design purposes, would adequately define the storm event (i.e., peaks, volume, time of occurrence). A closer fit may have been obtained by comparing computed with measured depths, since the cross-sectional area of the storm conduit is so great (21 by 24 feet) that minor depth changes make large changes in flow.

It should be noted however that the final model provides for three types of flow diversion:

Type 18 - Diverts all surplus flow above a specified maximum.

Type 21 - Special case of Type 18 for cunnette sections.

Type 20 - Diverts a percentage of the surplus flow above a specified maximum according to a linear relationship (such as a weir formula).

The use of these diversion models is discussed in Volume III.

Combined Sewage Overflows - Quality

Table 5-4 compares the computed quality results with the reported composite sample results. The computed quality results for BOD and suspended solids for the storm of August 3-4 are shown in Figure 5-7. The curves show how the removals in the first phase of the storm substantially reduced the net removals in the second phase. Correlation with the reported data is only fair possibly due to the low estimate for "dry days" (3.0 days) used for each storm.

Receiving Waters

The Frankford Creek-Delaware River receiving water system was modeled by the 18-node system shown in Figure 5-8. A tide condition was imposed at node 1 and the Wingohocking overflows were received at node 18. For the July 3, 1967, storm, fresh water inflows were added as follows:

Node	Inflow, cfs
2	30.
4	1000.
13	60.
14	4130.
18	70.

The computed stages at nodes 1, 10, and 18 are shown in Figure 5-9 for the day of the storm. The storm flow can be seen superimposed on the tide induced stage for node 18. Although Frankford Creek is not tidal up to the point of discharge, this assumption was necessary to simplify the modeling. The computed flows and velocities in the Frankford Creek channels are shown in Table 5-5 for the day of the storm. A total of

Table 5-4. WINGOHOCKING COMBINED SEWER OVERFLOWS - QUALITY COMPARISONS

	Reported	Computed Values	
	Composite Sample Values	Combined Overflow	Average DWF
Storm #1, July 3, 1967			
5-Day BOD, mg/L	--	1-38	194
Suspended Solids, mg/L	17.4	7-210	212
Coliform, MPN/100 ml	7.2×10^6	$1 \times 10^3 - 3 \times 10^4$	9×10^7
Storm #2, August 3-4, 1967			
5-Day BOD, mg/L	36-148	1-48	194
Suspended Solids, mg/L	1-15	9-581	212
Coliform, MPN/100 ml	$1 \times 10^7 - 1 \times 10^8$	$4 \times 10^3 - 7 \times 10^4$	9×10^7

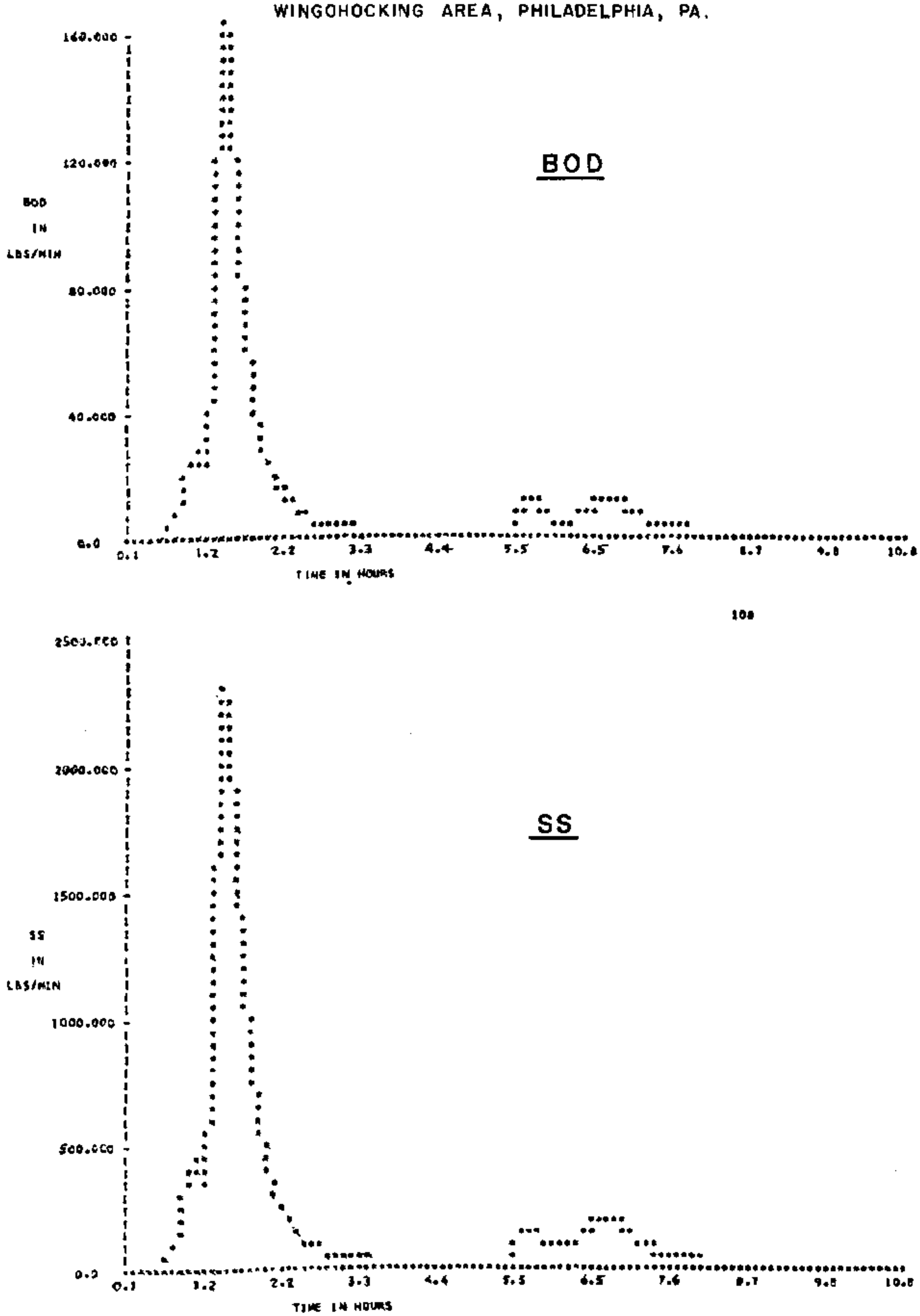


Figure 5-7. WINGOHOCKING COMBINED SEWER OVERFLOW RESULTS (QUALITY) - STORM OF AUGUST 3-4, 1967

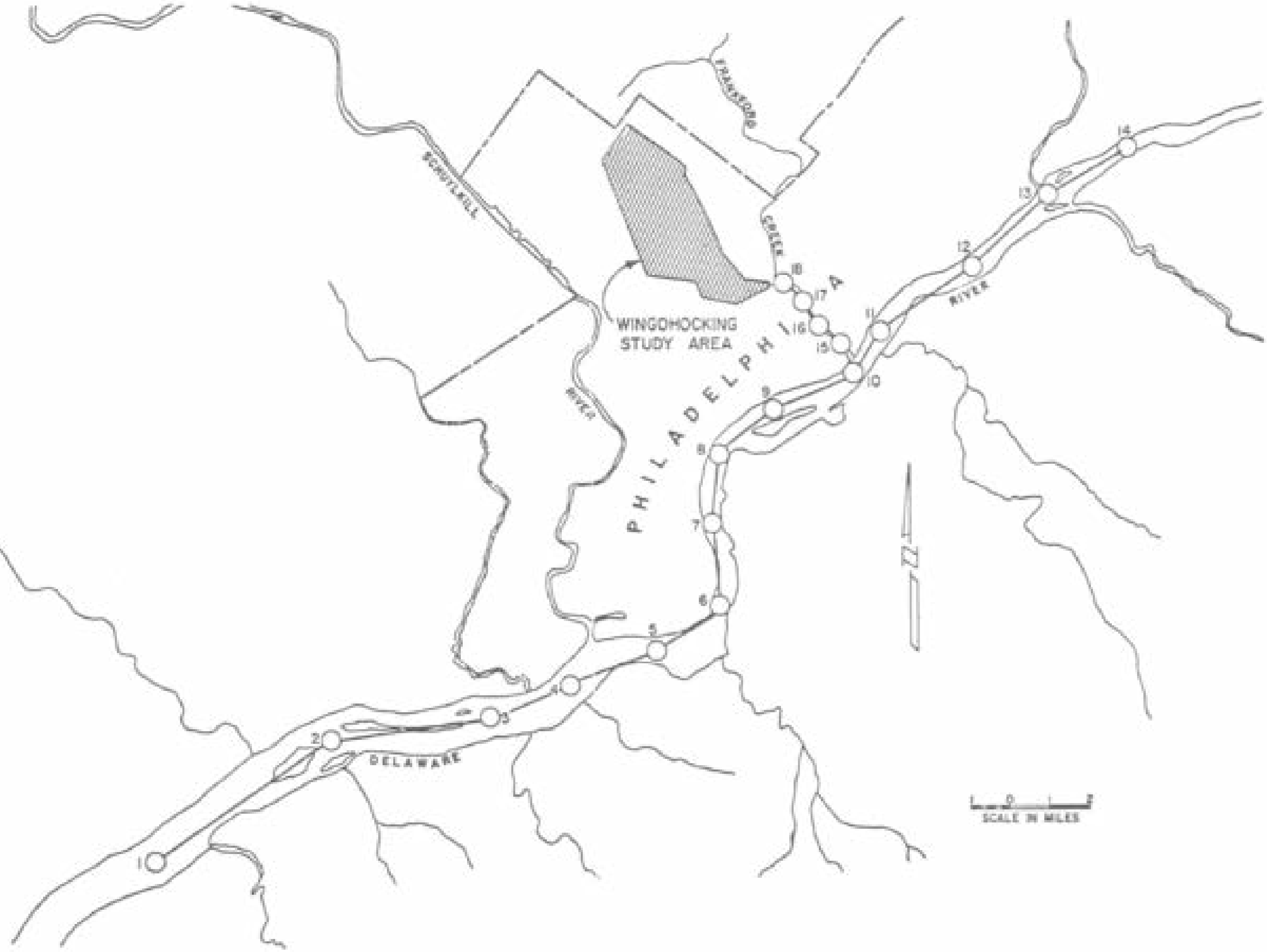


Figure 5-8. WINGOHOCKING RECEIVING WATER SYSTEM

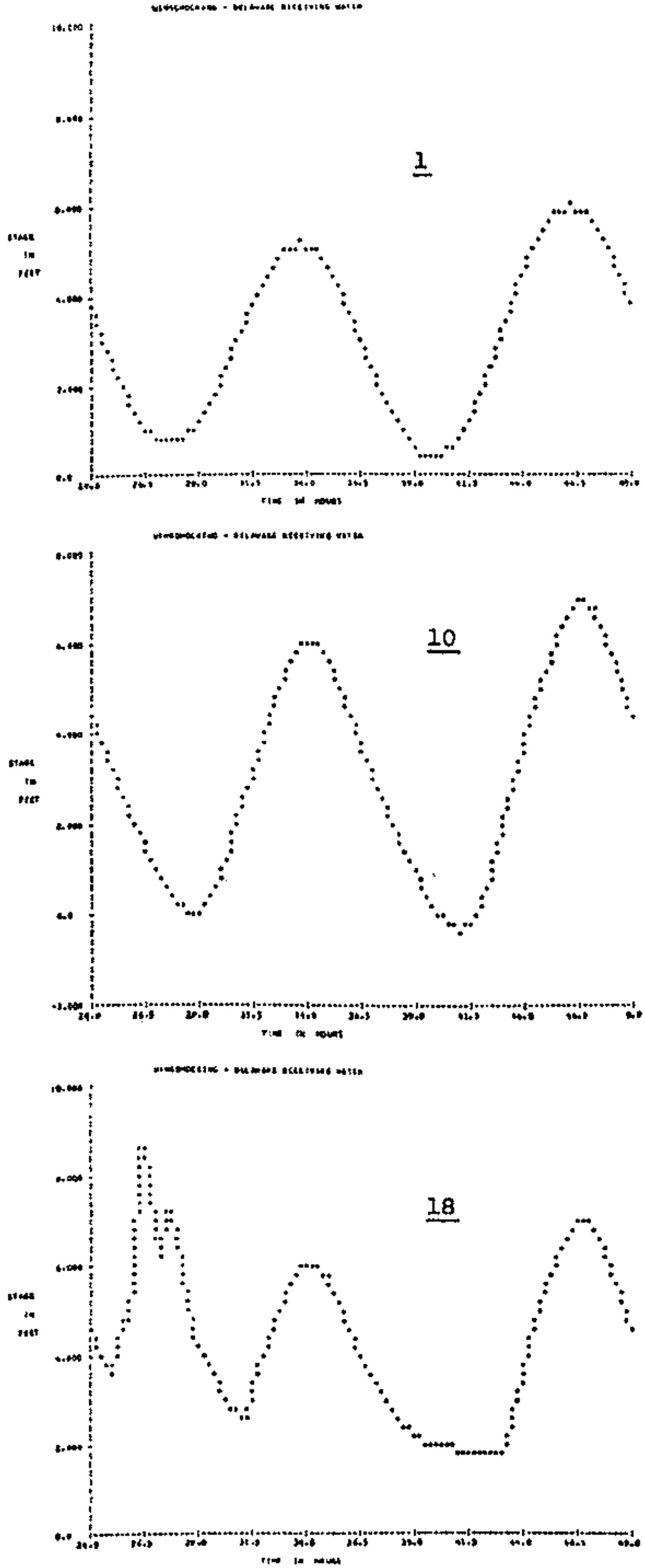


Figure 5-9. WINGOHOCKING RECEIVING WATER
COMPUTED STAGES AT NODES 1, 10, AND 18

Table 5-5. WINGOHOCKING RECEIVING WATER FRANKFORD CREEK FLOWS AND VELOCITIES

DELAWARE RIVER RECEIVING WATER

WINGOHOCKING AREA JULY 3, 1967 TIDE AT MARCUS HOOK

DAY IS 2

* * * * * * * * * * * * * * * T I M E H I S T O R Y O F F L O W A N D V E L O C I T Y * * * * * *

HOUR	CHANNEL 13 14 FLOW (CFS)	CHANNEL 13 14 VEL. (FPS)	CHANNEL 10 15 FLOW (CFS)	CHANNEL 10 15 VEL. (FPS)	CHANNEL 15 16 FLOW (CFS)	CHANNEL 15 16 VEL. (FPS)	CHANNEL 16 17 FLOW (CFS)	CHANNEL 16 17 VEL. (FPS)	CHANNEL 17 18 FLOW (CFS)	CHANNEL 17 18 VEL. (FPS)
24.00	-12276.	-0.26	-570.	-0.44	-339.	-0.67	-226.	-0.55	-116.	-0.37
25.00	-11265.	-0.25	-496.	-0.45	-279.	-0.73	-184.	-0.58	-122.	-0.51
26.00	-11188.	-0.26	-901.	-0.97	-720.	-2.24	-746.	-2.27	-1003.	-3.19
27.00	-10069.	-0.25	-2078.	-2.44	-1752.	-4.32	-1540.	-3.20	-1245.	-2.94
28.00	-8440.	-0.22	-1544.	-2.13	-1493.	-4.27	-1393.	-3.06	-1230.	-3.03
29.00	-3889.	-0.10	-778.	-1.22	-683.	-3.02	-592.	-1.86	-482.	-1.76
30.00	5318.	0.15	-226.	-0.30	-447.	-2.15	-379.	-1.52	-307.	-1.40
31.00	5971.	0.14	258.	0.28	-18.	-0.03	-158.	-0.67	-179.	-0.99
32.00	5177.	0.11	457.	0.38	198.	0.43	67.	0.18	-69.	-0.26
33.00	3138.	0.06	325.	0.23	130.	0.22	30.	0.06	-74.	-0.21
34.00	-2971.	-0.06	-23.	-0.02	-62.	-0.10	-83.	-0.16	-108.	-0.28
35.00	-9667.	-0.19	-439.	-0.31	-287.	-0.47	-216.	-0.44	-147.	-0.40
36.00	-12626.	-0.26	-597.	-0.47	-372.	-0.74	-264.	-0.65	-161.	-0.52
37.00	-11228.	-0.25	-542.	-0.50	-337.	-0.88	-242.	-0.77	-154.	-0.64
38.00	-11113.	-0.26	-484.	-0.53	-289.	-1.05	-210.	-0.88	-144.	-0.75
39.00	-10624.	-0.26	-401.	-0.53	-223.	-1.22	-173.	-0.95	-133.	-0.85
40.00	-9003.	-0.24	-283.	-0.46	-154.	-1.29	-141.	-0.91	-124.	-0.90
41.00	-5365.	-0.14	-138.	-0.25	-122.	-1.30	-123.	-0.82	-120.	-0.90
42.00	4462.	0.12	78.	0.12	-139.	-1.16	-124.	-0.86	-120.	-0.91
43.00	7130.	0.17	467.	0.54	113.	0.52	-32.	-0.14	-113.	-0.83
44.00	6918.	0.15	655.	0.57	329.	0.79	153.	0.46	-38.	-0.16
45.00	6303.	0.13	511.	0.36	230.	0.39	88.	0.19	-57.	-0.16
46.00	950.	0.02	202.	0.12	58.	0.08	-14.	-0.03	-88.	-0.21
47.00	-6354.	-0.12	-259.	-0.16	-192.	-0.26	-160.	-0.27	-131.	-0.30
48.00	-13236.	-0.26	-622.	-0.42	-389.	-0.60	-276.	-0.53	-165.	-0.42
49.00	-12276.	-0.26	-615.	-0.48	-384.	-0.75	-272.	-0.66	-164.	-0.52

3 days, starting 24 hours before the initial storm discharge, were simulated.

For the quality analyses, initial dissolved oxygen concentrations were set to 0.5 mg/L on the day preceding the storm. A quality integration step of 1 hour was used, as opposed to the 3-minute integration step necessary for the quantity computations. The computed junction concentrations at the end of 2 hours (from the start of overflow), 10 hours, and 20 hours are shown in Table 5-6. As computed, the dissolved oxygen in Frankford Creek was completely depleted after 5 hours, and maximum deficit in the Delaware due to the storm was 0.07 mg/L occurring at node 10, 25 hours after the start of the storm. Traces of coliforms from the storm had reached all node points by the 25th nour. Again it should be noted that the effects are limited to this single storm and single discharge.

CORRECTIVE ACTIONS MODELED

Two corrective actions were modeled for the Wingohocking system, both using the computed output of the storm of August 3-4, 1967:

1. In system storage using a simulated inflatable rubber dam across the mouth of the overflow conduit.
2. External storage with treatment by microstrainers.

In-System Storage

The concept of in-system storage is to create backwater impoundments in the pipe system by installing a temporary dam partially blocking the overflow. It is hoped that this action will completely trap runoffs

Table 5-6. WINGOHOCKING RECEIVING WATER (QUALITY) RESULTS

DELAWARE RIVER RECEIVING WATER

EPA STORMWATER MODEL
RECEIVING WATER QUALITY

WINGOHOCKING AREA JULY 3, 1967 TIDE AT MARCUS HOOK

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 2 ,QUALITY CYCLE 2

CONSTITUENT NUMBER 1BOD FROM WINGOHOCKING

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11 TO 18	0.00	0.00	0.0	0.0	0.00	0.00	1.13	33.63		

CONSTITUENT NUMBER 2SS FROM WINGO

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 TO 18	0.0	0.0	0.0	0.0	0.0	0.0	2.40	238.17		

CONSTITUENT NUMBER 3COLIFORM FROM WINGO

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 TO 18	0.0	0.0	0.0	0.0	0.0	0.0	**********	**********		

CONSTITUENT NUMBER 4BOD FROM WINGOHOCKIN(DO)

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
11 TO 18	0.50	0.50	0.50	0.50	0.50	0.50	0.49	0.37		

Table 5-6 (continued)

DELAWARE RIVER RECEIVING WATER

EPA STORMWATER MODEL

RECEIVING WATER QUALITY

WINGOHOCKING AREA JULY 3, 1967 TIDE AT MARCUS HOOK

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 2 ,QUALITY CYCLE 10

CONSTITUENT NUMBER 1BOD FROM WINGOHOCKING

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
11 TO 18	0.11	0.04	0.00	0.00	70.11	106.50	122.92	123.04		

CONSTITUENT NUMBER 2SS FROM WINGO

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.49
11 TO 18	0.63	0.20	0.02	0.00	1079.65	1641.80	1924.08	1937.78		

CONSTITUENT NUMBER 3COLIFORM FROM WINGO

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**********
11 TO 18	**********	**********	**********	6485.85	**********	**********	**********	**********		

CONSTITUENT NUMBER 4BOD FROM WINGOHOCKIN(DO)

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.49
11 TO 18	0.49	0.50	0.50	0.50	0.00	0.00	0.00	0.00		

Table 5-6 (continued)

DELAWARE RIVER RECEIVING WATER

E PA STORMWATER MODEL
RECEIVING WATER QUALITY

WINGOHOCKING AREA JULY 3, 1967 TIDE AT MARCUS HOOK

JUNCTION CONCENTRATIONS, DURING TIME CYCLE 2 ,QUALITY CYCLE 20

CONSTITUENT NUMBER 1BOD FROM WINGOHOCKING

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.36	0.85
11 TO 18	0.67	0.16	0.01	0.00	72.20	107.15	120.86	119.96		

CONSTITUENT NUMBER 2SS FROM WINGO

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.0	0.0	0.00	0.00	0.01	0.06	0.34	1.56	5.48	13.43
11 TO 18	10.47	2.27	0.13	0.00	1149.34	1702.23	1937.76	1937.78		

CONSTITUENT NUMBER 3COLIFORM FROM WINGO

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.0	0.0	967.97	147603.06	6892845.00	**********	**********	**********	**********	**********
11 TO 18	**********	**********	**********	831874.13	**********	**********	**********	**********		

CONSTITUENT NUMBER 4BOD FROM WINGOHOCKIN(DO)

JUNCTION	1	2	3	4	5	6	7	8	9	10
1 TO 10	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.49	0.47	0.44
11 TO 18	0.46	0.49	0.50	0.50	0.00	0.00	0.00	0.00		

from small storms, until they can be treated at the DWF treatment facility, and reduce overflows from large storms.

For Wingohocking, a dam height of 10 ft above the sewer invert was selected for the simulation. The plan areas of the storage basin thus created were then estimated at 2 ft-increments of depth to provide necessary data for the storage model. The resulting variation of the stage (depth) in the conduit is shown in Figure 5-10 assuming that <u>no</u> flow was diverted to the DWF interceptor. With no diversion the total volume overflowing was 10.9 million cubic feet or 92 percent of the arriving flow. However, had the DWF interceptor been capable of accepting 100 cfs throughout the storm, an additional 3.0 million cubic feet would have been diverted, reducing the overflow to 66 percent. *Thus in order for in-system dams to be effective for large storms there must be substantial available capacity in the DWF interceptor.* On the other hand, the percentage of diverted flow increases as the size of the storm decreases. The greater frequency of the smaller storms forms a significant basis of appeal of this type of impoundment.

External Storage With Treatment

To test the feasibility of linking in-system storage (of the type just described) with a pumped outflow to treatment, the following system was devised.

1. The storage chamber was held to the dimensions of the existing conduit except that the simulated dam crest was raised to 20 feet in an attempt to contain the entire storm.

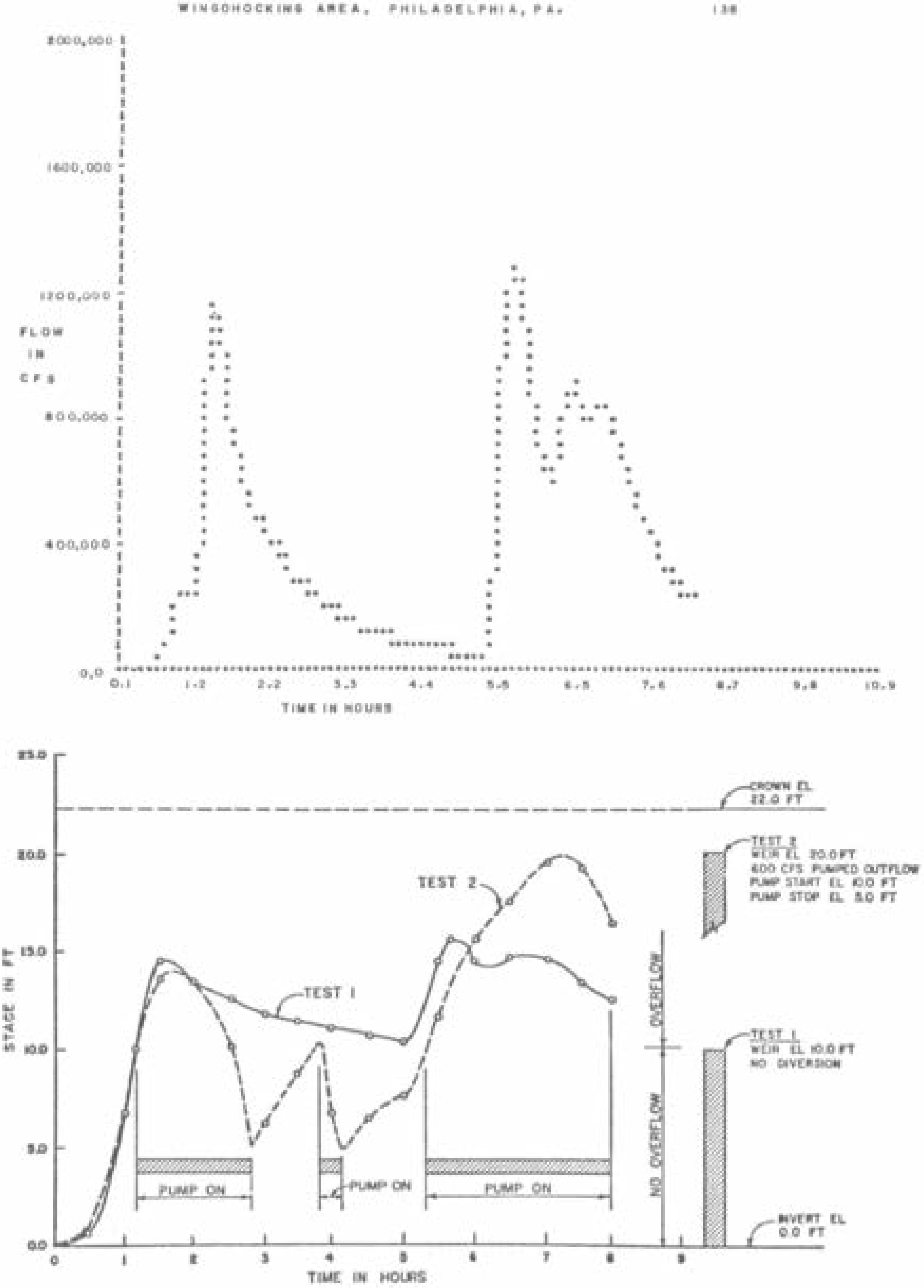


Figure 5-10. WINGOHOCKING STAGES IN STORAGE BASIN
STORM OF AUGUST 3-4, 1967

2. Several discharge pumping rates and settings were tested with the final selection of 600 cfs effluent pumps, starting at elevation 10.0 ft and stopping at elevation 5.0 ft.

3. This inflow set the treatment unit module size to 450.0 mgd as shown in Table 5-7. Microstrainers and mechanically cleaned bar racks were selected for the treatment units.

The resulting stages in the storage chamber and pump operation cycles are shown in Figure 5-10. The summaries of computed treatment effectiveness and costs are given in Tables 5-8 and 5-9 respectively. It appears that a more economical solution would be to supplement the in-system storage and reduce the number of treatment units.

Table 5-7. WINGOHOCKING BASIS OF DESIGN

```
DESIGN STORM USED.  TREATMENT CAPACITY WILL BE SELECTED TO SUIT.

          DESIGN FLOWRATE =     632.34 CFS.
               (= 0.500 TIMES MAXIMUM ARRIVAL RATE OF    1264.67 CFS.)
          TREATMENT SYSTEM INCLUDES MODULE UNITS
               DESIGN FLOW IS THEREFORE INCREASED TO NEXT LARGEST MODULE SIZE
               ADJUSTED DESIGN FLOWRATE =     696.15 CFS., =     450.00 MGD.
               (KMOD = 18)
               CHARACTERISTICS OF STORAGE UNIT ARE
                    OUTLET TYPE  =  6
                    STORAGE MODE =  1
                    STORAGE TYPE =  1
               IPOL = 1, PRINT CONTROL (ISPRIN) = 1
               NATURAL RESERVOIR, WITH MAX. DEPTH =  20.00 FT.          11 DEPTH/AREA PARAMETERS ARE
                    DEPTH(FT) AREA(SQ.FT)     DEPTH(FT) AREA(SQ.FT)     DEPTH(FT) AREA(SQ.FT)     DEPTH(FT) AREA(SQ.FT)
                        0.00          0.           2.00     31920.           4.00    57600.           6.00    82800.
                        8.00    111840.           10.00    176000.          12.00   138000.          14.00   155040.
                       16.00    168720.           18.00    185280.          21.00   185280.
               RESERVOIR OUTFLOW BY FIXED-RATE PUMPING
               PUMPING RATE = 600.00 CFS, PUMPING START DEPTH = 10.00 FT, PUMPING STOP DEPTH =  5.00 FT
               DEPTH(FT) STOR(CU.FT)     DEPTH(FT) STOR(CU.FT)     DEPTH(FT) STOR(CU.FT)     DEPTH(FT) STOR(CU.FT)
                  0.00          0.          2.00     31920.          4.00    121440.          6.00    261840.
                  8.00     456480.         10.00    694320.         12.00    958320.         14.00   1251360.
                 16.00    1575120.         18.00   1929120.         20.00   2299680.
               STORAGE BETWEEN PUMP START AND STOP LEVELS =         2.79 TIMES (QPUMP*DT)
               ASSUMED UNIT COST (EXCAVATION, LINING, ETC.) =15.00 $/CU.YD.

               PRELIMINARY TREATMENT BY MECHANICALLY CLEANED BAR RACKS  (LEVEL 1)
                    NUMBER OF SCREENS    =        2
                    CAPACITY PER SCREEN =     348.07 CFS
                    SUBMERGED AREA       =     116.02 SQ.FT. (PERPENDICULAR TO THE FLOW)
                    FACE AREA OF BARS    =     162.43 SQ.FT.
               INFLOW BY GRAVITY (NO PUMPING)  (LEVEL 2)
               TREATMENT BY SEDIMENTATION IN ASSOCIATED STORAGE - SEE LEVEL 0 ABOVE
                    NO CHLORINE ADDED
               TREATMENT BY MICROSTRAINERS
                    NUMBER OF UNITS      =          36
                    CAPACITY PER UNIT    =       12.50 MGD
                    SUBMERGED SCREEN AREA=     217.01 SQ.FT. PER UNIT
               NO EFFLUENT SCREENS  (LEVEL 5)
               OUTFLOW BY OUTLET PUMPING (LEVEL 6)
                    PUMPED HEAD =  30.00 FT. WATER
               NO CHLORINE CONTACT TANK FOR OUTFLOW  (LEVEL 7)
```

Table 5-8. WINGOHOCKING SUMMARY OF TREATMENT EFFECTIVENESS

SUMMARY OF TREATMENT EFFECTIVENESS

TOTALS	FLOW (M.G.)	BOD (LB)	SS (LB)	COLIF (MPN)
INPUT	78.091	6319.9	98974.9	7.08E 13
OVERFLOW (BYPASS)	0.000	0.0	0.0	0.00E-01
TREATED	78.091	6319.9	98974.9	7.08E 13
REMOVED	0.587	3524.4	68366.9	4.89E 13
RELEASED	77.504	2795.6	30479.3	2.20E 13

REMOVALS	FLOW(M.G.)	BOD (LB)	SS (LB)	
LEVEL 1	0.004	175.6	3512.6	= BAR RACKS
LEVEL 3 (TOTAL)	0.115	1697.6	47601.1	= STORAGE
LEVEL 4	0.469	1651.2	17253.3	= MICROSTRAINERS
LEVEL 5	0.000	0.0	0.0	= NO EFFL. SCREENS
LEVEL 7	0.000	0.0	0.0	= NO CONTACT TANK

TRASH:

BAR RACKS	468.348 CU.FT (AT 50 LB/CU.FT.)
EFFLUENT SCREENS	0.000 CU.FT (AT 50 LB/CU.FT.)

REMOVAL PERCENTAGES	FLOW (VOL)	BOD (LB)	SS (LB)	COLIF (MPN)
OF OVERALL INPUTS	0.75	55.77	69.07	69.01
OF TREATED FRACTIONS	0.75	55.77	69.07	69.01

CONSUMPTIONS (LB)	CHLORINE	POLYMERS	
LEVEL 3	0.0	0.0	= STORAGE
LEVEL 4	0.0	0.0	= MICROSTRAINERS
LEVEL 7	0.0	0.0	= NO CONTACT TANK
TOTAL	0.0	0.0	

REPRESENTATIVE VARIATION OF TREATMENT PERFORMANCE WITH TIME (OVERALL).

TIME	10:55	11:40	12:25	13:10	13:55	14:40	15:25	16:10	16:55	17:40	
WATER											
AV. FLOW (CFS)	-298.89	0.00	596.33	597.14	0.00	0.00	0.00	0.00	598.11	598.12	
BOD											
ARRIVING (MG/L)	0.00	0.00	47.34	20.42	0.00	0.00	0.00	0.00	2.28	2.05	
RELEASED (MG/L)	0.00	0.00	22.21	9.69	0.00	0.00	0.00	0.00	0.58	0.52	
% REDUCTION (LB)	0.00	0.00	49.12	52.93	100.00	0.00	0.00	0.00	74.53	74.89	
S. SOLIDS											
ARRIVING (MG/L)	0.00	0.00	563.24	359.85	0.00	0.00	0.00	0.00	36.04	34.39	
RELEASED (MG/L)	0.00	0.00	169.63	101.36	0.00	0.00	0.00	0.00	16.15	15.42	
% REDUCTION (LB)	0.00	0.00	70.21	72.06	100.00	0.00	0.00	0.00	55.39	55.37	
COLIFORMS											
ARR (MPN/100ML)	0.00E-01	0.00E-01	8.20E 04	5.79E 04	0.00E-01	0.00E-01	0.00E-01	0.00E-01	7.14E 03	6.76E 03	8
REL (MPN/100ML)	0.00E-01	0.00E-01	2.47E 04	1.63E 04	0.00E-01	0.00E-01	0.00E-01	0.00E-01	3.20E 03	3.03E 03	3
% REDUCTION (LB)	0.00	0.00	70.29	72.14	0.00	0.00	0.00	0.00	55.51	55.49	

Table 5-9. WINGOHOCKING SUMMARY OF TREATMENT COSTS

COST PARAMETERS . .
INTEREST RATE = 7.00 PERCENT
AMORTIZATION PERIOD = 25 YEARS
CAP. RECOVERY FACTOR = 0.0858
YEAR OF SIMULATION = 1970
SITE LOCATION FACTOR = 1.1452

UNIT COSTS . .
LAND = 20000.00 $/ACRE
POWER = 0.020 $/KWH
CHLORINE = 0.200 $/LB
POLYMERS = 1.250 $/LB
ALUM = 0.03 $/LB

		CAPITAL COSTS		ANNUAL COSTS			STORM EVENT COSTS		
TREATMENT	LEVEL	INSTAL	LAND	INSTAL	LAND	MIN MAINT	CHLORINE	CHEM	OTHER
BAR RACKS	1	1201669.	2199.	103116.	154.	12017.	0.	0.	197.
NO INLET PUMPING	2	0.	0.	0.	0.	0.	0.	0.	0.
STORAGE	3	1456435.	106336.	124978.	7444.	14564.	0.	0.	390.
MICROSTRAINERS	4	10306770.	50609.	886417.	3543.	206136.	0.	0.	483.
NO EFFL. SCREENS	5	0.	0.	0.	0.	0.	0.	0.	0.
OUTLET PUMPING	6	2378008.	1370.	204058.	96.	47560.	0.	0.	59.
NO CONTACT TANK	7	0.	0.	0.	0.	0.	0.	0.	0.
	SUBTOTAL	$15342900.	$ 160514.	$ 1316543.	$ 11736.	$ 280277.	$ 0.	$ 0.	$ 1125.
	TOTAL	$ 15503420.		$ 1608095.			$ 1125.		
	TOTAL PER TRIB ACRE	$ 2853.		$ 296.			$ 0.		

TOTAL LAND REQUIREMENT = 8.03 ACRES.

SECTION 6

ACKNOWLEDGMENTS

SECTION 6

ACKNOWLEDGMENTS

The consortium is deeply indebted to the following persons and their organizations for the services they rendered to the project group in the development, demonstration, and verification of the EPA Storm Water Management Model:

1. Mr. William A. Rosenkranz, Chief, and Mr. Darwin R. Wright, Project Officer, of the Storm and Combined Sewer Pollution Control Branch of the Environmental Protection Agency, Washington, D.C., for their generous assistance and guidance.
2. Mr. Alan O. Friedland, Chief, Mr. Harold C. Coffee, Jr., and Mr. Robert T. Cockburn of the Division of Sanitary Engineering, City of San Francisco, and Mr. T. G. Shea of Engineering-Science, Inc., for furnishing data on the Baker and Selby Street systems.
3. Dr. Louis M. Laushey and Dr. Herbert C. Preul of the Civil Engineering Department of the University of Cincinnati and the graduate student project group coordinated by Abdul S. Rashidi for providing necessary data on the Bloody Run drainage basin, Cincinnai, Ohio.
4. Mr. George A. Moorehead, Chief of Systems and Planning, Department of Sanitary Engineering, District of Columbia, and Mr. Michael S. Neijna of Roy F. Weston, Inc., for furnishing data on the Kingman Lake study area.
5. Mr. Joseph V. Radziul, Chief, and Mr. William L. Greene of the Research and Development Unit of the City of Philadelphia Water

Department for furnishing data on the Wingohocking and Callowhill study areas.

The consortium management and the project work of Metcalf & Eddy, Inc., were under the direction of Mr. Dean F. Coburn, Senior Vice President, and Mr. John A. Lager, Project Manager and Principal Investigator. Other key personnel of Metcalf & Eddy, Inc., were Drs. Byrne Perry, George Tchobanoglous, and E. John Finnemore, and Messrs. William G. Smith, Dennis A. Sandretto, Charles D. Tonkin, and Ferdinand K. Chen. Particular acknowledgment is given to Mr. Allen J. Burdoin, staff consultant, for his worthy contributions to the theoretical development of the surface quality and treatment models.

The project work of the Department of Environmental Engineering of the University of Florida was directed by Dr. Edwin E. Pyatt, Chairman and Principal Investigator, and Mr. Larry W. Russell, Senior Research Assistant. Other key personnel for the University of Florida were Drs. Wayne C. Huber and James P. Heaney, and Messrs. Ralph A. Aleman and B. James Carter. Dr. John C. Schaake, Jr., consultant, provided valuable assistance in the development of the Transport Model.

The project work of Water Resources Engineers, Inc., was directed by Drs. Gerald T. Orlob, President, and Robert P. Shubinski, Principal Engineer and Project Leader. Other key personnel for Water Resources Engineers were Mr. Marvin R. Lindorf, Vice President, Drs. Ian King and Carl W. Chen, and Mr. John R. Monser.

SECTION 7

REFERENCES

SECTION 7

REFERENCES

Introduction (Section 1)

1. Engineering-Science, Inc., "Characterization and Treatment of Combined Sewer Overflows."

San Francisco (Section 2)

1. Engineering-Science, Inc., "Characterization and Treatment of Combined Sewer Overflows."

2. Engineering-Science, Inc., Progress Reports to the City of San Francisco upon "Treatment of Combined Sewer Overflows by the Dissolved Air Flotation Process," February 1969 to January 1970.

3. U.S. Department of Commerce, Census Tract Data, 1960.

Washington, D.C. (Section 4)

1. Roy F. Weston, Inc., "Preliminary Draft Conceptual Engineering Report, Kingman Lake Project," Federal Water Quality Administration, Contract No. 14-12-829, May 1970.

2. Metcalf & Eddy, Inc., "Report to District of Columbia upon Investigation of Sewerage System," June 1955.

3. Metcalf & Eddy, Inc., "Report to District of Columbia upon Development Plan for the Water Pollution Control Plant with Implementation Program for 1969-1972," February 1969.

Philadelphia (Section 5)

1. American Society of Civil Engineers, "Technical Memorandum No. 10, Sewered Drainage Catchments in Major Cities," New York, March 1969.

<u>Philadelphia (Section 5) continued</u>

2. Guarino, Carmen F., Radziul, Joseph V., and Greene, William L., "Combined Sewer Considerations by Philadelphia," <u>Journal of the Sanitary Engineering Division</u>, Proceedings of the American Society of Engineers, Vol. 96, No. SA1, February 1970.

3. American Society of Civil Engineers, "Technical Memorandum No. 9, Raingage Networks in the Largest Cities," New York, March 1969.

SECTION 8

ABBREVIATIONS

SECTION 8

ABBREVIATIONS

JCL - job control language

DWF - dry weather flow

BOD - biochemical oxygen demand

SS - suspended solids

cfs - cubic feet per second

mg/L - milligrams per liter

SECTION 9

APPENDIX A

SAN FRANCISCO, BAKER STREET INPUT DATA

```
BAKER STREET          SAN FRANSICO, CAL
  1      187.0                              1
DEC. 19, 1969  AVERAGE=2.51
   0  10  10  11
   1   2   3   4  13
WATERSHED
 BAKER STREET (SAN FRANCISCO) 16 SUB-AREA SYSTEM
   STORM OF 19 DEC 1969 AT SF FOB GAGE. NO GUTTERS.
    1  150 2300    5.     1
   96 5.00
 .02  .02  .02  .02  .02  .02  .02  .02  .02  .02
 .02  .02  .15  .15  .15  .15  .15  .15  .15  .15
 .15  .15  .15  .15  .62  .62  .62  .62  .62  .62
 .62  .62  .62  .62  .62  .62  .54  .54  .54  .54
 .54  .54  .54  .54  .54  .54  .54  .54  .73  .73
 .73  .73  .73  .73  .73  .73  .73  .73  .73  .73
 .22  .22  .22  .22  .22  .22  .22  .22  .22  .22
 .22  .22  .19  .19  .19  .19  .19  .19  .19  .19
 .19  .19  .19  .19  .04  .04  .04  .04  .04  .04
 .04  .04  .04  .04  .04  .04
    1     1     1 300.13.23  60. .035
    1     3     3 300.12.93  60. .030
    1     5     5 150. 6.56  60. .061
    1     7     7 300. 8.13  60. .067
    1     9     9 300.12.60  60. .081
    1    11    11 200. 8.02  60. .134
    1    19    19 480.12.03  60. .168
    1    21    21 350. 8.38  60. .121
    1    23    23 900.15.00  60. .043
    1    25    25 330.12.86  60. .033
    1    29    29 340. 9.32  60. .200
    1    31    31 480.12.35  60. .088
    1    33    33 870.24.52  60. .055
    1    36    36    1. 0.05  60. .000
    1    38    38 880.13.93  60..0041
    1    40    40 520.12.79  60..0034


   16
    1     3     5     7     9    11    19    21    23    25    29    31    33    36    38    40
    9     5
    3     7     9    21    23    29    33    38    40
    1
   40
   17    16    5.    23    00   150     0
        .25          7.     2
         1.        100.        150.
    1     1     2       13.23       4720.
    1     3     2       12.93       5620.
    1     5     2        6.56       4740.
    1     7     2        8.13       3100.
    1     9     2       12.60       5320.
    1    11     2        8.02       4560.
    1    19     2       12.03       4640.
    1    21     2        8.38       3500.
    1    23     2       15.00       6220.
    1    25     2       12.86       4740.
    1    29     2        9.32       3800.
    1    31     2       12.35       4920.
    1    33     2       20.87       9800.
    2    33     3        3.65       2000.
    1    36     2        0.00          0.
    1    38     2       13.93       6240.
    1    40     2       12.79       6040.
```

```
TRANSPORT
    0
L BAKER ST. STORM OF 19 DEC. 1969. INFILTRATION COMP IN FILTH (20% OF DWF)
   39  150    16     1     2     0     1     1     2     4
 300.          .0001     .25
    1     0     1
    1     0     0    02 0.00.0000    0..0000 0.001.000
    2     1     0    01 320.14.0010.30.0130 0.001.000
    3     2     0    02 0.00.0000    0..0000 0.001.000
    4     3     0    01 250.21.0018.00.0130 0.001.000
    5     4     0    02 0.00.0000    0..0000 0.001.000
    6     5     0    05 260. 3.75 1.55.0130 2.501.000
    7     6     0    02 0.00.0000    0..0000 0.001.000
    8     7     0    01 320.12.0010.00.0130 0.001.000
    9     8     0    02 0.00.0000    0..0000 0.001.000
   10     9     0    01 320.15.00 6.00.0130 0.001.000
   11    10     0    02 0.00.0000    0..0000 0.001.000
   12    11     0    01 320.12.00 7.50.0130 0.001.000
   13    12     6    02 0.00.0000    0..0000 0.001.000
   14    13     0    05 790. 3.75 1.68.0130 2.501.000
   15    14     0    02 0.00.0000    0..0000 0.001.000
   16    15     0    051425. 5.50 2.90.0130 4.001.000
   17    16     0    02 0.00.0000    0..0000 0.001.000
   18    17     0    01 410.24.00 6.14.0130 0.001.000
   19    18     0    02 0.00.0000    0..0000 0.001.000
   20    19     0    05 320. 3.00 8.38.0130 2.001.000
   21    20     0    02 0.00.0000    0..0000 0.001.000
   22    21     0    05 685. 3.00 4.46.0130 2.001.000
   23    22     0    02 0.00.0000    0..0000 0.001.000
   24    23     0    05 685. 3.75 3.03.0130 2.501.000
   25     0     0    02 0.00.0000    0..0000 0.001.000
   26    25     0    01 345.16.0027.80.0130 0.001.000
   27    26     0    02 0.00.0000    0..0000 0.001.000
   28    27     0    01 345.16.0013.90.0130 0.001.000
   29    28     0    02 0.00.0000    0..0000 0.001.000
   30    29     0    011025.18.00 8.80.0130 0.001.000
   31    30     0    02 0.00.0000    0..0000 0.001.000
   32    31     0    051510. 3.75 3.54.0130 2.501.000
   33    24    32    02 0.00.0000    0..0000 0.001.000
   34    33     0    05 305. 3.75 4.35.0130 2.501.000
   36    34     0    02 0.00.0000    0..0000 0.001.000
   37    36     0    05 385. 3.75 4.35.0130 2.501.000
   38    37     0    02 0.00.0000    0..0000 0.001.000
   39    38     0    011000.60.00 3.27.0130 0.001.000
   40    39     0    02 0.00.0000    0..0000 0.001.000
   40
    1
   33    40
         1.          1.          1.          1.          1.          1.          1.
         1.          1.          1.          1.          1.          1.          1.
         1.          1.          1.          1.          1.          1.          1.
       1.01        0.77        0.51        0.41        0.44        0.46        1.09        1.49
       1.34        1.32        1.26        1.18        1.06        0.98        0.90        0.90
       1.00        1.14        1.27        1.20        1.12        1.13        1.08        1.02
       0.57        0.46        0.33        0.25        0.29        0.66        1.04        1.20
       1.19        1.18        1.19        1.21        1.26        1.19        1.10        1.01
       1.06        1.27        1.49        1.51        1.40        1.27        1.04        0.81
       0.63        0.48        0.38        0.28        0.34        0.89        1.39        1.58
       1.39        1.27        1.16        1.16        1.12        1.11        1.08        1.11
       1.06        1.10        1.13        1.14        1.15        1.16        1.10        0.86
  16     2     1     1    23    00
 1  12                       13.23 40.0 171. 2.8225.00 1.76                    8.89

 2  32                       12.93 40.0 166. 2.8225.00 1.81                    8.89

 3  52                        6.56 40.0  84. 2.8225.00 2.38                    8.89

 4  72                        8.13 40.0 104. 2.8225.00 1.90                    8.89
```

```
  5  92                         12.60 40.0 162. 2.8225.00 1.84                              8.89

  6 112                          8.02 40.0 103. 2.8225.00 1.42                              8.89
    1
 10 192                         12.03 36.0 175. 2.2825.00 4.62                             15.05

 11 212                          8.36 37.0 130. 2.3225.00 2.29                             10.49

 12 232                         15.00 38.0 248. 2.1025.00 4.73                              8.95
    1
 14 252                         12.86 35.0 164. 2.3825.00 5.85                             18.28

 16 292                          9.32 35.0 119. 2.3825.00 5.05                             18.28

 17 312                         12.35 38.0 198. 2.1425.00 3.05                              9.94

 13 332                         24.52 94.0 490. 2.0225.00 3.46                              8.75
    1
 18 364                            0.    0.    0.    0.25.00   0. 1.50 100. 120.   0.
    1
 19 382                         13.93 54.0 350. 1.9625.00 2.00                              9.31
    1
 20 402                         12.79 54.0 350. 1.9625.00 1.56                              9.31
    1
GRAPH
   27     1     2
  GRAPH OF THE TRANSPORT OUTPUT TAPE
          TIME IN HOURS
  FLOW      IN      CFS
ENDPROGRAM




BAKER STREET            SAN FRANSICO, CAL
    1      187.0                                  1
DEC. 19, 1969  AVERAGE=2.51
   11  12
    1    2    3    4   13
STORAGE
        40
         3          0.0
  01    12    21    32    41    51    61    71
         2           1           1           1
      37.0
   0     0      5000.0       15.0        10.0
  23    00
       7.0          25       1970      1.1452
      1314        1346       1378        1410        1442        1474        1506        1538
      1570        1602       1634
    20000.        0.02       0.20        1.25        0.03
  01    12    21    32    41    51    61    71
         2           1           1           1
      37.0
   1     1      5000.0       15.0        10.0
  23    00
       7.0          25       1970      1.1452
      1314        1346       1378        1410        1442        1474        1506        1538.
      1570        1602       1634
    20000.        0.02       0.20        1.25        0.03
```

```
02    12    22    32    41    51    61    71
       2           1           1           1
    37.0
 1     2     6
       2           1
     9.5
  49000.       785.        0.0
     37.         5.        0.0
      0.         0.
     15.
     15.
 1     1      5000.        15.        10.
23    00
      7.        25        1970     1.1452
   1314       1346        1378       1410      1442      1474      1506      1538
   1570       1602        1634
  20000.      0.02        0.20       1.25      0.03


STORAGE
      40                                 TRAN.OUT.BAKER2 ON SYS04
       1          0.
02    12    21    35    41    51    62    71
       2           1           1           1
     37.
 1     2     6
       2           1
     9.5
  49000.       785.         0.
     37.         5.       0.15
      0.         0.
     15.
     15.
23    00
      7.        25        1970     1.1452
   1314       1346        1378       1410      1442      1474      1506      1538
   1570       1602        1634
  20000.      0.02        0.20       1.25      0.03


STORAGE
      40                                 TREAT.OUT.BAKER2 ON SYS
       1          0.
01    12    22    32    41    51    61    71
       2           1           1           1
     37.
 1     2     6
       2           1
     9.5
  49000.       785.         0.
     37.
      0.         0.
     15.
     15.
 1     1      5000.        15.        10.
23    00
      7.        25        1970     1.1452
   1314       1346        1378       1410      1442      1474      1506      1538
   1570       1602        1634
  20000.      0.02        0.20       1.25      0.03
ENDPROGRAM
```

CINCINNATI, BLOODY RUN INPUT DATA

```
CINCINNATI BLOODY RUN SEWER SYSTEM    STORM I
    1     2380.      0.00    0        0.0    1       0.0
 MAY 12, 1970        1.80
   0   8   8   9   9  10  10  11  11  12  12  14
   1   2   3   4  13
WATERSHED
 BLOODY RUN WATERSHED, CINCINNATI      COMBINED SEWER SYSTEM
 STORM OF MAY 12, 1970                 FWQA STORMWATER MODEL
   38   50 0730   5.0    1  25.
   40  5.0
 .000 .080 .430 .77 1.15 1.52 1.52 1.52 1.52 1.27
1.27 1.03 1.03 1.03 1.03  .80  .80  .61  .61  .610
 .61  .40  .40  .21  .21  .21  .21  .21  .005 .005
 .005 .005
    1    1     11530.176.0 33.7.0310                               .01   .01     .00113
    1    2      91138. 68.6 29.7.0545                              .01   .01     .00113
    1    3    151262. 73.2 43.5.0545                               .01   .01     .00113
    1    4    174112. 59.0 34.7.0320                               .01   .01     .00113
    1    5    191558. 38.0 36.8.1120                               .01   .01     .00113
    1    6    21 970. 33.4 38.9.1050                               .01   .01     .00113
    1    7    25 481. 69.0 73.3.0450                               .01   .01     .00113
    1    8    271701. 53.7 56.8.0940                               .01   .01     .00113
    1    9    312389.250.2 51.9.0393                               .01   .01     .00113
    1   10    332625. 45.2 58.5.0200                               .01   .01     .00113
    1   11    351487. 38.4 81.4.0430                               .01   .01     .00113
    1   12    372591. 81.8 54.5.0320                               .01   .01     .00113
    1   13    391523. 49.8 10.8.0500                               .01   .01     .00113
    1   14    41 380. 20.2 34.7.0350                               .01   .01     .00113
    1   15   1121167. 72.0 45.6.0370                               .01   .01     .00113
    1   16    435515.116.0 45.6.0375                               .01   .01     .00113
    1   17    451598. 91.2 64.5.0238                               .01   .01     .00113
    1   18   108 830. 14.3  5.0.0400                               .01   .01     .00113
    1   19    512053. 58.9 39.8.0220                               .01   .01     .00113
    1   20    531646. 42.5 39.7.0150                               .01   .01     .00113
    1   21    571798. 36.1 42.3.0420                               .01   .01     .00113
    1   22    591545. 39.9 46.4.0250                               .01   .01     .00113
    1   23    613571. 87.1 60.8.0570                               .01   .01     .00113
    1   24    652461. 88.3 38.7.0630                               .01   .01     .00113
    1   25    71 839. 30.1 43.6.0830                               .01   .01     .00113
    1   26    751310. 29.9 71.7.0640                               .01   .01     .00113
    1   27    771072. 21.9 56.4.0590                               .01   .01     .00113
    1   28    872335. 60.3 48.7.0430                               .01   .01     .00113
    1   29    892091. 48.0 39.9.0360                               .01   .01     .00113
    1   30    911954. 50.6 29.7.0660                               .01   .01     .00113
    1   31    931243. 66.0  5.0.0495                               .01   .01     .00113
    1   32    95 904. 54.0  4.9.0250                               .01   .01     .00113
    1   33   114 725. 25.0 16.8.0270                               .01   .01     .00113
    1   34    97 896. 54.0 10.9.0235                               .01   .01     .00113
    1   35   116 838. 62.5 39.5.0125                               .01   .01     .00113
    1   36   1017600.122.0 49.7.0659                               .01   .01     .00113
    1   37   1051138. 49.0 33.8.0710                               .01   .01     .00113
    1   38   109 210.  3.6 95.0.0400                               .01   .01     .00113


   38
    1    9   15   17   19   21   25   27   31   33   35   37   39   41   43  112
   45   51   53  108   57   59   61   65   71   75   77   87   89   91   93   95
  114   97  116  101  105  109
    0    0
    0    0    0
   71   38  5.0   07   30   50    0
       15.       14.     1
        1.      125.      100.
```

1	1	1	105.6	454.
2	1	5	52.8	1.
3	1	3	17.6	47.
4	9	1	34.3	147.
5	9	5	34.3	1.
6	15	1	58.6	252.
7	15	3	14.6	38.
8	17	3	14.8	39.
9	17	1	44.2	190.
10	19	1	38.0	164.
11	21	1	20.0	86.
12	21	5	13.4	1.
13	25	3	69.0	180.
14	27	4	43.0	43.
15	27	2	10.7	46.
16	31	3	37.5	98.
17	31	1	212.7	916.
19	33	1	21.1	117.
20	33	2	18.1	78.
21	35	3	23.0	60.
22	35	2	11.6	50.
23	35	1	3.8	16.
24	37	1	81.8	352.
25	39	5	37.4	1.
26	39	3	12.4	32.
27	41	2	13.5	58.
28	41	3	7.3	19.
29	112	5	43.2	1.
30	112	3	28.8	75.
31	43	1	58.0	250.
32	43	3	58.0	151.
33	45	3	36.7	96.
34	45	5	27.5	1.
35	45	2	27.5	108.
36	108	5	14.3	1.
37	109	3	3.6	9.
38	51	1	58.9	254.
39	53	1	42.5	183.
40	57	1	10.8	46.
41	57	5	14.5	1.
42	57	3	10.8	28.
43	59	2	29.9	129.
44	59	5	10.0	1.
45	61	1	21.8	94.
46	61	3	47.9	125.
47	61	2	17.4	75.
48	65	2	22.1	95.
49	65	1	66.2	285.
50	71	5	10.5	1.
51	71	4	19.6	20.
52	75	4	29.9	30.
53	77	2	10.9	47.
54	77	1	11.0	47.
55	87	1	36.1	155.
56	87	5	12.1	1.
57	87	4	12.1	12.
58	89	1	48.0	211.
59	91	5	30.4	1.
60	91	1	20.2	87.
61	93	5	66.0	1.
62	95	5	54.0	1.
63	114	5	25.0	1.
64	97	5	40.1	1.
65	97	1	10.0	43.
66	116	1	62.5	269.
67	101	2	24.4	105.

```
   68  101     5        24.4          1.
   69  101     1        54.9        236.
   70  101     3        18.3         48.
   71  105     5        24.5          1.
   72  105     4        24.5         25.
TRANSPORT

1                CINCINNATI'S  BLOODY  RUN  WATERSHED, TRANSPORT
  117    50    38    1     5     5    0    3    4
      300.        .0001          15.
    1     1     1    1     0
   1    0    0    0   16
   2    1    0    0    1    394.0      4.5      2.60      .015
   3    2    0    0   16
   4    3    0    0    1    689.3      4.5      2.30      .015
   5    4    6    0   16
   6    7    0    0    1    380.4      4.0      2.20      .015
   7    8    0    0   16
   8    9    0    0    1    467.0      4.0      2.60      .015
   9    0    0    0   16
  10    5    0    0    1    319.4      5.5      1.40      .015
  11   10    0    0   16
  12   11    0    0    1    345.3      6.0      0.90      .015
  13   12    0    0   16
  14   13    0    0    1    577.0      6.0      1.00      .015
  15   14    0    0   16
  16   15    0    0    1    462.7      6.0      1.40      .015
  17   16    0    0   16
  18   17    0    0    1   1428.5      6.0      1.80      .015
  19   18    0    0   16
  20   19    0    0    1   1641.0      6.5      1.25      .015
  21   20    0    0   16
  22   21    0    0    1    432.0      7.0      1.10      .015
  23   22   25    0   16
  24   25    0    0    1    149.7      5.0      1.00      .015
  25    0    0    0   16
  26   23    0    0    1   1238.5      7.5      1.30      .015
  27   26   28    0   16
  28   29    0    0    1    750.0      5.0      1.20      .015
  29   30    0    0   16
  30   31    0    0    1    700.0      5.0      1.00      .015
  31    0    0    0   16
  32   27    0    0    2    700.0      8.0      0.70      .015      10.0
  33   32    0    0   16
  34   33    0    0    2    900.0      8.0      0.70      .015      10.0
  35   34    0    0   16
  36   35    0    0    2    438.3      8.0      0.70      .015      10.0
  37   36    0    0   16
  38   37    0    0    2   1473.6      9.0      0.40      .015      11.0
  39   38    0    0   16
  40   39    0    0    2    350.0      9.0      0.40      .015      11.0
  41   40   42    0   16
  42   43    0    0    9   1673.1     8.63      0.30      .015
  43   44  113    0   16
  44   45    0    0    9   1433.4     8.63      0.28      .015
  45   46   66    0   16
  46   47    0    0    1    595.4      8.0      0.60      .015
  47  110  111    0   16
  48   49    0    0    1    291.2      4.5      1.30      .015
  49   50   52    0   16
  50   51    0    0    1    231.0      3.5      2.40      .015
  51    0    0    0   16
  52   53    0    0    1     76.0      3.0      3.40      .015
  53    0    0    0   16
  54   55    0    0    1    698.7      6.5      0.90      .015
  55   56   58    0   16
```

```
 56  57   0   0   1   209.3     3.5    2.10    .015
 57   0   0   0  16
 58  59   C   0   1   442.8     6.5    0.80    .015
 59  60   0   0  16
 60  61   0   0   1  1086.0     5.5    1.30    .015
 61  62   0   0  16
 62  63   0   0   1   463.4     5.0    1.50    .015
 63  64   0   0  16
 64  65   0   0   1   475.5     4.5    1.50    .015
 65   0   0   0  16
 66  67   0   0   1  1251.9     6.5    0.86    .015
 67  68   0   0  16
 68  69   0   0   1   930.4     6.0    1.00    .015
 69  70   0   0  16
 70  71   0   0   1   365.0     5.5    1.90    .015
 71  72   0   0  16
 72  73   0   0   1   404.7     5.5    2.30    .015
 73  74   C   0  16
 74  75   C   0   1   800.2     5.5    1.10    .015
 75  76  88   0  16
 76  77   0   0   1   481.0     4.0    1.57    .015
 77  78   C   0  16
 78  79   0   0   1   354.4     4.0    2.18    .015
 79  80   C   0  16
 80  81   0   0   1   253.6     3.5    5.70    .015
 81  82   0   0  16
 82  83   0   0   1   389.4     3.0    1.42    .015
 83  84   0   0  16
 84  85   0   0   1   342.0    2.75    1.67
 85  86   0   0  16
 86  87   0   0   1   325.9    2.25    1.65
 87   0   C   0  16
 88  89   0   0   1   858.0    4.00    2.10    .015
 89  90   0   0  16
 90  91   0   0   1  1700.0     3.5    1.50    .015
 91   0   0   0  16
 92  41   0   0  12  2190.0    9.25    0.28    .015    15.0          23.125
 93  92  94   0  16
 94  95   C   0   1   170.0     4.0    0.90    .015
 95   0   C   0  16
 96  93   0   0  12   775.0    9.25    0.32    .015    15.0          23.125
 97  96 115 117  16
 98  97   0   0  12   495.0    9.25    0.32    .015    15.0          23.125
 99  98 100   0  16
100 101   0   0   1   706.5     4.5    0.50    .015
101   0   0   0  16
102  99   C   0  12   500.0    9.25    0.32    .015    15.0          23.125
103 102   C   0  16
104 103   0   0  12  1556.0    9.25    0.34    .015    15.0          23.125
105 104   C   0  16
106 105   0   0  12   334.0    9.25    0.34    .015    15.0          23.125
107 106   0   0  16
108  54   0   0  16
109  48   C   0  16
110 109   C   0   1     1.0     8.0    2.00
111 108   0   0   1     1.0     8.0    2.00
112   0   C   0  16
113 112   C   0   1     1.0     8.0    2.00
114   0   0   0  16
115 114   0   0   1     1.0     8.0    2.00
116   0   C   0  16
117 116   0   0   1     1.0     8.0    2.00
 109  108    45    41   107
  51
 109  108    41    45   107
  2550.    0.0      0.0
 316   2550.
   0     0    39   208   558   862   915   790   642   294    96     6
```

```
      0.96      1.08      1.05      0.90      1.04      1.00      0.97
      1.00      1.00      1.00      1.00      1.00      1.00      1.00
      1.00      1.00      1.00      1.00      1.00      1.00      1.00
      0.74      0.67      0.63      0.59      0.54      0.56      0.67      0.96
      1.42      1.19      1.20      1.15      1.17      1.11      1.08      1.15
      1.21      1.23      1.25      1.21      1.17      1.15      0.88      1.07
      0.85      0.71      0.60      0.41      0.46      0.49      0.72      0.87
      0.77      1.57      1.02      0.87      0.91      0.94      1.07      1.07
      1.14      0.99      1.45      1.16      1.55      1.29      0.99      1.60
      1.05      1.05      1.10      0.50      0.66      1.33      1.10      0.88
      1.03      0.91      0.66      0.63      0.94      0.94      1.05      1.05
      1.16      0.94      1.33      1.22      1.44      1.10      0.88      1.05
      1.10      0.64      0.45      0.87      0.54      0.48      1.29      1.18
      1.37      1.49      1.30      1.12      0.89      0.58      0.45      0.67
      0.96      1.18      0.84      1.01      2.82      1.77      0.84      0.71
   24    2    3    2    0    0             50.000
  1 591                259.3  10.               25.                      10. 1
  2 511                101.4  20.               15.                       7. 1
  3 751                160.7  10.               15.                       8.
 31 755                 50.0   1.
  4 452                 50.0  25.               25.                      10.
 41 453                 41.8                          .2 200. 200.
 42 454                 30.0                          .2 300. 300.          1
  5 431                 50.0  20.               10.                       7.
 51 432                 20.0  25.               10.                       7.
 52 433                 50.0                          .3 200. 200.
 53 435                 88.8
  6 155                100.0
 61 151                150.0  20.               40.                      15.
 62 152                 67.8  25.               30.                      12.
  7 211                130.4  20.               10.                       8.
  8 274                122.7                       2.01000. 800.
  9 331                295.4  20.               10.                       8.
 10 415                 50.0
101 411                 90.0  22.               15.                       9.
102 412                 18.0  30.               40.                      15.
103 413                 11.0                          .2 180. 200.          1
 11 975                195.1
111 971                184.5  20.               20.                      10.
121054                  49.0                          .4 300. 400.          1
GRAPH
    9    1    0    5
  108  109   45   41  107
           GRAPHS  OF  CINCINNATI'S  BLOODY  RUN  WATERSHED
                               TIME   IN   HOURS
Q - CFS BOD #/MISS #/MIN
ENDPROGRAM
```

WASHINGTON, D.C., KINGMAN LAKE INPUT DATA

```
KINGMAN LAKE     WASHINGTON, D.C.
    2     4060.0       27.8    15      8600.0     3     4000.00
JULY     20 1969               1.04
JULY     22 1969               3.20
AUG.     20 1969               0.64
   0    8    8    9    8   10
   1    2    3    4   13
WATERSHED
      KINGMAN LAKE DISTRICT, WASHINGTON DC
      STORM OF JULY 22 1969. NO GUTTERS
    1     95 1700    5.     2
   64    5.
 0.00 0.00 0.60 0.48 2.16 0.00 0.24 0.72 0.36 0.36
 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
 0.96 1.44 0.72 1.21 0.36 0.72 0.48 1.20 1.20 2.40
 4.80 3.60 7.20 0.24 0.36 0.60 0.60 0.48 0.24 0.12
 0.00 0.12 0.12 0.12 0.60 1.20 1.80 1.80 1.20 1.20
 1.20 0.96 0.24 0.12 0.12 0.24 0.12 0.00 0.00 0.00
 0.00 0.00 0.00 0.00
 0.00 0.00 0.00 0.00 0.00 0.00 2.04 0.36 0.30 0.30
 0.60 0.60 0.60 0.24 0.48 0.24 0.60 0.24 0.36 0.36
 0.36 0.24 1.08 1.08 0.24 0.00 0.24 0.96 1.20 2.40
 2.40 1.20 2.40 1.80 1.20 0.84 C.96 0.60 0.60 0.12
 0.12 0.12 0.00 0.12 0.12 0.00 0.12 0.00 1.08 0.60
 0.84 0.36 0.00 0.12 0.00 0.12 0.12 0.12 0.00 0.12
 0.00 0.00 0.00 0.12
    2     1       1 300. 20.7   40.0.070
    2     3      31800.140.1   40.0.070
    2     5      51200. 94.1   80.0.070
    2     7      71800. 98.1   80.0.020
    2     9      91600. 73.5   85.0.020
    2    11     111800.183.0   70.0.020
    2    13     13 600. 13.8   90.0.020
    2    15     151100. 20.2   90.0.020
    2    17     171800.116.2   90.0.020
    2    19     191300. 74.2   85.0.020
    2    21     21 700. 43.5   90.0.020
    2    23     23 750. 36.4   80.0.020
    2    25     251300. 79.2   90.0.020
    2    27     27 200. 23.4   90.0.020
    2    29     291200.186.3   40.0.070
    2    31     31 600. 36.0   90.0.050
    2    33     33 600. 12.3   90.0.020
    2    35     35 400. 36.9   80.0.020
    2    37     371400.156.8   40.0.070
    2    39     39 400. 39.9   30.0.050
    2    41     41 750.150.4   40.0.070
    2    43     43 600.101.4   60.0.050
    2    45     45 950. 75.2   90.0.020
    2    47     47 800. 41.2   90.0.020
    2    49     49 550. 32.8   90.0.020
    2    51     511500. 79.6   85.0.020
    2    53     53 800. 49.3   90.0.020
    2    55     551900. 78.3   90.0.020
```

```
  2    57    571200.  78.2   85.0.020
  2    59    59 350.  33.3   90.0.020
  2    61    611000.158.5    85.0.020
  2    63    631700.225.0    60.0.020
  2    65    651000.121.0    75.0.020
  2    67    672000.151.1    80.0.020
  2    69    691900.145.4    60.0.020
  1    73    732400.185.3    80.0.020
  1    75    751100.  62.1   50.0.020
  1    77    772500.220.3    90.0.020
  1    81    811500.  50.0   90.0.020
  1    87    871000.  50.0   90.0.020
  1    93    93 500.  20.4   90.0.020
  1    95    95 500.  49.6   90.0.020
  1    97    97 200.   4.7   90.0.020
  1    98    98 450.  32.0   90.0.020
  1   100   1001000.  22.8   90.0.020
  1   102   102 500.  39.1   90.0.020
  1   104   104 250.   8.0   90.0.020
  1   106   106 500.  14.6   90.0.020
  1   108   1081700.  70.7   90.0.020
  1   110   1101500.  79.1   90.0.020
  1   112   112 450.  11.4   90.0.020
  1   114   1141600.  61.4   85.0.020
  1   116   1161000.  73.3   90.0.020


 53
  1     3     5     7     9    11    13    15    17    19    21    23    25    27    29    31
 33    35    37    39    41    43    45    47    49    51    53    55    57    59    61    63
 65    67    69    73    75    77    81    87    93    95    97    98   100   102   104   106
108   110   112   114   116
  5     2
  3    25    63    77   116
  1     1     0
116
 57    53    5.    17    00    95     0
    11.0        10.0      1
     1.5      125.        100.
  1     1     5      20.7       48.44
  3     3     5     140.1      327.84
  5     5     5      94.1      220.00
  7     7     1      98.1      695.48
  9     9     1      73.5      520.38
 11    11     1     183.0     1006.48
 13    13     2      13.8       97.70
 15    15     2      20.2      143.08
 17    17     2     116.2      822.72
 19    19     2      74.2      374.74
 21    21     2      43.5      308.00
 23    23     2      36.4      224.32
 25    25     2      79.2      505.56
 27    27     2      23.4       94.00
 29    29     5     186.3      435.94
 31    31     2      36.0      198.00
 33    33     2      12.3       87.08
 35    35     5      36.9      159.40
 37    37     5     156.8      366.92
 39    39     5      39.9      164.40
 41    41     5     150.4      351.92
 43    43     1     101.4      469.26
```

```
   45   45    2       75.2      532.42
   47   47    2       41.2      291.72
   49   49    2       32.8      232.20
   51   51    2       79.6      453.72
   53   53    2       49.3      352.56
   55   55    2       78.3      554.36
   57   57    2       78.2      481.92
   59   59    2       33.3      235.76
   61   61    2      145.5     1030.0
 1061   61    4       13.0       40.0
   63   63    2      141.0     1000.0
 1063   63    4       84.0      280.0
   65   65    5      121.0      605.52
   67   67    1      151.1      753.78
   69   69    2       80.4      568.0
 1069   69    4       65.0      240.0
   73   73    2       92.6      655.62
 1073   73    5       92.6      400.4
   75   75    1       61.1      249.98
   77   77    2      220.3     1560.0
   81   81    2       50.0      354.0
   87   87    2       50.0      354.0
   93   93    2       20.4      144.42
   95   95    2       49.6      351.18
   97   97    2        4.7       33.28
   98   98    2       32.0      204.48
  100  100    2       22.8      161.40
  102  102    2       39.1      276.82
  104  104    2        8.0       56.64
  106  106    2       14.6      103.38
  108  108    2       70.7      483.48
  110  110    2       79.1      560.02
  112  112    2       11.4       80.70
  114  114    2       61.4      274.30
  116  116    2       73.3      478.68
TRANSPORT
    0    0
1  KINGMAN LAKE DATA USING REVISED FORMAT AND VERSION. JUL 22, 1969 STORM
  152   95   53    1    5    1    0    3    4
  300.                 11.0
    1    1    1    1    0
   1    0    0    0  16   0.0      0.0      0.0      0.013    0.0      0.0      0.0
   2    1    0    0   32940.000   4.500    1.570    0.013    2.800    0.0      0.0
   3    2    0    0  16  11.000   0.0      0.0      0.013    0.0      0.0      0.0
   4    3    0    0   11780.000   5.500    1.300    0.013    0.0      0.0      0.0
   5  137    0    0  16   0.0      0.0      0.0      0.013    0.0      0.0      0.0
   6    5    0    0   11900.000   6.500    1.600    0.013    0.0      0.0      0.0
   7    0    0    0  16   0.0      0.0      0.0      0.013    0.0      0.0      0.0
   8    7    0    0   11320.000   5.750    1.600    0.013    0.0      0.0      0.0
   9    8    0    0  16   0.0      0.0      0.0      0.013    0.0      0.0      0.0
  10    9    0    0   1 510.000   5.750    1.700    0.013    0.0      0.0      0.0
  11    6  135    0  16  11.000   0.0      0.0      0.013    0.0      0.0      0.0
  12   11    0    0   14685.000   8.000    1.000    0.013    0.0      0.0      0.0
  13    0    0    0  16   0.0      0.0      0.0      0.013    0.0      0.0      0.0
  14  119    0    0  16  11.000   0.0      0.0      0.013    0.0      0.0      0.0
  15    0    0    0  16   0.0      0.0      0.0      0.013    0.0      0.0      0.0
  16   15    0    0   31055.000   4.125    1.880    0.013    2.800    0.0      0.0
  17  120  143    0  16  11.000   0.0      0.0      0.013    0.0      0.0      0.0
  18   17    0    0   11059.000   6.000    2.030    0.013             030
  19   18    0    0  16  11.000   0.0      0.0      0.013    0.0      0.0      0.0
  20   19    0    0   11622.000   6.000    1.320    0.013    0.0      0.0      0.0
```

21	20	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
22	21	0	0	3 405.000	6.5	0.500	0.013		0.0	0.0
23	22	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
24	23	0	0	31956.000	9.750	0.500	0.013	6.500	0.0	0.0
25	24	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
26	25	0	0	3 525.000	9.750	0.500	0.013	6.500	0.0	0.0
27	26	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
28	27	0	0	3 656.000	9.750	0.620	0.013	6.500	0.0	0.0
29	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
30	29	0	0	2 385.000	6.000	0.850	0.013	6.000	0.0	0.0
31	30	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
32	31	0	0	32819.000	9.000	1.080	0.013	6.000	0.0	0.0
33	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
34	33	0	0	32333.000	3.000	1.190	0.013	2.000	0.0	0.0
35	32	34	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
36	35	0	0	680.000	9.000	3.100	0.013	6.000	0.0	0.0
37	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
38	37	0	0	1 210.000	2.750	1.800	0.013	0.0	0.0	0.0
39	36	127	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
40	39	0	0	11567.000	6.550	1.010	0.013	0.0	0.0	0.0
41	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
42	41	0	0	11013.000	5.000	1.300	0.013	0.0	0.0	0.0
43	40	129	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
44	43	0	0	12165.000	7.640	1.180	0.013	0.0	0.0	0.0
45	44		0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
46	150	0	0	12616.000	10.000	0.810	0.013	0.0	0.0	0.0
47	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
48	47	0	0	11150.000	6.000	1.000	0.013	0.0	0.0	0.0
49	48	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
50	49	0	0	1 378.000	8.5	0.840	0.013	0.0	0.0	0.0
51	50	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
52	51	0	0	1 171.000	8.500	0.390	0.013	0.0	0.0	0.0
53	52	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
54	53	0	0	11281.000	8.500	0.480	0.013	0.0	0.0	0.0
55	131	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
56	55	0	0	11542.000	9.000	0.430	0.013	0.0	0.0	0.0
57	56	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
58	57	0	0	1 480.000	9.000	0.430	0.013	0.0	0.0	0.0
59	58	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
60	59	0	0	12105.000	10.000	0.300	0.013	0.0	0.0	0.0
61	46	60	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
62	61	0	0	5 544.000	17.500	0.350	0.013	15.000	0.0	0.0
63	12		0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
64	151	0	0	51350.000	17.500	0.380	0.013		0.0	0.0
65	64	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
66	65	0	0	14544.000	22.000	0.220	0.013	0.0	0.0	0.0
67	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
68	67	0	0	12590.000	7.000	1.060	0.013	0.0	0.0	0.0
69	68	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
70	152	0	0	13430.000	7.500	0.490	0.013	0.0	0.0	0.0
71	76	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
72	71	0	0	1 180.000	22.000	1.500	0.013	0.0	0.0	0.0
73	70	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
74	73	0	0	12650.000	9.750	0.450	0.013	0.0	0.0	0.0
75	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
76	75	0	0	32820.000	4.875	1.490	0.013	3.300	0.0	0.0
77	66	74	72	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
78	77	0	0	1 315.000	22.000	0.540	0.013	0.0	0.0	0.0
79	91	0	0	11165.000	3.500	0.340	0.013	0.0	0.0	0.0
80	92	0	0	11525.000	4.500	1.580	0.013	0.0	0.0	0.0
81	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0

82	81	0	0	1000.000	4.500	0.950	0.013	3.000	0.0	0.0
83	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
84	83	0	0	11250.000	3.500	0.590	0.013	0.0	0.0	0.0
85	82	84	145	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
86	142	0	0	53980.000	6.000	0.800	0.013	4.500	0.0	0.0
87	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
88	87	0	0	12260.000	3.000	1.670	0.013	0.0	0.0	0.0
89	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
90	89	0	0	11550.000	3.250	0.760	0.013	0.0	0.0	0.0
91	90	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
92	79	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
93	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
94	93	0	0	11071.000	3.500	2.000	0.013	0.0	0.0	0.0
95	80	94	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
96	95	0	0	1 425.000	4.500	0.730	0.013	0.0	0.0	0.0
97	78	86	148	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
98	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
99	98	0	0	32542.000	4.500	1.770	0.013	2.800	0.0	0.0
100	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
101	100	0	0	32062.000	4.875	1.500	0.013	3.000	0.0	0.0
102	99	101	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
103	102	0	0	3 422.000	6.750	0.350	0.013	4.500	0.0	0.0
104	96	103	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
105	97	0	0	11601.000	22.000	0.540	0.013	0.0	0.0	0.0
106	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
107	106	0	0	12170.000	4.000	1.250	0.013	0.0	0.0	0.0
108	107	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
109	108	0	0	11290.000	4.500	0.660	0.013	0.0	0.0	0.0
110	109	139	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
111	110	0	0	5 585.000	23.500	0.100	0.013	22.000	0.0	0.0
112	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
113	112	0	0	31670.000	4.875	2.800	0.013	2.500	0.0	0.0
114	111	113	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
115	114	0	0	5 670.000	23.500	0.100	0.013	22.000	0.0	0.0
116	141	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
117	13	0	0	3 713.000	3.000	1.760	0.013	2.300	0.0	0.0
118	117	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
119	118	0	0	3 720.000	4.125	2.270	0.013		0.0	0.0
120	14	0	0	31370.000	4.500	1.700	0.013		0.0	0.0
121	16	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
122	38	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
123	122	0	0	1 830.000	4.000	1.210	0.013	0.0	0.0	0.0
124	123	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
125	124	0	0	2 712.000	4.000	1.700	0.013	3.000	0.0	0.0
126	125	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
127	126	0	0	13300.000	5.000	2.000	0.013	0.0	0.0	0.0
128	42	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
129	128	0	0	12041.000	5.250	1.950	0.013	0.0	0.0	0.0
130	54	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
131	130	0	0	1 552.000	9.000	0.320	0.013	0.0	0.0	0.0
132	10	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
133	132	0	0	2 470.000	4.000	0.960	0.013	9.000	0.0	0.0
134	133	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
135	134	0	0	1 800.000	6.500	0.350	0.013	0.0	0.0	0.0
136	4	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
137	136	0	0	1 400.000	5.750	1.030	0.013	0.0	0.0	0.0
138	105	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
139	138	0	0	51199.000	23.500	0.100	0.013		0.0	0.0
140	115	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
141	140	0	0	101520.000	18.250	0.120	0.013	22.000	0.0	0.0
142	88	147	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0

```
143 121    0    0    3 762.000    4.500    1.500    0.013    3.000    0.0    0.0
144   0    0    0   16   0.0      0.0      0.0      0.013    0.0      0.0    0.0
145 144    0    0    1 970.000    3.000    0.680    0.013    0.0      0.0    0.0
146 116    0    0   21260.000   16.500    0.230    0.013   15.500    3.000   0.0
147  85    0    0    5 800.000    6.000    0.800    0.013    4.500    0.0    0.0
148 104    0    0    1   1.090   22.000    0.500    0.013    0.0      0.0    0.0
149 146    0    0   16   0.0      0.0      0.0      0.013    0.0      0.0    0.0
150  28   45    0   16  11.000    0.0      0.0      0.013    0.0      0.0    0.0
151  62   63    0   16  11.000    0.0      0.0      0.013    0.0      0.0    0.0
152  69    0    0   16  11.00     0.0      0.0      0.013    0.0      0.0    0.0
 149
  13
  45   63   69  140  149
  1000.
   7   4100.     6.0
   0    0   33  217  519  834  871  762  626  288   74    0
 0.96      1.08      1.05      0.90      1.04      1.00      0.97
   1.       1.        1.        1.        1.        1.        1.
   1.       1.        1.        1.        1.        1.        1.
   0.74     0.67      0.63      0.59      0.54      0.56      0.67      0.96
   1.42     1.19      1.20      1.15      1.17      1.11      1.08      1.15
   1.21     1.23      1.25      1.21      1.17      1.15      0.88      1.07
   0.85     0.71      0.60      0.41      0.46      0.49      0.72      0.87
   0.77     1.57      1.02      0.87      0.91      0.94      1.07      1.07
   1.14     0.99      1.45      1.66      1.55      1.29      0.99      1.60
   1.05     1.05      1.10      0.50      0.66      1.33      1.10      0.88
   1.03     0.91      0.66      0.63      0.94      0.94      1.05      1.05
   1.16     0.94      1.33      1.22      1.44      1.10      0.88      1.05
   1.10     0.64      0.45      0.87      0.54      0.48      1.29      1.18
   1.37     1.49      1.30      1.12      0.89      0.58      0.45      0.67
   0.96     1.18      0.84      1.01      2.82      1.77      0.84      0.71
  47    1   10    2   17   00             146.078
    27.8      190.0      220.0  4.00E+06
  4060.     52.7      22.                    3985.
  21         .07      150.      150.
  39         .30      150.      150.
  24         .15      300.      350.
  41         .22      300.      350.
  45         .14      300.      350.
  11         .05      150.      150.
  63        2.00      200.      250.
  65         .05      150.      150.
  67        2.00      200.      250.
  81         .08      300.      350.
 30 1521                   35.6 102.1338. 2.56 15.4
 3612121                   43.2 100.1779. 2.39 14.3
 31 1421                   62.5  60.1103. 3.35 12.7
 35 2121                   90.2  29. 772. 3.35 12.3
351 2131                                                .80 190. 220.
352 2141                                                .07 150. 150.     1
 32 3121                   69.8  71.1308. 3.72 13.8
23212411                  471.1   4.  22. 3.09 13.9
23312441                                                .15 300. 350.
 34 3921                  247.6  28.1679. 3.13 12.7
341 3941                                                .30 150. 150.
 41 4141                                                .22 300. 350.
 33 4521                  144.8  66.2541. 3.65 13.7
331 4541                                                .14 300. 350.
332 4531                                                .80 190. 220.     1
951  111                   87.6   5. 125. 2.43 14.4
 9313421                  168.9  18. 928. 3.20 15.0
```

```
  44 4721                       63.5  58.1147. 2.99 12.6
  45 4921                       50.8  48. 722. 3.27 12.5
  50 5121                       68.6  60.1841. 2.21 14.0
  49 5321                       64.8  76.1556. 2.99 12.3
  4813021                       96.5  61.1557. 3.59 12.1
  46 5921                       90.2  68.1442. 4.18 11.1
  92 1121                      367.0  22.2158. 3.00 13.0
 921 1141                                                       .05 150. 150.
  87 6321                      232.4  31.1863. 3.79 12.8
 871 6341                                                      2.00 200. 250.
 872 6331                                                       .80 190. 220.      1
  85 6521                       49.5  64. 740. 4.17 12.3
 851 6531                                                       .20 190. 220.
 852 6541                                                       .05 150. 150.
  91 6721                      336.5  13.1301. 3.25 14.2
 911 6741                                                      2.00 200. 250.
 881 6921                      370.7  18.1954. 3.21 12.3
 882 7721                       87.6  87.2107. 3.56 13.2
  84 7721                      105.4  43.1163. 3.79 12.1
  89 7721                      141.0  61.2733. 3.13 12.6
 891 7731                                                       .80 190. 220.      1
  82 8321                       39.4  32. 557. 2.18 16.5
  66 8121                       17.8  34. 244. 2.40 17.9
  83 8521                        8.9 111. 260. 3.75 12.1
  67 8721                       10.2  67. 190. 3.55 12.9
  81 9121                       72.4  77.1532. 3.63 12.9
 661 8141                                                       .08 300. 350.
  8010421                      187.9  53.2975. 4.07 12.5                           1
  7913821                      104.1  64.1920. 3.47 13.3                           1
  6811621                       71.1  29. 440. 3.77 12.9                           1
GRAPH
    9    1    3
  GRAPH OF THE TRANSPORT OUTPUT TAPE
         TIME IN HOURS
  FLOW       IN      CFS
TRANSPORT
    0    0
1  KINGMAN LAKE AREA WITH DIVERSION OF STORM FLOW FROM ELEMENTS #45,63,&69.
  156    95    53    1     6    2    0     3     4
  300.                    11.0
    1     1     1     1     0
    1    0    0    0  16    0.0      0.0       0.0       0.013     0.0       0.0      0.0
    2    1    0    0   32940.000    4.500     1.570     0.013     2.800     0.0      0.0
    3    2    0    0  16   11.000    0.0       0.0       0.013     0.0       0.0      0.0
    4    3    0    0   11780.000    5.500     1.300     0.013     0.0       0.0      0.0
    5  137    0    0  16    0.0      0.0       0.0       0.013     0.0       0.0      0.0
    6    5    0    0   11900.000    6.500     1.600     0.013     0.0       0.0      0.0
    7    0    0    0  16    0.0      0.0       0.0       0.013     0.0       0.0      0.0
    8    7    0    0   11320.000    5.750     1.600     0.013     0.0       0.0      0.0
    9    8    0    0  16    0.0      0.0       0.0       0.013     0.0       0.0      0.0
   10    9    0    0   1 510.000    5.750     1.700     0.013     0.0       0.0      0.0
   11    6  135    0  16   11.000    0.0       0.0       0.013     0.0       0.0      0.0
   12   11    0    0   14685.000    8.000     1.000     0.013     0.0       0.0      0.0
   13    0    0    0  16    0.0      0.0       0.0       0.013     0.0       0.0      0.0
   14  119    0    0  16   11.000    0.0       0.0       0.013     0.0       0.0      0.0
   15    0    0    0  16    0.0      0.0       0.0       0.013     0.0       0.0      0.0
   16   15    0    0   31055.000    4.125     1.880     0.013     2.800     0.0      0.0
   17  120  143    0  16   11.000    0.0       0.0       0.013     0.0       0.0      0.0
   18   17    0    0   11059.000    6.000     2.030     0.013               030
   19   18    0    0  16   11.000    0.0       0.0       0.013     0.0       0.0      0.0
   20   19    0    0   11622.000    6.000     1.320     0.013     0.0       0.0      0.0
```

21	20	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
22	21	0	0	3 405.000	6.5	0.500	0.013		0.0	0.0
23	22	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
24	23	0	0	31956.000	9.750	0.500	0.013	6.500	0.0	0.0
25	24	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
26	25	0	0	3 525.000	9.750	0.500	0.013	6.500	0.0	0.0
27	26	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
28	27	0	0	3 656.000	9.750	0.620	0.013	6.500	0.0	0.0
29	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
30	29	0	0	2 385.000	6.000	0.850	0.013	6.000	0.0	0.0
31	30	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
32	31	0	0	32819.000	9.000	1.080	0.013	6.000	0.0	0.0
33	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
34	33	0	0	32333.000	3.000	1.190	0.013	2.000	0.0	0.0
35	32	34	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
36	35	0	0	680.000	9.000	3.100	0.013	6.000	0.0	0.0
37	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
38	37	0	0	1 210.000	2.750	1.800	0.013	0.0	0.0	0.0
39	36	127	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
40	39	0	0	11567.000	6.550	1.010	0.013	0.0	0.0	0.0
41	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
42	41	0	0	11013.000	5.000	1.300	0.013	0.0	0.0	0.0
43	40	129	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
44	43	0	0	12165.000	7.640	1.180	0.013	0.0	0.0	0.0
45	44		0	18 11.000	20.0	0.0	0.013	0.0	0.0	150.0
46	150	0	0	12616.000	10.000	0.810	0.013	0.0	0.0	0.0
47	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
48	47	0	0	11150.000	6.000	1.000	0.013	0.0	0.0	0.0
49	48	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
50	49	0	0	1 378.000	8.5	0.840	0.013	0.0	0.0	0.0
51	50	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
52	51	0	0	1 171.000	8.500	0.390	0.013	0.0	0.0	0.0
53	52	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
54	53	0	0	11281.000	8.500	0.480	0.013	0.0	0.0	0.0
55	131	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
56	55	0	0	11542.000	9.000	0.430	0.013	0.0	0.0	0.0
57	56	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
58	57	0	0	1 480.000	9.000	0.430	0.013	0.0	0.0	0.0
59	58	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
60	59	0	0	12105.000	10.000	0.300	0.013	0.0	0.0	0.0
61	46	60	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
62	61	0	0	5 544.000	17.500	0.350	0.013	15.000	0.0	0.0
63	12	153	0	18 11.000	18.0	0.0	0.013	0.0	0.0	151.0
64	151	0	0	51350.000	17.500	0.380	0.013		0.0	0.0
65	64	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
66	65	0	0	14544.000	22.000	0.220	0.013	0.0	0.0	0.0
67	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
68	67	0	0	12590.000	7.000	1.060	0.013	0.0	0.0	0.0
69	68	154	0	18 11.000	11.0	0.0	0.013	0.0	0.0	152.0
70	152	0	0	13430.000	7.500	0.490	0.013	0.0	0.0	0.0
71	76	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
72	71	0	0	1 180.000	22.000	1.500	0.013	0.0	0.0	0.0
73	70	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
74	73	0	0	12650.000	9.750	0.450	0.013	0.0	0.0	0.0
75	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
76	75	0	0	32820.000	4.875	1.490	0.013	3.300	0.0	0.0
77	66	74	72	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
78	77	0	0	1 315.000	22.000	0.540	0.013	0.0	0.0	0.0
79	91	0	0	11165.000	3.500	0.240	0.013	0.0	0.0	0.0
80	92	0	0	11525.000	4.500	1.580	0.013	0.0	0.0	0.0
81	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0

82	81	0	0	1000.000	4.500	0.950	0.013	3.000	0.0	0.0
83	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
84	83	0	0	11250.000	3.500	0.590	0.013	0.0	0.0	0.0
85	82	84	145	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
86	142	0	0	53980.000	6.000	0.800	0.013	4.500	0.0	0.0
87	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
88	87	0	0	12260.000	3.000	1.670	0.013	0.0	0.0	0.0
89	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
90	89	0	0	11550.000	3.250	0.760	0.013	0.0	0.0	0.0
91	90	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
92	79	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
93	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
94	93	0	0	11071.000	3.500	2.000	0.013	0.0	0.0	0.0
95	80	94	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
96	95	0	0	1 425.000	4.500	0.730	0.013	0.0	0.0	0.0
97	78	86	148	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
98	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
99	98	0	0	32542.000	4.500	1.770	0.013	2.800	0.0	0.0
100	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
101	100	0	0	32062.000	4.875	1.500	0.013	3.000	0.0	0.0
102	99	101	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
103	102	0	0	3 422.000	6.750	0.350	0.013	4.500	0.0	0.0
104	96	103	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
105	97	0	0	11601.000	22.000	0.540	0.013	0.0	0.0	0.0
106	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
107	106	0	0	12170.000	4.000	1.250	0.013	0.0	0.0	0.0
108	107	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
109	108	0	0	11290.000	4.500	0.660	0.013	0.0	0.0	0.0
110	109	139	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
111	110	0	0	5 585.000	23.500	0.100	0.013	22.000	0.0	0.0
112	0	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
113	112	0	0	31670.000	4.875	2.600	0.013	2.500	0.0	0.0
114	111	113	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
115	114	0	0	5 670.000	23.500	0.100	0.013	22.000	0.0	0.0
116	141	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
117	13	0	0	3 713.000	3.000	1.760	0.013	2.360	0.0	0.0
118	117	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
119	118	0	0	3 720.000	4.125	2.270	0.013		0.0	0.0
120	14	0	0	31370.000	4.500	1.700	0.013		0.0	0.0
121	16	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
122	38	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
123	122	0	0	1 830.000	4.000	1.210	0.013	0.0	0.0	0.0
124	123	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
125	124	0	0	2 712.000	4.000	1.700	0.013	3.000	0.0	0.0
126	125	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
127	126	0	0	13300.000	5.000	2.000	0.013	0.0	0.0	0.0
128	42	0	0	16 0.0	0.0	0.0	0.013	0.0	0.0	0.0
129	128	0	0	12041.000	5.250	1.950	0.013	0.0	0.0	0.0
130	54	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
131	130	0	0	1 552.000	9.000	0.320	0.013	0.0	0.0	0.0
132	10	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
133	132	0	0	2 470.000	4.000	0.960	0.013	9.000	0.0	0.0
134	133	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
135	134	0	0	1 800.000	6.500	0.350	0.013	0.0	0.0	0.0
136	4	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
137	136	0	0	1 400.000	5.750	1.030	0.013	0.0	0.0	0.0
138	105	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
139	138	0	0	51199.000	23.500	0.100	0.013		0.0	0.0
140	115	0	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0
141	140	0	0	101520.000	18.250	0.120	0.013	22.000	0.0	0.0
142	88	147	0	16 11.000	0.0	0.0	0.013	0.0	0.0	0.0

```
143 121    0    0    3 702.000    4.500    1.500    0.013    3.000    0.0      0.0
144   0    0    0   16   0.0      0.0      0.0      0.013    0.0      0.0      0.0
145 144    0    0    1 970.000    3.000    0.680    0.013    0.0      0.0      0.0
146 116    0    0    21260.000   16.500    0.230    0.013   15.500    3.000    0.0
147  85    0    0    5 800.000    6.000    0.800    0.013    4.500    0.0      0.0
148 104    0    0    1    1.090   22.000    0.500    0.013    0.0      0.0      0.0
149 146    0    0   16   0.0      0.0      0.0      0.013    0.0      0.0      0.0
150  28   45    0   16  11.000    0.0      0.0      0.013    0.0      0.0      0.0
151  62   63    0   16  11.000    0.0      0.0      0.013    0.0      0.0      0.0
152  69    0    0   16  11.00     0.0      0.0      0.013    0.0      0.0      0.0
153  45              13500.000    8.5      0.8      0.013    0.0      0.0      0.0
154  63              14500.000   11.0      0.8      0.013    0.0      0.0      0.0
155  69              19400.000   12.0      1.0      0.013    0.0      0.0      0.0
156 155             16  11.00     0.0      0.0      0.013    0.0      0.0      0.0
  149  156
   13
   45   63   69  140  149  156
   1000.
    7   4100.     6.0
    0    0   33  217  519  834  871  762  626  288   74    0
  0.96       1.08       1.05       0.90        1.04      1.00       0.97
   1.         1.         1.         1.         1.         1.         1.
   1.         1.         1.         1.         1.         1.         1.
   0.74       0.67       0.63       0.59       0.54       0.56       0.67       0.96
   1.42       1.19       1.20       1.15       1.17       1.11       1.08       1.15
   1.21       1.23       1.25       1.21       1.17       1.15       0.88       1.07
   0.85       0.71       0.60       0.41       0.46       0.49       0.72       0.87
   0.77       1.57       1.02       0.87       0.91       0.94       1.07       1.07
   1.14       0.99       1.45       1.66       1.55       1.29       0.99       1.60
   1.05       1.05       1.10       0.50       0.66       1.33       1.10       0.88
   1.03       0.91       0.66       0.63       0.94       0.94       1.05       1.05
   1.16       0.94       1.33       1.22       1.44       1.10       0.88       1.05
      1.10       0.64       0.45       0.87       0.54       0.48       1.29       1.18
      1.37       1.49       1.30       1.12       0.89       0.58       0.45       0.67
      0.96       1.18       0.84       1.01       2.82       1.77       0.84       0.71
   47    1    10    2    17   00                146.076
      27.8       190.0      220.0   4.00E+06
   4060.     52.7       22.                     3985.
   21        .07        150.       150.
   39        .30        150.       150.
   24        .15        300.       350.
   41        .22        300.       350.
   45        .14        300.       350.
   11        .05        150.       150.
   63       2.00        200.       250.
   65        .05        150.       150.
   67       2.00        200.       250.
   81        .08        300.       350.
 30 1521                  35.6 102.1338. 2.56 15.4
 3612121                  43.2 100.1779. 2.39 14.3
 31 1421                  62.5  60.1103. 3.35 12.7
 35 2121                  93.2  29. 772. 3.35 12.3
351 2131                                                  .80 190. 220.
352 2141                                                  .07 150. 150.      1
 32 3121                  69.8  71.1308. 3.72 13.8
23212411                 471.1   4.  22. 3.09 13.9
23312441                                                  .15 300. 350.
 34 3921                 247.6  28.1679. 3.13 12.7
341 3941                                                  .30 150. 150.
 41 4141                                                  .22 300. 350.
 33 4521                 144.8  66.2541. 3.65 13.7
```

```
331 4541                                                                    .14 300. 350.
332 4531                                                                    .80 190. 220.         1
951  111                     87.6    5. 125. 2.43 14.4
 9313421                    168.9   18. 928. 3.20 15.0
 44 4721                     63.5   58.1147. 2.99 12.6
 45 4921                     50.8   46. 722. 3.27 12.5
 50 5121                     68.6   60.1941. 2.21 14.0
 49 5321                     64.8   76.1556. 2.99 12.3
 4813021                     96.5   61.1557. 3.59 12.1
 46 5921                     90.2   68.1442. 4.18 11.1
 92 1121                    367.0   22.2158. 3.00 13.0
921 1141                                                                    .05 150. 150.
 87 6321                    232.4   31.1863. 3.79 12.8
871 6341                                                                   2.00 200. 250.
872 6331                                                                    .80 190. 220.         1
 85 6521                     49.5   64. 740. 4.17 12.3
851 6531                                                                    .20 190. 220.
852 6541                                                                    .05 150. 150.
 91 6721                    336.5   13.1301. 3.25 14.2
911 6741                                                                   2.00 200. 250.
881 6921                    370.7   18.1954. 3.21 12.3
882 7721                     87.6   87.2107. 3.56 13.2
 84 7721                    105.4   43.1163. 3.79 12.1
 89 7721                    141.0   61.2733. 3.13 12.6
891 7731                                                                    .80 190. 220.         1
 82 8321                     39.4   32. 557. 2.18 16.5
 66 8121                     17.8   34. 244. 2.40 17.9
 83 8521                      8.9  111. 260. 3.75 12.1
 67 8721                     10.2   67. 190. 3.55 12.9
 81 9121                     72.4   77.1532. 3.63 12.9
661 8141                                                                    .08 300. 350.
 8010421                    187.9   53.2975. 4.07 12.5                                            1
 7913821                    104.1   64.1920. 3.47 13.3                                            1
 6811621                     71.1   29. 440. 3.77 12.9                                            1
GRAPH
   10    1    3
  GRAPH OF THE TRANSPORT OUTPUT TAPE
          TIME IN HOURS
  FLOW      IN      CFS
ENDPROGRAM
```

```
KINGMAN LAKE     WASHINGTON, D.C.
    2     4060.0        27.8     15      8600.0     3     4000.00
JULY     20 1969                 1.04
JULY     22 1969                 3.20
AUG.     20 1969                 0.64
  11    1
  12    3    4   13
STORAGE
     149
       1
 02     12     22     35     43     51     61     72
        2             1             1             1
     75.
  1     2     6
        2             1
   35.0
 670000.      3272.         0.
```

```
   77.4        10.        0.0
     0.         0.
    15.
    35.
    20.          1        12.        3.0
 0    0
   7.00         25       1970     1.1452                                   MONEY FACTORS
   1314       1346       1378      1410       1442       1474       1506        1538
   1570       1602       1634                                      END INDECES
  20000.   0.02000       0.20       1.25       0.03                UNIT COSTS
ENDPROGRAM




KINGMAN LAKE     WASHINGTON, D.C.
    2     4060.0        27.8    15      8600.0     3    4000.00
JULY     20 1969                1.04
JULY     22 1969                3.20
AUG.     20 1969                0.64
  11    1
  12    3    4   13
RECEIVING
QUANTITYQUALITY
            POTOMAC-ANACOSTIA RECEIVING WATER

    20 JULY TIDE 1969 TIDE AT ALEXANDRIA

    1     0
    2   25.    1.   60. 17.      6      6      2     0.     0.     0.     1     1     0    32
          1           7           13          19           25           32
      1   2       14 15       15 16       30 32       40 42       48 49
          1           15
    1     4    50      1
 5.52       0.5        11.38       2.9        17.72       0.3       23.98       3.1
    1               .73   20.               3.5       .018
    2               .65                     3.5       .018
    3               .2>                     3.5       .018
    4               .65                     4.0       .018
    5               .26                     5.0       .018
    6               .26                     4.0       .018
    7               .25                     4.0       .018
    8               .65                     4.0       .018
    9               .65                     4.0       .018
   10               .65                     4.0       .018
   11               .65                     4.0       .018
   12               .26                     8.0       .018
   13               .65                     8.0       .018
   14              1.30   20.              11.0       .018
   15              1.30                    15.0       .018
   16              1.30                    20.0       .018
   17              1.30                    16.0       .018
   18              1.30                    18.5       .018
   19              2.26                    24.0       .018
   20              2.86                    17.0       .018
   21              2.86                    17.0       .018
   22              3.08                    16.0       .018
   23              4.45                    18.0       .019
   24             34.70   40.              20.0       .018
   25             25.00                    18.0       .018
   26              5.97                    16.0       .018
```

27	17.80	21.3	.018
28	14.70	20.0	.018
29	4.16	14.0	.018
30	38.10	25.0	.018
31	14.70	15.0	.018
32	27.90	30.0	.018
33	4.95	24.0	.018
34	2.31	22.0	.018
36	4.56	10.0	.018
37	7.18	8.0	.018
38	1.71	10.0	.018
39	.52	7.0	.018
40	6.96	10.0	.018
41	1.63	12.0	.018
42	2.93	20.0	.018
43	3.41	30.0	.018
44	4.68	50.0	.018
45	4.10	40.0	.018
46	3.25	35.0	.018
47	.912000.	35.0	.018
48	13.00	10.0	.018
49	8.17	15.0	.018

9999

1	1	2	1500.	450.	3.5	.018
2	2	3	1500.	300.	3.5	.018
3	3	4	1500.	300.	3.5	.018
4	4	5	1500.	300.	4.5	.018
5	5	6	1500.	300.	4.5	.018
6	6	7	1500.	300.	4.0	.018
7	7	8	1500.	300.	4.0	.018
8	8	9	1500.	300.	4.0	.018
9	9	10	1500.	300.	4.0	.018
10	10	11	1500.	300.	4.0	.018
11	11	12	1500.	417.	6.0	.018
12	12	13	1500.	533.	7.8	.018
13	13	14	1500.	550.	10.6	.018
14	14	15	1500.	600.	15.0	.018
15	15	16	1500.	600.	20.0	.018
16	16	17	1500.	675.	16.0	.018
17	17	18	1500.	775.	18.5	.018
18	18	19	1500.	800.	24.0	.018
19	19	20	2500.	850.	16.5	.018
20	20	21	2500.	900.	17.8	.018
21	21	22	2500.	1200.	17.5	.018
22	22	23	2500.	1300.	16.0	.018
23	23	24	2500.	1800.	20.0	.018
24	24	25	7500.	3000.	18.0	.018
25	25	26	3000.	1600.	12.0	.018
26	25	27	6000.	2800.	18.6	.018
27	27	28	5400.	1800.	24.0	.018
28	28	29	2100.	900.	17.0	.018
29	28	30	5400.	1400.	26.0	.018
30	30	31	3000.	1400.	17.0	.018
31	30	32	4800.	1400.	31.7	.018
32	36	37	2700.	150.	9.0	.018
33	37	38	1800.	150.	9.0	.018
34	38	39	3000.	600.	6.6	.018
35	37	40	5300.	1850.	17.5	.018
36	40	41	2300.	125.	12.0	.018
37	40	42	3900.	1162.	20.5	.018
38	42	43	3300.	938.	25.0	.018
39	41	43	4500.	550.	6.0	.018
40	43	44	2700.	1050.	10.0	.018
41	44	45	4500.	900.	43.3	.018
42	45	46	5100.	650.	32.3	.018
43	46	47	4800.	220.	35.2	.018

```
   44    39    41                  4800.      150.      4.0      .018
   45    48    49                  4300.     2100.     14.0      .018
   46    37    49                  2200.     2250.     18.0      .018
   47    24    48                  3900.     3030.     11.0      .018
   48    34    36                  2100.      900.     10.0      .018
   49    33    34                  4800.      900.     23.0      .018
   50    24    33                  6000.     1350.     22.0      .018
 9999
           POTOMAC-ANACOSTIA RECEIVING WATER
                  TIME IN HOURS
  STAGE     IN     FEET
   42
       0.         0.         0.
 63000.
 64800.     3000.
 66600.    1300.
 72000.
10000000.
ENDQUANT
       QUALITY
                    1    1
    0     2     1   25
    2     2     1 .50
   32      0.     8.  4.E-92.E-1     BOD FROM KINGMAN LAKE
99999
   32                                SS FROM KINGMAN
99999
ENDPROGRAM
```

PHILADELPHIA, WINGOHOCKING INPUT DATA

```
WINGOHOCKING AREA       PHILADELPHIA, PA.
    3     5434.0          .                     .      2
JULY 3, 1967      4-GAGE AVG.=1.43
AUG. 3, 1967      4-GAGE AVG.=1.31
   0    8    8    9
   1    2    3    4   13
WATERSHED
     WINGOHOCKING AREA. PHILADELPHIA, PA.
     STORM OF JULY 3, 1967. NO GUTTERS
    1    99 2400   5.0     4
   66    5.
 0.00 0.12 0.00 0.24 0.48 0.72 0.72 0.36 0.24 0.24
 0.12 0.12 0.12 0.00 0.00 0.24 0.36 0.36 1.20 2.16
 0.84 0.48 0.36 0.72 0.00 0.12 0.12 0.00 0.12 0.00
 0.00 0.00 0.00 1.08 2.28 0.84 0.48 0.36 0.00 0.24
 0.12 0.00 0.00 0.00 0.00 0.12 0.00 0.00 0.00 0.00
 0.00 0.00 0.00 0.12 0.00 0.03 0.00 0.00 0.00 0.00
 0.00 0.00 0.00 0.00 0.00 0.00
 0.12 0.12 0.12 0.00 0.24 0.48 0.60 0.72 0.60 0.48
 0.24 0.12 0.00 0.24 0.00 0.12 0.24 0.24 0.12 0.19
 1.56 0.24 1.20 1.08 1.32 1.08 0.12 0.60 0.24 0.24
 0.12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.12 0.48
 0.00 0.60 0.24 0.12 0.00 0.00 0.00 0.00 0.00 0.12
 0.12 0.00 0.00 0.00 0.00 0.00 0.24 0.03 0.00 0.00
 0.24 0.24 0.12 0.12 0.00 0.00
 0.00 0.00 0.00 0.00 0.60 0.96 0.72 0.48 0.03 0.03
 0.24 0.24 0.00 0.12 0.12 0.12 0.03 0.12 0.24 2.04
 0.84 0.24 0.84 2.04 1.20 0.72 0.00 0.12 0.60 0.24
 0.03 0.00 0.00 0.00 0.00 0.00 0.00 0.12 0.00 0.12
 0.00 0.12 0.00 0.12 0.00 0.12 0.00 0.12 0.00 0.00
 0.00 0.00 0.00 0.00 0.00 0.00 0.48 0.48 0.24 0.00
 0.03 0.24 0.00 0.00 0.00 0.00
 0.00 0.12 0.00 0.48 0.96 1.08 0.48 0.24 0.24 0.12
 0.12 0.12 0.12 0.12 0.12 0.12 0.03 0.03 1.80 1.80
 1.08 0.48 0.48 0.12 0.24 0.24 0.00 0.12 0.00 0.00
 0.00 0.00 0.00 0.12 0.12 0.12 0.00 0.72 0.03 0.12
 0.84 0.24 0.00 0.00 0.00 0.00 0.00 0.12 0.24 0.24
 0.24 0.00 0.00 0.24 0.00 0.00 0.00 0.00 0.00 0.00
 0.00 0.00 0.00 0.00 0.00 0.00
    1     1      11300.  64.9   80..0100
    1     2      3 800.  39.7   90..0100
    1     3      51100.  31.4   80..0100
    1     4      71400.  53.3   80..0100
    1     5      9 800.  79.3   80..0100
    1     6     111200.  66.0   80..0100
    1     7     13 500.  74.2   50..0100
    1     8     15 900.  42.1   80..0100
    1     9     17 800.  53.9   50..0100
    1    10     191900.  87.4   80..0100
    1    11     212400.119.0    80..0100
    1    12     231500.152.9    80..0100
    1    13     251200.  64.1   80..0100
    1    14     272100.  93.3   80..0080
    1    15     291100.122.2    80..0080
    2    16     311000.  79.9   80..0080
```

```
    1    17    33 900. 72.7   80..0100
    1    18    352300.126.7   80..0100
    1    19    371000. 50.8   80..0100
    1    20    392500.128.4   80..0100
    1    21    411300. 45.4   80..0100
    1    22    431200. 66.1   80..0100
    1    23    451200. 51.8   80..0100
    1    24    47 800. 65.4   80..0100
    1    25    491100.119.5   80..0100
    1    26    512400.147.0   65..0100
    1    27    531400. 67.9   80..0100
    1    28    551100. 70.6   80..0080
    1    29    57 700. 67.4   80..0100
    1    30    59 800. 51.1   80..0080
    1    31   1131800.210.3   80..0100
    1    32    612800.188.9   80..0090
    1    33    63 800. 89.5   80..0080
    1    34    651100. 75.7   80..0080
    1    35    671300.106.1   80..0080
    1    36    691200. 75.0   80..0080
    2    37    712500.179.5   80..0080
    4    38    731300. 86.4   80..0080
    2    39    751200. 72.7   80..0080
    4    40    772100.271.0   80..0080
    4    41    792100.143.4   80..0080
    4    42    81 800. 44.4   80..0080
    4    43    831800. 92.3   80..0080
    2    44    852100.197.9   80..0080
    2    45    874400.242.6   80..0080
    2    46    89 900. 69.7   80..0080
    3    47    92 700. 55.1   60..0080
    3    48    941200. 39.4   80..0080
    3    49    951600. 52.7   80..0080
    3    50    982300.125.9   80..0060
    3    51   1001200. 37.4   40..0060
    3    52   1091900. 86.9   75..0060
    3    53   1112200.144.4   40..0060
    3    54   1021900.142.1   45..0060
    3    55   1041300. 93.1   40..0060
    3    56   1061100. 40.3   80..0060
    3    57   1081000. 63.5   80..0060


   57
    1     3     5     7     9    11    13    15    17    19    21    23    25    27    29    31
   33    35    37    39    41    43    45    47    49    51    53    55    57    59   113    61
   63    65    67    69    71    73    75    77    79    81    83    85    87    89    92    94
   96    98   100   109   111   102   104   106   108
    5     2
    1    39    59    77    98
    1     1     0
  108
   58    57    5.    24    00    99     0
        3.0         5.0     1
        1.2       150.0       110.0
    1     1     1          68.9      561.54
    2     3     1          39.7      323.56
    3     5     1          81.4      663.41
    4     7     1          53.3      434.40
    5     9     1          79.3      646.30
    6    11     1          66.0      537.90
```

```
   7   13    1      74.2     140.98
   8   15    1      42.1     343.12
   9   17    1      58.9     480.04
  10   19    1      67.4     712.31
  11   21    1     119.0     226.30
  12   23    1     152.9    2920.39
  13   25    1      64.1    1224.31
  14   27    1      93.3     760.40
  15   29    1     122.2    2334.02
  16   31    1      79.9    1526.09
  17   33    1      72.7     592.50
  18   35    1     126.7    1022.61
  19   37    1      50.8     414.02
  20   39    1     128.4    1046.47
  21   41    1      45.4     370.01
  22   43    1      66.1     538.72
  23   45    1      51.8     422.17
  24   47    1      65.4    1249.14
  25   49    1     119.5     973.93
  26   51    1     147.0    1198.05
  27   53    1      67.9    1296.89
  28   55    1      70.6     575.39
  29   57    1      67.4     549.31
  30   59    1      51.1     416.47
  31  113    2     210.3    1713.95
  32   61    2     188.9    1539.54
  33   63    2      89.5     729.43
  34   65    1      75.7     162.83
  35   67    1     106.1     864.72
  36   69    1      75.0     142.50
  37   71    1      79.5     647.93
  38   71    5     100.0     190.00
  39   73    1      86.4     704.16
  40   75    1      72.7     592.51
  41   77    1     271.0    2208.65
  42   79    1     143.4    1163.71
  43   81    1      44.4     348.04
  44   83    1      92.3     752.25
  45   85    1     197.9    2418.81
  46   87    1     242.6    4248.22
  47   89    1      69.2    1321.72
  48   92    1      55.1    1449.07
  49   94    1      33.4     733.44
  50   96    1      52.7    1006.57
  51   98    1     125.9    1924.81
  52  100    5      37.4      71.06
  53  109    1      85.0     700.90
  54  111    1     144.4    1176.86
  55  102    5     142.1     269.99
  56  104    5      90.1     171.19
  57  106    1      40.3      76.57
  58  108    1      63.5     517.53
TRANSPORT
    0     0
1     WINGOHOCKING AREA RUN - DEMONSTRATION PHASE - STORM OF JULY 3, 1967
  129    99    57    1    8    1    0    3    4
      300.       .0001        1.0
    1     1     1     1     0
   1    0    0    0   16    0.0       0.0       0.0       0.0       0.0       0.0
   2    1    0    0   01    780.      5.        1.79      .013
   3    2    0    0   16   11.000     0.0       0.0       0.0       0.0       0.0
```

4	3	0	0	02	1170.	6.	1.53	.013	5.	
5	4	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
6	5	0	0	02	1397.	7.5	1.50	.013	6.0	
7	6	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
8	7	0	0	02	988.	7.5	.59	.013	7.5	
9	8	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
10	9	0	0	02	1170.	8.0	.80	.013	7.5	
11	10	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
12	11	0	0	02	480.	8.0	.94	.013	7.5	
13	12	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
14	13	0	0	02	670.	8.0	1.13	.013	7.5	
15	14	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
16	15	0	0	02	1025.	8.0	1.57	.013	7.5	
17	16	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
18	17	0	0	01	564.	8.5	1.65	.013		
19	18	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
20	19	0	0	01	870.	8.5	1.09	.013		
21	20	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
22	21	0	0	01	1530.	8.5	.88	.013		
23	22	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
24	23	0	0	01	1524.	8.5	1.75	.013		
25	24	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
26	25	0	0	01	371.	8.5	2.68	.013		
27	26	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
28	27	0	0	01	2536.	9.2	1.16	.013		
29	28	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
30	29	0	0	01	1527.	10.0	1.19	.013		
31	30	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
32	31	0	0	01	2065.	10.5	1.03	.013		
33	0	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
34	33	0	0	01	945.	4.0	3.98	.013		
35	34	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
36	35	0	0	01	1000.	6.0	1.11	.013		
37	36	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
38	37	0	0	01	1013.	7.0	1.14	.013		
39	38	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
40	39	0	0	01	1090.	7.5	.94	.013		
41	40	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
42	41	0	0	02	396.	10.0	.73	.013	9.	
43	42	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
44	43	0	0	01	1162.	7.5	.68	.013		
45	44	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
46	45	0	0	01	280.	8.25	1.18	.013		
47	0	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
48	47	0	0	01	220.	8.25	2.25	.013		
49	48	46	0	16	0.0	0.0	0.0	0.0	0.0	0.0
0	49	0	0	01	1410.	8.25	.85	.013		
1	50	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
2	51	0	0	01	1410.	8.25	.95	.013		
53	52	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
54	53	0	0	01	1260.	8.5	.90	.013		
5	54	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
56	55	0	0	01	1485.	8.5	.90			
57	56	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
58	57	0	0	01	530.	8.5	.90	.013		
59	59	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0
60	59	0	0	01	220.	12.	.90	.013		
61	114	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0
62	61	0	0	02	800.	6.5	.90	.013	8.	
63	62	60	0	16	11.000	0.0	0.0	0.0	0.0	0.0
64	63	0	0	09	1357.	12.0	.90	.013		

65	64	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0	
66	65	0	0	01	1570.	9.5	.90	.013			
67	66	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
68	67	0	0	01	1830.	9.5	1.62	.013			
69	68	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0	
70	69	0	0	01	1497.	11.	1.3	.013			
71	70	32	0	16	11.000	0.0	0.0	0.0	0.0	0.0	
72	71	0	0	02	794.	15.	.67	.013	17.		
73	72	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0	
74	73	0	0	01	1390.	13.	.37	.013			
75	74	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
76	75	0	0	01	1252.	13.	.37	.013			
77	0	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
78	77	0	0	01	1900.	7.0	.90	.013			
79	0	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
80	79	0	0	01	250.	6.0	.37	.013			
81	80	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
82	81	0	0	01	1500.	6.5	.37	.013			
83	82	78	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
84	83	0	0	01	475.	8.0	1.33	.013			
85	76	84	0	21							86.
86	85	0	0	11	145.	6.2	.54	.013	10.5	3.	1.
87	86	0	0	01	2300.	14.	.54	.013			
115	87	0	0	16							
116	115	0	0	01	119.	15.	.54	.013			
117	116	0	0	16							
118	117	0	0	01	199.	16.	.54	.013			
119	118	0	0	16							
120	119	0	0	01	263.	17.25	.54	.013			
121	120	0	0	16							
88	121	0	0	04	628.	17.25	.54	.013			
89	88	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
90	89	0	0	04	1450.	17.5	.54	.013			
122	90	0	0	16							
123	122	0	0	01	415.	17.5	.54	.013			
91	85	0	0	02	146.	6.26	.54	.013	10.	3.	
92	91	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
93	92	0	0	02	305.	16.	.54	.013	14.		
124	93	0	0	16							
125	124	0	0	04	2347.	16.0	.54	.013			
126	125	0	0	16							
127	126	0	0	02	2374.	17.	.54	.013	21.		
94	127			16							
95	94	0	0	02	475.	15.	.54	.013	17.		
96	95	123	0	16							
97	96	0	0	02	50.	15.	.29	.013	17.		
98	97	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
99	98	0	0	10	2080.	7.5	.35	.013	21.		
100	99	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0	
101	100	0	0	04	252.	19.0	.33	.013			
103	102	0	0	10	2919.	9.0	.17	.013	24.		
104	103	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
105	104	0	0	10	515.	9.0	.13	.013	24.		
106	105	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
107	106	0	0	02	1312.	21.0	.24	.013	24.		
108	107	0	0	16	11.000	0.0	0.0	0.0	0.0	0.0	
109	0	0	0	16							
110	109	0	0	01	2765.	5.5	1.0	.013			
111	110	0	0	16	0.0	0.0	0.0	0.0	0.0	0.0	
112	111	0	0	01	2730.	7.0	1.0	.013			
128	101	0	0	16							

```
129 129   0   0  10   833.     8.0    .33     .013    22.
102 129 112   0  16
113   0   0   0  16   0.0      0.0    0.0     0.0     0.0     0.0
114 113   0   0  02  3100.     6.     2.5     .013    7.
 108
  85
  85   91   86   95  123   96  101  108
 1000.
 353  5500.   6.0
   0    0   30  205  513  856  924  823  691  351   93    0

    1.        1.        1.        1.        1.        1.        1.
    1.        1.        1.        1.        1.        1.        1.
   0.60      0.53      0.50      0.53      0.55      0.60      0.75      1.12
   1.40      1.46      1.44      1.42      1.36      1.34      1.32      1.25
   1.23      1.16      1.10      1.03      0.95      0.86      0.80      0.70
    .73       .55       .34       .30       .30       .30       .61       .88
   1.22      1.22      1.25      1.25      1.22      1.19      1.16      1.13
   1.07      1.04      1.28      1.52      1.77      1.49      1.22      0.94
    .84       .57       .37       .27       .23       .15       .57       .99
   1.31      1.46      1.54      1.58      1.48      1.31      1.07      1.01
    .97       .92      1.04      1.24      1.46      1.41      1.17      1.01
      1.10      0.64      0.45      0.87      0.54      0.48      1.29      1.18
      1.37      1.49      1.30      1.12      0.89      0.58      0.45      0.67
      0.96      1.18      0.84      1.01      2.82      1.77      0.84      0.71
  51    2    0    1   24   00
221 211                    84.7  59.1441.      7.9
222 531                   189.7  67. 401.      9.0
223 511                   130.2  19. 793.     16.4
224 431                   198.8  28.1991.     15.5
225 371                   193.5  17.1141.     14.4
226 331                    74.6       303.    15.8
231 431                   145.3  44.2029.      8.2
232 531                   239.1  41.3268.      9.0
233 571                    79.1  34. 830.      9.6
234 651                   237.7  31.2373.      7.8
235 651                   157.3  29.1442.      7.1                   1
236 691                   209.1  30.2137.      7.3
3331081                    20.2       136.    11.2
3341061                    66.2  1.    8.       .
3351001                   212.6  1.   42.       .
336 961                    71.6  15. 811.      7.2
381 771                    96.0       320.     6.4
424 891                    13.6  33. 236.      8.3
425 981                    24.4  38. 243.      8.0
4271061                    52.8       647.     8.3
428 961                   105.5  30.1261.      8.0                   1
429 981                    80.5  27. 859.      7.9
431 941                   198.9  31.2159.      7.6
432 791                   107.7  47.1673.      7.0
4341091                    32.0  50.  20.      7.5
491 211                   151.6  32.  28.     11.8
492 311                   151.6  32.2152.     11.8
493 311                   326.9  28.2925.      8.5
494 711                    65.7  26. 685.      9.5                   1
495 851                   130.4  34.1517.     10.5
496 851                   183.1  30.1805.      7.7
497 921                   167.9  51.3154.      9.4
498 891                   103.1  50.1448.      8.6
509  31                    63.3       283.    15.3
510  51                   145.6  23.1024.     18.3
```

```
511  91                        131.7  42.1838.        13.7
512 131                        166.7  34.2024.        12.5
513 211                         75.8      1143.        9.6
514 291                         23.3       414.        9.7
516 231                         91.8      1176.        8.2
591 771                        126.2  37.1800.         8.1
592 771                         58.0  22. 555.         9.4
593 671                        117.3  37.1912.         8.2
594 611                         86.6  15. 556.         9.0
595 611                         86.6  15.1479.         9.7
5961131                        125.6  30. 211.        12.1
599 531                         25.4       140.       11.5
600 411                         20.2         2.       14.4
602 351                                     21.        8.5
433 851                         34.6       413.        7.4
100 771              0.12
    1
GRAPH
    9     1     3
  GRAPH OF THE TRANSPORT OUTPUT TAPE
         TIME IN HOURS
  FLOW      IN      CFS
ENDPROGRAM
```

```
WINGOHOCKING AREA       PHILADELPHIA, PA.
    3     5434.0         .                .       2
JULY 3, 1967     4-GAGE AVG.=1.43
AUG. 3, 1967     4-GAGE AVG.=1.31
   9   10    8    9
   1    2    3    4   13
STORAGE
       108
         1          .50
   02   12    21    35    42    51    62    71
         2           1           1           1
    1    1     6
         1           1
       20.
        0.          0.          2.     31920.        4.     57600.         6.     82800.
        8.     111840.         10.    126000.       12.    138000.        14.    155040.
       16.     168720.         18.    185280.       21.    185280.
      600.         10.         5.0
        0.          0.
       15.
       30.
   10   50
      7.00          25        1970     1.1452                              MONEY FACTORS
      1314        1346        1378       1410      1442       1474      1506       1538
      1570        1602        1634                                       ENR INDECES
    20000.     0.02000        0.20       1.25      0.03                  UNIT COSTS
ENDPROGRAM
```

1 Accession Number	2 Subject Field & Group	
	013B	**SELECTED WATER RESOURCES ABSTRACTS** INPUT TRANSACTION FORM

5 Organization

Metcalf & Eddy, Inc., Palo Alto, California ; Florida University, Gainesville, Dept. of Environmental Engineering ; Water Resources Engineers, Inc., Walnut Creek, Calif.

6 Title

STORM WATER MANAGEMENT MODEL

10 Author(s)

Lager, John A.,
Pyatt, Edwin E., and
Shubinski, Robert P.

16 Project Designation

EPA Contract Nos. 14-12-501, 502, 503

21 Note

Set of four volumes: Volume I - Final Report, Volume II - Verification and Testing, Volume III - User's Manual, Volume IV - Program Listing

22 Citation

23 Descriptors (Starred First)

Water Quality Control*, Computer Model*, Storm Water*, Simulation Analysis, Rainfall-Runoff Relationships, Sewerage, Storage, Waste Water Treatment, Cost Benefit Analysis

25 Identifiers (Starred First)

Combined Sewer Overflows*, Urban Runoff

27 Abstract

A comprehensive mathematical model, capable of representing urban storm water runoff, has been developed to assist administrators and engineers in the planning, evaluation, and management of overflow abatement alternatives. Hydrographs and pollutographs (time varying quality concentrations or mass values) were generated for real storm events and systems from points of origin in real time sequence to points of disposal (including travel in receiving waters) with user options for intermediate storage and/or treatment facilities. Both combined and separate sewerage systems may be evaluated. Internal cost routines and receiving water quality output assisted in direct cost-benefit analysis of alternate programs of water quality enhancement. Demonstration and verification runs on selected catchments, varying in size from 180 to 5,400 acres, in four u.s. cities (approximately 20 storm events, total) were used to test and debug the model. The amount of pollutants released varied significantly with the real time occurrence, runoff intensity duration, pre-storm history, land use, and maintenance. Storage-treatment combinations offered best cost-effectiveness ratios. A user's manual and complete program listing were prepared.

Abstractor	Institution
John A. Lager	Project Manager, Metcalf & Eddy, Inc.

SEND TO: WATER RESOURCES SCIENTIFIC INFORMATION CENTER
U.S. DEPARTMENT OF THE INTERIOR
WASHINGTON, D. C. 20240

* GPO: 1969-359-339

Continued from inside front cover....

11022	---	08/67	Phase I - Feasibility of a Periodic Flushing System for Combined Sewer Cleaning
11023	---	09/67	Demonstrate Feasibility of the Use of Ultrasonic Filtration in Treating the Overflows from Combined and/or Storm Sewers
11020	---	12/67	Problems of Combined Sewer Facilities and Overflows, 1967 (WP-20-11)
11023	---	05/68	Feasibility of a Stabilization-Retention Basin in Lake Erie at Cleveland, Ohio
11031	---	08/68	The Beneficial Use of Storm Water
11030	DNS	01/69	Water Pollution Aspects of Urban Runoff, (WP-20-15)
11020	DIH	06/69	Improved Sealants for Infiltration Control, (WP-20-18)
11020	DES	06/69	Selected Urban Storm Water Runoff Abstracts, (WP-20-21)
11020	---	06/69	Sewer Infiltration Reduction by Zone Pumping, (DAST-9)
11020	EXV	07/69	Strainer/Filter Treatment of Combined Sewer Overflows, (WP-20-16)
11020	DIG	08/69	Polymers for Sewer Flow Control, (WP-20-22)
11023	DPI	08/69	Rapid-Flow Filter for Sewer Overflows
11020	DGZ	10/69	Design of a Combined Sewer Fluidic Regulator, (DAST-13)
11020	EKO	10/69	Combined Sewer Separation Using Pressure Sewers, (ORD-4)
11020	---	10/69	Crazed Resin Filtration of Combined Sewer Overflows, (DAST-4)
11024	FKN	11/69	Stream Pollution and Abatement from Combined Sewer Overflows - Bucyrus, Ohio, (DAST-32)
11020	DWF	12/69	Control of Pollution by Underwater Storage
11000	---	01/70	Storm and Combined Sewer Demonstration Projects - January 1970
11020	FKI	01/70	Dissolved Air Flotation Treatment of Combined Sewer Overflows, (WP-20-17)
11024	DOK	02/70	Proposed Combined Sewer Control by Electrode Potential
11023	FDD	03/70	Rotary Vibratory Fine Screening of Combined Sewer Overflows, (DAST-5)
11024	DMS	05/70	Engineering Investigation of Sewer Overflow Problem - Roanoke, Virginia
11023	EVO	06/70	Microstraining and Disinfection of Combined Sewer Overflows
11024	---	06/70	Combined Sewer Overflow Abatement Technology
11034	FKL	07/70	Storm Water Pollution from Urban Land Activity
11022	DMU	07/70	Combined Sewer Regulator Overflow Facilities
11024	EJC	07/70	Selected Urban Storm Water Abstracts, July 1968 - June 1970
11020	---	08/70	Combined Sewer Overflow Seminar Papers
11022	DMU	08/70	Combined Sewer Regulation and Management - A Manual of Practice
11023	---	08/70	Retention Basin Control of Combined Sewer Overflows
11023	FIX	08/70	Conceptual Engineering Report - Kingman Lake Project
11024	EXF	08/70	Combined Sewer Overflow Abatement Alternatives - Washington, D.C.