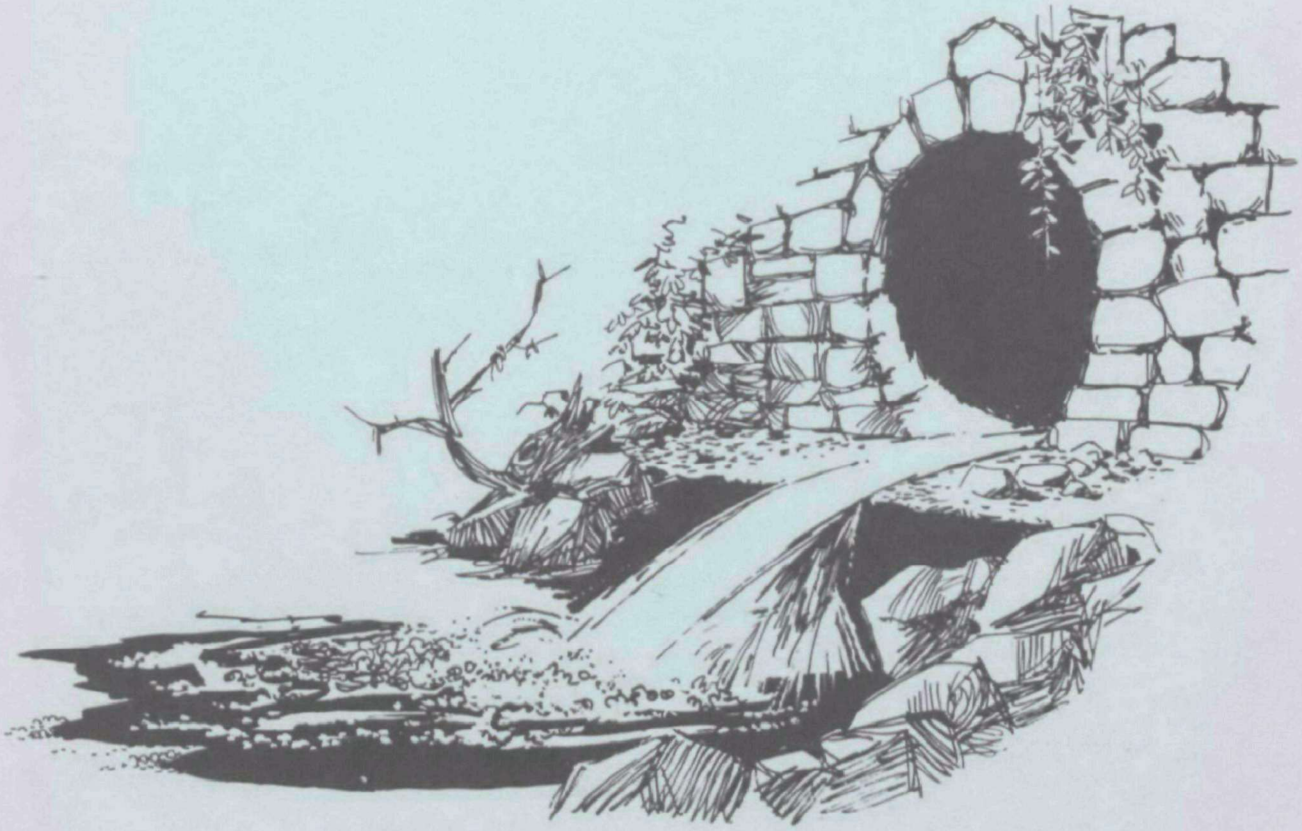
WATER POLLUTION CONTROL RESEARCH SERIES 11024DOC09/71

Storm Water Management Model

Volume III—User's Manual



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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.

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To be continued on inside back cover...

STORM WATER MANAGEMENT MODEL

Volume III USER'S MANUAL

by

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for the

Environmental Protection Agency

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ABSTRACT

A comprehensive mathematical model, capable of representing urbai storm water runoff, has been developed to assist administrators and en gineers 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 system may be evaluated. Internal cost routines and receiving water quality ou put 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 occurrenc 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
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STORM WATER MANAGEMENT MODEL Volume III - User's Manual	11024 DOC 09/71
STORM WATER MANAGEMENT MODEL Volume IV - Program Listing	11024 DOC 10/'

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

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 II, "Verification and Testing," describes the methods and results of Model application in four urban catchment areas.

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

THE COMPREHENSIVE MODEL

The comprehensive Storm Water Management Model uses a high speed digital computer to simulate real storm events on the basis of rainfall (hyetograph) inputs and system (catchment, conveyance, storage/treatment, and receiving water) characterization to predict outcomes in the form of quantity and quality values.

The simulation technique--that is, the representation of the physical systems identifiable within the Model--was selected because it permits relatively easy interpretation and because it permits the location of remedial devices (such as a storage tank or relief lines) and/or denotes localized problems (such as flooding) at a great number of points in the physical system.

Since the program objectives are particularly directed toward complete time and spatial effects, as opposed to simple maxima (such as the rational formula approach) or only gross effects (such as total pounds of pollutant discharged in a given storm), it is considered essential to work with continuous curves (magnitude versus time), referred to as hydrographs and "pollutographs." The units selected for quality representation, pounds per minute, identify the mass releases as these portray both the volume and the concentration of the release in a single term. Concentrations are also printed out within the program for comparisons with measured data.

An overview of the Model structure is shown in Figure 1-1. In simplest terms the program is built up as follows:

1. The input sources:

   RUNOFF generates surface runoff based on an arbitrary rainfall hyetograph, antecedent conditions, land use, and topography.

   FILTH generates dry weather sanitary flow based on land use, population density, and other factors.

   INFIL generates infiltration into the sewer system based on available groundwater and sewer condition.

2. The central core:

   TRANS carries and combines the inputs through the sewer system in accordance with Manning's equations and continuity; it assumes complete mixing at various inlet points.

   QUAL routes pollutants through transport and models quality changes due to sedimentation or scour.

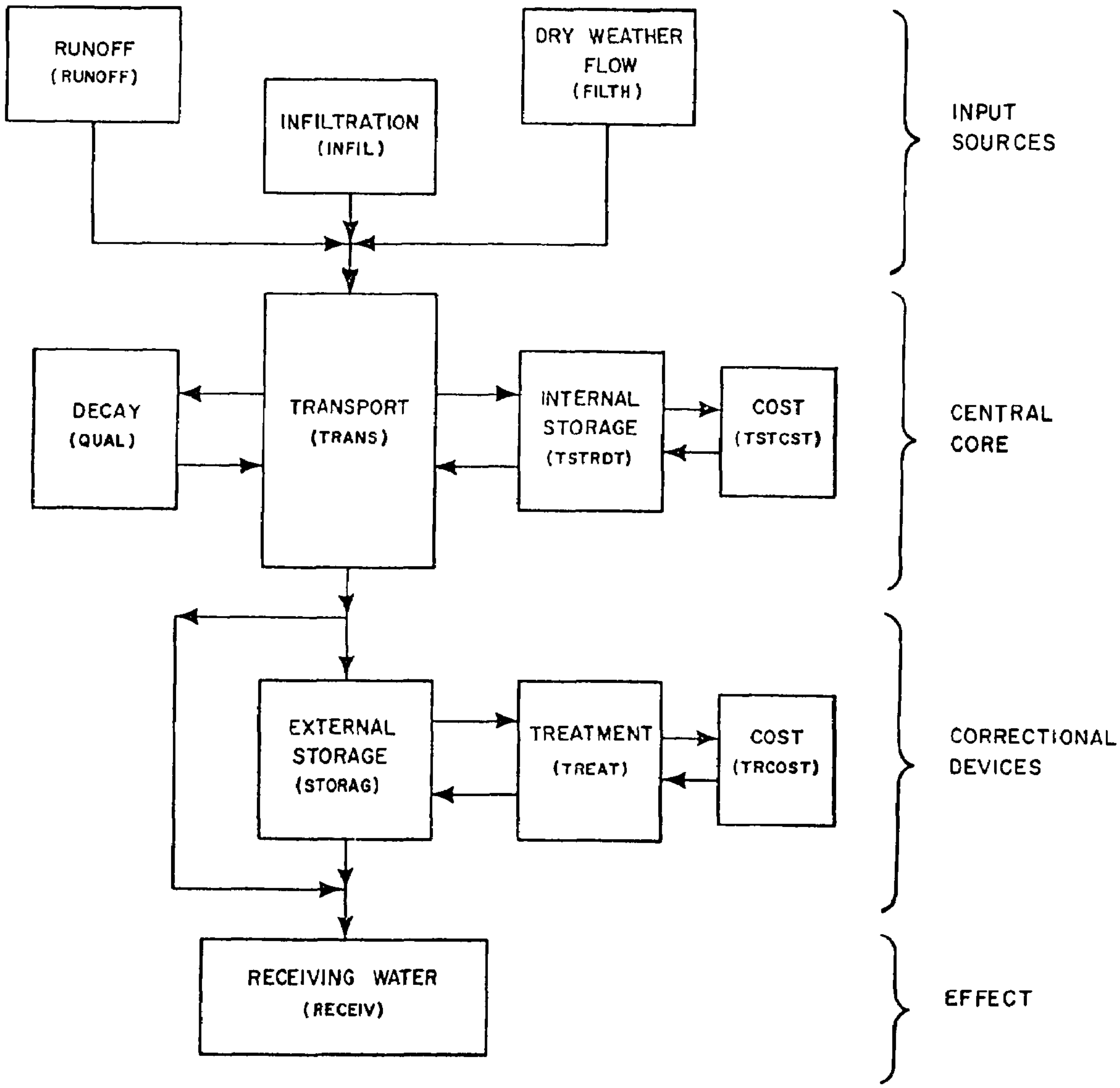
3. The correctional devices:

   TSTRDT, TSTCST, STORAG, TREAT, and TRCOST modify hydrographs and pollutographs at selected points in the sewer system, accounting for retention time, treatment efficiency, and other parameters; associated costs are computed also.

4. The effect (receiving waters):

   RECEIV routes hydrographs and pollutographs through the receiving waters, which may consist of a stream, stream bed; lake or estuary.

The quality constituents considered for simulation are the 5-day BOD,



Note: Subroutine names are shown in parentheses.

Figure 1-1. OVERVIEW OF MODEL STRUCTURE

total suspended solids, total coliforms (represented as a conservative pollutant), and DO. These constituents were selected on the basis of available supporting data and importance in treatment effectiveness evaluation. Notable omissions, such as floatables, nutrients, and temperature, fell outside the scope of this initial work. Other parameters, such as COD, volatile suspended solids, settleable solids, and fecal coliforms, can be developed by paralleling the structures of their modeled counterparts.

PROGRAM BLOCKS

The adopted programming arrangement, as shown in Figure 2-1, consists of a main control and service block, the Executive Block, and four computational blocks: (1) Runoff Block, (2) Transport Block, (3) Storage Block, and (4) Receiving Water Block.

Executive Block

The Executive Block assigns logical units (disk/tape/drum), determines the block or sequence of blocks to be executed, and, on call, produces graphs of selected results on the line printer. Thus, this Block does no computation as such, while each of the other four blocks are set up to carry through a major step in the quantity and quality computations. All access to the computational blocks and transfers between them must pass through subroutine MAIN of the Executive Block. Transfers are accomplished on offline devices (disk/tape/drum) which may be saved for multiple trials or permanent record.

Runoff Block

The Runoff Block computes the storm water runoff and its characteristics for a given storm for each subcatchment and stores the results in the form of hydrographs and pollutographs at inlets to the main sewer system.

Transport Block

The Transport Block sets up pre-storm conditions by computing DWF and infiltration and distributing them throughout the conveyance system. The block then performs its primary function of flow and quality routing, picking up the runoff results, and producing combined flow hydrographs and pollutographs for the total drainage basin and at selected intermediate points.

Storage Block

The Storage Block uses the output of the Transport Block and modifies the flow and characteristics at a given point or points according to the predefined storage and treatment facilities provided. Costs associated with the construction and operation of the storage/treatment facilities are computed.

Receiving Water Block

The Receiving Water Block accepts the output of the Transport Block directly, or the modified output of the Storage Block, and computes the dispersion and effects of the discharge in the receiving river, lake, or bay.

In principle, the capability exists to run all blocks together in a given computer execution, although from a practical and sometimes necessary (due to computer core limitations) viewpoint, typical runs involve one or two computational blocks together with the Executive Block. Using this approach avoids overlay and, moreover, allows for examination of intermediate results before continuing the computations. Further, it permits the use of intermediate results as start-up data in subsequent execution runs, thereby avoiding the waste of repeating the computations already performed.

This manual expands on these block descriptions by providing for each block:

1. Descriptions of the program subroutines with flow charts.
2. Instructions on data preparation with tables for data card input requirements and an alphabetical list of variables.
3. Examples of the application of procedures described with sample I/O information reproduced.

NOTE: Where maximum quantities (i.e., number of watersheds, number of elements, etc.) are specified, these represent the maximum array areas reserved by the program. These numbers cannot be exceeded without revising the appropriate common, dimension, and related statements. For special runs it may be desirable to reallocate this available array area (e.g., to increase the total number of time-steps above 150).

SECTION 2

EXECUTIVE BLOCK

SECTION 2

EXECUTIVE BLOCK

BLOCK DESCRIPTION

The Executive Block performs three functions:

1. Assignment of logical units and files
2. Control of the computational block(s)
3. Graphing of data files by line printer.

The Executive Block consists of a MAIN program and four subroutines that are used to produce graphical output by means of the line printer. The line count for the FORTRAN program is close to 380 lines. No computations as such are performed, except those having to do with scaling variables for graphing. A flow chart of the Executive Block is shown in Figure 2-1.

SUBROUTINE DESCRIPTIONS

MAIN Program

The MAIN program assigns logical units and files, and controls the computational block(s) to be executed. These functions depend on reading in a few data cards which must be supplied according to the needs of a given computer run. In addition, the MAIN program reads certain general data and title information from cards and prints a suitable heading at the beginning of the line-printer output. A flow chart of the MAIN program is shown in Figure 2-2.

Since the various blocks use logical devices for input and output of computations, the MAIN program has provision for assigning logical unit numbers by reading two data cards. The first card may contain up to 20

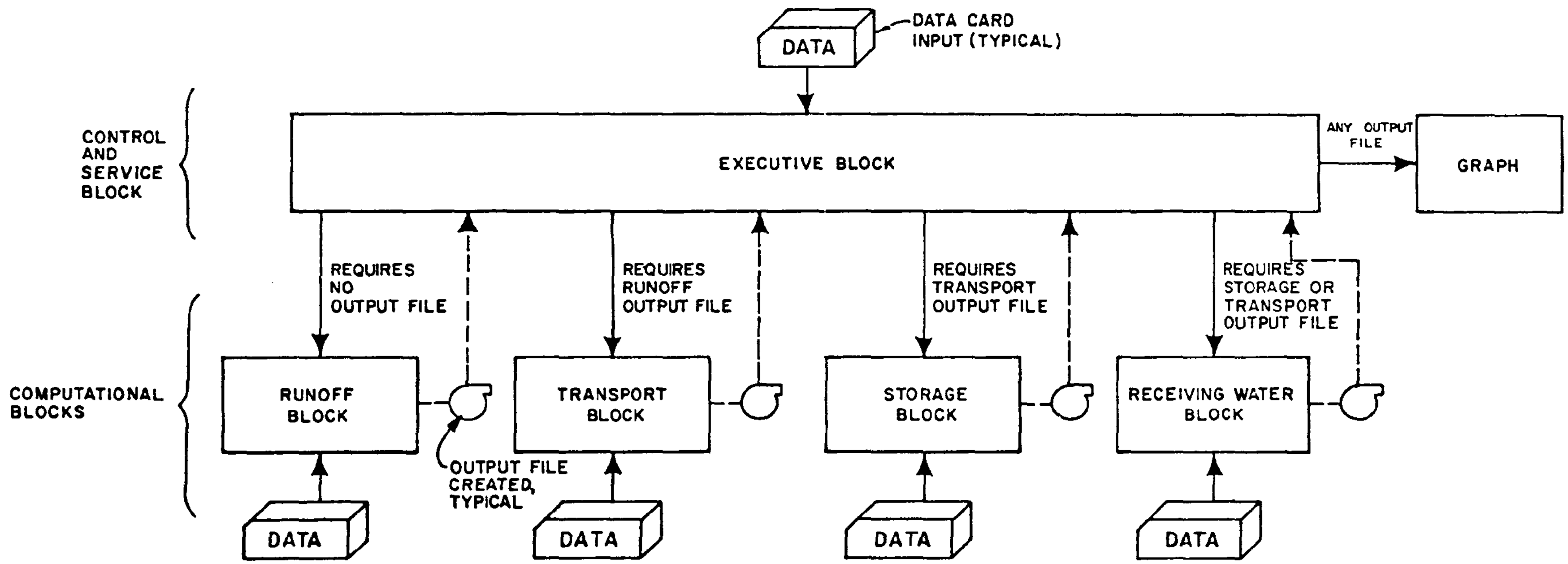
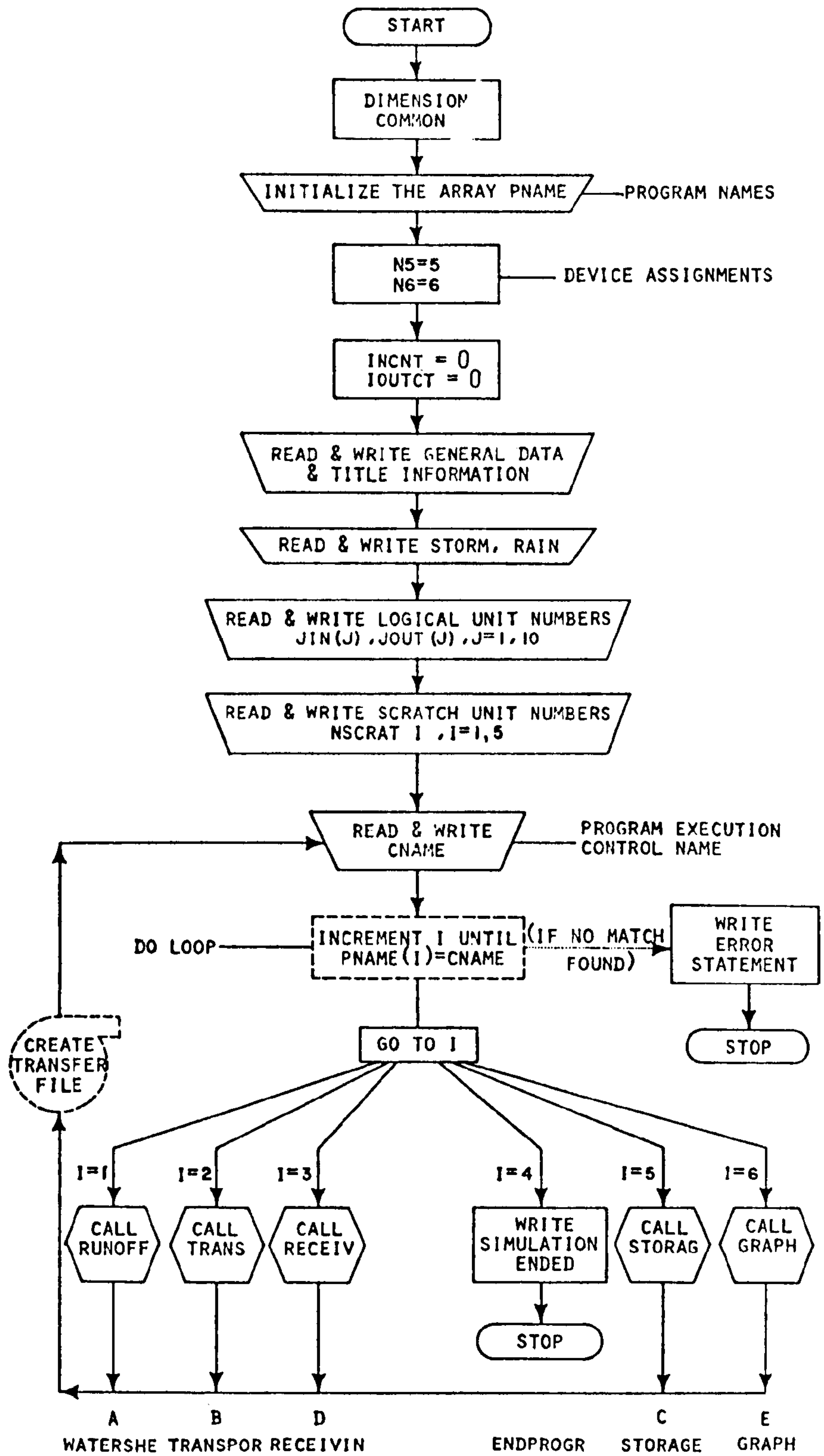


Figure 2-1. MASTER PROGRAMMING ROUTINE



NOTE: A SUBSCRIPT ON CNAME & A SECOND ONE ON PNAME, TAKING VALUES OF ONLY 1 OR 2, ALLOWS NAME TO BE COMPRISED OF 2 PARTS, I.E., TO HAVE FORMAT 2A4.

Figure 2-2. MAIN PROGRAM

integer numbers, corresponding to 10 input and 10 output units. It is not necessary, however, to make such a large number of assignments for the usual run; in fact, there have been few occasions during the development and testing of the model when more than 4 units have been needed. The files that are produced on these units are saved for use by a subsequent computational block; also, the information contained in them can be examined directly by using the graphing capability of the Executive Block. The other unit assignments on the second data card are for scratch files, i.e., files that are generated and used during execution of the program, and are erased at the end of the run. Again, there is provision for up to 5 such units, but only 1 or 2 are typically needed. The unit numbers are passed from the MAIN program to all pertinent subroutines by use of a labeled COMMON statement.

Subroutine GRAPH (E)

The graphing subroutines enable hydrographs and pollutographs to be plotted on the printer for selected locations on the data file. GRAPH is the driving subroutine, and it calls CURVE to produce the actual page of plotted output.

The subroutine GRAPH (IC) operates on two modes which are dependent upon the value of IC in the calling sequence.

If IC = 0 (when called by the Runoff Block), control information is read from cards.

If IC = 1 (when called in the Executive Block), both control information and title information are read from cards.

Subsequently, both options join and the subroutine proceeds as one flow sequence as follows:

1. Information is read from the data file indicating the structure that file.
2. An array ITAB is set up indicating which locations of the data file record are to be plotted.
3. All hydrograph and pollutograph information is read from the data file.
4. For each type of hydrograph and pollutograph, individual curves are selected, transferred into plotting arrays, and outputted in a final plotted form by subroutine CURVE.

Subroutine CURVE

The subroutine CURVE performs the following operations:

1. Determines maximum and minimum of arrays to be plotted.
2. Calculates the range of values and selects appropriate scale intervals.
3. Computes vertical axis labels based upon the calculated scales.
4. Computes horizontal axis labels based upon the calculated scales.
5. Joins individual parts of the curve by subroutine PINE.
6. Outputs final plot.

Subroutine PINE

This subroutine joins two coordinate locations with appropriate characters in the output image array A of PPLOT.

Subroutine PPLOT

This subroutine initializes the plotting array, stores individual locations, and outputs the final image array A for the printer plot.

INSTRUCTIONS FOR DATA PREPARATION

The instructions for data preparation are divided into three parts corresponding to the JCL, the MAIN program usage, and the graphing portion of the Executive Block. Figure 2-3 and Tables 2-2 and 2-3 at the end of these instructions give the procedure for data card preparation and list the variables that are used.

Job Control Language (JCL)

The assignment of logical units requires, in general, the provision for files to be written on specific physical devices. To accomplish this the programmer must supply the necessary JCL. As a rule, JCL is highly machine-dependent; in fact, it often differs on two identical machines at different installations. Therefore, the Storm Water Management Model cannot include JCL that is universally applicable. The following remarks, however, may be useful in gaining insight into what is involved on systems such as an IBM 360/65 or IBM 360/67.

It is convenient on these machines to use the 2314 Disk Storage Devices rather than tape units because of the inherently faster reading and writing speed. At most installations the logical unit corresponding to the card reader is given the number 5 and the line printer is given the number 6. The Storm Water Management Model is programmed on the assumption that units 5 and 6 are so used. Typically, the systems programmers have provided the necessary JCL for these units and also for the card punch. Moreover, JCL may have been provided for scratch units, in which case the unit assignments for scratch files can take advantage of the existing JCL.

Usually, however, the data file and scratch file assignments require JCL to be supplied for each unit. The rules for such JCL must be ascertained from the systems programmers at the installation, since there is considerable variation in unit number availability, etc. In general, one should only set up the units needed in a given run, since there may be a charge for file space that is reserved, even if it is not used.

MAIN Program

The MAIN program controls the computational block(s) to be executed by reading alphameric information on sentinel cards. The array CNAME is read as two alpha words on a single card, each in format of type A4.

Thus, for example, CNAME (1) might be WATE and CNAME (2) might be RSHE. When combined, as in printout, the resulting match gives the control word WATERSHE. The program compares this word with a dictionary of such words stored by a DATA statement in the array PNAME. If a match is found, as it would be in this case, control is passed to the appropriate point in the MAIN program to call the initial subroutine of the computational block. Here, for example, a call would be made to the subroutine RUNOFF, which is the initial subroutine for the Runoff Block. After execution of the Runoff Block, which involves calls, in turn, to a number of subsidiary routines, control is eventually returned to the

MAIN program.

The MAIN program again reads a sentinel data card, which might indicate that another block is to be executed. For example, if the Transport Block is to be executed, the control word TRANSPOR would be given, etc. If results are to be graphed, the control word GRAPH would be on the sentinel card, or, if the run is to be terminated, the word ENDPROGR is given on the card. A summary of the control words and corresponding action is given in Table 2-1.

The use of control words on sentinel cards allows considerable flexibility in utilization of the Storm Water Management Model. The most common type of run involves execution of one of the computational blocks along with the graphing of results on the line printer. Thus, for the Runoff Block, such a run would be made by appropriate use of the words RUNOFF, GRAPH, and ENDPROGR. If the entire Model were to be run with graphical output at the end of, say for example, the Transport Block, the sequence would be RUNOFF, TRANSPOR, GRAPH, STORAGE, RECEIVIN, and ENDPROGR. Actually, such a run is prohibitive from the standpoint of machine core storage for most systems, but the program capability is available if such a run is desired.

In order that the program may be used in the way outlined above, dummy subroutines were added to the various blocks so that the program will not terminate because of a "missing" subroutine. This seemed a small price to pay for the convenience and flexibility of the present method.

Table 2-1. SUMMARY OF CONTROL WORDS AND CORRESPONDING ACTION FOR MAIN PROGRAM

Control Word	Action to be Taken
WATERSHE	Execute Runoff Block
TRANSPOR	Execute Transport Block
STORAGE	Execute Storage Block
RECEIVIN	Execute Receiving Water Block
GRAPH	Produce graphs on line printer
ENDPROGR	Terminate run
Any other word	Terminate run

Subroutine GRAPH

The data cards required for subroutine GRAPH are minimal. The first card supplies control information, such as in which tape/disk the hydrographs and pollutographs are stored, the number of curves per graph, and number of pollutants. Element numbers of which plots are to be made are given on the next card. The last three cards supply the titles for the curves, the horizontal axis label, and the vertical axis label. The vertical axis label card is repeated for each pollutant to be plotted and for the hydrograph in the order in which they are to be printed out.

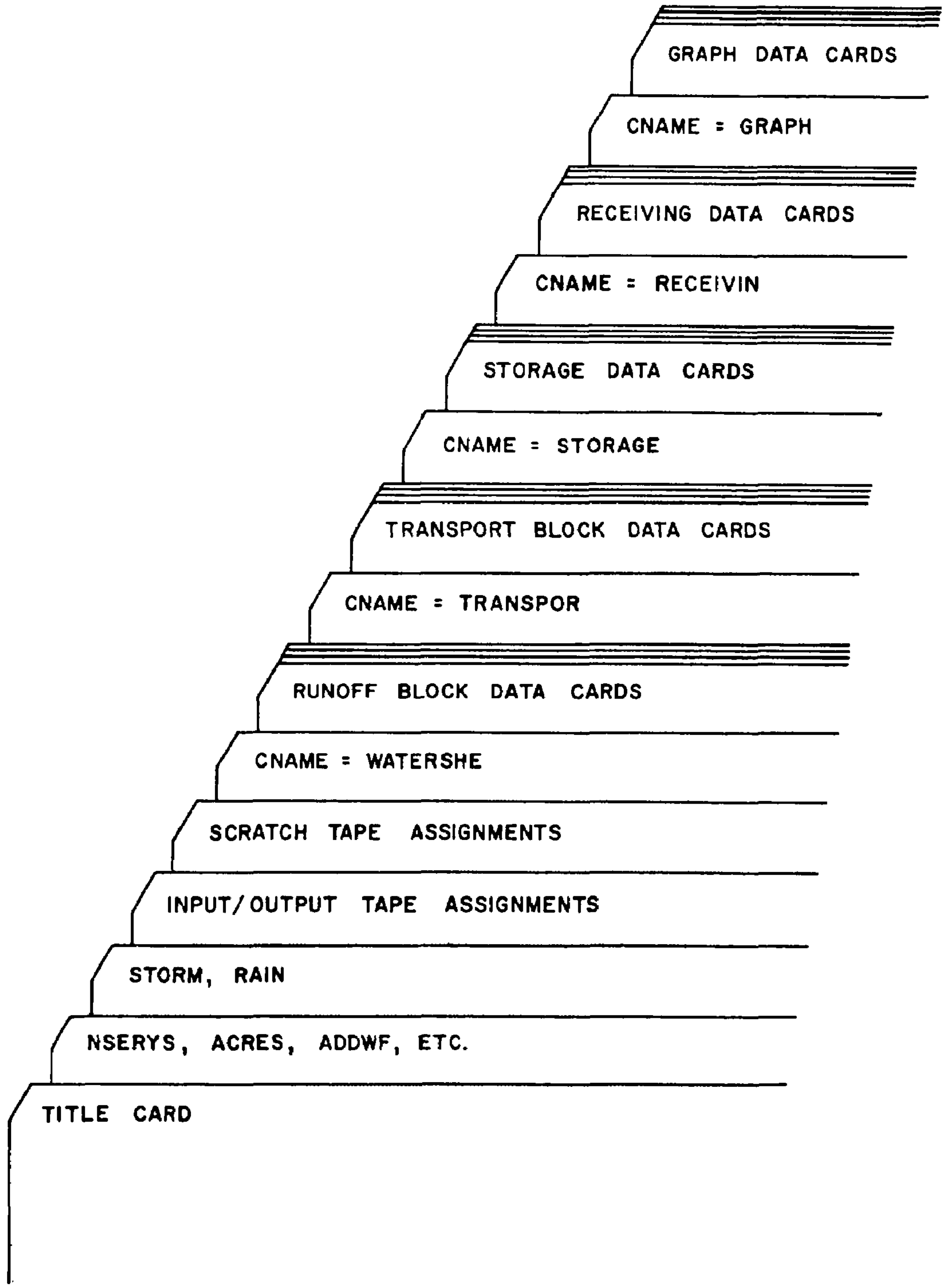


Figure 2-3. DATA DECK FOR THE EXECUTIVE BLOCK

Table 2-2. EXECUTIVE BLOCK CARD DATA

Card Group	Format	Card Columns	Description	Variable Name	Default Value
1	10A4	1-40	Title Card, title of the area being studied.	TITLE1	none
2			General information about the studied area.		
	I5	1-5	Demonstration series number.	NSERYS	none
	F10.1	6-15	Number of acres of the study area.	ACRES	none
	F10.2	16-25	The average daily DWF for the study area.	ADDWF	none
	I5	26-30	Design flow rate frequency, yrs.	NDESYR	none
	F10.1	31-40	Design flow rate (cfs).	DESFLO	none
	I5	41-45	Number of storms being studied.	NSTRMS	none
	F10.1	46-55	Maximum available trunk sewer capacity (cfs).	QTRUNK	none
			REPEAT FOR THE NUMBER OF STORMS.		
3			Storm data cards.		
	4A4	1-16	Date of storm.	STORM	none
	4A4	17-32	Amount of rainfall for this storm.	RAIN	none
4			I/O tape/disk assignments.		
	20I4	1-4	Input tape assignment for first block to be run.	JIN(1)	none
		5-8	Output tape assignment for first block to be run.	JOUT(1)	none
		9-12	Input tape assignment for second block to be run (usually the same as the output tape from first block).	JIN(2)	none
		13-16	Output tape for second block to be run.	JOUT(2)	none
		⋮		⋮	
		77-80	Output tape for tenth block to be run.	JOUT(10)	none
5			Scratch tape/disk assignments.		
	20A4	1-4	First scratch tape assignment.	NSCRAT(1)	none
		5-8	Second scratch tape assignment.	NSCRAT(2)	none
		9-12	Third scratch tape assignment.	NSCRAT(3)	none
		13-16	Fourth scratch tape assignment.	NSCRAT(4)	none
		17-20	Fifth scratch tape assignment.	NSCRAT(5)	none

NOTE: All non-decimal numbers must be right-justified.

Table 2-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			REPEAT CARD 6 FOR EACH BLOCK TO BE CALLED.		
6			Control cards indicating which blocks in the program are to be called.		
	20A4	1-80	Name of block to be called.*	CNAME	none
			= WATERSHED for Runoff Block,		
			= TRANSPORT for Transport Block,		
			= RECEIVING for Receiving Water Block,		
			= STORAGE for Storage Block,		
			= GRAPH for GRAPH subroutines.		
			= ENDPROGRAM for ending the storm water simulation.		
			INSERT THE REMAINING CARDS, IF CARD GROUP 6 INCLUDES CNAME = GRAPH, IMMEDIATELY FOLLOWING EACH GRAPH CARD.		
7			Control card.		
	4I5	1-5	Tape/disk (logical unit) assignment where graph information is stored.	NTAPE	none
		6-10	Number of curves of a graph.	NPCV	5
		11-15	Number of pollutants to be plotted.	NQP	0
		16-20	Number of inlets to be plotted.	NPLOT	All curves on file
			IF NPLOT = 0 (OR BLANK) DELETE THIS CARD.		
8			Inlet selection card.		
	16L5	1-5	First inlet number to be plotted.	IPLOT(1)	none
		6-10	Second inlet number to be plotted.	IPLOT(2)	none
		⋮		⋮	
			Last inlet number to be plotted.	IPLOT(NPLOT)	none
9			Title card.		
	18A4	1-72	Title printed with the plots.	TITL	none
10			Horizontal axis label.		
	20A4	1-80	Horizontal axis label.	HRIZ	none
			REPEAT NQP + 1 TIMES		
11			Vertical axis label.**		
	2A4	1-8	Line 1 of vertical axis label.	VERT(1)	none
		9-16	Line 2 of vertical axis label.	VERT(2)	none
	3A4	17-28	Line 3 of vertical axis label.	VERT(3)	none

*Name must start in column 1. GRAPH may be called more than once.
**The first plot to be printed is a flow hydrograph; the second is BOD; the third is SS; and the last is coliform.

Table 2-3. EXECUTIVE BLOCK VARIABLES

Variable Name	C*	Description	Unit
A		The log base 10 of the range of values of y coordinate to be plotted (subroutine CURVE)	
ACRES		Number of acres of study drainage basin	acres
ADDWF		Average DWF	cfs
AXA		X-coordinate of value previously plotted	
AXB		X-coordinate of value to be plotted	
AYA		Y-coordinate of value previously plotted	
AYB		Y-coordinate of value to be plotted	
CURVE		Name of subroutine	
CNAME	C	Computational block name read from data cards	
DESFLO		Design flow rate (of main trunk)	cfs
DUMMY	C	Dummy location to fill data record	
FRANG		Expanded range (even intervals) of y coordinates of curve to be plotted	
GRAPH		Name of subroutine	
HORIZ	C	Horizontal label of curve	
I		The Block selection counter (MAIN)	
IC		Calling sequence control parameter	
ILAB		Output label with plot	

Variable Name	C*	Description	Unit
INCNT	C	Array of input logical data file number	
IOUTCT	C	Array of output logical data file number	
IPLOT	C	Array of nodes to be plotted	
ITAB	C	Array indicating which locations of the data file are to be plotted	
IX		Dummy variable	
IXA		Integer value of AXA	
IXB		Integer value of AXB	
IY		Dummy variable	
IYA		Integer value of AYA	
IYB		Integer value of AYB	
J		Subscript counter	
JJ		Subscript counter	
JIN		Array of input disk/tape units	
JOUT	C	Array of output disk/tape units	
K		Subscript counter	
L		Subscript counter	
LX		Transfer location from data file to plot storage	

*Variable names shared in common blocks.

Table 2-3 (continued)

Variable Name	C*	Description	Unit
M		Subscript counter	
MC		Do loop counter	
MM		Subscript counter	
N		Subscript counter	
NCT		Number of plots	
NCURVE		Number of curves to be plotted	
NCV		Number of curves/plot	
NDESYR		Frequency of design flow	yr
NLP		Number of types of plot (hydrographs and pollutographs)	
NLOC	C	Node number of hydrograph point	
NPCV		Maximum number of curves/plot	
NN		Subscript counter	
NPLOT		Number of plots	
NPOINT		Number of points on a plot	
NPT		Number of point/curve (array) (CURVE)	
NPT	C	Array containing number of points to be plotted (GRAPH)	
NPTM		Numerical value of NPT	
NQP		Number of quality constituents to be plotted	
NQUAL		Number of quality constituents on data file	

Variable Name	C*	Description	Unit
NR		Subscript counter	
NSCRAT	C	Array of variable scratch units	
NSERYS		Demonstration series number	
NSTEPS		Number of steos in plot	
NSTRMS		Number of storms being studied	
NSYM		Plot number	
NTAPE		Input tape number for plotting	
NVAL		Number of points/data record on a file	
N5		Card input unit number	
N6		Print output unit number	
PINE		Subroutine name	
PNAME		Name used to call the blocks of the Storm Water Model	
PPLOT		Subroutine name	
QTRUNK		Maximum flow rate possible in trunk sewer	cfs
RAIN		Amount of rainfall for a storm	
RANGE		Range of y values to be plotted	
RECEIV		Subroutine name	
RUNOFF		Subroutine name	
STORAG		Subroutine name	
STORM		Date of storm	

Table 2-3 (continued)

Variable Name	C*	Description	Unit
TDELT		Time-step interval	
TIMES		Time-step interval	sec
TITL	C	Title printed out with graphs	
TITLE	C	Title printed out on curves	
TITLE1		Title of drainage basin	
TRANS		Subroutine name	
TZERO		Zero time	sec
VERT	C	Vertical label	
X		X coordinate array (CURVE)	
X	C	X coordinate array (GRAPH)	
XA		X increment used for interpolation	
XINT		Label interval for X	
XMAX		Maximum X value	
XMIN		Minimum X value	
XLAB	C	Numerical scale labels for X	
XO		Start point of line (X coordinate)	
XSCAL		X scale factor	
XT		End point of line (X coordinate)	
X1		Same as XO	
X2		Same as XT	
Y		Y coordinates of curves to be drawn	
Y	C	Y coordinates of curves to be drawn	
YA		Y increment used for interpolation	
YINT		Label interval for Y	
YLAB		Numerical scale labels for Y	
YMAX		Maximum Y value	
YMIN		Minimum Y value	
YO		Start point of line (Y coordinate)	
YSCAL		Y scale factor	
YT		End point of line (Y coordinate)	
YT	C	Hydrograph-pollutograph information on data file	
Y1		Same as YO	
Y2		Same as YT	

EXAMPLE

A hypothetical test area, Smithville, U.S.A., is used to show the data input and portions of the resulting output as required and accomplished by the Executive Block. Table 2-4 is an example of the data deck. The first card is the job title card, the following card supplies general information about the study area used in the title printout, and the third card gives the data and quantity of rainfall for the storm being studied. The next two cards are the tape/disk (file) assignments for transferring information from one program block to another, and the scratch tape/disk assignments, respectively. The first two numbers, zero and eight, refer to the input and output files for the Runoff Block. Since an input file for this Block is not required, the first number is zero.

The output file for Runoff is also the input file for Transport and therefore eight is the first number in the next group of two numbers denoting Transport Block's tape/disk assignments. Nine is the Transport output file. When no other blocks are to be called, the rest of the card is left blank or replaced with zeros. The numbers on the second card refer to the scratch files. A maximum of four are required when using the Transport Block. (Note: all required tape/disk assignments must be properly defined with JCL cards.)

This first group of data cards is used by subroutine MAIN for the logical unit assignment (tape/disk) and title information for the Storm Water Management Model. The succeeding groups of cards are preceded with a control card used by subroutine MAIN. This card transfers control to the appropriate program block. In this example, four such cards exist, WATERSHED, TRANSPORT, GRAPH, and ENDPROGRAM. The data following the first two control cards has been deleted for clarity. The GRAPH card is followed by input data for the plotting of output found on tape/disk nine. ENDPROGRAM needs no succeeding cards.

Partial output from the Executive Block is shown in Table 2-5 and Figure 2-4.

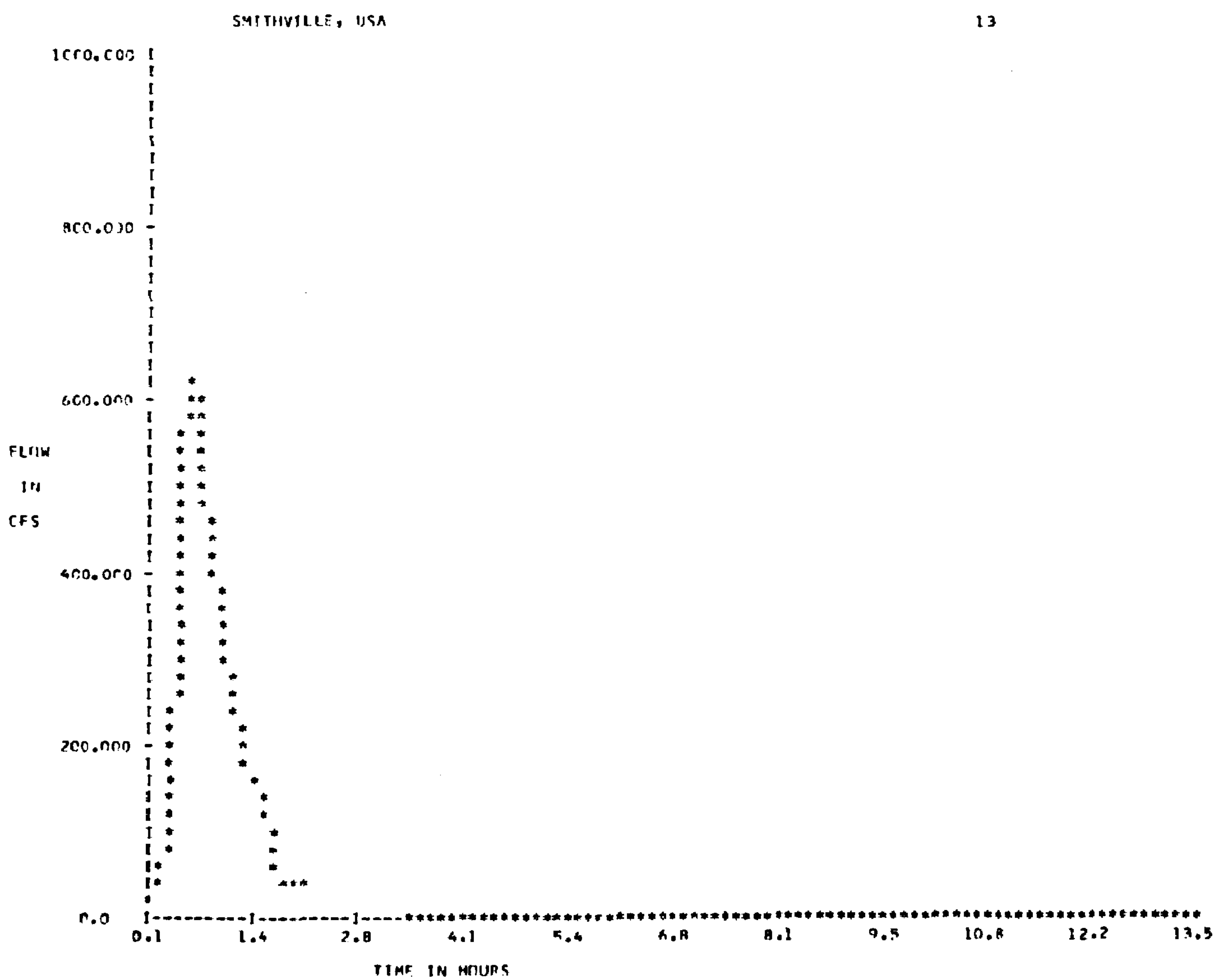
Table 2-4. DATA INPUT FOR SMITHVILLE TEST AREA

DATA	CARD GROUP NO.
SMITHVILLE, USA PROGRAM CHECK	1
1 500.0 0.00 0 0.0 1 0.0	2
MADE-UP STORM 1.22	3
0 8 8 9 9 0	4
1 2 3 4 13	5
WATERSHED ⋮ TRANSPORT ⋮ GRAPH	6
9 1 3 1	7
13	8
GRAPH OF THE TRANSPORT OUTPUT TAPE	9
TIME IN HOURS	10
FLOW IN CFS	11
ENDPROGRAM	6

Table 2-5. OUTPUT FOR SMITHVILLE TEST AREA

```
          FEDERAL WATER QUALITY ADMINISTRATION          CONTRACTS 14-12-501
          STORMWATER MANAGEMENT PROJECT                           14-12-502
                                                                  14-12-503

          METCALF & EDDY, INC

          WATER RESOURCES ENGINEERS, INC

          UNIVERSITY OF FLORIDA


               DEMONSTRATION SERIES NO. 1

               SMITHVILLE, USA    PROGRAM CHECK
               COMBINED SEWER AREA OF 500.00 ACRES
               AVERAGE DAILY DRY WEATHER FLOW =    0.0 CFS
                0-YEAR DESIGN FLOW =       0.0 CFS
               AVAILABLE MAX. TRUNK CAPACITY =     0.0 CFS

               STORMS STUDIED:          TOTAL RAINFALL, INCHES
              MADE-UP STORM                               1.22


TAPE ASSIGNMENTS
      0        8        9        0        0        0        0        0        0        0
      8        9        0        0        0        0        0        0        0        0

TAPE ASSIGNMENTS
      1        2        3        4       13
```

Figure 2-4. OUTPUT FOR SMITHVILLE TEST AREA



SECTION 3

RUNOFF BLOCK

SECTION 3

RUNOFF BLOCK

BLOCK DESCRIPTION

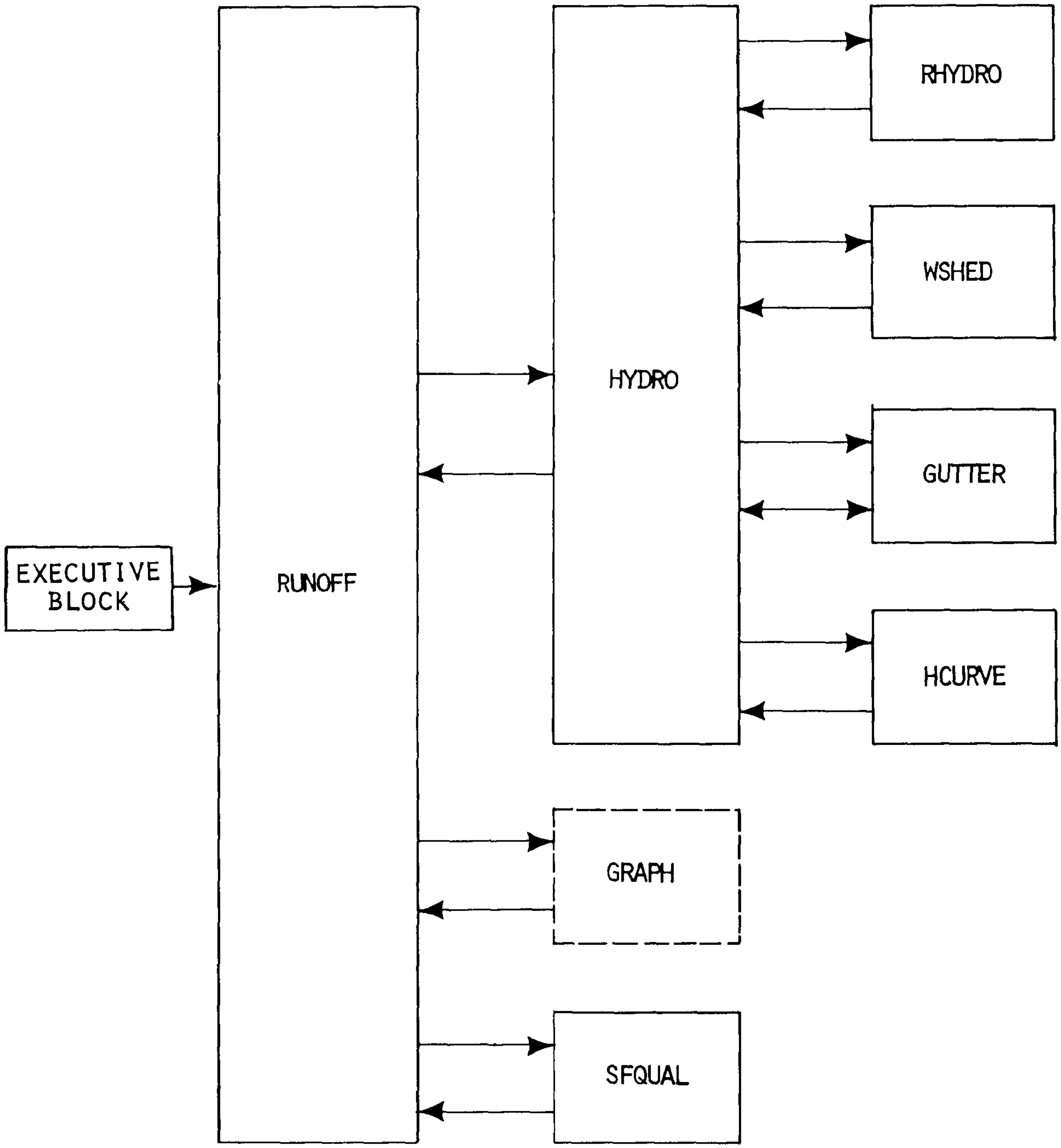
The Runoff Block has been developed to simulate both the quantity and quality runoff phenomena of a drainage basin and the routing of flows and contaminants to the major sewer lines. It represents the basin by an aggregate of idealized subcatchments and gutters. The program accepts an arbitrary rainfall hyetograph and makes a step by step accounting of rainfall infiltration losses in pervious areas, surface detention, overland flow, gutter flow, and the contaminants washed into the inlet manholes leading to the calculation of a number of inlet hydrographs and pollutographs.

The drainage basin may be subdivided into a maximum of 100 subcatchment areas. These, in turn, may drain into a maximum of 100 gutters or pipes which finally connect to the inlet points for the Transport Model. The relationships among the eight subroutines which make up the Runoff Block are shown in Figure 3-1. The total number of cards required is about 1,300.

This section describes the subroutines used in the Transport Block, provides instructions on data preparation, and furnishes examples of program usage.

Surface Flows

The core of the Runoff Model is the routing of hydrographs through the system. This is accomplished by a combination of overland flow and pipe routing.



Note: Subroutine GRAPH is a part of the Executive Block but is shown here since it is called directly by RUNOFF.

Figure 3-1. RUNOFF BLOCK

Three types of elements are available to the user:

1. Subcatchment elements (overland flow)
2. Gutter elements (channel flow)
3. Pipe elements (special case of channel flow).

Flow from subcatchment elements is always into gutter/pipe elements, or inlet manholes. The subcatchment elements receive rainfall, account for infiltration loss using Horton's equation, and permit surface storage such as ponding or retention on grass or shrubbery. If gutter/pipe elements are used, these route the hydrographs from the watershed elements to the entry to the main sewer system. Pipes are permitted to surcharge when full.

Surface Quality

The quality of the inlet flows is determined separately (subroutine SFQUAL) from the inlet hydrographs. The quantity of pollutants washed off the land surface of the drainage basin is added directly to the inlet manholes. Initially the program calculates the amount of contaminants allowed to accumulate on the ground prior to the storm, and then, taking into account rainfall intensity, major land use, and land slope, the washed off pollutants are added to the inlet manholes resulting in pollutographs.

Output from the program consists of hydrographs and pollutographs on disk/tape for use in the Transport Block and printed and/or plotted information for the user.

SUBROUTINE DESCRIPTIONS

Subroutine RUNOFF (A)

This is the subroutine called by the Executive Block to gain entrance to the Runoff Block. This program prints "entry made to the Runoff Model" and then acts as the driver routine for the block. Figure 3-2 is the appropriate flow chart.

Subroutine HYDRO (1)

This subroutine computes the hydrograph coordinates with the assistance of three core subroutines, i.e., RHYDRO, WSHED, and GUTTER, as shown in Figure 3-3. It initializes all the variables to zero before calling RHYDRO to read in the rainfall hyetograph and information concerning the inlet drainage basin. According to the upstream and downstream relationship, the subroutine sequences the computational order for gutters/pipes.

A DO loop is formed to compute the hydrograph coordinate for each incremental time-step. In each step, subroutine WSHED is first called to calculate the rate of water flowing out of the idealized subcatchments. GUTTER is then called to route the flow, according to the input from tributary subcatchments and gutters. Water flowing into the inlet point, be it from gutters or direct drainage from subcatchments, is added up for a hydrograph coordinate.

During the process of computation, an accounting is made for the deposition of rainfall water in the form of runoff, detention, and infiltration loss. A mass continuity can therefore be checked and printed for reference.

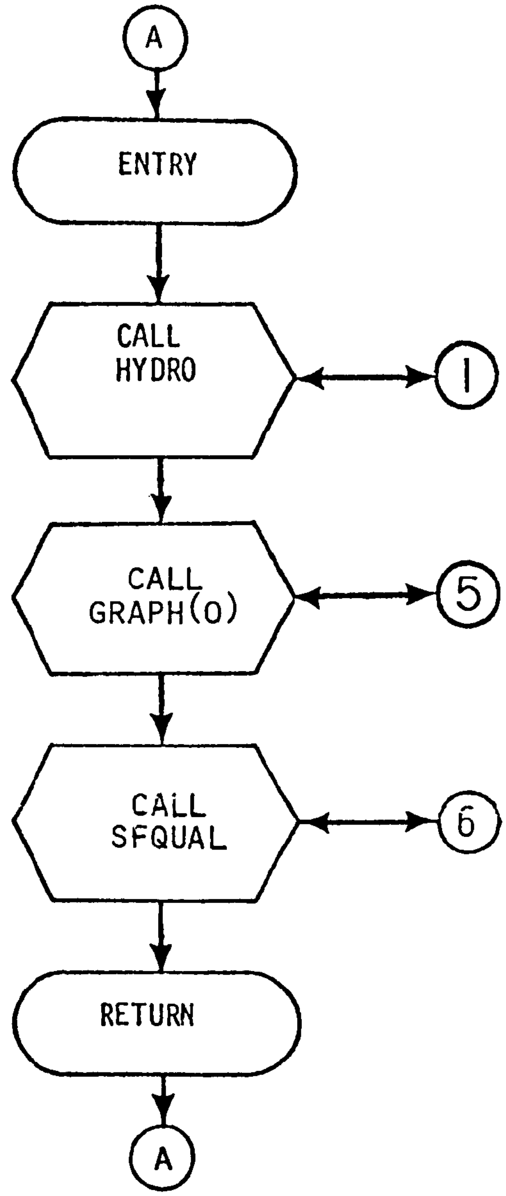


Figure 3-2. SUBROUTINE RUNOFF

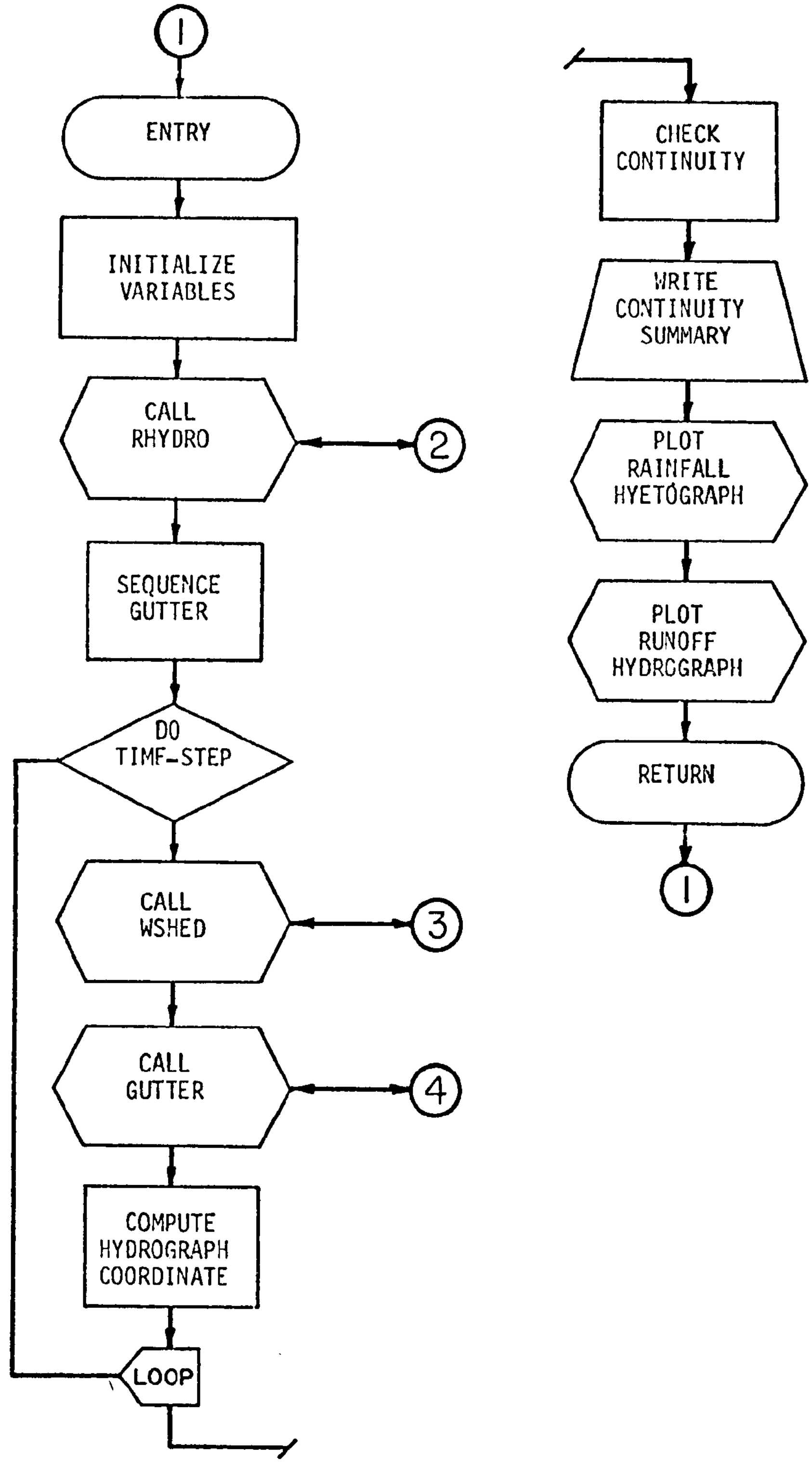


Figure 3-3. SUBROUTINE HYDRO

Finally, the rainfall hyetograph and the inlet hydrograph are plotted as an output. The control is then returned to subroutine RUNOFF.

Subroutine RHYDRO (2)

This subroutine is called by HYDRO to read input data related to the subcatchment areas and to perform some initial preparatory work, such as unit conversion and error detection. A normal execution of RHYDRO should provide all the necessary information for the calculation of a runoff hydrograph. Figure 3-4 shows the flow chart for subroutine RHYDRO.

There are four basic categories of input data. The general information includes a number representing the subcatchment area, period of simulation, and a key indicating if the rainfall hyetograph is spatially different from that of the previous basin. A new rainfall hyetograph will be read if it is so indicated. Otherwise, that part of the read operation will be skipped and the rainfall of the previous inlet drainage basin will be used. The first basin must have a rainfall input.

The program proceeds to read subcatchment data, e.g., the size, width, ground slope. The gutter information is read soon afterward.

It must be noted that the program can detect only logical errors such as indexing numbers. However, the input data are tabulated by the computer to check against the original for absolute correctness.

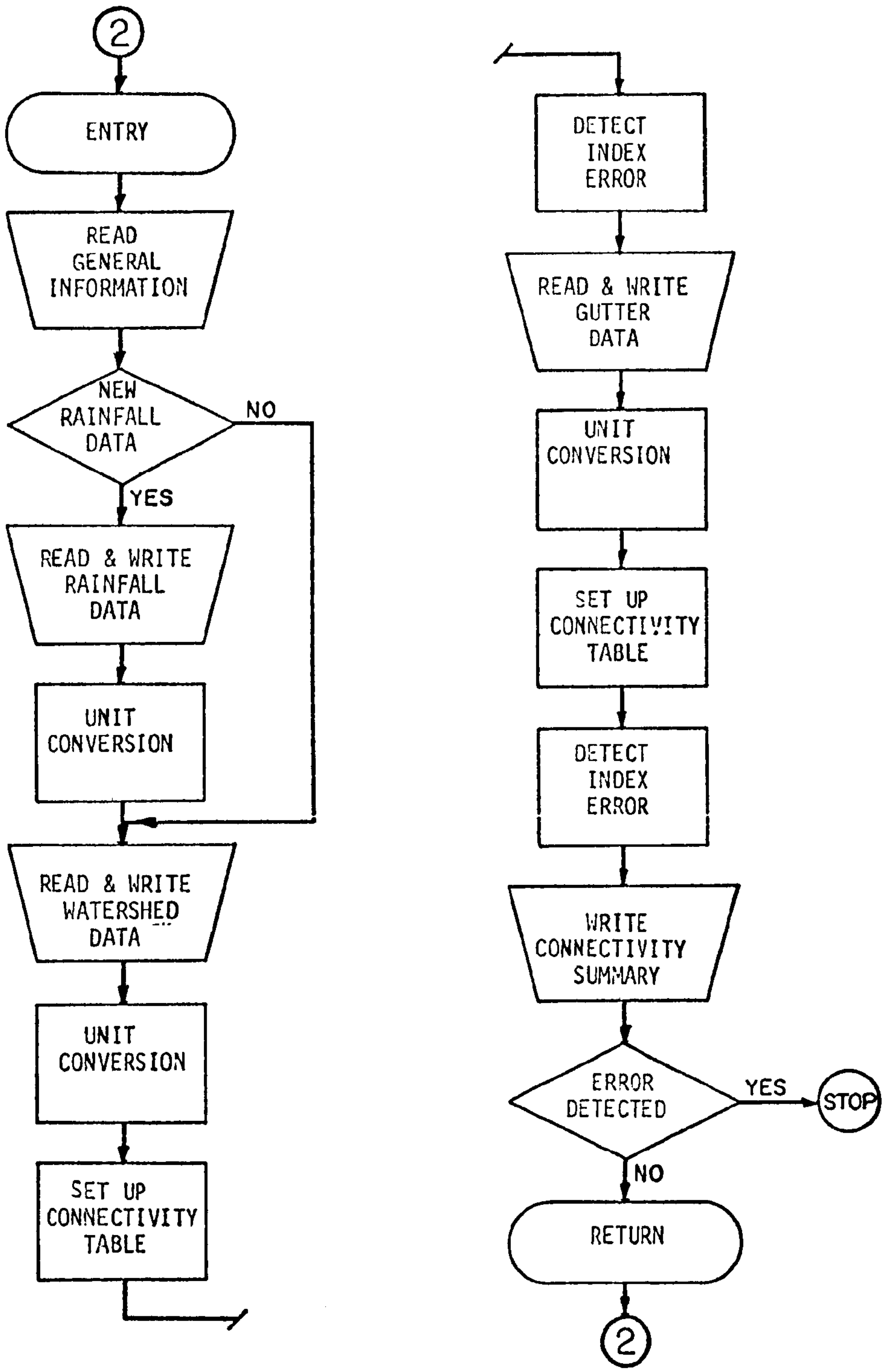


Figure 3-4. SUBROUTINE RHYDRO

Subroutine WSHED (3)

This subroutine computes the depth and flow rate of water overland. The logic of subroutine WSHED can be seen in Figure 3-5. As shown in Figure 3-3, the subroutine is called by HYDRO at each incremental period of integration. During that period, the rainfall intensity is first interpolated from the designated rainfall hyetograph for each subcatchment. This rainfall intensity is assumed uniform over each subcatchment.

A DO loop is set up to treat the subcatchments, one at a time. For a subcatchment, the amount of infiltration loss is calculated using Horton's equation,

$$\text{Infiltration loss} = f_o + (f_i - f_o)\, e^{-\alpha t} \qquad (1)$$

where f_o, f_i and α are coefficients and t is the time from the start of rainfall. The loss is compared with the amount of water existing on the subcatchment plus the rainfall. If the loss is larger, it is set equal to the amount available and the remainder of the computation is skipped.

The water depth will thus increase without inducing an outflow until it reaches the specified detention requirement. Beyond that, the outflow rate is calculated by Manning's equation using depth as the hydraulic radius. An iterative procedure termed Newton-Raphson's technique is established to determine the water depth and the outflow rate so that the continuity of water mass is satisfied.

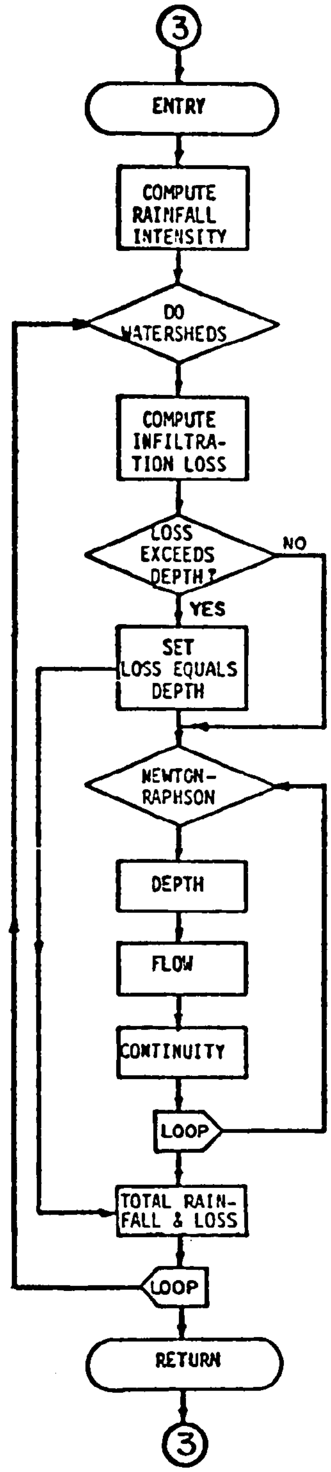


Figure 3-5. SUBROUTINE WSHED

Upon completion, the subroutine will return with a set of water depths on each subcatchment for the next time-step. It also produces the flow necessary for subsequent routing in the gutters.

Subroutine GUTTER (4)

The function of subroutine GUTTER is very similar to that of WSHED and is shown in Figure 3-6. It calculates a complete set of water depth and flow for gutters and pipes.

The computation also proceeds one gutter at a time. For a gutter, the inflow from tributary subcatchments and gutters is first computed. The Newton-Raphson's iterative procedure is again used to determine the depth and outflow of gutters so that the mass (volume) of water is conserved. The flow is computed by Manning's equation. The hydraulic radius of trapezoidal gutters and circular pipes is calculated separately in different paths of the program.

A pipe may surcharge when it is full and the inflow is larger than the outflow capacity. In this case, the surcharged amount will be computed and stored at the head end of the pipe. A message will be printed to indicate the time, location, and total amount of the surcharge. The pipe will remain full until the stored water is completely drained.

Subroutine GRAPH (5)

This subroutine, a part of the Executive Block, is called directly by the RUNOFF subroutine. For further description see Section 2.

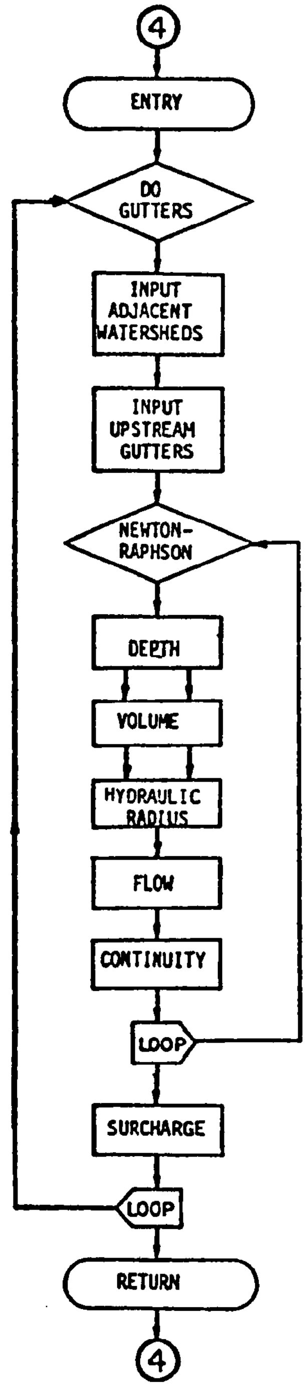


Figure 3-6. SUBROUTINE GUTTER

Subroutine SFQUAL (6)

The surface quality program simulates the removal of pollutants from the ground surface and from catchbasins by storm water runoff. This program is driven by the RUNOFF subroutine. It is called after HYDRO completes its task of computing runoff hydrographs for each inlet.

This subroutine has the capability of computing the BOD, suspended solids, and coliforms carried by the runoff for 50 inlets. Each inlet can have as many as five separate subareas contributing to it, each one having a different type of land use.

A flow chart of the program is shown in Figure 3-7. The general information for computation instructions is read first, e.g., number of subareas, inlets, time-steps. Data which are general for the total system are read next. General computations are made including initializing all variables.

The next step in the program is to read specific subarea information so that the quantities of pollutants on their surface prior to the start of the storm are set. The runoff values obtained from HYDRO are read for every inlet in each time-step. Pollutant removals for each subarea are computed. The removals in each subarea during each time-step are added for the subareas having a common inlet point.

Pollutants removed by the runoff for each inlet area are written for each time-step. Total pollutant quantities removed from each inlet area

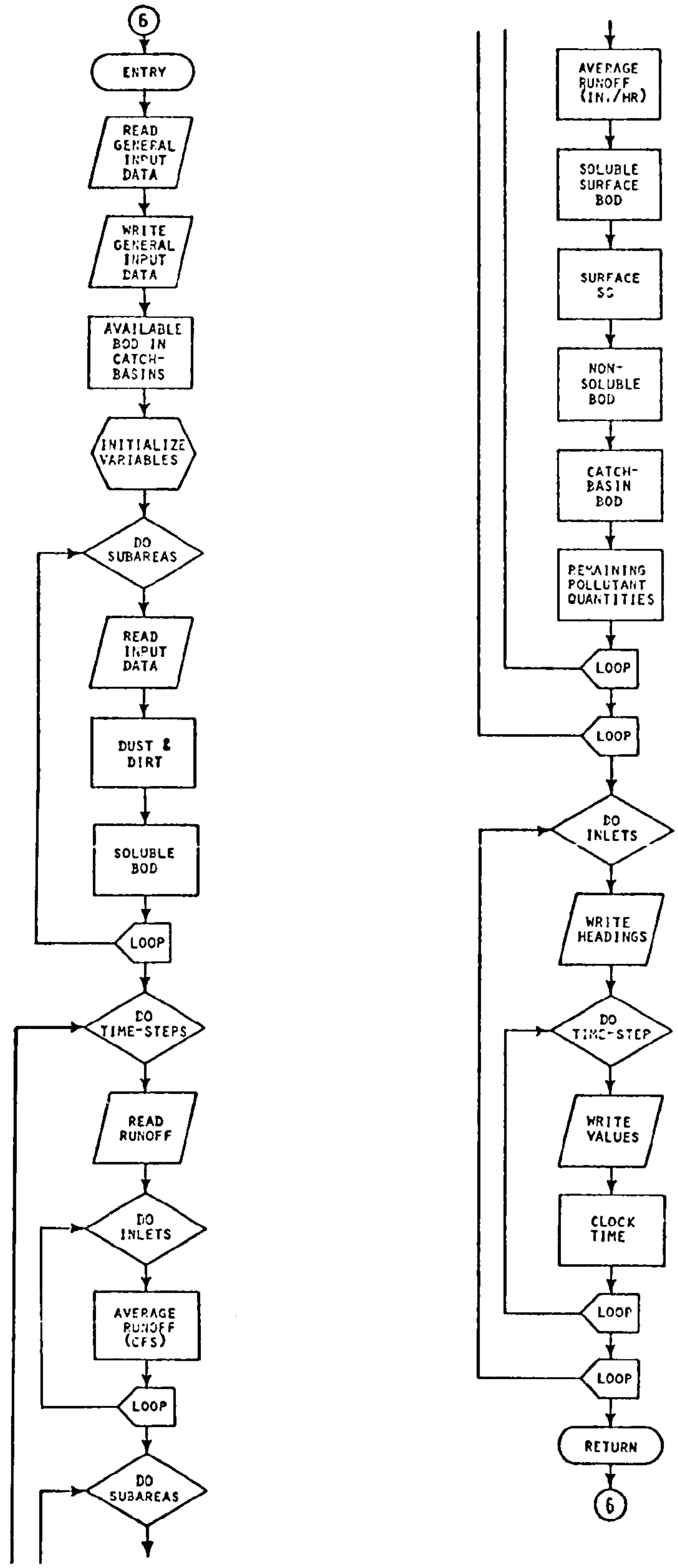


Figure 3-7. SUBROUTINE SFQUAL

are also written. Pollutant quantities on the surface prior to the start of runoff are written so that a comparison may be made between pollutant quantities available and those removed.

INSTRUCTIONS FOR DATA PREPARATION

Instructions on the use of the Runoff Block are divided into two sections, surface flows and surface quality.

Surface Flows

Use of the surface flows portion of the Runoff Block requires three basic steps:

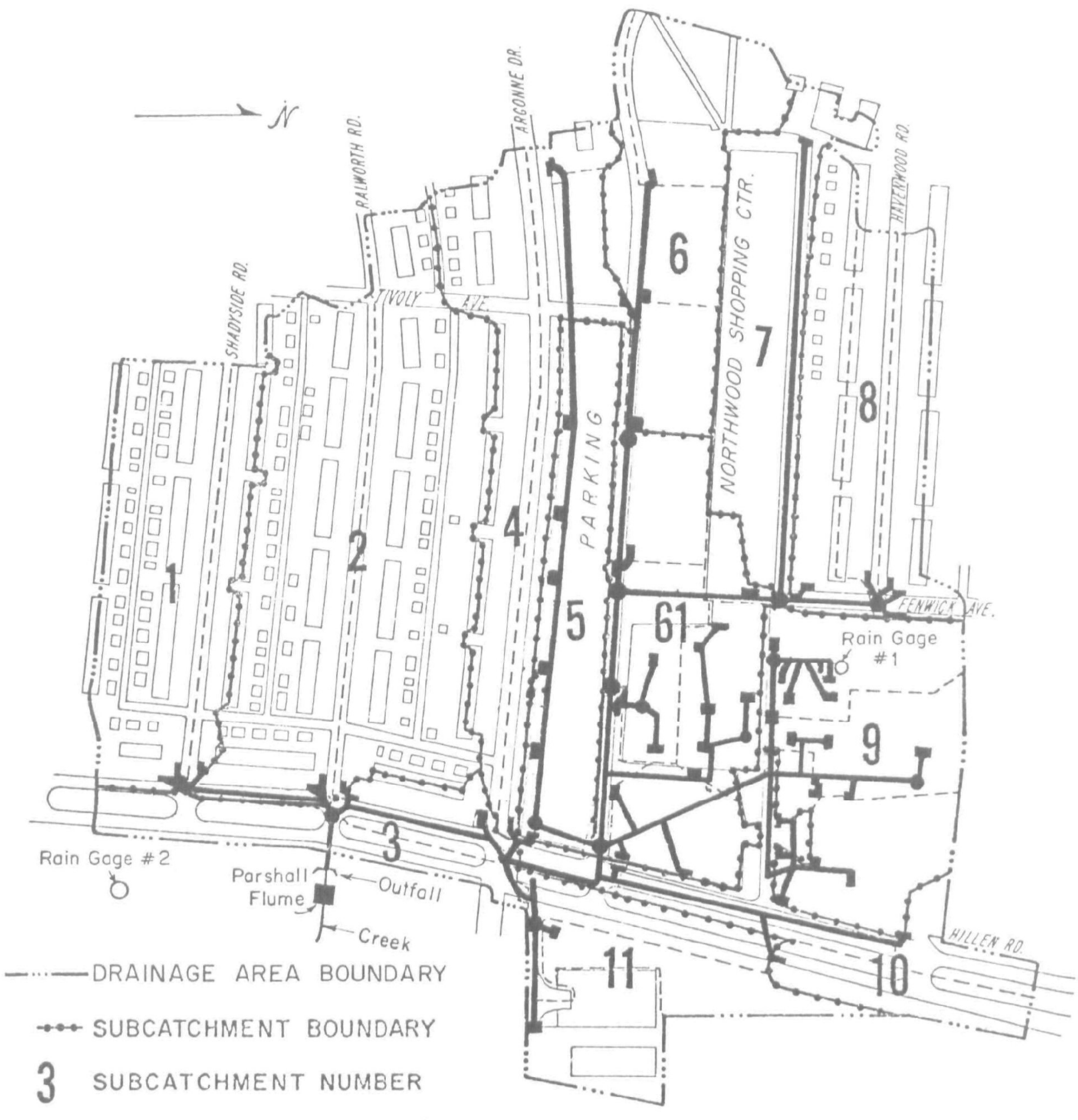
Step 1 - Geometric representation of the drainage basin

Step 2 - Estimate of coefficients

Step 3 - Preparation of data cards for the computer program.

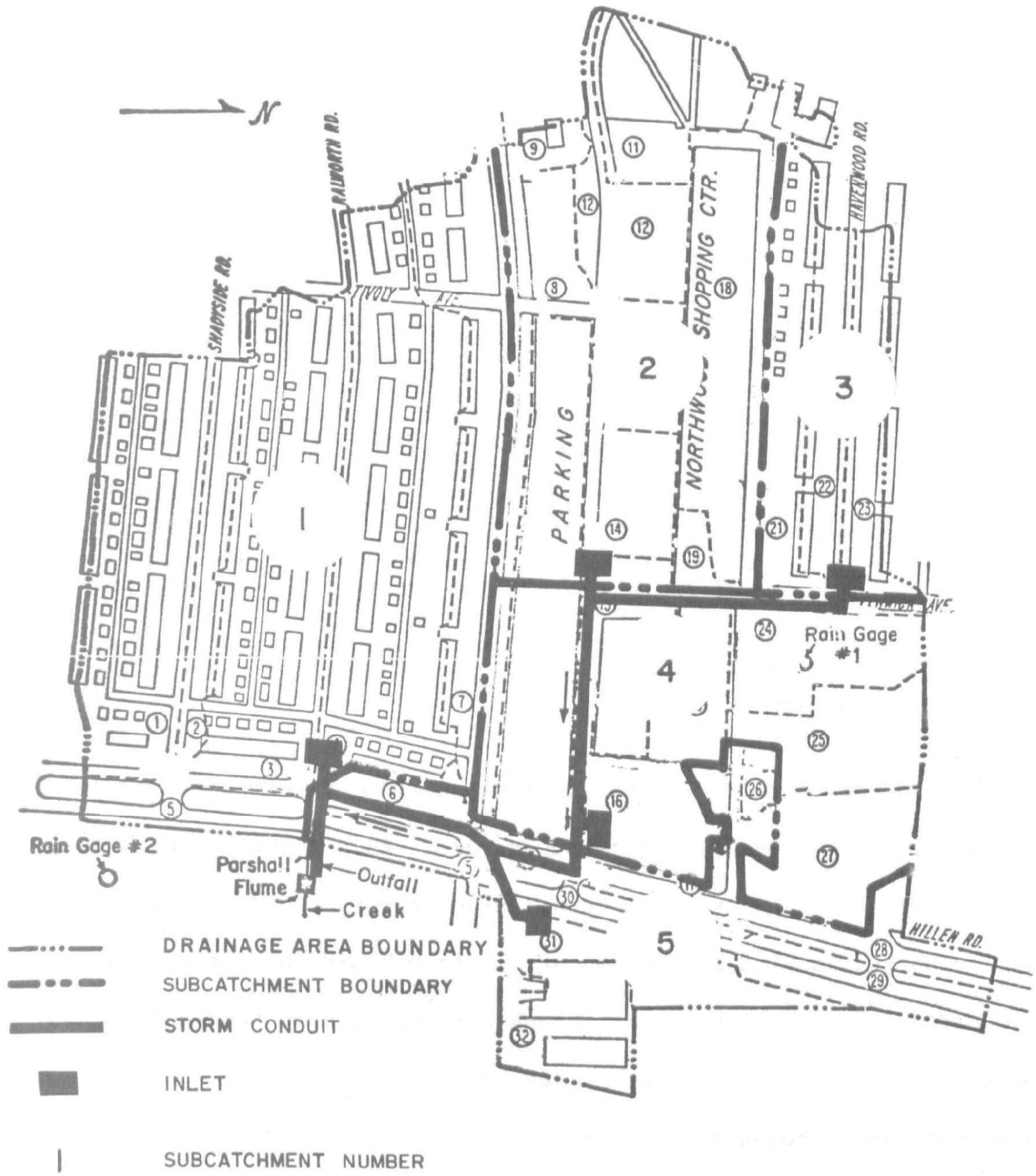
Step 1 - Method of Discretization. Discretization is a procedure for the mathematical abstraction of the physical drainage system. For the computation of hydrographs, the drainage basin may be conceptually represented by a network of hydraulic elements, i.e., subcatchments, gutters, and pipes. Hydraulic properties of each element are then characterized by various parameters, such as size, slope, and roughness coefficient.

Discretization begins with the identification of drainage boundaries, the location of major sewer inlets, and the selection of those gutters/pipes to be included in the system. This is best shown by an example. Figures 3-8 and 3-9 indicate possible discretizations of the Northwood section of Baltimore. In Figure 3-8, a "fine" approach was used resulting in 12 subcatchments and 13 pipes leading to the inlet. In Figure 3-9,



Source: L. S. Tucker, "Northwood Gaging Installation, Baltimore-Instrumentation and Data" (Ref. 1).

Figure 3-8. NORTHWOOD (BALTIMORE) DRAINAGE BASIN "FINE" PLAN



Source: L. S. Tucker, "Northwood Gaging Installation, Baltimore-Instrumentation and Data," (Ref. 1).

Figure 3-9. NORTHWOOD (BALTIMORE) DRAINAGE BASIN "COARSE" PLAN a "coarse" discretization was used resulting in 5 subcatchment areas and no pipes or gutters. In both cases, the outfall to the creek represents the downstream point in the Runoff Model. This could lead, in a larger system, to inlets in the Transport Model. The criteria for breaking between major sewer lines (Transport Model) and the Runoff Model are determined by three factors:

1. If backwater effects are significant, the Transport Model must be used.
2. If hydraulic elements other than pipes and gutters, such as pumps, are used, the Transport Model is required.
3. At the point where the water quality constituents are introduced and are to be routed, the Transport Block must be used since the Runoff Block is not able to route contaminates through a pipe network.

Subcatchments are idealized rectangular areas with uniform slope and groundcover, i.e., asphalt, concrete, or turf. Each subcatchment has unique properties in terms of slope and groundcover. Thus, the roof of a house may be represented by two subcatchments because the water drains in two different directions, even though both units have the same groundcover and absolute ground slope. Likewise, dirt and pavement can be treated separately because of the difference in groundcover.

While the subdivision described can be taken to infinitesimal detail in theory, computation time and manpower requirements become prohibitive in practice. No ready rule for the subdivision can be offered, but a minimum of five subcatchments per drainage basin is recommended. This permits flow routing (time offset) between hydrographs.

Step 2 - Estimate of Coefficients. Coefficients and parameters necessary to characterize the hydraulic properties of a subcatchment include surface area, width, ground slope, roughness coefficient, detention depth, infiltration rate, and percent imperviousness. Since real subcatchments are not rectangular areas experiencing uniform overland flow, average values must be selected for computation purposes.

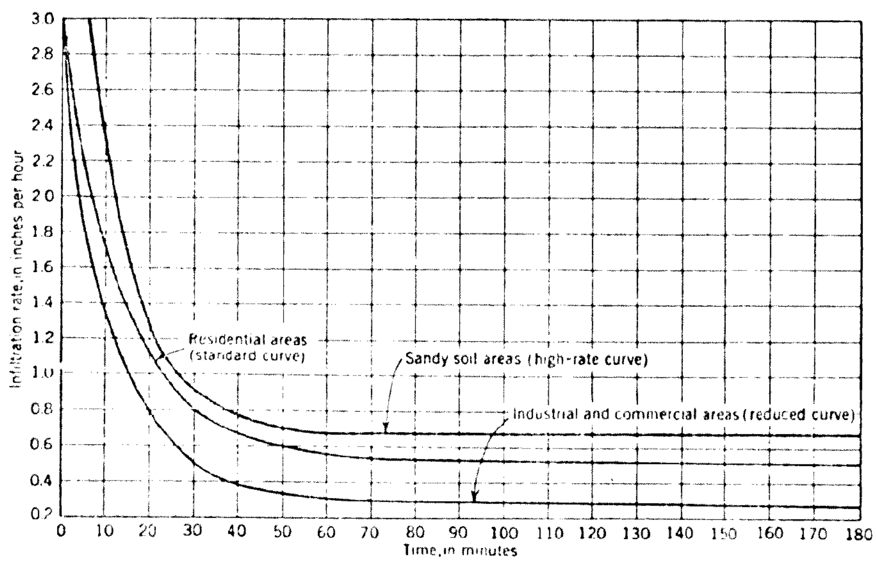
For the roughness coefficient, one can use the values given in Table 3-1, as suggested by Crawford and Linsley (Ref. 2). Detention depths are taken by the program as 1/16th-inch for impervious areas and 1/4-inch for pervious areas, unless specified at other values by the user. The infiltration rate can be estimated from "standard infiltration capacity curves" shown in Figure 3-10, which was produced by the American Society of Civil Engineers (ASCE). Infiltration is important only in pervious areas. Resistance factors for the pervious and impervious parts of a subcatchment are specified separately with default values of .250 and .013 (Manning's n for overland flow) being taken in the absence of other information.

Step 3 - Data Card Preparation. The data cards should be prepared according to Figure 3-11 and Tables 3-2 and 3-3 found at the end of this subsection. Figure 3-11 shows the layout of the data cards, including those for the quality routine, in the order in which they must appear. Tables 3-2 and 3-3, respectively, show how the data cards are to be punched and list the description of variables used in this program Block.

Table 3-1. ESTIMATE OF MANNING'S ROUGHNESS COEFFICIENTS

Ground Cover	Manning's n for Overland Flow
Smooth asphalt	0.012
Asphalt or concrete paving	0.014
Packed clay	0.03
Light turf	0.20
Dense turf	0.35
Dense shrubbery and forest litter	0.4

Source: N. H. Crawford and R. K. Linsley, "Digital Simulation in Hydrology, Stanford Watershed Model IV" (Ref. 2).



Source: American Society of Civil Engineers, Manual of Engineering Practice No. 37, 1960 (Ref. 3).

Figure 3-10. STANDARD INFILTRATION-CAPACITY CURVES FOR PERVIOUS SURFACE

The first step in the data preparation is the determination of the number of time-steps to be used and the length of each time-step. The time-step length is usually 5 or 10 minutes but may range from 1 to 30 minutes, depending on the length and intensity of storm and the degree of accuracy required. The number of time-steps is limited to a maximum of 150 and should extend past the storm termination sufficiently to account for the storm runoff. Along with the input of time-steps, the number of hyetographs for the drainage basin is needed.

The rainfall data cards are then prepared for each hyetograph from rainfall records or are assumed if a hypothetical test case is being run. The time interval need not be the same as in the flow and quality portion of the Block. The major preparation is forming the tree structure sewer system and dividing the drainage basin into subcatchments. The sewer network is obtained from sewer maps. Pipes smaller than 2-3 feet with no backwater effects, flow dividers, or lift stations are usually designated as gutter/pipes for computation by the Runoff Block. These pipes are not connected to one another by manholes but join directly and lead to an inlet manhole for further routing by TRANSPORT. Once the sewer system is labeled with numbers less than 1,000, the subcatchment areas are formed reflecting the existing sewer network, ground cover, and land slope. Data cards are then made up for each numbered subcatchment, defined by its width, area, slope, percent imperviousness, etc., along with the gutter/pipe or inlet manhole into which the flows are routed. Next, the gutter/pipe cards are punched giving the required information.

the final data cards for the surface flow portion of the block are output control cards. The first two, NSAVE and ISAVE(I), designate the inlet manholes to which enter flows and pollutants are routed for further simulation by the Transport Block. The last four cards are for printing and plotting out inlet hydrographs and pollutographs for the user.

Surface Quality

Data input to this surface quality program are prepared at the same time as the rest of the Runoff Block. Thus, when an inlet drainage basin is selected, it may be subdivided into areas containing a single type of land use. Five land uses which may be modeled are: single family residential, multi-family residential, commercial, industrial, and undeveloped or parklands.

Once the basin is broken into subareas the number of areas, along with other control information such as start time, number of time-steps, and print control, is specified on the first SFQUAL data card. The time interval and number of time-steps to be modeled depends on the interval and length of runoff values provided. Time-steps in multiples of those for which runoff values are provided may be used if desired, but will usually be the same as for subroutine RUNOFF. The actual format for the data cards is shown in Table 3-2.

The program may be used with runoff from a design storm or an actual storm. If an actual storm is being modeled, the number of dry days prior to that storm is determined from rainfall records. Otherwise, the number of dry days is part of the information associated with a design storm.

In determining dry days from actual storms the real number of continuous antecedent days without rainfall should be increased to allow for residual surface solids from the earlier storms. A suggested starting estimate for dry days is the total consecutive antecedent days until the sum of daily rainfalls equals or exceeds 1.0 inch. If a sizable storm (rainfall greater than 0.3 inch) occurs within the four days prior to the test storm the earlier storm should also be modeled. The equivalent dry days should then be calculated using the actual surface residual plus the between-storm accumulation.

The data needed on the frequency of street cleaning and the number of passes made by the sweeper can be found from a public works department.

The number of catchbasins (gutter inlets) per acre may be estimated from visual observation or obtained from a public works department. The volume of liquid remaining in the catchbasins may be found by analysis of the construction drawings. The BOD of the remaining liquid can be estimated or measured.

The last data cards, each defining an individual subarea, provide the model with the subarea number, the inlet manhole number receiving the pollutant outflows, type of land use, area, and the length of gutters for each area. Land use information may be obtained from a governmental planning department, direct observation, or by other means. The length of gutters within each subarea may be obtained by scaling them from a street map.

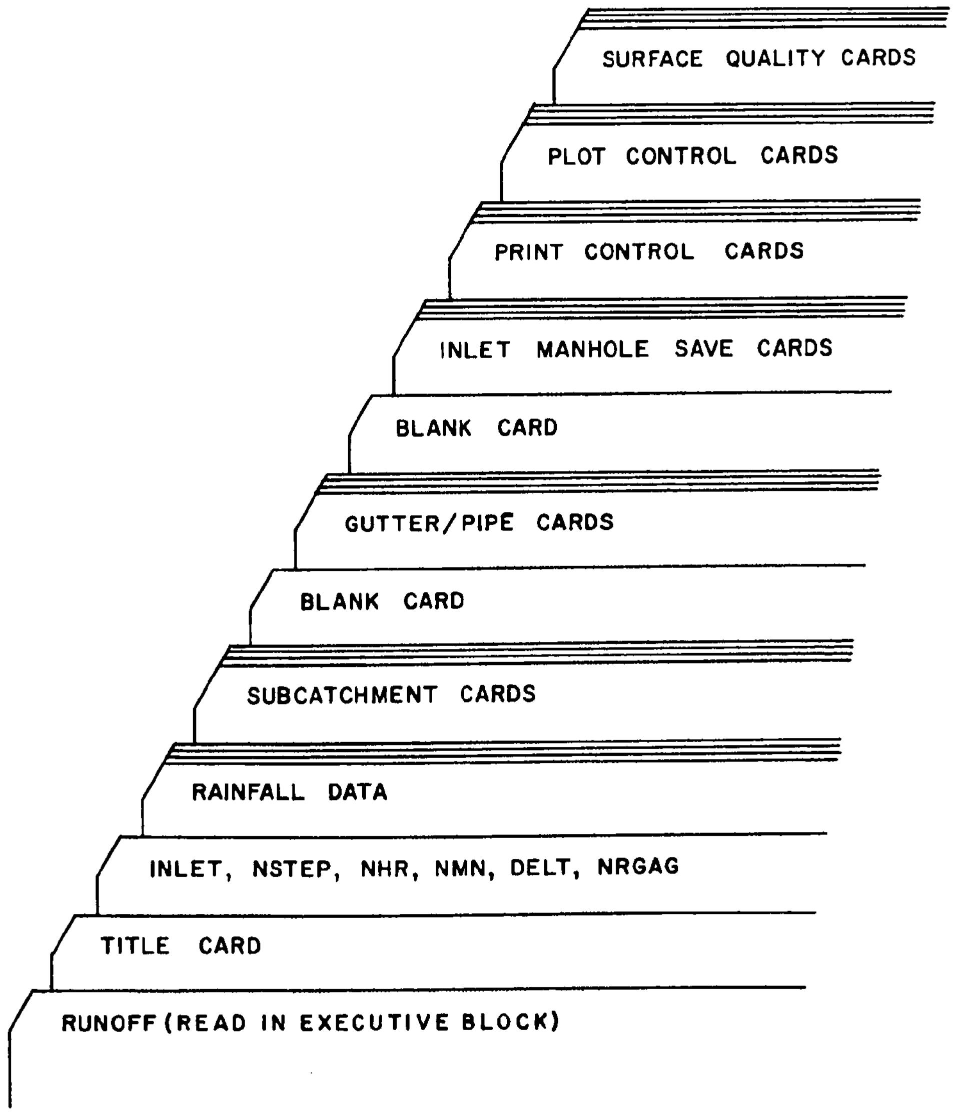


Figure 3-11. DATA DECK FOR THE RUNOFF BLOCK

Table 3-2. RUNOFF BLOCK CARD DATA

Card Group	Format	Card Columns	Description	Variable Name	Default Value
1	20A4		Title cards: two cards with heading to be printed on output.	TITLE	none
2			Control card: one card.		
	2I5	1-5	Number of inlets.	INLET	none
		6-10	Number of time-steps to be calculated.	NSTEP	none
	I3	11-13	Hour of start of storm (24-hour clock).	NHR	none
	I2	14-15	Minutes of start of storm.	NMN	none
	F5.1	16-20	Integration period (min).	DELT*	none
	I5	21-25	Number of hyetographs.	NRGAG	none
	F5.0	26-30	Percent of impervious area with zero detention (immediate runoff).	PCTZER	25.0
3			Rainfall control card.		
	I5	1-5	Number of data points for each hyetograph.	NHISTO	none
	F5.0	6-10	Time interval between values (min).	THISTO *	none
			REPEAT CARD GROUP 4 FOR EACH HYETOGRAPH.		
4 **			Rainfall hyetograph cards: 10 intervals per card.		
	10F5.0	1-5	Rainfall intensity, first interval (in./hr).	RAIN(1)*	none
		6-10	Rainfall intensity, second interval (in./hr).	RAIN(2)*	none
		11-15	Rainfall intensity, third interval (in./hr).	RAIN(3)*	none
		16-20 ⋮	Rainfall intensity, fourth interval (in./hr).	RAIN(4)* ⋮	none
			REPEAT CARD 5 FOR EACH SUBCATCHMENT.		
5			Subcatchment cards (3I5, 10F5.0, F10.5): one card per subcatchment.		
	3I5	1-5	Hyetograph number (Based on the order in which they are read in).	JK	1

*Decimal point should be punched in this field.

**Problems occur when 0.0 rainfall occurs several time-steps before the actual start of the rainfall (the computer underflows).

NOTE: All non-decimal numbers must be right-justified.

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		6-10**	Subcatchment number.****	N	none
		11-15**	Gutter or manhole number for drainage.****	NGOTO	none
	10F5.0	16-20	Width of subcatchment (ft).***	WWIDTH=W1*	none
		21-25	Area of subcatchment (acres).	WAREA =W2*	none
		26-30	Percent imperviousness of subcatchment.	PCIMP =W3*	none
		31-35	Ground slope (ft/ft).	WSLOPE=W4*	0.030
		36-40	Impervious area } Resistance Factor.	W5 =W5*	0.013
		41-45	Pervious area } Resistance Factor.	W6 =W6*	0.250
		46-50	Impervious area } Retention storage (in.).	WSTORE=W7*	0.062
		51-55	Pervious area } Retention storage (in.).	WSTORE=W8*	0.184
		56-60	Maximum infiltration rate (in./hr).	WLMAX =W9*	3.00
		61-65	Minimum infiltration rate (in./hr).	WLMIN =W10*	0.52
	F10.5	66-75	Decay rate of infiltration (1/sec).	DECAY =W11*	0.00115
6			Blank card to terminate subcatchment cards: one card.		
			REPEAT CARD 7 FOR EACH GUTTER/PIPE		
7			Gutter/pipe cards: one card per gutter/pipe (if none, leave out).		
	4I5	1-5	Hyetograph number.	NHYET	none
		5-10	Gutter number.	N	none
		11-15	Gutter or manhole number for drainage.	NGOTO	none
		16-20	{ = 1 for gutter = 2 for pipe.	NP	none
	7F8.0	21-28	Bottom width of gutter or pipe diameter (ft).	GWIDTH=G1*	none
		29-36	Length of gutter (ft).	GLEN =G2*	none
		37-44	Invert slope (ft/ft).	GSLOPE=G3*	none
		45-52	Left-hand side slope (ft/ft).	GS1 =G4*	none
		53-60	Right-hand side slope (ft/ft).	GS2 =G5*	none
		61-68	Manning's coefficient.	GN =G6*	none
		69-76	Depth of gutter when full (in.).	DFULL =G7*	10

*Decimal point should be punched in this field.
**Need one inlet or gutter/pipe for each subcatchment basin.
***Twice the length of main drainage pipe through the subcatchment.
****Maximum number = 160.

Table 3-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
8*			Blank card to terminate gutter cards: one card.		
9			Manhole save control: one card.		
	I5	1-5	Number of inlet manholes for which entering flows are to be saved on peripheral storage for TRANSPORT.	NSAVE	none
			IF NSAVE=0, SKIP CARDS 10		
10			Manhole save cards: 16 values per card.		
	16I5	1-5	Inlet manhole numbers for which entering flows are saved (same elements that are used by TRANSPORT).	ISAVE(1)	none
		6-10		ISAVE(2)	none
		11-15		ISAVE(3)	none
		⋮		⋮	
				ISAVE(NSAVE)	none
11			Manhole print control: one card.		
	2I5	1-5	Number of inlet manholes for which entering flows are to be printed.	NPRNT	none
		6-10	Number of time-steps between printings.	INTERV	none
			IF NPRNT=0, SKIP CARDS 12		
12			Manhole print cards: 16 values per card.		
	16I5	1-5	Inlet manhole numbers for which entering flows are to be printed.	IPRNT(1)	none
		6-10		IPRNT(2)	none
		11-15		IPRNT(3)	none
		⋮		⋮	
				IPRNT(NPRNT)	none
13			Manhole plot control: one card.		
	3I5	1-5	Number of inlet manholes for which entering flows are to be plotted (maximum = 25).	NPLOT**	none
		6-10	Number of curves per figure (maximum = 5).	NPCV	1

*Need this card even though there are no gutter/pipe cards.

**(NPOL + 1)(NPLOT) cannot exceed 150 without changing variable YT(160, 150) size in Common block.

Table 3-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			IF NPLOT=0, SKIP CARDS 14.		
14			Manhole plot cards: 16 values per card.		
	16I5	1-5		IPLOT(1)	none
		6-10	Inlet manholes in which entering flows are to be plotted.	IPLOT(2)]	none
		11-15		IPLOT(3)	none
		⋮		IPLOT(NPLOT)	none
			THE FOLLOWING CARDS ARE SURFACE QUALITY DATA.		
15			Control card.		
	2I5	1-5	Number of subareas (may exceed number of subcatchments due to multiple land uses) (maximum = 160).	KTNUM	none
		6-10*	Number of inlets.	NINLTS	none
	F5.0	11-15*	Time interval (min).	DT	none
	4I5	16-20*	Hour of start of storm (24-hr clock).	KHOUR	none
		21-25*	Minute of start of storm.	KMIN	none
		26-30*	Number of time-steps.	NTSTEP	none
		31-35	Use 1 for printing output in sentence form, 0 for printing in table form.	NPRINT	none
16			Cleaning data card.		
	2F10.0	1-10	Number of dry days prior to this storm in which the accumulative rainfall is <1.0 in.	DRYDAY	none
		11-20	Cleaning frequency (days).	CLFREQ	none
	I5	21-25	Number of street sweeper passes.	NOPASS	none
17			Catchbasin data card.		
	3F10.0	1-10	Number per acre.	CBDEN	none
		11-20	Concentration of BOD (mg/L), of the stored water in each catchment basin.	CBBOD	none
		21-30	Stored volume in each catchment basin (gal.)	CBVOL	none

*These values must be the same as in card group 2.

Table 3-2. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			REPEAT DATA CARD 18 FOR EACH SUBAREA.		
			(Maximum = 160 subareas).		
18			Subarea data card.		
	3I5	1-5	Number of this subarea.	KNUM	none
		6-10	Inlet number of this subarea.*	INPUT	none
		11-15	Land use =1 for single family residential =2 for multi-family residential =3 for commercial =4 for industrial =5 for undeveloped or park lands.	KLAND	none
	2F10.2	16-25	Area of this subarea (acres).	ASUB	none
		26-35	Total length of gutters for each subarea (hundreds of ft).	GUTTER	none
			END OF RUNOFF BLOCK CARDS.		

*All subareas with the same inlet member must be placed together and these groups must be in the order in which the inlets are saved as described by card group 10.

Table 3-3. RUNOFF BLOCK VARIABLES

Variable Name	C*	Description	Units
A		SS removing coefficient	
ASUB	C	Area of subarea	acre
ATOT	C	Total area of subarea draining to all inlets	acre
AVAIL		Fraction of total dust and dirt available at start of time-step	
AVGFLO	C	Average runoff within a time-step	cfs
AXO		Trapezoidal cross-sectional area, starting	sq ft
AX1		Trapezoidal cross-sectional area, final	sq ft
B		SS removing coefficient	
BOD	C	BOD removed at each time-step to the inlet	lb/DT
BODNS		Non-soluble BOD from dust and dirt removed during each time-step	lb/DT
C	C	Removing coefficient	
CBASTM	C	BOD removed during one time-step including both catchbasin and surface area	lb/DT
CBBOD		Concentration of BOD in each catchbasin	mg/L
CBCENT		Pollution removed from the catchbasin	
CBDEN		Density of catchbasin	No./acre
CBINC	C	BOD removed from catchbasins during one time-step	lb/DT
CBLBS	C	BOD remaining after each time-step	lb
CBNUM		Number of catchbasins within a subarea	

Variable Name	C*	Description	Units
CBSUM	C	Sum of the drainage to catchbasin in each time-step	gal.
CBVOL		Volume of liquid remaining in a catchbasin	gal.
CCOLI	C	Concentration of coliform bacteria of a subarea during one time-step	MPN/100 ml
CLEAN		Number of cleanings since last storm	
CLFREQ		Frequency of street sweepings	
CONBOD		Average concentration of BOD during each time-step	mg/L
CONCSS		Average concentration of SS during each time-step	mg/L
CONVER		Factor for converting lb/DT/cfs to mg/L	
CONV2		Integer that converts flow unit from cfs to 100 ml/min	
CURVE		Name of subroutine	
D		Computational variable, internal	
DAX1		Change in trapezoidal cross-sectional area	sq ft
DCORR		Time-step water depth	ft
DD		Dust and dirt accumulation rate for each subarea	
DDELV		Rate of change in volume change	
DECAY	C	Exponential decay rate for infiltration	1/sec
DEL		Time-step change in depth of watershed flow	
DELD	C	Instantaneous pipe diameter in radians	radian
DELR		Newton-Raphson change in depth for correction	
DELT	C	Integration time interval	sec, min
DELT2	C	One half of a time-step	min
DELV		Average volume change	

*C = Variable names shared in common blocks.

Table 3-3 (continued)

Variable Name	C*	Description	Units
DF		Sum of volume change plus flow change times time	
DFLOW1		Change in flow	
DFULL		Gutter's maximum depth (for pipes DFULL = 2.62)	in.
DO		Instantaneous depth	ft
DRAIN		Runoff to each catchbasin during each time-step	gal.
DRYDAY		Number of dry days prior to storm	days
DT		Time-step interval	min
DUMMY	C	Dummy common block	
DWP1		Change in wetted perimeter	
D1		Estimated final depth	in.
E		Hundred times average runoff	
ENDTIM		Time of simulation, 24 hour clock	hr
ERROR		Name of error statement	
ERT		Computational variable	
EXPON		Computational variable	
F		Newton-Raphson volume correction (WSHED)	
F		SS removed during one time-step (SFQUAL)	lb/DT
FLOW		Average flow	cfs
FLOWO		Starting flow	cfs
FLOW1		Final flow	cfs
GCON	C	Manning's equation less hydraulic radius	
GDEPTH	C	Instantaneous gutter depth	in.

Variable Name	C*	Description	Units
GFLOW	C	Gutter flow	cfs
GLEN	C	Length of gutter/pipe	ft
GN	C	Manning's roughness coefficient	
GRAPH	XF	Name of subroutine	
GS		Factor in a geometric series	
GSLOPE	C	Slope of gutter/pipe	ft/ft
GS1	C	Gutter side slope, left	ft/ft
GS2	C	Gutter side slope, right	ft/ft
GUTTER	C	Length of gutter in subarea	100-ft
GWIDTH	C	Pipe diameter or gutter width	ft
G1		Read in value of bottom width of gutter or pipe diameter	ft
G2		Read in value of length of gutter	ft
G3		Read in value of invert slope	ft/ft
G4		Read in value of left-hand side slope	ft/ft
G5		Read in value of right-hand side slope	ft/ft
G6		Read in value of Manning's coefficient	
G7		Read in value of depth of gutter when full	in.
HCURVE		Name of subroutine	
HGRAPH	C	Magnitude of variable to be printed in vertical coordinate of the curve	
HISTOG	C	Length of histogram expressed in time	sec
HORIZ	C	Horizontal title unit of hydrograph in time	hr

Table 3-3 (continued)

Variable Name	C*	Description	Units
HTIME	C	Time interval to be printed in the horizontal coordinate of the curve	
HYDRO		Name of subroutine	
I		Bookkeeping integer	
IA		Do loop counter	
IFLG		Surcharge indicator	
IFPRNT		Name of scratch tape	
IHOUR		Hour of start of storm, 24-hour clock	hr
II		Bookkeeping integer	
IJ		Bookkeeping integer	
IK		Bookkeeping integer	
IKOUNT	C		
IMIN		Minute of start of storm	min
INCNT	C	Name of the tape	
IND		Bookkeeping integer, time interval	
INLET		Inlet number	
INPT		Variable which transfer program from tape to compiler	
INPUT	C	Inlet number	
INTCNT		Printing counter	
INTERV	C	Interval integrization cycles for printed hydrographs	
IOUTCT	C	Name of the tape	
IPOINT	C	Internal pointer	
IPRNT	C	Points for which hydrograph will be printed	
ISAVE	C	Points for which hydrograph will be saved	
ISKIP		Number of inlets minus one	
ISUB		Bookkeeping integer	
J		Bookkeeping integer	
JIN	C	Name of input tape	
JJ		Bookkeeping integer	
JK		Bookkeeping integer	
JKL		Do loop counter	
JN	C	Number of input manholes	
JOUT	C	Name of output tape	
JT		Bookkeeping integer	
K		Bookkeeping integer	
KHOUR		Hour of start of storm, 24-hour clock	
KK		Bookkeeping integer	
KL		Do loop counter	
KLAND	C	Land use	
KMIN		Minute of start of storm	min
KNUM	C	Temporary subarea number reset to inlet number	
KOUNT		Computational counter	
KSKIP		Do loop counter for SKIPN	
KSPOT		Bookkeeping integer	
KTNUM		Number of subarea	
KTSTEP		Time-step counter	

Table 3-3 (continued)

Variable Name	C*	Description	Units
L		Bookkeeping integer	
LL		Bookkeeping integer	
M		Bookkeeping integer	
MKOUNT		Computational counter	
MM		Bookkeeping integer	
N		Bookkeeping integer	
NAMEW	C	External subcatchment number	
NCLEAN		Number of cleanings since last storm	
NEW		Bookkeeping integer	
NEXDAY		Number of days after start of storm simulation ends	day
NG	C	Number of gutters	
NGAGP		Number of graphic point	
NGOTO		Gutter number to which watershed drains	
NGTOG	C	Gutter connections	
NGTOI	C	Inlet connections	
NGUT	C	Bookkeeping integer	
NHISTO	C	Number of rainfall time interval	
NHR		Hour of the start of storm	hr
NHYET	C	Number of hyetograph	
NIN	C	Maximum number of gutters draining to gutter, and watersheds draining to gutter	

Variable Name	C*	Description	Units
NING	C	Do loop counter	
NINLTS		Total number of inlets	
NMN		Minutes of the start of storm	min
NOG	C	Total number of gutters/pipes	
NOLD		Bookkeeping integer	
NOPASS		Number of street sweeper passes	
NOUT		Output file variable	
NP		Read in value of NPG	
NPG	C	Control switch for type of gutter, 1=regular, 2=pipe, 3=dummy connected directly to inlet	
NPRINT		Number of time-steps between printing	
NPRNT	C	Number of points where hydrographs are printed	
NPT	C	Number of points to be plotted	
NQUAL		Number of quality constituents used as zero in Runoff quantity	
NRAIN	C	Number of rainfall	
NRANVL		Rain data points limiter	
NRGAG	C	Number of hyetographs	
NSAVE	C	Number of points where hydrographs are saved	
NSCRAT	C	Name of the tape	
NSHED	C	Number of the watershed	
NSPOT		Bookkeeping integer	
NSTEP	C	Number of time-steps	
NSTOP		Error switch	
NTIMEH		Hour of day of simulation (24-hour clock)	hr

Table 3-3 (continued)

Variable Name	C*	Description	Units
NTQUAL		Scratch output file indentifier	
NTSTEP		Number of time-steps modeled	
NTYPE		Number of types	
NUSTEP		Number of printed hydrograph points	
NW	C	Number of watershed	
NWTOG	C	Gutter connection	
NWTOI		Inlet connection	
NX		Bookkeeping integer	cfs
ORIZ		Horizontal title unit for hydrograph in time	hr
OUTFLW	C	Flow out of the gutter	cfs
P			
PCIMP	C	Percent imperviousness of watershed	%
PCNTCB		Percent removal of BOD by catchbasin of one subarea	%
PCNTSS		Percent removal of SS from total dust and dirt of one subarea	%
PCTBOD		Percent removal of BOD from available surface BOD of one subarea	%
PCTZER	C	Percent of impervious area with zero detention depth	%
PO	C	Soluble BOD in dust and dirt	lb
POCB		Total BOD available from catchbasins	lb
POOCB		BOD available in each catchbasin at start	lb

Variable Name	C*	Description	Units
POP	C	BOD removed from dust and dirt during one time-step	lb/DT
POPSS	C	SS removed during one time-step	lb/DT
QIN	C	Input from upstream gutter	cfs
QSUR	C	Surcharge	cf
RAD0		Starting hydraulic radius	ft
RAD1		Final hydraulic radius	ft
RAIN	C	Rainfall	in./hr
REFF		Street sweeper removal efficiency	percent, decimal
REMDD	C	Remaining dust and dirt after each time-step	lb
RHYDRO		Name of subroutine	
RI	C	Instantaneous rainfall rate	in./hr
RLOSS	C	Infiltration loss, instantaneous	in./hr
RUNCFS	C	Instantaneous runoff for each inlet	cfs
RUNOFF		Average runoff over a time-step	in./hr
RUNTMP	C	Flow entering input manholes	cfs
SFCOLI	C	Total coliform in runoff	MPN/min
SFQUAL		Name of subroutine	
SKIP1		Scratch tape variable, unformatted	
SKIP2		Scratch tape variable, unformatted	
SKIP3		Scratch tape variable, unformatted	

Table 3-3 (continued)

Variable Name	C*	Description	Units
SKIP4		Scratch tape variable, unformatted	
SKIP5		Scratch tape variable, unformatted	
SKIP6		Scratch tape variable, unformatted	
SKIP7		Scratch tape variable, unformatted	
SS	C	Suspended solids	lb
SUMBOD		Sum of total surface BOD in each area	lb
SUMCB		Sum of total BOD in catchbasins	lb
SUMDD		Sum of the dust and dirt	lb
SUMI	C	Total infiltration into ground	cf
SUMOFF	C	Total gutter flow @ inlet manhole	cf
SUMQW	C	Total flow for each subcatchment	cf
SUMR	C	Total rainfall	cf
SUMST	C	Total surface storage	cf
T		Time-step interval	hr
TAREA		Total area	acres
TBOD		Total BOD in surface runoff	lb
TCBAST	C	Total BOD removed for each inlet	lb
TCBINC	C	Total BOD removed from catchbasins for each inlet	lb
TCCOLI	C	Total concentration of coliform during one time-step	NPN/ 100 ml
TGS		Sum of the gemetric series plus 1.0	
THISTO		Time of rainfall time intervals	min

Variable Name	C*	Description	Units
TIME	C	Time	sec
TIMEH		Time of simulation (24-hour clock)	min
TIMES		Time of simulation (SFQUAL)	sec
TIME2	C	Time minus half-step	sec
TITEL		Description of curve in horizontal coordinates	
TITL		Description of curve in vertical coordinate	
TITLE	C	Description of problem	
TMAX		Maximum time to be printed in curve	hr
TMINS		Time-step interval	min
TOTDD	C	Total dust and dirt on ground at start of storm for each inlet	lb
TPCBOD		Percent of total BOD removed from each area	%
TPCTBD		Total percent removal of BOD from catchbasin of all areas	%
TPCTCB		Total percent removal of BOD from catchbasin and surface of all areas	%
TPCTSS		Total percent removal of SS from surface of all areas	%
TPOP	C	Total BOD removed from dust and dirt for each inlet	lb
TPOPSS	C	Total SS removed for each inlet	lb
TPTBOD		Total percent removal of BOD from surface of all areas	%
TRAIN	C	Time when rainfall ends	min, sec
TSEC		Time-step interval	sec
TSMBD		Sum of total BOD for the study area	lb

Table 3-3 (continued)

Variable Name	C*	Description	Units
TSUMCB		Sum of the original dust and dirt available in the catchbasin	lb
TSUMDD		Sum of the original dust and dirt available on surface drainage area	lb
TTCBNC		Total removal of BOD from all of catchbasin and surface area	lb
TTCBST		Total removal of BOD of all catchbasins	lb
TTPOP		Total removal of BOD from all surface area	lb
TTPPSS		Total removal of SS of all areas	lb
TZERO		Starting time of the hydrograph	sec
VER		Vertical title unit for hydrograph	in./hr
VERT	C	Vertical title unit for hydrograph	in./hr
WAR		Impervious area of watershed with immediate runoff	sq ft
WAREA	C	Area of watershed	acres, sq ft
WCON	C	Modified Manning's equations, impervious and pervious portions of watershed	
WDEPTH	C	Instantaneous depth on watershed	ft
WFLO		Average watershed flow during time interval	cfs
WFLOW	C	Instantaneous flow from watershed	cfs
WLMAX	C	Maximum infiltration rate	in./hr
WLMIN	C	Minimum infiltration rates	in./hr
WN	C	Dummy variable	
WPO		Wetted parameter, starting	ft
WP1		Wetted parameter, final	ft
WSHED		Name of subroutine	
WSLOPE	C	Average slope of watershed	ft/ft
WSTORE	C	Minimum and maximum storage depth on surface of watershed	ft
WWIDTH	C	Average width of watershed	ft
W1		Read in value of the average width of watershed	ft
W2		Read in value of the area of watershed	acre
W3		Read in value of the percent of imperviousness	%
W4		Read in value of slope of watershed	ft/ft
W5		Resistance factor for impervious area	
W6		Resistance factor for pervious area	
W7		Retention storage for impervious area	in.
W8		Retention storage for pervious area	in.
W9		Read in value of maximum infiltration rate	in./hr
W10		Read in value of minimum infiltration rate	in./hr
W11		Read in value of decay rate of infiltration	1/sec
X	C	Number of time interval used in the horizontal coordinate	
XLAB	C	Minimum point in the horizontal scale	
Y		Number of point used in the vertical coordinate	
YLAB	C	Minimum point in the vertical scale	

EXAMPLES

Two examples are given, one for rainfall runoff and the other for quality runoff.

Example 1 - Surface Flows

The "fine" schematization of the Northwood (Baltimore) test area is used as an example; the area is shown in Figures 3-8 and 3-12. A sample of the data cards is shown in Table 3-4. Selected output pages are reproduced in Tables 3-5 through 3-10 and in Figures 3-13 and 3-14.

Example 2 - Surface Quality

A portion of a combined sewer area is shown in Figure 3-15. It is a copy of a U.S. Geological Survey topographic map (7-1/2 minute). The drainage basin was determined for the Runoff program as was the inlet numbering.

As an example consider only one of the numbered inlets for a computer run. The land use for the area draining to inlet number 65 was determined by zoning maps. This information is used to determine the subareas (each having one type of land use) within each inlet drainage basin. The area of each subarea and the length of gutters within it are measured from the map. The subareas of inlet drainage basin 65 and the input data for this basin are also shown in Figure 3-15. The subareas are numbered for informational purposes only (i.e., they are not used in the execution of the program).

Information about the number of catchbasins per acre and volume of liquid remaining in the catchbasins was gathered from the public works department. The average BOD of the liquid remaining in the catchbasins was estimated.

For this example the catchbasin density is 1 per acre, the volume of liquid remaining is 150 gallons, and the BOD is 100 mg/L.

The data for frequency of street sweeping and number of passes were obtained from the public works department. For this example the frequency is 14 days and there were two passes. The number of dry days preceding the start of the runoff being modeled was found from rainfall records to be 50 days.

The clock time of the start of rainfall was also determined from rainfall records. The time-step to be used is that which the Runoff program used or 10 minutes. The time selected will depend to some extent upon the observed data used as input, i.e., rainfall, or that used to check output, i.e., runoff hydrographs. The number of time-steps modeled here is 30, or 5 hours. The runoff for each inlet was found from the Runoff program.

Sample input for this example is shown in Table 3-11 and the output for the computer run made is shown in Tables 3-12 and 3-13.

Figure 3-12. NORTHWOOD (BALTIMORE) GUTTER/PIPES "FINE" PLAN

Table 3-4. TYPICAL DATA CARDS

DATA	CARD GROUP NO.
AFTERNOON STORM OF 8-1-65	1
RUNOFF BLOCK ONLY	
1 100 1. 1	2
60 1.	3
1.20 1.08 0.24 1.14 0.24 0.24 0.72 1.56 1.80 2.58	4
3.06 3.54 2.56 2.94 2.10 0.84 0.96 1.80 1.38 1.20	
0.72 0.72 1.02 0.54 0.36 0.30 0.24 0.30 0.42 0.24	
0.18 0.12 0.06 0.12 0.12 0.06 0.00 0.00 0.00 0.00	
1 1 51 250. 4.47 58	5
1 2 80 430. 9.05 60	
1 3 80 750. 1.99 36	
1 4 52 120. 4.44 69	
1 5 531200. 2.68 99	
1 6 63 780. 3.64 71	
1 61 60 550. 4.47 99	
1 7 67 800. 2.83 85	
1 8 70 230. 4.05 48	
1 9 72 650. 4.19 95	
1 10 77 800. 2.71 49	
1 11 75 280. 2.89 87	
	6
1 51 80 2 1.75 260. 0.02 0.0 0.0 .012	7
1 52 80 2 3.5 320. 0.007 .012	
1 53 76 2 1.25 600. 0.041 .012	
1 60 76 2 2.5 470. 0.04 .012	
1 63 60 2 1.75 810. 0.04 .012	
1 66 60 2 2.0 150. 0.036 .012	
1 67 66 2 1.5 420. 0.026 .012	
1 70 66 2 1.5 150. 0.03 .012	
1 72 76 2 2.0 335. 0.036 .012	
1 77 76 2 1.5 550. 0.04 .012	
1 76 52 2 2.75 219. 0.043 .012	
1 75 52 2 1.5 290. 0.04 .012	
1 80 0 2 4.0 121. 0.0085 .012	
	8
1	9
80	10
5 5	11
52 60 66 76 80	12, 13
1	14
80	

Table 3-5. TYPICAL OUTPUT, GENERAL INFORMATION

```
    ENTRY MADE TO RUNOFF MODEL
AFTERNOON STORM OF 8-1-65
RUNOFF BLOCK ONLY

INLET NUMBER     1

NUMBER OF  TIME  STEPS  100

INTEGRATION TIME INTERVAL (MINUTES),     1.00

25.0 PERCENT OF IMPERVIOUS AREA HAS ZERO DETENTION DEPTH

FOR    60 RAINFALL STEPS, THE TIME INTERVAL IS   1.00 MINUTES

FOR RAINGAGE NUMBER   1   RAINFALL HISTORY IS
```

1.20	1.08	0.24	1.14	0.24	0.24	0.72	1.56	1.80	2.58
3.06	3.54	2.55	2.94	2.10	0.84	0.96	1.80	1.38	1.20
0.72	0.72	1.02	0.54	0.36	0.30	0.24	0.30	0.42	0.24
0.18	0.12	0.06	0.12	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

Table 3-6. TYPICAL SUBCATCHMENT OUTPUT

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.	INFILTRATION RATE(IN/HR) MAXIMUM	INFILTRATION RATE(IN/HR) MINIMUM	INFILTRATION RATE(IN/HR) DECAY RATE	GAGE NO
1	51	250.	4.	58.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
2	80	430.	9.	60.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
3	80	750.	2.	36.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
4	52	120.	4.	69.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
5	53	1200.	3.	99.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
6	63	780.	4.	71.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
61	60	550.	4.	99.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
7	67	800.	3.	85.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
8	70	230.	4.	48.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
9	72	650.	4.	95.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
10	77	800.	3.	49.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
11	75	280.	3.	87.0	0.030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1

TOTAL NUMBER OF SUBCATCHMENTS, 12

TOTAL TRIBUTARY AREA (ACRES), 47.41

Table 3-7. TYPICAL GUTTER/PIPE OUTPUT

GUTTER NUMBER	GUTTER CONNECTION	WIDTH (FT)	LENGTH (FT)	SLOPE (FT/FT)	SIDE SLOPES L	SIDE SLOPES R	MANNING N	OVERFLOW (IN)
51*	80	1.8	260.	0.020	0.0	0.0	0.012	0.0
52*	80	3.5	320.	0.007	0.0	0.0	0.012	0.0
53*	76	1.3	600.	0.041	0.0	0.0	0.012	0.0
60*	76	2.5	470.	0.040	0.0	0.0	0.012	0.0
63*	60	1.8	810.	0.040	0.0	0.0	0.012	0.0
66*	60	2.0	150.	0.036	0.0	0.0	0.012	0.0
67*	66	1.5	420.	0.026	0.0	0.0	0.012	0.0
70*	66	1.5	150.	0.030	0.0	0.0	0.012	0.0
72*	76	2.0	335.	0.036	0.0	0.0	0.012	0.0
77*	76	1.5	550.	0.040	0.0	0.0	0.012	0.0
76*	52	2.8	219.	0.043	0.0	0.0	0.012	0.0
75*	52	1.5	290.	0.040	0.0	0.0	0.012	0.0
80*	0	4.0	121.	0.008	0.0	0.0	0.012	0.0

TOTAL NUMBER OF GUTTERS/PIPES, 13

ASTERISK (*) DENOTES CIRCULAR PIPE, DIAMETER=.WIDTH.

Table 3-8. COMPUTED ARRANGEMENT OF SUBCATCHMENTS AND GUTTER/PIPES

ARRANGEMENT OF SUBCATCHMENTS AND GUTTERS/PIPES

GUTTER	TRIBUTARY GUTTER/PIPE	TRIBUTARY SUBAREA
51		1
52	76 75	4
53		5
60	63 66	61
63		6
66	67 70	
67		7
70		8
72		9
75		11
76	53 60 72 77	
77		10
80	51 52	2 3

INLET	TRIBUTARY GUTTER-PIPE-MANHOLE	TRIBUTARY SUBAREA
1	80	

HYDROGRAPHS WILL BE STORED FOR THE FOLLOWING 1 POINTS
80

Table 3-9. PRINTED OUTPUT OF SELECTED HYDROGRAPHS

HYCROGRAPHS ARE LISTED FOR THE FOLLOWING 5 POINTS

TIME	52	60	66	76	80
0 5.00	1.15	0.76	0.34	1.14	1.02
0 1C.00	12.99	7.81	3.32	12.40	14.07
0 15.C0	59.59	28.58	11.11	49.56	77.33
0 20.00	38.38	17.60	6.68	29.96	52.33
0 25.00	24.43	10.59	3.97	18.23	34.24
0 30.00	13.30	5.65	2.09	9.47	19.08
0 35.C0	7.81	3.15	1.14	5.31	11.43
0 4C.00	4.40	1.67	0.60	2.81	6.58
0 45.C0	2.54	0.92	0.32	1.51	3.86
0 5C.00	1.64	0.57	0.20	0.92	2.50
0 55.00	1.13	0.38	C.13	0.61	1.73
1 C.0	0.83	0.27	0.09	0.43	1.26
1 5.00	0.63	0.20	0.07	0.31	0.96
1 10.00	0.49	0.15	0.05	0.24	0.75
1 15.00	0.39	0.12	0.04	0.19	0.60
1 20.00	0.32	0.10	0.03	0.15	0.48
1 25.00	0.26	0.08	0.03	0.12	0.40
1 30.00	0.22	0.07	0.02	0.10	0.34
1 35.00	0.19	0.05	0.02	0.08	0.28
1 40.00	0.16	0.05	0.02	0.07	0.24

Table 3-10. COMPUTED RAINFALL INFORMATION

TOTAL RAINFALL (CU FT)	105241.
TOTAL INFILTRATION (CU FT)	30579.
TOTAL GUTTER FLOW AT INLET (CU FT)	68199.
TOTAL SURFACE STORAGE AT END OF STORM (CU FT)	6231.
ERROR IN CONTINUITY, PERCENTAGE OF RAINFALL,	0.22029

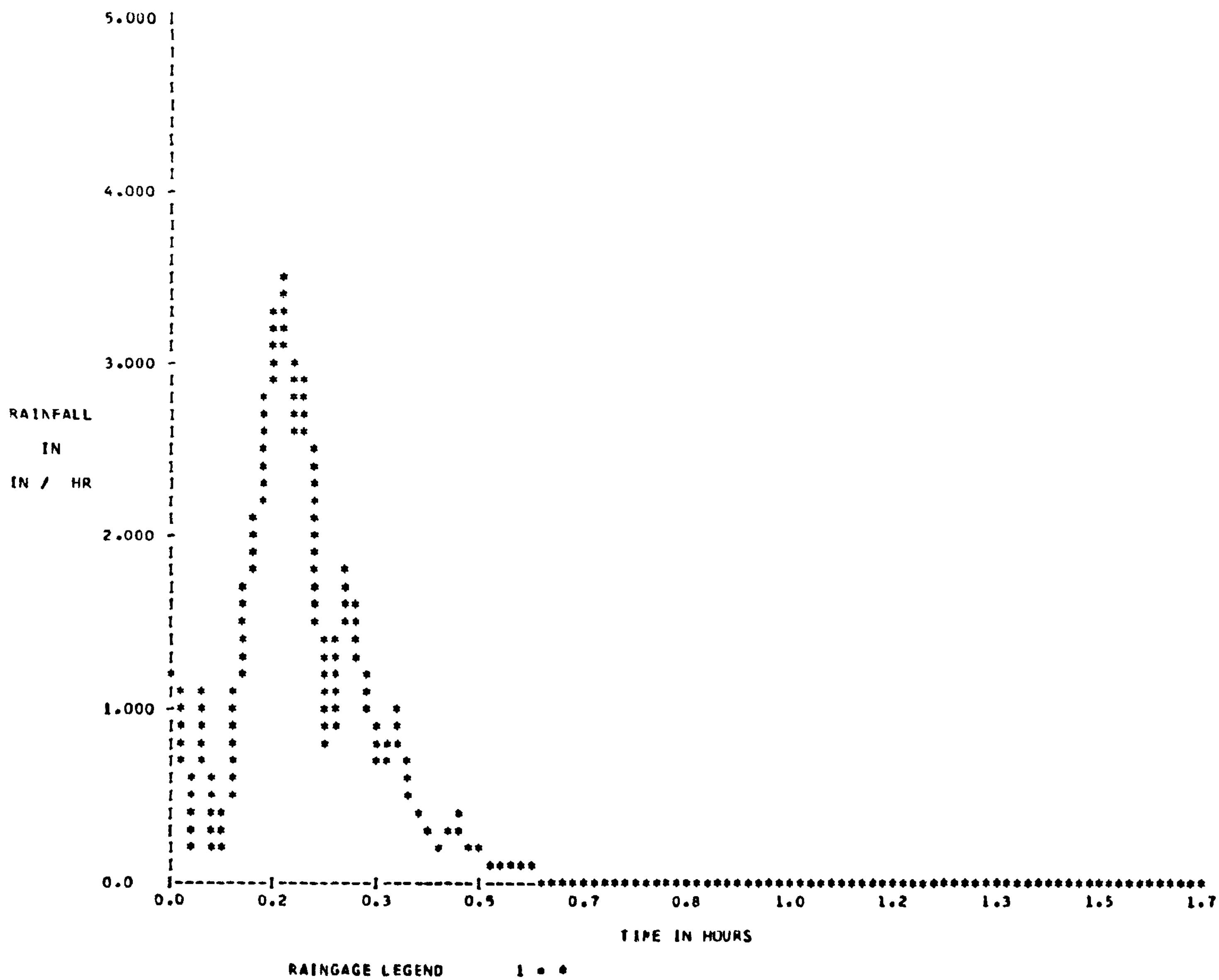


Figure 3-13. TYPICAL OUTPUT HYETOGRAPH

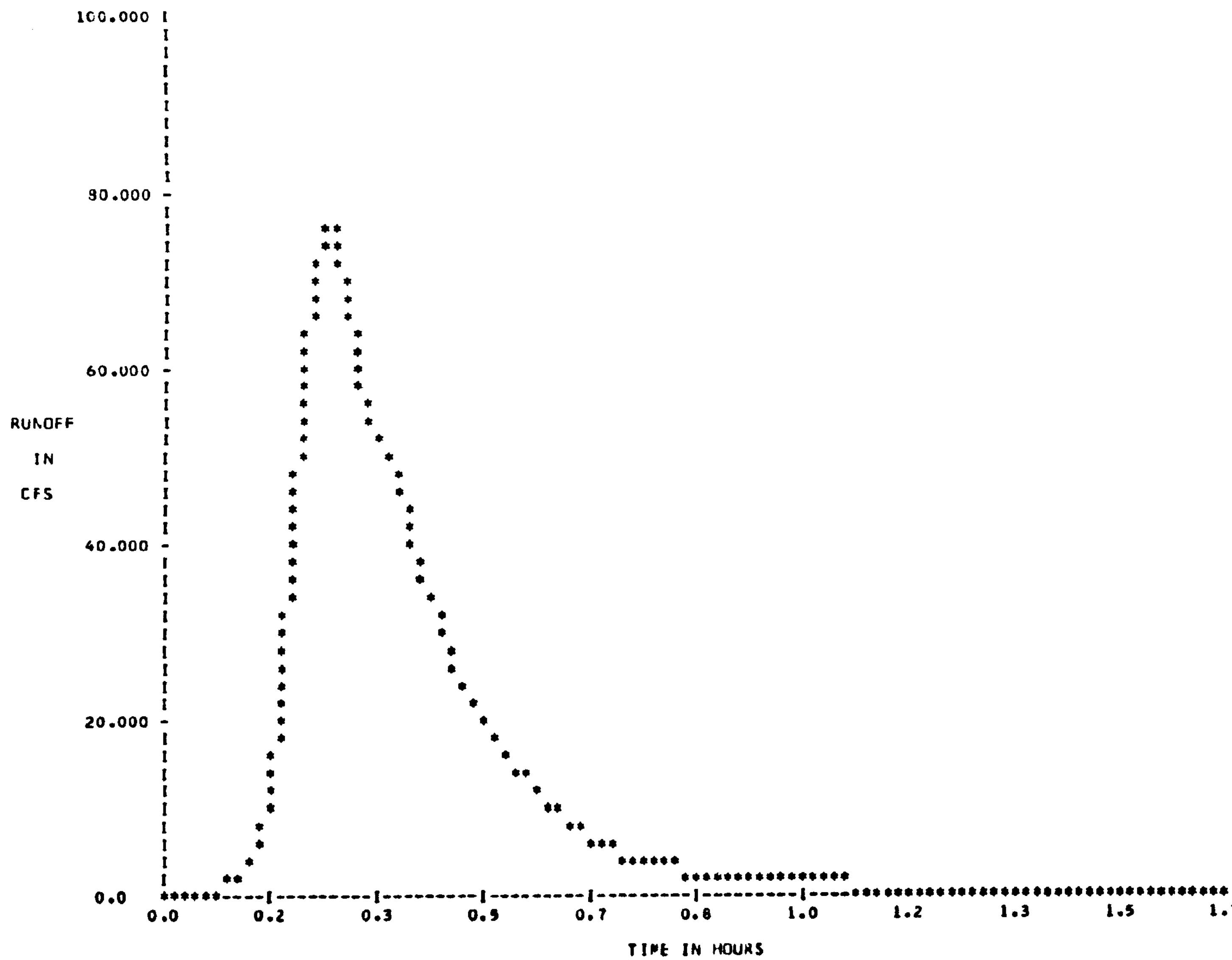
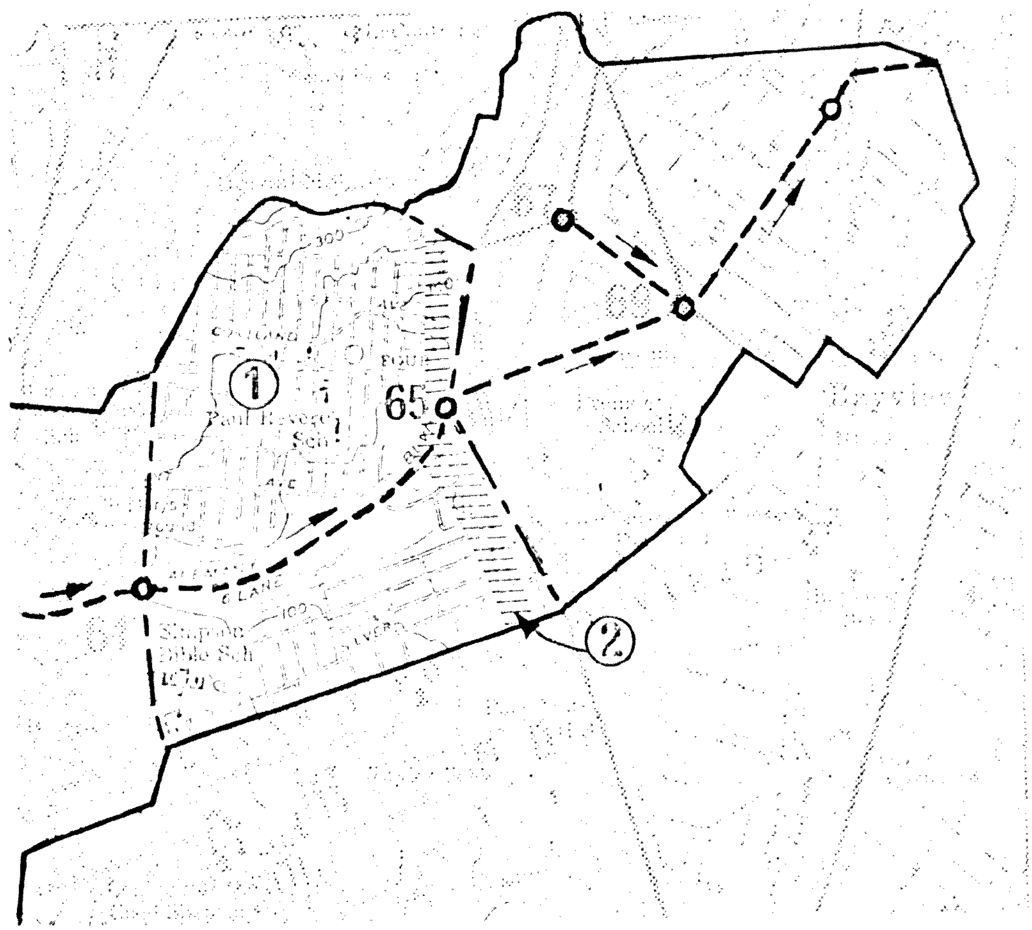


Figure 3-14. TYPICAL OUTPUT HYDROGRAPH



SCALE: 1 in. = 2,000 ft

INPUT DATA

Subarea number, KNUM = 1
Inlet point number, INPUT = 65
Land use, KLAND = 2 (multi-family residential)
Subarea area, ASUB = 351 acres
Gutter length, GUTTER = 1,716 hundred ft

Subarea number, KNUM = 2
Inlet point number, INPUT = 65
Land use, KLAND = 3 (commercial)
Subarea area, ASUB = 15 acres
Gutter length, GUTTER = 72 hundred ft

Figure 3-15. SYSTEM REPRESENTATION OF THE EXAMPLE PROBLEM, SELBY STREET, SAN FRANCISCO

Table 3-11. EXAMPLE PROBLEM DATA INPUT, SURFACE QUALITY

DATA						CARD GROUP NO.
2	1	10.	8	55	30	15
	50.		14.	2		16
	1.		100.		150.	17
1	65	2		351.00	1716.00	18
2	65	3		15.00	72.00	18

Table 3-12. EXAMPLE PROBLEM OUTPUT, SURFACE QUALITY, GENERAL INFORMATION

```
NUMBER OF SUBAREAS, KTNUM =    2
NUMBER OF INLETS,   NINLTS =   1
TIME INTERVAL (MIN),    DT = 10.00
STORM START TIME (HR:MIN) =  8:55

DRYDAY =         50., CLFREQ=        14., NOPASS =      2

AVERAGE NO. CB/ACRE,     CBDEN =        1.
CB CONTENTS BOD (MG/L), CBBOD =      100.
CB STORED VOLUME (GAL), CBVOL =      150.
```

Table 3-13. EXAMPLE PROBLEM OUTPUT, SURFACE QUALITY, CALCULATED VOLUMES

TOTAL QUANTITIES REMOVED FROM THE AREA SERVING INPUT NO. 65,
DURING EACH TIME INCREMENT FOR 30 TIME STEPS

LAND USES TO THIS INLET	AREA ACRES	LENGTH OF GUTTERS HUNDREDS OF FEET	DUST & DIRT PRIOR TO STORM, LBS.	SOLUBLE BOD PRIOR TO STORM, LBS.
MULTI-FAMILY RESIDENTIAL:	351.00	1716.00	60057.45	216.21
COMMERCIAL:	15.00	72.00	3615.50	27.84

TIME	RUNCFS CFS	SUSPENDED SOLIDS (POPSS) LBS/DT	SUSPENDED SOLIDS (CONCSS) MG/L	FIVE-DAY BIOCHEMICAL OXYGEN DEMAND (CBINC) + LBS/DT	(POP) = LBS/DT	(CBASTM) LBS/DT	(CONBOD) MG/L
8:55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9: 5	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9:15	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9:25	0.33	3.27	529.13	0.78	0.48	1.25	203.10
9:35	3.46	82.24	1159.11	5.83	7.55	13.38	188.58
9:45	7.67	515.00	2471.75	10.71	34.55	45.26	217.25
9:55	11.63	1207.99	3343.49	12.02	72.18	84.19	233.03
10: 5	15.59	1474.09	2892.88	8.86	85.57	94.43	185.33
10:15	19.23	697.29	1069.73	4.77	45.79	50.56	77.56
10:25	21.78	451.47	588.07	1.94	32.63	34.57	45.03
10:35	27.84	462.83	498.27	0.67	33.55	34.21	36.83
10:45	35.63	633.16	532.89	0.18	43.65	43.83	36.89
10:55	34.18	721.53	552.12	0.03	48.18	48.22	36.89
11: 5	41.32	809.24	572.56	0.00	52.53	52.53	37.17
11:15	52.67	1162.62	660.77	0.00	71.82	71.82	40.82
11:25	71.47	1864.93	802.50	0.00	109.30	109.30	47.03
11:35	82.57	2663.45	923.65	0.00	150.29	150.29	52.12
11:45	88.00	3049.20	954.94	0.00	168.34	168.34	52.72
11:55	60.94	2237.87	802.63	0.00	123.54	123.54	44.31
12: 5	46.82	1191.65	590.73	0.00	66.90	66.90	33.16
12:15	39.80	790.86	487.72	0.00	44.83	44.83	27.65
12:25	36.03	617.79	435.20	0.00	35.13	35.13	24.74
12:35	27.00	445.97	377.96	0.00	25.56	25.56	21.66
12:45	17.33	249.74	300.94	0.00	14.65	14.65	17.66
12:55	11.90	132.26	241.71	0.00	7.98	7.98	14.59
13: 5	8.59	80.05	208.69	0.00	4.94	4.94	12.87
13:15	6.44	53.09	188.70	0.00	3.33	3.33	11.83
13:25	4.97	37.55	175.82	0.00	2.38	2.38	11.15
13:35	3.93	27.84	167.10	0.00	1.78	1.78	10.69
13:45	3.18	21.43	161.03	0.00	1.38	1.38	10.36
POUNDS REMOVED		21684.36		45.79	1288.80	1334.59	

SECTION 4

TRANSPORT BLOCK

SECTION 4

TRANSPORT BLOCK

BLOCK DESCRIPTION

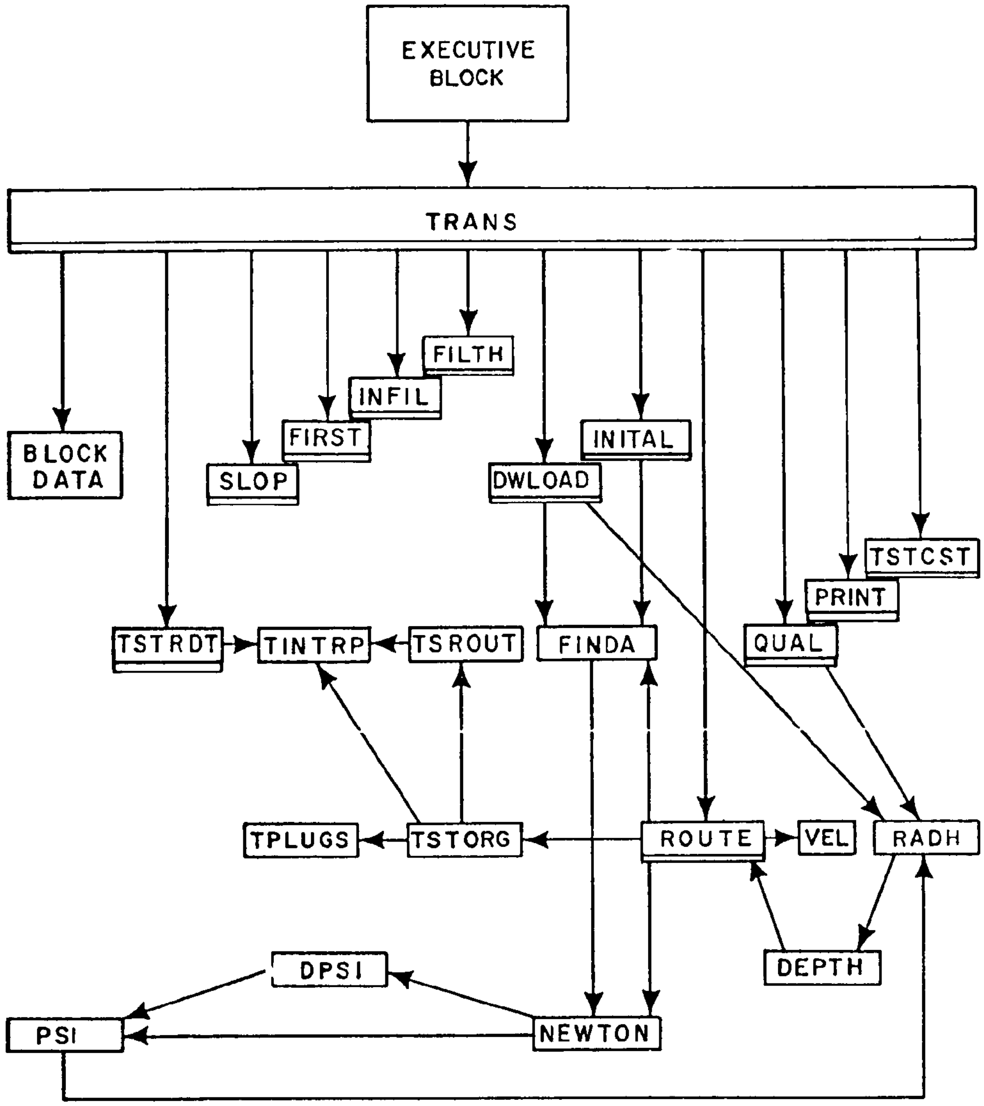
Flow routing through the sewer system is controlled by subroutine TRANS which is called from the Executive Block program. TRANS has the responsibility of coordinating not only routing of sewage quantities but also such functions as routing of quality parameters (subroutine QUAL), estimating dry weather flow (subroutine FILTH), estimating infiltration (subroutine INFIL), and calling internal storage (subroutine TSTRDT). The relationships among the subroutines which make up the Transport Block are shown in Figure 4-1. The FORTRAN program is about 4,050 cards long, consisting of 25 subroutines and functions.

This section describes the subroutines and functions used in the Transport Block, provides instructions on data preparation, and furnishes examples of program usage.

The 12 major subroutines are described in the order in which they are called in a typical computer run. The 11 minor subroutines and functions, which may be called by any of several subroutines, are described in alphabetical order at the end of the subsection.

Instructions are provided for these subroutines requiring card input data, namely: transport, internal storage, infiltration, and DWF.

Examples, with sample I/O data, are given for transport, infiltration, and DWF computations. Internal storage procedures are similar to those described in Section 5; hence they are not presented here.



Note: Arrows point from the calling program to the called program. Boxes with double underline represent major subroutines.

Figure 4-1. TRANSPORT BLOCK

Broad Description of Flow Routing

To categorize a sewer system conveniently prior to flow routing, each component of the system is classified as a certain type of "element." All elements in combination form a conceptual representation of the system in a manner similar to that of links and nodes. Elements may be conduits, manholes, lift stations, overflow structures, or any other component of a real system. Conduits themselves may be of different element types depending upon their geometrical cross-section (e.g., circular, rectangular, horseshoe). A sequencing is first performed (in subroutine SLOP) to order the numbered elements for computations. Flow routing then proceeds downstream through all elements during each increment in time until the storm hydrographs have been passed through the system.

An option in the program is the use of the internal storage model which acts as a transport element. The model provides the possibility of storage of the routing storm at one or two separate points within the sewer system (restricted by computer core capacity). The program routes the flow through the storage unit for each time-step based on the equation Qinflow = Qoutflow + change in storage. Entry to the internal storage subroutines is through TSTRDT (for data), TSTORG (for computations), and TSTCST (for cost).

Broad Description of Quality Routing

Contaminants are also handled by the Transport Block. Pollutants may be introduced, at the user's option, to the sewage system at three locations:

1. Storm-generated pollutographs computed by the Runoff Block are transferred on tape/disk devices to enter the system at designated inlet manholes.
2. Residual bottom sediment in the pipes may be resuspended due to the flushing action of the storm flows (subroutine DWLOAD).
3. For combined systems, DWF pollutographs (subroutine FILTH) are also entered at designated inlet manholes.

The routing of the pollutants is then done for each time-step by subroutine QUAL. The maximum number of contaminants that can be routed is four.

SUBROUTINE DESCRIPTIONS

Subroutine TRANS (B)

Subroutine TRANS is the coordinating program for all quantity and quality routing in the sewer system. Most of the I/O is performed in this program, the principal exceptions being I/O to subroutines FILTH and INFIL described later. All interfacing with the Executive Block, hence with other Storm Water Management programs, is done through TRANS, and all I/O statements requiring tape/disk units are located in TRANS; some scratch tapes are also used in conjunction with subroutine PRINT. The program also performs certain functions in relation to quantity routing which will be described subsequently. A detailed flow chart of TRANS is shown in Figure 4-2.

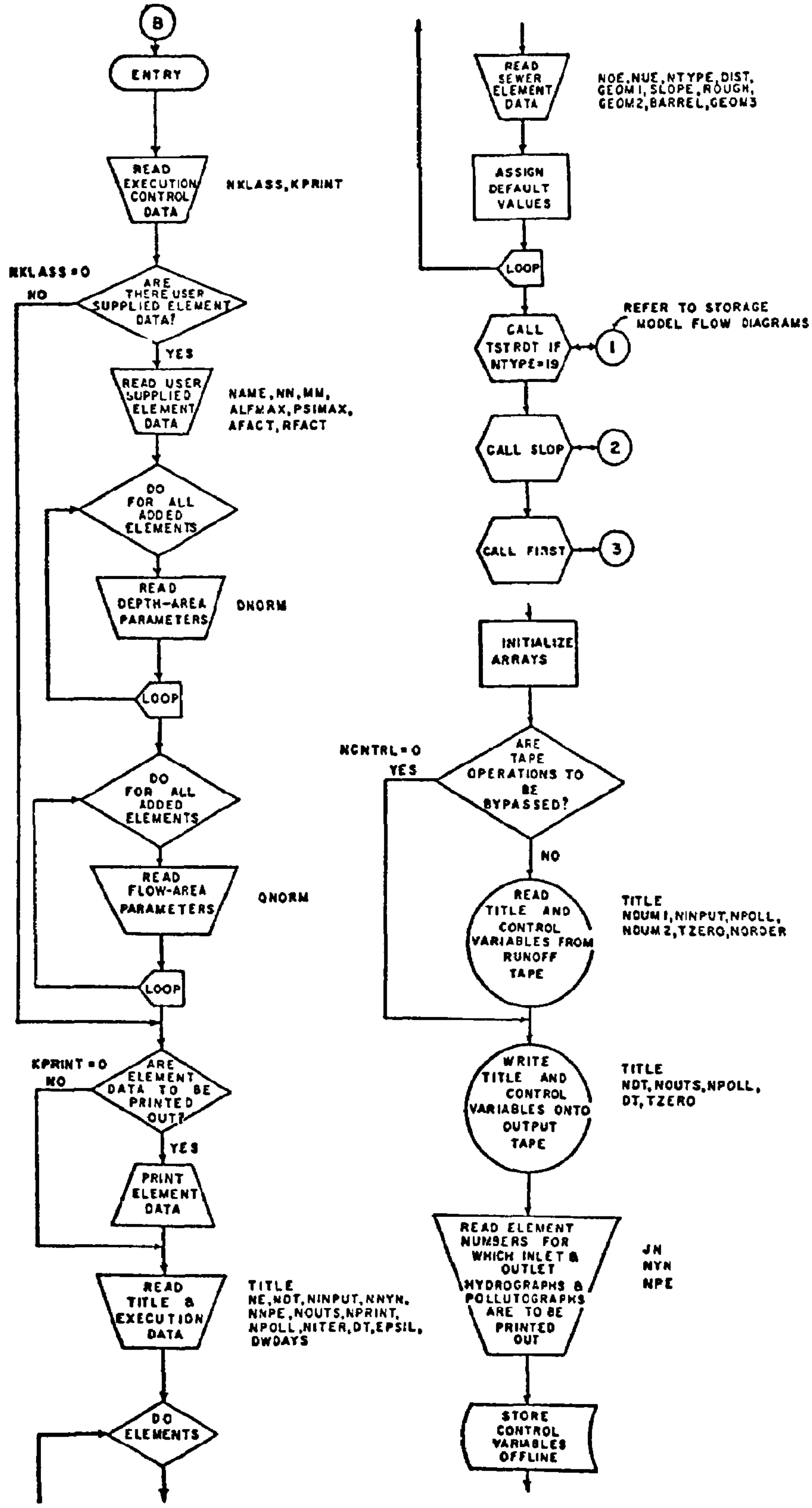


Figure 4-2. SUBROUTINE TRANS

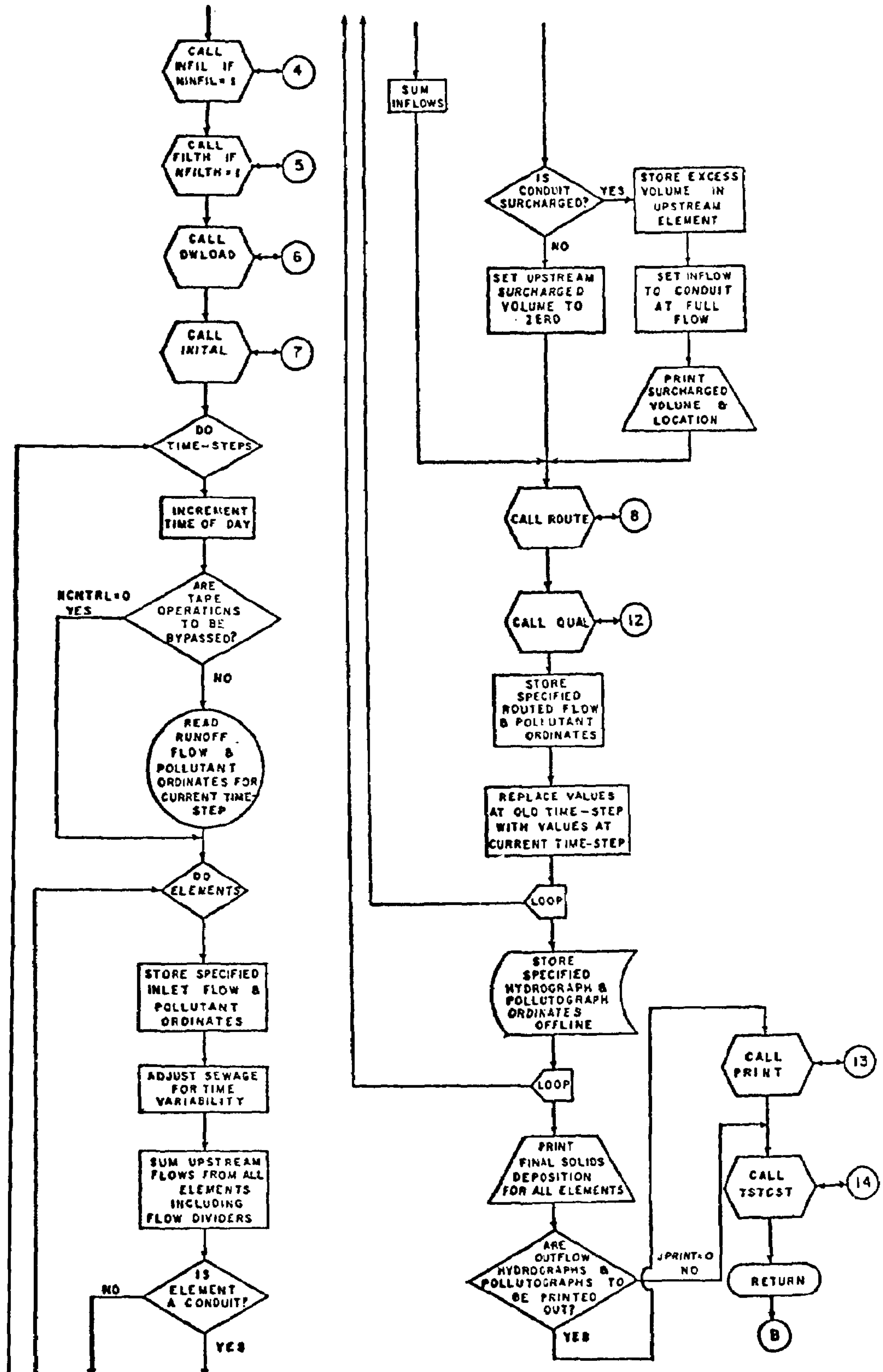


Figure 4-2. (continued)

Most of the input to TRANS relates to data needed to describe the particular sewer system being modeled (e.g., dimensions, slopes, roughnesses, etc.) and parameters needed to solve the governing flow routing equations.

Following input of these data, the sewer elements are sequenced for computations in subroutine SLOP. Certain geometric and flow parameters are then initialized in subroutine FIRST while others are initialized in TRANS. The various program parameters and initialized variables describing the elements are then printed.

Element numbers at which storm hydrographs and pollutographs will enter the system are read from a tape in the order in which hydrograph and pollutograph ordinates will be read at each time-step from tapes. Parameters relating to the amount of data to be stored and printed out are also read (from cards).

If indicated, infiltration values will be calculated in subroutine INFIL and DWF quantity and quality parameters will be calculated in subroutine FILTH. Subroutine DWLOAD then initializes suspended solids deposition, and subroutine INITAL initializes flows and pollutant concentrations in each element to values corresponding to a condition of only dry weather flow and infiltration.

The main iterations of the program consist of an outer loop on time-steps and an inner loop on element numbers in order to calculate flows and concentrations in all elements at each time-step. Inlet hydrographs and pollutograph ordinates are read from a tape at each time-step prior to entering the loop on element numbers.

When in the loop on element numbers (with index I), the current sewer element through which flows are to be routed, indicated by the variable M, is determined from the vector JR(I). This array is calculated in subroutine SLOP in a manner to insure that prior to flow routing in a given element, all flows upstream will have been calculated.

When calculating flows in each element, the upstream flows are summed and added to surface runoff, DWF, and infiltration entering at that element. These latter three quantities are allowed to enter the system only at non-conduits, (e.g.,manholes, flow dividers). If the element is a conduit, a check for surcharging is made. If the inflow exceeds the conduit capacity, excess flow is stored at the element just upstream (usually a manhole) and the conduit is assumed to operate at full-flow capacity until the excess flow can be transmitted. A message indicating surcharging is printed.

Flows are then routed through each element in subroutine ROUTE and quality parameters are routed in subroutine QUAL. When routing flows in conduits, ROUTE may be entered more than once depending upon the value of ITER, the number of iterations. It is necessary to iterate upon the solution in certain cases because of the implicit nature of calculating the energy grade line in ROUTE (see description of ROUTE).

Upon completion of flow and quality routing at all time-steps for all elements, TRANS then performs the task of outputting the various data.

Hydrograph and pollutograph ordinates for the outfall point(s) are written onto tape for further use by the Executive Block, and subroutine PRINT is then called for printing outflows for any other desired elements.

Subroutine TSTRDT (1)

Subroutine TSTRDT is the data input program for internal storage and is equivalent to subroutine STRDAT in the Storage Block. Basin geometry, flood level, and outlet controls must be specified. An outline flow chart of subroutine TSTRDT is shown in Figure 4-3.

Note that in order for subroutine TSTRDT to be called (from subroutine TRANS), element type 19 must be specified in one or more locations on the TRANS data cards. Presently, restrictions on machine capacity limit the maximum number of internal storage or backwater sites to 2 locations.

Subroutine SLOP (2)

Subroutine SLOP orders the elements for computation so that all flows upstream of a given element will have been routed prior to flow routing in the given element. In this way routing at each time-step proceeds downstream from those elements farthest upstream.

All elements are numbered for identification, and all parameters describing a given element are read in from one data card. In the ensuing discussion, external element numbers refer to those numbers assigned to sewer elements by persons responsible for reducing the physical sewer system data. For example, the external element number assigned

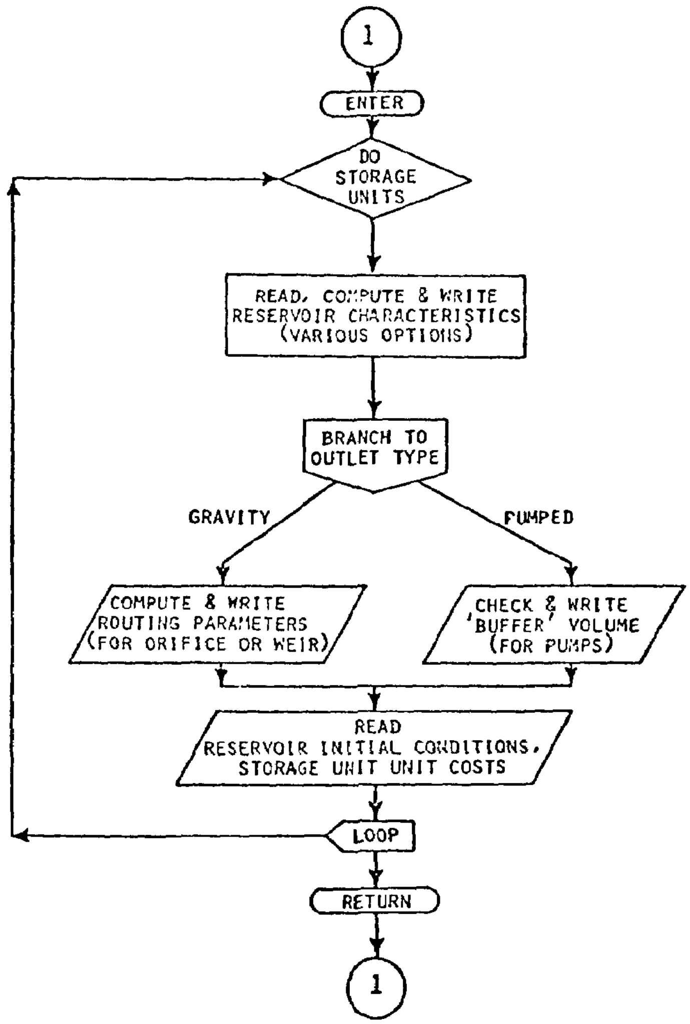


Figure 4-3. SUBROUTINE TSTRDT

to a manhole on a map might be 213. However, due to the fact that the element data cards can be read into the computer in a random order, the internal element number is the subscript assigned to data parameters of the element by the program. For example, the card with the data for manhole number 213 may be the 49th element card read in. The internal number (subscript) associated with all data for that element will be 49.

The first task of SLOP is to determine the internal numbers of upstream elements (INUE) corresponding to the external upstream element number (NUE) entered on each data card. If an element has no elements upstream, an artificial value equal to NE+1 is assigned to the upstream element number, where NE is the total number of elements. All flows subscripted by NE+1 are subsequently assigned zero values.

After determining the internal upstream element numbers, SLOP sequences elements for computation. An element may be sequenced only after all its upstream elements have been sequenced. The vector IR indicates whether upstream elements have met this condition. When an element is found available for sequencing at step i, the internal element number is placed in the ith location of the vector JR. Thus, JR(1) contains the internal number of the element through which flows will be routed first at each time-step. JR(2) contains the number of the second element, etc.

Upon completion of the sequencing, the computation sequence and other element information is printed out. A flow chart of SLOP is shown in Figure 4-4.

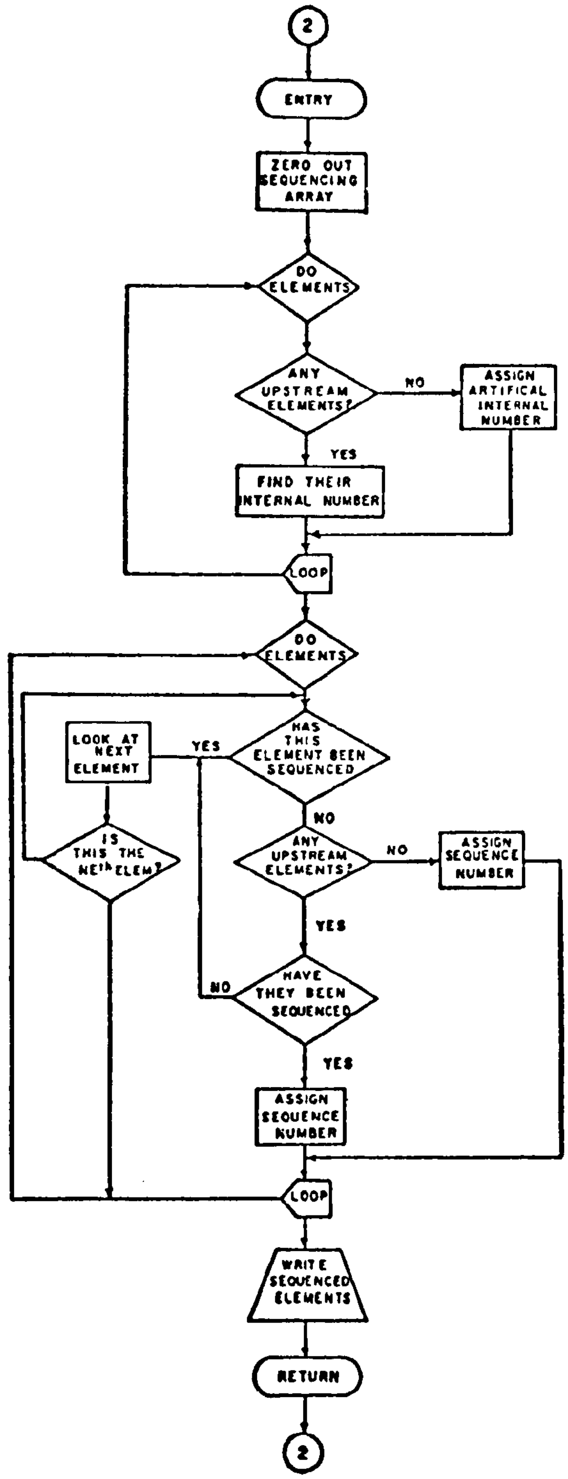


Figure 4-4. SUBROUTINE SLOP

Subroutine FIRST (3)

Subroutine FIRST calculates parameters of each element that will remain constant throughout flow routing, such as the cross-sectional area of the conduit when flowing full (AFULL), the ratio of the conduit length to the time-step (DXDT), and other geometrical and flow parameters. Manning's equation is used in the calculation of flow parameters. Non-conduit parameters, in general, require little initialization in this subroutine. A flow chart of FIRST is shown in Figure 4-5.

Subroutine INFIL (4)

The infiltration program, INFIL, has been developed to estimate infiltration into a given sewer system based upon existing information about the sewer, its surrounding soil and groundwater, and precipitation.

Using these data, INFIL has been structured to estimate average daily infiltration inflows at discrete locations along the trunk sewers of a given sewer system. A typical urban drainage basin in which infiltration might be estimated is shown in Figure 4-6.

Since the Storm Water Management Model's principal use will be to simulate individual storms which cover a time period of less than a day, average daily estimates from INFIL are calculated only once prior to sewer flow routing. INFIL is called from subroutine TRANS by setting the variable, NINFIL, equal to 1, thus signaling the computer to estimate infiltration. Figure 4-7 represents a flow chart of the subroutine.

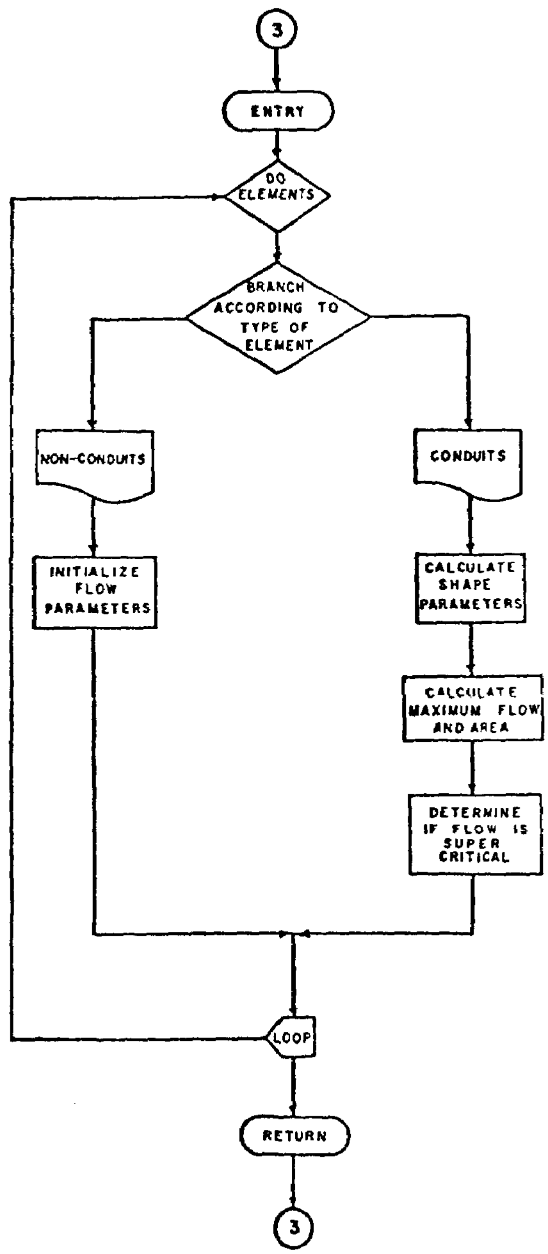


Figure 4-5. SUBROUTINE FIRST

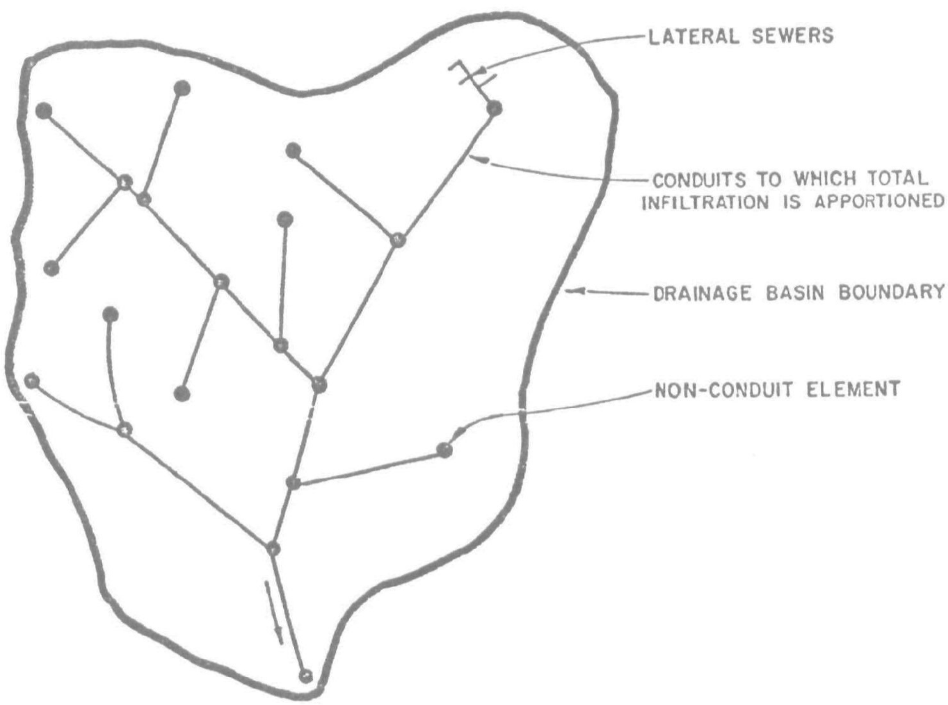


Figure 4-6. TYPICAL DRAINAGE BASIN IN WHICH INFILTRATION IS TO BE ESTIMATED

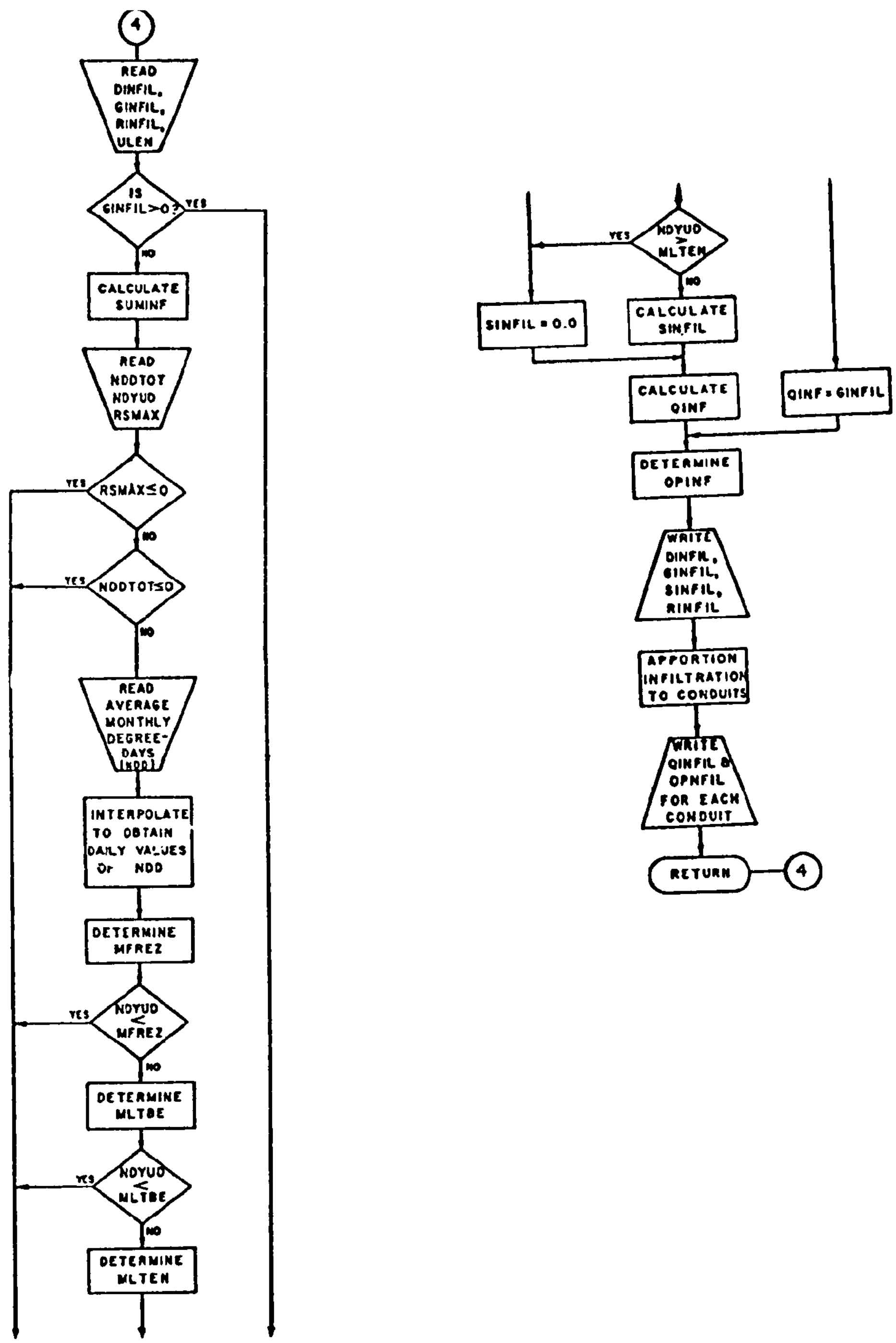


Figure 4-7. SUBROUTINE INFIL

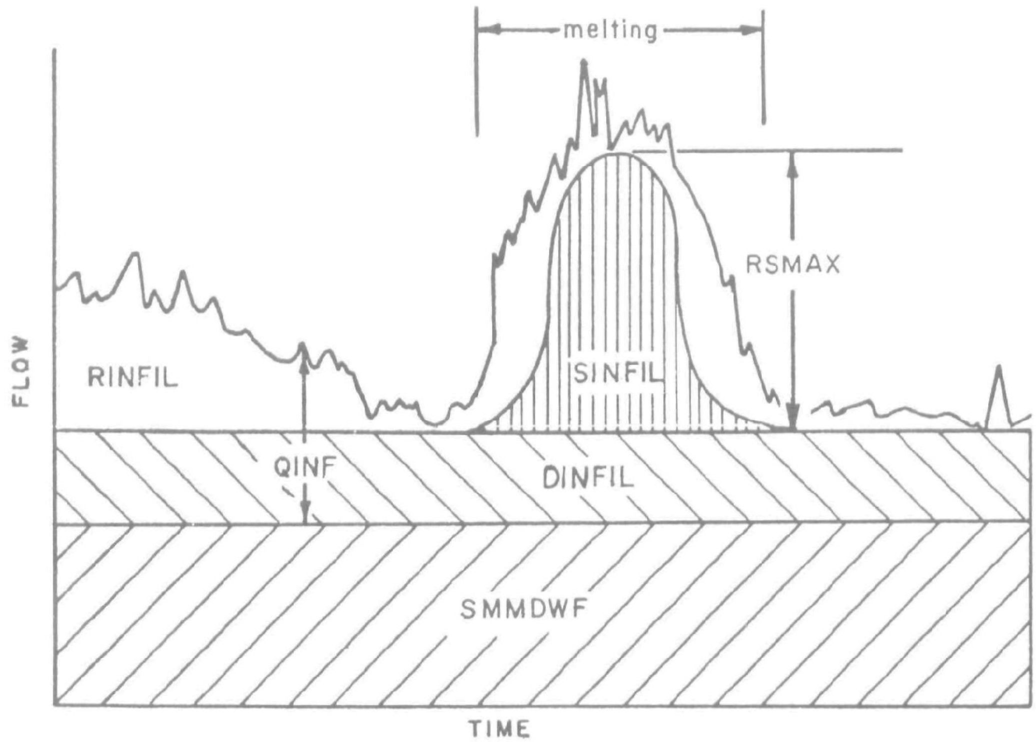
For the purposes of analysis, infiltration was classified into four categories, i.e., miscellaneous sources causing a base dry weather inflow, frozen residual moisture, antecedent precipitation, and high groundwater. The cumulative effects of the first three sources can be seen in Figure 4-8 which excludes surface runoff. Figure 4-8 shows total infiltration QINF as the sum of dry weather infiltration DINFIL, wet weather infiltration RINFIL, and melting residual ice and frost infiltration SINFIL. However, in cases where the groundwater table occurs above the sewer invert, it was assumed that groundwater GINFIL alone will be the dominant source of infiltration. Thus, infiltration is defined according to Eq. 1.

$$\text{QINF} = \begin{cases} \text{DINFIL + RINFIL + SINFIL} \\ \qquad\text{or} \\ \text{GINFIL for high groundwater table} \end{cases} \tag{1}$$

Throughout subroutine INFIL, observations and estimates based upon local data are given preference over generalized estimates for infiltration. Thus, the hierarchy for basing estimates is as stated in the following list:

1. Use historical data for the study area under consideration.
2. Use historical data for a nearby study area and adjust results accordingly.
3. Use estimates of local professionals.
4. Use generalized estimates based upon countrywide observations.

Dry Weather Infiltration (DINFIL). If the study area under consideration has been gaged, base dry weather infiltration can be taken by



QINF = Total infiltration
DINFIL = Dry weather infiltration
RINFIL = Wet weather infiltration
SINFIL = Melting residual ice and snow infiltration
RSMAX = Residual moisture peak contribution
SMMDWF = Accounted for sewage flow

Figure 4-8. COMPONENTS OF INFILTRATION

inspection from the flow data. In the absence of flow data, an estimate of the unit infiltration rate XLOCAL (gpm/in. diam/mile) for dry weather must be obtained from local professionals. From data in the form of calculated values of DIAM and PLEN, Eq. 2 can then be used to determine DINFIL.

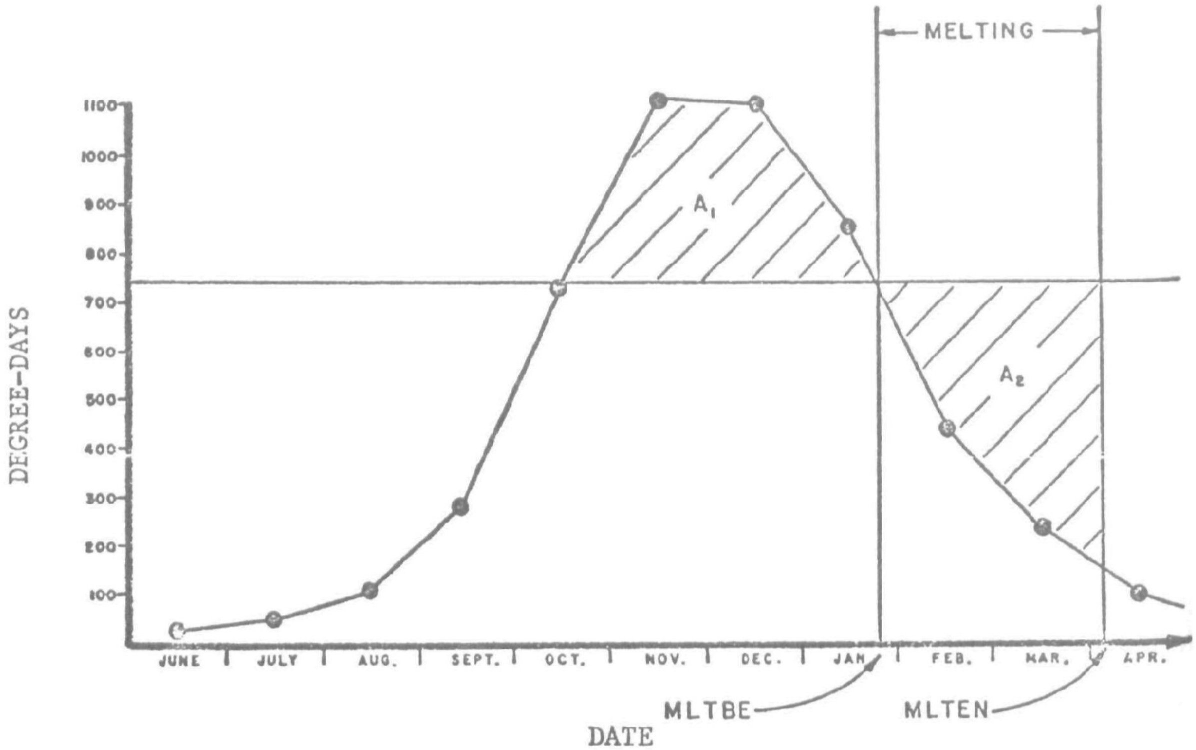
$$DINFIL = XLOCAL * DIAM * PLEN \qquad (2)$$

where DIAM = Average sewer diameter (in.)

PLEN = Pipe length (mi).

Residual Melting Ice and Frost Infiltration (SINFIL). SINFIL arises from residual precipitation such as snow as it melts following cold periods. Published data (Ref. 1) in the form of monthly degree days (below 65°F) provide an excellent index as to the significance of SINFIL. Average monthly degree-days for cities in the United States are reproduced in Appendix A. The onset and duration of melting can be estimated by noting the degree days NDD above and immediately below a value of 750. Refer to Figure 4-9 for the following description.

Within subroutine INFIL, the beginning of melting MLTBE is taken as the day on which NDD drops below 750. Next, MLTEN is determined so that A_1 equals A_2. In the absence of evidence to the contrary, it is assumed that the melting rate is sinusoidal. The maximum contribution RSMAX from residual moisture can be determined from previous gaging of the study area or local estimates. In either case SINFIL is determined within the program by Eq. 3.



MLTBE = Day on which melting period begins
MLTEN = Day on which melting period ends

Figure 4-9. PRESCRIBED MELTING PERIOD

$$\text{SINFIL} = \begin{cases} \text{RSMAX*sin } [180*(\text{NDYUD-MLTBE})/(\text{MLTEN-MLTBE})] \\ 0.0 \text{ if NDYUD is not in melting period or if NDD never exceeds 750.} \end{cases} \quad (3)$$

where NDYUD = Day on which infiltration estimate is desired

RSMAX = Residual moisture peak contribution (gpm)

MLTBE = Beginning of melting period (day)

MLTEN = End of melting period (day).

Antecedent Precipitation (RINFIL). RINFIL depends upon antecedent precipitation occurring within 9 days prior to an estimate. If antecedent rainfall is unavailable or less than 0.25 inch, the RINFIL contribution to QINFIL is set equal to 0.0. From analyses on reported sewer flow data not affected by melting, RINFIL was found to satisfy the following linear relationship:

$$\text{RINFIL} = \text{ALF} + \text{ALF0} * \text{RN0} + \text{ALF1} * \text{RN1} + \ldots + \text{ALF9} * \text{RN9} \quad (4)$$

where RINFIL = SWFLOW - DINFIL - SMMDWF

ALFN = Coefficient to rainfall for N days prior to estimate

RNN = Precipitation on N days prior to estimate (in.)

SWFLOW = Daily average sewer flow excluding surface runoff (gpm)

SMMDWF = Accounted for sewage flow (gpm).

To determine the coefficients in Eq. 4, a linear regression should be run on existing flow and rainfall data. For comparative purposes, the results of regression analyses for study areas (Ref. 2) in three selected cities are given in Table 4-1.

Table 4-1. RINFIL EQUATIONS FOR THREE STUDY AREAS

Study Area	Equation
Bradenton, Florida	RINFIL = 4.1 + 2.9RN0 + 17.5RN1 + 15.0RN2 + 12.8RN3 + 13.0RN4 + 10.4RN5 + 13.2RN6 + 10.1RN7 + 11.8RN8 + 9.5RN9
Baltimore, Maryland	RINFIL = 2.4 + 11.3RN0 + 11.6RN1 + 5.5RN2 + 6.4RN3 + 4.8RN4 + 3.6RN5 + 1.0RN6 + 1.5RN7 + 1.4RN8 + 1.8RN9
Springfield, Missouri	RINFIL = 2.0 + 18.3RN0 + 13.9RN1 + 8.9RN2 + 5.5RN3 + 6.7RN4 + 16.4RN5 + 5.2RN6 + 4.6RN7 + 4.4RN8 + 1.3RN9

High Groundwater Table (GINFIL). For locations and times of the year that cause the groundwater table to be above the sewer invert, groundwater infiltration GINFIL supersedes any notations of DINFIL, RINFIL, and SINFIL. GINFIL can be determined from historical sewer flow data by inspection or regression analysis. Regression analysis would involve determineation of the BETA coefficients in Eq. 5.

GINFIL = BETA + BETA1 * GWHD + BETA2*GWHD**2 + BETA3 * GWHD**0.5 (5)

where GWHD = Groundwater table elevation above sewer invert (ft)

BETAN = Coefficient for term N in Eq. 5.

Apportionment of Infiltration. Once an estimate of local infiltration QINF has been obtained, this flow must be apportioned throughout the designated study area. The criterion chosen for apportionment is an opportunity factor OPINF which represents the relative number and length of openings susceptible to infiltration. Pipe joints constitute the primary avenue for entry of infiltration (Ref. 3).

OPINF for an entire study area is determined within INFIL using Eq. 6:

$$OPINF = \sum_{\text{conduits}} (\pi * DIAM * DIST/ULEN) \quad (6)$$

where π * DIAM = Pipe circumference (ft)

DIST/ULEN = Number of joints in each conduit

ULEN = Average distance between joints.

Hydrologic Data. Concurrent historical rainfall, water table, and sewer flow data of several weeks' duration are needed to completely describe infiltration. In addition, rainfall for the 9 days prior to the flow estimate is required to satisfy the regression equation for RINFIL.

Ideally, the rainfall record would be from a rain gage which is located near the center of the study area and which records daily rainfall in inches. If more than one rain gage is located within the study area, daily measurements from all gages should be averaged. Missing data (e.g., from a malfunctioning gage) or a total absence of measurements due to no gaging within the study area can be overcome with measurements taken from a rain gage located within a few miles. If Weather Bureau Climatological Data recorded at the nearest airport or federal installation are not available, contact the National Weather Bureau Records Center for assistance (Ref. 4).

Should some other form of precipitation, e.g., snowfall, be encountered, it will be necessary to convert this to equivalent rainfall. If estimates are unavailable from the Weather Bureau, the ratio of 10 inches of snow to 1 inch of rain may be used.

Water table data should also be obtained from gaging within the study area. However, shallow-well data from the U. S. Geological Survey or state geological office can be used to supplement missing data. Water table elevations are not required if they are below the sewer inverts for the day on which QINF is to be estimated.

Sewer Data. Sewer flow data for regression analysis should be taken from a gage located at the downstream point within the study area. Upstream gaging may be used to estimate flows at the downstream point by simply adjusting flows based upon respective surface area.

Physical sewer data (e.g., lengths, diameters, shapes) are taken from information used within TRANS to route sewer flow. To assist in determining the number of joints in the trunk sewer, an estimate of the average pipe section length ULEN should be supplied.

Subroutine FILTH (5)

Subroutine FILTH has been developed to estimate average sewage flow and quality from residential, commercial, and industrial urban areas. FILTH estimates sewage inputs at discrete locations along the trunk sewers of any specified urban drainage basin. These estimates are calculated from data describing drainage basin subsections (subcatchments and subareas) under which the trunk sewer passes. An example of a hypothetical sewer system and input situation is given in Figure 4-10 To save repetition all drainage basin subdivisions will be referred to

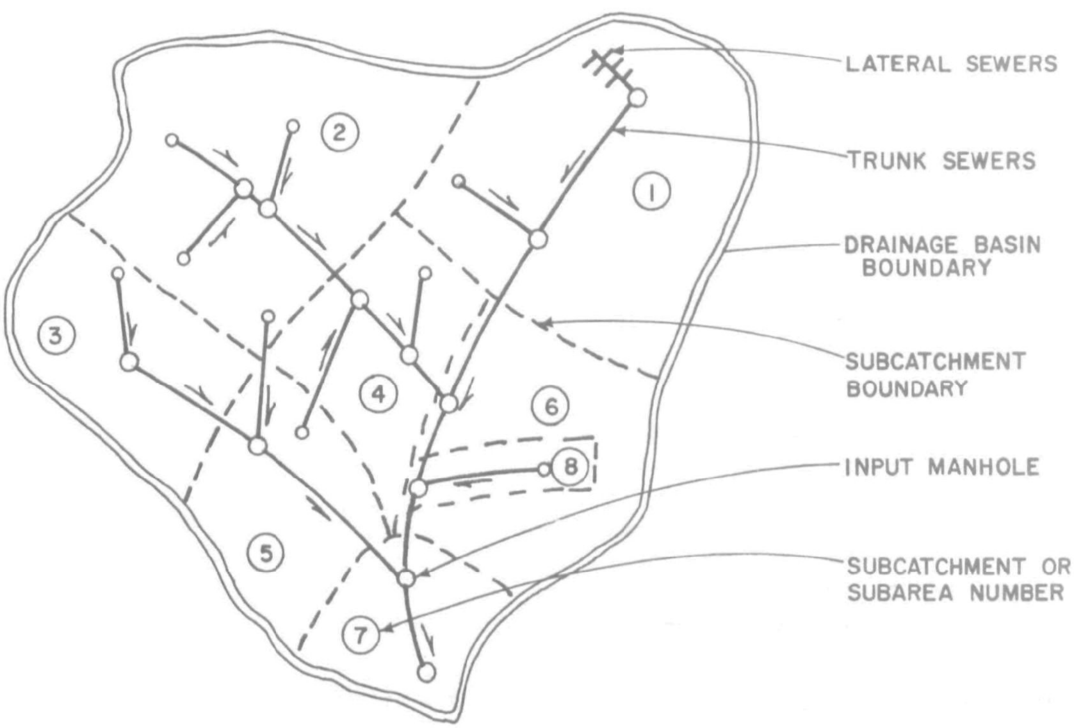


Figure 4-10. TYPICAL DRAINAGE BASIN IN WHICH DRY WEATHER FLOW IS TO BE ESTIMATED

as subareas in the following discussion. As shown in the figure, an input manhole near the center of each subarea is assumed to accept all sewage flow from that subarea. Criteria for establishing subarea boundaries and input locations are discussed later in the text.

In the context of the Storm Water Management Model, FILTH calculates daily sewage flow (cfs) and characteristics (BOD, SS, and total coliforms) averaged over the entire year for each subarea. FILTH is called from the program TRANS by setting the parameter NFILTH equal to 1. Flow and characteristic estimates and corresponding manhole input numbers are then returned to TRANS where the estimates undergo adjustment depending upon the day of the week and hour of the day during which simulation is proceeding. Reference to Figure 4-11 will assist in understanding the structure and logic of FILTH.

The subroutine is omitted when modeling separate storm sewers.

FILTH is designed to handle an unrestricted number of inlet areas and individual process flow contributors. As a safeguard against faulty data, however, a program interrupt is provided if the combined number exceeds 150, which is a limit set by the Transport Model.

Quantity Estimates. The three data categories used to estimate sewage flows are: (1) drainage basin data, (2) subarea data, and (3) decision and adjustment parameters.

Study area data are TOTA, KTNUM and ADWF. KTNUM denotes the number of subareas into which a drainage basin, having a surface area TOTA (acres),

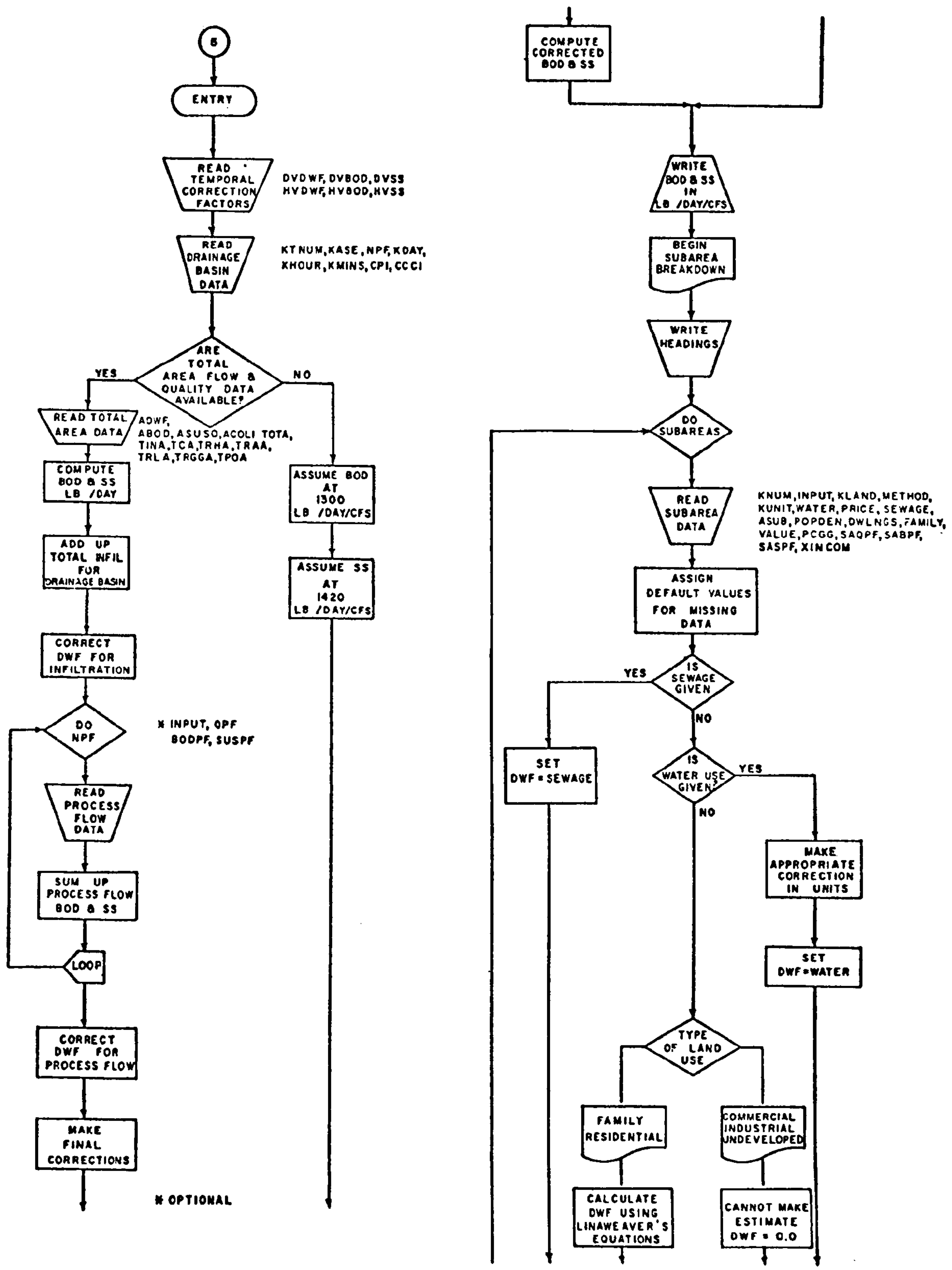


Figure 4-11. SUBROUTINE FILTH

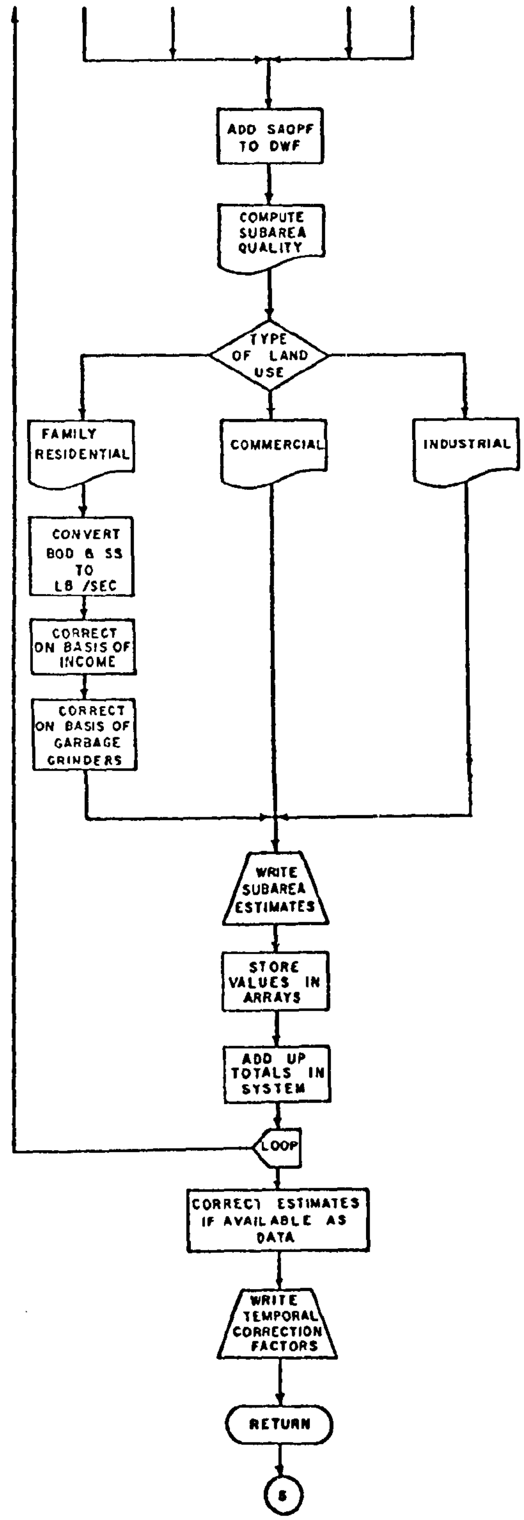


Figure 4-11. (continued)

is being divided. ADWF, which is optional depending upon its availability, gives the average sewage flow (cfs) originating from the entire drainage basin (e.g., average flow data from a treatment plant serving the study area).

Subarea data requirements consist of several options depending upon availability and choice of input. Discussion later in the text will assist in data tabulation by noting the order of preference where options exist. Subarea data can be broken into three categories as follows: (1) identification parameters, (2) flow data, and (3) estimating data.

1. Identification Parameters

Identification parameters are KNUM, INPUT, and KLAND. KNUM identifies each subarea by a number less than or equal to KTNUM. For each of the KTNUM subareas, INPUT indicates the number of the manhole into which DWF is assumed to enter. Land use within each subarea which approximately corresponds to zoning classification, is categorized according to Table 4-2. KLAND serves as an important factor in deciding subarea locations and sizes. Figure 4-12 will assist in describing how the above data are determined and tabulated.

2. Flow Data

Flow data are optional inputs that eliminate the need for using predictive equations. Two possible types of flow data are average sewage flow measurements, SEWAGE, and metered water use, WATER. Commercial or industrial sewage flow or

Table 4-2. LAND USE CLASSIFICATION

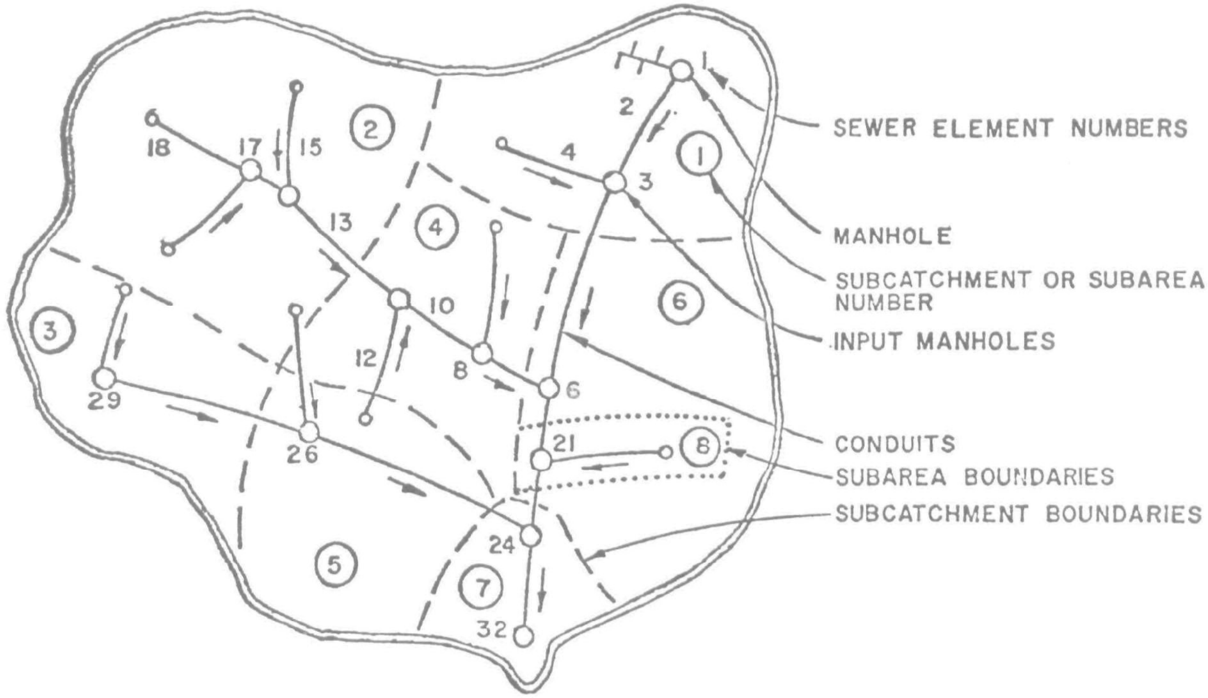
KLAND	
1	Single-family residential
2	Multi-family residential
3	Commercial
4	Industrial
5	Park and open area

water use measurements should be input using the variable SAQPF. Flows from commercial and industrial establishments located in residential subareas may be included using SAQPF, also.

Metering at lift stations and other flow control structures within the study area is occasionally available and should be used whenever possible. Metered water use offers a more available source of subarea flow data. Unfortunately, considerable effort in locating, tabulating, and averaging these data is often required.

3. Estimating Data

For each subarea where SEWAGE and WATER measurements are not available, estimated water use must be used as an estimate of sewage flow. In the case of a factory or commercial establishment, estimates can be made by multiplying the number of employees by an established coefficient (gpd per employee). In the case of a large factory or commercial establishment,



Sewer and Subcatchment Data

1. Manhole 32 is the most downstream point.
2. Subcatchments 1,2,3, and 4 are single-family residential areas, each 100 acres in size and each with water metering.
3. Subcatchments 5 and 7 are 220-acre industrial areas.
4. Subarea 6 is a 250-acre park.
5. Subarea 8 is a 50-acre commercial area.

Subareas 6 and 8 constitute a subcatchment draining to input manhole number 21.

Resulting Data

8 sewage estimates
KTNUM, total subcatchments and subareas in drainage basin = 8.
TOTA, total acres in drainage basin = 1,140.

KNUM, subcatchment or subarea	INPUT, input manhole number	KLAND, land use category	ASUB, acres in subcatchment or subarea
1	3	1	100
2	17	1	100
3	29	1	100
4	8	1	100
5	26	4	220
6	21	5	250
7	24	4	220
8	21	3	50

Figure 4-12. DETERMINATION OF SUBCATCHMENT AND IDENTIFICATION DATA TO ESTIMATE SEWAGE AT 8 POINTS

one subarea may be established with estimated water use tabulated as SAQPF for that subarea. On the other hand, estimates of water use for established non-residential areas (e.g., industrial parks or shopping centers) may be summed and tabulated as SAQPF for one large subarea. A list of the above mentioned coefficients is given in Appendix A.

In the case of residential areas, estimating data for each subarea are METHOD, PRICE, ASUB, POPDEN, DWLNGS, FAMILY, and VALUE. Default values and definitions of each of these are given in the description of input data.

Decision and adjustment parameters consist of DVDWF, HVDWF, KDAY, KHOUR, KMINS, CPI, and CCCI. DVDWF and HVDWF are daily and hourly correction factors, respectively, for DWF. DVDWF is comprised of 7 numbers that are ratios of daily average sewage flows to weekly average flow. Likewise, HVDWF is comprised of 24 numbers that are ratios of hourly average sewage flows to daily average flow. Both groups of numbers have been derived from observed flow variation patterns throughout the country (Refs. 5, 6). Their use is to correct measured or estimated average sewage flow to more accurate estimates depending upon the day and hour. Typical sewage flow variations are shown in Figures 4-13 and 4-14. Even though these flow patterns are suggested, locally observed patterns more accurately describe local variations and should be used when available.

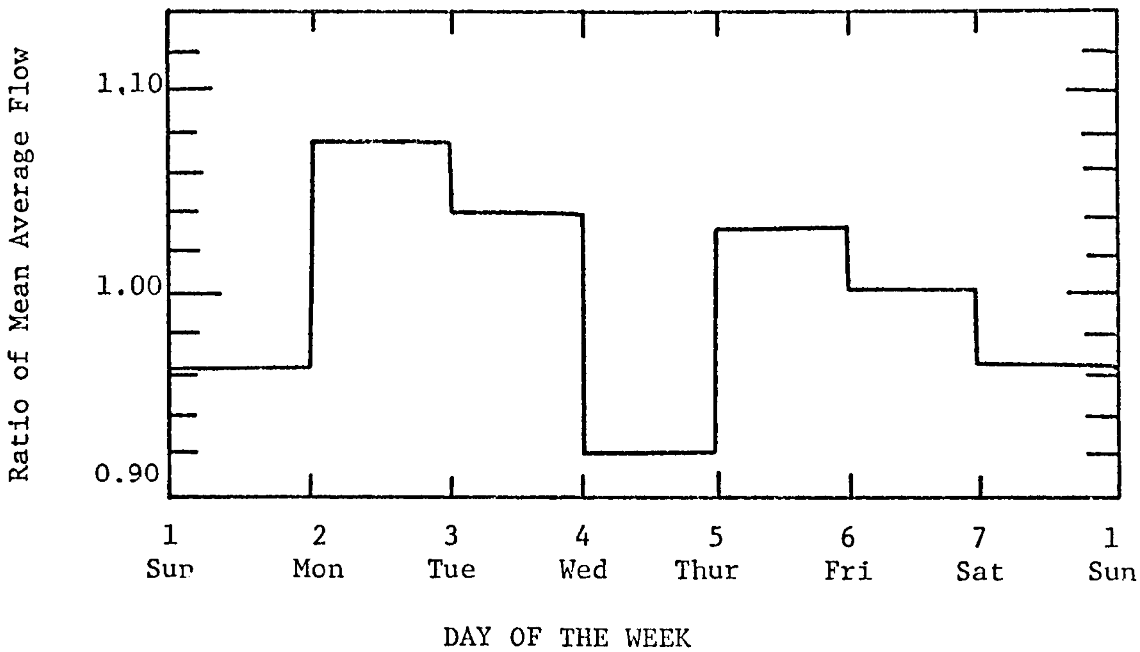


Figure 4-13. REPRESENTATIVE DAILY FLOW VARIATION

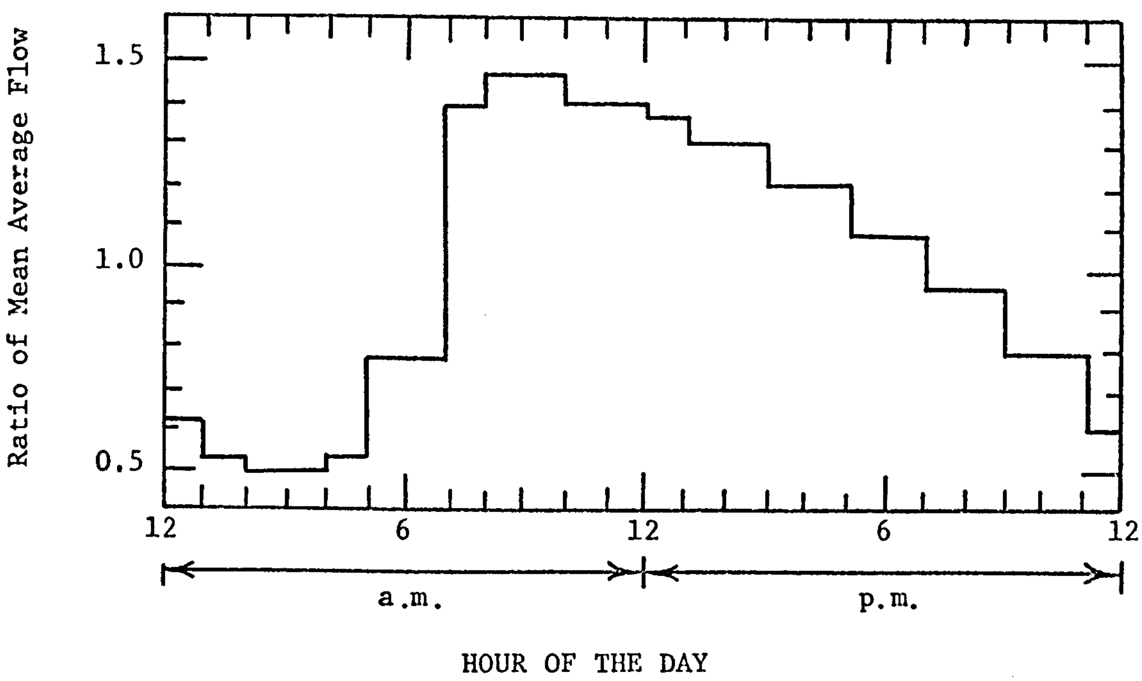


Figure 4-14. REPRESENTATIVE HOURLY FLOW VARIATION

KDAY, KHOUR, and KMINS denote the day, hour, and minute at which simulation is to begin. As simulation proceeds, these values are continually updated to their correct values. By noting the current day and hour, the appropriate values of DVDWF and HVDWF can be multiplied by average flow to determine the correct value. KDAY ranges from 1 to 7 with Sunday being day number 1. KHOUR ranges from 1 to 24 with midnight to 1 a.m. being hour number 1. Likewise, KMINS ranges from 1 to 60 with minute 1 being the first minute after the hour.

Two cost indices are employed to adjust current house valuations and water prices to appropriate 1960 values and 1963 prices, respectively. This is done because estimating equations within FILTH are based upon 1960 values and 1963 prices. CPI, consumer price index, has been chosen to adjust water price by multiplying water price by 1960 CPI divided by the current CPI. CCCI, composite construction cost index, has been chosen to adjust house valuations similarly. Both indices can be found in most libraries in journals on economic affairs (Refs. 7, 8).

Quality Estimates. The purpose of the DWF quality computation is to apportion waste characteristics (such as would be measured at a sewage treatment plant before treatment) among the various subareas in the drainage basin under study, or, in the event no measured data are available, to estimate and apportion usable average values. The apportionment is based upon the flow distribution, land use, measured or estimated industrial flows, average family income, the use or absence of garbage grinders, and infiltration. A generalized flow diagram showing the interrelationships with the quantity computations is shown in Figure 4-11.

When called, subroutine FILTH first reads in an array of daily and hourly flow and characteristic variations. All are expressed as ratios of their respective yearly or daily averages and they are stored in real time sequence (one set of values for each day starting with Sunday or each hour starting at 1:00 a.m.).

The next card read gives the total number of subareas and process flow sources to be processed; the type case--that is, whether the total DWF characteristics are known or to be estimated; the number of process flow contributors; the starting time of the storm event; the cost indices; and the total drainage basin population.

The next series of computations sets values for A1BOD, A1SS, and A1COLI, which are the average weighted DWF characteristics in lb/day/cfs for BOD and SS and in MPN/day/capita for total coliforms. Depending upon the instructions given, computations proceed along Case 1 or Case 2 channels.

<u>Case 1</u>

In this instance the total DWF quality characteristics are known at a point well downstream in the system. These characteristics may be obtained from treatment plant operating records (raw sewage) or by a direct sampling program. The average daily values are read into the program for flow, BOD, SS, and coliforms. The total pounds per day of BOD and SS and the total MPN per day of coliforms are then calculated. Then, infiltration is subtracted from the average daily flow. (Note that infiltration is computed by a separate subroutine of the Transport Model and must be executed prior to subroutine FILTH or a default value will be assumed.)

Next, the known process flow contributions are summed and deducted from the daily totals, yielding a further corrected flow, C2DWF, and characteristics, C1BOD and C1SS.

Finally, corrections are made for personal income variations, degree of commercial use, and garbage grinder status. The DWF quantity does not change but the characteristics obtain new, weighted values, C2BOD and C2SS.

A1BOD and A1SS are then computed directly. A1COLI is computed by dividing the total MPN per day by the total population.

Case 2

Here no direct measurements are available; thus, estimates must be made or default values will be assumed. A typical application of Case 2 would be in a situation where several catchments are to be modeled, yet funds will permit monitoring the DWF only in a single area. A1BOD, A1SS, and A1COLI would be computed via the Case 1 subroutine for the known area and the results would be transferred as Case 2 for the remaining catchments.

The default values for A1BOD, A1SS, and A1COLI are 1,300, 1,420, and 200 billion respectively. These values assume 85 gal./capita/day, 0.20 lb/capita/day BOD, 0.22 lb/capita/day SS, and 200 billion MPN/capita/day for average income families.

A loop is next formed to compute and design average daily quality values for all inlets and individual process flow sources. This loop also computes the DWF quantities as described earlier.

Two data cards are required to read in all the flow and quality parameters for each subarea and each individual process flow source. After computation of the DWF quantity for the subarea, the population is computed and totalized. Next, the quality characteristics are computed on the basis of land use, family income, and garbage grinder status, and the results are tabulated (printed) and totalized (printed only on call - subtotals - or completion).

The computational sequence is complete when all areas and process flow sources have been executed (i.e., number of iterations equals KTNUM) and totals have been printed. Upon completion, control returns to TRANS.

Subroutine DWLOAD (6)

Subroutine DWLOAD was developed to assist subroutine QUAL (which will be discussed later) by establishing the initial sediment load within a sewer system. This was accomplished by using Shield's and Manning's works to estimate daily sediment accumulation in each section of the sewer under DWF conditions. By assuming a constant daily buildup of sediment during consecutive dry weather days, DWDAYS, initial sediment load estimates were made possible. Thus, a substantial portion of the solids that might contribute to a first flush of the sewers was allowed. Refer to Figure 4-15 for further description of DWLOAD.

Program usage of DWLOAD is quite simple, as DWDAYS, the number of days since the last storm that caused cleansing of the sewer, is the only data input. This number must be included with the data for TRANS.

Subroutine INITAL (7)

Combined sewer systems will seldom if ever be dry because of their dual function of carrying DWF as well as storm flow. In the case of a storm sewer, DWF will consist of only infiltration. Subroutine INITAL thus initializes flows in the system to the appropriate DWF values. Pollutant concentrations are initialized to those corresponding to wastewater diluted by infiltration, which is assumed to contain no pollutants.

Flow areas in conduits are determined from Manning's equation assuming normal depths initially. A flow chart of INITAL is shown in Figure 4-16.

Subroutine ROUTE (8)

Subroutine ROUTE contains the fundamental aspects of flow routing through all elements. Upon entering ROUTE, a check is made to determine if the element is a conduit or not, using the variable KLASS.

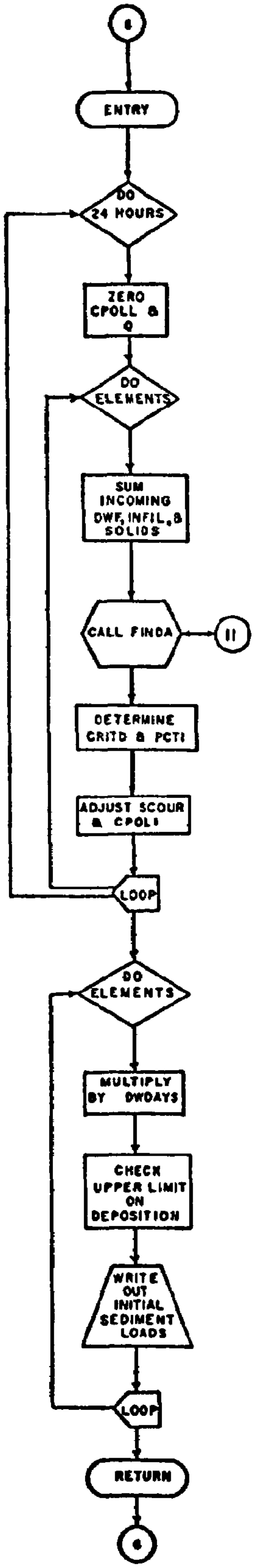


Figure 4-15. SUBROUTINE DWLOAD

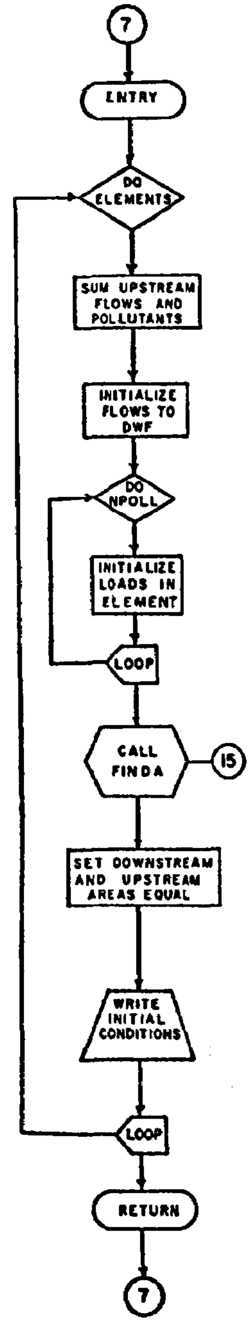


Figure 4-16. SUBROUTINE INITAL

KLASS is a function of the element type (not the individual element number) and has the following values:

KLASS = 1 Conduit with a functional flow-area relationship

KLASS = 2 Conduit with a tabular flow-area relationship

KLASS = 3 Element is not a conduit.

If KLASS = 3, a branch is made to the appropriate routing technique for that particular element type (e.g., manhole, lift station, flow divider). The flow chart of ROUTE is shown in Figure 4-17.

Functional flow-area relationships are those in which the governing equations are actually programmed. This is done only for conduits with simplified geometries, specifically rectangular, modified basket handle, rectangular (triangular bottom), and rectangular (round bottom) All other conduits use tabular data to describe the flow-area curve (discussed later).

Different element types supplied with the Storm Water Management Model are described in Table 4-3.

Conduit Routing (NTYPES 1 to 15 Inclusive). When an element is a conduit, the first step is to determine the slope of the energy grade line (unless the conduit is flowing full because of surcharging). In calculating the energy slope, velocities and normalized depths are found from functions VEL and DEPTH, respectively. The value of the energy slope is used in computing the full flow and maximum flow capacity using Manning's equation and constants specified in subroutine FIRST. When more than one iteration is used for conduits, the energy

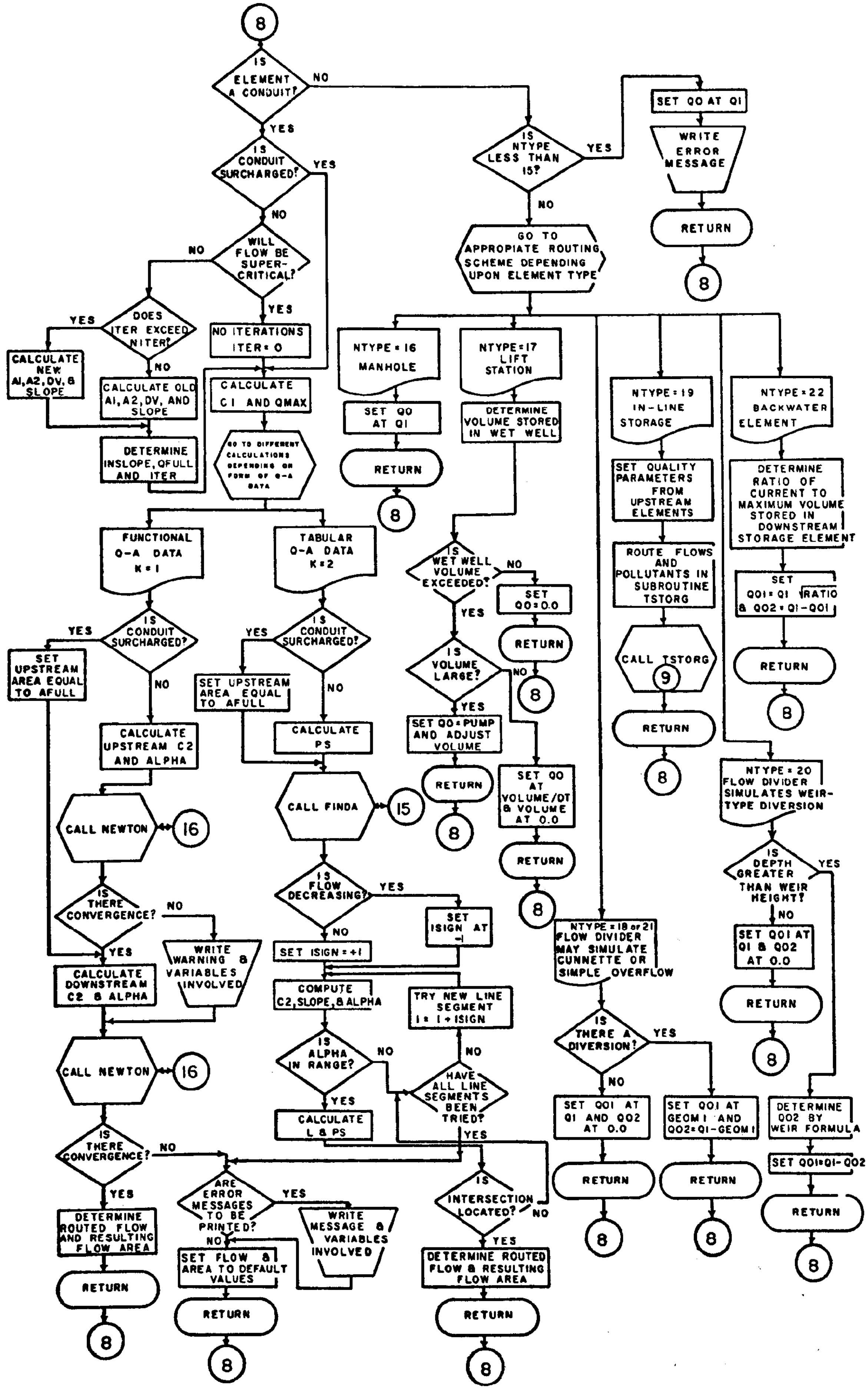


Figure 4-17. SUBROUTINE ROUTE

Table 4-3. DIFFERENT ELEMENT TYPES SUPPLIED WITH THE STORM WATER MANAGEMENT MODEL

NTYPE	DESCRIPTION
	Conduits
1	Circular
2	Rectangular
3	Phillips standard egg shape
4	Boston horseshoe
5	Gothic
6	Catenary
7	Louisville semielliptic
8	Basket-handle
9	Semi-circular
10	Modified basket-handle
11	Rectangular, triangular bottom
12	Rectangular, round bottom
13, 14, 15	User supplied
	Non-conduits
16	Manhole
17	Lift station
18	Flow divider
19	Storage Unit
20	Flow divider
21	Flow divider
22	Backwater element

slope is computed using velocities and depths from the previous iteration. Only one iteration will be used when the flow in the conduit can be expected to be supercritical at nearly all depths (as determined in FIRST for each conduit and indicated by the variable SCF).

The problem of flow routing is basically one of determining the downstream flow and area in a conduit, given the flow and area upstream and conditions at the previous time-step. The continuity equation in finite difference form and Manning's equation based upon the energy slope are used for this purpose. The mathematical problem then becomes one of determining the intersection of the straight line $-C_1\alpha - C_2$ with a normalized flow-area relationship determined from Manning's equation for a particular conduit geometry, as shown in Figure 4-18. In general, the variable α, (ALPHA), represents A/AFULL where A is the cross-sectional area of flow at the upstream or downstream end of the conduit and AFULL is the full-flow area. The variable ψ, (PSI or PS), represents Q/QFULL where Q is the flow at the upstream or downstream end of the conduit and QFULL is the full-flow value.

For a particular element type, the flow-area curve may be given in a functional form, i.e., in its exact mathematical form. In this event (KLASS = 1), the intersection of the straight line and the curve is found using a Newton-Raphson iteration performed in subroutine NEWTON.

The flow-area curve for a particular element type may also be represented in a piecewise-linear or "tabular" form (KLASS = 2). The different line segments describing the curve are then tried until the one is found that intersects the straight line $-C_1\alpha - C_2$ on the curve itself. The value of ALPHA (A/AFULL) at this location is determined and the value of PSI (Q/QFULL) corresponding to ALPHA is also determined.

In the event that no intersection of the curve and the straight line is found (i.e., non-convergence), default values are assigned to the down-

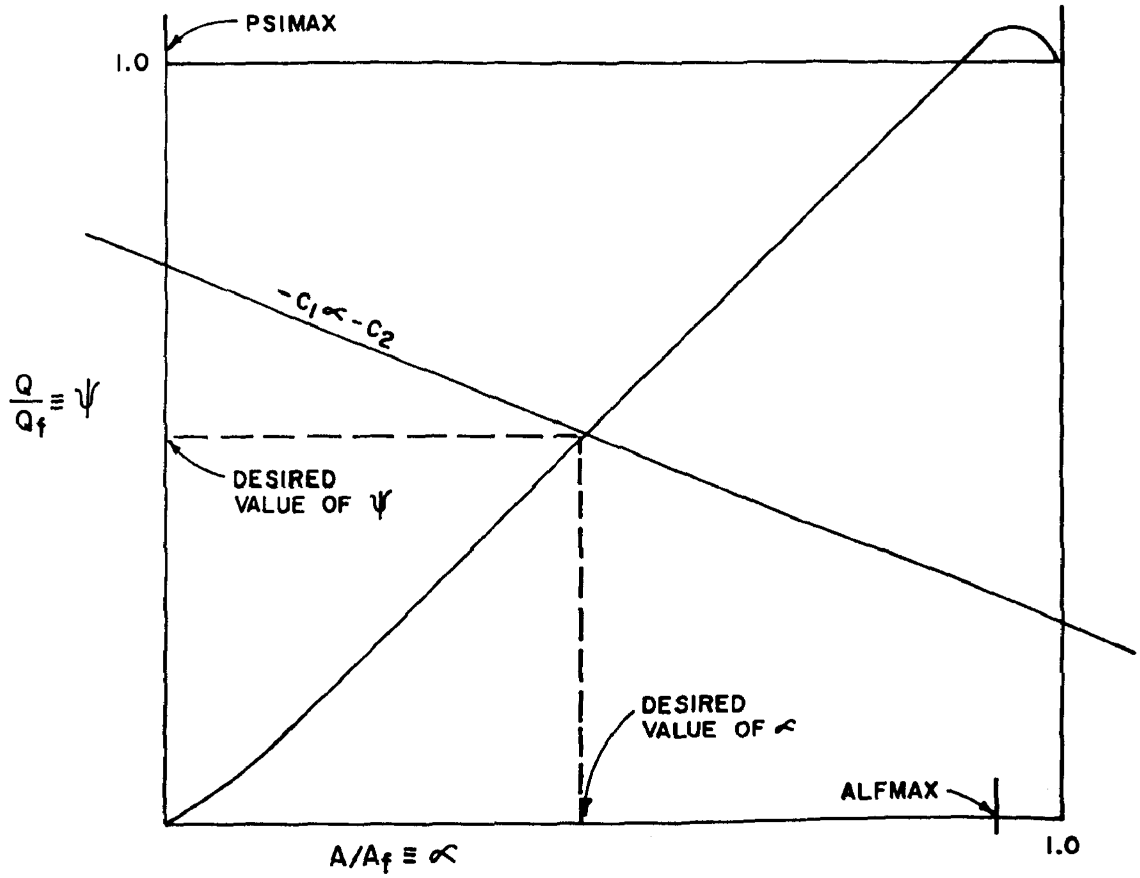


Figure 4-18. THE INTERSECTION OF THE STRAIGHT LINE AND THE NORMALIZED FLOW-AREA CURVE AS DETERMINED IN ROUTE

stream flow and area of the conduit. This occasionally occurs when the conduit is initially dry. (The downstream flow and area will be assigned zero values in this instance.) In the event of non-convergence, a message to that effect will be printed if the variable NPRINT was specified greater than 0.

Routing in Manholes (NTYPE = 16). Flow routing is accomplished in manholes by specifying that the outflow equals the sum of the inflows.

Routing at Lift Stations (NTYPE = 17). When the volume of sewage in the wet well reaches capacity, the pumps begin to operate at a constant rate. This continues until the wet well volume equals zero.

Routing at Flow Dividers(NTYPE = 18 and 21). Both types will divide the inflow, QI, into two outflows, QO1 and QO2. The divider then acts as follows:

For $0 \leq QI \leq GEOM1$	,	QO1	=	QI
		QO2	=	0.0
For $GEOM1 < QI$	,	QO1	=	GEOM1
		QO2	=	QI-GEOM1

The undiverted outflow, QO1, will flow into the downstream element denoted by GEOM3. (The element into which flows QO2 does not need to be specified).

Routing at a Flow Divider (NTYPE = 20). This element is used to model a weir-type diversion structure, in which a linear relationship between flow rate and flow depth is assumed to exist. The parameters of the element are defined in Table 4-4.

Table 4-4. PARAMETERS REQUIRED FOR NON-CONDUITS

NTYPE	DESCRIPTION	DIST	GEOM1	SLOPE	ROUGH	GEOM2	BARREL	GEOM3
16	Manhole	N.R.*	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.
17	Lift station	Pumping rate, assumed constant (cfs).	Volume in wet well at which pumps will start (cf).	N.R.	N.R.	N.R.	N.R.	N.R.
18	Flow divider	N.R.	Maximum undiverted flow. Inflow in excess of this value is diverted (cfs).	N.R.	N.R.	N.R.	N.R.	Number of element into which flows the undiverted flow (include decimal point).
19	Storage unit**	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	If parameter ISTOUT = 9 for storage unit, GEOM3 = number of element into which flows the outflow from the orifice outlet. Otherwise, N.R.
20	Flow divider	Maximum inflow without flow over the weir (cfs).	Weir height, above zero flow depth (ft).	Maximum inflow through whole structure (cfs).	Weir constant times weir length (ft).	Depth in structure at time of maximum inflow (ft).	N.R.	Number of element into which flows the undiverted flow (weir flow is the diverted flow).
21	Flow divider	N.R.	N.R. (assigned in program)	N.R.	N.R.	N.R.	N.R.	Number of element into which flows the undiverted flow.
22	Backwater element	N.R.	N.R.	N.R.	N.R.	N.R.	N.R.	Element number of downstream storage unit.

NOTE: All elements require an element number (NOE), three upstream element numbers (NUE), and type (NTYPE). Parameters for conduits are defined in Table 4-5.

* N.R. = Not required.

** Additional parameters are read in subsequently.

The flow divider behaves as a function of the inflow, QI; as follows:

For $Q \le QI \le DIST$, Q01 = QI

Q02 = 0.0

For $DIST < QI$, Q01 and Q02 are computed as follows:

1. Compute depth of flow above the weir, assuming a linear flow-depth relationship:

   DH = (QI-DIST)*(GEOM2-GEOM1)/(SLOPE-DIST)

2. Compute the diverted flow from the weir formula:

   Q02 = ROUGH*DH**1.5

3. Compute the undiverted flow:

   Q01 = QI-Q02.

<u>Routing Through a Storage Element (NTYPE = 19).</u> This element is specified only when internal storage computations are required. The supporting data must have previously been fed into the program in subroutine TSTRDT. The inflowing pollutant concentrations are determined first. Then quantity and quality routing are accomplished in subroutine TSTORG (Figure 4-19), and its subroutines: TSROUT (Figure 4-20) and TPLUGS (Figure 4-21). Subroutine TSTORG is called from ROUTE each time-step to compute movements within the storage unit. TSROUT provides the hydraulic routing computation and TPLUGS traces and identifies the plug elements when the plug flow-through option is selected. If the alternate option, complete mixing, is selected, necessary computations are completed within TSTORG. A more comprehensive description of the storage routines is presented in Section 5 of this manual.

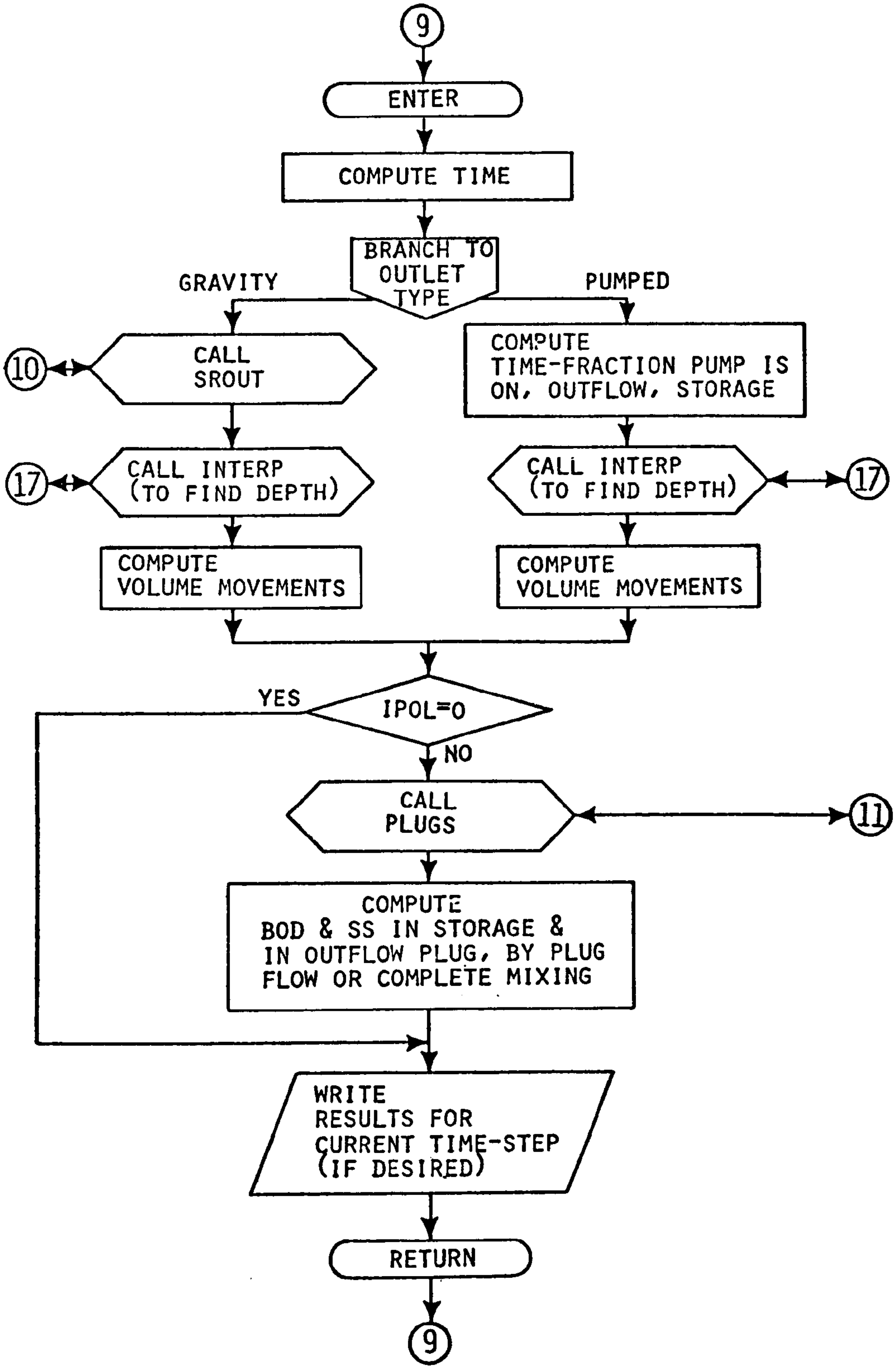
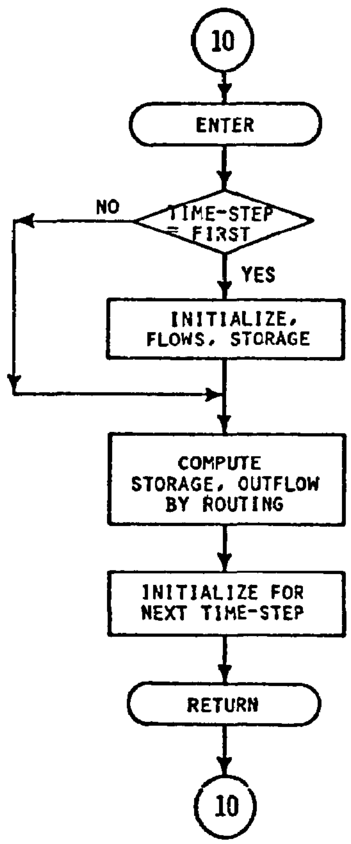


Figure 4-19. SUBROUTINE TSTORG



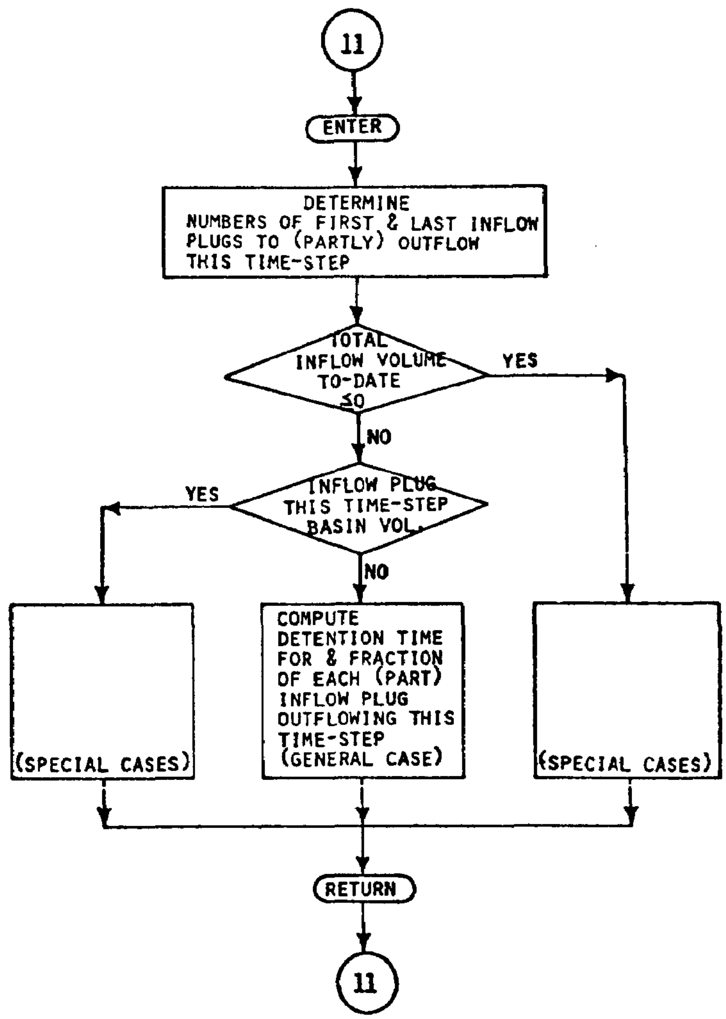


Figure 4-20. SUBROUTINE TSROUT

Figure 4-21. SUBROUTINE TPLUGS

Routing at a Backwater Element (NTYPE = 22). The ratio of the volume of flow currently stored in the downstream storage element to the maximum possible storage is determined. The inflow to the storage unit, QO1, is then proportional to the square root of this ratio.

Subroutine QUAL (12)

The sewer decay (quality routing) program is divided into two major subroutines, QUAL and DWLOAD. QUAL was developed to describe pollutant movement through any specified sewer system , given sewer data and concurrent flows and velocities. The processes of organic decay, reaeration, deposition, and sediment uptake were included to modify pollutant concentrations under DWF or storm conditions. Using these processes, QUAL has been designed to route the following four pollutants: BOD, DO, suspended solids, SS, and any conservative pollutant, P. Refer to Figure 4-22 for further descriptions of QUAL.

The lack of data input for subroutine QUAL simplifies program usage considerably. However, a few user options do exist, each of which requires minor modification to QUAL.

Rate constants for deoxygenation and reaeration have been chosen as 0.2 per day and 0.3 per day, respectively. If locally observed rate constants for flowing sewage have been determined, these should be used to recalculate D1 in the section on BOD and D1 and D2 in the section on DO in QUAL. Likewise, assumed saturation of 7 mg/L should be replaced by inserting a more appropriate value of S under the section on DO in QUAL.

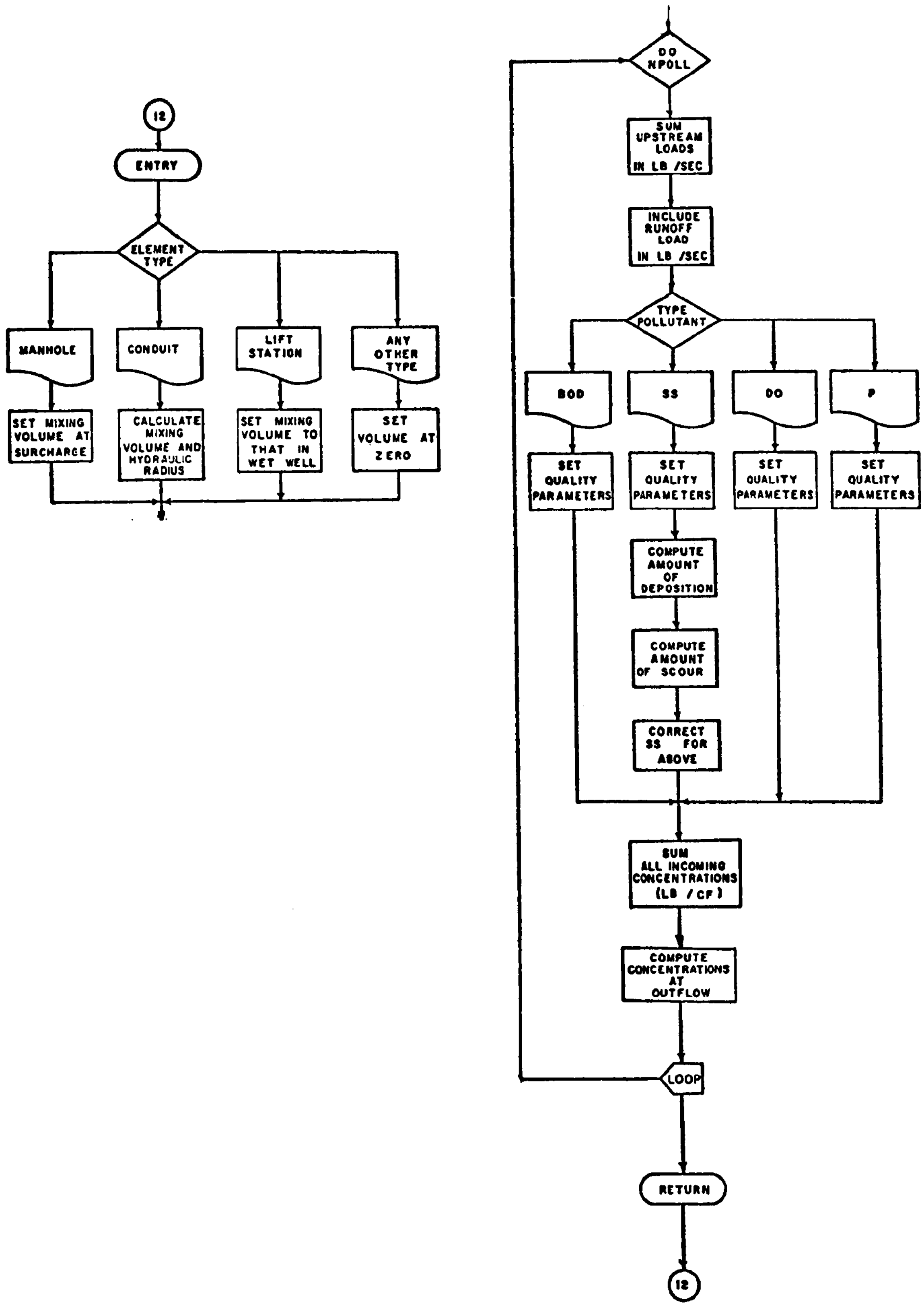


Figure 4-22. SUBROUTINE QUAL

Specific gravity of sediment in the sewer has been assumed as 2.70. To override this assumption, SPG = 2.7 should be replaced with measured specific gravity in the section on suspended solids in QUAL. A sieve analysis curve has been selected to describe typical sediment within the sewer. The curve as it exists in QUAL is shown in Figure 4-23. However, if actual sieve analyses of sewer sediment have been taken, these should be averaged and plotted. Three straight lines are usually sufficient to approximate any sieve analysis plot. The resulting representation of the plot in equation form should then replace the existing equations under suspended solids in QUAL.

Subroutine PRINT (13)

During execution of TRANS, output data are stored on off-line devices (e.g., tapes, disks). After all routing is completed, subroutine PRINT is used to print the data from these devices, overlaying the previous common block as it does so. The flow chart of PRINT is shown in Figure 4-24.

Subroutine TSTCST (14)

When internal storage units have been used, capital and operating costs of the designated units may be computed by setting the parameter ICOST to a non-zero value. A flow chart of TSTCST is shown in Figure 4-25.

Support Subroutines and Functions

The remaining subroutines and functions are placed in alphabetical order since they may be called by several different subroutines.

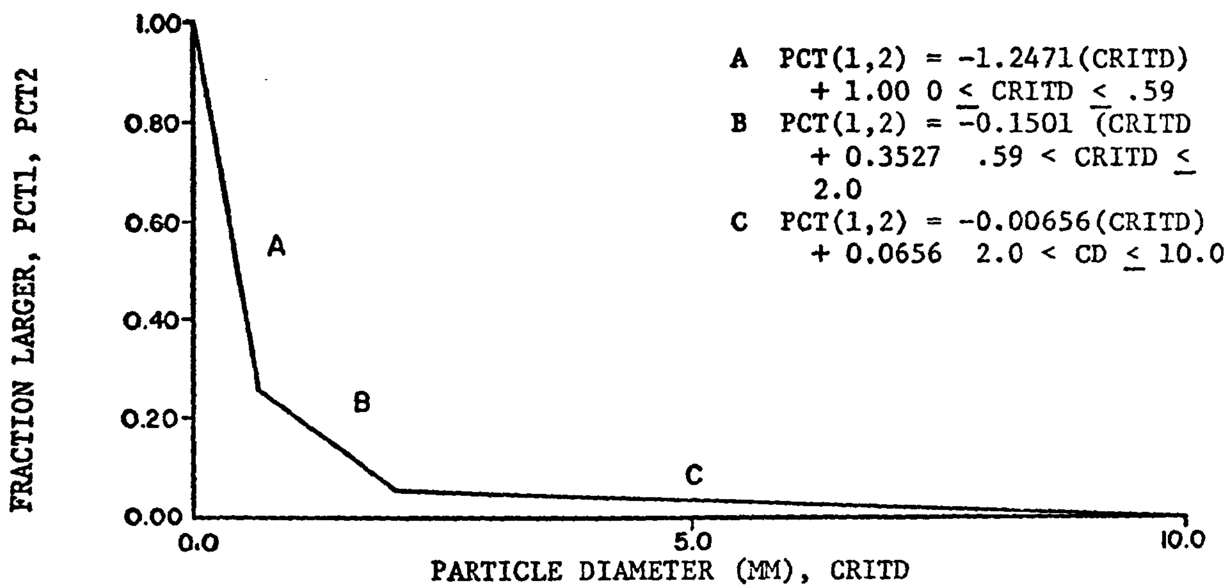


Figure 4-23. SIEVE ANALYSIS PLOT FOR SEWER SEDIMENT

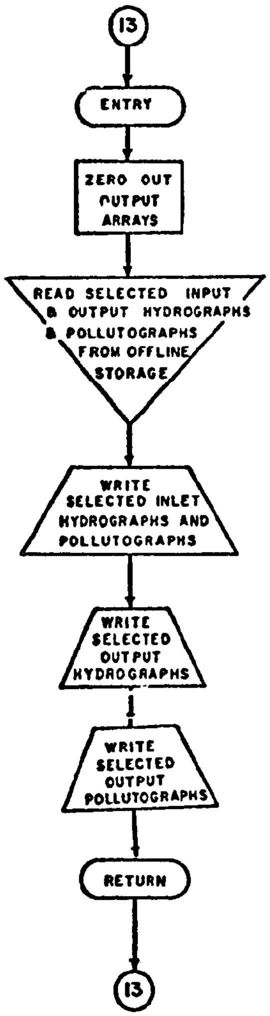


Figure 4-24. SUBROUTINE PRINT

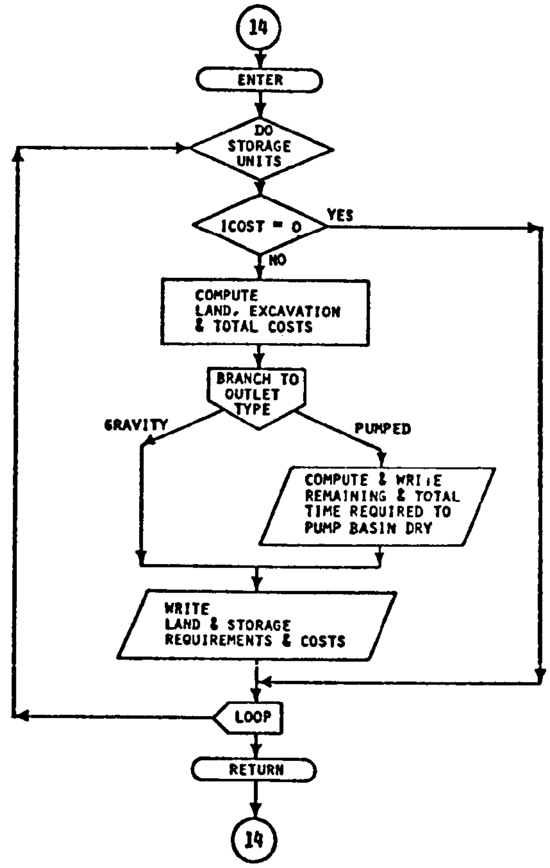


Figure 4-25. SUBROUTINE TSTCST

Block Data. This subprogram initializes, through the use of DATA statements, several arrays in the common blocks labeled "NAMES" and "TABLES." Most of these arrays contain data used during the flow routing process, such as the flow-area and depth-area curves. The data for the supplied conduit shapes are stored here.

Function DEPTH. (18) This function determines the normalized depth of flow in a conduit, given the normalized area of flow for a conduit with either a functional (KDEPTH = 1) or tabular (KDEPTH = 2) depth-area relationship. A flow chart of DEPTH is shown in Figure 4-26.

Function DPSI. (19) This function returns a value of the derivative ($d\psi/d\alpha$) of the normalized flow (ψ)-area(α) curve for a functional relationship. The equations describing the derivative of the flow-area curves for four conduits are programmed. Function PSI must have been called immediately prior to calling DPSI because certain scratch variables must be initialized in PSI. This will always be the case as long as DPSI is called only from NEWTON. A flow chart of DPSI is shown in Figure 4-27.

Subroutine FINDA. (15) This subroutine, called from DWLOAD, ROUTE, and INITAL, determines the flow area given the flow rate in conduits with either tabular or functional flow-area curves. In the event of a functional curve, the area is found from a Newton-Raphson iteration in subroutine NEWTON. A flow chart of FINDA is shown in Figure 4-28.

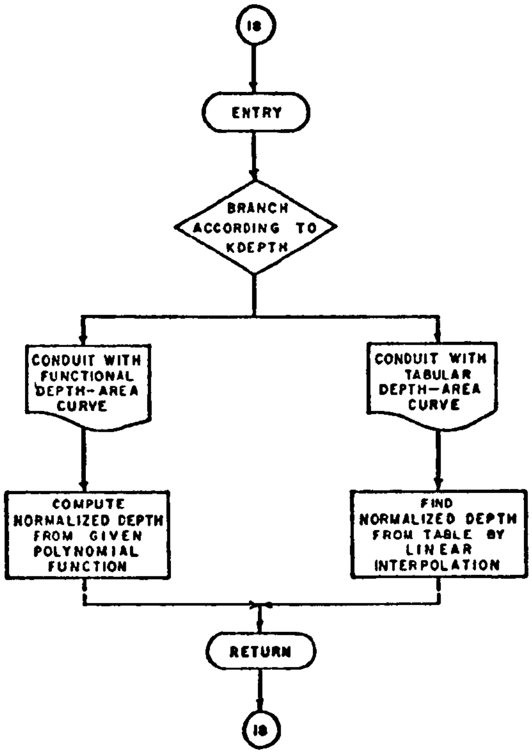


Figure 4-26. FUNCTION DEPTH

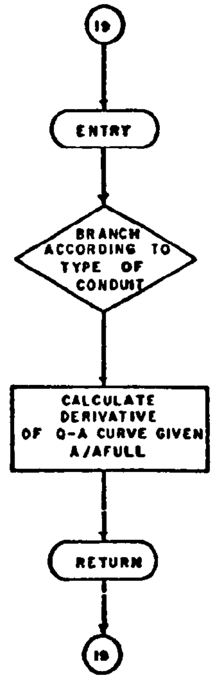


Figure 4-27. FUNCTION DPSI

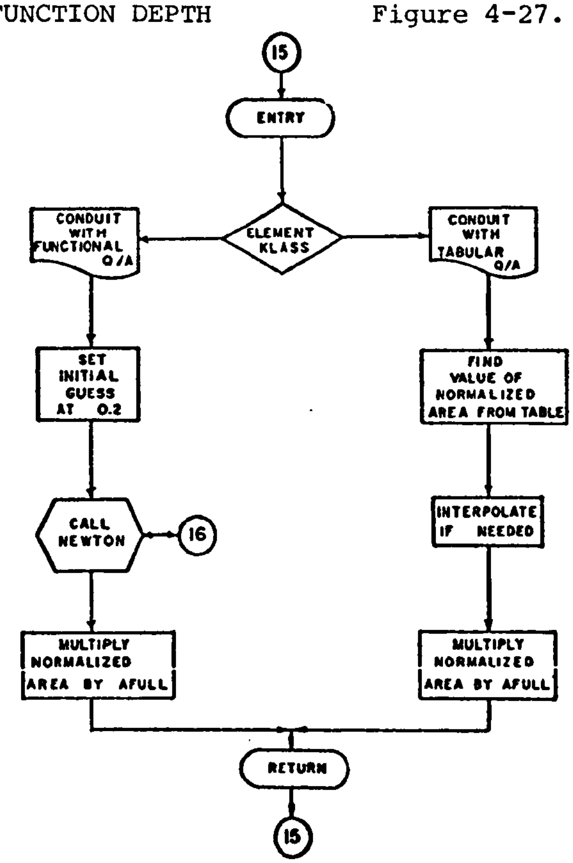


Figure 4-28. SUBROUTINE FINDA

Subroutine NEWTON. (16) This subroutine performs a Newton-Raphson iteration to determine the intersection of the straight line $-C_1\alpha - C_2$ with the normalized flow-area (ψ-α) curve given in functional form. Functions PSI and DPSI return values of $\psi(\alpha)$ and $d\psi(\alpha)/d\alpha$, respectively. The value of KFLAG is set to one if there is convergence and to two if there is not. The flow chart of NEWTON is shown in Figure 4-29.

Function PSI. (20) This function returns a value of normalized flow (ψ), given a value of normalized area (α) for conduits with a functional flow-area curve. The equations describing the flow-area curves for four conduits are programmed. A flow chart of PSI is shown in Figure 4-30.

Function RADH. (21) This function determines the hydraulic radius, given the area of flow in a conduit. It is found exactly for circular, rectangular (including triangular and round bottoms), and modified basket-handle conduits. For other types, the diameter of an equivalent circular conduit is found, (i.e., one with an equal full-flow area). The hydraulic radius is then found using the given flow area and the equivalent circular section. The flow chart of RADH is shown in Figure 4-31.

Subroutine TINTRP. (17) This subroutine performs simple linear interpolation between points identified by coordinate values. The flow chart for TINTRP is shown in Figure 4-32.

Function VEL. (22) This function calculates a velocity by dividing the flow by the area. The reason for having a separate function for this purpose is that it also checks for zero flow and area to avoid a divide

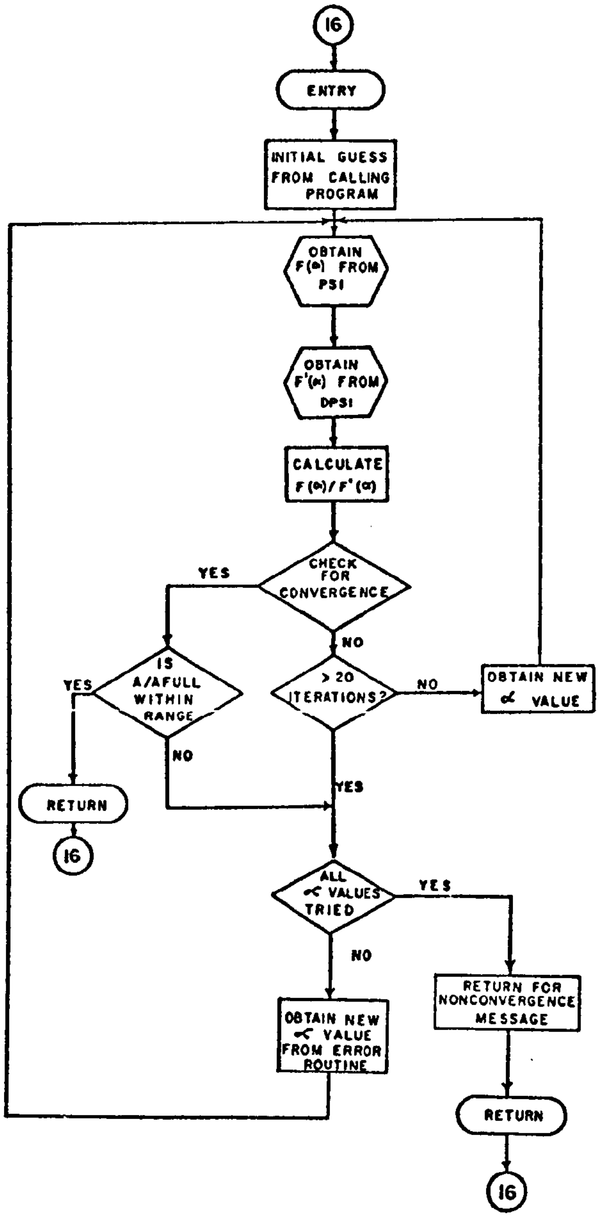


Figure 4-29. SUBROUTINE NEWTON

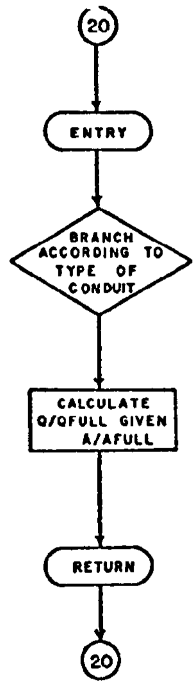


Figure 4-30. FUNCTION PSI

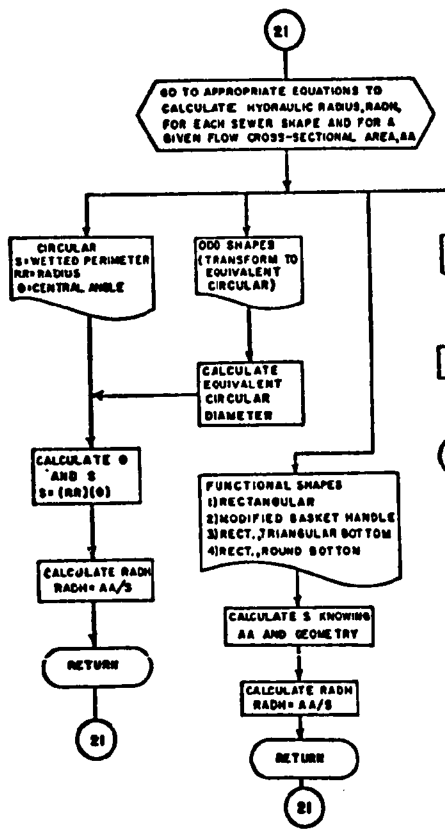


Figure 4-31. FUNCTION RADH

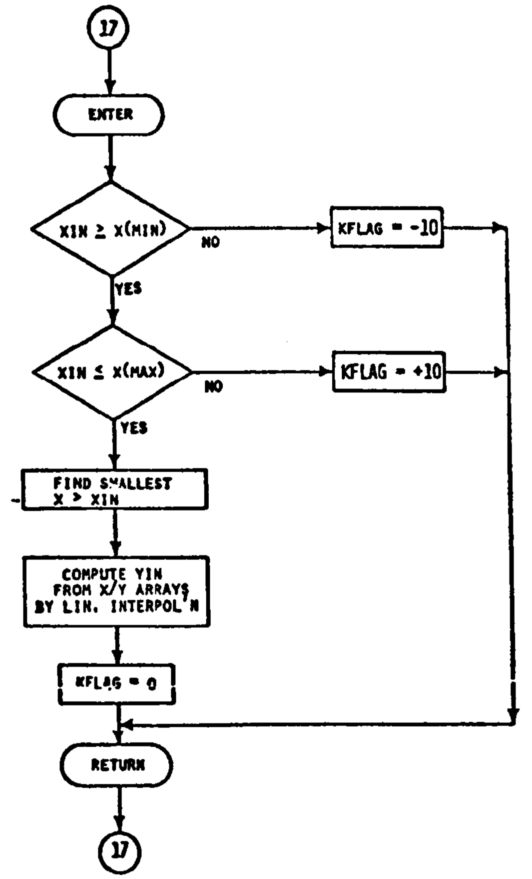


Figure 4-32. SUBROUTINE TINTRP

check error during program execution. Flow chart for VEL is given in Figure 4-33.

INSTRUCTIONS FOR DATA PREPARATION

Instructions for data preparation for the Transport Block have been divided along the lines of the major components for clarity of the presentation. These components are: Transport, Internal Storage, Infiltration, and Dry Weather Flow. All data input card and tape/disk sources enter the Transport Block through one of these components. The typical data deck setup for the complete Transport Block is shown in Figure 4-34. Transport data describe the physical characteristics of the conveyance system. Internal Storage data describe a particular type of Transport element. Infiltration and DWF data describe the necessary area characteristic to permit the computation of the respective inflow quantities and qualities.

Data card preparation and sequencing instructions for the complete Transport Block are given at the end of these instructions in Table 4-6 followed by an alphabetical listing of the variable names and descriptions in Table 4-7.

Transport Model

Use of the Transport program involves three primary steps:

Step 1 - Preparation of theoretical data for use by subroutines engaged in hydraulic calculations in the program.

Step 2 - Preparation of physical data describing the combined sewer system.

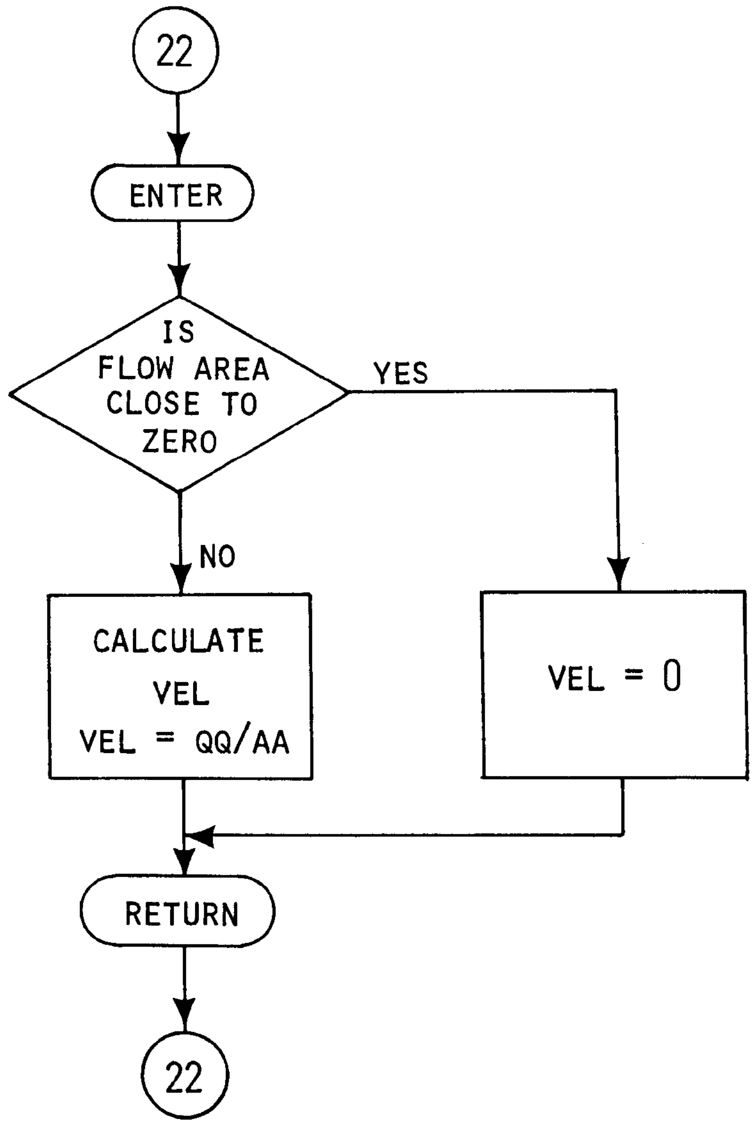


Figure 4-33. FUNCTION VEL

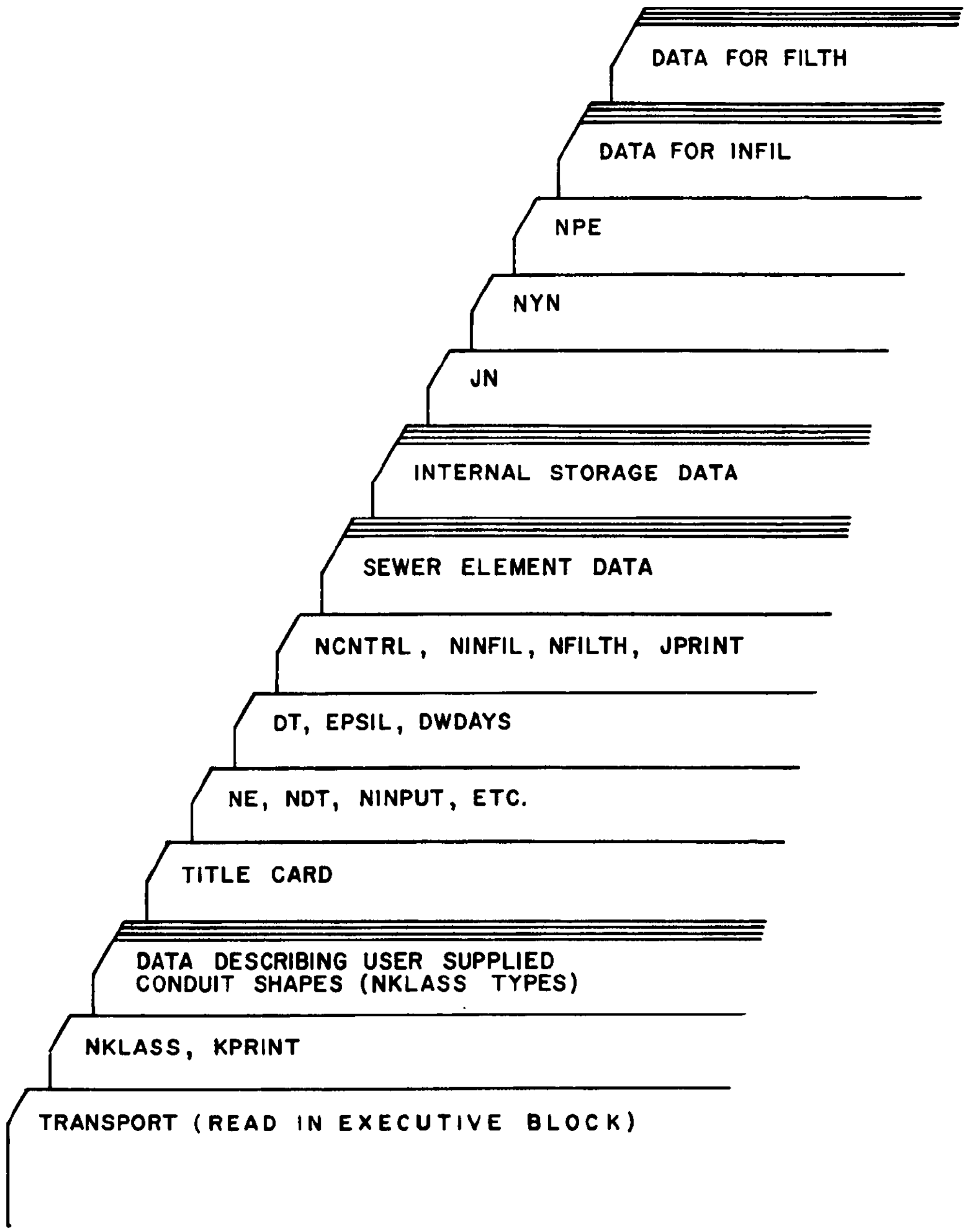


Figure 4-34. DATA DECK FOR THE TRANSPORT BLOCK

Step 3 - Generation of inlet hydrographs and pollutographs required as input to the Transport Model and computational controls.

Data for Step 1 are supplied with the Storm Water Management program for 12 different conduit shapes, and it will only be necessary for the user to generate supplemental data in special instances. These instances will occur only when conduit sections of very unusual geometry are incorporated into the sewer system. Generation of such data will be discussed below.

The primary data requirements for the user are for Step 2, the physical description of the combined sewer system. This means, essentially, the tabulation of sewer shapes, dimensions, slopes, roughness, etc., which will be discussed in detail below.

The data for Step 3 will be generated by the Runoff Block, described in Section 3 of this manual, and by subroutine INFIL and FILTH.

Step 1 - Theoretical Data. The first data read by TRANS describe the number and types of different conduit shapes found in the system. Only in the case of a very unusual shape should it become necessary to generate theoretical data to supplement the data supplied by the program. The required data describe flow-area relationships of conduits, as shown in Figure 4-18, through the parameters ANORM and QNORM. A similar depth-area relationship is also required, using the parameter DNORM.

The flow-area data are generated from Manning's equation, normalized by dividing by the corresponding equation for the conduit flowing full, denoted by the subscript f. Thus,

$$Q/Q_f = A*R**0.667/(A_f*R_f**0.667) = f(A/A_f) \tag{7}$$

where Q = Flow

A = Flow area

R = Hydraulic radius.

For a given conduit shape (e.g., circular, rectangular, horseshoe), the hydraulic radius is a unique function of the area of flow; hence, Q/Q_f is a function only of A/A_f. This function is tabulated for circular conduits in Appendix I of Ref. 9, for example, and on page 443 of Ref.10 for a Boston horseshoe section. It is shown in graphical form for several conduit shapes in Chapter XI, Ref. 11,from which some data supplied with this program have been generated. A list of the conduit shapes supplied with the Storm Water Management program as well as all other element types was given in Table 4-3. The conduits are illustrated in Figure 4-35.

It will often be satisfactory to represent a shape not included in Table 4-3 by one in the list of similar geometry, to be discussed later. This use of "equivalent" sewer sections will avoid the problem of generating flow-area and depth-area data. An equivalent section is defined as a conduit shape from Table 4-3 whose dimensions are such that its cross-sectional area and the area of the actual conduit are equal. Only very small errors should result from the flow routing when this is done.

If it is desired to have the exact flow-area and depth-area relationships, then the product $AR^{2/3}$ must be found as a function of area. In general, the mathematical description of the shape will be complex and the task is most easily carried out graphically. Areas may be planimetered, and the wetted perimeter measured to determine R. In addition, the depth may be measured with a scale. The required flow-area relationship of Eq. (7) may then be tabulated as can the depth-area relationship. The number of points on the flow-area and depth-area curves required to describe the curves is an input variable (MM and NN, respectively). Note that the normalized flows (QNORM) and depths (DNORM) must be tabulated at points corresponding to MM-1 and NN-1, respectively, equal divisions of the normalized area axis (ANORM).

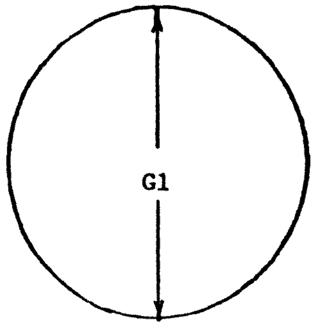
Step 2 - The Physical Representation of the Sewer System. These data are the different element types of the sewer system and their physical descriptions. The system must first be identified as a system of conduit lengths, joined at manholes (or other non-conduits). In addition, either real or hypothetical manholes should delineate significant changes in conduit geometry, dimensions, slope, or roughness. Finally, inflows to the system (i.e., storm water, wastewater, and infiltration) are allowed to enter only at manholes (or other non-conduits). Thus manholes must be located at points corresponding to inlet points for hydrographs generated by the Runoff Block and input points specified in subroutines FILTH and INFIL. In general, the task of identifying elements of the sewer system will be done most conveniently in conjunction with the preparation of data for these other subroutines.

Description of Conduits

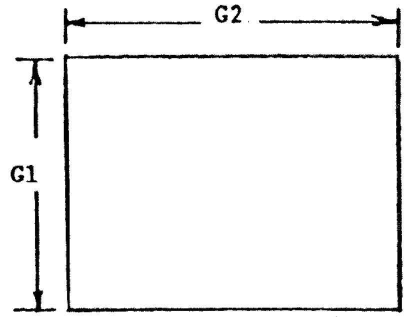
The 12 conduit shapes supplied with the Storm Water Management program are shown in Figure 4-35. For each shape, the required dimensions are illustrated in the figure and specified in Table 4-5. In addition, Table 4-5 gives the formula for calculating the total cross-sectional area of the conduit.

Usually, the shape and dimensions of the conduit will be indicated on plans. It is then a simple matter to refer to Figure 4-35 for the proper conduit type and dimensions. If the shape does not correspond to any supplied by the program, it will ordinarily suffice to choose a shape corresponding most nearly to the one in question. For example, an inverted egg can be reasonably approximated by a catenary section. The dimensions of the substitute shape should be chosen so that the area of the substitute conduit and that of the actual conduit are the same. This is facilitated by Table 4-5, in which the area is given as a function of the conduit dimensions. If desired, the flow-depth-area parameters for up to three additional conduit shapes may be read in at the beginning of the program. (See Card Groups 2-10, Table 4-6.)

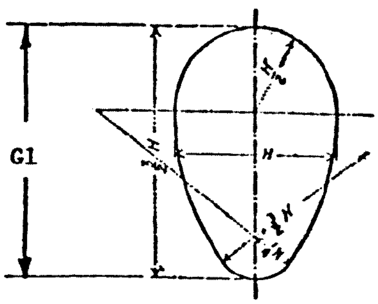
Occasionally, the conduit dimensions and area may be given, but the shape not specified. It will sometimes be possible to deduce the shape from the given information. For example, a conduit may have an area of 4.58 square feet and dimensions of 2 feet by 3 feet. First, assume that the 2-foot dimension is the width, and the 3-foot dimension is the depth of the conduit. Second, note from Figure 4-35 that the ratio of depth to width for an egg-shaped conduit is 1.5:1. Finally, the area



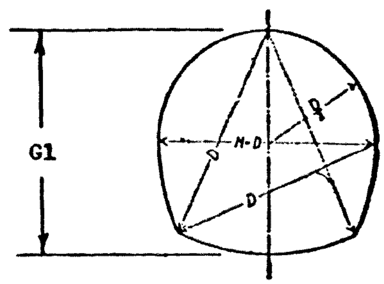
Type 1: Circular



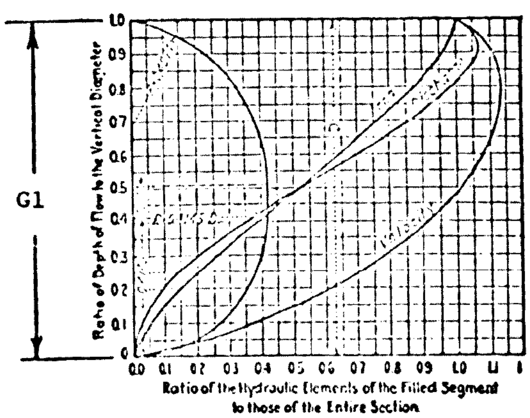
Type 2: Rectangular



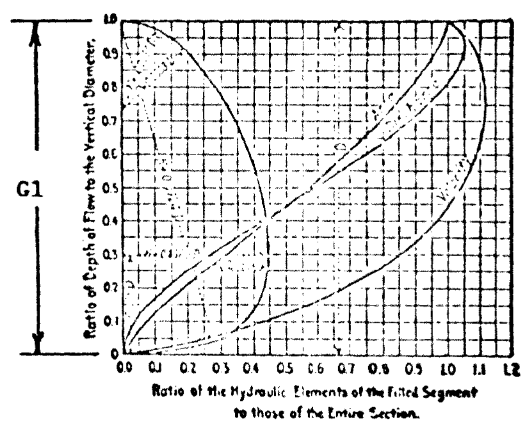
Type 3: Phillips Standard Egg Shape



Type 4: Boston Horseshoe

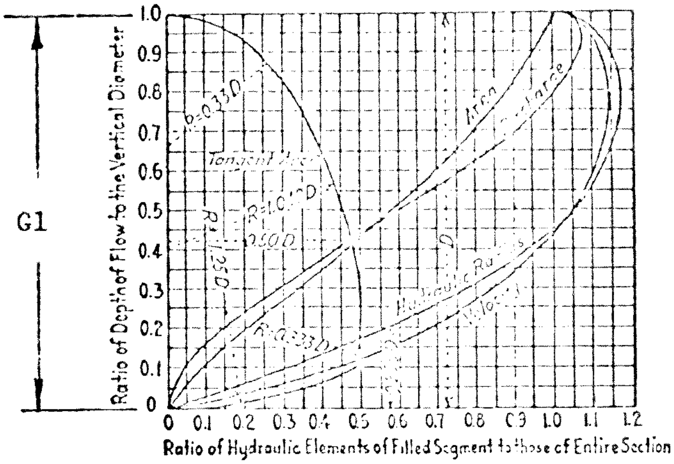


Type 5: Gothic

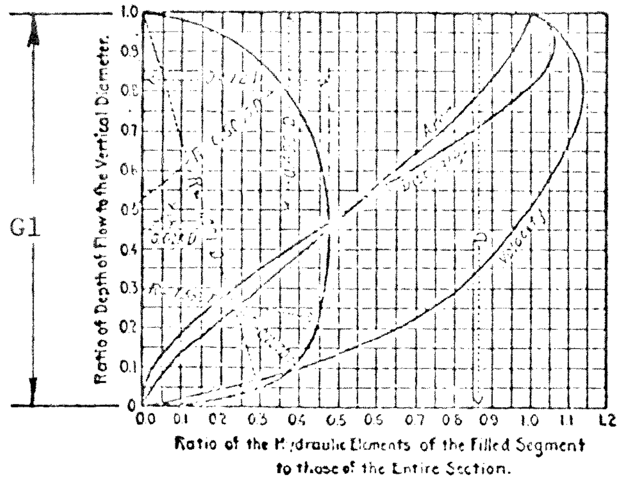


Type 6: Catenary

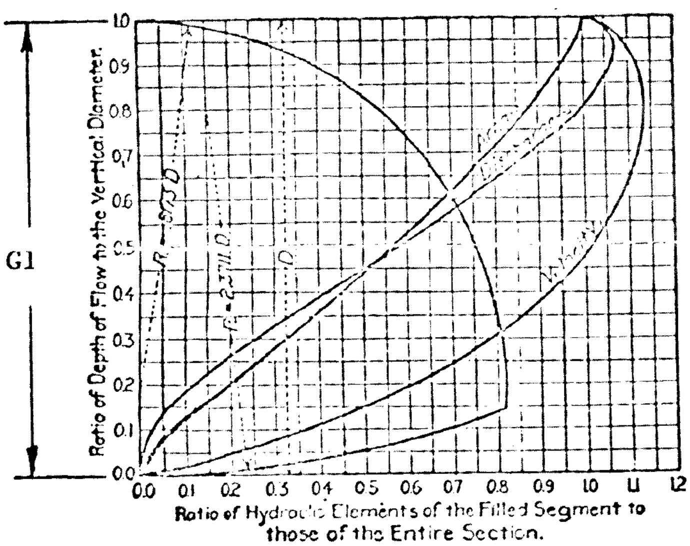
Figure 4-35. SEWER CROSS-SECTIONS



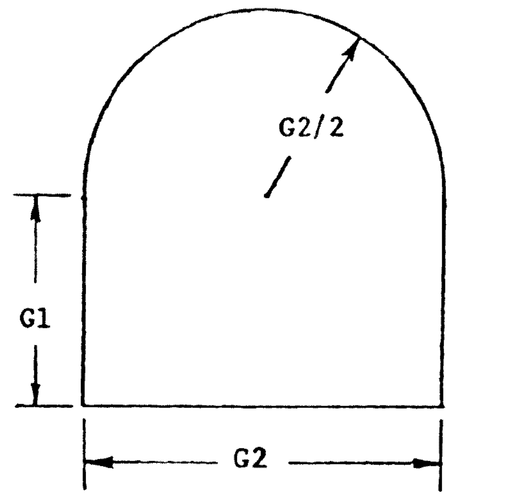
Type 7: Louisville Semielliptic



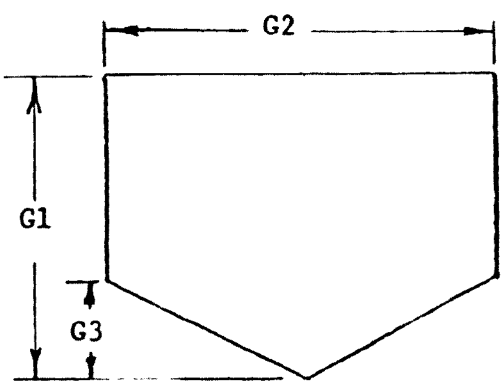
Type 8: Basket-handle



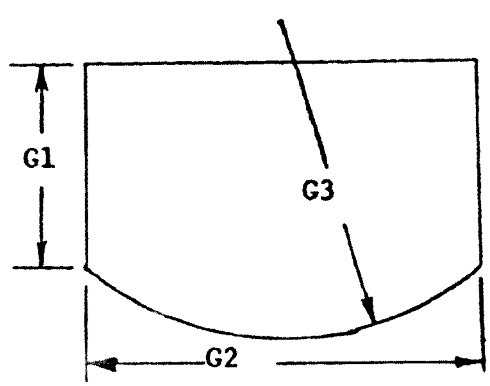
Type 9: Semi-circular



Type 10: Modified Basket-handle



Type 11: Rectangular, Triangular Bottom



Type 12: Rectangular, Round Bottom

Figure 4-35 (continued)

Table 4-5. SUMMARY OF AREA RELATIONSHIPS AND REQUIRED CONDUIT DIMENSIONS*

Ntype	Shape	Area	Required Dimensions, ft
1	Circular	$(\pi/4)*(G1)**2$	GEOM1 = Diameter
2	Rectangular	G1*G2	GEOM1 = Height GEOM2 = Width
3	Egg-shaped	$0.5105*(G1)^2$	GEOM1 = Height
4	Horseshoe	$0.829*(G1)^2$	GEOM1 = Height
5	Gothic	$0.655*(G1)^2$	GEOM1 = Height
6	Catenary	$0.703*(G1)^2$	GEOM1 = Height
7	Semielliptic	$0.785*(G1)^2$	GEOM1 = Height
8	Basket-handle	$0.786*(G1)^2$	GEOM1 = Height
9	Semi-circular	$1.27*(G1)^2$	GEOM1 = Height
10	Modified basket-handle	$G2(G1 + (\pi/8)G2)$	GEOM1 = Side Height GEOM2 = Width
11	Rectangular, triangular bottom	G2(G1 - G3/2)	GEOM1 = Height GEOM2 = Width GEOM3 = Invert height
12	Rectangular, round bottom	$\Theta = 2*ARSIN *(G2/(2G3))$ Area = G1*G2 + (G3)**2/2 $*(\Theta - SIN(\Theta))$	GEOM1 = Side height GEOM2 - Width GEOM3 = Invert radius

*Refer to Figure 4-34 for definition of dimensions, G1, G2, and G3.

of an egg-shaped conduit of 3-foot depth is 0.5105 x 9 = 4.59 square feet. It is concluded that the conduit should be type 3 with GEOM1 = 3 feet.

Because of limits on the size of the computer program, it will usually not be possible to model every conduit in the drainage basin. Consequently, aggregation of individual conduits into longer ones will usually be the rule. Average slopes and sizes may be used provided that the flow capacity of the aggregate conduit is not significantly less than that of any portion of the real system. This is to avoid simulated surcharge conditions that would not occur in reality. In general, conduits should not be over 3,000 to 4,000 feet long in order to maintain reasonable routing accuracy. Conduit lengths should always be separated by manholes (or other non-conduit type elements). The conduit length should be measured from the center of the adjacent manholes.

Values of Manning's roughness may be known by engineers familiar with the sewer system. Otherwise, they may be estimated from tables in many engineering references (Refs. 9 and 12), as a function of the construction material and sewer condition. The value may be adjusted to account for losses not considered in the routing procedure (e.g., head losses in manholes or other structures, roots, obstructions). However, the flow routing is relatively insensitive to small changes in Manning's n.

Description of Non-Conduits

The sewer system consists of many different structures, each with its own hydraulic properties. Elements 16 through 22 are designed to simulate such structures. Data requirements for these elements were given in Table 4-4. Brief descriptions of these elements follow.

Manholes. No data are required for manholes except their numbers and upstream element numbers. Note that the number of upstream elements is limited to three. If more than three branches of the system should joint at a point, two manholes could be placed in series, allowing a total of five branches to joint at that point.

Lift Stations. The data requirements for lift stations were given in Table 4-4. It is assumed that the force main will remain full when the pump is not operating, resulting in no time delay in the flow routing (i.e., no time is required to fill the force main when the pump starts).

Type 18 and Type 21 Flow Dividers. The routing procedure through these elements is explained in the discussion of subroutine ROUTE. Typical uses are given below.

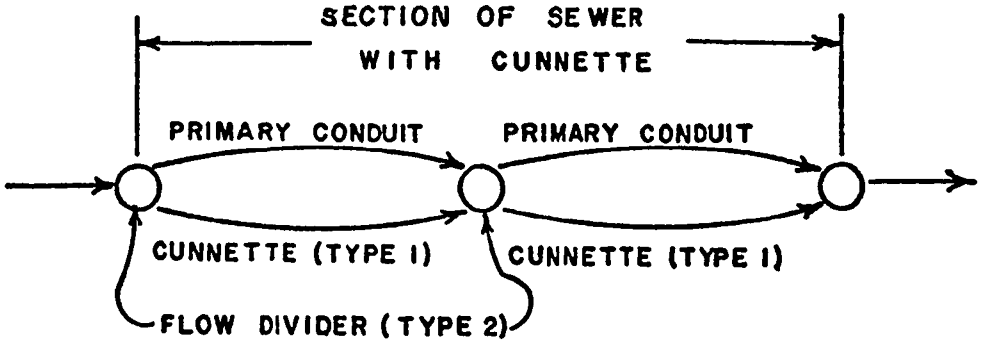
1. Simple Diversion Structure.

   A type 18 flow divider may be used to model a diversion structure in which none of the flow is diverted until it reaches a specified value (GEOM1). When the inflow is above this value, the non-diverted flow (Q01) remains constant at its capacity, GEOM1, and the surplus flow (Q02) is diverted.

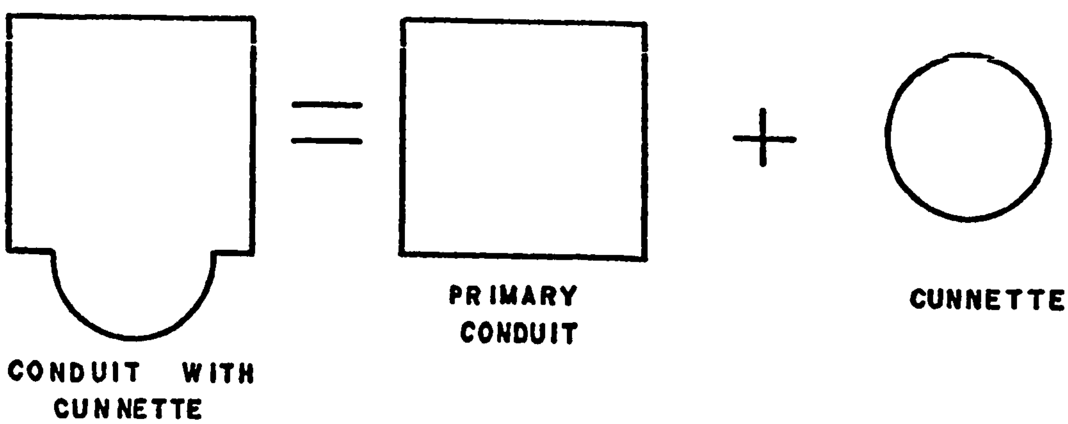
2. Cunnette Section.

A type 21 flow divider may be used to model a downstream cunnette section. The cunnette section is considered as a separate circular conduit to be placed parallel to the primary conduit as shown in Figure 4-36. In order to model the cunnette as a semi-circle, the separate circular conduit is given a diameter (GEOM1) so that its area will be twice that of the actual total cunnette flow area. (The distance, slope, and roughness will be the same as for the primary conduit). A type 21 flow divider is then the upstream element common to both conduits, as shown in Figure 4-36a. The program assigns a value of GEOM1 of the flow divider equal to half the full flow capacity of the circular pipe simulating the cunnette so that it has the hydraulic characteristics of a semi-circle). Any flow higher than GEOM1 will be diverted to the primary conduit. Note that the parameter GEOM3 of the flow divider will be the element number assigned to the cunnette section. Note further that the element downstream from the two parallel conduits must list them both as upstream elements.

Type 20 Flow Divider. This element is used to model a weir-type diversion structure in which a linear relationship can adequately relate the flow rate and the depth of flow at the weir. Input parameters were defined in Table 4-4. The operation of the element is explained in the discussion of subroutine ROUTE.



a. SCHEMATIC OF HYPOTHETICAL FLOW DIVISION



b. SPLIT OF CONDUIT INTO PRIMARY CONDUIT AND CUNNETTE

Figure 4-36. CUNNETTE SECTION

The weir constant, incorporated into the variable ROUGH, can be varied to account for the type of weir. Typical values of the weir constant are 3.3 for a broad crested weir and 4.1 for a side weir (Ref. 13).

Type 19 - Storage Unit. This element may be placed anywhere in the sewer system where appreciable storage may exist, such as at an overflow or diversion structure. The required data inputs and a description of the routing procedure are described elsewhere in this manual. It should be noted that the storage area or "reservoir" now consists of a portion of the sewer system itself, and area-depth relationships must be worked out accordingly.

Backwater Element. This element may be used to model backwater conditions in a series of conduits due to a flow control structure downstream. The situation is modeled as follows:

1. A storage element (type 19) is placed at the location of the control structure. The type of storage element will depend upon the structure (i.e., weir, orifice, or combination of weir and orifice). One inflow to this storage element is then from the conduit just upstream.
2. If the water surface is extended horizontally upstream from the flow control structure at the time of maximum depth at the structure, it will intersect the invert slope of the sewer at a point corresponding to the assumed maximum length of backwater. The reach between this point and the structure may encompass several conduit lengths. A backwater element, type 22, is placed at this point of maximum backwater, in place of a manhole, for instance.

3. The backwater element then diverts flow directly into the storage element depending upon the volume of water (and hence, the length of backwater) in the storage element. If the backwater extends all the way to the backwater element, the total flow is diverted to the storage element; none is diverted to the conduits.
4. The amount of diverted flow (Q01) is assumed directly proportional to the length of the backwater. The storage area in reality consists of the conduits. Since most conduits can be assumed to have a constant width, on the average, the backwater length is assumed proportional to the square root of the current storage volume, obtained from the storage routine.
5. The parameter GEOM3 of the backwater element must contain the element number of the downstream storage unit.
6. Parameters for the storage element are read in as usual. Note that the depth-area values will correspond to the storage area of the upstream conduits. Note also that the storage unit must list the backwater element as one of its upstream elements, as well as the conduit immediately upstream.
7. At each time-step, the backwater element computes the ratio of current to maximum storage volume in the downstream storage element. Call this ratio r.

   Then Q01 = QI r**0.5

   and Q02 = QI-Q01

where Q01 = Flow directly into storage unit

Q02 = Flow into intermediate conduits

QI = Inflow to backwater element.

Step 3 - Input Data and Computational Controls. The basic input data, hydrographs and pollutographs are generated outside of the Transport Model. However, certain operational controls are available within Transport.

Choice of Time-Step

The size of the time-step, DT, may be chosen to coincide with the spacing of the ordinates of the inflow hydrographs and pollutographs. However, it should not be greater than five minutes.

Choice of Number of Time-steps

The total number of time-steps should not be less than the number used in the Runoff Block nor greater than 150.

Choice of Number of Iterations

The purpose of iterations in the computations is to reduce flow oscillations in the output. The flatter pipe slopes (less than 0.001 ft/ft) require iterations of the flow routing portion of the Transport Model to help dampen these oscillations. Four iterations have proven to be sufficient in most cases.

Internal Storage Model

Use of the internal storage routine involves 5 basic steps.

Step 1 - Call. The internal storage routine is called by subroutine TRANS when element type 19 is specified. No more than two locations may be specified in a single run.

Step 2 - Storage Description: Part 1. Describe the storage unit mode (in-line); construction (natural, manmade and covered, manmade and uncovered); and type of outlet device (orifice, weir, or pumped).

Step 3 - Output. Select output and computational options according to the following:

1. Flow routing by plug flow or complete mixing.
2. Complete printout or supressed.
3. Costs estimated or costs supressed.

Step 4 - Storage Description: Part 2. Describe the basin flood depth and geometry. Describe design parameters of outlet control. Describe initial conditions in basin.

Step 5 - Unit Costs. Specify unit costs to be used if cost output is desired.

The sequence of cards and choices (Steps 2-5) are repeated for each storage basin location.

Infiltration Model

Effective use of the Infiltration Model requires estimates of its component flows, namely:

DINFIL = Dry weather infiltration

RINFIL = Wet weather infiltration

SINFIL = Melting residual ice and snow

GINFIL = Groundwater infiltration.

Step 1 - Determine Groundwater Condition. If the groundwater table is predominently above the sewer invert, all infiltration is attributed to this source. In this case an estimate of the total infiltration is made directly (in cfs for the total drainage basin) and read in on a data card. This card followed by two blank cards would complete the infiltration data input. If the groundwater table is not predominently above the sewer invert, proceed to Step 2.

Step 2 - Build Up Infiltration from Base Estimates. From measurements, historical data, or judgment, provide estimates of DINFIL and RINFIL. In this case GINFIL must be set equal to 0.0. Next, provide the control parameters: the day the storm occurs (a number from 1 to 365 starting with July 15 as day 1), the peak residual moisture (see Example 2 below), and the average pipe length (in feet). Finally, read in the 12 monthly degree-day totals taken from Appendix A or a local source.

Dry Weather Flow Model

Use of the Dry Weather Flow model involves 3 basic steps.

Step 1 - Establishing Subareas. Establishment of subareas constitutes the initial step in applying subroutine FILTH. Both detail of input data and assumptions made in developing FILTH impose constraints on the type, size, and number of subareas. However, most important in subarea establishment is the type of estimating data available. An upper limit of 200 acres per subarea is assumed in the following discussion. This is a somewhat arbitrary limit based in part on previous verification results from FILTH.

Subareas should be located and sized to utilize existing sewer flow measurements taken within the drainage basin. These measurements should be recent and of sufficient duration to provide a current average sewage flow value for the period of time during which simulation is to proceed. Daily and hourly flow variation should be compared to assumed values as described earlier in the text. A gaging site with less than 200 acres contributing flow provides a very convenient data input situation. A subarea should be established upstream from the gage with average sewage flow tabulated as SEWAGE for that subarea.

If metered water use is to be used to estimate sewage flow, subareas should be located to coincide with meter reading zones or other zones used by the water department that simplify data takeoff. Since water use would be used to estimate sewage flow, average winter readings should be used to minimize the effects of lawn sprinkling and other summer uses.

If neither gaging nor metered water use are input, sewage estimates must be made. Subareas should then be established to yield appropriate input data for the residential estimating equations in FILTH. Zero sewage flow is assumed from commercial, industrial, and parkland subareas for which estimates or measurements of SAQPF are not given. Since KLAND and VALUE are the significant variables in estimating subarea sewage flow, subareas should be located and sized to include land with uniform land use and property valuation. To utilize existing census data, subarea boundaries should be made to coincide with census tract boundaries.

Criteria for establishing subareas are listed in the following summary:

1. Subareas in general should:
   a. Be less than or equal to 200 acres in size
   b. Be less than or equal to 150 in number
   c. Conform to the branched pipe network.
2. Subareas should be established to employ any existing sewer flow measurements.
3. Subareas for which metered water use is used to estimate sewage flow should be compatible with meter reading zones.
4. Residential subareas for which estimated water use is used to estimate sewage flow should:
   a. Be uniform with respect to land use
   b. Be uniform with respect to dwelling unit valuation
   c. Coincide with census tracts.

Step 2 - Collection of Data. Other than the establishment of measured data described hereinbefore, the primary data source is the U.S. Bureau of the Census for census tract information. This source provides readily available data on population distribution, family income, and the number and relative age of dwelling units. City records, aerial photographs, and on-site inspection may be necessary to define land use activities, process flows, and dwelling density variations within tracts.

Step 3 - Data Tabulation. Once subareas have been established, several alternatives exist regarding data tabulation. An identification number KNUM should be given to each subarea prior to data takeoff. However, once KNUM's have been established, corresponding INPUT manhole numbers are selected from a previously numbered schematic diagram of the trunk sewer. This numbered schematic serves as the mechanism to coordinate runoff, infiltration, and sewage inputs. Refer to the subroutine TRANS discussion for additional information about the numbered schematic. If water use estimates are necessary, land use should be determined from city zoning maps and the previously tabulated values for KLAND.

ADWF should be tabulated as average drainage basin sewage flow. As with ADWF, SEWAGE should be averaged from flow data for the appropriate month, season, or year. ADWF, SAQPF, or SEWAGE may be obtained from routine or specific gaging programs done by the city, consulting engineers, or other agencies. SAQPF may be estimated for commercial and industrial areas using water use coefficients. Also, SAQPF and WATER may be determined for all land use categories from water meter records.

Table 4-6. TRANSPORT BLOCK CARD DATA

Card Group	Format	Card Columns	Description	Variable Name	Default Value
1	16I5	5	Number of sewer cross-sectional shapes, in addition to the 12 program-supplied for which element routing parameters are to follow (maximum value = 3).	NKLASS	0
		10	Control parameter for printing out routing parameters for all shapes, i.e., KPRINT = 0 to suppress printing, KPRINT = 1 to allow printing.	KPRINT	0
			DELETE CARD GROUPS 2 TO 10 IF NKLASS = 0.		
2			Name of user-supplied shapes.	NAME	
	20A4	1-16	16-letter name of shape 1.	NAME(I,13)	none
		17-32	16-letter name of shape 2.	NAME(I,14)	none
		33-48	16-letter name of shape 3.	NAME(I,15)	none
3			Number of values of DNORM to be supplied (maximum value = 51, minimum value = 2).	NN	
	16I5	4-5	Number of values for shape 1.	NN(13)	none
		9-10	Number of values for shape 2.	NN(14)	none
		14-15	Number of values for shape 3.	NN(15)	none
4			Number of values of ANORM or QNORM to be read (maximum value = 51, minimum value = 2).	MM	
	16I5	4-5	Number of values for shape 1.	MM(13)	none
		9-10	Number of values for shape 2.	MM(14)	none
		14-15	Number of values for shape 3.	MM(15)	none
5			Value of A/A_f* corresponding to the maximum Q/Q_f** value for each shape.	ALFMAX	
	8F10.5	1-10	A/A_f value for shape 1.	ALFMAX(13)	none
		11-20	A/A_f value for shape 2.	ALFMAX(14)	none
		21-30	A/A_f value for shape 3.	ALFMAX(15)	none

*A/A_f is the cross-sectional flow area divided by the cross-sectional flow area of the pipe running full.

**Q/Q_f is the flow rate of the flow divided by the flow rate of the conduit flowing full.

NOTE: All non-decimal numbers must be right-justified.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
6			Maximum Q/Q_f value for each shape.	PSIMAX	
	8F10.5	1-10	Maximum Q/Q_f value for shape 1.	PSIMAX(13)	none
		11-20	Maximum Q/Q_f value for shape 2.	PSIMAX(14)	none
		21-30	Maximum Q/Q_f value for shape 3.	PSIMAX(15)	none
7			Factor used to determine full flow area for each shape, i.e., for use in equation $AFULL = AFACT(GEOM1)^2$.	AFACT	
	8F10.5	1-10	Factor for shape 1.	AFACT(13)	none
		11-20	Factor for shape 2.	AFACT(14)	none
		21-30	Factor for shape 3.	AFACT(15)	none
8			Factor used to determine full flow hydraulic radius for each shape, i.e., for use in equation. RADH = RFACT(GEOM1).	RFACT	
	8F10.5	1-10	Factor for shape 1.	RFACT(13)	none
		11-20	Factor for shape 2.	RFACT(14)	none
		21-30	Factor for shape 3.	RFACT(15)	none
			REPEAT CARD GROUP 9 FOR EACH ADDED SHAPE.		
9			Input of tabular data (area of flow, A, divided by area of conduit, A_f, (A/A_f)) for each added shape corresponding to the equal divisions of the conduit as given by NN on card group 3.	DNORM	
	8F10.5	1-10	First value for A/A_f for shape 1.	DNORM(I,1)	none
		11-20	Second value for A/A_f for shape 1.	DNORM(I,2)	none
		⋮		⋮	
			Last value of A/A_f for shape 1.	DNORM(I,NN(I))	none
			(Total of NN(13)/8 + NN(14)/8 + NN(15)/8 data cards.)		
			REPEAT CARD GROUP 10 FOR EACH ADDED SHAPE.		
10			Input of tabular data (flow rate of flow, Q, divided by the flow rate of the conduit running full, Q_f, (Q/Q_f)) for each added shape corresponding to the equal divisions of the conduit as given by MM on card group 4.	QNORM	
	8F10.5	1-10	First value of Q/Q_f for shape 1.	QNORM	none
		11-20	Second value of Q/Q_f for shape 1.	QNORM(I,2)	none
		⋮		⋮	
			Last value for Q/Q_f for shape 1.	QNORM(I,MM(I))	none
			(Total of MM(13)/8 + MM(14)/8 + MM(15)/8 data cards.)		

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
11	20A4		Title card containing a one-line heading to be printed above output. A numeral 1 should be placed in card column 1 for neat spacing print out.	TITLE	none
12			Execution control data.		
	16I5	3-5	Total number of sewer elements (maximum = 150).	NE	
		8-10	Total number of time-steps (maximum = 150).	NDT	none
		14-15*	Total number of non-conduits into which there will be input hydrographs and pollutographs (maximum = 60, minimum = 1).	NINPUT	none
		19-20	Total number of non-conduit elements at which input hydrographs and pollutographs are to be printed out (maximum = 10, minimum = 1).	NNYN	none
		24-25	Total number of non-conduit elements at which routed hydrographs and pollutographs are to be printed out (maximum = 10, minimum = 1).	NNPE	none
		30**	Total number of non-conduit elements at which flow is to be transferred to the Receiving Water Model by tape (maximum = 5, minimum = 1).***	NOUTS	none
		35	Control parameter for program-generated error messages concerning irregularities occurring in the execution of the flow routing scheme, i.e., NPRINT = 0 to suppress messages, NPRINT = 1 to print messages from ROUTE, NPRINT = 2 to print messages from ROUTE and TRANS.	NPRINT	0
		40	Total number of pollutants being routed (minimum =1, maximum = 4).	NPOLL	none
		45	Total number of iterations to be used in routing routine (4 recommended).	NITER	4
13			Execution control data.		
	8F10.5	1-10	Size of time-step for computations (sec).	DT	none
		11-20	Allowable error for convergence of iterative methods in routing routine (0.0001 recommended).	EPSIL	0.0001
		21-30	Total number of days (dry weather days) prior to simulation during which solids were not flushed from the sewers.	DWDAYS	none

*Must be the same as in the RUNOFF Block (NSAVE).

**These are the only points that can be plotted by subroutine GRAPH after being routed by TRANSPORT.

***A maximum of 37 may be transferred to subroutine GRAPH.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
14			Execution control data.		
	16I5	5	Control parameter specifying means to be used in transferring inlet hydrographs, i.e., NCNTRL = 1, normal transfer by tape or disk, NCNTRL = 0, special transfer requiring additional input specifications.	NCNTRL	0
		10	Control parameter in estimating ground-water infiltration inflows, i.e., NINFIL = 1, infiltration to be estimated (subroutine INFIL called), NINFIL = 0, infiltration not estimated (INFIL not called and corresponding data omitted).	NINFIL	0
		15	Control parameter in estimating sanitary sewage inflows, i.e., NFILTH = 1, sewage inflows to be estimated (subroutine FILTH called), NFILTH = 0, sewage inflows not estimated (FILTH not called and corresponding data omitted).	NFILTH	0
		20	Control parameter concerning printed output, i.e., JPRINT = 1, flows and concentrations printed out in tabular form, JPRINT = 0, flows and concentration not printed or plotted.	JPRINT	0
			REPEAT CARD GROUP 15 FOR EACH NUMBERED SEWER ELEMENT		
15			Sewer element data.		
	5I4	1-4	External element number. No element may be labeled with a number greater than 1000, and it must be a positive numeral (maximum value = 1000).	NOE	none
			External number(s) of upstream element(s). Up to three are allowed. A zero denotes no upstream element (maximum value = 1000).		
		5-8	First of three possible upstream elements.	NUE(1)	none

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		9-12	Second of three possible upstream elements.	NUE(2)	none
		13-16	Third of three possible elements.	NUE(3)	none
		17-20	Classification of element type. Obtain value from Table 4-3.	NTYPE	16
			THE FOLLOWING VARIABLES ARE DEFINED BELOW FOR CONDUITS ONLY. REFER TO TABLE 4-4 FOR REQUIRED INPUT FOR NON-CONDUITS.		
	7F8.3	21-28	Element length for conduit (ft).	DIST	none
		29-36	First characteristic dimension of conduit (ft). See Figure 4-34 and Table 4-5 for definition.	GEOM1	0.0
		37-44	Invert slope of conduit (ft/100 ft).	SLOPE	0.1
		45-52	Manning's roughness of conduit.	ROUGH	0.013
		53-60	Second characteristic dimension of conduit (ft). See Figure 4-34 and Table 4-5 for definition. (Not required for some conduit shapes.)	GEOM2	none
		61-68	Number of barrels for this element. The barrels are assumed to be identical in shape and flow characteristics.	BARREL	1.0
		69-76	Third characteristic dimension of conduit (ft). See Figure 4-34 and Table 4-5 for definition. (Not required for some conduit shapes.)	GEOM3	none
********************************			CARDS 16 THROUGH 26 ARE DATA INPUT FOR INTERNAL STORAGE. (NTYPE = 19). OMIT THESE DATA CARDS IF INTERNAL STORAGE IS NOT DESIRED.	************************	
			REPEAT STORAGE MODEL DATA FOR EACH STORAGE ELEMENT (MAXIMUM = 2).		
16			Storage unit data card.		
	10I5	1-5*	Storage mode parameter. = 1 In-line storage.	ISTMOD	none
		6-10	Storage type parameter. = 1 Irregular (natural) reservoir. = 3 Geometric (regular) uncovered reservoir.	ISTTYP	none
		11-15	Storage outlet control parameter. = 1 Gravity with orifice center line at zero storage tank depth. = 2 Gravity with fixed weir. = 6 Existing fixed-rate pumps. = 9 Gravity with both weir and orifice.	ISTOUT	none

*Must be set equal to one since other storage mode parameters are not programmed.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
17			Computation/print control card.		
	3I10	1-10	Pollutant parameter. = 0 No pollutants (hydraulics only). = 1 Perfect plug flow through basin. = 2 Perfect mixing in basin.	IPOL	none
		11-20	Print control parameter. = 0 No print each time-step. = 1 Print each time-step in storage.	IPRINT	none
		21-30	Cost computation parameter. = 0 No cost computations. = 1 Costs to be computed.	ICOST	none
18			Reservoir flood depth data card.		
	F10.2	1-10	Maximum (flooding) reservoir depth (ft).	DEPMAX	none
			INCLUDE EITHER CARD GROUP 19 OR 20, NOT BOTH.		
			INCLUDE CARD GROUP 19 ONLY IF ISTTYP ON CARD 16 HAS THE VALUE 1.		
19			Reservoir depth-area data card (4(F10.2, F10.0)).		
	F10.2	1-10	A reservoir water depth (ft).	ADEPTH(1)	none
	F10.0 ⋮	11-20	Reservoir surface area corresponding to above depth (sq ft).	AASURF(2) ⋮	none
	F10.2	61-70	A reservoir water depth (ft).	ADEPTH(4)	none
	F10.0	71-80	Reservoir surface area corresponding to above depth (sq ft). (NOTE: The above pair of variables is repeated 11 times, 4 pairs per card.)	AASURF(4)	
			INCLUDE CARD 20 ONLY IF ISTTYP ON CARD 16 HAS THE VALUE 3.		
20			Reservoir dimensions data card.		
	2F10.0	1-10	Reservoir base area (sq ft)	BASEA	none
		11-20	Reservoir base circumference (ft)	BASEC	none
	F10.5	21-30	Cotan of sideslope (horizontal/vertical).	COTSLO	none

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			INCLUDE ONLY ONE OF THE OUTLET DATA CARDS 21, 22, 23, or 24.		
			INCLUDE CARD 21 ONLY IF ISTOUT ON CARD 16 HAS THE VALUE 1.		
21			Orifice outlet data card.		
	F10.3	1-10	Orifice outlet area x discharge coefficient (sq ft).	CDAOUT	none
			INCLUDE CARD 22 ONLY IF ISTOUT ON CARD 16 HAS THE VALUE 2.		
22			Weir outlet data card.		
	2F10.3	1-10	Weir height (ft) above depth = 0.	WEIRHT	none
		11-20	Weir length (ft).	WEIRL	none
			INCLUDE CARD 23 ONLY IF ISTOUT ON CARD 16 HAS THE VALUE 6.		
23			Pump outlet data card.		
	3F10.3	1-10	Outflow pumping rate (cfs).	QPUMP	none
		11-20	Depth (ft) at pump startup.	DSTART	none
		21-30	Depth (ft) at pump shutdown (DSTOP > 0.0).*	DSTOP	none
			INCLUDE CARD 24 ONLY IF ISTOUT HAS THE VALUE 9.		
24			Weir and orifice outlet data card.		
	8F10.5	1-10	Weir height above depth = 0 (ft).	WEIRHT	none
		11-20	Weir length (ft).	WEIRL	none
		21-30	Orifice outlet area x discharge coefficient (sq ft).	CDAOUT	none
		31-40	Orifice centerline elevation above zero depth (ft).	ORIFHT	none
25			Initial conditions data card.		
	2F10.2	1-10	Storage (cf) at time zero.	STORO	none
		11-20	Outflow rate (cfs) at time zero.	QOUTO	none

*DSTOP must equal or be greater than the level in storage that contains enough volume to handle the pumping rate, QPUMP, for one time-step.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			CARD 26 MUST BE INCLUDED: IT MAY BE BLANK IF ICOST ON CARD 17 HAS THE VALUE 0.		
26			Cost data card.		
	F10.2	1-10	$/cy for storage excavation.	CPCUYD	none
	2F10.0	11-20	$/acre for storage land.	CPACRE	none
		21-30	$/pump station with related structures.	CPS	none

******************************** END OF INTERNAL STORAGE DATA CARDS. **************************

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			TO BE READ FROM TAPE (unformatted) IF NCNTRL = 1.		
A*			Description of following inlet hydrographs. (160 character string)	TITLE(I)	none
B*			Control variable.		
			Total number of time-steps in RUNOFF.	NDUMI	none
			Total number of inlet hydrographs.	NINPUT	none
			Total number of pollutants.	NPOLL	none
			Time-step length (sec) in RUNOFF.	NDUM2	none
			Clock time for beginning of rain (sec).	TZERO	none
C*			Non-conduit element numbers into which hydrographs and pollutographs (transferred from the Runoff Model) enter the sewer system. These must be in the order in which hydrograph and pollutograph ordinates appear at each time-step.	NORDER(I)	none
27**			List of external non-conduit element numbers at which outflows are to be transferred to Receiving Water Model (minimum number of elements specified = 1, maximum number = 5).	JN	
	16I5	1-5	First element number.***	JN(1)	none
		6-10	Second element number.***	JN(2)	none
		⋮			
			Last element number.***	JN(NOUTS)	none
28			List of external non-conduit element numbers at which input hydrographs and pollutographs are to be stored and printed out (minimum number of elements specified = 1, maximum number = 10).	NYN	
	16I5	1-5	First input location number.	NYN(1)	none
		6-10	Second input location number.	NYN(2)	none
		⋮			
			Last input location number.	NYN(NNYN)	none

*Information that is transferred from RUNOFF Block, data cards are not required.
**Only these element numbers can be plotted by subroutine GRAPH.
***Element numbers transferred to the Receiving Water Block must be numbered less than 100.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
29			List of external non-conduit element numbers at which output hydrographs and pollutographs are to be stored and printed out (minimum number of elements specified = 1, maximum number = 10).	NPE	
	16I5	1-5	First output location number.	NPE(1)	none
		6-10	Second output location number.	NPE(2)	none
		⋮		⋮	
			Last output location number	NPE(NNPE)	none
			IF SUBROUTINE INFIL IS TO BE CALLED (NINFIL = 1), INSERT CARDS 30 THROUGH 32, OTHERWISE OMIT.		
30			Estimated infiltration.		
	10F8.1	1-8	Base dry weather infiltration (gpm).	DINFIL	0.0
		9-16	Groundwater infiltration (gpm).	GINFIL	0.0
		17-24	Rainwater infiltration (gpm).	RINFIL	0.0
31			Control parameters.		
	I5	3-5	Day of estimate.	NDYUD*	none
	6F8.1	6-13	Peak residual moisture (gpm).	RSMAX	0.0
		14-21	Average joint distance (ft).	ULEN	6.0
32			Monthly degree-days.	NDD	
	16I5	1-5	July degree-days.	NDD(1)	none
		6-10	August degree-days.	NDD(2)	none
		⋮		⋮	⋮
		56-60	June degree-days.	NDD(12)	none
			IF SUBROUTINE FILTH IS TO BE CALLED (NFILTH = 1), INSERT CARD GROUPS 33 TO 44, OTHERWISE OMIT.		
33			Factors to correct yearly average sewage flows to daily averages by accounting for daily variations throughout a typical week.		
	7F10.0	1-10	Flow correction for Sunday.	DVDWF(1)	1.0
		11-20	Flow correction for Monday.	DVDWF(2)	1.0
		⋮		⋮	
		61-70	Flow correction for Saturday.	DVDWF(7)	1.0

*Day one is July 15.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
34			Factors to correct BOD yearly averages to daily averages.		
	7F10.0	1-10	BOD correction for Sunday.	DVBOD(1)	1.0
		⋮			⋮
		61-70	BOD correction for Saturday.	DVBOD(7)	1.0
35			Factors for correction of yearly SS averages to daily averages.		
	7F10.0	1-10	SS correction for Sunday.	DVSS(1)	1.0
		⋮			⋮
		61-70	SS correction for Saturday.	DVSS(7)	1.0
36			Factors to correct daily average sewage flow to hourly averages by accounting for hourly variations throughout a typical day (3 cards needed).		
	8F10.0	1-10	Midnight to 1 a.m. factor (first card).	HVDWF(1)	1.0
		⋮			⋮
		1-10	8 a.m. to 9 a.m. factor (second card).	HVDWF(9)	1.0
		⋮			⋮
		1-10	4 p.m. to 5 p.m. factor (third card).	HVDWF(17)	1.0
37			Factors for BOD hourly corrections (3 cards needed).		
	8F10.0	1-10	Midnight to 1 a.m. factor (first card).	HVBOD(1)	1.0
		⋮			⋮
		71-80	11 a.m. to midnight factor (third card).	HVBOD(24)	1.0
38			Factors for SS hourly corrections (3 cards needed).		
	8F10.0	1-10	Midnight to 1 a.m. factor (first card).	HVSS(1)	1.0
		⋮			⋮
		71-80	11 a.m. to midnight factor (third card).	HVSS(24)	1.0
			INCLUDE ONLY WHEN 3 POLLUTANTS ARE SPECIFIED.		
39			Factors for E. coli hourly corrections (3 cards needed).		
	8F10.0	1-10	Midnight to 1 a.m. factor (first card).	HVCOLI(1)	1.0
					⋮
		71-80	11 a.m. to midnight factor (third card).	HVCOLI(24)	1.0

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
40			Study area data.		
	6I5	1-5	Total number of subareas within a given study area in which sewage flow and quality are to be estimated.	KTNUM	none
		6-10	Indicator as to whether study area data, such as treatment plant records, are to be used to estimate sewage quality, i.e., KASE = 1, yes, KASE = 2, no.	KASE	1
		11-15	Total number of process flows within the study area for which data are included in one of the following card groups.	NPF	0
		16-20	Number indicating the day of the week during which simulation begins (Sunday = 1).	KDAY	0
		21-25	Number indicating the hour of the day during which simulation begins (1 a.m. = 1).	KHOUR	0
		26-30	Number indicating the minute of the hour during which simulation begins.	KMINS	0
	2F5.1	31-35	Consumer Price Index.	CPI	109.5
		36-40	Composite Construction Cost Index.	CCCI	103.0
	F10.3	41-50	Total population in all areas (thousands).	POPULA	none
			IF KASE = 1, INCLUDE CARD GROUPS 41, 42 AND 43.		
41			Average study area data.		
	3F10.0	1-10*	Total study area average sewage flow, i.e., from treatment plant records (cfs).	ADWF	0.0
		11-20	Total study area average BOD (mg/L).	ABOD	none
		21-30	Total study area average SS (mg/L).	ASUSO	none
	E10.2	31-40	Total coliforms (MPN/100 ml).	ACOCI	none
42			Categorized study area data.		
	8F8.0	1-8	Total study area from which ABOD and ASUSO were taken (acres).	TOTA	none
		9-16	Total contributing industrial area (acres).	TINA	none
		17-24	Total contributing commercial area (acres).	TCA	none

*If ADWF = 0.0, then total BOD, SS, and COLI will = 0.0.

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
		25-32	Total contributing high income (above $15,000) residential area (acres).	TRHA	none
		33-40	Total contributing average income (above $7,000 but below $15,000) residential area (acres).	TRAA	none
		41-48	Total contributing low income (below $7,000) residential area (acres).	TRLA	none
		49-56	Total area from the above three residential areas that contribute additional waste from garbage grinders (acres).	TRGGA	none
		57-64	Total park and open area within the study area (acres).	TPOA	none
			IF PROCESS FLOW DATA ARE AVAILABLE (NPF NOT EQUAL 0 AND KASE = 1), REPEAT CARD GROUP 43 FOR EACH PROCESS FLOW.		
43			Process flow characteristics.		
	I5	1-5	External manhole number into which flow is assumed to enter (maximum value = 150, minimum value = 1).	INPUT	none
	6F10.3	6-15	Average daily process flow entering the study area system (cfs).	QPF	none
		16-25	Average daily BOD of process flow (mg/L).	BODPF	none
		26-35	Average daily SS of process flow (mg/L).	SUSPF	none
			REPEAT CARD GROUP 44 FOR EACH OF THE KTNUM SUBAREAS.		
44			Subarea data.		
	2I3	1-3	Subarea number.	KNUM	none
		4-6	External number of the manhole into which flow is assumed to enter for subarea KNUM (maximum value = 150, minimum value = 1).	INPUT	none
	3I1	7	Predominant land use within subarea.	KLAND	none
		8	Parameter indicating whether or not water usage within subarea KNUM is metered.	METHOD	2
			METHOD = 1, metered water use,		
			METHOD = 2, incomplete or no metering.		
		9	Parameter indicating units in which water usage estimates (WATER) are tabulated.	KUNIT	0
			KUNIT = 0, thousand gal./mo,		
			KUNIT = 1, thousand cf/mo.		

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
	13F5.1	10-14	Measured winter water use for subarea KNUM in the units specified by KUNIT (not required).	WATER	none
		15-19	Cost of the last thousand gal. of water per billing period for an average consumer within subarea KNUM (cents/1,000 gal.) (not required).	PRICE	none
		20-24	Measured average sewage flow from the entire subarea KNUM (cfs) (not required).	SEWAGE	none
		25-29	Total area within subarea KNUM (acres) (maximum = 200).	ASUB	none
		30-34*	Population density within subarea KNUM (population/acre).	POPDEN	none
		35-39*	Total number of dwelling units within subarea KNUM.	DWLNGS	10.0/ac.
		40-44*	Number of people living in average dwelling unit within subarea KNUM.	FAMILY	3.0
		45-49*	Market value of average dwelling unit within subarea KNUM (thousands of dollars).	VALUE	20.0
		50-54*	Percentage of dwelling units possessing garbage grinders within subarea KNUM.	PCGG	none
		55-59**	Total industrial process flow originating within subarea KNUM (cfs).	SAQPF	0.0
		60-64	BOD contributed from industrial process flow originating within subarea KNUM (mg/L).	SABPF	none
		65-69	SS contributed from industrial process flow originating within subarea KNUM (mg/L).	SASPF	none
		70-74	Income of average family living within	XINCOM	VALUE/2.5
	I2	75-76	MSUBT = 0, subtotals not made, MSUBT = 1, subtotal made.	MSUBT	0
			END OF FILTH DATA CARDS.		

*Not required if KLAND greater than 2.

**If SAQPF = 0.0, then DWBOD and DWSS will be zero for Land Use 4 (i.e., for industrial flows to be considered KLAND must equal 4).

Table 4-6. (continued)

Card Group	Format	Card Columns	Description	Variable Name	Default Value
			TO BE READ FROM TAPE AT EACH TIME-STEP (unformatted).		
D*			Time-step number.	DTIM	none
			Runoff at each inlet point (cfs).	RNOFF(I)	none
			Pollutant rates for each pollutant at each inlet point (lb/min).	PLUTO(I,J)	none
			i.e., for each record.	DTIM RNOFF(1) ⋮ RNOFF(NINPUT) PLUTO(1,1) ⋮ PLUTO(NINPUT,1) ⋮	
			FOR GRAPHING TRANSPORT OUTPUT, CALL GRAPH SUBROUTINE THROUGH THE EXECUTIVE BLOCK.		
			END OF TRANSPORT BLOCK DATA CARDS.		

*Information that is transferred from RUNOFF Block; data cards not required.

Table 4-7. TRANSPORT BLOCK VARIABLES

Variable Name	C*	Description	Units
A	C	Cross-sectional areas of flow	sq ft
AA		Cross-sectional areas of flow	sq ft
AAA	C	Flow depth computational variable	
AASURF		Surface area (data array member)	sq ft
AB		Area computational variable	
ABOD		Average BOD concentration measured in sewer or at treatment facility	mg/L
ACOLI		Total coliforms	MPN/100 ml
ADEPTH		Depth (data array member)	ft
ADWF		Average measured DWF	cfs
AF		Cross-sectional area of conduit	sq ft
AFACT	C	Factor to calculate AFULL	
AFULL	C	Full flow area for conduits	sq ft
AINFIL		Total infiltration within drainage basin	cfs
ALF	C	Value of A/A_f corresponding to Q/Q_f value	
ALFMAX	C	Value of A/A_f corresponding to maximum Q/Q_f value	
ALM		Computational variable associated with conduit area	
ALPHA		Normalized area flow, A/A_f	
ANORM	C	Normalized depths, D/D_f, corresponding to A/A_f	
AO2DT2		Routing parameter (data array member)	
APLAN	C	Land area requirement	sq ft
AQQ		Average computed infiltration	cfs
AREAF		Flow area of given flow rate in conduit	sq ft
ARG		Cotangent of angle which is formed from radius and wetted surface	
ASUB		Total area within subarea KNUM	acres
ASUSO		Average SS concentration measured in sewer or at treatment facility	mg/L
ATERM	C	Variable used to calculate area of a conduit, area flow/area full	
A1		Normalized depth of conduit upstream, A/A_f	ft
A1BOD		Average weighted BOD	lb/day/cfs
A1COLI		Average number of coliform bacteria	MPN/day/cfs
A1SS		Average weighted SS	lb/day/cfs
A2		Normalized depth of conduit downstream, A/A_f	ft
BARREL	C	Total number of barrels in each conduit	
BASEA		Base area (geometric basin)	sq ft
BASEC		Base circumference (geometric basin)	ft
BDEPTH	C	Depth (array member)	ft
BLANK	C	Supercritical flow indicator	
BODCON		Computed BOD concentration	mg/L
BODCOT		BOD outflow concentration	mg/L
BODIN	C	BOD input to storage element	lb/DT
BODOUT	C	BOD output from storage element	lb/DT
BODPF		Average BOD of a process flow	mg/L
BSTOR	C	Maximum storage capacity of storage element	cf

C* = Variable names shared in common blocks.

Table 4-7 (continued)

Variable Name	C*	Description	Units
CATH	C	Flow depth computation variable	
CATHY		Flow depth variable used in computing the hydraulic radius	
CCCI		Composite construction cost index	
CDAOUT		Orifice area x discharge coefficient	sq ft
CF		Correction factor to weight sewage strength	
CF2		Correction factor for DWF	
CLAND	C	Cost of land	$
COSTSLO		Basin sideslopes cotangent	ft/ft
CPACRE	C	Unit cost of land	$/acre
CPCUYD	C	Unit cost of excavation	$/cy
CPI		Consumer Price Index	
CPOLL	C	Pollutant concentrations	lb/cf
CPS	C	Pumping station and structure cost	$/ps
CRITD		Critical settling diameter of particles undergoing deposition in conduits	mm
CSTOR	C	Cost of excavation for storage	$
CTOTAL	C	Total cost	$
CUMIN		Cumulative water inflow	cf
CUMOUT	C	Cumulative water outflow	cf
C1	C	Flow routing variable	variable
C1BOD		Computed BOD total after deducting process flows	lb/day
C1DT		Time-step	days
C1DWF		Total DWF less infiltration	cfs
C11		Normalized flow-area computational variable	
C2		Negative value of normalized flow rate	
C2BOD		Computed BOD total further corrected for weighting effects	lb/day
C2DWF		C1DWF less process flows	cfs
C2SS		Weighted SS strengths according to subarea	lb/day
D		Computational variable used in subroutine NEWTON	
DALPHA		Increment for normalized area data	
DD		Wetted depth of the modified element cross-section area, i.e., basket-handle conduit and rectangular with triangular bottom	
DDEPTH		Depth increment	ft
DDWF		Daily adjusted sewage inflows, ADWF	cfs
DELQ		Incremental difference of the flows between each time-step	cfs
DEPMAX	C	Maximum flooding depth of reservoir	ft
DEPTH		Water depth of reservoir	ft
DEPTHL		Depth of reservoir for the previous time-step	ft
DETENT	C	Reservoir plug flow detention time	sec
DH		Computation variable used in determining the flow over a flow divider	
DIAM		Diameter of circular pipe	ft

Table 4-7 (continued)

Variable Name	C*	Description	Units
DINFIL		Dry weather infiltration	gpm
DIST	C	Conduit length	ft
DNORM	C	Normalized depths of flow	
DPSI		Derivative of Q/Q_f with respect to A/A_f	
DPSI		Name of subroutine	
DSTART	C	Depth at the pump startup	ft
DSTOP	C	Depth at pump shutdown	ft
DT	C	Size of time-step	sec
DTIM		Time on input tape from RUNOFF	sec
DTMORE	C	Extra time-step needed to pump dry	
DTON	C	Number of time-steps pumped	
DTPUMP	C	Total time-steps to pump dry	
DUMDEP	C	Dummy depth used in internal storage reservoir calculations	ft
DUMSTR	C	Dummy storage volume used in internal storage reservoir calculations	cf
DUMY1		Corrected hourly DWF	cfs
DUMY2		Corrected hourly BOD concentration	lb/sec
DUMY3		Corrected hourly SS concentration	lb/sec
DUMY4		Corrected hourly concentration of fourth pollutant	(not yet programmed)
DUMY5		Corrected hourly coliform concentration	MPN/sec
DV		The change in flow velocity between two succeeding flow routing iterations	
DVBOD	C	Daily BOD variation factor	
DVDWF	C	Daily sewage flow variation factor	
DVSS	C	Daily SS variation factor	
DWBOD		BOD of DWF of each subarea	lb/sec/DT
DWCOLI		Coliform load of DWF in each subarea	MPN/100 mL
DWDAYS		Total number of antecedent dry days	days
DWF		Dry weather flow	cfs
DWLNGS		Total number of dwelling units within subarea KNUM	
DWLOAD		Name of subroutine	
DWSS		SS of DWF in each subarea	lb/sec/DT
DW1BOD		DWF BOD in each subarea for each time-step	lb/DT
DW1SS		DWF SS in each subarea for each time-step	lb/DT
DXDT	C	Length of conduit divided by time-step interval in seconds	ft/sec
D1	C	Perimeter of rectangular, round bottom conduit	ft
D1		Rate constant for decay	1/day
D2	C	Wetted perimeter of rectangular, round bottom conduit	ft
D2		Rate constant for reaeration	1/day
D2COLI		Total DWF coliform per subarea	MPN/sec
EPSIL	C	Allowable error for convergence in routing routine	
FAMILY		Number of people living in average dwelling unit within subarea KNUM	
FILTH		Name of subroutine	
FINDA		Name of subroutine	

Table 4-7 (continued)

Variable Name	C*	Description	Units
FIRST		Name of subroutine	
PON		Fraction of time-step pumped	
PRAC	C	Fraction of an inflow plug	
GEOM1	C	Conduit vertical dimension	ft
GEOM2	C	Conduit horizontal dimension	ft
GEOM3	C	Conduit dimension	ft
GINFIL		Groundwater infiltration	gpm
GNO	C	Supercritical flow indicator, flow not super-critical	
H		Head over weir	ft
HELP		Normalized area flow (= ALPHA)	
HVBOD	C	Hourly BOD variation factor	
HVCOLI	C	Hourly coliform variation factor in DWF	
HVDWF	C	Hourly sewage flow variation factor	
HVSS	C	Hourly SS variation factor	
I		Dimension and do loop counter	
I		Ratio of A/ΔA for linear interpolation counter (DPSI, PSI)	
ICHK		Newton-Raphson iteration check	
ICOST	C	Cost output control parameter	

Variable Name	C*	Description	Units
IFLOOD	C	Flood Indicator	
II		Do loop counters	
III		Do loop counters	
IK		Do loop counter for element number	
INCNT	C	Counting parameter for I/O input files	
INFIL		Name of subroutine	
INITAL	XP	Name of subroutine	
INPUT		External element number for flow and quality inputs to the sewer	
INUE	C	Internal upstream element numbers	
IOLD	C	Routing solution indicator	
IOUTCT	C	Counting parameter for I/O output files	
IP		Pollutant number	
IPOL	C	Pollution control parameter	
IPRINT	C	Print control parameter	
IR	C	Element number sequencing array	
ISTMOD	C	Storage mode parameter	
ISTOUT	C	Storage outlet type parameter	
ISTTYP	C	Storage reservoir type parameter	
ITER	C	Iteration number for routing	
J		Do loop counter	
JIN	C	Input file reference numbers	

Table 4-7 (continued)

Variable Name	C*	Description	Units
JJ		Do loop counter	
JN		External element numbers at which flow enters receiving water	
JOUT	C	Output file reference numbers	
JP		Number of first inlet plug in outflow	
JPLOT		Control parameter for plotting routed hydrographs and pollutographs	
JR	C	Element number sequencing array	
K		Interpolation warning flag	
KASE		Study area indicator	
KDAY		Number for the day of the week (Sunday = 1)	
KDEPTH	C	Parameter indicating form of input for D-A data	
KDT		Time-step number	
KFLAG		Interpolation warning flag	
KFULL	C	Parameter indicating surcharging	
KHOUR	C	Number for the hour of a day	hr
KJ		Do loop counter for time	
KLAND		Predominant land use within subarea	
KLASS	C	Parameter indicating form of input for Q-A data	
KMINS	C	Number for the minute of an hour	min
KNUM		Total number of subareas within a given study area in which sewage flow and quality are to be estimated	

Variable Name	C*	Description	Units
KP		Inlet plug number	
KPRINT		Control parameter for printing sewer cross-section data	
KSTOR	C	Storage unit number	
KSTORE	C	Storage element array	
KTNUM	C	Total number of subareas	
KTSTEP	C	Total Number of time-steps	
KUNIT	C	Parameter indicating units in which water usages are tabulated	
KVAL		Shields K as criterion for deposition and resuspension	
L		Size of data array	
L		GEOM3	
LABEL	C	Flag to label last increment of flow in plug flow	
LP	C	Number of last inlet plug in outflow	
LPREV	C	LP for previous time-step	
L1		Half width of the wetted surface in the element cross-sectional area	
M	C	Current internal element number	
METHOD		Parameter indicating whether or not water usage is metered	
MLTBE		Day on which melting period begins	
MLTEN		Day on which melting period ends	
MM	C	Total number of values of ANORM and QNORM	
MMM	C	Total number of values of ANORM and QNORM	

Table 4-7 (continued)

Variable Name	C	Description	Units
MSUBT		Subtotaling indicator for DWF output	
N	C	Current time-step number	
NAME	C	Name given to each user-supplied sewer cross-section	
NAREA1		Dummy variables used to calculate length of melting in INFIL	
NCNTRL		Control parameter for type of I/O interfacing mechanism	
ND		Do loop counter for converting unit	
NDD		Monthly degree/day values	degree-day
NDDAY		Subscript variable	
NDT	C	Total number of time-steps	
NDUM1		Total number of time-steps in runoff	
NDUM2		Size of time-step in RUNOFF, read off input file	sec
NDXDAY		Assigned daily degree/day values	degree-day
NDYUD		Day on which infiltration estimate is desired	
NE	C	Total number of sewer elements	
NEE		NE + 1	
NEP1		NE + 1	
NEWTON		Name of subroutine	
NFILTH		Control parameter for calling subroutine FILTH	
NGOTO		Element type number minus fifteen	
NIN	C	Internal element sequencing number	
NINFIL		Control parameter for calling subroutine INFIL	

Variable Name	C*	Description	Units
NINPUT		Total number of rainfall input locations to the sewer	
NITER		Maximum number of iterations to be made in flow routing	
NJ		Do loop counter for converting units	
NKLAS		NKLASS + 12	
NKLASS	C	Total number of user-supplied sewer cross-sections	
NN	C	Total number of values of DNORM	
NNEED		Dummy variable for sequencing elements	
NNN		Total number of values of DNORM	
NNPE		Total number of routed sewer hydrographs to be printed out	
NNYN		Total number of input hydrographs to be printed out	
NOE	C	External number of an element	
NORDER	C	External non-conduit element numbers at which runoff enters sewer	
NOS		Dummy variable	
NOUTS		Total number of hydrographs to the receiving water	
NPE	C	External element numbers at which routed outflow is printed	
NPF		Number of process flow	
NPOLL	C	Total number pollutants being routed	
NPOLS		NPOLL + 1	
NPRINT	C	Control parameter for printing sewer routing error messages	
NSCRAT	C	Data set reference numbers for temporary storage of data	

Table 4-7 (continued)

Variable Name	C*	Description	Units
NSCRAT	C	Scratch tape number	
NSTOR	C	Total number of storage units	
NT		Element type	
NTOT		Total number of degree days above 750	degree-day
NTRIN		Data set reference numbers for I/O file	
NTROUT		Data set reference numbers for I/O file	
NTU		Element type	
NTX		Scratch file	
NTYPE	C	Element type	
NUE	C	External upstream element numbers	
NX		Day numbers used in assigning daily degree/day values	
NX1		Day numbers used in assigning daily degree/day values	
NX2		Day numbers used in assigning daily degree/day values	
NY		Assigned daily degree/day values	
NYN	C	External element number at which inflow to sewer is printed	
NY1		Assigned daily degree/day values	degree-day
NY2		Assigned daily degree/day values	degree-day
OP		The preparation of total infiltration for each conduit	

Variable Name	C*	Description	Units
OPINF		Opportunity factor representing length of openings susceptible to infiltration for total areas	ft
OPNFIL		Opportunity factor representing susceptibility of each conduit to infiltration for individual areas	ft
OUT	C	Overflow hydrograph and pollutograph storage array	variable
OUTIN	C	Inflow hydrograph and pollutograph storage array	variable
OUT1	C	Printed outflows	cfs
OUT2	C	Printed pollutants	lb/min, MPN/min
O2DT2		Interpolated storage volume	cf
PCGG		Percent of dwelling units possessing garbage grinders within subarea KNUM	
PCT1		Fraction of sediment on bottom of sewer with diameter greater than or equal to CRITD	
PCT2		Fraction of sediment in suspension with diameter greater than or equal to CRITD	
PER		Wetted perimeter of modified cross-section area	ft
PLUTO	C	Pollutant ordinates from surface runoff	lb/min
POP		Total population in each subarea	
POPDEN		Population density per acre	
POPULA		Total population in all areas	thousands
PP		Same as OUT2	
PRICE		Cost of last thousand gallons of water per billing period	¢/1,000 gal.
PRINT		Name of subroutine	

Table 4-7 (continued)

Variable Name	C*	Description	Units
PS		Normalized flows	
PSI		Name of function	
PSI		Normalized flow, same as PS	
PSIMAX	C	Maximum Q/Q_f value	
PUMP	C	Constant pumping rate of pumps	cfs
P1	C	Conduit dimensional variable for computation purposes (FIRST)	
P2	C	Conduit dimensional variable for computation purposes (FIRST)	
P4	C	Conduit dimensional variable for computation purposes (FIRST)	
P5	C	Conduit dimensional variable for computation purposes (FIRST)	
P6	C	Conduit dimensional variable for computation purposes (FIRST)	
P7	C	Conduit dimensional variable for computation purposes (FIRST)	
Q	C	Sewer flows	cfs
QDWF	C	Sewage inflows	cfs
QFULL	C	Full flow capacity for conduits	cfs
QI	C	Sewer element inflow	cfs
QINF		Total infiltration	gpm
QINFIL	C	Groundwater infiltration inflows	cfs

Variable Name	C*	Description	Units
QINST	C	Water inflow rate to storage unit	cfs
QINSTL	C	Inflow rate previous time-step	cfs
QMAX	C	Maximum flow capacity for conduits	cfs
QNORM	C	Normalized flows	Q/Q_f
QO	C	Sewer element outflow	cfs
QOLD		Flow rate for previous time-step	cfs
QOUST	C	Outflow rate from storage unit	cfs
QOUSTL	C	Outflow rate previous time-step	cfs
QOUT		Outflow rate	cfs
QOUTO	C	Initial outflow rate	cfs
QO1	C	Undiverted flow in a flow divider or the flow going to the element number given in GEOM3	cfs
QO2	C	Diverted flow in a flow divider	cfs
QPF		Average daily process flow entering study system	cfs
QPUMP	C	Pumped outflow rate	cfs
QQ		Infiltration flow rate	cfs
QQDWF		Sum of DWF and infiltration flow	cfs
QQF		Ratio of total infiltration flow to DWF flow	
QUAL		Name of subroutine	
R	C	Same as P5, conduit dimensional variable for depth calculations	
RADH		Name of function	
RECEIV		Name of subroutine	

Table 4-7 (continued)

Variable Name	C*	Description	Units
RFACT	C	Factor to calculate full-flow hydraulic radius	
RH		Computation variable associated with conduit flow area	
RHYD		Hydraulic radius	ft
RINFIL		Average infiltration due to rain water infiltrating into pipes from the ground	gpm
RNOFF	C	Flow ordinates from surface runoff	cfs
ROUGH	C	Conduit roughness (Manning's n)	
ROUTE		Name of subroutine	
RR		Radius of the element (circular pipe)	
RSMAX		Peak infiltration caused by residual melting ice	gpm
S		Wetted perimeter (RADH)	ft
S		Saturation value for DO (QUAL)	mg/L
SABPF		BOD contributed from industrial process flow	mg/L
SAQPF		Total industrial process flow originating within subarea KNUM	cfs
SASPF		SS contributed by industrial process flows	mg/L
SBOD	C	BOD in storage unit	lb
SBODC		BOD concentration in storage unit	mg/L
SCF	C	Supercritical flow indicator	
SCOL		Coliform concentration in storage unit	lb
SCOLC		Coliform concentration in storage unit	MPN/ml
SCOUR	C	Sediment removed from conduits	lb
SEWAGE		Measured average sewage flow	cfs
SINFIL		Infiltration due to melting residual ice	gpm
SLOP		Name of subroutine	
SLOPE	C	Conduit invert slope	ft/ft ft/100 ft
SLUPE		Slope of line $-C_1\alpha - C_2$ on Figure 4-18	
SMMBOD		Summation of BOD in system	lb/sec/DT
SMMDWF		Summation of DWF in system	cfs
SMMQQ		Summation of infiltration flow rate in system	cfs
SMMSS		Summation of SS in system	lb/sec/DT
SMTDWF		Sum total of DWF and infiltration	cfs
SPG		Specific gravity of sediment	
SSCONC		Total and subtotal SS concentration of DWF	mg/L
SSCOUT		SS concentration in outflow	mg/L
SSIN	C	SS inflow rate	lb/DT
SSOUT	C	SS outflow rate	lb/DT
SSS	C	SS in storage unit	lb
SSSC		SS concentration in storage unit	mg/L
STOR	C	Water in storage	cf
STORF	C	Storage at end of storm	cf
STORL	C	Stored water previous time-step	cf
STORMX	C	Maximum storage during storm	cf
STORO	C	Initial storage	cf
SUMBOD		Sum of BOD from all process flow	lb/sec
SUMINF		Sum of DINFIL and RINFIL	gpm
SUMQPF		Sum of the process flows from all locations	cfs

Table 4-7 (continued)

Variable Name	C*	Description	Units
SUMSS		Sum of SS from all process flow	lb/sec
SUM1		Sum for sewer flows	cfs
SUM2		Sum for concentration of pollution, SS	lb/sec
SUM3		The amount of solids held in suspension due to velocity of flow	lb/sec
SURGE1	C	Surcharged flow volume, last time-step	cf
SURGE2	C	Surcharged flow volume, this time-step	cf
SUSPF		Average daily SS of process flow	
TBODOT		Total BOD discharged from outfall	lb
TCA		Total contributing commercial area	acres
TCOLI		Total coliform in DWF per day	MPN/day
TDTR		Total contributing area except industrial and park and open space area	acres
TDWFA		Total computed residential and commercial area which contributed to DWF	acres
TERM		Term in routing equation	
THETA		The angle which is drawn from center of cross-section area to the wetted surface	radian
TIME	C	Time from start of simulation	sec
TIME2M		Time since start of inflow	min
TINA		Total contributing industrial area	acres
TITLE	C	Title associated with I/O	
TOTA		Total study area from which ABOD and ASUSO were taken	acres
TOTAL		Sum of all incoming sewer flow	cfs
TOTAL1		Sum of all pollutant flow rates from sewer element immediately upstream	lb/sec
TOTAL2		Pollutant flow rate of incoming DWF	variable
TOTAL3		Pollutant flow rate of incoming runoff	lb/sec
TOTAL4		Pollutant flow rate of all flow and scouring effect	lb/sec
TOTBOD		Total of BOD	lb/day
TOTPOP		Total population	
TOTSS		Total SS	lb/day
TPOA		Total park and open space area	acres
TRAA		Total contributing average income below $15,000 but above $7,000 residential area	acres
TRANS		Name of subroutine	
TRGGA		Total area from TRHA, TRAA, TRLA that contributes additional waste from garbage grinders	acres
TRHA		Total contributing high income above $15,000 residential area	acres
TRLA		Total contributing low income below $7,000 residential area	acres
TSSOUT		Total SS discharged from outfall	lb
TSTCST		Name of subroutine	
TSTORG		Name of subroutine	
TSTRDT		Name of subroutine	
TZERO		Time storm started	sec
ULEN		Average distance between joints in study area sewers	ft
ULIMIT		Upper limit of bed load of solids	lb

Table 4-7 (continued)

Variable Name	C*	Description	Units
VALUE		Market value of average dwelling unit within subarea KNUM	$1000's
VEL		Name of a function	
VOLIN	C	Water inflow per time-step	cf
VOLOUT	C	Water outflow per time-step	cf
VOL1		Previous volume of wastewater within each element	cf
VOL2		Current volume of wastewater within each element	cf
WATER		Winter water use for KNUM (units of KNUM)	variable
WD		Weight on spatial derivative in routing flows	
WDWF	C	Sewage pollutant concentrations	lb/sec
WTDWFA		Weight strength of DWF contributing area (not including industrial and park and open area)	acres
WDWF1		Daily adjusted sewage BOD concentration	lb/sec
WDWF2		Daily adjusted sewage SS concentration	lb/sec
WDWF3		Daily adjusted sewage coliform concentration	MPN/sec
WEIRHT		Weir height	ft
WEIRL		Weir length	ft
WELL1	C	Wet well volume for lift stations	cf
WELL2	C	Wet well volume for lift stations	cf
WSLOPE		Slope of water surface	ft/ft
WT		Weight on time derivative in routing flows	
X		Data array member	
XE		Input to interpolation routine	
XINCOM		Income of average family living	$1000's
XL		Width of rectangular pipe	ft
XMLTBE		Floating point number MLTBE	
XMLTEN		Floating point number MLTEN	
XNDYUD		Floating point number NDYUD	
XXARG		Dummy variable used to calculate SINFIL	
Y		Data array member	
YE		Output value from interpolation routine	
YES	C	Supercritical flow indicator, flow is supercritical	

EXAMPLES

Three examples of the use of the Transport Block or its subroutines are given:

Example 1 - The complete Transport Block but with Internal Storage and Infiltration not called.

Example 2 - Subroutine INFIL.

Example 3 - Subroutine FILTH.

Actual I/O information are used in part to illustrate these examples.

Example 1 - Transport Block

The sewer system shown in Figure 4-37 will be used to illustrate I/O sections of the Transport program. The system is a hypothetical one made up of 17 conduits linked by manholes or other types of non-conduits. All 12 program-provided conduit shapes have been utilized in the system for purposes of illustration. The system outfall is at element 114.

Description of Sample Data. Table 4-8 shows a listing of actual data presented to the program for execution. The data have been broken up into four sections; a verbal description of the implications of each section follows.

Section A

Section A lists the following example I/O specifications:

- No new conduit shapes are to be added.
- It is desired to print all flow-area relationships.
- Title card.
- There are 32 total elements in the system.

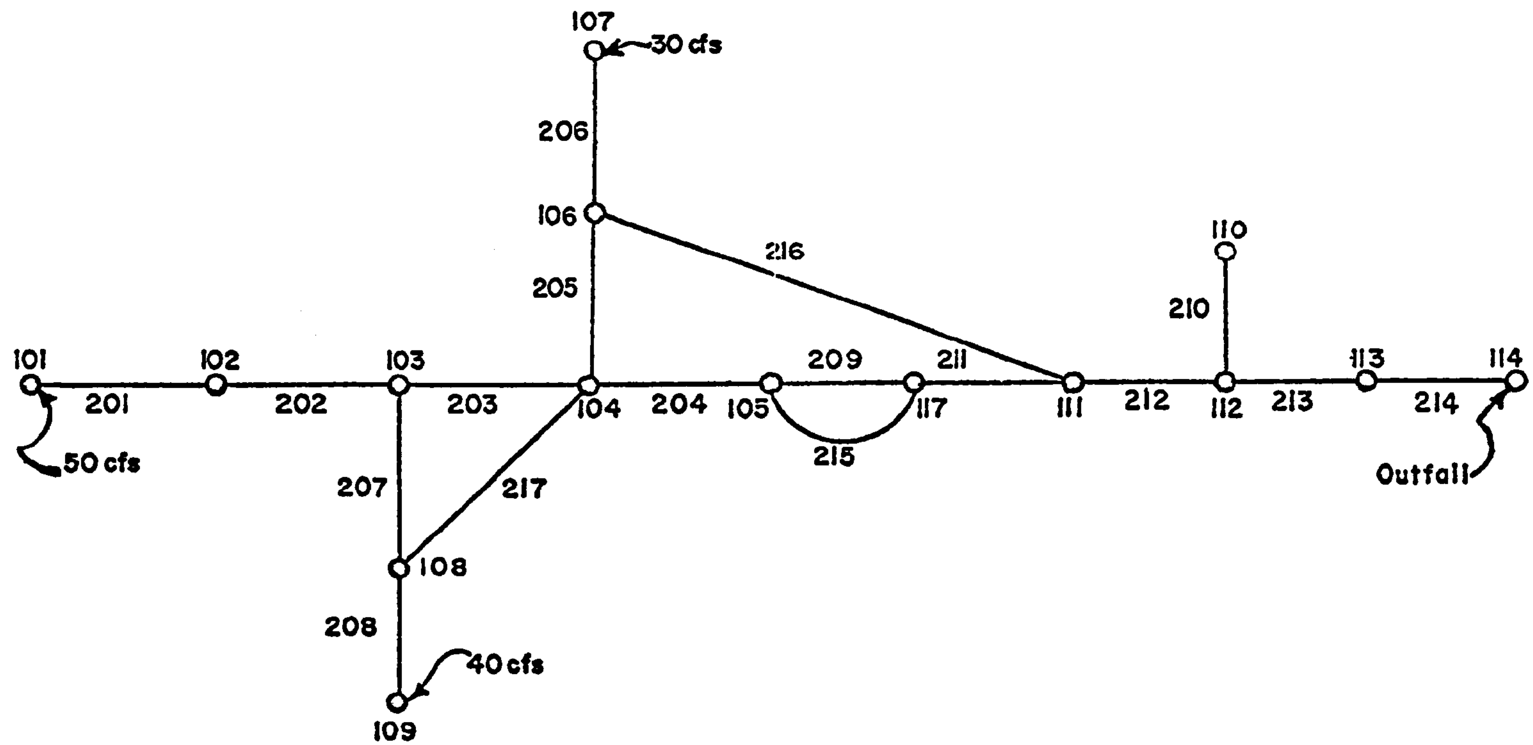


Figure 4-37. EXAMPLE SYSTEM FOR I/O DISCUSSION

Table 4-8. HYPOTHETICAL INPUT DATA

	DATA												CARD GROUP NO.
A	0	1											1
	1 HYPOTHETICAL SYSTEM TO TEST LATEST VERSION W/NEW TYPES MAY 1970												11
	32	50	3	3	10	1	0	2	4				12
	240.	.0001	1.										13
	1	0	1	1									14
B	101	0	0	0	16	8.							
	102	201	0	0	16	8.							
	103	202	207	0	16	8.							
	104	203	205	217	16	8.							
	105	204	0	0	21	8.						215.	
	106	206	0	0	18		20.					205.	
	107	0	0	0	16	8.							
	108	208	0	0	20	22.	2.0	62.	13.	4.5		217.	
	109	0	0	0	16	8.							
	110	0	0	0	16	8.							
	111	211	216	0	16	8.							
	112	212	210	0	16	8.							
	113	213	0	0	16	8.							
	114	214	0	0	16	8.							
	117	215	209	0	16	8.							
	201	101	0	0	1	50.	5.	.06	.013	.			15
	202	102	0	0	2	50.	4.	.08	.013	6.			
	203	103	0	0	3	50.	7.0	.09	.013	.			
	204	104	0	0	4	50.	8.	.1	.013	.			
	205	106	0	0	5	50.	4.	.11	.013	.			
	206	107	0	0	6	50.	5.5	.10					
	207	108	0	0	7	50.	4.	.05	.013	.			
	208	109	0	0	8	50.	4.5	.10	.013	.			
	209	105	0	0	9	50.	6.	.12	.013	.			
	210	110	0	0	10	50.	4.5	.1	.013	4.			
	211	117	0	0	11	50.	5.0	3.	.013	4.5		.5	
	212	111	0	0	12	50.	5.0	.1	.013	6.0		8.	
	213	112	0	0	2	50.	6.0	.05	.013	8.0	2.		
	214	113	0	0	11	50.	6.0	.08	.013	8.0	2.	.6	
	215	105	0	0	1	55.	2.	.06	.013				
	216	106	0	0	1	70.	6.	.01	.013				
	217	108	0	0	9	60.	4.	.12	.013				
C	114												27
	101	109	107										28
	208	207	217	203	206	205	216	204	209	111			29
D	0.96	1.08	1.05	0.90	1.04	1.00	0.97						33
	1.	1.	1.	1.	1.	1.	1.						34
	1.	1.	1.	1.	1.	1.	1.						35
	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					36
	1.21	1.23	1.25	1.21	1.17	1.15	0.98	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					37
	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					38
	1.16	0.94	1.33	1.22	1.44	1.10	0.88	1.05					
	3	2	0	6	6	6	14.2						40
	11011	0.5	25.0	0.0									
	21111	1500.	50.0	0.0									44
	31041	0.61	25.0	0.0									

- Simulation will occur over 50 time-steps.
- There are three inflows to the system. All three of these inputs are to be printed out.
- Ten outflows are to be printed out.
- Outflow for one element is to be written on tape.
- No tracing messages are to be generated.
- Two pollutants (BOD and SS) are to be routed.
- Four iterations will be used in the routing routine.
- Time-step interval is 240 sec.
- The iteration convergence criterion is 0.0001.
- One day of dry weather occurred prior to the storm.
- Transfer between Model blocks is by either tape or disk.
- Infiltration into the sewer is not estimated.
- Combined sewer will be modeled by estimating sanitary flows.
- The output will be printed in tabular form.

Section B

This section physically describes the sewer system in terms of its geometry and dimensions. Refer to Table 4-4 for data requirements of each type of conduit shape. The three non-conduits that are not manholes are elements 105 (type 21 flow-divider), 106 (type 18 flow-divider), and 108 (type 20 flow-divider).

Section C

These three input records specify that the outflow hydrograph and pollutographs for element 114 will be provided on tape for subsequent use by other programs of the Storm Water Management Model, that input hydrographs and pollutographs will be printed out for elements 101, 109, and 107, and that the ten elements for which outflow hydrographs and pollutographs to be printed out are elements 208, 207, 217, 203, 206, 205, 216, 204,209, and 111.

It should be pointed out that input hydrographs and pollutographs for the three elements mentioned were provided via tape by the Runoff program and they consisted of a constant inflow rate over the time of simulation, i.e.,

Manhole Number	Input Hydrograph, cfs	Input Pollutograph, lb/min
101	50	1
109	40	2
107	30	1

Section D

These data satisfy the requirements of subroutine FILTH as applied to this particular system. Only a small amount of wastewater flow enters the system at elements 101, 111, and 104. The description of data for a similar system is covered elsewhere in this manual.

Notice that data for infiltration are omitted (Card Group 14 set INFIL = 0). For purposes of simplicity in this execution, infiltration was assumed non-existent in this hypothetical sewer system.

Description of Sample Output. Many options are available to the user for output retrieval from the Transport program. In this example, only the most illustrative ones have been selected and these are shown in Tables 4-9 and 4-10.

Table 4-9. FLOW-AREA PARAMETERS FOR TRANS EXAMPLE

UNIVERSITY OF FLORIDA TRANSPORT MODEL

LIST OF PARAMETERS DESCRIBING DIFFERENT SEWER ELEMENTS.

CCNDUITS

NTYPE	DESCRIPTICN	ALFMAX	PSIMAX	AFACT	RFACT	KDEPTH	KLASS	INDEX	ANORM	QNORM	DNORM
1	CIRCULAR SHAPED	0.9600	1.080C	0.7854	0.2500	2	2	1	C.0	0.0	0.0
								2	C.020	0.00526	0.05273
								3	0.040	0.01414	0.08574
								4	0.060	0.02553	0.24194
								5	C.080	0.03862	C.41581
								6	C.100	0.05315	0.15280
								7	0.120	0.06877	0.16653
								8	0.140	0.08551	0.18558
								9	C.160	0.10326	C.20799
								10	C.180	0.12195	0.23186
								11	0.200	0.14144	0.25386
								12	0.220	0.16162	0.27118
								13	C.240	0.18251	C.28900
								14	0.260	0.20410	0.30658
								15	C.28C	0.22636	C.32349
								16	C.300	0.24918	0.34017
								17	C.320	0.27246	0.35666
								18	0.340	0.29614	0.37298
								19	C.360	0.32027	0.38915
								20	C.380	0.34485	C.40521
								21	0.400	0.36989	0.42117
								22	0.420	0.39531	0.43704
								23	C.440	0.42105	0.45284
								24	0.460	0.44704	0.46858
								25	0.480	0.47329	0.48430
								26	0.500	0.49980	0.5C000
								27	C.520	0.52658	0.51572
								28	0.540	0.55354	0.53146
								29	0.560	0.58064	0.54723
								30	0.580	0.60777	0.56305
								31	C.60C	0.63499	C.57892
								32	0.620	0.66232	0.59487
								33	0.640	0.68995	0.61C93
								34	0.660	0.71770	0.62710
								35	C.680	0.74538	0.64342
								36	C.700	0.77275	C.65991
								37	0.720	0.79979	0.67659
								38	0.740	0.82658	0.69350
								39	C.760	0.8532C	C.71068
								40	0.780	0.87954	0.72816
								41	0.800	0.90546	0.74602
								42	0.820	0.93095	0.76424
								43	0.840	0.95577	C.78297
								44	0.860	0.97976	C.80235
								45	0.880	1.00291	0.82240
								46	0.900	1.02443	0.84353
								47	C.920	1.04465	0.86563
								48	0.940	1.06135	0.88970
								49	0.960	1.08208	0.91444
								50	0.980	1.07662	0.94749
								51	1.000	1.C0000	1.CC000
15	USER SLPPLIEC	0.9600	1.0000	0.0	0.0	2	2	1	0.0	0.0	0.0

NCN-CCNDUITS

NTYPE	KCEPTH	KLASS	DESCRIPTICN
16	3	3	MANHCLE
17	3	3	LIFT STATICN
18	3	3	FLCW CIVICER
19	3	3	STORAGE UNIT
2C	3	3	FLOW CIVICER
21	3	3	FLOW DIVICER
22	3	3	BACKWATER UNIT

Table 4-10. SEQUENCE NUMBERING FOR TRANS EXAMPLE

HYPOTHETICAL SYSTEM TO TEST LATEST VERSION W/NEW TYPES MAY 1970

EXTERNAL ELEMENT NUMBER	TYPE	DESCRIPTION	UPSTREAM ELEMENTS 1	2	3	INTERNAL ELEMENT NUMBER	ELEMENT COMPUTATION SEQUENCE EXTERNAL NUMBER	INTERNAL NUMBER	INTERNAL UPSTREAM ELEMENT NUMBERS		
101	16	MANHOLE	0	0	0	1	101	1	33	33	33
102	16	MANHOLE	201	0	0	2	107	7	33	33	33
103	16	MANHOLE	202	207	0	3	109	9	33	33	33
104	16	MANHOLE	203	205	217	4	110	10	33	33	33
105	21	FLOW DIVIDER	204	0	0	5	201	16	1	33	33
106	18	FLOW DIVIDER	206	0	0	6	102	2	16	33	33
107	16	MANHOLE	0	0	0	7	202	17	2	33	33
108	20	FLOW DIVIDER	208	0	0	8	206	21	7	33	33
109	16	MANHOLE	0	0	0	9	106	6	21	33	33
110	16	MANHOLE	0	0	0	10	205	20	6	33	33
111	16	MANHOLE	211	216	0	11	208	23	9	33	33
112	16	MANHOLE	212	210	0	12	108	8	23	33	33
113	16	MANHOLE	213	0	0	13	207	22	8	33	33
114	16	MANHOLE	214	0	0	14	103	3	17	22	33
117	16	MANHOLE	215	209	0	15	203	18	3	33	33
201	1	CIRCULAR SHAPED	101	0	0	16	210	25	10	33	33
202	2	RECTANGULAR	102	0	0	17	216	31	6	33	33
203	3	EGG-SHAPED	103	0	0	18	217	32	8	33	33
204	4	HORSE SHOE	104	0	0	19	104	4	18	20	32
205	5	GOTHIC SHAPED	106	0	0	20	204	19	4	33	33
206	6	CATENARY SHAPED	107	0	0	21	105	5	19	33	33
207	7	SEMI ELLIPTICAL	108	0	0	22	209	24	5	33	33
208	8	BASKET HANDLE	109	0	0	23	215	30	5	33	33
209	9	SEMI CIRCULAR	105	0	0	24	117	15	30	24	33
210	10	MODIFIED B. H.	110	0	0	25	211	26	15	33	33
211	11	RECT. - TRIANG.	117	0	0	26	111	11	26	31	33
212	12	RECT. - ROUND	111	0	0	27	212	27	11	33	33
213	2	RECTANGULAR	112	0	0	28	112	12	27	25	33
214	11	RECT. - TRIANG.	113	0	0	29	213	28	12	33	33
215	1	CIRCULAR SHAPED	105	0	0	30	113	13	28	33	33
216	1	CIRCULAR SHAPED	106	0	0	31	214	29	13	33	33
217	9	SEMI CIRCULAR	108	0	0	32	114	14	29	33	33

Table 4-9 shows the first piece of output relating to flow-area parameters for the different types of conduit shapes. In total, 12 of these tables are printed. Only the table for type 1 (circular conduit) is shown here. At the end of these tables, parameters for non-conduit types are also printed. This section of the output is constant for all runs made. In other words, it will not change from sewer system to sewer system, unless the user wishes to insert additional conduit shapes. In that case, the added flow-area relationships will also appear in this section.

Table 4-10 shows the next section of output. It consists of the external and internal numbering system used by the program in sequencing the sewer elements.

The most important part of the output is shown in Table 4-11, which describes the sewer system in terms of element types, dimensions, slopes, areas, and flow capacities. This information is strictly based upon the data provided by the user. Careful inspection of this output will detect any errors made during data preparation.

The output from subroutine FILTH follows and is shown in Table 4-12.

Table 4-13 contains the section of output describing the initial conditions prior to the storm to be simulated. Notice that flow initial conditions are simply set equal to wastewater flow (infiltration was zero in this case).

Table 4-11. ELEMENT DATA FOR TRANS EXAMPLE

HYPOTHETICAL SYSTEM TO TEST LATEST VERSION W/NEW TYPES MAY 1970
NUMBER OF ELEMENTS= 32
NUMBER OF TIME INT= 50
TIME INTERVAL= 240.0 SECONDS.

ELEMENT PARAMETERS

EXT. ELE. NUM.	TYPE	DESCRIPTION	SLOPE (FT/FT)	DISTANCE (FT)	MANNING ROUGHNESS	GEOM1 (FT)	GEOM2 (FT)	GEOM3 (FT)	NUMBER OF BARRELS	AFULL (SQ.FT)	QFULL (CFS)	QMAX (CFS)	SUPER-CRITICAL FLOW WHEN LESS THAN 95 FULL
101	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
102	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
103	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
104	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
105	21	FLOW DIVIDER	0.0	8.00	0.0	2.778	0.0	215.000	1.0	0.0	0.0	0.0	
106	18	FLOW DIVIDER	0.0	0.0	0.0	20.000	0.0	205.000	1.0	0.0	0.0	0.0	
107	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
108	20	FLOW DIVIDER	62.00000	22.00	13.0000	2.000	4.500	217.000	1.0	0.0	0.0	0.0	
109	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
110	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
111	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
112	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
113	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
114	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
117	16	MANHOLE	0.0	8.00	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	
201	1	CIRCULAR SHAPED	0.00060	50.00	0.0130	5.000	0.0	0.0	1.0	19.635	63.967	69.084	NO
202	2	RECTANGULAR	0.00080	50.00	0.0130	4.000	6.000	0.0	1.0	24.000	87.859	107.155	NO
203	3	EGG-SHAPED	0.00090	50.00	0.0130	7.000	0.0	0.0	1.0	25.014	105.150	111.985	NO
204	4	HORSE SHOE	0.00100	50.00	0.0130	8.000	0.0	0.0	1.0	53.075	308.452	332.203	NO
205	5	GOTHIC SHAPED	0.00110	50.00	0.0130	4.000	0.0	0.0	1.0	10.486	37.368	39.796	NO
206	6	CATENARY SHAPED	0.00100	50.00	0.0130	5.500	0.0	0.0	1.0	21.259	90.573	95.102	NO
207	7	SEMI ELLIPTICAL	0.00050	50.00	0.0130	4.000	0.0	0.0	1.0	12.560	31.499	32.917	NO
208	8	BASKET HANDLE	0.00100	50.00	0.0130	4.500	0.0	0.0	1.0	15.921	61.816	65.573	NO
209	9	SEMI CIRCULAR	0.00120	50.00	0.0130	6.000	0.0	0.0	1.0	45.709	265.313	282.922	NO
210	10	MODIFIED B. H.	0.00100	50.00	0.0130	4.500	4.000	18.000	1.0	24.283	108.963	108.196	NO
211	11	RECT. - TRIANG.	0.03000	50.00	0.0130	5.000	4.500	0.500	1.0	21.375	473.920	559.577	YES
212	12	RECT. - ROUND	0.00100	50.00	0.0130	5.000	6.000	6.000	1.0	32.353	150.953	181.793	NO
213	2	RECTANGULAR	0.00050	50.00	0.0130	6.000	8.000	0.0	2.0	48.000	176.207	212.155	NO
214	11	RECT. - TRIANG.	0.00080	50.00	0.0130	6.000	8.000	0.600	2.0	45.600	210.220	259.302	NO
215	1	CIRCULAR SHAPED	0.00060	55.00	0.0130	2.000	0.0	0.0	1.0	3.142	5.556	6.001	NO
216	1	CIRCULAR SHAPED	0.00010	70.00	0.0130	6.000	0.0	0.0	1.0	28.274	42.465	45.862	NO
217	9	SEMI CIRCULAR	0.00120	60.00	0.0130	4.000	0.0	0.0	1.0	20.315	89.988	95.960	NO

EPSILON=0.000100 NO. OF ITERATIONS IN ROUTING ROUTINE =

HYDROGRAPHS AND POLLUTOGRAPHS PROVIDED TO SUBSEQUENT PROGRAMS FOR THE FOLLOWING ELEMENTS
114

Table 4-12. DRY WEATHER FLOW FOR TRANS EXAMPLE

QUANTITY AND QUALITY OF D W F FOR EACH SUBAREA

A1BOD = 1300.00 LBS/DAY/CFS
A1SS = 1420.00 LBS/DAY/CFS

KNUM	MANHOLE INPUT	KLAND	AVERAGES CFS DWF	LBS/SEC DWBOD	LBS/SEC DWSS	ACRES AREA
1	101	1	0.50	1.44	1.58	25.00
2	111	1	0.08	0.22	0.24	50.00
3	104	1	0.61	1.76	1.92	25.00

DAILY AND HOURLY CORRECTION FACTORS
FOR SEWAGE DATA

DAY	DVDWF	DVBOD	DVSS
1	0.960	1.000	1.000
2	1.080	1.000	1.000
3	1.050	1.000	1.000
4	0.900	1.000	1.000
5	1.040	1.000	1.000
6	1.000	1.000	1.000
7	0.970	1.000	1.000
HOUR			
1	0.740	0.850	1.050
2	0.670	0.710	1.050
3	0.630	0.600	1.100
4	0.590	0.410	0.500
5	0.540	0.460	0.660
6	0.560	0.490	1.330
7	0.670	0.720	1.100
8	0.960	0.870	0.880
9	1.420	0.770	1.030
10	1.190	1.570	0.910
11	1.200	1.020	0.660
12	1.150	0.870	0.630
13	1.170	0.910	0.940
14	1.110	0.940	0.940
15	1.080	1.070	1.050
16	1.150	1.070	1.050
17	1.210	1.140	1.160
18	1.230	0.990	0.940
19	1.250	1.450	1.330
20	1.210	1.660	1.220
21	1.170	1.550	1.440
22	1.150	1.290	1.100
23	0.880	0.990	0.880
24	1.070	1.600	1.050

Table 4-13. INITIAL CONDITIONS FOR TRANS EXAMPLE

INITIAL BED OF SOLIDS (LBS) IN SEWER DUE TO
1.C DAYS OF DRY WEATHER PRIOR TO STCRM

ELEMENT NUMBER	SOLIDS IN BOTTOM (LBS)
201	13.03258
202	28.48965
2C6	C.0
205	C.0
208	0.0
207	0.0
203	2.22038
210	0.0
216	0.0
217	0.0
2C4	3.80130
2C9	C.0
215	4.56354
211	0.0
212	5.54245
213	138.90474
214	29.25818

ELEMENT FLOWS, AREAS, AND CCNCENTRATICNS ARE INITIALIZED TO DRY WEATHER FLOW AND INFILTRATICN VALUES.

ELE.NO.	TYPE	FLOW	AREA	CONC1	CONC2	CONC3	CONC4	CONC5	CONC6
101	16	0.500	0.0	0.0120	0.C131				
107	16	C.C	0.0	0.0	0.0				
109	16	C.C	0.C	C.C	0.C				
110	16	C.C	0.C	0.0	0.C				
201	1	0.500	0.506	0.0120	0.C131				
102	16	0.500	0.0	0.0120	0.0131				
202	2	0.5C0	0.677	C.C120	0.C131				
206	6	C.C	0.C	0.0	0.C				
106	18	0.C	0.C	0.0	0.C				
205	5	0.0	0.0	0.C	0.C				
208	8	C.C	0.0	C.C	0.C				
108	20	C.C	0.0	C.0	0.C				
207	7	0.C	0.C	C.0	0.C				
103	16	0.5C0	0.0	0.C120	0.0131				
203	3	C.5C0	0.587	C.C120	0.C131				
210	10	C.C	0.C	0.0	0.C				
216	1	0.0	0.C	0.0	0.C				
217	9	0.C	0.0	0.0	0.C				
104	16	1.110	0.0	0.C120	0.C131				
204	4	1.110	0.818	0.0120	0.C131				
105	21	1.110	0.0	0.0120	0.C131				
209	9	0.C	0.0	0.C	0.0				
215	1	1.110	0.804	0.C120	0.C131				
117	16	1.110	0.0	C.C120	0.C131				
211	11	1.110	0.241	0.C120	0.C131				
111	16	1.187	0.0	0.C120	0.C131				
212	12	1.187	0.475	C.C120	0.C131				
112	16	1.187	0.0	0.0120	0.C131				
213	2	1.187	0.968	0.0120	0.0131				
113	16	1.187	0.0	0.0120	0.0131				
214	11	1.187	0.641	0.C120	0.C131				
114	16	1.187	0.0	0.0120	0.C131				

After the storm has passed through the system, the total pounds of solids left deposited within the sewer elements are printed out. This is shown in Table 4-14.

The final section of the output relates to input and output hydrographs and pollutographs which were specified by the user to be printed out. Table 4-15 shows the three described inflows and Table 4-16 shows the ten desired outflows.

Example 2 - Subroutine INFIL

The Pine Valley area of Baltimore, Maryland, is used in the following example to demonstrate the application of INFIL. In this case, the groundwater table was taken as being below the sewer. Historical climatalogical and flow data are available for estimating infiltration on April 15.

1. DINFIL

   Historical flow data from the previous year indicate that minimum average flow was approximately 50 gpm. Since only 30 gpm can be attributed to sewage, DINFIL is taken as 20 gpm.

2. SINFIL

   From a heating and air conditioning handbook (Ref. 1), degree-days are found to be well above 750 prior to April. Since frost and other residual moisture will contribute if melting occurs during April 15, degree-days NDD were input to subroutine INFIL. Based upon these data, INFIL computed that thawing begins on March 10 (i.e.,238 days from beginning of degree day data or MLTBE = 238 and ends on May 1 (i.e.,

Table 4-14. FINAL CONDITIONS FOR TRANS EXAMPLE

BED OF SOLIDS IN SEWER AT END OF STORM

ELEMENT NUMBER	SOLIDS IN BOTTOM (LBS)
201	0.01315
202	0.01148
206	0.00762
2C5	0.CC537
208	0.01294
207	0.04432
2C3	0.01204
21C	0.0
216	1.86356
217	0.00791
2C4	0.C1414
2C9	C.CC759
215	0.02499
211	0.0
212	0.01659
213	0.C5283
214	0.03813

Table 4-15. INFLOWS FOR TRANS EXAMPLE

HYPOTHETICAL SEWER SYSTEM FOR ILLUSTRATION PURPOSES
TOTAL SIMULATION TIME=12000.0 SECONDS. TIME STEP= 240.0 SECONDS.

INFLOW POLLUTOGRAPHS AND HYDROGRAPHS AT THE FOLLOWING EXTERNAL ELEMENT NUMBERS
101 109 107

SELECTED INLET HYDROGRAPHS - CFS

EXTERNAL ELEMENT NUMBER	TIME STEP 1	2	3	4	5	6	7	8	9	10
101	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000
	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000
	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000
	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000
	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000	50.000
109	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000
	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000
	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000
	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000
	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000	40.000
107	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000
	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000	30.000

SELECTED INLET POLLUTOGRAPHS - LBS/DT

*** BOD ***

EXTERNAL ELEMENT NUMBER	TIME STEP 1	2	3	4	5	6	7	8	9	10
101	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

** SUSPENDED SOLIDS **

EXTERNAL ELEMENT NUMBER	TIME STEP 1	2	3	4	5	6	7	8	9	10
101	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Table 4-15. (continued)

				*** BOD ***						
109	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
				** SUSPENDED SOLIDS **						
109	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
				*** BOD ***						
107	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
				** SUSPENDED SOLIDS **						
107	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000
	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000	4.000

Table 4-16. OUTFLOWS FOR TRANS EXAMPLE

SELECTED OUTFLOW HYDROGRAPHS - CFS

EXTERNAL ELEMENT NUMBER	TIME STEP 1	2	3	4	5	6	7	8	9	10
208	36.343	42.936	38.476	40.414	39.771	40.018	39.979	40.016	39.983	40.011
	39.987	40.008	39.989	40.006	39.991	40.004	39.993	40.002	39.994	40.001
	39.995	40.000	39.996	40.000	39.996	39.999	39.996	39.998	39.998	39.998
	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998
	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998	39.998
207	9.312	19.969	13.636	15.964	15.195	15.513	15.479	15.525	15.489	15.525
	15.494	15.522	15.498	15.519	15.501	15.517	15.503	15.515	15.505	15.514
	15.506	15.513	15.507	15.512	15.507	15.511	15.508	15.509	15.509	15.509
	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509
	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509	15.509
217	22.226	25.954	23.539	24.813	24.256	24.607	24.414	24.521	24.469	24.496
	24.484	24.489	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489
	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489
	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489
	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489	24.488	24.489
203	46.289	78.932	60.753	65.903	65.344	65.685	65.733	65.796	65.762	65.802
	65.772	65.811	65.777	65.846	65.836	65.846	65.830	65.855	65.840	65.847
	65.841	65.861	65.845	65.840	65.843	65.844	65.842	65.842	65.970	65.998
	65.978	65.995	65.993	65.995	65.993	65.995	65.994	65.995	65.994	65.995
	65.994	65.995	65.994	66.185	66.242	66.210	66.217	66.211	66.227	66.219
206	27.217	32.189	28.811	30.429	29.759	30.022	29.971	30.004	29.996	29.999
	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999
	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999
	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999
	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999	29.999
205	17.972	21.590	19.192	20.222	19.853	20.036	19.979	20.016	19.984	20.012
	19.988	20.009	19.991	20.007	19.993	20.005	19.995	20.004	19.996	20.003
	19.997	20.002	19.998	20.002	19.998	20.001	19.999	20.001	19.999	20.001
	19.999	20.001	19.999	20.000	20.000	20.000	20.000	20.000	20.000	20.000
	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000	20.000
216	4.364	13.382	8.640	10.286	10.312	10.005	10.041	9.999	9.990	9.993
	9.993	9.995	10.012	9.997	9.992	9.997	10.010	9.998	10.001	10.000
	10.000	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999
	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999
	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999	9.999

Table 4-16. (continued)

204	80.697	129.826	103.011	111.077	109.842	110.619	110.517	110.624	11C.601	110.607
	110.623	110.613	11C.630	110.714	11C.755	11C.719	11C.746	110.731	11C.753	110.727
	11C.751	110.743	11C.754	11C.725	110.749	110.731	11C.747	110.731	111.035	111.C70
	111.055	111.C67	111.069	111.067	111.069	111.067	111.069	111.068	111.069	111.068
	111.068	111.069	111.068	111.516	111.613	111.559	111.576	111.561	111.580	111.575
209	71.852	129.761	99.464	108.218	107.121	107.804	1C7.746	107.849	1C7.838	1C7.833
	107.859	107.841	107.865	107.946	107.993	107.953	107.982	107.966	107.989	107.963
	107.986	1C7.980	1C7.989	107.961	107.984	107.968	107.982	107.968	108.233	108.31C
	108.268	108.295	108.285	108.294	108.286	108.293	108.287	108.293	108.288	108.292
	108.287	108.293	108.288	108.720	108.844	108.777	108.800	108.781	108.8C2	1C8.796
111	77.122	146.626	110.925	121.119	120.423	120.482	12C.728	120.571	12C.728	12C.583
	12C.724	120.616	12C.730	120.723	120.853	120.748	12C.845	120.774	12C.834	120.833
	12C.833	120.833	120.833	120.833	12C.833	120.833	120.833	120.833	121.051	121.187
	121.C99	121.162	121.162	121.162	121.162	121.162	121.162	121.162	121.162	121.162
	121.162	121.162	121.162	121.582	121.748	121.650	121.650	121.650	121.650	121.713

Table 4-16. (continued)

SELECTED OUTFLOW POLLUTOGRAPHS - LBS/DT

EXTERNAL ELEMENT NUMBER	TIME STEP 1	2	3	4	5	6	7	8	9	10
				*** BOD ***						
208	7.201	8.765	7.460	8.315	7.751	8.174	7.856	8.117	7.903	8.079
	7.935	8.053	7.956	8.036	7.970	8.024	7.980	8.016	7.986	8.011
	7.990	8.007	7.993	8.005	7.995	8.003	7.997	8.002	7.998	8.001
	7.999	8.001	7.999	8.000	7.999	8.000	7.999	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
				** SUSPENDED SOLIDS **						
208	7.190	8.763	7.460	8.315	7.753	8.173	7.858	8.116	7.904	8.078
	7.936	8.053	7.956	8.036	7.971	8.024	7.980	8.016	7.986	8.011
	7.991	8.008	7.994	8.005	7.996	8.004	7.997	8.002	7.998	8.002
	7.999	8.001	7.999	8.001	7.999	8.000	8.000	8.000	8.000	8.000
	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
				*** BOD ***						
207	1.815	4.121	2.624	3.272	2.995	3.124	3.091	3.100	3.108	3.092
	3.113	3.091	3.112	3.092	3.110	3.094	3.108	3.096	3.107	3.098
	3.105	3.099	3.104	3.100	3.103	3.101	3.103	3.101	3.103	3.101
	3.102	3.101	3.102	3.101	3.102	3.102	3.102	3.102	3.102	3.102
	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102
				** SUSPENDED SOLIDS **						
207	1.772	4.107	2.635	3.256	3.007	3.123	3.094	3.099	3.109	3.092
	3.113	3.091	3.112	3.093	3.110	3.095	3.108	3.097	3.107	3.098
	3.105	3.099	3.104	3.100	3.103	3.101	3.103	3.101	3.103	3.101
	3.103	3.101	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102
	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102	3.102
				*** BOD ***						
217	4.348	5.411	4.415	5.213	4.661	5.054	4.795	4.958	4.863	4.914
	4.893	4.895	4.904	4.888	4.908	4.887	4.907	4.888	4.906	4.890
	4.904	4.892	4.902	4.893	4.901	4.895	4.900	4.896	4.899	4.896
	4.899	4.897	4.899	4.897	4.898	4.897	4.898	4.897	4.898	4.897
	4.898	4.897	4.898	4.898	4.898	4.898	4.898	4.898	4.898	4.898
				** SUSPENDED SOLIDS **						
217	4.334	5.406	4.417	5.212	4.664	5.053	4.797	4.957	4.864	4.914
	4.893	4.895	4.905	4.889	4.908	4.888	4.908	4.889	4.906	4.891
	4.904	4.892	4.903	4.894	4.901	4.895	4.900	4.896	4.900	4.896
	4.899	4.897	4.899	4.897	4.899	4.897	4.898	4.898	4.898	4.898
	4.898	4.898	4.898	4.898	4.898	4.898	4.898	4.898	4.898	4.898

Table 4-16. (continued)

				*** BOD ***						
203	6.760	8.796	7.569	7.580	7.932	7.669	7.883	7.765	7.826	7.806
	7.801	7.823	7.793	8.072	8.178	8.124	8.144	8.146	8.132	8.152
	8.130	8.152	8.132	8.149	8.134	8.147	8.137	8.145	8.300	8.394
	8.335	8.370	8.352	8.360	8.359	8.356	8.361	8.355	8.361	8.355
	8.360	8.356	8.360	8.252	8.190	8.227	8.205	8.217	8.213	8.212
				** SUSPENDED SCLIDS **						
203	4C.586	27.333	0.0	15.196	5.261	11.562	7.860	9.835	9.C23	9.C89
	9.481	8.831	9.605	8.529	9.163	8.520	9.133	8.571	9.C73	8.634
	9.C11	8.692	8.960	8.737	8.919	8.772	8.890	8.796	8.617	8.408
	8.543	8.458	8.5C8	8.482	8.493	8.492	8.487	8.495	8.485	8.495
	8.486	8.495	8.487	8.670	8.762	8.707	8.736	8.723	8.727	8.729
				*** BOD ***						
206	3.594	4.383	3.723	4.175	3.863	4.093	3.924	4.060	3.952	4.C38
	3.969	4.025	3.979	4.016	3.987	4.011	3.991	4.007	3.994	4.C04
	3.996	4.003	3.997	4.002	3.998	4.001	3.999	4.001	3.999	4.CC0
	3.999	4.C00	4.0C0	4.CC0	4.000	4.C00	4.0C0	4.C00	4.CC0	4.CC0
	4.CCC	4.C00	4.0C0	4.C00	4.0C0	4.000	4.0C0	4.C00	4.CC0	4.C00
				** SUSPENDED SCLIDS **						
206	3.588	4.381	3.723	4.175	3.864	4.092	3.924	4.059	3.952	4.C38
	3.969	4.025	3.980	4.016	3.987	4.011	3.991	4.C07	3.994	4.C05
	3.996	4.003	3.998	4.002	3.998	4.001	3.999	4.001	3.999	4.C01
	4.CCC	4.C00	4.CC0	4.CC0	4.000	4.CC0	4.0C0	4.C00	4.CC0	4.CC0
	4.CC0	4.C0C	4.0C0	4.C00	4.000	4.000	4.0C0	4.C00	4.CC0	4.000
				*** BOD ***						
205	2.348	2.989	2.414	2.823	2.547	2.743	2.616	2.699	2.647	2.677
	2.662	2.667	2.669	2.663	2.671	2.661	2.672	2.662	2.671	2.662
	2.67C	2.663	2.669	2.664	2.669	2.665	2.668	2.665	2.668	2.666
	2.667	2.666	2.667	2.666	2.667	2.666	2.667	2.666	2.667	2.666
	2.667	2.666	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667
				** SUSPENDED SCLIDS **						
205	2.340	2.986	2.416	2.822	2.549	2.743	2.617	2.698	2.647	2.677
	2.662	2.667	2.669	2.663	2.671	2.662	2.672	2.662	2.671	2.663
	2.67C	2.664	2.669	2.664	2.669	2.665	2.668	2.665	2.668	2.666
	2.667	2.666	2.667	2.666	2.667	2.666	2.667	2.667	2.667	2.667
	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667	2.667

Table 4-16. (continued)

				*** BOD ***						
216	C.55C	1.857	1.1C1	1.397	1.375	1.324	1.350	1.322	1.341	1.325
	1.338	1.327	1.339	1.329	1.335	1.331	1.336	1.331	1.335	1.332
	1.334	1.332	1.334	1.333	1.333	1.333	1.333	1.333	1.333	1.333
	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333
	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333
				** SUSPENDEC SCLIDS **						
216	C.317	1.310	C.975	1.215	1.245	1.139	1.2C0	1.223	1.262	1.285
	1.306	1.314	1.324	1.320	1.328	1.330	1.333	1.329	1.331	1.331
	1.332	1.332	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333
	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333
	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333	1.333
				*** BOD ***						
204	14.C66	18.242	15.273	16.333	16.131	16.203	16.278	16.171	16.3C2	16.166
	16.303	16.172	16.295	16.786	17.106	16.878	17.043	16.922	17.C13	16.942
	17.CCC	16.952	16.994	16.956	16.989	16.960	16.986	16.962	17.380	17.498
	17.43C	17.467	17.450	17.455	17.457	17.452	17.458	17.452	17.457	17.453
	17.456	17.454	17.455	17.196	17.096	17.158	17.119	17.142	17.129	17.137
				** SUSPENDED SCLIDS **						
204	5C.115	43.082	7.314	26.394	15.248	21.246	18.702	19.149	19.934	18.510
	2C.195	18.487	20.081	18.018	18.967	18.142	18.821	18.288	18.688	18.405
	18.588	18.487	18.525	18.535	18.488	18.561	18.471	18.571	17.841	17.711
	17.753	17.765	17.722	17.780	17.716	17.780	17.720	17.775	17.726	17.768
	17.732	17.763	17.738	18.190	18.325	18.245	18.290	18.266	18.278	18.274
				*** BOD ***						
209	12.424	18.838	14.129	16.462	15.264	16.189	15.522	16.069	15.623	16.CC0
	15.678	15.959	15.712	16.479	16.556	16.572	16.502	16.602	16.490	16.604
	16.494	16.597	16.5C3	16.587	16.512	16.579	16.519	16.573	16.885	17.1C4
	16.962	17.054	16.953	17.035	17.005	17.028	17.009	17.026	17.C10	17.C25
	17.011	17.024	17.012	16.793	16.656	16.738	16.689	16.716	16.703	16.709
				** SUSPENDED SCLIDS **						
209	44.238	47.C97	5.136	26.098	15.312	19.914	19.087	17.906	2C.029	17.635
	19.920	17.944	19.532	17.750	18.268	17.936	18.088	18.090	17.968	18.178
	17.908	18.213	17.895	18.210	17.907	18.190	17.933	18.162	17.398	17.275
	17.301	17.326	17.276	17.334	17.279	17.326	17.289	17.316	17.298	17.308
	17.305	17.302	17.3C9	17.694	17.897	17.772	17.847	17.802	17.830	17.812

Table 4-16. (continued)

				*** BOD ***						
111	14.232	20.812	16.043	18.134	17.349	17.859	17.544	17.758	17.624	17.698
	17.673	17.663	17.704	18.238	18.619	18.353	18.553	18.392	18.532	18.400
	18.530	18.400	18.533	18.396	18.535	18.395	18.536	18.395	18.927	18.982
	19.008	18.933	19.035	18.919	19.042	18.917	19.040	18.921	19.036	18.925
	19.032	18.929	19.028	18.679	18.632	18.620	18.665	18.600	18.676	18.597
				** SUSPENDED SOLIDS **						
111	48.955	52.512	6.356	28.096	17.851	21.216	21.767	19.305	22.655	19.250
	22.431	19.731	21.943	19.582	20.527	19.811	20.326	19.981	20.193	20.078
	20.131	20.115	20.118	20.112	20.131	20.093	20.155	20.068	19.564	19.105
	19.441	19.173	19.404	19.191	19.397	19.192	19.398	19.191	19.390	19.192
	19.395	19.196	19.390	19.631	20.023	19.728	19.959	19.768	19.934	19.786

MLTEN = 289) with April 15 (i.e., NDYUD = 274) occurring during this period. From historical flow data, the maximum incremental flow due to spring thaw appears to be nearly 65 gpm. It follows that SINFIL is:

SINFIL = RSMAX*SIN(360°/2*(NDYUD - MLTBE)/(MLTEN - MLTBE)) (8)

= 65*SIN(127°)

= 52 gpm.

3. RINFIL

Total precipitation on April 15 and the previous 9 days was 1.81 inches for this example. RINFIL could then be estimated from a regression equation based upon previous flow data.

For Pine Valley, sewer flow data not affected by spring thaw were correlated with antecedent rainfall in the following manner. These sanitary sewage flows were first adjusted to remove accounted for sewage and dry weather infiltration for each day.

RINFIL(I) = SWFLOW(I) - SMMDWF - DINFIL (9)

where

SWFLOW(I) = Average sewer flow on day I.

Linear regression was then performed on the following data yielding Eq. 10.

Date	RINFIL, gpm	X_1	X_2	X_3	X_4 in./day	X_5	X_6	X_7	X_8	X_9	X_{10}
June											
1	28.87	0.12	0.02	0.00	0.06	0.00	0.00	0.36	0.00	0.00	0.00
2	24.64	0.00	0.12	0.02	0.00	0.06	0.00	0.00	0.36	0.00	0.00
3	19.68	0.11	0.00	0.12	0.02	0.00	0.06	0.00	0.00	0.36	0.00
etc.	dependent	etc.			independent variables						

$$RINFIL = 2.40 + 11.3X_1 + 11.6X_2 + 5.5X_3 + 6.4X_4 + 4.8X_5 + 3.6X_6 + 1.0X_7 + 1.5X_8 + 1.4X_9 + 1.8X_{10} \quad (10)$$

For April 15, RINFIL was then calculated to be 10.2 gpm. Therefore, QINFIL = 20.0 + 52.0 + 10.2 = 82.2 gpm.

Example 3 - Subroutine FILTH

A hypothetical test area, Smithville, total population 15,000, is used as an example to demonstrate the application of subroutine FILTH. The test area is made up of six subcatchment basins and nine land use areas as shown in Figure 4-38. It was assumed that flow records and water metering records were unavailable. The industrial and commercial flows, however, were known for subareas 3, 4, and 5.

A Case 2 procedure was followed using the default values for A1BOD, A1SS and A1Coli. The areas, population density, cost of the dwellings, percentage of houses having garbage disposal units, and the average income of the families within each subarea are given in Table 4-17. The start of the storm simulation is on a Monday at 1:30 p.m.

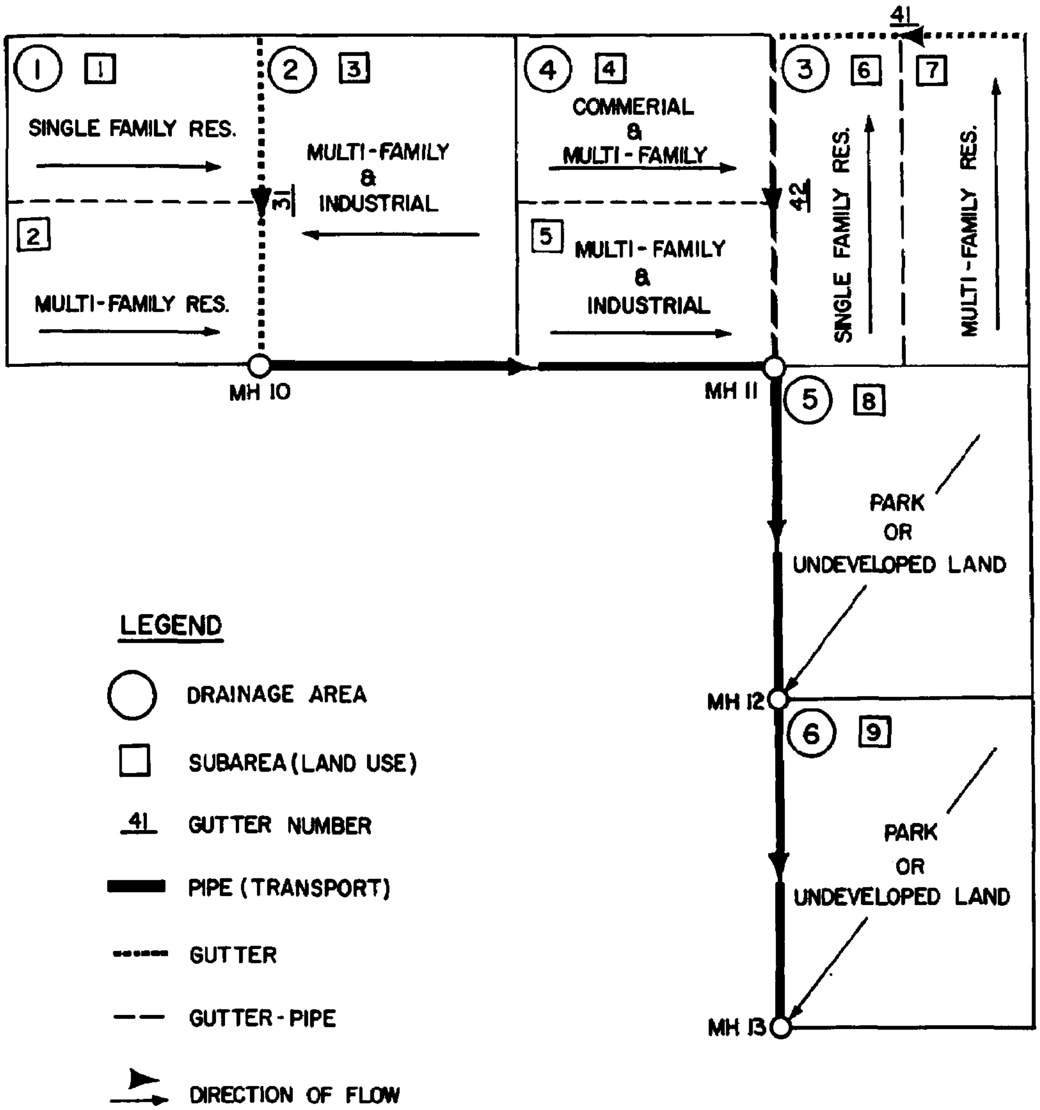


Figure 4-38. SCHEMATIC OF SMITHVILLE TEST AREA

Table 4-17. LAND USE DATA FOR SMITHVILLE TEST AREA

Subarea	Area, acres	Population Density per acre	Average Cost of Dwellings	Percentage of Garbage Disposals	Average Family Yearly Income
1	10.0	10.0	$50,000	25.0%	$15,000
2	10.7	50.0	10,000	10.0	7,000
3	140.1	30.0	10,000	0.0	5,000
4	60.0	50.0	10,000	10.0	7,000
5	38.1	50.0	10,000	10.0	7,000
6	50.0	10.0	50,000	25.0	15,000
7	44.1	50.0	10,000	10.0	7,000
8	73.5	0.0	N.A.	N.A.	N.A.
9	73.5	0.0	N.A.	N.A.	N.A.

The data deck for FILTH is shown in Table 4-18. The first three data cards are the average daily variations for DWF, BOD, and SS. No daily variation for coliforms is modeled. The following 12 cards, in groups of threes, define the changes from daily averages to hourly flow rates and concentrations for flow, BOD, SS, and coliforms, respectively. The starting value of each group represents the 1 a.m. condition. These factors are reproduced in the computer output as a check (shown in Table 4-20.) The remaining card groups represent the information about each subarea. Card group 39 is a control card. It should be noted that for subareas 3, 4, and 5, dummy subareas (31, 41, and 51) were introduced giving a total of 12 subareas to account for the multiple land uses.

The output from FILTH (Table 4-19) is in two parts. The first group of values expresses the default concentrations of BOD, SS, and coliforms along with the yearly average daily flow. The second block gives the calculated values for each subarea taking into account the time and the day of the week the simulation occurred. Subtotals were requested for each inlet manhole.

Table 4-18. DATA DECK FOR SMITHVILLE TEST AREA

DATA								CARD GROUP NO.
0.96	1.08	1.05	0.90	1.04	1.00	0.97		32-34
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	0.54	0.67	0.96	35
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	36
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	37
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	1.19	0.88	1.05	
1.10	0.64	0.45	0.87	0.54	0.48	1.29	1.18	38
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	
12 2	3 2	13 30		15.000				39
1 101		10.0	10.0	50.0 25.0		15.0		43
2 102		10.7	50.0	10.0 10.0		7.0		
3 102		140.1	30.0	10.0 0.0		5.0		
31 104					5.00 200. 200.		1	
4 112		60.0	50.0	10.0 10.0		7.0		
41 113					0.80 190. 220.			
5 112		38.1	50.0	10.0 10.0		7.0		
51 114					3.00 200. 200.			
6 111		50.0	10.0	50.0 25.0		15.0		
7 112		44.1	50.0	10.0 10.0		7.0	1	
8 125		73.5					1	
9 135		73.5					1	

Table 4-19. DATA OUTPUT FOR SMITHVILLE TEST AREA

DAILY AND HOURLY CORRECTION FACTORS
FOR SEWAGE DATA

DAY	DVDWF	DVBOD	DVSS	DVCOLI
1	0.960	1.000	1.000	
2	1.080	1.000	1.000	
3	1.050	1.000	1.000	
4	0.900	1.000	1.000	
5	1.040	1.000	1.000	
6	1.000	1.000	1.000	
7	0.970	1.000	1.000	
HOUR				
1	0.740	0.850	1.050	1.100
2	0.670	0.710	1.050	0.640
3	0.630	0.600	1.100	0.450
4	0.590	0.410	0.500	0.870
5	0.540	0.460	0.660	0.540
6	0.560	0.490	1.330	0.480
7	0.670	0.720	1.100	1.290
8	0.960	0.870	0.880	1.180
9	1.420	0.770	1.030	1.370
10	1.190	1.570	0.910	1.490
11	1.700	1.020	0.660	1.300
12	1.150	0.870	0.630	1.120
13	1.170	0.910	0.940	0.890
14	1.110	0.940	0.940	0.580
15	1.080	1.070	1.050	0.450
16	1.150	1.070	1.050	0.670
17	1.210	1.140	1.160	0.960
18	1.230	0.990	0.940	1.180
19	1.250	1.450	1.330	0.840
20	1.210	1.160	1.220	1.010
21	1.170	1.550	1.440	2.820
22	1.150	1.290	1.100	1.770
23	0.880	0.990	0.880	0.840
24	1.070	1.600	1.050	0.710

Table 4-20. DATA OUTPUT FOR SMITHVILLE TEST AREA

QUANTITY AND QUALITY OF D W F FOR EACH SUBAREA

```
A1BOD  =    1300.00LBSPERDAY/CFS
A1SS   =    1420.00 LBSPERDAY/CFS
A1COLI =    2.00E 11 MPN/DAY PER CAPITA
ADWF   =       2.32 CFS
```

KNUM	INPUT	DWF CFS	+ INFIL CFS	= QODWF CFS	KLAND	DWBOD LBS/MIN	DWSS LBS/MIN	TOTPOP PERSONS	BODCONC MG/L	SSCONC MG/L	COLIFORMS MPN/100ML
1	10	0.02	0.01	0.03	1	0.02	0.02				
2	10	0.05	0.02	0.07	2	0.04	0.05				
3	10	C.38	0.17	0.55	2	0.27	0.30				
31	10	5.00	2.27	7.27	4	3.74	3.74				
SUBTOTALS											
		5.44	2.47	7.91		20.39 LBS	20.55 LBS	4838.	138.	139.	6.14F 07
4	11	0.27	0.12	0.39	2	0.25	0.27				
41	11	0.80	0.36	1.16	3	0.65	0.71				
5	11	0.17	0.08	0.25	2	0.16	0.17				
51	11	3.00	1.36	4.36	4	2.25	2.25				
6	11	0.09	0.04	0.13	1	0.09	0.10				
7	11	0.20	0.09	0.29	2	0.18	0.20				
SUBTOTALS											
		9.97	4.52	14.49		38.28 LBS	39.05 LBS	12448.	141.	144.	7.16E 06
8	12	0.0	0.0	0.0	5	0.0	0.0				
SUBTOTALS											
		9.97	4.52	14.49		38.28 LBS	39.05 LBS	12448.	141.	144.	7.02E 06
9	13	0.0	0.0	0.0	5	0.0	0.0				
SUBTOTALS											
		9.97	4.52	14.49		38.28 LBS	39.05 LBS	12448.	141.	144.	7.C2F 06
TOTALS											
		9.97	4.52	14.49		38.28 LBS	39.05 LBS	12448.	141.	144.	7.02E 06

SECTION 5

STORAGE BLOCK

SECTION 5

STORAGE BLOCK

BLOCK DESCRIPTION

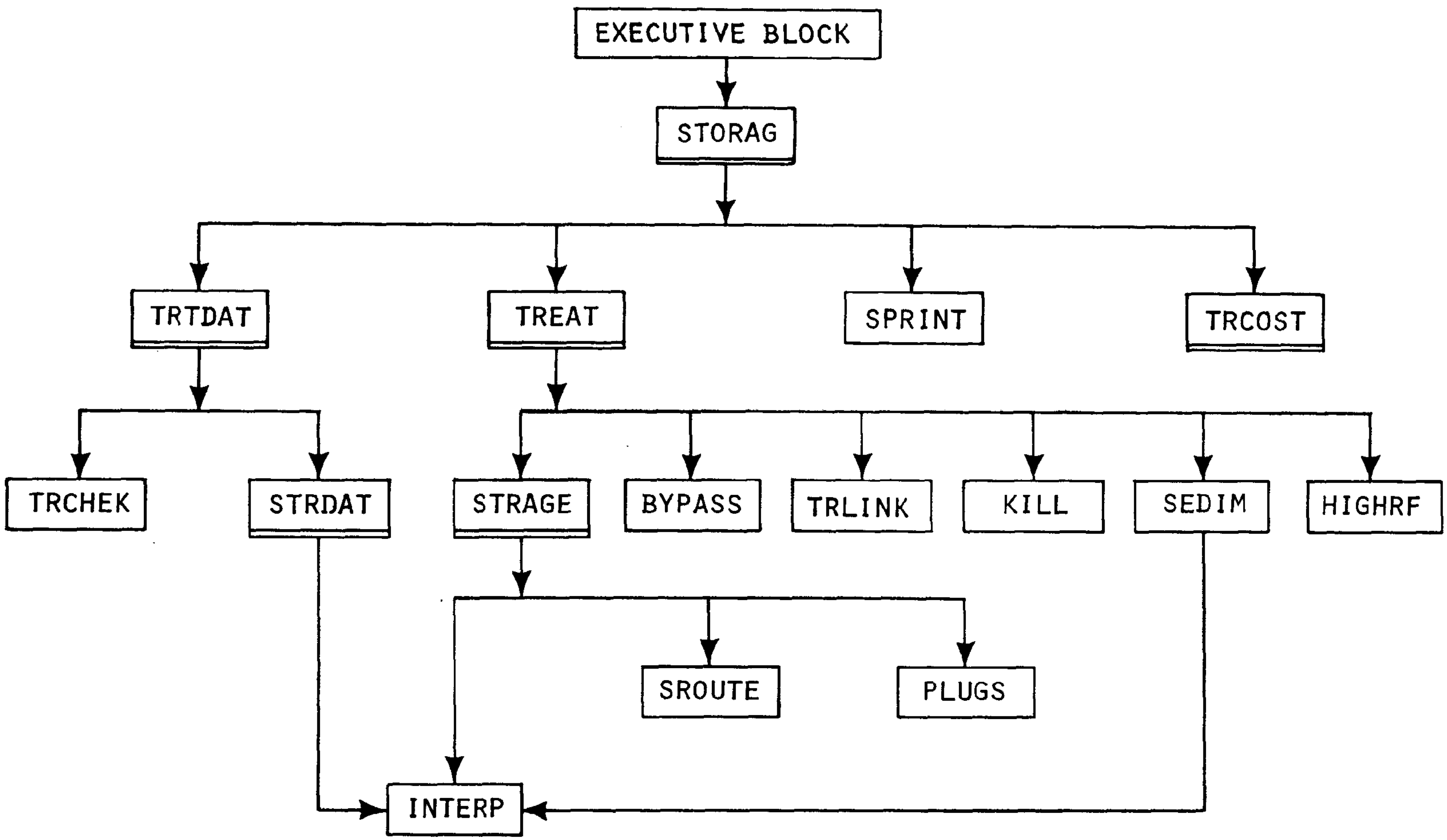
The routing of flow through the storage-treatment package is controlled by subroutine STORAG which is called from the Executive Block program. STORAG coordinates the sewage quantities and qualities, the specifications of storage and treatment facilities to be modeled, and the estimation of their costs. The FORTRAN program is about 3,700 lines in length, comprising 16 subroutines. The relationships among the subroutines which comprise the Storage Block are shown in Figure 5-1.

This section describes the subroutines used in the Storage Block, provides instructions on data preparation, and furnishes examples of program usage.

The 6 major subroutines are described in the order in which they are called in a typical computer run. The remaining 10 minor subroutines are described at the end of the subsection.

Instructions are given for those subroutines requiring card input data, namely, the coordinating subroutine STORAG, the subroutines specifying the treatment and storage facilities, and the cost estimation subroutine.

Examples, with sample I/O data, are given for treatment, storage, and cost computations.



NOTE: BOXES WITH DOUBLE UNDERLINE REPRESENT MAJOR SUBROUTINES.

Figure 5-1. STORAGE BLOCK

Broad Description of Storage

With the Storage Model, holding or routing functions may be modeled in irregular or geometric shaped storage units, and with alternative inlet and outlet controls such as by weir, orifice, or pumping. The characteristics of the storage unit are first specified in subroutine STRDAT, and the flow of water and pollutants are then simulated each time-step by subroutine STRAGE. With gravity outflows, routing is performed by subroutine SROUTE. Two optional types of through-flow are suitable, i.e., plug flow (subroutine PLUGS) and complete mixing.

This external version of storage, as opposed to the internal version incorporated within the Transport Model, cannot be used without including specifications for sedimentation within the storage basin. The re-suspension of solids settled in storage is not modeled.

Broad Description of Treatment

The quality of the storm or combined sewer overflow may be improved by passing the sewage through a treatment package made up by the user. The treatment package is composed by selecting treatment processes from the options indicated in Figure 5-2, thus forming a computational string. The characteristics of the treatment package are first specified in subroutine TRTDAT, and the sewage flows and treatment are then simulated each time-step by subroutine TREAT, aided by a number of minor subroutines (see Figure 5-1) as needed.

Treatment packages not including storage may be modeled by specifying the appropriate bypass, Option 01.

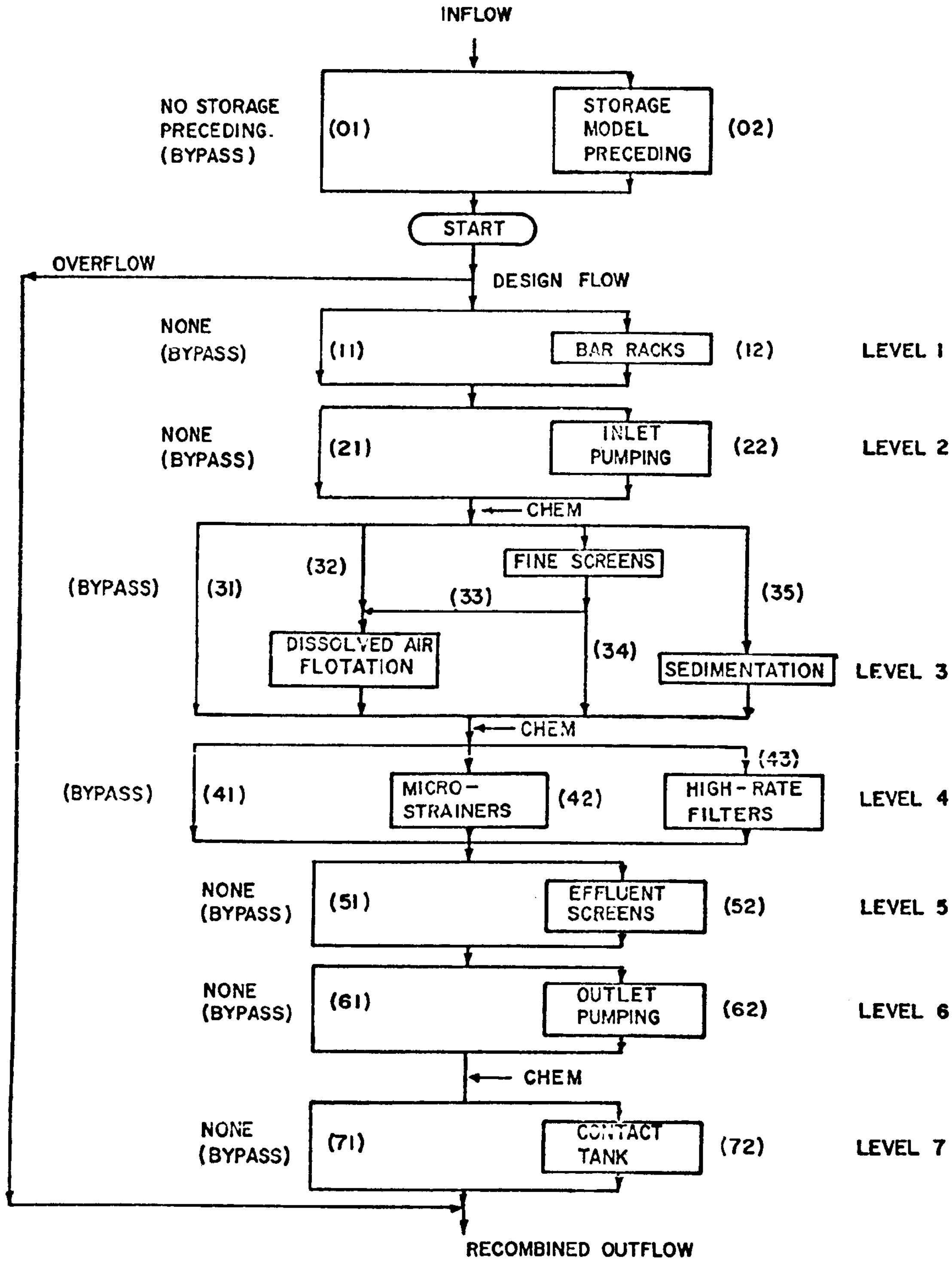


Figure 5-2. AVAILABLE TREATMENT OPTIONS

Broad Description of Cost Estimation

Subroutine TRCOST handles the estimation of all storage and treatment costs after the storm simulation has been completed. Capital costs for the supply, installation, and required land for each process included in the string are computed, from which annual costs are derived. Storm event costs, such as those for chemicals consumed and operation and maintenance, are also computed.

SUBROUTINE DESCRIPTIONS

Subroutine STORAG (C)

Subroutine STORAG is the coordinating program for all water and pollutant movements through the storage and treatment facilities modeled. The Storage Block handles the following pollutants: BOD, suspended solids, and total coliforms.

All interfacing with the Executive Block, and thus I/O statements requiring off line (tape/disk) units are located in STORAG. The inflow hydrographs and pollutographs received in this way are fed on a time-step basis to the appropriate subroutines for processing. Any number of runs with different storage/treatment options and the same inflow data may be executed at the one time, but only the first has output written on the output file. This output is written in the same format as the Transport Model output, in order to be equally acceptable as input to the Receiving Water Model. STORAG also controls the input of storage/treatment specifications (subroutine TRTDAT), the printing of final quantity and quality outputs (subroutine SPRINT), and the estimation of storage/treatment costs (subroutine TRCOST).

A flow chart of subroutine STORAG is shown in Figure 5-3.

Subroutine TRTDAT (1)

This subroutine reads in all the data needed to specify the various treatment processes selected, and computes from them any further parameters needed.

Parameters specifying the treatment options required are read in first (see Figure 5-2 for options available at various levels of treatment). Parameters which control printout of intermediate and summarized treatment information are then read in.

The design flow capacity for the entire treatment installation is then determined by specification or by the inflow hydrograph. If chlorination is specified somewhere within the treatment package, the chlorinator is sized in this subroutine.

Last, any design criteria needed for selected treatment processes are read in on a process-by-process basis in accordance with the specified computational string.

An outline flow chart of subroutine TRTDAT is shown in Figure 5-4.

Subroutine STRDAT (5)

If a storage unit is to be included in the Block, this subroutine reads in all the data needed to specify its various characteristics, and computes from them any further parameters needed. A diagrammatic sketch of a storage unit is shown in Figure 5-5.

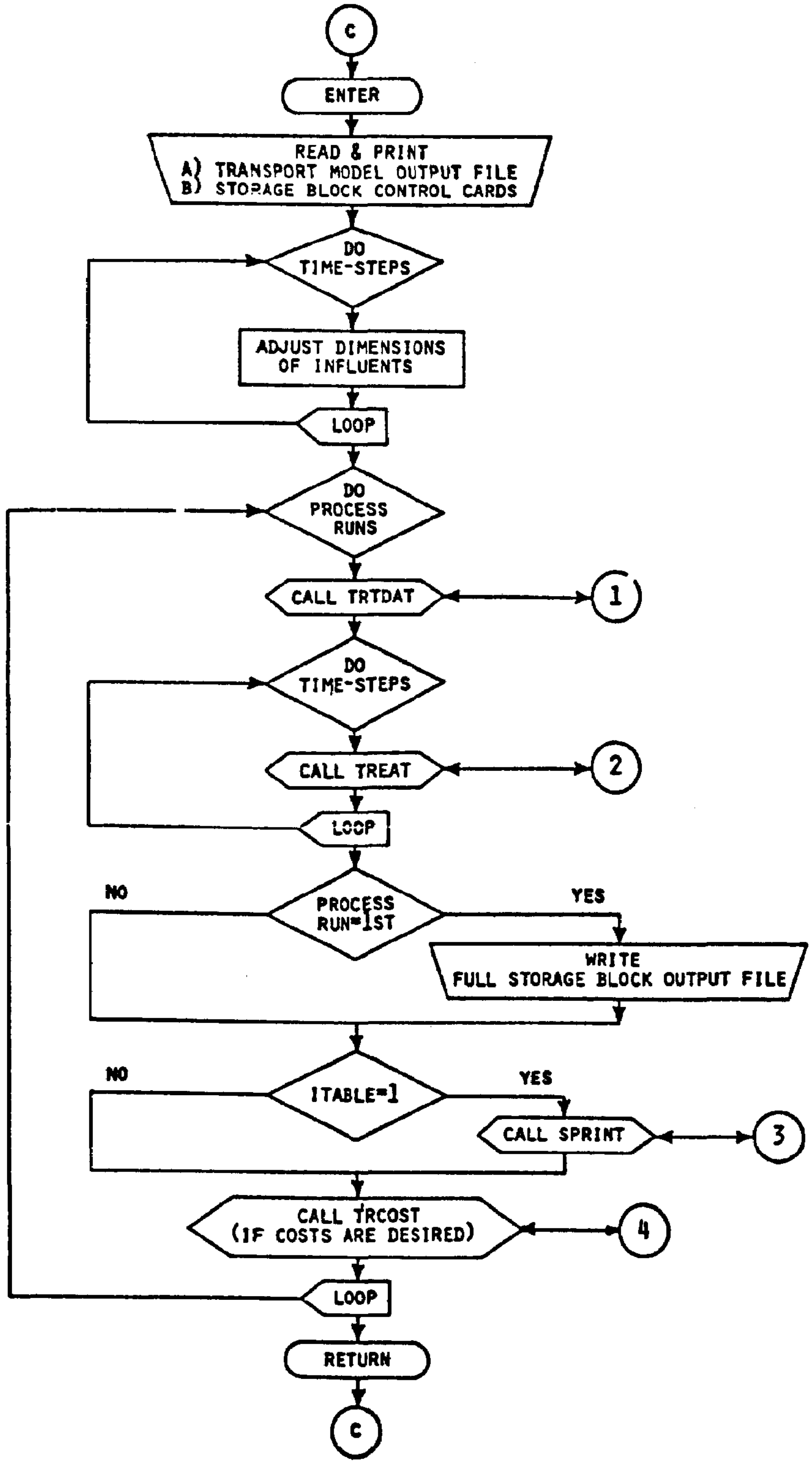


Figure 5-3. SUBROUTINE STORAG

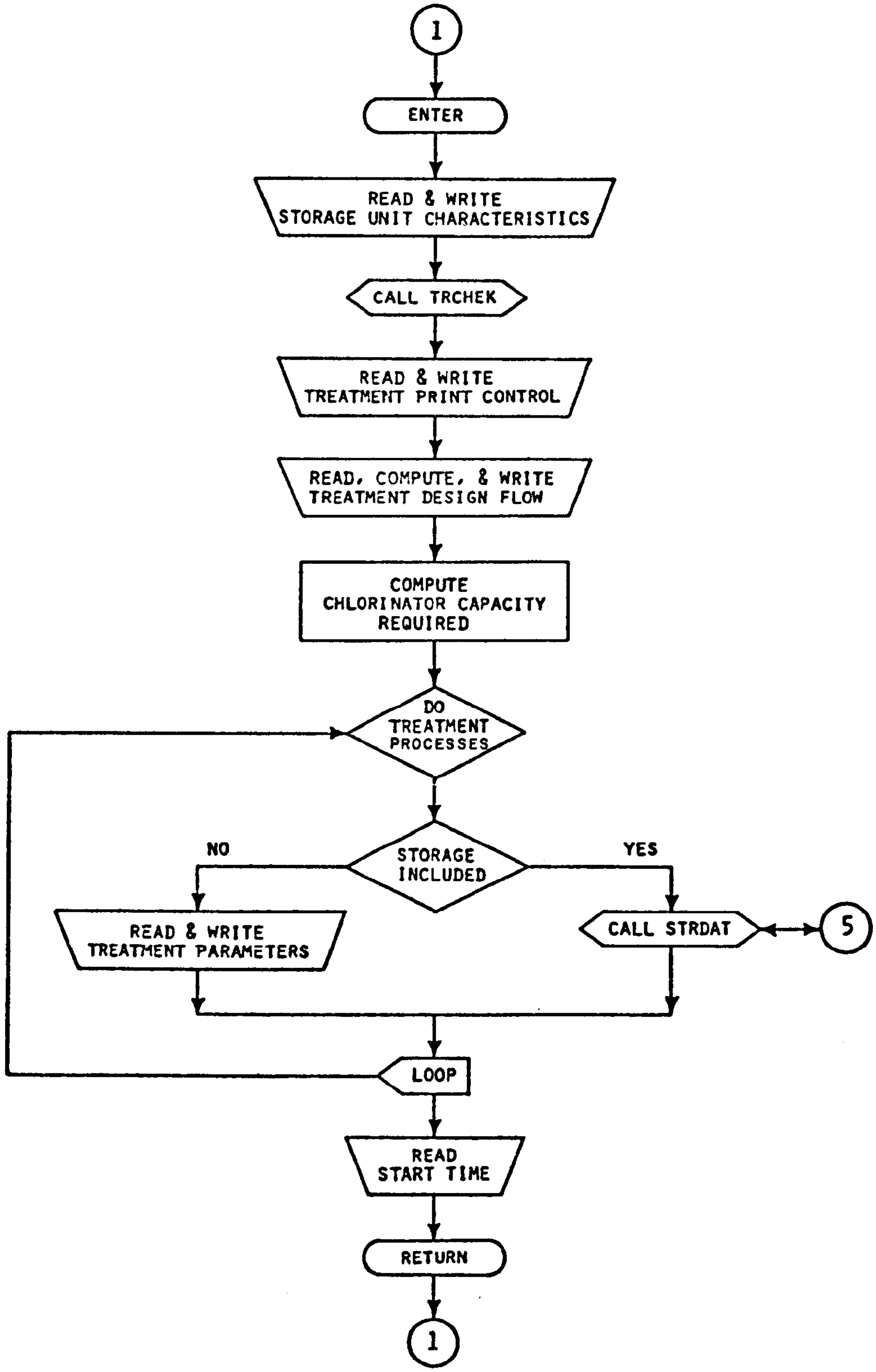


Figure 5-4. SUBROUTINE TRTDAT

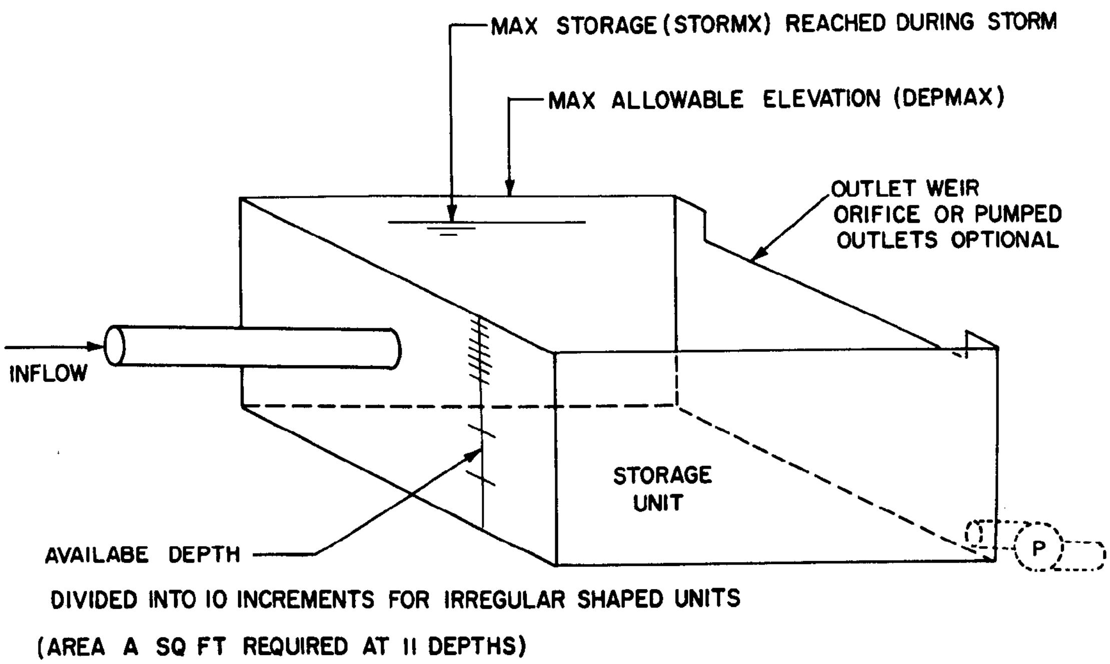


Figure 5-5. DIAGRAMMATIC SKETCH OF STORAGE UNITS

Parameters specifying alternative characteristics, such as irregular or geometric shape, and outflow control by gravity flow through an orifice or over a weir, or by pumping, are read in first.

The maximum permissible water depth is read in next. Subsequent inflows are partially bypassed if they would otherwise cause the storage depth to exceed this value.

Reservoir shape parameters, or alternatively, 11 pairs of depth versus surface area measurements, are read in next. These are followed by the outlet characteristics, selected from: (1) orifice area times its discharge coefficient, (2) weir height and length, or (3) outlet pumping rate with pumping start and stop depths.

The program then computes arrays of 11 depths versus storages, generally dividing the maximum depth into 10 equal increments. With a weir outlet, however, as most change occurs in the small height just above the weir crest, this zone is divided into 7 increments with the remaining 3 larger increments below the crest.

For gravity outflows, 11 pairs of routing parameters are computed from the storage and the outlet control selected. For pumped outflows, the "buffer" volume in storage between pump start and stop depths is computed and compared with the volume capable of being pumped out each time-step. Warning messages will be written if this comparison is not favorable.

Finally, initial storage and outflow conditions of the reservoir are read in. An outline flow chart of subroutine STRDAT is shown in Figure 5-6.

Subroutine TREAT (2)

This subroutine is the heart of the Treatment model. It computes the movements and removals of water and pollutants on a process-by-process basis, every time-step. The various process characteristics specified earlier by subroutine TRTDAT are used.

If treatment by settling in new sedimentation tanks, or by high rate filters, is specified, then subroutine SEDIM or HIGHRF, respectively, is called into play. Where chlorination is specified, subroutine KILL models the reduction in coliform counts.

When a storage unit is included in this Block, subroutine TREAT calls upon subroutine STRAGE to model the movements within storage. In this case sedimentation within storage is modeled at the same time.

Depending upon the print control specified in subroutine TRTDAT, this subroutine may print out reports on intermediate progress and summaries of removal performances. An outline flow chart of subroutine TREAT is shown in Figure 5-7.

Subroutine STRAGE (6)

Subroutine STRAGE is the heart of the Storage model. When a storage unit is included in the model, it computes the movements of water and pollutants through the unit every time-step. The various basin characteristics computed earlier by STRDAT are used.

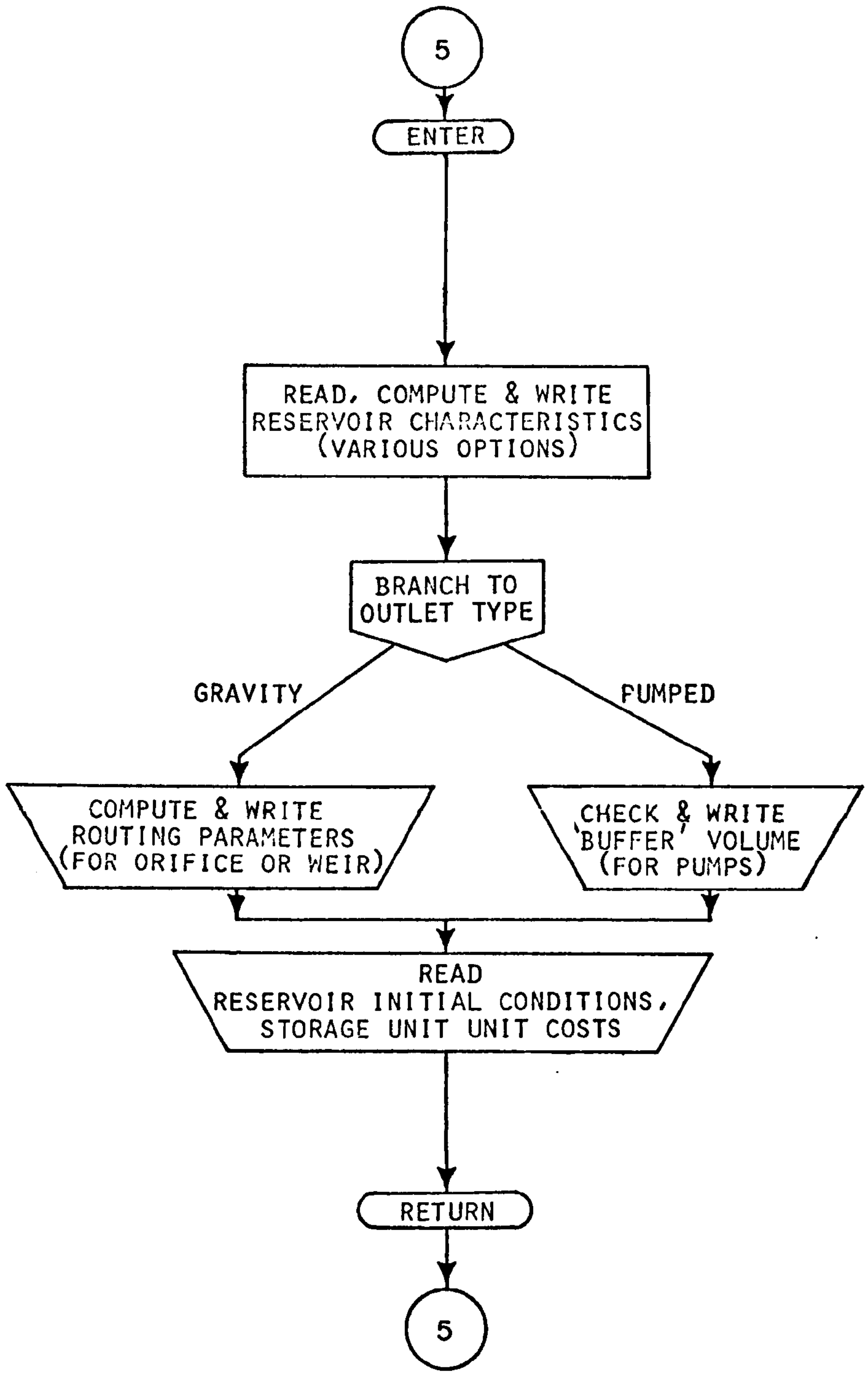


Figure 5-6. SUBROUTINE STRDAT

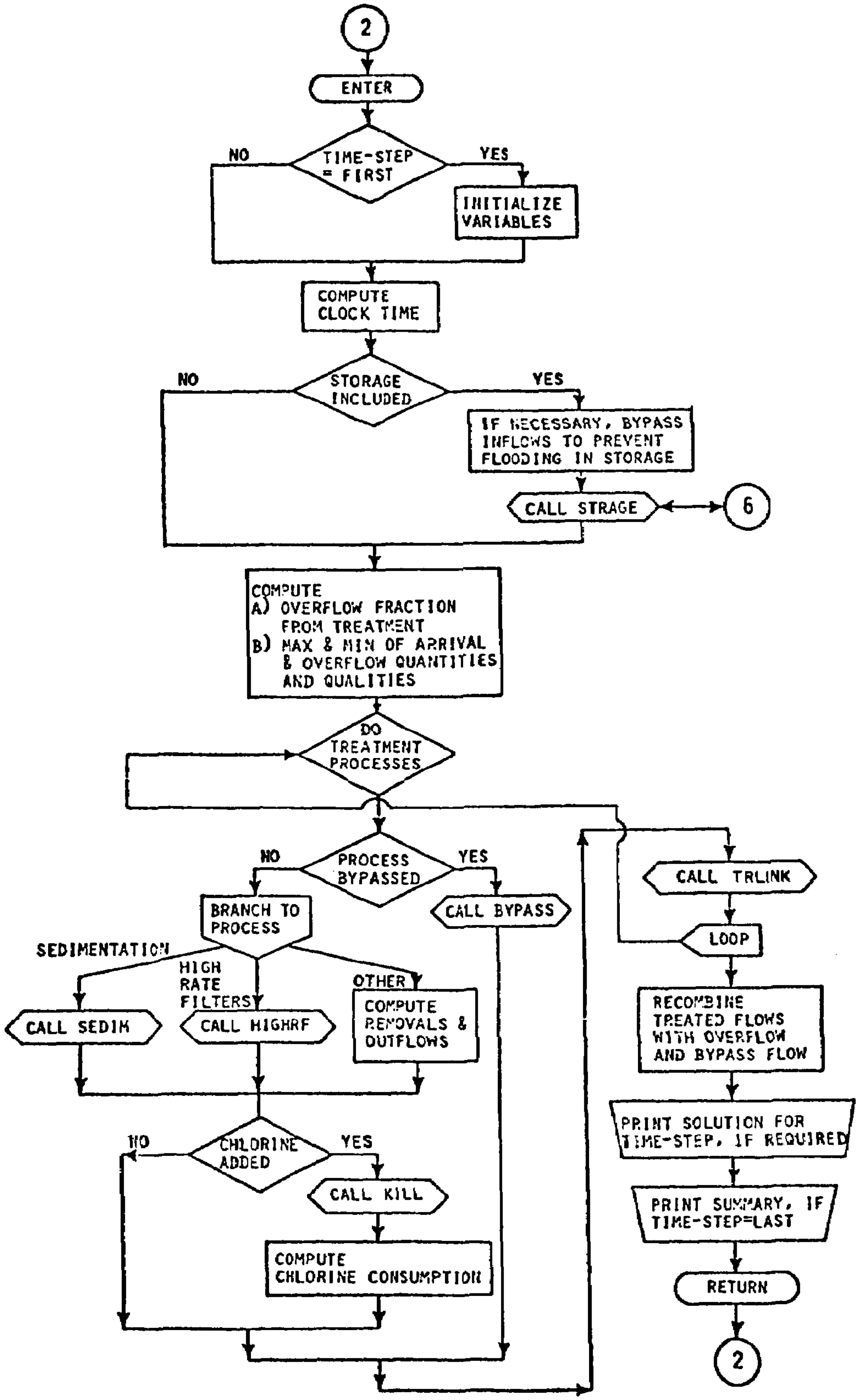


Figure 5-7. SUBROUTINE TREAT

The hydraulics are computed first. For pumped outflow, the rate simply depends upon a comparison of the reservoir depth with the pump start and stop depths. However, checks are made for the possibility of pumps cutting in or out part way through the time-step, in which case appropriate adjustments are made. For gravity outflow, subroutine SROUTE is called to compute the storage and outflow rate at the end of the time-step. Subroutine INTERP is called to find the depth corresponding to the computed storage, by interpolation within the depth/storage arrays.

The incremental water volumes of the inflow and outflow plugs for all time-steps and storage units are stored permanently in arrays for later reference. Each time-step, the cumulative total inflow and outflow volumes are also computed, to enable a final continuity check.

Next, the movements of the pollutants through the units are computed. Subroutine PLUGS is called first, to compute and keep a record of which inflow plugs comprise the outflow plugs. Then the BOD and suspended solids in storage and in the inflow are computed, by two alternative methods. Either perfect plug flow through the reservoir or complete mixing must be assumed.

Last, if this intermediate printout is requested, the program prints each time-step the inflow, storage and outflow conditions in all reservoirs.

An outline flow chart of subroutine STRAGE is shown in Figure 5-8.

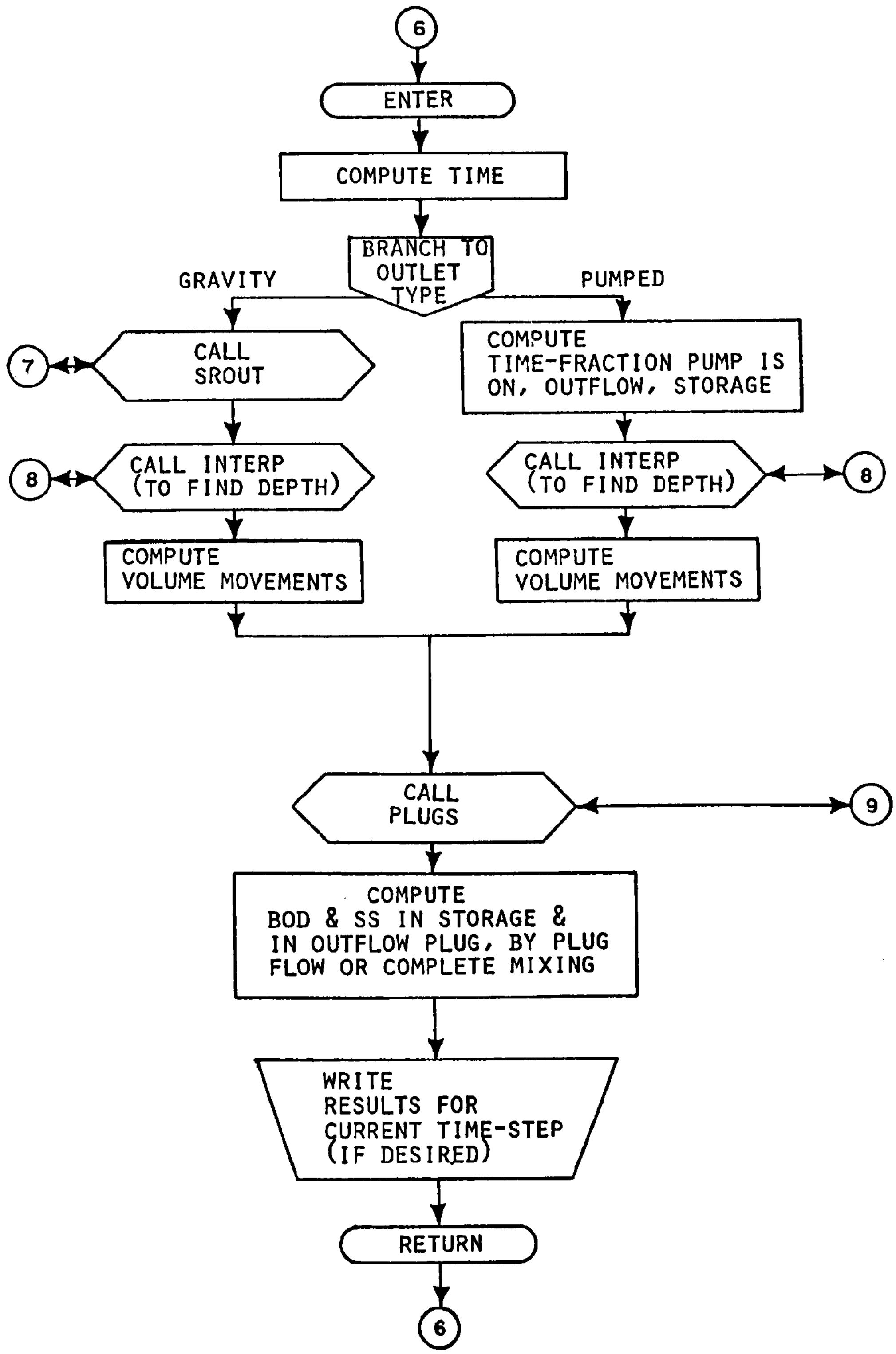


Figure 5-8. SUBROUTINE STRAGE

Subroutine TRCOST (4)

Subroutine TRCOST computes and prints estimated costs for (1) the provision of the storage and treatment facilities specified, and (2) the operation and maintenance of these facilities during the storm event modeled.

The required money factors and unit costs are first read in and processed. Default values are included for many of these (see Table 5-1).

The various costs are then computed on a process-by-process basis. These costs are (1) the capital costs of providing the process in question and its land requirement, (2) their equivalent annual costs together with irreducible annual maintenance, and (3) storm event costs for chemicals consumed, if any, and operation and maintenance. They are printed in a summary table with totals and subtotals, together with a statement of the total land requirement.

An outline flow chart of subroutine TRCOST is shown in Figure 5-9.

Support Subroutines

Brief descriptions follow of the support subroutines, whose relationships with the major subroutines were shown in Figure 5-1.

Subroutine TRCHEK is called by subroutine TRTDAT to check the specified treatment options for inadmissible or uneconomical combinations (see Figure 5-10). It terminates execution or writes a warning message as appropriate.

Table 5-1. DEFAULT VALUES USED IN SUBROUTINE TRCOST

Item	Default Value
Interest rate	7%
Amortization period	25 yr
Site factors	1.00
Unit cost land	$20,000/acre
Unit cost power	2¢/kwh
Unit cost chlorine	20¢/lb
Unit cost polymers	$1.25/lb
Unit cost alum	3¢/lb
Storage construction unit cost (excavation, lining, etc.)	$3.00/cy

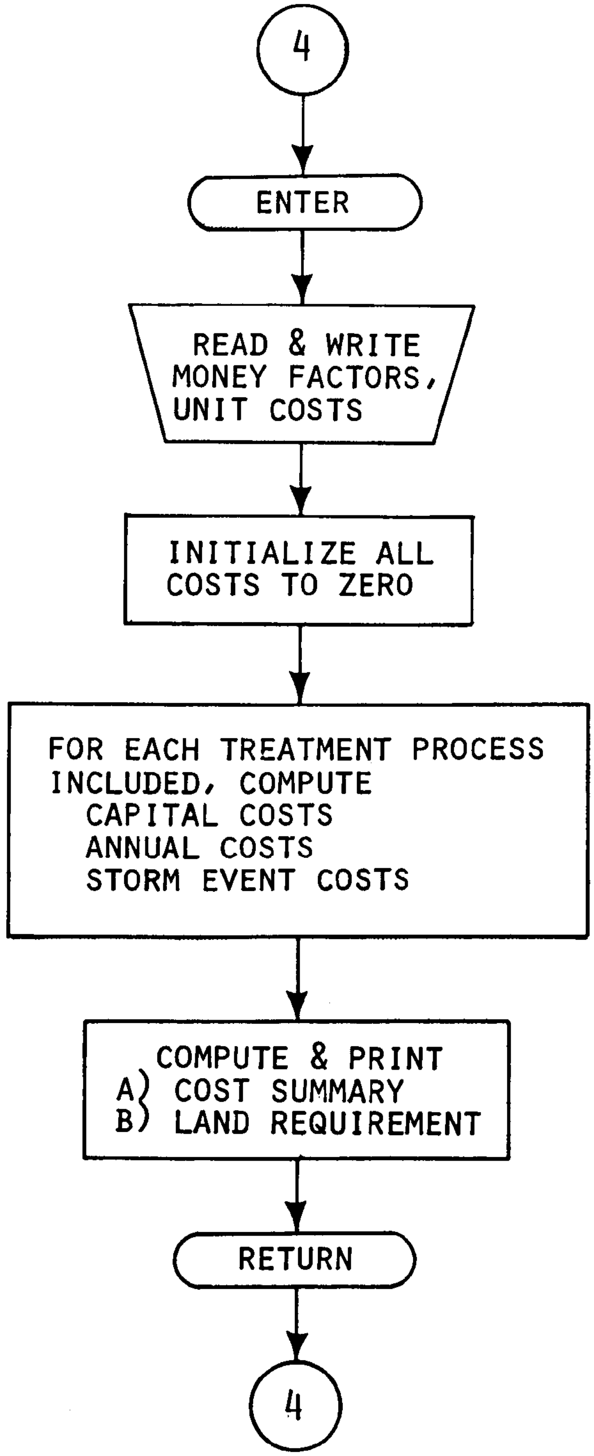
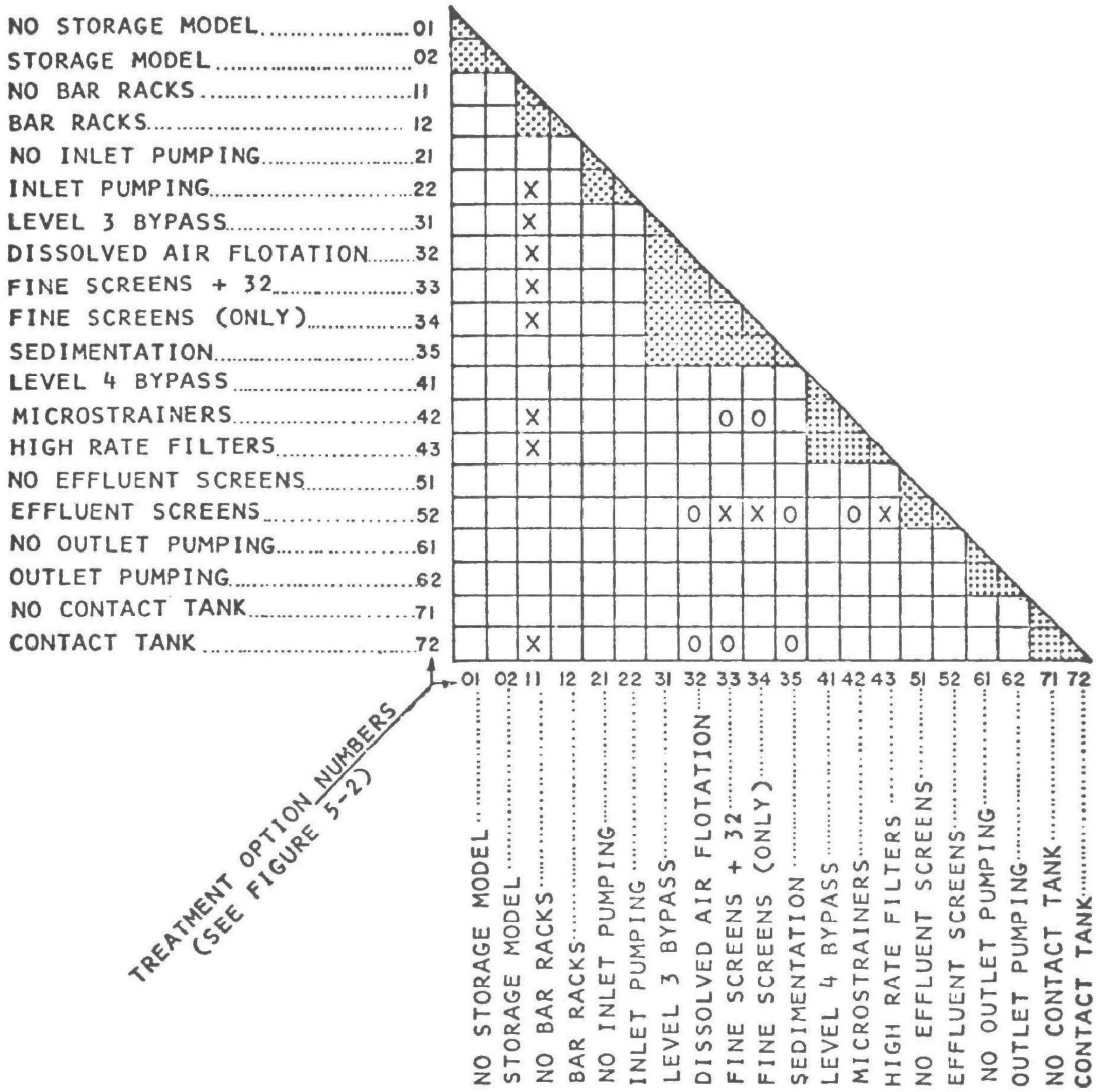


Figure 5-9. SUBROUTINE TRCOST



LEGEND

[shaded box] COMBINATIONS IMPOSSIBLE DUE TO THE STRUCTURE OF THE PROGRAM

[X] INADMISSIBLE COMBINATIONS

[O] UNECONOMICAL COMBINATIONS

Figure 5-10. INADMISSIBLE AND UNECONOMICAL TREATMENT OPTIONS

Subroutines SROUTE and PLUGS assist subroutine STRAGE with the modeling and tracing of water movement through the storage basin, by simulating routing and plug flow respectively.

Subroutines BYPASS and TRLINK serve subroutine TREAT to link up successive treatment processes within the Treatment model. Subroutine TRLINK also collects cumulative totals of water and pollutant through-flows at each process level.

Subroutines KILL, SEDIM, and HIGHRF assist subroutine TREAT with, respectively, the modeling of coliform reduction by chlorination, sedimentation, and high rate filter operation.

Subroutine INTERP serves subroutines STRDAT, STRAGE, and SEDIM with a simple linear interpretation procedure, which may be required when data are stored in array form. It flags error conditions when data fall outside the range of an array.

Subroutine SPRINT will print, if desired, an extensive summary of input and treated output hydrographs and pollutographs.

Outline flow charts of subroutines SROUTE, PLUGS, and INTERP are shown, respectively, in Figures 5-11, 5-12 and 5-13.

INSTRUCTIONS FOR DATA PREPARATION

Instructions for data preparation for the Storage Block have been divided along the lines of the major components for clarity of the presentation. These components are: Storage, Treatment, and Cost. Programming options permit the deletion of the cost and/or storage routines;