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STORM WATER MANAGEMENT MODEL USER'S MANUAL Version II

National Environmental Research Center
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STORM WATER MANAGEMENT MODEL

USER'S MANUAL

Version II

By

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FOREWORD

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

- studies on the effects of environmental contaminants on man and the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

This study describes the use of the EPA Storm Water Management Model (SWMM) for aiding in planning abatement alternatives due to overflows of combined sewer and storm water runoff in urban areas. The material supersedes the original User's Manual for the SWMM and reflects the latest updating and modifications to the Model.

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ABSTRACT

A comprehensive mathematical model (the EPA Storm Water Management Model (SWMM)) capable of representing urban stormwater runoff and combined sewer overflow phenoma was developed. SWMM portrays correctional devices in the form of user-selected options for storage and/or treatment with associated estimates of cost. Effectiveness is portrayed by computed treatment efficiencies and modeled changes in receiving water quality. The original project report published in 1971 is divided into four volumes: Volume I, "Final Report," Volume II, "Verification and Testing," Volume III, "User's Manual," and Volume IV, "Program Listing" (EPA Report Nos. 11024 DOC 07/71, 11024 DOC 08/71, 11024 DOC 09/71, and 11024 DOC 10/71, respectively).

Effort on modification and improvement of the SWMM has been, and is being continued since its release. As a result, this official "Release 2" of the SWMM includes additional program components, i.e., new runoff routine, urban erosion prediction, new treatment process performance and cost functions, and new receiving water quality. This report provides a revised and improved User's Manual to accompany "Release 2" program. As much as possible, instructions for input formats have been kept the same as in the original User's Manual, Volume III.

This report was submitted in partial fulfillment of Project R-802411 by the University of Florida under the sponsorship of the Environmental Protection Agency. Work was completed as of August 1974.

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ACKNOWLEDGEMENTS

The material presented in this report is based on extensions and revisions of the first version of the Storm Water Management Model, and that original work is gratefully acknowledged. Both Metcalf and Eddy, Incorporated and Water Resources Engineers, Incorporated have continued their model development efforts, and have contributed to the additional work performed at the University of Florida. In particular, Drs. Robert Shubinski and Larry Roesner of WRE and Mr. John Lager of M & E made many useful suggestions concerning program "bugs" and modifications and proposed alterations in the presentation format. In addition, the Release 2 version of the Runoff Model is based on development work by WRE for the Seattle District, Corps of Engineers.

The guidance and considerable interest of Mssrs. Harry Torno, Chi-Yuan Fan and Richard Field of the Environmental Protection Agency has been most beneficial and appreciated. Mssrs. M. T. Augustine and M. A. Ports of the State of Maryland, Department of Natural Resources were instrumental in obtaining useful information on the Universal Soil Loss Equation. Data for the Lancaster, Pennsylvania example were obtained through the courtesy of the City of Lancaster and Meridian Engineering, Incorporated of Philadelphia. Data for the St. Johns River example were obtained with the help of Frederic R. Harris, Incorporated of Jacksonville.

The extensive typing job was performed with dedication by Ms. Mary Polinski. Ms. Gena Ellis conscientiously drafted many new figures. Computations were performed at the Northeast Regional Data Center at the University of Florida.

SECTION 1

INTRODUCTION

PROBLEMS OF URBAN RUNOFF

An enormous pollution load is placed on streams and other receiving waters by combined and separate storm sewer overflows. It has been estimated that the total pounds of pollutants (BOD and suspended solids) contributed yearly to receiving waters by such overflows is of the same order of magnitude as that released by all secondary sewage treatment facilities (2,3). The Environmental Protection Agency (EPA) has recognized this problem and led and coordinated efforts to develop and demonstrate pollution abatement procedures. These procedures include not only improved treatment and storage facilities, but also possibilities for upstream abatement alternatives such as rooftop and parking lot retention, increased infiltration, improved street sweeping, retention basins and catchbasin cleaning or removal (2). The complexities and costs of proposed abatement procedures require much time and effort to be expended by municipalities and others charged with decision making for the solution of these problems.

It was recognized that an invaluable tool for decision makers would be a comprehensive mathematical computer simulation program that would accurately model quantity (flows) and quality (concentrations) during the total urban rainfall-runoff process. This model would not only provide an accurate representation of the physical system, but also provide an opportunity to determine the effect of proposed pollution abatement procedures. Alternatives could then be tested on the model, and least cost solutions could be developed.

The resulting EPA Storm Water Management Model is introduced below, and its use is the subject of this report. However, since its initial release in 1970, there has been an insurgence of urban runoff modeling, and it is worthwhile to review briefly objectives and options pertinent to management of urban stormwater runoff.

URBAN RUNOFF MODELS

Objectives

Models are generally used for studies of quantity and quality problems associated with urban runoff in which three broad objectives may be identified: planning, design and operation. Each objective typically produces models with somewhat different characteristics, and the different models overlap to some degree.

Planning Models

Planning models are used for an overall assessment of the urban runoff problem as well as estimates of the effectiveness and costs of abatement procedures. They may be used for "first cut" analyses of the rainfall-runoff process and illustrate trade-offs among various control options, e.g., treatment versus storage. They are typified by relatively large time steps (hours) and long simulation times (months and years). Data requirements are kept to a minimum and their mathematical complexity is low.

A current example of such a model is the Storage, Treatment, Overflow, and Runoff Model (STORM) (4,12) developed by the Corps of Engineers Hydrologic Engineering Center (HEC) and Water Resources Engineers, Incorporated (WRE) for the City of San Francisco. It utilizes hourly time steps and precipitation inputs and has simple quantity and quality prediction procedures based on such parameters as per cent imperviousness and land use. Included are the effects of snow melt and soil erosion as well as treatment and storage options. The output may be used to illustrate, for example, the frequency and/or volumes of discharges to receiving waters of untreated urban runoff for a given treatment-storage combination. STORM has been run for simulation periods of up to 25 years, depending upon the desired definition of return periods.

A planning model such as STORM may also be run to identify hydrologic events that may be of special interest for design or other purposes. These storm events may then be analyzed in detail using a more sophisticated design model. Planning or long-term models may also be used to generate initial conditions (i.e., antecedent conditions) for input to design models.

Design Models

Design models are oriented toward the detailed simulation of a single storm event. They provide a complete description of flow and pollutant routing from the point of rainfall through the entire urban runoff system and often into the receiving waters as well. Such models may be used for accurate predictions of flows and concentrations anywhere in the rainfall/runoff system and can illustrate the detailed and exact manner in which abatement procedures or design options affect them. As such, these models are a highly useful tool for determining least-cost abatement procedures for both quantity and quality problems in urban areas. Design models are generally used for simulation of a single storm event and are typified by short time steps (minutes) and short simulation times (hours). Data requirements may be moderate to very extensive depending upon the particular model employed.

The EPA Storm Water Management Model (8,9,10,11), frequently abbreviated "SWMM," is an example of a model developed specifically for simulation of urban quantity and quality processes and useful for the purposes mentioned above. It is also versatile enough to be used for certain planning studies or adapted to uses other than were originally intended. For instance, the surface runoff portion may be used to simulate natural drainage systems, and the receiving water portion may be applied to a variety of natural configurations independent of the urban runoff context. Use of the SWMM is described in detail in this report.

Many other urban runoff models have been described in the literature and are too numerous to enumerate here. Examples range from relatively simple models, e.g., RRL (15), Chicago (6), to highly complex models that utilize the complete dynamic equations of motion to simulate every aspect of the drainage systems, e.g., the WRE version of the SWMM (13), Hydrograph Volume Method (5), and Sogreah (14). Many of these other models lack quality calculations; of the aforementioned ones, quality routing is included only in the WRE version of the SWMM. Furthermore, many are either proprietary or ill-documented. The EPA SWMM is well documented, widely tested and of a fairly high level of sophistication. In addition, through its broad use, improvements and updating have been continuous. It is a widely accepted, detailed simulation model.

Operational Models

Operational models are used to produce actual control decisions during a storm event. Rainfall is entered from telemetered stations and the model is used to predict system responses a short time into the future. Various control options may then be employed, e.g., in-system storage, diversions, regulator settings.

These models are frequently developed from sophisticated design models and applied to a particular system. Examples are operational models designed for Minneapolis-St. Paul (1) and Seattle (7).

DEVELOPMENT OF THE STORM WATER MANAGEMENT MODEL

Under the sponsorship of the Environmental Protection Agency, a consortium of contractors -- Metcalf and Eddy, Incorporated, the University of Florida, and Water Resources Engineers, Incorporated -- developed in 1969-70 a comprehensive mathematical model capable of representing urban stormwater runoff and combined sewer overflow phenomena. The SWMM portrays correctional devices in the form of user-selected options for storage and/or treatment with associated estimates of cost. Effectiveness is portrayed by computed treatment efficiencies and modeled changes in receiving water quality.

The project report is divided into four volumes. Volume I, the "Final Report" (8), contains the background, justifications, judgments, and assumptions used in the 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 effectively. Although many modifications and improvements have since been added to the SWMM, the material in Volume I still accurately describes most of the theory behind updated versions.

Volume II, "Verification and Testing," (9), describes the methods and results of the application of the original model to four urban catchments.

Volume III, the "User's Manual" (10), contains program descriptions, flow charts, instructions on data preparation and program usage, and test examples. This present report will replace the old User's Manual and reflects the extensive updating that has occurred since the completion of the SWMM project in September, 1970.

Volume IV, "Program Listing" (11), lists the entire original program and Job Control Language (JCL) as used in the demonstration runs. Since many routines in the updated version are similar or identical to the original, it is still a useful reference.

All three original contractors have continued to modify and improve the SWMM, as have numerous other users since its release. Through EPA research grants, the University of Florida has conducted extensive research on urban runoff and SWMM development, and has evolved into an unofficial "clearinghouse" for SWMM improvements. As a result, an official "Release 2" of the SWMM has been made in August, 1974. Although it has been prepared for EPA by the University of Florida, it also relies heavily upon contributions by Water Resources Engineers and Metcalf and Eddy. This report provides a revised and improved User's Manual to accompany Release 2. As much as possible, instructions for input formats have been kept the same as in the original User's Manual, Volume III (10).

OVERALL SWMM DESCRIPTION

Overview

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 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 arbitrary rainfall hyetographs, antecedent conditions, land use, and topography.

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

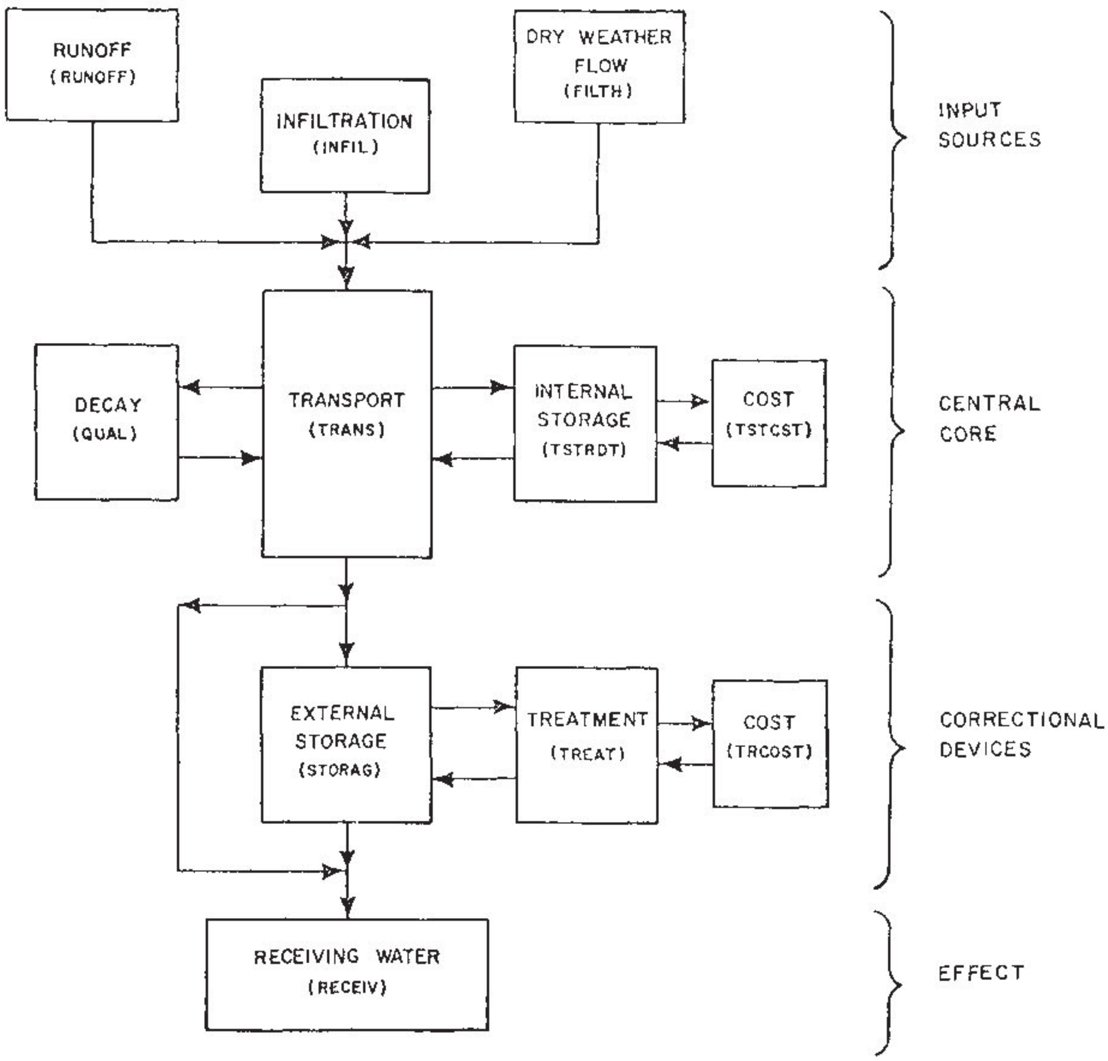
   INFIL generates infiltration into the sewer system based on available groundwater and sewer condition.

2) The central core:

   TRANS carries and combines the inputs through the sewer system using a modified kinematic wave approach in accordance with Manning's equation and continuity; it assumes complete mixing at various inlet points.

3) The correctional devices:

   TSTRDT, TSTCST, STORAG, TREAT, and TRCOST modify hydrographs and pollutographs at



Note: Subroutine names are shown in parentheses.

Figure 1-1. Overview of Model Structure

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, river, lake, estuary, or bay.

The quality constituents considered for simulation are the 5-day BOD, 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. In addition, the Runoff Block also models COD, settleable solids, total nitrogen, phosphate and grease. However, routing of these parameters through subsequent blocks usually involves special programming efforts. The contribution of suspended solids by urban erosion processes is also simulated by the program.

Program Blocks

The adopted programming arrangement consists of a main control and service block, the Executive Block, a service block (Combine), 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.

Combine Block --

This block allows the manipulation of data sets (files stored on offline devices) in order to aggregate results of previous runs for input into subsequent blocks. In this manner large, complex drainage systems may be partitioned for simulation in smaller segments.

Runoff Block --

The Runoff Block computes the stormwater 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. Of course, the program may also be used strictly for stormwater routing, with neither DWF nor infiltration.

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 or Runoff Blocks directly, or the modified output of the Storage Block, and computes the resulting hydrodynamics and concentration distributions in the receiving river, lake, estuary, or bay.

Total Simulation

In principle, the capability exists to run all blocks together in a given computer execution, although from a practical and sometimes necessary viewpoint (due to computer core limitations), typical runs usually involve only 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 operation.

2) Instructions on data preparation with tables for data card input requirements and an alphabetical list of variables.

3) Examples of the application of procedure 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).

USER REQUIREMENTS

Computer Facilities

A large, high-speed computer is required for operation of the SWMM such as an IBM 360, UNIVAC 1108 or CDC 6600. The largest of the blocks requires on the order of 90,000 words of storage. Through considerable efforts, users have been able to adapt portions of the program to small-core machines such as the IBM 1130, but only with extensive use of off-line storage and considerable increase in execution time.

Data Requirements

As will be seen from a review of following sections, the data requirements for the SWMM are extensive. Collection of the data from various municipal and other offices within a city is possible to accomplish within a few days. However, reduction of the data for input to the Model is time consuming and may take up to three man-weeks for a large area (e.g., greater than 2000 acres). On an optimistic note, however, most of the data reduction is straight forward (e.g., tabulation of slopes, lengths, diameters, etc., of the sewer system). The SWMM is flexible enough to allow different modeling approaches to the same area, and a specific, individual modeling decision upstream in the catchment will have little effect on the predicted results at the outfall.

Verification and Calibration

The SWMM is designed as a "deterministic" model, in that if all input parameters are accurate, the physics of the processes are simulated sufficiently well to produce accurate results without calibration. This concept may fail in practice because the input data or the numerical methods may not be accurate enough for most real applications. Furthermore, many computational procedures within the Model are based upon limited data themselves. For instance, surface quality predictions are based almost totally on data from Chicago, and are unlikely to be of universal applicability.

As a result it is essential that some local verification/calibration data be available at specific application sites to lend credibility to the predictions of any urban runoff model. These data are usually in the form of measured flows and concentrations at outfalls or combined sewer overflow locations. Note that quality measurements without accompanying flows are of little value. The SWMM has sufficient parameters that may be "adjusted," particularly in the Runoff Block, such that calibrating the Model against measured data is usually readily accomplished.

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SECTION 2

INITIAL JOB SET-UP

COMPUTER SYSTEM REQUIREMENTS

The Storm Water Management Model can be run on a machine having core storage capacity of at least 350K bytes (or equivalent) and using overlay. In addition, the program uses peripheral storage devices which may consist of disk, tape, or drum units, depending on the machine configuration. All parts of the original program were initially run on at least two machines, the UNIVAC 1108, IBM 360 and now an IBM 370/165.

PROGRAM COMPILATION AND EXECUTION TIME AND COST

A sample of the compilation and execution times with run costs for separate program blocks are shown on Table 2-1. This table illustrates the savings which were made by storing compiled blocks of the program in a permanent job library (Load Modules). At most computer installations, there is a daily or monthly charge for storing Load Modules. If the SWMM is going to be used more than a few times, it would be advisable to use Load Modules.

From the Central Processing Unit (CPU) and Execution times in this table a time and cost estimate can be arrived at for different machines. A systems analyst can obtain these figures.

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 user 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 SWMM 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 370/165.

It is convenient on these machines to use disk storage devices rather than tape units because of the inherently faster reading and writing speed of the former. At most installations, the logical unit

Table 2-1. SAMPLE PROGRAM COMPILATION AND EXECUTION TIME AND COST

Program blocks[c]	Uncompiled[a] CPU time[d] (sec)	Uncompiled[a] Execution time[e] (sec)	Uncompiled[a] Cost[f] ($)	Load module[b] CPU time[d] (sec)	Load module[b] Execution time[e] (sec)	Load module[b] Cost[f] ($)
Runoff[g]						
Quantity only	10.69	10.60	5.48	1.58	10.28	4.10
Quantity and Quality	11.12	18.56	6.46	1.73	18.89	5.61
Transport[h]						
Quantity only	29.57	18.04	11.11	2.10	21.14	4.70
Quantity and Quality	29.90	39.62	14.57	2.15	39.79	7.75
Storage/Treatment[i]						
Quantity and Quality				2.41	4.54	2.40
Receiving Water[j]						
Quantity only				2.17	78.53	14.00
Quantity and Quality	19.38	79.67	18.11	2.29	83.16	15.49

[a] Includes compile, link-edit, and execute.

[b] Includes compile, for dummy subroutines only, link-edit, and execute (all subroutines in object form on data set).

[c] All blocks include Executive Block (Load Module form), maximum core storage required for any one block and the Executive Block is 350K.

[d] Time required for compile and link-edit.

[e] Time required for execution only.

[f] Total cost for running block on University of Florida's IBM 370/165 computer at half the commercial rate.

[g] North Lancaster, Pennsylvania, Drainage District, Study No. 3, 100 time steps, integration period 5 minutes, 66 subcatchments and no gutter/pipe network.

[h] North Lancaster, Pennsylvania, Drainage District, Study No. 3, 100 time steps, integration period 5 minutes, 147 sewer elements, infiltration and sewage flows to be estimated by model.

[i] North Lancaster, Pennsylvania, Drainage District Treatment Plant, Study No. 3, 100 time steps, integration period 5 minutes, treatment control options used high rate disinfection device for overflow, bar racks, sedimentation, biological treatment, and contact tank (cost includes graphing input and output).

[j] Conestoga River, Lancaster, Pennsylvania, with input from North Treatment Plant and rainfall from Study No. 3, 3 days simulated, water quality cycles per day 24, length of integration step 60 seconds, 20 junctions and 19 channels.

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 (usually given the logical unit number of 7). 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.

Table 2-2 shows sample JCL, overlay and preliminary input data to run the SWMM from a tape. Many users may prefer to store a compiled version on a disk rather than run from the cards or tape. This example is for the University of Florida's IBM 370/165.

The following is a description of Table 2-2:

Line "0" is the job card unique to the University of Florida Computing Center.

Line "1" is the tape mount and setup card.

Lines "2-3" are for execution and overlay of the SWMM source program.

Lines "4-13" describe the files on the source tape called MASTER. Example: LABEL = 2 stands for the Runoff Block on the tape.

Lines "14-26" describe the overlay of each block of the SWMM used.

Lines "27-33" describe scratch disk files for use in running the SWMM. These could alternatively be set up as permanent files if the same input or output is to be used for another run, for example. An example of a tape or disk unit number: //GO.FXXF001 DD... where XX stands for the symbolic unit number.

Table 2-2. SAMPLE OF JCL REQUIRED TO RUN SWMM ON AN IBM 370/165

```
//SWMM  JOB    (1006,3422,30,15,0),'W. ALAN PELTZ',CLASS=L
/*SETUP        TAPE9,1,MASTER
// EXEC F4HCLM,PARM.FORT='SIZE=350K,NOSOURCE,NOMAP',
//    PARM.LKED='LIST,MAP,OVLY'
//FORT.SYSIN DD UNIT=TAPE9,VOL=SER=MASTER,DSN=MAIN,DISP=(OLD,PASS),
//    LABEL=1
//             DD UNIT=TAPE9,VOL=SER=MASTER,DSN=RUNOFF,DISP=(OLD,PASS),
//    LABEL=2
//             DD UNIT=TAPE9,VOL=SER=MASTER,DSN=TRANSPRT,DISP=(OLD,PASS),
//    LABEL=3
//             DD UNIT=TAPE9,VOL=SER=MASTER,DSN=STORAGE,DISP=(OLD,PASS),
//    LABEL=4
//             DD UNIT=TAPE9,VOL=SER=MASTER,DSN=RECEIVE,DISP=(OLD,PASS),
//    LABEL=5
//LKED.SYSIN DD *
   OVERLAY ALPHA
      INSERT  RUNOFF,HYDRO,RHYDRO,QSHED1,WSHED,GUTTER,GQUAL,HCURVE,RECAP
   OVERLAY ALPHA
      INSERT  TRANS,DEPTH,DPSI,DWLOAD,FILTH,FINDA,FIRST,INFIL,INITAL,PSI
      INSERT  NEWTON,PRINT,QUAL,RADH,ROUTE,SLOP,VEL,TSTRDT,TSTORG,TSTCST
      INSERT  TPLUGS,TSROUT,TINTRP,ACOS
   OVERLAY ALPHA
      INSERT  STORAG,TRTDAT,TRCHEK,INTERP,STRDAT,TREAT,BYPASS,TRLINK,KILL
      INSERT  SEDIM,HIGHRF,STRAGE,PLUGS,        SPRINT,TRCOST
   OVERLAY ALPHA
      INSERT  RECEIV,SWFLOW,MANING,INDATA,TIDCF,TRIAN,OUTPUT,PRTOUT
      INSERT  SWQUAL,INQUAL,LOOPQL,QPRINT
//GO.FT01F001 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//GO.FT02F001 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//GO.FT03F001 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//GO.FT04F001 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//GO.FT08F001 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//GO.FT09F001 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//GO.FT10F001 DD UNIT=SYSDA,SPACE=(CYL,(2,1))
//GO.SYSIN DD *
    0    9    9   10   10    9    9   10
    1    2    3    4    8
RUNOFF
    .
  (DATA FOR RUNOFF BLOCK)
    .
    .
TRANSPORT
    .
  (DATA FOR TRANSPORT BLOCK)
    .
    .
STORAGE
    .
  (DATA FOR STORAGE/TREATMENT BLOCK)
    .
    .
RECEIVING
    .
  (DATA FOR RECEIVING WATER BLOCK)
    .
    .
ENDPROGRAM
/*
```

OVERLAY PROCEDURES

In computers with small core capacity the technique of overlaying is most important. It reduces machine core storage which is necessary to run the model.

In Table 2-2, Lines "15-26" describe the overlay of each block of the model in its simplest form, but it can be broken down even further. A systems programmer would be most helpful in setting up the overlay.

DUMMY SUBROUTINES

Dummy subroutines are required if only a few of the blocks are to be used. A programmer would be most helpful in setting up the dummy subroutines (to avoid compiling unneeded large programs).

DATA SETS

Data sets for the SWMM are used to transfer information from one program block to another or to store and transfer information between subroutines. They are usually magnetic tapes or disks.

SCRATCH DATA SETS

Scratch data sets should be used almost exclusively when running the SWMM. The information on them is erased after the simulation is over. The following definitions are for scratch data sets used to make a typical run of the SWMM. The unit numbers assigned to the various data sets are arbitrary. Any desired values compatible with the descriptions of lines "27-33," Table 2-2, could be used. Furthermore, the following definitions assume Runoff, Transport, Storage/Treatment and Receiving are to be run in order. However, various sequences may be used, and the parameters would correspond to the sequence defined in lines "37-56" of Table 2-2:

JIN(1) = unit number of tape/disk input into the first block to be run (Runoff Block). JIN(1) = 0 means there is no tape/disk input.

Line "34" tells the computer that input data follow.

Line "35" is tape/disk assignments and corresponds to card group 1 of the Executive Block Card Data Section.

Line "35" may be interpreted as follows:

JIN(1),	JOUT(1),	JIN(2),	JOUT(2),	JIN(3),	JOUT(3),	JIN(4),	JOUT(4)
0	9	9	10	10	9	9	10

Here, JIN(N) = I refers to an input device or file and JOUT(N) = I refers to an output device or file. For example, a typical read statement in a FORTRAN program may be READ(I,80). The I is replaced by the symbolic unit number of an input device (e.g., card reader). On most computer systems, I is equal to 5 for reading cards and 6 or 7 for writing or punching output. The same applies for JIN(N) = I or JOUT(N) = I where I is substituted with the symbolic unit number of an input or output device such as a tape or disk unit, as defined by lines "27-33." Since the numbers 5, 6, and 7 have standard meanings, their descriptions are omitted.

Line "36" is scratch tape/disk assignments and corresponds to card group 2 of the Executive Block Card Data Section. Line "36" may be interpreted as follows:

NSCRAT(1),	NSCRAT(2),	NSCRAT(3),	NSCRAT(4),	NSCRAT(5)
1	2	3	4	8

Here, NSCRAT(N) = I refers to an input/output device or file. I is substituted with the symbolic unit number of an input/output device such as a tape or disk unit defined in lines "27-33." There should be a scratch tape/disk assignment for NSCRAT(1) through NSCRAT(5). Most blocks do not use all NSCRAT(I) tape/disk assignments; however, there is no storage or CPU time charged for the ones not used at most installations.

JOUT(1) = unit number of tape/disk output from the first block to be run (Runoff Block). JOUT(1) = 9 means there is such output to be saved and line "32" describes the disk utilized.

JIN(2) = unit number of tape/disk input to the second block to be run (Transport Block). (This is normally the same as the output number from the preceeding block.) JIN(2) = 9 means there is such input (from the Runoff Block) and line "32" describes the disk utilized.

JOUT(2) = unit number of tape/disk output from the second block to be run (Transport Block). JOUT(2) = 10 means there is such output to be saved and line "32" describes the disk utilized.

JIN(3) = unit number of the tape/disk input to the third block to be run (Storage/Treatment Block). (This is normally the same as the output unit number from the preceeding block.) JIN(3) = 10 means there is such input (from the Transport Block) and line "33" describes the disk utilized.

JOUT(3) = unit number of the tape/disk output from the third block to be run (Storage/Treatment Block). JOUT(3) = 9 means there is such output to be saved and line "32" describes the disk utilized. (Note that Runoff output will be written over.)

JIN(4) = unit number of the tape/disk input to the fourth block to be run (Receiving Block). (This is normally the same as the output unit number from the preceeding block) and line "32" describes the disk utilized.

JOUT(4) = unit number of tape/disk output from the fourth block to be run (Receiving Block). JOUT(4) = 10 means there is such output and line "33" describes the disk utilized. (Note that Transport output will be written over.)

JIN(5) - JIN(10) and JOUT(5) - JOUT(10) allow more than just four blocks to be run sequentially and are defined similarly if required.

PERMANENT DATA SETS

Permanent data sets should be used only when the output from a block is to be saved for later runs. The JCL for set up of these data sets is not included because of the differences in computer systems.

SECTION 3

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.

No computations as such are performed. A flow chart of the Executive Block is shown in Figure 3-1.

Program Operation

The Executive Block 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.

Since the various blocks use logical devices for input and output of computations, the Executive Block has provision for assigning logical unit numbers by reading two data cards. (Logical units and data sets have been discussed in Section 2.) The first card may contain up to 20 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 four 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 five such units, but only one or two are typically needed. The unit numbers are passed from the Executive Block to all pertinent blocks. The graphing subroutines enable hydrographs and pollutographs

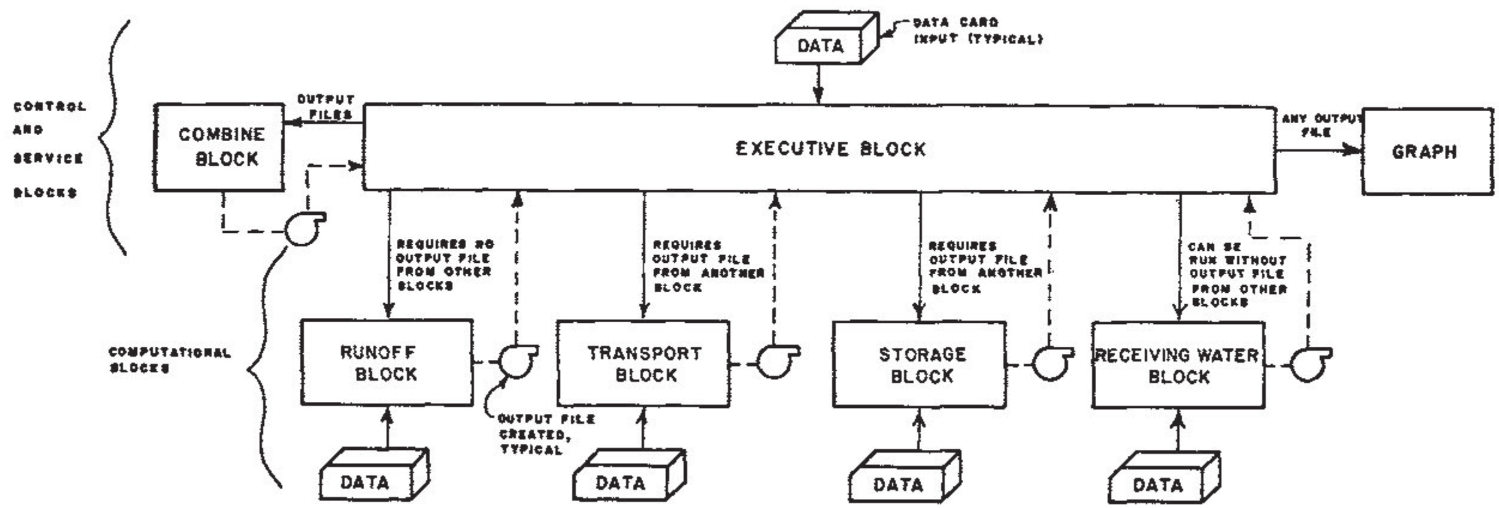

Figure 3-1. Master Programming Routine

to be plotted on the printer for selected locations on the data file. 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.

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 joins two coordinate locations with appropriate characters in the output image array A of PPLOT. Subroutine PPLOT 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 two parts corresponding to control of the SWMM block selection and capability. Figure 3-2 and Tables 3-2 and 3-3 at the end of these instructions give the procedure for data card preparation and list the variables that are used.

Block Selection

The program controls the computation block(s) to be executed by reading alphameric information, CNAME, on sentinel cards. Thus, for example, CNAME might be RUNOFF. The program compares this word with a dictionary of such words. If a match is found, as it would be in this case, control is passed to the appropriate block. Here, for example, a call would be made to the Runoff Block. After execution of the Runoff Block, control is eventually returned to the Executive Block.

The 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 TRANSPORT 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 ENDPROGRAM is given on the card. A summary of the control words and corresponding action is given in Table 3-1.

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 ENDPROGRAM. If the entire model were to be run with graphical output at the end of, say for example, the Transport and Storage Blocks, the sequence would be RUNOFF, TRANSPORT, GRAPH, STORAGE, GRAPH, RECEIVING and ENDPROGRAM.

Graph Routine

The data cards required for graphing 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.

Table 3-1. SUMMARY OF CONTROL WORDS AND CORRESPONDING ACTION FOR MAIN PROGRAM

Control word	Action to be taken
RUNOFF	Execute Runoff Block
TRANSPORT	Execute Transport Block
STORAGE	Execute Storage Block
RECEIVING	Execute Receiving Water Block
COMBINE	Execute Combine Block
GRAPH	Produce graphs on line printer
ENDPROGRAM	Terminate run
Any other word	Terminate run

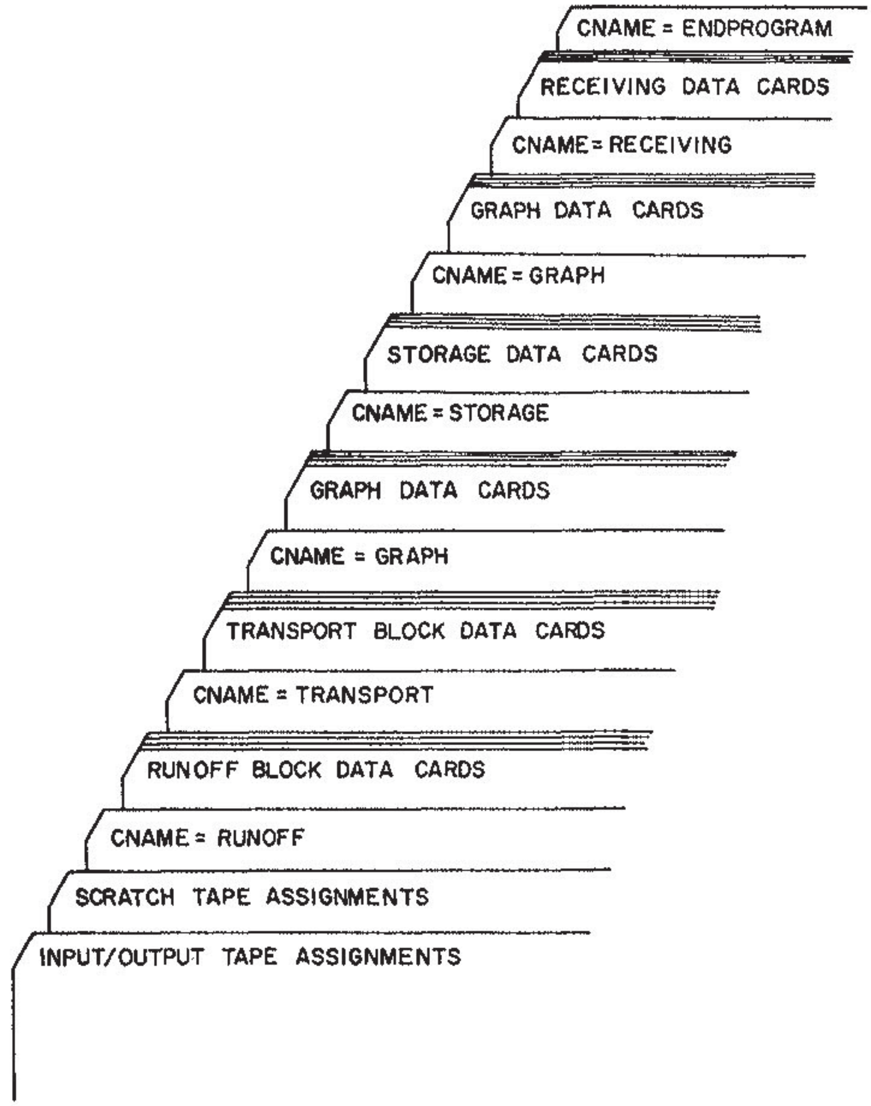

Figure 3-2. Data Deck for the Executive Block

Table 3-2. EXECUTIVE BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
1			I/O tape/disk assignments.		
	20I4	1-4	Input tape assignment for first block to be run.	JIN(1)	0
		5-8	Output tape assignment for first block to be run.	JOUT(1)	0
		9-12	Input tape assignment for second block to be run (usually the same as the output tape from first block).	JIN(2)	0
		13-16	Output tape for second block to be run.	JOUT(2)	0
		. . . .		. . . .	
		77-80	Output tape for tenth block to be run.	JOUT(10)	0
2			Scratch tape-disk assignments.		
	5I4	1-4	First scratch tape assignment.	NSCRAT(1)	0
		5-8	Second scratch tape assignment.	NSCRAT(2)	0
		9-12	Third scratch tape assignment.	NSCRAT(3)	0
		13-16	Fourth scratch tape assignment.	NSCRAT(4)	0
		17-20	Fifth scratch tape assignment.	NSCRAT(5)	0
			REPEAT CARD 6 FOR EACH BLOCK TO BE CALLED.		
3			Control cards indicating which blocks in the program are to be called.		
	3A4	1-12	Name of block to be called.[a]	CNAME	None

[a]Names must start in column 1. All blocks may be called more than once if overlay is not used or if overlay is used one or more blocks may be repeated if overlay is set up for this. See Section 2, Initial Job Set-Up.

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

Table 3-2 (continued). EXECUTIVE BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
			CNAME = RUNOFF for Runoff Block,		
			= TRANSPORT for Transport Block,		
			= RECEIVING for Receiving Water Block		
			= STORAGE for Storage Block,		
			= COMBINE for Combine Block,		
			= GRAPH for GRAPH subroutine,		
			= ENDPROGRAM for ending the storm water simulation.		
			INSERT THESE CARDS AFTER EACH CNAME = GRAPH IN CARD GROUP 3.		
4			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. (maximum = 5)[a]	NPCV	5
		11-15	Number of pollutants to be plotted.	NQP	0
		16-20	Number of inlets to be plotted. (If NPLOT = 0 plots all curves on file)	NPLOT	0
			IF NPLOT = 0 DELETE THIS CARD.		
5			Inlet selection card.		
	16I5	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

[a]This refers to the number of different inlets (curves) that will be plotted on one graph; e.g. if NPCV = 3, hydrographs, say, from three inlets will be overlayed on one graph.

Table 3-2 (continued). EXECUTIVE BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
6			Title card.		
	18A4	1-72	Title printed with the plots.	TITL	None
7			Horizontal axis label.		
	20A4	1-80	Horizontal axis label.	HRIZ	None
			REPEAT NQP + 1 TIMES.		
8			Vertical axis label.[a]		
	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 vemtical axis label.	VERT(3)	None

[a]The first plot to be printed is a flow hydrograph, the second is BOD, the third is SS, and the last is coliform.

Table 3-3. EXECUTIVE BLOCK VARIABLES[a]

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	

[a]Does not include variables added during updating.

*Variable names shared in common blocks.

Table 3-3 (continued). EXECUTIVE BLOCK VARIABLES

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 steps 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 3-3 (continued). EXECUTIVE BLOCK VARIABLES

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	
YINT		Label interval for Y	
Y		Y coordinates of curves to be drawn	
Y	C	Y coordinates of curves to be drawn	
YA		Y increment used for interpolation	
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 test area, North Lancaster, Pennsylvania, Drainage District, is used to show the data input and portions of the resulting output as required and accomplished by the Executive Block. Table 3-4 is an example of the data deck. The first two cards are the tape/disk (file) assignments for transferring information from one program block to another, and the scratch tape/disk assignments, respectively. On the first card 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 two may be 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 the Executive Block 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 the Executive Block. This card transfers control to the appropriate program block. In this example, seven such cards exist, RUNOFF, TRANSPORT, GRAPH, STORAGE, GRAPH and ENDPROGRAM. The data following the first two control cards have been deleted for clarity. The GRAPH cards are followed by input data for the plotting of output found on tape/disk nine and eight. ENDPROGRAM needs no succeeding cards.

Table 3-4. DATA INPUT FOR NORTH LANCASTER PENNSYLVANIA DRAINAGE DISTRICT

DATA	CARD GROUP NO.
0 8 8 9 9 8 8 9	1
1 2 3 4 0	2
RUNOFF . . . . TRANSPORT . . . . GRAPH	3
9 1 3 0	4
OUTPUT FROM TRANSPORT BLOCK NORTH LANCASTER, PA. DRAINAGE DISTRICT	6
TIME IN HOURS	7
FLOW IN CFS BOD LBS/MIN SS LBS/MIN COLIFORM MPN/MIN	8
STORAGE . . . . GRAPH	3
8 1 3 0	4
OUTPUT FROM STORAGE/TREATMENT BLOCK NORTH LANCASTER, PA. DRAINAGE DISTRICT	6
TIME IN HOURS	7
FLOW IN CFS BOD LBS/MIN SS LBS/MIN COLIFORM MPN/MIN	8
RECEIVING . . . . ENDPROGRAM	3

SECTION 4

COMBINE BLOCK

BLOCK DESCRIPTION

In order to add the capability of modeling larger areas, the Combine Block has been added to the Storm Water Management Model. This block has two main objectives.

The first objective is to collate different data sets into one, e.g., three separate output data sets, two Transports and one Storage/Treatment, are to be inputted into the Receiving Water Block. The Combine Block would be used to collate the three output data sets into one which, in turn, would be input into the Receiving Water Block.

The second objective is to combine different data sets and nodes into a single data set and one node, e.g., using the Transport Block on two different drainage networks gives two separate output data sets. Both data sets go to the same treatment facility at the same inlet node. This program would be used to combine the two different Transport output data sets into one data set with a single node which then could be inputted into the Storage/Treatment Block.

The Combine Block can be used in a number of different ways and now gives the Storm Water Management Model the capability of simulating the largest and most diverse cities. For example, Figure 4-1 shows how the Combine Block was used on a combination of SWMM runs for Lancaster, Pennsylvania.

INSTRUCTIONS FOR DATA PREPARATION

Instructions on the use of the Combine Block are divided into two sections, Collate and Combine.

Collate

The first objective is to collate two or more different output data sets from Runoff, Transport, Storage/Treatment, or any combination thereof. This new data set could then be used as input into any block (Transport, Storage/Treatment or Receiving Water), except

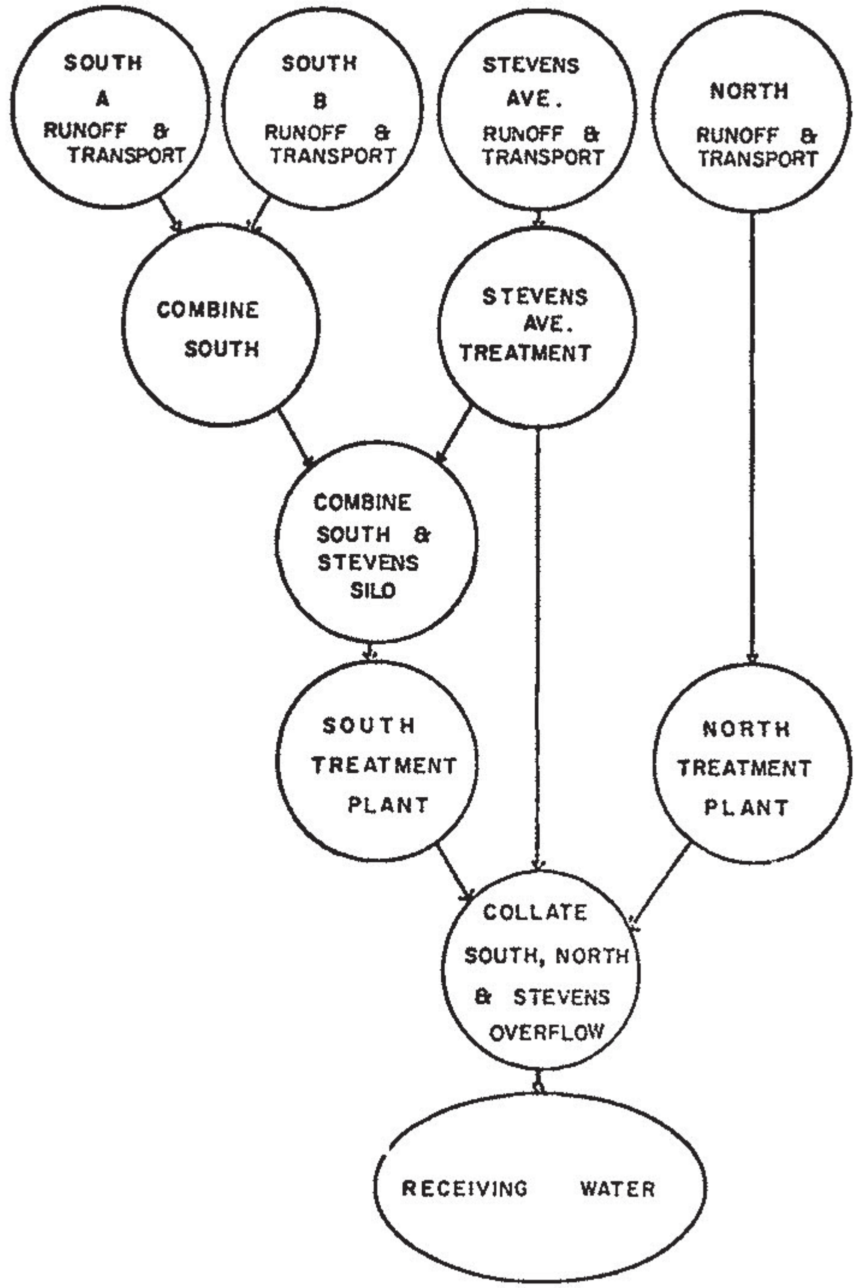

Figure 4-1. Combination of SWMM Runs for Overall Lancaster Simulation

Runoff. For example (Figure 4-2), an output data set from Transport area 'A' with manhole numbers 5, 6, 12 was collated with an output data set from Transport area 'B' with manhole numbers 1, 3, 6, 19. Manhole number 6 is common between both output data sets, therefore the hydrographs and pollutographs from both manholes are added together. The new output data sets produced from the Combine Block has manhole numbers 1, 3, 5, 6, 12, 19. This new data set could then be used as input to either the Transport, Storage/Treatment, or Receiving Water Blocks.

Combine

The Combine section combines different data sets and manholes into a single data set with one manhole. For example (Figure 4-3), an output data set from Transport area 'X' with manhole number 16 and an output data set from Transport area 'Y' with manhole number 23 are to be used as input into the Receiving Water Block junction[a] number 14. The Combine portion of the Combine Block would be used to combine the two output data sets into one data set with one manhole. This manhole number would correspond to the junction number of the Receiving Water Block. The Combine Block card data are shown in Table 4-1.

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[a]Junction number and manhole number are synonymous.

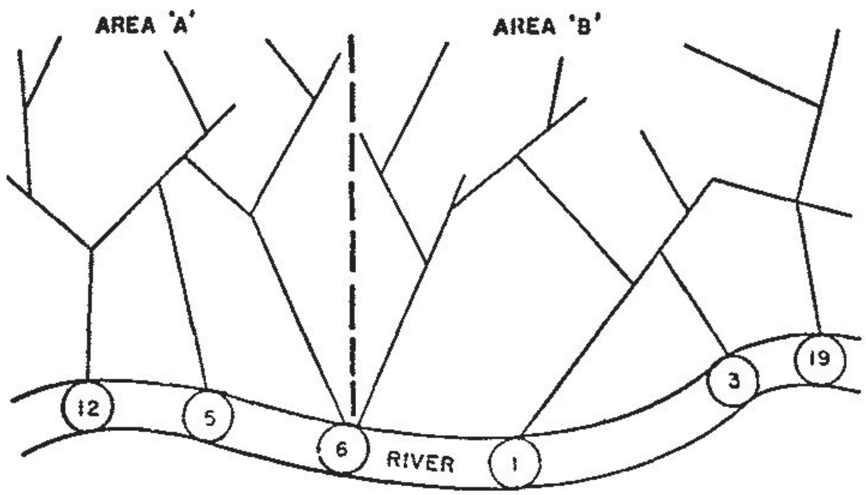


Figure 4-2. Hypothetical Drainage Network

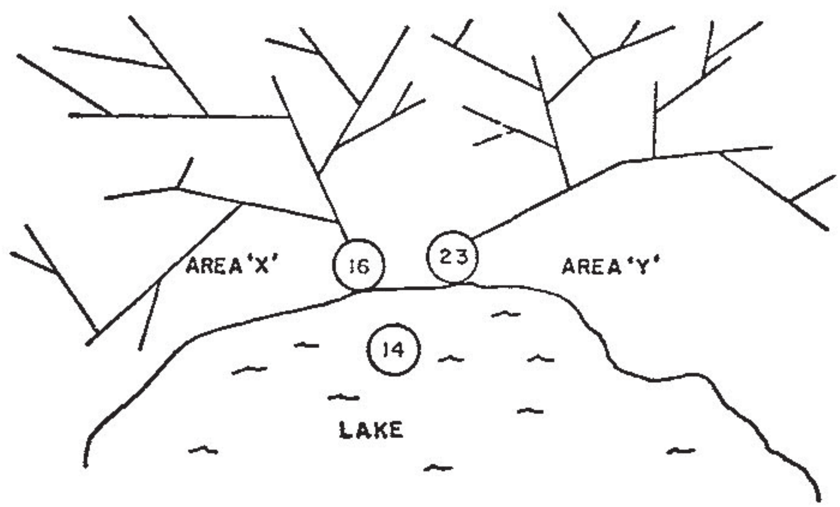


Figure 4-3. Hypothetical Drainage Network

Table 4-1. COMBINE BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
1	I5	1-5	Program Control.[a]	ICOMB	1
			= 1, Collate only,		
			= 2, Collate and then combine,		
			= 3, Combine only,		
			= 4, Combine then collate.		
2			IF ICOMB = 1, INCLUDE CARDS 2, 3 AND 4 ONLY.		
			IF ICOMB = 2, INCLUDE CARDS IN THE FOLLOWING ORDER: 2, 3, 4, 5, 6, 7.		
			IF ICOMB = 3 OR 4, SKIP TO CARD 5 FIRST.		
	20A4	1-80	Title cards: two cards with heading to be printed on output.	TITLE	None
3	2I5	1-5	Output data set number.[b]	NDOUT	None
		6-10	Number of input data sets. (maximum = 16)	NIN	None
			Input data set numbers.[b]	NDATAS	
4	16I5	1-5	First input data set number.	NDATAS(1)	
		6-10	.	NDATAS(2)	
		.	.	.	
		76-80	N^{th} input data set number.	NDATAS(NIN)	
5			IF ICOMB = 1, SKIP CARDS 5, 6, AND 7 IF ICOMB = 3, INCLUDE CARDS 5, 6, AND 7 ONLY.		

[a] The collate portion of the Combine Block uses two scratch data-sets. It is desirable to use the Graphing Routine in the Executive Block after the Combine Block has been run.

[b] See Section 2, Initial Job Set-up, for discussion of data sets and input/output files.

Table 4-1 (continued). COMBINE BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
			IF ICOMB = 4, INCLUDE CARDS IN THE FOLLOWING ORDER: 5, 6, 7, 2, 3, 4.		
	20A4	1-80	Title cards: two cards with heading to be printed on output.	TITLE	None
6	3I5	1-5	Node number for output.	NODEOT	None
		6-10	Output data set number.[a]	NDOUT	None
		11-15	Number of input data sets. (maximum = 16)	NIN	None
7	16I5		Input data set numbers.[a]	NDATAS	
		1-5	First input data set number.	NDATAS(1)	
		6-10	.	NDATAS(2)	
		.	.	.	
		76-80	N^{th} input data set number.	NDATAS(NIN)	

[a]See Section 2, Initial Job Set-up, for discussion of data sets and input/output files.

SECTION 5

RUNOFF BLOCK

BLOCK DESCRIPTION

Introduction

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 200 subcatchment areas. These, in turn, may drain into a maximum of 200 gutters or pipes which finally connect to the inlet points for the Transport Model. However, the user must be cautioned that if the Transport Model is to be run also, the total number of sewer elements (conduit and non-conduit) must not exceed 160.[a] The maximum number of non-conduit elements (manholes) into which there can be input hydrographs and pollutographs[b] is 70 for the Transport Model. The maximum number of time steps that may be computed is 150 for both Runoff and Transport.

This section describes the program operation of the Runoff Block, provides instructions on data preparation and input data card formats, defines Runoff Block variables, shows sample runs, and presents the results of a calibration of the Runoff Block.

Program Operation

The relationships among the subroutines which make up the Runoff Block are shown in Figure 5-1. The subroutine RUNOFF is called by the Executive Block to gain entrance to the Runoff Block. The

[a]This is the total for the Transport Model only. Up to 200 additional gutter/pipes may be contained in Runoff.

[b]These correspond to inlets in the Runoff Model.

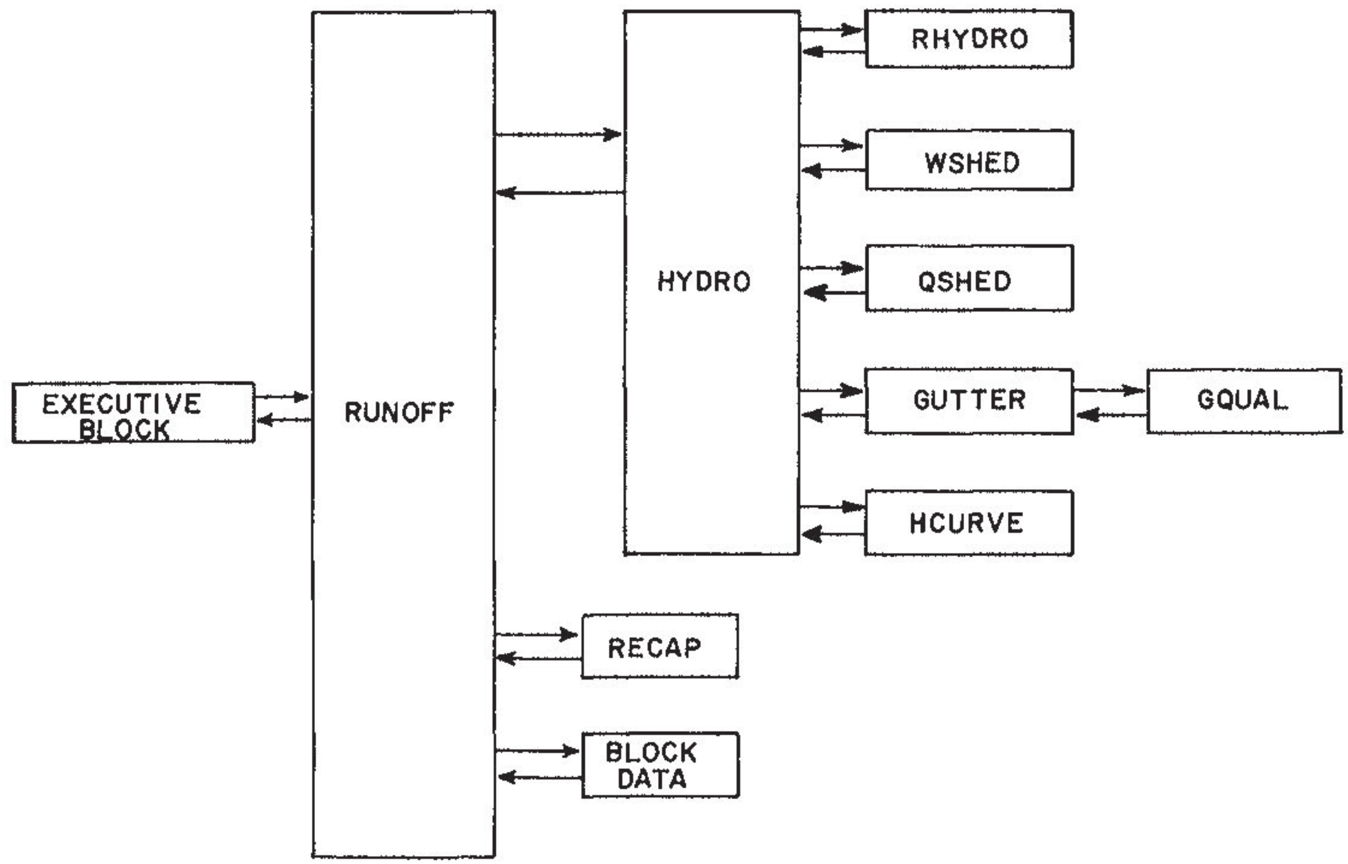


Figure 5-1. Runoff Block

program prints "ENTRY MADE TO RUNOFF MODEL" and then acts as the driver routine for the block. Subroutine Runoff directly calls subroutines HYDRO and RECAP. Although BLOCK DATA is not actually a subroutine, it is automatically activated by RUNOFF. Its main function is to set the initial pollution loadings such as pounds of pollutant per day per 100 feet of curb, and milligrams of pollutant per gram of dust and dirt. Subroutine RECAP reads tape headers, and prints the table headings and results of the quantity and quality simulations.

Subroutine HYDRO computes the hydrograph coordinates and the watershed quality contributions with the assistance of four core subroutines, i.e., RHYDRO, WSHED, QSHED, and GUTTER. It initializes all the variables to zero before calling RHYDRO to read in the rainfall hyetograph and information concerning the inlet drainage basin. Next HYDRO sets up an ordering array to sequence the computational order for gutters/pipes according to the upstream and downstream relationships. If quality is to be simulated, QSHED is called to initialize the watershed pollution loads.

HYDRO then sets up a DO loop 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. If quality is to be simulated, QSHED is called to compute the watershed quality contributions from catchbasins, erosion, dust and dirt, and other sources. GUTTER is then called to compute the instantaneous water depth and flow rate for the gutters/pipes and to route the flow. Water flowing into the inlet point, be it from gutters/pipes or direct drainage from subcatchments, is added up for a hydrograph coordinate. A continuity check is then made for the deposition of rainfall water in the form of runoff, detention, and infiltration loss. The error in continuity is computed and printed as a percentage of rainfall. With the assistance of subroutine HCURVE, HYDRO plots the rainfall hyetograph and the runoff hydrograph for the drainage basin. Subroutine GQUAL routes quality in each gutter/pipe for the flow values computed in subroutine GUTTER.

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.

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 as explained under Program Operation (subroutine QSHED). The quantity of pollutants washed off the land surface of the drainage basin is added to gutter/pipes or 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 routed through any gutter/pipes to generate pollutographs at inlet manholes.

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

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 5-2 and 5-3 indicate possible discretizations of the Northwood section of Baltimore, Maryland. In Figure 5-2, a "fine" approach was used resulting in 12 subcatchments and 13 pipes leading to the inlet. In Figure 5-3, 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) If solids deposition or suspension is important (e.g., to simulate a first flush phenomenon), the Transport Model should be used.

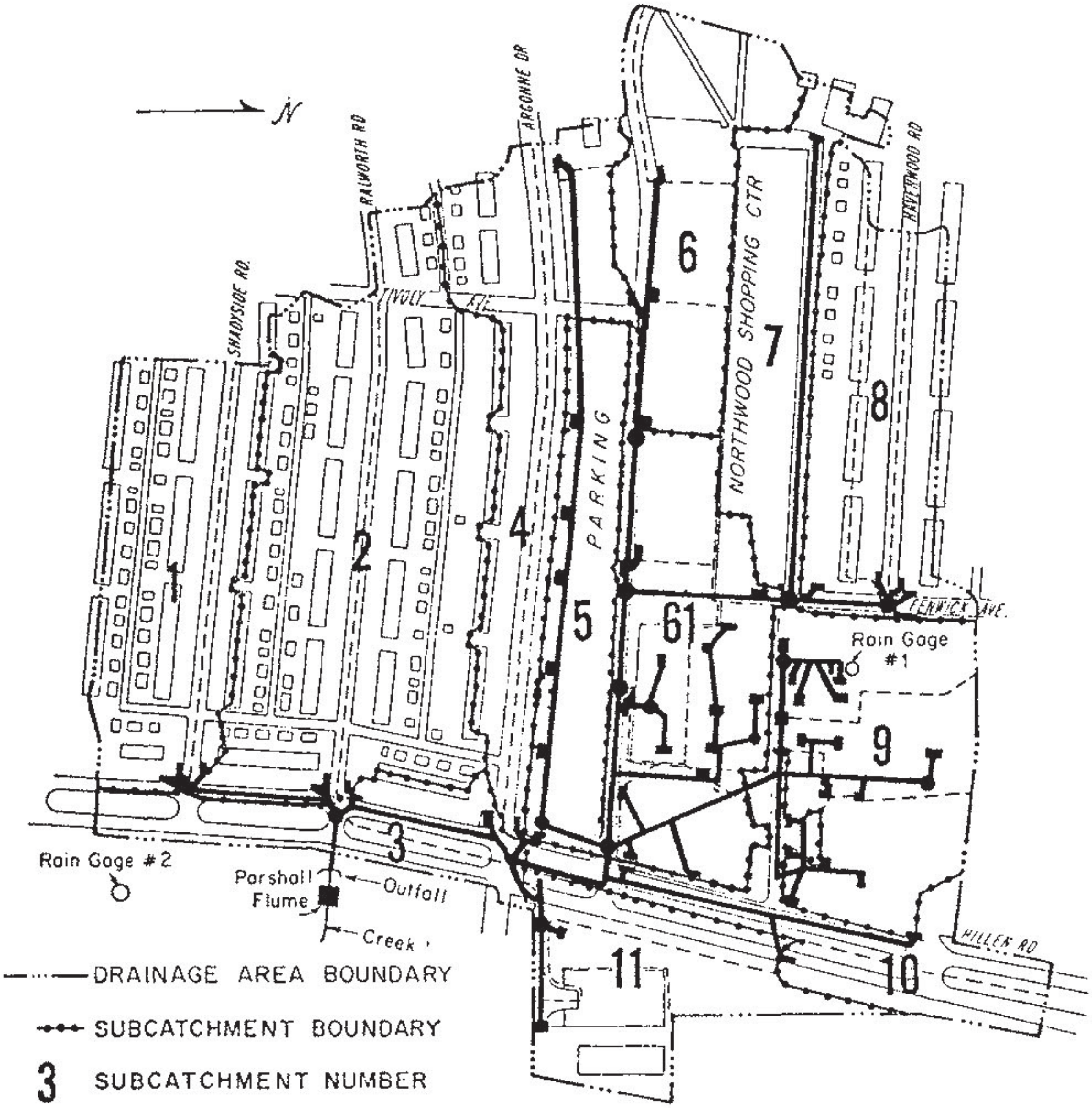


Figure 5-2. Northwood (Baltimore) Drainage Basin "Fine" Plan (9)

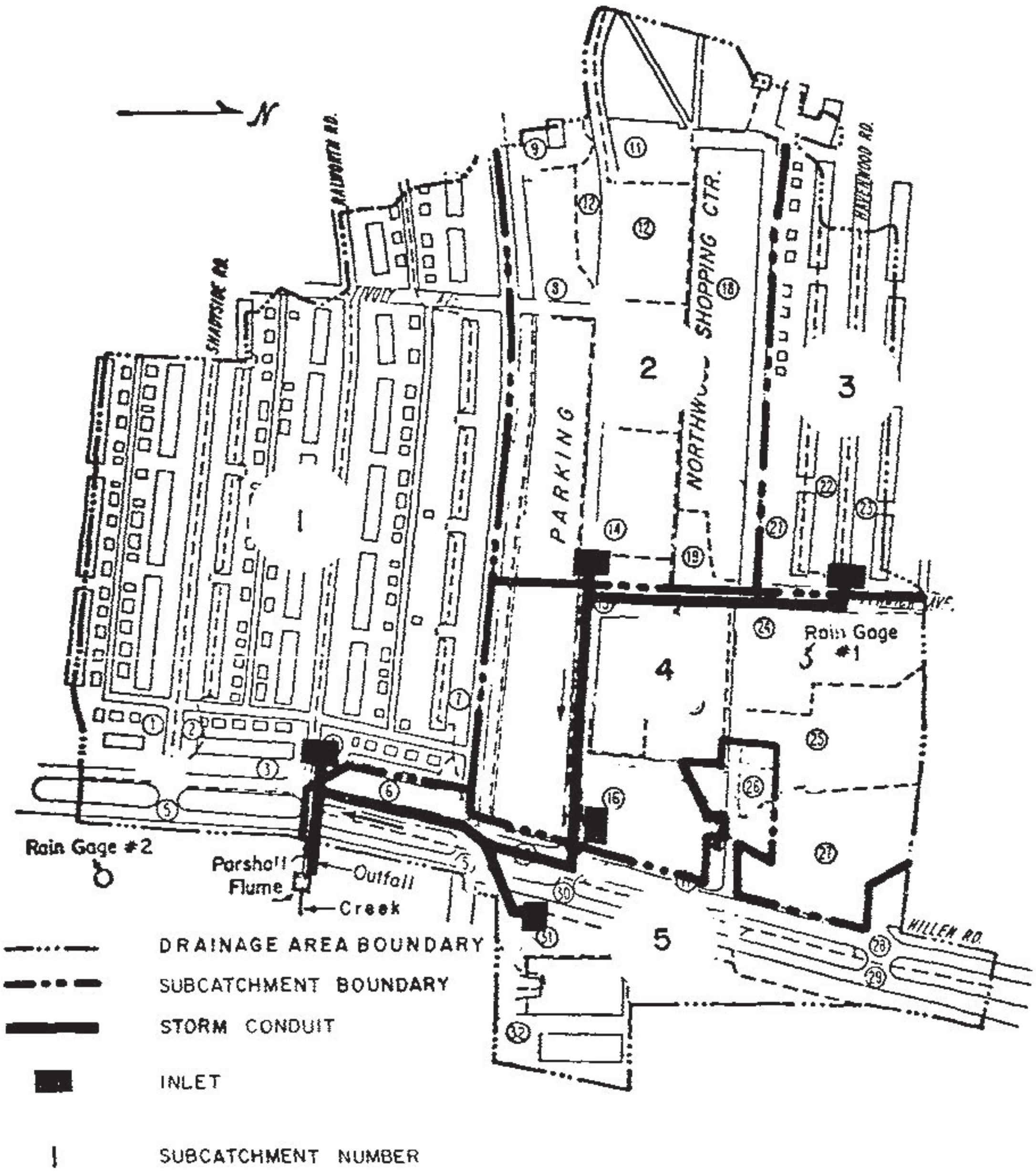


Figure 5-3. Northwood (Baltimore) Drainage Basin "Coarse" Plan (9)

Subcatchments represent idealized runoff areas with uniform slope. Parameters such as roughness values, detention depths and infiltration values are taken as constant for the area and usually represent averages, although pervious and impervious areas have different characteristics within the model. If roofs drain onto pervious areas, such as lawns, they are usually considered part of the pervious area, although conceivably, they could be treated as miniature subcatchments themselves.

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, approximate total width of overland flow, ground slope, roughness coefficients, detention depths, infiltration rates (maximum, minimum, and decay rate), and percent imperviousness. For a given amount of rainfall over the subcatchment, these parameters ultimately determine the outflow rate of surface runoff and the transient water depth over the subcatchment. Since real subcatchments are not rectangular areas experiencing uniform overland flow, average values must be selected for computation purposes.

For the roughness coefficient, the values given in Table 5-1, as suggested by Crawford and Linsley (3), may be used. Detention depths (retention storage) are taken by the program as 0.062 inch for impervious areas and 0.184 inch for pervious areas, unless otherwise specified by the user. Infiltration rates can be estimated from "standard infiltration capacity curves" as shown in Figure 5-4, which was produced by the American Society of Civil Engineers (ASCE). The program calculates the amount of infiltration loss using Horton's equation (subroutine WSHED):

$$\text{Infiltration loss } I_t = f_o + (f_i - f_o)e^{-\alpha t} \qquad (5\text{-}1)$$

where f_o = minimum infiltration rate (WLMIN), inches/hour

Table 5-1. ESTIMATE OF MANNING'S ROUGHNESS COEFFICIENTS (3)

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

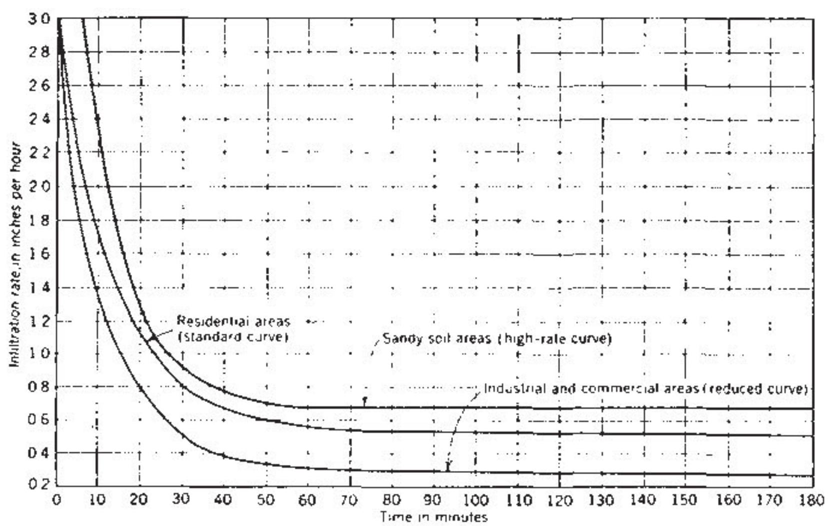


Figure 5-4. Standard Infiltration-Capacity Curves for Pervious Surface (2)

f_i = maximum infiltration rate (WLMAX), inches/hour

α = decay rate of infiltration (DECAY), 1/second

t = time from the start of rainfall, seconds

The user specifies WLMAX, WLMIN, and DECAY; otherwise, the program defaults to 3.00 inches/hour, 0.52 inch/hour, and 0.00115 second^{-1}, respectively. 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. Resistance factors for the pervious and impervious parts of a subcatchment are specified separately with default values of 0.250 and 0.013 (Manning's n for overland flow) being taken in the absence of other information.

The water depth over the subcatchment will thus increase without inducing an outflow until it reaches the specified detention requirement. If and when the resulting water depth of the subcatchment, D_r, is larger than the specified detention requirement, D_d, an outflow rate is computed using Manning's equation:

$$V = \frac{1.49}{n}(D_r - D_d)^{2/3} s^{1/2} \qquad (5\text{-}2)$$

and

$$Q_w = VW(D_r - D_d) \qquad (5\text{-}3)$$

where V = velocity

n = Manning's coefficient

s = ground slope

W = width of overland flow

Q_w = outflow rate

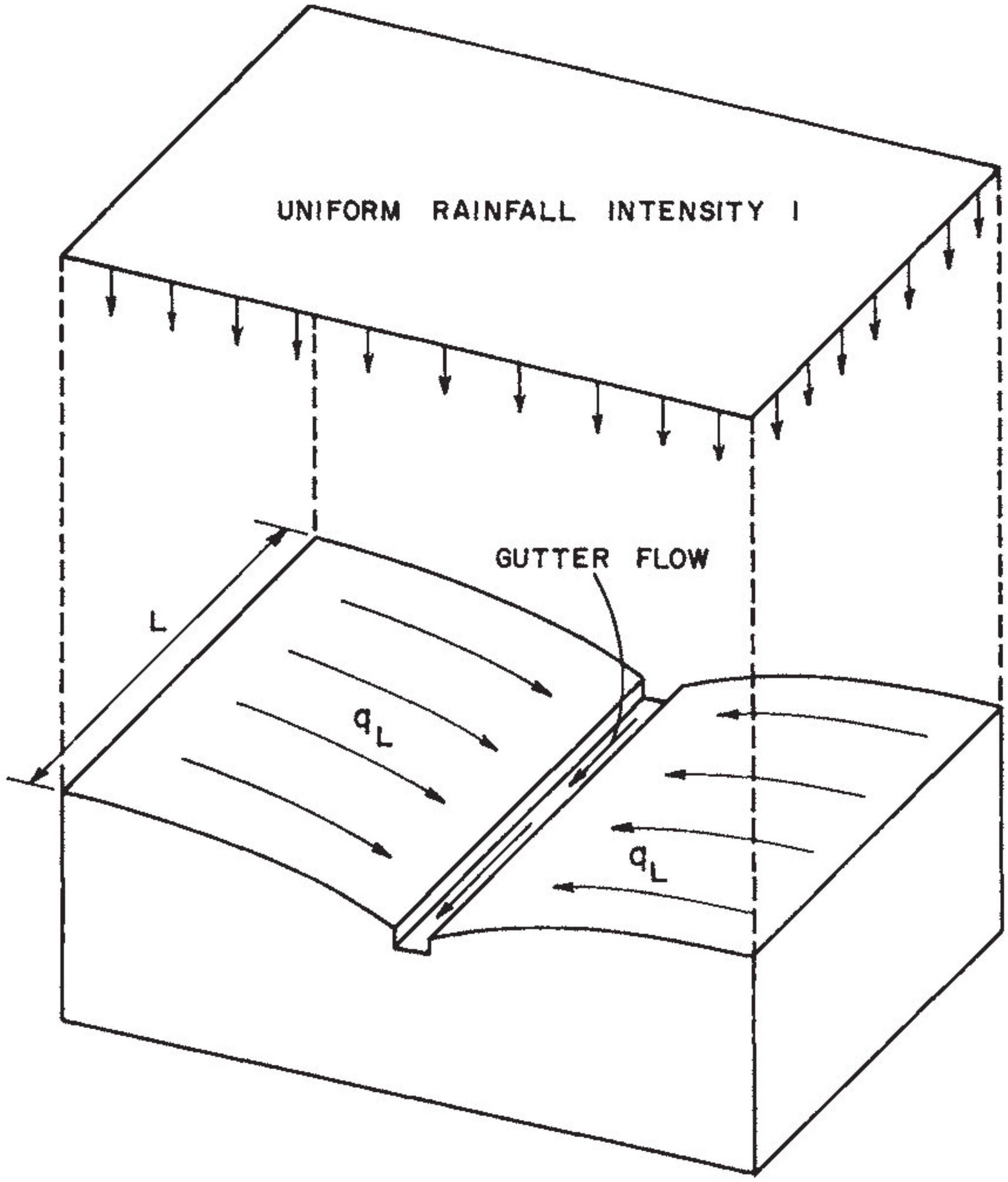
The parameter W, width of overland flow, must be supplied by the user for each subcatchment. This value is read in by subroutine RHYDRO along with other physical descriptors of the subcatchment. In RHYDRO, the width is lumped with all of the constants in Manning's equation into a single watershed constant. This constant multiplies the water depth (used as the hydraulic radius) in the subcatchment per time interval in subroutine WSHED. The change in depth due to outflow rate is determined by the continuity equation.

The definition of what constitutes the width of overland flow in a subcatchment is best visualized by the use of several examples. In Figure 5-5, an idealized rectangular subcatchment experiencing uniform overland flow is shown. The total width of overland flow is twice the length of the drainage gutter, since <u>two</u> plane catchments contribute flow along a distance L. Overland flow is perpendicular to gutter flow. In Figure 5-6, irregular-shaped subcatchments are shown, but the same principle applies. These approximations are accurate enough, since the continuity equation adjusts the water depth and outflow rate during each time interval.

<u>Step 3. Data Card Preparation</u> --

The data cards should be prepared according to Figure 5-8 and Tables 5-7 and 5-8 found at the end of this subsection. Figure 5-8 shows the layout of the data cards, including those for the quality routines, in the order in which they must appear. Tables 5-7 and 5-8, respectively, show how the data cards are to be punched and list the description of variables used in this program block.

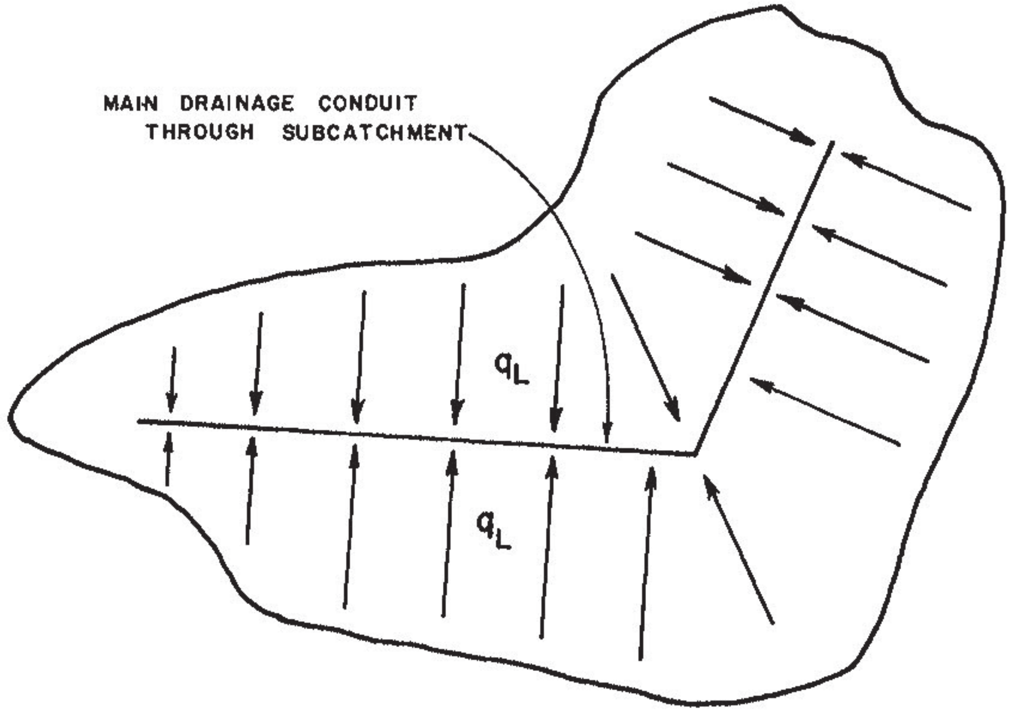
The first step in the data preparation is the determination of the number of time steps to be used and the length of each time step (see Table 5-7, card group 2). The time step length (integration period) is usually 3 or 5 minutes, but may range from 1 to 30 minutes, depending on the length and intensity of the storm and the degree of accuracy required. The number of time steps is limited to a maximum of 150. Enough time steps should be allowed to extend the simulation past the storm termination and thus account adequately for the storm runoff. Along with the input of time steps, the number of hyetographs for the drainage basin is required. If the percent impervious area with zero detention is known, this value must be supplied; otherwise, the Model uses a



q_L = RATE OF OVERLAND FLOW/UNIT WIDTH

W = 2L = TOTAL WIDTH OF OVERLAND FLOW

Figure 5-5. Idealized Subcatchment-Gutter Arrangement



L = TOTAL LENGTH OF MAIN DRAINAGE CONDUIT

W = 2L = TOTAL WIDTH OF OVERLAND FLOW

q_L = AVERAGE RATE OF OVERLAND FLOW/UNIT WIDTH

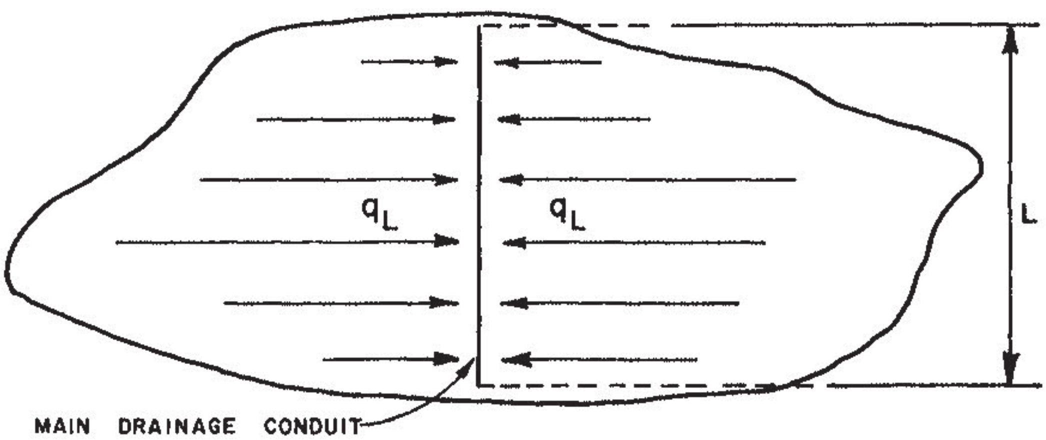


Figure 5-6. Irregular-Shaped Subcatchment-Drainage Conduit Arrangement

default value of 25 percent. This insures an immediate runoff response and a steep rising limb on the inlet hydrograph for the basin. If erosion is to be included in the quality simulation, it must be so stated in card group 2, and the highest average 30-minute rainfall intensity in inches per hour provided. It is convenient to do so because erosion is a function of a rainfall factor which is in turn a function of time interval, intensity, total depth per interval, and the 30-minute rainfall intensity.

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 the integration period in the quantity and quality portions of the Runoff Block. If 5-minute interval rainfall data are available, they would be preferred over 15-minute interval data because a more accurate runoff hydrograph would be produced. Up to one different hyetograph for each subcatchment may be provided by the user. However, the number of data points and the time interval between values for each hyetograph must remain constant, as specified by the rainfall control card.

For larger catchments, runoff and consequent model predictions are very sensitive to spatial variations of the rainfall. For instance, summer thunderstorms may be very localized, and nearby gages may have very dissimilar readings. For modeling accuracy, it is thus essential that rain gages be located within the catchment. Averages of gages surrounding the catchment will produce much less satisfactory results unless the storm is uniform spatially.

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 to 3 feet with no backwater effects, flow dividers, or lift stations are usually designated as gutters/pipes for computation by the Rnnoff 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. The elements (gutters, larger pipes, manholes) may be numbered by any scheme, for example:

001-100 : Existing manholes (known invert elevations)

200's: Pipe elements leaving an imaginary manhole; for example, 246 carries flow out of imaginary manhole 546 (where two large pipes come together and no manhole is indicated)

300's: Large pipe elements carrying flow out of existing manholes (350 leaves MH 50)

400's: Gutters/pipes carrying runoff into system (460 flows into MH 60)

500's: Imaginary manholes.

Once the sewer system is labeled with numbers less than 1000, the subcatchment areas are formed reflecting the existing sewer network, ground cover, and land slope. The gutter/pipe cards are then punched giving the required information. Next, data cards are 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. Care must be exercised by the user to specify the hyetograph number (based on the order in which they are read in) which applies to each subcatchment if this number is other than one (default value). The manhole number specified for drainage in card group 7, for each subcatchment, automatically designates the inlet manholes to which inlet hydrographs and pollutographs are routed for further simulation by the Transport Block.

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.

The start time, number of time steps, and length of integration period for the quality portion of the Runoff Block are identical to those in the quantity portion, where they are specified only once for the entire Runoff Block. The number of dry days prior to the storm event being modeled must be specified. This number may be obtained from rainfall records and includes all days, prior to the storm events, in which cumulative rainfall is less than 1 inch. The street cleaning frequency is determined by specifying the number of days between cleanings. The number of passes per cleaning made by the street sweeper is also specified. The accumulation of dust and dirt on city streets is a function of the street cleaning frequency. If the interval between storms is long and the cleaning frequency is low, a shock loading of suspended and settleable solids is imposed on the sewer system. These solids also generate an organic demand (BOD, COD). Pollutant loading rates in the SWMM are based on the studies made by APWA in Chicago (1). Industrial areas tended to provide maximum street litter. Commercial areas tended to generate a somewhat lesser quantity of dust and dirt than industrial areas, but higher than residential areas. The residential areas tended to show increasing amounts of dust and dirt as the population density increased, reflecting the increased usage made of the streets by pedestrians and vehicles.

From estimates of factors such as average daily traffic and average daily litter production, APWA developed dust and dirt accumulation factors for each type of land use, as listed in Table 5-2. The program generates the initial mass of dust and dirt (DD) as a function of total curb length, dry days, and the APWA factors for pounds of DD per day per 100 feet of curb (parameter DDFACT). The mass of each pollutant (including the organic demand parameters BOD and COD) is in turn generated as a fraction of the DD present. These factors (QFACT) are expressed as milligram of pollutant per gram of DD (or MPN/g for coliforms). In addition to BOD, COD, and coliforms, the Runoff Block quality portion simulates suspended solids (SS), erosion and its sediment contribution, settleable solids, nitrogen, phosphate (PO_4), and grease. The pollutant loading factors used are listed in Table 5-3, except for erosion. The calculations for erosion and its SS contribution are handled separately and are discussed later in this section. The catchbasin storage volume in card group 9 refers to the volume of water stored or trapped in the catchbasin prior to the storm event. The concentration of BOD (mg/l) of the stored water in each catchbasin should be verified by the SWMM user; otherwise, a value of 100 is recommended. If an initial concentration of 100 mg/l is chosen, the program automatically assigns a value of 300 mg/l for catchbasin COD (DATA CBFACT statement in BLOCK DATA). An average ratio of COD:BOD of 3.0 has been found in catchbasins from Chicago field tests (1).

Although not routinely required as card input data, all of the above loading and pollutant generation factors may be easily changed by altering appropriate DATA statements in subroutine BLOCK DATA. This is encouraged if the user has better values based upon local data.

Two different methods are included for suspended solids generation. If ISS = 0 (Card 9, Table 5-7), the exponential washoff described in Volume I (4) will be used. If ISS = 1, a special method included in the original SWMM Release 1 (see statement SFQU215 of

SFQUAL in Volume IV (4)) will be used. The latter method (ISS = 1) is based on calibrations in San Francisco and will produce concentrations early in the storm that are one or two orders of magnitude higher than the former method (ISS = 0). Later in the storm, the former method (ISS = 0) will still produce some suspended solids while the latter is likely to have already removed the entire surface load. No clear recommendation can be given to either method due to the lack of surface quality data measured at a catchbasin or other inlet point.

Urban Erosion

An erosion modeling capability has been added to the SWMM by application of the Universal Soil Loss Equation. The user specifies IROS = 1 in card group 2 (see Table 5-7) and the highest average 30-minute rainfall intensity (RAINIT), inches per hour. This latter value may be obtained from the input hyetograph.

The Universal Soil Loss Equation was derived from statistical analyses of soil loss and associated data obtained in 40 years of research by the Agricultural Research Service (ARS) and assembled

Table 5-2. DUST AND DIRT ACCUMULATION[a]

Type	Land use	Pounds DD/dry day/100 ft-curb
1.	Single family residential	0.7
2.	Multi-family residential	2.3
3.	Commercial	3.3
4.	Industrial	4.6
5.	Undeveloped or park	1.5

[a]Based on 1969 APWA report for Chicago (1).

Table 5-3. MG POLLUTANT PER GRAM OF DUST AND DIRT[a] FOR EACH LAND USE TYPE

Parameter	Land Use Type (Table 5-2) 1	2	3	4	5[b]
SS	1000.0	1000.0	1000.0	1000.0	1000.0
BOD	5.0	3.6	7.7	3.0	5.0
COD	40.0	40.0	39.0	40.0	20.0
Coliforms[c]	$1.3x10^6$	$2.7x10^6$	$1.7x10^6$	$1.0x10^6$	0.0
Settleable solids	100.0	100.0	100.0	100.0	100.0
N	0.48	0.61	0.41	0.43	0.05
PO_4	0.05	0.05	0.07	0.03	0.01
Grease[d]	1.00	1.00	1.00	1.00	1.00

[a] Most values are based on 1969 APWA report (1).

[b] Values for undeveloped and park lands are assumed.

[c] Units for coliforms are MPN/gram.

[d] All values are assumed.

at the ARS runoff and soil loss data center at Purdue University. The data include more than 250,000 runoff events at 48 research stations in 26 states, representing about 10,000 plot-years of erosion studies under natural rain. It was developed by Wischmeier and Smith (12) as an estimate of the average annual soil erosion from rainstorms for a given upland area, expressed as the average annual soil loss per unit area, A (tons per acre):

$$A = (R)(K)(LS)(C)(P) \tag{5-4}$$

where R = the rainfall factor

K = the soil erodibility factor

LS = the slope length gradient ratio

C = the cropping management factor or cover index factor

P = the erosion control practice factor

This equation represents the most comprehensive attempt at relating the major factors in soil erosion. It is used in the SWMM to predict the average soil loss for a given storm or time period. It is recognized that the Universal Soil Loss Equation was not developed for making predictions based on specific rainfall events. There are many random variables which tend to cancel out when computing annual time averages which would not cancel out when predicting individual storm yields: for example, the initial soil-moisture condition, or antecedent moisture condition (AMC), is a parameter which cannot be determined directly and used reliably. It should be understood by the SWMM user that Equation 5-4 enables land management planners to estimate gross erosion rates for a wide range of rainfall, soil, slope, crop, and management conditions.

The user supplies:

1) The area of each subcatchment subject to erosion

2) The flow distance in feet from the point of origin of overland flow over the erodible area to the point at which runoff enters the gutter or manhole

3) the soil factor K

4) The cropping management factor C

5) The control practice factor, P.

The program obtains the ground slope from the information supplied on each subcatchment in card group 7. Note, however, that the subcatchment numbers in card group 10 must be read in the same order as the subcatchment numbers in card group 7.

The rainfall factor, R, is equal to the sum of the rainfall erosion indexes for all storms during the period of prediction, $\sum EI$. For a single storm, R would simply equal EI for that storm. If we sum over all the time intervals, then the total storm's rainfall energy is given by:

$$R = EI = \sum_i [(9.16 + 3.31 \log X_i)D_i]I \qquad (5\text{-}5)$$

where E = storm's rainfall energy (hundreds of foot-tons/acre)

$$= \sum_i Y_i D_i = \sum_i (9.16 + 3.31 \log X_i) D_i$$

i = rainfall hyetograph time intervals

Y_i = kinetic energy in hundreds of foot-tons/acre-inch

X_i = rainfall intensity during time interval i, inches/hour

D_i = inches of rainfall during time interval i

I = maximum average 30-minute intensity of rainfall

It is important to note that the R factor does not account for soil losses due to snowmelt and wind erosion.

The soil factor, K, is a measure of the potential erodibility of a soil and has units of tons per unit of erosion index, EI. The soil erodibility nomograph shown in Figure 5-7 (10) is used to find the value of the soil factor once five soil parameters have been estimated. These parameters are: percent silt plus

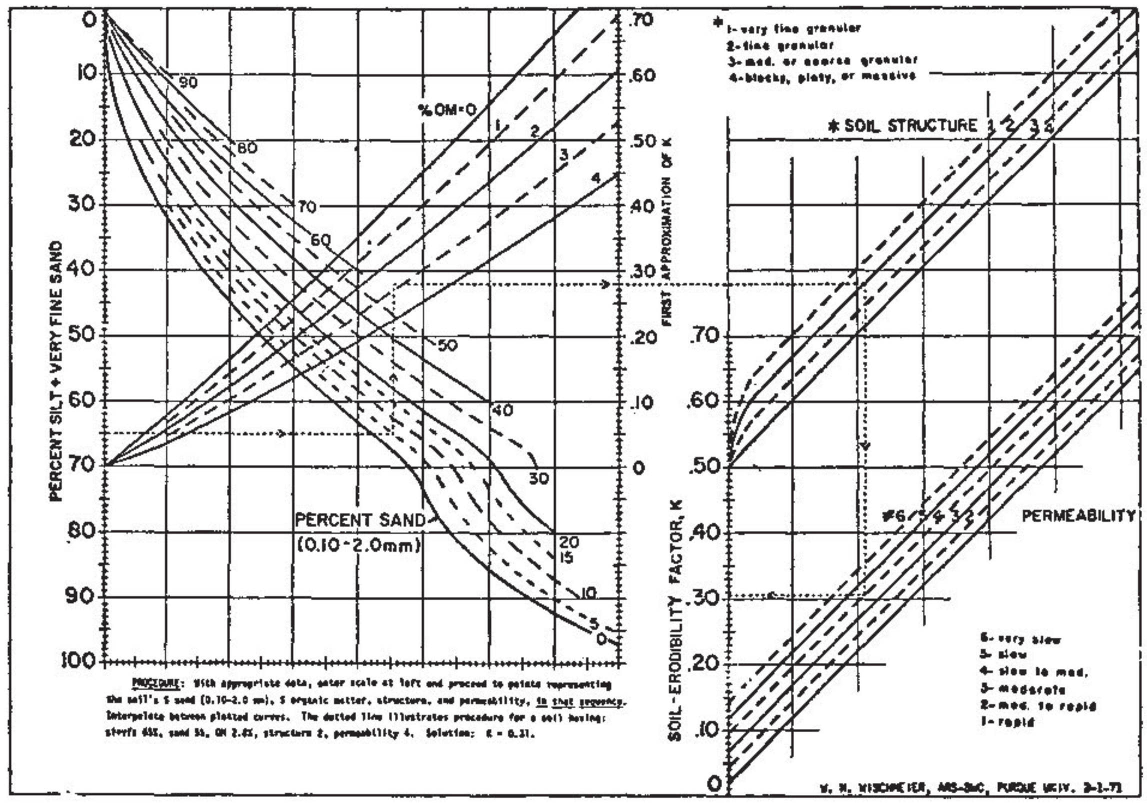


Figure 5-7. Soil Erodibility Nomograph (10)

very fine sand (0.05-0.10 mm), percent sand greater than 0.10 mm, organic matter content, structure, and permeability. To use the nomograph, enter on the left vertical scale with the appropriate percent silt plus very fine sand. Proceed horizontally to the correct percent sand curve, then move vertically to the correct organic matter curve. Moving horizontally to the right from this point, the first approximation of K is given on the vertical scale. For soils of fine granular structure and moderate permeability, this first approximation value corresponds to the final K value and the procedure is terminated. If the soil structure and permeability is different than this, it is necessary to continue the horizontal path to interact the correct structure curve, proceed vertically downward to the correct permeability curve, and move left to the soil erodibility scale to find K. This procedure is illustrated by the dotted line on the nomograph. For a more complete discussion on this topic, see Wischmeier, Johnson and Cross (10).

Table 5-4 (6) lists soil factor values for soil types found in Maryland. The user should request assistance from local Soil Conservation Service or Agricultural Research Service experts to obtain similar information.

The slope length-gradient ratio is a function of runoff length and slope and is given by:

$$LS = L^{1/2}(0.0076 + 0.0053S + 0.00076S^2) \tag{5-6}$$

where L = the length in feet from the point of origin of overland flow to the point where the slope decreases to the extent that deposition begins or to the point at which runoff enters a defined channel

S = the average percent slope over the given runoff length.

In using the average percent slope in calculating the LS factor, the predicted erosion will be different from the actual erosion when the slope is not uniform. Meyer and Kramer (7) show that when the actual slope is convex, the average slope prediction will underestimate the total erosion whereas for a concave slope, the

Table 5-4. SOIL ERODIBILITY INDEX K VALUES FOR MARYLAND SOIL SERIES (6)

Soil series	Horizon	Texture range	K Value
Adelphia	A	Sl,fsl,l	0.32
	B	L,scl,fsl	0.40
	C	Sl,ls	0.20
Athol	A	Sil	0.37
		Gsil,gl	0.32
	B	Sicl,cl	0.30
		G,cl	0.30
	C	Sicl,cl	0.30
		Gsl,gl	0.30
Aura	A	Sl,l	0.43
		Gl,gsl	0.30
		Ls	0.20
	B	Scl	0.40
		Gscl,gsl	0.30
	C	Scl,sl	0.40
		Gsl,gcl	0.30
		Ls	0.20
Bertie	A	Sil,l	0.37
	B	Sil,sicl,l	0.40
	C	Stratified	0.30
		Sl,l,ls	
		Gsl	0.20
Berks	A	Shsil,chsil	0.24
	B	Sh to vshsil	0.20
	C	Vshsil	0.20
		Shattered shale	0.20
Bermudian	A	Sil,l	0.43
		Fsl	0.40
	B	Stratified silt	0.50
		S	0.30
		G	0.20
Bibb	A	Sl to sicl	0.32
	B	Highly variable	0.20

Table 5-4 (continued). SOIL ERODIBILITY INDEX K VALUES FOR MARYLAND SOIL SERIES

Soil series	Horizon	Texture range	K Value
Birdsboro	A	Sil,l	0.28
	B	Sicl,cl	0.30
	C	Sl,s,g	0.20
		Sicl,l	0.30
Bucks	A	Sil	0.32
	B	Sicl,sil	0.40
	C	Shsil,vshsil	0.20
Chalfont	A	Sil,vstl	0.43
	B	Sil,sicl	0.60
	C	Shsil,shl	0.60
Chillum	A	Sil,sicl	0.32
		Gl	0.30
	B	Gscl,gl	0.30
		Gsl	0.20
Colemantown	A	L,sl	0.43
	B	Sc,scl	0.40
	C	Sl,cl,scl	0.40
Collington	A	Sl,fsl,l	0.28
		Ls	0.20
	B	Scl,cl,sl,l	0.40
	C	Sl,ls	0.20
Colts Neck	A	Sl	0.28
		Ls	0.20
	B	Scl,sl,l	0.40
	C	Sl	0.30
Croton	A	Sil	0.43
	B	Sil,sicl	0.50
	C	Shsil,shsicl	0.40
Donlonton	A	Fsl,ls,sil	0.43
	B	Sc,cl,sic	0.40
	C	Sc,sicl,cl,ls	0.30

Table 5-4 (continued). SOIL ERODIBILITY INDEX K VALUES FOR MARYLAND SOIL SERIES

Soil series	Horizon	Texture range	K Value
Duffield	A	Sil	0.32
	B	Sicl	0.30
	C	Sicl	0.40
		Shsil	0.30
Edgemont	A	Chl	0.24
	B	Chl,chscl	0.30
	C	Chl,shsl	0.20
Elkton	A	Sil,fsl,sl,l	0.43
	B	Sic,c	0.40
	C	Sic,sicl,scl	0.40
Evesboro	A	Ls,s	0.17
Fallsington	A	Sl,fsl,l	0.28
	B	Scl,sl	0.30
	C	S,ls,sl	0.20
Fort Mott	A	S,ls	0.20
	B	Sl	0.30
	C	S	0.20
Freneau	A	Sl,l	0.28
Galestown	A	Ls,s	0.17
Howell	A	Fsl,sil,l	0.43
	B	Cl,sicl	0.40
	C	C,sic,sicl	0.30
Keansburg	A	Sl,l	0.28
	B	Sl,l	0.30
Keyport	A	Sil,l,fsl	0.43
	B	C,sic,cl	0.40
	C	Sicl,sic	0.40
	Sandy substratum	Scl,sl	0.30
Klej	A	Ls,fs,lfs	0.17
	B	Ls,fs,lfs,sl	0.20

Table 5-4 (continued). SOIL ERODIBILITY INDEX K VALUES FOR MARYLAND SOIL SERIES

Soil series	Horizon	Texture range	K Value
Lakeland	A	Ls,lfs	0.17
Lansdale	A	L,sl	0.28
	B	Scl,sl	0.30
		L	0.40
	C	Chsil,gsl	0.30
		Chsl,gsl	0.20
Legore	A	Sil,sicl	0.24
		Gl	0.20
	B	Cl	0.30
		Gcl,gl,gsicl	0.20
	C	L,sil,sicl	0.30
		Gl,vgl,gcl	0.20
Lehigh	A	Sil	0.43
		Chsil	0.37
	B	Chsicl	0.40
	C	Chsicl,vchsil	0.30
Matapeake	A	Sil,fsl,l	0.32
	B	Sil,sicl	0.40
	C	S,ls,sl,l,gs	0.30
Matawan	A	Sl,ls,fsl	0.32
	B	Cl,scl,sc,sl	0.40
Mattapex	A	Sil,l,fsl	0.37
	B	Sicl,sil,cl	0.40
	C	Sl,ls,s,l,gs	0.20
Monmouth	A	Fsl,l,lfs	0.43
	B	Sc,scl	0.40
	C	Sl,scl,sc	0.30
Neshaminy	A	Sil	0.32
		Vstsil	0.28
	B	Sicl,cl,scl,sl	0.30
	C	Diabase bedrock	

Table 5-4 (continued). SOIL ERODIBILITY INDEX K VALUES FOR MARYLAND SOIL SERIES

Soil series	Horizon	Texture range	K Value
Norton	A	Sil,l	0.32
	B	Sicl	0.40
	C	Sil	0.40
		Vgl,shl	0.30
Othello	A	Sil,l,fsl,sicl	0.37
	B	Sicl,sil	0.40
	C	Sl,ls,scl	0.30
Penn	A	L	0.32
		Shsil	0.28
	B	Sil	0.40
		Shsil,sicl	0.30
Pocomoke	A	Sl,l,fsl,ls,lfs	0.28
	B	Ls,s	0.20
Raritan	A	Sil	0.43
	B	Cl,sicl	0.30
	C	Stratified silt,fsl	0.20
		C,sil,l,g	0.30
Readington	A	Sil	0.43
	B	Sil,sicl	0.40
	C	Sil	0.40
		Vshsil	0.30
Rowland	A	Sil,l	0.43
		Sicl	0.40
	B	Stratified silt and gravel	0.30
		Sil	0.40
Rutlege	A	Ls,lfs	0.17
	B	S,fs,ls,lfs	0.20
Sassafras	A	Fsl,l,sl,lfs	0.28
		Ls	0.20
		Gfsl,gsl	0.24
	B	Scl,sl,l	0.30
	C	Sl,ls,fsl,gsl,gls	0.20

Table 5-4 (continued). SOIL ERODIBILITY INDEX K VALUES FOR MARYLAND SOIL SERIES

Soil series	Horizon	Texture range	K Value
Shrewsbury	A	Sl,fsl,l	0.28
	B	Scl,sl	0.30
	C	S,ls,sl	0.20
Steinsburg	A	Sl	0.28
		Gsl,vgsl	0.24
	B	Gsl	0.20
	C	Sandstone	
Watchung	A	Sil	0.43
	B	C,cl,sicl	0.40
	C	Sil,sicl,l	0.40
Westphalia	A	Fsl,lfs	0.49
	B	Fsl,lfs,vfsl	0.40
	C	Fs,lfs,fsl	0.30
Woodstown	A	Sl,fsl,l	0.28
		Ls	0.20
	B	Scl,l,sl	0.40
	C	S,ls,sl,gsl,gls	0.20

USDA SOIL TEXTURE ABBREVIATIONS USED IN TABLE 5-4

C	Clay
Ch	Channery
Cl	Clay loam
Co	Coarse
Fs	Fine sand
Fsl	Fine sandy loam
G	Gravelly
Gcl	Gravelly clay loam
Gl	Gravelly loam
Gscl	Gravelly sandy clay loam
Gsl	Gravelly sandy loam
L	Loam
Lfs	Loamy fine sand
Ls	Loamy sand
S	Sand
Scl	Sandy clay loam
Sh	Shaly
Sic	Silty clay
Sicl	Silty clay loam
Sil	Silt loam
Sl	Sandy loam
St	Stony
Vfs	Very fine sand
Vfsl	Very fine sandy loam

prediction equation will overestimate the actual erosion. If possible, to minimize these errors, large eroding sites should be broken up into areas of fairly uniform slope.

The cropping management factor, C, is dependent upon the type of ground cover, the general management practice and the condition of the soil over the area of concern. The C factor is set equal to one for continuous fallow ground which is defined as land that has been tilled and kept free of vegetation and surface crusting. Values for the cropping management factor are given in Table 5-5 (6). Again consultation with local soils experts is recommended.

The control practice factor is similar to the C factor except that P accounts for the erosion-control effectiveness of superimposed practices such as contouring, terracing, compacting, sediment basins and control structures. Values for the control practice factor for construction sites are given in Table 5-6 (8). Agricultural land use P factor values can be found in Agriculture Handbook 282 (11).

The C and P factors are the subject of much controversy among erosion and sedimentation experts of the US Department of Agriculture (USDA) and the Soil Conservation Service (SCS). These factors are estimates and many have no theoretical or experimental justification. It has been suggested that upper and lower limits be placed on these factors by local experts to increase flexibility of Universal Soil Loss Equation for local conditions.

The P factors in the upper portion of Table 5-6 were designated as estimates when they were originally published. SCS scientists have found no theoretical or experimental justification for factors significantly greater than 1.0. Surface conditions 4, 6, 7 and 8 ($P \leq 1.0$), Table 5-6 also are estimates with no experimental verification.

After the erosion calculations are made, the program computes the suspended solids contribution from erosion and adds the value to the suspended solids from other sources. When erosion is modeled, the program prints out, for each subcatchment the total suspended solids and the suspended solids without erosion, as shown in Table 5-9. Following the erosion cards, the subcatchment surface quality cards are prepared. These pertain to land use information which can be obtained from city maps (see card group 11, Table 5-7). The last two card groups refer to print control information. Figure 5-8 shows the sequencing of the data deck for the Runoff Block.

Table 5-5. CROPPING MANAGEMENT FACTOR C
(6)

Type of cover	C Value	Mulch	Rate of application (tons/acre)	C Value	Maximum allowable slope length
None (fallow)	1.00	Hay or straw	0.5	0.35	20 feet
			1.0	0.20	30
Temporary seedings:			1.5	0.10	40
First sixty days	0.40		2.0	0.05	50
After sixty days	0.05				
		Stone or gravel	15.0	0.80	15
Permanent seedings:			60.0	0.20	80
First sixty days	0.40		135.0	0.10	175
After sixty days	0.05		240.0	0.05	200
After one year	0.01				
		Chemical mulches			
Sod (laid immediately)	0.01	First ninety days	a	0.50	50
		After ninety days	a	1.00	50
		Woodchips	2.0	0.80	25
			4.0	0.30	50
			7.0	0.20	75
			12.0	0.10	100
			20.0	0.06	150
			25.0	0.05	200

[a] As recommended by manufacturer

Table 5-6. EROSION CONTROL PRACTICE FACTOR P FOR CONSTRUCTION SITES (8)

Surface condition with no cover	Factor P
1. Compact, smooth, scraped with bulldozer or scraper up and down hill	1.30
2. Same as above, except raked with bulldozer root raked up and down hill	1.20
3. Compact, smooth, scraped with bulldozer or scraper across the slope	1.20
4. Same as above, except raked with bulldozer root raked across slope	0.90
5. Loose as a disced plow layer	1.00
6. Rough irregular surface, equipment tracks in all directions	0.90
7. Loose with rough surface greater than 12" depth	0.80
8. Loose with smooth surface greater than 12" depth	0.90
Structures	
1. Small sediment basins:	
0.04 basin/acre	0.50
0.06 basin/acre	0.30
2. Downstream sediment basins:	
with chemical flocculants	0.10
without chemical flocculants	0.20
3. Erosion control structures:	
normal rate usage	0.50
high rate usage	0.40
4. Strip building	0.75

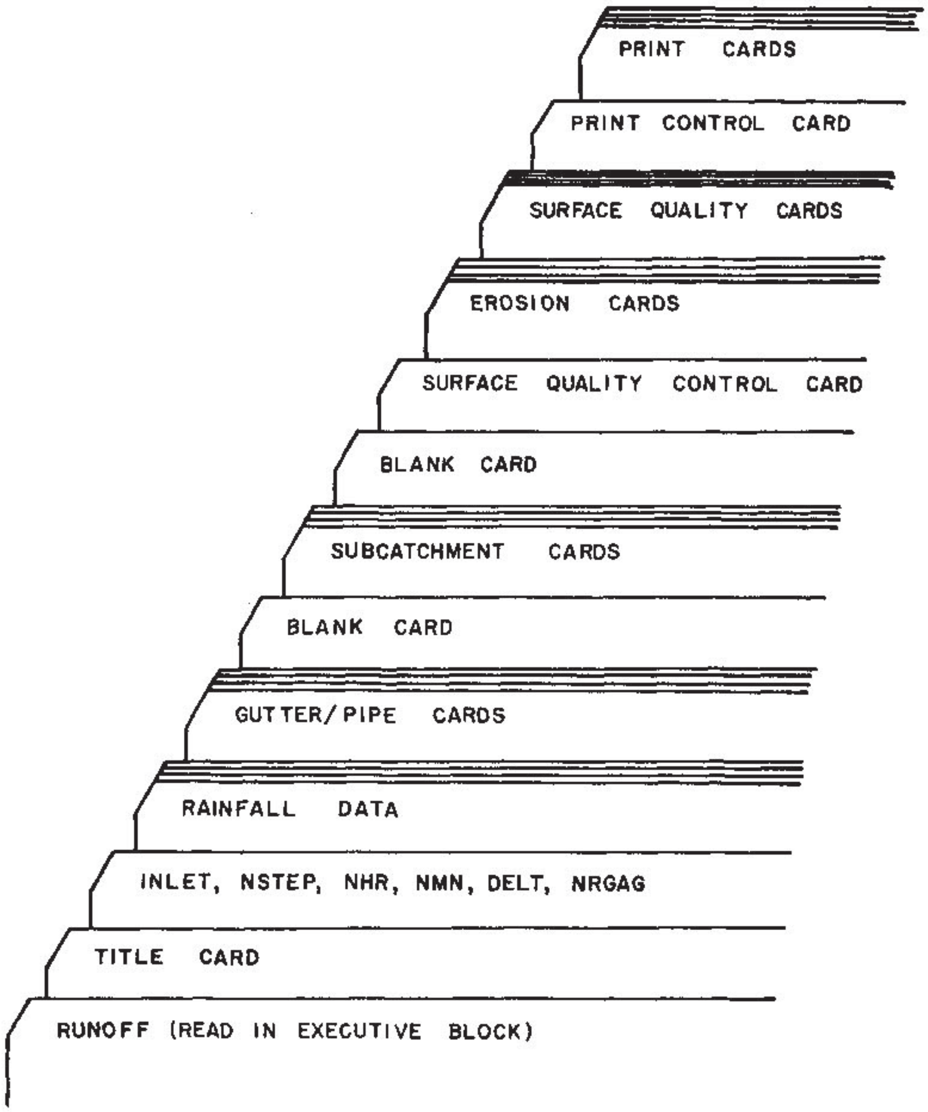


Figure 5-8. Data Deck for the Runoff Block

Table 5-7. 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	Blanks
2			Control card: one card.		
	2I5	1-5	Basin identification number.	BASIN	0
		6-10	Number of time-steps to be calculated (maximum = 150).	NSTEP	None
	I3	11-13	Hour of start of storm (24-hour clock).	NHR	0
	I2	14-15	Minutes of start of storm.	NMN	0
	F5.0	16-20	Integration period (time step), min.	DELT	None
	I5	21-25	Number of hyetographs (rain gages) (maximum = 10).	NRGAG	None
	F5.0	26-30	Percent of impervious area with zero detention (immediate runoff).	PCTZER	25.0
	I5	31-35	IROS = 1, Erosion for subcatchment is to be modeled.	IROS	0
	F5.0	36-40	If IROS = 1, Highest average 30-minute rainfall intensity, in/hr.	RAINIT	0.0
3			Rainfall control card.		
	I5	1-5	Number of data points for each hyetograph (maximum = 200).	NHISTO	None
	F5.0	6-10	Time interval between values, min.	THISTO	None

NOTE: The Runoff block requires only one scratch data-set.
All non-decimal numbers must be right-justified.

Table 5-7 (continued). RUNOFF BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
			REPEAT CARD GROUP 4 FOR EACH HYETOGRAPH.		
4			Rainfall hyetograph cards: 10 intervals per card" (maximum number of values = 200).[a]		
	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 GUTTER/PIPE.		
5			Gutter/pipe cards: one card per gutter/pipe (if none, leave out) (maximum number = 200).		
	I10	1-10	Gutter/pipe number.[b]	NAMEG	None
	2I5	11-15	Gutter or inlet number for drainage.[b]	NGTO	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

[a]Problems may occur when zero rainfall occurs several time-steps before the actual start of the rainfall (the computer underflows).

[b]Numbers may be arbitrarily chosen. However, if inlet number is to correspond to inlet manhole for Transport Block, it must be ≤ 1000. The maximum total number of inlets must be ≤ 50 for input to Receiving or ≤ 70 for input to Transport.

Table 5-7 (continued). RUNOFF BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
		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	0.018
		69-76	Depth of gutter when full, in.	DFULL =G7	10.0
6			Blank card to terminate gutter cards: one card (must always be included).		
			REPEAT CARD 7 FOR EACH SUBCATCHMENT.		
7	3I5	1-5	Hyetograph number (based on the order in which they are read in).	JK	1
		6-10	Subcatchment number.[a]	NAMEW	None
		11-15	Gutter or manhole number for drainage.[a,b]	NGTO	None
	10F5.0	16-20	Width of subcatchment, ft.	WWIDTH=W1	None
			This term actually refers to the physical width of <u>overland flow</u> in the subcatchment and may be obtained as illustrated under Instructions for Data Preparation.[c]		
		21-25	Area of subcatchment, acres.	WAREA =W2	None
		26-30	Percent imperviousness of subcatchment.	PCIMP =W3	0.001
		31-35	Ground slope, ft/ft.	WSLOPE=W4	0.030

[a] Numbers may be arbitraily chosen. However, if inlet number is to correspond to inlet manhole for Transport Block, it must be ≤ 1000. The maximum total number of inlets must be ≤ 70 for input to Transport or ≤ 50 for input to Receiving.

[b] Need one inlet or gutter/pipe for each subcatchment basin.

[c] As an approximation, twice the length of the principal drainage couduit through the subcatchment may be used.

Table 5-7 (continued). RUNOFF BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
		36-40	Impervious area. } Resistance factor. (Manning's n)	W5 =W5	0.013
		41-45	Pervious area. } Resistance factor. (Manning's n)	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 in Horton's equation, 1/sec.	DECAY =W11	0.00115
8			Blank card to terminate subcatchment cards: one card.		
9			SURFACE QUALITY CONTROL CARD		
	I10	1-10	Surface Quality NQS = 0, no quality modeled NQS = 1, quality to be modeled	NQS	0
		******	THE FOLLOWING PARAMETERS ARE NEEDED ONLY IF NQS = 1:	******	
	2F10.0	11-20	Number of dry days prior to this storm in which the accumulative rainfall is less than 1.0 inch.	DRYDAY	0.0
		21-30	Street cleaning frequency, days.	CLFREQ	0.0
	I10	31-40	Number of street sweeper passes.	NPASS	0
	2F10.0	41-50	Catchbasin storage volume, ft^3.	CBVOL	0.0
		51-60	Concentration of BOD (mg/l), of the stored water in each catchbasin (100 recommended)	CBFACT(4)	0.0
	I5	61-65	Method for calculating suspended solids	ISS	0

Table 5-7 (continued). RUNOFF BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
			ISS = 0, same as for all other pollutants (Vol. I).		
			ISS = 1, special technique. Same as in original Release 1 of the SWMM.		
10			Erosion card.		
			If IROS = 0 on Card 2, SKIP TO CARD 11.		
			REPEAT CARD 10 FOR EACH SUBCATCHMENT.		
	I5	1-5	Subcatchment number (must be read in same order as Card Group 7).	N	None
	5F5.0	6-10	Area of subcatchment subject to erosion, acres.	ERODAR(N)	0.0
		11-15	Flow distance in feet from point of origin of overland flow over erodible area to point at which runoff enters gutter or manhole.	ERLEN(N)	0.0
		16-20	Soil factor 'K'.[a]	SOILF(N)	0.0
		21-25	Cropping management factor 'C'.[b]	CROPMF(N)	0.0
		26-30	Control practice factor 'P'.[b]	CONTPF(N)	0.0
11			SUBCATCHMENT SURFACE QUALITY DATA CARDS (one card per subcatchment and must be read in the same order as Card Group 7). If NQS = 0, skip to Card 12.		
	5X	1-5	Not used.		
	2I5	6-10	Subcatchment number	N	None

[a]See instructions for data preparation

[b]See instructions for data preparation and consult with local Soil Conservation Service or Agricultural Research Service experts.

Table 5-7 (continued). RUNOFF BLOCK CARD DATA

Card group	Format	Card columns	Description	Variable name	Default value
		11-15	Land use classification.	KL	5
			= 1, For single family residential,		
			= 2, For multiple family residential,		
			= 3, For commercial,		
			= 4, For industrial,		
			= 5, For undeveloped or park lands.		
	2F10.0	16-25	Number of catchbasins in subcatchment.	BA	None
		26-35	Total length of all gutters within subcatchment, hundreds of feet.	GQ	None
12			GUTTER/INLET PRINT CONTROL: ONE CARD		
	2I5	1-5	Number of gutters/inlets for which flows are to be printed (maximum = 200).	NPRNT	0
		6-10	Number of time-steps between printings.	INTERV	None
13			IF NPRNT = 0, SKIP CARD 13.		
			GUTTER/INLET PRINT CARDS: 16 VALUES/CARD.		
	16I5	1-5	Gutter/inlet numbers for which flows and/or pollutants are to be printed.	IPRNT(1)	None
		6-10		IPRNT(2)	None
		11-15		IPRNT(3)	None
		.		.	
		.		.	
		.		.	
		.		.	
		.		IPRNT(NPRNT)	None

Table 5-8. RUNOFF BLOCK VARIABLES[a]

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 catchbasins	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	

[a] Does not include variables added during updating.

*C = Variable names shared in common blocks.

Table 5-8 (continued). RUNOFF BLOCK VARIABLES

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 5-8 (continued). RUNOFF BLOCK VARIABLES

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	

Variable Name	C*	Description	Units
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 5-8 (continued). RUNOFF BLOCK VARIABLES

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 5-8 (continued). RUNOFF BLOCK VARIABLES

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
RADO		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 5-8 (continued). RUNOFF BLOCK VARIABLES

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	MPN/ 100 ml
TGS		Sum of the geometric series plus 1.0	
THISTO		Time of rainfall time intervals	min

Variable Name	C*	Description	Units
TIME	C	Time	sec
TIMEM		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 5-8 (continued). RUNOFF BLOCK VARIABLES

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 perimeter, starting	ft
WP1		Wetted perimeter, final	ft

Variable Name	C*	Description	Units
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	

Table 5-9. SAMPLE OF EROSION PRINTOUT

LANCASTER PENNSYLVANIA STEVENS AVE DISTRICT **** RELEASE II ****
STORM OF SEPTEMBER 14, 1973 DURATION 9 HOURS

SUMMARY OF QUANTITY AND QUALITY RESULTS AT LOCATION 31

FLOW IN CFS AND QUALITY IN (MG/L)

TIME	FLOW	BOD	SUS-S	COLIF	COD	SET-S	NIT	PO4	GREASE	SUS-S WITHOUT EROSION
6 25.0	0.27	38.39	1013.93	.140E 06	117.54	0.03	0.08	0.01	0.10	.782883E 00
6 50.0	1.12	4.74	244.82	.140E 06	15.17	0.05	0.13	0.01	0.11	.170686E 01
7 15.0	1.39	0.61	198.68	.125E 06	3.94	0.06	0.14	0.01	0.10	.207176E 01
7 40.0	0.88	0.53	102.36	.115E 06	3.55	0.05	0.12	0.01	0.09	.169623E 01
8 5.0	0.51	0.45	173.49	.101E 06	3.12	0.04	0.09	0.01	0.08	.121371E 01
8 30.0	0.70	0.41	210.57	.888E 05	2.73	0.04	0.09	0.01	0.07	.126962E 01
8 55.0	0.83	0.39	178.32	.830E 05	2.56	0.04	0.10	0.01	0.06	.143401E 01
9 20.0	1.48	0.34	425.87	.663E 05	2.04	0.05	0.10	0.01	0.05	.171272E 01
9 45.0	3.58	0.38	263.58	.524E 05	1.61	0.12	0.18	0.02	0.04	.358665E 01
10 10.0	1.84	0.27	150.49	.408E 05	1.26	0.07	0.12	0.01	0.03	.225552E 01
10 35.0	1.57	0.22	95.01	.324E 05	0.99	0.06	0.10	0.01	0.02	.187092E 01
11 0.0	0.84	0.17	106.74	.280E 05	0.86	0.04	0.07	0.01	0.02	.123880E 01
11 25.0	0.37	0.15	0.93	.275E 05	0.85	0.04	0.05	0.01	0.02	.929881E 00
11 50.0	0.63	0.12	329.56	.212E 05	0.65	0.03	0.05	0.00	0.02	.854406E 00
12 15.0	0.89	0.14	166.49	.210E 05	0.65	0.04	0.06	0.01	0.02	.115358E 01
12 40.0	0.98	0.14	150.44	.189E 05	0.58	0.04	0.06	0.01	0.01	.124167E 01
13 5.0	1.09	0.11	442.20	.150E 05	0.46	0.04	0.05	0.01	0.01	.108614E 01
13 30.0	1.09	0.13	82.44	.150E 05	0.46	0.05	0.07	0.01	0.01	.142452E 01
13 55.0	2.23	0.13	250.13	.107E 05	0.33	0.06	0.09	0.01	0.01	.181339E 01
14 20.0	3.65	0.16	279.06	.762E 04	0.23	0.11	0.12	0.01	0.01	.254702E 01
14 45.0	2.43	0.12	142.05	.545E 04	0.17	0.09	0.09	0.01	0.00	.192927E 01
15 10.0	1.73	0.07	279.04	.365E 04	0.11	0.05	0.05	0.00	0.00	.104022E 01
15 35.0	1.61	0.08	56.20	.336E 04	0.10	0.06	0.06	0.01	0.00	.122568E 01
16 0.0	1.79	0.05	270.14	.245E 04	0.08	0.05	0.05	0.00	0.00	.100727E 01

SAMPLE APPLICATION

An example of an application of the Runoff Block, SWMM, to the North Lancaster Drainage District, Lancaster, Pennsylvania, is presented in this section. Both surface quantity and quality are modeled. The study area is marked by a dotted ellipse in Figure 5-9. Some of the subcatchments, their boundaries, and inlet manholes are shown in Figure 5-10. A coarse discretization of the physical drainage system was followed. The storm event of March 22, 1972, with an approximate duration of 4 hours, was selected because an accurate rainfall history was available. Input data are shown in Table 5-10.

The rainfall history, in 5 minute intervals, is shown in Table 5-11. Included are the number of time steps, percent impervious area with zero detention depth (immediate runoff), and the integration time interval. For simulation purposes, the time of start of storm is 1100 hours, with actual rainfall first observed at 1125 hours. The information displayed in Table 5-12 may be obtained by the user from city sewer maps, topographic maps, or zoning maps. The values shown for the resistance factors, surface storage, and infiltration rate are default values. If values more appropriate than these are available, then they should be specified by the user (see the following section on calibration of the Runoff Block). Note that the subcatchments are numbered for identification purposes only, i.e., they are not used in the execution of the program. No gutter/pipes are used. Figure 5-11 shows the total basin inlet hydrograph computed from the input rainfall hyetograph and subcatchment data. Table 5-13 lists the inlets for which hydrographs will be listed (specified by user). It also shows the computed total rainfall, infiltration, gutter flow, surface storage, and the error in continuity (numerical solution technique). In Table 5-14, the program prints the inlets for which hydrographs will be stored (for transfer to Transport), and the quality input parameters. Table 5-15 identifies land use types for each subcatchment, the number of catchbasins in each subcatchment, and the total gutter length within each subcatchment. The catchbasin density for Lancaster is approximately one per acre. These parameters are important elements of the quality simulation.

The final quantity and quality results for each subcatchment are summarized in Tables 5-16 and 5-17. Table 5-16 is essentially a heading printed by the program to advise the user of the summary that follows (Table 5-17). The inlets for which quantity and quality results are to be printed are specified by the user in the print control cards.

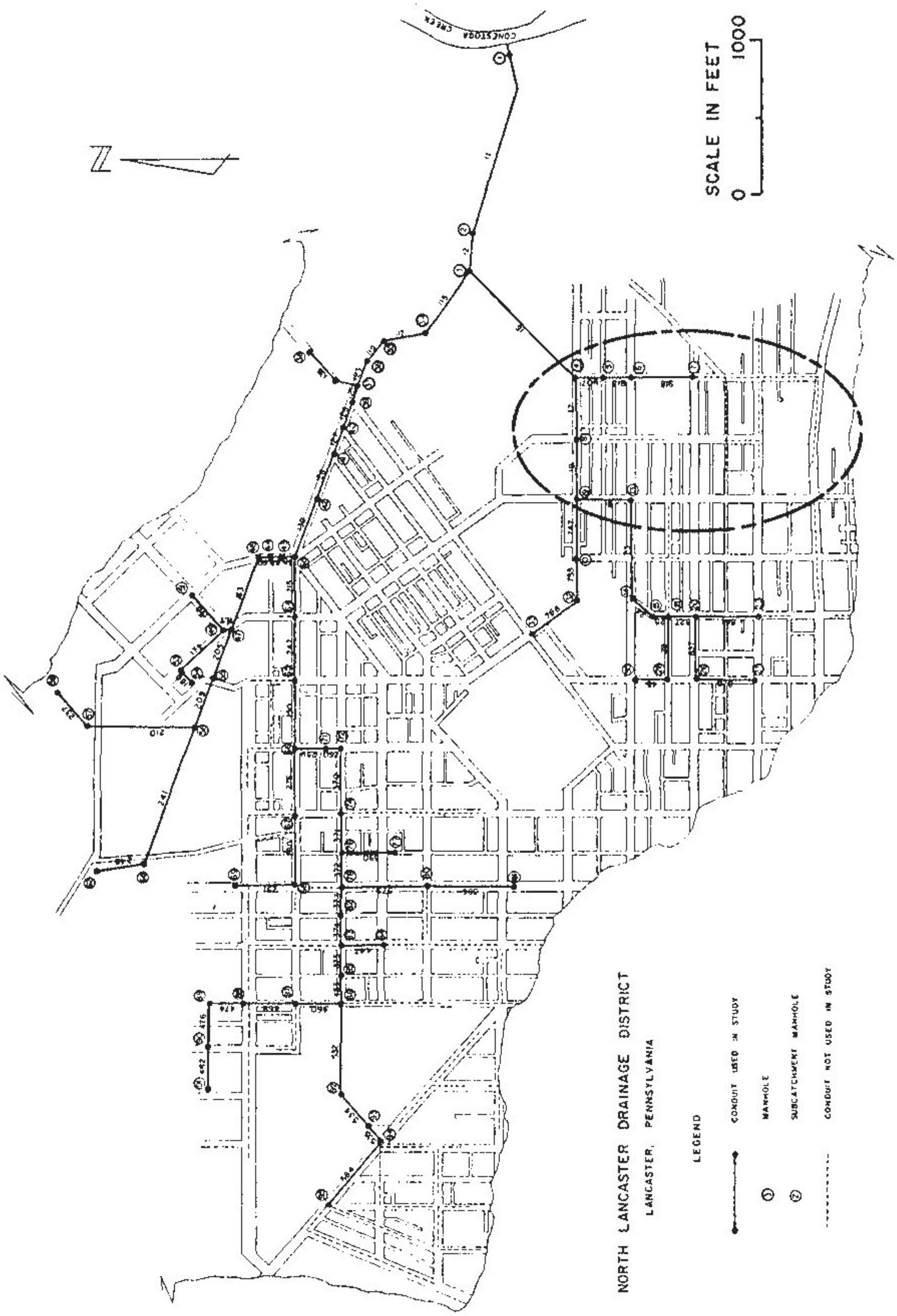


Figure 5-9. Sample Application Study Area

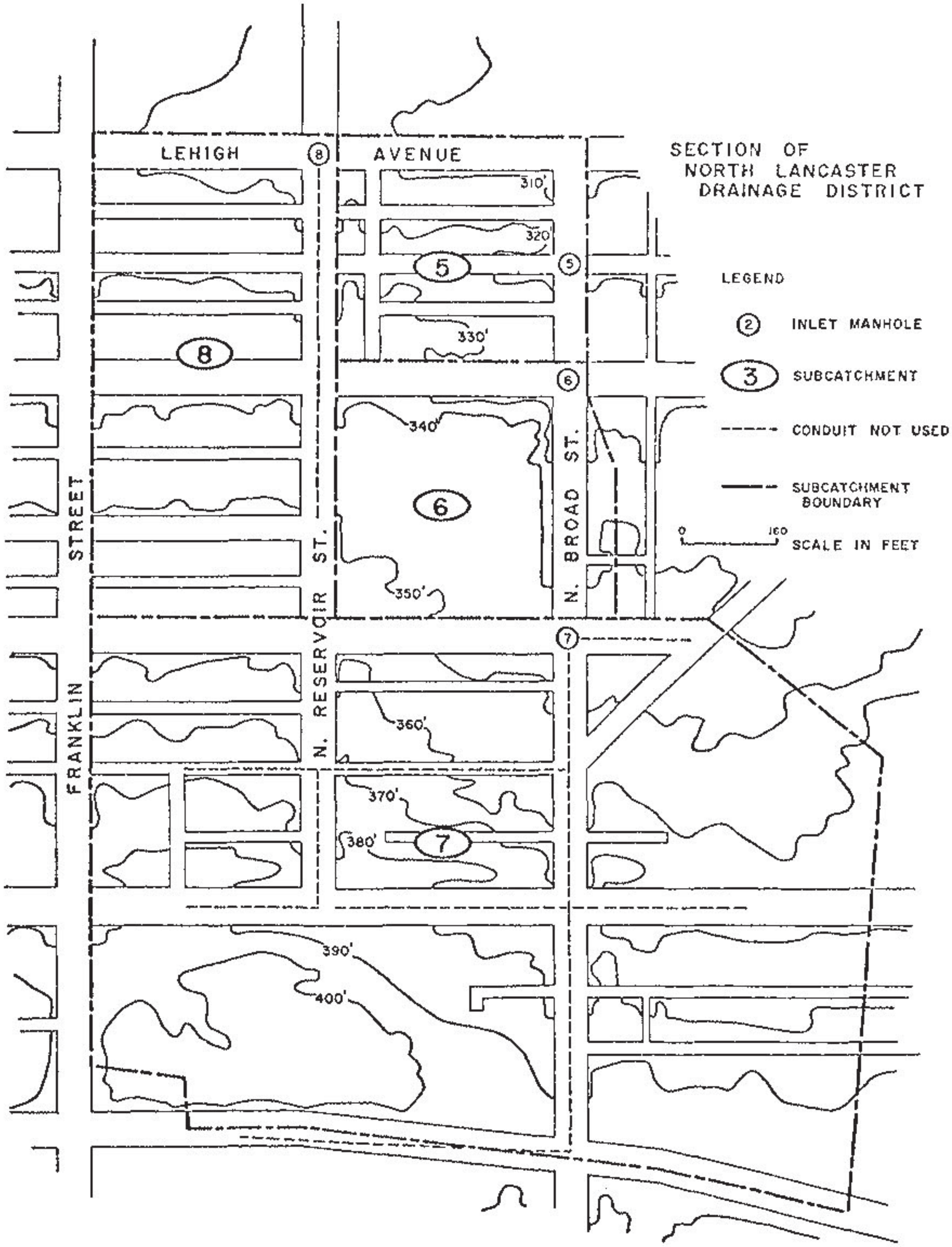


Figure 5-10. Sample Application Subcatchment Boundaries

Table 5-10. INPUT DATA NORTH LANCASTER, PENNSYLVANIA, DRAINAGE DISTRICT

DATA	CARD GROUP NUMBER
	(READ IN EXECUTIVE BLOCK)

```
RUNOFF
    LANCASTER  PENNSYLVANIA  NORTH  DRAINAGE  DISTRICT                 } 1
    STORM OF MARCH 22, 1972 DURATION 4 HRS. STUDY 3  (STORM #7)       }
  66  100 11 0   5.    1  25.                                            2
  48  .5.0                                                               3
0.0   0.0   0.0   0.0   .12   .36   .48   .36   .12   .12
.06   .06   .12   .12   .24   0.0   0.0   0.0   0.0   .12
.06   .06   .06   .06   .12   0.0   0.0   0.0   0.0   0.0                4
0.0   0.0   0.0   0.0   0.0   0.0   .12   .48   .24   .36
.06   .06   .06   .06   .06   .06   0.0   0.0
                                                (Blank Card)             5,6
     5      5  1  800.   7.   31.0.028
     6      6  1  672.   9.   20.0.031
     7      7  18108.   46.   32.0.044
     8      8  11700.   16.   46.0.035
     9      9  11010.    8.   17.0.020
    10     10  1  730.   12.  10.0.025
    13     13  1  684.    9.  46.0.025
    14     14  1  684.    5.  37.0.025
    15     15  1    6.   31.   0.0.030
    18     18  1  928.    3.  47.0.025
    20     20  12684.   12.   58.0.025
    22     22  13536.   21.   58.0.025
    26     26  12354.   12.   54.0.032
    27     27  11180.   22.   58.0.035
    28     28  12370.    9.   47.0.019
    30     30  17032.   34.   42.0.019
    32     32  1  420.    4.  24.0.025
    33     33  16358.   47.   28.0.022
    38     38  113664   78.   43.0.018
    39     39  13100.    5.   51.0.019
    40     40  12465.   19.   57.0.019
    41     41  15554.   25.   59.0.016
    42     42  11608.    9.   59.0.018
    43     43  1  130.  0.4   51.0.008
    44     44  1  120.  0.3   51.0.007
    46     46  1  170.  0.3   51.0.012
    47     47  1  360.    3.  45.0.005
    49     49  1  290.    2.  45.0.007
    51     51  11633.   17.   38.0.012
    53     53  1  598.   18.  38.0.010
    54     54  1  780.   14.  23.0.008
    55     55  1  210.    1.  38.0.017                                    7
    56     56  1  210.    1.  38.0.009
    57     57  11600.   48.   23.0.012
    58     58  11200.   32.   23.0.008
    60     60  11600.   30.   23.0.006
    62     62  1  690.   18.  23.0.006
    63     63  11100.    6.   58.0.021
    64     64  12558.    8.   58.0.014
    65     65  1  780.    9.  49.0.009
    66     66  1  800.    6.  54.0.010
    67     67  1  400.   13.  51.0.018
    68     68  1  630.    9.  45.0.010
    69     69  1  960.   21.  43.0.008
    71     71  11020.    2.   51.0.005
    72     72  17830.   35.   57.0.014
    74     74  12250.   14.   51.0.023
    76     76  1  290.    2.  51.0.015
    77     77  13700.   21.   51.0.021
    78     78  1  880.    7.  61.0.012
    80     80  1  560.   19.  56.0.024
    81     81  1  700.   11.  58.0.018
    82     82  1  400.    6.  63.0.007
    83     83  11680.    8.   52.0.017
    84     84  11370.    9.   56.0.020
    85     85  11400.   11.   52.0.021
    86     86  11200.   12.   24.0.015
    87     87  1  360.    3.  38.0.003
    88     88  11810.   29.   22.0.004
    89     89  1  290.    2.  45.0.004
    90     90  11080.    6.   40.0.004
    91     91  11150.   30.   17.0.004
    92     92  1  360.    3.  10.0.019
    93     93  12920.    8.   23.0.011
    94     94  14160.   20.   32.0.021
    95     95  15110.   56.   22.0.021
                                                (Blank Card)             8
```