Environmental Protection Technology Series

STORM WATER MANAGEMENT MODEL: DISSEMINATION AND USER ASSISTANCE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

National Environmental Research Center
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

EPA-670/2-75-041
May 1975

STORM WATER MANAGEMENT MODEL:
DISSEMINATION AND USER ASSISTANCE

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Project No. R-802716
Program Element No. 1BB034

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CINCINNATI, OHIO 45268

REVIEW NOTICE

FORWORD

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 documents a program of dissemination and user assistance for the EPA Storm Water Management Model. The program offers municipalities a simple, inexpensive method of utilizing SWMM for stormwater management.

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ABSTRACT

A program of dissemination and user-assistance for the EPA Storm Water Management Model (SWMM) has been developed and implemented at the University City Science Center (UCSC).

Services available to SWMM users under this grant include distribution of the SWMM program itself and technical assistance in problem delineation, data preparation, execution debug, and output interpretation. Costs of this service extend only to actual computing costs, with all technical assistance covered by the EPA grant.

Several case studies of SWMM applications completed with UCSC assistance in the past year are included in this report. These studies include a combined sewer overflow problem in Binghamton, New York; a land use plan in the Stony Brook basin in Princeton, New Jersey; and RUNOFF/TRANSPORT calculations on the Wingohocking basin in Philadelphia, Pennsylvania.

The UCSC SWMM dissemination program is now self-sustaining and continues to assist the user community.

This report was submitted in fulfillment of the Office of Research and Development, U.S. Environmental Protection Agency (EPA) research grant EPA No. R-802716 by the UCSC under the sponsorship of the EPA.

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ACKNOWLEDGMENTS

Support from EPA project personnel, especially Mr. Richard Field, Mr. Chi-Yuan Fan and Mr. Harry Torno, was invaluable in this project.

The support of the staff of UNI-COLL Corporation, Philadelphia, Pennsylvania was appreciated for general computing support.

Assistance in modeling in Binghamton was provided by the Staff of Quirk, Lawler and Metusky, Inc., Tappan, New York, especially Dr. Mohamed M. Elsahragty.

Assistance in modeling the Stony Brook basin was provided by the Department of Regional Planning, University of Pennsylvania, Philadelphia, Pennsylvania, especially Mr. Lanny Maxwell.

SECTION I

CONCLUSIONS

1. The SWMM dissemination method utilized in this study has introduced the SWMM technology to a wide range of potential-users.

2. The SWMM user-assistance program utilized in this study provides the computer program in several easy-to-use modes and covers technical assistance in problem delineation, data reduction, debugging, and output interpretation.

3. The dissemination effort reached a wide geographic assortment of consulting engineers, but touched only a rather narrow geographic sampling of municipal planning groups.

4. SWMM modeling assistance was supplied to an engineering consulting firm for a study of combined sewer overflows in Binghamton, New York. The first phase of this study was completed and served to locate and quantify overflows in the Binghamton combined sewer system.

5. The adaptability of SWMM was demonstrated in the Binghamton study by modification of the TRANSPORT block of SWMM to allow direct routing of sewer surcharges to the receiving water rather than holding in the sewers for later release.

6. SWMM can be applied to stormwater runoff problems in developing watersheds, as demonstrated in a study of the Stony Brook basin near Princeton, New Jersey. Proper accounting of soil infiltration losses in pervious areas is essential for good results. Small streams can be idealized as "gutters" within the RUNOFF block.

7. Quality data for verification of SWMM quality results was found to be very scarce.

8. SWMM modeling serves purposes apart from its primary output of quantity and quality of storm or combined sewer flows. Setting up for SWMM modeling naturally directs thought and data collection along sensible lines. The overall organization of SWMM forces users to realize the importance of dynamic modeling of both quantity and quality of storm flows and thus directs data collection towards continuous measurement of pollutant levels and flow quantities.

9. Assistance in defining the problem, relating it to SWMM, and, outlining the capabilities and requirements of SWMM is necessary. It appears, so far, that simply mailing a SWMM tape to a potential-user is insufficient support to generate use. Although heavy support is required in the early stages of modeling, effective transfer must also include education to promote user independence.

SECTION II

RECOMMENDATIONS

1. Use of the Storm Water Management Model (SWMM) and appropriate data collection as an integral part of municipal planning for control of storm or combined sewer pollution is highly recommended.

2. Use of SWMM for storm water pollution control in developing watersheds should be further explored.

3. The quality portions of SWMM must be better verified. Programs of data collection for such verification should be undertaken both in urbanized areas and in developing watersheds.

4. The SWMM dissemination effort should be expanded to cover a wider geographic range of municipal planners.

5. The SWMM user-assistance program should be extended to support continuing modeling efforts as well as data-collection programs presently underway.

6. A simple, eye-catching document should be prepared to introduce SWMM to the user-community. A follow-up document outlining capabilities and data requirements of SWMM is also required for further dissemination of this technology.

7. Use of SWMM is strongly recommended for all EPA 208 and 303-type grants. Appropriate data collection for SWMM verification should be closely tied to modeling efforts.

SECTION III

INTRODUCTION

GENERAL

The problems arising from stormwater runoff in urbanized areas have been proven to be extensive in a number of studies.[1] Stormwater runoff naturally collects the refuse of human and animal activity and efficiently transports this refuse to receiving waters. In this manner, storm flows become major pollutant sources during rainy periods. Combined sanitary and stormwater collection systems worsen the problem by including sanitary waste with the already polluted storm runoff. Extensive impervious cover in urbanized areas aggravates the storm runoff problem by decreasing infiltration and increasing total storm flows. Since impervious cover is generally smoother than natural, pervious cover, the storm flows are not only increased in volume but also transported across land surface more quickly, increasing peak flows downstream and shortening peak arrival times at downstream points.

In the past, treatment of combined storm and sanitary flows has been minimal. The excess quantity of the storm flow necessitated diversion of combined sewage from the normal treatment methods to the receiving waters. Most attempts to relieve pollution during wet weather have centered on holding as much storm flow as possible in either in-line sewers or off-line storage facilities until the storm period has passed. Stored stormwater is then routed to treatment during dry periods.

In order to plan sensibly for storage and treatment of wet-weather flows, a considerable amount of information concerning the duration, quantity, and quality of wet-weather flows must be available.

This necessary information depends upon the nature of the storm event in question along with a large number of physical characteristics of the watershed. The connection between a storm event, the physical characteristics of the watershed, and the timing, quantity and quality of storm flows is exceedingly complex. Simple rainfall/runoff models[2,3] do not consider the time-variance of wet-weather flows. For this reason simple models are inadequate for detailed stormwater planning.

STORM WATER MANAGEMENT MODEL

To assist anyone planning for the control of pollution from stormwater or combined sewer overflows, the U.S. Environmental Protection Agency has sponsored development of the Storm Water Management Model (SWMM) by a consortium of contractors including the University of Florida, Water Resources Engineers, and Metcalf & Eddy, Inc.

SWMM is a dynamic event-simulation model which can predict a time-history of quantity and quality of stormwater runoff at all points in a watershed. This model has been programed for computer-based use.

Starting with a time-history of a storm event (hyetograph), SWMM models a watershed (using data on land use, topography, population density, and natural and man-made drainage systems) to route stormwater overland, through open channels and pipes, and into a collection system. If the collection system is a storm or combined sewer, computer modeling of the sewer allows SWMM to further route the stormwater through the existing network of sewer elements. SWMM presents options to hold stormwater in storage systems for later removal, and, allows modeling of various types of storage devices. Stormwater treatment options can be examined (using a treatment package in SWMM) prior to routing into receiving waters.

Effects of quantity and quality of stormwater upon the receiving waters are also predicted based upon natural flow or tides in the receiving-water system. Time-histories of quantity and quality of flow can be obtained at all points in the stormwater conveyance system.

SWMM is designed to allow analysis of large areas using a "building block" approach, starting from intensive analyses of smaller constituent drainage basins.

OBJECTIVES

The University City Science Center (UCSC) has, for the past sixteen months, been executing an EPA grant specifically designed to disseminate the existence and capabilities of SWMM to the potential-user community, and, provide technical assistance in SWMM use where appropriate. The Science Center was specifically charged with responsibility for installing SWMM on in-house computers in a complete and correct format as tested by data supplied by the EPA. All revisions and corrections to SWMM as well as major new versions were to be implemented as they became available. SWMM was to be made available to users in several formats, depending on user need. Technical assistance for users was to be supplied in describing required data, reduction of engineering data to formats suitable for SWMM, debugging of SWMM execution runs and interpretation of SWMM output.

DISSEMINATION OF SWMM

The first step in the dissemination part of this project was the development of an informational brochure about SWMM. This document was designed to capture the interest of a prospective user through a simple and attractive format. The content of the brochure is technically simple and answers the basic question --What is SWMM? Examples of past and potential SWMM applications were outlined. Details of the available technical assistance were also given. The brochure was reviewed and approved by EPA personnel and 2,000 copies were printed. Mailing lists of potential users were then compiled and brochures sent. Approximately 750 brochures have been mailed to Engineering and Design Firms (550), government agencies in the states of Pennsylvania and New Jersey (5), planning boards (Pennsylvania and New Jersey - 100), educational institutions in the Delaware Valley (25), and conservationists and environmentalists (50). To date, approximately thirty responses have been received requesting more information on SWMM. Each response was contacted by mail or telephone and sent a SWMM OVERVIEW excerpted from Reference 1 giving further detail on SWMM capabilities and data requirements. Further discussions with interested parties led to the development of a talk and slide show on SWMM which was given five times over the course of the project to a wide variety of audiences. One talk was given at the 25th National Plant Engineering and Maintenance Conference in Cleveland, Ohio, March 20, 1974. Requests were also received for SWMM program tapes from four potential users. Although modeling is planned in each of these four cases, none has been actually undertaken to date.

SECTION IV

USE OF SWMM AT UCSC

COMPUTER SYSTEM DESCRIPTION

SWMM has been set up on a computing system at UNI-COLL Corporation. UNI-COLL Corporation is a neighbor to the University City Science Center and functions as an extremely large, regional computing center servicing universities, hospitals, government agencies and private corporations needing high-level computing. UNI-COLL houses an IBM 370/168 with 3 million bytes of fast core operating under the OS/VS2 operating system. OS/VS2 is a virtual system extending core space beyond real memory to virtual space available on high-speed disk. This feature not only allows large programs to reside in core without use of OVERLAY, but also facilitates job scheduling, allowing more efficient use of fast core. UNI-COLL has extensive service facilities for users and interactive capabilities supporting all conventional dial-up terminals. A schedule of UNI-COLL computing rates is given in Table 1.

Table 1. UNI-COLL COMPUTING RATES

USAGE TYPE		USAGE RATE[a]
CENTRAL PROCESSING UNIT (CPU)		
Batch Processing	$0.50/sec.	$1800/hr.
Terminal Processing (TSO)	$0.75/sec.	$2700/hr.
STORAGE		
Real CPU	$.00056 per kilobyte per sec.	$2.00/hr.
Virtual CPU	$.00028 per kilobyte per sec.	$1.00/hr.
On-Line-Storage (OLS-3330 disk)		$0.20/trk/day
TERMINAL CONNECT TIME		$3.60/hr.
INPUT/OUTPUT		
Cards Read		$0.60/1000
Cards Punched		$2.50/1000
Lines Printed		$0.60/1000

a. DISCOUNT - A discount is applied to the basic charge for CPU, Storage, Channel and Input/Output depending on the shift on which the job is submitted or specified to be run. CPU, Storage and Channel charges are discounted to 85 percent of base charges for second shift (1800-2400 hrs.) and 65 percent of base charges for third shift (2400-0830 hrs.). A weekend shift discount to 55 percent of base charges (Sunday 1800-2400) is also available. Print and punch charges are discounted by approximately eight percent and sixteen percent for second and third shift respectively

SWMM SETUP

The most recent version of SWMM has been made operational on an IBM 370/168 at UNI-COLL Corporation. The program has been stored for dissemination in several formats depending upon user need. A LOAD MODULE is kept in on-line disk storage and can be used for batch processing and remote processing. This LOAD MODULE can be copied to tape and sent to IBM users operating under IBM OS (operating system) with 328 K of core storage. Use of a LOAD MODULE is the simplest method of accessing SWMM and avoids costly compilation, overlay, and linkage editing. Both FORTRAN SOURCE and OBJECT files may also be copied to tape and sent to users unable to utilize a LOAD MODULE. SAMPLE DATA sets and JOB CONTROL LANGUAGE are also available to verify correctness of SWMM program tapes and are setup for simple batch or remote terminal processing. SWMM program correctness was established using data from the University of Florida study on the Stevens Avenue Drainage Basin in Lancaster, Pennsylvania.[4]

Two general modes of SWMM use are available through this grant as shown in Figure 1. SWMM may be used in-house at UNI-COLL

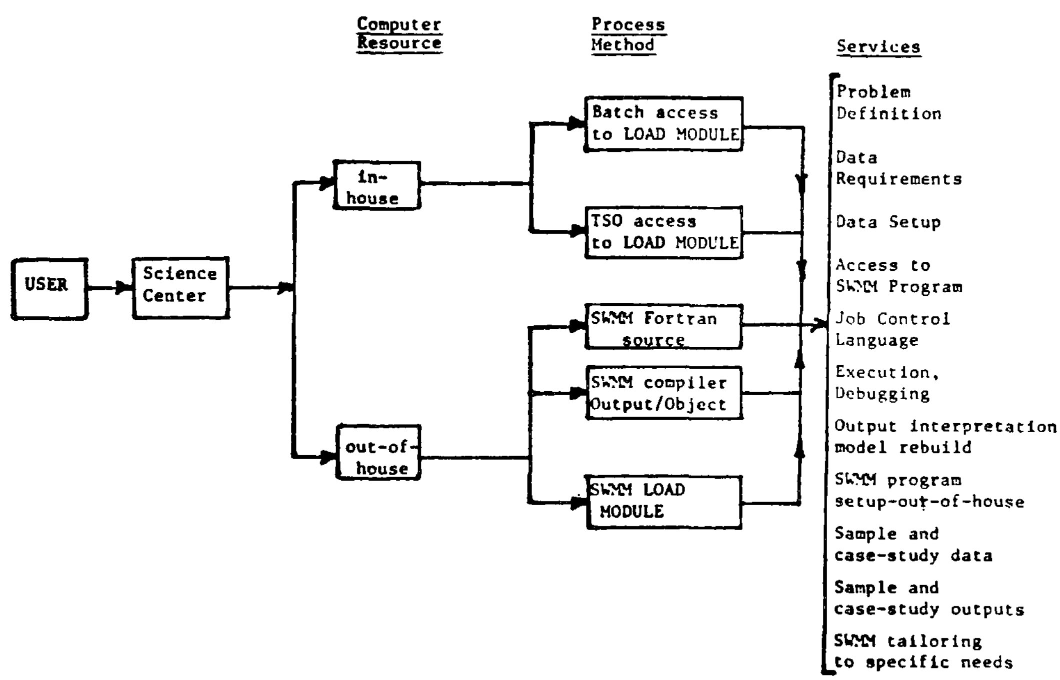

Figure 1. MODES OF SWMM USE

through batch processing or terminal (TSO). SWMM output from this use-mode can be examined under TSO or can be mailed to users in hand-copy form from the Science Center.

Both in-house and out-of-house users can obtain all appropriate grant services as shown in Figure 1.

SWMM EXECUTION

In order to execute SWMM at UNI-COLL, three data sets are required as shown in Figure 2.

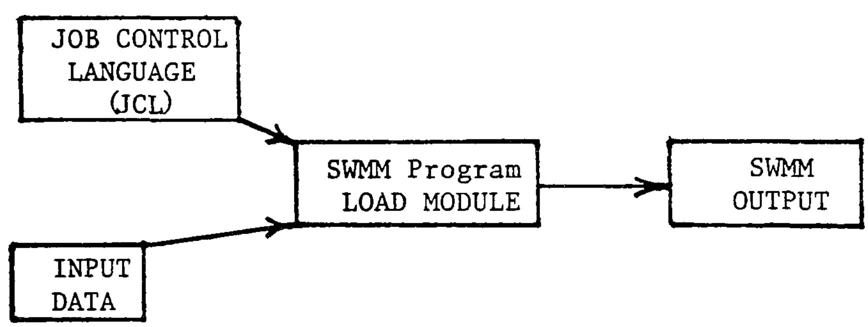

Figure 2. SWMM DATA SETS

Job Control Language

A Job Control Language (JCL) file is required to direct computer processing. JCL files can be prepared for specific users. Modifications to JCL files can be made by users through dial-up terminals using the simple IBM interactive language (TSO). This language is conversational and may be learned quickly.

SWMM Program

The SWMM computer program is written in FORTRAN IV and is constructed in a block format according to function as shown in Figure 3.

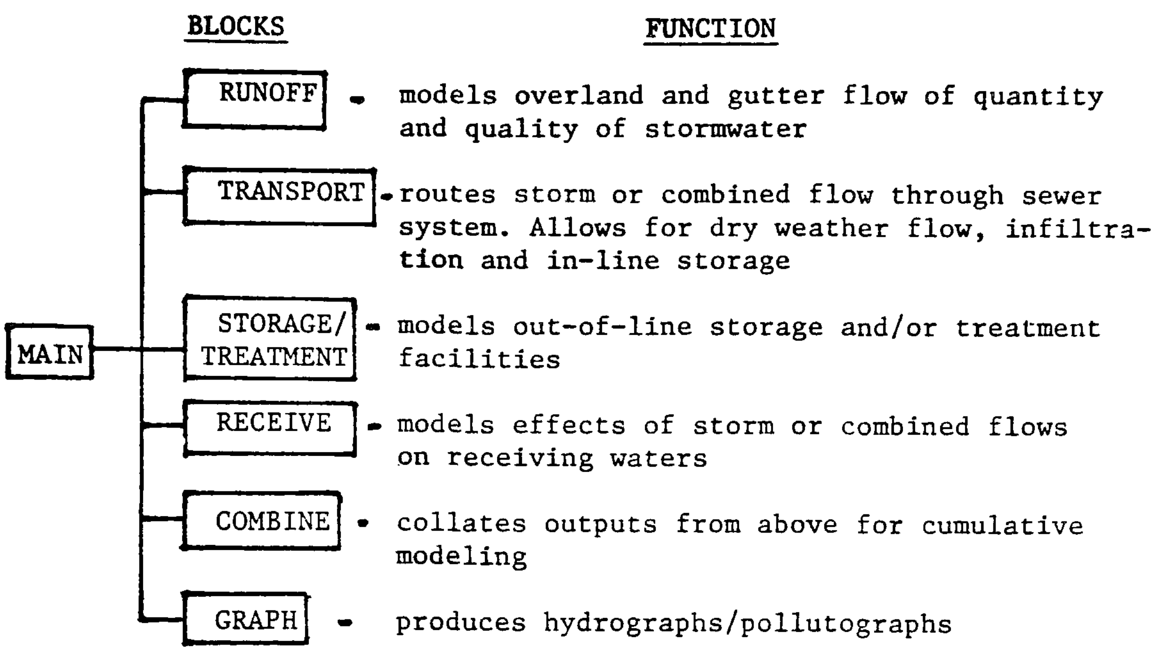

Figure 3. SWMM PROGRAM BLOCK STRUCTURE

The block structure of SWMM naturally divides the required data inputs as described in the section below. The LOAD MODULE (Ref. p. 7) for SWMM uses approximately 325K bytes of core storage with OVERLAY and approximately 715K of core without OVERLAY. Data files for SWMM use can be prepared as a joint effort between user and UCSC. Collaboration between users and UCSC personnel is initially required to define the technical problem at hand, and the function and capabilities of SWMM with respect to the problem. Once the function of SWMM is ascertained, the data requirements may then be outlined. Potential sources for required data may be provided by the Science Center. After required data is collected, users must reduce this data to formats acceptable to the SWMM program (either cards or coding forms), Users' Manual reference 5. A summary of the types of data for each block is given below.

Runoff Block--

The RUNOFF block of SWMM generally requires rainfall data and physical characteristics of the drainage basin to model overland flow of stormwater and routing of overland flow through gutters and small pipes.

Rainfall input -- A continuous record of rainfall over the period of several storm events is a necessity for SWMM modeling, especially verification runs. The recording rain gage or rain gages used for these measurements should adequately cover the watershed in question and provide adequate account of the movement of the storm.

Surface flow -- The major data preparation task in SWMM use involves discretization of the watershed into subcatchments according to natural drainage patterns and existing collection devices (gutters and storm sewers). The discretization level can vary for a single watershed from coarse to fine grade depending on the required accuracy of results. In the finest sense, a subcatchment is an area that drains to a common point with uniform slope, roughness, surface detention, and surface infiltration. It is possible to use coarser discretization schemes providing verification data are available.

Gutter and pipe flow -- Outputs from surface (overland) flows may be routed through gutters and small pipes within the RUNOFF section. Pipes and gutters are modeled by specifying length, size, slope and roughness.

Surface quality -- Subcatchments are further divided into subareas having a single land use. SWMM recognizes five distinct land use patterns: single-family residential, multi-family residential, commercial, industrial, and undeveloped or park lands. Quality of surface flows is computed by SWMM from street cleaning data, catchbasin data, and the total length of gutters in each subarea.

A summary of RUNOFF block data requirements is given in Table 2.

Table 2. RUNOFF BLOCK DATA REQUIREMENTS

Data type		Description
Rainfall input	-	time-history of rainfall (in./hr.) for each time increment (i.e., every 5 minutes)
Subcatchments (each)	-	area width (perpendicular to flow direction) imperviousness ground slope Manning's roughness factor retention storage infiltration rate constants (Horton's Eq.) maximum initial infiltration rate minimum final infiltration rate decay rate constant
Gutters/pipes (each)	-	width/diameter length slope roughness factor
Surface quality (each subcatchment)	-	street cleaning frequency antecedent moisture conditions number of catchbasins, capacity, catchbasin solids and BOD_5, total length of gutters

A connectivity matrix between subcatchments and subareas, and gutters and pipes must also be constructed so that flow from subcatchments can be directed through gutters and pipes in proper sequence to inlet manholes for the TRANSPORT block.

Transport Block --

The SWMM TRANSPORT section takes as input the hydrographs and pollutographs generated by the RUNOFF model. Manholes specified in RUNOFF as input manholes are thus the input points in TRANSPORT. The quantity section of transport then routes these flows through the sewer system. All sewer elements, manholes and pipes must be specified for SWMM according to type, length, size, slope, and roughness. A connectivity matrix must be constructed by the user to sequence flows correctly. Pipes are connected by manholes, some of which may be stormwater inputs. Infiltration into the sewers may be specified provided data on infiltration levels are available; otherwise, best estimates are used to account for dry-weather, groundwater, and wet-weather infiltration.

Combined sewers - dry-weather flows -- In the case of combined sewer systems, the quantity and quality of dry-weather flows (DWF) as well as the daily and hourly variation must be specified. Daily and hourly correction factors for DWF can be obtained from treatment plant records or measurements. DWF quantity and quality for each subarea may be either directly measured, or, calculated by SWMM from water use measurements or population data on each subarea. Contributing industrial process flows must also be specified.

Table 3 lists the data requirements for the TRANSPORT block of SWMM.

Table 3. TRANSPORT BLOCK DATA REQUIREMENTS

Input (from RUNOFF)	- RUNOFF hydrographs and pollutographs
sewer elements	- type (circular, rectangular, etc.) length slope Manning's roughness connectivity matrix
Infiltration	- dry weather infiltration (base estimate) ground water infiltration wet weather infiltration
Dry weather flow (DWF)	- measurements of DWF for each subcatchment or metered water use for each subcatchment or population data for each subcatchment i.e., area population density number of dwelling units people in average unit market value of average unit industrial process flows daily and hourly flow variation for DWF

Storage/Treatment Block--

STORAGE and TREATMENT options within SWMM can be used to provide for a number of different types of storage and treatment at any point in the TRANSPORT system. STORAGE requires information about the physical shape and dimensions of the storage unit as well as hydraulic information about flow within the storage unit and the outlet method from the storage unit. TREATMENT requires specification of the treatment alternatives to be included from among those modeled within SWMM. Costs of STORAGE and TREATMENT options can also be calculated within SWMM.

Table 4. STORAGE/TREATMENT DATA REQUIREMENTS

Storage	-	Physical dimensions of storage unit Type of outlet device Routing method in storage unit Unit costs
Treatment	-	Specify treatment string Unit Costs

Receive Block --

The major effort in SWMM modeling of receiving waters involves idealization into a system of channels connected by nodes (junctions). Options exist for inclusion of tides, wind and rain effects, as well as down-stream weir (dam) conditions. Elevation, area, and Manning's coefficients must be specified for junctions. Width, length, depth, and Manning's coefficients are required for channels. Storm water may be input at any mode from cards as well as from the primary transport output from disk file. RECEIVE data requirements are summarized in Table 5.

Table 5. RECEIVE BLOCK DATA REQUIREMENTS

Junctions	-	water surface elevation surface area depth Manning's coefficient
Channels	-	length width depth Manning's coefficient
Tides		tidal stage history
Rain	-	precipitation rates
Weir	-	weir factor, elevation, power law
Storm inputs	-	hydrographs-cards or disk file
Quality constitutents	-	pollutographs or loading rates for each constituent

The preceeding data descriptions are intended only to indicate the types of data required for SWMM. For actual input data preparation, the user is referred to the SWMM Users Manual.[5]

For verification and testing of SWMM models, measured runoff rates and quality loadings taken continously over storm periods are required. Measurements should be made at points of primary interest to the modeler (i.e., outfalls, overflow points). This verification data is especially critical in modeling of quality constituents of storm or combined sewer flows.

SECTION V

COSTS FOR MODEL APPLICATION

Cost for modification, application and verification of SWMM models may be divided into two parts, costs for personnel and computer costs.

PERSONNEL COSTS

Personnel costs include collection of physical data required for model set-up, data reduction to actually build the computer model, program execution and debug, and output interpretation. Although personnel costs vary widely based upon the availability of data and the fineness of the discretization effort, a general rule of thumb has been developed at UCSC to estimate personnel costs. Three man-weeks are allocated to physical data collection, discretization, data reduction, execution, debug and output interpretation for each basin being studied. Thus for an urban area with five distinct drainage basins, fifteen man-weeks would be required for model set-up, verification and application.

As SWMM is utilized at UCSC these manpower tasks may be divided between a primary user and UCSC. For example, data collection and discretization can be done in-house by the primary user, while actual input setup, verification, debug, etc., can be done by UCSC. Manpower costs are thus divided between primary user and UCSC.

COMPUTER COSTS

Computer costs include data file setup costs and verification and application execution runs. Typically, setup of data files for the initial run can be finalized for approximately $50.00. Costs of execution runs vary heavily with the number of time steps, the number of subcatchments, the number of sewer elements, and the portions of SWMM to be run. Typical costs for SWMM execution runs done at UNI-COLL Corporation are given in Table 6.

Table 6. SWMM EXECUTION COSTS

Application	SWMM blocks run	No. of time-steps	No. of subcatch-ments	No. of sewer elements	Cost ($)
Binghamton, N.Y.	RUNOFF & TRANSPORT	68	36	115	35.00
Stony Brook, N.J.	RUNOFF	64	20	NA	6.00
Wingohocking Phila., Pa.	RUNOFF & TRANSPORT	60	57	120	44.00
"	RECEIVE	2 days	NA	NA	11.00

NA: Not Applicable

SECTION VI

CASE STUDIES

Over the past year, six respondees to the dissemination program described in Section III indicated a definite interest in using SWMM on existing stormwater pollution problems. Early discussions with these potential users confirmed that much of the data required for modeling had already been collected or was easily available.

Extensive discussions were held with each of these potential users and the function of SWMM modeling in the context of their particular problem was defined. Data requirements for the needed modeling were generated. In four of the six cases, continuous discharge and quality data required for verification of SWMM was found lacking, and collection programs to obtain all data were begun by the potential users. Each of these modeling sites is briefly discussed below.

In the two remaining basins, discharge data was available but no continuous quality data had been collected. In both of these cases SWMM modeling was done and is described in detail below. Testing was also done on a series of ten storms which fell on the Wingohocking basin of Philadelphia. Storm data was supplied by the EPA.

DATA COLLECTION PROGRAMS

In each of the sites discussed below, all data required for modeling with exception of continuous quality and quantity testing (for verification of SWMM results) have been collected or are easily available. In each case the problem is similar. Development of suburban or near-rural areas is occurring rapidly with little concern for water planning. The local effects of increases in runoff quantity and pollution as well as the regional effects of development are being largely ignored, especially in the case of stormwater runoff. Local conservation groups and planning associations are attempting to sensibly control development and need assistance in quantifying both local and regional impacts.

Upper Raritan

The Upper Raritan Watershed Association (URWA) is concerned about the effects upon the Upper Raritan River of a proposed AT&T administrative office building. The building is planned for a 50 acre site in Far Hills, New Jersey, and includes stormwater drains for buildings and parking lots, and, a stormwater retention basin. The URWA is concerned that the retention basin has been improperly sized and that moderate storms could have disastrous effects on the stream and community below the site. All necessary data collection, except site discharge, has been collected and reduced to SWMM input. Modeling is planned for the site under natural cover initially, and then with the AT&T offices and parking lots imposed upon the natural cover. A study of varying intensity storms could determine the maximum storm which the retention basin can contain, as well as quality constituents of stormwater runoff as it is drained to the Upper Raritan.

Sandy Run

Sandy Run in Abington, Pennsylvania, is a tributary of the Wissahickon Creek and has been chosen by the Wissahickon Watershed Association (WWA) as a model subbasin for the Wissahickon Watershed. Six separate storm sewers drain most of this subbasin. Modeling of this basin as it presently exists, followed by extrapolation to future development, will form the basis for a land-use plan for similar watersheds in the Wissahickon basin. To date, data on one of the areas drained by one of the storm sewers has been collected and examined. Discretization of the basin has been done and data on sewers collected. Measurements of rainfall and discharge for this area are in planning stages in the WWA.

Schoeneke Creek

The Schoeneke Creek drains most of the city of Nazareth, Pennsylvania, and empties into the Bushkill River. Lafayette College in Easton, Pennsylvania has done several studies on the Bushkill and its upper tributaries and has routinely collected all necessary data for SWMM modeling except continuous quantity and quality of discharge. A heavy suspended sediment loading is introduced to the Bushkill through the Schoeneke and represents the first pollution of the Bushkill. This basin is especially interesting as it represents the edge of development in the area. The resources of both the Chemistry and Civil Engineering Departments at Lafayette College are also available for testing. Collection of required data is in the planning stage in this basin.

Rocky Run

The Rocky Run in Lima, Pennsylvania, is a small stream that has been heavily affected by development at the Penn State Extension at Lima. A large parking lot was built at the headwaters of this stream. Over the past year, the increased runoff from the parking lot has substantially altered both the size and channel of the Rocky Run. Severe erosion and undercutting have destroyed trees and has resulted in heavy buildup of rubble in downstream areas. These effects have interested both local residents and several faculty members at the Penn State Campus. A combined program of data collection between the Rocky Run Watershed Association (RRWA) and faculty at the Penn State Extension is planned to provide data required for SWMM modeling of the entire Rocky Run Basin. The primary purpose of this modeling is to avoid future damage and form the basis of a stormwater plan for the area. All required data for SWMM modeling has been collected or is easily accessible except for continuous monitoring of quality and quantity of discharge.

In each of the cases above, SWMM modeling is desired as a beginning step in sensible stormwater planning. All users will require moderate assistance in finalizing data collection programs and in the early stages of modeling.

MODELING ASSISTANCE

In the Stony Brook basin in New Jersey and in Binghamton, New York, discussions with parties interested in SWMM modeling uncovered required SWMM data including continuous discharge monitoring. No quality data were available.

Each application was carried through to initial verification studies. These modeling efforts have resulted in, at least, a partial solution to the existing stormwater pollution problem. In the sections that follow, a complete description of the application site, the application of SWMM, results of the modeling, and future use of SWMM are given.

Binghamton, New York

The city of Binghamton, New York, supports a population of 120,000. The storm sewer system is partially combined with sanitary sewers, has heavy infiltration in older sewers near the Susquehanna River, and allows direct overflows of combined sewage at surcharge points along the river. A new treatment plant with 30MGD capacity handles a daily dry-weather flow (DWF) of 15MGD regularly and routes combined sewage overflows directly to the river even during small storms (Figure 4).

The consulting engineering and design firm of Quirk, Lawler and Matusky (QLM) has been contracted by the U.S. Army Corps of Engineers and the City of Binghamton to produce a plan that would alleviate combined sewage overflows. A limited budget precludes rebuilding and separating major sections of the combined sewer. Possible alternatives include increases in treatment plant capacity to alleviate plant surcharging and storage of combined sewage during storm periods to eliminate interceptor surchages. Rebuilding of sewers is a possibility in areas known to be subject to heavy infiltration.

Study Objectives--

Discussions with engineers at QLM indicated a need for establishment of baseline data on surcharging. Of key interest was the quantity and quality (BOD) as well as location of sewer overflows into the Susquehanna River. Treatment plant records included continuous quantity monitoring at the plant, but no measure of surcharging was made at overflow points. In addition, neither the location nor the relative size of overflow points was well characterized. It was decided that SWMM would be used to locate and determine the quantity and quality of overflows as the first step toward water resource planning for the City of Binghamton.

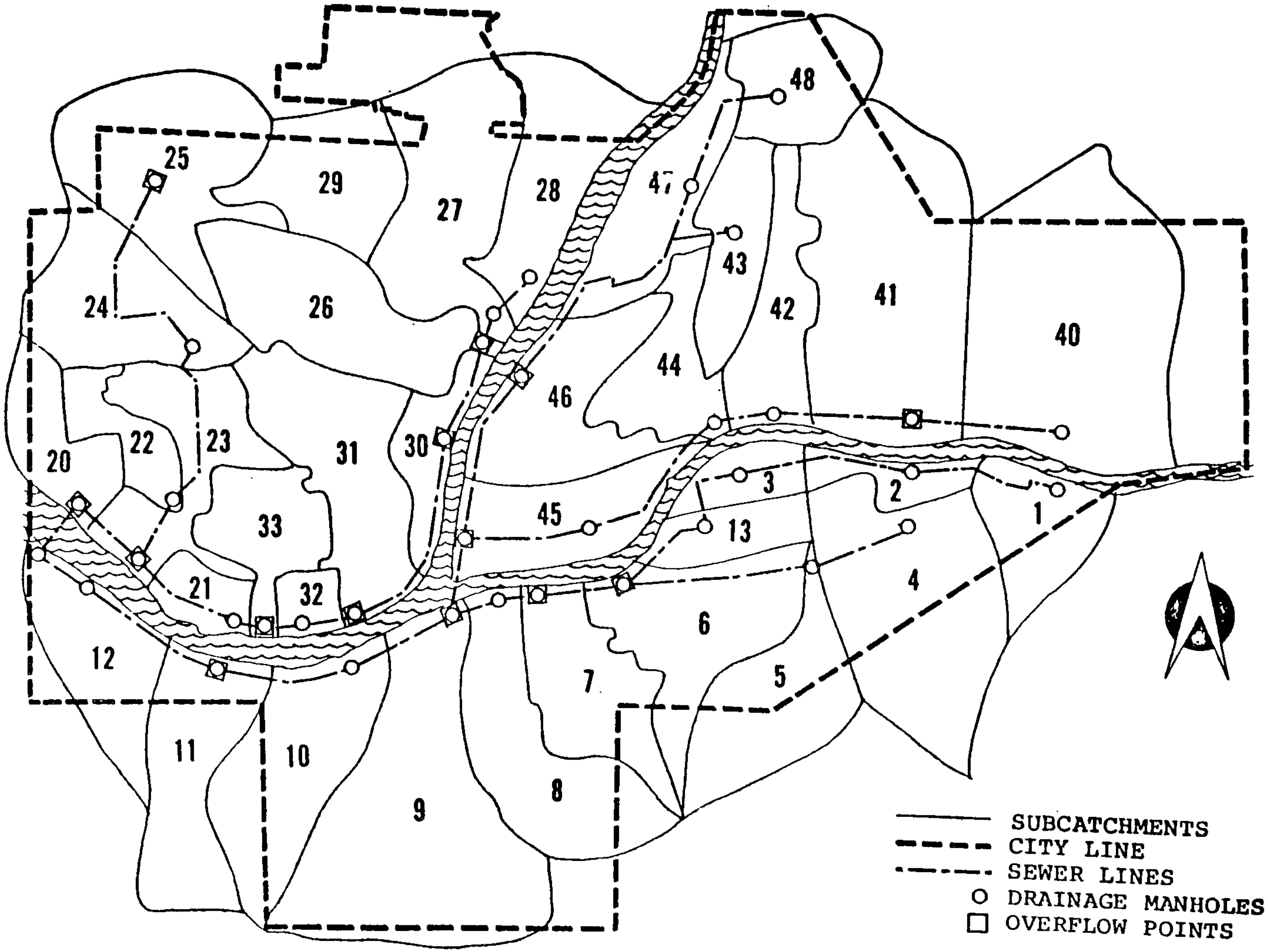

Figure 4. BINGHAMTON, NEW YORK - SWMM DISCRETIZATION

Study Development--

A plan for quantifying the surcharge problem in Binghamton using SWMM was developed. The RUNOFF portion of SWMM was used to generate inputs to the major sewer lines. Only areas drained by combined sewers were considered. Accumulated dust and dirt as well as sanitary flows from the entire city were also modeled. The TRANSPORT section of SWMM was used to route combined sewage to the treatment plant. At sewer surcharge points, SWMM was modified to route surcharges directly to the Susquehanna River rather than storing for later drainage. With these surcharges removed from the sewer system, correlation of treatment plant flows could be attempted. Primary outputs were: (1) quantity and quality (BOD) of flow at treatment plant, and (2) location, quantity, and quality (BOD) of sewer overflows.

Storm Inputs--

Two storms were chosen for verification studies. The first storm totaled 1.25 in. of rainfall which fell on October 30, 1973, over a period of 24 hrs. The second totaled .25 in. and occurred October 2, 1973, over 2 hrs. In both storms, hourly rainfall data from the U.S. Department of Commerce were interpolated to 15 minute intervals. All calculations were made using 15-minute time steps. Input hydrographs are given in Figures 5 and 6.

Runoff Block--

The city of Binghamton was discretized into 36 subcatchments as shown in Figure 4 using topographic maps and aerial photographs. Areas drained by separate storm sewers were delineated, resulting in combined connected subcatchments varying from 17.4 acres to 377.8 acres in size. Gutters and small pipes were ignored. Only overland flow was used to route stormwater to the outlet manhole for each subcatchment. Imperviousness of connected subcatchments was established from aerial photographs resulting in variations of 12 percent to 80 percent imperviousness. Slopes were calculated from topographic maps. Default values were taken for Manning's coefficients, detention depths, and infiltration constants. Subcatchment data are given in Table 7. Land-use types were determined by examination of aerial photographs. For each subarea, curb lengths were estimated using the method of Graham et al.[10]

It was determined by these researchers that:

$$C=423.7-420.8\ (.8797)^{P}$$

Where: C=specific curb length (ft/acre)

P=population per acre (1)

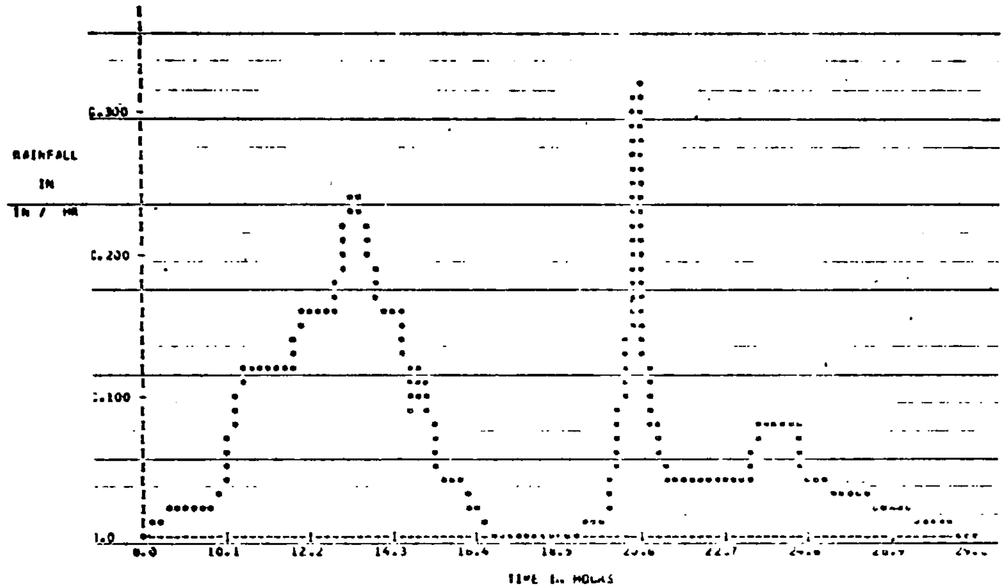

Figure 5. BINGHAMTON, NEW YORK - STORM 1-HYETOGRAPH

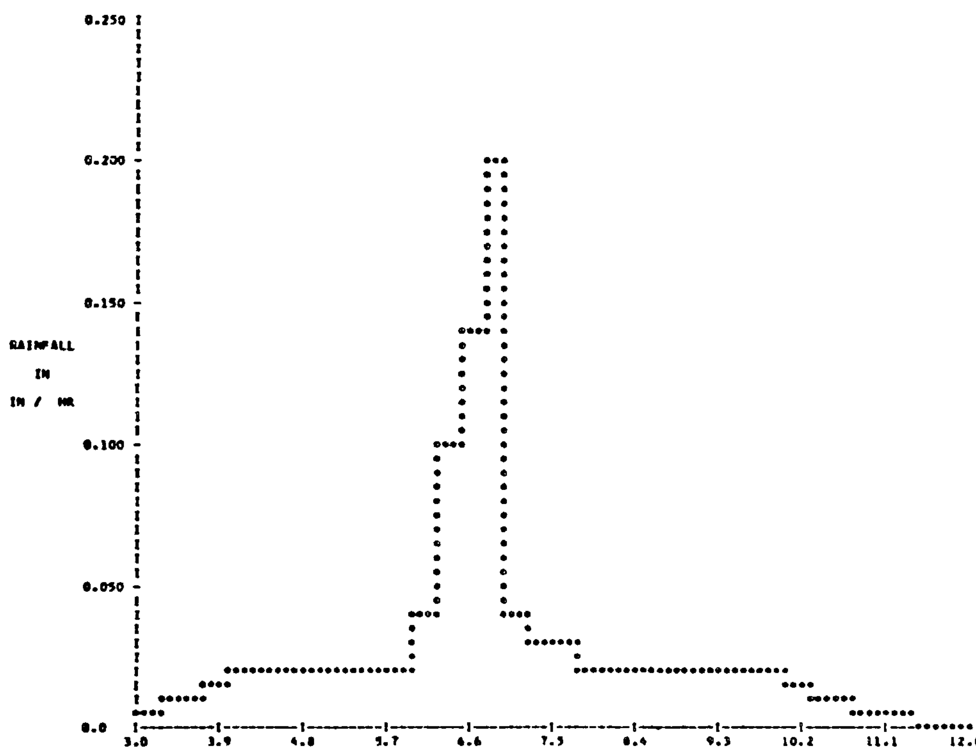

Figure 6. BINGHAMTON, NEW YORK - STORM 2-HYETOGRAPH

Table 7. BINGHAMTON, NEW YORK - SUBCATCHMENT DATA

SUBAREA NUMBER	GUTTER OR MANHOLE	WIDTH (FT)	AREA (AC)	PERCENT IMPERV.	SLOPE (FT/FT)	RESISTANCE FACTOR IMPERV.	RESISTANCE FACTOR PERV.	SURFACE STORAGE(IN) IMPERV.	SURFACE STORAGE(IN) PERV.	INFILTRATION RATE(IN/HR) MAXIMUM	INFILTRATION RATE(IN/HR) MINIMUM	INFILTRATION RATE(IN/HR) DECAY RATE	GAGE NO
1	51	2355.	83.5	28.0	0.1330	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
2	52	3335.	47.6	15.0	0.0710	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
3	53	2000.	36.7	30.0	0.0120	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
4	54	3335.	101.6	33.0	0.0900	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
5	55	3000.	19.5	12.0	0.0380	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
6	56	4000.	203.2	25.0	0.2250	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
7	57	4000.	95.2	35.0	0.0190	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
13	63	2000.	17.4	70.0	0.0410	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
8	58	4659.	142.6	30.0	0.0560	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
9	59	6667.	164.0	20.0	0.0430	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
10	60	2663.	229.4	13.0	0.2500	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
11	61	2000.	25.1	13.0	0.1390	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
12	62	2668.	82.7	20.0	0.0630	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
20	70	2000.	46.2	40.0	0.0480	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
21	71	2000.	27.4	20.0	0.0140	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
22	72	3335.	72.1	50.0	0.0130	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
23	73	5336.	166.3	40.0	0.0230	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
24	74	3335.	51.8	50.0	0.0270	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
25	75	2668.	211.9	50.0	0.0520	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
26	76	6000.	120.4	80.0	0.0260	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
27	77	4000.	208.8	30.0	0.0560	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
28	78	4000.	187.0	30.0	0.0830	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
29	79	2668.	65.9	20.0	0.0630	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
30	80	4659.	54.4	80.0	0.0190	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
31	81	6000.	256.9	40.0	0.0600	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
32	82	1668.	19.0	40.0	0.0400	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
33	83	3669.	86.1	60.0	0.0390	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
40	90	6000.	377.8	20.0	0.0600	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
41	91	3335.	288.4	60.0	0.0030	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
42	92	2000.	134.5	30.0	0.0080	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
43	93	4000.	33.2	40.0	0.0080	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
44	94	2668.	98.1	50.0	0.0010	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
45	95	4336.	124.6	70.0	0.0150	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
46	96	3000.	111.5	80.0	0.0160	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
47	97	7337.	119.4	40.0	0.0140	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1
48	98	2663.	73.1	35.0	0.0140	0.013	0.250	0.062	0.184	3.00	0.52	0.00115	1

TOTAL NUMBER OF SUBCATCHMENTS, 36

TOTAL TRIBUTARY AREA (ACRES), 4184.40

Population densities of each subarea were obtained from census data and specific curb lengths were calculated using formula (1). The RUNOFF portion of SWMM was run for both storms to produce input for TRANSPORT. Sample subcatchment hydrographs are given in Figures 7 and 8.

Transport Block--

The major combined sewers in Binghamton were modeled using the TRANSPORT section of SWMM. A total of 115 sewer elements, including 58 manholes and 57 sewer pipes were included. Shapes, lengths and slopes were obtained from sewer maps for each pipe. Default values were assumed for Manning's coefficients.

The TRANSPORT section of SWMM was altered slightly to route surcharges from the sewer system to the Susquehanna River. In subroutine TRANSPORT, surcharges in each sewer element were set to zero in each time step after printing surcharge quantity. SWMM was relinked with this modification and a LOAD MODULE for use with this project was produced. Engineers in the city of Binghamton estimated total infiltration of 1,500 gpm into the combined sewer. This level was used for all calculations. Using subareas and population densities from RUNOFF, and adding 9 cfs DWF from nearby communities, a total DWF of 25.03 cfs (16.6 MGD) was calculated. This figure correlates well with the measured average DWF of 15MGD. Hourly DWF correction factors were obtained from treatment plant records. Apportioned infiltration, sanitary flows, and total DWF are given in Table 8.

Results--

The TRANSPORT section of SWMM was run using output from RUNOFF as input for both storms. Output hydrographs at the treatment plant are compared to plant records in Figures 9 and 10. Correlation with measurements for the 1.25 in. storm was excellent. However, the smaller storm produced poorer correlation between calculated and observed plant flow. A possible explanation for this poor correlation is that overflow occurs continually at problem points rather than simply during pipe surcharge.

For the large storm, quantity and BOD loads for overflow points are given in Table 9. Locations of overflows are given in Figure 4. For this storm, 29.9 MG of a total runoff of 50.9 MG was discharged directly to the Susquehanna. Of a total BOD load of 25,000 lbs., 16,000 lbs. were discharged directly to the river. Specific quantities of BOD discharge were determined by calculating total BOD load at the manhole upstream of a surcharge point and multiplying this load by:

(total discharge at point/total flow at upstream manhole) = discharge BOD at discharge point.

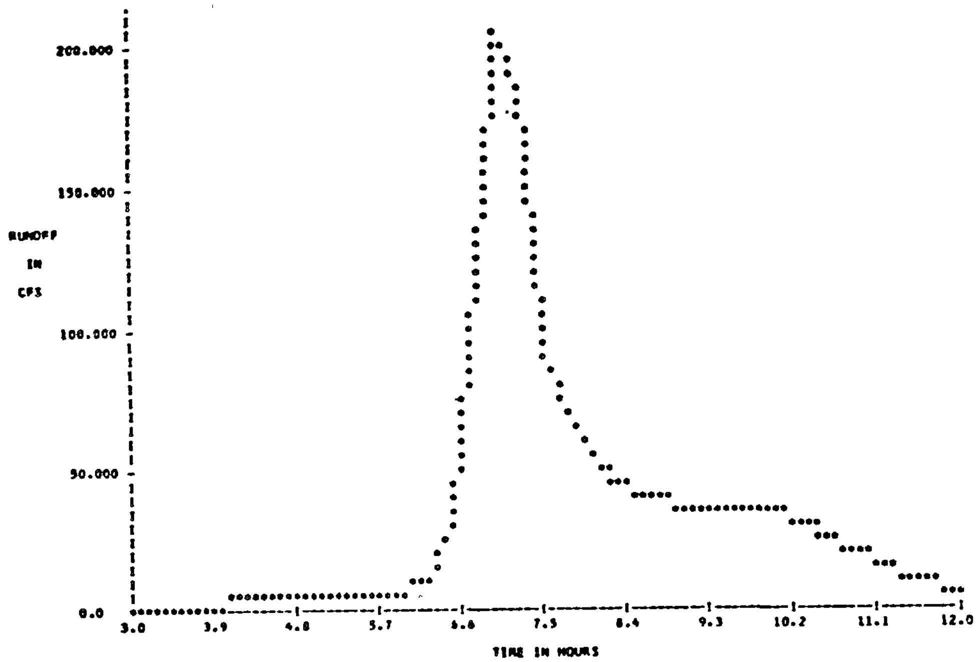

Figure 7. BINGHAMTON, NEW YORK - STORM 1-SUBCATCHMENT 36 HYDROGRAPH

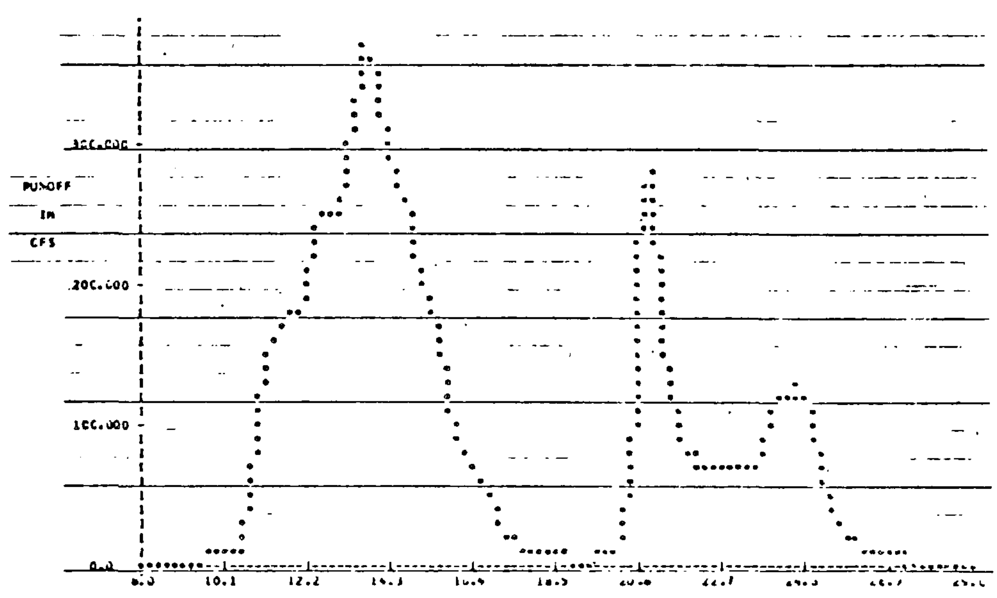

Figure 8. BINGHAMTON, NEW YORK - STORM 2-SUBCATCHMENT 36 HYDROGRAPH

Table 8. BINGHAMTON, NEW YORK - INFILTRATION AND DRY WEATHER FLOW

QUANTITY AND QUALITY OF D W F FOR EACH SUBAREA

ALBOD = 1330.00LBSPERDAY/CFS
ALSS = 1420.00 LBSPERDAY/CFS
ALCOLI = 2.00E+11 MPN/DAY PER CAPITA
ADWF = 9.28 CFS

KNUM	INPUT	DWF + CFS	INFIL = CFS	QQDWF CFS	KLAND	DWBOD LBS/MIN	DWSS LBS/MIN	TOTPOP PERSONS	BODCONC MG/L	SSCONC MG/L	COLIFORMS MPN/100ML
1	51	0.13	0.05	0.17	2	0.11	0.12				
2	52	0.04	0.01	0.05	1	0.03	0.04				
3	53	0.22	0.03	0.30	2	0.20	0.22				
4	54	0.52	0.17	0.71	1	0.47	0.51				
5	55	0.14	0.05	0.19	1	0.13	0.14				
6	56	0.21	0.07	0.20	1	0.19	0.20				
7	57	0.71	0.26	0.97	1	0.64	0.70				
8	58	3.51	1.26	4.77	1	3.17	3.46				
9	59	0.44	0.16	0.60	1	0.40	0.43				
10	60	0.15	0.06	0.21	1	0.14	0.15				
11	61	0.02	0.01	0.03	1	0.02	0.02				
12	62	5.76	2.07	7.83	1	5.20	5.63				
13	63	0.04	0.01	0.05	1	0.04	0.04				
20	70	0.12	0.04	0.17	2	0.11	0.12				
21	71	0.04	0.02	0.06	1	0.04	0.04				
22	72	0.13	0.05	0.20	2	0.13	0.14				
23	73	0.45	0.16	0.62	1	0.41	0.45				
24	74	0.65	0.23	0.88	1	0.59	0.64				
25	75	0.10	0.04	0.14	1	0.09	0.10				
26	76	0.93	0.35	1.33	1	0.88	0.96				
27	77	0.31	0.11	0.42	1	0.28	0.30				
28	78	0.01	0.00	0.02	1	0.01	0.01				
29	79	0.09	0.03	0.12	1	0.08	0.08				
30	80	0.0	0.0	0.0	3	0.0	0.0				
31	81	0.72	0.26	0.97	2	0.65	0.71				
32	82	0.09	0.03	0.13	1	0.08	0.09				
33	83	0.25	0.09	0.35	1	0.23	0.25				
40	90	0.58	0.21	0.79	1	0.52	0.57				
41	91	0.55	0.20	0.74	1	0.49	0.54				
42	92	0.0	0.0	0.0	4	0.0	0.0				
43	93	0.45	0.16	0.62	2	0.41	0.45				
44	94	0.0	0.0	0.0	4	0.0	0.0				
45	95	0.08	0.03	0.11	2	0.07	0.08				
46	96	0.19	0.07	0.26	2	0.17	0.19				
47	97	0.40	0.15	0.55	1	0.36	0.40				
48	98	0.30	0.11	0.41	1	0.27	0.30				
TOTALS		19.43	6.63	25.03		249.22 LBS	272.23 LBS	124464.	177.	194.	4.06E+07

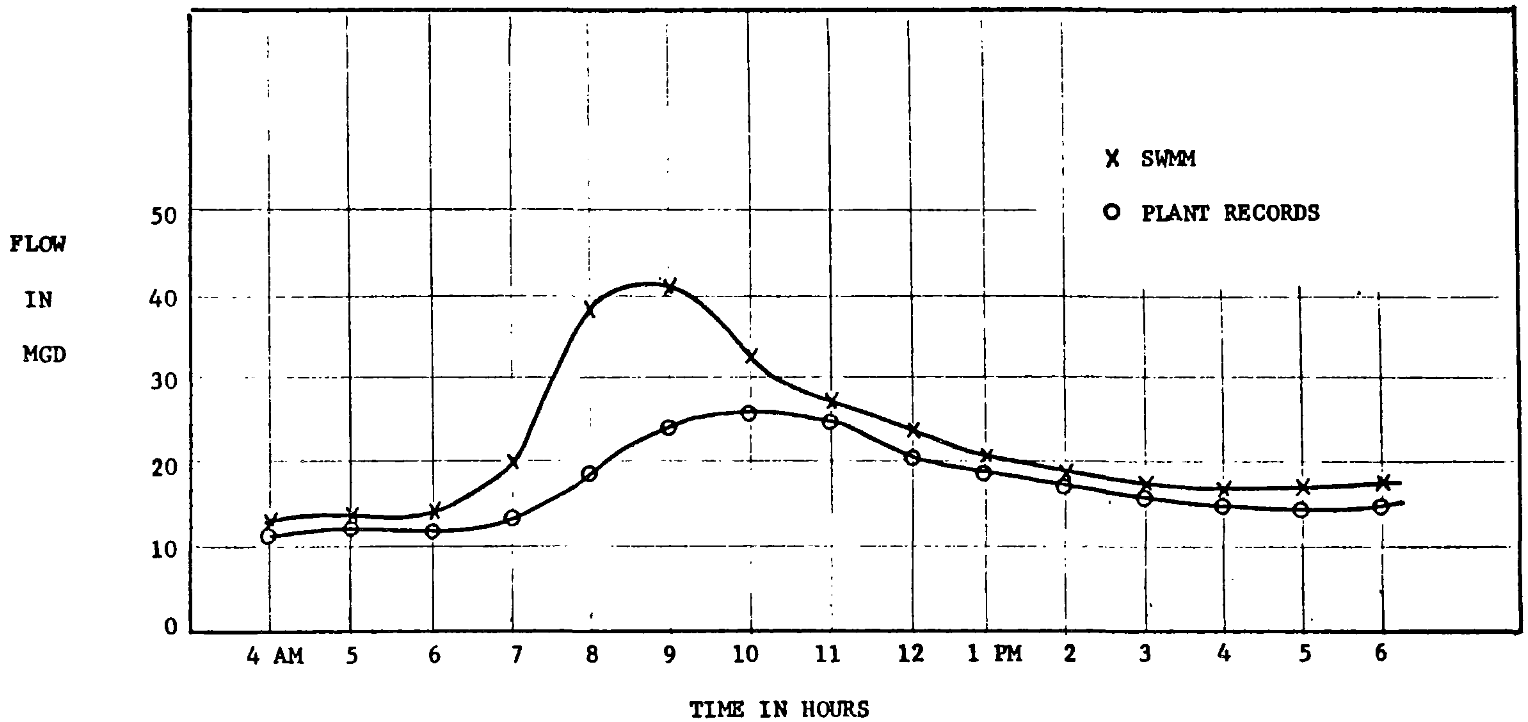

Figure 9. BINGHAMTON, NEW YORK - STORM 1-OUTFALL HYDROGRAPH

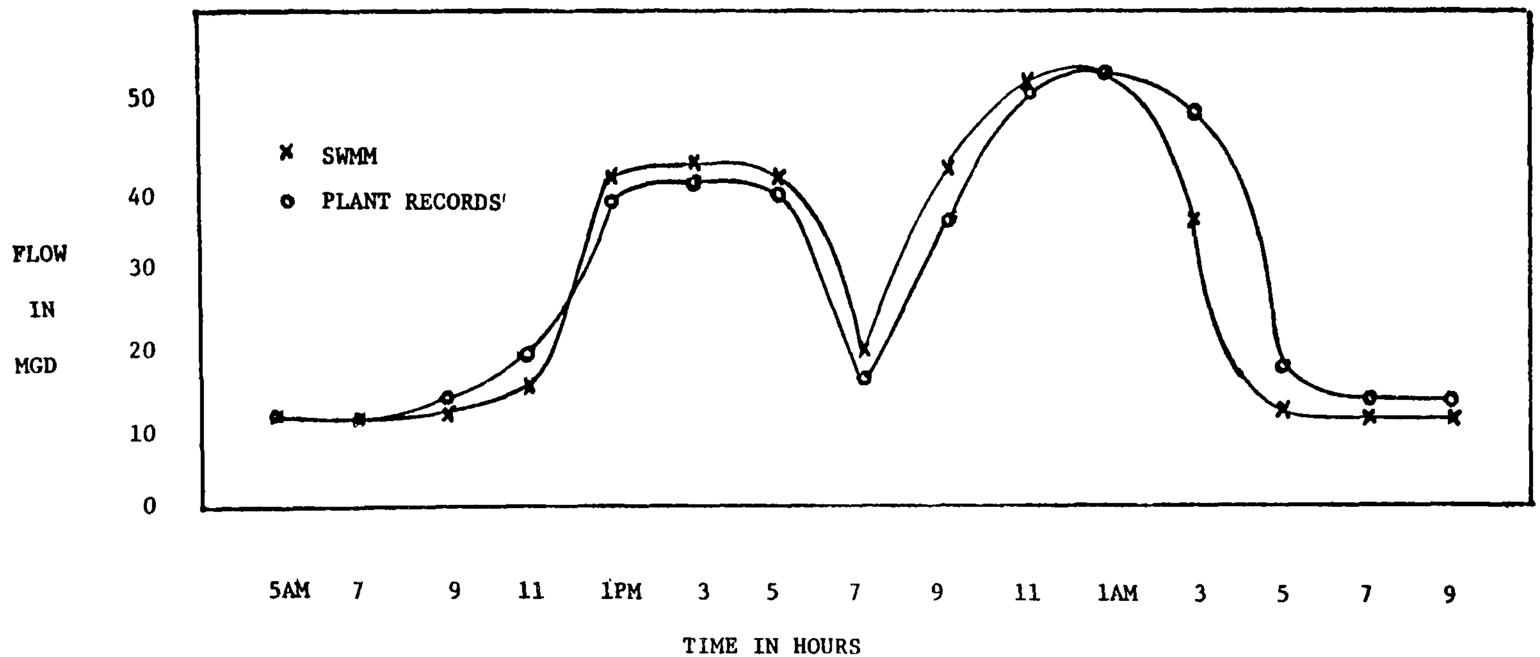

Figure 10. BINGHAMTON, NEW YORK - STORM 2-OUTFALL HYDROGRAPH

Table 9. BINGHAMTON, N. Y. - STORM 2 OVERFLOW QUANTITY AND BOD

Sewer Element No.	Overflow Volume (mil. gal.)	BOD_5 (lbs)
124	3.1	1550
133	3.0	1140
135	2.75	1030
119	2.7	2100
122	2.7	3200
123	2.4	1500
152	1.85	790
114	1.8	1100
153	1.7	730
172	1.6	790
144	1.5	710
125	1.3	150
151	1.15	440
117	1.0	850
Total	29.9	16,000

Although this computational method is not precisely correct, it produced the best possible upper estimate of discharge BOD levels.

Discussion--

The overall result of this study has been to quantify, for the 1.25 in. storm, the location, amount and BOD load of sewer surcharges. This represents the first attempt to determine the severity of the pollution load introduced to the Susquehanna by these combined overflows. The calculated severity of overflow pollution represents a major driving force in establishing programs to alleviate this problem in Binghamton.

SWMM will assist in planning to abate combined sewer overflows in Binghamton. Three pollution abatement schemes have been suggested to solve the Binghamton problem. The first scheme involves construction of external storage devices at each overflow point to store surcharges during wet periods. Existing interceptors will be used to route storm flow to the treatment plant after the storm periods subside. SWMM will be used to size and determine cost of this storage scheme. The second abatement scheme would utilize separate, additional treatment facilities to handle each of the combined overflows, and would be located as near as possible to the overflow points. Treatment methods suggested for scheme II include microstrainers or dissolved air flotation with chemical addition. SWMM will be used to determine removal efficiencies and costs of this scheme. The third abatement scheme considers use of a centralized treatment plant specifically for overflows and an appropriate interceptor system to route overflows to the treatment facility. Again SWMM will be used to predict pollutant removal efficiencies and construction costs.

A model of the receiving waters will also be constructed to determine effects of untreated overflows and of storage or treatment effluents upon the susquehanna River. Measurements of quantity and quality of overflow in Binghamton are presently being made in order to verify the SWMM models which will be built for this planning stage.

Stony Brook

Introduction--

The planning commissions of Princeton, New Jersey and Hopewell Township, New Jersey, have contracted a group of graduate students at the Department of Regional Planning at the University of Pennsylvania to produce a land use plan for the Stony Brook basin in New Jersey. Part of this work was a water resource planning study including quantitative modeling of stormwater flow in the basin. The use of SWMM was investigated to accomplish this modeling.

The Stony Brook Basin is approximately 90 square miles of largely rural land, with the only sizable population center in Princeton, New Jersey. Two gaging stations have been established on the Stony Brook, one at the mouth of Baldwin Creek, a tributary to the Stony Brook, the other on the Stony Brook itself near Princeton (Figure 11).

Study Development--

The general plan of this study was to break the Stony Brook Basin into subbasins, one of which would be Baldwin Creek. The RUNOFF portion of SWMM could then be used to model overland flow in the Baldwin Creek Basin. It was anticipated that some parametization of RUNOFF would be required to produce correlation with gaging results. Once a parametization of RUNOFF for Baldwin Creek was obtained, this modeling method could be extended to the other subbasins of the Stony Brook. Output hydrographs from each subbasin would then serve as input to a RECEIVING WATER model of the Stony Brook itself. The overall model could then be verified by comparisons with the Princeton gaging results. At first it was thought that suspended sediment measurements were available for both Baldwin Creek and Stony Brook. These measurements proved to be only daily recordings. Extrapolation of SWMM quantity results to future development levels could then be accomplished in two ways. First, a general development level in the entire basin or in specific areas of the basin could be modeled by appropriate increases in impervious cover. Effects of this level of development on stormwater quantity and quality could then be assessed. Second, specific development sites could be modeled to determine effects or proposed buildings, parking lots, etc.

Storm Inputs--

The first step in this application of SWMM was modeling the Baldwin Creek subbasin. To minimize effects of temperature and general ground water conditions, two storms were chosen from roughly the same time of the year - the summer of 1973. The first storm totaled 4.42 in. of rainfall. The ten days prior to this storm were very dry. The second storm (1.83 in. total rainfall) was preceded by a moderately wet ten-day period. It was anticipated that different infiltration-rate parametizations would be required to model these storms. Hourly rainfall data from the National Weather Service were interpolated to 15 minute intervals for each storm. Hyetographs are given in Figures 12 and 13.

Runoff Block--

The RUNOFF portion of SWMM was used to model both overland flow and small-stream flow. In some sections of the subbasin, subcatchments were delineated with two greatly different ground slopes. No stream rose to drain the high slope area so that overland flow occurred from the high slope area to the low slope area before collection by streams

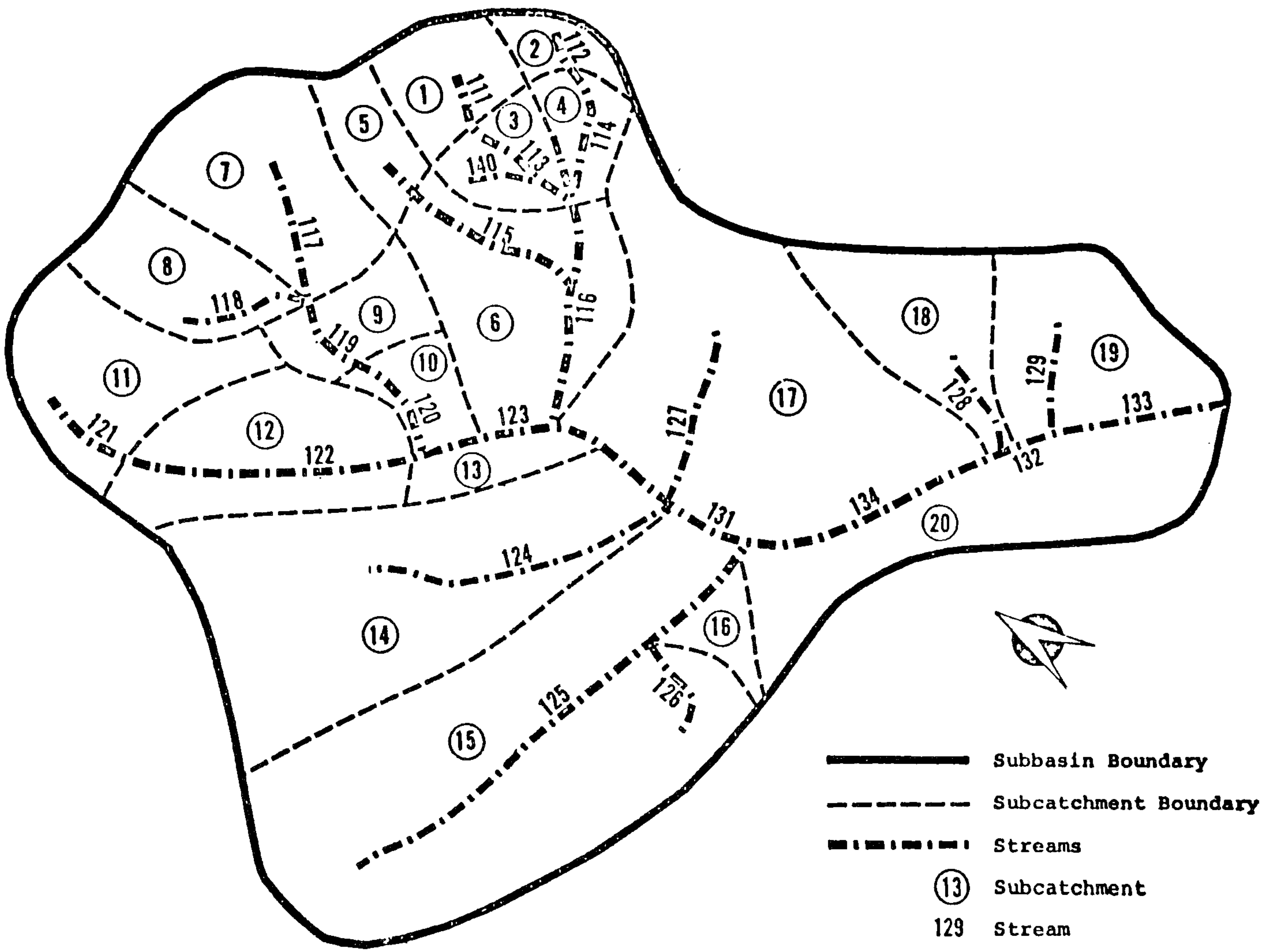

Figure 11. STONY BROOK-BALDWIN CREEK - SUBBASIN

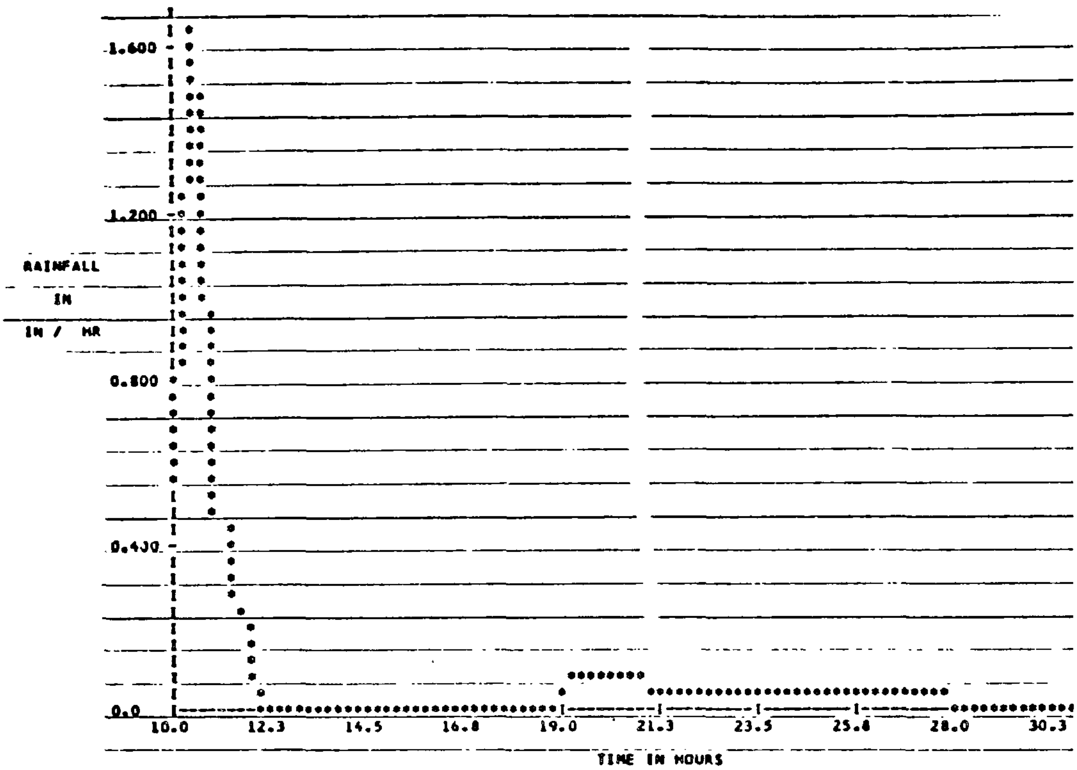

Figure 12. STONY BROOK-BALDWIN CREEK - STORM 1-HYETOGRAPH

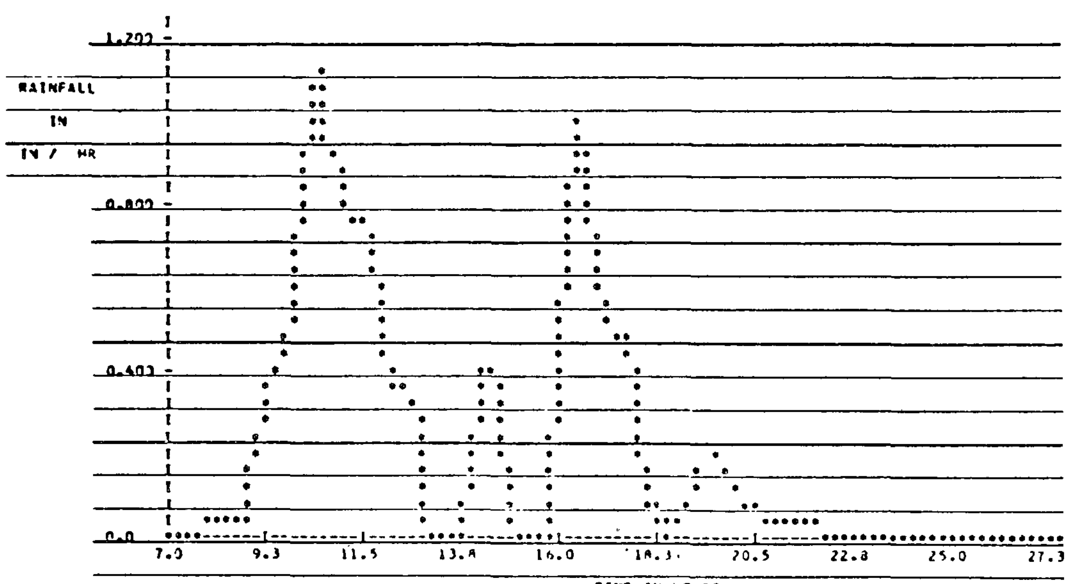

Figure 13. STONY BROOK-BALDWIN CREEK - STORM 2-HYETOGRAPH

began. In order to model this physical situation, the subcatchment was broken into two subcatchments. Runoff from the high-slope area was drained to a "gutter" having the geometry and slope of the low-slope area. Output from this gutter was then combined with runoff from the low slope area. This method effectively accounts for runoff over two widely differing slopes with no collection device; it effectively retards the hydrograph from the high slope area. Small streams in the Baldwin Creek Basin were treated as idealized channels within RUNOFF block. Overland flows from all subcatchments were combined and routed through channels to the gaging station. The Baldwin Creek Basin was discretized into 20 subcatchments using topographic maps; idealized gutters were utilized to route storm flows. First efforts (1.83 in. total rainfall) with relatively low Manning's coefficients for both subcatchments and streams produced hydrographs which were high in peak discharge and early in peak runoff. Adjustment of Manning's coefficients upwards produced reasonable correlation with gaging results (Figure 14). Default values were kept for infiltration coefficients. Tables 10 and 11 contain subcatchment data for this subbasin. These values for Manning's coefficients were then used to study the other storm. Initial results showed exaggeration of runoff peak. Infiltration constants were varied until good correlation was obtained (Figure 15). The project staff recognized that the parameter sets used to obtain correlation do not necessarily represent the only possibilities. Other combinations of Manning's coefficients and infiltration-rate coefficients could produce good results. The two variables are heavily interconnected since, for example, an increase in Manning's coefficient retains stormwater on land surfaces longer, allowing more time for infiltration. Lacking measurements on infiltration rates for the basin at differing antecedent moisture conditions, these coefficients could only be taken as variables. The results obtained and the method used to obtain them is simply a logical and effective procedure - it works.

Correlations of storm discharge at other times of the year (winter, spring) were very unsuccessful, because of drastic variations in infiltration rates due to groundwater or temperature variations. In addition to a verified model of this subbasin, a healthy regard for the dependence and interdependence of RUNOFF results, roughness coefficients, and infiltration coefficients was obtained.

Discussion--

The best parameterizations for the Baldwin Creek subbasin were extended to the rest of the Stony Brook Basin. Thirty-four separate subbasins were identified and discretized. Outflow hydrographs were generated with RUNOFF block. Outfall hydrographs for all sub-basins in the Stony Brook are available from the authors for further examination.

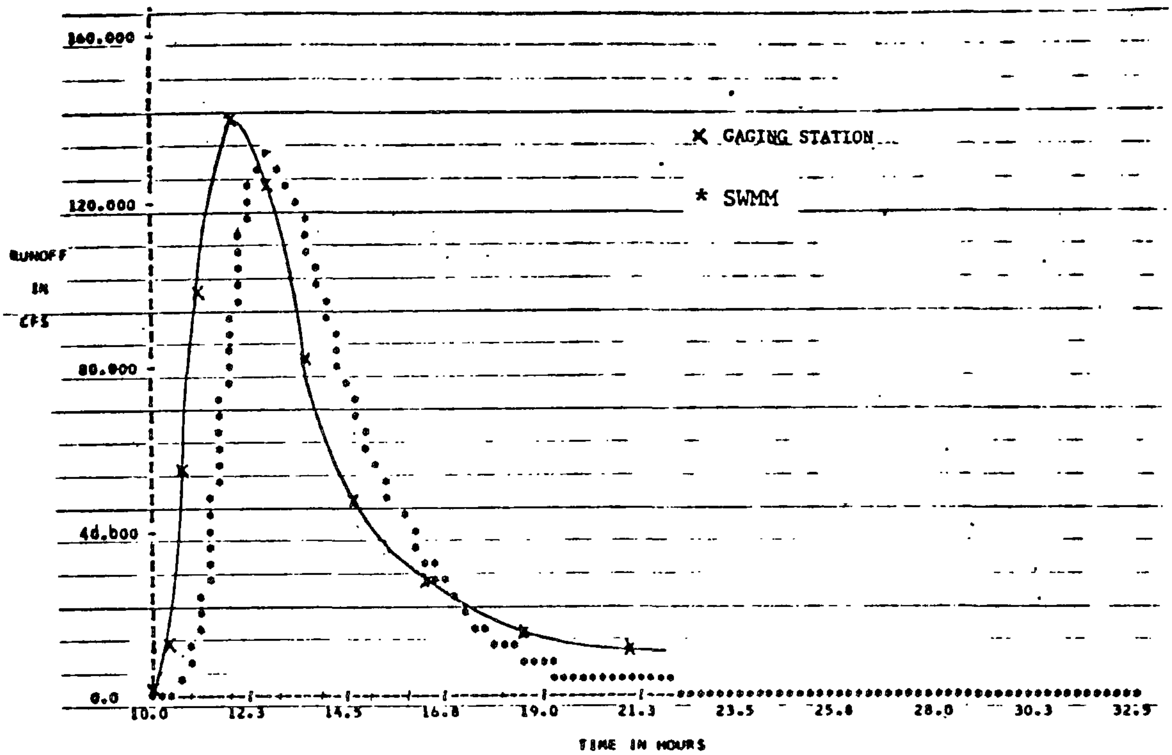

Figure 14. STONY BOOK-BALDWIN CREEK - STORM 1
OUTFALL HYDROGRAPH

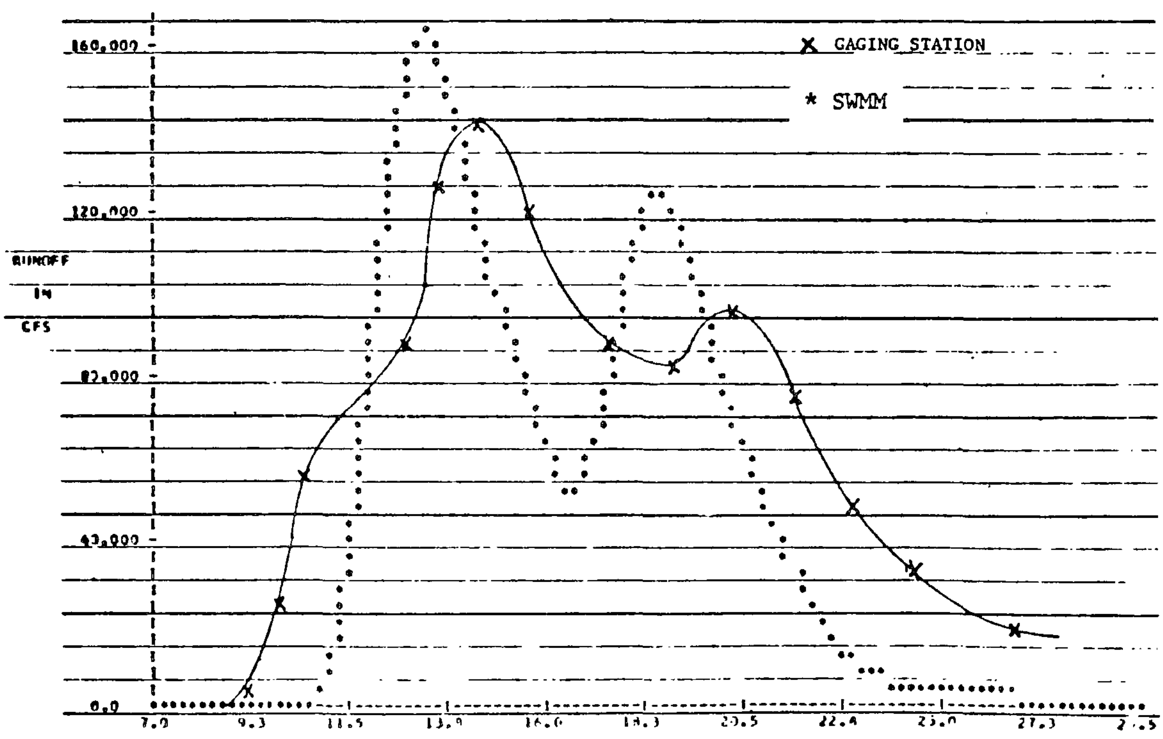

Figure 15. STONY BROOK-BALDWIN CREEK - STORM 2
OUTFALL HYDROGRAPH

Table 10. STONY BROOK-BALDWIN CREEK - SUBCATCHMENT DATA-STORM 1

SUBAREA NUMBER	GUTTER OR MANHOLE	WIDTH (FT)	AREA (AC)	PERCENT IMPERV.	SLOPE (FT/FT)	RESISTANCE FACTOR IMPERV.	RESISTANCE FACTOR PERV.	SURFACE STORAGE(IN) IMPERV.	SURFACE STORAGE(IN) PERV.	INFILTRATION RATE(IN/HR) MAXIMUM	INFILTRATION RATE(IN/HR) MINIMUM	INFILTRATION RATE(IN/HR) DECAY RATE	GAGE NO
1	111	1122.	27.0	10.0	0.1500	0.013	0.700	0.062	0.184	1.50	0.10	0.01000	1
2	112	1056.	15.0	10.0	0.2000	0.013	0.700	0.062	0.184	1.50	0.10	0.01000	1
3	113	1056.	15.0	10.0	0.0400	0.013	0.700	0.062	0.184	1.50	0.10	0.01000	1
4	114	792.	22.0	10.0	0.0700	0.013	0.700	0.062	0.184	1.50	0.10	0.01000	1
5	115	792.	25.0	10.0	0.1500	0.013	0.600	0.062	0.184	1.50	0.10	0.01000	1
6	116	1980.	101.0	10.0	0.0300	0.013	0.500	0.062	0.184	1.50	0.10	0.01000	1
7	117	1452.	81.0	10.0	0.1300	0.013	0.700	0.062	0.184	1.50	0.10	0.01000	1
8	118	1056.	50.0	10.0	0.1300	0.013	0.600	0.062	0.184	1.50	0.10	0.01000	1
9	119	1452.	9.0	10.0	0.0700	0.013	0.400	0.062	0.184	1.50	0.10	0.01000	1
10	120	924.	24.0	10.0	0.0400	0.013	0.600	0.062	0.184	1.50	0.10	0.01000	1
11	121	1848.	20.0	10.0	0.0900	0.013	0.500	0.062	0.184	1.50	0.10	0.01000	1
12	122	1452.	72.0	10.0	0.0600	0.013	0.500	0.062	0.184	1.50	0.10	0.01000	1
13	123	396.	87.0	10.0	0.0300	0.013	0.700	0.062	0.184	1.50	0.10	0.01000	1
14	124	1716.	17.5	10.0	0.0400	0.013	0.300	0.062	0.184	1.50	0.10	0.01000	1
15	125	2376.	276.0	10.0	0.0500	0.013	0.500	0.062	0.184	1.50	0.10	0.01000	1
16	126	924.	21.0	10.0	0.0700	0.013	0.700	0.062	0.184	1.50	0.10	0.01000	1
17	127	3564.	268.0	10.0	0.0400	0.013	0.500	0.062	0.184	1.50	0.10	0.01000	1
18	128	1452.	65.0	10.0	0.0300	0.013	0.560	0.062	0.184	1.50	0.10	0.01000	1
19	129	2112.	60.0	10.0	0.0300	0.013	0.460	0.062	0.184	1.50	0.10	0.01000	1
20	134	1056.	128.0	10.0	0.0800	0.013	0.700	0.062	0.184	1.50	0.10	0.01000	1
21	135	924.	88.0	10.0	0.0600	0.013	0.540	0.062	0.184	1.50	0.10	0.01000	1

Table 11. STONY BROOK-BALDWIN CREEK - SUBCATCHMENT DATA-STORM 2

SUBAREA NUMBER	GUTTER OR MANHOLE	WIDTH (FT)	AREA (AC)	PERCENT IMPERV.	SLOPE (FT/FT)	RESISTANCE FACTOR IMPERV.	RESISTANCE FACTOR PERV.	SURFACE STORAGE(IN) IMPERV.	SURFACE STORAGE(IN) PERV.	INFILTRATION RATE(IN/HR) MAXIMUM	INFILTRATION RATE(IN/HR) MINIMUM	INFILTRATION RATE(IN/HR) DECAY RATE	GAGE NO
1	111	1122.	27.0	0.0	0.1500	0.013	0.700	0.062	0.184	1.50	0.25	0.00115	1
2	112	1056.	15.0	0.0	0.2000	0.013	0.700	0.062	0.184	1.50	0.25	0.00115	1
3	113	1056.	15.0	0.0	0.0400	0.013	0.700	0.062	0.184	1.50	0.25	0.00115	1
4	114	792.	22.0	0.0	0.0700	0.013	0.700	0.062	0.184	1.50	0.25	0.00115	1
5	115	792.	25.0	0.0	0.1500	0.013	0.600	0.062	0.184	1.50	0.25	0.00115	1
6	116	1980.	101.0	0.0	0.0300	0.013	0.500	0.062	0.184	1.50	0.25	0.00115	1
7	117	1452.	81.0	0.0	0.1300	0.013	0.700	0.062	0.184	1.50	0.25	0.00115	1
8	118	1056.	50.0	0.0	0.1300	0.013	0.600	0.062	0.184	1.50	0.25	0.00115	1
9	119	1452.	9.0	0.0	0.0700	0.013	0.400	0.062	0.184	1.50	0.25	0.00115	1
10	120	924.	24.0	0.0	0.0400	0.013	0.600	0.062	0.184	1.50	0.25	0.00115	1
11	121	1848.	20.0	0.0	0.0900	0.013	0.500	0.062	0.184	1.50	0.25	0.00115	1
12	122	1452.	72.0	0.0	0.0600	0.013	0.500	0.062	0.184	1.50	0.25	0.00115	1
13	123	396.	87.0	0.0	0.0300	0.013	0.700	0.062	0.184	1.50	0.25	0.00115	1
14	124	1716.	17.5	0.0	0.0400	0.013	0.300	0.062	0.184	1.50	0.25	0.00115	1
15	125	2376.	276.0	0.0	0.0500	0.013	0.500	0.062	0.184	1.50	0.25	0.00115	1
16	126	924.	21.0	0.0	0.0700	0.013	0.700	0.062	0.184	1.50	0.25	0.00115	1
17	127	3564.	268.0	0.0	0.0400	0.013	0.500	0.062	0.184	1.50	0.25	0.00115	1
18	128	1452.	65.0	0.0	0.0300	0.013	0.560	0.062	0.184	1.50	0.25	0.00115	1
19	129	2112.	60.0	0.0	0.0300	0.013	0.460	0.062	0.184	1.50	0.25	0.00115	1
20	134	1056.	128.0	0.0	0.0800	0.013	0.700	0.062	0.184	1.50	0.25	0.00115	1

A model of the Stony Brook main stem was constructed with junctions located at subbasin outflows and channels connecting junctions. Attempts to run the quantity sections of RECEIVE block using hydrograph inputs have been thwarted, however, by instabilities resulting from short channel lengths and relatively long time steps. The standard fixup in SWMM for this instability is to increase channel length. This modification is impossible in this case because of the fixed junction location. Presently, changes in time-step size and SWMM print-out techniques are being investigated to alleviate or "work around" this problem.

Once the Stony Brook model is completed and verified with Princeton gaging results, the planning commissions in the Stony Brook Basin will be given a description of the model, its results, and its future uses. They will then decide whether to use the model in future water resource planning.

The work group at the University of Pennsylvania will strongly recommend continued model use. Technical assistance will be required both to extend the model to future development levels and to refine the model, especially in the Princeton area.

Wingohocking

EPA provided the Science Center with rainfall and runoff data for a series of sixteen storms which fell on the Wingohocking basin of Philadelphia, Pennsylvania between 1964 and 1968. Data from ten of these storms was used to test SWMM and to provide experience in SWMM modeling to Science Center personnel.

Storm Selection--

Of the sixteen storms for which rainfall and runoff data were provided, two had rainfall input for only one of the recording gages in the watershed, six storms had some combination of two or three of the four accessible gages, and eight had data for all four gages. In order to use the storms with two or three gages, reapportionment of the Thiessen polygons[7] used to assign rainfall to subcatchments would be required. Therefore, the ten storms with either data from one or all four gages were included in this study. Rainfall data was then reduced to the SWMM input format in preparation for execution of RUNOFF block (Refer to p. 9).

Runoff Block--

In order to apply the RUNOFF block to the rainfall data, the Wingohocking basin was discretized by the same method used in Reference 6. A brief investigation was made into a discretization scheme developed in a test of the British Road Research Laboratory (RRL) method[8] but this proved to be too fine in detail, resulting in too many sub-areas and sewer elements for present SWMM matrix dimensions. Since the only runoff data available was taken at the sewer outfall, no correlation of intermediate runoff results was possible other than the final results of TRANSPORT.

Transport Block--

In a manner analogous to that used in RUNOFF block calculations, the sewer system for the Wingohocking basin was modeled exactly as in Reference 6. Input from RUNOFF block was routed through this sewer system, resulting in the outfall graphs in Figures 16-21. On the same graphs is given the time-history of actual runoff as obtained from the Philadelphia Water Department[9]. These runoff results are corrected for an upstream dry-weather flow (DWF) interceptor and an estimated DWF of 100 cfs.* Table 12 gives actual and calculated total runoff volume for these studies.

Input data for the first two storms is of poor quality. A single rain gage for a variable storm on a basin as large as Wingohocking is insufficient. The last two storms have runoff data which is suspect. Runoff/rainfall ratios for the last two storms are much higher than the rest of the storms. Discussions with Philadelphia Water Department engineers[9] has substantiated these suspicions. These engineers also feel this data is suspect and suggest ignoring these two storms.

Therefore, although results for two of these four storms are good, SWMM cannot be reasonably expected to produce good correlations with data which may be of low quality.

Results--

SWMM gives uniformly good results for five of the other six storms with calculated runoff tending to be slightly early and slightly larger than reported values (Figures 16-21). The results for Storm #5 stand then as the only poor result which is not easily explicable. It is interesting to note that this storm produced the lowest runoff ratio (0.35) of those studies. Considering quality of data, size of the basin (5400 acres), and the coarseness of the discretization (57 subcatchments, 129 sewer elements), these results are considered to be quite good.

*Estimated DWF by Philadelphia Water Department Engineers, SWMM calculated DWF of approximately 15 cfs.

Another point of interest is the disparity between the rainfall hyetograph used in Reference 6 for the July 3, 1967 storm and that made available to the Science Center for the same storm. A comparison of these two hyetographs (Figures 22, 23) shows they are similar but not identical. Tracing this data back to the original recording graphs[9], it was found that the data made available to the Science Center were correct.

Storage Block--

TRANSPORT output from Storm #4 was used as input to the STORAGE block of SWMM. Storm #4 was similar in magnitude to the storm of August 3, 1967, which was studied in Reference 6.

A storage and treatment package similar to that used in SWMM was setup and the pumping rates (700cfs) and start/stop (14ft/9ft) levels in the storage system adjusted to hold the entire storm. Using this package, 51 percent of the BOD, 47 percent of the suspended solids and 19 percent of the coliforms were removed. A minor error in the STORAGE section of SWMM was detected and has been discussed with SWMM programmers at the University of Florida.

Table 12. WINGOHOCKING - SUMMARY OF SWMM TESTING

		VOLUME x 10^6 CU. FT.		
STORM	DATE	SWMM	ACTUAL	% DIFFERENCE
1	4/27/64	13.5	11.6	16
2	4/29/64	10.8	14.1	23
3	11/25/64	19.8	12.7	56
4	8/04/65	14.4	10.3	40
5	10/07/65	14.5	8.2	77
6	7/02/67	18.8	21.7	13
7	7/29/67	16.7	15.2	10
8	8/09/67	17.9	12.5	43
9	7/24/68	22.8	32.0	29
10	8/01/68	15.1	23.1	35

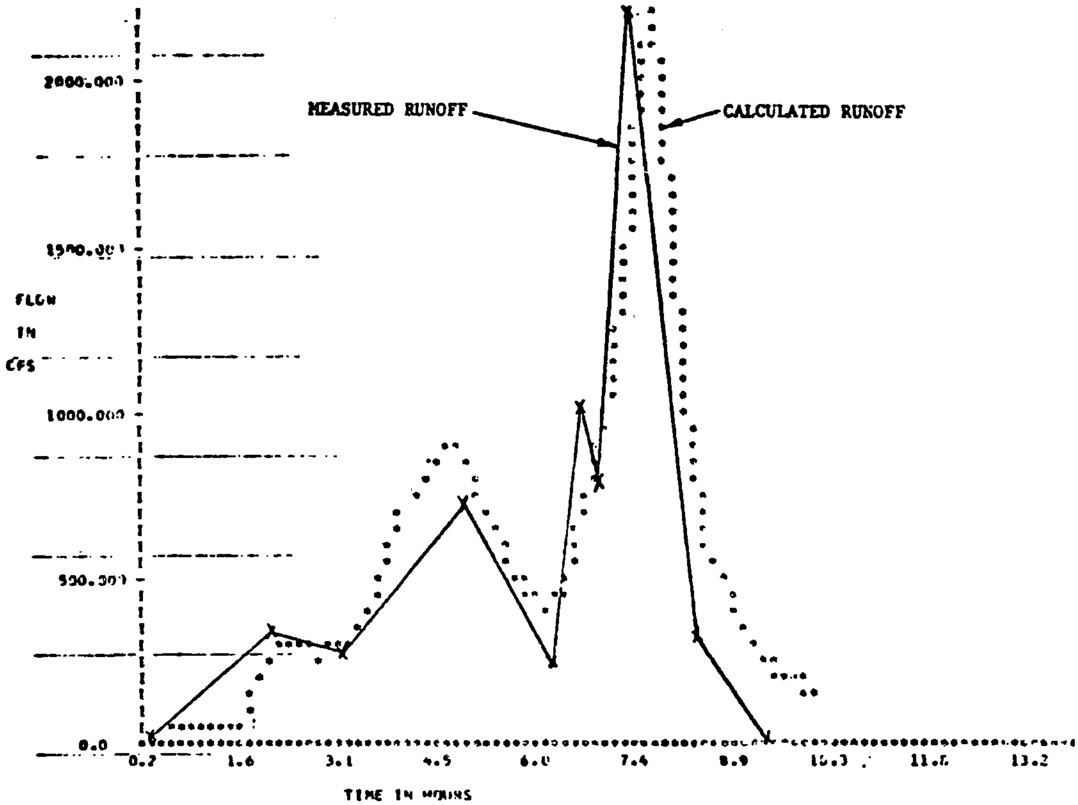

Figure 16. WINGOHOCKING - RUNOFF FOR STORM 3

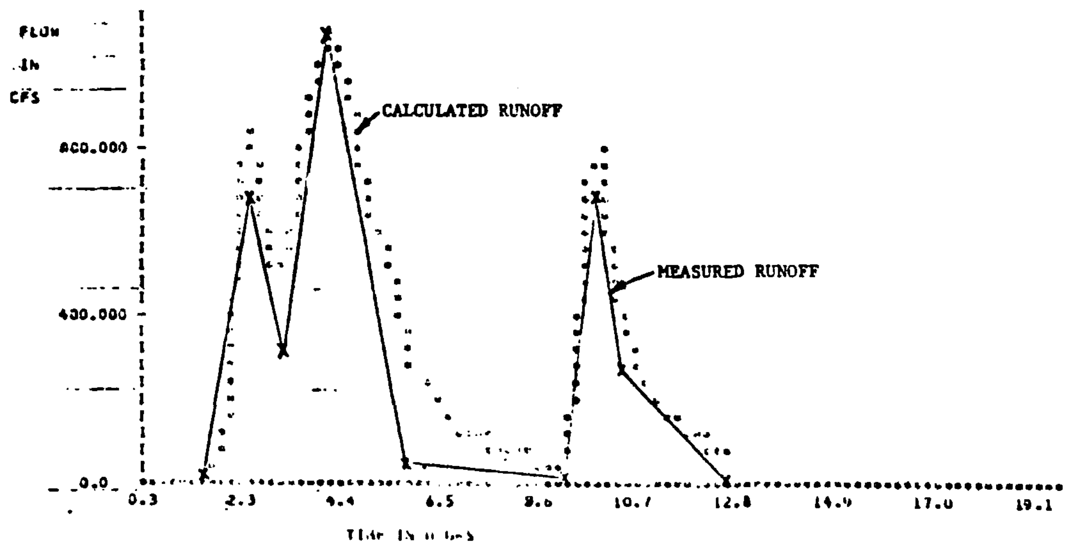

Figure 17. WINGOHOCKING - RUNOFF FOR STORM 4

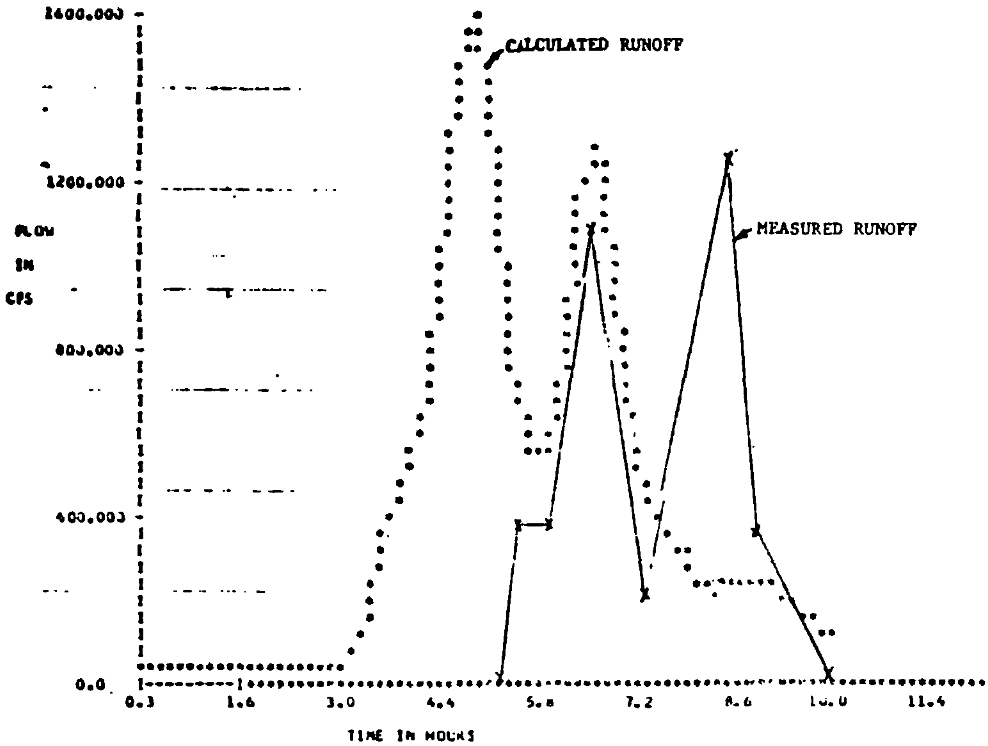

Figure 18. WINGOHOCKING - RUNOFF FOR STORM 5

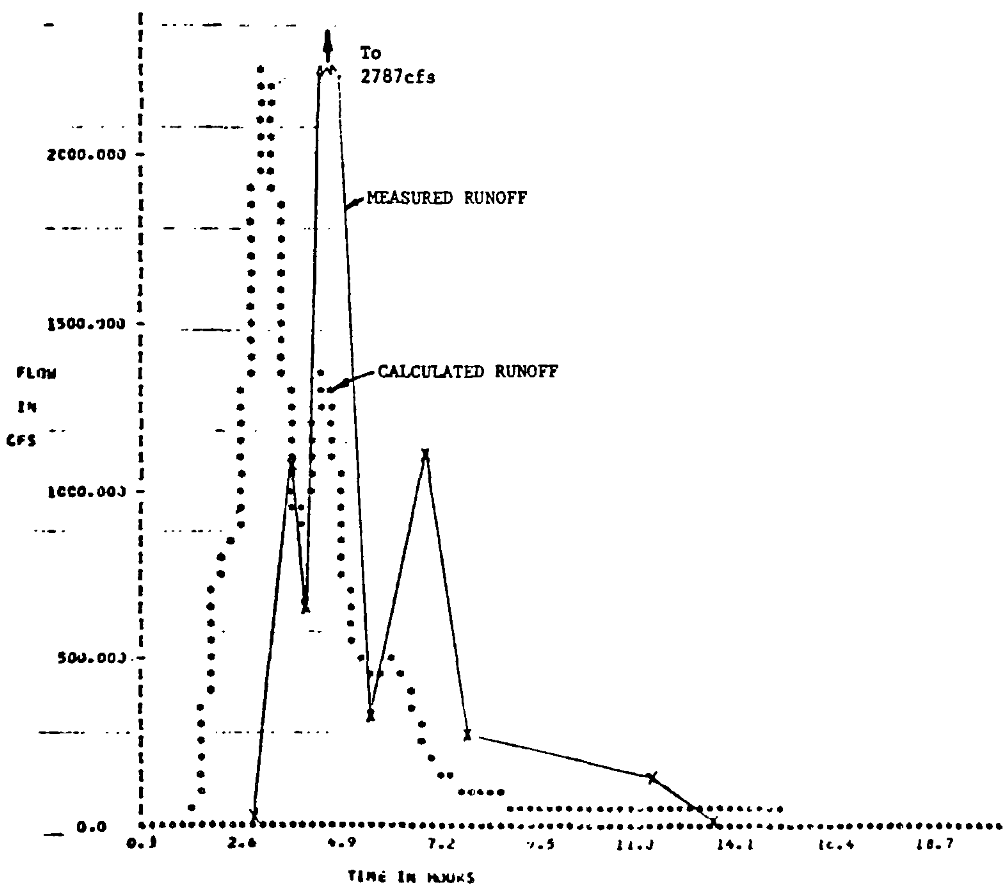

Figure 19. WINGOHOCKING - RUNOFF FOR STORM 6

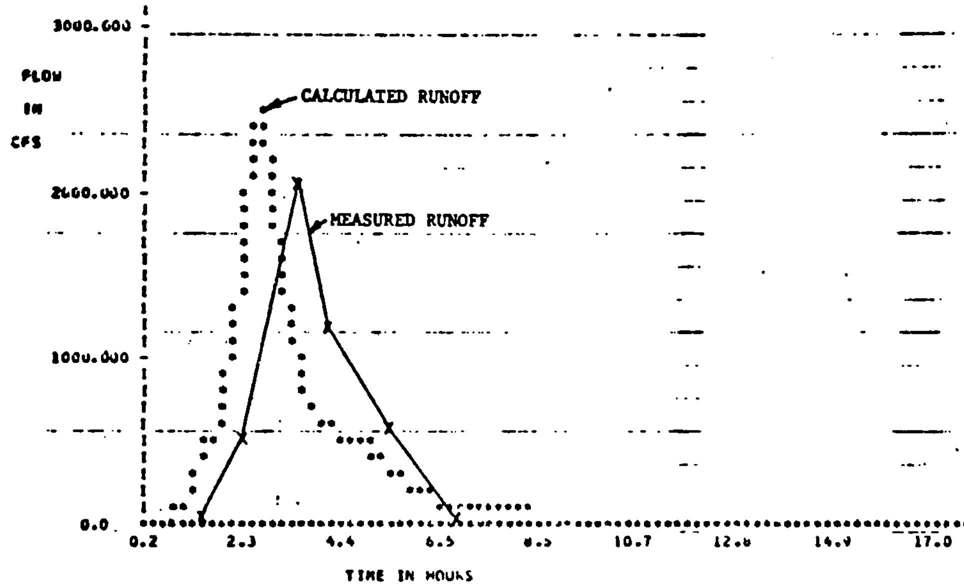

Figure 20. WINGOHOCKING - RUNOFF FOR STORM 7

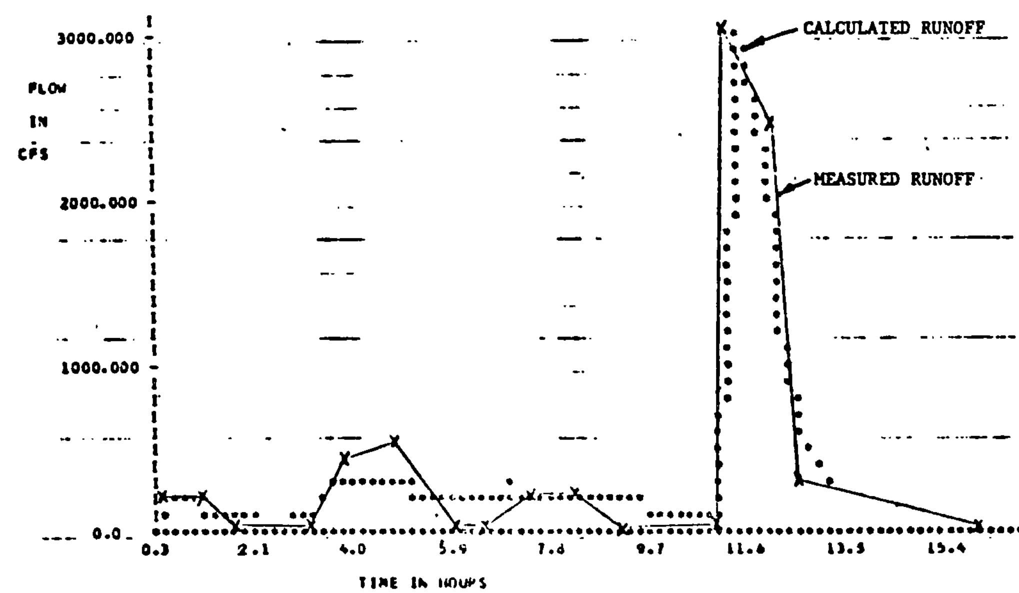

Figure 21. WINGOHOCKING - RUNOFF FOR STORM 8

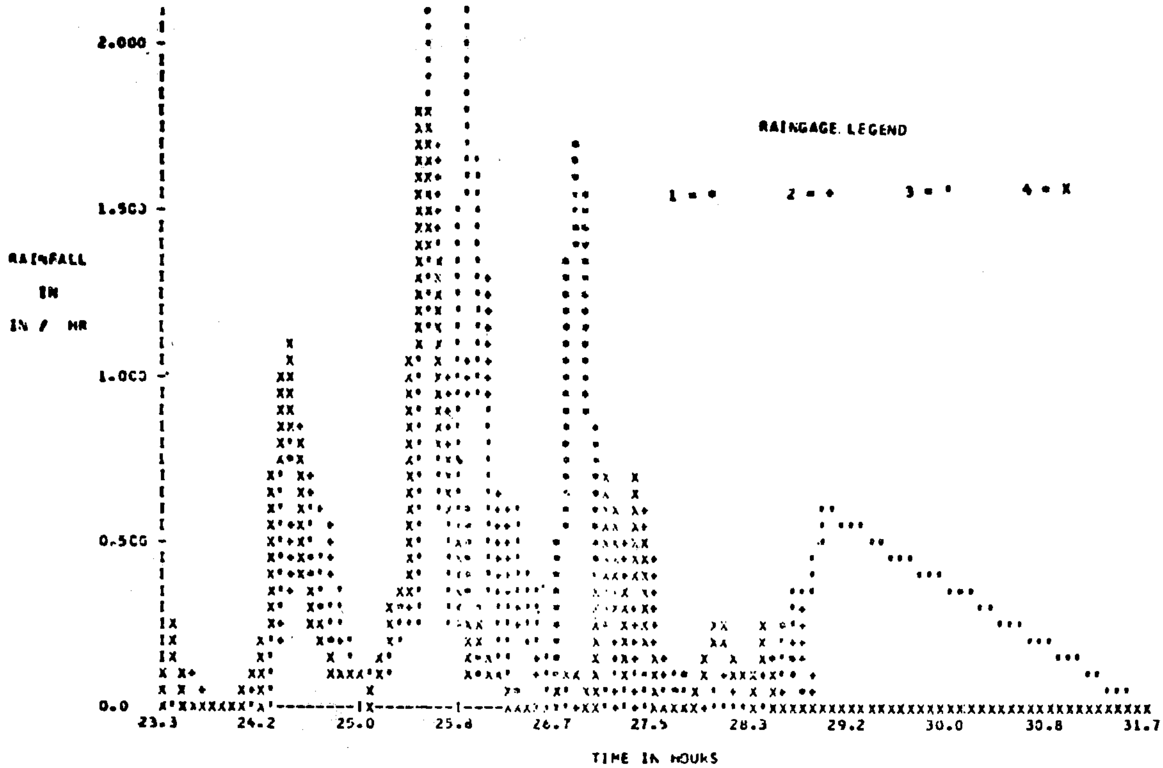

Figure 22. WINGOHOCKING - UCSC HYETOGRAPH FOR STORM 6

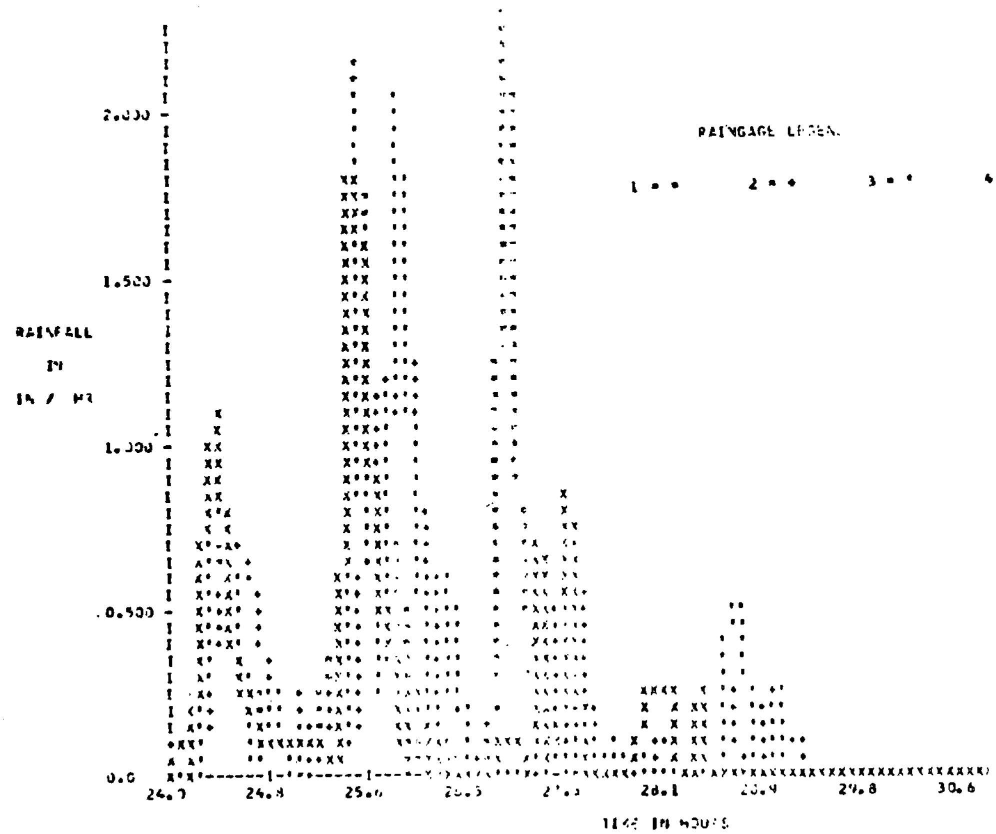

Figure 23. WINGOHOCKING - SWMM HYTEOGRAPH FOR STORM 6 FROM REF. 1

SECTION VII

DISCUSSION

Successful technology transfer should produce use commensurate with the capacities of the particular technology being transferred. Transfer of a high-quality, comprehensive technology must result in wide-spread application by a user community.

The potential SWMM user community includes everyone involved with water planning; including engineering and design firms, government officials at all levels, planning boards, the academic community, environmentalists, and conservationists. In order to utilize SWMM, each type user requires a different mode of support. Sophisticated engineering and design firms with experienced engineering staffs and well-developed computing capabilities should require moderate assistance in only the early phases of SWMM use and should quickly develop in-house expertise in SWMM use. A local planning board or conservationist group would probably need extensive technical assistance.

The dissemination of SWMM is seen then as a process of integrating a program announcing the existence and capabilities of the model with a program of flexible technical assistance. This assistance should, as rapidly as is proper, instruct in use of the model. The end result is optimum use-levels, done with minimum effort, producing a set of users skills commensurate with the abilities of the user group.

There are several important lessons to be learned about SWMM technology transfer from this project. First, a simple but eye-catching document for wide-spread mailings is essential. Several of the target potential-users were contacted in the local area only. All mailings should be expanded geographically to cover a larger region. Second, responses to mailings must bring competent assistance in both managing and technically developing a modeling project. Assistance in defining the problem, relating it to SWMM, and, outlining the capabilities and requirements of SWMM is essential. It appears, so far, that simply mailing a SWMM tape to a potential-user is insufficient support to generate use. Although heavy support is required in the early stages of modeling, effective transfer must also include education to promote user independence.

The EPA grant for this project has resulted in a self-sustaining SWMM dissemination-user assistance program under the UCSC, a non-profit organization, for the benefit of potential SWMM users.

SECTION VIII

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SECTION IX

APPENDIX

Table 13. CONVERSION FACTORS - ENGLISH TO METRIC

English unit	Abbr.	Multiplier	Abbr.	Metric unit
acre	acre	0.405	ha	hectare
acre-foot	acre-ft	1,233.5	cu m	cubic meter
cubic foot	cf	28.32	l	liter
cubic feet per minute	cfm	0.0283	cu m/min	cubic meters per minute
cubic feet per second	cfs	28.32	l/sec	liters per second
cubic inch	cu in.	16.39 0.0164	cu cm l	cubic centimeter liter
cubic yard	cy	0.765 764.6	cu m l	cubic meter liter
degree Fahrenheit	deg F	0.555 (°F-32)	deg C	degree Celsius
feet per minute	fpm	0.00508	m/sec	meters per second
feet per second	fps	0.305	m/sec	meters per second
foot (feet)	ft	0.305	m	meter(s)
gallon(s)	gal.	3.785	l	liter(s)
gallons per acre per day	gad	9.353	l/day/ha	liters per day per hectare
gallons per capita per day	gcd	3.785	l/capita/day	liters per capita per day
gallons per day	gpd	4.381×10^{-5}	l/sec	liters per second
gallons per day per square foot	gpd/sq ft	1.698×10^{-3} 0.283	cu m/hr/sq m cu m/min/ha	cubic meters per hour per square meter cubic meters per minute per hectare
gallons per minute	gpm	0.0631	l/sec	liters per second
gallons per minute per square foot	gpm/sq ft	2.445 0.679	cu/m/hr/sq m l/sec/sq m	cubic meters per hour per square meter liters per second per square meter
gallons per square foot	gpsf	40.743	l/sq m	liters per square meter
horsepower	hp	0.746	kw	kilowatts
inch(es)	in.	2.54	cm	centimeter
inches per hour	in./hr	2.54	cm/hr	centimeters per hour
million gallons	mil gal.	3.785 3,785.0	Ml cu m	megaliters (liters x 10^6) cubic meters
million gallons per acre per day	mgad	0.039	cu m/hr/sq m	cubic meters per hour per square meter
million gallons per day	mgd	43.808 0.0438	l/sec cu m/sec	liters per second cubic meters per second
mile	mi	1.609	km	kilometer
parts per billion	ppb	0.001	mg/l	milligrams per liter
parts per million	ppm	1.0	mg/l	milligrams per liter
pound(s)	lb	0.454 453.6	kg g	kilogram grams
pounds per acre per day	lb/acre/day	0.112	g/day/sq m	grams per day per square meter
pounds per day per acre	lb/day/acre	1.121	kg/day/ha	kilograms per day per hectare
pounds per 1,000 cubic feet	lb/1,000 cf	16.077	g/cu m	grams per cubic meter
pounds per million gallons	lb/mil gal.	0.120	mg/l	milligrams per liter
pounds per cubic foot	pcf	16.02	kg/cu m	kilograms per cubic meter
pounds per square foot	psf	4.882×10^{-4}	kg/sq cm	kilograms per square centimeter
pounds per square inch	psi	0.0703	kg/sq cm	kilograms per square centimeter
square foot	sq ft	0.0929	sq m	square meter
square inch	sq in.	6.452	sq cm	square centimeter
square mile	sq mi	2.590	sq km	square kilometer
square yard	sq yd	0.836	sq m	square meter
standard cubic feet per minute	scfm	1.699	cu m/hr	cubic meters per hour
ton (short)	ton	907.2 0.907	kg metric ton	kilograms metric ton
yard	yd	0.914	m	meter

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-670/2-75-041	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Storm Water Management Model: Dissemination and User Assistance		5. REPORT DATE May 1975; Issuing Date
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) James A. Hagarman, F.R.S. Dressler		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS University City Science Center, 3508 Science Center, Philadelphia, Pa. 19104		10. PROGRAM ELEMENT NO. 1BB034 ROAP: ATA Task 020
		11. CONTRACT/GRANT NO. 802716
12. SPONSORING AGENCY NAME AND ADDRESS National Environmental Research Center, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

A program of dissemination and user-assistance for the EPA Storm Water Management Model (SWMM) has been developed and implemented at the University City Science Center (UCSC).

Services available to SWMM users under this grant include distribution of the SWMM program itself and technical assistance in problem delineation, data preparation, execution debug, and output interpretation. Costs of this service extend only to actual computing costs, with all technical assistance covered by the EPA grant.

Several case studies of SWMM applications completed with UCSC assistance in the past year are included in this report. These studies include a combined sewer overflow problem in Binghamton, New York; a land use plan in the Stony Brook basin in Princeton, New Jersey; and RUNOFF/TRANSPORT calculations on the Wingohocking basin in Philadelphia, Pennsylvania.

The UCSC SWMM dissemination program is now self-sustaining and continues to assist the user community.

This report was submitted in fulfillment of the Office of Research and Development, U.S. Environmental Protection Agency (EPA) research grant EPA No. R-802716 by the UCSC under the sponsorship of the EPA.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water Quality,* Mathematical Models,* Rainfall, Surface Water Runoff, Waste Treatment,* Erosion Control, Water Pollution*	Water Quality Control, Stormwater Management, Urban Stormwater, Water Pollution Control, Binghamton, New York, U.S. EPA Storm Water Management Model (SWMM)	13B

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 55
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)

U. S. GOVERNMENT PRINTING OFFICE: 1975-657-593/5374 Region No. 5-11