URBAN HIGHWAY STORM DRAINAGE MODEL EXECUTIVE SUMMARY

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U.S. Department
of Transportation

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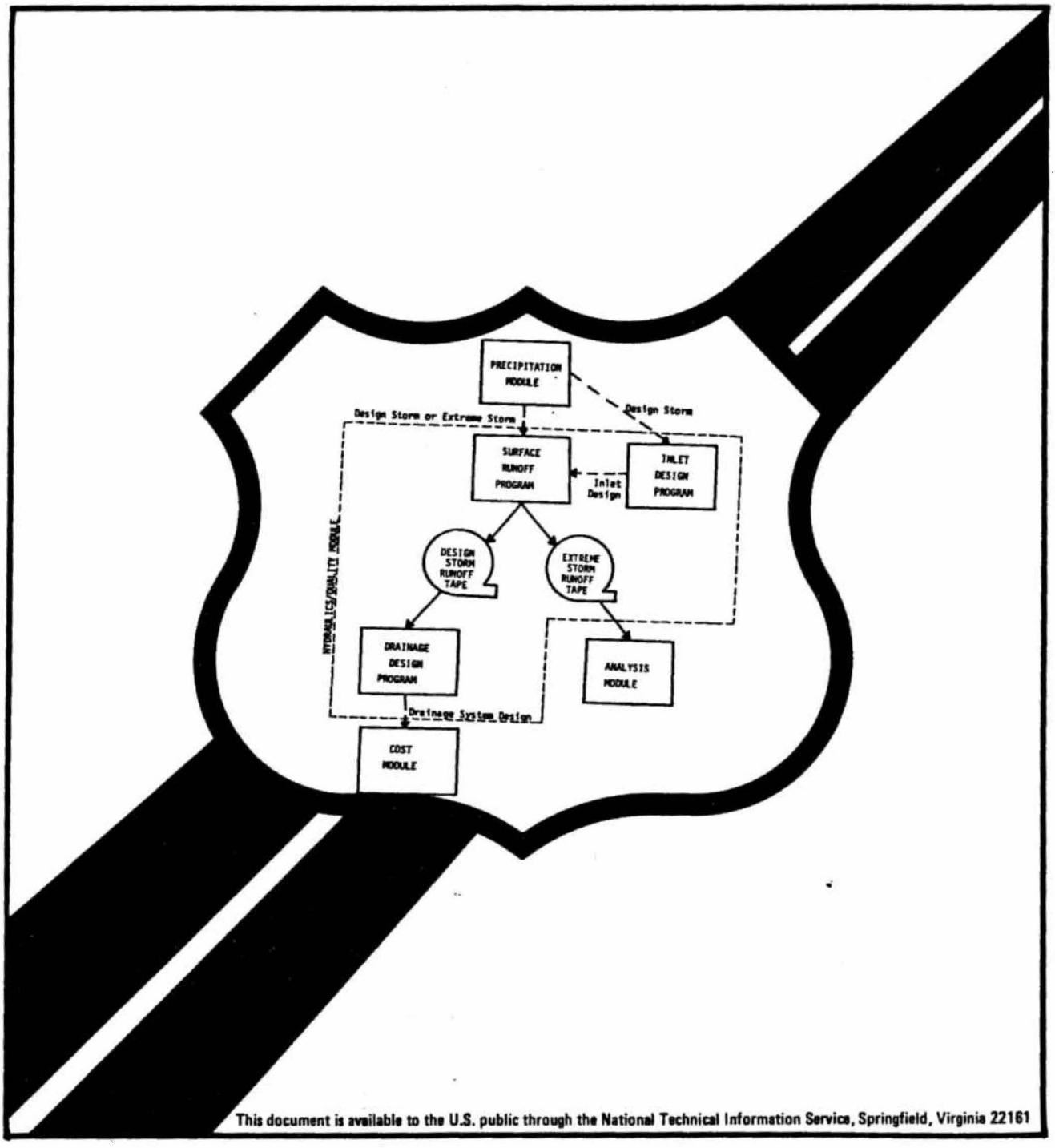

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16. Abstract

A package of six user-oriented computer programs has been developed and tested for the analysis and design of urban highway drainage systems and related nonpoint source pollution problems. These programs are organized into four related but independent modules.

This report is the Executive Summary for this study. It presents the major findings of the study and describes the computer programs that have been developed and the uses to which these programs may be put.

This report is the first in a series. The others in the series are:

Vol. No.	FHWA No.	Short Title
1	83-041	Model Development and Test Applications
2	83-042	Precipitation Module
3	83-043	Inlet Design Program
4	83-044	Surface Runoff Program
5	83-045	Drainage Design Program
6	83-046	Analysis Module
7	83-047	Cost Estimation Module

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EXECUTIVE SUMMARY

An urban highway storm drainage model has been developed for the Federal Highway Administration for use in the evaluation of existing drainage systems and in the preliminary design of new drainage systems. This model incorporates advances in urban hydrology and stormwater management of the past decade into a package of six computer programs. This model is also a valuable tool for the analysis of stormwater management and nonpoint source pollution problems related to urban highway storm drainage.

The general capabilities of the Urban Highway Storm Drainage Model include:

- Evaluation of existing urban highway storm drainage systems for adequacy against selected design storms;
- Preliminary urban highway storm drainage system design computations, including locating inlets, sizing pipes, and estimating construction costs;
- Hydraulic analysis of urban highway storm drainage systems under rainfall conditions more severe than those used in design; and
- Simulation of nonpoint source pollutant loads from the highway corridor to estimate storm water quality at highway drainage system outlets.

This package of computer programs offers several advantages over conventional techniques used in highway drainage design and analysis. These advantages include the following:

- A more accurate representation of the rainfall-runoff process than is given by empirical approaches such as the Rational Formula that may result in over-designed facilities;
- Ability to analyze facilities such as detention basins and conditions such as surcharge that are difficult or impossible to accurately analyze with empirical approaches and computations by hand;
- Ability to estimate nonpoint source pollutant loads from design storm events and pollutant load reductions by treatment facilities at drainage system outfalls;

- An efficient method of performing preliminary drainage system design computations that can be tedious and time-consuming to perform by hand; and
- Ability to quickly evaluate a number of alternative drainage system designs, a procedure that may be too time-consuming to perform by hand.

The model itself consists of six Fortran computer programs organized into four "modules" as follows:

- Precipitation Module
- Hydraulics/Quality Module
  - Inlet Design Program
  - Surface Runoff Program
  - Drainage Design Program
- Analysis Module
- Cost Estimation Module

The Model has purposely been structured in these related but independent Modules to maximize the flexibility of the package. The engineer may apply as many or as few of the Modules as are appropriate to his particular design or analysis problem. The relationship of these programs is shown in Figure 1. Each of these Modules and its potential uses is described in turn below.

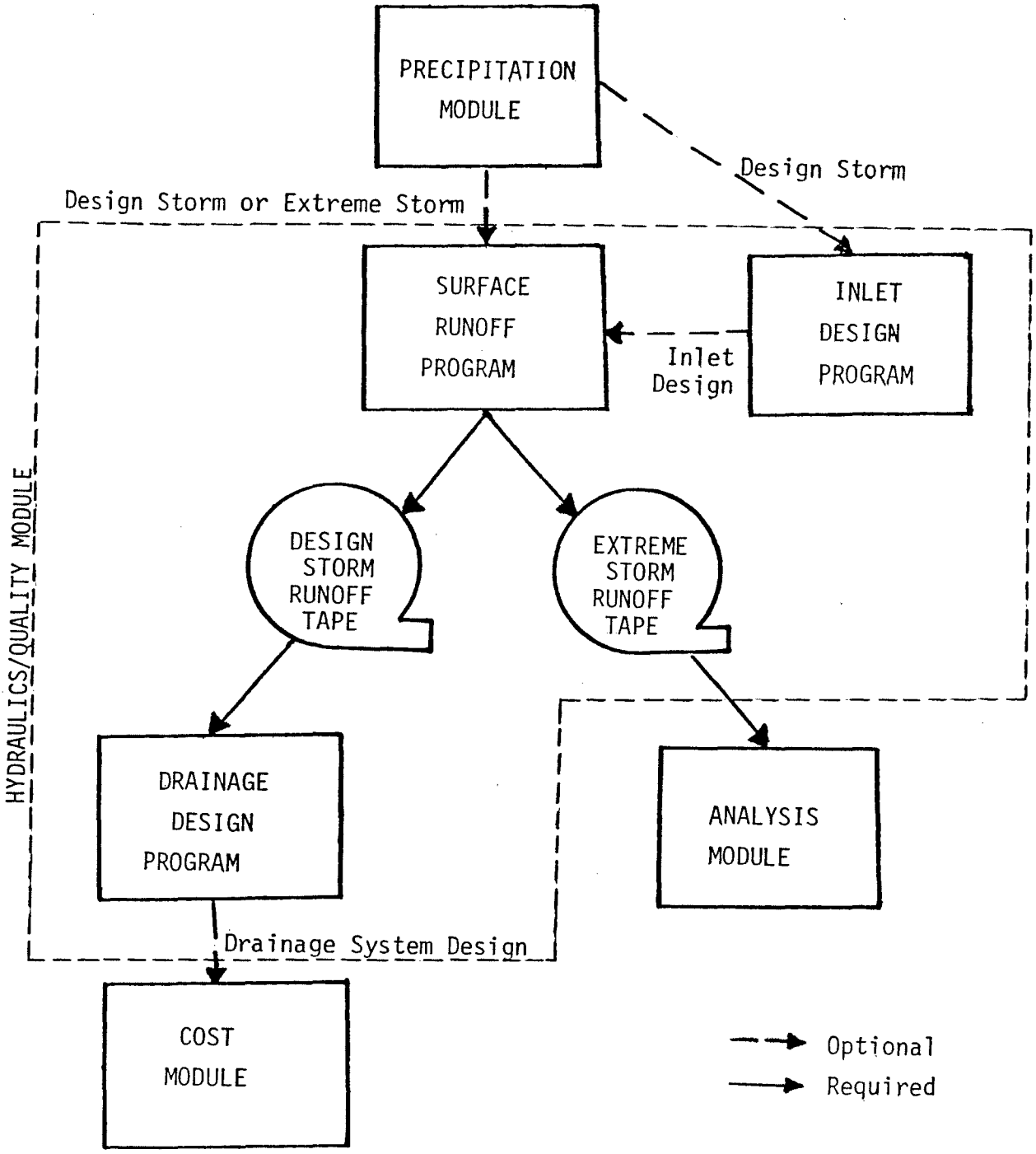

FIGURE 1. Urban Highway Storm Drainage Model

A seven-volume report to accompany the computer programs has been produced. These documents are as follows:

- "Volume 1: Model Development and Test Applications", FHWA-RD-81-011
- "Volume 2: Precipitation Module User's Manual and Documentation Report", FHWA-RD-81-012
- "Volume 3: Hydraulics/Quality Module - Inlet Design Program User's Manual and Documentation Report", FHWA-RD-81-013
- "Volume 4: Hydraulics/Quality Module - Surface Runoff Program User's Manual and Documentation Report", FHWA-RD-81-014
- "Volume 5: Hydraulics/Quality Module - Drainage Design Program User's Manual and Documentation Report", FHWA-RD-81-015
- "Volume 6: Analysis Module User's Manual and Documentation Report", FHWA-RD-81-016
- "Volume 7: Cost Estimation Module User's Manual and Documentation Report", FHWA-RD-81-017

The first volume describes the history of the project, gives a more detailed overview of the computer programs, and describes three test applications of the model to highway sites around the United States. Each of the remaining six volumes describes one of the computer programs, giving a technical description of the program, detailed instructions for its use, and complete Fortran listings and flow charts of the program's subroutines. The engineer who wishes to use one of these programs will need to obtain and study the accompanying one of the volumes listed above.

Precipitation Module

The Precipitation Module consists of a single computer program with two basic capabilities - generating single-peak synthetic hyetographs and performing a variety of statistical analyses on long-term precipitation data, such as the hourly precipitation data available from the National Weather Service. Some of the statistical analyses of which the program is capable are:

- Annual series analysis and partial duration series analysis, including the generation of intensity-duration-frequency curves;
- Frequency of occurrence analysis for such parameters as peak rainfall intensity per storm event, storm duration, and dry period duration; and

- Analysis of storm skew (i.e., the ratio of the time to peak rainfall intensity of a given storm to the total duration of the storm).

The statistical analyses that can be performed with the Precipitation Module can give the engineer responsible for drainage design much better local information than is generally available for developing required design storm events and associated conditions.

Hydraulics/Quality Module

The Hydraulics/Quality Module, the basic design tool in the package, consists of three computer programs - the Inlet Design Program, the Surface Runoff Program, and the Drainage Design Program. Together, these programs can perform most of the major computations involved in preliminary design of highway drainage systems. The programs have been designed to accomodate local drainage practices and design procedures. Most inlet, channel, and pipe types available can be simulated and the programs are structured to allow the use of local design criteria.

The purpose of the Inlet Design Program is to locate inlets in the surface runoff conveyance system of the highway right-of-way so as to maintain hydraulic conditions during the appropriate design storm event within specified criteria. Specifically, the Inlet Design Program determines the placement of inlets in gutters required to maintain flow spread within a maximum specified by the engineer or the placement of inlets in channels to maintain flow depth within a maximum specified by the engineer. The program also checks that the percentage of the gutter/channel flow that carries past each inlet to the next gutter/channel section does not exceed a given maximum, again specified by the engineer.

The Surface Runoff Program simulates time-varying runoff quantity and quality, routes these flows and pollutants through surface gutters, channels, and detention basins if appropriate, and computes inlet hydrographs and pollutographs. The inlet hydrographs and pollutographs can be saved as a computer file for subsequent use by either the Drainage Design Program or the Analysis Module. For use with the Drainage Design Program, the engineer would typically have the Surface Runoff Program calculate hydrographs from the design storm event required locally for sizing the subsurface drainage system. For use with the Analysis Module, the engineer would have the Surface Runoff Program calculate hydrographs from one or more extreme storm events for analyzing the performance of the drainage

system. The Surface Runoff Program can also be used separately for tasks such as selecting a surface detention basin of appropriate size to control peak outflows from a drainage area.

The Drainage Design Program reads the inlet hydrographs and pollutographs computed by the Surface Runoff Program for the design storm and sizes the major drainage system accordingly. Specifically, the program determines the diameter of circular pipes and the bottom width of trapezoidal channels so that each pipe and channel flows full at peak flow. The diameters of circular pipes so determined are rounded up to the nearest commercially-available pipe size. The Drainage Design Program can be used to size as few of the pipes and channels of a drainage system as the engineer desires. For example, if the engineer wishes to size a new subsurface drainage system, this program can be used to size all the pipes. If the engineer wishes to size a modification to an existing drainage system, then the sizes of existing pipes not to be changed can be prespecified and the program will size the remaining pipes. The program can also be used to route nonpoint source pollutants from a design storm through an existing drainage system and to estimate the pollutant reduction from treatment facilities at system outfalls.

Analysis Module

The Analysis Module consists of a single computer program that simulates unsteady, gradually-varied flow in the major drainage system of the highway right-of-way, using inlet hydrographs generated by the Surface Runoff Program as input. The program is basically a modified version of the Extended Transport program of the EPA Storm Water Management Model (SWMM) package. Its primary purpose is to analyze the performance of the drainage system under extreme storm events, a step generally included in the highway drainage design process. As such, this program can simulate complex hydraulic conditions, such as surcharge and backwater, that cannot be simulated with the simpler formulations of the Drainage Design Program. The Analysis Module can also simulate several special features of drainage systems, such as detention facilities and variable-rate pumping stations.

Cost Estimation Module

The final Module of this package, the Cost Estimation Module, also consists of a single computer program. The purpose of this program is to estimate the capital costs, operation and maintenance costs, and total annual costs associated with the construction and maintenance of a highway drainage system. All of the cost computations are based on unit costs for materials, installation, and O&M. As part of the cost analysis, the program also estimates the excavation and backfill associated with construction of the drainage system. Elevation of the highway grade line, invert elevations of the system conduits and junctions, and sizes of the conduits and junctions are employed in the excavation and backfill calculations. The engineer will be likely to find use for this program in relative cost comparison for alternative drainage system designs.

The Urban Highway Storm Drainage Model is a powerful and flexible package of six user-oriented computer programs for the analysis and design of urban highway drainage systems and the analysis of related nonpoint source pollution problems. The hydrology and hydraulics programs in the package are all dynamic in nature, representing a significant advance beyond conventional static techniques such as the Rational Formula generally used in highway drainage design. With capabilities such as the analysis of stormwater detention basins, the simulation of nonpoint source pollution, and the computation of unsteady, gradually-varied flow in the drainage system, this package includes analytical tools more powerful than those now available to the practicing highway engineer. In addition, these programs give the engineer the ability to perform a large number of preliminary design computations and to evaluate alternative drainage system designs with much less effort than would generally be required to do the same work by hand. This model is equally valuable in evaluation and modification of existing urban highway storm drainage systems.