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**POLLUTANT LOADINGS
AND IMPACTS FROM
HIGHWAY STORMWATER RUNOFF
Volume II: Users Guide For
Interactive Computer Implementation
Of Design Procedure**

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FOREWORD

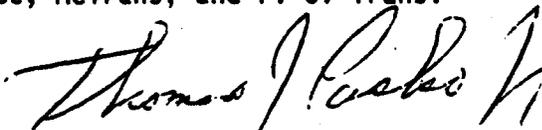
The highway system is a potential source of a wide variety of possible pollutants to surrounding surface and subsurface waters through the mechanisms of the natural hydrologic cycle. The effects of a highway system on the environment plays an increasingly important role in the planning, design, construction, and operation of a transportation system. The Federal Highway Administration and State highway agencies, charged with the responsibility of protecting the environment from pollution from highway sources, have approached the problem in a multi-phase, multi-million dollar research effort including studies to:

- Phase 1 - Identify and quantify the constituents of highway runoff.
- Phase 2 - Identify the sources and migration paths of these pollutants from the highways to the receiving waters.
- Phase 3 - Analyze the effects of these pollutants in the receiving waters.
- Phase 4 - Develop the necessary abatement/treatment methodology for objectionable constituents.

This investigation, primarily a Phase 3 item, is a culminating analytical effort utilizing other research studies and their data, coupled with applied hydraulics and related environmental and highway concerns. A largely statistical based design procedure for estimating highway stormwater pollutant loadings is presented.

This publication will be of interest to engineers involved in planning and designing for highway water quality impacts to lakes and streams. Also included in this manual is SYNOP, a program to determine rainfall input statistics from National Climatic Data Center. Engineers and scientists who have other interests in climatic effects on highways would be interested in SYNOP.

Copies of the computer program floppy disks and the Users Guide are being sent to FHWA Regional offices. These also are available from the National Technical Information Service, McTrans, and P. C. Trans.



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Operations Research and Development

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16. Abstract This is one of four final documents of an investigation dealing with the characterization of stormwater runoff pollutant loads from highways and the prediction of water quality impacts they cause. Study results are based on monitoring data from 993 individual storm events at 31 highway runoff sites in 11 States. Impact prediction is based on a methodology previously developed and applied to urban runoff and adapted for highway runoff applications. This document is a users guide for an interactive computer procedure for computing the estimated impacts on water quality of a stream or lake that receives highway runoff. The program provides guidance for evaluating whether or not a water quality problem will result, and the degree of pollution control required to mitigate predicted impacts to acceptable levels. The computer program is based on the methodology presented in the Design Procedures report of this study. The publications which collectively represent a final report are: FHWA-RD-88-006, Volume I: Design Procedure. This document presents a step-by-step procedure for determining and evaluating water quality impacts to receiving waters due to highway runoff. FHWA-RD-88-007, Volume II: Users Guide for Interactive Computer Implementation of Design Procedure. This document. FHWA-RD-88-008, Volume III: Analytical Investigation and Research Report. The basic research report, which provides a description of the analysis procedures employed and a summary and discussion of study results. FHWA RD-88-009, Volume IV: Research Report Data Appendix.					
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol When You Know Multiply By To Find Symbol

LENGTH

in	inches	25.4	millimetres	mm
ft	feet	0.305	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

sq in	square inches	645.2	millimetres squared	mm ²
sq ft	square feet	0.093	metres squared	m ²
sq yd	square yards	0.836	metres squared	m ²
ac	acres	0.405	hectares	ha
sq mi	square miles	2.59	kilometres squared	km ²

VOLUME

oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
cu ft	cubic feet	0.028	metres cubed	m ³
cu yd	cubic yards	0.765	metres cubed	m ³

NOTE: Volumes greater than 1000 L shall be shown in m³.

MASS

oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

TEMPERATURE (exact)

°F	Fahrenheit temperature	$(F-32)/9$	Celsius temperature	°C
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APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol When You Know Multiply By To Find Symbol

LENGTH

mm	millimetres	0.025	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

mm ²	millimetres squared	0.0016	square inches	sq in
m ²	metres squared	10.764	square feet	sq ft
ha	hectares	2.47	acres	ac
km ²	kilometres squared	0.386	square miles	sq mi

VOLUME

mL	millilitres	0.034	fluid ounces	oz
L	litres	0.264	gallons	gal
m ³	metres cubed	35.316	cubic feet	cu ft
m ³	metres cubed	1.351	cubic yards	cu yd

MASS

g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T

TEMPERATURE (exact)

°C	Celsius temperature	$1.8C + 32$	Fahrenheit temperature	°F
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* SI is the symbol for the International System of Measurement

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1.0 INTRODUCTION

This document presents a brief outline of background information and instructions on the use of the interactive computer program developed to assist a user to evaluate the water quality impact from highway stormwater runoff. The program allows a user to estimate the water quality impact that will be produced by stormwater runoff from a specific highway site, evaluate whether or not the resulting water quality conditions can be considered to cause a problem (indicated by the exceedance of water quality criteria or objectives), and when appropriate, to examine the extent to which selected control measures can be expected to mitigate any adverse impacts.

The use of the program is largely self-explanatory. The user is prompted to respond to a series of requests for information, either input data values or procedural choices. For the new or occasional user the program provides the opportunity for convenient call-up of information and guidance, and for examination of selected reference data to guide the assignment of input parameter values. For an experienced user, familiar with the procedure, the program allows for a faster, more direct path to the impact determination.

A schematic outline of the operation of the overall program is provided by figure 1, reproduced from the Design Procedures document (see below). A schematic which displays a simplified representation of the program operation is shown in figure 2. A brief discussion of the features of each of the main subsections is presented in the remainder of this document.

The information provided in this user guide is limited to identifying the elements of the program and how they are combined in the overall analysis procedure. For technical details of the computations performed, and on the input data references presented, the user is referred to the other volumes in this series. At a minimum the reader should review the Design Procedure report discussed below before using program results for analysis purposes. These other reports are:

1. FHWA-RD-88-006, Volume I: Design Procedure. This document provides a step-by-step procedure for manually performing the impact computations. The interactive program basically provides the same analysis as presented in this document and discussed in detail in appendix B. The differences are that the computer program provides a user with greater convenience and flexibility in examining a variety of alternative conditions and recording results of interest. It eliminates the possibility of manual computation errors. It also avoids the need to interpolate tabulated values and the rounding introduced in some hand calculations and in the tabulated data values.
2. FHWA-RD-88-008, Volume III: Analytical Investigation and Research Report. This document constitutes the basic reference for the data and analysis procedures incorporated in the interactive computer program and discussed in the Design Procedure Report.
3. FHWA-RD-88-009, Volume IV: Research Report Data Appendix. This document presents a summary of the data on stormwater runoff quantity and quality that were assembled and analyzed in this study.

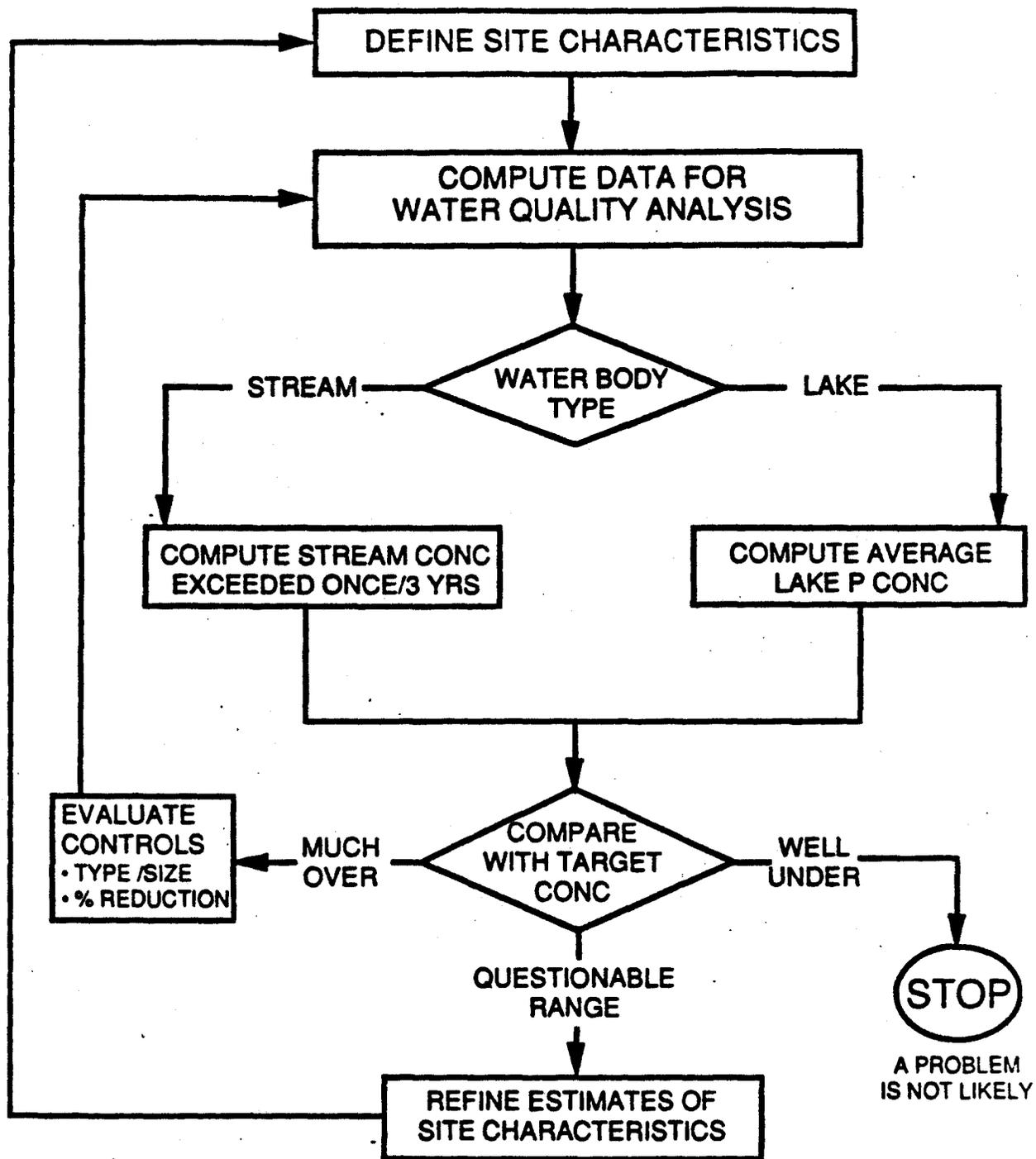


Figure 1. Outline of procedure for evaluating water quality impact from highway stormwater runoff.

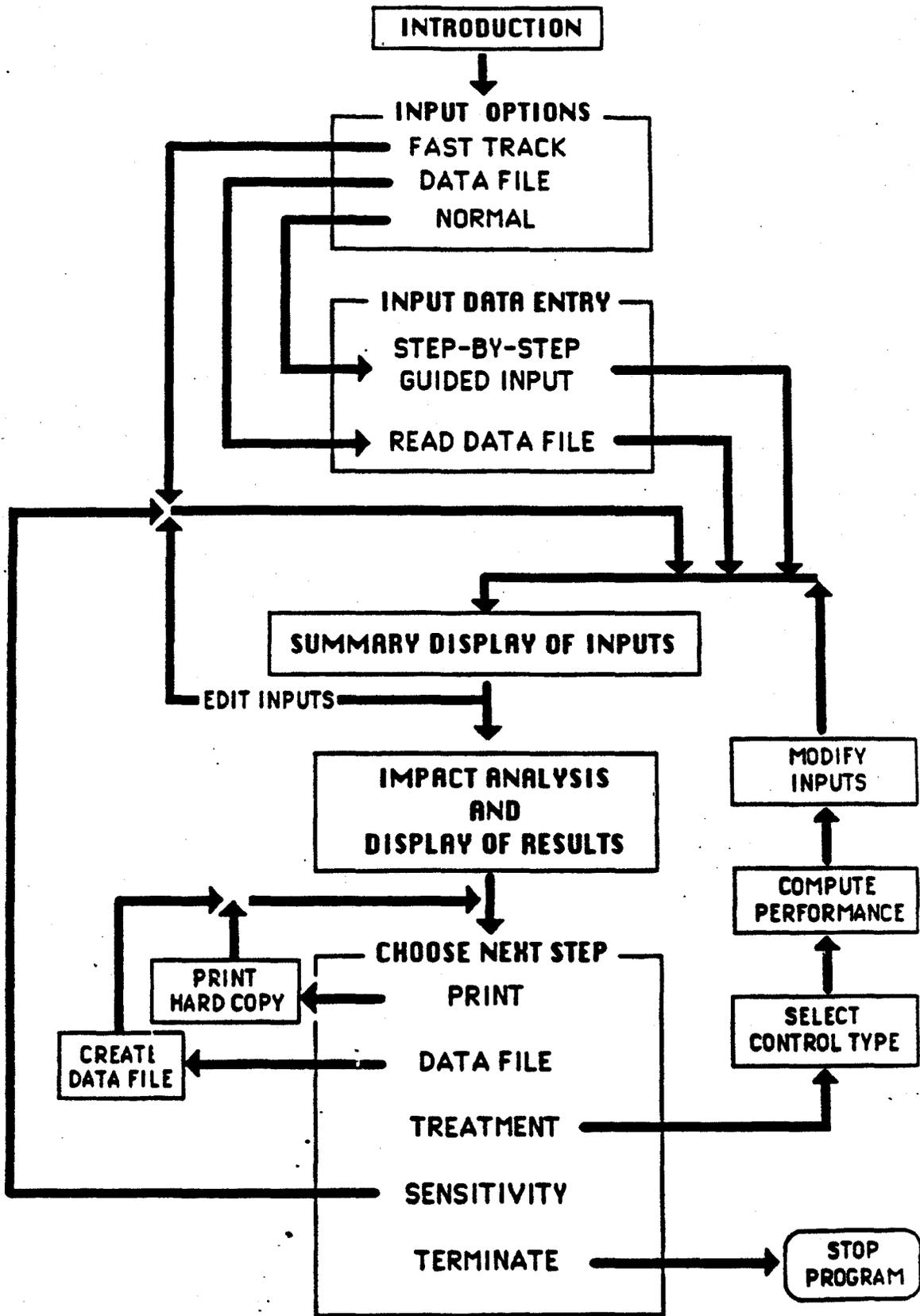


Figure 2. Schematic illustration of program flow.

2.0 INITIAL STARTUP

2.1 IBM PC

This section relates to the IBM PC Compatible version of the interactive program. For the Apple Macintosh version, please see section 2.2

The IBM version disk provided contains the interactive program, a set of program files, and three sets of reference data files. The latter contain sample data for rainfall, streamflow and sample input data sets.

The program and data files are included on a 1.2 MByte high density diskette. The program may be run on XT compatibles, but the program and data files will first have to be transferred to a set of 360K disks and the batch files which run the program modified, or the program will have to be installed on a hard disk. The program is set up to run directly from floppy disk, a hard disk is not required.

This program will appear to be very similar to Macintosh software. To initialize the computer system being used, two .COM files must be loaded. These .COM files are located in the SYN subdirectory of the supplied disk. The first .COM file that needs to be loaded depends on the type of video-card/monitor system that one has. The following options are supported and available:

EGARUN.COM	For Enhanced Graphics Adapter systems.
HGARUN.COM	For Hercules Graphics systems.
CGARUN.COM	For Color Graphics Adapter systems.
ATTRUN.COM	For ATT computer systems.
VGARUN.COM	For VGA systems.
MGARUN.COM	For MGA systems.

The other .COM file which must be loaded is the SYN FONTS.COM file. To initialize the system being used, invoke the appropriate graphics COM file and SYN FONTS. For example, using a hercules graphics adapter and monochrome monitor, one would type the following at the A: drive prompt.

```
A:>SYNHGARUN  
A:>SYNSYNFONTS
```

These two files will load instructions into RAM (Random Access Memory). Therefore when the highway runoff program is finished running, the user may wish to reboot the computer to free up the RAM for use by other programs.

Once the two files above are loaded, the highway runoff program is ready for execution. If the .COM files are not loaded, the computer will lock up and will have to be rebooted.

To run the program, type the following command from the A: drive prompt.

```
A:>FH
```

This command will invoke the program. Then follow the instructions that are given by the computer. The FH command is a batch file that will run the program. The IBM version of the highway runoff program is divided into two executable files, including NORMAL.EXE

and FHYMAIN.EXE. The first executable file includes the initial choice of data input and the "normal track" data input as described in section 3.0. The other executable file includes all analysis results and summary data editing.

Please note that the PC version of this program requires all memory besides that used by the DOS operating system. If memory is reduced by the loading of memory resident applications or drivers into RAM, the application may freeze unexpectedly. If this occurs, re-boot the computer and begin again.

2.2 APPLE MACINTOSH

This guide relates to the Apple Macintosh version of the interactive program. The Apple Macintosh version disk contains the interactive program, a set of program files, the BASIC language runtime program and three sets of reference data files. The latter contain sample data for rainfall, streamflow, and sample input data sets.

The disk provided does not include a "system folder" because its addition would exceed the capacity of a one-sided 400K disk. If the Macintosh does not have a hard disk, the user must first start up using a disk with a system folder. A system file which contains the usual sample of word processing system fonts is preferred. For example, the Excel system folder does not include one of the text fonts (Athens) used in the program displays.

If the available computer has only an internal drive, eject the startup disk and insert the enclosed program disk. If the system has an external disk drive, insert the program disk into this drive. If the Macintosh has a hard disk, insert the disk into the internal disk drive, and if desired, copy the disk contents onto the hard disk for convenience in future use. To start the program, either double-click with the mouse on the interactive program icon or highlight it with a single click and then select open from the "file" menu.

NOTE: The program provides an option for a hard copy printout of inputs and analysis results for each condition examined. This will execute only when an "IMAGEWRITER" printer is connected. The IMAGEWRITER LQ and LASERWRITER are not currently configured to respond to BASIC printing commands in the program.

3.0 DATA ENTRY MODES

The user is provided with three options for assigning the basic input data to initiate an analysis. You may select either **NORMAL TRACK**, **FAST TRACK**, or **DATA FILE** for assigning values for the necessary input parameters.

- **NORMAL TRACK** - This selection presents the user with a sequence of prompts that call for entry of the necessary input parameter values. At appropriate points, the program provides the ability to view condensed discussions (in the form of "help" windows) pertaining to the information called for and provides the user with the ability to call up and examine reference data to aid in the assignment of input values for the analysis.
- **FAST TRACK** - This selection leads the user directly to input the required data. It is provided as a convenience for an experienced procedure user who has an understanding of the inputs required and the appropriate values to assign.
- **DATA FILE** - The program, at a later stage, provides the user with an option to save the input data of a particular analysis as a data file. The file can be called up at a future time to continue the analysis. Selection of this option presents the user with a list of files

with previously saved input data, and the ability to select the one of interest. These sample files are contained in the folder (directory) DAT.

NOTE: A few sample INPUT DATA sets are contained on the disk, to serve as initial reference material for a new user becoming familiar with use of the program.

4.0 HELP SCREENS

At various places throughout the program, "HELP" options are provided. Their selection will call up either information or reference data on different topic areas. When entering the HELP mode, the user may either track through all of the remaining items in this sequence or return to the main program operation after viewing the information on a particular topic. In any event, the program will return to the place from which it branched off into the HELP sequence.

The material presented in this sequence is necessarily brief and condensed. The user should refer to the other study documents for more detailed treatment of the topics addressed.

5.0 DATA ENTRY

The program provides prompts for the entry of all of the data required to perform the analysis, and indicates the required dimensional terms (e.g., acres, square miles). These entries occur in edit boxes. Please note that when editing existing entries in a edit box, the user must edit the entire value as shown in the box. That is, the user must either use the backspace or delete keys to edit the entire number (and decimal places) as it appears in the edit box. Failure to do so will cause the number entry to include all digits that appear in the edit box.

Use the HELP selections where necessary for guidance in selecting specific input values to assign. There are five categories of inputs, and they are addressed in the following order:

1. **Site Data** - This includes selection of the type of waterbody (stream or lake) receiving the runoff, and information on drainage areas for the watershed and the highway segment. This information is provided by the user, based on the local situation.
2. **Rainfall** - The data required for rainfall analysis are the storm event statistics that apply in the local area. The desired statistics are developed from the analysis of hourly rainfall data from an appropriate rain gage with a reasonably long period of record, using the computer program, SYNOP. A microcomputer version of this program has been provided on a floppy disk. Floppy disks containing the desired long-term hourly rainfall record may be obtained from the National Climatological Data Center and analyzed by the SYNOP program that is provided, to develop site-specific values for the rain event statistics. Additional information on this program is provided in the section 9.0 of this document.

In this analysis program, the user is provided access to previously developed rainfall statistics generated by execution of the SYNOP program, for use in guiding initial estimates. A map showing typical regional values, and also data for selected cities, can be examined for reference. The RAIN DATA folder/directory provided, contains summary statistics for cities throughout the country. It is assumed that this file will be gradually replaced by one restricted to rain gauges of direct interest to a State highway agency, and created from values derived from SYNOP analyses of rain gauge stations in the State.

If you have used SYNOP to develop a new data set for a local rain gauge, you may use the option provided to enter this data and create and save it in a file for future reference or use.

3. **Streamflow** - Required for streamflow are the mean (long-term average flow rate in ft^3/s per square mile of drainage area) and the coefficient of variation of daily flows. The former is readily extracted from appropriate Water Supply Papers published by the USGS. The latter parameter is not one that is computed and summarized in the USGS publications. Guidance for estimating appropriate values for both of the required inputs is provided in the program.

The STREAM DATA file that is provided includes a sample of streamflow data for selected stream gauges in a number of western States. It is provided primarily as an illustration of how this element of the program works. It is assumed that a State highway agency will eventually replace the sample files that are provided with corresponding data for streams of interest in the State.

To guide initial estimates, the program also provides a map showing typical regional values for average streamflow (in ft^3/s per square mile).

4. **Pollutant Concentrations in Runoff** - The user may select any of the 10 pollutants for which comprehensive information on concentrations in highway runoff were developed in the study program. Note that the Lake analysis only allows the selection of phosphorus. The program initially selects the 50th percentile highway site for estimating the site median concentration (SMC) that will be used in the impact analysis. It allows the user to examine alternate exceedance percentiles and automatically computes the SMC that corresponds with the selected percentile. The final selection is then used in the computations.

A soluble fraction for each pollutant is assigned by the program, based on available data. This is used in two ways:

- For all pollutants, the computed removal efficiency of a wet pond detention basin is based only on the particulate fraction (because this is the basis on which the computation procedure was developed and calibrated). For the other control devices, source data on performance is based on total pollutant levels (soluble plus particulate), so the total concentration is used in these cases.
 - For the heavy metals (copper, lead and zinc), toxic effects are caused by soluble forms, so only the soluble fraction of these pollutants is employed in the stream impact analysis and compared with the EPA toxic criteria. For all other pollutants, the stream impact analysis is considered to provide only a reference analysis for comparison with some arbitrary (user-selected) target. In this case, the total, rather than the soluble concentration, is used in the computation. Total phosphorus is used in the lake impact analysis, because the empirical lake impact computation is based on total P.
5. **Target Concentrations** - For the heavy metals (copper, lead and zinc), the concentrations that produce toxic effects on stream biota are significantly influenced by the total hardness (TH) of the receiving water. The user is prompted to enter a

value for the TH, if the analysis is for a stream, and if one of the above heavy metals has been selected as the pollutant to be analyzed. From the TH the program computes the corresponding target concentration, using the relationships developed by EPA.

TH levels can be extracted from STORET records (where an appropriate station exists) or from local monitoring. The program provides a map showing the regional pattern of surface water total hardness that can be used to guide initial estimates.

For the other pollutants, the target concentration in a stream impact analysis, is a user-selected concentration for use as a reference against which the stream concentrations produced by highway runoff can be compared.

For a lake impact analysis, only phosphorus is accepted as a pollutant. The program's initial target selection is 10 micrograms per liter, a widely used reference value. The HELP selections provided caution the user that site-specific circumstances may dictate target concentrations that are either higher or lower.

6.0 INPUT SUMMARY DISPLAY

Following data entry, the user is presented with a window that summarizes the key input values that have been assigned. In the case that an entry error may have been made, or an adjustment desired for some other reason, the user is provided the option to return to an item by item listing and change any of the values. A new summary display is presented.

When the user indicates acceptance of the input values displayed for his inspection, the program computes values for the parameters actually used in the impact analysis computations from the foregoing basic input values. It then proceeds to the computation and display of the receiving water quality impacts.

7.0 IMPACT ANALYSIS DISPLAY OF RESULTS

STREAM - For a stream impact analysis, the program uses a Probabilistic Dilution Model (PDM) developed under EPA's NURP program, to compute the probability distribution of instream concentrations of the selected pollutant that occur during periods of highway stormwater runoff.^(1,2) From the rainfall statistics, the average number of storms per year is computed. The number of events, and the statistics of the instream concentrations are then used to compute the (probability) percent of storm events that will produce stream concentrations that exceed the target concentration. This probability is also expressed as a return period, or mean recurrence interval (MRI), for comparison with the once in 3-year frequency suggested by the EPA criteria for acute concentrations.

Results are displayed graphically in the form of a histogram of the estimated probability distribution, on which the target concentration is overlaid for reference. The exceedance probability and the average interval at which the target will be exceeded is also displayed.

From the relationship shown, the user may decide whether the runoff has a significant potential to cause a water quality problem. The presumption is that the criteria represent safe levels, and that if criteria are exceeded less frequently than 3 years on average, highway runoff will not create an adverse impact. At the same time, a user has the ability to apply a more conservative interpretation in cases (e.g., a sensitive water body of special significance) where this may be considered appropriate. This may be done either by arbitrarily modifying the target concentration, or by using a longer recurrence interval (say

5 years rather than 3) in evaluating the problem potential and deciding on the need to consider treatment, which may be a more appropriate approach.

If additional analyses are performed, either sensitivity analyses to examine the effect of modifying specific input values or the reductions provided by controls, the impact display will show present both the base case and the result using the new condition.

LAKE - For a lake impact analysis, the analysis employs the Vollenweider model to compute the average concentration of total phosphorus in the lake's water column, and this concentration is used to evaluate the significance of the discharge. Results are presented in narrative form.

8.0 CHOICE OF NEXT STEP

Based on an evaluation of the indicated impact of any condition that has been analyzed, the user is next offered the choice of a series of options for the next step. These are identified, and the action initiated is discussed below:

1. **TERMINATE** - This option ends the program. Any new data files that have been created will be saved and will be available for future access. All other data such as base case inputs and modified values created during the course of sensitivity of treatment tests will be erased.

If using the Macintosh version, the user may then select either **START** from the **RUN** menu to initiate a new analysis, or **QUIT** from the **FILE** menu to exit the program and return to the desktop. With the PC version, the program can be re-run by using the **FH** command (see startup).

2. **DATA FILE** - Selection of this option will create an **INPUT DATA** file of the basic input values assigned to the current condition (results of which have just been displayed). The user is first asked to assign a distinctive file name to assist in identifying the file in the future.

When the file has been created, the program returns to the list of choices for the next step.

3. **PRINT** - This selection prints a hardcopy listing of both the input values and the impact results for the current condition (results of which have just been displayed).

When the printout has been completed, the program returns to the list of choices for the next step.

4. **SENSITIVITY** - This selection returns the program to the sequence that lists each of the inputs in turn. Any of these may be changed to allow its influence on impact results to be determined. The program then proceeds as before, displaying a summary of inputs, computation and display of impact, and again presenting a choice for the next step.

5. **TREATMENT** - This option directs the program to the subroutines that allow the user to select a type of control device and arrive at an estimate of the reduction in pollutant discharges it will provide. Based on the removal efficiency determined by the user's assignment of device size, the program computes corresponding changes

in appropriate input values. It then returns to the part of the program where the summary of inputs is displayed, where it will indicate the modified values resulting from the treatment device. The program then proceeds as before, computing and displaying the impact, and again presenting a choice for the next step.

After the first treatment evaluation has been made, the user may apply the new treatment choice to either the base case condition (for comparing alternate controls), or to the output of a previously examined control (for examining the use of multiple controls operating in sequence).

Four different types of control are included in the analysis. The basis for the performance estimates assigned is discussed briefly below for each.

- (a) **GRASS CHANNEL** - Performance estimates are based on information presented in reference 3. Long-term average mass removal is indicated to be a function of the flow length of the channel. The removal vs length relationships shown in this document for TSS and lead are reproduced and displayed, together with our estimate of an extension of the relationship between removal and length of grass channel for use with other pollutants. The latter is based on the typical distribution between soluble and particulate forms.

Both this performance extrapolation and the model's assignment of the predicted mass load reduction to a corresponding reduction in runoff concentration, are based on the above report's conclusion that the principal removal mechanism for this type of device is sedimentation and filtration.

- (b) **OVERLAND FLOW** - Performance estimates are based on information presented in reference 3. Long-term average mass removal is indicated to be a function of the residence time that results from the length and width of the area and the long-term average runoff flow rate. The program computes the residence time from the previously computed average runoff rate and user-selected dimensions for the overland flow area. The user then assigns a removal efficiency based on this value. As with the grass channel, soluble fractions for pollutants other than those specifically documented are used to extend the estimate to other pollutants.

Both this performance extrapolation and the model's assignment of the predicted mass load reduction to a corresponding reduction in runoff concentration, are based on the above report's conclusion that the principal removal mechanism for this type of device is sedimentation and filtration.

- (c) **DETENTION (WET PONDS)** - Performance estimates are based on the procedure presented in reference 3. But since this was based directly on the analysis procedures described in reference 4, this interactive program computes performance directly with a subroutine that uses the original procedures. The user assigns dimensions for the detention basin and these are combined with the site values for the runoff characteristics to determine the long-term average mass removal that results.

Long-term average mass removal is the result of sedimentation, so it is converted to a corresponding reduction in runoff concentrations for the impact analysis.

- (d) **INFILTRATION** - The performance estimates are based on analysis procedures from reference 4. This program includes a subroutine computation that directly employs the analysis described in the latter reference. The conversion of the long-term average mass reduction to appropriate adjustments in the input parameters for the impact analysis is different here than for the other controls.

Infiltration devices capture some portion of the runoff flows and volumes. The portion of the runoff that escapes, and discharges to surface waters, has modified flow and volume characteristics, but the concentration of pollutants will not be affected. Because an infiltration device will completely capture the smaller storms, but a diminishing portion of increasingly larger ones, the nature of its effect on the characteristics of runoff quantities (vs quality) is as follows.

The mean runoff rate for storm events that escape the device will be higher than that for the basic highway runoff. The variability of these flow rates will be appreciably lower. Most significant in terms of the impact analysis however, is the fact that since many storm events will be completely captured, the number of discharges per year (or during the 3-year interval used for the toxic criteria evaluation) will be reduced. Reference 3 provides a basis for quantifying this effect and the results have been incorporated into this program.

It is important to recognize the nature of these effects from this type of control device when the stream impact displays are examined. The histogram shows the distribution of concentrations during those runoff events that occur, and will reflect the fact that the concentrations do not change, but that the mean of the runoff flows increases and its variability decreases. This produces a more peaked stream concentration curve but one shifted to the right (higher concentrations) than the base case. Unlike the other controls, whose relative effect is graphically displayed by the comparison curves because they all have the same reference (discharges per year) - this visual comparison is not appropriate in the case of an infiltration device. The appropriate reference point in this case is the comparison of the return period (MRI) at which the target concentration is exceeded.

9.0 SYNOP (Synoptic Rainfall Data Analysis Program) PROGRAM DOCUMENTATION

Introduction

The purpose of the SYNOP code is to provide the user with a tool for summarizing and statistically analyzing a long-term rainfall record of interest. It is included in this document for the purpose of providing a program to analyze rainfall records for use with the FHWA highway runoff water quality analysis program discussed above. SYNOP analyzes hourly precipitation data available from the National Climatic Data Center (NCDC). SYNOP provides as output a summary of storm event data and the statistics of the descriptive storm parameters, including duration, intensity, volume, and time between storm midpoints, by month and year for the entire period of record. SYNOP also provides a correlation matrix

between each of the descriptive storm parameters. Return period and probability data are also available as output options.

For each year, the storm event summary output by SYNOP includes starting time, duration (hours), volume (inches), intensity (inches/hour), time since the last storm ended and antecedent rainfall for each storm in the record. Also output are the number of hours of rainfall within 0.01 in (.254 mm) intervals between 0.0 and 0.2 in (0 and 5.08 mm).

SYNOP then outputs statistics grouped by month and then by year (or a specified subset of months as described below). Statistics, such as minimum, maximum, mean, variance and coefficient of variation, are output for storm duration, intensity, volume and time between storms. The user can also transform the rainfall data to lognormal, thereby obtaining the statistics for the log transformed data.

The rainfall statistics can be analyzed for various time periods within the data set. The user may choose to analyze calendar years, water years, or a subset of months (for example wet and dry seasons). Wet and dry seasons often have significantly different storm event statistical characteristics and therefore it is useful to analyze these periods independently.

Another option available in SYNOP is ability to be able to define a minimum allowable storm event volume for analysis. This option lets the user remove from the analysis storm events whose total volume is less than a user-specified minimum volume. This is particularly useful for rainfall-runoff analyses.

A key input variable is the interevent time which defines the minimum period of time (in hours) beyond which successive rainfall recordings are considered to be from separate storm events. SYNOP makes three passes through the rainfall record. The first two using interevent times provided by the user. The third and final pass uses an interevent time interpolated by the program. This interpolation is computed such that the coefficient of variation for the time between storm event midpoints is close to 1.0. Theoretically, this interpolated interevent time is the correct value because it results in an exponential probability distribution for time between storm event midpoints. This can, however, lead to erroneous results. Many gages on the West Coast require an interevent time in the hundreds to meet the exponential distribution requirement. SYNOP has an option to allow the user to select an interevent time more reasonable and bypass the interpolation procedure.

Installation and Hardware Requirements

The code has been modified for the PC and tested using the following configuration:

- IBM AT compatible with 640 Kbyte RAM.
- 80 Mbyte hard disk drive.
- 1.2 Mbyte floppy drive.
- 80287 math co-processor.

The Minimum configuration to run the SYNOP program is:

- IBM XT compatible with 640 Kbyte RAM.
- Hard disk with at least 1.4 Mbytes of free space.
- Math Co-processor (8087).
- 1.2 Mbyte floppy drive.
- ANSI.SYS device driver installed.

Every device attached to your system is controlled by a program called a device driver. DOS for example is a device driver that controls the operation and management of disks and disk files. ANSI.SYS is a device driver that provides more detailed control over the console display and keyboard. SYNOP takes advantage of the device driver ANSI.SYS for control over the display during execution. In order for DOS to use ANSI.SYS commands the CONFIG.SYS file must include a command line that names the device driver.

Before running SYNOP the user should be sure of the following:

- A CONFIG.SYS file must be in root directory on the system disk and must include the command line *device=ansi.sys*
- ANSI.SYS must be included in the root directory. If it isn't, a copy should be provided on the original DOS disk; copy it to the root directory.

If the user makes these changes to meet the above requirements, restart DOS by typing Ctrl-Alt-Del before continuing.

The PC version of SYNOP is provided on one 1.2 Mbyte floppy disk. Included on this disk are the following:

<u>File Name</u>	<u>Function</u>	<u>Size</u>
SYNOP.EXE	SYNOP Program	534 Kbytes
SYNPREP.EXE	SYNOP Data Preparation Program	34 Kbytes
SYNOP.CTL	SYNOP Program Control File For Example Data	80 bytes
FRES4867.PRN	Example Data File	110 Kbytes

The two executable codes require at least 570 Kbytes of disk storage, each input file from the NCDC and the associated output file created by SYNPREP requires about 420 Kbytes for the example Fresno gauge. Also note, that during the operation of SYNPREP and SYNOP temporary files are created then erased by the programs, these files require about 250 Kbytes each for the example file. The final output file created by SYNOP will require about 160 Kbytes or more depending on the printing options that are selected. Because of these disk storage requirements, SYNOP must run on a hard disk, unless the NCDC data file is very small.

Before installing the SYNOP program on the PC make a back-up copy and store the original in a safe place.

To install the SYNOP program create a subdirectory on the hard disk, called SYNOP by typing at the C: drive prompt:

```
C:>MD SYNOP
```

Then get into that directory by typing:

```
C:>CD SYNOP
```

To transfer the SYNOP files from the floppy disk to your hard disk insert your copy of the SYNOP Program Disk into drive A: and type:

```
C:>COPY A:*.*
```

Remove the floppy disk from drive A: and store it in an appropriate place. The program is now ready to run the program using the example data file provided.

Program Execution

Hourly, long-term rainfall records can be obtained from the NCDC on a PC diskette. These data files are formatted such that they can be read by either BASIC or FORTRAN programs or imported to LOTUS 123.

SYNPREP is a program which reads the raw data and converts them into a format readable by SYNOP. NCDC has changed formats of the data files they provide several times in recent years. This routine ensures that these differently formatted files can be read by the SYNOP program. Before executing the SYNPREP program the name of the NCDC file that will be used should be recorded. To execute SYNPREP, be sure to be in the SYNOP subdirectory and then type SYNPREP. The SYNPREP program will ask for the name of the file containing the NCDC rainfall record to be analyzed, for example FRES4867.PRN. Following the entry of the input file name, the user enters an output file name (of their choice) which will be the input file to SYNOP. SYNPREP needs to be executed only once per rainfall data file; provided the new file is not erased.

The user has two ways to control the operation of the program. The first option uses a control file (SYNOP.CTL) to give information on program execution to the program. This file contains the input and output file names along with a small group of control parameters. If no file titled SYNOP.CTL is present in the current directory the program will default to an interactive mode where the user is asked to input file names and choose program execution options. To run in the interactive mode, make sure that the SYNOP.CTL file is not present in the SYNOP subdirectory (rename the file).

For program execution the user must specify the following:

- (a) SYNOP input file name. This is the output file from SYNPREP.
- (b) SYNOP output file name.

This name is required to be between 1 to 8 characters in length and should not include an extension (e.g., .OUT)

- (c) Title (usually the site name or location).
- (d) The last two digits of the range of years to be analyzed.

This may be all or part of the range of years for which data is provided. User enters the starting year and ending year. If a water year analysis is desired, the beginning and ending year should be based on water year (October through September, with the water year number corresponding to the year number for the January through September period).

- (e) Starting and ending months for the analysis.

The starting and ending month numbers (January being month 1) can be used to limit the analysis to a subset of months (for instance the wet season) or can be used to force SYNOP to analyze rainfall statistics based on water

years (October through September) instead of calendar years. If the user provides a starting month greater than the ending month the program will regroup the data as water years, although the entire year does not need to be included. Note that if your data set begins in January of 1951, for example, the earliest water year that can be specified is 1952, because there is no data for the first 3 months of the 1951 water year. If an entire water year analysis is desired, the starting and ending month numbers entered would be 10 and 9, respectively. If a partial year analysis is desired enter the appropriate starting and ending month numbers. For example, entering 10 and 3 for the starting and ending month numbers will group and analyze the data for the subperiod from October to March.

- (f) Code to select the interpolated interevent time or the user-provided interevent time.

1 = compute and print the interpolated interevent time.
2 = compute and print the user-provided interevent time.

- (g) Interevent times, i.e. number of consecutive dry hours defining the end of a storm event.

For the first option (1) pick a lower and upper limit (suggested values are 3 hours and 24 hours, although the user may wish to adjust these depending on the results of the analysis). The program computes the rainfall statistics based on both of the user-entered interevent times and then interpolates to come up with the appropriate interevent time to compute the final results.

The second option (2) allows users to define an interevent time they think is appropriate. In some cases, especially in the western U.S., the interpolated interevent time can cause erroneous results due to the long dry periods that sometimes occur. In this case the user can select to run SYNOP with a single user-provided interevent time (i.e. 12 or 24 hours).

- (h) Code to print storm event data for external analysis.

0 = print, 1 = do not print.

- (i) Code to print a storm event summary.

0 = print, 1 = do not print.

- (j) Code to print storm event statistics.

0 = compute complete statistical output.

1 = do not compute statistics.

2 = compute brief statistical output.

- (k) Code to transform event volumes and intensities to lognormal.

0 = take logs, 1 = do not take logs.

- (l) Code to provide probability and recurrence interval data.
0 = output data, 1 = do not output data.
- (m) Minimum allowable storm event volume.
0 = do not limit storm event volumes, # = limit storm event volume to #
= any user-specified volume.

Input Files

The input file structure for SYNOP.CTL allows two types of information lines, 1) comment lines and, 2) data lines. A comment line is indicated by three asterisks (***) placed in the first three columns of a line. These comment lines are ignored by the program and allow the user to include comments, headings, or other useful information. The second type of information contains the program parameter data (figure 1).

Line 1 contains the input file name, line 2 contains the output file name, lines 3 contains the descriptive title of the run, while line 4 and 5 contain the rest of the control parameters given in the order listed in items (d) through (m) above. Note in reference to some of the above codes the user must provide the numeric code provided when using the control file method. If using the interactive mode the user will answer either "Y" or "N".

Figure 3. Example input file

```

*** Input file name
TEST.DAT
***
*** Output file name
TEST1
***
*** Location or gage name
Fresno, Calif.
***
***      starting      ending      starting      ending      interevent times      interevent
***      year          year          month          month          lower      upper      option
*****
***          48          87           1           12           12         00         2
***
***      event      summary      stats      log      prob      minimum
***      data       data       results    trans.   data       volume
*****
***          1          0           0           1           1         .10
***

```

The required format for the control file is as follows:

- line 1 (A20)
- line 2 (A8)
- line 3 (A60)
- line 4 (7I10)
- line 5 (5I10,F10.2)

Output Files

Several output files can be created depending on the user-selected options. Each file begins with the user-specified output file name followed by a model provided extension representing the output file type. The following list the output file extensions and the results they provide:

- .EVT =** Provides a listing of the generated storm event data for external analysis. It includes duration, intensity, volume and the time between storm midpoints.
- .SUM =** Provides for each year a storm event summary that includes starting time, duration (hours), volume (inches), intensity (inches/hour), time since the last storm ended and antecedent rainfall conditions within the previous 7 days for each storm in the record. Also output is the number of missing or deleted recordings found in the NCDC data set. Finally, the total volume of rainfall accumulated during a non-operating gage and the number of hours of rainfall within 0.01-in intervals between 0.0 and 0.2 in are output.

The NCDC rainfall data files include several measurement codes used to flag a particular condition. These codes are "A", "D", and "M".

A pair of "A" defines an accumulation period which indicates the precipitation amount is correct but the exact starting and ending times are only known to the extent that rainfall occurred during the accumulation period. This program assumes that rainfall occurred uniformly during this period and assigns the computed intensity to each of the hours during the accumulation period.

A "D" flag indicates deleted data and defines a value where the original data was received, but it was unreadable. The program assumes that this period is a wet period with a precipitation of 0.01 in.

An "M" flag indicates missing data and defines a value where the original data was never received. The program assumes no rainfall for this period and will ignore the time between storm midpoints for the first storm event following a missing data flag.

- .STA =** Provides complete or brief statistics for the descriptive storm parameters, storm duration, storm intensity, storm volume, and time between storm midpoints. The complete statistical output provides statistics grouped by month, year, event, and annual results for the entire period of record (or a specified subset of months as described above). The brief statistics option provides only the event and annual statistics for the entire period of record. The user can also transform the rainfall data to lognormal, thereby obtaining the statistics for the log transformed data.
- .PLT =** Provides the user with probability and recurrence interval data for each of the generated storm parameters for external plotting. The probability is the percent chance of seeing an event equal to or greater than the storm parameter for any given event. Whereas, the recurrence interval

is computed in terms of years and is therefore not the reciprocal of the computed probability. The probability of seeing a particular event during any given year can be computed by taking the reciprocal of the recurrence interval.

RAINFALL DATA ORDERING INFORMATION

NATIONAL CLIMATIC DATA CENTER (704) 259-0682

The rain gauge number and location must be furnished.

Storm records cost \$50.0 per diskette plus a small fee (\$11.0) for service and handling. Allow about 1 1/2 disks of memory (1.2 Mbyte) for a rainfall record of approximately 30 years.

Floppy disks from the NCDC are MSDOS IBM compatible DS/DD format.

The SYNPREP code can read either the Basic Sequential format (Release B - condensed) or the FORTRAN format (as on magnetic tape). Our recommendation is to order Basic Sequential format because it can also be read into LOTUS 1-2-3.

All gauges for an entire State can be obtained at nearly the same cost, but will be provided on magnetic tape. They must be down loaded to the PC from a machine which can read magnetic tapes.

Allow about 2 weeks delivery time.

10.0 REFERENCES

- (1) Environmental Protection Agency, Final Report of the NationWide Urban Runoff Program, EPA Water Planning Division, Washington D.C., December, 1983.
- (2) D. M. Di Toro, "Probability Model of Stream Quality Due to Runoff," Journal of Environmental Engineering 110, No. 3 (ASCE, June 1984)) pp. 607-628.
- (3) M.E. Dorman, J. Hartigan, F. Johnson, and D. Maestic, Retention, Detention and Overland Flow for Pollutant Removal from Highway Stormwater Runoff : Interim Guidelines for Management Measures, FHWA-RD-87-056, Federal Highway Administration, Washington D.C., March, 1988.
- (4) Environmental Protection Agency, Methodology for Analysis of Detention Basins for Control of Urban Runoff Quality, EPA Nonpoint Source Division, Washington D.C., September 1986.
- (5) Environmental Protection Agency, Combined Sewer Overflow Analysis Methodology, EPA Municipal Facilities Division, Washington D.C., October 1986.