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HYDRAIN--Integrated Drainage Design Computer System

Volume III,

PFP-HYDRA--Storm
Drains

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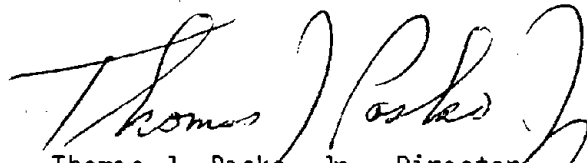
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Turner-Fairbank Highway Research Center
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McLean, Virginia 22101-2296

FOREWORD

This report (Volume III) documents the PFP-HYDRA, the microcomputer program which does the hydrologic analysis for the HYDRAIN integrated drainage design computer system. The HYDRAIN system which was developed under a pooled-fund study, includes a system shell and five engineering microcomputer programs for drainage design. The HYDRAIN documentation was published in 6 volumes so that there would be a separate volume for each of the engineering programs. This report will be of interest to hydraulic engineers for State highway agencies, consultants, and other Government agencies who deal with drainage design.

The HYDRAIN microcomputer programs, including PFP-HYDRA, which is the subject of this volume, have been distributed to the 25 States that participated in the pooled-fund study. Those States will evaluate the programs for a 6 to 12 month trial period after which the programs will be available through McTrans at the University of Florida, located in Gainesville, Florida and the PC-TRANS at the University of Kansas.

Sufficient copies of this report are being distributed by an FHWA transmittal memorandum to provide a minimum of one copy to each regional office, division office, and State highway agency. At least 10 copies are being distributed to those State highway agencies that participated in the study. Direct distribution is being made to the division offices. Additional copies may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.




Thomas J. Pasko, Jr., Director
Office of Engineering and Highway
Operations Research and Development

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16. Abstract <p>This project report, in six volumes, documents a system of computer programs for the design of drainage components: culverts, storm drains, and open channels. The system includes an input generator to estimate design rain, hyetographs, design flow, and hydrographs. Programs are facilitated with semi-expert system shells that generate input data for engineering programs. The system is expandable and designed for personal computers that operate within an MS-DOS environment.</p> <p>Volume III documents PFP-HYDRA, which is a storm drain analysis and design program. This report is intended to introduce PFP-HYDRA and guide the user through the necessary steps toward designing or analyzing stormwater drains and/or sanitary sewer systems. In the PFP-HYDRA design process, the program will select the pipe size, slope and invert elevations if given certain design criteria. Additionally, PFP-HYDRA will perform analyses on an existing system of pipes (and/or ditches).</p> <p>This volume is one of a series. The entire series is:</p> <table border="1"> <thead> <tr> <th>FHWA No.</th> <th>Vol. No.</th> <th>Short Title</th> <th>FHWA No.</th> <th>Vol. No.</th> <th>Short Title</th> </tr> </thead> <tbody> <tr> <td>RD-88-120</td> <td>I</td> <td>HYDRAIN</td> <td>RD-88-123</td> <td>IV</td> <td>CDS</td> </tr> <tr> <td>RD-88-121</td> <td>II</td> <td>HYDRO</td> <td>RD-88-124</td> <td>V</td> <td>WSPRO</td> </tr> <tr> <td>RD-88-122</td> <td>III</td> <td>PFP-HYDRA</td> <td>RD-88-125</td> <td>VI</td> <td>HY8</td> </tr> </tbody> </table> <p>To operate all the software, the user needs all six (6) volumes. To individually operate PFP-HYDRA, the user needs Volume I and Volume III.</p>						FHWA No.	Vol. No.	Short Title	FHWA No.	Vol. No.	Short Title	RD-88-120	I	HYDRAIN	RD-88-123	IV	CDS	RD-88-121	II	HYDRO	RD-88-124	V	WSPRO	RD-88-122	III	PFP-HYDRA	RD-88-125	VI	HY8
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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol When You Know Multiply By To Find Symbol

LENGTH

in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

in ²	square inches	645.2	millimetres squared	mm ²
ft ²	square feet	0.0929	metres squared	m ²
yd ²	square yards	0.836	metres squared	m ²
mi ²	square miles	2.59	kilometres squared	km ²
ac	acres	0.395	hectares	ha

MASS (weight)

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

VOLUME

fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft ³	cubic feet	0.0328	metres cubed	m ³
yd ³	cubic yards	0.0765	metres cubed	m ³

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

TEMPERATURE (exact)

°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C
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APPROXIMATE CONVERSIONS TO SI UNITS

Symbol When You Know Multiply By To Find Symbol

LENGTH

mm	millimetres	0.039	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	in ²
m ²	metres squared	10.764	square feet	ft ²
km ²	kilometres squared	0.39	square miles	mi ²
ha	hectares (10 000 m ²)	2.53	acres	ac

MASS (weight)

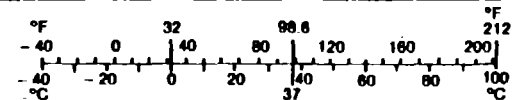
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m ³	metres cubed	35.315	cubic feet	ft ³
m ³	metres cubed	1.308	cubic yards	yd ³

TEMPERATURE (exact)

°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F
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These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

TABLE OF CONTENTS

	<u>Page</u>
Preface.....	1
HYDRO Program.....	1
PFP-HYDRA Program.....	2
CDS Program.....	3
WSPRO Program.....	4
HY8 Program.....	5
Operation.....	6
Report Contents.....	6
Disclaimer.....	6
1. Introduction.....	7
2. System Overview.....	8
Background and Purpose.....	8
Capabilities and Limitations.....	8
Structure of PFP-Hydra.....	10
Key to PFP-Hydra terms.....	10
3. System Technical Information.....	12
Storm Flow: The Rational Method.....	12
Storm Flow: Hydrographic Analysis.....	14
Sanitary Flow.....	16
Flow Conveyance.....	18
Cost Estimating.....	21
4. User Documentation	23
The Command Approach - Organizing the Data.....	23
PFP-Hydra and the Hydrain System Shell.....	27

Operating the Hydrain System Shell.....	27
Using the PFP-Hydra Shell.....	27
The Action Screen	28
The Data Screen.....	28
Executing PFP Hydra from Hydrain.....	30
Appendix A: Benchmark Examples.....	31
Appendix B: PFP-Hydra Commands.....	48
References.....	100

List of Figures

	<u>Page</u>
1. Measurement of θ	20
2. Triangular gutter shape.....	21
3. Example of a command string.....	24
4. Organization of PFP-Hydra commands.....	25
5. Sanitary sewer design.....	32
6. Rational method design.....	36
7. Combined system analysis.....	38
8. Hydrographic simulation.....	40
9. CST command trench and pipe geometric factors.....	51

List of Tables

	<u>Page</u>
1. Glossary of commands.....	26

Preface

This report presents documentation for the Hydrain system. HYDRO, PFP-HYDRA, CDS, WSPRO and HY8 are five nonproprietary engineering programs incorporated in the Hydrain system. The Hydrain personal computer oriented system operates the first three of these engineering programs with an interactive program shell written in the C language. The last program, HY8, also has an interactive program interspersed with the analysis code. It is written in BASIC and FORTRAN. Each program is in turn controlled by a common system shell, also in C. The system and program shells are designed with an open architecture for expansion. Hydrain is sponsored as a Pooled Fund Project (PFP) of 23 State highway departments and is managed by the Federal Highway Administration (FHWA). The latest State to join is Texas. The system and its support are expanding.

Within the Hydrain program shell concept, the HYDRO, PFP-HYDRA and CDS program shells allow the user to easily input, edit and run input data files and to scroll through output files. With these three applications, "short" (one-line) and "long" (multiple line) help is provided within the program logic.

The other two applications are incorporated into Hydrain without the high level of help and without program shells. WSPRO has the same type of batch operations as the first three but the input file has to be created with an input file generator (word processor or line editor). Hydrain system shell allows entry to this file generator, and reentry to Hydrain, but the user must rely on hard-copy documentation for help. HY8 is a stand-alone interactive BASIC program that accepts inputs during processing and produces screen outputs that the user can capture with the print screen command. All engineering programs but HY8 are batch oriented, and three steps are built into the process of using them: input file generation, programs execution, and output file screen review or listing. HY8 accepts inputs and generates outputs as the engineering program logic is executing.

HYDRO Program

FORTTRAN code for HYDRO was developed to combine existing approaches for rainfall and runoff analyses into one computerized program. Within the Hydrain system, it can be used independently or to generate input data for other engineering programs within the system.

HYDRO offers many hydrologic analysis options to the engineer. Each is site specific based on user-defined coordinates.

- Design Rain Using Digitized NWS Information - Calculates the rainfall intensity for a specific return period, duration, and site.
- Design Hyetograph using Yen and Chow's method - Calculates the rain versus time plot for a return period, duration and site.

- Intensity-Duration-Frequency Curve - Analyzes a specific site and creates two graphs: a plot of points for durations up to 24 hours, and a detail graph of the first 2 hours.
- Design Flow by Rational Method - Uses a specific return period, duration and intensity to determine the peak flow for the site.
- Design Flow by USGS Regression Method - Uses USGS three or seven parameter regression equations or user supplied equations to determine design flow.
- Design Flow by log Pearson type III - Calculates the peak flow for given data.
- Design Hydrograph by Rational Method and Snyder's Unit Graph - The rainfall intensity for a return period is used to calculate the peak flow. A hydrograph is created using Constant's modification of Snyder's method.
- Design Hydrograph by USGS Regression and Snyder's Unit Graph - Develops a hydrograph for a site based on peak flow and a unit hydrograph.
- Design Hydrograph by log Pearson type III and Snyder's Unit Graph - Develops a hydrograph for a site based on peak flow and a unit hydrograph.
- Hydrograph - Develops a hydrograph for a site based on its unit graph for a given flow.

PFP-HYDRA Program

FORTTRAN code for PFP-HYDRA previously existed and the Pooled Fund work effort included substantial improvements. PFP-HYDRA is a storm and sanitary sewer system analysis and design program. It is used either to model an existing sewer system or to design a new system.

PFP-HYDRA generates storm flows by using either the Rational Method technique, hydrologic simulation techniques, or accepting a hydrograph generated by a HYDRO analysis. It can be used to design or analyze storm, sanitary or combined collection systems. PFP-HYDRA can handle up to 1,000 contributing drainage areas and 2,000 pipes. Additionally, PFP-HYDRA can be used for cost estimating. The Rational Method approximates the peak rate of runoff from a basin resulting from storms of a given return period. PFP-HYDRA's hydrologic simulation models the natural rainfall-runoff process. In the simulation, runoff hydrographs are generated, merged together and routed through the collection system. Inlet limitations can be analyzed: inlet overflow can be passed down a gutter system, while inlets in sumps can store water in ponds.

In the PFP-HYDRA design process, the program will select the pipe size, slope and invert elevations given certain design criteria. Additionally, PFP-HYDRA will perform analyses on an existing system of pipes (and/or ditches). When an existing system of pipes is overloaded, PFP-HYDRA will show suggested flow removal quantities as well as an increased pipe diameter size as an alternative remedy.

PFP-HYDRA requires the forming of an input file of commands to describe the sewer system. The program shell facilitates this activity. The commands are placed in a logical sequence usually from upper to lower elevation. It is possible that several command sequences can produce the same result. An input file is established for a particular collection system by the engineer and then the PFP-HYDRA program is executed. To change the characteristics of the collection system, the input file can be edited using the program shell. The input file, in itself, is a line by line command language that identifies the computation and provides the required data. Each line of data is preceded with a three-letter command. A typical command is PDA, indicating the line contains the design parameters for pipe analysis (PIPE DATA). PFP-HYDRA reads the command line one line (command) at a time and executes each command individually. However, PFP-HYDRA maintains a memory of information, including prior command information and results. Error checking is performed on each command.

The PFP-HYDRA program requires design criteria for the pipes: friction factor (Manning's "n"), minimum diameter, ideal depth, minimum ground cover, minimum velocity (full flow), minimum slope, and maximum diameter. The friction factor is necessary for both analysis and design, while the remaining values are needed only for design. For design, the program selects invert elevations and slope as well as the physical sizing of each link given certain design criteria. In the analysis mode, pipe alignment and sizing are predetermined and the impact of proposed flows are analyzed. Design criteria can be changed for each pipe if so desired. PFP-HYDRA is not an optimization program, thus individual case studies need to be run and analyzed by the engineer.

CDS Program

The Culvert Design System provides the user with two broad options for investigating culvert characteristics. CDS can either (1) hydraulically design a culvert or (2) analyze an existing or proposed culvert. CDS has capabilities for investigating a variety of hydrograph relationships, culvert shapes, materials, and inlet types. With CDS, the engineer can request any of six culvert types: round concrete, round metal, arch concrete, arch metal, oval concrete, and concrete box. CDS routes hydrographs and considers ponding.

The Design option selects a culvert size and number of barrels that are compatible with engineering data, environmental constraints, and site geometry. In this option, hydraulic performance data are calculated for each new culvert system design. The Review option provides hydraulic performance data for any preselected combination of culvert type and size, inlet type, slope, and number of barrels. The initial design and analysis options may be followed by up to five additional culvert types or flow frequencies so a full spectrum of risk scenarios or economic considerations can be simulated at the same time.

Two possible flow scenario methods can be selected: (1) constant flow through the culvert (steady state or irrigation), or (2) time variable drainage flow conditions (dynamic). The dynamic option can route a hydrograph through the culvert system using three hydrograph alternatives: a user input hydrograph for a given discharge, a hydrograph produced by the HYDRO program, or the use of an internally produced default hydrograph (simulating semi-arid, high plains conditions). Additionally, the dynamic flow scenario can accommodate upstream pond storage.

CDS will determine culvert size based on the design headwater, headwater/diameter ratio, inundation, outlet velocity, cover limitations, or any combination of these parameters. The program will automatically increase the number of barrels when the maximum culvert size is exceeded. There is a limit of six barrels for commercial size culverts and five for concrete box culverts. The program can also be used to assess flood hazards, environmental assessments of upstream pond coverage, downstream flooding, channel impact, inlet type and beveled inlet evaluations, and reservoir facilities which use a culvert type structure for the spillway. Based on these data the program will proceed to identify the flow type and the outlet conditions for velocity, Froude number, and brink depth.

WSPRO Program

The Water Surface Profile Computation Model Microcomputer Program has been designed to provide a water-surface profile for six major types of open channel flow situations:

- Unconstricted flow.
- Single opening bridge.
- Bridge opening(s) with spur dikes.
- Single opening embankment overflow.
- Multiple alternatives for a single job.
- Multiple openings.

The United States Geologic Survey (USGS) originally developed WSPRO for the Federal Highway Administration. The model was a batch mode mainframe program, written in FORTRAN. The members of the Pooled Fund Project decided to use WSPRO as the bridge waterways analysis element of the Integrated Computerized Drainage Design System. WSPRO was downloaded to the microcomputer by the USGS and FHWA. The microcomputer version of WSPRO, is dated August 1987. As yet, WSPRO does not have a user friendly, interactive shell to aid in data input and manipulation, although this is planned as a future Hydrain enhancement. The result is that the user must create or edit an input file on a line editor or word processor.

The input file forms a logical description of the physical characteristics of a waterway. Once the user is comfortable with this method of data setup, the program will provide a simple method for determining water surface profiles. The scheme is similar to the Corps of Engineers HEC-2 program. Both WSPRO and HEC-2 are acceptable to the Federal Emergency Management Agency. WSPRO has the advantage that it uses more recent approximation techniques for the backwater effects associated with bridge constrictions.

HY8 Program

HY8 is an interactive culvert analysis program that uses the FHWA analysis methods and information published by pipe manufacturers. The program includes modules to allow the user to interactively enter, save, and edit data. HY8 will compute the culvert hydraulics for circular, rectangular, elliptical, arch and user defined geometry. Additionally, improved inlets can be specified and the user can: analyze inlet and outlet control for full and partially full culverts, analyze the tailwater in trapezoidal and coordinate defined downstream channels, analyze flow over the roadway embankment, and balance flows through multiple parallel culverts.

The initial logic involves calculating the inlet control and outlet control headwater elevations for the given flow. These elevations are compared and the larger of the two is used as the controlling headwater elevation. Tailwater effects are taken into consideration when calculating these elevations. If the controlling headwater elevation overtops the roadway embankment, an overtopping analysis is done in which flow is balanced between the culvert discharge and the surcharge over the roadway. A balancing technique is also used for multiple barrels. If the culvert is less than full for all or part of its length, open channel computations are performed.

A series of data menus, data screens, summary screens, and output screens guides the user through the program. Each menu contains several options to match the desired culvert configuration, while the data screens prompt the user for specific dimensions and coordinates. Summary screens allow the user to edit entered data or change menu selections. Output screens display the output as calculations proceed; hard copy is only obtained using the "print screen" key.

There are three main groups of data to be entered into the program: initial culvert data, downstream channel data, and roadway data. Within the program, the user is sequentially led from one group to the next. From these sets of data, the program develops culvert performance data with or without overtopping. A performance curve can be plotted on a computer with graphics capabilities by typing a V for view. In addition to developing performance curves, the program generates rating curves for uniform flow, velocity, and maximum shear for the downstream channel. Culvert outlet velocities, inlet control head, and outlet control head are also calculated.

Operation

To allow the software to be used by a wide audience, Hydrain operates on an IBM XT/PC or equivalent microcomputer with 640 K RAM, a hard disk, and a monochrome monitor. A math coprocessor is recommended. Engineering programs are in FORTRAN 77. Shells are in C. The HYDRO, HYDRA, and CDS programs are equipped with a "semi-expert" system that includes extensive input shells and "short" and "long" help files. The other programs available to the experienced to expert Hydrain user, WSPRO and HY8, have received a minimum level of development under the Hydrain system.

Report Contents

The remaining section of this volume provides technical reference and user instructions for the PFP-HYDRA program. There are a total of 6 such volumes for Hydrain.

Disclaimer

FHWA, the pooled fund States and their agents have, within the limits of their resources, tested and debugged the Hydrain shells. The engineering programs derive from several varied sources and were adapted to Hydrain and also underwent testing and debugging. However, this is a very large and somewhat complicated system of logic and computer code. Errors and omissions may remain in the software. Therefore, use at your own risk. Please document problems and errors and report to FHWA. User support and technical assistance will be provided to pooled fund States. Agents of these States using the system should channel their requests for support or assistance through their sponsor State.

1. Introduction

PFP-Hydra is a storm drain analysis and design program. This report is intended to introduce PFP-Hydra and guide the user through the necessary steps toward designing or analyzing stormwater drains and/or sanitary sewer systems. The goal of this documentation is to serve as a supplement to the PFP-Hydra Users Manual, within the Pooled Fund Project (PFP) context, recalling some of the system overview and user documentation aspects of the Users Manual, while providing new system technical information.⁽¹⁾ In this manner, the PFP-Hydra user will not only know the final results, but also the methods used to determine them.

In the PFP-Hydra design process, the program will select the pipe size, slope and invert elevations if given certain design criteria. Additionally, PFP-Hydra will perform analyses on an existing system of pipes (and/or ditches). When an existing system of pipes is overloaded, PFP-Hydra will indicate suggested flow removal quantities as well as an increased pipe diameter size as an alternative remedy. Additionally, PFP-Hydra can optionally consider the possibility of surcharged systems, although the design procedure is not optimized, so alternates should be examined.

PFP-Hydra requires the creation of an input file, consisting of commands to describe the drainage system. The program shell facilitates this activity. The commands are placed in a logical sequence, usually from higher to lower elevations. It is possible that several command sequences can produce the same result. The input file, established for a particular collection system by the user, is then executed using the PFP-Hydra analysis program.

This documentation consists of three sections. The first section provides the user with an overview of the components that form the PFP-Hydra program. The second section deals specifically with the technical methods utilized by PFP-Hydra, beginning with a general description of several topics, followed by narratives on methodologies and a discussion of relevant formulas and commands. The topics include: storm flow computed by the rational method, storm flow calculated using hydrographic methods, and sanitary flow. The section also discusses conveyance of the water (resulting from the three methods outlined above) when it has entered the system (i.e., a pipe or channel) and describes the methodologies used in calculating estimated costs. The third section provides the user with instruction on how to apply PFP-Hydra with the Hydrain System.

2. System Overview

This documentation is aimed at providing information to new users (as well as infrequent or "rusty" users) of PFP-Hydra to bring them to a level of ability sufficient for them to utilize any feature that PFP-Hydra offers. It is not meant to show every possible type of analysis or situation that PFP-Hydra can handle (however clear examples of five major types of applications are demonstrated).

This section will provide an overview of PFP-Hydra by briefly describing its purpose, capabilities and structure. A key to some of the more frequently used terms and concepts is included at the end of this section. The following sections provide more detailed information to help the user make the most of PFP-Hydra. The user is advised to scan the "Table of Contents" of this document to see exactly what this text offers, how it is arranged and where to turn to for specific information.

Background and Purpose:

The original HYDRA program, released in 1975, was designed and developed to be run on mainframe computer systems. The purpose of developing the original HYDRA program was to provide a means of accurately, easily and quickly designing and analyzing storm, sanitary or combined collection systems. It is thus oriented to hydraulic design engineers. HYDRA has achieved this goal with a high degree of success, and for this reason was selected for incorporation into the PFP system. PFP-Hydra does everything its mainframe-oriented predecessor does, with the same accuracy, ease and quickness. In fact, it offers some improvements over the older version for certain types of system calculations. Furthermore, if it is being used within Hydrain there are those advantages associated with PFP-Hydra's ability to interact with other related hydraulic design programs. These interactions are described later in the user documentation section.

Capabilities and Limitations

PFP-Hydra operates in two modes; **design** and **analysis**. There are three possible types of systems that PFP-Hydra can work on:

- Storm water systems.
- Sanitary (sewage) systems.
- Combined (storm and sanitary) sewer systems.

In this documentation, these types are collectively referred to as **storm drain systems** or **sewer systems**, or simply, **systems**.

As implied by the preceding text, PFP-Hydra is made to perform the following tasks:

- (1) It can either analyze a drainage system design given user-supplied specifications, or
- (2) It can "free design" its own drainage system based on design criteria supplied by the user.

To meet these broad objectives, PFP-Hydra was necessarily designed to be an extremely flexible and powerful program. The user is warned that care and responsibility should be exercised when the program is utilized as a decision making tool. PFP-Hydra is a design aid only and is not a substitute for sound engineering judgement. This being mentioned, the following is a list of some of PFP-Hydra's more useful features:

- **Cost estimation** - Capabilities that allow for consideration of dewatering, traffic control, sheeting, shrinkage of backfill, costs of borrow, bedding costs, surface restoration, rock excavation, pipe zone costs, etc. PFP-Hydra is also sufficiently flexible to allow cost criteria to be varied for any segment of pipe in a system, if desired. Ground profiles, either upstream or downstream from any specified point along the system, can also be accepted for consideration in cost estimation, if desired.
- **Models storm flow and offers choice of methods** - PFP-Hydra is capable of "generating" storm flow based on either the **rational method** or **hydrologic simulation**. This may be particularly advantageous for engineers who wish to compare designs or analysis results based on different methods.
- **Models sanitary flow** - PFP-Hydra "generates" sanitary flow based on the traditional "peaking factor" concept.
- **Models drainage systems of any size** - PFP-Hydra has a data handling algorithm especially designed to accept a drainage system of any realistically conceivable design.
- **Infiltration/Inflow analysis** - PFP-Hydra is ideally suited for making these analyses.
- **Easy data input structure and quick editing design** - Since all data needed to run PFP-Hydra is in one user-supplied file, data editing is simplified. Furthermore, if the program is run from within the Hydrain System Shell environment, the input file may be modified without leaving the Hydrain program by using the built-in PFP-Hydra program editor. (The capabilities of this screen editor and instructions for its use are described in the section on User Documentation.) Time required for data modification and job resubmission is thus minimized, which enables the user to spend more time on his or her own decision analysis.

- **Planning** - PFP-Hydra can be used for determining the most practical alternate choices for unloading an existing overloaded storm drain or wastewater system and for formulating Master Plans to allow for an orderly growth of these systems. The program's features and capabilities should have far-reaching implications for municipal agencies whose existing sewer systems are under stress from rapid population growth and/or changes in land use patterns.

Structure of PFP-Hydra

The structure and organization of the PFP-Hydra program is similar to many other computer programs. The program reads data, analyzes it, and outputs information for the users review. When the original HYDRA program was developed, a central design criterion was that the program would maximize simplicity in file maintenance and data editing. Unlike many other hydraulic analysis programs, PFP-Hydra requires only a single input data file. This data file is made up of a list of user-supplied **commands** that specify (describe) the system. All internal analysis by PFP-Hydra is performed according to these commands. Once the commands are assembled into a final working data set, they are collectively called a **command string**. (These concepts are explored in more detail in the following section.) During analysis (program execution), the command string is checked for proper format and executability. Output is generated according to the user-supplied instructions of the command string and sent to a separate output file which the user may in turn send to either a printer or screen display. If a run aborts prematurely (before intended analysis is completed), appropriate descriptive error messages are then sent to the output file. There is also a "status report" feature within PFP-Hydra itself that displays (on the screen) when each command in the command string is being worked on, in "echo" format. This allows the user to trace program progress.

Key to PFP-Hydra Terms

To use PFP-Hydra, an understanding of how to prepare a program data file is central. For this reason, it is important to have a clear grasp of the more fundamental modeling terms as they are used in this documentation. The more comfortable the user is with the following terms (and their associated concepts), the easier it will be to put this documentation to use.

- **Command** - A three-letter user-supplied "key word" and its associated completed data field, that PFP-Hydra recognizes and accepts as input data for performing a specific task. The user selects these commands according to the function(s) that he or she wishes for PFP-Hydra to perform. Each command must be listed (entered) on a separate line of data. These data lines make up the input data set, which is collectively referred to as a **command string** (See entry below.) Command names are three-letter "descriptors" (often abbreviations or acronyms) of the tasks that the commands perform. For example, **PDA** is the command name for "Pipe **DA**tA," the command that allows for user-provided specifications of pipes within the system. A complete

listing and explanation of available commands is provided in the appendix.

- **Command string** - An arrangement of **commands** that describes a given **system**. A command string is the fundamental user-provided data set that allows PFP-Hydra to analyze or design a system. This data set may be edited to adjust for modifications to the system without having to build a new command string from scratch. Commands and command strings are further discussed in the next section.
- **Lateral** - Either a single **link** (see entry below) or a number of links connected in a series. Other laterals may connect with any given lateral, but each lateral is continuous. Laterals can be any length, and there can be any number of links that describe a lateral and any number of laterals within a system. In this documentation, trunks, mains and interceptors are all referred to as laterals.
- **Link** - A segment connecting two **nodes** (synonymous to a connecting drainage or sewer pipe). As it represents a length, it is specified in feet. A link is the smallest unit that can transport a flow, and is the sole building block of **laterals**. The amount of flow in a given link is a constant.
- **Node** - A point where storm, sewage or combined flow can be either injected into or removed from the **system**.
- **System** - Collectively, the entire assemblage of **links** and **nodes** (and thus **laterals**) as defined by the user-supplied **commands** of the **command string**. The **system** in this modeling concept is totally synonymous with a stormwater system, a sanitary system, or a combined sewer system.

This concludes the first section of the PFP-Hydra documentation. The next section will provide a technical overview of the methods and operations found in the analysis program.

System Technical Information

Storm Flow: The Rational Method

Developed towards the end of the 19th century, the rational method is still widely used as a method for computing quantities of stormwater runoff. The rational method equation is of the form:

$$Q = C \cdot i \cdot A, \quad (1)$$

where:

Q = the peak flow, in ft³/s,

C = the dimensionless runoff coefficient,

i = the rainfall intensity, in inches per hour, and

A = the area of the watershed, in acres.

Intended for determining runoff from small, urban watersheds, use of the rational method hinges on several basic assumptions:

- The duration used to determine an intensity from an Intensity Duration Frequency (IDF) curve is that corresponding to the time it takes for water to flow from the most remote point in the watershed to the point in question, also known as the time of concentration.
- The intensity of the rainfall is constant and is applied to the entire watershed.
- The runoff coefficient remains constant throughout the storm event.

Taking a look at the above assumptions, it becomes clear why this method is intended for small, urban watersheds. To begin, picking an intensity from an IDF curve at a duration equal to the time of concentration makes the most sense in a small, urban environment. Consider, as an ideal case, a large, gently sloping parking lot to be a watershed and apply a rainfall of constant intensity over the entire watershed. It is apparent that the peak flow at the outfall will occur when the entire area is contributing flow; or, to put it another way, when flow from the most remote point in the watershed reaches the outfall. As the watershed characteristics deviate from this ideal case, it becomes more difficult to justify the rational method because this assumption is likely to be violated. This is particularly true of large rural watersheds.

Another good reason not to apply the rational method to large watersheds pertains to the second assumption: rainfall is constant throughout the entire watershed. Severe storms, say of a 100-year return period, generally cover a very small area. Applying the high intensity corresponding to a 100-year storm

to the entire watershed could produce greatly exaggerated flows, as only a fraction of the area may be experiencing such an intensity.

The variability of the runoff coefficient also favors the application of the rational method to small, urban watersheds. Although the coefficient is assumed to remain constant, it actually changes during a storm event. The greatest fluctuations take place on unpaved surfaces, as in rural settings. In addition, runoff coefficient values are much more difficult to determine and may not be as accurate for surfaces that are not smooth, uniform, and impervious.

To summarize, the rational method provides the most reliable results when applied to small, urban watersheds. If it is necessary to apply the method to large (greater than 300 acres) or rural areas, then the validity of each assumption should be verified for the site before proceeding.

PFP-Hydra generates storm flows using the rational method with the **RAI** and **STO** commands (see the appendix for the proper command syntax for these or any other commands mentioned in this documentation). The **RAI** command provides the IDF curve, while the **STO** command provides the balance of the data and triggers the calculations.

To produce flows using the rational method, PFP-Hydra multiplies the sum of the effective areas (effective area is defined as the product of the area and its respective runoff coefficient, i.e. $\sum C \cdot A$) by the intensity (from the IDF curve specified in the **RAI** command) corresponding to the longest time of concentration (T_C). To determine the longest T_C , the program examines the origin of all flows entering the junction. The longest time will either be: 1) the T_C specified in one or more **STO** commands directly contributing flow to the junction under analysis, or 2) the sum of the T_C specified by a previous **STO** command and the travel time of that flow through the system to the junction in question. Each time a **PIP** command is encountered, PFP-Hydra recalculates both the effective area and the time of concentration.

An exception to this approach occurs when the flow in an individual area exceeds the sum using the long T_C . In situations such as this, the time of concentration corresponding to the area contributing the largest flow is employed, rather than simply using the largest time of concentration. The effective area contributing the lesser flow is then reduced by the ratio of the respective times of concentration. The justification for such a reduction is that in utilizing the smaller T_C , only a fraction of the area corresponding to the greater T_C will contribute flow. This methodology produces greater flows, ultimately resulting in conservative estimates of pipe size. If such a recalculation occurs during a PFP-Hydra run, the user is notified in the output: ***** READJUSTING SUM OF C-A**". The appendix provides such an example, for the interested reader.

PFP-Hydra provides the user with three options for generating time of concentration. These are: 1) user supplied T_C , 2) overland T_C calculated, gutter T_C supplied by user and 3) both overland and gutter T_C calculated by the program. Should the user desire to supply their own values, they can consult numerous references (notably FHWA HEC-12 and HEC-19) that will provide theory

and guidance in calculating T_C .^(2,3) If, however, the user requests that PFP-Hydra calculate the time of concentration, a formula recommended by the Federal Aviation Administration, is used for overland time of concentration.⁽⁴⁾ The formula does not allow the user to enter a maximum overland flow length.

$$T_C = (1.8 \cdot (1.1 - C) \cdot L^{0.5}) / s^{0.33} \quad (2)$$

where:

C = the dimensionless runoff coefficient,

L = the distance traveled, in feet, and

S = the slope, in percent.

If the gutter time is to be calculated, a second formula is used:

$$T_C = L / (K \cdot s^{0.5}) \quad (3)$$

where:

L = the distance traveled, in feet,

S = the slope, in ft/ft, and

K = an empirical coefficient equal to 32, in ft/sec.

Storm Flow: Hydrographic Analysis

Hydrographic analysis enables the user to mathematically simulate "rain" on an area to determine runoff quantities. Unlike the rational method, which simply calculates peak flows, hydrographic simulation takes into account a very important factor when studying rainfall/runoff relationships - timing. PFP-Hydra actually "steps" through a rainfall event, at regular, user specified intervals, accounting for all the water that has fallen on the land segment. Once initial abstraction has been determined (initial abstraction is that portion of a rainfall event that is lost to storage, i.e., puddles, vegetation, etc. or infiltrates into the ground), PFP-Hydra develops a runoff hydrograph and routes it through the system.

The hydrograph can be developed in two ways: 1) by using an externally produced hydrograph, with the **UHY** command; or 2) by developing a hydrograph through a user supplied hyetograph, via the **HYE** command, and using PFP-Hydra to apply the procedure described in the following section.

The user begins by providing a rainfall hyetograph to the program, using the **HYE** command. By adjusting the time step as specified in the **STE** command, storm events of varying lengths can be modeled. To elaborate, when PFP-Hydra performs the calculations that convert a hyetograph into a runoff hydrograph,

up to 96 time steps are analyzed. If the step is set to 15 minutes, then the longest possible duration of the modeled event is 24 hours. A 5-minute time step can model a period of up to 8 hours, and so on.

After the hyetograph has been introduced, the land segment characteristics need to be defined. By manipulating the characteristics describing both pervious and impervious land types, as defined in the **UNP** and **PAV** commands, respectively, flows can be generated that very closely coincide with measurements taken from actual storm events.

On impervious land areas such as parking lots, roads, and sidewalks, losses are attributed almost entirely to puddle storage. PFP-Hydra accounts for puddle storage on impervious land areas through the use of several parameters defined in the **PAV** command. Two of the parameters, **depthpud** and **slope** work in conjunction with the "slope" parameter expressed in the **HYD** command to define the detention capacity of the depression on the land segment. This is accomplished as follows: **depthpud** provides what might be described as an "equivalent depth" the land segment would experience from the puddle storage, assuming that the area was flat. To set this factor, multiply the average depth of all the puddles (again, assuming the land segment has no slope) times the percentage of the area the puddles would occupy. To determine the puddle storage of the actual, sloped land segment, **depthpud** is multiplied by a ratio derived from the **slope** term in the **HYD** command, which is the actual slope of the land segment, and the **slope** term in the **PAV** command, which corresponds to the slope the land segment would have to be tilted in order to drain all the puddles.

Three additional parameters in the **PAV** command that also deal with puddle storage are **topud**, **toweep**, and **timedrain**. The first term is simply the portion of the rainfall that is diverted to puddle storage. Of this portion, a fraction, as defined by **toweep**, is diverted to "weeping" puddles. These puddles detain water, but not permanently. After a certain time period, as specified in **timedrain**, they leak their contents back into the system. The remainder of **topud** is the portion of the rainfall that is detained in "dead" puddle storage (water detained does not contribute to system flow), as described above.

Determining the quantity of runoff from unpaved land areas is more difficult; water can be lost, stored, or delayed in a variety of ways. Trees, shrubs, and grasses act as "buckets" which must be filled before rainfall reaches the ground. Once on the ground, a portion is lost to infiltration, the rate of which changes during the course of the rainfall event. Part of the flow introduced into the ground water does not reappear, while some may be reintroduced into the system. Modeling these complicated interactions and accounting for losses and delays on pervious areas is the task of the eleven parameters in the **UNP** command.

Three of the eleven required parameters, **intrcpt**, **depth1**, and **depth2** allow for interception storage, i.e., on trees, shrubs, and grass. PFP-Hydra allows the user to specify depths (**depth1** and **depth2**) corresponding to two different types of vegetation cover. The amount of precipitation detained by the surface described by **depth1** is defined as a ratio of the total precipitation by the

intrcpt parameter. The remainder of the rainfall is directed to that area as described by **depth2**.

Once **depth1** and **depth2** have been "filled", water reaches the ground and infiltration begins. PFP-Hydra calculates the effects of infiltration by solving the following equation:

$$\text{infiltrn} = \text{satinf} + (\text{maxinf} - \text{satinf}) \cdot e^{-\text{idecay} \cdot t} \quad (4)$$

where:

infiltrn = the infiltration capacity at time *t*, in inches per hour,

satinf = the saturated capacity, in inches per hour,

maxinf = the initial capacity (dry conditions, maximum capacity), in inches per hour,

idecay = the infiltration decay constant, and

t = the time from start of precipitation excess, in hours.

This formula, known as Horton's equation, calculates infiltration capacity as a function of time.⁽⁵⁾ Time variable infiltration is an important consideration as the infiltration rate of a given soil decays as the soil becomes more saturated. Ultimately, when the soil becomes fully saturated, the infiltration rate approaches a constant value. The infiltration capacity at each time step is determined. When precipitation ceases, the infiltration rate begins to recover towards the maximum capacity (**maxinf**) value. The time of recovery is defined by the **timerec** parameter, that becomes important during storms that have a period in which the precipitation actually stops and then begins again.

With the losses from both pervious and impervious areas essentially "removed" from the incoming hyetograph, the remainder of the precipitation is converted to a runoff hydrograph for conveyance.

Sanitary Flow

PFP-Hydra allows the user to generate average and peak sanitary flows for both the analysis of existing sewers and the design of new sewers. In addition, the program has the capability for investigating infiltration.

In PFP-Hydra, average sanitary flow is calculated using the parameters specified in one or both of the following combinations of commands: **GPC** and **SAN** or **IPU**, **GPC**, and **SUN**. In the first combination (**GPC**, **SAN**), average flow is calculated by multiplying the number of gallons produced per capita per day, (specified in the **GPC** command), by the number of people per acre times the

number of acres, (specified in the **SAN** command). Therefore, flow in a given conveyance is calculated as follows:

$$Q_a = \Sigma(\text{uflow} \cdot \text{pop} \cdot \text{area}) \quad (5)$$

where:

Q_a = the average flow, using the first combination, in gallons per day,

uflow = the unit flow of generated wastewater, in gallons per capita per day,

pop = the equivalent population density, in persons per acre, and

area = the area of sanitary collection, in acres.

The flow is internally converted to ft^3/s . In most circumstances, it will not be necessary to change the value of **uflow**, reducing the equation to:

$$Q_a = \text{uflow} \cdot \Sigma(\text{pop} \cdot \text{area}) \quad (6)$$

In the second combination (**IPU**, **GPC**, **SUN**), average flow is determined by multiplying the cumulative product of number of sanitary units (e.g. houses, apartment buildings, that are specified in the **SUN** command), multiplied by the number of individuals per sanitary unit (specified in the **IPU** command). This total is then multiplied by the number of gallons produced per capita per day. This is expressed as:

$$Q_a = \text{uflow} \cdot \Sigma(\text{units} \cdot \text{ipu}) \quad (7)$$

where:

Q_a = the average flow, using the second combination, in gallons per day,

uflow = the unit flow of generated wastewater, in gallons per capita per day,

units = the number of dwelling units contributing to the system at each node, and

ipu = the number of people per dwelling unit.

As with the first combination, flow is internally converted to ft^3/s .

The decision to utilize the methods discussed above is dependant on the type and availability of data. The **IPU** and **GPC** commands will in most cases

only have to be entered once at a point near the beginning of the command string. The **SAN** and **SUN** commands actually introduce flow into the system and are placed throughout the command string where needed.

In performing calculations to determine peak sanitary flow in a system, PFP-Hydra employs the "peaking factor" concept. The peaking factor is a number, greater than or equal to one, that is multiplied by the average flow to account for peak loads on the system. In the initial few links of a network, where flows are relatively low, experience has shown that the peaking factor may be as high as 4.0. Further down the line, where the physical length of the system, as well as the increase in flow, makes individual contributions less important, the peaking factor decreases. Since the peaking factor, which is entered in the **PEA** command, can have a significant effect on the amount of flow generated, great care should be taken in selecting the **flow/flow factor** ordered pairs.

Each time one of the transport commands, either **PIP** or **CHA**, is encountered, the average flow is calculated and a new peaking factor is calculated. At that point, the peak flow in the system is equal to the following:

$$Q_p = pkfctr \cdot Q_a \quad (8)$$

where:

Q_p = the peak daily flow, in gallons per day,

$pkfctr$ = the peaking factor, resulting from the **flow versus factor** curve provided in the **PEA** command,

Q_a = the average daily flow, in gallons per day.

In addition to accounting for known, anticipated inflows, undesirable inputs, namely infiltration, must also be taken into consideration. Infiltration plays a particularly important role in sanitary sewer systems in that it can comprise a significant percentage of the flow, especially in older networks. Infiltration can be included with the use of the **INF** command. This flow contribution is calculated each time the **SAN** and/or **SUN** command is encountered. It is added to the system flow after the peaking factor has been applied.

Flow Conveyance

Flow generated in any of the previously described sections is eventually transported through pipes and/or channels. Sizing of these conduits as well as the determination of other flow characteristics can now be accomplished.

To evaluate the adequacy of an existing system to analyze imposed flows or to design a new system, PFP-Hydra employs Manning's formula for gravity flow:

$$Q = \frac{1.486}{n} \cdot A \cdot R_h^{0.667} \cdot S^{0.5} \quad (9)$$

where:

Q = the pipe flow, in ft³/s,

A = the area of the flow cross-section, in square feet,

R_h = the hydraulic radius of the flow cross-section, in feet,

S = the pipe slope, in ft/ft, and

n = Manning's friction coefficient for the pipe.

In the design case, this equation is algebraically manipulated to solve for the diameter necessary to handle the design flow. When the pipe is between 6 and 36 inches in diameter, the calculated diameter is rounded up to the nearest 6-inch increment. When the calculated pipe diameter is greater than 36 inches, it is rounded up to the nearest 12-inch increment. This value, or the minimum diameter value as defined in the PIP command, whichever is larger, is then utilized as the design size. (It is important to note that even though in certain circumstances design flows may be very low, PFP-Hydra will design no pipe smaller than 6 inches in diameter).

Having utilized the design flow to determine the pipe diameter, both parameters can now be employed to calculate flow velocity. PFP-Hydra again makes use of Manning's equation:

$$V = \frac{1.486}{n} \cdot R_h^{0.667} \cdot S^{0.5} \quad (10)$$

where:

V = the pipe velocity, in ft/s,

R_h = the hydraulic radius of the flow cross-section, in feet,

S = the pipe slope, in ft/ft, and

n = Manning's friction coefficient for the pipe.

Since the hydraulic radius is a function of depth and in most cases the pipes will not be carrying capacity flows, this term is expressed as follows:

$$R_h = \frac{D}{4} \cdot \left(1 - \frac{\sin 2\theta}{2\theta}\right) \quad (11)$$

where:

D = the diameter of the pipe, in feet, and

θ = theta, in radians, measured as shown below in figure 1.

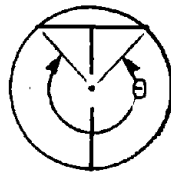


Figure 1. Measurement of θ . (6)

If water is transported through an open channel, PFP-Hydra presents the user with two alternatives for computing depth and velocity of flow. One alternative, as with calculating flow in pipes, is Manning's equation. Using the design flow and channel geometry, as defined in the **CHA** command, PFP-Hydra employs a trial and error process to determine depth. Once depth is obtained, Manning's equation is solved for velocity.

The second option available for determining depth and velocity of flow in open channels involves the use of a formula developed by Izzard, which is an approximation for hydraulics in gutters. (2)

$$Q = \frac{0.56}{n} \cdot S_x^{1.67} \cdot S^{0.5} \cdot T^{2.67} \quad (12)$$

where:

S_x = the roadway cross slope, in ft/ft,

S = the longitudinal slope of the gutter, in ft/ft,

T = the spread of flow in the gutter, in feet, and

n = Manning's friction coefficient for the gutter.

This equation was derived from Manning's equation to describe flow in wide, shallow, triangular channels. If this option is selected, PFP-Hydra selects the greater of the two side slopes entered and ignores the bottom width. In other words, a channel of the shape depicted in figure 2 is assumed:

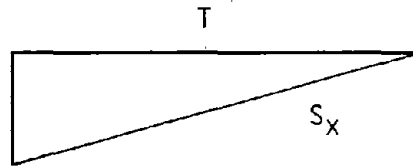


Figure 2. Triangular gutter shape.

The depth of flow is solved directly and the continuity equation is employed to solve for velocity. Note that composite cross slope gutter sections are not included in PFP-Hydra.

The two alternatives discussed above are also available to describe flow through gutters as defined in the **GUT** command. The difference between the **CHA** and **GUT** commands is that **GUT** is only recognized by PFP-Hydra during hydrographic analysis.

Cost Estimating

PFP-Hydra, through the use of criteria established in the following commands, performs a cost estimate to design pipe in place:

- 1) **CST** - ditch geometry and unit prices for material and haul,
- 2) **EXC** - ditch excavation costs,
- 3) **PCO** - pipe costs,
- 4) **TSL** - establishes trench side slopes,
- 5) **ECF** - extra excavation costs,
- 6) **PCF** - extra pipe costs, and
- 7) **LPC** - summary table of unit costs and materials

In order for PFP-Hydra to calculate costs for pipe in place, the first four of the above commands must be utilized; the remaining three are optional.

PFP-Hydra performs numerous calculations to arrive at the final cost estimates. These estimates are calculated by first determining the amount of a given material and then multiplying that value by its unit cost. This process is carried out on a link by link basis. As a general representation, cost can be said to be equal to the following:

$$\text{cost} = \sum(X_i \cdot U_i) + \text{lcost} \quad (13)$$

where:

cost = the cost associated with the sanitary sewer or storm drain project, in dollars,

X_j = the quantity of excavation, backfill material, pipe zone material, bedding material, and pipe,

U_j = the cost of excavation, backfill material, pipe zone material, bedding material, and pipe, in dollars per item or quantity, and

lcost = lump sum costs (e.g. inlets, pumps), in dollars.

The "lump sum costs" term includes monies that are simply added on directly. Included in this category is the **lcost** term in the **PIP** command as well as the **cost** parameter specified in the **PUM** command.

This section was intended to serve as a technical overview for PFP-Hydra. In the areas of flow generation, flow conveyance and cost estimating, equations employed by PFP-Hydra, as well as discussions on applied methodologies were presented to orient the user towards understanding how the program arrives at its results. The final section describes, in some detail, how to use the PFP-Hydra modules.

4. User Documentation

The Command Approach - Organizing the Data

PFH-Hydra operates through the command language concept. This means that data entry and data analysis are all dictated by user-supplied commands. A command is a very specific entity that describes one basic task that PFP-Hydra can recognize. There is only a set number of commands in PFP-Hydra's vocabulary and they must each follow a specific format. Currently there are 49 commands that PFP-Hydra can recognize, although this number is subject to change as long as improvements are being added to PFP-Hydra. A complete list, to date, of these commands along with their definitions and format specifications is included in appendix B.

Commands are the data that a user must specify to describe a system for analysis. These commands may be arranged in almost any order, provided they follow a few, simple guidelines. These guidelines ensure that the users system is described appropriately and logically, and will become more clear as the user gains familiarity with this section and the examples provided in the appendix. Once these commands are arranged in their final working order, they are collectively referred to as a command string. The command string is what PFP-Hydra needs to define a system model for analysis.

Figure 3 shows an example command string, broken down into its command name and accompanying data field, with an explanation of each command used. Figure 4 shows the organization of all the PFP-Hydra commands. Although the rules for ordering commands are not listed in this figure, the reader should grasp that PFP-Hydra command strings are assembled according to the loose hierarchy of figure 4. A brief glossary of all the commands is shown in table 1. Detailed descriptions, formatting templates and special notes for each command are provided by the software as long helps (obtained by using the F10 key) and are also reproduced in appendix B. Commands operate in "free format" fashion; that is, a space [], a comma [,] or a slash [/] are parameter subfield separators that may be used in any amount between each parameter value (spacing between subfields is not critical). All commands must be expressed in upper case letters. Continuation of a command with many or extremely lengthy variables is achieved by entering a plus sign [+] before the eightieth column and entering subsequent data into the next line.

Ordering commands in a PFP-Hydra command string is a relatively easily acquired skill. For instance, using figure 3 as an example, note that the **JOB** command is first. This establishes the file name that will be used for the output. The next command is the **PDA** command which establishes certain pipe data criteria such as the Manning's "n" friction factor, minimum diameter, ideal depth, minimum cover, minimum velocity, and minimum slope. The **PDA** command does not need to be the second command, but if it is used, it must precede the first **PIP** (pipe) command so that PFP-Hydra will have the criteria necessary to formulate a preliminary pipe design. The **PIP** command is the third command in the data set. In most cases, commands may be used more than once. This allows the user to change specifications or design criteria at any point

in the system. Again, with reference to the figure 3 example, the PDA command was used twice. Although this example shows modification only to the friction factor, any parameter value may be modified by changing the appropriate subfield in the data field.

In conclusion, recall that data are input into PFP-Hydra by way of **commands** and that a working arrangement of these commands is called a **command string**.

PFP-Hydra COMMAND*	DATA	DESCRIPTION
JOB	COMMAND STRING EXAMPLE	The name of the job.
PDA	.014 12 8 4 2 .005	Sets the design criteria, such as Manning's "n", minimum diameter, etc.
NEW	MAIN STREET	Starts a new lateral and names it.
FLO	11.0	Puts a flow of 11.0 cubic feet per second (ft ³ /s) into the system at this location.
PIP	300 110 110	Pipe parameters. (Transports the flow in a pipe 300 feet long - ground elevation at both the upper and lower ends is 110 feet.)
PIP	400 110 112	Continues to transport the flow into another pipe 400 feet long.
FLO	4	Adds another 4.0 ft ³ /s to the system at this point.
PDA	0.025 12 8 4 2 .005	Change the pipe friction factor to 0.025 (corrugated metal pipe).
PIP	450 112 100	Transports the flow another 450 feet.
END		Terminates the PFP-Hydra run and prints the results.

* All commands must be expressed in upper case letters.

Figure 3. Example of a command string.

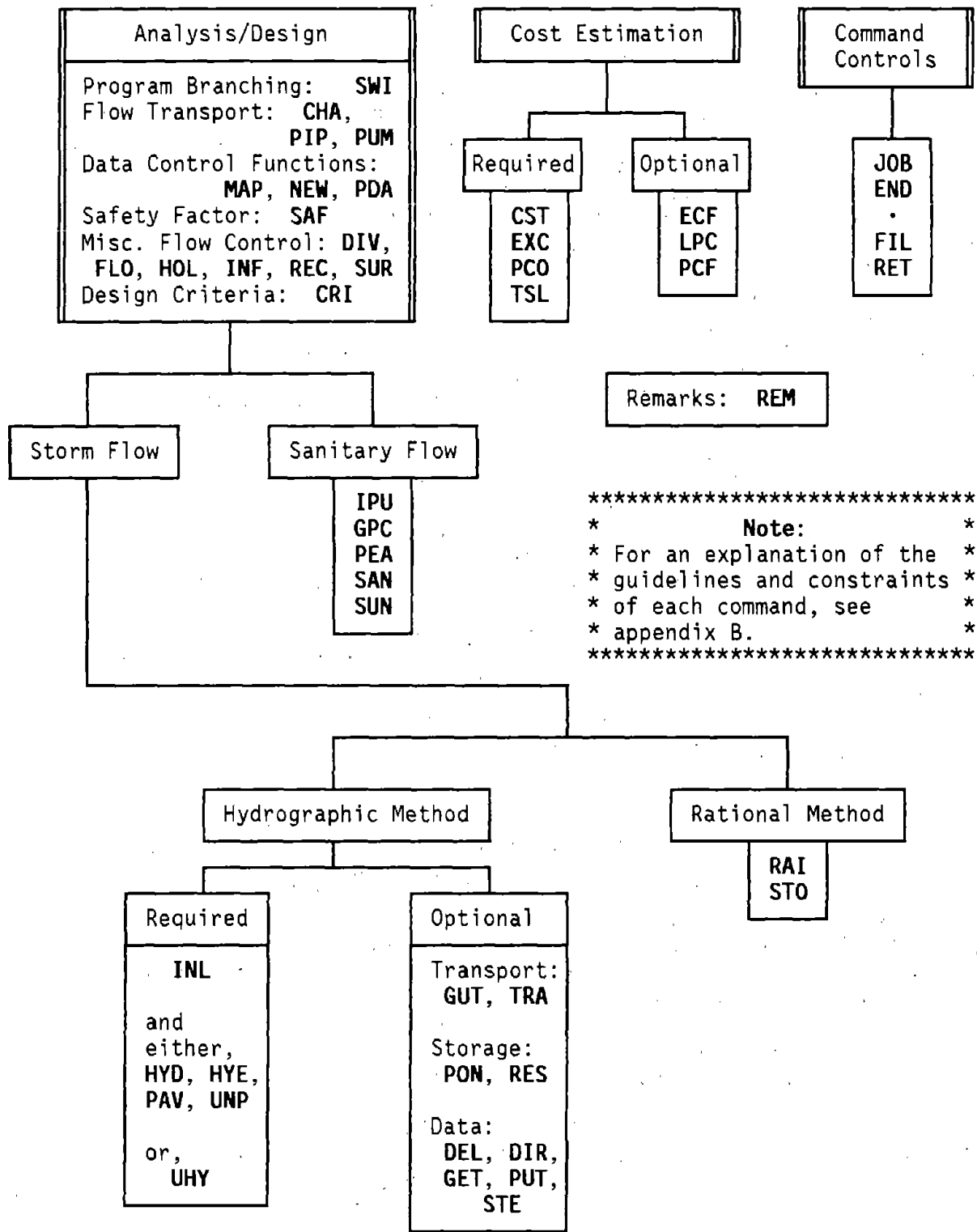


Figure 4. Organization of PFP-Hydra commands.

Table 1. Glossary of commands.

CHA	- allows you to define an open CH annel or ditch.
CRI	- determines whether inverts or crowns are to be matched (CR iteria).
CST	- sets geometry factors and unit prices (Co STs in place).
DEL	- sets the DEL ay time of a storm relative to its entry into a basin.
DIR	- establishes DIR ection and other characteristics of a storm cell.
DIV	- splits the system flow into two components (DIV erts flow).
ECF	- allows Extra Costs per linear Foot to be added to the pipe cost.
END	- END s a command string.
EXC	- establishes trench EXC avation costs.
FIL	- causes HYDRA to read commands from a slave FILE .
FLO	- adds or subtracts a constant FLOW to the system.
GET	- GET s a gutter hydrograph from storage.
GPC	- sets the Gallons Per Capita per day for flow calculations.
GUT	- establishes GUT ter characteristics.
HOL	- HOL ds system flow at the lower end of a lateral.
HYD	- generates a HYD rograph from a land segment.
HYE	- allows input of a HYE tograph.
INF	- inputs INF iltration flows by population or area.
INL	- sets parameters for a storm water IN let.
IPU	- establishes the number of Individuals Per sanitary Unit .
JOB	- initiates JOB and enters JOB title.
LPC	- calculates and Lists Pipe Costs in place.
MAP	- establishes factor for converting square inches on a MAP to acres.
NEW	- clears some registers and loads NEW lateral name.
PAV	- sets parameters for PAV ed portion of land.
PCF	- establishes a Pipe Cost Factor.
PCO	- establishes Pipe CO sts per foot in place.
PDA	- establishes Pipe design DA ta.
PEA	- translates average daily flow into PEAK daily flow.
PIP	- moves water from one point to another in a circular PIPE .
PON	- allows surface POND ing of flows HYD , GUT , GET commands.
PUM	- lifts the hydraulic gradient a specified amount (PUM p).
PUT	- PUT s gutter flow into storage.
RAI	- sets the values on a RAI nfall intensity versus duration curve.
REC	- RE calls flow previously stored using the HOL or DIV commands.
REM	- allows a line for RE marks or comments.
RES	- allows the analysis of in-line storage (RE servoir).
RET	- RE turns command reading to the master file.
SAF	- applies SAF ety factors to calculated flows.
SAN	- enters SAN itary flow into the system.
STE	- sets the length of time increments (STE ps).
STO	- enters sub-basin data for determining STO rm water design flow.
SUN	- enters the number of contributing SAN itary UN its.
SUR	- allows analysis of the possibility of SUR charging the system.
SWI	- sets SWI th for determining method of storm/sanitary flow analysis.
TRA	- TR ansfer system flow to surface flow.
TSL	- determines Trench side wall SL ope.
UHY	- enables use of externally produced hydrographs (U ser HY drograph).
UNP	- sets parameters for UNP aved area.

PFP-Hydra and the Hydrain System Shell

For those users who have obtained PFP-Hydra as part of the Federal Highway Administration's **HYDRAIN** package, additional information is required to run PFP-Hydra within that system. Furthermore, **HYDRO** - the hydrology component of **HYDRAIN** can be used to provide hydrographs, IDF curves, and hyetographs for use in drainage analyses. Hydrain and **HYDRO** documentation should be consulted for instructions. The following sections discuss the procedures for operating the Hydrain System Shell and PFP-Hydra Input Program.

Operating the Hydrain System Shell

PFP-Hydra, as well as the other PFP software packages, is implemented through the use of what is known as the PFP "shell". This shell is a separate program that ties the above-mentioned packages together and allows them to be accessed. The following text deals specifically with the interaction between the Hydrain System Shell and PFP-Hydra; the operation of the other packages will be dealt with separately in their respective documentation.

Before work on a specific PFP-Hydra dataset can begin, the Hydrain shell must first be entered and the desired package accessed. This process is begun, from DOS, with the command **HYDRAIN** and striking a carriage return (denoted by <CR>). A screen will appear showing the member States of the Pooled Fund Project as well as the companies involved in its development. Another <CR> reveals a message (a PFP "disclaimer") to the PFP user. A third <CR> will place the user in the Primary Menu, from which the desired PFP program can be accessed. To select a program, in this case PFP-Hydra, simply use the right and left ARROWS to bring the cursor under the program name and press <CR>. (An alternate approach is to simply enter the first letter of the desired name, for example, for PFP-Hydra, press P). The next screen that will appear is the **Job Option Menu**, which contains the following choices;

```
Input / Edit Data File
Run Program / Review File
Quit (Return to Primary Menu)
```

In addition to each option, a short description of their function appears at the bottom of the screen. Movement in this field, as before, is accomplished with the ARROWS (in this case, up and down) or by striking the first letter of the desired option. Since a new file is to be created, place the cursor under the first choice, **Input / Edit Data File**, and press <CR>. The user is now asked to input the name of the data file; any name can be used, as long as it contains no more than 8 characters. An **.HDA** filename extension is automatically assigned and need not be specified. Following a <CR>, work on a specific PFP-Hydra dataset can begin.

Using the PFP-Hydra Shell

The screen where the editing takes place is broken up into 2 components: the action screen and the datascreen. Movement between these two screens, as

well as within each screen, can be accomplished using the following keys: F1-F7, F10, Esc, <CR>, ARROWS, PgUp, PgDn, Home, and End. Since in some cases the functions of the above keys vary depending on which screen the user is in, both screens and their respective key actions will be discussed separately.

The Action Screen

(The description in brackets echoes that found at the bottom of the screen).

F1 - [prior field]	-	moves the cursor to the left
F2 - [next field]	-	moves the cursor to the right
F3 - [prior screen]	-	moves cursor to "LEAVE" but will not execute
F4 - [next screen]	-	initiates action specified by cursor (the function of each action will be discussed later)
F5 - [clear field]	-	clears the field
F6 - [leave]	-	saves current file while returning to "job option menu"
F7 - [abort]	-	returns to "job option menu" <u>without</u> saving file
F10- [help]	-	provides extensive information to the user
Esc	-	same as F6
<CR>	-	implements action specified by cursor
ARROWS	-	same as F1 and F2 above

The Data Screen

F1 - in "CHANGE" mode: If in data field, moves to command field; if in command field, moves to prior command field.
in "INSERT" mode: If in data field, moves to command field; if in command field, returns to action screen.

F2 - in "CHANGE" mode: Moves forward from command field to data field to command field, etc.
in "INSERT" mode: Returns to action screen.

F3 - Returns cursor to action screen to particular action being implemented.

F4 - in "INSERT" mode: Returns to action screen to "INSERT";
in "CHANGE" mode: Returns to action screen to "LEAVE".

F5 - clears the field.

F6 - returns to action screen to "LEAVE".

F7 - same as F6 above.

F10 - long help - provides help to the user by giving detailed information on each command.

Esc - same as F3 above.

<CR> - moves to next field.

PgUp - moves to the top of the current page of the data set.

PgDn - moves to the bottom of the current page of the data set.

Home - moves to the top of the data set.

End - moves to the end of the data set.

ARROWS - moves as directed within field, but not a means to go from one field to the other.

The action screen, as its name implies, initiates the "actions" contained within: CHANGE, INSERT, DELETE, RENUMBER, and LEAVE. When starting a new data file, the mode is automatically set to "INSERT" and the cursor is placed in the first line in the data screen. As mentioned above in the description of the keys, the data screen contains two fields; the command field and the data field.

The command field is three spaces wide and is directly beside the column containing the line numbers. Active commands, which are listed on the screen and which have been explained previously in the documentation, are entered here. By pressing <CR>, the data field, where the data itself is input, can be entered. Another <CR> moves the cursor to the next line to accept a new command. This process is repeated until the entire data set has been entered.

It is important to note that when in the "INSERT" mode, it is not possible to move to a prior command. If an alteration is necessary, the cursor must be moved back up to the action screen, by any of the means previously discussed, switched to the "CHANGE" mode, and returned to the data screen. Movement throughout the data screen is now possible and changes anywhere in the data file can be made. If it is desirable to input a new line of data between two existing lines, the cursor must first be placed between the desired lines, the switch made to the action screen, the cursor moved to "INSERT", and the switch made back to the data screen. A blank line has been added which can now be filled in as desired.

As mentioned earlier, continuation of a command with many or extremely lengthy variables in the data field, is achieved by following the last data element with a plus sign [+] and pressing <CR>. This brings the user to the subsequent command field. This field is left blank (as opposed to entering a new command) by simply striking <CR>. Once in the data field, the user continues to enter data. An example of the continuation feature is shown in example one in appendix A.

The "DELETE" mode works much the same way in that while in the change mode, the cursor must first be moved to the command to be deleted. Switching to the action screen and moving the cursor to "DELETE", the command and data string can now be deleted. Something to keep in mind here is that if there are

several commands in a row to be deleted, the command at the bottom of the string should be eliminated first because once gone, the cursor moves upward to the next command. Once all desired changes have been made, renumbering will be necessary if even increments are desired. This is easily accomplished by switching to the action screen, moving to "RENUMBER", and pressing <CR>. The desired increment will be asked for as well as the starting number. It is important to note that the F4 key does not work while in "RENUMBER" mode. Thus, <CR> must be used.

If everything is now correct and the program is ready to be run, return to the "Job Option Menu" using one of the above mentioned methods, but making sure the file is saved.

Executing PFP-Hydra from Hydrain

Upon returning from the PFP-Hydra Input Program, PFP-Hydra can be run by moving to the **Run Program / Review File** option, pressing <CR>, and entering the filename (although, as a default, the previous filename is provided). As the input file executes, the commands in the file will appear sequentially on the terminal screen. The user can "observe" the progress of the PFP-Hydra run by observing which commands are being processed.

Upon completion of the run, the output file, which is automatically assigned an .LST filename extension, will be displayed on the screen. Movement through this screen can be accomplished with the cursor, PgUp, PgDn, Home and End keys. After reviewing the file, pressing F6 will return the user to the **Job Option Menu**. From here, the user can once again edit the same, or any other, file. If it is desirable to run one of the other PFP programs, the primary menu can be brought up by pressing Q. Striking Q once more will enable the user to exit the Hydrain Shell to DOS.

Appendix A: Benchmark Examples

PFP-Hydra Example

The following examples are hypothetical systems modeled by PFP-Hydra which are provided to illustrate some of the program's capabilities to the user. It is intended that these examples will achieve at least these four objectives:

- (1) Provide guidance for creating command strings.
- (2) Demonstrate uses for many of the commands.
- (3) Provide information on how to set up a problem.
- (4) Demonstrate what to expect for output.

However, it should be recognized that the chapter examples are not meant to give a comprehensive guide of every command option. The user is referred to appendix B for this information.

The five examples offered here collectively make use of most of the available commands. In each case, a figure is included to schematically represent a given problem. Following each figure, the input data set for the run and its corresponding output are given. Each of the five examples provides a different type of application of PFP-Hydra. These are:

- 1) Sanitary sewer design.
- 2) Sanitary sewer analysis.
- 3) Rational method design.
- 4) Combined system analysis.
- 5) Hydrographic simulation.

Example One: Sanitary Sewer Design

This example demonstrates the use of PFP-HYDRA in the design mode. A sanitary sewer is planned in which each individual in the service area contributes 100 gallons per day to the sewer (GPC 100) and such that infiltration into the system occurs at a rate of 1000 gallons/day/acre, except in the area serviced by the Kenyon Street lateral where there is a rate of 2000 gallons/day/acre. Figure 5 shows the example site.

Peaking factor data are expressed in the PEA command which provides ordered pairs of flow versus peaking factor data for flows between 0.01 cfs and 10,000 cfs. Note that the PEA command data required two lines. The + symbol on the first line indicates to PFP-HYDRA to look for additional data on the following line.

Other commands shown in the example include the PDA command (pipe data), which gives pipe characteristics such as Manning's "n" value, and the CST, EXC, PCO, and TSL commands, which work together in making the cost estimates for the preliminary design. These costs include trench construction as well as pipe materials.

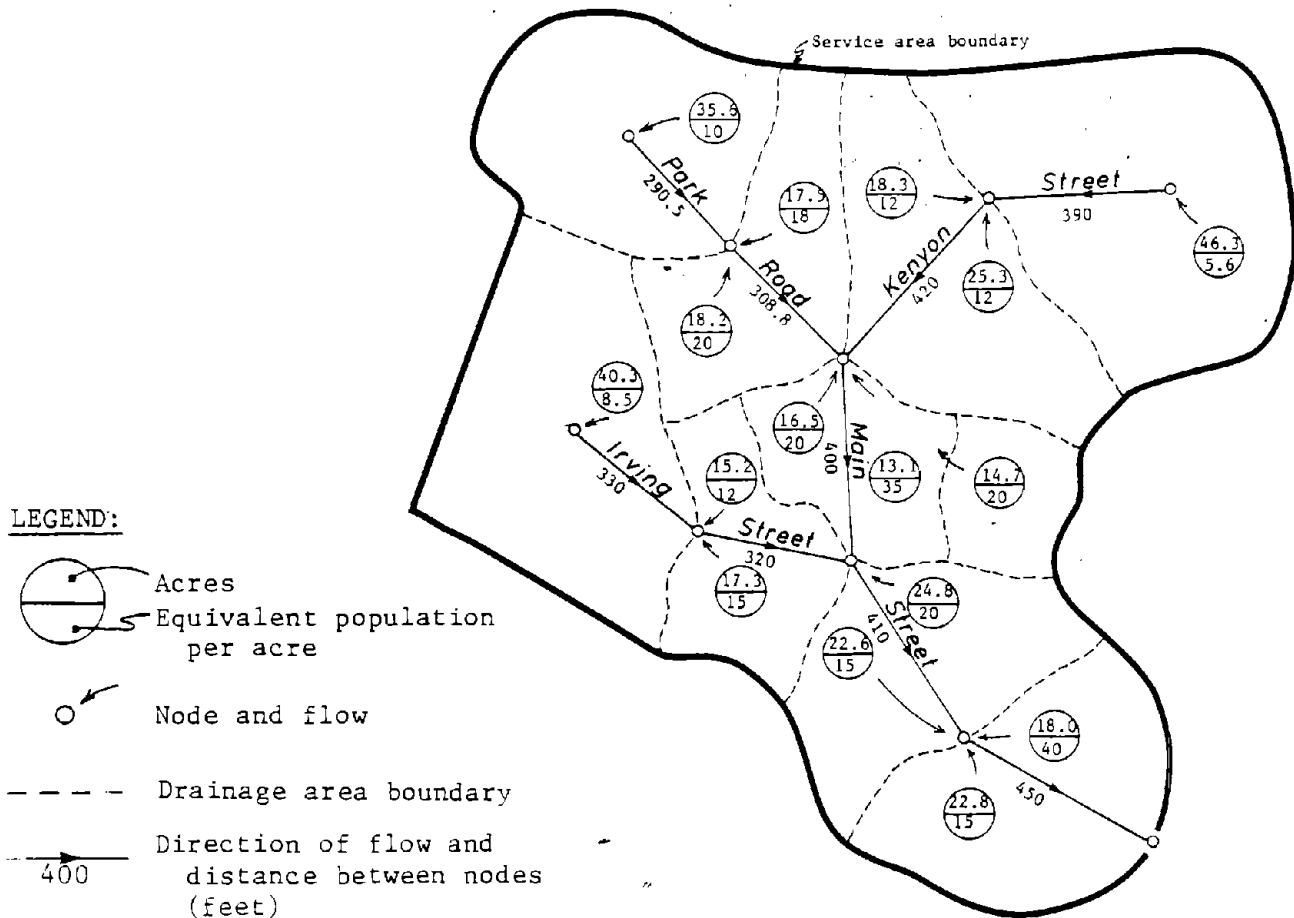


Figure 5. Sanitary sewer design.

EXAMPLE ONE: SANITARY SEWER DESIGN

OUTPUT

INPUT

*** PARK ROAD Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Cover (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
1	291	6	93.8 86.6	.02478	7.0 7.0	6.5	3.9 4.5	.26 .89	1213.
2	309	6	86.6 77.7	.02882	7.0 7.0	6.5	5.2 4.9	.63 .96	1289.

LENGTH = 599. TOTAL LENGTH = 599.
COST = 2502. TOTAL COST = 2502.

*** IRVING STREET Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Cover (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
3	330	6	88.0 74.2	.04182	7.0 7.0	6.5	4.7 5.9	.26 1.15	1378.
4	320	6	74.2 67.3	.02156	7.0 7.0	6.5	4.4 4.2	.51 .83	1336.

LENGTH = 650. TOTAL LENGTH = 650.
COST = 2714. TOTAL COST = 2714.

*** KENYON STREET Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Cover (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
5	390	6	90.5 82.0	.02179	7.0 7.0	6.5	3.9 4.2	.30 .83	1628.
6	420	12	82.0 77.7	.01024	7.0 7.0	5.9	3.5 4.6	.68 3.61	3126.

LENGTH = 810. TOTAL LENGTH = 810.
COST = 4754. TOTAL COST = 4754.

*** MAIN STREET Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Cover (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
7	400	12	77.7 67.3	.02600	7.0 7.0	5.9	6.5 7.3	1.82 5.76	2977.
8	410	12	67.3 60.0	.01780	7.0 7.0	5.9	6.1 6.1	2.47 4.77	3051.
9	450	18	60.0 58.1	.00422	7.0 7.0	5.4	3.8 3.9	3.04 6.84	4990.

LENGTH = 1260. TOTAL LENGTH = 3319.
COST = 11018. TOTAL COST = 20987.

```

0010 JOB EXAMPLE ONE: SANITARY SEWER DESIGN
0020 REM
0030 GPC 100
0040 PEA .01 4.46 .05 3.78 .1 3.3 1 2.6 10 2.1 100 1.7 +
0050 1000 1.4 10000 1.13
0060 INF 0 1000
0070 CST 1.5 1.5 0 0 .5 0 2.5 .5 0 4 1.15 .4 2.5 3.5 .25
0080 EVC 0 .75 10 .75
0090 PCO 8 2.5 10 3.5
0100 POA .013 6 7 4 2.5 .001
0110 TSL 0 .2 10 .2
0120 REM
0130 NEW PARK ROAD
0140 SAN 35.6 10
0150 PIP 290.5 100.8 93.6
0160 SAN 17.5 18
0170 SAN 18.2 20
0180 PIP 308.8 93.6 84.7
0190 HDL 1
0200 REM
0210 NEW IRVING STREET
0220 SAN 40.3 8.5
0230 PIP 330 95 81.2
0240 SAN 15.2 12
0250 SAN 17.3 15
0260 PIP 320 81.2 74.3
0270 HDL 2
0280 REM
0290 NEW KENYON STREET
0300 INF 0 2000
0310 SAN 46.3 5.6
0320 PIP 390 97.5 89
0330 SAN 18.3 12
0340 SAN 25.3 12
0350 PIP 420 89 84.7
0360 HDL 3
0370 REM
0380 NEW MAIN STREET
0390 INF 0 1000
0400 REC 1
0410 REC 3
0420 SAN 16.5 20
0430 SAN 13.1 35
0440 SAN 14.7 20
0450 PIP 400 84.7 74.3 .8
0460 REC 2
0470 SAN 24.8 20
0480 PIP 410 74.3 67
0490 SAN 22.6 15
0500 SAN 18.0 40
0510 SAN 22.8 15
0520 PIP 450 67 65.1
0530 END
    
```

Example Two: Sanitary Sewer Analysis

PPF-HYDRA is a useful tool in analyzing existing systems. For this example, the system suggested by PPF-HYDRA in example 1 is entered in the command string as an existing system and analyzed. (Note the extra parameters on the PIP commands.) If no other changes are made, the same flows would be calculated, but the costing data are ignored. However, to fully demonstrate the review features of PPF-HYDRA, additional flow is added to the system by adding to the person/acre numbers in the SAN commands and adding 3.5 ft³/s through a FLO command on Main Street. (The FLO command might represent the discharge of water from an industrial facility.)

The output shows that the sewer system is still able to adequately pass the flows on Park Road, Irving Street, and Kenyon Street, but portions of the Main Street lateral are overloaded. In these cases, PPF-HYDRA suggests remedies. For the 410-foot link 8 under Main Street, PPF-HYDRA suggests somehow removing 1.60 ft³/s or constructing an additional 12-inch pipe to pass the flow.

```
0010 JOB EXAMPLE TWO
0020 REM
0030 GPC 100
0040 PEA .01 4.46 .05 3.78 .1 3.3 1 2.6 10 2.1 100 1.7 +
0050      1000 1.4 10000 1.13
0060 INF 0 1000
0070 CST 1.5 1.5 0 0 .5 0 2.5 .5 0 4 1.15 .4 2.5 3.5 .25
0080 EXC 0 .75 10 .75
0090 PCO 8 2.5 10 3.5
0100 PDA .013 6 7 4 2.5 .001
0110 TSL 0 .2 10 .2
0120 REM
0130 NEW PARK ROAD
0140 SAN 35.6 13
0150 PIP 290.5 100.8 93.6 93.8 86.6 -6
0160 SAN 17.5 28
0170 SAN 18.2 30
0180 PIP 308.8 93.6 84.7 86.6 77.7 -6
0190 HOL 1
0200 REM
0210 NEW IRVING STREET
0220 SAN 40.3 11.5
0230 PIP 330 95 81.2 88.0 74.2 -6
0240 SAN 15.2 15
0250 SAN 17.3 18
0260 PIP 320 81.2 74.3 74.2 67.3 -6
0270 HOL 2
0280 REM
0290 NEW KENYON STREET
0300 INF 0 2000
0310 SAN 46.3 8.6
0320 PIP 390 97.5 89 90.5 82. -6
0330 SAN 18.3 15
0340 SAN 25.3 15
0350 PIP 420 89 84.7 82.0 77.7 -12
0360 HOL 3
0370 REM

0380 NEW MAIN STREET
0390 INF 0 1000
0400 FLO 3.5
0410 REC 1
0420 REC 3
0430 SAN 16.5 23
0440 SAN 13.1 38
0450 SAN 14.7 23
0460 PIP 400 84.7 74.3 77.7 67.3 -12
0470 REC 2
0480 SAN 24.8 23
0490 PIP 410 74.3 67 67.3 60.0 -12
0500 SAN 22.6 18
0510 SAN 18.0 43
0520 SAN 22.8 18
0530 PIP 450 67 65.1 60.0 58.1 -18
0540 END
```

← INPUT

EXAMPLE TWO: SANITARY SEWER ANALYSIS

*** PARK ROAD Analysis of Existing Pipes

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Cover Up/Dn (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	-Solutions- Load (%)	Remove (cfs)	Diam (in)
1	291	6	93.8	.02478	7.0	6.5	4.1	.31	35		
			86.6		7.0	6.5	4.5	.89			
2	309	6	86.6	.02882	7.0	6.5	5.5	.85	89		
			77.7		7.0	6.5	4.9	.96			

LENGTH = 599. TOTAL LENGTH = 599.

OUTPUT
→

*** IRVING STREET Analysis of Existing Pipes

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Cover Up/Dn (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	-Solutions- Load (%)	Remove (cfs)	Diam (in)
3	330	6	88.0	.04182	7.0	6.5	5.0	.32	28		
			74.2		7.0	6.5	5.9	1.15			
4	320	6	74.2	.02156	7.0	6.5	4.6	.62	75		
			67.3		7.0	6.5	4.2	.83			

LENGTH = 650. TOTAL LENGTH = 650.

*** KENYON STREET Analysis of Existing Pipes

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Cover Up/Dn (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	-Solutions- Load (%)	Remove (cfs)	Diam (in)
5	390	6	90.5	.02179	7.0	6.5	4.1	.37	44		
			82.0		7.0	6.5	4.2	.83			
6	420	12	82.0	.01024	7.0	5.9	3.7	.81	22		
			77.7		7.0	5.9	4.6	3.61			

LENGTH = 810. TOTAL LENGTH = 810.

*** MAIN STREET Analysis of Existing Pipes

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Cover Up/Dn (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	-Solutions- Load (%)	Remove (cfs)	Diam (in)
7	400	12	77.7	.02600	7.0	5.9	8.4	5.66	98		
			67.3		7.0	5.9	7.3	5.76			
8	410	12	67.3	.01780	7.0	5.9	8.1	6.37	134	1.60	12
			60.0		7.0	5.9	6.1	4.77			
9	450	18	60.0	.00422	7.0	5.4	4.0	6.99	102	.15	6
			58.1		7.0	5.4	3.9	6.84			

LENGTH = 1260. TOTAL LENGTH = 3319.

Example Three: Rational Method Design

The example shown in figure 6 illustrates the use of PFP-HYDRA for design of a storm sewer using the rational method. As for any design problem, the cost commands (EXC, TSL, PCO, and CST) must be used if cost estimates are desired. Also, a PDA command must be provided to tell PFP-HYDRA what pipe characteristics are desired. This command can be used as many times as desired, but must be used at least once.

Two additional commands are introduced here: STO (storm) and RAI (rain). The STO command provides the physical characteristics of a drainage area required for the rational method: size, runoff, coefficient, and time of concentration. The RAI command supplies the Intensity - Duration - Frequency (IDF) curve for the return period and location the user desires to analyze. PFP-HYDRA uses the time of concentration for each individual area and then consults the IDF curve to find an intensity for the rational formula. As PFP-HYDRA proceeds through the system, it continually adjusts the time of concentration as more areas are being aggregated.

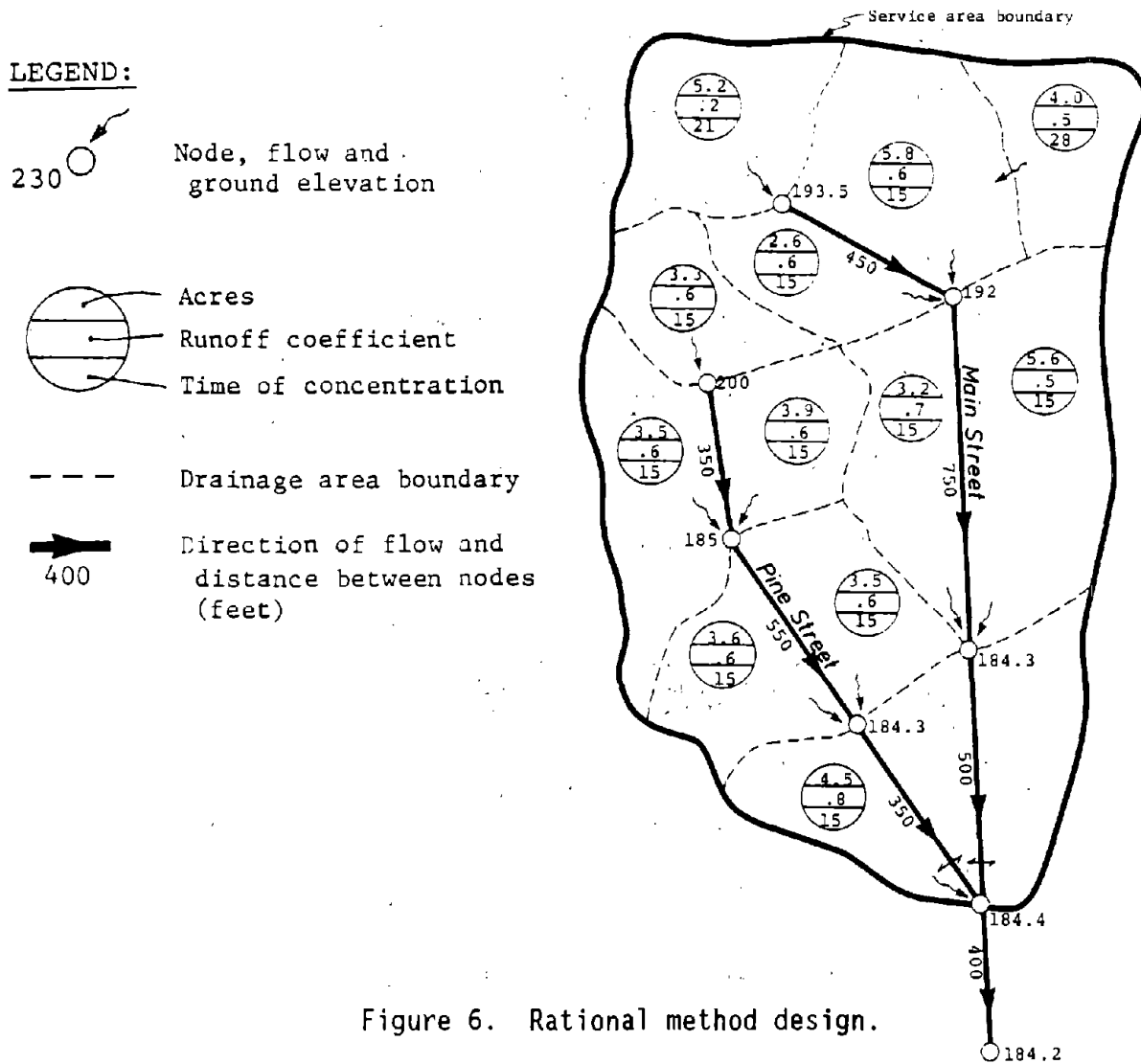
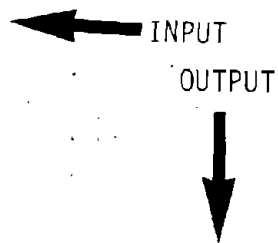


Figure 6. Rational method design.

```

0010 JOB EXAMPLE THREE: RATIONAL METHOD DESIGN
0020 SWI 2
0030 PDA .013 12 4 3 2 .001
0040 RAI FTCOL.IDF
0050 EXC 5 .72 25 1.13
0060 TSL 0 .25 10 .25
0070 PCO 12 4.58 36 24.84
0080 CST 1.5 1.5 0 0 0 .5 6.21 1 0 1.52 1.05 .6 1.56 1.52 0
0090 NEW PINE STREET
0100 STO 3.3 .6 15
0110 PIP 350 200 185
0120 STO 3.5 .6 15
0130 STO 3.9 .6 15
0140 PIP 550 185 184.4
0150 STO 3.6 .6 15
0160 STO 3.5 .6 15
0170 PIP 350 184.3 184.4
0180 HOL 1
0190 NEW MAIN STREET
0200 STO 5.2 .2 21
0210 PIP 450 193.5 192
0220 STO 4.0 .5 28
0230 STO 5.8 .6 15
0240 STO 2.6 .6 15
0250 PIP 750 192 184.3
0260 STO 5.6 .5 15
0270 STO 3.2 .7 15
0280 PIP 500 184.3 184.4
0290 STO 4.5 .8 15
0300 REC 1
0310 PIP 400 184.4 184.2
0320 END

```



***** PFP-HYDRA ***** (Version 803.A) *****

DATE 10-12-88
PAGE NO 3

EXAMPLE THREE: RATIONAL METHOD DESIGN

*** PINE STREET

Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Velocity Cover Act/Full (ft) (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
1	350	12	195.9	.04286	4.1	3.0 7.7	1.78	
			180.9		4.1	9.4	7.40	2093.
2	550	24	179.8	.00100	5.2	3.0 2.5	5.62	
			179.2		5.2	2.3	7.17	9545.
3	350	30	178.6	.00100	5.7	3.0 2.8	8.30	
			178.2		6.2	2.6	13.01	8137.

LENGTH = 1250. TOTAL LENGTH = 1250.
COST = 19775. TOTAL COST = 19775.

*** MAIN STREET

Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Velocity Cover Act/Full (ft) (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
4	450	12	189.4	.00333	4.1	3.0 2.4	.78	
			187.9		4.1	2.6	2.06	2691.
5	750	18	187.3	.01016	4.7	3.0 6.0	5.25	
			179.7		4.6	6.0	10.61	8720.
6	500	30	178.6	.00100	5.7	3.0 2.8	8.19	
			178.1		6.3	2.6	13.01	11637.
7	400	36	178.1	.00100	6.3	3.1 3.3	16.20	
			177.7		6.5	3.0	21.15	11662.

LENGTH = 2100. TOTAL LENGTH = 3350.
COST = 34709. TOTAL COST = 54484.

Example Four: Combined System Analysis

PFP-HYDRA may be used to design or analyze a combined sanitary and storm sewer system. The example shown in figure 7 illustrates an analysis of a small drainage and service area feeding into a lateral under Hitda Road. No new commands are required beyond those used in separate analyses of storm or sanitary sewers. The hydrographic technique may also be used for combined sewer analysis and/or design.

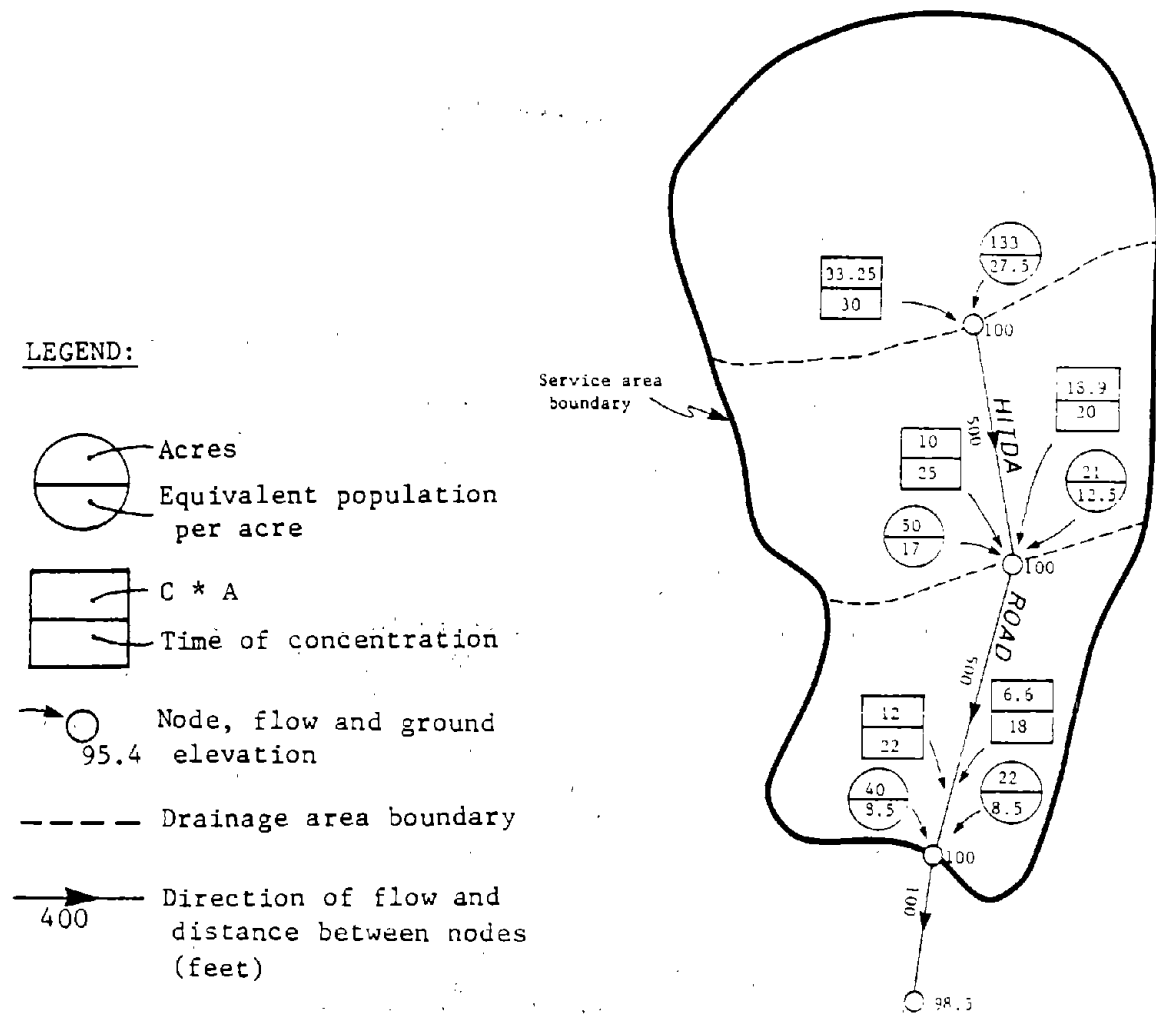


Figure 7. Combined system analysis.

INPUT →

```

0010 JOB EXAMPLE FOUR: COMBINED SYSTEM ANALYSIS
0020 PEA .015 3.71 .023 3.54 .03 3.45 .054 3.28 +
0030 .1 3.1 .5 2.67 1 2.5 5 2.15 10 2.01 50 1.73 100 1.62
0040 RAI 0 1.55 5 1.55 8 1.2 10 1.1 15 .9 18 .8 +
0050 24 .7 32 .6 44 .5 50 .46 65 .4 80 .36 180 .22 300 .22
0060 INF 0 500
0070 GPC 100
0080 PDA .013 8 4 3 2 .001
0090 EXC 5 .73 25 1.15
0100 TSL 3 .5 10 .5
0110 PCD 8 2.69 36 24.84
0120 CST 1.5 1.5 0 0 0 .5 6.21 1 0 1.52 1.05 .6 1.56 1.52 0
0130 NEW HITDA ROAD
0140 SAN 133 27.5
0150 STO 133 .25 30
0160 PIP 500 100 100 95.4 94.8 -18
0170 SAN 50 17
0180 STO 50 .2 25
0190 SAN 21 12.5
0200 STO 21 .9 20
0210 PIP 500 100 100 94.8 94.2 -18
0220 SAN 40 8.5
0230 STO 40 0.3 22
0240 SAN 22 8.5
0250 STO 22 0.3 18
0260 PIP 100 100 98.5 94.2 94.0 -21
0270 END

```

***** PFP-HYDRA ***** (Version 803.A) *****

DATE 10-12-88
PAGE NO 3

EXAMPLE FOUR: COMBINED SYSTEM ANALYSIS

*** HITDA ROAD

Analysis of Existing Pipes

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Cover Up/Dn (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	-Solutions- Load Remove (%)	Diam (in)
1	500	18	95.4	.00120	4.6	3.0	2.0	1.60	44	
			94.8							
2	500	18	94.8	.00120	5.2	3.6	2.1	2.07	57	
			94.2							
3	100	21	94.2	.00200	5.8	3.9	2.6	2.30	32	
			94.0							

LENGTH = 1100. TOTAL LENGTH = 1100.

OUTPUT →

Example Five: Hydrographic Simulation and Design

The site shown in figure 8 is a section of roadway between two high points in the centerline profile. A set of six inlets is used to capture flow from eight identical pavement sections each 0.5 acres in size. Gutter flow between the inlets is expected in situations where the inlet is not able to accept portions of the peak flow. Once captured by one of the six inlets, the flow is directed through a feeder network of pipes to the main outfall pipe which empties into a downstream channel.

The hydrographic commands featured in this example are STE (step), HYE (hyetograph), UNP (unpaved), PAV (paved), HYD (hydrograph), GUT (gutter), and INL (inlet). The STE command sets the time step for the analysis. In this example, it is set at 2.2 minutes which is relatively small for many analyses. The HYE command provides the rainfall data for the storm to be analyzed while the PAV and UNP commands describe most of the generic physical parameters for the drainage areas. The HYD command provides additional physical data for a specific drainage area including its slope and area. The HYD command also tells PFP-HYDRA that this is where a runoff hydrograph is to be generated. The GUT command, as mentioned previously, allows for surface flow at the curb's edge. It is a transport command but is only recognized in hydrographic analyses. Finally, the INL command serves to transfer surface flow either directly from runoff or from a gutter into the pipe network below.

Another transport command, the CHA (channel) command, is introduced in this example in addition to the gutter command. The CHA command models open channel flow for a variety of cross sections. The CHA and GUT commands, in addition to the PIP command, give the user significant flexibility in transporting flow.

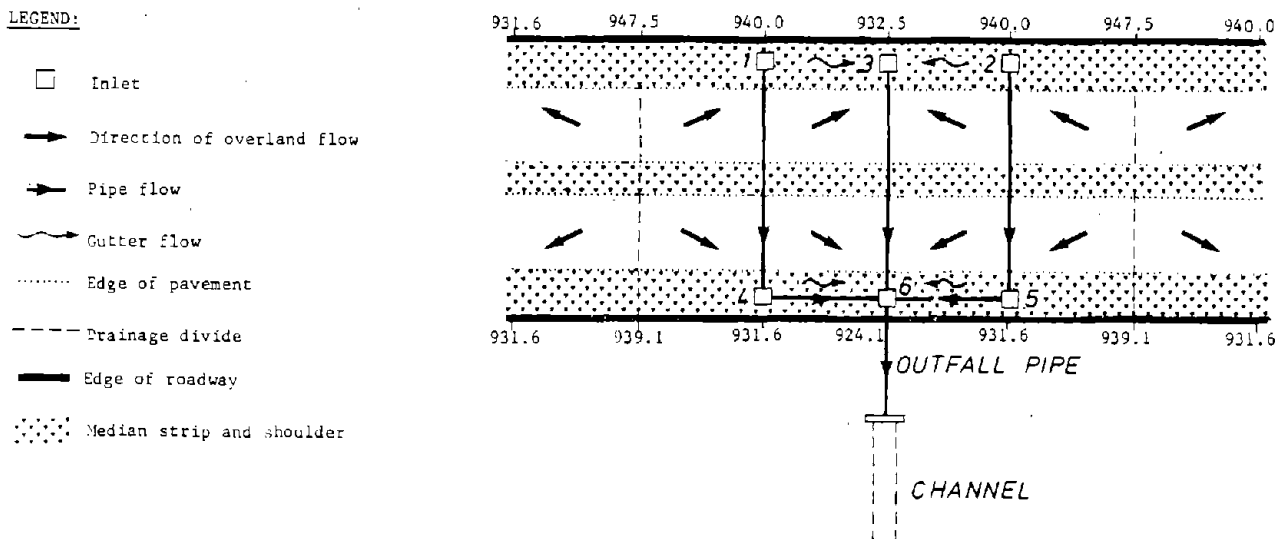


Figure 8. Hydrographic simulation.

Another capability demonstrated in this example is the PFP-HYDRA plots of the input hyetograph, the inlet hydrograph, and the system hydrograph. These plots provide additional data to the user who requires more than peak flow. However, since each plot uses nearly a page of output, only those hydrographs requested by the user are given. This is accomplished by setting the optional plot parameters to 1. (In all cases where an optional parameter is used, any other optional parameters preceding it must be acknowledged, and usually set to 0.0.)

INPUT →

```

0010 JOB EXAMPLE FIVE: HYDROGRAPHIC SIMULATION AND DESIGN
0020 SWI 3
0030 PDA .013 12 5 4 2.5 .001
0040 PCO 12 46 15 51 18 57 21 63 24 69 27 74 30 80 33 86 36 97 +
0050 42 109 48 126 54 143 60 160 66 177 72 206 84 297
0060 CST 1.5 1.5 0 0 0 .5 6.21 1 0 1.52 1.05 .6 1.56 1.52 0
0070 EXC 5 .72 25 1.13
0080 TSL 0 .25 10 .25
0090 STE 2
0100 HYE 0.0 3.51 7.03 10.54 9.03 7.53 6.02 4.52 3.01 1.51
0110 UNP .15 .5 .1 .1 4.0 1.5 .07 45 .03 24 48
0120 PAV .013 .1 .05 .2 .5 30 .4
0130 NEW FEEDER 1
0140 HYD .5 49 .025 .77 2.2
0150 INL 1 2.5 26 0 0 1
0160 PIP 88 940 931.62
0170 HOL 1
0180 NEW FEEDER 2
0190 HYD .5 49 .025 .77 2.2
0200 INL 2 2.5 27
0210 PIP 88 940 931.62
0220 HOL 2
0230 NEW FEEDER 3
0240 GET 26
0250 GUT 500 940 932.5 .013 0 0 50
0260 HYD 0.5 49 0.025 0.77 2.2
0270 PUT 28
0280 GET 27
0290 GUT 500 940 932.5 .013 0 0 50
0300 HYD 0.5 49 .025 .77 2.2
0310 GET 28
0320 INL 3 20.0
0330 PIP 88 932.5 924.1
0340 HOL 4
0350 NEW LEFT-SIDE MAIN
0360 REC 1
0370 HYD .5 49 .025 .77 2.2
0380 INL 4 2.5 29
0390 PIP 500 931.6 924.1
0400 HOL 5
0410 NEW RIGHT-SIDE MAIN
0420 REC 2
0430 HYD .5 49 .025 .77 2.2
0440 INL 5 2.5 30
0450 PIP 500 931.6 924.1
0460 HOL 6
0470 NEW OUTFALL PIPE
0480 REC 4
0490 REC 5
0500 REC 6
0510 GET 29
0520 GUT 500 931.6 924.1 .013 0 0 50
0530 HYD 0.5 49 0.025 0.77 2.2
0540 PUT 31
0550 GET 30
0560 GUT 500 931.6 924.1 .013 0 0 50
0570 HYD 0.5 49 0.025 0.77 2.2
0580 GET 31
0590 INL 6 6.5
0600 PIP 50 924.1 920 0 0 0 0 1 1
0610 HOL 7
0620 NEW OUTFALL CHANNEL
0630 REC 7
0640 CHA 1000 914.0 912.0 .034 1 4 1
0650 END

```

OUTPUT



***** PFP-HYDRA ***** (Version 610.B) *****

DATE 10-20-86

PAGE NO 1

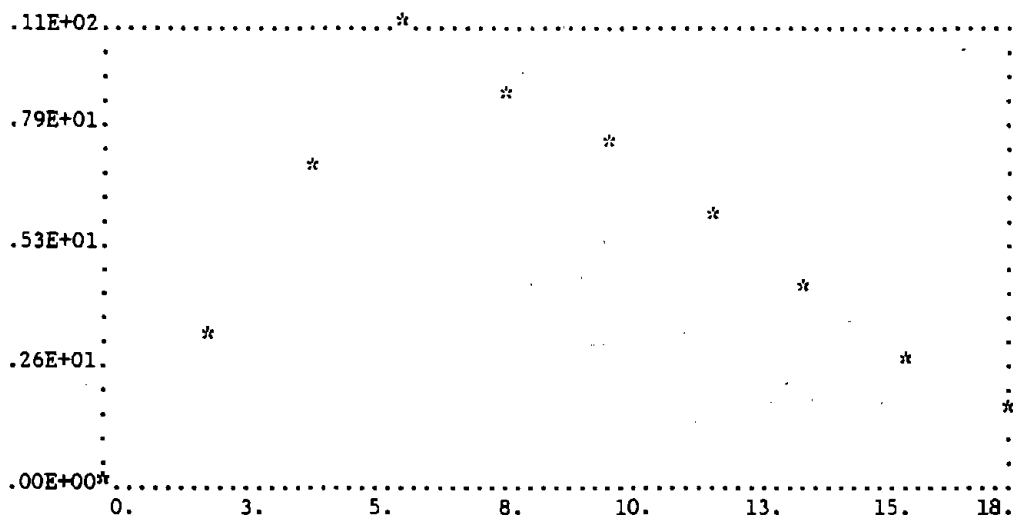
EXAMPLE FIVE: HYDROGRAPHIC SIMULATION AND DESIGN

Commands Read From File example5.hda

```

10 JOB
20 SWI 3
30 PDA .013 12 5 4 2.5 .001
40 PCO 12 46 15 51 18 57 21 63 24 69 27 74 30 80 33 86 36 97 +
    42 109 48 126 54 143 60 160 66 177 72 206 84 297
60 CST 1.5 1.5 0 0 0 .5 6.21 1 0 1.52 1.05 .6 1.56 1.52 0
70 EXC 5 .72 25 1.13
80 TSL 0 .25 10 .25
90 STE 2
***** STEP RESET FROM 15.0 MINUTES
100 HYE 0.0 3.51 7.03 10.54 9.03 7.53 6.02 4.52 3.01 1.51
    
```

HYETOGRAPH (IN/HR)



PLOT-DATA (VALUE Vs.TIME)

.0	.000	20.0	.000	40.0	.000	60.0	.000	80.0	.000
2.0	3.510	22.0	.000	42.0	.000	62.0	.000	82.0	.000
4.0	7.030	24.0	.000	44.0	.000	64.0	.000	84.0	.000
6.0	10.540	26.0	.000	46.0	.000	66.0	.000	86.0	.000
8.0	9.030	28.0	.000	48.0	.000	68.0	.000	88.0	.000
10.0	7.530	30.0	.000	50.0	.000	70.0	.000	90.0	.000
12.0	6.020	32.0	.000	52.0	.000	72.0	.000	92.0	.000
14.0	4.520	34.0	.000	54.0	.000	74.0	.000	94.0	.000
16.0	3.010	36.0	.000	56.0	.000	76.0	.000	96.0	.000
18.0	1.510	38.0	.000	58.0	.000	78.0	.000	98.0	.000

110 UNP .15 .5 .1 .1 4.0 1.5 .07 45 .03 24 48

OUTPUT



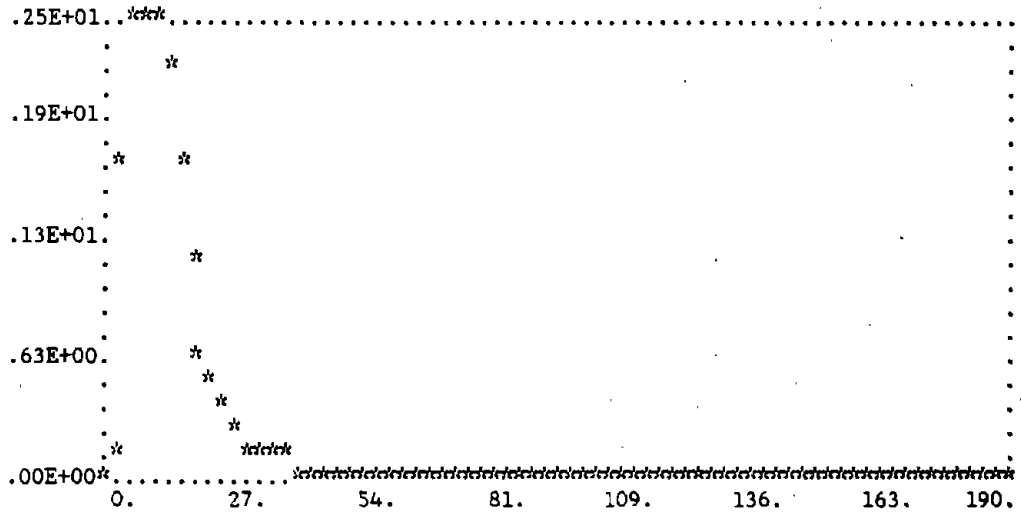
***** PFP-HYDRA ***** (Version 610.B) *****

DATE 10-20-86
PAGE NO 2

EXAMPLE FIVE: HYDROGRAPHIC SIMULATION AND DESIGN

120 PAV .013 .1 .05 .2 .5 30 .4
130 NEW FEEDER 1
140 HYD .5 49 .025 .77 2.2
150 INL 1 2.5 26 0 0 0 1

INLET 1 HYDROGRAPH IN CFS



PLOT-DATA (VALUE Vs. TIME)

.0	.000	20.0	.684	40.0	.059	60.0	.009	80.0	.003
2.0	.111	22.0	.519	42.0	.048	62.0	.008	82.0	.002
4.0	1.771	24.0	.347	44.0	.039	64.0	.007	84.0	.002
6.0	2.500	26.0	.299	46.0	.032	66.0	.006	86.0	.002
8.0	2.500	28.0	.226	48.0	.026	68.0	.005	88.0	.002
10.0	2.500	30.0	.181	50.0	.022	70.0	.005	90.0	.002
12.0	2.500	32.0	.143	52.0	.018	72.0	.004	92.0	.002
14.0	2.227	34.0	.114	54.0	.015	74.0	.004	94.0	.001
16.0	1.709	36.0	.091	56.0	.013	76.0	.003	96.0	.001
18.0	1.196	38.0	.073	58.0	.011	78.0	.003	98.0	.001

160 PIP 88 940 931.62
170 HOL 1
180 NEW FEEDER 2
190 HYD .5 49 .025 .77 2.2
200 INL 2 2.5 27
210 PIP 88 940 931.62
220 HOL 2

OUTPUT



***** PFP-HYDRA ***** (Version 610.B) *****

DATE 10-20-86
PAGE NO 3

EXAMPLE FIVE: HYDROGRAPHIC SIMULATION AND DESIGN

230 NEW FEEDER 3
 240 GET 26
 250 GUT 500 940 932.5 .013 0 0 50
 ***** DEPTH= .11 VEL= 2.38 WIDTH= 5.39
 DISCHARGE = .70 SLOPE = .01500 FT/FT
 260 HYD 0.5 49 0.025 0.77 2.2
 270 PUT 28
 280 GET 27
 290 GUT 500 940 932.5 .013 0 0 50
 ***** DEPTH= .11 VEL= 2.38 WIDTH= 5.39
 DISCHARGE = .70 SLOPE = .01500 FT/FT
 300 HYD 0.5 49 .025 .77 2.2
 310 GET 28
 320 INL 3 20.0
 330 PIP 88 932.5 924.1
 340 HOL 4
 350 NEW LEFT-SIDE MAIN
 360 REC 1
 370 HYD .5 49 .025 .77 2.2
 380 INL 4 2.5 29
 390 PIP 500 931.6 924.1
 400 HOL 5
 410 NEW RIGHT-SIDE MAIN
 420 REC 2
 430 HYD .5 49 .025 .77 2.2
 440 INL 5 2.5 30
 450 PIP 500 931.6 924.1
 460 HOL 6
 470 NEW OUTFALL PIPE
 480 REC 4
 490 REC 5
 500 REC 6
 510 GET 29
 520 GUT 500 931.6 924.1 .013 0 0 50
 ***** DEPTH= .11 VEL= 2.38 WIDTH= 5.39
 DISCHARGE = .70 SLOPE = .01500 FT/FT
 530 HYD 0.5 49 0.025 0.77 2.2
 540 PUT 31
 550 GET 30
 560 GUT 500 931.6 924.1 .013 0 0 50
 ***** DEPTH= .11 VEL= 2.38 WIDTH= 5.39
 DISCHARGE = .70 SLOPE = .01500 FT/FT
 570 HYD 0.5 49 0.025 0.77 2.2
 580 GET 31
 590 INL 6 6.5
 ***** MAXIMUM STORAGE 125.3 C.F.
 ***** PONDING TIME 6.0 MINUTES
 600 PIP 50 924.1 920 0 0 0 0 1 1

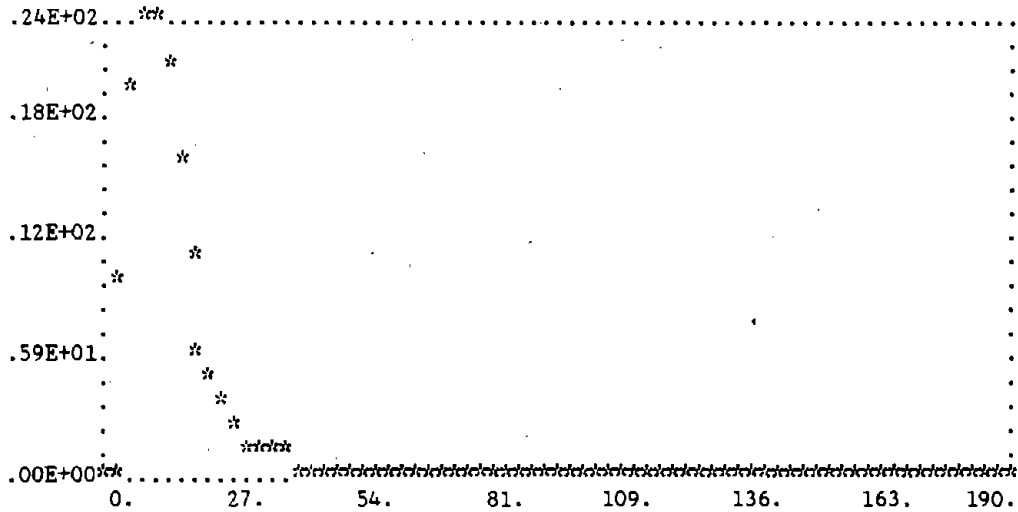
OUTPUT



***** PFP-HYDRA ***** (Version 610.B) *****

DATE 10-20-86
PAGE NO 4

EXAMPLE FIVE: HYDROGRAPHIC SIMULATION AND DESIGN
SYSTEM HYDROGRAPH IN CFS



PLOT-DATA (VALUE Vs.TIME)

.0	.000	20.0	6.841	40.0	.509	60.0	.079	80.0	.021
2.0	.598	22.0	4.620	42.0	.412	62.0	.068	82.0	.019
4.0	9.857	24.0	3.234	44.0	.335	64.0	.058	84.0	.017
6.0	20.011	26.0	2.531	46.0	.274	66.0	.051	86.0	.016
8.0	23.065	28.0	1.999	48.0	.225	68.0	.044	88.0	.015
10.0	23.684	30.0	1.567	50.0	.186	70.0	.039	90.0	.013
12.0	23.206	32.0	1.244	52.0	.155	72.0	.035	92.0	.012
14.0	21.407	34.0	.989	54.0	.129	74.0	.030	94.0	.012
16.0	15.616	36.0	.789	56.0	.109	76.0	.026	96.0	.011
18.0	10.953	38.0	.633	58.0	.092	78.0	.023	98.0	.010

610 HOL 7
620 NEW OUTFALL CHANNEL
630 REC 7
640 CHA 1000 914.0 912.0 .034 1 4 1
650 END
END OF RUN.

OUTPUT



***** PFP-HYDRA ***** (Version 610.B) *****

DATE 10-20-86
PAGE NO 5

EXAMPLE FIVE: HYDROGRAPHIC SIMULATION AND DESIGN

***** FEEDER 1

Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Velocity Cover (ft)	Velocity Act/Full (ft/sec)	Flow Act/Full (cfs)	Estimated Cost (\$)
1	88	12	934.9 926.5	.09523	5.1 5.1	4.0	11.3 14.0	2.50 11.02	4190.

 LENGTH = 88. COST = 4190.
 TOTAL LENGTH = 88. TOTAL COST = 4190.

***** FEEDER 2

Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Velocity Cover (ft)	Velocity Act/Full (ft/sec)	Flow Act/Full (cfs)	Estimated Cost (\$)
2	88	12	934.9 926.5	.09523	5.1 5.1	4.0	11.3 14.0	2.50 11.02	4190.

 LENGTH = 88. COST = 4190.
 TOTAL LENGTH = 88. TOTAL COST = 4190.

***** FEEDER 3

Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Velocity Cover (ft)	Velocity Act/Full (ft/sec)	Flow Act/Full (cfs)	Estimated Cost (\$)
3	88	12	927.4 919.0	.09545	5.1 5.1	4.0	15.0 14.1	7.21 11.04	4190.

 LENGTH = 88. COST = 4190.
 TOTAL LENGTH = 88. TOTAL COST = 4190.

OUTPUT



***** PFP-HYDRA ***** (Version 610.B) *****

DATE 10-20-86
PAGE NO 6

EXAMPLE FIVE: HYDROGRAPHIC SIMULATION AND DESIGN

***** LEFT-SIDE MAIN

Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Cover (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
4	500	18	925.9 918.5	.01487	5.7 5.6	4.0	6.8 7.3	5.00 12.85	29619.
LENGTH		=		500.		COST		= 29619.	
TOTAL LENGTH		=		588.		TOTAL COST		= 33809.	

***** RIGHT-SIDE MAIN

Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Cover (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
5	500	18	925.9 918.5	.01487	5.7 5.6	4.0	6.8 7.3	5.00 12.85	29619.
LENGTH		=		500.		COST		= 29619.	
TOTAL LENGTH		=		588.		TOTAL COST		= 33809.	

***** OUTFALL PIPE

Pipe Design

Link	Length (ft)	Diam (in)	Invert Up/Dn (ft)	Slope (ft/ft)	Depth Up/Dn (ft)	Min. Cover (ft)	Velocity Act/Full (ft/sec)	--Flow-- Act/Full (cfs)	Estimated Cost (\$)
6	50	18	917.8 914.4	.06950	6.3 5.6	4.0	17.7 15.7	23.68 27.77	2966.
LENGTH		=		50.		COST		= 2966.	
TOTAL LENGTH		=		1314.		TOTAL COST		= 74774.	

***** OUTFALL CHANNEL

Channel

Link	Length (ft)	-Channel Shape-- Left Ctr Right			Slope (ft/ft)	Invert Up/Dn (ft)	Surface Up/Dn (ft)	Surf Depth Width (ft) (ft)	Flow (cfs)	Vel (fps)
7	1000	1.0	4.0	1.0	.00200	914.00 912.00	915.86 913.86	1.9 7.7	23.6	2.2
LENGTH		=		1000.		COST		= 0.		
TOTAL LENGTH		=		2314.		TOTAL COST		= 74774.		

Appendix B: PFP-Hydra Commands

This appendix details the meaning and syntax of each command available in PFP-Hydra. The descriptions are ordered alphabetically and include information on the command name, its purpose, and its structure. Any important notes pertaining to the command are also included.

COMMAND CHA - CHAnnel

Purpose: CHAnnel is one of the PFP-Hydra transport commands. It allows you to define an open channel or ditch.

Structure:

CHA length, invup, invdn, "n", lslope, bwidth, rslope, eq, plot

- 1) length - length of link (distance between nodes) (feet).
- 2) invup - invert elevation at the upstream end of the link (feet).
- 3) invdn - invert elevation at the downstream end of the link.

If this value is less than 1.0 but greater than 0.0, PFP-Hydra will take the value as a slope. (feet).
- 4) "n" - friction factor (Manning's "n").
- 5) lslope - slope of the channel's left side in feet horizontal to feet vertical.
- 6) bwidth - width of the bottom (trapezoidal section), (feet).
- 7) rslope - right side slope in feet horizontal to feet vertical.
- 8) eq - (optional) - enter 1 if gutter equation is to be used; leave blank if Manning's equation is to be used.
- 9) plot - (optional) - enter 1 if plot is desired; enter 0 or leave blank if no plot is desired.

Notes:

- 1) There is an automatic ditto feature in this command in that "n", left slope, bottom width, right slope, and eq will all be copied from the previous CHA command unless overridden by subsequent entries in this command. The value of "n" may be changed without touching the geometry parameters, but all geometry parameters must be re-entered if one is. In other words, PFP-Hydra will accept 3, 4, 8, or 9 parameters for this command, but any other number of parameters is assumed to be an error.
- 2) PFP-Hydra does not check backwatering problems on upstream channels or pipes so the designer should review the output carefully to make sure he has not got a problem in this area.
- 3) The designer should watch out for "scour" in channels if the velocities are high.
- 4) The friction factor, "n", has a major influence in the CHA calculation, so it should be selected carefully. The selected value should take into consideration the possibility of poor maintenance.

COMMAND CRI - CRiteria

Purpose: A "switch" to tell PFP-Hydra how you want certain calculations to take place. At the present time it is a single switch that indicates if the inverts or the crowns are matched in a "free design".

Structure:

CRI switch1

switch1 - if set to zero, inverts will be matched in a free design; if set to 1, crowns will be matched.

Notes:

- 1) Initially, all switches are set to zero. In other words, if the command is not used inverts will be matched.
- 2) This command may be used at any location in the command string and any number of times.

COMMAND CST - CoSTs in place

Purpose: One of the required commands for a PFP-Hydra cost estimate of pipe in place. CST sets several trench geometry factors and unit prices for material and haul.

Structure:

CST wmul, wadd, wmin, bmul, badd, bmin, \$bed, pzmul, pzadd, \$pz, shrink, \$back, \$waste, \$borrow, \$surf

- 1) wmul - factor to establish trench width.
- 2) wadd - added to the product of wmul and interior pipe diameter (feet).
- 3) wmin - minimum trench width (feet).
- 4) bmul - factor to establish depth of bedding.
- 5) badd - added to above to get depth of bedding (feet).
- 6) bmin - minimum depth of bedding (feet).
- 7) \$bed - cost/cy of bedding in place.
- 8) pzmul - factor to establish the depth of pipe zone material.
- 9) pzadd - added to above to depth of pipe zone (feet).
- 10) \$pz - cost/cy of pipe zone material in place.
- 11) shrink - shrinkage of backfill material in place (>1.0).
- 12) \$back - cost/cy of replacing excavated backfill.
- 13) \$waste - cost/cy to remove excess native material.
- 14) \$borrow - cost/cy of borrow material in place.
- 15) \$surf - cost/sqft for surface restoration.

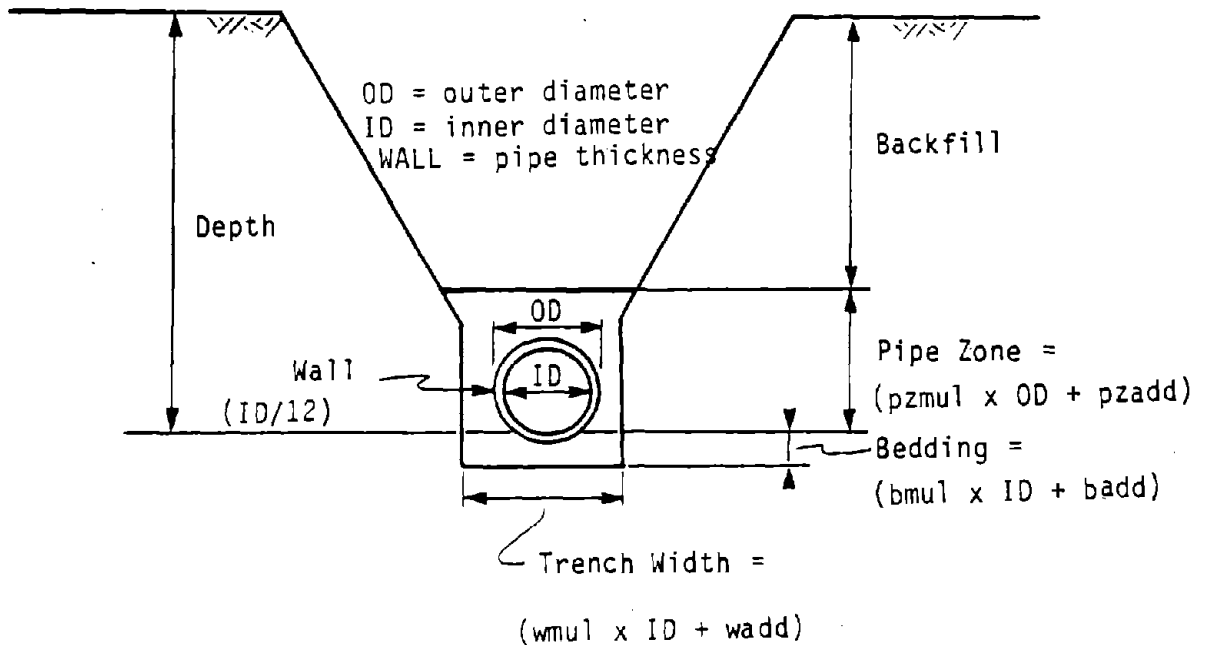


Figure 9. CST command trench and geometric factors.

COMMAND DEL - DELay rainfall

Purpose: This command allows the user to move the storm across the basin. The HYE command allows the intensity of the storm to be varied as it moves. The combination of these commands allows even a small cell of rainfall to be moved around the basin.

Structure:

DEL delay

delay - the delay time in minutes relative to the time the storm first entered the basin.

Notes:

- 1) This command is ignored if the DIR command is used.

COMMAND DIR - DIRection

Purpose: This is a hydrographic command establishing the starting location, size, direction, velocity, and other characteristics of a storm cell.

Structure:

DIR north, east, vel, azimuth, width1, width2, max

- 1) north - one of two starting coordinates for the storm cell. Both "north" and "east" must be positive and be SW of all land segments.
- 2) east - the second starting coordinate for the storm cell. Both "north" and "east" must be positive and be SW of all land segments.
- 3) vel - velocity of the storm cell (mph).
- 4) azimuth - direction of the storm cell from the origin in degrees clockwise from North.
- 5) width1 - width of the storm cell (feet).
- 6) width2 - width of the storm cell plus taper zone (feet).
- 7) max - maximum intensity of the storm outside the limits of the intense portion of the storm cell (iph).

Notes:

- 1) Radar maps prepared by the FAA may prove useful in establishing the normal direction, velocity and size of storm cells in your study area. Normally storm cells move about twice the ground windspeed and quite often at a slightly different direction (perhaps by as much as 30 degrees).
- 2) If this command is used, PFP-Hydra will ignore any DEL commands.
- 3) This command requires that North/East coordinates be established for the centroid of each land segment (HYD command). There is no need that this coordinate be very accurate, but it must be there. If it is not there, the HYD command will be ignored.

COMMAND DIV - DIVert flow

Purpose: The primary function of this command is to model some form of overflow weir. It splits the system flow into two components - one that continues down the main system and another that is diverted in another direction.

Structure:

DIV hold, Qsys, Qdiv, Qsys, Qdiv ... (max 20 sets, min 2 sets - all values of Qsys must increase)

- 1) hold - a HOLD number between 1 and 25 where DIVerted system flow is to be held. May be recalled with a REC command.
- nx) Qsys - system flow (ft³/s).
- ny) Qdiv - flow to be diverted. If the Qdiv exceeds Qsys then all of the system flow will be diverted, but not more than the system flow regardless of the value of Qdiv. If 0.0 then no flow is diverted. (ft³/s).

Notes:

- 1) A maximum of 10 points (10 sets of Qsys and Qdiv) can be defined on the sys/div curve. All values of sys must increase div can be any value (so long as it is positive and not greater than sys).
- 2) This is a very flexible command and can be used for any type of weir or regulator in a system. It could even be used to model a manhole that "blows its lid", by loosing the diverted flow or by taking it back into the system at another point by using the REC or GET commands depending upon the situation. (NOTE: The GET command would only work if you are doing hydrological analysis).
- 3) If you use this command without the SWI command or with the SWI command set to 1 or 2 PFP-Hydra calculates the "peak" flow, looks at the DIV curve to find the amount to divert and then splits the population (in the event of sanitary flow) or Sum of C*A (in the case of normal storm flow) into two units. As a result the sum of the 2 downstream flows may be slightly greater than the upstream flow in some cases.
- 4) If you are doing hydrological analysis, both sanitary and misc. flow are dumped into the storm hydrograph so a rational split can be made. This will cause the sanitary flow to start over again and because of the peaking factor, result in the downstream flows being slightly greater than the upstream flow.

COMMAND ECF - Extra Cost per lineal Foot

Purpose: An optional command, it allows costs that are related to depth to invert to be added to the pipe cost calculations. Examples of this are dewatering, sheeting, traffic control, etc.

Structure:

ECF depth, \$/foot, depth, \$/foot ... (max 20 sets, min 2 sets - depth must increase)

nx) depth - depth from the surface to the pipe invert (feet).
ny) \$/foot - added cost per foot of depth at the above depth.

Notes:

- 1) PFP-Hydra interpolates between the points supplied for any values needed. For this reason at least 2 sets of data must be supplied. The depth must always increase, the \$/foot can be any value.
- 2) More than one line may be used if needed.

COMMAND END - END of run

Purpose: This is the correct way to end a command string. When this command is encountered, PFP-Hydra will end the run no matter how many commands follow.

Structure:

END (no data)

COMMAND EXC - EXCavation costs

Purpose: One of the required commands for a PFP-Hydra cost estimate of pipe in place. It establishes trench excavation cost.

Structure:

EXC depth, \$/cy, depth, \$/cy ... (max 20 sets, min 2 sets - depth must increase)

nx) depth - depth from surface to excavation depth (feet).

ny) \$/cy - the cost at excavation "depth" (dollars per cubic yard).

Notes:

- 1) PFP-Hydra interpolates between the points supplied for any values needed. For this reason at least 2 sets of data must be supplied. The depth must always increase, the \$/cy can be any value.
- 2) More than one line may be used if needed.
- 3) PFP-Hydra calculates the excavation costs for every one foot strip. The cubic yards of every strip is calculated and then the excavation cost of that strip is determined from the data supplied.

COMMAND FIL - Read a "slave" FILE

Purpose: FIL, a command in the master file, transfers PFP-Hydra to another disk file. PFP-Hydra will read its commands from this new disk file until it encounters a RETURN command, at which time control will return to the master file.

Structure:

FIL name

name - up to five alphanumeric characters. This is the name of the "slave" disk file to which the reading is to be transferred. Do not indicate on which drive the file will be found (e.g. B:START): PFP HYDRA assumes it will be on the same drive as your master file.

Note:

Command not yet operational.

COMMAND FLO - miscellaneous FLOW

Purpose: FLO command adds a constant flow to the system. (A negative value indicates removal from the system.)

Structure:

FLO cuft/sec

cuft/sec - the number of cubic feet per second of water to be entered into or removed from the system. In the case of removing flow, the value would be negative.

Notes:

- 1) This command must be followed by a PIP command before a HOL command is used or the flow will not be taken into the system.
- 2) Some of the uses of this command:
 - a) known major sources of infiltration.
 - b) cooling water.
 - c) subdrain flow.
 - d) stream flow.
 - e) a given design flow.
 - f) irrigation tap (negative).

COMMAND GET - GET gutter hydrograph

Purpose: GET is very similar to the REC command in function except it retrieves a gutter hydrograph from data storage that was put there by the PUT or INL command. It has no use in non-hydrographic analysis.

Structure:

GET number

number - a number between 26 and 50 representing the gutter hydrograph that was put in data storage by the PUT or INL command.

COMMAND GPC - Gallons Per Capita per day

Purpose: This command allows you to set the gallons per capita per day that PFP-Hydra is to use in its flow calculation in the SAN and SUN commands.

Structure:

GPC uflow

uflow

- unit flow of wastewater (gal/capita/day) generated. This value will be used in conjunction with the peaking factor curve (PEA) and population data supplied through the SAN command to calculate actual sanitary flow.

COMMAND GUT - GUTter

Purpose: This is one of the transport commands and is only available for storm drain analysis using the hydrographic technique. It allows the user to transport the hydrograph "overland", in a gutter, before merging it into the main system hydrograph.

Structure:

GUT length, invup, invdn, "n", lslope, bwidth, rslope, eq, plot

- 1) length - total length of the gutter (feet).
- 2) invup - invert elevation at the upstream end (≥ 10.00 feet).
- 3) invdn - invert elevation at the downstream end (feet).
- 4) "n" - friction factor for the gutter (Manning's "n").
- 5) lslope - side slope in feet horizontal to feet vertical.
- 6) bwidth - width of the bottom of the gutter (feet).
- 7) rslope - side slope in feet horizontal to feet vertical.
- 8) eq - (optional) - enter 1 if Manning's equation is to be used; Enter 0 or leave blank if gutter equation is to be used.
- 9) plot - (optional) enter 1 if a plot is desired; enter 0 or leave blank if no plot is desired.

Notes:

- 1) There is an automatic ditto feature in this command in that "n", leftslope, bwidth and rightslope will all be copied from the previous GUT command unless overridden by entries in this command. The value of "n" may be changed without touching the gutter geometry parameters, but all geometry parameters must be reentered if one is. In other words, PFP-Hydra will accept 3, 4, 7, or 9 parameters for this command, but any other numbers of parameters will be assumed to be an error.
- 2) The friction factor or "n" has a major influence in the gutter calculations so it should be selected with care.

COMMAND HOL - HOLd lateral

Purpose: Holds system flow at the lower end of a lateral. This flow can then be recalled into a trunk at the appropriate time with the REC command.

Structure:

HOL number

number

- a register number from 1 to 25 in which lateral data is to be stored. The REC command can then be used to bring this data back into the system. You can re-use a register any number of times but previously stored data will be lost. This should be of no concern if a REC command has already retrieved the data.

Note:

- 1) It is good practice to immediately follow a HOL command by a NEW command. If you do not, it is possible to lose data.

COMMAND HYD - runoff HYDrograph

Purpose: To generate a runoff hydrograph from a land segment.

Structure:

HYD acres, dis, slope, paved, delay, roof, north, east

- 1) acres - acres in the land segment. If this value is negative, the map scale entered in the MAP command will be used to convert to acres.
- 2) dis - maximum distance that water must flow over the ground as sheet flow. (feet).
- 3) slope - average slope of the land segment for the ground surface where sheet flow takes place.
- 4) paved - ratio of paved surface to the total land segment area.
- 5) delay - (optional) - delay time in minutes before runoff hydrograph becomes "visible" to the system.
- 6) roof - (optional) - the ratio of flat roof area to paved area.
- 7) north - (optional) - the North coordinate of the centroid of the land segment.
- 8) east - (optional - but must be used with "north") - the East coordinate of the centroid of the land segment.

Note:

- 1) PFP-Hydra counts the number of parameters you use. It will accept 4, 5, 6 or 8 parameters, any other number of parameters is assumed to be an error. If you wish to use the "roof" parameter but not the delay parameter, then set the "delay" to 0.0. In other words, although the parameters are optional, if you need to use one that is "down the line" you must set those not used to zero (0 or 0. or 0.0).

COMMAND HYE - HYEtograph

Purpose: This command allows the input of a hyetograph, or "picture" of the rainfall over a period of time (say 6 hours).

Structure: Two forms of this command are available. The first involves entering the hyetograph values directly. The second is to provide the filename of a file with the desired values. Typically, this file is produced by the HYDRO program.

HYE int, int, ... (up to 96 values)

int - average intensity of rainfall during each step (inches/hour). Unless you use the STEP command, the default length of each step is 15 minutes or 24 hours for 96 steps.

or

HYE filename

filename - the filename of the hyetograph dataset. The HYDRO produced hyetographs have the file extension "HYE".

Note:

- 1) Data in the file for the second command form must be in the following format (HYDRO uses this format):

Line 1: Comment line 1

Line 2: NPTS

Line 3+: T(N), INT(N)

where: NPTS = number of points,

N = point number,

T(N) = time value (minutes), and

INT(N) = average rainfall intensity (inches/hour).

The data in lines three through the end must be in adjacent 10 space fields beginning in column 1.

- 2) Only two lines of data may be entered using the first command form. If additional data are required, the second form must be used.

COMMAND INF - INFiltration

Purpose: Inputs infiltration flows based on population or area.

Structure:

INF infp, infa

infp - infiltration of water on a population basis
(gal/capita/day).

infa - infiltration of water on an area basis
(gal/acre/day).

Notes:

- 1) Normally one would use gal/capita/day or gal/acre/day, but not both at the same time. The one not used would be set to 0.0. It is a matter of preference which to use. Some engineers feel the gal/capita/day better reflects the number of side sewer connections (where much of the problem exists), while others prefer the gal/acre/day. Remember this can be changed during a run to reflect changing ground water conditions.
- 2) Infiltration is only calculated on the sanitary data, not the storm data.
- 3) This is an important parameter in all "real" sanitary sewer systems. In numerous cases, infiltration into a sanitary sewer system exceeds the waste water flows. The value selected should be based on the assumption that the system has been in the ground for 50 years or more, not on new construction standards.

COMMAND INL - storm water INLet

Purpose: Adds a runoff hydrograph generated by a HYD command to the pipe described in the following PIP command (this is the system hydrograph).

Structure:

INL ID, capacity, store, gwidth, K, slot, plot

ID	- Identification number.
capacity	- inlet peak capacity in ft^3/s .
store	- (optional) - if not used, any flow greater than the inlet capacity will be stored until it can be taken into the inlet. If used, it must be a number from 26 to 50 to represent the storage location for all excess flows. Recall using GET command.
gwidth	- (optional) - width of inlet grate in feet. If used, GUT must precede with eq set to 1.0.
K	- (optional) - Suboption 1: Input K value selected from Neenah's rating curve. Suboption curve: Input 1 and K will be computed based on the preceding gutter.
slot	- (optional) - Suboption 1: decimal fraction of peak to be intercepted. Suboption 2: length of slotted drain in feet. Suboption 3: desired peak interception capacity (ft^3/s).
plot	- (optional) - enter 1 if a plot is desired; enter 0 or leave blank if no plot is desired.

Notes:

1) Option 1 (ID, capacity)

This command tells the program to intercept all of the runoff below peak capacity. This is the only option that can be used to simulate a sump condition.

2) Option 2 (ID, capacity, store)

The store registers are the same as those used for the PUT and GET commands. Do not overwrite them.

3) Option 3 (ID, capacity, store, gwidth)

The calculated capacity does not include side capture nor is there a check made to see if flow skips over the grate and bypasses the inlet. Check to see if flow skips over the grate. The Equation (Eq) selected in the preceding GUT command must be 1.

COMMAND INL (Continued)

- 4) Option 4 & 5 (ID, capacity, store, gwidth, k, (slot))

The store register of parameters #3 must be used for bypassed flow. This option cannot be used in a sump condition. The capacity of the slotted drain pipe is not considered and must presently be determined manually.

- 5) Option 5 (ID, capacity, store, gwidth, k, slot)

The slotted drain width of 1.75 inches is used in the computations which coincides with current WHD standards. The slotted drain can be used in combination with the grate width (option 3) or the Neenah K (option 4) of computing inlet capacity. Technology in FHWA/RD-80/081 was used in PFP-Hydra.

COMMAND IPU - Individuals Per Unit

Purpose: Establishes population per "sanitary unit" for SUN command.

Structure:

IPU ipu

ipu - number of individuals per each sanitary unit (SUN)

COMMAND JOB - JOB title

Purpose: Initiates job and enters job title.

Structure:

JOB jobtitle

jobtitle - up to 50 alphanumeric characters describing your job.

Note:

- 1) This must be the first command and there may be only one JOB in any command file. It allows you to "load" a job title into PFP-Hydra that will be printed on every page of your output.

COMMAND LPC - List the Pipe Costs

Purpose: This command calculates and prints cost of pipe in place in a tabular form. The costs calculated are the unit costs resulting from parameters that you define with CST, EXC, PCO, and TSL commands.

Structure:

LPC diam, sdepth, edepth, incr

- 1) diam - inside diameter of pipe (inches).
- 2) sdepth - invert depth at which cost estimate table is to start (feet).
- 3) edepth - invert depth of last cost estimate (feet).
- 4) incr - the number of feet between each cost estimate. If left blank or set to 0.0, PFP-Hydra will set to 1. This parameter must be a whole number.

Note:

- 1) All data used in this command must be whole numbers, for example 5.0 or 5 is acceptable; 5.5 is not.

COMMAND MAP - MAP scale

Purpose: The SAN, SUN, STO, and HYD commands all require entry of land segment areas in acres. If the user chooses, they may enter square inches instead with a negative sign preceding each value. PFP-Hydra converts square inches to acres using the value set by this command. Even if the MAP command is in the command file, the user may still choose to enter acres directly.

Structure:

MAP scale

scale - the scale of the map being used in feet/inch.

Notes:

- 1) As with nearly all PFP-Hydra commands this command can be used any number of times in the command string. This allows the user to use any number of different maps on a single system.
- 2) The formula used to calculate acres is illustrated below. This formula is used anytime "acres" are negative. The negative value is first changed to a positive value and then:

$$\text{Area in acres} = \frac{(\text{area in square inches}) \cdot (\text{scale})^2}{43,560}$$

COMMAND NEW - start NEW lateral

Purpose: This command is used to start a new lateral and load the lateral name.

Structure:

NEW name

name - lateral name up to 20 alphanumeric characters in length.

Notes:

- 1) This command starts off a new lateral. Any flow entering this lateral must follow this command in the command string.
- 2) After the first lateral be sure to use a HOL command before a NEW command if you intend to recall the flow from a lateral back into the system. The NEW command clears any flows calculated, but not explicitly saved.

COMMAND PAV - PAVed surface parameters

Purpose: Sets hydrographic parameters for paved portion of land segment used by HYD.

Structure:

PAV n, depthpud, slope, topud, toweep, timedrain, roofdrain

n	- friction factor (Manning's "n") for the paved area. (Default = 0.017)
depthpud	- average depth of the puddle storage in inches if the ground is very flat. (Default = 0.02)
slope	- slope of the paved surface for no puddles. (ft/ft). (Default = 5.0)
topud	- portion of rain on paved surface that is diverted to puddles. (Default = 0.2)
towweep	- maximum diversion ratio to "weeping" puddle storage. (Default = 0.2)
timedrain	- time in minutes to drain weeping puddle storage. (Default = 45)
roofdrain	- drainage rate from flat roof storage in ft ³ /s/acre. A good place to start is 0.4 ft ³ /s/acre. (Default = 0.0)

Note:

- 1) Although the values suggested above are reasonable, it is recommended that you establish these parameters in conjunction with a calibration program where both rainfall and actual system flows are recorded.
- 2) If all the default parameters are adequate, then the PAV command may be omitted. If one or more parameters required different values, the command must be included with all seven parameters.

COMMAND PCF - Pipe Cost Factor

Purpose: An optional command for cost estimates. Its purpose is to increase cost of pipe in place to reflect the additional cost of higher class pipe as trench depth increases and/or extra cost for laying the pipe.

Structure:

PCF depth, factor, depth, factor ... (max of 20 sets, min of 2 sets - depth must increase)

nx) depth - depth from the surface to the pipe invert (feet).

ny) factor - some factor which when multiplied by pipe cost from the PCO command will result in a reasonable adjustment for a class of pipe.

Notes:

- 1) PFP-Hydra interpolates between the points supplied for any values needed. For this reason at least 2 sets of data must be supplied. The depth must always increase; the factor can be any value.
- 2) More than one line may be used if needed.

COMMAND PCO - Pipe COsts

Purpose: One of the required commands for cost estimate. It establishes the cost per foot of pipe in place.

Structure:

PCO dia \$/ft, dia \$/ft, dia \$/ft ... (max of 20 sets, min of 2 sets -
dia must increase)

nx) dia - inside diameter of pipe (inches).

ny) \$/ft - cost in dollars per foot of pipe laid in place but
not backfilled.

Notes:

- 1) PFP-Hydra interpolates between the points supplied for any values needed. For this reason at least 2 sets of data must be supplied. The diameter must always increase, the \$/cy can be any value.
- 2) More than one line may be used if needed.

COMMAND PDA - Pipe DATA

Purpose: This command establishes design criteria for use with the PIP command.

Structure:

PDA "n", mindia, mindepth, mincover, minvel, minslope, maxdia

- 1) "n" - pipe friction factor (Manning's "n").
- 2) mindia - the minimum diameter of a pipe in a "free design" (inches).
- 3) mindepth - in a free design, PFP-Hydra will not place the invert shallower than this depth (feet).
- 4) mincover - in a free design, PFP-Hydra will not allow cover over the pipe to be less than this value (feet).
- 5) minvel - in a free design, PFP-Hydra will not allow the full flow velocity to drop below this value (feet/sec).
- 6) minslope - in a free design, PFP-Hydra will not select a slope less than this value (feet/foot, >0).
- 7) maxdia - (optional) - If it is used, PFP-Hydra will not select a pipe larger than this diameter. This parameter could probably not be used for the first run on any design.

COMMAND PEA - PEAKing factor

Purpose: In order to calculate sanitary flow in a sewer system, PFP-Hydra must be given a "peaking factor" curve. This peaking factor curve is used to translate average daily flow into peak daily flow. This command is used to supply PFP-Hydra with that curve.

Structure:

PEA flow, factor, flow, factor ... (max of 20 sets, min of 2 sets - flow must increase)

nx) flow - accumulated average daily flow from SAN and SUN commands (ft^3/s).

ny) factor - peaking factor. Normally ranges between 1.0 and 4.0.

Note:

The last data set should be greater than the maximum expected ft^3/s in the system, otherwise the interpolating features of the command may yield unexpected results. Also, experience indicates that your curve should start at zero, as initial flows in a system are often very small.

COMMAND PIP - Circular PIPE

Purpose: This is one of the transport commands. It moves water from one point to another in a circular pipe. A PDA command is required somewhere in the command file ahead of the first PIP command.

Structure:

PIP length, grup, grdn, invup, invdn, mindia, lscost, trfac, plot

- 1) length - the length of the link or pipe in feet.
- 2) grup - elevation of the ground at the upstream end of the link (feet).
- 3) grdn - elevation of the ground at the downstream end of the link (feet).
- 4) invup - (optional) - elevation of the invert of the pipe at the upstream end of the link (feet).
- 5) invdn - (optional) - invert elevation at the downstream end of the link (feet).
- 6) mindia - (optional) - minimum diameter of pipe (inches). See note 2 for analysis of existing pipes.
- 7) lscost - (optional) - the lump sum to be added to the link cost (\$) calculated by PFP-Hydra when cost parameters are used.
- 8) trfac - (optional) - trench cost factor (default = 1.0).
- 9) plot - (optional) - enter 1 if a system plot is desired, enter 0 or leave blank if no plot is desired.

Notes:

- 1) this command will accept 3, 5, 6, 7, 8, or 9 parameters.
- 2) if mindia is given as a negative number PFP-Hydra will analyze the pipe assuming that the absolute value is its diameter: for example, -12 indicates an existing 12-inch pipe.

COMMAND PON - surface PONding

Purpose: This command allows surface ponding of flows HYD, GUT, and GET commands. Pond size can be designed or reviewed.

Structure:

PON cap, disch

cap - desired pond capacity in cubic feet. (Enter 0 to design pond size.)

disch - maximum return discharge in ft^3/s . (Enter 0 to design maximum return discharge.)

Notes:

- 1) Caution if inflow hydrograph has multiple peaks. Option 1 may compute a larger return flow than necessary. In this case use Option 2 in a trail and error solution until desired pond capacity is obtained.

COMMAND PUM - PUMp

Purpose: Lifts hydraulic gradient the specified amount and sizes discharge pipe. (A PIP or CHA command must immediately precede the PUM command).

Structure:

PUM length, elevout, maxvel, dia, cost

- length - the length of the discharge pipe (feet).
- elevout - discharge invert elevation (feet).
- maxvel - maximum velocity in the discharge pipe (feet/sec).
- dia - (optional) - diameter (inches) either zero or a positive number. If zero, a diameter will be selected. If a diameter is given, maxvel will be ignored.
- cost - (optional) - lump sum cost of pump and station.

Note: Upstream and downstream inverts are at the same elevation in the pump discharge pipe. Recommend using 1-foot pipe.

COMMAND PUT - PUT gutter flow into storage

Purpose: This is one of the hydrographic commands. It is ignored by PFP-Hydra on non-hydrographic runs. It is very similar to the HOL command in function except it stores away the gutter hydrograph. This gutter hydrograph is recalled by GET.

Structure:

PUT number

number - a number from 26 to 50 that labels the storage location. These storage locations are identical to those used by the INLet command, and can be re-used any number of times - however, if the same register is used more than once the previous data will be destroyed. Recalling information from a PUT register can only be done with a GET command.

Note:

- 1) Recalling information from a PUT register can only be done with a GET command. Although the GET command recalls the information stored in a PUT register it does not destroy the data in the register. Therefore, if the user wishes to "see" the gutter hydrograph at any point, he may use the PUT command to store it away then the GET command to bring it back leaving an "image" of the hydrograph in the PUT register.

COMMAND RAI - RAI nfall data

Purpose: The Rational Formula requires an intensity vs. duration (IDF) curve. This command allows you to set the values on the curve.

Structure: Two forms of this command are available. The first involves entering the IDF values directly. The second is to provide the filename of a file with the desired values. Typically, this file is produced by the HYDRO program.

RAI dur, int, dur, int, dur, int ... (max of 20 sets, min of 2 sets - dur must increase)

nx) dur - the duration of a specific rainfall intensity which is experienced in a storm of a certain period, e.g. a 5-year storm (minutes).

ny) int - rainfall intensity (inches/hour).

or

RAI filename - the filename of the IDF dataset. The HYDRO produced IDF curves have the file extension "IDF".

Notes:

- 1) More than 1 line can be used if needed.
- 2) HYDRA interpolates between the points supplied for any values needed. For this reason, at least 2 sets of data must be supplied. The time must always increase; the intensity can be any value.
- 3) It is always wise to have the last two points have the same intensity, so the extension of the curve will never go negative.
- 4) The return period you select affects the flows. Select the curve with care.
- 5) Data in the file for the second command form must be in the following format (HYDRO uses this format):

Line 1: Comment line 1
Line 2: NPTS
Line 3+: DUR(N), INT(N)

where: NPTS = number of points,
N = point number,
DUR(N) = duration (minutes), and
INT(N) = intensity (inches/hour).

The data in lines three through the end must be in adjacent 10 space fields beginning in column 1.

COMMAND REC - RECall lateral

Purpose: Recalls flow into the system that was stored using the HOL or DIV command.

Structure:

REC number

number - a number from 1 to 25 representing the storage location of data previously stored by a HOL or DIV command.

Notes:

CAUTION - HOL and DIV commands use the same 25 registers to store flow, so do not inadvertently overwrite them - however, PFP-Hydra will warn you of this problem.

There is a limit to 6 recalls at one node. If more than 5 laterals contribute to a downstream link, insert a short PIPE (say, 1.0 foot) and then recall the rest.

COMMAND REM - REMarks

Purpose: allows a line for remarks or comments.

Structure:

REM any alphanumeric information.

COMMAND RES - REServoir

Purpose: Allows the user to analyze the effect of in-line storage on system flows. It is one of the hydrographic commands. It is ignored on non-hydrographic runs.

Structure:

RES cap, return

- cap - the capacity of the reservoir in cubic feet. If cap is set to 0.00, PFP-Hydra will select the required capacity and print the size immediately following the command. If you select the size, and it is not sufficient, PFP-Hydra will use what it can, bypass the excess and let you know the capacity was exceeded.
- return - the maximum rate of return to the system from the reservoir. If the upstream system flow is less than this value, the reservoir is not used. If the upstream system flow ever exceeds this value, the reservoir will start to fill. (units)

Notes:

- 1) Because this command must deal with a system hydrograph for its analysis, flows being carried in the INF, SAN and SUN registers are transferred to the storm hydrograph, and these registers cleared. This causes two minor problems. First the summaries of INF, FLO and SAN flows below the reservoir are only from the reservoir, downstream (although the volume is nearly correct since it is being carried in the storm hydrograph); and secondly, in the case of sanitary flows, since they start afresh, the peaking factor is increased resulting in a slight increase in flow over the value prior to the insertion of the RES command. Since this only happens when we are dealing with a combined system, and since in a combined system, sanitary flow are normally a small percentage of the total system flows, this does not normally have a significant impact on the results.
- 2) Must be immediately preceded by a transport command.

COMMAND RET - RETurn

Purpose: The FIL command in the master command file transfers reading to a slave disk command file - the RET command finishes the slave file and returns the reading sequence back to the master disk file. (The return can only be to the master file.)

Structure:

RET (no parameters)

Note:

Command not yet operational.

COMMAND SAF - SAFety factors

Purpose: Provides a safety factor to be applied to flows calculated by PFP-Hydra.

Structure:

SAF san, inf, storm, flo

- 1) san - safety factor for sanitary flows generated by the SAN and SUN commands.
- 2) inf - safety factor for infiltration flow generated by the INF command working on data supplied by the SAN and SUN commands.
- 3) storm - safety factor for all flows generated by either the STO or HYD commands.
- 4) flo - safety factor for flow generated by the FLO command.

Notes:

- 1) None of the parameters can be less than 1.00.
- 2) The above values should all be set to 1.00 when calibrating a system against recorded flows so PFP-Hydra will not indicate an overloaded condition, when none exists.
- 3) This command may be used any number of times in the command string, so if you are analyzing a system in which some laterals are existing and some are being designed, altering the safety factors from 1.0 to design values should be considered.
- 4) If this command is not used, all values will be set to 1.0.

COMMAND SAN - SANitary flow

Purpose: Enters sanitary flow into the system. It uses data supplied in the PEA and GPC commands.

Structure:

SAN area, pop

- 1) area - area in acres served by the following link. The user can input map measurements in square inches (as a negative value) using the MAP command to make the conversion to acres.
- 2) pop - equivalent population density (persons/acre). This value normally ranges from 6 to 50.

Notes:

- 1) This command must be followed by a transport command (PIP, CHA, PUM, etc.) before a HOL command is used.
- 2) This command generates flow as follows:
 - a) If the acres are negative (square inches), the MAP command is used to convert the square inches to acres.
 - b) The acres are multiplied by the density/acre to yield population, this is then added to upstream population.
 - c) This total population is converted to Ft³/s using criteria set in the GPC command.
 - d) The Peaking (PEA) factor curve is used to adjust this flow for peak loads on the system.
 - e) The acres or population in this command are used in conjunction with the data supplied by the INF command to calculate the infiltration into the system.

COMMAND STE - STEp

Purpose: Sets the length of the step in hydrographic simulation.

Structure:

STE step

step

- Simulation time step (minutes). If this command is not used the step defaults to 15 minutes. In this case there will be 15*96 or 24 hours total simulation.

Notes:

- 1) PFP-Hydra works with 96 internal registers in hydrographic simulation. For this reason when you set the step length to 5 minutes, the period of calculation is 8 hours. When you set the step to 15 minutes, the period of calculation is 24 hours, etc.
- 2) It is recommended that you work in 15-minute time steps (STE 15) as this turns out to be about the right match for the available rainfall data and PFP-Hydra's routing techniques.
- 3) This command can only be used once in a command string, and must precede the HYE command. It should be noted that the length of the time step must match the time assumed in the HYE command.
- 4) If a user supplied hyetograph file is used (i.e. from HYDRO or other source), the STE command must still be used. (Although future revisions will not require this).

COMMAND ST0 - ST0rm flow

Purpose: Enters sub-basin data for use in the Rational Formula determination of storm water design flow.

Structure:

The three forms of this command are outlined below. They are quite similar. The principle difference is in how the "minimum time to the inlet" is established. In the first form the user established the "min time to inlet", the next two forms allow the user to supply data which allow PFP-Hydra to make this calculation.

ST0 acres, C, time

- 1) acres - number of acres in service area (or square inches if input with a negative value).
- 2) C - a value between 0.0 and 1.0 which represents the fraction of rainfall that runs off.
- 3) time - minimum time(minutes) runoff takes to get from the most remote point of the sub-basin to the inlet.

or

ST0 acres, C, oup, odn, odis, gtime

- 3) oup - upper overland flow elevation in feet.
- 4) odn - lower overland flow elevation in feet.
- 5) odis - overland flow distance (from oup to odn) in feet.
- 6) gtime - gutter time in minutes (from odn to the inlet).

or

ST0 acres, runoff coef, oup, odn, odis, gup, gdn, gdis

- 6) gup - upper gutter elevation in feet.
- 7) gdn - lower gutter elevation in feet.
- 8) gdis - length of the gutter in feet (from odn to the inlet).

Notes:

- 1) Equation 2, discussed earlier in this volume, is used to calculate the overland flow time.
- 2) Equation 3, also discussed earlier in this volume, is used to calculate gutter flow time. Experience indicates that this is close enough to the actual gutter time in most situations. If the designer feels they must have greater accuracy they have two choices. They can precalculate the time using other methods and then use the 6 parameter option, or they can set the "gtime" to 0.0 and use the GUT command to transport the water down the gutter to inlet.
- 3) This command must contain 3, 6, or 8 parameters.

COMMAND SUN - Sanitary UNits

Purpose: Enters the number of "sanitary units" contributing to the sanitary flow at a node.

Structure:

SUN units, acres

- 1) units - The number of "units" (as in dwelling units) contributing to the system at this node.
- 2) acres - (optional) - The number of acres containing the units. If the MAP command has been used, square inches can be entered (as a negative value) and PFP-Hydra will calculate the acreage.

Notes:

- 1) IPU, GPC and PEA commands must precede this command.
- 2) The set of commands GPC, IPU, and SUN can be included in the same link with the SAN command and PFP-Hydra will assume that there are 2 contributing areas.

COMMAND SUR - SURcharge

Purpose: Provides the necessary parameters to analyze the possibility of surcharging the system.

Structure:

SUR entloss, dssurcharge

entloss - entrance loss coefficient ranging between 0.0 and 1.0

dssurcharge - downstream surcharge, the depth in feet of the tailwater over the top of the downstream end of the pipe. (Normally 0.0).

Notes:

- 1) The surcharge calculation is based on a culvert formula developed by the Bureau of Public Roads. The answers should be considered as a guide rather than as fact. It is also important to remember that if the downstream pipe is surcharged, this surcharge must be taken into account upstream. The second parameter can be used for this, but the best way is to plot out the hydraulic grade line for the system.
- 2) Values for entrance loss have been determined by different researchers with results ranging in the values below:

Inlet Type	Range	Average
Square-edged inlets, flush with vertical headwalls.	0.43 to 0.70	0.50
Round inlets, flush with vertical headwalls, R/D ratio = 0.15.	0.08 to 0.27	0.10
Grooved or socket-ended concrete pipe, flush with vertical headwall.	0.10 to 0.33	0.15
Projecting concrete pipe with grooved or socket ends.	-	0.20
Projecting steel or corrugated metal pipes.	0.50 to 0.90	0.85

COMMAND SWI - criteria SWitch

Purpose: This command establishes the method by which PFP-Hydra is to analyze storm flows.

Structure:

SWI switch

switch - a number 1, 2, 3, 4, or 5.

1 - Sanitary analysis only.

2 - Storm Analysis Rational method only.

3 - Storm Analysis Hydrographic method only.

4 - Sanitary and rational analysis.

5 - Sanitary and hydrographic analysis.

COMMAND TRA - TRAnsfer system flow to surface flow

Purpose: This command enables system flow (pipe flow) to be added to surface flow (gutter flow). This command is only used in hydrographic analysis.

Structure:

TRA (no parameters required)

Notes:

- 1) A HOL command cannot be used after TRA.

COMMAND TSL - Trench side Slope

Purpose: One of the required commands for PFP-Hydra to make a cost estimate of pipe in place. It sets the slope of the trench side walls above the top of the pipe.

Structure:

TSL depth, slope, depth, slope ... (max of 20 sets, min of 2 sets - depth must increase)

nx) depth - depth from ground surface to the invert (feet).

ny) slope - slope of the portion of the trench above the top of the pipe when the invert is at the above depth.
(ft/ft)

Notes:

- 1) PFP-Hydra interpolates between the points supplied for any values needed. For this reason at least 2 sets of data must be supplied. The depth must always increase; the slope can be any value.
- 2) More than one line may be used if needed.

COMMAND UHY - User HYdrograph

Purpose: Enables the user to use externally produced hydrographs in an analysis.

Structure:

UHY filename

filename - the filename of the hydrograph data set. The HYDRO produced hydrographs have the file extension "QT".

Note:

- 1) Data in the file must be in the following format (HYDRO uses this format):

Line 1 : Comment Line 1

Line 2 : NPTS

Line 3+: N, T(N), Q(N)

where: NPTS = number of points

N = point number

T(N) = time value (minutes)

Q(N) = flow value (ft³/s)

The data in lines three through the end must be in adjacent 10 space fields beginning in column 1.

COMMAND UNP - UNPaved surface parameters

Purpose: Sets the hydrographic parameters for unpaved or pervious area.
(Used with the HYD command.)

Structure:

UNP n, intrcpt, depth1, depth2, maxinf, satinf, idecay, timerec, interflo, delay, deplete

n - friction factor (Manning's "n") for unpaved ground surface. (Default = 0.05)

intrcpt - portion of precipitation directed to interception storage one. (Default = 0.5)

depth1 - maximum capacity of interception storage one (inches). (Default = 0.15)

depth2 - maximum capacity of interception storage two (inches). (Default = 0.15)

maxinf - maximum infiltration capacity (inches/hour). (Default = 0.5)

satinf - saturated infiltration capacity (inches/hour). (Default = 0.08)

idecay - infiltration decay constant. (Default = 0.05)

timerec - infiltration recovery time (minutes). (Default = 120)

interflo - portion of infiltration to interflow. (Default = 0.0)

delay - delay before interflow appears (hours). (Default = 2)

deplete - time to deplete interflow (hours). (Default = 48)

Notes:

- 1) The following parameters can be used as a guide for the selection of the above coefficients:

DESCRIPTION OF GROUND SURFACE	Depth 1	Maxin	satinf	idecay	timerec
	Depth 2				
Hilly forest	.40				
Flat woodland	.30				
Old pasture and fields	.25				
Flat lawn and parkland	.20				
Sloping lawns	.15				
Undisturbed forest		5.0	3.0		
Managed woodlot		4.0	1.0-1.5		
Grassland-shrubs		3.0	1.0-1.5		
Old pasture		2.0	0.7-1.0		
New pasture-lawns-playing fields		1.0	0.3-0.4		
Row crops-sandy loam		0.6	0.2-0.3		

COMMAND UNP (Continued)

DESCRIPTION OF GROUND SURFACE	Depth 1 Depth 2	Maxin	satin	idecay	timerec
Row crops-clay loam		0.4	0.1-0.2		
Bare soil-sand, gravel		0.7	.30-.45		
Bare soil-medium		0.4	.15-.30		
Bare soil-clay loam		0.2	.05-.10		
Woodland, slope 2%				.005	15
Woodland, flat				.01	60
Grass & gravel soil, slope 2%				.05	30
Grass & gravel soil, flat				.07	150
Bare soil (clay), slope 2%				.08	120
Bare soil (clay), flat				.1	480

- 2) If all default parameters are adequate, then the UNP command may be omitted. If one or more parameters require different values, the command must be included with all 11 parameters.

References

- 1) "Draft PFP-Hydra User's Manual", unpublished report developed under FHWA contract DTFH61-84-C-00082, October 1986.
- 2) Johnson, Frank L., and Fred F. M. Chang, "Drainage of Highway Pavements", FHWA Highway Engineering Circular Number 12, FHWA-TS-84-202, Washington D.C., March 1984.
- 3) Masch, Frank D., "Hydrology", FHWA Hydraulic Engineering Circular Number 19, FHWA-1P-84-15, Washington D.C., August 1984.
- 4) Federal Aviation Administration, Manual in Airport Drainage, Advisory Circular 150-5320-5B, Washington D.C., 1966.
- 5) Linsley, R., Kohler, M., Paulhus, J., Hydrology For Engineers, McGraw-Hill Book Company, 1958.
- 6) Daugherty, R., Franzini, B., Finnemore, E., Fluid Mechanics with Engineering Applications, McGraw-Hill Book Company, 1985.