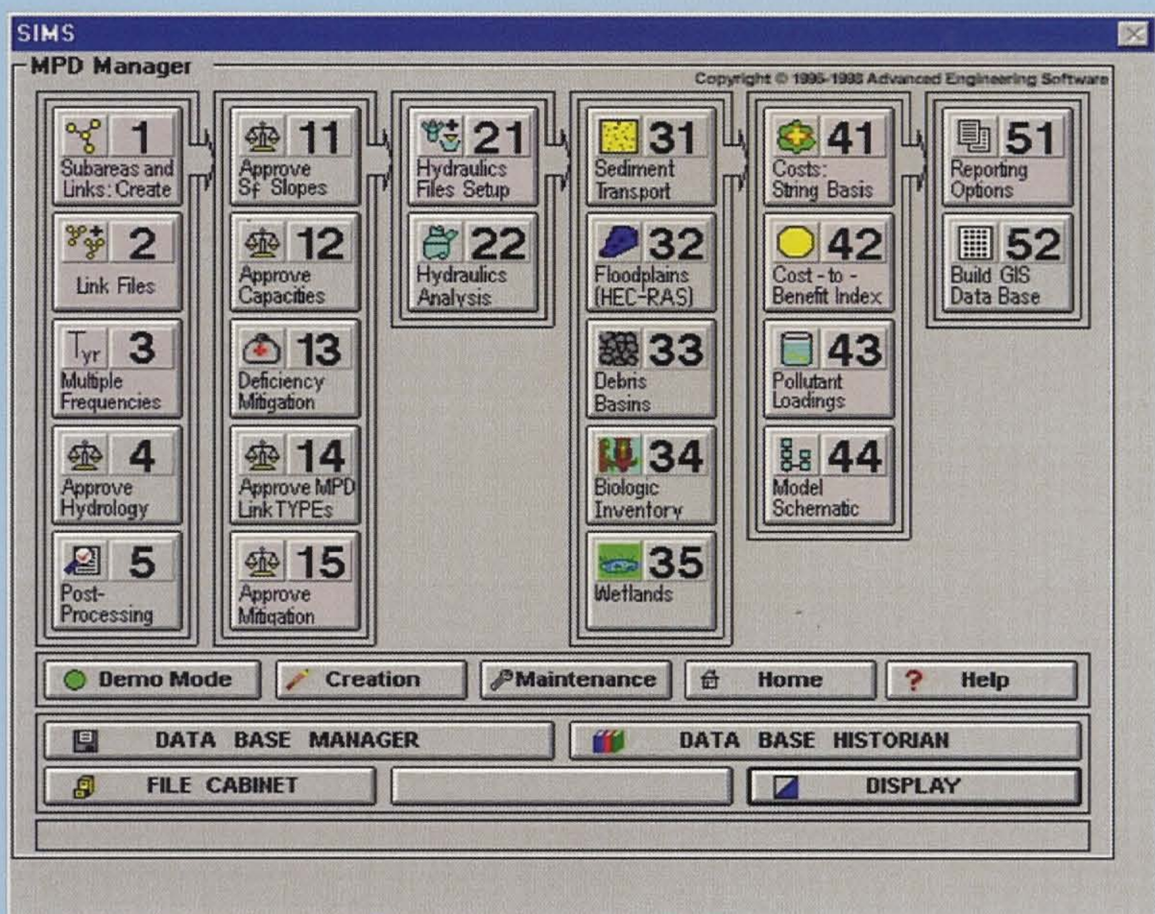
SIMS©

Stormwater Information Management Systems -

A Guide to Preparing GIS-Based Master Plan of Drainage Models



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Chapter 1
Introduction

1.1 About This Book

This book has evolved from the professional level course entitled "GIS in Water Resources" offered, from 1991 through 1996, by the University of California, Davis, University Extension, and thereafter by the Computational Hydrology Institute. The course presenters who lectured on the mechanics and development of a Stormwater Information Management System (SIMS), as applied to the disciplines of flood control and drainage master planning, are this book's principal author and Johannes J. DeVries, Ph.D., PH, PE.

In order to present the material in a more step-by-step fashion, this book illustrates the preparation of the SIMS approach as developed and marketed by Advanced Engineering Software[1] (AES) for their Master Plan of Drainage (MPD) SIMS. From 1995 through 1999, applications of the AES SIMS have been developed for several city-wide and county-wide Master Plans of Drainage in the southwest United States, by several consulting firms.

1.2 Book Presentation

The book presents a logical step sequence for the development of a Master Plan of Drainage (MPD). The work tasks (or steps) listed in Section 1.5 are primary self-contained processes typically undertaken in developing a MPD from scratch. Some of the steps listed in Section 1.5 contain feedback linkages in that prior steps may possibly be revisited due to program user choices that override the program's recommendations.

Other analysis tools can communicate with the computed results that are developed by the MPD analysis procedures of Table 1. For example, the tasks of financial planning, stormwater pollutant loading estimation, and system implementation prioritization, among others, can all interface with the MPD computed results and, in turn, also store their computed results in the Global Database structure (of the SIMS), for subsequent access by still other analysis tools.

The book presentation is as follows:

Chapter 1. Provides an overview of key terms and concepts used throughout the book in discussing various topics about Stormwater Information Management Systems and the development of master plans of drainage and environmental systems. This chapter also presents a stepwise approach towards development of such systems and master plans.

[1] Advanced Engineering Software is located in Riverside, California, and has a home page address www.aessoft.com

Chapter 2. Presents a detailed look at the computational methods and algorithms typically available for use in the development of a SIMS. Among the several topics considered include watershed system nodal point definition, network definition, hydraulic grade line (HGL) envelope analysis, deficiency analysis, prioritization of deficiency element replacement, cost-to-benefit analysis, multiple return frequency design storm analysis, and other topics.

Chapter 3. Presents a full exposition of a typical setup for an integrated rational method and unit hydrograph method hydrology model for use in the development of master plans of drainage. Using the commercially available computer program (published by Advanced Engineering Software; see website at www.aessoft.com), Chapter 3 takes you page by page through the data input screens for each of the several processes and modules used in the program. Data input help text files are also linked to the data input screens. The hydrology program is the cornerstone of the SIMS assemblage of analysis tools.

Chapter 4. Similar to Chapter 3, this chapter presents a complete exposition of the pre-and post processor program of the Advanced Engineering Software SIMS. The post-processor is a collection of dozens of modules, each module performing a separate task in the master planning process. Given the answers to about "Twenty Questions", the entire master planning endeavor is controlled in a near deterministic fashion. This chapter reviews the AES post-processor and how the MPD is controlled by the selection of planning options. This chapter also examines the program input screens for several of the AES SIMS analysis tools such as the Pollutant Loading Estimation module, the COSTS module, and the Cost-to Benefit module. An important product from the post-processor are the DIAGNOSTICS of the MPD files. An example output from the AES SIMS Diagnostics is included in Appendix B.

Chapter 5. The user interfaces with the SIMS via a Graphics User Interface, or GUI. The GUI published by AES is examined in detail as to each of its paths and logic decision lines.

Chapter 6. This chapter presents a look at master plans of drainage developed by several private engineering consulting firms using a SIMS. Using the experience developed from the preparation of city-wide MPDs, these case studies provide useful information in how to use a SIMS for similar projects.

Chapter 7. This chapter provides a detailed look at the hydrologic modeling methods typically employed for master plans of drainage and environmental systems. Included is discussion about the hydrology technique to be typically used, as well as computer output from the AES SIMS for several of the SIMS modules.

1.3 Interface of the SIMS with a GIS

A GIS is useful to synthesize hydrologic model properties and hydraulic system attributes from digital mapping data (see Figure 2.1). A GIS is also useful to display select numeric data when a MPD graphic element (e.g., a link, node, or subarea) is clicked upon. Additionally, a GIS is useful to query numerical data, create graphical displays and maps, and to edit numeric data on the graphical display.

The SIMS presented in this book is composed of a numerical database with an associated analysis tool set and a Graphical User Interface (GUI) to help the program user to navigate through the SIMS. The interface with a GIS is accomplished by the reading of GIS numeric data, by the SIMS, and the reading of SIMS numeric data, by the GIS. This passing of numeric data sets between the SIMS and the GIS is accomplished, in the chosen AES application, by the creation of ASCII text files that are written to conform to preselected data specifications (the reader may wish to visit the AES homepage at http://www.aessoft.com and inspect the database specifications). The AES SIMS creates a Global Database structure that contains much more information than the GIS attribute box display needs to contain. Consequently, a SUBSET Database is developed that contains only the information desired by the end user. This SUBSET Database can be configured by the program user, in a module contained in the SIMS program management tool set.

The GIS application communicates with the AES SIMS by creating an ASCII file of attribute data, resulting from polygon processing and map searching, to be read by the SIMS. Similarly, when the SIMS process path is completed and a new SUBSET Database is prepared by the SIMS, the GIS reads the SUBSET ASCII file to update the GIS data values.

These ASCII communication files can be printed out and reviewed by the program user just like any other text file.

1.4 Terminology

Several terms are used in this book as they are utilized in the subject AES software. These terms deal both with Master Plans of Drainage (MPD) as well as the Stormwater Information Management System.

Global Database Structure. The assemblage of the several individual input and output files created by the several automated analysis tools. Several pointer arrays coordinate these files into a linked database structure.

Analysis Tool. A program utilized in a particular step in the sequence of operations used for developing a MPD. An example is a hydraulics analysis program.

Primary Element. As applied to a link, a primary element is the principal flow path element of the subject link. Examples are pipes, boxes, or channels. Note that in the AES SIMS, flows are assumed to always drain into the primary element first until its flow capacity is reached.

Secondary Element. Once a primary element is subjected to a flow rate greater than its flow capacity, excess flows are assumed contained in the link's secondary element. A common example of a secondary element is a street section (whether or not it contains a primary flow element).

Regulatory Secondary Element Flow Capacity. In the MPD, regulatory goals define the MPD target flow depths or velocities (or other factors) that are acceptable for secondary flow elements. Primary elements are then planned and sizes estimated in order to meet the regulatory goals. Examples include the goals of specific street storm flow maximum depths such as, perhaps, top-of-curb street flows for a ten-year design storm and a back-of-walk limitation on street flow for a twenty-five year design storm.

Deficiency Analysis. The budget-keeping of primary element flow capacity plus regulatory secondary element flow capacity versus runoff demand.

Master Plan of Drainage (MPD). The MPD is a **plan. It is not a final design product.** An MPD is a target of planned improvements that are contemplated to be used in a future condition of urbanization. Consequently, the SIMS presented in this book contains numerous simplifying assumptions that make a MPD possible without the detailed calculations needed for a proper design analysis.

User-Specified Element. A user-specified element includes pipes, boxes, channels, or other flow elements that are fully specified by the program user. These elements include old systems, soon-to-be installed systems, or "what if" systems. All user-specified system elements are evaluated in the AES SIMS for deficiency with respect to the regulatory secondary element flow requirements.

MPD Elements. MPD elements are planned elements, and therefore are contemplated for possible future use. The user may select an MPD element type (pipe, box, channel, or template), and dictate all but one dimension of a MPD element, leaving one dimension as a planning variable to be estimated in the SIMS. However, the user can also "recommend" a MPD element by dictating all dimensions. Although this "user-recommended" element is still a planning MPD element, it will remain constrained to the user's specifications unless the user disengages the specifications or change their values.

Other terms are utilized in this book, but are defined in the text that introduces these terms. Additionally, the book's references contain other sources of information that the reader may find useful.

1.5 Steps in Developing a Master Plan of Drainage Using A Stormwater Information Management System

A Master Plan of Drainage, or MPD, typically involves several steps of work. Several of these steps are briefly described below:

1. Define study area. Given the city limits or sphere of influence, the total watershed involved is identified. Typically, the study area exceeds the city limits.

2. Develop discretization of study area, (flowpaths, regions, subregions, subareas). The major and minor flowpaths are identified, and the watersheds tributary to each flowpath are identified.

3. Define network topology (e.g., confluences, links) for hydrologic modeling needs. Where and how flowpaths combine (i.e. "confluence") is needed for network definition.

4. Define topography data to be used with respect to HGL estimates. Hydraulic grade lines (HGLs) are developed and need to be related to the local topography.

5. Define existing primary flow system specifications (e.g., pipes, boxes, channels) for every link. This step involves the description of the entire existing flood control system network.

6. Define secondary topographic flow system specifications (e.g. streetflow dimensions) for every link. The definition of streetflow characteristics, as well as all secondary element flow characteristics, is needed.

7. Define secondary system flow-capacity regulations for every return frequency. The governing agency may adopt specific goals of stormflow containment in secondary flow elements (e.g. streetflow).

8. Refine network topology for hydraulic modeling, secondary system, and deficiency analysis needs. The placement of modeling nodes need to address changes in system size, type (e.g., pipe or other element), slopes, or flow rate, among other factors.

9. Refine primary and secondary element specifications for every link (to correspond with step 8). Additional nodes may be necessary based on storm flow quantity estimates.

10. Using topographic slopes (S_t), estimate link regulatory secondary system topographic flow capacities (e.g., street flow). Generally, streets have flow depths that are a small fraction of the link length; therefore, normal depth flow estimates are generally adequate.

11. Develop hydrology model network (e.g., numbering of nodes, links, subareas). Based on the hydrology model specifications and rules, other nodes are added to the model network.

12. Resolve hydrology network model into strings (i.e., non-branched systems). Resolving the hydrology model network into hydraulic model "strings" is done automatically by the AES SIMS.

13. Estimate hydraulic EGL fiction slopes, S_f, for every link, on a string basis. In AES SIMS, two techinques are available: (1) use topographic slopes, adjusted by a "minor loss" factor, or (2) use a balanced HGL technique (see chapter 2).

14. User INTERFACES with S_f estimates, as needed. The user might adjust S_f estimates for safety or other reasons.

15. Develop MPD planning level hydrology estimates, for every return frequency (T) defined, assuming that the ultimate MPD network is in-place (i.e., develop hydrology assuming that all regulatory deficiencies are eliminated by a balanced flood control network).

16. User INTERFACES with runoff estimates as needed.

17. Using S_f estimates, estimate specified primary system flow link capacities using Manning's equation and pressure flow, (closed conduits), or full channel flow plus freeboard.

18. User INTERFACES with specified system flow capacity estimates as needed.

19. Estimate regulatory deficiency flow rates, for every link for every return frequency, and develop target deficiency flow rate for every link.

20. Estimate MPD primary system replacement, (and parallel pipe), elements for each link. These are the "computer estimated" MPD elements. Assume that MPD replacement elements are of similar primary system types, such as pipes for pipes, unless defined otherwise by step 22.

21. Perform “telescoping” analysis of each string piping system. The resulting system links are the “computer recommended” MPD links.

22. User INTERFACES with each link’s MPD primary system type selection and defines dimension variable. If there are changes, rewind to step 20 (this is a feedback step).

23. Inflate computer-recommended values of each link’s MPD primary system dimension variable to a constructable size (e.g., nearest 0.25 foot, or other).

24. User INTERFACES with the computer-recommended MPD primary element specifications as needed. The “adopted” MPD primary element specifications are the computer-recommended values, for each link, unless defined otherwise at this user interface. The user-recommended values for the MPD primary elements are constraints in the MPD, and will not vary unless disengaged or redefined. In order to keep these subject links a variable in the MPD, and hence, show impacts due to changes in the MPD, this interface is not recommended; a similar argument applies to the user interface of step 16. Rather, try to use step 20 if possible.

25. Print out Diagnostics Report to review constraints. Refine all user interface constraints imposed by the user-recommended values of steps 14, 16, 18, 22, and 24. If there are any adjustments, rewind to the earliest user interface adjustment step and again perform the remaining steps through step 25.

26. Develop HGL estimates of MPD primary system by a hydraulic analysis.

27. Review HGL estimates versus topography data. Review link S_f estimates, from the hydraulic analysis, versus S_f estimates of step 14. Adjust S_f estimates of step 14, as needed, until an acceptable calibration is achieved. (NOTE: The S_f estimates of step 14 also need to include the effects of minor losses, and should typically be smaller in value than the S_f values from the hydraulics analysis). Rewind to step 14 to make adjustments and again perform the remaining steps through step 27 until a reasonable calibration of the S_f values is achieved.

1.6 SIMS Logic Notes

In the AES SIMS for Master Plans of Drainage, a set of fundamental assumptions are used to establish the underpinnings of the SIMS. These assumptions regarding operations include the following:

1. The MPD Creation mode creates a MPD system of primary flow elements (“primary elements”). The calibration and decisions made during the creation process should not be changed in the Maintenance mode. Secondary flow elements (“secondary elements”) such as streets, channel overflow flow paths, and so forth, should not change in the Maintenance mode. Therefore, decisions regarding the MPD criteria typically should only occur in the Creation mode.

2. The only difference between a user-specified primary element (“specified elements”) that is “existing,” or “new,” is the date of installation. The date of installation affects the financial accounting status of that element and the Capital Improvement Program.

3. In the Maintenance mode, the Edit function only allows changes to MPD link and subarea parameters, not network topology. Therefore, a specified element should not be deleted from the network topology; only its parameters should be changed (e.g., friction factor, geometry, and so forth).

4. All specified elements, whether existing or new, should be evaluated for deficiency, and corresponding mitigation needs must be estimated in order to meet the MPD criteria. The decision to include an estimated deficiency measure in the financial analysis is a decision based on several factors including, but by no means limited to, the accuracy of the developed MPD SIMS.

5. The SIMS estimates MPD mitigation elements, on a link by link basis, using given primary element types with a specified free dimension variable.

6. In the SIMS, there are several decision sets that have a high correlation to known data. For example, deficiencies in a pipe link are usually mitigated by installing another pipe link, and so forth. The SIMS uses such correlations to simplify MPD specifications input; the various User-Interface modules enable the SIMS user to review and approve such SIMS correlations or to change such decisions appropriately.

7. In MPD hydrology, flow quantities are based upon the prescribed parameters, and it is assumed that all tributary runoff quantities are delivered to each respective point of concentration according to the MPD network.

8. Changing subarea attributes may change the MPD hydrology, and hence the MPD primary system network. Changing MPD network link attributes does not change the MPD hydrology, but may change the deficiency estimates, and may impact the network due to hydraulics and telescoping.

9. The MPD is a **Planning Solution** to a set of constraints; it does not represent a given response to an existing network, but an appropriate response for the contemplated conditions leading to the MPD. It is only a planning tool; it is generally not defined sufficiently with data to be a design tool.

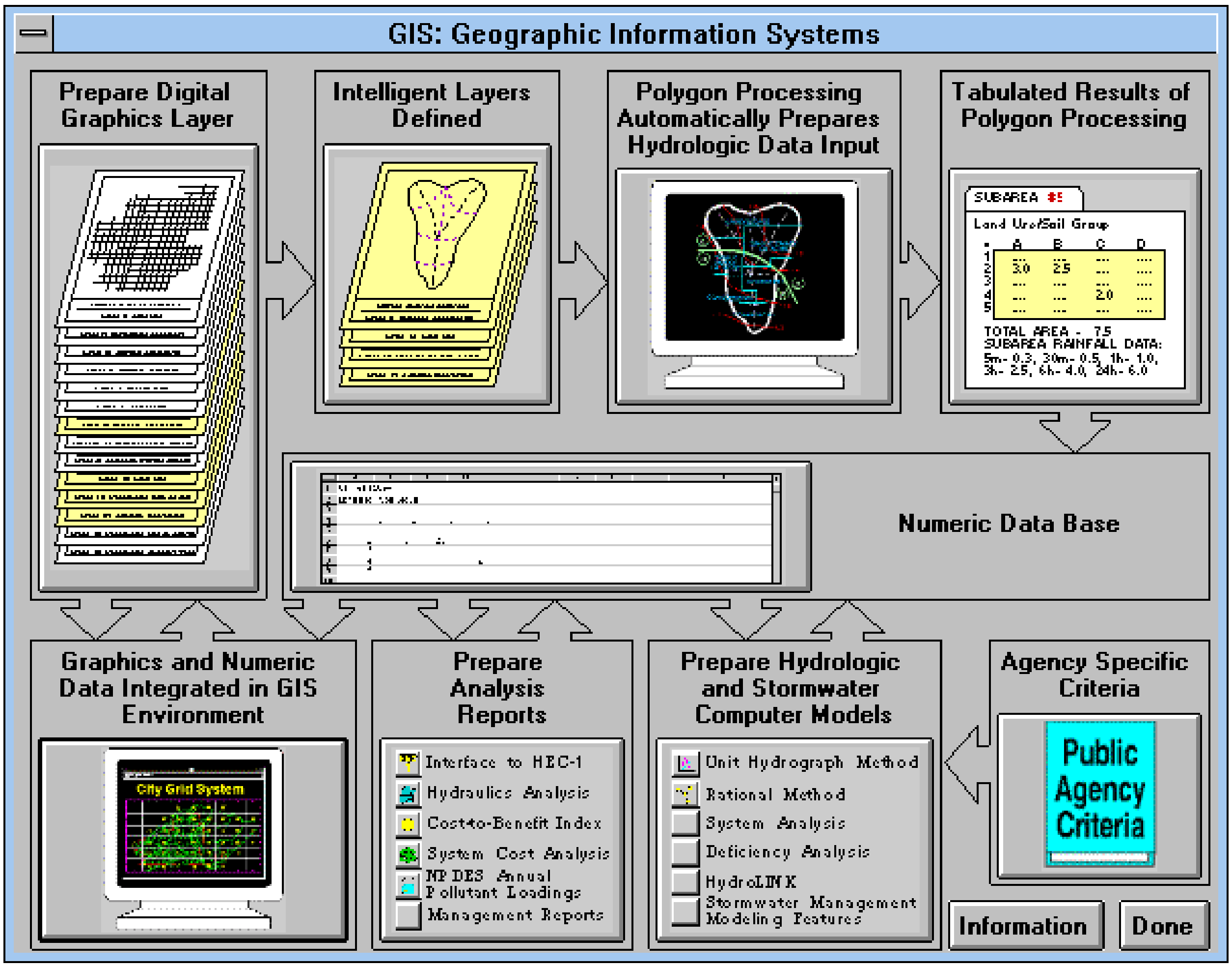
10. The SIMS will evaluate a newly specified network link attribute set for deficiency, (i.e., a new flood control system). Generally, its hypothesized deficiency, if any, will have a very low prioritization and CBI value, and typically may be deleted from the financial planning aspect of the SIMS.

11. In the Maintenance mode, network topology should not be changed as it makes the database inconsistent with the GIS graphic layers. Because the MPD already contains links to model each flowpath, only the link attributes need to change in order to reflect system evolution.

Chapter 2
A Stormwater Information Management System

2.1 Primary Operation Paths

As discussed in Chapter 1, a Stormwater information Management System (SIMS), can be developed for Master Plans of Drainage, (MPDs), which provides a variety of analysis tool sets and linkages. Figure 2.1 summarizes some of these linkages.



AES/GIS Interface Management Screen.

Figure 2.1

The SIMS has two primary logic paths (see Figure 2.2):

1. *Creation Mode* -- where the MPD is developed from scratch, with or without GIS information.

2. *Maintenance Mode* -- where the MPD has been developed via the Creation Mode, and can be updated and revised by using quick run procedures or a subset of the Creation Mode operations.

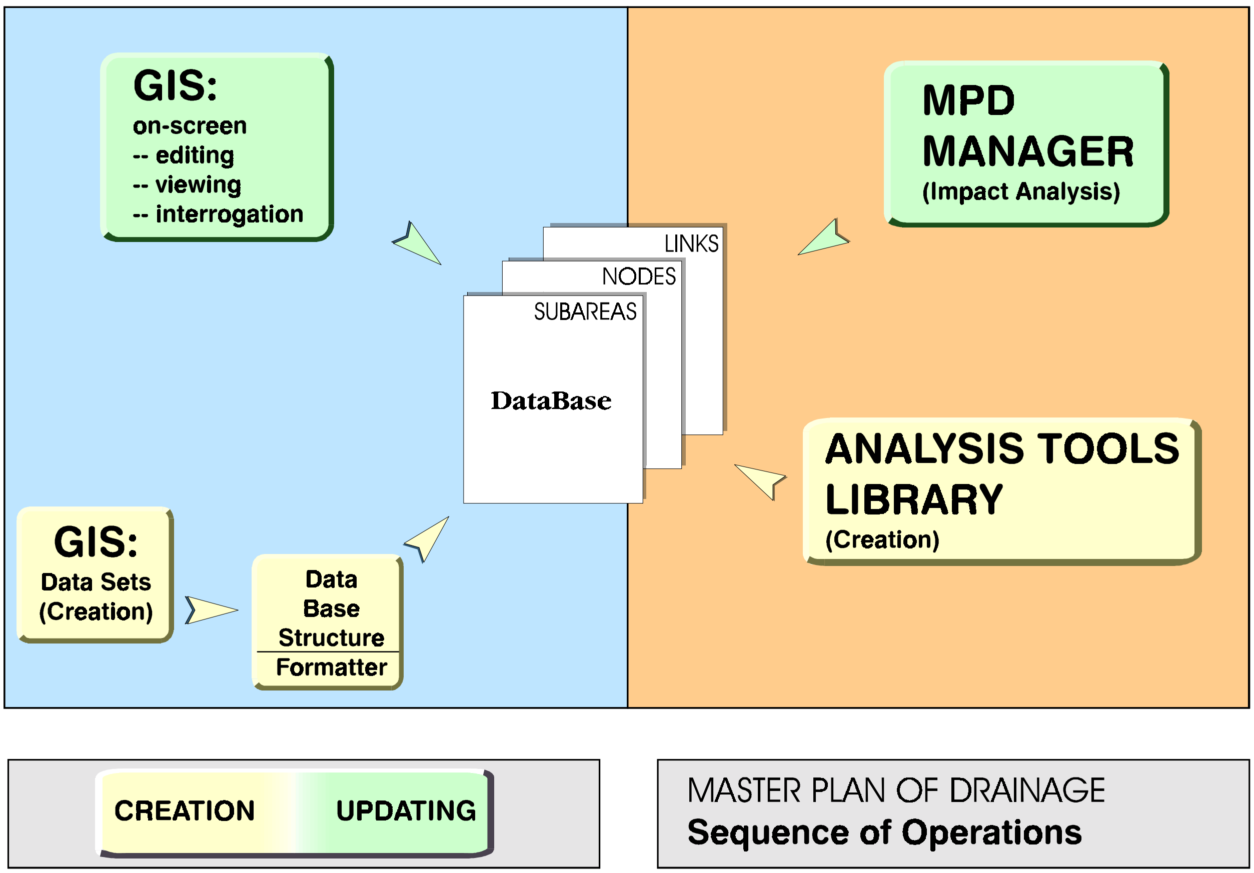


Figure 2.2

2.2 Databases

Three Databases are defined for this SIMS:

1. *Subareas* -- containing hydrologic data such as land use, precipitation, and SCS soil group designation.

2. *Nodes* -- containing topographic elevation data, system elevation data at nodal locations, hydrologic results, and other information.

3. *Links* -- containing hydraulic data such as length, flow conveyance properties and computed estimates, and other information.

Specifications for these three databases are contained in Appendix A.

A GIS can be used to develop parameter estimates for subarea hydrologic data link hydraulic parameters, and nodal elevation data. These data typically need to be computed by the GIS, usually by a polygon processor, (see Section 2.5), and then communicated to the SIMS by use of another but smaller subset of the three databases for *subareas, nodes and links*. In this way, memory allocation is reduced. Using a communications file formatter, files can be created that contain the GIS polygon processor results, which are then read by the SIMS and inserted appropriately into the Global Database structure.

The availability of GIS data significantly reduces the Network model, (i.e., the link-node model structure that defines the drainage system topology) input requirements in that the user can enter, for example, simply the subarea ID number rather than entering the tabulation of land-use/soils/precipitation data. The SIMS analysis tools operate on the input data and Network data to create intermediate results which are used, in turn, by other analysis tools. The ensemble of operations provides an “A to Z” analysis sequence which is essentially deterministic, except for a set of control questions, and a set of “User Interface” modules whereby the User can override computer recommended computed results, at various occasions in the global database evolution.

2.3 SIMS Linkages

Figure 2.3 depicts the linkage between the various components used in the SIMS. The upper left of the Figure depicts the availability of several GIS digital layers. Typically, an agency may already have available GIS layers for street right-of-way, street centerlines, street names, parcels, parcel numbers, land use or zoning data, and utility maps. For the MPD SIMS, layers for existing flood control and drainage systems are necessary in order to conduct a deficiency analysis; otherwise, only a MPD for future conditions can be developed. Several layers are useful in developing the MPD by a SIMS.

GIS Database Development

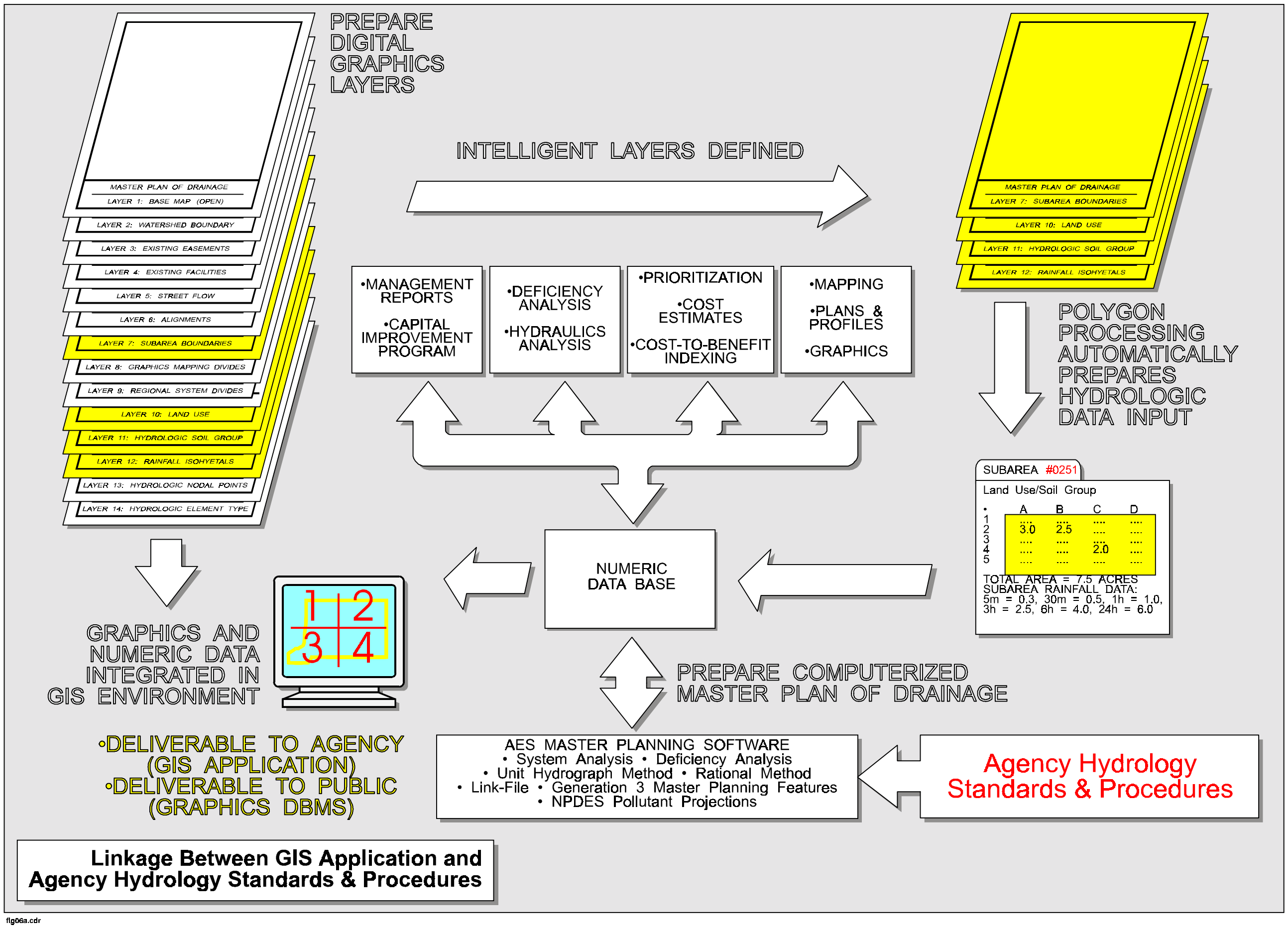


Figure 2.3

- The ***Land Use Layer*** is needed for hydrologic modeling purposes. Oftentimes, a layer is already available from a local agency planning department. Additionally, land use layers for different time periods (e.g., existing, prediction for ten years, prediction for 30 years, etc.) may be used to develop a time sequenced MPD.

- ***Soils Designations*** are needed in order to compute hydrology loss rate values.

- ***Rainfall Data*** are needed to determine runoff quantities.

- A ***Baseline Layer*** is needed in order to provide horizontal control across the set of layers and for navigating through the geographic area.

The above "intelligent" layers are used to intersect hydrologic model subareas in order to compute, via the polygon processor, proportions of soils/rainfall/land-use data for every subarea, (see upper right and middle right of Figure 2.3). These subarea (or other developed data) parameters are stored in the global database structure.

As shown on the bottom of Figure 2.3, the synthesized digital graphics data are then accessed by a succession of analysis models, which store computed results in the global database.

The lower left of Figure 2.3 shows that a subset of the global database (i.e., as selected by the user) is then available for read/display/editing via a GIS display routine.

2.4 Watershed Discretization

Central to any hydrologic method is the discretization of the total watershed or study area into hydrologic modeling subareas. Figure 2.4 demonstrates the method used in this SIMS:

Step 1. Identify the total watershed containing the study area. This includes upstream tributary areas, canyons, and so forth. Label the study area ***watershed*** by a two-letter ID. The watershed should also be represented by a digital layer for later use in developing other layers.

Step 2. Draw the ***major watercourses***, and make another digital layer.

Step 3. Using the major watercourse layer, determine the watershed ***regions***. Make a digital layer for the regions. Note that the regions may coincide with the watershed boundary layer at several locations. Also, there should not be more than 99 regions per study area. Leave room to grow by using no more than about 50 to 60 regions per study area. Regions are typically about 0.5 to over 5 square miles in size, and depend upon modeling complexity.

Step 4. Subdivide each region into subregions or “MAPs,” (i.e., between 1 and 99), as convenient. Again, leave room to grow, and use perhaps no more than about 50 subregions per region. Also, regions and subregions are defined to represent appropriate hydrologic drainage units, consistent with flow paths, and with no flow crossing drainage divides except along watercourses.

Step 5. Subdivide subregions into modeling subareas, of size appropriate for the hydrologic modeling technique used.

Step 6, 7. Hydrologic subareas and nodes are then numbered such as shown in Figure 2.4. CAUTION: The numbering sequence is important! Node numbers typically increase in the downstream direction. This rule is used in the SIMS logic to simplify several analysis steps. Node numbering issues are further discussed in a later section.

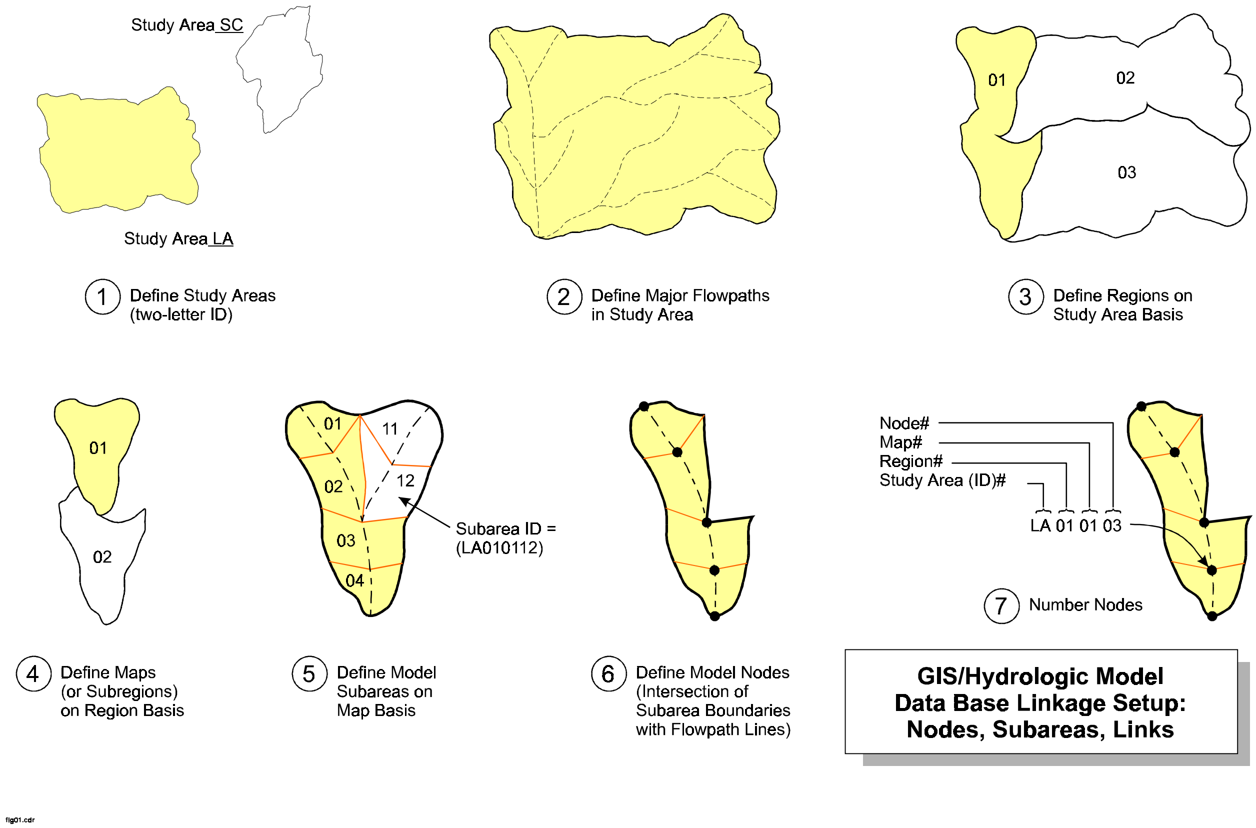


Figure 2.4

2.5 Polygon Processing - Subarea Data

After hydrologic modeling areas are established, a digital layer is made, and each subarea is defined by a unique ID according to Figure 2.4. Now, the parameter proportions attributed to each subarea can be computed by means of the GIS polygon processor. As shown in Figure 2.5, a typical subarea is geometrically intersected with the parameter attribute layers of rainfall, soils, and land use data, resulting in the relative proportions of area tabulated in the attribute file. This attribute file is then stored in the global database, for subsequent use and access by the analysis tools. Other parameters can also be geometrically defined for subareas by developing appropriate attribute layers; the polygon processor can then resolve the area proportions of each attribute value, for each subarea.

Hydrologic Layer Development.

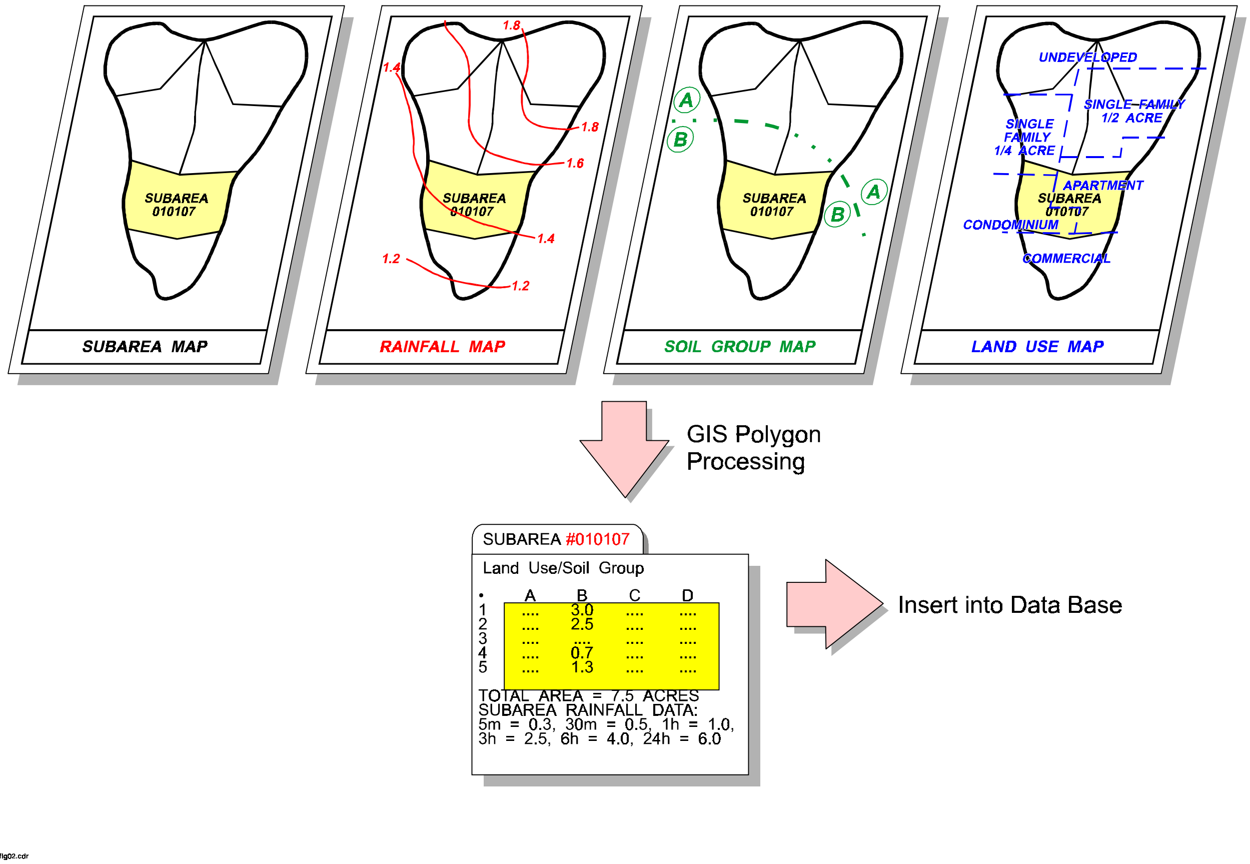


Figure 2.5

2.6 Unit Hydrograph Method Parameters

Many flood control agency hydrology manuals include two techniques for estimating runoff rates; namely, a Rational Method for tributary areas less than about one square mile, and a Unit Hydrograph (UH) Method for larger areas. In this SIMS, the UH technique needs the parameters of tributary catchment rainfall, land use, soils, longest watercourse, time of concentration of longest watercourse, and UH designation, (e.g., valley, foothill, mountain, desert), in order to compute runoff quantities. As depicted in Figure 2.6, these UH method parameters are readily developed by the GIS and Network model topology information. These data are then stored in the global database.

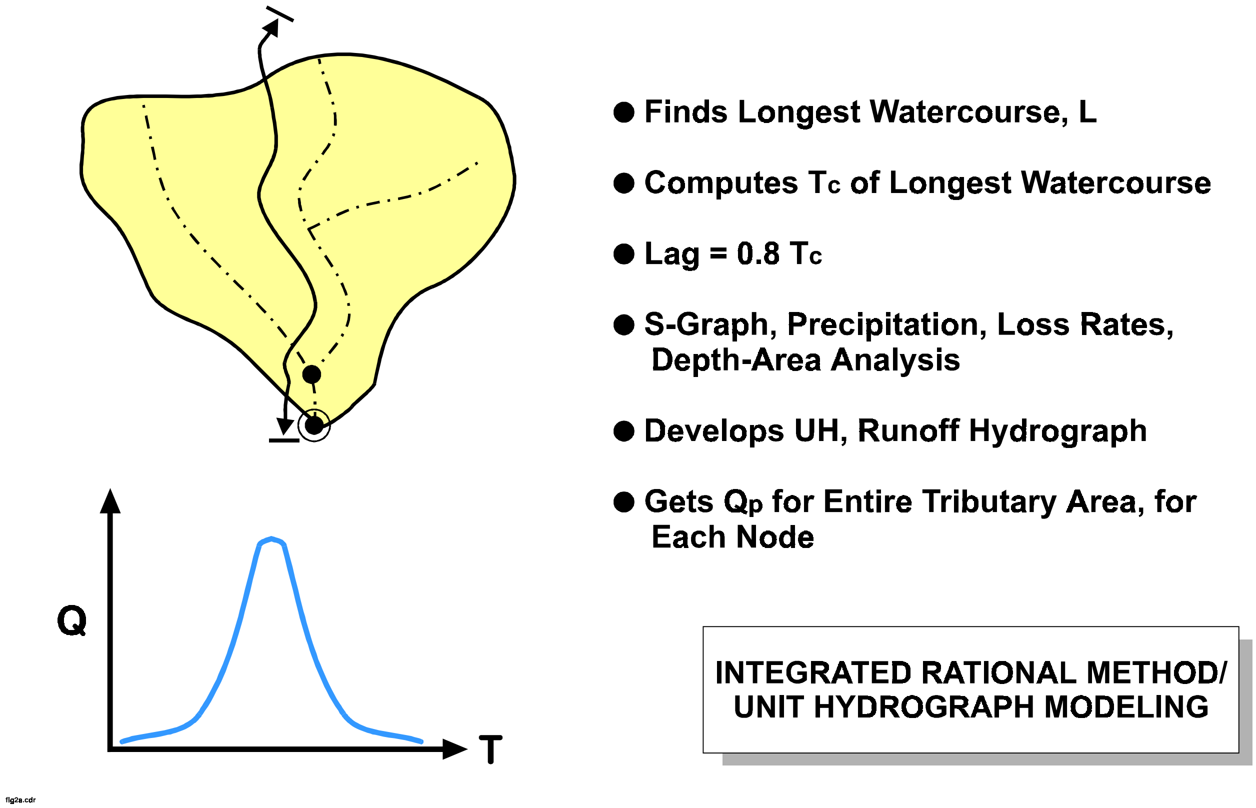


Figure 2.6

2.7 Link Information

A “link” in the model topology is a connection between two “nodes,” where a node is a point of concentration in the study area. A link connects an ***upstream*** node to a ***downstream*** node. Only at a ***confluence*** does more than one link connect to a given node. In this SIMS, proportional branching is undefined (i.e., where flow bifurcates into more than one path in the downstream direction). Thus, by definition, if a node is common to 2 or more links, it is a confluence node. Also, given that nodes are numbered monotonically increasing in a downstream direction, if a link downstream node number is less than its upstream node number, then the downstream node is a confluence point. This logic is used to perform diagnostic checks on the Network model topology.

Attributes of the link are needed in order to perform hydraulic estimates as well as deficiency analysis. Some of these characteristics may be entered via the GIS process, although such attributes are usually defined during the Network model building process.

Figure 2.7 shows a variety of link-node modeling processes that the user typically uses to build the network topology. For the Advanced Engineering Software (AES) SIMS application, specifics and data entry sequences are further discussed in Chapter 3.

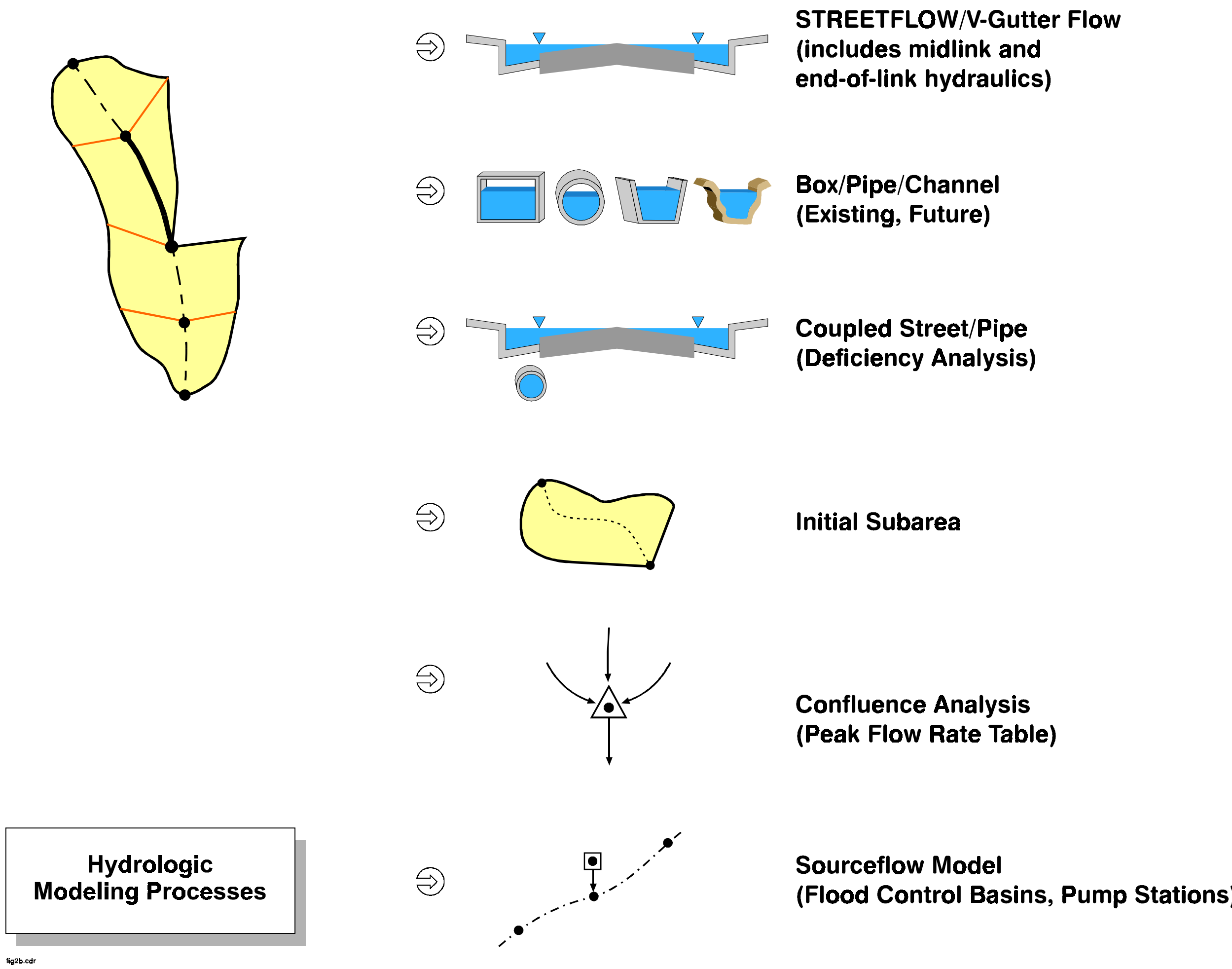


Figure 2.7

2.8 GIS Data Forms - Summary

From Sections 2.3 through 2.7, a variety of subarea/link/node data are typically available to the MPD developer via use of digital graphics data and a GIS polygon processor. Although the step of using a GIS is not mandatory in the SIMS, it typically greatly reduces costs and increases quality control. A review of topics concerning digital graphics is contained in Figure 2.8. Also shown in the figure's lower left corner is the link-node model topology or Network model. The Network is a description of the path-node model assemblage. The GIS process provides the data that is connected by the Network.

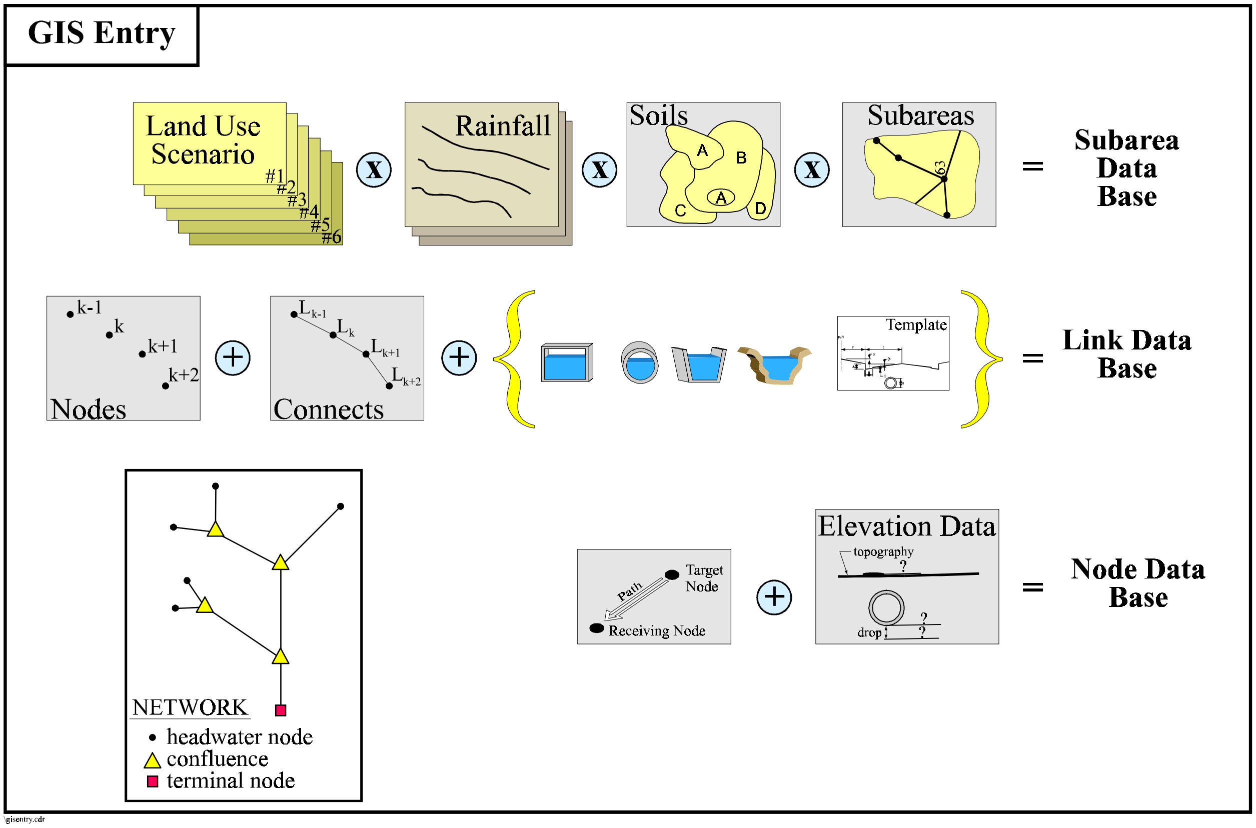


Figure 2.8

From Figure 2.8, the Subarea database is an intersection of a variety of parameters; consequently, additional parameters significantly increase memory allocation. In comparison, nodal and link attributes are generally a definition of values, such as channel type (pipe, box, open channel, natural channel, special template), and hence only increase the dimension of the memory allocation. These two concepts are depicted in Figure 2.8 by the multiplication and addition symbols, respectively, placed between the attribute types.

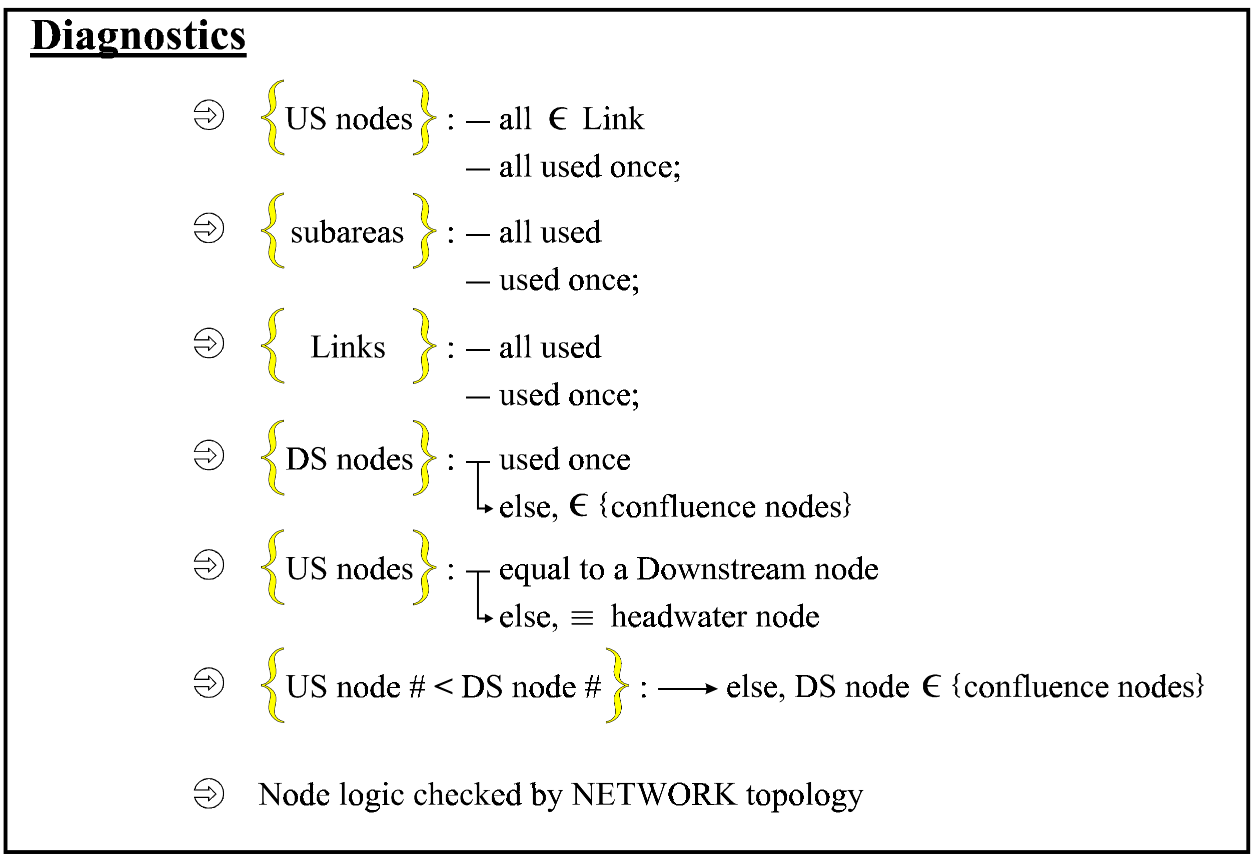
The Network model data, in contrast, is typically developed during the hydrologic model setup phase of the project, and is a data form assemblage that is typically handled separately from the GIS data forms.

Note that most of the previous discussion has been focused towards GIS layer development, polygon processing, and use of the resulting synthesized data in the development of the hydrologic Network model. The Network model is the underpinnings of the MPD. The GIS provides a procedure to synthesize Network model parameter values that typically provides a considerable cost savings over direct user entry of these parameter values in the Network model. Either way, using data access though GIS or by direct user entry, it is the Network model that is used in a SIMS for MPD development. Details of the Network model development, based upon the AES program series, is contained in Chapter 3. Chapter 4 focuses upon the SIMS and its use of hydrologic modeling results to initiate a series of sequential analysis steps that culminate in the MPD (i.e., the “Post-Processor”). The remainder of Chapter 2 will focus upon other MPD topics that are decision-based and significantly influence the MPD conclusions.

2.9 Getting Ready for Network Model Development - GIS Data Diagnostics

Once the data forms have been synthesized by the GIS from the digital graphics layers, and stored into the global database of the SIMS, the next step is to develop the hydrologic link-node model network, or network model.

Prior to beginning development of the Network model it is useful to evaluate the integrity of the GIS supplied information; that is, a diagnostics of the data is appropriate. Figure 2.9 shows several of the diagnostic tests conducted by the AES SIMS for MPDs.



\diagnos.cdr

Figure 2.9

In the first diagnostic test, all Upstream (US) nodes are checked to be an element of a link, and that all US nodes are used, and used only once, in the Network model. In Figure 2.9, the futuristic “E” symbol means, “is an element of.”

The second diagnostic test is to verify that all subareas are used, and used only once, in the Network.

The third diagnostic checks if all links are used, and used only once, in the Network.

The fourth diagnostic verifies that all Downstream (DS) nodes are used in the Network, and, if a node is used more than once it must be a confluence point.

The fifth diagnostic verifies that each US node is also a DS node of the upstream link (i.e., a connection); otherwise, it must be a headwater node (i.e., a node defined at the most upstream point of a flowpath).

The sixth diagnostic checks whether the US node number of a link is smaller than the DS node number of that link; otherwise, that DS node is probably a confluence point, and matched to the confluence nodes identified in diagnostic test four.

The seventh diagnostic test shown in Figure 2.9 is a comparison, of the Network model topology, to the topology deduced from the logic of the nodal point numbering.

Other diagnostic tests are performed in the AES SIMS, and results are included in the Diagnostics report. Appendix B includes a typical Diagnostics report from the AES SIMS.

2.10 Multiple Return Frequency Hydrology Model Results

A MPD typically has multiple design storm return frequency, (e.g., 10-year, 25-year, 100-year, etc.) criteria for flood control system planning guidelines. Generally, streetflow regulatory criteria is mandated such that, for example, (see Figure 2.10):

REGULATORY FLOOD PROTECTION GOALS AND EXISTING CAPACITY

Existing Regulatory Flood Control Capacity

Storm Frequency	Street Flow	Pipe Flow	TOTAL
T1 (10)	12	25	37
T2 (25)	18	$\boxed{26}$	44
T3 (50)	30	25	55
T4 (100)	60	18	78

flood.cdr

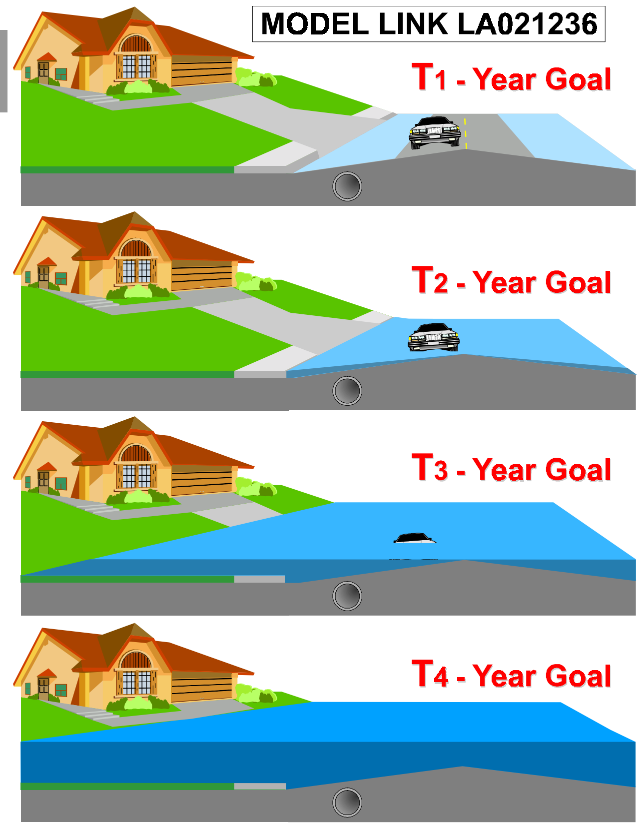


Figure 2.10

(i) one lane is open, in each direction, for a 10-year design storm;

(ii) flow cannot exceed top of curb for a 25-year storm;

(iii) flow cannot exceed 0.20 feet above top of curb for a 50-year event;

(iv) flow cannot exceed 0.50 feet above top of curb for a 100-year event.

For a typical street section and model reach length, the flow depths at issue are typically 1-foot or less, whereas the reach length (i.e., the link length) is well over several hundred feet. Thus, the hydraulics of this reach may be modeled as normal depth flow using Manning's equation,

$$Q = 1.486AR^{0.67}S^{0.50}/n \tag{1}$$

where Q is the flow capacity estimate; A is the cross section of street flow; R is the hydraulic radius; S is the street slope; and n is the friction factor.

Based on the given regulatory criteria, Q estimates for streetflow can be readily estimated and tabulated such as shown in Figure 2.10. Note that due to streetflow modeling being hydraulically "long", these normal depth flow estimates are usually accomplished independent of a hydrology analysis.

Similarly, the pipe shown in Figure 2.10 has a full flow capacity that can be estimated and tabulated (existing system capacity estimation is further discussed in a later section) as the pipe flow. The sum of street flow and pipe flow gives the existing system regulatory flow capacity estimate.

From Figure 2.10, the existing system regulatory flow capacity estimate, for the particular link, is 78 cfs and 44 cfs for the 100-year and 25-year design events, respectively. The difference in capacity estimates is, in this example, due to different regulatory rules regarding street flow depths. The estimates are subsequently used in comparison to the corresponding MPD peak flow runoff estimates in order to test whether the existing system meets regulatory street flow depth requirements.

2.11 Multiple Return Frequency Deficiency Analysis

Figure 2.11 carries through a tabulation of hydrologic peak flow runoff estimates, existing pipe system flow capacity estimates, regulatory street flow capacity estimates, deficiency estimates, and estimation of mitigation for the deficiencies.

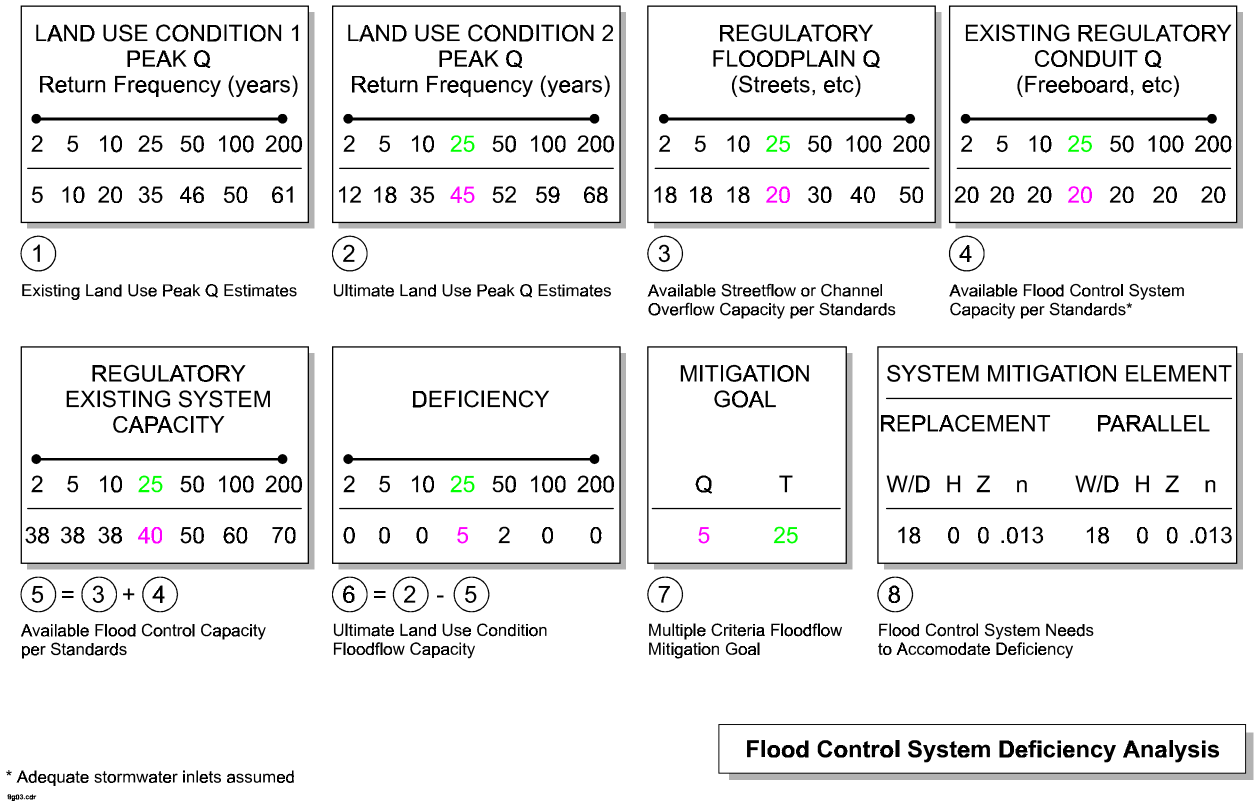


Figure 2.11

In Step 1 of Figure 2.11, existing condition peak flow estimates are shown for 2-year through 200-year return frequency design storms. These flow values are generated by the hydrologic model, but are stored appropriately in the global database so that these values are used in the deficiency analysis. The AES SIMS is set up in anticipation of up to six land use scenarios, and six return frequency peak flow estimates per land use scenario. Separate global databases (literally, separate MPDs) are constructed for each land use scenario. Usually, only one land use scenario is considered in an MPD, such as some ultimate land use target scenario. However, sometimes it is important to consider intermediate land use scenarios, such as at 10-year intervals, in order to better prioritize MPD elements according to anticipated build out versus time projections rather than some future 50-year build out land use scenario. In other words, it may not be appropriate to invest in a flood control system placed in a natural setting when there is no one to protect at that vicinity.

Steps 3 and 4 tabulate the regulatory streetflow and existing pipe flow capacity estimates, respectively. Step 5 is the sum of the computed results from Steps 3 and 4, and provides a tabulation of available regulatory flood protection versus return frequency. Step 6 provides the deficiency of Step 5 in meeting the demands of the ultimate land use scenario runoff estimates of Step 2. Note that deficiencies are values greater than or equal to zero. Step 7 is the mitigation goal. From Step 7, it is seen that an additional 5 cfs flow capacity is needed in order to meet all of the several regulatory rules regarding streetflow depth versus return frequency. The mitigation of a replacement or parallel pipe element is tabulated in Step 8, given a user-specified minimum pipe size of an 18-inch diameter RCP.

Note that it is probable that curing the estimated 5 cfs deficiency will not be considered as cost effective; these types of cost-to-benefit issues are handled by a cost-to-benefit index (CBI) analysis.

2.12 Existing System Flow Capacity Estimation: Salvage Test

Estimating the existing system flow capacity is a complex problem, and different results are obtained depending upon the decision or rule used to estimate a particular element's flow capacity. For example, considering a particular reach of pipe (box or open channel) described by a set of link specifications, the flow capacity may be the full flow capacity using Manning's equation with the slope set equal to the slope of the pipe. However under pressure conditions, it is the gradient of the hydraulic grade line (HGL) or energy grade line (EGL) that determines the flow rate, which typically is independent of the pipe slope. Indeed, one could have a high HGL that is adverse to the slope of the pipe. Or maybe we should use open channel flow at 0.82 or 0.93 times the pipe diameter (see top of Figure 2.12).

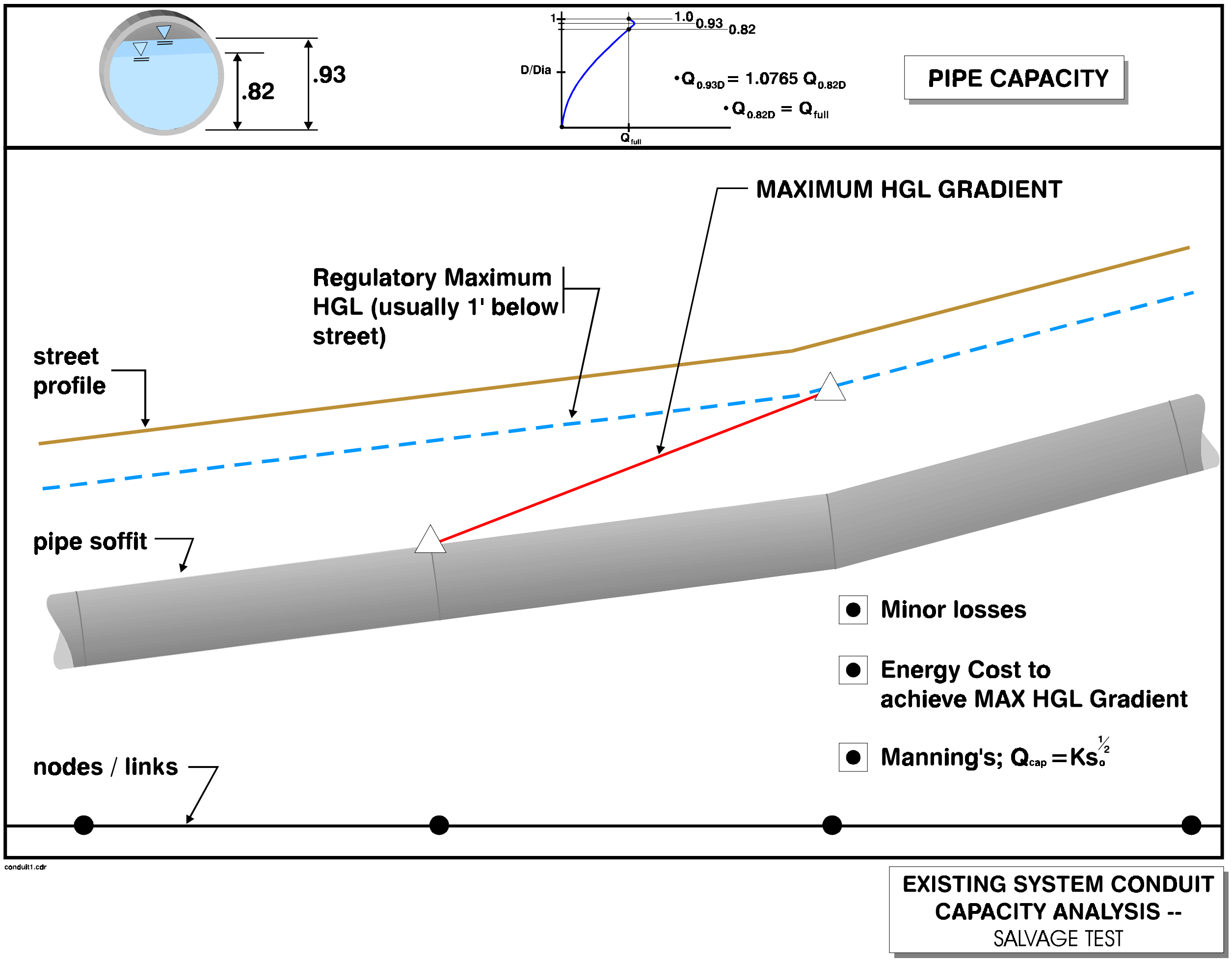


Figure 2.12

If a minimum allowable clearance between the topography and HGL is specified, a maximum HGL can be defined as shown as the dashed line in Figure 2.12. Then the maximum friction slope for the particular link shown is the gradient between the maximum HGL and the pipe soffit. This is called the salvageable friction slope, and gives a reasonable flow estimate of the maximum flow rate capacity; but such a gradient might be focusing the available energy of the entire system towards this one link.

Note that in order to achieve this salvageable friction slope, the rest of the system is constrained to meet other HGL controls.

Although not useful in estimating flow capacities for the entire system, the salvage test is useful as a threshold test to see if an existing system link is a candidate to be retained without mitigation.

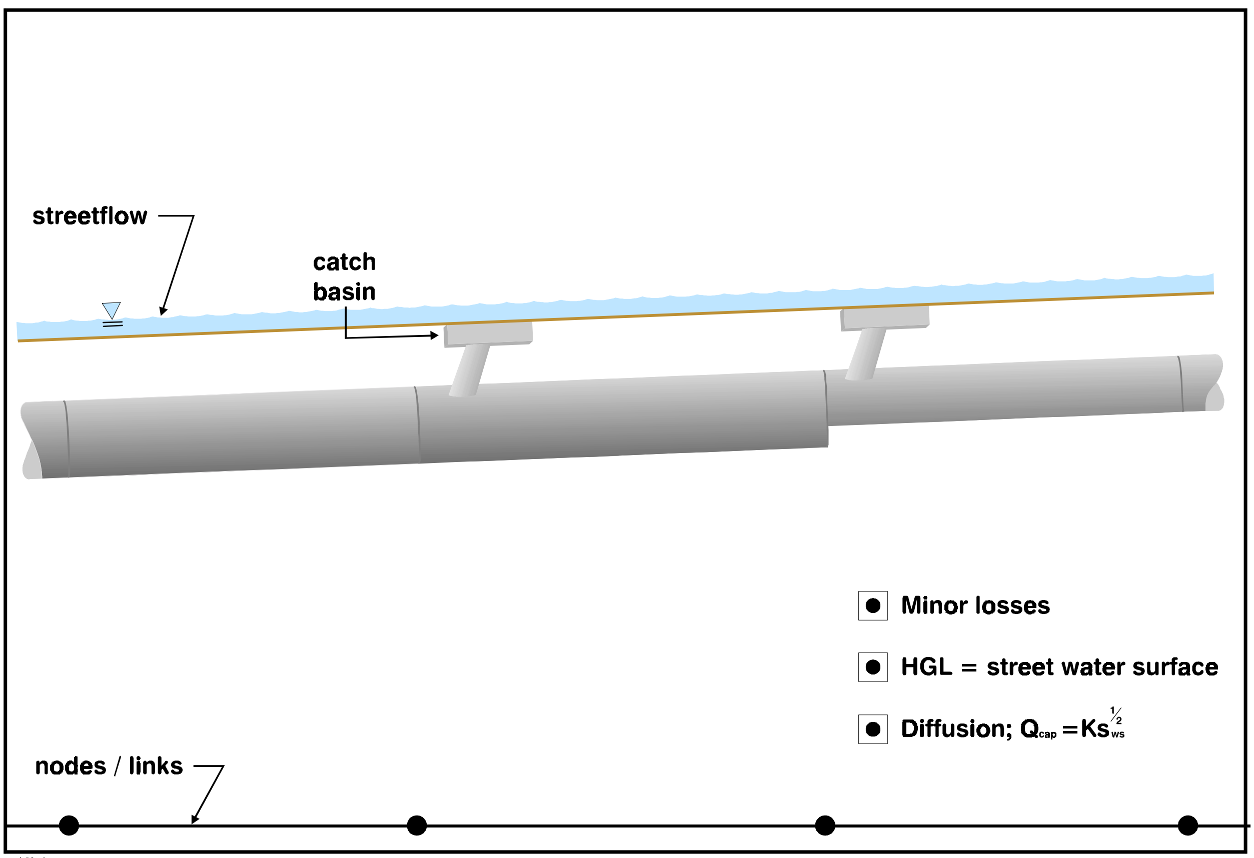
2.13 Existing System Flow Capacity Estimation: Diffusion Analogy

Another technique for estimating flow capacities of an existing system, on a link basis, is to consider the case of the existing system being under pressure (i.e., fully utilized), with significant runoff flows in the street, and with hydraulic contact between the flow in the street to the flow in the pipe; that is, the HGL of the pipe is assumed to coincide with the water surface in the street (see Figure 2.13).

In this case, the water surface in the street has a gradient that is approximately the gradient of the street, and hence the diffusion analogy would be to apply the gradient of the street as an estimate of the friction slope of the pipe. This technique does not need pipe slope data, (because of the pressure flow assumption), but instead relies on the gradient of the topography to estimate friction slopes of systems under pressure.

A disadvantage of the diffusion technique is in cases where topography is a mixture of positive and negative gradients; although one could default to a minimum gradient in cases of adverse topographic gradient, a significant discontinuity in the friction slopes still results which may be problematic.

An advantage of the diffusion analogy is that it may estimate the effects of significant backwater effects caused by severe flooding events. The topographic data needed to perform the diffusion technique is already contained in the global database.



EXISTING SYSTEM CONDUIT CAPACITY ANALYSIS --
FLOOD CONDITION

Figure 2.13

2.14 Existing System Flow Capacity Estimation: HGL Envelopes

Another technique for estimating existing system flow capacities is a decision-based method that constructs HGL envelopes that bound the resulting "balanced" HGL for the system.

The first step of the balanced HGL technique is to evaluate the minimum and maximum allowable clearances between the HGL and topography. These clearances are typically a decision made by the local agency. Figure 2.14 depicts the clearances being applied to a particular storm drain system reach, or "string." Note that a representative topography exists in the global database; therefore, specified clearances must be consistent with the topographic data stored in the global database.

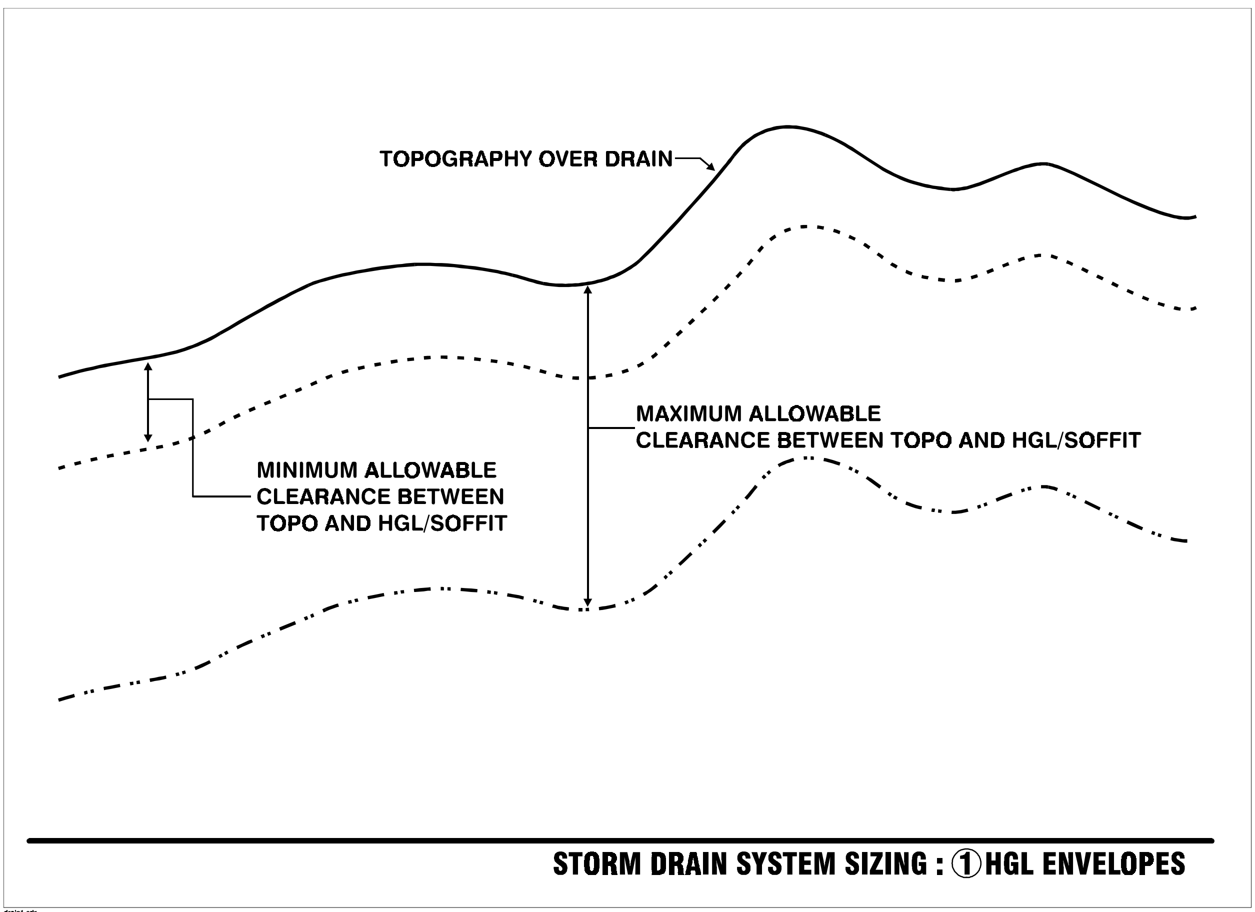


Figure 2.14

2.15 Existing System Flow Capacity Estimation: Minimum Friction Slopes

The second step in the balanced HGL technique is to modify the HGL envelopes of Section 2.14 in order to satisfy user-specified minimum friction slopes. Two decisions are made: minimum slope allowed, and minimum pressure flow velocity (at the peak flow rate). These two decisions transform the envelopes of Section 2.14 to look like the HGL envelopes of Figure 2.15.

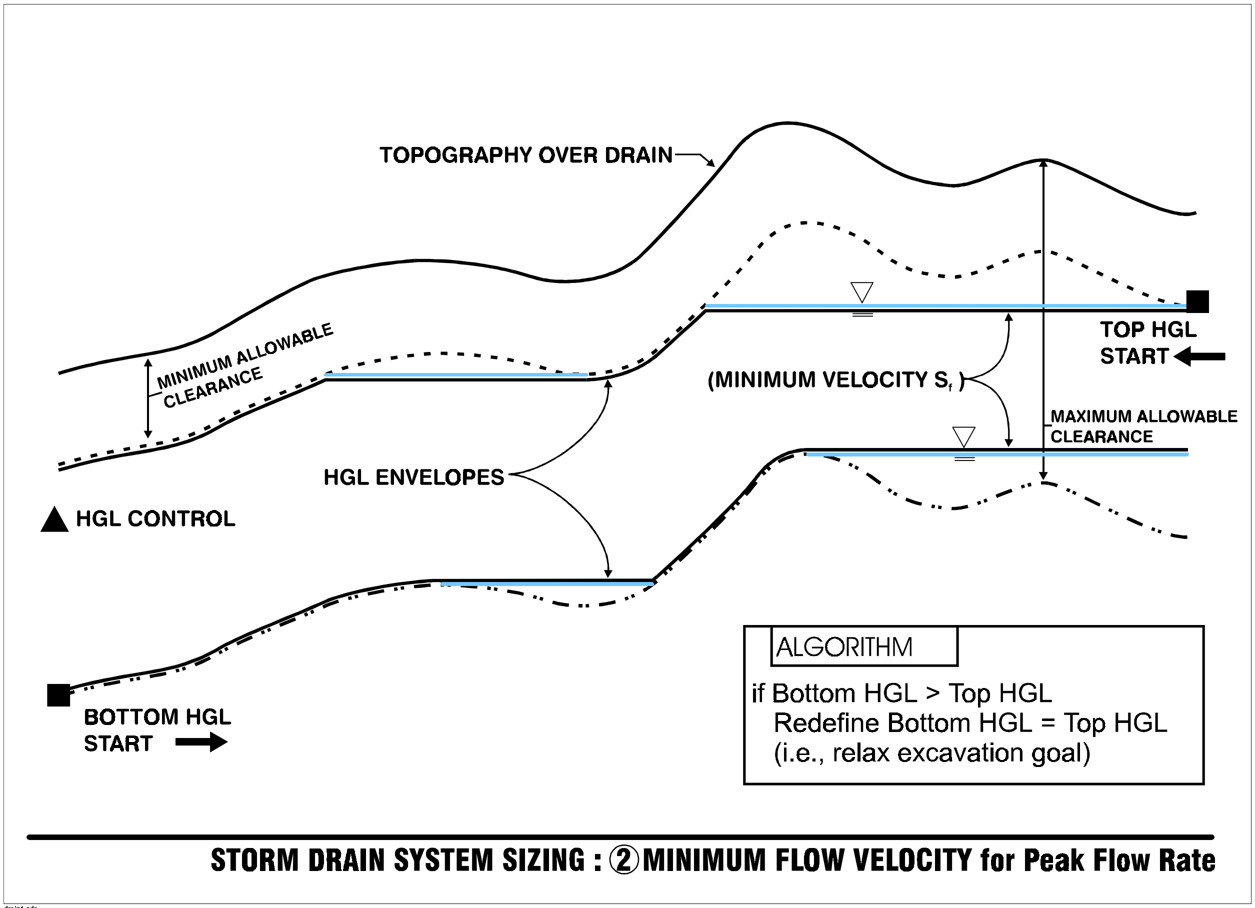


Figure 2.15

Included in Figure 2.15 is the HGL control for the string under study. The balanced HGL is a fit between the downstream control and the string's most upstream point's top HGL envelope. This fitting is discussed in the next section.

2.16 Existing System Flow Capacity Estimation: Balanced HGL

The balanced HGL is a minimum length fit between the downstream HGL control and the upstream end top HGL envelope. It is analogous to stretching a rubber band from the HGL control to the upstream end top HGL envelope, where the rubber band is constrained by the top and bottom HGL envelopes. Several cases are demonstrated in Figure 2.16. The easiest case is a direct connection without interference by either HGL envelope. The other two cases of this figure consider interference by one or both HGL envelopes.

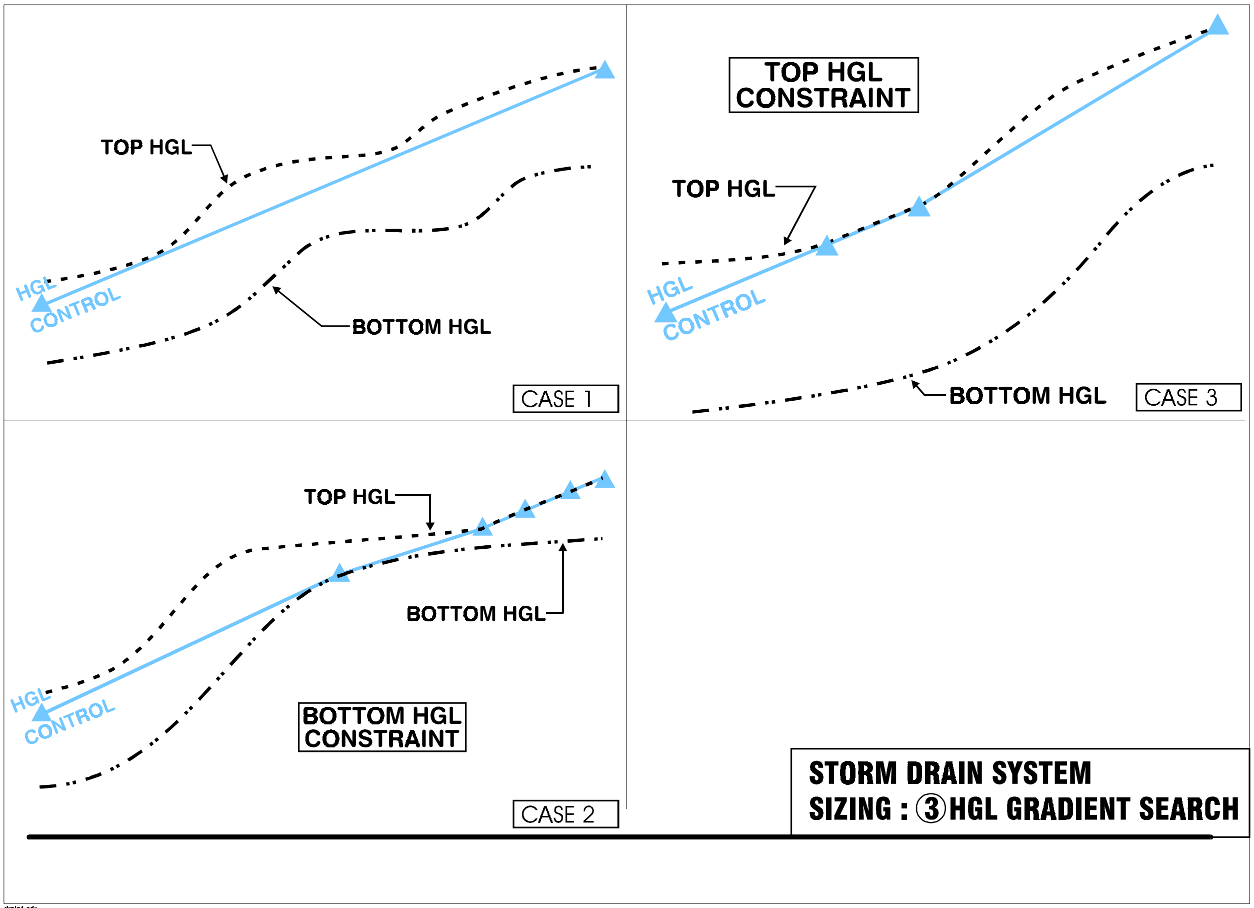


Figure 2.16

After constructing the balanced HGL, friction slope estimates may be computed using the balanced HGL, for each element, for each string.

Note that for strings where the topography is monotonically increasing in gradient in the upstream direction, the balanced HGL and the diffusion analogy typically result in similar estimates for link friction slope.

2.17 Existing System Flow Capacity Estimation

An advantage of the SIMS is that several opinions can be developed regarding a particular aspect of the analysis, and then rules can be applied as to the choice of what opinion to use. Here we have several opinions regarding existing system flow capacity. Given specifications regarding freeboard, or other topics, a tabulation of opinions can be made such as shown in Figure 2.17. Given a rule for choosing a link's flow capacity, the "computer estimated" existing system flow capacity can be developed. For example, one may select to use the maximum of all opinions, or the minimum of all opinions, or use a particular opinion for all estimates. This decision is made by the program user in the selection of program options.

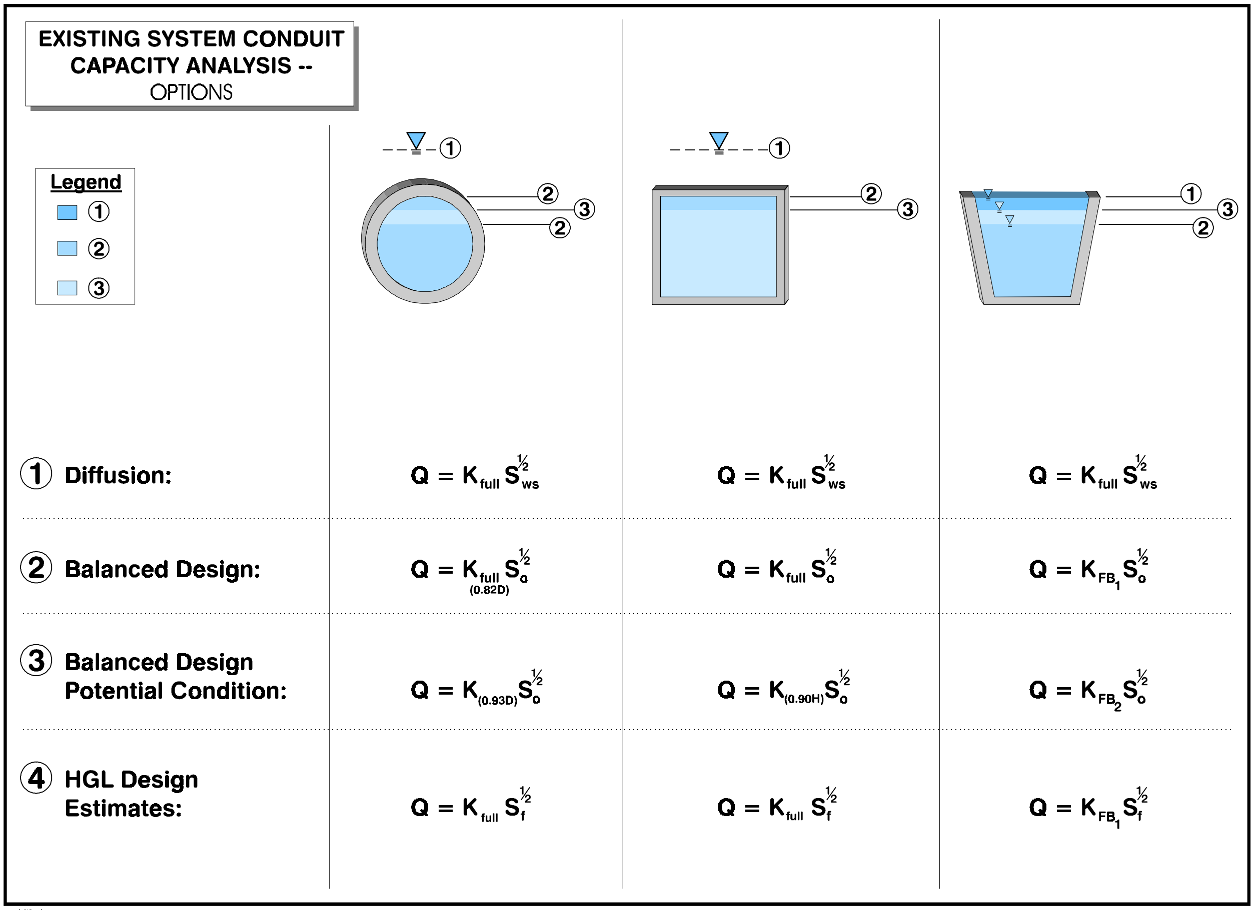


Figure 2.17

2.18 Telescoping Analysis

After the existing flow capacity estimates have been tabulated for all links, and stored in the global database, the deficiency analysis is performed and mitigation replacement and parallel elements are computed such as described in Section 2.11. These computed mitigation element sizes are the "computer estimated" sizes. Another analysis is needed to coordinate these elements, typically known as a "telescoping" analysis.

Rules are now applied to the computer estimated mitigation replacement system elements in order to control changes in pipe sizes (boxes or channels). Figure 2.18 depicts three "filters" typically applied: (i) minimum size constraint, (ii) drop in flow area, and (iii) drop in flow capacity, (i.e., "bubble-up" systems). Each string is filtered with respect to the telescoping rules, resulting in a "computer recommended" replacement mitigation, (or new), system.

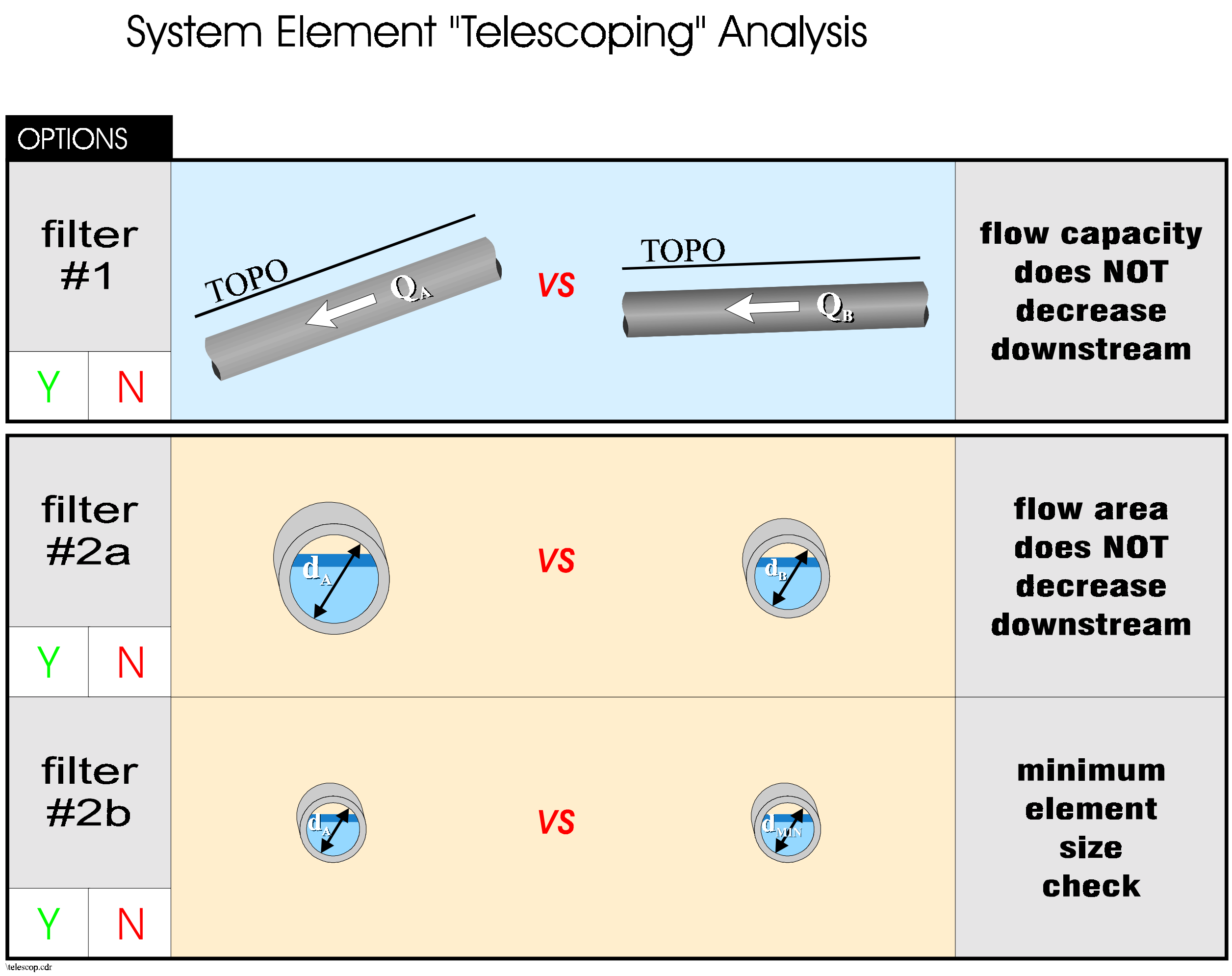


Figure 2.18

At this point of the SIMS, the program user may interface with the global database evolution and specify a "user recommended" system size. This user recommended set of values is used thereafter in the SIMS, without adjustment, until the user either modifies or removes the particular specification. Otherwise, the "computer recommended" set of values is used in the SIMS, and these computer recommended values remain variable depending on the analysis that preceded this particular step. Such "user interfaces" exist at other occurrences in the SIMS.

2.19 Hydraulic Analysis Using a WSPG Based Program

The Los Angeles County Water Surface Pressure Gradient (WSPG) computer program has gained widespread use among private and public engineers. It is a coupled pressure and gradually varied flow analysis model and includes several computational modules (the reader can refer to the LACFCD WSPG documentation manual for details).

In this SIMS, the hydrologic model Network is resolved into strings on a topology level basis. For example, the main trunk line in which a system ultimately drains into, is a “level zero” topology stream. All streams that confluence with a level zero stream are defined as being level one streams. All streams that confluence with a level one stream are “level two” streams, and so forth.

Necessarily, each string either begins downstream with a confluence (i.e., a junction) or begins with the system “terminal point.” There is only one terminal point per system (there may be branches, of level one topology, that confluence with the level zero stream at the terminal point). Also, each string ends upstream with a headwater node. Thus, the number of strings in a system equals the number of headwater nodes.

Given the string data, including peak flow rates, junction structure inflows, and system description data, a hydraulic analysis can be made using WSPG, and the modeled results stored in the global database.

For the system terminal point, the user must define an HGL control. For level 1 and higher topology streams, the HGL controls are computed from the WSPG computer model results for lower level topology streams.

Figure 2.19 shows the hydrology Network model being resolved into strings, their connectivity is shown, and the implementation of the WSPG program is depicted.

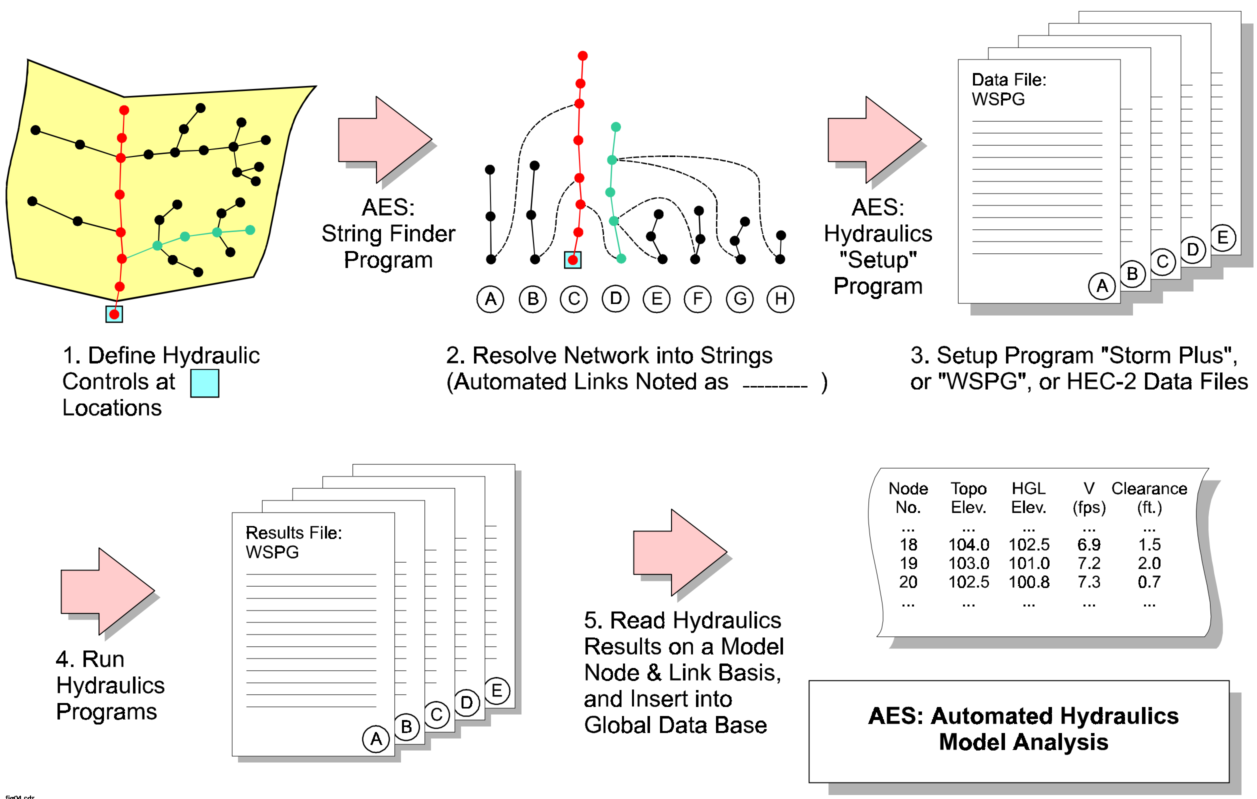


Figure 2.19

The AES SIMS performs all the steps depicted in Figure 2.19 automatically, including WSPG based data file setup, execution of WSPG, and reading of WSPG results for storage in the global database.

It is noted that the detail of the WSPG models are only as sophisticated as the detail of the WSPG input files. The user needs to make any changes necessary in order to insure that the SIMS-developed WSPG input files are of adequate detail for the user's intended purpose.

2.20 Link Templates

In Figure 2.8 is shown, in the Link Database portion, a reduced figure of a Link Template. Link Templates are designed hydraulic modules that contain a set of variables that are functions of the known or computed data values and link peak flow rate. These template modules are developed by the user for access by the SIMS. Such a template is shown in Figure 2.20.

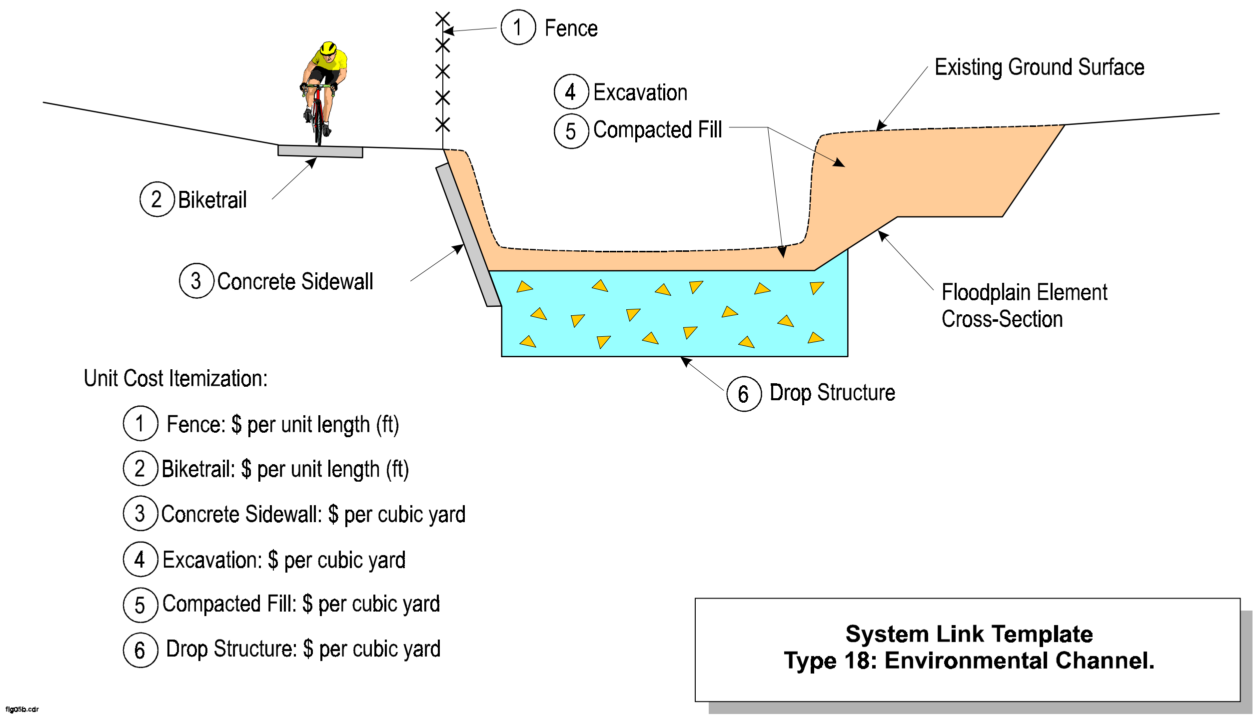


Figure 2.20

2.21 Link Templates: Integration into the SIMS

The templates may be integrated into the SIMS so that other modules may access the template module results. For example, it is useful to link cost estimation modules to each template module for financial planning. Figure 2.21 depicts such a linkage between unit costs and a complicated template.

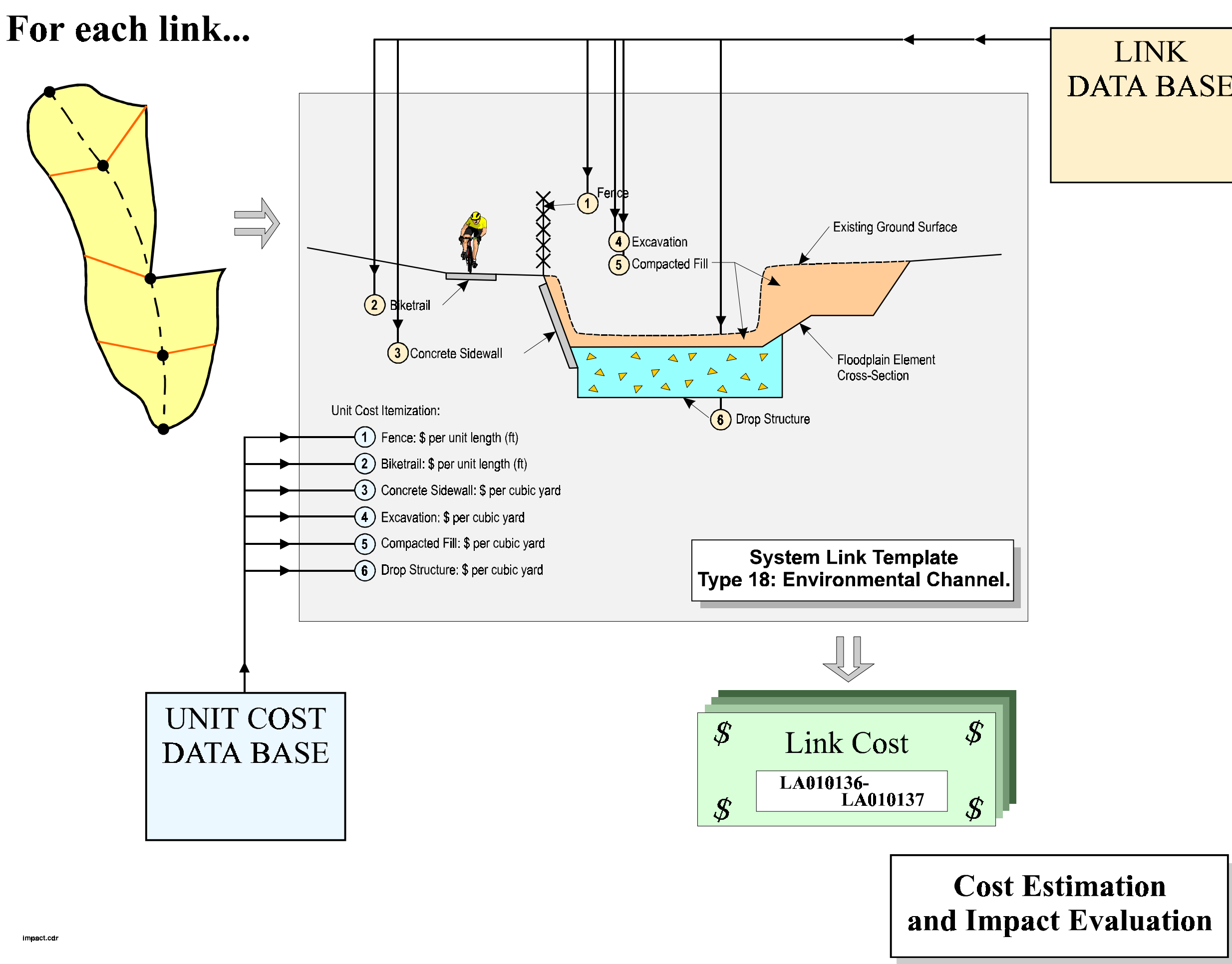


Figure 2.21

2.22 Network Model Node Numbering Convention

Now that an overview of the AES SIMS has been studied, the underpinnings of the data structure, i.e. the node numbering protocol, can be examined.

2.22.1 Locating Nodes

After the entire study area is discretized into regions, subregions (or Maps), and subareas, node numbering is then initiated by first overlaying the subarea layer over the flowpath layer. The intersection of subarea boundaries with flowpaths locates nodal points that are needed for hydrologic modeling purposes.

Additional Network model nodes are needed for hydraulic modeling purposes. Nodes usually are appropriate whenever there exists a change in system element:

(1) size (e.g., pipe diameter)
(2) type (e.g., pipe to box)
(3) shape (e.g., rectangular to trapezoidal channel)
(4) slope (e.g., mild gradient to steep)
(5) other significant hydraulic effects, depending on complexity detail desired.

After identifying the nodes deemed necessary to properly model the hydraulic effects, (to the level of detail assumed for the study purposes), it is useful to then overlay the hydrologic nodes defined previously. Typically, nodes should already have been located at confluences of system strings, or at catch basin or inlet clusters.

It is then useful, (but not necessary), to shift hydrologic node locations slightly to also fit hydraulic node locations in order to not proliferate the number of nodes. This massaging of nodal point locations may cause a redefinition of affected subarea boundaries.

2.22.2 Numbering Nodes

In the AES SIMS for MPDs, nodes are numbered, in increasing magnitude, in the downstream direction.

Generally, all the level zero topology strings are numbered first. Then, level 1 topology strings are numbered, followed by level 2, and so forth.

In this fashion, all nodes are smaller in value than a downstream node, except possibly at a confluence point.

It is useful to number all headwater nodes (i.e., the most upstream node of a string), to end with the digit zero. Note that the number of confluence nodes plus terminal nodes, (i.e., the most downstream node of a system), is typically less than the number of headwater nodes. Also, every string begins with a headwater node, and ends with either a confluence node or a terminal node. These facts are used in the AES Diagnostics program module to investigate the properties of the model Network, and in the AES String-Finder module to determine the network topology.

2.22.3 Node Number Sequence Interval

It is useful to number nodes along the string in anticipation of future nodal point additions. For example, numbering nodes by two's, (i.e., 0, 2, 4, 6, etc.), allows for future network model growth. Numbering nodes by three's provides for even more densification in the future. However, recall that there is a numerical limit to the number of nodes on a subregion or region basis (see Figure 2.4).

2.22.4 Confluences

At a confluence node, there will be two to five tributary branches, one branch being the “main” line. Consequently, there will be from two to five Network model links with a common downstream node number, but with differing upstream node numbers. And, for these branches, there may be some links that have the property that the upstream node number is greater than the downstream node number (i.e., the confluence node number). This fact is used in the AES String-Finder module to resolve the model Network into Strings and topology levels.

2.22.5 Subarea Numbers

It is useful to number a subarea according to the node number that the subject subarea is tributary to. At a confluence node, assemble all local subareas tributary to the confluence node, into one subarea; otherwise, link the subarea to the branch line downstream node before confluencing the branch with the confluence point.

2.23 The AES SIMS

This Chapter 2 reviewed many of the key aspects of a Stormwater Information Management System, or SIMS. In Chapters 3 and 4, we will examine, in detail, the input and decision requirements used in the AES SIMS. Actual program screens will be presented along with explanation text from the SIMS Help Files, to define input variables and decision points.

Chapter 3
RATSCx: The Rational Method

3.1 About This Chapter

Chapter 3 presents a full exposition of a typical setup for an integrated rational method and unit hydrograph method hydrology model for use in the development of master plans of drainage. Using the commercially available computer program published by Advanced Engineering Software (see website at www.aessoft.com), Chapter 3 takes you page by page through the data input screens for each of the several processes and modules used in the program. Data input help text files are also linked to the data input screens, at each prompt, just as they appear by typing “HELP”.. The hydrology program is the cornerstone of the SIMS assemblage of analysis tools.

3.2 The Integrated Rational Method Program (RATSCx)

```
         //                                                      //
        //                                                      //
       //                                                      //
      //    R A T I O N A L   M E T H O D   A N A L Y S I S   //
     //                                                      //
    //              INTEGRATED RATIONAL METHOD/             //
   //              UNIT HYDROGRAPH METHOD PROGRAM          //
  //                                                      //


         (c) Copyright 1983-1999 Advanced Engineering Software
                       Release date: 01/01/99
                             Ver. 7.0

                             .........
                                 .
                                 .
                                 .......> Press RETURN to continue
```

MAIN MENU

```
       COMPUTER PROGRAM OPTIONS:

          1= CREATE a data file to define initial study

          2= EXECUTE an existing data file

          3= EDIT an existing data file

          4= EXTEND an existing data file to continue study

          5= EXECUTE File Network Management Module

               Select program option desired ===>


________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page  ; HELP for Help
```

```
=========================
"JUST GETTING STARTED..."
=========================
```

INTRODUCTION:

The RATIONAL METHOD MASTER PLANNING program is a computer-aided design program where the user develops a link-node model of the watershed, and in this process estimates the conduit and channel sizes needed to accommodate the design storm peak flowrate. The study methodology is based on the well-known RATIONAL METHOD which estimates the peak flowrate (or Q in cfs) by the relation Q = CIA where Q is the peak flowrate used for design purposes, C is a runoff coefficient and represents the simple ratio of runoff-to-rainfall, and A is the watershed area (acres) tributary to the study point of runoff concentration. For an I=1 inch/hour and an A=1 acre, and a C=1.0, the Q=1.008 cfs. For sufficiently large catchment areas, YOU may elect to compute peak flow rates by a design storm unit hydrograph(UH) method.

Assuming that a uniform rainfall of constant intensity occurs over a watershed, then the peak flowrate will occur when the entire watershed is contributing runoff. This peak Q usually occurs when runoff from the most distant point on the watershed reaches the point of concentration. The time which it takes for the watershed runoff to reach the peak Q (from the beginning of the constant intensity storm) is called the time of concentration and is noted as Tc.

Some of the basic assumptions used in the RATIONAL METHOD are:

(1) the return frequency of the estimated Q is approximately the return frequency of rainfall; that is, to estimate a 25-year return frequency peak flowrate (a Q25), the I values are assumed to be of a 25-year return frequency;

(2) rainfall intensities are assumed to be approximately uniform over the watershed;

(3) the watershed runoff characteristics can be estimated sufficiently to be used in the runoff equation.

(4) for design storm UH estimates, a single area UH model is adequate for peak flow rate estimation purposes.

SETTING UP THE PROBLEM:

In order to develop a link-node model of the study watershed, the following steps are needed prior to beginning the study:

(1) Using a topographic map of the entire watershed, define the watershed boundaries and identify streams and channels to be modeled.

(2) Define the watershed boundary for each major stream or channel. These interior watersheds ("regions") should be self-contained in that they can be modeled independently from the total watershed. Generally, the interior watersheds will merge with another interior watershed at a point of CONFLUENCE.

(3) Subdivide each interior watershed into SUBAREAS. Subarea size should be about 0.02 to 0.04 sq km (or 5 to 10 acres) in the most upstream reaches, and may gradually increase as the study progresses downstream.

(4) Specify the runoff characteristics in each subarea. Basic information includes DEVELOPMENT TYPE such as commercial or agricultural; SCS (U.S. Soil Conservation Service) soil group, which is type A, B, C, or D where A is of low runoff potential (sands) and D is of high runoff potential (such as clay soil).

(5) Develop a runoff coefficient C in each subarea. The computer program allows YOU to specify a maximum loss rate (or Fm) to be used, or use the pre-entered Fm-values which are a function of development type and soil-group.

(6) Define nodal points along the major stream in each interior watershed. The study approach is to start at the most upstream point in an interior watershed and follow the main stream while runoff is accumulating and estimate channel sizes as the study progresses in the downstream direction. A method of node numbering is to use nodes 100.00 to 199.99 along stream #1, 200.00 to 299.99 along stream #2, and so forth, where node 100.00 is assigned to the most upstream point of interior watershed #1.

(7) At a point of CONFLUENCE (where two or more major channels merge), define the nodal numbers to be used downstream of the confluence. Usually, one of the major streams will have significantly more runoff than the other streams. The sequence of node numbers from this largest stream may then be continued downstream.

STUDY APPROACH:

The link-node model is developed by creating independent link-node models of each interior watershed and linking these submodels together at confluence points.

Consider an interior watershed, say #2, which has been subdivided into SUBAREAS and NODE NUMBERS have been defined. Starting at the most upstream subarea (between node #200 and #201), the runoff is estimated by modeling an INITIAL SUBAREA. This model estimates a Q based on the initial Tc, the corresponding I, the subarea area A, and the runoff potential.

The study continues downstream to node #202 by analyzing how long it takes for the initial subarea Q to reach point #202 by either (1) street-flow, (2) pipeflow, (3) channel flow, or (4) v-gutter flow. This TRAVEL TIME, Tt, is then added to the initial subarea Tc to estimate the next time of concentration by Tc(202) = Tc(201) + Tt.

Using Tc(202), the maximum values of I(202), area-averaged Fm:

$$((A(201)*Fm(201) + A(202)*Fm(202)) / (A(201) + A(202)))$$

and effective area are used to compute a new Q(202). The study continues to the next downstream node #203 by estimating a new Tt, and so forth.

COMPUTER INTERACTION:

The Program has been designed to be a Design-Interaction tool. The user-instruction manual is the Program itself. All instructions and program options will be visible to you at the bottom of the screen. Simply type these instructions at any time and the program will respond. For example, type MAIN and you will return to the main menu of program options. Type EXIT and the program will store the data files and finish the session. Type HELP and specific information will be displayed to YOU.

COMPUTER DESIGN-INTERACTION:

Because the analysis proceeds downstream along the main channel, design decisions can be made interactively. As the study progresses between two stream nodal points, the computer results are displayed showing peak flow information and channel flow data (such as depth and velocity). You will be requested to either ACCEPT the study results (in which case the subarea data are stored) or REJECT the results (in which case the program returns to the previous upstream point of concentration). By ACCEPTING or REJECTING the modeling results, YOU interact with and control the Program, tailoring the results to YOUR specifications.

The program has four OPERATING MODES:

(1) CREATION: This mode is used to create a watershed data file containing all the subarea data entries and hydrologic data. Two data banks are used:

  (i) HYDROLOGY CONTROL DATA. Includes the rainfall versus duration data (assumed to be tabular, or a straight line on log-log paper), C-value options, return frequency, a pipeflow friction slope reduction factor, among other options.

  (ii) SUBAREA DATA. A link-node model is made by defining successive subarea characteristics linked together by various flow hydraulic processes.

(2) EXECUTION. This mode is used to generate study results in report form. Four options are available:

  (i) DETAILED REPORT. This provides the same results as displayed on the viewer's screen during CREATION.

  (ii) SUMMARY REPORT. This summarizes the results into a tabular form.

(iii) SCHEMATIC REPORT. This depicts the watershed model in a schematic(block diagram flow chart) form. A "short" and "long" form schematic diagram are available.

(iv) FACILITY/COST ESTIMATE REPORT. This summarizes the dimensions and length of the storm drain facility and calculates a total cost opinion according to YOUR defined unit costs.

(3) EDITING. This mode allows YOU to change, add, or delete subarea data and modify the link-node model. Additionally, YOU can change the HYDROLOGY CONTROL DATA and generate a new study based on new rainfall or design criteria.

(4) EXTEND. This option allows YOU to return to the last entered link of the model and continue from that point in the CREATION mode.

HYDROLOGIC MODEL PROCESSES

CONFLUENCE:

The CONFLUENCE model is the mechanism which allows YOU to connect the interior watershed link-node models at a point of confluence. Up to 5 streams can be confluenced at a node. The stream entries must be made sequentially until all are entered.

For example, suppose 4 streams merge at node #318. When the CONFLUENCE option is selected at the end of the first interior watershed link-node model (at node #318) YOU will be requested to enter the TOTAL NUMBER OF STREAMS (which is 4). After a stream is confluenced, the program returns YOU to the PROCESS MENU so that the next interior watershed link-node model can begin creation for eventual confluence at node #318. When the last (4 of 4) stream is confluenced, the confluence values are estimated and the study can continue downstream with the new values.

The program allows only ONE POINT OF CONFLUENCE TO BE OPEN AT A TIME. This means that if 4 streams are for confluence, then until all 4 streams are entered no other points of confluence can be specified. After the 4 streams are entered, the confluence is modeled and the CONFLUENCE option is once again available for use. For a 2 stream confluence, a typical confluence model is as follows: Let Qa, Ta, Ia correspond to the stream with the largest Tc and Qb, Tb, Ib correspond to the other stream. If Ta = Tb, then the confluence time of concentration (Tp) is Tp = Ta and Q = Qa + Qb. If Qa is larger than Qb, then Tp = Ta and Q = Qa + Qb*((Ia - Fm(b)) / (Ib - Fm(b))) and Ae = Aa + Ab. If Qb is larger than Qa, Tp = Tb and Q = Qb + Qa * ((Ib - Fm(a)) / (Ia - Fm(a))) * (Tb / Ta) and Ae = Ab + (Tb / Ta) * Aa. The PEAK FLOW RATE TABLE which contains (Q,Tc,Ae,Fm) for the several confluenced stream values is tabulated and continually updated as the study progresses in the downstream direction. The program defaults to the confluence results with the greatest Q. Should different confluence values be needed, YOU can accept the confluence model results and then use the DEFINE MEMORY BANK FUNCTION to define YOUR data.

A watershed with multiple confluences can be modeled by using any of the three available memory banks to store the main-stream peak flowrate table (Q, Tc, Fm, Ae, and At) within the program's memory. For example, if two mainstreams (say 1 and 2) confluence at node #318 and both streams 1 and 2 have confluences upstream of node #318 (say at nodes #118 and #218, respectively), then stream 1 could be confluenced first at node #118, routed to node #318 and then stored in memory bank #1. Stream 2 could then be confluenced at node #218, routed to node #318 and then confluenced with memory bank #1. In this way, YOU only have one stream in confluence at a time but still achieve the multiple confluence results.

INITIAL SUBAREA:

Several methods for estimating an INITIAL SUBAREA Tc are reported in the literature (e.g., "Urban Stormwater Hydrology", Water Resources Monograph #7, American A.G.U., 1982). Because the INITIAL SUBAREA modeling procedure begins the watershed link-node model, this approximation may be the most critical. Consequently, YOU need to verify whether the approximation is reasonable. The program contains an INITIAL SUBAREA Tc approximation based on a Kirpich formula:

Tc = k(L**3/H)**.20

where L = watercourse length; H = drop in elevation; .20 is an extrapolation exponent; and k is a function of development type. YOU can also specify Tc values at a node.

PIPEFLOW AND TRAPEZOIDAL TRAVEL TIME:

Two groups of options for modeling pipeflow are available:
(1) let the computer estimate a buildable pipesize, and
(2) YOU specify the pipesize.

Both models assume no inflow into the pipe system as it connects the upstream and downstream nodes. Both models use the upstream node peak Q and the computed gradient of the land between nodes to compute normal depth flow velocity. The velocity is used to estimate travel time, Tt, between nodes. The Tt is then added to the upstream Tc to estimate the Tc at the downstream node. Flow is assumed to be under pressure (full pipeflow) when the normal depth exceeds .84 times the pipe diameter.

The trapezoidal channel flow model is based upon normal depths calculations using Manning's equation between nodes, and that Tt is estimated based on the upstream peak Q and the gradient of the land.

STREET-FLOW ANALYSIS THROUGH SUBAREA:

The street-flow groups of models estimates the traveltime of the peak Q between the upstream and downstream nodes. Since runoff generally accumulates in the street between nodes, the model estimates the average flow between nodes to analyze the street-flow characteristics. YOU can use a symmetrical cross-section with either a standard curb face, or YOU can select a street cross section pre-defined(by YOU) from a street section table created in the Program Controls. YOU specify the arbitrary street halfwidth. Flow is modeled by two methods:

(1) all the flow is on one side of the street, in which case the flow may cross over the street crown and form "splitflow", or
(2) the flow is evenly divided on both sides of the street. The model assumes all water outside of the curb as ponded, with zero flow.

USER-SPECIFIED INFORMATION (Define a Memory-Bank):

YOU can specify the time of concentration (Tc,minutes); peak flowrate (Q, cfs); total tributary area (acres); the effective area (acres); and maximum loss rate (Fm, in./hr.) at a nodal point. These values will then be defined at the specified nodal point and will be used as an "over-ride" for further downstream calculations. The rainfall intensity will be based on YOUR specified Tc. These data will remain in effect unless modified by YOU, Thus, YOU have total control over any computer modeling estimates and results.

ADDITION OF SUBAREA TO MAINLINE:

As the study progresses in the downstream direction along the main stream or channel, runoff can be added to the peak flowrate at the Tc of the main stream. This model group uses SUBAREA information of runoff potential and area, and uses the Tc of the main stream to estimate incremental runoff. Consequently, should the link-node model be changed upstream of the subject subarea, the link-node model automatically estimates the appropriate incremental runoff. It is noted that the incremental or subarea runoff however may not be equal to the difference in upstream and downstream peak flowrates due to any non-homogeneity of the watershed and the computation of a new Q total at each concentration point (as opposed to Q2 = Q1 + dQ).

V-GUTTER FLOW ANALYSIS THROUGH SUBAREA:

The V-Gutter flow model estimates the traveltime of the peak Q between the upstream and downstream nodes. Since runoff generally accumulates in the v-gutter between nodes, the model estimates the average flow between nodes to analyze the v-gutter flow characteristics using Manning's equation.

MEMORY FUNCTIONS:

In addition to the CONFLUENCE MODEL, six memory functions are available:

(1) CONFLUENCE MAIN STREAM WITH MEMORY BANK.
(2) CLEAR MEMORY BANK.
(3) CLEAR MAIN STREAM MEMORY.
(4) DEFINE MEMORY BANK.
(5) COPY MAIN STREAM MEMORY TO MEMORY BANK.
(6) COPY MEMORY BANK TO MAIN STREAM MEMORY.

Use of the MEMORY functions enables the link-node model to be constructed in a logic-flow manner, similar to the register logic of a hand calculator containing memory addresses. With the availability of the main stream memory and the three memory banks, four levels of branching flow can be modeled using the above memory functions.

The first memory function - CONFLUENCE MAIN STREAM WITH MEMORY BANK - confluences the specified memory bank peak flow rate data with the main stream peak flow rate data and creates a new or updated main stream peak flow rate table. The main stream memory can either be COPIED to one of three memory banks or a memory bank can be DEFINED by YOUR input of the peak flow rate table data (Q's,Tc's,Ae's,Fm's). Once a memory bank has been CONFLUENCED with the main stream memory, it can be CLEARED for later use.

```
=================
"IS THERE MORE ?"
=================
```

Yes, there are many more options and features available in this Program! The Program was originally developed and has been continually enhanced as a water resources engineering Education Tool, which is used by several Universities, and contains numerous HELP FILEs that guide YOU through the Program.

OF COURSE, YOU NEED TO BE COMPETENT IN HYDROLOGY AND HYDRAULICS IN ORDER TO PROPERLY USE THE PROGRAM RESULTS IN PROFESSIONAL LEVEL DESIGN AND PLANNING STUDIES.

Since 1980, various versions of the computer software has been used in numerous university level courses and workshops, has been adopted for use by several City, County, State and Federal agencies, and has been used by hundreds of private engineering firms.

3.3 Setting Up the Problem

(from MAIN MENU: CREATE)

```
    SELECT COUNTY HYDROLOGY MANUAL TO BE MODELED:

        1. KERN COUNTY (ACTIVE)
        2. ORANGE COUNTY (ACTIVE)
        3. SAN BERNARDINO COUNTY (ACTIVE)
        4. SAN JOAQUIN COUNTY (ACTIVE)
        5. CITY OF COALINGA (ACTIVE)
        6. LOS ANGELES COUNTY F0601 PRE-PROCESSOR (ACTIVE)
        7. RIVERSIDE COUNTY (ACTIVE)
        8. SAN DIEGO COUNTY (ACTIVE)
        9. CITY OF LOS ANGELES (ACTIVE)

    Enter Model NUMBER ................................. ===>




______________________________________________ RATSCx
    TYPE: EXIT to leave program
```

```
   METRIC/U.S. CUSTOMARY(ENGLISH) UNITS:
        1= Metric
        2= U.S. Customary(English)
    Select "Units" Option NUMBER........................ ===>


    COMPUTER MODEL COMPLEXITY LEVELS:
      ¦
      ¦
      +-1. BASIC
      +-2. INTERMEDIATE(includes Street Table and Deficiency Models)
      +-3. ADVANCED(includes Integrated Design Storm
        ¦  Unit Hydrograph/Rational Method Model)
        +--------4. (N/A) Data Base Mode
                 +-------5. GIS Data Set Entry

    Enter Model Complexity NUMBER....................... ===>






_____________________________________ RATSCx -----[ORANGE COUNTY]------
    TYPE: EXIT to leave program; TOP to go to top of page
```

```
Define Data Base Mode FILENAME:
(Note: an Example Filename is “EX4133”)

1. Enter a TWO LETTER study name ID…………………………………………… ===>
(Note: Both characters must be letters!)
:ALLOWABLE VALUES ARE [AA] to [ZZ]

2. Enter Region Number, of Study ID  ……………………………………… ===>
:ALLOWABLE VALUES ARE [01] to [99]

3. Enter sub-Region (or Map) Number of REGION ………………… ===>
:ALLOWABLE VALUES ARE [01] to [99]

This Program allows up to 6 Return Frequency studies in the Data Base.
4. Enter the Return Frequency Scenario NUMBER ………………… ===>
:ALLOWABLE VALUES ARE [1] to [6]





_____________________________________ RATSCx -----[ORANGE COUNTY]------
    TYPE: EXIT to leave program; TOP to go to top of page
```

```
--------------------- DATA BASE STATUS TABLE --------------------------
DATA BASE         FILE NAME        EXISTS ?
=========         ============     ========
SUBAREA           XXSUBSZZ.ASC        NO
LINK              XXLINKZZ.ASC        NO
NODE              XXNODEZZ.ASC        NO

*NONE OF THE NECESSARY DATA FILES EXIST.
  PROGRAM will RETURN YOU to the Main Menu to
  Reselect PROGRAM COMPLEXITY LEVEL.




                               Press RETURN to continue ===>
```

```
    Enter Hydrology Control Information Options......... ===>A.1
      1 = USER defines all Hydrology Control Data
      2 = Program imports Hydrology Control Data from a Data File










_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

A.1. HYDROLOGY CONTROL INFORMATION OPTIONS:

Option 2 allows YOU to import hydrology control information from an existing data file.

3.4 Hydrologic Model Processes

```
                              HYDROLOGY CONTROL

                             Information Entry:





                             Press RETURN to continue ===>
```

```
    Enter Rational Method storm event year.............. ===>A.2
    :ALLOWABLE VALUES ARE [1] TO [1000  ]

    RAINFALL INTENSITY-DURATION RELATIONSHIPS:
        1: Use 2-, 5-, 10-, 25-, 50- or 100-year PRESET values
        (i.e., logarithmic equations per Hydrology Manual Figure B-3)
        2: Enter a NEW tabulated relationship for rainfall
           intensity versus Time-of-Concentration
        3: Use a LOGARITHMIC relationship
    Select relationship desired......................... ===>A.3

    Select SCS Antecedent Moisture Condition (AMC)...... ===>A.4
    (For Rational method peak flowrate estimation.)
    :ALLOWABLE VALUES ARE [1] TO [3     ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.2 STORM EVENT YEAR:

The Rational Method attempts to estimate peak runoff flow quantities as a function of return frequency(years). This data entry prompt requests the specified return frequency(years) YOU define as being associated to the rainfall data that YOU are entering in the prompts below.

A.3. RAINFALL INTENSITY-DURATION OPTION:

The rainfall intensity(I) versus Rational Method Time-of-Concentration(Tc) data may be entered via two models: (1) in tabular form, whereby ordered pairs of (Tc,I) data are entered and are subsequently used in linear interpolation between data point values; or (2) a logarithmic fit is used whereby Tc and rainfall intensity are assumed to be logarithmically related. Once the rainfall data are entered, the entire Rational Method results are based on these data. Should YOU redefine the rainfall data later, the Rational Method results are recomputed using the redefined data. Consequently, several studies may be prepared by simply redefining the rainfall data and executing the PROGRAM. It is recalled that the rainfall data entered must correspond to the storm event return frequency YOU specified above. For the AES Orange County PROGRAM, 10-, 25-, and 100-year return frequency rainfall data are available for use via OPTION 1.

A.4. ANTECEDENT MOISTURE CONDITION:

AMC refers to the quantity of rainfall that occurred prior to the design event. AMC I usually refers to dry conditions, II to average conditions, and III to wet conditions. The Agency Hydrology Guidelines dictate what AMC to use. The AMC can be changed, via EDITOR mode, for entire redevelopment of the master plan of storm drains, and hydrologic calculations.

```
    To define rainfall intensity information, the user must
    provide some TIME-VERSUS-RAINFALL INTENSITY values.  This
    information is provided by the USER in a table form where:

    TIME-VERSUS-INTENSITY is entered in the fashion:

                               TIME(MINUTES)
                               INTENSITY(INCH/HOUR)




    Enter the number of [TIME,INTENSITY] data pairs
    to be provided by the USER.......................... ===>A.5
    :ALLOWABLE VALUES ARE [2] TO [20    ]



_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.5. TIME, INTENSITY DATA PAIRS

A Table of Time-of-Concentration (Tc) versus rainfall intensity(I) data pairs can be entered into the PROGRAM for use in the calculations. The size of the Table is determined by the number of data pairs. Generally, YOU need enough data pairs to adequately represent the true rainfall tendencies by linear interpolation. Thus, a check on accuracy may be obtained by plotting the data pairs upon a graph of the actual Tc versus I data and connecting the data pairs by straight line segments between successive data pairs(i.e., straight line interpolation). The closeness of fit between the actual curves and the straight interpolation lines indicate the accuracy. Accuracy is improved by including additional interpolation points. Discussions on linear interpolation and accuracy can be found in many standard texts on Numerical Analysis, among others.

The PROGRAM uses the last entered Tc versus I data pair for estimating rainfall intensity beyond that Tc value. For example, if the last data pair YOU enter has a Tc value of say 65-minutes and an associated rainfall intensity of say "X", then the PROGRAM will use the entered rainfall intensity of "X" for all Tc values greater than the entered 65- minutes.

Thus, YOU need to ensure that a sufficiently large Table is created for YOUR study, and YOU need to ensure that linear interpolation is adequate for study purposes.

```
         ENTER [ 5] RAINFALL INTENSITY DATA PAIRS AS REQUESTED BELOW:

         (NOTE: ENTER (TIME ; INTENSITY) IN ORDER OF INCREASING TIME)

    Enter time(MINUTES)................................ ===>A.6
    :ALLOWABLE VALUES ARE [ 15.05] TO [180   ]

    Enter intensity(INCHES/HOUR)....................... ===>A.7
    :ALLOWABLE VALUES ARE [.08   ] TO [  4.85]
-----------------------------------------------------------------------
    1)   5.000;   6.00
    2)  15.000;   5.00






_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.6. TIME ORDINATES:

A tabular data bank of rainfall intensity versus time-of-concentration (Tc) can be made. In this PROGRAM, all Tc values are held greater than 5-minutes. The last Tc value YOU enter will be used to define the rainfall intensity for all larger Tc values. Linear interpolation (straight-line fit) is used between successive data pairs.

The USER should plot the entered data on a graph of Intensity versus Tc for both report submittal and as a check for sufficient accuracy. The PROGRAM is only as accurate as the rainfall data accuracy!

A.7. RAINFALL INTENSITY ORDINATES:

The tabular data bank is defined on a return frequency basis. The rainfall intensity is generally the corresponding catchment area-averaged rainfall intensity, for the desired return frequency.

```
    LOGARITHMIC RELATIONSHIP INTERPOLATION SCHEMES:

        1: Use NOAA Atlas II (1973) 1-hour point rainfall
           interpolation to estimate   25-year values

        2: Enter the 1-hour   25-year point rainfall DIRECTLY

    Select interpolation scheme desired................. ===>A.8



    Enter logarithm slope of intensity-duration curve... ===>A.9
    (Note: English units are log(I;IN/HR) vs. log(Tc;MIN))
    :ALLOWABLE VALUES ARE [.1    ] TO [1.0   ]






_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.8. LOGARITHMIC RELATIONSHIP OF RAINFALL:

Oftentimes, a logarithmic relationship may be used to defined rainfall intensity versus time-of-concentration (Tc). Such a relationship can be defined by use of a single data pair, i.e., the 1-hour point rainfall value and the slope of the line. Two options are available for the point rainfall value: (1) interpolation of point rainfall values between 10-year and 100-year return frequencies, or (2) specified point rainfall value by USER.

A.9. LOGARITHMIC SLOPE:

The absolute value of the slope of the rainfall intensity versus time-of-concentration (Tc) line plotted on Log-Log paper. YOU should always verify the accuracy of YOUR model by verifying several test Tc versus I values.

```
Enter 10-year storm 60-minute rainfall(INCHES)...... ===>A.10
:ALLOWABLE VALUES ARE [.1    ] TO [9.95  ]




Enter 100-year storm 60-minute rainfall(INCHES)..... ===>A.11
:ALLOWABLE VALUES ARE [.1    ] TO [15.0  ]




_______________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.10. INTERPOLATION OF POINT RAINFALL:

For return frequencies of point rainfall values that are between 10-year and 100-year, an interpolation scheme is sometimes appropriate. One such scheme is available in NOAA Atlas II (1973). Many Hydrology Manuals contain plots or tabular listings of appropriate values.

A.11. POINT RAINFALL:

The 1-hour point rainfall is used with the slope of the rainfall intensity line to define a logarithmic Tc versus I relationship. Many Hydrology Manuals contain plots or tabular listings of appropriate values.

```
    LOGARITHMIC RELATIONSHIP INTERPOLATION SCHEMES:

        1: Use NOAA Atlas II (1973) 1-hour point rainfall
           interpolation to estimate   25-year values

        2: Enter the 1-hour   25-year point rainfall DIRECTLY

    Select interpolation scheme desired................. ===>A.8


    Enter logarithm slope of intensity-duration curve... ===>A.9
    (Note: English units are log(I;IN/HR) vs. log(Tc;MIN))
    :ALLOWABLE VALUES ARE [.1    ] TO [1.0   ]

    Enter the 1-hour   25-year point rainfall(INCH/HOUR) ===>A.11
    :ALLOWABLE VALUES ARE [.01   ] TO [30.   ]




_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

```
    This PROGRAM estimates design pipe sizes.
    Enter MINIMUM pipe size acceptable(INCHES).......... ===>A.12
    :ALLOWABLE VALUES ARE [3] TO [240   ]

    This PROGRAM estimates a design pipe size through
    a subarea using the Mannings equation, with the friction
    slope set equal to the gradient of the land.  The PROGRAM
    determines a CONSTRUCTABLE pipe size such that non-pressure
    flow is calculated. The USER can specify a percentage of the
    land-gradient to be used for the pipeflow friction slope.
    (SUGGESTION:
                Use [.95] for pipesystems with FEW minor losses
                Use [.85] for pipesystems with CONSIDERABLE minor
                          losses)

    Enter percentage of subarea land-gradient to be used for
    the pipeflow friction slope(DECIMAL)................ ===>A.13
    :ALLOWABLE VALUES ARE [.001  ] TO [1.00  ]
    Note: This PERCENTAGE of subarea land-gradient
          will also be used in sizing BOXes, but not open CHANNELs.

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.12. MINIMUM PIPE SIZE:

When sizing pipes, a typical goal is to optimize the use of available hydraulic energy in the transport of runoff flows.
The available energy, for gravity systems, is the elevation drop across the topography to the system's downstream EGL.
Generally, another goal is to design the pipe system such that the HGL is not far below ground nor above ground. An HGL far below ground may indicate a pipe system is not economical, whereas an HGL above ground may be unacceptable for design safety purposes. The available energy in the system is used to satisfy minor losses and friction losses. Generally, a pipe system that is most economical will have a HGL that is roughly parallel with and below the ground surface. Thus, use of the topographic gradient as an indicator of the HGL gradient is generally appropriate for planning purposes.

Pipe sizes are determined in the PROGRAM by taking the peak flow and computing a pipe conveyance factor(see King's Handbook) based upon Manning's equation, using the slope of the topography(as defined by nodal point elevations entered by YOU) as the friction slope. The computed conveyance factor corresponds to a pipeflow condition with a flow depth equal to the pipe diameter (i.e., "soffit" flow). It is noted that this same pipeflow rate also corresponds to a normal depth of about 0.84 diameter. This "soffit" flow pipe is then upsized to fit available constructed pipe sizes. Finally, normal depth is computed in the pipe, and used for hydraulics estimating purposes. If YOU specified the pipe size, then normal depth hydraulics are estimated; if the pipe is under pressure, flow velocity is estimated to be the peak flow divided by the pipe cross-section area.

A minimum pipe size needs to be specified for the PROGRAM pipe sizing algorithm. This minimum pipe size is the smallest size used for pipe-sizing purposes.

Note that after the PROGRAM sizes the pipes, YOU need to evaluate these estimated sizes as to appropriateness in YOUR plan design.

A.13. PIPE FRICTION SLOPE USED:

If the USER ignores all minor losses in the system and only considers friction losses, then the topographic gradient is used in computing pipe sizes, directly. To consider minor energy losses, the available energy may be reduced by a reduction factor. In this way, a larger pipe system is determined than that obtained by ignoring minor losses. Because the pipes are sized by the PROGRAM in a downstream direction, and with open-channel flow conditions, backwater effects due to downstream HGL constraints are not considered. To ignore all minor losses in this model, enter 1.0 for the reduction factor. YOU may calibrate this "reduction factor" by computing minor losses and then developing a corresponding "reduction factor." Note: This PERCENTAGE of subarea land-gradient will also be used in sizing BOXes, but not open CHANNELs.

```
    Enter Default Manning's friction factor for pipes... ===>A.14

      (NOTE: FOR RCP USE n = .013;
             FOR CSP(or CMP) USE n = .024)
      :ALLOWABLE VALUES ARE [.005  ] TO [.9999 ]



    Enter Topographic Data Entry Option................. ===>A.15
      1 = Use Representative ELEVATIONS
          for all Hydraulic Model calculations
      2 = Use Representative SLOPE
          for all Hydraulic Model calculations




_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.14. MANNING'S FRICTION FACTOR:

Manning's equation is generally used to describe friction energy losses. For normal depth flow,

$$Q = \frac{c}{n} A R^{.67} S^{.5}$$

where Q is the steady flow rate, A is the flow area, R is the hydraulic radius, and S is the gradient of the HGL and EGL which, in normal depth flow, is the slope of the pipe. The parameter, n, is the Manning's friction factor. The constant "c" is a unit conversion factor.

A.15. TOPOGRAPHIC DATA ENTRY OPTION:

Topographic information is used to estimate both streetflow and conduit hydraulic properties. YOU have the option to enter actual elevation data, or enter a representative slope to be used in Manning's equation.

```
*This PROGRAM allows YOU to build up a street cross-section table.
 The TABLE enables you to specify customized street cross-section
 data and target street flow depths, and then access these data
 by Section Number. (Note: The FIRST cross-section is pre-defined.)

 If YOU wish to use coupled street and pipe flow models,
 the STREETFLOW TABLE is needed to be defined for modeling
 streetflow effects.  YOU may also use the STREETFLOW TABLE
 to model streetflow only; otherwise, YOU may use either
 of two provided standard curb sections.

SELECT OPTION NUMBER................................ ===>A.16
     1 = DEVELOP STREETFLOW TABLE
     2 = DO NOT USE STREETFLOW TABLE
:ALLOWABLE VALUES ARE [1] TO [2     ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
TYPE: D to display COMMAND definitions
```

A.16. STREETFLOW TABLE OPTIONS:

The PROGRAM provides YOU the ability to use a street cross-section without re-entering all the street cross-section data. The FIRST street cross-section is pre-defined by the PROGRAM and can be modified. YOU can create up to 10 street cross-sections per data file. Once the streetflow table is created, YOU can modify the data but not delete the data.

```
***********************************************************************
>>>>STREETFLOW HYDRAULICS MODEL: SECTION DATA<<<<
-----------------------------------------------------------------------
    HALF-  CROWN TO  STREET-CROSSFALL:  CURB GUTTER-GEOMETRIES: MANNING
    WIDTH  CROSSFALL IN-  / OUT-/PARK-  HEIGHT WIDTH LIP HIKE   FACTOR
NO. (FT)     (FT)    SIDE / SIDE/ WAY    (FT)  (FT) (FT) (FT)    (n)
=== =====  ========= ================= ====== ===== ==== ====  =======
  1  30.0    20.0    .018/ .018/ .020    .67   2.00 .03125 .1670 .01500






    Enter [1] to ADD a street-section
          [2] to CHANGE a street-section
          or Press Return to ACCEPT/CONTINUE............ ===>

    ---DATA ENTRY FOR SYMMETRICAL STREET CROSS-SECTION #  2---PAGE 1

    Enter constant symmetrical street curb-height(INCHES) ==>A.17
    :ALLOWABLE VALUES ARE [1.    ] TO [36.   ]

    Enter constant symmetrical street half-width(FEET).. ===>A.18
    :ALLOWABLE VALUES ARE [10.   ] TO [100.  ]

    Enter distance from street crown to
    crossfall gradebreak(FEET).......................... ===>A.19
    :ALLOWABLE VALUES ARE [1.    ] TO [99.   ]

    Enter CENTER lane street crossfall(DECIMAL)......... ===>A.20
    :ALLOWABLE VALUES ARE [.001  ] TO [.5    ]

    Enter OUTSIDE lane street crossfall(DECIMAL)........ ===>A.20
    :ALLOWABLE VALUES ARE [.001  ] TO [.5    ]

    Enter PARKWAY crossfall(DECIMAL;100=NO FLOW ON PARKWAY)=>A.21
    :ALLOWABLE VALUES ARE [.005  ] TO [.05   ]
_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.17. CURB HEIGHT:

Two "standard" curb models are available in this model. The specifications used are shown on the screen.

A.18. SYMMETRICAL STREET HALFWIDTH:

The streetflow model assumes a symmetrical section. The "halfwidth" is the distance from the street centerline (or "crown") to the street "top of curb". The curb face is modeled to be vertical.

A.19. STREET GRADEBREAK:

The symmetrical street section may be modeled to have a gradebreak (i.e., a change in crossfall). This prompt asks for the distance from the street centerline (or crown) to the gradebreak. If there is no gradebreak, enter an appropriate distance (such as one half the "halfwidth") and use the same crossfall for both the Center lane and the Outside lane.

A.20. STREET CROSSFALL:

The "crossfall" value is usually in the range of 0.010 to 0.030. The PROGRAM assumes a Manning's n value of 0.015 for each of the Center and Outside lanes in the streetflow gradebreak model.

A.21. PARKWAY CROSSFALL:

If flow in the parkway is to be included in the analysis, YOU must enter the crossfall. A crossfall of 100.0 is arbitrarily set to define a near-vertical parkway, with no flow allowed.

```
    Enter Curb and Gutter Data Options.................. ===>A.17
      1 = Use Standard 6 or 8 inch curb and gutter dimensions
      2 = Enter all curb and gutter dimensions









_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

```
    ---DATA ENTRY FOR SYMMETRICAL STREET CROSS-SECTION #  2---PAGE 2

    Enter gutter-width(FEET)............................ ===>A.22
    NOTE: For 6-inch curb, GUTTER-WIDTH IS USUALLY [1.5]
          For 8-inch curb, GUTTER-WIDTH IS USUALLY [2.0]
    :ALLOWABLE VALUES ARE [.1    ] TO [5     ]

    Enter gutter-lip(FEET).............................. ===>A.22
    NOTE: For 6-inch curb, GUTTER-LIP IS USUALLY [.03125]
          For 8-inch curb, GUTTER-LIP IS USUALLY [.03125]
    :ALLOWABLE VALUES ARE [.01   ] TO [1     ]

    Enter gutter-hike(FEET)............................. ===>A.22
    NOTE: For 6-inch curb, GUTTER-HIKE IS USUALLY [.125]
          For 8-inch curb, GUTTER-HIKE IS USUALLY [.167]
    :ALLOWABLE VALUES ARE [.01   ] TO [1     ]

    Enter average friction factor(Manning).............. ===>A.23
    (NOTE: RECOMMENDED VALUE IS [0.015])
    :ALLOWABLE VALUES ARE [.008  ] TO [.1    ]

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.22. GUTTER GEOMETRIC DATA:

The gutter geometric data of width, lip, and hike refer to the gutter flow-width, the rise in elevation between the gutter and roadway pavement, and the rise in elevation between the gutter flowline and edge of gutter flow-width.

```
                 ---SYMMETRIC STREET CROSS-SECTION ASSUMED---


             PARKWAY :                       :
                     :                       :
            <------->:<--STREET HALF-WIDTH-->:
                                          *  ^  *     ^
            *          GUTTER-WIDTH   *     /       * |
                 *      |         *        /          |-Y
            ^        *<->   *             CROWN       |
            |        *   *                            v
            |-CURB   *   *<---GUTTER-LIP
            |HEIGHT  *  * <---GUTTER-HIKE
            v        ***  <--FLOWLINE
```

A symmetrical street cross-section is assumed with a roadway CROSSFALL = (Y)/(STREET HALF-WIDTH)-(GUTTER-WIDTH)). Water outside of street is assumed ponded with a negligible flowrate. "Splitflow" occurs when flows exceed the capacity of a halfstreet section and then cross over to the street crown. YOU can specify either equal flow on both sides of the street, or that flow is only on one side of the street (which may then result in splitflow).
Remember that in the STREETFLOW SECTION Table, all data are assumed to correspond to street sections that are symmetrical with respect to the street centerline.

A.23. STREET FRICTION FACTOR:

A constant Manning's friction factor will be used for normal depth calculations of streetflow. Usually, friction values are between 0.015 and 0.025, depending upon the local Agency criteria.

```
**********************************************************************
>>>>STREETFLOW HYDRAULICS MODEL: SECTION DATA<<<<
----------------------------------------------------------------------
    HALF-  CROWN TO  STREET-CROSSFALL:  CURB GUTTER-GEOMETRIES: MANNING
    WIDTH  CROSSFALL IN-  / OUT-/PARK-  HEIGHT WIDTH LIP HIKE   FACTOR
NO. (FT)     (FT)    SIDE / SIDE/ WAY    (FT)  (FT) (FT) (FT)    (n)
=== =====  ========= ================= ====== ===== ==== ====  =======
  1  30.0    20.0    .018/ .018/ .020    .67   2.00 .03125 .1670 .01500
  2  10.0     4.5    .300/ .300/ .030    .30   1.50 .02750 .1500 .01250



    Enter Street-Section Number to be CHANGED………………………… ===>
    :ALLOWABLE VALUES ARE [1     ] TO [ 2    ]
```

```
    This PROGRAM contains Options to size pipes
    with respect to streetflow hydraulic constraints.

    GLOBAL STREET FLOW-DEPTH CONSTRAINTS:


    Enter Relative Flow-Depth(FEET) as (Maximum Allowable
    Street Flow-Depth) - (Top-of-Curb).................. ===>A.24
    :ALLOWABLE VALUES ARE [-0.5  ] TO [1.0   ]

    Enter (Depth)*(Velocity) Constraint(FT*FT/S)........ ===>A.25
    :ALLOWABLE VALUES ARE [.1    ] TO [10.   ]







_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.24. ALLOWABLE STREET FLOWDEPTH:

The maximum allowable depth of flow in the street can be expressed as a specified depth, or relative to the street top-of-curb by subtracting: (allowable flow-depth) minus (street top-of-curb). two values are linked, and so only one of the two values are requested as input. YOU may change all such constraints in the GLOBAL EDITING FUNCTIONS (see Editor).

A.25. DEPTH*VELOCITY CONSTRAINT

A frequently used constraint is the product of street flow-depth and the flow velocity. This constraint corresponds to a flow depth, which is then used in the PROGRAM as a flow depth constraint. These values can be changed throughout the data bank by the GLOBAL EDITING FUNCTIONS (see Editor.)

```
    Depending on street grade, smaller pipes may be sized
    based on an increase in street flow carrying capacity.

    Select Pipe Sizing Constraint Option................ ===>A.26

      1 = size pipe with a flow capacity greater than
          or equal to the upstream tributary pipe.
      2 = pipe may be sized to have a flow capacity less than
          upstream tributary pipe.

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.26. PIPE SIZING OPTION:

When sizing pipes, while analyzing flow in the street, conditions may occur where the streetflow carrying capacity may increase (such as an increase in grade). If streetflow carrying capacity is increased, YOU may elect to "burp out" flow from the pipes by designing smaller pipes. YOU have the Option to select the model used in sizing pipes: Option 1 attempts to model reduced use of "burp-out" systems, whereas Option 2 is appropriate for plans including "burp-out" systems.

It is noted that at confluences, YOU may need to further evaluate the hydraulic effects; the PROGRAM simply analyzes the streetflow.

```
    Integrated Unit Hydrograph Model Selection Constraints:
    Enter lower limit of the TOTAL area(Acres) such that
    the UH model is available........................... ===>A.27
    :ALLOWABLE VALUES ARE [300.0 ] TO [2560.0]
    (Suggested value is [640.] Acres.)

    Enter lower limit of the time-of-concentration(min.)
    of the longest tributary watercourse (to each node),
    such that the UH model is available................. ===>A.27
    :ALLOWABLE VALUES ARE [12.49 ] TO [60.0  ]
    (Suggested value is [12.5] minutes.)

    Select Rational Method to UH Method
    "Switchover" Option Number.......................... ===>A.27

       1 = Automatically "switch over" from the Rational Method to the
        UH method, on any stream, when above model constraints are met

       2 = User SELECTS when to "switch over" BETWEEN Methods

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

A.27. INTEGRATED UH/RATIONAL METHOD MODEL OPTION:

This Program provides an integration between the Rational Method and the design storm unit hydrograph(UH) Method. The Rational Method is used to compute peak flow rates until certain minimum constraints are met (set by YOU) regarding minimum allowable tributary area and the minimum allowable time of concentration of the longest tributary watercourse(to each point of concentration). For UH applications,

lag = .8 * Tc

where Tc is the time of concentration of the longest watercourse tributary to the model node.
Single area design storm UH applications are modeled where depth-area effects, loss rates, and S-graph modifications are recomputed for each nodal point. That is, a single area UH model is developed on a node by node basis, where parameters are reaveraged and recomputed for each UH application. The peak Q is then computed, using a minimum of 2.5-minute unit time intervals, to be used for the hydrology study including travel time estimation.
When the UH method is initiated by YOU, the UH method will be used to compute downstream peak Q values. As with the Rational method, if an upstream peak Q is larger than the current peak Q, the upstream peak Q is used as a default value; thus, the transition between Rational and UH Methods is accomplished by use of this upstream node peak Q check.
If YOU do NOT select the integrated UH/Rational Method Model option, the PROGRAM will compute all peak Q values based on only the Rational Method. YOU may elect to choose a different modeling option after the data file is completed.

```
UNIT-HYDROGRAPH METHOD LAG ESTIMATION OPTIONS:

    Select LAG value Estimation Technique Option NUMBER  ===>A.28
      1 = Use LAG = K * Tc relationship
      2 = Use U.S. Army Corps of Engineers LAG Equation


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.28. LAG OPTIONS:

Lag is a statistical parameter that describes the timing of runoff at a node. There are two options available for entering catchment lag:

1. The U.S. Army Corps of Engineers Formula:
   This formula requires four input variables: the length of the longest watercourse, the length of the longest watercourse measured upstream to a point opposite the centroid of area for the watershed, the elevation difference of the drainage area between the point of concentration and the hydrologically most remote point, and the basin factor.
2. Time of Concentration Lag Estimate:
   Rainfall-runoff data suggests that Lag can be estimated by 0.8 x Tc, where Tc is the time of concentration from a detailed rational method analysis.

```
BASIN        GENERAL DESCRIPTION OF DRAINAGE AREA
FACTOR       (Ref. U.S. Corps of Engineers)

N= .015 >>> Drainage area has fairly uniform gentle slopes.
            Most watercourses either improved or along paved streets.
N= .020 >>> Drainage has some graded and non-uniform gentle slopes.
            Over half of the area watercourses are improved or paved streets.
N= .025 >>> Drainage area is generally rolling with gentle side slopes.
            Some drainage improvements in the area - streets and canals.
N= .030 >>> Drainage area is generally rolling with rounded ridges and
moderate
            side slopes.
            No drainage improvements exist in the area.
N= .040 >>> Drainage area is composed of steep upper canyon with moderate
            slopes in lower canyons.
            No drainage improvements exist in the area.
N= .050 >>> Drainage area is quite rugged with sharpedges and steep canyons.
            No drainage improvements exist in the area.
N= .200 >>> Drainage area has comparatively uniform slopes.
            No drainage improvements exist in the area.
    Enter BASIN FACTOR to be used for this entire File.. ===>A.29

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.29. BASIN FACTOR:

A visually estimated parameter that correlates lag to catchment shape data. This parameter is developed from runoff data of selected catchments where data are available.

```
    Enter "Length-to-Centroid"(Lca) versus "Longest Watercourse
    Length"(L) Ratio FACTOR, k, to be used for this entire File:
    Lca = k * L........................................ ===>A.30
    :ALLOWABLE VALUES ARE [0.10  ] TO [0.90  ]

    S-GRAPH MODEL OPTIONS:

       1: User Specified Fixed S-Graph Proportions.
       2: Use (i) Valley Undeveloped S-Graph for developments
                  of 2 Units/Acre and less; and
             (ii) Valley Developed S-Graph for developments
                  of 3-4 Units/Acre and more.
    Select option desired.............................. ===>A.31



_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.30. LENGTH OF LONGEST WATERCOURSE:

The distance from the point of concentration of a watershed to the hydrologically most remote point in that watershed.

LENGTH TO CENTROID:

The distance from the point of concentration of a watershed to the point along the longest watercourse that is opposite the centroid of the watershed.

A.31. S-GRAPH MODEL OPTIONS:

Two S-graph model options are available, for use throughout the entire data file.

```
    UNIT-HYDROGRAPH METHOD LAG ESTIMATION Definition:

    Enter K Factor for relating LAG to Tc (Lag = K*Tc).. ===>A.32
    NOTE: In Orange, San Bernardino, and Kern Counties, LAG = 0.8*(Tc)
    :ALLOWABLE VALUES ARE [0.2   ] TO [2.00  ]


    S-GRAPH MODEL OPTIONS:

       1: User Specified Fixed S-Graph Proportions.
       2: Use (i) Valley Undeveloped S-Graph for developments
                  of 2 Units/Acre and less; and
             (ii) Valley Developed S-Graph for developments
                  of 3-4 Units/Acre and more.
    Select option desired.............................. ===>A.31

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.32. LAG AND Tc RELATION:

Several lag estimation procedures have been correlated to time-of-concentration (Tc). For Orange, San Bernardino, and Kern Counties, among others,

lag = 0.8*Tc.

```
    UNIT-HYDROGRAPH "S" GRAPH OPTIONS:
     1:Valley(Developed/URBAN) 2:Foothill 3:Mountain
4:Valley(Undeveloped) 5: Desert 6: Combination of options 1 through 5
    Select appropriate S-GRAPH......................... ===>A.33







_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.33. WEIGHTED S-GRAPH:

To compute a weighted S-graph, the ordinates of each contributing S-graph is weighted by the decimal proportion YOU enter. The sum of the proportions are used as the WEIGHTED S-Graph. Note that any "left-over" weighting is lumped into a proportion of the Valley-Undeveloped S-Graph.

```
UNIT-HYDROGRAPH "S" GRAPH OPTIONS:
     1:Valley(Developed/URBAN) 2:Foothill 3:Mountain
4:Valley(Undeveloped) 5: Desert 6: Combination of options 1 through 5
    Select appropriate S-GRAPH.......................... ===>A.33


    Enter VALLEY(Developed, or URBAN) "S" graph fraction ===>A.34
    :ALLOWABLE VALUES ARE [0.00  ] TO [1.00  ]

    Enter FOOTHILL "S" graph fraction................... ===>A.34
    :ALLOWABLE VALUES ARE [0.00  ] TO [1.00  ]

    Enter MOUNTAIN "S" graph fraction................... ===>A.34
    :ALLOWABLE VALUES ARE [0.00  ] TO [1.00  ]

    Enter VALLEY(Undeveloped) "S" graph fraction........ ===>A.34
    :ALLOWABLE VALUES ARE [0.00  ] TO [1.00  ]

    Desert "S" graph fraction............................ = [    ]

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.34. S-GRAPH:

S-graphs are normalized and artificially-smoothed transfer function realizations reconstituted by fitting known runoff data to assumed effective rainfall data, via an unit hydrograph convolution procedure. S-graph data are typically simple averages of several S-graphs normalized via the Lag definition used, and represents a statistical expected realization of possible outcomes. S-graphs are labeled according to hydrologic regions where data are available.

```
DESIGN STORM RAINFALL OPTIONS:

    PRECIPITATION MODELS:
      1: Uniform precipitation data for entire File
      2: Precipitation data entered on Subarea basis
    Select desired model................................ ===>A.35

    PRECIPITATION DEPTH-AREA FACTOR MODELS:
      1: Sierra Madre values
      2: User-specified depth-area factors
    Select desired model................................ ===>A.36

    Select SCS Antecedent Moisture Condition (AMC)...... ===>A.4
    (For Unit-Hydrograph peak flowrate estimation.)
    :ALLOWABLE VALUES ARE [1] TO [3     ]
_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.35. UH PRECIPITATION MODEL:

The two Options enable for the unit hydrograph method design storm to be based on variable rainfall depths distributed over the catchment, or simply a uniform set of rainfall data. The Subarea model requires rainfall data for each subarea; consequently, a Uniform model is simpler to use. The rainfall data are used in the construction of the County design storm pattern.

A.36. DEPTH AREA FACTORS:

Depth-Area factors are an averaged reduction set of relationships correlating the chance of catchment storm coverage to T-year rainfall depths. Data are sparse, and only a few severe storm events can be used to develop such relationships. The U.S. Army Corps of Engineers has developed the Sierra-Madre relationships that are stored in this program.

A.4. ANTECEDENT MOISTURE CONDITION:

AMC refers to the quantity of rainfall that occurred prior to the design event. AMC I usually refers to dry conditions, II to average conditions, and III to wet conditions. The Agency Hydrology Guidelines dictate what AMC to use. The AMC can be changed, via EDITOR mode, for entire redevelopment of the master plan of storm drains, and hydrologic calculations.

```
TO CONSTRUCT THE SYNTHETIC CRITICAL STORM PATTERN, AREA-AVERAGED
 WATERSHED RAINFALL VALUES ARE NEEDED FOR THE PEAK 5-MINUTES,
 30-MINUTES,1-,3-,6-,AND 24-HOURS OF RECORDED RAINFALL.

 YOU have two OPTIONS:

   1 = Enter the 2- and 100-yr 6- and 24-hour, and use previously
       entered rainfall intensity slope value and logarithmic
       interpolation to compute the 5-,30-minute and 3-hour rainfall; OR
   2 = Enter 5-,30-minute, 1-, 3-, 6-, and 24-hour rainfall values.


 Select desired option..................................... ===> A.37








_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.37 DESIGN STORM :

Design storm nested rainfalls are entered as T-year rainfall depths versus peak storm duration. By area-averaging T-year point rainfall values over the catchment, a T-year "unadjusted point rainfall" value may be computed. These data are then used to scale the selected design storm rainfall pattern for use in estimating effective rainfalls.

The nested design storm provides T-year return frequency rainfalls for each peak design storm duration.

After generating loss rates, the resulting effective rainfalls are used in the unit hydrograph model to develop T-year design storm runoff data.

Option 1:

```
Enter 2-year storm 6-hour rainfall(mm) ………………………………………….………===> A.38
:ALLOWABLE VALUES ARE [.1    } TO [300.  ]

Enter 2-year storm 24-hour rainfall(mm) ……………………………………………..…===> A.38
:ALLOWABLE VALUES ARE [.1    } TO [300.  ]

Enter 100-year storm 6-hour rainfall(mm) ………………………………….………===> A.38
:ALLOWABLE VALUES ARE [.1    } TO [300.  ]

Enter 100-year storm 24-hour rainfall(mm) ……………………………………………===> A.38
:ALLOWABLE VALUES ARE [.1    } TO [300.  ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

A.38. INTERPOLATION OF POINT RAINFALL:

For return frequencies of point rainfall values that are between 2-year and 100-year, an interpolation scheme is sometimes appropriate. One such scheme is available in NOAA Atlas II (1973). Many Hydrology Manuals contain plots or tabular listings of appropriate values.

```
    Enter  5-minute depth-area adjustment factor........ ===>A.36
    :ALLOWABLE VALUES ARE [  .010] TO [1.    ]
                                      +--------------------------------+
                                      |  DEPTH-AREA ADJUSTMENT FACTORS|
                                      |--------------------------------|
                                      |      5-MINUTE   [       ]      |
                                      |     30-MINUTE   [       ]      |
                                      |        1-HOUR   [       ]      |
                                      |        3-HOUR   [       ]      |
                                      |        6-HOUR   [       ]      |
                                      |       24-HOUR   [       ]      |
                                      +--------------------------------+

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

Option 2:

```
    TO CONSTRUCT THE SYNTHETIC CRITICAL STORM PATTERN, AREA-AVERAGED
    WATERSHED RAINFALL VALUES ARE NEEDED FOR THE PEAK 5-MINUTES,
    30-MINUTES,1-,3-,6-,AND 24-HOURS OF RECORDED RAINFALL.

    Enter watershed area-averaged  5-minute point
    rainfall(INCHES)................................... ===>A.11
    :ALLOWABLE VALUES ARE [   .01] TO [    5.]

    Enter  5-minute depth-area adjustment factor........ ===>A.36
    :ALLOWABLE VALUES ARE [  .010] TO [1.    ]
  +----------------------------------++--------------------------------+
  |WATERSHED AREA-AVGED PT RAINFALLS ||  DEPTH-AREA ADJUSTMENT FACTORS|
  |----------------------------------||--------------------------------|
  | 5-MINUTE   [       ] INCHES      ||      5-MINUTE   [       ]      |
  | 30-MINUTE  [       ] INCHES      ||     30-MINUTE   [       ]      |
  |   1-HOUR   [       ] INCHES      ||        1-HOUR   [       ]      |
  |   3-HOUR   [       ] INCHES      ||        3-HOUR   [       ]      |
  |   6-HOUR   [       ] INCHES      ||        6-HOUR   [       ]      |
  |  24-HOUR   [       ] INCHES      ||       24-HOUR   [       ]      |
  +----------------------------------++--------------------------------+

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

3.5 Subarea Analysis

```
                        Rational
                     Method Analysis

                         SUBAREA
                    Information Entry:




                    Press RETURN to continue ===>
```

(still under MAIN MENU: CREATE...)
RATI0NAL METHOD: SUBAREA MENU

```
*---------------------------NODE NUMBERS------------------------------*
| [0 to 999999.9] Upstream => B.1          Downstream => B.1          |
|--------------------LINK-NODE MODELING PROCESSES---------------------|
|      0: ENTER Comment                1: CONFLUENCE analysis at node |
|      2: INITIAL subarea analysis                                    |
|      3: PIPE/BOX traveltime (COMPUTER Estimated pipe/box size)      |
|      4: PIPE/BOX traveltime …………(USER Specified pipe/box size)      |
|      5: OPEN CHANNEL traveltime                                     |
|      6: STREETFLOW analysis thru subarea traveltime                 |
|      7: USER Specified Hydrology at a Node (Basic/Intermed Mode)    |
|      8: ADDITION of subarea runoff to MAIN-Stream                   |
|      9: V-GUTTER flow thru subarea                                  |
|     10: COPY MAIN-Stream data onto a memory BANK                    |
|     11: CONFLUENCE a memory BANK with the Main-Stream memory        |
|     12: CLEAR a memory BANK            13: CLEAR the MAIN-Stream    |
|     14: COPY a memory BANK onto the Main-Stream memory              |
|     15: HYDROLOGIC data BANK storage functions                      |
|     16: USER-SPECIFIED Source Flow at a Node                        |
|---------------------------------------------------------------------|
|            Select Link-Node Modeling Process Number => B.2          |
*---------------------------------------------------------------------*

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, MAIN      -Data Area-
    TYPE: D to display COMMAND definitions                  ( 98% free)
```

B.1. NODE NUMBERS:

The link-node model representation of the catchment utilizes flow processes or logic processes that direct modeling information in the DOWNSTREAM DIRECTION, with accumulation of flow and catchment area. Nodal points are used to correlate hydrology reference points to the computer output. For each model process, an upstream and downstream node is assigned. The nodal numbers do not affect computational results. Generally, a useful numbering scheme is to sequentially increase node numbers, starting with the initial subarea of each stream. Numbering major streams by the hundreds (e.g., 200,201,202, etc.) is often useful in identifying individual streams. Also, YOU may wish to number the most upstream node as 00,100, 200, etc., to indicate the initial node of a stream or flowpath.
The network model is composed of link processes and point processes. In general, link processes connect nodes. A point process is a logic path or model that occurs at a point (i.e., node). In the data base mode, the PROGRAM helps YOU to organize YOUR network data by screening node ID data.

B.2. HYDROLOGIC PROCESS :

The Rational Method constructs a link-node model of catchment peak-flow hydraulics by assembling hydraulic and hydrologic (i.e., runoff producing) elements. The link-node model is constructed in a strict downstream direction, where all flows are accounted at each nodal point prior to the next downstream node via a hydraulic link. The link-node model is constructed just as YOU would do by hand calculations, starting at the upstream end of each stream and proceeding with the analysis in the downstream direction. Runoff is generated in terms of peak flow only; there are no runoff volume calculations. The various link-node processes are described in the PROGRAM HELP files. To see the HELP file, type "TUTOR" at any data entry point.

0: ENTER Comment

```
DESCRIPTIVE COMMENTS FOR PRINTOUT (3-LINES MAXIMUM)

Enter 1st comment line (or press RETURN for blank line)
[                                                                          ]
 ^START                                                                END^

 ------------------------Description of Study-------------------------
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
|                                                                     |
 ---------------------------------------------------------------------
```

1: CONFLUENCE analysis at node

```
------------ Confluence of Independent Streams at a Node ------- page 1



    Enter the total number of independent streams
    to confluence at NODE #      3.00 .................. ===>1.A
    :ALLOWABLE VALUES ARE [2] TO [5     ]








_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

1.A. STREAM CONFLUENCE:

The Rational Method only estimates peak flow rates. Runoff hydrographs are not used for small areas. Therefore, a means to estimate the peak flow rate at the confluence (or merging) of streams is needed.

Many formulae are suggested in the literature, almost all of which use a formula that involves multiplying each stream peak flow by an adjustment factor, and then adding the adjusted peak flow rates.

In the PROGRAM, the User-selected confluence formula is used to estimate the resulting peak flow rate.

To begin the Confluence Model, the USER needs to supply the number of streams that enter the confluence point. Up to 5 are available. YOU probably have already computed flows for the first stream, and have arrived at the first confluence point. After specifying the total number of streams, the PROGRAM stores the streamflow estimates, and then YOU proceed to the beginning of the next stream that also is tributary to the confluence point. Until all the streams are specified, the confluence point is held "open" by the PROGRAM.

Many Agencies require that all possible confluence values be examined. That is:" What happens downstream had YOU used a different set of confluence values?"

The PROGRAM, when applicable, generates a "Peak Flowrate Table" that summarizes the computations for all confluences combinations (developed by YOUR input data). Each stream estimate is continued independently in order to evaluate the possible downstream combinations.

2: INITIAL subarea analysis

```
-------------------- Initial Subarea Analysis ----------------- page 1





    Initial Subarea Time-of-Concentration Options:

         1. Use Time-of-Concentration Nomograph for Initial Subarea
         2. Use Specified Tc Value for Initial Subarea

    Select option NUMBER................................ ===>2.1.A





____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

2.1.A. INITIAL SUBAREA Tc:

Initial Subarea Tc estimates can be computed by use of a nomograph, or by the USER specifying a Tc value (in minutes). Generally, the Initial Subarea may be a principal contributor to downstream Tc estimates; the USER needs to apply caution in the Initial Subarea Tc estimate.

2.1: Use Time-of-Concentration Nomograph for Initial Subarea

```
------------------------- Initial Subarea Analysis ------------ page 1A


    Enter upstream node      1.00 elevation(FEET)....... ===>2.1.B
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node      2.00 elevation(FEET)..... ===>2.1.C
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter runoff travel-length through subarea(FEET).... ===>2.1.D
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]
    (NOTE: SUGGESTED RANGE(FEET) IS [0.01] TO [1000])

    Enter Total Number of Homogeneous Cells in Subarea.. ===>2.1.E
    :ALLOWABLE VALUES ARE [1     ] TO [6         ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

2.1.B. UPSTREAM ELEVATION:

The elevation of the most remote point of the subarea is generally used for the initial subarea Tc estimation.

2.1.C. DOWNSTREAM ELEVATION:

The elevation at the subarea downstream concentration point (i.e., the subarea outlet).

2.1.D. RUNOFF TRAVEL-LENGTH:

Runoff travel-length is generally the length of the flowpath from the most remote point of the subarea to the concentration point.

2.1.E. HOMOGENEOUS REGION:

A subarea may contain different SCS soil groups and/or different development types. The Number of Homogeneous Regions refers to the number of smaller areas which have a uniform soil group and development type. A maximum of 6 per subarea are allowed in this Program. If more, subdivide the subarea into smaller areas.

2.1, page 2

```
------------------------ Initial Subarea Analysis ------------- page 2

   HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    "URBAN" LAND USE OR DEVELOPMENT TYPE   -   (% PERVIOUS):
                            1:            Commercial ( 10%)
                            2:      Mobile Home Park ( 25%)
                            3:            Apartments ( 20%)
                            4:          Condominiums ( 35%)
              ----------    5:   11+  Dwellings/Acre ( 20%)
             |              6:   8-10 Dwellings/Acre ( 40%)
        SINGLE FAMILY       7:    5-7 Dwellings/Acre ( 50%)
         RESIDENTIAL        8:    3-4 Dwellings/Acre ( 60%)
             |              9:      2 Dwellings/Acre ( 70%)
             |             10:       1 Dwelling/Acre ( 80%)
              ----------   11:      .4 Dwelling/Acre ( 90%)
                           12:                School ( 60%)
                           13:           Public Park ( 85%)

    *Note: Press RETURN to Display NATURAL COVERS*
    Select cell # 1 development classification NUMBER... ===>2.1.F

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

2.1.F. DEVELOPMENT TYPE:

Runoff coefficients and the loss rates may be estimated by use of the Development Type Table given on this input page. The Table shows several classifications by development type name, dwellings per acre, and percent pervious. Generally, impervious areas are assumed to have a zero loss rate and have total runoff. The subarea is defined such as to be generally homogeneous.

```
------------------------ Initial Subarea Analysis ------------- page 3
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    SUB-REGION RUNOFF COEFFICIENT OPTIONS:

        1= Assume soil group A
        2= Assume soil group B
        3= Assume soil group C
        4= Assume soil group D
    Select cell # 1 runoff coefficient option NUMBER.... ===>2.1.G

    Enter subarea cell # 1 area(ACRES).................. ===>2.1.H
    :ALLOWABLE VALUES ARE [.01   ] TO [100   ]
    (NOTE: SUGGESTED TOTAL AREA IS BETWEEN [0.1] AND [10])

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

2.1.G. RUNOFF COEFFICIENT:

The U. S. Soil Conservation Service (SCS) Soil Groups are available to describe soil runoff tendencies; or the USER may elect to describe the soil runoff characteristics directly.

2.1.H. SUBAREA AREA:

The total area of the subject subarea.

2.2. Use Specified Tc Value for Initial Subarea

```
------------------------- Initial Subarea Analysis ------------ page 1


    Initial Subarea Time-of-Concentration Options:

         1. Use Time-of-Concentration Nomograph for Initial Subarea
         2. Use Specified Tc Value for Initial Subarea

    Select option NUMBER............................... ===>2.2.A


    Enter Specified Tc(min.) Value...................... ===>2.2.A
    :ALLOWABLE VALUES ARE [5.0   ] TO [60.0      ]

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

2.2.A. INITIAL SUBAREA Tc:

Initial Subarea Tc estimates can be computed by use of a nomograph, or by the USER specifying a Tc value (in minutes). Generally, the Initial Subarea may be a principal contributor to downstream Tc estimates; the USER needs to apply caution in the Initial Subarea Tc estimate.

```
---------------------- Initial Subarea Analysis ------------- page 1A




    Enter runoff travel-length through subarea(FEET).... ===>2.2.B
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]
    (NOTE: SUGGESTED RANGE(FEET) IS [0.01] TO [1000])


    Enter Total Number of Homogeneous Cells in Subarea.. ===>2.2.C
    :ALLOWABLE VALUES ARE [1     ] TO [6         ]




_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

Go to 2.1, page 2

2.2.B. RUNOFF TRAVEL-LENGTH:

Runoff travel-length is generally the length of the flowpath from the most remote point of the subarea to the concentration point.

2.2.C. HOMOGENEOUS REGION:

A subarea may contain different SCS soil groups and/or different development types. The Number of Homogeneous Regions refers to the number of smaller areas which have a uniform soil group and development type. A maximum of 6 per subarea are allowed in this Program. If more, subdivide the subarea into smaller areas.

3. Computer Estimated Pipe/Box Size -- Menu

```
    COMPUTER ESTIMATED PIPE/BOX SIZE MODEL OPTIONS:

        1: Size PIPE for Total Flow Pickup at Upstream Node #      4.00
        2: Size PIPE such that Streetflow Does Not Exceed
           User-Specified Depth Limits at Downstream Node #      5.00
        3: Coupled Street and USER Specified-Pipe Flow Model,
           with REPLACEMENT and PARALLEL Pipesize Estimated to
           satisfy streetflow depth criteria at Downstream Node #  5.00
        4: (N/A)
        5: (N/A)
        6: Size BOX for Total Flow Pickup at Upstream Node #      4.00
        7: (N/A)
        8: (N/A)
        9: (N/A)

    Select option NUMBER................................ ===>3.1.A


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

3.1.A. PIPE/BOX FLOW MODEL OPTIONS:

YOU can select whether to size pipes assuming a total flow pickup at the Upstream Node, or to achieve the flow depth constraints (defined by YOU) in the street at the Downstream Node.

An assumption made in the Program is that the runoff pickup(into the pipe/box) only occurs at the Upstream Node. Consequently, the pipe/ box is sized based on Upstream Node flow rates, the gradient between nodal elevations, and Manning's Equation.

For Coupled Street and Pipe flow modeling, YOU specify a street section from the STREETFLOW SECTION Table to be used uniformly in the model link element through the subarea.

The Street Flow Capacity is computed as the streetflow design objective to occur at the Downstream Node. The runoff peak flowrate at the Downstream Node is the sum of the pipe and street flow rates. The Program iterates until the constructable pipe section runoff traveltime approximately balances with the Downstream Node time-of-concentration value(Tc).

It is noted that with this Coupled model, flows are modeled to include "bubble-out" options at the Upstream Node in order to meet YOUR streetflow carrying capacity constraints at the Downstream Node. Consequently, YOU must evaluate this "bubbling-out" modeling objective, and where necessary YOU may elect to User-Specify the Pipesize to be used (see Menu). Also, it needs to be noted that this Program computes subarea runoff additions at the Mainline Tc value; consequently, YOU need to evaluate Subarea peak flow rates for streetflow capacity analysis, because the subarea Tc is generally smaller than the Mainline Tc, resulting in higher peak flowrates for the subarea had the subarea Tc analysis been made. A crude estimate of the Initial Subarea flowrate is made in the PROGRAM, using the length of the street LINK, and the elevation drop in the nodes as Initial Subarea data. Generally, the HGL is designed to be parallel to the mean topographic gradient. Additionally, the pipe system is placed parallel to the topographic gradient, or at a prescribed minimum gradient(otherwise, there will be excess excavation costs or pipe cover problems). Both of these conditions may be generally satisfied by assuming the HGL to be parallel with the topographic gradient(if draining downstream!).

That is, the gradient of the energy grade line is approximately equal to the mean topographic gradient, as averaged over a sufficiently large distance. There are no other supplies of energy, unless pumps, or other means, are introduced.

If the gradient of the hydraulic grade line is steeper than the topographic gradient for a significant distance, then the HGL may surface above the street or topography. Thus, the HGL gradient should be, in general, less than or equal to the mean topographic gradient. If the HGL gradient is flatter than the topographic gradient for a significant distance, then a more economic pipe system may be available in which the pipe system size can reduced.

In the coupled street and pipeflow model, the maximum amount of water carried in the pipe system is the upstream node total flow rate (as there are no other inflow points until the next downstream node is reached). Additionally, it is assumed that inflow catch basins and laterals are sized to allow any runoff to enter the pipe system that the pipe system can carry. Under these assumptions, a straight reach of pipe generally flows full when the supply of runoff tributary to the pipe exceeds the pipe capacity. Such conditions usually occur when street flow is significant throughout the reach under study. For such conditions, this PROGRAM computes flow velocity based upon FULL pipe flow (i.e., full flow capacity with the friction slope set equal to the pipe flow line slope), with the HGL gradient parallel with the mean local topographic gradient. In this PROGRAM, system flow carrying deficiencies and new systems are computed to obtain an HGL (and EGL) gradient parallel to the mean local topographic gradient. Minor energy loss computations are included via the adjustment factor selected by YOU in the PROGRAM CONTROLS. YOU need to verify the computed system sizes as to reasonableness and appropriateness.

Option 3 provides several models in one hydrologic link process:

1. Estimate hydrologic routing by using the existing pipe hydraulic characteristics.
2. Based on street flow depth conditions, test whether the existing pipe is satisfactory. If so, the existing pipe system is assumed to be adequate, and the hydrologic data used, and the LINK PROCESS is finished.
3. If the existing pipe system cannot satisfy YOUR streetflow depth constraints, then a new pipe (replacement) is sized, to meet the streetflow depth constraints, such as OPTION 2, (code 3.2).
4. Upon development of the Replacement system, hydrologic data is recomputed, and the streetflow re-analyzed based upon the constructable pipe size determined.
5. If the constructable pipe can carry all the upstream flows (entering the LINK), then the pipe flow velocity is based upon normal depth. If flow by-passed the upstream node of the LINK, then pipe flow velocity is based upon full pipe flow.
6. A PARALLEL line size is estimated, based upon the Replacement system hydrology, by finding that constructable pipe size which carries the incremental flow not carried by the existing pipe system, given the street flowdepth constraints.
7. For all the above steps, the pipes are required to carry all pipeflow from the upstream link, unless "burp-out" conditions are specified.

3.1, 3.2, 3.3

```
----------------- Pipe-Flow Travel Time through Subarea -------- page 1

    Enter upstream node      4.00 elevation(FEET)....... ===>3.1.B
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node      5.00 elevation(FEET)..... ===>3.1.C
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter pipe length through subarea(FEET)............. ===>3.1.D
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]

    Enter Manning's friction factor for pipe............ ===>3.1.E
    (NOTE: FOR RCP USE n = .013;
           FOR CSP(or CMP) USE n = .024;
           or Press Return to USE n = .0130)
    :ALLOWABLE VALUES ARE [.005  ] TO [.9999 ]

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

If 3.1 (Total Flow Pickup), stop. For 3.2, 3.3, continue--

3.1.B. UPSTREAM ELEVATION:

The elevation at the upstream end of the runoff hydraulic element conveyance system. Each "link" is analyzed by the PROGRAM for peak flow normal depth hydraulics for flow velocity estimation purposes. It may sometimes be appropriate to enter nodal elevations that better approximate the Manning's Equation friction slope for normal depth computations. The PROGRAM uses the UPSTREAM and DOWNSTREAM nodal elevations, and the LENGTH of the link, to compute HGL and EGL gradients for use in Manning's Equation.
The Manning's equation friction slope is then set equal to the gradient defined by YOUR nodal elevations and YOUR flowpath length.

3.1.C. DOWNSTREAM ELEVATION:

The elevation at the downstream end of the runoff conveyance system, used for normal depth hydraulics computations.

3.1.D. LENGTH:

The length of the runoff conveyance system, used in Manning's Equation for normal depth computations.

3.1.E. MANNING'S FRICTION FACTOR:

Manning's equation is generally used to describe friction energy losses. For normal depth flow,

$$Q = \frac{c}{n} A R^{.67} S^{.5}$$

where Q is the steady flow rate, A is the flow area, R is the hydraulic radius, and S is the gradient of the HGL and EGL which, in normal depth flow, is the slope of the pipe. The parameter, n, is the Manning's friction factor. The constant "c" is a unit conversion factor.

3.3(USER Specified Pipeflow Model, Estimate Parallel/Replacement) ONLY:

```
---------------- Pipe-Flow Travel Time through Subarea --------- page 2


    Enter diameter of given pipe size(INCHES)........... ===>3.3.E
    :ALLOWABLE VALUES ARE [3         ] TO [240       ]

    Enter number of pipes in subarea reach.............. ===>3.3.F
    :ALLOWABLE VALUES ARE [1         ] TO [3         ]



_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

3.3.E. PIPE DIAMETER:

The pipe diameter is the pipe circumference divided by pi.

3.3.F. NUMBER OF PIPES:

For more than one pipe in the link, the peak flow rate is assumed in the PROGRAM to be evenly distributed between all the pipes.

3.2(User-Specified Depth Limits), and 3.3, continued:

```
    HALF-   CROWN TO  STREET-CROSSFALL:  CURB GUTTER-GEOMETRIES: MANNING
    WIDTH   CROSSFALL IN-  / OUT-/PARK-  HEIGHT WIDTH LIP HIKE   FACTOR
NO. (FT)     (FT)     SIDE / SIDE/ WAY    (FT)  (FT) (FT) (FT)    (n)
=== =====   ========= ================= ====== ===== ==== ====  =======
  1  30.0     20.0    .018/ .018/ .020    .67   2.00 .03125 .1670 .01500
  2  40.0     20.0    .017/ .017/ .020    .50   1.50 .03125 .1250 .01500



  Enter Street-Section Number......................... ===>3.2.E
  :ALLOWABLE VALUES ARE [1     ] TO [ 2    ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
  COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
  TYPE: D to display COMMAND definitions
```

3.2.E. STREET SECTION NUMBER:

The Street-Section Number follows from the Streetflow Section Table YOU defined in the Program Controls.

```
    STREET FLOW OPTIONS:
        1: Runoff flows on one side of the street
        2: Runoff flows evenly on both sides of the street
    Select streetflow option desired.................... ===>3.2.F

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

3.2.F. STREET FLOW OPTIONS:

Two options are available in the PROGRAM for computing normal depth hydraulics in the streetflow model: (1) assume the peak flow is all on one side of the street; or (2) assume the peak flow to be evenly split, hence, one-half of the peak flow is on each side of the street.
The STREETFLOW model, like the "V"-Gutter model, includes a hydrologic element component in that the street generally accumulates runoff along the length of the street.
The PROGRAM computes traveltime estimates of the average runoff peak flow rate through the subarea that the street traverses.

```
DEVELOP STREETFLOW "MAXIMUM ALLOWABLE DEPTH"

    Enter Maximum Allowable Street Flow-Depth(FEET);
    or Press Return for Next Option.................... ===> 3.2.F1
    :ALLOWABLE VALUES ARE [.01   ] TO [5.0   ]

    Relative Flow-Depth(FEET) as (Maximum Allowable
    Street Flow-Depth) - (Top-of-Curb)................. ===>   .00
    :ALLOWABLE VALUES ARE [-0.5  ] TO [5.0   ]

    Enter (Depth)*(Velocity) Constraint(FT*FT/S);
    or Press Return to use "6"......................... ===> 3.2.F2
    :ALLOWABLE VALUES ARE [.1    ] TO [10.   ]




    * Streetflow Maximum Allowable Depth =    .50 FEET.*

_____________________________________ RATSCx -----[ORANGE COUNTY]------
             Press T to Top of Page or Return to continue ===>
```

3.2.F1. ALLOWABLE STREET FLOWDEPTH:

The maximum allowable depth of flow in the street can be expressed as a specified depth, or relative to the street top-of-curb by subtracting: (allowable flow-depth) minus (street to-of-curb). These two values are linked, and so only one of the two values are requested as input. YOU may change all such constraints in the GLOBAL EDITING FUNCTIONS (see Editor).

3.2.F2. DEPTH*VELOCITY CONSTRAINT

A frequently used constraint is the product of street flow-depth and the flow velocity. This constraint corresponds to a flow depth, which is then used in the PROGRAM as a flow depth constraint. These values can be changed throughout the data bank by the GLOBAL EDITING FUNCTIONS (see Editor).

```
------------- Addition of Subarea to Mainline Peak Flow -------- page 1








    Enter Total Number of Homogeneous Cells............. ===>3.2.G
    :ALLOWABLE VALUES ARE [1     ] TO [6         ]



_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

3.2.G. HOMOGENEOUS REGION:

A subarea may contain different SCS soil groups and/or different development types. The Number of Homogeneous Regions refers to the number of smaller areas which have a uniform soil group and development type. A maximum of 6 per subarea are allowed in this Program. If more, subdivide the subarea into smaller areas.

```
--------------- Addition of Subarea to Mainline Peak Flow ------ page 2
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    "URBAN" LAND USE OR DEVELOPMENT TYPE   -   (% PERVIOUS):
                        1:           Commercial ( 10%)
                        2:      Mobile Home Park ( 25%)
                        3:           Apartments ( 20%)
                        4:         Condominiums ( 35%)
             ----------    5:   11+  Dwellings/Acre ( 20%)
            |              6:   8-10 Dwellings/Acre ( 40%)
        SINGLE FAMILY      7:    5-7 Dwellings/Acre ( 50%)
         RESIDENTIAL       8:    3-4 Dwellings/Acre ( 60%)
            |              9:      2 Dwellings/Acre ( 70%)
            |             10:       1 Dwelling/Acre ( 80%)
             ----------   11:      .4 Dwelling/Acre ( 90%)
                          12:               School ( 60%)
                          13:          Public Park ( 85%)

    *Note: Press RETURN to Display NATURAL COVERS*
    Specify assumed uniform subarea land use/development ===>3.2.H

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

3.2.H. DEVELOPMENT TYPE:

Runoff coefficients and the loss rates may be estimated by use of the Development Type Table given on this input page. The Table shows several classifications by development type name, dwellings per acre, and percent pervious. Generally, impervious areas are assumed to have a zero loss rate and have total runoff. The subarea is defined such as to be generally homogeneous.

```
------------- Addition of Subarea to Mainline Peak Flow -------- page 3
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    SUBAREA RUNOFF COEFFICIENT OPTIONS:

        1= Assume soil group A
        2= Assume soil group B
        3= Assume soil group C
        4= Assume soil group D
    Select Cell # 1 runoff coefficient option NUMBER.... ===>3.2.I



    Enter Subarea Cell #  1 area(ACRES)................. ===>3.2.J
    :ALLOWABLE VALUES ARE [0.0   ] TO [9999  ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

3.2.I. RUNOFF COEFFICIENT:

The U. S. Soil Conservation Service (SCS) Soil Groups are available to describe soil runoff tendencies; or the USER may elect to describe the soil runoff characteristics directly.

3.2.J. SUBAREA AREA:

The total area of the subject subarea.

3.6 Size BOX for Total Flow Pickup

```
---------------- BOX-Flow Travel Time through Subarea ---------- page 1


    Enter upstream node      4.00 elevation(FEET)....... ===>3.6.A
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node      5.00 elevation(FEET)..... ===>3.6.B
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter Box length through subarea(FEET).............. ===>3.6.C
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]

    Enter Manning's friction factor for BOX............. ===>3.6.D
    :ALLOWABLE VALUES ARE [.005  ] TO [.9999 ]







_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

3.6.A. UPSTREAM ELEVATION:

The elevation at the upstream end of the runoff hydraulic element conveyance system. Each "link" is analyzed by the PROGRAM for peak flow normal depth hydraulics for flow velocity estimation purposes. It may sometimes be appropriate to enter nodal elevations that better approximate the Manning's Equation friction slope for normal depth computations. The PROGRAM uses the UPSTREAM and DOWNSTREAM nodal elevations, and the LENGTH of the link, to compute HGL and EGL gradients for use in Manning's Equation.
The Manning's equation friction slope is then set equal to the gradient defined by YOUR nodal elevations and YOUR flowpath length.

3.6.B. DOWNSTREAM ELEVATION:

The elevation at the downstream end of the runoff conveyance system, used for normal depth hydraulics computations.

3.6.C. LENGTH:

The length of the runoff conveyance system, used in Manning's Equation for normal depth computations.

3.6.D. MANNING'S FRICTION FACTOR:

Manning's equation is generally used to describe friction energy losses. For normal depth flow,

$$Q = \frac{c}{n} A R^{.67} S^{.5}$$

where Q is the steady flow rate, A is the flow area, R is the hydraulic radius, and S is the gradient of the HGL and EGL which, in normal depth flow, is the slope of the pipe. The parameter, n, is the Manning's friction factor. The constant "c" is a unit conversion factor.

```
---------------- BOX-Flow Travel Time through Subarea ---------- page 2




    BOX Height to Basewidth Relationship Options:
        1: USER specified BOX Basewidth
        2: USER specified Ratio of Height/Basewidth
    Select option NUMBER................................ ===>3.6.E

    Enter basewidth of estimated BOX size(FEET)......... ===>3.6.E
    :ALLOWABLE VALUES ARE [1         ] TO [100       ]






_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

3.6.E. COMPUTER ESTIMATED BOX SIZE:

The two OPTIONS available to YOU will be used to size the BOX element between nodal points. Total flow pickup is assumed in the BOX at the upstream node, with no inflow to the BOX between nodes. The BOX is sized using Manning's equation for pressure flow, with the friction slope set equal to the product of the topographic slope(as defined by YOU) multiplied by the friction slope adjustment factor used for pipe sizing defined by YOU in the PROGRAM CONTROL section of data input. The PROGRAM computes the BOX size needed; YOU need to recommend a constructable BOX size.

```
---------------- BOX-Flow Travel Time through Subarea ---------- page 2


    BOX Height to Basewidth Relationship Options:
        1: USER specified BOX Basewidth
        2: USER specified Ratio of Height/Basewidth
    Select option NUMBER................................ ===>3.6.E

    Enter Ratio of Height/Basewidth..................... ===>3.6.E
    :ALLOWABLE VALUES ARE [.2        ] TO [5         ]










_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

4. User-Specified Pipe/Box Size -- Menu

```
    USER Specified PIPE/BOX SYSTEM MODEL OPTIONS:

        1: Assume Total Flow Pickup into USER Specified Pipe System
           (i.e., forced flow)
        2: Analyze USER Specified Pipe System with PARALLEL and
           REPLACEMENT Pipesize Estimated (all flow is carried in
           pipeflow)
        3: Hydrologic Analysis of USER Specified Pipe System with
           Coupled Streetflow (Models existing pipe and street system
           with traveltime based on pipeflow velocity)
        4: (N/A)
        5: (N/A)
        6: Assume Total Flow Pickup into USER Specified BOX System
           (i.e., forced flow)
        7: (N/A)
        8: (N/A)
        9: (N/A)

    Select option NUMBER................................ ===>4.1.A


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

4.1.A. EXISTING PIPE FLOW MODEL OPTION:

This model has three Options:

1. total peak flow is routed through the pipe, such that flow velocity (under pressure) is (peak Q)/(full pipe area). There is zero streetflow modeled.

2. in Option 2, the existing pipe flow capacity is based on Manning's equation, using the entered nodal elevation to compute the friction slope. Residual flows not carried by the existing pipe are picked up by a parallel pipe, or the existing pipe is sized to carry all flows. There is zero streetflow modeled. This Option is useful in Deficiency analysis.

3. in Option 3, the Manning's equation is used(using nodal elevations for friction slope) to compute pipe flow velocity. Flows in excess of the pipe flow capacity are carried in the street section. Street flows are then analyzed as to hydraulic properties.

4.1, 4.2, 4.3, 4.6, page 1

```
---------------- Pipe-Flow Travel Time through Subarea --------- page 1


    Enter upstream node      5.00 elevation(FEET)....... ===>4.1.B
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node      6.00 elevation(FEET)..... ===>4.1.C
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter pipe length through subarea(FEET)............. ===>4.1.D
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]

    Enter Manning's friction factor for pipe............ ===>4.1.E
    (NOTE: FOR RCP USE n = .013;
           FOR CSP(or CMP) USE n = .024;
           or Press Return to USE n = .0130)
    :ALLOWABLE VALUES ARE [.005  ] TO [.9999 ]




_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

4.1.B. UPSTREAM ELEVATION:

The elevation at the upstream end of the runoff hydraulic element conveyance system. Each "link" is analyzed by the PROGRAM for peak flow normal depth hydraulics for flow velocity estimation purposes. It may sometimes be appropriate to enter nodal elevations that better approximate the Manning's Equation friction slope for normal depth computations. The PROGRAM uses the UPSTREAM and DOWNSTREAM nodal elevations, and the LENGTH of the link, to compute HGL and EGL gradients for use in Manning's Equation.
The Manning's equation friction slope is then set equal to the gradient defined by YOUR nodal elevations and YOUR flowpath length.

4.1.C. DOWNSTREAM ELEVATION:

The elevation at the downstream end of the runoff conveyance system, used for normal depth hydraulics computations.

4.1.D. LENGTH:

The length of the runoff conveyance system, used in Manning's Equation for normal depth computations.

4.1.E. MANNING'S FRICTION FACTOR:

Manning's equation is generally used to describe friction energy losses. For normal depth flow,

$$Q = \frac{c}{n} A R^{.67} S^{.5}$$

where Q is the steady flow rate, A is the flow area, R is the hydraulic radius, and S is the gradient of the HGL and EGL which, in normal depth flow, is the slope of the pipe. The parameter, n, is the Manning's friction factor. The constant "c" is a unit conversion factor.

4.1, 4.2, 4.3, page 2 (note: 4.2 does not show Financial Planning)

```
---------------- Pipe-Flow Travel Time through Subarea --------- page 2


    Enter diameter of given pipe size(INCHES)........... ===>4.1.F
    :ALLOWABLE VALUES ARE [3         ] TO [240       ]

    Enter number of pipes in subarea reach.............. ===>4.1.G
    :ALLOWABLE VALUES ARE [1         ] TO [3         ]

    Select Financial Planning STATUS Designation........ ===>4.1.H

        1: INCLUDE this Element in the Deficiency Mitigation
           Cost Opinion and Cost-to-Benefit Index (CBI) Analysis.
        2: Do NOT include this Element in the Deficiency Mitigation
           Cost Opinion and Cost-to-Benefit Index (CBI) Analysis.



_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

For 4.3, only: go to “3.2, and 3.3, continued”

4.1.F. PIPE DIAMETER:

The pipe diameter is the pipe circumference divided by pi.

4.1.G. NUMBER OF PIPES:

For more than one pipe in the link, the peak flow rate is assumed in the PROGRAM to be evenly distributed between all the pipes.

4.1.H. FINANCIAL PLANNING STATUS:

YOU have the OPTION of including or excluding this particular element in the Deficiency Mitigation Cost Opinion and CBI analysis. For example, for elements that are exterior of your financial plan study area, YOU may wish to select OPTION #2. Note that User-Specified LINK Elements are typically Existing System Elements that already exist and are a functioning part of the system. The PROGRAM assumes there are no costs associated to an User-Specified LINK element. However, if a Mitigation is needed to offset an estimated drainage deficiency, that Deficiency Mitigation element has an associated COST opinion that the PROGRAM includes in its financial planning modules (unless YOU specify the PROGRAM to NOT include the subject Mitigation element in the financial planning; i.e., OPTION #2).

4.6, page 2

```
---------------- BOX-Flow Travel Time through Subarea ---------- page 2


    Enter basewidth of given BOX size(FEET)............. ===>4.6.E
    :ALLOWABLE VALUES ARE [1         ] TO [100       ]

    Enter height of given BOX size(FEET)................ ===>4.6.E
    :ALLOWABLE VALUES ARE [1         ] TO [20        ]

    Select Financial Planning STATUS Designation........ ===>4.6.F

        1: INCLUDE this Element in the Deficiency Mitigation
           Cost Opinion and Cost-to-Benefit Index (CBI) Analysis.
        2: Do NOT include this Element in the Deficiency Mitigation
           Cost Opinion and Cost-to-Benefit Index (CBI) Analysis.






_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

4.6.E. USER SPECIFIED BOX SIZE:

For a USER specified BOX size, the PROGRAM computes travel time simply as Q/A for pressure flow conditions. If the BOX flows open(according to Manning's equation applied to the link independent of all other links), a normal depth is computed.

4.6.F. FINANCIAL PLANNING STATUS:

YOU have the OPTION of including or excluding this particular element in the Deficiency Mitigation Cost Opinion and CBI analysis. For example, for elements that are exterior of your financial plan study area, YOU may wish to select OPTION #2. Note that User-Specified LINK Elements are typically Existing System Elements that already exist and are a functioning part of the system. The PROGRAM assumes there are no costs associated to an User-Specified LINK element. However, if a Mitigation is needed to offset an estimated drainage deficiency, that Deficiency Mitigation element has an associated COST opinion that the PROGRAM includes in its financial planning modules (unless YOU specify the PROGRAM to NOT include the subject Mitigation element in the financial planning; i.e., OPTION #2).

5. Open Channel traveltime

```
--- DATA ENTRY FOR OPEN CHANNEL TRAVEL TIME ---PAGE 1

    OPEN CHANNEL TRAVELTIME OPTIONS:
        1: USER Specified CHANNEL for total flow pickup
           at Upstream Node #     7.00
        2: Use natural VALLEY channel nomograph
           (Ref: LACFCD Hydrology Manual)
        3: Use natural MOUNTAIN channel nomograph
           (Ref: LACFCD Hydrology Manual)
        4: (N/A)
        5: (N/A)
        6: Computer Estimated CHANNEL for total flow pickup
           at Upstream Node #     7.00
        7: (N/A)
        8: (N/A)
        9: (N/A)
    Select option NUMBER................................ ===>5.1.A


    (NOTE: LACFCD = Los Angeles County Flood Control District)


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

5.1.A. CHANNEL TRAVEL TIME:

Three different "open channel" type algorithms are available as shown. The TRAPEZOIDAL channel algorithm computes travel time of peak flow in a reach for normal depth flow, given data based on Manning's Equation.
The LACFCD Natural Valley/Mountain flow velocity nomographs are also available (such as used in the Riverside County Hydrology Manual, among others).

All of these options result in a normal depth flow type hydraulic computation, with a flow velocity estimate used to compute travel time.

5.1, 5.6

```
    --- DATA ENTRY FOR OPEN CHANNEL TRAVEL TIME ---PAGE 2


    Enter upstream node      7.00 elevation(FEET)....... ===>5.1.B
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node      8.00 elevation(FEET)..... ===>5.1.C
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter channel length through subarea(FEET).......... ===>5.1.D
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]

    Enter Manning's friction factor for channel......... ===>5.1.E
    (NOTE: FOR CONCRETE SECTIONS,   USE n = .015
           FOR GOOD EARTH CHANNELS, USE n = .03
     SEE COUNTY MANUAL FOR MORE INFORMATION)
    :ALLOWABLE VALUES ARE [.005  ] TO [.9999 ]




_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

5.1: go to 5.1, page 3; 5.6: go to 5.6, page 3

5.1.B. UPSTREAM ELEVATION:

The elevation at the upstream end of the runoff hydraulic element conveyance system. Each "link" is analyzed by the PROGRAM for peak flow normal depth hydraulics for flow velocity estimation purposes. It may sometimes be appropriate to enter nodal elevations that better approximate the Manning's Equation friction slope for normal depth computations. The PROGRAM uses the UPSTREAM and DOWNSTREAM nodal elevations, and the LENGTH of the link, to compute HGL and EGL gradients for use in Manning's Equation.
The Manning's equation friction slope is then set equal to the gradient defined by YOUR nodal elevations and YOUR flowpath length.

5.1.C. DOWNSTREAM ELEVATION:

The elevation at the downstream end of the runoff conveyance system, used for normal depth hydraulics computations.

5.1.D. LENGTH:

The length of the runoff conveyance system, used in Manning's Equation for normal depth computations.

5.1.E. MANNING'S FRICTION FACTOR:

Normal Depth hydraulics is assumed when computing travel time and flow velocities. Depending on channel type, Manning's n varies. For example, the OCEMA Design Manual provides the following parameter values:

TABLE (from OCEMA Design Manual)

DESCRIPTION	MANNING'S n
Concrete Sections	
Rectangular...............	.014
Trapezoidal...............	.015
Asphalt Concrete Sections...	.017
Engineered Earth Channels	
Fine sand and silt	
size determination.......	.030
scour determination......	.020
River sand and gravel.....	.025
Coarse gravel mixed	
with boulders............	.035
Rock Slope Protection	
Levee riprap..............	.035
Flush Grouted Riprap........	.020
Sacked Concrete.............	.025
Greenbelt Channels	
Maintained turf...........	.030
Heavily weeded	
no brush.................	.040
moderate shrubs..........	.050
Some weeded, heavy brush...	.060

5.1, page 3

```
    --- DATA ENTRY FOR OPEN CHANNEL TRAVEL TIME ---PAGE 3

    Enter horizontal base width of channel(FEET)........ ===>5.1.F
    :ALLOWABLE VALUES ARE [0] TO [1000. ]

    Enter uniform symmetrical channel "Z" factor........ ===>5.1.G
    (NOTE: THE CHANNEL "Z" FACTOR IS THE SIDE SLOPE
           RATIO OF [HORIZONTAL/VERTICAL]
     EXAMPLE: FOR A 2:1 SIDE SLOPE, "Z"=2)
    :ALLOWABLE VALUES ARE [0] TO [99.99 ]

    Enter maximum allowable depth of flow
    in channel(FEET).................................... ===>5.1.H
    :ALLOWABLE VALUES ARE [.001  ] TO [500   ]

    Select Financial Planning STATUS Designation........ ===>5.1.I

        1: INCLUDE this Element in the Deficiency Mitigation
           Cost Opinion and Cost-to-Benefit Index (CBI) Analysis.
        2: Do NOT include this Element in the Deficiency Mitigation
           Cost Opinion and Cost-to-Benefit Index (CBI) Analysis.

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

5.1.F. BASE WIDTH:

The base width which is used in Manning's Equation is generally less than or equal to the true measured width, depending on debris or other design obstructions in the channel.

5.1.G. SYMMETRICAL SIDE SLOPE:

A Symmetrical side slope is assumed in this PROGRAM. A "Z = 0" corresponds to a rectangular channel.

5.1.H. MAXIMUM ALLOWABLE DEPTH:

The PROGRAM computes normal depth, but the normal depth may exceed the allowable design flow-depth limits of the channel. The PROGRAM therefore computes normal depth hydraulics based upon the "maximum allowable depth of flow", and if the subject flowrate exceeds this computed "maximum" flow, the model notifies the USER, and the PROGRAM continues by computing travel time and hydraulics based upon the given flowrate and the "maximum" flow area (this use of "maximum" flow area results in flow velocities that are faster than the actual normal depth velocities, and hence travel times are computed that are smaller in value than those based upon normal depth hydraulics). Generally, one uses the depth of the channel as the Maximum Allowable Depth.

5.1.I. FINANCIAL PLANNING STATUS:

YOU have the OPTION of including or excluding this particular element in the Deficiency Mitigation Cost Opinion and CBI analysis. For example, for elements that are exterior of your financial plan study area, YOU may wish to select OPTION #2. Note that User-Specified LINK Elements are typically Existing System Elements that already exist and are a functioning part of the system. The PROGRAM assumes there are no costs associated to an User-Specified LINK element. However, if a Mitigation is needed to offset an estimated drainage deficiency, that Deficiency Mitigation element has an associated COST opinion that the PROGRAM includes in its financial planning modules (unless YOU specify the PROGRAM to NOT include the subject Mitigation element in the financial planning; i.e., OPTION #2).

5.2. Use natural VALLEY channel nomograph

```
--- DATA ENTRY FOR OPEN CHANNEL TRAVEL TIME ---PAGE 2


    Enter upstream node      7.00 elevation(FEET)....... ===>5.2.A
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node      8.00 elevation(FEET)..... ===>5.2.B
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter channel length through subarea(FEET).......... ===>5.2.C
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]









_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

5.2.A. UPSTREAM ELEVATION:

The elevation at the upstream end of the runoff hydraulic element conveyance system. Each "link" is analyzed by the PROGRAM for peak flow normal depth hydraulics for flow velocity estimation purposes. It may sometimes be appropriate to enter nodal elevations that better approximate the Manning's Equation friction slope for normal depth computations. The PROGRAM uses the UPSTREAM and DOWNSTREAM nodal elevations, and the LENGTH of the link, to compute HGL and EGL gradients for use in Manning's Equation.
The Manning's equation friction slope is then set equal to the gradient defined by YOUR nodal elevations and YOUR flowpath length.

5.2.B. DOWNSTREAM ELEVATION:

The elevation at the downstream end of the runoff conveyance system, used for normal depth hydraulics computations.

5.2.C. LENGTH:

The length of the runoff conveyance system, used in Manning's Equation for normal depth computations.

5.3. Use natural MOUNTAIN channel nomograph

```
--- DATA ENTRY FOR OPEN CHANNEL TRAVEL TIME ---PAGE 1

    OPEN CHANNEL TRAVELTIME OPTIONS:














    NATURAL MOUNTAIN CHANNEL SLOPE ADJUSTMENT OPTIONS:
        1 : Use Slope adjustment curve
           (see LACFCD Hydrology Manual)
        2 : Do NOT use Slope adjustment curve
    Select option desired............................... ===>5.3.A

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

Go to 5.2

5.3.A. SLOPE ADJUSTMENT:

The LACFCD nomograph (Figure C-11 of Hydrology Manual, Revised 1989) includes a slope adjustment for its Natural Mountain flow velocity estimates in order to account for vertical drops and other such effects.

5.6, page 3

```
--- DATA ENTRY FOR OPEN CHANNEL TRAVEL TIME ---PAGE 3

    Enter channel FREEBOARD(FEET)....................... ===>5.6.E
    :ALLOWABLE VALUES ARE [0] TO [10.   ]

    Enter uniform symmetrical channel "Z" factor........ ===>5.6.F
    (NOTE: THE CHANNEL "Z" FACTOR IS THE SIDE SLOPE
           RATIO OF [HORIZONTAL/VERTICAL]
     EXAMPLE: FOR A 2:1 SIDE SLOPE, "Z"=2)
    :ALLOWABLE VALUES ARE [0] TO [99.99 ]

    Channel Height to Basewidth Relationship Options:
        1: USER specified Channel Basewidth
        2: USER specified Ratio of Height/Basewidth
    Select option NUMBER................................ ===>5.6.G

    Option 1:
    Enter basewidth of estimated Channel size(FEET)..... ===>5.6.G
    :ALLOWABLE VALUES ARE [1         ] TO [300       ]

    ~ or ~

    Option 2:
    Enter Ratio of Height/Basewidth..................... ===>5.6.G
    :ALLOWABLE VALUES ARE [.2        ] TO [5         ]



_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

5.6.E. CHANNEL FREEBOARD:

FREEBOARD is usually an Agency specified criteria. In this PROGRAM, Channel HEIGHT equals the sum of FREEBOARD plus the flow normal DEPTH.

5.6.F. SYMMETRICAL SIDE SLOPE:

A Symmetrical side slope is assumed in this PROGRAM. A "Z = 0" corresponds to a rectangular channel.

5.6.G. COMPUTER ESTIMATED CHANNEL SIZE:

The two OPTIONS available to YOU in this PROGRAM for channel sizing is used directly in Manning's equation with the friction slope set equal to the topographic gradient defined by YOU. In this PROGRAM, Channel HEIGHT equals the sum of FREEBOARD plus the flow normal DEPTH.

6. STREETFLOW Analysis Through Subarea

```
--------------------- STREETFLOW through Subarea --------------- page 1



    Enter upstream node      8.00 elevation(FEET)....... ===>6.1.A
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node      9.00 elevation(FEET)..... ===>6.1.B
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter runoff travel-length through subarea(FEET).... ===>6.1.C
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]


    Enter Total Number of Homogeneous Cells in Subarea.. ===>6.1.D
    :ALLOWABLE VALUES ARE [1     ] TO [6         ]





_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

6.1.A. UPSTREAM ELEVATION:

The elevation of the most remote point of the subarea is generally used for the initial subarea Tc estimation.

6.1.B. DOWNSTREAM ELEVATION:

The elevation at the subarea downstream concentration point (i.e., the subarea outlet).

6.1.C. RUNOFF TRAVEL-LENGTH:

Runoff travel-length is generally the length of the flowpath from the most remote point of the subarea to the concentration point.

6.1.D. HOMOGENEOUS REGION:

A subarea may contain different SCS soil groups and/or different development types. The Number of Homogeneous Regions refers to the number of smaller areas which have a uniform soil group and development type. A maximum of 6 per subarea are allowed in this Program. If more, subdivide the subarea into smaller areas.

```
--------------------- STREETFLOW through Subarea --------------- page 2
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    "URBAN" LAND USE OR DEVELOPMENT TYPE   -   (% PERVIOUS):
                           1:           Commercial ( 10%)
                           2:      Mobile Home Park ( 25%)
                           3:           Apartments ( 20%)
                           4:         Condominiums ( 35%)
              ----------   5:   11+  Dwellings/Acre ( 20%)
             |             6:   8-10 Dwellings/Acre ( 40%)
        SINGLE FAMILY      7:    5-7 Dwellings/Acre ( 50%)
         RESIDENTIAL       8:    3-4 Dwellings/Acre ( 60%)
             |             9:      2 Dwellings/Acre ( 70%)
             |            10:       1 Dwelling/Acre ( 80%)
              ----------  11:      .4 Dwelling/Acre ( 90%)
                          12:               School ( 60%)
                          13:          Public Park ( 85%)

    *Note: Press RETURN to Display NATURAL COVERS*
    Select cell # 1 development classification NUMBER... ===>6.1.E

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

6.1.E. DEVELOPMENT TYPE:

Runoff coefficients and the loss rates may be estimated by use of the Development Type Table given on this input page. The Table shows several classifications by development type name, dwellings per acre, and percent pervious. Generally, impervious areas are assumed to have a zero loss rate and have total runoff. The subarea is defined such as to be generally homogeneous.

```
-------------------- STREETFLOW through Subarea ---------------- page 3
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    SUB-REGION RUNOFF COEFFICIENT OPTIONS:

        1= Assume soil group A
        2= Assume soil group B
        3= Assume soil group C
        4= Assume soil group D
    Select cell # 1 runoff coefficient option NUMBER.... ===>6.1.F



    Enter subarea cell # 1 area(ACRES).................. ===>6.1.G
    :ALLOWABLE VALUES ARE [0     ] TO [100   ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

6.1.F. RUNOFF COEFFICIENT:

The U. S. Soil Conservation Service (SCS) Soil Groups are available to describe soil runoff tendencies; or the USER may elect to describe the soil runoff characteristics directly.

6.1.G. SUBAREA AREA:

The total area of the subject subarea.

```
    STREETFLOW MODEL OPTIONS:

        1: Enter Street Cross-Section Information
        2: Select Street Cross-Section from STREETFLOW Table

    Select option NUMBER................................ ===>6.1.H









_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

6.1.H. STREETFLOW MODEL OPTION:

The CONTROLS section of this PROGRAM allowed YOU to defined street cross-sections for used in hydraulics of streetflow. YOU have the choice of using a standard curb face section, or a section from the Table.

6.1: Enter Information

```
------------------- Street Flow through Subarea --------------- page 4

    Enter standard curb height(INCHES).................. ===>6.1.I
    :ALLOWABLE VALUES ARE [6] OR [8]

    Enter the symmetrical street halfwidth(FEET)........ ===>6.1.J
    :ALLOWABLE VALUES ARE [10    ] TO [99.99 ]

    Enter distance from street crown to
    crossfall gradebreak(FEET).......................... ===>6.1.K
    :ALLOWABLE VALUES ARE [1     ] TO [99.99     ]

    Enter CENTER lane street crossfall(DECIMAL)......... ===>6.1.L
    :ALLOWABLE VALUES ARE [.001  ] TO [.5    ]

    Enter OUTSIDE lane street crossfall(DECIMAL)........ ===>6.1.L
    :ALLOWABLE VALUES ARE [.001  ] TO [.5    ]

    Enter PARKWAY crossfall(DECIMAL;100=NO FLOW ON PARKWAY)=>6.1.M
    :ALLOWABLE VALUES ARE [.005  ] TO [.05   ]

____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

6.1.I. CURB HEIGHT:

Two "standard" curb models are available in this model. The specifications used are shown on the screen.

6.1.J. SYMMETRICAL STREET HALFWIDTH:

The streetflow model assumes a symmetrical section. The "halfwidth" is the distance from the street centerline (or "crown") to the street "top of curb". The curb face is modeled to be vertical.

6.1.K. STREET GRADEBREAK:

The symmetrical street section may be modeled to have a gradebreak (i.e., a change in crossfall). This prompt asks for the distance from the street centerline (or crown) to the gradebreak. If there is no gradebreak, enter an appropriate distance (such as one half the "halfwidth") and use the same crossfall for both the Center lane and the Outside lane.

6.1.L. STREET CROSSFALL:

The "crossfall" value is usually in the range of 0.010 to 0.030. The PROGRAM assumes a Manning's n value of 0.015 for each of the Center and Outside lanes in the streetflow gradebreak model.

6.1.M. PARKWAY CROSSFALL:
If flow in the parkway is to be included in the analysis, YOU must enter the crossfall. A crossfall of 100.0 is arbitrarily set to define a near-vertical parkway, with no flow allowed.

6.1, page 5

```
----------------- Street Flow through Subarea ------------------ page 5








    STREETFLOW OPTIONS:
        1: Runoff flows on one side of the street
        2: Runoff flows evenly on both sides of the street
    Select streetflow option desired.................... ===>6.1.N









_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

6.1.N. STREET FLOW OPTIONS:

Two options are available in the PROGRAM for computing normal depth hydraulics in the streetflow model: (1) assume the peak flow is all on one side of the street; or (2) assume the peak flow to be evenly split, hence, one-half of the peak flow is on each side of the street.

The STREETFLOW model, like the "V"-Gutter model, includes a hydrologic element component in that the street generally accumulates runoff along the length of the street.

The PROGRAM computes traveltime estimates of the average runoff peak flow rate through the subarea that the street traverses.

6.2: Select Information from Table

```
    STREETFLOW MODEL OPTIONS:

        1: Enter Street Cross-Section Information
        2: Select Street Cross-Section from STREETFLOW Table

    Select option NUMBER................................ ===>6.2.H

    COUPLED STREET/PIPE FLOW MODEL OPTIONS:

        1: Street carries total runoff
        2: Size pipe only if streetflow constraints are not met
           (Manning's n = 0.013 assumed)

    Select option NUMBER................................ ===>6.2.I


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

6.2.H. STREETFLOW MODEL OPTION:

The CONTROLS section of this PROGRAM allowed YOU to defined street cross-sections for used in hydraulics of streetflow. YOU have the choice of using a standard curb face section, or a section from the Table.

6.2.I. COUPLED STREET/PIPE FLOW MODEL OPTION:

In option 2, streetflow is used for hydrologic calculation initially, and then streetflow constraints are examined to see if they are met. If not satisfied, another hydrologic analysis is made using a constructable pipe sized to meet streetflow constraints. Hydrologic travel-time estimates are then based on the pipeflow velocity.

```
    HALF-  CROWN TO  STREET-CROSSFALL:  CURB GUTTER-GEOMETRIES: MANNING
    WIDTH  CROSSFALL IN-  / OUT-/PARK-  HEIGHT WIDTH LIP HIKE   FACTOR
NO. (FT)     (FT)    SIDE / SIDE/ WAY    (FT)  (FT) (FT) (FT)    (n)
=== =====  ========= =================  ====== ===== ==== ====  =======
  1  30.0    20.0    .018/ .018/ .020    .67   2.00 .03125 .1670 .01500
  2  40.0    20.0    .017/ .017/ .020    .50   1.50 .03125 .1250 .01500


    Enter Street-Section Number......................... ===>6.2.J
    :ALLOWABLE VALUES ARE [1     ] TO [ 2    ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

Go to 6.1, page 5

6.2.J. STREET SECTION NUMBER:

The Street-Section Number follows from the Streetflow Section Table YOU defined in the Program Controls.

(if this Option selected in 6.2)

```
    DEVELOP STREETFLOW "MAXIMUM ALLOWABLE DEPTH"

    Enter Maximum Allowable Street Flow-Depth(FEET);
    or Press Return for Next Option.................... ===> 6.2.K
    :ALLOWABLE VALUES ARE [.01   ] TO [5.0   ]

    Relative Flow-Depth(FEET) as (Maximum Allowable
    Street Flow-Depth) - (Top-of-Curb)................. ===>   .00
    :ALLOWABLE VALUES ARE [-0.5  ] TO [5.0   ]

    Enter (Depth)*(Velocity) Constraint(FT*FT/S);
    or Press Return to use "6"......................... ===> 6.2.L
    :ALLOWABLE VALUES ARE [.1    ] TO [10.   ]




    * Streetflow Maximum Allowable Depth =    .50 FEET.*

_____________________________________ RATSCx -----[ORANGE COUNTY]------
             Press T to Top of Page or Return to continue ===>
```

6.2.K. ALLOWABLE STREET FLOWDEPTH:

The maximum allowable depth of flow in the street can be expressed as a specified depth, or relative to the street top-of-curb by subtracting: (allowable flow-depth) minus (street to-of-curb). These two values are linked, and so only one of the two values are requested as input. YOU may change all such constraints in the GLOBAL EDITING FUNCTIONS (see Editor).

6.2.L. DEPTH*VELOCITY CONSTRAINT

A frequently used constraint is the product of street flow-depth and the flow velocity. This constraint corresponds to a flow depth, which is then used in the PROGRAM as a flow depth constraint. These values can be changed throughout the data bank by the GLOBAL EDITING FUNCTIONS (see Editor).

7. User Specified Hydrologic Data at a Node (Basic/Intermediate Mode)
(for Advanced Mode, switch to Unit Hydrograph Method)

```
--------------- User Specified Hydrology at a Node ------------- page 1

    Enter user-specified time of concentration(MIN.).... ===>7.A
    :ALLOWABLE VALUES ARE [5] TO [1000  ]

    Enter user-specified total area(ACRES) tributary
    to node............................................ ===>7.B
    :ALLOWABLE VALUES ARE [.0001     ] TO [10000     ]

    Enter user-specified EFFECTIVE area(ACRES).......... ===>7.C
    :ALLOWABLE VALUES ARE [.0001     ] TO [10000     ]

    Enter user-specified total runoff(CFS).............. ===>7.D
    :ALLOWABLE VALUES ARE [.0001 ] TO [100000]






_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

7.A. TIME-OF-CONCENTRATION:

YOU have elected to define hydrologic information at a nodal point -- YOUR entered data will over-ride any computer estimates.
With this PROGRAM model, the USER interacts with the computer model by defining information that will be used by the PROGRAM.

The time-of-concentration (Tc) is currently being requested -- this is the Tc from which the Rational Method rainfall data is computed.

7.B. TOTAL AREA:

The total catchment area that may deliver runoff to the point of concentration.

7.C. EFFECTIVE AREA:

The effective area is that portion of the total catchment area, that delivers runoff at the peak flow rate time-of-concentration -- analogous to the concept of contributory area.

7.D. TOTAL RUNOFF:

What is the peak flow rate to be defined with YOUR specified effective area and YOUR specified time-of-concentration?

```
---------------- User Specified Hydrology at a Node ------------ page 2

    Enter pervious loss rate, Fp(INCH/HR)............... ===>7.E
    :ALLOWABLE VALUES ARE [0.01      ] TO [2.00      ]

    Enter pervious area fraction(DECIMAL)............... ===>7.F
    :ALLOWABLE VALUES ARE [0.001     ] TO [1.0       ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

7.E. PERVIOUS LOSS RATE:

Fp is analogous to the unit hydrograph area-averaged pervious loss rate; a lumped loss parameter.

7.F. PERVIOUS AREA FRACTION:

The ratio of (pervious area)/(total catchment area).

8. ADDITION of Subarea Runoff to MAIN-Stream

```
    ADDITION OF SUBAREA TO MAIN STREAM MODEL OPTIONS:

        1: Add Subarea Flow at Main Stream Tc
        2: Compute Initial Subarea Flow, and Add at Main Stream Tc

    Select option NUMBER................................ ===>8.1.A


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

8.1.A. ADD SUBAREA FLOW OPTIONS:

YOU have the choice of computing subarea runoff flow quantities by adding the subarea runoff estimates to the Mainline at the Mainline time-of-concentration, Tc,(i.e., Process #81), OR, compute initial subarea runoff quantities for Reference, but then ADD the subarea runoff to the Mainline at the Mainline Tc(i.e.,Process #82). This latter Option is useful for simultaneously estimating runoff quantities for lateral drain and catch-basin sizing, while also sizing the Mainline system for Subarea Addition. Remember, that in Process #82, the Initial Subarea portion of the algorithm focuses upon the subarea response as an INITIAL SUBAREA. YOU must properly identify the NOMOGRAPH input data corresponding to an Initial Subarea analysis, and NOT just Subarea Addition.

8.1: Add Subarea Flow at Main Stream Tc

```
---------- Addition of Subarea to Mainline Peak Flow ----------- page 1







    Enter Total Number of Homogeneous Cells............. ===>8.1.B
    :ALLOWABLE VALUES ARE [1     ] TO [6         ]





_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

Go to 8., cont.

8.1.B. HOMOGENEOUS REGION:

A subarea may contain different SCS soil groups and/or different development types. The Number of Homogeneous Regions refers to the number of smaller areas which have a uniform soil group and development type. A maximum of 6 per subarea are allowed in this Program. If more, subdivide the subarea into smaller areas.

8.2: Compute Initial Subarea Flow, and Add at Main Stream Tc

```
------------- Addition of Subarea to Mainline Peak Flow -------- page 1



    Enter upstream node      8.00 elevation(FEET)....... ===>8.2.A
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node      9.00 elevation(FEET)..... ===>8.2.B
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter runoff travel-length through subarea(FEET).... ===>8.2.C
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]
    (NOTE: SUGGESTED RANGE(FEET) IS [0] TO [1000])

    Enter Total Number of Homogeneous Cells............. ===>8.2.D
    :ALLOWABLE VALUES ARE [1     ] TO [6         ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

Go to 8., cont.

8.2.A. UPSTREAM ELEVATION:

The elevation of the most remote point of the subarea is generally used for the initial subarea Tc estimation.

8.2.B. DOWNSTREAM ELEVATION:

The elevation at the subarea downstream concentration point (i.e., the subarea outlet).

8.2.C. RUNOFF TRAVEL-LENGTH:

Runoff travel-length is generally the length of the flowpath from the most remote point of the subarea to the concentration point.

8.2.D. HOMOGENEOUS REGION:

A subarea may contain different SCS soil groups and/or different development types. The Number of Homogeneous Regions refers to the number of smaller areas which have a uniform soil group and development type. A maximum of 6 per subarea are allowed in this Program. If more, subdivide the subarea into smaller areas.

8., cont.

```
------------- Addition of Subarea to Mainline Peak Flow -------- page 2
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    "URBAN" LAND USE OR DEVELOPMENT TYPE   -   (% PERVIOUS):
                            1:           Commercial ( 10%)
                            2:      Mobile Home Park ( 25%)
                            3:           Apartments ( 20%)
                            4:         Condominiums ( 35%)
              ----------    5:   11+  Dwellings/Acre ( 20%)
             |              6:   8-10 Dwellings/Acre ( 40%)
        SINGLE FAMILY       7:    5-7 Dwellings/Acre ( 50%)
         RESIDENTIAL        8:    3-4 Dwellings/Acre ( 60%)
             |              9:      2 Dwellings/Acre ( 70%)
             |             10:       1 Dwelling/Acre ( 80%)
              ----------   11:      .4 Dwelling/Acre ( 90%)
                           12:               School ( 60%)
                           13:          Public Park ( 85%)

    *Note: Press RETURN to Display NATURAL COVERS*
    Specify assumed uniform subarea land use/development ===>8.1.C

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

8.1.C. DEVELOPMENT TYPE:

Runoff coefficients and the loss rates may be estimated by use of the Development Type Table given on this input page. The Table shows several classifications by development type name, dwellings per acre, and percent pervious. Generally, impervious areas are assumed to have a zero loss rate and have total runoff. The subarea is defined such as to be generally homogeneous.

```
-------------- Addition of Subarea to Mainline Peak Flow ------- page 3
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    SUBAREA RUNOFF COEFFICIENT OPTIONS:

        1= Assume soil group A
        2= Assume soil group B
        3= Assume soil group C
        4= Assume soil group D
    Select Cell # 1 runoff coefficient option NUMBER.... ===>8.1.D






    Enter Subarea Cell #  1 area(ACRES)................. ===>8.1.E
    :ALLOWABLE VALUES ARE [0.01  ] TO [9999  ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

8.1.D. RUNOFF COEFFICIENT:

The U. S. Soil Conservation Service (SCS) Soil Groups are available to describe soil runoff tendencies; or the USER may elect to describe the soil runoff characteristics directly.

8.1.E. SUBAREA AREA:

The total area of the subject subarea.

9. V-GUTTER Flow Through Subarea

```
--------------- Pavement "V" Gutter Flow through Subarea ------- page 1



    Enter upstream node      9.00 elevation(FEET)....... ===>9.A
    :ALLOWABLE VALUES ARE [.01   ] TO [99999.99  ]

    Enter downstream node     10.00 elevation(FEET)..... ===>9.B
    :ALLOWABLE VALUES ARE [0     ] TO [99999.99  ]

    Enter runoff travel-length through subarea(FEET).... ===>9.C
    :ALLOWABLE VALUES ARE [.01   ] TO [10000 ]


    Enter Total Number of Homogeneous Cells in Subarea.. ===>9.D
    :ALLOWABLE VALUES ARE [1     ] TO [6         ]





_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

9.A. UPSTREAM ELEVATION:

The elevation of the most remote point of the subarea is generally used for the initial subarea Tc estimation.

9.B. DOWNSTREAM ELEVATION:

The elevation at the subarea downstream concentration point (i.e., the subarea outlet).

9.C. RUNOFF TRAVEL-LENGTH:

Runoff travel-length is generally the length of the flowpath from the most remote point of the subarea to the concentration point.

9.D. HOMOGENEOUS REGION:

A subarea may contain different SCS soil groups and/or different development types. The Number of Homogeneous Regions refers to the number of smaller areas which have a uniform soil group and development type. A maximum of 6 per subarea are allowed in this Program. If more, subdivide the subarea into smaller areas.

```
--------------- Pavement "V" Gutter Flow through Subarea ------- page 2
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    "URBAN" LAND USE OR DEVELOPMENT TYPE   -   (% PERVIOUS):
                            1:            Commercial ( 10%)
                            2:      Mobile Home Park ( 25%)
                            3:            Apartments ( 20%)
                            4:          Condominiums ( 35%)
              ----------    5:   11+  Dwellings/Acre ( 20%)
             |              6:   8-10 Dwellings/Acre ( 40%)
        SINGLE FAMILY       7:    5-7 Dwellings/Acre ( 50%)
         RESIDENTIAL        8:    3-4 Dwellings/Acre ( 60%)
             |              9:      2 Dwellings/Acre ( 70%)
             |             10:       1 Dwelling/Acre ( 80%)
              ----------   11:      .4 Dwelling/Acre ( 90%)
                           12:                School ( 60%)
                           13:           Public Park ( 85%)

    *Note: Press RETURN to Display NATURAL COVERS*
    Select cell # 1 development classification NUMBER... ===>9.E

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

9.E. DEVELOPMENT TYPE:

Runoff coefficients and the loss rates may be estimated by use of the Development Type Table given on this input page. The Table shows several classifications by development type name, dwellings per acre, and percent pervious. Generally, impervious areas are assumed to have a zero loss rate and have total runoff. The subarea is defined such as to be generally homogeneous.

```
-------------- Pavement "V" Gutter Flow through Subarea -------- page 3
    HYDROLOGIC INFORMATION FOR SUBAREA CELL # 1 OF  1:

    SUB-REGION RUNOFF COEFFICIENT OPTIONS:

        1= Assume soil group A
        2= Assume soil group B
        3= Assume soil group C
        4= Assume soil group D
    Select cell # 1 runoff coefficient option NUMBER.... ===>9.F



    Enter subarea cell # 1 area(ACRES).................. ===>9.G
    :ALLOWABLE VALUES ARE [0     ] TO [100   ]

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

9.F. RUNOFF COEFFICIENT:

The U. S. Soil Conservation Service (SCS) Soil Groups are available to describe soil runoff tendencies; or the USER may elect to describe the soil runoff characteristics directly.

9.G. SUBAREA AREA:

The total area of the subject subarea.

```
-------------- Pavement "V" Gutter Flow through Subarea -------- page 4

    Enter "V" gutter width(FEET)........................ ===>9.H
    :ALLOWABLE VALUES ARE [1.0   ] TO [5.0   ]

    Enter "V" gutter-hike(FEET)......................... ===>9.H
    :ALLOWABLE VALUES ARE [.05   ] TO [.8    ]

    Enter pavement lip(FEET)............................ ===>9.H
    :ALLOWABLE VALUES ARE [.01   ] TO [.4    ]

    Enter assumed uniform Manning's friction factor..... ===>9.I
    (NOTE: SUGGESTED VALUE FOR MANNING'S n IS [.015])
    :ALLOWABLE VALUES ARE [.005  ] TO [.9999 ]

    Enter symmetric pavement crossfall[DECIMAL NOTATION] ===>9.J
    :ALLOWABLE VALUES ARE [.002  ] TO [.2    ]

    Enter maximum allowable depth of flow(FEET)......... ===>9.K
    :ALLOWABLE VALUES ARE [.001      ] TO [100       ]

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

9.H. V-GUTTER MODEL:

The "V"-gutter model, like the streetflow model, accounts for normal depth hydraulics in the V-gutter, and also accounts for the addition of flow through the subarea. Certain default estimates are used:
1. If the normal depth of flow is less than the gutter-hike, then hydraulics are based on a normal depth equal to the gutter hike.
2. If the normal depth is between the gutter-hike and (gutter-hike + lip), then the hydraulics are based on the normal depth equal to (gutter-hike + lip).

Otherwise, hydraulics are based on normal depths less than allowable depth of flow.

It is anticipated in the PROGRAM that the V-gutter routine be used for "V"-gutters such as normally seen in parking lots; otherwise for open channel hydraulics, use the Trapezoidal channel routine.

If runoff contributes to the "V"-gutter, the traveltime estimates are iterated until the traveltime approximately equals that value computed by use of the mean value of runoff through the subarea.

The "V"-gutter "width" is the width of the gutter from edge to edge, with the "hike" being the change in elevation from the flowline to the gutter edge. The "lip" is the change in elevation from the gutter edge to the edge of pavement.

9.I. MANNING'S FACTOR:

Manning's formula is used in this PROGRAM for normal depth hydraulics estimates.

9.J. PAVEMENT CROSSFALL:

The pavement slope: (change in elevation)/ (length) perpendicular to the "V"-gutter.

9.K. MAXIMUM ALLOWABLE DEPTH:

As a design check, YOU are asked to establish a maximum depth of flow (normal depth) allowable in YOUR hydrology computations. This is measured from the "V"-gutter flowline.

9. (F0601 only)

```
    Enter MAIN-Stream Relief Drain Model Option NUMBER.. ===>9.L

       1: MAIN-Stream Hydrograph to be proportioned on percentage
          basis such that the hydrograph remaining in the MAIN-
          Stream has USER-specified Peak Flow Rate.
       2: MAIN-Stream Hydrograph to be proportioned on percentage
          basis such that the hydrograph remaining in the MAIN-
          Stream has PERCENTAGE of Total Flow.
       3: MAIN-Stream Hydrograph to be separated such that all flow up
          to the USER-specified Peak Flow Rate remains in the MAIN-
          Stream.
       4: MAIN-Stream Hydrograph to be separated such that ONLY flow
          above a base value (equal to the Peak Flow Rate MINUS
          the USER-specified Flow Rate) remains in the MAIN-Stream.

    Enter Memory Bank NUMBER that Relief Drain flows
    are to be ADDED..................................... ===>9.M
    :ALLOWABLE VALUES ARE BETWEEN [ 1] and [ 3]

_____________________________________ RATSCx -[LAF0601 Pre-Processor]--
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

9.L. MAIN-STREAM RELIEF DRAIN:

There are FOUR model options available to modify a hydrograph at a relief drain junction and transfer a portion of the flow to other drain. See Computer Program F0601 section in the Los Angeles County Hydrology Manual for detail discussions.

9.M. MEMORY BANK RECEIVING RELIEF DRAIN FLOWS:

There are THREE memory banks available to receive the relief drain flows and add to its contents.

9.F0601, cont.

```
    Enter USER-specified Relief Drain Cutoff Flow(CFS).. ===>9.N
    :ALLOWABLE VALUES ARE BETWEEN [0.1] and [9999.9]





_____________________________________ RATSCx -[LAF0601 Pre-Processor]--
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

9.N. RELIEF DRAIN CUTOFF FLOW:

The relief drain cutoff flow will be used in model options 1, 3, and 4.

9.F0601, cont.

```
    Enter USER-specified PERCENTAGE of Total Flow that
    remains in the Drain .............................. ===>9.O
    :ALLOWABLE VALUES ARE BETWEEN [1] and [100]



_____________________________________ RATSCx -[LAF0601 Pre-Processor]--
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

9.O. TOTAL FLOW PERCENTAGE:

The USER-Specified percent of total flow will remain in the MAIN-stream.

10. COPY MAIN-Stream Data onto a Memory BANK

```
------------- Copy Main-Stream Data onto a Memory Bank --------- page 1


    Enter MEMORY BANK number that receives main-stream
    data.............................................. ===>10.A
    :ALLOWABLE VALUES ARE [1] TO [3     ]



_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

10.A. MEMORY BANK:

In order to allow multiple confluence points, Memory Banks are used in this PROGRAM. The Memory Bank is a data storage for confluence and peak flow data values or data contained in a Peak Flow Rate Table (The Peak Flow Rate Table represents available peak flow confluence combinations used in YOUR link-node model). The Main Stream is the focus of YOUR study as the Rational Method link-node model develops. By combining or swapping the data contents between Memory Banks and the Main Stream, YOU are able to build complex link-node models.

11. CONFLUENCE a Memory BANK with the Main-Stream Memory

```
-------- Confluence a Memory Bank with the Main-Stream Memory -- page 1





    Enter MEMORY BANK number to confluence with
    the Main-Stream memory............................ ===>11.A
    :ALLOWABLE VALUES ARE [1] TO [1     ]



_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

11.A. CONFLUENCE WITH MEMORY BANK:

When a Memory Bank is confluenced with the Main Stream, the appropriate Agency confluence formula is used for the computations, and combinations for stream confluences are computed (when the Peak Flow Rate Table option is used).

12. CLEAR a Memory BANK

```
----------------------- Clear a Memory Bank ------------------- page 1





    Enter MEMORY BANK number to be cleared............. ===>12.A
    :ALLOWABLE VALUES ARE [1] TO [1     ]









_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

12.A. CLEAR A MEMORY BANK:

This operation simply erases the contents of a Memory Bank, freeing it up for later reuse.

13. CLEAR the MAIN-Stream

```
--------------------- Clear the MAIN-Stream ------------------ page 1



    Enter MEMORY BANK number to be cleared............. ===>
    :ALLOWABLE VALUES ARE [1] TO [1     ]





_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

14. HYDROLOGIC Data BANK Storage Functions

```
---------- Copy a Memory Bank onto the Main-Stream Memory ------ page 1







    Enter MEMORY BANK number to copy onto the
    Main-Stream memory.................................. ===>14.A
    :ALLOWABLE VALUES ARE [1] TO [1     ]





_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

14.A. COPY MEMORY BANK:

A Copy of the Memory Bank is installed as the Main Stream data. The Main Stream is redefined to become the selected Memory Bank data, whereas the Memory Bank data remains untouched.

15. HYDROLOGIC Data BANK Storage Functions

```
----------------- Hydrologic Data Storage Functions -------------page 1

    HYDROLOGIC DATA STORAGE FUNCTIONS:

      1 = Create/Read Peak Flowrate Table file into a Memory Bank

      2 = Store the Main Stream Peak Flowrate Table to a Data File

    Select desired function NUMBER...................... ===>15.A

    Enter MEMORY BANK number to be defined.............. ===>15.A
    :ALLOWABLE VALUES ARE [1] TO [3     ]

    Enter Peak Flowrate Table file name.. ===>
    (PROGRAM USES DEFAULTED EXTENSION "DNA")


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    TYPE: EXIT to leave program ; TOP to go to top of page
```

15.A. HYDROLOGIC DATA STORAGE FUNCTIONS:

The PROGRAM can read or store the hydrologic and hydraulic data from a FILE. Using this PROCESS, YOU can connect PROGRAM files into a Global link-node model.

```
I.    This portion of the MODULE develops a Tc versus Qp versus Ae
   database (i.e. time of concentration, versus peak flow rate,
   versus effective area).  The PEAK FLOW RATE Table is analogous
   to a time area diagram of the catchment upstream of the subject
   node in the model network.  Each initial subarea begins an
   individual flow path that has its own Tc, flow rates, and loss
   rate properties.  The possible confluence combinations, with
   respect to each and every such flow path, in the model network,
   results in the PEAK FLOW RATE Table developed automatically in
   the RATSCx PROGRAM.  The number of initial subareas in the model
   network equals the number of flow paths used in the PEAK FLOW
   RATE Table.  The PROGRAM stores up to 20 flow path combinations,
   at any one time, after which a data base reduction is made that
   eliminates Tc entries which are close to other Tc values already
   in the Table, simplifying the confluencing accounting.



                                  Press RETURN to continue ===>
```

```
    Enter total number of (Tc,Q,Ae,Fp,Ap) data sets..... ===>15.B
    :ALLOWABLE VALUES ARE [1] TO [20    ]
    (NOTE: IT IS RECOMMENDED THAT THE PEAK FLOW RATE DATA
     CORRESPONDING TO THE TOTAL CATCHMENT AREA BE INCLUDED IN THE
     TABLE.)

________________________________________________________________________
    TYPE: EXIT to return to Parent Program; TOP to go to top of page
```

15.B. MEMORY BANK DATA SETS:

The Memory Bank stores sets of data that are used to define Rational Method peak flow information. Each data set represents an effective-area vs. peak-Q combination, such as computed by upstream confluences.

```
 DATA SET [ 1] OF [ 2]
    Enter time of concentration(MINUTES)................ ===>15.C
    :ALLOWABLE VALUES ARE [5] TO [180   ]

    Enter flow rate(CFS)................................ ===>15.D
    :ALLOWABLE VALUES ARE [.1    ] TO [9999.99   ]

    Enter EFFECTIVE area(ACRES)......................... ===>15.E
    :ALLOWABLE VALUES ARE [.01   ] TO [9999.99   ]

    Enter area-averaged PERVIOUS loss rate, Fp(INCH/HR). ===>15.F
    :ALLOWABLE VALUES ARE [0.0   ] TO [9.99      ]

    Enter area-averaged pervious area fraction(DECIMAL). ===>15.G
    :ALLOWABLE VALUES ARE [0.0   ] TO [1.0       ]

    Enter Most Upstream Node NUMBER..................... ===>15.H
    :ALLOWABLE VALUES ARE [0.00      ] TO [9999.99   ]

________________________________________________________________________
    TYPE: EXIT to return to Parent Program; TOP to go to top of page
                                          ; BACK to go back one page
```

15.C. TIME-OF-CONCENTRATION:

YOU have elected to define hydrologic information at a nodal point -- YOUR entered data will over-ride any computer estimates. With this PROGRAM model, the USER interacts with the computer model by defining information that will be used by the PROGRAM.
The time-of-concentration (Tc) is currently being requested -- this is the Tc from which the Rational Method rainfall data is computed.

15.D. TOTAL RUNOFF:

What is the peak flow rate to be defined with YOUR specified effective area and YOUR specified time-of-concentration?

15.E. EFFECTIVE AREA:

The effective area is that portion of the total catchment area, that delivers runoff at the peak flow rate time-of-concentration -- analogous to the concept of contributory area.

15.F. PERVIOUS LOSS RATE:

Fp is analogous to the unit hydrograph area-averaged pervious loss rate; a lumped loss parameter.

15.G. PERVIOUS AREA FRACTION:

The ratio of (pervious area)/(total catchment area).

15.H. MOST UPSTREAM NODE:

The most remote point of a stream.

15.1: Read Peak Flowrate Table File into a Memory Bank

```
-------------- Hydrologic Data Storage Functions ---------------page 1

    HYDROLOGIC DATA STORAGE FUNCTIONS:

      1 = Read a Peak Flowrate Table file into a Memory Bank

      2 = Store the Main Stream Peak Flowrate Table to a Data File

    Select desired function NUMBER...................... ===>15.1.A

    Enter MEMORY BANK number to be defined.............. ===>15.1.A
    :ALLOWABLE VALUES ARE [2] TO [3     ]

    Enter Peak Flowrate Table file name.. ===>
    (PROGRAM USES DEFAULTED EXTENSION "DNA")


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    TYPE: EXIT to leave program ; TOP to go to top of page
```

15.1.A. HYDROLOGIC DATA STORAGE FUNCTIONS:

The PROGRAM can read or store the hydrologic and hydraulic data from a FILE. Using this PROCESS, YOU can connect PROGRAM files into a Global link-node model.

15.2: Store the Main Stream Peak Flowrate Table to a Data File

```
---------------- Hydrologic Data Storage Functions --------------page 1

    HYDROLOGIC DATA STORAGE FUNCTIONS:

      1 = Read a Peak Flowrate Table file into a Memory Bank

      2 = Store the Main Stream Peak Flowrate Table to a Data File

    Select desired function NUMBER...................... ===>15.1.A




    Enter Peak Flowrate Table file name.. ===>
    (PROGRAM USES DEFAULTED EXTENSION "DNA")






_____________________________________ RATSCx -----[ORANGE COUNTY]------
    TYPE: EXIT to leave program ; TOP to go to top of page
```

16. USER-SPECIFIED Source Flow at a Node

```
------------ Constant Source Flow at a Node -------------------- page 1

    Enter constant Source Flow Rate (CFS)
    Added to NODE     13.00............................ ===>16.A
    :ALLOWABLE VALUES ARE [0.1   ] TO [99999.99  ]

    Enter the Catchment Area(ACRES)
    Associated to the above constant Source Flow........ ===>16.B
    :ALLOWABLE VALUES ARE [.01   ] TO [90000.00  ]











_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD
    TYPE: D to display COMMAND definitions
```

16.A. CONSTANT SOURCE FLOW:

YOU can specify a constant flow rate to be added at a node. This added flow rate (or "source") will then be also applied to all nodes downstream, regardless of time of concentration (Tc) or rainfall values. Typical uses of this model process is to approximate the effects of pump stations, flood control basin outflow, baseflow or other flows that are essentially constant over the range of Tc values being modeled. Generally, one may specify the peak pumping rate or the peak outflow rate from a flood control basin in analyzing downstream hydrology and system sizing.

16.B. AREA ASSOCIATED TO CONSTANT SOURCE FLOW:

YOU can specify the area of the catchment that corresponds to the source flow. For example, the area of the catchment tributary to a particular pump station may be appropriate. This area is then included in the summed total area of the catchment tributary to a node. Parameter values of this associated area, such as loss rates or land use, are NOT included in the modeling.

(from MAIN MENU: EXECUTE)

```
REPORT OPTIONS:

     1= DETAILED Report

     2= Summary FORM Data File
     (Note: See AES Utility PROGRAM for
            " Subarea SCHEMATIC, and FACILITY summary modules")
     3= Data Base Preparation


Select desired report option.................................. ===>

______________________________________________________________________
TYPE: EXIT to leave program; TOP to go to top of page
```

```
VIEWING OPTIONS FOR RESULTS:


     1= CRT Screen (No printout generated)

     2= Printout


                           Select viewing option desired ===>
```

```
RESULTS LISTING OPTIONS:


     1= Send results directly to PRIMARY printer (LPT1)

     2= Send results directly to SECONDARY printer (LPT2)

     3= Create a print image results FILE on disk
        (Example: MYJOB.RES)


                           Select listing option desired ===>
```

```
USER SUPPLIED HEADING FOR RESULTS PRINTOUT OPTIONS:

    0: No Heading desired

    1: Heading desired

Select Heading option desired................................ ===>
```

(from MAIN MENU: EDIT)
EDITOR MENU

```
EDITOR OPTIONS:
   1= Edit the SUBAREAS only
   2= Change the PROBLEM CONTROLS before editing subareas
   3= Execute data file to obtain PRINTED RESULTS for reference
Select desired editor........................................ ===>

______________________________________________________________________
TYPE: EXIT to leave program; TOP to go to top of page
```

EDITOR.1

```
----------------------------------------------------------------------


 +--------------------------------+
 |          EDITOR WINDOW         |
 +--------------------------------+
 | Upstream   Downstream  Process |
 |    Node         Node    Number |
 +--------------------------------|
 |                                |  Functions:
T| --------     --------    --    |   A= Insert ABOVE target
a|                                |   B= Insert BELOW target
r|>    2.00         3.00    2.1  <|   C= CHANGE target
g|                                |   D= DELETE target
e|     3.00         4.00      1   |   F= FIRST at target
t|                                |   G= GLOBAL edit functions
 +--------------------------------+   P= PREVIOUS at target
                                      S= SKIP forward/backward (Sn/S-n)
                                      or Press RETURN to advance

                                     Select function ===>

______________________________________________________________________
TYPE: EXIT to leave program;          (Edit Data Area   92% Free)
      MAIN to go to main menu
```

EDITOR.1.A,B: go to RATIONAL METHOD: SUBAREA MENU

EDITOR.1.C

```



Enter upstream node number…………………………………………… ===>[     2.0000]<=?
:ALLOWABLE VALUES ARE [0.00  ] TO [999999.99 ]

Enter downstream node number……………………………………… ===>[     3.0000]<=?
:ALLOWABLE VALUES ARE [0.00  ] TO [999999.99 ]



                                        (Press RETURN to ACCEPT entry)

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, CHANGE, WINDOW, EXIT, HELP, PARAM, HYD, TOP
    TYPE: D to display COMMAND definitions
```

Go to 2.1 of RATIONAL METHOD: SUBAREA

NODE NUMBERS:

The link-node model representation of the catchment utilizes flow processes or logic processes that direct modeling information in the DOWNSTREAM DIRECTION, with accumulation of flow and catchment area. Nodal points are used to correlate hydrology reference points to the computer output. For each model process, an upstream and downstream node is assigned. The nodal numbers do not affect computational results. Generally, a useful numbering scheme is to sequentially increase node numbers, starting with the initial subarea of each stream.

Numbering major streams by the hundreds (e.g., 200,201,202, etc.) is often useful in identifying individual streams. Also, YOU may wish to number the most upstream node as 00,100, 200, etc., to indicate the initial node of a stream or flowpath.

The network model is composed of link processes and point processes. In general, link processes connect nodes. A point process is a logic path or model that occurs at a point (i.e., node). In the data base mode, the PROGRAM helps YOU to organize YOUR network data by screening node ID data.

EDITOR.1.D: deletes Target in EDITOR WINDOW

EDITOR.1.F: adjusts Target in EDITOR WINDOW

EDITOR.1.G

```
GLOBAL EDITING FUNCTIONS:
  1= Globally CHANGE a Manning's friction factor for
      Computer-Estimated Pipesize processes(Code=3.1,3.2,3.3)
      to another Manning's friction factor
  2= CHANGE all User-Specified Pipesize processes(Code=4.1)
      to Computer-Estimated Pipesize processes(Code=3.1)
  3= Change all Streetflow Incremental Depth (with respect to top-
      of-curb) constraints (Code=3.2,3.3,6.3) to another constraint
      value
  4= Change all Streetflow depth*velocity constraints
      (Code=3.2,3.3,6.3) to another constraint value
 --= Multiply all Subarea Rainfall data by a Constant
 --= Change all Subarea Rainfall data to a New set of Subarea Rainfall
    data
 --= Change some Subarea Rainfall data to a New set of Subarea Rainfall
    data
  8= Return to EDITOR menu
 Select desired Editor function........................ ===> ED.1.G.1

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

ED.1.G.1. GLOBAL EDITING FUNCTIONS:

The GLOBAL Editing functions enable the USER to consider large scale changes in the data file. By changing Manning's n for all the pipes from .013 to .015 enables the entire Master Plan System to be reanalyzed with respect to a different type of conduit. By changing the streetflow constraints values, such as the allowable flow depth minus the street top-of-curb, or the allowable product of depth and flow velocity, YOU can re-execute the data file and generate new hydrologic results based upon these new streetflow constraints.
The subarea rainfall data may be multiplied by a constant factor, enabling YOU to uniformly increase or decrease all rainfall data throughout the file. Also, YOU can replace all subarea rainfall data, by a set of data YOU define. This is equivalent to using a uniform rainfall data set for the entire file.

EDITOR.1.G.1,2,3,4

```
Enter value of OLD ____________________
 to be changed ……………………………………………………………………===>

Enter value of NEW ____________________ ………………………………===>
:ALLOWABLE VALUES ARE [ MIN ] TO [ MAX ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

EDITOR.1.P,S: adjusts TARGET in EDITOR WINDOW

EDITOR.2

```
    Enter Rational Method storm event year.............. ===>[   10]<=?
    :ALLOWABLE VALUES ARE [1] TO [1000  ]

    RAINFALL INTENSITY-DURATION RELATIONSHIPS:
        1: Use 2-, 5-, 10-, 25-, 50- or 100-year PRESET values
        (i.e., logarithmic equations per Hydrology Manual Figure B-3)
        2: Enter a NEW tabulated relationship for rainfall
           intensity versus Time-of-Concentration
        3: Use a LOGARITHMIC relationship
    Select relationship desired......................... ===>[    3]

    Select SCS Antecedent Moisture Condition (AMC)...... ===>[    1]
    (For Rational method peak flowrate estimation.)
    :ALLOWABLE VALUES ARE [1] TO [3     ]


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

From this screen, go through RATIONAL METHOD: Hydrologic Control Section to end, then go to EDITOR.1

EDITOR.3

```
RESULTS LISTING OPTIONS:


     1= Send results directly to PRIMARY printer (LPT1)

     2= Send results directly to SECONDARY printer (LPT2)

     3= Create a print image results FILE on disk
        (Example: MYJOB.RES)


                           Select listing option desired ===>
```

(from MAIN MENU: EXTEND)

```
                              Rational
                           Method Analysis

                               SUBAREA
                         Information Entry:




                         Press RETURN to continue ===>
```

Go to RATIONAL METHOD: SUBAREA MENU

(from MAIN MENU: EXECUTE File Network Management Module)

```
-----------------------------------------------------------------------

    FILE NETWORK MANAGEMENT OPTIONS:

       1= CREATE a RATSCx File Network
       2= EXTEND an existing RATSCx File Network
       3= EDIT an existing RATSCx File Network
       4= EDIT link-node data files globally
       5= EXECUTE a RATSCx File Network
       6= EXECUTE Multiple Return Frequency Analysis Module



           Select program option desired ===>

Specify FILE NETWORK MANAGEMENT filename ===>


_______________________________________________________________________
TYPE: EXIT to leave program; TOP to go to top of page
```

EXECUTE NETWORK.1

```
---------------- HydroLINK: RATSCx File Network Manager ---------------
    +----[PATH:                                                 ]----+
    |  ITEM#         DATA FILE                                       |
    +----------------------------------------------------------------+
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    +----------(Note: RATSCx filenames must be entered in -----------+
                a strictly DOWNSTREAM orientation.)

       Enter data file name ===>

______________________________________________________________________
   TYPE: MAIN to go to main menu
         BACK to go back one entry; TOP to go to first data entry
```

EXECUTE NETWORK.2

```
---------------- HydroLINK: RATSCx File Network Manager ---------------
    +----[PATH:                                                 ]----+
    |  ITEM#         DATA FILE                                       |
    +----------------------------------------------------------------+
    |  1.            DEMO.DAT                                        |
    |  2.            DEMO2.DAT                                       |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    |                                                                |
    +----------(Note: RATSCx filenames must be entered in -----------+
                a strictly DOWNSTREAM orientation.)

       Enter data file name ===>

______________________________________________________________________
   TYPE: MAIN to go to main menu
         BACK to go back one entry; TOP to go to first data entry
```

EXECUTE NETWORK.3

```
----------------------------------------------------------------------



 +--------------------------------+
 |  HydrolLINK: EDITOR WINDOW     |
 +--------------------------------+
 |  ITEM         FILENAME         |
 +--------------------------------|
 |                                |  Functions:
T|  ---         -----------       |   A= Insert ABOVE target
a|                                |   B= Insert BELOW target
r|>   1        DEMO.DAT          <|   C= CHANGE target
g|                                |   D= DELETE target
e|    2        DEMO2.DAT          |   F= FIRST at target
t|                                |   G= GLOBAL edit functions
 +--------------------------------+   P= PREVIOUS at target
                                      S= SKIP forward/backward (Sn/S-n)
                                      or Press RETURN to advance

                                     Select function ===>

______________________________________________________________________
TYPE: MAIN to go to main menu
```

EXECUTE NETWORK.4

```
GLOBAL EDITING FUNCTIONS:
  1= Globally CHANGE a Manning’s friction factor for
       Computer-Estimated Pipesize processes(Code=3.1,3.2,3.3)
       to another Manning’s friction factor
  2= CHANGE all User-Specified Pipesize processes(Code=4.1)
       to Computer-Estimated Pipesize processes(Code=3.1)
  3= Change all Streetflow Incremental Depth (with respect to top-
       of-curb) constraints (Code=3.2,3.3,6.3) to another constraint
       value
  4= Change all Streetflow depth*velocity constraints
       (Code=3.2,3.3,6.3) to another constraint value
  5= Multiply all Subarea Rainfall data by a Constant
  6= Change all Subarea Rainfall data to a New set of Subarea Rainfall
     data
  7= Change all AMC conditions for RATIONAL method analysis
  8= Change all AMC conditions for UNIT-HYDROGRAPH analysis
  9= Return to MAIN menu
 Select desired Editor function.......................................... ===>

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

For options 1-4, please refer to EDITOR.1.G.1-4
For options 5-8, see below

EXECUTE NETWORK.4.5

```


Enter Constant Multiplier
 for all Subarea Rainfall data ..........................................===>
:ALLOWABLE VALUES ARE [0.1   ] TO [10.0  ]

______________________________________________________________________
TYPE: EXIT to go to Parent Program; TOP to go to top of page
                                  ; BACK to go back one page
```

EXECUTE NETWORK.4.6

```

TO CONSTRUCT THE SYNTHETIC CRITICAL STORM PATTERN, AREA-AVERAGED
 SUBAREA RAINFALL VALUES ARE NEEDED FOR THE PEAK 5-MINUTES,
 30-MINUTES,1-,3-,6-,AND 24-HOURS OF RECORDED RAINFALL.

 YOU have two OPTIONS:

  1 = Enter ONLY the 1-,6-, and 24-hour values, and use previously
      entered rainfall intensity slope value and logarithmic
      interpolation to compute 5-,30-minute and 3-hour rainfall; OR
  2 = Enter 5-,30-minute, 1-, 3-, 6-, and 24-hour rainfall values


Select desired option ...................................................===>


_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

EXECUTE NETWORK.4.6.1,2

```
TO CONSTRUCT THE SYNTHETIC CRITICAL STORM PATTERN, AREA-AVERAGED
 SUBAREA RAINFALL VALUES ARE NEEDED FOR THE PEAK 5-MINUTES,
 30-MINUTES,1-,3-,6-,AND 24-HOURS OF RECORDED RAINFALL.

 Enter subarea area-averaged  1-hour point
 Rainfall(mm) ..........................................===>
:ALLOWABLE VALUES ARE [ 0.010] TO [   20.]


SUBAREA AREA-AVERAGED POINT RAINFALLS

       5-MINUTE  [        ] mm
      30-MINUTE  [        ] mm
         1-HOUR  [        ] mm
         3-HOUR  [        ] mm
         6-HOUR  [        ] mm
        24-HOUR  [        ] mm

_____________________________________ RATSCx -----[ORANGE COUNTY]------
    COMMANDS: TUTOR, EXIT, TOP, HELP, PARAM, HYD, BACK
    TYPE: D to display COMMAND definitions
```

EXECUTE NETWORK.4.7,8

```
  Enter NEW AMC condition.................................===>
   :ALLOWABLE VALUES ARE [1] AND [3]

______________________________________________________________________
TYPE: EXIT to go to Parent Program; TOP to go to top of page
                                  ; BACK to go back one page
```

EXECUTE NETWORK.5

```
  REPORT OPTIONS:

       1= DETAILED Report

       2= Summary FORM

Select desired report option ................................===>

______________________________________________________________________
TYPE: EXIT to go to Parent Program; TOP to go to top of page
```

EXECUTE NETWORK.6

```
                   Multiple Return Frequency Analysis Module
                  ==========================================

    This PROGRAM runs the File Network Management module for
    up to 6 return frequencies, and places the computed results
    into the Data Base.  An inventory of RATSCx data files is first
    made to check on completeness of data file sets; if there are
    gaps, the DIAGNOSTICs file lists missing RATSCX data files.

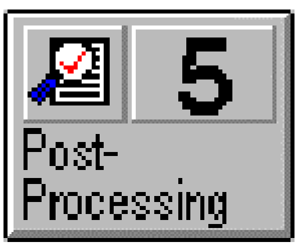

                       Enter Study Name ID ===>
                     (BETWEEN [AA] AND [ZZ])

______________________________________________________________________
TYPE: EXIT to go to Parent Program; TOP to go to top of page
```

Chapter 4
RATPPRO: The Post-Processor

4.1 About This Chapter

Similar to Chapter 3, this chapter presents a complete exposition of the pre-and post processor program of the Advanced Engineering Software SIMS. The post-processor is a collection of dozens of modules, each module performing a separate task in the master planning process. Given the answers to about "Twenty Questions", the entire master planning endeavor is controlled in a near deterministic fashion. This chapter reviews the AES post-processor and how the MPD is controlled by the selection of planning options. This chapter also examines the program input screens for several of the AES SIMS analysis tools such as the Pollutant Loading Estimation module, the COSTS module, and the Cost-to Benefit module. An important product from the post-processor are the DIAGNOSTICS of the MPD files. An example output from the AES SIMS Diagnostics is included in Appendix A.



4.2 Post-Processing and the "TWENTY QUESTIONS"

```
        //                                                   //
       //                                                   //
      //   Stormwater Information Management System (SIMS):  //
     //                   Program Library                   //
    //                                                   //
   //                                                   //


          (c) Copyright 1983-1999 Advanced Engineering Software
                       Release date: 01/01/99
                            Ver. 7.2
                            .........
                                .
                                .
                                .......> Press RETURN to continue
```

```
POSTPROCESSOR PROGRAM –- Main Menu Options:

       1 = DIAGNOSTICS/DEFICIENCY/STRING-FINDER MODULE
       2 = USER-INTERFACE MODULE
       3 = DATA BASE “SUBSET” MODULE
       4 = COUPLED DATA BASE AND NETWORK MODEL EDITOR MODULE
       5 = DATA BASE “DIFFERENCES” SUBSET MODULE
       6 = SCENARIO ADOPT/REJECT/ABANDON MODULE
       7 = GIS-to-DATA BASE UPDATE MODULE
       8 = N/A
       9 = N/A
      10 = N/A

Enter POSTPROCESSOR Option NUMBER…………………………………………………… ===>

______________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
```

4.2.1 Diagnostics / Deficiency / String-Finder Module

```
         //                                                     //
        //                                                     //
       //                        DATA BASE                    //
      //                    PRE/POSTPROCESSOR                //
     //                                                     //
    //                                                     //



                                 .........
                                     .
                                     .
                                     .......> Press RETURN to continue
```

```
This PROGRAM contains several modules:
   * Sort routines for link, node, and subarea data bases
   * Link, node, subarea and NETWORK diagnostics programs
   * HealthCHECK (some diagnostics on YOUR hydrology network model)
   * STRING-FINDER (resolves Hydrology Link-Node network into hydraulic
STRINGS)
   * HGLOPT (estimates balanced HGL gradients for each link for each STRING)
   * Existing System Flow Capacity Estimation
   * Deficiency Analysis (for each link)
   * System Element Sizing
   * System Telescoping Analysis
   * Data Base Construction
In the following programs, YOU need to specify/select several PROGRAM OPTIONS,
or simply accept default values by pressing the RETURN button.


                                    Press RETURN to continue ===>
```

```
POSTPROCESSOR CONTROL Data Options

      1 = Define/EDIT CONTROL parameters
      2 = Execute POSTPROCESSOR

 Enter POSTPROCESSOR Option Desired…………………………………………………… ===>



Specify 2-letter STUDY NAME(between [AA] to [ZZ] ………………… ===>


______________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
```

1. FRICTION SLOPE ESTIMATION:

```
    Enter FRICTION-SLOPE MODEL NUMBER to be used for estimating the
    normal depth (or pressure flow) friction-slope, Sf, for each link.
    (Note: YOUR selected Sf model will be used as a parameter to model
    existing system elements and also for sizing new system elements.)

      1 = Use topographic slope, constrained by a DEFAULT MINIMUM slope
      2 = Use Balanced HGL Estimation Module results as the
          approximation of the friction-slope
      3 = Use OPTION #1, EXCEPT use User-Specified slopes
          whenever available
      4 = Use OPTION #2, EXCEPT use User-Specified slopes
          whenever available
      5 = N/A
      6 = N/A
      7 = N/A
      8 = N/A
    Enter Friction-Slope Model NUMBER................... ===>_______
   * Note: Press Enter Key to ACCEPT Default Values. *

____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

* If Model #1 or 3 was selected, please answer Question 1A and go to Question 4.

1A. MINIMUM FRICTION SLOPE:

```
MINIMUM FRICTION SLOPE:

    Enter DEFAULT Minimum Friction-Slope, Sf............ ===>_______
    :ALLOWABLE VALUES ARE [0.0003] TO [0.0100]

* Note: Press Enter Key to ACCEPT Default Values. *
____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

2. HGL ENVELOPE SETTINGS:

```
HGL ENVELOPE SETTINGS:

    Enter Minimum Allowable Flow Velocity for
    Peak flow rate(fps)................................ ===>_______
    :ALLOWABLE VALUES ARE [2.00] TO [10.00]

    Enter Minimum Allowable Friction-Slope, Sf.......... ===>_______
    :ALLOWABLE VALUES ARE [0.0002] TO [0.0500]

    Enter Manning's Friction Factor to be used to estimate
    HGL Envelopes....................................... ===>_______
    :ALLOWABLE VALUES ARE [0.01] TO [0.04]
    (Note: Above values will be used to Define TOP and BOTTOM
     HGL Envelopes for each STRING)




* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

3. TOPOGRAPHY-HGL CLEARANCE:

```
TOPOGRAPHY-HGL CLEARANCE:

    Enter Minimum Allowable Clearance(feet) Between topography
    and HGL............................................. ===>_______
    :ALLOWABLE VALUES ARE [0.00] TO [10.00]

    Enter Maximum Allowable Clearance(feet) Between topography
    and HGL............................................. ===>_______
    :ALLOWABLE VALUES ARE [  2.00] TO [500.00]




* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

4. HYDRAULIC CONTROL SETTING:

```
HYDRAULIC CONTROL SETTING:

    Enter HYDRAULIC CONTROL MODEL NUMBER to be used to define
    the Downstream HGL Control for each system Trunk Line.
    (This PROGRAM will use HGL estimates at confluence
    points to estimate HGL controls for branch lines)... ===>_______

      1 = use TOP HGL ENVELOPE, at downstream node of TRUNK LINE string,
          minus an offset, to define downstream Hydraulic Control.
      2 = User defines Downstream HGL CONTROL for each system Trunk Line.
      3 = N/A
      4 = N/A
      5 = N/A
      6 = N/A
      7 = N/A



* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

If Model #1 is selected, please answer Question 4A and go to Question 5.

4A. DEFINE DOWNSTREAM HYDRAULIC CONTROL OFFSET:

```
    Enter OFFSET (feet) to define downstream Hydraulic
    Control for each string............................ ===>_______
    :ALLOWABLE VALUES ARE [ 0.01] TO [ 98.99]



* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

4B. TRUNK LINE HYDRAULIC CONTROLS:

```
TRUNK LINK HYDRAULIC CONTROLS:

    YOU also need to define HYDRAULIC CONTROLS for the
    DOWNSTREAM NODE of each SYSTEM OUTLET. (Otherwise, the
    WSPG based program assumes Critical Depth)
    There are [ xx] system outlets identified.
    System [  1] of [ xx]
    Enter the HGL Control Elevation for NODE [ zzzzzz.z].. ==>_______
    :ALLOWABLE VALUES BETWEEN [-9999.9] AND [9999.9]








* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

5. SELECTING THE MAINSTREAM BRANCH AT A CONFLUENCE:

```
SELECTING THE MAINSTREAM BRANCH AT A CONFLUENCE:

    At a confluence, several upstream branches merge into one outlet.
    In order to choose which branch is the MAIN-LINE, YOU
    need to select the MODEL NUMBER to be used.......... ===>1 [Default]

      1 = Select BRANCH that has the LARGEST PEAK FLOW RATE
      2 = N/A
      3 = N/A
      4 = N/A
      5 = N/A





* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

6. PIPE CAPACITY ESTIMATION SETTINGS:

```
PIPE CAPACITY ESTIMATION SETTINGS:

    Select MODEL NUMBER for sizing new pipe elements and
    for estimating existing pipe element flow capacities
    (e.g., for each link)

      1 = Size pipe elements flowing at full flow capacity
          (or 0.82*Diameter as normal depth)
      2 = Size pipe elements flowing at 0.93*Diameter as normal depth
      3 = N/A
      4 = N/A
      5 = N/A
      6 = N/A
      7 = N/A
      8 = N/A


    Enter MODEL NUMBER................................. ===>_______


* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

7. PIPE "Bubble-out" SETTINGS:

```
PIPE “Bubble-out” SETTINGS:

    Select PIPE element FLOW CAPACITY sizing constraints ===>_______


      1 = On a STRING BASIS, size each PIPE element to have a flow
          capacity (or normal depth flow rate) greater than or
          equal to upstream elements' target flow rate
          (i.e., including the estimated target deficiency mitigation)
          (Note: In order to perform WSPG-based hydraulics,
          telescoping for increasing flow rates must be completed.)
      2 = Size each PIPE element independent of the
          upstream element (e.g., ALLOW "bubble-up" systems)
      3 = N/A
      4 = N/A
      5 = N/A



* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

8A. TELESCOPING SETTINGS:

```
TELESCOPING SETTINGS (Page 1):

    Select PIPE element SIZE constraints................ ===>_______
    (Note: this Telescoping module only analyzes Links
    on a STRING BASIS.  At a confluence, or Junction of
    Branch lines, only the MAIN LINE is considered in this
    Telescoping analysis)

      1 = Size each PIPE element to have a cross-section
          area greater than or equal to the UPSTREAM Pipe's
          cross-section area.
          (e.g., do NOT allow reduction in cross-section area)
      2 = Size each PIPE element independent of the
          Upstream Element.
          (e.g., allow reduction in cross-section area)
      3 = N/A
      4 = N/A
      5 = N/A



* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

8B. TELESCOPING SETTINGS:

```
TELESCOPING SETTINGS (Page 2):
 Select OPTION regarding telescoping EXISTING ELEMENTs ==>_______
      1 = Apply above telescoping rules to EXISTING PIPEs
          (i.e., replace Existing Pipes even if they are Estimated
          to NOT be deficient).
      2 = Do NOT Apply above telescoping rules to EXISTING PIPEs
          (i.e., if Existing Pipes are estimated to NOT be deficient
          and even though they do NOT satisfy YOUR telescoping rules,
          they will be RETAINED in the system).
          Note: in this MODEL, downstream new pipe elements will be
          telescoped with respect to the retained Existing Pipe.
      3 = Same as OPTION #2, except that new pipe elements located
          downstream of retained Existing Pipe elements will be
          telescoped as though the Existing Pipe elements had been
          telescoped (i.e., this models an anticipated future
          telescoped pipe when all RETAINED existing pipe elements
          are eventually replaced).
      4 = Same as OPTION #3, EXCEPT, use the maximum of the Existing
          Pipe or Future (New) Pipe, in Telescoping Downstream Pipe
          Elements (i.e., this OPTION may be consistent with both
          Future and Retained Existing Pipe Elements).

* Note: Press Enter Key to ACCEPT Default Values. *
_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

9A. PIPEFLOW HYDRAULICS SETTINGS:

```
PIPEFLOW HYDRAULICS SETTINGS:
    Enter MINIMUM ALLOWABLE Pipe DIAMETER(inches)....... ===>_______
    :ALLOWABLE VALUES ARE [6] TO [60]

* Note: Press Enter Key to ACCEPT Default Values. *
_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

9B. PIPEFLOW HYDRAULICS SETTINGS:

```
PIPEFLOW HYDRAULICS SETTINGS:
    Enter MINIMUM ALLOWABLE Pipe DIAMETER(inches)....... ===>_______
    :ALLOWABLE VALUES ARE [6] TO [60]

    The PROGRAM estimates pipe sizes using Manning's equation,
    with the friction slope set equal to the Value estimated by
    YOUR selected Friction Slope Modeling Option.  The PROGRAM
    next upsizes to a CONSTRUCTABLE pipe size.  The USER can
    specify a proportion of the Estimated Friction Slope to be
    used for the pipeflow friction slope.
    (SUGGESTION:
       Use [.95] for pipesystems with FEW minor losses
       Use [.85] for pipesystems with CONSIDERABLE minor losses)

    Enter proportion of the Estimated Friction Slope to be used
    for the pipeflow friction slope(DECIMAL)............ ===>_______
    :ALLOWABLE VALUES ARE [.001] TO [1.00]
    Note: this PROPORTION factor will also be used in sizing BOXes,
    but NOT open CHANNELs.

* Note: Press Enter Key to ACCEPT Default Values. *
_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

10. "TOTAL FLOW PICKUP" PIPE SIZING SETTINGS:

```
"TOTAL FLOW PICKUP" PIPE SIZING SETTINGS:

    Pipe systems are sized according to Rules
    selected by YOU.  YOU need to specify what Flow Rate is to
    be used by the PROGRAM in Sizing System Elements.

      1 = Use Link Upstream Node Peak Flow Rate
      2 = Use Link Downstream Node Peak Flow Rate
      3 = Use AVERAGE of OPTIONs 1 and 2
      4 = Use MAXIMUM of OPTIONs 1 and 2
      5 = N/A
      6 = N/A
      7 = N/A
      8 = N/A

    Enter Option NUMBER................................. ===>_______



* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

11. ELEMENT "CONSTRUCTIBLE" SIZING SETTINGS:

```
ELEMENT "CONSTRUCTIBLE" SIZING SETTINGS:

    For BOXES and CHANNELS, the Computer-Estimated DIMENSION can be
    increased to meet USER-SPECIFIED increments.

    Select Sizing Increment Option...................... ===>_______
    1 = Do Not Modify Computer-Estimated DIMENSIONs

    INCREASE Computer-Estimated DIMENSIONs to nearest:
          2 = 0.25 FT
          3 = 0.50 FT
          4 = 1.00 FT



* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

12. BOX/CHANNEL SIZING SETTINGS:

```
BOX/CHANNEL SIZING SETTINGS:

    Boxes and Open Channels are sized according to Rules
    selected by YOU.  YOU need to specify what Flow Rate is to
    be used by the PROGRAM in Sizing System Elements.

      1 = Use Link Upstream Node Peak Flow Rate
      2 = Use Link Downstream Node Peak Flow Rate
      3 = Use AVERAGE of OPTIONs 1 and 2
      4 = Use MAXIMUM of OPTIONs 1 and 2
      5 = N/A
      6 = N/A
      7 = N/A
      8 = N/A

    Enter Option NUMBER................................ ===>_______


* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

13. BOX Element TELESCOPING SETTINGS:

```
BOX Element TELESCOPING SETTINGS:

    Select BOX element Telescoping constraints.......... ===>2 [Default]
    (Note: this Telescoping module only analyzes Links
    on a STRING BASIS.  At a confluence, or Junction of
    Branch lines, only the MAIN LINE is considered in this
    Telescoping analysis)

    N/A = Size each Box element to have a cross-section
          area greater than or equal to the upstream
          element's cross-section flow area (with freeboard, if defined).
          (e.g., do NOT allow reduction in cross-section flow area)
      2 = Size each Box element independent of the
          upstream element.
          (e.g., allow reduction in cross-section flow area)
      3 = N/A
      4 = N/A
      5 = N/A

* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

14. CHANNEL Element TELESCOPING SETTINGS:

```
CHANNEL Element TELESCOPING SETTINGS:

    Select CHANNEL element Telescoping constraints...... ===>2 [Default]
    (Note: this Telescoping module only analyzes Links
    on a STRING BASIS.  At a confluence, or Junction of
    Branch lines, only the MAIN LINE is considered in this
    Telescoping analysis)

    N/A = Size each Channel element to have a cross-section
          flow area greater than or equal to the upstream
          element's cross-section flow area.
          (e.g., do NOT allow reduction in cross-section flow area)
      2 = Size each Channel element independent of the
          upstream element.
          (e.g., allow reduction in cross-section flow area)
      3 = N/A
      4 = N/A
      5 = N/A

* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

15. ELEMENT INTERFACING:

```
ELEMENT INTERFACING:

    Select PIPE/BOX/CHANNEL element
    Telescoping INTERFACE constraints.................. ===>1 [Default]
    (Note: this Telescoping module only analyzes Links
    on a STRING BASIS.  At a confluence, or Junction of
    Branch lines, only the MAIN LINE is considered in this
    Telescoping analysis)

      1 = Do NOT Telescope at INTERFACE between PIPE/BOX/CHANNEL
          elements (e.g., do NOT telescope PIPE/BOX, PIPE/CHANNEL,
          and BOX/CHANNEL interfaces).
    N/A = Telescope at PIPE/BOX/CHANNEL Element Interfaces
          (i.e., Estimate Downstream Element Sizing Dimension to
           achieve flow area greater than or equal to Upstream Element
           flow area).
      3 = N/A
      4 = N/A
      5 = N/A

* Note: Press Enter Key to ACCEPT Default Values. *

_____________________________________________________________________________
TYPE: EXIT to leave program ; TOP to go to top of page
                            ; BACK to go back one page
```

4.3 Hydraulics Files Setup

```
    HydrauLINK Program OPTIONS:
    SETUP input data files, for each STRING file, for YOUR PROGRAM:
    (Note: ONLY OPTIONs 1 and 2 Link to the Data Base.
    OPTIONs 3 and 4 ONLY CREATE DATA FILES.)
        1.= WSPG (from Woodcrest)
        2.= STORM PLUS (from CivilSoft)
        3.= PipeFLOW (for PIPE System Strings ONLY; from AES)
        4.= WSPGN (from CivilDesign)
        5.= N/A
        6.= N/A
        7.= N/A
        8.= N/A
        9.= N/A
       10.= N/A
    Enter OPTION desired................................ ===>1



    * Note: Press Enter Key to ACCEPT default values. *

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
```

```


    For Hydraulics Analysis by YOUR WSPG Program,
    FLOWLINE ELEVATION data are needed for all elements.


    Select system link FLOWLINE data entry option NUMBER ===>2

        1= User-specified CLEARANCE value to be used in
           estimating Pipe/Box/Channel flowlines.
        2= Use AES POSTPROCESSOR HGL Estimates MINUS a CLEARANCE
           in estimating flowlines.
        3= Use RATSCx NODAL ELEVATIONs as Estimates of FLOWLINE DATA.
        4= Use OPTION #2, EXCEPT use USER-SPECIFIED invert elevations
           whenever available
        5= N/A
        6= N/A
    * Note: Press Enter Key to ACCEPT default values. *

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
    For this option, FLOWLINE ELEVATIONS are estimated as follows:

    Pipe/Box/Channel: Flowline Elevation = AES POSTPROCESSOR
    ESTIMATED HGL Elevation - Diameter/Box Height/Channel Height
    - CLEARANCE

    Enter CLEARANCE values to be used in estimating
    Pipe/Box/Channel flowlines:

    Enter Pipe CLEARANCE
    (Estimated HGL Elevation-soffit)(FEET).............. ===>  2.00

    Enter Box CLEARANCE
    (Estimated HGL Elevation-soffit)(FEET).............. ===>  2.00

    Enter Channel CLEARANCE
    (Estimated HGL Elevation-Top of Wall)(FEET)......... ===>  2.00
    :ALLOWABLE VALUES ARE BETWEEN [   1.0] AND [   8.0]



----* Note: Press Enter Key to ACCEPT default values. *----------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
    This PROGRAM develops data files, for each STRING,
    for WSPG based programs.  This PROGRAM also connects the
    strings and defines HGL controls by rules selected by YOU.
    Select the RULE to be used in defining HGL downstream
    controls, for each STRING, at each junction:

      1= Use DOWNSTREAM HGL value of each junction structure
      2= Use UPSTREAM HGL value of each junction structure
      3= Use AVERAGE of above OPTIONS 1 and 2
      4= Use MAXIMUM VALUE of above OPTIONS 1 and 2
      5= N/A
      6= N/A
      7= N/A
      8= N/A

    Enter Option Number................................ ====>4




    * Note: Press Enter Key to ACCEPT default values. *

-----------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
    Hydraulics Analysis Diagnostics Setting:

    In this PROGRAM, each String is hydraulically analyzed
    using a WSPG (or other) based Program.  The HGL results are
    stored in the Node and Link Databases.
    You must define a tolerance, between Nodal Topographic
    Elevations and computed Water Surface Elevations, that is
    acceptable for this study.  Exceptions to these Tolerances
    are printed in the Diagnostics Report.

    Enter Minimum Allowable Tolerance between Nodal Topographic
    Elevation and Computed HGL Elevation............... ====>  1.00
    :ALLOWABLE VALUES ARE BETWEEN [-100.] AND [10.00]

    Enter Maximum Allowable Tolerance between Nodal Topographic
    Elevation and Computed HGL Elevation............... ====> 10.00
    :ALLOWABLE VALUES ARE BETWEEN [ 0.11] AND [300.00]




    * Note: Press Enter Key to ACCEPT default values. *

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
    YOU also need to define HYDRAULIC CONTROLS for the
    DOWNSTREAM NODE of each SYSTEM OUTLET. (Otherwise, the
    WSPG based program assumes Critical Depth)
    There are [103] system outlets identified.
    System [  1] of [103]
    Enter the HGL Control Elevation for NODE [ 10109.0].. ==>  762.00
    :ALLOWABLE VALUES BETWEEN [-9999.9] AND [9999.9]









    * Note: Press Enter Key to ACCEPT default values. *

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

4.4 Costs

```
    Pipe System costs are typically computed as simply:

         (UNIT COST) * (Pipe Diameter(inch)) * (Length(Feet))

    To initialize YOUR pipe system UNIT COST TABLE,
    a Default UNIT COST (see above formula) is needed.

    Enter a DEFAULT Unit Cost(dollars)................. ===>    5.00
    :ALLOWABLE VALUES ARE BETWEEN [ 1.0] AND [20.]







------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
          OR Press Enter to ACCEPT displayed value
```

```
          Pipe System Unit Cost Table(Cost per linear foot)
       ========================================================
       Cost      Pipe         Unit    Cost      Pipe         Unit
       Item    Diameter       Cost    Item    Diameter       Cost
       ----   -----------   ------    ----   -----------   ------
         1    15"( 375mm)   $  84.0     9    39"( 975mm)   $ 147.0
         2    18"( 450mm)   $ 101.0    10    42"(1050mm)   $ 155.0
         3    21"( 525mm)   $ 107.0    11    45"(1125mm)   $ 162.0
         4    24"( 600mm)   $ 114.0    12    48"(1200mm)   $ 173.0
         5    27"( 675mm)   $ 119.0    13    51"(1275mm)   $ 185.0
         6    30"( 750mm)   $ 126.0    14    54"(1350mm)   $ 195.0
         7    33"( 825mm)   $ 134.0    15    57"(1425mm)   $ 203.0
         8    36"( 900mm)   $ 140.0    16    60"(1500mm)   $ 215.0

    TO CHANGE tabulated data:
    Enter Cost Item Number............................. ===>
    :ALLOWABLE VALUES ARE BETWEEN [1] AND [32]

    Enter Cost Item #[  ] Unit Cost(dollars)............ ===>
    :ALLOWABLE VALUES ARE BETWEEN [   0.0] AND [9999.9]

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
          Press Enter Key to go to NEXT Page
```

```
    Reinforced Concrete Box Unit Cost Opinion Data:

    Enter Box Top Wall THICKNESS(inches) to be used
    to compute Wall Volume.............................. ===>   6.00
    :ALLOWABLE VALUES ARE BETWEEN [3] TO [36]

    Enter Box Side Walls THICKNESS(inches) to be used
    to compute Wall Volume.............................. ===>
    :ALLOWABLE VALUES ARE BETWEEN [3] TO [36]

    Enter Box Base Wall THICKNESS(inches) to be used
    to compute Wall Volume.............................. ===>
    :ALLOWABLE VALUES ARE BETWEEN [3] TO [36]

    Enter UNIT COST(dollars) per Box Wall
    VOLUME(cubic yards)................................. ===>
    :ALLOWABLE VALUES ARE BETWEEN [50] TO [2000]



------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
          BACK to go back one page; OR Press Enter to ACCEPT displayed value
```

```
    Reinforced Concrete Open Channel Unit Cost Opinion Data:

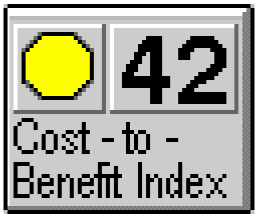
    Enter Channel BOTTOM THICKNESS(inches) to be used
    to compute Wall Volume.............................. ===>   6.00
    :ALLOWABLE VALUES ARE BETWEEN [4] TO [36]

    Enter Channel SIDEWALL THICKNESS(inches)(measured vertically)
    to be used to compute Wall Volume................... ===>
    :ALLOWABLE VALUES ARE BETWEEN [4] TO [36]

    Enter UNIT COST(dollars) per Open Channel Wall
    VOLUME(cubic yards)................................. ===>
    :ALLOWABLE VALUES ARE BETWEEN [50] TO [2000]



------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
          BACK to go back one page; OR Press Enter to ACCEPT displayed value
```



4.5 CBI:Cost-to-Benefit Index

```
        COST-TO-BENEFIT INDEX (CBI) ANALYSIS

-- DEFAULT STREET SLOPE

   The CBI Program computes normal depth for street flow by using
the DOWNSTREAM node(of the link) peak flow rate minus the computed
drainage element flow capacity.  If the street grade (upstream
elevation - downstream elevation) / (link-length) is less than a
TOLERANCE, the TOLERANCE is used as a DEFAULT value for use in
Manning's Equation.

Enter DEFAULT Street Slope......................... ===> .0015
:ALLOWABLE VALUES ARE BETWEEN [0.0001] AND [0.0990]


* Note: Press Enter Key to ACCEPT default values. *

------------------------------------------------------------------------------
TYPE: EXIT to leave program ; TOP  to go to top of page
```

```
-- DEFAULT STREET SECTION

   A DEFAULT STREET SECTION is used by the PROGRAM to associate
flood damage potential/penalty to model links that are not coupled
to a streetflow module (e.g., open channels, pipes not coupled to
streets, etc.).  This DEFAULT STREET SECTION is linked to each
model network link that does not already have a street section
defined with it. (To define LAND USE data associated to the DEFAULT
STREET SECTION, the PROGRAM first looks at the subarea associated
to the downstream node of the subject link; if there is no such
subarea associated to the downstream node, the PROGRAM looks at
the subarea associated to the upstream node of the subject link;
if there are no subareas associated to either the upstream or
downstream node of the subject link, the PROGRAM uses the highest
penalty value, for any defined Land Use, in the CBI control
input data.)



                              Press RETURN to continue ===>
```

```
YOU need to ENTER data to define the DEFAULT STREET SECTION.
A standard 8-inch curb, symmetric street section is assumed,
with zero street flow in the parkway(and beyond) and
the following data:
  Manning's n = 0.015      Gutter width = 2.0 ft.
  Gutter hike = 0.167 ft.   Gutter lip = 0.03125 ft.
  Crossfall = .017

Enter TOTAL Street Width(Feet) for Pipe Link....... ===> 20.00
:ALLOWABLE VALUES ARE BETWEEN [5] AND [200]

Enter TOTAL Street Width(Feet) for Open Channel Link ==> 60.00
:ALLOWABLE VALUES ARE BETWEEN [5] AND [200]




* Note: Press Enter Key to ACCEPT default values. *

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
-- CBI Peak Flow Rate OPTIONs

    The CBI technique estimates "existing-condition" modeled peak
 flow rate streetflow hydraulics using Manning's equation,
 USER-SPECIFIED street section data, and streetflow depth versus
 damage-potential/penalty data.  To estimate "existing condition"
 streetflow depths, the flow in excess of the estimated existing
 system element capacity, is used to estimate a normal depth in
 the street, with zero flow assumed in the parkway and beyond.

 YOU need to select Peak Flow Rate OPTIONS to be used by the PROGRAM:

 Select Peak Flow Rate Option NUMBER................. ===>2
   1= Use Peak Flow Rate Estimated for UPSTREAM NODE
   2= Use Peak Flow Rate Estimated for DOWNSTREAM NODE
   3= N/A
   4= N/A
   5= N/A


 * Note: Press Enter Key to ACCEPT default values. *

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
Select RETURN FREQUENCY Option NUMBER............... ===>1
      1= Use MAXIMUM RETURN FREQUENCY flow estimates
      2= N/A
      3= N/A
      4= N/A
      5= N/A

    Select CBI Output Option NUMBER..................... ===>1
      1= Output based upon LINK-NODE Model setup
      2= Output based upon STRING setup






    * Note: Press Enter Key to ACCEPT default values. *

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
    A set of flood damage potential curves (see below) are needed
    for each deficiency category.  The flood damage potential curves
    define a relationship for street flow depth versus flood damage
    potential, for various land use designations.

                 ^
                 |                         C <--COMMERCIAL
    FLOOD        |                     C
    DAMAGE    2. +                 C
    POTENTIAL    |               C         R <--RESIDENTIAL
    (RELATIVE)   |             C       R
              1. +            C    R       O <--OPEN SPACE
                 |           C  R      O
                 |          C  R   O
              0. +-----+---C-+R--O-+-----+-----+------>
                0.    0.5   1.0   1.5   2.0   2.5

                STREET FLOW DEPTH(FT.) ABOVE GUTTER FLOWLINE
                      (WITHOUT DEFICIENCY MITIGATION)



                                 Press RETURN to continue ===>
```

```
    Enter TOTAL NUMBER of flood damage potential curves. ===>
    :ALLOWABLE VALUES ARE BETWEEN [1] AND [70]

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
    "URBAN" LAND USE OR DEVELOPMENT TYPE for Damage Potential Curve No.  1

       1: Commercial                    8: 3-4  Dwellings/Acre
       2: Mobile Home Park              9: 2    Dwellings/Acre
       3: Apartments                   10: 1    Dwelling/Acre
       4: Condominiums                 11: 2.5 Acre Lot
       5: 11+  Dwellings/Acre          12: School
       6: 8-10 Dwellings/Acre          13: Public Park
       7: 5-7  Dwellings/Acre          14: Open Space/Agriculture

    Enter Land Use Number............................... ===>
    :ALLOWABLE VALUE ARE BETWEEN [1] AND [14]

    DEFICIENCY CATEGORIES for Damage Potential Curve No.  1

       1. Roadway Sump                 2. Arterial Streets
       3. Residential Streets          4. Box/Channel Links
       5. Storm Drain Pipe Links
    Enter Deficiency Category Number.................... ===>
    :ALLOWABLE VALUE ARE BETWEEN [1] AND [5]

------------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

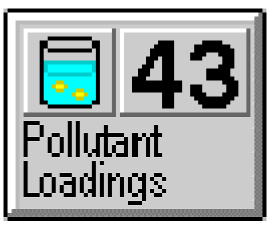
```
    DATA SET 2 of 6 for Damage Potential Curve No.  1

    Enter Street Flow Depth above Gutter Flowline(FEET). ===>
    :ALLOWABLE VALUE ARE BETWEEN [ .1] AND [5.0]

    Enter Relative Flood Damage Potential............... ===>
    :ALLOWABLE VALUE ARE BETWEEN [  .0] AND [10.0]


       Data         Street Flow Depth        Relative Flood
       Set               (feet)             Damage Potential
       ----         -----------------       ----------------
        1                    .0                     .0
        2
        3
        4
        5
        6


-----------------------------------------------------------------------------
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```



4.6 PLM: Pollutant Loadings

```
    Enter long-term annual average precipitation(in/yr). ===>[ 12.00]
    :ALLOWABLE VALUES ARE [0.1   ] TO [99.9      ]







                       ***** Enter Your Command..........====>

                             (Press RETURN to ACCEPT above entries)

    _____________________________________________________________________________
    TYPE: C to CHANGE above entries
```

```
Define Hydrologic Land Use and "Event Mean Concentrations" Land Use Linkage

   "Event Mean Concentrations" Land Use    Hydrologic         EMC
       Number   Type                        Land Use          Number
       ======   ==================          ==========        ======
          1     Forest/Open                 Commercial        [     7]      <=?
          2     Agriculture/Pasture         Mobile Home       [     6]
          3     Cropland                    Apartment         [     6]
          4     Low Density Res.            Condominium       [     6]
          5     Medium Density Res.         11+ DU/Ac         [     6]
          6     High Density Res.           8-10 DU/Ac        [     6]
          7     Commercial                  5-7 DU/Ac         [     6]
          8     Office/Light Ind.           3-4 DU/Ac         [     5]
          9     Heavy Industrial            2 DU/Ac           [     5]
         10     Water                       1 DU/Ac           [     4]
         11     Wetland                     2.5Ac lot         [     4]
         12     Major Highway               School            [     6]
                                            Public Park       [     4]
                                            Natural           [     1]
                                            Agriculture       [     2]
                                                 (Press RETURN to ACCEPT entry)
_______________________________________________________________________________
    TYPE: C to CHANGE entry  ;
          E to leave program ; T to go to TOP of page ; B to go BACK one page
```

```
 "Event Mean Concentrations(mg/L)" and Impervious Percentages
                                                   Oxygen Demand & Sediment
  Number   Land Use            Impervious         BOD    COD    TSS    TDS
 ======   ==================  ==========         ========================
    1      Forest/Open           .0050            8.0   51.0  216.0  100.0
    2      Agriculture/Pasture   .0050            8.0   51.0  216.0  100.0
    3      Cropland              .0050            8.0   51.0  216.0  100.0
    4      Low Density Res.      .1000           10.8   83.0  140.0  100.0
    5      Medium Density Res.   .3000           10.8   83.0  140.0  100.0
    6      High Density Res.     .5000           10.8   83.0  140.0  100.0
    7      Commercial            .9000            9.7   61.0   91.0  100.0
    8      Office/Light Ind.     .7000            9.7   61.0   91.0  100.0
    9      Heavy Industrial      .8000            9.7   61.0   91.0  100.0
   10      Water                1.0000            3.0   22.0   26.0  100.0
   11      Wetland               .0050            8.0   51.0  216.0  100.0
   12      Major Highway         .9000            9.7  103.0  142.0  100.0

    Enter Land Use Number(to redefine parameter values). ===>
    (or Press Enter Key to accept data)

_______________________________________________________________________________
    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
"Event Mean Concentrations(mg/L)"
                                                Nutrients
  Number   Land Use                 TP     SP    TKN   NO2&3
  ======   ==================    ============================
     1     Forest/Open           .230   .060  1.360   .730
     2     Agriculture/Pasture   .230   .060  1.360   .730
     3     Cropland              .230   .060  1.360   .730
     4     Low Density Res.      .470   .160  2.350   .960
     5     Medium Density Res.   .470   .160  2.350   .960
     6     High Density Res.     .470   .160  2.350   .960
     7     Commercial            .240   .100  1.280   .630
     8     Office/Light Ind.     .240   .100  1.280   .630
     9     Heavy Industrial      .240   .100  1.280   .630
    10     Water                 .030   .010   .600   .600
    11     Wetland               .230   .060  1.360   .730
    12     Major Highway         .440   .170  1.780   .830

    Enter Land Use Number(to redefine parameter values). ===>
    (or Press Enter Key to accept data)

    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
 "Event Mean Concentrations(mg/L)"
                                           Heavy Metals
  Number   Land Use                  Pb     Cu      Zn     Cd
  ======   ==================    =========================
     1     Forest/Open           .000   .000   .000   .000
     2     Agriculture/Pasture   .000   .000   .000   .000
     3     Cropland              .000   .000   .000   .000
     4     Low Density Res.      .180   .050   .180   .002
     5     Medium Density Res.   .180   .050   .180   .002
     6     High Density Res.     .180   .050   .180   .002
     7     Commercial            .130   .040   .330   .002
     8     Office/Light Ind.     .130   .040   .330   .002
     9     Heavy Industrial      .130   .040   .330   .002
    10     Water                 .000   .000   .110   .000
    11     Wetland               .000   .000   .000   .000
    12     Major Highway         .530   .050   .370   .002

    Enter Land Use Number(to redefine parameter values). ===>
    (or Press Enter Key to accept data)

    TYPE: EXIT to leave program ; TOP  to go to top of page
                                ; BACK to go back one page
```

```
   ** Master Plan Pollutant Loadings Estimation Node Numbers **

   TOTAL NUMBER OF NODES TO BE ANALYZED =  20

   M.P.D. NODAL POINTS:
 60015.0   71008.0   70015.0   90012.0  100011.0
210005.0  220004.0  250005.0  230005.0  270004.0
320004.0  330018.0  370013.0  380028.0  420021.0
440010.0  450014.0  460010.0  530008.0  540007.0



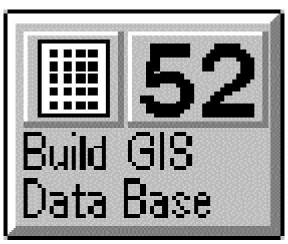



   Enter Option Desired.............................===>






------------------------------------------------------------------------
   TYPE: A to Add a M.P.D. nodal point;D to Delete a M.P.D. nodal point
   or Press RETURN to ACCEPT entry
```



4.7 Build GIS Database SUBSET

```
   Data Base SUBSET Options

     1 = Create/Edit NODE Subset Specifications
     2 = Create/Edit SUBAREA Subset Specifications
     3 = Create/Edit LINK Subset Specifications
     4 = Prepare LINK, NODE, and SUBAREA Data Base SUBSETS
     5 = N/A

   Enter Data Base Option NUMBER....................... ===>


   Specify 2-letter STUDY NAME(between [AA] to [ZZ])... ===>


------------------------------------------------------------------------------
   TYPE: EXIT to leave program ; TOP  to go to top of page
```

```
 NODE DATA BASE SUBSET SPECIFICATIONS:
 Enter Global Data Base Field Number to be Mapped into the SUBSET Field
Number:
      SUBSET     GLOBAL DATA BASE       SUBSET     GLOBAL DATA BASE
     FIELD NO.     FIELD NUMBER        FIELD NO.     FIELD NUMBER
         1            [  1]                16            [  0]
         2            [  2]<==?            17            [  0]
         3            [  4]                18            [  0]
         4            [ 55]                19            [  0]
         5            [ 56]                20            [  0]
         6            [ 57]                21            [  0]
         7            [226]                22            [  0]
         8            [227]                23            [  0]
         9            [228]                24            [  0]
        10            [229]                25            [  0]
        11            [230]                26            [  0]
        12            [231]                27            [  0]
        13            [295]                28            [  0]
        14            [296]                29            [  0]
        15            [297]                30            [  0]

    ----------------------------------------------------------------------
    TYPE: A:Insert Above; B:go BACK one Entry; C:Change Entry;
    D:Delete Entry; E:Exit to Main Menu; R:Reinstall Default Field Numbers
```

```
 SUBAREA DATA BASE SUBSET SPECIFICATIONS:
 Enter Global Data Base Field Number to be Mapped into the SUBSET Field
Number:
      SUBSET     GLOBAL DATA BASE       SUBSET     GLOBAL DATA BASE
     FIELD NO.     FIELD NUMBER        FIELD NO.     FIELD NUMBER
         1            [  1]                16            [127]
         2            [ 99]<==?            17            [128]
         3            [114]                18            [129]
         4            [115]                19            [130]
         5            [116]                20            [131]
         6            [117]                21            [132]
         7            [118]                22            [133]
         8            [119]                23            [134]
         9            [120]                24            [135]
        10            [121]                25            [136]
        11            [122]                26            [137]
        12            [123]                27            [  0]
        13            [124]                28            [  0]
        14            [125]                29            [  0]
        15            [126]                30            [  0]

    ----------------------------------------------------------------------
    TYPE: A:Insert Above; B:go BACK one Entry; C:Change Entry;
    D:Delete Entry; E:Exit to Main Menu; R:Reinstall Default Field Numbers
```

```
 LINK DATA BASE SUBSET SPECIFICATIONS:
 Enter Global Data Base Field Number to be Mapped into the SUBSET Field
Number:
      SUBSET     GLOBAL DATA BASE       SUBSET     GLOBAL DATA BASE
     FIELD NO.     FIELD NUMBER        FIELD NO.     FIELD NUMBER
         1             [  1]               16            [ 18]
         2             [  2]               17            [ 19]
         3             [  3]<==?           18            [ 20]
         4             [  4]               19            [ 22]
         5             [  5]               20            [ 23]
         6             [  7]               21            [ 24]
         7             [  8]               22            [ 25]
         8             [ 10]               23            [ 26]
         9             [ 11]               24            [ 27]
        10             [ 12]               25            [ 28]
        11             [ 13]               26            [ 29]
        12             [ 14]               27            [129]
        13             [ 15]               28            [131]
        14             [ 16]               29            [132]
        15             [ 17]               30            [133]

    ----------------------------------------------------------------------
    TYPE: A:Insert Above; B:go BACK one Entry; C:Change Entry;
    D:Delete Entry; E:Exit to Main Menu; R:Reinstall Default Field Numbers
```

Chapter 5
A Graphic User Interface: Layout and Design

5.1 A Graphic User Interface (GUI) for the SIMS

A GUI is designed for coordination of the sequence of operations needed to develop a Master Plan of Drainage (MPD). In this case, the GUI is a melding of 3 paths:

1. An MPD file manager - handles the operations of saving the baseline MPD as it evolves through time.

2. A CREATION mode GUI - guides the program user, in a stepwise fashion, through the sequence of computerized analysis steps needed to create an MPD from scratch.

3. A MAINTENANCE mode GUI - guides the program user through the subset of steps (contained in the CREATION mode GUI) needed to update the MPD.

Figure 5.1

The case study herein is the Advanced Engineering Software (AES) GUI for the MPD development and real-time maintenance. Figure 5.1 depicts the entrance page to the AES HydroWIN GUI. The cover page branches to the standard AES library of drainage related programs, which can be activated by clicking on the appropriate button (see Figure 5.2). Most of the HydroSoft programs are also utilized in the MPD creation and maintenance, but with some different access points and options.

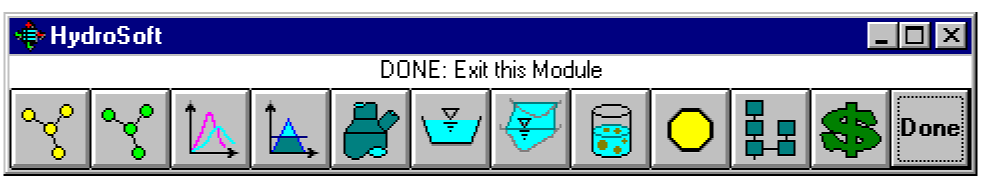


Figure 5.2

Click on the HEC button, (HEC is the standard acronym for the U.S. Army Hydrologic Engineering Center, located in Davis, California), and the program branches to a library of standard HEC software which are available to the user (see Figure 5.3).

Figure 5.3

Naturally, the HydroWIN GUI only provides access to particular programs that are loaded in the computer; otherwise, a “not available” or “not found” message is usually displayed.

5.2 AES / GIS Interface GUI Display

Figure 5.4 shows the AES display when the “GIS Interface” button is clicked, (Figure 5.1). Each figure is also a button that, when clicked, produces a larger image and accompanying explanatory text. In the AES GUI, this screen is an information and instruction tool. The “Numeric Database” button, however, contains the specifications for the Node, Link and Subarea databases of the SIMS Global Database Structure. These specifications disclose the column definitions of the tabulated database for each of the Node, Link and Subarea databases.

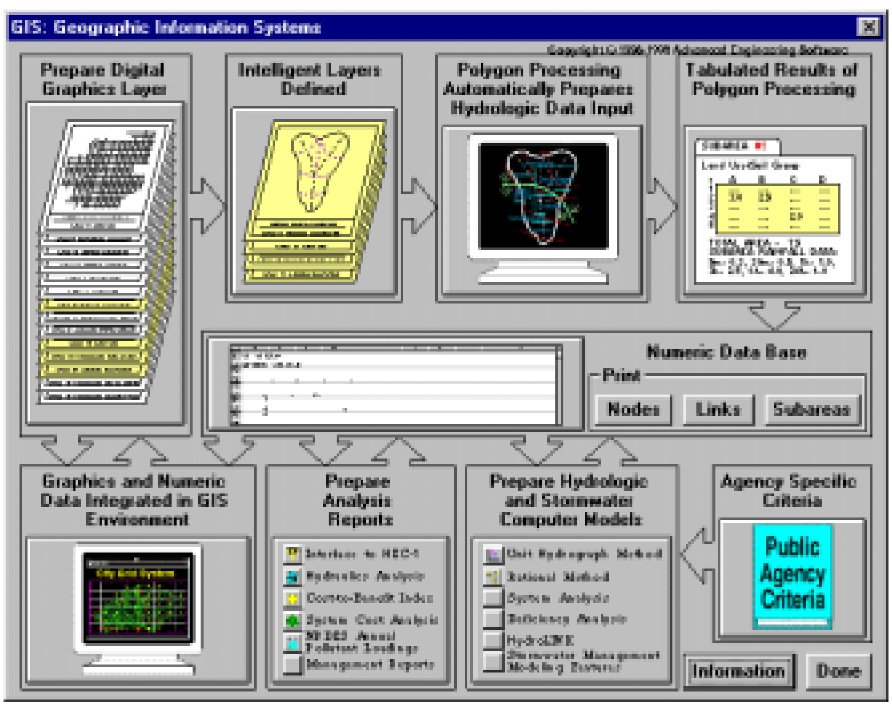


Figure 5.4

Because the entire GIS/SIMS process is so complex, it is useful to dedicate an instructional page in the GUI so that future instructional data can be accumulated into one location.

5.3 License Agreement

The entire AES Software License Agreement is displayed to the user if the License Agreement button is clicked. Other security techniques are available to computer programs; however, it is useful to provide the program user with a readily available copy of the Agreement.

5.4 MPD Manager / SIMS

The Database Manager button connects the user to the SIMS GUI (shown in Figure 5.5), which controls the program execution sequentially, whether in Creation mode (the SIMS GUI), or in Maintenance mode (the MPD Manager GUI).

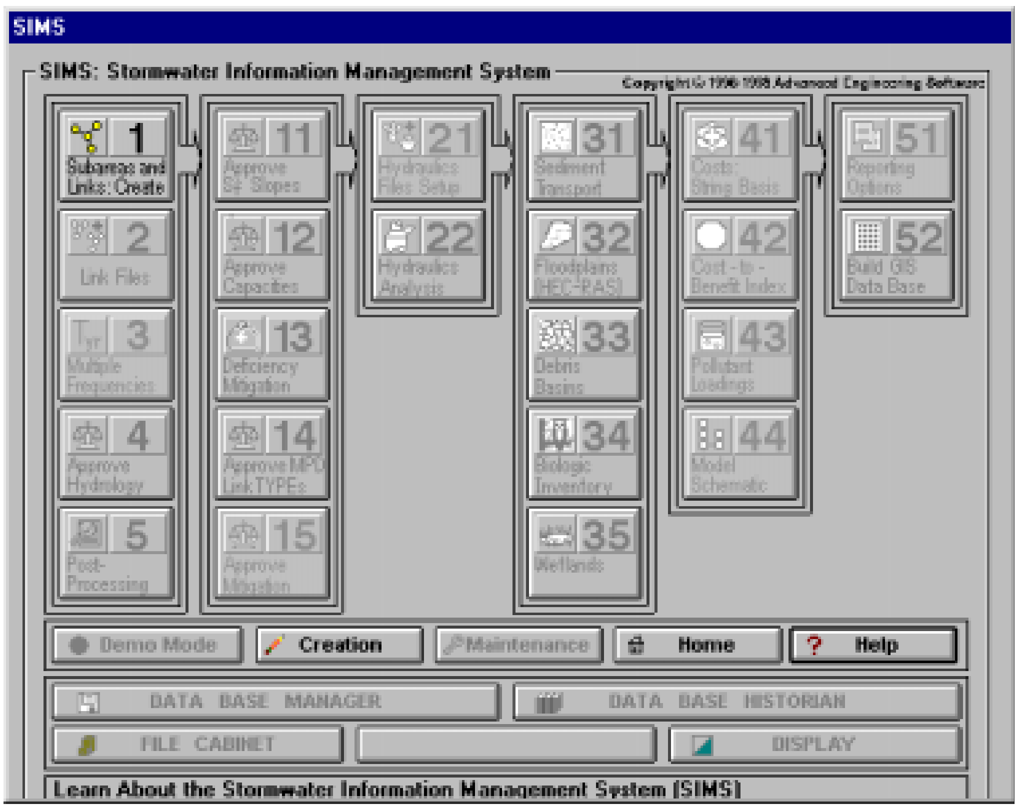


Figure 5.5

The AES GUI is usually customized to better meet particular project deliverable needs (e.g., buttons may be added or deleted depending on software options chosen to be implemented). The SIMS GUI used in this chapter is a base GUI from which other GUIs are developed by AES. For example, the Database Manager Button connects the program user to the Database Manager Menu, which in turn allows the user to select between the two Program Modes (Creation of a Baseline MPD, Maintenance of a Scenario), or to update the database settings, inventory, etc. The particular program names are easily interchanged, to better meet client naming preferences.

5.5 MPD Manager

The operation of the SIMS and the MPD Manager programs are analogous, so only the MPD Manager will be focused upon. Recall, we will be discussing only the Maintenance Mode; therefore, the focus will be on editing data.

To initialize the Maintenance process, the user selects the “Database Manager” button from the main SIMS display. This will bring up the Database Manager Menu. The user then chooses “Select Program Mode”, from which the user can then choose “Start Maintenance Sequence”. The user is then asked to select which Baseline database to edit; only previously saved Baselines (constructed during the Creation Mode) are available for editing. The user then selects the appropriate Baseline, and the Maintenance process begins.

To start, only button 1 is available as an event. Upon clicking button 1, control is transferred to the appropriate AES hydrology program and the user can, (in Maintenance Mode), edit particular attribute data for links and subareas. However, for this version of the GUI, the user cannot alter network topology; rather, in order to keep topology consistent between the graphics layers and the numeric database, topology is modified via the GIS, and then a new MPD is generated in the creation mode.

The link and subarea attribute data are editable directly in the Global Database structure using the AES database program editor. When the user exits the AES database editor, the control is returned to the GUI, which displays that Step One is “DONE!” and activates the SIMS button two (see Figure 5.6).

Figure 5.6

Continuing in this fashion, the first three steps of the SIMS are accomplished, resulting in the first three “DONE!” displays shown in Figure 5.7.

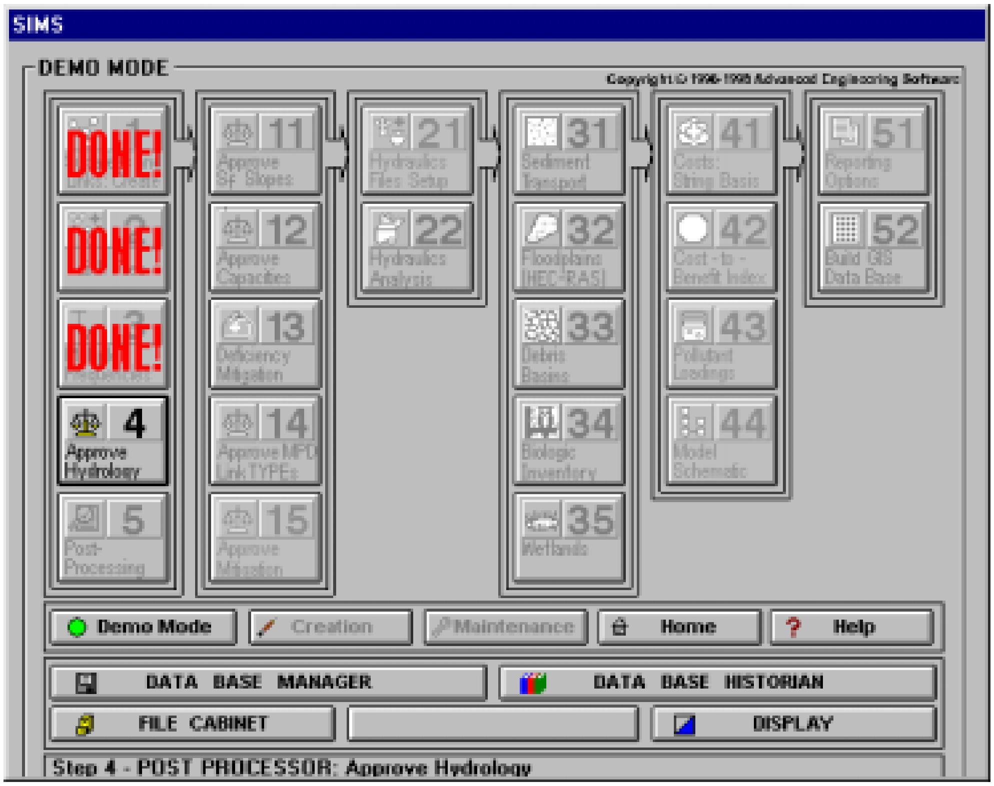


Figure 5.7

The user can halt the process at any step, and return to it later, simply by choosing “Continue Maintenance Sequence” from the Database Manager’s Program Mode menu. Similarly, the user can also choose to completely Abandon a Maintenance Sequence, from the same menu.

An analogous sequence of events occurs in the Creation Mode, except that the connected programs are not necessarily restricted to an edit mode environment. Also, oftentimes only a subset of the Creation mode set of buttons is made available to the user when in Maintenance mode.

In Creation mode, all buttons of the GUI are typically activated and are available to the user in a sequential mode. This is because the generation of a MPD, from scratch, is an iterative process that usually involves returning to a previous analysis step, (i.e., there exists a feedback between some of the SIMS steps). However, for consistency, rewinding to a previous step means that the SIMS process has rewound to that logic point, and the subsequent analysis steps need to be revisited.

Upon completion of a Creation Sequence, the user is asked to save (or abandon) the created Baseline as an MPD before being allowed to Start a new Creation or Maintenance sequence. Warnings will be issued if there is already a saved Baseline database of the same name. Note the user is always free to go back and make changes in an unsaved Baseline; after saving, the Baseline must be edited through the Maintenance process.

5.6 Additional Topics

5.6.1 Introduction

Figure 5.8 shows all of the buttons activated for this basic version of the SIMS GUI. Since the AES program set is the case study, the appropriate AES routines will be discussed; obviously, other programs can be linked to other GUI platforms and setups. The essential point is that the MPD generation and update process has been automated and made accessible to a User by means of a SIMS and an appropriate GUI.

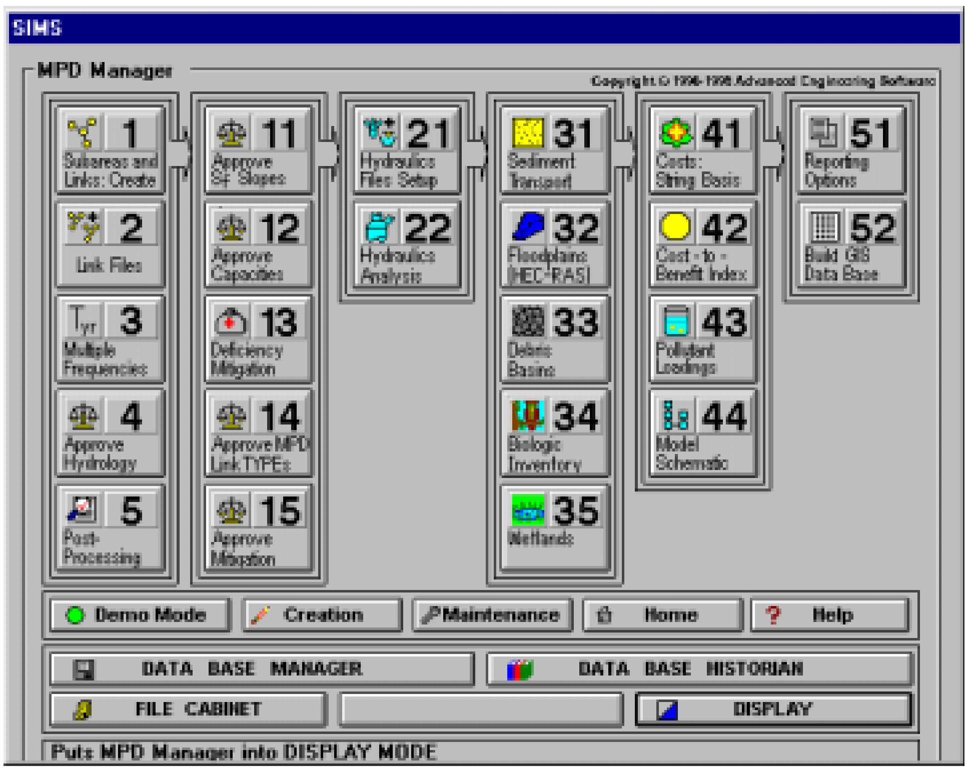


Figure 5.8

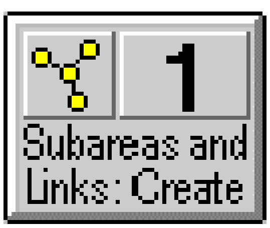
5.6.2 Creation Mode versus Maintenance Mode

The GUI branches to other particular programs that perform appropriate analysis steps. When you click on a GUI button, SIMS prepares data files for the analysis program, and reads the computed results. These data and results are also communicated automatically within the Global Database Structure. The main difference between the GUI in Creation mode versus Maintenance mode is that in Creation mode, usually all branches within a particular analysis program are available to the user, whereas in Maintenance mode, usually only the editing features of the analysis program (and editing is usually restricted to non-topological data) or step-wise execution of the programs are available.

For example, in Creation mode, BUTTON ONE accesses all branches of the particular AES hydrology program, with certain file naming and other conventions imposed so that a logic-based flow network model is developed. In Maintenance mode, BUTTON ONE still accesses the particular AES hydrology program, but only the hydrologic attribute data files are made available to the user.

5.6.3 Button One: Creating / Editing the Network Model

Details regarding the AES model network development are provided in Chapter 3, where AES screens and accompanying help file texts are displayed. The AES hydrologic model network development is analogous to other hydrologic models, and the user is referred to those texts or handbooks (see, for example, Hromadka et al, 1987).

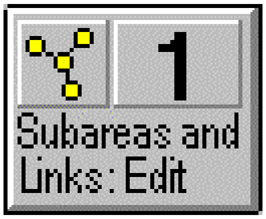


In CREATION Mode, this step guides you through the development of a link-node hydrologic model network. The program provides you with either a database or an imported GIS graphics layers environment. GIS layers include soil, rainfall, and other parameters, as well as subarea, link and node specifications.

This module also contains an extensive diagnostics submodule that checks numerous items including topology of the network, existence and uniqueness of nodes, links and subareas, and many other topics.

The RATSCx program is integrated into the BUTTON 1 module tool set.

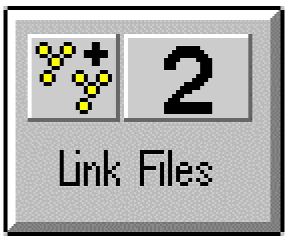
When finished, your hydrology link-node model is developed, and the database underpinnings will be used in several of the subsequent SIMS module steps.



In MAINTENANCE Mode, this step accommodates changes to your link-node model. The module editor allows YOU to change links, subareas, and other properties of the network.

The DIAGNOSTICS module performs a check of numerous network and database items to aid in reducing modeling and subsequent analysis inconsistencies.

5.6.4 Button Two: Hydrologic File Connections (Link-File)



Chapter 2 provides the user with node numbering and filename conventions that may be used in developing a logic based Network model. It is recalled that in the model network development, it is useful for hydrologic model results to be stored in temporary files which, at a subsequent location in the link-node model instruction sequence, can be read and inserted into the model Network. That is, complex model topologies can be modeled by breaking up the topology into a set of subsystems where each subsystem can be solved independently, and their respective results combined in a proper sequence to represent the correct topology. The HEC-1 computer program utilizes such memory files, and so do the AES hydrology programs, as do other hydrology computer programs. In the AES technique for storage of intermediate hydrologic model results, "DNA" files are used, named due for the analogy of the total representation of a catchment subsystem to the subsystem "genetics". Given DNA files, complex topologies can be resolved into subsystems that can be modeled independently of the other subsystems. In AES, 3 "memory banks" are also available for storing intermediate hydrologic results. Although analogous to DNA files, the memory banks allow up to a level 4 topology system (see Chapter 2) to be modeled without the use of exterior DNA files. DNA files are reintroduced into a network when the DNA file results are needed to proceed downstream. AES reads the DNA file into a memory bank and then networks the memory bank within the link-node model.

Using DNA files, or their equivalents in other models, a watershed can be discretized into regions and subregions as shown in Chapter 2, and each subregion can be modeled independently by reading the DNA files generated at the downstream node of each hydrologic flow path of an upstream model subregion. Consequently, subregion model networks are developed in an upstream-to-downstream fashion, just like how subareas are connected in the link-node model. To develop a subregion or region model network, all tributary DNA files must already be in existence. In this way, an arbitrary size model network can be developed and managed by the SIMS.

The Link-File module executes the AES hydrologic model set of Networks on a subregion basis, (or if appropriate, on a region basis, such as for the Los Angeles County LAF0601/Computer program, or HEC-1), in a sequence such that for any subregion (or region), all tributary subregions (or regions) have already been executed.

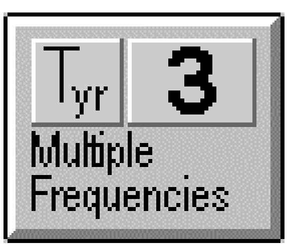
The several subregions' (or region's) hydrologic model results are then scanned and data are stored into the Global Database Structure, for subsequent access by other analysis tools and programs.

The hydrologic model network is often composed of several hydrologic model files, representing the total watershed broken up into sub-watersheds that link together along major watercourses.

Nodes numbers increase in the downstream direction (hint: try numbering nodes in increments of 2 or 5, in order to allow future additions of nodes to the network). Because the hydrologic model network is developed according to this nodal numbering specification, the topology of the network is described by the node numbers themselves. This property is extensively used throughout the SIMS module set in order to develop other networks for hydraulics models, costing models, pollution models, floodplains, sediment transport models, and so forth.

This BUTTON connects the numerous branches developed in each hydrology model file to the appropriate branch in neighboring files according to the topology properties associated with the node numbering layout set up by YOU. Once finished, the entire watershed is setup for processing by the selected hydrologic model.

5.6.5 Button Three: Multiple Frequencies

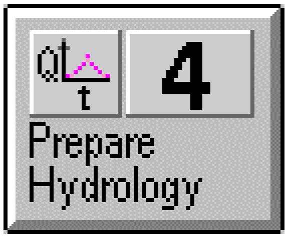


At this stage of the SIMS, a watershed can be analyzed for more than one design storm return frequency.

Typical hydrologic studies, including citywide master plans of drainage, require different regulatory protection flood levels according to storm event return frequency. For example, one may target that streets have storm flow contained below street top-of-curb for a 25-year event whereas one traffic lane is kept open for a 5-year event.

BUTTON 3 executes the hydrology model for the variety of return frequency storm events specified by YOU, according to the street flow depth requirements specified by YOU. These results are then used for existing system deficiency analysis, and other study modeling inputs.

5.6.6 Button Four: Approve Hydrology



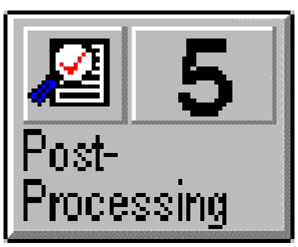
At this point in the process, the user is asked to verify the input data. Changes can be made by rewinding to the appropriate step button.

At this stage of the SIMS development, YOU are provided the opportunity to override the hydrology model estimated results of runoff quantities at any nodal point within the hydrology model network (peak flow rate, etc.) and enter, as a parameter, a substitute set of runoff values. These substituted values will remain fixed in the database unless further modified by YOU, or unless YOU remove the user-specification value option designation from that database field.

Reasons for overriding the computed runoff values include:

...Increasing the flow rate to provide additional flood protection
...Changing the flow rate for sensitivity testing purposes
...Changing the flow rate to accommodate supplemental calculations not included in the hydrology model module options
...Other reasons

5.6.7 Button Five: Post-Processing



The Post-Processor is one of the most important programs of SIMS. From the Post-Processor, the user can perform deficiency diagnostics, edit coupled or networked databases, analyze differences between the test Scenario and the adopted Baseline MPD, move GIS data to an AES database, and many other tasks.

This BUTTON activates over two dozen modules that perform a variety of functions. A major function is the diagnostic checking of the hydrologic network system and hydrologic results, and the distribution of computed information throughout the SIMS database.

BUTTONS 11 through 22 uses the information assembled by the POST-PROCESSOR.

Another major function of the POST-PROCESSOR is the development of estimated friction slopes for all the hydraulic elements defined in the hydrology model network. One of the OPTIONS available to YOU includes decisions regarding the minimum and maximum allowable distance from the street elevation to the estimated HGL, the minimum allowable flow velocity (at peak flow conditions), and a minimum friction slope or slope of the hydraulic element. These hydraulic friction slope estimates are subsequently used in the several SIMS hydraulics modules to evaluate element deficiencies and possible upgrade needs. Using these estimated friction slopes also provides estimates of flow rate capacities, according to YOUR flow depth/velocity requirements. When summed to the street flow or floodplain element regulatory flow capacity, these slopes result in an estimate of the available flood protection flow capacity of the system at any nodal point defined in the hydrologic model.

Knowing the existing system regulatory flow capacity for several storm event return frequencies and knowing the storm event peak flow rates for these same return frequency events (for the selected land use conditions or other parameter definitions), enables an evaluation of the DEFICIENCY of each hydraulic link defined in the hydrology model, according to the rules set up by YOU.

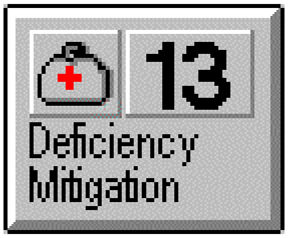
5.6.8 Buttons 11 and 12: Approve Slopes and Capacity Estimates

These BUTTONS enable YOU to override a hydraulic friction slope or hydraulic element flow capacity estimated in BUTTON 5. This override remains in effect unless removed or changed by YOU.

Reasons to override a friction slope or hydraulic element flow capacity estimate include:

...Add additional flow capacity to a particular hydraulic element due to supplemental calculations not included in the hydraulics models
...Reduce flow capacity estimates in order to increase future flood protection at a particular location due to increased safety needs
...Other reasons.

5.6.9 Buttons 13, 14 & 15: Deficiency Mitigation and Link TYPE Approval



Using the hydraulic element friction slopes estimated in BUTTON 5 by the algorithm selected by YOU, and approved or overridden by YOU via BUTTON 11, remedies to flow deficiencies (i.e., links in the model that do not satisfy the regulatory flow depth or flow velocity requirements, specified by YOU, for any of the storm event return frequencies considered) are estimated in this set of modules that satisfy the regulatory flow requirements defined by YOU in BUTTON 1.

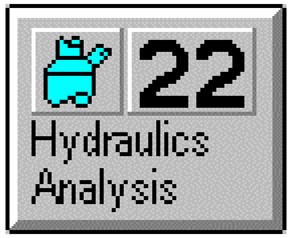
These remedies are estimated on a link-by-link basis for every link in the model network. The module target is to estimate either a replacement hydraulic element of similar type (i.e., pipe for pipe, box for box, etc.) or a parallel pipe hydraulic element, computed to meet the regulatory flow depth or flow velocity requirements.

The result of this set of modules is a set of replacement and parallel hydraulic elements for each link defined in the hydrology network.

The next step in the SIMS process is for YOU to approve both the sizing of the deficiency elements as well as the TYPE of hydraulic element used; that is, YOU may decide to use a box element instead of a pipe element even though the existing element is a pipe. These two approval steps occur in SIMS BUTTONS 14 and 15. The PROGRAM assumes that the highest probability occurs with the selection of self-similar hydraulic elements to replace a deficient hydraulic element; YOU need to evaluate the appropriateness of this assumption via the use of BUTTONS 14 and 15.

If YOU elect to change a hydraulic element deficiency remedy to different size or type, these decisions will remain in force unless YOU either remove the specification or unless YOU again change the specification.

5.6.10 Buttons 21 and 22: Hydraulics



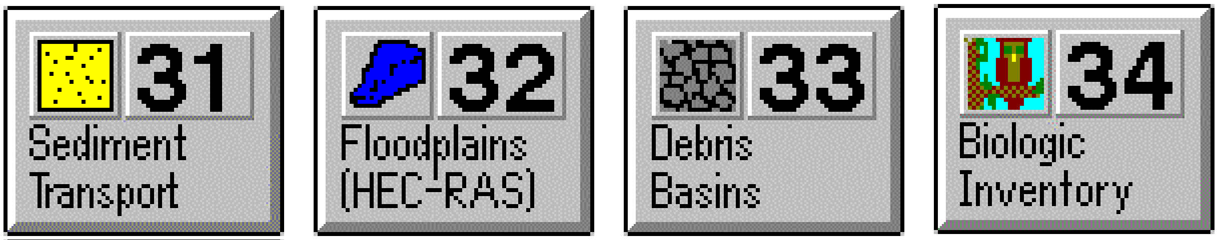
BUTTON 21 performs several functions in the SIMS processing. First, the hydrology network defined in BUTTON 1 is resolved into topology levels of successive branchings, where, for example, topology level 1 streams are the most receiving streams (e.g., the collectors that do not branch or confluence into other streams). Topology level 1 streams confluence into topology level 0 streams, and so forth.

After topology levels are determined, individual STRINGS of drainage system lines are assembled appropriate for analysis by hydraulics analysis programs such as the Los Angeles Water Surface and Pressure Gradient program or WSPG. Using the hydrology results stored in the SIMS database, and the approved model network configuration developed in BUTTONS 5 to 15, including "telescoping" of system hydraulic elements according to rules selected by YOU (e.g., pipes do not downsize more than 1 pipe size in the downstream direction, or other rules selected by YOU), data files are developed for processing by the WSPG or other available hydraulics programs.

Hydraulic controls are specified by YOU for the "level 0" topology lines (or the PROGRAM can use normal depth or soffit controls); otherwise, the myriad of other internal system junctions have HGL controls computed using junction structure analysis rules decided by YOU (e.g., use the upstream HGL of a junction structure as the control for laterals, or other rules).

BUTTON 22 executes the set of data files assembled via BUTTON 21. The selected hydraulics program is executed for each file automatically, reading the results and interim HGL data for subsequent file usage, and automatically executing those files as well. All of the relevant HGL data are then read and stored in the SIMS database. This tremendous set of operations is done automatically without any further user intervention to operate the program modules!

5.6.11 Buttons 31, 32, 33, 34 & 35: Environmental Analysis



These buttons execute several separate program module sets that perform a variety of storm water management and environmental tasks.

Using the most recently updated data stored in the SIMS database, these various task module sets automatically update the respective component analysis data files, read the new computed results, and store the new results in the SIMS database for even further subsequent analysis.

Consequently, a change in the master plan or drainage study may have a "domino effect" that ripples through numerous aspects of the total study.

The SIMS tracks and captures these possible changes for further analysis by other analysis tools supplied in subsequent task module sets in SIMS.

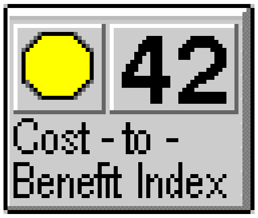
BUTTONS 31 to 35 provide task module sets for:

...sediment transport analysis
...floodplain analysis
...debris analysis
...biologic inventory update
...wetlands water quality enhancement analysis

5.6.12 Button 41: Cost Summary

This program provides a cost summary for a multiple file RATSCx (or later version) master plan of drainage. Each computer-sized pipe, box, and open channel, and user-specified pipe, box, and open channel sections is identified from the selected rational method program results, tabulated with respect to conduit size and length, and cost-estimated according to user-defined unit costs. The COST MANAGER provides a direct link to the Database application supplied by the Stormwater Information Management System software.

5.6.13 Button 42: Cost-to-Benefit Index



Computes a cost-to-benefit index (CBI) as a ratio of estimated flood damage potential versus cost to upgrade the local drainage system. The user defines a street flood depth versus flood damage cost potential (or "penalty" cost) for various land use types.

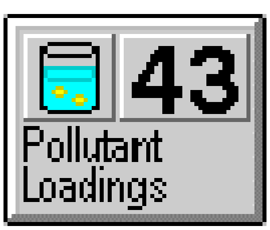
The CBI program computes unimproved "penalty" costs and divides by drainage system improvement cost opinions for each link used in the drainage system network. Upon ranking in increasing order, the highest CBI value corresponds to the highest cost-to-benefit ratio. The CBI results aid in prioritizing storm drain system improvements.

To define the penalty function, the user establishes approximately what street flood depth initiates flooding for structures; for example, a 1-foot depth may be appropriate. For the selected land use being studied, the corresponding damage, or "penalty", value may be assigned to be "1.0". Similarly, for another land use type, a 1.5-foot depth in the street may be the suitable street flood depth at which structures begin to be flooded; however, in comparison to the previous land use type, the "penalty" value is say 2.5 -- that is, this second land use type has about 2.5 times the flood damage potential as the previous land use type. The user then defines the beginning flood depth and the "relative" damage potential for each hydrologic land use type.

For lesser flood depths, the user also defines flood damage potential with respect to the "relative" damage versus land use types.

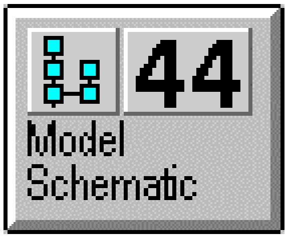
Next, the hydrology is rerun without new systems in-place, and assuming all flows remain within street section boundaries. For each link in the model, a street flow depth is estimated for the "unimproved" condition in order to obtain flood damage potential or penalty values. These values are then divided by the cost-to-improve, on a link-by-link basis, to obtain the CBI values.

5.6.14 Button 43: Pollutant Loadings



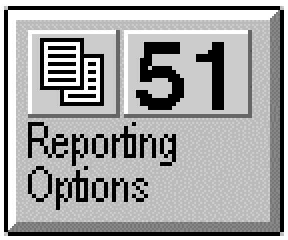
Estimates non-point source annual pollutant loadings according to the Appendix B procedure of the State of California Best Management Practices (BMP) Handbook (Municipal). The computer program allows for editing of the Event Mean Concentration (EMC) coefficients for each of the pollutants analyzed (see cited BMP Handbook), and is initialized using standard NURP EMC coefficients. The PLM interfaces with RATSCx and HydroLINK, enabling an automatic Computation of annual pollutant loadings given RATSCx data files.

5.6.15 Button 44: Schematic



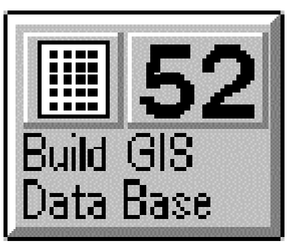
This program provides a box-link schematic representation of a multiple file rational method RATSCx link-node model network and subarea data. Two modes are available: (1) a detailed schematic, and (2) a "brief" schematic flowchart. This program provides the user a tool for evaluating completeness of the model network.

5.6.16 Button 51: Reports



This BUTTON generates output reports and spreadsheets for the current SIMS BASELINE or SCENARIO.

5.6.17 Button 52: Build GIS Database



This BUTTON prepares a database extracted from the SIMS database. The BUTTON 52 database is only a small subset of the global SIMS database, and its contents are designed by YOU in a provided specifications module within the BUTTON 52 task module set.

The smaller database is suitable for transport into YOUR GIS tool set for subsequent use in preparing exhibits, maps, graphics, or for other analysis tool sets.

5.7 Database Management Buttons

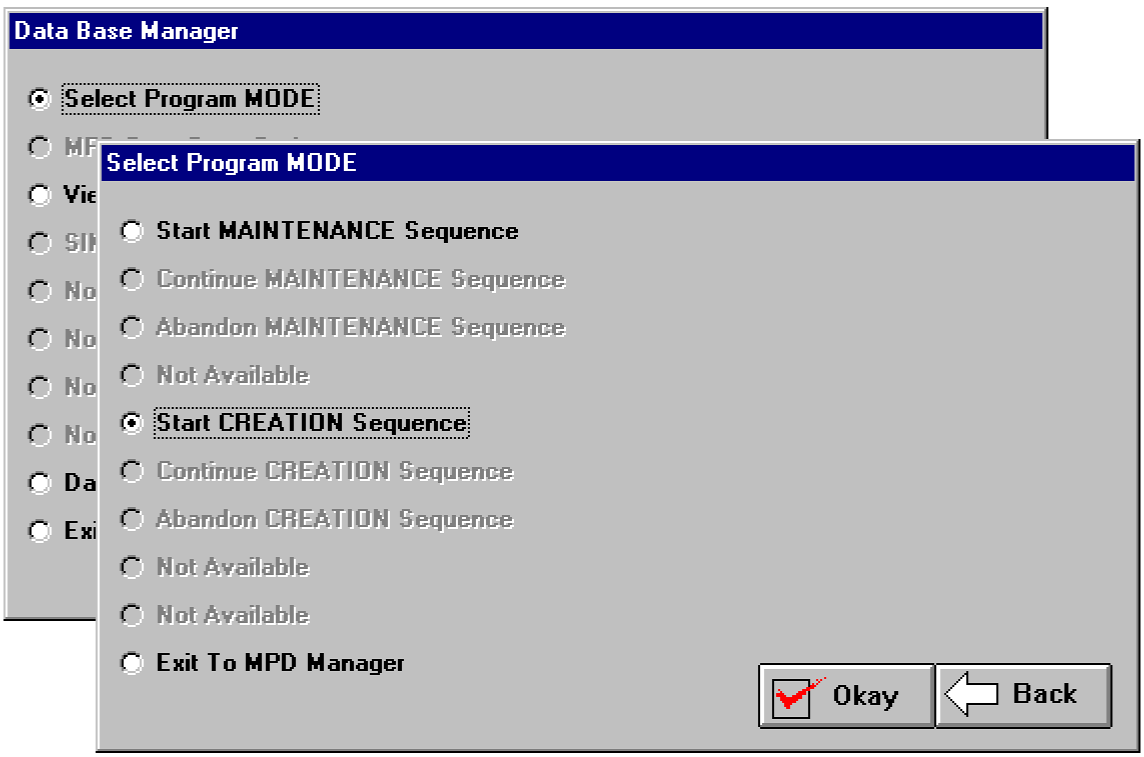
Several buttons are common to both the Creation and Maintenance mode paths, and are discussed in the text below. Figure 5.8 depicts the several buttons that are the focus of this section.

5.7.1 Demo Mode

This BUTTON activates the internal sequencing logic of the SIMS MPD Manager without accessing the analysis tool sets attached to each button. In this mode, YOU can navigate through the SIMS MPD Manager in order to see how the system operates and what to expect.

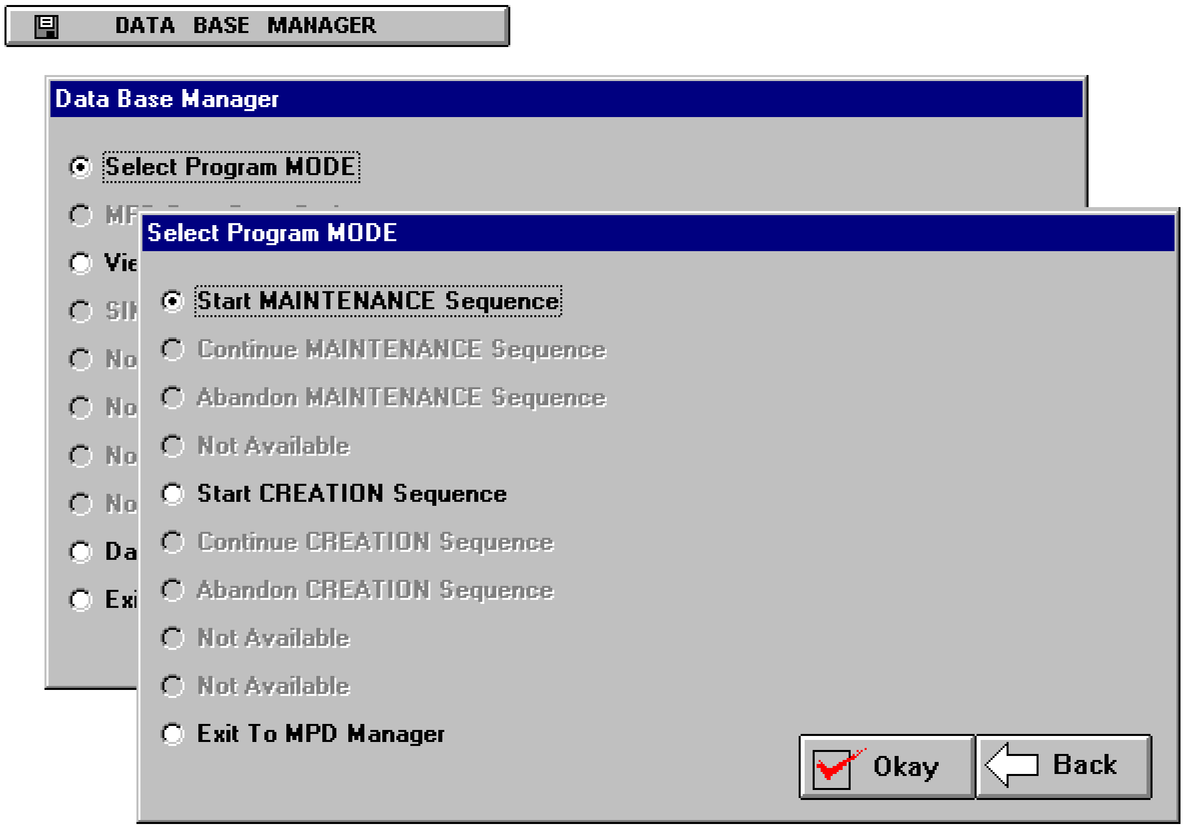
This mode of operation is useful to illustrate the workings of SIMS, and how the various analysis processes interlink and cooperate in the development of a fully integrated plan for flood control, environmental management, and economic impact analysis.

5.7.2 Creation



At this level of operation, YOU are creating a project study from scratch. Of course, there exist tools for simplifying data input, such as coordination software sets for GIS interface, but at this level the study is at the beginning stage, or is in the continuing stage of development.

5.7.3 Maintenance



Once a master plan (MPD) has been adopted, it becomes the baseline for measurement of future impacts (environmental and economic) due to changes in the MPD assumptions. Such changes include:

...Land Use
...Hydrologic Parameters (e.g., rainfall statistics update)
...Hydrologic Methods (e.g., change in hydrology criteria)
...Hydraulic System (e.g., new flood control channel, pump station, basin, etc.)
...Economic Factors (e.g., unit costs, interest rates, etc.)
...Other

To measure these impacts, YOU utilize the MAINTENANCE MODE in SIMS. YOU generally make edits to the model network in BUTTON 1, and possibly changes to criteria at any of the SIMS BUTTONs that control analysis tool sets. This MAINTENANCE work results in a new master plan called a "SCENARIO". Once YOU have completed the SIMS circuit in the MPD Manager, YOU will have a completed SCENARIO, which is an entirely new master plan, with all computations regenerated and results updated to reflect the new conditions at issue. YOU literally have reinvested all the efforts paid in generating the BASELINE master plan in developing a SCENARIO master plan.

And now YOU can estimate the environmental and economic impacts to the BASELINE master plan (i.e., the master plan that has been officially adopted for the community) should the SCENARIO master plan be adopted instead. The SIMS can now be used to develop a master plan of DIFFERENCES!

The DIFFERENCES database is composed of the variations between the BASELINE and SCENARIO master plans. Any estimated changes in the network elements (e.g., pipe sizes, box sizes, etc.), water quality constituents, total costs, and so forth, are captured and stored by SIMS in the DIFFERENCES database.

Now YOU have an estimate of master plan system impacts, cost impacts, and environmental impacts, as well as prioritization impacts (e.g., which element should be built first?). This information may be used to evaluate and mitigate for the effects of changes to the approved BASELINE master plan.

And if the SCENARIO is acceptable, YOU may then use SIMS to update the BASELINE master plan to the SCENARIO master plan conditions, by redefining the SCENARIO to be the new BASELINE. Thus, the BASELINE is an evolving plan with time.

The evolutionary steps that connect the first BASELINE to the current BASELINE are stored in the HISTORIAN database that is available in SIMS.

5.7.4 Home

This BUTTON returns YOU to the Main Page of SIMS.

5.7.5 Help

Provides a reminder of how to use the mouse buttons to access help files.

5.7.6 Database Manager

This BUTTON is the core of the SIMS MPD Manager. Essentially all of the user options are controlled and navigated via this BUTTON task set. The options are controlled to serve both the CREATION and MAINTENANCE modes in SIMS.

5.7.7 Database Historian

This BUTTON takes YOU to the HISTORIAN database, which stores the evolutionary steps that connect the first adopted BASELINE master plan to the currently adopted BASELINE master plan, via a sequence of SCENARIO master plans. Refer to the above text regarding the MAINTENANCE mode of SIMS for further information.

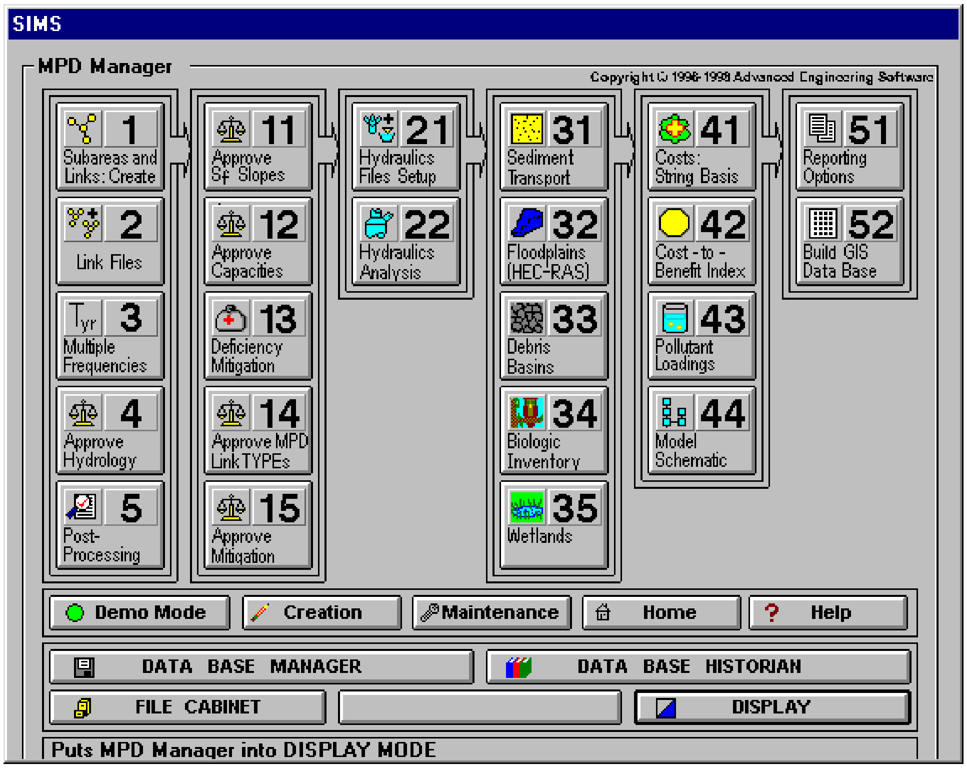
5.7.8 File Cabinet

Keeps track of the state of the BASELINE and any SCENARIOs YOU have in progress.

5.7.9 Display

Lights up the SIMS MPD Manager display screen.

Chapter 6
Case Studies



In this chapter, two case studies are presented by users of the AES SIMS in the development of a Master Plan of Drainage (MPD). The presentation is provided as two separate contributions, each authored by their respective engineering firm.

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RICK ENGINEERING COMPANY

GIS – Based Master Drainage Plan: Ocean Beach

By: Dennis Bowling [1], Wayne Chang [2] and Roberta Cronquist [3]

Abstract

Rick Engineering Company has prepared a Master Drainage Plan (MDP) for the Ocean Beach area within the city of San Diego. The MDP was unique because it was the first such application in the city of San Diego based on a Geographic Information System (GIS). Rick Engineering Company developed routines that automated many of the more traditional, tedious manual calculations, such as determining basin areas, flow lengths, and runoff coefficients. The end result was a GIS-based plan that could be continuously updated as development and infrastructure change, rather than the traditional hardcopy document that is out-of-date almost immediately after it is published

Introduction

Rick Engineering Company prepared a Master Drainage Plan (MDP) using a Geographic Information System for a portion of the Ocean Beach area within the city of San Diego. The study area covered roughly 552 acres and consisted of a hillside region and a low lying region separated approximately by Sunset Cliffs Boulevard (See Figure 1). The hillside region was southeasterly of Sunset Cliffs Boulevard and primarily consisted of medium-density residential areas on moderate to steep terrain with slopes as high as 12 percent. Elevations ranged from approximately 35 to 260 feet above mean sea level. The low lying region was northwesterly of Sunset Cliffs Boulevard and primarily consisted of commercial, and medium- to high-density residential areas on relatively level terrain with slopes generally less than three percent. Elevations ranged from approximately 10 to 35 feet above mean sea level.

There has been a history of flooding and drainage problems within the low lying region. The purpose of the MDP was to perform hydrologic analyses for the study area in order to calculate the surface runoff, analyze the existing drainage systems, identify the inadequate facilities, and provide alternatives to alleviate flooding in the low lying region. For each alternative, an opinion of probable costs was prepared.

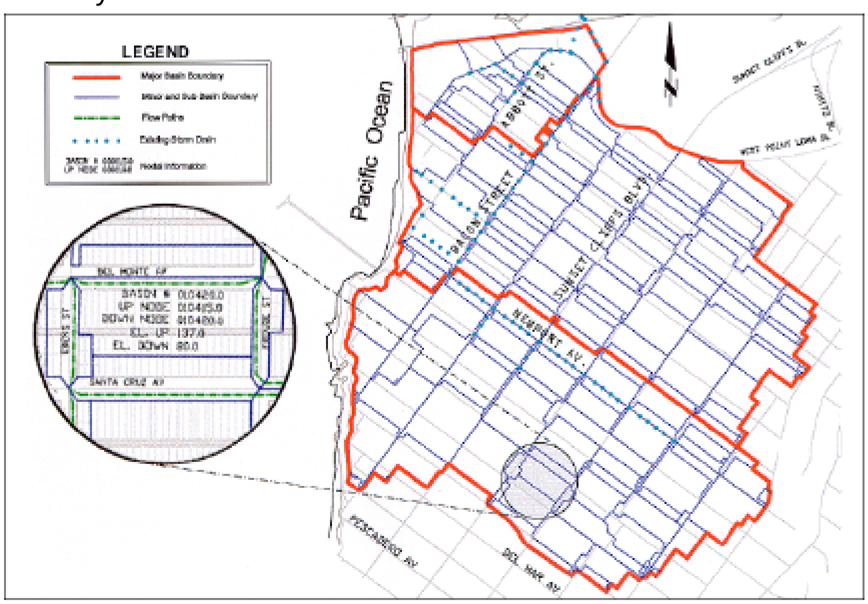

Figure 1 – Master Drainage Plan Study Area

The difference between this study and the traditional method of preparing a MDP is in the use of a GIS. The GIS automates much of the data acquisition process that is traditionally done with a planimeter. The GIS also creates a graphical query system for viewing output rather than pages of hardcopy output. Finally, the GIS allows the MDP to be easily updated as the study area changes.

The following sections give a brief summary of the existing drainage systems and hydrologic methodology used in the MDP. Furthermore, a discussion of the requirements, processes, and results for the GIS-based MDP are given.

Existing Drainage Systems

According to the City of San Diego s as-built drawings, the existing drainage system in Ocean Beach consists of three major trunk systems. The first trunk system (Newport) is located along Newport Avenue and is composed of reinforced concrete pipe (RCP) with diameters ranging from 18 to 36 inches. The approximate drainage area for the Newport system is 244 acres. The Newport system ties into the second major trunk system, the Bacon system. The Bacon system is located along Bacon Street and outlets into the San Diego River. The Bacon system consists of RCP with diameters ranging from 36 to 60 inches. The approximate drainage area for the Bacon system is 256 acres. The third trunk system (Abbott) is located along Abbott Street and also outlets into the San Diego River. The Abbott line consists of RCP pipe with diameters ranging from 30 to 36 inches. The approximate drainage area for the Abbott system is 52 acres.

Hydrologic Methodology

The entire watershed for the study area covered 552 acres (0.86 square miles). The City of San Diego s *Drainage Design Manual* requires that the Modified Rational Method be used for hydrologic analysis of a watershed between 0.5 and 1 square mile. The Rational Method program by Advanced Engineering Software (AES) was used for the analysis because it satisfied this design criteria. The Rational Method program can be used to calculate the runoff in the watershed and to determine whether the existing drainage facilities are adequate. The program can also size the proposed drainage facilities that may be required in order to convey the design storm runoff.

The hydrologic model was developed by creating independent node-link models of each interior subbasin and linking the subbasins together at confluence points. The program has the capability to perform calculations for 15 hydrologic processes. These processes are assigned code numbers. The code numbers and their significance are as follows:

Code 1: Confluence analysis at a node

Code 2: Initial subarea analysis

Code 3: Pipe/Box travel time (computer-estimated pipe sizes)

Code 4: Pipe/Box travel time (user-specified pipe size)

Code 5: Open channel travel time

Code 6: Streetflow analysis through a subarea

Code 7: N/A

Code 8: Addition of the subarea runoff to mainline

Code 9: V-Gutter flow thru subarea

Code 10: Copy main-stream data onto a memory bank

Code 11: Confluence a memory bank with the main-stream memory

Code 12: Clear a memory bank

Code 13: Clear the main-stream memory

Code 14: Copy a memory bank onto the main-stream memory

Code 15: Hydrologic data bank storage functions

Code 16: User-specified source flow at a node

The GIS-Based MDP

Figure 2 presents a flow chart that outlines the processes that make up the GIS-based Master Drainage Plan. The following describe each process in the flow chart.

The first process contains three components. One of the components is an AutoCAD file containing base information for the study area. This information includes the existing drainage facility locations and sizes, land uses, flow paths, drainage basin boundaries, and topographic elevations. The City of San Diego provided an AutoCAD 14 drawing of the study area containing street and lot boundaries, street names, and topographic information. The additional required base information was then added to the AutoCAD drawing as described next. The existing drainage facilities were added to the AutoCAD drawing first. The facility locations were obtained from as-built drawings and verified during field investigations. Next, the major drainage basin boundaries and flow paths were determined and added to the drawing. A major drainage basin boundary was delineated for each of the three existing systems--Newport, Bacon, and Abbott. The major basin boundaries were delineated using topographic information and then verified in the field.

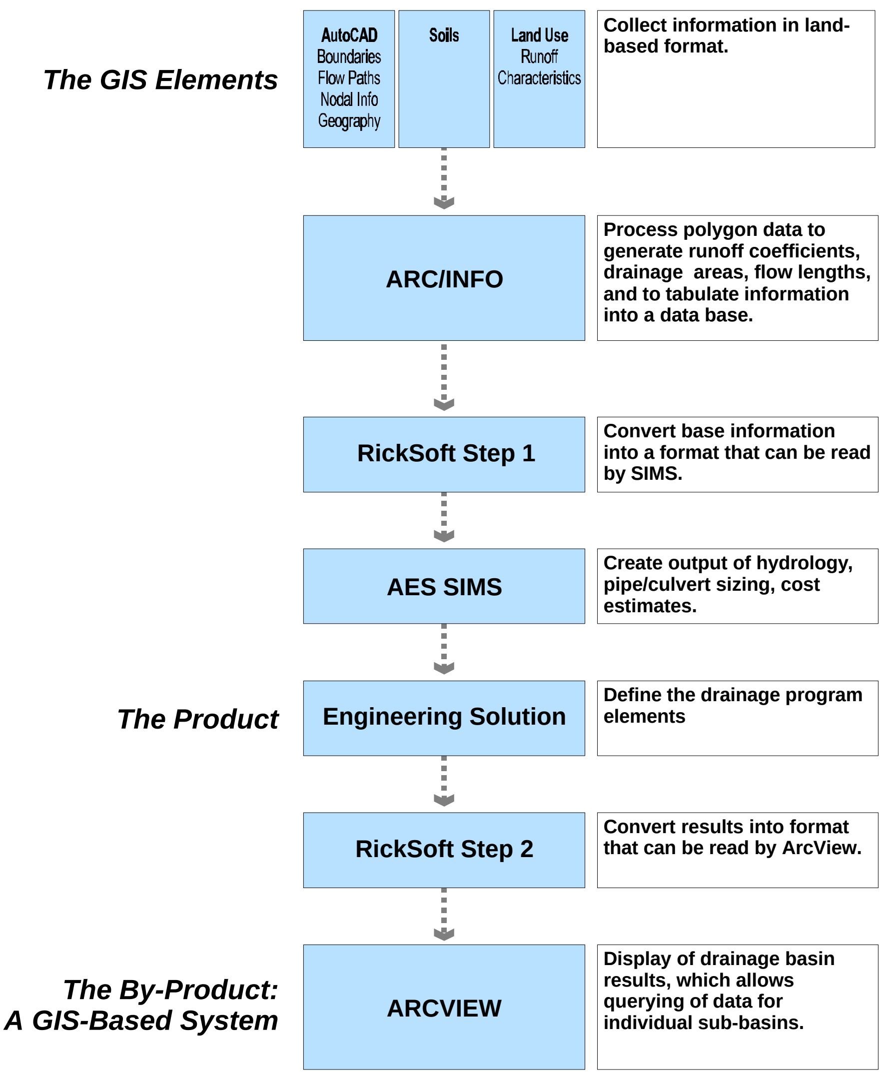

Figure 2 – The GIS-based Master Drainage Plan Process

The flow paths were determined by reviewing as-built drawings, topographic information, and performing field investigations. Finally, each major basin was subdivided into minor basins and subbasins within the minor basins. The minor basins and subbasins were selected to allow the discharge at significant locations within the study area to be determined.

Once the basins and flow paths were determined, information for each subbasin was added to the drawing. This information consisted of the subbasin number, upstream node number, downstream node number, upstream node elevation, and downstream node elevation. The node numbers are required at each intersection of a subbasin boundary and flow path. The information for a particular subbasin must be placed entirely within the boundary of that subbasin in the AutoCAD drawing. The detail in Figure 1 gives an example of the block of information. The basin and node numbering shown in the detail must follow a specified format, which is discussed under process four below.

The first process also requires soils and land use coverages. These coverages were available in digital format for most of San Diego County and all of the study area.

The second process involves polygon processing of the AutoCAD, soils, and land use files using ARC/INFO. Rick Engineering Company developed a polygon processing procedure that calculates a runoff coefficient, area, and flow length for each subbasin. This data along with the other required base information necessary for the hydrologic calculations--node numbers, node elevations, etc. will be written to database files.

The third process sorts base information from the database files into three separate files containing node, link, and subarea information. Rick Engineering Company developed a program for this routine, which is known as “RickSoft”.

In the fourth process, the node, link, and subarea files are read by the Stormwater Information Management System (SIMS) developed by AES. SIMS is a comprehensive package that allows hydrologic analyses, cost estimates, and several other tasks to be performed in conjunction with a Geographic Information System (GIS). AES’s Rational Method program, as described previously, is included in SIMS for the hydrologic analysis. A primary benefit from SIMS is that the node, link, and subarea base information is automatically input into the hydrologic analysis. As a result, the engineer is primarily responsible for making engineering decisions and not the tedious task of data input.

In order to use SIMS, the basin and node numbers must be in a specific format. The format is two characters followed by six digits. The characters should describe the entire study area. Therefore, for this Ocean Beach MDP, OB was used. The first two digits then represent the major basins. For example, the three major basins, Newport, Bacon, and Abbott, were labeled OB01, OB02, and OB03, respectively. The next two digits represent the minor basins within a major basin. For example, OB0102 represents minor basin 02 in major basin 01. The last two digits represent the subbasin or node number. For example, OB010203 could represent either node or subbasin number 03 in minor basin 02 and major basin 01.

In SIMS, a node’s location along a given flow path determines the node’s number. The first, and lowest, node number must be located at the most upstream node of the longest flow path in a minor basin. For example, the most upstream node located within major basin 01 and minor basin 03 could be numbered OB010301. The downstream nodes would then be numbered in increasing value--not necessarily consecutive--to the farthest downstream node along the same flow path within the minor basin, e.g., the next downstream node could be numbered OB010305. Node numbers along the tributary flow paths were numbered according to the same principle. However, at a confluence, the last node number in a tributary flow path would be the node number in the main flow path. Each node number in the study must be unique.

Basin numbers in SIMS are determined by the upstream and downstream node numbers, and must also be unique. Typically, the basin number is the same as the downstream node number, with the exception of a confluence where two or more basins share the same downstream node. In this situation the basin(s) within the lateral flow path must be numbered independently of the downstream node number.

The fifth and sixth processes in the flow chart relate to the MDP results. In the fifth process, SIMS writes the results such as calculated runoff, pipe and culvert sizes, cost estimates, etc. into node, link, and subarea output files. In the sixth process, RickSoft converts the node, link, and subarea output files into files that can be read by ArcView.

In the final process, ArcView is used to view and query the MDP results. Figure 3 gives a sample ArcView display. The View1 window on the right portion of the display shows all the subbasins in the entire study area. Pertinent data for each subbasin can be queried by selecting the dot within the desired subbasin. The Identify Results window on the left portion of the display shows the information for the selected basin. This information includes the subbasin and node identifiers, drainage facility size and length, runoff, and estimated cost.

Master Drainage Plan Results

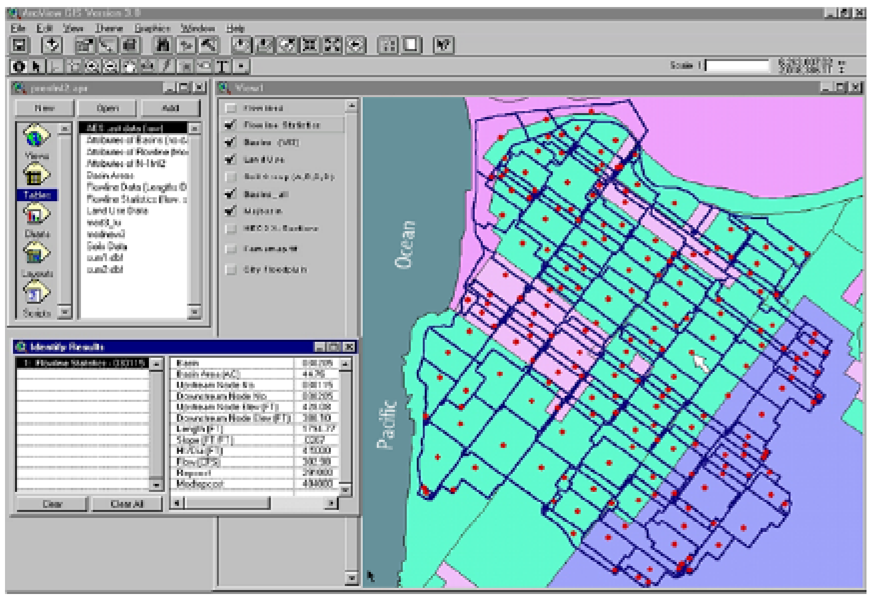

Figure 3 - ArcView Display of Results

The analyses determined the existing runoff within the Ocean Beach study area and the existing drainage system capacities. For the Abbott system (OB03), the Rational Method results showed that the 100-year peak discharge at the system outlet was approximately 72 cubic feet per second (cfs), whereas the capacity of the existing 36-inch RCP at that location was only 22 cfs. For the Newport and Bacon systems (OB01 and OB02), the Rational Method results showed that the 100-year peak discharge at the downstream end of both systems was 427 and 834 cfs, respectively. The capacity of the existing 36-inch RCP at the downstream end of the Newport system was 48 cfs, and the capacity of the existing 60-inch RCP at the downstream end of the Bacon system was 67 cfs. The inadequacy of these systems would cause flooding to depths of 1.3 and 2.3 feet, respectively. Therefore, the analyses indicated that each major trunk system in the study area had significant deficiencies.

Several alternatives were examined to eliminate the flooding. For the Abbott system, the drainage area size and shape, street layout, and topography quickly eliminated all but a replacement system alternative. This involved replacing the existing drainage facilities with larger facilities. For the Bacon/Newport systems, several alternatives were possible. After a review of the existing drainage area and facilities, utilities, street layout, and topography, four alternatives were analyzed and one was recommended. The recommended alternative involved keeping the Bacon system, adding an additional system in a parallel street, and replacing the

Newport system.

The cost estimates for replacement of the existing storm drain system with several lateral storm drain systems was completed for each “phase” or branch of the new storm drain to lessen the financial burden on the city. The phases were then prioritized according to their maximum benefit.

Phase 1 of the project would involve the placement of a new storm drain along Cable Street significantly reducing the runoff conveyed in the existing Bacon Street storm drain. The cost for phase 1 was approximately $5.7 million. Phase 2 of the project would involve the placement of a parallel system along Bacon Street. The cost for phase 2 was approximately $1.8 million. Phase 3 of the project would involve the replacement of laterals connected to the Bacon Street System. The cost for phase 3 was approximately $1 million. Phase 4 of the project would involve the replacement of the Abbott Street System. The cost for phase 4 was approximately $1.1 million. The final phase of the project, phase 5, would be to replace portions of the Newport System. The cost for phase 5 was approximately $0.6 million. The total cost for the replacement of the inadequate storm drains to comply with City of San Diego requirements would be approximately $10.2 million.

Conclusion

A GIS-based Master Drainage Plan was prepared for the Ocean Beach area in San Diego. Using GIS provided several benefits. First, the required hydrologic base information such as subbasin areas, flow lengths, and runoff coefficients could be more accurately calculated with ARC/INFO polygon processing than with the traditional method of planimetering and hand calculations. Second, base data input into the hydrologic software was automated. Third, the SIMS package could quickly calculate facility costs based on user-specified unit prices. Fourth, the MDP could be updated as the study area changes. For instance, if the land use changes in a particular area, the land use coverage file would be revised to reflect the change. Polygon processing and SIMS could then be re-executed to obtain revised facility sizes and cost estimates. The updated MDP could be completely processed within a few hours. Finally, ArcView provides a concise, user-friendly graphical interface for presenting the results.

1. **Dennis Bowling** *Rick Engineering Company, Principal-in-Charge Water Resources Division*

2. **Wayne Chang** *Rick Engineering Company, Director Water Resources Division*

3. **Roberta Cronquist** *Rick Engineering Company, Engineering Designer*

GIS – Based MPD Case Study: City of Corona

By: Robert R. Harryman[1], M.A., P.E.; Theodore V. Hromadka[2], II, Ph.D., Ph.D., P.E., P.H.; Michael R. Barton[3], M.A.; Gary H. Eikermann[4], P.E.; Ned A. Ibrahim[5], P.E.; and Joe Indrawan[6], P.E.

1. Introduction

A well-conceived Drainage Master Plan (DMP) enables a community to develop an efficient network of flood control facilities and provides a basis for establishing funding mechanisms and prioritizing drainage system improvements. Boyle Engineering Corporation (Boyle) and Exponent Failure Analysis Associates (Exponent) prepared the Drainage Master Plan for the City of Corona, California. This DMP identifies the major drainage system deficiencies and proposes corrective improvements that incorporate future land use development patterns. A cost opinion of implementing the identified improvements was then developed along with recommended prioritized / time-phased improvements, from which the City can develop ongoing capital improvement programs in consideration of funding limitations.

Recent developments in linking Geographic Information System (GIS) data and drainage analysis software have significantly decreased the effort required to develop a DMP while increasing the usability of the DMP. The Advanced Engineering Software (AES) Stormwater Information Management System (SIMS) software was specifically developed to process drainage related data from any GIS system and incorporate it into a hydrologic / hydraulic computer model. Additionally, the SIMS program was used to develop cost opinions and prioritize proposed drainage improvements.

1.1. Project Location

The City of Corona, which is approximately 40 miles southeast of the City of Los Angeles, encompasses approximately 32 square miles in the extreme western portion of Riverside County, California. The northern City limits are shared with the City of Norco, and the far northeastern City limits are shared with the City of Riverside. The southern City limits are generally defined by the foothills at the base of the Santa Ana Mountains.

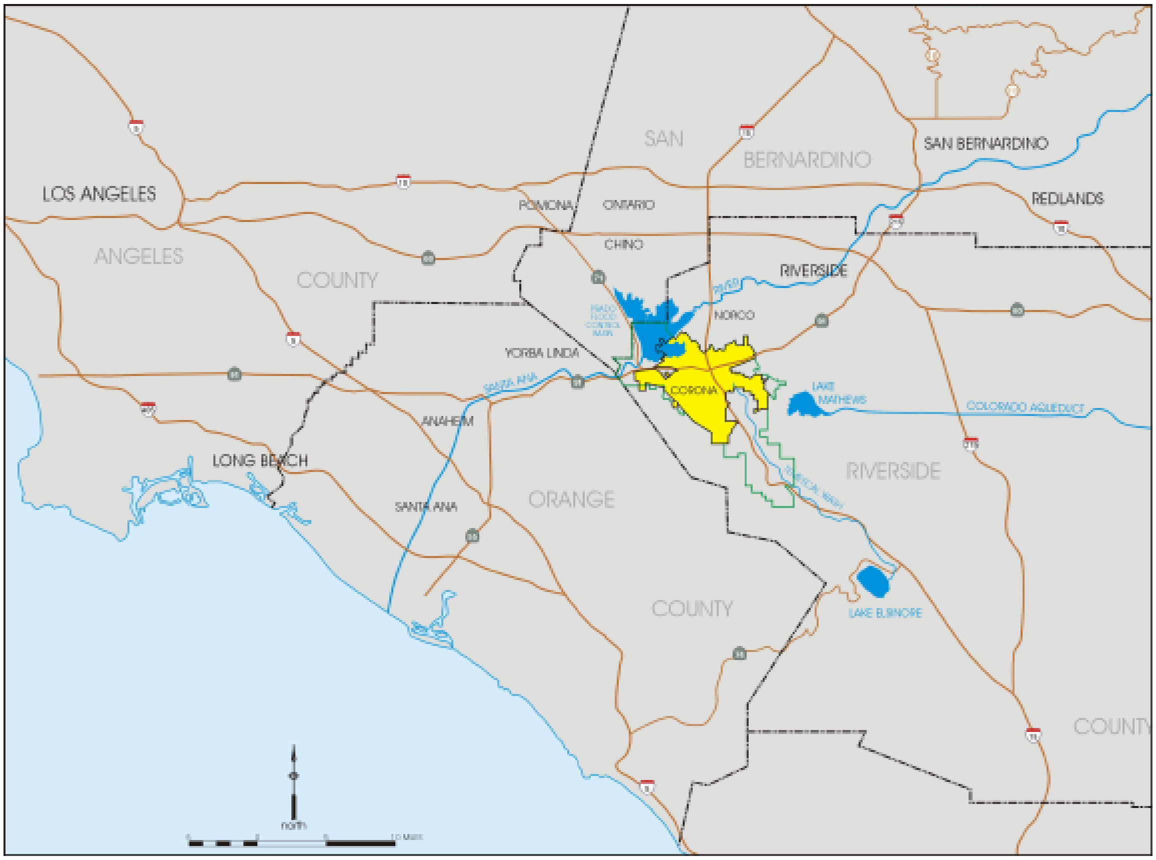

Figure 1. Vicinity Map

1.2. Watershed Characteristics

Two distinct geographical features characterize the drainage conditions of the City. The northerly part of the City consists of a sloping alluvial fan toward Prado Dam Flood Control Basin, a U.S. Army Corps of Engineers flood control reservoir that was completed in 1941. The southerly portion of the City consists primarily of abruptly rising foothills. The general drainage pattern is first from the foothills of the Santa Ana Mountains to the northeast, and then, via Temescal Wash, to the northwest. Substantial flows reach the mouths of the canyons and then spread out onto the alluvial fan formed by several watercourses draining the mountains. Several major watercourses provide some protection against major flood flows from runoff generated in watersheds south of the City. The smaller drainage facilities, which drain into these major channels, are the general responsibility of the City of Corona for implementation, operation, and maintenance. It is these facilities, or the lack of such facilities, which is the primary concern of the DMP report.

The average annual rainfall is approximately 12 inches in the vicinity of Corona, increasing to approximately 18 inches in the tributary Santa Ana Mountains. The population of the City of Corona at the time of the DMP study (1997) was just over 100,000. The City is one of the most rapidly growing urban areas in the nation, and much of the potential growth is in the City's Sphere of Influence (SOI) areas to the south, which have been included in the DMP study area.

2. Study Approach

The study approach can be broken down into three main components:

1. Data Gathering and Processing

2. Development of Drainage Criteria

3. Computer Modeling

Data gathering and processing includes the development of all GIS graphical and data base information. The development of drainage criteria includes both City and County regulatory requirements for hydrologic analysis and hydraulic evaluation. The computer modeling portion incorporates all of the above data and design criteria into one model that evaluates the hydrologic condition and hydraulic characteristics, recommends replacement drainage systems, determines a cost opinion for proposed facilities and prioritizes these proposed facilities.

2.1. Data Gathering and Processing

The development of a hydrologic / hydraulic model traditionally has been a data, and more importantly time, intensive undertaking. Now that Cities are beginning to store data on Geographic Information Systems (GIS), the task of cataloging and even overlaying data has become a relatively simple process once the data base is in place.

2.1.1. Development of Coverages for Model Input

Coverages utilized for computer model analysis of the City of Corona storm drainage system were created and provided to the City engineering department for its use. Specific coverages developed are discussed below.

Base Map

The City's GIS street base coverage includes basic line work showing outlines of City streets and parcels and was, therefore, suitable for use as a City street / block base map. The base map was used for the mark up of other coverages such as tributary subareas, land use patterns, soil types, and storm drain analysis flow paths.

Watershed Boundary

The first step in setting up the model was to establish the overall watershed boundary, and then the boundaries of the five main drainage areas. Watershed boundaries for the City of Corona and its influence areas were determined based on the areas' natural flow characteristics and existing drainage facilities. The overall watershed boundary is approximately four times larger then the City limits.

Subareas

The City of Corona is divided into a number of major drainage areas based on the previous Master Plan. These are shown in Figure 2. As a further refinement to these major drainage areas, subareas are defined in accordance with criteria established for the drainage model and include various data needed to determine corresponding flows. Subarea data includes the tributary area expressed in acres and broken down according to land use and soil types. Each subarea is identified by a label corresponding to the node along the analysis flow path at which the subarea is applied.

Flowpaths

An initial point was located at the most upstream end (most hydrologically remote point) of a drainage area. The actual drainage link node model was then developed by connecting the most hydrologically remote node of each initial subarea to the collection point for that initial subarea. Generally, this collection point was at the initial section of storm drain to allow pipe diameter modeling. The primary subarea flowpath, or link, normally began as lot, or overland flow, then became street flow before entering a catch basin at the subarea collection point. Subsequent downstream subareas were connected by extending the primary flowpath from the upstream (previous subarea) to the downstream collection node. The confluence of branch lines also occurred at model nodes. This process continued downstream, ultimately reaching the discharge point for the entire watershed.

Node and Subarea Numbers

Once the major basins, sub-basins, subareas and flowpaths were delineated, the link-node network was set up. Nodes were placed at appropriate locations to define the water course. Nodes were also located at catch basins and where pipes changed slope or size. The most hydrologically remote point was identified using a six digit number. The first two digits refer to the City of Corona region (storm drain line number per previous Master Plan) containing the watershed. The second pair of digits identifies the map area (sub-basin). The final two digits identify each node, beginning with the most hydrologically remote point (00) and increasing sequentially through the subarea collection points. The subareas are then identified using the six digit tag of the collection point they drain into.

Land Use

Land use attributes, within the existing City limits, used in this study are contained in the City's General Plan. However, most of the City's Sphere of Influence (SOI) areas are not covered by the City's General Plan. To estimate impervious area and runoff coefficients in the SOI, the foothill areas are assumed to be open space and the flatter areas adjacent to

Temescal Wash were assumed to be low to medium residential developments. For hydrologic modeling purposes, the land use plans had to be further defined to comply with the 1978 Riverside County Flood Control and Water Conservation District (RCFC&WCD) Hydrology Manual.

Soil Types

The United States Department of Agriculture, Soil Conservation Service (SCS), has defined four general soil groups for use in hydrologic studies, namely Soil Groups A through D. Hydrologic soil type attributes are contained in the 1978 RCFC&WCD Hydrology Manual with additional data provided by the County of Riverside to cover foothill areas adjacent to the Riverside and Orange County boundary. The Hydrology Manual provides maps delineating a detailed breakdown of the City watershed into four hydrologic soil groups.

Existing Facilities

The existing drainage system in the City of Corona is made up of both City and County facilities. Storm runoff within the City limits is generally intercepted by a network of City facilities, which are then conveyed to the major County facilities which, in turn, convey the flows to the Prado Dam Flood Control Basin. The City storm drain system consists primarily of reinforced concrete pipe (RCP) ranging in diameter from 18 inches to 90 inches; however, there are also a number of reinforced concrete box (RCB) and trapezoidal open channel facilities.

Mainline storm drain system sizes were obtained from the storm drain system data base of the City's Geographic Information System (GIS) and additional research by the consultant to complete missing data. Alignments of the storm drain systems were incorporated into the hydrologic computer model for peak flow rate analyses. The existing drainage system pipe sizes were incorporated into the hydraulic computer model for use in the deficiency analyses.

Topographic Data

The topographic information used in this DMP update was obtained from the Riverside County topographic maps and United States Geological Survey (USGS) topographic maps. These data were stored in a database file that can be extracted while creating the computer link-node model.

2.1.2. Coverage Processing

A powerful function of GIS software is the ability to intersect area polygons to form subset polygons. For this DMP, the subarea, land use and soil types were intersected. The result of this intersection is a breakdown of each subarea according to land use and soil type. Each resulting intersected area includes a unique subarea, land use and soil type. With this information, the drainage modeling software can more accurately estimate the expected runoff from each subarea and analyze the resulting accumulated flows at each link / node included in the model. Additionally, an existing drainage facility and topographic nodal elevation data base was created for direct input into the drainage model.

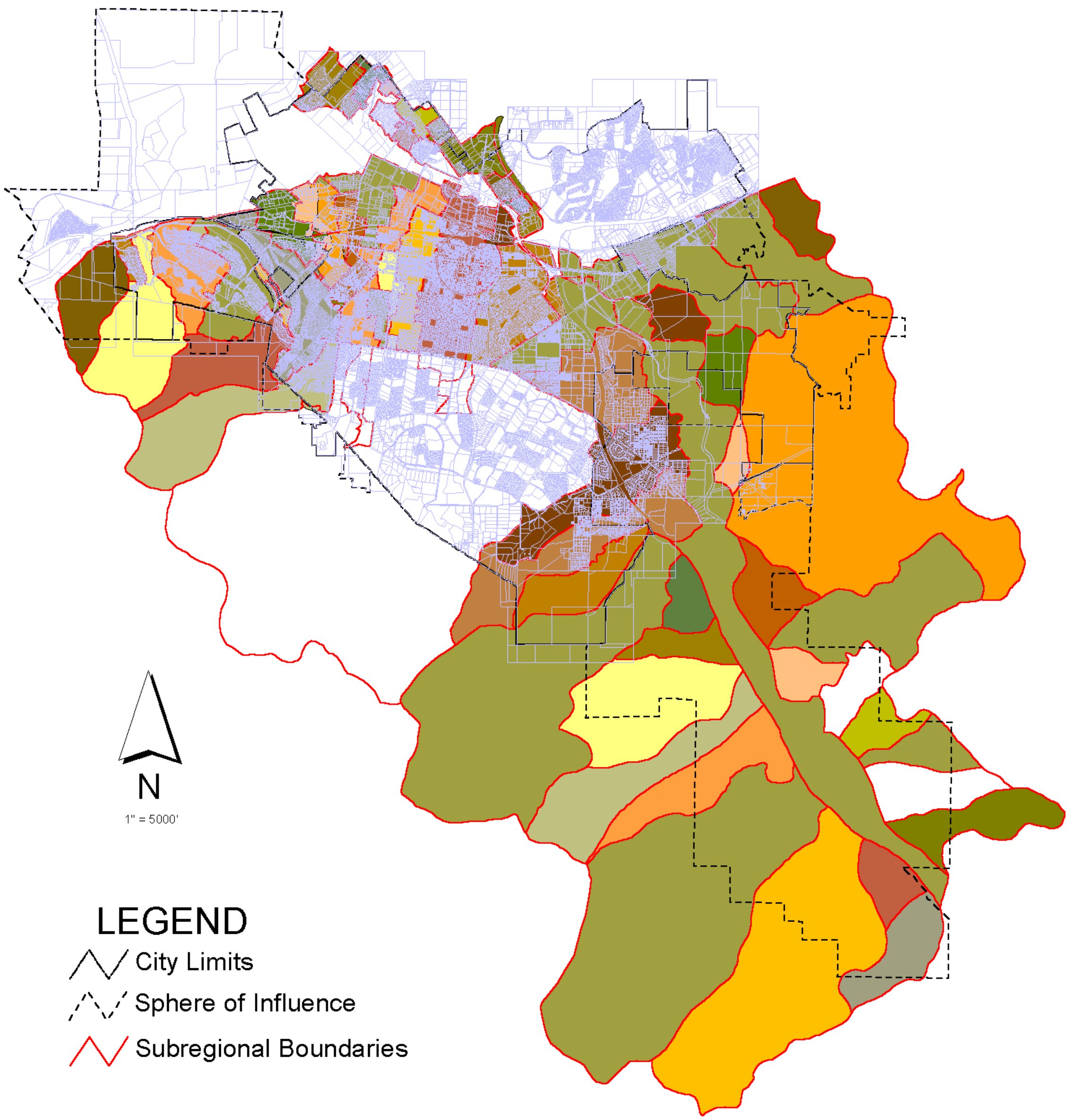

Figure 2. Hydrologic Boundary & Major Subareas Map

2.2. Development of Drainage Criteria

The City of Corona has identified the need to determine the adequacy of existing drainage facilities in providing drainage protection to the City, and to establish a master plan for installation of future facilities.

2.2.1. Design Protection Level

The City decided to use 10-year and 100-year design storms to determine peak runoff quantities in analyzing existing storm drain facilities and sizing potential improvements. Additionally, to determine the "most" deficient drainage facilities, or those with the highest priorities, a 2-year design storm was used to analyze the existing system. The City's goal in developing the DMP was to determine the necessary facilities needed to achieve City flood protection goals for the 2-, 10- and 100-year storm events.

2.2.2. Street Conveyance

Streets and surface conditions are considered in computing flood runoff carrying capacity. The City of Corona's street base map was used to determine streetflow capacity. This base map is shown in Figure 3. Streetflow capacity was defined by the three street types:

1. Major Arterial Highways
2. Secondary Arterial Highways
3. Collector Streets

The surface flow carrying capacity of an arterial highway is determined by two factors: first, one land should remain free of flow for the 10-year return frequency design storm event; second, the street flow depth should not exceed street right-of-way for the 100-year return frequency storm event.

2.2.3. RCP and RCB Conveyance

Adopted size constraints for reinforced concrete pipe (RCP) are between 18 inches (as a minimum) and 84 inches (as a maximum). For any deficient reach that requires a conduit dimension greater than 84-inch RCP, an equivalent reinforced concrete box (RCB) shall be recommended. The minimum dimensions of the RCB shall be 7.5 feet in width and 6.5 feet in depth; and the width to depth ratio cannot exceed a value of 2. Due to the constraints of depth of existing downstream facilities (especially outlet inverts) the depth of the RCB shall be no greater than 8.0 feet.

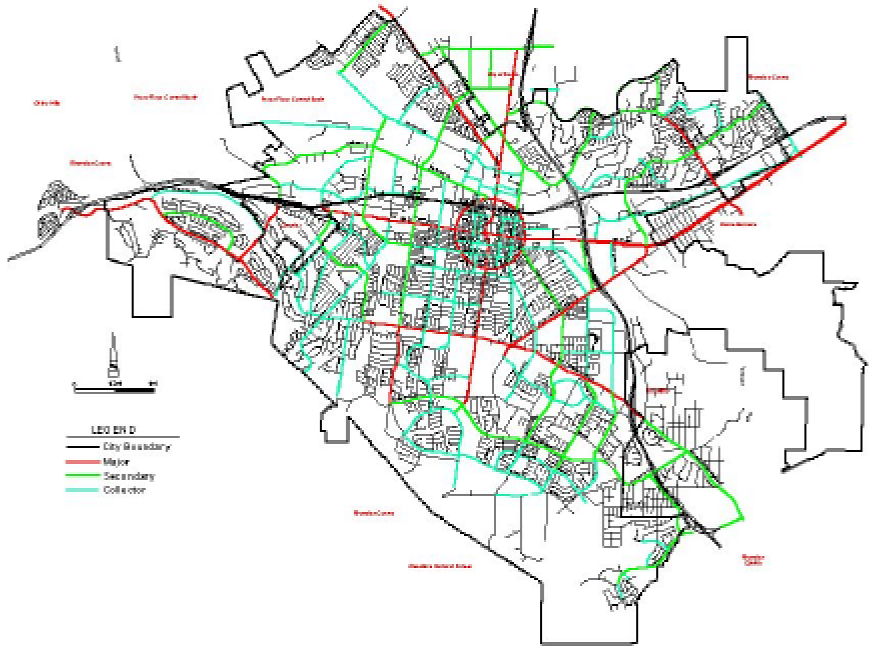

Figure 3. Street Base Map

2.3. Computer Modeling

2.3.1. Software

Various computer programs have been used to organize and generate the data needed for modeling of the City of Corona storm drainage system. Due to the volume of data required to accurately model and analyze the system and the need to provide detailed checking of model input and results data, it is advantageous to use Geographic Information System (GIS) technology for data handling.

The GIS software utilized for the modeling effort is based upon the Environmental Systems Research Inc. (ESRI) ArcINFO program. The City is currently using this software to maintain land use and parcel information within the City limits. Many cities utilize ArcINFO to maintain data for street maintenance, utility systems such as water, sanitary sewer, and storm drain, street lighting, signing inventories, and many other types of data. ArcINFO is the most widely used GIS software in the United States.

Use of this type of software also provides several benefits for the modeling of utility systems, including storm drainage systems. This is beneficial to both the City and the modeling consultant for several reasons including:

- Modeling data can be graphically represented using GIS coverages and database files that can be plotted in map format.
- Graphical data can be readily checked for integrity/omissions.
- GIS coverages can be integrated with the City's existing parcel and land use coverages adding another "building block" to the city's overall database.
- GIS analytical tools such as polygon processing greatly reduce the time required to build input data for modeling related to area loadings to the storm drainage system.
- Changes to the GIS data sets can be easily made for future model updates and analysis of "what-if" scenarios.

ArcINFO is a relatively expensive program the operates best in the UNIX environment. It is often impractical to utilize ArcINFO directly to build the data sets since many municipal engineering departments responsible for maintaining the data, as well as consultants, use IBM-PC compatible hardware and software. To address this problem, ESRI developed software that allows the creation of ArcINFO data sets within AutoCAD, the most widely used PC drafting program among municipal engineering departments and consultants. The City of Corona Engineering department also uses AutoCAD. ESRI's software, ArcCAD, works as an add-on to AutoCAD and allows ArcINFO coverages to be created from line work and labels drawn in AutoCAD.

Viewing and plotting of ArcINFO coverages and linked data sets can be accomplished using ESRI's ArcView software. ArcView works in the Microsoft Windows environment. Using ArcView, powerful querying tools can be used to link model input and results data to graphic entities such as lines and polygons so that data can be displayed as a series of colored lines, colored polygons, and symbols. For instance, results data from the modeling software can be queried for storm drainage capacity, capacity deficiency, cost-to-benefit index for pipeline construction, etc., and displayed on-screen using color legends, symbols and line weights. Final color plots can also be generated using ArcView.

Model input data, such as land use information, soil type information, drainage subarea data, flow path data as well as model results data are maintained in dBASE .dbf file format. This type of data structure is used by ArcCAD and ArcView for linking to graphic entities and display. Using dBASE, the data is organized and exported to ASCII format for use by the modeling software.

The Advanced Engineering Software (AES) Stormwater Information Management System (SIMS) software was used to prepare the City of Corona DMP. SIMS is a software package that links hydrologic and hydraulic software with powerful modules to prepare cost estimates, prioritize proposed drainage facilities and even determine NPDES pollutant loadings.

The linked Rational Method / Unit Hydrograph method hydrology computer program for Riverside County (RATSC) was used to estimate peak flow rates. With the information generated by the polygon processing (where area, land use and soil type are obtained for each subarea), the coupled model generates street and conduit flow, multiple confluence analyses and interface to GIS.

SIMS was used to take the results of the hydrologic model and perform detailed hydraulic computations to calculate existing capacities and generate recommendations for replacement or parallel systems for those links found to be deficient. The Cost Plus cost estimating module and the Cost-to-Benefit Index (CBI) module were linked to the deficiency analysis to estimate cost requirements of new facilities and a method of ranking the proposed improvements.

2.3.2. Hydrologic Analysis

In this Drainage Master Plan, two hydrologic models were utilized: the Rational Method and the Unit Hydrograph Method. According to the 1978 Riverside County Hydrology Manual, the Rational Method is to be used for drainage areas smaller than 300 to 500 acres, and the Unit Hydrograph Method is to be used for areas larger than 300 to 500 acres. In this study, the City decided to use 300 acres as an approximate break point to switch from the Rational Method to the Unit Hydrograph method to estimate the peak flow rates.

The AES RATSC hydrologic model has the ability to switch between these two peak flow estimation methods using one data base of hydrologic information. The computer model has an internal bookkeeping system which develops the area-averaged values of the loss rate, low loss rate fraction and rainfall depths for the Unit Hydrograph analysis. The time of concentration (Tc) of the longest flow path is used in the Unit Hydrograph lag estimation. If the total tributary area at any concentration point is greater than 300 acres and the time of concentration (Tc) is greater than 12.5 minutes, the hydrologic analysis can then be switched from the Rational Method to the Unit Hydrograph Method without leaving the computer model. The advantages of using the RATSC hydrologic model are that:

- The whole DMP can be completed in one computer model for both the Rational Method and Unit Hydrograph analyses based on the criteria required by the County Hydrology Manual.

- No second efforts are needed to develop the Unit Hydrograph parameters and to perform the Unit Hydrograph study separately.

The Rational Method modeling approach is widely used due to the simplicity in application, and the capability for estimating peak runoff rates throughout the study watershed. The Unit Hydrograph Method was used to develop peak flow rates for drainage area greater than 300 acres. The Unit Hydrograph lag time is calculated as (0.8) Tc, where Tc is the Rational Method time of concentration for the longest flowpath. In the Unit Hydrograph study, the “Valley” S-graph was used except for City’s SOI areas and steeper terrain areas where the “Foothill” S-graph was used.

2.3.3. Hydraulic Analysis

The hydraulic analysis consists of two steps: facilities conveyance analysis and deficiency analysis. The facilities conveyance analysis includes an estimate of roadway capacity, reinforced concrete pipe (RCP) capacity, and reinforced concrete box (RCB) capacity. The deficiency analysis considers both parallel and replacement systems for the existing deficient system.

The hydraulic deficiency analysis compares the runoff carrying capacity for the existing facilities (e.g., streets, open channels, reinforced concrete pipes and reinforced concrete boxes), to the peak flow rates of the 2-, 10- and 100-year return frequency storm events. If the runoff carrying capacity for the existing facilities is less than the peak runoff rates of the various return frequency criteria, the existing facilities are determined to be deficient. The deficient capacity is defined as follows:

Deficient Capacity = Peak runoff rate - Street capacity - existing storm drain capacity.

The hydraulic grade line, used in determining conduit capacity, was modeled as being parallel to the surface slope. This is generally the case since, under flood conditions, flows are either on the verge of entering the street (10 year storm event), or are partitioned between the conduit and the street (100-year storm events). Likewise, there is little economic incentive for diverging significantly away from a shallow pipe trench that follows the predominant surface topography, or unnecessarily over-sizing a pipe to eliminate surface flows beyond those of the 10-year design storm. The hydraulic gradient was determined by identifying the surface elevation of both the upstream and downstream nodes, then finding their difference and dividing by the length of drain between them. Flow path links with adverse or extremely low surface slopes were assumed to have been constructed with a slope of 0.002 (0.2%), which is a practical minimum slope for the design of urban drainage facilities.

Due to the methodology used in the hydraulic analysis (i.e., normal depth flow analysis), it is likely that pipe reaches in a system may decrease in size, or “telescope downward”. For this Drainage Master Plan, decreases in pipe sizes were manually adjusted, therefore, storm drain facilities always increase in dimensions from the upstream reach to the downstream reach.

2.3.4. Cost Opinions

Basic RCP and RCB unit costs and associated appurtenance costs were established for the purpose of developing a Storm Drain Capital Improvement Program for the City of Corona. The unit cost for storm drain facilities was provided by the County of Riverside. Improvement costs, for each deficient street / storm drain reach, is provided by the DMP results. These costs reflect the cost to remove deficiencies, consistent with agency standards, for the selected design storm event.

2.3.5. Cost-to-Benefit Index (CBI)

In urbanized areas, where development patterns are essentially uniform with respect to drainage to streets, the flood damage potential may be related to the flood depth in the adjacent street section. For a particular street geometric cross-section, a given flood depth may be correlated to different levels of flood damage potential depending upon the contiguous developmental land use. Additionally, the greater the flood depth in the street section, the higher the flood damage potential to the adjacent property. The flood damage potential can be estimated if there exist relationships between the street section flood depth and the various associated land use designations. By a master plan study of the flood control system, a cost to reduce the flood damage potential (according to local agency standards) can be estimated.

For the City of Corona DMP, the following elements of concern have been considered in assigning priorities:

- Possible loss of life or injury to people would obviously take precedence over major property damage, while major property damage should certainly take precedence over major occasional flooding which results primarily in inconvenience and annoyance.

- Main drains which serve as collectors for tributary reaches have priority over more localized reaches.

- More highly developed areas should be protected prior to less developed areas.

- A downstream reach would normally have priority over an upstream reach in creating relief, as adequate downstream capacity is required before upstream improvements can be effective.

Dividing the flood damage potential by the associated cost to upgrade the appropriate flood control system determines a Cost-to-Benefit Index. A higher CBI value indicates that a higher benefit can be achieved with the associated cost to upgrade the local flood control system. A prioritization of the Drainage Master Plan system elements can then be developed based upon a ranking of each element’s cost-to-benefit index. Use of this CBI approach enables a prioritization of master plan system improvements in order to increase utilization of agency funds to remove system deficiencies. By graphically displaying CBI values, prioritization becomes more visually apparent in that systems demonstrating a more efficient use of agency funds (in removing deficiencies) are graphically identified.

Manning's equation for normal depth flow is used to determine the existing condition (i.e., no new drainage improvements) street flow depth, for each system element, by using the peak flow rate, existing storm drain capacity, and street cross-section information. This flow depth corresponds to the condition where storm drain improvements have not yet been made to remove deficiencies, for the selected design storm event.

After determining the existing condition street flow depth, the flood damage potential is determined from the flood damage potential curves, based upon the proper street deficiency category and the adjacent land use. If the system element under study contains mixed land uses, the flood damage potential for each land use is calculated, and an area-averaged value is used to represent a composite flood damage potential, for the selected design storm event.

A typical drainage system element in a master plan of drainage consists of the combined capacity of a particular street section, with an underlying pipe or box flood control system. For evaluation purposes, five types of coupled street and storm drain deficiency model classifications are used in the CBI analysis; these categories reflect the varying storm-flow carrying capacity of each street section used in the study. The categories are:

1. Deficiency Category I (Roadway Sumps): For street grades equal to zero, deficiencies typically correlate to the volume of runoff ponded at the particular vicinity, for the selected design storm event.

2. Deficiency Category II (Arterial Streets): For any street with a maximum allowable design flow depth less than or equal to the street top-of-curb. A typical case is when it is required to maintain one or more lanes of traffic flood-free during a design storm event. Generally, such a criterion applies to major or secondary arterial highways.

3. Deficiency Category III (Collector Streets): For any street with a maximum allowable design flow depth greater than or equal to top-of-curb, for the selected design storm event. Generally, residential streets fit into this category.

4. Deficiency Category IV (Box/Open Channel): For any link where there is an existing box culvert or open channel that does not fall into categories I, II, or III.

5. Deficiency Category V (Storm Drain Pipe): For any link where there is a storm drain pipe that does not have a coupled streetflow capacity.

A set of flood damage potential curves is needed for each deficiency category. The flood damage potential curves define a street flow depth versus flood damage potential relationship, for various land use designations. In order to define flood damage potential for a particular system element, damage potential versus street flow depth data are needed. Generally, flood damage of habitable structures can be estimated to occur at a specific depth of flow above street top-of-curb (such as a one-foot depth above top-of-curb). At this depth, it is assumed that flood flows are damaging property, and actual damage costs can be computed. For greater depths, higher damage potential values may be assigned. For lesser flow depths, where property damage might not occur, a “penalty” may be assigned that generalizes “damage” due to traffic obstruction, risks to emergency services, among other factors. For example, assuming a ten-percent damage potential for flow depths 0.5-foot above top-of-curb may be appropriate. Although actual costs may be computed, they are not necessary in the CBI approach as a subsequent normalization of CBI values is used for prioritization purposes. Consequently, the key to the CBI analysis is a relative flood damage potential definition, with respect to both flood depth in the street and land use designation. The ranking of master plan system elements with respect to CBI values is analogous to the more standardized cost-to-benefit ratio approach such as is used by the U.S. Army Corps of Engineers (Sheaffer et. al., 1982).

The cost-to-benefit index is calculated as follows:

CBI (Cost-to-Benefit Index) = (Flood Damage Potential) / (Improvement Costs)

The CBI value computed for each street / storm drain reach is then stored in the computer data base with respect to its deficiency category. After completion of the CBI analysis for the entire DMP, statistical calculations of mean value and standard deviation, for each of the five different deficiency categories, are prepared. By dividing the entire CBI range of values by the maximum CBI value (based upon the deficiency category), normalized CBI values are computed with a range of zero to one. These normalized values are written to another data file for subsequent graphics display purposes. Note that a CBI value of zero corresponds to a zero deficiency pursuant to Agency standards and the selected designed storm event. A CBI value less than 0.001 does not mean that there is no deficiency, just that it has a significant relative cost to benefit ratio. A CBI value of 1.000 corresponds to the maximum value of the CBI.

3. Conclusions

Two separate hydraulic analyses were completed for the deficiency portion of this DMP, the baseline hydraulic analysis and the 2-year hydraulic analysis. The baseline hydraulic analysis utilizes the City's current drainage design criteria, that are based on both 10- and 100-year design storms. The 2-year hydraulic analysis was completed to identify facilities that are deficient for a 2-year design storm, thus, pinpointing the most deficient systems.

The baseline hydraulic analysis found that 371 of the 1320 analyzed links were insufficient to convey the runoff for at least one of the two design storms and were therefore deficient. Replacement conduits were identified for each of the deficient links, such that the runoff from each design storm can be conveyed within the given criteria. The total estimated cost of the recommended improvements is approximately $52 million.

The 2-year hydraulic analysis found that 194 of the 1320 analyzed links were insufficient to convey the runoff for the 2-year design storm and were therefore deficient. Replacement conduits were identified and sized by the current drainage design criteria, 10- and 100-year design storms, for each of the deficient links, such that the runoff from each design storm can be conveyed within the given criteria. The total estimated cost of the recommended improvements associated with 2-year deficiencies is approximately $23 million.

The prioritization of the recommended improvements should be based not only on the numerical results of the deficiency and cost benefit analyses, but should also take into account the preferences of the City. As a first approach, the cost-to-benefit index (CBI), especially the 2-year analysis, can be used to prioritize the improvements, either on a link by link basis, or, more usefully, on a project basis. Several methods of prioritizing projects based on CBI are possible, such as identifying priority projects as those containing two or more links with high CBI's, or analyzing each project to estimate an average CBI value for the project.

Additional considerations may include: project size and capital investment, priority of downstream and main drains over more localized reaches, any areas of particular concern to the City, and so forth. The final time-phased Capital Improvement Program will be based in large part on the financial strategies analysis and the revenue stream which can realistically be developed to finance desired stormdrain improvements.

The computer model developed will allow variations in runoff to be predicted due to changes in land use, rainfall records, or changes in agency criteria. Similarly, the system costs can be updated as cost factors change. The results and tools developed in this DMP will aid the City in a selective system implementation program that will meet the most critical flood protection needs on a priority basis.

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[6] **City of Corona**, Project Manager

Chapter 7

Master Plan of Drainage: Hydrologic Network Modeling

7.1 Introduction

Some design problems must be concerned with the time dependency in watershed, channel, and reservoir storages. Other types of design problems only require estimates of maximum flow rates (or peak discharges) and the time characteristics of the runoff. These design problems can be handled using the methods such as those outlined in this chapter.

The time from the beginning of rainfall excess to the occurrence of the peak runoff rate is important both in determining the duration of the rainfall and in balancing discharge rates from subareas of a watershed. The most important time parameter is the time of concentration, which is discussed in the first part of this chapter. The time of concentration is a necessary input in most hydrologic models, including the rational method, which is the subject of the remaining parts of this chapter. In addition to basic rational method computations, methods for designing on subdivided watersheds are included.

7.2 Time of Concentration Estimation

The time of concentration (Tc) is usually defined as the duration required for runoff at the point of concentration to become a maximum under a uniform and constant rainfall intensity. This occurs when all parts of the drainage area are contributing to the flow. Generally, the time of concentration is the interval of time from the beginning of rainfall for water from the hydraulically most remote point of the drainage area to reach the point of concentration (e.g., a drainage structure). The Tc is a function of several variables including the length of the flow path from the most remote point of the watershed to the concentration point, the slope of the flowpath, characteristics of natural and improved channels within the drainage area, the infiltration properties of the soil, and the extent and type of development.

Recognizing the importance of the time of concentration as input to hydrologic models, a wide array of methods have been proposed for estimating Tc. Most methods are a function of two or more of the following factors: (1) flow length, (2) flowpath slope, (3) land use or a representative surface roughness, and (4) the intensity of the rainfall. Since times of concentration are required for all types of flow regimes, including overland flow, street flow, pipe flow, and channel flow, the inputs for estimating Tc should reflect the primary flow regime in the flowpath being analyzed. Given the wide array of methods available, it is important to select for design a Tc method that uses inputs that correspond directly to the character of the flowpath being analyzed. The following paragraphs describe the methods most commonly used for design.

Over two dozen overland flow formulas have been proposed in the literature to estimate the initial subarea Tc. A variation of the Kirpich (1940) formula that is widely used has the form:

$$Tc = k(L^3/H)^E \qquad (7.1)$$

where

L = length of initial subarea flowpath (feet)
H = drop in elevation along flowpath (feet)
k = coefficient depending on development type
E = constant exponent.

A nomograph for the solution of Eq. (7.1) with E = 0.20 is given in Figure 7.1. Due to the inherent inaccuracy in the determination of a generalized overland flow Tc, Eq. (7.1) should only be used on initial subareas of less than about 10 acres.

An alternative version of the Kirpich formula is:

$$Tc = 0.00013L_f^{0.77}S_f^{-0.385} \qquad (7.2)$$

in which L_f is the hydraulic length in feet, S_f is the slope in feet/feet, and Tc is the time of concentration in hours. Equation (7.2) is based on watersheds in Tennessee that have areas from 1 to 112 acres and slopes from 3% to 10%. The computed times of concentration should be multiplied by 0.4 and 0.2 for watersheds where the overland flow path is either concrete or asphalt and the channel is lined, respectively.

The simplest method is to estimate a Tc at the point of concentration by using a generalized overland flow formula or corresponding nomograph. For example, Figure 7.2 provides a nomograph for the California Culvert Practice (1942) formula of Eq. (7.1) with k = 0.0078.

In comparison, the Federal Aviation Agency (1970) proposed:

$$Tc = 1.8(1.1 - C)L^{0.50}S^{-0.333} \qquad (7.3)$$

where

C = runoff coefficient for the rational method
S_f = average surface slope (percent)
L = characteristic flow length.

The kinematic wave equation is widely used for very small flow lengths:

$$Tc = 0.94L^{0.6}n^{0.6}i^{-0.4}Sf^{-0.3} \qquad (7.4)$$

in which L is the flow length in feet, n is the Manning's roughness coefficient, i is the excess rainfall rate (inch/hour), and S_f is the slope in feet/feet. Equation (7.4) is valid only for very shallow sheet flow over lengths of 300 feet or less. It is especially useful for Tc estimation of gutter flow in urban areas.

For watersheds having flow paths of mixed land covers, the time of concentration (Tc) can be estimated by summing the runoff travel times (Tt) through the several flow regimes as the flood peak travels downstream to the watershed outlet. These flow regimes include overland flow, streetflow, pipeflow, and open channel flow in natural or improved channels, and must include the effects of the flood peak rate (Q) increasing the magnitude as the tributary area to the main collection stream increases. The mixed velocity method is applied to watersheds that have flow paths of mixed land covers. For upland flow paths an equation such as Eq. (7.1) or (7.4) can be used. As the runoff enters an area of more concentrated flow the flow velocity can be estimated with Manning's equation or Figure 7.3. The travel time for the flow path with velocity V(feet/sec) can be computed with:

$$Tt = L/V \tag{7.5a}$$

where Tt is the travel time in seconds and L is the length in feet. The total travel time for the watershed is the sum of the individual travel times:

$$Tt = \sum_{i=1}^{n} L_i / V_i \tag{7.5b}$$

in which n is the number of flow paths. Any travel times computed with Eq. (7.1) or Eq. (7.4) would have to be added to the summation of Eq. (7.5b).

For larger watersheds where conditions are not homogeneous, the watershed should be divided into subareas and the times of concentration computed for each subarea. The main flowpath is identified such that the watershed can be subdivided into m subareas with each subarea tributary to the collection stream (Figure 7.7, of example 7.2). The main flowpath is segmented into reaches that are relatively homogeneous in runoff characteristics. From the figure, it is noted that the initial (the most upstream) subarea is relatively small (about 10 acres) and has an associated overland flowpath length of less than about 1000 feet. The subareas gradually increase in size in the downstream direction along the collection stream. Additionally, nodal points (i = 1,2,…,m) are defined along the main stream so that each subarea has an associated upstream and downstream node number. The initial subarea time of concentration for the overland flow between node numbers 1 and 2 is estimated by some overland flow formula or an assumed average flow velocity for the runoff traveling along the main flowpath within the initial subarea. Subsequent Tc values are determined by:

$$Tc(i+1) = Tc(i) + Tt(i,i+1) \tag{7.6}$$

where

Tc(i+1) = Tc at node number i+1
Tc(i) = Tc at node number i
Tt(i,i+1) = traveltime of Q between nodes i and i+1

The travel time for each segment of the flowpath is then computed. To estimate travel time values $T_t(i,i+1)$, the Manning's formula is used to calculate a normal depth for the runoff flowing in both the channel linking nodes i and i+1 and the corresponding flow velocities used to estimate the time for the peak Q to move from node i to node i+1. The time of concentration then computed by the velocity method is:

$$Tt(i,i+1) = L(i,i+1)/V(i,i+1) \tag{7.7}$$

where

L(i,i+1) = length of channel linking nodes i and i+1
V(i,i+1) = normal depth flow velocity of Q(i)

7.3 Rational Method

The most widely used hydrologic model for estimating watershed peak runoff rates is the rational method. Currently, this approach is typically used to estimate runoff rates from small urban areas of variable size. Some older versions of this method have been directly applied to watersheds with sizes in excess of several square miles. Modern versions of this approach generally limit the watershed size to about one square mile.

The rational method equation relates rainfall intensity, a runoff coefficient, and drainage area size to the direct peak runoff rate. This relationship is expressed by the equation:

$$Q = CIA \tag{7.8}$$

where

Q = the peak runoff rate in cubic feet per second (cfs) at the point of concentration
C = a runoff coefficient representing the area-averaged ratio of runoff to rainfall rates
I = the time-averaged intensity in inches per hour corresponding to the time of concentration
A = the drainage area (acres)

The values of the runoff coefficient and rainfall intensity are based on a study of drainage area characteristics such as the type and condition of the runoff surfaces and the time of concentration. These factors and the limitations of the rational method equation are discussed in the following sections.

Data required for the computation of peak discharge by the rational method include (1) rainfall intensity for a storm of specified duration and selected return frequency; (2) drainage area characteristics of size, shape, slope; and (3) a land use index that reflects the amount of rainfall that will appear as direct runoff. The drainage area may be determined by planimetering a suitable topographic map of the tributary watershed areas. The duration of the storm rainfall required in the rational method equation is based on the time of concentration of the tributary drainage area. Rainfall intensity (I) is determined from the local precipitation intensity-duration curves of the desired return frequency (see Figure 7.8). Since one acre-inch/hour is equal to 1.008 cfs, the rational method is generally assumed to estimate a peak flowrate in cfs.

Computer programs, such as the AES SIMS, also integrates a design storm unit hydrograph method with the rational method in order to provide a single fully integrated modeling tool. For simplicity, this chapter only focuses on the rational method application.

7.4 Runoff Coefficient

The runoff coefficient (C) is the ratio of peak rate of runoff to the rate of rainfall at an average intensity when the total drainage area is contributing runoff to the point of concentration. The selection of the runoff coefficient depends on drainage area slope, type and amount of vegetative cover, distribution and magnitude of the soil infiltration capacity, and various other factors.

For calculation purposes, the runoff coefficient is most often defined to be either (1) a constant value depending on soil cover type and quality, or (2) a function of rainfall intensity, soil cover type, and quality. Table 7.1 lists typical C values for use with the rational method.

The second class of runoff coefficient representations relates to the C value to the rainfall intensity. One approach used for urban design purposes is to assume that the watershed loss rate is equal to the infiltration loss rate which corresponds to the limiting value of the infiltration capacity curve. For design storm conditions, it can be argued that the impervious area runoff rate is independent of the rainfall intensity and that the pervious area infiltration loss rate is a constant. For urban design studies, the runoff coefficient is sometimes assumed to be a function of the impervious and pervious area fractions, a characteristic infiltration rate (Fp) for the pervious area fraction, and the effects of watershed detention in the estimation of travel time of the peak runoff rate through the watershed channel system. Then estimates for runoff coefficients are developed using a relationship of the form:

$$Cm = 0.85\,(Ai + (I - Fp)Ap/I) \qquad (7.9)$$

where

Cm = modified runoff coefficient
I = rainfall intensity (inch/hour)
Fp = infiltration rate for pervious area fraction
Ai = impervious area fraction
Ap = pervious area fraction
0.85 = calibrated (or assumed) coefficient to correlate rainfall and runoff frequencies

The infiltration rate for the pervious area (Fp) can be estimated for various combinations of soil type, cover, and antecedent moisture conditions. For the most common types of urban development and soil covers, typical runoff coefficient curves based on Eq. (7.9) are shown in Figs. 7.4a through 7.4d for SCS oil groups A through D, respectively.

When the drainage area is composed of several types of runoff surfaces, an area-averaged runoff coefficient can be developed as demonstrated by the following example problem.

7.5 Example 7.1 Area-Averaged Runoff Coefficient

The watershed is composed of 3.5 acres of parking lot pavement and the associated street system, 35.6 acres of a condominium development, and 12.5 acres of a neighboring apartment complex. The area-averaged runoff coefficient is estimated by tabulating each area fraction's contribution:

Area (acres)	Type of Surface	C	CA
3.5	concrete pavement	1.0	3.50
35.6	condominiums	0.67	23.85
12.5	apartments	0.77	9.63
51.6 (sum)			36.98

area-averaged C = 36.98/51.6 = 0.72

Table 7.1
RUNOFF COEFFICIENTS FOR THE RATIONAL FORMULA FOR A HYROLOGIC SOIL GROUP AND SLOPE RANGE

	A			B			C			D		
Land use	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+	0-2%	2-6%	6%+
Cultivated land	0.08[1]	0.13	0.16	0.11	0.15	0.21	0.14	0.19	0.26	0.18	0.23	0.31
	0.14[2]	0.18	0.22	0.16	0.21	0.28	0.20	0.25	0.34	0.24	0.29	0.41
Pasture	0.12	0.20	0.30	0.18	0.28	0.37	0.24	0.34	0.44	0.30	0.40	0.50
	0.15	0.25	0.37	0.23	0.34	0.45	0.30	0.42	0.52	0.37	0.50	0.62
Meadow	0.10	0.16	0.25	0.14	0.22	0.30	0.20	0.28	0.36	0.24	0.30	0.40
	0.14	0.22	0.30	0.20	0.28	0.37	0.26	0.35	0.44	0.30	0.40	0.50
Forest	0.05	0.08	0.11	0.08	0.11	0.14	0.10	0.13	0.16	0.12	0.16	0.20
	0.08	0.11	0.14	0.10	0.14	0.18	0.12	0.16	0.20	0.15	0.20	0.25
Residential lot	0.25	0.28	0.31	0.27	0.30	0.35	0.30	0.33	0.38	0.33	0.36	0.42
size 1/8 acre	0.33	0.37	0.40	0.35	0.39	0.44	0.38	0.42	0.49	0.41	0.45	0.54
Residential lot	0.22	0.26	0.29	0.24	0.29	0.33	0.27	0.31	0.36	0.30	0.34	0.40
size 1/4 acre	0.30	0.34	0.37	0.33	0.37	0.42	0.36	0.40	0.47	0.38	0.42	0.52
Residential lot	0.19	0.23	0.26	0.22	0.26	0.30	0.25	0.29	0.34	0.28	0.32	0.39
size 1/3 acre	0.28	0.32	0.35	0.30	0.35	0.39	0.33	0.38	0.45	0.36	0.40	0.50
Residential lot	0.16	0.20	0.24	0.19	0.23	0.28	0.22	0.27	0.32	0.26	0.30	0.37
size 1/2 acre	0.25	0.29	0.32	0.28	0.32	0.36	0.31	0.35	0.42	0.34	0.38	0.48
Residential lot	0.14	0.19	0.22	0.17	0.21	0.26	0.20	0.25	0.31	0.24	0.29	0.35
size 1 acre	0.22	0.26	0.29	0.24	0.28	0.34	0.28	0.32	0.40	0.31	0.35	0.46
Industrial	0.67	0.68	0.68	0.68	0.68	0.69	0.68	0.69	0.69	0.69	0.69	0.70
	0.85	0.85	0.86	0.85	0.86	0.86	0.86	0.86	0.87	0.86	0.86	0.88
Commercial	0.71	0.71	0.72	0.71	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
	0.88	0.88	0.89	0.89	0.89	0.89	0.89	0.89	0.90	0.89	0.89	0.90
Streets	0.70	0.71	0.72	0.71	0.72	0.74	0.72	0.73	0.76	0.73	0.75	0.78
	0.76	0.77	0.79	0.80	0.82	0.84	0.84	0.85	0.89	0.89	0.91	0.95
Open Space	0.05	0.10	0.14	0.08	0.13	0.19	0.12	0.17	0.24	0.16	0.21	0.28
	0.11	0.16	0.20	0.14	0.19	0.26	0.18	0.23	0.32	0.22	0.27	0.39
Parking	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87	0.85	0.86	0.87
	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97	0.95	0.96	0.97

[1] Runoff coefficients for storm recurrence intervals less than 25 years.

[2] Runoff coefficients for storm recurrence intervals of 25 years or more.

7.6 Limitations of the Rational Method

The relationship expressed by the rational method equation holds true only if certain assumptions are reasonably correct and limitations are observed. Four basic assumptions are that (1) the frequency of the storm runoff is the same as the return frequency of rainfall producing the runoff (that is, a 25-year recurrence interval rainfall will result in a 25-year recurrence interval storm runoff); (2) the peak runoff rate occurs when all parts of the drainage area are contributing to the runoff; (3) the design rainfall is uniform over the watershed area tributary to the point of concentration; and (4) the rainfall intensity is essentially constant during the storm duration, which is equal to the time of concentration.

The rational method is only applicable where the rainfall intensity can be assumed uniformly distributed over the drainage area at a uniform rate throughout the storm duration. This assumption applies fairly well to small drainage areas of less than about one square mile. Beyond this limit, the rainfall distribution may vary considerably from the point values given in rainfall isohyetal maps.

The selection of the runoff coefficient is another major limitation of the method. For small urban areas, the runoff coefficient can be reasonably estimated from field investigations and studies of aerial photographs. For larger areas, the determination of the runoff coefficient is to be based on vegetation type, cover density, the infiltration capacity of the soil, and the slope of the drainage area. For larger areas, an estimate of the runoff coefficient may be subject to a much greater error due to the variability of the drainage area characteristics, watershed storage, and the greater importance of hydraulic flow characteristics. Rainfall losses due to evaporation, transpiration, and both depression and channel storage cannot be properly evaluated and may appreciably affect the estimate of the watershed peak rate of runoff.

7.7 Modeling with the Rational Method

The preceding discussion of the rational method is oriented toward design problems for a single drainage area. Where it is necessary to subdivide a watershed because of nonhomogeneities in hydrologic processes or to evaluate the effects of development of a part of the watershed, then the method of modeling is a bit more involved than just applying Eq. (7.8). The following paragraphs describe alternative ways of modeling with the rational method.

7.8 The Link-Node Method

This approach estimates the peak runoff at a watershed point of concentration by the following steps:

(1) Subdivide the watershed into m subareas such as shown in Figure 7.7. The subareas are chosen such that the initial subarea is relatively small and subsequent subareas gradually increase in size in the downstream direction. Each subarea has an associated runoff coefficient C_i and a tributary drainage area A_i.

(2) Estimate a time of concentration Tc' at the point of concentration of the watershed (that is, the most downstream nodal point, node m).

(3) Using Tc', determine a corresponding rainfall intensity (I') from the local precipitation intensity-duration curves.

(4) If the C_i are assumed to be functions of rainfall intensity, determine appropriate C_i' values for the intensity I'.

(5) Calculate a total watershed peak runoff (Q') by

$$Q' = (C_1'A_1 + C_2'A_2 + \ldots + C_m'A_m)I'$$

(6) Distribute Q' throughout the watershed according to the area proportion of runoff $Q_i' = C_i'A_iI'$, where Q_i' is the assumed runoff estimate at nodal point i in the estimation of the peak Q for node m.

(7) Estimate the time of concentration at node 1 for the initial subarea, Tc(1).

(8) In the next downstream subarea, calculate the travel time Tt(1,2) for the runoff Q' to flow to the next nodal point and determine Tc(2) = Tc(1) + Tt(1,2).

(9) In each subsequent downstream subarea, use Q_i' to estimate the travel time Tt(i,i+1) between nodes i and i+1, and estimate Tc(i+1) = Tc(i) + Tt(i,i+1).

(10) Using step 9, determine the final node Tc(m).

(11) Compare Tc(m) to the estimated Tc'.

(12) Calculate a new Tc'' by Tc'' = (Tc(m) + Tc')/2.

(13) Return to step 3 where Tc'' is substituted for Tc'.

This link-node model is based on the rational method attempts to estimate a Tc(m) by accounting for the several flow regimes through which the runoff peak flow rate must travel through and is thought to provide an improvement over the nomograph method when studying larger watersheds.

7.9 The Nodal Point Method

This approach attempts to reduce the calculation effect required by the Link-Node Method. The procedure for the Nodal Point Method is as follows:

(1) Subdivide the watershed into m subareas such as shown in Figure 7.7. Similar to the Link-Node Method, the subareas are selected such that the initial subarea is less than 10 acres and the subsequent downstream subareas gradually increase in size in order to reduce the computational effort in dealing with small subareas.

(2) Estimate an initial subarea Tc(1) for the overland flow concentrating at node 1.

(3) Using Tc(1), estimate the corresponding rainfall intensity $I_1 = I(Tc(1))$ and the runoff coefficient C_1. Then $Q(1) = C_1 I_1 A_1$.

(4) Using Q(1), estimate the travel time $T_t(1,2)$ between nodes 1 and 2 of the next downstream subarea.

(5) Calculate Tc(2) = Tc(1) + Tt(1,2). Determine the rainfall intensity $I_2 = I(Tc(2))$. Using I_2, determine an area-average runoff factor for the entire watershed tributary to node 2 by:

$$(CA)_2 = (C_1A_1 + C_2A_2)$$

Then $Q(2) = (CA)_2 I_2$.

(6) Repeat steps 4 and 5 for each subsequent downstream subarea as the study proceeds in the downstream direction. At each node, the area-averaged runoff factor $(CA)_i$ is calculated based on the new TC and I values.

A computational advantage for the Nodal-Point Method over the Link-Node Method is that the entire watershed is analyzed for peak flow rate estimates at each watershed nodal point with only one pass of the method. Consequently, computational effort is considerably reduced. A disadvantage of the model is that it is possible to estimate a downstream peak runoff rate (at a node i+1) which is less than the preceding nodal point (at node i). This is due to the variation of the runoff factor $(CA)_i$ with rainfall intensity.

7.10 The Subarea Summation Method

This rational method modeling approach is widely used due to the simplicity in application, and the capability for estimating peak runoff rates throughout the interior of a study watershed. In this respect, it is analogous to the Nodal-Point Method. The procedure for the Subarea Summation Model is as follows:

(1) Subdivide the watershed m subareas with the initial subarea being approximately 10 acres in size, and the subsequent subareas gradually increasing in size. Assign upstream and downstream nodal point numbers to each subarea in order to correlate calculations to the watershed map (see Figure 7.7).

(2) Estimate a Tc(1) by using a nomograph or overland flow velocity estimation.

(3) Using Tc(1), determine the corresponding values of I_1 and C_1. Then Q(1) = $C_1I_1A_1$.

(4) Using Q(1), estimate the travel time between nodes 1 and 2 by Manning's equation as applied to the particular channel or conduit linking nodes 1 and 2.

(5) Then Tc(2) = Tc(1) + Tt(1,2). Using Tc(2), estimate the rainfall intensity I_2 = I(Tc(2)) and the runoff coefficient corresponding to both I_2 and the runoff coefficient corresponding to both I_2 and the properties of the subarea between nodes 1 and 2. Then:

$$Q(2) = Q(1) + C_2I_2A_2$$

(6) Repeat steps 4 and 5 as the analysis proceeds in the downstream direction along the principal collection stream.

Of the models, the Subarea Summation Model is generally the easiest to use and formulate into a digital computer program. Computer applications of this model are easily used for the master plannings of large cities in urbanized regions. Because the calculations proceed in the downstream direction exclusively, the entire watershed tributary to each nodal point is characterized by only three variables: Q(i), Tc(i), and total area. The Nodal-Point Method is also easily programmable for use in master planning and design purposes.

7.11 Confluence of Streams (Junction Analysis)

Each of the above rational modeling approaches determines peak runoff rates for major collection streams within a watershed. At the confluence of two or more collection streams, a procedure for adjusting the total summation of peak flow rates is required in order to account for each stream's time of concentration at the junction. The following procedure provides an estimate of the confluence peak flow rate assuming that each stream's runoff hydrograph is triangular in shape (Riverside County Hydrology Manual, 1978).

Let Qa, Ta, Ia be the peak runoff flowrate, time of concentration, and rainfall intensity that corresponds to the collection stream with the longer time of concentration. Let Qb, Tb, Ib correspond to the collection stream with the shorter time of concentration. Let Qp and Tp correspond to the confluence peak discharge and time of concentration, respectively. Then the following situations are possible:

(1) If the collection streams have the same time of concentration, then the values are directly summed:

$$Qp = Qa + Qb;\ Tp = Ta = Tb$$

(2) If the collections streams have different times of concentration, the tributary discharge values may be adjusted as follows:

(i) The most frequent case is where the collection stream with the longer time of concentration has the larger discharge. Then the smaller discharge value is adjusted by the ratio of rainfall intensities

$$Qp = Qa + Qb(Ia/Ib);\ Tp = Ta$$

(ii) In some cases, the collection stream with the shorter time of concentration has the larger discharge. Then the smaller discharge is adjusted by a ratio of the Tc values

$$Qp = Qb + Qa(Tb/Ta);\ Tp = Tb$$

7.12 Presentation of Product

Of interest to many civil engineers in both the private and public sectors is a standardized means of presenting rational method calculations. Many local governmental flood control agencies at the city and county levels use a standard tabulation form such as shown in Figure 7.5. Consequently, a computer program prepared to perform master planning and design studies within a flood control district should be designed to produce a product which exactly satisfies the local agency requirements for study submittals. A typical study format is shown later, in this chapter (Figure 7.6) which includes the necessary hydrologic and geographic data requirements as well as the overall presentation of the product.

7.13 A Rational Method Planning/Design Computer Program

Each of the rational method subarea modeling approaches utilize identical submodels for estimating (1) the initial time of concentration, (2) channel or pipeflow travel time, (3) runoff coefficients, (4) rainfall intensity values, and (5) confluence values at the junction of two or more collection streams. Therefore, once computer program subroutines are developed for each of these submodels, a main driver program can be developed that manipulates the individual hydrologic processes to formulate a link-node model of the watershed based on the rational method strategy desired. In Table 7.2, descriptions are listed for the computer programs used to approximate the hydrologic processes, which occur in a rational method study of an urban watershed. Combining these subroutines using a simple main menu that branches to the selected submodel will result in a totally design-interactive computer program. Program 7.5 estimates pipeflow travel time by computing the peak flow normal depth and determining the time of travel based upon the normal depth flow velocity. Flows which result in a normal depth greater than 0.82 of the pipe diameter are assumed to cause the pipe to flow full. If the pipe size is not specified, this program estimates a pipe size in 3- and 6-inch increments by utilizing a pipe flow with a normal depth less than or equal to 0.82 of the pipe diameter. Pipe slope is based on the gradient computed from the ground surface elevations entered concurrently with the subarea's upstream and downstream node numbers. However, a factor is included (set by the user) such that the natural gradient of the land is reduced (usually by about 10 percent) in order to account for minor losses within the pipe system. The pipe sizes are estimated by assuming this adjusted gradient of the topography between two nodal points to equal the slope of the pipe for normal depth flows. Program 7.6 estimates trapezoidal channel flow travel time based upon the normal depth flow velocity.

Table 7.2
RATIONAL METHOD PROGRAM SUBROUTINES

Program Number	Description
7.1	Main driver program
7.2	Utilizes the Kirpich formula for estimating the initial subarea time of concentration Tc (Figure7.1)
7.3 (no input)	Calculates rainfall intensities by log-log interpolation (Figure 7.8)
7.4 (no input)	Estimates a runoff coefficient from Figs. 7.4a, b, c, d
7.5	Estimates pipeflow travel time for a user-specified or computer estimated pipe size
7.6	Estimates travel time in a trapezoidal channel
7.7	Estimates travel time in a street section of arbitrary size
7.8	Estimates travel time in a pavement V-gutter
7.9	Estimates confluence values
7.10	Allows entry of specified data at a node
7.11	Permits addition of subarea runoff to the mainline collection stream

Program 7.7 examines street flow travel time for two conditions: (1) all flow on one side of the street section, including the spit flow effects when the flow depth exceeds the street crown, and (2) equal flow on both sides of the street centerline. All flows outside of the street curbs are assumed negligible (that is, the water is in a ponded condition). Program 7.9 models a confluence with up to five independent collection streams. It is based upon the linear confluence formula presented in the text.

The study approach is to subdivide the watershed into subareas such as shown in Figure 7.7. Nodal points are defined along the main flowpath at the upstream and downstream points of each subarea. Computer results are correlated to the watershed schematic by means of these nodal points. The programs are intended to be combined into a menu-driven program system in which the user interacts with the main menu. Starting at the most upstream nodal point of a collection stream, the program user selects which submodel is to be first employed. Usually, the first model used is the initial subarea program and the user enters the appropriate hydrologic data such as the subarea development type, soil group, area size, upstream and downstream node elevations, and length of the main flowpath. The subroutine computes the initial subarea Tc, the corresponding runoff coefficient and rainfall intensity, and the initial subarea runoff. The program should display this information on the CRT for the user to review and accept or reject. If the information is acceptable, the entered hydrologic data is permanently stored in a data file; if the computer results are unacceptable, the user rejects the submodel results and the computer program returns to the previous nodal point and the main menu for process selection.

If the user had accepted the most recently computed information, the main program returns to the menu display for the user to select the next hyrologic submodel. The main program should store the recently computed Q, Tc, and the total area. In this manner, should the user now elect to employ the channel travel time program, the normal depth computed will be based on the stored peak Q value, and the travel time will be directly added to the stored Tc value, providing the time of concentration at the downstream point of the channel. Thus, the computer program follows the rational method modeling approach interactively rather than the user creating a data file to be operated upon by the program in a batch mode. Using such a menu-driven approach allows the watershed to be studied on the first pass, and in addition, the entered hydrologic data are stored for subsequent editing and master plan updating.

In the following pages, computer listings are provided for several of the discussed submodels. The language used is FORTRAN, and the codes can be keyed into most of the currently available personal computers. The data entry requirements are presented in the form of screen text pages that contain suggested user-friendly data entry prompts, as well as other user-friendly program commands and features. Details of these screen text pages are discussed in the following section.

7.14 Computer-Aided Design Interaction

The computer programs were developed to aid the engineer in a computer-aided interactive mode rather than the batch mode that is associated to water resources software. In this fashion, the software is formulated on a system level where the individual submodels are employed as selected by the engineer from the main menu, and the computer results reviewed by the engineer prior to proceeding to the next hydrologic process. This type of programming approach can be directly applied to other link-node models where the links direct the logic process in one direction only. For example, the rational method planning/design program system proceeds in the "downstream" direction with the entire watershed tributary to a node completely described by three characteristic variables: peak runoff rate, time of concentration, and total area. Thus the hydrologic process used to link to the next downstream node acts only upon the most recently computed values of the three characteristic variables. Because the main purpose of studying the watershed is to determine an appropriate flood control system to safely contain the design peak flow rates, each link of the link-node model can be properly sized and evaluated as to "success or failure" prior to proceeding to the next link or hydrologic process.

In comparison, the various submodels can be combined into a batch mode of operation where the engineer builds a data file containing all the necessary data for each hydrologic process or link used to develop a link-node model of the watershed. The program system then operates upon the data file to generate the model solutions. The user then reviews the computed results for unacceptable design conditions (e.g., such as streetflow above the top of curb, or excessively high flow velocities in a user-specified pipe size linking two nodal points, etc.) and identifies the necessary alterations in the link-node model data file to remedy the unacceptable condition. The program is re-executed and another review of the computed results is performed. This procedure is repeated until the entire link-node model provides an acceptable flood control system design.

The batch mode of operation requires considerably more computational effort, time expenditure, and frustration to the engineer than the interactive mode. Therefore, the engineer should develop the main driver branching program using the basic user-friendly environment as discussed in Hromadka et al. (1983). The main program data entry sequences for each submodel should be developed such that the communication/presentation (C/P) provides an easy-to-use and self-teaching environment. Some of the major requirements for such a user-friendly environment are as follows:

(1) The C/P should present all data entry prompts and computed results in such a way that any engineer could readily evaluate the information. Avoid use of abbreviations and other ‘short-cuts’.
(2) All engineering units should be displayed.
(3) Any program system flow logic should be clearly described in the program in order to reduce the first-time user learning curve.
(4) All program system commands should be consistently displayed between submodels (and between separate computer programs) so that the user can operate special data entry or editing features without confusion.
(5) All data file management operations (such as opening, closing, and saving data files) should be programmed interior to the system program in order to provide ease of use.

The submodel data entry prompts for the provided program listings are presented in a typical C/P for use on currently available personal computers. The viewing displays are constructed as pages that contain sets of data entry prompts grouped together according to the submodel process selected. Each of the pages contain the following set of operational commands located at the bottom of the CRT screen:

(1) TOP. Clears the screen, redisplays the page information, and returns the program to the first data entry prompt of the page.
(2) BACK. Returns the program to the previous page (if one exists), and positions the program to the first data entry prompt.
(3) MAIN. This command performs several important tasks. First, the program system data file is properly saved and closed so that all data entries are protected, and the data file is available for later use. Second, the command terminates the submodel process. Third, the command returns the program system to the main driver program menu.
(4) EXIT. This command is identical to the MAIN command, except the program system is terminated.

It should be noted that these four commands can be entered at any time and at any data entry prompt within the program system. Thus, if the user should wish to exit the program while entering the data needed to solve for pipeflow travel time between two nodal points (Program 7.5), then the user simply enters the word EXIT at any data entry prompt. It should also be noted that the C/P pages contain a description of each data entry as well as the allowable value range for data entry. Each data entry is checked for range limits prior to proceeding to the next data entry prompt. If the entered data is outside of the allowable value range, an error message is displayed to the user and the program returns to the invalid data entry point for another data entry attempt. In this way, the data file development is error free with the first pass of the data entry sequence.

7.15 Example 7.2 Rational Method Program Application

The following example problem illustrates the use of the Subarea Summation Model for rational method hydrologic studies of urban watersheds. The example problem presentation contains the following information:

Figure Number	Description
7.7	Example problem drainage system
7.8	Intensity-duration point rainfall plot
7.9	Example problem computer program results
7.10	Example tabulation form output
7.11	Spreadsheet output from AES SIMS
7.12	AES cost module output
7.13	AES cost-to-benefit module output
7.14	AES Pollutant Loading Module (PLM) output
7.15	Balanced HGL and friction slope
7.16	Balanced HGL vs. WSPG estimated HGL (Analysis Iteration #1)

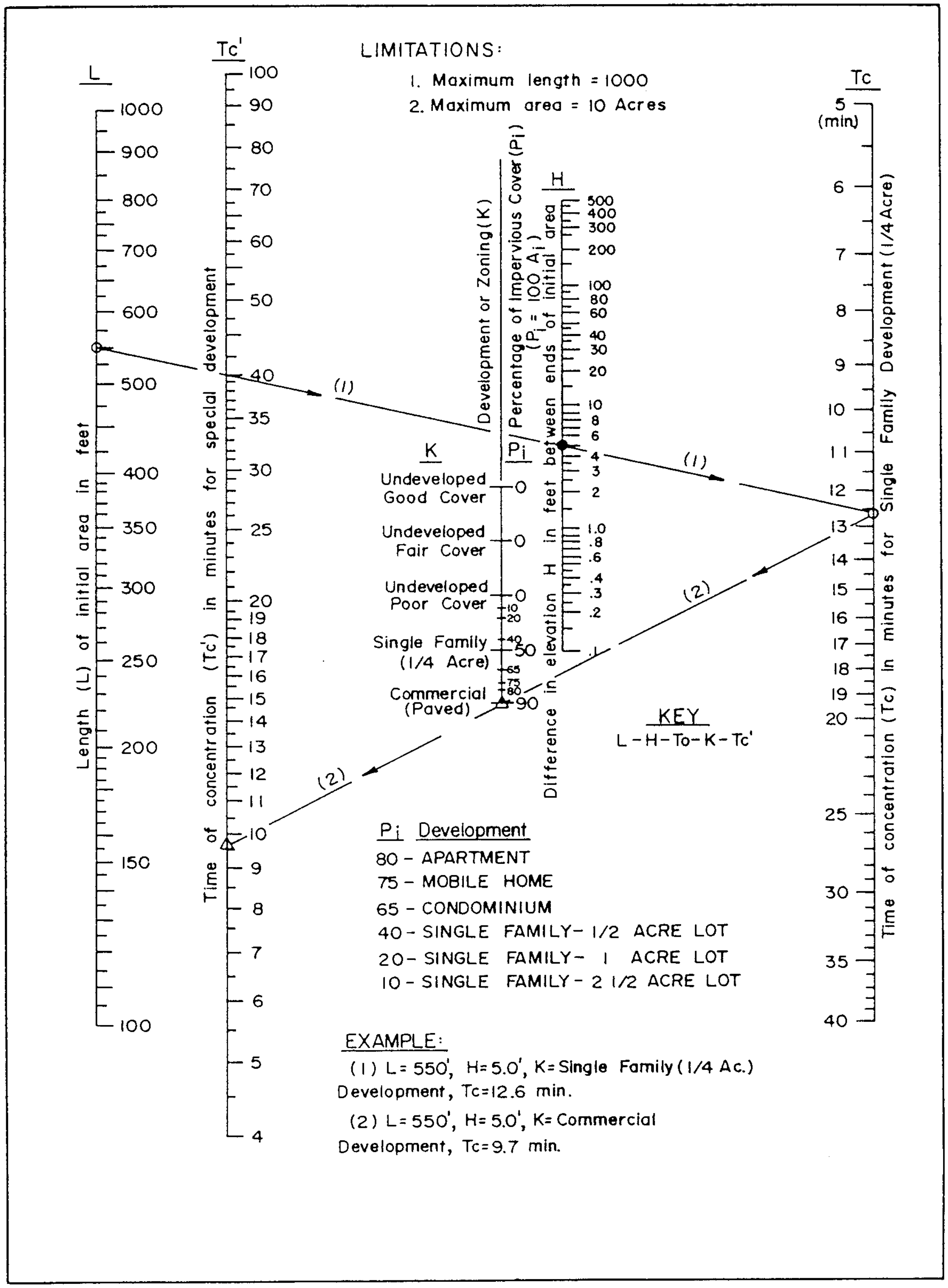

Figure 7.1 An Overland Flow Tc Estimation Nomograph

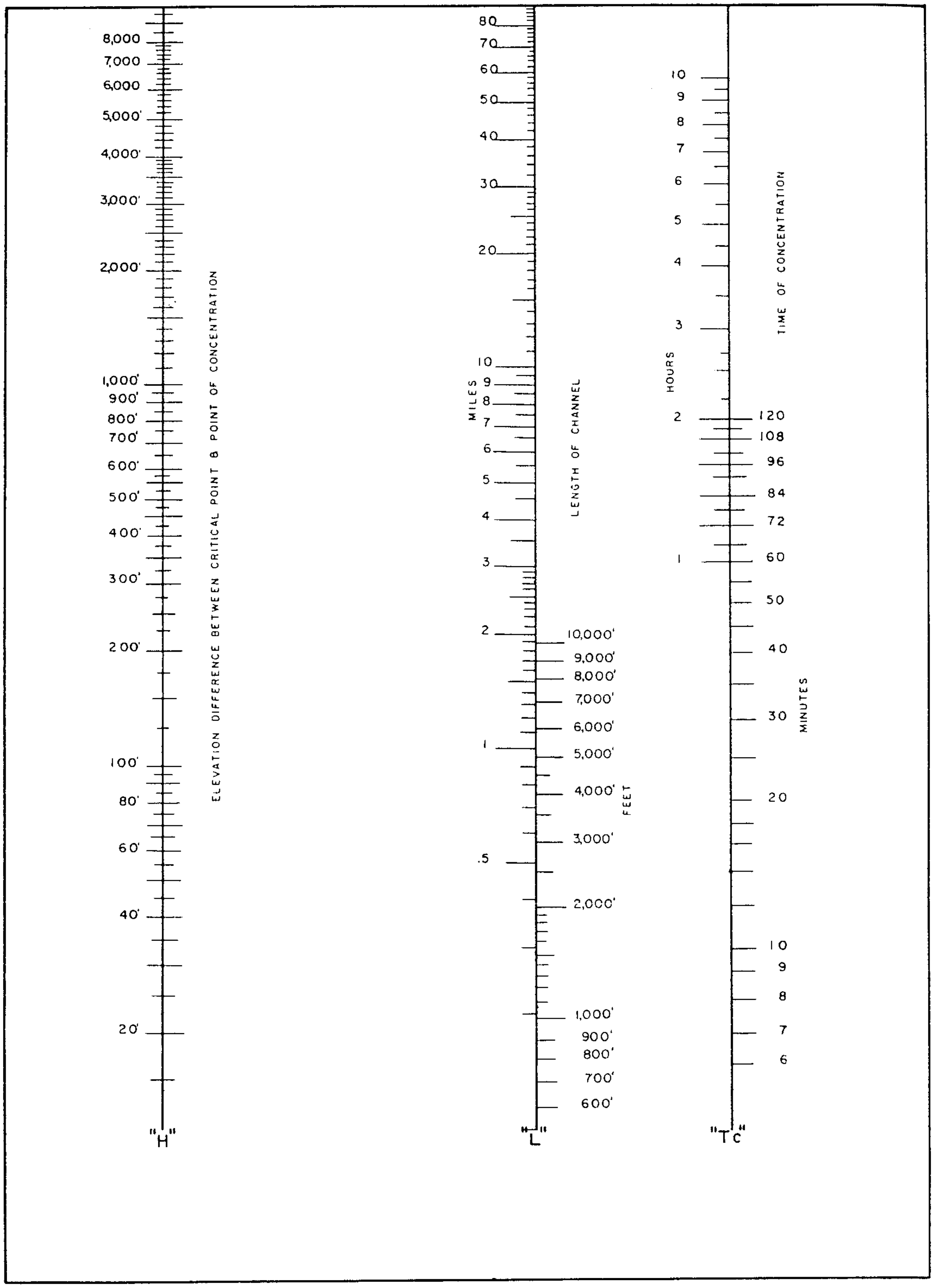

Figure 7.2 A Tc Estimation Nomograph

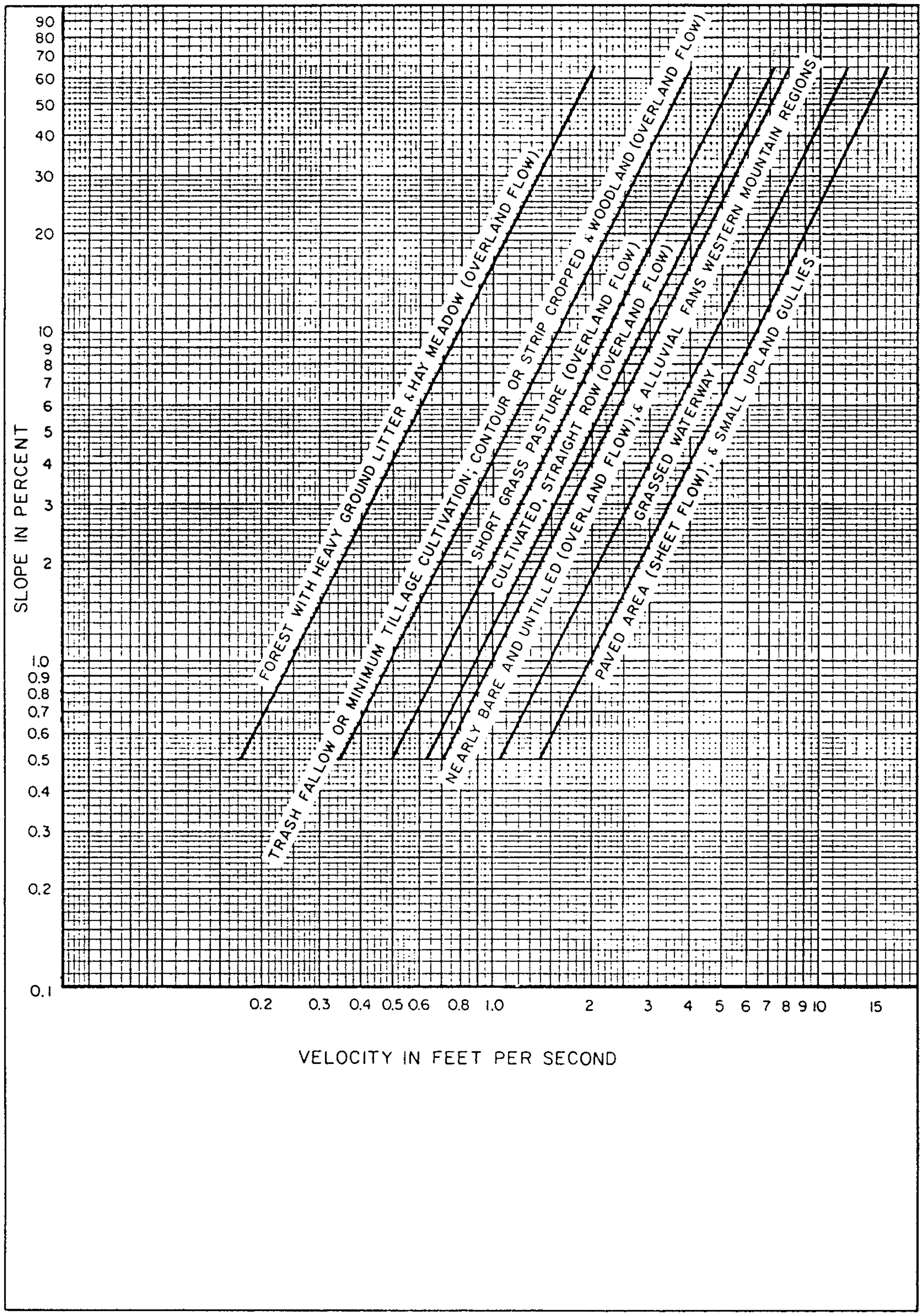

Figure 7.3 An Overland Flow Velocity Estimation Nomograph

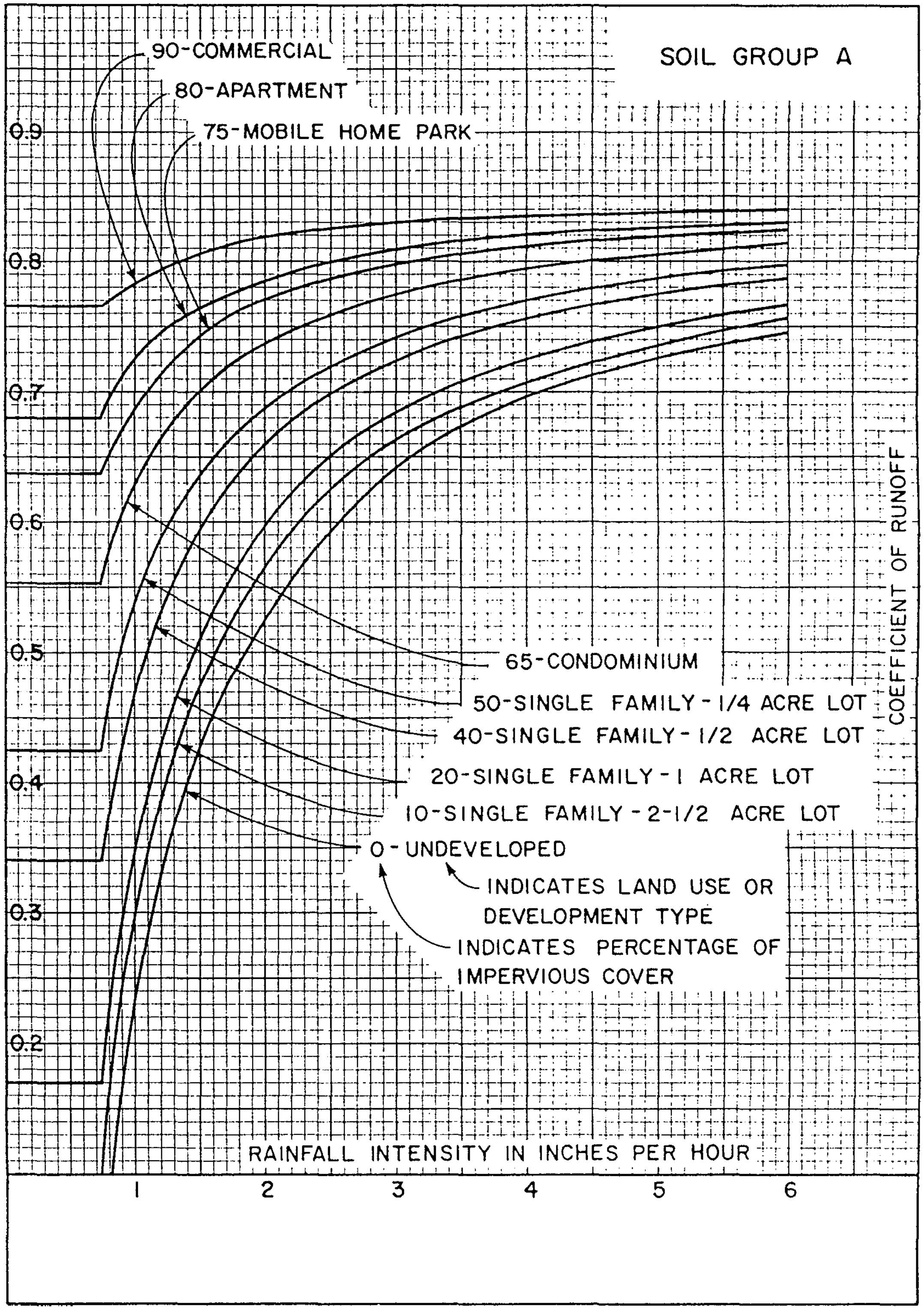

Figure 7.4a Example Rational Method Runoff Coefficients Using A Modified "C" technique

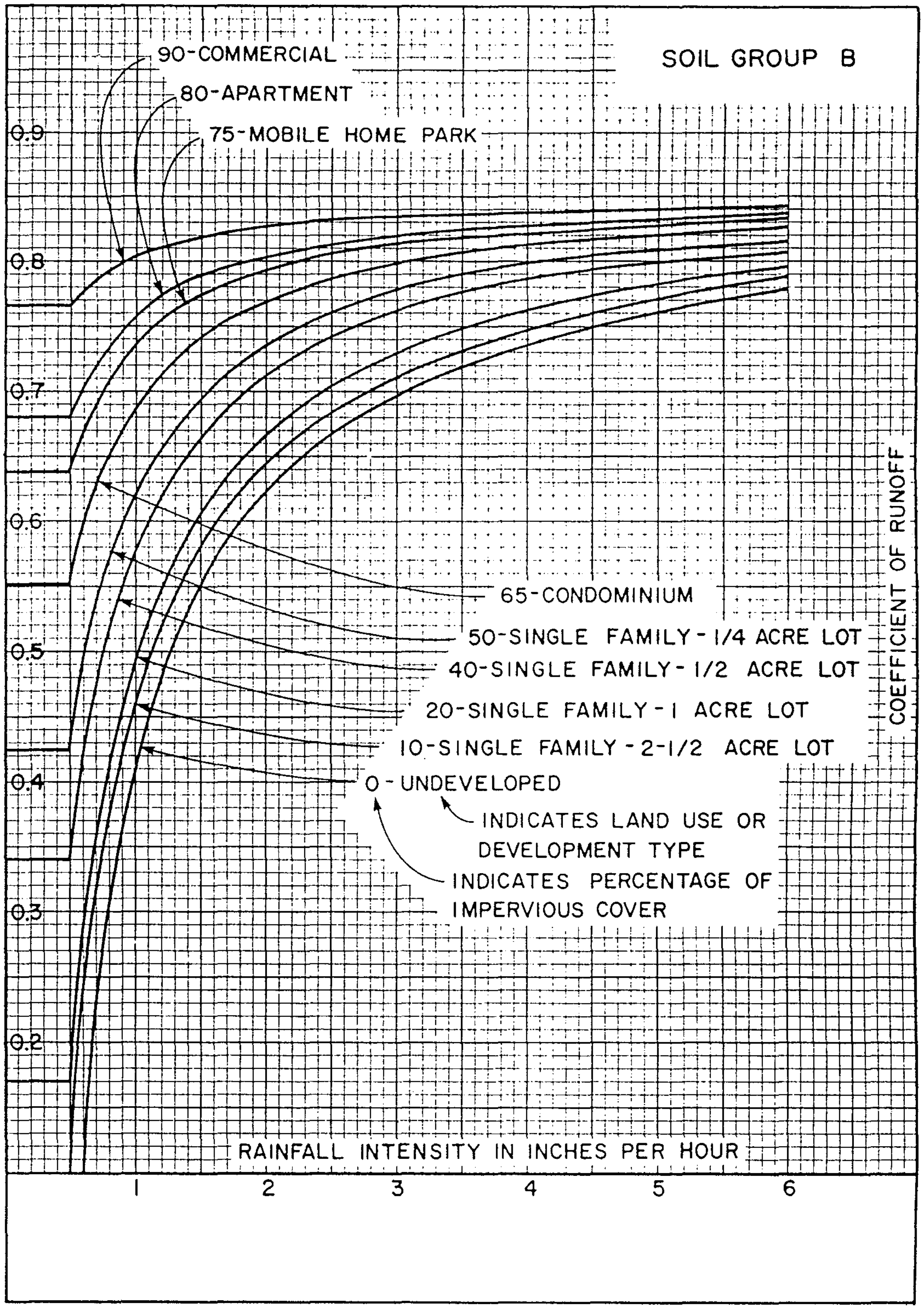
SOIL GROUP B
90-COMMERCIAL
80-APARTMENT
75-MOBILE HOME PARK
65-CONDOMINIUM
50-SINGLE FAMILY - 1/4 ACRE LOT
40-SINGLE FAMILY - 1/2 ACRE LOT
20-SINGLE FAMILY - 1 ACRE LOT
10-SINGLE FAMILY - 2-1/2 ACRE LOT
0 - UNDEVELOPED
INDICATES LAND USE OR DEVELOPMENT TYPE
INDICATES PERCENTAGE OF IMPERVIOUS COVER
COEFFICIENT OF RUNOFF
RAINFALL INTENSITY IN INCHES PER HOUR
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
1
2
3
4
5
6

Figure 7.4b

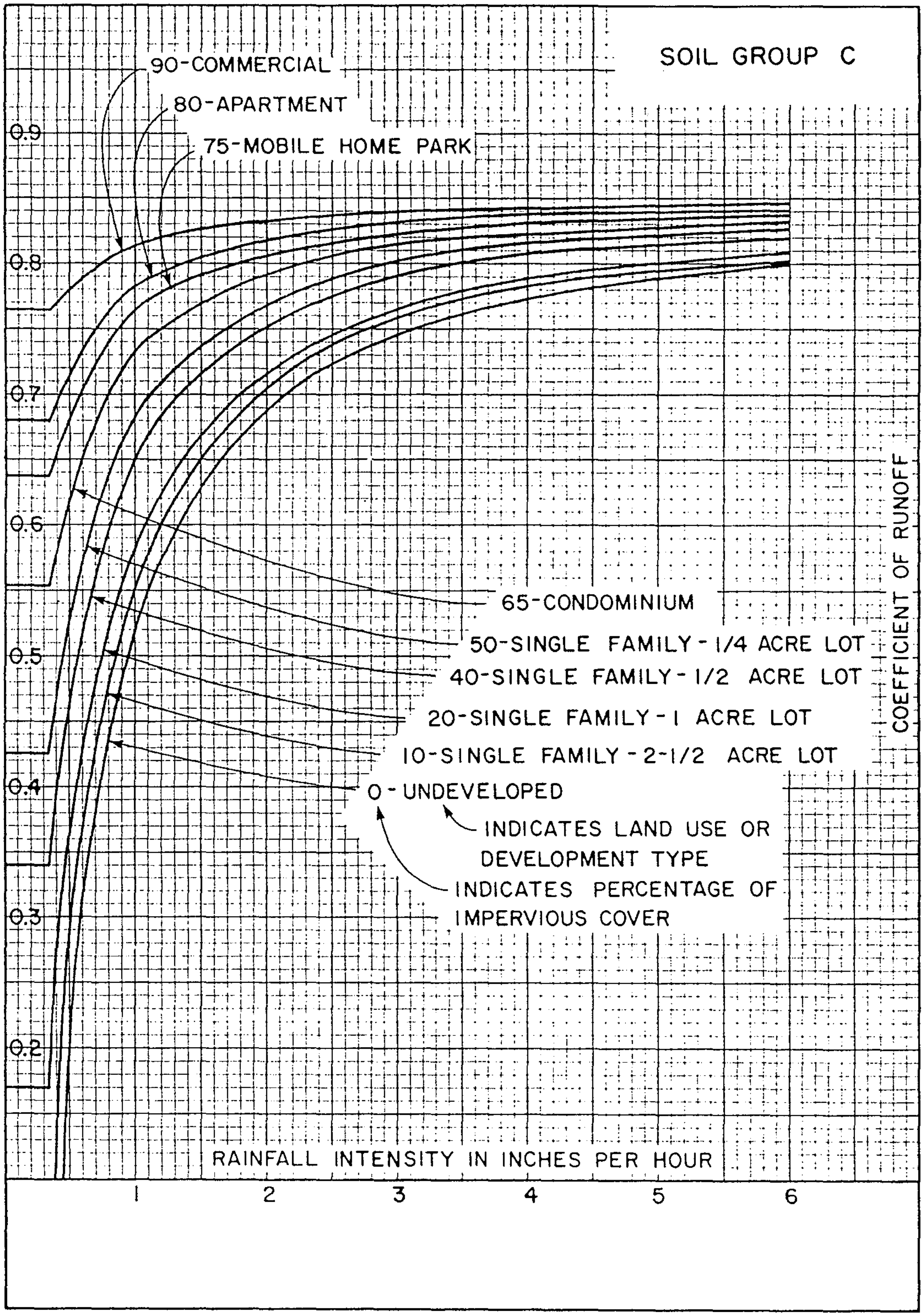
SOIL GROUP C
90-COMMERCIAL
80-APARTMENT
75-MOBILE HOME PARK
65-CONDOMINIUM
50-SINGLE FAMILY - 1/4 ACRE LOT
40-SINGLE FAMILY - 1/2 ACRE LOT
20-SINGLE FAMILY - 1 ACRE LOT
10-SINGLE FAMILY - 2-1/2 ACRE LOT
0 - UNDEVELOPED
INDICATES LAND USE OR DEVELOPMENT TYPE
INDICATES PERCENTAGE OF IMPERVIOUS COVER
COEFFICIENT OF RUNOFF
RAINFALL INTENSITY IN INCHES PER HOUR
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
1
2
3
4
5
6

Figure 7.4c

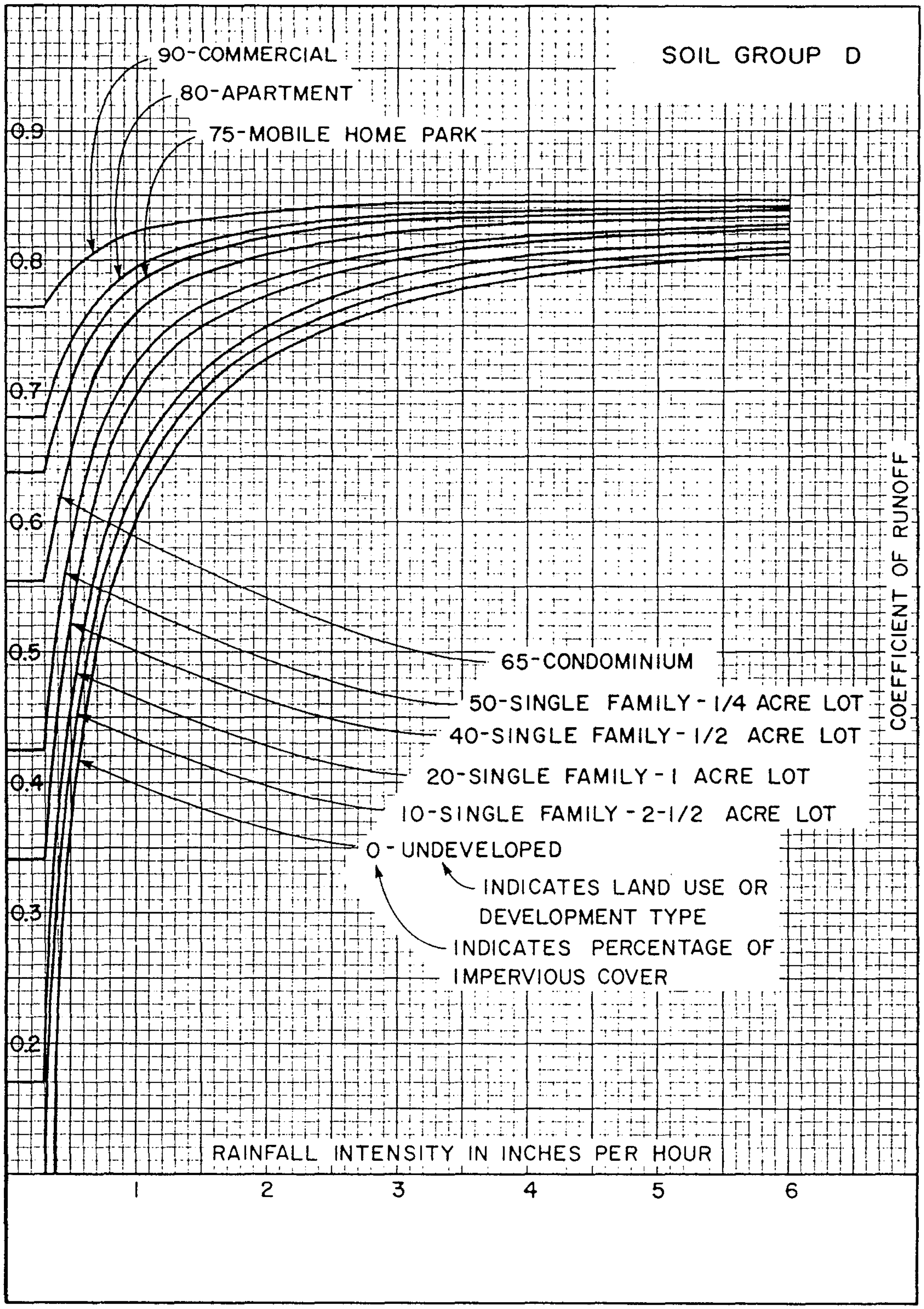
SOIL GROUP D
90-COMMERCIAL
80-APARTMENT
75-MOBILE HOME PARK
65-CONDOMINIUM
50-SINGLE FAMILY-1/4 ACRE LOT
40-SINGLE FAMILY-1/2 ACRE LOT
20-SINGLE FAMILY-1 ACRE LOT
10-SINGLE FAMILY-2-1/2 ACRE LOT
0-UNDEVELOPED
INDICATES LAND USE OR DEVELOPMENT TYPE
INDICATES PERCENTAGE OF IMPERVIOUS COVER
COEFFICIENT OF RUNOFF
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
RAINFALL INTENSITY IN INCHES PER HOUR
1
2
3
4
5
6

Figure 7.4d

STUDY NAME:

____ YEAR STORM 1-HOUR RAINFALL (inch)= ____ ; INTENSITY SLOPE = ____

CALCULATED BY:
CHECKED BY:
PAGE NUMBER   OF

CONCENTRATION POINT NUMBER	SOIL TYPE	DEV. TYPE	AREA (ACRES)	I in/h	C	Q (SUB)	Q TOTAL	SLOPE ft/ft	SECTION	V fps.	PATH ft.	T min.	TC min.	HYDRAULICS AND NOTES

Figure 7.5 Example Rational Method Computation Form

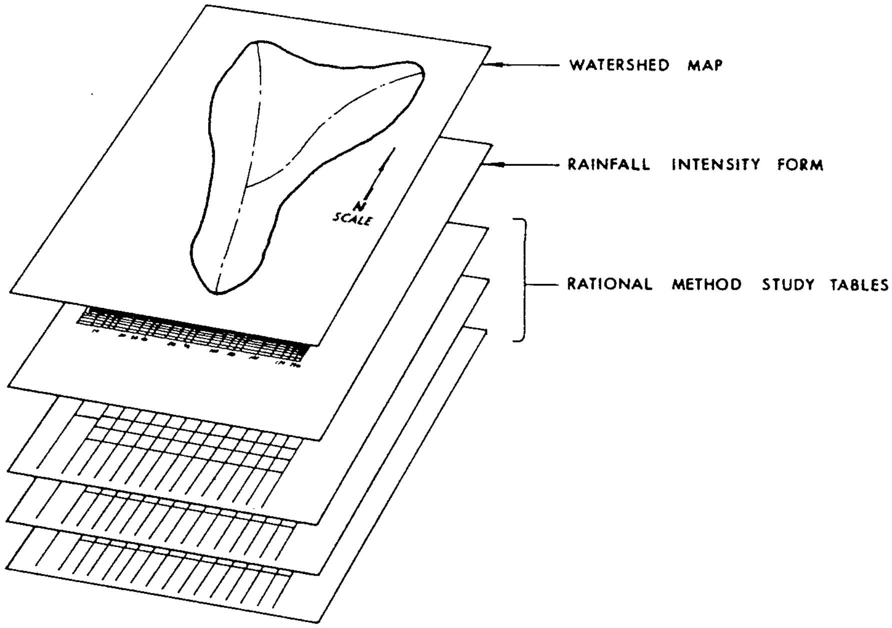

Figure 7.6 Rational Method Study Submittal Form

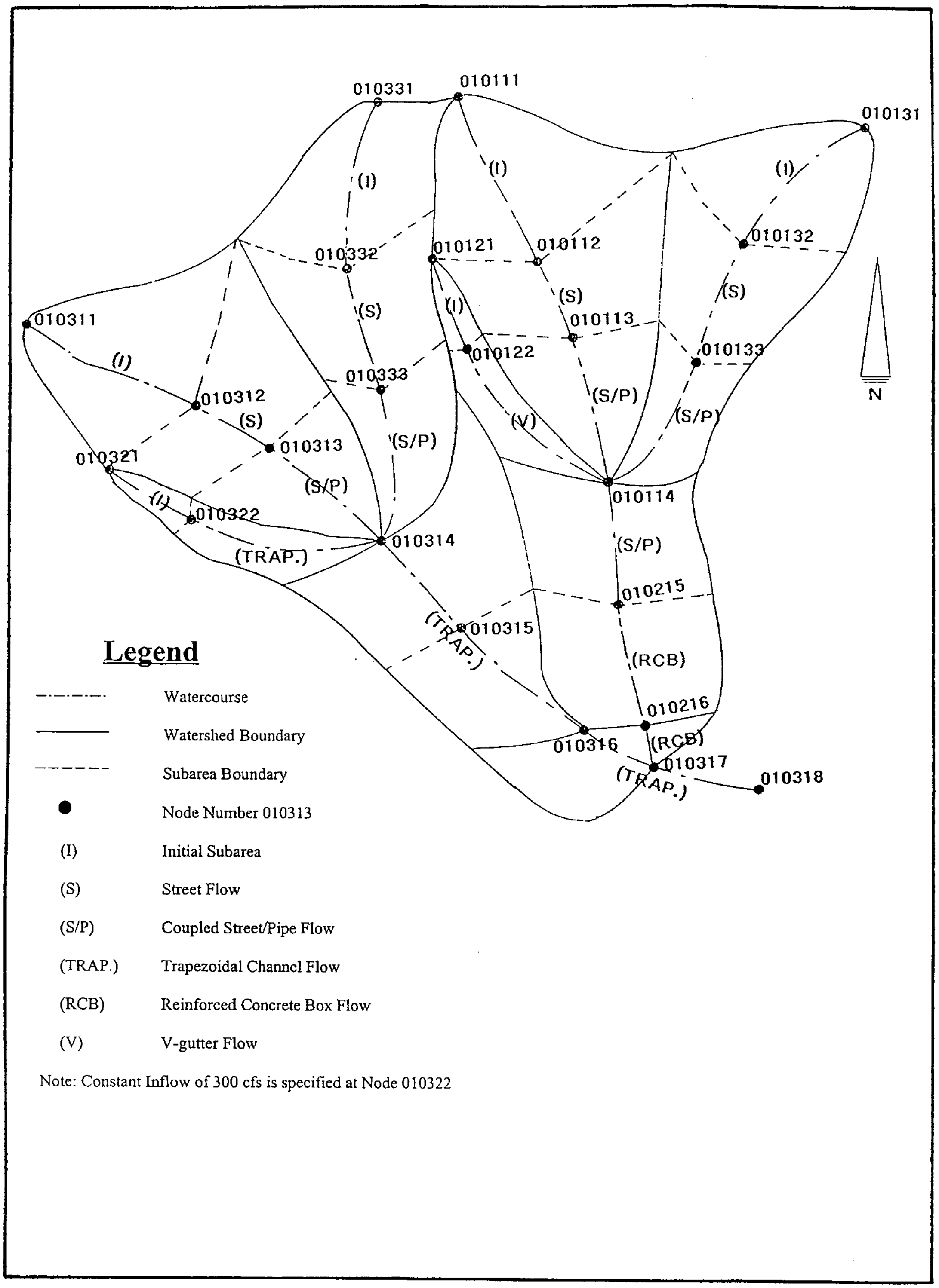

Figure 7.7 Example Problem Schematic

Regression Equations: $D(t) = at^b$
(D= Depth in inches, t= duration in minutes)

Return Frequency (years)	a	b
2	0.095	0.426
5	0.131	0.438
10	0.170	0.427
25	0.200	0.434
50	0.225	0.434
100	0.259	0.427

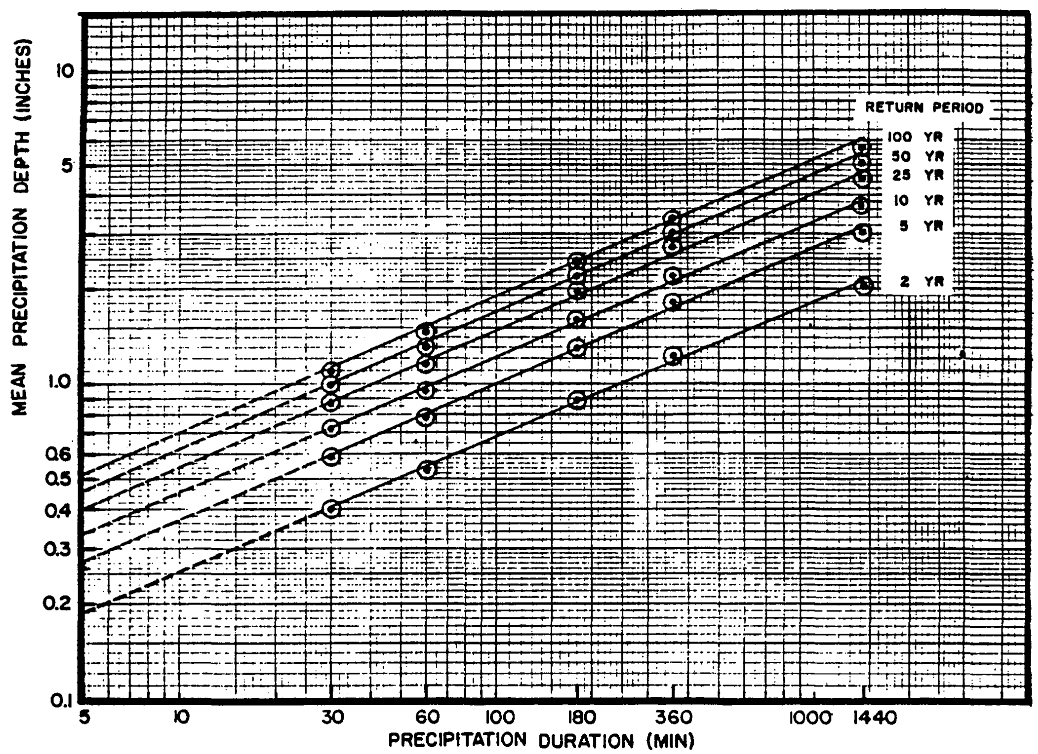

Figure 7.8 Example Problem Rainfall Intensity-Duration Plot

```
****************************************************************************
             RATIONAL METHOD HYDROLOGY COMPUTER PROGRAM PACKAGE
                (Reference: 1986 OCEMA HYDROLOGY CRITERION)
         (c) Copyright 1983-99 Advanced Engineering Software (aes)
             Ver. 8.0  Release Date: 01/01/99  License ID 1201
----------------------------------------------------------------------------
  FILE NAME: EX0101ZZ.Z11
  TIME/DATE OF STUDY: 13:31   1/18/1999
============================================================================
  USER SPECIFIED HYDROLOGY AND HYDRAULIC MODEL INFORMATION:
============================================================================
                    --*TIME-OF-CONCENTRATION MODEL*--

  USER SPECIFIED STORM EVENT(YEAR) =   10.00
  SPECIFIED MINIMUM PIPE SIZE(INCH) =  24.00
  SPECIFIED PERCENT OF GRADIENTS(DECIMAL) TO USE FOR FRICTION SLOPE = 0.90
  *DATA BANK RAINFALL USED*
  *ANTECEDENT MOISTURE CONDITION (AMC) II ASSUMED FOR RATIONAL METHOD*
  *USER-DEFINED STREET-SECTIONS FOR COUPLED PIPEFLOW AND STREETFLOW MODEL*
     HALF-  CROWN TO   STREET-CROSSFALL:   CURB  GUTTER-GEOMETRIES:  MANNING
     WIDTH  CROSSFALL  IN-  / OUT-/PARK-  HEIGHT  WIDTH  LIP   HIKE  FACTOR
NO.   (FT)     (FT)    SIDE / SIDE/ WAY    (FT)    (FT)  (FT)  (FT)    (n)
===  =====  =========  =================  ======  ===== ====== ===== =======
  1   20.0     15.0    0.020/0.020/0.020   0.67    2.00 0.0313 0.167 0.0150

  GLOBAL STREET FLOW-DEPTH CONSTRAINTS:
    1. Relative Flow-Depth = -0.50 FEET
       as (Maximum Allowable Street Flow Depth) - (Top-of-Curb)
    2. (Depth)*(Velocity) Constraint =  6.0 (FT*FT/S)
  *SIZE PIPE WITH A FLOW CAPACITY GREATER THAN
   OR EQUAL TO THE UPSTREAM TRIBUTARY PIPE.*

  UNIT-HYDROGRAPH MODEL SELECTIONS/PARAMETERS:
    WATERSHED LAG = 0.80 * Tc
    VALLEY(DEVELOPED) S-GRAPH USED.
    SIERRA MADRE DEPTH-AREA FACTORS USED.
                      AREA-AVERAGED
         DURATION    RAINFALL(INCH)
         5-MINUTES         0.34
        30-MINUTES         0.72
         1-HOUR            0.95
         3-HOUR            1.59
         6-HOUR            2.20
        24-HOUR            3.68
 *ANTECEDENT MOISTURE CONDITION (AMC) II ASSUMED FOR UNIT HYDROGRAPH METHOD*
****************************************************************************
  FLOW PROCESS FROM NODE EX010111.0 TO NODE EX010112.0 IS CODE =  21
----------------------------------------------------------------------------
  >>>>>RATIONAL METHOD INITIAL SUBAREA ANALYSIS<<<<<
  >>USE TIME-OF-CONCENTRATION NOMOGRAPH FOR INITIAL SUBAREA<<
============================================================================
  INITIAL SUBAREA FLOW-LENGTH(FEET) =   800.00
  ELEVATION DATA: UPSTREAM(FEET) =    100.00  DOWNSTREAM(FEET) =     98.00

  Tc = K*[(LENGTH** 3.00)/(ELEVATION CHANGE)]**0.20
  SUBAREA ANALYSIS USED MINIMUM Tc(MIN.) =   21.044
  *  10 YEAR RAINFALL INTENSITY(INCH/HR) =  1.782
  SUBAREA Tc AND LOSS RATE DATA(AMC  II):
   DEVELOPMENT TYPE/      SCS SOIL   AREA       Fp         Ap     SCS   Tc
       LAND USE             GROUP   (ACRES)  (INCH/HR)  (DECIMAL)  CN  (MIN.)
  RESIDENTIAL
  "2 DWELLINGS/ACRE"          B       10.00      0.30      0.70    56   21.04
  SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) =  0.30
  SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap =  0.70
  SUBAREA RUNOFF(CFS) =     14.15
  TOTAL AREA(ACRES) =     10.00   PEAK FLOW RATE(CFS) =     14.15
```

Figure 7.9 AES Hydrology Module Output for Example Problem (First 2 Pages only)

```
****************************************************************************
  FLOW PROCESS FROM NODE EX010112.0 TO NODE EX010113.0 IS CODE =  63
----------------------------------------------------------------------------
  >>>>>COMPUTE STREET FLOW TRAVEL TIME THRU SUBAREA<<<<<
  >>>>>(STREET TABLE SECTION #  1 USED)<<<<<
============================================================================
  UPSTREAM ELEVATION(FEET) =   98.00  DOWNSTREAM ELEVATION(FEET) =   96.00
  STREET LENGTH(FEET) =   350.00   CURB HEIGHT(INCHES) =  8.0
  STREET HALFWIDTH(FEET) = 20.00

  DISTANCE FROM CROWN TO CROSSFALL GRADEBREAK(FEET) =  15.00
  INSIDE STREET CROSSFALL(DECIMAL) =  0.020
  OUTSIDE STREET CROSSFALL(DECIMAL)  =  0.020

  SPECIFIED NUMBER OF HALFSTREETS CARRYING RUNOFF =  2
  STREET PARKWAY CROSSFALL(DECIMAL)  =  0.020
  MAXIMUM ALLOWABLE STREET FLOW DEPTH(FEET) =   0.30

    **TRAVEL TIME COMPUTED USING ESTIMATED FLOW(CFS) =      20.61
    STREETFLOW MODEL RESULTS USING ESTIMATED FLOW:
    STREET FLOW DEPTH(FEET) =  0.55
    HALFSTREET FLOOD WIDTH(FEET) =   19.62
    AVERAGE FLOW VELOCITY(FEET/SEC.) =    2.55
    PRODUCT OF DEPTH&VELOCITY(FT*FT/SEC.) =    1.41
  STREET FLOW TRAVEL TIME(MIN.) =   2.29   Tc(MIN.) =  23.33
  *  10 YEAR RAINFALL INTENSITY(INCH/HR) =  1.677
  SUBAREA LOSS RATE DATA(AMC  II):
   DEVELOPMENT TYPE/      SCS SOIL   AREA      Fp         Ap     SCS
       LAND USE            GROUP   (ACRES)  (INCH/HR)  (DECIMAL)  CN
  RESIDENTIAL
  "3-4 DWELLINGS/ACRE"       B        9.60      0.30      0.60    56
  SUBAREA AVERAGE PERVIOUS LOSS RATE, Fp(INCH/HR) =  0.30
  SUBAREA AVERAGE PERVIOUS AREA FRACTION, Ap =  0.60
  SUBAREA AREA(ACRES) =    9.60      SUBAREA RUNOFF(CFS) =   12.93
  EFFECTIVE AREA(ACRES) =   19.60    AREA-AVERAGED Fm(INCH/HR) =  0.20
  AREA-AVERAGED Fp(INCH/HR) =  0.30  AREA-AVERAGED Ap =  0.65
  TOTAL AREA(ACRES) =   19.60        PEAK FLOW RATE(CFS) =      26.13

  END OF SUBAREA STREET FLOW HYDRAULICS:
  DEPTH(FEET) = 0.58   HALFSTREET FLOOD WIDTH(FEET) =  20.00
  FLOW VELOCITY(FEET/SEC.) =  2.79   DEPTH*VELOCITY(FT*FT/SEC.) =   1.63


  *NOTE: ESTIMATED STREET FLOW DEPTH IS GREATER THAN
         THE MAXIMUM ALLOWABLE STREET FLOW DEPTH(FEET) = 0.30
  SIZE PIPE(S) TO SATISFY THE STREET CONSTRAINT AS FOLLOWS:
  ** PIPE SIZED TO MAXIMIZE STREETFLOW AT DOWNSTREAM NODE **
  ESTIMATED PIPE DIAMETER(INCH) =  24.00    NUMBER OF PIPES =   1
  DEPTH OF FLOW IN  24.0 INCH PIPE IS  17.3 INCHES
  PIPE-FLOW VELOCITY(FEET/SEC.) =   5.82
  PIPE-FLOW(CFS) =     14.15
  PIPEFLOW TRAVEL TIME(MIN.) =   1.00    Tc(MIN.) =  22.05
  *  10 YEAR RAINFALL INTENSITY(INCH/HR) =  1.732
  SUBAREA AREA(ACRES) =    9.60      SUBAREA RUNOFF(CFS) =   13.41
  TOTAL AREA(ACRES) =   19.60        PEAK FLOW RATE(CFS) =     27.10
  *NOTE: STREET-CAPACITY MAY BE EXCEEDED*
  STREETFLOW HYDRAULICS BASED ON MAINLINE Tc :
  STREET HYDRAULICS COMPUTED USING ESTIMATED FLOW(CFS) =   12.96
    STREETFLOW MODEL RESULTS USING ESTIMATED FLOW:
    STREET FLOW DEPTH(FEET) =  0.48
    HALFSTREET FLOOD WIDTH(FEET) =   16.28
    AVERAGE FLOW VELOCITY(FEET/SEC.) =    2.28
    PRODUCT OF DEPTH&VELOCITY(FT*FT/SEC.) =    1.10
  *NOTE: INITIAL SUBAREA NOMOGRAPH WITH SUBAREA PARAMETERS,
         AND L =   350.0 FT WITH ELEVATION-DROP =   2.0 FT, IS   19.7 CFS,
         WHICH EXCEEDS THE SPECIFIED STREET CAPACITY AT NODE  10113.00
  LONGEST FLOWPATH FROM NODE  10111.00 TO NODE  10113.00 =  1150.00 FEET.
```

Figure 7.9 Continued

```
+-+-------------------------------------------------------------------------------------------------------+-+
| |                                                                                                       | |
| |                                                                                                       | |
| |                                                                                                       | |
| |                                                                                                       | |
| |-------------------------------------------[ORANGE COUNTY]---------------------------------------------| |
| |  FILE NAME:EX0101ZZ.Z11                    *ENGLISH UNITS*            | CALCULATED BY:                | |
| |  TIME/DATE OF STUDY:  9:55   1/18/1999                                |    CHECKED BY:                | |
| |  10.0-YEAR STORM RATIONAL METHOD STUDY (AMC  II LOSSES)               | PAGE NUMBER   1 OF            | |
| |----------------------------[(c) 1983-1999 ADVANCED ENGINEERING SOFTWARE]------------------------------| |
| |CONCENTRATION| AREA (ACRES) |SOIL|DEV.| Tt |  Tc | I  | Fm |  Fm |Q-SUM |PATH|SLOPE| V  |   HYDRAULICS   | |
| | POINT NUMBER|SUBAREA|  SUM |TYPE|TYPE|MIN.| MIN.| (in/hr) |(Avg)|(cfs) |(ft)|ft/ft|FPS.|    AND NOTES   | |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |             |       |      |   |     | .. |     |    |    |     |      | 800|.0025| .. |INITIAL SUBAREA| |
| |EX010112.0   |   10.0|  10.0| B |2D/AC|----| 21.0|1.78|0.21|0.210|  14.1|----|-----|----|----------------| |
| |-------------|-------|------|---|-----|    |-----|----|----|-----|------| 350|.0057| 5.8|Qpipe=    14.15| |
| |             |       |      |         |    |     |    |    |     |      |    |     |    |n=.0130 D= 2.00| |
| |EX010113.0   |       |      |         | 1.0|     |    |    |     |      |    |     |    |    24.0"-PIPE | |
| |COUPLED PIPE/|       |      |              |     |    |    |     |      |    |     | 2.3|Qstreet=  13.0 | |
| | 40.ft-STREET|       |      |              |     |    |    |     |      |    |     |    |D=0.48;D*V= 1.1| |
| | FLOW TO PT.#|       |      |              |     |    |    |     |      |    |     |    |FLOODWIDTH=16.3| |
| |EX010113.0   |    9.6| 19.60| B |4D/AC|----| 22.0|1.73|0.18|0.195|  27.1(SUBAREA FLOW EXCEEDS STR. CAP.)| |
| |-------------|-------|------|---|-----|    |-----|----|----|-----|------| 650|.0031| 5.3|Qpipe=    27.10| |
| |             |       |      |              |     |    |    |*EXISTING:  24.0"-PIPE*|    |n=.0130 D= 2.19| |
| |EX010114.0   |       |      |         | 2.0|     |    |    |*REPLACEMENT:  33.0"-PIPE*  |    33.0"-PIPE | |
| |COUPLED PIPE/|       |      |              |     |    |    |*PARALLEL:  27.0"-PIPE*| 1.5|Qstreet=   6.4 | |
| | 40.ft-STREET|       |      |              |     |    |    |     |      |    |     |    |D=0.43;D*V= 0.7| |
| | FLOW TO PT.#|       |      |              |     |    |    |     |      |    |     |    |FLOODWIDTH=13.8| |
| |EX010114.0   |    6.0| 25.60| B |4D/AC|----| 24.1|1.65|0.18|0.192|  33.5(SUBAREA FLOW EXCEEDS STR. CAP.)| |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |EX010114.0   |       |  25.6|   |     |----| 24.1|1.65|    |     |  33.5|----|-----|----|FOR CONFLUENCE  | |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |             |       |      |   |     | .. |     |    |    |     |      | 400|.0075| .. |INITIAL SUBAREA| |
| |EX010122.0   |    1.0|   1.0| B |2.5AC|----| 14.2|2.23|0.27|0.270|   1.8|----|-----|----|----------------| |
| |-------------|-------|------|---|-----|    |-----|----|----|-----|------| 850|.0200| 4.0|Qest.=   4.4    | |
| | 2.0ft-GUTTER|       |      |              |     |    |    |     |      |    |     |    | XFALL= 0.02000| |
| | FLOW TO PT.#|       |      |         | 3.5|     |    |    |     |      |    |     |    |n=.0150 D= 0.40| |
| |EX010114.0   |    3.2|  4.20| B |4D/AC|----| 17.7|1.97|0.18|0.201|   6.7|----|-----|----|----------------| |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |EX010114.0   |       |   4.2|   |     |----| 17.7|1.97|    |     |   6.7|----|-----|----|FOR CONFLUENCE  | |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |             |       |      |   |     | .. |     |    |    |     |      | 750|.0027| .. |INITIAL SUBAREA| |
| |EX010132.0   |    9.5|   9.5| B Chaparral-N| 32.6|1.39|0.30|0.300|   9.3|----|-----|----|----------------| |
| |             |       |      |   |     |    |     |    |    |     |      |    |     |    |                | |
| |             |       |      |   |     |    |     |    |    |     |      |    |     |    |                | |
| |             |       |      |   |     |    |     |    |    |     |      |    |     |    |                | |
| |-------------------------------------------------------------------------------------------------------| |
| *                                                                                                       * |
| *                                                                                                       * |
+-+-------------------------------------------------------------------------------------------------------+-+
```

Figure 7.10 AES Hydrology Model Output in FORM Option, for Example Problem

```
+-+------------------------------------------------------------------------------------------------------------+-+
| |                                                                                                            | |
| |                                                                                                            | |
| |                                                                                                            | |
| |                                                                                                            | |
| |--------------------------------------------[ORANGE COUNTY]---------------------------------------------------| |
| |  FILE NAME:EX0101ZZ.Z11                      *ENGLISH UNITS*             | CALCULATED BY:                   | |
| |  TIME/DATE OF STUDY:  9:55   1/18/1999                                   |    CHECKED BY:                   | |
| |  10.0-YEAR STORM RATIONAL METHOD STUDY (AMC  II LOSSES)                  | PAGE NUMBER   2 OF               | |
| |-----------------------------[(c) 1983-1999 ADVANCED ENGINEERING SOFTWARE]------------------------------| |
| |CONCENTRATION| AREA (ACRES) |SOIL|DEV.| Tt |  Tc | I  | Fm |  Fm |Q-SUM |PATH|SLOPE| V  |   HYDRAULICS   | |
| | POINT NUMBER|SUBAREA|  SUM |TYPE|TYPE|MIN.| MIN.| (in/hr) |(Avg)|(cfs) |(ft)|ft/ft|FPS.|    AND NOTES   | |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |-------------|-------|------|---|-----|    |-----|----|----|-----|------| 550|.0036| 4.5|Qpipe=     9.29| |
| |             |       |      |         |    |     |    |    |     |      |    |     |    |n=.0130 D= 2.00| |
| |EX010133.0   |       |      |         | 2.0|     |    |    |     |      |    |     |    |    24.0"-PIPE | |
| |COUPLED PIPE/|       |      |              |     |    |    |     |      |    |     | 1.7|Qstreet=   8.0 | |
| | 40.ft-STREET|       |      |              |     |    |    |     |      |    |     |    |D=0.45;D*V= 0.8| |
| | FLOW TO PT.#|       |      |              |     |    |    |     |      |    |     |    |FLOODWIDTH=14.6| |
| |EX010133.0   |    8.8| 18.30| B |2.5AC|----| 34.7|1.34|0.27|0.286|  17.3(SUBAREA FLOW EXCEEDS STR. CAP.)| |
| |-------------|-------|------|---|-----|    |-----|----|----|-----|------| 700|.0014| 3.6|Qpipe=    17.33| |
| |             |       |      |              |     |    |    |*EXISTING:  24.0"-PIPE*|    |n=.0130 D= 2.07| |
| |EX010114.0   |       |      |         | 3.2|     |    |    |*REPLACEMENT:  33.0"-PIPE*  |    33.0"-PIPE | |
| |COUPLED PIPE/|       |      |              |     |    |    |*PARALLEL:  27.0"-PIPE*| 1.0|Qstreet=   4.1 | |
| | 40.ft-STREET|       |      |              |     |    |    |     |      |    |     |    |D=0.43;D*V= 0.4| |
| | FLOW TO PT.#|       |      |              |     |    |    |     |      |    |     |    |FLOODWIDTH=13.4| |
| |EX010114.0   |    4.8| 23.10| B |  MH |----| 37.9|1.27|0.08|0.242|  21.4(SUBAREA FLOW EXCEEDS STR. CAP.)| |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |  CONFLUENCE |                  PEAK FLOW RATE =    57.6 (cfs)                           |                | |
| |   ANALYSIS  |                  TIME OF CONCENTRATION(MIN.) =  24.1                      |    LARGEST     | |
| |  FOR POINT# |      MEAN VALUES: Fp =  0.300 (in/hr); Ap = 0.697; Fm =  0.209 (in/hr)     |   CONFLUENCE   | |
| |EX010114.0   |      EFFECTIVE AREA =      44.47 (Acres);  TOTAL AREA =      52.90 (Acres)|   Q=      57.6| |
| |             |    Q(cfs)   Tc(min)  Fp(avg)  Ap(avg)  Fm(avg)  I(in/hr)  Ae(Acres)  NODE |                | |
| |             |    53.54     17.72    0.300     0.70    0.209      1.97    33.843  10121.0|                | |
| |             |    57.55     24.07    0.300     0.70    0.209      1.65    44.474  10111.0|                | |
| |             |    50.35     37.90    0.300     0.71    0.214      1.27    52.900  10131.0|                | |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |EX010114.0   |      STORE HYDROLOGIC DATA TO A FILE                                      |                | |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |EX010114.0   |       |  44.5|   |     |----| 24.1|    |    |     |  57.6|----|-----|----|STREAM SUMMARY  | |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| | EFFECTIVE AREA =     44.47 Acres   TOTAL AREA =     52.90 Acres  PEAK FLOW RATE =     57.55 cfs         | |
| | TIME OF CONCENTRATION(MIN.)=   24.07  MEAN VALUES: Fp =  0.300 (in/hr); Ap = 0.697; Fm =  0.209 (in/hr)| |
| |-------------|-------|------|---|-----|----|-----|----|----|-----|------|----|-----|----|----------------| |
| |             |       |      |   |     |    |     |    |    |     |      |    |     |    |                | |
| |             |       |      |   |     |    |     |    |    |     |      |    |     |    |                | |
| |------------------------------------------------------------------------------------------------------------| |
| *                                                                                                            * |
| *                                                                                                            * |
+-+------------------------------------------------------------------------------------------------------------+-+
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Figure 7.10 Continued

LINK LOCATION U/S NODE	LINK LOCATION D/S NODE	LINK TOPOGRAPHIC DATA: U/S ELEVATION(FEET)	D/S ELEVATION(FEET)	LENGTH (FEET)	TOPO SLOPE	LINK EXISTING PRIMARY ELEMENT SYSTEM DESCRIPTION: DIA./ HEIGHT	PIPE #/ WIDTH	SIDE- SLOPE	MANNING'S FACTOR	ELEMENT TYPE
10112.0	10113.0	98.00	96.00	350.00	0.0057	0.00	0.00	0.00	0.0000	
10113.0	10114.0	96.00	94.00	650.00	0.0031	2.00	1.00	0.00	0.0130	PIPE
10122.0	10114.0	111.00	94.00	850.00	0.0200	0.00	0.00	0.00	0.0000	
10132.0	10133.0	97.00	95.00	550.00	0.0036	0.00	0.00	0.00	0.0000	
10133.0	10114.0	95.00	94.00	700.00	0.0014	2.00	1.00	0.00	0.0130	PIPE
10114.0	10215.0	94.00	92.00	550.00	0.0036	2.00	1.00	0.00	0.0130	PIPE
10215.0	10216.0	92.00	90.00	700.00	0.0029	2.00	2.00	0.00	0.0140	BOX
10312.0	10313.0	98.00	96.00	350.00	0.0057	0.00	0.00	0.00	0.0000	
10313.0	10314.0	96.00	94.00	650.00	0.0031	3.00	1.00	0.00	0.0130	PIPE
10322.0	10314.0	110.00	94.00	850.00	0.0188	5.00	5.00	1.00	0.0150	CHANNEL
10332.0	10333.0	97.00	95.00	550.00	0.0036	0.00	0.00	0.00	0.0000	
10333.0	10314.0	95.00	94.00	700.00	0.0014	3.50	1.00	0.00	0.0130	PIPE
10314.0	10315.0	94.00	92.00	550.00	0.0036	5.00	5.00	1.00	0.0150	CHANNEL
10315.0	10316.0	92.00	90.00	700.00	0.0029	5.00	5.00	1.00	0.0150	CHANNEL
10316.0	10317.0	90.00	88.00	450.00	0.0044	5.00	5.00	1.00	0.0150	CHANNEL
10216.0	10317.0	90.00	88.00	250.00	0.0080	3.00	3.50	0.00	0.0140	BOX
10317.0	10318.0	88.00	85.00	500.00	0.0060	5.00	5.00	1.00	0.0150	CHANNEL

Figure 7.11a Spreadsheet Output from the AES SIMS, for Example Problem

LINK LOCATION U/S NODE	LINK LOCATION D/S NODE	RUNOFF ANALYSIS UPSTREAM NODE PEAK FLOW RATE ESTIMATES(Q) Q(1)	Q(2)	Q(3)	Q(4)	Q(5)	Q(6)
10112.0	10113.0	14.15	17.36	22.55	0.00	0.00	0.00
10113.0	10114.0	27.10	32.34	42.11	0.00	0.00	0.00
10122.0	10114.0	1.77	2.17	2.83	0.00	0.00	0.00
10132.0	10133.0	9.29	11.72	15.56	0.00	0.00	0.00
10133.0	10114.0	17.33	20.88	27.92	0.00	0.00	0.00
10114.0	10215.0	57.55	67.29	88.84	0.00	0.00	0.00
10215.0	10216.0	59.41	69.88	92.71	0.00	0.00	0.00
10312.0	10313.0	14.15	17.36	22.55	0.00	0.00	0.00
10313.0	10314.0	27.10	32.34	42.11	0.00	0.00	0.00
10322.0	10314.0	301.40	301.74	302.29	0.00	0.00	0.00
10332.0	10333.0	9.59	12.09	16.05	0.00	0.00	0.00
10333.0	10314.0	17.61	21.24	28.39	0.00	0.00	0.00
10314.0	10315.0	357.85	369.08	390.26	0.00	0.00	0.00
10315.0	10316.0	372.83	387.24	413.55	0.00	0.00	0.00
10316.0	10317.0	382.68	398.80	428.21	0.00	0.00	0.00
10216.0	10317.0	83.13	96.68	127.63	0.00	0.00	0.00
10317.0	10318.0	467.61	497.96	559.28	0.00	0.00	0.00

Figure 7.11b Spreadsheet Output from the AES SIMS, for Example Problem

LINK LOCATION U/S NODE	D/S NODE	RUNOFF ANALYSIS DOWNSTREAM NODE PEAK FLOW RATE ESTIMATES(Q) Q(1)	Q(2)	Q(3)	Q(4)	Q(5)	Q(6)	ESTIMATED BALANCED HGL: U/S HGL	D/S HGL
10112.0	10113.0	27.10	32.34	42.11	0.00	0.00	0.00	95.67	94.22
10113.0	10114.0	33.53	39.34	51.76	0.00	0.00	0.00	94.22	91.51
10122.0	10114.0	6.67	8.12	10.56	0.00	0.00	0.00	106.12	91.51
10132.0	10133.0	17.33	20.88	27.92	0.00	0.00	0.00	95.57	93.78
10133.0	10114.0	21.42	25.34	33.80	0.00	0.00	0.00	93.78	91.51
10114.0	10215.0	59.41	69.88	92.71	0.00	0.00	0.00	91.51	89.22
10215.0	10216.0	59.41	69.88	92.71	0.00	0.00	0.00	89.22	86.31
10312.0	10313.0	27.10	32.34	42.11	0.00	0.00	0.00	96.22	95.00
10313.0	10314.0	33.58	40.21	52.09	0.00	0.00	0.00	95.00	93.00
10322.0	10314.0	301.40	301.74	302.29	0.00	0.00	0.00	106.60	93.00
10332.0	10333.0	17.61	21.24	28.39	0.00	0.00	0.00	95.69	94.00
10333.0	10314.0	21.72	26.25	34.85	0.00	0.00	0.00	94.00	92.95
10314.0	10315.0	357.85	369.08	390.26	0.00	0.00	0.00	93.00	90.50
10315.0	10316.0	372.83	387.24	413.55	0.00	0.00	0.00	90.50	87.32
10316.0	10317.0	382.68	398.80	428.21	0.00	0.00	0.00	87.32	85.27
10216.0	10317.0	83.13	96.68	127.63	0.00	0.00	0.00	86.31	85.27
10317.0	10318.0	467.61	497.96	559.28	0.00	0.00	0.00	85.27	83.00

Figure 7.11c Spreadsheet Output from the AES SIMS, for Example Problem

LINK LOCATION U/S NODE	D/S NODE	STREET WIDTH	LINK REGULATORY FLOW CAPACITY ESTIMATES(Qreg) SECONDARY FLOW ELEMENT TYPE: STREET Qreg(1)	Qreg(2)	Qreg(3)	Qreg(4)	Qreg(5)	Qreg(6)
10112.0	10113.0	40.00	2.06	44.02	44.02	0.00	0.00	0.00
10113.0	10114.0	40.00	1.51	32.30	32.30	0.00	0.00	0.00
10122.0	10114.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10132.0	10133.0	40.00	1.64	35.12	35.12	0.00	0.00	0.00
10133.0	10114.0	40.00	0.38	22.01	22.01	0.00	0.00	0.00
10114.0	10215.0	40.00	0.61	35.12	35.12	0.00	0.00	0.00
10215.0	10216.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10312.0	10313.0	40.00	2.06	44.02	44.02	0.00	0.00	0.00
10313.0	10314.0	40.00	0.56	32.30	32.30	0.00	0.00	0.00
10322.0	10314.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10332.0	10333.0	40.00	1.64	35.12	35.12	0.00	0.00	0.00
10333.0	10314.0	40.00	0.38	22.01	22.01	0.00	0.00	0.00
10314.0	10315.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10315.0	10316.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10316.0	10317.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10216.0	10317.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10317.0	10318.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Figure 7.11d Spreadsheet Output from the AES SIMS, for Example Problem

LINK LOCATION U/S NODE	D/S NODE	EXISTING CONDUIT CAPACITY	DOWNSTREAM (D/S) NODE: REGULATORY + EXISTING PRIMARY ELEMENT FLOW CAPACITY ESTIMATES(Qsum) Qsum(1)	Qsum(2)	Qsum(3)	Qsum(4)	Qsum(5)	Qsum(6)
10112.0	10113.0	0.00	2.06	44.02	44.02	0.00	0.00	0.00
10113.0	10114.0	13.91	15.42	46.21	46.21	0.00	0.00	0.00
10122.0	10114.0	99999.00	99999.00	99999.00	99999.00	0.00	0.00	0.00
10132.0	10133.0	0.00	1.64	35.12	35.12	0.00	0.00	0.00
10133.0	10114.0	12.14	12.52	34.15	34.15	0.00	0.00	0.00
10114.0	10215.0	13.91	14.52	49.03	49.03	0.00	0.00	0.00
10215.0	10216.0	16.44	16.44	16.44	16.44	0.00	0.00	0.00
10312.0	10313.0	0.00	2.06	44.02	44.02	0.00	0.00	0.00
10313.0	10314.0	35.23	35.79	67.53	67.53	0.00	0.00	0.00
10322.0	10314.0	1188.39	1188.39	1188.39	1188.39	0.00	0.00	0.00
10332.0	10333.0	0.00	1.64	35.12	35.12	0.00	0.00	0.00
10333.0	10314.0	36.97	37.35	58.98	58.98	0.00	0.00	0.00
10314.0	10315.0	630.24	630.24	630.24	630.24	0.00	0.00	0.00
10315.0	10316.0	630.24	630.24	630.24	630.24	0.00	0.00	0.00
10316.0	10317.0	630.24	630.24	630.24	630.24	0.00	0.00	0.00
10216.0	10317.0	59.43	59.43	59.43	59.43	0.00	0.00	0.00
10317.0	10318.0	630.24	630.24	630.24	630.24	0.00	0.00	0.00

Figure 7.11e Spreadsheet Output from the AES SIMS, for Example Problem

LINK LOCATION U/S NODE	LINK LOCATION D/S NODE	DEFICIENCY ANALYSIS — LINK DEFICIENCY FLOW ESTIMATES(Qdef) Qdef(1)	Qdef(2)	Qdef(3)	Qdef(4)	Qdef(5)	Qdef(6)	MITIGATION Qmitig	MITIGATION Event
10112.0	10113.0	25.04	0.00	0.00	0.00	0.00	0.00	25.04	1
10113.0	10114.0	18.11	0.00	5.55	0.00	0.00	0.00	18.11	1
10122.0	10114.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
10132.0	10133.0	15.69	0.00	0.00	0.00	0.00	0.00	15.69	1
10133.0	10114.0	8.90	0.00	0.00	0.00	0.00	0.00	8.90	1
10114.0	10215.0	44.89	20.85	43.68	0.00	0.00	0.00	44.89	1
10215.0	10216.0	42.97	53.44	76.27	0.00	0.00	0.00	76.27	3
10312.0	10313.0	25.04	0.00	0.00	0.00	0.00	0.00	25.04	1
10313.0	10314.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
10322.0	10314.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
10332.0	10333.0	15.97	0.00	0.00	0.00	0.00	0.00	15.97	1
10333.0	10314.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
10314.0	10315.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
10315.0	10316.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
10316.0	10317.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
10216.0	10317.0	23.70	37.25	68.20	0.00	0.00	0.00	68.20	3
10317.0	10318.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0

Figure 7.11f Spreadsheet Output from the AES SIMS, for Example Problem

LINK LOCATION		ESTIMATED MITIGATION ELEMENT DESCRIPTIONS											
U/S	D/S	PARALLEL		REPLACEMENT					ADOPTED SYSTEM				
NODE	NODE	Q	DIA.	Q	DIA./H	WIDTH	Z	FB	DIA./H	WIDTH	Z	FB	TYPE
10112.0	10113.0	25.04	2.50	25.04	2.50	0.00	0.0	0.0	2.50	0.00	0.0	0.0	PIPE
10113.0	10114.0	18.11	2.25	32.02	2.75	0.00	0.0	0.0	2.75	0.00	0.0	0.0	PIPE
10122.0	10114.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.0	
10132.0	10133.0	15.69	2.25	15.69	2.25	0.00	0.0	0.0	2.25	0.00	0.0	0.0	PIPE
10133.0	10114.0	8.90	2.00	21.04	2.50	0.00	0.0	0.0	2.50	0.00	0.0	0.0	PIPE
10114.0	10215.0	44.89	3.25	58.80	3.50	0.00	0.0	0.0	3.50	0.00	0.0	0.0	PIPE
10215.0	10216.0	76.27	4.00	92.71	2.00	8.25	0.0	0.0	2.00	8.25	0.0	0.0	BOX
10312.0	10313.0	25.04	2.75	25.04	2.75	0.00	0.0	0.0	2.75	0.00	0.0	0.0	PIPE
10313.0	10314.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.0	
10322.0	10314.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.0	
10332.0	10333.0	15.97	2.25	15.97	2.25	0.00	0.0	0.0	2.25	0.00	0.0	0.0	PIPE
10333.0	10314.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.0	
10314.0	10315.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.0	
10315.0	10316.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.0	
10316.0	10317.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.0	
10216.0	10317.0	68.20	3.75	127.63	3.00	6.50	0.0	0.0	3.00	6.50	0.0	0.0	BOX
10317.0	10318.0	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.00	0.00	0.0	0.0	

----Notes--
Parallel: parallel pipe system element estimate to handle deficiency;
DIA: pipe diameter; H: box or open channel height (includes freeboard);
Z: ratio of vertical to horizontal in open channel; FB: freeboard;
ADOPTED SYSTEM: Adopted System, after telescoping analysis.

Figure 7.11g Spreadsheet Output from the AES SIMS, for Example Problem

LINK LOCATION U/S NODE	D/S NODE	ADOPTED SYSTEM DIA./H	WIDTH	Z	FB	TYPE	UNIT COST	COST OPINION	COST-TO-BENEFIT C. B. I.
10112.0	10113.0	2.50	0.00	0.0	0.0	PIPE	75.00	26250.	0.000
10113.0	10114.0	2.75	0.00	0.0	0.0	PIPE	82.50	53625.	0.201
10122.0	10114.0	0.00	0.00	0.0	0.0		0.00	0.	0.000
10132.0	10133.0	2.25	0.00	0.0	0.0	PIPE	67.50	37125.	0.000
10133.0	10114.0	2.50	0.00	0.0	0.0	PIPE	75.00	52500.	0.000
10114.0	10215.0	3.50	0.00	0.0	0.0	PIPE	105.00	57750.	1.000
10215.0	10216.0	2.00	8.25	0.0	0.0	BOX	104.17	72919.	1.000
10312.0	10313.0	2.75	0.00	0.0	0.0	PIPE	82.50	28875.	0.000
10313.0	10314.0	0.00	0.00	0.0	0.0		0.00	0.	0.000
10322.0	10314.0	0.00	0.00	0.0	0.0		0.00	0.	0.000
10332.0	10333.0	2.25	0.00	0.0	0.0	PIPE	67.50	37125.	0.000
10333.0	10314.0	0.00	0.00	0.0	0.0		0.00	0.	0.000
10314.0	10315.0	0.00	0.00	0.0	0.0		0.00	0.	0.000
10315.0	10316.0	0.00	0.00	0.0	0.0		0.00	0.	0.000
10316.0	10317.0	0.00	0.00	0.0	0.0		0.00	0.	0.000
10216.0	10317.0	3.00	6.50	0.0	0.0	BOX	97.22	24305.	0.228
10317.0	10318.0	0.00	0.00	0.0	0.0		0.00	0.	0.000

ESTIMATED "ADOPTED SYSTEM" INFORMATION

----Notes----
Parallel: parallel pipe system element estimate to handle deficiency;
DIA: pipe diameter; H: box or open channel height (includes freeboard);
Z: ratio of vertical to horizontal in open channel; FB: freeboard;
ADOPTED SYSTEM: Adopted System, after telescoping analysis.

Figure 7.11h Spreadsheet Output from the AES SIMS, for Example Problem

```
                 Program COST Summary Information:

        *Pipe System Unit Cost Table(Cost per linear foot)*
    ============================================================
    Cost      Pipe        Unit       Cost      Pipe        Unit
    Item    Diameter      Cost       Item    Diameter      Cost
    ----   -----------   ------      ----   -----------   ------
      1    15"( 375mm)  $  37.5       17    63"(1575mm)  $ 157.5
      2    18"( 450mm)  $  45.0       18    66"(1650mm)  $ 165.0
      3    21"( 525mm)  $  52.5       19    69"(1725mm)  $ 172.5
      4    24"( 600mm)  $  60.0       20    72"(1800mm)  $ 180.0
      5    27"( 675mm)  $  67.5       21    75"(1875mm)  $ 187.5
      6    30"( 750mm)  $  75.0       22    78"(1950mm)  $ 195.0
      7    33"( 825mm)  $  82.5       23    81"(2025mm)  $ 202.5
      8    36"( 900mm)  $  90.0       24    84"(2100mm)  $ 210.0
      9    39"( 975mm)  $  97.5       25    87"(2175mm)  $ 217.5
     10    42"(1050mm)  $ 105.0       26    90"(2250mm)  $ 225.0
     11    45"(1125mm)  $ 112.5       27    93"(2325mm)  $ 232.5
     12    48"(1200mm)  $ 120.0       28    96"(2400mm)  $ 240.0
     13    51"(1275mm)  $ 127.5       29   102"(2550mm)  $ 255.0
     14    54"(1350mm)  $ 135.0       30   108"(2700mm)  $ 270.0
     15    57"(1425mm)  $ 142.5       31   114"(2850mm)  $ 285.0
     24    60"(1500mm)  $ 150.0       32   120"(3000mm)  $ 300.0

       *Reinforced Concrete Box Unit Cost Opinion Data:*

Box Top Wall THICKNESS(inches) =  6.0
Box Side Wall THICKNESS(inches) =  6.0
Box Base THICKNESS(inches) =  6.0
UNIT COST(dollars) per Box Wall VOLUME(cubic yards) =  250.0

       *Reinforced Concrete Open Channel Unit Cost Opinion Data:*

Channel BOTTOM THICKNESS(inches) =  6.0
Channel SIDEWALL THICKNESS(inches)(measured vertically) =  6.0
UNIT COST(dollars) per Open Channel Wall VOLUME(cubic yards) =  250.0



*----------------------------------------------------------------------*
* COST OPINION FORMULA USED:                                           *
*  1.  PIPE COST = (UNIT COST) * (LENGTH)                              *
*  2a. BOX VOLUME: BVOL = (W + 2Ts) * Tb + 2*(H + Tt) * Ts + W * Tt    *
*   b. BOX COST = (UNIT COST) * BVOL                                   *
*  3a. RECTANGULAR CHANNEL VOLUME:                                     *
*                  RVOL = (W + 2Ts) * Tb + 2 * H * Ts                  *
*   b. RECTANGULAR CHANNEL COST = (UNIT COST) * RVOL                   *
*  4a. OPEN CHANNEL VOLUME:                                            *
*                  CVOL = 2 * Z * H * Ts + W * Tb + Ts * Ts / Z +      *
*                         Z * Ts * Ts + 2 * (Tb - Ts) * Ts             *
*   b. OPEN CHANNEL COST = (UNIT COST) * CVOL                          *
*   c. If (4b) is less than (3b), COST from (3b) is USED as DEFAULT.   *
*  5.  Variables Definitions:                                          *
*      W = basewidth; Ts = sidewall thickness; Tb = base thickness     *
*      Tt = top thickness; H = height.                                 *
*      Note: for open channels(see #4), Ts is measured vertically.     *
*----------------------------------------------------------------------*
```

Figure 7.12a AES COST Module Output for Example Problem

```
*-------------------------------------------------------------------------------------------*
*                                FACILITY COST OPINION SUMMARY                              *
* STRING FILENAME: EX0001ZZ.ZST                                                             *
* MOST UPSTREAM NODE: EX010112.0                         MOST DOWNSTREAM NODE: EX010317.0 *
*-------------------------------------------------------------------------------------------*
  Upstream  Downstream  Length   System  Diameter/  Height  Side-     Unit         Cost
    Node       Node      (FT)     Type   Base(FT)    (FT)   Slope     Cost        Opinion
  --------  ----------  -------  ------  ---------  ------  -----  -----------  ----------
EX010112.0  EX010113.0    350.0  PIPE       2.50                   $   75.0     $   26250.0
EX010113.0  EX010114.0    650.0  PIPE       2.75                   $   82.5     $   53625.0
EX010114.0  EX010215.0    550.0  PIPE       3.50                   $  105.0     $   57750.0
EX010215.0  EX010216.0    700.0   BOX       8.25      2.00         $  104.2     $   72916.7
EX010216.0  EX010317.0    250.0   BOX       6.50      3.00         $   97.2     $   24305.6
  ------------------------------------------------------------------------------------------
  (Note: "DEF"=vertical wall channel unit cost opinion used.)         Total = $    234847.2

*-------------------------------------------------------------------------------------------*
*                                FACILITY COST OPINION SUMMARY                              *
* STRING FILENAME: EX0003ZZ.ZST                                                             *
* MOST UPSTREAM NODE: EX010132.0                         MOST DOWNSTREAM NODE: EX010114.0 *
*-------------------------------------------------------------------------------------------*
  Upstream  Downstream  Length   System  Diameter/  Height  Side-     Unit         Cost
    Node       Node      (FT)     Type   Base(FT)    (FT)   Slope     Cost        Opinion
  --------  ----------  -------  ------  ---------  ------  -----  -----------  ----------
EX010132.0  EX010133.0    550.0  PIPE       2.25                   $   67.5     $   37125.0
EX010133.0  EX010114.0    700.0  PIPE       2.50                   $   75.0     $   52500.0
  ------------------------------------------------------------------------------------------
  (Note: "DEF"=vertical wall channel unit cost opinion used.)         Total = $     89625.0

*-------------------------------------------------------------------------------------------*
*                                FACILITY COST OPINION SUMMARY                              *
* STRING FILENAME: EX0004ZZ.ZST                                                             *
* MOST UPSTREAM NODE: EX010312.0                         MOST DOWNSTREAM NODE: EX010313.0 *
*-------------------------------------------------------------------------------------------*
  Upstream  Downstream  Length   System  Diameter/  Height  Side-     Unit         Cost
    Node       Node      (FT)     Type   Base(FT)    (FT)   Slope     Cost        Opinion
  --------  ----------  -------  ------  ---------  ------  -----  -----------  ----------
EX010312.0  EX010313.0    350.0  PIPE       2.75                   $   82.5     $   28875.0
  ------------------------------------------------------------------------------------------
  (Note: "DEF"=vertical wall channel unit cost opinion used.)         Total = $     28875.0

*-------------------------------------------------------------------------------------------*
*                                FACILITY COST OPINION SUMMARY                              *
* STRING FILENAME: EX0006ZZ.ZST                                                             *
* MOST UPSTREAM NODE: EX010332.0                         MOST DOWNSTREAM NODE: EX010333.0 *
*-------------------------------------------------------------------------------------------*
  Upstream  Downstream  Length   System  Diameter/  Height  Side-     Unit         Cost
    Node       Node      (FT)     Type   Base(FT)    (FT)   Slope     Cost        Opinion
  --------  ----------  -------  ------  ---------  ------  -----  -----------  ----------
EX010332.0  EX010333.0    550.0  PIPE       2.25                   $   67.5     $   37125.0
  ------------------------------------------------------------------------------------------
  (Note: "DEF"=vertical wall channel unit cost opinion used.)         Total = $     37125.0
```

```
MASTER PLAN OF DRAINAGE STRING COST OPINION SUMMARY STATISTICS:

STRING                                        UPSTREAM DOWNSTREAM    COST
FILENAME                                        NODE     NODE      OPINION
--------------------------------------------- -------- --------   ------------
EX0001ZZ.ZST                                  010112.0 010317.0  $    234847.2
EX0003ZZ.ZST                                  010132.0 010114.0  $     89625.0
EX0004ZZ.ZST                                  010312.0 010314.0  $     28875.0
EX0006ZZ.ZST                                  010332.0 010314.0  $     37125.0
-----------------------------------------------------------------------------------
                                                         TOTAL = $    390472.2
```

Figure 7.12b AES COST Module Output for Example Problem

```
DAMAGE POTENTIAL CURVE #  1 DATA:
 LAND USE TYPE =  2.; DEFICIENCY CLASS =  3.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                1.00
     2.00                2.00
     3.00                3.00
     4.00                4.00
```

```
DAMAGE POTENTIAL CURVE #  2 DATA:
 LAND USE TYPE =  2.; DEFICIENCY CLASS =  4.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                1.00
     2.00                2.00
     3.00                3.00
     4.00                4.00
```

```
DAMAGE POTENTIAL CURVE #  3 DATA:
 LAND USE TYPE =  9.; DEFICIENCY CLASS =  3.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                0.50
     2.00                1.00
     3.00                1.50
     4.00                2.00
```

```
DAMAGE POTENTIAL CURVE #  4 DATA:
 LAND USE TYPE =  9.; DEFICIENCY CLASS =  4.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                0.50
     2.00                1.00
     3.00                1.50
     4.00                2.00
```

```
DAMAGE POTENTIAL CURVE #  5 DATA:
 LAND USE TYPE = 14.; DEFICIENCY CLASS =  3.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                0.50
     2.00                1.00
     3.00                1.50
     4.00                2.00
```

```
DAMAGE POTENTIAL CURVE #  6 DATA:
 LAND USE TYPE = 14.; DEFICIENCY CLASS =  4.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                1.00
     2.00                2.00
     3.00                3.00
     4.00                4.00
```

```
DAMAGE POTENTIAL CURVE #  7 DATA:
 LAND USE TYPE =  3.; DEFICIENCY CLASS =  2.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                0.50
     2.00                1.00
     3.00                1.50
     4.00                2.00
```

```
DAMAGE POTENTIAL CURVE #  8 DATA:
 LAND USE TYPE =  4.; DEFICIENCY CLASS =  2.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                0.50
     2.00                1.00
     3.00                1.50
     4.00                2.00
```

```
DAMAGE POTENTIAL CURVE #  9 DATA:
 LAND USE TYPE =  8.; DEFICIENCY CLASS =  2.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                0.50
     2.00                1.00
     3.00                1.50
     4.00                2.00
```

```
DAMAGE POTENTIAL CURVE # 10 DATA:
 LAND USE TYPE = 11.; DEFICIENCY CLASS =  2.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
      .00                 .00
     0.67                0.00
     1.00                0.50
     2.00                1.00
     3.00                1.50
     4.00                2.00
```

Figure 7.13a AES Cost-to-Benefit Module Output for Example Problem

```
DAMAGE POTENTIAL CURVE # 11 DATA:
 LAND USE TYPE =  1.; DEFICIENCY CLASS =  3.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                1.00
      2.00                2.00
      3.00                3.00
      4.00                4.00
```

```
DAMAGE POTENTIAL CURVE # 12 DATA:
 LAND USE TYPE =  3.; DEFICIENCY CLASS =  3.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                0.50
      2.00                1.00
      3.00                1.50
      4.00                2.00
```

```
DAMAGE POTENTIAL CURVE # 13 DATA:
 LAND USE TYPE =  4.; DEFICIENCY CLASS =  3.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                0.50
      2.00                1.00
      3.00                1.50
      4.00                2.00
```

```
DAMAGE POTENTIAL CURVE # 14 DATA:
 LAND USE TYPE =  8.; DEFICIENCY CLASS =  3.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                0.50
      2.00                1.00
      3.00                1.50
      4.00                2.00
```

```
DAMAGE POTENTIAL CURVE # 15 DATA:
 LAND USE TYPE = 11.; DEFICIENCY CLASS =  3.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                0.50
      2.00                1.00
      3.00                1.50
      4.00                2.00
```

```
DAMAGE POTENTIAL CURVE # 16 DATA:
 LAND USE TYPE =  1.; DEFICIENCY CLASS =  4.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                1.00
      2.00                2.00
      3.00                3.00
      4.00                4.00
```

```
DAMAGE POTENTIAL CURVE # 17 DATA:
 LAND USE TYPE =  3.; DEFICIENCY CLASS =  4.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                0.50
      2.00                1.00
      3.00                1.50
      4.00                2.00
```

```
DAMAGE POTENTIAL CURVE # 18 DATA:
 LAND USE TYPE =  4.; DEFICIENCY CLASS =  4.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                0.50
      2.00                1.00
      3.00                1.50
      4.00                2.00
```

```
DAMAGE POTENTIAL CURVE # 19 DATA:
 LAND USE TYPE =  8.; DEFICIENCY CLASS =  4.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                0.50
      2.00                1.00
      3.00                1.50
      4.00                2.00
```

```
DAMAGE POTENTIAL CURVE # 20 DATA:
 LAND USE TYPE = 11.; DEFICIENCY CLASS =  4.
 STREET FLOW         RELATIVE FLOOD
 DEPTH (FEET)       DAMAGE POTENTIAL
 ============       ================
       .00                 .00
      0.67                0.00
      1.00                0.50
      2.00                1.00
      3.00                1.50
      4.00                2.00
```

Figure 7.13b AES Cost-to-Benefit Module Output for Example Problem

```
-----------------------------------------------------------------------------------
 (1):UPSTREAM NODE; (2):DOWNSTREAM NODE; (3):DEFICIENCY CATEGORY
 (4):STREET FLOW DEPTH; (5) LAND USE TYPE/FRACTION
 (6):NON-NORMALIZED DAMAGE POTENTIAL; (7):APPROXIMATE UNIT COST OPINION
 (8):NORMALIZED COST-TO-BENEFIT INDEX(BASED UPON EACH DEFICIENCY CATEGORY)
 (9):NORMALIZED COST-TO-BENEFIT INDEX (BASED UPON MAXIMUM CBI)
 (10):TOTAL COST OPINION
 Notes: (a):HIGH FLOW DEPTH APPROXIMATED ONLY; (b):DEFAULT SLOPE(0.0015) USED;
        (c): (a) and (b)
-----------------------------------------------------------------------------------
   (1)       (2)    (3)  (4)        (5)       (6)    (7)      (8)   (9)   (10)
10112.00  10113.00 3.0  0.66      8./1.00    0.00    75.00 0.000 0.000     26250.
10113.00  10114.00 3.0  0.70      8./1.00    0.05    82.50 0.201 0.116     53625.
10132.00  10133.00 3.0  0.63     11./1.00    0.00    67.50 0.000 0.000     37125.
10133.00  10114.00 3.0  0.66(b)   8./1.00    0.00    75.00 0.000 0.000     52500.
10114.00  10215.00 3.0  0.87(a)   3./0.48    0.30   105.00 1.000 0.577     57750.
                                  4./0.52
10215.00  10216.00 4.0  0.84      1./1.00    0.52   104.17 1.000 1.000     72917.
10312.00  10313.00 3.0  0.66      8./1.00    0.00    82.50 0.000 0.000     28875.
10332.00  10333.00 3.0  0.63     11./1.00    0.00    67.50 0.000 0.000     37125.
10216.00  10317.00 4.0  0.71      1./1.00    0.11    97.22 0.228 0.228     24306.
-----------------------------------------------------------------------------------


STATISTICS FOR STREET CLASS III --  RESIDENTIAL
(NON-NORMALIZED DAMAGE POTENTIAL)
MEAN =      0.18  STANDARD DEVIATION =     0.18

STATISTICS FOR STREET CLASS IV -- BOX/CHANNEL
(NON-NORMALIZED DAMAGE POTENTIAL)
MEAN =      0.32  STANDARD DEVIATION =     0.29
```

Figure 7.13c AES Cost-to-Benefit Module Output for Example Problem

```
*** ANNUAL POLLUTANT LOADING ***
(Ref. State of California Storm Water Best Management Practice Handbook -- Municipal, Appendix B)

LONG-TERM AVERAGE PRECIPITATION (IN/YR) = 12.00
```

ANNUAL POLLUTANT LOADINGS (LBS/YR)

NODE	OXYGEN DEMAND & SEDIMENT				NUTRIENTS				HEAVY METALS			
NUMBER	BOD	COD	TSS	TDS	TOTAL-P	DISSOLVED-P	TKN	NO2&NO3	LEAD	COPPER	ZINC	CADMIUM
EX010114.0	449.	3423.	6123.	4228.	19.	6.	97.	40.	7.	2.	7.	0.
EX010314.0	447.	3400.	6133.	4214.	19.	6.	96.	40.	7.	2.	7.	0.
EX010318.0	1727.	12493.	21191.	16676.	65.	23.	330.	141.	26.	8.	37.	0.

Figure 7.14 AES Pollutant Loading Module (PLM) Output for Example Problem

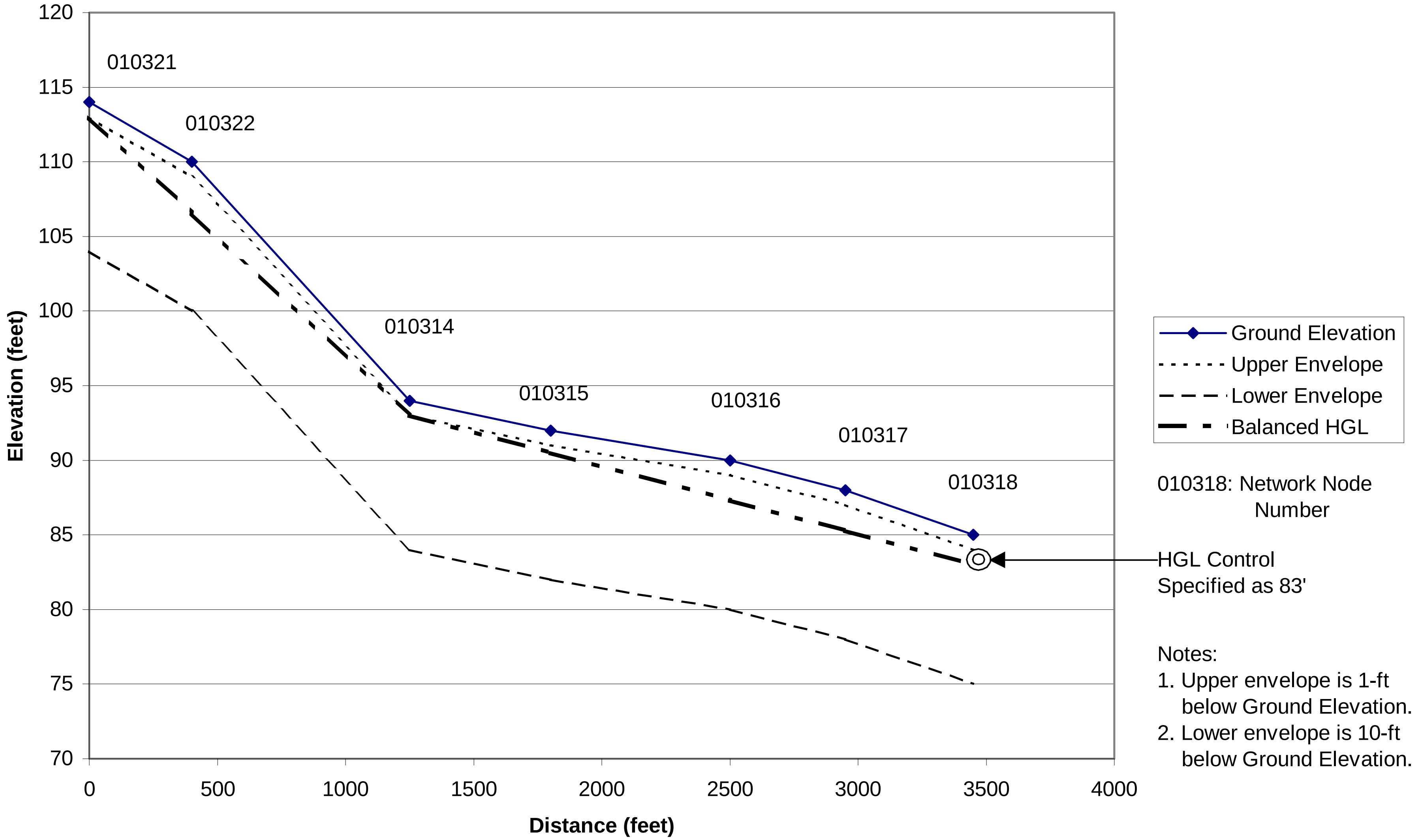

Figure 7.15a Balanced HGL and Friction Slope

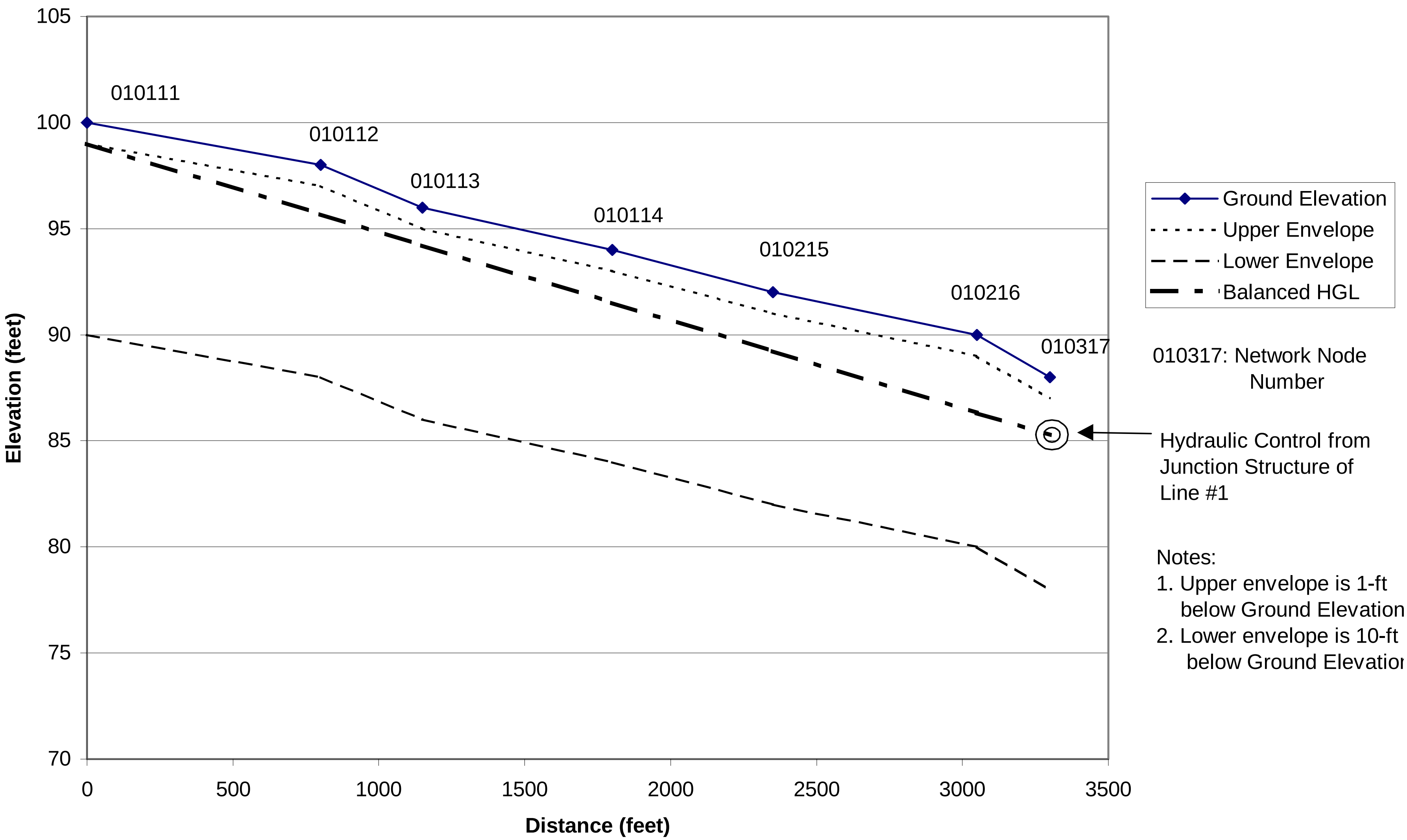

Figure 7.15b Balanced HGL and Friction Slope

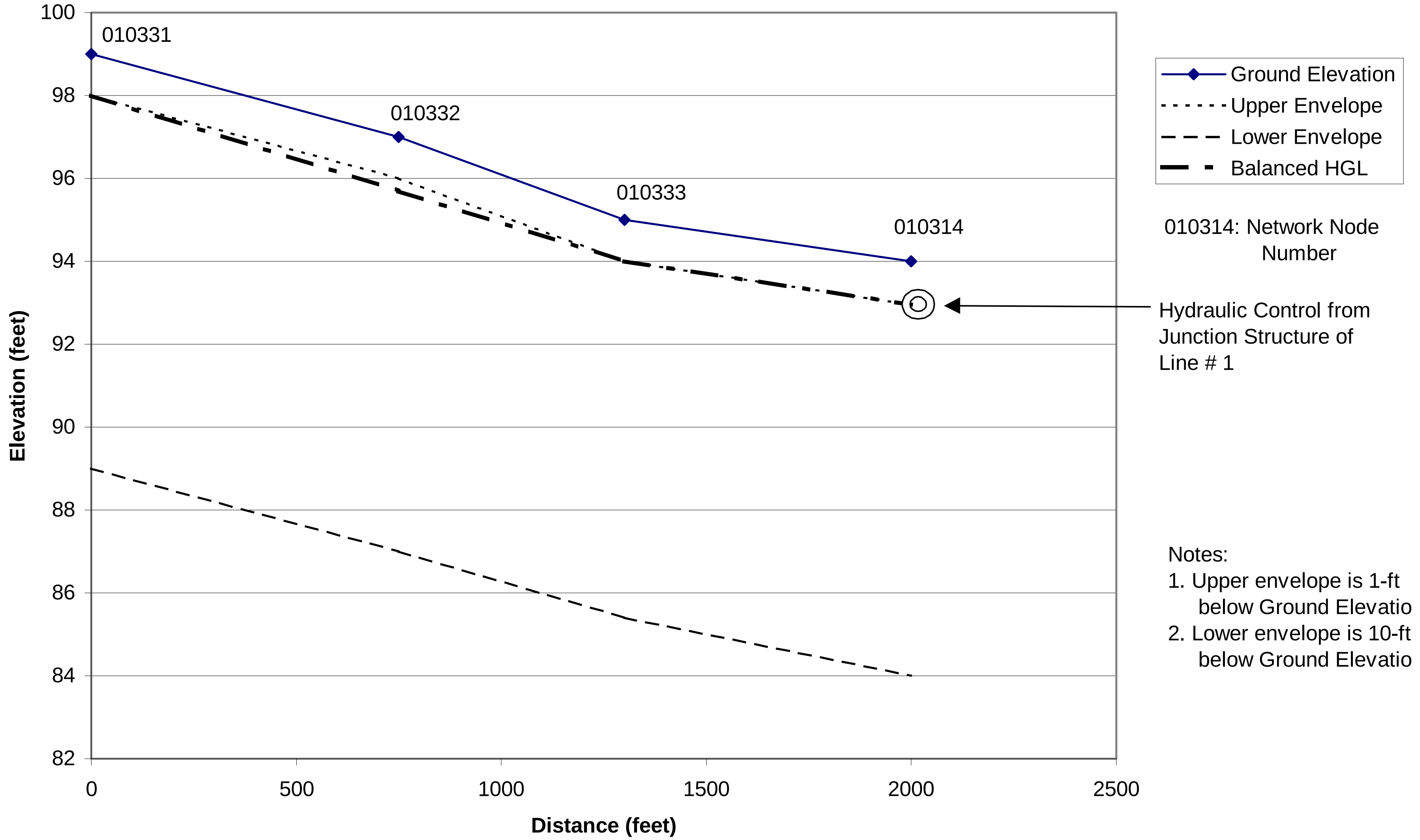

Figure 7.15c Balanced HGL and Friction Slope

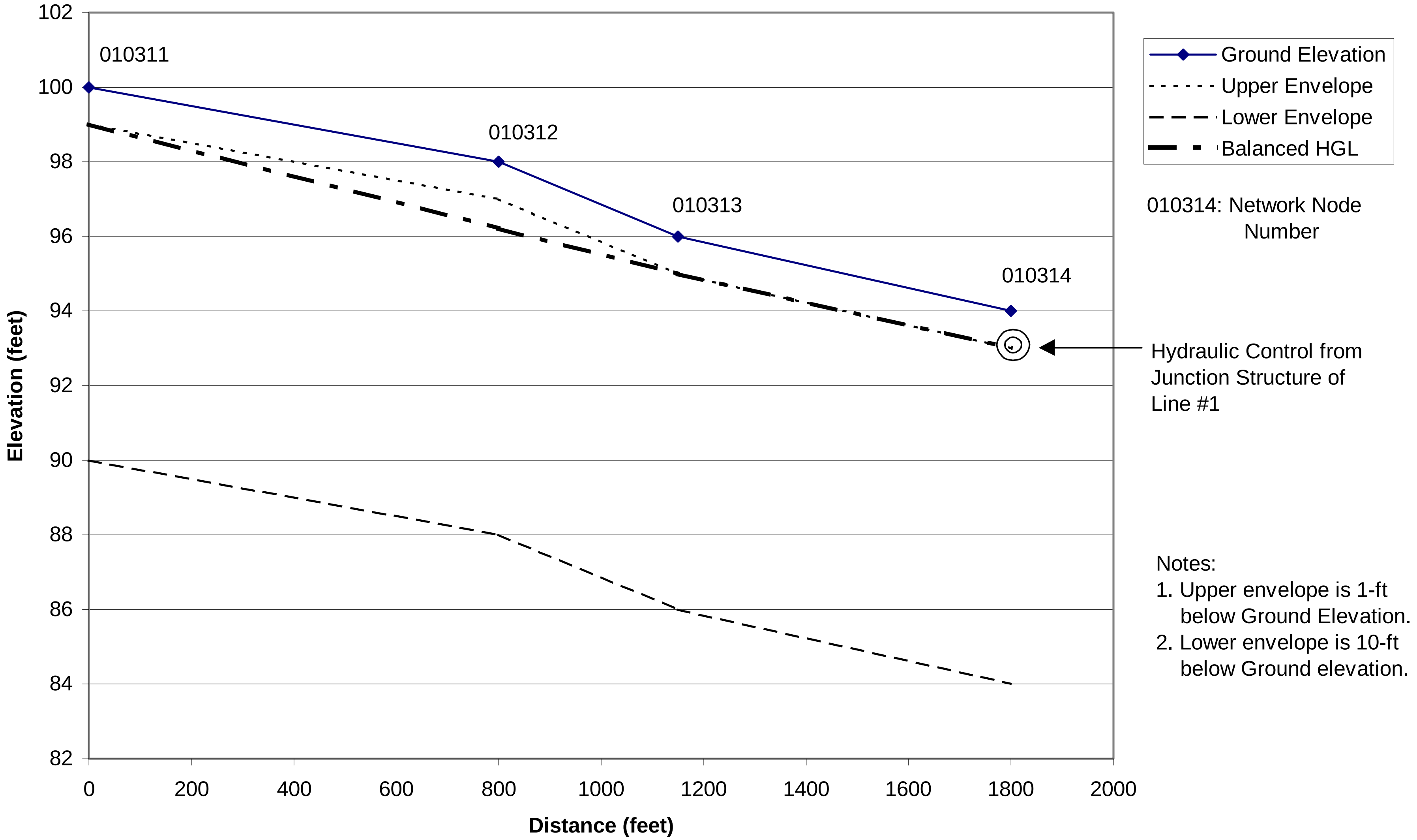

Figure 7.15d Balanced HGL and Friction Slope

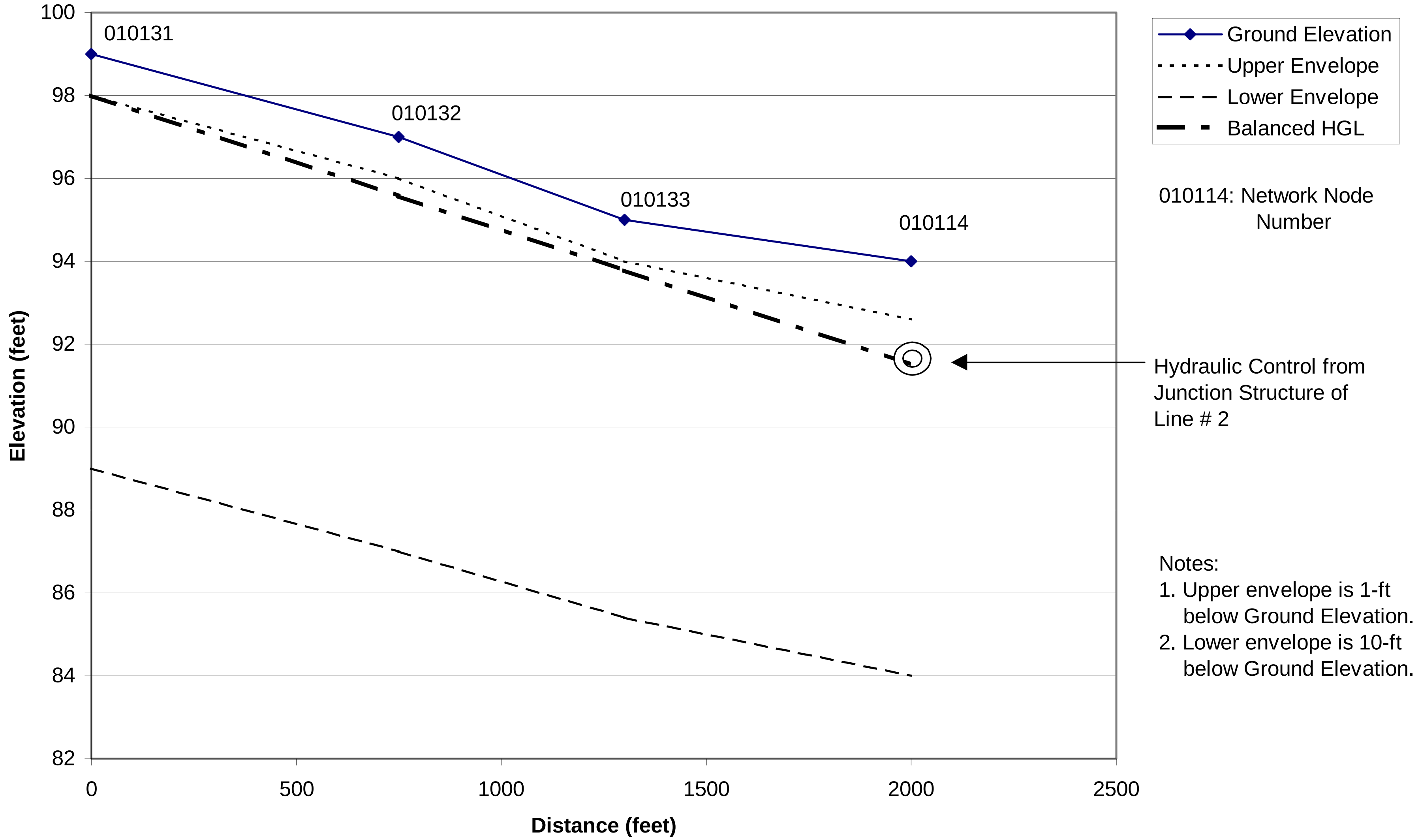

Figure 7.15e Balanced HGL and Friction Slope

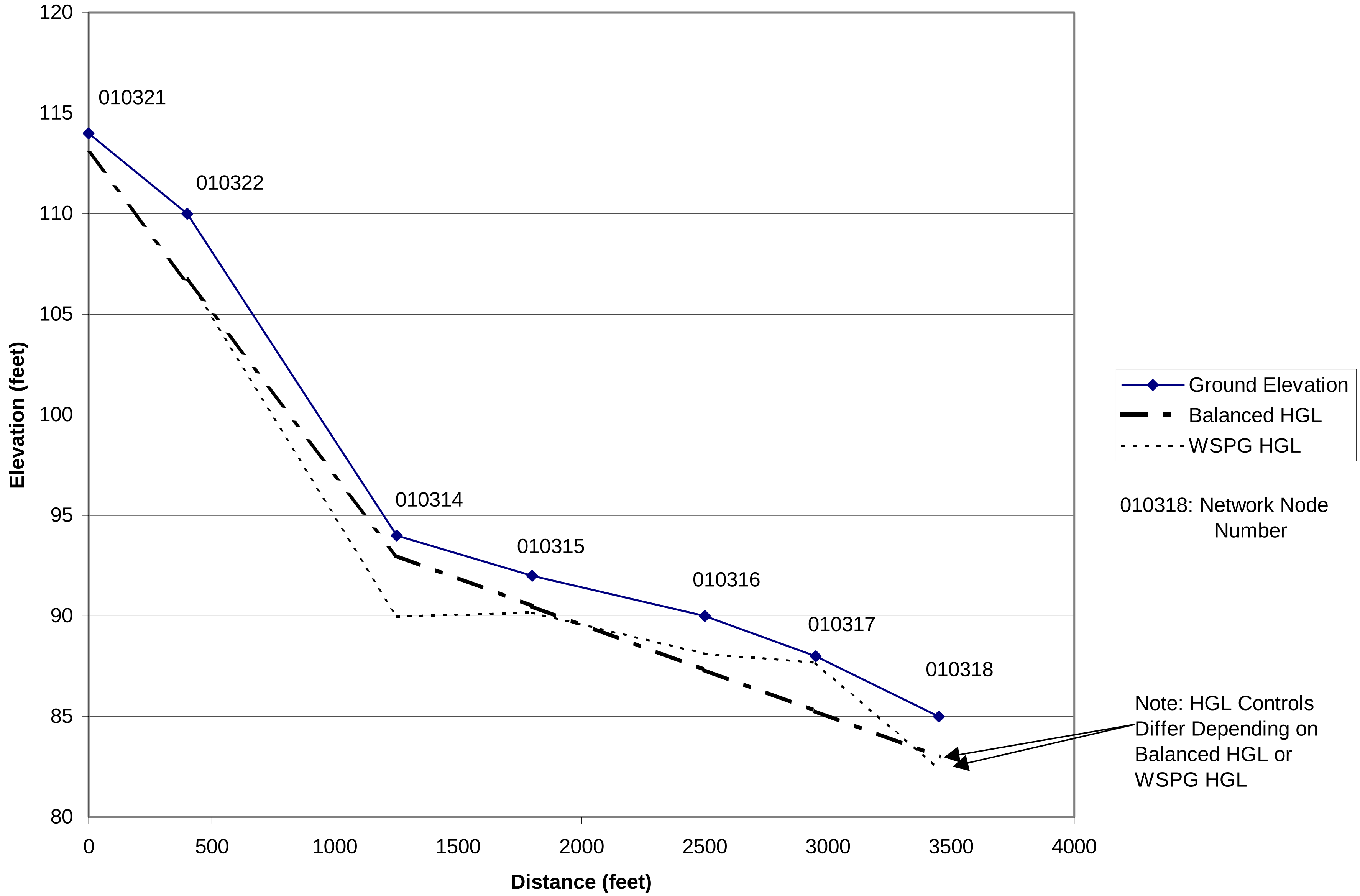

Figure 7.16a Balanced HGL vs. WSPG estimated HGL (Analysis Iteration #1)

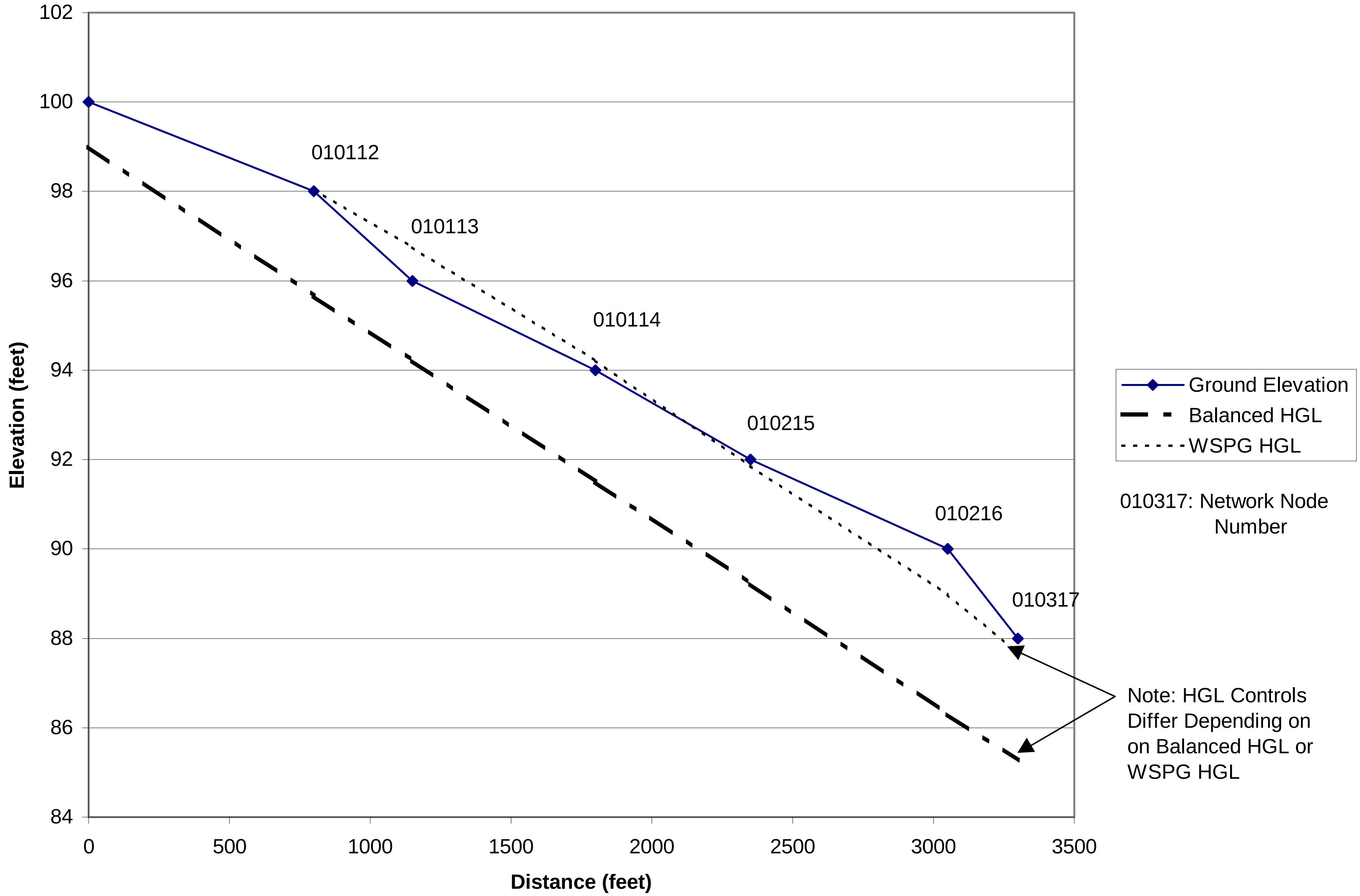

Figure 7.16b Balanced HGL vs. WSPG estimated HGL (Analysis Iteration #1)

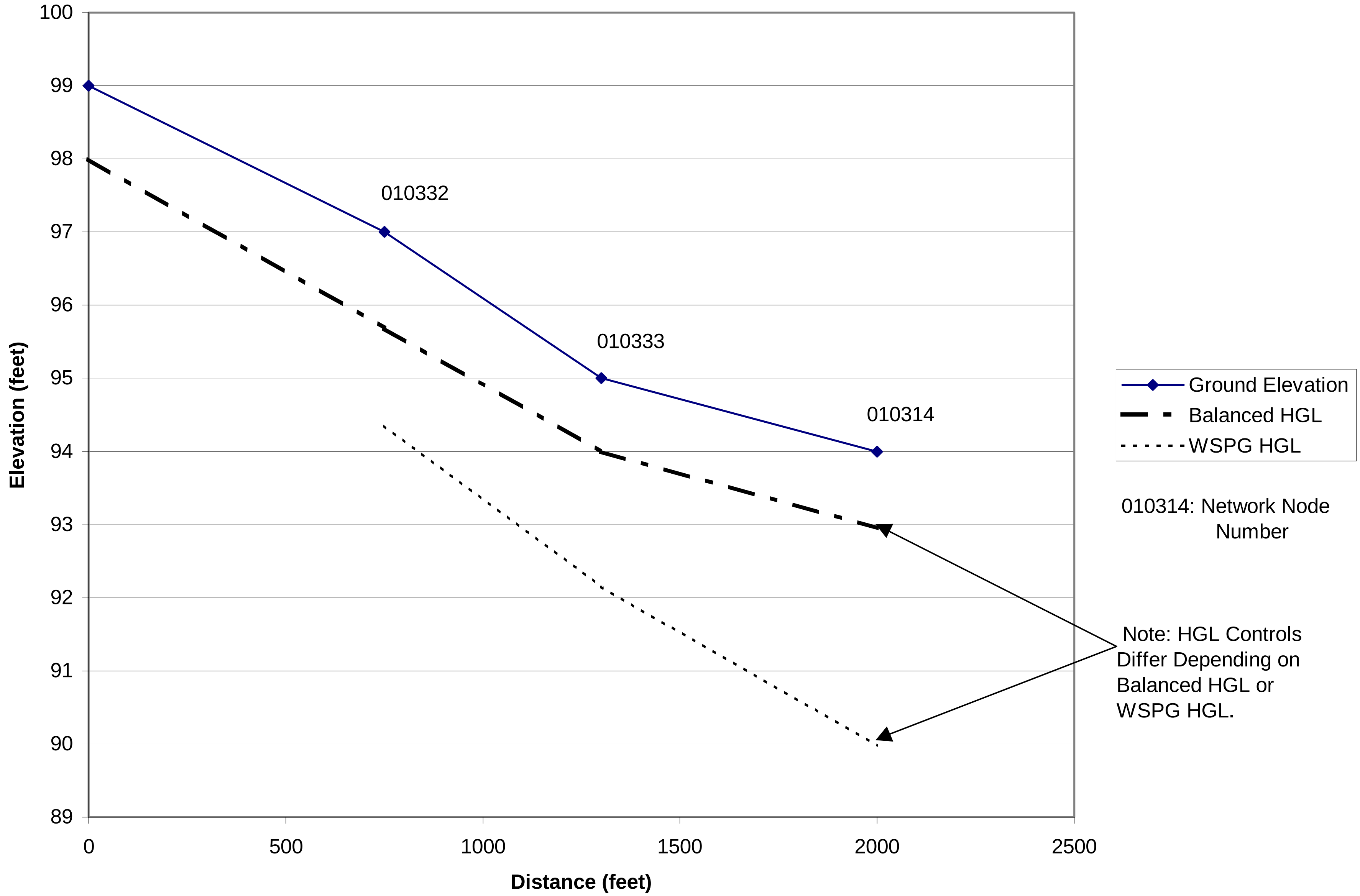

Figure 7.16c Balanced HGL vs. WSPG estimated HGL (Analysis Iteration #1)

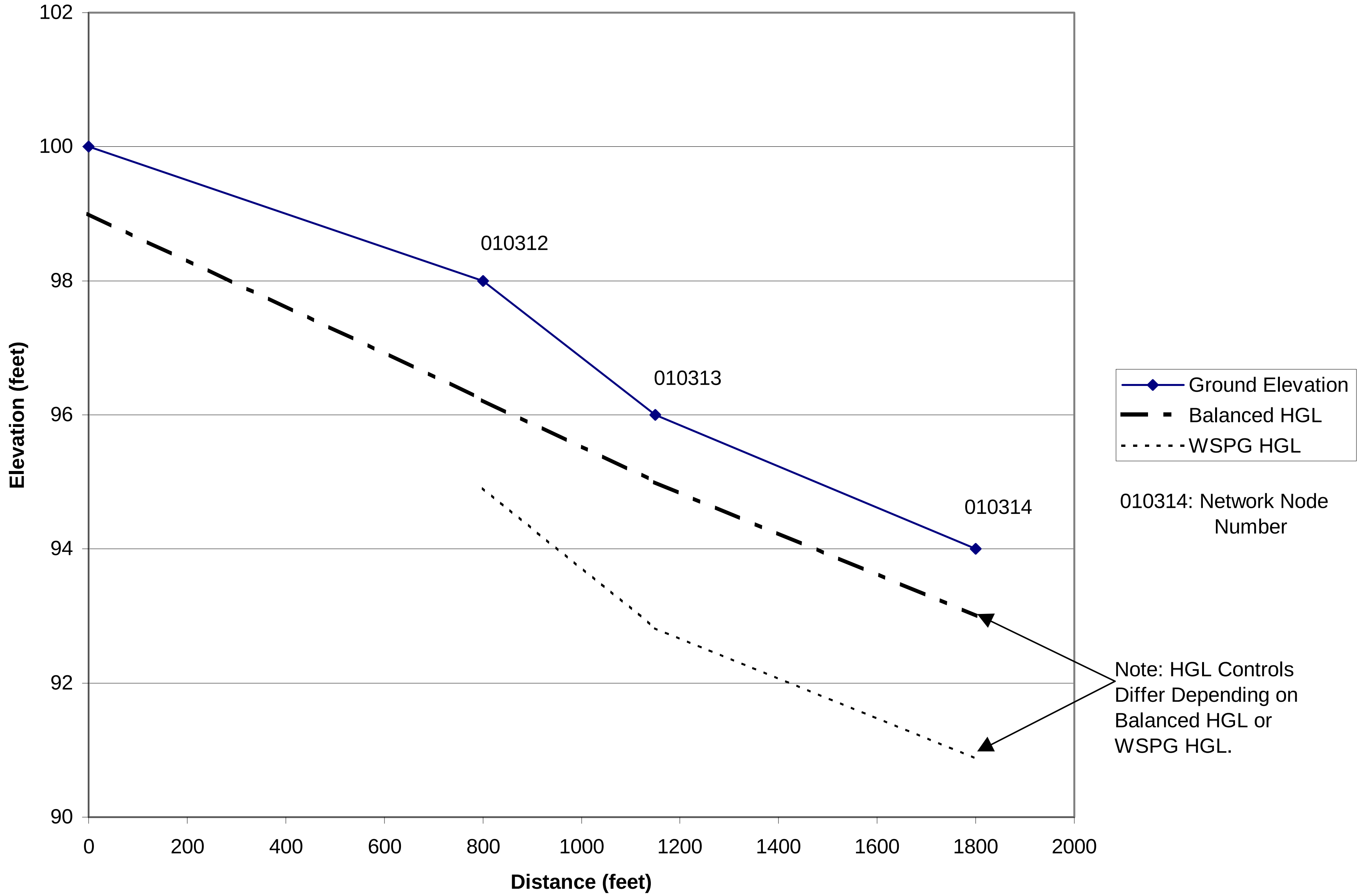

Figure 7.16d Balanced HGL vs. WSPG estimated HGL (Analysis Iteration #1)

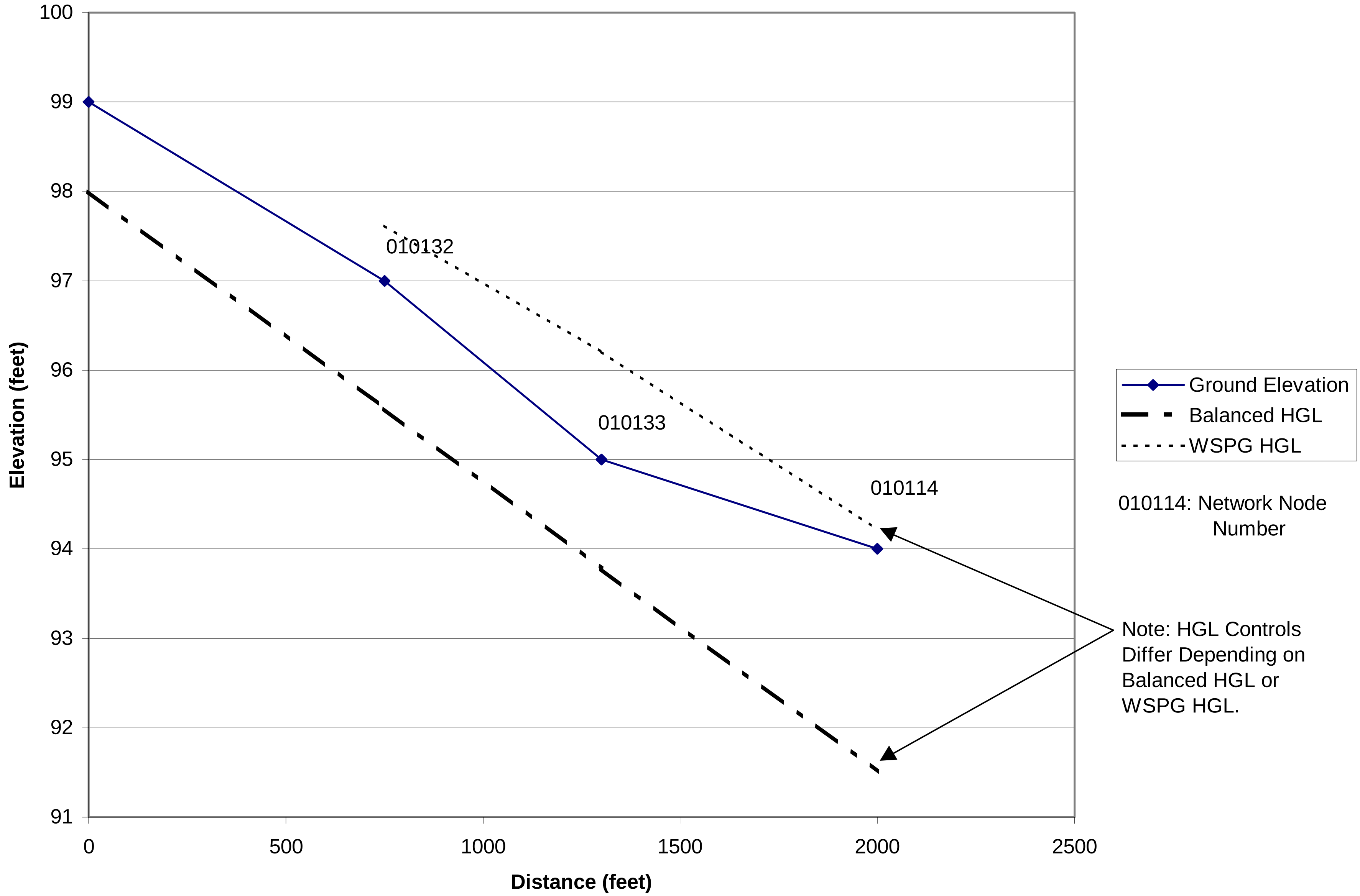

Figure 7.16e Balanced HGL vs. WSPG estimated HGL (Analysis Iteration #1)

Appendix A
Example SIMS Data Base Specifications

CONCEPTUAL NODAL DATA BASE

Field Number	Description	
1	Node Number	(F8.1)
2	Nodal Elevation	(F8.2)
3	Label	('10 CHARACTERS')
4	Associated Downstream Node Number	(F8.1)
5 ~ 54	Future Development	(F8.2)
55	Most upstream node number of the longest flowpath.	(F8.1)
56	Length of the longest flowpath.	(F8.1)
57	Total Area (Ac.)	(F9.3)
58	Depth-area factor for 5-minute rainfall depth.	(F6.4)
59	Depth-area factor for 15-minute rainfall depth.	(F6.4)
60	Depth-area factor for 30-minute rainfall depth.	(F6.4)
61	Depth-area factor for 1-hr. rainfall depth.	(F6.4)
62	Depth-area factor for 2-hr. rainfall depth.	(F6.4)
63	Depth-area factor for 3-hr. rainfall depth.	(F6.4)
64	Depth-area factor for 6-hr. rainfall depth.	(F6.4)
65	Depth-area factor for 12-hr. rainfall depth.	(F6.4)
66	Depth-area factor for 24-hr. rainfall depth.	(F6.4)
67	Depth-area factor for 2-day rainfall depth.	(F6.4)
68	Depth-area factor for 3-day rainfall depth.	(F6.4)
69	Depth-area factor for 4-day rainfall depth.	(F6.4)
70	Depth-area factor for 5-day rainfall depth.	(F6.4)
71	Depth-area factor for 6-day rainfall depth.	(F6.4)
72	Depth-area factor for 7-day rainfall depth.	(F6.4)
73	Accumulative Area-Average Valley-Developed S-graph fraction	(F6.4)
	F0601 Rainfall Zone I fraction.	(F6.4)
74	Accumulative Area-Average Foothill S-graph fraction	(F6.4)
	F0601 Rainfall Zone J fraction.	(F6.4)
75	Accumulative Area-Average Mountain S-graph fraction	(F6.4)
	F0601 Rainfall Zone K faction.	(F6.4)
76	Accumulative Area-Average Desert S-graph fraction	(F6.4)
	F0601 Rainfall Zone L fraction.	(F6.4)
77	Accumulative Area-Average Valley-Undeveloped S-graph fraction	(F6.4)
	F0601 Rainfall Zone M fraction.	(F6.4)
78	Accumulative Area-Average Future (A) S-graph fraction.	(F6.4)
79	Accumulative Area-Average Future (B) S-graph fraction.	(F6.4)
80	Accumulative Area-Average Future (C) S-graph fraction.	(F6.4)
81	Accumulative Area-Average Future (D) S-graph fraction.	(F6.4)
82	Accumulated area-average 5-minute rainfall depth for storm event #1.	(F7.4)
83	Accumulated area-average 15-minute rainfall depth for storm event #1.	(F7.4)
84	Accumulated area-average 30-minute rainfall depth for storm event #1.	(F7.4)
85	Accumulated area-average 1-hr rainfall depth for storm event #1.	(F7.4)
86	Accumulated area-average 2-hr rainfall depth for storm event #1.	(F7.4)
87	Accumulated area-average 3-hr rainfall depth for storm event #1.	(F7.4)
88	Accumulated area-average 6-hr rainfall depth for storm event #1.	(F7.4)
89	Accumulated area-average 12-hr rainfall depth for storm event #1.	(F7.4)
90	Accumulated area-average 24-hr rainfall depth for storm event #1.	(F7.4)
91	Accumulated area-average 2-day rainfall depth for storm event #1.	(F7.4)
92	Accumulated area-average 3-day rainfall depth for storm event #1.	(F7.4)
93	Accumulated area-average 4-day rainfall depth for storm event #1.	(F7.4)
94	Accumulated area-average 5-day rainfall depth for storm event #1.	(F7.4)
95	Accumulated area-average 6-day rainfall depth for storm event #1.	(F7.4)
96	Accumulated area-average 7-day rainfall depth for storm event #1.	(F7.4)

97	Accumulated area-average 5-minute rainfall depth for storm event #2.	(F7.4)
98	Accumulated area-average 15-minute rainfall depth for storm event #2.	(F7.4)
99	Accumulated area-average 30-minute rainfall depth for storm event #2.	(F7.4)
100	Accumulated area-average 1-hr rainfall depth for storm event #2.	(F7.4)
101	Accumulated area-average 2-hr rainfall depth for storm event #2.	(F7.4)
102	Accumulated area-average 3-hr rainfall depth for storm event #2.	(F7.4)
103	Accumulated area-average 6-hr rainfall depth for storm event #2.	(F7.4)
104	Accumulated area-average 12-hr rainfall depth for storm event #2.	(F7.4)
105	Accumulated area-average 24-hr rainfall depth for storm event #2.	(F7.4)
106	Accumulated area-average 2-day rainfall depth for storm event #2.	(F7.4)
107	Accumulated area-average 3-day rainfall depth for storm event #2.	(F7.4)
108	Accumulated area-average 4-day rainfall depth for storm event #2.	(F7.4)
109	Accumulated area-average 5-day rainfall depth for storm event #2.	(F7.4)
110	Accumulated area-average 6-day rainfall depth for storm event #2.	(F7.4)
111	Accumulated area-average 7-day rainfall depth for storm event #2.	(F7.4)
112	Accumulated area-average 5-minute rainfall depth for storm event #3.	(F7.4)
113	Accumulated area-average 15-minute rainfall depth for storm event #3.	(F7.4)
114	Accumulated area-average 30-minute rainfall depth for storm event #3.	(F7.4)
115	Accumulated area-average 1-hr rainfall depth for storm event #3.	(F7.4)
116	Accumulated area-average 2-hr rainfall depth for storm event #3.	(F7.4)
117	Accumulated area-average 3-hr rainfall depth for storm event #3.	(F7.4)
118	Accumulated area-average 6-hr rainfall depth for storm event #3.	(F7.4)
119	Accumulated area-average 12-hr rainfall depth for storm event #3.	(F7.4)
120	Accumulated area-average 24-hr rainfall depth for storm event #3.	(F7.4)
121	Accumulated area-average 2-day rainfall depth for storm event #3.	(F7.4)
122	Accumulated area-average 3-day rainfall depth for storm event #3.	(F7.4)
123	Accumulated area-average 4-day rainfall depth for storm event #3.	(F7.4)
124	Accumulated area-average 5-day rainfall depth for storm event #3.	(F7.4)
125	Accumulated area-average 6-day rainfall depth for storm event #3.	(F7.4)
126	Accumulated area-average 7-day rainfall depth for storm event #3.	(F7.4)
127	Accumulated area-average 5-minute rainfall depth for storm event #4.	(F7.4)
128	Accumulated area-average 15-minute rainfall depth for storm event #4.	(F7.4)
129	Accumulated area-average 30-minute rainfall depth for storm event #4.	(F7.4)
130	Accumulated area-average 1-hr rainfall depth for storm event #4.	(F7.4)
131	Accumulated area-average 2-hr rainfall depth for storm event #4.	(F7.4)
132	Accumulated area-average 3-hr rainfall depth for storm event #4.	(F7.4)
133	Accumulated area-average 6-hr rainfall depth for storm event #4.	(F7.4)
134	Accumulated area-average 12-hr rainfall depth for storm event #4.	(F7.4)

135	Accumulated area-average 24-hr rainfall depth for storm event #4.	(F7.4)
136	Accumulated area-average 2-day rainfall depth for storm event #4.	(F7.4)
137	Accumulated area-average 3-day rainfall depth for storm event #4.	(F7.4)
138	Accumulated area-average 4-day rainfall depth for storm event #4.	(F7.4)
139	Accumulated area-average 5-day rainfall depth for storm event #4.	(F7.4)
140	Accumulated area-average 6-day rainfall depth for storm event #4.	(F7.4)
141	Accumulated area-average 7-day rainfall depth for storm event #4.	(F7.4)
142	Accumulated area-average 5-minute rainfall depth for storm event #5.	(F7.4)
143	Accumulated area-average 15-minute rainfall depth for storm event #5.	(F7.4)
144	Accumulated area-average 30-minute rainfall depth for storm event #5.	(F7.4)
145	Accumulated area-average 1-hr rainfall depth for storm event #5.	(F7.4)
146	Accumulated area-average 2-hr rainfall depth for storm event #5.	(F7.4)
147	Accumulated area-average 3-hr rainfall depth for storm event #5.	(F7.4)
148	Accumulated area-average 6-hr rainfall depth for storm event #5.	(F7.4)
149	Accumulated area-average 12-hr rainfall depth for storm event #5.	(F7.4)
150	Accumulated area-average 24-hr rainfall depth for storm event #5.	(F7.4)
151	Accumulated area-average 2-day rainfall depth for storm event #5.	(F7.4)
152	Accumulated area-average 3-day rainfall depth for storm event #5.	(F7.4)
153	Accumulated area-average 4-day rainfall depth for storm event #5.	(F7.4)
154	Accumulated area-average 5-day rainfall depth for storm event #5.	(F7.4)
155	Accumulated area-average 6-day rainfall depth for storm event #5.	(F7.4)
156	Accumulated area-average 7-day rainfall depth for storm event #5.	(F7.4)
157	Accumulated area-average 5-minute rainfall depth for storm event #6.	(F7.4)
158	Accumulated area-average 15-minute rainfall depth for storm event #6.	(F7.4)
159	Accumulated area-average 30-minute rainfall depth for storm event #6.	(F7.4)
160	Accumulated area-average 1-hr rainfall depth for storm event #6.	(F7.4)
161	Accumulated area-average 2-hr rainfall depth for storm event #6.	(F7.4)
162	Accumulated area-average 3-hr rainfall depth for storm event #6.	(F7.4)
163	Accumulated area-average 6-hr rainfall depth for storm event #6.	(F7.4)
164	Accumulated area-average 12-hr rainfall depth for storm event #6.	(F7.4)
165	Accumulated area-average 24-hr rainfall depth for storm event #6.	(F7.4)
166	Accumulated area-average 2-day rainfall depth for storm event #6.	(F7.4)
167	Accumulated area-average 3-day rainfall depth for storm event #6.	(F7.4)
168	Accumulated area-average 4-day rainfall depth for storm event #6.	(F7.4)
169	Accumulated area-average 5-day rainfall depth for storm event #6.	(F7.4)
170	Accumulated area-average 6-day rainfall depth for storm event #6.	(F7.4)
171	Accumulated area-average 7-day rainfall depth for storm event #6.	(F7.4)
172	Accumulated Mean Annual Precipitation (in.)	(F7.4)
173	Future Rainfall A	(F7.4)

174	Future Rainfall B	(F7.4)
175	Future Rainfall C	(F7.4)
176	Future Rainfall D	(F7.4)
177	Future Rainfall E	(F7.4)
178	Tc for the longest flowpath for storm event #1.	(F7.3)
179	Tc for the longest flowpath for storm event #2.	(F7.3)
180	Tc for the longest flowpath for storm event #3.	(F7.3)
181	Tc for the longest flowpath for storm event #4.	(F7.3)
182	Tc for the longest flowpath for storm event #5.	(F7.3)
183	Tc for the longest flowpath for storm event #6.	(F7.3)
184	LAG for the longest flowpath for storm event #1.	(F7.4)
185	LAG for the longest flowpath for storm event #2.	(F7.4)
186	LAG for the longest flowpath for storm event #3.	(F7.4)
187	LAG for the longest flowpath for storm event #4.	(F7.4)
188	LAG for the longest flowpath for storm event #5.	(F7.4)
189	LAG for the longest flowpath for storm event #6.	(F7.4)
190	Area-average Loss Rate (Fm) for storm event #1.	(F7.4)
191	Area-average Low Loss Fraction (Ybar) for storm event #1.	(F7.5)
192	Future Loss Rate A for storm event #1.	(F7.4)
193	Future Loss Fraction B for storm event #1.	(F7.5)
194	Future Loss Rate C for storm event #1.	(F7.4)
195	Future Loss Fraction D for storm event #1.	(F7.5)
196	Area-average Loss Rate (Fm) for storm event #2.	(F7.4)
197	Area-average Low Loss Fraction (Ybar) for storm event #2.	(F7.5)
198	Future Loss Rate A for storm event #2.	(F7.4)
199	Future Loss Fraction B for storm event #2.	(F7.5)
200	Future Loss Rate C for storm event #2.	(F7.4)
201	Future Loss Fraction D for storm event #2.	(F7.5)
202	Area-average Loss Rate (Fm) for storm event #3.	(F7.4)
203	Area-average Low Loss Fraction (Ybar) for storm event #3.	(F7.5)
204	Future Loss Rate A for storm event #3.	(F7.4)
205	Future Loss Fraction B for storm event #3.	(F7.5)
206	Future Loss Rate C for storm event #3.	(F7.4)
207	Future Loss Fraction D for storm event #4.	(F7.5)
208	Area-average Loss Rate (Fm) for storm event #4.	(F7.4)
209	Area-average Low Loss Fraction (Ybar) for storm event #4.	(F7.5)
210	Future Loss Rate A for storm event #4.	(F7.4)
211	Future Loss Fraction B for storm event #4.	(F7.5)
212	Future Loss Rate C for storm event #4.	(F7.4)
213	Future Loss Fraction D for storm event #4.	(F7.5)
214	Area-average Loss Rate (Fm) for storm event #5.	(F7.4)
215	Area-average Low Loss Fraction (Ybar) for storm event #5.	(F7.5)
216	Future Loss Rate A for storm event #5.	(F7.4)
217	Future Loss Fraction B for storm event #5.	(F7.5)
218	Future Loss Rate C for storm event #5.	(F7.4)
219	Future Loss Fraction D for storm event #5.	(F7.5)
220	Area-average Loss Rate (Fm) for storm event #6.	(F7.4)
221	Area-average Low Loss Fraction (Ybar) for storm event #6.	(F7.5)
222	Future Loss Rate A for storm event #6.	(F7.4)
223	Future Loss Fraction B for storm event #6.	(F7.5)
224	Future Loss Rate C for storm event #6.	(F7.4)
225	Future Loss Fraction D for storm event #6.	(F7.5)
226	Peak Flow Rate for storm event #1 for AES Rational Model.	(F10.2)
227	Peak Flow Rate for storm event #2 for AES Rational Model.	(F10.2)
228	Peak Flow Rate for storm event #3 for AES Rational Model.	(F10.2)
229	Peak Flow Rate for storm event #4 for AES Rational Model.	(F10.2)
230	Peak Flow Rate for storm event #5 for AES Rational Model.	(F10.2)
231	Peak Flow Rate for storm event #6 for AES Rational Model.	(F10.2)
232	Peak Flow Rate for storm event #1 for LAF0601 Model.	(F10.2)
233	Peak Flow Rate for storm event #2 for LAF0601 Model.	(F10.2)
234	Peak Flow Rate for storm event #3 for LAF0601 Model.	(F10.2)
235	Peak Flow Rate for storm event #4 for LAF0601 Model.	(F10.2)
236	Peak Flow Rate for storm event #5 for LAF0601 Model.	(F10.2)
237	Peak Flow Rate for storm event #6 for LAF0601 Model.	(F10.2)
238	Peak Flow Rate for storm event #1 for HEC-1 Model.	(F10.2)
239	Peak Flow Rate for storm event #2 for HEC-1 Model.	(F10.2)
240	Peak Flow Rate for storm event #3 for HEC-1 Model.	(F10.2)
241	Peak Flow Rate for storm event #4 for HEC-1 Model.	(F10.2)
242	Peak Flow Rate for storm event #5 for HEC-1 Model.	(F10.2)
243	Peak Flow Rate for storm event #6 for HEC-1 Model.	(F10.2)
244	Peak Flow Rate for storm event #1 for AES FLOOD Model.	(F10.2)
245	Peak Flow Rate for storm event #2 for AES FLOOD Model.	(F10.2)
246	Peak Flow Rate for storm event #3 for AES FLOOD Model.	(F10.2)
247	Peak Flow Rate for storm event #4 for AES FLOOD Model.	(F10.2)
248	Peak Flow Rate for storm event #5 for AES FLOOD Model.	(F10.2)
249	Peak Flow Rate for storm event #6 for AES FLOOD Model.	(F10.2)

250	Peak Flow Rate for storm event #1 for AES FLOOD Model with Basins.	(F10.2)
251	Peak Flow Rate for storm event #2 for AES FLOOD Model with Basins.	(F10.2)
252	Peak Flow Rate for storm event #3 for AES FLOOD Model with Basins.	(F10.2)
253	Peak Flow Rate for storm event #4 for AES FLOOD Model with Basins.	(F10.2)
254	Peak Flow Rate for storm event #5 for AES FLOOD Model with Basins.	(F10.2)
255	Peak Flow Rate for storm event #6 for AES FLOOD Model with Basins.	(F10.2)
256	Peak Flow Rate for storm event #1 for Multiple Objective Model.	(F10.2)
257	Peak Flow Rate for storm event #2 for Multiple Objective Model.	(F10.2)
258	Peak Flow Rate for storm event #3 for Multiple Objective Model.	(F10.2)
259	Peak Flow Rate for storm event #4 for Multiple Objective Model.	(F10.2)
260	Peak Flow Rate for storm event #5 for Multiple Objective Model.	(F10.2)
261	Peak Flow Rate for storm event #6 for Multiple Objective Model.	(F10.2)
262	Computer Estimated Peak Flow Rate for storm event #1.	(F10.2)
263	Computer Estimated Peak Flow Rate for storm event #2.	(F10.2)
264	Computer Estimated Peak Flow Rate for storm event #3.	(F10.2)
265	Computer Estimated Peak Flow Rate for storm event #4.	(F10.2)
266	Computer Estimated Peak Flow Rate for storm event #5.	(F10.2)
267	Computer Estimated Peak Flow Rate for storm event #6.	(F10.2)
268	Computer Recommended Peak Flow Rate for storm event #1.	(F10.2)
269	Computer Recommended Peak Flow Rate for storm event #2.	(F10.2)
270	Computer Recommended Peak Flow Rate for storm event #3.	(F10.2)
271	Computer Recommended Peak Flow Rate for storm event #4.	(F10.2)
272	Computer Recommended Peak Flow Rate for storm event #5.	(F10.2)
273	Computer Recommended Peak Flow Rate for storm event #6.	(F10.2)
274	User Recommended Peak Flow Rate for storm event #1.	(F10.2)
275	User Recommended Peak Flow Rate for storm event #2.	(F10.2)
276	User Recommended Peak Flow Rate for storm event #3.	(F10.2)
277	User Recommended Peak Flow Rate for storm event #4.	(F10.2)
278	User Recommended Peak Flow Rate for storm event #5.	(F10.2)
279	User Recommended Peak Flow Rate for storm event #6.	(F10.2)
280	Peak Flow Rate Adjustment Factor for storm event #1.	(F6.4)
281	Peak Flow Rate Adjustment Factor for storm event #2.	(F6.4)
282	Peak Flow Rate Adjustment Factor for storm event #3.	(F6.4)
283	Peak Flow Rate Adjustment Factor for storm event #4.	(F6.4)
284	Peak Flow Rate Adjustment Factor for storm event #5.	(F6.4)
285	Peak Flow Rate Adjustment Factor for storm event #6.	(F6.4)
286	NPDES Flag (1 = Yes; 0 = No.)	(I2)
287	Flood Control Basin Flag (1 = Yes; 0 = No.).	(I2)
288	Future Data.	(F8.2)
289	Future Data.	(F8.2)
290	Future Data.	(F8.2)
291	Future Data.	(F8.2)
292	Future Data.	(F8.2)
293	Upstream Conduit Invert Elevation. (Drop Structure)	(F8.2)
294	Downstream Conduit Invert Elevation. (Drop Structure)	(F8.2)
295	Upstream Conduit HGL Elevation. (Drop Structure)	(F8.2)
296	Downstream Conduit HGL Elevation. (Drop Structure)	(F8.2)
297	Freeboard Depth = Topographic Elevation – Max (Upstream HGL, Downstream HGL).	(F8.2)
298	Future Development	(F8.2)
299	Future Development	(F8.2)
300	Future Development	(F8.2)
301	Land Use Type.	(F8.2)
302	Soil Grouping (N/A for F0601).	(F8.2)
303	Accumulated Area up to this Node Number. Repeat 301,302 and 303 as needed (maximum triplets are limited to 100).	(F10.2)
602	Confluence Upstream Node Number #1.	(F8.1)
603	Confluence Upstream Node Number #2.	(F8.1)
604	Confluence Upstream Node Number #3.	(F8.1)
605	Confluence Upstream Node Number #4.	(F8.1)
606	Confluence Upstream Node Number #5.	(F8.1)
607 ~ 636	PDES Annual Pollutant Loadings Estimation (values need to be multiplied by 100).	(F8.2)
Add 20 fields for future development.		(F8.2)

CONCEPTUAL LINK DATA BASE

Field Number	Description	
1	Upstream Node Number	(F8.1)
2	Downstream Node Number	(F8.1)
3	Upstream Topographic Elevation	(F8.2)
4	Downstream Topographic Elevation	(F8.2)
5	Associated Node Number	(F8.1)
6	Label	('10 CHARACTERS')
7	Hydrologic/hydraulic process ID	(I3)
8	Length	(F8.2)
9	Topographic Slope	(F7.5)
10	Curb Height	(F6.3)
11	Half Street Width	(F8.2)
12	Gutter Lip	(F8.4)
13	Gutter Width	(F8.4)
14	Gutter Hike	(F8.4)
15	Distance from Crown to Grade Break	(F8.2)
16	Interior Street Grade	(F8.4)
17	Exterior Street Grade	(F8.4)
18	Parkway Grade	(F8.4)
19	Street Carry Capacity (1 = one-side; 2 = two-side)	(I2)
20	Street Friction Factor	(F8.4)
21	Street ID	(I3)
22	Existing Conduit ID	(I3)
23	Diameter/Height(Existing system)	(F8.3)
24	Width(Existing system)	(F8.3)
25	Side slope(Existing system)	(F8.3)
26	Friction factor(Existing system)	(F8.4)
27	Freeboard(Existing system)	(F8.2)
28	Upstream Invert Elevation(Existing system)	(F8.2)
29	Downstream Invert Elevation(Existing system)	(F8.2)
30	Invert Slope(Existing system)	(F8.4)
31	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #1 for Upstream Node Number.	(F10.2)
32	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #2 for Upstream Node Number.	(F10.2)
33	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #3 for Upstream Node Number.	(F10.2)
34	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #4 for Upstream Node Number.	(F10.2)
35	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #5 for Upstream Node Number.	(F10.2)
36	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #6 for Upstream Node Number.	(F10.2)
37	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #1 for Downstream Node Number.	(F10.2)
38	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #2 for Downstream Node Number.	(F10.2)
39	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #3 for Downstream Node Number.	(F10.2)
40	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #4 for Downstream Node Number.	(F10.2)
41	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #5 for Downstream Node Number.	(F10.2)
42	Recommended Peak Flow Rate(includes Street Flow) for Storm Event #6 for Downstream Node Number.	(F10.2)
43	Street Allowable Flow Depth for Storm Event #1.	(F8.3)
44	Street Allowable Flow Depth for Storm Event #2.	(F8.3)
45	Street Allowable Flow Depth for Storm Event #3.	(F8.3)
46	Street Allowable Flow Depth for Storm Event #4.	(F8.3)
47	Street Allowable Flow Depth for Storm Event #5.	(F8.3)
48	Street Allowable Flow Depth for Storm Event #6.	(F8.3)
49	Street Capacity for Storm Event #1.	(F8.2)
50	Street Capacity for Storm Event #2.	(F8.2)
51	Street Capacity for Storm Event #3.	(F8.2)
52	Street Capacity for Storm Event #4.	(F8.2)
53	Street Capacity for Storm Event #5.	(F8.2)
54	Street Capacity for Storm Event #6.	(F8.2)
55	HGL Optimized Friction Slope.	(F8.4)
56	Maximum Possible Friction Slope.	(F8.4)
57	Balanced U/S HGL.	(F8.4)

58	Balanced D/S HGL.	(F8.4)
59	Future Development.	(F8.4)
60	Future Development.	(F8.4)
61	Future Development.	(F8.4)
62	User Recommended Replacement/Parallel System Flag. (1 = Replacement; 2 = Parallel)	(F8.4)
63	Computer Estimated Friction Slope for Estimating Existing Conduit Capacity.	(F8.4)
64	Computer Recommended Friction Slope for Estimating Existing Conduit Capacity.	(F8.4)
65	User-Recommended Friction Slope for Estimating Existing Conduit Capacity.	(F8.4)
66	Ratio	(F8.4)
67	Future Development	(F8.4)
68	Computer Estimated Friction Slope for Estimating Future Conduit Capacity.	(F8.4)
69	Computer Recommended Friction Slope for Estimating Future Conduit Capacity.	(F8.4)
70	User-Recommended Friction Slope for Estimating Future Conduit Capacity.	(F8.4)
71	Ratio	(F8.4)
72	Future Development	(F8.4)
73	Computer Estimated Existing Conduit Conveyance Capacity.	(F8.2)
74	Computer Recommended Existing Conduit Conveyance Capacity.	(F8.2)
75	User-Recommended Existing Conduit Conveyance Capacity.	(F8.2)
76	Ratio	(F8.2)
77	Future Development	(F8.2)
78	Existing Total Conveyance Capacity for Storm Event #1.	(F10.2)
79	Existing Total Conveyance Capacity for Storm Event #2.	(F10.2)
80	Existing Total Conveyance Capacity for Storm Event #3.	(F10.2)
81	Existing Total Conveyance Capacity for Storm Event #4.	(F10.2)
82	Existing Total Conveyance Capacity for Storm Event #5.	(F10.2)
83	Existing Total Conveyance Capacity for Storm Event #6.	(F10.2)
84	Deficiency for Storm Event #1 (based upon user-recommended peak flow rate).	(F10.2)
85	Deficiency for Storm Event #2 (based upon user-recommended peak flow rate).	(F10.2)
86	Deficiency for Storm Event #3 (based upon user-recommended peak flow rate).	(F10.2)
87	Deficiency for Storm Event #4 (based upon user-recommended peak flow rate).	(F10.2)
88	Deficiency for Storm Event #5 (based upon user-recommended peak flow rate).	(F10.2)
89	Deficiency for Storm Event #6 (based upon user-recommended peak flow rate).	(F10.2)
90	Deficiency Target Delta Peak Flow Rate.	(F10.2)
91	Deficiency Target Return Frequency.	(I4)
92	Diameter/Height(Computer Estimated Replacement System).	(F8.3)
93	Width(Computer Estimated Replacement System).	(F8.3)
94	Side slope(Computer Estimated Replacement System).	(F8.5)
95	Friction factor(Computer Estimated Replacement System).	(F8.5)
96	Freeboard(Computer Estimated Replacement System).	(F8.2)
97	System Peak Flow Rate(Computer Estimated).	(F8.2)
98	Diameter (Computer Estimated Parallel System).	(F8.2)
99	Friction Factor (Computer Estimated Parallel System).	(F8.5)
100	System Cost Status.	(F8.2)
101	Other Data (Computer Estimated Parallel System).	(F8.2)
102	Diameter/Height(Computer Recommended Replacement System).	(F8.3)
103	Width(Computer Recommended Replacement System).	(F8.3)
104	Side slope(Computer Recommended Replacement System).	(F8.5)
105	Friction factor(Computer Recommended Replacement System).	(F8.5)
106	Freeboard(Computer Recommended Replacement System).	(F8.2)
107	System Peak Flow Rate(Computer Recommended).	(F8.2)
108	Diameter (Computer Recommended Parallel System).	(F8.2)
109	Friction Factor (Computer Recommended Parallel System).	(F8.5)
110	Computer Recommended System ID.	(F8.2)
111	Other Data (Computer Recommended Parallel System).	(F8.2)
112	Diameter/Height(User Recommended Replacement System).	(F8.3)
113	Width(User Recommended Replacement System).	(F8.3)
114	Side slope(User Recommended Replacement System).	(F8.5)
115	Friction factor(User Recommended Replacement System).	(F8.5)
116	Freeboard(User Recommended Replacement System).	(F8.2)
117	Other Data(User Recommended Replacement System).	(F8.2)
118	Diameter (User Recommended Parallel System).	(F8.2)
119	Friction Factor (User Recommended Parallel System).	(F8.5)
120	Other Data (User Recommended Parallel System).	(F8.2)

121	Other Data (User Recommended Parallel System).	(F8.2)
122	Recommended System Code.	(I3)
123	Recommended System ID	(I3)
124	Upstream Invert Elevation(Recommended system)	(F8.2)
125	Downstream Invert Elevation(Recommended system)	(F8.2)
126	Upstream flow velocity for Recommended system.	(F8.2)
127	Downstream flow velocity for Recommended system.	(F8.2)
128	Upstream flow depth for Recommended system.	(F8.2)
129	Upstream HGL for Recommended system.	(F8.2)
130	Downstream flow depth for Recommended system.	(F8.2)
131	Downstream HGL for Recommended system.	(F8.2)
132	Difference of upstream HGL and Nodal Elevation for Recommended system.	(F8.2)
133	Difference of downstream HGL and Nodal Elevation for Recommended system.	(F8.2)
134	Normal Depth	(F8.2)
135	Critical Depth	(F8.2)
136	Unit cost opinion	(F8.2)
137	Cost-to-Benefit Index	(F8.2)
138	Priority Grouping	(I3)
Add 50 fields for string template data.		(F8.2)

CONCEPTUAL SUBAREA DATA BASE

Field Number	Description	
1	Subarea Number	(F8.1)
2	Label	('10 CHARACTERS')
3	Subarea average 5-minute rainfall depth for storm event #1	(F8.3)
4	Subarea average 15-minute rainfall depth for storm event #1	(F8.3)
5	Subarea average 30-minute rainfall depth for storm event #1	(F8.3)
6	Subarea average 1-hr rainfall depth for storm event #1	(F8.3)
7	Subarea average 2-hr rainfall depth for storm event #1	(F8.3)
8	Subarea average 3-hr rainfall depth for storm event #1	(F8.3)
9	Subarea average 6-hr rainfall depth for storm event #1	(F8.3)
10	Subarea average 12-hr rainfall depth for storm event #1	(F8.3)
11	Subarea average 24-hr rainfall depth for storm event #1	(F8.3)
12	Subarea average 2-day rainfall depth for storm event #1	(F8.3)
13	Subarea average 3-day rainfall depth for storm event #1	(F8.3)
14	Subarea average 4-day rainfall depth for storm event #1	(F8.3)
15	Subarea average 5-day rainfall depth for storm event #1	(F8.3)
16	Subarea average 6-day rainfall depth for storm event #1	(F8.3)
17	Subarea average 7-day rainfall depth for storm event #1	(F8.3)
18	Subarea average 5-minute rainfall depth for storm event #2	(F8.3)
19	Subarea average 15-minute rainfall depth for storm event #2	(F8.3)
20	Subarea average 30-minute rainfall depth for storm event #2	(F8.3)
21	Subarea average 1-hr rainfall depth for storm event #2	(F8.3)
22	Subarea average 2-hr rainfall depth for storm event #2	(F8.3)
23	Subarea average 3-hr rainfall depth for storm event #2	(F8.3)
24	Subarea average 6-hr rainfall depth for storm event #2	(F8.3)
25	Subarea average 12-hr rainfall depth for storm event #2	(F8.3)
26	Subarea average 24-hr rainfall depth for storm event #2	(F8.3)
27	Subarea average 2-day rainfall depth for storm event #2	(F8.3)
28	Subarea average 3-day rainfall depth for storm event #2	(F8.3)
29	Subarea average 4-day rainfall depth for storm event #2	(F8.3)
30	Subarea average 5-day rainfall depth for storm event #2	(F8.3)
31	Subarea average 6-day rainfall depth for storm event #2	(F8.3)
32	Subarea average 7-day rainfall depth for storm event #2	(F8.3)
33	Subarea average 5-minute rainfall depth for storm event #3	(F8.3)
34	Subarea average 15-minute rainfall depth for storm event #3	(F8.3)
35	Subarea average 30-minute rainfall depth for storm event #3	(F8.3)
36	Subarea average 1-hr rainfall depth for storm event #3	(F8.3)
37	Subarea average 2-hr rainfall depth for storm event #3	(F8.3)
38	Subarea average 3-hr rainfall depth for storm event #3	(F8.3)
39	Subarea average 6-hr rainfall depth for storm event #3	(F8.3)
40	Subarea average 12-hr rainfall depth for storm event #3	(F8.3)
41	Subarea average 24-hr rainfall depth for storm event #3	(F8.3)
42	Subarea average 2-day rainfall depth for storm event #3	(F8.3)
43	Subarea average 3-day rainfall depth for storm event #3	(F8.3)
44	Subarea average 4-day rainfall depth for storm event #3	(F8.3)
45	Subarea average 5-day rainfall depth for storm event #3	(F8.3)
46	Subarea average 6-day rainfall depth for storm event #3	(F8.3)
47	Subarea average 7-day rainfall depth for storm event #3	(F8.3)
48	Subarea average 5-minute rainfall depth for storm event #4	(F8.3)
49	Subarea average 15-minute rainfall depth for storm event #4	(F8.3)
50	Subarea average 30-minute rainfall depth for storm event #4	(F8.3)
51	Subarea average 1-hr rainfall depth for storm event #4	(F8.3)
52	Subarea average 2-hr rainfall depth for storm event #4	(F8.3)
53	Subarea average 3-hr rainfall depth for storm event #4	(F8.3)
54	Subarea average 6-hr rainfall depth for storm event #4	(F8.3)
55	Subarea average 12-hr rainfall depth for storm event #4	(F8.3)
56	Subarea average 24-hr rainfall depth for storm event #4	(F8.3)
57	Subarea average 2-day rainfall depth for storm event #4	(F8.3)
58	Subarea average 3-day rainfall depth for storm event #4	(F8.3)
59	Subarea average 4-day rainfall depth for storm event #4	(F8.3)
60	Subarea average 5-day rainfall depth for storm event #4	(F8.3)
61	Subarea average 6-day rainfall depth for storm event #4	(F8.3)
62	Subarea average 7-day rainfall depth for storm event #4	(F8.3)
63	Subarea average 5-minute rainfall depth for storm event #5	(F8.3)
64	Subarea average 15-minute rainfall depth for storm event #5	(F8.3)
65	Subarea average 30-minute rainfall depth for storm event #5	(F8.3)
66	Subarea average 1-hr rainfall depth for storm event #5	(F8.3)
67	Subarea average 2-hr rainfall depth for storm event #5	(F8.3)
68	Subarea average 3-hr rainfall depth for storm event #5	(F8.3)
69	Subarea average 6-hr rainfall depth for storm event #5	(F8.3)
70	Subarea average 12-hr rainfall depth for storm event #5	(F8.3)
71	Subarea average 24-hr rainfall depth for storm event #5	(F8.3)

72	Subarea average 2-day rainfall depth for storm event #5	(F8.3)
73	Subarea average 3-day rainfall depth for storm event #5	(F8.3)
74	Subarea average 4-day rainfall depth for storm event #5	(F8.3)
75	Subarea average 5-day rainfall depth for storm event #5	(F8.3)
76	Subarea average 6-day rainfall depth for storm event #5	(F8.3)
77	Subarea average 7-day rainfall depth for storm event #5	(F8.3)
78	Subarea average 5-minute rainfall depth for storm event #6	(F8.3)
79	Subarea average 15-minute rainfall depth for storm event #6	(F8.3)
80	Subarea average 30-minute rainfall depth for storm event #6	(F8.3)
81	Subarea average 1-hr rainfall depth for storm event #6	(F8.3)
82	Subarea average 2-hr rainfall depth for storm event #6	(F8.3)
83	Subarea average 3-hr rainfall depth for storm event #6	(F8.3)
84	Subarea average 6-hr rainfall depth for storm event #6	(F8.3)
85	Subarea average 12-hr rainfall depth for storm event #6	(F8.3)
86	Subarea average 24-hr rainfall depth for storm event #6	(F8.3)
87	Subarea average 2-day rainfall depth for storm event #6	(F8.3)
88	Subarea average 3-day rainfall depth for storm event #6	(F8.3)
89	Subarea average 4-day rainfall depth for storm event #6	(F8.3)
90	Subarea average 5-day rainfall depth for storm event #6	(F8.3)
91	Subarea average 6-day rainfall depth for storm event #6	(F8.3)
92	Subarea average 7-day rainfall depth for storm event #6	(F8.3)
93	Mean Annual Precipitation (in.)	(F8.3)
94	Future Rainfall A (F0601 rainfall zone)	(F8.3)
95	Future Rainfall B	(F8.3)
96	Future Rainfall C	(F8.3)
97	Future Rainfall D	(F8.3)
98	Future Rainfall E	(F8.3)
99	Subarea Time-of-concentration, Tc (minute), for storm event #1	(F8.3)
100	Subarea Time-of-concentration, Tc (minute), for storm event #2	(F8.3)
101	Subarea Time-of-concentration, Tc (minute), for storm event #3	(F8.3)
102	Subarea Time-of-concentration, Tc (minute), for storm event #4	(F8.3)
103	Subarea Time-of-concentration, Tc (minute), for storm event #5	(F8.3)
104	Subarea Time-of-concentration, Tc (minute), for storm event #6	(F8.3)
105	Subarea Valley-Developed S-graph fraction/ F0601 Rainfall Zone I fraction	(F7.3)
106	Subarea Foothill S-graph fraction/ F0601 Rainfall Zone J fraction	(F7.3)
107	Subarea Mountain S-graph fraction/ F0601 Rainfall Zone K fraction	(F7.3)
108	Subarea Desert S-graph fraction/ F0601 Rainfall Zone L fraction	(F7.3)
109	Subarea Valley-Undeveloped S-graph fraction/ F0601 Rainfall Zone M fraction	(F7.3)
110	Future A S-graph fraction	(F7.3)
111	Future B S-graph fraction	(F7.3)
112	Future C S-graph fraction	(F7.3)
113	Future D S-graph fraction	(F7.3)
114	Land Use Type for Cell #1	(F9.4)
115	Soil Group Number for Cell #1	(F9.4)
116	Imperviousness Factor For Cell #1	(F9.4)
117	Acreage For Cell #1	(F9.4)
118	Land Use Type for Cell #2	(F9.4)
119	Soil Group Number for Cell #2	(F9.4)
120	Imperviousness Factor For Cell #2	(F9.4)
121	Acreage For Cell #2	(F9.4)
122	Land Use Type for Cell #3	(F9.4)
123	Soil Group Number for Cell #3	(F9.4)
124	Imperviousness Factor For Cell #3	(F9.4)
125	Acreage For Cell #3	(F9.4)
126	Land Use Type for Cell #4	(F9.4)
127	Soil Group Number for Cell #4	(F9.4)
128	Imperviousness Factor For Cell #4	(F9.4)
129	Acreage For Cell #4	(F9.4)
130	Land Use Type for Cell #5	(F9.4)
131	Soil Group Number for Cell #5	(F9.4)
132	Imperviousness Factor For Cell #5	(F9.4)
133	Acreage For Cell #5	(F9.4)
134	Land Use Type for Cell #6	(F9.4)
135	Soil Group Number for Cell #6	(F9.4)
136	Imperviousness Factor For Cell #6	(F9.4)
137	Acreage For Cell #6	(F9.4)
138	Area of Parameter Default.	(F9.2)
Add 50 more fields for future development.		(F9.4)

Appendix B

Example SIMS Diagnostics Report

```
*-----------------------*
* POST-PROCESSOR REPORT *
*   FOR STUDY ID [EX]   *
*-----------------------*
```

I. USER-SELECTED POSTPROCESSOR OPTIONS AND SETTINGS:

*FRICTION-SLOPE MODEL to be used for estimating the normal depth (or pressure flow) friction-slope, Sf, for each link:
(Note: Selected Sf model will be used as a parameter to model existing system elements and also for sizing new system elements.)

Use BALANCED HGL Estimation Module results as the approximation of the friction-slope. Model Settings are:

```
  Minimum Allowable Flow Velocity for Peak flow rate(fps) =  3.00
  Minimum Allowable Friction-Slope, Sf, =  .0020
  Manning's Friction Factor used to estimate HGL Envelopes =  .0130
  (Note: Above values will be used to Define TOP and BOTTOM HGL
  Envelopes for each STRING)
  Minimum Allowable Clearance(feet) Between topography and
  HGL or Soffit =  1.00
  Maximum Allowable Clearance(feet) Between topography and
  HGL or Soffit =  10.00
```

*User defines Downstream HGL CONTROL for each system Trunk Line.

*At a confluence, several upstream branches merge into one outlet.
In order to choose which branch is the MAIN-LINE:
Select BRANCH that has the LARGEST PEAK FLOW RATE

*MODEL for sizing new system elements and for estimating existing system element flow capacities (e.g., for each link):
Size all elements as pipes, flowing at full flow capacity (or 0.82*Diameter as normal depth)

*System element(i.e., pipe, box, channel) FLOW CAPACITY sizing constraints:
On a STRING BASIS, size each link element to have a flow capacity (or normal depth flow rate) greater than or equal to upstream elements' target flow rate (i.e., the estimated target deficiency mitigation).

*System element SIZE constraints (Note: this Telescoping module only analyzes Links on a STRING BASIS. At a confluence, or Junction of Branch lines, only the MAIN LINE is considered in this Telescoping analysis):
Size each pipe link element to have a pipe cross-section area greater than or equal to the upstream element's pipe cross-section area.
(e.g., do NOT allow reduction in cross-section area)

*OPTION regarding telescoping EXISTING ELEMENTs:
Apply above telescoping rules to EXISTING SYSTEMs

*MINIMUM ALLOWABLE Pipe DIAMETER(inches) = 18.

```
    The PROGRAM estimates pipe sizes using Manning's equation,
    with the friction slope set equal to the Value estimated by
    YOUR selected Friction Slope Modeling Option.  The PROGRAM
    next upsizes to a CONSTRUCTABLE pipe size.  The USER-
    specified proportion ( .900) of the Estimated Friction Slope
    to be used for the pipeflow friction slope.

   *Total Flow Pickup Pipe sizing used Link Downstream Node Peak Flow Rate.
   *Box or Channel sizing used Link Upstream Node Peak Flow Rate.
*----------------------------------------------------------------------*


                       II. DIAGNOSTICS REPORT



   II.A. POSTPROCESSOR VALIDITY CHECKS: LINKS
*----------------------------------------------------------------------*
 A. Upstream Node Number Exceeds Downstream Node Number:
    (EXCEPTIONS need to be at a confluence)
    (Note: Any Downstream Node Number = Upstream Node Number is FATAL!)
                 Link ID
  Link      Upstream   Downstream
 Number       Node        Node
    1        11022.0    11008.0
    2        10912.0    10903.0
    3        10823.0    10806.0
    4        10855.0    10843.0
    5        10844.0    10836.0
    .
    .
    .
*----------------------------------------------------------------------*
 B. Number of Upstream Nodes that are NOT unique
    in the Link Database = 0
    (EXCEPTIONS are FATAL!)
*----------------------------------------------------------------------*
 C. Downstream Nodes that are NOT unique in the Link Database:
    (EXCEPTIONS must be all and only confluence nodes)
                 Link ID
  Link      Upstream   Downstream
 Number       Node        Node
    1        11007.0    11008.0
    2        11022.0    11008.0
    3        10902.0    10903.0
    4        10912.0    10903.0
    5        10805.0    10806.0
    .
    .
    .
```

```
*----------------------------------------------------------------------*
 D. Number of LINKS in Set [A] that are not an element in Set [C] =  14:
    (EXCEPTIONS are FATAL at a Confluence Node!)
                 Link ID
  Link      Upstream   Downstream
 Number       Node        Node
    1        10194.0    10100.0
    2        50102.0    50001.0
    3        50203.0    50003.0
    4        60015.0    50007.0
    5        50603.0    50010.0
    .
    .
    .
*----------------------------------------------------------------------*
 E. Number of Downstream Nodes that do not connect
    to an Upstream Node located on a downstream Link = 259:
    (EXCEPTIONS are: (i) Downstream end of a STRING, and
    (ii) interface node between MAPs(subregions).)
 11403.0  11010.0  10906.0  10810.0  10705.0  10605.0  10502.0  10403.0
 10303.0  10209.0  10109.0  10109.0  10026.0  10026.0  20805.0  20704.0
    .
    .
    .
*----------------------------------------------------------------------*
 F. Number of Upstream Nodes that do not connect
    to a Downstream Node located on an upstream Link = 426:
    (EXCEPTIONS are: (i) headwater node, (ii) MAP(subregion)
    interface node, and (iii) User-Defined information node.)
 11400.0  11000.0  11020.0  10900.0  10910.0  10800.0  10820.0  10830.0
 10840.0  10850.0  10870.0  10860.0  10700.0  10600.0  10500.0  10400.0
    .
    .
    .
*----------------------------------------------------------------------*
 G. Number of Links where Length is less than or equal to [0.001] = 0
    (EXCEPTIONS are FATAL!)
*----------------------------------------------------------------------*
 H. Number of Upstream Nodal Point NUMBERS out of range =   0:
    (EXCEPTIONS are FATAL!)
*----------------------------------------------------------------------*
 I. Number of Downstream Nodal Point NUMBERS out of range =   0:
    (EXCEPTIONS are FATAL!)
*----------------------------------------------------------------------*
 J. Number of Upstream Nodes NOT defined in the Node Database =   0:
    (EXCEPTIONS are FATAL!)
*----------------------------------------------------------------------*
 K. Number of Downstream Nodes NOT defined in the Node Database =   0
    (EXCEPTIONS are FATAL!)
```

```
*----------------------------------------------------------------------*
 L. The following LINKS have Topographic Slopes
    LESS than 0.002, or Greater than 0.100:
 Upstream   Downstream    Topographic
   Node        Node          Slope
 410404.0   410405.0        -.0851
 410004.0   410005.0        -.0819
 330107.0   330010.0         .0000
 540004.0   540005.0         .0011
    .
    .
    .
*----------------------------------------------------------------------*


   II.B. POSTPROCESSOR VALIDITY CHECKS: NODES
*----------------------------------------------------------------------*
 A. Number of Nodes that are NOT unique in the Node Database =   0:
    (EXCEPTIONS are FATAL!)
*----------------------------------------------------------------------*
 B. Number of Nodal Elevations that are less than
    [-2000.] or greater than [25000.] =   0:
*----------------------------------------------------------------------*
 C. Number of Nodal Point NUMBERS out of range =   0:
    (EXCEPTIONS are FATAL!)
*----------------------------------------------------------------------*
 D. Number of Nodes that are NOT used in the Link Database =   0:
    (EXCEPTIONS are FATAL!)
*----------------------------------------------------------------------*
```

```
   II.C. POSTPROCESSOR VALIDITY CHECKS: SUBAREAS
*----------------------------------------------------------------------*
             (EXCEPTIONS are FATAL!)
                           |<========= Data  Out  of  Range =========>|
       Subarea             Subarea                    Land
        Number  Uniqueness   Number  Rainfall  S-Graph  Use  Soil  Area
       -------  ----------  -------  --------  ------- ----  ----  ----
 ==> No Errors!
*----------------------------------------------------------------------*
    * Check Subarea Data Base (FATAL ERRORs!) *
    * Subarea Used More Than ONCE in Link-Node Model
      (EXCEPTIONS are FATAL!)
      None
    * Subarea NOT Used in Link-Node Model
      (EXCEPTIONS are FATAL!)
      None
    * Subarea does NOT EXIST in Data Base
      (EXCEPTIONS are FATAL!)
      None
   * CAUTION: Subareas that are NOT added to respective node number
     (EXCEPTIONS may be FATAL!)
      Subarea Number    Node Number
       870203.0         870202.1
*----------------------------------------------------------------------*

    * Check Link Data Base *
    * Link Used More Than ONCE in Link-Node Model
      (EXCEPTIONS are FATAL!)
            LINK  ID
        U/S NODE  D/S NODE
             None
    * Link NOT Used in Link-Node Model
      (EXCEPTIONS are FATAL!)
            LINK  ID
        U/S NODE  D/S NODE
              None
    * Link does NOT EXIST in Data Base
      (EXCEPTIONS are FATAL!)
            LINK  ID
        U/S NODE  D/S NODE
               None

    Confluence nodes that do not match NETWORK:
    (EXCEPTIONS are FATAL!)
 50004.0  50005.0  71008.0
*----------------------------------------------------------------------*
```

```
II.D. MASTER PLAN OF DRAINAGE STATISTICAL ANALYSIS
                            STUDY ID = [cr]

 1. Subarea SIZE (Acres)
    Total Number of Subareas = 1220
    Maximum Value =   539.45
    Minimum Value =      .65
                                 NUMBER
          Interval             of Values        % of Total
    (      .64,   54.53]         1142             93.61%
    (    54.53,  108.41]           40              3.28%
    (   108.41,  162.29]           15              1.23%
    (   162.29,  216.17]           14              1.15%
    (   216.17,  270.05]            4               .33%
    (   270.05,  323.93]            2               .16%
    (   323.93,  377.81]            1               .08%
    (   377.81,  431.69]            0               .00%
    (   431.69,  485.57]            1               .08%
    (   485.57,  539.46]            1               .08%

    25th Percentile =     5.54
    Median (50th Percentile) =     8.58
    75th Percentile =    15.25
    IQR =    15.25 -    5.54 =    9.71
    PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
    (median - 1.5*IQR, median + 1.5*IQR)
    = (    -5.981,    23.141)

    ESTIMATED OUTLIERS ARE:
     SUBAREA ID       ACREAGE
      860008.0       539.450
      460208.0       455.100
       60010.0        34.960
      870503.0        23.240
      890102.0        23.160
          .
          .
          .
```

```
2. Initial Subarea Statistics
 2a. Area (Acres)
   Total Number of Initial Subareas =  278
   Maximum Value =    23.93
   Minimum Value =      .79
                                  NUMBER
         Interval              of Values        % of Total
   (      .78,    3.10]           18              6.47%
   (     3.10,    5.42]          113             40.65%
   (     5.42,    7.73]          100             35.97%
   (     7.73,   10.05]           27              9.71%
   (    10.05,   12.36]           12              4.32%
   (    12.36,   14.67]            4              1.44%
   (    14.67,   16.99]            1               .36%
   (    16.99,   19.30]            1               .36%
   (    19.30,   21.62]            1               .36%
   (    21.62,   23.94]            1               .36%

   25th Percentile =     4.42
   Median (50th Percentile) =     5.51
   75th Percentile =     6.93
   IQR =     6.93 -    4.42 =    2.52
   PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
   (median - 1.5*IQR, median + 1.5*IQR)
   = (     1.734,     9.286)

   ESTIMATED OUTLIERS ARE:
    SUBAREA ID       ACREAGE
      70601.0         23.930
      71401.0         19.990
     380001.0          9.500
     420721.0          1.660
     240101.0           .790
         .
         .
         .
```

```
2b. Time-of-Concentration (minutes) for Storm Event # 1
  Maximum Value =    23.00
  Minimum Value =     5.00
                                         NUMBER
        Interval                       of Values          % of Total
  (    4.99,    6.80]                     18                 6.47%
  (    6.80,    8.60]                     41                14.75%
  (    8.60,   10.40]                     71                25.54%
  (   10.40,   12.20]                     78                28.06%
  (   12.20,   14.00]                     42                15.11%
  (   14.00,   15.80]                     10                 3.60%
  (   15.80,   17.60]                      7                 2.52%
  (   17.60,   19.40]                      8                 2.88%
  (   19.40,   21.20]                      2                  .72%
  (   21.20,   23.01]                      1                  .36%

  25th Percentile =     8.95
  Median (50th Percentile) =    10.57
  75th Percentile =    12.24
  IQR =    12.24 -    8.95 =    3.29
  PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
  (median - 1.5*IQR, median + 1.5*IQR)
  = (     5.644,    15.506)

  ESTIMATED OUTLIERS ARE:
   SUBAREA ID       Tc (min.)
    410201.0         23.000
    390101.0         20.460
    860301.0          5.270
    450501.0          5.160
    420501.0          5.000
       .
       .
       .
```

```
2b. Time-of-Concentration (minutes) for Storm Event # 2
  Maximum Value =    23.00
  Minimum Value =     5.00
                                NUMBER
        Interval              of Values        % of Total
  (    4.99,    6.80]            18               6.47%
  (    6.80,    8.60]            41              14.75%
  (    8.60,   10.40]            71              25.54%
  (   10.40,   12.20]            78              28.06%
  (   12.20,   14.00]            42              15.11%
  (   14.00,   15.80]            10               3.60%
  (   15.80,   17.60]             7               2.52%
  (   17.60,   19.40]             8               2.88%
  (   19.40,   21.20]             2                .72%
  (   21.20,   23.01]             1                .36%

  25th Percentile =     8.95
  Median (50th Percentile) =    10.57
  75th Percentile =    12.24
  IQR =    12.24 -    8.95 =    3.29
  PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
  (median - 1.5*IQR, median + 1.5*IQR)
  = (     5.644,    15.506)

  ESTIMATED OUTLIERS ARE:
   SUBAREA ID       Tc (min.)
    410201.0         23.000
    390101.0         20.460
    860301.0          5.270
    450501.0          5.160
    420501.0          5.000
       .
       .
       .
```

```
2c. Flowpath Length (feet)
  Maximum Value =  1571.00
  Minimum Value =   140.00
                                NUMBER
        Interval               of Values        % of Total
  (  139.99,  283.10]             1                  .36%
  (  283.10,  426.20]             3                 1.08%
  (  426.20,  569.30]            17                 6.12%
  (  569.30,  712.40]            73                26.26%
  (  712.40,  855.50]           106                38.13%
  (  855.50,  998.60]            64                23.02%
  (  998.60, 1141.70]            10                 3.60%
  ( 1141.70, 1284.80]             3                 1.08%
  ( 1284.80, 1427.90]             0                  .00%
  ( 1427.90, 1571.01]             1                  .36%

  25th Percentile =   684.00
  Median (50th Percentile) =   774.50
  75th Percentile =   872.25
  IQR =   872.25 -  684.00 =  188.25
  PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
  (median - 1.5*IQR, median + 1.5*IQR)
  = (   492.125,  1056.875)

  ESTIMATED OUTLIERS ARE:
   SUBAREA ID    Length(feet)
    880601.0       1571.000
    880311.0       1196.000
    380301.0        418.000
    900201.0        350.000
    270001.0        140.000
       .
       .
       .
```

```
3. Link Travel Times (minutes) for Storm Event # 1
   Maximum Value =    13.72
   Minimum Value =      .04
                              NUMBER
         Interval            of Values          % of Total
   (      .03,    1.41]         776               58.79%
   (     1.41,    2.78]         339               25.68%
   (     2.78,    4.14]         118                8.94%
   (     4.14,    5.51]          51                3.86%
   (     5.51,    6.88]          20                1.52%
   (     6.88,    8.25]           6                 .45%
   (     8.25,    9.62]           5                 .38%
   (     9.62,   10.98]           1                 .08%
   (    10.98,   12.35]           1                 .08%
   (    12.35,   13.73]           3                 .23%

   25th Percentile =      .43
   Median (50th Percentile) =     1.08
   75th Percentile =     2.17
   IQR =     2.17 -     .43 =    1.74
   PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
   (median - 1.5*IQR, median + 1.5*IQR)
   = (    -1.530,     3.690)

   ESTIMATED OUTLIERS ARE:
    U/S Node    D/S Node      Travel Time(min.)
    60007.0     60008.0           13.72
   270111.0    270112.0           13.65
   850207.0    850208.0            3.72
   370113.0    370114.0            3.71
   890103.0    890104.0            3.70
      .
      .
      .
```

```
3. Link Travel Times (minutes) for Storm Event # 2
   Maximum Value =    12.31
   Minimum Value =      .04
                                       NUMBER
         Interval                    of Values          % of Total
   (      .03,    1.27]           765                57.95%
   (     1.27,    2.49]           335                25.38%
   (     2.49,    3.72]           134                10.15%
   (     3.72,    4.95]            54                 4.09%
   (     4.95,    6.18]            18                 1.36%
   (     6.18,    7.40]             4                  .30%
   (     7.40,    8.63]             5                  .38%
   (     8.63,    9.86]             2                  .15%
   (     9.86,   11.08]             0                  .00%
   (    11.08,   12.32]             3                  .23%

   25th Percentile =      .40
   Median (50th Percentile) =     1.00
   75th Percentile =     1.99
   IQR =     1.99 -     .40 =    1.59
   PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
   (median - 1.5*IQR, median + 1.5*IQR)
   = (    -1.385,     3.385)

   ESTIMATED OUTLIERS ARE:
    U/S Node    D/S Node      Travel Time(min.)
   270111.0    270112.0           12.31
    60007.0     60008.0           11.64
   370301.0    370302.0            3.41
    50612.0     50603.0            3.41
   260103.0    260002.0            3.40
      .
      .
      .
```

```
4. Link Lengths (feet)
   Maximum Value =  5490.00
   Minimum Value =    56.00
                                    NUMBER
         Interval                 of Values          % of Total
   (   55.99,  599.40]           776                48.56%
   (  599.40, 1142.80]           628                39.30%
   ( 1142.80, 1686.20]           124                 7.76%
   ( 1686.20, 2229.60]            33                 2.07%
   ( 2229.60, 2773.00]            18                 1.13%
   ( 2773.00, 3316.40]             9                  .56%
   ( 3316.40, 3859.80]             5                  .31%
   ( 3859.80, 4403.20]             1                  .06%
   ( 4403.20, 4946.60]             2                  .13%
   ( 4946.60, 5490.01]             2                  .13%

   25th Percentile =   349.75
   Median (50th Percentile) =   614.50
   75th Percentile =   870.00
   IQR =   870.00 -  349.75 =  520.25
   PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
   (median - 1.5*IQR, median + 1.5*IQR)
   = (  -165.875,  1394.875)

   ESTIMATED OUTLIERS ARE:
    U/S Node    D/S Node      Length (feet)
   860404.0    860405.0         5490.00
   870006.0    870007.0         5289.00
   890005.0    890006.0         1419.00
    70011.0     70012.0         1406.00
   880524.0    880506.0         1396.00
       .
       .
       .
```

```
5. Ratios of Computed Peak Flow:
   T1 =  10. Year; T2 = 100. Year
   Maximum Value =      .68
   Minimum Value =      .54
                              NUMBER
         Interval            of Values        % of Total
   (      .53,     .55]          9                .68%
   (      .55,     .57]         11                .83%
   (      .57,     .58]         24               1.82%
   (      .58,     .59]         60               4.55%
   (      .59,     .61]         97               7.35%
   (      .61,     .62]        219              16.59%
   (      .62,     .64]        379              28.71%
   (      .64,     .65]        342              25.91%
   (      .65,     .66]        161              12.20%
   (      .66,     .69]         18               1.36%

   25th Percentile =      .62
   Median (50th Percentile) =      .63
   75th Percentile =      .64
   IQR =      .64 -     .62 =     .03
   PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
   (median - 1.5*IQR, median + 1.5*IQR)
   = (      .591,      .673)

   ESTIMATED OUTLIERS ARE:
    U/S Node    D/S Node      T1/T2
   210202.0    210203.0         .68
   860009.0    860010.0         .59
    10025.0     10026.0         .54
    10024.0     10025.0         .54
    10023.0     10024.0         .54
      .
      .
      .
```

```
6. Flowrate vs. Total Tributary Area Ratios:

   Design Storm Event # 1, return frequency =   10. years.
   Maximum Value =     2.69
   Minimum Value =      .30
                                NUMBER
         Interval             of Values         % of Total
   (      .29,     .54]          12                 .81%
   (      .54,     .78]          69                4.66%
   (      .78,    1.02]         108                7.30%
   (     1.02,    1.26]         312               21.08%
   (     1.26,    1.50]         441               29.80%
   (     1.50,    1.74]         286               19.32%
   (     1.74,    1.97]         180               12.16%
   (     1.97,    2.21]          47                3.18%
   (     2.21,    2.45]          19                1.28%
   (     2.45,    2.70]           6                 .41%

   25th Percentile =     1.19
   Median (50th Percentile) =     1.37
   75th Percentile =     1.63
   IQR =     1.63 -    1.19 =     .44
   PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
   (median - 1.5*IQR, median + 1.5*IQR)
   = (      .705,     2.031)

   ESTIMATED OUTLIERS ARE:
    Subarea Number    Ratio
       420502.0        2.69
       420501.0        2.68
       420503.0        2.64
       270004.0         .31
       270002.0         .31
       270001.0         .30
          .
          .
          .
```

```
Design Storm Event # 2, return frequency =  100. years.
Maximum Value =     4.05
Minimum Value =      .47
                           NUMBER
      Interval            of Values        % of Total
(     .46,     .83]          12                 .81%
(     .83,    1.18]          29                1.96%
(    1.18,    1.54]         101                6.82%
(    1.54,    1.90]         222               15.00%
(    1.90,    2.26]         459               31.01%
(    2.26,    2.62]         338               22.84%
(    2.62,    2.97]         212               14.32%
(    2.97,    3.33]          71                4.80%
(    3.33,    3.69]          30                2.03%
(    3.69,    4.06]           6                 .41%

25th Percentile =     1.90
Median (50th Percentile) =     2.18
75th Percentile =     2.55
IQR =     2.55 -    1.90 =     .65
PROGRAM ASSUMES OUTLIERS ARE OUTSIDE OF INTERVAL
(median - 1.5*IQR, median + 1.5*IQR)
= (     1.200,     3.150)

ESTIMATED OUTLIERS ARE:
 Subarea Number    Ratio
    420501.0        4.05
    420502.0        4.03
    270004.0         .48
    270002.0         .47
    270001.0         .47
       .
       .
       .
```

II.E. MASTER PLAN OF DRAINAGE HEALTH CHECK

1. The following links have subarea-added AREA that is equal to or greater than 35% of the mainline tributary area:

Link ID U/S Node	Link ID D/S Node	Mainline Area	Subarea Area	Sum	Ratio
900202.00	900202.00	3.73	22.17	25.90	5.94
90601.00	90602.00	6.06	30.13	36.19	4.97
870501.00	870502.00	3.91	16.30	20.21	4.17
71401.00	71402.00	19.99	7.10	27.09	.36
90308.00	90308.00	136.82	48.51	185.33	.35
340204.00	340205.00	12.20	4.28	16.48	.35
.					
.					
.					

2a. The following links have estimated flow runoff TRAVEL TIMES greater than 3 minutes, AND time-of-concentration values less than 30 minutes:

Link ID U/S Node	Link ID D/S Node	Travel Time	Estimated Tc at U/S Node
270111.00	270112.00	12.31	11.60
60007.00	60008.00	11.64	28.45
70211.00	70212.00	3.03	10.02
450403.00	450404.00	3.03	9.59
340201.00	340202.00	3.01	11.42
.			
.			
.			

2b. The following links have estimated flow runoff TRAVEL TIMES greater than 5 minutes, AND time-of-concentration values less than 60 minutes:

Link ID U/S Node	Link ID D/S Node	Travel Time	Estimated Tc at U/S Node
270111.00	270112.00	12.31	11.60
60007.00	60008.00	11.64	28.45
880402.00	880403.00	5.08	15.47
900001.00	900002.00	5.06	11.79
890002.00	890003.00	5.04	21.62
.			
.			
.			

```
  2c. The following links have estimated flow runoff TRAVEL
      TIMES greater than 10 minutes, AND time-of-concentration
      values greater than or equal to 60 minutes:
               Link ID           Travel    Estimated Tc
                         ** None **

  User-Defined Downstream HGL CONTROLs for each system
  Trunk Line are:
  Node Number  User-Defined HGL    Node Number  User-Defined HGL
     10109.0     762.00               10027.0     570.00
     20602.0     639.00               20030.0     568.00
    880507.0     864.00              880704.0     850.00
    880014.0     784.00              900003.0     918.00
    900104.0     918.00              900204.0     918.00
       .
       .
       .
*----------------------------------------------------------------------*

  III. BALANCED HGL GRADIENT ESTIMATION MODULE DIAGNOSTICS REPORT*

 *WARNING : The HGL CONTROL for STRING #  27
  (UPSTREAM NODE =  10160.0; DOWNSTREAM NODE =  10109.0) is ABOVE
  the modeled TOP HGL Envelope at the String's most Downstream Node.
  Estimated HGL Control:  762.00; TOP HGL Envelope:  760.47
  Bottom HGL Envelope:  754.00 *HGL Control RESET to TOP HGL Envelope
 *WARNING : The HGL CONTROL for STRING #  66
  (UPSTREAM NODE =  50200.0; DOWNSTREAM NODE =  50003.0) is ABOVE
  the modeled TOP HGL Envelope at the String's most Downstream Node.
  Estimated HGL Control:  812.00; TOP HGL Envelope:  811.00
  Bottom HGL Envelope:  802.00 *HGL Control RESET to TOP HGL Envelope
 *WARNING : The HGL CONTROL for STRING #  44
  (UPSTREAM NODE =  30000.0; DOWNSTREAM NODE =  50004.0) is ABOVE
  the modeled TOP HGL Envelope at the String's most Downstream Node.
  Estimated HGL Control:  765.00; TOP HGL Envelope:  762.00
  Bottom HGL Envelope:  753.00 *HGL Control RESET to TOP HGL Envelope
     .
     .
     .

 The following links are assigned a FRICTION SLOPE of  .0020,
 (or are within 0.001 of the User-Specified minimum
 friction slope of  .0020):
             Link ID
         Upstream  Downstream
           Node       Node
         10162.0     10109.0
         10009.0     10010.0
         10018.0     10019.0
        860406.0    860016.0
        880523.0    880524.0
            .
            .
            .
```

```
     The following Links appear to have a gap between Existing
     System Primary Elements:
                 Link ID
            Upstream  Downstream
              Node       Node
            10852.0     10853.0
            10704.0     10705.0
            10142.0     10133.0
           880505.0    880524.0
           880701.0    880702.0
           880005.0    880006.0
             .
             .
             .
 *----------------------------------------------------------------------*

     IV. USER-RECOMMENDED EXISTING SYSTEM FLOW CAPACITY SPECIFICATIONs
REPORT:

     The following LINKS contain USER-RECOMMENDED flow capacity
specifications:
     Upstream   Downstream    Computer Recommended    User-Recommended
       Node         Node     Flow Capacity Estimate     Flow Capacity
                      ** NONE **

     V. USER-RECOMMENDED LINK DEFICIENCY MITIGATION SIZE SPECIFICATIONs
REPORT:

     The following LINKS contain USER-RECOMMENDED LINK Deficiency
     Mitigation Size Specifications:
     Upstream    Downstream    Diameter   Base-   Side-  Manning's
       Node         Node       (Height)   Width   Slope  Factor(n)
                      ** NONE **

     VI. USER-RECOMMENDED LINK FRICTION SLOPE SPECIFICATIONs REPORT:

     The following LINKS contain USER-RECOMMENDED LINK Friction
     Slope Specifications:
     Upstream    Downstream     User-RECOMMENDED
       Node         Node       Friction Slope(Sf)
                      ** NONE **

     The following LINKS have EXISTING SYSTEM or PROPOSED
     SYSTEM Pipe Diameters Greater than or Equal to 84-inch:
            LINK ID         Existing System     Proposed System
       U/S Node   D/S Node      (inches)           (inches)
        10013.0    10014.0         84.00                 .00
        10014.0    10015.0         84.00                 .00
       420020.0   420021.0         78.00               90.00
       450009.0   450010.0         96.00                 .00
       870014.0   870015.0         63.00              114.00
          .
          .
          .
```

```
Existing system LINKS that are UPGRADED due to telescoping
rules, and are not estimated to be deficient (i.e., as
estimated by USER-SPECIFIED criteria):
       LINK ID           Existing System          Proposed System
  U/S Node   D/S Node   Dia./H      B      Z     Dia/H      B      Z
   10842.0    10843.0      .00     .00     .0     1.75     .00     .0
   10853.0    10854.0      .00     .00     .0     2.00     .00     .0
  530502.0   530503.0      .00     .00     .0     2.75     .00     .0
  530503.0   530504.0     2.00     .00     .0     2.75     .00     .0
  880703.0   880704.0      .00     .00     .0     2.75     .00     .0
      .
      .
      .
*----------------------------------------------------------------------*

VII. WSPG HGL DIAGNOSTICS REPORT: TOPOLOGY LEVEL  0

*WARNING : HGL at Node  30302.0 =   759.04 is NOT within the
 Tolerance of [  750.00] and [  759.00]; TOPO - HGL =      .96
*WARNING : HGL at Node  50907.0 =   980.35 is NOT within the
 Tolerance of [  981.00] and [  990.00]; TOPO - HGL =    10.65
*WARNING : HGL at Node  50907.0 =   980.35 is NOT within the
 Tolerance of [  981.00] and [  990.00]; TOPO - HGL =    10.65
   .
   .
   .

VII. WSPG HGL DIAGNOSTICS REPORT: TOPOLOGY LEVEL  1

*WARNING : HGL at Node  10209.0 =   737.70 is NOT within the
 Tolerance of [  739.00] and [  748.00]; TOPO - HGL =    11.30
*WARNING : HGL at Node  10209.0 =   737.70 is NOT within the
 Tolerance of [  739.00] and [  748.00]; TOPO - HGL =    11.30
*WARNING : HGL at Node  10011.0 =   732.07 is NOT within the
 Tolerance of [  734.00] and [  743.00]; TOPO - HGL =    11.93
*WARNING : Velocity of LINK ( 30103.0- 30003.0) =     2.33 FPS
   .
   .
   .

VII. WSPG HGL DIAGNOSTICS REPORT: TOPOLOGY LEVEL  2

*WARNING : HGL at Node  10842.0 =   689.15 is NOT within the
 Tolerance of [  690.00] and [  699.00]; TOPO - HGL =    10.85
*WARNING : HGL at Node  10842.0 =   689.15 is NOT within the
 Tolerance of [  690.00] and [  699.00]; TOPO - HGL =    10.85
*WARNING : HGL at Node  10843.0 =   660.25 is NOT within the
 Tolerance of [  661.00] and [  670.00]; TOPO - HGL =    10.75
   .
   .
   .

VII. WSPG HGL DIAGNOSTICS REPORT: TOPOLOGY LEVEL  3

*WARNING : HGL at Node  10823.0 =   621.58 is NOT within the
 Tolerance of [  622.00] and [  631.00]; TOPO - HGL =    10.42
   .
```

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