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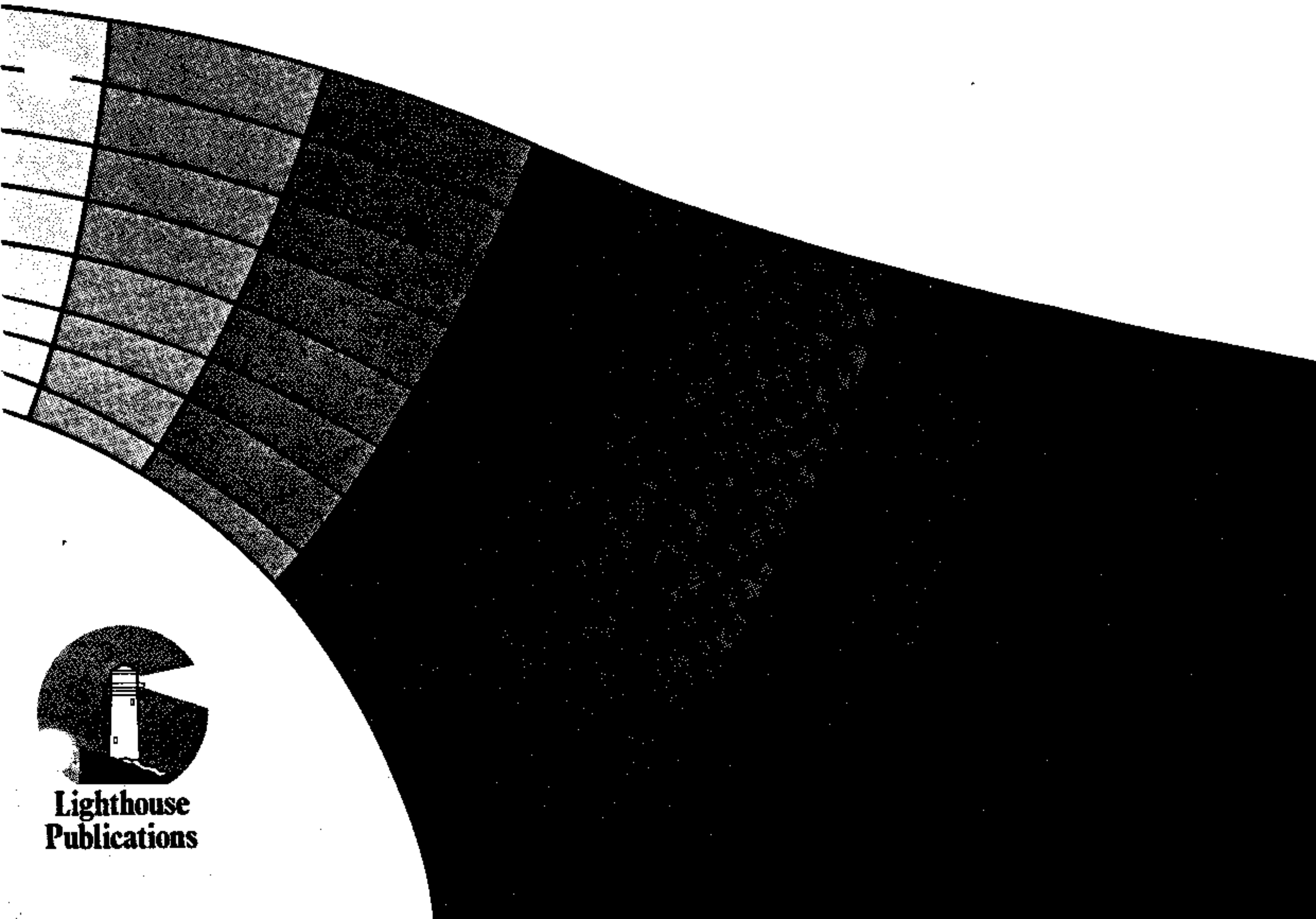

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Master Plan Of Drainage - Application of a User-Friendly Computer Model

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Abstract

In order to implement a regional flood control system, an assessment based on property holdings is commonly used to initiate a long term bond to finance the construction of the project. This assessment often includes the cost of major drainage facilities and also the cost of storm drain collector systems that drain small portions of the catchment, yet are still too costly for a small development project to finance. This layout of the collector systems and the ultimate regional flood control facilities is called the master plan of drainage or MPD. Fundamental to the MPD is the planning and development of the MPD system schematic. A new and convenient approach is to develop a computerized link-node model of the entire MPD system by means of the rational method. Such a model is discussed in this paper.

Introduction

With land development, the issues of how to control the change in runoff quantities have resulted in the development of policy statements that stipulate the design criteria for flood control. Due to fractional development, however, where only portions of a watershed are developed at any one time, the global flood control issues must be handled at a governmental level such as a city, county, state, or Federal agency. Capital must be obtained to develop the entire mainline flood control system when only a small portion of the entire watershed is currently developed.

In order to implement a regional flood control system, an assessment based on property holdings (or other policy statement) is used to initiate a long term bond to finance the construction of the project. This assessment often includes the cost of major drainage facilities and also the cost of storm drain collector systems that drain small portions of the catchment, yet are still too costly for a small development project to finance. This layout of the collector systems and the ultimate regional flood control facilities is called the master plan of drainage or MPD.

The MPD study develops a schematic of the entire flood control system and includes all major capital expenses including land costs, construction, engineering, maintenance over the life span of a facility, and the cost of storm drains down to a nominal size such as a 36-inch diameter pipe. Based on the MPD, a total regional system cost can be estimated (and adjusted for inflation) in order to develop an acreage fee to charge for development building permits. That is, all future development would be required to pay an equitable drainage fee based on land holding size (or other policy). The drainage fee oftentimes can be offset by the actual construction of necessary off-site flood control facilities for the specific development project. Should the off-site costs exceed the acreage fee charges, the agency reimburses the developer when other acreage fees can be safely directed accordingly. The use of an MPD acreage fee enables large regions, watersheds, or cities to modernize flood control systems, remove system deficiences, or construct new facilities.

Fundamental to the MPD is the planning and development of the MPD system schematic. A new and convenient approach is to develop a computerized link-node model of the entire MPD system by means of a rational method technique based on the subarea summation model or the nodal point method (discussed later in the text). Such an MPD schematic can be stored on a few microcomputer data discs, which enables the MPD to be updated by a simple editing of the data file, resulting in an updated MPD acreage fee.

The computer model discussed in this paper (RATNAT, Copyright 1987, Advanced Engineering Software) enables such a MPD to be developed. Although the MPD is based on the rational method, which has theoretical difficulties for large areas, the main purpose of the MPD is to provide an equitable drainage fee which, due to mass-produced pipeline sizes, the errors in the rational method typically do not significantly impact a change in design pipe sizes.

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 1 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

$$Q = CIA \qquad (1)$$

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 rainfall 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 area. 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. Since one acre-inch/hour is equal to 1.008 cfs, the rational method is generally assumed to estimate a peak flowrate in cfs.

Intensity duration curves for a particular region can be developed using log-log paper, plotting the area-averaged point rainfall value for the one hour duration, and drawing a straight line through the one hour value with a slope based on shorter duration rainfall intensity values.

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.

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. 1. The following paragraphs describe three alternative approaches of modeling with the rational method.

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 Fig. 1. 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 Ci and a tributary drainage area Ai.

(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 Ci are assumed to be functions of rainfall intensity, determine appropriate Ci' values for the intensity I'.

(5). Calculate a total watershed peak runoff (Q') by

$$Q' = (C1'A1 + C2'A2 + \dots + Cm'Am)I'$$

(6). Distribute Q' throughout the watershed according to the area proportion of runoff Qi' = Ci'AiI', where Qi' 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 Qi' 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'.

The Nodal Point Method

This approach attempts to reduce the calculation effort 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 Fig. 1. 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 I1 = I(Tc(1)) and the runoff coefficient C1. Then Q(1) = C1I1A1.

(4). Using Q(1), estimate the travel time Tt(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 I2 = I(Tc(2)). Using I2, determine an area-averaged runoff factor for the entire watershed tributary to node 2 by

$$(CA)2 = (C1A1 + C2A2)$$

Then Q(2) = (CA)2I2.

(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

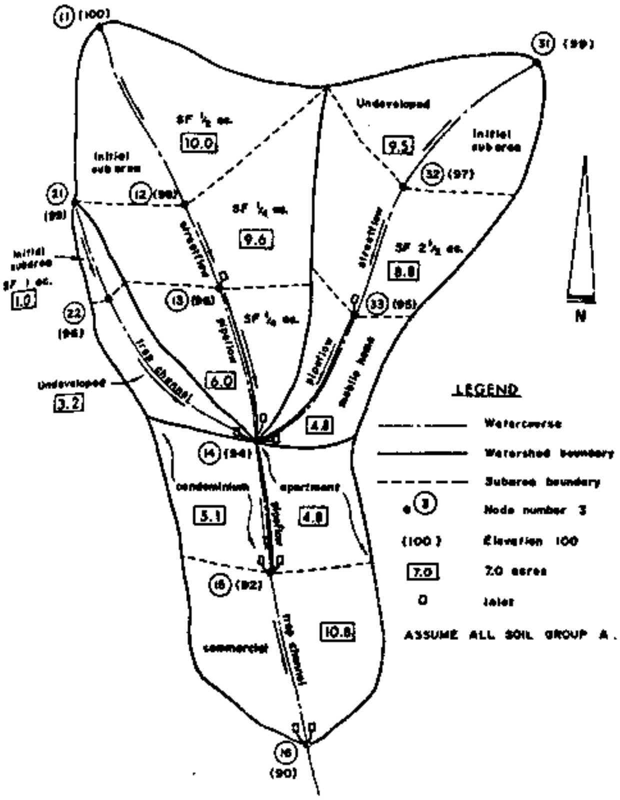


FIGURE 1 - EXAMPLE WATERSHED MAP

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 preceeding nodal point (at node i). This is due to the variation of the runoff factor (CA)i with rainfall intensity.

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 into 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 Fig. 1).

(2). Estimate a Tc(1) by using a nomograph or overland flow velocity estimation.

(3). Using Tc(1), determine the corresponding values of I1 and C1. Then Q(1) = C1I1A1.

(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 I2 = I(Tc(2)) and the runoff coefficient corresponding to both I2 and the properties of the subarea between nodes 1 and 2. Then

$$Q(2) = Q(1) + C2I2A2$$

(6). Repeat steps 4 and 5 as the analysis proceed 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.

Development of Major Facility Watershed Boundaries

The city MPD can generally be subdivided into several major flood control systems that oftentimes serve several square miles of area. These watersheds are analyzed as separate problems and lead to the convenient representation of a separate MPD link-node schematic for each major system. Using topographic information supplemented by field inspection, and after analyzing the existing storm drain system layouts, the watershed boundaries for each major facility can be developed and a separate catchment map prepared.

Development of MPD Link-Node Schematics

Each of the major system catchments can now be independently studied in detail. After the hydrologic and ultimate development land use patterns are plotted on the catchment map, the link-node schematic is developed by subdividing the watershed area into small subareas tributary to their respective flowpaths (see Case Study). Runoff flowpaths are identified and "links" defined through successive subareas such as to result in a rational method link-node schematic. Node numbers are usually numbered sequentially, increasing in value along the flowpath in the downstream direction. It is convenient to number separate streams by hundreds (e.g., 101, 102, 103, etc. for stream #1; 201, 202, 203, etc. for stream #2, and so forth), and separate major facilities in the thousands (or ten-thousands).

Development of the Link-Node Models

Each subarea should have the appropriate hydrologic data written on the link-node schematic map to facilitate an easy data entry to the computer program. Data includes subarea size, development type, SCS soil group, upstream and downstream node number and associated topographic elevations, flowpath length, and necessary hydraulic information such as Manning's friction factor, channel basewidth, and so forth.

The hydrologic information is entered into the data base starting from the upstream subarea and proceeding in a downstream direction to a confluence point where two or more streams merge. After all streams tributary to the confluence have been entered into the model, the confluence is solved to estimate a representative peak flow rate (Q) for the entire catchment tributary to the confluence point. Once the confluence analysis is completed, the study resumes in the downstream direction from the now solved confluence point. In this fashion, the link-node schematic is built up in a manner analogous to an analysis prepared "by hand" in that successive reaches are analyzed and the MPD facility (e.g., pipe or channel, streetflow, etc.) is sized and approved before proceeding to the next link in the schematic.

It is noted that the computer program should normally be operated such as to have only one confluence point in the computer memory at any one time. After all streams which are tributary to the confluence have been entered into the confluence submodel and the analysis completed, the computer memory is freed of the confluence stream data enabling identification of another confluence point. With this technique, the link-node schematic is constructed in a proper sequence with link sizing always completed before proceeding downstream.

Preparation of MPD System Information

After incorporating the calibrated or estimated hydrologic parameters in the several link-node schematics, the MPD system can be sized. Usually, the smaller pipeline systems that drain to the major open channel facilities are a major MPD cost. Additionally, changes in MPD alignment or development patterns typically are reflected in changes in the smaller pipelines with minor changes in the open channels. Consequently, the link-node model computer program includes an option for the computer program to "size" pipelines. Preparing the MPD with computer estimated pipesizes greatly increases analysis efficiency due to the ability to quickly "update" the MPD from minor changes in the link-node schematic.

Once the MPD is developed and the data file stored for future editing, all the MPD pipeline, channel, engineering, right-of-way, and other costs can be estimated on a facility-by-facility basis. The resulting cost, adjustable for inflation and contingency formulas, can now be applied on an acreage basis or other policy statement in order to secure moneys for major MPD facility improvements.

The Rational Method Planning/Design Computer Program

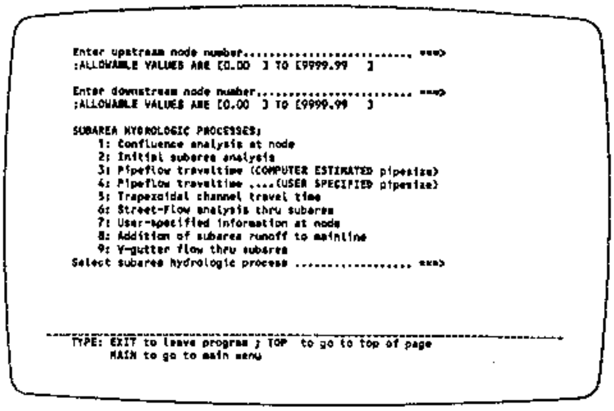
Each of the rational method subarea modeling approaches utilize identical submodels for estimating (1) the initial time of concentration, (2) channel or pipeflow travel time, (3) runoff coefficients, (4) rainfall intensity values, (5) and confluence values at the junction of two or more collection streams. Therefore, a computer program subroutine is developed for each of these submodels and a main driver program manipulates the individual hydrologic processes to formulate a link-node model of the watershed based on the rational method strategy desired. In Table 1, 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 results in a totally design-interactive computer program. Program 0 (up-front loader) allows the user to set up a configuration file of rational method parameters (i.e., rainfall (2 sets); pervious area fractions for each development type; pervious loss rates corresponding to soil types A, B, C, and D; rational method calibration factor; and Kirpich formula coefficients) corresponding to local drainage criteria. These values need only be specified once, but can be changed at any time by editing the configuration file. *Program 1 specifies the initial or control* conditions for the current file only (i.e., rational method approach, storm event, rainfall, etc.).Programs 2, 3, and 4 follow directly from the text. Program 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 pipesize in 3- and 6-inch increments by utilizing a pipeflow 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 6 estimates trapezoidal channel flow travel time based upon the normal depth flow velocity. Program 7 examines street flow travel time for two conditions: (1) all flow on one side of the street section, including the splitflow 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 9 models a confluence with up to 5 independent collection streams. Figure 2 illustrates typical CRT screen interaction, in this case for the

TABLE 1
RATIONAL METHOD PROGRAM SUBROUTINES

Program Number	*Description*
0	up-front loader (configuration file)
1	main driver program
2	utilizes the Kirpich formula for estimating the initial subarea time of concentration Tc
3	calculates rainfall intensities by log-log interpolation or specified table of time-versus-intensity data pairs
4	estimates a runoff coefficient
5	estimates pipeflow travel time for a user-specified or computer estimated pipe size
6	estimates travel time in a trapezoidal channel
7	estimates travel time in a street section of arbitrary size
8	estimates travel time in a pavement V-gutter
9	estimates confluence values
10	allows entry of specified data at a node
11	permits addition of subarea runoff to the mainline collection stream

selection of the desired hydrologic process.

The study approach is to subdivide the watershed into subareas such as shown in Fig. 1. 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 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 displays 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.



```
Enter upstream node number............................ ===>
;ALLOWABLE VALUES ARE [0.00  ] TO [9999.99   ]

Enter downstream node number.......................... ===>
;ALLOWABLE VALUES ARE [0.00  ] TO [9999.99   ]

SUBAREA HYDROLOGIC PROCESSES;
    1: Confluence analysis at node
    2; Initial subarea analysis
    3: Pipeflow traveltime (COMPUTER ESTIMATED pipesize)
    4: Pipeflow traveltime ....(USER SPECIFIED pipesize)
    5; Trapezoidal channel travel time
    6: Street-Flow analysis thru subarea
    7: User-specified information at node
    8: Addition of subarea runoff to mainline
    9: V-gutter flow thru subarea
Select subarea hydrologic process ..................... ===>

--------------------------------------------------------------------
TYPE: EXIT to leave program ; TOP  to go to top of page
      MAIN to go to main menu
```

FIGURE 2 - EXAMPLE C.R.T. SCREEN INTERACTION

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 hydrologic submodel. The main program stores the recently computed Q, Tc, and the effective 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.

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 effective 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.

Case Study

A master plan of drainage was developed for the City of Rancho Cucamonga, California by Williamson and Schmid Civil Engineers (Irvine, California) using a locally adopted version of RATNAT. The MPD preparation process included (1) data collection and synthesis; (2) collection of existing condition and ultimate planned condition development patterns; (3) development of major facility watershed boundaries; (4) development of the MPD link-node schematics; (5) development of the MPD link-node models based on the subarea addition method; (6) calibration of the rational method peak flow rate equation to local rainfall and runoff frequency data; and (7) preparation of MPD system sizing, maps, atlasses and the MPD acreage fees.

The entire city (approximately 35 square miles) was subdivided into sixteen individual watersheds. A separate watershed map (Atlas map) was developed for each watershed showing the subarea boundaries, drainage areas, soil types, development types, node numbers, storm drain alignments and sizes, and peak flow rates (Fig. 3). Figure 4 shows the rational method summary results for a portion of Area XII (Fig. 3). The computer estimated pipe sizes may need to be "averaged" to compensate for significant variations in land gradients. (Note: land gradients are used as an estimate of friction slope in Manning's Equation which is used to estimate the required pipe diameters.) The cost estimate for each "Line" was calculated including storm drain pipe (36 inches or greater), costs for excavation and fill, channel lining, pavement sawcutting, in additiion to engineering and contingencies. Then, based on the undeveloped area tributary to each line or system of lines, a drainage fee

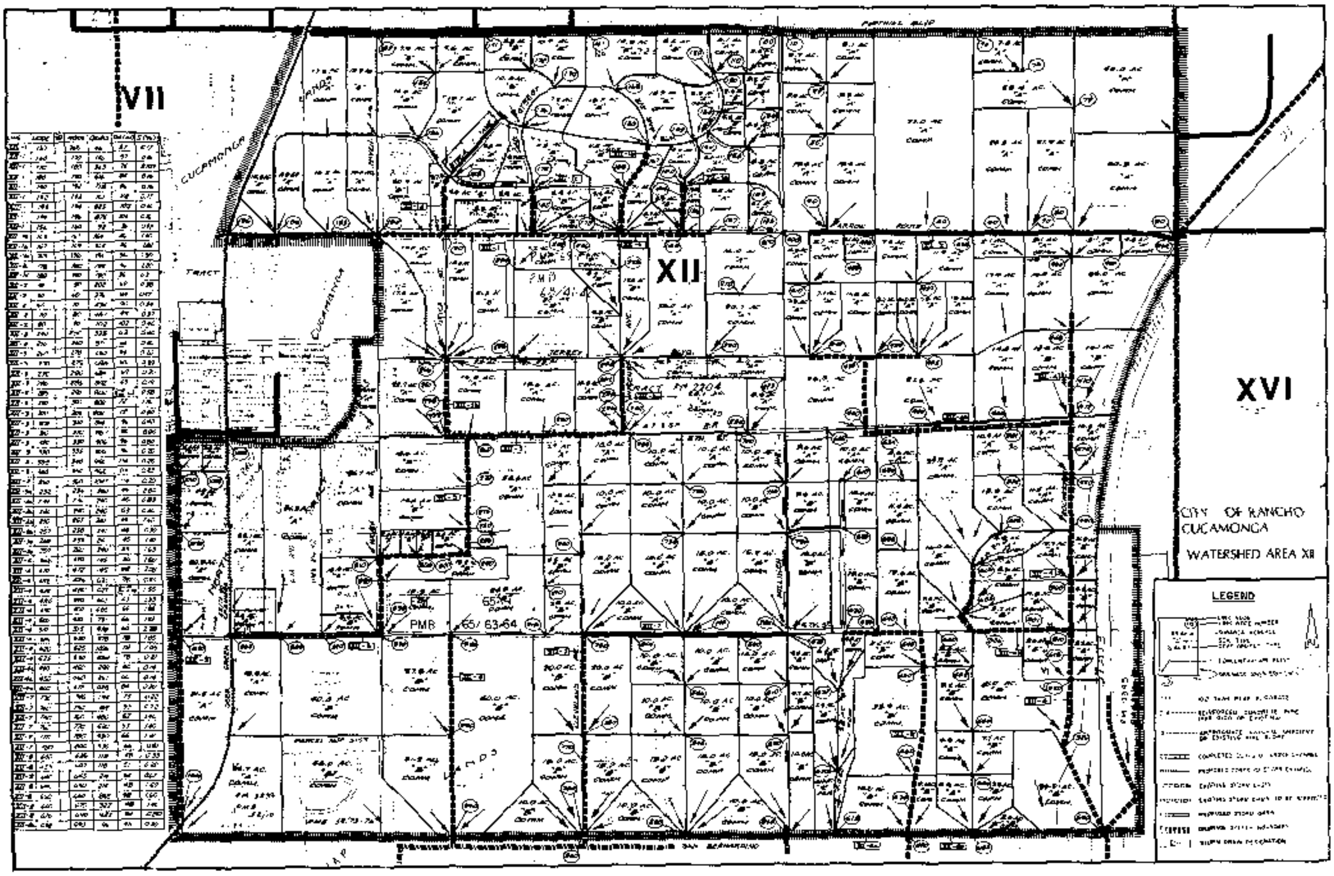
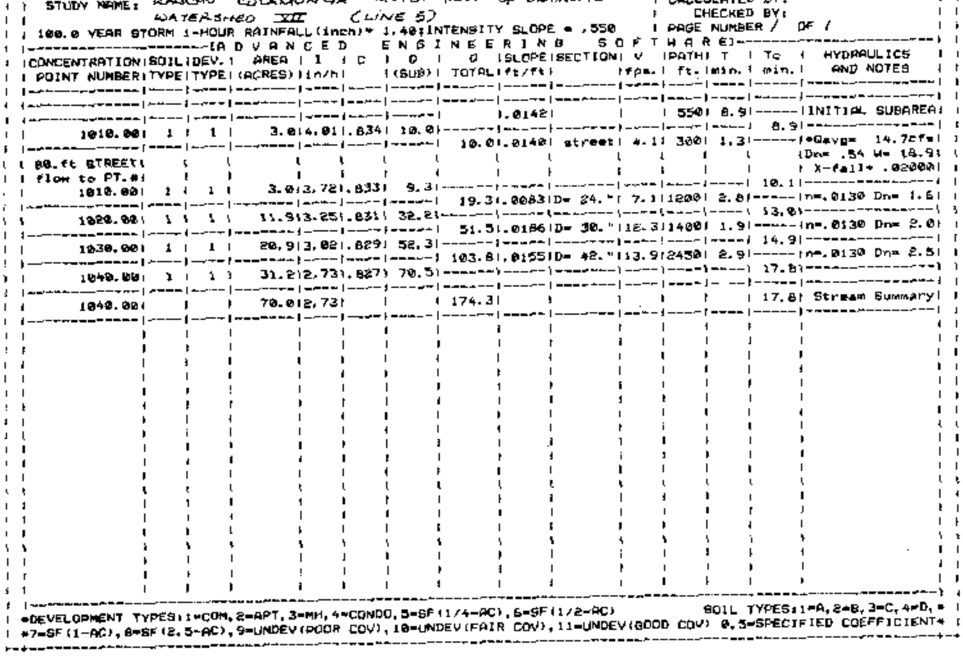


FIGURE 3 - EXAMPLE ATLAS MAP (AREA XII)



STUDY NAME: RANCHO CUCAMONGA MASTER PLAN OF DRAINAGE
WATERSHED XII (LINE 5)
100.0 YEAR STORM 1-HOUR RAINFALL(inch)= 1.40;INTENSITY SLOPE = .550
CALCULATED BY:
CHECKED BY:
PAGE NUMBER / OF /

[ADVANCED ENGINEERING SOFTWARE]

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
								.0142			550	8.9		INITIAL SUBAREA
													8.9	
1010.00	1	1	3.0	4.01	.834	10.0								
							10.0	.0140	street	4.1	300	1.3		*Qavg= 14.7cfs Dn= .54 W= 18.9 X-fall= .02000
80.ft STREET flow to PT.#													10.1	
1010.00	1	1	3.0	3.72	.833	9.3								
							19.3	.0083	D= 24."	7.1	1200	2.8		n=.0130 Dn= 1.6
													13.0	
1020.00	1	1	11.9	3.25	.831	32.2								
							51.5	.0186	D= 30."	12.3	1400	1.9		n=.0130 Dn= 2.0
													14.9	
1030.00	1	1	20.9	3.02	.829	52.3								
							103.8	.0155	D= 42."	13.9	2450	2.9		n=.0130 Dn= 2.5
													17.8	
1040.00	1	1	31.2	2.73	.827	70.5								
1040.00			70.0	2.73			174.3						17.8	Stream Summary

*DEVELOPMENT TYPES:1=COM,2=APT,3=MH,4=CONDO,5=SF(1/4-AC),6=SF(1/2-AC)
7=SF(1-AC),8=SF(2.5-AC),9=UNDEV(POOR COV),10=UNDEV(FAIR COV),11=UNDEV(GOOD COV) 0,5=SPECIFIED COEFFICIENT
SOIL TYPES:1=A,2=B,3=C,4=D,*

FIGURE 4 - EXAMPLE RATIONAL METHOD SUMMARY RESULTS

(cost per acre) was developed.

Conclusions

In order to implement a regional flood control system, an assessment based on property holdings (or other policy statement) is used to generate long term income for the construction of the project facilities. With the use of an advanced, highly interactive computer program (i.e., RATNAT), the development of a computerized master plan of drainage (MPD) can easily provide the necessary information on which to base the drainage fees. Once the MPD model has been developed, modifications to the watershed (i.e., storm drain alignments, development types, etc.) can easily be incorporated into the model and drainage fees updated if necessary.

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