A MATHEMATICAL MODEL FOR URBAN STORM DRAINAGE SYSTEM DESIGN

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by
Mehmet Doğan Pekçağlıyan
May 1981

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

Assist. Prof. Dr. Osman Akan ....

Supervisor

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Assoc. Prof. Dr. Rüştü Yüce ....

Chairman of the Department

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Assist. Prof. Dr. Semra Siber ....

Assist. Prof. Dr. Mustafa Y. Kılınç ....

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Assist. Prof. Dr. Nurünnisa Usul ....

Committee Chairman

ABSTRACT

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PEKÇAĞLIYAN, M. Doğan
M.S. in C.E.
Supervisor: Asst. Prof. Dr. Osman Akan
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A hydraulic design model is developed for urban storm drainage systems. The objective of the model is to determine the required number and locations of gutter inlets, section sizes and slopes of both sewers and collectors in a drainage system. Since the failure of different elements in a storm drainage system causes different magnitudes of flood damages, the elements of the system are designed considering design storms of different periods. In the model, gutter inlets and street sewers are designed for a rainstorm of a small return period, and collectors are designed considering a more severe rainstorm by simulating the hydraulic response of previously designed elements. A hydrograph time-lag method is adopted for gutter, sewer and collector flows. Also a simplified kinematic -wave routing method is provided for sewer and collector flows as an option. Additional options concerning cross -section types of sewer and collectors; number of sewers under a street are provided in the model. A computer program in FORTRAN IV language is developed. The model is applied by using both sewer and collector flow routing schemes to an approximately 29.3 ha basin in the Batıkent Satellite Town near Ankara. These applications illustrate the use of the mathematical model developed and also provide a comparison of the two routing schemes.

Key words : urban storm drainage, sewer, flow routing,
hydraulic design.

ÖZET

KENTSEL ALANDA YAĞMURSUYU DRENAJ SİSTEM TASARIMI İÇİN MATEMATİKSEL MODEL

PEKÇAĞLIYAN, M. Doğan
Yüksek Lisans Tezi, İnşaat Müh. Bölümü
Tez Yöneticisi: Asst. Prof. Dr. Osman Akan
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Kentsel alanda yağmursuyu drenaj sistemi için hidrolik tasarım modeli geliştirildi. Modelin amacı yağmursuyu ızgaralarının yerlerinin ve sayısının belirlenmesi, sokak mecralarının ve kollektörlerin eğimlerinin ve boyutlarının hesaplanmasıdır. Sistemde elemanların değişik tekerrür süreli yağışlardaki yetersizlikleri değişik oranlarda sel hasarlarına sebep olması nedeniyle elemanların tasarımı değişik tekerrür süreli yağışlar için yapılmaktadır. Modelde yağmursuyu ızgaralarının ve sokak mecralarının küçük tekerrür süreli bir yağış için; kollektörlerin ise uzun tekerrür süreli bir yağış için tasarımı yapılmaktadır. Hendek, sokak mecrası ve kollektör akımları için hidrograf kaydırma metodu, öteleme yöntemi olarak uygulanmış ayrıca basitleştirilmiş kinematik-dalga metodu sokak mecrası ve kollektör akımları için seçenek olarak sağlanmıştır. Diğer ek seçenekler, bir sokaktaki mecra sayısı, sokak mecraları ve kollektörler için kesit tiplerinin tercih imkanıdır. Model için FORTRAN IV dilinde bir bilgisayar programı geliştirilmiş; Ankara yakınında Batıkent'te 29.3 ha lık bir havzaya uygulanmıştır. Bu uygulamalar her iki öteleme yöntemini karşılaştırmakta ve modelin kullanılışını açıklamaktadır.

Anahtar kelimeler : Kentsel alanda yağmursuyu drenajı, mecra, akım ötelemesi, hidrolik tasarım.

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A : Flow area, also basin area in Table 2.1,

A_i: Subcatchment area of an inlet,

A_f: Full flow area in circular section,

B : Water surface width,

b : Width of rectangular section,

C : Runoff coefficient,

d_g: Depth in a gutter for peak flow,

d_s: Circular sewer diameter,

g : Gravitational acceleration,

I : Rainfall intensity,

I_s: Design storm intensity,

K_1, K_2: Conversion factors,

k_1, k_2: Coefficients,

L : Overland flow length of a basin,

L_o: Length of subcatchment of an inlet,

L_g: Gutter length,

L_s: Sewer length,

n : Manning roughness factor,

n_g: Manning roughness factor for gutters,

n_s: Manning roughness factor for circular sections,

n_r: Manning roughness factor for rectangular sections,

n_f: Manning roughness factor for full flow in circular sections,

Q : Flow rate,

Q_i: Inlet flow rate,

Q_j: Incoming sewer flow rate,

Q_s: Sewer flow rate,

NOMENCLATURE (continued)

Q_u: Sewer upstream flow rate,

Q_G: Gutter flow rate,

Q_{ip}: Gutter peak flow rate,

Q_p: Sewer peak flow rate,

Q_c: Carry-over flow rate,

Q_1: Inflow rate,

Q_o: Outflow rate,

q, q_l: Lateral inflow rates,

R : Hydraulic radius,

R_f: Hydraulic radius for full flow in circular section,

R_g: Hydraulic radius for peak gutter flow,

S : Average slope of basin, also channel bed slope in Eqs. 3.11 and 3.12,

S_f: Friction slope, also full flow slope in Eqs. 3.11 and 3.12,

S_o: Bed slope of a channel,

S_s: Sewer slope,

S_g: Longitudinal gutter slope,

t : Time,

t_c: Time of concentration,

t_g: Gutter flow time,

t_d: Storm duration,

t_f: Lag time,

t_i: Inlet time,

U_l: Lateral inflow velocity,

V : Flow velocity,

NOMENCLATURE (concluded)

V_f: Full flow velocity,

V_p: Peak flow velocity,

x : Distance,

y : Flow depth, also height of rectangular section in Eq. 3.22,

z : Street crown slope,

α: Percentage of impervious areas,

θ : Angle of channel bed, also central angle of water surface in Eqs. 3.9 and 3.10,

ϕ : Abstraction index.

1. INTRODUCTION

Urban storm drainage implies the collection of storm runoff and conveying it to the nearest point of disposal. An adequate and properly functioning storm water collection system is one of the vital facilities in preserving and improving the urban environment. In newly developing urban areas the first need is certainly a sanitary sewer system as the storm water can be dealt with to a certain extent by the aid of street gutters and the natural water courses. As the city grows, however the underground conveyance of storm water runoff will be necessary. In fact, attempts to provide the greater safety of sewerage, and freedom from nuisance have caused seperate storm water collection systems to be adopted wherever finances permit even in small towns of many developed countries. Quite a few recent sewerage project reports among which are those prepared for Ankara (Camp-Harris-Mesara, 1969) and Batıkent (Orta Doğu Teknik Üniversitesi, 1979) recommend the construction of seperate storm water collection systems also in the Turkish cities.

The importance of storm water collection systems is usually ignored in the public, since the storm sewers which constitute the main part of the system are buried under the ground and are invisible. However, the investments required for the construction and the maintanence of storm water collection systems are of significant magnitudes. Hence, in order to secure a well functioning storm water collection system, a design engineer must make the best use of the upto date technological tools.

The analysis aspect of the urban storm water collection systems has caught considerable attentions during the last decade. A review and comparisons of a number of rainfall -runoff simulation models have been given by Chow and Yen (1976). Concerning the design of urban drainage systems on the other hand, a limited number of studies are available in the literature. Yet, these few studies cover a broad spectrum of sophistication varying from very simple models based on rational method (ASCE and WPCF, 1969) to rather sophisticated ones based on the solution of the St. Venant equations (Sevük, 1973). However, as pointed out by Chow (1978), the selection of the most "suitable" model for the field conditions is very difficult since the most suitable does not necessarily mean the most sophisticated. Indeed, there still is much need for research in the design aspect of the stormwater drainage problems in attempts of developing suitable models. Accordingly, the objectives of the present study are:

i. To develop a suitable mathematical model and a computer program for the design of stormwater collection systems.

ii. To illustrate the use of the model through its application to a real world design problem.

iii. To provide a User's Guide for the computer program of the model for future users.

The mathematical model developed is not the most sophisticated one possible. However, it aims to satisfy the basic principles of hydraulics within the limitations of not being inmanagable for practising engineers. The design of both the surface and the subsurface elements of a stormwater collection system is considered. A unique feature of the model makes it possible to group the elements of a system in two different classes according to their importance and accomplish their design by using design storms of two different return periods.

2. THEORETICAL BACKGROUND AND RELATED PAST RESEARCH

A stormwater collection system consists of basically street gutters, inlets, sewers, manholes, and main collectors as shown schematically in Fig. 2.1. Street gutters usually constructed on both sides of the street collect stormwater from surfaces such as sidewalks, building roofs, front yards, and driveways and direct it to the inlets. Through the inlets, stormwater is delivered to the subsurface system consisting of stormsewers, collectors and manholes. A storm sewer is a pipe or a conduit of any shape which is intended to carry stormwater or other types of surface runoff reaching the subsurface system. Domestic and industrial wastes are not included in the sewer flow. A collector or main trunk is the principal sewer into which a number of branch sewers discharge. Manholes are structures that provide joining of the sewers as well as convenient access to sewers with the least hydraulic inference for observation and maintenance.

In addition to the basic elements of gutters, inlets, sewers, collectors and manholes; a stormwater collection system may include some special structures like catch basins, syphons and disposal structures. These structures are discussed in detail elsewhere (ASCE and WPCF,1969) and will not be covered in the present study since they are needed only under special conditions.

2.1. Hydraulics of Stormwater Collection Systems

Various types of flows occur in a stormwater collection system. From hydraulics viewpoint these flows can be classified according to their nature into the groups of

i. overland flow,

ii. gutter flow,

iii. flow in sewers and collectors.

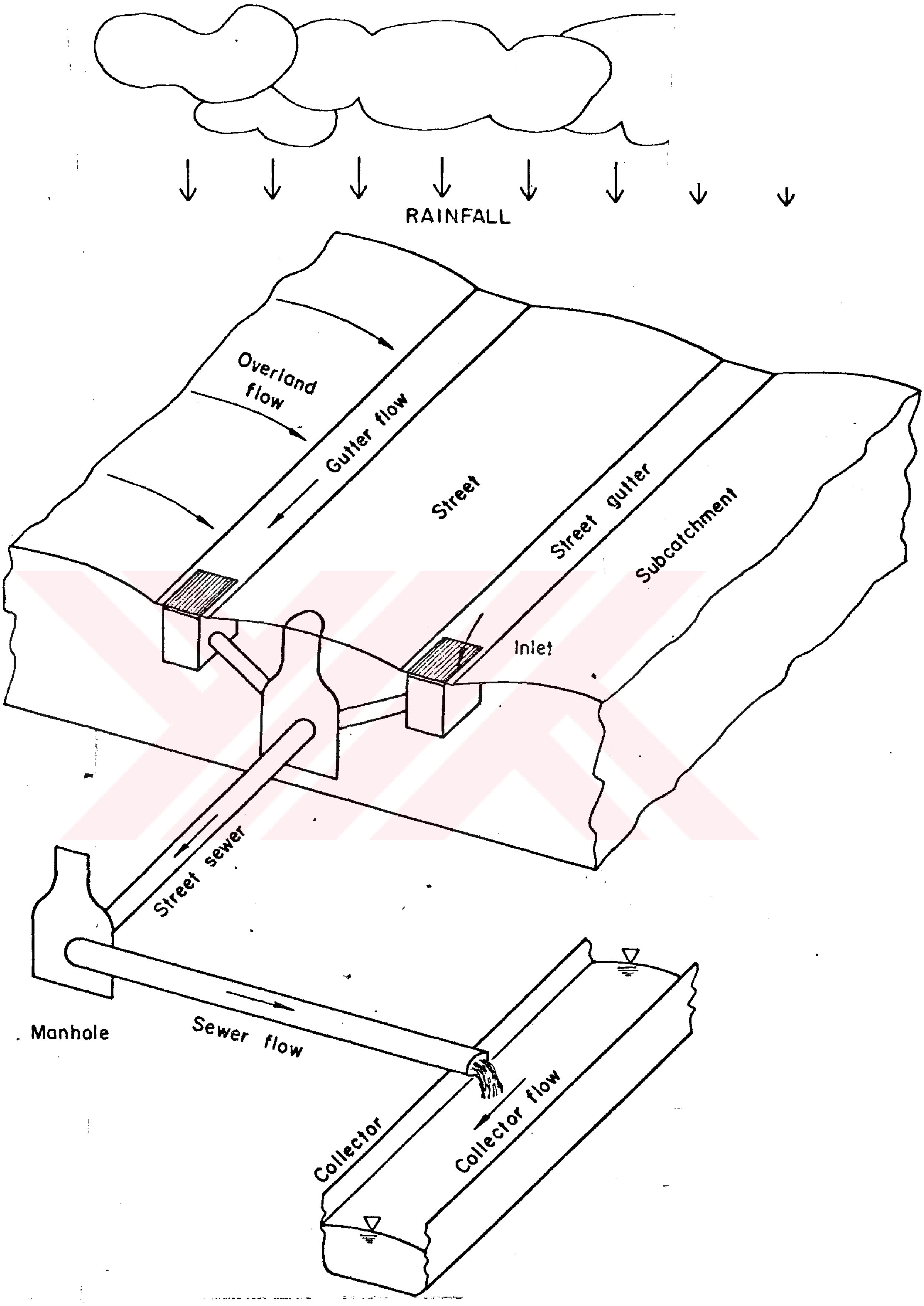

Fig. 2.1 Schematic Representation of a Stormwater Collection System

These flow components are shown in Fig. 2.1. All these components are of unsteady and nonuniform flow type, and they are subject to backwater effects from both ends. They can mathematically be expressed by a set of nonlinear partial differential equations attributed to St. Venant (Chow, 1959). Solutions of such equations can possibly be obtained by numerical techniques, but require a considerable amount of computation time. Therefore certain simplified approaches are inevitable in mathematical models developed for use in the practising engineering.

2.1.1. Overland Flow

The movement of rainwater from the point it drops on the earth to a gutter can be represented by an overland flow. This component includes flow over building roofs, gardens, and pedestrian ways. Being a special type of spatially varied unsteady shallow water flow, the overland runoff can be represented by the St. Venant equations (Chow,1959; Chow and Yen,1976). For overland flow, St. Venant's continuity and momentum equations can respectively be expressed as

$$\frac{\partial y}{\partial t} + y\frac{\partial V}{\partial x} + V\frac{\partial y}{\partial x} = q \tag{2.1}$$

$$y\frac{\partial V}{\partial t} + yV\frac{\partial V}{\partial x} + gy\cdot\cos\theta\,\frac{\partial y}{\partial x} = gy(S_o - S_f) + q(U_1 - V) \tag{2.2}$$

in which x is the direction of the flow measured along the bed, t is time, V is the cross-sectional average flow velocity, y is the flow depth, θ is the angle between the channel bed and the horizontal, $S_o = \sin\theta$ is the bed slope, S_f is the friction slope, g is the gravitational acceleration, q is the lateral inflow which is defined as the rate of rainfall reaching the ground minus the rate of infiltration, and U_1 is the velocity of lateral inflow in the direction of x.

Analytical solutions can not be obtained to the St. Venant equations due to the nonlinear nature of these expressions. A number of numerical schemes have been proposed in the past to solve these equations by using high speed digital computers (Baltzer and Lai, 1968; Amein and Fang, 1969). However, these solutions are cumbersome. Also the boundary conditions for these equations can not be truly and accurately defined in the field conditions. Hence in mathematical modeling of urban storm drainage, overland flow component is determined by simplified approaches rather than attempting to solve the St. Venant equations.

In the practice, peak flow rate of the overland runoff from an urban basin is computed by simple formulas relating the storm intensity and the basin characteristics. Most of such expressions are of empirical nature. Summarized in Table 2.1 are the rainfall-runoff formulas commonly used in urban storm drainage analysis. In this table A is the basin area in ha, I is the rainfall intensity in mm/hr, and S is the average slope of the basin; and C is a coefficient related to basin characteristics. Among the formulas in the table, Rational formula is the most popular one; and its runoff coefficient C can be found elsewhere (ASCE and WPCF, 1969).

The expressions of the types given in Table 2.1 are generally based on the assumption that the peak flow rate due to a uniform rainfall occurs when a raindrop from the most remote point in the basin reaches the gutter. The time elapsed from the beginning of the rainfall to occurrence of peak discharge is called the time of concentration of the basin, t_c. Hence, the intensity I to be adopted in the expressions given in Table 2.1 should correspond to a rainfall duration of t_c. The relationship between the intensity and duration depends also on the frequency of the rainfall. These relationships can be exemplified by the family of intensity-duration-frequency curves in Fig. 2.2.

Table 2.1. Some Rainfall-Runoff Formulas for Small Drainage Basins (Chow, 1962)

Name	Peak Flow Rate (m^3/s)
Adams	$0.00723C \cdot A \cdot I \sqrt[12]{\frac{S}{AI^2}}$
Burkli-Ziegler	$0.06236C \cdot A \cdot I \sqrt[4]{\frac{S}{A}}$
Chamier	$0.011C \cdot A^{0.75} \cdot I$
Hawksley	$0.02778C \cdot A \cdot I \sqrt[4]{\frac{S}{A\ I}}$
McMath	$0.00917C \cdot A \cdot I \sqrt[5]{\frac{S}{A}}$
Rational	$0.00278C \cdot I \cdot A$

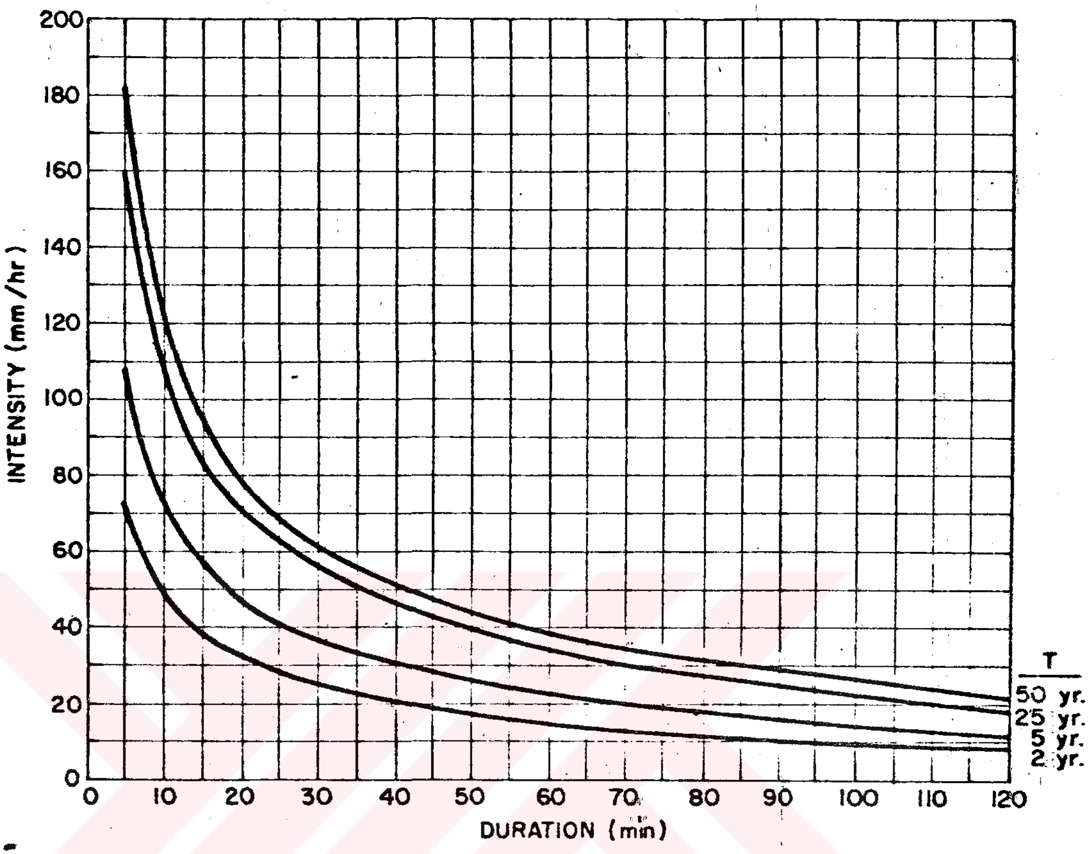

Fig. 2.2. Rainfall Intensity-Duration-Frequency Curves for Ankara

Several formulas proposed for estimating the time of concentration are listed in Table 2.2. In this table k_1 and k_2 are coefficients representing flow resistance, n is the Manning roughness factor, L is the overland flow length in m, α is the percentage of impervious areas, I is the intensity in mm/hr, and S is the average slope of the basin.

Table 2.2. Selected Time of Concentration Formulas for Overland Flow (Yen, 1978)

Name	Time of Concentration (min)
Izzard	$526.44(2.754\times10^{-5} I^{1/3}\frac{k_1}{I^{2/3}})(\frac{L}{C^2 S})^{1/3}$
Kerby	$1.446(\frac{k_2 L}{S^{1/2}})^{0.476}$
Kinematic-wave	$\frac{6.92}{I^{0.4}}(\frac{n^2 L^2}{S})^{0.3}$
Shake et.al.	$\frac{0.670\ L^{0.24}}{S^{0.16}\ \alpha^{0.26}}$

2.1.2. Gutter Flow

Runoff in a street gutter occurs in the form of a spatially varied, unsteady open channel flow. As pointed out by Akan and Yen (1980) gutter flow can be represented by St. Venant equations expressed as

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q_1 \tag{2.3}$$

$$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} + g\frac{\partial y}{\partial x} = g(S_o - S_f) - \frac{Vq_1}{A} \tag{2.4}$$

in which Q is the flow rate, t is time, x is the distance along the gutter, y is the average depth of flow measured normal to x, V is the average velocity of flow, q_1 is the lateral inflow rate from the overland runoff per unit length of the gutter.

As in the case of overland flow component, the solution of the St. Venant equations for gutter flow is costly and impractical. Hence, simplified approaches are necessary also for gutter flow.

A number of researchers including Huber et. al.(1975), and Chow and Yen (1976) represent the gutter flow by using the variations of the kinematic-wave approximations. The main assumption of the kinematic-wave method is that the friction slope S_f can be set equal to the bottom slope of an open channel. Hence Eq. 2.4 is simplified to

$$S_o = S_f \tag{2.5}$$

where S_f is computed by a steady flow friction equation like Manning formula written in metric units as

$$Q = \frac{1}{n} A R^{2/3} S_f^{1/2} \tag{2.6}$$

in which Q is the flow rate, n is the Manning roughness factor, A is the cross-sectional area of the flow, R is the hydraulic radius, and S_o is the bottom slope of the gutter. Numerical simultaneous solutions of Eqs. 2.3, 2.5 and 2.6 constitute the gutter flow computations based on a kinematic-wave approach. Further simplifications of gutter flow calculations can be suggested by assuming the flow is steady and uniform with a flow rate equal to the peak surface runoff discharge from the contributing basin (Metcalf and Eddy, 1974). In such an oversimplified approach, Eqs. 2.5 and 2.6 are adopted for gutter flow computations.

2.1.3. Flow in Sewers and Collectors

The propagation of stormwater in sewers and collectors can also be described mathematically by the St. Venant equations (Sevük, 1973) as

$$B\frac{\partial y}{\partial t} + BV\frac{\partial y}{\partial x} + A\frac{\partial V}{\partial x} = 0 \tag{2.7}$$

$$\frac{\partial V}{\partial t} + V\frac{\partial V}{\partial x} = gS_o - g\frac{\partial y}{\partial x} - gS_f \tag{2.8}$$

in which A,B and y are respectively the cross-sectional area, water surface width, and depth of flow in sewers, V is the cross-sectional mean velocity, S_o and S_f are respectively the sewer or collector bottom and energy grade line slopes, x is the distance along the sewer, and t denotes time. As mentioned in Sections 2.1.1 and 2.1.2, analytical solution of Eqs. 2.7 and 2.8 is not possible and the solution of these equations by numerical techniques is cumbersome and costly for urban storm drainage conditions. Therefore, simplified approaches among which is the kinematic-wave method have been deviced in the past for flow routing in storm sewers (Huber et. al.,1975; Yen and Sevük, 1975). The application of the kinematic-wave to sewer flow is essentially the same as for gutter flow.

Another simplified approach for sewer flow routing is the hydrograph time-lag method. In this approach an upstream inflow hydrograph of a sewer is carried to the downstream end without any distortion in its shape. However, the hydrograph is shifted by a lag time estimated from the length of the sewer and a characteristic flow velocity.

2.2. Review of Major Urban Storm Drainage Models

A review of the major existing models for the analysis and design of urban storm drainage system are given here in view of the basic hydraulic considerations discussed in the preceding sections. Such a review is especially useful for evaluating the mathematical model developed in the present study.

2.2.1. Rational Method

Rational method is the most popular approach for practising engineers for sewer system design due to its simplicity. The method is based on the rational formula given in Table 2.1. On the other hand, in application of the rational formula to sewer design, the time of concentration is taken as the summation of the inlet time and the sewer flow time. The sewer system is designed starting from the most upstream sewers and proceeding sequencially towards downstream. The rational method has no theoretical justification.

2.2.2. Chicago Hydrograph Method

The overland flow component in the Chicago Hydrograph Method is calculated by using Izzard's synthetic hydrograph approach (Tholin and Keifer, 1960). Gutter and sewer flows are determined from a linearized version of the kinematic-wave approximation. Sewers are designed in a sequential manner starting from the upstream ones. The peak inflow rate for each sewer is adopted as the design discharge.

2.2.3. Transport Road Research Laboratory (TRRL) Method

The inlet hydrographs are determined by algebraically summing the contributions from the subcatchment of impervious surfaces which have equal flow times to the point of inlet. Contributions from pervious surfaces are neglected. Inlet hydrographs are routed in the sewer system by using a hydrograph time-lag method in corporation with a storage routing scheme. The downstream hydrograph of each sewer is first appoximately determined by a time-lag approach, then it is modified by using a storage routing scheme (Terstriap and Stall, 1969). Again the peak inflow rate of each sewer is adopted as the design discharge.

2.2.4. Illinois Urban Drainage Area Simulator (ILLUDAS)

ILLUDAS is a modification of the TRRL method essentially to account for the surface runoff from pervious areas (Terstriap and Stall, 1974). Also the sewer routing scheme is somehow improved by using a scheme which can be classified as a linearized kinematic-wave method.

2.2.5. EPA Stormwater Management Model (SWMM)

SWMM is a relatively comprehensive model considering both quantity and quality aspects of stormwater runoff. It utilizes linear kinematic-wave approximations for overland and gutter flows, and a modified nonlinear kinematic-wave approach for sewer flow computations. The modification of the nonlinear scheme is provided for the purpose of accounting for the backwater effects to a certain extent in the sewer system.

2.2.6. Illinois Urban Storm Runoff (IUSR) Method

IUSR employes a nonlinear kinematic-wave scheme for flow routing in the overland flow surfaces and gutters. Inlet hydrographs are computed considering the interception capacities of the inlets which may behave either as weirs or orifices depending on the gutter flow conditions. Carry-overs from inlets are allowed (Chow and Yen, 1976). A dynamic-wave flow routing scheme is employed for flow in the sewers. Backwater effects from the joining sewers and the manholes on sewer flow are considered.

3. DESCRIPTION OF PROPOSED MATHEMATICAL MODEL

The proposed mathematical model differs from most of the existing models in several aspects. The highlights of the model can be summarized as follows:

i. The required number and the locations of the gutter inlets in the drainage area are determined as part of the model output.

ii. Neither the sewer section sizes nor the slopes are to be specified by the user. The model attempts to select a proper combination of a sewer section size and a slope according to a minimum soil cover and a maximum allowable velocity criterion.

iii. Considering possible flood damages due to a failure of each element, components of a storm drainage system are categorized into two groups. Then those elements in different groups are designed by use of design storms of different return periods.

iv. A hydrograph time-lag method is adopted for flow routing in the gutters, sewers and the collectors. Also an optional simplified kinematic-wave technique is provided for unsteady flow computations in the sewers and the collectors.

3.1. Grouping of the Elements

Since the failure of different elements in a storm drainage system cause different magnitudes of flood damages; from engineering economy viewpoint, these elements need to be designed considering design storms of different return periods. In the proposed model the elements of an urban drainage system are categorized into two groups.

Gutter inlets, street sewers, and manholes constitute the first group; and they are designed for a rainstorm of a small return period like 2 to 5 years. Main collectors are in the second group and they are designed considering a more severe rainstorm with a return period of 10 to 25 years. Accordingly, the design of a storm drainage system is completed in two stages. Elements of the first group are designed in the first stage; and the main collectors are dimensioned in the second stage. Evidently, the hydraulic response of the first group Elements under a rainstorm more severe than their design -storm need to be simulated in the second stage of the design procedure.

3.2. Design of First-Group Elements

Gutter inlets, street sewers, and manholes are included in the first group. These elements are designed according to a design storm with a return period of 2 to 5 years. Manholes are selected among the standard types with sizes depending upon the section sizes of the incoming and outgoing sewers. Hence no means are provided in the model to compute the manhole dimensions.

3.2.1. Gutter Inlets

Gutter inlets are first placed at the corners of each block. The number and the locations of additional gutter inlets required are then determined such that no carry -over from an inlet is allowed under the conditions of the design storm. This is accomplished by providing an inlet wherever the peak gutter discharge is likely to exceed a specified magnitude. Alternatively, the spacings of the inlets may be controlled such that the flow depth in the gutter will not exceed a specified maximum allowable depth.

3.2.1.1. Inlet Hydrographs

The drainage area is divided into a number of subcatchments, each flowing into a gutter inlet existing in the drainage system. Since no carry-over is allowed from an inlet under the design-storm conditions, the entire rainfall excess from a subcatchment is intercepted by the associated gutter inlet. As suggested by Yen and Cheng (1980) the inlet hydrographs are assumed to be triangular or trapezoidal in shape as shown in Fig. 3.1 depending upon the relative magnitudes of the inlet time t_i and the duration of the design storm t_d. If the storm duration t_d is equal or greater than inlet time t_i, the peak discharge is equal to

$$Q_{ip} = A_i(I_s - \phi) \qquad (3.1)$$

in which Q_{ip} is the peak inflow rate of the inlet, A_i is the subcatchment area of the inlet, I_s is the intensity of design storm, and ϕ is the abstraction index. For the inlets which have inlet times greater than the rainfall duration, the peak flow rate of the inlet hydrograph is calculated as

$$Q_{ip} = \frac{t_d}{t_i} A_i(I_s - \phi) \qquad (3.2)$$

in which the terms are as defined previously. An inspection of Fig. 3.1 together with Eqs. 3.1 and 3.2 reveals that the volumes of the inlet hydrographs are equal to the net effective rainfall volume occuring over the corresponding subcatchment.

The abstraction index ϕ in Eqs. 3.1 and 3.2 consist of the losses mainly due to the infiltration into the soil and depressions storage. As pointed out by ASCE and WPCF (1969) the infiltration capacity of various types of bare soils after one hour of continuous rainfall can be estimated as 12.5-25.0 mm/hr for sandy, open-structured soils; 2.5-12.5 mm/hr for loam; and 0.2-2.0 mm/hr for clay, close-structured soils. The infiltration capacity is 3-7.5 times greater for surfaces covered with grass. For detention losses 0.25 cm loss throughout the rainfall duration must be taken into account. Evidently the soil conditions such as saturation of the soil prior to

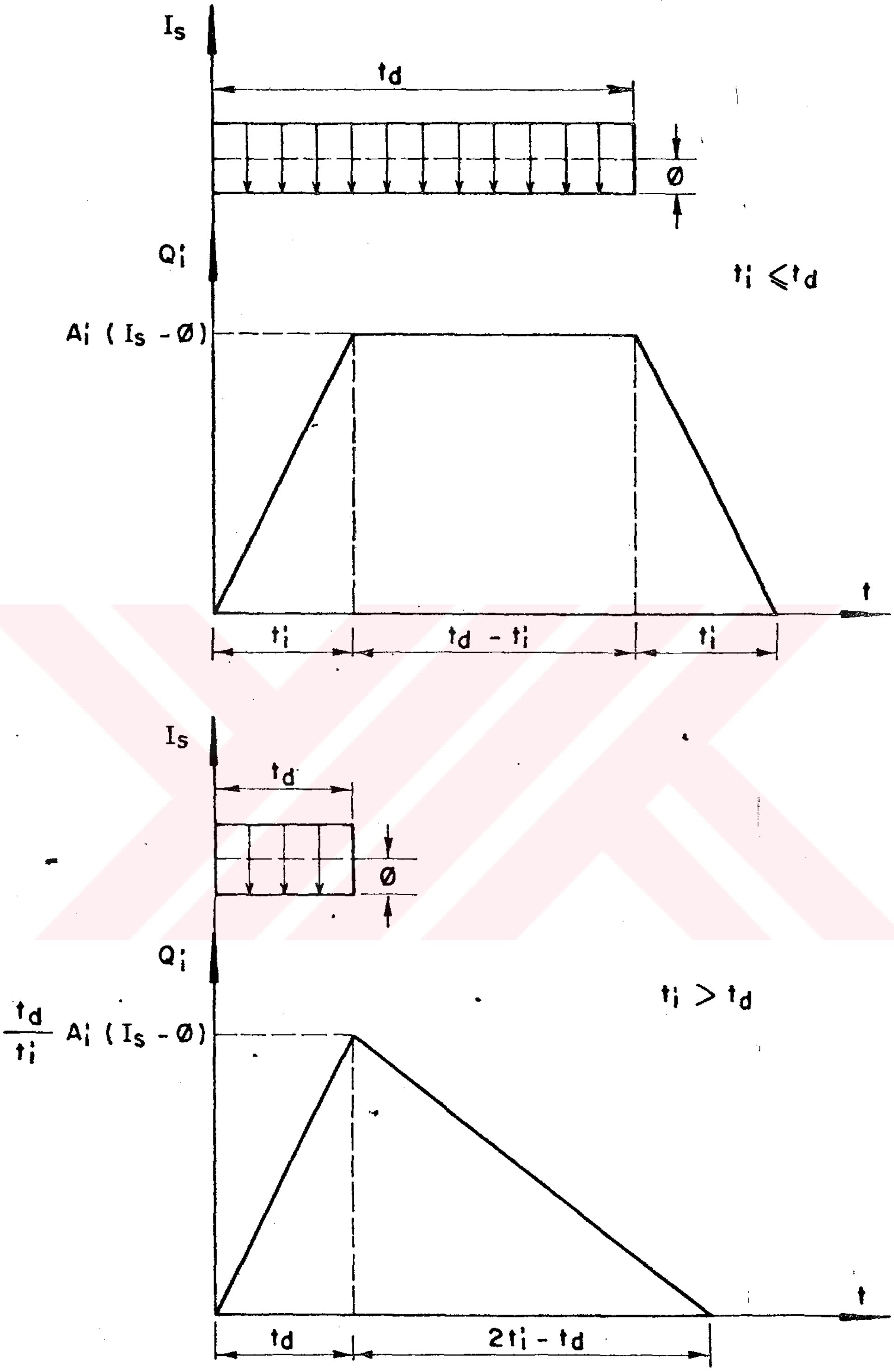

Fig. 3.1. Inlet Hydrograps

the rainfall greatly affect the infiltration capacity. In design, the selection of lower limits will provide safety.

The inlet time t_i is equal to the summation of the time of concentration t_c for the subcatchment and the gutter flow time t_g. The time of concentration is computed by using the kinematic-wave formula (Yen, 1978).

$$t_c = \frac{K_1}{I_s^{0.4}} \left[\frac{n^2 \ L_o^2}{S_s} \right]^{0.3} \tag{3.3}$$

in which L_o is the subcatchment flow length, S_s is the the average slope of the subcatchment, n is Manning roughness factor, and K_1 is a conversion factor. Suggested values of n for different types of land use are given in Appendix A. The conversion factor K_1 is 0.93 for the British unit system and it becomes 6.92 when t_c is in min, I_s is in mm/hr, and L_o is in m. The gutter flow time t_g is computed from Manning formula as

$$t_g = K_2 L_g n_g \ / \ (R_g^{2/3} \cdot S_g^{1/2}) \tag{3.4}$$

in which L_g is the length of the gutter, n_g is the Manning roughness factor, S_g is the longitudinal gutter slope and R_g is the hydraulic radius corresponding to the peak flow rate. The conversion factor K_2 is 1/60 when t_g is in min; and R_g and L_g are both in m.

3.2.1.2. Additional Inlets

The peak flow rate of an inlet hydrograph is checked against the allowable maximum gutter discharge in order not to permit any carry-over from an inlet. Allowable gutter discharge corresponds to the interception capacity of a standard-type inlet, and it is about 50 lt/s (İller Bankası, 1971).

Exceedance of the maximum allowable gutter discharge by a peak inlet flow rate implies a need for additional inlets along the gutter. These additional inlets are placed with equal spacing; the number of which is calculated such as the maximum gutter discharge criterion is not violated. The calculation of the number of the additional inlets requires a trial-and-error procedure.

Optionally the mathematical model permits a maximum allowable gutter flow depth to be specified instead of an allowable discharge for controlling the inlet spacing. The maximum allowable gutter flow depth may be limited by the curb height or it can be selected such that the top width of the gutter flow will not exceed the width of the inlet. The gutter flow depth corresponding to the peak discharge is computed by using the Manning formula written in metric units as

$$d_g = 1.54 \left[\frac{Q_{ip} \cdot n_g}{z \cdot S_g^{1/2}} \right]^{3/8} \qquad (3.5)$$

in which d_g is the flow depth in the gutter assumed triangular in cross section, z is the reciprocal of street crown slope, S_g is the longitudinal slope of the gutter, and n_g is the Manning roughness factor of the gutter. If d_g thus computed exceeds the specified allowable depth, then additional inlets are placed with equal spacings along the gutter. The number of these additional inlets are determined such that the allowable depth criterion is satisfied.

Main assumption of placing additional inlets at equal intervals is that the basin area, and the characteristics of the basin is uniformly distributed along the gutter; and the slope of the gutter is constant. Where additional inlets are placed, the inlet hydrographs are recomputed following the procedure given in Section 3.2.1.1.

3.2.2. Design of Street Sewers

Street sewers are designed sequentially starting from the most upstream ones and proceeding in the downstream direction. The size of a sewer is computed such that a maximum allowable velocity will not be exceeded at the peak discharge of the upstream inflow hydrograph of the sewer. The upstream inflow for a sewer consists of the outflows from the further upstream sewers, and the surface runoff contributing directly to the manhole attached to the upstream end of the sewer. The direct surface runoff input is expressed by the corresponding inlet hydrographs. Also, a flow routing scheme is provided to find the discharge hydrographs at the downstream ends of the sewers. This information is necessary to carry out the design procedure to further downstream sewers.

3.2.2.1. Selection of Sewer Size and Slope

Street sewers are designed starting from the most upstream pipes and progressing in sequence one by one towards downstream. The inflow hydrograph of a sewer is computed by using the formula

$$Q_u = \sum Q_i + \sum Q_j \tag{3.6}$$

in which Q_u is the upstream inflow rate for the sewer, $\sum Q_i$ is the summation of the inlet flow rates discharging directly into the manhole connected to the upstream end of the sewer, and $\sum Q_j$ is the sum of the discharges from the upstream sewers joining the same manhole. Evidently $\sum Q_j$ is zero for the sewers located at upstream extremeties of the system. The peak flow rate Q_p of the upstream inflow hydrograph is selected to be the design discharge. The required sewer size is determined from the Manning formula according to a specified section type. If circular sections are desired, the required sewer diameter d_s is calculated in m as

$$d_s = 1.548(Q_p n_s / \sqrt{S_s})^{0.375} \tag{3.7}$$

in which Q_p is the peak inflow rate in m^3/s, n_s is the Manning roughness factor for circular sewer, and S_s is the sewer slope. The next standard sewer size larger than d_s is selected. If rectangular sections are desired, the required section type is determined by calculating the conveyance factor

$$A \cdot R^{2/3} = \frac{Q_p n_r}{\sqrt{S_s}} \tag{3.8}$$

in which n_r is the Manning roughness factor for rectangular sections, and the other terms are as defined previously. Standard rectangular section with a greater conveyance factor is chosen for that peak discharge at the adopted sewer slope.

In order to minimize the excavation work, first the associated street slope is adopted and employed in Eqs. 3.7 and 3.8 as the sewer slope. Then the design flow velocity is calculated by using the selected sewer slope and the size. If the computed velocity is smaller than the maximum allowable velocity, the design is accepted. In cases the calculated velocity exceeds the maximum allowable velocity, depending upon the choice of the user, either the sewer size is increased or the sewer slope is decreased to values at which the maximum velocity criterion is satisfied. If a change in sewer slope is preferred, chute structures are added to the system for the purpose of satisfying the minimum soil cover requirement. the heights of the chute structures are also computed in the model. The user is allowed to specify the number of the larger standard size sections to be tried as an alternative to the chute structures for satisfying the maximum allowable velocity criterion.

Since sewers are designed to flow partially filled, the design flow velocity to be checked against the maximum allowable velocity is computed for partially filled flow conditions. In circular sections, due to the geometry, no explicit expressions are available to compute the flow velocity. The relationships between the cross-sectional properties of partially filled circular sewers are expressed in terms of the full flow parameters as

$$\frac{A}{A_f} = \frac{\theta}{360} - \frac{\text{Sin}\theta}{2\pi} \qquad (3.9)$$

$$\frac{R}{R_f} = 1 - \frac{360\text{Sin}\theta}{2\pi\theta} \qquad (3.10)$$

$$\frac{V}{V_f} = \frac{n_f}{n} \cdot \left|\frac{R}{R_f}\right|^{2/3} \cdot \left|\frac{S}{S_f}\right|^{1/2} \qquad (3.11)$$

$$\frac{Q}{Q_f} = \frac{n_f}{n} \cdot \frac{A}{A_f} \cdot \left|\frac{R}{R_f}\right|^{2/3} \cdot \left|\frac{S}{S_f}\right|^{1/2} \qquad (3.12)$$

in which A is the flow area, R is the hydraulic radius, V is the flow velocity, Q is the flow rate, n is the Manning roughness factor, S is the slope of the sewer, and θ is the central angle of the surface in degrees. The parameters with subscript f denotes the hydraulic properties for full flow case. These relationships can also be represented graphically as shown in Fig. 3.2 (ASCE and WPCF, 1969). The variation in Manning roughness factor with flow depth is accounted for Eqs. 3.11 and 3.12, and as well as in Fig. 3.2. In the mathematical model the flow velocity is computed by using the relationships given above. Values for Manning roughness factor for full flow conditions are given in Appendix A.

Since the slopes of the sewers in the system vary, Eqs. 3.7 or 3.8 may yield a sewer section size smaller than that of upstream one. However as recommended by ASCE and WCPF (1969), the mathematical model does not allow any reduction in sewer size in the flow direction. In other words, a sewer outgoing from a manhole can not be smaller in size than any one of the incoming sewers.

As the design of a sewer is completed the discharge hydrograph at its downstream end is calculated by use of a routing scheme.

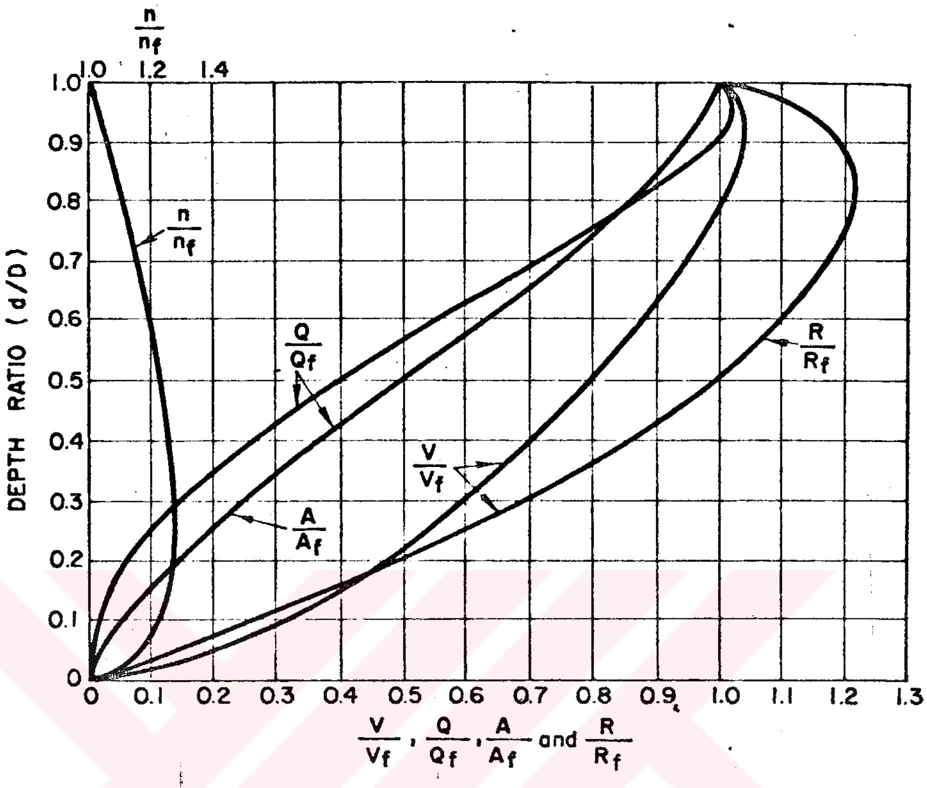

Fig. 3.2. Hydraulic Elements of Partly Filled Circular Sewers (ASCE and WPCF, 1969)

3.2.2.2. Sewer Flow Routing

The user of the model is allowed to select one of the two routing schemes deviced for determining discharge hydrographs at the downstream ends of the sewers. The first scheme is based on a hydrograph time-lag method, and the second scheme is a simplified version of a kinematic-wave model.

The sewer flow time t_f required in the hydrograph time-lag scheme is computed by

$$t_f = \frac{L_s}{V_p} \tag{3.13}$$

in which L_s is the length of the sewer and V_p is the peak flow velocity. Then, as shown in Fig. 3.3, the upstream inflow hydrograph of a sewer is shifted by t_f along the time axis to determine the sewer outflow hydrograph.

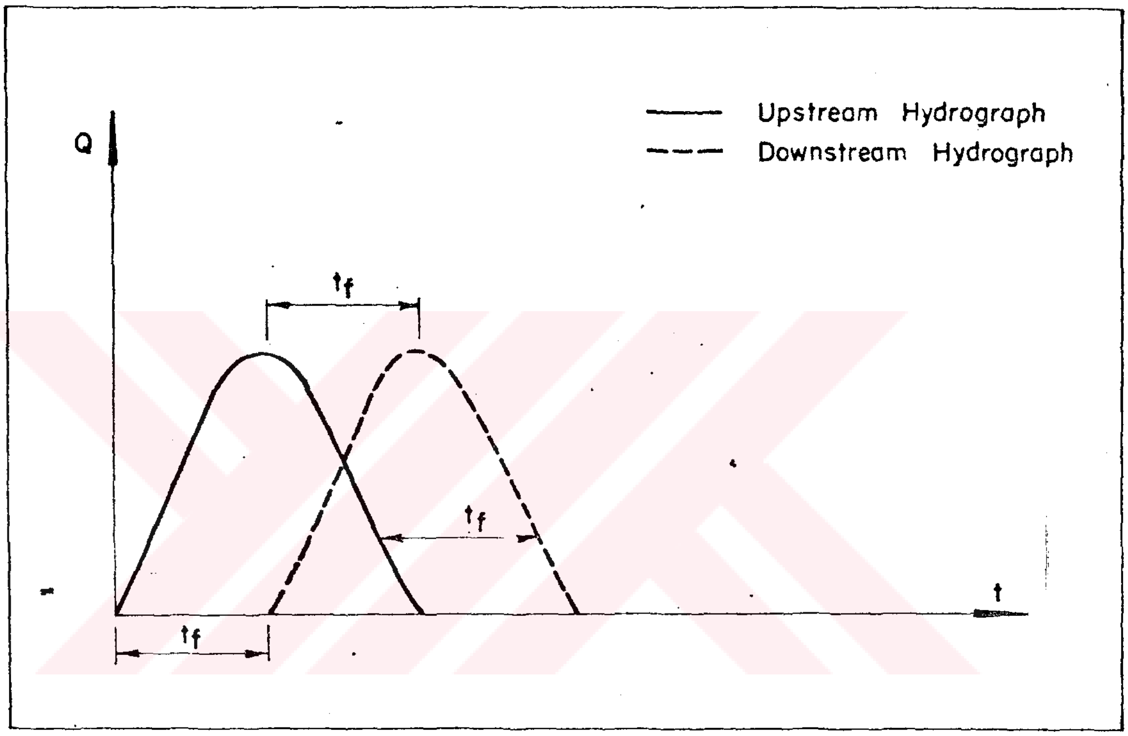

Fig. 3.3. Hydrograph Time - Lag Method for Sewers

The simplified kinematic-wave scheme is based on the continuity equation of unsteady flow and the Manning formula given in Eqs. 2.7 and 2.6 respectively. For a sewer in the system, Eq. 2.7 can be written in finite difference form as

$$\frac{A^{j+1} - A^{j}}{\Delta t} + \frac{Q_1^{j+\frac{1}{2}} - Q_0^{j+\frac{1}{2}}}{L_s} = 0 \qquad (3.14)$$

in which the subscript j and j+1 represent the time steps of computation, A is the average flow area in the sewer, Δt is time increment, Q_1 is the inflow rate, Q_o is the outflow rate, and L_s is the length of the sewer.

In the routing procedure, the variables at the j th level of computation are known from the previous time step calculations or from the initial conditions. Also Q_1^j and Q_1^{j+1} values are known from sewer inflow hydrograph. The computations are carried to the j+1 st time step as follows:

i. The rate of inflow to the sewer is averaged over a time increment Δt by

$$Q_1^{j+\frac{1}{2}} = \frac{1}{2} (Q_1^j + Q_1^{j+1}) \qquad (3.15)$$

ii. The increase in sewer flow area over the half time increment $\Delta t/2$ is expressed by $\Delta A'$ and computed approximately as

$$\Delta A' = \frac{\Delta t}{2L_s} (Q_1^{j+\frac{1}{2}} - Q_o^j) \qquad (3.16)$$

iii. The average rate of outflow from the sewer Q_o^j is calculated as a function of $A^{j+\frac{1}{2}} = A^j + \Delta A'$ in the form of

$$Q_o^{j+\frac{1}{2}} = f(A^{j+\frac{1}{2}}) \qquad (3.17)$$

by using the Manning formula together with Eqs. 3.9 to 3.12

iv. The change in the average sewer flow area ΔA over the time interval Δt is calculated as

$$\Delta A = \frac{\Delta t}{L_s} (Q_1^{j+\frac{1}{2}} - Q_o^{j+\frac{1}{2}}) \qquad (3.18)$$

v. The average sewer flow area at the j+1 st time level is calculated as

$$A^{j+1} = A^j + \Delta A \qquad (3.19)$$

vi. The sewer outflow rate at the j+1 st time level is computed in the form of

$$Q_o^{j+1} = f(A^{j+1}) \qquad (3.20)$$

by using The Manning formula together with Eqs. 3.9 to 3.12

3.3. Design of Second-Group Elements

Design discharges adopted for sizing the first-group elements are exceeded in the second-stage of design in which the collectors are dimensioned considering a more severe rainstorm. Hence under the conditions of the second-stage design storm, part of the storm water floods the streets even though the street sewers may be discharging continuously at their full capacity. This excess storm water which can not enter the sewer system is routed in the gutters towards the nearest collector following a surface drainage pattern specified by the user. A simulation of flow in first group elements is deviced to find the design discharges for the second-group elements.

3.3.1. Simulation of Flow in First-Group Elements

Simulation of the first-group elements consists of the routing of flow in the street gutters and the street sewers. The procedure is started from the most upstream gutters and sewers, and carried in a sequential manner towards downstream following the specified drainage pattern.

3.3.1.1. Gutter Flow Routing

Besides the carry-over from an upstream inlet, a gutter receives lateral inflow from the contributing subcatchment. The lateral inflow hydrographs are determined in a similar fashion as in Fig. 3.1 except that the inlet time t_i is replaced by the time of concentration t_c. The routing for the gutter flow is accomplished by a hydrograph time-lag approach. In this approach, a gutter is divided into a number of segments as specified by the user. As illustrated in Fig. 3.4 the upstream inflow hydrograph is first carried down along the most upstream segment of the gutter by a time-lag equal to the flow time calculated from the length of this segment. The flow time is computed for the peak flow rate of the gutter hydrograph as in Eq. 3.4 except the length of the gutter segment is substituted in place of the entire gutter length L_g. The shifted hydrograph is then algebraically summed up with the lateral inflow of this segment. The resulting hydrograph is routed through the next segment downstream in the same manner and added to the lateral inflow of that segment. The same procedure is repeated until the downstream end of the gutter is reached.

3.3.1.2. Flow into Gutter Inlets

Since in the design of second-group elements, the design discharges of the first-group exceeded, surcharge conditions are likely to occur in the system. Under the surcharge conditions only part of the surface runoff is captured by the gutter inlets. The flow interception capacity of a gutter inlet is assumed to be controlled by the full flow discharge capacity, Q_f of the street sewer downstream as shown in Fig. 3.5. The full capacity Q_f is computed in m^3/s from the Manning formula as

$$Q_f = 0.312\, d_s^{8/3} \cdot S_o^{1/2} / n_s \qquad (3.21)$$

for circular sewers, and Q_f is computed as

$$Q_f = \frac{1}{n_r} \cdot b \cdot y \cdot \left[\frac{b \cdot y}{b+2y}\right]^{2/3} \cdot S_o^{1/2} \qquad (3.22)$$

for rectangular sewers. In Eqs. 3.21 and 3.22 d_s is the sewer diameter in m, S_o is the longitudinal street slope, b and y are width and height of the rectangular section in m respectively. The use of the street slope S_o in Eqs. 3.21 and 3.22 is based on the assumption that the hydraulic grade line is approaximately parallel to the

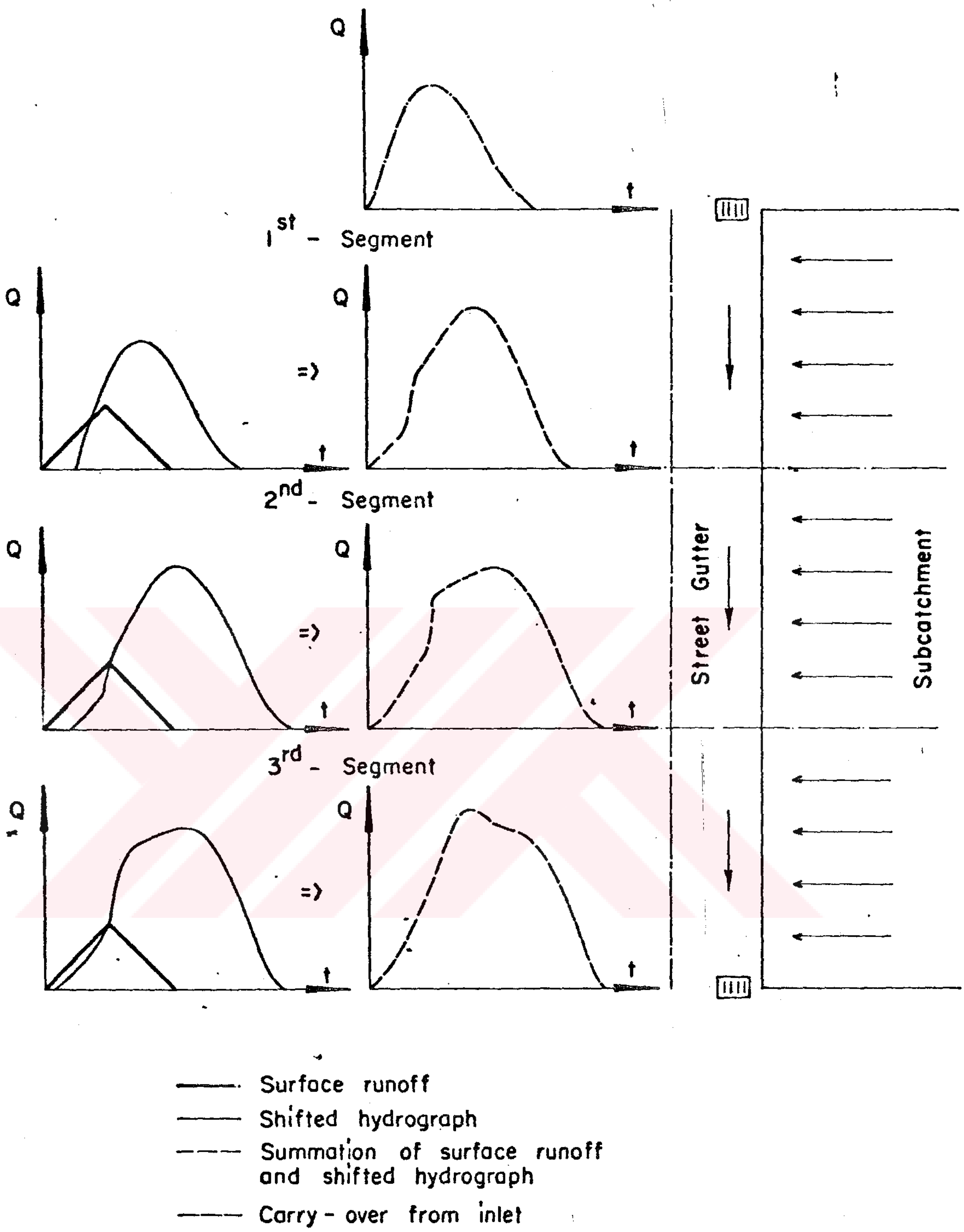

Fig. 3.4. Time - Lag Method for Gutter Flow Routing

street surface under the surcharge conditions.

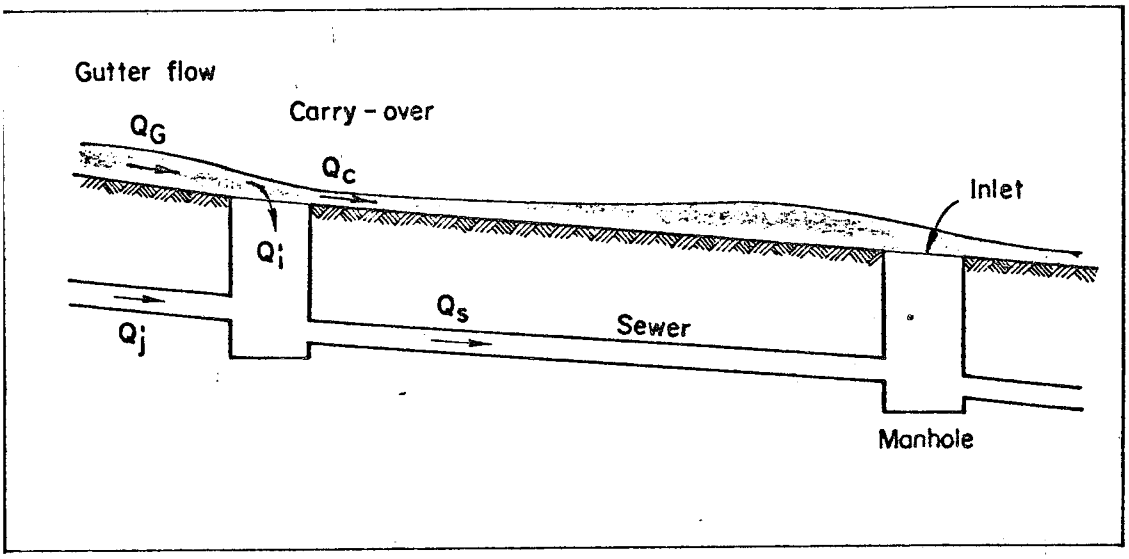

Fig. 3.5 Surcharge Condition

At any time of computation knowing Q_G and $\sum Q_j$ computed respectively from upstream gutter and sewer routing schemes and Q_f determined from Eq. 3.21 or 3.22; the intercepted flow Q_i, the carry-over Q_C and the sewer inflow Q_s are estimated as follows:

i. If $Q_f \leqslant Q_G + \sum Q_j$

$$Q_i = Q_f - \sum Q_j \qquad (3.23)$$

$$Q_C = Q_G - Q_i \qquad (3.24)$$

$$Q_s = Q_f \qquad (3.25)$$

ii. If $Q_f > Q_G + \sum Q_j$

$$Q_i = Q_G \qquad (3.26)$$

$$Q_C = 0.0 \qquad (3.27)$$

$$Q_s = Q_G + \sum Q_j \qquad (3.28)$$

Calculating Q_i, Q_C and Q_s at different time step computations, the inflow hydrographs for the downstream gutters and the street sewers are determined.

3.3.1.3. Sewer Flow Routing

Upstream inflow of a street sewer is computed as described in Section 3.3.1.2. This hydrograph is then routed along the sewer, by using one of the routing schemes as discussed in detail in Section 3.2.2.2.

3.3.2. Design of Collectors

Storm water reaching the collectors partly through the sewer system and partly over the street surfaces constitute the inflows for these elements. Mathematical model allows the use of additional direct inflow hydrographs to be specified for the collectors which may be contributions from those parts of the drainage basin not included in the simulation.

Collectors are designed starting from the most upstream canals and progressing in sequence towards downstream. The design procedure of the collectors is the same as that of the street sewers as discussed in Section 3.2.2.

3.4. Options of model

The major options of the mathematical model can be summarized as follows:

i. Two sewer routing schemes namely a hydrograph time-lag and a simplified kinematic-wave method are provided.

ii. Sewers can be designed circular or rectangular in cross section.

iii. Collectors can be designed circular, rectangular or trapezoidal in cross section

iv. For any street in the drainage area, a pair of sewers on the two sides of the street or a single sewer at the center can be selected. However, when a single sewer is used, the sewer size is not recomputed where additional inlets are required.

v. Where the maximum flow velocity is exceeded in a sewer or collector laid parallel to the ground surface, the size of the sewer may be increased, or the slope may be decreased with the incorporation of the chute structures. Also the user may desire checking the both alternatives by specifying the number of the larger standard sizes to be tried as a preference over the chute structures.

3.5. Computer Program

A computer program in FORTRAN IV language is developed for the mathematical model proposed in this study. It consists of a main program and seven subroutine programes with 1002 FORTRAN statements. The description, listing, and a user's guide of the computer program is given in Appendix B.

4. APPLICATION OF PROPOSED MODEL

The proposed model is applied to an approximately 29.3 ha basin in the Batıkent Satellite Town near Ankara. The topography and the land use of this area is shown in Fig. 4.1. Also shown in this figure are the drainage pattern and the abstraction indices of the subcatchments as well as the sewer layout and the collectors. The sewers and the collectors are circular in cross section. The design storm adopted for the street sewers has an intensity of 68 mm/hr and a duration of 15 min, and that for collectors has an intensity of 88 mm/hr and a duration of 35 min. The collector receives an upstream inflow from a 7.21 ha basin not shown in Fig. 4.1. This upstream inflow is represented by a hydrograph with a peak discharge of 553 lt/s and a time base of 121 min entering the collector at the flow section marked 77 in Fig. 4.1.

In order to provide a comparison of the two schemes, solutions are obtained by using both the hydrograph time -lag-and simplified kinematic-wave routing methods. The major input data and the results are summarized in Table 4.1.

An inspection of Table 4.1 reveals that the sewer design discharges computed are very close and the sewer diameters are identical. On the other hand, the sizes of the collectors computed by the two schemes are different. This is mainly due to the fact that equilibrium (steady state) conditions are reached in the sewers and hence the peak discharges estimated by the two methods are essentially the same. Steady state conditions can be obser-served from Fig. 4.2 and 4.3 which show the flow hydrographs obtained at sections 15 and 76 in the sewer system. Conversely, in the collectors, steady state is not reached, and hence the attenuation of the peak flow which is accounted for by the simplified kinematic-wave approach but not considered in the time-lag method becomes an important factor. Expectedly the hydrograph peaks are greater

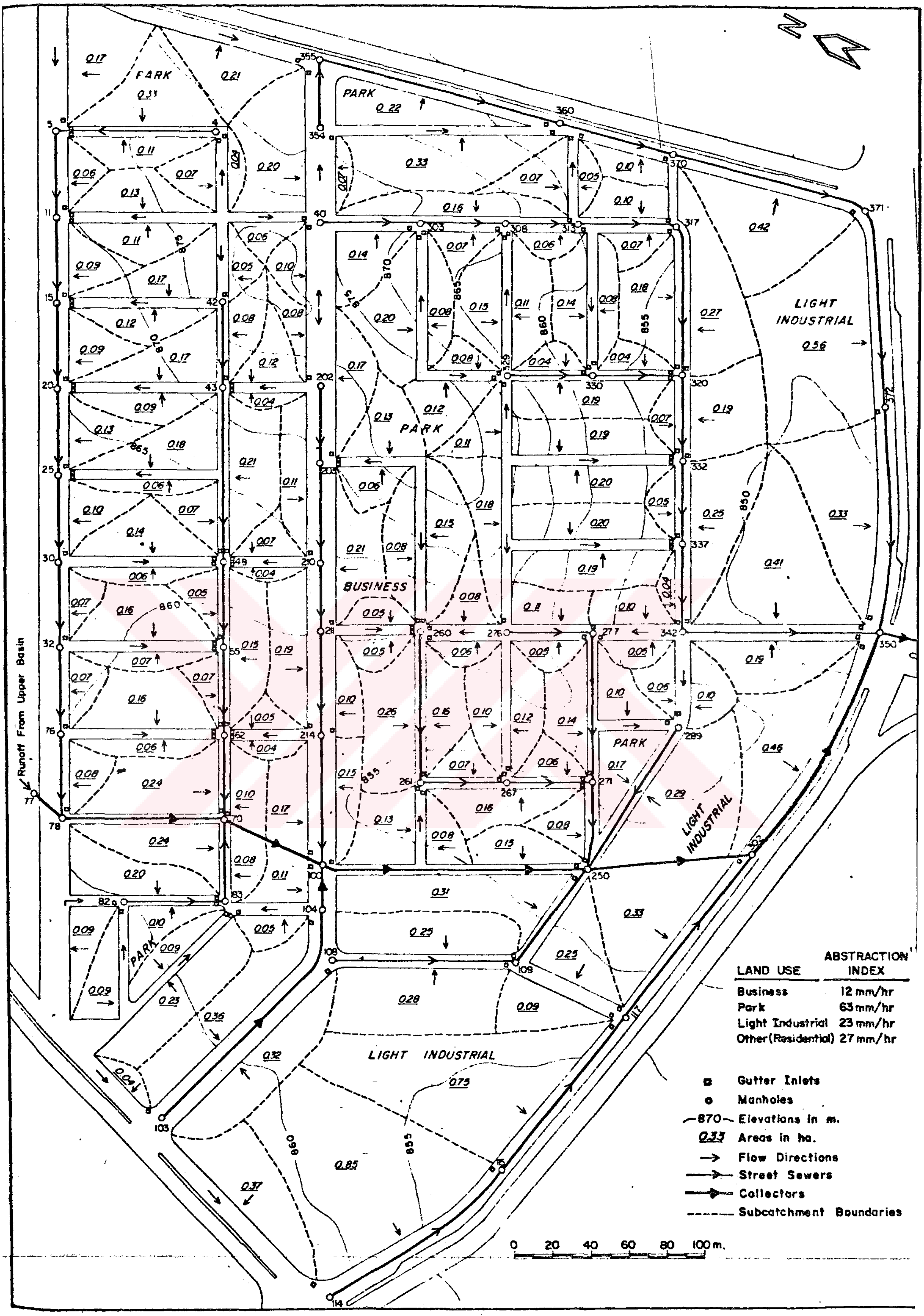

Fig. 4.1. Details of Drainage Basin

Table 4.1. Computed Street Sewer and Collector Discharges and Diameters (to be continued)

From Node	To Node	Drained Area ha	Slope %	Kinematic-wave		Hydrograph time-lag	
				Discharge lt/s	Diameter mm	Discharge lt/s	Diameter mm
4	5	0.11	8.23	9	200	9	200
5	11	0.72	2.71	28	200	28	200
11	15	1.02	3.40	62	250	62	250
15	20	1.40	3.70	105	300	105	300
20	25	1.75	5.59	145	300	105	300
25	30	2.12	2.41	187	400	187	400
30	32	2.22	1.66	199	400	199	400
42	43	0.05	12.51	6	200	6	200
43	48	0.29	10.66	33	200	33	200
48	55	0.88	5.38	100	250	100	250
55	62	1.16	2.77	132	350	132	350
32	76	2.29	1.52	207	400	206	400
77	78	7.21	8.94	553	500	553	500
76	78	2.36	0.53	215	500	213	500
78	70	9.65	3.84	546	500	808	600
62	70	1.69	1.64	193	400	193	400
82	83	0.18	5.48	21	200	21	200
83	70	0.85	0.26	73	400	73	400
70	100	12.85	1.09	1021	800	1315	1000
103	104	0.04	4.10	5	200	5	200
104	100	0.40	10.14	46	200	46	200
202	203	0.08	6.96	9	200	9	200
203	210	0.44	6.96	23	200	23	200
210	211	0.55	5.46	30	200	30	200
211	214	0.76	8.17	56	200	56	200
214	100	1.05	4.08	89	250	89	250
100	250	14.73	0.29	1491	1200	1819	1400
260	261	0.47	5.86	36	200	36	200
261	267	1.10	0.22	108	500	108	500
267	271	1.39	0.22	141	500	141	500

Table 4.1 Computed Street Sewer and Collector Discharges and Diameters (concluded)

		Drained		Kinematic-wave		Hydrograph time-lag	
From Node	To Node	Area ha	Slope %	Discharge lt/s	Diameter mm	Discharge lt/s	Diameter mm
276	277	0.18	8.22	3	200	3	200
277	271	0.49	5.66	38	200	38	200
271	250	2.73	0.23	220	600	220	600
289	250	0.26	2.85	31	200	31	200
108	109	0.32	1.28	40	250	40	250
109	250	0.85	3.37	104	300	104	300
114	115	0.37	1.60	46	250	46	250
115	117	1.22	2.48	153	350	153	350
250	302	19.57	0.71	2178	1200	2507	1400
117	302	2.31	2.13	289	500	289	500
40	303	0.16	5.19	12	200	12	200
303	308	0.58	5.87	25	200	25	200
308	313	0.91	5.96	63	200	63	200
313	317	1.13	4.50	88	250	88	250
317	320	1.30	2.54	97	300	97	300
329	330	0.31	0.74	12	200	12	200
330	320	0.57	0.75	42	300	42	300
320	332	2.55	0.53	220	500	220	500
332	337	3.20	0.18	296	700	296	700
337	342	3.64	0.19	346	800	346	800
302	350	22.21	2.42	2663	1200	2990	1400
342	350	3.93	2.26	382	800	382	800
354	355	0.07	3.94	8	200	8	200
355	360	0.48	4.02	14	200	14	200
360	370	1.15	1.75	63	250	63	250
370	371	1.25	0.78	64	300	64	300
371	372	1.67	2.50	117	300	117	300
372	350	2.23	2.62	187	350	187	350
350	400	29.30	2.20	3747	1200	4121	1400

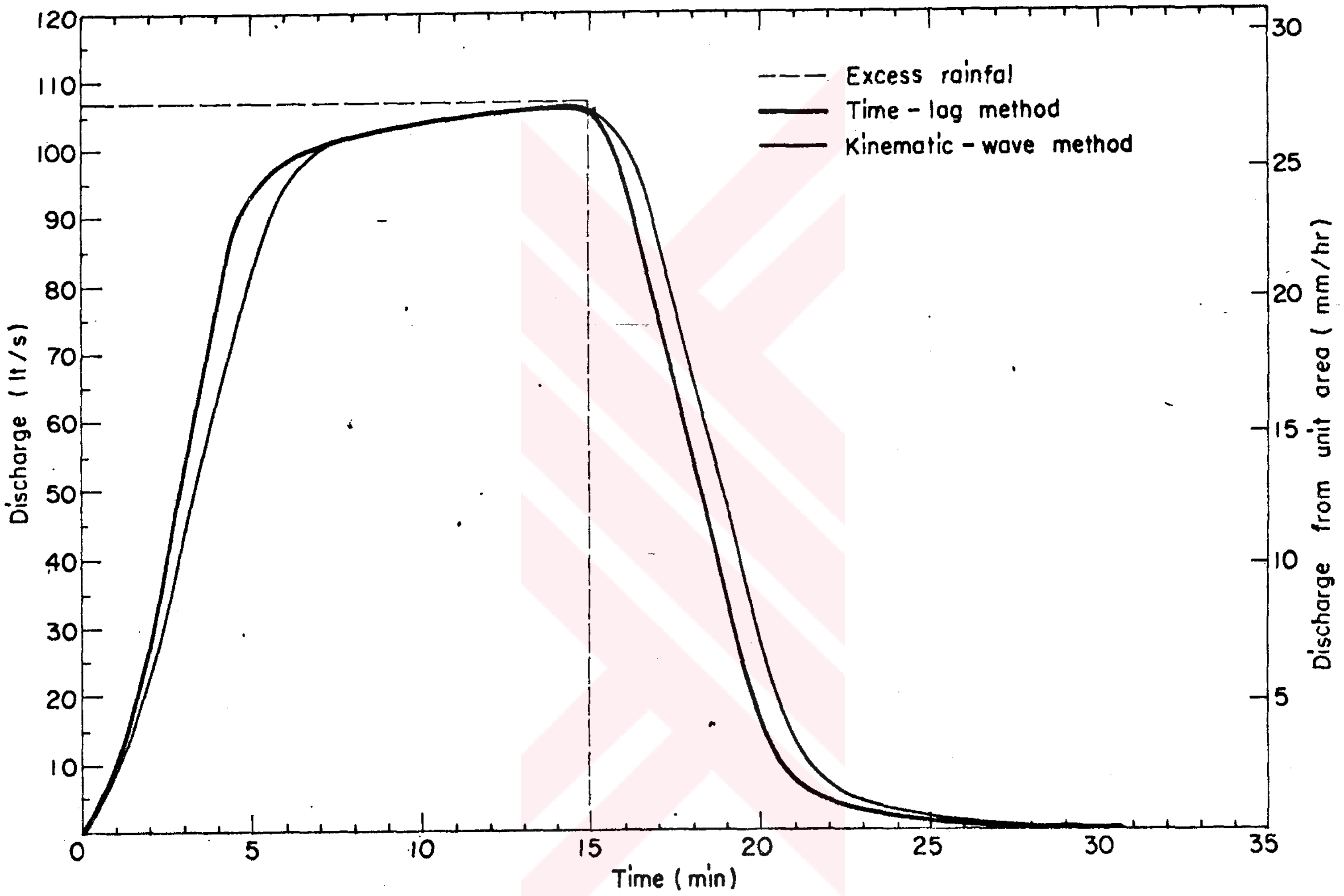

Fig. 4.2. Flow Hydrographs at Section 15

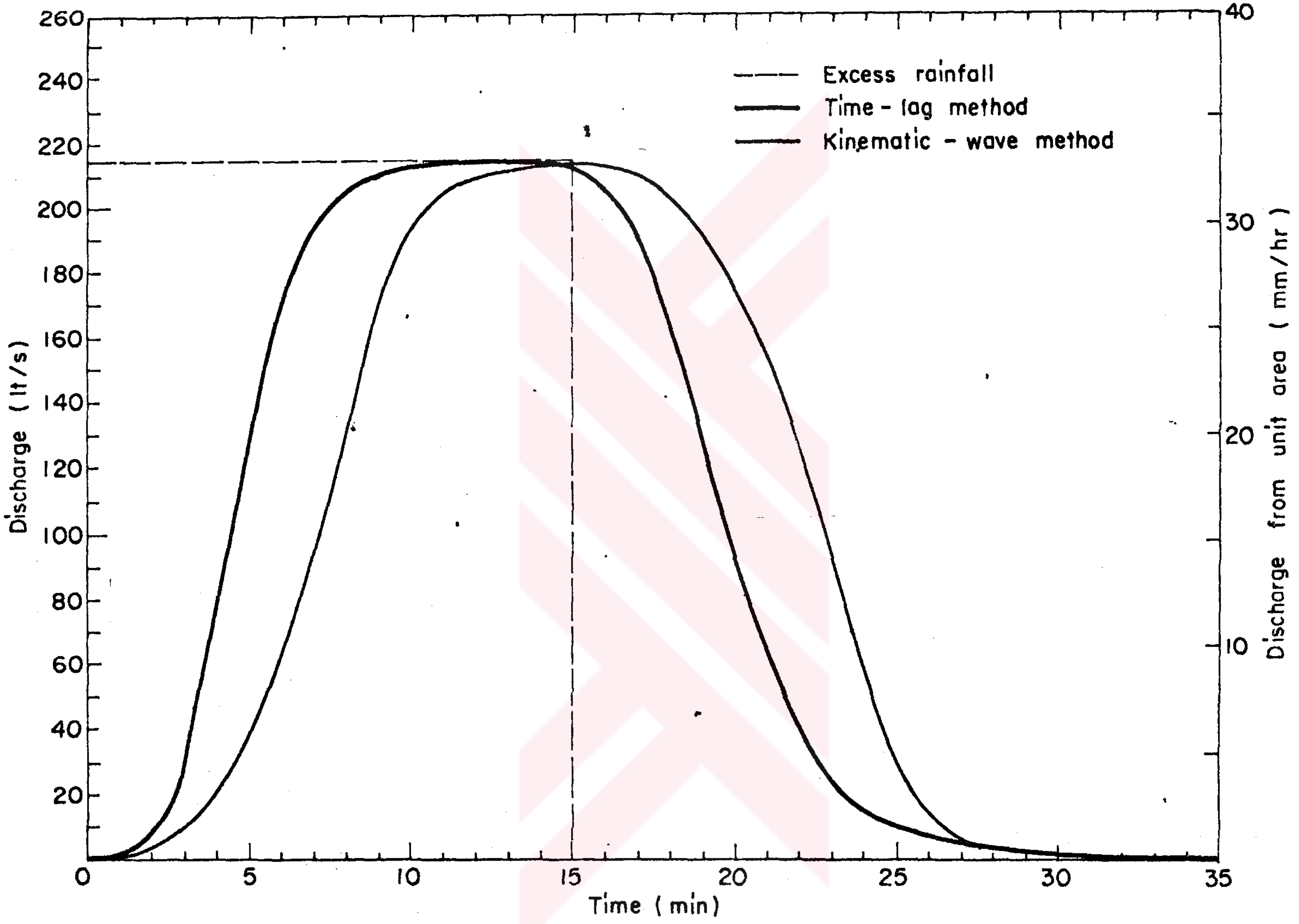

Fig. 4.3. Flow Hydrographs at Section 76

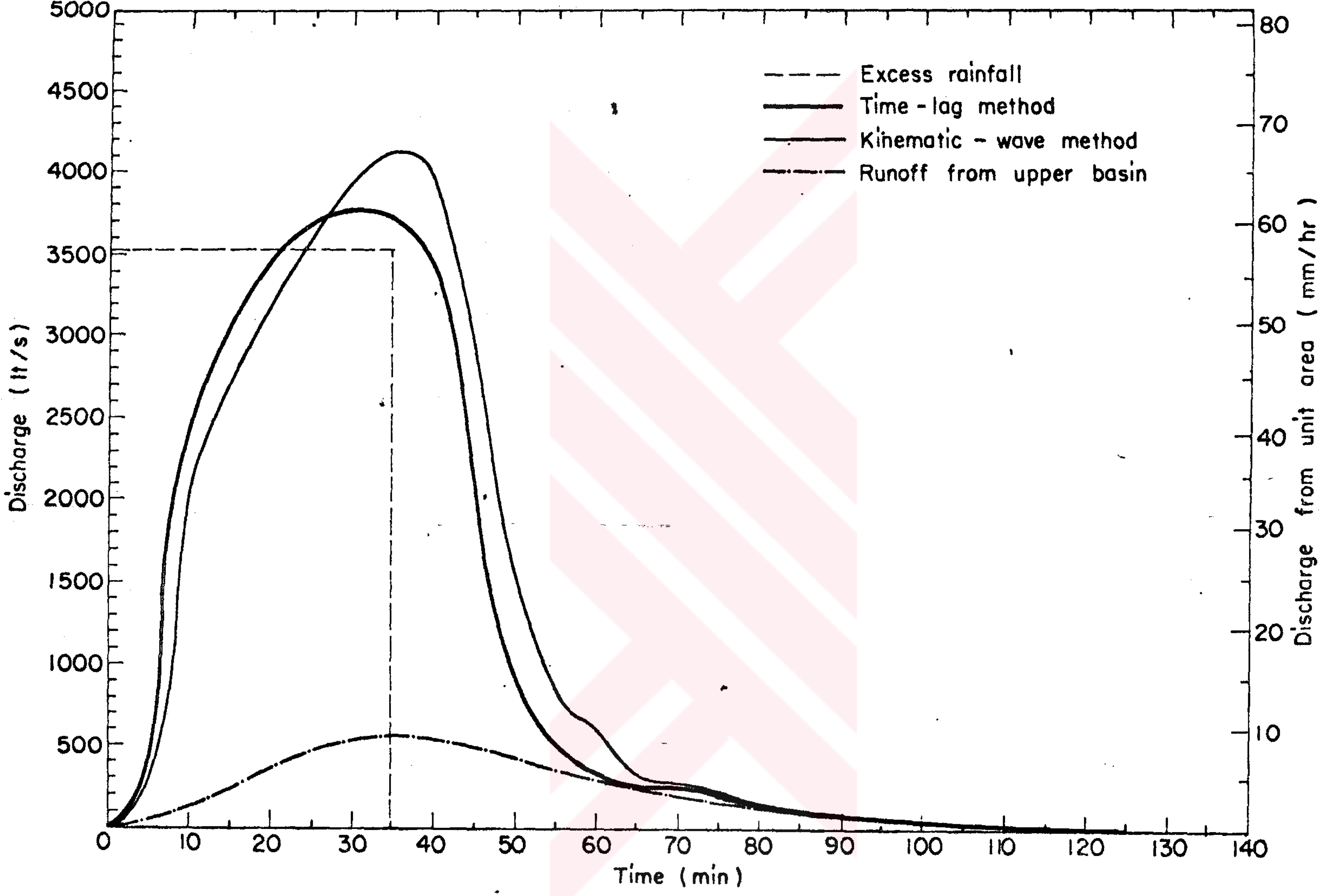

Fig. 4.4. Flow Hydrographs at Section 350

in the hydrograph time-lag method as shown in Fig. 4.4 of the hydrograph at section 350 along the collectors, and hence the sewer diameters are overestimated.

A comparison of the volumes under these hydrographs to that of excess rainfall indicates that continuity is satisfied within acceptable limits in the model. Errors concerning the flow continuity are listed in Table 4.2. The two schemes have comparable accuracy.

Table 4.2. Flow Continuity Errors

	Excess Rainfall	Hydrograph Time-Lag Method		Kinematic-Wave Method	
Flow Section	Volume 10^3 m^3	Volume 10^3 m^3	Error %	Volume 10^3 m^3	Error %
15	96.1	96.5	1.7	94.9	1.2
76	193.3	198.0	2.4	196.9	1.9
350	7377.0	7788.9	5.7	7089.6	3.9

The execution time for the example application given here is 30 seconds for the hydrograph time-lag method and is 144 seconds for the simplified kinematic -wave scheme. The difference in the execution times of the two methods is mainly due to the use of smaller time steps in the kinematic-wave scheme required to overcome numerical stability problems.

5. CONCLUSIONS AND RECOMMENDATIONS

The most evident outcome of this study is a mathematical model and the corresponding computer program for the design of urban storm drainage systems. The mathematical model is not the most sophisticated one possible. It is rather a simple model which can be adopted in the real world problems without violating the basic principles of hydraulics.

The two options provided in the model concerning the flow routing in the sewer and collectors are hydrograph time-lag, and simplified kinematic-wave methods. The applications of these two scheme to drainage basin in the Batıkent area near Ankara, indicates that, as expectedly similar results can be obtained for sewers especially on the upstream portions of the basin. However, the sizes of the main collectors or the downstream sewers of large basins would be over estimated by the hydrograph time-lag method.

Additional options concerning the types of the sewers and the collectors as well as the system layout provides a reasonable flexibility for the model. Hence a variety of different types of storm drainage system can be designed by using the model developed.

The input data required by the model consists of variables most of which can easily be obtained from the maps of the drainage area under consideration. Engineering judgement may be necessary only in the selection of the abstraction indices and the design-storms. If no information is available on the abstraction indices a reasonable approach would be to set the index equal to zero for impervious surfaces directly connected to the drainage system, and set it equal to the storm intensity for pervious areas like gardens and lawns. A weighted abstraction index then can be computed for each subcatchment. As to the selection of the design-storms, it is suggested to try several combinations of the design-storms and select the couple which results in the most conservative design. Certainly the intensity and duration of these storms must be related through the intensity-duration-frequency curves for the region considered.

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APPENDIX A

Table A.1. Values of n for Kinematic Wave Time of Concentration Formula (Yen, 1978)

Surface	n
Asphalt pavement	0.012
Concrete pavement	0.014
Bare packed soil	0.020
Rough bare packed soil	0.03
Mowed poor grass	0.03
Cultivated rows, no crop	0.03
Cultivated rows, with crop	0.04
Pasture-average grass	0.04
Dense grass	0.06
Shrubs and Brushes	0.08
Woods and forests	0.20

Land use	n
Business	0.015 - 0.030
Semi-business	0.020 - 0.035
Dense residential	0.025 - 0.040
Suburban residential	0.030 - 0.055
Parks	0.04 - 0.08
Light industrial	0.015 - 0.035

Table A.2. Values of Roughness Coefficient n of Manning Formula (ASCE and WPCF, 1969)

Conduit Material	Manning n
Closed Conduits	
Asbestos-cement pipe	0.011-0.015
Brick	0.013-0.017
Concrete (monolithic)	
Smooth forms	0.012-0.014
Rough forms	0.015-0.017
Concrete pipe	0.011-0.015
Open Channels	
Lined channels	
a. Asphalt	0.013-0.017
b. Brick	0.012-0.018
c. Concrete	0.011-0.020
d. Rubble or Riprap	0.020-0.035
e. Vegetal	0.030-0.040
Excavated or Dregged	
Earth, straight and uniform	0.020-0.030
Earth, winding fairly uniform	0.025-0.040
Rock	0.030-0.045
Unmaintained	0.050-0.14

APPENDIX B

DESCRIPTION OF COMPUTER PROGRAM

B. DESCRIPTION OF COMPUTER PROGRAM

In this chapter the computer program developed basing on the proposed mathematical model is described. In Section B.1, general features of the program are summarized. The major flow chart of the computer program is given in Section B.2. Then, Section B.3 is devoted to functioning of the main program and subroutines. The variables concerning the input data are described in Section B.4, whereas a description for preparing the input data is given in Section B.5. The deck and a sample output for the computer application of the model described in Chapter 4 are given as well as a listing of the computer program in Sections B.6, B.7, and B.8 respectively.

B.1. General Features of Computer Program

The computer program developed for the mathematical model is coded in FORTRAN IV language. It consists of 1002 FORTRAN statements with a main program and seven subroutines. The storage requirement of the program is 126 K bytes approximately, and is independent of the number of the sewers to be considered at once. The computer program is general and can be applied to a variety of urban storm water drainage systems.

First subscript of matrices occuring in the common blocks and dimension statements of the program may need to be increased if the user prepares the data cards in an order deviating considerably from natural drainage pattern. Second subscript of the matrices and those of the vectors including characters "HYD" need to be increased if more than 250 time steps of computations are required.

The computer program terminates when input errors are detected, and computed section sizes are beyond the standard sizes specified for sewers and collectors.

The compilation time of the program for H-level/ FORTRAN compiler on the IBM-SYSTEM 370/145 is 110 seconds.

B.2. Major Flow Chart of Computer Program

The flow chart of the computer program developed for the mathematical model is given in Fig. B.1.

B.3. Functions of Main Routine and Subprograms

Computer program is composed of a main program with seven subprograms and thirteen common blocks.

MAIN Program: All input data are read by the MAIN routine. The inputs are checked and a set of preliminary computations are performed and printed according to the option selections of the user. It also prints the design results in form of a table. The normal termination of the program is provided in the Main routine only.

Subprogram DESIGN: Determines the sections of sewers and collectors according to the peak discharges of inflow hydrographs by satisfying maximum allowable velocity criterion, and the heights of the chute stuctures if necessary. Subprogram also routes the hydrographs of sewers in the first-stage of design, and those of the collectors in the second-stage of design. Either hydrograph time-lag or simplified kinematic-wave method employed depending upon the selection of the user.

Subprogram HYDCAL: Determines the inlet hydrographs in the first-stage of design, and also computes the overland flow hydrographs in the second-stage of design. These hydrographs are of trapezoidal and triangular shapes as discrete ordinates at equal time intervals which specified by the user.

Subprogram TOPLAM: Determines the discharge intercepted by a gutter inlet and the carry-over in the second -stage of design

Subprogram RATIO: Determines the required number of the additional inlets between those initially placed to

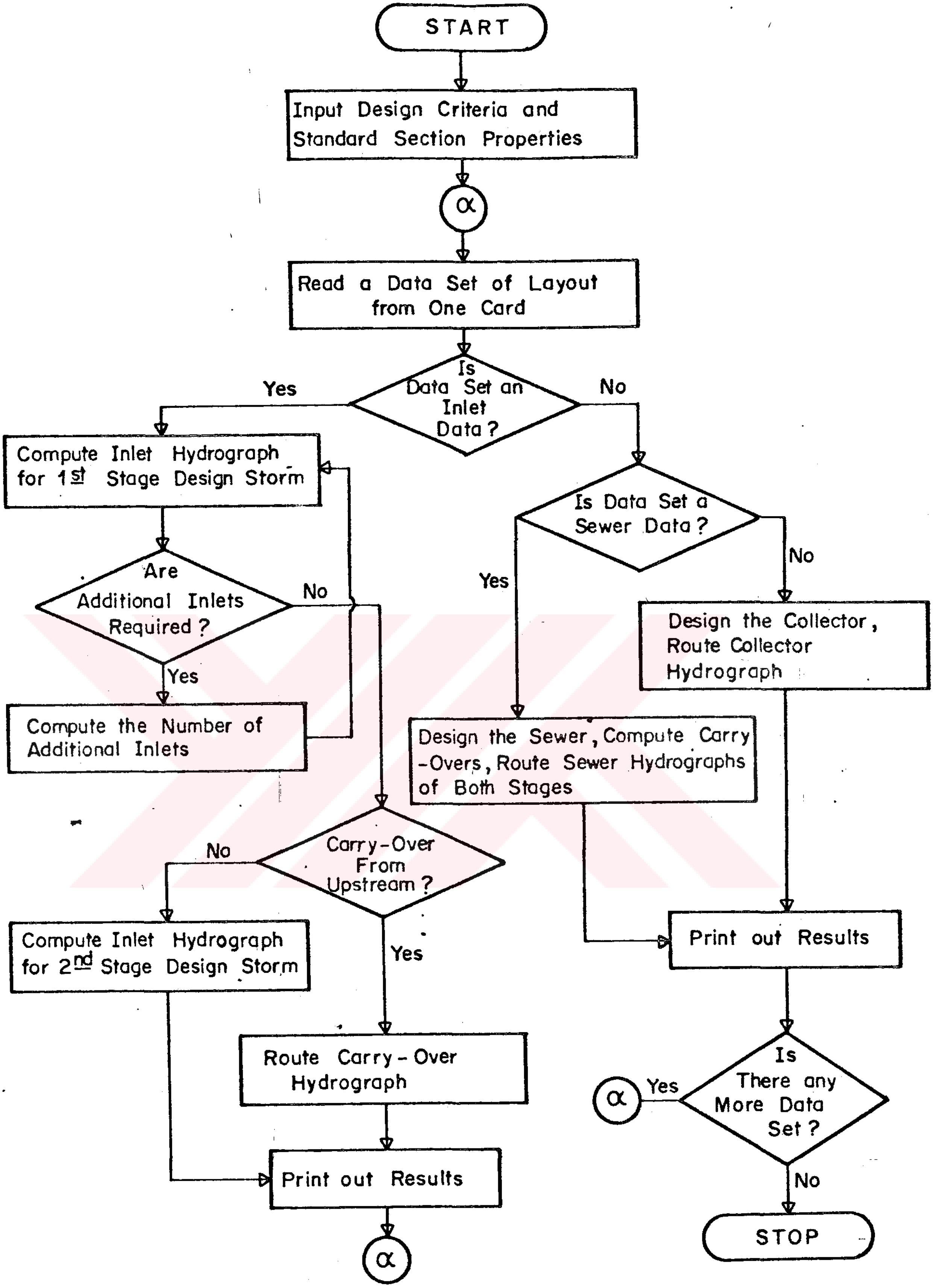

Fig. B.1. Major Flow Chart of Computer Program keep the gutter discharge and flow depth below the specified limits.

Subprogram SIMULM: Routes the sewer hydrograph in the second-stage of design by one of the schemes, hydrograph time-lag or simplified kinematic-wave methods.

Subprogram ROUTE: Performes gutter flow routing by summing carry-over and surface runoff hydrographs in the second-stage of design.

Subprogram YNORM: Calculates the normal flow depth corresponding to a specified discharge and channel geometry in rectangular and trapezoidal canals by an iteration technique.

B.4. Description of Input Variables

The user should provide the data for the input variables described below:

TITLE : Title of the design problem which appears on the top of the program output.

JK : The number of hydrographs that need to be stored, and should be small than the first subscript of matrices.

IJK : Total number of time steps which sould be small than the second subscript of mutrices and dimension of vectors containing characters "HYD".

IDES : Number of segments which a gutter is divided for carry-over routing, and should be large than zero.

IROUTE : Selection for routing scheme to be adopted for flow in sewers and collectors.
- ≠0 : Simplified kinematic-wave method is selected.
- =0 : Hydrograph time-lag method is selected.

ISTEP : Number of subdivisions of the time increment DELT which to be employed in simplified kinematic-wave routing.

ITR : Return period for the design of first-group elements (Years).

JTR : Return period for the design of second-group elements (Years).

NCANAL : Number of standard rectangular sections.

NPIPE : Number of standard circular sections.

NTRAP : Number of standard trapezoidal sections.

NMEC : Number of sewers under a street. 1 or 2.

NSECA : Selection of section type for the design of sewers.
=0 : Circular sections,
=1 : Rectangular sections.

NSECB : Selection of section type for the design of collectors.
=0 : Circular sections,
=1 : Rectangular sections,
=2 : Trapezoidal sections.

NART : Maximum number of larger section sizes tried as an alternative chute structures.

LMIN : Standard section type number below which a list of the computed sewer sizes can optionally be obtained.

AINTA : Rainfall intensity for the design of first -group elements (mm/hr).

AINTB : Rainfall intensity for the design of second -group elements (mm/hr).

TDA : Rainfall duration for AINTA (min).

TDB : Rainfall duration for AINTB (min).

VMAX : Maximum allowable velocity for sewers (m/s).

QMAX : Maximum allowable gutter discharge (lt/s).

YMAX : Maximum allowable gutter flow depth (cm).

VMAXB : Maximum allowable velocity for collectors (m/s).

DELT : Time increment for hydrographs (min).

GUTRZ : Reciprocal of street crown slope.

GUTRN : Manning roughness factor for gutters.

CANALN : Manning roughness factor for rectangular sections.

PIPEN : Manning roughness factor for circular sections.

TRAPN : Manning roughness factor for trapezoidal sections.

DROP : Minimum soil cover for pipes (m)

RATK : Maximum depth ratio for rectangular sections.

RATT : Maximum depth ratio for trapezoidal sections.

TYPEA (I,J) : Dimensions of standard rectangular sections.
J=1,NCANAL
I=1 : Width of the section (m),
I=3 : Height of the section (m).

TYPEB(I): Diameters of standard circular sections (mm)
I=1,NPIPE

TYPEC (I,J) : Dimensions of standard trapezoidal sections
J=1,NTRAP
I=1 : Bottom width of the section (m),
I=2 : Side slope of the section (m/m),
I=3 : Height of the section (m).

ITH : Upstream node number.

KP : Upstream node condition.
=0 : Upstream end of a gutter of most extreme inlet,
=I : Inlet,
=M : Manhole on a sewer,
=B : Inflow to a collector junction from upper basin,
=P : Collector junction.

JTH : Downstream node number.

KR : Downstream node condition.
=I : Inlet,
=M : Manhole on a sewer,
=P : Collector junction.

AREA : Area of the subcatchment or exterior drainage area (ha).

ALEN : Length of the gutter, street sewer or collector between the nodes ITH and JTH (m).

AELEV : Upstream node topographic elevation (m).

BELEV : Downstream node topographic elevation (m).

PHY : Abstraction index for the subcatchment (mm/hr)

AN : Manning roughness factor of the subcatchment.

SLOPY : Average slope of the subcatchment (m/m).

ALENY : Length of the drain path of the subcatchment (m).

LP : Index indicating if the computed inflow hydrograph at a node is desired to be printed out,
≠0 : Hydrograph is desired,
=0 : Hydrograph is not desired.

NODI,
NODJ : Node numbers of inlets from which carry-over is delivered directly into a downstream gutter. Also, NODJ represent the total number of ordinates of upper basin hydrograph if KP is defined as B.

HYD(I,J): Upper basin hydrograph ordinates (lt/s).
I=1,NODJ

B.5. Preparation of Data

Information on the design criteria, standard section sizes, basin characteristics and the drainage pattern of the urban area must be prepared by the user. Also he should number all the inlets, manholes, sewer and collector junctions; and optionally the upstream ends of all the exterior gutters. Numbering can be done arbitrarily but each number should be used only once. Each data card contains all the information necessary about the drainage area, or the sewer between the numbered points depending upon whether these numbers represent inlets or sewers. The user should also specify the inlet-manhole connections.

The data deck for the computer program can be classified into four groups containing information on:

a. Design criteria,

b. Standard sewer and collector section sizes,

c. Description of the layout following the drainage pattern

d. Upper basin hydrograph(s).

Data Set a

This data set is supplied in subsets to be given in the order of a1, a2, a3, a4.

Subset a1 : This subset contains of 3 cards on which the variable TITLE is written in alphanumeric characters on 1-80 columns of each card.

Subset a2 : This subset consists of a single card and contains the following inputs.

Variable Name	Type of Variable	Columns
JK	Integer	1- 5
IJK	Integer	6-10
IDES	Integer	11-15
IROUTE	Integer	16-20
ISTEP	Integer	21-25

If IROUTE is zero, ISTEP does not have to be defined.

Subset a3 : This subset contains of a single card and contains the following inputs.

Variable Name	Type of Variable	Columns
ITR	Integer	1- 5
JTR	Integer	6-10
NCANAL	Integer	11-15
NPIPE	Integer	16-20
NTRAP	Integer	21-25
NMEC	Integer	26-30
NSECA	Integer	31-35
NSECB	Integer	36-40
NART	Integer	41-45
LMIN	Integer	46-50

The variable NPIPE is defined if NSECA=0 and/or NSECB=0. The variable NCANAL is defined if NSECA=1 and/or NSECB=1. The variable NTRAP must be defined if NSECB=2.

Subset a4 : This subset consists of three cards and contains the following inputs.

First card of subset a4:

Variable Name	Type of Variable	Columns
AINTA	Real	1-10
AINTB	Real	11-20
TDA	Real	21-30
TDB	Real	31-40
VMAX	Real	41-50
QMAX	Real	51-60
YMAX	Real	61-70
VMAXB	Real	71-80

Second card of subset a4:

Variable Name	Type of Variable	Columns
DELT	Real	1-10
GUTRZ	Real	11-20
GUTRN	Real	21-30
CANALN	Real	31-40
PIPEN	Real	41-50
TRAPN	Real	51-60
DROP	Real	61-70
RATK	Real	71-80

Third card of subset a4:

Variable Name	Type of Variable	Columns
RATT	Real	1-10

The variable PIPEN is defined if NSECA =0 and/or NSECB = 0. The variable CANALN is defined if NSECA = 1 and/or NSECB = 1. The variable TRAPN must be defined if NSECB = 2. Also, the variable RATK is defined if NSECA = 1 or NSECB =1. The variable RATT must be defined if NSECB = 2.

Data Set b

This data set is to be given in three subsets in the order of b1, b2, b3.

Subset b1 : This subset must be provided if NCANAL already given is greater than zero. Otherwise this subset must be omitted. The number of cards in this subset can be computed by truncating the result of (NCANAL/8 +1). This subset contains the following inputs.

Variable Name	Type of Variable	Columns
TYPEA(1,1)	Real	1-5
TYPEA(3,1)	Real	6-10

Variable Name	Type of Variable	Columns
TYPEA(1,2)	Real	11-15
TYPEA(3,2)	Real	16-20
....	Real	.....
....	Real	.....
TYPEA(1,NCANAL)	Real	.....
TYPEA(3,NCANAL)	Real	.....

Subset b2 : This subset must be provided if NPIPE already given is greater than zero. Otherwise it must be omitted. The number of cards in this subset can be computed by truncating the result of (NPIPE/16 +1).

This subset contains the following inputs.

Variable Name	Type of Variable	Columns
TYPEB(1)	Real	1-5
TYPEB(2)	Real	6-10
TYPEB(3)	Real	11-15
....	Real	.....
....	Real	.....
TYPEB(NPIPE-1)	Real	.....
TYPEB(NPIPE)	Real	.....

Subset b3 : This subset must be provided if NTRAP already given is greater than zero. Otherwise it must be omitted. The number of cards in this subset can be computed by truncating the result of (NTRAPx3/16 +1).

This subset contains the following inputs.

Variable Name	Type of Variable	Columns
TYPEC(1,1)	Real	1-5
TYPEC(2,1)	Real	6-10
TYPEC(3,1)	Real	11-15

Variable Name	Type of Variable	Columns
TYPEC(1,2)	Real	16-20
TYPEC(2,2)	Real	21-25
TYPEC(3,2)	Real	26-30
....	Real	.....
....	Real	.....
....	Real	.....
TYPEC(1,NTRAP)	Real	.....
TYPEC(2,NTRAP)	Real	.....
TYPEC(3,NTRAP)	Real	.....

Data Set c

This data set contains information about catchments, and sewer layout. For each inlet, there are two cards. The first one contains the contributing subcatchment characteristics, and the second one indicates what manhole the inlet is connected to. Also there will be a single card for each sewer and each collector. Additional cards may be needed each corresponding to a junction on the collector which receives direct inflow from upper basins.

Each card of data set c contains the following inputs.

Variable Name	Type of Variable	Columns
ITH	Integer	1-44
KP	Alphanumeric	5
JTH	Integer	6- 9
KR	Alphanumeric	10
AREA	Real	11-16
ALEN	Real	17-22
AELEV	Real	23-28

Variable Name	Type of Variable	Columns
BELEV	Real	29-36
PHY	Real	37-42
AN	Real	43-48
SLOPY	Real	49-54
ALENY	Real	55-60
LP	Integer	69-72
NODI	Integer	73-76
NODJ	Integer	77-80

On each card of this data set ITH, KP, JTH, and KR must always be defined. If KP and KR are defined both as M; or respectively as M and P; the variables other than AELEV, BELEV, NODI, and NODJ need not to be defined. If KP and KR are defined both as P, the variables other than AELEV and BELEV need not to be defined. The variable LP is defined in cases that the design flow hydrograph is desired at section ITH. If KP and KR are defined respectively as I and M; variables other than ITH and JTH need not to be defined. If KP and KR are defined respectively as B and P; AREA and NODJ should be defined in addition to ITH and JTH.

If a card contains KP defined as B then a set of cards described in data set d are placed between this particular card and the following one.

Data Set d

This data set must be provided inside the data set c each time a card in data set c has KP defined as B. The set d is placed after the related card. The number of cards in this data set can be computed by truncating the result of (NODJ/8+1); and contains the following inputs.

Variable Name	Type of Variable	Columns
HYD(I,1)	Real	1-10
HYD(I,2)	Real	11-20
HYD(I,3)	Real	21-30
....	Real	.....
....	Real	.....
HYD(I,NODJ)	Real	.....

I is a variable defined by the model and not related to input data.

B.6. INPUT DATA DECK

```
.........1.........2.........3.........4.........5.........6.........7.........8
         APPLICATION OF THE MODEL TO        1                                      DATA    1
         BATIKENT SATELLITE TOWN AREA                                              DATA    2
         NEAR ANKARA                                                               DATA    3
   10  250     4                                                                   DATA    4
    5   25    10    16    10     1     0     0     2                               DATA    5
  68.         98.         15.         35.     7.         50.       7.        15.   DATA    6
   1.         50.         0.02        0.022   0.016      0.025     1.        0.75  DATA    7
  0.30        0.75        1.5                                                      DATA    8
 1.75 1.40 1.75 1.75 2.00 1.80 2.00 2.15 2.50 2.20 2.50 2.55 3.50 2.40 4.50 3.05   DATA    9
 5.00 3.55 5.00 4.00                                                               DATA   10
 200. 250. 300. 350. 400. 500. 600. 700. 800. 1000.1200.1400.1600.1800.2000.2400.DATA   11
 0.50 1.50 0.50 0.60 1.50 0.60 0.75 1.50 0.75 0.90 1.50 0.90 1.00 1.50 1.00 1.25DATA   12
 1.50 1.00 1.25 1.50 1.25 1.50 1.50 1.25 1.50 1.50 1.50 1.75 1.50 1.50             DATA   13
   79    30I0.09  25.     861.40860.01027.  0.04   0.05  64.                       DATA   14
   79    31I0.00  64.     862.46860.01027.  0.04   0.05  25.                       DATA   15
   80I   32M                                                                       DATA   16
   81I   32M                                                                       DATA   17
   82M   83M      54.     860.01857.11                                           80DATA   18
   80I   34I0.1   54.     860.01857.11063.  0.06   0.07  60.                       DATA   19
   85    86I0.09  94.     862.46857.11063.  0.06   0.07  13.                       DATA   20
   55    96I0.05  41.     858.53857.11063.  0.06   0.035 24.                       DATA   21
   87    38I0.23  111.    864.67857.11027.  0.04   0.07  22.                       DATA   22
   89    90I0.20  80.     861.40857.1127.0  0.04   0.02  40.                       DATA   23
   90I   83M                                                                       DATA   24
   84I   83M                                                                       DATA   25
   86I   33M                                                                       DATA   26
   96I   33M                                                                       DATA   27
   88I   83M                                                                       DATA   28
   83M   70P      43.     857.11857.00                                       96  90DATA   29
   90I   70P0.24  43.     857.11857.00027.  0.04   0.045 80.                       DATA   30
   96I   70P0.03  43.     857.11857.00027.  0.04   0.05  20.                       DATA   31
    1     2I0.07  45.     879.00876.28027.  0.04   0.065 23.                       DATA   32
    1     3I0.04  45.     879.00876.28063.  0.06   0.02  10.                       DATA   33
    2I   4M                                                                        DATA   34
    3I   4M                                                                        DATA   35
    4M   5M       77.     876.28869.94                                            2DATA   36
    2I    6I0.11  77.     876.28869.94027.  0.04   0.06  20.                       DATA   37
    7     3I0.33  77.     876.28869.94063.  0.06   0.02  50.                       DATA   38
    9    10I0.17  65.     870.70869.94063.  0.06   0.02  40.                       DATA   39
    6I    5M                                                                       DATA   40
.........1.........2.........3.........4.........5.........6.........7.........8
```

```
.........1.........2.........3.........4.........5.........6.........7.........8
   3I   5M                                                                      CATA  41
  10I   5M                                                                      CATA  42
   5M  11M       45.  869.94868.72                                             6CATA  43
   6I  12I0.06   45.  869.94868.72027.  0.040 0.10  18.                         CATA  44
   1   13I0.13   79.  879.00868.72027.  0.040 0.090 23.                         CATA  45
   1   14I0.11   78.  879.00868.72027.  0.040 0.02  18.                         CATA  46
  12I  11M                                                                      CATA  47
  13I  11M                                                                      CATA  48
  14I  11M                                                                      CATA  49
  11M  15M       47.  868.72867.12                                            14CATA  50
  14I  16I0.09   47.  868.72867.12 27.  0.040 0.07  39.                         CATA  51
  17   19I0.17   79.  877.11867.12 27.  0.040 0.042 45.                         CATA  52
  17   19I0.12   78.  877.11867.12 27.  0.040 0.021 20.                         CATA  53
  19I  15M                                                                      CATA  54
  18I  15M                                                                      CATA  55
  16I  15M                                                                      CATA  56
  15M  20M       46.  867.12865.42                                            19CATA  57
  21   22I0.17   79.  871.49865.42 27.  0.040 0.042 45.                         CATA  58
  21   23I0.09   73.  871.48865.42 27.  0.040 0.02  12.                         CATA  59
  19I  24I0.09   46.  867.12865.42 27.  0.040 0.07  40.                         CATA  60
  24I  20M                                                                      CATA  61
  22I  20M                                                                      CATA  62
  23I  20M                                                                      CATA  63
  20M  25M       46.  865.42862.85                                            23CATA  64
  23I  28I0.13   46.  865.42862.85 27.  0.040 0.06  62.                         CATA  65
  26   27I0.18   77.  865.70862.85 27.  0.040 0.10  47.                         CATA  66
  26   29I0.06   77.  865.70862.85 27.  0.040 0.02   9.                         CATA  67
  29I  25M                                                                      DATA  68
  27I  25M                                                                      CATA  69
  23I  25M                                                                      CATA  70
  25M  30M       46.  862.85861.74                                            29CATA  71
  29I  31I0.10   46.  862.85861.74 27.  0.04  0.02  38.                         CATA  72
  31I  30M                                                                      CATA  73
  30M  32M       44.  861.74861.01                                              CATA  74
  31I  33I0.14   77.  861.74861.46 27.  0.04  0.05  34.                         DATA  75
  34   35I0.06   77.  861.74861.46 27.  0.04  0.02  11.                         CATA  76
   1   41I0.05   45.  875.00877.11 27.  0.04  0.25  20.                         CATA  77
  41I  42M                                                                      CATA  78
  42M  43M       45.  877.11871.48                                            41CATA  79
  41I  44I0.08   45.  877.11871.48 27.  0.04  0.25  20.                         DATA  80
.........1.........2.........3.........4.........5.........6.........7.........8
```

```
.........1.........2.........3.........4.........5.........6.........7.........8
  44I  43M                                                                     CATA  81
  45   46I0.12  43.   873.11871.48 27.  0.04  0.20  57.                        CATA  82
  46I  43M                                                                     CATA  83
  45   47I0.04  43.   872.11871.48 27.  0.040 0.02  12.                        CATA  84
  47I  43M                                                                     CATA  85
  43M  48M      94.   871.48861.46                                           47CATA  86
  47I  49I0.21  94.   871.48861.46 27.  0.04  0.08  32.                        CATA  87
  50   51I0.07  47.   865.57861.46 27.  0.04  0.07  27.                        DATA  88
  50   52I0.04  47.   865.57861.46 27.  0.04  0.02  10.                        CATA  89
  26   53I0.07  47.   865.70861.46 27.  0.04  0.04  34.                        CATA  90
  33I  48M                                                                     CATA  91
  35I  48M                                                                     CATA  92
  52I  43M                                                                     CATA  93
  51I  48M                                                                     CATA  94
  49I  43M                                                                     DATA  95
  53I  43M                                                                     CATA  96
  48M  55M      45.   861.46859.04                                       35  52CATA  97
  35I 555I0.05  45.   861.46859.04 27.  0.04  0.02  24.                        DATA  98
  56   57I0.07  44.   861.74861.01 27.  0.04  0.03  23.                        CATA  99
  57I  32M                                                                     CATA 100
  58   59I0.16  77.   861.01859.04 27.  0.04  0.06  29.                        CATA 101
  58   60I0.07  77.   861.01859.04 27.  0.04  0.03  11.                        CATA 102
  59I  55M                                                                     CATA 103
  60I  55M                                                                     CATA 104
 555I  55M                                                                     CATA 105
  55M  62M      47.   859.04857.74                                           60DATA 106
  60I  63I0.07  47.   859.04857.74 27.  0.04  0.05  21.                        CATA 107
  52I  61I0.15  92.   861.46857.74 27.  0.04  0.05  23.                        CATA 108
  64   65I0.16  78.   860.31857.74 27.  0.04  0.05  32.                        CATA 109
  64   66I0.06  78.   860.31857.74 27.  0.04  0.02   9.                        CATA 110
  67   68I0.05  47.   859.30857.74 27.  0.04  0.05  23.                        CATA 111
  67   69I0.04  47.   859.30857.74 27.  0.04  0.05  10.                        DATA 112
  65I  62M                                                                     CATA 113
  66I  62M                                                                     CATA 114
  63I  62M                                                                     CATA 115
  61I  62M                                                                     CATA 116
  68I  62M                                                                     CATA 117
  69I  62M                                                                     CATA 118
  32M  76M      46.   861.01860.31                                           57CATA 119
  57I  75I0.07  46.   861.01860.31 27.  0.04  0.02  20.                        CATA 120
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
 777B  77P7.21                                                              121DATA 121
2.5       5.        7.5       12.5      20.       27.5      50.       55.      DATA 122
75.       100.      110.      140.      130.      205.      225.      250.     DATA 123
280.      300.      325.      350.      395.      410.      425.      445.     DATA 124
455.      470.      493.      505.      515.      530.      540.      545.     DATA 125
548.      550.      553.      550.      548.      545.      540.      533.     DATA 126
525.      518.      510.      500.      490.      465.      465.      455.     DATA 127
443.      433.      425.      413.      400.      383.      368.      355.     DATA 128
340.      330.      323.      313.      305.      293.      283.      265.     DATA 129
253.      243.      230.      218.      210.      200.      195.      183.     DATA 130
175.      168.      163.      158.      153.      148.      143.      133.     DATA 131
133.      130.      118.      113.      105.      95.       88.       83.      DATA 132
78.       73.       69.       65.       60.       58.       56.       55.      DATA 133
50.       45.       44.       43.       40.       38.       35.       33.      DATA 134
30.       28.       26.       25.       24.       23.       21.       20.      DATA 135
18.       16.       15.       14.       13.       12.       11.       9.       DATA 136
8.                                                                             DATA 137
  77P  73P      31.   862.84860.07                                             DATA 138
  75I  76M                                                                     DATA 139
  76M  78P      45.   860.31860.07                                   1       75DATA 140
  75I  78P0.03  45.   860.31860.07 27.  0.04  0.02  17.                        DATA 141
  78P  70P      80.   860.07857.00                                             DATA 142
  62M  70P      45.   857.74857.00                                       66  69DATA 143
  66I  70P0.24  45.   857.74857.00 27.  0.04  0.05  80.                        DATA 144
  69I  70P0.1   45.   857.74857.00 27.  0.04  0.02  22.                        DATA 145
  70P 100P      55.   857.00856.40                                             DATA 146
 101  102I0.04  46.   864.67864.43 27.  0.04  0.01  10.                        DATA 147
 102I 103M                                                                     DATA 148
 103M 104M      144.  864.43858.53                                          102DATA 149
 102I 107I0.36  144.  864.43858.53 27.  0.04  0.02  21.                        DATA 150
 107I 104M                                                                     DATA 151
 104M 100P      21.   858.53856.40                                          107DATA 152
 107I 100P0.11  21.   858.53856.40 27.  0.04  0.03  41.                        DATA 153
 200  201I0.03  45.   873.04872.11 27.  0.04  0.09  14.                        DATA 154
 201I 202M                                                                     DATA 155
 202M 203M      47.   872.11868.84                                          201DATA 156
 201I 204I0.11  54.   872.11865.57 27.  0.04  0.05  16                         DATA 157
 205  206I0.17  92.   873.04868.84 63.  0.06  0.1   30.                        DATA 158
 207  208I0.13  46.   877.11868.84 63.  0.06  0.1   47.                        DATA 159
 207  209I0.06  46.   877.11868.84 12.  0.02  0.04  12.                        DATA 160
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
208I 203M                                                                       DATA 161
209I 203M                                                                       DATA 162
206I 203M                                                                       DATA 163
203M 210M       47.   868.84865.57                                           209DATA 164
204I 219M                                                                       DATA 165
210M 211M       46.   865.57863.06                                           204DATA 166
204I 212I0.13   92.   865.57859.30 27.  0.04  0.04  23.                         DATA 167
209I 213I0.21   90.   868.84863.06 12.  0.02  0.04  33.                         DATA 168
213I 211M                                                                       DATA 169
211M 214M       46.   863.06859.30                                           213DATA 170
213I 215I0.1    46.   863.06859.30 27.  0.04  0.02  11.                         DATA 171
215I 214M                                                                       DATA 172
212I 214M                                                                       DATA 173
214M 100P       71.   859.30856.40                                       212 215DATA 174
212I 100P0.17   71.   859.30856.40 27.  0.04  0.04  22.                         DATA 175
215I 100P0.15   71.   859.30856.40 27.  0.04  0.02  13.                         DATA 176
100P 250P      140.   856.40856.00                                              DATA 177
207  252I0.03   90.   877.10861.10 12.  0.02  0.01  10.                         DATA 178
207  253I0.15   90.   877.10861.10 63.  0.06  0.06  28.                         DATA 179
254  255I0.09   45.   864.33861.10 63.  0.06  0.07  29.                         DATA 180
254  256I0.06   45.   864.33861.10 27.  0.04  0.02  9.                          DATA 181
257  258I0.05   47.   863.69861.10 12.  0.02  0.03  10.                         DATA 182
257  259I0.05   47.   863.69861.10 27.  0.04  0.02  10.                         DATA 183
252I 260M                                                                       DATA 184
253I 260M                                                                       DATA 185
255I 260M                                                                       DATA 186
256I 260M                                                                       DATA 187
258I 260M                                                                       DATA 188
259I 260M                                                                       DATA 189
260M 261M       82.   861.10856.30                                       256 259DATA 190
256I 262I0.16   82.   861.10856.30 27.  0.04  0.05  25.                         DATA 191
259I 263I0.26   92.   861.10856.30 27.  0.04  0.04  32.                         DATA 192
264  265I0.13   45.   856.35856.30 27.  0.04  0.04  40.                         DATA 193
264  266I0.08   45.   856.35856.30 27.  0.04  0.02  25.                         DATA 194
262I 261M                                                                       DATA 195
263I 261M                                                                       DATA 196
265I 261M                                                                       DATA 197
266I 261M                                                                       DATA 198
261M 267M       46.   856.30856.20                                       266 262DATA 199
262I 268I0.07   46.   856.30856.20 27.  0.04  0.06  26.                         DATA 200
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
254  269I0.1   80.   864.33856.20 27.  0.04  0.04  15.                              DATA 201
254  270I0.12  80.   864.33856.20 27.  0.04  0.05  19.                              DATA 202
263I 267M                                                                           DATA 203
269I 267M                                                                           DATA 204
270I 267M                                                                           DATA 205
267M 271M      45.   856.2 856.1                                                 270DATA 206
270I 272I0.06  45.   856.2 856.1  27.  0.04  0.065 18.                              DATA 207
266I 273I0.16  91.   856.3 856.1  27.  0.04  0.03  29.                              DATA 208
272I 271M                                                                           DATA 209
273I 271M                                                                           DATA 210
274I 275I0.18  91.   871.76864.33 63.  0.06  0.075 40.                              DATA 211
275I 276M                                                                           DATA 212
276M 277M      45.   864.33860.63                                                275DATA 213
275I 278I0.11  45.   864.33860.63 27.  0.04  0.08  22.                              DATA 214
280  279I0.05  45.   864.33860.63 27.  0.04  0.02  17.                              DATA 215
291  282I0.1   40.   861.39860.63 27.  0.04  0.07  21.                              DATA 216
281  283I0.35  40.   861.39860.63 27.  0.04  0.02  15.                              DATA 217
273I 277M                                                                           DATA 218
279I 277M                                                                           DATA 219
282I 277M                                                                           DATA 220
283I 277M                                                                           DATA 221
277M 271M      80.   860.63856.10                                            279 283DATA 222
279I 284I0.14  80.   860.63856.10 27.  0.04  0.05  22.                              DATA 223
284I 271M                                                                           DATA 224
283I 271M                                                                           DATA 225
271M 250P      43.   856.10856.00                                                273DATA 226
273I 250P0.23  43.   856.10856.00 27.  0.04  0.05  61.                              DATA 227
583  285I0.10  93.   860.63858.31 27.  0.04  0.03  38.                              DATA 228
286  287I0.06  48.   858.39858.31 27.  0.04  0.04  20.                              DATA 229
286  288I0.10  43.   858.39858.31 23.  0.03  0.02  23.                              DATA 230
285I 289M                                                                           DATA 231
287I 289M                                                                           DATA 232
283I 289M                                                                           DATA 233
289M 250P      81.   858.31856.00                                            288 287DATA 234
287I 250P0.17  81.   858.31856.00 63.  0.06  0.04  33.                              DATA 235
293I 250P0.29  81.   858.31856.00 23.  0.03  0.03  52.                              DATA 236
105  106I0.32  129.  864.43859.34 23.  0.03  0.03  19.                              DATA 237
106I 108M                                                                           DATA 238
108M 109M      58.   859.34858.09                                                106DATA 239
106I 110I0.28  58.   859.34858.09 23.  0.03  0.05  30.                              DATA 240
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
111I  112I0.25  99.   859.34858.09 27.  0.04  0.05  24.                         DATA 241
110I  109M                                                                      DATA 242
112I  109M                                                                      DATA 243
109M  250P      62.   858.09856.00                                       110 112DATA 244
112I  250P0.31  62.   858.09856.00 27.  0.04  0.06  108.                        DATA 245
105I  113I0.37  100.  864.43862.25 23.  0.03  0.02  32.                         DATA 246
113I  114M                                                                      DATA 247
114M  115M      128.  862.25860.20                                           113DATA 248
113I  116I0.85  128.  862.25860.20 23.  0.03  0.065 111.                        DATA 249
116I  115M                                                                      DATA 250
115M  117M      101.  860.20857.70                                           116DATA 251
116I  118I0.75  101.  860.20857.70 23.  0.03  0.065 111.                        DATA 252
110I  119I0.09  61.   858.09857.70 23.  0.03  0.04  25.                         DATA 253
300I  301I0.25  61.   858.09857.7  23.  0.03  0.03  62.                         DATA 254
301I  117M                                                                      DATA 255
118I  117M                                                                      DATA 256
119I  117M                                                                      DATA 257
250P  302P      95.   856.00855.4                                               DATA 258
117M  302P      108.  857.70855.4                                            301DATA 259
301I  302P0.33  108.  857.70855.4  23.  0.03  0.03  55.                         DATA 260
   1   37I0.06  43.   879.00871.12 27.  0.04  0.075 24                          DATA 261
  38   39I0.1   45.   873.04871.12 27.  0.04  0.08  24.                         DATA 262
 37I   40M                                                                      DATA 263
 39I   40M                                                                      DATA 264
 40M  303M      57.   871.12868.16                                            37DATA 265
205   304I0.14  46.   871.34868.16 63.  0.06  0.06  39.                         DATA 266
306   305I0.20  82.   876.62868.16 63.  0.06  0.05  43.                         DATA 267
306   307I0.08  82.   876.62868.16 27.  0.04  0.02  12.                         DATA 268
307I  303M                                                                      DATA 269
305I  303M                                                                      DATA 270
304I  303M                                                                      DATA 271
303M  308M      45.   868.16865.52                                           307DATA 272
307I  309I0.07  45.   868.16865.52 27.  0.04  0.05  21.                         DATA 273
310   311I0.15  82.   866.11865.52 27.  0.04  0.04  36.                         DATA 274
310   312I0.11  82.   866.11865.52 27.  0.04  0.03  21.                         DATA 275
309I  308M                                                                      DATA 276
311I  308M                                                                      DATA 277
312I  308M                                                                      DATA 278
303M  313M      45.   865.52862.84                                           312DATA 279
312I  314I0.06  45.   865.52862.84 27.  0.04  0.04  22.                         DATA 280
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
315  316I0.16  126.  871.34862.84 27.  0.04  0.02  10.                         DATA 281
316I 313M                                                                      DATA 282
314I 313M                                                                      DATA 283
313M 317M       44.  862.84860.86                                      314 316DATA 284
314I 318I0.07   44.  862.84860.86 27.  0.04  0.03  17.                         DATA 285
316I 319I0.1    44.  862.84860.86 63.  0.06  0.02  16.                         DATA 286
318I 317M                                                                      DATA 287
319I 317M                                                                      DATA 288
317M 320M       81.  860.86858.80                                      319 318DATA 289
318I 321I0.18   81.  860.86858.80 27.  0.04  0.05  32.                         DATA 290
319I 322I0.27   81.  860.86858.80 23.  0.03  0.02  39.                         DATA 291
321I 320M                                                                      DATA 292
322I 320M                                                                      DATA 293
600  601I0.03   45.  876.86866.11 27.  0.04  0.04  22.                         DATA 294
600  602I0.12   45.  876.86866.11 63.  0.06  0.06  40.                         DATA 295
274  603I0.11   45.  871.76866.11 63.  0.06  0.04  38.                         DATA 296
601I 329M                                                                      DATA 297
602I 329M                                                                      DATA 298
603I 329M                                                                      DATA 299
329M 330M       45.  866.11859.16                                      601 603DATA 300
603I 324I0.19   93.  866.11858.80 27.  0.04  0.04  19.                         DATA 301
601I 326I0.04   45.  866.11859.16 27.  0.04  0.03  15.                         DATA 302
324I 320M                                                                      DATA 303
327  328I0.14   81.  862.84859.16 27.  0.04  0.06  23.                         DATA 304
327  399I0.03   81.  862.84859.16 27.  0.04  0.02  10.                         DATA 305
399I 330M                                                                      DATA 306
328I 330M                                                                      DATA 307
326I 330M                                                                      DATA 308
330M 320M       43.  859.16858.80                                          399DATA 309
399I 331I0.04   43.  859.16858.80 27.  0.04  0.03  12.                         DATA 310
331I 320M                                                                      DATA 311
320M 332M       45.  858.80858.56                                      322 324DATA 312
322I 333I0.19   45.  858.80858.56 23.  0.03  0.02  32.                         DATA 313
324I 334I0.57   45.  858.80858.56 27.  0.04  0.06  18.                         DATA 314
274  335I0.19   93.  871.76858.56 27.  0.04  0.04  20.                         DATA 315
274  336I0.2    93.  871.76858.56 27.  0.04  0.04  21.                         DATA 316
336I 332M                                                                      DATA 317
335I 332M                                                                      DATA 318
334I 332M                                                                      DATA 319
333I 332M                                                                      DATA 320
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
 332M 337M      45.   858.56858.48                                      333 336DATA 321
 336I 338I0.05  45.   858.56858.48 27.  0.04  0.06  22.                        DATA 322
 339I 340I0.20  93.   869.88858.48 27.  0.04  0.04  20.                        DATA 323
 339I 341I0.19  93.   868.88858.48 27.  0.04  0.04  20.                        DATA 324
 341I 337M                                                                     DATA 325
 340I 337M                                                                     DATA 326
 338I 337M                                                                     DATA 327
 337M 342M      40.   858.48858.39                                          341DATA 328
 333I 343I0.25  93.   858.56858.39 23.  0.03  0.02  36.                        DATA 329
 341I 344I0.04  43.   858.48858.39 27.  0.04  0.05  15.                        DATA 330
 344I 342M                                                                     DATA 331
 343I 342M                                                                     DATA 332
 302P 350P      132.  855.40852.20                                             DATA 333
 342M 352P      97.   858.39852.20                                      351 343DATA 334
 343I 350P0.41  97.   858.39852.20 23.  0.03  0.03  91.                        DATA 335
 351I 350P0.19  97.   858.39852.20 23.  0.03  0.03  28.                        DATA 336
 352I 353I0.07  43.   871.12866.58 27.  0.04  0.02  9.                         DATA 337
 353I 354M                                                                     DATA 338
 354M 355M      35.   866.58865.20                                          353DATA 339
  37I 357I0.20  80.   971.58865.20 63.  0.06  0.05  43.                        DATA 340
 359I 359I0.21  92.   872.06865.20 63.  0.06  0.04  45.                        DATA 341
 359I 355M                                                                     DATA 342
 357I 355M                                                                     DATA 343
 355M 360M      135.  865.20859.77                                          359DATA 344
 359I 361I0.22  135.  865.20859.77 63.  0.06  0.04  30.                        DATA 345
 353I 362I0.33  135.  865.58859.77 27.  0.04  0.04  37.                        DATA 346
 363  364I0.07  40.   863.42859.77 27.  0.04  0.03  32.                        DATA 347
 363  365I0.05  40.   863.42859.77 63.  0.06  0.02  12.                        DATA 348
 361I 360M                                                                     DATA 349
 362I 360M                                                                     DATA 350
 364I 360M                                                                     DATA 351
 365I 360M                                                                     DATA 352
 360M 370M      57.   859.77858.77                                          365DATA 353
 365I 366I0.10  57.   859.77858.77 63.  0.06  0.04  21.                        DATA 354
 366I 370M                                                                     DATA 355
 370M 371M      105.  858.77857.95                                          366DATA 356
 366I 367I0.42  105.  858.77857.95 23.  0.03  0.02  66.                        DATA 357
 367I 371M                                                                     DATA 358
 371M 372M      118.  857.95855.00                                          367DATA 359
 367I 368I0.56  118.  857.95855.00 23.  0.03  0.03  66.                        DATA 360
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
368I 372M                                                                      DATA 361
372M 350P       107.  855.00852.20                                          368DATA 362
368I 350P0.33   107.  855.00852.20 23.  0.03  0.04  59.                        DATA 363
350P 400P       100.  852.20850.00                                   1         DATA 364
.........1.........2.........3.........4.........5.........6.........7.........8
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B.7. SAMPLE OUTPUT

```
***************************************************************************************
*                                                                                     *
*         APPLICATION OF THE MODEL TO                                                 *
*                                                                                     *
*         BATIKENT SATELLITE TOWN AREA                                                *
*                                                                                     *
*         NEAR ANKARA                                                                 *
*                                                                                     *
***************************************************************************************


           **********D E S I G N   C R I T E R I O N**********
                     ------------------------------------------

           RECURRENCE PERIOD FOR SEWERS..............=   5    YEAR
           RECURRENCE PERIOD FOR COLLECTORS.........=  25    YEAR
           RAINFALL DURATION FOR SEWERS.............=  15.0  MIN.
           RAINFALL DURATION FOR COLLECTORS.........=  35.0  MIN.
           RAINFALL INTENSITY FOR SEWERS............=  68.0  MM/HOUR
           RAINFALL INTENSITY FOR COLLECTORS........=  88.0  MM/HOUR
           ALLOWABLE MAX. VELOCITY IN SEWERS........=   7.0  M/SEC
           ALLOWABLE MAX. VELOCITY IN COLLECTORS....=  15.0  M/SEC
           MAX. FLOW RATE IN GUTTERS................=  50.0  LT/SEC
           MAX. FLOW DEPTH IN GUTTERS...............=   7.0  CM
           CROSS-SECTIONAL SLOPE OF GUTTERS.........= 0.020
           MANNING ROUGHNESS COEF. IN GUTTERS.......= 0.020
           TIME INCREMENT FOR HYDROGRAPHS...........=  1.00  MIN.
           MIN SOIL COVER FOR PIPES.................=  1.00  METER
           MAX.NUMBER OF LARGER SECTION SIZES TRIED
           AS AN ALTERNATIVE TO CHUTE STRUCTURES....=   2


     ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
               HYDROGRAPH TIME LAG METHOD IS SELECTED
     ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
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```
**********ONLY CIRCULAR PIPES WILL BE USED FOR SEWERS**********
          NUMBER OF STANDARD DIAMETERS : 16
          MANNING ROUGHNESS COEFFICIENT FOR PIPES : 0.016
          MAXIMUM RATIO OF DEPTH TO DIAMETER : 0.900

         PIPE TYPE :  1     DIAMETER: D =  200. MM
         PIPE TYPE :  2     DIAMETER: D =  250. MM
         PIPE TYPE :  3     DIAMETER: D =  300. MM
         PIPE TYPE :  4     DIAMETER: D =  350. MM
         PIPE TYPE :  5     DIAMETER: D =  400. MM
         PIPE TYPE :  6     DIAMETER: D =  500. MM
         PIPE TYPE :  7     DIAMETER: D =  600. MM
         PIPE TYPE :  8     DIAMETER: D =  700. MM
         PIPE TYPE :  9     DIAMETER: D =  800. MM
         PIPE TYPE : 10     DIAMETER: D =1000. MM
         PIPE TYPE : 11     DIAMETER: D =1200. MM
         PIPE TYPE : 12     DIAMETER: D =1400. MM
         PIPE TYPE : 13     DIAMETER: D =1600. MM
         PIPE TYPE : 14     DIAMETER: D =1800. MM
         PIPE TYPE : 15     DIAMETER: D =2000. MM
         PIPE TYPE : 16     DIAMETER: D =2400. MM

**********IN BOTH SEWERS AND COLLECTORS THE SAME ABOVE SECTIONS WILL BE USED**********
```

```
DESCRIPTION OF OUTPUT TITLE PARAMETERS
--------------------------------------

ITH   : UPSTREAM NODE NUMBER
U     : UPSTREAM NODE CONDITION
  BLANK : UPSTREAM END OF A GUTTER OF MOST EXTREME INLET
        I : INLET
        M : MANHOLE
        P : COLLECTOR JUNCTION
        B : INFLOW TO A COLLECTOR JUNCTION FROM UPPER BASIN
JTH   : DOWNSTREAM NODE NUMBER
D     : DOWNSREAM NODE CONDITION
        I : INLET
        M : MANHOLE
        P : COLLECTOR JUNCTION
TAREA: TOTAL AREA DRAINED AT NODE ITH ( HA )
AREA : AREA DRAINED BY THE INLET JTH ( HA )
ALEN : LENGTH OF GUTTER ( M )
SLOPY: SLOPE OF SUBCATCHMENT ( M/M )
UELEV: UPSTREAM NODE TOPOGRAPHIC ELEVATION ( M )
DELEV: DOWNSTREAM NODE TOPOGRAPHIC ELEVATION ( M )
UP    : ELEVATION OF SEWER OR COLLECTOR AT UPSTREAM END (M)
DOWN  : ELEVATION OF SEWER OR COLLECTOR AT DOWNSTREAM END (M)
TYPE  : STANDARD SECTION TYPE
QDES  : DESIGN DISCHARGE OF SEWER OR COLLECTOR ( LT/SEC )
QFUL  : FULL CAPACITY OF SEWER OR COLLECTOR ( LT/SEC )
Y     : FLOW DEPTH IN SEWER OR COLLECTOR ( M )
V     : DESIGN FLOW VELOCITY IN SEWER OR COLLECTOR ( M/SEC )
TIM   : PEAK FLOW TIME ( MIN )
QPIK  : PEAK FLOW RATE IN GUTTER FOR SMALL INTENSITY ( LT/SEC )
YPIK  : PEAK FLOW DEPTH IN GUTTER FOR QPIK ( CM )
PHY   : ABSTRACTION INDEX FOR SUBCATCHMENT ( MM/HR )
KN    : MANNING ROUGHNESS FACTOR OF SUBCATCHMENT
NC    : HEIGHT OF CHUTE STRUCTURES ( CM )
I     : NUMBER OF ADDITIONAL INLETS
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|ITH |L|JTH |D| TAREA |AREA |ALEN |SLOPY | UELEV| DELEV| UP    | DOWN |TYPE| QDES | QFUL | Y  |  V  |TIM| QPIK|YPIK|PHY|  KN  |NC |I|
|   1| |   2|I|       | 0.07| 45.0|0.0650|879.00|876.28|       |      |    |      |      |    |     |   | 7.97| 2.3|27.|0.040|   | |
|   1| |   3|I|       | 0.04| 45.0|0.0200|879.00|876.28|       |      |    |      |      |    |     |   | 0.56| 0.8|63.|0.060|   | |
|   2|I|   4|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|   3|I|   4|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|   4|M|   5|M|   0.11|     | 77.0|      |876.28|869.94|875.08 |868.74| 200|   8.5|  76.5|0.06|  1.1|  6|     |    |   |      |  0| |
|   2|I|   6|I|       | 0.11| 77.0|0.0600|876.28|869.94|       |      |    |      |      |    |     |   |12.53| 2.5|27.|0.040|   | |
|   7| |   8|I|       | 0.33| 77.0|0.0200|876.28|869.94|       |      |    |      |      |    |     |   | 4.50| 1.7|63.|0.060|   | |
|   9| |  10|I|       | 0.17| 55.0|0.0200|870.70|869.94|       |      |    |      |      |    |     |   | 2.30| 2.0|63.|0.060|   | |
|   6|I|   5|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|   8|I|   5|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  10|I|   5|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|   5|M|  11|M|   0.72|     | 45.0|      |869.94|868.72|868.74 |867.52| 200|  28.0|  43.9|0.13|  1.3| 12|     |    |   |      |  0| |
|   6|I|  12|I|       | 0.06| 45.0|0.1000|869.94|868.72|       |      |    |      |      |    |     |   | 6.83| 2.5|27.|0.040|   | |
|   1| |  13|I|       | 0.13| 78.0|0.0900|879.00|868.72|       |      |    |      |      |    |     |   |14.81| 2.5|27.|0.040|   | |
|   1| |  14|I|       | 0.11| 78.0|0.0200|879.00|868.72|       |      |    |      |      |    |     |   |12.53| 2.3|27.|0.040|   | |
|  12|I|  11|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  13|I|  11|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  14|I|  11|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  11|M|  15|M|   1.02|     | 47.0|      |868.72|867.12|867.47 |865.87| 250|  62.2|  89.1|0.17|  1.7| 13|     |    |   |      |  0| |
|  14|I|  16|I|       | 0.09| 47.0|0.0700|868.72|867.12|       |      |    |      |      |    |     |   |10.25| 2.3|27.|0.040|   | |
|  17| |  18|I|       | 0.17| 73.0|0.0420|877.11|867.12|       |      |    |      |      |    |     |   |19.36| 2.8|27.|0.040|   | |
|  17| |  19|I|       | 0.12| 73.0|0.0210|877.11|867.12|       |      |    |      |      |    |     |   |13.67| 2.4|27.|0.040|   | |
|  19|I|  15|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  18|I|  15|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  16|I|  15|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  15|M|  20|M|   1.40|     | 46.0|      |867.12|865.42|865.82 |864.12| 300| 105.4| 151.1|0.21|  2.0| 14|     |    |   |      |  0| |
|  21| |  22|I|       | 0.17| 73.0|0.0420|871.48|865.42|       |      |    |      |      |    |     |   |19.36| 3.0|27.|0.040|   | |
|  21| |  23|I|       | 0.09| 78.0|0.0200|871.48|865.42|       |      |    |      |      |    |     |   |10.25| 2.4|27.|0.040|   | |
|  19|I|  24|I|       | 0.09| 46.0|0.0700|867.12|865.42|       |      |    |      |      |    |     |   |10.25| 2.7|27.|0.040|   | |
|  24|I|  20|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  22|I|  20|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  23|I|  20|M|       |     |     |      |      |      |       |      |    |      |      |    |     |   |     |    |   |      |   | |
|  20|M|  25|M|   1.75|     | 46.0|      |865.42|862.85|864.12 |861.55| 300| 145.3| 185.7|0.23|  2.6| 15|     |    |   |      |  0| |
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B.8. PROGRAM LISTING

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.........1.........2.........3.........4.........5.........6.........7.........8
C-----METU DESIGN MODEL FOR URBAN STORMWATER DRAINAGE SYSTEMS                   METU
      INTEGER TIME,GGG/'I'/                                                     METU
      INTEGER KR,BBB/' '/,CCC/'I'/,DDD/'M'/,EEE/'P'/,FFF/'B'/,KP,P,R             METU
C-----FIRST SUBSCRIPT OF MATRICES MAY NEED TO INCREASE                          METU
C-----IF THE USER PREPARES DATA CARDS IN AN ORDER DEVIATING                      METU
C-----CONSIDERABLE FROM NATURAL DRAINAGE PATTERN.                                METU
C                                                                               METU
      DIMENSION HYDA(10,250),HYDB(10,250),HYDC(10,250),HYD(10,250),             METU
     *AHYD(250),BHYD(250),CHYD(250),FHYD(250),TITLE(60),TEMPA(20),              METU
     *TEMPB(20),TEMPC(20),ITEMP(20),JTEMP(20),LOGIC(20),KTEMP(20)               METU
      DIMENSION ITHS(100),JTHS(100)                                             METU
      COMMON/CHY/ALENY,SLOPY,PHY,AN,TDA,TDB,AINTA,AINTB,AREA                    METU
      COMMON/LAMDA/QFULL,F,R                                                    METU
      COMMON/SIGMA/IJK                                                          METU
      COMMON/TAU/DHYD(250)                                                      METU
      COMMON/RHO/EHYD(250)                                                      METU
      COMMON/GAMA/ALEN,DELT                                                     METU
      COMMON/BETA/CUTRZ,Z,SLOPE                                                 METU
      COMMON/ALFA/QPIK,YPIK                                                     METU
      COMMON/CRA/QMAX,YMAX,N                                                    METU
      COMMON/CRC/IDES,KKK,CHYD                                                  METU
      COMMON/TETA/UPA,DOWNA,PIPEN,CANALN,L,TYPEA(4,20),IJKL,IROUTE,ISTEP        METU
      COMMON/CCT/NSECA                                                          METU
      COMMON/CCE/TYPEB(20),TYPEC(5,20),AELEV,BELEV,DROP,NPIPE,NCANAL,           METU
     *NTRAP,TRAPN,TIME,BIG,Y,NART,NCHUTE,UP,DOWN,V                              METU
C-----P IS THE INPUT DEVICE NUMBER                                              METU
C-----R IS THE OUTPUT DEVICE NUMBER                                             METU
      P=5                                                                       METU
      R=8                                                                       METU
      NMN=1                                                                     METU
      NN=3000                                                                   METU
C-----READ TITLE OF THE PROBLEM TO BE PRINTED FROM THE CARDS                     METU
      READ(P,20) TITLE                                                          METU
   20 FORMAT(20A4)                                                              METU
C-----JK AND IJK ARE THE NUMBER OF HYDROGRAPHS THAT CAN BE STORED AND           METU
C     HYDROGRAPH BASE LENGTH RESPECTIVELY.                                      METU
C     THEY SHOULD BE CONSISTENT WITH ARRAY DIMENSIONS                           METU
      READ(P,30) JK,IJK,IDES,IROUTE,ISTEP                                       METU
      IF(ISTEP.EQ.0) ISTEP=1                                                    METU
      IJKL=IJK-1                                                                METU
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
      DO 10 I=1,JK                                                              METU  41
      ITEMP(I)=-9999                                                            METU  42
      JTEMP(I)=0                                                                METU  43
      KTEMP(I)=0                                                                METU  44
      LOGIC(I)=0                                                                METU  45
      DO 10 J=1,IJK                                                             METU  46
      HYD(I,J)=0.                                                               METU  47
      HYDA(I,J)=0.                                                              METU  48
      HYDB(I,J)=0.                                                              METU  49
      HYDC(I,J)=0.                                                              METU  50
   10 CONTINUE                                                                  METU  51
      DO 15 I=1,IJK                                                             METU  52
      AHYD(I)=0.                                                                METU  53
      BHYD(I)=0.                                                                METU  54
      CHYD(I)=0.                                                                METU  55
      DHYD(I)=0.                                                                METU  56
   15 EHYD(I)=0.                                                                METU  57
C-----READ THE FOLLOWING PARAMETERS:                                            METU  58
C-----ITR   :RETURN PERIOD FOR SEWERS                                           METU  59
C-----JTR   :RETURN PERIOD FOR COLLECTORS                                       METU  60
C-----NCANAL: NUMBER OF STANDARD RECTANGULAR SECTIONS                           METU  61
C-----NPIPE :NUMBER OF STANDARD DIAMETERS                                       METU  62
C-----NTRAP :NUMBER OF STANDARD TRAPEZOIDAL SECTIONS                            METU  63
C-----NMEC  :NUMBER OF SEWERS ON A STREET: 1 OR 2                               METU  64
C-----NSECA : SECTION SELECTION FOR SEWERS  0:CIRCULAR,1:RECTANGULAR            METU  65
C-----NSECB : SECTION SELECTION FOR COLLECTORS 0:CIRCULAR,1:RECTANGULAR         METU  66
C     2:TRAPEZOIDAL                                                             METU  67
      READ(P,30) ITR,JTR,NCANAL,NPIPE,NTRAP,NMEC,NSECA,NSECB,NART,LMIN          METU  68
   30 FORMAT(15I5)                                                              METU  69
      READ(P,35)AINTA,AINTB,TCA,TCB,VMAX,QMAX,YMAX,VMAXB,DELT,                  METU  70
     *GUTRZ,GUTRN,CANALN,PIPEN,TRAPN,DROP,RATK,RATT                             METU  71
   35 FORMAT( 8F10.0)                                                           METU  72
      WRITE(R,40)TITLE                                                          METU  73
   40 FORMAT(1H1,10(/),24X,84('*')/24X,'*',82X,'*'/3(24X,'* ',20A4,' *'/        METU  74
     *24X,'*',82X,'*'/),24X,84('*'))                                            METU  75
      Z=1/GUTRZ                                                                 METU  76
      WRITE(R,50) ITR,JTR,TCA,TCB,AINTA,AINTB,VMAX,VMAXB,QMAX,YMAX,Z,           METU  77
     *GUTRN,DELT,DROP,NART                                                      METU  78
   50 FORMAT(///43X,10('*'),'D E S I G N   C R I T E R I O N',10('*')/          METU  79
     *53X,31('-')//                                                             METU  80
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
     A41X,'RECURRENCE PERIOD FOR SEWERS..............=',I4,'   YEAR'/          METU  81
     B41X,'RECURRENCE PERIOD FOR COLLECTORS..........=',I4,'   YEAR'/          METU  82
     C41X,'RAINFALL DURATION FOR SEWERS..............=',F6.1,' MIN.'/          METU  83
     D41X,'RAINFALL DURATION FOR COLLECTORS..........=',F6.1,' MIN.'/          METU  84
     D41X,'RAINFALL INTENSITY FOR SEWERS.............=',F6.1,' MM/HOUR'/       METU  85
     F41X,'RAINFALL INTENSITY FOR COLLECTORS.........=',F6.1,' MM/HOUR'/       METU  86
     G41X,'ALLOWABLE MAX. VELOCITY IN SEWERS.........=',F6.1,' M/SEC'/         METU  87
     I41X,'ALLOWABLE MAX. VELOCITY IN COLLECTORS.....=',F6.1,' M/SEC'/         METU  88
     J41X,'MAX. FLOW RATE IN GUTTERS.................=',F6.1,' LT/SEC'/        METU  89
     K41X,'MAX. FLOW DEPTH IN GUTTERS................=',F6.1,' CM'/            METU  90
     L41X,'CROSS-SECTIONAL SLOPE OF GUTTERS..........=',F6.3/                  METU  91
     M41X,'MANNING ROUGHNESS COEF. IN GUTTERS........=',F6.3/                  METU  92
     N41X,'TIME INCREMENT FOR HYDROGRAPHS............=',F6.2,' MIN.'/          METU  93
     P41X,'MIN SOIL COVER FOR PIPES..................=',F6.2,' METER'/         METU  94
     R41X,'MAX.NUMBER OF LARGER SECTION SIZES TRIED'/                          METU  95
     S41X,'AS AN ALTERNATIVE TO CHUTE STRUCTURES...=',I4/)                     METU  96
      IF(IROUTE.NE.0) WRITE(R,41) ISTEP                                        METU  97
   41 FORMAT(///33X,60('+')/43X,'MODIFIED KINEMATIC ROUTING IS SELECTED'       METU  98
     */35X,'EACH OUTFLOW HYDROGRAPH ORDINATE IS COMPUTED AT',I3,' STEPS'       METU  99
     */33X,60('+'))                                                            METU 100
      IF(IROUTE.EQ.0) WRITE(R,42)                                              METU 101
   42 FORMAT(///33X,60('+')/43X,'HYDROGRAPH TIME LAG METHOD IS SELECTED'       METU 102
     */33X,60('+'))                                                            METU 103
C------IN THIS SECTION OF THE PROGRAM STANDARD DIAMETERS AND SECTIONS           METU 104
C       WILL BE READ, AND PRINTED ACCORDING TO THE CHOICE OF DESIGN            METU 105
      IF(NSECA.EQ.0) WRITE(R,60) NPIPE,PIPEN                                   METU 106
   60 FORMAT(1H1,10(/),30X,10('*'),'ONLY CIRCULAR PIPES WILL BE USED FOR       METU 107
     1 SEWERS',10('*')//41X,'NUMBER OF STANDARD DIAMETERS :',I3//41X,'MA       METU 108
     2NNING ROUGHNESS COEFFICIENT FOR PIPES :',F6.3//41X,'MAXIMUM RATIO        METU 109
     3OF DEPTH TO DIAMETER : 0.900'///)                                        METU 110
      IF(NSECA.EQ.1) WRITE(R,70) NCANAL,CANALN,RATK                            METU 111
   70 FORMAT(1H1,10(/),30X,10('*'),'ONLY RECTANGULAR SECTIONS WILL BE US       METU 112
     4ED FOR SEWERS',10('*')//41X,'NUMBER OF STANDARD SECTIONS :',I3//41       METU 113
     5X,'MANNING ROUGHNESS COEFFICIENT FOR RECTANGULAR SECTIONS :',F6.3/       METU 114
     6/41X,'MAXIMUM DEPTH RATIO FOR RECTANGULAR SECTIONS :',F6.3//)            METU 115
      IF(NCANAL.GT.0) GO TO 100                                                METU 116
   30 IF(NPIPE.GT.0) GO TO 140                                                 METU 117
      WRITE(R,90)                                                              METU 118
   90 FORMAT(///1X,120('*')/10X,'ERROR: NUMBER OF STANDARD SECTIONS FOR        METU 119
     *SEWERS HAS NOT BEEN FOUND IN INPUT DATA')                                METU 120
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
      STOP
  100 READ(P,110) (TYPEA(1,I),TYPEA(3,I),I=1,NCANAL)
  110 FORMAT(16F5.0)
      IF(NSECA.EQ.0) GO TO 80
      DO 130 I=1,NCANAL
      WRITE(R,120) I,TYPEA(1,I),TYPEA(3,I)
  120 FORMAT(30X,'CANAL TYPE : ',I2,5X,'WIDTH: B =',F6.2,' METER',5X,
     *'HEIGHT: Y =',F6.2,' METER')
      TEMP=TYPEA(3,I)*RATK
      A=TYPEA(1,I)*TEMP
      TYPEA(4,I)=A
  130 TYPEA(2,I)=(A/(TYPEA(1,I)+2*TEMP))**(2./3)*A
      GO TO 80
  140 READ(P,110) (TYPEB(I),I=1,NPIPE)
      IF(NSECA.EQ.1) GO TO 160
      DO 145 I=1,NPIPE
  145 WRITE(R,150) I,TYPEB(I)
  150 FORMAT(40X,'PIPE TYPE : ',I2,5X,'DIAMETER: D =',F5.0,' MM')
      GO TO 170
  160 DROP=0.
  170 CONTINUE
      GUTRZ=GUTRN**0.375*(GUTRZ+1)**0.25 /(0.5*GUTRZ)**0.625
      Z=1/Z
      IF(NTRAP.GT.0)  READ(P,110) ((TYPEC(I,J),I=1,3),J=1,NTRAP)
      IF(NSECB.NE.2) GO TO 220
      IF(NTRAP.LE.0.AND.NSECB.EQ.2) GO TO 180
      GO TO 195
  180 WRITE(R,190)
  190 FORMAT(///1X,130('*'),/10X,'ERROR : NUMBER OF STANDARD SECTIONS FO
     *R COLLECTORS HAS NOT BEEN FOUND IN INPUT DATA')
      STOP
  195 WRITE(R,200)NTRAP,TRAPN,RATT
  200 FORMAT(////31X,10('*'),'ONLY TRAPEZOIDAL SECTIONS WILL BE USED FOR
     * COLLECTORS',10('*')//41X,'NUMBER OF STANDARD SECTIONS :',I3//41X,
     *'MANNING ROUGHNESS COEFFICIENT FOR TRAPEZOIDAL SECTIONS :',F6.3//,
     *41X,'MAXIMUM DEPTH RATIO FOR TRAPEZOIDAL SECTIONS :',F6.3//)
      DO 210 I=1,NTRAP
      TYPEC(5,I)=(TYPEC(1,I)+TYPEC(2,I)*TYPEC(3,I)*RATT)*TYPEC(3,I)*RATT
      TYPEC(4,I)=TYPEC(5,I)**(5./3)/(TYPEC(1,I)+2*TYPEC(3,I)*RATT*SQRT(1
     *+TYPEC(2,I)**2))**(2./3)
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
  210 WRITE(R,220) I,(TYPEC(J,I),J=1,3)                                 METU 161
  220 FORMAT(20X,'CANAL TYPE : ',I2,5X,'WIDTH: B =',F6.2,' METER',5X,   METU 162
     *'SIDE SLOPE: Z =',F5.2,5X,'HEIGHT: Y =',F6.2,' METER')            METU 163
      GO TO 290                                                         METU 164
  230 IF(NSECB.EQ.NSECA) GO TO 250                                      METU 165
      IF(NSECB.EQ.0) GO TO 270                                          METU 166
      WRITE(R,240) NCANAL,CANALN,RATK                                   METU 167
  240 FORMAT(///31X,10('*'),'ONLY RECTANGULAR SECTIONS WILL BE USED FOR METU 168
     * COLLECTORS',10('*')//41X,'NUMBER OF STANDARD SECTIONS :',I3//41X, METU 169
     *'MANNING ROUGHNESS COEFFICIENT FOR RECTANGULAR SECTIONS :',F6.3//, METU 170
     *41X,'MAXIMUM DEPTH RATIO FOR RECTANGULAR SECTIONS :',F6.3//)      METU 171
      DO 245 I=1,NCANAL                                                 METU 172
      WRITE(R,120) I,TYPEA(1,I),TYPEA(3,I)                              METU 173
      TEMP=TYPEA(3,I)*RATK                                              METU 174
      A=TYPEA(1,I)*TEMP                                                 METU 175
      TYPEA(4,I)=A                                                      METU 176
  245 TYPEA(2,I)=(A/(TYPEA(1,I)+2*TEMP))**(2./3)*A                      METU 177
      GO TO 290                                                         METU 178
  250 WRITE(R,260)                                                      METU 179
  260 FORMAT(//24X,10('*'),'IN BOTH SEWERS AND COLLECTORS THE SAME ABOVE METU 180
     * SECTIONS WILL BE USED',10('*'))                                  METU 181
      GO TO 290                                                         METU 182
  270 WRITE(R,280) NPIPE,PIPEN                                          METU 183
  280 FORMAT(///31X,10('*'),'ONLY CIRCULAR PIPES WILL BE USED FOR COLLE METU 184
     *CTORS',10('*')//41X,'NUMBER OF STANDARD DIAMETERS :',I3//41X,'MANN METU 185
     *ING ROUGHNESS COEFFICIENT FOR PIPES :',F6.3//41X,'MAXIMUM RATIO OF METU 186
     * DEPTH TO DIAMETER : 0.900'//)                                    METU 187
      DO 285 I=1,NPIPE                                                  METU 188
  285 WRITE(R,150) I,TYPEB(I)                                           METU 189
  290 CONTINUE                                                          METU 190
      WRITE(R,291)                                                      METU 191
  291 FORMAT(1H1,15(/),20X,'DESCRIPTION OF OUTPUT TITLE PARAMETERS'/20X METU 192
     *,39('-')//                                                        METU 193
     120X,'ITH   : UPSTREAM NODE NUMBER'/,                              METU 194
     220X,'U     : UPSTREAM NODE CONDITION'/,                           METU 195
     322X,'BLANK : UPSTREAM END OF A GUTTER OF MOST EXTREME INLET'/,    METU 196
     427X,'I : INLET'/ 27X,'M : MANHOLE'/ 27X,'P : COLLECTOR JUNCTION'/, METU 197
     527X,'B : INFLOW TO A COLLECTOR JUNCTION FROM UPPER BASIN'/,       METU 198
     620X,'JTH   : DOWNSTREAM NODE MUMBER'/,                            METU 199
     720X,'D     : DOWNSREAM NODE CONDITION'/,                          METU 200
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
     827X,'I : INLET'/ 27X,'M : MANHOLE'/27X,'P : CCLLECTCR JUNCTICN'/,
     920X,'TAREA: TOTAL AREA CRAINED AT NODE ITH ( HA )')
      WRITE(R,292)
  292 FORMAT(20X,'AREA : AREA CRAINED BY THE INLET JTH ( HA )'/,
     *20X,'ALEN : LENGTH CF GUTTER ( M )'/,
     *20X,'SLOPY: SLCPE CF SUBCATCHMENT ( M/M )'/,
     *20X,'UELEV: UPSTREAM NCDE TOPOGRAPHIC ELEVATICN ( M )'/,
     *20X,'DELEV: DOWNSTREAM NCDE TOPOGRAPHIC ELEVATICN ( M )'/,
     *20X,'UP   : ELEVATICN CF SEWER OR COLLECTOR AT UPSTREAM END (M)'/,
     *20X,'DOWN : ELEVATICN CF SEWER OR COLLECTCR AT DOWNSTREAM END (M)'
     */,20X,'TYPE : STANDARD SECTION TYPE'/,
     *20X,'QDES : DESIGN DISCHARGE OF SEWER OR CCLLECTOR ( LT/SEC )'/,
     *20X,'QFUL : FULL CAPACITY CF SEWER OR COLLECTCR ( LT/SEC )'/,
     *20X,'Y    : FLOW DEPTH IN SEWER OR COLLECTCR ( M )'/,
     *20X,'V    : DESIGN FLOW VELOCITY IN SEWER CR CCLLECTCR ( M/SEC )'/
     *20X,'TIM  : PEAK FLOW TIME ( MIN )'/,
     *20X,'QPIK : PEAK FLOW RATE IN GUTTER FOR SMALL INTENSITY ( LT/SEC
     *)'/,20X,'YPIK : PEAK FLOW DEPTH IN GUTTER FOR QPIK ( CM )'/,
     *20X,'PHY  : ABSTRACTION INDEX FOR SUBCATCHMENT ( MM/HR )'/,
     *20X,'KN   : MANNING ROUGHNESS FACTOR OF SUBCATCHMENT'/,
     *20X,'NC   : HEIGHT OF CHUTE STRUCTURES ( CM )'/,
     *20X,'I    : NUMBER CF ADDITIONAL INLETS'/)
      WRITE(R,4)
    4 FORMAT(1H1///1X,131('-'))
      WRITE(R,5)
    5 FORMAT(1X,'!     !  !     !  !          !         !        !       !
     *!          !     !        !        !         !      !      !     !      !
     *   !     !  !')
      WRITE(R,7)
    7 FORMAT(1H+,
     *           ITH   U  JTH   D   TAREA   AREA   ALEN   SLOPY   UELEV  DELEV
     *  UP     DOWN  TYPE  QDES    QFUL     Y        V     TIM  QPIK YPIK PHY
     *KN  NC  I')
      WRITE(R,6)
    6 FORMAT(1X,131('-'))
C-----PROGRAM STARTS TO READ THE INPUT OF THE SYSTEM ON ONE CARD FROM
C     ONE NODE TO ANOTHER
  300 READ(P,310,END=9999) ITH,KP,JTH,KR,AREA,ALEN,AELEV,BELEV,PHY,AN,
     *SLOPY,ALENY,LP,NCDI,NCDJ
  310 FORMAT(2(I4,A1),8F6.0,T69,3I4)
.........1.........2.........3.........4.........5.........6.........7.........8
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.......1.........2.........3.........4.........5.........6.........7.........8
      IF(AELEV-BELEV) 311,315,313                                        METU 241
  315 IF(ALEN.EQ.0.) GO TO 313                                           METU 242
  311 WRITE(R,312) ITH,KP,JTH,KR,AREA,ALEN,AELEV,BELEV,PHY,AN,SLOPY,     METU 243
     *ALENY,LP,NODI,NODJ                                                 METU 244
  312 FORMAT(///1X,130('*')/10X,'ERROR : NON POSITIVE SLOPE FOR THE FOLL METU 245
     *OWING DATA CARD'//10X,2(I4,A1), 8F9.4,5X,3I6)                      METU 246
      STOP                                                               METU 247
  313 CONTINUE                                                           METU 248
      IF(KP.EQ.BBB) GO TO 340                                            METU 249
      IF(KP.EQ.CCC) GO TO 320                                            METU 250
      IF(KP.EQ.DDD) GO TO 330                                            METU 251
      IF(KP.EQ.EEE) GO TO 2000                                           METU 252
      IF(KP.EQ.FFF) GO TO 1200                                           METU 253
  320 IF(KR.EQ.DDD) GO TO 800                                            METU 254
      IF(KR.EQ.CCC.OR.KR.EQ.EEE) GO TO 530                               METU 255
  330 IF(KR.EQ.DDD.OR.KR.EQ.EEE) GO TO 900                               METU 256
      WRITE(R,335)                                                       METU 257
  335 FORMAT(///1X,130('*')/10X,'ERROR : BOUNDARY CONDITION AT DOWNSTREA METU 258
     *M END IS NOT GIVEN')                                               METU 259
      STOP                                                               METU 260
C-----COMPUTATION OF EACH CARD DATA STARTS FROM HERE ACCORDING TO         METU 261
C     THE TRANSFER OF DATA CARD                                          METU 262
  336 DO 337 I=1,JK                                                      METU 263
      IF(ITH.EQ.ITEMP(I)) GO TO 338                                      METU 264
  337 CONTINUE                                                           METU 265
      GO TO 8889                                                         METU 266
  338 DO 339 J=1,IJK                                                     METU 267
      DHYD(J)=HYDB(I,J)                                                  METU 268
  339 HYDB(I,J)=0.                                                       METU 269
      LOGIC(I)=0                                                         METU 270
      ITEMP(I)=-9999                                                     METU 271
  340 DO 350 I=1,JK                                                      METU 272
      IF(LOGIC(I).EQ.0) GO TO 360                                        METU 273
  350 CONTINUE                                                           METU 274
      GO TO 9388                                                         METU 275
  360 ITEMP(I)=JTH                                                       METU 276
      TEMPC(I)=AREA                                                      METU 277
      LOGIC(I)=1                                                         METU 278
      SLOPE=(AELEV-BELEV)/ALEN                                           METU 279
      CALL HYDCAL(1,AHYD,NNN)                                            METU 280
.......1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
      APIK=GPIK                                                         METU 231
      BPIK=YPIK                                                         METU 282
      DO 370 J=1,IJK                                                    METU 283
      HYDA(I,J)=AHYD(J)                                                 METU 284
  370 AHYD(J)=0.                                                        METU 285
      CALL HYDCAL(IDES,CHYD,KKK)                                        METU 286
      CALL ROUTE                                                        METU 287
      DO 400 J=1,IJK                                                    METU 288
      HYDB(I,J)=CHYD(J)                                                 METU 289
      DHYD(J)=0.                                                        METU 290
  400 CHYD(J)=0.                                                        METU 291
      IF(YMAX.LT.YPIK.OR.GMAX.LT.GPIK) GO TO 410                        METU 292
      TEMP3(I)=BELEV-DFCP                                               METU 293
      WRITE(R,5)                                                        METU 294
      WRITE(R,405) ITH,KR,JTH,KR,AREA,ALEN,SLOPY,AELEV,BELEV,GPIK,YPIK, METU 295
     *PHY,AN                                                            METU 296
  405 FORMAT(1H+,2(I5,1X,A1),8X,F6.2,F6.1,F7.4,2F7.2,48X,F6.2,F5.1,F4.0,METU 297
     *F6.3,I6)                                                          METU 298
      WRITE(R,6)                                                        METU 299
      IF(KR.EQ.EEE) GO TO 441                                           METU 300
      GO TO 300                                                         METU 301
  410 CALL RATIO                                                        METU 302
  420 N=N+1                                                             METU 303
      ALEN=ALEN/N                                                       METU 304
      AREA=AREA/N                                                       METU 305
      CALL HYDCAL(1,AHYD,NNN)                                           METU 306
      IF(YMAX.LT.YPIK.OR.GMAX.LT.QPIK) GO TO 430                        METU 307
      IF(NMEC.EQ.2) GO TO 450                                           METU 308
      GO TO 440                                                         METU 309
  430 ALEN=ALEN*N                                                       METU 310
      AREA=AREA*N                                                       METU 311
      GO TO 420                                                         METU 312
  440 AREA=AREA*N                                                       METU 313
      ALEN=ALEN*N                                                       METU 314
      N=N-1                                                             METU 315
      WRITE(R,5)                                                        METU 316
      WRITE(R,405) ITH,KR,JTH,KR,AREA,ALEN,SLOPY,AELEV,BELEV,APIK,BPIK, METU 317
     *PHY,AN,N                                                          METU 318
      WRITE(R,6)                                                        METU 319
      IF(KR.EQ.EEE) GO TO 441                                           METU 320
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
      GO TO 300                                                         METU 321
  441 LI=I                                                              METU 322
      DO 442 I=1,JK                                                     METU 323
      IF(JTH.EQ.ITEMP(I).AND.LI.NE.I) GO TO 443                         METU 324
  442 CONTINUE                                                          METU 325
      GO TO 444                                                         METU 326
  443 DO 1443 J=1,IJK                                                   METU 327
 1443 HYD(I,J)=HYD(I,J)+HYDB(LI,J)                                      METU 328
      TEMPC(I)=TEMPC(I)+AREA                                            METU 329
      LOGIC(LI)=0                                                       METU 330
      ITEMP(LI)=-9999                                                   METU 331
      TEMPC(LI)=0.                                                      METU 332
      GO TO 300                                                         METU 333
  444 I=LI                                                              METU 334
      DO 1445 J=1,IJK                                                   METU 335
 1445 HYD(I,J)=HYDB(LI,J)                                               METU 336
      GO TO 300                                                         METU 337
  450 CALL HYDCAL(IDES,CHYD,KKK)                                        METU 338
      NN=NN+1                                                           METU 339
      BELEV=AELEV-SLOPE*ALEN                                            METU 340
      WRITE(R,5)                                                        METU 341
      WRITE(R,405) ITH,KP,JTH,KR,AREA,ALEN,SLOPY,AELEV,BELEV,QPIK,YPIK, METU 342
     *PHY,AN                                                            METU 343
      WRITE(R,6)                                                        METU 344
      DO 460 J=1,NNN                                                    METU 345
  460 BHYD(J)=AHYD(J)                                                   METU 346
      UPA=BELEV-DROP                                                    METU 347
      CALL ROUTE                                                        METU 348
      L=0                                                               METU 349
      N=N-1                                                             METU 350
      DO 510 K=1,N                                                      METU 351
      NK=NN                                                             METU 352
      NN=NN+1                                                           METU 353
      IF(K.EQ.N) NN=JTH                                                 METU 354
      IF(K.EQ.N) CCC=KP                                                 METU 355
      AELEV=BELEV                                                       METU 356
      BELEV=AELEV-SLOPE*ALEN                                            METU 357
      CALL DESIGN(BHYD,VMIN,VMAX,NSECA,NK ,NN)                          METU 358
      CALL TOPLAN                                                       METU 359
      CALL SIMULM                                                       METU 360
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.........1.........2.........3.........4.........5.........6.........7.........8
      TAREA=AREA*K                                                               METU 361
      WRITE(R,5)                                                                 METU 362
      WRITE(R,470) NK,CCC,NN,CCC,TAREA,AREA,ALEN,SLCFY,AELEV,BELEV,UP,           METU 363
     *DOWN,L,BIG,QFUL,Y,V,TIME,QPIK,YPIK,PHY,AN,NCHUTE                           METU 364
  470 FORMAT(1H+,2(I5,1X,A1),F8.2,F6.2,F6.1,F7.4,4F7.2,I5,2F7.1,F5.2,F6.         METU 365
     *1,I4,F6.2,F5.1,2F5.2,I4)                                                   METU 366
      WRITE(R,6)                                                                 METU 367
      IF(L.LE.LMIN) GO TO 521                                                    METU 368
      GO TO 471                                                                  METU 369
  521 ITHS(NMN)=NK                                                               METU 370
      ITHS(NMN)=NN                                                               METU 371
      NMN=NMN+1                                                                  METU 372
  471 UPA=DOWNA                                                                  METU 373
      DO 490 J=1,NNN                                                             METU 374
  490 BHYD(J)=BHYD(J)+AHYD(J)                                                    METU 375
      CALL ROUTE                                                                 METU 376
  510 CONTINUE                                                                   METU 377
      CCC=3GG                                                                    METU 378
      NN=NK                                                                      METU 379
      DO 520 J=1,IJK                                                             METU 380
      HYDA(I,J)=BHYD(J)                                                          METU 381
      HYDB(I,J)=DHYD(J)                                                          METU 382
  520 HYDC(I,J)=EHYD(J)                                                          METU 383
      JTEMP(I)=L                                                                 METU 384
      TEMPB(I)=DOWNA                                                             METU 385
      GO TO 300                                                                  METU 386
  530 IF(NMEC.NE.2) GO TO 336                                                    METU 387
      DO 540 I=1,JK                                                              METU 388
      IF(ITH.EQ.ITEMP(I)) GO TO 550                                              METU 389
  540 CONTINUE                                                                   METU 390
      GO TO 3389                                                                 METU 391
  550 DO 560 J=1,IJK                                                             METU 392
      DHYD(J)=HYDB(I,J)                                                          METU 393
      BHYD(J)=HYDA(I,J)                                                          METU 394
      EHYD(J)=HYDC(I,J)                                                          METU 395
      HYDA(I,J)=0.                                                               METU 396
      HYDB(I,J)=0.                                                               METU 397
  560 HYDC(I,J)=0.                                                               METU 398
      ITEMP(I)=-3399                                                             METU 399
      AAAA=TEMPC(I)                                                              METU 400
.........1.........2.........3.........4.........5.........6.........7.........8
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........1.........2.........3.........4.........5.........6.........7.........8
      SLOPE=(AELEV-BELEV)/ALEN                                          METU 401
      UPA=TEMPB(I)                                                      METU 402
      L=JTEMP(I)                                                        METU 403
      JTEMP(I)=0                                                        METU 404
      LOGIC(I)=0                                                        METU 405
      ITEMP(I)=-9999                                                    METU 406
      TEMPC(I)=0.                                                       METU 407
      CALL HYDCAL(1,AHYD,NNN)                                           METU 408
      IF(YMAX.LT.YPIK.OR.QMAX.LT.QPIK) GO TO 570                        METU 409
      CALL DESIGN(BHYD,VMIN,VMAX,NSECA,ITH,JTH)                         METU 410
      WRITE(R,5)                                                        METU 411
      WRITE(R,470) ITH,KP,JTH,KR, AAAA,AREA,ALEN,SLOPE,AELEV,BELEV,UP,  METU 412
     *DOWN,L,BIG,QFUL,Y,V,TIME,QPIK,YPIK,PHY,AN,NCHUTE                  METU 413
      WRITE(R,6)                                                        METU 414
      IF(L.LE.LMIN) GO TO 611                                           METU 415
  564 CALL TOPLAN                                                       METU 416
      CALL SIMLIN                                                       METU 417
      CALL HYDCAL(IDES,CHYD,KKK)                                        METU 418
      CALL ROUTE                                                        METU 419
  565 LT=I                                                              METU 420
      DO 561 I=1,JK                                                     METU 421
      IF(JTH.EQ.ITEMP(I)) GO TO 562                                     METU 422
  561 CONTINUE                                                          METU 423
      I=LT                                                              METU 424
      DO 610 J=1,IJK                                                    METU 425
      HYDA(I,J)=BHYD(J)                                                 METU 426
      HYDB(I,J)=DHYD(J)                                                 METU 427
      HYDC(I,J)=EHYD(J)                                                 METU 428
      HYD(I,J)=DHYD(J)+EHYD(J)                                          METU 429
      BHYD(J)=0.                                                        METU 430
      DHYD(J)=0.                                                        METU 431
  610 EHYD(J)=0.                                                        METU 432
      ITEMP(I)=JTH                                                      METU 433
      JTEMP(I)=L                                                        METU 434
      TEMPB(I)=DOWNA                                                    METU 435
      TEMPC(I)=AAAA+AREA                                                METU 436
      LOGIC(I)=1                                                        METU 437
      GO TO 300                                                         METU 438
  611 ITHS(NMN)=ITH                                                     METU 439
      JTHS(NMN)=JTH                                                     METU 440
........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
      NMN=NMN+1                                                           METU 441
      GO TO 564                                                           METU 442
  562 DO 600 J=1,IJK                                                      METU 443
      HYDA(I,J)=HYDA(I,J)+BHYD(J)                                         METU 444
      HYDB(I,J)=HYDB(I,J)+CHYD(J)                                         METU 445
      HYDC(I,J)=EHYD(J)+HYDC(I,J)                                         METU 446
      AHYD(J)=0.                                                          METU 447
      BHYD(J)=0.                                                          METU 448
      CHYD(J)=0.                                                          METU 449
      DHYD(J)=0.                                                          METU 450
  600 EHYD(J)=0.                                                          METU 451
      TEMPC(I)=AAAA+TEMPC(I)+AREA                                         METU 452
      IF(JTEMP(I).LT.L) JTEMP(I)=L                                        METU 453
      GO TO 300                                                           METU 454
  570 CALL RATIO                                                          METU 455
  575 N=N+1                                                               METU 456
      ALEN=ALEN/N                                                         METU 457
      AREA=AREA/N                                                         METU 458
      CALL HYDCAL(1,AHYD,NNN)                                             METU 459
      IF(YMAX.GT.YPIK.AND.QMAX.GT.QPIK) GO TO 580                         METU 460
      ALEN=ALEN*N                                                         METU 461
      AREA=AREA*N                                                         METU 462
      GO TO 575                                                           METU 463
  580 BELEV=AELEV-SLOPE*ALEN                                              METU 464
      NK=ITH                                                              METU 465
      DO 530 K=1,N                                                        METU 466
      TAREA=AREA*(K-1)*AAAA                                               METU 467
      NN=NN+1                                                             METU 468
      IF(K.EQ.N) NN=JTH                                                   METU 469
      CALL DESIGN(BHYD,VMIN,VMAX,NSECA,NK ,NN)                            METU 470
      WRITE(R,5)                                                          METU 471
      WRITE(R,470) NK,CCC,NN,CCC,TAREA,AREA,ALEN,SLOPY,AELEV,BELEV,UP,    METU 472
     *DOWN,L,BIG,QFUL,Y,V,TIME,QPIK,YPIK,PHY,AN,NCHUTE                    METU 473
      WRITE(R,6)                                                          METU 474
      IF(L.LE.LMIN) GO TO 591                                             METU 475
      GO TO 531                                                           METU 476
  591 ITHS(NMN)=NK                                                        METU 477
      JTHS(NMN)=NN                                                        METU 478
      NMN=NMN+1                                                           METU 479
  531 AELEV=BELEV                                                         METU 480
.........1.........2.........3.........4.........5.........6.........7.........8
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........1.........2.........3.........4.........5.........6.........7.........8
      BELEV=AELEV-SLOPE*ALEN                                            METU 481
      UPA=DOWNA                                                         METU 482
      NK=NN                                                             METU 483
      DO 551 J=1,NNN                                                    METU 484
  551 BHYD(J)=BHYD(J)+AHYD(J)                                           METU 485
      CALL TOPLAN                                                       METU 486
      CALL SIMULN                                                       METU 487
      CALL HYDCAL(IDES,CHYD,KKK)                                        METU 488
      CALL ROUTE                                                        METU 489
  590 CONTINUE                                                          METU 490
      AREA=AREA*N                                                       METU 491
      GO TO 565                                                         METU 492
  800 DO 810 I=1,JK                                                     METU 493
      IF(ITEMP(I).EQ.ITH) GO TO 820                                     METU 494
  810 CONTINUE                                                          METU 495
      GO TO 8389                                                        METU 496
  820 DO 830 J=1,JK                                                     METU 497
      IF(ITEMP(J).EQ.JTH) GO TO 840                                     METU 498
  830 CONTINUE                                                          METU 499
      GO TO 850                                                         METU 500
  840 DO 860 K=1,IJK                                                    METU 501
      HYDA(J,K)=HYDA(I,K)+HYDA(J,K)                                     METU 502
      HYDB(J,K)=HYDB(I,K)+HYDB(J,K)                                     METU 503
      HYDC(J,K)=HYDC(I,K)+HYDC(J,K)                                     METU 504
      HYDA(I,K)=0.                                                      METU 505
      HYDB(I,K)=0.                                                      METU 506
  860 HYDC(I,K)=0.                                                      METU 507
      LOGIC(I)=0                                                        METU 508
      ITEMP(I)=-9999                                                    METU 509
      TEMPC(J)=TEMPC(J)+TEMPC(I)                                        METU 510
      JTEMP(I)=0                                                        METU 511
      TEMPB(I)=0                                                        METU 512
      TEMPC(I)=0                                                        METU 513
      GO TO 851                                                         METU 514
  850 ITEMP(I)=JTH                                                      METU 515
  851 WRITE(R,5)                                                        METU 516
      WRITE(R,2) ITH,KF,JTH,KR                                          METU 517
    2 FORMAT(1H+,2(I5,1X,A1))                                           METU 518
      WRITE(R,6)                                                        METU 519
      GO TO 300                                                         METU 520
........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
  900 DO 910 I=1,JK                                                     METU 521
      IF(ITH.EQ.ITEMP(I)) GO TO 920                                     METU 522
  910 CONTINUE                                                          METU 523
      GO TO 8889                                                        METU 524
  920 DO 930 J=1,IJK                                                    METU 525
      BHYD(J)=HYDA(I,J)                                                 METU 526
      DHYD(J)=HYDB(I,J)                                                 METU 527
      EHYD(J)=HYDC(I,J)                                                 METU 528
      HYDA(I,J)=0.                                                      METU 529
      HYDB(I,J)=0.                                                      METU 530
  930 HYDC(I,J)=0.                                                      METU 531
      ITEMP(I)=-9999                                                    METU 532
      LOGIC(I)=0                                                        METU 533
      AAAA=TEMPC(I)                                                     METU 534
      SLOPE=(AELEV-BELEV)/ALEN                                          METU 535
      LPA=TEMPB(I)                                                      METU 536
      L=JTEMP(I)                                                        METU 537
      JTEMP(I)=0                                                        METU 538
      IF(LP.NE.0) WRITE(R,9) ITH,(BHYD(J),J=1,IJK)                      METU 539
      IF(LP.NE.0) WRITE(R,6)                                            METU 540
      CALL DESIGN(BHYD,VMIN,VMAX,NSECA,ITH,JTH)                         METU 541
      WRITE(R,5)                                                        METU 542
      WRITE(R,1) ITH,KP,JTH,KR,AAAA,ALEN,AELEV,BELEV,LP,DOWN,L,BIG,QFUL,METU 543
     *Y,V,TIME,NCHUTE                                                   METU 544
    1 FORMAT(1H+,2(I5,1X,A1),F8.2,6X,F6.1,7X,4F7.2,I5,2F7.1,F5.2,F6.1,I4METU 545
     *,21X,I4)                                                          METU 546
      WRITE(R,6)                                                        METU 547
      IF(L.LE.LMIN) GO TO 946                                           METU 548
  931 CALL TOPLAM                                                       METU 549
      CALL SIMULM                                                       METU 550
      IF(NODI.NE.0.AND.NODJ.NE.0) GO TO 990                             METU 551
      IF(NODI.EQ.0.AND.NODJ.NE.0) GO TO 1005                            METU 552
      IF(NODI.NE.0.AND.NODJ.EQ.0) GO TO 1007                            METU 553
  935 DO 940 K=1,JK                                                     METU 554
      IF(JTH.EQ.ITEMP(K)) GO TO 970                                     METU 555
  940 CONTINUE                                                          METU 556
      DO 941 I=1,JK                                                     METU 557
      IF(LOGIC(I).EQ.0)GOTO 942                                         METU 558
  941 CONTINUE                                                          METU 559
      GOTO 8888                                                         METU 560
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
  942 ITEMP(I)=JTH                                                      METU 561
      JTEMP(I)=L                                                        METU 562
      TEMPB(I)=DOWNA                                                    METU 563
      TEMPC(I)=AAAA+AREA                                                METU 564
      LOGIC(I)=1                                                        METU 565
      DO 945 J=1,IJK                                                    METU 566
      HYDA(I,J)=BHYD(J)                                                 METU 567
      HYDC(I,J)=EHYD(J)                                                 METU 568
      BHYD(J)=0.                                                        METU 569
  945 EHYD(J)=0.                                                        METU 570
      IF(KR.EQ.EEE) GO TO 950                                           METU 571
      GO TO 300                                                         METU 572
  946 ITHS(NMN)=ITH                                                     METU 573
      JTHS(NMN)=JTH                                                     METU 574
      NMN=NMN+1                                                         METU 575
      GO TO 931                                                         METU 576
  950 JTEMP(I)=0                                                        METU 577
      DO 960 J=1,IJK                                                    METU 578
  960 HYD(I,J)=EHYD(J)                                                  METU 579
      GO TO 300                                                         METU 580
  970 DO 980 J=1,IJK                                                    METU 581
      HYDA(K,J)=HYDA(K,J)+BHYD(J)                                       METU 582
  980 HYDC(K,J)=HYDC(K,J)+EHYD(J)                                       METU 583
      TEMPC(K)=AAAA+TEMPC(K)+AREA                                       METU 584
      IF(TEMPB(K).GT.DOWNA) TEMPB(K)=DOWNA                              METU 585
      IF(JTEMP(K).LT.L) JTEMP(K)=L                                      METU 586
      IF(KR.EQ.EEE) GO TO 985                                           METU 587
      GO TO 300                                                         METU 588
  985 JTEMP(K)=0                                                        METU 589
      DO 986 J=1,IJK                                                    METU 590
  986 HYD(K,J)=HYD(K,J)+EHYD(J)                                         METU 591
      GO TO 300                                                         METU 592
  990 DO 1000 M=1,JK                                                    METU 593
      IF(LOGIC(M).EQ.0) GO TO 1001                                      METU 594
 1000 CONTINUE                                                          METU 595
      GO TO 8388                                                        METU 596
 1001 LOGIC(M)=1                                                        METU 597
      DO 1002 MM=1,JK                                                   METU 598
      IF(LOGIC(MM).EQ.0) GO TO 1003                                     METU 599
 1002 CONTINUE                                                          METU 600
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      GO TO 8388                                                                 METU 601
 1003 DO 1004 J=1,IJK                                                            METU 602
      HYDB(M,J)=CHYD(J)/2.                                                       METU 603
      HYDB(MM,J)=CHYD(J)/2.                                                      METU 604
 1004 DHYD(J)=C.                                                                 METU 605
      ITEMP(M)=NODI                                                              METU 606
      ITEMP(MM)=NODJ                                                             METU 607
      LOGIC(MM)=1                                                                METU 608
      GO TO 935                                                                  METU 609
 1005 DO 1006 M=1,JK                                                             METU 610
      IF(LOGIC(M).EQ.0) GO TO 1090                                               METU 611
 1006 CONTINUE                                                                   METU 612
      GO TO 8388                                                                 METU 613
 1007 DO 1008 M=1,JK                                                             METU 614
      IF(LOGIC(M).EQ.0) GO TO 1095                                               METU 615
 1008 CONTINUE                                                                   METU 616
      GO TO 8389                                                                 METU 617
 1090 ITEMP(M)=NODJ                                                              METU 618
      GO TO 1100                                                                 METU 619
 1095 ITEMP(M)=NODI                                                              METU 620
 1100 DO 1105 J=1,IJK                                                            METU 621
      HYDB(M,J)=CHYD(J)                                                          METU 622
 1105 DHYD(J)=C.                                                                 METU 623
      LOGIC(M)=1                                                                 METU 624
      GO TO 935                                                                  METU 625
 1200 DO 1210 I=1,JK                                                             METU 626
      IF(LOGIC(I).EQ.0) GO TO 1220                                               METU 627
 1210 CONTINUE                                                                   METU 628
      GO TO 8388                                                                 METU 629
 1220 READ(P,1230) (HYD(I,J),J=1,NODJ)                                           METU 630
 1230 FORMAT(8F10.0)                                                             METU 631
      TEMPC(I)=AREA                                                              METU 632
      ITEMP(I)=JTH                                                               METU 633
      LOGIC(I)=1                                                                 METU 634
      IF(LP  .EQ.0) GO TO 851                                                    METU 635
      WRITE(R,9) JTH,(HYD(I,J),J=1,NODJ)                                         METU 636
    9 FORMAT(//10X,'INFLOW HYDROGRAPH AT NODE',I5,' IN LT/SEC'//(5X,15F8         METU 637
     *.1))                                                                       METU 638
      WRITE(R,6)                                                                 METU 639
      GO TO 951                                                                  METU 640
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........1.........2.........3.........4.........5.........6.........7.........8
 2000 DO 2010 I=1,JK                                                    METU 641
      IF(ITH.EQ.ITEMF(I)) GO TO 2020                                    METU 642
 2010 CONTINUE                                                          METU 643
      GO TO 9389                                                        METU 644
 2020 DO 2030 J=1,IJK                                                   METU 645
      FHYD(J)=HYD(I,J)                                                  METU 646
 2030 HYD(I,J)=0.                                                       METU 647
      UPA=AELEV-DROP                                                    METU 648
      AAAA=TEMPC(I)                                                     METU 649
      L=KTEMP(I)                                                        METU 650
      ITEMP(I)=-9999                                                    METU 651
      TEMPC(I)=0.                                                       METU 652
      LOGIC(I)=0                                                        METU 653
      IF(LP  .NE.0) WRITE(R,9) ITH,(FHYD(J),J=1,IJK)                    METU 654
      IF(LP  .NE.0) WRITE(R,6)                                          METU 655
      CALL DESIGN(FHYD,0.,VMAXB,NSECB,ITH,JTH)                          METU 656
      WRITE(R,5)                                                        METU 657
      WRITE(R,1) ITH,KF,JTH,KR,AAAA,ALEN,AELEV,BELEV,UP,DOWN,L,BIG,QFUL,METU 658
     *Y,V,TIME,NCHUTE                                                   METU 659
      WRITE(R,6)                                                        METU 660
      DO 2040 I=1,JK                                                    METU 661
      IF(JTH.EQ.ITEMF(I)) GO TO 2080                                    METU 662
 2040 CONTINUE                                                          METU 663
      DO 2050 I=1,JK                                                    METU 664
      IF(LOGIC(I).EQ.0) GO TO 2060                                      METU 665
 2050 CONTINUE                                                          METU 666
 2060 ITEMP(I)=JTH                                                      METU 667
      KTEMP(I)=L                                                        METU 668
      TEMPC(I)=AAAA+AREA                                                METU 669
      TEMPA(I)=BELEV                                                    METU 670
      LOGIC(I)=1                                                        METU 671
      DO 2070 J=1,IJK                                                   METU 672
 2070 HYD(I,J)=FHYD(J)                                                  METU 673
      GO TO 300                                                         METU 674
 2080 DO 2090 J=1,IJK                                                   METU 675
 2090 HYD(I,J)=HYD(I,J)+FHYD(J)                                         METU 676
      TEMPC(I)=AAAA+TEMPC(I)+AREA                                       METU 677
      GO TO 300                                                         METU 678
 9888 WRITE(R,9890)                                                     METU 679
 9890 FORMAT(///1X,130('*')/10X,'ERROR : INSUFFICIENT DIMENSION OF ARRAY METU 680
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     * LOGIC')                                                          METU 681
      GO TO 9999                                                        METU 682
 8889 WRITE(R,8891) ITH                                                 METU 683
 8891 FORMAT(///1X,130('*')/10X,'ERROR : UPSTREAM NODE',I5,' CAN NOT BE  METU 684
     *FOUND IN ARRAYS')                                                 METU 685
 9999 NMN=NMN-1                                                         METU 686
      IF(NMN.GT.0) WRITE(R,8) (ITHS(I),JTHS(I),I=1,NMN)                 METU 687
    8 FORMAT(////,10X,'SEWERS BETWEEN THE FOLLOWING NODES HAVE SMALL SECMETU 688
     %TIONS THEN THE SPECIFIED.'/ 10X,'A NEW RUN MAY BE NECESSARY BY  REMETU 689
     *MOVING CORRESPONDING INLETS'//10X,'NODES: FROM     TO'/(17X,I4,2X,METU 690
     <I4))                                                              METU 691
      WRITE(R,5555)                                                     METU 692
 5555 FORMAT(//10X,'POINT(S) OF DISPOSAL :'//)                          METU 693
      DO 5557 I=1,JK                                                    METU 694
      IF(ITEMP(I).GT.0) WRITE(R,5556) ITEMP(I)                          METU 695
 5556 FORMAT(25X,I5)                                                    METU 696
 5557 CONTINUE                                                          METU 697
      STOP                                                              METU 698
C-----END OF THE MAIN PROGRAM                                            METU 699
      END                                                               METU 700
C-----------------------------------------------------------------------METU 701
C                                                                       METU 702
C-----SUBPROGRAM TCPLAN DETERMINES THE DISCHARGE INTERCEPTED            METU 703
C-----AND THE CARRY-OVER FROM AN INLET                                  METU 704
C                                                                       METU 705
      SUBROUTINE TCPLAN                                                 METU 706
      COMMON/LAMDA/QFUL,P,R                                             METU 707
      COMMON/SIGMA/IJK                                                  METU 708
      COMMON/TAU/DHYD(250)                                              METU 709
      COMMON/RHO/EHYD(250)                                              METU 710
      DO 1000 J=1,IJK                                                   METU 711
      DHYD(J)=DHYD(J)+EHYD(J)-QFUL                                      METU 712
      IF(DHYD(J).LT.0.) GO TO 2000                                      METU 713
      EHYD(J)=QFUL                                                      METU 714
      GO TO 1000                                                        METU 715
 2000 EHYD(J)=DHYD(J)+QFUL                                              METU 716
      DHYD(J)=0.                                                        METU 717
 1000 CONTINUE                                                          METU 718
      RETURN                                                            METU 719
      END                                                               METU 720
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C-----END OF THE SUBPROGRAM ICFLAM                                              METU 721
C-------------------------------------------------------------------            METU 722
C                                                                               METU 723
C-----SUBPROGRAM HYDCAL DETERMINES THE INLET HYDROGRAPHS FOR SMALL              METU 724
C     RETURN PERIODS,AND SURFACE HYDROGRAPHS FOR LARGE RETURN PERIODS           METU 725
      SUBROUTINE HYDCAL(IDES,AHYD,NNN)                                          METU 726
      DIMENSION AHYD(250)                                                       METU 727
      COMMON/GAMA/ALEN,DELT                                                     METU 728
      COMMON/CHY/ALENY,SLOPY,PHY,AN,TDA,TDB,AINTA,AINTB,AREA                    METU 729
      COMMON/BETA/GLTRZ,Z,SLOPE                                                 METU 730
      COMMON/ALFA/QPIK,YPIK                                                     METU 731
      COMMON/SIGMA/IJK                                                          METU 732
      TC=6.92/AINTA**0.4*((AN*ALENY)**2./SLOPY)**0.3                            METU 733
      IF(IDES.NE.1) GO TO 2100                                                  METU 734
      QP=AREA*(AINTA-PHY)/360                                                   METU 735
      QS=QP                                                                     METU 736
      TD=TDA                                                                    METU 737
      I=1                                                                       METU 738
 2010 Q=QP                                                                      METU 739
      I=I+1                                                                     METU 740
      Y=(Q/SQRT(SLOPE))**0.375*GLTRZ                                            METU 741
      A=0.5*Z*Y**2.                                                             METU 742
      VH=Q/A                                                                    METU 743
      TH=ALEN/VH/60                                                             METU 744
      TA=TC+TH                                                                  METU 745
      IF(TD.GE.TA) GO TO 2040                                                   METU 746
      QP=TD/TA*QS                                                               METU 747
      IF(I.EQ.2) GO TO 2010                                                     METU 748
 2015 QP=QP*1000                                                                METU 749
      Q2=QP/(2*TA-TD)*DELT                                                      METU 750
      Q1=QP/TD*DELT                                                             METU 751
      NN=TD/DELT+0.5                                                            METU 752
      NNN=2*TA/DELT                                                             METU 753
      IF(NNN.GT.IJK) NNN=IJK                                                    METU 754
      DO 2020 I=1,NN                                                            METU 755
 2020 AHYD(I)=Q1*I                                                              METU 756
      NN=NN+1                                                                   METU 757
      DO 2030 I=NN,NNN                                                          METU 758
 2030 AHYD(I)=QP-Q2*(I-NN+1)                                                    METU 759
      GO TO 2070                                                                METU 760
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.........1.........2.........3.........4.........5.........6.........7.........8
 2040 N=TD/DELT+1.01                                                    METU 761
      NN=TA/DELT                                                        METU 762
      NNN=N+NN                                                          METU 763
      IF(NNN.GT.IJK) NNN=IJK                                            METU 764
      QP=QP*1000                                                        METU 765
      Q=QP/TA*DELT                                                      METU 766
      DO 2050 I=1,NN                                                    METU 767
      AHYD(I)=Q*I                                                       METU 768
 2050 AHYD(NNN-I)=AHYD(I)                                               METU 769
      NN=NN+1                                                           METU 770
      N=NNN-NN                                                          METU 771
      DO 2060 I=NN,N                                                    METU 772
 2060 AHYD(I)=QP                                                        METU 773
 2070 IF(IDES.NE.1) RETURN                                              METU 774
       QPIK=QP                                                          METU 775
      YPIK=(QP/1000/SQRT(SLOPE))**0.375*GUTRZ*100                       METU 776
      RETURN                                                            METU 777
 2100 TD=TDB                                                            METU 778
      TA=6.92/AINTB**0.4*((AN*ALENY)**2./SLOPY)**0.3                    METU 779
      QP=AREA/IDES*(AINTB-PHY)/360                                      METU 780
      IF(TD.GE.TA) GO TO 2040                                           METU 781
      QP=QP*TD/TA                                                       METU 782
      GO TO 2015                                                        METU 783
      END                                                               METU 784
C-----END OF THE SUBPROGRAM HYDCAL                                       METU 785
C-----------------------------------------------------------------------METU 786
C-----SUBPROGRAM RATIO DETERMINES THE REQUIRED NUMBER OF INLETS BETWEEN  METU 787
C     TWO NODES  TO KEEP GUTTER DISCHARGE AND FLOW DEPTH BELOW          METU 788
C     THE SPECIFIED LIMITS                                              METU 789
      SUBROUTINE RATIO                                                  METU 790
      COMMON/ALFA/QPIK,YPIK                                             METU 791
      COMMON/CRA/QMAX,YMAX,N                                            METU 792
      RATA=(YMAX/YPIK)**(5./3)                                          METU 793
      RATB=QMAX/QPIK                                                    METU 794
      IF(RATA.GT.RATB) RATA=RATB                                        METU 795
      N=1/RATA                                                          METU 796
      RETURN                                                            METU 797
      END                                                               METU 798
C-----END OF THE SUBPROGRAM RATIO                                        METU 799
C-----------------------------------------------------------------------METU 800

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C-----SUBPROGRAM ROUTE ROUTES THE GUTTER HYDROGRAPH ICES TIMES BY         METU 801
C     ADDING HYDROGRAPH OF LARGE RETURN PERIOD EACH TIME                  METU 802
      SUBROUTINE ROUTE                                                    METU 803
      DIMENSION CHYD(250)                                                 METU 804
      COMMON/CRC/ICES,NNN,CHYD                                            METU 805
      COMMON/TAU/DHYD(250)                                                METU 806
      COMMON/BETA/GUTRZ,Z,SLOPE                                           METU 807
      COMMON/SIGMA/IJK                                                    METU 808
      COMMON/GAMA/ALEN,DELT                                               METU 809
      DO 480 M=1,ICES                                                     METU 810
      DO 470 J=1,NNN                                                      METU 811
  470 DHYD(J)=DHYD(J)+CHYD(J)                                             METU 812
      Q=DHYD(1)                                                           METU 813
      DO 1000 I=2,IJK                                                     METU 814
      IF(DHYD(I).GT.Q) Q=DHYD(I)                                          METU 815
 1000 CONTINUE                                                            METU 816
      Y=(Q/1000/SQRT(SLOPE))**0.375*GUTRZ                                 METU 817
      A=0.5*Z*Y**2.                                                       METU 818
      V=Q/1000./A*60.                                                     METU 819
      IT=ALEN/ICES/V/DELT+1                                               METU 820
      K=IJK-IT                                                            METU 821
      IF(K.LT.1) K=1                                                      METU 822
      DO 2000 I=1,K                                                       METU 823
 2000 DHYD(IJK-I+1)=DHYD(K-I+1)                                           METU 824
      DO 2010 I=1,IT                                                      METU 825
 2010 DHYD(I)=0.                                                          METU 826
  480 CONTINUE                                                            METU 827
      RETURN                                                              METU 828
      END                                                                 METU 829
C-----END OF THE SUBPROGRAM ROUTE                                          METU 830
C-------------------------------------------------------------------       METU 831
C-----SUBPROGRAM DESIGN DETERMINES THE SECTIONSOF SEWERS AND COLLECTORS    METU 832
C     ACCORDING TO THE PEAK DISCHARGES OF HYDROGRAPHS.SUBPROGRAM ALSO      METU 833
C     ROUTES THE HYDROGRAPHS OF SEWERS FOR SMALL RETURN PERIOD  AND OF     METU 834
C     COLLECTORS FOR LARGE RETURN PERIOD                                   METU 835
      SUBROUTINE DESIGN(BHYD,VMIN,VMAX,NSEC,III,JJJ)                       METU 836
      INTEGER F,R,TIME                                                     METU 837
      DIMENSION CHYD(250)                                                  METU 838
      DIMENSION BHYD(250)                                                  METU 839
      COMMON/TETA/LPA,DOWNA,PIPEN,CANALN,L,TYPEA(4,20),IJKL,IROUTE,ISTEP   METU 840

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.........1.........2.........3.........4.........5.........6.........7.........8
      COMMON/CDE/TYPEB(20),TYPEC(5,20),AELEV,BELEV,DFCP,NPIPE,NCANAL,    METU 841
     *NTRAP,TRAPN,TIME,BIG,Y,NART,NCHUTE,UP,DOWN,V                       METU 842
      COMMON/LAMDA/QF,P,R                                                METU 843
      COMMON/SIGMA/IJK                                                   METU 844
      COMMON/GAMA/ALEN,DELT                                              METU 845
C                                                                        METU 846
      NCHUTE=0                                                           METU 847
      II=0                                                               METU 848
      QC=0.                                                              METU 849
      ARA=DELT*30/ALEN                                                   METU 850
      BIG=BHYD(1)                                                        METU 851
      KK=1                                                               METU 852
      DO 1000 I=2,IJK                                                    METU 853
      IF(BHYD(I).GT.BIG) KK=I                                            METU 854
      BIG=BHYD(KK)                                                       METU 855
 1000 CONTINUE                                                           METU 856
      BIG=BIG/1000.                                                      METU 857
      TIME=KK*DELT                                                       METU 858
      SLOPE=(UPA-BELEV+DFCP)/ALEN                                        METU 859
      IF(NSEC.EQ.1) GO TO 1130                                           METU 860
      IF(NSEC.EQ.2) GO TO 3000                                           METU 861
      D=1.548*(PIPEN*BIG/SLOPE**0.5)**0.375 *1000.                       METU 862
 1010 DO 1020 I=1,NPIPE                                                  METU 863
      IF(D.LE.TYPEB(I))GO TO 1060                                        METU 864
 1020 CONTINUE                                                           METU 865
 1030 WRITE(R,1040) III,JJ                                               METU 866
 1040 FORMAT(///1X,130('*')/10X,'ERROR : STANDARD DIAMETERS ARE NOT BIG  METU 867
     *ENOUGH TO DESIGN THE SEWER BETWEEN THE NODES',I5,'TH AND',I5,'TH') METU 868
      WRITE(R,1) BIG,SLOPE,D,V                                           METU 869
    1 FORMAT(4F10.4)                                                     METU 870
      STOP                                                               METU 871
 1050 IF((I+II).GT.NPIPE) GO TO 1030                                     METU 872
 1060 D=TYPEB(I+II)                                                      METU 873
      IF(L.GT.D) D=L                                                     METU 874
 1080 AF=3.141593*(D/1000)**2/4                                          METU 875
 1090 QF=AF*(D/4000)**(2./3)*SQRT(SLOPE)/PIPEN                           METU 876
      QR=BIG/QF                                                          METU 877
      DR=0.67333*QR+0.227778                                             METU 878
      TH=2*ARCOS(1-2.*DR)                                                METU 879
      AR=(TH-SIN(TH))/6.283185                                           METU 880
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      V=BIG/AR/AF                                                       METU 881
      II=II+1                                                           METU 882
      IF(V.GT.VMAX.AND.II.LE.NART) GO TO 1050                           METU 883
      IF(V.GT.VMAX) GO TO 2100                                          METU 884
      BIG=BIG*1000.                                                     METU 885
      Y=D*DR/1000                                                       METU 886
      DOWNA=BELEV-DROP                                                  METU 887
      DOWN=DOWNA-D/1000.                                                METU 888
      UP=UPA-D/1000.                                                    METU 889
      L=0                                                               METU 890
      IF(IROUTE.NE.0) GO TO 2020                                        METU 891
      GO TO 1990                                                        METU 892
 1130 AR=BIG*CANALN/SQRT(SLOPE)                                         METU 893
      DO 1140 I=1,NCANAL                                                METU 894
      IF(AR.LT.TYPEA(2,I)) GO TO 1150                                   METU 895
 1140 CONTINUE                                                          METU 896
      GOTO 1030                                                         METU 897
 1150 IF(L.LE.NCANAL.AND.L.GT.I) I=L                                    METU 898
 1160 M=I+II                                                            METU 899
      IF(M.GT.NCANAL) GO TO 1030                                        METU 900
 1165 QF=TYPEA(2,M)*SQRT(SLOPE)/CANALN                                  METU 901
      B=TYPEA(1,M)                                                      METU 902
      CALL YNORM(YN,BIG,CANALN,SLOPE,B,0.)                              METU 903
      Y=YN                                                              METU 904
      A=Y*B                                                             METU 905
      II=II+1                                                           METU 906
      IF(V.GT.VMAX.AND.II.LE.NART) GO TO 1160                           METU 907
      V=BIG/A                                                           METU 908
      IF(V.GT.VMAX) GO TO 2200                                          METU 909
      BIG=BIG*1000.                                                     METU 910
      DOWNA=BELEV-DROP                                                  METU 911
      DOWN=DOWNA-TYPEA(3,M)                                             METU 912
      UP=UPA-TYPEA(3,M)                                                 METU 913
      L=M                                                               METU 914
      IF(IROUTE.NE.0) GO TO 7030                                        METU 915
 1990 IT=ALEN/V/DELT/60+1                                               METU 916
      K=IJK-IT                                                          METU 917
      IF(K.LT.1) K=1                                                    METU 918
      DO 2000 M=1,K                                                     METU 919
 2000 BHYD(IJK-M+1)=BHYD(K-M+1)                                         METU 920
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      DO 2010 M=1,IT                                                    METU 921
 2010 BHYD(M)=0.                                                        METU 922
 2015 QF=QF*1000                                                        METU 923
      RETURN                                                            METU 924
 2020 A=0.                                                              METU 925
      DO 2023 J=1,IJKL                                                  METU 926
      IF(BHYD(J).EQ.0.0.AND.BHYD(J+1).EQ.0.0.AND.GC.LT.0.0001)GO TO 5145METU 927
      XX=(BHYD(J+1)-BHYD(J))/ISTEP/2000                                 METU 928
      YY=BHYD(J)/1000.                                                  METU 929
      DO 20 I=1,ISTEP                                                   METU 930
      DELTAP=ARA/ISTEP*(YY+XX-GC)                                       METU 931
      AP=A+DELTAP                                                       METU 932
      IF(AP.LT.0.) AP=0.                                                METU 933
      AR=AP/AF                                                          METU 934
      QR=1.037725*AR**1.388456                                          METU 935
      IF(AR.GT.0.26)QR=1.075165*AR**1.418482                            METU 936
      QCB=QF*QR                                                         METU 937
      DELTA=ARA/ISTEP*2*(YY+XX-QCB)                                     METU 938
      A=A+DELTA                                                         METU 939
      IF(A.LT.0.) A=0.                                                  METU 940
      AR=A/AF                                                           METU 941
      QR=1.037725*AR**1.388456                                          METU 942
      IF(AR.GT.0.26)QR=1.075165*AR**1.418482                            METU 943
      GC=QR*QF                                                          METU 944
      YY=YY+2*XX                                                        METU 945
   20 CONTINUE                                                          METU 946
      GHYD(J+1)=GC*1000                                                 METU 947
      GO TO 2023                                                        METU 948
 5145 GHYD(J+1)=0.                                                      METU 949
 2023 CONTINUE                                                          METU 950
 5150 GHYD(1)=0.                                                        METU 951
      DO 5160 J=1,IJK                                                   METU 952
 5160 BHYD(J)=GHYD(J)                                                   METU 953
      GO TO 2015                                                        METU 954
 2100 WA=BIC/VMAX                                                       METU 955
      D=1128.379*SQRT(WA)                                               METU 956
      DO 2110 K=1,NPIPE                                                 METU 957
      IF(D.LE.TYPER(I)) GO TO 2160                                      METU 958
 2110 CONTINUE                                                          METU 959
      GO TO 1030                                                        METU 960
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 2160 DD=D/2000                                                         METU 961
      ASLOPE=(BIG*PIPEN/DD**(8./3.)) **2*0.2553134                      METU 962
      NCHUTE=ALEN*(SLOPE-ASLOPE)*100.                                   METU 963
      SLOPE=ASLOPE                                                      METU 964
      GO TO 1080                                                        METU 965
 2200 WA=BIG/VMAX                                                       METU 966
      DO 2210 K=1,NCANAL                                                METU 967
      IF(WA.LE.TYPEA(4,I)) GO TO 2260                                   METU 968
 2210 CONTINUE                                                          METU 969
      GO TO 1030                                                        METU 970
 2260 ASLOPE=(BIG*CANALN/TYPEA(2,I))**2.                                METU 971
      NCHUTE=ALEN*(SLOPE-ASLOPE)*100.                                   METU 972
      SLOPE=ASLOPE                                                      METU 973
      GO TO 1165                                                        METU 974
 3000 AR=BIG*TRAPN/SQRT(SLOPE)                                          METU 975
      DO 3140 I=1,NTRAP                                                 METU 976
      IF(AR.LT.TYPEC(4,I)) GO TO 3160                                   METU 977
 3140 CONTINUE                                                          METU 978
      GO TO 1030                                                        METU 979
 3160 M=I+II                                                            METU 980
      IF(M.GT.NTRAP) GO TO 1030                                         METU 981
 3165 QF=TYPEC(4,M)*SQRT(SLOPE)/TRAPN                                   METU 982
      B=TYPEC(1,I)                                                      METU 983
      Z=TYPEC(2,I)                                                      METU 984
      CALL YNORM(YN,BIG,TRAPN,SLOPE,B,Z)                                METU 985
      Y=YN                                                              METU 986
      A=(TYPEC(1,I)+TYPEC(2,I)*Y)*Y                                     METU 987
      V=BIG/A                                                           METU 988
      II=II+1                                                           METU 989
      IF(V.GT.VMAX.AND.II.LE.NART) GO TO 1160                           METU 990
      IF(V.GT.VMAX) GO TO 4000                                          METU 991
      BIG=BIG*1000                                                      METU 992
      DOWNA=BELEV-DROP                                                  METU 993
      DOWN=DOWNA-TYPEC(3,M)                                             METU 994
      L=M                                                               METU 995
      IF(IROUTE.NE.0) GO TO 8130                                        METU 996
      GO TO 1950                                                        METU 997
 4000 WA=BIG/VMAX                                                       METU 998
      DO 4010 I=M,NTRAP                                                 METU 999
      IF(WA.LE.TYPEC(5,I)) GO TO 4020                                   METU1000
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
 4010 CONTINUE                                                          METU1001
      GO TO 1030                                                        METU1002
 4020 ASLOPE=(BIG*TRAPN/TYPEC(4,I))**2                                  METU1003
      NCHUTE=ALEN*(SLOPE-ASLOPE)*100.                                   METU1004
      SLOPE=ASLOPE                                                      METU1005
      N=I                                                               METU1006
      GO TO 3165                                                        METU1007
 7030 A=0.                                                              METU1008
      DO 7160 J=1,IJKL                                                  METU1009
      IF(BHYD(J).EQ.0.0.AND.BHYD(J+1).EQ.0.0.AND.QC.LT.0.0001)GO TO 7140METU1010
      XX=(BHYD(J+1)-BHYD(J))/ISTEP/2000                                 METU1011
      YY=BHYD(J)/1000                                                   METU1012
      DO 21 I=1,ISTEP                                                   METU1013
      DELTAP=ARA/ISTEP*(YY+XX-QC)                                       METU1014
      AP=A+DELTAP                                                       METU1015
      IF(AP.LT.0.) AP=0.                                                METU1016
      QCB=SQRT(SLOPE)/CANALN*AP**(5./3)*(B/(B**2+2*AP))**(2./3)         METU1017
      DELTA=ARA/ISTEP*2*(YY+XX-QCB)                                     METU1018
      A=A+DELTA                                                         METU1019
      IF(A.LT.0.) A=0.                                                  METU1020
      QC=SQRT(SLOPE)/CANALN*A**(5./3)*(B/(B**2+2*A))**(2./3)            METU1021
      YY=YY+2*XX                                                        METU1022
   21 CONTINUE                                                          METU1023
      GHYD(J+1)=QC*1000                                                 METU1024
      GO TO 7160                                                        METU1025
 7140 GHYD(J+1)=0.                                                      METU1026
 7160 CONTINUE                                                          METU1027
      GO TO 5150                                                        METU1028
 8130 A=0.                                                              METU1029
      DO 8160 J=1,IJKL                                                  METU1030
      IF(BHYD(J).EQ.0.0.AND.BHYD(J+1).EQ.0.0.AND.QC.LT.0.0001)GO TO 8140METU1031
      XX=(BHYD(J+1)-BHYD(J))/ISTEP/2000                                 METU1032
      YY=BHYD(J)/1000                                                   METU1033
      DO 22 I=1,ISTEP                                                   METU1034
      DELTAP=ARA/ISTEP*(YY+XX-QC)                                       METU1035
      AP=A+DELTAP                                                       METU1036
      IF(AP.LT.0.) AP=0.                                                METU1037
      QCB=SQRT(SLOPE)/TRAPN*AP**(5./3)*(1/(B+(-B+SQRT(B**2+4*AP*Z))/Z)* METU1038
     *SQRT(1+Z**2))                                                     METU1039
      DELTA=ARA/ISTEP*2*(YY+XX-QCB)                                     METU1040
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
      A=A+DELTA                                                                 METU1041
      IF(A.LT.0.) A=0.                                                          METU1042
      QC=SQRT(SLOPE)/TRAFN*A**(5./3)*(1/(B+(-B+SQRT(B**2+4*A*Z))/Z)*            METU1043
     *SQRT(1+Z**2))                                                             METU1044
      YY=YY+2*XX                                                                METU1045
   22 CONTINUE                                                                  METU1046
      GHYD(J+1)=QC*1000                                                         METU1047
      GO TO 8160                                                                METU1048
 8140 GHYD(J+1)=0.                                                              METU1049
 8160 CONTINUE                                                                  METU1050
      GO TO 5150                                                                METU1051
      END                                                                       METU1052
C-----END OF THE SUBPROGRAM DESIGN                                               METU1053
C-----------------------------------------------------------------------         METU1054
C                                                                               METU1055
C-----SUBPROGRAM SIMLLM ROUTES THE SEWER HYDROGRAPH OF LARGE RETURN              METU1056
C     PERIOD ACCORDING TO THE PEAK DISCHARGE OF THE HYDROGRAPH                  METU1057
      SUBROUTINE SIMLLM                                                         METU1058
      DIMENSION GHYD(250)                                                       METU1059
      COMMON/TETA/UPA,DOWNA,PIPEN,CANALN,L,TYPEA(4,20),IJKL,IROUTE,ISTEP        METU1060
      COMMON/SIGMA/IJK                                                          METU1061
      COMMON/GAMA/ALEN,DELT                                                     METU1062
      COMMON/RHO/EHYD(250)                                                      METU1063
      COMMON/CCI/NSEC                                                           METU1064
      SLOPE=(UPA-DOWNA)/ALEN                                                    METU1065
      IF(IROUTE.NE.0) GO TO 1010                                                METU1066
      BIG=EHYD(1)                                                               METU1067
      DO 1000 I=2,IJK                                                           METU1068
 1000 IF(EHYD(I).GT.BIG) BIG=EHYD(I)                                            METU1069
      BIG=BIG/1000                                                              METU1070
      IF(NSEC.EQ.1) GO TO 1130                                                  METU1071
 1005 D=L                                                                       METU1072
      AF=3.141593*(D/1000)**2/4                                                 METU1073
      QF=AF*(D/4000)**(2./3)*SQRT(SLOPE)/PIPEN                                  METU1074
      IF(IROUTE.NE.0) GO TO 1020                                                METU1075
      QR=BIG/QF                                                                 METU1076
      DR=0.67333*QR+0.2237778                                                   METU1077
      TH=2*ARCOS(1.-2*DR)                                                       METU1078
      AR=(TH-SIN(TH))/6.283185                                                  METU1079
      V=BIG/AR/AF                                                               METU1080
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
 1990 IT=ALEN/V/DELT/60+1                                               METU1081
      K=IJK-IT                                                          METU1082
      IF(K.LT.1) K=1                                                    METU1083
      DO 2000 M=1,K                                                     METU1084
 2000 EHYD(IJK-M+1)=EHYD(K-M+1)                                         METU1085
      DO 2010 M=1,IT                                                    METU1086
 2010 EHYD(M)=0.                                                        METU1087
      RETURN                                                            METU1088
 1130 QF=TYPEA(2,L)*SQRT(SLOPE)/CANALN                                  METU1089
      B=TYPEA(1,L)                                                      METU1090
      CALL YNORM(YN,BIG,CANALN,SLOPE,B,0.)                              METU1091
      Y=YN                                                              METU1092
      A=Y*TYPEA(1,L)                                                    METU1093
      V=BIG/A                                                           METU1094
      GO TO 1990                                                        METU1095
 1010 ARA=DELT*30/ALEN                                                  METU1096
      QC=0.                                                             METU1097
      A=0.                                                              METU1098
      IF(NSEC.EQ.1) GO TO 7130                                          METU1099
      GO TO 1005                                                        METU1100
 1020 DO 5140 J=1,IJKL                                                  METU1101
      IF(EHYD(J).EQ.0.0.AND.EHYD(J+1).EQ.0.0.AND.QC.LT.0.0001)GO TO 5145METU1102
      XX=(EHYD(J+1)-EHYD(J))/ISTEP/2000                                 METU1103
      YY=EHYD(J)/1000                                                   METU1104
      DO 20 I=1,ISTEP                                                   METU1105
      DELTAP=ARA/ISTEP*(YY+XX-QC)                                       METU1106
      AP=A+DELTAP                                                       METU1107
      IF(AP.LT.0.) AP=0.                                                METU1108
      AR=AP/AF                                                          METU1109
      QR=1.037725*AR**1.388456                                          METU1110
      IF(AR.GT.0.26)QR=1.075165*AR**1.418482                            METU1111
      QCB=QF*QR                                                         METU1112
      DELTA=ARA/ISTEP*2*(YY+XX-QCB)                                     METU1113
      A=A+DELTA                                                         METU1114
      IF(A.LT.0.) A=0.                                                  METU1115
      AR=A/AF                                                           METU1116
      QR=1.037725*AR**1.388456                                          METU1117
      IF(AR.GT.0.26)QR=1.075165*AR**1.418482                            METU1118
      QC=QR*QF                                                          METU1119
      YY=YY+2*XX                                                        METU1120
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8
   20 CONTINUE                                                                  METU1121
      GHYD(J+1)=GC*1000                                                         METU1122
      GO TO 5140                                                                METU1123
 5145 GHYD(J+1)=0.                                                              METU1124
 5140 CONTINUE                                                                  METU1125
 5150 GHYD(1)=0.                                                                METU1126
      DO 5160 J=1,IJK                                                           METU1127
 5160 EHYD(J)=GHYD(J)                                                           METU1128
      RETURN                                                                    METU1129
 7130 B=TYPEA(1,L)                                                              METU1130
      DO 7160 J=1,IJKL                                                          METU1131
      IF(EHYD(J).EQ.0.0.AND.EHYD(J+1).EQ.0.0.AND.GC.LT.0.0001)GO TO 7140        METU1132
      XX=(EHYD(J+1)-EHYD(J))/ISTEP/2000                                         METU1133
      YY=EHYD(J)/1000                                                           METU1134
      DO 21 I=1,ISTEP                                                           METU1135
      DELTAP=ARA/ISTEP*(YY+XX-GC)                                               METU1136
      AP=A+DELTAP                                                               METU1137
      IF(AP.LT.0.) AP=0.                                                        METU1138
      QCB=SQRT(SLOPE)/CANALN*AP**(5./3)*(B/(B**2+2*AP))**(2./3)                 METU1139
      DELTA=ARA/ISTEP*2*(YY+XX-GCB)                                             METU1140
      A=A+DELTA                                                                 METU1141
      IF(A.LT.0.) A=0.                                                          METU1142
      QC=SQRT(SLOPE)/CANALN*AP**(5./3)*(B/(B**2+2*A))**(2./3)                   METU1143
      YY=YY+2*XX                                                                METU1144
   21 CONTINUE                                                                  METU1145
      GHYD(J+1)=QC*1000                                                         METU1146
      GO TO 7160                                                                METU1147
 7140 GHYD(J+1)=0.                                                              METU1148
 7160 CONTINUE                                                                  METU1149
      GO TO 5150                                                                METU1150
      END                                                                       METU1151
C-----END OF THE SUBPROGRAM SIMULM                                              METU1152
C-----------------------------------------------------------------------        METU1153
C                                                                               METU1154
C-----SUBPROGRAM YNORM CALCULATES THE FLOW DEPTH IN RECTANGULAR AND             METU1155
C     TRAPEZOIDICAL CANALS BY ITERATION                                         METU1156
      SUBROUTINE YNORM(YN,Q,XN,S,B,Z)                                           METU1157
      Y=0.001                                                                   METU1158
      YY=0.001                                                                  METU1159
      DELY=0.1                                                                  METU1160
.........1.........2.........3.........4.........5.........6.........7.........8
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.........1.........2.........3.........4.........5.........6.........7.........8

 102 YN  =((Q*XN)/(S**0.5))*((B+2*Y*(1+Z**2)**0.5)**0.6667)/(((B+Z*Y)**               METU1161
     *1.6667)*(Y**0.6667))                                                              METU1162
      DELTA=Y-YN                                                                        METU1163
      IF(ABS(DELTA).LT.0.001) RETURN                                                    METU1164
      IF(Y.GT.YN) GO TO 101                                                             METU1165
      YY=Y                                                                              METU1166
 106  Y=Y+DELY                                                                          METU1167
      GO TO 102                                                                         METU1168
 101  Y=YY                                                                              METU1169
      DELY=DELY/10.                                                                     METU1170
      GO TO 106                                                                         METU1171
C                                                                                       METU1172
C-----END OF THE METU DESIGN MODEL PROGRAM                                              METU1173
C                                                                                       METU1174
      END                                                                               METU1175

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