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ILLINOIS LEAST-COST SEWER SYSTEM DESIGN MODEL: ILSD-1&2 USER'S GUIDE

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ABSTRACT

ILLINOIS LEAST-COST SEWER SYSTEM DESIGN MODEL: ILSD-1&2 USER'S GUIDE

ILSD models are sewer system models for least-cost optimal design of the entire system. ILSD-1 designs for a specified layout the size and slope of the sewers with or without detention storages with user supplied rainfall and/or inlet hydrographs. ILSD-2 is similar to ILSD-1 but also with risk consideration; i.e., with the risk damage cost included in the optimization procedure and a risk equation supplied by the user. The user may choose either ILSD-1 or 2 as he (she) wishes and according to the available data. This user's guide provides the necessary information to use the computer program. Data preparation for various options to fit different engineering situations is presented.

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I. INTRODUCTION

1.1 Background

In terms of engineering application purposes, urban storm sewer simulation models can be classified into two groups. The larger group consists of flow prediction models whose purpose is to predict or evaluate the flow due to input (usually rainfall) into an existing or pre-determined sewer system for which the size and slope of the sewers are already specified. The other group is design models for which at least the sewer sizes and perhaps also the slope and layout of the sewers are to be determined on the basis of the design inflow. There are relatively few design models in existence. The most famous and simplest is the rational method. A few models, such as SWMM and ILLUDAS, were originally developed as flow prediction models and have added the required sewer size computation capability, making them pseudo hydraulic design models. However, since different sewers should be designed for different rainfall durations as amply demonstrated in the rational method (Yen and Cheng, 1980), several computer runs are required for these models to complete a design. In many cases the flow prediction models require high hydraulic sophistication in order to obtain the needed flow prediction accuracy. Conversely, for a design model, because of the discrete commercial pipe sizes actually used, a less sophisticated hydraulic scheme is usually acceptable and can still provide satisfactory designs.

One special subgroup of design models consists of models with the objective of achieving a lowest total cost design for the entire sewer system through optimization. These models usually design for the size and slope of the sewers and in some cases also for the sewer layout. The Illinois Least-Cost Sewer System Design Model (ILSD) is one of the earliest and perhaps presently still the most practical least-cost design model. ILSD actually consists of four submodels (Yen et al., 1976; Yen, 1978):

- ILSD-1: optimal design of sewer sizes and slopes with predetermined layout and without risk cost consideration in the optimization.
- ILSD-2: same as ILSD-1 but with risk cost consideration included in the optimization
- ILSD-3: optimal design of sewer sizes, slopes and layout without risk cost consideration in the optimization
- ILSD-4: same as ILSD-3 but with risk cost consideration included in the optimization.

The models are developed primarily for least-cost optimal design of new sewer systems or extention of existing systems. They can also be used to evaluate the hydraulic performance of existing systems with an accuracy similar to SWMM or ILLUDAS. However, it is suggested that when high accuracy evaluation is required a high level hydraulic model should be used.

This guide provides the necessary information to use ILSD-1&2. The user's guide for ILSD-3&4 has yet to be written when appropriate funding is secured. The initial development of the models was completed and released to the public in 1976. Based on the feedback from the users, a revised version of ILSD-1&2 incorporating detention storage optimization, adapting ILLUDAS surface runoff generation, and allowing different modes of rain input was released in 1980. This guide is the third generation release of ILSD-1&2, incorporating an improved surface runoff generation scheme and many small improvements to make the model more adaptable to field situations.

This guide is written in such a manner that once the program is implemented on a computer, the user can apply ILSD-1&2 to his or her designs following the data format instruction given in Chapter IV. Reading of Chapter II is not necessary for the use of the model. Hence, that chapter can be omitted by those less inquisitive users. Neverthless, it is felt that a user should not have blind faith of any model he or she is using, and we recommend a minimum degree of understanding of the model be achieved. The user is also urged to become familar with the capabilities and restrictions of the model described in Section 1.2 in order to minimize the chance of misusing the model.

1.2 Capabilities of ILSD-1&2

The computer program package described herewith consists of two sewer-system least-cost design models: ILSD-1 and ILSD-2. Both models perform for a specified layout, the design of sewers and detention storages using a minimum cost criterion. The sewer systems are restricted to dentritic networks of sewers, manholes, and detention storages. ILSD-1 considers only installation costs whereas ILSD-2 minimizes both the installation and flood damage costs associated with flood risk for the entire system. Both models are included in the same computer program with the one actually used being user specified. Either English or SI units can be chosen.

The program requires as input the layout of sewers as identified by manhole numbers, length of sewers, ground elevation at manholes, detention storage restrictions, data on costs, restricted elevations for sewers, manholes and outlets, and other constraints, if applicable. The inflow hydrographs at manholes can be input by the user as well as generated through hydrologic simulation of surface runoff from rainfall provided by the user. Areas of different land uses and soil conditions within the basin and different values of Manning's n for different sewers can also be specified. If ILSD-2 is used, a risk function and damage costs are also required.

The output from the program consists of the diameter and slope of the sewer pipes provided by the design, the corresponding upstream and downstream invert and crown elevations of the pipes, the minimum total cost of the network, and the volumes of detention storage, if applicable. Various options are provided for printout of input data on hydrographs, hyetographs, and costs, and for computed subcatchment inlet time and inlet hydrographs. For ILSD-2 the output also gives the risk of flooding due to inadequacy of the pipe capacity for each sewer, and the installation cost and expected damage cost for the entire network.

The standard program can accept up to 50 manholes, excluding the outlet. No more than 10 manholes are allowed along the longest drainage path, i.e., a maximum of 11 isonodal lines, and there must be no more than 5 manholes having an equal number of pipes between them and the outlet, i.e., a maximum of 5 manholes on each isonodal line. The dimension statements of the program can be enlarged to handle larger systems. Each manhole can have detention storage associated with it.

In addition to sewers, junctions, manholes and inlets, a storm sewer system may also contain regulating or operational devices such as gates, valves, weirs, overflows, regulators, and pumping stations. These devices do have an effect upon the system, hydraulically dividing it into a number of subsystems and affecting the optimal design. However, these special devices are not considered in the optimial design model ILSD-1&2 described here.

The sewer systems that can be handled by ILSD-1&2 ranges from a completely new network with all sewers to be designed, to any mixture of some new sewers and some existing sewers, to a completely existing sewer system with known pipe sizes and no design of new pipes. However, only the new sewers are included in the optimization and installation cost computations.

The computer program is written in Fortran IV language. The program as presented here requires for a CDC Cyber 175 system a compute storage capacity of around 14,000 words or 55K bytes. The design mode of the program requires an execution time roughly of the order of 1/4 sec/pipe for ILSD-1 and about 1/2 sec/pipe for ILSD-2.

1.3 Availability of Computer Program

The computer program of ILSD-1&2 is released at cost on magnetic tape. Tapes are usually released in 1600 bpi, 9-track, EBCDIC, odd parity, labelled for CDC CYBER, IBM 4341 or compatible computer systems. Other specifications such as 800 bpi, 7-track, ASCII or unlabelled tape may be possible at special request. When ordering the tape, additional information pertinent to tape implementation such as the type (make) of computer would also be helpful. Inquires should be sent to Dr. B. C. Yen, Hydrosystems Laboratory, Department of Civil Engineering, University of Illinois at Urbana-Champaign, 208 N. Romine Street, Urbana, Illinois 61801, USA.

It is understood that the program developers bear no responsibility for the consequences of using the program. The program can be duplicated only when the source (the Hydrosystems Laboratory of the University of Illinois) is clearly identified, and under no circumstances can the program be renamed, whether modified or in original form, and then released for sale without advanced agreement of the developers.

II. BRIEF DESCRIPTION OF METHODOLOGIES

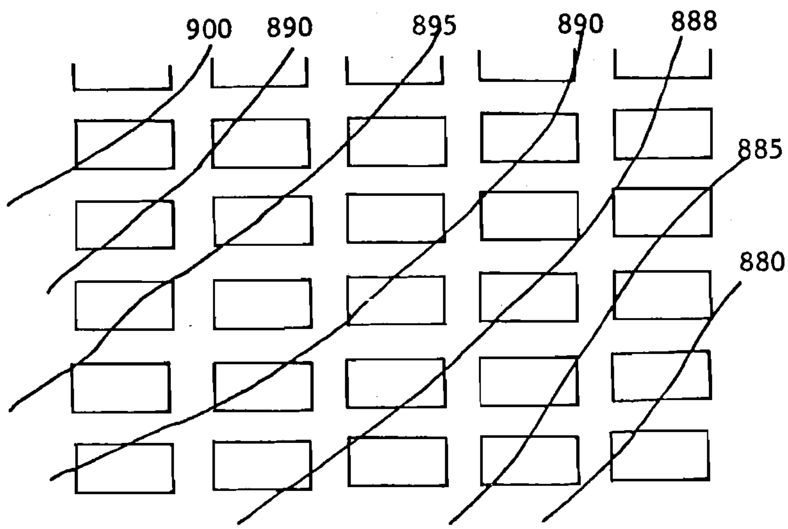
In this chapter a brief description is presented on the techniques for sewer network and catchment representation, inlet hydrograph generation from rainfall, sewer routing, and optimization.

2.1 Sewer Network Representation

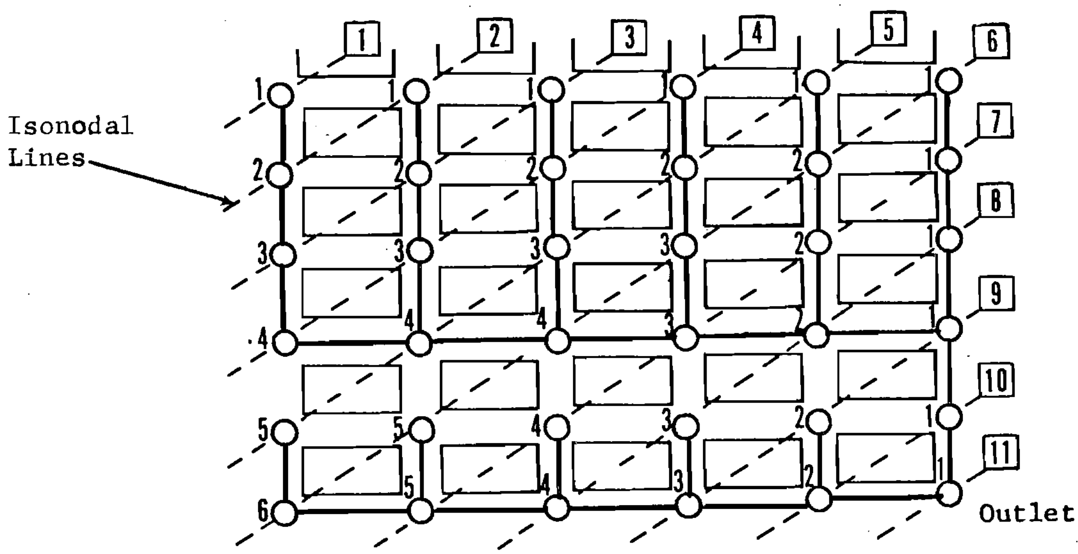
For clear identification of the composition (connectivity) of the sewers in a network system and efficient computer digital manipulation, an effective means of representing the network is very important. A node-link technique can be used effectively in identifying such a network. The layout, which is determined before using ILSD-1&2, is identified by the location of the manholes (junctions), i.e., the nodes. Each node is assigned a number. Different nodes are assigned different numbers. A link is a sewer which connects the manholes (nodes) at its two ends. Therefore, a sewer (link) is uniquely identified by the node numbers at its upstream and downstream ends together with the specified sewer length. Two sewers having the same downstream node number indicate they join together at their downstream end. Two sewers with the downstream node number of one identical with the upstream node number of the other implies they are joined in series. For gravity flow sytems, sewers are generally sloped towards low ground surface elevations. Hence, manholes located at higher ground elevations usually have sewer pipes connecting them to manholes at lower ground elevations. This concept gives rise to a rather simple approach of representing arbitrary sewer networks for digital manipulation on the computer.

For computer digital manipulation for optimization and flow routing, a more orderly description of the network than the arbitrarily designated node numbers is necessary. This is accomplished by using a set of imaginary lines called isonodal lines (INL). These lines are defined such that they pass through manholes (nodes) which are separated from the sewer system outlet by the same number of sewers (links). For example, in Fig. 1 the manholes on isonodal line 8 for the simple street system are connected to the outlet by three sewers (pipe links). The isonodal lines are constructed starting at the outlet of the system and proceeding upstream, and are numbered in the reverse order starting with the upstream and proceeding downstream as shown for the example. The sub-number of the manholes in an INL can be assigned randomly.

In ILSD the user can assign an arbitrary number (not exceeding 9999) to a manhole, but a given number is assigned to no more than one manhole. The



(a) Street System with Elevation Contours



(b) Layout and Isonodal Lines

Fig. 1. Isonodal Lines for a Sewer System

isonodal-line description for digital manipulation is accomplished through sorting by the computer.

Advantages of using the isonodal lines and manhole numbering scheme include:

(a) the burden of ordering the calculation is placed upon the computer;

(b) the computer can readily construct a network from a simple input list;

(c) any arbitrary multi-level branching network can be easily described;

(d) a layout change such as addition of pipes and manholes can be handled easily by only numbering and adding the new manholes which results in only minor changes in the input deck.

2.2 Rainfall Input

ILSD-1&2 allows direct input of inlet hydrographs. However, in most cases users prefer to input rainfall and let the model generate the inlet hydrographs. To suit the need of various situations, four different options of rainfall input are provided in the model:

(1) Arbitrary hyetographs -- The user specifies the amounts of rain in successive time increments. The hyetograph is applied to the entire watershed.

(2) Triangular hyetograph -- The user specifies the rainfall duration, depth, and the relative peaking time, a_p (Fig. 2). The statistical expected value of a_p usually ranges from 0.2 to 0.45.

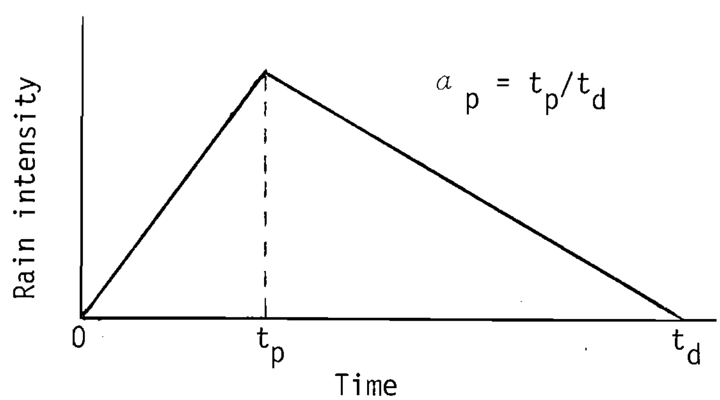


Fig. 2. Triangular Input Hyetograph

(3) Triangular hyetograph from equation -- The user specifies the design return period and supplies the rainfall average intensity-duration-return period formula for the design location in one of the following two forms:

$$\bar{i} = \frac{C_1 T_r^a}{C_2 + t_d^b} \tag{1a}$$

or

$$\bar{i} = \frac{C_1 T_r^a}{(C_2 + t_d)^b} \tag{1b}$$

in which

C_1 and C_2 = constant coefficients

a and b = constant exponents

T_r = return period in years

t_d = duration in min

$\bar{i}$ = average rainfall intensity over t_d, in in./hr or mm/hr

The rainfall duration is computed in the program as the sum of the time required to satisfy the initial losses of rainfall to overland surface and a user specified duration of rain excess, t_e, as shown in Fig. 3, i.e., when $t_e \geq t_d - t_p > 0$,

$$t_d = t_e + (t_p \text{ Loss}/\bar{i})^{\frac{1}{2}} \tag{2}$$

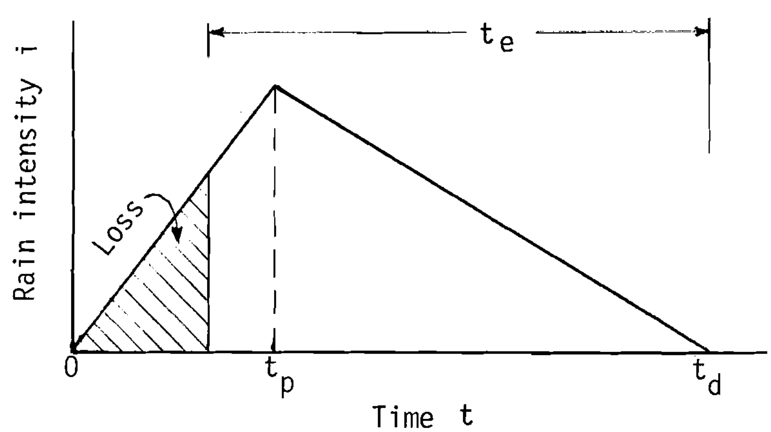


Fig. 3. Triangular Hyetograph

or when $t_d - t_p > t_e > 0$,

$$t_d = \frac{1}{2}(t_p + \frac{Loss}{\bar{i}}) \pm \sqrt{\frac{1}{4}(t_p + \frac{Loss}{\bar{i}})^2 + t_e^2 - t_p \frac{Loss}{\bar{i}}} \quad (3)$$

With the computed rain duration t_d and given return period, the triangular hyetograph is determined and applied to the entire drainage basin.

(4) Different triangular hyetographs for design of different sewers -- The user supplies the rainfall average intensity-duration-return period formula and specifies the design return period as in (3). Similar to the rational method, each sewer has its own design duration and hyetograph. The duration is computed as the sum of the time of concentration, t_c, at the upstream end of the sewer plus the time required for rainfall to compensate for the initial losses on the overland area corresponding to the critical flow path producing t_c (as shown in Fig. 3 except replacing t_e by t_c), i.e., if $t_c \geq t_d - t_p > 0$,

$$t_d = t_c + (t_p \; Loss/\bar{i})^{1/2} \quad (4)$$

if $t_d - t_p > t_c > 0$,

$$t_d = \frac{1}{2}(t_p + \frac{Loss}{\bar{i}}) \pm \sqrt{\frac{1}{4}(t_p + \frac{Loss}{\bar{i}})^2 + t_c^2 - t_p \frac{Loss}{\bar{i}}} \quad (5)$$

The time of concentration for a sewer is the longest of the flow time from the different contributing catchments, i.e., the sum of catchment inlet time and the sewer flow time to the upstream end of the sewer being designed. The triangular hyetograph for a sewer is applied to all the catchments draining into the sewer. A catchment is defined here as the area drained by an inlet. A drainage basin may contain many catchments. This rain option is specifically provided for sizing all new sewers in a single computer run.

2.3 Overland Runoff and Inlet Hydrographs

For a drainage basin, ILSD-1&2 permits the direct input of inlet hydrographs to some or all of the catchments simultaneously with inlet hydrographs generated from rainfall for the rest of the catchments in the basin. For the purpose of transforming rainfall into runoff, the overland surface of a catchment is classified into five catagories:

(1) Directly contributing impervious areas such as paved streets, sidewalks, driveways, parking lots that drain either through the street gutter or directly into the inlets, and also houses and buildings that drain directly into the inlet or a directly connecting paved area.

(2) Directly contributing pervious areas such as grass, permeable soil surface, gravel streets that drain either through a ditch or directly into the inlet.

(3) Supplemental impervious areas that drain into a directly contributing pervious area. They do not connect directly to any inlets or gutters.

(4) Supplemental pervious areas that drain into a directly contributing impervious area.

(5) Noncontributing areas such as local ponds and low lands that do not drain into the inlet.

In reality,in a catchment there are many different parcels of impervious and pervious areas, and they are connected in numerous different ways. For practical reasons, these areas are lumped together in each one of the five categories and are considered to follow two flow paths as shown in Fig. 4. One path is for the water from the supplemental impervious area to drain into the direct pervious area and then into the inlet. The other path is from the supplemental pervious area draining into the direct impervious area and then into the inlet. The time-area method is used to route the runoff through the direct pervious, supplemental pervious, and direct impervious areas. The flow time of each of these three areas is either supplied by the user or computed in the program with user supplied length and slope of the longest flow path of the area. The overland flow time is computed from the following equation,

$$t_o = K\left(\frac{nL}{\sqrt{S}} \right)^{0.6} \tag{6}$$

in which

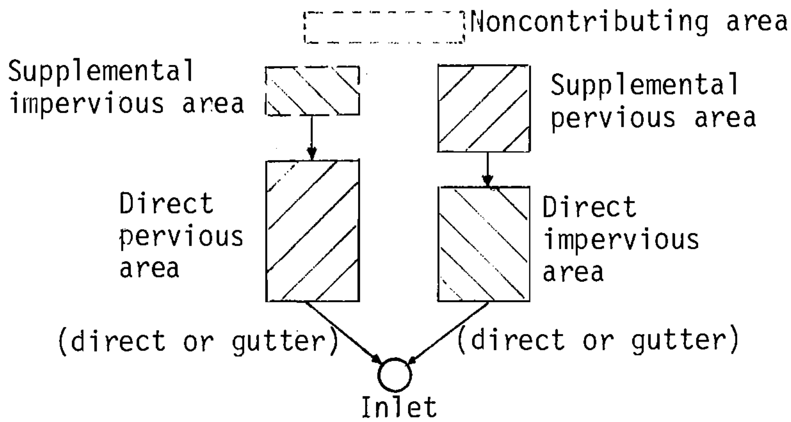


Fig. 4. Catchment Surface Composition

L = length of the longest flow path of the area in ft (m)

S = average slope of the longest flow path of the area

n = a land surface roughness coefficient; assumed equal to 0.02 for impervious area and 0.05 for pervious area

K = a constant, unless specified by the user, equal to 0.6 for L in ft and t_o in min, and 1.2 for L in m and t_o in min.

The flow time of the supplemental impervious area is assumed equal to zero and the rainfall on this area is translated immediately to the upstream end of the direct pervious area. This simplification is made because, in practice, it is often rather difficult to establish the flow path and estimate the flow time satisfactorily for the supplemental impervious area, and its flow time is usually short in comparison to that of the directly contributing pervious area.

The inlet time of a catchment which is used in the determination of the rainfall duration (if not specified by the user) is taken as the longer of the flow time of the two paths. That is, the larger of

$$t_{pi} = (t_o)_{sp} + (t_o)_{di} \quad (7a)$$

and

$$t_{ip} = (t_o)_{dp} \quad (7b)$$

in which the subscripts of t_o indicates the abbreviation of supplemental pervious (sp), direct impervious (di), and direct pervious (dp), respectively; t_{pi} is the time for the flow path from supplemental pervious to direct impervious to the inlet; and t_{ip} is the time for the flow path from supplemental impervious to direct pervious and inlet. The reason of taking the longer one as the inlet time is a common hydrologic practice with which presumably all the areas would contribute to the peak flow. However, in some cases the longer-time areas may have little contribution to the runoff because of high abstractions or relatively small size. To account for such rare cases, the following supplemental criteria are also programmed into ILSD. If

$$(A_{sp} + 2A_{di}) > 4(2A_{si} + A_{dp})$$

the contribution from the path through the direct pervious area is insignificant, and hence t_{pi} is used as the inlet time. The symbol A represents the size of the area and the subscripts are the same as in Eqs. 7a and b. Conversely, if

$$(2A_{si} + A_{dp}) > 4(A_{sp} + 2A_{di})$$

the contribution from the path through the direct impervious area is insignificant and hence t_{ip} is taken as the inlet time.

The flow time between the inlet and the connecting sewer junction or manhole is small and neglected. A manhole can accept zero, one, or more hydrographs from different inlets of different catchments, some of these hydrographs can be generated from rainfall input while other inlet hydrographs can be supplied by the user directly. The user may input hydrographs of arbitrary shape or triangular hydrographs with equal or different initial and final base flows.

The initial interception and depression losses of rainfall, if not specified by the user, is taken as 0.1 in. (2.5 mm) for impervious surfaces and 0.2 in. (5 mm) for pervious surfaces. The soil type for pervious surfaces is classified according to USDA Soil Conservation Service (SCS) soil groups A, B, C, and D, designated here as types 1, 2, 3, and 4, respectively. The antecedent land surface moisture condition is also classified into four groups as follows:

1 = bone dry

2 = rather dry

3 = rather wet

4 = saturated

All of these three items, the antecedent soil moisture, soil type, and initial losses can be specified for the entire drainage basin, or different values can be specified for individual catchments. However, for the two options of rainfall duration computed accounting for the initial losses as discussed in Section 2.2 and shown in Fig. 3, the loss used in the computation is the larger of the pervious and impervious values for the entire basin.

For pervious surfaces infiltration is computed based on Horton's formula

$$f = f_c + (f_o - f_c)e^{-kt} \tag{8}$$

in which

f = infiltrability (infiltration capacity)

f_o = initial infiltrability of dry soil

f_c = final infiltrability of saturated soil

t = time starting from dry soil infiltration

k = constant

At any time if the available water for infiltration is less than the infiltrability, an adjustment must be made in order to compensate for the deficiency. Hence, in the program the cumulative infiltration from dry soil is used instead of Eq. 8. The cumulative or integrated infiltration of Eq. 8 is

$$F = \int f \, dt = f_c \, t - \frac{f_o - f_c}{k} (e^{-kt} - 1) \tag{9}$$

In a time increment Δt from t_o to $t_o + \Delta t$,

$$\Delta F = f_c \, \Delta t + \frac{f_o - f_c}{k} e^{-kt_o} (1 - e^{-k\Delta t}) \tag{10}$$

When the rainfall intensity is less than the infiltrability, the latter may still be satisfied if there is sufficient water retained on the land surface. In ILSD, the available surface retention water is assumed equal to the currently available initial loss, LI, which consist primarily of depression storage. Hence, at the time $t_{i+1} = t_i + \Delta t$, the cumulative soil moisture F_{i+1} is

$$F_{i+1} = F_i + \Delta F \qquad \text{if} \quad \Delta F \leq \Delta Rain \tag{11a}$$

$$F_{i+1} = F_i + \Delta F \qquad \text{if} \quad \Delta F > \Delta Rain \quad \text{but} \quad \Delta F \leq \Delta Rain + (LI)_i \tag{11b}$$

$$F_{i+1} = F_i + \Delta Rain + (LI)_i \qquad \text{if} \quad \Delta F > \Delta Rain + (LI)_i \tag{11c}$$

For the second case (Eq. 11b) the depletion of the initial loss is

$$(LI)_{i+1} = (LI)_i - (\Delta F - \Delta Rain) \tag{12}$$

For the third case (Eq. 11c) all the available initial loss is presumably infiltrated; and hence at the time t_{i+1} the initial time for dry soil is adjusted for subsequent computations. For these two cases, later as soon as $\Delta Rain > \Delta F$, the initial loss deficiency will be refilled; i.e.,

$$(LI)_{i+1} = (LI)_i + (\Delta Rain - \Delta F), \qquad (LI) \leq (LI)_{max} \tag{13}$$

The antecedent soil moisture index for the pervious surfaces can be related to the initial F_o values as shown in Table 1. The infiltration properties f_c and f_o for the SCS soil groups are given in Table 2. The constant k used in the program is 2.0 hr^{-1}.

Table 1. Values of initial soil moisture F_o in in. (mm) for pervious surface

Antecedent moisture condition	SCS Soil Type			
	A(1)	B(2)	C(3)	D(4)
1	0	1.71 (43.3)	3.57 (90.7)	10.75 (273)
2	0	1.39 (35.2)	2.58 (72.4)	6.91 (176)
3	0	0.98 (24.8)	1.99 (50.5)	4.28 (109)
4	0	0.51 (12.8)	1.03 (26.1)	2.17 (55)

Table 2. Values of f_c and f_o in in./hr (mm/hr) for pervious surface

Infiltration parameter	SCS Soil Type			
	A(1)	B(2)	C(3)	D(4)
f_c	1.094 (27.8)	0.535 (13.6)	0.262 (6.7)	0.128 (3.3)
f_o	10.0 (254)	8.2 (208)	5.8 (147)	3.0 (76)

2.4 Sewer Size and Detention Storage Computations and Hydrograph Routing

The required diameter of a sewer is computed by using Manning's formula assuming just-full gravity flow

$$d_r = \left(C \frac{n}{\sqrt{S_o}} Q_p\right)^{3/8} \tag{14}$$

in which

Q_p = peak discharge of the inflow hydrograph of the sewer, cfs or m^3/s

S_o = sewer slope

n = Manning's roughness factor n, usually ranges from 0.012 to 0.016

C = constant, equal to 2.16 for English units with d_r in ft, and 3.21 for SI units with d_r in m.

The nearest commercial pipe size no smaller than d_r is adopted as the size of the sewer being designed.

The inflow hydrograph of a sewer is obtained from combining all the inflow hydrographs into the manhole at the upstream end of the sewer, adjusted for storage effect if the manhole (or storage element) storage volume is significant. For a detention storage element with specified volume, the method to route the flow is the continuity relationship,

$$\Sigma(\bar{Q}_{in})_j - \bar{Q}_{out} = \frac{\Delta s}{\Delta t} \tag{15}$$

in which

$(Q_{in})_j$ = flow into the detention element from the jth sewer

Q_{out} = outflow from the detention element to the downstream sewer

Δs = change of detention storage in time interval Δt

For a new detention element for which the storage capacity is to be designed, the technique adopted to route the flow through it is illustrated in Fig. 5. The solid curve represents the hydrograph into the detention element, whereas the three broken curves represent three different cases of outflow hydrograph with different design outflow discharge capacities from the detention element. The inflow hydrograph is the combined hydrograph of all the upstream sewers and direct surface inflow. The outflow to the downstream sewer is assumed to rise with the inflow until the design discharge capacity, Q_c, of the connecting downstream sewer is reached (point A in Fig. 5). The value of Q_c is calculated by using the Manning formula

$$Q_c = \frac{c}{n} d_n^{8/3} S_o^{\frac{1}{2}} \tag{16}$$

in which

n = Manning's roughness factor

S_o = sewer slope

d_n = sewer diameter used

c = constant, 0.463 for d_n in ft and Q_c in cfs, and 0.912 for d_n in m and Q_c in m^3/s.

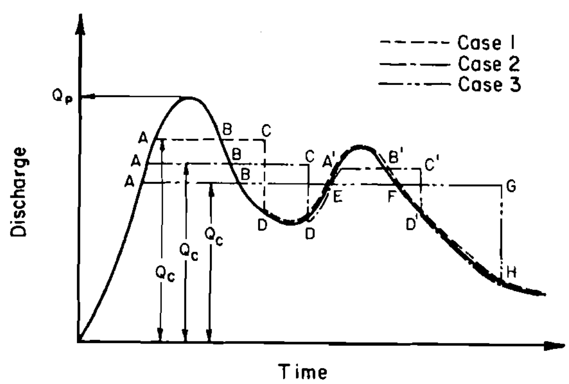


Fig. 5. Operation of Detention Storage

As the inflow rate exceeds Q_c after point A, the outflow is assumed to remain constant at Q_c, and the storage begins to accumulate in the detention element as shown from point A to point B in Fig. 5. For Cases 1 and 2, after point B when the inflow rate is below Q_c, the outflow is assumed to remain at Q_c until the storage is completely depleted (point C), at which time the outflow rate is assumed to drop to the inflow rate, shown as point D in Fig. 5. For Case 1 the outflow rate is assumed equal to the inflow rate in the remaining of the recession after point D. The required storage volume, $\forall_s$, for Case 1 is simply the area above AB between the inflow hydrograph and outflow hydrograph. Thus,

$$\forall_s = \int_A^B (Q_{in} - Q_c)\, dt \tag{17}$$

For Case 2 after point D, the outflow rate is assumed equal to the inflow rate until point A' where the inflow rate again exceeds the outflow rate. The assumed process of outflow hydrograph after A' is repeated as for points A through D. The required storage volume for Case 2 is the larger of the two areas above AB and A'B' between the inflow hydrograph and outflow hydrograph in Fig. 5. Whereas for Case 3 the depletion of storage is not complete until point G. The outflow rate is assumed to remain at Q_c from point A to point G and then drop to the inflow rate after point H. The required storage volume for this case is equal to the areas above AB and EF minus the area below BE between the inflow hydrograph and outflow hydrograph. In general, the required storage volume of these cases can be calculated by

$$\forall_s = \text{Max of} \int (Q_{in} - Q_c)\, dt > 0 \tag{18}$$

The inflow hydrograph of a sewer is routed through the sewer using the hydrograph-time-lag method described in Yen et al. (1976). Although kinematic wave and Muskingum-Cunge routing methods have also been programmed into different versions of ILSD, they do not produce a significant difference in design and hence the hydrograph-time-lag method is adopted as the recommended routing version in ILSD-1&2 for sewer design. The lag time t_f in minutes for the shifting of the inflow hydrograph is computed as

$$t_f = L\pi d_n^2/240Q_p \tag{19}$$

in which

L = length of sewer in ft (m)

d_n = diameter of commercial pipe size adopted in ft (m)

Q_p = peak discharge of sewer inflow hydrograph in cfs (m^3/s)

2.5 Optimization Procedure

The problem concerning optimal design of sewers is how to determine the least-cost combination of size and slope of the sewers and the depth of the manholes for a sewer network to collect and drain the water from an urban drainage basin. Since for a given sewer length the slope depends on the end elevations of the sewer, the design variables considered are the diameter and the crown elevation at the upstream and downstream ends of the sewers, and the depth of the manholes. As explained in the preceding section, the diameter computation is based on the peak discharge of the inflow hydrograph of the sewer. Thus, the preliminary information required for the optimization procedure includes the topography of the drainage area and the sewer system layout, system constraints, costs of materials and installation of sewers and manholes, and the inlet hydrographs at the manholes. In ILSD the layout of the sewer system is described by the connectivity of the manholes (nodes) and the length of the sewers (links), and the topography is represented by the ground elevation of the manholes.

The optimization technique used in ILSD-1&2 is a special form of dynamic programming called discrete differential dynamic programming (DDDP). This technique is not discussed here but a detailed description of its application to sewer design can be found in several references (e.g, Yen et al., 1976), and its application to sewers with detention storage optimization is given in Cheng (1982). A brief description of how the procedure selects minimum cost systems is given in the following without reference to the technical terms relating to the optimization theory. Knowledge of the optimization theory is not required to use the computer program.

The optimization procedure starts at the upstream end of the system considering each of the sewers connecting manholes on isonodal lines (INL) 1 and 2, then proceeding in a downstream fashion stage-by-stage considering the sewers in each stage. In the node-link INL representation of a sewer system described in Section 2.1, an arbitrary stage n includes all the sewers connecting manholes on an upstream INL n to the adjacent downstream INL n + 1.

For each possible connection of manholes, there are many possible sewer slopes and corresponding diameters which could carry the design discharge, although only one of these gives the least-cost system. However, the slope is equal to the difference of crown elevations between the ends of the sewer divided by its length, and the diameter is determined from the slope and discharge (Eq. 14). Hence, the crown elevation at each end of the sewer is chosen as the optimization variable. At a manhole, the joining sewers are assumed crown aligned unless specified.

The objective is to select the set of upstream and downstream crown elevations among the many possible crown elevations as shown in Fig. 6 that gives the least-cost sewer system. In the computation procedure, these possible crown elevations at the upstream and downstream ends of the sewer are evenly spaced in the vertical, and they must be below the elevation for the minimum soil cover depth at each end of the sewer. Any pair of upstream and downstream crown elevations representing a positive drop in elevation across the sewer constitutes a feasible slope. The procedure considers each crown elevation at the downstream end of the sewer, and for each of these considers each upstream crown elevation. For each feasible slope to a downstream crown elevation, the smallest commercial pipe diameter that satisfies the requirements of design discharge (Eq. 14), minimum and maximum allowable velocities (and the not-smaller-than-upstream-pipe diameter constraint, if applicable) is selected. The cost of pipe installation and upstream manhole of this feasible-slope connection to the downstream crown elevation is computed accordingly for comparison. The minimum cost slope is found for each downstream crown elevation considered and is stored in the computer.

For a sewer having no upstream connecting sewers, the cost associated with a downstream crown elevation for the sewer is just the cost for that sewer and the upstream manhole. However, for a sewer with upstream connecting sewers, the cost is a cumulative cost of upstream sewers and manholes plus the cost of the sewer being designed.

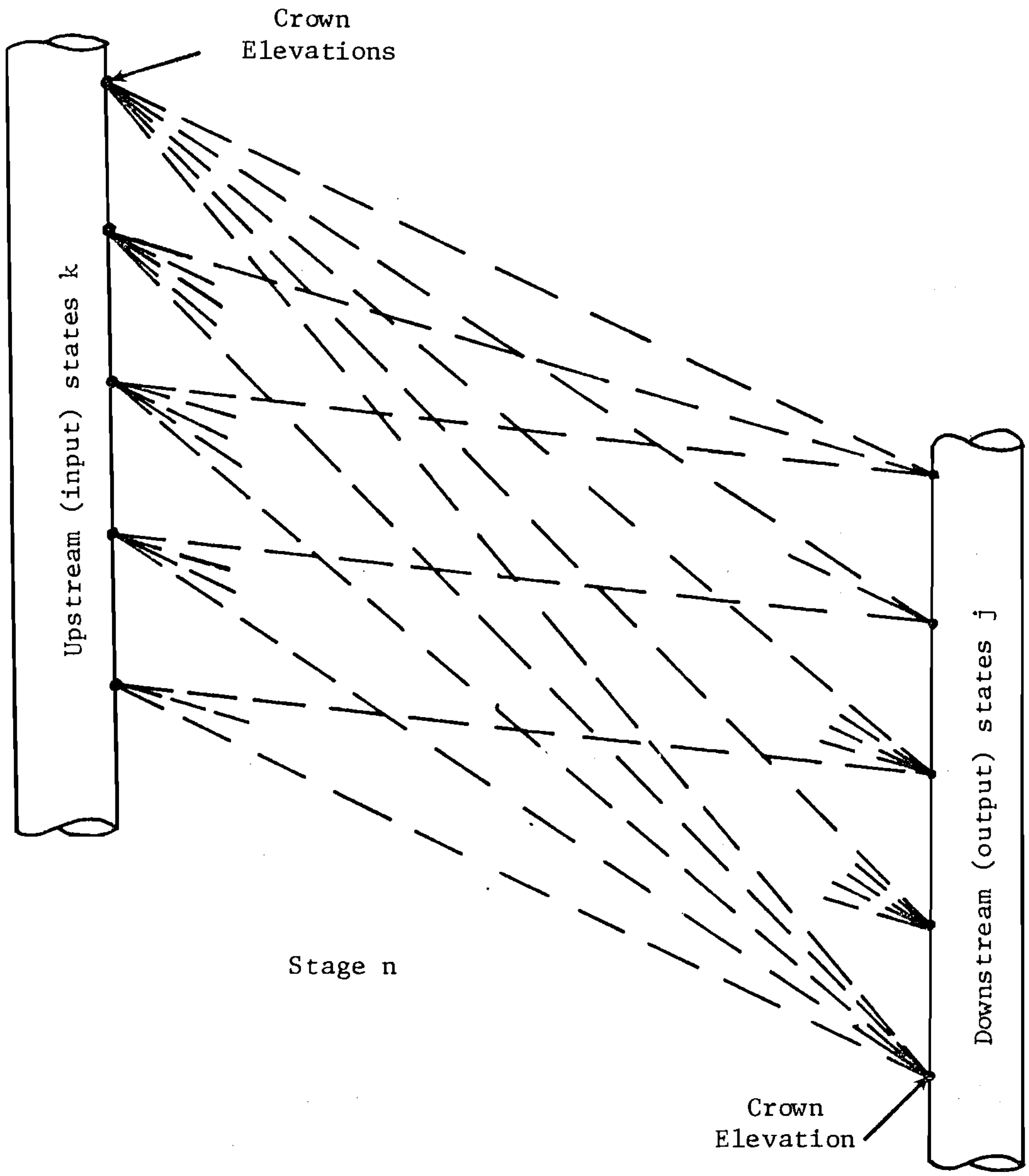


Fig. 6. Possible Combinations of Crown Elevations for a Sewer

The algorithm continues downstream stage-by-stage until the computation has been performed for the last (most downstream) stage. There now exists a set of minimum cumulative costs for each downstream crown elevation considered for each sewer in the network. A traceback procedure is subsequently performed to retrieve the minimum-cost design. The traceback begins at the downstream end (last stage, or outlet) of the system. At the outlet the crown elevation with the minimum cumulative cost is selected as the optimal (unless the outlet elevation is restricted). The traceback then proceeds upstream stage-by-stage selecting the upstream crown elevation that resulted in the minimum-cost slope connecting to the downstream crown elevation. This procedure, as illustrated in Fig. 7, continues upstream until all sewer connections in the network have been selected. The result of the traceback is a minimum cost design for all the sewers and manholes in the network, including the sewer slope, upstream and downstream crown elevations of the sewer, sewer diameter, and the upstream manhole size. This procedure is repeated using DDDP with a new set of crown elevations throughout the network to see if a cheaper cost network design can be found.

DDDP is an iterative technique for which a trial set of crown elevations for the entire system (called the initial trial trajectory) is first selected. Then a range of crown elevations (a corridor) along the trajectory is set up with a specified crown elevation (state) increment, subject to the feasible elevation constraints. As described in the preceding paragraph, a search is then made within the corridor to find the set of minimum cost elevations which is subsequently used as the new, improved trial trajectory. The improved trajectory is then used to set up the new corridor for the next iteration. This procedure is repeated using the initial elevation increment until the improvement in the system design cost is within a small specified percentage. The elevation increment is then reduced (halved) and the iteration is repeated. This process is repeated for successive reduced elevation increments until the specified minimum elevation increment is reached and the change of the system design cost is within the specified percentage. The final result is accepted as the least cost design.

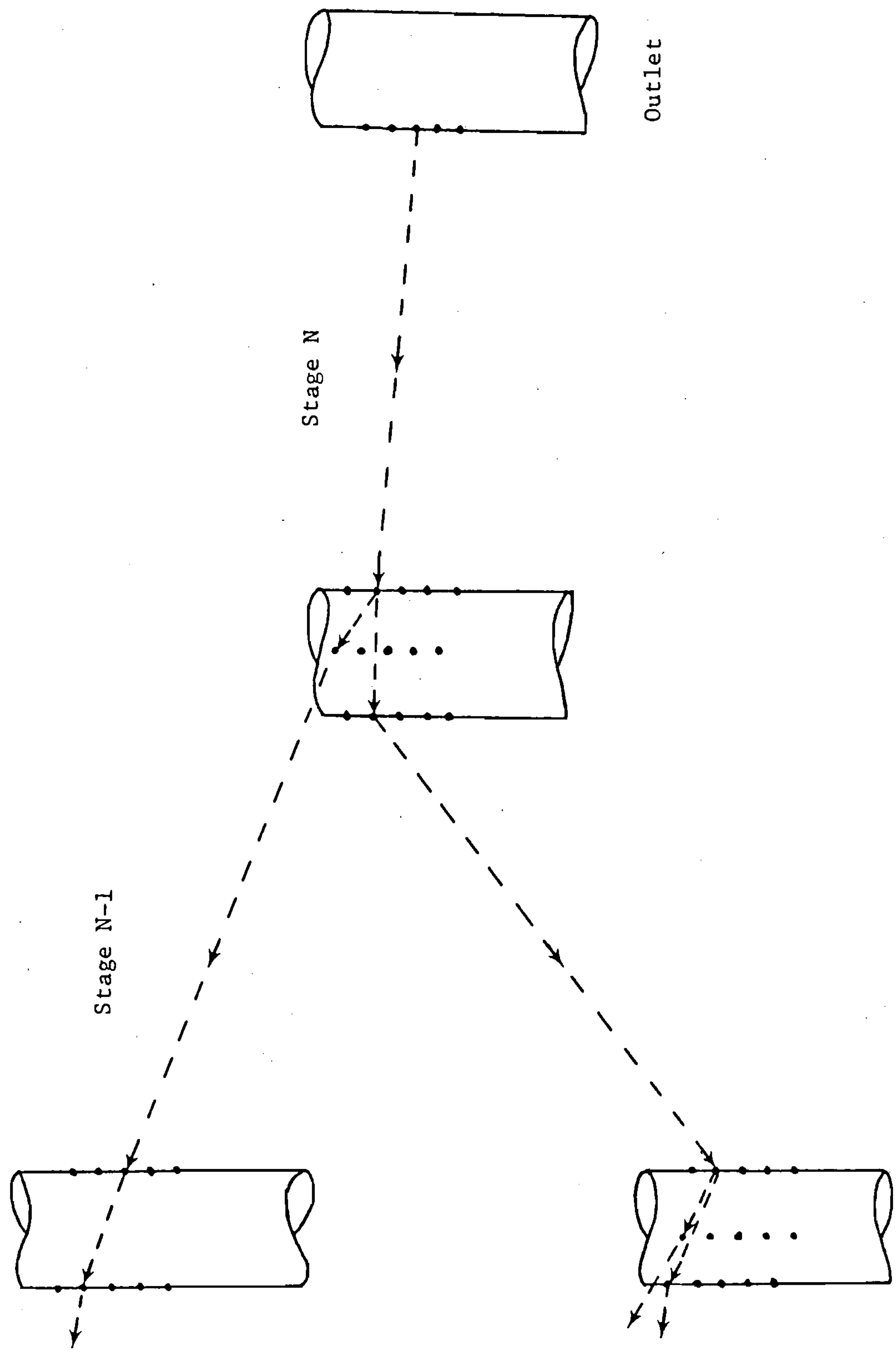


Fig. 7. Traceback Starting at System Outlet

III. INPUT DATA AND COMPUTER PRINTOUT

3.1 Input Data

Input data to run ILSD-1&2 can be classified into two types: mandatory and optional. The user must supply information for the mandatory input. For optional input built-in default values or alternatives will be followed if the input information is not supplied by the user. For clarification, the required input data are described in this section in the following categories: sewer system, cost data, drainage basin catchment data, input hydrographs, and rain. The sequence of entering these data does not follow the order just described. They follow the format given in Chapter IV.

If ILSD-2 is used, the required input data include, in addition to those needed for ILSD-1, also the risk-safety factor relationship as defined by the quadratic-exponential equation, and the assessed damage cost resulting from inadequacy of the pipe capacity for each sewer.

3.1.1 Input Data of Sewer System

Model ILSD-1 requires as input the layout of the sewer network as identified by the manhole numbers at the upstream and downstream ends of the sewers, the length of the sewers, the total number of manholes, ground elevation at each manhole, minimum soil cover depth for the sewers, Manning's roughness factor n for the pipes, and the maximum and minimum permissible velocities in the sewers. The manhole numbers are numerals up to 4 digits, in any random order. The inflow hydrographs for the manholes are either provided by the user or generated through the built-in surface runoff simulation scheme. If detention storage facilities are to be considered, it is also necessary to specify the unit cost for new detention storage, as well as the maximum allowable storage volume and/or maximum allowable outflow from the storage element if such constraints exist. If constraints for the invert or crown elevations for sewers exist, these values should also be specified.

The mandatory input data of sewer system are:

(1) The total number of manholes including the outlet.

(2) The identification numbers of the manholes at the upstream end and downstream end of each of the sewers.

(3) Length of sewers.

(4) Ground elevation at each of the manholes.

(5) The total number of inlet hydrographs that enter the sewer networks, including those supplied directly by the user and those to be generated from rainfall.

All other sewer system input are optional with their default values or alternatives given in the data format description given in Chapter IV.

3.1.2 Catchment Data

If any inlet hydrograph is to be generated from input of rainfall through the built-in catchment runoff procedure, user supplied data on that catchment is required. The mandatory input data required are:

(1) The manhole number into which the catchment drains.

(2) The size of the catchment in acres (ha).

(3) The size either in acres (ha) or in percentage of the catchment size of each of the four types of the runoff contributing areas: direct impervious, direct pervious, supplemental impervious and supplemental areas.

Optional input data are the following.

(1) Basin SCS hydrologic soil type for the pervious surfaces for the entire basin. The default soil type is B.

(2) Soil type of any catchment if it is different from the basin soil type.

(3) Antecedent soil moisture condition for the entire basin. The default value is 3, rather wet.

(4) Antecedent moisture condition of a catchment if it is different from the basin condition.

(5) Initial losses of rainfall for impervious and pervious surfaces, respectively, for the entire basin. Default values are 0.1 in. (2.5 mm) and 0.2 in. (5 mm), respectively.

(6) Initial losses of rainfall for a catchment if different from those for the basin.

(7) The size of noncontributing area of the catchment either in percentage of the catchment size or in acres (ha) so that an arithmetic check of the catchment area data can be made.

(8) The overland flow entry times of the direct impervious, direct pervious and supplemental pervious areas of the catchment, by either (a) supplied by the user (default values are 5 min, 20 min, and 20 min, respectively), or (b) computed in the program from user supplied length and slope of the longest flow path of these three types of surfaces. These two alternatives are not mutually exclusive for a catchment. For example, for a given catchment the user may enter the entry times for the direct and supplemental pervious areas together with the length and slope of the longest flow path of the direct impervious area.

3.1.3 Rain Data

If any one or more of the catchment inlet hydrographs are to be generated from rainfall through the model simulation, input of rain data is necessary. Conversely, if all the inlet hydrographs are supplied by the user, there is no need to input any rain and catchment data.

Four mutually exclusive options of rain hyetographs are allowed in ILSD-1&2 as described in Section 2.2. The default option is hyetograph Option 0. The rain data input for these options are as follows.

Option 1, user supplied arbitrary hyetograph -- The mandatory input data are the total number of rain values to be input, and the rain values. The optional input data are the time interval that the rain values will be entered (default value 5 min), the total rain depth as a check, and the return period.

Option 2, one triangular hyetograph -- The mandatory input rain data are: total rainfall depth in inches (mm) and duration of rainfall in minutes. The optional input data are the relative time of peak rain rate, a_p (Fig. 2) and the return period in years.

Option 3, one triangular hyetograph from formula, and

Option 0, different triangular hyetographs from formula for different sewers -- The mandatory input rain data for these two options are the two coefficients and two exponents of the rain intensity formula (Eqs. 1a and 1b) and the design return period in years. The optional input data is the relative time of peak rain rate, a_p.

For all the four options, the time interval of the generated inlet hydrograph can be an optional input independent of other time intervals used in the program.

3.1.4 Inlet Hydrograph Data

Three inlet hydrograph options are available in ILSD-1&2:

Option 1, user supplied triangular inlet hydrographs

Option 2, user supplied arbitrary inlet hydrographs

Option 3, rain generated inlet hydrographs as described in Sections 2.2, 2.3, 3.1.2, and 3.1.3.

These options are *not* mutually exclusive. For a computer run mixed mode is permitted for different inlets, and a manhole can accept more than one inlets. Thus, dry weather flow can be entered as Option 2 in conjunction with Option 3 for rain generated hydrographs and/or Option 1.

If any one or more of the inlet hydrographs are supplied by the user using Options 1 or 2, they are input into the program in terms of discharges at the manholes that receive the corresponding inflows. For both Options 1 and 2, a time interval DDT is required as an input data to specify the constant time interval of the discharge (ordinate) values of the hydrograph. This time interval can be different for different inlet hydrographs, and its default value is the time step DT used for sewer routing computations.

For Option 1, the user specified inlet hydrograph is approximated by a triangle as shown in Fig. 8. The symbols in the figure are defined as follows.

QP = peak flow Q_p

QB = Initial base flow of the hydrograph

QE = Final base flow of the hydrograph

DUR = duration of the inflow hydrograph

TAU = time between reference initial time and start of rising limb of the inflow hydrograph

DDT = time interval for hydrograph discharge values

PT = time from beginning of rise to peak

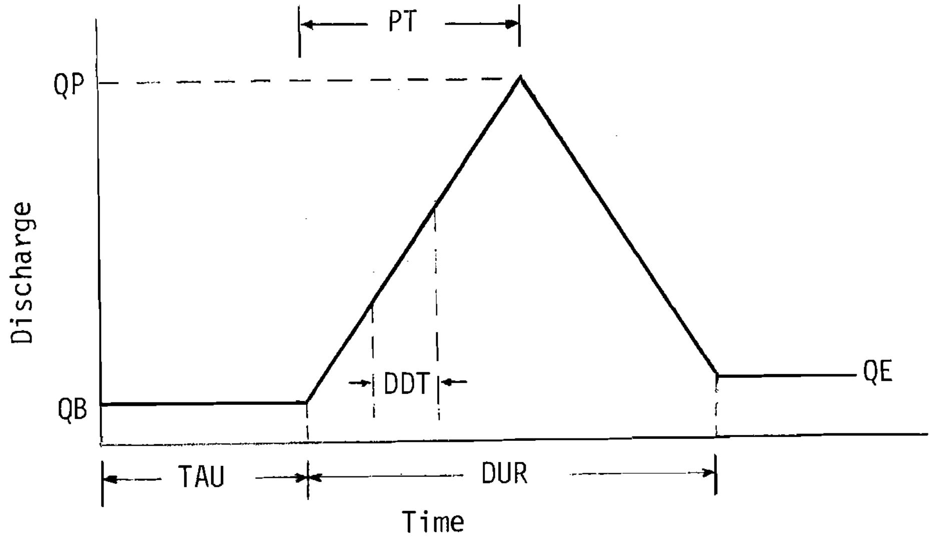


Fig. 8. Triangular Inflow Hydrograph

The mandatory input data for Option 1 are the manhole number that the inlet hydrograph enters, and the duration and peak discharge of the inlet hydrograph, DUR and QP, respectively. The optional input data are TAU (default value 0), QB and QE (default value 0 for both), DDT, and the relative peak flow time AO = PT/DUR (default value 0.5).

For Option 2 the mandatory input data are the manhole number that the hydrograph enters, the time period of the inlet hydrograph values (DUR), and the values of the hydrograph. The optional input data are the time when the first inlet hydrograph value at the manhole starts (TAU, default value 0); the initial and final base flow rates before and after the inlet hydrograph (QB and QE, default value 0 for both); and the time interval that the hydrograph values will be entered (DDT).

3.1.5 Cost Data

Four options of costs concerning pipe material, excavation, and manholes are provided in ILSD-1&2. Option 1 allows the user to input data in table form for the costs of different sizes of pipes of different classes (or schedules), different excavation costs for up to three different types of soils at different depths, costs of manholes of different sizes at different depths, and cost of in-line detention storages, if any. Option 2 allows the user to supply the same information in quadratic equation form. The excavation cost includes the costs for excavation, trench preparation, and backfilling charges.

The other two options are available only for English units. They are Option 0 for built-in cost tables and Option 3 for built-in cost functions. The built-in cost tables are based mainly on the cost values at Central Illinois in spring 1978. The cost functions are adopted from a 1969 study at Baltimore. Since the excavation, pipe and manhole costs varies with both location and time, the built-in cost tables and functions should be used only as a reference for comparison of different designs.

The default option is Option 0, built-in cost tables. If ILSD-2 is used, unit costs of flooding damage should also be specified.

If either Option 0 or Option 3 (built-in cost tables or functions) is used, the mandatory input data is the option selection. The optional input data are the unit cost of in-line detention storage in \$/cu ft for the basin and the unit cost for specific manholes if different from the basin common value, and whether to print the cost tables or functions in the computer output.

If Option 1, user supplied cost tables is used, the mandatory input data are the following.

(a) Identification number of the option selected

(b) Pipe cost data:

- Number of pipe classes (schedules), maximum 3
- Maximum allowable burial depth of each pipe class
- Number of pipe sizes (up to 24) in each pipe class
- Commercial pipe sizes in each pipe class
- Cost per linear ft (m) for each pipe size in each class

(c) Excavation cost data

- Number of different types of soils, maximum 3
- Number of depth ranges for each type of soil, maximum 10
- Largest depth of each range
- Unit cost of excavation in \$/cu yard (\$/m^3) for each range of depth of each type of soil

(d) Manhole cost data

- Number of depth intervals of different unit manhole costs, maximum 10
- Largest depth in ft (m) of each interval
- Unit cost of manhole per ft (m) depth in each depth interval

The optional input data are the detention storage unit cost and the code to print out the input cost data.

If Option 2, user supplied cost functions is used, the optional input data are the same as Option 1. The mandatory input are:

(a) The values of the coefficients of the excavation cost function

$$C_E = a + bH + cD + dHD + eH^2$$

in which

C_E = excavation cost in \$/cu yard (\$/m^3)

H = excavation depth in ft (m)

D = pipe diameter in ft (m)

Up to three different sets of coefficients for three cost functions representing three different types of soils are allowed in the program.

(b) The values of the coefficients of the manhole cost function

$$C_M = a' + b'H + c'D_M + d'HD_M + e'H^2 + f'D_M{}^2$$

in which

C_M = manhole unit cost in \$/ft depth (\$/m depth)

H = manhole depth in ft (m)

D_M = manhole diameter in ft (m)

In computing manhole cost in the program, H is taken as the lowest invert elevation of the joining sewers and D_M is taken as the largest diameter among the joining sewers.

(c) The values of the coefficients of the pipe cost function

$$C_p = k + mD + nD^2$$

in which

C_p = pipe cost per linear ft (m)

D = pipe diameter in ft (m)

(d) The total number of commercial size pipes (maximum 24) and the nominal diameter in in. (m) of each size. This informationm could be optional if the built-in English unit commercial sizes in the program are used.

3.1.6 Operational Input Data

The operational input data include those specifying the model used (ILSD-1 or 2), units (English or SI), computational time range and interval for sewer flow routing, and whether downstream pipe size can be smaller than upstream sizes. Also to be specified for optimization operation are the number of trial elevations to be used (maximum 9), the initial trial elevation increment and the minimum elevation increment for the final trial. Normally, for those who are not familar with the DDDP procedure used in the program, the built-in default values of elevation (state) increments can be used.

Since DDDP does not guarantee global optimization and the design result depends to some extent on the initial trial elevations of the sewers (initial trajectory), when in doubt it is advisible to try larger and smaller initial elevation (state) increment (built-in default value 3.2 ft or 0.8 m) to see if there is a significant change in the design in order to ensure the selection of the lowest cost option as the design. Furthermore, the initial trial trajectory is computed based primarily on the minimum soil cover depth, the largest pipe size specified and the user specified elevation constraints. Therefore, a warning signal may be printed out if unfavorable initial trajectory conditions are encountered due to negative local ground slope or severe elevation constraints. However, printing of the warning signal does not necessarily imply the failure of the model to complete the design. If the design is printed out, the warning should be ignored. Even when the warning is printed and no design is provided, the user is suggested to try different runs with different values of initial state (elevation) increments. For some cases, a design may be accomplished.

3.2 Computer Printout

The computer printout of the ILSD-1&2 program again consists of mandatory printout and optional printout.

The mandatory printout consists of an echo of the input data, a list of input rain and catchment information and user specified inlet hydrographs, if any, a list of input sewer information, and a table of design results. A sample design result is shown in Fig. 9.

Optional printout includes the inlet hydrographs at any or all of the manholes, sewer inflow hydrographs for user selected sewers, and the cost tables or functions. Printing of the computed hydrographs is generally not recommended as there are many of them and it could be costly. Printing of these hydrographs are suggested only for special inspections. Particularly for rain Option 0 described on p. 25 for different hyetographs for the design of different sewers, an inlet may have several hydrographs for different storms. For this option, a print command for a manhole will print the design hyetograph for the design of the sewer immediately downstream of this manhole and all the inlet hydrographs upstream of this manhole produced by this design hyetograph.

```
***************************
*                         *
* TABLE OF DESIGN RESULTS *
*                         *
***************************
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TRACE BACK RESULTS OF MINIMUM COST DESIGN: ITERATION 8

U/S MAN	D/S MAN	U/S CROWN ELEVATION (FT)	U/S INVERT ELEVATION (FT)	D/S CROWN ELEVATION (FT)	D/S INVERT ELEVATION (FT)	SLOPE	DIAM (IN.)	Q DESIGN (CFS)	Q CAPACITY (CFS)	STORAGE (CU.FT)	TOTAL COST ($)	PIPE CLASS
71	81	711.46	708.96	708.16	705.66	.01315	30.	43.60	43.67	0.	4589.	1
61	71	712.98	710.48	711.46	708.96	.00939	30.	36.17	36.92	0.	3239.	1
51	61	715.51	713.26	712.98	710.73	.01103	27.	30.00	30.21	0.	3662.	1
52	61	715.60	714.60	714.60	713.60	.01429	12.	1.76	3.95	0.	724.	1
53	61	718.50	717.50	714.60	713.60	.03000	12.	3.03	5.73	0.	959.	1
41	51	717.21	714.96	715.51	713.26	.00939	27.	27.72	27.87	0.	2807.	1
742	51	716.40	715.15	715.95	714.70	.00225	15.	2.66	2.85	0.	1536.	1
31	41	718.31	716.06	717.40	715.15	.00585	27.	18.18	21.99	0.	2508.	1
32	41	720.00	719.00	717.40	716.40	.01238	12.	2.55	3.68	0.	1273.	1
33	41	717.90	716.65	717.21	715.96	.00529	15.	4.25	4.36	0.	1146.	1
21	31	720.80	719.05	718.31	716.56	.01405	21.	17.29	17.44	0.	2046.	1
22	31	719.60	718.60	718.94	717.94	.00331	12.	1.84	1.90	0.	1235.	1
9111	21	727.60	726.35	720.80	719.55	.01744	15.	5.64	7.92	0.	2481.	1
812	21	722.00	720.75	720.80	719.55	.00656	15.	4.04	4.86	0.	1416.	1

STORM SEWER SYSTEM INSTALLATION COST = 29622. DOLLARS

STORAGE COST = 0. DOLLARS

TOTAL COST = 29622. DOLLARS

Fig. 9. Sample Printout of Result

IV. PREPARATION OF INPUT DATA CARDS

4.1 Input Data Format

The input data are entered in 8 data card sets as shown in Fig. 10. Depending on the model and options used, up to two of the card sets may not be required. If ILSD-1 is used and no risk is considered, Card Set 5-RISK is omitted. If all the inlet hydrographs are supplied by the user and no inlet hydrograph will be generated from rain and catchment runoff simulation, Card Set 8-RAIN is omitted.

In the following description of the card sets and cards, for items having an I-format, the number must be entered right justified, i.e., the last digit of the number must be placed in the last (most right-hand) space allotted to this item. For example, if the upstream manhole number of a sewer is 9001, this number will be entered as the first item of card number 1 of Card Set 6-NETWORK by placing the numeral 1 in column 5 since this item is allotted the space I5, from column 1 to column 5, of the card. A decimal point must not be used for a number having an I-format. For a number with an F-format, it is suggested that a decimal point be always specified and the number with the decimal point can be placed anywhere within the space allotted to this number. For instance, for a space of columns 21-30 allotted for F10.0, if the number is 12, one can enter this number as "12." or "12.0" anywhere between columns 21 and 30.

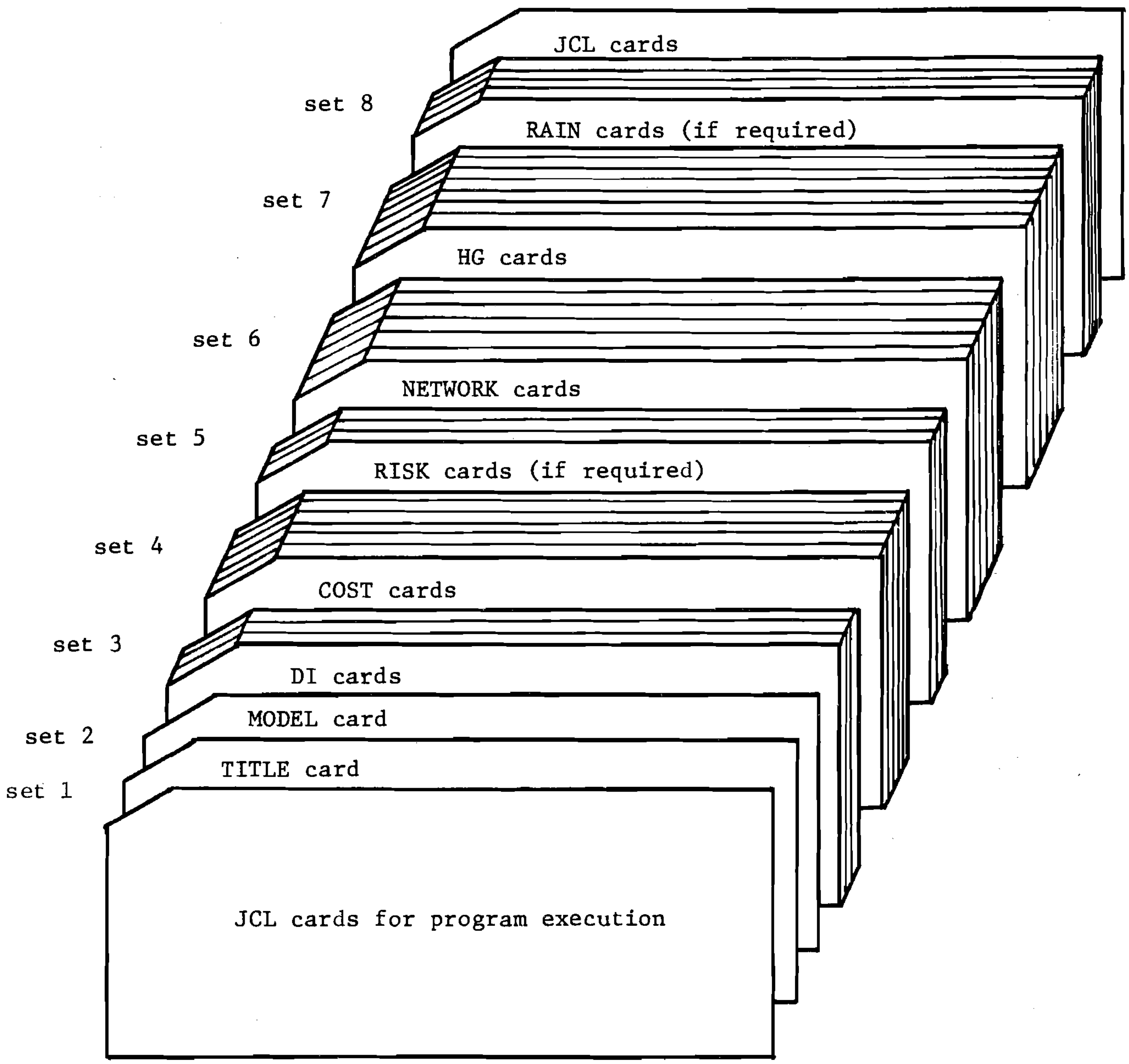

Fig. 10. Input Data Card Sets

Set 1 - TITLE

Set 1 - TITLE

Card Number	Card Column	Format	Description	Variable Name	Default Value
1	1-80	20A4	User defined title card	CARDI	None

Set 2 - MODEL

Set 2 - MODEL

Card Number	Card Column	Format	Description	Variable Name	Default Value
****			*This set contains one card and is called the MODEL card. This card specifies whether ILSD-1 or ILSD-2 is to be used and defines the option of dimensional units.*	****	
1	1-5	I5	This number specifies which model is to be used. If ILSD-1 (no risk) is desired a "1" is placed in column 5. If ILSD-2 (risk) is to be used, a "2" is placed in column 5.	MODEL	None
	6-10	I5	This number specifies which dimensional units is to be used. If the English unit system is to be used, a "0" is placed in column 10. If the metric unit system is to be used, a "1" is placed in column 10.	NUNIT	0

Card Number	Card Column	Format	Description	Variable Name	Default Value
****			*This DI card set consists of four cards. These cards contain the design information to be used for the sewer system.* ****		
1		***	*This card specifies minimum soil cover, velocity restrictions, and basin Manning's n.* ***		
	1-10		Leave blank.		
	11-20	F10.0	The minimum soil cover depth in ft (m); e.g., "4.5".	COVMIN	3.5ft 1.0m
	21-30	F10.0	The maximum allowable sewer flow velocity in ft/sec (m/s); e.g., "20.0".	VMAX	30.0ft/sec 10.0m/s
	31-40	F10.0	The minimum allowable sewer flow velocity in ft/sec (m/s); e.g., "2.0".	VMIN	2.0ft/sec 0.6m/s
	41-50	F10.0	(a) If one value of Manning's n is used for all the sewers, this is the common n value; e.g., "0.014". (b) If different values of Manning's n are used for different sewers, the value entered here will serve as the default value when the Manning's n of a particular sewer is not specified, i.e., by leaving columns 21-30 (ANK) of Card 2, Set 6-NETWORK for this sewer blank.	ANN	0.015
2		***	*This card specifies the time interval and total time for sewer hydrograph routing.* ***		
	1-10	F10.0	The time increment DT in minutes for sewer flow routing computations; e.g., "3."	DT	2.
	11-20	F10.0	The total time in minutes for the routing computations; e.g., "180."	TLMT	100.
	***		*The value of TLMT/DT must be smaller than 60.* ***		

Card Number	Card Column	Format	Description	Variable Name	Default Value
3	***		*This card specified information for optimization procedure.* ***		
	1-5	I5	The number of lattice points to be used in the computations; e.g., "7". This number must be placed right justified.	NELEV	5
	6-15	F10.0	The initial state increment in ft (m); e.g., "2.0".	DSTATE	3.2 ft 0.8 m
	16-25	F10.0	The minimum state increment in ft (m). It is a measure of the overall accuracy required in the state elevation determined by the program; e.g., "0.05".	DSMIN	0.1ft 0.025m
4	***		*This card specified the total manhole number and connecting pipe size constraint.* ***		
	1-5	I5	The total number of manholes in the network including the outlet. This number must be placed right justified; e.g., "12".	MANT	None
	6-10	I5	This number specifies whether the nondecreasing downstream pipe size constraint for all sewers will be employed in design. If the constraint is employed, a "0" is placed in column 10. Otherwise, if smaller downstream pipes are allowed, place "1" in column 10.	ICONT	0

Card Number	Card Column	Format	Description	Variable Name	Default Value
****			*This card set specifies the options for costs of pipes, manholes, and excavation.* ****		
1	1-5	I5	This number specifies which one of the four cost options is to be used: (a) If the built-in cost tables (for English units only) are to be used, place a "0" in column 5. (b) If the cost tables are to be supplied by the user, a "1" is placed in column 5. This cost information will be entered in Card Set 4a to 4c. (c) If a set of cost functions is to be supplied by the user, place a "2" in column 5. The coefficients of the functions will be entered in Card Set 4d. (d) If the built-in cost function (for English units only) is to be used, place a "3" in column 5.	ICOST	
	6-10	I5	This number specifies whether the design cost tables or functions are to be printed out. If yes, place a "1" in column 10. If no print out is desired, place a "0" in column 10.	WRITCO	0
	11-20	F10.0	This number provides the common (or default) unit cost for detention storage in \$/cu ft (\$/m^3). For sewers having unit storage costs different from this common value, the specified values for these sewers are entered in column 41-50 of Card 3, Set 6-NETWORK. If no detention storage is considered or no common unit cost is used for the entire system, leave this space blank.	USTORC	1.

**** *If the built-in cost tables or functions (Options 0 or 3) are used, omit all the following cards in this set and no blank card is needed.* ****

The following cards in this Set 4, COST, belong to two mutually exclusive parts for Options 1 and 2, respectively. Omit the cards which belong to the option that is not used and do not replace them with blank cards.

(a) The part for Option 1 which is user supplied cost tables, consists of three card groups: 4a-PICOT for pipe costs, 4b-EXCAV for excavation costs, and 4c-MHCOT for manhole costs.

(b) The part for Option 2, user supplied cost functions, consists of one card group, 4d-COSTFN.

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4a-PICOT	****			*This PICOT card group is needed only for Cost Option 1, user supplies cost tables. It contains a minimum of 4 cards giving information for the pipe classes, pipe sizes, and pipe costs.*	****	
	1	1-5	I5	Number of pipe classes to be considered, up to a maximum of 4. This number is placed in column 5, e.g., "2".	NCLASS	None
	2		***	*This card specifies the ranges of burial depths.* *If "1" is specified in the preceding card (i.e., in Column 5 of Card 1 of 4a-PICOT), this card must be omitted.*	***	
		1-5	F5.0	Maximum burial depth in ft (m) for the first pipe class; e.g., "4."	CLASSB(1)	None
		6-10	F5.0	Maximum burial depth in ft (m) for the second pipe class; e.g., "6." If there are only one or two classes of pipes, leave this space blank.	CLASSB(2)	None
		11-15	F5.0	Maximum burial depth in ft (m) for the third pipe class if there are four classes; e.g., "10." If there are three or fewer classes, leave this space blank.	CLASSB(3)	None
			***	*The maximum burial depths specified must be increasing with each pipe class. This process is continued until the second to last pipe class is encountered. Each value must be placed in the appropriate five columns allocated, i.e., 1-5, 6-10, and 11-15.* *The last pipe class is assumed capable of burial at all depths, i.e., no maximum burial depth. If only one pipe class is being considered then it is assumed that pipe class is capable of burial at all depths.*	***	

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4a-PICOT	3		***	*This card specifies number of pipe sizes in each pipe class.* ***		
		1-5	I5	The number of commerical pipe sizes available in the first pipe class. This number must be placed right justified; e.g., "11".	NPIPE(1)	None
		6-10	I5	The number of commercial pipe sizes available in the second pipe class. This number must be placed right justified; e.g., "11".	NPIPE(2)	None
		11-15 16-20	I5 I5	Repeat for each pipe class, each value is placed right justified in the five columns allocated.	NPIPE(3) NPIPE(4)	None None
			***	*Maximum number of pipe sizes in any class is 24.* ***		
	4		***	*This card specifies commercial pipe sizes.* ***		
		1-5	F5.0	The nominal diameter in in. (m) of the smallest commercial pipe in the first pipe class specified; e.g., "12."	PSIZE(1)	None
		6-10	F5.0	Diameter in in. (m) of the second smallest pipe size in the first pipe class specified; e.g., "15."	PSIZE(2)	None
		11-15 16-20 ⋮	F5.0 F5.0 ⋮	Repeat until all the commericial pipe sizes for the first class are specified. Each value must be placed in the five columns allotted.	PSIZE( )	None
			***	*If more than 16 pipe sizes are listed in a pipe class the remaining values are placed on another card immediately following in the same format as above. Repeat until all the pipe sizes in the same class are specified.* ***		

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4a-PICOT	5			**** This card specifies pipe costs. ****		
		1-5	F5.0	Cost in $ per linear ft (m) for the first pipe size specified in the first pipe class; e.g., "3.40".	PPCOST(1)	None
		6-10	F5.0	Cost in $ per linear ft (m) for the second pipe size specified in the first pipe class; e.g., "4.45".	PPCOST(2)	None
		11-15 16-20 . . .	F5.0 F5.0 . . .	Repeat for each pipe size until the costs for all the pipe sizes for the first class are considered. Each value must be placed anywhere in the 5 columns allocated. If more than 16 pipe sizes are specified the remaining cost values are placed on a successive card immediately following in the same format as above.	PPCOST( )	None
				**** The above process, i.e., specifying pipe size then pipe cost, (Cards PICOT-4 and PICOT-5) is repeated, one subset for each pipe class, in the same order in which the pipe classes were specified for the maximum burial depths (PICOT-2 card) and for the number of pipes (PICOT-3 card), until the sizes and costs for all the pipe classes are specified. ****		

Set 4 - COST

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4b-EXCAV	****			*This EXCAV card group is needed only for cost Option 1, user provided cost tables. It contains a minimum of 2 and maximum of 7 cards giving information regarding the excavation cost for different types of soils at different depths that may be encountered in the sewer system. A maximum of three sets of excavation costs is allowed, corresponding to three different types of soil (e.g., soft soil, hard soil, rock). For each soil type Card 3 specifies the different costs for different depth ranges which are entered on Card 2. A maximum of 10 depth ranges is allowed for each type of soil.*	****	
	1		***	*This card specifies the number of soil types and number of depth ranges for each type of soil.*	***	
		1-5	I5	Number of types of soil. A minimum of 1 and maximum of 3 types are allowed; e.g., if there are two different types of soil excavation unit costs enter "2" in column 5.	NEXTYP	1
		6-10	I5	This number specifies for the first soil type the number of depth ranges for which different unit costs of excavation will be provided by the user. This number must be placed right justified; e.g., "2".	NDEPTH(1)	None
		11-15	I5	This number specifies the number of depth ranges for the second soil type.	NDEPTH(2)	None
		16-20	I5	This number specifies the number of of depth ranges for the third soil type.	NDEPTH(3)	None
		21-25	F5.0	This number specifies the additional excavation width of the pipe trench in ft(m). The standard trench width is equal to the pipe diameter. The number specified is added to this diameter to give the width to compute excavation volume; e.g. "1.5".	EXWIDT	0.

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4b - EXCAV	2		***	*This card specifies the depth ranges for different excavation unit costs for the first soil type. If for this soil type only one unit excavation cost is specified it is assumed to apply to all depths of this soil. In this case the number specified on the first EXCAV card for the number of depth ranges for this soil is 1 and the EXCAV-2 card for this soil must be omitted.*	***	
		1-5	F5.0	Largest depth in ft (m) that the first unit cost of excavation is applicable; e.g., "4.5".	DEPTH(1,1)	None
		6-10	F5.0	Largest depth in ft (m) that the second unit cost is applicable.	DEPTH(1,2)	None
		11-15 16-20 . . .	F5.0 F5.0 . . .	Repeat until the second to last depth range for the second to last unit cost of excavation is specified. Each value must be placed in the 5 columns allocated.	DEPTH( )	None
			***	*The depth limits must be specified in the order of increasing depth. The last depth range is assumed to extend from the lowest depth limit of the previous unit cost to all depths below it.*	***	

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4b-EXCAV	3		***	*This card provides the unit excavation costs for different depth ranges for the first soil type.*	***	
		1-5	F5.0	Cost of excavation for the first depth range in $/cu yd ($/m^3), i.e., cost of excavation from ground surface to the first lower depth limit (if only one depth range is specified this is the cost of excavation for all depths); e.g., "3."	CDEPTH(1,1)	None
		6-10	F5.0	Cost of excavation for the second depth range in $/cu yd ($/m^3), i.e., cost of excavation from the first lower depth limit to the second lower depth limit; e.g., "4."	CDEPTH(1,2)	None
		16-20 21-25	F5.0 F5.0	Continue until all the excavation costs have been specified. Each value must be placed in the 5 columns allocated.	CDEPTH( )	None

**** *Repeat Card 2 (if required) and Card 3, in pairs, for the second and then the third soil types (if applicable).* ****

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4c-MHCOT	****			*This MHCOT card group contains 2 or 3 cards specifying the manhole costs.*	****	
	1	1-5	I5	Number of depth intervals up to 10 for which the unit manhole cost changes. This value must be placed right justified, e.g., "1".	NMAND	None
	2		***	*If the number specified on the first MHCOT card, i.e., the number of depth intervals, is 1, this card must be omitted.*	***	
		1-5	F5.0	Largest depth limit in ft (m) above which the first unit manhole cost applies; e.g., "8.0".	DPMAN(1)	None
		6-10	F5.0	Largest depth limit in ft (m) for the second unit manhole cost to apply.	DPMAN(2)	None
		11-15 16-20	F5.0 F5.0	Continue until the second to last depth interval is specified. Each value must be placed in the 5 columns allocated.	DPMAN( )	None
			***	*The depth limits must be specified in the order of increasing depth. The last depth interval is assumed to extend from the lower depth limit of the previous interval to all depths below it. If only one depth interval is specified the manhole cost is assumed applicable to all depths.*	***	

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Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4c-MHCOT	3	1-5	F5.0	Manhole cost in $ per ft-depth ($ per m-depth) within the first depth interval extending between the ground surface and the first depth limit; e.g., "100." If only one depth interval is specified this value applies to all manhole depths.	MANCST(1)	None
		6-10	F5.0	Manhole cost in $ per ft-depth ($ per m-depth) of a manhole extending from the ground surface to any depth within the second depth interval.	MANCST(2)	None
		11-15 16-20	F5.0 F5.0	Continue until manhole costs for all depth intervals have been specified. Each value must be placed in the 5 columns allocated.	MANCST( )	None

Set 4 - COST

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4d-COSTFN	****			*This COSTFN card group is needed only for Option 2, user supplied cost functions. It contains 4 or 5 cards. If other cost options are used, omit this card group.*	****	
	1		***	*This card specifies the values of the coefficients in the following excavation cost function.* $C_E = a + b*H + C*D + d*H*D + e*H^2$ *D = pipe diameter in ft (m)* *H = excavation depth in ft (m)* *Up to three different cost functions for a maximum of three different types of soil are allowed. For the spaces allocated to the functions that are not used, leave these spaces blank.*	***	
		1-5	F5.0	The value of coefficient "a" for the first type of soil; e.g., "57.2".	AE(1)	None
		6-10	F5.0	The value of coefficient "b" for the first type of soil; e.g., "7.7".	BE(1)	None
		11-15	F5.0	The value of coefficient "c" for the first type of soil; e.g., "4."	CE(1)	None
		16-20	F5.0	The value of coefficient "d" for the first type of soil; e.g., "0.1".	DE(1)	None
		21-25	F5.0	The value of coefficient "e" for the first type of soil; e.g., "11.0".	EE(1)	None
		26-30	F5.0	The value of coefficient "a" for the second type of soil.	AE(2)	None
		31-35	F5.0	The value of coefficient "b" for the second type of soil.	BE(2)	None
		36-40	F5.0	The value of coefficient "c" for the second type of soil.	CE(2)	None
		41-45	F5.0	The value of coefficient "d" for the second type of soil.	DE(2)	None
		46-50	F5.0	The value of coefficient "e" for the second type of soil.	EE(2)	None

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4d-COSTFN	1	51-55	F5.0	The value of coefficient "a" for the third type of soil.	AE(3)	None
		56-60	F5.0	The value of coefficient "b" for the third type of soil.	BE(3)	None
		61-65	F5.0	The value of coefficient "c" for the third type of soil.	CE(3)	None
		66-70	F5.0	The value of coefficient "d" for the third type of soil.	DE(3)	None
		71-75	F5.0	The value of coefficient "e" for the third type of soil.	EE(3)	None

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Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4d-COSTFN	2		***	*This card specifies the values of the coefficients in the following manhole cost function:* $C_M = a' + b'*H + C'*D_M + d'*H*D_M + e'*H^2 + f'*D_M^2$ *H = manhole depth in ft (m)* *D_M = manhole diameter in ft (m)*	***	
		1-10	F10.0	The value of coefficient "a' "; e.g., "5.0".	AM	None
		11-20	F10.0	The value of coefficient "b' "; e.g., "6.6".	BM	None
		21-30	F10.0	The value of coefficient "c' "; e.g., "0.5".	CM	None
		31-40	F10.0	The value of coefficient "d' "; e.g., "1.0".	DM	None
		41-50	F10.0	The value of coefficient "e' "; e.g., "0.8".	EM	None
		51-60	F10.0	The value of coefficient "f' "; e.g., "11.1".	FM	None

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4d-COSTFN	3		***	*This card specifies the values of the coefficients in the following pipe cost function* $C_p = k + m*D + n*D^2$ D = pipe diameter in ft (m)	***	
		1-10	F10.0	The value of constant "k"; e.g., "32.2".	PCA	None
		11-20	F10.0	The value of coefficient "m"; e.g., "6.0".	PCB	None
		21-30	F10.0	The value of coefficient "n"; e.g., "7.1".	PCC	None
		31-35	I5	The number of commercially available pipe sizes that will be provided by the user. This number must not exceed 24, and is placed right justified; e.g., "22". If the user prefers to use the built-in pipe sizes set in the program instead of entering specified pipe sizes, leave this location blank or, equivalently, enter a "0"; in this case the following one or two cards on pipe sizes are omitted.	NSIZE	0

Subset	Card Number	Card Column	Format	Description	Variable Name	Default Value
4d-COSTFN	4		***	*If the user specifies a non-zero value of NSIZE in columns 31-35 of the preceding card (Card 3 of 4d-COSTFN), but does not enter any pipe size values in this card 4, the built-in pipe sizes, starting from 8 in. diameter, will automatically be entered as the default values, up to the pipe whose rank in size is equal to NSIZE.*	***	
		1-5	F5.0	Diameter in in. (m) of the smallest pipe sizes; e.g., "12."	PDIA(1)	None
		6-10	F5.0	Diameter in in. (m) of the second smallest pipe size; e.g., "15."	PDIA(2)	None
		11-15 16-20	F5.0 F5.0	Repeat until all the pipe sizes are specified. Each value is entered within the five columns allocatted.		
			***	*If the number of pipe sizes exceeds 16, the remaining values are entered in another card (Card 5) immediately following, in the same format as above, until all the pipe sizes (maximum 24) are specified.*	***	

Card Number	Card Column	Format	Description	Variable Name	Default Value
****			*The RISK card set provides information concerning risk consideration and it is required only for ILSD-2. If ILSD-1 is used, this card set must be omitted.* *This card set contains either one of the following two mutually exclusive options:* *(a) Cards 1 and 2 only are needed when the single integration risk evaluation method is used. In this case, omit Card 3.* *(b) Cards 1 and 3 are needed if the risk functions are used. In this case, omit Card 2.*	****	
1	1-5	I5	This number specifies which one of the two risk options is used. If the single integration method is used, place a "0" in column 5. If the quadratic risk equations are used, enter the number of equations in column 5. This number must not exceed 4.	IRISK	0
	6-10	I5	This number specifies whether the input data on risk will be printed out. If print out is desired, place "1" in column 10. If no print out is desired, place a "0" in column 10.	WRITRI	0
	11-20	F10.0	The common or default assessed damage cost in dollars for a sewer in the event of flooding due to inadequate capacity of this sewer. For a given sewer whose assessed damage cost is different from this default value, the particular value is entered in Card 3 of Set 6 NETWORK for that particular sewer. This number is required only for ILSD-2 using the risk function option (Option 1 in column 5). Otherwise, leave this space blank. If there is no common or default value, also leave this space blank. This value is entered in scientific format with the last digit placed in column 20; e.g., 1.E4 is equivalent to 10,000 or 10^4 1.5E6 is equivalent to 1,500,000 or 1.5×10^6.	DEDAMC	None
	21-30	F10.0	The expected service period of the sewer system in years; e.g., "50."	TR	None

Card Number	Card Column	Format	Description	Variable Name	Default Value
2	***		*This card is needed only when the single integration method is used* ***		
	1-10	F10.0	This number specifies the coefficient of variation for pipe capacity; e.g., "0.13".	SIGMAC	None
	11-20	F10.0	This number specifies the coefficient of variation of pipe loading; e.g., "0.23".	SIGMAL	None
3	***		*This card specifies the values of the coefficients in the risk functions of the following form:* *** $\text{Risk} = \exp(a + b*SF + c*SF^2)*T_r^d$		
	1-10	F10.0	The value of coefficient "a" for the first risk equation; e.g., "0.5".	RA(1)	None
	11-20	F10.0	The value of coefficient "b" for the first risk equation; e.g., "37."	RB(1)	None
	21-30	F10.0	The value of coefficient "c" for the first risk equation; e.g., "2.2".	RC(1)	None
	31-40	F10.0	The value of the exponent "d" for the first risk equation; e.g., "0.33".	RD(1)	None
	***		*Repeat this card for the values of the coefficients for each of the remaining risk equations up to a maximum of four equations. The total number of this Card 3 is equal to the number of risk equations specified in column 5 of Card 1 of this set.* ***		

Card Number	Card Column	Format	Description	Variable Name	Default Value
****			*This NETWORK card set contains, in addition to the system outlet node card, two or three cards for each sewer in the system. These cards provide information concerning the sewer connectivity and physical parameters of the system. The manhole numbers should be an integer between 1 and 9999 but can follow any random order. Each manhole has only one number and no number can be assigned to more than one manhole.*	****	
1		***	*This card specifies elevations of the sewer.*	***	
	1-5	I5	The upstream manhole number of the sewer; e.g., "100". This number must be placed right justified.	CNODE (MANT)	None
	6-10	I5	The downstream manhole number of the sewer; e.g., "90". This number must be placed right justified.	SNODE (MANT)	None
	11-20	F10.0	Ground surface elevation in ft (m) at the upstream manhole; e.g., "98.4".	GEL (MANT)	None
	21-30	F10.0	Maximum allowable crown elevation (in addition to the minimum soil cover constraint) in ft (m) at the upstream end of the sewer; e.g., "96.5". If there is no constraint on the crown elevation, leave this space blank.	ELDC	None
	31-40	F10.0	Minimum allowable invert elevation in ft (m) at the upstream end of the sewer; e.g., "90.0". If there is no constraint on the invert elevation, leave this space blank.	ELDI	None
		***	*(A) If the crown elevation of a sewer at its entrance is to be fixed at a particular value, punch "-99." in columns 31-40 and specify the fixed crown elevation in columns 21-30.* *(B) For an existing sewer, specify its upstream crown elevation in columns 21-30 and leave columns 31-40 blank.*	***	

Card Number	Card Column	Format	Description	Variable Name	Default Value
1	41-50	F10.0	Maximum allowable crown elevation in ft (m) at the downstream end of the sewer; e.g., "96.2". If there is no constraint (in addition to the minimum soil cover requirement) on the crown elevation of this sewer, leave this space blank.	ELUC	None
	51-60	F10.0	Minimum allowable invert elevation in ft (m) at the downstream end of the sewer; e.g., "89.0". If there is no constraint on the invert elevation, leave this space blank.	ELUI	None
		***	*(A) If the crown elevation of a sewer at its exit is to be fixed at a particular value, punch "-99." in columns 51-60 and specify the fixed crown elevation in columns 41-50.* *(B) For an existing sewer, specify its downstream crown elevation in columns 41-50 and leave columns 51-60 blank.*	***	
		***	*If both the crown and invert elevations at either one or both ends of the sewer are to be constrained, the design may not proceed and a warning will be printed if the minimum difference between these elevations is less than either (1) the largest pipe diameter specified by the user in Set 4-COST, or (2) 10 ft which is the largest size in the built-in cost tables and functions.*	***	
	61-70	F10.0	Pipe size of existing sewer in in. (m); e.g., "24.0". If the sewer is to be designed, leave this space blank.	PIDIA	None

Card Number	Card Column	Format	Description	Variable Name	Default Value
2		***	*This card specifies sewer length, Manning's n, and soil information.*	***	
	1-10		Leave blank.		
	11-12	F10.0	Length of the sewer in ft (m); e.g., "400."	PLEN	None
	21-30	F10.0	Manning's n for this sewer; e.g., "0.013". If the common value of n for the sewer system ("ANN" in columns 41-50 of Card 1, Set 3-DI) is used for this sewer, leave this space blank.	ANK	ANN
		***	*The following five items, columns 31-65, are needed only for user supplied cost options (Options 1 and 2 in column 5 of Card 1, Set 4-COST) to specify the depths of soil layers (maximum 3 layers) for different excavation costs for this sewer. If for this sewer there is only one layer of soil over all the depths, specify the soil type (1, 2, or 3, see Cards 4b-EXCAV or Card 2 of 4d-COSTFN) in column 55 and leave the other four items blank. If cost Options 0 or 3 are used, leave these five items blank.*	***	
	31-40	F10.0	This value specifies the depth in ft (m) below the ground surface that divides the top soil layer from the second soil layer; e.g., "10.0".	SDEPTH(1)	1.0E25
	41-50	F10.0	This value specifies the depth in ft (m) below the ground surface that divides the second soil layer from the third (lowest) soil layer; e.g., "25.0". If there are only two soil layers, leave this space blank. The lowest soil layer is assumed to extend all the way below this depth.	SDEPTH(2)	1.0E25
	51-55	I5	This number identifies the type of soil for the top soil layer; e.g., if the soil is type 2, enter "2" in column 55.	SOTYPE(1)	1
	56-60	I5	This number identifies the type of soil for the second soil layer, e.g., "1".	SOTYPE(2)	SOTYPE(1)
	61-65	I5	This number identifies the type of soil for the third soil layer, e.g., "3". If there are only two soil layers for this sewer, leave this space blank.	SOTYPE(3)	SOTYPE(2)

Card Number	Card Column	Format	Description	Variable Name	Default Value
3		***	*This card is needed only if any one or more of the following conditions are considered. Otherwise, omit this card.* *(A) If detention storage is considered at the upstream of this sewer.* *(B) If ILSD-2 is used while either (1) the assessed damage cost for this sewer is different from the default value specified in columns 11-20 of Card 1, Set 5-RISK, or (2) the risk equation for this sewer is not the first risk equation (specified in the first card of Cards 3, Set 5-RISK) when the risk equation option is used and the number of risk equations is more than 1 (i.e., column 5 in Card 1, Set 5-RISK is 2, 3, or 4).* *(C) If the sewer is an existing sewer.*	***	
	1-10		Leave blank		
	11-20	I10	This number specifies the options for accounting for detention storage at the upstream end of the sewer. (a) If no detention storage is allowed at the upstream end of the sewer in the design optimization process leave this space blank, or place a "0" in column 20. (b) If the cost of detention storage is included in the optimization, whether the detention storage at the upstream of the sewer is with or without constraints on maximum outflow, on maximum storage volume, or on both, place a "1" in column 20. (c) For an existing sewer, if the user desires to compute the required storage volume to relieve the surcharge condition when the sewer capacity is inadequate, place a "2" in column 20. In cost computation existing sewers are not included. (d) For an existing sewer, if its flow capacity is inadequate and approximate surcharge flow computation is adopted and no computation of storage to relieve the surcharge condition is requried, place a "3" in column 20.	NSTOR	0

Card Number	Card Column	Format	Description	Variable Name	Default Value
3	21-30	F10.0	Maximum outflow in cfs (m^3/s) allowed from the detention storage element at the upstream of the sewer. If there is no maximum outflow constraint or no detention storage is considered (Options 0 and 3) leave this space blank.	MAXF	1.0E25
	31-40	F10.0	Maximum allowable volume in cu ft (m^3) for the detention storage element at the upstream of the sewer. If there is no maximum volume constraint, leave this space blank. For Options 0, 2, and 3 also leave this space blank.	SSMAX	1.0E25
	41-50	F10.0	For an existing sewer, the volume in cu ft (m^3) of the existing storage element at the upstream end of the sewer. Otherwise, leave this space blank.	ESTOR	0.
	51-60	F10.0	Cost of detention storage in $/cu ft ($/m^3) for this particular sewer if it is different from the value entered in columns 11-20, Card 1, Set 4-COST. If detention storage is not considered in the optimization for this sewer (Options 0, 2, and 3) leave this space blank.	STORC	USTORC
	61-70	F10.0	Assessed damage cost in dollars for this sewer in the event of flooding due to inadequate capacity of this sewer and if this value is different from the default value specified in columns 11-20 of Card 1, Set 5-RISK. If ILSD-1 is used, leave this space blank. For ILSD-2 using the integration risk analysis ("0" in column 5 of Card 1, Set 5-RISK), also leave this space blank. For ILSD-2 using risk functions ("1" in column 5 of Card 1, Set 5-RISK) this value is specified in scientific format with the last digit placed in column 60.	DAMC	DEDAMC
	71-75	I5	Risk equation identification number referring to Card 3 of Set 5-RISK; e.g., for the second risk equation enter a "2" in column 65. This number is required only when more than one risk equations ("2", "3", or "4" in column 5 of Card 1, Set 5-RISK) of ILSD-2 is used and the risk equation used for this sewer is not the first equation. Otherwise, leave this space blank.	RISKF	1

Set 6 - NETWORK

Card Number	Card Column	Format	Description	Variable Name	Default Value
****			*Repeat the sub-group of cards 1, 2, and 3 (if required) for each sewer until all the sewers are accounted for. Then Set 6-NETWORK is concluded with card number 4 identifying the exit node number.*	****	
4	1-5	I5	The node number at the exit of the last sewer of the entire system. This number is placed right justified e.g., "9001".	CNODE (MANT)	None
	6-10		Leave blank.		
	11-20	F10.0	Ground elevation in ft (m) of the last node; e.g., "88.0".	GEL (MANT)	None

Set 7 - HG

Card Number	Card Column	Format	Description	Variable Name	Default Value
****			*This HG card set provides information concerning the inflow hydrographs into the manholes.*	****	
1	1-5	I5	The total number of inlet hydrographs that enter the sewer network, including those supplied directly by the user and those to be generated from rainfall. This number can be equal to, greater, or less than the number of manholes. This number must be placed right justified; e.g., "12".	NK	None
	6-10	I5	If any of the inlet hydrographs are to be produced from surface runoff simulation, place a "1" in column 10. If none, leave this space blank.	IRAIN	0
	11-15	I5	If the user desires to print out the values of *all* of the simulated inlet hydrographs generated from rainfall, a "1" is placed in column 15. User supplied inlet hydrographs directly into manholes are always printed out. If only selected inlet hydrographs generated from rainfall are to be printed out, leave this space blank.	WRITHY	0

**** *Following the first card in this Set 7-HG are the cards pertinent to individual inlet hydrographs. Each inlet hydrograph contains one or more cards according to* **one** *of the following three options:* ****

(a) Card 2 only is used for triangular inlet hydrographs.
(b) Cards 2 and 3 together are used for arbitrary-shape inlet hydrographs supplied by the user.
(c) Cards 4 and 5 only are used when the inlet hydrograph is generated through surface runoff simulation.

Different options are allowed for different inlet hydrographs, whether they are entering to the same or different manholes. But for a given hydrograph only one option is allowed. A manhole can have zero, one or more than one hydrographs entering into it. Different inlet hydrographs, irrespect of the options, can be entered at any random order. For each inlet omit the cards for the options that are not used. No blank cards are required for an inlet without an inflow hydrograph.

Card Number	Card Column	Format	Description	Variable Name	Default Value
2	1-5		Leave blank.		
	6-10	I5	Manhole number where the inlet hydrograph enters; e.g., "9001". This number must be placed right justified.	MAN	None
	11-20	F10.0	Time when inlet hydrograph into the manhole inlet starts, in minutes; e.g., "4." This time is the time, TAU, after the initial time specified, at which the inflow hydrograph begins to rise from the base flow (see Fig. 8).	TAU	0.
	21-30	F10.0	Duration of the inlet hydrograph in minutes; e.g., "22." This value is the time base DUR (see Fig. 8) of the input hydrograph at the manhole.	DUR	None
	31-40	F10.0	Time interval of inlet hydrograph values in minutes (see Fig. 8); e.g., "5.0". This time interval is constant for a hydrograph but can be different for different inflow hydrographs. The default value is the same as DT in Card 2 of Set 3-DI.	DDT	DT
	41-50	F10.0	Magnitude of initial base flow into the manhole inlet in cfs (m^3/s); e.g., "0.1". This value is QB in Fig. 8.	QB	0.
	51-60	F10.0	Magnitude of final base flow into the manhole in cfs (m^3/s); e.g., "0.2". This value is QE in Fig. 8.	QE	0.
	61-70	F10.0	For a triangular inlet hydrograph, the magnitude of peak discharge of the hydrograph in cfs (m^3/s); e.g., "5.42". This value is QP as defined in Fig. 8. If the inlet hydrograph is not triangular, leave this space blank.	QP	None
	71-80	F10.0	For a triangular inlet hydrograph the ratio of the time when peak flow occurs to the duration of the inlet hydrograph; i.e., A0= PT/DUR (see Fig. 8) e.g., "0.4". For the case of A0=0, enter "1.E-25". If the inlet hydrograph is not triangular, leave this space blank.	AO	0.5

Set 7 - HG

Card Number	Card Column	Format	Description	Variable Name	Default Value
3	***		*This card is needed only for user provided arbitrary shape inlet hydrographs. It gives the discharge values for each time interval of the inlet hydrograph. Referring to the value in columns 21-30 of Card No. 2 of this card set as DUR and the value in columns 31-40 of Card No. 2 as DDT, the total number of discharges specified in the format below must be equal to (DUR/DDT) +1. If DUR/DDT is not an integer, the truncated value will be used.* *If more than 8 values are required it is necessary to continue these flow values on successive cards in the same format. A maximum of 60 values can be specified, i.e., a maximum of 8 cards of Card 3 for each inlet hydrograph.*	***	
	1-10	F10.0	The inlet hydrograph flow rate in cfs (m^3/s) at time t = 0; e.g., "0.42".	QX(1)	None
	11-20	F10.0	The inlet hydrograph flow rate in cfs (m^3/s) at the end of the first time interval, t = DDT; e.g., "0.66".	QX(2)	None
	21-30	F10.0	The inlet hydrograph flow rate in cfs (m^3/s) at time t = 2 * DDT; e.g., "1.01".	QX(3)	None
	31-40 41-50 . . .	F10.0 F10.0 . . .	Repeat for each DDT increment until the inlet hydrograph is completely specified. Each value must be placed in the ten columns allocated.	QX( )	None

Card Number	Card Column	Format	Description	Variable Name	Default Value
4	***		*This card number 4 is used only when one or more inlet hydrographs are generated from rain input. In this case a "1" must appear in column 10 of Card 1 of this card set, and Card Set 8-RAIN must be entered.*	***	
	1-5	I5	A "1" must be placed in column 5 to indicate that this inlet hydrograph will be generated through surface runoff simulation.	IHY	None
	6-10	I5	Manhole number where the inlet hydrograph enters the system. This number must be placed right justified.	INLET1	None
	11-20	F10.0	Total drainage area of the subcatchment for this inlet hydrograph in acres (ha).	BA	None
	21-25	F5.0	Directly connected impervious area in acres (ha).	CPA	None
	26-30	F5.0	Directly connected impervious area in percent of total subcatchment area for this inlet. This is an alternate to the preceding item (CPA). Only one should be specified, not both.	PCPA	None
	31-35	F5.0	Supplemental impervious area in acres (ha). This is the area which flows onto directly contributing pervious areas before reaching the inlet.	SPA	None
	36-40	F5.0	Supplemental impervious area as percent of total subcatchment area for this inlet. This is an alternate to specifying the preceding item (SPA). Only one should be specified, not both.	PSPA	None
	41-45	F5.0	Directly contributing pervious area in acres (ha).	CGA	None
	46-50	F5.0	Directly contributing pervious area as percent of the total subcatchment area for this inlet. This is an alternate to the preceding item (CGA). Only one should be specified, not both.	PCGA	None

Card Number	Card Column	Format	Description	Variable Name	Default Value
4	51-55	F5.0	Supplemental pervious area in acres (ha). This is an area which flows onto directly connected impervious area before reaching the inlet.	SGA	None
	56-60	F5.0	Supplemental pervious area in percent of the total subcatchment area for this inlet. This is an alternate to specifying the preceding item (SGA). Only one should be specified, not both.	PSGA	None
	***		*The following two mutually exclusive items concerning the non-contributing area are entered only as a check, whether the sum of the component areas is equal to the total subcatchment area (BA). If the checking is not desired, "-1" must be entered for either one of the values, not both.*	***	
	61-65	F5.0	Non-contributing area in acres (ha).	NCA	0.
	66-70	F5.0	Non-contributing area in percent of the total subcatchment area for this inlet This is an alternate to specifying the preceding item (NCA) Only one should be specified, not both.	PNCA	0.
	71-80	I10	If the rain-generated hydrographs for all the inlets will not be printed (Option "0" in columns 15 of Card 1 of this card set 7-HG) and yet it is desired to print out the simulated inlet hydrograph for this inlet, enter a "1" in column 80. For RAIN Optin "0" in Set 8-RAIN, Card 1, column 5, this print command "1" will print out the hyetograph for the design of the sewer whose upstream end is connected to the manhole specified in columns 6-10 of this card, and it will also print all the simulated inlet hydrographs upstream of this sewer which are generated from the design hyetograph. Otherwise, leave this space blank.	HYD	0

Card Number	Card Column	Format	Description	Variable Name	Default Value
5		***	*This card is needed only when rain-generated inlet hydrographs are involved.*	***	
	1-5		Leave blank.		
	6-10	I5	Manhole number where the inlet hydrograph enters. This number is right justified.	INLET	None
	***	*Two options are allowed to specify the time of concentration for the direct impervious area, direct pervious area, and supplemental pervious area.* *(a) It can be provided by the user; or* *(b) It can be computed by inputting the slope and length of the flow path.* *Different options are allowed for different component areas of the same inlet and for different inlets. However, for each component area only one option is allowed, not both.*		***	
	11-15	F5.0	User provided direct impervious area entry time in minutes. This is the time of concentration at the inlet for the directly connected impervious area.	PENT	5.
	16-20	F5.0	Length in ft (m) of the longest directly connected impervious area flow path to the inlet. If the direct impervious entry time (PENT) is specified, this space must be left blank.	PL	None
	21-25	F5.0	Slope (in percent) of the directly connected impervious area flow path. If the impervious entry time (PENT) is specified, this space must be left blank.	PS	None
	26-30	F5.0	User provided direct pervious area entry time in minutes. This is the time of conetration at the inlet for the directly contributing pervious area.	GENT	20.

Set 7 - HG

Card Number	Card Column	Format	Description	Variable Name	Default Value
5	31-35	F5.0	Length in ft (m) of the longest directly contributing pervious area flow path to the inlet. If the direct pervious entry time (GENT) is specified, this space must be left blank.	GL	None
	36-40	F5.0	Slope (in percent) of the directly contributing pervious area flow path. If the direct pervious entry time (GENT) is specified, this space must be left blank.	GS	None
	41-45	F5.0	User provided supplemental pervious area time of concentration to the directly connected impervious area, in minutes.	SGENT	20.
	46-50	F5.0	Length in ft (m) of the longest supplemental pervious area flow path to the directly connected impervious area. If the supplemental pervious area time of concentration (SGENT) is specified, this space must be left blank.	SGL	None
	51-55	F5.0	Slope (in percent) of the supplemental pervious area flow path. If the supplemental pervious area time of concentration (SGENT) is specified, this space must be left blank.	SGS	None
	***		*The following four items specify the values of the soil type, antecedent soil moisture condition, and initial abstraction losses for the impervious and pervious areas for this particular subcatchment only if they are different from the common values specified in Card 2, Set 8-RAIN. Otherwise leave the corresponding spaces blank.*	***	
	56-60	I5	This number identifies the SCS hydrologic soil group for the subcatchment drained by the specified inlet. Enter the number in column 60 only if it is different from that specified in column 45 (SOIL) of Card 2, Set 8-RAIN.	GROUP	SOIL

Set 7 - HG

Card Number	Card Column	Format	Description	Variable Name	Default Value
5	61-65	I5	Antecedent soil moisture condition for the subcatchment. Enter the number in column 65 only if it is different from that specified in column 20 (AMC) of Card 2, Set 8-RAIN.	SAMC	AMC
	66-70	F5.0	Initial abstraction loss in in. (mm) for impervious areas in the subcatchment. Enter the value here only if it is different from that specified in columns 21-30 (ABSTRT) of Card 2, Set 8-RAIN. If the initial loss is zero, enter "1.E-9".	SABS	ABSTRT
	71-75	F5.0	Initial abstraction loss in in. (mm) for pervious areas in the sub-catchment. Enter the value here only if it is different from that specified in columns 31-40 (DEPG) of Card 2, Set 8-RAIN. If the initial loss is zero, enter "1.E-9".	SDEPG	DEPG
	76-80	F5.0	A rainfall area adjustment factor which can be used to adjust all rainfall hyetograph ordinates for this inlet. If no adjustment is needed leave this space blank.	FREQR	1.0

**** *Repeat Cards 2, 2 plus 3, or 4 plus 5 until all the inlet hydrographs are accounted for. Card number 3 must follow the corresponding card number 2 of the same inlet hydrograph. Likewise, card number 5 must follow the corresponding card number 4 of the same inlet hydrograph. Otherwise, the cards (i.e., the inlet hydrographs) can be entered or generated in any random order.* ****

Set 8 - RAIN

Card Number	Card Column	Format	Description	Variable Name	Default Value
****			*If all the inlet hydrographs are supplied by the user and there is no need to generate any inlet hydrographs through surface runoff simulation, i.e., if a "0" or blank is placed in Column 10 of Card number 1 of Card Set 7-HG, omit Card Set 8-RAIN.* *This RAIN card set contains at least two cards and it provides the rainfall and abstraction data necessary for inlet hydrograph generation.*	****	
1	***		*This card enters information concerning rainfall.*	***	
	1-5	I5	Hyetograph source identification. Four options are available. A "0", "1", "2", or "3" is entered in column 5. (a) A "0" denotes different triangular hyetographs for the design of different sewers; these hyetographs are generated from user supplied design return period and intensity formula. (b) A "1" indicates the user will supply the values of a hyetograph of arbitrary shape which will be applied to the entire drainage basin. (c) A "2" indicates a triangular hyetograph, which is generated from user supplied rainfall duration and depth. It will be applied to the entire drainage basin. (d) A "3" represents a triangular hyetograph which is generated from user supplied design return period, rainfall excess duration, and intensity formula. It will be applied to the entire drainage basin.	RAIN	0
	6-10	F5.0	Time interval in minutes for user supplied hyetograph (RAIN=1). Leave blank for all other RAIN options.	DELT	5.0
	11-15	F5.0	Time interval in minutes for the values of the hydrographs generated by surface flow simulation (IHY=1 on card set 7-HG, Card 4). This value should not be greater than that specified for DELT if a user supplied hyetograph is used (RAIN=1).	DELTIH	DELT

Card Number	Card Column	Format	Description	Variable Name	Default Value
1	16-20	F5.0	Total rainfall depth in in. (mm); e.g., "1.27". For Option "1" this number is optional and if entered, serves as a check. If the rainfall intensity formula is used, i.e., if Options "0" or "3" is entered in column 5 of this card, leave this space blank.	TRAIN	None
	21-25	F5.0	For RAIN Option "2" this value is the user specified rainfall duration in minutes; e.g., "120." For RAIN Option "3" this value is the user specified duration of rainfall excess in minutes; the total rain duration is this value added to the computed time required to satisfy the initial losses. For the other two options (0 and 1) leave this space blank. For RAIN Option "1" the duration is computed as NRI*DELT.	DURA	None
	26-30	I5	The number of hyetograph values to be provided by the user in Card 3 of this set if RAIN Option "1" is used, maximum 60. This value is ignored for other RAIN Options.	NRI	None
	31-35	F5.0	Rainfall return period in years; e.g., "5." For Options "1" and "2" in column 5 of this card, return period is not included in computation and this space can be left blank; and if entered, the value will be printed out.	FREQ	None
	36-40	F5.0	Ratio of time of peak rainfall to rainfall duration; e.g., "0.35". If the value of this ratio is zero, enter "1.E-9". If the hyetograph is supplied by the user (Option 1 in Column 5 of this card) leave this space blank.	AP	0.33

Set 8 – RAIN

Card Number	Card Column	Format	Description	Variable Name	Default Value
1	***		*If the rainfall intensity formula is not used, (i.e., Options "1" and "2" in column 5 of this card) leave spaces 41-65 blank. The following values are required only for Options "0" and "3" in column 5. They are the coefficients of either one of the following two formulas* *Intensity* = C_1x FREQ^a/(C_2+DUR^b) *or* *Intensity* = C_1x FREQ^a/(C_2+DUR)$^{b'}$	***	
	41-45	F5.0	Coefficient C_1 in the average rainfall intensity formula; e.g., "120."	C1	None
	46-50	F5.0	Coefficient C_2 in the average rainfall intensity formula; e.g., "10."	C2	None
	51-55	F5.0	Exponent a in the average rainfall intensity formula; e.g., "0.18".	EXPA	None
	56-60	F5.0	Exponent b in the average rainfall intensity formula; e.g., "0.70".	EXPB	None
	61-65	F5.0	Exponent b' in the average rainfall intensity formula; e.g., "0.8".	EXPC	None
	***		*Either EXPB or EXPC is specified according to the equation used, not both.*	***	

Card Number	Card Column	Format	Description	Variable Name	Default Value
2	***		*This card provides information on common abstractions for the entire drainage basin.*	***	
	1-10		Leave blank		
	11-20	I10	Antecedent soil moisture condition. The user must enter one of the following four numbers: 1 = bone dry 2 = rather dry 3 = rather wet 4 = saturated	AMC	3
	21-30	F10.0	Initial abstraction losses for impervious areas in in. (mm), e.g., "0.15". If the initial loss is zero, enter "1.E-9".	ABSTRT	0.1
	31-40	F10.0	Initial abstraction losses for pervious areas in in. (mm), e.g., "0.3". If the initial loss is zero, enter "1.E-9".	DEPG	0.2
	41-45	I5	Predominant soil type in integer designation: 1 = SCS soil group A 2 = SCS soil group B 3 = SCS soil group C 4 = SCS soil group D	SOIL	2
	***		*The above values are assumed for all the subcatchments of the entire drainage system unless they are overridden by specifying for the particular items for a given subcatchment as indicated in the appropriate spaces in columns 56 to 75 on Card 5 of Set 7-HG.*	***	

Set 8 - RAIN

Card Number	Card Column	Format	Description	Variable Name	Default Value
3	***		*The user supplied hyetograph is entered in this card. If there are more than 8 data values, enter them on succeeding cards. This card is needed only when Option "1" is entered in Column 5 (RAIN) of Card 1 of this set. If a "0", "2" or "3" is entered in that column, this card must be omitted.*	***	
	1-10	F10.0	Hyetograph values in in. (mm) for successive time intervals DELT. A value is entered in each 10 column space with a maximum of 8 values per card. Sufficient cards are used to specify the entire hyetograph.	RR( )	None
	11-20	F10.0			
	.	.			
	.	.			
	.	.			
	.	.			

4.2 Example Input Data

The input data for the design of the sewers of a drainage basin using ILSD-1 and English units is given in the following as an example. The drainage basin is located at Goodwin Avenue, Urbana, Illinois shown in Fig. 11. The data concerning the catchments are summarized in Table 3. The catchments are identified by the number of the manholes they drain into. The sewer system input data are summarized in Table 4. Inlet hydrographs are generated from rainfall for only four catchments (No. 21, 41, 61, and 71). Rain Option 0 is used and the intensity formula is

$$\bar{i}(\text{in./hr}) = \frac{111\ T_r^{0.17}}{t_d + 19}$$

where the design return period T_r is 5 years and the duration t_d is in minutes. As a simple illustration, the inlet hydrographs for other inlets are assumed known, triangular in shape with the peak discharge and time to peak (PT in Fig. 8) given in Table 4, whereas the initial time (TAU in Fig. 8) is zero.

The cost option used is Option 1, user supplied cost tables. There are two classes of pipes, each has 11 different sizes. There are two types of soil in the basin, type 1 - soft soil, and type 2 - hard soil. For each soil there are three different excavation costs for three different depth ranges. It is desired to print the cost tables in the computer output.

The input data for the example are arranged according to the input data format described in Section 4.1 and listed in Table 5.

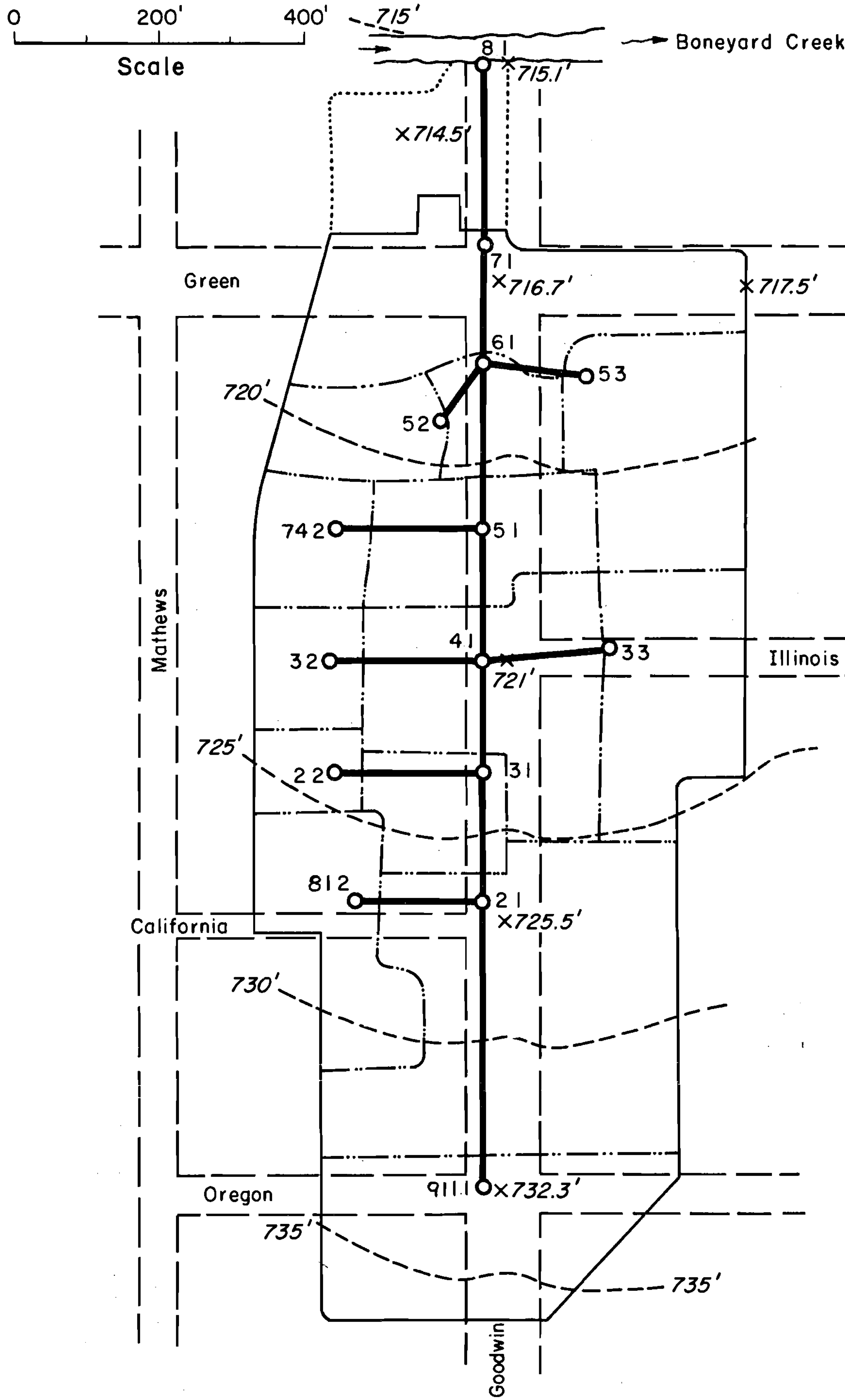

Fig. 11. Goodwin Avenue Drainage Basin at Urbana, Illinois

Table 3. Characteristics of catchments of Goodwin Avenue Drainage Basin

Catchment	Total area A	Direct contributing impervious area				Direct contributing pervious area				Supplemental pervious area				Supplemental impervious area	Non-contributing area
		Size	Flow length	Slope	Entry time	Size	Flow length	Slope	Entry time	Size	Flow length	Slope	Entry time	Size	Size
	ac		ft	%	min		ft	%	min		ft	%	min		
9111	2.20														
812	1.20														
21	3.90	40%			11	30%			20					25%	5%
22	0.45														
31	0.70														
32	0.60														
33	1.70														
41	2.00	1.10 ac			9.5	0.20 ac	40	0.30		0.40 ac			15	0.30 ac	
742	0.65														
51	1.25														
52	0.70														
53	1.70														
61	0.60	80%	180	1.03		10%			25	10%			20		
71	2.30	70%			10	0.46 ac			20	10%	80	1.20			

Additional Input Data:

Antecedent moisture = rather wet
Pervious surface soil type = SCS type C
Initial losses = Default values

Table 4. Input sewer data for example drainage basin

Manhole Number Upstream	Downstream	Ground Elevation at Upstream Manhole ft	Sewer Length ft	Peak Flow Q_p cfs	Time to Peak, t_c min
9111	21	731.1	390	5.72	11.0
812	21	725.5	183	4.13	9.2
21	31	724.3	177		
22	31	723.1	200	1.91	5.2
31	41	722.5	156	2.16	8.7
32	41	723.5	210	2.59	5.9
33	41	721.9	130	4.32	11.8
41	51	720.9	181		
742	51	719.9	200	2.75	6.2
51	61	721.2	230	3.61	10.3
52	61	719.1	70	1.79	11.8
53	61	722.0	130	3.10	17.6
61	71	718.1	161		
71	81	715.4	251		
81 (outlet)		715.1			

Additional Input Data:

Minimum invert elevation at Outlet (81) = 705.5

Minimum Soil Cover Depth = 3.5 ft

Velocity Constraints: V_{max} = 20.0 fps
V_{min} = 2.0 fps

Manning's n = 0.014

Number of Lattice Points = 7

Initial State Increment = 2.0 ft

Minimum State Increment = 0.05 ft

Time Increment = 1 min

Total Time for Routing Computations = 59 min

Hydrograph Initial Base Time TAU = 0.0 for all manholes with input inlet hydrographs

Hydrograph Base Flow QB = 0.1 cfs for all manholes with input inlet hydrographs

Detention storage is allowed at Manhole 41 with a maximum storage volume = 50000 cu ft; and at this location, soft soil (type 1) covers the top 7 ft, below which is hard soil. The detention storage cost is $2 per cu ft.

Table 5. Input data card format for the example basin

Card set	Card No. (column)	Entry cols 1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55
1-Title	1		GOODWIN AV. EXAMPLE DATA									
2-Model	1	1	0									
3-DI	1				3.5		20.0				0.014	
	2		1.		59.							
	3	7		2.		.05						
	4	15	1									
4-Cost	1	1	1		2.							
	4a-1	2										
	4a-2	7.										
	4a-3	11	11									
	4a-4	12.	15.	18.	21.	24.	27.	30.	36.	42.	48.	54.
	4a-5	3.40	4.45	5.90	7.40	9.20	10.25	13.15	18.40	24.10	30.25	37.95
	4a-4	12.	15.	18.	21.	24.	27.	30.	36.	42.	48.	54.
	4a-5	3.40	4.45	5.90	7.40	9.20	11.05	14.20	19.05	25.00	32.45	39.45
	4b-1	2	3	3								
	4b-2	4.	9.									
	4b-3	3.	4.	5.5								
	4b-2	3.	8.									
	4b-3	5.	7.5	10.								
	4c-1	1										
	4c-3	100.										
6-Network	1	9111	21	731.1								
	2				390.							
	1	812	21		725.5							
	2			183.								
	1	21	31		724.3							
	2				177.							
	1	22	31		723.1							
	2				200.							
	1	31	41		722.5							
	2				156.							
	1	32	41		723.5							
	2				210.							
	1	33	41		721.4							
	2				130.							

Card set	Card No. (Column)	Entry 1–5	6–10	11–15	16–20	21–25	26–30	31–35	36–40	41–45	46–50	51–55	56–60	61–65	66–70	71–75	76–80
6-Network	1	41	51		720.9												
	2				181.				7.				2				
	3				1				50000.								
	1	742	51		719.9												
	2				200.												
	1	51	61		721.2												
	2				230.												
	1	52	61		719.1												
	2				70.												
	1	53	61		722.												
	2				130.												
	1	61	71		718.1												
	2				161.												
	1	71	81		715.4								705.5				
	2				251.												
	4	81			715.1												
7-HG	1	14	1														
	2		812		0.		18.4		2.		0.1		0.2		4.13		.5
	2		9111		0.		22.		2.		0.1		.2		5.72		.4
	2		22		0.		10.4		2.		0.1		.2		1.91		.5
	2		31		0.		17.4		2.		0.1		.2		2.16		
	2		32		0.		11.8		2.		0.1		.2		2.59		
	2		33		0.		23.6		2.		0.1		.2		4.32		
	2		53		0.		35.2		2.		0.1		.2		3.10		
	2		742		0.		12.4		2.		0.1		.2		2.75		
	2		51		0.		20.6		2.		0.1		.2		3.61		
	2		52		0.		23.6		2.		0.1		0.2		1.79		
	4	1	21		3.90		40.		25.		30.				5.		
	5		21	11.			20.										
	4	1	41		2.0	1.10		0.3		0.2		0.4					
	5		41	9.5				40.	0.3	15.							
	4	1	61		0.6		80.				10.		10.				
	5		61		180.	1.03	25.			20.							
	4	1	71		2.3		70.			0.46			10.				
	5		71	10.			20.				80.	1.20					
8-Rain	1			1.				5.		111.	19.	0.17	1.				
	2										3						

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