Urban Hydrology Design Using Soil Conservation Service TR-55 and TR-20 Models

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The Soil Conservation Service for many years has been using two computer models for urban hydrology planning and design: *Computer Program for Project Formulation—Hydrology* (TR-20) and *Urban Hydrology for Small Watersheds* (TR-55). The needed revisions to TR-20 do not directly affect its application in urban areas, whereas the proposed revisions to TR-55 could affect the peak discharges. The primary change is in the velocity method for computing time of concentration, which deals with the sheet flow and concentrated flow.

The Soil Conservation Service (SCS) has two watershed computer models that can be used in urban hydrology design: *Computer Program for Project Formulation—Hydrology* (TR-20) (*1*) and *Urban Hydrology for Small Watersheds* (TR-55) (*2*). The TR-20 computer program was developed in 1965 and has been modified several times since then. The TR-55 document was initially issued in May 1975 (*3*) and was revised and issued with a computer program in June 1986 (*2*); it has not been modified since then.

GENERAL

TR-20 (*1*) is a more complex computer model that

- Develops hydrographs,
- Routes hydrographs through reservoirs,
- Routes hydrographs through valley reaches, and
- Adds hydrographs.

TR-55 is a simplified procedure that uses the results from running TR-20. The calculations can be performed without using a computer. TR-55 does not develop or route individual hydrographs.

Neither model is to be used for storm sewer design, but the models can be used to show the effects of urbanization on the peak rates and volumes of runoff. In urban situations they are used most often to design or plan storm water management structures.

INPUT

TR-20 and TR-55 both require the same basic inputs of runoff curve number (*CN*), time of concentration (T_c), and drainage area (*DA*) for computation of peak discharge and the volume of runoff for a specific rainfall distribution. TR-20 allows the user to define the rainfall temporal distribution. TR-55 has four design rainfall distributions. In dealing with smaller drainage areas, the principal concern among the three variables *CN*, T_c, and *DA* is T_c.

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Time of Concentration

The original TR-55 (*3*), published in 1975, had two methods for calculating T_c: the lag method and the velocity method. The velocity method involved computing the travel time for overland flow, storm sewer or road gutter flow, and channel flow. The 1986 version (*2*) changed the procedure for computing overland flow and eliminated storm sewer or road gutter flow. Both methods of estimating T_c are described in the following sections.

Lag Equation

The lag equation is strictly empirical and was developed from data from small agricultural watersheds. The flow from or in small agricultural watersheds was primarily overland flow, in comparison with primarily channel flow in large watersheds.

The lag equation is

$$\text{Lag} = L^{0.8}(S + 1)^{0.7}/1{,}900Y^{0.5} \quad (1)$$

where

Lag = lag (hr);
Y = average slope of watershed (%);
S = [(1,000/CN') − 10], where CN' is the curve number; and
L = hydraulic length of watershed (ft).

Velocity Method

The velocity method incorporates three kinds of flow: sheet, shallow concentrated, and channel. The sheet flow portion is of primary concern.

The time of travel (T_t) for sheet flow is given as

$$T_t = 0.007\,(nL)^{0.8}/(P_2^{0.5}\,S^{0.4}) \quad (2)$$

where

T_t = travel times (hr);
n = Manning's roughness coefficient;
L = flow length (ft);
P_2 = 2-year, 24-hr rainfall (in.); and
S = slope of hydraulic grade line (land slope) (ft/ft).

Equation 2 was developed from the Manning's kinematic solution using the four SCS standard rainfall distributions. The original kinematic wave equation included rainfall intensity as a variable. Several studies were done to develop a relationship between the standard design rainfall distribution, 24-hr rainfall amount, and maximum hourly intensity.

For shallow concentrated flow, a graph of average velocity versus watercourse slope for only paved and unpaved conditions is used. The velocity is translated into travel time. Velocity for shallow concentrated flow assuming normal flow is given by the following generalized relationships:

$$V = 16.1345\,(S)^{0.5} \quad (3)$$

$$V = 20.3282\,(S)^{0.5} \quad (4)$$

These relationships assume that n is equal to 0.05 and the hydraulic radius is 0.4 ft for unpaved conditions and that n is equal to 0.025 and the hydraulic radius is 0.2 ft for paved conditions. They were developed assuming Manning's equation for wide rectangular channel conditions.

TR-55

The primary use for TR-55 is for before and after urbanization calculations. Therefore, the same T_c method should be used for both before and after. It would not be rational or consistent to use the lag equation for before conditions (agriculture) and the velocity method for after conditions (urbanized). In addition, the velocity method is more accurate and physically based.

Thus, when TR-55 was revised in June 1986, the lag equation was eliminated and the velocity method was expanded, especially with the addition of sheet flow in the headwaters. Concern is principally with the guidance given to use Equation 2 for a sheet flow of less than 300 ft, which was meant to be a maximum. Many users employ 300 ft regardless of the nature of the ground surface and the condition of the surface. In most cases the maximum length should be much less than 300 ft, possibly in the range of 75 to 125 ft, depending on the surface conditions. For small watersheds this choice of sheet flow length can affect T_c and the resulting peak discharge considerably.

TR-55 uses a short-cut routing procedure developed from routing of many storms through actual structures. The resulting regression equations were developed by a polynomial curve-fitting technique. The curves in Figure 6-1 in TR-55 are a function of both storm duration (24 hr) and rainfall distribution (Types 1, 2, 3, and 1a).

TR-20

The primary use of TR-20 is for watershed planning and evaluation studies. These studies involve determining the economic evaluation of various alternative structure measures. Such structures could include improvements to flood-retarding structure channels and land treatment and use changes. TR-20 can also be used to simulate recorded hydrographs. It is assumed that the same T_c calculation procedures will be used for all alternatives.

The velocity method for computing T_c is used with TR-20. This is the procedure explained in detail in TR-55 and discussed earlier.

TR-20 uses the storage indication method of reservoir routing and is not limited by storm duration and rainfall distribution. The ATT-KIN procedure is used for channel routing. The ATT-KIN procedure uses actual reach length and actual cross-section rating curves.

TR-55 uses the ATT-KIN routing procedure with an assumed velocity for a selected reach length to give a fixed routing interval as shown in Exhibits 5-I, 5-IA, 5-II, and 5-III in TR-55.

FUTURE WORK

Proposed changes in the next revision of TR-55 are as follows:

- For sheet flow:
  –Give more guidance on the maximum length criteria, and
  –Give more surface descriptions and corresponding n-values.
- For shallow concentrated flow, add more curves for other surface conditions instead of grouping them all into unpaved-type conditions.
- A new version of TR-20 is being developed. The new version will correct minor program problems, update the user's manual, provide a new input program, and provide the documentation for the ATT-KIN channel routing procedure.

REFERENCES

1. *Computer Program for Project Formulation—Hydrology.* Technical Release 20. Soil Conservation Service, U.S. Department of Agriculture, 1982.
2. *Urban Hydrology for Small Watersheds.* Technical Release 55. Soil Conservation Service, U.S. Department of Agriculture, June 1986.
3. *Urban Hydrology for Small Watersheds.* Technical Release 55. Soil Conservation Service, U.S. Department of Agriculture, May 1975.

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