

Chapter 17

Characteristic Width and Infiltration for Continuous SWMM

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A SWMM computer model was developed for the Detroit Water and Sewerage Department (DWSD) collection system to gain an understanding of overflows of combined and wet sanitary sewage (Camp, Dresser and McKee, 1993). This system serves both the City of Detroit and surrounding communities, with a service area of 800 square miles (2067 km²), which includes both combined and separated service areas. It contains a number of complex interconnections, loops, and overflow points within the system. Both SWMM EXTRAN and SWMM TRANSPORT were used to provide estimates of overflows within the system, while SWMM RUNOFF was used to compute the wet-weather inflows from the combined sewer service areas.

The SWMM EXTRAN model was developed for specific calibration and design events. The use of EXTRAN enabled a more detailed analysis of the complex hydraulic interactions within the large collection system. The information gained from this analysis was used as a basis for the continuous modeling. A continuous SWMM model was developed to

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provide estimates on annual overflows volumes and frequencies that could be expected for existing conditions and for a variety of alternative control strategies. For the continuous modeling, the SWMM TRANSPORT model was used for analysis of the collection system.

During the calibration of the continuous model, it was determined that the conventional approach of accounting for a subarea's internal routing by reducing the subarea's characteristic width resulted in underpredicting runoff volumes from pervious areas. This chapter deals with the problem of underpredicting runoff from pervious areas when the width parameter is used to account for internal routing and attenuation, and how this problem was addressed in the study of the DWSD collection system.

17.1 Traditional Internal Routing

The width of a subarea is one of several parameters used by RUNOFF in generating runoff from a subarea during wet-weather. RUNOFF calculates an overland flow length from the user-supplied width parameter as the area divided by the width. The SWMM user's manual suggests that the width parameter can be used to account for internal routing and attenuation, enabling delineation of larger subareas with less detail needed in defining the conveyance network: *To summarize, many subcatchments may be aggregated into a single lumped or equivalent subcatchment by using areally weighted subcatchment parameters and by adjustment of the subcatchment width.* (Huber, 1988). Reducing the width increases the flow length and storage within a subarea, resulting in effective attenuation of the runoff hydrograph without modeling in-system storage and pipe networks.

An example of how a reduction in the width parameter attenuates a runoff hydrograph is shown in Figure 17.1. The two hydrographs shown are for a 1,267 acre (515 ha) subarea, with a one-inch (25.4 mm) rainfall occurring over 4 hours. The two hydrographs are for the same subarea, the only difference being in their respective widths. In one case, the subarea was defined as having a flow length of 100 feet (30.5 m), with a resulting width being 550,000 feet (167,683 m). For the other case, the overland flow length was defined to be 7,400 feet (2,256 m), with a resulting width being 7,400 feet (2,256 m). As can be seen, the reduction in the peak flow rate is significant, with the peak rate dropping from approximately 850 cfs (24 m³/s) to 300 cfs (8.5 m³/s). Because of this attribute, the width parameter is commonly used for calibration of a runoff hydrograph shape.

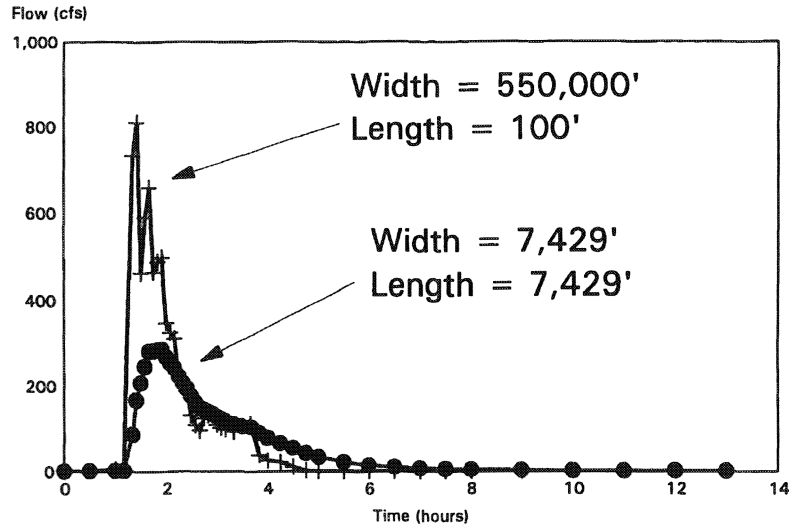


Figure 17.1
Impact of subarea width.

While several parameters can be adjusted to affect the runoff hydrograph volume and shape, the width parameter is often the primary parameter adjusted to obtain desired peak flow rates and hydrograph shapes.

For the study of the DWSD collection system, the subareas were delineated using both United States Geological Services (USGS) maps and local sewer maps. Directly-Connected Impervious Area (DCIA) estimates were made from an examination of aerial maps. Two sites were selected for calibration of RUNOFF, while both flow and stage data collected at over 30 sites within the conveyance system were used to check EXTRAN.

In defining the width for the subareas, the conventional method of using width to account for internal routing and attenuation was used. As the focus of the study was on the primary portions of the conveyance system, this level of detail was considered adequate. Reasonable results were obtained for the specific calibration event simulations. The use of this method with the continuous modeling, however, resulted in poor calibration. A closer examination of this method indicated that runoff from pervious areas was greatly underestimated. The cause of this problem is now discussed.

17.2 Problem with using Width Parameter for Routing

A reduction in the width parameter effectively increases overland flow length and overland flow travel time. This increase in overland flow length and travel time results in more time for infiltration to occur. As a result, decreasing the width not only provides for internal routing, it also allows additional infiltration to occur. It is this increase in the infiltration volume that is at the root of the potential problem with using width for a subarea's internal routing. For the previous example shown, the infiltration volume increased from 0.71 to 0.93 inches (18.03 to 23.62 mm) over the pervious area, a 22% increase. The total runoff volume is also reduced, from 0.59 to 0.45 inches (14.98 to 11.43 mm), a 14% reduction. The larger the subarea, the more clearly this problem is seen.

The continuous model was calibrated in a system with several very large subareas. The widths defined for these subareas resulted in unrealistically long travel lengths. During a 10-year simulation, the runoff generated from the pervious areas was extremely low. A review of the results indicated that the pervious areas were essentially infiltrating all of the rainfall occurring.

17.3 Possible Solutions

There are several possible solutions to this problem. First of all, the infiltration rates could be set artificially low to avoid overpredicting infiltration. This approach, however, would likely result in the model underpredicting infiltration in smaller subareas, a dubious and problematic solution at best.

Another approach to this problem would be to avoid "large" subareas and develop a more detailed conveyance system network. This approach may or may not be feasible, depending on whether the required information is available, and project time and money constraints.

For this modeling study, the system was already divided into seven submodels due to its size. In addition, an additional level of detail of flow routing within the subareas was not needed. To provide the desired internal routing and attenuation within the subareas, a more straightforward, empirical methodology was desired.

17.4 System Routing Alternative

Rather than using the subarea width to provide the routing and attenuation, an alternative strategy was developed. First, the width parameter was set to limit overland flow length to an actual distance that flow typically could be expected to travel before reaching an impervious surface or a natural channel in an urban setting. This process corrected the problem of overestimating infiltration. The problem was not with the infiltration rates, but with the use of the width parameter for internal routing, which resulted in longer travel lengths than would actually occur. For this study, a travel length of 100 feet (30.5 m) was considered appropriate for the urban areas in the DWSD collection system based on field inspection. The width accordingly was calculated as:

$$W = \frac{A}{100} \quad (17.1)$$

where:

- W = width of the subarea in feet, and
- A = subarea area in square feet.

Next, an artificial “routing channel” or ATC was developed to simulate in-system attenuation of flows. These ATCs consisted of large trapezoidal channels to provide routing and attenuation of a RUNOFF generated hydrograph before input into EXTRAN or TRANSPORT. A sensitivity analysis was performed with various ATC sizes, with the results compared to both calibration data and hydrographs generated using the Soil Conservation Service CN methodology. Through this process, the following empirical relationship for ATC sizing was developed and found to provide good results:

$$L = \sqrt{A} \quad (17.2)$$

$$W = \frac{\sqrt{A}}{2} \quad (17.3)$$

where:

- L = length of ATC in feet, and
- W = width of ATC in feet.

Figure 17.2 shows results for the same subarea used in the previous example, but with the above formulation. The two curves shown are before and after routing through the ATC. As can be seen, the peak rate is reduced from 850 cfs to 300 cfs (24 m³/s to 8.47 m³/s). This reduction demonstrates the ability of using ATCs for internal routing.

A problem did arise from the use of these large ATCs for routing: the way evaporation was being performed in RUNOFF. RUNOFF allows evaporation to occur from these channels. Since these channels represent sub-surface and saturated channel routing, this evaporation would be erroneous. Therefore, RUNOFF was modified to disable the calculation of evaporation from these ATCs.

Figure 17.3 compares the results for this ATC method versus using the width routing method. Both methods are able to attenuate the runoff hydrograph; however, the ATC method results in 0.71 inches (18 mm) of infiltration over the pervious area, while the width routing method results in 0.93 inches (23.6 mm) of infiltration. Thus, the ATC avoids overestimating infiltration volume. In addition, the total runoff volume is not underestimated, with the ATC method computing 0.59 inches (14.98 mm) of runoff versus 0.45 inches (11.43) obtained with the other method. These impacts are obviously more important as smaller rain events are considered, which of course is the case during continuous modeling work.

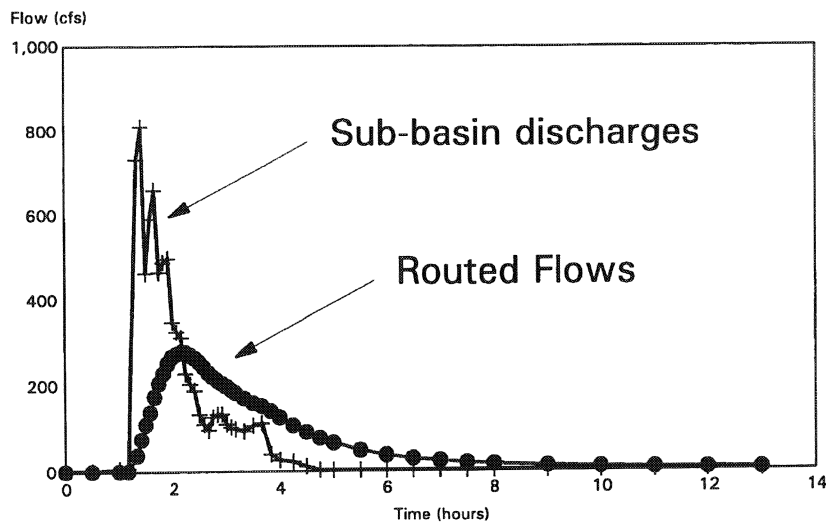


Figure 17.2
Routing channel attenuation.

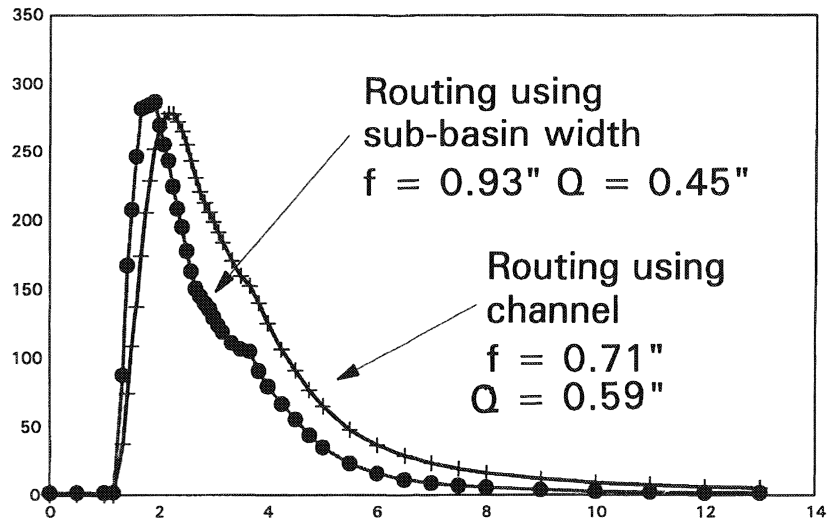


Figure 17.3
 Routing channel vs. characteristic width.

17.5 Summary

In developing a CSO model for the City of Detroit collection and treatment system, a new technique was developed to empirically account for overland flow length, infiltration, and internal routing/attenuation of a RUNOFF generated hydrograph for a combined service area. The conventional formulation of using the width parameter to account for a subarea's internal routing resulted in overestimating infiltration and underestimating pervious runoff. The larger the subarea, the more obvious the problem was. The use of a realistic flow length resulted in a more valid infiltration volume and a better estimate of runoff volumes from pervious areas. "Large" artificial trapezoidal channels (ATCs) were used to account for the internal routing/attenuation of a subarea's rainfall response. Empirical relationships were developed to size these ATCs to provide the desired level of attenuation of a subarea's hydrograph before being used as input to either EXTRAN or TRANSPORT.

References

Huber, W.C. and R.E. Dickinson. 1988. Storm Water Management Model, Version 4: User's Manual. Cooperative Agreement CR-811607. United States Environmental Protection Agency. Athens, Georgia. pp:64-104, 119-122.

Camp, Dresser and McKee, 1993. DWSD Model Development Status Report. Consultant Services Contract No: CS-1049, Detroit Water and Sewerage Department, Detroit, Michigan.