UTC Project Information

Project Title	MPC-481 – Incorporating River Network Structure for Improved Hydrologic Design of Transportation Infrastructure
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Project Duration	September 30, 2013 to September 30, 2018
Brief Description of Research Project	Sustainable construction and maintenance of transportation infrastructure requires accurate hydrologic design. A critical element of the hydrologic design is the estimation of the flow rates that bridges and culverts must convey and their abutments must withstand. It is difficult to determine reliable design flows because most channels are ungauged. Furthermore, urbanization and climate change are altering basins and introducing additional uncertainty. For ungauged basins, storm flows are most commonly estimated using synthetic unit hydrograph (UH) methods. Synthetic UHs are closely related to the travel time distribution for runoff that is produced throughout the basin to the outlet, and they are commonly estimated from the physical characteristics of the basin. Using an assumption that the storm flows are linearly related to the excess rainfall amounts, the synthetic UH can be used to determine the flow rates that are produced by any selected storm. Several methods are available in software such as HEC-HMS to estimate synthetic UHs. For example, the Soil Conservation Service (SCS) method in HEC-HMS is based on a single dimensionless UH that is assumed to apply in all cases. To develop the synthetic UH for a given basin, the dimensionless UH is simply rescaled using values for the time to peak and the peak UH value. Those two values can be calculated from the basin area, length, slope, and curve number. Similarly, the Clark method in HEC-HMS is based on a single time-area curve that describes the distribution of travel times to the outlet. The time coordinates are multiplied by the time of concentration, which is estimated in a similar

	manner as the time to peak in the SCS method. The resulting UH is then routed through a linear reservoir to determine the final synthetic UH.

The use of synthetic UHs has two recognized limitations. First, the approach assumes linearity between the excess rainfall amounts and storm flows at the basin outlet. However, it is well-known that higher volumes of flow tend to move faster. That behavior violates linearity and can increase the magnitude of the peak flow and potentially affect the suitability of a bridge or culvert design. Second, these synthetic UHs do not account for differences in the channel network structure. Channel networks are known to exhibit distinct structures (such as dendritic, parallel, pinnate, rectangular, or trellis) depending on the conditions under which they developed (Figure 1a). Such diverse networks are abundant in the mountains-plains region, and they convey flow to their outlets using very different flow-path distributions (Figure 1b).

Some synthetic UH methods have been proposed to allow consideration of basin shape. For example, the modified Clark method (Kull and Feldman, 1998) replaces the standardized time-area curve with one that is derived for the basin of interest. The geomorphic instantaneous unit hydrograph (Rodríguez-Iturbe and Valdés, 1979) describes the channel network using locally-derived Horton's ratios. Although these methods include the actual basin shape, they still rely on the linearity assumption. Other methods have been proposed to relax the linearity assumption, but they do not consider the channel network type.

Research Objectives:
This project has three primary goals:
1. Implement an alternative to the synthetic UH approach that allows nonlinearity and considers different network structures,
2. Identify conditions where nonlinearity affects the peaks flows,
3. Determine whether the network type provides sufficient information to determine the distribution of travel times. |
| Describe Implementation of Research Outcomes (or why not implemented)

Place Any Photos Here | The research outcomes were implemented in a journal publication that (1) thoroughly describes the proposed methodology and (2) tests the methodology against other existing approaches. Hydrologic engineers can read this article to develop the methodology in their own spreadsheet framework or more sophisticated model. |
| Impacts/Benefits of Implementation (actual, not anticipated) | The method produced in this project overcomes key limitations of existing methods that estimate stream flow in response to specified rainfall (e.g., a design storm). In particular, it accounts for the nonlinearity in the relationship between basin runoff and stormflow at the basin outlet. In addition, it considers the channel network type that occurs in the basin (e.g., dendritic or parallel). The method is simple enough to be implemented in a spreadsheet by practicing engineers and could be implemented in modeling software such as HEC-HMS because it does not require hydrologic computations on a grid. |
| Web Links | https://www.ugpti.org/resources/reports/details.php?id=984 |

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