MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 20-412 (project 481) | March 2020

Incorporating River Network Structure for Improved Hydrologic Design of Transportation Infrastructure

the ISSUE

Transportation infrastructure, such as bridges and culverts, must safely convey storm flows to assure functionality and public safety. To assess the hydrologic performance of such infrastructure, consultants frequently use modeling software. Many widely used hydrologic models, such as HEC-HMS (Feldman, 2000) and SWAT (Arnold and Fohrer, 2005), represent spatial variability within a watershed using a semi-distributed approach. Synthetic unit hydrograph methods currently used to assess hydrologic aspects of transportation infrastructure do not account for the channel network type such as dendritic (with tree-like networks), parallel (with major channels aligned with each other, pinnate (feather-like with a single main channel), rectangular (with right-angle bends and tributaries that merge at right angles) or trellis(resembling a garden trellis). This assumption may lead to errors in estimating storm flows, resulting in damage to infrastructure and risks to public safety.

the RESEARCH

The proposed research approach is based on flood-wave travel times that are derived from kinematic wave theory. A digital elevation model (DEM) was used to determine the basin topography and channel network. Each grid cell was identified as either a hillslope or channel cell based on its drainage area. The total travel time from each grid cell to the outlet was calculated by summing the travel times in each cell along the path to the outlet. Because the travel time expressions depend on the excess rainfall (i.e. runoff), the calculated unit hydrograph varies in time and higher flow rates have faster travel times. The storm flow hydrographs were determined using the time-varying unit hydrographs and the associated excess rainfall amounts. The approach was tested by application to ten basins in each of the five classifications. The results were compared to methods that explicitly consider the actual flow path networks and methods that neglect consideration of the network type.

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North Dakota State University
South Dakota State University
University of Colorado Denver
University of Denver
University of Utah
Utah State University
University of Wyoming

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Project Title

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the FINDINGS

The results show that consideration of the flow path network is important for hydrologic analysis of transportation infrastructure. The five different network types exhibit statistically distinct unit hydrographs that also result in distinct streamflow responses to design storms. Explicit consideration of the actual flow path network for a given basin is needed for most network types. However, for the pinnate type, the individual network structure can be described with adequate accuracy based on the network type and the size of the basin (and its hillslope size).

the IMPACT

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.

The method will increase the accuracy of predicting stormflows and so that transportation infrastructure can be designed appropriately to assure transportation reliability and public safety.

For more information on this project, download the entire report at https://www.ugpti.org/resources/reports/details.php?id=984

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.