OFFICE OF BRIDGE DEVELOPMENT
MANUAL FOR HYDROLOGIC AND HYDRAULIC DESIGN

CHAPTER 8 HYDROLOGY

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Chapter Table of Contents

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8.1. Introduction

Federal and State policies that apply to the hydraulic design of structures are presented throughout the various chapters of the Manual for Hydrologic and Hydraulic Design. The policies presented in this Chapter are those of the Office of Bridge Development which are to be used in preparing hydrologic studies for use in the design of SHA hydraulic structures and in the evaluation of scour for off-system bridges. These policies have been developed for the purpose of meeting the objectives of applicable Federal and State laws and regulations regarding flood plains while achieving the transportation objectives of a safe, efficient and cost-effective structure that is compatible with the geomorphology of the stream being crossed.

\8.2 Purpose of Hydrology Studies

Hydrology studies are conducted *for proposed bridges* for the purpose of obtaining the following types of information. (Conditions of ultimate development in a watershed, as mentioned below, are to be based on current zoning as depicted on applicable County or Municipal zoning maps):

1. The discharge associated with the bankfull stage for conditions of existing development in a watershed;

2. A flood frequency plot of the magnitude of flood peak flows for recurrence intervals of the 2, 10, 25, 50, and 100-year floods for conditions of existing development in the watershed.

3. A flood frequency plot of the magnitude of flood peak flows for recurrence intervals of the 2, 10, 25, 50, and 100-year floods for conditions of ultimate development in the watershed.

4. The design flood discharge, normally based on conditions of ultimate development in the watershed for purposes of evaluating the adequacy of the stream crossing for traffic service and safety as defined in Chapter 10. (We have experienced the rare situation where the ultimate development discharge is less that the existing condition discharge. For such a case, the existing development discharge is to be used). The maximum elevation of the design flood discharge shall be limited so that floodwaters do not encroach upon the bridge deck or the traffic lanes of the approach roads. Typically, the design flood will be one of the floods listed in Item 3 above.

5. The overtopping flood, the magnitude of which is determined by a trial and error evaluation of the HEC-RAS water surface profiles developed in accordance with the methodology described in Chapter 10. The frequency of the overtopping flood, determined for conditions of ultimate development in the watershed, is obtained from the flood frequency plot described in Item 3 of this list.

6. The 500-year flood, based on conditions of existing development in the watershed, for purposes of evaluating the stability of bridge structures to resist scour and hydraulic forces as required by the policies presented in Chapter 11, Bridge Scour.

7. The flood hydrograph associated with any of the flood peaks listed above.

Hydrology studies are also conducted for the purpose of evaluating the safety and efficiency of existing bridges. These studies generally are concerned with the magnitude and frequency of the overtopping flood, and the ability of the bridge foundations to resist scour, as discussed in Chapter 11. Depending upon the nature and the extent of these studies, the Office of Bridge Development will determine whether the hydrology of the site will be based on existing conditions or conditions of ultimate development.

8.3 Hydrologic Design Methodology for Maryland

The basic policy affecting the design approach to be used in estimating the magnitude and recurrence interval of floods is established by Maryland State Regulations; COMAR 08.05.03, Waterway Construction (2):

1. Hydrologic and hydraulic computations shall use methods in the public domain which are verifiable (Section .04K), and

2. Hydrologic calculations shall be based on the ultimate development of the watershed for conditions of existing zoning (Section .04F).

In 1997, the Maryland State Highway Administration and the Maryland Department of the Environment commissioned a Hydrology Panel to investigate how the above noted state regulations could best be accomplished with available hydrologic methodologies. The panel members were engineers and hydrologists with extensive experience and backgrounds in the field of hydrology.

The latest Hydrology Panel report entitled Application of Hydrologic Methods in Maryland, Second Edition (1) was approved by both the Maryland State Highway Administration and the Maryland Department of the Environment. *Both agencies have endorsed the report and have agreed that future hydrologic studies shall be conducted in accordance with the recommendations set forth in the report.*

The Office of Bridge Development continues to initiate studies to provide ways and means of improving the accuracy of hydrologic estimates of the magnitude and frequency of floods. However, it is clear that all hydrologic methodologies require the application of engineering judgment in order to take into consideration the many factors influencing the rainfall and runoff at a particular site. The Hydrology Panel recommendations and the GIS HYDRO program discussed below are not to be viewed as inflexible requirements or methodologies, restricting the application of common sense. The engineer or hydrologist conducting hydrologic studies is expected to use engineering judgment in preparing

hydrology reports. The Office of Bridge Development is to be consulted in the event that any guidance in this chapter appears to conflict with the application of engineering judgment.

8.4 GIS Hydro 2000

The SHA in cooperation with the University of Maryland has developed a software program entitled GIS HYDRO 2000 (3). This program provides extraordinary computational capabilities that greatly facilitate use of the TR-20 program of the National Resources Conservation Service (NRCS) as well as the use of the regression equations developed by the United States Geological Survey (USGS). The GIS HYDRO program is to be used as the basic tool for estimating flood discharges and flood hydrographs in Maryland. The recommendations of the Hydrology Panel, discussed in Section 8.3 above, are to be used in applying the GIS HYDRO program and in evaluating the program results.

The engineer or hydrologist using the GIS HYDRO 2000 program is expected to use engineering judgment in the application of this program. *The Office of Bridge Development is to be consulted in the event that any aspect of the program guidance appears to conflict with the application of engineering judgment.*

As of February, 2006, SHA continues to work with Dr. Glenn Moglen, University of Maryland, on a cooperative study effort to improve the effectiveness of GISHYDRO 2000:

- Preliminary exploratory programming has been performed to begin the conversion of GISHydro2000 from its ArcView-based platform to ArcGIS.
- A major new development this year has been the creation of a web-based version of GISHydro2000. With this version, users are able to access/use this program without needing a local installation of GISHydro2000 or associated software (ArcView and Spatial Analyst). The development of this web version has been supported by MDSHA, the Maryland Department of the Environment and the Maryland Department of Natural Resources
- Preliminary tools for developing water quality and stream biodiversity estimates and nutrient loads have been developed in conjunction with funding from the Maryland Department of Natural Resources.

- Finally, continued maintenance and development has seen the addition of a velocity method segment generation tool and the addition of SSURGO soils data for nine counties and 2002 land use for both Maryland and Delaware

8.5 Bankfull Flow

Sections 8.3 and 8.4 above address flood flows, generally defined as flows that exceed the capacity of the channel banks. These larger discharges represent severe hydrologic

conditions that need to be addressed for the structural stability of the highway structure and roadway, and the safety of the highway user and abutting property owners. However, a knowledge and understanding of the bankfull flow condition is also important in the location and design of a highway structure.

Bankfull flows typically have a recurrence interval of 1.1 to 1.5 years. Typically, bankfull flows occur within the limits of the channel banks. SHA determines the characteristics of bankfull flow using the procedures developed by Rosgen (4). Detained discussions and examples of bankfull flow are contained in the Maryland Stream Study (5).

Most of the sediment load moved by a river or stream over a long period of time will be moved by flows of the magnitude of the bankfull flow. Therefore, it is important that the effect of the highway structure on the bankfull flow be evaluated. The Office of Bridge Development conducts a geomorphology study as a part of the design of every highway structure for the purpose of maintaining or, in some cases, establishing a stable channel design. Geomorphology studies are discussed in Chapter 14.

One of the key elements in the geomorphology study is the determination of the characteristics of the bankfull flow, and such determination should be made as a part of the stream geomorphology study for every bridge project unless specifically waived by the Office of Bridge Development.

8.6 Federal Emergency Management Agency (FEMA)

FEMA is responsible for managing the National Flood Insurance Program. The agency has conducted flood studies throughout Maryland for purposes of limiting development on flood plains. Property owners within communities that are in compliance with the FEMA regulations are eligible for flood insurance. FEMA establishes limits on flood plain development for new studies, and maintains control over the development on flood plains where studies have been completed.

If a highway project affects a FEMA flood study, the SHA is required to prepare studies to show that (1) the project is consistent with the regulations of FEMA and (2) the project is consistent with the State regulations discussed in Section 8.3. FEMA is concerned with flood flows based on existing conditions in the watershed, and therefore has different standards than the state which estimates flood flows based on ultimate development in the watershed. It has been the experience of the SHA that, in general, the State requirements are more restrictive than the FEMA requirements, but this is not always the case. Procedures for addressing the requirements of FEMA are set forth in Chapter 4 of this manual.

8.7 Scheduling of the Hydrology Report

Preparation of the Hydrology Study is to be done early in the design process (See Chapter 3). If there is a FEMA flood study affected by the highway project, the study to show consistency with FEMA requirements shall proceed concurrently with the regular hydraulics

study; however, determination of the bankfull discharge is typically made as a part of the geomorphology study (See Chapter 3) for the project.

8.8 Hydrology Studies for Off-System Bridges

The SHA has reached an agreement with the Federal Highway Administration (FHWA) that SHA (Office of Bridge Development) will review scour evaluations for proposed off-system bridge projects which utilize Federal Highway funds to verify that the structures are designed in accordance with the FHWA standards for safety and structural stability. The standard SHA review and approval procedure for most off-system bridge locations is explained below:

- The Maryland Department of the Environment (MDE) is responsible for the hydrologic and hydraulic review and approval of off-system bridges. However, in some cases, MDE will issue permits approving the hydraulic design of an off-system bridge even though complete hydrologic and hydraulic studies were not performed. For example, a replacement-in-kind of an existing off-system bridge may be approved by the MDE without detailed hydrologic and hydraulic studies.

- For such cases where a TR-20 study is not required by the MDE, the SHA will accept the use of discharges determined from regression analysis (Fixed-Region equations in Appendix 3 of the Maryland Hydrology Panel report dated January 2005) for the estimation of the discharge for the 100-year flood and the incipient overtopping discharge (if less than the 100-year discharge). These discharges are to be based on the values of the upper 67% confidence limit as determined by the Tasker Program contained in the GISHYDRO Program or the standalone version. Using the values associated with the upper 67% confidence limit curve provides for a means of taking into account certain factors that cannot be assessed by regression analysis, such as the effects of ultimate development in the watershed.

- The upper 67% confidence limit curve is not recommended for estimating the magnitude of the 500-year flood for scour studies, because it is unlikely that ultimate development will result in such substantial increases for a flood discharge of this magnitude and frequency. Instead, the recommended procedure is to select the magnitude of the 500-year flood as the larger of (1) the upper 67% confidence limit value of the 100-year discharge or (2) the regression curve value for the 500-year flood.

- Proposed stream crossings in urban areas require additional consideration where 10% or more of the watershed has impervious areas. For such cases, the urban equations in the GISHYDRO 2000 Program should be used for watersheds in the Piedmont and Western Coastal Plain hydrologic regions. The effect of urbanization will be taken into account for watersheds in these regions by entering the percent of impervious areas in the regression equations. There currently is no generally accepted method for evaluating runoff from urban areas in other hydrologic regions in Maryland. The engineer is requested to consult with the Structures H&H Unit

regarding flood discharge estimates from urban areas in these other hydrologic regions.

8.8 References

1. Application of Hydrologic Methods in Maryland, Second Edition, Maryland State Highway Administration and Maryland Department of the Environment, August 2006.
2. Maryland State Regulations (COMAR 08.05.03, Waterway Construction).
3. Geographic Information System for Hydrologic Analysis, (GIS Hydro 2000), Glenn E. Moglen, Department of Civil Engineering, University of Maryland, College Park, MD.
4. Rosgen, David, Applied River Morphology, Wildlands Hydrology, Pagosa Springs, CO, 1996.
5. Maryland Stream Survey, Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region, U.S. Fish and Wildlife Service, March, 2002.
6. Maryland Stream Survey, Bankfull Discharge and Channel Characteristics of Streams in the Allegheny Plateau and the Valley and Ridge Hydrologic Regions, U.S. Fish and Wildlife Service, May 2003.
7. Maryland Stream Survey, Bankfull Discharge and Channel Characteristics of Streams in the Coastal Plain Hydrologic Region, U.S. Fish and Wildlife Service, July 2003.