OFFICE OF STRUCTURES

HYDROLOGIC AND HYDRAULIC DESIGN MANUAL

CHAPTER 4

PROJECT DEVELOPMENT

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STATE HIGHWAY ADMINISTRATION

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CHAPTER 4 PROJECT DEVELOPMENT

4.1 INTRODUCTION

This chapter describes the tasks and responsibilities of the Structure Hydrology and Hydraulics Division (SHHD) within the context of the Office of Structures (OOS) project development process for projects with structures in a floodplain (i.e., structures that provide waterway crossing). Detail regarding the specific tasks to be undertaken or reviewed by personnel of the SHHD, and how these tasks fit within the overall OOS project development process, are provided in Section 4.4 and Tables 4-1 and 4-2 (SHHD Project Milestones). The information provided in this chapter also applies to city or county projects which are constructed with Federal and/or State funds.

Structure design projects developed by the OOS are undertaken for the preservation, maintenance and safety of the highway system. Specifically, the OOS is responsible for design and maintenance of highway structures (replacement and rehabilitation of bridges, culverts, and retaining walls). There are two units within the OOS involved in this work; the Structure Engineering Divisions (SED) and the Structures Inspection and Remedial Engineering Divisions (SIRED). Herein, the term OOS Design Team is used to reference either the SED or SIRED project design teams. OOS Team Leader refers to the MDOT SHA personnel designated as the overall project leader. SHHD Team Leader refers to the MDOT SHA personnel assigned to lead the SHHD project team.

The OOS formal review stages for design projects are provided in the Office of Structures Design Manual (OOS Design Manual, MDOT SHA OOS, 2020). Chapters 2 and 3 of the OOS Design Manual provide information regarding the overall OOS project development process. Chapter 4 of the OOS Design Manual provides general information regarding the SHHD role and coordination required. Note that the OOS Design Manual and this Hydrologic and Hydraulic Design Manual (referred to as the SHHD Manual) are separate documents that together present the integrated guidelines and procedures of the Office of Structures.

This chapter focuses on the SHHD analyses and study required for the design element of OOS projects. The evaluation of environmental impacts and the preparation of environmental documents are handled by the Office of Planning and Preliminary Engineering (OPPE) in a collaborative effort with OOS.

4.2 TYPES OF PROJECTS

This section provides a description of the various OOS project types with which the SHHD is involved. This includes structure replacement, major and minor rehabilitation projects, and the replacement or repair of small structures.

Some OOS projects can be categorized as an “in-kind” replacement. A simplified analysis and expedited MDE Waterway Construction permit review process may be allowed for projects meeting this classification, as per the Maryland Department of Natural Resources (DNR) 1993 Operational Policy (SHHD Manual Appendix A), which represents current MDE policy. The majority of OOS replacement or improvement projects are considered “out-of-kind” replacement. These are replacement structures that are “sufficiently different from existing structures that they must

be considered as new bridge and culverts" (DNR, 1993). This includes the removal and replacement of a structure with a different facility type or size, as well as the modification (extension or widening) of a bridge or culvert.

The SHHD is not typically involved in planning projects, which include major highway projects such as interstate highways on new location. When such studies are undertaken, a process will be established at that time to provide for appropriate SHHD review and coordination throughout the planning, location and design phases of the project. Accordingly, detailed information regarding the project milestones for planning projects is not provided in this chapter. The hydrologic and hydraulics analysis procedures described in this manual are applicable in the structure design phase of such projects.

4.2.1 Structure Replacement Projects

OOS structure replacement projects typically require the most significant level of hydrologic and hydraulic study and analysis. In addition to the design of the replacement bridge or culvert, structure replacement projects may or may not include roadway improvements, channel stability improvements, and/or aquatic organism passage (AOP) improvements. Roadway improvements may be required in order to meet the design storm criteria, public safety or future roadway needs, context driven design, and/or AASHTO requirements. Channel stability improvements may be required to address existing instabilities that threaten infrastructure, or to address instabilities that are expected to occur due to the replacement design (e.g., increases in shear stresses caused by the backwater reduction when significantly increasing the hydraulic capacity of a structure). AOP improvement may be required to address structure related passage blockages (e.g., a perched outlet or a steep structure slope causing high outlet velocities).

4.2.2 Rehabilitation and Deck Replacement Projects

Structure rehabilitation and deck replacement projects typically do not involve the degree of study and analysis required for the design of a replacement structure. These projects can be categorized as either in-kind or out-of-kind, depending on the project specifics, but typically have negligible impacts to the stream and its floodplain and create negligible changes to hydraulic flow conditions at the structure. A scour evaluation or scour assessment study is required for a bridge rehabilitation or deck replacement project in order to confirm that the structure will remain stable for the scour design and check floods. This evaluation may require supporting hydrologic, hydraulic and stream morphology studies. The need and level of analysis required is to be determined on a per project basis, through coordinated effort of the SHHD Team Leader and the OOS Design Team.

4.2.3 Small Structure Projects

The OOS inventory includes small structures, which are defined as structures with a total span length measured along the roadway centerline, between extreme ends of openings, of 20-ft or less. Hydrologic and hydraulic analysis associated with small structures may be simplified, especially when the structure is a culvert which is categorized as a structurally or hydraulically in-kind replacement. The need and level of analysis required is to be determined on a per project basis, through coordinated effort of the SHHD Team Leader and the OOS Design Team.

The degree of analysis and study required for a project is contingent on the project type. Section 4.4 provides a summary of SHHD project milestones (Table 4-1 and Table 4-2), with notes regarding applicability based on the project type.

4.3 OOS PROJECT MILESTONES

The OOS project design process is typically divided between 1) Preliminary Design and 2) Final Design. The preliminary design phase of project development includes review and investigation related to bridge geometry (i.e., roadway width, vertical clearances, horizontal clearance, and curve alignments), structure type selection, rehabilitation versus replacement, construction consideration (i.e., maintenance of traffic), impacts to resources, development of stormwater management concepts, and other items necessary to receive NEPA approval. The hydrologic and hydraulic analyses provide essential data used for determination of the structure type, size, and location. Therefore, the majority of SHHD involvement and analyses occur during the preliminary design phase. However, coordination and communication between SHHD and the OOS Design Team is essential throughout the project development process.

The OOS plan preparation and review submission process includes the following review submittals and project milestones. Note that some milestones include OOS internal submissions and approvals only, while other milestones include submittals which are circulated amongst all MDOT SHA offices for review and approval. OOS internal submission and approval milestones are indicated below using an asterisk (*).

- *Typical Section: This review submission includes the proposed typical roadway section at the crossing, which must be developed in consideration of all design requirements, long-term MDOT SHA planning goals, and long-term local roadway improvement goals. An initial approximate deck drainage analysis should be completed for sizing of shoulder widths.
- *Preliminary Type, Size, & Location (Pre-TS&L): This milestone is not required for all projects. Rather, the Pre-TS&L step is used only if there are major structural options and roadway alternatives to be evaluated. This review submission must include a general plan showing all pertinent dimensions, an elevation plan showing pertinent clearances, general notes, and structural typical sections. A summary of the considered structural options (selected and not selected) should accompany this submission, including any related hydraulics analyses. No foundation design data is required for this submission.
- *Type, Size, and Location (TS&L): This review submission must include a general plan showing all pertinent dimensions, an elevation plan showing pertinent clearances, general notes, and structural typical sections. No foundation design data is required for this submission.
- Preliminary Investigation (PI): This submission includes the TS&L design plans, with design revisions made based on in-house (MDOT SHA) reviews. In addition, the submission should include the roadway plan, profile, typical road section(s), preliminary traffic control plan, and a preliminary estimate of construction cost.
- *Foundation Review: This submission includes the TS&L design plans, with the addition of boring and drive test sheets, seismic data, foundation type recommendations, and the

SHHD scour evaluation memo. Substructure foundation plans and a foundation report shall be included.

- *Structural Review: The submission shall include a complete set of contract drawings with all details and special features of the project. Although the full plans need not be complete all structure design must be complete and checked. A detailed cost estimate and rough draft special provisions shall be included.
- Final Review: The submission shall include a complete set of contract drawings, complete special provisions, and revised cost estimate.
- Plans, Specifications, & Estimate (PS&E): Complete plan set which incorporates revisions resulting from structural and final review. Data submitted must be ready for advertisement.
- Constructability Review: Same submission data as PS&E which is sent to the district Engineer concurrent with the PS&E submittal.

4.4 SHHD PROJECT MILESTONES

This section provides a summary of the SHHD milestones, with study phases that relate to the overall OOS project development process presented (Section 4.3). There are two significant project criteria that impact the SHHD project development process: (1) whether the project is located within a FEMA designated Special Flood Hazard Areas (i.e., a FEMA mapped floodplain), and (2) whether the proposed replacement structure is categorized as an in-kind or out-of-kind replacement, as defined in Section 4.2.

Table 4-1 and Table 4-2 present an overview of the project development process components which are the responsibility of SHHD. These milestones are presented according to the corresponding review stage of the OOS design process (e.g., TS&L or Foundation Report). Table 4-1 presents the milestones that apply to projects located within a FEMA mapped floodplain. Table 4-2 presents the milestones that apply to projects that are not located within a FEMA mapped floodplain. Both tables include an asterisk (*) to indicate the steps that may not be required, or may be required in a simplified form, if it is determined that a project can be categorized as an in-kind replacement.

The milestones in Table 4-1 and Table 4-2 are generally listed in the required sequential completion order. However, project specifics may require some modification of this order (e.g., stream morphology conducted before survey in order to inform the survey request). The project specific completion order is based on individual project need and is to be determined by the SHHD Team Leader and approved by the SHHD Division Chief.

Table 4-1 SHHD Design Project Milestones, Projects in a FEMA Mapped Floodplain

A	PRIOR TO TS&L APPROVAL
A-1	Project assignment and kick-off meeting.
A-2	Gather and review project background information. Conduct initial hydrologic and hydraulic evaluations. Review environmental commitments or constraints (review data provided by OPPE and provided on watershedresourceregistry.com).
A-3	Confirm project is located within a FEMA mapped floodplain and determine status (e.g., Zone AE or Zone A). Obtain and evaluate the FEMA model (effective or the best available data from mdfloodmaps.com).
A-4	Hold concept meeting. Determine design objectives/goals, priorities, and approach (i.e., in-kind or out-of-kind). Obtain preliminary approval from OOS Deputy Director.
A-5	Obtain mapping data. Identify adjacent property owners and send notification letters to all within the limits of the design reach.
A-6	Prepare and submit survey request. Set proposed cross section survey at same location as cross sections in the FEMA model, to the extent possible. Verify proposed survey cross section locations in the field. Coordinate with the OOS Design Team Leader to determine required survey data collection extent to meet all OOS needs.
A-7	Evaluate deck drainage requirements for consideration in typical section approval (determine shoulder width required to accommodate the design spread). Coordinate with the OOS Design Team Leader.
A-8*	Conduct hydrologic analysis. Obtain approval from MDE Waterway Construction Division for ultimate development design discharges, which shall be used for all hydraulics analyses related to structure design and MDE regulatory approvals. FEMA effective discharges shall be used for FEMA related hydraulic analysis.
A-9*	Conduct existing conditions hydraulics analysis using the MDE approved design discharges. Update the FEMA hydraulics model to develop an integrated MDE/FEMA model or develop an independent existing conditions hydraulics model. Use survey data (e.g., cross sections, structure, and field data collection) and current topographic data (e.g., contours or DEM) for existing conditions model geometry. Review all model parameters, methods, and details to ensure that the existing conditions analysis meets MDOT SHA standards. Note that for projects in a FEMA Zone AE (detailed study) areas, the integrated MDE/FEMA modeling approach is required. For projects is Zone A (approximate study) areas, the integrated approach may be required based on community requirements and should be used if possible and practical as determined in the step A-3 evaluation.
A-10*	If an integrated model is developed in A-9, conduct existing conditions hydraulics analysis using the FEMA effective discharges. Compare results to the FEMA effective floodplain water surface elevations (WSELs). Obtain MDE State NFIP Coordinating Office concurrence for the integrated model and engage community if changes in WSELs and/or floodway revisions.

A-11	Conduct stream morphology assessment. Evaluate channel stability and obtain design information for hydraulics and scour studies. Evaluate and address aquatic organism passage (AOP) constraints. If channel stability design is recommended, hold another concept meeting with the design team and seek Deputy Director's approval. Perform a detailed stream morphology study if approved.
A-12*	Conduct proposed conditions hydraulics analyses. Evaluate proposed bridge/culvert design options and any road profile modifications (structure design team should first evaluate the road profile to confirm compliance with AASHTO requirements). If not possible to propose a viable replacement option that meets design flood requirement, obtain design exception approval from the OOS Director.
A-13*	Develop channel stability and AOP design (if applicable) for the selected option. Update the proposed conditions hydraulics analysis. Initiate environmental/permitting agencies reviews through OED-EPD liaison.
A-14	Develop preliminary scour study.
B	**AFTER TS&L APPROVAL**
B-1*	Review the approved TS&L plan to confirm hydraulic model consistency; update the hydraulics model if required. Complete the hydraulics analysis report and submit to MDE Waterway Construction Division for approval.
B-2*	Complete proposed conditions hydraulics analysis using FEMA effective discharges and submit to MDE State NFIP Coordinator for concurrence.
B-3*	If a CLOMR or LOMR is required, schedule and hold FEMA pre-submission meeting. Prepare and submit CLOMR request to FEMA, if applicable.
B-4	Coordinate with the OOS Design Team Leader to request geotechnical studies and soil borings. Conduct scour studies using boring results and data from the stream morphology study.
B-5	Conduct final deck drainage analysis, if applicable.
B-6	Assist with maintenance of stream flow analysis for OOS use in construction sequence. Coordinate with OOS Team Leader to determine analysis requirements. If required, conduct hydraulics analysis for the proposed diversion based on the design storm frequency selected for the construction period.
C	**PRIOR TO FOUNDATION REPORT SUBMITTAL**
C-1	Complete scour studies and prepare final scour report. Prepare scour memo and obtain approval. Note that scour memo to be included with final foundation report.
C-2	Prepare recommendations for design of scour countermeasures as needed. Finalize channel stability design (if applicable).
C-3	Provide any required information for Joint Permit Application (typically prepared by OOS Team Leader and submitted to MDE by OED).

D	**PRIOR TO STRUCTURAL REVIEW SUBMITTAL**
D-1	Resolve any outstanding issues pertaining to scour, scour countermeasures, and channel stability/reconstruction design.
E	**FINAL REVIEW AND PS&E (Design Plans)**
E-1	Review design plans for consistency with approved integrated MDE/FEMA hydraulics model including temporary measures during construction. Prepare H&H Data Sheet.
F	**PRIOR TO ADVERTISING AND AWARDING PROJECT**
F-1*	Confirm receipt of MDE/COE permit and FEMA approval (CLOMR), if applicable.
G	**AFTER PROJECT CONSTRUCTION**
G-1	Obtain as-built plans upon the completion of the project.
G-2*	If a LOMR is required, schedule and hold FEMA pre-submission meeting. Prepare and submit LOMR to FEMA.
G-3	Confirm that all project analysis and documentation files are archived per SHHD procedures.

*Milestones which may not be required, or may be required in simplified form, for in-kind projects.

Table 4-2 SHHD Design Project Milestones, Projects not in a FEMA Mapped Floodplain

A	PRIOR TO TS&L APPROVAL
A-1	Project assignment and kick-off meeting.
A-2	Gather and review project background information. Conduct initial hydrologic and hydraulic studies. Review environmental commitments or constraints (review data provided by OPPE and provided on watershedresourceregistry.com).
A-3	Confirm project is not located within a FEMA mapped floodplain.
A-4	Hold concept meeting. Determine design objectives, priorities, and approach (i.e., in-kind or out-of-kind). Obtain preliminary approval from Deputy Director of OOS.
A-5	Obtain mapping data. Identify adjacent property owners and send notification letters to all within the limits of the design reach.
A-6	Prepare and submit survey request. Verify proposed survey cross section location in the field.
A-7	Evaluate deck drainage requirements for consideration in typical section approval.
A-8*	Conduct hydrologic analysis. Obtain approval from MDE Waterway Construction Division for ultimate development design discharges, which shall be used for all hydraulic analysis related to structure design and MDE regulatory approvals.
A-9*	Conduct existing conditions hydraulics analysis using the MDE approved design discharges. Develop existing conditions hydraulic model using survey data (e.g., cross sections, structure, and field data collection) and the most current topographic data (e.g., contours or DEM).
A-10	Conduct stream morphology assessment. Evaluate channel stability and obtain design information for hydraulics and scour studies. Evaluate and address aquatic organism passage (AOP) constraints. If channel stability design is recommended, hold another concept meeting with the design team and seek Deputy Director's approval. Perform a detailed stream morphology study if approved.
A-11*	Conduct proposed conditions hydraulics analyses. Evaluate proposed bridge/culvert design options and any road profile modifications (structure design team should first evaluate the road profile to confirm compliance with AASHTO requirements). If not possible to propose a viable replacement option that meets design flood requirement, obtain design exception approval from the OOS Director.
A-12*	Develop channel stability and AOP design (if applicable) for the selected option. Update the proposed conditions hydraulics analysis. Initiate environmental/permitting agencies reviews through OED-EPD liaison.
A-13	Develop preliminary scour study.
B	**AFTER TS&L APPROVAL**
B-1*	Review the approved TS&L plan to confirm hydraulic model consistency; update the hydraulics model if required. Complete the hydraulics report and submit to MDE Waterway Construction Division for approval.

B-2	Coordinate with the Structural Design Division Team Leader to request geotechnical studies and soil borings. Continue scour studies using boring results and data from the stream morphology study.
B-3	Conduct deck drainage analysis, if applicable.
B-4	Develop maintenance of stream flow for construction sequence. If required, conduct hydraulics analysis for the proposed diversion based on the design storm frequency selected for the construction period.
C	**FOUNDATION REPORT**
C-1	Complete scour studies and prepare final scour report. Prepare scour memo and obtain approval. Note that scour memo to be included with final foundation report.
C-2	Prepare recommendations for design of scour countermeasures as needed. Finalize channel stability design (if applicable).
C-3	Provide any required information for Joint Permit Application (typically prepared by OOS Team Leader and submitted to MDE by OED).
D	**STRUCTURAL REVIEW**
D-1	Resolve any outstanding issues pertaining to scour, scour countermeasures, and channel stability/reconstruction design.
E	**FINAL REVIEW AND PS&E (Design Plans)**
E-1*	Review design plans for consistency with approved MDE hydraulics model including temporary measures during construction. Prepare H&H Data Sheet.
F	**ADVERTISE AND AWARD PROJECT**
F-1*	Confirm receipt of MDE/COE permit.
G	**CONSTRUCT PROJECT**
G-1	Obtain as-built plans upon the completion of the project.
G-2	Confirm that all project analysis and documentation files are archived per SHHD procedures.

*Milestones which may not be required, or may be required in simplified form, for in-kind projects.

4.4.1 Initial Hydrology and Hydraulics Studies

The SHHD should be involved in all OOS design projects containing structures in a floodplain (i.e., structures that provide waterway crossing). This involvement should begin at project initiation and the formation of the OOS Project Team. The SHHD Team Leader, who is selected to manage the project by the SHHD Division Chief, will represent the SHHD on the OOS Project Team. At this early stage, the SHHD Team Leader shall review the project objectives and priorities to determine the primary SHHD design tasks and analysis requirements. This typically includes coordination with the Office of Environmental Design and a review of any environmental commitments that may have been made regarding the project. Note that this phase may or may not involve development of Pre-TS&L plans by the OOS Design Team but in all cases SHHD Division Chief will seek the approval of the proposed structural options by the Deputy Director in charge of the appropriate OOS Engineering Division.

Initial hydrology and hydraulics studies are conducted by the SHHD Team Leader in order to understand the project requirements. The extent and timing of these studies shall be determined by the SHHD Team Leader based on the specific details of the project. These initial investigations are typically undertaken prior to the step A-4 concept meeting, in order to gather the information needed to assist the OOS Design Team in defining the design objectives and priorities. Initial studies may include any of the following:

- Field investigations at the site to assess current structure and stream conditions, drainage patterns, significant hydrologic or hydraulic features, and land use conditions.
- Communication with district engineer or maintenance personnel to determine if there are any known problems at the crossing or frequent flooding complaints.
- Verification of FEMA floodplain status (i.e., use mdfloodmaps.com to determine if the project in a Zone AE, Zone A, or not mapped area) and review of the FEMA hydrology and hydraulics analysis, if data/models are available. Also, determine if there is a FEMA restudy of the stream in progress or planned for the near future that should be considered.
- Determination if the project impacts a waterway designated under the Scenic and Wild Rivers System (DNR, 2019). Notify DNR regarding the proposed work and coordinate regarding any related special design requirements.
- Initial hydrologic analysis using GISHydro2000 to estimate drainage area and flood discharges based on the Fixed Region Regression Equation estimates.
- Initial hydraulic analysis to assess hydraulic capacity of the structure and floodplain extent using either the FEMA model (if available) or an approximate HEC-RAS model with cross sections developed from contour or digital elevation model (DEM) data.

Initial hydraulic analysis to determine if the waterway opening of the existing structure meets MDOT SHA design criteria (Section 4.4.2) should be completed prior to the concept meeting (step A-4), as this condition is a primary consideration in the decision whether to pursue either an in-kind or out-of-kind replacement.

The initial review and studies are necessary to inform and define the survey request and survey extent limits. If the project is located in a FEMA mapped floodplain, the proposed cross section survey should be completed at the same location as the FEMA cross sections, where feasible. The

longitudinal extent of cross section survey along the stream reach will be partially determined by the sensitivity of the hydraulic model to the boundary conditions (see Chapter 10 for information on boundary sensitivity analysis). Therefore, the boundary sensitivity should be evaluated in the initial study. The survey request should include consideration of any important features noted during the site visit, such as other natural or manmade hydraulic structures impacting the study location.

The timing of the stream morphology study within the project development process will also be informed by the initial analysis results, as well as the initial field visit findings. The stream morphology assessment is typically initiated after hydrology studies are complete and hydraulic analysis of the existing conditions has begun. However, this may be modified based on project specifics. Stream morphology can be conducted at an earlier stage if required (e.g., if a crossing is frequently flooded and this condition may be improved by roadway or stream realignment, or if site instabilities are determined and the survey request should include data collection needed for stream stability design). If the stream morphology study is completed prior to survey, the assessment should define any critical locations for cross section survey.

4.4.2 Design Flood Exceptions

OOS structures are typically designed to provide conveyance of an assigned design flood which is based on the roadway classification. For some projects it may be decided that it is not feasible or practicable to design a structure that can pass the design flood flows with no roadway overtopping. For these cases, a design flood exception is required.

During the initial studies phase, the SHHD Team Leader, or an engineer they assign, should contact the District Engineer or his/her designated representative to determine the known frequency of flooding, any known maintenance concerns, and any known impacts to public transportation potential. These findings should be discussed with the OOS Project Team and the Division chiefs to determine whether an in-kind or out-of-kind design should be pursued. Additional factors to consider in weighing the merits of a design exception should include:

- Frequency of overtopping, resulting safety hazards and delays to traffic. This should include a determination of present and anticipated future AADT and the type of service provided by the highway (school bus route, emergency evacuation route, etc.). It should also include consideration of the availability of alternative routes for detouring of traffic in the event the structure or highway is closed to traffic.
- Location and extent of the overtopping section(s) and whether it is practical and environmentally acceptable to upgrade the structure and the roadway approaches to meet the design criteria.
- Environmental impacts associated with designing the structure and its roadway approaches to meet current design criteria.
- Project cost estimate, including the comparison of cost to meet design criteria versus cost for in-kind replacement option.
- Other existing nearby structures on the subject roadway that may also not meet the design criteria and therefore inhibit use of the route during the design flood condition.

If the OOS Project Team decides to pursue a design exception, written concurrence of the SHHD Chief, the OOS Deputy Director, and the OOS Director is required. This is typically obtained via a design exception memo, which summarizes the project existing conditions and the proposed course of action. If a design exception is not warranted or approved, the project will advance following the typical project development steps as detailed in Table 4-1 and Table 4-2.

4.4.3 FEMA Coordination

Projects located within a FEMA Special Flood Hazard Area (SFHA) require FEMA coordination. The SHHD design process and project milestones presented in Table 4-1 incorporate steps to include the analysis required to meet FEMA requirements. If the structure is located within a FEMA mapped floodplain area, the project should proceed according to Table 4-1. If the structure is not located within a floodplain included in the NFIP program, the project should proceed according to Table 4-2.

The National Flood Insurance Program (NFIP) administered by FEMA includes flood risk studies and floodplain mapping. FEMA flood maps for the State of Maryland are available at http://www.mdfloodmaps.com (*mdfloodmaps*). The Digital Flood Insurance Rate Maps (DFIRMs) provided on *mdfloodmaps* should be reviewed to determine the following:

- Whether the floodplain is under the jurisdiction of the NFIP
- What type of analysis has been completed: detailed (Zone AE) or approximate (Zone A)
- Whether a regulatory floodway has been established
- Whether the status of the provided floodplain mapping is effective or preliminary

4.4.3.1 FEMA Effective Model Availability and Acquisition

FEMA effective hydraulic models for most Maryland FEMA communities are available for download at http://www.mdfloodmaps.com. Beginning in 2006, as part of the *mdfloodmaps* program, new FEMA floodplain models in both detailed (Zone AE) and approximate (Zone A) study areas across Maryland were developed. As of 2020, more than 2500 georeferenced HEC-RAS models have been completed and are available for download from *mdfloodmaps*. FEMA effective models can also be obtained from the FEMA Engineering Library (https://www.fema.gov/engineering-library). Data at the FEMA website should be reviewed to confirm whether any map updates (LOMRs) have been approved by FEMA that would change the mapping shown on the MDE floodmaps website. The relevant models can be obtained from FEMA.

For some communities, where floodplain modeling and mapping is still underway, the effective model is not available from *mdfloodmaps*. For these locations, the MDE State NFIP Coordinator should be contacted to determine FEMA mapping status and to acquire the best available data (e.g., a preliminary hydraulic model). Contact information is available at *mdfloodmaps*, as well as a current schedule of mapping updates and DFIRM release dates.

4.4.3.2 Analyses for Projects in FEMA SFHAs

The MDOT SHA and the Maryland Department of the Environment (MDE) Waterways and Floodplain Divisions have developed a process to integrate the hydraulic modeling efforts required for FEMA and Maryland state regulation compliance. This process is detailed in the Maryland Hydraulics Panel report, titled *Recommendations for Hydraulic Analyses in FEMA Special Flood Hazard Areas in Maryland* (2018). The goal of this process is to improve the efficiency of SHA analysis and subsequent project approval, while also providing MDE, FEMA, and the community with the best available data regarding the regulated floodplain. The report provides detailed information regarding the recommended methods for model development and the recommended process for FEMA submittals and approvals. A summary of the key coordination efforts required for OOS projects is provided here.

For FEMA related analyses, the SHHD typically uses the effective flood discharges as determined in the approved FEMA studies (based on existing land use conditions), unless there is a compelling reason to revise the FEMA approved hydrologic analyses. Note that for the bridge and culvert design and for all state permit related submittals, flood discharges are estimated based on ultimate development conditions as per Maryland regulations (COMAR 26.17.04.04, DSD, 2018).

For projects located in a FEMA Zone AE floodplain, the SHHD analysis procedure includes modification of the effective FEMA model to develop a hydraulic model that can be used for the required FEMA analysis as well as the analysis required for MDE review and approval. If the FEMA effective model is not available, a preliminary model may be used if the MDE State NFIP Coordinator confirms that this is the best available data. Detailed information about this integrated approach is provided in the Hydraulics Panel Report (Panel, 2018). Generally, the FEMA model should be updated and improved using MDOT SHA field collected survey data and the most current topographic data. The model should also be reviewed and verified to confirm that all input parameters, methods, and details meet MDOT SHA standards. This updated FEMA model becomes the existing conditions model. The proposed conditions model should be based on the existing conditions model, with incorporation of all proposed changes to structures (addition and/or removal), channel geometry, and/or parameters of the channel and floodplain.

For projects located in a FEMA Zone A floodplain, the SHHD analysis procedure allows for two approaches. The first approach is to follow the integrated modeling procedure used for FEMA Zone AE areas. For Zone A (approximate study) areas, the quality level of the FEMA model should be evaluated, and the integrated approach should be used for design analysis if it is determined that use of the FEMA model is possible and practical. Note that in cases when the community has more restrictive requirements than FEMA, and therefore requires a CLOMR for Zone A areas, the integrated approach is required. The second approach allowed for Zone A floodplain areas is development of a hydraulic model using survey and other topographic data, without use or consideration of the FEMA model. This approach should be used if it is determined that it is not possible or practical to use the FEMA model as a base model for design analysis. If the second approach is used, the final model and analysis documentation must be submitted to the MDE NFIP Coordinator for use in updates to the FEMA model after the MDE Waterway Construction Division approval is received.

4.4.3.3 LOMC Applications

For some OOS projects, a submittal to FEMA in the form of a Letter of Map Change (LOMC) application is required. Typically, this is a Conditional Letter of Map Revision (CLOMR) application for proposed revisions, followed by a Letter of Map Revision (LOMR) application once construction of a proposed project is complete. The conditions resulting in this requirement are detailed in the Hydraulics Panel Report, specifically in two separate flowcharts relating to either Zone AE or Zone A floodplains.

Generally, if a floodway has been established, or if a community regulates the floodplain as the floodway, an encroachment on the floodway that results in any increase to the 100-year flood water surface elevations is not allowable. The term floodway, as used here and as used in connection with the National Flood Insurance Program, is that portion of the floodplain required to pass a flood that has a 1-percent chance of being equaled or exceeded in any given year without cumulatively increasing the water surface elevation by more than 1-ft.

If possible, it is preferable to design and construct structures so that their components do not impact the floodway extent and floodplain elevations. This is the simplest way to be consistent with the standards and should be the initial alternative evaluated. If a project element encroaches on the floodway but has a very minor effect on the floodway water surface elevation (e.g., piers in the floodway), the project may normally be considered consistent with the standards, if hydraulic conditions can be improved so that no water surface elevation increase is computed in comparison of pre-project (existing) to post-project (proposed) conditions.

Where it is not possible or cost-effective to design a crossing to avoid encroachment on an established floodway, a second alternative would be a modification of the floodway itself. Often, the community will be willing to accept an alternative floodway configuration to accommodate a proposed crossing provided NFIP limitations on increases in the base flood elevation are not exceeded. This approach is useful where the highway crossing does not cause more than a 1-ft rise in the base flood elevation. For OOS projects, the SHHD is responsible for analysis to demonstrate that an alternative floodway configuration meets NFIP requirements. Floodway revisions must be based on the hydraulic model which was used to develop the currently effective floodway but updated to reflect existing encroachment conditions. This will allow determination of the increase in the base flood elevation that has been caused by encroachments since the original floodway was established. Alternate floodway configurations may then be analyzed. Floodway surcharge values are referenced to the profile obtained for existing conditions when the floodway was first established.

A request to FEMA for a proposed or constructed floodway revision is made through an application for CLOMR or LOMR, respectively. The complete list of required information to be included with a submittal can be found on FEMA's MT-2 instruction forms. The revised and current computer data required should extend far enough upstream and downstream of the floodway revision area to tie back into the original floodway and profiles using sound hydraulic engineering practices. This distance will vary depending on the magnitude of the requested floodway revision and the hydraulic characteristics of the stream. The revised 100-year water surface elevations must match the FEMA effective elevations within 0.5 foot at the limits of revision. MDOT SHA must seek community concurrence before submitting the CLOMR application, although FEMA will accept the application if the community refuses to review or

acknowledge the concurrence form. In addition, property owner notification is required if the map revisions cause increases in the flood hazards (property owner acceptance or concurrence is not required by FEMA).

4.4.4 Projects in Tidal Areas

Structure replacement projects that are located in tidally impacted areas require further analysis in addition to the hydrologic and hydraulic analyses completed for projects in non-tidal areas. The typical project milestones are generally still applicable to projects in tidal areas. Guidance regarding the approved OOS tidal analysis methodologies for hydrology, hydraulics, and scour are presented in Chapter 8 Hydrology, Chapter 10 Bridge Hydraulics, and Chapter 11 Scour Evaluations, respectively.

4.4.5 Survey Requirements

Survey data is typically collected early in the project development process. OOS projects typically require the collection of field data in addition to the topographic data collected for use in the structure design, including detailed survey of the existing structure, the crossing roadway, the stream channel at the crossing, and surveyed stream channel cross sections (number and cross section extent dependent on project specific requirements). Initial hydrologic and hydraulic studies are generally completed prior to development of the survey request in order to determine the survey data collection extent requirements and the minimum number of cross sections needed.

If a project is located with a FEMA SFHA, the effective FEMA model should be reviewed and used to inform the survey data request. Specifically, where possible, cross section survey should be obtained at the same location as the FEMA cross sections. Note that additional cross sections at other locations may also be required to meet SHHD analysis needs.

All survey requests shall be coordinated with the OOS Design Team Leader, in order to ensure the coordination of data needs and therefore reduction of project costs and improvement of project efficiencies. Chapter 5, Data Sources and Field Surveys, provides details regarding survey request procedures.

4.4.6 Deck Drainage

Initial deck drainage analysis should be conducted early in project development as part of typical roadway section design. This includes computations to ensure that the proposed typical section at the structure meets minimum standards for surface runoff which limit spread into the travel lanes. The initial analysis should be completed prior to typical section approval. The analysis must also be reviewed and updated later in project development after the structure type, size, and location is approved and other roadway design details are determined. Chapter 12, Bridge Deck Drainage Analysis, provides details regarding the deck drainage analysis procedures and design criteria.

4.4.7 Hydrologic Analysis

SHHD hydrologic analysis includes study based on existing conditions land use and ultimate development land use. The peak flow rates determined using the ultimate development land use data are used for hydraulic analysis of the proposed structure. Hydrologic analysis includes:

- Computation of peak flow estimates using regression equations based on USGS stream flow records of Maryland watersheds.
- Computation of peak flow estimates using TR-20 or WinTR-20.
- Comparison of the values obtained from these two methods as part of the calibration procedures set forth in the Maryland Hydrology Panel report.
- Computation of ultimate development peak flow estimates using the "calibrated" TR-20 or WinTR-20 model.

Peak flow rates for the 2, 10, and 100-year floods are required for hydraulic analysis for compliance with State floodplain regulations, and therefore MDE review approvals. Peak flow rates for the 100 and 500-year floods, and for the incipient overtopping flood, are needed for scour analyses. Other peak flow rates (25-year and 50-year flood events) are also typically computed. The values may be required based on the highway classification of the particular roadway crossing and the associated design flood recurrence interval. Chapter 8, Hydrology, provides details regarding the required hydrologic analysis methodologies and procedures.

If it is determined that a project can be classified as an in-kind replacement, per the current state policy, the hydrologic analysis required for MDE review and approval may be waived or simplified (DNR, 1993). The in-kind replacement policy document provided in Appendix A of this manual should be reviewed to confirm project classification, and that the project meets all applicable supplemental requirements, in order to confirm the hydrologic analysis requirements related to MDE approval. Regardless of the in-kind classification, some level of hydrologic analysis will still be required for purposes of OOS design. This is to be determined on a per project basis through coordinated effort of the SHHD Team Leader and the OOS design team.

Once the hydrologic analysis is complete, the hydrologic analysis report and associated appendices are submitted to the MDE Waterway Construction Division for review and approval. This approval is recorded for use as supporting documentation as part of the MDE/USACE Joint Permit Application process.

4.4.8 Stream Morphology and Channel Stability

The study of stream morphologic conditions is generally completed for all OOS projects involving a structure over a waterway. The stream morphology assessment should provide recommendations for the structure design based on river mechanics and morphological conditions, as well as the required input parameters necessary to complete the scour study. This includes anticipated scour type at the structure (live bed or clear water), potential lateral channel movement, potential long-term bed degradation, and the bedload particle size distribution. If the assessment results indicate a need for further analysis or for channel stability design measures, the SHHD may decide to complete a detailed stream morphology study. Chapter 14, Stream Morphology, provides details regarding stream morphology study procedures to be followed for SHHD projects.

The results of stream morphology study, as documented in the stream morphology assessment report, should be considered and incorporated into the hydraulics analysis of the proposed conditions. Based on the study results, channel modification or stability design may be recommended. If SHHD determines that stream stability design measures are required, this effort should be coordinated with the OOS Design Team and considered in the hydraulics analysis study.

Additional project requirements related to construction oversite and as-built survey should be considered when the stream stability design scope of work is developed.

4.4.9 Hydraulic Analysis

Development and analysis of the existing site hydraulics provides base conditions for evaluating the proposed structure design alternatives. Field survey data, including cross-sections and topographic data, are used in development of SHHD hydraulic models and analyses.

Proposed condition hydraulics analysis is conducted as a part of process used to select the type, size, and location of the proposed structure. The analysis results are also used in the design of the approach roadways. This hydraulics analysis includes:

- Analysis to determine structure Type, Size, and Location (TS&L) recommendations.
- Development of water surface and energy profiles, and other related hydraulics parameters for the selected alternative.
- Final hydraulic analysis and report for submittal to MDE and FEMA, as necessary, for permits and approvals.
- Resolution of environmental issues pertinent to obtaining necessary permits and approval (i.e., evaluation of aquatic organism passage).

Detailed requirements and procedures for hydraulics analysis are provided in Chapter 9, Open Channel Hydraulics, Chapter 10, Bridge Hydraulics, and Chapter 13, Culvert Hydraulics.

If it is determined that a project can be classified as an in-kind replacement, per the current state policy, the hydraulic analysis required for MDE review and approval may be waived or simplified (DNR, 1993). The in-kind replacement policy document provided in Appendix A of this manual should be reviewed to confirm project classification, and that the project meets all applicable supplemental requirements, in order to confirm the hydraulic analysis requirements related to MDE approval. Regardless of the in-kind classification, some level of hydraulic analysis will still be required for purposes of OOS design and SHHD scour evaluation. This is to be determined on a per project basis through coordinated effort of the SHHD Team Leader and the OOS design team.

Once the hydraulic analysis is complete and TS&L plans have been approved by the OOS Division Chief, the hydraulic analysis report and associated appendices are submitted to the MDE Waterway Construction Division for review and approval. This approval is recorded for use as supporting documentation as part of the MDE/USACE Joint Permit Application process.

4.4.10 Scour Evaluation

The typical SHHD project development process includes a preliminary scour evaluation after the stream morphology assessment and initial proposed conditions hydraulics analysis are complete. Final scour studies and the scour report shall be completed prior to submission of the OOS Foundation report. The scour report must include a summary memo which shall indicate that the study is approved by the SHHD Division Chief. Evaluation of the potential for scour must be completed for all highway structures over a waterway to ensure public safety through adequate foundation design. Detailed guidelines and methodologies for the evaluation of scour at OOS bridges and bottomless culverts are provided in Chapter 11, Scour Evaluations.

4.4.11 Study Documentation and Data Archive

Detailed requirements for the documentation of studies and analyses are provided in Chapter 6, Documentation. Chapter 6 provides guidance regarding the format to be followed and minimum content to be provided in Hydrology, Stream Morphology, Hydraulics, and Bridge Scour Evaluation reports. Guidance regarding the procedures to be followed in the studies and analyses is presented in the individual respective chapters of the Manual.

Summary information from the Hydrology, Stream Morphology, Hydraulics, and Bridge Scour Evaluation reports is provided on the H&H Data Sheet, which is included in the final PS&E plans. Instructions for the compilation of the data is provided in Chapter 6. All SHHD analyses and study report shall be archived for future use. Archive instructions are provided in Chapter 6.

4.4.12 As-Built Plans

The SHHD Team Leader responsible for a project should review the as-built plans developed after the project is constructed. Primary emphasis in these reviews should be placed on verifying that:

- As-built survey provides the required information to confirm that structure and structure foundation were constructed per the design.
- Documentation of key hydraulic features should be provided including structure low chord, roadway overtopping location and elevation, and number, size and shape of any piers.
- The minimum pile tip elevations for foundation units (as constructed) are indicated on the plans.
- The scour countermeasures are constructed in substantial conformance with the final plans (PS&E).
- Any field modifications to the plans or changes to the substructure or superstructure details do not adversely affect the hydraulic performance or stability of the structure.
- The final as-built plans are used in any required LOMR application to FEMA.

The following may be required for projects that include channel stabilization and/or restoration (mitigation):

- Stream Restoration Site As-built Certification which may include (1) inspection; (2) surveys; (3) population of as-built checklist items within the construction plans during and post construction; and (4) submission of the Final Checklist Package to MDOT SHA. Special provisions for the Stream Construction As-Built Certification, Stream Specialist and/or Designated Specialist may also be required.
- The As-Built Inspector responsible for submission of the Final As-Built Certification Package will typically require licensure in the State of Maryland as a Professional Engineer or Professional Land Surveyor that is experienced in stream stabilization/ restoration and construction.
- The Final Checklist Package certifies that the stream construction area has been constructed as specified in the plans including the items identified in the As-built Checklist. The submittal package may include certification of items in the as-built

checklist including in-stream structures; survey logs; delivery tickets for materials, photographs and documentation of any field changes/decisions.

- Stream Restoration/Stabilization Specialist, which is an individual provided by the Contractor and required as part of the invitation to bid (IFB). This individual should be experience in all aspects of stream stabilization and restoration including construction.
- Designated Specialist, which is an individual provided by MDOT SHA, that does not direct the contractor but coordinates with the MDOT SHA Project Engineer and is typically familiar with the design or is part of the design team. For large or complex projects involving in-stream construction, both the Stream Restoration/Stabilization Specialist and the Designated Specialist may be requested to be on-site during construction.

REFERENCES

DNR (1993). Maryland Department of Natural Resources. In-Kind Replacement of Bridges and Culverts Operational Policy Memorandum 93-1 dated July 1, 1993. Provided in Appendix A of this Manual.

DNR (2019). Maryland Department of Natural Resources. Stewardship, Scenic and Wild Rivers, https://dnr.maryland.gov/land/Pages/Stewardship/Scenic-and-Wild-Rivers.aspx.

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FEMA (2019). Federal Emergency Management Agency. Flood Mapping Related Forms, https://www.fema.gov/flood-mapping-related-forms.

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