

---

# **Chapter 12 – Bridge, Structure and Riverine Hydraulics**

---

## **TABLE OF CONTENTS**

---

<b>CHAPTER 12 - BRIDGE, STRUCTURE AND RIVERINE HYDRAULICS .....</b>	<b>12-1</b>
<b>12.1 Introduction .....</b>	<b>12-1</b>
12.1.1 Definition .....	12-1
12.1.2 Analysis/Design .....	12-1
12.1.3 Riverine Hydraulics .....	12-1
<b>12.2 Design Policy/Criteria .....</b>	<b>12-2</b>
12.2.1 FEMA Floodplain Compliance .....	12-2
12.2.2 FHWA Compliance .....	12-2
12.2.3 AASHTO General Criteria .....	12-2
12.2.4 Department Criteria .....	12-3
12.2.4.1 Stream Crossing Design Storm .....	12-3
12.2.4.2 1' Freeboard Event .....	12-3
12.2.4.3 Backwater/Increases Over Existing Conditions .....	12-3
12.2.4.4 Flow Distribution .....	12-3
12.2.4.5 Scour .....	12-4
12.2.4.6 Multibarrel Culverts .....	12-4
12.2.4.7 Culvert Countersinking .....	12-4
12.2.4.8 Lateral Encroachments .....	12-4
12.2.4.9 Stream Restoration .....	12-4
12.2.4.10 Impounding Structures (Dams) .....	12-4
<b>12.3 Design Concepts .....</b>	<b>12-5</b>
12.3.1 Hydraulic Computation Methodologies .....	12-5
12.3.2 Bridge Scour or Aggradation .....	12-5
12.3.3 Riprap .....	12-5
12.3.4 Engineering Assessment of No Adverse Impact .....	12-6
<b>12.4 Riverine H&amp;HA .....</b>	<b>12-7</b>
12.4.1 Background .....	12-7
12.4.2 Necessary Resources .....	12-7
12.4.3 Hydrologic Analysis .....	12-8
12.4.4 Hydraulic Analysis .....	12-8
12.4.4.1 Existing Effective Model .....	12-8
12.4.4.2 Existing Conditions Model (Adjusted) .....	12-9
12.4.4.3 Calibration .....	12-9
12.4.4.4 Proposed Conditions Model .....	12-9
12.4.5 Documentation .....	12-9
12.4.5.1 Detailed Hydrologic & Hydraulic Analysis – LD-293 .....	12-9
12.4.5.2 Engineering Assessment of No Adverse Impact .....	12-10
12.4.5.3 System of Units .....	12-10
12.4.5.4 Level of Precision for Documentation .....	12-10
12.4.6 H&HA Submission .....	12-11
<b>12.5 Tidal H&amp;HA .....</b>	<b>12-12</b>
12.5.1 Background .....	12-12

12.5.2	Necessary Resources .....	12-12
12.5.3	Coastal Bridge and Culvert Design Techniques .....	12-13
12.5.4	Computer Modeling.....	12-14
12.5.5	Hydrologic Analysis.....	12-15
12.5.5.1	Bridge Location.....	12-15
12.5.5.2	Channel Cross Section .....	12-15
12.5.5.3	Drainage Area Characteristics.....	12-16
12.5.5.4	Storm Tides .....	12-16
12.5.5.5	Flow Velocity.....	12-17
12.5.6	Hydraulic Analysis.....	12-17
12.5.7	Documentation .....	12-18
12.5.8	H&HA Submission.....	12-18
12.6	<b>Riprap for Protection of Bridge Abutments and Piers .....</b>	<b>12-19</b>
12.7	<b>Removal of Existing Bridge and Approach Embankments .....</b>	<b>12-20</b>
12.8	<b>Temporary Construction Causeway Design .....</b>	<b>12-22</b>
12.8.1	Background.....	12-22
12.8.2	Causeway Design .....	12-22
12.8.2.1	Design Objectives.....	12-22
12.8.2.2	Plans.....	12-22
12.8.2.3	General Notes.....	12-23
12.8.3	Design Procedure .....	12-24
12.9	<b>References .....</b>	<b>12-25</b>

### List of Figures

Figure 12-1.	Removal of Approach Embankment.....	12-21
Figure 12-2.	Quantifying Removal of Approach Embankment .....	12-21
Figure 12-3.	Temporary Construction Causeway Design.....	12-23

### List of Appendices

Appendix 12A-1	LD-293 Major Crossing H&HA
Appendix 12B-1	LD-23 Structure and Bridge Data Sheet
Appendix 12C-1	Tidal Bridge Scour Data and Worksheet
Appendix 12C-2	Table of Storm Tide Description of Virginia Coast
Appendix 12C-3	Virginia Coastal Maps Showing Predicted Water Surface Elevations
Appendix 12D-1	Engineering Assessment of No Adverse Impact

---

# **Chapter 12 - Bridge, Structure and Riverine Hydraulics**

---

## **12.1 Introduction**

---

### **12.1.1 Definition**

Bridges are defined as:

- Structures that transport traffic over waterways or other obstructions
- Part of a stream crossing system that includes the approach roadway over the floodplain, relief openings, and the bridge structure
- Structures with a combined centerline span of 20' or more. However, structures designed hydraulically as bridges, as described above, are treated as bridges in this chapter, regardless of length
- Major Culvert crossings with a total 100-year discharge > 500 cfs are to be evaluated and documented as if they were bridges, unless otherwise exempted by VDOT Hydraulics Staff.
- Three sided structures (bottomless culverts, precast concrete arches, cast in place concrete frames, corrugated metal plate arches and similar structures) shall be treated as bridges.

### **12.1.2 Analysis/Design**

Proper hydraulic analysis and design is as vital as the structural design. Streamcrossing systems should be designed for:

- Minimum cost subject to criteria
- Desired level of hydraulic performance up to an acceptable risk level
- Mitigation of impacts on stream environment
- Accomplishment of social, economic, and environmental goals
- The requirements of existing Federal Emergency Management Agency (FEMA) or other officially delineated or regulatory floodplains

### **12.1.3 Riverine Hydraulics**

In addition to stream crossings other VDOT projects have the potential to adversely impact flood elevations by modifying the flood plain or the stream channel. The project types are listed below, these should also be evaluated using the methods and criteria found in this chapter.

- Stream Restoration Projects
- Lateral Encroachments into the Flood Plain

---

\* Rev. 7/16

---

## 12.2 Design Policy/Criteria

---

### 12.2.1 FEMA Floodplain Compliance

- The final design should not significantly alter the flow distribution in the floodplain
- Where design considerations permit, the "crest-vertical curve profile" should be considered as the preferred highway crossing profile when allowing for embankment overtopping at a lower discharge
- For FEMA Zones determined by Approximate Methods it is allowable to increase the flood elevations up to 1.0' provided that coordination with the community shows that the cumulative impact requirements have been addressed.
- For FEMA Zones determined by Detailed Methods it is not allowable to increase the 100-year flood elevation.

### 12.2.2 FHWA Compliance

- Degradation or aggradation of the river should be estimated and contraction and local scour determined. The appropriate positioning of the foundation, below the total scour depth if practicable, should be included as part of the final design

### 12.2.3 AASHTO General Criteria

Design criteria are the tangible means for placing accepted policies into action and become the basis for the selection of the final design configuration of the stream-crossing system. Criteria are subject to change when conditions so dictate as approved by the Department.

Following are certain American Association of State Highway Transportation Officials (AASHTO) general criteria adopted by the Department related to the hydraulic analyses for bridges as stated in their highway drainage guidelines:

- Backwater will not significantly increase flood damage to property upstream of the crossing
- Velocities through the structure(s) will not damage either the highway facility or increase damages to adjacent property
- Maintain the existing flow distribution to the extent practicable
- Pier spacing and orientation and abutment designed to minimize flow disruption and potential scour
- Foundation design and/or scour countermeasures to avoid failure by scour
- Minimal disruption of ecosystems and values unique to the floodplain and stream

## 12.2.4 Department Criteria

These criteria augment the general criteria. They provide specific, quantifiable values that relate to local site conditions. Evaluation of various alternatives according to these criteria can be accomplished by using a water surface profile program such as those identified in Chapter 16.

### 12.2.4.1 Stream Crossing Design Storm

Inundation of the travelway and clearance below the low shoulder dictates the level of traffic services provided by the facility. New construction and projects that increase the level of service of the roadway shall have an 18" freeboard from the low shoulder of the crossing to the design storm as determined by the functional classifications of roadways presented in Chapter 6, Hydrology.

### 12.2.4.2 1' Freeboard Event

For FHWA reporting purposes the S&B Division has requested that they be provided with information that notes largest customarily documented event (i.e. the 2, 5, 10, 25, 50, 100, & 500-year floods) that will pass under the bridge superstructure at its lowest elevation with at least one foot of freeboard. This would not apply to culverts being evaluated as a part of this Chapter.

### 12.2.4.3 Backwater/Increases Over Existing Conditions

Designers shall conform to FEMA flood elevation increase limitations for sites covered by the National Flood Insurance Program (NFIP). It is the Department's policy not to allow any increase in the level of the 1% (100-year)\* flood for delineated floodplains established under the NFIP. An increase is permitted in FEMA Zones determined by Approximate Methods of up to 1.0' provided that coordination with the community shows that the cumulative impact requirements have been addressed and the increase doesn't impact upstream development. For areas not covered by an existing mapped flood zone the increases are not to exceed one foot during the passage of the 1% flood and the increase does not impact upstream development. Refer to section 12.4.1 for additional details.

### 12.2.4.4 Flow Distribution

The conveyance of the proposed stream crossing should be calculated to determine the flow distribution and to establish the location of bridge opening(s). The proposed facility should not cause any significant change in the existing flow distribution. Relief openings in the approach roadway embankment or other appropriate measures should be investigated if there is more than a 10% redistribution of flow provided such openings do not create a concentration of flow which could damage downstream properties.

---

\* Rev 9/09

### 12.2.4.5 Scour

Design and Check scoured bed elevations are reported to Structure and Bridge for their use to aid in the design of the bridge foundations. These should consider the magnitude of the flood that generates the maximum scour depth up to the the 100-year and 500-year events respectively. However the Structure and Bridge Division may request that a lower event be considered the design scour event for certain rural low volume roadways.\*

### 12.2.4.6 Multibarrel Culverts

For Culvert Crossings with multiple barrels the hydraulic analysis shall consider any culvert opening area that is below the natural flood plain elevation up or downstream of the crossing to be obstructed.

### 12.2.4.7 Culvert Countersinking

All Culvert crossings should comply with the USACOE countersinking requirements as outlined in Chapter 8 of this manual.

### 12.2.4.8 Lateral Encroachments

When a project places fill that is parallel to a stream within a flood plain this is considered a lateral encroachment. This reduces the effective flow area of the flood plain and has the potential to increase the flood elevations. The analytical methods and impact limits described in this chapter shall be applied to projects of this type. Documentation shall conform to the requirements of this chapter and shall include 100-year flood elevation comparison tables for the reach impacted by the encroachment.

### 12.2.4.9 Stream Restoration

To meet the environmental regulations VDOT is engaged in a number of projects to improve impaired streams through restoring sediment transport and creating wildlife habitats. The filling of oversized channels and the planting of riparian vegetation has the potential to adversely impact flood elevations. The analytical methods and impact limits described in this chapter shall be applied to projects of this nature. Documentation shall conform to the requirements of this chapter and shall include 100-year flood elevation comparison tables for the reach impacted by the stream restoration.

### 12.2.4.10 Impounding Structures (Dams)

As discussed in Chapter 8 a structure that is not designed as an impounding structure or dam shall not be evaluated as such to reduce the hydrology or ultimate headwater elevation. VDOT does not encourage the use of roadways as dams for impounding water. It is not VDOT practice not accept responsibility for portions of new roadways that have been designed as dams. Where there are existing roadways that are dams, it may be necessary to address current DCR Dam Safety Regulations prior to making any improvements to the roadway or outfall structure.

---

\* Rev. 7/16

---

## 12.3 Design Concepts

---

### 12.3.1 Hydraulic Computation Methodologies

At a minimum, a one dimensional step-backwater computer model will be employed to perform the hydraulic analysis in these situations due to the complexity of the hydraulic conditions and the risk involved. No single method is ideally suited for all situations. If a satisfactory computation cannot be achieved with a given method, an alternate method should be attempted. Where the use of a one-dimensional step backwater computer model is indicated, the Department accepts any computer model currently approved by FEMA but prefers HEC-RAS. A two dimensional flow model may be necessary to adequately represent the hydraulic conditions found at the stream and road crossings. The Department accepts any current two dimensional flow model approved by FEMA. See Chapter 16 for additional discussion regarding software.\*

### 12.3.2 Bridge Scour or Aggradation

The Department employs the procedures and criteria presented in the FHWA's "Evaluating Scour at Bridges" (HEC-18) and "Stream Stability at Highway Structures" (HEC-20) to determine and counteract the impact of scour and long term aggradation/degradation on bridges.

### 12.3.3 Riprap

Riprap is not to be used for scour protection at piers for new bridges. Riprap may be used to protect exposed abutment slopes. It may be used as a scour countermeasure at existing bridge piers as well as new or existing abutments. Design guidelines for placement and sizing of riprap are presented in the FHWA's "Bridge Scour and Stream Instability Countermeasures" (HEC-23) publication. To qualify as a scour countermeasure the riprap must be placed as prescribed in HEC-23, otherwise it is only considered as being slope protection.

---

\* Rev. 7/16

#### 12.3.4 Engineering Assessment of No Adverse Impact

The goal of the Hydraulic Analysis is to document that the proposed project does not have an unacceptable impact on the flooding in the vicinity of the crossing and to provide scoured bed data to aid in the foundation design. In the event that it can be reasonably concluded that there is no increase to the flood elevations and a scoured bed profile is not needed it would be acceptable (with the Hydraulic Section's approval) to make a determination by using engineering judgment\* without performing a detailed hydraulic study.

When the proposed structure is hydraulically equivalent to the existing structure in **all** parameters, the Hydraulic Engineer (with the concurrence of the Department) can state that the crossing is a Hydraulically Equivalent Replacement Structure (HERS) and document this in a brief memo to the file, sample documents are included in the Appendix 12D.

Alternately if there are differences between the existing and proposed structure AND if **all** the changes to the proposed structure are neutral or beneficial to the hydraulic capacity of the crossing, this may be documented in a Memo to the project file discussing each change and its effect on the hydraulic capacity.

In the event that any of the modified properties of the crossing being evaluated have the potential to have a negative impact on flooding or if scour computations are needed for foundation design this section would not apply.

---

\* Rev. 7/16

---

## 12.4 Riverine H&HA

---

### 12.4.1 Background

A detailed hydrologic and hydraulic analysis (H&HA) should be performed for all of the Department's new or replacement major drainage structures, bridged waterways, significant lateral encroachments (resulting from the placement of highway fill embankments within a floodplain) and stream restoration projects. It is necessary to do this such that Department construction is in compliance with national (i.e. FHWA, FEMA, etc.), State (i.e. Department of Conservation and Recreation), and municipal (locally delineated floodplains) rules and regulations. Detailed analysis, as used here, means that the hydraulic analysis shall be performed using an appropriate step-backwater computer model. In the case of Department construction in or in proximity to a FEMA detailed study floodplain, the existing effective analysis should be obtained as a basis for a revised step-backwater computer model.

Regardless of whether a bridged waterway, culvert, lateral encroachment or stream restoration project\* is being evaluated, in situations where a FEMA or other officially delineated floodplain is being considered, no increase in the established natural 100-year flood level will be permitted either up or downstream. In situations where no FEMA or other officially delineated floodplain exists (including FEMA Zone A designated floodplains), it will be acceptable to increase the cumulative level of the 100-year flood event not to exceed one foot upstream, provided such increase does not adversely impact adjacent properties, buildings, etc. If an increase in the 100-year flood level will cause such adverse impact then no increase shall be permitted. An exception allowing more than 1' increase may be granted in the case of a non-officially delineated floodplain provided the increase is fully contained within the right of way and/or a permanent drainage easement. A design waiver issued by the Department would be required under such circumstances.

### 12.4.2 Necessary Resources

The resources necessary to perform an H&HA usually include, but would not be limited to: topographic maps, aerial photographs, maintenance records for the existing bridge, bridge data sheet, bridge situation survey, proposed bridge plans, sufficient roadway plans, profiles, and typical sections to cover the width of the floodplain in the vicinity of the crossing.

In the event a FEMA floodplain (or other officially delineated floodplain) is involved, it will be necessary to have any available flood profiles, maps, and hydraulic model data. The Department will secure and provide any necessary hydraulic model data. In the event a bridged waterway is involved, it will be necessary to have a schematic bridge layout or proposed bridge plan, bridge situation survey, and bridge data sheet.

---

\* Rev 7/16

### 12.4.3 Hydrologic Analysis

If the site is not covered by a FEMA (or other officially delineated) floodplain, it will be necessary to determine a range of design peak discharges to use in the subsequent hydraulic analysis. See Chapter 6, Hydrology, for detailed information on application and procedures of hydrologic methods.

Methods employing total storm runoff (i.e. a hydrograph) consideration, such as the USACE HEC-1 or HEC-HMS or the NRCS' TR-20 and TR-55 models can be employed but aren't normally be necessary unless a hydrograph (as opposed to an instantaneous peak) is otherwise needed as in the case of an impoundment structure.

If the site is covered by a FEMA (or other officially delineated) floodplain, the published discharges shall be compared to other established method and assess if they are within acceptable limits. If so, the published peak discharges employed in making the official floodplain delineation shall be employed. If it is determined that the published discharges are not valid this should be documented and submitted in the H&HA report.

In all cases the 2, 5, 10, 25, 50, 100, and 500-year flood magnitudes will either be determined or obtained (from appropriate sources) and employed and documented in the subsequent hydraulic analysis.

### 12.4.4 Hydraulic Analysis

When an existing study is available the Department prefers a three-step procedure for performing the hydraulic analysis using an approved (or preferred) step-backwater computer model. When there is no Existing Effective Model then proceed directly to the Existing Conditions Model. When the existing effective model includes a floodway this must be included in the analysis procedure.

#### 12.4.4.1 Existing Effective Model

If a FEMA (or other officially delineated) floodplain is involved, the first step will be to mathematically reproduce the hydraulic model if practicable using the same step-backwater computer model on which the original floodplain was based. If the step-backwater computer model used to perform the original hydraulic analysis is no longer available or is not readily available, one of the approved step backwater computer models may be employed as long as it is adjusted to match the official model as closely as practicable. In accordance with FEMA directives HEC-RAS may be used in lieu of the originally employed computer model provided: (1) the program version employed must be at least version 3.1.1 or higher and (2) it ties back in to the original study model within 0.5' at the upstream and downstream ends for the reach being modeled. Any exception to this criterion must be approved by the VDOT Hydraulics Section. The first hydraulic model will be referred to as the "EXISTING EFFECTIVE" model.

---

\* Rev 7/16

#### 12.4.4.2 Existing Conditions Model (Adjusted)

The next step would be to use the most recent survey and detailed bridge data to create or update any natural ground cross sections to the locations necessary to subsequently model any proposed construction. Any new model should extend sufficiently downstream and upstream of the crossing to adequately evaluate the conditions. This is typically at 1000' in both directions. It should be emphasized that any changes made in the "EXISTING EFFECTIVE" model should be for the purpose of facilitating the modeling of proposed conditions, updating the survey and correcting any observed errors in modeling methodology within the area of the project. This model then becomes the basis for measurement of any changes that would take place as a result of the proposed construction. This second hydraulic model will be referred to as the "EXISTING CONDITIONS" model.

#### 12.4.4.3 Calibration

Reasonable efforts should be made to assess any existing studies or historical data (if available) at the crossing and if the model can be calibrated using this information. Calibration efforts should be discussed in the submitted documentation.

#### 12.4.4.4 Proposed Conditions Model

Once the Existing Condition Model has been calibrated the hydraulic model will be modified to include any and all proposed construction and will be referred to as the "PROPOSED CONDITIONS" model. The allowable impacts to the 100-year flood elevation are subject to the limitations discussed previously in Section 12.2.4.3

### 12.4.5 Documentation

#### 12.4.5.1 Detailed Hydrologic & Hydraulic Analysis – LD-293

The purpose of the form is to summarize the primary data sources and results of the analysis for review and used by others. A blank document is included in Appendix 12A and is available on the forms section of the VDOT website. In the case of a lateral floodplain encroachment due to a highway fill embankment or stream restoration projects, the outline may be adjusted to allow for the fact that a drainage structure is not involved. In such cases it should also be modified or supplemented as necessary to include a tabulation or spreadsheet showing existing and proposed water surface elevations at various locations along the highway embankment. A separate narrative and tabulation may be prepared in lieu of using the outline in this case. This documentation may be used as the Hydraulic Commentary for the purpose of environmental permits. This form along with the bridge front sheet, roadway plan and profile and any scour or riprap computations as appropriate are to be submitted to Project PM for distribution as well as the District and Central Office Hydraulics Staff.

---

\* Rev. 7/16

#### **12.4.5.2 Engineering Assessment of No Adverse Impact**

When a crossing is evaluated using engineering judgment there is little to no data to include in an LD293 Documentation. In the event of a HERS determination, a brief paragraph stating this will suffice. In the event that the determination was made using qualitative means and engineering judgment, a memo discussing the hydraulic properties of the crossing and how they are modified by the project and the potential impact on the flooding.\*

This memo is to be submitted to Project PM for distribution in lieu of the LD-293 and will serve as the Hydraulic Commentary for the purpose of environmental permits.

See Appendix 12D for examples.

#### **12.4.5.3 System of Units**

The LD-293 assembly will be prepared using English Units.

#### **12.4.5.4 Level of Precision for Documentation**

The following are guidelines governing the level of accuracy to show in the LD-293 assembly:

1. Elevations, etc. obtained from the survey are to be shown as obtained up to two decimal places.
2. Elevations, distances, etc. obtained from the plans are to be shown as obtained up to two decimal places.
3. The magnitude of peak discharges should be shown to three significant figures. For example, show 12,687 cfs as 12,700 cfs.
4. Show velocities to the nearest 0.1 fps.
5. Show calculated water surface elevations to the nearest 0.1'.
6. Show changes in calculated water surface elevations to the nearest 0.1'.
7. Show watershed areas to the nearest  $\text{mi}^2$  or 3 significant figures if less than  $100 \text{ mi}^2$ .

---

\* Rev. 7/16

### 12.4.6 H&HA Submission

When the H&HA has been performed by the consultant for the Department, the following items should be submitted to the Department:

1. The completed LD-293, as an electronic\* document file and as a hard copy printout (including the anticipated final scoured bed profile for both the design and check flood events) in the event the H&HA was for a bridged waterway.
2. Electronic copies of any and all copies of the hydraulic model data on which the H&HA was based (i.e. HEC-2, HEC-RAS, etc. data files).
3. PDF copies of the Bridge Front Sheet, relevant sections of the Roadway Plan and Profiles,
4. Copies of any supplemental calculations incidental to the H&HA, i.e. Hydrology, scour, outlet control, slope protection etc.
5. Copies of any supplemental documentation not covered in the LD-293. Any materials and/or resources that have been loaned out by the Department to assist in performing the H&HA such as FEMA studies, etc.
6. Regardless of whether the project crosses or otherwise impacts a FEMA regulatory floodplain or floodway, a FEMA Firmette or an excerpt from the FEMA Community Map Panel covering the site should be included.

This information is to be submitted to the VDOT contact person who has been designated as the coordinator for drainage design.

---

\* Rev. 7/16

---

## 12.5 Tidal H&HA

---

### 12.5.1 Background

A detailed hydrologic and hydraulic analysis (H&HA) should be performed for all of the Department's new or replacement major tidal drainage structures and/or bridged tidal waterways. It is necessary to do this in order that VDOT construction be in compliance with national (i.e., FHWA, FEMA, etc.), state (DCR, etc.), and municipal (locally delineated floodplains) rules and regulations. The recommended procedures are described in the FHWA publication "Tidal Hydrology, Hydraulics and Scour at Bridges" (HEC-25).

Detailed analysis, as used here, also means that a three-level analysis such as outlined in HEC-20 and HEC-18 will be employed to evaluate the potential for scour around bridge foundations in order to design new and replacement bridges to resist scour. The complexity of the hydraulic analysis increases if the tidal structure or bridge constrict the flow and affect the amplitude of the storm surge (storm tide) so that there is a large change in elevation between the ocean and the estuary or bay, thereby increasing the velocities in the constricted waterway opening.

### 12.5.2 Necessary Resources

The resources necessary to perform an H&HA of tidal crossings, as for riverine crossings, usually include, but would not be limited to: topographic maps, aerial photographs, maintenance records for the existing bridge, bridge data sheet, bridge situation survey, proposed bridge plans, sufficient roadway plans, profiles, and typical sections to cover the width of the floodplain in the vicinity of the crossing.

Other resources **that may be**\* necessary for tidal analysis are: velocity meter readings, cross section soundings, location of bars and shoals, magnitude and direction of littoral drift, presence of jetties, breakwater, or dredging of navigation channels, and historical tide records. Sources of data include NOAA National Ocean Service, USACE, FEMA, USGS, U.S. Coast Guard, local universities, oceanographic institutions and publications in local libraries. NOAA maintains tidal gage records, bathymetric charts, and other data on line at [www.nos.noaa.gov](http://www.nos.noaa.gov). Also refer to Chapter 13, Shore Protection, for details on working with tidal datum.

---

\* Rev. 7/16

### 12.5.3 Coastal Bridge and Culvert Design Techniques

The hydraulic design guidelines for coastal or tidally influenced waterway bridge openings are complicated phenomenon is difficult to simulate. Coastal waterways are subject to storm surges and astronomical tides which play an important role in hydraulic behavior. The collection of adequate data to represent the actual condition also adds to the complexity of the problem. Data such as flows and storm surge description may be difficult to estimate. For small bridges, complex modeling may not be cost effective since the cost of the study may exceed the cost of the bridge.

Presently there is no standard procedure for the design of tidally influenced waterways. In many cases, the bridge hydraulic opening is designed to extend across the normal open water section. This may be an appropriate design from an economic standpoint; since the total cost of a larger bridge may approximate the cost of a smaller bridge considering approach embankments and abutment protection measures. This design is also desirable from an environmental perspective since it results in minimal environmental impacts. In most designs, the extent of detail in the analysis must be commensurate with the project size or potential environmental impacts. However, analytical evaluation of the opening is often required and is necessary when a full crossing cannot be considered or when the existing exhibits hydraulic problems. The complexity of these analyses lends themselves to computer modeling.

Because of the lack of standard procedures for the design of coastal waterways, research is being conducted on this matter. A FHWA pooled fund study coordinated by the South Carolina Department of Transportation has developed recommendations for modeling of tidally influenced bridges. In addition to design guidelines, technical research needs to be conducted to better understand the hydraulics in tidally influenced waterways.

Research is needed in the following areas: sediment transport and scour processes, coastal and tidal marsh ecosystems, environmental impacts and the development of comprehensive coastal hydraulics models.

---

\* Rev. 7/16

### **12.5.4 Computer Modeling**

Existing models cover a wide range from simple analytical solutions to heavy computer intensive numerical models. Some models deal only with flows through inlets, while others describe general one-dimensional or two-dimensional flow in coastal areas. A higher level includes hurricane or other storm behavior and predicts the resulting storm surges.

One-dimensional steady state models are the most commonly used models because they demand less data and computer time than the more comprehensive models. Most analyses for tidal streams are conducted with steady state models where the tidal effects are not simulated. This may be an adequate approach if the crossing is located inland from the mouth where the tidal effects are insignificant. Computer modeling for steady state hydraulics is generally performed with the Corps of Engineers HEC-RAS (or HEC-2).

In the event that either tidal fluctuations or tidal storage are significant, simulation of the unsteady hydraulics is more appropriate. Unsteady flow computer models were evaluated under a FHWA pooled fund research project administered by the South Carolina Department of Transportation (SCDOT). The purpose of this study was to identify the most promising unsteady tidal hydraulic models for use in scour analyses. The study identified UNET, FESWMS-2D, and RMA-2V as being the most applicable for scour analysis. The research funded by the FHWA pooled fund project is being continued to enhance and adapt the selected models so that they are better suited to the assessment of scour at tidal bridges.

The pooled fund research project also resulted in guidance on the appropriate methodology to use based on the geomorphic characteristics of the tidal waterway. Where complicated hydraulics exists, for instance as in wide floodplains with interlaced channels or where flow is not generally in one direction, a one-dimensional model may not represent adequately the flow phenomena and a two-dimensional model is more appropriate. Two-dimensional models in common use to model tidal flow hydraulics are FESWMS-2DH and RMA-2V. FESWMS-2DH, a finite element model was prepared for the FHWA by David C. Froehlich and includes highway specific design functions such as pier scour, weirs, and culverts. RMA-2V, also a finite element model, was developed by the US Army Corps of Engineers. FESWMS-2DH and RMA-2V can also incorporate surface stress due to wind. These models require considerable time for model calibration. Thus, they do not lend themselves for analysis of smaller structure sites.

The US Army Corps of Engineers' UNET model is widely accepted in situations where the more complicated two-dimensional models are not warranted or for use in making preliminary evaluations. UNET is a one-dimensional, unsteady flow model. The Corps of Engineers has now modified HEC-RAS to incorporate dynamic routing features similar to UNET.

Alternatively, either a procedure by Neill for unconfined waterways, or an orifice equation for constricted tidal inlets can be used to evaluate the hydraulic conditions at bridges influenced by tidal flows. The procedure developed by Neill can be used for tidal inlets that are unconfined. This method, which assumes that the water surface in the tidal prism is level, and the basin has vertical sides, can be used for locations where the boundaries of the tidal prism can be well defined and where only small portions of the inundated overbank areas are heavily vegetated or consists of mud flats. The friction loss resulting from thick vegetation tends to attenuate tide levels thereby violating the assumption of a level tidal prism. The discharges and velocities may be over estimated using this procedure. In some more complex cases a simple tidal routing technique (TIDEROUT) or a simple UNET or other 1-dimensional model (HEC-RAS) can be substituted with a similar level of effort. UNET includes storage areas that are assumed to fill as level pools.

### **12.5.5 Hydrologic Analysis**

The flow associated with a tidal bridge generally consists of a combination of riverine and tidal flows. VDOT's Tidal Bridge Scour Data & Worksheet (Appendix 12C-2) will be used to calculate both the tidal and riverine flow components for tidal crossings. This worksheet utilizes a "VDOT only" modification of Neill's method for calculating tidal flow and USGS Regression equations for riverine flow. The data required to complete this worksheet is generally available from field data and limited research. A discussion which addresses the information needed to complete the Tidal Bridge Scour Data & Worksheet follows.

#### **12.5.5.1 Bridge Location**

- Bridge Number, Route, County, Length and River Crossing can be obtained from bridge plans and inspection reports.
- Tidal Bridge Category:
  - Islands: Passages between islands or between an island and the mainland where a route to the open sea exists in both directions.
  - Semi-Enclosed Bays & Inlets : Inlets between the open sea and an enclosed lagoon or bay where most of the discharge results from tidal flows.
  - Estuaries : River estuaries where the discharge consists of river flow as well as tidal flow.

#### **12.5.5.2 Channel Cross Section**

Channel cross section data may be obtained from several sources such as VDOT Central or District offices, bridge plans and/or bridge inspection reports.

### **12.5.5.3 Drainage Area Characteristics**

Drainage area characteristics are required for estimating peak flood discharges using the USGS regression equations for Virginia. (See FHWA Tidal Pooled Fund Study “Tidal Hydraulic Modeling For Bridges” Section 3.4 for guidance in combining storm surge and upland runoff.)

- Drainage area estimated from USGS topographic maps (1:24000), NOAA Navigation maps or similar topographic maps from other sources such as county topographic maps.
- Percentage of forested area, main channel slope, average basin elevation and main channel length can be estimated from USGS topographic maps, street maps or other types of topographic maps.

### **12.5.5.4 Storm Tides**

- The surface area of the tidal basin is required for estimating tidal flows. From USGS topographic maps or NOAA navigation maps, the surface area of the tidal basin can be obtained by planimetry several different contour line levels, and then developing a graph of the surface area versus elevation. Since the maximum tidal flow normally occurs at mid-tide, the preferred method of analysis is to determine the surface area of the tidal basin at this elevation. The surface area of the tidal basin at the mid-tide elevation can be determined from the graph by interpolation.
- The 10, 50, 100 and 500-year storm tides can be obtained from the maps and figures of the coastal regions of Virginia located in the appendix. The maps and table of storm tide description have been compiled and developed from existing FEMA Flood Insurance Study reports, NOAA tidal records, US Army Corps’ tidal analysis and Ho’s Hurricane Tide Frequencies Along The Atlantic Coast.
- Tidal flow is the product of the surface area and the rate change of the tidal height and may be expressed by the following equation:

$$Q=24312 A_s \frac{H}{T}$$

where Q = Tidal flow, in cfs

$A_s$  = Surface area of the tidal area upstream from the bridge at the mid-tide elevation, in sq. mi.

H = Tidal height, between low tide and high tide, in feet.

T = Period of the storm tide, in hours. (See Note 1)

Note 1: Obtain both H and T from the maps and table in Appendix 12C-3 and 12C-4.

### 12.5.5.5 Flow Velocity

The flow velocities should be calculated for the flow conditions that may result in higher velocities. These conditions include: (a) the peak riverine flow with a low downstream water level and (b) the combined tidal flow and the flood peak flow, with the water level at the mid-tide elevation.

There is an additional condition, (c), that needs to be investigated for tidal bridges located on estuaries some distance upstream from a bay or ocean. The flow depth at bridges in such cases is less likely to be controlled by the tidal elevation in the bay and more likely to be controlled by the channel slope, boundary roughness and channel geometry. Using the low sea level to calculate the flow velocity for such bridges may result in an unreasonably high velocity due to underestimation of the flow depth and cross-sectional area. Manning's equation should be used to estimate the flow velocity in such cases. Engineering judgment should be applied when estimating the flow conditions and appropriate flow depth to be used in calculating the velocity of flow. Particular attention needs to be directed at determining the appropriate combination of riverine and tidal flows for use in estimating worst case scour conditions.

The flow velocities estimated by the above methods represent an approximate value for use in the screening process. A detailed H&H Study is required if a more accurate estimation of velocities is desired.

The analysis of the flow velocity in this Worksheet assumes steady flow even though tidal flow is an unsteady flow phenomenon. The resulting velocity will generally be slightly different from a velocity calculated on the basis of unsteady flow. Since the rate of the vertical motion of storm tides is on the order of only three to eight thousandths of a foot per second, the velocity estimates obtained from the method discussed above should be reasonable for locations in unconstricted bays and estuaries where velocities are on the order of 3 fps or less.

Maps and figures of the coastal regions of Virginia that describe the tidal storm surge periods and predicted water surface elevations for the 10, 50, 100 and 500-year storms are shown in Appendix 12C-3 and 12C-4

## 12.5.6 Hydraulic Analysis

VDOT's Tidal Bridge Scour Data and Worksheet (Appendix 12C-2) will be used during the Level 1 Analysis (see HEC-18) in order to estimate the maximum flow velocities through the tidal bridge during the passage of a storm tide. This estimate should be considered as a first approximation for use in judging whether the proposed tidal bridge requires a more detailed H&HA.

Normally, Neill's method of analysis should provide an acceptable degree of accuracy for tidal inlets and estuaries that are not significantly constricted and where flow velocities are 3 fps or less.

Where the waterway is constricted and estimated flow velocities exceed 3 fps, it may be appropriate to route the storm tide through the structure for purposes of obtaining a more accurate estimate of storm tide velocities. The TIDEROUT computer program is recommended for use when making calculations involving tide routing through a structure. TIDEROUT is a BASIC computer program developed by Mr. Raja Veeranachaneni, MD SHA. A copy of the TIDEROUT program is available on request from the department's Hydraulics Section. If the estimated flow velocity from the Tidal Worksheet is 7 fps second or greater, routing of the storm tide through the structure should be considered.

Where the simplified methods yield overly conservative results, the use of routing techniques or unsteady flow computer models (Level 2) will provide more realistic predictions of hydraulic properties and scour.

For certain types of open tidal waterway crossings, worst-case scour conditions may be caused by the action of the wind. In other cases, such as passages between islands or an island and the mainland, the worst-case condition may represent a combination of tidal flow and wind forces. These specialized cases require careful analysis and should be studied by engineers with a background in tidal hydraulics.

Electronic spreadsheets are available which assist in the generation of storm surge hydrographs for use in defining downstream boundary conditions during hydrodynamic modeling. These spreadsheets are available on request from the Department's Hydraulics Section. Maps showing the locations of ADCIRC stations along the Virginia coast where storm surge hydrographs are available are included in Appendix C of the "Tidal Hydraulic Modeling for Bridges" publication. Also available are spreadsheets that assist in the computation of time dependent scour and wave heights for tidal sites.

The FHWA Tidal Pooled Fund Study's "Tidal Hydraulic Modeling for Bridges" publication presents guidance on the appropriate methodology to use based on the geomorphic characteristics of the tidal waterway.

### **12.5.7 Documentation**

The documentation for a tidal H&HA will be the same as required for a riverine H&HA.

### **12.5.8 H&HA Submission**

When the H&HA has been performed for a tidal site by the consultant for the Department, the level of documentation to submit to the Department should be the same as required for a riverine site.

## 12.6 Riprap for Protection of Bridge Abutments and Piers

---

Riprap is frequently used for protection of the earthen fill slopes employed in spill-through abutments. In such situations, it can serve the two-fold purpose of protecting the underlying shelf abutment and piers against runoff coming from the approach roadway and bridge superstructure as well as from scouring due to impinging flow resulting from floodwaters. However, in order to qualify as a scour countermeasure, the riprap thickness, placement, and coverage must be in accordance with the procedures described in HEC-23. Riprap can also be used around solid, gravity abutments to protect against scour. Riprap is considered an acceptable scour countermeasure for protection of bridge abutments. The use of riprap at bridge piers, on the other hand, is not acceptable for use in new construction and is considered only as a temporary countermeasure in the case of rehabilitation. The Department employs the riprap design procedures presented in the FHWA publication “Bridge Scour and Stream Instability Countermeasures Experience, Selection, and Design Guidance” (HEC-23). The Department has developed a computer program entitled “BRRIPRAP” which sizes the riprap necessary for abutment protection in accordance with HEC-23. It is available in the VDOT web based Hydraulic Application.

This riprap shall be placed over an appropriate bedding material. For geotextile bedding under the riprap being used for bridge spill slopes, a stone cushion layer consisting of VDOT no. 25 or 26 aggregate should be placed between the riprap and geotextile bedding in accordance with the following:

- In the case of Class AI and I riprap, the aggregate cushion layer should be 4 inches thick
- In the case of Class II, Class III, Type I, and Type II riprap, the aggregate cushion layer should be 6” thick

When it is found necessary to employ riprap as a scour countermeasure around existing bridge piers for rehabilitation purposes, the design shall be performed in accordance with HEC-23 and/or must be reviewed and approved by an appropriate Department River Mechanics Engineer. Bedding requirements in such situations shall be in accordance with the above or as directed by the District Materials Engineer.

---

\* Rev. 7/16

---

## 12.7 Removal of Existing Bridge and Approach Embankments

---

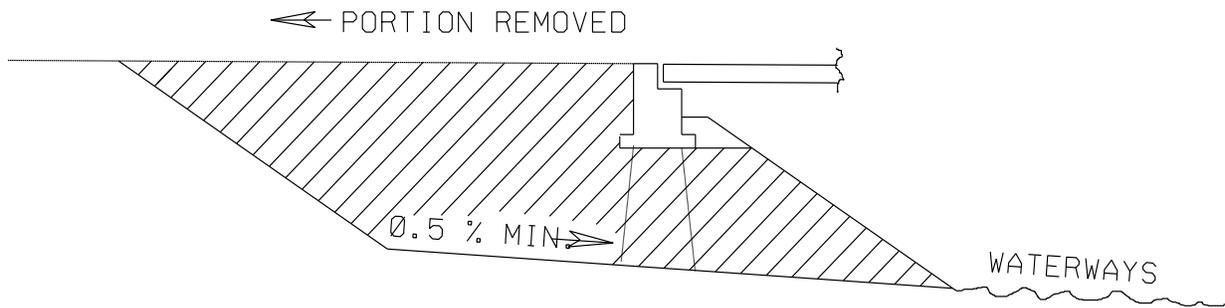
In the process of building a new bridged waterway and approaches, it often becomes necessary to remove all or a portion of the existing bridge approach roadway fill throughout the floodplain area. This is necessary for two reasons. First, leaving portions of the old bridge approaches in place may hinder the hydraulic capacity and efficiency of the new facility. In most instances the hydraulic performance of the new facility is predicated on the complete removal of the old one. Second, many State and/or Federal Environmental review agencies require that the old bridge and roadway approaches be removed in their entirety and the land graded back to its natural contour as a contingency for the issuance of certain environmental permits. The hydraulic engineer responsible for the performance of the hydrologic and hydraulic analysis for the proposed bridged waterway will notify the road designer as to whether or not it will be necessary to remove all or portions of the existing bridge and approaches.

When an existing bridge is to be removed, the bid item for removal of the existing bridge will include the entire superstructure and all portions of the substructure, such as abutments, wing walls and piers, pilings and riprap or slope protection. No portion of the approach roadway embankment is to be included in this bid item.

The limits of the approach roadway embankment to be removed will be furnished to the road designer by the Hydraulics Section and shown on Form LD-293B (Appendix 12B-3). These limits are to be shown on the road grading plans along with the following note:

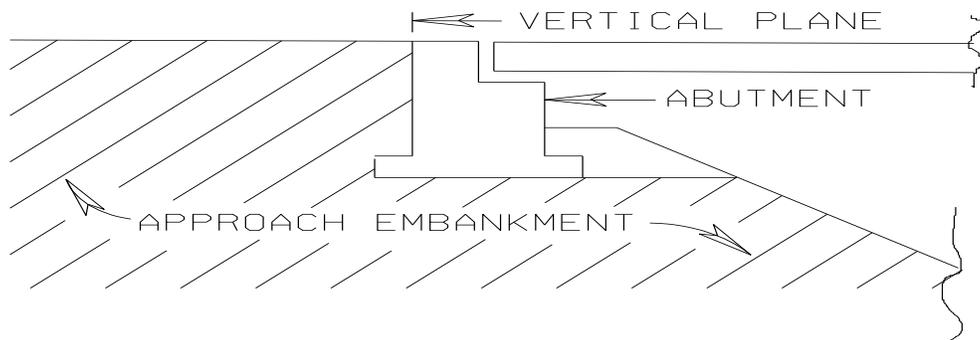
“The existing approach roadway embankments will be removed between Station \_\_\_\_\_ and Station \_\_\_\_\_ and will be included in the quantity for regular excavation.”

When a portion of existing approach embankments are removed for flood control, the remaining approach embankment surface should be graded on an approximate 0.5% slope toward the waterway in such a manner as not to impound any water on the surface after the flood waters have receded or after normal rainfall as shown in Figure 12-1.



**Figure 12-1. Removal of Approach Embankment**

The determination of quantities for the removal of approach embankment should be set up on a cubic yard basis and included in the plan quantity for regular excavation. The limits for computing the quantity is a vertical plane through the joint between the approach pavement and the end of the bridge as shown in Figure 12-2.



**Figure 12-2. Quantifying Removal of Approach Embankment**

The road designer will request such additional survey information as is necessary to delineate and estimate the quantities of the embankment to be removed.

The District Engineer must be afforded an opportunity to review and comment on the embankment removal proposal prior to completing the plans.

## **12.8 Temporary Construction Causeway Design**

---

### **12.8.1 Background**

The need to provide a construction access facility that will not have a significant impact on normal flow conditions is mandated by the state and federal agencies that issue and/or approve the issuance of appropriate environmental permits.

### **12.8.2 Causeway Design**

#### **12.8.2.1 Design Objectives**

- Provide a design that is reasonably convenient, economical, and logistically feasible for the contractor to build and remove.
- Provide a design that will not be subject to failure due to normal stream flow conditions. This should consider in-stream obstructions such as piers or islands that could direct high velocity jets at points along the causeway.
- Provide a design that will not cause a significant increase in the base flow ( $Q=1.1 \text{ DA mi}^2$ )\* stage, will not significantly increase the velocity of flow through the causeway opening(s) for that flow rate, will not significantly alter flow distribution, and will not concentrate flow on the piers and foundations that would subject them to forces for which they were not designed. The causeway's influence on flood flow elevations should be checked in the event that it does not wash out during a significant flood.
- Provide a design that will not obstruct over 50% of the width of the normal stream unless sufficient temporary drainage structures are placed under the causeway to offset greater reduction.

#### **12.8.2.2 Plans**

The temporary construction causeway should be designed as a rock prism. The design details and required notes should be shown on the typical section sheets (series 2 plan sheets) in the project plans or on a separate detail sheet for "Bridge Only" projects. A note, "Temporary Construction Causeway Required, See Sheet \_\_\_\_\_ of \_\_\_\_\_ for details" should be shown on the road plan sheet where the causeway appears. The design details and required notes for the "Temporary Construction Causeway" will be shown on the front sheet of Bridge plans for "Bridge Only" projects. A typical causeway design detail is shown in Figure 12-3.

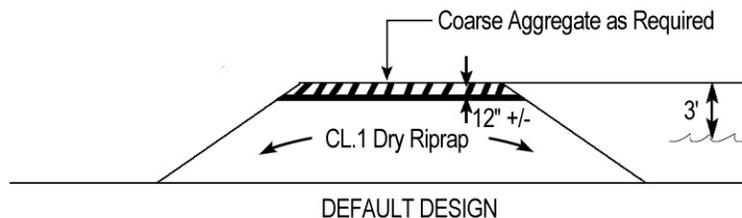
---

\* Rev. 7/16

The pay item(s) for causeways will be included with the road plans. For "Bridge Only" projects, the causeway pay item(s) will be included in the bridge plans.

The contractor should bid the rock causeway as shown on the plans. The contractor may elect to revise the design or substitute another design after being awarded the contract. If so, he should submit a revised design including necessary sketches and notes for review by the district construction, hydraulic and environmental personnel. The Department should obtain a revised environmental permit if necessary, for the contractor's revised design.

The material used in construction of the causeway should normally be Standard Class I Dry Riprap. The Hydraulic Engineer performing the hydraulic design for the causeway may, at his discretion, specify or authorize larger stone for the causeway's slope faces but must have sufficient justification for doing so. Such justification should be fully addressed in the hydraulic design documentation.



**Figure 12-3. Temporary Construction Causeway Design**

Show the top of the causeway as being 3' over "base flow".\*

### 12.8.2.3 General Notes

1. The basis of payment for the temporary causeway will be lump sum, which price should include all labor, equipment, materials and incidentals needed for construction, maintenance, removal and disposal of the causeway.
2. The Project Engineer may make minor adjustment in the location of the causeway provided that the adjustment does not change the design of the causeway.

\* Rev. 7/16

### 12.8.3 Design Procedure

- Step 1 Set the alignment of the causeway to facilitate construction activity. Set the finished grade 3'± above the base flow elevation. Set the side slope angle at approximately 1.5:1.*
- Step 2: Determine the required waterway opening(s) and the resulting hydraulic performance using appropriate hydraulic design techniques. It is recommended that pipes be used whose diameter (or rise as appropriate) is 2' less than the causeway is high. In other words, if the causeway is 6' high, then use 48" pipe(s).*

---

\* Rev. 7/16

---

## 12.9 References

---

American Association of State Highway and Transportation Officials. (2014). AASHTO Drainage Manual (First Edition). Washington, D.C.: American Association of State Highway and Transportation Officials.\*

American Association of State Highway and Transportation Officials. (2007). AASHTO Highway Drainage Guidelines (Fourth Edition). Washington, D.C.: American Association of State Highway and Transportation Officials.

Federal Highway Administration Hydraulic Engineering Circular No. 17, “The Design of Encroachments on Flood Plains Using Risk Analysis” – October 1980.

Federal Highway Administration Hydraulic Engineering Circular No. 18, “Evaluating Scour at Bridges” – April 2012.

Federal Highway Administration Hydraulic Engineering Circular No. 20, “Stream Stability at Highway Structures” – April 2012.

Federal Highway Administration Hydraulic Engineering Circular No. 23, “Bridge Scour and Stream Instability Countermeasures” – September 2009.

Survey Instructions Manual – Virginia Department of Highways & Transportation.

U. S. Army Corps of Engineers - HEC-2 Water Surface Profiles

U. S. Army Corps of Engineers - HEC-RAS River Analysis System

Federal Highways administration Hydraulic Design Series No. 6 “Highways in the River Environment” – December 2001.

---

\* Rev. 1/17

The documentation to include a completed electronic copy of the LD293 form which is available at the VDOT Website. Sections that are not applicable should be deleted.

LD293 (Rev 8/15)

Page 1 of 6

VDOT MAJOR STREAM CROSSING REPORT

UPC: <XXXXXX> Route <X> over <X> in <X City/X County> Project Number: <XXXX-XXX-XXX>

Prepared By: <X> Organization: <X> Date: <XX/XX/XXXX>

1. SUMMARY

The Hydrologic and Hydraulic Analysis has been completed for the stream crossing located on Plan Sheet <X> at approximate Roadway Station <X>. This is a <skewed / perpendicular> crossing of <X>. The proposed bridge/culvert <will replace the existing crossing on a similar alignment / will be on a new alignment and the existing crossing and embankment from Station <X> to Station <X> will be removed / will be placed on a new alignment and the existing crossing will remain in place. / is in a new location.>

ROADWAY: Based on the roadway classification the Design Event for the crossing should be the <X>-year event. The analysis shows that the crossing as designed <meets / does not meet > this design criteria by meeting the minimum shoulder freeboard requirement.

\* NOTE if the crossing does not meet the design criteria the design should be assessed to determine if a design waiver/exception is required.

BRIDGE / ENVIRONMENTAL: Based on the floodplain conditions the maximum impact allowed by the project on the 100-year flood elevation is <0.0 / 1.0> ft. The analysis shows that the crossing as designed <meets / does not meet > this performance criteria.

\*\* NOTE if the crossing does not meet the performance criteria, additional coordination measures will be required with the property owners, DCR Floodplains and the Locality and may require a design exception or waiver.

<No recommendations are being made that would affect the road or bridge plans. / The following recommendations are made that may affect the road or bridge plans: list >

DCR FLOODPLAINS / LOCALITY: The project is located in the <X> <City/Town/County> and <is / is not> located in a mapped Flood Zone <A, AE, A#, VE>. The effective Base Flood Elevation (BFE) at the site is <mapped elevation, not determined>. See attached FIRMette.

2. STRUCTURE DESCRIPTION

<Bridge only>

- Abutment A Station: <X> Finished Grade Elevation <X> ft.
Abutment B Station: <X> Finished Grade Elevation <X> ft.
Minimum Low Chord Elevation: <X> ft.
Skew <X> degrees to Flood Flow
Total Span Length: <X> ft.
Abutment Type: <X>
Number/Type Piers: <X>

<Culvert only>

- Size, Material and Shape of Culvert: <X>
Number of Barrels: <X> Length: <X> ft. Height of Cover: <X> ft.
Invert In: <X> ft. Invert Out: <X> ft.

LD293 (Rev 8/15)

Page 2 of 6

**VDOT MAJOR STREAM CROSSING REPORT**

UPC: <XXXXXX> Route <X> over <X> in <X City/X County> Project Number: <XXXX-XXX-XXX>

Prepared By: <X> Organization: <X> Date: <XX/XX/XXXX>

Allowable Headwater: <X> ft. HW/D: <X>

Skew <X> degrees to Flood Flow

**3. HYDROLOGY**

The hydrology used in the hydraulic analysis was based upon the <Flood Insurance Data / (method) using data obtained by VDOT / (other)>.

Drainage Area at this location is <X> square miles

**4. HYDRAULIC PERFORMANCE**

The hydraulic analysis was performed using the <FHWA water surface profile computer model WSPRO / USACOE water surface profile computer model HEC-RAS (or HEC-2) / (describe the approach, method or model)>.

Discharge (cfs)	Exceedance Probability %	Change in existing flood levels (ft.)	Flood Elev. at common upstream sect <X> (ft.)	Velocity in the vicinity of the bridge (fps)
	50%			
	20%			
	10%			
	4%			
	2%			
	1% (natural)			
	1% (floodway)			
	0.2%			

Design Summary	Exceedance Probability %	Elevation (ft.)
100-Year Base Flood	1%	
Roadway Design Flood		
Bridge 1 ft. Freeboard Flood*		
Overtopping Flood		
Historical Flood <date>		

\* Report the nearest standard storm event analyzed that would provide at least 1 ft. minimum clearance to the lowest low chord elevation on the bridge deck.

**5. APPLICABLE FLOODPLAIN MANAGEMENT CRITERIA**

<Select applicable statement>

For a project within a FEMA delineated floodplain:

LD293 (Rev 8/15)

Page 3 of 6

**VDOT MAJOR STREAM CROSSING REPORT**

UPC: <XXXXXX> Route <X> over <X> in <X City/X County> Project Number: <XXXX-XXX-XXX>

Prepared By: <X> Organization: <X> Date: <XX/XX/XXXX>

- FEMA establishes flood level, flood velocity, and flow distribution and this project is within FEMA community panel number: <X> and Zone <A, AE, VE>. This project complies with FEMA requirements because there will be no increase in flood levels, velocities or flow distribution. This project complies with DDM-7 of the VDOT Drainage Manual, and the general understanding of floodplain development process coordinated between VDOT, DCR and FEMA; or

For a project in a FEMA floodplain with a Zone A designation that does not have base flood elevations, an increase in the cumulative 100-year flood elevation not exceeding one foot (1.0') is acceptable:

- FEMA establishes flood level, flood velocity, and flow distribution and this project is within FEMA community panel number: <X> and Zone A. This project complies with FEMA requirements because there will be no more than a cumulative one foot (1.0') increase in the 100-year flood elevation and velocities and flow distribution will not be significantly altered. This project complies with DDM-7 of the VDOT Drainage Manual, and the general understanding of floodplain development process coordinated between VDOT, DCR and FEMA; or

For a project in a FEMA floodplain with a Zone A or AE designation that does has an increase greater than the allowable limits:

- FEMA establishes flood level, flood velocity, and flow distribution and this project is within FEMA community panel number: <X> and Zone <A, AE>. This project complies with FEMA requirements because a CLOMR has been submitted to the county. This project complies with DDM-7 of the VDOT Drainage Manual, and the general understanding of floodplain development process coordinated between VDOT, DCR and FEMA; or

For projects not within a FEMA delineated floodplain, include the following statement:

- This project is not within a delineated FEMA floodplain. There are no FEMA requirements applicable within the project area.

**6. FEMA DATA COMPARISON** <if applicable in a FEMA AE or A# Zone>

In order to provide additional data to FEMA to help identify potential candidate areas for restudy, a comparison of the VDOT analyses and the FEMA published study is provided below. Note that these comparisons show the differences in the two analyses and do not represent the actual project impact.

FEMA Datum: <NGVD29 / NAVD88> Adjustment needed

The VDOT data reported in the following tables are based upon the proposed conditions analyses:

LD293 (Rev 8/15)

Page 4 of 6

**VDOT MAJOR STREAM CROSSING REPORT**

UPC: <XXXXXX> Route <X> over <X> in <X City/X County> Project Number: <XXXX-XXX-XXX>  
 Prepared By: <X> Organization: <X> Date: <XX/XX/XXXX>

**HYDROLOGY**

Event	FEMA Discharge (cfs)	VDOT Discharge (cfs)
10-year		
50-year		
100-year		
500-year		

<if it can be determined, provide a brief discussion of why there are differences between the two analyses>

**HYDRAULICS**

Event	Elevation Upstream of Structure (ft)			Elevation at Upstream Limit of VDOT Study (ft)		
	FEMA (adj)	VDOT	Difference	FEMA (adj)	VDOT	Difference
10-year						
50-year						
100-year						
500-year						

<if it can be determined, provide a brief discussion of why there are differences between the two analyses>

**7. RIPRAP RECOMMENDATIONS**

Riprap for abutment slope protection: <Bridge only - select applicable option or amend as necessary>

- Riprap protection is not being employed; or
- The following riprap protection is being employed:
  - 26" Class I Dry Riprap over 4" no. 25 or 26 aggregate over filter cloth
  - 38" Class II Dry Riprap over 6" no. 25 or 26 aggregate over filter; or
- The indicated riprap protection was sized in accordance with the FHWA's BRIDGE SCOUR AND STREAM INSTABILITY COUNTERMEASURES (HEC-23) publication. Slope protection alone does not qualify as a bridge scour countermeasure

Riprap for outlet protection: <Culvert only - select applicable option or amend as necessary>

- Riprap outlet protection is not required at this structure; or
- The following riprap protection is being employed:
  - 26" Class I Dry Riprap over 4" no. 25 or 26 aggregate over filter cloth

LD293 (Rev 8/15)

Page 5 of 6

**VDOT MAJOR STREAM CROSSING REPORT**

UPC: <XXXXXX> Route <X> over <X> in <X City/X County> Project Number: <XXXX-XXX-XXX>

Prepared By: <X> Organization: <X> Date: <XX/XX/XXXX>

- 38" Class II Dry Riprap over 6" no. 25 or 26 aggregate over filter
- The riprap apron should be <X> ft. wide and <X> ft. long; or
- The design is based upon DEQ approved methodologies

**8. STANDARD STATEMENTS <for both bridges and culverts>**

CAUSEWAYS: The use of causeways for temporary construction access was not considered in this analysis. If it is subsequently found necessary to use causeways, they must be submitted to the Hydraulics Staff for analysis and documentation.

<Select the statement(s) below, as applicable to the project>

Temporary construction access causeways for this project should be composed of <specify>.

The high flow profiles will not be affected.

The causeway will not affect the water surface profile of base flow.

The maximum causeway elevation is <X> ft.

From Abutment A to Station <X>

From Station <X> to Abutment B

Only one will be in place at a time

EROSION AND SEDIMENT CONTROL: An Erosion and Sediment Control Plan will be prepared and implemented in compliance with Virginia Erosion and Sediment Control Law and Regulations, and VDOT's Annual Erosion and Sediment Control Standards and Specifications approved by the Department of Environmental Quality.

STORMWATER MANAGEMENT: Design of this project will be in compliance with the Virginia Stormwater Management Act and Regulations, and VDOTs Annual Stormwater Management Standards and Specifications, as approved by the Department of Environmental Quality.

STREAM BANK STABILIZATION: <The banks should reestablish themselves to the natural conditions. / The Riprap should be placed on all areas that will not support vegetation. / Disturbed areas outside the bridge should be seeded.>

**9. BRIDGE SCOUR <Bridge only>**

<Select the appropriate statement>

- A scour analysis has not been performed at this time. Please provide the Hydraulics Staff with the geotechnical report once it is available; or
- A review of the Geotechnical Report and coordination with the S&B geotechnical staff have determined that the Bridge Foundations will be constructed on scour resistant material. No scour computations have been performed; or

LD293 (Rev 8/15)

Page 6 of 6

**VDOT MAJOR STREAM CROSSING REPORT**

UPC: <XXXXXX> Route <X> over <X> in <X City/X County> Project Number: <XXXX-XXX-XXX>  
Prepared By: <X> Organization: <X> Date: <XX/XX/XXXX>

- Scour computations and a sketch of the design and check scoured bed profiles are attached. If scour countermeasures are required, a request must be submitted to the Hydraulics Staff for their design and documentation

**10. COUNTERSINKING AND MULTIPLE BARRELL CULVERTS <Culvert only>**

<Select ONLY the statements that are applicable>

- The upstream and downstream inverts of culverts with diameters greater than 24" (or equivalent) will be countersunk a minimum of 6" below the stream bed; and/or
- The upstream and downstream inverts of culverts with diameters equal to or less than 24" (or equivalent) will be countersunk a minimum of 3" below the stream bed; and/or
- At least one barrel of a multiple barrel culvert structure will be countersunk a minimum of 6" for a diameter greater than 24" (or equivalent) or a minimum of 3" for a diameter equal to or less than 24" (or equivalent); and/or
- The width of the countersunk culvert barrel(s) receiving the low flow is approximately the width of the normal stream bed; and/or
- Low flow design measures have been implemented for multiple barrel culverts in which all barrels will be countersunk; and/or
- Culverts on bedrock will be countersunk a minimum of 3" below the stream bed; and/or
- Culverts on bedrock will be countersunk a minimum of 3" at the upstream end and stone step pools, low rock weirs or other measures will be constructed at the downstream end; and/or
- Countersinking of the culverts is not practicable due to <X> (See Drainage Manual Section 8.3.7). See attached supporting documentation

**11. COMMENTS**

<Note any channel modifications, floodplain impacts and impact mitigation measures, as well as other data pertinent to the design. Also comment on the feasibility of using a smaller structure>

This analysis is only applicable to the structure(s) and approaches described. Any changes in these conditions may invalidate this analysis and should be reviewed by Hydraulics Staff.

This design represents the smallest structure practicable for use at this site.

If this project is an interstate or other NHS project and is expected to be in excess of \$1,000,000.00, please notify the FHWA that (1) no hydraulic impacts are anticipated or (2) the following hydraulic impacts are anticipated: <list>

If you have any questions or need additional information, please contact <X> at <X> or via electronic mail at <X>.

**Appendix 12B-1 LD-23 Structure and Bridge Data Sheet**

---

VIRGINIA DEPARTMENT OF TRANSPORTATION  
STRUCTURE AND BRIDGE DATA SHEET

Project \_\_\_\_\_ County \_\_\_\_\_  
Federal Route Base No. \_\_\_\_\_ Situation data for design of bridge on Route \_\_\_\_\_  
Over \_\_\_\_\_  
Plane Coordinates or Latitude and Longitude \_\_\_\_\_  
Date of Survey: \_\_\_\_\_ Location (Nearest Town, etc.) \_\_\_\_\_

GENERAL INSTRUCTION

Fill out all blanks carefully, giving information on all points. High water data is especially important and should be thoroughly investigated. Comments on any item covered in Survey Instruction Manual which are not covered below should be noted on an attached sheet.

HYDRAULIC SURVEY

Existing structure is any structure at, or in the vicinity of the proposed site have comparable drainage area.

Date of original construction: \_\_\_\_\_

Was present bridge in place at time of extreme high water? \_\_\_\_\_

Elevation of maximum high water and location:

Upstream side of existing structure Elevation/Location \_\_\_\_\_

Downstream side of existing structure Elevation/Location \_\_\_\_\_

At other locations on the flood plain (describe)

\_\_\_\_\_  
\_\_\_\_\_

Date of maximum high water: \_\_\_\_\_ Mo. \_\_\_\_\_ Yr. \_\_\_\_\_ Source of information \_\_\_\_\_

Elev. of normal water: \_\_\_\_\_ Date: \_\_\_\_\_ Mo. \_\_\_\_\_ Yr. \_\_\_\_\_

Source of information \_\_\_\_\_

Amount and character of drift present: \_\_\_\_\_

Location, description and ID of any water-gaging stations in the immediate vicinity: \_\_\_\_\_

\_\_\_\_\_

Elevation \_\_\_\_\_ on gage corresponds to elev. \_\_\_\_\_ on survey datum.

REMARKS

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



**Appendix 12C-2 Table of Storm Tide Description of Virginia Coast**

---

**VIRGINIA DEPARTMENT OF TRANSPORTATION  
Table of Storm Tide Description of Virginia Coast**

DERIVED CHARACTERISTICS	STORM TIDE DESCRIPTION			
	500-Year (P-0.002)	100-Year (P-0.01)	50-Year (P-0.075)	10- Year (P-0.1)
Suitable R/V Probability	p-0.50	p-0.12	p-0.075	p-0.05
<b>Part A – General Values for Virginia Tidal Waters</b>				
Correspondence R/V Value	2 hr	1 hr	0.8 hr	0.7 hr
Tide Duration, D – 10 R/V	20 hr	10 hr	8 hr	7 hr
<b>Part B – Specific Example for Hampton Roads</b>				
Storm Tide Elevation, E	11.2 ft	8.8 ft	7.8 ft	5.8 ft
E/D, ft/hr	0.56	0.88	0.97	0.83

Appendix 12C-3 Virginia Coastal Maps Showing Predicted Water Surface Elevations

VIRGINIA DEPARTMENT OF TRANSPORTATION  
Maps of the Coastal Regions of Virginia

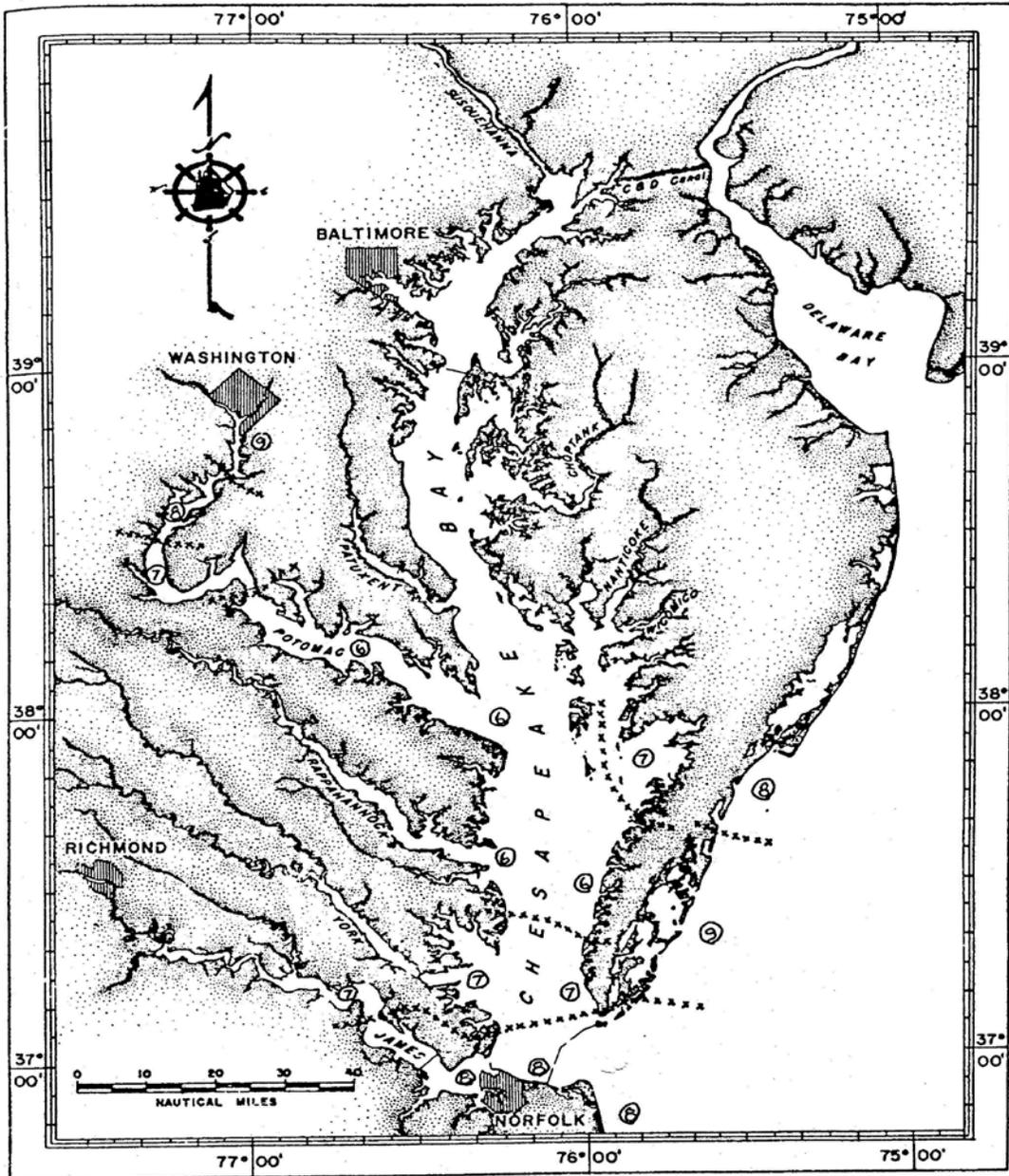


FIGURE 24A. ESTIMATED TIDAL FLOOD ELEVATIONS FOR 50-YEAR EVENT.

Appendix 12C-3 Virginia Coastal Maps Showing Predicted Water Surface Elevations

VIRGINIA DEPARTMENT OF TRANSPORTATION  
Maps of the Coastal Regions of Virginia

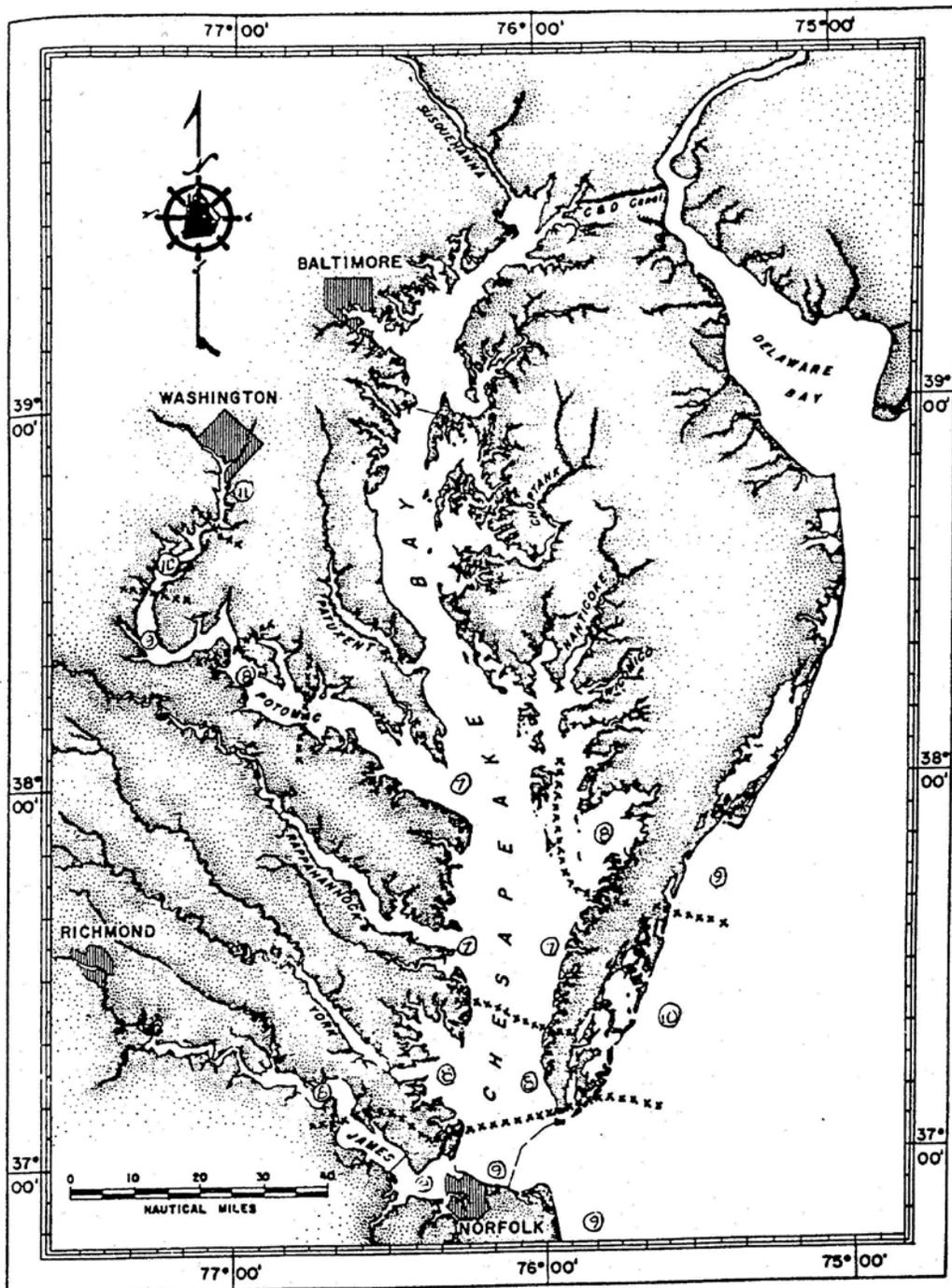


FIGURE 0. ESTIMATED TIDAL FLOOD ELEVATIONS FOR 100-YEAR EVENT, IN FEET ABOVE NGVD. 10 HOURS FOR FLOOD RISE AND FALL IS APPROPRIATE TO HURRICANE PASSAGES CAUSING THIS EVENT.

Appendix 12C-3 Virginia Coastal Maps Showing Predicted Water Surface Elevations

VIRGINIA DEPARTMENT OF TRANSPORTATION  
Maps of the Coastal Regions of Virginia

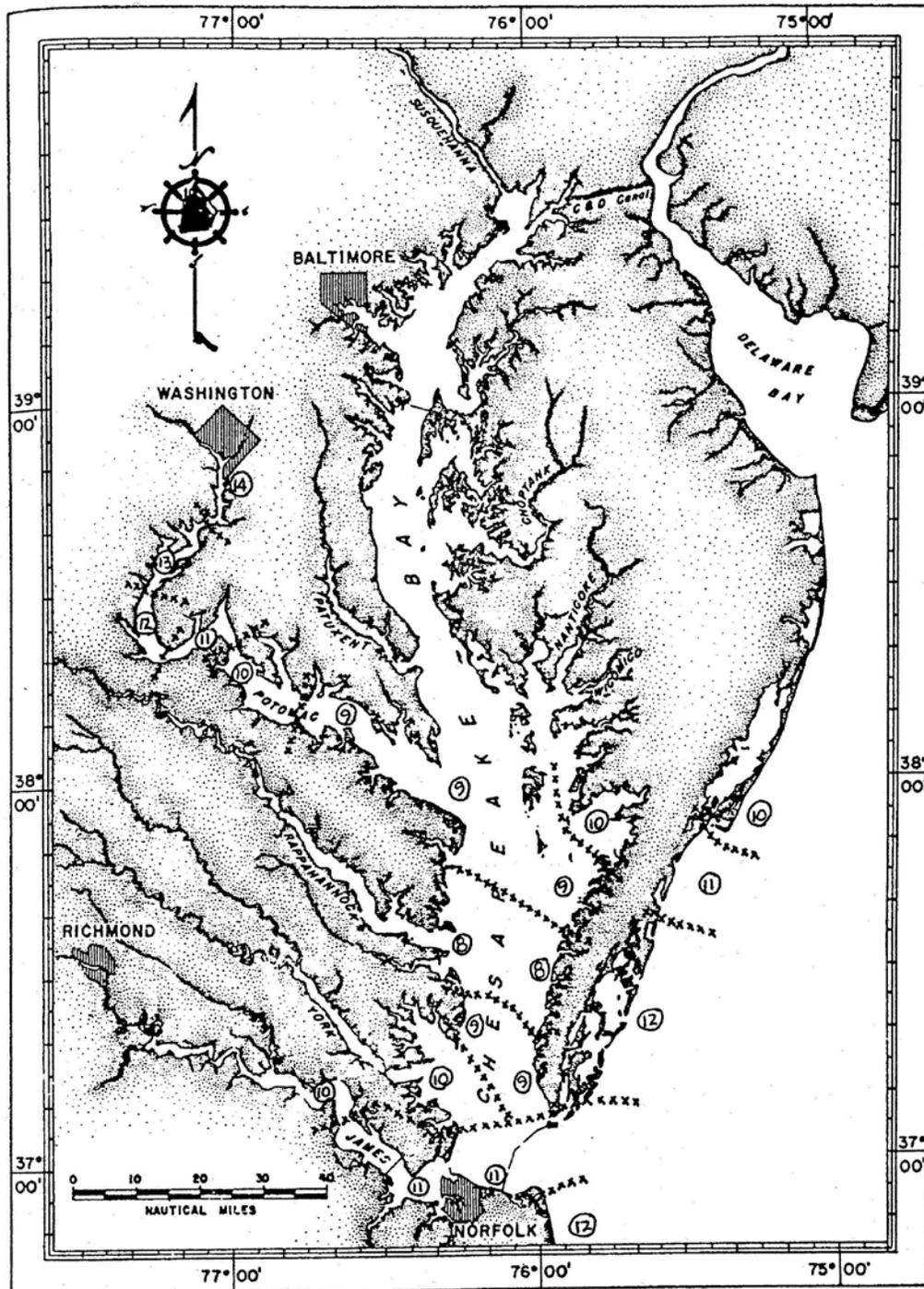


FIGURE 24C. ESTIMATED TIDAL FLOOD ELEVATIONS FOR 500-YEAR EVENT.

**Appendix 12D-1     Samples Memos documenting no adverse impact  
or Hydraulically Equivalent Replacement Structure  
(HERS)**

---

January 8, 2012

**MEMORANDUM**

**TO:** Bruce Shepard, PE, Central Office Structure and Bridge

**FROM:** John Matthews, Assistant State Hydraulic Engineer

**CC:** File

**SUBJECT:** Hydraulic Commentary for the Route 205 bridge replacement over  
Tide Mill Stream in Westmoreland County  
0205-096-101 UPC 61028

The revised road profile and bridge plans for this project for the design dated October 2011 have been reviewed to assess the potential impact to flooding. In these plans the road profile at the bridge has been raised by approximately 1.5 feet above the existing bridge elevation. This increase in profile elevation tapers to 0 at 180 feet east of the bridge and 150 west of the bridge. The proposed bridge opening is slightly narrower than the existing bridge opening but the low chord has been raised to allow for easier access during inspections. This results in an overall increase in flow area under the bridge but an overall reduction of the area available for overtopping.

The flooding at this location is controlled by storm surge from the Chesapeake Bay. Due to this flood control situation the changes to the structure by this project will have no impact on the 100-year flood elevation at this location.

Coordination with the Structure and Bridge Division indicated that they did not need scour computations for this crossing.

Based on both these factors it was determined that no detailed hydraulic analysis of the crossing was necessary.

**Standard Hydraulic Non-Study Permit Statement:**

This project should not cause more than minimal changes to peak flow characteristics, should not increase the flooding potential, nor cause more than minimal degradation of the water quality of the stream. This project should pose no restriction to the normally expected range of flows, should withstand expected normal high flows and will not restrict low flows. This project complies with applicable FEMA-approved state floodplain management requirements and the Department of Conservation and Recreation's annual approval of VDOT's Erosion and Sediment Control and Stormwater Management Program.

Appendix 12D-1      **Samples Memos documenting no adverse impact  
or Hydraulically Equivalent Replacement Structure  
(HERS)**

---



COMMONWEALTH of VIRGINIA

DEPARTMENT OF TRANSPORTATION  
1401 EAST BROAD STREET  
RICHMOND, 23219-2000

PHILLIP A. SHUCET  
COMMISSIONER

MOHAMMAD MIRSHAHI, P.E.  
STATE LOCATION AND DESIGN ENGINEER

July 2, 2004

**MEMORANDUM**

**TO:** Wendy McAbee, Suffolk District Structure and Bridge

**FROM:** John Matthews, Central Office L&D Hydraulics

**CC:** John Dewell, Assistant State Hydraulic Engineer  
David LeGrande, Assistant State Hydraulic Engineer  
Keith Rider, Central Office L&D Hydraulics  
Jack Harrell, Suffolk District L&D Hydraulics  
Jennifer Salyers, Suffolk District Environmental

**SUBJECT:** Hydraulic Impacts of Virginia Capital Trail over Shellbank Creek

I have been asked by John Dewell, Assistant State Hydraulic Engineer to evaluate the hydraulic impacts of the proposed Virginia Capital Trail crossing of Shellbank Creek in James City County. This crossing is located immediately south of Route 5 approximately 3000 feet east of the intersection with Monticello Avenue.

The FEMA Flood Insurance Maps for James City County reports that this area is subject to flooding from the anticipated 100-year storm surge to elevation 8.5. A detailed riverine analysis of Shellbank Creek was not performed. A detailed analysis does not seem to have been warranted based on the watershed area, which is less than 1 square mile.

Shellbank Creek flows under Route 5 through an existing 6' x 6' concrete box culvert approximately 1 mile from the mouth of the stream at the James River. No information concerning any existing problems has been provided. It does not appear that at this location on

**Appendix 12D-1     Samples Memos documenting no adverse impact  
or Hydraulically Equivalent Replacement Structure  
(HERS)**

---

Shellbank creek is subject to daily tide cycles. At present the detailed hydraulic computations for this crossing are not available. The existing roadway elevation is approximately elevation 15, which is 12 feet above the invert of the stream at elevation 3.2. The existing roadway is not overtopped by the 100 year surge elevation nor should it be overtopped by flooding from within the watershed. Because of the limited storage area upstream of the roadway excessive velocities are not anticipated during the ebb flows after a storm surge event.

The proposed bridge on the Capital Trail will span the entire flood plain on a timber and steel structure that is 260 feet long. The low chord of the proposed bridge is above elevation 16, which is well above the anticipated 100 year event. The bridge is to be founded on pile bents. Because the outfall of the Route 5 crossing is located only 30 feet up stream, a large portion of the flood plain is not effective for flood flow. Only Bents 1 and 2 will be subject to any potentially high velocities as they are in the vicinity of the flows exiting the Route 5 culvert.

Discussions with the District Structure and Bridge Division report that the bridge is to be founded on piles that may be over 70 feet long will extend well below the streambed. The anticipated scour at this location will be limited because of the upstream constraints imposed by Route 5 and the fact that the watershed is small.

**Conclusion:**

A detailed hydrologic study of this site to assess the hydraulic impacts of the proposed structure is not warranted. The proposed structure will have no impact to the 100 year flooding and will have very limited impact on the existing flood flows.

If an alternate foundation is considered in lieu of the very long piles currently planned a hydraulic engineer should evaluate the revised design to assess if there is a potential for scour to be a concern.

**Appendix 12D-1 Samples Memos documenting no adverse impact  
or Hydraulically Equivalent Replacement Structure  
(HERS)**

---



**COMMONWEALTH of VIRGINIA**

**DEPARTMENT OF TRANSPORTATION**  
1401 EAST BROAD STREET  
RICHMOND, 23219-2000

**PHILLIP A. SHUCET**  
COMMISSIONER

**MOHAMMAD MIRSHAHI, P.E.**  
STATE LOCATION AND DESIGN ENGINEER

August 30, 2004

**MEMORANDUM**

**TO:** Jason L. Henry, EIT

**FROM:** John H. Matthews, PE

**CC:** David M. LeGrande, Assistant State Hydraulic Engineer  
Hurley F. Minish

**SUBJECT:** Fentress Airfield Road Improvements  
0165-131-102, PE101, R201, C501

We recently discussed the potential flooding impacts of the Fentress Airfield Road improvements in the City of Chesapeake. You have asked that the Hydraulics Section to assess the project for any potential impact to a FEMA Designated Floodplain.

The proposed project is to widen and existing roadway from 2 to 4 lanes and improve an existing intersection with the addition of turning lanes. The roadway will not be raised in this process and the proposed lanes will be largely below the existing roadway elevation on the interior of a super elevated turn. Any existing crossing will be extended with the same size pipes that currently exist. There are no defined streams shown crossing the roadway on the USGS quad map. The area is shown to be a swamp. There are existing pipes through the roadway embankment to allow for water movement north towards the river. Route 165 crosses the North Landing River and Intercoastal Waterway just north and east of the project area. There are no proposed improvements at these crossings.

**Appendix 12D-1      Samples Memos documenting no adverse impact  
or Hydraulically Equivalent Replacement Structure  
(HERS)**

---

The proposed project is located in a FEME Zone AE. The 100 Year flooding for the North Landing River is noted as at elevation 5.0 for the entire reach evaluated in the FIS. There is no floodway designation on the North Landing River. The FIS reports states that the flooding elevations were established using storm surge conditions and not riverine flooding.

Base on the limited scope of the project and the nature of the flooding, this project should have no impact on the 100-year flooding of the North Landing River. Thus, it is not necessary to perform a detailed H&HA.