6.1 Hydrologic Design Practice

6.1.1 Introduction

Following is a summary of practices which should be followed for hydrologic analysis. For a more detailed discussion refer to the publication, Highway Drainage Guidelines, published by the American Association of State Highway and Transportation Officials. Some of the recommended methods have been developed in the English system. When the agency responsible provides a metric conversion, this manual will be updated.

6.1.2 Surveys

Since hydrologic considerations can influence the selection of a highway corridor and the alternate routes within the corridor, studies and investigations, including consideration of the environmental and ecological impact of the project, should be undertaken. Also special studies and investigations may be required at sensitive locations. The magnitude and complexity of these studies should be commensurate with the importance and magnitude of the project and problems encountered. Typical data to be included in such surveys or studies are: topographic maps, aerial photographs, streamflow records, historical highwater elevations, flood discharges and locations of hydraulic features such as reservoirs, water projects and designated or regulatory floodplain areas.

6.1.3 Flood Hazards

When not clearly identified on NFIP maps and FIS studies, a hydrologic analysis is a prerequisite to identifying flood hazard areas and determining those locations at which construction and maintenance will be unusually expensive or hazardous.

6.1.4 Coordination

Since many levels of government plan, design and construct highways and water resource projects which might have an affect on each other, interagency coordination is desirable and often necessary. In addition, agencies can share data and experiences within project areas to assist in the completion of accurate hydrologic analysis.

6.1.5 Documentation

Experience indicates that the design of highway drainage facilities should be adequately documented. Frequently, it is necessary to refer to plans, specifications, and analyses, long after the actual construction has been completed. Thus it is necessary to fully document the results of all hydrologic analysis.

The following items shall be included in the documentation file (see Chapter 1, Section 1.6). The intent is not to limit data to only those items listed, but rather to establish a minimum requirement consistent with the design procedures as outlined in this chapter. If circumstances are such that the hydrology is prepared other than the normal procedures or is governed by factors other than hydrologic factors, a narrative summary detailing the design basis shall appear with the other data.

The following items used in the design or analysis shall be included in the documentation file:
- contributing watershed area size and identification of source (map name, etc.)
- design frequency and decision for selection
- hydrologic discharge and hydrograph estimating method and findings
- flood frequency curves to include design, 100-year flood, discharge hydrograph and any historical floods
- expected level of development in upstream watershed over the anticipated life of the facility (include sources of and basis for these development projections)
- Appendix D of this chapter provides a format for the Hydrologic Design Report

6.1.6 Evaluation Of Runoff Factors

For all hydrologic analysis, the following factors should be evaluated and included when they will have a significant effect on the final results.

- drainage basin characteristics including: size, shape, slope, land use, geology, soil type, surface infiltration and storage
- stream channel characteristics including: geometry and configuration, natural and artificial controls, channel modification, aggradation - degradation and possibilities for ice and debris to be a significant problem
- flood plain characteristics
- meteorological characteristics

6.1.7 Flood History

All hydrologic analyses should consider the flood history of the area and the effect of these historical floods on existing and proposed structures. The flood history should include the historical floods and the flood history of any existing structures. Appendix E has mapping showing major floods in Connecticut since 1927. USGS water resources data should also be referenced for floods of record and stream flow records.

6.1.8 Hydrologic Method

Many hydrologic methods are available. The methods to be used and the circumstances for their use are listed below. If possible the results should be compared to a gage station which has a watershed with similar characteristics.

6.1.9 Design Discharge

The design discharge is based on an independent hydrologic analysis as outlined in the approved methods below. This discharge may be different from the FEMA or SCEL discharge. However, in all cases where these discharges have been established, the hydraulic analysis shall also include these discharges.

6.1.10 Approved Methods

The following hydrologic methods are acceptable for use with conditions as noted.

- Rational Method - This method shall be used only for drainage areas less than 81 ha (200 acres).
- Stream Gage Data - The U.S. Geological Survey maintains a network of stream gaging stations throughout Connecticut. From long term periods of observation and through statistical analysis of the resultant data, peak flow rates for various return frequencies can be developed. This data shall be used wherever possible in the design of hydraulic facilities.
- U.S.G.S. Regression Equations (L.A. Weiss) shall be used for all routine designs at sites greater than 2.59 km^2 (1 mi^2) in tributary area unless stream gage data is available or unique watershed characteristics, such as significant detention storage dictate otherwise.
- Computer Models for Hydrograph Generation - Many watersheds exhibit characteristics which require the use of a computer model to estimate design discharge quantities from run-off hydrographs. Additionally, hydrograph generation models are useful in the analysis of "before and after" conditions as related to proposed activities within a given basin. Where use of a computer model is indicated, the methods described in Section 6.14 shall be used.
- FEMA Flood Insurance Study Discharge Rates - Discharges specified in the appropriate flood insurance study shall be used for ANALYSIS where the regulatory floodway is adopted or where FEMA has established discharge for a watercourse. The DESIGN discharge may vary from the flood insurance study quantity if the results of an independent analysis so indicate.
- SCEL – Stream Channel Encroachment Discharge Rates – Discharges specified in the appropriate stream channel encroachment study shall be used for analysis where SCEL are established. The design, FEMA and SCEL discharges may vary, as they are all developed independently and use different methods.
- Tidal Hydrology – The maximum discharge associated with astronomical tides or storm surges at a tidal crossing can be determined using either Neill's procedure, the orifice equation or Chang's procedure as outlined in HEC-18. Alternately, the discharge can be determined using one of several unsteady flow models as discussed in Chapter 9, Section 9.4.5. The level of effort and accuracy of these methods varies greatly. The selected method will depend on site conditions and should be commensurate with the scope and cost of the project. Coordination with the Hydraulics and Drainage Section is recommended. See also Section 6.1.14.

6.1.11 Design Frequency

Design frequencies are selected commensurate with the facilities cost, amount of traffic, potential flood hazard to property, expected level of service, and budgetary constraints as well as the magnitude and risk associated with damages from larger flood events. (See Appendix A)

6.1.12 Economics

Hydrologic analysis should include the determination of several design flood frequencies for use in the hydraulic design. These frequencies are used to size different drainage facilities so as to allow for an optimum design, which considers both risk of damage and construction cost.

Consideration should be given to what frequency flood was used to design other structures along a highway corridor.

6.1.13 Review Frequency

All proposed culverts and bridges conveying watercourses designed using the designated return frequency shall be checked using a flood of greater magnitude.

6.1.14 Tidal Conditions

Unlike inland rivers where the design discharge is fixed by runoff and is virtually unaffected by the waterway provided, the size of the waterway opening of a tidal structure can modify the tidal regime and the associated tidal discharges.

Extreme events associated with riverine floods and tidal storm surges should be used to determine the hydraulic adequacy of a bridge. These events would have a return period based on the structure classifications as defined in the culvert and bridge chapters, Chapters 8 and 9, Sections 8.3 and 9.3. Difficulty arises in determining whether the storm surge, flood or the combination of the storm surge and flood should be considered controlling.

When inland flood discharges are small in relationship to the magnitude of the storm surge and are the result of the same event, then the flood discharge can be added to the discharge associated with the design tidal flow, or the volume of the runoff hydrograph can be added to the volume of the tidal prism. If the inland flood and the storm surge may result from different storm events, then a joint probability approach may be warranted to determine the magnitude of the design discharge.

In some cases there may be a lag time between the storm surge discharge and the stream flow discharge at the highway crossing. For this case, stream flow-routing methods such as the NRCS TR-20, USACOE HEC-1 or HEC-HMS model can be used to estimate the timing of the flood hydrograph derived from runoff of the watershed(s) draining into the sound or estuary.

The selection of the method to use to combine flood and tidal surge flows is a matter of judgement and must consider the characteristics of the site and the storm events.