# Hydraulic Guidelines

This document provides guidance for the hydraulic design of bridge structures and the related approach roadways.

## Overtopping Design Frequency Guidelines for Bridges

The design flood is equal to the overtopping flood when overtopping occurs before the 100- year event; otherwise use a design flood of Q100. Existing overtopping sections that will be left alone might be an odd year (e.g. Q18), use this as the design flood. You may want to use the term Design/Overtopping Flood rather than Design Flood, in these instances, to avoid confusion.

Overtopping frequency is selected based on ADT. MnDOT's Hydraulics Section has recommended the following *minimum* overtopping frequencies:

| ADT | Minimum Overtopping Frequency |
|---|---|
| 0-10 | 2 years (Q2) |
| 11-49 | 5 years (Q5) |
| 50-399 | 10 years (Q10) |
| 400-1499 | 25 years (Q25) |
| 1500+ | 50 years (Q50) |

The State Aid Bridge Unit will start to question the design if the overtopping is higher than the following:

| ADT | Minimum Overtopping Frequency |
|---|---|
| 0-149 | 10 years (Q10) |
| 150-499 | 25 years (Q25) |
| 500-1499 | 50 years (Q50) |

For economic reasons, the overtopping frequency should not be greater than recommended unless the design of the profile grade dictates. When existing profiles have less frequent overtopping, the condition can remain, but a more frequent overtopping should at least be considered.

### Some additional things to consider:

- Limitations to the overtopping frequency can be imposed by roadway geometrics such as maximum or minimum grade lines, site-distance, vertical curvature, in-place road grades, etc.
- Check clearance requirements for ice and debris.
- Consider the topographical features such as stream levees, elevation of the watershed divide and clearances for highways or railroads that have bridges.
- Note any navigation clearance requirements.
- Flood plain ordinances or other legislative mandates may limit allowable backwater or encroachment on the flood plain.
- Channel stability considerations, which may limit velocity or the amount of constriction.
- Consideration should be given to ecological features such as wetlands or other sensitive environments, geological or geomorphic conditions or constraints, including subsurface conditions.
- Note any social considerations such as the importance of the facility as an emergency evacuation route in time of peril.
- Availability of funds to construct the facility. (This item may or may not be a consideration in a first appraisal but could ultimately govern the design selection.)

## Minimum Low Member Elevation

*For overtopping year less than 100*

| | Concrete Slab Span or Inverted T | Pre-stressed I-Girder, Steel Girder or Box Beam | Double Tee, Timber Beam, Timber Slab or Steel Pedestrian Truss |
|---|---|---|---|
| **No debris problem or velocity less than 5 fps** | Overtopping TW – 1’ | Overtopping TW | Overtopping TW + 1’ |
| **Debris problem and velocity greater than or equal to 5 fps** | Overtopping TW | Overtopping TW + 1’ | Overtopping TW + 2’ |

*For overtopping year greater than or equal to 100*

| | Concrete Slab Span or Inverted T | Pre-stressed I-Girder, Steel Girder or Box Beam | Double Tee, Timber Beam, Timber Slab or Steel Pedestrian Truss |
|---|---|---|---|
| **No debris problem or velocity less than 5 fps** | $Q_{100}$ TW – 1’ | $Q_{100}$ TW | $Q_{100}$ TW + 1’ |
| **Debris problem and velocity greater than or equal to 5 fps** | $Q_{100}$ TW | $Q_{100}$ TW + 1’ | $Q_{100}$ TW + 2’ |

- “TW” denotes tailwater or stage.

- Any low member elevations less than the above criteria will require a complete structural design for buoyant and lateral forces due to stream flow, ice and debris. Consideration must be given to the possibility that the debris will increase the upstream water surface elevation.
- A higher low member elevation can be used when the roadway design dictates or there are hydraulic considerations such as increased flood damage potential to upstream properties.
- When there is no overtopping, use the design flood.
- Where it is necessary to intercept deck drainage at intermediate points along the bridge, the design of the interceptor shall conform to the procedures presented in Chapter 13, HEC 21 "Bridge Deck Drainage System" FHWA and HEC 22 "Urban Drainage Design Manual" FHWA.

## Risk Assessment

Risk analysis and/or assessment is based on the theory that roads should not all be designed for an arbitrary design frequency. Instead the design selected for an encroachment should be supported by analysis of design alternatives with consideration given to capital cost and risks; and other economic, engineering, social and environmental concerns.

MnDOT has developed a risk assessment procedure to screen projects. The purpose of the questionnaire is to determine the level of analysis required. It is not a comprehensive design checklist nor should it replace good engineering judgment. Culverts that are 54 inches or larger will require an assessment to determine whether or not a risk analysis is necessary to determine the frequency of design flood.

The Risk Assessment Form should be filled out and signed by the engineer making the hydraulic recommendation and placed in the documentation file. The procedure consists of a DATA REQUIREMENTS section and a LTEC DESIGN section. Start with the first question and follow directions included in the form. All questions do not have to be answered. The column on the right hand side is titled LTEC DESIGN. LTEC refers to the Least Total Economic Cost. If any checks are made in the LTEC column the designer must then proceed with a Risk Analysis or document justification of why the Risk Analysis is not needed.

Click here to download Risk Assessment Form.

## Hydraulic Data Form

The Hydraulic Bridge Data Form (Word) and Hydraulic Culvert Data Form (Word) must be submitted with the Preliminary Bridge Plan.

## Scour Code Summary

| MnDOT Code | Literal Definition | Description |
|---|---|---|
| A | NON-WATERWAY | Bridge not over waterway. |
| B | CLOSED-SCOUR | Bridge is closed to traffic; field review indicates that failure of piers and/or abutments due to scour is imminent or has occurred. |

| MnDOT Code | Literal Definition | Description |
|---|---|---|
| C | CLOSED-NOT SCOUR | Bridge is closed to traffic for reasons other than scour. Prior to reopening the bridge it must be evaluated for scour and recoded. |
| D | OBS SCOUR – IMMEDIATE PROTECTION REQUIRED | Bridge is scour critical; field review indicates that extensive scour has occurred at bridge foundations. Immediate action is required to provide scour countermeasures. |
| E | CULVERT | Culvert structure. Scour calculation, evaluation, and/or screening has not been made. |
| F | NO EVAL-FOUND KNOWN | Bridge Structure. Scour calculation, evaluation, and/or screening has not been made. All substructure foundations are known. |
| G | NO EVAL-FOUND UNKNOWN | Scour calculation, evaluation and/or screening has not been made. Bridge on unknown foundations. |
| H | FOUND ABOVE WATER | Bridge foundations (including piles) well above flood water elevations. |
| I | SCREEN-LOW RISK | Bridge screened, determined to be low risk for failure due to scour. |
| J | SCREEN-SCOUR SUSC | Bridge screened, determined to be scour susceptible. |
| K | SCREEN-LIMITED RISK | Bridge screened, determined to be of limited risk to public, monitor in lieu of evaluation and close if necessary. |
| L | STABLE-EVAL | Scour evaluation complete, bridge judged to be low risk for failure due to scour. |
| M | STABLE-SCOUR ABOVE FTG | Bridge foundations determined to be stable for calculated scour conditions; calculated scour depth from the scour prediction equations is above top of footing. |
| N | STABLE-SCOUR IN FTG/PILE | Bridge foundations determined to be stable for calculated scour conditions; calculated scour depth from the scour prediction equations is within limits of footing or piles. |
| O | STABLE-ACTION REQUIRED | Bridge foundations determined to be stable for scour conditions; Scour action plan requires additional action. |
| P | STABLE DUE TO PROT | Countermeasures have been installed to correct a previously existing problem with scour. Bridge is no longer scour critical. Scour countermeasures should be inspected at least once every 4 years and after major flows, or as recommended in the scour action plan. Report any changes that have occurred to countermeasures. |

| MnDOT Code | Literal Definition | Description |
|---|---|---|
| R | CRITICAL-MONITOR | Bridge has been evaluated to be scour critical. Scour action plan recommends monitoring the bridge during high flows and closing if necessary. |
| U | CRITICAL-PROT REQ | Bridge has been evaluated to be scour critical. Scour action plan recommends this bridge as a priority for installation of countermeasures. Until countermeasures are installed, monitor bridge during high flows and close if necessary. |

## Bridges in a Designated Floodplain

When working in floodplains zoned Zone A- Approximate Method, there is no need to involve FEMA, just follow the State Permitting Process. MnDNR requests that a courtesy notification be sent to:

Suzanne Jiwani, PE
Floodplain Mapping Hydrologist
500 Lafayette Road
St. Paul, MN 55155-4040

Phone: 651-259-5681
Email: suzanne.jiwani@state.mn.us

All floodplains zoned Zone AE that are in detailed study areas; FEMA will need to be contacted if the water surface elevation is impacted. There are two types of floodway models, one with a detailed analysis of the floodway and one without a floodway detailed analysis (this type is becoming very rare).

- Flowchart for new bridges and culverts in AE Zones (PDF).
- Flowchart for replacement bridges and culverts in AE Zones (PDF).

If the new or revised structure does not change the Flood Insurance Study's Water Surface Profile, FEMA requires a copy of your model, a copy of the as-built plans and a cover letter stating that the BFE (Base Flood Elevation) is unaffected.

This information should be sent within six months of the project completion to FEMA along with a courtesy notification to Suzanne Jiwani.

If the water surface elevation is increased by more than 0.01 foot upstream of the structure, a CLOMR (Conditional Letter of Map Revision) needs to be submitted to FEMA before work has begun and is a condition of the DNR Permit. If you decrease the water surface elevation published in the floodway data table, usually 0.1 foot or more, then a LOMR (Letter of Map Revision) needs to be submitted within six months of the project completion.

### *FEMA has four types of models for CLOMR or LOMR Submittal:*

1. **Duplicate Effective Model**: This is the model FEMA supplies you. They may contain errors.
2. **Duplicate Corrected Effective Model**: The above model with the errors corrected and any additional cross sections you may need for your model added.
3. **Existing or Pre Project Condition Model**: A model of what is out there at present time.
4. **Post Project Condition Model**: The model of what you are proposing.

MnDNR and FEMA look at the difference between models 4 and 3 for stage increase. The location for the difference is taken sufficiently upstream, as to not include effects of draw down, etc.

HEC-RAS models are preferred. They can be of just the reach you are impacting and must be of sufficient length of the reach for the water surface elevation to tie into the existing model within 0.5 ft., although FEMA prefers 0.1 ft. If problems are found in the existing models, please notify Suzanne via email. She will note the problem areas and use the information as part of the prioritization for study updates.

Any questions or concerns can be addressed to Suzanne Jiwani at the above phone number or email address.

## Online Resources

- StreamStats
  - Delineates drainage areas and calculates flood frequency flow rates using regression equations.
- USGS Minnesota water resources data
  - Includes links to real time data on gages operated by the U.S. Geological Survey. Also includes rating curves for selected gages, Water Resources Data Reports and links to a host of water related web sites.
- FHWA hydraulics publications
  - Downloadable publications for design of Hydraulic Structures
- National Oceanic and Atmospheric Administration National Weather Service (NOAA)
  - A source for gage information nationwide; includes precipitation data.