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1 SCOPE

The Arizona Department of Transportation (ADOT) Bridge Hydraulics Guidelines are prepared to supplement provisions of AASHTO LRFD Bridge Design Specifications, Section 2, Article 2.6, Hydrology and Hydraulics Section; the AASHTO Highway Drainage Guidelines; and the various Hydraulic Engineering Circulars published by the Federal Highway Administration. Unless specified otherwise, the hydraulics design engineer should consult the most recent edition of these references for procedures and guidelines.

Adhering to these guidelines does not relieve the hydraulics design engineer from the responsibility of applying sound engineering principles throughout the project development stages. While the guidelines apply to the majority of bridge hydrologic and hydraulics design of new and existing bridges and culverts owned by the state of Arizona, they are not intended to be exhaustive.

The hydraulics design engineer shall seek input from other disciplines as cited in relevant federal publications. For scour related issues, a consensus among geotechnical, structural and bridge hydraulics team members is necessary.

2 GENERAL DESIGN REQUIREMENTS

In addition to ADOT policies and guidelines, the design of all bridges and culverts shall comply with all applicable Federal, State, local government and local flood control districts statutes and regulations.

3 SITE DATA

Careful consideration shall be given to existing studies, such as any existing floodplain studies that may have been performed by FEMA or local jurisdictions. Prior to the hydrology study, a preliminary assessment of possible effects on adjacent public and private properties is necessary. For existing structures, the hydraulics design engineer shall not proceed to hydrologic analysis if the constraints from FEMA studies or the effects to the existing drainage pattern are significant, unless approved by the ADOT Bridge Group. Any effect to FEMA Base Flood Elevations (BFEs) shall be confined within the drainage easement or within the right of way. If existing flood studies are used, validity of assumptions and accuracy of the results of such studies shall be verified.

Channel morphology shall account for the effects of stream gravel mining and long term degradation. These effects shall be included in the estimation of scour depth. The geotechnical report shall contain information regarding the scour resistance of the soil strata to stream forces.

4 HYDROLOGIC ANALYSIS

Whenever historical USGS flood gage records of stream flow are available, design discharges could be estimated using these hydrologic data. The hydraulics design engineer shall follow the hydrologic design methods detailed within the ADOT Highway Drainage Design Manual Hydrology, FHWA-AZ93-281. This manual may be obtained from ADOT Engineering Records Publications, Publication Number 35-234. Discharge estimates calculated using regression equations could be used for verification purposes.

To determine the minimum design storm frequency, the hydraulics design engineer should refer to Table 5.1 below. Route classification is depicted on the map in Appendix A. Required design frequencies are identical for both new construction and reconstruction projects. Bridge scour retrofit projects are classified as spot improvement projects and not as reconstruction projects.

For deck drainage design, the frequency and the spread criteria shall match with those of the approach roadways pavement drainage.

5 HYDRAULIC ANALYSIS

The freeboard, which is defined as the clearance between the lowest point of the superstructure (bridge soffit or bottom of girder) and the design water surface elevation, should not be less than 3 feet for bridges on Class 1 routes and 1 foot for bridges on Classes 2 through 4 routes. The above minimum freeboard requirement also applies to bridges designated as super box structures. For new construction, the hydraulics design engineer shall additionally ensure that the hydraulic opening would adequately pass the FEMA base flood (100-year flood).

Table 5.1 Hydraulic Opening Requirements for waterway bridges:

Route Classification	**Minimum Freeboard - ft**	**Frequency - years**
Class 1	3	50
Class 2	1	50
Class 3	1	25
Class 4	1	10

For culverts, the design headwater elevation shall be no higher than 3 inches below the lowest elevation of the pavement structure. Also, the allowable headwater depth to culvert height ratio may not exceed 1.5. For outlet velocities above 7 feet per second (fps), outlet protection is necessary. A concrete apron is recommended at the outlet of culverts whenever there is potential for undercutting or when the outlet velocity is above 15 fps. The backwater from the culvert shall not adversely affect the FEMA Base Flood Elevations.

Prior to performing a hydraulic analysis of a bridge site and when requesting a survey, the hydraulics design engineer shall specify the following limits: from 1000 to 2000 ft for upstream cross-sections and from 800 to 1000 ft for downstream cross-sections. The survey must take into account the presence of any existing control structures that may affect the hydraulic model. It is customary that cross-section stations decrease in the direction of flow. It is important to note that unlike roadway stationing conventions, left and right within a channel cross-section are defined by looking in the direction of decreasing stations (downstream).

Bank protection for abutments shall be provided for the design flow conditions with one foot of freeboard and the abutment foundation shall be designed to withstand the super flood event, which is defined as the lesser of the 500-year flood event discharge Q_{500} or the flood event causing overtopping of the roadway or bridge deck. Use of dumped riprap shall be limited to a velocity less than 12 feet per second. Otherwise, anchored wire-tied riprap protection is recommended. When grout or lined concrete is used, drainage weep holes shall be provided. Approach roadway embankment slopes on either side of the bridge shall be protected against erosion from both deck drainage and from the roadway flow ditch.

The hydraulics design engineer shall ensure that the contractor uses Best Management Practices, as required by the Arizona Department of Environmental Quality, Storm Water Pollution Prevention Plan, and other environmental constraints listed in the environmental clearance document. Temporary drainage structures shall not cause any safety concerns to the traveling public and shall not cause flooding of adjacent properties.

6 BRIDGE WATERWAY

6.1 General

The hydraulic opening of a waterway bridge is determined based on a combination of the following:

- the contributing watershed area,
- the magnitude and frequency of the design flood,
- the roadway alignment and profile, and
- physical and environmental constraints.

The hydraulic design process for sizing the bridge waterway opening shall include the evaluation of water surface elevations in the main channel for existing conditions and for proposed conditions. A comparison of the elevations between these two conditions shall be made to identify the effects of the bridge on the waterway. These results shall clearly identify and mitigate any backwater effects caused by the project.

6.2 Bridge Scour

Bridge foundations shall be designed to withstand the effects of scour estimated using the methods described in the latest FHWA's HEC 18 and HEC 23 publications. The recommendations from these publications shall be the basis for the design of new bridge foundations and for the design of scour countermeasures.

Every effort shall be made to minimize the effects of scour, such as, placing piers outside the waterway, aligning piers to the direction of flow, and using round piers or columns. Unless otherwise approved by the ADOT Bridge Group, the methods described in HEC 18 and these guidelines shall be used to estimate scour depths.

Bridge foundations shall be designed to withstand scour resulting from the lesser of the following two events:

- The 500-year flood event (the 500-year discharge value shall be computed as follows: $Q_{500} = 1.7 \times Q_{100}$), or
- The event causing overtopping of the approach roadway or the bridge deck. The hydraulics design engineer should strive to avoid overtopping of the bridge deck.

Pile and drilled shaft foundations shall not rely on lateral support from soil within the estimated scour depth. If the pile or the drilled shaft is embedded into a rock formation, a geotechnical engineer shall confirm the non-erodibility of the rock.

For calculating local pier scour depth, the practice of increasing the pier width by 2 ft on either side of the pier to account for debris effects is acceptable. In addition, 15 degrees minimum angle of attack may be used to account for the effects of meandering of the stream to evaluate local scour. Usually, canal bridges are not designed to carry rainfall runoff and hence bridge foundations located within such sites need not be designed for debris and meandering effects.

When the clear distance between columns or drilled shafts is 16 feet or greater, each column or drilled shaft shall be treated as an independent unit for stream forces and debris effects. When the clear distance is less than 16 feet, methods described in HEC 18 shall be used to estimate equivalent effective widths.

A durable scour countermeasure, which has been successfully used in Arizona over the years, is a concrete floor with cut-off walls upstream and downstream of the bridge. This countermeasure, while withstanding high stream velocity, requires minimal inspection and maintenance and provides the most life cycle cost effectiveness in many scour vulnerable situations. The hydraulics design engineer shall research ADOT bridge scour retrofit and culvert erosion repair past practices prior to recommending the most suitable alternative.

6.3 Roadway Approaches to Bridge

It is the responsibility of the bridge design engineer to coordinate with the roadway design engineer to ensure that the runoff from the roadway ditches are properly discharged without causing erosion concerns near the bridge abutment. The abutments could be concrete lined or riprap protected against erosion.

In addition, protecting bridge abutments against roadway drainage induced erosion, may be achieved through providing spillways or down drains. These appurtenances shall not affect the integrity of the abutment or that of the approach roadway. They should be appropriately designed to drain away from the ends of the bridge.

6.4 Roadway Drainage

Usually the runoff from roadway ditches drains to the wash. The bridge design engineer shall ensure that this runoff would not cause any erosion near the abutment fill. Likewise, where catch basins are used, the outlet from the basins shall be designed to properly discharge to the wash.

6.5 Deck Drainage

The criterion for bridge deck drainage and the pavement drainage spread requirements is identical. The methods described in HEC 21 (1993) should be used as guidelines. The hydraulics design engineer may extend the pavement drainage calculations to estimate the spread. However, pavement drainage shall be intercepted prior to running into the bridge and discharged away from the bridge ends and approach roadways. Potential for hydroplaning should be minimized using special rough road surfaces. Zero gradients and sag vertical curves should be avoided.

7 DEVELOPMENT OF BRIDGE HYDRAULICS REPORTS

A stand alone Bridge Hydraulics Report shall be prepared for all new construction and reconstruction projects. When traffic capacity is increased, the project may be considered as a reconstruction project.

The Bridge Hydraulics Report should address flooding history of the site, erosion of the abutments from roadway and bridge deck drainage. For a new alignment, the location of the drainage structures and the hydrology analysis should be finalized during the scoping stage.

The construction plans shall clearly indicate:

- the design discharge value and the water surface elevation, and

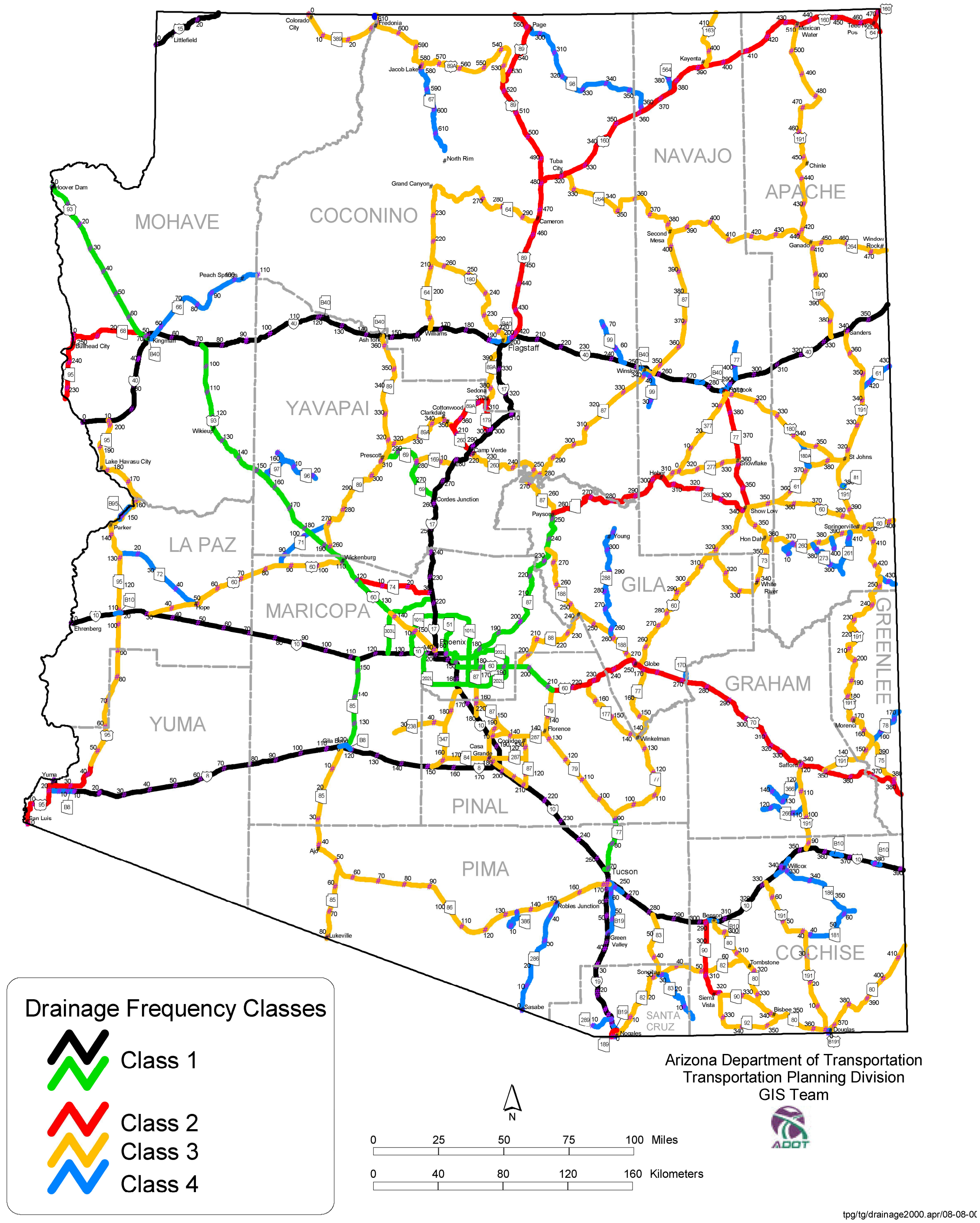
- the 100-year design discharge elevations if in FEMA floodplain, and
- the super flood discharge (either 500-year discharge or overtopping discharge).

The above values shall be marked on the elevation view. This requirement is applicable for all new waterway bridges and for any bridge project that may affect the existing drainage pattern.

Typical Table of Contents of a Bridge Hydraulics Report and a Project Assessment Report for a bridge scour retrofit project are shown in Appendices B and C respectively. The Bridge Hydraulics Report shall be a stand-alone document and not be combined with other documents. The final Bridge Hydraulics Report shall be distributed during Stage III project submittal. The document shall contain details of the location of the piers and scour depth estimates. These reports and their supporting documents shall be submitted electronically, in Acrobat® format, to the Bridge Hydraulics Section.

APPENDIX A - DRAINAGE FREQUENCY CLASSIFICATIONS

Operational Drainage Frequency Classes



APPENDIX B - SAMPLE TABLE OF CONTENTS
BRIDGE HYDRAULICS REPORT

APPENDIX C - SAMPLE TABLE OF CONTENTS PROJECT ASSESSMENT REPORT FOR BRIDGE SCOUR RETROFIT PROJECTS