SECTION VIII

PRELIMINARY DESIGN

METRICATION

The design of all new Local Agency projects will begin in English units. It is still the intent of the law to design in metric, however TEA 21 removed the timeline for complete conversion to the metric measurement system. MoDOT will continue to maintain dual unit versions of the Project Development Manual, Standard Specifications, Standard Plans and other contract provisions for reference by design and operation personnel.

DESIGN CRITERIA

Roadway design standards are governed by *A Policy on Geometric Design of Highways and Streets* ("Green Book") published by the American Association of Highway and Transportation Officials, FHWA's *Manual on Uniform Traffic Control Devices* ("MUTCD"), AASHTO's *Roadside Design Guide*, and the *Highway Capacity Manual*, published by the Transportation Research Board. Minimum standards are based on the functional class of the road and are given in **Figure VIII-1**.

The National Cooperative Highway Research Program (NCHRP) has issued guidance, Report 350, on the standards for guardrail and bridge railing design. This new guidance must be incorporated into roadway and bridge contracts. (See "Barrier Railing Systems" in this Section for additional information and requirements).

Structural design for roadway bridges, culverts and retaining walls shall be governed by the 2002 AASHTO *Standard Specifications for Highway Bridges*, 17th Edition.

Local Agencies can establish their own standards to be used for roadway and bridge design provided the standards meet or exceed the minimum design standards established by AASHTO. These standards need to be adopted by the Local Agency by an ordinance, and a copy of the ordinance and standards need to be filed with MoDOT. Design improvements or features of projects designed or constructed in excess of the LPA standard design requirements are considered to be non-participating for federal funds and are at the expense of the Local Agency unless these improvements or features are in conformance with the appropriate standards adopted by the Local Agency through local ordinance - or, where hydraulic design criteria to satisfy FEMA floodplain development regulations for the National Flood Insurance Program (if the Local Agency is a participant in the NFIP) is determined to be in excess of the design criteria shown in this Section of the LPA Manual.

The design of bicycle and pedestrian facilities is governed by the MoDOT *General Pedestrian and Bicycle Guide* that is based on publications of the American Association of State Highway and Transportation Officials (AASHTO) such as the *Guide for the Development of Bicycle Facilities* and *A Policy on Geometric Design of Streets and Highways*. MoDOT's publication defines highway and street design standards that accommodate bicyclists and pedestrians and is available on MoDOT's web site at **www.modot.org/othertransportation/bicyclepedprogram.htm.** The design for pedestrian bridges shall also be in conformance with the AASHTO *Guide Specifications for*

Design of Pedestrian Bridges, August 1997 (or latest edition). (See additional information in this Section).

In addition, the Americans with Disabilities Act (ADA) require that all facilities must be designed to current accessibility standards. The FHWA is concerned with the design of the pedestrian environment in the public right of way as it relates to disabled individuals. Curb cut ramps for wheelchair users have been required at pedestrian crossings on Federal-aid projects for many years. The *Americans With Disabilities Act Accessibility Guidelines* (ADAAG) have been adopted as standards by the Department of Justice and the Department of Transportation. The publication is available free of charge on the Internet at **www.access-board.gov/adaag.html/adaag.htm**.

Currently these accessibility standards are for buildings and sites. Standards for pedestrians in the public right of way are yet to be developed, but the ADAAG guidance shall be applied to the maximum extent feasible for sidewalks, crosswalks, grades, etc. Additional information on standards and guidelines for accommodating the disabled may be obtained from the Architectural and Transportation Barriers Compliance Board.

DESIGN VARIANCES

Any deviation from the minimum standards in this Manual shall require the Local Agency to request a design variance from the minimum standards. If the Local Agency desires to provide less than the minimum standards and requests full FHWA funding participation, then the Local Agency shall submit a design variance request with justification for MoDOT review. Adequate justifications should indicate the level of the safety problem that exists, how the safety problem will be mitigated by the new design, and the estimated cost savings derived by the proposed variance. (See additional information in this Section regarding hydraulic design variances.) Likewise, if design standards in excess of those listed in this manual are requested with full FHWA funding participation, a design variance request with appropriate justification must also be submitted. (See **Figure VIII-2** for the design variance request form.)

ACCURACY

Figure VIII-3 lists detail design information for the accuracy of plan dimensions. This chart is a guide to assist users in the transition to metric plans production, and can be varied as needed.

PRELIMINARY PLANS

A preliminary layout of the proposed improvements should be submitted after the general geometric concepts have been determined. Three copies should be submitted to MoDOT.

The preliminary layout of the proposed improvements should show topography, alignment, grades, design criteria, typical section, geometrics, present and proposed traffic, turning movements, pavement type, proposed parking restrictions, property ownership, and approximate right-of-way requirements. The layout may be in schematic form, or plans may be developed to the stage where they can be used for this purpose. For projects involving bridges or culverts, see "Preliminary Bridge Submittals" in this Section for additional requirements.

If the proposed improvements include a bridge, the bridge width shall be designed to match the shoulder-to-shoulder width, including the curb section, of the improved road as per the geometric requirements based on the functional classification of the route. A design variance may be considered for construction of a single lane bridge for rural local roads. See note 10 of **Figure VIII-1** for requirements. Required information at the preliminary stage for bridge design and hydraulic design are discussed later in this Section.

Projects involving resurfacing, restoration, or rehabilitation (3R projects) commonly do not involve the development of detailed plan sheets. The preliminary design layout for these projects may consist of only typical sections and the limits of the project. However, if the geometrics of the project do not meet the standards listed in this section, a design variance (**Figure VIII-2**) should be submitted to obtain approval. If a bridge is within the limits of the 3R project, the Local Agency should follow the design criteria as shown later in this Section. This should be submitted at the preliminary stage. Obvious safety hazards within the right-of-way should be removed or mitigated.

TRAFFIC SIGNAL PLANS AND SIGNAL WARRANTS

The Local Agency should submit signal warrants prior to the preparation of traffic signal plans for review. If the warrants are approved by MoDOT, the Local Agency should submit traffic signal plans at the preliminary design stage for review (2 copies).

No specific format for the signal plan layout information is specified. The following information should be shown: proposed intersection geometrics, approach grades, present and projected traffic, peak hour turning movements, locations of crosswalks and stoplines, locations of signals and other proposed appurtenances, proposed signal indications, lane control signing, traffic phasing, type of control, adjacent land use, additional right-of-way requirements, pavement markings, and any nearby traffic signals or other traffic features that might have a direct influence on the operation of the intersection.

Signal warrant forms are available at the MoDOT district office. Traffic counts which are recorded for time intervals of less than one hour should be subtotaled for each hour in order to facilitate proper review of warrants.

UTILITY RELOCATION

The Local Agency should, in the preliminary phase, identify existing utility locations and determine if any adjustments will be required. The Local Agency can begin coordinating with the utility companies prior to preliminary approval for new utility locations, but no utility agreements can be executed until preliminary approval is given and a Categorical Exclusion has been granted from

FHWA if reimbursement is desired. Local Agencies should consult *Program Guide – Utility Adjustments and Accommodations on Federal-Aid Highway Projects*, published by FHWA, for assistance regarding utilities within the highway corridor. This publication can be found on the FHWA web site at **www.fhwa.dot.gov/reports/utilguid**.

The cost of necessary utility relocations for which the Local Agency is responsible is eligible for federal participation. If the Local Agency elects to receive federal participation, utility agreements should conform to 23 CFR Section 645A, which is the applicable Federal Regulation regarding utility relocation on federally funded highways. MoDOT can assist the Local Agency with information about the above regulation.

The Local Agency is required to provide the necessary audit of the utility's actual cost incurred in accordance with applicable federal reimbursement requirements if the payment type is other than lump sum. Provisions for the audit should be stated in the agreement between the utility and the local.

BRIDGE PRESERVATION

3 R Projects

Bridges may be located within a road project involving resurfacing, restoration, or rehabilitation (3R projects). The safety railing system shall be upgraded to meet current requirements for replacement structures. The bridge will have the load capacity investigated for the dead load due to the additional slab weight and the posting signs modified if necessary. If the condition of the slab is poor, consideration should be given for a complete bridge rehabilitation project. The costs of associated structural maintenance repairs, which are insufficient in scope to be classified as a full rehabilitation to remove all deficiencies in the bridge, are considered to be non-participating.

Seismic Retrofit

The design of seismic improvements shall follow applicable AASHTO and current FHWA publication guidelines pertaining to bridge rehabilitation. The costs of associated structural maintenance repairs, which are insufficient in scope to be classified as a full rehabilitation to remove all deficiencies in the bridge, are considered to be non-participating.

Bridge Steel Painting

The complete blast-cleaning and repainting of the structural steel will be eligible where the existing paint system is approaching a failed condition (10% or greater overall rusting per SSPC VIS Std. No. 2). The preparation and three-coat paint system shall be in conformance with MoDOT Standard Specification Section 712. The manufacturer's system must be on MoDOT's approved list. The costs of associated structural maintenance repairs, which are insufficient in scope to be classified as a full rehabilitation to remove all deficiencies in the bridge, are considered to be non-participating.

BRIDGE REHABILITATION

Design Criteria

The minimum design criteria are based on the current edition of the following publications:

A Policy on Geometric Design of Highways and Streets,
by AASHTO.

Highway Drainage Guidelines, by AASHTO.

Standard Specifications for Highway Bridges, by AASHTO.

Manual for Railroad Engineering, by AREA.

Funding

Rehabilitation will be considered for HBRRP or STP funding when the following investigations indicate that the improvement provides the best value while meeting the needs of the Local Agency. If determined at the Program Eligibility Review project stage that structure improvements are eligible only for partial federal participation in funding as needed to rehabilitate the structure, the Local Agency may still elect to replace the structure, rather than to rehabilitate the existing structure per the following guidelines. However, the amount of eligible federal funding will be limited to that which will not exceed the rehabilitation cost estimate. If the Local Agency elects to replace a structure eligible only for partial, or "rehabilitation" funding, it is still necessary that all of the six items identified under this "Bridge Rehabilitation" section – specifically under the heading "Preliminary Bridge Submittal" – be fully addressed in the Preliminary Submittals to provide the appropriate justification for the estimated cost of rehabilitation.

Removal of Deficiencies

Bridge deficiencies are indicated by the bridge inspection report. The inventory criteria will be based on the current edition of the *Bridge Inspection Rating Manual*, by MoDOT as well as the latest version of the FHWA publication *Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges*. The deficient items are listed as follows on the inspection report:

1.	Item 58	Deck Condition	≤ 4
2.	Item 59	Superstructure Condition	≤ 4
3.	Item 60	Substructure Condition	≤ 4
4.	Item 62	Culvert Condition	≤ 4

5.	Item 67	Structural Evaluation rating	≤ 3
6.	Item 68	Deck Geometry	≤ 3
7.	Item 69	Under Clearance	≤ 3
8.	Item 71	Waterway Adequacy rating	≤ 3 and last digit for
	Item 42	Type of Service	= 0, 5-9
9.	Item 72	Approach Roadway Alignment	≤ 3

The bridge improvements shall remove any deficiency as listed above and shall be designed to provide an increased life expectancy of at least 25 years before significant deficiencies develop.

Condition Rating Which May be Left in Place

The following condition rating shall be improved to meet or may be left in place if they meet the following criteria:

1.	Item 58	Deck Condition	= 6
2.	Item 59	Superstructure Condition	= 6
3.	Item 60	Substructure Condition	= 6
4.	Item 62	Culvert Condition	= 6

Truck Load Capacity

The load capacity of the superstructure shall be improved to remove all load posting restrictions for the Missouri legal load as based on the current edition of the *Bridge Inspection Rating Manual*, by MoDOT. In commercial zone areas, the structure may be posted at a level above the legal load.

Bridge Width

The bridge width shall be improved to at least a width where the bridge would not be considered functionally obsolete due to deck geometry based on the number of traffic lanes and future design year ADT or type of roadway classification. This width shall be determined in accordance with the latest version of the FHWA publication *Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges*. Refer to “Bridge Replacement - Bridge Width” in this Section for detailed information on this requirement.

(The above publication can be accessed at **www.fhwa.dot.gov/bridge/mtguide.pdf**).

Bridge Rail System

The structure shall be improved to meet the same design criteria as for a replacement structure.

Seismic Requirements

Seismic Investigations will generally be required in conjunction with the design of bridge rehabilitation improvements. The design of seismic improvements shall follow applicable AASHTO and current FHWA publication guidelines pertaining to bridge rehabilitation. Existing and widened new portions of structures including substructures are expected to meet applicable AASHTO seismic requirements pertaining to new structures.

Investigations

For stream crossings with span type or culvert type bridges, a risk analysis to the structure and adjoining property shall be made for the 25 year frequency flood. A scour investigation shall be made for the structure foundation for the 100 year frequency flood. The methods indicated for designing replacement structures may be used.

Where the superstructure can be rehabilitated the substructure shall be investigated to determine if it has the capacity for the rehabilitated superstructures or can be improved to support the capacity of the Missouri legal load.

Preliminary Bridge Submittal

The Project Summary Report shall include the results of the design investigations regarding the following:

1. indicated deficiencies
2. locations of items to be improved
3. level of improvement
4. conceptual estimation of load capacity improvement
5. results of hydraulic and scour investigations
6. estimated cost of improvement

BRIDGE REPLACEMENT

Design Criteria

The minimum design criteria are based on the current edition of the following publications:

A Policy on Geometric Design of Highways and Streets, by AASHTO.

Highway Drainage Guidelines, by AASHTO.

Standard Specifications for Highway Bridges, by AASHTO.

Manual for Railroad Engineering, by AREA.

Preliminary Plans

All preliminary drainage structure layouts should be submitted with the preliminary roadway design layout. Roadway drainage structure submittals are required for drainage areas less than or equal to 1000 acre (400 ha). The hydraulic design requirements for roadway drainage structures are defined in this Section. Preliminary bridge or culvert layout submittals are required for all larger drainage areas, road crossings and railroad crossings. Layouts should also be submitted for retaining walls over 3 ft (0.9m) high.

Structure Type

1. The structure type for all span type bridges or culvert type bridges shall be based on economic comparisons. However, for projects with bridge estimates in excess of $500,000, cost estimates for several types of structures shall be prepared and submitted to MoDOT.

2. Span type structures may be either single span or multiple single or continuous span. The structures may be steel, prestressed concrete or reinforced concrete based on economics. Culvert type bridges may be concrete box culverts, either cast in place or precast, or pipe, either concrete or metal, or arch type structures.

3. Geometric design requirements for grade crossing structures, railroad crossing structures and retaining walls are defined in this Section.

Low Water Stream Crossing

1. For bridge replacements found to be eligible for HBRRP funding under Section 123(d) of the 1987 STURAA Act which provides for the replacement of an existing low water stream crossing not on the FHWA Bridge Inventory with a new all-weather bridge, the following additional hydraulic requirements shall apply to the project.

   a. The approach road should be improved to avoid inundation from the 10-year frequency flood.

   b. The structure length should be investigated for the 25-year design frequency for the structure with roadway overflow, which will produce no more than 1 ft (0.3m) of backwater.

2. Low water stream crossing structures, which replace structures on the MoDOT eligible list, will use the design criteria as defined in this Section.

Truck Loadings

The AASHTO HS 20 design truck shall be used on all routes except NHS routes. On NHS routes a loading of 1.25 X the AASHTO HS 20 loading is required (HS25).

Seismic Requirements

Seismic Investigations will generally be required in conjunction with the design of bridge replacements. The design of seismic improvements shall follow applicable AASHTO and current FHWA publication guidelines pertaining to bridges. (Also see **Section IX**, Final Design).

Bridge Width

The structure width shall be designed to match the shoulder-to-shoulder width or the curb-to-curb width of the improved road as per the geometric requirements based on the functional classification of the route. The functional classification of the route as approved by FHWA is important for establishing the design criteria the Local Agency will be required to follow throughout the various stages of the project. If the Local Agency is not sure of the FHWA approved functional status of the route, the MoDOT district project representative should be contacted. New bridges shall be constructed using a width, which will provide an anticipated service life of at least 25 years before becoming functionally obsolete as defined by National Bridge Inventory Standards.

Bridge "curb-to-curb" (or "bridge roadway") widths that are less than the combined lane and shoulder width indicated by **Figure VIII-1**, and as requested by design variance with appropriate justification, are generally permissible provided the following two conditions are met:

1. The proposed bridge width shall not result in a bridge, which would be considered functionally obsolete due to deck geometry based on the design year ADT. The calculation to determine suitability of deck widths to meet this condition shall be in accordance with the December 1995 metric edition of the FWHA publication *Recording and Coding Guide for the Structural Inventory and Appraisal of the Nation's Bridges*. (This publication can be accessed at **www.fhwa.dot.gov/bridge/mtguide.pdf**).

   Item 68 in the above publication addresses "deck geometry" – a characteristic of a bridge that is based on number of lanes of traffic and ADT or type of roadway classification. **A bridge roadway width that results in a deck geometry rating of 3 or less will also result in a functionally obsolete bridge rating. As a result, a bridge roadway width that will produce a minimum deck geometry code rating of 4 is required for all new structures.** This requirement also applies to horizontal clear width provided on the approaches to the bridge. Under Item 68 in the 1995 metric edition of the above FHWA publication, formulas to determine the minimum bridge roadway width to achieve a deck geometry code rating of

4 (or greater) are provided for the engineer's use. In order to avoid a functionally obsolete bridge rating due to metric/English conversion, it is recommended that the engineer should round up to the nearest foot when converting the minimum bridge roadway width obtained by the metric formulas to English units.

2. The curb-to-curb bridge width shall not be less than the width of the curbed street sections approved for use on the project. The street approaches to the bridge also shall not represent a narrowing effect in regard to the normal traffic flow along the route that incorporates the bridge.

A design variance for bridge width may be considered for construction of a single lane bridge for rural local roads carrying 2-way traffic with a future design ADT of 100 or less. The curb-to-curb width of the single lane bridge shall be greater than or equal to the existing roadbed width, but not less than 16 feet. A public hearing will be required to allow public input prior to programming submittal and shall be summarized in the variance request.

STRUCTURES AT STREAM CROSSINGS WITH DRAINAGE AREAS > 1000 ACRES

Investigations

For stream crossings with span type bridges or culvert type bridges with drainage areas over 1000 acres (400 ha), several hydraulic investigations should be made. These will include investigation of field conditions related to the hydraulic design of the structure, investigation for FEMA design restrictions as related to the National Flood Insurance Program, and investigation for scour potential, embankment protection and potential channel modification requirements. Other investigations may also be found to be appropriate.

Hydraulic Field Investigations

1. An appropriate number of design valley sections will be taken as described by the hydraulic design model chosen.

2. Streambed profile for 1000ft (300m) upstream and 1000 ft (300m) downstream from the proposed structure.

3. A site visit should provide the following information:
   selection of roughness coefficients
   evaluation of overall flow directions
   observation of land use and related flood hazards
   geomorphic observations (bank and channel stability)
   highwater marks
   evidence of drift and debris

interviews with local residents on flood history
approximate annual low water elevation at the bridge
location and elevation of buildings or other improvements, such as levees and dams, in or adjacent to the upstream flood plain.

Design Discharges

Floodwater discharge due to the flood frequency appropriate for the design of the structure (and for prevention of approach roadway overtopping, for STP projects) shall be determined using the most precise method available. Approved methods for determining the design discharge are as follows:

1. If the structure is located at or near a USGS stream gaging station, the gage data should be used. For this data use *Magnitude and Frequency of Missouri Floods*, Water Resources Report 23, 1968 and addenda, by USGS. Stream gage data is available on the Internet at **http://missouri.usgs.gov/** under "Real Time Stream Flow Data" for the appropriate river basin.

2. For urban areas in general, use *Technique for Estimating Flood-Peak discharges for Urban Basins in Missouri*, Report 86-4322, 1986, by USGS.

3. For rural areas, use *Technique for Estimating the 2 to 500 year Flood Discharge on the Unregulated Streams in Rural Missouri*, Report 95-4231, 1995, by USGS. Note that the 1974 Missouri Rural USGS Equations are considered by MoDOT to be obsolete and will typically not be accepted.

4. When situations unique to a project site are such that design discharges determined by the above methods result in inconsistencies with information determined from the engineer's investigation, the engineer may choose to determine design discharges from other accepted methods as defined in the FHWA publication, *Highway Hydrology: Hydraulic Design Series No. 2*, FHWA-SA-96-067.

5. When a FEMA Flood Insurance Study has been prepared and the LPA is a participant in the National Flood Insurance Program, this information shall be used for the hydrologic analysis. Design discharges identified in a current FEMA Flood Study where water surface elevations have been determined for existing conditions during the design frequency flood will take precedence over discharges determined by the other methods listed above.

6. For reference, additional information regarding design discharges (along with other hydraulic design information) may be found in Section 8.2 of the MoDOT Bridge Manual, which can be accessed at **www.modot.org/business/bridgedesign.htm**

Hydraulic Analysis

1. The preferred method for determining the water surface elevations for both span type structures and culverts is to use the program *River Analysis System*, HEC-RAS, 1997 and revisions, by US Army Corps of Engineers, or the program *Bridge Waterways Analysis Model*, WSPRO, HY 7, 1990 and revisions, by FHWA.

2. The preferred method for design of span type structures for backwater and freeboard is to use the program *River Analysis System*, HEC-RAS, 1997 and revisions, by US Army Corps of Engineers, or the program *Bridge Waterways Analysis Model*, WSPRO, HY 7, 1990 and revisions, by FHWA.

3. The preferred method for design of culvert structures for backwater and freeboard is the design publication Hydraulic Design of Highway Culverts, HDS 5, 1985 and revisions, by FHWA and the program Culvert Analysis Micro Computer Program, HY 8, 1987 and revisions, by FHWA. The program *River Analysis System*, HEC-RAS, 1997 and revisions, by US Army Corps of Engineers, may also be used.

4. High water elevations determined with the Manning equation in the hydraulic analysis should be compared to known historical flood elevations to determine compatibility of the calculated elevations and the actual observed elevations. Reasonable adjustment of the Manning roughness coefficients, described below, may be required to calibrate the analysis model to known conditions.

5. Proper application of the hydraulic analysis methods requires care in the determination of the representative Manning roughness coefficients ("n-values"). For streams in Missouri, the recommended n-value for the channel will generally vary from 0.03 to 0.06. For overflow areas of the floodplain, the recommended n-value will generally vary from 0.08 to 0.15. However, n-values used should represent the actual stream and overbank conditions particular to the vicinity of the project site.

6. Floodplain cross-sections used in the hydraulic analysis model should represent effective stream flow conditions in the vicinity of the project (both upstream and downstream). Cross sections representing the most constricted waterway condition will therefore be the most appropriate for use in the analysis.

7. When overtopping of the roadway approaches to the structure is anticipated, the cross section used for the roadway in the computer analysis should be modeled to represent effective flow conditions. For example, when the roadway is cut through a hillside - the cross section at the roadway itself may indicate overtopping conditions that would not actually occur because of the blockage of the effective flow by the hillside (upstream or downstream of the roadway).

Valley Slope

Valley slope is used in the USGS regression equations to determine the design discharge. Valley slope, in feet per mile, is the average slope between points 10% and 85% of the distance along the main-stream channel from the proposed structure to the drainage divide. The distance between these points is obtained using USGS topographic maps; and distance is measured by setting draftsman's dividers at 0.1 mile (0.1 km) spread and stepping along the main channel. The main channel is defined above stream junctions as the one draining the largest area. The valley slope is then defined as the elevation difference between the 10% and 85% points, divided by the distance between the points.

Streambed Slope

It should be noted that the streambed slope (the hydraulic gradient) used in the hydraulic analysis computer models WSPRO or HEC-RAS should not be taken as the "valley slope" of the drainage area upstream of the proposed crossing (if used in the determination of the design discharge by the USGS regression equations).

The hydraulic gradient is the slope of the water surface in the vicinity of the structure. It is generally assumed equal to the slope of the streambed in the vicinity of the structure. Note that the hydraulic gradient is typically much smaller than the valley slope used in the USGS regression equations. Hydraulic gradient is a localized slope, while valley slope is the average slope of the entire drainage basin.

The hydraulic gradient is determined by one of two methods, depending on drainage area:

1. For drainage areas less than 10 square miles (25 sq. km.), the gradient is determined by fitting a slope to the streambed profile within 1000 feet upstream and downstream of the structure.

2. For drainage areas greater than 10 square miles, the gradient is determined from USGS topographic maps by measuring the distance along the stream between the nearest upstream and downstream contour crossings of the stream. The hydraulic gradient is then given by the vertical distance between the contours divided by the distance along the stream between contours. Dividers set to 0.1 mi or 0.1 km should be used to measure the distance along the stream.

Backwater Limitations

Backwater is the increase in upstream water surface elevation that occurs as the result of placement of a constriction, such as a bridge and its roadway embankments, across the flood path of the natural floodplain. The amount of backwater produced during the design flood is determined by comparing the water surface elevation at a location approximately one bridge length upstream of the proposed structure (based on hydraulic analysis with the proposed structure in place) to the water surface elevation that would exist at the same location as determined by hydraulic analysis for natural conditions without any structure in place. "Backwater", upstream of the structure, is therefore defined as the difference between the water surface elevations obtained by hydraulic analysis for proposed conditions and hydraulic analysis for natural conditions. The amount of backwater allowed will be dependent upon the most restrictive hydraulic design criteria applicable to the project site. Hydraulic design criteria provided in this Section (**Figure VIII-4**) are intended as minimum criteria. If the Local Agency is a participant in the National Flood Insurance Program, FEMA regulations regarding allowable backwater may be found to be more restrictive. Likewise, a Local Agency's specific hydraulic design criteria (if applicable) may also be found to be more restrictive. If possible, backwater should be evaluated at various points upstream of the structure to assure that the "worst case" increase in water surface elevation has been identified.

Due to hydraulic conditions unique to an individual job site, a higher amount of backwater may be found to occur at a flood frequency more recurrent than the design frequency. For example; if the design frequency is a 50-year flood (per the LPA Manual criteria), the engineer shall also ensure that the upstream water surface elevation as allowed for the maximum 1 foot of backwater during the design frequency flood is not exceeded during more recurrent floods.

The same restriction in water surface elevations produced by more recurrent floods will apply when the Local Agency is a participant in the National Flood Insurance Program and the project is within an area identified by FEMA as "subject to 100-year flooding" with a maximum allowable backwater of 1.0 foot during a 100-year flood and where water surface elevations have been determined in the FEMA Study.

Also, in cases where a FEMA-defined "floodway" is to be crossed, the restrictive "No-Rise" in water surface elevation for the 100-year "base flood" will also apply to the more-frequent flooding situations; i.e., water surface elevations produced during floods more recurrent than the 100-year flood must not exceed the 100-year water surface elevations. (See "Federal Emergency Management Agency (FEMA) and Required Certifications", later in this Section).

While satisfying "maximum allowable backwater" limitations imposed by appropriate regulations, consideration should also be given to safety or property damage concerns that could result at a lesser amount of backwater.

If design of the structure is desired to satisfy flooding conditions other than would occur simply due to flooding of the stream being crossed during the design frequency indicated in Figure VIII-4, then a design variance request should be provided. (See "Hydraulic Design Variances" later in this Section).

Hydraulic Capacity

1. The headwater design should be based on a peak discharge analysis. The design frequency will be determined from the functional classification and type of the inventory route as indicated in **Figure VIII-4**.

2. The length of the structure shall be established to provide a waterway opening that is large enough such that no more than 1.0 foot of backwater or excessive stream flow velocities are produced during a design frequency flood as a result of the constriction of the natural floodplain by a bridge and the roadway embankments. Note that to satisfy minimum requirements of the LPA Manual, the structure is to be designed for the frequency indicated in the last column of **Figure VIII-4**. In addition to backwater limitations, the amount of provided freeboard between the high water elevation and the underside of the structure is also to be based on this design frequency.

3. If conditions are such that the approach roadway will be overtopped during the design flood for the structure, the hydraulic analysis shall account for flow both through the bridge opening and over the approach roadway in determination of the backwater created. (Also see related discussion above in Item 7 of "Hydraulic Analysis").

4. Freeboard, the amount of clearance between the underside of the bridge structure and the high water elevation for the design frequency, is recommended to allow for the passage of drift and to reduce the potential for damage to bridge deck-supporting structural members by collision from drift material. The appropriate amount of freeboard shall be determined from site history of drift problems and from risk analysis as described in the "Freeboard Capacity" portion of this Section.

5. Overtopping of a bridge structure during the design frequency flood will generally not be allowed. If it becomes apparent during the preliminary design process that overtopping of the structure will be unavoidable due to existing constraints, the allowance of overtopping of the structure must be fully justified through a design variance request and reviewed by MoDOT in order to satisfy eligibility requirements for federal funding. The design variance request must also state any provisions that will be taken by the Local Agency to mitigate safety risks to the public during overtopping events. (See “Hydraulic Design Variances” later in this Section for more information).

6. For projects utilizing STP funds, all routes designated on the federal aid system which encroach on flood plains shall be designed to avoid inundation of the approach roadways during the design frequency flood which is indicated in the forth column of **Figure VIII-4**. The structure shall be designed to convey the discharge due to the design frequency flood indicated in the fifth column of **Figure VIII-4** while creating no more than 1.0 foot of backwater or creating excessive stream flow velocities. Note, however, that backwater

limitations to satisfy FEMA floodplain management regulations (if applicable to this project site) may be more restrictive than those identified in this Section. The engineer shall ensure that the most restrictive conditions are satisfied in the hydraulic design. For projects utilizing HBRRP funds, participation will be limited to a minimum amount of roadway construction, which will provide touchdown to touchdown of the existing road. For these projects, therefore, it is assumed that overtopping of the approach roadways may likely occur. However, as with STP projects, the structure shall be designed to convey the discharge due to the design frequency flood indicated in the fifth column of **Figure VIII-4** while creating no more than 1.0 foot of backwater or creating excessive stream flow velocities. Again, note that applicable FEMA backwater limitations may take precedence over the LPA Manual requirements.

7. The effects of existing flood control channels, levees and reservoirs shall be considered in determining the discharge and water surface elevations for all floods considered in the design.

8. Span type bridges and culvert type bridges shall be designed for stability as well as for hydraulic conveyance. The minimum length of structure for span type bridges shall provide adequate stability for the end abutments. Recommendations for the maximum slope of end fills for bridge stability should be stated in the geotechnical investigation report. The minimum length along C/L roadway for culverts shall not substantially restrict the stream channel.

9. The location of intermediate substructure piers shall be designed to allow the maximum passage of drift through the structure opening while providing the most economical superstructure design.

10. Although the hydraulic design may allow submergence of a culvert inlet during the design frequency flood, the elevation of the headwater depth should not exceed the elevation of the roadway shoulder line at the low point, less 1.0 foot (0.3 m), except in situations where approach roadway overtopping is allowed per the criteria in **Figure VIII-4**.

11. In establishing the waterway opening for a bridge, it is permissible to construct a bridge exceeding minimum LPA guidelines in order to correspond to future plans for waterway construction of the U. S. Army Corps of Engineers, drainage districts, sewer districts, and similar entities having jurisdiction. However, unless it can be established that the future waterway improvements will actually be constructed within a reasonable amount of time, the federal participation in the project will be limited to the cost of a bridge meeting minimum LPA guidelines. The Local Agency shall submit a letter from the drainage entity to substantiate the schedule for the actual construction of the waterway improvements.

12. Although Federal participation in HBRRP funding applies to a minimal amount of roadway improvements, as stated in this Manual, Local Agencies should also be aware that future increase in grade of approach roadways to reduce the occurrence of overtopping may create additional backwater problems unless relief structures are provided. The Local Agency may therefore wish to have the engineer also consider the hydraulic impacts of intended future approach improvements on existing upstream properties or developments during the process of the hydraulic design of the replacement structure.

If design of the structure is desired to satisfy flooding conditions other than would occur simply due to flooding of the stream being crossed during the design frequency indicated in Figure VIII-4, then a design variance request should be provided. (See “Hydraulic Design Variances” later in this Section).

Design High Water Elevation

Design high water elevation, as referred to in this Manual, is intended to represent the water surface elevation at the bridge (or culvert) structure resulting from the design frequency discharge. The design high-water elevation is used to establish the elevation of the bottom of the bridge superstructure as needed to provide the desired amount of freeboard for passage of drift material as well as to determine requirements for abutment protection with rock blanket. The hydraulic analysis should consider the effects of "draw-down" in the water surface elevation, as generally occurs when a stream's discharge is forced through a constriction (bridge opening) in the natural unconstricted waterway. Reference is given to *"Hydraulics of Bridge Waterways"*, Hydraulic Design Series No. 1, 1978 and revisions, by FHWA. Because of this "draw-down" effect, the design high water elevation should represent the highest water surface elevation within the bridge opening.

When using WSPRO for the hydraulic analysis (since both the WSPRO "Full Valley" and "Bridge" sections are located at the downstream face of the bridge opening), MoDOT recommends adjusting the water surface elevation indicated in the analysis at both of these sections by the streambed slope to arrive at the water surface elevation at the upstream face of the bridge opening and then using the "worst case" (highest elevation) to represent the design high water elevation at the bridge.

However; because of the effects of backwater produced by the bridge constriction of the waterway, the water surface elevation therefore rises both upstream from the bridge opening as well as along the upstream roadway embankment. When the hydraulic analysis indicates that approach roadway overtopping will occur during the design frequency flood, the engineer may prefer to use the water surface elevation indicated for overtopping of the approach roadway ("Road" section in WSPRO) to represent the design high water elevation. This elevation will likely be somewhat higher (and more conservative) than that determined for the bridge opening as described in the above paragraph - however, a "design high water elevation" identified in this manner would also be more representative of flooding conditions at the immediate bridge site for the design frequency flood.

It is noted that the water surface elevation at the upstream "Approach" stream cross section (in WSPRO) should not be used as the design high water elevation.

Freeboard Capacity

Freeboard is defined as the distance from the design water surface elevation to the lowest member of the bridge superstructure.

After determining the size and severity of the historical drift problem at the project site, the engineer shall determine the appropriate amount of freeboard to provide for the span or culvert type structure. The method for determining the appropriate amount of freeboard is left to the discretion of the engineer; however, the findings by the engineer should be fully addressed in the Hydraulic Report. For reference, minimum freeboard standards used for State projects can be found in Section 8.2 “Hydraulic Design” of the MoDOT Bridge Manual, which can be accessed at **www.modot.org/business/bridgedesign.htm**

The freeboard dimension above the design frequency high water elevation at the bridge opening shall be indicated in the "Hydraulic Summary Data Table", **Figure VIII-6**, which shall be shown both in the hydraulic report and on the drawings.

A minimal amount of freeboard, in accordance with the engineer's evaluation, will not require a design variance request. Similarly, if the engineer determines that a "negative freeboard", i.e., partial submergence of the bridge deck-supporting members, will be acceptable, then this conclusion should be clearly stated and justified in the hydraulic report. **However, proposed overtopping of the structure itself for the design frequency flood is highly undesirable and must be fully justified by the design variance process and approved by MoDOT.**

When determining the appropriate amount of freeboard and size of bridge opening, the engineer shall also modify the design as needed to minimize any adverse effects to the structure, roadway, channel, or upstream or downstream property due to drift problems.

Consideration should also be given for backwater from other nearby streams when evaluating the freeboard requirements. (See the following information)

Backwater due to Flooding from a Nearby Stream

Occasionally, a stream being crossed by a proposed structure will be a tributary to a larger stream in the project vicinity, where the high water elevation due to flooding of the larger stream will be greater than the design high water elevation due to flooding of the stream being crossed by the project. In addition, the high water elevation due to flooding of the larger stream will often be established by a FEMA Flood Study, where further FEMA design restrictions may apply.

In these cases, the design high water elevation at the project site should be taken as due to flooding resulting from rainfall within the drainage area of only the stream being crossed (and as resulting during the design frequency as defined in Figure VIII-4); although the engineer shall ensure that any FEMA design restrictions imposed regarding flooding of the larger stream (as established by a FEMA Flood Study) will not be violated due to the new construction.

Often, a new structure over a stream that is tributary to a larger nearby stream evaluated by a FEMA Flood Study, and is affected by flooding of the larger stream, can be shown (due to increased bridge opening size) to have no negative impact on the existing FEMA Flood Study by comparison of "proposed" hydraulic conditions (with the new structure in place) to "existing" conditions at the time the Flood Study was performed (i.e., with the existing structure in place).

The effects of flooding of a larger nearby stream on the proposed structure shall be addressed in the hydraulic report. If design of the structure is desired to satisfy flooding conditions other than would occur simply due to flooding of the stream being crossed during the design frequency indicated in Figure VIII-4, then a design variance request should be provided. (See "Hydraulic Design Variances" later in this Section).

Federal Emergency Management Agency (FEMA) and Required Certifications

Local Agencies that participate in the National Flood Insurance Program (NFIP) have the responsibility to ensure that floodplain developments meet the regulations established by the NFIP as identified in the Title 44, Code of Federal Regulations, Parts 59 through 78. (Parts 59 and 60 contain the most applicable information for a typical project). These regulations are made available on the Internet by the National Archives and Records Administration and can be found at the following address: **www.gpoaccess.gov/cfr/index.html**

A current list of communities for which FEMA Flood Insurance Studies have been performed is available in the Community Status Book (CSB), available on the Internet at:
www.fema.gov/cis/mo.pdf

The hydraulic report shall provide information regarding participation of the Local Agency in the National Flood Insurance Program (NFIP) and related FEMA hydraulic design criteria that applies.

Because of the Local Public Agency's responsibility to enforce their Floodplain Management Regulations (if a participant in the NFIP) and to ensure that the proposed structure will satisfy those regulations, the engineer shall include a certification with the Summary Report regarding investigations into FEMA NFIP requirements that may apply. Provision of this certification will be taken as indication that federally regulated hydraulic design criteria potentially in excess of those hydraulic design criteria listed in this Manual have been investigated and addressed by the engineer. The appropriate certification information to be provided is shown in **Figure VIII-8**.

If the Local Agency is a participant in the NFIP, this certification shall also provide reference to the appropriate FEMA Flood Insurance Study data; such as Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map (FHBM) Community Panel map numbers and date of the map's issue. The certification shall also indicate the classification of the site; such as "floodway", "Zone A - subject to 100 year flooding", "not subject to 100 year flooding", etc.

For the convenience of the Local Agencies and engineers in investigating FEMA Flood Insurance Studies and Flood Maps pertaining to a project site, FEMA Flood Insurance Studies and Maps can now be viewed on the Internet at the following address by selecting "FEMA Flood Map Store": www.fema.gov (Hardcopies of the FEMA Flood Insurance Studies and Flood Maps can also be ordered at the same site.)

For FEMA flood zones where flooding water surface elevations have been determined through a detailed FEMA Flood Insurance Study, maximum backwater may be limited to 1.0 foot or less during the 100-year flood. In these zones subject to 100-year flooding (other than Zone A), FEMA hydraulic design criteria may be found to take precedence over the criteria of this Manual. (As stated earlier in this Section, water surface elevations for more recurrent floods shall not exceed the allowable water surface elevations during the 100-year flood in these FEMA flood zones).

In addition; if the proposed structure is in a site identified by the NFIP as a "floodway", separate certification will also be required to state that the new structure will create **no increase** in the 100-year water surface elevations per the FEMA Flood Insurance Study. This information is to be shown on the Engineering "No-Rise" Certificate. (See **Figure VIII-5**). This certificate shall be signed and sealed by a Missouri Registered Professional Engineer and a copy shall be included with the preliminary design submittals.

The following information, as a recommendation to engineers regarding No-Rise Certificates, was provided to MoDOT for inclusion in the LPA Manual:

The No Rise Certification should be sent to the NFIP community is which the project is located. In addition, you should forward a copy to the FEMA Regional Office in Kansas City, Missouri. That address is:

Federal Emergency Management Agency

Community Mitigation Program Branch

2323 Grand Avenue, Suite 900

Kansas City, MO 64108

If the No-Rise Certification information relates to an ongoing mapping or letter activity with FEMA, then you should provide the case number it pertains to and it should be submitted to FEMA Headquarters in Washington, DC at the address below.

Federal Emergency Management Agency

FIMA, Hazard Mapping Division, Hazards Study Branch

500 C Street, SW

Washington, DC 20472

Hydraulic Summary Data Table

Two Hydraulic Summary Data Tables are shown in **Figure VIII-6**. Information indicated in the first table is to be provided in the Hydraulic Report. The information indicated in the second table in **Figure VIII-6** shall be shown on the preliminary drawings.

Scour Evaluation

1. Bridge foundations shall be designed to withstand the effects of scour without failing for the worst conditions resulting from floods equal to or less than the 100-year flood and checked for the 500-year flood. The analysis shall be in accordance with the publication *Evaluating Scour at Bridges*, HEC 18, 1993 and revisions, by FHWA.

2. Stream stability should be investigated to determine appropriate countermeasures to mitigate potential damages to the bridge structure. This investigation should be in accordance with the publication *Stream Stability at Highway Structures*, HEC 20, 1991 and revisions, by FHWA.

3. Where the roadway is on fill and overtopped by the 100-year frequency flood, an investigation should be performed to determine the embankment damage and assess protective measures. This investigation should be in accordance with the publication *Development of a Methodology for Estimating Embankment Damage Due to Flood Overtopping*, FHWA/RD-86/126, 1987 and revisions, by FHWA.

4. For end abutments on fill, the design requirements for scour at abutments may be omitted when rock blankets are placed up to the lower of the top of spill slope elevation or 500 year flood elevation. Consideration should also be given to wrapping the rock blanket spill slope protection around the sides of the end fill (both upstream and downstream sides).

5. For intermediate bents, the bottom of footings shall be placed no higher in elevation than the computed depth of scour, or a minimum 6.0ft (2m) below the streambed unless rock is encountered. If the footing is designed as a pile cap, Item 6 will also apply.

6. For intermediate bents with trestle or foundation piles, the bottom of piles shall be terminated a minimum of 10 ft (3m) below the calculated depth of scour to provide lateral restraint.

7. Providing a rock blanket generally offsets scour concerns at culverts. If the outlet stream velocity will be over 10 feet/second for the scour design discharge, consideration should be given to also placing rock blanket across the streambed for about 50 feet downstream. Generally, the scour review should consider the outlet velocities for the appropriate design discharges and provide a general discussion of the scour considerations and provisions, as appropriate, for higher outlet velocities in the hydraulic report. If excessive outlet velocities (20 feet/second or more) are indicated, consideration should also be given to energy dissipation techniques.

Channel Modification

1. Channel changes alter the conditions of the natural waterway. These changes may cause an increase in velocity of the flowing water, sometimes enough to cause damage to the highway embankment near the stream or excessive scour around footings of structures. A channel change should be minimized to the fullest extent practical. Where it is unavoidable, an evaluation should be made to include consideration of the environment, hydraulic, legal and geomorphic aspects involved. The investigation should determine the effect on peak flow downstream and the effected flow area.

2. The new channel should duplicate the existing stream and flood plain characteristics as nearly as possible. These characteristics should include the stream width, depth, slope, flow regime, sinuosity, bank cover, side slopes and flow and velocity distribution.

3. Major channel modification may be constructed if the average channel velocity would not be increased beyond the scour velocity of the predominant soil type at the project site.

Hydraulic Design Variances

When the road or structure cannot be designed to meet the hydraulic design requirements identified in this Manual, then a design variance request shall be made by the Local Agency with an appropriate justification by the engineer. Similarly, a design variance is required when the desired hydraulic design criteria is in excess of that defined in this Manual regarding flooding of the stream being crossed during the design frequency flood identified in Figure VIII-4.

For reduced hydraulic performance during the design flood, the engineer shall perform a risk analysis and prepare a summary report. When preparing the design variance request for this situation, the Local Agency/engineer should address the conditions that occur during the design frequency defined in this Manual, rather than seek a reduced design frequency. In addition to stating the reason for the design variance request, the report should address the following items under the "Justification" heading on page 2 of the Design Variance form (Figure VIII-2-2):

1. What is the backwater for the required design frequency?

2. Will there be adverse effects to the structure, roadway or channel due to the possible increase in stream velocity? If so, what is the mitigation plan?

3. Will there be any adverse effects to the property owners upstream or downstream from increased backwater. If so, what is the mitigation plan?

4. Are there other issues regarding public safety that are anticipated as a result of not meeting the stated design criteria? If so, what are the plans to mitigate these concerns?

5. What is the estimated cost savings for the proposed project that would result from the design variance?

For increased hydraulic capacity to satisfy hydraulic design restrictions established by a current FEMA Flood Study, the design variance request should fully justify the need for the increased capacity. Increased hydraulic capacity to satisfy FEMA design restrictions (identified by a current FEMA Flood Study) that are more restrictive than the hydraulic design criteria identified in this Manual will typically be allowed to supercede the LPA Manual criteria. When increased hydraulic capacity is desired for other situations, such as to provide additional freeboard or hydraulic capacity for flooding that occurs when the stream being crossed is affected by flooding from a larger adjacent stream; or when additional hydraulic capacity is desired for other reasons – MoDOT review may determine that a portion of the cost resulting from design criteria in excess of that indicated in this Manual should appropriately be borne by the Local Agency.

Geotechnical Investigation

1. Adequate borings for foundation design are required. Where "hard rock" is encountered in the investigation, the investigation shall also determine that the hard rock is of sufficient thickness for support of the foundation.

2. Maximum allowable side slopes and spill fill slopes are to be recommended in the geotechnical investigation report in view of existing soil conditions and anticipated fill heights and fill materials at the project location.

3. Probing for rock at proposed box culverts may be necessary. If adequate rock is encountered within 0.5 ft (0.15m) of the bottom slab, then the bottom slab may be omitted and the walls keyed into the rock. If fractured rock is encountered within 0.5 ft (0.15m) of the bottom slab or aprons, under-grading of the rock and backfilling with suitable material from at least 1.0 ft (0.30m) below low concrete is recommended.

4. Appropriate information from the geotechnical investigation shall be indicated on the preliminary design drawings to allow MoDOT assessment of the intended foundation types and layouts.

Barrier Railing Systems

All proposed barrier railing systems for bridge structures including attachments to the structure (and approach systems, when required) must be documented as satisfying appropriate crash-test level ("TL") standards, as indicated below, per the NCHRP Report 350 criteria. **With the PS&E (Final Design) submittals, this documentation is now to be provided by specifically indicating the TL capacity of the barrier system on the barrier railing system drawings.**

It is recommended that information of sufficient detail regarding the proposed bridge barrier railing system be shown on the Preliminary drawings. (This information should include type of railing system, and the railing width, height and TL capacity.) It is beneficial for the engineer to provide this information with the Preliminary submittals so that MoDOT review can confirm that a barrier railing system with the appropriate TL capacity is intended. Otherwise, if a bridge barrier railing of increased TL capacity is found to be required at the PS&E submittals stage, it is possible that resulting changes to the barrier system will also result in changes to the required bridge width and the structural design.

In general, barrier railing systems for bridges or culverts must satisfy TL-3 criteria - except on roadways with functional classification of "local road" or "rural minor collector" (off-federal-system routes) where a design-year ADT = 400 and a legal driving speed = 50 mph (80 km/hr) will exist – in which case, a barrier railing system meeting TL-2 criteria will be acceptable. These requirements are further defined below. In all cases, the barrier railing system selected shall be evaluated by the engineer to determine that it can adequately contain and redirect vehicles without snagging, penetrating or vaulting.

Details of many barrier railing systems that have been evaluated and accepted by FHWA along with indications of the crash-test level ("TL") capacity of these systems are provided at the following FHWA Internet address: **http://safety.fhwa.dot.gov/fourthlevel/hardware/longbarriers.htm**

When selecting an FHWA-accepted barrier railing system, the engineer shall ensure that the details for attachment of the railing system to the structure are compatible with the proposed type of structure. A railing system not listed on this FHWA Internet site may also be acceptable for use if documentation that the railing system will meet the appropriate TL design criteria is stated on the drawings.

As general guidance regarding selection of a barrier railing system, any of the following approaches can be taken:

1. An existing FHWA-accepted barrier railing system listed at the FHWA Internet address referenced above may be used to satisfy the appropriate TL-2 or TL-3 criteria requirement for the project. The engineer shall also ensure that the proposed barrier railing system attachment to the structure will meet the appropriate TL criteria.

2. An existing barrier railing system that meets the appropriate TL criteria may be modified to conform to project-specific requirements; but the engineer shall ensure that the modified barrier railing system and attachment to the structure will also meet the appropriate TL criteria.

3. A new barrier railing system may be used; but the engineer shall ensure that the proposed barrier railing system and attachment to the structure will meet the appropriate TL criteria.

The consultant may substantiate a modified or new barrier railing system's TL rating by methods such as by FHWA evaluation, independent testing or by calculation. Calculations that compare the strength of the proposed system to a similar system already accepted by FHWA as meeting the appropriate TL rating may also be performed to substantiate a barrier railing system TL rating.

For modified or new railing systems, the engineer may also find current information regarding the design of railing systems in Section 13 "Railings" of the 2001 Interim AASHTO *LRFD Bridge Design Specifications* to be helpful.

When pedestrian sidewalks are to be provided, the vehicular barrier railing system on the structure shall be located between the traffic lanes and the sidewalk, unless omission of the separating barrier can be adequately justified by a design variance request and accepted by MoDOT. However in all cases, a vehicular barrier railing system providing the appropriate TL capacity shall be provided on the structure. When the sidewalk is to be adequately elevated above the roadway and MoDOT has accepted that the vehicular barrier railing system for the bridge may be located at the outside edge of the sidewalk, then the vehicular barrier railing system must also provide appropriate pedestrian railing features.

On-Federal-System Routes

1. Barrier railing systems that meet the TL-3 requirements of the National Cooperative Highway Research Program (NCHRP), Report 350 criteria shall be provided along the edges of structures for protection of the vehicular traffic.

   As indicated above, many railing systems exist that are accepted by FHWA as providing TL-3 capacity, although it is noted that the MoDOT concrete jersey barrier and thrie beam rail with channel also meet this requirement. Standard drawings for the MoDOT barrier railing systems may be accessed at: **www.modot.org/business/bridgestandards.htm**

2. A crashworthy approach railing system at all corners of the structure (including a bridge anchor, transition section, approach section and end terminal section) shall be provided unless it can be demonstrated that these are precluded by other design provisions. All of these items shall meet the TL-3 criteria.

   The following "Missouri Standard Plans For Highway Construction" may be used to meet this criterion (This information may also be accessed on MoDOT's Internet address at **www.modot.org/business/standardplans.htm)**

Bridge Anchor Section	Standard Plan 606.22 or 606.23
Approach Section	Standard Plan 606.00
Transition Section	Standard Plan 606.22 or 606.23

   End Terminal - Flared or non-flared Type A crashworthy end terminal may be used per the Standard Plan 606.00 sheet 1 of 10. A list of several proprietary end terminals that meet these requirements may be found at **www.modot.org/business/endterminals.htm**

3. Bridge railing systems are not required for culverts when the headwalls are located outside the clear zone. The clear zone concept and suggested clear zone dimensions are provided in the AASHTO publication, *Roadside Design Guide*. Object markers shall be provided when no railing is required. When railing is required, roadway guardrail should be used above the culvert when there is sufficient fill to support it - otherwise a bridge railing system meeting TL-3 criteria shall be required.

4. Allowable exceptions to the above items are:

   For streets located in the urban areas with city standard curb and gutter sections and speed restrictions ≤ 30 mph (50 km/hr), the end terminal may be provided by a suitable transition section to the curb and gutter section.

Off-Federal-System Routes designated Local or Rural Minor Collector

1. Barrier railing systems that, as a minimum, meet the TL-2 requirements of the National Cooperative Highway Research Program (NCHRP), Report 350 criteria shall be provided along the edges of structures for protection of the vehicular traffic on routes with design ADT $\leq$ 400 and legal driving speed $\leq$ 50 mph (80 km/hr). However, for projects that do not meet this reduced ADT and legal driving speed criteria, the barrier railing system shall be required to meet all requirements for an on-federal-system route.

   For convenience, the following information is provided regarding some of the railing systems often used for off-federal-system routes to meet TL-2 requirements: The SL-1 Bridge Rail with a flared BCT end terminal anchor, as shown on the FHWA Internet site referenced above as Figure B7.4, "NCHRP SL1 Thrie Beam, Steel Posts" meets the TL-2 requirements, although approach railing is required as part of the overall railing system integrity.

   When approach railing is not required by design (as for cases identified below in Item 3), a modified SL-1 railing system on the bridge can be used in combination with the transition section shown on Standard Plan 606.22 and the roll-down terminal section (now shown on the drawing titled as "Special Sheet – Roll-Down Terminal Section") to meet TL-2 requirements. The "Special Sheet – Roll-Down Terminal Section" is a modification of the voided Standard Plan 606.30E (no longer used for State System projects) and is available electronically with the listing of Missouri Standard Plans. This drawing may be accessed at the following address: **http://www.modot.org/business/standardplans.htm.** However, the engineer shall assume the responsibility to determine if the usage of this detail is appropriate for the design conditions at the project site).

   When the approach guardrail is not necessary by design, the SL-1 railing may also be used in combination with the BCT end terminal anchor if the engineer determines that the system will meet TL-2 criteria. Alternately, the Modified Kansas Corral bridge rail and the Illinois WT bridge rail (which is similar to the Ohio Box Beam rail), are often used to meet the TL-2 requirements. These standard drawings are available from their respective State Departments of Transportation.

   Although various railing systems are referenced above, any barrier railing system and attachment to the structure meeting the required TL criteria may be used.

2. Bridge barrier railing systems are not required for culverts when the headwalls are located outside the clear zone. The clear zone concept and suggested clear zone dimensions are provided in the AASHTO publication, *Roadside Design Guide*. Object markers shall be provided when no railing is required. When railing is required, roadway guardrail shall be used above the culvert when there is sufficient fill to support it - otherwise a bridge railing system meeting the appropriate TL criteria shall be required.

3. Allowable exceptions to the above items are:

With a design ADT ≤ 400 and legal driving speed ≤ 50 mph (80 km/hr), bridge anchor sections, transition sections, approach sections and end terminal railing are not required. However, the engineer shall determine that the bridge barrier railing end condition is not conducive to vehicle snagging, penetration or vaulting, if impacted. If, in the opinion of the engineer, approach railing is needed because of other safety concerns such as high fills, then the bridge anchor section and end terminal shall be provided with the approach railing and transition section where appropriate.

For culverts on roadways with a design ADT ≤ 100, the travel way shall be assumed as a single 12 ft (3.6m) centered lane and the clear zone measured from the edge of the imaginary lane.

Sidewalks

Sidewalks are an eligible feature on bridge structures where such access currently exists for pedestrian or combined pedestrian and bikeway use. For pedestrian use, the sidewalk width should be 5 ft (1.5 m) clear between the vehicular barrier and the pedestrian rail or fence. For combined pedestrian and bikeway use, the sidewalk width should be 10 ft (3.0 m) clear between the vehicular barrier and the pedestrian rail or fence.

Preliminary Bridge Submittal

Data submitted for preliminary bridge review shall include, as a minimum, a Project Summary Report and preliminary design drawings. A Preliminary Design Submittals Checklist, **Figure VIII-7**, is provided at the end of this Section to identify typical information that is to be shown in the Preliminary submittals and to assist the engineer in reviewing submittals content prior to submittal of the Preliminary design package to MoDOT for review. Although certain items on the checklist may not apply for all situations (or information that might be considered appropriate may not be listed), the checklist is intended to identify needed information that is typical for most jobs.

Because hydraulic design criteria and considerations at the preliminary stage determine the basic requirements for the final design stage for structures crossing streams, additional preliminary submittal information is required for these projects. Note that the hydraulic design portion of the Project Summary Report shall include the Hydraulic Summary Data Table (**Figure VIII-6**) and show the calculations and method used to determine the peak discharges (including the drainage area and the valley slope). The report shall identify the streambed slope used in the hydraulic analysis as well as the method in which the streambed slope was determined. Hydraulic analysis and design computations shall be of sufficient clarity and detail to allow MoDOT review confirmation of indicated high water elevations and backwater amounts. Both data input and output from the computer analysis shall be provided. A written summary shall also be provided regarding scour investigation for the structure and freeboard considerations. The report shall provide all appropriate information regarding FEMA National Flood Insurance Program regulations applicable to the project as defined in this section ("FEMA and Required Certifications"). If the Local Public Agency is not a participant in the NFIP, this should also be identified in the report.

All appropriate certifications pertaining to the hydraulic analysis and capacity of the structure (as identified in this Section) shall be included in the hydraulic report.

If appropriate, a completed design variance request with adequate justification shall be provided as a separate attachment.

Bridge layout plan and profile drawings shall be drawn to a scale that adequately allows MoDOT review of the preliminary design parameters that will be used to complete the final design. **All drawings submitted to MoDOT for review are to be half-size (11" x 17").**

When the structure is to be located within or near a horizontal curve, the drawings (or report) shall adequately address superelevation provisions and critical locations where the typical roadway section will transition from a normal crown to superelevated cross sections.

Although not required (unless specifically requested) it is preferable that a preliminary cost estimate (and cost comparison of structural alternates, when appropriate) be provided with the Preliminary submittals as advance notice of potential increases in project funding requirements. However, it is again noted that cost estimates for several types of structures shall be prepared and submitted to MoDOT for projects with bridge estimates in excess of $500,000.

All of the items identified above for inclusion in the Preliminary design submittals have been established by MoDOT with the intention of providing accurate and complete information at an early stage of the project. This information allows an effective quality assurance review by MoDOT regarding appropriate adherence to the design criteria in this Manual. The provision of this information at the preliminary design stage also helps to clarify the minimum design issues that will be critical to effective completion of the final design.

ROADWAY DRAINAGE STRUCTURES DRAINAGE AREAS ≤ 1000 acre (400 ha)

Structure Type

The structure type will normally be a culvert, either a box or a pipe. Box culverts may be either cast in place or precast.

Hydrologic Analysis

Determine the design peak discharge using one of the following methods. For rural areas with drainage areas > 200 acre (80 ha), use *Technique for Estimating the 2 to 500 year Flood Discharge on the Unregulated Streams in Rural Missouri,* Report 95-4231, 1995, by USGS. For urban areas with drainage areas > 200 acre (80 ha), use *Technique for Estimating Flood-Peak discharges for Urban Basins in Missouri*, Report 86-4322, 1986, by USGS. For this method; either the basin development factor or the impervious area may be used. For all drainage areas < 200 acre (80 ha), use the Rational Method.

The design frequency will be determined by the design ADT as follows:

ADT	DESIGN FREQUENCY
0-400	10
>400-1700	10-25
>1700-5000	25
>5000	50

Hydraulic Design

The design of the culvert will be based on the allowable headwater depth which is measured from the flow line (invert) of the culvert inlet to the allowable water surface elevation. The allowable headwater depth shall be the smallest value given by the following criteria:

1. The elevation of the allowable headwater depth may not exceed the elevation of the roadway shoulder line at the low point, less 1 ft (0.3m).

2. The elevation of the allowable headwater shall be such that damage to upstream property will be minimized.

3. The allowable headwater depth shall not exceed 12 ft (3.5m) above the culvert flow line.

An acceptable method for determining the headwater depth is to use the larger of the inlet control and outlet control equations.

Preliminary Submittal

See **Figure VIII-7** for Preliminary Submittal requirements.

ROADWAY CROSSINGS

The geometrical design shall meet AASHTO publication *Geometrical Design of Highways and Streets* and the design criteria on **Figure VIII-1** of this manual. See **Figure VIII-7** for Preliminary Submittal requirements.

RAILROAD CROSSINGS

The geometrical design shall, as a minimum, meet AREA requirements unless accepted otherwise by MoDOT through the design variance process. Because design requirements often differ between railway companies, the Railway Company shall also approve the geometric design. See **Figure VIII-7** for Preliminary Submittal requirements.

RETAINING WALLS

The design shall meet AASHTO requirements. See **Figure VIII-7** for Preliminary Submittal requirements. Consideration should be given for an alternate Mechanically Stabilized Earth Wall (MSE) when the height is over 6.0 ft (2m). Adequate soil boring information should be included.

PEDESTRIAN BRIDGES

Design Criteria

The minimum design criteria are based on the current edition of the following publications:

Guide for the Development of Bicycle Facilities, by AASHTO.
Guide Specifications for the Design of Pedestrian Bridges, By AASHTO.

Other design criteria, such as local building codes, may also apply. If so, this information shall also be indicated on the drawings.

Structure Type

1. The structure type for span type bridges shall be based on economical comparisons.

2. Span type bridges may be either prefabricated or built in place. When prefabricated bridges are not pre-engineered, then the design shall provide the minimum geometric requirements and design criteria. The specifications shall offer a minimum of three alternate suppliers who can design and build an acceptable prefabricated bridge.

Design Loadings

All design loadings shall be indicated on the drawings.

Vehicular Load

The structure should be designed for an occasional single maintenance vehicle load unless vehicular access is not provided. The AASHTO *Guide Specifications for Design of Pedestrian Bridges* recommends a single H-5 truck (10,000 lb) for a clear deck width from 6 ft to 10 ft; or a single H-10 truck (20,000 lb) for a clear deck width over 10 ft. This AASHTO Guide indicates that deck widths of less than 6 ft. need not be designed for a maintenance vehicle load. The vehicular load shall not be placed in combination with the pedestrian or bicycle load. If the structure is not to be designed for maintenance or emergency vehicular loading, the drawings should indicate measures to restrict vehicles from gaining access to the structure.

Geometric

1. Grades - pedestrian/bikeway - The grades across the structure shall meet the ADA requirements for wheelchairs.

2. Width

    a. Pedestrian only - For normal volumes provides 5 foot clear between the pedestrian rail or fence. For sidewalks on bridges, provide 5 foot clear between the vehicular barrier and the pedestrian rail or fence. This is normally detailed as a cantilever sidewalk with no additional girder line.

    b. Pedestrian/bikeway - For normal volume, provide 10 foot clear between the bike rails. For trails on bridges, provide 10 clear between the vehicular barrier and the pedestrian rail or fence.

    c. Pedestrian/bikeway - Provide 10 foot vertical clearance above the riding surface of the pedestrian/bikeway structure.

3. Clearances – When a non-state roadway is to be crossed by the pedestrian bridge, minimum vertical and horizontal clearances shall be provided in accordance with Section 5-04 of the MoDOT Project Development Manual, which may be accessed at the following Internet address: **www.modot.org/business/projectdevelopment.htm** However, when a state-owned roadway is to be crossed by a pedestrian structure, a minimum vertical clearance of 17’-6” is to be provided unless accepted otherwise by MoDOT through the design variance process. It is recommended that the proposed vertical clearance be submitted for MoDOT review and acceptance as soon as possible in the Preliminary design stage.

Hydraulic Investigations

1. When the bridge crosses a stream, the preferred minimum grade across the structure shall not be lower than the approach grade on the banks of the stream.

2. When the structure is located in a flood plain designated by a FEMA flood study, an investigation to ensure satisfaction of the FEMA requirements should be made.

3. The bridge foundations shall be designed for the effects of scour, where this situation is applicable.

4. For pedestrian bridges over streams, drawings shall indicate a design high water elevation and corresponding frequency at the structure along with appropriate hydrologic data defined in this Section as sufficient to indicate the level of hydraulic investigation performed.

Geotechnical Investigations

1. Adequate soil investigations shall be performed to determine proper foundation type.

2. The foundation type may be spread footing on adequate soil or rock; or friction pile or point bearing pile.

Preliminary Submittals

See **Figure VIII-7** for Preliminary Submittal requirements.

LOW WATER STREAM CROSSING DESIGN CRITERIA

Suitability

1. A low water stream crossing (LWSC) is defined as a stream crossing that will be flooded periodically and closed to traffic. This structure should be a vented ford (one having a number of pipes) designed so the hydraulic capacity thru the structure will be not less than the normal flow but not greater than the 2 year frequency.

2. A low water bridge (LWB) is also a stream crossing that will be flooded periodically and closed to traffic. These structures will be span type bridges or box culverts designed to have a conveyance capacity equal to the channel conveyance but no greater than the 5 year frequency flood.

3. The functional classification of the route will be Rural Local, Local Road or Street, or Rural Minor Collector only.

4. For LWSC the ADT shall be $\leq$ 150. For LWB the ADT shall be $\leq$ 250.

5. For LWSC the drainage area shall be $\leq$ 100 sq. miles (250 sq. km). For LWB the drainage area shall be $\leq$ 400 sq. miles (1000 sq. km).

Hydraulic Variance

1. A hydraulic capacity variance will be required for structures that will be flooded periodically and closed to traffic. The variance request will be prepared by the LPA and include the following statement. "The LPA approves the use of a LWSC or LWB for this structure with the following qualifications:"

   a. "No sole resident has sole access over the structure."

   b. "The route is not critical for the school board, postal service, ambulance service, police or fire department."

   c. "During times of flooding, the detour length is acceptable for the local residents."

   d. "The LPA also agrees to provide adequate maintenance of warning signs and the removal of all drift when practicable to prevent damage to the low water crossing and prevent degradation of the channel."

2. A public hearing will be required to furnish general design information and allow the public to express their ideas about the social, economical and environmental effects of this type of structure. A summary of the public hearing shall be included in the Project Summary Report.

3. All-weather structures are generally preferred over low water installations if the all-weather structure is at all feasible. Cost comparisons should be submitted along with an engineer's analysis to demonstrate there are clear and substantial cost/benefit advantages for the low water installation over the all weather bridge.

Hydraulic Design

1. For drainage areas $\leq$ 50 sq. miles (125 sq. km), the design capacity shall be the normal low stream flow.

2. For drainage areas > 50 sq. miles (125 sq. km), the hydraulic analysis should indicate that there will be no more than 2 ft (0.6m) between the upstream and downstream water surface elevation to reduce scour potential. The structure should be checked for the 2, 5, 10 and 25 year frequency floods.

3. The preferred method for determining the water surface elevations is to use the program *River Analysis System*, HEC-RAS, 1997 and revisions, by US Army Corps of Engineers, or the program *Bridge Waterways Analysis Model*, WSPRO, HY 7, 1990 and revisions, by FHWA.

Scour Evaluation

A scour analysis is required for flows overtopping the crossing to control erosion to the structure and the roadway. The material selection for the crossing foreslopes and roadway surface will be a function of the channel velocity. Other considerations may call for cutoff walls or riprap blankets.

Structural and Roadway Design

1. The roadway geometry including grades, vertical and horizontal curves shall be designed to the same standards as all weather structures.

2. Bridge railing systems will not be required for LWSC when the bridge width is designed utilizing the clear zone concept as shown in the current publication of the *Roadside Design Guide* by AASHTO. For ADT ≤ 250, the clear zone will be adjacent to the outside edge of the outer 10 ft (3m) traffic lanes except for ADT ≤ 100, the clear zone will be adjacent to the outside edge of the single 12 ft (3.6m) center lane.

3. A structural curb having a vertical face not less than 0.5 ft (0.15m) and not more than 1 ft (0.3m) will be required with intermittent openings.

4. An appropriate crash-tested bridge railing systems will be required for all LWSC and LWB's when the height of the travel surface is 5 feet or more above the streambed. The railing system and the supporting structure must be designed for water and drift forces.

5. A square stream crossing is preferred if the roadway alignment allows.

Traffic Signing

1. The following warning signs will be used on each approach to a LWSC or LWB structure:

   a. A 36 in. (900mm) X 36 in. (900mm) diamond shaped sign, with black legend on a yellow background, which reads IMPASSABLE DURING HIGH WATER, MoDOT STD W18-1, will be placed 450 ft. (135m) before the structure.

b. A 36 in. (900mm) X 36 in. (900mm) diamond shaped sign, with black legend on a yellow background, which reads FLOOD AREA AHEAD, will be placed 750 ft. (225m) before the structure. Use the same specifications as MoDOT Standard W18-1.

2. If the location of the structure is not apparent from a point 1000 ft. (300m) in advance of the crossing, a supplemental distance plate will be used and installed in conjunction with the FLOOD AREA AHEAD sign.

3. An advisory speed plate may be used if the maximum recommended speed at the crossing is less than the posted speed limit in effect. If used, the advisory speed plate is installed in conjunction with the FLOOD AREA AHEAD sign unless a supplemental distance plate is used, in which case the advisory speed plate is to be installed in conjunction with the IMPASSABLE DURING HIGH WATER sign.

4. Gauge boards and Type III object markers are optional, however, the potential for damage by drift material should be considered when evaluating their appropriateness.

Preliminary Submittals

See **Figure VIII-7** for Preliminary Submittal requirements.