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# 3 Preliminary

## 3.1 General

The following series of articles provides a set of guidelines for development of type, size, and location (TS&L) plans for bridges, walls, and culverts that require final design. The TS&L plans will include a

Preliminary Situation Plan and may additionally include Site Plan or Miscellaneous Detail sheets. Within the guidelines and throughout the development of TS&L plans it is important that the designer apply sound engineering judgment, including technical and economic analysis. For additional information on culvert design, see BDM Section 4.

Additional information regarding preliminary design is also contained within BDM Section 1.

### 3.1.1 Policy overview

Within the Bridges and Structures Bureau, the Preliminary Bridge Design Unit develops the concepts and the preliminary layouts for highway structures. For bridges, walls, culverts, and miscellaneous structures that require final design, the Unit assembles information and develops TS&L sheets so that a designer in one of the Final Design Units can perform the structural design and develop final plans for a contract letting.

The preliminary design process for new or replacement structures begins with a concept statement developed by the Preliminary Road Design Unit within the Design Bureau. The Preliminary Bridge Design Unit contributes to the concept statement by providing the type and size of the proposed structure along with its estimated construction cost.

The development of all preliminary structure plans includes a number of tasks such as:

- Analyzing hydrology and hydraulics;
- Analyzing road geometrics;
- Determining the type, size, and location of structures;
- Developing a layout in the CADD system;
- Attending field reviews;
- Coordinating with other Iowa DOT Bureaus, public entities, and outside agencies;
- Estimating cost alternatives;
- Obtaining flood plain permit approvals;
- Coordinating with other regulatory agencies; and
- Consideration of accelerated bridge construction (ABC).

### 3.1.2 Design information

The designer will need to access information from several sources to perform preliminary design, including the following:

- Plans for existing structures, including as-built plans, from Electronic Records Management System (ERMS) or SIIMS;
- Bridge maintenance reports from ERMS and SIIMS;
- LiDAR ground surfaces (2020 is available from USGS)
- A new site survey from the Design Bureau;
- Soil boring information from the Design Bureau;
- Aerial photographs from the Design Bureau and/or web sites;
- Aerial agricultural photographs (drainage maps) from the Photogrammetry/Preliminary Survey Unit in the Design Bureau;
- Topographic maps from the Bridges and Structures Bureau, the Design Bureau and/or web sites; and
- Field exams.

Plans for existing structures will give a good indication of the site when an existing structure was built, widened, and/or extended, and comparison with a new survey will indicate any site changes that have occurred since previous construction.

The designer should make appropriate use of CADD to integrate support programs such as Open Bridge Designer and Open Road Designer when developing type, size, and location (TS&L) plans. For more information on CONNECT Applications, refer to our web site under Automation Tools.

Guidance for concept development can be found on the Iowa DOT website.

Concept Development

### 3.1.3 Definitions

**Annual Exceedance Probability Discharge (AEPD)** is an estimate of the flood discharge for the annual flood frequency recurrence intervals as determined by a regional regression analysis method described in USGS SIR 2013-5086.

**Average low water** is the water level expected during a normal season and may be defined by the vegetation line along a stream bank or by typical low flow. The average low water can generally be represented by the water surface elevation at time of survey or can be defined as one foot above the average design stream bed.

~~**Bridge**~~ **Backwater** is caused by the encroachment of the road embankment onto the floodplain which constricts flood flows through the bridge opening. Backwater is the difference between the modeled water surface elevations for topography being evaluated and the base topographic condition. Backwater for the purpose of the hydraulic data block is determined at the modeled upstream location with the maximum difference between proposed and pre-development water surface elevations.

**Base Flood** is the flood having a one percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the “100-year flood.” The base flood is the national standard used by the National Flood Insurance Program (NFIP) and all Federal agencies for the purposes of requiring the purchase of flood insurance and regulating new development.

**Base Flood Elevation (BFE)** is the computed elevation to which floodwater is anticipated to rise during the base flood. BFEs are shown on Flood Insurance Rate Maps (FIRMS) and on the flood profiles. The BFE is the regulatory requirement for the elevation or flood-proofing of structures. The relationship between the BFE and a structure’s elevation determines the flood insurance premium.

**Berm slope location table (BSLT)** gives toe and top of berm information to aid the contractor in construction of the berm.

**Bicycle lane** or **bike lane** is a portion of a roadway which has been designated by striping, signing, and pavement markings for the preferential or exclusive use of bicyclists.

**Bridge chord** is defined as the straight line between intersection points of the centerline approach roadway (or alignment baseline) at the centerline of bridge abutments.

**Censored gage record** includes discharges (low and high outliers) and historical flood discharges that the USGS may adjust or integrate for use in peak flow analysis. There are two types of censored data (1) annual peak discharges collected at gage sites for which the discharge is only known to be less than the minimum recordable discharge threshold, or (2) in the case of historical periods, annual peak discharges that are only known not to have exceeded a recorded historical flood discharge.

**Channel Low Beam / Freeboard** is the bottom of the lowest low beam spanning the surveyed or anticipated extent of the channel within the bridge waterway. It may be located on the upstream or downstream side. It is utilized to determine the available space the design provides for passage of ice and debris.

**Check scour** is based on the occurrence of a 500-year or lesser flood used to ensure pile capacity and stability will not fail at the extreme scour event.

**Detailed Flood Insurance Study (FIS)** analysis of a community's flood prone areas which determines the 100-year flood elevation and floodway for certain streams.

**Design scour** is based on the occurrence of a 200-year or lesser flood used to evaluate pile capacity and stability.

**Design streambed elevation** is the theoretical thalweg elevation at a proposed structure. Based on the streambed profile where the profile has been developed by extrapolation of up and downstream thalweg elevations that are beyond the influence of existing structures (local scour).

**Drainage Districts** in Iowa provide a legally organized means to construct and maintain adequate drainage outlets and levees. In most cases, the Board of Supervisors in the county in which the district is located becomes the board of trustees (managing board) for that district. When designing a replacement structure that crosses a Drainage District, coordination is required. Design features such as flowline, channel slope, cross section, etc. may be dictated by the Drainage District requirements.

**Drainage Easement** (a.k.a. Permanent Easement for Drainage Purposes) – A Drainage Easement is a legal document that describes the right to increase flow upon a property owner as a result of impacts associated with a project. Typically, the area identified as a Drainage Easement is a draw or drainage way. Another application would be when areas are inundated that otherwise would not be impacted by a project (e.g., lowering of a private levee to meet bridge backwater requirements). The property owners are provided compensation by acquiring the easement and the document is filed with the County Recorder. The designer shall show the limits of the drainage easement along the draw/drainage way for acquisition as part of the B1/B2 submittal. An elevation is typically not provided for a drainage easement.

**Electronic Reference Library (ERL)** contains plans, specifications, and manuals and is available on the Iowa Department of Transportation's web site.

**Electronic Records Management System (ERMS)** has been developed to enable electronic use and management of documents within the Iowa Department of Transportation. ERMS includes aerial photographs, existing bridge plans, bridge inspection records, and other documents useful for preliminary bridge design.

**EMA/MGB** is the method used in Scientific Investigations Report 2013-5086 to compute log-Pearson Type III exceedance probability analysis for stream gages evaluated for use in the development of the Iowa regional regression equations. The method allows for the integration of censored (low and high outliers) and historical peak-discharge data in the analysis. This is the method used in the updated Bulletin 17C "Guidelines for Determining Flood Flow Frequency".

**Existing condition** reflects the current (at time of study) topography for hydraulic modeling, including the existing development being evaluated.

**Expected moments algorithm (EMA)** is an annual exceedance-probability analysis method used for continuous-record stream gages. EMA analysis method needs a consistent statistical test (MGB) to identify potentially influential low flows in an annual peak-discharge series to properly reduce the effect of low outliers.

**Extreme highwater** is the highest water level recorded for a particular location. Information can be obtained from USGS or Corps flood reports, when available.

**Flowage Easement** – A Flowage Easement is a legal document that describes the right to create a flood elevation upon a property. Typically, the area identified for a flowage easement does not meet regulatory backwater criteria for a project that requires a flood plain permit. The flowage easement is required by the DNR to mitigate the impacts of a project not meeting their backwater criteria. The property owners are provided compensation by acquiring the easement and the document is filed with the County Recorder.

The designer shall include the areas that do not meet backwater criteria and the associated 100-year stage elevation as part of the B1 submittal.

**Floodway** is the portion of the floodplain that must be left unobstructed for the conveyance of the 100-year flood.

**Flood Risk Reduction Project (FRRP)** is typically defined as a Corps of Engineers designed flood protection levee system.

**Freeboard** is the vertical clearance measured between the channel or operational low beam, and the stage for the given discharge with the proposed bridge in place.

**Grading surface** is the finished earthwork surface within the limits of project grading and the existing ground surface outside the limits of project grading. At locations where the finished earthwork surface represents non-earthen materials (rock revetment, concrete block mats, pavement etc.) plan details will define the grading surface relative to these materials. Earthwork quantities are calculated relative to the grading surface. Key bridge berm grading surface points shall be defined in the Berm Slope Location Table [BDM 3.7.3.3].

**Hydraulic Grade Line (HGL)** is used to derive the design slope for use in the hydraulic design of the structure. HGL is the top of water, and the slope of the HGL at the point of interest is assumed as representative of the slope of the Energy Grade Line ($S_o$) used in hydraulic design.

**Inundation** of beams occurs when the flood stage reaches the bottom of the lowest beam anywhere along the entire bridge (operational low beam).

**Mean highwater (MHW)** is a term used in the AASHTO Guide Specification for Vessel Collision Design of Highway Bridges and is defined by the Coast Guard as the average of the height of the diurnal (each day) high waters at a particular location measured over a period of 19 years.

**Multiple Grubbs-Beck (MGB)** test is a statistical method to identify low gage data outliers that depart substantially from the trend of the rest of the annual peak discharge data. Annual peak discharges identified as low outliers by the method are excluded from the dataset. EMA/MGB exceedance-probability analysis computed for the Scientific Investigations Report 2013-5086 used the MGB test for the development of the skew analysis and the Iowa regional regression equations.

**Multi-region basin** is a site drainage area that drains more than one hydrologic region (crosses a hydrologic region boundary) as defined by a given USGS methodology for calculating annual exceedance probability discharges.

**National Bridge Inspection Standards (NBIS)** This program requires inspection of all publicly owned highway bridges longer than 20 feet defined at intervals not to exceed 24 months, or as otherwise approved for a specific situation.

**Natural Stage/Normal Stage** is the stage in the bridge waterway related to pre-development conditions.

**Operational low beam / Freeboard** is the bottom of the lowest low beam along the entire bridge for use in identifying the stage in which beam inundation will begin to occur. It may be located on the upstream or downstream side.

**Ordinary high water mark** means that line on the shore established by the fluctuations of water and indicated by physical characteristics such as clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, the presence of litter and debris, or other appropriate means that consider the characteristics of the surrounding areas [Code of the Federal Register 33 CFR Part 328.3].

**Ponding Easement –** A Ponding Easement is a legal document that typically describes the right to increase a ponding elevation upon a property owner as a result of impacts associated with a project. Typically, this has been used when a roadway project fills in a low area or prairie pothole. The reduction in storage volume is compensated via a Ponding Easement for a potential increase in inundation area as a result of the roadway fill. The property owner is provided compensation by acquiring the easement and the document is filed with the County Recorder. The designer shall include the boundaries of the ponding easement and an elevation for acquisition of the easement as part of the B2 submittal. The elevation should be the maximum elevation that could occur before water is able to convey out of the depression/prairie pothole.

**Pre-Development condition** is a topographic assumption for hydraulic modeling with the development being evaluated removed (e.g. existing roadway embankment with associated structures). Adjacent topography is included in the Pre-Development condition if it is not a part of the development being evaluated. Pre-Development condition is analogous to natural condition referenced in Iowa DNR floodplain development regulations.

**Proposed condition** reflects the current (at time of study) topography for hydraulic modeling including the proposed development being evaluated.

**Q50** is a flood that has a 2% statistical probability (chance) of being equaled or exceeded in any year.

**Q100** is a flood that has a 1% statistical probability (chance) of being equaled or exceeded in any year.

**Revetment** is a relatively general term for a facing that supports an embankment. **Riprap** is a more specific term for the layer of various sized rocks or broken concrete used to protect a streambank from erosion. With respect to streambank protection the terms **revetment** and **riprap** usually are interchangeable. **Revetment Stone** is the quarry industry's product that may be used for streambank erosion protection.

**Riverine Infrastructure Database** is a database of Iowa Department of Transportation facilities in the riverine environment. The database consists of location data in addition to hydrologic and hydraulic data so impacts to facilities during a flood event can be rapidly evaluated.

**Section 408 Approval** is required from the Corps of Engineers for any project within 300 feet riverward or 500 feet landward of a Corps Flood Risk Reduction Project (FRRP).

**Shallow bedrock** at a pier may be conservatively defined as rock, regardless of type (e.g. shale, limestone, etc.) and quality (e.g. solid, hard, broken, weathered, highly weathered, etc.), that is 30 feet or less from the lowest of the ground line, stream bed, or design scour elevation.

**Shared use path** is a bikeway physically separated from motorized vehicular traffic by an open space or a barrier and either within the highway right-of-way or within an independent right-of-way. Shared use paths may also be used by pedestrians, skaters, wheelchair users, joggers, and other non-motorized users. See the current edition of AASHTO's *Guide for the Development of Bicycle Facilities* [BDM 3.1.5.2].

**Span chord** is defined as the straight line between intersection points of the centerline approach roadway (or alignment baseline) at the centerline of each substructure unit.

**Stage** is the water surface elevation for a given discharge and site conditions being evaluated. Stage for the purpose of the hydraulic data block is the engineer's best estimate of the PROPOSED water surface elevation within the bridge waterway. The stage determination depends on the hydraulic analysis model type, as described in the policy guidance.

**Streambed Profile (SP)** is a profile based on design streambed elevation (thalweg) up and downstream of the proposed structure.

**Structure Inventory and Inspection Management System (SIIMS)** is the single source location for entering and reviewing condition information on all Iowa bridges, both local and state owned. The system provides a data base of bridge sized structures and inspection information. Preliminary engineers can find site photos, As-Built plans, and ground profile (cross section) under the bridge.

**Thalweg** is a line extending down a channel that follows the lowest elevation of the stream bed.

**Uncensored gage record** includes peak discharge data at given gage site, exclusive of censored record. Uncensored data represents actual observed values, whereas censored data reflects historical or otherwise estimated data values. Statistics developed using only uncensored data will generally be presented as ‘period-of-record’ whereas statistics that include censored data generally be presented as ‘historical period’.

**Unit Leader** is the supervisor of the Bridges and Structures Bureau Preliminary Bridge Unit, Final Design Unit, or Consultant Coordination Unit.

**Weighted Independent Estimate (WIE)** is a method for weighting two independent estimates inversely proportional to their associated variances. Annual exceedance-probability discharges (AEPD) by the log-Pearson Type III estimate (EMA/MGB) and the regional regression equations are assumed to be independent and can be weighted by this method and the variance of the weighted estimate will be less than the variance of either of the independent estimates.

### 3.1.4 Abbreviations and notation

**3R,** Resurfacing, Restoration, Rehabilitation; a series of terms that refers to a Federal Highway Administration highway project funding program
**ADT,** average daily traffic
**AEPD,** annual exceedance-probability discharge
**AREMA,** American Railway Engineering and Maintenance-of-Way Association
**B0,** event code for Bridges and Structures Bureau concept
**B1,** event code for Bridges and Structures Bureau layout
**B2,** event code for structural/hydraulic design plans to Design Bureau
**BFE,** base flood elevation
**BTB, BTC, BTD, BTE,** standard cross sections for pretensioned prestressed concrete bulb tee beams
**BNSF,** Burlington Northern Santa-Fe Railway
**BSLT,** berm slope location table
**CCS,** continuous concrete slab
**CFR,** Code of Federal Regulations
**CLOMR,** Conditional Letter of Map Revision issued by FEMA
**CMP,** corrugated metal pipe
**CWPG,** continuous welded plate girder
**$D_{50}$,** median revetment stone diameter
**D0,** event code for predesign concept
**D2,** event code for design field exam
**DA,** drainage area
**EMA**, expected moments algorithm annual exceedance-probability analysis
**ERL,** Electronic Reference Library
**ERMS,** Electronic Records Management System
**FEMA,** Federal Emergency Management Agency
**FHWA,** Federal Highway Administration
**FIS,** Flood Insurance Study
**HDPE,** high density polyethylene
**HEC-2,** U.S. Army Corps of Engineers **H**ydrologic **E**ngineering **C**enter hydraulic analysis software

**HEC-RAS,** U.S. Army Corps of Engineers **H**ydrologic **E**ngineering **C**enter – **R**iver **A**nalysis **S**ystem hydraulic analysis software
**HGL,** Hydraulic Grade Line
**IAC,** Iowa Administrative Code
**IFC,** Iowa Flood Center
**IFIS,** Iowa Flood Information System
**IFI,** intermediate foundation improvement
**IHRB,** Iowa Highway Research Board
**Iowa DNR,** Iowa Department of Natural Resources
**Iowa DOT,** Iowa Department of Transportation
**LOMR,** Letter of Map Revision issued by FEMA
**LP3,** log-Pearson Type III
**LT,** left
**M,** distance between chord and arc at midpoint of horizontally curved bridge [BDM 3.6.3]
**MCS,** main-channel slope, a variable in USGS WRIR 03-4120
**MGB,** Multiple Grubbs-Beck low-outlier test
**MSE,** mechanically stabilized earth, generally associated with retaining walls
**N or N-value,** standard penetration test number of blows per foot. N also may be given as SPT NO, the Standard Penetration Test Number in the soils information chart.
**n-coefficient,** Manning's Coefficient [BDM 3.2.2.3]
**NBIS,** National Bridge Inspection Standards
**NFIP,** National Flood Insurance Program
**NHS,** National Highway System
**NOAA,** National Oceanic and Atmospheric Administration
**NRCS,** Natural Resources Conservation Service
**PE,** preliminary engineering
**PEP,** polyethylene pipe
**POT,** point on tangent
**PPCB,** pretensioned prestressed concrete beam
**$Q_2$, $Q_{50}$, $Q_{100}$, $Q_{200}$, $Q_{500}$,** estimated channel discharge at 2-, 50-, 100-, 200- or 500-year design flood frequency
**RBLT,** recoverable berm location table
**RCB,** reinforced concrete box, a type of culvert
**RCP,** reinforced concrete pipe
**RIDB,** Riverine Infrastructure Database
**ROW,** right of way
**RRE,** regional regression equation
**RSB,** rolled steel beam
**RSS,** reinforced steepened slope
**RT,** right
**SI&A,** Structure Inventory and Appraisal
**SIIMS,** Structure Inventory and Inspection Management System
**SIR,** scientific investigations report
**SP,** streambed profile
**SUDAS,** (Iowa) Statewide Urban Design and Specifications
**TS&L,** type, size, and location
**TSS,** Texas single slope
**UP** or **UPRR,** Union Pacific Railroad
**USGS,** United States Geological Survey
**WIE,** weighted independent estimates
**WRIR,** water-resources investigation report
**WSPRO,** water surface profile software developed by the U.S. Geological Survey

## 3.1.5 References

### 3.1.5.1 Direct

[IDOT PPM policy number] refers to a policy in the Iowa Department of Transportation *Policies and Procedures Manual.*

[IDOT SS article] refers to Iowa Department of Transportation *Standard Specifications for Highway and Bridge Construction, Series 2015* with article number. (Available on the Internet at: http://www.iowadot.gov/erl/current/GS/Navigation/nav.htm)

[DB DM article, table, or figure] refers to the Design Bureau, Highway Division *Design Manual* with article, table, or figure number. (Available on the Internet at: https://iowadot.gov/design/Design-manual)

[DB RDD sheet number] refers to the Design Bureau, Highway Division "Road Design Details" with sheet number. Formerly the detail manual was referred to as the "green book." (Available on the Internet at: https://iowadot.gov/design/Road-design-details)

[DB SRP sheet number] refers to an Design Bureau, Highway Division "Standard Road Plan" with sheet number. Formerly the plan manual was referred to as the "red book." (Available on the Internet at: https://iowadot.gov/design/Standard-road-plans)

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## 3.2 Bridges

The information in Article 3.2 for preliminary design of bridges generally is organized by task in the design process. The sequence of the tasks for a specific design project will not necessarily follow the sequence in this article but, before completing a preliminary design, the designer should review the information on each of the following topics that are applicable.

- Identification numbers
- Stream and river crossings
- Highway Crossings
- Railroad crossings
- Pedestrian and Shared Use Path Crossings
- Superstructures
- Substructures
- Cost estimates
- Preliminary Situation plans
- Permits and approvals
- Forms

When developing the site for bridge projects the designer should endeavor to use standard bridges as much as possible. The Bureau has four types of standard bridges described in the superstructures article:

- Three-span continuous concrete slab (CCS) bridges, J-series [BDM 3.6.1.1],
- Single-span pretensioned prestressed concrete beam (PPCB), HSI-series [BDM 3.6.1.2],
- Three-span pretensioned prestressed concrete beam (PPCB) bridges, H-series [BDM 3.6.1.4], and
- Three-span rolled steel beam (RSB) bridges [BDM 3.6.1.5].

Additionally the Bureau has several series of standard pretensioned prestressed concrete beams [BDM 3.6.1.6] that may be used to assemble bridges with lengths and numbers of spans that vary from the standard bridges. For spans above 155 feet or for bridges on significant horizontal curves the designer may select a continuous welded plate girder superstructure [BDM 3.6.1.7].

The designer shall document the key details that lead to the proposed bridge configuration with a Preliminary Bridge TSL Development Report. See the commentary for an example.

### 3.2.1 Identification numbers

A new bridge sized structure will be assigned three identification numbers: a bridge design number, an FHWA number, and a bridge maintenance number. The preliminary designer need only assign the bridge design number and the FHWA number; bridge maintenance numbers are assigned later by others. Assigning the bridge design number requires consideration of record keeping, letting dates, and final design plan preparation.

A structure is “bridge sized” if the structure as measured along the centerline of roadway is greater than 20 feet in length between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening. Bridge sized structures shall be assigned an FHWA number, as they are required to meet National Bridge Inspection Standards (NBIS). When the proposed structure is bridge sized and within 300 feet from the centerline of the existing FHWA numbered structure, a replacement FHWA number should be assigned. Otherwise a new FHWA number should be assigned. A twin 8’ x 8’ RCB with a 9-inch interior wall would require an FHWA number if constructed at a 34-degree or greater skew to the roadway since the extreme ends of opening distance along the roadway would be greater than 20 feet. On replacement projects, the existing and proposed structure’s FHWA number shall be shown on the proposed TS&L. Design numbers for temporary bridges utilized for on-site detours shall be assigned under the replacement bridge FHWA number.

Each bridge should be assigned a separate design number even if there are two bridges with the same geometry in the same letting. A bridge with a common approach roadway crown that requires a 2-inch separation to reduce temperature forces should be assigned one design number if both portions are in the same letting. However, if a bridge is separated by a 2-inch gap with a separate roadway approach crown, two design numbers should be assigned. The designer shall consult with the Preliminary Bridge Design Unit Leader if there are any unique situations for assigning design numbers.

Structures that are less than bridge sized (non-NBIS structures) requiring final structural design shall be similarly assigned a design number (RCBs, bottomless culverts, pipes with special inlets or flumes, etc.). However, an Asset ID number is assigned for non-NBIS structures in lieu of an FHWA number. Maintenance numbers are not assigned to non-NBIS structures. For additional information on structure ID number assignment procedure and the electronic documentation system policy organized by Asset ID, please refer to BDM 1.11.4.

For corridor projects the preliminary designer shall assign a file number for each preliminary engineering (PE) number. For smaller projects without a PE number, assign a file number for each project. To minimize file numbers, miscellaneous structures generated before a project is complete shall be associated with the original file number.

### 3.2.2 Stream and river crossings

Stream and river crossings require the designer to consider the waterway in detail and, in some cases, obtain permits for the bridge. The topics listed below are to be considered in design of bridges over streams and rivers and are discussed in sub-articles that follow.

- Hydrology
- Hydraulics
- Backwater
- Freeboard
- Roadgrade overflow
- Streambank Protection
- Scour
- Riverine Infrastructure Database
- Datum Correlation
- Stream Slope and Streambed Profile
- State Water Trails and Paddling Routes

Design discharges should be based on current methodologies for determining compliance with Iowa DOT policy or Iowa DNR regulations. As a general rule, the design discharge for rural structures on Iowa's primary highway system is the 50-year flood. For bridge locations where the upstream flood damage potential is high or where the site is located in a detailed Flood Insurance Study (FIS) area, the 100-year flood should be the design discharge.

When a project is located in a detailed FIS area, the published peak discharges and flood elevations are used for evaluating compliance with NFIP criteria. The discharges used to satisfy DNR criteria and for the design of the structure may not be the published FIS discharges. The designer should calculate the following discharges and stage for each bridge:

- $Q_2$, $Q_5$, $Q_{10}$, $Q_{25}$ - when the bridge site rating curve will be included in the Riverine Infrastructure Database
- $Q_{25}$ - when the need for coffer dams is anticipated in a river setting
- $Q_{50}$ - to determine velocity through bridge opening, and freeboard to the regulatory low beam
- $Q_{100}$ - to determine backwater and velocities through the bridge opening
- $Q_{200}$ - to determine design scour
- $Q_{500}$ or $Q_{Overtopping}$ - to determine check (maximum) scour

Stage is the water surface elevation for a given discharge. Stage for the purpose of the hydraulic data block is the engineer's best estimate of the PROPOSED water surface elevation at the downstream toe of the road embankment.

For preliminary design of new or replacement bridges at a waterway crossing, a certified report to document the Hydrology and Hydraulic information is required. See the commentary for more information.

## 3.2.2.1 Hydrology

Reliable estimates of flood-frequency discharges are essential for the economic planning and safe design of bridges and other structures located over streams. Hydrology for bridges should include the following peak discharges for design: $Q_{50}$, $Q_{100}$, $Q_{200}$ and $Q_{500}$ or $Q_{overtopping}$. In special cases the designer may need to determine additional discharges for the project.

Drainage area should be determined by using the USGS web based program called Iowa "StreamStats". This method supersedes the Bulletin 7 (Red Book) for determining drainage areas at bridge sites.

"StreamStats" is capable of delineating a watershed from a point and computing the drainage area in square miles. The engineer may use LiDAR or other more accurate information to check the results for accuracy and to make and document appropriate corrections.

The designer has several methods for determining estimated discharges, which are listed below.

- **Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS)**
  Many cities and counties in Iowa have detailed FISs. Typically, a community with an FIS has adopted regulations that can prohibit increasing the 100-year flood elevation or encroaching upon a regulated floodway. The discharges and flood elevations in an FIS are usually legally binding and are used by the Iowa Department of Natural Resources for ensuring compliance with NFIP criteria. When a project is located outside the detailed area of an FIS but could impact flood elevations or flood prone properties of an FIS community, the FIS information should be used for analysis.

  In addition to using the FIS 100-year discharge to assure compliance with NFIP requirements, the designer should use current methodologies for estimating peak discharges for the design of structures and to satisfy DNR backwater and freeboard criteria.

  ~~It should be noted that when a project involves development within a regulatory floodway (including bridge piers), the analysis must show that the project will not cause an increase in the 100-year flood elevation. If a "no rise" condition cannot be obtained when encroaching upon a regulatory floodway, the designer may need to apply to FEMA for revisions to the FIS by means of a Conditional Letter of Map Revision (CLOMR). After a CLOMR is issued and construction is completed a Letter of Map Revision (LOMR) is obtained by submitting as-built plans.~~

~~For Iowa DOT projects, a "No-Rise" certification is not required since the Iowa DOT does not obtain approval from local entities (city or county) for projects. However, we do submit a "Record of Coordination" [BDM 3.10.1] for projects that do not require DNR approval to document for local communities that our structures will comply with NFIP requirements.~~

~~The designer should check the FEMA website to determine the current status of a community's FIS.~~

~~Projects located in communities that are mapped by the National Flood Insurance Program as flood prone but do not show the 100-year flood elevation are not subject to the same requirements as a project located in a detailed FIS area. If a community does not have an adopted floodway or established base (100 year) flood elevations, it may be possible to construct a structure smaller than the existing structure as long as the upstream damage potential is low. Sound engineering judgment should be used when downsizing an existing structure.~~

- **U.S. Geological Survey (USGS) and U.S. Army Corps of Engineers (USACE) stream gage information**
  Stream gage data may be used for estimation of peak discharges when the structure site is at or near a gaging station and the streamflow record is fairly complete and of sufficient length. Information for stream gages in Iowa is available from USGS and USACE web sites as follows:

  USGS - Iowa Water Science Center:

  USGS - StreamStats - Annual Exceedance-Probability Discharge (AEPD) per Scientific Investigations Report (SIR) 2013-5086. May be updated in the future to use Open File Report 2015-1214:

  USGS - SIR 2013-5086 - Methods for Estimating Annual Exceedance-Probability Discharges for Streams in Iowa - Based on Data through Water Year 2010. Provides Expected Moments Algorithm/Multiple Grubbs-Beck (EMA/MGB) and Weighted Independent Estimates (WIE) AEPD's for gage data through water year 2010:

  USGS - Statistical summaries of selected Iowa streamflow data through September 2013. Open-File Report 2015-1214 provides EMA/MGB and WIE AEPD's for gage data through water year 2013:

  USGS – SIR 2015-5055 - Comparisons of Estimates of Annual Exceedance-Probability Discharges for Small Drainage Basins in Iowa, Based on Data through Water Year 2013 provides a comparison of AEPD estimates from five different AEPD-estimation methods.

  USACE – Rock Island District

  USACE – Omaha District

  - Use of Gage Information

  If the drainage area at the project site is within 50% of the drainage area of the gage, the gage discharges should be used and transferred to the project site per the method specified in USGS SIR 2013-5086. Generally, a regression-weighted estimate should be utilized to ensure a smooth transition from gage-weighted to regression equation discharge estimates for a stream. When the project site falls between two stream gages (within 50% of gage drainage area per above) an area-weighted estimate should generally be utilized. The gage parameters used for weighting (gage site regression equation discharge or drainage area) should be reviewed for consistency with the project (ungaged) site estimate.

The Iowa DOT AEPD spread sheet, addressed in more detail in the following section, includes estimation of AEPD's at ungaged sites on gaged streams per SIR 2013-5086. A future version of the USGS StreamStats web site will also provide this functionality. Refer to the Iowa DOT AEPD Spread Sheet Usage Guide, Section 4, for additional information on gage weighting methodologies for ungaged sites on gaged streams.

A thorough review of gage derived AEPD estimates at gaged and ungaged sites should be performed. Generally, the published gage AEPD estimates per SIR 2013-5086 will be adequate (data through 2010). AEPD estimates per Open File Report 2015-1214 (data through 2013) can be utilized and may be preferable for sites with limited years of uncensored records (less than 30 yrs.). A request can be made to the USGS through the DOT for updated statistics as required at a gage. Considerations would be limited years of record or significant recent floods not captured by the above reports.

For gaged sites USGS guidelines advise use of the WIE estimate. Since the WIE estimate makes use of a Regional Regression Equation (RRE) AEPD estimate per SIR 2013-5086, applicability of the RRE AEPD used in the WIE estimate should be determined. For gage sites with 25 years or more of uncensored record, preference (weight) should be given to the EMA/MGB estimate in the event of a significant discrepancy between the EMA/MGB and WIE AEPD estimates. Uncensored data represents actual observed values, whereas censored data reflects historical or otherwise estimated data values. Statistics developed using only uncensored data will generally be presented as 'period-of-record' whereas statistics that include censored data generally be presented as 'historical period'.

For ungaged sites the gage weighted AEPD estimate should be reasonably consistent with the gage AEPD estimate, particularly for gage sites with 25 years or more of uncensored record. For example, that the ungaged site downstream of gaged site has an AEPD estimate greater than gaged site estimate, etc.

- **USGS Scientific Investigation Report 2013-5086 RRE estimates**
  If an AEPD estimation using stream gage data is not possible, the Regional Regression Equation (RRE) methodology contained in USGS Scientific Investigation Report (SIR) 2013-5086 should be used to estimate Annual Exceedance-Probability Discharge (AEPD) for the design of bridges and culverts. A copy of the report can be obtained at the USGS web site per the link provided in the previous section.

  The USGS has developed a web based program called "StreamStats" that calculates the estimated AEPD's per SIR 2013-5086. Refer to the StreamStats web link per the above section.

  For drainage basins larger than 20 square miles, the USGS SIR 2013-5086 Report ~~(StreamStats)~~ should be used for estimating design discharges.

  For drainage basins between 2 and 20 square miles, WRIR 87-4132 may be used for the design discharge. A thorough review of the basin characteristics and history of flooding along with engineering judgement is needed when determining design discharges for small basins.

  For drainage basins of 2 square miles or less, the Iowa DOT currently recommends that the Iowa Runoff Chart should be used for calculating peak discharges.

  - Iowa AEPD Spread Sheet

  The Iowa DOT has developed an AEPD spread sheet which provides an alternative method to StreamStats for calculating AEPD's per SIR 2013-5086. The variables for each regression equation, including the Main-Channel Slope (MCS) variable, <u>must</u> be calculated by the StreamStats program. AEPD's per past USGS Regional Regression Equation (RRE) procedures (USGS WRIR 87-4132 & WRIR 00-4233) can also be calculated for comparison purposes.

The AEPD spread sheet should be used as a tool for comparing the different methodologies to determine if any outliers are present in estimating the AEPD's per SIR 2013-5086. In general, USGS SIR 2013-5086 provides higher peak discharges than the previous regression equations, particularly WRIR 87-4132. If the AEPD spread sheet determines that AEPD's calculated per SIR 2013-5086 are significantly different from those estimated using previous RRE procedures (USGS WRIR 87-4132 & 00-4233), then engineering judgment can be used to adjust SIR 2013-5086 AEPD estimates for the design of bridges and culverts in Iowa. Preliminary Unit Leader approval will be required when a methodology other than StreamStats is recommended for proposed design discharges for drainage areas greater than 20 square miles.

USGS SIR 2013-5086 has defined three different flood regions for the state and utilizes a multi-variable equation for each region. For basins that cross region boundaries (multi-region basins), StreamStats will provide a SIR 2013-5086 RRE AEPD estimate for each region falling in the basin, and a weighted AEPD estimate per SIR 2013-5086 based on the ratio of the area of each contributory flood region to the total basin area.

The AEPD spread sheet can calculate AEPD's for basins that cross region boundaries per the above. In addition, the AEPD spread sheet allows for alternate weighting of flood regions in multi-region basins.

For multi-region RRE estimates, IaDOT recommendation/policy is to use an additional weighting factor in the RRE estimate for the region where the site is located (outfall region). IaDOT recommendation is to use an outfall region weighting of 2. Refer to the AEPD Spreadsheet Usage Guide referenced above, Section 5, for guidelines on weighting of RRE AEPD multi-region estimates.

- **USGS WRIR 87-4132 and USGS WRIR 00-4233 RRE estimates**
  The regression equations contained in USGS WRIR 87-4132 & WRIR 00-4233 have been superseded. However, the previous reports can be utilized for comparative purposes when engineering judgment is used to estimate peak discharges for the design of bridges and culverts in Iowa. WRIR 87-4132 may be used for small basins (D.A. between 2 and 20 square miles).

  See commentary for Q50/Q500 Chart to be used with WRIR 87-4132 analysis.

- **USGS SIR 2015-5055**
  For project drainage basins between 2 to 20 square miles, the information contained in this report should be utilized to aid in selecting an appropriate method for calculating design AEPD estimates.

- **USGS flood reports**
  Open file flood reports by the USGS have been developed and can be valuable supplemental information when evaluating discharges and water surface elevations. The reports are listed in the commentary and, in some cases, available for download as follows.
  USGS Publications Warehouse

- **Urban Hydrology**
  When development/urbanization is located within the drainage basin, other hydrologic methodologies should be considered to account for the higher runoff potential due to additional impervious areas and the decreased travel time. In general, urban hydrology for a basin should be considered when 25% or more of the watershed has been developed.

  For urban basins with less than 160 acres, the Rational Method may be used for determining peak discharges. For urban basins larger than 160 acres, and for some complex basins that are less in size, the design storm runoff may be analyzed by other methods such as TR-55 for watersheds up to 2000 acres. For areas larger than 2000 acres TR-20 may be used or other methodologies such as HEC-HMS or other programs.

Hydrologic analysis that use precipitation/frequency relationships should use NOAA Atlas 14, Volume 8: Precipitation-Frequency Atlas of the United States, Midwestern States.

Engineering judgment should be used when determining design discharges for basins that have development/urbanization within its watershed.

### 3.2.2.2 Hydraulics

Once the peak discharges are determined for design, the structure must be analyzed to determine the hydraulic capacity or conveyance of the bridge waterway opening. Bridges with a Q100 average bridge velocity through a waterway opening (Q/A) of 6 feet/second or less typically do not experience excessive scour or backwater. Therefore, it is desirable that the average bridge velocity for a proposed bridge typically be near 6 feet/second. If the Q100 average bridge velocity for a proposed bridge is higher than 8 feet/second, backwater and scour potential needs to be closely reviewed with regard to waterway adequacy.

Bridge hydraulics (freeboard, average bridge velocity, and backwater) can be analyzed by utilizing various hydraulic programs such as HEC-2 or HEC-RAS, which are available from the Corps of Engineers or other sources; the Iowa DOT Bridge Backwater program based on the publication *Hydraulics of Bridge Waterways, HDS 1*; or WSPRO, which is available from FHWA. For complex hydraulic situations, 2-D models such as TUFLOW, SRH-2D, HEC-RAS2D, MIKE FLOOD, etc. may be used. The designer should be aware of the assumptions and limitations for using the methodology in any hydraulic analysis program.

- **HEC-2 or HEC-RAS analysis**
  When a bridge is located within a detailed Flood Insurance Study (FIS) area, or the upstream flood plain has a high damage potential (such as a residence or business located in the upstream flood plain), the designer should perform a HEC-2 or HEC-RAS analysis to determine the impacts on flood elevations.

- **Iowa DOT Bridge Backwater program analysis**
  For bridges located in a rural area where the flood plain has a low damage potential, the designer may use the Iowa DOT Bridge Backwater program to analyze backwater and freeboard provided the conditions listed below are met.

  (1) The channel is relatively straight.
  (2) The floodplain cross section is fairly uniform.
  (3) The stream slope is approximately constant.
  (4) The flow is free to contract and expand.
  (5) There is no appreciable scour hole in the bed at the constriction.
  (6) The flow is in the sub critical range (Type I, non-pressure flow)

- **WSPRO analysis**
  For bridges located in a rural area where the flood plain has a low damage potential, the designer may use WSPRO program to analyze backwater and freeboard.

- **2-Dimensional hydraulic analysis**
  For complex hydraulic locations, a 1-D hydraulic analysis may not adequately capture the effects of flooding and backwater. These locations may include overflow bridges, flood plains with flank or lateral levees and roadways that are significantly skewed to the flood plain. In those situations, 2-D hydraulic models such as TUFLOW, SRH-2D, HEC-RAS2D, MIKE FLOOD, etc. may be more appropriate for analyzing the impacts associated with a bridge project.

### 3.2.2.3 Backwater

Bridge backwater is caused by the encroachment of the road embankment onto the floodplain which constricts flood flows through the bridge opening. This constriction causes an increase in the normal stage (flood elevation without a bridge and road embankment in place). The maximum backwater typically occurs one or two bridge lengths upstream.

Iowa DNR Criteria-

Iowa DNR backwater criteria are listed in Table 3.10.1-2. In general, bridges should be designed to meet the backwater criteria even when a project does not require Iowa DNR approval. Variances to the backwater criteria can be requested when it is not feasible to meet the backwater criteria and when flowage easements are obtained for all affected landowners of low damage potential areas.

Federal Emergency Management Agency (FEMA) Flood Insurance Studies (FIS) Criteria-

It should be noted that when a project involves development within a regulatory floodway (including bridge piers), the analysis must show that the project will not cause an increase in the 100-year regulatory flood elevation. If a “no rise” condition cannot be obtained when encroaching upon a regulatory floodway, the designer may need to apply to FEMA for revisions to the FIS by means of a Conditional Letter of Map Revision (CLOMR). After a CLOMR is issued and construction is completed a Letter of Map Revision (LOMR) is obtained by submitting as-built plans.

For Iowa DOT projects, a “No-Rise” certification is not required since the Iowa DOT does not obtain approval from local entities (city or county) for projects. However, we do submit a “Record of Coordination” [BDM 3.10.1] for projects that do not require DNR approval to document for local communities that our structures will comply with NFIP requirements.

The designer shall check the FEMA website to determine the current status of a community’s FIS. The Designer shall consider a Preliminary FIS to be effective for the purpose of project development, unless informed otherwise.

Projects located in communities that are mapped by the National Flood Insurance Program as flood prone but do not show the 100-year flood elevation are not subject to the same requirements as a project located in a detailed FIS area. If a community does not have an adopted floodway or established base (100 year) flood elevations, it may be possible to construct a structure smaller than the existing structure as long as the upstream damage potential is low. Sound engineering judgment should be used when downsizing an existing structure.

Manning’s Equation is used to determine normal depth and a stage-discharge relationship (rating curve) for analyzing bridges. Typical roughness coefficients for the equation are given in Table 3.2.2.3.

**Table 3.2.2.3. Manning’s Roughness Coefficients for natural stream valleys (n-coefficients)**

| **Description** | **Detailed Description** | **Manning’s Coefficient** |
|---|---|---|
| Channel, small to medium drainage areas | Irregular section, meandering channel, rocky or rough bottom, medium to heavy growth on bank and side slopes | 0.04-0.05 |
| | Uniform section, relatively straight, smooth earthen bottom, medium to light growth on bank and side slopes | 0.03-0.04 |
| Channel, large drainage area | --- | 0.025-0.035 |
| Overbank flood plain, pasture land | No brush or trees | 0.05-0.07 |
| | Light brush and trees | 0.06-0.08 |
| Overbank flood plain, crop land | --- | 0.07-0.09 |
| | Heavy weeds, scattered brush | 0.08-0.10 |

| | | |
|---|---|---|
| Overbank flood plain, brush and trees | Medium to dense brush and trees | 0.09-0.12 |
| | Dense brush and trees | 0.10-0.15 |
| | Heavy stand of timber, a few downed trees, little undergrowth | 0.07-0.10 |

## 3.2.2.4 Freeboard

The purpose of freeboard is to provide adequate clearance for passage of debris and ice during high flows and to reduce the potential of superstructure submergence. Debris and ice jams can create horizontal and buoyant forces on the bridge superstructure and can reduce the bridge waterway opening resulting in increased velocity, scour, and upstream flood levels. When policy desired freeboards are not initially provided, the preliminary engineer should coordinate with Road Design regarding the roadway profile, preferably during concept development.

The bridge stage determination differs based on the type of hydraulic model and analysis selected for a site:

1. Iowa Bridge Backwater (IBB) Program
2. 1D model (eg. HEC-RAS)
3. 2D model (eg. TUFLOW, SRH-2D, HEC-RAS 2D)

For a 1D analysis and IBB, the stage for a given discharge is estimated using the proposed water surface elevation at the downstream bounding section. This method is preferred, because it is thought to give a dependable and representative stage elevation at the bridge. A proposed bridge upstream bounding section in a 1D model has potential to vary due to the internal bridge calculations. For IBB, the downstream valley section stage is translated to the downstream bounding section location using a stream slope multiplied by channel distance adjustment.

When analysis is by 2D model, the proposed water surface elevations should be more accurate under and around the bridge. The hydraulic engineer shall review results and determine the representative stages to document in the Hydraulic Data Block and to utilize for scour calculations. Also, the engineer shall determine the appropriate stage to check freeboard and inundation at specific locations along the bridge.

If the operational freeboard for the 500-year event is less than 0 (no freeboard), consult the Unit Leader for guidance.

When hydraulic modeling predicts that a span in a pretensioned prestressed concrete beam (PPCB) bridge will be inundated by the 100-year or lesser floods, the designer should recommend that beams in the span be vented to prevent buoyancy forces. (See BDM 5.4.2.4.2 for beam vent details.) The designer also should recommend venting a steel superstructure with integral abutments that will be inundated from abutment to abutment by the 100-year or lesser floods [BDM 5.5.1.4.2].

For streams draining more than 100 square miles in rural (unincorporated) areas and for streams draining more than 2 square miles in urban (incorporated) areas, the Iowa DNR 50-year event operational freeboard is 3 ft. minimum, unless a licensed engineer provides certification that the bridge is designed to withstand the applicable effects of ice and the horizontal stream loads and uplift forces associated with the Q100. For streams draining less than 100 square miles in rural areas and streams draining less than 2 square miles in urban areas, no Iowa DNR permit is needed. In this case 3 ft. of 50-year event operational freeboard is still desirable to facilitate passage of debris and ice. In addition, for all bridges it is desirable that 500-year event channel freeboard is provided (>=0) to reduce potential for pressure flow conditions. Channel freeboard is critical for sites that do not have relief (roadway overtop and/or overflow bridges). For sites such as this, 500-year event channel freeboard should be considered a requirement, unless waived by the Unit Leader.

**Table 3.2.2.4 Freeboard Policy Summary**

| Freeboard Type | Event (year) | Minimum Clearance | Comments |
|---|---|---|---|
| Operational - DNR Permit required | 50 | 3’ | Required, unless floodplain development permit notes (below) are included on the TS&L |
| Operational - DNR permit not required | 50 | 3’ | Preferred |
| Operational | 100 | >0’ | Preferred. For less clearance, consult with Unit Leader. TS&L note regarding venting of beams may be required. |
| Operational | 500 | >0’ | Preferred. For less clearance, consult with Unit Leader. |
| Channel | 500 | >=0’ | Preferred. For less clearance, consult with Unit Leader. Clearance is critical for bridges that do not have overtopping or overflow relief. |

Note: Consult the article for more complete information.

For situations where one or more of the following conditions are present, it may be acceptable to consider a design with a reduced freeboard:

- The bridge is a floodplain overflow structure,
- Ice or debris is not expected to be a problem,
- Road grade overflow readily provides relief in the event the bridge opening is obstructed,
- Raising an existing grade will result in excessive costs or damages, as in heavily developed urban areas,
- The proposed bridge provides channel freeboard (>=0) for the 500-year event, or
- The proposed bridge channel freeboard is increased as compared to the existing bridge to the extent feasible.

If a project requires a DNR permit and the Q50 freeboard is less than 3.0 feet, the preliminary designer shall add the following design note to the T,S&L:

> Floodplain Development Permit Notes:
> The bridge will be designed to withstand the applicable effects of ice and horizontal stream loads and uplift forces associated with the $Q_{100}$.

### 3.2.2.5 Road grade overflow

New primary road profile grades generally should be designed to ensure that the 100-year flood elevation including backwater is not greater than the outside edge of shoulder. However, the designer should recognize that if the road grade is much higher, road grade overflow will not serve as a relief valve for the bridge during an extreme flood.

Changes to existing primary road profile grades on bridge replacement projects also need careful consideration. The designer should ensure that raising profile grades in areas with a history of roadway overtopping does not have a negative impact to adjacent property owners.

Coordination of the road grades with the Design Bureau may be required.

There are situations when roadway overtopping can cause significant damage to the roadway embankment and pavement due to the duration of overtopping and the head differential across the road. To mitigate damages due to roadway overtopping during floods, a Grid Tied Concrete Block Mat per DB RDD 570-20 or 570-22 should be used.

SRD 570-22 (Major Overtopping) should be used for overtopping events with long durations (greater than 12 hours) or when the head differential for a flood is greater than 1.5 feet. SRD 570-20 (Minor Overtopping) should be used for shorter duration overtopping events (less than 12 hours) or when the head differential across the roadway is less than 1.5 feet during the overtopping event. The difference between the two Standards is the anchor block detail to prevent the Mat separating from the existing pavement.

The Mat should also be used when significant damage has occurred to the embankment or pavement due to a flood especially if along an Interstate or high volume NHS route. The vulnerability of an asset and need for additional protective measures due to roadway overtopping should be evaluated economically and based on the critical usage of the highway.

### 3.2.2.6 Streambank protection

Streambank erosion is a natural process in which the stream adjusts to changing conditions within its channel and watershed. The main factors contributing to streambank erosion are the velocity of water, angle of attack, soil type, lack of vegetation, and changes in land use.

When stream velocities exceed 8 to 10 feet per second, riprap may be considered. Past aerial photos should be examined to determine an approximate rate of erosion.

There are many streambank stabilization practices used by the engineering profession. A detailed description of the different methods is beyond the scope of these guidelines. However, because 75% of the streambank failures are caused by toe scour, a common design practice for bank protection with riprap is to provide adequate protection at the toe of the bank: a minimum 6-foot from the toe or to the maximum scour elevation. The riprap should be a minimum 2-foot thick layer of Class E Revetment [IDOT SS 2507.03]. For situations where greater protection is recommended, a minimum 3-foot thick layer of Class C revetment may be considered. The bank slope generally should be 2 horizontal to 1 vertical. The designer should identify the limits of the riprap by station and offset on the TSL sheet.

As a general rule, any streambank protection design should not extend more than 25% of the width of the eroded channel, which includes the sandbar. The streambank protection design should be sufficiently keyed into the bank to prevent undercutting. For a bank toe protection example see the commentary for this article.

### 3.2.2.7 Scour

Scour calculations should be made for all new and replacement bridges. The most common cause of bridge failure is from floods scouring bed material from bridge piers and abutments. Bridge scour is the engineering term for the movement of soil caused by the erosive action of water. Bridge scour is a complex process and difficult to analyze but very important in terms of bridge safety and maintenance cost. For guidance on calculating bridge scour the Bureau generally relies on the Federal Highway Administration (FHWA) publication *HEC-18* *Evaluating Scour at Bridges, 5TH Edition* and the recommendations and guidelines published in “Iowa DOT Bridge Scour Guidelines.” See the commentary for this article.

The effects of scour should involve a multidisciplinary review of hydraulic, geotechnical, and structural engineers to assess the stability of a structure.

“Iowa DOT Bridge Scour Guidelines” is derived from *HEC-18*. The main difference between the FHWA publication and the Iowa DOT methodology is the way pier scour is calculated. For most cases pier scour in Iowa has been calculated using the research performed by Laursen under “Iowa Highway Research Board Bulletin No. 4, Scour Around Bridge Piers and Abutments.” *HEC-18* recommends the Colorado

State University (CSU) equation for calculating pier scour. The Laursen equations and the CSU method give comparable results.

## 3.2.2.7.1 Types

There are two types of bridge scour: general or contraction scour and local scour.

- General or contraction scour is the decrease in streambed elevation due to encroachment of the road embankment onto the flood plain causing a contraction of flood flows, and
- Local scour is the loss of material around piers, abutments, wing dikes, and embankments.

There are two conditions for contraction and local scour: clear water and live-bed.

- Clear water scour occurs when there is little to no movement of the bed material of the stream upstream of the crossing. Typical situations include most overflow bridges without a defined channel, coarse bed material streams that could be found in northeast Iowa, flat gradient streams during low flow, and bridges over main channels with a significant overbank length.
- Live-bed scour occurs when velocities are high enough to move the bed material upstream of the crossing. Most Iowa streams experience live-bed scour since they consist of sands and silts.

The designer should calculate the individual estimates of contraction, pier, and abutment scour. The designer should also consider long-term degradation when determining the total contraction scour depth. Local scour should be added below the contraction scour at each pier and abutment for evaluation. The designer should also apply engineering judgment when comparing results obtained from scour computations with available hydrologic and hydraulic data to achieve a reasonable and prudent design.

## 3.2.2.7.2 Design conditions

The design scour is determined for the 200-year or lesser flood, depending on which results in the most severe scour conditions. Usually the overtopping flood results in the worst scour, so evaluate this discharge if it is less than the 200-year flood. This scour depth is used by the final designer to check pile capacity and stability using load factors for the strength limit state.

The check scour is based on the occurrence of a 500-year or lesser flood, depending on which results in the most severe scour conditions. Bridge foundations will be evaluated by the final designer to ensure that they will not fail at the extreme event limit state due to the check (maximum) scour.

The preliminary situation plan hydraulic data block shall show the design and check scour elevations.

## 3.2.2.7.3 Evaluating existing structures

When evaluating an existing bridge for scour, the designer should be aware of the procedures to evaluate the structure by engineering judgment to determine if it is scour-safe. A “Bridge Scour Stability Worksheet” and “Intermediate Scour Assessment Procedures” evaluation should be performed before proceeding with a calculated *HEC-18* scour analysis. This may significantly reduce the cost of analyzing structures for scour that could be considered scour-safe.

The “Bridge Scour Stability Worksheet” was developed in the early 1990s to assess structures based on the type of structure, observed conditions, and stream geomorphics. The structures were considered stable or scour-critical based on the point total determined from the worksheet.

The “Intermediate Scour Assessment Procedures” were developed in 1997 to provide additional assessment of existing structures that have not been evaluated for scour. A flowchart was developed to assess those bridges that could be considered scour-safe.

If the structure is not determined to be scour-safe after assessment by the “Bridge Scour Stability Worksheet” or the “Intermediate Scour Assessment Procedure,” a full computational analysis (*HEC-18*) must be performed.

### 3.2.2.7.4 Depth estimates

{Text for this article will be added in the future.}

### 3.2.2.7.5 Countermeasures

{Text for this article will be added in the future.}

### 3.2.2.7.5.1 Riprap at abutments

{Text for this article will be added in the future.}

### 3.2.2.7.5.2 Riprap at piers

{Text for this article will be added in the future.}

### 3.2.2.7.5.3 Wing dikes

The use of wing dikes (also called spur dikes or guide banks) shall be considered at any bridge site that has appreciable overbank discharge (25% or more of the total design Q in an overbank area). Wing dikes help minimize backwater and scour effects. See the commentary for a table on selecting appropriate lengths of wing dikes and the Design Bureau's manual [DB SRP EW-210] for construction details. The riprap should typically be extended through the end of the wing dike.

### 3.2.2.7.6 Coding

{Text for this article will be added in the future.}

### 3.2.2.8 Riverine Infrastructure Database

The Riverine Infrastructure Database (RIDB) is a database of Iowa Department of Transportation facilities in the riverine environment. The database consists of location data in addition to hydrologic and hydraulic data so impacts to facilities during a flood event can be rapidly evaluated.

A riverine location for this purpose is a stream crossing a waterway having a drainage area greater than 10 square miles. The RIDB determination should be made before work begins since additional hydraulic studies will generally be made as part of the concept development.

For more information, refer to the Riverine Infrastructure Database – Data Compilation and Data Guideline documents. These documents are available on the Iowa DOT website.

RIDB – Data Compilation
RIDB - Data Guidelines

For a bridge project concept requiring an RIDB dataset, the Bridge Bureau Concept Attachment shall include the RIDB site identification code. The site identification code is used for database indexing and consists of two parts, the stream ID and River Mile. Stream ID and River Mile shall be obtained through use of GIS mapping. Map information has been made available through the Iowa DOT ArcGIS Online web application (see link below). The Iowa DOT preliminary staff reviewer shall verify all consultant site identification locations during the concept review process. The RIDB site identification code shall be documented on the TSL in the Hydraulic Data Block.

It is good practice during Concept level development to inquire or check to see if an existing site has a completed RIDB dataset. If available, RIDB survey and portions of the dataset will be helpful to the engineer. However, an updated/finalized existing and proposed bridge dataset deliverable will still be required with the B1 RIDB submittal.

RIDB Stream WebApp

For project development, the RIDB dataset deliverables shall be placed in the project directory under the preliminary bridge RIDB subfolder. Upon dataset completion, Iowa DOT preliminary bridge staff shall place a text file within a “pending_PW” subfolder containing the engineer’s name, completion date, and pathway or link to the completed dataset. The dataset information will be added to the GIS map and database by others.

### 3.2.2.9 Datum Correlation

All data utilized for project development shall be based on the project datum. The designer shall correlate all data sources to the project datum. Data source correlation information shall be documented in the Hydraulic Report and stored in the project directory.

Sources including USGS/COE flood studies and Flood Insurance Studies may be based on NGVD 29 datum. Past roadway/bridge projects were developed utilizing a variety of datums. LiDAR and other non-project datasets based on NAVD 88 datum will need to be verified and adjusted for systematic error (bias).

Guidance on datum correlation procedures can be reviewed under the Part 6 “Survey Requirements” of the Riverine Infrastructure Database – Data Guidelines.

### 3.2.2.10 Hydraulic Grade Line and Streambed Profile Determination

The determination of design Hydraulic Grade Line (HGL) and design Streambed Profile (SP) are critical to the hydraulic design of structures. The design HGL is typically utilized to determine the stage-discharge relationship at the downstream boundary for the project hydraulic model and is the source for slope at the structure location which will be published on the TS&L. The design SP is utilized in calculating scour elevations and for publication on the TS&L longitudinal section as the Design streambed elevation. The SP (and low water offsets) are also typically used to “carve” out a channel within a LiDAR dataset for use in hydraulic modeling.

Following is the recommended procedure for SP determination utilizing LiDAR data. An SP derived from LiDAR data is recommended in that it may indicate a degrading channel, or slope changes within the hydraulic model reach, both of which can influence the structure design. Other procedures may be used, as long as the process accounts for existing local scour (bend, contraction, etc.) and stream degradation in determination of the design streambed elevation.

The Iowa statewide LiDAR datasets (circa 2008 and 2020) can be utilized for SP determination. Use of a LiDAR derived SP, as follows, can be considered as representing top of water, in general, at the time of the LiDAR flight. A profile of the LiDAR derived surface (ground returns) along approximate centerline channel is obtained. The profile will generally be jagged due to triangulation across the stream channel of ground returns. The LiDAR SP is derived by plotting a ‘best fit’ profile against the lowest points on this plot, as these represent the lowest ground returns in the dataset, and therefore approximate water surface at the time of the LiDAR data collection.

Once a LiDAR derived top water SP is established, the depth to design low water and thalweg from LiDAR SP can be estimated through consideration of project survey, aerial photography, and bridge maintenance reports. Low water and streambed elevations can be plotted against the LiDAR top water SP to estimate offsets to design SP (thalweg) and design low water.

For locations with limited data, an estimate of water level at riffle locations upstream and downstream of the structure, with offset to thalweg at the riffle, can be used to estimate design low water and streambed elevation at the structure. Bridge maintenance reports, aerial photography and site photos, in conjunction with interpretation of the LiDAR dataset, can be used to establish these elevations. The LiDAR top water SP can then be shifted to these elevations to establish design and low water SP’s.

For culvert projects, this process can be utilized to determine appropriate design inlet and outlet streambed elevations. Buried culvert flowlines would be relative to the design streambed elevations.

Once the design SP has been determined per the above, the design HGL slope can be estimated.

For projects on small watersheds (culverts, small bridges) the preferred method for determining the HGL slope is to determine the slope from the LiDAR derived SP. For larger watersheds USGS Flood Profiles or detailed National Flood Insurance Program (NFIP) Flood Insurance Study (FIS) profiles, when available, can be utilized to determine the HGL slope. Use of these sources to estimate HGL slope is preferred, with the slope determined from these sources compared to the LiDAR derived SP to review for outliers in the flood profile data.

### 3.2.2.11 State Water Trail and Paddling Routes

State Water Trails and Paddling Routes are recreational corridors and routes on rivers and lakes that provide a unique experience for canoeists and kayakers. The Iowa DNR provides information on these routes for recreational users including adequate access points. A Paddling Map identifying State Water Trails and Paddling Routes is available on the DNR web site. Projects that will obstruct a waterway identified on the DNR Paddling Map will be subject to requirements. The process for coordinating and implementing the requirements is summarized in the following paragraphs.

Project types listed may result in a potential obstruction to a Water Trail or Paddling Route, and will require coordination with DNR to determine project requirements. Waterway obstructions typically include temporary stream crossings (including temporary detour bridges) and causeways, equipment in the river such as platform barges, cofferdams, and significant amounts of debris such as might occur with a bridge removal or bridge deck replacement. Work types requiring coordination with the DNR are:

1. New structures
2. Replacement structures
3. Bridge widening
4. Superstructure replacement
5. Superstructure strengthening – when the waterway is obstructed
6. Deck replacements
7. Bridge removal
8. Bridge repairs – when the waterway is obstructed

Coordination with the Iowa DNR is initiated after the B0 or D0 Final Concept is complete, through use of the Iowa DNR Permit and Environmental Review Management Tool (PERMT), as an Environmental Review Request. Preliminary design unit staff will make the PERMT submittal and track status, regardless of project type. The Iowa DNR will respond with a Letter of Agreement, which shall be stored in the project Permits_Regulatory folder. Typical requirements listed in the Agreement will include notification to the DNR when signage is placed and removed, and minimum signage specifications and placement locations to make recreational users aware of the paddling route closures that will be in place for the duration of the project construction.

Project sign details, plan notes, and bid items associated with the requirements will be addressed by the Design Bureau and incorporated into the plan set.

The role of the Preliminary Bridge Designer will be:

1. Indicate that the State Water Trail and Paddling Route requirements will be applicable in the BSB Attachment for Concept Statement (see BDM C3.11 for an example).
2. Include a note to the Final Designer on the B01 TSL that states the requirements for a State Water Trail or Paddling Route are applicable, and that the signage, plan notes, and bid items shall be addressed by the Design Bureau and included in the Road Plans. The note is intended for designer information only and should be removed from the final bridge plan.

## 3.3 Highway crossings

### 3.3.1 Clearances

A grade separation design must satisfy both vertical clearance and horizontal clear zone requirements.

Vertical clearance distances at grade separation structures depend upon the mainline and side-road highway type and whether an interchange is present. Vertical clearance is measured from the low point of the overhead structure to the roadway, including the traffic lanes and shoulders. Minimum vertical clearance to be provided for a new or replacement bridge over primary highways is 16.5 feet and over non-primary highways is 15.0 feet [DB DM 1C-1]. For all primary over non-primary grade separations with an interchange, it is desirable to provide a clearance of 16.5 feet [DB DM 6B-2, 1C-1]. The specified minimum vertical clearances are inclusive of an allowance for possible 6-inch future overlay. The minimum vertical clearance for the permanent condition and any interim condition, due to staging, shall be shown on the TS&L.

Horizontal clear zone distances depend on design speed, average daily traffic (ADT), horizontal curvature and roadside geometry; see the Preferred Clear Zone and Acceptable Clear Zone Tables in the Design Bureau's manual [DB DM 8A-2]. Any structure not meeting the preferred clear zone but meeting Design Bureau's acceptable clear zone will need Preliminary Unit Leader approval and documentation in the file.

Use values in the fill slope portion of the table (fs ≥ 6:1). The horizontal clear zone is measured either from the edge of the traveled way in rural sections or from the back of curb in urban sections. Do not determine the clear zone based on the edge of the pavement, as this is typically 2 feet wider than the traveled way. If multiple highway types (mainline, ramps, loops auxiliary lanes, etc.) are present, use the clear zone that governs. Clear zones apply to both the bridge pier and berm slope together when a side pier is proposed. However, clear zone does not apply to the berm slope alone when there will be no side pier and a recoverable berm is proposed.

A vertical clearance of 14.5 feet should be provided within the horizontal clear zone [DB DM 8A-2]. This vertical clear zone is to be maintained throughout the entire horizontal clear zone area.

### 3.3.2 Ditch drainage

If ditch drainage must be carried through the approach fills of a highway crossing structure, the designer should use a culvert rather than an open ditch, which increases the bridge length and cost. Ditch drainage may be conveyed behind the abutment due to excessive length and/or size of culvert.

## 3.4 Railroad crossings

The following articles are intended to provide guidance for obtaining agreements with the railroad for constructing within their right-of-way (ROW). Each project is unique and early coordination with the railroad regarding their design requirements and guidelines will help in the design process for grade separation structures. All Iowa DOT projects involving railroads should be coordinated at the concept stage through the Rail Transportation Bureau.

The design requirements and guidelines for grade separation structures over the Burlington Northern Santa-Fe (BNSF) Railway and Union Pacific Railroad (UP) may be different than other railroad crossings. Canadian National Railway (CN) and Canadian Pacific Railway (CP) have been requesting similar design standards to BNSF and UP. For preliminary bridge design of overhead structures, the guidelines are divided into two groups: BNSF, UP, CN and CP ownership, and Non-BNSF, UP, CN and CP ownership. The sections covering submittals and underpass structures will apply to all railroads.

The preliminary designer should be aware that federal funding will not include costs associated with improvements that increase the cost of the bridge above the limits specified in the Code of Federal Regulations (CFR 646). Considerations include the level of commitment for future track expansion, vertical and horizontal clearances, and berm placement location. In general, it is Iowa DOT policy to accommodate the railroad's requirements unless a significant cost will be incurred. For BNSF, UP, CN and CP, the designer should review all feasible options. Additional guidance for these Railroads is provided in article 3.4.1. In some cases, two bridge TS&Ls may be required to determine the limit of federal participation for a project.

## 3.4.1 BNSF, UP, CN, and CP overhead structures

The guidelines provided within this section are intended for overhead grade separation projects impacting the BNSF, UP, CN, and CP Railroads. The requirements and guidelines generally follow BNSF and UP Railroad guidelines, but are applied also to CN and CP Railroads and are written from an Iowa DOT project development perspective. For additional information and detail, the designer may refer to sections 1, 2, 3, 4 and 5 of BNSF-UP's *Guidelines for Railroad Grade Separation Projects* [BDM 3.1.5.2], AREMA's *Manual for Railway Engineering* [BDM 3.1.5.2], and any applicable sections of the AASHTO LRFD Specifications.

### 3.4.1.1 Vertical clearance

The minimum vertical clearance from the top of rail elevation to low beam is 23'-4 (UPRR/CN/CP) and 23'-6 (BNSF). The BNSF and UP Railroads also require that the extent of the permanent vertical clearance shall be a minimum of 9 feet to the field side of the outer most existing or future tracks, measured perpendicular to the centerline of said tracks, and shall include all spaces between. A wider envelope may be required for curved track situations. Additional vertical clearance may also be requested by the railroad for correction of a sag in the track, construction requirements, and future track raises. To assist the railroad in evaluating the site specific needs, the profile of the existing top-of-rail, measured 1000 feet each side of proposed overhead structure, shall be shown on the standard sheet [BSB SS 1067].

Federal funding limits may not allow for participation in the additional project costs associated with the desired 18 feet wide vertical clearance envelope and additional clearance for future track raises. However, it is Iowa DOT policy to accommodate the requested clearances unless a significant expense will be incurred. Iowa DOT requests for variance to these desired additional clearances should be limited to these cases.

### 3.4.1.2 Horizontal clearance

The BNSF, UP, CN and CP Railroads prefer all bridge berms, piers (including pier caps) and abutments to be located outside the railroad right-of-way. For a project concept, contact the Iowa DOT Rail Transportation Bureau for ROW information. If this is not feasible, all piers and abutments should be located to provide the widest feasible horizontal clearance. At a minimum the placements shall meet the requirements listed in BDM 3.4.2.

Where it is impractical to clear span the Railroad ROW, written justification and request for variance should be submitted through the Rail Transportation Bureau as part of the Concept coordination. The request shall describe the geometric, structural, and other constraints which make a clear-span alternative unfeasible and shall show that all options have been exhausted. A variance request should not be submitted for non-engineering reasons such as cost or time savings.

Note that pier placement at the right-of-way line may also require an associated shifting of the bridge berm. Since the berm location determines the bridge length, shifting the berm out to the right-of-way may result in a bridge exceeding the length and cost allowed for federal participation. The cost difference may need to be provided to FHWA to determine the appropriate level of funding.

### 3.4.1.3 Piers

Piers within 25 feet, measured perpendicular from centerline of existing or anticipated future track shall be of heavy construction as defined in the AREMA Manual for Railway Engineering. Generally, for new bridges the Bureau prefers the T-pier to satisfy heavy construction requirements in lieu of a pier protection wall. Top of pier footings located within 25 feet from centerline of track shall be a minimum of 6 feet below base of rail and a minimum 1 foot below the flow line of the ditch.

### 3.4.1.4 Bridge berms

When feasible, the bridge berm locations should be set beyond the Railroad ROW. It is recognized that this policy will in most cases exceed the federal policy and requirements summarized below.

FHWA has indicated that full funding participation applies when the location of a bridge berm with a 2.5:1 slope is set at the top of rail elevation 26 feet from centerline of the outermost track (27.5 feet for 3:1 berm slope). This FHWA method of setting the berm location provides for a small ditch sufficient for ballast to drain. Additional ditch drainage may require a culvert through the bridge berms to adequately convey the drainage. If a culvert is proposed, it must be analyzed to meet the BNSF and UP hydraulic design criteria summarized in the drainage section below.

Macadam stone slope protection should be proposed on the bridge berms. The railroad standard shows the slope protection terminating at the bottom of drainage ditch and must have a cut-off wall to protect the slope from scour/erosion. In all cases, the toe of slope shall be below the finished track or roadway sub-grade.

### 3.4.1.5 Drainage

Railroad corridors are constructed with a drainage system designed to keep runoff away from the tracks and ballast. The proposed construction shall safely pass high flows and not inhibit low flows. A complete hydrologic and hydraulic study is required whenever new or additional drainage is added to the railroad right of way, or when a drainage structure is scheduled to be added, removed, or replaced. The drainage report and support documentation must include hydraulic data (EGL, water surface elevations, and velocities) for both the existing and proposed conditions. If the proposed bridge structure will not change the quantity and characteristics of the flow in railroad ditches and drainage structures, the plan shall include a general note stating so.

The BNSF and UP Railroad standard provides for an open ditch under a bridge to convey drainage. For DOT projects, in most cases the existing railroad ditches will be spanned and used as constructed. In rare situations when the berm construction impacts the existing open ditch, use of a culvert or non-standard railroad ditch to convey drainage will need to be justified and a variance requested. In this case, the justification would need to demonstrate that the proposed design is in compliance with the railroad's hydraulic criteria.

### 3.4.1.6 Barrier rails and fencing

Early coordination with the railroad regarding recommendations for barrier rail and fencing is desired.

On sidewalk or trail facilities the top of the fence should be curved to discourage climbing. A minimum 8-foot vertical clearance should be provided for the full clear width of the trail or sidewalk. To prevent surface water from draining onto the railroad right of way, a one-foot parapet is required.

Fencing is also requested by the BNSF and UP on top of barrier rail on overhead structures without sidewalks or trails. Due to traffic safety concerns related to fencing on top of roadway barrier rail, the Iowa DOT generally proposes to the railroad that the fencing be omitted and that a 44-inch barrier rail be provided to control the amount of snow and debris falling onto the track. This proposal is subject to site specific review and variance by the railroad.

The 44-inch barrier rail and railroad fence requirements should be carried at a minimum to the limits of the railroad right-of-way or 25 feet beyond the centerline of track, future track or access road, whichever is greater. Barrier and fence may be reduced back to a more standard configuration on the bridge once the railroad minimum requirements have been met. The bridge final designer will determine based on cost and constructability whether it is more economical to keep the fence and rail uniform for the full length of the bridge or to taper back as soon as allowable.

## 3.4.2 Non-BNSF, UP, CN and CP overhead structures

The guidelines provided within this section are intended for overhead grade separation projects impacting non-BNSF, UP, CN and CP Railroads. The requirements and guidelines for each railroad may be different, but generally follow AREMA's *Manual for Railway Engineering* [BDM 3.1.5.2] and any applicable sections of the AASHTO LRFD Specifications.

### 3.4.2.1 Vertical clearance

The preferred minimum vertical clearance from the top of rail elevation to low beam is 23'-4 directly above the rail.

### 3.4.2.2 Horizontal clearance

The need to accommodate future track and/or access road and the determination of applicable rail company guidelines for horizontal clearance must be coordinated with the Rail Transportation Bureau. These needs and requirements should be coordinated at the project concept stage, as they are a fundamental part of the bridge and roadway design development. Once the design criteria for track and access road elements have been determined, the designer will be able to proceed to the next step of establishing pier and berm locations.

It is desirable to provide pier (including pier caps) and abutment locations at least 25 feet measured perpendicular from the centerline of nearest existing or future track. In unique situations and subject to site conditions, the preferred minimum horizontal clearance shall be 18 feet measured perpendicular from the centerline of the track to the face of the pier protection wall. Horizontal clearance less than 18 feet may be allowed on a case-by-case basis, if approved by the railroad.

### 3.4.2.3 Piers

Piers within 25 feet, measured perpendicular from centerline of existing or anticipated future track shall be of heavy construction as defined in the AREMA Manual for Railway Engineering. Generally, for new bridges the Bureau prefers the T-pier to satisfy heavy construction requirements in lieu of a pier protection wall.

Top of pier footings shall be a minimum of one foot below finished ground line.

### 3.4.2.4 Bridge berms

It is the Iowa DOT policy to set the bridge berm location in accordance with the federal requirements. FHWA has indicated that full participation applies when the location of a bridge berm with a 2.5:1 slope is set at the top of rail elevation 26 feet from centerline of the outermost track (27.5 feet for 3:1 berm slope).

This method of setting the berm location provides for a small ditch sufficient for ballast to drain. Additional ditch drainage may require a culvert through the bridge to adequately convey the drainage.

Macadam stone slope protection should be proposed on the bridge berms.

### 3.4.2.5 Drainage

Railroad corridors are constructed with a drainage system designed to keep runoff away from the tracks and ballast. If drainage must be carried through the approach fills, this should be accomplished by using a culvert, not by using an open ditch which increases the bridge length and cost. If the proposed bridge structure will not change the quantity and characteristics of the flow in railroad ditches and drainage structures, the plan shall include a general note stating so.

### 3.4.2.6 Barrier rails and fencing

Early coordination with the railroad regarding recommendations for barrier rail and fencing is desired.

Most of the railroad bridges carrying vehicular traffic will make use of the Iowa standard single slope barrier rail~~Texas Single Slope (TSS) barrier rail~~. The designer shall determine the appropriate barrier rail height by consulting the Iowa DOT policy for bridge rail height. See BDM 5.8.1.1.1 and BDM 5.8.1.2.1.

Fencing shall be provided for the full length of bridge on all sidewalk or trail facilities. The standard 6-foot high chain link fence is generally proposed.

On a case by case basis, there may be an alternative to rail or fence proposed. Reasons may include a request by the railroad or project aesthetics. A statement shall be included with the TS&L submittal to the Iowa DOT Rail Transportation Bureau, relative to the proposal for barrier rail and fencing.

### 3.4.3 Underpass structures

Requirements for railroad underpass structures will follow the recommendations and guidelines applicable to the railroad company owner. Contact the Iowa DOT Rail Transportation Bureau for coordination of applicable standards at the concept level of project development. Early coordination is necessary, as some railroad structures (including BNSF and UP) will require additional vertical clearance as compared to highway grade separation structures.

Once the proper design guidelines have been identified, the preliminary bridge design effort may be initiated. Special attention should be given to minimize project impacts on the railroad company service. If new alignment is not feasible or if staging is not agreeable to the railroad company, a shoofly bridge may be considered. All options shall be closely coordinated with the Iowa DOT Rail Transportation Bureau.

### 3.4.4 Submittals

After TS&L completion, the Preliminary Bridge Unit Leader will make the following documentation available to the Iowa DOT Rail Transportation Bureau for submittal to the railroad:

(1) A response to railroad review comments on the concept submittal.
(2) A pdf file of the bridge TS&L.
(3) The site drainage report, if drainage is affected.
(4) A bridge plan view showing the location of the proposed shoofly (only for railroad underpass bridges).
(5) If the project will be constructed in stages, controlling dimensions should be included on the TS&L.
(6) For BNSF and UP RR submittals (See BDM C3.4.4).

## 3.5 Pedestrian and shared use path crossings

There are several pedestrian and shared use path crossing types. Guidance related to each type of crossing is provided in this article.

The following references provide additional information related to the design of shared use paths and bicycle facilities: AASHTO's *Guide for the Development of Bicycle Facilities (4th Edition, 2012)*[1] [BDM 3.1.5.2]; the design guidelines (Chapter 4) in *Iowa Trails 2000* [BDM 3.1.5.2], and *SUDAS Standard Specifications* [BDM 3.1.5.2].

- **Pedestrian or shared use path on a highway structure**

Guidance for sidewalk and shared use paths on roadway bridges is covered under [BDM 3.6.2.2 & 1.5], and Design Bureau's Design Manual [DB DM 12A and B].

[1] Note that the 5th edition should be available soon.

- **Separate pedestrian or shared use path bridge**

  The following paragraphs do not apply to pedestrian or shared use paths on a highway structure. For a separate pedestrian or shared use bridge, the Bureau recommends a minimum clear width of 14 feet. This is different than our recommended 10-foot clear width on vehicular bridges due to the minimal increase in cost to provide 14 feet on a separate bridge.

  To assist in drainage and snow removal, the maximum deck cross slope shall be 2% in one direction across the full width. Concrete parapets at the base of the fence or railing may be proposed based on aesthetics and safety concerns. Parapets also protect the fence from being damaged by snowplow blades. Such parapets require a minimum footprint of 16 inches (plus 2-inch setback from slab edge) in order to accommodate the fence/railing anchorages. If no parapet is used, 12 inches is a sufficient fence/railing footprint on each side. The designer shall consult with the Methods Unit in the Bridges and Structures Bureau regarding usage of parapets.

  For structures over a roadway, the desirable minimum vertical clearance is 17.50 feet. Provisions for additional clearance may be considered for unique bridges. It is undesirable to use truss bridges over our highways due to damage from over-height loads and the lack of proper fencing to prevent debris from falling/thrown onto the roadway below. A girder bridge with a concrete deck and proper fencing is preferred for recreational or trail bridges over a roadway.

  For structures over a waterway, the structure low beam should generally be designed at the $Q_{10}$ water surface elevation. Typically, relief in the approach grading should be provided for discharges greater than the $Q_{10}$. Since waterway structures will be inundated by larger floods, the designer should consider the expected buoyant forces. In general, the bridge approach fill within the floodplain should be designed close to the floodplain grade. This is especially true if the construction will be within a detailed FIS area.

- **Pedestrian or shared use path under a roadway bridge**

  Adjacent to an urban roadway section, the desirable horizontal clearance from back of curb to sidewalk or shared use path is 6 feet to allow for snow storage. If the offset from back of curb to shared use path is less than 5 feet, a separation barrier is required. Adjacent to a rural roadway section or at a river or stream crossing, the location and offset of the pedestrian or shared used path should be coordinated with Design Bureau. The desirable minimum vertical clearance is from bridge low superstructure to sidewalk or shared use path is 10 feet, with a minimum of 8 feet.

  For both crossing types above, a 2-foot shy distance is desired from sidewalk or shared use path to bridge berm, and a 3-foot horizontal clearance is desired from sidewalk or shared use path to pier column.

  Greater shy distance should be considered for slopes steeper than 3:1 sloping down or away. Railings or dense plantings may have to be considered alongside certain grade conditions or ground covering (such as rip rap).

- **Pedestrian or shared use path through roadway embankment**

  An RCB is typically utilized for this type of crossing. Please refer to BDM 4.5.16.

## 3.6 Superstructures

For typical highway bridge superstructures, the Bureau generally selects among multiple options. If site and project conditions are appropriate the Bureau prefers the following bridge types for which standard plans are available. A designer should consider using a standard bridge even if up to 10 feet of additional bridge length is needed. The additional cost will be offset by final design cost savings. The standard plans are available on the Bridges and Structures Bureau web site.

- **Three-span standard continuous concrete slab (CCS), J24, J30, J40, and J44 series [BDM 3.6.1.1]:** These standard CCS bridges are used for short spans up to 59 feet or where minimum superstructure depth is required. There are nine bridge lengths from 70 feet to 150 feet. The series includes roadway widths of 24 (which is not for primary highway system bridges), 30, 40, and 44 feet and 0-, 15-, 30- and 45-degree skews. The bridges are designed for HL-93 loading under the AASHTO LRFD Specifications.

- **Single span standard pretensioned prestressed concrete beam (PPCB), H30SI series [BDM 3.6.1.2]:** The standard bridges designed according to the AASHTO Standard Specifications were withdrawn. The H30SI standard plans have been redesigned for HL-93 loading under the AASHTO LRFD Specifications and now have been reissued. The H30SI bridges have seven lengths from 46'-8 to 110'-0 and skews of 0, 15, and 30 degrees.

- **Three-span standard pretensioned prestressed concrete beam (PPCB), H24, H30, H40, and H44 series [BDM 3.6.1.4]:** These bridges are intended for highway or stream crossings. The standard beam bridges have nine lengths from 138'-10 to 243'-0; 24- (which is not for primary highway system bridges), 30-, 40-, and 44-foot roadways; and skews in 15-degree increments from 0 to 45 degrees, except that the H44 series is limited to a skew of 30 degrees. The bridges are designed for HL-93 loading under the AASHTO LRFD Specifications.

- **Three-span standard rolled steel beam (RSB) [BDM 3.6.1.5]:** These standard rolled steel beam bridges, which are intended primarily for stream crossings, have ten lengths from 160 to 340 feet, a roadway width of 40 feet, skews from 0 to 45 degrees, and span ratios of 0.75-1.00-0.75. The bridges are designed for HL-93 loading under the AASHTO LRFD Specifications.

If site conditions, roadway width, live loading, curvature, design method, or other considerations prevent use of the standard bridge designs the Bureau prefers that the bridge be individually designed with either of the following.

- **Pretensioned prestressed concrete beam (PPCB) [BDM 3.6.1.6]:** PPCB bridges are used for spans to 155 feet. The designer shall select a single standard series of beams or bulb tee beams for the entire bridge. Within the series the designer should select among available beam lengths. For integral abutments the designer should limit skew to 45 degrees, and for stub abutments the designer should limit skew to 45 degrees.

- **Continuous welded plate girder (CWPG) [BDM 3.6.1.7]:** CWPG bridges are used for spans longer than 155 feet or where minimum superstructure depth is required or where the horizontal alignment is sharply curved. There are no standard girder cross sections or lengths; each CWPG bridge is designed for the specific site and project conditions. For integral and stub abutments the designer should limit skew to 45 degrees.

Grade separation design shall include the use of two-span bridges whenever practical as they minimize the use of piers, thereby increasing public safety. The designer shall consider various span arrangements based on the standard beam types available to optimize safety and cost efficiency. The face of pier and toe of berm slope shall be at or beyond the required clear zone distance for span arrangements with side piers. For the arrangements with no side piers, reference the article on berms [BDM 3.7.3] for additional guidance.

The guidelines listed above will cover most preliminary bridge designs. For exceptions and decisions regarding unusual project conditions the designer shall request approval from the supervising Unit Leader.

## 3.6.1 Type and span

### 3.6.1.1 CCS J-series

For relatively small stream and valley crossings the Bureau selects standard three-span continuous concrete slab superstructures. To facilitate the design of CCS bridges the Bureau has prepared the signed standard J-series of plans.

The plans have the following parameters.

- The structures are designed for HL-93 loading.
- Roadway width is 24, 30, 40, or 44 feet. The 24-foot width is intended for county bridges only.
- Skews may be 0, 15, 30, or 45 degrees.
- Bridge lengths range from 70 to 150 feet as listed in Table 3.6.1.1.
- The maximum interior span of 59 feet is approximately the upper limit for slab bridge economy.
- The ratios between interior and end spans are approximately 1.3 for efficiency.
- Substructure plans cover integral abutments and the option of monolithic or non-monolithic pier caps.
- There is the option for either an F-shape barrier or an open railing, except that only the open rail is available for the 24-foot roadway width. The open railing is not intended for use on Iowa DOT highway bridges.

**Table 3.6.1.1 Lengths, spans, and depths for J24, J30, J40, and J44 three-span continuous concrete slab bridges (This table is the same as Table 5.6.2.1.1.)**

| Length (1) feet | End Span (2) feet | Interior Span (3) feet | Depth inches |
|---|---|---|---|
| 70 | 21.00 | 28.00 | 14.50 |
| 80 | 24.50 | 31.00 | 15.25 |
| 90 | 27.50 | 35.00 | 16.25 |
| 100 | 30.50 | 39.00 | 17.50 |
| 110 | 33.50 | 43.00 | 18.50 |
| 120 | 36.50 | 47.00 | 20.00 |
| 130 | 39.50 | 51.00 | 21.25 |
| 140 | 42.50 | 55.00 | 22.50 |
| 150 | 45.50 | 59.00 | 24.00 |

Table notes:

(1) Length is measured from centerline of abutment to centerline of abutment.
(2) End span is measured from center of abutment to center of pier.
(3) Interior span is measured from center of pier to center of pier.

### 3.6.1.2 Single-span PPCB HSI-series

This series of standard plans temporarily was withdrawn for revision to the AASHTO LRFD Specifications, and now the H30SI standard plans have been reissued.

The signed standard plans have the following parameters.

- The structures are designed for HL-93 loading.
- Roadway width is 30 feet.
- Skews may be 0, 15, or 30 degrees.
- The five-beam cross section makes use of standard A, B, C, and D beams, depending on span.
- Substructure plans cover integral abutments.
- There is the option for either an F-shape barrier or an open railing. The open railing is not intended for use on Iowa DOT highway bridges.

## 3.6.1.3 Two-span BT-series

This series of standard plans has been withdrawn and will not be reissued.

## 3.6.1.4 Three-span PPCB H-series

For typical highway and stream crossings the Bureau has developed standard plans for three-span pretensioned prestressed concrete beam (PPCB) bridges.

The signed standard plans have the following parameters.

- The structures are designed for HL-93 loading.
- Roadway width is 24, 30, 40, or 44 feet. The 24-foot width is intended for county bridges only.
- Skews may be 0, 15, 30, or 45 degrees, except that the 45-degree skew is not available for the H44 series.
- The four- to seven-beam cross section makes use of standard A, B, and C beams, depending on span.
- Substructure plans cover integral abutments and pile bent or T-piers.
- There is the option for either an F-shape barrier or an open railing for all but the H24 series. The H24 series has an open railing only. The open railing is not intended for use on Iowa DOT highway bridges.

The ranges of lengths, spans, and beam depths are given in Table 3.6.1.4.

**Table 3.6.1.4 Lengths, beams, and beam depths for H24, H30, H40, and H44 three-span PPCB bridges**

| Length (1) feet-inches | End Span (2) feet-inches | Interior Span (3) feet-inches | Beam Series | Beam Depth (4) feet-inches |
|---|---|---|---|---|
| 138-10 | 43-3 | 52-4 | A | 2-8 |
| 151-4 | 47-5 | 56-6 | A | 2-8 |
| 163-10 | 51-7 | 60-8 | B | 3-3 |
| 176-4 | 55-9 | 64-10 | B | 3-3 |
| 188-10 | 59-11 | 69-0 | B | 3-3 |
| 201-4 | 64-1 | 73-2 | C | 3-9 |
| 213-10 | 68-3 | 77-4 | C | 3-9 |
| 226-4 | 72-5 | 81-6 | C | 3-9 |
| 243-0 | 80-9 | 81-6 | C | 3-9 |

Table notes:

(1) Length is measured from centerline of abutment to centerline of abutment.
(2) End span is measured from centerline of abutment to centerline of pier.
(3) Interior span is measured from centerline of pier to centerline of pier.
(4) Add beam depth, 8.5-inch deck, and 2-inch estimated haunch to determine superstructure depth.

## 3.6.1.5 Three-span RSB-series

For typical stream crossings the Bureau has developed signed standard plans for weathering steel, three-span rolled beam bridges. The 2010 plans meet the AASHTO LRFD Specifications. Because cost experience with these bridges is limited, if a standard rolled beam bridge is feasible for a bridge site the designer also shall layout an equivalent PPCB bridge and consult with the supervising Unit Leader regarding the choice of bridge type.

The rolled beam plans have the following parameters.

- The structures are designed for HL-93 loading.
- Roadway width is 40 feet.
- Skews may be 0, 10, 20, 30, or 45 degrees.

- The six-beam cross section makes use of W30 to W44 shapes.
- Substructure plans cover integral abutments and T-piers.
- Only an F-shape barrier rail is provided.

The range of lengths and spans are given in Table 3.6.1.5.

**Table 3.6.1.5 Lengths, spans, and beam depths for RSB three-span continuous bridges**

| Length (1) Feet | End Span (2) feet | Interior Span (3) Feet | Beam Depth (4) feet-inches |
|---|---|---|---|
| 160 | 48 | 64 | 2-6 |
| 180 | 54 | 72 | 2-6 |
| 200 | 60 | 80 | 2-9 |
| 220 | 66 | 88 | 2-9 |
| 240 | 72 | 96 | 3-0 |
| 260 | 78 | 104 | 3-4 |
| 280 | 84 | 112 | 3-4 |
| 300 | 90 | 120 | 3-4 |
| 320 | 96 | 128 | 3-4 |
| 340 | 102 | 136 | 3-8 |

Table notes:

(1) Length is measured from centerline of abutment to centerline of abutment.
(2) End span is measured from centerline of abutment to centerline of pier.
(3) Interior span is measured from centerline of pier to centerline of pier.
(4) Add beam depth, 8.5-inch deck, and 2-inch estimated haunch to determine superstructure depth.

These three-span standard bridges are not readily adaptable to other span, length, width or skew conditions.

## 3.6.1.6 PPCB

The majority of the bridges designed for Iowa highways make use of standard pretensioned prestressed concrete beams (PPCB). Presently there are eight series of beams listed in Table 3.6.1.6 that are available. The eight series allow for design of bridges with single spans or multiple spans with varying span lengths.

In general, the bulb tee beam series BTB through BTE are preferred. The A-D series beams may be utilized with approval by the supervising Unit Leader.

Various factors should be considered with the BTB through BTE series beams:

- High skews: The bulb tee beams are generally limited to use with bridge skews of 30 degrees or less. Use of the bulb tees with higher skews may require wider abutment and pier caps to accommodate the wide bottom flange of 30 inches. Bulb tee beams shall not be used for skews greater than 60 degrees. In some situations, a longer span may be available as an option to reduce the bridge skew. For bridges with skews greater than 30 degrees, the designer should consult with the supervising Unit Leader. If non-standard abutment or additional pier width is proposed, a note shall be included on the TSL.
- Estimated haunch limitations: When considering the use of bulb tee beams, take into account the geometrics of the roadway. For long spans on roadways with sharp vertical curves, the longer bulb tee beams may not be feasible because of the large haunches necessary for vertical curves. The preliminary designer may estimate the haunch dimensions using the calculation method given in the commentary. In cases where the estimated haunch limitations are exceeded, the designer should consider the following approaches:
    - Coordinate with road design regarding flattening of the roadway profile grade vertical curve to reduce the beam haunch calculation.

    - Consult with the Final Design Project Development Engineer to determine a preferred approach:
        - The Final Design Project Development Engineer may review the anticipated haunch maximum and location (mid-span or end of span) and determine that the condition should result in an acceptable design. Maximum haunch at mid-span is generally of more concern due to flexural design capacity. Such a determination should be documented by a Designer Note on the TSL.
        - A final design solution such as special design of prestressed beams to adjust camber or reduction of beam spacing to minimize deflection. If special design consideration is the desired approach, a Designer Note shall be placed on the TSL.
        - A change to the span arrangement (for example the addition of a pier to reduce the span length, resulting in a reduced haunch)
        - Changing the bridge beam type to steel.
- Maximum offset on horizontal curve limitations: Sharp horizontal curves may limit the use of precast concrete beams. For more information, see [BDM 3.6.3]

For exceptions to the guidelines above and decisions regarding unusual project conditions the designer shall request approval from the supervising Unit Leader.

**Table 3.6.1.6 Standard pretensioned prestressed concrete beams**

| **Beam Type** | | | | | | | |
|---|---|---|---|---|---|---|---|
| A (1) | B (1) | C (1) | D (1) | BTB (2) | BTC (2) | BTD (2) | BTE (2) |
| **Beam Depth, feet-inches** | | | | | | | |
| 2-8(3) | 3-3(3) | 3-9(3) | 4-6(3) | 3-0(3) | 3-9(3) | 4-6(3) | 5-3(3) |
| **Span Length, Centerline to Centerline of Bearing, feet-inches** | | | | | | | |
| 30-0 | | 30-0 | | 30-0 | 30-0 | | |
| 34-2 | 34-2 | 34-2 | 35-0 | 35-0 | 35-0 | | |
| 38-4 | 38-4 | 38-4 | 40-0 | 40-0 | 40-0 | | |
| 42-6 | 42-6 | 42-6 | | | | | |
| 46-8 | 46-8 | 46-8 | 45-0 | 45-0 | 45-0 | | |
| 50-10 | 50-10 | 50-10 | 50-0 | 50-0 | 50-0 | 50-0 | |
| 55-0 | 55-0 | 55-0 | 55-0 | 55-0 | 55-0 | 55-0 | |
| | 59-2 | 59-2 | 60-0 | 60-0 | 60-0 | 60-0 | 60-0 |
| | 63-4 | 63-4 | 65-0 | 65-0 | 65-0 | 65-0 | 65-0 |
| | 67-6 | 67-6 | | | | | |
| | | 71-8 | 70-0 | 70-0 | 70-0 | 70-0 | 70-0 |
| | | 75-10 | 75-0 | 75-0 | 75-0 | 75-0 | 75-0 |
| | | 80-0 | 80-0 | 80-0 | 80-0 | 80-0 | 80-0 |
| | | | 85-0 | 85-0 | 85-0 | 85-0 | 85-0 |
| | | | 90-0 | 90-0 | 90-0 | 90-0 | 90-0 |
| | | | 95-0 | 95-0 | 95-0 | 95-0 | 95-0 |
| | | | 100-0 | 100-0(4) | 100-0 | 100-0 | 100-0 |
| | | | 105-0 | 105-0(4) | 105-0 | 105-0 | 105-0 |
| | | | 110-0 | | 110-0 | 110-0 | 110-0 |
| | | | | | 115-0 | 115-0 | 115-0 |
| | | | | | 120-0(4) | 120-0 | 120-0 |
| | | | | | | 125-0 | 125-0 |
| | | | | | | 130-0 | 130-0 |
| | | | | | | 135-0 | 135-0 |
| | | | | | | | 140-0 |
| | | | | | | | 145-0 |
| | | | | | | | 150-0 |
| | | | | | | | 155-0(4) |

Table notes:

(1) Use of the BTB-BTE series beams is preferred. Use of the A-D series beams may be utilized with approval from the supervising Unit Leader. The normal distance from centerline of beam bearing to centerline of pier is 9 inches. Exceptions require approval of the supervising Unit Leader.

(2) The normal distance from centerline of bulb tee bearing to centerline of pier is 12 inches. Exceptions require approval of the supervising Unit Leader.

(3) Add beam, 8.5-inch deck, and 2-inch estimated haunch depth to determine superstructure depth. Recently released standards utilize an 8.5-inch deck.

(4) May need an additional beam line. (see standard cross section sheets)

Standard cross sections for PPCB bridges have roadway widths of 30, 40, and 44 feet [BSB SS 4380, 4383-4385, 4556-BTC-4 to 4561-BTE-6, 4380-BTB-4 to 4385-BTE-6].

### 3.6.1.7 CWPG [AASHTO-LRFD 2.5.2.6.3]

Continuous welded plate girder (CWPG) bridges are used for spans longer than 155 feet or where minimum superstructure depth is required or where the horizontal alignment is sharply curved. The approximate maximum economical span is 300 feet for constant depth girders and about 550 feet for haunch girders. The Bureau has standard CWPG bridge cross sections but custom designs the girder cross sections for each project.

Because of continuity, span lengths generally are balanced to avoid uplift and other undesirable conditions. To avoid uplift at the abutment and significant imbalance the Bureau prefers that an end span be a minimum of 60% of the length of the adjacent interior span. For balanced moments the end span should be in the range of 75 to 80% of the length of the adjacent interior span. As a maximum, the Bureau prefers that the end span not exceed 80% of the adjacent interior span.

Unless the bridge site presents vertical clearance or profile grade issues, the goal is to set composite girder depths (slab + girder) at about 1/25 of the span. If it is necessary to use shallower girders, the Bureau prefers that the designer consider the AASHTO LRFD span-to-depth ratios to be minimum [see BDM 5.5.1.4.1.12, BDM C3.6.1.7, and AASHTO-LRFD 2.5.2.6.3]. CWPG superstructures typically have four or five girders spaced at 8.25 feet to 10.25 feet. Spacings to 12 feet are considered on a case-by-case basis. Usually interior and exterior girders are designed to be the same.

For exceptions to the guidelines above and decisions regarding unusual project conditions the designer shall request approval from the supervising Unit Leader.

### 3.6.1.8 Cable/Arch/Truss

Span lengths or other unusual project conditions may dictate a cable, arch or truss bridge type. Use of an unusual bridge type shall require approval from the supervising Unit leader.

Bridges utilizing cables, arch members or truss members that are not redundant shall consider Zone of Intrusion [BDM 3.14] to lessen the likelihood of contact from vehicle impact.

## 3.6.2 Width

### 3.6.2.1 Highway

Guidelines for bridge widths for new and reconstructed highways and for county roads are given in two chapters of the Design Bureau's Design Manual [DB DM 1C-1, 6B]. However, to allow for maintenance a minimum 40-foot width should be proposed for state highway bridges with two-way traffic. See also bridge width needs for bridge inspection and maintenance accessibility [BDM 3.6.7].

For new bridges carrying freeways, expressways, super-two highways, rural two-lane highways, transitional facilities, and ramps and loops, the recommended bridge width is the lane widths plus shoulder widths. A minimum 40-foot width is desired for two-lane rural and transitional highway facilities. For new bridges carrying reduced-speed urban facilities and for existing bridges carrying all types of highways the recommended bridge width may be different than the approach roadway width [DB DM 1C-1]. A desirable bridge width for an urban roadway (45 mph or less) is the lane plus shoulder widths (curbed or uncurbed) or the design lane width plus 3-foot offset on each side (curbed), whichever is greater. On single lane flyover ramp bridges, a 32-foot~~feet~~ width should be considered (in lieu of a 26-foot ~~feet~~ wide ramp bridge) to facilitate future deck maintenance and improve horizontal sight distance.

For bridges carrying county roads in interchanges, the width should be set as for non-National Highway System (NHS), rural two-lane highways [DB DM 6B-2, 1C-1].

For bridges carrying county roads not in interchanges, the minimum width should be 30 feet for an average daily traffic (ADT) of 1500 or less and 40 feet for an ADT greater than 1500 [DB DM 6B-3]. The 30-foot minimum width provides for wide farm machinery. For county roads, in all cases the designer shall discuss the proposed width with the county engineer.

For bridge widths greater than 120 feet, the designer should consider that a 2-inch gap may be needed to reduce temperature forces.

For interstate projects with paved medians, the bridge width may be greater than the lane widths plus shoulder width. AASHTO's *A Policy on Design Standards--Interstate System, 5th Edition* [BDM 3.1.5.2] states that the width of all bridges, including grade separation structures, measured between rails, parapets, or barriers shall equal the full paved width of the approach roadways. Special considerations are listed below.

- **A single median roadway barrier rail**

  It is usually desirable to provide a 2-inch gap between bridge decks and a 6-inch gap between back of bridge barrier rail. If the median portion of the bridges will be used for temporary traffic staging and the barrier rail will be installed in a later stage, it will be desirable to construct a slotted drain between the bridges to provide drainage in the area of staged traffic.

- **A separated median roadway barrier rail**

  The barrier rail on the bridges will normally align with the approach roadway barrier rail, with the deck slab extending the typical 2 inches. To retain the approach fill and median roadway pavement, the abutments should maintain the 2-inch gap. To accommodate staged traffic in the median portion, the bridge decks should follow the temporary traffic staging guideline in the paragraph above.

- **Bridges where a light pole blister or sign truss are proposed in the median between the bridges.**

  For urban corridor projects, contact the Traffic and Safety Bureau to coordinate signing and lighting needs. In some cases, the proposed light poles or signs can be relocated beyond the bridges or shifted to the outside.

  When light poles or sign trusses cannot be relocated, these structures are preferred to be mounted behind the barrier rail with an offset beyond the minimum zone of intrusion. Offset guidelines below are from top traffic face of “F” shaped barrier to obstruction proposed to be mounted on a bridge:
    - A minimum offset of 18 inches at a height of 120 inches from gutter line shall be provided for light poles and bridge mounted signs (TL-3 or TL-4). A sufficient clear distance between bridge decks to accommodate light poles or bridge mounted signs is 2’-10.
    - A 34-inch offset at a height of 96 inches from gutter line is preferred for overhead sign trusses (TL-4). A sufficient clear distance between bridge decks to accommodate overhead sign trusses is 6’-10.
    - Cantilever sign trusses are not allowed on bridges due to vibration and fatigue concerns.

  If the need for sign or light pole structures is anticipated at the preliminary design stage, the designer should review the available clearance between the bridges to check that sufficient clear width is available. It should be noted that in a median installation the loss of shoulder to accommodate light poles, signs or sign trusses is undesirable. Exceptions will be allowed based on consultation with the Design Bureau and the Chief Structural Engineer.

### 3.6.2.2 Sidewalk, shared use path, and bicycle lane

This article addresses sidewalks, shared use paths and bicycle lanes on highway structures. Refer to article ~~BDM 3.5~~BDM 3.5 for superstructure width requirements in other situations.

Because sidewalks on highway structures are costly, the Bureau generally includes sidewalks only on urban structures or where a local agency agrees to pay the cost [DB DM Chapter12A]. The minimum clear width is 5 feet. Wider sidewalks may be considered on the basis of approach sidewalks. When a sidewalk is proposed on a bridge, the designer should review the commentary for this article to determine whether to design raised sidewalks or sidewalks at grade. To assist in coordination with the Design Bureau, the determination should be noted on the TS&L.

To accommodate shared use paths on highway structures, the Bureau normally follows the width guidelines in the Design Bureau's Design Manual [DB DM Chapter 12B]. A separated path on a bridge should normally be 10 feet wide. This path width does not require a design exception even though it is narrower than the width recommended by AASHTO's *Guide for the Development of Bicycle Facilities* [BDM 3.1.5.2]. If especially heavy use is anticipated, a 12- or 14-foot wide ~~bike~~ path should be considered.

In determining width for sidewalk or separated shared use path, consideration should be given to bridge inspection and maintenance (See [~~BDM 3.6.7~~BDM 3.6.7]). If there is good access underneath the bridge, a high lift can be used from below. However, special consideration should be given to bridges with limited access underneath or very high structures. For these cases, some additional guidance is listed below:

- To provide access for a typical bridge layout, a snooper on the bridge can reach over a 5-foot wide sidewalk.
- To provide access for a steel welded girder bridge, a system of catwalks or cables on the girders may be considered. The girders need to be more than 6 feet deep so the inspectors can stand up straight.
- To provide access for a very limited subset of bridges, such as tied arches or deck trusses, the designer should first coordinate with the Bureau's maintenance and inspection unit staff before setting sidewalk or path dimensions. In some cases, sidewalk or path widths greater than 5 feet should be increased to 12 feet to allow for snooper access.

For both paths and sidewalks, the width should be labeled as clear width on the TS&L. This is to ensure that rail attached to the back side of the separation barrier does not encroach on the needed design width.

Although less common on roadway structures, designated bike lanes without barrier separation from traffic may also need accommodation. To provide for a bicycle lane adjacent to a driving lane on a bridge, the bicycle lane width should be 5 feet wide, as measured from barrier rail to bicycle lane stripe at edge of driving lane.

## 3.6.3 Horizontal curve

If a bridge is to be placed along a horizontally curved alignment, the designer will need to decide how to configure the superstructure. For relatively insignificant curves, a superstructure may be constructed with straight beams or girders between locations of support, but for significant curves the beams or girders will need to be curved. With straight beams or girders, the Bureau prefers that all substructure units be skewed at the same angle so that all members within a span are the same length. The decision to require horizontally curved members generally limits the superstructure type and increases both final design and construction cost, so the designer needs to make the decision carefully.

The designer shall note the terminology "bridge chord" and "span chord." Bridge chord is defined as the straight line between intersection points of the centerline roadway (or alignment baseline) at the centerline of bridge abutments. Span chord is defined as the straight line between intersection points of the centerline roadway (or alignment baseline) at the centerline of each substructure unit.

The Bureau has the following policy for horizontal curves. First, the designer shall determine the distance between the bridge chord and arc, defined here as M, at the midpoint of the bridge, and the offset between the span chord and the arc, defined here as S. Tables 3.6.3-1 through 3.6.3-3 provide policy guidance for preferred bridge layouts based on the bridge chord and span chord offsets. Site conditions may dictate a different approach. Contact the Unit Leader for special cases or unique circumstances that are not covered below.

**Table 3.6.3-1 Pretensioned, Prestressed Concrete Beam (PPCB) Bridge**

| | M < 1’ | M > 1’, S < 9” | M > 1’, S > 9” |
|---|---|---|---|
| Deck | Straight with proposed gutterlines parallel to the bridge chord. | Curved | (2) |
| Deck Width | Increase width to provide full shoulder at all locations. (1) | Width per design guidelines. | (2) |
| Substructure Units | Consistent skew to the bridge chord. | Consistent skew to the bridge chord. | (2) |
| Beams | Parallel to the bridge chord. | Parallel to the span chords. | (2) |

(1) End to end of bridge wings. See paragraphs below.
(2) Consider a curved steel beam bridge. Consult with the Unit supervisor before proceeding with a PPCB bridge.

**Table 3.6.3-2 Continuous Concrete Slab (CCS) Bridge**

| | M < 1’ | M > 1’ |
|---|---|---|
| Deck | Straight with proposed gutterlines parallel to the bridge chord. | (2) |
| Deck Width | Increase width to provide full shoulder at all locations. (1) | (2) |
| Substructure Units | Consistent skew to the bridge chord. | (2) |
| Span Length (1-foot transverse width of slab) | Parallel to the bridge chord. | (2) |

(1) End to end of bridge wings. See paragraphs below.
(2) This geometry typically doesn’t occur for slab bridges due to the short bridge lengths.

**Table 3.6.3-3 Steel Girder Bridge**

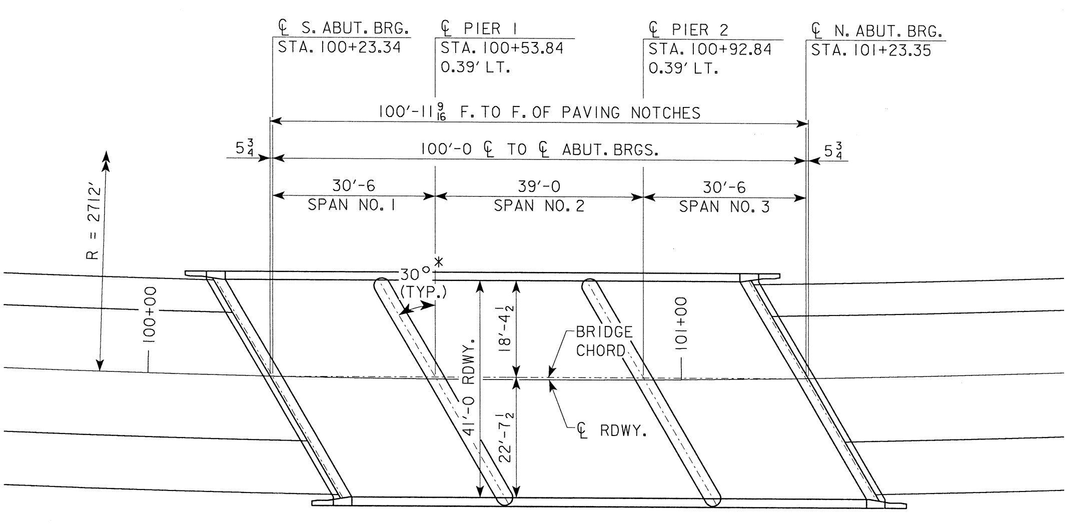
| | M < 1’ | M > 1’ |
|---|---|---|
| Deck | Straight with proposed gutterlines parallel to the bridge chord. | Curved. |
| Deck Width | Increase width to provide full shoulder width at all locations. (1) | Width per design guidelines. |
| Substructure Units | Consistent skew to the bridge chord, so that beams will be the same length | Radial. A consistent skew to the bridge chord may be preferred for a bridge over side road crossing. |
| Beams | Straight – parallel to the bridge chord | Concentric beam lines. |

(1) End to end of bridge wings. See paragraphs below.

For straight bridge decks built on a curved roadway, the bridge roadway width will typically increase by 1' (M plus the additional width to round the bridge roadway width up to the nearest whole foot). Extra width due to whole foot rounding may be distributed equally on each side of the bridge or placed asymmetrically to avoid barrier rail shoulder encroachment. The TS&L shall define the distribution of the bridge roadway width right and left.

For bridges with standard wing end sections (no wing extension), the bridge width shall be set to avoid barrier rail encroachment. For bridges with wing extensions, a curved or kinked wing may be needed. The TS&L shall contain a note defining the wing alignment, if different from the alignment on the bridge.

For straight bridge decks with normal crown, the top of crown should follow the bridge chord. For straight bridge decks with normal crown or superelevated conditions, the grade calculated along the curvilinear alignment shall be shifted radially to the bridge chord. Bridge deck cross slopes shall be calculated using elevations along the bridge chord and cross slopes relative (perpendicular) to the bridge chord. The piers should be dimensioned to the bridge chord location at centerline pier, with station and offset provided from centerline roadway (or baseline). An example layout for a straight bridge based on the chord is shown in Figure 3.6.3-1.




* THE SKEW ANGLE IS MEASURED TO THE CHORD AND IS THE SAME FOR BOTH ABUTMENTS AND PIERS.

**Figure 3.6.3.-1 Stationing layout for a straight bridge based on the chord**

For curved bridge decks, the bridge deck grades will be calculated based on the roadway profile grade along the curvilinear alignment and radial cross slopes. The designer shall label bridge stationing from the centerline of the approach roadway (or baseline alignment). The stationing should be referenced from the design alignment as shown in Figure 3.6.3-2.

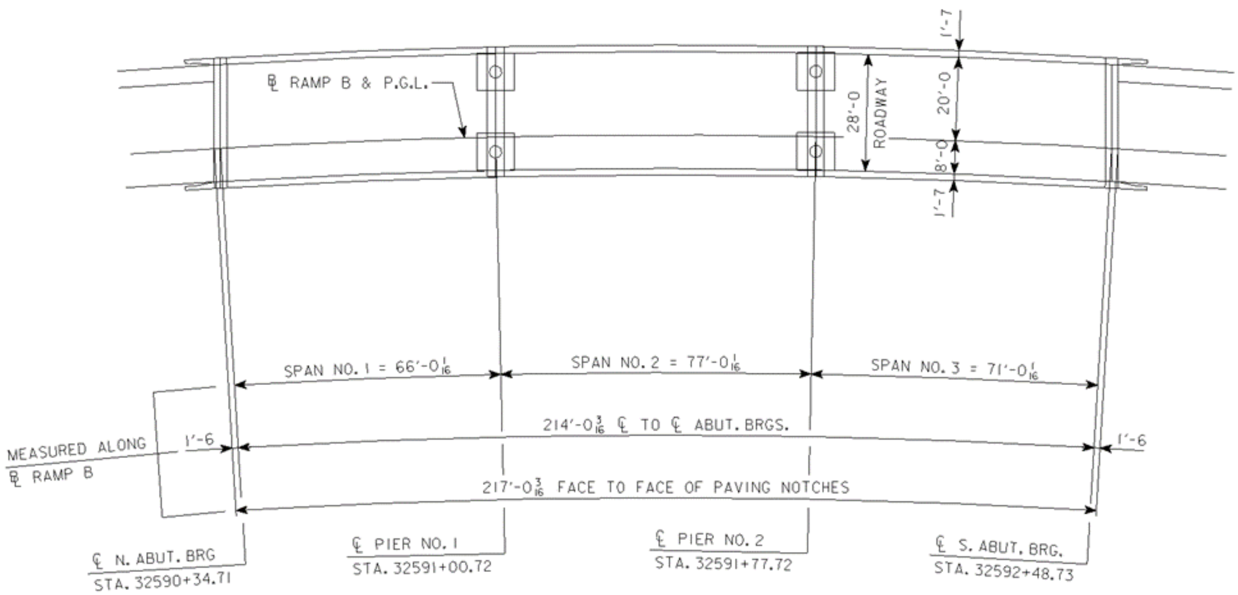



**Figure 3.6.3.-2 Horizontally curved bridge stationing layout**

### 3.6.3.1 Spiral curve

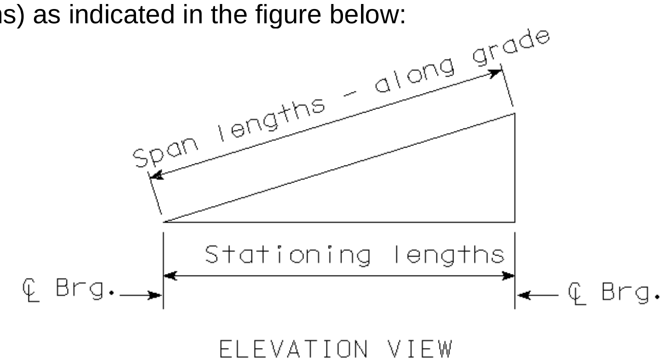
The use of spiral curves in roadways in Iowa is an accepted practice to improve alignment and safety. In order to minimize the effects of complicated roadway geometry in bridges, spiral curves will either be moved off the bridge or eliminated from use [DB DM 2C-1] in order to simplify design and construction.

## 3.6.4 Alignment and profile grade

It is preferable that the horizontal alignment for a bridge be straight. Final design software usually can expedite the final design for a straight bridge. Where a curve in the alignment affects only part of a bridge, the designer should consult with the Design Bureau to adjust the horizontal alignment to move the curve off the bridge, if possible.

It is preferable that the vertical alignment not create a flat, difficult-to-drain location on the bridge. If a low point is located on the bridge, the designer should consult with the Design Bureau to adjust the vertical alignment to move the low point off the bridge [DB DM 2B-1].

When the difference between the horizontal length and the profile grade length for any span within a PPCB bridge is greater than ½ inch the following applies. Bridge stationing shall be measured along the horizontal from centerline to centerline of bearings (vertical), but individual spans and bridge length are to be measured along the grade from the centerline to centerline of bearings (normal to grade based on standard beam lengths) as indicated in the figure below:



The preliminary situation plan should dimension the horizontal lengths of the bridge, centerline to centerline of abutment bearings and centerline to centerline of spans, and the corresponding stations. The plan should also include the dimension lengths from centerline to centerline of abutment bearings and face to face of paving notches for the lengths along the profile grade. Label these lengths “Horizontal” and “Along Grade”. All other applicable plan lengths should be labeled accordingly. Although the span lengths based on profile grade will be known approximately during preliminary design, the final designer may need to adjust the lengths slightly depending on camber.

For a two-span overpass in an urban location, a convex vertical alignment may cause excessive haunch above pretensioned prestressed concrete beams (PPCBs). The designer should be aware of the potential difficulty and consult with the Design Bureau, if necessary.

A minimum grade of 0.5% for bridge replacement projects is the preferred design criteria [DB DM 1C-1]. However, a grade of 0.3% with roadway curb and 0.0% without roadway curb is the acceptable design criteria.

When developing plans for bridges on four lane divided highways:

- Do not use the term “Centerline of Bridge Roadway” in the plans.
- Show the “Profile Grade Line” on the Situation Plan.
- Stations on the “Situation Plan” view should be shown at the “Centerline of Approach Roadway”. The elevations shown in the “Longitudinal Section Along Centerline of Approach Roadway” should coincide with the stations shown in the “Situation Plan” view.

For all bridges shown in longitudinal section, show top of bridge deck elevation taking parabolic crown into account (see commentary for this article).

## 3.6.5 Bridge Deck Cross Slopes

In most cases, bridge deck cross slopes are desired to match roadway lane cross slopes and bridge shoulder cross slopes are desired to match adjacent lanes. A “Typical Bridge Section” detail shall be included on the TSL to differentiate the intended bridge deck cross slopes, as compared to the “Typical Approach Section” detail shown to the left of the Situation Plan. Consultant’s shall provide additional detail as outlined on the Preliminary Design Checklist-Bridge.

## 3.6.6 Deck drainage

If a bridge contains an area that is flat or difficult to drain, a revision to the profile grade or cross slope may be desired. In cross slope transition areas, the preliminary designer shall check the slope gradients on the bridge. Each gradient is the vector sum of the cross slope and the grade. If the slope gradient is less than 2%, a revision to the profile grade or cross slope is desired. If a grade or cross slope cannot be revised to obtain a 2% gradient, the preliminary designer shall work with the roadway designer and the Unit Leader to find an acceptable solution.

Bridge deck drain locations are determined in final design [BDM 5.8.4].

## 3.6.7 Bridge inspection/maintenance accessibility

For bridges with limited access underneath or with very high structures, inspections are normally performed from the roadway above requiring the use of a snooper. The maximum reach under a bridge with a snooper arm is 45 feet based on a zero-degree skew. Inspection access may also be obtained from a pedestrian/recreational pathway. See the article on Sidewalk, separated path, and bicycle lane [BDM 3.6.2.2]. The designer should coordinate with BSB Bridge Maintenance and Inspection to determine maintenance needs.

Dual bridges, 45 feet or wider, may require access from both the outside and median side. The desired median clear width to provide snooper access is 7 feet. If the maintenance needs for separation will result in a shift of the roadway alignment or barrier rail, the designer should coordinate with the Design Bureau.

When access from above is not practical for steel girder bridges, the following options will need to be considered.

- Inspection walkways
- Safety cables attached to girder webs

Other considerations for steel girder bridges:

- Weathering steel may require periodic washing.
- Painting of the exterior fascia in the median is recommended.

## 3.6.8 Railings~~Barrier rails~~ [AASHTO-LRFD 13.7.2]

~~The Highway Division Management Team recently approved a new policy for determining Test Levels (TL) and the associated heights for railings on new bridges on interstate and primary road bridges. The policy is intended to be a supplement to the current AASHTO LRFD Specifications [AASHTO-LRFD 13.7.2].~~

~~The new policy states the following:~~
Test Levels (TL) and the associated heights for railings on interstate and primary road bridges is as follows:

- The need for a TL-6~~, minimum height 92 inches~~ railing is not anticipated for the vast majority of bridges in Iowa.
- All interstate mainline bridges shall require a TL-5 railing, minimum height 44 inches, 42 inches plus 2 inches for future overlay.
- Bridge railing test level and the associated height for other primary highways shall be evaluated by the Pre-Design Unit in the Design Bureau for replacement structures and the Preliminary Bridge Unit in the Bridges and Structures Bureau for other bridges. Basically, the evaluation will follow the flow chart in the commentary [BDM C3.6.8] and additional information in the policy statement.
- TL-2 and TL-3 barrier railings may also be used in low speed applications with favorable roadway characteristics.

The preliminary designer should note on the TS&L when TL-5 or another special rail is proposed.

Normally the preliminary designer is not involved in bridge rehabilitation projects. However, if the preliminary designer is involved with retrofit barrier rails on deck replacement, superstructure replacement, or widening projects on interstate or primary highway systems the designer shall consult with the Methods~~Chief Structural~~ Engineer. There may be special circumstances that require exceptions to the flow chart in the commentary [BDM C3.6.8].

Several standard bridge options have alternatives for an open barrier rail. The open rail option is not intended for use on Iowa DOT highway bridges.

### 3.6.8.1 Barrier Rail End Treatments

Bureau standard sheets detail the blunt end either with or without guardrail attachment details for typical conditions [BDM 5.8.1.1.1]. The barrier rail end section is a vertical end post section type, which if left unprotected could be impacted head-on by an errant vehicle. The approach end of all bridge rail end sections located within the clear zone shall require end treatment. For bridges on high-speed roadways, steel beam guardrail is the preferred treatment. However, crash cushions may be used where site conditions cannot accommodate steel beam guardrail. Sloped end transition (SET) end section type (BA-108 or other) for low-speed highways is required in the approach pavement. For bridges in urban areas, posted speed and roadway characteristics determines which type of treatment should be used [DB DM 8A-4]:

- If the posted speed is 35 mph or greater, use guardrail or a crash cushion.
- If the posted speed is 30 mph or less, use of guardrail or crash cushion is preferred. If constraints don't allow for placement of either of these options, a sloped concrete end treatment may be used.
- End treatment type will be determined by the Design Bureau.

In cases where the bridge is near an intersection, sight distance may not be adequate. The designer should consult with the Design Bureau at the field exam if the barrier rail may restrict sight distance near intersections. In some cases, the bridge geometry and barrier choice may be impacted, and therefore the sight distance adequacy shall be determined before the B1. Evaluation of appropriate sight distance is a Design Bureau responsibility.

### 3.6.8.2 Separation Rail

When a bridge provides for pedestrian and/or bicycle traffic in addition to vehicular traffic, the designer shall provide appropriate separation between the different streams of traffic. Although a barrier curb may be used for traffic speeds of 45 mph or less [AASHTO-LRFD C13.7.1.1], the Bureau has the policy of providing a separation railing for all but unusual circumstances.

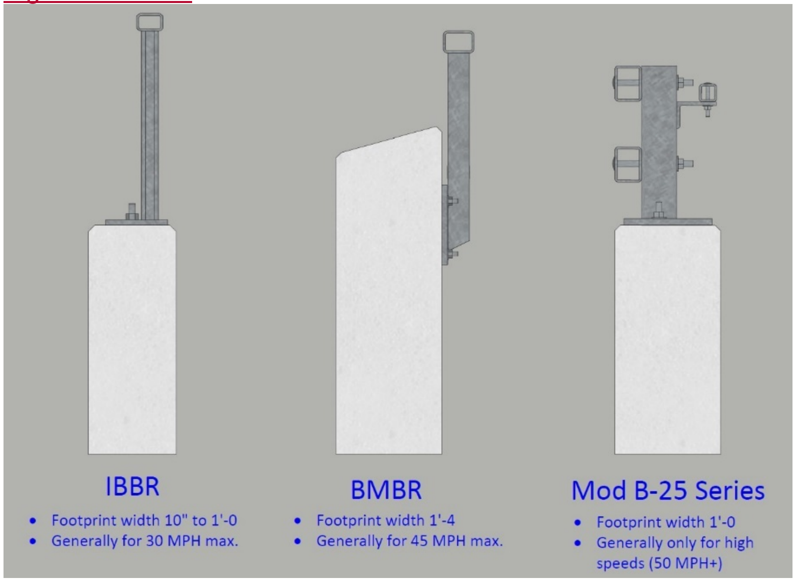
Separator type will usually be determined during preliminary design. The selection will generally be based on roadway posted speed, though there are other factors that may affect barrier selection for a project (e.g. aesthetic special railings, local preferences, or roadway characteristics). Iowa DOT standard practice is to use combination traffic and pedestrian railings that are also bicycle height compliant, since some bicycle traffic can be expected to occur on sidewalks that are not trail width compliant. A barrier and rail selection shall be carried through the full length of the bridge at a minimum. The preliminary designer should refer to BDM 5.8.1.2.4 for more detailed information and dimensions. If a separator type or footprint width changes after B1 completion, final design shall make any necessary adjustments.

The most common separator options meeting the Iowa DOT's MASH implementation policy for use on Iowa bridge projects are listed below:

- **IBBR (Iowa Barrier with Bicycle Railing) TL-2 Separation Barrier**
  - Restricted to roadways with posted speeds of 30 MPH or less, and it is the preferred separator type for those conditions due to its greater transparency and potential for reducing or eliminating sight distance conflicts, especially in urban areas.
  - Footprint width 10 inches to 1'-0. For preliminary design, 1'-0 should be assumed. The rail is mounted on the top without encroachment on the front (vehicle) or back side.
  - Raised sidewalk allowed (6 inches at back side of barrier)
- **BMBR (Back-Mounted Bicycle Railing) TL-2 Separation Barrier**
  - Restricted to roadways with posted speeds of 45 MPH or less. At posted speeds of 35 MPH and higher, a guardrail end connection or crash cushion is required (DB DM 8A-4) unless space restrictions prevent it. The BMBR may be used in place of the IBBR for lower posted speeds if desired for aesthetic reasons or to meet local municipality expectations or preferences. Check the application for sight distance conflicts before substituting the BMBR for the IBBR and contact the Methods Engineer for guidance.
  - Raised sidewalk allowed (6 inches at back side of barrier)
  - Footprint width is 1'-4. The footprint width includes sufficient space for the rail to be mounted on the back side.
  - May be used without its bicycle railing attachment for the traffic-only side(s) of bridges or as a sidewalk separation barrier with review and approval by the Methods Engineer.
- **Mod B-25 Series TL-3/TL-4 Separation Barrier**
  - Typically reserved for high-speed roadway bridges that include a trail or path. Bridges carrying roadways with posted speeds greater than 45 MPH must use this design unless there are mitigating circumstances. Contact the Methods Engineer for guidance on possible alternate solutions.

- o Raised sidewalk or trail not allowed. Consider using an at grade sidewalk or trail on the bridge and warp the trail profile and connection past the ends of the bridge wings.
- o May be used in a vehicular traffic-only condition when used on both sides of a bridge that has a sidewalk or trail only along one side. Omit the back-mounted bicycle railing attachment for vehicular traffic-only applications.
- o Footprint width is 1'-0. The rail is top mounted with no encroachment on the vehicle or back sides.
- o Requires guardrail or crash cushion termination in accordance with DB DM 8A-4.

Figure 3.6.8.2-1




Note: For more detail and dimensions, refer to BDM 5.8.1.2.4

### 3.6.9 Staging

For some bridge replacement projects, staged construction is desired in order to maintain traffic. It is the preliminary designer's responsibility to assure that the staging plan is workable. Staging refinement and details will be determined during final design; however, issues affecting the bridge type, size, location or profile are best resolved during preliminary design.

Staged construction of beam bridges generally may be considered. However, due to construction difficulties on CCS bridges, Unit Leader approval is required. In all cases, the designer should consult with the Design Bureau to coordinate the bridge staging options and needed traffic widths. To accommodate deck construction for staged beam bridges, a 4' preferred gap width should be provided between the Stage 1 existing deck removal cut-line and the proposed Stage 1 constructed deck. The intent is to provide sufficient space for Stage 1 construction deck reinforcing bar extensions needed for lap lengths. If the preferred gap width cannot be obtained with the proposed bridge width, coordinate with Bridge Methods and the Preliminary Design Unit Leader to select an acceptable option. Options may include one or a combination of the following:

- Propose using stainless steel reinforcing bars (SSR) (minimum 3' gap)
- Widen the proposed bridge deck (generally widen to accommodate the preferred 4' gap width)
- Propose using mechanical couplers (1.5' preferred, 1' minimum gap. A 16-inch wider gap may be needed if sheet pile is anticipated at the ends of the bridge.)

If a PPCB or steel bridge has only two beams supporting staged traffic, the capacity of the existing structure must be evaluated to ensure that it will carry all legal loads. This should be evaluated and documented before finalizing the concept. Rating of the existing bridge shall be based on the requirements in BDM 12.1.7. Slab bridges that are staged do not require review for legal loads.

Placing of the TBR during staged construction should be planned carefully with respect to the existing superstructure at each stage. Bureau policy is to place the TBR along the centerline of an existing beam wherever possible. If the TBR must be placed on a deck cantilever, the designer shall consult with the supervising Unit Leader and shall follow the guideline below.

- Place the TBR on the deck cantilever, limiting the placement so that the traffic side of the barrier face is a maximum of one foot from the centerline of the stage exterior beam. Also, provide a minimum of 6-inch clearance from the outside edge of the TBR to the edge of the deck. The maximum temporary deck cantilever length should be approximately 3.50 feet from centerline of the stage exterior beam.

Tie-downs are required for TBR near drop-offs. For severe dropoffs such as the edge of a bridge deck, tie-downs are required when the backside of the TBR to deck edge is less than 3.75 feet. With a Type B tie down strap the backside of the TBR may be as close as 6 inches to the edge of a bridge deck [DB DM 9B-9]. See the commentary for example concept staging sketches.

In addition to the superstructure issues listed above, substructure issues should also be considered by the preliminary designer. If an existing frame pier cannot be removed in stages due to stability, a sufficient profile is preferred such that there will be a vertical clearance of 1’ between the existing top of pier and the bottom of the new low beam. However, there may be times when partial removal of the existing pier cap may be allowed to facilitate placement of the new beams provided approval from the Unit Leader is obtained. The clearance allows sufficient space for the existing pier to be removed in its entirety once the traffic is placed on new construction.

## 3.7 Substructures

### 3.7.1 Skew

For horizontally straight bridges, skew is measured from centerline of roadway. For horizontally curved bridges, skew may be measured from centerline of roadway, a chord, or a tangent. Generally, if the abutments and piers for a curved bridge will be radial it is convenient to measure the skew from the centerline of roadway, and if the abutments and piers will be parallel it is convenient to measure the skew from a chord or tangent. The method for determining skew on curved bridges should be noted on the TS&L.

Except in unusual cases the Bureau limits skew to a maximum of 45 degrees. The Bureau prefers to use integral abutments, and the 45-degree maximum skew will allow use of integral abutments for most bridges. A skew larger than 45 degrees requires approval of the supervising Unit Leader. A highly skewed superstructure may require special final design, and the superstructure may require extra maintenance during its service life.

If the bridge will require stub abutments the Bureau prefers that the skew not exceed 30 degrees. Except in unusual cases, the Bureau limits the skew to a maximum of 45 degrees.

The skew for a straight bridge should be the same for all substructure components. If all substructure components have the same skew, beams or girders in the superstructure will be the same length, which will promote ease of fabrication and economy. The designer should seek approval of the supervising Unit Leader if skews of substructure components will vary.

The Bureau prefers that the designer set the skew to the nearest whole degree. The designer then should list this rounded skew in the title block for the TS&L but label the actual intersecting angle between the two roads on the plan view. However, if the new grade separation structure is adjacent to an existing structure that will remain in use, if horizontal clearance is limited, if a pier needs to fit a median barrier, or if the bridge is wide, the designer may set the superstructure to the appropriate exact skew angle rather than a rounded angle.

### 3.7.2 Abutments

Because of lower construction and maintenance costs the Bureau prefers integral abutments as shown on standard sheets and standard plans for bridges. Integral abutments are limited by bridge length, end span length, and soil or rock conditions at abutment sites. For most sites, downdrag due to compressible fills will not affect the use of integral abutments because only the top portions of the piles flex, and the downdrag stresses occur below these regions of high bending stresses.

The conditions and table below are summarized from the detailed information in the abutment section of Bridge Design Manual, and that section should be consulted for additional information [BDM 6.5.1.1.1]. Table 3.7.2 assumes that a bridge has approximately parallel abutments and piers and that a bridge is straight or horizontally curved with straight beams or girders. The Bureau generally does not use integral abutments for bridges with horizontally curved girders.

**Table 3.7.2. Bridge length limits for use of integral abutments**

| Superstructure Type / Typical Pile | Length and Skew Limits for Standard Integral Abutments (3) | Maximum End Span / Prebore Length (2) / Minimum Pile Length |
|---|---|---|
| PPCB / HP 10x57 | 575 feet at 0-degree skew to 425 feet at 45-degree skew (1) | Maximum A-D and BTB-BTE length / 10 or 15 feet depending on load / 15 feet to bedrock [BDM Table 6.5.1.1.1-1] |
| CWPG / HP 10x57 | 400 feet at 0-degree skew to 300 feet at 45-degree skew (1) | 120 to 150 feet / 10 or 15 feet depending on load / 15 feet to bedrock [BDM Table 6.5.1.1.1-2] |
| CCS / HP 10x42 | 400 feet at 0-degree skew to 300 feet at 45-degree skew (1) | 45.5 feet / 10 feet / 15 feet to bedrock |

Table notes:

(1) Use linear interpolation of length for intermediate skew.

(2) Prebore depth is related to axial structural resistance of the pile. Final designer may adjust the depth. The preliminary designer shall show a 10-foot deep by 16-inch wide prebore on the TSL for integral abutments on bridge lengths greater than 130'.

(3) The bridge length limits assume the thermal origin of the bridge is at the center of the bridge. The final designer will need to determine if integral abutments can be used if the thermal origin is not at the center of the bridge per the table notes in BDM 6.5.1.1.1.

If a working integral abutment is feasible at only one end of a bridge, the maximum length limit for the bridge shall be one-half the limit in the table, with no change in maximum end span length. In cases where a MSE retaining wall is used near an integral abutment, each pile shall be sleeved with a corrugated metal pipe (CMP) to control compaction near the pile as the embankment and MSE wall are built. Because the limits in Table 3.7.2 are more liberal than past limits, exceptions to these guidelines are not encouraged.

For relatively long, significantly curved, highly skewed, and other bridges that do not meet the integral abutment guidelines in Table 3.7.2, the designer should consider stub abutments. For many bridge and bridge site conditions stub abutments as detailed on standard sheets will be feasible. However, the designer will need to consider modifications to standard abutments and alternate abutment types for highly unusual bridges and bridge sites.

To estimate the bottom footing elevations for continuous concrete slab bridges, the designer should review the applicable standard sheets. To estimate the bottom footing elevation for beam bridges, the designer should first determine the deck elevation at the low side exterior beam centerline. From the top of deck subtract superstructure depth (deck/haunch/beam), estimated bearing height (3-inch integral/6-inch stub), and low step to bottom footing height (3.5 feet integral/4'-1 stub). The estimated bottom footing elevation will be level, except as noted below.

For integral abutments it is desirable to slope the abutment footing and top of berm when the difference in elevation from the centerline of exterior beams is greater than 1.5 feet.

For stub abutments it is typically desirable to keep the bottom of footing level and adjust the beam seats.

For the usual bridge deck profile or a moderately super-elevated deck profile the bottom of the stub abutment footing should be horizontal but, if the difference in bearing seat elevations is greater than 2.5 feet, the designer should consider sloping the bottom of the footing.

## 3.7.3 Berms

### 3.7.3.1 Slope

A bridge berm slope is generally normal to the bridge abutment, but also may be normal to a roadway or railroad under the bridge. Under normal situations the designer may make the following initial assumptions for berm slopes:

- For fill heights less than 30 feet from grade to toe of berm, the steepest berm slope may be taken as 2.5:1, horizontal to vertical.
- For fill heights from 30-40 feet, the steepest berm slope may be taken as 3:1.
- For fill heights greater than 40 feet, contact the Soils Design Unit for an initial berm slope estimate.

However, the designer shall also consider the following special situations:

- For bridges located over streams and rivers in the western Iowa Loess Hills counties (Woodbury, Monona, Harrison, Pottawattamie, Mills, and Fremont), and for bridges situated in meandered stream and river alluvial sites/environments statewide (See list in C3.10.1.), the designer should use a 3:1 berm slope with fill heights less than 30 feet unless a steeper slope has previously been reviewed by the Soils Design Unit. Note that bridges located over roads in upland Loess Hills areas are exempt from this shallower slope.
- For fill heights greater than 30 feet on either Iowa Loess Hills stream and river sites or meandered stream and river alluvial sites statewide (See list in C3.10.1.), the designer shall contact the Soils Design Unit for an initial slope estimate.
- For bridges statewide located in areas with special, unusual, extremely variable, and/or questionable soil conditions, the designer shall contact the Soils Design Unit for an initial slope estimate.

If steeper slopes are required, they may be accommodated by reinforced steepened slope (RSS) techniques, by lightweight fill techniques, and/or by soil remediation techniques such as intermediate foundation improvements (IFIs) or core-outs, but steeper slopes require full coordination with and design by the Soils Design Unit.

The initial assumptions for berm slopes discussed above are used to develop a preliminary Type, Size, and Location (TS&L) plan for a bridge. When final soils analysis shows that an alternate berm slope is required, either shallower or steeper, revisions to the TS&L may be required at that time.

The designer shall check the berm slope at all potential critical points along the berm. This will ensure that the required berm slope is provided anywhere on the berm.

Objects such as bridge piers and bridge berms can create a sight obstruction on the inside curve of a highway. Minimum sight distance is required based on curve radius, design speed, etc., measured along the centerline of the inside lane around the curve [DB DM 6D-1]. Bridge piers located at clear zones typically do not cause an obstruction. Bridge berms located at the edge of the shoulder and within or close to a horizontal curve need to be checked by the Design Bureau to verify that the berm is not causing an obstruction. These bridges may need to be lengthened to accommodate sight distance.

### 3.7.3.2 Toe offset

To improve snow removal operations and storage and reduce maintenance costs for roadway grade-separation structures with no side piers, it is desirable to design the finished grade of the berm toe 5 feet from the edge of shoulder. A minimum of 4 feet offset is acceptable for PPCB bridges if sufficient beam length remains to obtain the 4-foot minimum from the edge of shoulder to the toe. Use the next beam increment for that span if the minimum offset cannot be obtained. For CWPG bridges, set the toe of berm at the 5-foot offset location. For standard design bridges, ensure that minimum toe offsets are obtained.

### 3.7.3.3 Berm slope location table

The berm slope location table (BSLT) provides key points on the bridge berm to define the grading surface. This information is used by the Design Bureau to calculate earthwork quantities and by the road contractor to assist in constructing the bridge berms. A BSLT shall be placed on the TS&L for all new bridges, or when a bridge is replaced or widened. Older versions of the BSLT on completed TS&L sheets will be grandfathered.

See the Design Bureau's Standard Road Plans for earthwork [DB SRP EW 201-204] as these standards work with the BSLT. The grading surface represents the top of slope protection for grade separation structures. For river crossings, riprap may be placed on top of the grading surface or embedded below when needed to increase the bridge opening area. A typical section riprap detail identifying the grading surface must be included on the TSL sheet to clearly show the intent. Refer to the commentary for additional guidance related to typical berm situations and example design details.

Points A, B, D and W are the key points used to describe the grading surface. All points are defined by their elevation, station and offset (as referenced from the centerline of construction survey or survey baseline). The points are located a distance of 3 feet from the outside edge of the bridge. W is defined as the grading surface at the end of wing. To determine the elevation at W, drop 0.15 feet from the edge of shoulder elevation. B is at the top of berm and A at the toe of berm. The Point B, top of berm elevation, should be set at an elevation 2' above the estimated bottom abutment footing elevation. Sometimes additional A or B points are needed to better define the berm, especially for bridges with skews greater than 15 degrees.

For dual bridges with complex or non-uniform berms, the addition of D points may be desired. The intent of the D points is to define a single grading control line for both bridges at a constant elevation. See commentary for examples.

Potential differences between preliminary design BSLT estimates and final calculated values are a normal part of the design process and should be addressed during final design. The intent is to avoid re-involving preliminary design to update a BSLT or berm terrain model.

The letters A, B, C, D and W are reserved for the bridge berm grading. If additional points are desired to better define the grading needed, use a different lettering scheme.

For roadway grade separation structures with no side piers, A points are defined where the finished grade of the berm meets the edge of the shoulder plus offset [DB SRP EW-203 and EW-204, BDM 3.7.3.2]. For roadway grade separation structures with side piers, A points are usually defined at the clear zone [DB SRP EW-211]. The designer can determine the elevations of A points from existing or proposed grade information for the roadway under the bridge and cross slopes of the pavement and shoulder. For a bridge over a stream, railroad, or urban roadway A points are defined where the toe of the berm meets the existing ground or proposed ground surface.

### 3.7.3.4 Recoverable berm location table

A recoverable berm location table (RBLT) provides bridge baseline station/offset and elevations for the various points to provide sufficient information for the contractor to construct the recoverable berm [DB SRP EW 203 & EW-204]. A recoverable berm is constructed for bridge berms with no outside piers and provides a flattened slope for errant vehicles. When the toe of the bridge berm is not located within the clear zone, an RBLT is not required.

The recoverable berm is represented by points B, C1, C2, and C3, as shown on the standard construction details sheet [DB SRP EW 203 & EW-204]. Point B is located 3 feet from the outside edge of the bridge deck at the top of the bridge berm. In order to create the flattened area for the recoverable berm, a line must be established that is 15 degrees or less from the edge of the lane (traveled way) to point B. This will establish the line segment BC from point B to point C2, which should be at a 6:1 horizontal to vertical or flatter slope. If the slope is greater than 6:1, the angle from the lane to point B must be lowered to graphically determine the limits of the recoverable berm.

The line segment BC intersects the edge of the shoulder at point C3. The elevation of point C3 is the edge of the shoulder elevation at that location. Point C2 is on line BC and is located a distance equal to twice the shoulder width from the edge of the traveled way. Continuation of the shoulder slope to point C2 determines the elevation.

The station distance between point C2 and C3 is defined as “X”. A station distance “X” toward the bridge should be applied to determine the location of point C1. Point C1 should be 5 feet from the edge of the shoulder unless otherwise noted on the TS&L, minimum of 4 feet. See the standard road plan for bridge berms with no outside piers for more information [DB SRP EW 203 & EW-204, BDM 3.7.3.2]. The elevation of point C1 is based on a continuation of the shoulder slope to that location. Point C1 is established to provide a transition from the recoverable berm back to the normal toe of the bridge berm. See the example RBLT in the commentary for this article.

Potential differences between preliminary design RBLT estimates and final calculated values are a normal part of the design process and should be addressed during final design. The intent is to avoid re-involving preliminary design to update an RBLT or berm terrain model.

### 3.7.3.5 Slope protection

This article covers slope protection guidelines for all except railroad bridges [BDM 3.4.1.4, 3.4.2.4].

- **Bridges over roadway**

  For bridges over a roadway, macadam slope protection is typically used. Concrete slope protection should be shown on berms adjacent to path or sidewalk facilities. Exceptions to this include proposing slope protection to conform to project aesthetic guidelines.

- **Bridges over waterway**

  For bridges over a waterway it is recommended that riprap be placed on the bridge berms due to limited maintenance resources and the potential for significant abutment scour. See also the article for riprap at abutments [BDM 3.2.2.7.5.1, to be added in the future].

  In most cases, specify riprap to a minimum 50-year flood elevation with erosion stone extending from the riprap to the front face of the abutment. When the top of berm is significantly higher than the 50-year flood elevation, it is recommended that erosion stone be placed from the top of riprap to the top of berm to protect the berm slope from deck drains and local erosion/scour.
  The exception is when designing riprap for a bridge with a pressure flow condition. A pressure flow condition for the purpose of determining type of slope protection is defined below. For the pressure flow condition, extend riprap placement to the front face of the abutment.

1. The 100-year water surface exceeds the low beam at the abutment creating a pressure flow situation.
2. Bridges behind levee systems, where levee failure could create a pressure flow condition.

For projects that require a sovereign lands permit, a broken concrete substitute for riprap will not be allowed. The prelim designer should place a note on the TSL directing the final designer to include this restriction in the revetment bid item reference notes.

## 3.7.3.6 Grading control points

If channel shaping, benches, wing dikes, or other special grading is required, the designer shall provide the grading intent in a proposed grading surface terrain. Key grading control point stations, offsets and elevations may be included on the TS&L labeled as “G” points. A typical stream crossing example showing proposed channel grading is shown in the commentary. The purpose of the proposed grading surface terrain and grading control is to communicate channel or special grading needs to the Design Bureau, which will assist them in the preparation of the grading plans.

Generally, channel grading control would be shown in one of two ways:

- By centerline stream – provide the alignment, profile, typical cross section and begin/end locations
- By toe of channel – provide a series of grading control points along each side of channel at the toe of slope

## 3.7.3.7 Mechanically Stabilized Earth (MSE) Walls adjacent to abutments

The Bureau discourages the use of MSE walls in lieu of sloped berms to shorten a bridge. However, the Bureau accepts the use of MSE walls in lieu of sloped berms as part of a solution to avoid ROW impacts or to address unique site conditions. If an MSE wall solution is proposed, the preliminary designer shall coordinate with the Design Bureau (DB) and the Bridge Bureau aesthetics coordinator relative to structure geometry, MSE wall alignment and aesthetic accommodations.

MSE walls may be proposed for the approach roadway and terminate at the back face of abutment footing/diaphragm or at the end of a bridge wing extension/wing. MSE walls may also continue past the abutment and along the edge of bridge fore slope to terminate at the toe of the berm, or they may wrap around the bridge abutment from the front to the sides. The “W” points in the BSLT table are not required for corners of the bridge with proposed roadway approach MSE walls.

**Considerations for Integral Abutments:**

For MSE walls along the front face of an integral abutment, the centerline abutment bearing shall be placed at least 4.5 feet from the front face of an MSE wall.

**Considerations for Stub Abutments:**

The centerline of the piling shall be a minimum of three feet from the face of the MSE wall at the bottom of the MSE wall. The front row of piles shall be battered unless the batter increases the bridge length by more than five feet due to the interference with the MSE wall. The preliminary designer should consult final design before proposing a stub abutment with 6:1 or vertical piling.

Considerations for MSE Wall/Abutment Systems:

- If an MSE wall/abutment system is located outside of the clear zone and the abutment is supported on deep foundations such as piling or drilled shafts, redirection/absorption or design consideration of the collision load will not be required.
- If an MSE wall/abutment system is located within the clear zone or if the abutment is outside of the clear zone but is not supported on a deep foundation, redirection/absorption or design consideration of the collision load may be required. The preliminary designer shall coordinate with the Project Development Engineer to determine project requirements.
- MSE Wall location should consider zone of intrusion [BDM 3.14].

### 3.7.4 Piers and pier footings [AASHTO-LRFD-2020 3.6.5]

For typical bridges the Bureau selects among four pier types: frame pier, T-pier (hammerhead pier), pile bent, and diaphragm pier. Pier selection criteria include the following:

- **Waterway conditions:** For stream or river crossings, the most significant considerations in choice of pier type are the potential for ice or driftwood flow and anticipated depth to bedrock. If the drainage area is small, 50 square miles or less, pile bents usually are acceptable for spans up to 100 feet. Consideration shall be given to the unbraced length of pile bent piers with respect to scour.

  Superstructure spans exceeding 100 feet could require excessive number of piles and pile bent piers may not be economical. For longer spans the designer should consider T-piers [6.6.1.1.2], and in certain situations a frame pier may be considered. Regardless of drainage area, however, if significant ice or driftwood flow is expected, the pile bent shall be fully encased [BDM 6.6.1.1.3].

  If the drainage area is large, more than 50 square miles, or there is potential for significant ice or driftwood flow, the Bureau strongly recommends T-piers.

  Since the thalweg of channels can migrate within a bridge opening, all piers, whether in the channel or in the overbank, should be designed for scour. The Bureau requires the designer to set the bottom of the footing about 6 feet below the streambed elevation for all channel and overbank piers within a stream or river crossing, regardless of the calculated scour elevations.

  In cases where it can be determined with a reasonable degree of certainty over the life of the bridge that the overbanks will remain stable and the main channel will not migrate toward the overbank piers, the Bureau may allow exceptions to the overbank pier design with the Preliminary Bridge Design Unit Supervisor approval.

  For situations with anticipated bedrock 30 feet or less below the streambed elevation, the preliminary designer should assume drilled shafts are possible for the foundations. Early coordination with final design will be required to obtain a conservative estimate of drilled shaft size and associated pier width. The estimated drilled shaft pier diameter shall be considered in the proposed bridge hydraulic modeling.

  **Roadway conditions:** For grade separations the most economical choice usually is frame piers. The preferred clear zone width should be provided for the location of piers [DB DM 8A-2].

  For bridge widths up to 30 feet the T,S&L should show a T-pier, because a 2 column frame pier is not redundant when collision is a consideration. A designer note should be placed on the TSL stating that the pier type may be changed in final design. For bridge widths greater than 30 feet that would typically warrant three or more columns with a pier cap, the T,S&L should show a minimum column diameter of 4.0 feet for determining horizontal clearance [BDM 6.6.4.1]. For situations with anticipated bedrock 30 feet or less below the grading surface, the preliminary designer should assume drilled shafts are possible for the foundations. If drilled shafts at the piers are possible at the site, the preliminary designer may need to coordinate with final design for potential shaft and column diameters to be assumed. Final bridge design may change the bridge pier type after considering aesthetics, maintenance, depth to bedrock, and cost.

Abutments and piers located within the acceptable clear zone shall be investigated for collision [AASHTO-LRFD-2020 3.6.5]. Collision shall be addressed by either providing structural resistance or by redirecting or absorbing the collision load. An exemption to collision force resistance may be granted by the Project Development Engineer for low traffic speeds.

The final designer will confirm the appropriate method for addressing vehicular collision force requirements. However, the Preliminary Designer shall consider the following situations, and place an appropriate note to the Final Designer on the TSL.

- Iowa DOT policy is to exempt design for vehicle collision force when the annual frequency of bridge collapse ($AF_{BC}$) is less than the AASHTO thresholds. The $AF_{BC}$ calculations and resulting design accommodations shall be determined in bridge final design.

- In urban areas with low traffic speeds, the Bridge Project Development Engineer may grant an exemption to collision force investigation on a case-by-case basis. Consideration shall be given to the traffic control devices present along the route.

- In most cases, providing structural resistance in the pier is thought to be a better and more economical option than providing redirection or absorption. Where the design choice is to redirect or absorb the collision load for new or retrofit construction, protection shall consist of a minimum 42-inch high MASH crash tested rigid TL-5 barrier located such that the top edge of the traffic face of the barrier is 3.25 ft or more from the face of the substructure component being protected.

- In urban areas where a median barrier is necessary, the Bureau prefers using a 54-inch high barrier routed around and directly adjacent to a median pier in order to limit intrusion into the shoulder. In such cases it is Iowa DOT policy to design the pier for structural resistance since the barrier is not structurally independent.

Additional guidance related to substructure offsets behind barrier rail is provided under [BDM 3.14].

- Bridge locations where ROW, environmental or other economic impacts could occur, the clear zone may be designed to meet the acceptable clear zone width with approval from the supervising Unit Leader. If a frame pier is within the acceptable horizontal clear zone [BDM 6.6.2.6] and not sufficiently protected it will require a crash strut [BDM 6.6.4.1]. In that situation a T-pier is an alternative.

  Dual bridges placed edge to edge with a 2-inch gap generally should have separate piers for each bridge.

  Unless pier footings will bear on rock, the preliminary designer should set the preliminary bottom of pier footings 5 feet below finished grade. The final bridge designer shall verify that the final bottom footing elevation allows for a minimum one-foot cover thickness over the top of footing.

- **Railway conditions:** For railroad crossings, pier and footing guidelines are given in previous articles [BDM 3.4.1.3 and BDM 3.4.2.3]

- **Subsurface conditions:** Depth to bedrock is a factor in pier foundation type selection. Shallow bedrock at a pier may be conservatively defined as rock, regardless of type (e.g. shale, limestone, etc.) and quality (e.g. solid, hard, broken, weathered, highly weathered, etc.), that is 30 feet or less from the lowest of the ground line, stream bed, or design scour elevation. In the absence of shallow rock, piers are often supported on a footing with steel H piles. When shallow rock is present the designer should consider pier foundation options more closely. The majority of Iowa pier foundations are supported on steel H-piles. If rock is close to the surface, spread foundations for piers may be notched into the rock layer.

Drilled shafts socketed into rock may be an option on some sites with anticipated shallow bedrock. For more detailed information on substructure policy and drilled shafts see BDM 6.3.1.1. In all cases the designer shall consider existing foundations, utilities, and drainage when locating drilled shafts.

- **Aesthetics:** If aesthetics is a consideration, the designer will need to follow the pier type and style established for the bridge.

- **Accelerated Bridge Construction (ABC):** Multi-span bridge replacement projects whether using traditional construction or ABC have occasionally utilized drilled shaft foundations just outside the footprint of the existing bridge before removal of the existing structure. This method allows the road to remain open to traffic for a longer period of time. In these situations, it is preferred the designer supply at least 18 inches of clearance between the perimeter of the drilled shaft and the closest edge of the existing superstructure, but a minimum clearance of 12 inches is acceptable. In some cases, it may be possible to increase clearance by removing a portion of the existing superstructure near the proposed shaft (for example remove a portion of a curb overhang on an existing bridge which is not structurally necessary). Early coordination with final design may be required when considering this option.

### 3.7.5 Wing walls

The preliminary designer shall verify that abutment wing walls provide an acceptable slope from the end wing to the berm. For typical PPCB or CWPG bridges, there should be no need to change standard wing wall lengths. However, if any of the following conditions apply, the designer shall check the need to increase wing wall lengths per criteria defined by BDM 6.5.4.3.1:

- Skew greater than 30 degrees
- Superelevation
- Beam depth greater than 63 inches, the BTE beam depth.

Refer to the commentary for details on the wing length check and design methods. Note that a 2.5:1 slope extended from the top of berm should be used for designing wings, even for situations with flatter berm slopes.

Any wing walls requiring more than 5 feet beyond the standard wing extension length may be steepened to a 2:1 slope pending approval by the Unit Leader. Non-standard wing lengths should be noted as such on the TSL. Final design will determine how the additional wing length will be addressed.

### 3.7.6 Foundation Conflicts

To simplify design and construction of a replacement bridge, it is the BSB preference to avoid existing foundation conflicts where possible. The preference to avoid foundations may affect the recommended bridge length, beam type, or span arrangements.

When a contractor removes a bridge, the existing foundations are typically left in place just below the grading surface. Some bridge replacement project locations may have had a previous bridge replacement project which could indicate the presence of additional foundations from a past bridge removal. Designers should review previous bridge plan sets to determine whether there may be additional foundations that could interfere.

Refer to the bridge standards for proposed pier pile bent and abutment footing geometry. For proposed T-Piers or spread footings, example final plans may be used to estimate the proposed footing width. It is desirable for the layout to provide 2' minimum horizontal clearance from proposed footings to existing footings to help facilitate construction.

As approved by the Unit Leader, some projects may have unavoidable conflicts that must be addressed during final design. For these cases, all potential conflicts with existing structures, including old timber piling shall be noted on the TS&L Situation Plan and/or the Longitudinal Section and included in the designer notes.

## 3.8 Cost estimates

For preliminary cost estimating, the designer should use the costs in Table 3.8, recognizing that the estimates will be reasonably valid for comparing bridge options but not accurate for current construction costs. For a typical new bridge cost estimate, multiply the unit cost in the table by the bridge deck area, measured from outside edge to outside edge of deck and from face to face of paving notch. Adjust the cost upward for complexity, staging, and other applicable costs using the amounts listed in the table for each bridge type and bridge removals. If the construction situation is highly unusual, consult the supervising Unit Leader.

Refer to BDM 1.12 for additional guidance on preparing bridge and RCB culvert construction cost estimates.

**Table 3.8. Preliminary costs for typical Iowa bridges**

| **Cost Item** | **Unit Cost (1), (2)** |
|---|---|
| New continuous concrete slab (CCS) bridge | $\$130/ft^2$ |
| New pretensioned prestressed concrete beam (PPCB) bridge | $\$135/ft^2$ |
| New rolled steel beam three-span standard bridge | $\$140/ft^2$ |
| New continuous welded plate girder (CWPG) bridge | $\$160/ft^2$ |
| Complex bridges: variable width, urban area such as Des Moines, construction over traffic | Add for each item $\$10/ft^2$ |
| Staged bridges | Add 10% |
| Cofferdam for pier construction | $50,000 per pier |
| Detour Bridge | (6) |
| Bridge removal | $\$10/ft^2$ |
| Bridge widening, including removal and staging | $\$ 220/ft^2$ |
| Bridge aesthetics | Add 3% (5) |
| RCB Culvert (CIP), in close proximity or corridor projects | $\$850/yd^3$ (4) |
| RCB Culvert (CIP), individual projects or extensions | $\$900/yd^3$ (4) |
| Revetment | $50/Ton (7) |
| Mobilization | 10% |
| Contingency | B0, D0 = 20% (3) |

| | |
|---|---|
| | ~~D0,~~ B1, D2 = 15%<br>B2= 15% Prelim. designs<br>B2 = 0% Final designs(8) |

Table notes:

(1) Unit costs for new construction do not include mobilization, removal of an existing structure, extensive river or stream channel work, large quantities of riprap, clearing and grubbing, approach slabs, and other construction work not part of the bridge.
(2) Unit costs were current as of August 2022.
(3) See abbreviations [BDM 3.1.4] for definitions of these event codes. Utilize BRG-15002 (LS) to represent contingency cost for preliminary design estimates.
(4) Unit cost includes concrete, reinforcing bars, minor grading and construction.
(5) Additional aesthetic costs should be considered for gateway or signature structures. See the Draft Aesthetic Guidelines for more information.
(6) The state-owned detour bridge components are no longer being used. Detour bridges are rented on a case-by-case basis and budgeting costs should be obtained from the venders.
(7) Include revetment costs with bridge and RCB culvert estimates. After the B1 completion, revetment costs for RCB culverts are included with the roadway estimate.
(8) Final plans delivered to the Design Bureau that do not require structural design, complete with final notes, bid items, and quantities (example: a scour countermeasure).

## 3.9 Type, Size & Location Plans (TS&Ls)

The Bureau requires a TS&L for each new bridge, bridge sized culvert, or bridge that is to be widened or lengthened. The plan and longitudinal section (or profile) views should be plotted at a 1 inch = 40 feet scale on an 11-inch by 17-inchdrawing. For long bridges the designer may use an alternate scale, provided that the alternate scale meets the approval of the supervising Unit Leader.

Detailed structural design generally is not required for preparation of a TS&L. Thus pier and abutment details, pile types and lengths, and beam spacing need not be determined unless they affect vertical clearance, constructability, beam type, or structure length. Example TS&Ls are shown in the commentary.

A TS&L for a bridge or culvert of bridge length over a waterway requires the following additional items:

- Hydraulic computations
- Backwater computations
- Scour computations

TS&L plan submittal information to Iowa DOT should include the situation plan, site plan, miscellaneous detail sheet(s), and hydraulic calculations.

A Connect Preliminary Bridge Plan Checklist is provided on the Iowa DOT Bridge Bureau website. Designers shall apply the checklist as needed and include it with the submittal. Sheet layout guidelines are provided in the commentary.

## 3.10 Permits and Approvals

Iowa DOT projects are subject to federal and state laws and regulations and approval by agencies outside of the Iowa DOT. The majority of the permits and approvals apply to work in or over waterways, but there are also approvals applicable to railroad and highway grade separations.

### 3.10.1 Waterway

This article covers waterway requirements related to the following permits and coordination:

- Iowa Department of Natural Resources (Iowa DNR) Flood Plain Construction Permits (also called Flood Plain Development Permits),
- Records of Coordination of Flood Plain Development for cities and counties that participate in the National Flood Insurance Program (NFIP),

- Iowa DNR Sovereign Lands Construction Permits,
- Corps of Engineers 404 Permits,
- Corps of Engineers 408 Approval,
- Coast Guard Approval,
- Drainage District Approval.

Iowa DNR Flood Plain Construction Permits

For a bridge or large culvert over a waterway the designer is obligated to meet the requirements of the Iowa DNR and other government agencies. Cases that require an Iowa DNR permit are summarized from the Iowa Administrative Code (IAC) in Table 3.10.1-1. Please review the DNR website for checklist and other required submittal information.

The DNR's Flood Plain Permit web-based application process automatically sends a copy of the Flood Plain permit application to the Corps of Engineers for their Section 404 permit review. Since the Iowa DOT Environmental and Location Bureau submits the 404 application and pertinent information to the Corps at a later date, this automation has caused confusion. The resolution is to place a note in the electronic application stating that "Section 401/404 permit information will be submitted by the Iowa DOT at a later date, and no action is required by the Corps with this application at this time."

**Table 3.10.1-1. Iowa DNR Flood Plain Construction Permit requirements (summary of IAC 567—Chapter 71)**

| **Project Type** | **Location** | **Construction Permit Required? Yes, if drainage area meets threshold.** |
|---|---|---|
| Bridges, culverts, or road embankments that cross the stream | Rural area(1) – floodway | 100 square miles or more |
| | Urban area(2) | 2 square miles or more |
| Road embankments that do not cross the stream | Rural area(1) – floodway and flood plain | 10 square miles or more if obstructing 3% or more of the channel, or 15% or more of the flood plain |
| Channel changes(3) | Rural area(1) not associated with a road project | 10 square miles or more |
| | Rural area(1) associated with a road project | 10 square miles or more if (1) more than 500 feet of channel is being altered or (2) length of existing channel is reduced by more than 25% |
| | Urban area(2) | 2 square miles or more |
| | Protected streams(4) | Any area |
| Bank stabilization, includes grade control structures if bank stabilization is involved | Rural area(1) | 100 square miles or more |
| | | 10 to 100 square miles if channel cross section is being reduced by 3% or more |
| | Urban area(2) | 100 square miles or more |
| | | 2 to 100 square miles if channel cross section area is being reduced by 3% or more |
| Levees, dams (ponds), flood plain excavation, or stockpiling | Varies(5) | Varies(5) |
| Misc. structures, obstructions or deposits. Includes grade control structures. Some | Rural area(1) | 10 square miles or more if obstructing 3% or more of the channel, or 15% or more of the flood plain |
| | Urban area(2) | 2 square miles or more |

| | | |
|---|---|---|
| exemptions exist for signs, utility poles and navigational objects | | |

Table notes:

(1) Rural area is defined as the entire project (bridge, culvert, embankment and related work) outside of an area defined or designated as an urban area (completely outside incorporated City limits).

(2) Urban area is defined as part of the project (bridge, embankment and related work) is within the City limits.

(3) Channel change means either (a) the alteration of the alignment, location, or length of a channel of a stream or (b) a substantial modification of the size, slope, or flow characteristics of a channel of a stream for a purpose related to the use of the stream's flood plain surface…. Increasing the cross-sectional area of a channel by less than 10 percent is not considered a substantial modification of the size, slope, or flow characteristics of a channel of a stream. See IAC 567—70.2.

(4) See IAC 567—Chapter 72 for a list of protected streams. Because petitioners may request that streams be added to the list at any time, the designer should contact the Iowa DNR regarding updates to the list if a project involves channel changes.

(5) See IAC 567—Chapter 71.

Through the permit process the Iowa DNR checks that a project's design and supporting documents submitted with the permit application meets the requirements of Flood Insurance Studies (FIS) of cities and counties participating in the National Flood Insurance Program (NFIP). It should be noted that a "no-rise" certification is not required for Iowa DOT projects since the State does not obtain approval from local entities.

For a bridge that requires a Flood Plain Construction Permit the Iowa DNR establishes maximum backwater and minimum freeboard limits, and the limits are summarized in Table 3.10.1-2. Refer to Backwater Definition section below for the topographic assumptions. If the structure exceeds the maximum backwater limits, the Iowa DNR may require that the Iowa DOT obtain flowage easements for the excess backwater. The preliminary designer shall provide preliminary flowage easement limits.

**Table 3.10.1-2. Iowa DNR backwater and freeboard requirements for bridges and culverts (summary of Iowa Administrative Code 567—Chapter 72)**

| **Bridges and Rpad Embamkments, and Associated Channel Changes(1)** | | | |
|---|---|---|---|
| **Damage Potential** | **Maximum Backwater** | | **Minimum Freeboard** |
| | | **$Q_{100}$** | |
| Low(2) | | 1.5 feet | 3.0 feet above $Q_{50}$(3) |
| | | | |
| High(4) or Maximum(5) | | 1.0 foot(6),(8),(9).~~New bridges 1.0 foot(6), except as noted(8),(9). Replacement bridges the lesser of existing backwater or 1.0 foot(6),(9).~~ | 3.0 feet above $Q_{50}$(3) |
| **Culverts and Associated Channel Changes(1)** | | | |
| **Culvert Type** | **Maximum Backwater** | | **Minimum Freeboard** |
| New culverts or culverts replacing bridges | Same as for bridges | | No minimum(7) |

| | | |
|---|---|---|
| Culverts replacing culverts | Backwater of existing culvert, or maximum backwater allowed for bridges, whichever is greater | |

Table notes:

(1) These rules are applicable to bridges and culverts including channel changes on the floodway of any stream draining between 10 and 100 square miles when either (a) more than 500 feet of the existing channel is being altered or (b) the length of the existing channel is being reduced by more than 25 percent.

(2) Low damage potential means all buildings, building complexes, or flood plain use not defined as maximum, high, or moderate damage potential. See IAC 567—70.2.

(3) Unless a licensed engineer provides certification that the bridge will be designed to withstand the applicable effects of ice and the horizontal stream loads and uplift forces associated with the $Q_{100}$…. See IAC 567—72.1 and BDM 3.2.2.4.

(4) High damage potential means the flood damage potential associated with habitable residential buildings or industrial, commercial, or public buildings or building complexes of which flooding would result in high public damages…. See IAC 567—70.2.

(5) Maximum damage potential means the flood damage potential associated with hospitals and like institutions; buildings or building complexes containing documents, data, or instruments of great public value; buildings or building complexes containing materials dangerous to the public or fuel storage facilities; power installations needed in emergency or buildings or building complexes similar in nature or use to those listed above. See IAC 567—70.2.

(6) Backwater cannot exceed these values unless increase is mitigated or other measures are taken. See IAC 567—72.1(2).

(7) The Iowa DNR may evaluate freeboard on a case-by-case basis if debris and ice are a problem.

(8) For a ~~new~~ bridge and roadway embankment located within a stream reach for which the Federal Emergency Management Agency has published a detailed Flood Insurance Study which includes a floodway, the backwater for $Q_{100}$ shall not exceed the surcharge associated with the delineation for the floodway at that location.

(9) In no case shall the $Q_{100}$ backwater effects of a bridge or road embankment reduce the existing level of protection provided by certain flood control works, unless equivalent remedial measures are provided.

Backwater Definition - Iowa DNR Floodplain Development Regulations

Unless noted otherwise, the base topographic condition evaluated is the ‘Pre-Development’ condition. This is a topographic assumption with the development being evaluated removed (e.g. roadway embankment with associated structures). Adjacent topography is included in the Pre-Development condition if it is not a part of the development being evaluated.

Backwater is the difference between the topography being evaluated (e.g. Proposed) and the base topographic condition (Pre-Development).

Exceptions to the Backwater definition above are related to the criteria in footnotes (8) FIS Floodway and (9) Flood Control Works of Table 3.10.1-2.

For (8) which includes criteria related to an established FIS Regulatory Floodway, the base topographic condition evaluated is the ‘FIS Base’ condition. FIS Base condition is the topography utilized in the FEMA FIS being used for study purposes (effective or pending). If not practical to use the FIS topography (older 1D model, 2D models etc.), ‘Existing’ condition, adjusted as possible to reflect the conditions on adoption of the FIS, can be utilized as the FIS Base condition. ‘Existing’ condition reflects the current (at time of study) topography including the existing development being evaluated.

For (9) which includes criteria related to flood protection work, the base topographic condition evaluated is the ‘FIS Base’ or ‘Existing’ condition if an FIS is not in effect, similar to the above.

For the above two cases, (8) and (9), backwater is the difference in water surface between the topography being evaluated (e.g. Proposed) and the base topographic condition (FIS Base or Existing).

NFIP Record of Coordination Flood Plain Development

Any project on a stream that does not meet the drainage area thresholds in Table 3.10.1-1 does not require a flood plain permit or approval from the Iowa DNR. However, if the project is in a city or county that is participating in the National Flood Insurance Program (NFIP), the designer shall perform a hydraulic review and coordinate with the community to ensure compliance with the NFIP. If a consultant is the designer a Record of Coordination of Floodplain Development form [BDM 3.11 as required under IDOT PPM 500.10] shall be forwarded to the Iowa DOT for distribution to the Iowa DNR and the appropriate District Engineer. The coordination effort is not considered a permit from the community. A complete list of cities and counties in the NFIP and status of their flood insurance studies is available at the following FEMA web site:

http://msc.fema.gov/portal/advanceSearch

Iowa DNR Sovereign Lands Construction Permits

Any construction activity on, above, or under state-owned water and land requires an Iowa DNR Sovereign Lands Construction Permit. This permit is different from the Flood Plain Development Permit. There are portions of 14 rivers in Iowa that are legally classified as “meandered”, which means the State of Iowa owns the streambed and banks up to the ordinary high water mark. The meandered rivers are listed in the commentary for this article [BDM C3.10.1].

Corps of Engineers 404 Permits

A Corps of Engineers 404 Permit is needed for all bridges over water, major highway projects, and stream bank repair projects. The designer should notify the Location and Environment Bureau when the TS&L for a bridge is complete. The Location and Environment Bureau will complete and submit a “Joint Application Form” [BDM 3.11] that will request the Corps of Engineers 404 Permit.

Corps of Engineers 408 Approval

The Corps of Engineers also has requirements under 33 USC Section 408 to ensure that project modifications within a critical area of a Flood Risk Reduction Project (FRRP) constructed by the U.S. Army Corps of Engineers do not adversely impact the operation or integrity of the FRRP. The critical area is generally defined as 300’ riverward to 500’ landward of a FRRP centerline, but may be a greater distance if identified in a specific Operations and Maintenance Manual.

Bridge replacement projects typically do not change the alignment or elevation of a flood protection levee. Therefore, most bridge projects will be considered a minor impact to the FRRP, but will still require Section 408 approval. Most bridge projects can be reviewed by the Corps with submittal of a TS&L and concurrence from the local agency in support of the project. The District will obtain concurrence from the local agency for the project, and preliminary bridge design will submit the Section 408 information. If the physical characteristics of the flood protection levee are modified or the operation or hydraulic capacity of the FRRP is changed,408 reviews may take 12 to 18 months to review since approval from Corps Headquarters is required.

There may be situations when hydraulic modeling of a temporary stream crossing would be required to assess the impacts to an FRRP during construction of a bridge. The design of a temporary stream crossing should be submitted as part of the Section 408 review. Coordination with the Construction and Materials Bureau may be warranted to address constructability issues to determine the appropriate height, width and location of a temporary stream crossing to provide a contractor a basic plan for accessing the bridge.

Coast Guard Permit

The U.S. Coast Guard requires a permit for all projects over the Mississippi and Missouri Rivers. Appropriate horizontal and vertical clearances for the navigation channel shall be coordinated with the USCG during preliminary design. A letter from the USCG documenting the design criteria is desired for the file. Bridge Final Design submits the USCG permit application 6 months prior to project letting.

Drainage District Approval

Design approval from a Drainage District is required when a culvert (or bridge) is constructed over a Drainage District channel. Statewide Drainage District information is available at either of the links below to determine whether an Iowa DOT project crosses a Drainage District channel.

> Iowa DOT Web App Viewer (includes the statewide Drainage District shape file from the Iowa DNR website, June 2021):
> https://iowadot.maps.arcgis.com/apps/webappviewer/index.html?id=ad99c079f70044a09091c6d59ed5ea8b
>
> or Iowa DNR website (statewide Drainage District shape file for downloading):
> https://www.arcgis.com/home/item.html?id=fd42f39703d84dffb73c99dfcfc70c85

Iowa DOT District staff should be able to verify when the coordination will be required. Coordination should be initiated in the concept phase of a project to request the required channel design flowline (may be buried to allow future clean out), datum correlation (if applicable), cross section, and slopes, etc. The Iowa DOT District staff will generally be the contact for all communications with the Drainage District representatives. When applicable, the need for Drainage District coordination shall be identified on the Bridge Bureau Attachment for Concept Statement.

### 3.10.2 Railroad

All bridges over railroads shall be reviewed and approved by the railroad company. The Bridges and Structures Bureau (BSB) preliminary designer is referred to article BDM 3.4.4 for railroad bridge submittal requirements.

### 3.10.3 Highway

In some cases, Federal Highway Administration (FHWA) approval is required for federal funding programs. FHWA approval is required for major interstate projects or projects with modified interchanges. On a case by case basis, FHWA would also like to review bridges that are unique or controversial due to environmental or ROW issues. (Estimated contract value is no longer a consideration.)

The Bridges and Structures Bureau will coordinate the FHWA approvals. The BSB preliminary designer shall submit a copy of the transmittal form and TS&L to the FHWA.

## 3.11 Forms

Preliminary design involves the use of several forms, not all of which are used on every project. A summary of the forms is given in Table 3.11. Blank Iowa DOT forms that have a form number can be downloaded from the form library.

**Table 3.11. Preliminary forms**

| **Form Title** | **Form Number** |
|---|---|
| Bridge Cost Estimate for Concept Statement (1) (2) | --- |
| Bridge Bureau Attachment for Concept Statement (1) (3) | --- |

| | |
|---|---|
| Joint Application for requesting Iowa DNR Flood Plain Construction Permits, Iowa DNR Sovereign Lands Construction Permits, and Corps of Engineers 404 Permits (4) | 5423234 |
| Record of Coordination, Floodplain Development (1) | 532001 |
| | |
| | |

Table notes:

(1) See the commentary for examples of completed forms.
(2) Not required for consultant prepared concept statements.
(3) Required for all bridge replacement D00 events. Attach to final concept statement.
(4) When using the DNR web-based permit application process, Form 36 information is filled out electronically in lieu of the separate completed form. When using the DNR's web-based form for Iowa DOT projects, place a note in of the application stating that "Section 401/404 permit information will be submitted by the Iowa DOT at a later date and no action is required by the Corps with this application at this time."

## 3.12 Noise Walls

The noise wall design process is described in DB DM 11D-2. In general, the Design Bureau is responsible for the noise wall geometry, and the BSB is responsible for the structural design. The wall type may be pre-determined by aesthetic guidelines and will require coordination between the Design Bureau, the Location and Environment Bureau, the District and the Bridges and Structures Bureau. Consistent with the selected wall type, noise wall geometry including horizontal alignment, top of wall profile, bottom of wall profile and proposed grading surface will be provided by the Design Bureau.

The preliminary bridge design engineer will initiate the structural design process, including design number assignment and creation of TSL. Preliminary design shall include several responsibilities:

- Verify that the proposed geometry is consistent with the wall type and structural design needs.

  A common noise wall type may be a precast column/panel system with 4-foot height full panels and 2-foot high half panels. An “H” shaped concrete column (typical spacing on 16’-0 center to center) embedded into a drilled shaft will secure each end of the panels. Bends in the wall horizontal alignment can be accommodated at center column locations. Wall top profile steps up or down should be made in two foot increments, except in some cases at the end of the wall where a 4-foot top step can be used. If a half panel is required, it is typically placed at the bottom. However, in final design panel positions may be shifted to accommodate final details or aesthetics. One foot of panel embedment below proposed ground surface is desired (6 inches min.) to reduce the possibility of gaps forming under the wall.

- Verify horizontal alignment adequacy with respect to Vehicle Collision Force guidelines listed in AASHTO LRFD Section 15.8.4: Design of Sound Barriers.

  Cases where vehicle collision forces need not be considered are summarized below.

  - Noise walls located beyond the acceptable clear zone.
  - Noise wall/barrier rail systems within the clear zone that have been successfully crash tested.
  - Noise walls behind a crashworthy traffic railing with a setback of more than 4.0 feet. The setback is measured from the traffic face of the traffic barrier rail.
  - Noise walls or portions thereof at locations where the collapse of the wall has minimal safety consequences, as determined by the Owner.

The typical noise wall precast column/panel design is not conducive to collision force design. If AASHTO guidelines would require consideration of vehicular collision force in the design, the preliminary designer should coordinate with the Design Bureau to determine an acceptable solution.

- Verify that the noise wall does not conflict with utilities

  Depending on the confidence level of survey data, a request to have the utility depth and location potholed at the crossing may be prudent. Input from the utility owner may also be requested if there is a question relative to the adequacy of design vertical or horizontal clearance. In some cases, utilities may need to be relocated. To avoid conflicts with drilled shafts in precast column and panel designs, a "utility bridge" can be considered. In other cases, the utility can pass under the noise wall panels between drilled shafts without being impacted (a minimum of 2 feet of vertical clearance is desired, but less can be considered on a case by case basis).

  For existing or proposed utilities that will be longitudinal to a proposed noise wall, a desired horizontal clearance should be 15 feet or as otherwise determined by the District and Design team. Utility type, depth, construction impacts, utility related features (vent pipes, hand holes, access points, etc.), and potential for future utility maintenance shall be considered.

  Utility features may need temporary removal/replacement or need to be otherwise protected. Issues that could affect contractor work area or access should be considered.

- Verify that surface water drainage is addressed

- Review design to identify spilt profiles with differential grading

  It is desired to keep the difference in proposed grade on each side of a wall to less than 2 feet. When proposed grade differences greater than 2 feet are required, the noise wall will also need to function as a retaining wall. These areas should be noted on the TSL.

- Additional coordination will be required between BSB and DB when a noise wall is located in close proximity behind a retaining wall.

An example noise wall TSL can be provided upon request.

## 3.13 Submittals

Project Wise folder structure, CADD/pdf file submittals, and other deliverables shall follow the policy guidelines available on the website. Preliminary design guidance includes but is not limited to the documents listed below:

V8i: Preliminary Bridge - Electronic Deliverable Format
Connect: https://iowadot.gov/bridge/Automation-Tools/CONNECT-Applications
Connect: Preliminary Design Plan and Model Deliverables for B1
Connect: B01 Completion Designer Checklist – Bridge

## 3.14 Zone of Intrusion

A truck or high-center of gravity vehicle may lean over a barrier upon impact. For this reason, an offset to structure elements will lessen the likelihood of vehicle contact.

The region measured above and behind the barrier during an impact is known as the Zone of Intrusion (ZOI). ZOI guidelines for different barrier test level and height have been developed based on crash data and published in the AASHTO Roadside Design Guide (4$^{th}$ Edition). Where practical on new or reconstruction projects, the designer should try to accommodate this clearance when locating piers, abutments, walls, or other structural elements behind a barrier.

Recommendations for preferred and minimum clearance behind standard Iowa DOT ~~TSS~~ standard single slope TL-4 and TL-5 barrier rail are provided below. Other barrier types may require additional clearance and the designer should refer to the Design Bureau and the Roadside Design Guide. Stated horizontal clearances are from the top of traffic barrier system face and vertical clearances are from the gutterline elevation. Note that the considerations regarding the need to design piers and abutments for collision force resistance will still need to be reviewed [BDM 3.7.4].

- The desired clearance from traffic face of barrier to the obstacle is 80 inches at a height of 120 inches, based on the ZOI for truck cargo box zone (commentary Figure 1).
- The minimum clearance from the traffic face of barrier to the obstacle is 18 inches to a height of 78 inches (commentary Figure 2).
- The designer may need to consider the use of a taller barrier where the lean of the vehicle over the rail is a concern. When a 54-inch rail is used on a bridge to shield a specific feature, the preliminary designer may follow the guidance below:

    - 10-foot length for transition height change from 44 to 54-inch tall rail (or 1 foot length per inch height change)
    - 60-foot length for 54-inch tall rail in direction of traffic leading up to the obstacle.
    - 50-foot length for 54-inch tall rail in direction of traffic leading away from the obstacle.
    - 10-foot length for transition height change from 54 to 44-inch tall rail (or 1 foot length per inch height change)
    - Configuration/Design of the 54-inch tall rail on bridge deck- it is preferred that the base will be 18 inches, with a reduced deck lip on the backside reduced from 2 inches to 1 inch.

Required clearances for specific features:

    - 3.25 ft at a height of 14'-6 for flyover pier caps and columns (or similar situations for piers) behind an independently supported minimum 42.0-inch high ~~TSS~~ Iowa DOT standard single slope TL-5 barrier rail. Protection coverage up to the obstacle shall be 60 feet in the direction of traffic. Design for collision resistance is not required. A minimum barrier length of 60.0 feet upstream of the leading edge of the pier system plus the entire length of the pier system shall be shielded.
    - It is recommended that flyover bridge columns not be placed at a clearance less than the required. However, should site conditions dictate this case, a 54-inch rail should be used and the column should be designed for collision force.

- 80 inches at a height of 120 inches for fracture critical bridge elements, such as a cable, arch or truss. The failure of these features is the highest risk for injury or long term closure of the roadway. The designer may need to consider the use of a taller barrier where the lean of the vehicle over the rail is a concern.
- 18 inches at a height of 78 inches for light poles and bridge mounted signs. In the majority of cases hitting one of these structures would result in property damage and limited closure of the roadway so the minimum is acceptable.
- 34 inches at a height of 96 inches for cantilever and overhead sign trusses. There is some increased risk with the failure of these features and there would be a greater possibility of injury. That is why it is desired to increase the clearance to include the criteria for truck cab zone. It should be noted that in a median installation the loss of shoulder to accommodate this clearance is undesirable. Reducing the clearance to the minimum and maintaining the shoulder would be preferred. Also, note that cantilever sign trusses are not allowed on bridges due to vibration concerns.
- The standard 34-foot closed median used on urban area multi-lane highways will satisfy ZOI for a light pole or sign truss [DM 3E-1].

## 3.15 Temporary Bridges

The state-owned temporary bridge components utilized for on-site detours have been retired as of 2020. Our current policy when temporary or on-site detour bridges are needed, is to use bridge components either rented or owned by the contractor. Typically, the temporary structure type may be a beam or truss bridge. However, for competitive bidding purposes, a bridge type will not be explicitly defined. The preliminary design engineer will need to coordinate with potential vendors relative to the likely bridge type and estimated cost. Each temporary bridge will have a design number assigned under the replacement bridge FHWA number and a TSL completed. An example TSL is included in the Commentary.

The Temporary Bridge TSL shall specify key design features. Detailed specifications will be completed by the final bridge designer. Key features may include but are not limited to the list below:

- minimum roadway width
- minimum overall bridge clear span length
- minimum low beam elevation
- maximum superstructure depth (based on the road profile)
- minimum area of opening below the design stage
- maximum number of piers, if applicable

Roadway Profile

The design roadway profile will be based on the anticipated bridge type and estimated superstructure depth. A note shall be provided on the TSL stating that if the contractor chooses a system with deeper superstructure, they will need to field adjust the roadway upward to keep the low beam at or above the specified elevation.

Stream Crossings/Hydraulic analysis

A hydraulic model with the temporary bridge in place is necessary to determine the design stage and other hydraulic parameters. Freeboard and backwater criteria required for permanent bridges do not apply.

It is desired to set the operational low beam above the 10-year stage, if possible. Stage, calculated scour, and average bridge velocity shall be considered for the lesser of the 10-year or incipient overtop event. In addition, the 25-year stage and average bridge velocity shall be provided. The 25-year data will be used to establish buoyancy and stream forces related to temporary bridge tiedowns and possibly other final design requirements for the temporary bridge.

Spill through berms and/or revetment design may be specified in the plans. If abutment, berm, and revetment conditions are subject to the temporary bridge features, these conditions may be specified to be contractor design and paid as incidental to the substructure bid item. An appropriate note to the final designer is required to convey this need in the plan’s bid item reference notes.

Bridge Watch Dataset

Temporary bridges over streams or rivers will be classified as scour critical. For these sites, a Bridge Watch Dataset shall be developed by the preliminary design engineer. The Bridge Watch Dataset will be entered by others into the Bridge Watch application after contractor notification of construction completion.

The Bridge Watch Dataset requires the following information:

1. Monitoring Plan Text (a.k.a. Plan of Action or POA). Format shall be as .doc or .txt for cut and paste capability into the database. A B1 level plan example is included in the Commentary. Utilize as a template, edit as required. The template addresses information that needs to be provided at a minimum. If the responsible maintenance garage name is readily available, include, otherwise the name will be provided by others. Data not included in the template but included in the final Monitoring Plan (FHWA No., rainfall depths, etc.) is provided by others.

For temporary bridges, the B1 level plan will contain some unknown items (example actual low beam elevation). Once known, these outstanding items will be provided by the contractor and an updated version of the plan will be required.

2. B1 TSL in pdf format. Include any sheets showing revetment or countermeasures.
3. Detour roadway Plan and Profile Sheet.
4. StreamStats Basin Area GIS file (globalWatershed.shp) (ESRI ShapeFile format)

A copy of the pending Bridge Watch dataset/transmittal will be placed by the Iowa DOT assigned preliminary bridge engineer in the following folder:

W:\Highway\Bridge\PrelimSection\Scour\Scour_Management_Plan_Work\2B_AppB_BridgeSpecificProvisions\Active\[FHWANO]pending

Once Preliminary Bridge is notified that the detour is being constructed, the Monitoring Plan, TSL and Roadway plan sheets will be updated to the as-built versions, and the package transmitted to Bridge Watch for initiation of alerts.

## 3.16 Resiliency/Climate Change

{Text for this article will be added in the future.}