2.5 Bridge Numbers

An official number referred to as the Bridge Number is assigned to every structure on the State Highway System for the purpose of having a definite designation. The Bridge Number is hyphenated with the first digit being either a B, C, P, S, R, M or N. B is assigned to all structures over 20 ft. in length, including culverts. C is assigned to all structures 20 ft. or less in length but must have a cross-sectional area greater than 25 square feet. Do not include pipes that do not require structural computations. P designates structures for which there are no structural plans on file. S is for sign structures, R is for Retaining Walls, and N is for noise barriers. M is for miscellaneous structures where it is desirable to have a plan record. Bridges on state boundary lines also have a number designated by the adjacent state.

WisDOT Policy Item:

No new P numbers will be assigned as we should always request plans.

Regional Offices should assign numbers to structures before submitting information to the Bureau of Structures for the structural design process or the plan review process. Unit numbers are only assigned to long bridges or complex interchanges where it is desirable to have only one bridge number for the site.

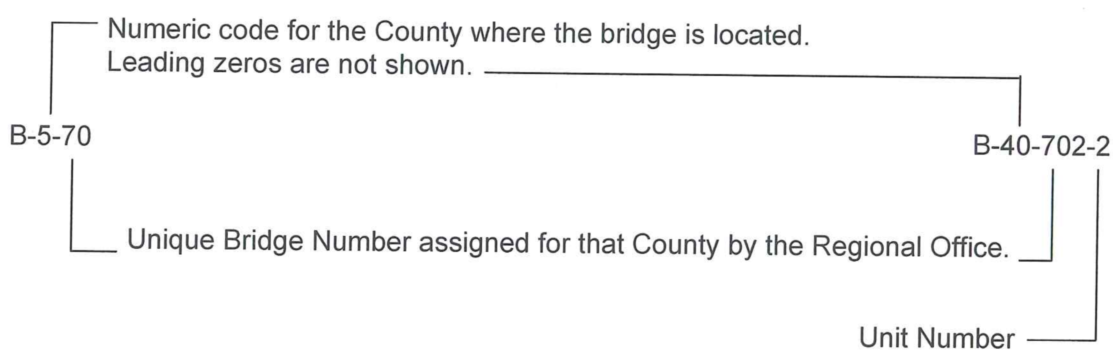


Figure 2.5-1
Bridge Number Detail

A set of nested pipes may be given a Bridge Number if the distance between the outside walls of the end pipes exceeds 20 ft. and the clear distance between pipe openings is less than half the diameter of the smallest pipe.

See 14.1.1.1 for criteria as to when a retaining wall gets assigned a R number and receives a name plate. A Structure Survey Report should be sent to the Structures Design Section, even if designed by the Regional Office.

See Section 6.3.3.7 for guidance on location of name plate on structures.

K_1 = 1.0

W_C = 0.15 kcf, unit weight of concrete

n = Es / Ec = 8, modular ratio **LRFD [5.7.1]**

36.2.2 Bridge or Culvert

Occasionally, the waterway opening(s) for a highway-stream crossing can be provided for by either culvert(s) or bridge(s). Consider the hydraulics of the highway-stream crossing system in choosing the preferred design from the available alternatives. Estimates of life cycle costs and risks associated with each alternative help indicate which structure to select. Consider construction costs, maintenance costs, and risks of future costs to repair flood damage. Other considerations which may influence structure-type selection are listed in Table 36.2-1.

Bridges	
Advantages	Disadvantages
Less susceptible to clogging with drift, ice and debris	Require more structural maintenance than culverts
Waterway width increases with rising water surface until water begins to submerge structure	Piers and abutments susceptible to scour failure
Natural bottom for waterway	Susceptible to ice and frost forming on deck
Culverts	
Grade rises and widening projects sometimes can be accommodated by extending culvert ends	Silting in multiple barrel culverts may require periodic cleanout
Minimum structural maintenance	No increase in waterway area as stage rises above top of culvert
Usually easier and quicker to build than bridges	May clog with drift, debris or ice

Table 36.2-1
Advantages/Disadvantages of Structure Type

36.2.3 Staged Construction for Box Culverts

The inconvenience to the traveling public has often led to staged construction projects. Box culverts typically work well with staged construction. Any cell joint can be used for a staging joint. When the construction staging line cannot be determined in design to locate a cell joint, a contractor placed construction joint can be done with an extra set of dowel bars and the contractor field cutting the longitudinal bars.

36.12 Precast Four-Sided Box Culverts

In general, structural contractors prefer cast-in-place culverts while grading contractors prefer precast culverts. Precast culverts have been more expensive than cast-in-place culverts in the past, but allow for reduced construction time. Box culverts that are 4 feet wide by 6 feet high or less are considered roadway culverts. All other culverts require a B or C number along with the appropriate plans. All culverts requiring a number should be processed through the Bureau of Structures.

When a precast culvert is selected as the best structure type for a particular project during the design study phase, preliminary plans and complete detailed final plans are required to be sent to the Bureau of Structures for approval. The design and fabrication must be in accordance with ASTM Specification C1577, *AASHTO LRFD Specifications*, and the Bridge Manual.

Sometimes a complete set of plans is created for a cast-in-place culvert and a precast culvert is stated to be an acceptable alternate. If the contractor selects the precast alternate, the contractor is to submit shop drawings, sealed by a professional engineer, to the Bureau of Structures for approval. The design and fabrication must be in accordance with ASTM Specification C1577, *AASHTO LRFD Specifications*, and the Bridge Manual.

36.13 Three-Sided Structures

Three-sided box culvert structures are divided into two categories: cast-in-place three sided structures and precast three-sided structures. These structures shall follow the criteria outlined below.

36.13.1 Cast-In-Place Three-Sided Structures

To be developed

36.13.2 Precast Three-Sided Structures

Three-sided precast concrete structures offer a cost effective, convenient solution for a variety of bridge needs. The selection of whether a structure over a waterway should be a culvert, a three-sided precast concrete structure or a bridge is heavily influenced by the hydraulic opening. As the hydraulic opening becomes larger, the selection process for structure type progresses from culvert to three-sided precast concrete structure to bridge. Cost, future maintenance, profile grade, staging, skew, soil conditions and alignment are also important variables which should be considered. Culverts generally have low future maintenance; however, culverts should not be considered for waterways with a history or potential of debris to avoid channel cleanout maintenance. In these cases a three-sided precast concrete structure may be more appropriate. Three-sided precast concrete structures have the advantage of larger single and multiple openings, ease of construction, and low future maintenance costs.

A precast-concrete box culvert may be recommended by the Hydraulics Team. The side slope at the end or outcrop of a box culvert should be protected with guardrail or be located beyond the clear zone.

The hydraulic recommendations will include the Q_{100} elevation, the assumed flowline elevation, the required span, and the required waterway opening for all structure selections. The designer will determine the rise of the structure for all structure sections.

A cost comparison is required to justify a three-sided precast concrete structure compared to other bridge/culvert alternatives.

To facilitate the initiation of this type of project, the BOS is available to assist the Owners and Consultants in working out problems which may arise during plan development.

Some of the advantages of precast three-sided structures are listed below:

- Speed of Installation: Speed of installation is more dependent on excavation than product handling and placement. Precast concrete products arrive at the jobsite ready to install. Raw materials such as reinforcing steel and concrete do not need to be ordered, and no time is required on site to set up forms, place concrete, and wait for the concrete to cure. Precast concrete can be easily installed on-demand and immediately backfilled.

- Environmentally Friendly: Precast concrete is ready to be installed right off the delivery truck, which means less storage space needed for scaffolding and rebar. There is less noise pollution from ready-mix trucks continually pulling up on site and less waste as a result of using precast (i.e. no leftover steel, no pieces of scaffolding and no waste concrete piles). The natural bottom on a three-sided structure is advantageous to meet fish passage and DNR requirements.

- Quality Control: Because precast concrete products are produced in a quality-controlled environment with proper curing conditions, these products exhibit higher quality and uniformity over cast-in-place structures.

- Reduced Weather Dependency: Weather does not delay production of precast concrete as it can with cast-in-place concrete. Additionally, weather conditions at the jobsite do not significantly affect the schedule because the "window" of time required for installation is small compared to other construction methods, such as cast-in-place concrete.

- Maintenance: Single span precast three-sided structures are less susceptible to clogging from debris and sediment than multiple barrel culvers with equivalent hydraulic openings.

36.13.2.1 Precast Three-Sided Structure Span Lengths

WisDOT BOS allows and provides standard details for the following precast three-sided structure span lengths:

14’-0, 20’-0, 24’-0, 28’-0, 36’-0, 42’-0

Dimensions, rises, and additional guidance for each span length are provided in the standard details.

36.13.2.2 Segment Configuration and Skew

It is not necessary for the designer to determine the exact number and length of segments. The final structure length and segment configuration will be determined by the fabricator and may deviate from that implied by the plans.

A zero degree skew is preferable but skews may be accommodated in a variety of ways. Skew should be rounded to the nearer most-practical 5 deg., although the nearer 1 deg. is permissible where necessary. The range of skew is dependent on the design span and the fabrication limitations. Some systems are capable of fabricating a skewed segment up to a maximum of 45 degrees. Other systems accommodate skew by fabricating a special trapezoidal segment. If adequate right-of-way is available, skewed projects may be built with all right angle segments provided the angle of the wingwalls are adjusted accordingly. The designer shall consider the layout of the traffic lanes on staged construction projects when determining whether a particular three-sided precast concrete structure system is suitable.

Square segments are more economical if the structure is skewed. Laying out the structure with square segments will result in the greatest right-of-way requirement and thus allow

When a highway is to be reconstructed essentially on the location of the existing highway, the engineer shall evaluate old culvert locations for possible culvert replacement. This will aid in minimizing changes in existing drainage conditions on private lands.

When a highway is to be constructed on relocation, the designer shall provide a culvert wherever there is an appreciable natural draw or depression. If there are no significant draws or depressions, culverts shall be placed so as not to collect and concentrate a large drainage flow.

5.3 Structure Size Selection

In general, pipe drainage structures shall be selected in accordance with the current culvert selection standard (refer to FDM 13-1-15). The size of culvert may be chosen knowing the following data:

1. Estimated runoff (Q).
2. Approximate length and slope of culvert.
3. Allowable headwater depth in feet, which is taken as the vertical distance from the conduit flow line at the entrance to the water surface in the channel.
4. Entrance type. The type of entrance must be predetermined by the designer.
5. Barrel cross-sectional shape. Determined considering available headroom.
6. Barrel roughness factor. The roughness factor that produces the largest size pipe should be used when alternate materials are allowed at the contractor's option.
7. Tail-water conditions known or computed. Tail water is defined as the distance in feet from the outlet invert to the water surface in the outlet channel.

Following is a detailed discussion of the minimum required data for culvert design along with a discussion of additional design criteria required to perform a thorough hydraulic analysis of a culvert.

5.3.1 Minimum Pipe Size

In accordance with Department of Transportation practice, the minimum size of pipe for culvert cross drains shall be 24 inches, except that on multi-lane highways in fill of 10 feet or more, the minimum size shall be 30 inches.

5.4 Allowable Headwater

As noted previously, existing field conditions and channel geometry will determine a maximum depth of water that can be tolerated at the entrance of a culvert. This depth of water is known as the maximum allowable headwater depth. The information that has been accumulated during the field review of the culvert crossing can now be used to determine the maximum allowable headwater depth for the structure. When the highway profile is established, the headwater depth may also be controlled by the low point in the roadway subgrade or by high points in the roadway ditches. Generally, the maximum high-water elevation should not be higher than the subgrade shoulder point.

Sometimes field conditions will dictate a depth of headwater that is too low to allow an economical design for the culvert crossing. When this occurs, the engineer may consider the use of artificial conditions that will allow a greater depth of headwater to develop. These artificial means are berms or dikes at the inlet ends of culverts, or a depressed profile for the culvert. These artificial means of forcing a headwater depth should not cause any appreciable increase of existing flooding conditions upstream from the culvert.

5.5 Design Freeboard and Headwater-to-Depth Ratio

The headwater depth at the inlet of a pipe culvert is normally expressed as a ratio (HW/D) where HW is the total depth of water (measured from the invert of a culvert) and D is the interior height of the culvert barrel.

The design ratio can be as high as 1.50 for the culverts under 15 feet in diameter or rise. The design ratio for culverts in excess of 15 feet in diameter or rise should be 1.00. Smaller ratios for pipes less than 15 feet may be justified by safety factors of flooding conditions, velocities, scouring, economy, etc. If damage to the culvert is anticipated, or if adverse flooding conditions will be caused upstream of the culvert from the accumulation of ice and debris, the headwater-depth ratio shall be reduced. The reduction of the ratio shall be sufficient to allow an increase in the design flow capacity and freeboard (if needed) at the entrance of the structure to eliminate flood damage or to reduce it to within acceptable limits.

Since the advent of the large sections for round pipe, it has become economical in special cases to design for these culverts with a low headwater to depth ratio. In essence, the headwater to depth ratio plays no part as a control for the design of these culverts, but instead economics is the major controlling factor. To illustrate this

On a superelevated divided highway where a “narrow” median is present, it may be desirable to rollover the high side shoulder and bring up the median shoulder to reduce the elevation difference between the divided highways. This special situation may be desirable in an urban condition when the highways are divided by a barrier wall.

5.4 Vertical Alignment

The highway vertical alignment consists of tangents or grades and vertical curves. Vertical curves are based on sight distance considerations. Headlight sight distance is the primary factor used to determine the length of sag vertical curves (see Attachment 5.6 and Attachment 5.7).

Although grade changes without a vertical curve are discouraged, there may be situations where it is necessary. This must be explained and justified in the DSR. Table 5.8 shows the maximum change in grade without a vertical curve. Some rounding of the deflection point is anticipated during construction.

Table 5.8 Maximum Change in Grade Without a Vertical Curve

Design Speed mph	20	30	40	45	50	60	65	70
Maximum Change in Grade in Percent	1.20	1.00	0.80	0.70	0.60	0.40	0.30	0.20

5.4.1 Grades

Maximum grades (see Attachment 5.3 of this procedure and FDM 11-15 Attachment 1.4) vary with terrain, design speed and functional classification.

The minimum grade on roadways with rural cross sections is 0.0 percent, i.e., flat, except in areas of superelevation transition and other areas with pavement rotation. Do not use flat grades in areas of superelevation transition and other areas with pavement rotation because the combination of a flat longitudinal grade with a flat cross-slope results in pavement surface drainage problems. Provide a minimum grade in these areas based on AASHTO guidance for “Minimum Transition Grades”[38]. This applies to both rural and urban roadways.

If grades of less than 0.5 percent are used, then side ditches should be specially designed to provide sufficient longitudinal gradient for drainage. On divided highways, grade lines of opposing roadways should be treated independently except where topographic or other conditions require them to be identical. The minimum gradient on structures is 0.5 percent to ensure positive drainage.

Compatibility of curb and gutter grades with the existing development is essential in reducing damage to abutting property and the amount of right-of-way to be acquired. To ensure drainage the minimum gradient of curb and gutter is desirably 0.50 percent but at least 0.30 percent. Special attention may be required to assure proper drainage of curbed pavements at the apex of crest vertical curves where a level point occurs. Drainage should be adequate for vertical curves having "k" values of 167 or less (see Attachment 5.4, Attachment 5.5 and pages 270, & 274, GDHS 2004).

An exception to standards is required for grades that are either greater than maximum or less than minimum.

5.4.1.1 Climbing Lanes

See FDM 11-15-10 for guidance on climbing lanes.

5.4.2 Vertical Curves

Design vertical curves to provide adequate sight distance, safety, comfortable driving, good drainage, and pleasing appearance. They are normally symmetrical parabolas. A notable exception would be the use of an asymmetrical parabolic curve to provide better drainage of a structure located on a crest vertical curve.

Vertical curves are generally identified by their “K” values. K is the rate of curvature and is defined as the length of the vertical curve (L) divided by the algebraic difference in grade (A); i.e. the horizontal distance in feet required for a 1 percent change in gradient. K is affected by sight distance, comfort, drainage, and aesthetic quality. Sight distances and vertical curve k-values are shown in Attachment 5.4 through Attachment 5.7 for each of the sight distance categories discussed earlier in FDM 11-10-5.1.1.1 “Application of Stopping Sight Distance (SSD) and Decision Sight Distance (DSD)”. Crest vertical curve values are shown in Attachment 5.4 and Attachment 5.5. Sag vertical curve values are shown in Attachment 5.6 and Attachment 5.7.

[38] See(*1) A Policy on Geometric Design of Highways and Streets 2004*, 5th edition. AASHTO, 2004.

2.6 Drainage Features and Cattle Passes

Drainage features like (list not all inclusive): culverts, bridges, large drainage conduits have unique challenges that can make it difficult to select an appropriate roadside treatment option. Cattle passes can have many of the same roadside design issues as drainage features and will be discussed in this section.

Drainage features or cattle passes can be a hazard depending on orientation, number of drainage features and size. Drainage features or cattle passes with diameters greater than the value listed in the table below are hazards.

Table 2.17 Drainage Feature or Cattle Pass Size [lx]

Pipe Orientation to Roadway	Number of Culverts	Culvert diameters or box culvert opening width (inches)
Perpendicular	1	36
	2 or more	30
Parallel	1	24
	2 or more	All multi-culvert runs are hazards

A drainage feature or cattle pass can become a hazard, regardless of size of drainage feature or cattle pass, if a portion a of the structure can snag the undercarriage of an errant vehicle (e.g. 4 inch object on a 5-foot chord) or the vehicle bumper can impact the structure (e.g. headwall, pipe sticks out of slope, etc.).

Drainage features that are equal to or smaller than the values listed in Table 2.17 are not considered roadside hazards. However, treatment of smaller parallel drainage features can be considered. In many cases treating smaller parallel drainage features could be considered a best practice.

In addition, other objects near a drainage feature or cattle pass can be hazards (refer to Figures 2.56 and Figure 2.57). Some examples are:

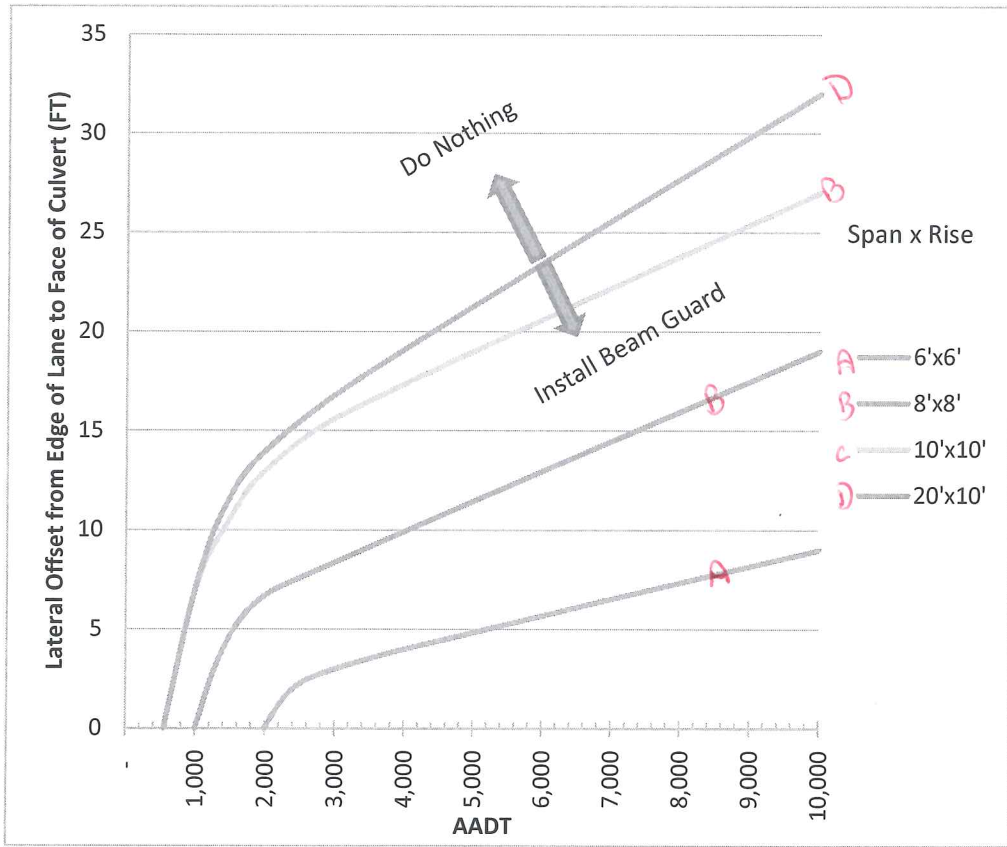
- Water [45]
- Slopes
  - Leading to and departing from drainage feature.
  - Slopes that blend into drainage feature.
- Ditches
  - Non traversable roadway's ditches.
  - Drainage ditches' slopes (i.e. non-roadway ditches).
  - Blending slopes:
    - Roadway backslopes and drainage ditch slopes.
    - Foreslopes and drainage feature or cattle pass.
- Other fixed object hazards.
- Overall drop from structure to ditch bottom.[46]

Other hazards typical increase the traveling public's crash exposure (refer to Figure 2.55).

[45] Water 2 feet or deeper.

[46] Vertical drops of 8 feet or more are hazardous. Vertical drops of 6 feet or more combined with other hazards (e.g. rip rap or water) are hazardous.

Existing


35
30
25
20
15
10
5
0
Lateral Offset from Edge of Lane to Face of Culvert (FT)
Do Nothing
Install Beam Guard
Span x Rise
6'x6'
8'x8'
10'x10'
20'x10'
-
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
9,000
10,000
AADT