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4 Preliminary Design of Culverts

4.1 General

The following series of articles provides a set of guidelines for development of pipes, and type, size, and location (TS&L) plans for box culverts/structural designs. Within these guidelines sound engineering judgment, including technical and economic analysis, must be applied in all situations.

Additional information regarding preliminary design is also contained within BDM Sections 1 and 7.

4.1.1 Policy overview

Within the Bridges and Structures Bureau, the preliminary bridge design unit develops the concepts and the preliminary layouts for highway culverts and associated structures. For culverts/structures that require final design, the unit assembles information and develops a preliminary situation plan sheet so that a designer in one of the final design units can perform the structural design and develop final plans for a contract letting. For pipe culverts the unit develops the layout in sufficient detail that the Design Bureau can reference the information on their final road plans for a contract letting.

The preliminary design process for new and replacement structures begins with a concept statement developed by the Preliminary Road Design Unit within the Design Bureau. When a culvert is an option for replacement, the Preliminary Bridge Design Unit contributes to the concept statement by providing the type and size of the proposed culvert along with its estimated construction cost and the Bridge Bureau attachment which summarizes critical considerations.

The development of all preliminary culvert 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

4.1.2 Design information

The designer will need to access information from several sources to perform preliminary design, including, but not limited to, the following:

- Plans for existing structures, including as-built plans, from Electronic Records Management System (ERMS);
- A new site survey 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;
- LiDAR data 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 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

4.1.2.1 Identification numbers

Refer to BDM 3.2.1 and 1.11.4 for guidance on assigning identification numbers for new and replacement RCB culverts, and other structures requiring final structural design.

4.1.3 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.

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 floodproofing of structures. The relationship between the BFE and a structure’s elevation determines the flood insurance premium.

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.

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.

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 drainage structure that crosses a Drainage District, coordination is required. Design features such as flowline, channel slope, and cross section may be dictated by the Drainage District requirements.

Electronic Reference Library (ERL) contains plans, specifications, and manuals and is available on the Iowa Department of Transportation 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 streamgages 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 Bulletin 17C "Guidelines for Determining Flood Flow Frequency."

Expected moments algorithm (EMA) is an annual exceedance-probability analysis method used for continuous-record streamgages. 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.

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.

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.

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.

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.

Unit Leader is the supervisor of the Bridges and Structures Bureau preliminary bridge unit, final design unit, or consultant coordination unit.

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 AASHTO's ~~1999~~ 2012 *Guide for the Development of Bicycle Facilities* [BDM 4.1.5.2].

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'.

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.

4.1.4 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
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
BNSF, Burlington Northern Santa-Fe Railway
CFR, Code of Federal Regulations
CIP, Cast in place
CLOMR, Conditional Letter of Map Revision issued by FEMA
CMP, corrugated metal pipe
D_{50}, median revetment stone diameter
D0, event code for predesign concept
D2, event code for design field exam
DA, drainage area
DOCT, design outlet channel thalweg
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
IAC, Iowa Administrative Code
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
MCS, main-channel slope, a variable in USGS WRIR 03-4120
MGB, Multiple Grubbs-Beck low-outlier test
n-coefficient, Manning's Coefficient [BDM 3.2.2.3]
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
Q_2, Q_{50}, Q_{100}, Q_{200}, Q_{500}, estimated channel discharge at 2-, 50-, 100-, 200- or 500-year design flood frequency
RCB, reinforced concrete box, a type of culvert
RCP, reinforced concrete pipe
ROW, right of way
RRE, regional regression equation
RT, right
SI&A, Structure Inventory and Appraisal
SIIMS, Structure Inventory and Inspection Management System
SIR, scientific investigation report
SUDAS, (Iowa) Statewide Urban Design and Specifications
TS&L, type, size, and location
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

4.1.5 References

4.1.5.1 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 2023* with article number. (Available on the Internet at: https://www.iowadot.gov/erl/index.html)

[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)

4.1.5.2 Indirect

American Association for State Highway and Transportation Officials (AASHTO). *A Policy on Design Standards—Interstate System, 5th Edition*. Washington: AASHTO, 2005.

American Association for State Highway and Transportation Officials (AASHTO). *Guide for the Development of Bicycle Facilities, 3rd Edition*. Washington: AASHTO, 1999.

American Association for State Highway and Transportation Officials (AASHTO). *Roadside Design Guide, 3rd Edition*. Washington: AASHTO, 2002.

BNSF Railway – Union Pacific Railroad. *Guidelines for Railroad Grade Separation Projects.* Union Pacific Railroad, Omaha, NE, 2016~~2007~~. (Available on the Union Pacific web site at: https://www.up.com/cs/groups/public/documents/up_pdf_nativedocs/pdf_rr_grade_sep_projects.pdf)

Cronshey, R., R.H. McCuen, N. Miller, W. Rawls, S. Robbins, and D. Woodward. *Urban Hydrology for Small Watersheds, 2nd Edition, 210-VI-TR-55.* Washington: Natural Resources Conservation Service (NRCS), 1986. (Current edition of Technical Release 55 (TR-55); available on the U.S. Department of Agriculture web site at: https://data.nal.usda.gov/dataset/small-watershed-hydrology-wintr-55)

Eash, D.A., Barnes, K.K., and Veilleux, A.G., 2013, *Methods for Estimating Annual Exceedance-Probability Discharges for Streams in Iowa Based on Data through Water Year 2010: U.S. Geological Survey Scientific Investigation Report 2013-5086 (*Available on the U.S.G.S. website at http://pubs.usgs.gov/sir/2013/5086).

Eash, David A. *Techniques for Estimating Flood-Frequency Discharges for Streams in Iowa, WRIR 00-4233.* Iowa City: U.S. Geological Survey (USGS), 2001.

Eash, David A. *Main-Channel Slopes of Selected Streams in Iowa for Estimation of Flood-Frequency Discharges, WRIR 03-4120.* Iowa City: U.S. Geological Survey (USGS), 2003

Eash, David A. *Comparisons of Estimates of Annual Exceedance-Probability Discharges for Small Drainage Basins in Iowa, Based on Data through Water Year 2013, SIR 2015-5055.* U.S. Geological Survey (USGS), 2015. (Available on the USGS website at https://pubs.usgs.gov/sir/2015/5055/pdf/sir2015-5055.pdf)

Federal Highway Administration. "Hydraulic Engineering" web page with links to publications and software. http://www.fhwa.dot.gov/engineering/hydraulics/index.cfm

Golden Hills Resource Conservation and Development, Inc. *Stream Stabilization in Western Iowa: Structure Elevation and Design Manual, Iowa DOT HR-385.* 1998. (Available on the State Library of Iowa web site at: https://publications.iowa.gov/16075/)

Hadish, G.A., M. Braster, R.A. Lohnes, and C.P. Baumel. *Stream Stabilization in Western Iowa, Iowa DOT HR-352.* 1994. (Available on the Iowa DOT web site at: https://iowadot.gov/research/reports/Year/2003andolder/fullreports/hr352.pdf)

Iowa Administrative Code. Des Moines: Legislative Services Agency, 2004. (Available on the Internet at https://www.legis.iowa.gov/agencies/nonpartisan/lsa)

Iowa State University. *SUDAS Standard Specifications*. Iowa State University, Ames, IA, 2011. (Available on the SUDAS web site at: https://iowasudas.org/manuals/design-manual/)

Lagasse, P.F., J.D. Schall, and E.V. Richardson. *Stream Stability at Highway Structures, Third Edition; Hydraulic Engineering Circular No. 20 (HEC-20)*. Washington: Federal Highway Administration (FHWA),

2001. (Available on the FHWA web site at: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec20ed3.pdf)

Lagasse, P.F., P.E. Clopper, J.E. Pagan-Ortiz, L.W. Zevenbergen, L.A. Arneson, J.D. Schall, and L.G. Girard. *Bridge Scour and Stream Instability Countermeasures: Experience, Selection and Design Guidance, Volumes 1 and 2, Third Edition; Hydraulic Engineering Circular No. 23 (HEC-23).* Washington: Federal Highway Administration (FHWA), 2009. (Available on the FHWA web site at: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec23ed2.pdf)

Lara, Oscar G. *Method for Estimating the Magnitude and Frequency of floods at Ungaged Sites on Unregulated Rural Streams in Iowa, WRIR 87-4132.* Iowa City: U.S. Geological Survey (USGS), 1987.

Larimer, O.J. *Drainage Areas of Iowa Streams.* U.S. Geological Survey (USGS), Iowa Highway Research Board Bulletin No. 7 (Red Book). (Available on the Iowa DOT web site at: https://www.iowadot.gov/research/reports/Year/2003andolder/fullreports/HR-29%20FINAL%20Drainage%20Areas%20of%20Iowa%20Streams.pdf)

Norman, J.M., R.J. Houghtalen, and W.J. Johnston. *Hydraulic Design of Highway Culverts, Second Edition; HDS No. 5.* Washington: Federal Highway Administration (FHWA), 2001.

U.S. Department of Transportation, April 2012, Hydraulic Design Series Number 5, *Hydraulic Design of Highway Culverts, Third Edition,* FHWA Publication No. FHWA-HIF-12-026. (Available on the FHWA web site at: http://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=7&id=13

4.2 General Culvert Design

In the construction of rural highways in Iowa it is of primary importance that there be minimal diversion of surface water. Water entering the highway right of way in a draw (swale or ditch) should generally be carried through the highway embankment and discharged into the same draw. Although it is not possible to leave unchanged every square foot of watershed, this policy of “minimal diversion” shall be adhered to as closely as practical.

The term “minimal” is difficult to quantify but may be viewed in terms of percentage change and of potential impacts to affected properties. For example, altering a 150-acre watershed to 152 acres may have minor effects on peak flow, but altering a 5-acre watershed to 10 acres may adversely affect farming practices on a given property. Basically, a 10% increase in watershed area due to diversion is usually acceptable. In much rarer instances, <u>decreasing</u> drainage area may also have an adverse impact. One actual example is a 7-acre watershed that was diverted to a much larger basin. During construction, the landowner made IDOT aware that the 7-acre watershed was a significant water supply source to a pond used for watering livestock.

On highway relocations, be aware that field fences may have enough soil built up to create a “ridge” where water does not cross. In effect, these fences may create distinct watershed boundaries and become as important as any “natural” watershed boundary. Avoiding diversion in these instances must be considered when the highway relocation cuts through these fence “ridges”.

Existing tile lines should also be considered in design. For example, if a tile line outlets into or near an existing culvert inlet, care should be taken to keep the same tile flowline elevation.

4.2.1 Hydrology

Reliable estimates of flood-frequency discharges are essential for the economical and proper design of culverts located over streams.

For the design of culverts within a detailed FIS or with the potential for impacting insurable structures, use the 100-year discharge. For the design of crossroad (mainline) culverts and for most sideroad culverts (city or county roads) use a 50-year flood. For entrances and driveways, use a 10-year flood unless the mainline is adversely affected. For temporary culverts under a “runaround”, generally use the 5-year discharge.

For pipes or RCB’s sized less than 6’x6’ within rural basins with drainage areas less than two square miles (1280 acres), the Iowa Runoff Chart (see commentary) or the Iowa DOT culvert program may be used.

For RCBs sized 6’x6’ or larger or drainage basins between 2 and 20 square miles, a thorough review of basin characteristics and history of flooding along with engineering judgement is needed when determining design discharges for small basins. For designer reference, accuracy of AEPD estimates for small drainage basins in Iowa using different calculation methodologies have been studied by the USGS. Results are presented in USGS SIR 2015-5055.

For drainage areas greater than 20 square miles, USGS Scientific Investigation Report 2013-5086 may be used.

The USGS has developed a web based program called “StreamStats” that calculates the estimated peak discharges from Report 2013-5086. The program will delineate a watershed from a point as long as the stream is shown as perennial flow (solid blue line) on a USGS topographic map. The designer may use LiDAR or other more accurate information to check the results for accuracy and to determine the appropriate drainage area.

USGS Report 2013-5086 has defined three different regions for the state and utilizes a three-variable equation for each region. For basins that cross region boundaries (multi-region basins), StreamStats will provide an estimated peak discharge for each region within 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 (See BDM 3.2.2.1).

If a proposed culvert is located within a drainage basin where 25% or more of the watershed is developed, urban hydrology should be considered. 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, the design storm runoff may be analyzed by other methods such as TR-55 for watersheds up to 2000 acres. For basins larger than 2000 acres, TR-20, HEC-HMS or other programs may be used.

When a proposed culvert site is located near a USGS stream gage, is within a detailed FIS or requires DNR approval the designer should refer to the Bridge Hydrology Section under BDM 3.2.2.1.

4.2.2 Hydraulics

For culvert hydraulics, use FHWA's publication, “Hydraulic Design of Highway Culverts,” Hydraulic Design Series No. 5 April 2012. Computer software such as the Iowa DOT culvert program, HY-8 or Haestad Methods’ “CulvertMaster” is also acceptable for analyzing computer hydraulics. The Iowa DOT Culvert program is available on the DOT website.**Error! Hyperlink reference not valid.** Check with the bureau for approval of other software.

Culverts should generally be designed to have one foot to two feet of head above the top of the opening at the design discharge. This can be exceeded in some instances if the culvert is under high fill and there is minimal flood damage potential upstream. For culverts with the potential to impact insurable structures, the Q100 design head should be minimized.

An Iowa DOT standard pipe apron should typically be analyzed with an entrance loss coefficient (Ke) of 0.5 (square edge with headwall). This is the value used in the Iowa DOT culvert program. A Ke value of 0.5 will account for conditions in the field (sediment, debris, etc.) as opposed to the pristine flume studies that were used to determine the entrance loss coefficients.

For RCB projects, the Bureau has developed parallel wing headwall standards for both cast-in-place and precast box culverts which should be used in typical situations. An entrance loss coefficient (Ke) value of 0.4 is recommended for both types of parallel wing headwalls. To improve RCB inlet capacity in rare critical upstream situations, hydraulic designers may choose to use the cast-in-place flared wing standards which are available for limited use. In this case, an entrance loss coefficient (Ke) value of 0.2 is recommended.

The Iowa DOT culvert program is commonly used for most of the Bureau's RCB projects. It conservatively estimates the headwater depths equivalent to the energy grade line (e.g., a velocity = 0 ft./s at the entrance of the culvert). For projects that could impact high damage potential structures, it is recommended that HEC-RAS be used to more accurately determine water surface elevations upstream of box culverts.

For larger culverts where the drainage area requires a DNR permit or is located within a detailed Flood Insurance Study area, the design will be similar to what is required for bridges.

For RCB's 6 ft. in width and larger, the designer should consider burying the flowline (invert) up to 2 feet below design outlet channel thalweg (DOCT). The DOCT represents the low-flow outlet channel thalweg. The additional depth will promote a natural stream bottom through the culvert, provide a lower invert in the event of stream degradation and surge hydraulic capacity. For example, if an RCB flowline is set 2 feet below the DOCT, the DOCT is the maximum elevation anticipated that sediment would accumulate over time within the RCB. Sediments should be blown out during floods. Excavate and embed revetment at inlet/outset sumps to the RCB flowline (when justified).

For channel (live bed sediment transport) locations, the culvert depth below DOCT will not be considered for Regulatory hydraulic performance (compliance with IADNR, NFIP, etc.). This depth can be considered, up to 2 ft., for operational hydraulic performance dependent on the stream bed material. If the stream bed is composed of silt or coarse sand and finer, it can be assumed that a major flood event will result in scouring to this depth. For multi-barrel RCB's, consideration of this additional depth in hydraulic capacity assumes installation of self-cleaning RCB features [BDM 4.5.14].

For overflow (clear water sediment transport) locations, the culvert depth below DOCT up to 2 ft. can be considered for Regulatory hydraulic performance (compliance with IADNR, NFIP, etc.). Early coordination with regulatory agencies is recommended when the culvert buried depth is considered for determining compliance with regulatory criteria. For operational hydraulic performance, up to 4 ft. below DOCT can be considered. Since infilling of the culvert will be silt and fine sand, it can be assumed that a major flood event will result in significant scouring of the culvert invert. Design thalweg for overflow locations is considered the thalweg elevation of the outlet ditch or channel.

Inclusion of the additional depth below design thalweg in determining hydraulic capacity per the above will be as determined by the Engineer certifying the Hydraulic design.

When the upstream terrain is very flat, be aware that a calculated highwater may not be reached due to large available flood storage. In this circumstance, the designer may need to consider less culvert height and more width to accommodate flows at lower water surface levels. In some instances, a ditch dike may be needed at the inlet and sometimes outlet to prevent diversion when designing a culvert.

4.2.2.1 Riverine Infrastructure Database

For new and replacement projects with drainage areas greater than 10 sq. mi. a Riverine Infrastructure Database (RIDB) dataset shall be developed. Refer to BDM 3.2.2.8 for guidance on developing the RIDB dataset.

4.2.3 Culverts in Series

If two culverts in series are near each other, such as a mainline culvert and a culvert downstream under a ramp, generally keep the slope between the culverts to a minimum, perhaps 1% or less. This helps avoid erosion between the culverts. If a significantly steeper slope is unavoidable, a rock-lined ditch may be needed.

The hydraulics of the culverts in series should be carefully checked to accurately determine the influence of one culvert on any upstream culverts (e.g. the headwater created from the downstream culvert should be considered in determining the tailwater for the next upstream culvert in the series).

4.2.4 Bedding and Backfill

All pipe culverts under primary and secondary roadways shall meet the Class “B” Bedding and Backfill requirements and for temporary pipes, entrances, driveways and levees or dikes, Class “C” Bedding and Backfill per DB SRP DR-101 should be used.

For box culverts, the backfill requirements are shown on DB SRP DR-111.

4.2.5 Settlement and Camber

The Soils Unit of the Design Bureau provides estimated settlements for culverts on relocated or raised highway embankments. The estimated settlements for pipe culverts can be mitigated per DB SRP DR-102. The camber should be noted in the appropriate column on the pipe culvert bid tabulation 104-3.

For box culverts where the settlement is estimated as 6 inches or greater, the culvert shall be cambered. Bell joints shall be provided when anticipated settlements are 12 inches or greater for CIP single box culverts and 6 inches or greater for CIP twin and triple box culverts. Regardless of the estimated settlement, bell joints shall be provided when the fill is greater than 35 feet. See BDM Article 7.2.4.5.3 for additional information on bell joint requirements. When the anticipated settlement is 12 inches or more, a single line precast RCB option is not allowed. When the anticipated settlement is 6 inches or more, precast side-by-side single cell and precast multiple cell boxes are not allowed.

This paragraph is focused on situations where it is proposed to add new fill near to existing bridge substructures, for example when replacing a bridge with a culvert. Downdrag on existing piles occurs when placement of the new fill causes settlement of compressible soils below the fill. Bridges in service, during or after placement of the additional fill, need to be evaluated for the additional downdrag forces. This could impact staging, maintenance of traffic, and the overall project concept. Therefore, when considering this type of work, the Concept Team shall coordinate early with the Soils Design Unit. In some cases, final bridge design will also need to be consulted. A potential downdrag issue shall be identified on the BSB Attachment for Concept Statement. When applicable, the Concept Statement shall include preliminary downdrag mitigation cost.

4.2.6 Minimum Allowable Cover

Minimum allowable cover for all concrete and metal pipes is 2 feet for roadway and 1 foot for entrance culverts, measured at the edge of shoulder [DBDM SRP DR-102 & DR-104]. The top of the structure should be at or below the subgrade elevation within the roadway limits (outside to outside of shoulder). Minimum cover for culvert in a divided roadway for the median is one foot.

When minimum cover cannot be obtained with a single round pipe, consider using low clearance pipe or twin pipes. Also, the designer may use a concrete pipe or a low clearance pipe with end wall. Other options include partially burying a larger diameter pipe while providing an equivalent water area or recommending a cast-in-place drop inlet. Total cost of the various structure options considered shall also be a determining factor.

When specifying an arch or elliptical pipe, the bid item should reference the round pipe equivalent (e.g., 48” Equivalent Low Clearance Reinforced Concrete Pipe). Also see DB SRP DR-202.

Spacing for twin pipes shall be approximately 2-3 feet between culvert walls or as needed to provide at least 6 inches between the flared outside edges of the aprons.

[Reference DB SRP DR 201-206]

Minimum fill height (cover) for Reinforced Concrete Boxes (RCB) is measured at edge of shoulder. For precast RCBs minimum cover is 2 feet. For cast-in-place RCBs cover less than 2 feet is allowable. The top of the structure should be at or below the subgrade elevation within the mainline pavement limits (typically outside to outside of lanes).

For projects where future widening is planned, minimum cover should be measured based on the ultimate lane configuration.

4.2.7 High Fill Pipes

For culvert installations where maximum allowable cover is exceeded, as indicated on the DBDM SRP DR-102 & DR-104, pipe strength may be modified to account for the additional cover. While standard pipe strength ranges from 2000D to 3750D, the concrete pipe industry does provide higher pipe strengths of 4000D and above for high fill situations. Prior approval from the Unit Leader is required.

4.2.8 DB Standard Road Plans and Road Design Details

See the commentary for guidelines on properly using the Road Design Standard Road Plans and Road Design Details.

4.2.9 Stream Stability

For larger culverts, with spans greater than 8’, the designer shall consider the stream stability guidance within BDM article 3.2.2.10. The article provides guidance on determining the location and depth of degradation within streams, and types of possible design solutions including structures with flumes. For culvert projects, the streambed profile determination guidance can be utilized to define design streambed elevations, channel slope, and proposed culvert flowlines. Buried culvert flowlines would be relative to the design streambed.

If downstream channel degradation is identified, designers should be aware of potential concerns. At a culvert outlet, the damage from degradation might include headwall settlement, joint separation, or undermining. Precast box culverts are not as robust regarding degraded streams as cast-in-place box culverts. The increased number of joints and the tie-bolt joint connections between each precast element are more at risk for piping failure.

4.3 Culvert Plan Preparation

For Connect projects, Plat Plans are no longer required for pipe culverts designed by consultants. The plan and profile for an RCB culvert or pipes with flumes or drop inlets will require final structure design and should be developed as a TS&L (see Commentary for an example of an RCB TS&L).

The TS&L should include enough ground elevations and contours to accurately define the area. All draws, banks, existing structures (including flowlines and lengths), fence lines, tile lines, utilities, and other pertinent existing features should be shown. The proposed structure, including flowlines, lengths, skews and special features should be shown. See the culvert plan review checklist for information to include on TS&Ls for RCBs.

Ground elevations should be shown along the drainage way at least 100 feet upstream and downstream of the culvert. Contours should be clearly labeled. Proposed toe of slope lines (fore slope, ditch lines, back slopes) should be shown at least 150 feet ahead and back of the culvert stationing.

Both the plan and the profile view should be <u>plotted</u> with a 1"=40' scale as measured on an 11"x17" drawing. (This refers only to the <u>plotted</u> scale and does not refer to any "working scales" as used while actually in a CADD file.) Do **not** use an exaggerated scale in the profile view.

For Connect projects, the culvert should be oriented horizontally on the TS&L sheet, with the roadway position consistent with the culvert skew. It follows that RCB bend(s) will be oriented on the TS&L sheet at the defined bend angle to the horizontal. The profile view is drawn as a Longitudinal Section along centerline culvert. Therefore, for skewed culverts, the true length at centerline will be represented on the profile view. Generally, the match line for RCB plan and profile view shall be the roadway centerline (or baseline), or as close as practical.

For pipe culverts with concrete flumes, drop inlets or other features that require structural design, the plan should be developed as a TS&L.

Sample plans may be found online with the review checklist for both pipes and RCBs.

Preliminary Design Checklist - RCB Culvert or Preliminary Design Checklist -Drainage

4.3.1 Culvert Database (old Pink Sheets)

The DOT maintains a culvert database (Bridges&Structures.accdb) where all new and replacement culverts shall be stored. The database serves as a repository for all culvert information going forward and to provide a means to automate the creation of the 104-3 Tab and Culvert Schedule Sheet for project development. Usage of the database is described in online workflow documentation CW08~~9~~ Entering Pipe and Structure Information into Database.

The database format allows for documentation of existing conditions such as drainage area, culvert flowlines, condition of the structure and other properties. The database also documents the proposed culvert properties such as size, type, Standard Road Plan (DR series), proposed flowlines, lengths, and other design features. For a complete list of database requirements, refer to the workflow documentation.

For pipe design, the pink sheet calculation method, and submittal of hard copy or scanned Pink Sheet forms are no longer required by the Preliminary Bridge Unit. Proposed culvert lengths will be determined graphically as opposed to the computational method on the original pink sheets. The ORD file with models, the culvert database, Culvert Schedule Sheet, ASCII text file, and Hydrology/Hydraulic Support data submitted in their proper subfolders within the Project Directory are considered sufficient to serve as the culvert design record.

4.3.2 Pipe Sizes

In general, concrete pipe culvert sizes will range from 18 to 84 inches in 6-inch increments. Minimum pipe size for roadways, side roads, and ditch letdowns is 24 inches. This provides adequate opening for maintenance inspections and minimizes the potential for plugging with debris. Details for other available sizes and types are shown on [DB SRP DR-104]. For areas with low clearance or minimum cover, an arch pipe or smaller diameter twin pipe culverts can be used. See BDM 4.2.6 for information on minimum cover. For arch pipe equivalent diameters, refer to [DB SRP DR-202].

Preferred minimum size for median pipes for divided highways is 24 inches. In some instances, the median ditch may be too shallow to place a 24-inch pipe under the pavement and subbase, and D sections with various bevels may be used. For areas with minimal drainage or clearance restrictions such as a gore area, an 18-inch pipe may be used. A concrete apron with end wall may also be considered to provide additional clearance. Refer to [DB SRP DR-205] for details.

Minimum pipe size for entrances is 18 inches.

The site history of the existing culvert may provide useful information when sizing a proposed culvert. IDOT maintenance personnel may have information related to landowners' complaints or road overtopping, which may indicate a larger structure should be designed or the road grade needs to be raised. Any such history should be documented in project files.

4.3.3 Culvert Type

For most highway locations, concrete pipe is required under the road. For highway locations where there is less than 3000 ADT (Average Daily Traffic) and the highway is not an NHS (National Highway System) route, the culvert type used shall be bid as Unclassified Roadway Pipe (Coated CMP or HDPE pipe). For an extension of an existing concrete pipe culvert or small box, the extension will be bid as concrete pipe regardless of the ADT. The ADT is estimated for future 30-year traffic.

Concrete pipe culverts shall be used under all highways with greater than 3000 ADT or designated as an NHS route, including county or city roadways.

Corrugated metal pipe shall be specified for any temporary pipes used for roadway construction staging purposes (aprons are generally not needed). For bridge replacement projects utilizing a temporary run-around, concrete pipes with inlet/outlet aprons shall be specified instead of CMP to reduce the potential for uplift.

Unclassified Entrance Pipes (Non-Coated CMP, HDPE or Concrete) shall be specified for entrances and driveways. Culverts under county or city roads should be replaced in-kind. When a new culvert is proposed under a side road, the local jurisdiction should be consulted for their preference regarding culvert type.

New or replacement stock passes shall be 6’ x 7’ precast RCB. Existing stock passes can be extended utilizing DB RDD 510-4.

Precast RCBs are typically bid as an alternative to Cast-in-Place for single, twin and triple box culverts. See BDM 4.5.2 for more information.

4.3.4 Horizontal Alignment

Generally, culverts should be aligned with the waterway, especially on the outlet end. However, high skews should be avoided where possible to minimize costs. New or replacement pipe and box culverts shall be designed with a whole degree skew to the roadway alignment. Culvert and excavation costs should be considered when selecting the alignment. The constructability of the culvert during traffic staging, including maintaining drainage during construction, may also be an important factor.

4.3.5 Vertical Alignment

Generally, the slope of a pipe or box culvert should approximate the natural stream or draw slope. When the slope of a pipe culvert is 5% or steeper, give consideration to a culvert type such as DB SRP DR-611 or DR-641. When the slope of a box culvert exceeds approximately 2%, give consideration to some type of energy dissipater such as a drop inlet, impact basin or a flume outlet. Also, give consideration to putting in verticals breaks in the slope, such as a “broken back” culvert, to minimize outlet velocities.

4.3.6 Length Determination

The length of culvert is determined by either the clear zone or by matching the proposed cross section, such as the barnroof slope. See the commentary for design aid "Determining Culvert Lengths” which provides a more detailed explanation of how to determine this length. For Connect projects, the proposed embankment terrain surface intercept can be utilized in determining a culvert length instead of a pink sheet. For skewed culverts, the determined length must include getting all corners of a headwall or top of pipe/apron far enough out to intercept the embankment terrain surface and extend beyond the clear zone. See DB RDD 4311 for fore slope shaping and cover for extensions or spot replacement culverts.

It should be noted that clear zone distance is measured from the edge of traveled way and the design speed is 5 mph greater than the posted speed. See [DB DM 8A-2]. Clear zone is determined by the Design Bureau.

Calculated concrete pipe lengths will be rounded up to the nearest even-numbered foot. Calculated lengths of Unclassified pipes will be rounded up to the nearest foot.

The length of cast-in-place (CIP) reinforced concrete box culverts shall be referenced from the back to back of parapet rounded up to the nearest foot. Precast box culvert barrel lengths (not the back to back of parapet) shall be rounded up to the nearest foot.

The designer should note that our policy for determining box culvert length differs between precast and CIP. Culvert length for the CIP option is determined by the foreslope intercept with the top of parapet, while the length for the precast option is determined by the intercept with the top of box. For more information on precast box culvert layout requirements, refer to BDM article 4.5.2.

4.3.7 Culvert Tabulation Sheets

Culvert Schedule Sheet
The Culvert Schedule Sheet is a summary of culvert information to serve as a project record. Culvert length, flowline, and other pertinent information is tabulated. The Sheet will be created for the B02 event through an automated process utilizing the project culvert database. See Commentary C4.3.7 for an example.

104-3 Tab - Drainage Structures by Road Contractor

The 104-3 tab is a summary of pipe culvert information for a project. Culvert length, flowline and other pertinent information is provided to the contractor for construction of the drainage structures. This tabulation shall be completed by the Design Bureau through an automated process utilizing the project culvert database.

110-9 Tab – Culvert Abandonment and 110-2 Tab – Removal of Existing Structures

Existing culverts that need to be removed or plugged and abandoned should be designated in the appropriate tab. Existing culverts within the project limits that are not specifically listed as removals or abandonments, will be used as constructed. These tabulations shall be completed by the Design Bureau with coordination from the Bridge Bureau for the B2 event date.

104-4 Tab – Roadway Items for Drainage Structures Installed by Culvert Contractor

This tabulation sheet is used for box culverts or other structural designs and is to be completed by the Design Bureau during final design as needed.

4.4 Pipe Culverts

4.4.1 Extensions

Existing RCBs and pipes shall generally be extended with an equivalent size and shape to closely approximate the hydraulic opening. For example, extend a 2’ x 2’ RCB with a 30” RCP culvert, and extend a 3’ x 2’ RCB with a 37” x 23” concrete arch pipe or a 36” RCP.

For skewed RCBs, the pipe culvert should be cut to the skew angle of the headwall so the pipe can be placed flush with the face of the parapet. For headwalls with a skew angle greater than 30 degrees, it may be advantageous to cut the barrel of the RCB so that the pipe can be connected better with the RCB. Use DB SRP DR-122 to connect the RCB to the pipe with a Type “C-2” concrete adapter for pipe culvert connections. The largest RCB for extension with a pipe is 6’ x 6’. See chart below for appropriate pipe size extensions.

RCB EXTENSIONS WITH PIPES

RCB Width x Height	Round Pipe Extension Size	Low Clearance Pipe Extension Size
2' x 2'	30"	
3' x 2'	36"	37" x 23"
3' x 3'	42"	
4' x 2'		52" x 32"

4' x 3'	48"	59" x 36"
4' x 4'	54"	
5' x 3'		65" x 40"
5' x 4'	60"	
5' x 5'	66"	
5' x 6'	72"	
6' x 4'		88" x 54"
6' x 5'	72"	
6' x 6'	78"	

The pipe and the DB SRP DR-122 connections should have adequate earth cover and not project up into the subgrade or shoulder. There is not a practical equivalent low clearance pipe shape for some existing RCBs (such as a 6’ x 3’), so consider using the largest practical precast size that provides adequate hydraulic opening. If adequate earth cover is not possible with a precast extension, these RCBs may need to be extended in-kind.

A horizontal or vertical change of alignment between the existing pipe and the pipe extension requires an adapter (DB SRP DR-122 or DB SRP DR-141). See the Commentary 4.2.8 DB SRP and RDD for more details on adapters, elbows and “D-sections”

See DB SRP DR-Series typicals for determining and labeling skews of extensions that are skewed to the existing culvert and/ or skewed to the roadway.

4.4.2 Median Pipes

Median drains should be placed to maintain the natural drainage as much as practical. Maximum spacing of median drains is 2000 feet in sag vertical curves and 1500 feet on tangent grades. For tangent grades greater than 2%, consideration should be given to 1000-foot spacing. If 18-inch diameter median drains must be used, spacing should not exceed 1000 feet.

For safety and settlement reasons, median drains should be placed transverse to the centerline of the roadway rather than "teed" into a crossroad pipe. These drains should generally outlet to the upstream side of the highway, when practical, so that outlet velocities and erosion is confined to the highway right of way and will not adversely affect adjacent property. An exception to outletting upstream is when outletting along the flood plain of a stream. In those instances, the median pipe should drain to the downstream side of the highway to minimize water backing into the median.

Median pipes can be designed with up to a 10% slope due to the small drainage area (2 to 3 acres) and short duration of peak flows. There are instances when a median pipe has been designed to outlet onto the roadway embankment but the preferred method is to outlet the pipe to the ditch. Allowing drainage to outlet onto a roadway embankment instead of a ditch can cause long-term maintenance and embankment stability problems.

When a straight concrete median pipe does not have sufficient vertical clearance under the pavement (minimum 2 feet), the designer should utilize a vertical bend created by single bevel “D” section (see SRP DR-141 and DR-613). A typical situation for use of a “D” section with a median pipe occurs for 4-foot median ditches on a multi-lane highway or interstate or when a widening project to the median side reduces the median ditch depth making it difficult to fit a straight median pipe under the pavement.

Where left turn lanes are present, consider a pipe near the median crossing, and another pipe at the beginning of the turn lane with a median dike to capture most of the drainage.

Vertical riser pipes into RCBs or pipes are generally not preferred.

4.4.3 Cross Road Culvert Letdowns

When the slope of a cross road culvert exceeds 5%, a letdown structure should be considered (see DR-641). Under Standard Road Plan DR-641, a concrete pipe is required under the roadway and either a coated CMP or HDPE can be used for the letdown.

If a culvert diameter is greater than 42 inches, a concrete flume should be designed to outlet the drainage. Culvert letdowns larger than 42 inches have a greater potential for failure.

4.4.4 Ditch Letdowns

Designing the outlets of letdowns through an RCB wall or flume wall is not desirable due to potential cracking in these walls. Rather, the outlets can be set beyond the headwall or on top of the wingwall or flume wall. The pipes should be anchored to the wall if resting on top of it.

Although the use of culvert letdowns is dependent on site conditions, a rough rule of thumb is that drainage areas of up to 10 acres or less do not warrant culvert letdowns. In those instances, a riprap letdown could be considered. The existing site conditions often provide helpful information in deciding if a culvert is necessary. For example, if the existing side ditch does not have a letdown or any erosion problems, then the proposed project may not need one either.

Consideration should be given in some circumstances to ditch treatments such as special ditch control, turf reinforced mat, erosion stone, or riprap. Cost, type of soil, ditch slope, drainage area, and the preferences of the local DOT maintenance personnel are all factors in determining the proper ditch treatment.

4.4.5 Culvert Liners

Some common problems with culverts approaching the end of their design lives include corrugated metal pipes that have rusted through, concrete pipes where joints have separated and soil is coming through the joints, and small box culverts with deteriorated floors and walls where concrete is spalling badly and reinforcing steel is exposed and corroded.

Traditional solutions include open excavation and replacement, or jacking a new culvert alongside the existing one. However, another option is to push a liner, either metal or plastic, through the existing culvert and then grout the void between the liner and culvert.

There are many important factors to consider when designing and installing a liner.

Advantages of these types of liners are as follows:
1. Installation is quick, generally less than a day, which is significantly less than it takes to excavate, remove, replace, cover, and place new pavement.
2. Traffic disruption is minimal, which is especially important for higher-traffic roads.
3. Equipment needs are minimal compared to conventional cut and cover.
4. Since open excavation is not needed, spot pavement replacement is not needed.
5. Potential settlement caused by excavating and then backfilling is eliminated.

6. Lining a pipe may be less expensive than open excavation or jacking, but comparisons should be made at each site. Obviously, as fill heights increase, the costs of open excavation increase.
7. DOT maintenance forces may be able to install the liner, although contracting this work is also an option.

Disadvantages are as follows:

1. If the culvert has some bends or poorly aligned joints, a liner may not work unless it is significantly smaller than the existing pipe. Metal or PVC liners will bend very little, if at all. Polyethylene liners can bend a small amount, but if bent or kinked too much, the strength of the pipe may be significantly reduced leading to cracking or buckling in the future.
2. Reduced hydraulic capacity is potentially one of the biggest drawbacks to liners. Each site should be reviewed in the field and for existing and proposed hydraulics. Examine the risks of potential flooding upstream, water over the road, and inadvertent diversion of drainage during high flows to a culvert in an adjacent watershed. A full hydraulic analysis of both the existing and liner culverts should be made, including inlet and outlet control calculations. At least one pipe liner manufacturer suggests that a smooth liner with a lower Manning's n-value will give better hydraulics than an existing culvert with a higher n-value. However, this may not be true depending on site conditions, so the full hydraulic analysis is important.
3. Both corrugated metal and plastic liners are defined as flexible pipes and therefore do not have much strength to carry earth pressures without surrounding material, such as grout, to support them. Without this support, the liner can crush or fail over time. If the liner is installed in a concrete pipe where the joints have pulled apart slightly but the pipe itself is still in good condition, the existing concrete pipe may still carry the earth load for many years. However, if the culvert is in very poor structural condition, such as a badly corroded metal pipe, the liner will need to carry all the earth load. Therefore, the backfill material, i.e., grout, is critical. Do not underestimate the importance of this.
4. The life of the liner material may not be as long as the life of a concrete pipe installed by jacking or open excavation.

A higher headwater depth (2 to 4 feet above the top of the culvert) can be considered for culvert liners as long as the upstream flood plain has a low damage potential and the headwater elevation will not cause roadway overtopping.

4.4.6 Culvert Maintenance

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

4.4.7 Uplift of Culvert Inlets

For corrugated metal or polyethylene pipes with diameters of 48" and larger, cast-in-place headwalls, precast concrete aprons (DB SRP DR-201), or concrete collars should be considered on the inlet to prevent failure due to uplift forces. For 48" to 84" diameter culverts, an alternative is to use a concrete pipe instead of CMP. For temporary run-arounds used to maintain traffic, use concrete pipes to reduce potential for uplift at the culvert inlet.

4.4.8 Trenchless Construction

There are many situations where trenchless construction to replace a culvert is preferable to open cut construction especially on high ADT roadways or where out of distance detours are long. Most trenchless construction methods may have a higher dollar cost than that of their open cut counterparts. However, one needs to consider the benefits that trenchless construction provides and weigh all the costs before deciding against using a trenchless technique (especially for excavations greater than 10 feet). Trenchless construction avoids the cost of pavement removal and replacement, dewatering, staging and traffic control. The benefits of trenchless construction also avoid inconvenience to the traveling public and lost business revenue caused by a closed roadway; minimizing utility conflicts; avoiding potential safety issues and other environmental impacts.

The preferred method for jacking a culvert is from the downstream side to the upstream inlet. Trenchless construction can be performed from the upstream side of a highway if environmental or ROW issues dictate. However, for larger culverts (e.g. 54 inch or greater) and for grades of 2 percent or more, it may not be possible to jack from the upstream side. Consultation with the trenchless industry is recommended when a site requires jacking a culvert from the upstream side. The minimum temporary easement area for a jacking pit is 60 feet from the embankment and 50’ ahead and back for access and the storage of materials.

4.4.9 Slope Tapered Inlets for Pipes

Slope tapered inlets for pipe culverts can be used to reduce construction costs by reducing pipe sizes when the elevation difference between inlet and outlet is at least four to six feet. Cost savings may be realized when the culvert length is greater than 150 feet. Due to high velocities and large drop in elevation, most tapered inlet culverts will need a flume and a basin to dissipate energy.

Design guidelines for slope tapered inlets for pipe culverts are shown in the commentary.

4.4.10 Revetment for Pipes

To address regulatory changes requiring stream mitigation for the placement of revetment, the outlet of all new, replacement or extended pipe culverts will no longer require revetment splash basins to minimize scour/erosion (DB SRP EC-301). The need for revetment will be determined and justified on a case-by-case basis by the Design Bureau, unless the preliminary designer communicates a need. Preliminary designers may refer to the commentary BDM C4.5.8 for guidance. Revetment will typically not be required at the inlet of culverts. Revetment will be shown on the CADD design file by the Design Bureau, and the Design Bureau will calculate revetment quantities for cross road culverts, median pipes and RCBs extended with pipes.

Splash basins for median pipes will depend upon the ditch grade they outlet to. Consultation with the Design Bureau may be necessary when determining if a median pipe will require a splash basin.

4.4.11 Fish Passable Pipe Culverts for Regulatory Compliance

The Location and Environment Bureau (LEB) will identify streams at culvert locations that are classified as Waters of the United States (WOTUS) and require fish passage at the W00 (Preliminary Wetland Review) event. When a culvert location is identified as WOTUS and requires fish passage, any new or replacement culvert 48 inches and greater in diameter must be buried at least 12 inches below the natural streambed. When a pipe culvert is buried one foot below the streambed, the culvert size should be increased to the next 6-inch increment to provide sufficient hydraulic capacity (e.g., a 60” RCP buried one foot is hydraulically equivalent to a 54” culvert).

For locations not identified as WOTUS or not requiring fish passage, the culvert may be designed to match the natural streambed or as determined by the designer. For pipe culvert extensions, fish passable mitigation will not be required for the design of the extension.

Revetment for buried pipes shall match the natural streambed and be placed at the inlet and outlet for all new and replacement culverts per Standard Road Plan EC-301. Revetment at the inlet is intended to mitigate the potential for the stream to head-cut (degrade) upstream of the culvert. The Design Bureau will calculate the revetment quantities for cross road culverts, median pipes and RCBs extended with pipes.

4.4.12 Temporary Run Around (on-site detour)

For some smaller stream bridge replacement projects that do not have a good detour, a temporary run around using pipes to handle drainage may be considered for maintenance of traffic. Concrete pipe(s) with inlet and outlet aprons shall be used in lieu of CMP(s) to reduce potential for uplift. Connected pipe joints are recommended (DR-121), and if the site is located in the Loess Hills, it is recommended that the joints be wrapped. The pipes shall be designed to pass a 5-year flood to meet headwater guidance and below the edge of travelled way. A Plan Sheet for Temporary Detour Pipes at a Stream Crossing is required to be provided with the B2 deliverable, intended for placement in the road plans.

In order to minimize embankment material cost and environmental/ROW impacts, the roadway profile for a run around will often be lower than the adjacent roadway. To reduce the risk to the travelling public during the temporary conditions, a Monitoring Plan (a.k.a. Plan of Action or POA), shall be implemented. Preparation of a Bridge Watch Dataset, including a Monitoring Plan shall be developed by the Preliminary Design engineer. For more information on the Monitoring Plan requirements, refer to BDM 3.15. The dataset will need to be modified as needed per the differences between a temporary bridge and roadway with culvert(s). When the temporary run around is to be put into service, the DOT Preliminary Design Unit Leader shall be notified by the contractor, and the DOT shall implement the site Monitoring Plan (POA). The following note shall be placed on the top left corner of the replacement bridge TSL sheet:

"The temporary run around shall be monitored for the duration that it is under traffic. When the construction of the run around is installed, the contractor shall notify the Preliminary Design Unit Leader at 515-233-7949 so a Flood Management Plan can be developed in advance of the temporary run around being put into service. Upon notification, the DOT will add the site to the Bridge Watch Management Plan for monitoring."

4.5 Reinforced Concrete Boxes (RCBs) and Designs

4.5.1 Cast in Place RCBs

The following standard box culvert sizes are measured in feet of clear Span x Height. Culvert sizes are available in 1'-0 increments with the sizes listed below. These standard sizes should be used whenever practical. No RCBs smaller than a 3' x 3' shall be used. Cast-In-Place (CIP) Twin and Triple Culverts are multiple barrels sharing common interior walls, i.e. Twin 12 x 8 is two 12-foot spans with a height of 8 foot.

SINGLE REINFORCED CONCRETE BOX CULVERT STANDARDS (span x height in feet):

3 X 3										
4 X 4										
5 X 3	5 X 4	5 X 5	5 X 6							
6 X 3	6 X 4	6 X 5	6 X 6	6 X 7	6 X 8					
8 X 4	8 X 5	8 X 6	8 X 7	8 X 8	8 X 9	8 X 10				
10 X 4	10 X 5	10 X 6	10 X 7	10 X 8	10 X 9	10 X 10	10 X 11	10 X 12		
12 X 4	12 X 5	12 X 6	12 X 7	12 X 8	12 X 9	12 X 10	12 X 11	12 X 12		
14 X 4	14 X 5	14 X 6	14 X 7	14 X 8	14 X 9	14 X 10	14 X 11	14 X 12	14 X 13	14 X 14
16 X 4	16 X 5	16 X 6	16 X 7	16 X 8	16 X 9	16 X 10	16 X 11	16 X 12	16 X 13	16 X 14

Fill range for standard Cast-In-Place Single Box Culverts is 0 to 55 feet for 3’ to 12’ span RCBs and 0 to 16 feet for 14’ and 16’ span RCBs. Design fill height is defined as the maximum depth of fill measured from the top of pavement to the top of the Culvert.

TWIN REINFORCED CONCRETE BOX CULVERT STANDARDS (span x height in feet)

8 X 4	8 X 5	8 X 6	8 X 7	8 X 8	8 X 9	8 X 10		
10 X 4	10 X 5	10 X 6	10 X 7	10 X 8	10 X 9	10 X 10	10 X 11	10 X 12
12 X 4	12 X 5	12 X 6	12 X 7	12 X 8	12 X 9	12 X 10	12 X 11	12 X 12

Fill range for standard Cast-In-Place Twin Box Culverts is 0 to 25 feet.

TRIPLE REINFORCED CONCRETE BOX CULVERT STANDARDS (span x height in feet)

10 X 4	10 X 5	10 X 6	10 X 7	10 X 8	10 X 9	10 X 10	10 X 11	10 X 12
12 X 4	12 X 5	12 X 6	12 X 7	12 X 8	12 X 9	12 X 10	12 X 11	12 X 12

Fill range for standard Cast-In-Place Triple Box Culverts is 0 to 25 feet.

Standard RCB headwall skews (0°, 15°, 30° and 45°) should be used in almost all cases, even when the barrel is at a non-standard skew to the roadway. For example, if the barrel is skewed 20° to the roadway, use a 15° standard headwall with additional barrel length to account for the corner that will be closer to the roadway. Exceptions would include when the RCB headwall is near the intersection of two roads, and the slope shaping and safety on both roads need to be considered.

If a twin or triple standard size precast option with barrel size exceeding the maximum CIP multi-box standards is proposed, a similar CIP option shall be offered. For this situation, the CIP design shall be noted as non-standard on the TS&L.

4.5.1.1 Cast-in-Place RCB Headwalls

To provide relative parity between cast-in-place and precast box culvert options, the Bureau has developed parallel wing headwall standards for cast-in-place and precast box culverts which should be used in typical situations. The cast-in-place flared wing headwall standards are available for limited use in critical upstream hydraulic situations as discussed in BDM 4.2.2.

Slope tapered inlets, scour floors and pedestrian RCB culverts use flared wing headwalls.

Cast-in-place RCB headwalls shall be constructed level. An exception is a cast in place headwall for pedestrian tunnels, where sloped cast-in-place headwalls are required to maintain positive drainage (see BDM 4.5.16).

4.5.2 Precast RCBs

Unless otherwise specified, for primary road projects the bureau now allows both cast-in-place (CIP) and precast box culvert alternatives under the following project conditions:

- The culvert is an Iowa DOT standard size single, twin or triple box with standard size headwalls at both ends. For precast twin and triple box culverts use side-by-size standard size precast single boxes [SS 1082P],
- The barrel span or spans are each 6 to 16 feet,
- Design earth fill heights are in the range from 2 feet to 25 feet,
- The culvert is not placed directly on bedrock,
- Anticipated culvert settlement is less than 12 inches for single boxes and 6 inches for twins or triple box culverts under these fill heights, and

- There are no conditions requiring bell joints or other details which are available only with cast-in place box culverts.

Projects meeting these requirements will require the designer to develop plans allowing for two alternate designs: one for cast-in-place, and one for precast. If the RCB is designed with a bend, consult with the preliminary design unit leader before proceeding. If the RCB has a drop inlet, flume, unique headwall or scour floor, the plan should allow for a precast alternate with a cast-in-place drop inlet, flume, unique headwall or scour floor as noted on the TS&L. During development of the TS&L in the preliminary design stage, the settlement is not known and the precast option may be eliminated during final plan development if it is determined that the site exceeds the settlement criteria.

The list of precast single box sizes (span x height) provided below correspond with the box sizes developed for the CIP single box culvert standards, with spans less than 6 ft. being excluded.

SINGLE PRECAST REINFORCED CONCRETE BOX CULVERT STANDARDS (span x height in feet):

6 X 3	6 X 4	6 X 5	6 X 6	6 X 7	6 X 8					
8 X 4	8 X 5	8 X 6	8 X 7	8 X 8	8 X 9	8 X 10				
10 X 4	10 X 5	10 X 6	10 X 7	10 X 8	10 X 9	10 X 10	10 X 11	10 X 12		
12 X 4	12 X 5	12 X 6	12 X 7	12 X 8	12 X 9	12 X 10	12 X 11	12 X 12		
14 X 4	14 X 5	14 X 6	14 X 7	14 X 8	14 X 9	14 X 10	14 X 11	14 X 12	14 X 13	14 X 14
16 X 4	16 X 5	16 X 6	16 X 7	16 X 8	16 X 9	16 X 10	16 X 11	16 X 12	16 X 13	16 X 14

Fill range for standard precast RCBs is 2 to 25 feet for 6' to 12' span RCBs and 2 to 16 feet for 14' and 16' span RCBs. Design fill height is defined as the maximum depth of fill measured from the top of pavement to the top of the Culvert.

Standards for precast culvert end sections are available in 0, 15, 30 and 45 degree skews.

Following are the plan development guidelines for projects when precast concrete boxes are required or an alternate to cast-in-place culverts.

- The preliminary designer shall include a precast option layout model.
- Preliminary Bridge will prepare the precast option preliminary design (TS&L).
- For a single culvert pedestrian or shared use path structure through roadway embankment where a cast in place flared headwall is proposed, the preliminary designer will prepare the (TS&L) for both the CIP and precast culvert options.
- The twin/triple precast culvert will be laid out assuming side-by-side single precast culverts with parallel wing headwalls and six-inch gap between the structures.

The designer should note that our policy for determining culvert length differs between precast and CIP box culvert options. Culvert lengths for the CIP option are determined by the foreslope intercept with the top of parapet, while the lengths for the precast option are determined by the intercept with the bottom of parapet at the top of box. The rationale for this policy difference is based on the tie-in locations for the wings. CIP wings tie-in at the top of the parapet, while precast culvert wings tie-in at the top of box. As a result, when the foreslope intercept governs the length, the barrel for the precast option will be longer than the barrel for the CIP option, but the wing will be shorter. However, when the clear zone governs, the barrel for the precast and CIP option lengths may be similar, and the flattened foreslope may vary.

The following guidelines are provided for a precast RCB layout:

- The overall back to back of parapet length will include the end to end of barrel length rounded up to the nearest whole foot increment, plus the additional end section barrel length at each end of the culvert (variable "G" as described below).
- The end section barrel length is provided in the LRFD precast reinforced concrete box culvert standards. The dimension is 6 inches for skews up to 7.5 degrees and is noted as variable "G" for higher skews. The layout should be based on Type 3 end section details.

- The overall length from back to back of parapet, the end to end barrel length, the additional barrel length as part of the end sections “G”, and the end section shall be dimensioned on the TSL.
- If the parapet of the end section is not parallel to the roadway (example a 15-degree skew standard end section with a 22-degree skewed barrel), then one corner of the parapet will be closer to the roadway than the centerline of the culvert.
    - The culvert length shall be adjusted such that the closer corner is extended to the calculated length.
    - For multi-barrel box culverts, parapet and curtain walls shall form one continuous line and shall not be staggered or offset. The designer shall adjust each culvert such that the closer corner is sufficiently extended. All the barrels will be the same design length, but the distances right and left will be different for each barrel.
    - An example layout for a 22-degree skew culvert with a 15-degree end section is provided in the commentary.
- For a single box trail or pedestrian structure, the use of flared, cast in place headwalls results in the identical calculated back to back of parapet length to the CIP option.
- Precast concrete box culvert end sections shall be constructed along the barrel slope.

4.5.3 RCB Extensions

Existing single barrel CIP RCB that are 6’ x 6’ or larger may also be extended with precast RCB. A connection detail that transitions the CIP box culvert to the precast box culvert is shown in the standard sheets (BSB SS 1043P-1045P). The precast box culvert extension must satisfy the same requirements for use as new precast box culvert projects (BSB BDM 4.5.2).

Precast extensions for twin and triple barrel CIP RCBs are not allowed.

4.5.4 Flumes and Scour Floors

A flume/basin can be used when there is a significant elevation difference between the inlet and outlet of a culvert. A concrete flume basin should be used in lieu of a letdown structure when the pipe culvert is greater than 42 inches in diameter. If the slope of a box culvert is excessive (greater than 2%) then a flume may be considered depending upon site conditions to dissipate outlet velocities.

So that there is adequate wall thickness around the pipe for the cast-in-place, one-foot collar, the designer shall size the flume using Table 4.5.4. Refer to BDM Figure 7.4.4.8.1 and Iowa DOT LRFD flume standards if more information is required relative to the reinforced concrete pipe flume collar and flume details.

Table 4.5.4. Flume size and height for standard reinforced concrete pipe

Reinforced Concrete Pipe Size (inches)	Flume Size (feet x feet)	Height from flowline to top of parapet (ft-in)
24	3 x 3	5’-4
30	4 x 4	6’-4
36	5 x 3	5’-4
42	5 x 4	6’-4
48	6 x 4	6’-4
54	6 x 5	7’-4
60	8 x 5	7’-4
66	8 x 6	8’-4
72	8 x 6	8’-4
84	10 x 8	10’-4

For skewed pipe culvert alignments 30 degrees and greater with an embankment slope of 3:1, the slope of the top of the flume wall should be set to 4:1 to accommodate the skew.

The flow lines for flume basins are usually set approximately 5 feet below the bed of the waterway. This allows for the natural development of a scour hole which helps dissipate the energy above the basin and create a higher tail water elevation to contain the hydraulic jump. Adequate right of way should be purchased to encompass the scour hole. Riprap is generally not needed at flumes.

Minimum cast-in-place flume length is determined by the parabolic length, L_3, as shown in OB&S Final Design Manual [BDM 7.2.4.8.1]. Maximum flume lengths should be limited to approximately 60 feet, if possible, in order to reduce settlement problems and joint separations. See the Final Design Manual for other dimensions and notes.

When less than 3 feet of drop is needed on the outlet of short lengths of RCB extensions, consider using a “scour floor” in the headwall. A scour floor is a concrete extension of the apron at the bottom of the curtain wall elevation. Scour floors may also be used in situations where streambed degradation is anticipated. See the commentary for a sample sketch.

4.5.5 Drop Inlets

Cast-in-place drop inlets are used for minimum headwater depth situations for both RCB and pipe culverts. Drop inlets can minimize the ROW required by raising the ditch grade and also provide good energy dissipation within the culvert. These inlets provide a convenient method of carrying flow from drainage tile across the roadway by discharging the tile through the inlet wall. Generally, it is good practice to replace existing drop inlets in-kind in order to prevent an increase in headwater.

See the commentary for design guidelines, a sample plan and profile, and a typical inlet detail. Design highwater elevation should not exceed the top of the butterfly wing, 3 feet maximum above the drop inlet [weir] flowline). This wing has two purposes: 1. To hold the fore slope soil, and 2. To serve as an anti-vortex device.

Pipe railings are generally required on all drop inlets, even in rural areas, to prevent pedestrians from inadvertently falling into the culverts. In some urban areas, a grate over the drop inlet may also be needed to prevent deliberate entrance into the culvert, especially where pedestrian traffic is expected to be high or there is a large vertical drop, say greater than 6 feet.

4.5.6 Slope Tapered Inlets for RCBs

Slope tapered inlets on cast-in-place RCBs should be considered in some situations to reduce culvert costs and/or to create ponds for upstream landowners. The barrel size shall not be less than 50% of the inlet size. Also, to make construction simpler, the inlet dimensions shall be tapered only in the width, not in the height, e.g., a 12’ x 8’ inlet may be tapered to an 8’ x 8’ barrel section but not to an 8’ x 6’. Due to high velocities and large drop in elevation, most tapered inlet culverts will need a flume and a basin to dissipate energy.

Design guidelines for slope tapered inlets are shown in the commentary.

4.5.7 Bridge Replacements with RCBs Using Flowable Mortar

Reinforced concrete box culverts may be placed and buried under an existing bridge instead of replacing the bridge. If there is adequate height under the bridge, the space is filled first with floodable backfill and then flowable mortar [DB RDD 4317] or, if there is restricted height, the space is filled entirely with flowable mortar [DB RDD 4318].

Minimum clearance and constructability guidance provided in this section should be reviewed for both cast-in-place and precast options during concept development. The intent is to identify potential constructability concerns early in the process.

The vertical clearance between the bridge and culvert needs to be verified. The elevation of the lowest beam (or slab) on the existing structure and the top of slab elevation of the proposed culvert need to be shown on the TS&L with the following criteria:

- For slab bridges use a minimum clearance of 3 feet between the top of the culvert slab and the bottom of the bridge low slab.
- For beam bridges use a minimum clearance of 1 foot between the top of the culvert slab and the bottom of the lowest beam.

The designer shall also provide a minimum horizontal clearance of 1.5 feet between existing substructure components and the new culvert [BDM 7.2.4.10]. It should be noted that a precast multi-barrel RCB option takes up more horizontal space than CIP. The additional space for a precast multi-barrel option is needed due to adjacent box culvert walls and required minimum space between each barrel.

When a bridge will be in service during the RCB construction, the designer shall consider the anticipated excavation relative to the bottom of bridge footings. An excavation for a 1'-0" deep working blanket shall be assumed for both RCB types and an additional 6" leveling material on top of the working blanket shall be assumed for precast RCBs. The excavation width extends 2' beyond the inside face of exterior barrel walls [BDM 7.2.4.4.1]. If the bottom of bridge footing will be potentially exposed for assumed construction excavation, consult with the BSB Methods Engineer.

If any of the above guidance cannot be met, the designer will need to consider other options such as:

- Burying the flowline of an RCB to meet vertical clearance if the hydraulics meet criteria.
- Eliminating an RCB design alternative (cast-in-place or precast) if guidance cannot be met.
- Closure of the road or staged construction with removal of the bridge to allow an RCB.

The designer shall discuss these options with the Unit Leader.

If a flowable mortar option is determined to meet clearance and constructability requirements, the designer shall refer to BDM 4.2.5 for additional requirements relative to potential settlement.

4.5.8 Revetment for RCBs

The placement of revetment within a stream channel for RCB inlets and outlets on new and extended structures has been determined by the regulatory agencies as needing stream mitigation, unless justified by Iowa DOT policy. Therefore, revetment will typically not be proposed at an RCB inlet. At an RCB outlet, revetment will be proposed only when it's placement can be justified for the design. A decision matrix to assist in evaluating the need for inlet and outlet revetment is provided in the commentary.

The following is general guidance and should be modified based on site conditions. When revetment is proposed, the preliminary designer shall determine the quantity of Class 'E' Revetment (typical 2-foot thickness), engineering fabric, and Class 10 channel excavation (for revetment core out below grading surface) and show them in the quantity table on the TS&L. A typical section will be created and the revetment station and offset limits will be defined. Class "C" Revetment (typical 3-foot thickness) shall be considered for outlet velocities exceeding 10 ft/sec. Revetment quantity bid items for RCB projects will be included in the road sheets regardless of whether it is a Design or Bridge let project. Accordingly, the MicroStation cell for the revetment quantity table on the TS&L includes the notes "Excavation quantity calculated from grading surface. Excavation quantity is for embedded revetment and core out only and does not include excavation to the grading surface. Excavation quantity to the grading surface is determined by Road Design and included in the Road Plans. Quantities shown for information only. See Road Sheets."

For cast-in-place RCBs, (when revetment is proposed) revetment shall be placed to a width of three feet along the sides of the parallel outlet wing walls up to the face of the parapet as shown in the LRFD Cast-in-Place Culvert Standard SS 1092. Standard SS 1092 is only applicable when revetment is indicated on the box culvert TSL, and only at the end where revetment is shown. The SS 1092 details will be modified to reflect the multi-barrel situation in final design.

For single and multi-barrel precast box culverts, (when revetment is proposed) revetment shall be placed to a width of three feet along the sides of the parallel outlet wing walls up to the face of the parapet and extend across the top of the parapet as shown in the LRFD Precast Culvert Standard PEP 12-20. Standard PEP 12-20 is only applicable when revetment is indicated on the box culvert TSL, and only at the end where the revetment is shown.

For multi-barrel cast-in-place RCBs with flared headwalls, no revetment is required along the flared wing headwall.

When outlet revetment is proposed, it should be extended in the direction of flow normal to the headwall a minimum distance of 10' as measured from the outermost tip of the headwall wing. If no additional ROW is being acquired, revetment should stay within existing ROW. Additional revetment may be needed to tie into the existing stream channel.

4.5.9 Grading control points

If channel shaping or special grading is required, the designer shall collaborate with Road Design and provide grading intent or grading control information on the TSL or Site Plan Sheet. The grading intent may be supplemented with stations, offsets and elevations labeled as "G" points. The purpose of the grading control is to communicate channel or special grading needs to Design, 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

{An example showing grading control points on a culvert TS&L will be added in the future}

4.5.10 Stock Passes

The Design Bureau will no longer use [DB RDD 510-4] for new stock passes. Instead, designers should use a 6' X 7' precast box culvert. Refer to PRCB 6-~~13~~20 of the Bridges and Structures Bureau Culvert Standards. Minimal fill height is 2' and maximum is 25' with exceptions of 40' with approval of the Bridges and Structures Bureau. With projects involving several Design RCBs, a cast in place may be preferred.

The [DB RDD 510-4] should be used for stock pass extensions only.

When stock passes can be abandoned, a 24" concrete pipe may be placed in the stock pass and filled with flowable mortar and abandoned. However, sometimes a considerable amount of drainage flows through the stock pass and the appropriate culvert size needs to be designed.

4.5.11 Costs

Cost Item	**Unit Cost (1), (2)**
Staged culverts	Add 10%
RCB Culvert (CIP), in close proximity or corridor projects	$1150~~850~~/yd^3 (4)
RCB Culvert (CIP), individual projects or extensions	$1200~~900~~/yd^3 (4)
RCB Removal	$80~~40~~/cy
Revetment	$65~~50~~/Ton (5)
Flowable mortar to plug/abandon culverts	$290~~200~~/yd^3
Mobilization	10%
Contingency	B0 = 20% (3) D0, B1, D2 = 15% B2 = 15% Prelim. designs B2 = 0% Final designs(6)

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 culvert~~bridge~~.

(2) Unit costs were current as of January 2025~~April 2014~~. Add 4% to the base unit cost for each calendar year beyond January 2026.

(3) See abbreviations [BDM 4.1.4] 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. Use the same cost for precast boxes.

(5) Include revetment costs with RCB culvert estimates. After the B1 completion, revetment costs for RCB culverts are included with the roadway estimate.

(6) Final plans delivered to the Design Bureau that do not require structural design, complete with final notes, bid items, and quantities (example: a stream revetment repair plan).

4.5.12 Alternative Structure Type

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

4.5.13 Staging

When an RCB is proposed to be constructed in stages, the preliminary designer should consider the following items:

- The staged culvert joint line should be normal to the culvert centerline. This is desired even if the culvert is on a skew to the roadway.
- The designer should establish the staged barrel lay lengths in whole foot increments from centerline, as measured from the back of parapet for cast in place culverts and the back of end section for precast culverts. Note that the variable dimension "G" from precast culvert parapet to back of end section can be obtained from the precast culvert standard sheets and resulting back to back of parapet length may not be a whole foot increment.
- The staging joint line shall be at the same location for both precast and cast in place alternates.

The following guidance is provided for temporary fill slopes (duration up to 2 years):

- For temporary embankment slopes that are 2:1, an RSS may not be needed for heights up to 15 feet.
- For temporary embankment slopes that are 2.5:1, an RSS may not be needed for heights up to 25 feet.
- If the temporary embankment slope for Stage 1 construction is steeper than 2:1, then an RSS will be required for any height.

For situations where sloping the staged fill may not be cost effective or practical, soil retainment may be considered. A method of retainment, such a sheet pile, may be considered adjacent to a box culvert. Above the culvert, vertical retainment with geotextile reinforcement may be considered for heights up to 6 feet. (See commentary for more information.) For higher fill heights or unique situations, contact Iowa DOT Soils Design Unit.

4.5.14 Multi-Barrel RCB Culvert Sedimentation Mitigation

There are many parameters that impact the potential for sedimentation in a multi-barrel box culvert. The Iowa DOT has developed a program called Iowa DOT Culverts that assesses the parameters of a project site for the potential of sedimentation to occur in a multi-barrel culvert location. The application is available at the following link:

https://apps.iowadot.gov/culverts/

Sedimentation for multi-barrel culverts with flared headwalls may be mitigated by using a "self-cleaning" culvert concept. The solution does not affect current culvert design protocols, but provides a grading plan to enhance flow and sediment transport. For more information, refer to the State Transportation Innovative Councils (STIC) Incentive Funds Final Report ST-001. The report and an Iowa DOT example plan are available upon request. Additional information is available under the Iowa Highway Research Board Projects TR-545 and (TR-545 Tech Brief); TR-619 and (TR-619 Tech Brief); and TR-719 and (TR-719 Tech Brief).

4.5.15 Fish Passable Box Culverts for Regulatory Compliance

The Location and Environment Bureau (LEB) will identify streams at box culvert locations that are classified as Waters of the United States (WOTUS) and require fish passage at the W00 (Preliminary Wetland Review) event. When a box culvert location is identified as WOTUS and requires fish passage, any new or replacement culvert (typically 6' x 6' or greater) must be buried at least 12 inches below the natural streambed. When a box culvert is buried one foot below the streambed, the culvert height must be increased by at least one foot to provide sufficient hydraulic capacity (e.g., a 10' x 10' RCB buried one foot is hydraulically equivalent to a 10' x 9' RCB culvert).

For locations not identified as WOTUS or not requiring fish passage, the box culvert may be designed to match the natural streambed or as determined by the designer. For box culvert extensions, fish passable mitigation will not be required for the design of the extension.

When justified, revetment for buried RCB culverts shall match the design streambed [see BDM 3.2.2.10]. The Bridges and Structures Bureau will calculate the revetment quantities for box culverts.

4.5.16 Pedestrian or Shared Use Path RCB

In most cases, a standard sized 12-foot x 11'-4 reinforced concrete box (RCB) structure is desired. The RCB size may be larger based on site conditions. For additional guidance, see DB DM 12-B-2 C5b. Pedestrian Tunnel Standards are available on the Iowa DOT BSB web site. Available sizes are summarized in the tables below:

REINFORCED CONCRETE PEDESTRIAN TUNNEL STANDARDS (span x height):

12' X 11'-4	12' X 12'-4

	14' X 12'-4

PRECAST PEDESTRIAN TUNNEL STANDARDS (span x height):

12' X 10'-10	12' X 11'-10
	14' X 11'-10

Fill range for standard Pedestrian Tunnel Standards is 0 to 15 feet (cast in place and precast). For fill heights greater than 15 feet, place a note on the TSL identifying the structure as a non-standard design. Design fill height is defined as the maximum depth of fill measured from the top of pavement to the top of the Culvert. The standards for both cast in place and precast include zero-degree skew, flared cast-in-place headwalls with safety rail. Special headwall design will be required for non-zero degree skew situations.

The standard frost trough on the floor of the pedestrian tunnel RCBs has been omitted. A minimum 0.5% longitudinal slope on pedestrian or shared use path culvert structure shall be used to maintain positive drainage and minimize ponding. This slope shall carry through the entire length of culvert, including both headwalls.

It is preferred that a flared-wing headwall be utilized for a path or trail. All pedestrian or shared use path culverts should have a fence or safety rail around the headwall to provide fall protection. The designer shall typically show the standard safety rail along wing headwall and parapet. Aesthetic considerations may lead to a different fall protection type or detail in final design.

A precast option with flared, cast in place headwalls shall normally be offered. The 12-foot x 10'-10 size will be adequate in most cases, which provides a minimal vertical clearance of 10 feet to account for lighting fixtures and an overlay. The 1' x 1' haunch on the box floor is omitted in the standard design. Because floor joints between precast box culvert sections are likely to exceed ½ inch in the direction of travel, the precast culvert floor standard includes a 2-inch, unreinforced PC overlay to create a smooth surface. The precast option TS&L will be completed in final design.

Depending on the length of the structure required, the location, and concerns about pedestrian safety, tunnel-type lighting may be appropriate. If a local municipality is involved this subject should be discussed during project concept/field exam stages and the information briefly noted on the TS&L.

4.6 Permits and Approvals

Iowa Department of Natural Resources must approve new culverts if the drainage area is greater than two square miles in an urban (incorporated) area or 100 square miles in a rural (unincorporated) area. If the project is on a stream with a drainage area below DNR's thresholds and the community (city or county) is participating in the National Flood Insurance Program (NFIP), a hydraulic review and Record of Coordination with the community are necessary to ensure compliance with the NFIP. See BDM 3.2.10 for additional information.

A Corps of Engineers 404 Permit may be necessary for most stream crossings and road work if a channel change or wetland is involved. IDOT's Location and Environment Bureau coordinates this effort.

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 during the concept development The preliminary designer should request the required channel design flowline (may be buried to allow future clean out), 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.

4.7 Submittals

Project Wise folder structure and CADD/pdf file submittals shall follow the policy guidelines and checklists available on the website:

Connect Applications (MicroStation Connect Projects)
Preliminary Bridge Plan and Model Deliverables for B02