Chapter V - Hydraulic Studies and Drainage Design
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Hydrology is generally defined as a science dealing with the interrelationship between water on and under the earth and in the atmosphere. For the purpose of this manual, hydrology will deal with estimating flood magnitudes as the result of precipitation. In the design of highway drainage structures, floods are usually considered in terms of peak runoff or discharge in cubic feet per second (cfs) and hydrographs as discharge per time. The entire discharge hydrograph shall be used for the design of facilities which are intended to control volume of runoff, such as detention facilities.

V–01.01 Hydrologic Design Policies

Following is a summary of general practices which should be used in performing hydrologic analyses: [For a more detailed discussion refer to the publication," Highway Drainage Guidelines," published by the American Association of State Highway and Transportation Officials. (AASHTO)]

1. Studies–Hydrologic considerations can influence the selection of a highway corridor. Special studies may be required at some locations. The magnitude and complexity of these studies should be commensurate with the importance and magnitude of the project and problems encountered. Typical data to be included in such studies are:

    - Topographic Maps
    - Aerial Photographs
    - Stream Flow Records
    - Historical High Water Elevations

2. Coordination–It is desirable and often necessary to share information with other agencies to assure the completion of accurate hydrologic analyses.

3. Documentation–The design of highway drainage facilities should be adequately documented and records should be retained indefinitely.

V–01.02 Design Flood Frequency

Design flood frequency (recurrence interval) shall comply with the requirements of Article 89-14 of North Dakota Administrative Code.

V–01.03 Hydrologic Analysis

V–01.03.1 General

The following factors may need to be considered in performing a hydrologic analysis:

1. Drainage basin characteristics including: size, shape, slope, land use, geology, soil type, surface infiltration and storage.

2. Stream channel characteristics including slope, geometry and configuration, natural and artificial controls, channel deposition or erosion, ice and debris.

3. Flood plain characteristics.

4. Drainage history of the area and any drainage problems relating to existing and proposed structures. The NDDOT Bridge Division may be able to provide historical information relative to drainage problems.

5. Precipitation amount and storm distribution.

6. Ground cover

7. Type of soil

8. Soil moisture condition.

9. Storage potential (overbank, ponds, wetlands, reservoirs, channel, etc.).

10. Type of precipitation.

V–01.03.2 100-Year Frequency

Discharges for 100 year frequencies and associated water surface elevations shall be computed and these should be listed on the plans for all drainage structures and centerline culverts.

V–01.04 Hydrologic Methods

The hydrologic methods to be used are listed below. If possible the method should be calibrated to local conditions and tested for accuracy and reliability.

Approved Methods:

<u>Rural:</u> For all sizes of drainage areas on the rural roadway system, design discharge shall be calculated using USGS Regression Equations, in accordance with the methods described in U.S. Geological Survey Scientific Investigations Report 2015-5096.

The Ruggedness Number is used in the Regression Equations for Hydrologic Zones B and C. When calculating the Ruggedness Number, the stream lines to be used in determining the stream density shall be the total length of all NHD Flowlines within a drainage area which are represented on the USGS National Hydrography Dataset (NHD). The NHD can be downloaded from the USGS website. For small drainage areas which do not contain any NHD stream lines, a single stream line representing the longest drainage path in the drainage area shall be drawn, and its length shall be used for the stream length in calculating the Ruggedness Number.

<u>Urban:</u> For urban drainage areas, the method used to determine design discharge shall be the Rational Method. This method is limited to drainage areas of less than 200 acres. Storm rainfall intensity for use in the Rational Method estimation of discharge shall be determined using the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 - Precipitation-Frequency Atlas of the United States (Atlas 14).

Other Methods:

Deviations from these methods must be approved by the NDDOT Bridge Division.

V–02.01 General

1. Primary guidelines for hydraulic modeling of structures are those set forth in this manual, in the Code of Federal Regulations (23 CFR 650), and in Article 89-14 of North Dakota Administrative Code.

2. A hydraulic review is required for structural rehabilitation projects if there are upstream flood concerns, significant scour, unstable channels, or a history of flow-related problems.

3. A Hydraulic Analysis and Structure Selection Report (hydraulic report) shall be prepared for all new structures.

4. Three alternatives will typically be required for hydraulic analysis and cost comparison purposes when new box culverts are modeled. For new bridges, two to three alternatives will typically be considered. In some cases, due to channel or roadway geometry, only one alternative may be appropriate. In such cases, analysis of impractical alternatives is not necessary, and only one alternative may be considered. The Bridge Division should be contacted when site/hydraulic conditions limit the possible alternatives to less than three.

5. The 2, 10, 25, 50, 100, and 500-year discharges shall be determined and published in every hydraulic report. The 200-year discharge will also need to be determined and published if required for scour analysis.

   The 2, 5, 10, 25, 50, 100, 200, and 500-year discharges can be determined from gage data and the methodology provided in USGS Bulletin 17B where bridges are located adjacent to a USGS stream gauge. For bridges which are not near a stream gage, USGS Regression Equations shall be used to determine the 2, 5, 10, 25, 50, 100, and 500-year discharges. At these locations, the 200-year discharge shall be interpolated from the plot of the discharge curve, using the "200 Year Discharge (Interpolated Estimate for Structures)" excel spreadsheet which is on the Reference and Forms page of the Design Manual on the web at:

   http://www.dot.nd.gov/manuals/design/designmanual/reference-forms.htm

6. Hydraulic analyses shall compare modeled upstream water surface elevations for the proposed structure with those of the existing structure at the Hydraulic Design, Scour Design, and Scour Design Check Flood events as described in HEC-18. For sites with upstream buildings which may be affected by high-flow events, the 500-year discharge shall also be determined.

7. Water surface profiles for existing and proposed conditions shall be included in all hydraulic reports for new bridges or box culverts on new alignments, and for all structures (either bridges or box culverts) which replace existing bridges.

8. Cross sections should be obtained perpendicular to the direction of flow of the main channel and floodplain. Cross sections should be wide enough laterally to span the floodplain at the maximum peak flood discharge scenario and the reach should be extended

longitudinally far enough upstream and downstream of the structure to minimize the boundary condition's influence on the hydraulic model. As a general rule of thumb, the boundary cross sections for a hydraulic model should be set approximately 2 floodplain widths upstream and downstream of the structure.

The number of cross sections required for a hydraulic model will vary based on site conditions. For a 1D HEC-RAS hydraulic model, a minimum of four cross sections is required to compute the hydraulics through a structure. These cross sections are defined as follows:

- Cross Section 1 should be located sufficiently downstream from the structure so that the flow is not affected by the structure (i.e., the flow has fully expanded) at the maximum peak flow discharge to be evaluated.
- Cross Section 2 is located a short distance downstream of the structure. The cross section should be located far enough downstream of the structure to avoid capturing the roadway embankment.
- Cross Section 3 is located a short distance upstream of the structure. Like Cross Section 2, this cross section should be located far enough upstream of the structure to avoid capturing the roadway embankment.
- Cross Section 4 is located sufficiently upstream of the structure such that the flow is not affected by the structure and flow is fully effective at the maximum peak flow discharge to be evaluated.

Intermediate cross sections between the above referenced locations may be required to ensure sufficient coverage is obtained to accurately represent the stream and floodplain geometry. Additional cross sections may also be required at locations where changes in discharge, slope, shape, or roughness occur. Further guidance on selection of cross section locations can be found in the US Army Corps of Engineers (USACE) HEC-RAS Hydraulic Reference Manual. An example cross section layout is shown below in Figure 1.

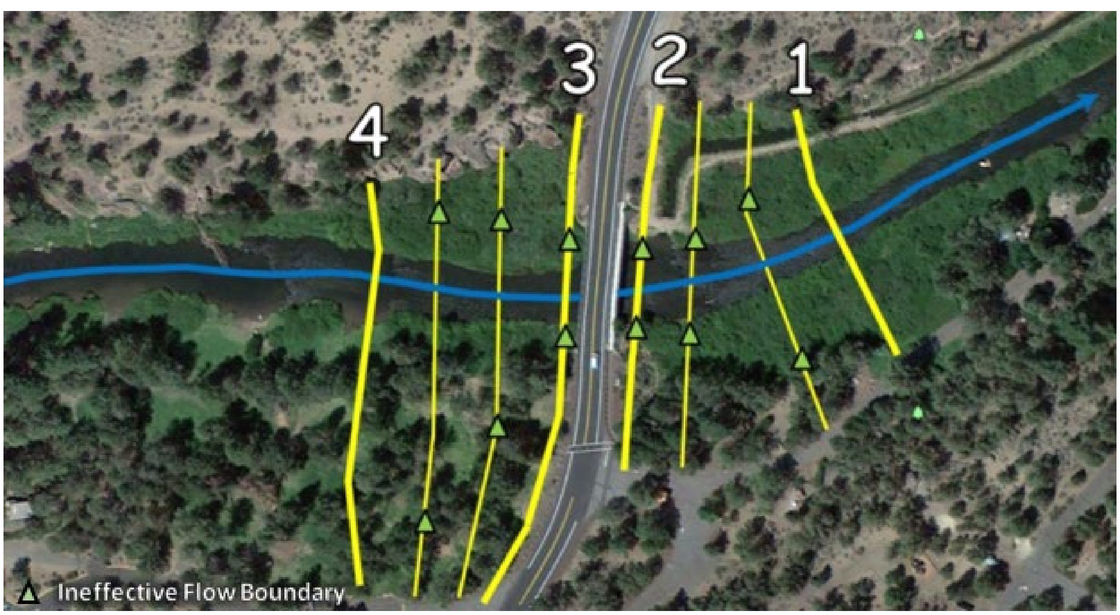

Figure 1

Field survey is required for collecting the portion of the cross sections below the normal water surface (bathymetry). If adequate LiDAR coverage is available, LiDAR may be used in substitution of field survey for the portions of the cross sections above the normal water surface. A channel profile following the thalweg of the channel for the entire length of the studied reach shall be obtained.

9. Modeling for replacement of existing box culverts or large diameter pipe culverts or structural plate pipes with new box culverts shall generally be performed using FHWA's HY-8 software. For box culvert crossings on new roadway alignments or at flood sensitive locations, HY-8 software shall not be used. In these instances, 1D hydraulic modeling using US Army Corps of Engineers HEC-RAS software or 2D hydraulic modeling using SMS/SRH-2D may be appropriate for modeling these crossings. A 1D hydraulic model (using HEC-RAS) or 2D hydraulic model (using SMS/SRH-2D) is required for modeling the replacement of bridges (with either new bridges or box culverts) or for bridge crossing locations on new alignments. Generally, 1D models are suitable for small rivers or streams with narrow to moderate-width floodplains and have a low degree of skew to the roadway alignment (<20°). Locations where 2D models should be considered include large waterways, wide floodplains, highly sinuous channels, relief structures, urbanized areas, or channels with a moderate to high degree of skew (20°). Justification for model selection should be provided to the NDDOT Hydraulics Section and approval received prior to proceeding with hydraulic modeling for a structure.

10. Box culverts may be hydraulically modeled and designed up to a maximum size of a quad 16' x 16' reinforced concrete box culvert. If a larger opening than this is required, then only bridge alternatives shall be considered. Cost comparisons shall be performed to determine the most cost-effective structure. A bridge may be more cost effective than a large box culvert.

11. If a structure is in a flood hazard area, this should be documented in the Hydraulic Analysis and Structure Report, and the new structure should not increase the 100-year stage by more than the amount allowed by FEMA regulations. For structures not located within FEMA floodplains/floodways, a statement shall be provided in the hydrology section of the report noting that the structure is not within a FEMA floodplain/floodway.

V–02.02 Structure Hydraulic Reports

Generally, a hydraulic report shall be prepared for all locations where the design discharge for culverts (which is the 25-year discharge for state highways) is greater than 500 cfs, and a structure will be considered rather than the installation of pipe culverts. Hydraulic reports shall include completion of SFN forms 18323, 9634 (for bridges), and 9636 (for box culverts). Example hydraulic reports are provided in the Appendix.

V–02.02.1 Design Frequency

Design frequency (recurrence interval) shall comply with the requirements of Article 89-14 of the North Dakota Administrative Code.

V–02.02.2 Contributing Drainage Area

Research of existing plans, files, special studies, etc. shall be performed to determine the drainage area and discharge values used in the previous design. These materials shall also be used if any hydraulic concerns relative to the site have been documented.

United States Geological Survey (USGS) Quad Maps or other available topographic maps or data (including LiDAR) shall be used to delineate the drainage area. The use of aerial imagery may be helpful in delineating drainage areas, particularly in regions where there is little topographic relief.

Some lakes or sloughs may be considered to be non-contributing areas if it is evident that they cannot be expected to rise enough to overflow. Care shall be used in excluding non-contributing areas.

For larger drainage areas, the contributing drainage area may be published with USGS gauge data, and when available, these areas and associated gauged discharges will be used in determining the design discharge to be used for the hydraulic analysis of a structure. Discharges should be determined from gauge data in accordance with USGS Bulletin 17B, "Guidelines for Determining Flood Flow Frequency."

V–02.02.3 Design Discharge

Discharges that have been determined in special flood studies or from stream gages shall be used for hydraulic modeling of structures. If this information is not available, the design discharge shall be calculated. PeakFQ software may be used to analyze a continuous series of annual peak discharges for a gaged site so that the design frequency discharge for the gaged site can be obtained. Calculation of design discharge, and use of gage data shall be in accordance with US Geological Survey Water Resources Investigation Report 2015-5096 entitled "Regional regression equations to estimate peak-flow frequency at sites in North Dakota using data through 2009."

V–02.02.4 Waterway Opening Requirements

There are two main factors used in determining the size of the waterway needed. These are design velocity and headwater limitations. See the discussion of these factors in the paragraphs below. Other factors which may affect waterway opening may include estimated scour, economics or special site conditions.

V–02.03 Design Velocity of Flow

The size and configuration of bridges and structures without a floor are typically selected by consideration of acceptable velocities and allowable backwater fitting local site conditions. Bridge openings that generate increases in the natural channel velocity may significantly increase the scour potential and should be avoided unless the scour analysis verifies an acceptable design.

A maximum design velocity of 5 ft./sec. through bridges is typically considered an acceptable maximum velocity for streams and rivers on flat slopes with natural velocities less than 5 ft./sec.. Bridges spanning streams with natural velocities greater than 5 ft./sec. often require a design that supports a velocity through the bridge that better aligns with the natural stream velocity. For box culverts and other structures with a floor, velocities up to 10 ft./sec. are generally found to be acceptable. Higher or lower values may be used if it is deemed appropriate for a particular site.

V–02.04 Allowable Box Culvert Headwater

The design headwater elevation for box culverts shall be established in accordance with the requirements prescribed by Article 89-14 of North Dakota Administrative Code. Additionally, the Department generally avoids overtopping of the highway during the 100-year discharge, and this should be a goal of the hydraulic design as much as practicable.

V–02.05 Berms

Bridge openings shall typically be modeled with berm widths of 7 feet, measured from the back face of the abutment to the top of the channel slope. Also, the minimum clearance between the berm and the girders should be 2 feet. See Figure 2 below:

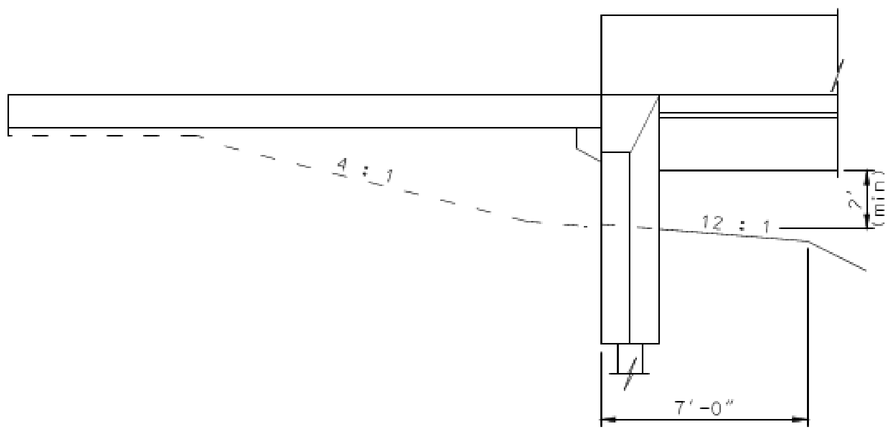

Figure 2

V–02.06 Bridge Freeboard

All new bridge alternatives shall be developed such that 1 foot of freeboard, measured from the water surface to the bottom of the lowest girder, is provided at the design discharge. Additionally, at the 100-year discharge, some minimal freeboard should be provided. Deviations from these criteria may be allowed with the approval of the NDDOT Bridge Engineer.

V–02.07 Box Culvert and Bridge Scour and Riprap

1. Scour analysis is not required for box culverts. The use of rock riprap for minimum distances of 10 feet upstream and 20 downstream from the box culvert ends is generally considered to be adequate protection for box culverts sized in accordance with the criteria previously presented in this section. If it is recognized during the modeling of the box culvert that additional riprap may be necessary, the possible need for additional protection should be addressed in the report, and the TS&L party should discuss the need for added riprap. Grade II riprap will be sufficient for installation at most box culverts which have been sized within the guidelines provided in this section.

2. For bridges, scour analyses for the Hydraulic Design, Scour Design, and Scour Design Check Flood discharges shall be performed in accordance with Hydraulic Engineering Circular No. 18 (HEC 18), and the results, and recommended scour countermeasures should be addressed in the report. The automated scour calculations provided in HEC-RAS are not to be used for scour analyses. Scour depths should be calculated manually or by using FHWA's Hydraulic Toolbox. Abutment scour calculations shall be completed using either NCHRP or HIRE abutment scour equations. Scour calculations using Froehlich's abutment scour equation are not to be used. Structures must be stable for the scour design check flood scour conditions. Before a hydraulic report for a bridge is completed, all acceptable structure alternatives should be evaluated by the hydraulic modeler, bridge design personnel, and the deep foundation designer. A statement relative to these parties' concurrence that the modeled alternatives will be stable for the scour design check flood scour event shall be provided in the discussion on scour in the hydraulic report.

   Riprap for new bridge abutments shall extend from the abutment wall down the abutment end slope and beyond the toe of the end slope for a distance equal to 2 times the 100-year depth of flow at the toe of the end slope (2 *Y_{100}). The distance beyond the toe of the end slope may be limited to 25 feet. Abutment riprap on the side slopes shall extend from the abutment down to the toe of the slope on each side at a minimum, and shall extend upstream and downstream from the ends of the abutment wings for a distance of at least to 2 times the 100-year depth of flow (2 *Y_{100}).

   Riprap for new bridge piers shall be placed on each side of the piers to cover the entire estimated scour envelope resulting from the 100-year discharge. Riprap shall be extended upstream and downstream from the pier ends for a distance equivalent to the width of the riprap placed along the sides of the piers. For piers with minimal scour envelopes, riprap shall extend, at a minimum, from the pier face on each side for a distance equal to 2 times the pier width and shall extend upstream and downstream from the pier ends for a minimum distance of 2 times the pier width. Scour envelope width at the channel bottom can be determined from the scour envelopes produced using the HEC-RAS software.

   Riprap shall be installed on geosynthetic material type RR and shall have a thickness of 24". Grade II riprap will be sufficient for installation at most bridges which have been sized within the guidelines provided in this section.

   Minimum riprap limits are illustrated in Figure 3. For bridges with shorter spans, the abutment and pier riprap may overlap, or only small gaps would be left between the riprap areas, in which case, installation of riprap continuously across the channel may be preferred.

3. NBI Item 113- Scour Critical Bridge should be assessed according to the most recent version of the FHWA Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges. The assessed rating should be documented in the hydraulic report.

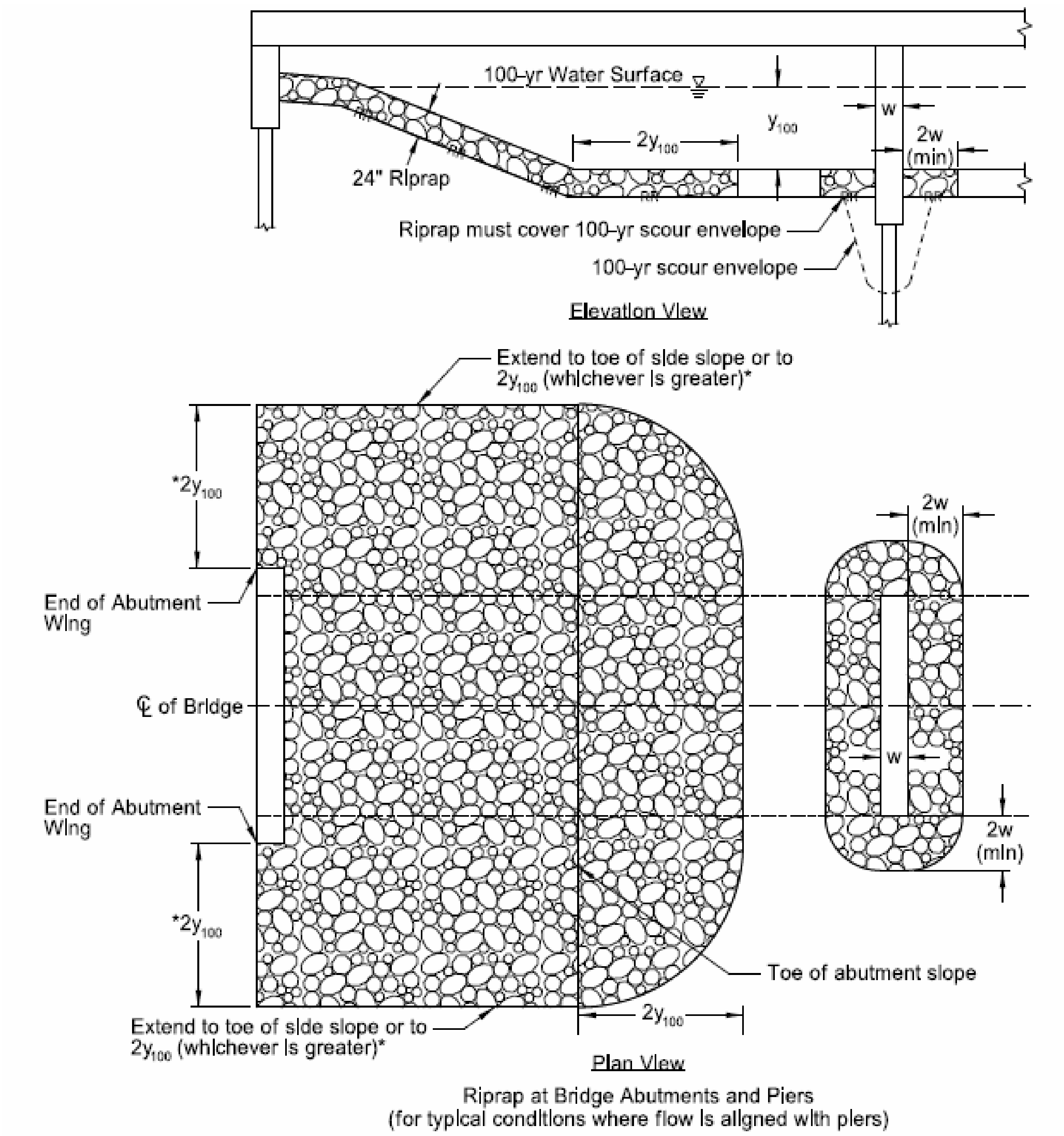

Figure 3

V–02.08 Bridge Deck Drainage

The need for, and spacing of bridge deck drains shall be determined in accordance with Section IV-02.06.26 and FHWA's HEC 21 publication. Drain openings shall be either 4" by 4" square or 6" diameter openings. Deck drain calculations are not included in the hydraulic report, but calculations need to be submitted with other design calculations for a bridge.

V–02.09 Type, Size and Location Review (TS&L)

When the Hydraulic Report has been completed, a TS&L Review shall be held to discuss the structural recommendations. Typically, these reviews will be held at the project site, although virtual TS&L reviews are permissible if approved by NDDOT Bridge Division. Items which should be discussed at the TS&L Review are as follows:

1. Structure selection
2. Temporary bypass / detour need and location
3. The need for riprap / scour countermeasures
4. Disposal of the existing structure
5. Utilities
6. Right–of–Way
7. Environmental concerns that may not have been addressed in the environmental documentation.

V–02.10 Reference Documents

V–02.10.1 Hydraulic Design Series (HDS) - FHWA

1. HDS 1 Hydraulics of Bridge Waterways
2. HDS 2 Highway Hydrology
3. HDS 4 Introduction to Highway Hydraulics
4. HDS 5 Hydraulic Design of Highway Culverts
5. HDS 7 Hydraulic Design of Safe Bridges

V–02.10.2 Hydraulic Engineering Circulars (HEC) - FHWA

1. HEC 9 Debris–Control Structures
2. HEC 11 Design of Riprap Revetment
3. HEC 14 Hydraulic Design of Energy Dissipaters for Culverts and Channels
4. HEC 15 Design of Roadside Channels with Flexible Linings
5. HEC 18 Evaluating Scour at Bridges
6. HEC 20 Stream Stability at Highway Structures
7. HEC 21 Design of Bridge Deck Drainage
8. HEC 22 Urban Drainage Design Manual
9. HEC 23 Bridge Scour and Stream Instability Countermeasures

V–02.10.3 Software

1. HY- 8 FHWA Hydraulic Design of Highway Culverts
2. HEC-HMS USACE Hydrologic Modeling System
3. HEC-RAS USACE Hydrologic Engineering Center River Analysis System
4. FHWA Hydraulic Toolbox
5. Aquaveo Surface-water Modeling System (SMS/SRH-2D)
6. PeakFQ Annual Flood Frequency Analysis Using Bulletin 17C and Bulletin 17B Guidelines

V–02.10.4 Other Reports and Manuals

1. AASHTO Highway Drainage Guidelines
2. WRI 2015-5096 Regional regression equations to estimate peak-flow frequency at sites in North Dakota using data through 2009
3. WRI 96-4178 Analysis of the Peak–Flow Gaging Network in North Dakota
4. HIRE-Highways in the River Environment
5. HEC-RAS–Applications Guide
6. HEC-RAS–Hydraulic Reference Manual
7. HEC-HMS–User's Manual
8. FHWA Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges
9. FHWA Two-Dimensional Hydraulic Modeling for Highways in the River Environment Reference Document

HYDRAULIC ANALYSIS AND STRUCTURE SELECTION

BRIDGE NO. 0011-083.957

PROJECT NO. SS-BRS-2-011(035)083

PCN 20280

DICKEY COUNTY

PREPARED BY

DESIGNER OR CONSULTANT NAME

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

BRIDGE DIVISION

DECEMBER 2014

SS-BRS-2-011(035)083

6 Miles East of Ellendale

CERTIFICATION

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly registered professional engineer under the laws of the State of North Dakota. This document was originally issued and sealed by John Doe, Registration number PE-#### on MM/DD/YYYY and the original document is stored at the North Dakota Department of Transportation.

This document was originally issued and sealed by *John Doe*, Registration Number PE-####, on MM/DD/YY and the original document is stored at the North Dakota Department of Transportation.on MM/DD/YY and the original document is stored at the North Dakota Department of Transportation.

______________________________ MM/DD/YY
John Doe, P.E. /s/ Date

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APPENDICES

I. PURPOSE

The purpose of this report is to determine the hydraulic requirements for a new structure which conveys the flows of the Maple River through ND Highway 11 at RP 83.957 in Dickey County.

II. EXISTING STRUCTURE

A. Location

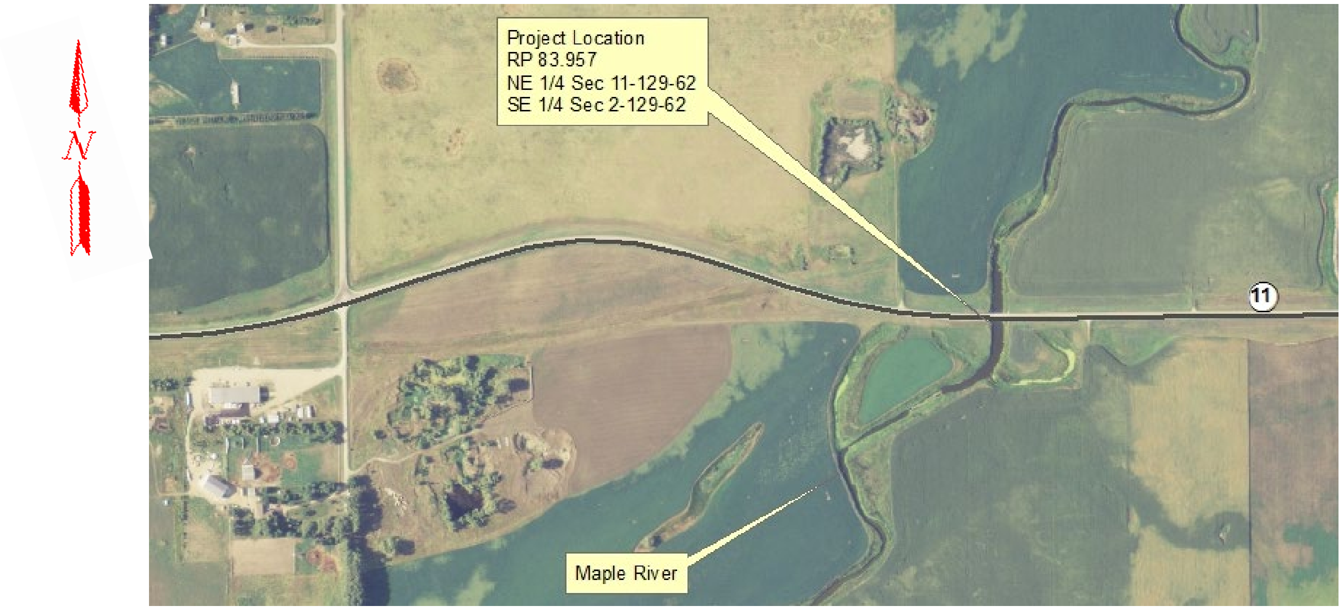


Figure 1 - Project Location Map

B. Project Construction History

Bridge 11-083.957 was constructed in 1955 to carry ND Highway 11 traffic across the Maple River. The structure is a 90 foot long by 27.9 foot three-span concrete slab bridge. A double box beam rail retrofit was added in 2004.

C. Existing Geometry

Bridge 11-083.957

Length – 90 ft
Skew – 0 degrees
Clear Roadway Width – 27.9 ft

III. HYDROLOGY

The drainage area for this structure was determined to be 440.66 square miles with a stream gradient of 3.17 feet per mile and is located in Hydrologic Region C. A map of the drainage area is provided in the appendix. This structure is not located in a FEMA floodplain. The USGS Regression Equations were used to determine flood frequency discharge values. The results from the USGS Regression Equations are shown below in Table 1.

Table 1 – USGS Regression Equations

USGS REGRESSION RESULTS

Contributing Drainage Area	Channel Slope	Hydrologic Region
440.66 Sq. Mi	3.17 Ft/Mi	Region C

RESULTS

Recurrence Interval (years)	Peak Flow Q
2	296 CFS
10	1756 CFS
15	2325 CFS
25	3127 CFS
50	4375 CFS
100	5822 CFS
500	9913 CFS

The new structure alternatives have been modeled for a 50-year discharge. The US Army Corps of Engineers HEC-RAS computer program was used for the hydraulic analysis of the existing structure and for the proposed alternatives considered. The results of these alternatives are contained in the appendix.

IV. STRUCTURE SELECTION

In the Documented CatEx, it was proposed to replace the existing bridge. The existing structure and four structure alternatives were analyzed for comparison. The selection process was governed by *Article 89-14 of the North Dakota Administrative Code* (ND Stream Crossing Standards), and Chapter V of the NDDOT Design Manual.

According to the NDDOT minimum bridge width guidelines, a new bridge on a District Corridor with an ADT between 400 and 750 should have a minimum clear roadway width of 36 feet. Therefore, all bridge alternatives were evaluated with a width of 36 feet.

As per the Stream Crossing Standards and the NDDOT Design Manual, the new structure alternatives were designed to pass the 50-year flow. The NDDOT Design Manual recommends that the maximum velocity for the design discharge shall be 5.0 ft/sec, generally.

Selection of the alternatives was completed by modeling the flows through the existing structure against the structure alternatives in HEC-RAS. Alternative 1 is to install a 3-span, 120' bridge with 2.5:1 end slopes and 27" girders. Alternative 2 is to install a 3-span, 140' bridge with 3:1 end slopes and 21" girders. Alternative 3 is to install a 2-span, 120' bridge with 2.5:1 end slopes and 27" girders. Alternative 4 is to install a 2-span, 138' bridge with 3:1 end slopes and 27" girders. Each of the alternatives were evaluated with an approximate channel width of 23 to 26 feet. The estimated cost for each alternative is shown in Table 2 – Cost Estimate.

Table 2 – Cost Estimate

Alternative Number and Size	Estimated Cost
Alternative #1 – 120' bridge, 3-span, 27" girders, 2.5:1 side slopes	$1,010,000
Alternative #2 – 140' bridge, 3-span, 21" girders, 3:1 side slopes	$1,132,000
Alternative #3 – 120' bridge, 2-span, 27" girders, 2.5:1 side slopes	$970,000
Alternative #4 – 138' bridge, 2-span, 27" girders, 3:1 side slopes	$1,116,000

The structure alternatives all maintained flow velocities at the structure below 5 feet per second during a 50-year flood event. Each of the structure alternatives also provided at least 1 foot of freeboard between the bottom of bridge girders and the 50-year water elevation. The overtopping discharges for the alternatives were not calculated, but it exceeds the 500-year discharge of 9,913 cfs. Materials and Research Division recommends 2.5:1 abutment slopes for this bridge. Therefore, it is recommended that Alternative 1, a 3-span, 120' bridge with 27" girders, be constructed.

Figure 2 – Alternative 1 Bridge Layout

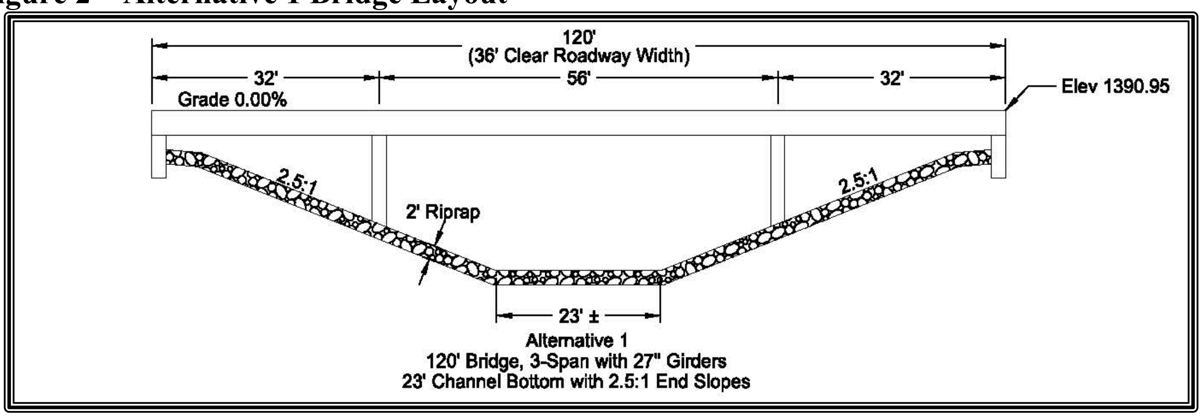


Figure 3 – Alternative 2 Bridge Layout

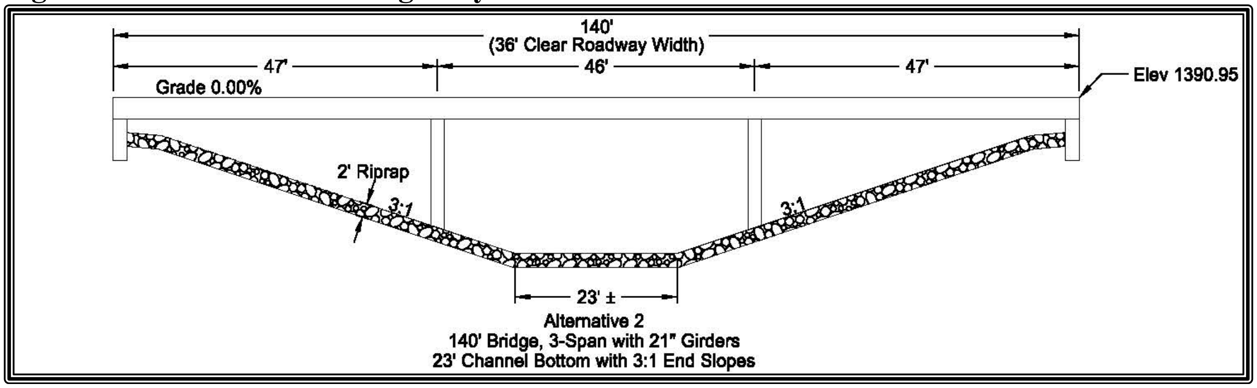


Figure 4 – Alternative 3 Bridge Layout

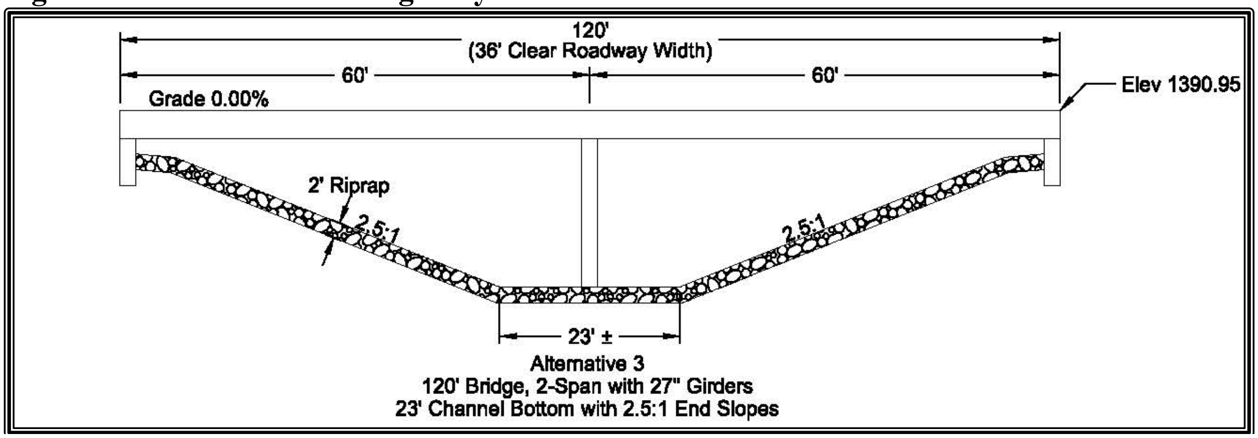
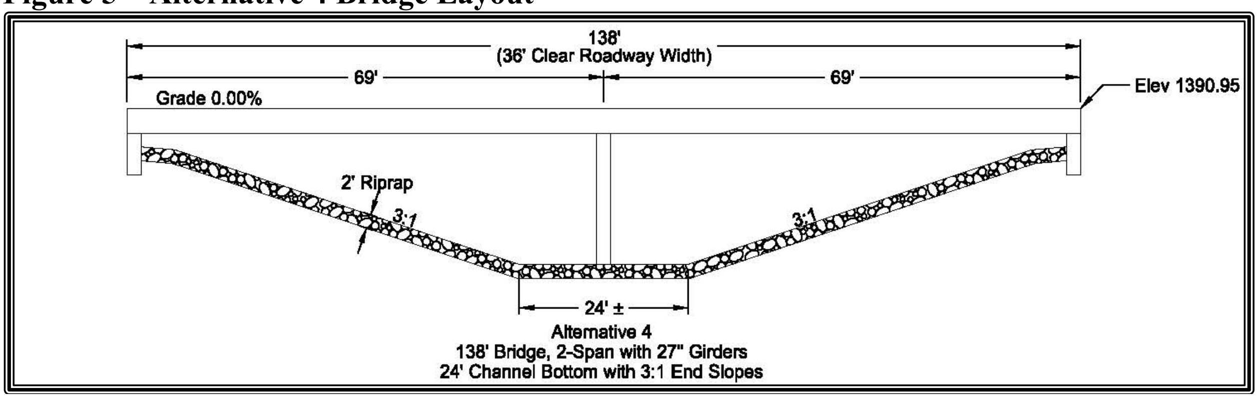


Figure 5 – Alternative 4 Bridge Layout



V. SCOUR ANALYSIS

Scour calculations at the bridge were performed using HEC-RAS software. HEC-RAS provides estimates for contraction, abutment, and pier scour based upon methods outlined in Hydraulic Engineering Circular No. 18 (HEC 18).

Table 3 – Estimated Scour, Alternative 1

Recurrence Interval	Discharge (cfs)	Contraction Scour (ft)	Pier Scour (ft)	Abutment Scour (ft)
100-yr	5,822	2.57	3.89	2.85
500-yr	9,913	6.05	4.65	7.46

A summary of the calculated scour is provided in the appendix. It is recommended that a 24” layer of riprap on filter fabric be placed at the bridge to protect the channel and structure from possible scour. This riprap should cover the entire waterway through the bridge and extend 55’ upstream and downstream, measured from the roadway centerline.

VI. MISCELLANEOUS

The following items should be discussed at the TS&L inspection:

- Structure Selection & Location
- Riprap Requirements
- Utilities
- Disposal of Existing Structure
- Temporary Bypass

HYDRAULIC ANALYSIS AND STRUCTURE SELECTION

BRIDGE NO. 32-006.121

PROJECT NO. SS-8-032(033)006

PCN 19853

SARGENT COUNTY

PREPARED BY

DESIGNER OR CONSULTANT NAME

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

BRIDGE DIVISION

MAY 2013

SS-8-032(033)006

4 Miles South of ND 11 East

CERTIFICATION

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly registered professional engineer under the laws of the State of North Dakota. This document was originally issued and sealed by John Doe, Registration number PE-#### on MM/DD/YY and the original document is stored at the North Dakota Department of Transportation.

This document was originally issued and sealed by *John Doe*, Registration Number PE-####, on MM/DD/YY and the original document is stored at the North Dakota Department of Transportation.on MM/DD/YY and the original document is stored at the North Dakota Department of Transportation.

____
John Doe, P.E. /s/

_____MM/DD/YY_______________
Date

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APPENDICES

I. PURPOSE

The purpose of this report is to determine the hydraulic requirements for a new structure which conveys the flows of the Wild Rice River through ND Highway 32 at RP 6.121 in Sargent County.

II. EXISTING STRUCTURE

A. Location

Figure 1 - Project Location Map

B. Project Construction History

Structure 32-006.121 was reconstructed in 1952 to carry ND Highway 32 traffic across the Wild Rice River. The structure is a 65 foot long by 32.8 foot wide steel stringer bridge. The abutments of the old bridge (a 30 foot long single-span I-beam bridge) were cut off to an elevation of 1244.5' (1929 National Geodetic Vertical Datum) when the bridge was reconstructed in 1952, and are located within the banks of the river underneath the bridge. The deck of the existing structure has been overlaid with HBP.

C. Existing Geometry

Structure 32-006.121

Length – 65 ft
Skew – 0 degrees
Clear Roadway Width – 27.9 ft

III. HYDROLOGY

Design flows were determined using methodology set forth in USGS Water-Resource Investigations Report 92-4020 *Techniques for Estimating Peak-Flow Frequency Relations for North Dakota Streams (USGS W-RI Report)*.

Structure 32-006.121 is located on a gaged stream and is upstream of a gaging station near Rutland, ND. The contributing drainage area at the gaging station was reported to be 296 square miles. After estimating the area between downstream of the bridge to the gage station to be 35.44 square miles, the ungaged contributing drainage area at the bridge was calculated to be 260.56 square miles. Peak flows at the gage station were calculated using annual peak flows collected from gage station data and the software program PeakFQ. Because the ratio of contributing drainage areas for the ungaged site is between 75 and 150 percent of the contributing drainage area for the gaged site, the Weighted Peak-Flow method for estimating design flows for ungaged sites near a gaging station on the same stream can be used. The results of this method are shown below in Table 1:

$$Q_{T(u)} = Q_{TW(g)}\ (CA_u/CA_g)^x,$$

where

$Q_{T(u)}$ = peak flow, in cubic feet per second, for the ungaged site for a recurrence interval of T-years;

$Q_{TW(g)}$ = weighted peak flow, in cubic feet per second, for the gaging station for a recurrence interval of T-years;

CA_u = contributing drainage area, in square miles, for the ungaged site;

CA_g = contributing drainage area, in square miles, for the gaging station; and

x = mean exponent for the appropriate hydrologic region.

<u>Downstream Gage Extrapolation Calculations</u>

Q_2 = 192.4 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_2 = 178.9 cfs

Q_{10} = 1,297 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{10} = 1,206.1 cfs

Q_{50} = 3,297 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{50} = 3,065.8 cfs

Q_{100} = 4,424 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{100} = 4,113.8 cfs

Q_{200} = 5,701 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{200} = 5,301.3 cfs

Q_{500} = 7,601 cfs x (260.56 sq mi/296 sq mi)$^{0.57}$
Q_{500} = 7,068.1 cfs

Table 1 – Calculated Peak Flows

Frequency (Years)	Discharge at Gaging Station (cfs)	Discharge at Br. 32-006.121 (cfs)
2	192.4	178.9
10	1,297.0	1,206.1
50*	3,297.0	3,065.8
100	4,424.0	4,113.8
200	5,701	5,301.3
500	7,601.0	7,068.1

*Design Frequency ....

The new structure alternatives have been modeled for a 50-year discharge. The US Army Corps of Engineers HEC-RAS computer program was used for the hydraulic analysis of the existing structure and for the proposed alternatives considered. The results of these alternatives are contained in the appendix.

IV. STRUCTURE SELECTION

In the Environmental Document, it was proposed to replace the existing bridge with a reinforced concrete box culvert. The existing structure and three structure alternatives were analyzed for comparison. Alternative 1 is to install a quad 10' x 10' reinforced concrete box culvert. Alternative 2 would require installation of a triple 14' x 10' reinforced concrete box culvert. Alternative 3 is to install a quad 11' x 10' reinforced concrete box culvert. All alternatives were analyzed with a length of 98 feet and skewed approximately 10 degrees from perpendicular to the proposed roadway. For each of the alternatives, the box will be placed 1 foot lower than the existing channel bottom in order to provide for aquatic organism passage. The estimated cost for Alternative 1 is $714,000. The estimated cost for Alternative 2 is $801,400. The estimated cost for Alternative 3 is $779,650. Rock riprap will be necessary for installation of the new structures and is not included in this cost estimate. The estimated cost for each alternative is shown in Table 2 – Cost Estimate.

Selection of the alternatives was completed by modeling the flows through the existing structure against the structure alternatives in HEC-RAS. Each of the structure alternatives result in an increase in headwater compared to the existing structure. However, the increase is less than 2 feet at the 100-year storm event, and no structures are located upstream. The structure alternatives all maintained flow velocities at the structure below 10 feet per second on a 50-year storm event. The overtopping discharge for Alternative 1 is 6,539.3 cfs. Alternatives 2 and 3 produced slightly lower headwaters and outlet velocities than Alternative 1. However, it is recommended that Alternative 1, Quad 10’ x 10’ x 98’, be constructed since it has the lowest cost.

Table 2 – Cost Estimate

Alternative Number and Size	Estimated Cost
Alternative #1 – Quad 10’ x 10’ x 98’	$714,000
Alternative #2 – Triple 14’ x 10’ x 98’	$801,400
Alternative #3 – Quad 11’ x 10’ x 98’	$779,650

V. SCOUR

Scour calculations were not performed for the box culvert alternatives. It is recommended that riprap be placed in the channel at the ends of the RCB aprons for a distance of 10 feet upstream and 20 feet downstream to protect the channel and structure from possible scour.

VI. MISCELLANEOUS

The following items should be discussed at the TS&L inspection:

- Structure Selection
- Riprap Requirements
- Utilities
- Disposal of Existing Structure
- Temporary Bypass

V-03.01 General

V-03.01.01 City Participation

Local government cost sharing for storm drain trunk lines shall be determined in accordance with Appendix V-03D – City Participation.

V-03.01.02 Design Guidance

"Highway Drainage Guidelines," published by the American Association of State Highway and Transportation Officials, (AASHTO) shall be referred to for additional guidance. Additional design and engineering guidance can be found in "Urban Drainage Design Manual," (HEC 22) published by Federal Highway Administration.

Some communities have adopted Storm Water Design Manuals or Master Plans. When designing in these communities, the local criteria should be followed, in addition to NDDOT criteria. Conflicts should be addressed as early as possible in the hydraulic study.

V-03.01.03 Design Considerations

Design guidelines for the storm drain systems are as follows:

1. Storm drain systems shall be designed for the recurrence intervals specified by Article 89-14 of North Dakota Administrative Code.

2. Wherever possible, trunk lines should be located behind the curb and gutter. However, it is recognized that this will not be possible in many locations.

3. A minimum 0.4% longitudinal roadway profile grade is desirable to facilitate inlet flow and prevent ponding.

4. Manholes in a storm drain system should be labeled numerically in the plans, with manhole numbers increasing in the direction of increasing plan stationing. Inlets should be labeled with the number of the associated manhole that they drain to, along with an alpha designation. As an example, the first inlet at the beginning of a project might be Inlet 1A. If an Inlet-Special (as shown on Standard Drawing D-722-1B) will be installed and will function also as a manhole for the trunk line, then it should be labeled with a sequential number and alpha (typically "A"). For example, the third manhole in a trunk line, if it is an Inlet-Special, would be labeled "3A".

V-03.02 Design Parameters

V-03.02.01 Computing Runoff (Rational Method)

Determination of the runoff is the first step in the design of an urban storm drainage system. The Rational Method, as described in Section V-01.04 shall be used to calculate discharge.
The Rational Method is as follows:
$Q = CIA$

Q = Maximum design rate of runoff, cfs.

C = Runoff coefficient representing a ratio of runoff to rainfall (Appendix V-03 A).

I = Average rainfall intensity for a duration equal to the time of concentration, for a selected return period, in/hr. Intensity shall be determined using the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 – Precipitation-Frequency Atlas of the United States (Atlas 14).

A = Drainage area tributary to the design location, acres.

V-03.02.02 Time of Concentration

The time of concentration is the time required for water to flow from the most remote point of the drainage area to the point of interest. Use of the Rational Method formula requires the time of concentration for each design point within the drainage basin. The duration of rainfall is then set equal to the time of concentration and is used to estimate the design average rainfall intensity (I).

For a specific drainage basin, the time of concentration consists of an inlet time plus the time of flow in a closed conduit or open channel to the design point. Inlet time is the time required for runoff to flow over the surface to the nearest inlet and is primarily a function of the length of overland flow, the slope of the drainage basin, and surface cover. Pipe or open channel flow time can be estimated from the hydraulic properties of the conduit or channel. In all cases the time of concentration shall not be less than 5 minutes. An alternative way to estimate the overland flow time is to use Figure 2 in Appendix V-03 B.

V-03.02.03 Drainage Area (A)

The following may be used in determining the drainage areas:

- Digital Terrain Models (DTMs)

Watershed areas for urban drainage studies can be delineated from digital terrain models which have been developed from surveys. The coverages for the surveys are limited to the project corridor and are usually inadequate alone to compute the drainage areas. The value of the DTMs is that the coverage allows for 3-dimensional evaluation. The software used by NDDOT for this purpose is Geopak coupled with the Microstation drafting package.

- USGS Maps

Contour maps developed by the US Geological Survey are available through the North Dakota Geological Survey office in Bismarck. Another source to access the maps is through the ArcGIS software. The maps are essential to supplement the DTMs mentioned above.

- LiDAR Data

LiDAR can provide supplemental data to aerial or ground survey data. LiDAR data is available for download from the North Dakota State Water Commission website as part of their Map Services.

- Photography

Aerial imagery may be available from Design Division's Photogrammetry Section.

- On-Site Inspection

Once delineation of drainage areas has been performed, on-site reviews are conducted to verify drainage boundaries.

V-03.02.04 Design Spread

Allowable spread width should be calculated in accordance with the methodology provided by HEC 12, for the design frequency runoff. Typically, the width of the water surface (spread) should not exceed the following criteria:

Speed limit 45 mph or less:

ROADWAY	DESIGN SPREAD
Two-Lane (No Parking Lane)	Shoulder width plus the width of one-half the driving lane
Two Lane (With Parking Lane)	Parking lane plus the width of one-half the driving lane
Three-Lane	Shoulder width (whether or not it is a parking lane) plus the width of one-half the outside driving lane
Four-Lane*	Shoulder width (whether or not it is a parking lane) plus the width of one-half the outside driving lane

* For multi-laned curb and gutter without parking, it is not practical to avoid the travel lane flooding when the longitudinal grades are flat (0.2 to 1 percent). The width of half of the outside driving lane has been designated for allowable spread, however in some cases the full width of the outside driving lane may be considered.

Speed limit greater than 45 mph:

On roadways with speed limits greater than 45 mph, the spread should be limited to the shoulder width. For roadways with a shoulder width of less than 6 ft, the maximum design spread shall be 6 ft.

V-03.03 Design of Inlets and Manholes

V-03.03.01 Inlet Locations

Inlets should generally be placed at the following locations:

- At on-grade locations where the design spread is achieved.
- Sag point in the gutter grade.
- Immediately upstream of median breaks, entrance/exit ramp gores, cross walks and street intersections.
- Immediately up-grade of cross slope reversals.
- Immediately up-grade from pedestrian cross walks.
- At the end of channels in cut sections.
- On side streets immediately up-grade from intersections.
- Behind curbs, shoulders, or sidewalks to drain low areas.
- At underpasses, flanking inlets are recommended on either side of the sag point to avoid debris buildup at the sag point inlet.

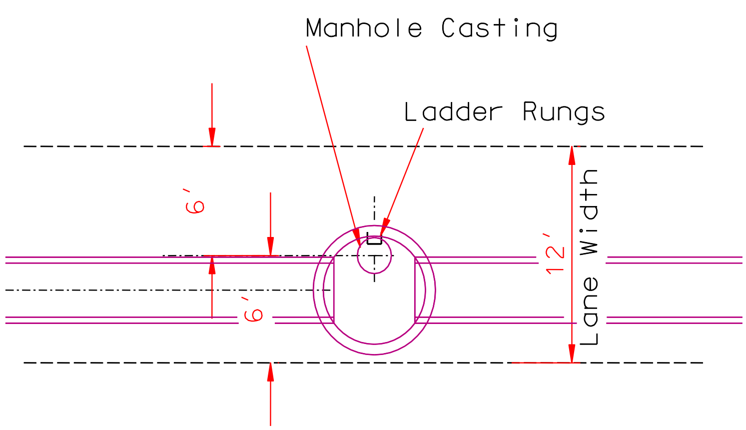
V-03.03.02 Inlet Types

NDDOT uses the inlet types shown on the Standard Drawings D-722-1 through D-722-3A, and the median drain shown on Standard Drawing D-722-7. A brief description of the typical applications for the various inlets is provided in Appendix V-03 C.

V-03.03.03 Storm Drain Manholes

Manholes are recommended in storm drains wherever the pipe changes direction. Sometimes 7.5 degree bends can be used instead of a manhole if the distance is short or the drain is not under the roadbed. Manholes used by NDDOT range from 48" to 120" in diameter. The following criteria apply to manholes:

- Manhole details are provided on Standard Drawing D-722-5.
- Floating Castings, recommended for concrete paved surfaces, are shown on Standard Drawing D-722-5A.
- Manhole spacing should generally be limited to a maximum of 400 feet. Additional guidance on manhole location and spacing is provided in the AASHTO Model Drainage Manual.
- Manholes located under the roadway shall have their covers located such that the castings are midway between the lane lines if possible.



V-03.03.06 Manhole Sizing

Manhole sizing shall be determined using the following formula and table (AASHTO Model Drainage Manual).

$$K = \frac{R_1 + T_1 + R_2 + T_2 + 14\,in}{\Delta}$$

Where:
R_1 and T_1 are the interior radius and wall thickness of Pipe #1, in inches
R_2 and T_2 are the interior radius and wall thickness of Pipe #2, in inches
Δ = angle between the pipes, in degrees

Manhole Dia (in.)	*K* (in./degree)	Max Pipe Size (in.)
48	0.42	30
54	0.47	36
60	0.52	42
66	0.58	48
72	0.63	54
84	0.73	66
96	0.84	72
108	0.94	84

V-03.04 Design of Trunk and Lead Lines

V-03.04.01 Pipe Size and Slope

As the design of each reach of the storm drain depends on the characteristics of the previous reach, the design must start at the upper-most part of the drain and proceed downstream a reach at a time. The required capacity for a pipe within a reach is dependent on its time of concentration and contributing drainage area. The time of concentration used to determine drain size and slope for a drain is the inlet time at the most remote point, plus the total flow time in the drain. The minimum time of concentration for trunk line design should be 15 minutes for basins with pervious surfaces and 10 minutes for impervious. For inlets the minimum time of concentration is 10 minutes for pervious surfaces and 5 minutes for impervious surfaces.

The design time of concentration for a point below the junction of two or more drain branches is not necessarily the longer of the two periods. A greater flow could result with a shorter time of concentration. All conditions must be investigated when determining the appropriate time of concentration for any multiple branch storm drain design. The junction of flows from more than one inlet may require a recalculation of discharges, depending upon which time of concentration controls the combined flow.

After the flow in a reach has been determined, a pipe diameter and slope may be selected to accommodate this flow. When possible, the pipe slope should approximate the roadway profile. Generally, when the pipe selected for the length and slope of the reach exceeds 80% full (depth), the next larger size pipe should be used. However, there may be situations in which flow greater than 80% full, or pressure flow is justified. For example, near the outfall of a system, there may be adequate headroom between the conduit and inlet/access hole elevations to tolerate pressure flow, and a significant cost savings could be realized if the pressure flow condition was utilized.

The velocity of flow in storm drain pipes should not be less than 3 ft/sec. The diameter and slope should also be established to fit all control elevations. When Manning’s equation is used for storm drain design, the design “n” (roughness) value should be .012.

It is necessary to analyze the hydraulic grade line of the storm drain system in order to determine if the design flows can be accommodated without water coming out of inlets or manhole access holes due to pressure flow.

V-03.04.02 Outfall Design

The purpose of the storm drain outfall is to transport the storm water to a natural drainage watercourse and discharge it with as little erosion as practicable. A storm drain outfall consists of the outfall line (or channel) draining a storm drain system or detention pond.

If the storm drain is too deep and no low water discharge elevation is available, a pump station will be required. Whenever possible, the pump station should provide for a high water overflow.

Another feature to always evaluate is the need to detain flows in ditches or detention ponds. This results in smaller pipe sizes, possibly lower costs, and can reduce downstream impacts.

V-03.04.03 Median Barriers

Type 2 inlets with vane grates are generally used in concrete median jersey barriers. Curb boxes can be adjusted lower to conform with the 3" high slope break near the bottom of the barrier. If reinforcing details for the median barrier allow for their installation, slotted drains can also be used. These may need to be located a distance away from the face of the barrier in order to avoid conflicts with the barrier slab reinforcing. Other transversely installed drains may provide good performance in median barrier slabs as well. Depending upon length of the system, depth and location of outside ditches, and other factors, the drainage may either be conveyed by a trunk to a discharge point, or discharged via lead lines to adjacent ditches.

V-03.04.04 Underpasses and Pump Stations

Wherever underpasses are planned, the goal should be to minimize the amount of flow into the depressed section while at the same time providing as much underground storage as possible.

Underpasses typically are designed for a higher design discharge than the rest of the roadway. Therefore, additional care is required in underpass design. Article 89-14 of North Dakota Administrative Code specifies the minimum design frequencies to be used for underpasses.

The designer is referred to FHWA's publication "Highway Storm Water Pumping Stations", (FHWA-IP-82-17, Vols. 1&2), and FHWA's "Highway Stormwater Pump Station Design, Hydraulic Engineering Circular No. 24" (HEC-24) for general guidance and information on all aspects of pump station design.

The designer will prepare and send a lift station feed point letter to the power supply company. This should be coordinated with the Design Division Utilities Engineer. A copy of the letter will be sent to the District office and the Utilities Engineer.

V-03.05 Storm Drain Materials

Material selection for storm drains shall conform to the pipe selection criteria in Section V-05 "Pipe Material Selection."

Ductile iron sewer pipe is generally recommended for the discharge pipe of pump stations.

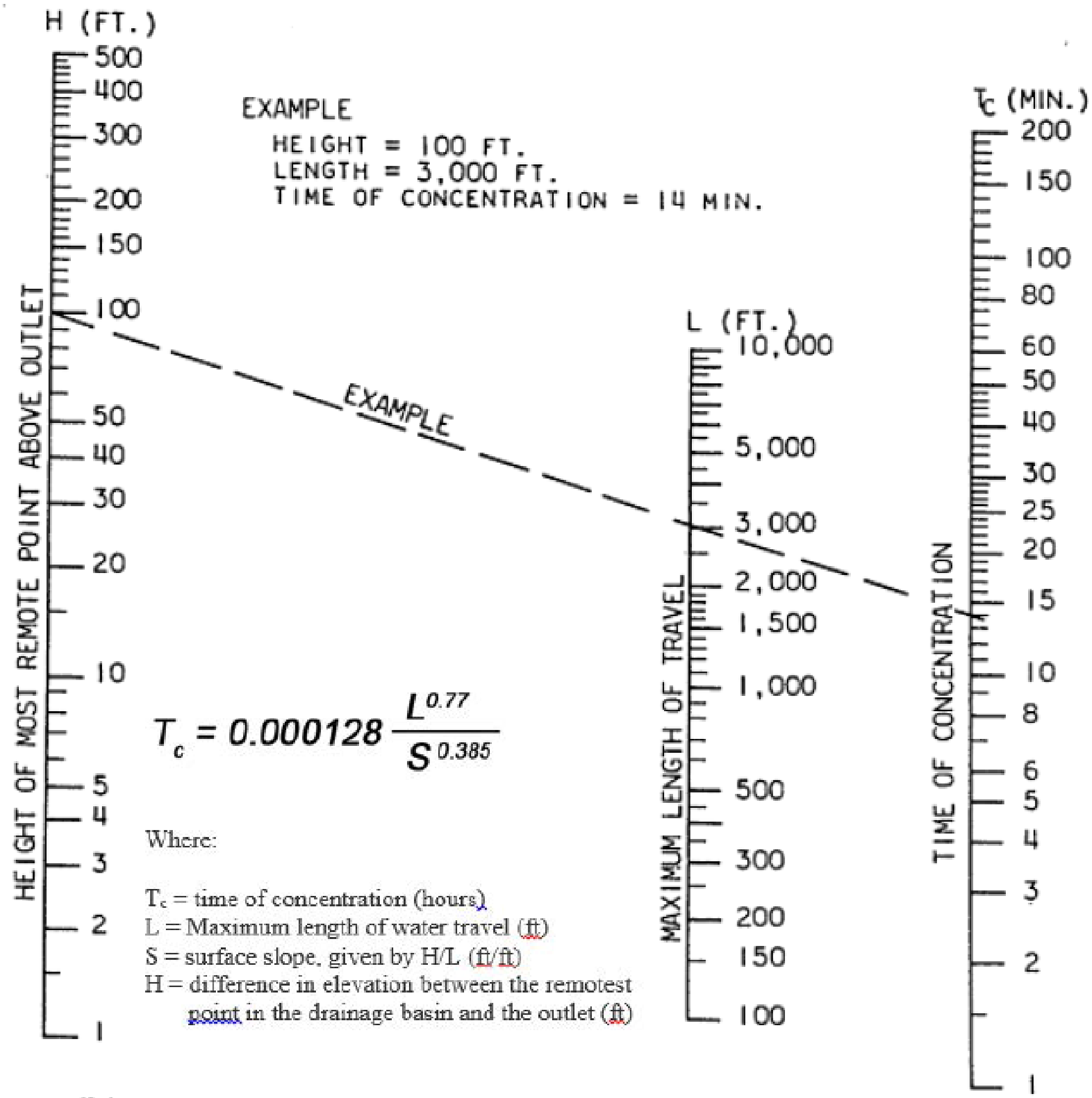
Description of Area	Runoff Coefficients
Business:	
Downtown Areas	0.70 to 0.95
Neighborhood Areas	0.50 to 0.70
Residential:	
Single-Family Areas	0.30 to 0.50
Multi-Units, Detached	0.40 to 0.50
Multi-Units, Attached	0.60 to 0.70
Residential (Suburban)	0.25 to 0.40
Apartment Dwelling Areas	0.50 to 0.70
Industrial:	
Light Areas	0.50 to 0.80
Heavy Areas	0.60 to 0.90
Unimproved Storage Areas	0.20 to 0.50
Parks, Cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad Yard Areas	0.20 to 0.35
Unimproved Areas	0.10 to 0.30
Streets:	
Concrete	0.80 to 0.95
Asphalt	0.70 to 0.95
Drives and Walks	0.75 to 0.85
Roofs	0.75 to 0.95
Lawns, Sandy Soil:	
Flat, 2%	0.05 to 0.10
Average, 2-7%	0.10 to 0.15
Steep,>7%	0.15 to 0.25
Lawns, Heavy Soil:	
Flat, 2%	0.10 to 0.20
Average, 2-7%	0.15 to 0.25
Steep, >7%	0.25 to 0.35

Runoff Coefficients (Rural Areas)

Description of Area	Runoff Coefficients
Roadways:	
Concrete	0.80 to 0.95
Asphalt	0.70 to 0.95
Gravel	0.40 to 0.60
Roadway Ditches	0.20 to 0.50
Forested Areas	0.10 to 0.30
Meadows	0.10 to 0.40
Pasture Land	0.20 to 0.45
Cultivated Land, Sand and Gravel:	
Flat, 2%	0.20 to 0.30
Average, 2-7%	0.30 to 0.35
Steep, >7%	0.35 to 0.45
Cultivated Land, Clay and Loam:	
Flat, 2%	0.30 to 0.45
Average, 2-7%	0.45 to 0.55
Steep, >7%	0.55 to 0.70

Note: For all of the above, use the lower values for flat slopes or permeable soils; use the higher values for steep slopes or impermeable soils.

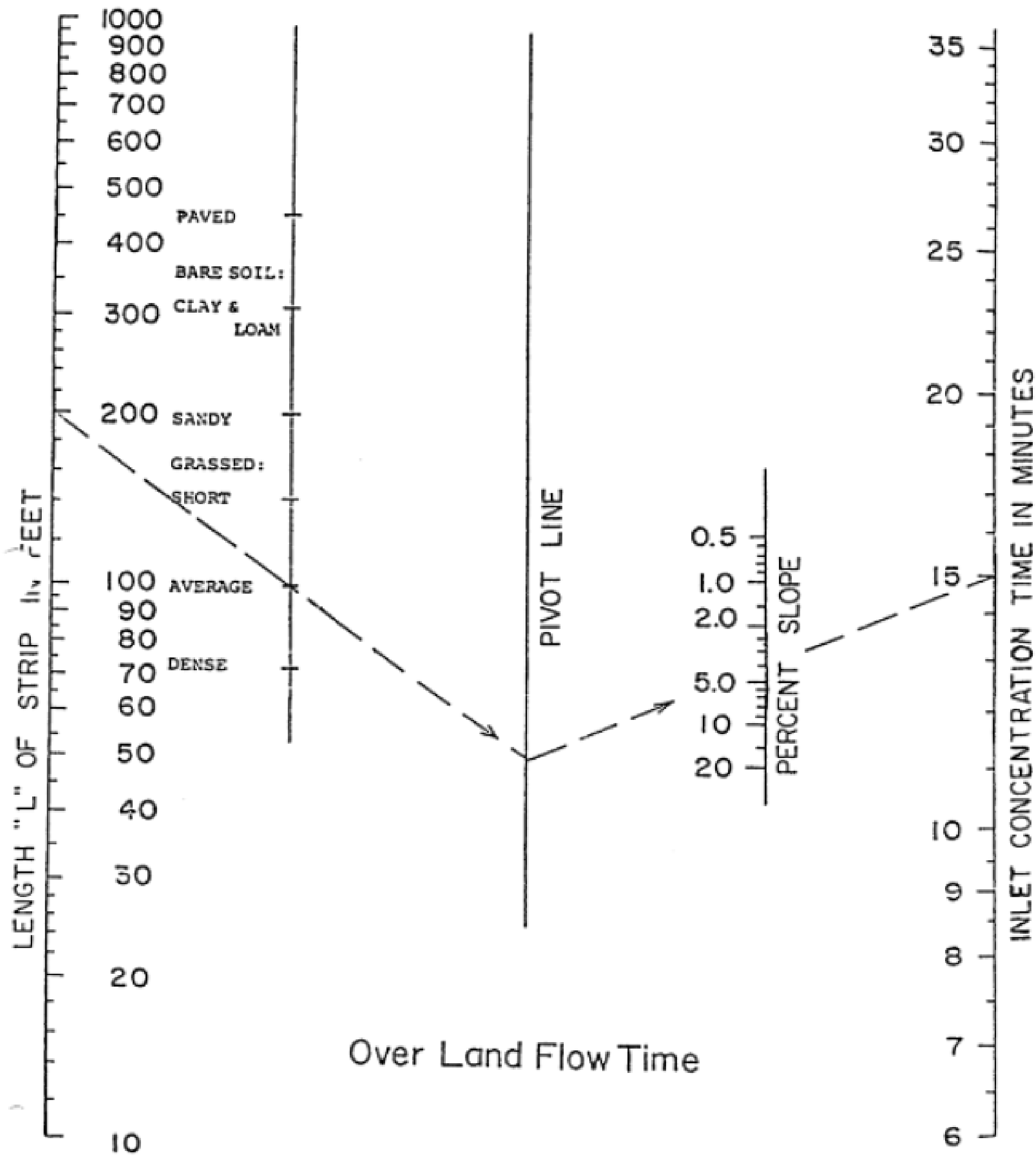
Appendix V-03B



Note:

Use nomograph T_c for natural basins with well defined channels, for overland flow on bar earth, and for mowed grass roadside channels.
For overland flow, grassed surfaces, multiply T_c by 2.
For overland flow, concrete or asphalt surfaces, multiply T_c by 0.4.
For concrete channels, multiply T_c by 0.2.

TIME OF CONCENTRATION OF SMALL DRAINAGE BASINS


LENGTH "L" OF STRIP IN FEET
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
PAVED
BARE SOIL:
CLAY &
LOAM
SANDY
GRASSED:
SHORT
AVERAGE
DENSE
PIVOT LINE
0.5
1.0
2.0
5.0
10
20
PERCENT SLOPE
35
30
25
20
15
10
9
8
7
6
INLET CONCENTRATION TIME IN MINUTES
Over Land Flow Time

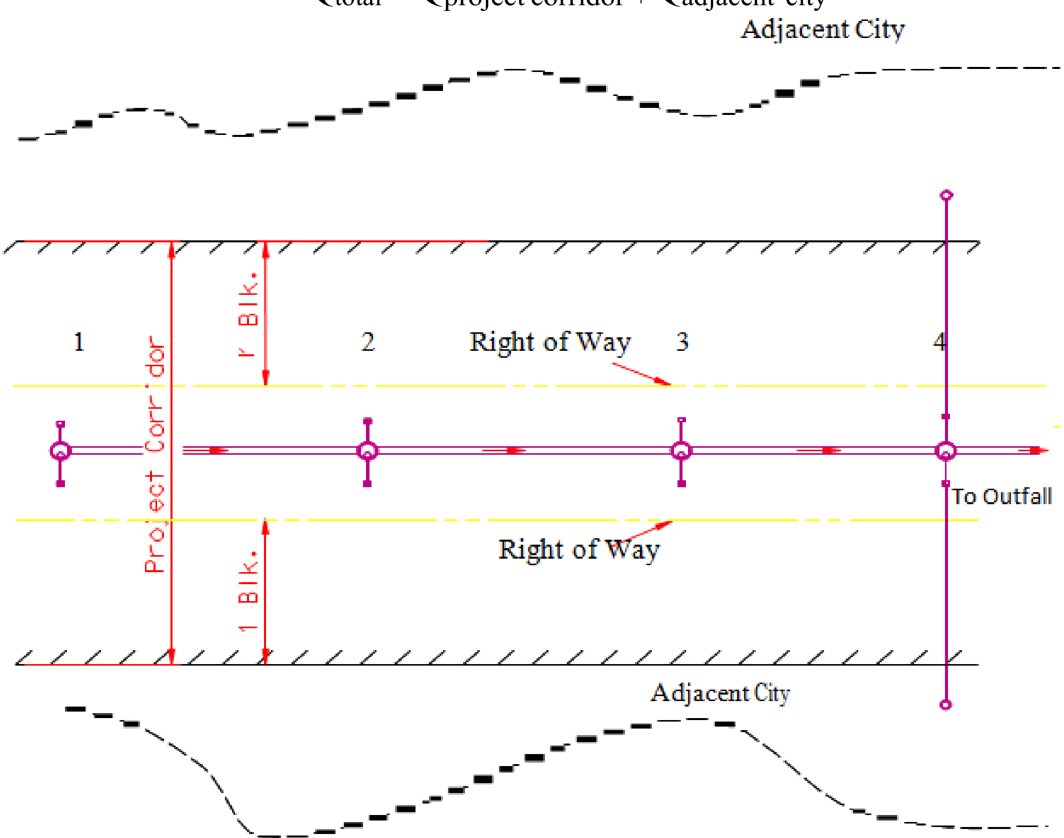
Standard Drawing	Type and Use
D-722-1	Inlet - Type 1: This curb inlet is typically recommended for discharges of 1 cfs or less. Grate styles are available for sags (D) or continuous grades (L or V).
D-722-1A	Inlet - Catch Basin - Type A: Recommended for areas of pavement depressions such as parking lots.
D-722-1A	Inlet - Catch Basin - 6 in. or 9 in. Beehive: Recommended for areas of vegetation, such as ditches or parks. Not for use in the clear zone. If the inlet is in the clear zone, alternate choices for this inlet are Inlet - Catch Basin, Type A or Inlet - Mountable, Type B (D-722-3).
D-722-1B	Inlet - Special: This inlet is recommended for locations on trunk lines or lead lines where the storm pipes are larger than an Inlet - Type 1 or Inlet -Type 2 riser can accommodate.
D-722-2	Inlet - Type 2: This curb inlet is recommended for locations where discharges exceed the capacity of an Inlet - Type 1. Grate styles are available for sags (D) or continuous grades (L or V).
D-722-2	Inlet - Type 2 - Double: This curb inlet, comprised of two Type 2 inlets, is recommended for locations where discharges exceed the capacity of an Inlet - Type 2. Grate styles are available for sags (D) or continuous grades (L or V). If the spread on the pavement is greater than the allowable, additional inlets or slotted drain sections upstream are recommended.
D-722-3	Inlet - Mountable Curb, Type A: This inlet is recommended for sag conditions with mountable curbs where typical discharges are 1 cfs or less.
D-722-3	Inlet - Mountable Curb, Type B: This inlet is recommended for use with mountable curb and gutters either in sags or on continuous grades depending on grate type. It can also be used in parking lots or ditches.
D-722-3A	Inlet - Slotted Drain: This inlet is recommended for use on continuous grades where the flow cannot be adequately captured by an Inlet - Type 2. It is typically used with an Inlet - Type 2.
D-722-7	Precast Concrete Median Drain: This inlet is used for rural medians where concrete pipes provide cross drainage. The inlet accepts larger debris or solids, and is not recommended for urban storm drains.

The NDDOT has a policy that enables cities to share drainage costs for storm drain trunk lines, whenever it is feasible to combine efforts to drain areas within and outside of the project corridor. The most economical way to accomplish both the Department's and the City's goal for drainage is when each is willing to participate in paying for a single drainage system to avoid duplication of infrastructure elements.

The first step in this process is to determine how much land the highway project is responsible to drain. The general guideline the Department has adopted to define the project corridor is the area that lies within the highway right of way plus one block on either side. In areas where adjacent city property has not been divided into blocks, then the distance to use to define the project corridor shall be set to be consistent with other adjacent areas where city blocks do exist, up to a distance of 450 feet, measured from the centerline of the project highway/street.

The policy requires that the Department and the City participate in the costs on a percentage basis in proportion to their contribution to the total flow rate, Q. (where Q is the flow rate in cubic feet per second). The cost sharing is proportional to how much surface water drains from the project corridor land versus the water that drains from city land. The general formula for participation is:

$$Q_{total} = Q_{project\ corridor} + Q_{adjacent\ city}$$



There are two cases to consider as follows:

Case 1. Drainage from an adjacent city area that results in an increased discharge. In this case the city would participate in the percentage of Q increase for the trunk line cost from the point where city flow joins with project flow to the outfall location.

Case 2. Drainage from an adjacent city area that does not result in an increased discharge. Sometimes drainage from outlying areas does not result in a higher combined discharge. In this case the Time of Concentration factor or the Land Use Runoff factor (c) results in a discharge that is equal to or less than that required for the project corridor only, so the city will not be assessed any additional percentage of cost for the trunk line.

If Case 1 applies the cost breakdown is as follows:

$$\text{Project \%} = \frac{Q_{\text{Project Corridor}}}{Q_{\text{Project Corridor + Adjacent City}}}$$

Project Cost (Q Participation) = (Total Cost) x

(Project %) City Cost (Q Participation) = Total Cost -

Project Cost

Federal Cost (Project Participation) = (Project Cost) x

(Federal %) State Cost (Project Participation) = (Project Cost)

x (State %)

City Cost (Project Participation) = (Project Cost) x (City %)

Total City Cost = Project Cost (Q Participation) + City Cost (Project Participation)

Example: The total discharge (Q) computed for the project corridor is 50 cfs to manhole 4. At manhole 4 additional flow is added from an area considered to be adjacent city land. The total Q now is 80 cfs. The funding for this project is 80% Federal, 10% city and 10% State.

Cost of the trunk and lead lines from manhole 1 to manhole 4 is $ 200,000. The cost of the trunk line from manhole 4 to the outfall is $ 80,000. The lead line cost from manhole 4 to the outfall is $ 20,000. Total Cost is $ 300,000

Find: The cost participation for each governmental entity.

Project % = $\frac{50 \text{ cfs}}{80 \text{ cfs}}$ = 62.5 %

Project Cost (Q participation) = (80,000)(.625) + 220,000 =	$ 270,000
City Cost (Q participation) = 80,000 - 50,000 =	<u>$ 30,000</u>
	$ 300,000

Federal Cost (Project Part.) = (50,000)(.80) + (220,000)(.80) =	$ 216,000
State Cost (Project Participation) = (50,000)(.10) + (220,000)(.10) =	$ 27,000
City Cost (Project Participation) = (50,000)(.10) + (220,000)(.10) =	$ 27,000
City Cost (Q Participation) =	<u>$ 30,000</u>
	$300,000

Example Storm Drain Data

Date: 9/11/2014
Project Number: SOIA-7-804(049)247
Region: New Town

Location	Drainage Area (Acres)	Rational C Value	Time of Concentration (min)	Rainfall Intensity (in/hr)	Peak Discharge (cfs)	Design Event
1A	0.344	0.55	11.61	4.25	0.8	10-yr
1B	0.148	0.75	5	5.66	0.63	10-yr
2A	0.534	0.55	5.83	5.38	1.58	10-yr
3A	0.324	0.7	12.6	4.13	0.94	10-yr
3B	0.219	0.75	5	5.66	0.93	10-yr
4A	0.918	0.7	16.04	3.73	2.39	10-yr
5A	0.120	0.9	5.77	5.41	0.59	10-yr

Example Storm Drain Data

Date: 9/11/2014
Project Number: NHU-8-010(032)932
Location: West Fargo
Design Frequency: 10-year

Start Location	Stop Location	Pipe Diameter (in)	Pipe Length (ft)	Start Invert (ft)	Stop Invert (ft)	Pipe Slope (ft/ft)	Manning's n	Flow (ft^3/s)	Flow Velocity (ft/s)	Flow Depth (ft)	Allowable Flow Depth (ft)
MH-01	MH-02	30	200	892.1	891.8	0.002	0.012	11.52	3.76	1.5	2
MH-02	MH-03	30	400	891.8	891.4	0.001	0.012	11.61	3.2	1.73	2
MH-03	MH-04	30	101	891.4	891.3	0.001	0.012	11.49	3.18	1.73	2
MH-04	MH-05	30	99	891.3	891.2	0.001	0.012	11.39	3.2	1.7	2
MH-05	MH-06	42	254	891.2	890.8	0.002	0.012	21.55	4.49	1.75	2.8
MH-06	MH-07	42	397	890.8	890.26	0.001	0.012	22.17	4.28	1.86	2.8
MH-07	MH-08	42	220	890.26	890.02	0.001	0.012	24.35	4.02	2.11	2.8
MH-08	MH-09	48	174	890.02	889.84	0.001	0.012	35.28	4.32	2.48	3.2
MH-09	MH-10	48	400	889.84	889.56	0.001	0.012	35.07	3.68	2.84	3.2
MH-10	MH-11	48	128	889.56	889.27	0.002	0.012	34.18	5.78	1.91	3.2

V–04.01 General

This Section is intended to provide a guide for the sizing of pipe culverts to convey a design discharge of less than approximately 500 cubic feet per second (cfs).

A hydraulic report is generally not required to document the size selection for pipe culvert crossings. However, the hydrology, hydraulics and culvert modeling data shall be retained in the project files. Example hydrologic and hydraulic data for a pipe culvert crossing are provided in Appendix V-04 A.

The function of a culvert is to convey surface water discharges through a highway, or through an approach roadway. In addition to this hydraulic function, a culvert must also be able to withstand construction and highway loads passing over it. This Section only addresses hydrology and hydraulics for these crossings. Structural features, culvert selection criteria, and culvert height of fill data are provided on the Standard Drawings, in Section V-05 and in Appendix V-05 A of the Design Manual, respectively.

The designer should consult AASHTO'S, "Highway Drainage Guidelines" as a reference.

V–04.02 General Policies

The following general policies apply to the sizing of culvert crossings:

1. The minimum diameter of new centerline pipe culverts shall be 24 in. The maximum length of this diameter culvert shall be 100 feet (measured by pay length, from opening of end section to opening of end section at the crown of the pipe) for new installations. If more length is needed, a 30 in. diameter culvert should be used. Existing culverts smaller than 30" in diameter may be extended to lengths greater than 100 feet.

2. The minimum diameter for approach culverts up to 75 feet in length shall be 18 inches. Approach culverts longer than 75 feet shall have a minimum diameter of 24 inches.

3. Culvert material types for centerline and approach culverts shall be in accordance with the requirements of Section V-05 of the Design Manual. Both smooth-walled and corrugated culvert types shall be modeled.

4. New centerline culvert crossings should first be modeled using a smooth-walled (such as RCP or spiral rib corrugated) culvert (Manning's' n = .012). Next, the crossing should be modeled using corrugated pipe (Manning's n=.024), and the diameter shall be adjusted as necessary such that a design headwater is provided which is either lower than that provided by the smooth-walled pipe type, or no greater than 2% higher than the headwater provided by the smooth-walled pipe. Most often, increasing the diameter of the corrugated alternative by one size (6 inches) is sufficient to satisfy these requirements.

For new centerline culvert installations, only hydraulic design data for the smooth-walled culvert types shall be shown in Section 50 of the plans. For any culvert which needs to be extended and also is categorized by Article 89-14 as requiring analysis and sizing, the hydraulic data for the proposed culvert extension shall be shown in Section 50 of the plans.

5. When approach culverts for private drives, field drives or township roads are sized, the corrugated alternative shall be hydraulically sized first, and if the corrugated alternative size is 24" diameter or less, then the smooth-walled alternative shall be specified in the same (either 18" or 24") diameter. When the corrugated pipe size has been determined to be 30" or larger, then the smooth-walled alternative size shall be determined by modeling, and a smooth-walled alternative size shall be selected which provides a headwater sufficiently equivalent to that of the corrugated alternative. A smooth-walled approach culvert alternative shall be considered sufficiently equivalent when the headwater is either lower than, or up to 2% higher than the headwater provided by the corrugated alternative. Further discussion relative to culvert modeling is provided below in Section V-04.06.

6. End sections shall be used on all culverts.

7. Multiple pipe installations shall have a minimum space of 1.5 feet between the flared end sections. Stationing for culverts needs to be established based upon the largest diameter culvert alternative, and the widest end section that could be used. Corrugated steel pipe culverts will generally be a larger diameter as compared to the smooth-walled alternatives, and the steel end sections are also wider at their outer ends. Therefore, culvert locations most often need to be based upon dimensional requirements of the corrugated steel pipe alternative.

8. Where practicable, when culvert extension is necessary, culverts should be extended so that the open portion of the end section is beyond the clear zone.

9. Where practicable, all culverts shall be sized such that the discharge velocity does not exceed 10 feet per second. Modeling and installation of broken-back culverts in order to reduce outlet velocity is acceptable, and encouraged. Refer to Section V-04.08 for a discussion of broken-back culverts. If sizing and culvert slope adjustments cannot practically limit discharge velocity to 10 feet per second or less, then some form of outlet erosion control should be provided. See Section V-04.07 for a discussion of energy dissipation. Most often, the installation of riprap is the preferred measure. In some areas where very poor soils are prevalent, such as in the badlands, the use of riprap for discharge velocities of 7 feet per second or higher may be warranted. Sizing of riprap aprons is addressed in Section V–04.07.

10. Headwater elevations shall comply with the requirements of Article 89-14 of North Dakota Administrative Code. For new centerline culvert installations, it is preferred that all crossings be sized to adequately convey the 100-year discharge without overtopping of the roadway. It is recognized that while this practice is desirable, it may not be practical at all locations to achieve such protection from overtopping. An

example of such a location may be where pipe crossings are within a floodway, where the road may overtop during extreme events.

11. It is required that 100-year flood data be provided in the hydraulic data in Section 50 of the plans for centerline culvert crossings.

12. Changes to the established drainage patterns, which result in water being discharged from the highway right of way at a different location than where it presently discharges should not be made without the direction of the respective Water Resource District.

13. Care shall be taken to maintain culvert invert elevations for existing centerline and approach culvert crossings, unless minor adjustments are necessary to match a culvert crossing to the upstream and downstream channel due to extension of the culvert length.

V–04.03 Determination of Drainage Areas

The following procedures shall be used in determining the drainage area:

1. Drainage areas shall be outlined on county maps, aerial photographs, U.S. Geological Survey Contour Maps, or specially prepared maps. Typically this task is accomplished using ArcGIS or some similar GIS software.

2. All drainage area boundaries shall be drawn from the highway centerline, surrounding the area being covered, and closing again at the centerline. Note any exceptions to this on the map. These notations shall show location, and if possible, elevation of break-over or diversion to or from the drainage area.

3. It should be shown on the map when two or more culverts operate together to drain an area.

4. Drainage areas for each centerline culvert requiring analysis, and for any approach culvert crossing requiring analysis shall be represented on a contour map. Along with the stationing of each crossing, the longest drainage path, and drainage area in acres, shall be listed. All pertinent data required to calculate the discharge for each culvert shall be summarized, either on the map, or in a separate table.

5. At locations where accurate delineation of the drainage areas from maps is difficult, the map information should be supplemented with a survey, or there should be a field review of the project to verify the drainage area.

V–04.04 Determination of Design Discharge

Peak discharge shall be determined in accordance with Section V-01.04 of the Design Manual. Most culverts are rural installations, so the USGS regression equations will most often be used.

V–04.05 Allowable Headwater

Allowable headwater shall comply with Article 89-14 of North Dakota Administrative Code. The culverts for field drives and private drives shall be sized using a 10-year discharge, the same as is prescribed for township roads.

When sizing the culverts for approach roadways (including township or county roads, and field or private drives), the headwater developed upstream from the approach roadway needs to be compared to the mainline roadway. At some locations, such as where the adjacent land is higher than the mainline roadway, the headwater developed upstream from an approach culvert may result in flooding of the mainline. At these locations, the approach culvert needs to be sized to provide similar protection from flooding of the mainline as would be required of a centerline culvert.

Potential damage to adjacent property or inconvenience to the owners should be of primary concern.

The allowable headwater should be compared to the elevation of the watershed's natural divides. It may be necessary to construct ditch blocks so a culvert may operate efficiently and to prevent flow from one drainage area to another.

V–04.06 Modeling and Selection of Culvert Size

Pipe culvert modeling shall be performed using the FHWA's HY-8 software in order to determine the proper culvert sizes required. Headwater depth, outlet velocity, tailwater depth and Froude number shall be determined using the HY-8 software.

At a minimum, the model for each crossing shall include the 2-year discharge, the design discharge, and the 100-year discharge.

Tailwater conditions, including Manning's n value, slope, channel bottom width, and side slopes of the downstream channel shall be estimated using contour maps, photographs, aerial photographs, and if necessary, site visits. These data shall be incorporated into the modeling of each crossing. Roadway ditches, and most natural and man-made channels are most often appropriately modeled as trapezoidal channels. Where a reservoir, weir, or some other feature controls the tailwater elevation, modeling should take this into account, and the use of either a rating curve, or constant tailwater elevation may be necessary to accurately model the crossing.

Inlet configuration shall be modeled as "Square Edge with Headwall" for all pipe culvert types with either standard end sections or traversable end sections.

Manning's n value for smooth-walled (RCP or spiral rib corrugated) shall be 0.012, and the n value for corrugated steel pipes shall be 0.024.

For reference, Appendix V-04A provides an example of a delineated drainage area, design discharge values, and an example HY-8 Report.

V–04.07 Energy Dissipation

The following is a guide for energy dissipation at the outlet ends of culverts:

1. Riprap shall be used when the discharge velocity of a culvert exceeds 10 feet per second. Generally where the Froude number is less than 2.5, a riprap apron will provide sufficient energy dissipation. Table 10.1 of HEC 14 lists classes of riprap with rock size, apron length, and apron depth. This table shall be used along with the method described in Section 10.2 of HEC 14, except that maximum riprap apron thickness shall be limited to 3 feet. Table 10.1 of HEC 14 specifies riprap classes, from Class 1 to Class 6. The apron length and depth shall be dimensioned in accordance with Table 10.1. In the project plans, NDDOT Grade 1 riprap shall be specified where class 1, 2, 3 or 4 riprap is indicated by the table, NDDOT Grade 2 riprap shall be specified for Class 5 riprap, and NDDOT Grade 3 riprap shall be specified when Table 10.1 indicates Class 6 riprap. NDDOT riprap gradations are provided in Section 256 of the Standard Specifications.

   Individual sizing of riprap aprons for each culvert that has a high discharge velocity (typically exceeding 10 feet per second in most areas) on a project is not always necessary. Riprap apron dimensions shall be sized for each culvert diameter for which riprap is necessary on a project. The worst-case (highest velocity, highest discharge, highest Froude number, or some reasonable combination) culvert of a particular size should be analyzed, and then the riprap apron dimensions which have been determined for that culvert shall be used for all other high-velocity (requiring riprap) culverts of the same diameter on the project. For example, if there are three 30-inch diameter culverts on a project having discharge velocities of 11, 14 and 15 feet per second, and Froude numbers of 1, 1.2 and 1.3 respectively, with discharges of 28, 33, and 40 cfs respectively, the culvert with 15 feet/sec. velocity, Froude number of 1.3, and discharge of 40 cfs would be used for sizing the riprap apron for all three of these culverts. In some cases, where velocity, Froude number and discharge do not increase correspondingly, engineering judgment may be necessary to determine which culvert to use for riprap sizing. When uncertain, size riprap for more than one location, and use the largest apron size in the plans for all similarly-sized culverts with high velocities on a project.

   Articulating concrete block mats can be used where it is necessary to provide energy dissipation within the clear zone of a roadway. When installed properly, these mats do not present an obstruction to errant vehicles.

2. Where reinforced concrete pipe culverts are used, and discharge velocity cannot be reduced sufficiently by a reasonable culvert size adjustment, or via the use of a broken-back installation, the use of baffle rings may be beneficial in some cases. These rings restrict the normal flow causing a hydraulic jump within the culvert, resulting in a reduced outlet velocity. The design and spacing of the rings are such that the culvert will flow full at design discharge. Baffle rings should only be considered when the discharge

Froude Number is greater than 2.5, and where culvert slope is approximately 3% or higher. The viability of baffle ring energy dissipation can be determined using FHWA's HY-8 software. Baffle rings are not available for culvert types other than RCP.

3. Energy dissipaters such as blocks, sills, or other roughness elements used to impose exaggerated resistance to flow, may be required when the outlet conditions can't be controlled with the above measures.

V-04.08 Broken-Back Culverts

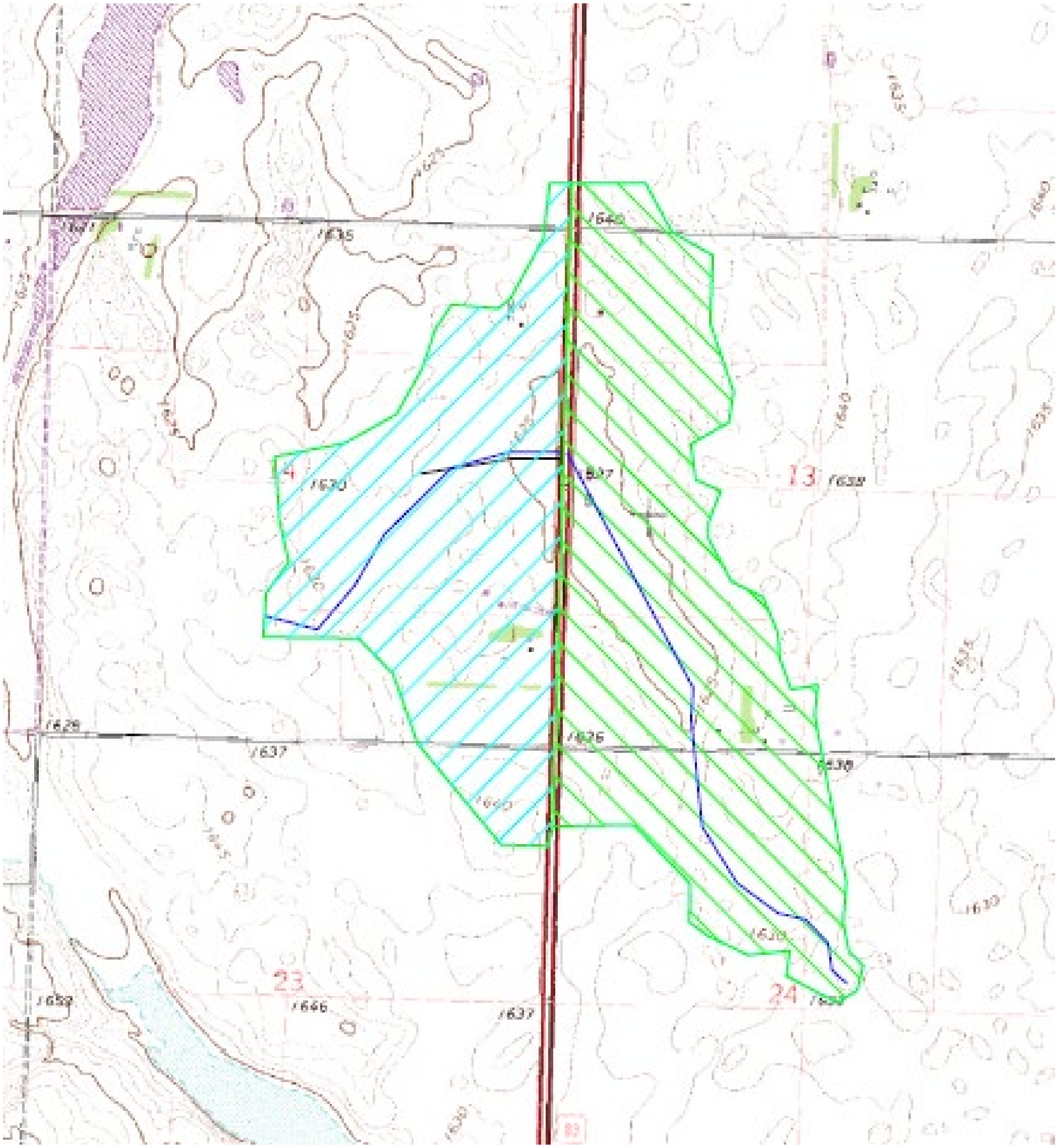
Broken-back culvert installations may be modeled using either FHWA's HY-8 software or Nebraska DOT's BCAP broken-back culvert program.

For all sizes of RCP culverts, deflection angles shall be achieved by distributing the total required deflection angle between multiple culvert sections, using a maximum of 1 degree of deflection per joint. The plans shall specify how many joints are deflected, and the deflection angle for each joint. Mortar and filter fabric shall be installed on all open joints, and this also shall be specified in the plans.

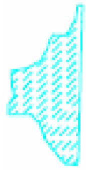
For culvert types other than RCP, prefabricated bend sections will need to be furnished to accomplish the required deflection. The plans need to specify the bend angle required.

V-04.09 Sizing of Equalizer Culverts

The method provided in the example below in this section, which takes into consideration the drainage area and flows from each side of the highway, shall be used for sizing equalizer culverts. The size of the culvert is determined by distributing the total discharge proportionately to the storage areas on each side of the road. It is generally assumed with this method, that storage volume is proportional to storage area. As a brief example of this method, consider the closed basin depicted on the following page.



USGS Regression Equation Calculations are performed to determine the contributing peak flow from each of the two sub-basins. Hydrologic Data for each of the sub-basins for this example are provided below.



Drainage Area = 258.6517 acres
Drainage Path = 3847'
Drainage Path 10% = 384.7' - Elev = 1624'
Drainage Path 85% = 3270' - Elev = 1630'
Basin Slope = (1630' - 1624') / (3270' - 384.7')
= .002 ft/ft

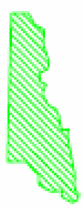
USGS REGRESSION RESULTS

Contributing Drainage Area	Channel Slope	Hydrologic Region
259 Acres	.002 Ft/Ft	Region C

RESULTS

Recurrence Interval (years)	Peak Flow Q
2	5 CFS
10	23 CFS
15	30 CFS
25	39 CFS
50	53 CFS
100	69 CFS
500	111 CFS

Location
West Side of Basin



Drainage Area = 334.7083 acres
Drainage Path = 6477'
Drainage Path 10% = 648' - Elev = 1621.5'
Drainage Path 85% = 5506' - Elev = 1630'
Basin Slope = (1630' - 1621.5') / (5506' - 648')
= .0017 ft/ft

USGS REGRESSION RESULTS

Contributing Drainage Area	Channel Slope	Hydrologic Region
334.71 Acres	.0017 Ft/Ft	Region C

RESULTS

Recurrence Interval (years)	Peak Flow Q
2	6 CFS
10	26 CFS
15	34 CFS
25	44 CFS
50	61 CFS
100	79 CFS
500	128 CFS

Location
East Side of Basin

Using the 25-year peak discharges, the total peak flow to the basin is summed as: 39 CFS (on the west side of the highway) + 44 CFS (contributed from the east side of the highway) = 83 CFS.

The storage area, determined from a contour map using Arcmap software, is determined, and then divided at the highway. For this example, the total storage area was found to be 63.27 acres, with the storage on the west side of the highway determined to be 11.57 acres, and the east storage area
was determined to be 51.7 acres. With less storage on the west side of the highway, and nearly equivalent discharges on each side, it is apparent that equalization flow will be from west to east.

The flow is distributed proportionately to the two storage areas as follows:

Q_W = 83 CFS * (11.57 Ac/63.27 Ac) = 15.18 CFS

And,

Q_E = 83 CFS * (51.7 Ac/63.27 Ac) = 67.82 CFS

Since 67.82 CFS of the total flow is distributed to the east storage area, resultant flow, as was previously assumed, is from west to east to equalize the slough. The resultant equalization flow is then determined by subtracting the discharge distributed to the west storage area above from the discharge originating from the west sub-basin, as follows:

Q_{25} = 39 CFS – 15.18 CFS = 23.82 CFS

The crossing is then modeled in HY-8, generally using a fixed tail water elevation to determine culvert size.

At locations where flows may become more 'directional' due to the overflow of a closed basin, it may be necessary to increase the size of equalizer culverts to accommodate the unidirectional flow. In these cases, the culvert is essentially acting as a typical stream crossing, and typical culvert sizing methods shall be used.

V–04.10 Grade Raise Analyses for Closed Basins

Grade raises through closed basins are generally constructed for roadways with imminent risk of inundation, or roadways that are currently inundated by the adjacent water body or basin.

Typically, 3 build alternates are proposed for a given grade raise project:

1. Grade Raise above the natural outlet elevation
2. Grade Raise above the 3-year forecast water surface elevation
3. 5' Grade Raise above the existing water surface elevation

The natural outlet elevation for the basin shall be determined by survey. The grade raise analysis shall include an estimate of the 3-year forecast water surface elevation, and should estimate the time forecast when the storage of the basin will reach the natural outlet and/or exceed the 5' Grade Raise elevation. Riprap shall typically be placed 2' above the 3-year forecast water surface elevation. In some cases, where higher waves are anticipated, such as locations with long fetches, riprap may be necessary to a higher elevation.

The NDDOT monitors closed basins which may threaten adjacent state or interstate highways by obtaining water surface elevations via ground survey at approximately one-year intervals. The 3-year forecast water surface elevation shall be determined as follows:

1. Based upon two (past and present) elevations, the basin storage volume which has been occupied by the rising water during a known time will be determined using contours or other geographical data.
2. Assuming that present meteorological/hydrologic conditions will prevail for 3 years into the future, the storage volume which will be occupied by future precipitation will be estimated by extrapolation/interpolation to arrive at a 3-year forecast storage volume.
3. The 3-year forecast rise in water surface elevation shall be determined using the 3-year forecast storage volume and contours or other geographic data.

V–04.11 Hydrologic and Hydraulic Data to be Submitted with Deliverables

For consultant-prepared plans, the following hydrologic and hydraulic data for the Milestone Activity “Roadway Hydraulics” (RDHYD) shall be retained and submitted electronically concurrently with the PS&E plans for a project:

1. Drainage area maps with contours showing each centerline and approach culvert. At a minimum, longest drainage path, drainage area, and stationing for each culvert shall be shown on the map. See Appendix V-04A for an example showing a single culvert crossing. Multiple crossings may be shown on each map, provided that information is clear and legible. Separate sets of maps may be appropriate to show centerline and approach culverts.

2. A summary of the hydrologic data for each drainage area, including, at a minimum, USGS region, slope of the upstream channel, 2-year, design discharge, and 100-year discharge values. In the example in Appendix V-04A, this data is shown on the drainage area map. This data is often tabulated by various engineers in spreadsheets, and the output from the spreadsheet or other software will be sufficient. Provision of this data on the drainage map is not necessary.

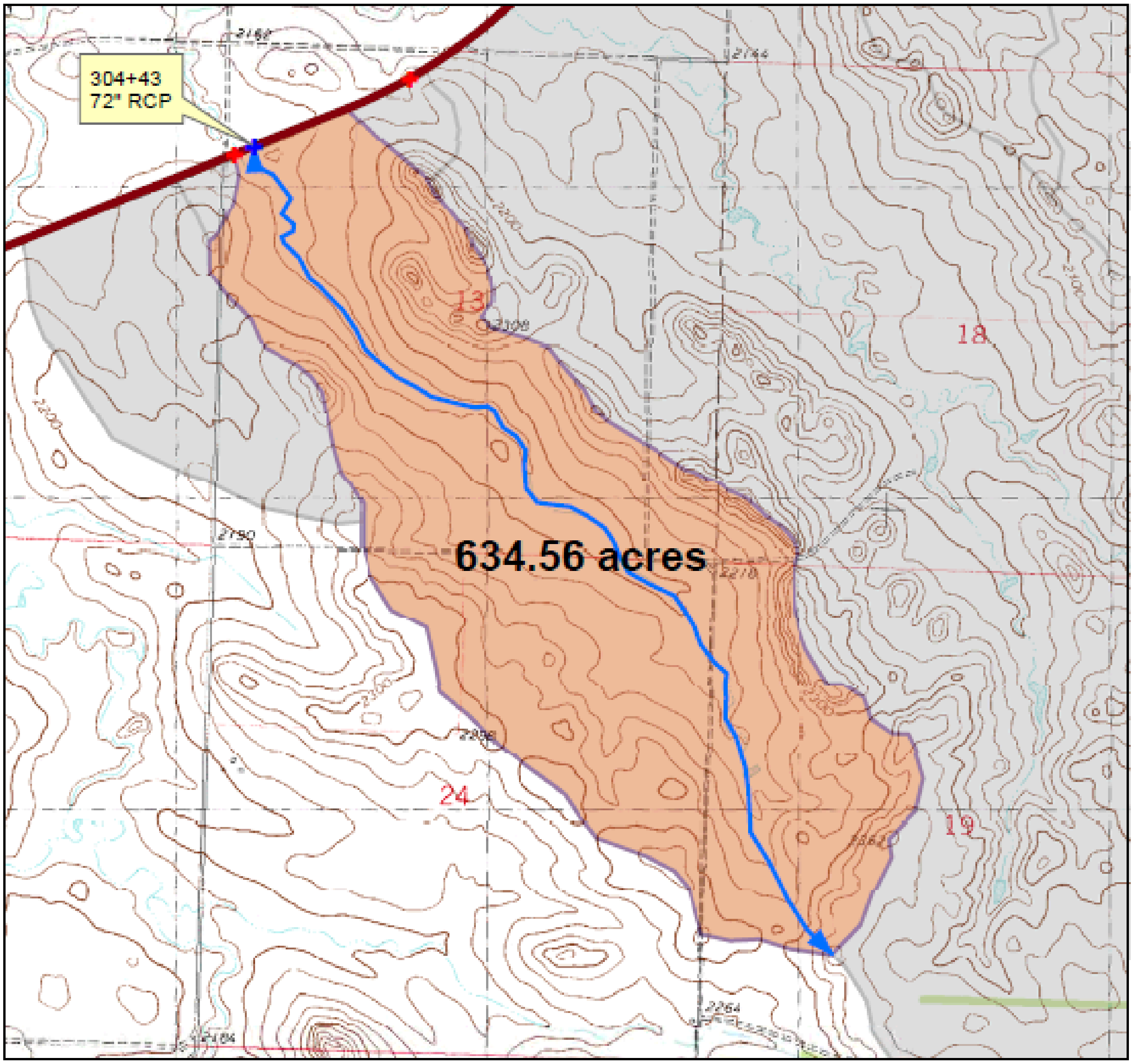
3. An HY-8 Culvert Analysis Report for each crossing. Appendix V-04A provides an example HY-8 report for reference. A report for each crossing shall be prepared for each alternative culvert type and size. The report for each crossing shall include the following information:

   A. Summary of Culvert Flows
   B. Culvert Summary Table
   C. Water Surface Profile
   D. Downstream Channel Rating Curve Data
   E. Tailwater Channel Data
   F. Roadway Data

4. ArcGIS or other GIS computer files, HY-8 computer files, and any other spreadsheet or computer files used to calculate peak discharge, riprap sizing, or any other hydrologic or hydraulic-related computer files shall be submitted. HY-8 files shall include the analysis of each crossing for both the existing and proposed conditions. The report generated by HY-8 (as discussed in item 3 above) only needs to include the information for the proposed culvert.

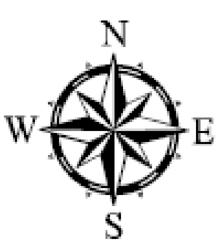
V–04.12 Standard Drawings Pertaining to Highway Culverts

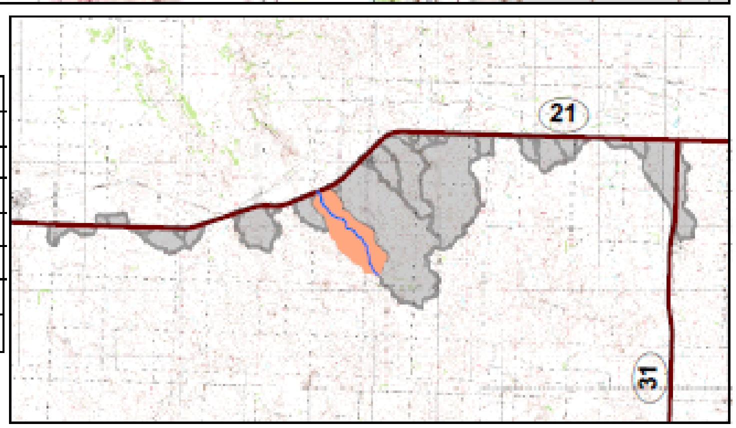
Standard	Description
D–714–1	Reinforced Concrete Pipe Culverts and End Sections.
D–714–2	Reinforced Concrete Pipe Arch Culverts and End Sections
D–714–4	Corrugated Steel Pipe Culverts and End Sections
D–714–5	Corrugated Steel Pipe Arch Culverts and End Sections
D-714–11	Traversable End Sections for Corrugated Steel Pipe Culverts
D-714–13	Reinforced Concrete Pipe Baffle Rings
D–714–16	Jacked and Bored Pipe



304+43

Region	B
Slope	51.15 ft/mi
Q2	24.76 cfs
Q10	103.35 cfs
Q25	162.23 cfs
Q50	212.89 cfs
Q100	267.41 cfs
Q500	418.5 cfs





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HY-8 Culvert Analysis Report

Table 1 - Summary of Culvert Flows at Crossing: 304+43

Headwater Elevation (ft)	Total Discharge (cfs)	72"x86' RCP Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2142.15	24.80	24.80	0.00	1
2143.01	49.06	49.06	0.00	1
2143.70	73.32	73.32	0.00	1
2144.30	97.58	97.58	0.00	1
2144.86	121.84	121.84	0.00	1
2145.38	146.10	146.10	0.00	1
2145.72	162.20	162.20	0.00	1
2146.38	194.62	194.62	0.00	1
2146.87	218.88	218.88	0.00	1
2147.36	243.14	243.14	0.00	1
2147.87	267.40	267.40	0.00	1
2151.99	397.11	397.11	0.00	Overtopping

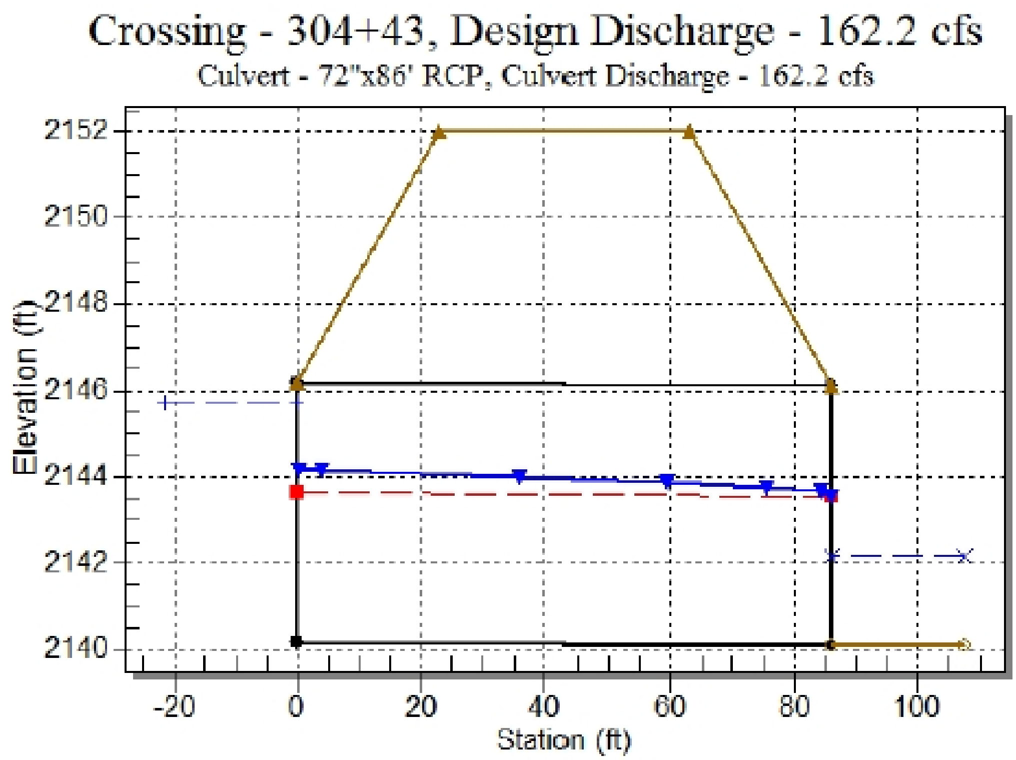
Table 2 - Culvert Summary Table: 72"x86' RCP

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
24.80	24.80	2142.15	1.785	1.965	2-M2c	1.639	1.292	1.292	0.715	5.506	3.036
49.06	49.06	2143.01	2.561	2.820	2-M2c	2.370	1.852	1.852	1.061	6.603	3.814
73.32	73.32	2143.70	3.208	3.507	2-M2c	2.974	2.277	2.277	1.334	7.436	4.340
97.58	97.58	2144.30	3.837	4.112	2-M2c	3.545	2.642	2.642	1.566	8.130	4.744
121.84	121.84	2144.86	4.397	4.667	2-M2c	4.135	2.982	2.982	1.772	8.685	5.075
146.10	146.10	2145.38	4.914	5.190	2-M2c	4.833	3.268	3.268	1.958	9.284	5.361
162.20	162.20	2145.72	5.246	5.528	2-M2c	6.000	3.457	3.457	2.074	9.621	5.529
194.62	194.62	2146.38	5.915	6.189	2-M2c	6.000	3.799	3.799	2.289	10.325	5.832
218.88	218.88	2146.87	6.436	6.678	2-M2c	6.000	4.039	4.039	2.439	10.825	6.032
243.14	243.14	2147.36	6.991	7.169	2-M2c	6.000	4.264	4.264	2.579	11.323	6.219
267.40	267.40	2147.87	7.591	7.676	2-M2c	6.000	4.461	4.461	2.714	11.889	6.388

Inlet Elevation (invert): 2140.19 ft, Outlet Elevation (invert): 2140.10 ft

Culvert Length: 86.00 ft, Culvert Slope: 0.0010

Water Surface Profile Plot for Culvert: 72"x86' RCP



Site Data - 72"x86' RCP

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2140.19 ft

Outlet Station: 86.00 ft

Outlet Elevation: 2140.10 ft

Number of Barrels: 1

Culvert Data Summary - 72"x86' RCP

Barrel Shape: Circular

Barrel Diameter: 6.00 ft

Barrel Material: Concrete

Embedment: 0.00 in

Barrel Manning's n: 0.0120

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: 304+43)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
24.80	2140.81	0.71	3.04	0.43	0.67
49.06	2141.16	1.06	3.81	0.64	0.71
73.32	2141.43	1.33	4.34	0.81	0.73
97.58	2141.67	1.57	4.74	0.95	0.74
121.84	2141.87	1.77	5.08	1.07	0.75
146.10	2142.06	1.96	5.36	1.18	0.76
162.20	2142.17	2.07	5.53	1.25	0.77
194.62	2142.39	2.29	5.83	1.38	0.78
218.88	2142.54	2.44	6.03	1.47	0.78
243.14	2142.68	2.58	6.22	1.56	0.79
267.40	2142.81	2.71	6.39	1.64	0.79

Tailwater Channel Data - 304+43

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 10.00 ft

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0097

Channel Manning's n: 0.0350

Channel Invert Elevation: 2140.10 ft

Roadway Data for Crossing: 304+43

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 500.00 ft

Crest Elevation: 2151.99 ft

Roadway Surface: Paved

Roadway Top Width: 40.00 ft

Table 4 - Summary of Culvert Flows at Crossing: 304+43 (Corrugated Alternate)

Headwater Elevation (ft)	Total Discharge (cfs)	78"x86" CSP Discharge (cfs)	Roadway Discharge (cfs)	Iterations
2142.24	24.80	24.80	0.00	1
2143.08	49.06	49.06	0.00	1
2143.75	73.32	73.32	0.00	1
2144.34	97.58	97.58	0.00	1
2144.87	121.84	121.84	0.00	1
2145.38	146.10	146.10	0.00	1
2145.70	162.20	162.20	0.00	1
2146.34	194.62	194.62	0.00	1
2146.81	218.88	218.88	0.00	1
2147.29	243.14	243.14	0.00	1
2147.76	267.40	267.40	0.00	1
2151.99	427.64	427.64	0.00	Overtopping

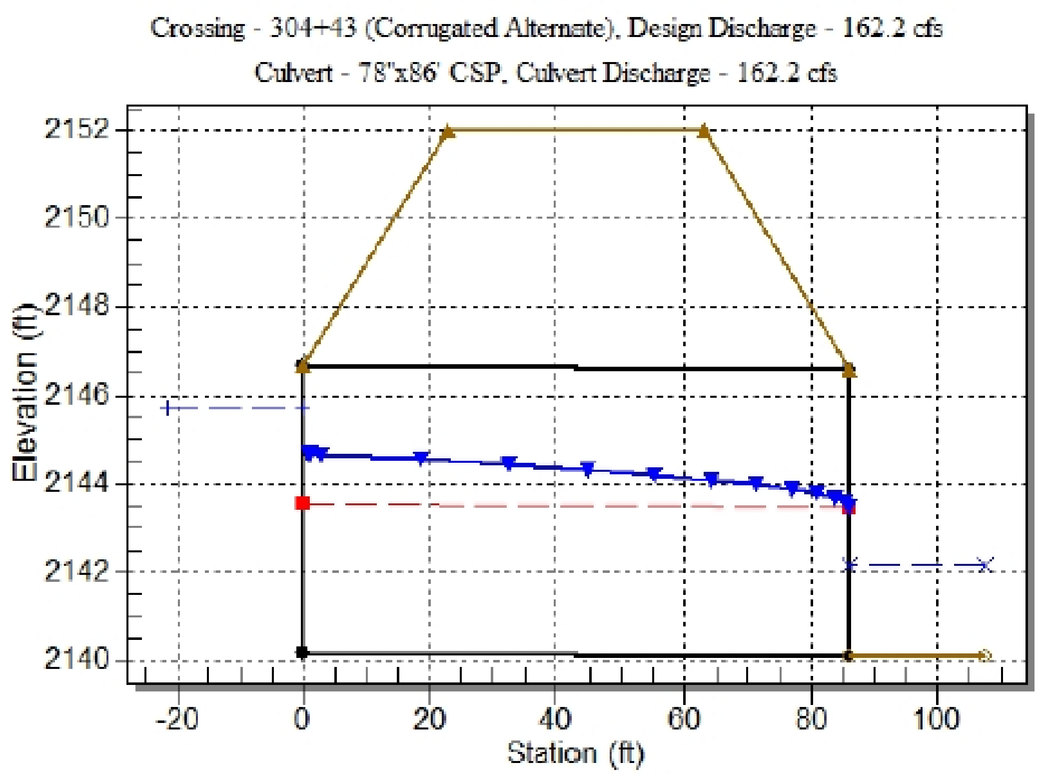
Table 5 - Culvert Summary Table: 78"x86' CSP

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
24.80	24.80	2142.24	1.751	2.049	2-M2c	2.289	1.274	1.274	0.715	5.385	3.035
49.06	49.06	2143.08	2.498	2.885	2-M2c	3.375	1.797	1.797	1.061	6.531	3.814
73.32	73.32	2143.75	3.097	3.558	2-M2c	4.390	2.214	2.214	1.334	7.326	4.340
97.58	97.58	2144.34	3.634	4.146	2-M2c	5.808	2.592	2.592	1.566	7.906	4.744
121.84	121.84	2144.87	4.136	4.678	2-M2c	6.500	2.895	2.895	1.772	8.521	5.075
146.10	146.10	2145.38	4.610	5.189	2-M2c	6.500	3.196	3.196	1.958	8.994	5.361
162.20	162.20	2145.70	4.915	5.513	2-M2c	6.500	3.372	3.372	2.074	9.333	5.529
194.62	194.62	2146.34	5.518	6.151	2-M2c	6.500	3.708	3.708	2.289	9.955	5.832
218.88	218.88	2146.81	5.970	6.619	2-M2c	6.500	3.950	3.950	2.439	10.373	6.032
243.14	243.14	2147.29	6.431	7.096	2-M2c	6.500	4.163	4.163	2.579	10.847	6.219
267.40	267.40	2147.76	6.908	7.573	2-M2c	6.500	4.376	4.376	2.714	11.268	6.388

Inlet Elevation (invert): 2140.19 ft, Outlet Elevation (invert): 2140.10 ft

Culvert Length: 86.00 ft, Culvert Slope: 0.0010

Water Surface Profile Plot for Culvert: 78"x86' CSP



Site Data - 78"x86' CSP

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 2140.19 ft

Outlet Station: 86.00 ft

Outlet Elevation: 2140.10 ft

Number of Barrels: 1

Culvert Data Summary - 78"x86' CSP

Barrel Shape: Circular

Barrel Diameter: 6.50 ft

Barrel Material: Corrugated Steel

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Inlet Type: Conventional

Inlet Edge Condition: Square Edge with Headwall

Inlet Depression: None

Table 6 - Downstream Channel Rating Curve (Crossing: 304+43 (Corrugated Alternate))

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
24.80	2140.81	0.71	3.04	0.43	0.67
49.06	2141.16	1.06	3.81	0.64	0.71
73.32	2141.43	1.33	4.34	0.81	0.73
97.58	2141.67	1.57	4.74	0.95	0.74
121.84	2141.87	1.77	5.08	1.07	0.75
146.10	2142.06	1.96	5.36	1.18	0.76
162.20	2142.17	2.07	5.53	1.25	0.77
194.62	2142.39	2.29	5.83	1.38	0.78
218.88	2142.54	2.44	6.03	1.47	0.78
243.14	2142.68	2.58	6.22	1.56	0.79
267.40	2142.81	2.71	6.39	1.64	0.79

Tailwater Channel Data - 304+43 (Corrugated Alternate)

Tailwater Channel Option: Trapezoidal Channel

Bottom Width: 10.00 ft

Side Slope (H:V): 2.00 (_:1)

Channel Slope: 0.0097

Channel Manning's n: 0.0350

Channel Invert Elevation: 2140.10 ft

Roadway Data for Crossing: 304+43 (Corrugated Alternate)

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 500.00 ft

Crest Elevation: 2151.99 ft

Roadway Surface: Paved

Roadway Top Width: 40.00 ft

HYDRAULIC DATA FOR PROJECT ### (A)									
				25-YEAR DATA				100-YEAR DATA	
STATION	EXISTING PIPE	PROPOSED PIPE SIZE	DRAINAGE AREA (ACRES)	DESIGN DISCHARGE (CFS)	DESIGN HEADWATER (FT)	DESIGN VELOCITY (FPS)	DESIGN STAGE (NAVD 88)	100-YEAR DISCHARGE (CFS)	100-YEAR STAGE (NAVD 88)
304+43	72" RCP	72"	634.6	162.2	5.53	9.62	2145.72	267.4	2147.87

(A) Hydraulic data provided is for smooth-walled (Manning's n=0.012) type conduits.

V-05.01 Introduction

The North Dakota Department of Transportation (NDDOT) will follow its standard practices for the hydraulic and structural design of pipes. The NDDOT will adopt additional performance criteria that will be used to evaluate the acceptability of alternate pipe materials based on application, local, and regional factors.

V-05.02 Selection Considerations

The NDDOT will evaluate the risk associated with the performance of the pipe materials and the long-term performance of the completed end product. Risk will be considered to the extent that it is influenced by the pipe, other materials, or installation techniques as they are used in the construction practice. It is the owner's prerogative and responsibility to establish reasonable performance standards. Project design and material selection is inherently based on balancing the engineering requirements with the budgetary constraints of the project.

Risk is mitigated for NDDOT by following the AASHTO and ASTM national standards for pipe material. When reviewing the installation procedures of pipes the following criteria are considered:

- AASHTO standards;
- NDDOT research and experience;
- Other DOTs research and experience; and
- Manufacturers' recommendations.

During the design process it may become necessary to eliminate certain types of pipes due to physical characteristics of the pipe material, and project specific design constraints (e.g. matching existing inverts). A larger pipe diameter may be required if the Manning's "n" value is higher than 0.012.

Storm drains are limited to smooth interior pipe with a maximum Manning's "n" value of 0.012. This allows for the use of the following pipe materials:

- Reinforced Concrete;
- Plastic; and
- Spiral-Rib Metal.

Project location is considered for evaluation of alternate pipe materials as they relate to the following:

- Engineering;
- Cost; or
- Performance criteria.

Local agencies can provide the NDDOT with soil samples from the project for consideration to variances in the Corrosion Zone.

Pipe material selection for **projects on the state highway system** will follow the guidance of this document. If local agencies want a specific pipe material, that is not covered in this document, installed on a state highway system, the local agency may request bidding it as an option along with the alternative pipe materials. The request should be made in writing, and addressed to the Director of the Office of Project Development.

For all **projects off of the state highway system** and not receiving federal funds, the local governing authority has the ability to specify culvert and storm sewer material types they want to include on their construction project.

The following sections describe the selection procedure that supports the general policy statement. They refer to the processes and procedures that identify the specific engineering, cost analysis, and performance criteria used to evaluate the acceptability of alternate pipe materials. It is NDDOT's practice to allow alternate pipe materials where they can be used.

Any limitations to materials will be documented and will be kept in order to ensure valid engineering reasoning for any material limitations.

V-05.03 Bid Items

New Pipe Installations
Bid items for new pipe installations are broken into 3 main categories which are:

1. **Pipe Conduit __ IN:** Typical transverse centerline culvert

2. **Pipe Conduit __ IN – Storm Drain:** Urban/storm sewer drainage

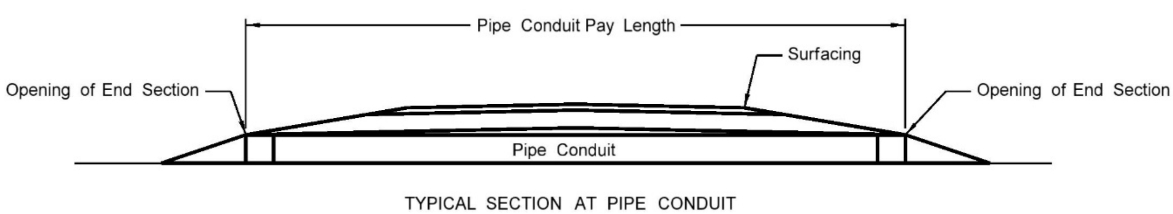
3. **Pipe Conduit __ IN – Approach:** All approach pipe designations.

The plans, specifications and bid documents for the project identify all alternate pipe materials deemed to be acceptable for each installation application, based on the results of the evaluation.

End sections for new pipe installation are included in the contract unit price for "Pipe Conduit__".

The pay length for pipe conduit is measured along the top of the conduit between the openings of the end sections, as shown in Figure V-05.03.01. When using cross sections to determine pipe length, include the topsoil to ensure the proper total length of pipe is found. Calculate length to the nearest foot. Include the barrel lengths for Reinforced Concrete Pipe.

Figure V-05.03.01 – Pipe Conduit Pay Length



Pipe Extensions
Pipe extensions and their bid item will match the existing pipe material. End sections will be bid separately for pipe extensions. Reuse the existing end section if they are in satisfactory condition. If the end sections need to be replaced, they should be paid for by the each installed of the type and size required.

For example, a 30" concrete pipe extension needing a new end section would be paid for as "PIPE CONC REINF 30IN CL III" (LF) and "END SECT-CONC REINF 30 IN" (EA). If the end section is in a condition to be reused, the end section should be paid for as "REMOVE & RELAY END SECTION-ALL TYPE & SIZES" (EA).

V-05.04 Design Service Life

The DSL of highway drainage structures is the period of little to no rehabilitative maintenance and is not assumed to be at or near collapse at the end of their service life. Drainage structures are designed to provide a minimum DSL. The minimum DSL for Mainline Drainage and Storm Drain Trunk Lines & Lateral pipes is 75 years, while Approach Drainage pipes have a minimum DSL of 40 years.

The DSL for reinforced concrete pipe is from installation to the exposure of the reinforcing steel or the appearance of significant cracking due to distress. The DSL for metal pipe for Mainline Drainage, Storm Drain Trunk lines, and Lateral Drainage application is from installation until the point where perforation to the metal occurs on any portion of the pipe. The DSL for metal pipes used for Approaches is from installation until the point where perforation of the metal occurs on the invert. The DSL for plastic pipe is from installation until the point where excessive cracking, perforation, or deflection occurs.

V-05.05 Pipe Material

Table 1, "Pipe Materials" lists the pipe material's corresponding references to the NDDOT *Standard Specifications for Road and Bridge Construction.* These pipe materials are considered appropriate for Mainline Drainage, Approach Drainage, and Storm Drains; with certain exceptions for Plastic Pipes under paved roadways. For the purpose of this manual, a paved roadway is defined as any public roadway with an HBP or concrete surface, including raised median islands. Areas not considered paved roadways would include such items as parking lots, private drives, or pedestrian/bike paths.

Plastic Pipes are only allowed under paved roadways if all the following conditions are met:

- Pipe material is Polypropylene Pipe (Type S);
- Pipe diameter is 36 inches or less;
- Paved roadway is on either a Level 2 or 3 State Strategic Freight System route. -See link "Freight Map" at http://www.dot.nd.gov/divisions/planning/freight/
- Paved roadway is classified as a State Corridor, District Corridor, or District Collector; and
- Paved roadway has a current ADT less than 2,000.

Concrete is the only type of pipe material allowed to be installed under divided highways with depressed medians. These pipes will likely be connected in the median with shallow cover and possibly require a slotted drain. The shallow cover in these areas makes pipes susceptible to crushing and replacement activities would have detrimental impacts to the traveling public.

- One exception to the above requirement is that smooth-walled steel pipe for Jacked/Bored pipe shall be allowed under divided highways with depressed medians. However, the non-Jacked/Bored portions of the crossing (as shown on Standard Drawing D-714-16) must still be concrete pipe only.

Table 1 – Pipe Materials	
Material	**NDDOT Specifications**
Concrete Pipe	714.03 & 830.01
Metal Pipe	714.03 & 830.02
Plastic Pipe	714.03 & 830.03

The NDDOT may consider new pipe materials or products for inclusion in future projects based on:

- Conformance with national standard specifications (AASHTO or ASTM);
- Product performance history; and
- NDDOT or other DOT research findings.

If a product or material is found to be acceptable, it may be considered for evaluation on specific projects or on an experimental basis, before it is included into the NDDOT Standard Specifications.

Consider the following factors when selecting pipe materials:

- Hydraulic Capacity,
- Structural Capacity,
- Service Life,
- Soil/Water Corrosivity,
- Fill Height,
- Bed Load Abrasion,
- Resistance to Fire, and
- Water Tight Joints.

The list of factors to be considered above are not intended to be all inclusive, therefore a proper engineering analysis is required for all installations. For large installations, the analysis should include installation cost comparisons.

The fill height tables for various pipes are located in Section V-05A of the NDDOT Design Manual. These tables will be used to determine the applicability of the various alternate pipe materials, shape, gauge, and wall thickness. If tables for an allowable pipe material do not exist, the manufacturer's recommendations will be followed.

V-05.06 Pipe Material Selection Process

The Designer will follow the selection steps shown in the flow chart for the specific pipe application. Flow charts titled Mainline Drainage, Approach Drainage, and Storm Drain Trunk Line and Laterals; guide the Designer through the process of evaluating the critical criteria to determine the alternate pipe materials allowable for the project application.

The Designer will use the following resources in the Procedure based for the specific design application:

- Application Requirements (Allowable Pipe Materials)
  - Section V-05.05 Pipe Materials (in this document)
  - NDDOT Standard Specifications for Road and Bridge Construction
    - Section 714, "Culverts, Storm Drains, Edgedrains, and Underdrains" and Section 830, "Pipe and Drainage Structures"
    - NDDOT Supplemental Specifications

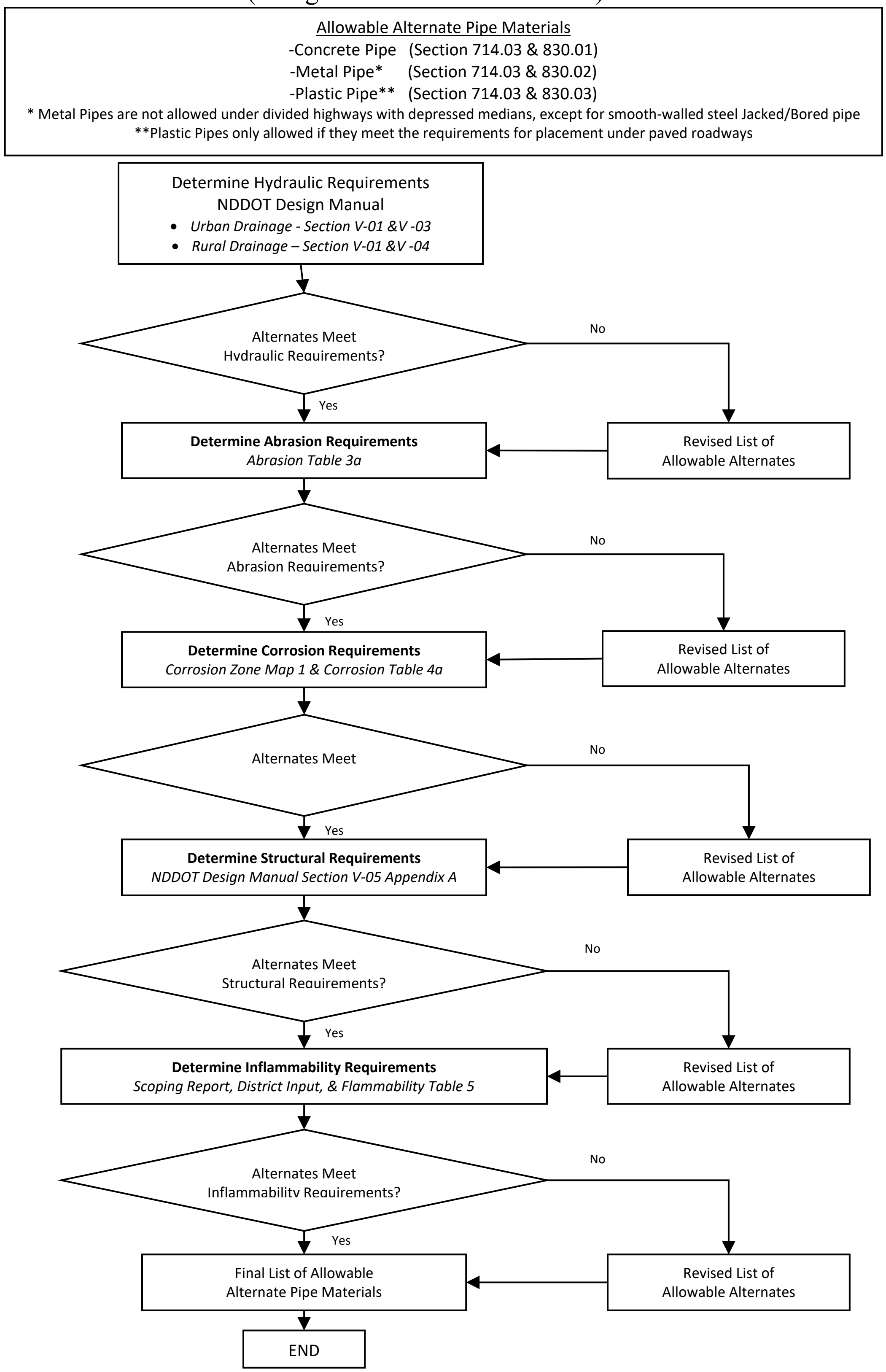
- Hydraulic & Hydrostatic Design Requirements
  - NDDOT Design Manual
    - Rural Drainage – Section V-01 & V-04
    - Urban Drainage – Section V-01 & V-03

- Abrasion Requirements
  - Abrasion Tables 3a and 3b (in this document)

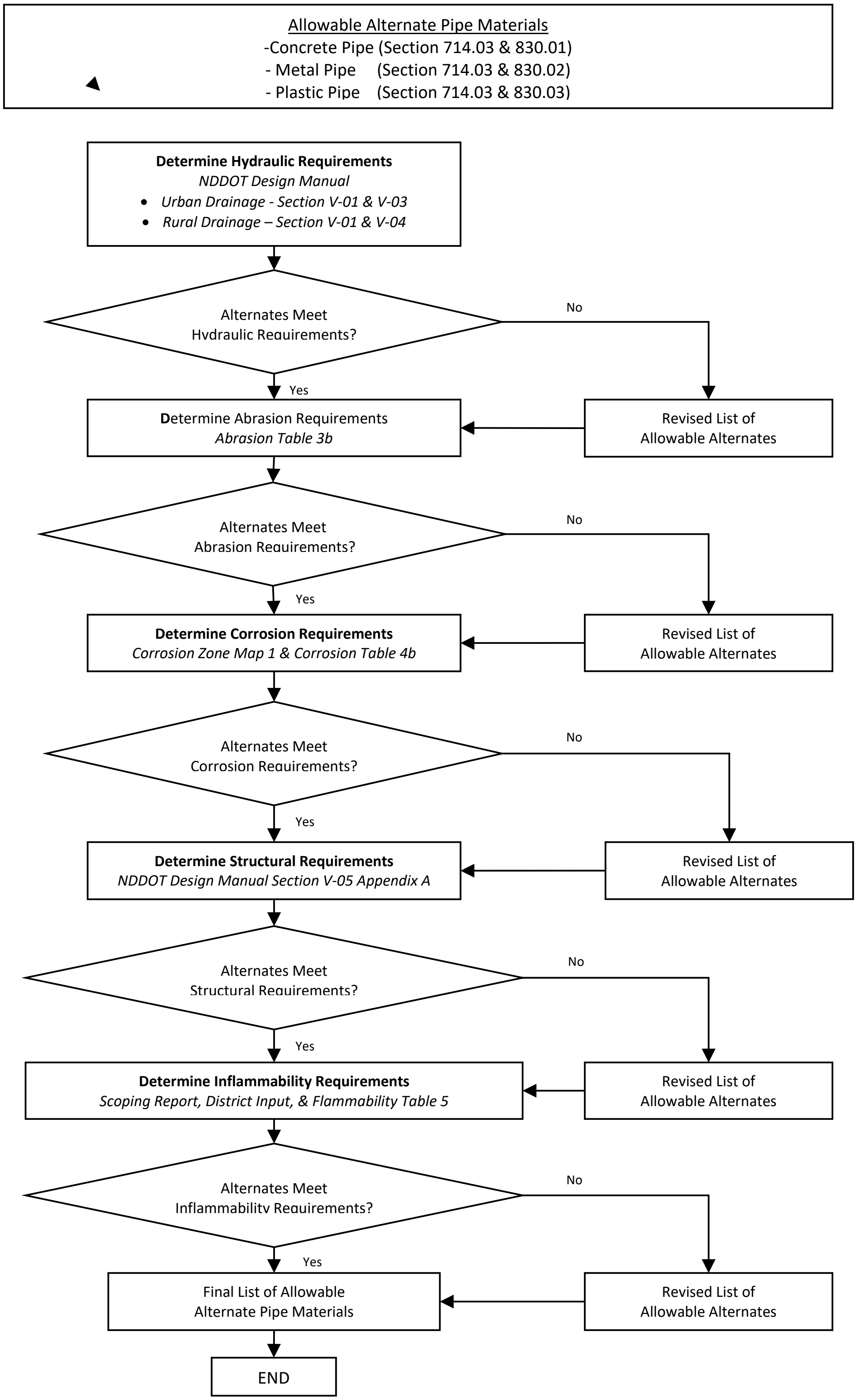
- Corrosion Requirements
  - Corrosion Zone Map 1 (in this document)
  - Corrosion Table 4a – Mainline Drainage (in this document)
  - Corrosion Table 4b – Approach Drainage (in this document)
  - Corrosion Table 4c – Storm Drain Trunk Line & Lateral Drainage (in this document)
- Structural Requirements
  - Concrete Pipe : NDDOT Design Manual Section V-05 Appendix A
  - Metal Pipe: NDDOT Design Manual Section V-05 Appendix A
  - Plastic Pipe
    - High-Density Polyethylene (HDPE): Manufacturer's Recommendation
    - Polypropylene (PP): NDDOT Design Manual Section V-05 Appendix A

- Inflammability Requirements
  - NDDOT Project Scoping Report
  - NDDOT District Engineer Input
  - Flammability Table 5 (in this document)

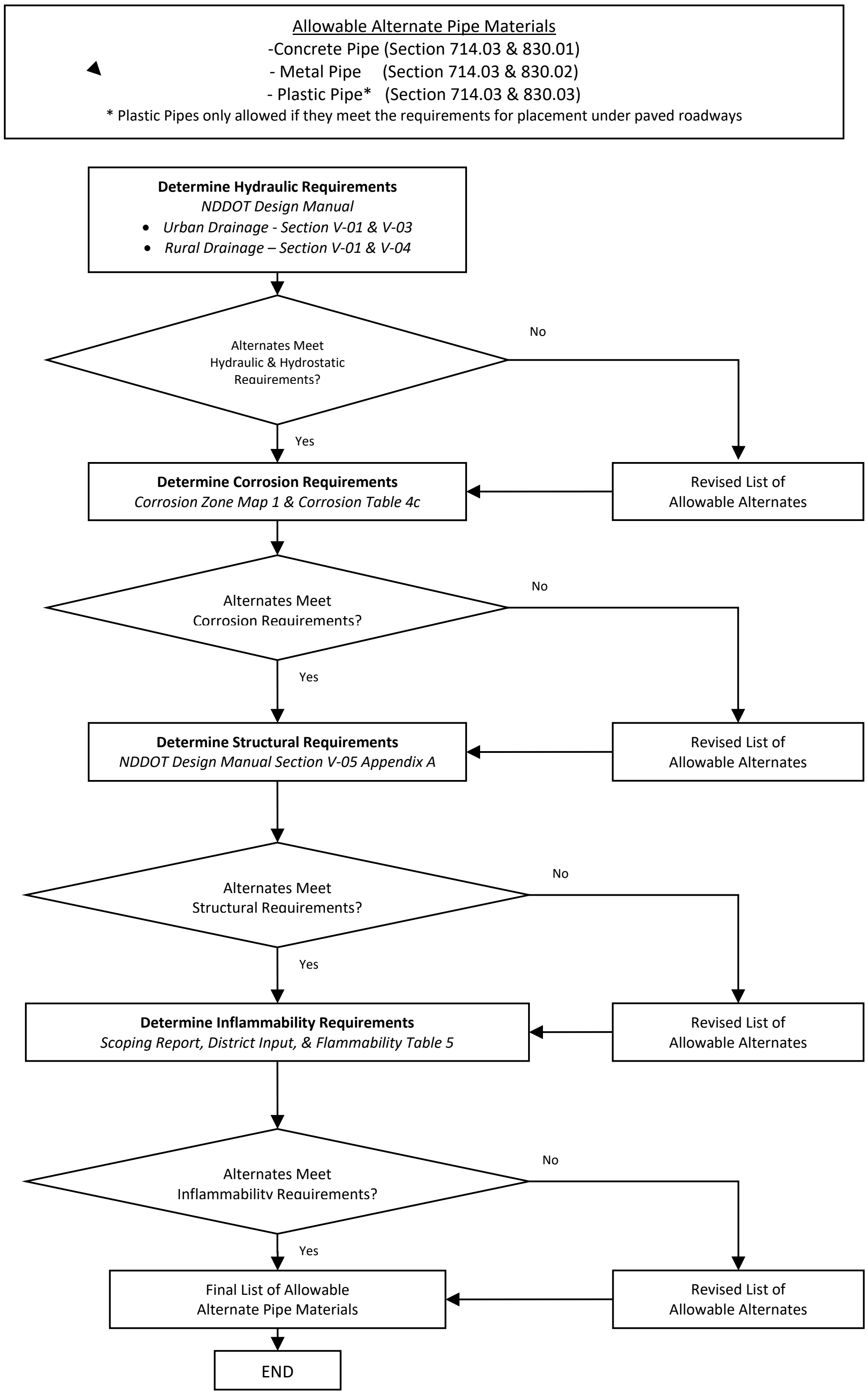
Mainline Drainage Flowchart
(Design Service Life – 75 Years)



Approach Drainage Flowchart
(Design Service Life – 40 Years)



Storm Drain Trunk Line & Lateral Drainage Flowchart
(Design Service Life – 75Years)



Abrasion Table: 3a

Mainline Drainage
(Design Service Life – 75 Years)

Pipe Material	Abrasion Level				
	Level 1	Level 2	Level 3	Level 4	Level 5
Concrete Pipe (Section 830.01)	Y	Y	Y	Y	Y
Metal Pipe (Section 830.02)					
Zinc Coated Corrugated Steel	Y	Y			
Aluminum Coated Corrugated Steel (Type 2)	Y	Y	Y		
Polymeric Coated Steel (over Zinc or Aluminum Coated Steel)	Y	Y	Y	Y	
Plastic Pipe (Section 830.03)					
Polypropylene Pipe (Type S)	Y	Y	Y	Y	Y

Level 1 – No bedload – regardless of velocity.
Level 2 – Bedload of sand, gravel, and debris with velocities of 0 to 5 ft/s.
Level 3 – Bedload of sand, gravel, and debris with velocities of 5 to 10 ft/s.
Level 4 – Bedload of sand, gravel, and debris with velocities of 10 to 15 ft/s.
Level 5 – Bedload of sand, gravel, and debris with velocities greater than 15 ft/s.

Abrasion velocities based on a 2 year design frequency.

Source: National Corrugated Steel Pipe Association, West Virginia DOT Design Directive DD-503 and ADS Inc. Drainage Handbook Section 4 - Durability.

Abrasion Table: 3b

Approach Drainage
(Design Service Life – 40 Years)

Pipe Material	Abrasion Level				
	Level 1	Level 2	Level 3	Level 4	Level 5
Concrete Pipe (Section 830.01)	Y	Y	Y	Y	Y
Metal Pipe (Section 830.02)					
Zinc Coated Corrugated Steel	Y	Y			
Aluminum Coated Corrugated Steel (Type 2)	Y	Y	Y		
Polymeric Coated Steel (over Zinc or Aluminum Coated Steel)	Y	Y	Y	Y	
Plastic Pipe (Section 830.03)					
High-Density Polyethylene (Type S)	Y	Y	Y	Y	Y
Polypropylene Pipe (Type S)	Y	Y	Y	Y	Y

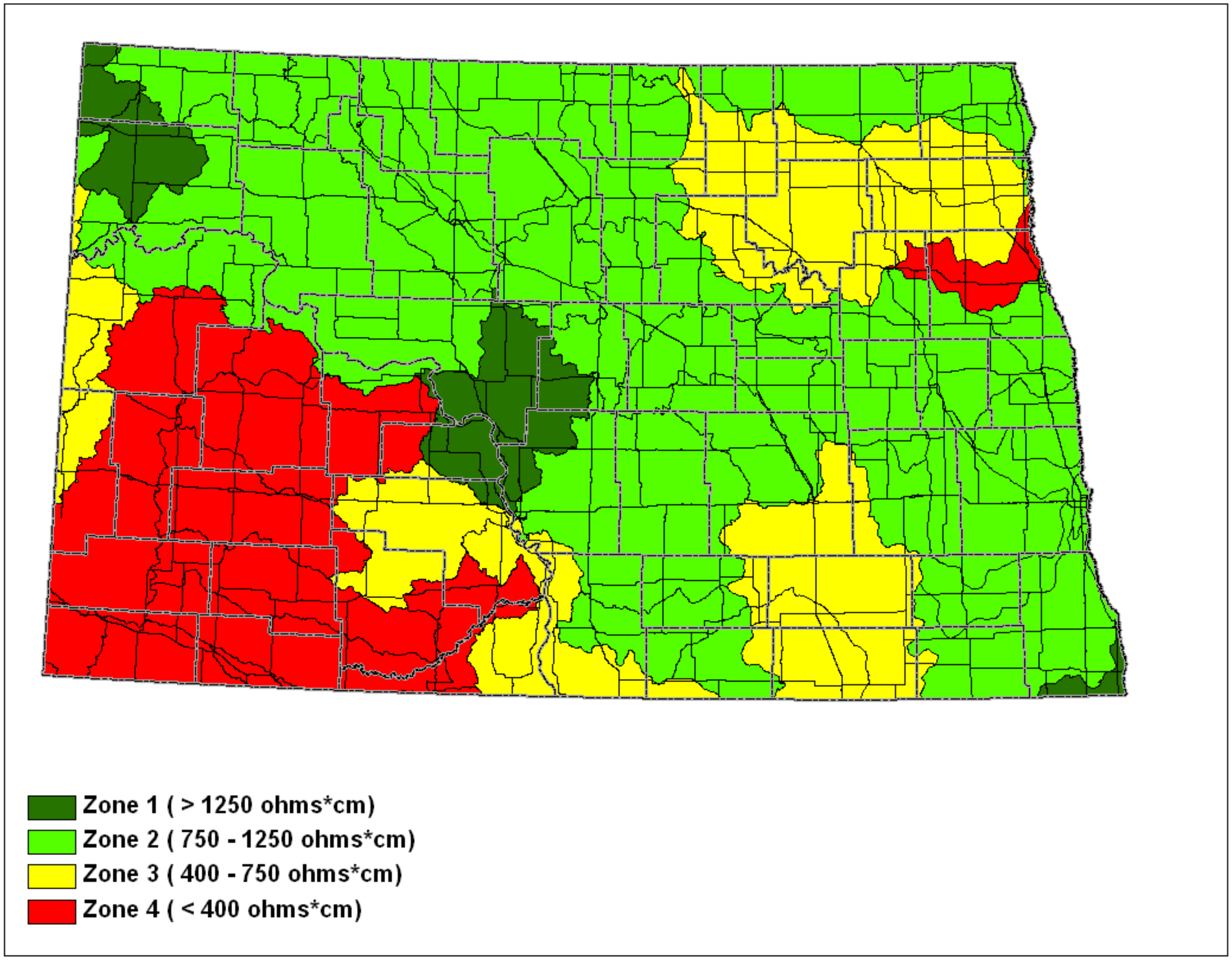
Level 1 – No bedload – regardless of velocity.
Level 2 – Bedload of sand, gravel, and debris with velocities of 0 to 5 ft/s.
Level 3 – Bedload of sand, gravel, and debris with velocities of 5 to 10 ft/s.
Level 4 – Bedload of sand, gravel, and debris with velocities of 10 to 15 ft/s.
Level 5 – Bedload of sand, gravel, and debris with velocities greater than 15 ft/s.

Abrasion velocities based on a 2 year design frequency.

Source: National Corrugated Steel Pipe Association, West Virginia DOT Design Directive DD-503 and ADS Inc. Drainage Handbook Section 4 - Durability.

Corrosion Zone Map & Tables

North Dakota Corrosion Zones (Map 1)
(Based on Soil Resistivity)



Data Source: United States Environmental Protection Agency's (EPA) Environmental Monitoring Assessment Program.

Corrosion Table: 4a

Mainline Drainage
(Design Service Life – 75 Years)

		Corrosion Zone			
Pipe Material		Zone 1	Zone 2	Zone 3	Zone 4
Concrete Pipe (Section 830.01)		Y	Y	Y	Y
Metal Pipe (Section 830.02)	Gauge				
Zinc Coated Corrugated Steel	16 ga.				
	14 ga.				
	12 ga.				
	10 ga.	Y			
	8 ga.	Y	Y		
Aluminum Coated Corrugated Steel (Type 2)	16 ga.				
	14 ga.				
	12 ga.	Y			
	10 ga.	Y	Y		
	8 ga.	Y	Y	Y	
Polymeric Coated Steel (over Zinc or Aluminum Coated Steel)	16 ga.	Y	Y	Y	Y
	14 ga.	Y	Y	Y	Y
	12 ga.	Y	Y	Y	Y
	10 ga.	Y	Y	Y	Y
	8 ga.	Y	Y	Y	Y
Plastic Pipe (Section 830.03)					
Polypropylene Pipe (Type S)		Y	Y	Y	Y

(Based on Caltrans research formula for metal pipe service life and industry service life multipliers for coated metal pipe)

Corrosion Table: 4b

Approach Drainage
(Design Service Life – 40 Years)

		Corrosion Zone			
Pipe Material		Zone 1	Zone 2	Zone 3	Zone 4
Concrete Pipe (Section 830.01)		Y	Y	Y	Y
Metal Pipe (Section 830.02)	Gauge				
Zinc Coated Corrugated Steel	16 ga.	Y	Y	Y	Y
	14 ga.	Y	Y	Y	Y
	12 ga.	Y	Y	Y	Y
	10 ga.	Y	Y	Y	Y
	8 ga.	Y	Y	Y	Y
Aluminum Coated Corrugated Steel (Type 2)	16 ga.	Y	Y	Y	Y
	14 ga.	Y	Y	Y	Y
	12 ga.	Y	Y	Y	Y
	10 ga.	Y	Y	Y	Y
	8 ga.	Y	Y	Y	Y
Polymeric Coated Steel (over Zinc or Aluminum Coated Steel)	16 ga.	Y	Y	Y	Y
	14 ga.	Y	Y	Y	Y
	12 ga.	Y	Y	Y	Y
	10 ga.	Y	Y	Y	Y
	8 ga.	Y	Y	Y	Y
Plastic Pipe (Section 830.03)					
High-Density Polyethylene (Type S)		Y	Y	Y	Y
Polypropylene Pipe (Type S)		Y	Y	Y	Y

(Based on AISI formula for metal pipe invert life and industry service life multipliers for coated metal pipe)

Corrosion Table: 4c

Storm Drain Trunk Line & Lateral Drainage
(Design Service Life – 75 Years)

		Corrosion Zone			
Pipe Material		Zone 1	Zone 2	Zone 3	Zone 4
Concrete Pipe (Section 830.01)		Y	Y	Y	Y
Metal Pipe (Section 830.02)	Gauge				
Zinc Coated Corrugated Steel	16 ga.				
	14 ga.				
	12 ga.				
	10 ga.	Y			
	8 ga.	Y	Y		
Aluminum Coated Corrugated Steel (Type 2)	16 ga.				
	14 ga.				
	12 ga.	Y			
	10 ga.	Y	Y		
	8 ga.	Y	Y	Y	
Polymeric Coated Steel (over Zinc or Aluminum Coated Steel)	16 ga.	Y	Y	Y	Y
	14 ga.	Y	Y	Y	Y
	12 ga.	Y	Y	Y	Y
	10 ga.	Y	Y	Y	Y
	8 ga.	Y	Y	Y	Y
Plastic Pipe (Section 830.03)					
High-Density Polyethylene (Type S)		Y	Y	Y	Y
Polypropylene Pipe (Type S)		Y	Y	Y	Y

(Based on Caltrans research formula for metal pipe service life and industry service life multipliers for coated metal pipe)

Flammability Table: 5

Pipe Material Allowable Where Burning is Anticipated

Pipe Material	Application		
	Mainline Drainage	Approach Drainage	Storm Drain Trunk Line and Lateral Drainage
Concrete Pipe (Section 830.01)	Y	Y	Y
Metal Pipe (Section 830.02)			
Zinc Coated Corrugated Steel	Y	Y	Y
Aluminum Coated Corrugated Steel (Type 2)	Y	Y	Y
Polymeric Coated Steel (over Zinc or Aluminum Coated Steel)	Y*	Y*	Y*
Plastic Pipe (Section 830.03)			
High-Density Polyethylene (Type S)	N	Y*	Y*
Polypropylene Pipe (Type S)	Y*	Y*	Y*

Notes:
* Only used in flammable applications with the addition of non-flammable segments and/or end treatments as determined by the Designer.

Concrete Pipe Backfill Heights[i]

Round Pipe

	Pipe Class						
Pipe Size	Class I	Class II	Class III	Class IV	Class IV Alternate	Class V	Class V Alternate
(inches)	Round Reinforced Concrete Pipe Backfill Heights (feet)						
12			1-16	16-24		24-35	
15			1-16	16-24		24-35	
18			1-16	16-24		24-35	
21			1-16	16-24		24-35	
24			1-16	16-24		24-35	
27		3-11	1-3, 11-16	16-24		24-35	
30		3-11	1-3, 11-16	16-24		24-35	
33		3-11	1-3, 11-16	16-24		24-35	
36		3-11	1-3, 11-16	16-24		24-35	
42		3-11	1-3, 11-16	16-24		24-35	
48		3-11	1-3, 11-16	16-24		24-35	24-35
54		3-11	1-3, 11-16	16-24		24-35	24-35
60	6-9	3-11	1-3, 11-16	16-24	16-24	24-35	24-35
66	6-9	3-11	1-3, 11-16	16-24	16-24	24-35	24-35
72	6-9	3-11	1-3, 11-16	16-24	16-24	24-35	24-35
78	6-9	3-11	1-3, 11-16	16-24	16-24		24-35
84	6-9	3-11	1-3, 11-16	16-24	16-24		24-35
90	6-9	3-11	1-3, 11-16		16-24		24-35
96	6-9	3-11	1-3, 11-16		16-24		24-35
102	6-9	3-11	1-3, 11-16		16-24		24-35
108	6-9	3-11	1-3, 11-16		16-24		24-35

Backfill heights for Sewer Trench Conditions other than Class I				
Pipe Size	Pipe class			
	Class II	Class III	Class IV	Class V
	FT			
2" thru 54"	3-9	1-3, 9-13	13-23	23+
60" thru 108"	1-9	9-13	13-23	23+

[i] The Table is based on the following criteria:

1. Minimum cover shall be 12”
2. Minimum cover for unpaved roadways is from the top of gravel surfacing.
3. Minimum cover for paved roadways is:
   a) To the top of the base for asphalt surfaces
   b) To the top of the pavement for concrete surfaces

Concrete Pipe Backfill Heights[ii]

Arch Pipe

	Pipe Class					
Pipe Size	Class II		Class III		Class IV	
Span - Rise	Normal Backfill	Sewer Trench	Normal Backfill	Sewer Trench	Normal Backfill	Sewer Trench
(inches)	Arch Reinforced Concrete Pipe Minimum and Maximum Cover Heights (feet)					
22x13	3-10		2-3, 10-14	2-13	1-2, 14-21	1-2, 13-50
29x18	3-10	4-6	2-3, 10-14	2-4, 6-12	1-2, 14-22	1-2, 12-26
36x23	3-10	3-7	1-3, 10-14	1-3, 7-13	14-22	13-25
44x27	2-10	2-8	1-2,10-14	1-2, 8-13	14-22	13-25
51x31	1-10	2-8	10-15	8-14	15-22	14-25
58x36	1-10	1-8	10-15	8-14	15-22	14-25
65x40	1-11	1-8	11-15	8-12	15-22	12-21
73x45	1-11	1-8	11-15	8-12	15-22	12-21
88x54	1-12	1-9	12-15	9-13	15-23	13-22
102x62	1-12	1-9	12-16	9-14	16-23	14-22
115x72	1-14	1-13	14-17	13-16	17-24	16-24
122x78	1-14	1-13	14-17	13-16	17-24	16-24
138x88	1-14	1-14	14-18	14-17	18-25	17-25
154x97	1-15	1-14	15-19	14-17	19-25	17-25

[ii] The Table is based on the following criteria:

1. Minimum cover shall be 12”
2. Minimum cover for unpaved roadways is from the top of gravel surfacing.
3. Minimum cover for paved roadways is:
   a) To the top of the base for asphalt surfaces
   b) To the top of the pavement for concrete surfaces

Concrete Pipe Backfill Heights[iii]

Elliptical Pipe

Minimum and Maximum Cover for Reinforced Concrete Horizontal Elliptical Culverts											
Span	Rise	Class A		Class I		Class II		Class III		Class IV	
		Normal Backfill	Sewer Trench	Normal Backfill	Sewer Trench	Normal Backfill	Sewer Trench	Normal Backfill	Sewer Trench	Normal Backfill	Sewer Trench
inch	inch	feet	feet	feet	feet	feet	feet	feet	feet	feet	feet
91	58	1-4	1-2	4-6	2-4	6-12	4-9	12-15	9-13	15-23	13-22
98	63	1-4	1-2	4-6	2-5	6-12	5-9	12-15	9-14	15-23	14-22
106	68	1-4	1-3	4-7	3-5	7-12	5-9	12-16	9-14	16-23	14-22
113	72	1-5	1-3	5-8	3-5	8-12	5-9	12-16	9-14	16-23	14-23
121	77	1-5	1-3	5-8	3-5	8-13	5-9	13-16	9-14	16-23	14-23
128	82	1-5	1-3	5-8	3-6	8-13	6-10	13-17	10-14	17-23	14-23
136	87	1-5	1-4	5-8	4-6	8-13	6-10	13-17	10-14	17-23	14-23

- Fill heights in Class IV shown for information purposes only.

[iii] The Table is based on the following criteria:
1. Minimum cover shall be 12”
2. Minimum cover for unpaved roadways is from the top of gravel surfacing.
3. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[iv]

Round Pipe

2-2/3" x 1/2" Corrugations						
		Steel Thickness (gauge)				
		16	14	12	10	8
	Minimum	Galvanized Thickness (inches)				
Pipe Size	cover	0.064	0.079	0.109	0.138	0.168
(inches)	(inches)	Corrugated Steel Pipe Backfill Heights (feet)				
12	12	219	273			
15	12	183	228	255		
18	12	146	182	191		
24	12	109	137	191		
30	12	87	108	153		
36	12	73	91	127	164	
42	12	62	78	109	141	172
48	12	55	68	96	123	150
54	12		61	85	109	134
60	12			76	98	120
66	12				89	109
72	12				82	100
78	12					89
84	12					77

[iv] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.043
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[v]

Round Pipe

3" x 1" Corrugations						
Pipe Size (inches)	Minimum cover (inches)	Steel Thickness (gauge)				
		16	14	12	10	8
		Galvanized Thickness (inches)				
		0.064	0.079	0.109	0.138	0.168
		Corrugated Steel Pipe Backfill Heights (feet)				
48	12	63	78	110	142	173
54	12	56	70	98	126	154
60	12	50	63	88	113	139
66	12	46	57	80	103	126
72	12	42	52	73	94	116
78	12	39	48	68	87	107
84	12	36	45	63	81	99
90	12	33	42	59	76	92
96	12		39	55	71	87
102	24		37	52	67	82
108	24			49	63	77
114	24			46	60	73
120	24			44	57	69

[v] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.033
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[vi]

Round Pipe

5" x 1" Corrugations						
Pipe Size (inches)	Minimum cover (inches)	Steel Thickness (gauge)				
		16	14	12	10	8
		Galvanized Thickness (inches)				
		0.064	0.079	0.109	0.138	0.168
		Corrugated Steel Pipe Backfill Heights (feet)				
48	12	56	70	98	126	154
54	12	50	62	87	112	137
60	12	45	56	78	101	123
66	12	41	51	71	92	112
72	12	37	47	65	84	103
78	12	34	43	60	78	95
84	12	32	40	56	72	88
90	12	30	37	52	67	82
96	12		35	49	63	77
102	24		33	46	59	73
108	24			44	56	69
114	24			41	53	65
120	24			39	50	62

Corrugated Steel Pipe Backfill Heights[vii]

[vi] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.033
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

[vii] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)

Round Pipe

3/4" x 3/4" Rib @ 7-1/2"					
Pipe Size (inches)	Minimum cover (inches)	Steel thickness (gauge)			
		16	14	12	10
		Galvanized Thickness (inches)			
		0.064	0.079	0.109	0.138
		Corrugated Steel Pipe Backfill Heights (feet)			
15	12	130	182	302	
18	12	108	151	252	
24	12	72	100	167	
30	12	57	80	134	
36	12	48	67	111	
42	12	41	57	95	
48	12	36	50	83	
54	18		45	74	
60	18		40	67	97
66	18			61	88
72	18			56	81
78	24			51	75

4. Flexibility factor = 0.0217 $I^{\wedge 1/3}$
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[viii]

Round Pipe

3/4" x 1" Rib @ 11-1/2"				
Pipe Size (inches)	Minimum cover (inches)	Steel thickness (gauge)		
		16	14	12
		Galvanized Thickness (inches)		
		0.064	0.079	0.109
		Corrugated Steel Pipe Backfill Heights (feet)		
15	12	95	134	225
18	12	79	111	188
24	12	53	74	125
30	12	42	59	100
36	12	35	49	83
42	12	30	42	71
48	12	26	37	62
54	18	23	33	55
60	18		30	50
66	18		27	45
72	18			42

[viii] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.140 $I^{\wedge 1/3}$
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[ix]

Arch Pipe

2 2/3" x 1/2" Corrugations								
Equivalent Pipe Diameter	Span	Rise	Minimum Cover (inches)	Steel Thickness (gauge)				
				16	14	12	10	8
				Galvanized Thickness (inches)				
				0.064	0.079	0.109	0.138	0.168
Inches				Corrugated Steel Pipe Backfill Heights (feet)				
15	17	13	18	14				
18	21	15	18	13				
21	24	18	18	14				
24	28	20	18	13				
30	35	24	18	13				
36	42	29	18	13				
42	49	33	18		13			
48	57	38	18			13		
54	64	43	18			13		
60	71	47	18				13	
66	77	52	18					13
72	83	57	18					13

[ix] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.043
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[x]

Arch Pipe

3" x 1" Corrugations							
Equivalent Pipe Diameter	Span	Rise	Minimum Cover (inches)	Steel Thickness (gauge)			
				14	12	10	8
				Galvanized Thickness (inches)			
				0.079	0.109	0.138	0.168
Inches				Corrugated Steel Pipe Backfill Heights (feet)			
48	53	41	18	21			
54	60	46	18	21			
60	66	51	18	21			
66	73	55	18	21			
72	81	59	18	18			
78	87	63	18	17			
84	95	67	18	17			
90	103	71	18		17		
96	112	75	18		17		
102	117	79	24		17		
108	128	83	24			16	
114	137	87	24			16	
120	142	91	24				16

[x] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.033
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[xi]

Arch Pipe

5" x 1" Corrugations							
Equivalent Pipe Diameter	Span	Rise	Minimum Cover (inches)	Steel Thickness (gauge)			
				14	12	10	8
				Galvanized Thickness (inches)			
				0.079	0.109	0.138	0.168
Inches				Corrugated Steel Pipe Backfill Heights (feet)			
48	53	41	12		21		
54	60	46	12		21		
60	66	51	12		21		
66	73	55	12		21		
72	81	59	12		18		
78	87	63	12		17		
84	95	67	12		17		
90	103	71	18		17		
96	112	75	18		17		
102	117	79	18		17		
108	128	83	24			16	
114	137	87	24			16	
120	142	91	24				16

[xi] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.033
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[xii]

Arch Pipe

3/4" x 3/4" Rib @ 7-1/2"							
Equivalent Pipe Diameter	Span	Rise	Minimum Cover (inches)	Steel Thickness (gauge)			
				16	14	12	10
				Galvanized Thickness (inches)			
				0.064	0.079	0.109	0.138
Inches				Corrugated Steel Pipe Backfill Heights (feet)			
18	20	16	12	16			
21	23	19	12	15			
24	27	21	12	14			
30	33	26	12	14			
36	40	31	12	14			
42	46	36	12	14			
48	53	41	18		14		
54	60	46	18		21		
60	66	51	18			21	
66	73	55	18			21	
72	81	59	20				18
78	87	63	22				17
84	95	67	24				17

[xii] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.0217 $I^{\wedge 1/3}$
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Steel Pipe Backfill Heights[xiii]

Arch Pipe

3/4" x 1" Rib @ 11-1/2"						
Equivalent Pipe Diameter	Span	Rise	Minimum Cover (inches)	Steel Thickness (gauge)		
				16	14	12
				Galvanized Thickness (inches)		
				0.064	0.079	0.109
Inches				Corrugated Steel Pipe Backfill Heights (feet)		
18	20	16	12	16	21	
21	23	19	12	15	21	
24	27	21	12	14	21	
30	33	26	12	14	21	
36	40	31	12	14	18	
42	46	36	12	14	17	
48	53	41	18	14	17	
54	60	46	18		21	
60	66	51	18			21

[xiii] The Table is based on the following criteria (ASTM/ASSHTO embankment)

1. Pipe Type = Helical
2. Design Method = LRFD
3. Fill Density = 120pcf (prism above pipe)
4. Flexibility factor = 0.140 I^$^{1/3}$
5. Safety Factor on Wall Area = 2.00
6. Safety Factor on Buckling = 2.00 based on equations of AASHTO/ASTM
7. Seam Strength check not required for helical pipe
8. Minimum Fill height taken as Span/8 but not less than 12"
9. Minimum cover for unpaved roadways is from the top of gravel surfacing.
10. Minimum cover for paved roadways is:
    a) To the top of the base for asphalt surfaces
    b) To the top of the pavement for concrete surfaces

Corrugated Aluminum Pipe Backfill Heights

Round Pipe

2 2/3" x 1/2" Corrugations						
Pipe Size (inches)	Minimum cover (inches)	Aluminium Thickness (gauge)				
		16	14	12	10	8
		Galvanized Thickness (inches)				
		0.060	0.075	0.105	0.135	0.164
		Corrugated Aluminum Pipe Backfill Heights (feet)				
18	12	30	30	52	54	56
24	12	22	22	39	41	42
30	12	18	18	31	32	34
36	12	15	15	26	27	28
42	12		26	43	43	44
48	12			40	41	43
54	12			35	37	38
60	12				33	34
66	12				30	31
72	12					29

Arch Pipe

2 2/3" by 1/2" Corrugations									
Pipe Size (inches)	Minimum cover (inches)	Span	Rise	Minimum cover (inches)	Aluminium Thickness (gauge)				
					16	14	12	10	8
					Galvanized Thickness (inches)				
					0.060	0.075	0.105	0.135	0.164
		Inches			Corrugated Steel Pipe Backfill Heights (feet)				
18	12	18	11	18	51				
24	12	22	13	18	14				
30	12	25	16	18	12				
36	12	29	18	18	10				
42	12	36	22	18	9				
48	12	43	27	18		9			
54	12	50	31	18			8		
60	12	58	36	18				8	

Polypropylene Pipe Backfill Heights

Round Pipe – Type S

Pipe Size (inches)	Minimum cover (inches)	Maximum Fill Height (feet)
12	12	20
15	12	20
18	12	20
21	12	20
24	12	20
30	12	20
36	12	20

At different times the DOT will receive requests from a Water Board or a City to drain water onto highway right-of- way.

Other requests that the DOT receives are to look at changing the existing drainage. Generally, when these requests are received, they are handled by the Design Division.

V–06.01 Drainage Permits

When a request comes to the DOT, (Central Office or District), from a Water Board or City, it is forwarded to the Design Division for review and preparation of the permit, if granted.

The Design Division will determine what impact such drainage would have on DOT facilities. If the review concludes that a permit could be issued, it will be issued in the name of the Water Board or the City.

Each permit will be specific to the respective site, but Appendices V–06A and V–06B will provide guidance to what should be in the permit.

V–06.01.1 Procedure for Issuing Permit

When it has been concluded that a permit will be issued the following procedure should be followed:

- Draft the permit and have it signed by the Design Engineer.
- Send it to the Legal Division for review and approval as-to-form stamp.
- Send it to the Water Board or City for signature.
- Send it to Legal for review and for approval stamp.
- Send it to the Deputy Director for Engineering for signature.
- Keep original and send copies to the Water Board or City and the respective District Engineer.

V–06.02 Drainage Reviews

Drainage reviews can occur in a couple ways. One is when a highway is being reconstructed or some major work is being done. The other is when a special request comes from an individual, District, Water Board, or City.

V–06.02.1 Project Review

When a highway is being reconstructed or having some major work done, it is a good time to look at the drainage, particularly if there have been some areas where problems exist.

If the recommendation is to modify the existing drainage or drainage patterns in any areas, the respective Water Board should be given a chance to comment.

V–06.02.2 Special Drainage Review

There are times when a private property owner requests a review or change in the drainage affecting their property. The property owner should contact the respective District with a formal request.

When the formal request is received the Design Division will make the review and in so doing will review the following records seeking the cause of the problem:

- Old Plans
- Cross Sections
- Aerial Photographs
- USGS Quad Maps
- Consult District
- Make a field review of the site

When the review has been complete the conclusions will be sent to the respective Water Board and District.

Appendix V-06A Sample Permit to Water Resource B oard

P E R M I T

The Maple River and Rush River Water Resource Boards, hereinafter called the Permittee, is hereby granted permission from the North Dakota Department of Transportation, hereinafter called the NDDOT, to enter Interstate 94 right of way for the purpose of constructing a drainage channel in the north ditch of Interstate 94 as part of the "Phase II - I-94 Swan Creek Diversion" in Sections 2,
3, and 4, Township 139N, Range 52W. The construction of the drainage channel on interstate right of way shall conform to the plan sheets submitted by Moore Engineering, Inc., dated April 21, 2000, and the following provisions:

1. The Permittee shall sponsor the project and guarantee that no environmental conflicts are involved.

2. The Permittee shall be responsible for all costs incurred for all items of work, complete in place, and shall include the furnishing of all labor, equipment, and relocation of utilities, if necessary.

3. The Permittee shall be responsible for all costs incurred for the removal, disposal and abandonment of all wells, septic systems, lagoons, and lift stations.

4. Permittee shall be responsible for all maintenance and repair costs of the overflow channel, low water crossing and siltation, vegetation and erosion control. If immediate maintenance and repairs are not made when requested by the NDDOT Fargo District Engineer, maintenance and repairs will be made by the NDDOT at the cost of the Permittee.

5. The Permittee shall provide 50 Black Hills Spruce trees, 6' in height balled and burlaped, 20 Patmore Ash trees, 3 inch diameter balled and burlaped to replace trees that are removed. The Fargo District will determine the location of the trees. The Permittee shall provide a two year warranty to replace any trees that die within two years.

6. The overflow channel shall be constructed on the outer edge of the interstate right of way and in no case shall any construction activities be closer than 58 feet from the centerline of the roadway without prior consent from the NDDOT Fargo District Engineer.

7. The Permittee shall notify the NDDOT Fargo District Engineer, forty-eight (48) hours prior to the beginning of the work. Immediately following the final cleanup of the area, the Permittee shall again notify the District Engineer.

8. All work on interstate right of way shall be done in a neat and professional manner, subject to inspection and approval by the NDDOT Fargo District Engineer.

9. Excess dirt shall be wasted outside of interstate right of way and all excavated areas

shall be reseeded.

10. Protection to the free and safe flow of Interstate traffic shall be required in accordance with the "Manual on Uniform Traffic Control Devices," current edition.

11. The overflow channel shall be completed by November 15, 2000, and the trees shall be planted by June 1, 2001. This Permit shall expire upon final acceptance by the NDDOT Fargo District Engineer of the work performed by the Permittee or Subcontractor.

12. The Risk Management Appendix (RMA), attached, is hereby incorporated into this Permit by reference. Insurance requirements of the RMA extend only to the expiration of the Permit. Other terms of the RMA shall survive the expiration of the Permit.

13. By entering upon the interstate right of way to perform the work authorized by this Permit and thereby accepting the benefits of this Permit, the Permittee agrees to be bound by all the terms and conditions of this Permit.

Executed the date last below signed

RECOMMENDED FOR APPROVAL

____
Kenneth E. Birst - Design Engineer

____
Date

Name of Water Resource District: ______________________________

____
Authorized WRB Signature

____
Date

APPROVED:

____
Grant Levi
Deputy Director for Engineering

____
Date

20:P094336.WPD:emv:permit

Appendix V-06B Sample Permit To City

P E R M I T

The City of Bismarck, hereinafter called the Permittee, is hereby granted permission from the North Dakota Department of Transportation, hereinafter called the NDDOT, to enter Interstate 94 right of way for the purpose of conveying surface runoff to a storm sewer by installing 54" RCP and constructing an overflow channel all in the south ditch of Interstate 94 in the SE 1/4 of Section 27, Township 139N, Range 80W. The construction of the overflow channel and installation of RCP pipe on interstate right of way shall conform to the plan sheets submitted by the Permittee dated April 11, 2000, and the following provisions:

1. The Permittee shall sponsor the project and guarantee that no environmental conflicts are involved.

2. The Permittee shall be responsible for all costs incurred for all items of work, complete in place, and shall include the furnishing of all labor, equipment, and relocation of utilities, if necessary.

3. The Permittee shall be responsible for necessary maintenance involving erosion in the interstate right of way as a result of this project, and shall make immediate repairs, when needed, at the request of the NDDOT Bismarck District Engineer.

4. The 54" RCP pipe and overflow channel shall be constructed on the outer edge of the interstate right of way and in no case shall any construction activities be closer than 58 feet from the centerline of the roadway without prior consent from the NDDOT Bismarck District Engineer.

5. The Permittee shall notify the NDDOT Bismarck District Engineer, forty-eight (48) hours prior to the beginning of the work. Immediately following the final cleanup of the area, the Permittee shall again notify the District Engineer.

6. All work on interstate right of way shall be done in a neat and professional manner, subject to inspection and approval by the NDDOT Bismarck District Engineer.

7. Excess dirt shall be wasted outside of interstate right of way and all excavated areas shall be reseeded. Trees and shrubs that are damaged during construction shall be replaced.

8. Protection to the free and safe flow of the Interstate traffic shall be required in accordance with the “Manual on Uniform Traffic Control Devices,” current edition.

9. This Permit shall expire upon final acceptance by the NDDOT Bismarck District Engineer of the work performed by Permittee or Subcontractor.

10. The Risk Management Appendix (RMA), attached, is hereby incorporated into this Permit

by reference. Insurance requirements of the RMA extend only to the expiration of the Permit. Other terms of the RMA shall survive the expiration of the Permit.

11. By entering upon the interstate right of way to perform the work authorized by this Permit and thereby accepting the benefits of this Permit, the Permittee agrees to be bound by all the terms and conditions of this Permit.

Executed the date last below signed.

RECOMMEND FOR APPROVAL:

____
Kenneth E. Birst, P.E. - Design Engineer

____
Date

____
Permittee (Name)

____
Signature

____
Date

APPROVED:

____
Grant Levi
Deputy Director for Engineering

____
Date

20:P094161.WPD:emv:permit